Air Quality Impact Assessment Report for Cluster 2 of the Gas Gathering Project in Virginia, South Africa

Project done on behalf of EIMS (Pty) Ltd

Report Compiled by:
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Report No: 21EIM07 | Date: June 2022

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Report Details

Project Name	Air Quality Impact Assessment Report for Cluster 2 of the Gas Gathering Project in Virginia, South Africa
Client	Environmental Impact Management Services (EIMS) (Pty) Ltd
Report Number	21EIM07
Report Version	Rev 2
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Revision Record

Revision Number	Date	Reason for Revision
Rev 0	June 2022	For Client Review
Rev 1	September 2022	Alignment with Cluster1 Management Plan
Rev 2	November 2022	Define Set Back distances in Section 4.3.3

COMPETENCY PROFILES

Report author and Project Manager: H Liebenberg-Enslin, PhD Geography (University of Johannesburg).

Hanlie Liebenberg-Enslin started her professional career in Air Quality Management in 2000 when she joined Environmental Management Services (EMS) after completing her MSc degree at the University of Johannesburg (then RAU) in the same field. She is one of the founding members of Airshed Planning Professionals in 2003 where she has worked as a company Director until she took over as Managing Director in May 2013.

She has extensive experience on the various components of air quality management including emissions quantification for a range of source types, using different dispersion models, and conducting impact assessments and health risk screening assessments. Hanlie was the project manager on a number of ground-breaking air quality management plan (AQMP) projects and the principal air quality specialist on regional environmental assessments. Her work experience, although mostly in South Africa, range over various countries in Africa, including extensive experience in Namibia, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality.

Hanlie has lectured several Air Quality Management Courses and is actively involved in the International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA) and the South African National Association for Clean Air (NACA), where she served as President for both organisations. Being an avid student, she received her PhD from the University of Johannesburg in June 2014, specialising in Aeolian dust transport.

Report author: R Bornman (M.Phil in GIS and Remote Sensing, University of Cambridge)

Rochelle Bornman started her professional career in Air Quality in 2008 when she joined Airshed Planning Professionals (Pty) Ltd after having worked in malaria research at the Medical Research Council in Durban. Rochelle has worked on several air quality specialist studies between 2008 and 2022. She has experience on the various components including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality. Whilst most of his working experience has been in South Africa, a number of investigations were made in countries elsewhere, including Mozambique, Namibia, Saudi Arabia and Mali.

EXECUTIVE SUMMARY

Tetra4 wishes to expand the natural gas operations within the approved production right area and around the Cluster 1 project. This planned expansion to the existing approved production activities will involve up to 300 new production wells, gas transmission pipelines and associated infrastructure, three (3) compressor stations and an additional new combined Liquid Natural Gas (LNG) and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure.

A quantitative air quality impact assessment was conducted for the planning and design, construction, operation, decommissioning, rehabilitation and closure phase activities of the Tetra4 Cluster 2 Project. The assessment included an estimation of atmospheric emissions, the simulation of pollutant levels and determination of the significance of impacts. This section summarises the main findings of the impact assessment.

The conclusions and recommendations of the assessment are summarised below:

- The receiving environment:
    - The area is dominated by winds from the north-northeast and northeast, followed by northerly and easterly winds with an average wind speed of 3.7 m/s.
    - Ambient air pollutant levels in the project area are currently affected by the following sources of emission: agricultural activities, gold mining and ore processing, fugitive and process emissions, vehicle tailpipe emissions, household fuel combustion, biomass burning and windblown dust from exposed areas.
    - AQSRs such as residences and farm holdings are located within and beyond the project boundary. Nearby towns include Welkom, Virginia, Bronville, Harmony and Theunissen.

- Impact of the Project:
    - Planning, design and construction phase impacts:
        - Construction activities for the roads/pipeline, wells and booster stations (where the location may vary depending on the gas reserves in the area) vehicle and equipment (vehicle entrainment and vehicle exhaust gas), three compressor stations and the plant might include land clearing, topsoil removal, material loading, bulk services construction, hauling, excavation, back-filling, road construction (where necessary) and traffic, rig-move/drilling, pipeline installation, and wind erosion of exposed areas.
        - Resulting potential air quality health and nuisance impacts at the nearest residential receptors resulted in a medium significance without mitigation and low significance with mitigation. Worst-case simulated construction impacts are not anticipated to occur over long intervals since construction activities will only last a few weeks and peak activities will not be consistent over the specified period.

    - Operational phase impacts:
        - Potential air quality impacts, including health and nuisance impacts, as a result of operational phase activities such as operation of the well pad, roads, pipelines, compression station, booster station and combined LNG/LHe plant, as well as associated emissions from movement of trucks and other vehicles, flaring (if applicable), and gas processing as well as operation of heavy machinery.
        - Vehicles on unpaved roads, and specifically the plant access road, even under mitigated conditions are likely to result in medium significance at the nearest receptors but will reduce to low significance should the road be paved.
        - Air quality impacts due to booster station (generator) operations of medium significance but low significance at the nearest receptors with mitigation measures in place.

- Plant (flaring) operations are unlikely to result in exceedances of the respective NAAQS's and are therefore considered to be of low significance at the nearest receptors.

- Decommissioning, rehabilitation and closure phase impacts:
  - Potential air quality impacts, including health impacts as a result of decommissioning, rehabilitation and closure phase activities such as decommissioning/ removal of all berms, trenches and other storm water infrastructure, stationary infrastructure, pipeline infrastructure, and wastes.
  - The environmental risk was assigned a score of low significance due to localised impacts of the various emissions, their temporary nature, and the likelihood that these activities will not occur concurrently at all portions of the site.

In conclusion, it is the specialist opinion that the project may be authorised provided that the recommended air quality management measures are implemented. These air quality management measures include:

- Source emissions monitoring and reporting;
- Ambient air quality monitoring;
- Mitigation measures aimed at reducing emissions at source;
- Paving of the unpaved road from plant to provincial R30 road; and
- The delineation of impact zones around production wells, pipeline routes, compressor and booster stations and the plant site. As a conservative approached the following setback distances are recommended, where these are seen as management zones where the potential for air quality impacts can be mitigated and managed:

<table>
<tr><th colspan="2">Project phase and associated activities</th><th>Setback distance (m)</th><th>Indicator Pollutant</th><th>Description</th></tr>
<tr><td rowspan="6">Construction</td><td>Well construction site</td><td>750</td><td rowspan="4">NO_2</td><td rowspan="4">Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit, where the distance will be significantly less based on the allowable frequency of exceedance.</td></tr>
<tr><td>Booster station site</td><td>500</td></tr>
<tr><td>Pipeline construction site</td><td>150</td></tr>
<tr><td>Road construction site</td><td>150</td></tr>
<tr><td>Compressor station construction site</td><td>200</td><td rowspan="2">PM_{10}</td><td></td></tr>
<tr><td>Plant construction site</td><td>270</td><td>Based on exceedance of NAAQ daily limit.</td></tr>
<tr><td rowspan="3">Operational</td><td>Booster station</td><td>100</td><td>PM_{10} and NO_2</td><td rowspan="2">Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit and of the daily PM_{10} NAAQS limit, where the distance will be less based on the allowable frequency of exceedance.</td></tr>
<tr><td>Unpaved road</td><td>80</td><td>PM_{10}</td></tr>
<tr><td>Plant</td><td>none</td><td>none</td><td>The flare is an intermittent source with no exceedances</td></tr>
</table>

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ABBREVIATIONS

Airshed	Airshed Planning Professionals (Pty) Ltd
AEL	Atmospheric Emissions Licence
AERMIC	AMS/EPA Regulatory Model Improvement Committee
AERMOD	AERMIC Dispersion Model
AIR	Atmospheric Impact Report
AMS	American Meteorological Society
APPA	Air Pollution and Prevention Act
AQM	Air quality management
AQMS	Air quality monitoring station
AQSRs	Air Quality Sensitive Receptor(s)
AST	Anemometer starting threshold
ASTM	American Society for Testing and Materials
CE	Control Efficiency
DEA	Department of Environmental Affairs (now DEFF)
DEFF	Department of Environment, Forestry, and Fisheries (previously DEA)
DMRE	Department of Mineral Resources and Energy
EA	Environment Australia
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
EMP	Environmental Management Plan
EMPr	Environmental Management Programme
ER	Environmental Risk
ESL	Effects Screening Level
GLC	Ground level concentration
IRP	Integrated Resource Plan
LHe	Liquid Helium
LNG	Liquid Natural Gas
MES	Minimum Emission Standards
NAAQ Limit	National Ambient Air Quality Limit concentration
NAAQS	National Ambient Air Quality Standards (as a combination of the NAAQ Limit and the allowable frequency of exceedance)
NAEIS	National Atmospheric Emissions Inventory System
NDCR	National Dust Control Regulations
NEMAQA	National Environmental Management Air Quality Act
SAAELIP	South African Atmospheric Emission Licencing and Inventory Portal
SAWS	South African Weather Services
TCEQ	Texas Commission for Environmental Quality
Tetra4	Tetra4 (formerly known as Molopo South Africa Exploration and production (Pty) Ltd)
US EPA	United States Environmental Protection Agency
VKT	Vehicle kilometres travelled

SYMBOLS AND UNITS

°C	Degree Celsius
C_6H_6	Benzene
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
ha	Hectare
H_2S	Hydrogen Sulfide
HC	Hydrocarbons
HFC	Hydrofluorocarbons
kg	Kilograms
1 kilogram	1 000 grams
km	Kilometre
m	Metres
mm	Millimetres
mamsl	Metres above mean sea level
m/s	Metres per second
mm	Millimetres
NO	Nitrogen oxide
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
Pb	Lead
PFC	Perfluorocarbons
PM	Particulate Matter
$PM_{2.5}$	Inhalable particulate matter (aerodynamic diameter less than 2.5 µm)
PM_{10}	Thoracic particulate matter (aerodynamic diameter less than 10 µm)
SF6	Sulfur hexafluoride
SO_2	Sulfur dioxide (1)
tpa	Tonnes per annum
VOC	Volatile organic compound(s)
1 ton	1 000 000 grams

Notes:

(1) The spelling of “sulfur” has been standardised to the American spelling throughout the report. The International Union of Pure and Applied Chemistry, the international professional organisation of chemists that operates under the umbrella of UNESCO, published, in 1990, a list of standard names for all chemical elements. It was decided that element 16 should be spelled “sulfur”. This compromise was to ensure that in future searchable data bases would not be complicated by spelling variants. (IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). XML on-line corrected version: http://goldbook.iupac.org (2006) created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. ISBN 0-9678550-9-8.doi: 10.1351/goldbook)"

GLOSSARY

Air pollution[(a)]	The presence of substances in the atmosphere, particularly those that do not occur naturally
Dispersion[(a)]	The spreading of atmospheric constituents, such as air pollutants
Dust[(a)]	Solid materials suspended in the atmosphere in the form of small irregular particles, many of which are microscopic in size
Instability[(a)]	A property of the steady state of a system such that certain disturbances or perturbations introduced into the steady state will increase in magnitude, the maximum perturbation amplitude always remaining larger than the initial amplitude
Mechanical mixing[(a)]	Any mixing process that utilizes the kinetic energy of relative fluid motion
Oxides of nitrogen (NO_x)	The sum of nitrogen oxide (NO) and nitrogen dioxide (NO_2) expressed as nitrogen dioxide (NO_2)
Particulate matter (PM)	Total particulate matter, that is solid matter contained in the gas stream in the solid state as well as insoluble and soluble solid matter contained in entrained droplets in the gas stream
PM_{10}	Particulate Matter with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of less than 2.5 µm
Stability[(a)]	The characteristic of a system if sufficiently small disturbances have only small effects, either decreasing in amplitude or oscillating periodically; it is asymptotically stable if the effect of small disturbances vanishes for long time periods

Notes:

(a) Definition from American Meteorological Society's glossary of meteorology (AMS, 2014)

1 INTRODUCTION

Tetra4 holds the first and only petroleum production right in South Africa, making Tetra4 the front runner in domestic natural gas distribution. A Production Right (Ref: 12/4/1/07/2/2) was granted in 2012, spanning approximately 187 000 hectares (ha) for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within this approval, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1). Activities within the Production Right areas include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500 km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original Environmental Impact Assessment (EIA) and approved EMPr).

An integrated environmental authorisation (EA) for the first phase gas field production referred to as Cluster 1, in terms of the National Environmental Management Act (NEMA), was issued on 21 September 2017 by the Department of Mineral Resources and Energy (DMRE) to Tetra4 ("Cluster 1 EA", reference: 12/04/07) and amended on 26 August 2019 and 1 September 2021. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and Liquid Natural Gas (LNG) Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Tetra4 now plans to expand the natural gas operations (referred to as Cluster 2) to be located within the approved production right area and around the Cluster 1 project (Figure 2). This planned expansion to the existing approved production activities will include:

- Drilling and establishment of further production wells (up to 300 new production wells);
- Installation of gas transmission pipelines and associated infrastructure;
- Installation of three (3) compressor stations;
- An additional new combined LNG and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure, and
- Establishment of powerlines as part of the Cluster 2 expansion of the Project in order to meet the future production requirements.

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Environmental Impact Management Services (EIMS) (Pty) Ltd to conduct an air quality impact assessment (AQIA) for the project. The main objective of the air quality study is to determine air quality related impacts as a result of the proposed project on air quality sensitive receptors (AQSRs).

1.1 Study Objective

The main objective of the air quality impact assessment is to determine the significance of impacts on the surrounding environment and human health as a result of the air pollution generated by activities proposed as part of the project.

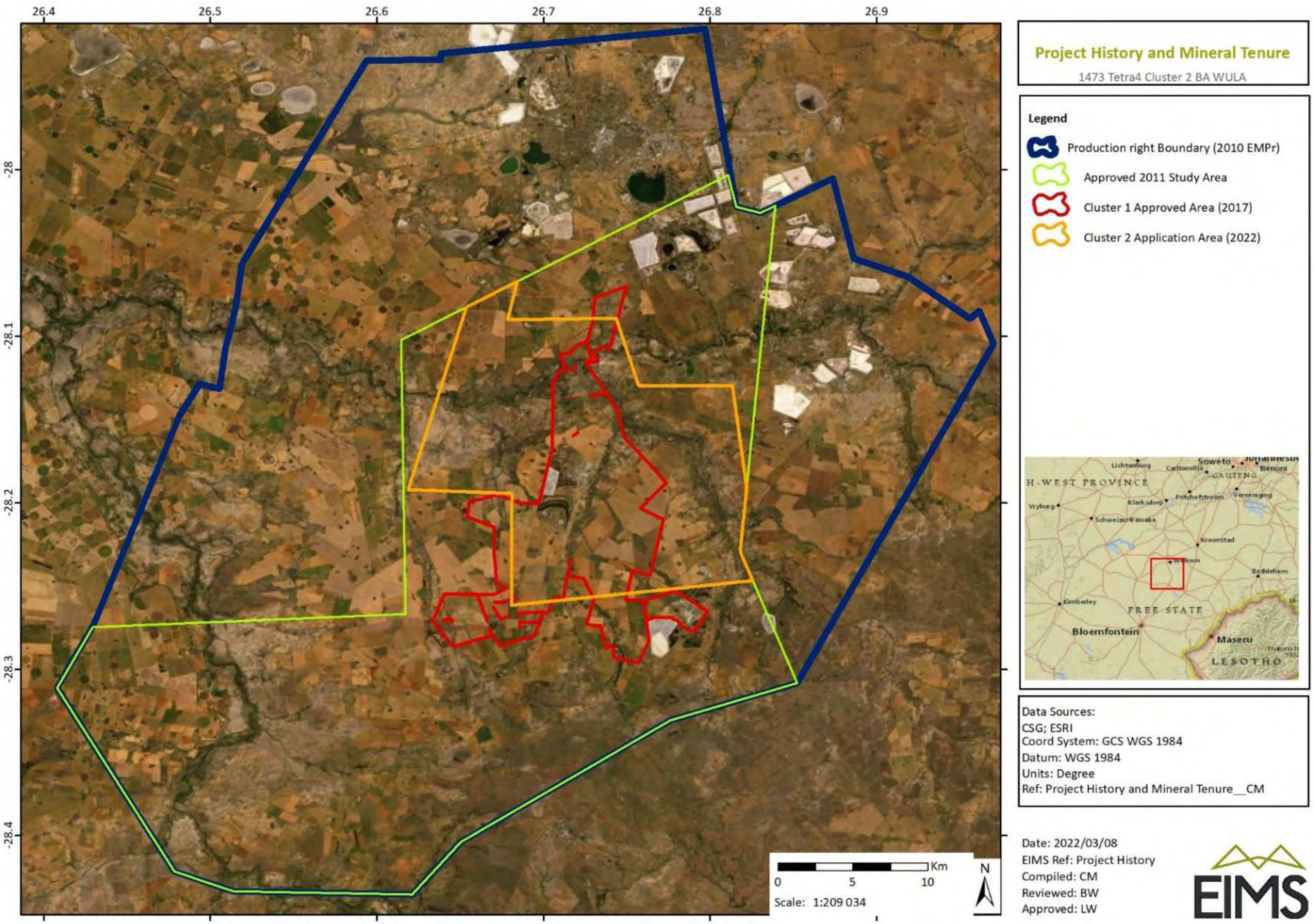

Figure 1: Project history and mineral tenure

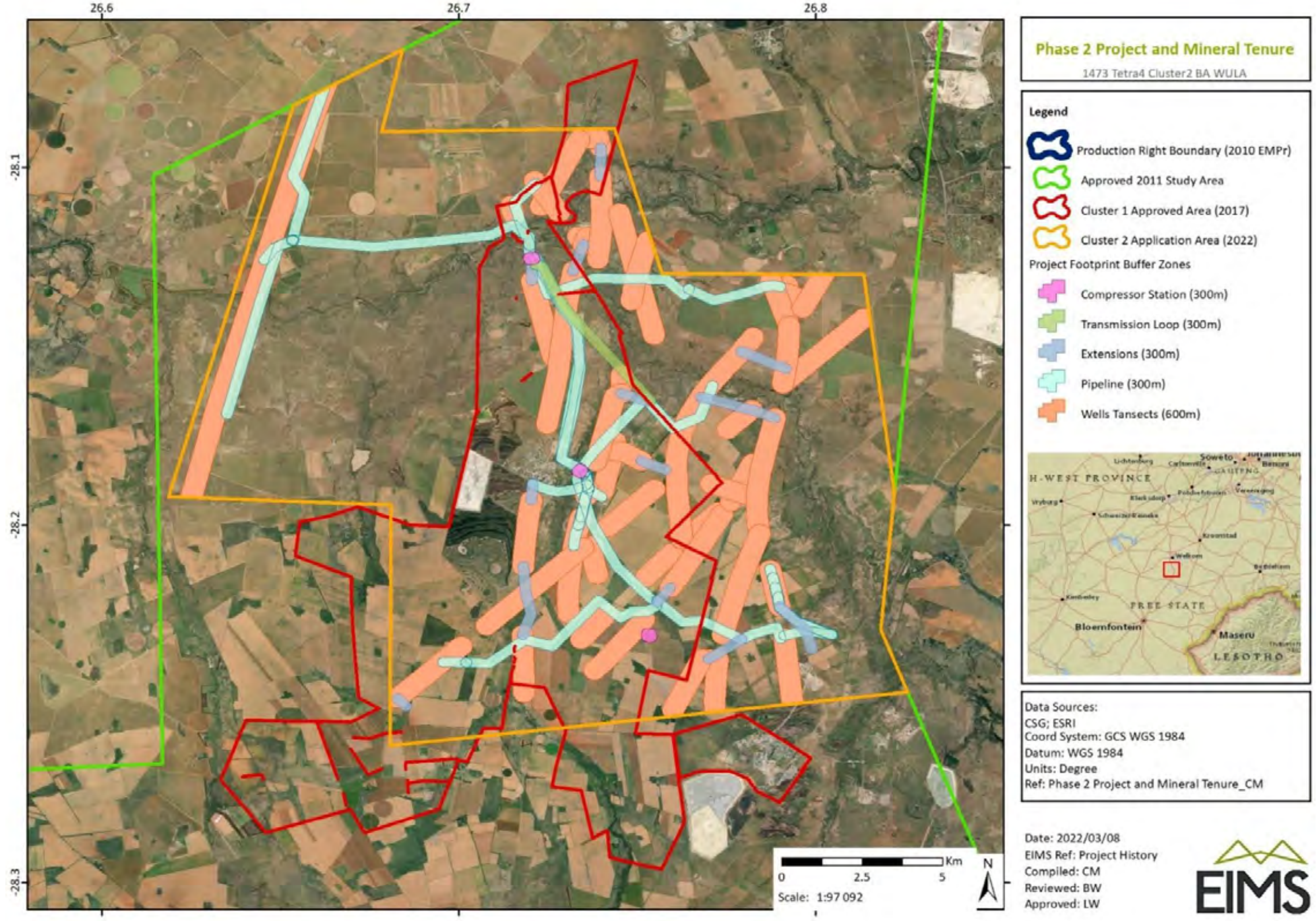

Figure 2: Cluster 2 study area and proposed infrastructure footprint buffer zones

1.2 Scope of Work

The AQIA study encompasses the following tasks:

- A study of legal requirements pertaining to air quality:
  - National Ambient Air Quality Standards,
  - Minimum Emission Limits (if applicable), and
  - National Dustfall Control Regulations.
- A study of the receiving environment by referring to:
  - Desktop review of all available project and associated data, including metrological data, previous air quality assessments, EIAs and technical air quality data and models (specifically the AQIA conducted for Cluster 1 in 2017);
  - Identification of existing air pollution sources;
  - Identification of air quality-sensitive receptors, including any nearby residential dwellings, hospitals, schools and places of worship, etc. including the location of proposed receptors (temporary or permanent workers accommodation site(s)) in the vicinity of the project infrastructure;
  - Collection of local weather conditions from the South African Weather Services (SAWS) station in Welkom for a period of three consecutive years (2019 - 2020) – the data used in the 2017 study falls outside the Department of Forestry, Fisheries and the Environment (DFFE) dispersion modelling guidelines of not older than 5 years;
  - Collect and analyse baseline air pollutant measurements data collection and analysis (if available); and
  - Compilation of an air quality sensitivity map.
- Impact Assessment, including:
  - The compilation of an emissions inventory incl. the identification and quantification of all emissions associated with the construction and operational phases of the project.
  - Atmospheric dispersion simulations of all gaseous pollutants, PM_{10}, $PM_{2.5}$ and dust fallout for the operations reflecting highest hourly, highest daily and annual average concentrations and total daily dust deposition due to routine and upset emissions from the mining operations. The US EPA approved AERMOD model will be used.
  - Compliance and impact assessment by comparing ambient pollutant concentration levels to the relevant air quality requirements.
  - The identification of air quality management and mitigation measures based on the findings of the compliance and impact assessment.
  - A specialist air quality impact assessment report.
  - The development of an air quality monitoring programme to be included in the Environmental Management Plan (EMP).

1.3 Study Approach and Methodology

The baseline description and ranking following the following approach.

1.3.1 Project and Information Review

A review of the project from an air quality perspective in order to identify sources of emission and associated pollutants of concern was conducted. In the review the following documents were referenced:

- Project information supplied by EIMS, including the AQIA conducted in 2017 (Akinshipe, 2017); and

- Section 21 of the National Environmental Management: Air Quality Act (NEMAQA); and,

1.3.2 A Study of the Receiving Environment

The baseline environment was studied by taking into account:

- The local atmospheric dispersion potential;
- The position of air quality sensitive receptors (AQSRs) in relation to the project; and
- Measured ambient air quality in the study area.

An understanding of the atmospheric dispersion potential of the area is essential to an air quality impact assessment. Physical environmental parameters that influence the dispersion of pollutants in the atmosphere include terrain, land cover and meteorology.

Data from the SAWS Welkom meteorological station was used to establish baseline meteorological conditions for the project site. The dataset included a minimum of hourly average wind speed, wind direction and temperature station. For the purposes of establishing the local climatology, it is necessary to analyse at least one year of on-site data; and at least three years of off-site data (DEA, 2014).

Measured air quality data as part of the passive sampling campaign initiated by Environmental Impact Management Services (EIMS) (Pty) Ltd in 2018 around the Tetra 4 (Pty) Ltd in 2018 around the Tetra4 Virginia Compression Plant, was accessed for this study. The dataset includes bi-annual ambient concentrations of sulfur dioxide (SO_2), nitrogen dioxide (NO_2), hydrogen fluoride (HF) and, total volatile organic compounds (TVOCs) for the period 2019 to 2021.

Readily available terrain data was obtained from the United States Geological Survey (USGS) web site (https://earthexplorer.usgs.gov/) in January 2022. A study was made of Shuttle Radar Topography Mission (STRM) 1 arc-sec data.

Potential AQSRs, residential areas, schools and medical facilities, were identified from recent maps of the area using Google Earth™ aerial imagery.

1.4 Project Description

1.4.1 Construction

The construction phase comprises activities, such as drilling and construction of new wells, construction of access roads, installation of pipelines, construction of the helium and LNG plant, as well as site clearing or upgrade activities on existing wells. Each of these operations has its own duration and potential for dust generation with typical activities land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, well drilling etc. It is anticipated therefore that the extent of dust emissions would vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions. This is in contrast to most other fugitive dust sources where emissions are either relatively steady or follow a discernible annual cycle. It is therefore often necessary to estimate area wide construction emissions, without regard to the actual plans of any individual construction process.

Activities applicable to the Project that would result in air pollution during the construction phase are listed Table 1.

Table 1: Construction activities resulting in air pollution

Activity	Associated pollutants
Handling and storage area for construction materials (paints, solvents, oils, grease) and waste	particulate matter (PM)[a] and fumes (Volatile Organic Compounds [VOCs])
Pipeline and power supply infrastructure	sulfur dioxide (SO_2); oxides of nitrogen (NOx); carbon monoxide (CO); carbon dioxide (CO_2)[b]; particulate matter (PM)
Drilling of production wells	SO_2; NOx; CO; PM, CO_2
Clearing and other earth moving activities	mostly PM, gaseous emissions from earth moving equipment (SO_2; NOx; CO; CO_2)
Foundation excavations	mostly PM, gaseous emissions from excavators (SO_2; NOx; CO; CO_2)
Opening and backfill of material (specific grade) from borrow pits	mostly PM, gaseous emissions from trucks and equipment (SO_2; NOx; CO; CO_2)
Delivery of materials – storage and handling of material such as sand, rock, cement, chemical additives, etc.	mostly PM, gaseous emissions from trucks (SO_2; NOx; CO; CO_2)
General building/construction activities including, amongst others: mixing of concrete; operation of construction vehicles and machinery; refuelling of machinery; civil, mechanical and electrical works; painting; grinding; welding; etc	mostly PM, gaseous emissions from construction vehicles and machinery (SO_2; NOx; CO; CO_2)

Notes: [a] Particulate matter (PM) comprises a mixture of organic and inorganic substances, ranging in size and shape and can be divided into coarse and fine particulate matter. Total Suspended Particulates (TSP) represents the coarse fraction >10μm, with particulate matter with an aerodynamic diameter of less than 10μm (PM_{10}) and particulate matter with an aerodynamic diameter of less than 2.5μm ($PM_{2.5}$) falling into the finer inhalable fraction. TSP is associated with dust fallout (nuisance dust) whereas PM_{10} and $PM_{2.5}$ are considered a health concern.
[b] CO_2 is a greenhouse gas (GHG).

1.4.2 Operations

The operational phase of the Project will include mainly the combined Helium/LNG plant (pumps, compressors, motors, cooling towers, trucks and generators) and vehicles on roads.

Activities at Tetra4 Project likely to result in pollutants to air are listed in Table 2.

Table 2: Operational activities resulting in air pollution

Activity	Associated pollutants
Transport of consumables and product	PM from road surfaces and windblown dust from trucks, gaseous emissions from truck exhaust (PM, SO_2; NOx; CO; CO_2)
Management of waste	PM, gaseous emissions from machinery (PM, SO_2; NOx; CO; CO_2) and VOCs
Flaring	PM, SO_2; NOx; CO; CO_2 and VOCs
Helium and LNG plant	PM, SO_2; NOx; CO; CO_2 and VOCs
Diesel generators	PM, metals[(a)(e)], NOx, SO_2, CO, TVOC, PAH, TEQ

1.5 Assumptions and Limitations

The following important limitation applies to the study and should be noted:

- Project information required to calculate emissions for proposed operations were provided by Tetra4 and EIMS. Where necessary, assumptions were made based on common industry practice and experience.
- Only routine emissions for the operational phase were estimated and simulated. Atmospheric releases occurring as a result of non-routine conditions were not accounted for limited to emergency flaring at the plant, with other non-routine releases expected to be minimal.
- Emission factors were used to estimate all fugitive and processing emissions resulting from plant, construction activities and transport. These emission factors generally assume average operating conditions.
- The access road from the R30 road to the plant was assumed to be unpaved.
- The compressor stations were assumed to be electrically powered, whereas the booster stations were assumed to use diesel generators.
- Flaring was simulated at the plant only (no flaring of wells was included). Throughput data were provided for two designs (continuous and emergency design) and modelled accordingly.
- Assumptions on flare stack metrics were made based on similar operation elsewhere (Burger and Akinshipe, 2014).
- It was assumed that no smoke/soot will be emitted by the flare.
- The impact assessment was limited to airborne particulates (including TSP, PM_{10} and $PM_{2.5}$) and gaseous pollutants from combustion and non-combustion machinery, including CO, NOx, VOCs and SO_2.
- Nitrogen monoxide (NO) emissions are rapidly converted in the atmosphere into nitrogen dioxide (NO_2). NO_2 impacts where calculated by using a NO_2/NOx emission ratio of 0.2 (Howard, 1988).
- Planning and design, decommissioning, closure and rehabilitation phase impacts were not quantified. Impacts associated with these phases are highly variable and generally less significant than construction and operational phase impacts. Mitigation and management measures recommended for the construction and operational phases are however also applicable to the planning and design, decommissioning, closure and rehabilitation phases.

2 Regulatory Requirements and Assessment Criteria

Prior to assessing the impact of proposed activities on human health and the environment, reference needs to be made to the environmental regulations governing the impact of such operations i.e. emission standards, ambient air quality standards and dust control regulations.

Emission standards are generally provided for point sources and specify the amount of the pollutant acceptable in an emission stream and are often based on proven efficiencies of air pollution control equipment.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality standards and guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging or exposure periods.

This section summarises legislation for criteria pollutants relevant to the current study and dustfall. A discussion on inhalation health risk for VOC is also provided.

2.1 National Minimum Emission Standards and AEL Application and Reporting Requirements

2.1.1 National Minimum Emission Standards

The NEMAQA (Act No. 39 of 2004 as amended) mandates the Minister of Environment to publish a list of activities which result in atmospheric emissions and consequently cause significant detrimental effects on the environment, human health and social welfare, economic conditions, ecological conditions or cultural heritage. All scheduled processes as previously stipulated under the Air Pollution Prevention Act are included as listed activities with additional activities added to the list. The updated Listed Activities and Minimum National Emission Standards (MES) were published in 2013 (GN 893, in Government Gazette No. 37054) as amended by GN 551, 12 June 2015; GN 1207, 81 October 2018 and GN 687, 22 May 2019). Based on the information available during the scoping phase of assessment, the proposed project will trigger Minimum Emission Standards (MES) subsection (a) under Subcategory 2.4: Storage and Handling of Petroleum Products[1]. The MES of concern for the project is provided in Table 3.

Table 3: Subcategory 2.4 – Storage and Handling of Petroleum Products

Description:	Storage and handling of petroleum products.	
Application:	All permanent immobile liquid storage facilities at a single site with a combined storage capacity of greater than 1,000 m^3.	
Substance or mixture of substances	Plant status	mg/Nm^3 under normal conditions of 273 Kelvin and 101.3 kPa.
Total Volatile Organic Compounds (TVOC) from vapour recovery/destruction units using thermal treatment	New	150
Total Volatile Organic Compounds (TVOC) from vapour recovery/destruction units using non-thermal treatment	New	40,000

[1] Petroleum Products, according to the NEMAQA, refers to production of gaseous and liquid fuels as well as petrochemicals from crude oil, coal, gas or biomass.

(a) The following transitional arrangement shall apply for the storage and handling of raw materials, intermediate and final products with a vapour pressure greater than 14kPa at operating temperature: -
Leak detection and repair (LDAR) program approved by licensing authority to be instituted, by 01 January 2014.

2.1.2 Reporting of Atmospheric Emissions

The National Atmospheric Emission Reporting Regulations (Government Gazette No. 38633) came into effect on 2 April 2015. The purpose of the regulations is to regulate the reporting of data and information from an identified point, non-point and mobile sources of atmospheric emissions to an internet-based National Atmospheric Emissions Inventory System (NAEIS). The NAEIS is a component of the South African Atmospheric Emission Licencing and Inventory Portal (SAAELIP). Its objective is to provide all stakeholders with relevant, up to date and accurate information on South Africa's emissions profile for informed decision making.

Emission sources and data providers are classified according to groups. The proposed project would be classified under Group A (“Listed activity published in terms of section 21(1) of the NEMAQA”). Emission reports from Group A must be made in the format required for NAEIS and in accordance with the atmospheric emission license or provisional atmospheric emission license.

As per the regulation, Tetra 4 and/or their data provider must register on the NAEIS within 30 days after commencing with proposed activities. Data providers must inform the relevant authority of changes if there are any:

- Change in registration details;
- Transfer of ownership; or
- Activities being discontinued.

A data provider must submit the required information for the preceding calendar year to the NAEIS by 31 March of each year. Records of data submitted must be kept for a period of 5 years and must be made available for inspection by the relevant authority.

The relevant authority must request, in writing, a data provider to verify the information submitted if the information is incomplete or incorrect. The data provider then has 60 days to verify the information. If the verified information is incorrect or incomplete the relevant authority must instruct a data provider, in writing, to submit supporting documentation prepared by an independent person. The relevant authority cannot be held liable for cost of the verification of data. A person guilty of an offence in terms of section 13 of these regulations is liable for penalties.

2.2 Screening Criteria

2.2.1 National Ambient Air Quality Standards (NAAQS)

Criteria pollutants are considered those pollutants most commonly found in the atmosphere, that have proven detrimental health effects when inhaled and are regulated by ambient air quality criteria. South African NAAQS for SO_2, NO_2, PM_{10}, carbon monoxide (CO), ozone (O_3), benzene (C_6H_6), and lead (Pb) were published on 13 March 2009. Standards for $PM_{2.5}$ were published on 24 June 2012. All standards are listed in Table 4 where pollutants of interest to the proposed project are shaded in blue.

Table 4: National Ambient Air Quality Standards for criteria pollutants

Pollutant	Averaging Period	Limit Value (µg/m³)	Limit Value (ppb)	Frequency of Exceedance	Compliance Date
SO_2	10-minute	500	191	526	Currently enforceable
	1-hour	350	134	88	Currently enforceable
	24-hour	125	48	4	Currently enforceable
	1-year	50	19	-	Currently enforceable
NO_2	1-hour	200	106	88	Currently enforceable
	1-year	40	21	-	Currently enforceable
PM_{10}	24-hour	75	-	4	Currently enforceable
	1-year	40	-	-	Currently enforceable
$PM_{2.5}$	24-hour	40	-	4	1 Jan 2016 – 31 Dec 2029
		25	-	4	1 Jan 2030
	1-year	20	-	-	1 Jan 2016 – 31 Dec 2029
		15	-	-	1 Jan 2030
CO	1-hour	30 000	26 000	88	Currently enforceable
	8-hour	10 000	8 700	11	Currently enforceable
Benzene (C_6H_6)	1-year	5	1.6	-	Currently enforceable
Ozone (O_3)	8 hours (running)	120	61	11	Currently enforceable
Lead (Pb)	1-year	0.5	-	-	Currently enforceable

2.2.2 *Inhalation Health Criteria for non-criteria Pollutants*

The potential for health impacts associated with non-criteria pollutants (VOCs) emitted from combustion sources are assessed according to guidelines published by the Texas Commission on Environmental Quality (TCEQ) - Effects Screening Levels (ESLs) (TCEQ (2013).

Table 5: Chronic inhalation screening criteria for non-criteria pollutants

Pollutant	Acute/Short term Screening Criteria (µg/m³)	Chronic/Long term Screening Criteria (µg/m³)	Reference
VOC (*Diesel fuel* used as indicator)	1000	100	TCEQ

2.2.3 *National Dust Control Regulations (NDCR)*

NDCR were published on the 1st of November 2013 (Government Gazette No. 36974 R.827). Acceptable dustfall rates according to the Regulation are summarised in Table 6.

Table 6: Acceptable dustfall rates

Restriction areas	Dustfall rate (D) in mg/m²-day over a 30 day average	Permitted frequency of exceedance
Residential areas	D < 600	Two within a year, not sequential months.
Non-residential areas	600 < D < 1 200	Two within a year, not sequential months.

The regulation also specifies that the method to be used for measuring dustfall and the guideline for locating sampling points shall be ASTM D1739 (1970), or equivalent method approved by any internationally recognized body. Dustfall is assessed for nuisance impact and not inhalation health impact.

2.2.4 Screening criteria for animals and vegetation

Limited information is available on the impact of dust on vegetation and grazing quality. While there is little direct evidence of the impact of dustfall on vegetation in the South African context, a review of European studies has shown the potential for reduced growth and photosynthetic activity in sunflower and cotton plants exposed to dust fall rates greater than 400 mg/m²- day (Farmer, 1993). In addition, there is anecdotal evidence to indicate that over extended periods, high dustfall levels in grazing lands can soil vegetation and this can impact the teeth of livestock (Farmer, 1993).

2.3 Atmospheric Dispersion Modelling Regulations

Air dispersion modelling provides a cost-effective means for assessing the impact of air emission sources, the major focus of which is to determine compliance with the relevant ambient air quality standards. Dispersion modelling provides a versatile means of assessing various emission options for the management of emissions from existing or proposed installations. Regulations regarding Air Dispersion Modelling were promulgated in GN 533, in Government Gazette No. 37804; 11 July 2014, and recommend a suite of dispersion models to be applied for regulatory practices as well as guidance on modelling input requirements, protocols and procedures to be followed. The Regulations regarding Air Dispersion Modelling are applicable –

(a) in the development of an air quality management plan, as contemplated in *Chapter 3* of the NEMAQA;
(b) in the development of a priority area air quality management plan, as contemplated in *Section 19* of the NEMAQA;
(c) in the development of an AIR, as contemplated in *Section 30* of the NEMAQA; and,
(d) in the development of a specialist air quality impact assessment study, as contemplated in *Chapter 5* of the NEMAQA.

Three *Levels of Assessment* are defined in the Regulations. The three levels are:

- Level 1: where worst-case air quality impacts are assessed using simpler screening models
- Level 2: for assessment of air quality impacts as part of license application or amendment processes, where impacts are the greatest within a few kilometres downwind (less than 50km)
- Level 3: require more sophisticated dispersion models (and corresponding input data, resources and model operator expertise) in situation:
  - where a detailed understanding of air quality impacts, in time and space, is required;
  - where it is important to account for causality effects, calms, non-linear plume trajectories, spatial variations in turbulent mixing, multiple source types & chemical transformations;
  - when conducting permitting and/or environmental assessment process for large industrial developments that have considerable social, economic and environmental consequences;
  - when evaluating air quality management approaches involving multi-source, multi-sector contributions from permitted and non-permitted sources in an air-shed; or,
  - when assessing contaminants resulting from non-linear processes (e.g. deposition, ground-level O_3, particulate formation, visibility).

The first step in the dispersion modelling exercise requires a clear objective of the modelling exercise and thereby gives clear direction to the choice of the dispersion model most suited for the purpose. Accordingly, a Level 2 assessment is considered suitable for proposed project during the Environmental Impact Assessment phase of the study.

3 Description of the Receiving Environment

3.1 Air Quality Sensitive Receptors (AQSRs)

Air quality sensitive receptors (AQSRs) refer to places where humans reside. Ambient air quality guidelines and standards, as discussed under section 2.2, have been developed to protect human health. Ambient air quality, in contrast to occupation exposure, pertains to areas outside of an industrial site or boundary where the public has access to and according to the Air Quality Act, excludes air regulated by the Occupational Health and Safety Act (Act No 85 of 1993).

A map showing locations of AQSRs within the Project boundary is included in Figure 3. These include residences, farmsteads, and Holdings, as well as a mine village. The closest towns in the immediate region of the project include Welkom (located about 6 kilometres (km) north-northeast of the Project boundary), Virginia (located about 2 km east of the Project boundary), Bronville (located about 11 km northeast of the Project boundary), Harmony (located about 11 kilometres south of the Project boundary) and Theunissen (located about 16 km south of the Project boundary).

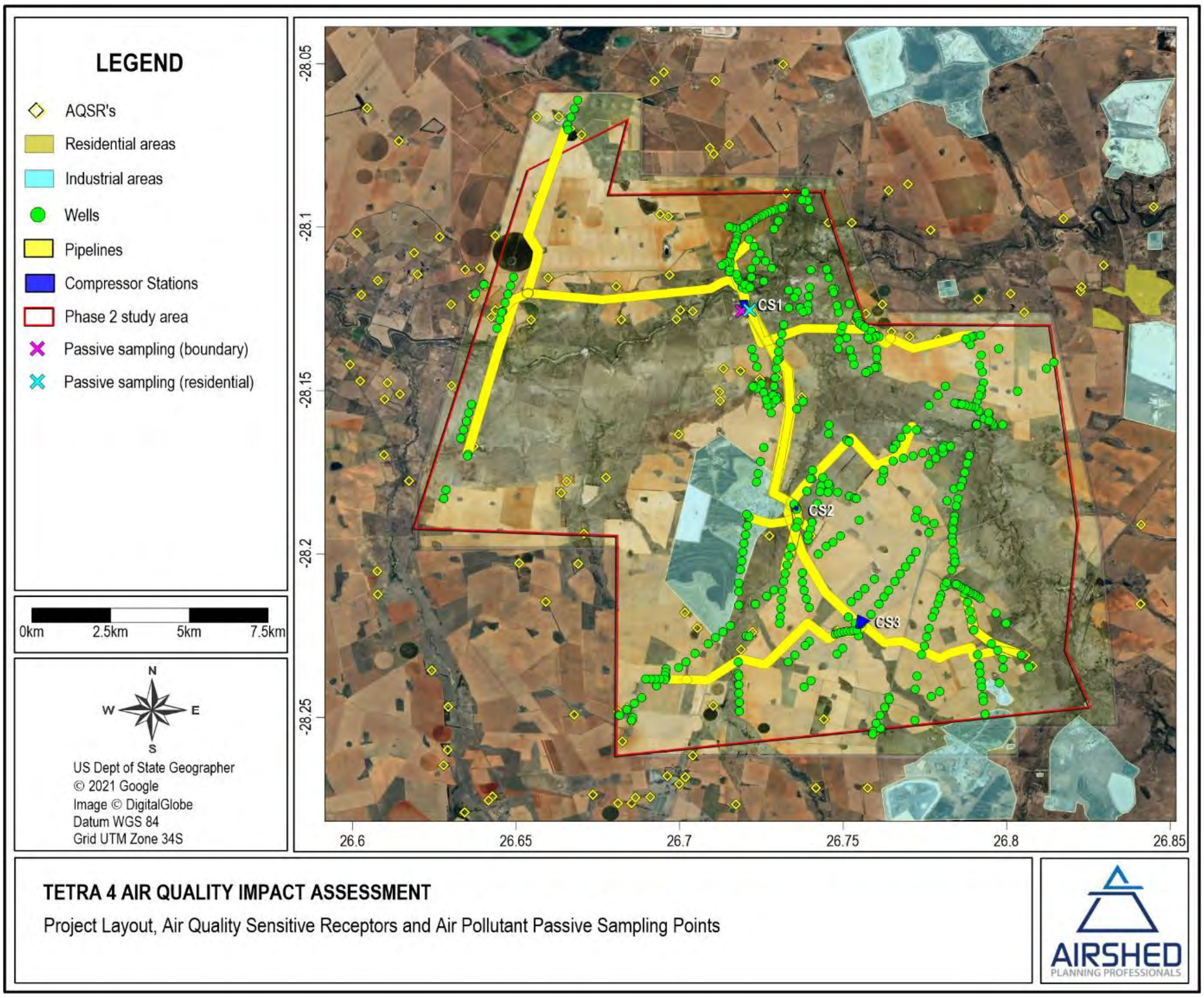

Figure 3: Location map and Air Quality Sensitive Receptors of the proposed project

3.2 Atmospheric Dispersion Potential

Physical and meteorological mechanisms govern the dispersion, transformation, and eventual removal of pollutants from the atmosphere. The analysis of hourly average meteorological data is necessary to facilitate a comprehensive understanding of the dispersion potential of the site. Parameters useful in describing the dispersion and dilution potential of the site i.e. wind speed, wind direction, temperature and atmospheric stability, are subsequently discussed. For the purpose of this study, surface and profile weather data for the period January 2019 to December 2021 was obtained from the South African Weather Service (SAWS) station at Welkom. The Welkom weather station is located 12 km northwest of the Project site.

3.2.1 Topography

The study area is characterised by a flat surface with sparse vegetation. An analysis of topographical data indicated a slope of less than 1:10 from over most of the project area. Dispersion modelling guidance recommends the inclusion of topographical data in dispersion simulations only in areas where the slope exceeds 1:10 (US EPA, 2004). The topography for the study area is provided in Figure 4.

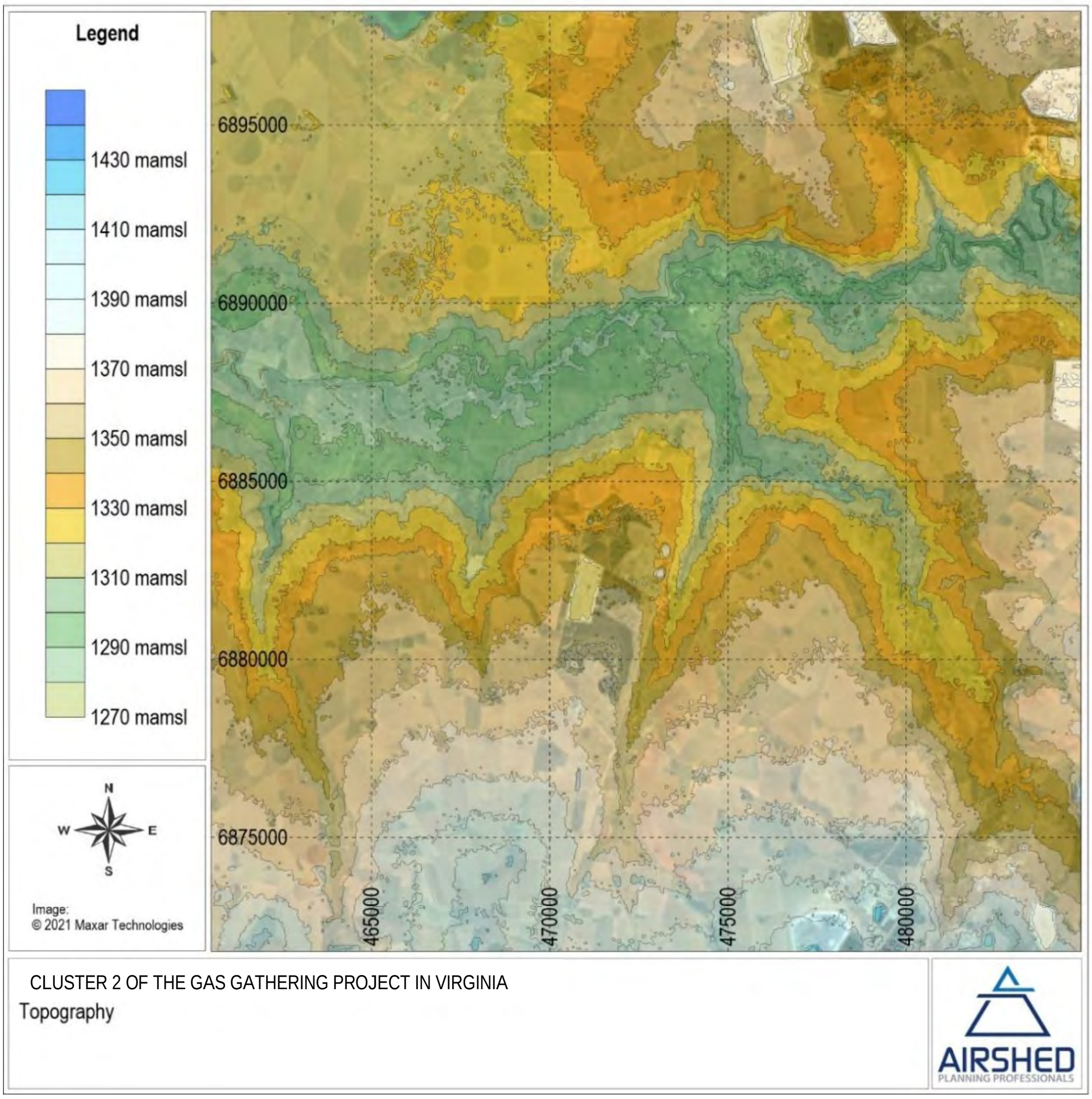

Figure 4: Topography for the study area

3.2.2 Surface Wind Field

The wind roses comprise 16 spokes, which represent the directions from which winds blew during a specific period. The colours used in the wind roses below, reflect the different categories of wind speeds; the yellow area, for example, representing winds in between 4 and 5 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are also indicated.

The period wind field and diurnal variability in the wind field are shown in Figure 5, while the seasonal variations are shown in Figure 6.

During the 2019 to 2021 period, the wind field was dominated by winds from the north-northeast and northeast, followed by northerly and easterly winds. During the day (6AM – 6PM), the prevailing wind field is from the north to northeast and the west, with less frequent winds from the north-westerly sector, the easterly sector and the south-west. During the night, the wind field shifts to the easterly sector (north-northeast to east-southeast), with very little flow from the westerly sector. Long-term air quality impacts are therefore expected to be the most significant to the south and southwest of the project area. The strongest winds (more than 6 m/s) were also from the north and northeast and occurred mostly during the day, with 15 m/s the highest wind speed recorded. The average wind speed over the three years is 3.7 m/s, with calm conditions occurring for 3.5% of the time (Figure 5).

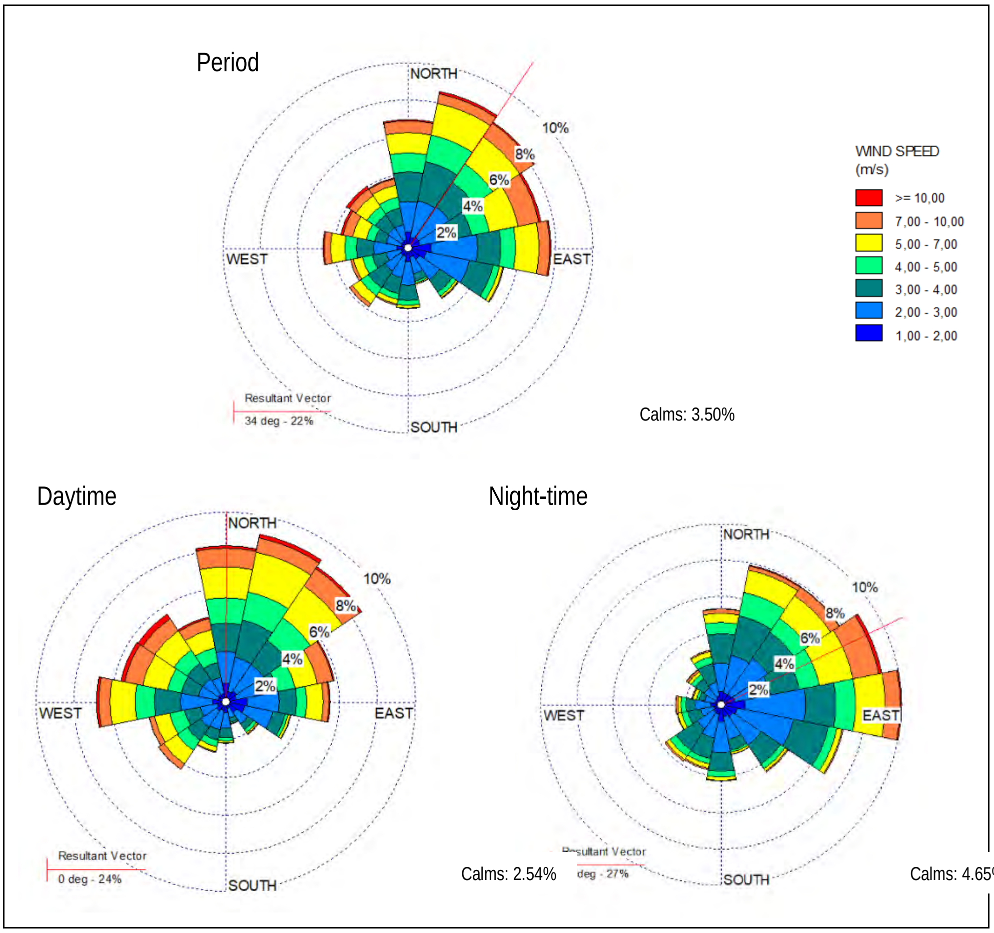

Figure 5: Period, day- and night-time wind roses (SAWS Welkom Data, 2019 to 2021).

Seasonally, the wind flow pattern conforms to the period average wind flow pattern. The seasonal wind field shows little seasonal differences in the wind fields. During summer and spring, the dominant winds are from the north-northeast to east, with more frequent westerly winds during spring. Autumn reflects dominant north-easterly and easterly winds, with a similar wind field during winter, but with more frequent north-northeasterly and east-southeasterly winds (Figure 6).

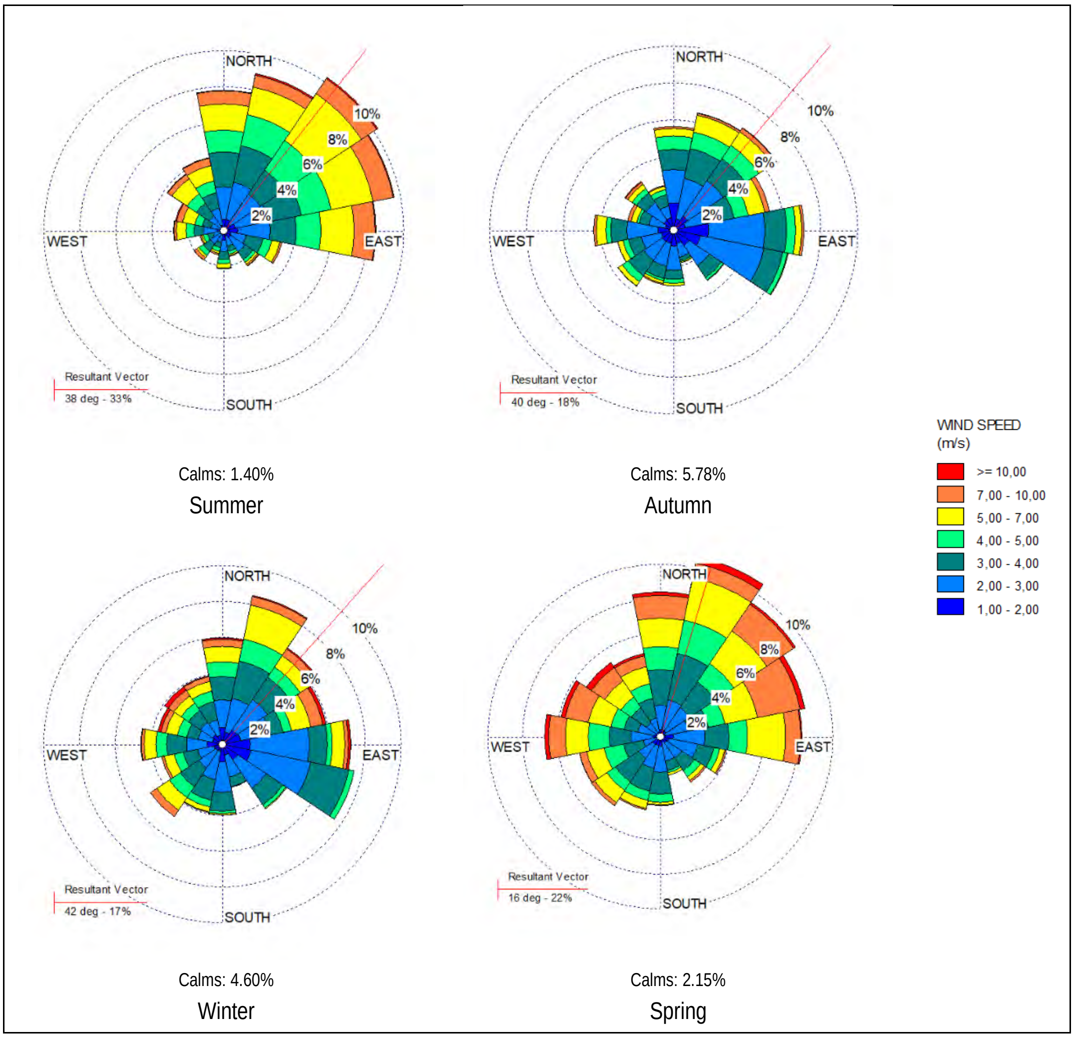

Figure 6: Seasonal wind roses (SAWS Welkom Data, 2019 to 2021)

3.2.3 Temperature and Relative Humidity

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the emission plume and the ambient air, the higher the plume is able to rise), and determining the development of the mixing and inversion layers.

Monthly mean, maximum and minimum temperatures are given in Table 5. Temperatures ranged between -6.1°C in July and 40.8°C in January. During the day, temperatures increase to reach maximum at around 15:00 in the afternoon. Ambient air temperature decreases to reach a minimum at around 06:00 i.e. just before sunrise.

Table 7: Monthly minimum, average and maximum temperature (°C) (SAWS Welkom Data, 2019 to 2021)

	Temperature (°C)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	11.7	10.1	8.1	1.6	-2.8	-4.3	-6.1	-4.8	1.3	3.3	3.0	10.5
Average	23.2	22.4	20.6	17.6	14.2	10.8	10.6	13.6	18.0	20.6	22.1	22.7
Maximum	40.8	36.9	33.3	32.8	28.7	26.9	25.6	31.0	34.0	37.3	36.7	39.0

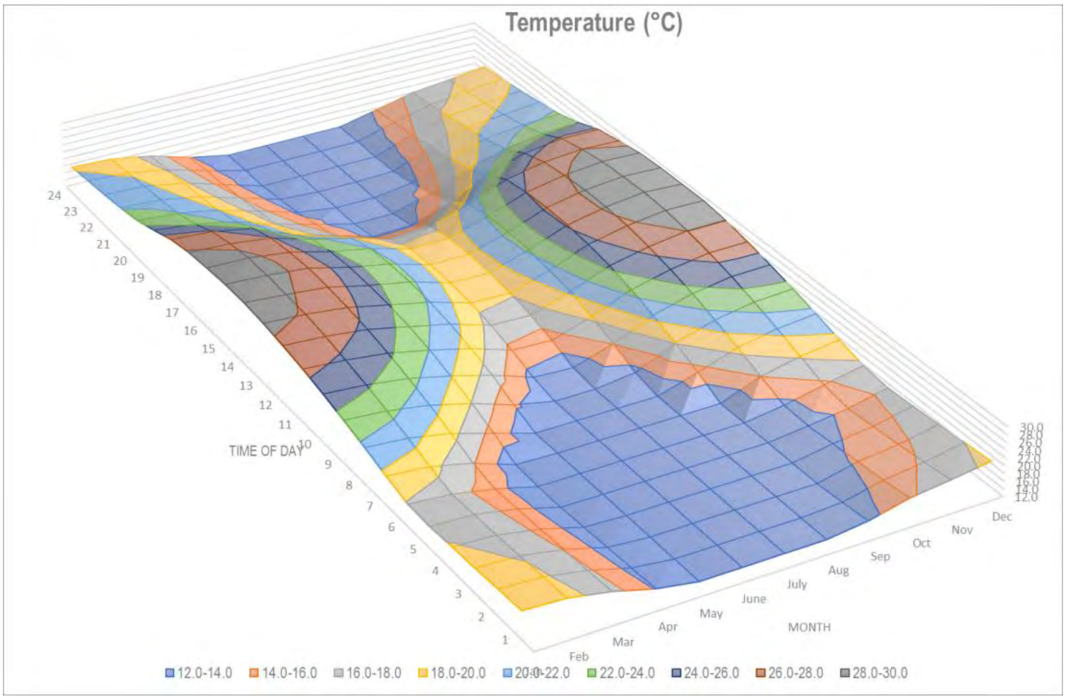

Figure 7: Diurnal temperature profile (SAWS Welkom Data, 2019 to 2021)

3.2.4 *Atmospheric Stability and Mixing Depth*

The new generation air dispersion models differ from the models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes. The atmospheric boundary layer properties are therefore described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class.

The Monin-Obukhov length (L_{Mo}) provides a measure of the importance of buoyancy generated by the heating of the ground and mechanical mixing generated by the frictional effect of the earth's surface. Physically, it can be thought of as representing the depth of the boundary layer within which mechanical mixing is the dominant form of turbulence generation (CERC, 2004). The atmospheric boundary layer constitutes the first few hundred meters of the atmosphere. During daytime, the atmospheric boundary layer is characterised by thermal turbulence due to the heating of the earth's surface. Night-times are characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds and lower dilution potential.

The atmospheric stability is frequently categorised into one of six stability classes. These are briefly described in Table 8.

Table 8: Atmospheric stability classes

Stability Class	Stability	Description of Conditions
A	Very unstable	calm wind, clear skies, hot daytime conditions
B	Moderately unstable	clear skies, daytime conditions
C	Unstable	moderate wind, slightly overcast daytime conditions
D	Neutral	high winds or cloudy days and nights
E	Stable	moderate wind, slightly overcast night-time conditions
F	Very stable	low winds, clear skies, cold night-time conditions

Diurnal variation in atmospheric stability, as calculated from Welkom SAWS data, and described by the inverse Monin-Obukhov length and the boundary layer depth is provided in Figure 8. The highest concentrations for ground level, or near-ground level releases from non-wind dependent sources would occur during weak wind speeds and stable (night-time) atmospheric conditions. For elevated releases, unstable conditions can result in very high concentrations of poorly diluted emissions close to the stack. This is called *looping* (Figure 8(c)) and occurs mostly during daytime hours. Neutral conditions disperse the plume fairly equally in both the vertical and horizontal planes and the plume shape is referred to as *coning* (Figure 8(b)). Stable conditions prevent the plume from mixing vertically, although it can still spread horizontally and is called *fanning* (Figure 8(a)) (Tiwary & Colls, 2010). For ground level releases such as fugitive dust the highest ground level concentrations will occur during stable night-time conditions.

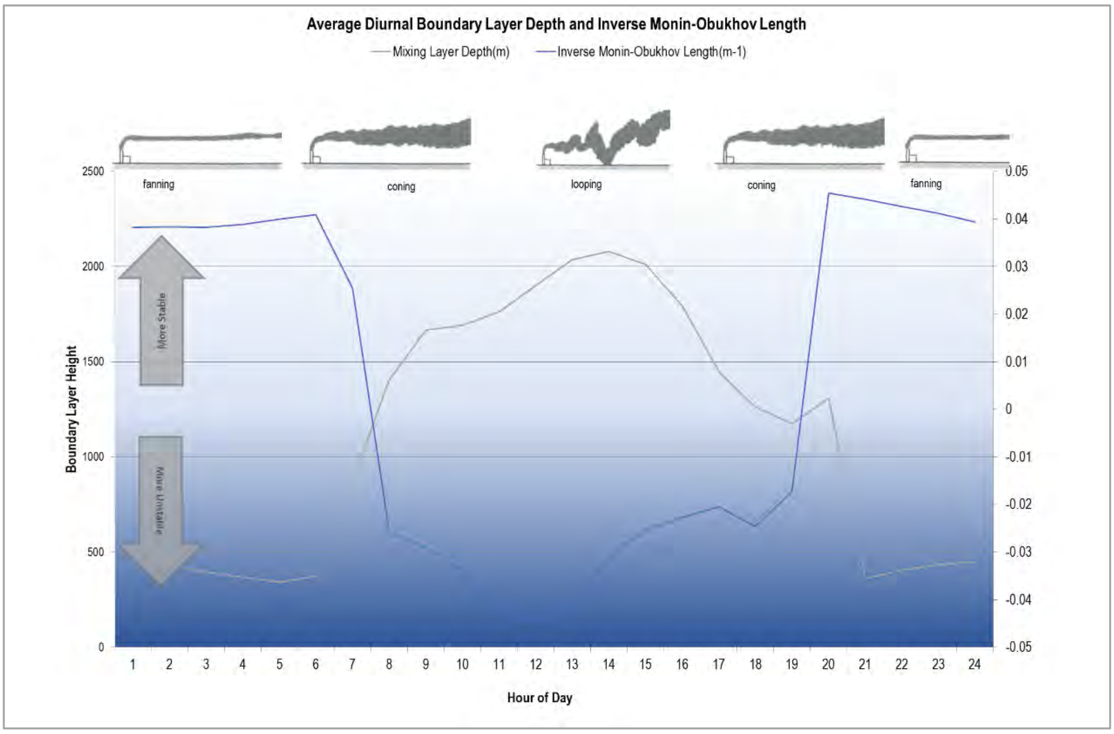

Figure 8: Diurnal atmospheric stability for Welkom (SAWS data, 2019 to 2021)

3.2.5 Precipitation

Precipitation represents an effective removal mechanism of atmospheric pollutants. Precipitation reduces wind erosion potential by increasing the moisture content of materials. Rain-days are defined as days experiencing 0.1 mm or more rainfall.

Rainfall in the region is almost exclusively due to showers and thunderstorms and falls mainly in summer, from October to March. The maximum rainfall occurs during the December-January period. The long term annual average rainfall (1955- 1978) for Welkom is given in Table 9 (Schulze, 1986).

Table 9: Long-term average monthly rainfall at Welkom (Schulze, 1986)

Rainfall	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Average (mm)	99	67	67	49	23	8	7	5	17	49	63	56	526
No. of rain days	10	9	9	7	4	2	2	1	2	7	9	10	72

3.3 Ambient Air Quality within the Region

3.3.1 Sources of Pollution in the Region

Neighbouring land-use in the surrounding of the proposed project comprises predominantly of agriculture activities. These land-uses contribute to baseline pollutant concentrations via fugitive and process emissions, vehicle tailpipe emissions, household fuel combustion, biomass burning and windblown dust from exposed areas.

3.3.1.1 Agriculture

Agriculture is a major land-use activity within and beyond the Project boundary. These activities include crop farming such as maize, and livestock farming. Particulate matter is the main pollutant of concern from agricultural activities as particulate emissions are derived from windblown dust, burning crop residue, and dust entrainment as a result of vehicles travelling along dirt roads. In addition, pollen grains, mould spores and plant and insect parts from agricultural activities all contribute to the particulate load. Should chemicals be used for crop spraying, they would typically result in odiferous emissions. Crop residue burning is also an additional source of particulate emissions and other toxins. Due to the small scale of farming activities these are regarded to have an insignificant cumulative impact.

Livestock farms, especially cattle, are also significant sources of fugitive dust especially when feedlots are used and the cattle trample in confined areas. Pollutants associated with dairy production for instance include ammonia (NH_3), hydrogen sulfide (H_2S), methane (CH_4), carbon dioxide (CO_2), oxides of nitrogen (NOx) and odour related trace gasses. According to the US-EPA, cattle emit methane through a digestive process that is unique to ruminant animals called enteric fermentation. The calf-cow sector of the beef industry was found to be the largest emitter of methane emissions. Where animals are densely confined the main pollutants of concern include dust from the animal movements, their feed and their manure, ammonia (NH_3) from the animal urine and manure, and hydrogen sulfide (H_2S) from manure pits.

Organic dust includes dandruff, dried manure, urine, feed, mould, fungi, bacteria and endotoxins (produced by bacteria, and viruses). Inorganic dust is composed of numerous aerosols from building, materials and the environment. Since the dust is biological it may react with the defence system of the respiratory tract. Odours and VOCs associated with animal manure is also a concern when cattle are kept in feedlots. The main impact from methane is on the dietary energy due to the reduction of carbon from the rumen. Dust and gasses levels are higher in winter or whenever animals are fed, handled or moved.

3.3.1.2 Mining Sources

Particulates represent the main pollutant of concern at mining operations, whether it is underground or opencast. The amount of dust emitted by these activities depends on the physical characteristics of the material, the way in which the

material is handled and the weather conditions (e.g. high wind speeds, rainfall, etc.). Mining of gold, as well as ore extraction and processing plants are all commercial activities situated in the region of the Project.

3.3.1.3 Domestic Fuel Combustion

Domestic households are known to have the potential to be one the most significant sources that contribute to poor air quality within residential areas. Individual households are low volume emitters, but their cumulative impact is significant. It is likely that households within the local communities or settlements utilize coal, paraffin and/or wood for cooking and/or space heating (mainly during winter) purposes. Pollutants arising from the combustion of wood include respirable particulates, CO and SO_2 with trace amounts of polycyclic aromatic hydrocarbons (PAHs), in particular benzo(a)pyrene and formaldehyde. Particulate emissions from wood burning have been found to contain about 50% elemental carbon and about 50% condensed hydrocarbons.

Coal is relatively inexpensive in the region and is easily accessible due to the proximity of the region to coal mines and the well-developed coal merchant industry. Coal burning emits a large amount of gaseous and particulate pollutants including SO_2, heavy metals, PM including heavy metals and inorganic ash, CO, PAHs (recognized carcinogens), NO_2 and various toxins. The main pollutants emitted from the combustion of paraffin are NO_2, particulates, CO and PAHs.

3.3.1.4 Biomass Burning

Biomass burning includes the burning of evergreen and deciduous forests, woodlands, grasslands, and agricultural lands. Within the project vicinity, crop-residue burning and wildfires (locally known as veld fires) may represent significant sources of combustion-related emissions. The frequency of wildfires in the grasslands varies between annual and triennial.

Biomass burning is an incomplete combustion process (Cachier, 1992), with carbon monoxide, methane and nitrogen dioxide gases being emitted. Approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% is left in the ashes, and it may be assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds (Held, et al., 1996). The visibility of the smoke plumes is attributed to the aerosol (particulate matter) content. In addition to the impact of biomass burning within the vicinity of the Project activity, long-range transported emissions from this source can be expected to impact on the air quality between the months of August to October. It is impossible to control this source of atmospheric pollution loading; however, it should be noted as part of the background or baseline condition before considering the impacts of other local sources.

3.3.1.5 Fugitive Dust Sources

These sources are termed fugitive because they are not discharged to the atmosphere in a confined flow stream. Sources of fugitive dust identified in the study area include paved and unpaved roads and wind erosion of sparsely vegetated surfaces.

3.3.1.6 Unpaved and paved roads

Emissions from unpaved roads constitute a major source of emissions to the atmosphere in the South African context. When a vehicle travels on an unpaved road the force of the wheels on the road surface causes pulverization of surface material. Particles are lifted and dropped from the rolling wheels, and the road surface is exposed to strong turbulent air shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. Dust emissions from unpaved roads vary in relation to the vehicle traffic and the silt loading on the roads. Unpaved roads in the region are mainly haul and access roads.

Emissions from paved roads are significantly less than those originating from unpaved roads, however they do contribute to the particulate load of the atmosphere. Particulate emissions occur whenever vehicles travel over a paved surface. The fugitive dust emissions are due to the re-suspension of loose material on the road surface. Paved roads in the region include the R710, M4, R708 and R30.

3.3.1.7 Wind erosion of open areas

Windblown dust generates from natural and anthropogenic sources. For wind erosion to occur, the wind speed needs to exceed a certain threshold, called the threshold velocity. This relates to gravity and the inter-particle cohesion that resists removal. Surface properties such as soil texture, soil moisture and vegetation cover influence the removal potential. Conversely, the friction velocity or wind shear at the surface is related to atmospheric flow conditions and surface aerodynamic properties. Thus, for particles to become airborne, its erosion potential has to be restored; that is, the wind shear at the surface must exceed the gravitational and cohesive forces acting upon them, called the threshold friction velocity. Every time a surface is disturbed, its erosion potential is restored (US EPA, 2004). Erodible surfaces may occur as a result of agriculture and/or grazing activities.

3.3.1.8 Vehicle Tailpipe Emissions

Emissions resulting from motor vehicles can be grouped into primary and secondary pollutants. While primary pollutants are emitted directly into the atmosphere, secondary pollutants form in the atmosphere as a result of chemical reactions. Significant primary pollutants emitted combustion engines include carbon dioxide (CO_2), carbon (C), sulfur dioxide (SO_2), oxides of nitrogen (mainly NO), particulates and lead. Secondary pollutants include NO_2, photochemical oxidants such as ozone, sulfur acid, sulphates, nitric acid, and nitrate aerosols (particulate matter). Vehicle type (i.e. model-year, fuel delivery system), fuel (i.e. oxygen content), operating (i.e. vehicle speed, load) and environmental parameters (i.e. altitude, humidity) influence vehicle emission rates.

Transport in the vicinity of the Project is via trucks and private vehicles along the R710, M4, R708 and R30 roads (which are the main sources of vehicle tailpipe emissions), as well as vehicles and machinery travelling on unpaved and private roads.

3.3.2 Air Quality Sampling Results

Airshed was appointed by Environmental Impact Management Services (EIMS) (Pty) Ltd to sample identified potential pollutants of concern, as stipulated in the Environmental Management Programme (EMPr), around the Tetra4 Virginia Compression Plant. The passive sampling campaign used Radiello® passive diffusive samplers at three (3) sites around the property and at an upwind background site located near a residential receptor. Sampling and assessment of ambient concentrations include sulfur dioxide (SO_2); nitrogen dioxide (NO_2); hydrogen fluoride (HF) and, total volatile organic compounds (TVOCs).

Passive sampling was conducted at two (2) locations near the boundary of the facility and at a background location close to a nearby residential receptor. Sampling site locations are shown in Figure 9, with the coordinates, elevation and site classification detailed in Table 10.

Table 10: Sampling site coordinates, elevation, and classification

Site ID	Site location	Latitude	Longitude	Elevation (m)	Classification
TET1	HDR1 Wellhead	-28.12576	26.718934	1 299	Boundary
TET2	HDR1 Compressor	-28.12701	26.719149	1 299	Boundary
TET3	Background site	-28.12011	26.720198	1 296	Residential

The aim of the passive sampling campaign was to quantify ambient air pollutant concentrations which could present odour and health issues for Tetra4 personnel and the neighbouring communities. Two 14-day campaigns were conducted at the Tetra4 Virginia Compression Plant, one in summer and one in winter since 2019. Pollutants assessed included SO_2, NO_2, and VOCs.

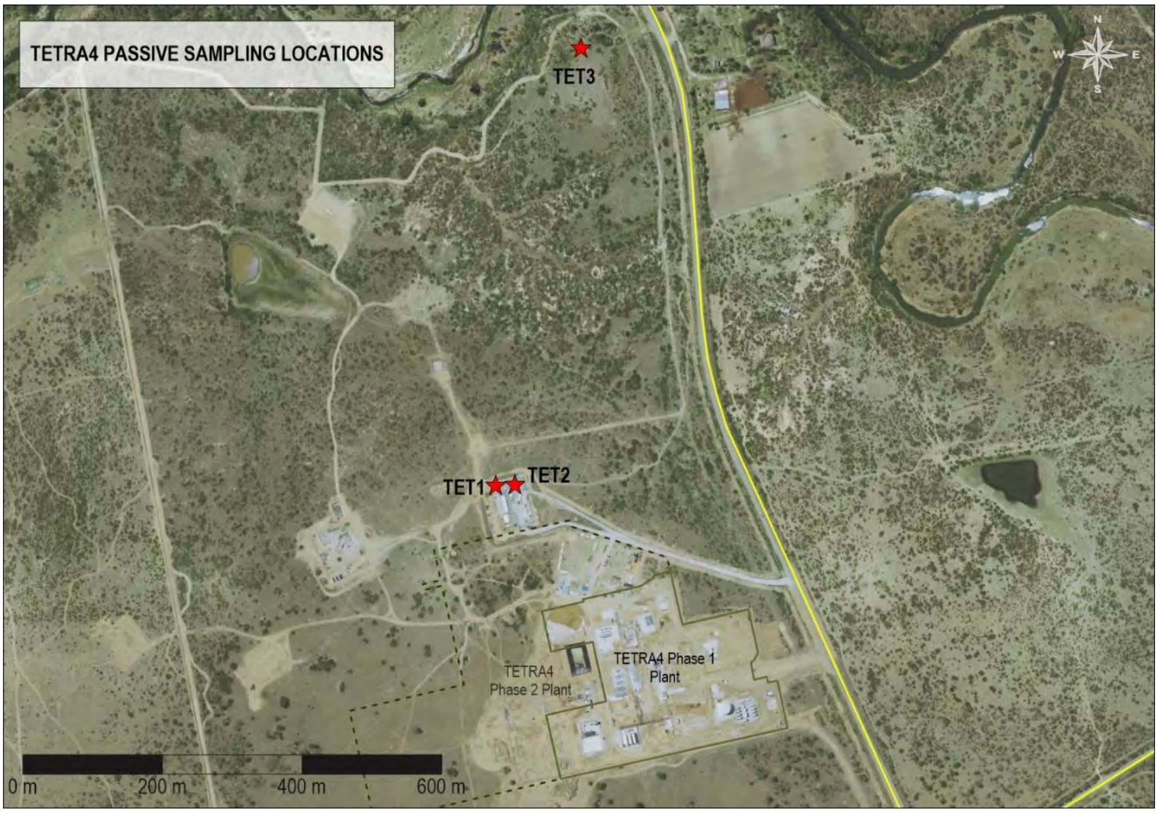

Figure 9: Tetra4 passive sampling locations

Radiello® passive diffusive tubes were used to sample pollutant concentrations at the three sampling locations. Passive diffusive sampling relies on the movement of pollutants through a diffusive surface onto an adsorbent. After sampling, the analytes are chemically desorbed by solvent extraction or thermally desorbed and analysed. Passive sampling does not involve the use of pumping systems and does not require electricity and is therefore an ideal sampling method at rural sampling locations. The concentration of pollutants adsorbed during the exposure period can be calculated to time-frames comparable with the NAAQS for criteria pollutants, international chronic inhalation reference concentrations, and inhalation unit risk factors.

Passive diffusive samplers were placed in a manufacturer approved rain shelter and attached to a post at eye level, ensuring protection against adverse weather conditions while allowing adequate ventilation. Supporting plates were assembled and operated according to manufacturer instructions. The analysis of the adsorbed compounds was conducted by the accredited Biograde Laboratory Services (SANAS Facility T0574) in Pretoria.

To compare the average sampled concentrations to long term (annual average) evaluation criteria (Section 2.2), equivalent annual average concentrations were extrapolated. For extrapolating time averaging periods from 24 hours to 1 year, Beychock (2005)[2], recommends the following equation:

$$\frac{C_x}{C_p} = \left(\frac{t_p}{t_x}\right)^{0.53}$$

where:

C_x *and* C_p are concentrations over any two averaging periods between 24 hours and 1 year,

[2] Beychock, M. R. (2005). *Fundamentals of Stack Gas Dispersion* (4th Edition ed.).

t_x *and* t_p are corresponding averaging times in days.

All pollutant concentrations, including the suite of VOC compounds detected, were screened against NAAQS, chronic inhalation reference concentrations, and inhalation unit risk factors (for increased life-time cancer risk) published by international agencies.

Limitations include:

1. Theoretical hourly peak concentrations were extrapolated from each 14 or 15-day campaign. It is not possible to confirm the date or time of peak concentrations, or if any peaks occurred.
2. Equivalent annual average concentrations of pollutants were calculated based from campaign length averages for each of the sampling campaigns.
3. Where campaign length concentrations were reported as below detection level, the detection level was conservatively used as the campaign length concentration.

All period-length concentrations of SO_2, NO_2, and HF were extrapolated to equivalent hourly, daily, and annual average concentrations are listed in Tables 11, 12 and 13 to allow for comparison against the assessment criteria including, the NAAQS (Table 4). Period-length HF concentrations at all sites for both sampling periods were below detection level and therefore extrapolated concentrations are not presented. Equivalent SO_2 concentrations were compliant with all applicable NAAQS for hourly, daily, and annual averaging periods (Table 4).

Extrapolated results from the seven (7) sampling campaigns indicate low background SO_2 concentrations, falling well within the NAAQSs. Background NO_2 concentrations indicate fairly high short-term (hourly) levels but still below the NAAQ limit and well below the annual limit. Sampled concentrations of HF are very low. Chronic exposure to total VOCs (TVOCs) concentration was less than 6 µg/m³ at all sites, and therefore lower than the 100 µg/m³ health-effect screening level (Table 14).

Table 11: Exposure period and extrapolated concentrations of SO_2 for Campaigns 2019 to 2022 (all units: µg/m³)

Campaign	Sampling period	Annual	Daily	Hourly
	NAAQS	50	125	350
Summer 2019	Mar/Apr 2019	0.2	5.5	32.50
Winter 2019	Aug-19	0.1	2.6	16.00
Summer 2020	Mar-20	5.0	0.2	29.50
Winter 2020	Jul/Aug 2020	0.3	6.3	37.10
Summer 2021	Mar/Apr 2021	0.2	5.1	30.10
Winter 2021	Jul/Aug 2021	0.3	6.2	37.00
Summer 2022	Feb-22	0.3	5.8	34.20
Average		0.9	4.53	30.91

Table 12: Exposure period and extrapolated concentrations of NO_2 for Campaigns 2019 to 2022 (all units: µg/m³)

Campaign	Sampling period	Annual	Hourly
	NAAQS	40	200
Summer 2019	Mar/Apr 2019	0.9	115.00
Winter 2019	Aug-19	0.8	107.00
Summer 2020	Mar-20	0.5	67.60
Winter 2020	Jul/Aug 2020	1.0	133.74
Summer 2021	Mar/Apr 2021	0.7	96.00
Winter 2021	Jul/Aug 2021	1.1	150.50

Summer 2022	Feb-22	0.6	86.10
Average		0.8	107.99

Table 13: Exposure period and extrapolated concentrations of HF for Campaigns 2019 to 2022 (all units: µg/m³)

Campaign	Sampling period	Annual	Hourly
	NAAQS	BDL	BDL
Summer 2019	Mar/Apr 2019	BDL	BDL
Winter 2019	Aug-19	BDL	BDL
Summer 2020	Mar-20	BDL	BDL
Winter 2020	Jul/Aug 2020	0.01	1.88
Summer 2021	Mar/Apr 2021	0.01	1.55
Winter 2021	Jul/Aug 2021	0.01	1.87
Summer 2022	Feb-22	0.02	2.68
Average		0.01	2.00

Notes: BDL – below detection limit

Table 14: Exposure period and extrapolated concentrations of VOCs for Campaigns 2019 to 2022 (all units: µg/m³)

Campaign	Sampling period	Annual
	Health-effect screening level	100 (a)
Summer 2019	Mar/Apr 2019	6.5
Winter 2019	Aug-19	3.1
Summer 2020	Mar-20	5.1
Winter 2020	Jul/Aug 2020	3.10
Summer 2021	Mar/Apr 2021	3.20
Winter 2021	Jul/Aug 2021	3.80
Summer 2022	Feb-22	7.50
Average		4.6

Notes: (a) Texas Commission on Environmental Quality (TCEQ) inhalation reference concentrations (diesel fuel used as indicator)

4 Impact on the Receiving Environment

4.1 Atmospheric Emissions Inventory

The establishment of a comprehensive emission inventory formed the basis for the assessment of the air quality impacts from the project's operations on the receiving environment. The proposed project operations will consist of planning and design, construction, operational, decommissioning and rehabilitation and closure phases. Emissions are quantified for criteria pollutants associated with natural gas production operations and can be divided into two categories, namely; fugitive emissions and process emissions. Fugitive emissions refer to emissions that are spatially distributed over a wide area and not confined to a specific discharge point as would be the case for process related emissions (IFC, 2007).

A discussion on the expected activities typical of natural gas production operations is provided in the sections below with a summary on the typical activities and sources as well as emission inventory for the construction, operational, decommissioning and rehabilitation and closure phases of the Project.

4.1.1 Planning and Design Phase

The planning and design phase of the project is not expected to generate any routine atmospheric emissions. These activities will be intermittent in nature and the extents of the associated emissions are typically minimal. The only impact to be assessed in this study during the planning and design phase is fugitive emissions from exploration drilling.

4.1.2 Construction Phase

Construction activities are a source of primarily criteria pollutants, including CO, SO_2, NO_X and particulate matter (PM, PM_{10} and $PM_{2.5}$). Air emissions (Table 15) would occur from the construction of the Cluster 2 plant, well heads, booster and compressor stations and access roads (where necessary), rig-move/drilling and associated traffic, pipeline installation and associated traffic, and wind erosion of exposed areas during construction activities. Emissions would include fugitive PM_{10} and $PM_{2.5}$ emissions from construction activities and traffic to and from the construction sites. Diesel particulate matter (DPM) and other criteria pollutant emissions would occur from diesel combustion in haul trucks and heavy construction equipment. Malodourous compounds, including H_2S, could be released from the well cuttings, depending on the quantity of hydrocarbon (HC) compounds. It should be noted that venting and flaring (completion and testing) is not planned as part of the Project development.

Table 15: Potential air pollutants emitted during typical construction phase for natural gas production

Location of Emission	CO_2	CO	NO/NO_2	SO_2	VOCs	PM	Odours	Total HC
Road Construction	✓ a	✓	✓	✓	✓	✓		
Pipeline Construction	✓	✓	✓	✓	✓	✓		
Well Construction	✓	✓	✓	✓	✓	✓		
Booster Station Construction	✓	✓	✓	✓	✓	✓		
Compressor Station Construction	✓	✓	✓	✓	✓	✓		
Plant construction	✓	✓	✓	✓	✓	✓		
Road Traffic	✓	✓	✓	✓	✓	✓		
Drilling	✓	✓	✓	✓	✓	✓	✓	✓

Notes: The size of the tick is used to indicate the potential extent of release of emissions; and is not directly related to quantity of emissions

4.1.2.1 General Infrastructure Construction

Fugitive particulate emissions due to the construction of roads, pipelines, wells, booster and compressor stations and the Cluster 2 plant were calculated using an area wide average particulate generation emission factor (US EPA AP-42, Section 13.2.3, "Heavy Construction Operations", US EPA 2004).

The US-EPA documents emissions factors which aim to provide a general rule-of-thumb as to the magnitude of emissions which may be anticipated from construction operations. The quantity of dust emissions is assumed to be proportional to the area of land being worked and the level of construction activity. The approximate emission factors for general construction activity operations are given as:

$$E = 2.69 \text{ Mg/hectare/month of activity } (269 \text{ g/m}^2\text{/month})$$

The PM_{10} fraction is given as ~39% of the US-EPA total suspended particulate factor. These emission factors are most applicable to construction operations with (i) medium activity levels, (ii) moderate silt contents, and (iii) semiarid climates. The emission factor for TSP considers 42 hours of work per week of construction activity. Test data were not sufficient to derive the specific dependence of dust emissions on correction parameters.

The dimensions of sources used in the model, footprint area (in m²), and estimated construction periods (in days) for each construction activity are given in Table 16. Estimated average emissions (in kg/hr) due to general infrastructure construction are presented in Table 19.

Table 16: Estimated fugitive particulate emissions (in kg/hr) due to general infrastructure construction

Location of Emission	Dimensions	Area (m²)	Period (days)
Road construction (per section)	500m x 10m[(a)]	5 000	15 [(f)(g)]
Pipeline construction (per section)	500m x 5m[(b)]	2 500	15 [(f)(g)]
Well construction (single)	30m x 30m[(c)]	900	150 [(d)]
Booster station construction (single)	30m x 30m[(c)]	900	150 [(d)]
Compressor station construction (single)	60m x 60m[(d)]	3 600	150 [(d)]
Plant construction	See note [(e)]	93 979	750 [(d)]

Notes:

(a) An area measuring 500 m by 10 m was simulated to represent proposed road construction, since the road construction schedule is not yet known and activities will only occur at a section per time.

(b) Similarly, an area measuring 500 m by 5 m was simulated to represent proposed pipeline construction, since pipeline construction activities will only occur at a section per time.

(c) Area assumed for equipment movement and setup

(d) Information provided by engineer

(e) Digitised from project layout

(f) Assumed to be same construction period as that for a single well, viz. 15 days

(g) Construction of all roads, pipelines, wells, booster/compressor stations was given as 150 days (maximum)

4.1.2.2 Engine Exhaust Emissions

Engine exhaust emissions cover a wide variety of industrial applications of both gasoline and diesel internal combustion engines, including mobile (road sources, i.e. buses, trucks, etc. and non-road sources, such as forklifts, backhoes, etc.) and non-mobile sources (such as power generators and pumps). The Australian NPi (2008) manual for combustion engines were used to estimate emission rates for this equipment.

Table 17: Description of equipment per construction activity

Construction Activity	Description of Equipment	Capacity (horsepower) [a]	Load Factor [a]	Number of Units per Equipment	No of Equipment Hours per Year[b]
Drilling	Truck mounted crane (high-up)	325	40%	1	1500
	Concrete mixer truck	325	59%	1	1500
	Forklift	100	20%	1	1500
	Cable percussion drilling rig	425	59%	1	1500
	Water bowser discharging	325	55%	1	1500
Construction of Well/ Booster station/ Compressor station	Dozer	410	55%	1	1500
	Tracked Excavator	268	50%	1	1500
	Grader	297	50%	1	1500
	Water bowser discharging	325	55%	1	1500
	Tractor towing water bowser	530	55%	1	1500
	Truck with trailer	325	50%	1	1500
	Generator [c]	188	100%	1	1500
Construction of Pipeline	Back-actor	93	40%	1	1500
	Truck mounted crane (high-up)	325	40%	1	1500
	Compactor	315	50%	1	1500
	Tracked Excavator	268	50%	1	1500
	Grader	297	50%	1	1500
	Ditcher/Digging wheel	150	55%	1	1500
	Backhoe (TLB)	93	40%	2	1500
Construction of Plant	Dozer	410	55%	2	3650
	Tracked Excavator	268	50%	4	3650
	Grader	297	50%	2	3650
	Water bowser discharging	325	55%	2	3650
	Tractor towing water bowser	530	55%	1	3650
	Hauling: Dump truck	351	50%	2	3650
	Backhoe (TLB)	93	40%	4	3650
	Truck mounted crane (high-up)	325	40%	1	3650
	Rough terrain / telescope crane	516	25%	1	3650
	Compactor	315	50%	1	3650
	Forklift	100	20%	2	3650
	Low-bed/flat-bed truck	325	50%	2	3650
	Hydraulic hammer	600	59%	1	3650
	Concrete mixer truck	325	59%	4	3650

Notes:

(a) Capacity of equipment and load factors were obtained from a similar study for the construction of well fields https://www.nrc.gov/docs/ML1306/ML13067A306.pdf
(b) Maximum construction period for wells, booster stations, compressor stations, roads and pipelines, was given as 150 days. Construction working hours were given as 10 hours per day, seven days a week.
(c) Generator only applicable to booster station construction

Table 18: Emission factors (in lb/hp-hr) for diesel industrial engine exhaust emissions

Description of Equipment	Emission factor (lb/hp-hr)					
	NO_x	CO	SO_2	PM_{10}	$PM_{2.5}$	VOC
Back-actor [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Backhoe (TLB) [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Cable percussion drilling rig [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Compactor [c]	0.02877	0.01328	0.000014	0.00171	0.00157	0.00214
Concrete mixer truck [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Ditcher/Digging wheel [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Dozer [d]	0.01792	0.00773	0.000012	0.00091	0.00083	0.00082
Forklift [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Generator [a]	0.031	0.0067	0.000007	0.0022	0.0022	0.0023
Grader [e]	0.01573	0.00339	0.000012	0.00138	0.00127	0.00079
Hauling: Dump truck [f]	0.01792	0.00773	0.000013	0.00111	0.00102	0.00082
Hydraulic hammer [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Low-bed/flat-bed truck [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Rough terrain/ telescope crane [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Tracked Excavator [g]	0.02055	0.00498	0.000012	0.00144	0.00133	0.00245
Tractor towing water bowser [h]	0.02630	0.01618	0.000012	0.00279	0.00256	0.00388
Truck mounted crane (high-up) [b]	0.02433	0.01013	0.000013	0.00199	0.00182	0.00222
Truck with trailer [f]	0.01792	0.00773	0.000013	0.00111	0.00102	0.00082
Water bowser discharging [h]	0.02630	0.01618	0.000012	0.00279	0.00256	0.00388

Notes:

(a) Australian NPi Table 49, Emission factors for stationary small (less than 450 kW) diesel engines
(b) Australian NPi Table 35, Emission factors for diesel industrial vehicle (miscellaneous) exhaust emissions
(c) Australian NPi Table 34, Emission factors for diesel industrial vehicle (roller) exhaust emissions
(d) Australian NPi Table 28, Emission factors for diesel industrial vehicle (wheeled dozer) exhaust emissions
(e) Australian NPi Table 30, Emission factors for diesel industrial vehicle (motor grader) exhaust emissions
(f) Australian NPi Table 33, Emission factors for diesel industrial vehicle (off-highway truck) exhaust emissions
(g) Australian NPi Table 32, Emission factors for diesel industrial vehicle (track-type loader) exhaust emissions
(h) Australian NPi Table 27, Emission factors for diesel industrial vehicle (wheeled tractor) exhaust emissions

Engine exhaust emissions were quantified through the application of emission factors (specified in Table 18) as published by the Australian NPI, to the power output and loading factor of each type of equipment during a unit of use (specified in Table 17). Estimated average emissions (in kg/hr) due to engine exhaust emissions are presented in Table 19.

4.1.2.3 Summary of Calculated Emission Rates for Construction

A summary of emissions quantified due to general construction activities and equipment and vehicle exhaust is provided in Table 19.

Table 19: Total estimated average emission rates (in kg/hr) due to the construction of general infrastructure and equipment and vehicle exhaust

Construction Emissions - Area wide Construction							
Sources	Emissions (kg/hr)						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NOx	CO	SO_2
Proposed well construction (single well)	0.03	0.52	0.80				
Proposed booster station construction (single station)	0.03	0.52	0.80				
Proposed compressor station construction (single station)	0.14	2.09	3.19				
Pipeline construction (500 m)	0.09	1.45	2.21				
Road construction (500 m)	0.19	2.90	4.42				
Plant construction	1.72	26.49	40.45				
Construction Emissions - Equipment and Vehicle Exhaust							
Sources	Emissions (kg/hr)						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NOx	CO	SO_2
Proposed well construction (single well)	1.57	1.71		2.09	19.74	9.37	0.01
Proposed booster station construction (single station) [(a)]	1.06	1.14		1.37	13.71	5.91	0.00
Proposed compressor station construction (single station)	0.87	0.95		1.17	11.07	5.34	0.01
Pipeline construction (500 m)	0.55	0.60		0.68	7.94	2.97	0.00
Road construction (500 m)	0.55	0.60		0.86	7.94	2.97	0.00
Plant construction	3.26	3.55		4.20	44.33	18.89	0.02

Notes:

(a) Including emissions from a 140 kW diesel generator at booster station

4.1.3 Operational Phase

Operational activities were assumed to take place 24 hour per day, 7 days per week. Sources of emission and associated pollutants considered in the emissions inventory for the operational phase include:

- Combined LNG/LHe plant flaring emissions – CO, NO_X and VOC
- Generator emissions at booster stations – $PM_{2.5}$, PM_{10}, CO, SO_2, NO_X and VOCs
- Entrained PM from unpaved roads – $PM_{2.5}$, PM_{10}, and TSP.

In the quantification of these releases use was made of the predictive emission factors published by

- the US EPA AP-42, Section 13.2.2 "Unpaved Roads" to estimate particulate emissions from unpaved road surfaces;
- the Australian NPi Manual for Combustion Engines (2008) Table 49 to estimate $PM_{2.5}$, PM_{10}, CO, SO_2, NO_X and VOC emissions from generators with a power rating less than 450 kW; and
- the Australian NPi Manual for Oil and Gas Extraction and Production (2013) Table 8 to estimate CO, NO_X and VOC emissions from industrial flares.

4.1.3.1 Vehicle Entrained Dust from Unpaved Roads

Vehicle-entrained dust emissions have been found to account for a great portion of fugitive dust emissions from industrial operations. The force of the wheels of vehicles travelling on unpaved roads causes the pulverisation of surface material. Particles are lifted and dropped from the rotating wheels, and the road surface is exposed to strong air currents in turbulent shear with the surface. The turbulent wake behind the vehicle continues to act on the road surface after the vehicle has passed. The quantity of dust emissions from unpaved roads varies linearly with the volume of traffic.

Nitrogen (N_2) will be trucked to the plant, and the LNG and LHe products will be exported by truck from the plant via unpaved road. The number of truck trips per day was given as 20 trips per day (information provided by the client).

4.1.3.2 Emissions from Stationary Engines

Stationary engines are those that do not power vehicles but are used for some other operation (e.g., generators). The three primary fuels for combustion engines are petrol, diesel and natural gas. It was assumed that the three proposed compressor stations would be powered by electricity (due to their locations near existing power lines), but the booster stations may require generators in order to operate in the field. Emissions due to diesel generators located at the respective booster stations were calculated based on engine power and operating hours.

4.1.3.3 Flaring

Gas is flared on oil and gas production installations for safety reasons. For example, a lack of process or transport capacity for gas, a continuous surplus gas flow, start-ups, maintenance and emergency (need for pressure relief) could all lead to flaring actions (NPi, 2013). The emissions of pollutants from flaring are either unburnt fuel or by-products of the combustion process. Emission factors from the US EPA AP42, the California Air Resources Board (CARB) and the European Pollutant Release and Transfer Register (E-PRTR) Guidelines indicate that emissions of *metals* from flaring are negligible.

The plant layout includes a wet flare system to collect natural gas vents containing humidity, and a cold flare system to collect natural gas dropouts. Warm or cold flare header blanket gas and pilot gas will be emitted either continuously (as part of normal operations) or under emergency conditions (as part of an intermittent design case).

A summary of emission sources quantified, estimation techniques applied, and source input parameters are included in Table 20. Estimated average emissions, per source group or activity, are presented in Table 21.

Table 20: Emission estimation techniques and metrics (operational phase)

Product Transport (Vehicle Entrained Dust on Unpaved Roads)	US EPA emission factor equation (US EPA, 2006) $$E = k \cdot \left(\frac{s}{12}\right)^{a} \cdot \left(\frac{W}{3}\right)^{0.45} \cdot 281.9$$ Where EF is the emission factor in g/vehicle kilometre travelled (VKT) k is the particle size multiplier (k_{TSP} – 4.9, k_{PM10} – 1.5, $k_{PM2.5}$ – 0.15) a is an empirical constant (a_{TSP} – 0.7, a_{PM10} – 0.9, $a_{PM2.5}$ – 0.9) s is the road surface material silt content in % W is the average vehicle weight in tonnes	Transport activities include the transport of LNG and Helium product and N_2 import on unpaved roads from the plant site towards the paved provincial road R30. VKT were calculated from road lengths, truck capacities and the number of trips required for transporting ore, waste and product. Average capacity of trucks = 24 tonnes (given) Average vehicle weight in tonnes = 25.68 (calculated) A default road surface silt content of 15% (US EPA, 2006) was applied in calculations Hours of operation: 24 hours per day, 365 days per annum Metrics: • LNG and Helium production rates = 470 tons/day (given) • Unpaved road length to paved road R30 = 500 m • Road width = 10m (assumed) • Number of trips per day for product delivery =20 (calculated)
Booster Station Emissions	NPI single valued emission factors for diesel internal combustion engines (generators) (NPI, 2008) CO – 4.06 x10^{-03} kg/kWh $PM_{2.5}$ – 1.31 x10^{-030} kg/kWh PM_{10} – 1.34 x10^{-03} kg/kWh SO_2 – 4.28 x10^{-06} kg/kWh VOC – 1.37 x10^{-03} kg/kWh NOx – 1.88 x10^{-02} kg/kWh	Emission rate was estimated for diesel generators at each booster station using their individual power rating and load factor. The emissions for plant operation) utilizing various equipment were quantified based on: • Hours/day and days/annum: 24 hours/ day, 365 days maximum Equipment list: Operation generator – 140 kW <u>Specifications for Caterpillar D150 GC</u> • Flow rate = 15.3 m^3/min • Stack temperature = 441 ^{o}C <u>Assumption based on similar engine type</u> • Stack diameter = 0.2 m • Stack height = 3.0 m
Flaring at Plant (Normal and/or Upset conditions)	NPI single valued emission factors for flaring (NPI, 2013) <u>Emission Factor</u> VOC **–** 15 kg/t of gas NOx **–**1.5 kg/t of gas CO **–** 8.7 kg/t of gas PM_{10}, $PM_{2.5}$ **–** 0 kg/t of gas (non-smoking flares)	Flaring Metrics on the Basis of Continuous or Intermittent design Flare emissions based on two types of design were given as: <u>Continuous design</u> • Flue gas emissions (constant) = 18 kg/hr <u>Intermittent design (Emergency/Upset conditions)</u> • Flue gas emissions (warm flare) = 37 048 kg/hr • Flue gas emissions (cold flare) = 10 539 kg/hr

	PM_{10}, $PM_{2.5}$ – 0.056 kg/t of gas (lightly smoking flares) PM_{10}, $PM_{2.5}$ – 0.25 kg/t of gas (average smoking flares) PM_{10}, $PM_{2.5}$ – 0.38 kg/t of gas (heavily smoking flares) <u>NOTE:</u> The EF of PM from flaring is based on soot, assumed to apply to PM_{10}, $PM_{2.5}$	It was assumed that the flare stack would not give off any soot (hence no PM emissions) Assumptions on flare stack metrics were made based on similar operation elsewhere (Burger & Akinshipe, 2014). • Exit velocity = 20 m/s • Exit temperature = 1400 °C • Calculated heat release = 178 562.83 MJ/s • Release height = 4.0 m (not confirmed yet, conservative assumption) • Radiation loss = 30% Venting is not planned as part of the routine operation for the Project (consequently, odour impacts will be typically minimal).

Table 21: Estimated average emission rates per source (operational phase)

Operational Phase Emissions – Routine Conditions							
Sources	Emissions (tpa)						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NOx	CO	SO_2
Road (from plant to public road)	0.99	9.88	30.88				
Plant emissions (continuous flare)				2.39	0.24	1.39	
Booster station emissions (generator)	1.61	1.64		1.68	23.12	4.98	0.01
Operational Phase Emissions – Upset Conditions							
Sources	Emissions (tpa)						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NOx	CO	SO_2
Emergency flaring at plant (warm flare)				202.8	20.28	117.7	
Emergency flaring at plant (cold flare)				57.50	5.77	33.47	

4.1.4 Decommissioning, Rehabilitation and Closure Phase

All operational activities will have ceased by the rehabilitation and closure phase of the project. This will obviously result in a positive impact on the surrounding environment and human health. The potential for impacts during the closure phase will therefore depend on the extent of rehabilitation efforts to be undertaken at the plant, production wells, pipeline and roads. While impacts associated with rehabilitation and closure phase have been qualitatively assessed and finalized during the scoping phase, the following impacts will be assessed for the decommissioning phase of the Project:

Pollutants of concern during the decommissioning, rehabilitation and closure phase include:

- Fugitive emissions (dust) – This pertains to the potential entrainment of dust by machinery, the potential release of particulates from combustion engines used during decommissioning/ removal of all berms, trenches and other stormwater infrastructure and decommissioning/removal of pipeline infrastructure, and the potential entrainment of dust and particulates during removal of waste and recycling of recyclable / reclaimable waste.

4.2 Atmospheric Dispersion Modelling

The assessment of the impact of the project's operations on the environment is discussed in this section. To assess impact on human health and the environment the following important aspects need to be considered:

- The criteria against which impacts are assessed (Section 2.2);
- The potential of the atmosphere to disperse and dilute pollutants emitted by the project (Section 3.2); and
- The methodology followed in determining ambient pollutant concentrations and dustfall rates (Section 4.2)

The impact of operations on the atmospheric environment was determined through the simulation of dustfall rates and ambient pollutant concentrations. Dispersion models simulate ambient pollutant concentrations and dustfall rates as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose.

4.2.1 Dispersion Model Selection

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. One of the most widely used Gaussian plume model is the US EPA AERMOD model that was used in this study. AERMOD is a model developed with the support of AERMIC, whose objective has been to include state-of the-art science in regulatory models (Hanna, Egan, Purdum, & Wagler, 1999). AERMOD is a dispersion modelling system with three components, namely: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD terrain pre-processor), and AERMET (AERMOD meteorological pre-processor).

AERMOD is an advanced new-generation model. It is designed to predict pollution concentrations from continuous point, flare, area, line, and volume sources. AERMOD offers new and potentially improved algorithms for plume rise and buoyancy, and the computation of vertical profiles of wind, turbulence and temperature however retains the single straight-line trajectory limitation. AERMET is a meteorological pre-processor for AERMOD. Input data can come from hourly cloud cover observations, surface meteorological observations and twice-a-day upper air soundings. Output includes surface meteorological observations and parameters and vertical profiles of several atmospheric parameters. AERMAP is a terrain pre-processor designed to simplify and standardise the input of terrain data for AERMOD. Input data includes receptor terrain elevation data. The terrain data may be in the form of digital terrain data. The output includes, for each receptor, location, and height scale, which are elevations used for the computation of air flow around hills.

A disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Input data types required for the AERMOD model include: Source data, meteorological data (pre-processed by the AERMET model), terrain data, information on the nature of the receptor grid and pre-development or background pollutant concentrations or dustfall rates. Version 10.0 of AERMOD and its pre-processors were used in the study.

4.2.1.1 Meteorological Requirements

For the purpose of this study, surface and profile weather data for the period January 2019 to December 2021 was obtained from the South African Weather Service station at Welkom (Section 3.2).

4.2.1.2 Source and Emission Data Requirements

The AERMOD model is able to model point, jet, area, line and volume sources. Sources were modelled as follows:

- Plant flare emissions – modelled as flare sources;
- Generator emissions at booster stations – modelled as point sources; and
- Area wide construction, unpaved roads and vehicle exhaust – modelled as area sources.

The sources and AQSRs that were included in the AERMOD model are shown in Figure 10.

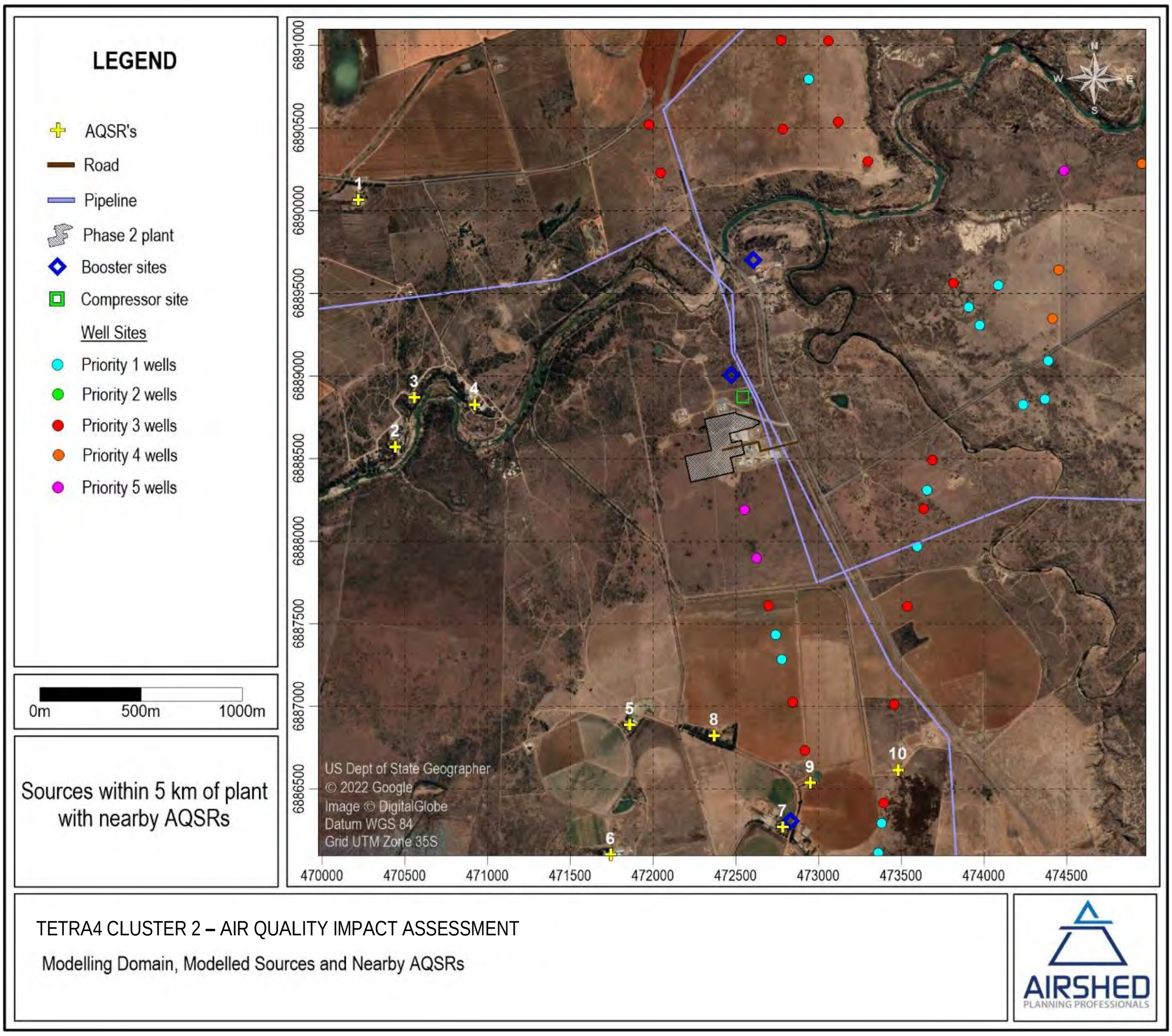

Figure 10: Sources and AQSRs included in the AERMOD model

4.2.1.3 Simulation of NO/NO_2 Transformation

Nitrogen monoxide (NO) emissions are rapidly converted in the atmosphere into the much more poisonous nitrogen dioxide (NO_2) which is regulated by SA NAAQS. The rate of this conversion process is determined by the rate of the physical processes of dispersion and mixing of the plume and the chemical reaction rates as well as the local atmospheric ozone concentration. In the absence of accurate ozone (O_3) data required to estimate the conversion ratio, 20% of all NOx was assumed to be NO_2 as per literature (Howard, 1988).

4.2.1.4 Modelling Domain

The dispersion of pollutants expected to arise from the project was modelled for the following aspects or activities:

- Proposed plant, compressor station, wells, booster stations, road and pipelines – an area covering 5 km (east-west) by 5 km (north-south)

A grid matrix resolution of 100 m was used, with the various project aspects or activities located centrally. AERMOD calculates ground-level (1.5 m above ground level) concentrations and dustfall rates at each grid and discrete receptor point.

4.2.1.5 Presentation of Results

Dispersion modelling was undertaken to determine highest hourly, highest daily and annual average ground level concentrations as well as dustfall rates for each of the pollutants considered in the study. Averaging periods were selected to facilitate the comparison of predicted pollutant concentrations to relevant ambient air quality and inhalation health criteria as well as dustfall regulations. Results are primarily provided in form of isopleths to present areas of exceedance of assessment criteria. Ground level concentration or dustfall isopleths presented in this section depict interpolated values from the concentrations simulated by AERMOD for each of the receptor grid points specified. The reader should take note that isopleths showing 1-hour or 24-hour concentrations reflect the 2nd highest 1-hour or 24-hour concentration simulated at grid receptor locations and not the frequency at which the specific concentration occurred over the simulation period. Separate isopleth plots are given to indicate the frequencies of exceedance where applicable.

Isopleth plots reflect the incremental ground level concentrations (GLCs) for $PM_{2.5}$, PM_{10}, NO_2 and SO_2 and VOCs. While there is a case for assessing the impacts of the proposed project individually, i.e. the incremental effect, potentially affected receptors are more interested in the overall end result, i.e. the cumulative effect. The National Environmental Management Act (NEMA), 107 of 1998 Act 1991 also requires this. This means that modelling results should be added to current background air pollution discharged by other sources. However, due to the unavailability of ambient baseline concentrations, the total cumulative pollutant concentrations could not be quantitatively determined; but qualitative assessment and commentary is provided in the discussion of impact significance in Section 5.

It should also be noted that ambient air quality criteria applies to areas where the Occupational Health and Safety regulations do not apply, thus outside the property or lease area. Ambient air quality criteria are therefore not occupational health indicators but applicable to areas where the general public has access i.e. off-site.

4.3 Dispersion Simulation Results, Health Risk and Nuisance Screening

Pollutants with the potential to result in human health impacts which are assessed in this study include CO, NO_2, $PM_{2.5}$, PM_{10}, SO_2 and VOC. Dustfall is assessed for its nuisance potential.

The impact assessment methodology as discussed under section 4.2 was followed. Isopleth plots are provided for all pollutants where exceedances of the relevant NAAQSs were simulated. Isopleth plots reflect the incremental GLCs and deposition rates for all pollutants assessed.

4.3.1 Construction Phase Results

4.3.1.1 Proposed Wells/Booster Stations

Simulated maximum GLCs and deposition rates depicting worst-case air quality impacts during the construction of wells and booster stations are discussed in the below sections for PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, VOCs and dustfall.

4.3.1.1.1 PM_{10} GLC's

Simulated maximum daily GLCs depicting worst-case air quality impacts during construction as a function of perpendicular distance from wells and booster stations are shown in Figure 11. Maximum daily PM_{10} GLCs due to well and booster station construction are illustrated in Figure 12 and Figure 13 respectively. From Figure 11 simulated PM_{10} GLCs exceed the NAAQS daily limit up to 180 m beyond the well site and up to 150 m beyond the booster station (BL1-10), but not at any AQSRs. Isopleths for other proposed wells and booster stations are not shown since they are all similar in terms of extent, concentration and spatial distribution.

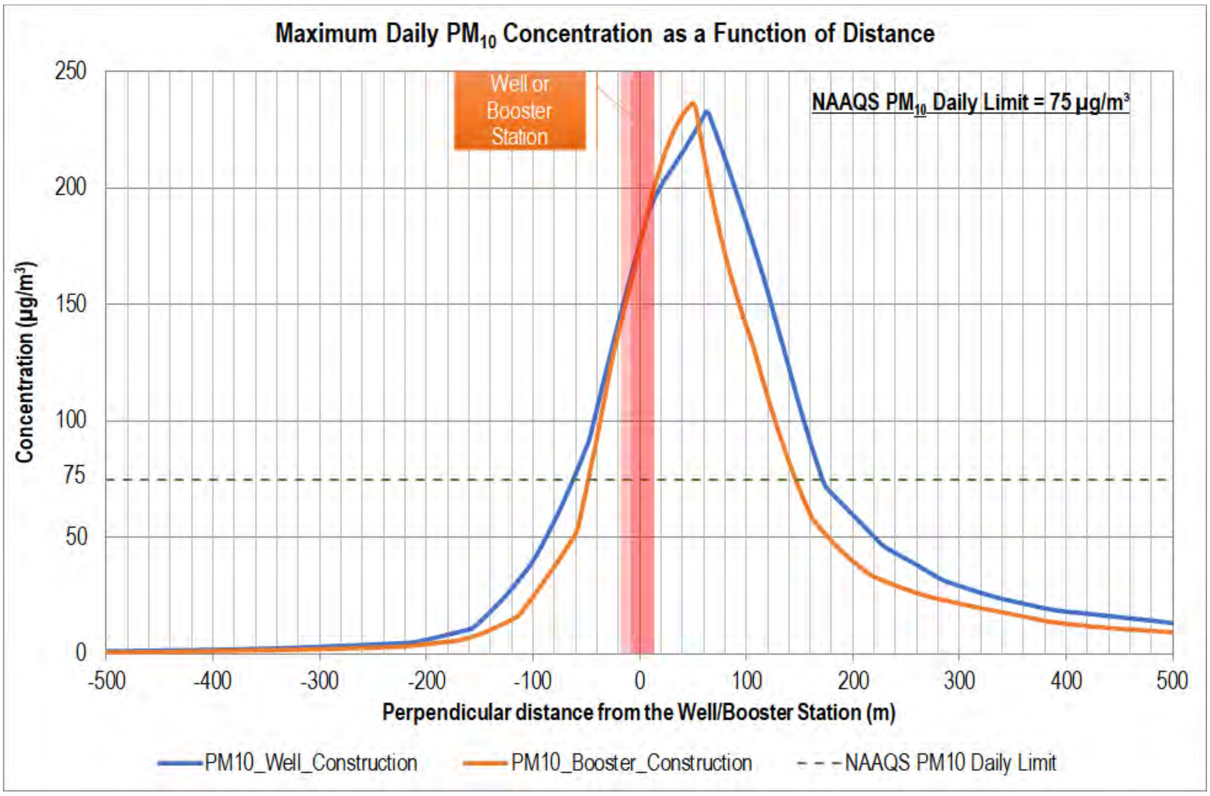

Figure 11: Simulated maximum daily PM_{10} GLCs due to well/booster station construction emissions (exceedances of NAAQS limit up to 150 m perpendicular distance from booster station and 180 m from well were simulated)

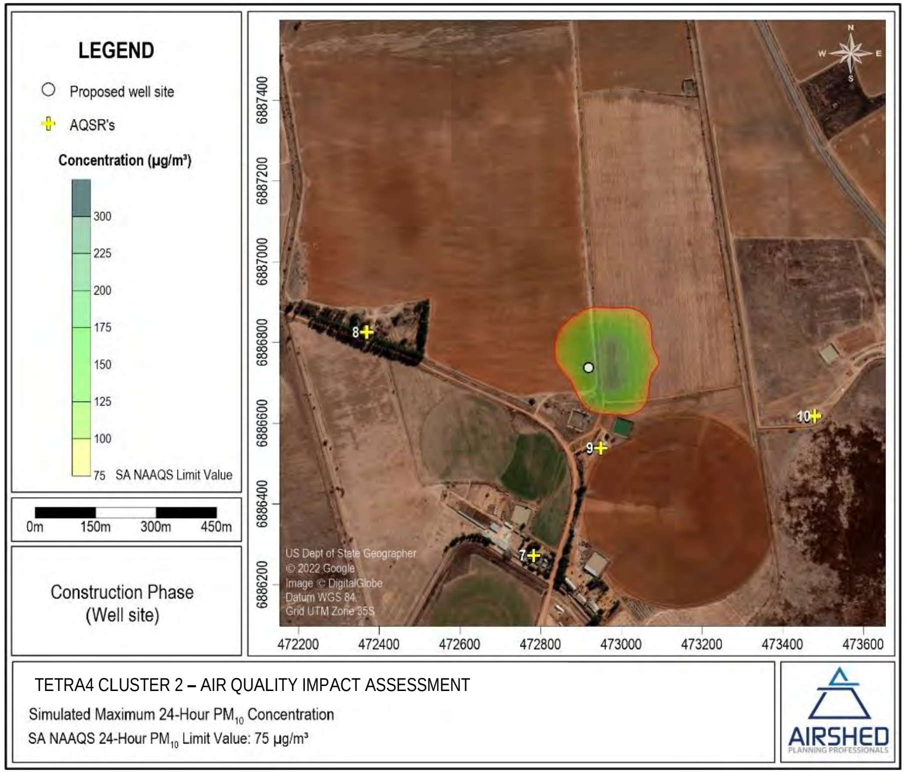

Figure 12: Simulated maximum 24-hour PM_{10} GLCs due to proposed well construction emissions (single exceedance of NAAQS limit up to 180 m beyond well site indicated as red line)

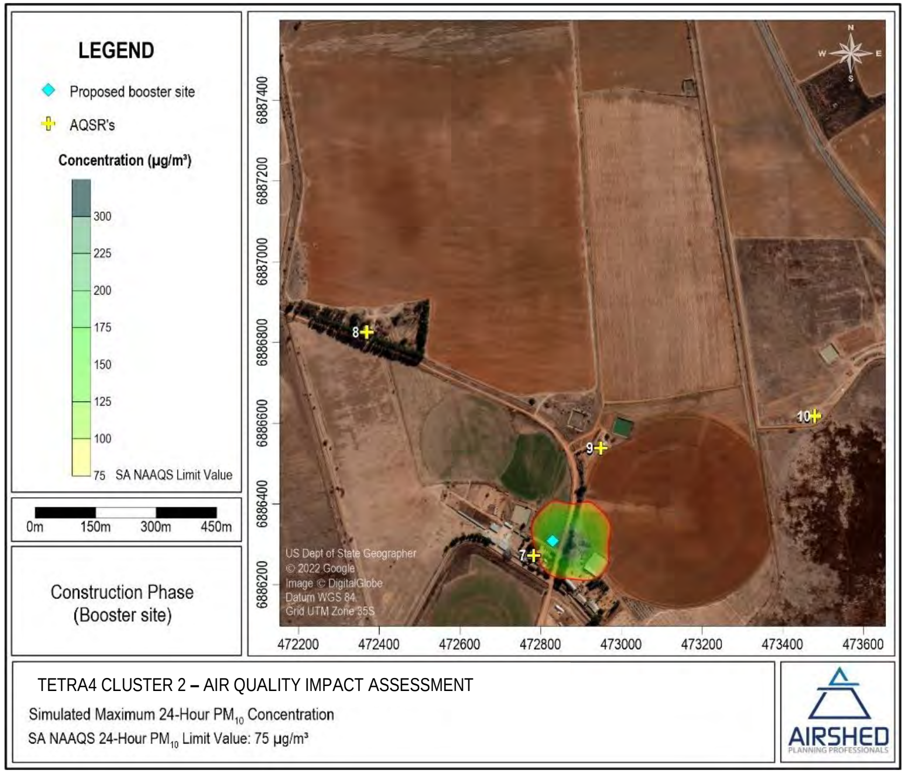

Figure 13: Simulated maximum 24-hour PM_{10} GLCs due to proposed booster station construction emissions (single exceedance of NAAQS limit up to 150 m beyond booster site indicated as red line)

4.3.1.1.2 $PM_{2.5}$ GLC's

Maximum daily GLCs depicting worst-case $PM_{2.5}$ impacts during the construction of proposed wells and booster stations are shown in Figure 15 and Figure 16 respectively. Simulated daily $PM_{2.5}$ GLCs depicting worst-case air quality impacts as a function of perpendicular distance from wells and booster stations are shown in Figure 14. From Figure 14 simulated $PM_{2.5}$ GLCs exceed the NAAQS daily limit up to 290 m beyond the well site and up to 200 m beyond the booster station. Simulated $PM_{2.5}$ GLCs did not exceed the NAAQS limit at any AQSRs for the well site (Figure 15) but did exceed at AQSR 7 for the proposed BL1-10 booster station (Figure 16). However, worst case impacts are not anticipated to occur over long intervals since construction occurs over the short-term and peak activities will not be consistent over the specified period.

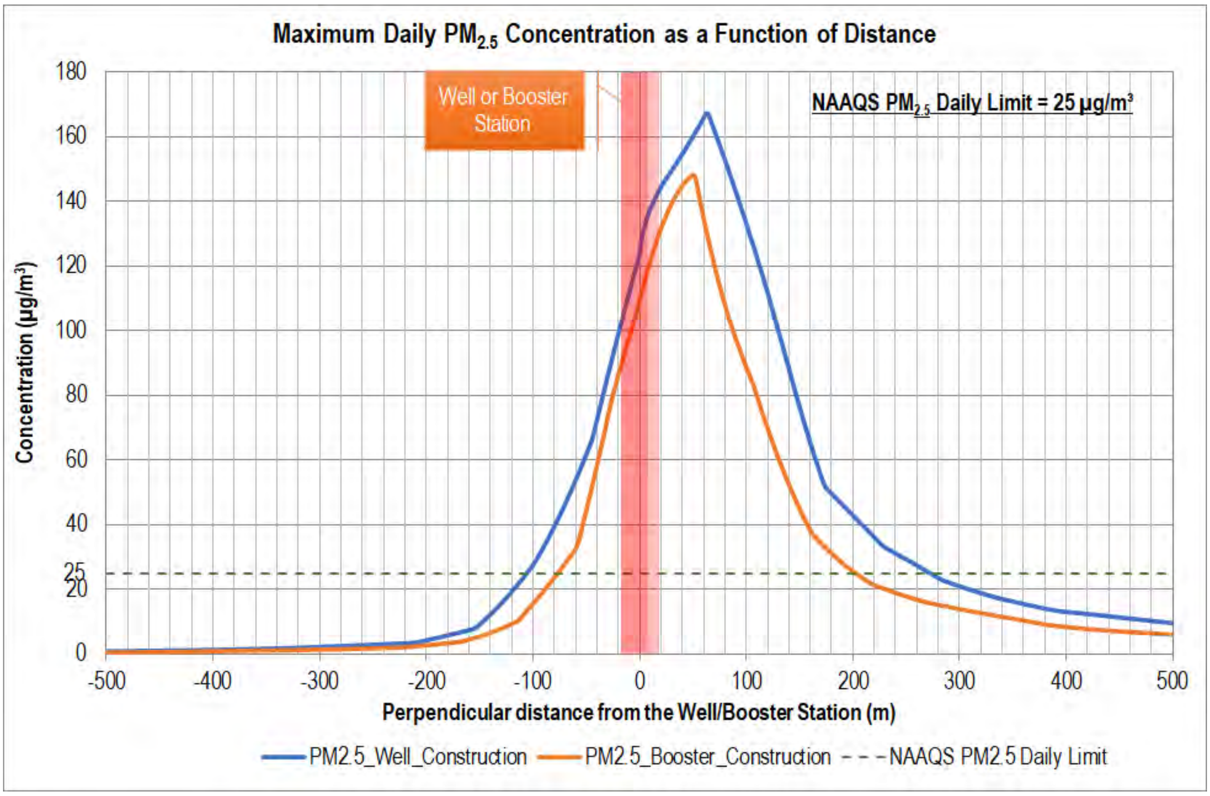

Figure 14: Simulated maximum daily $PM_{2.5}$ GLCs due to well/booster station construction emissions (exceedances of NAAQS limit up to 200 m perpendicular distance from booster station and 290 m from well were simulated)

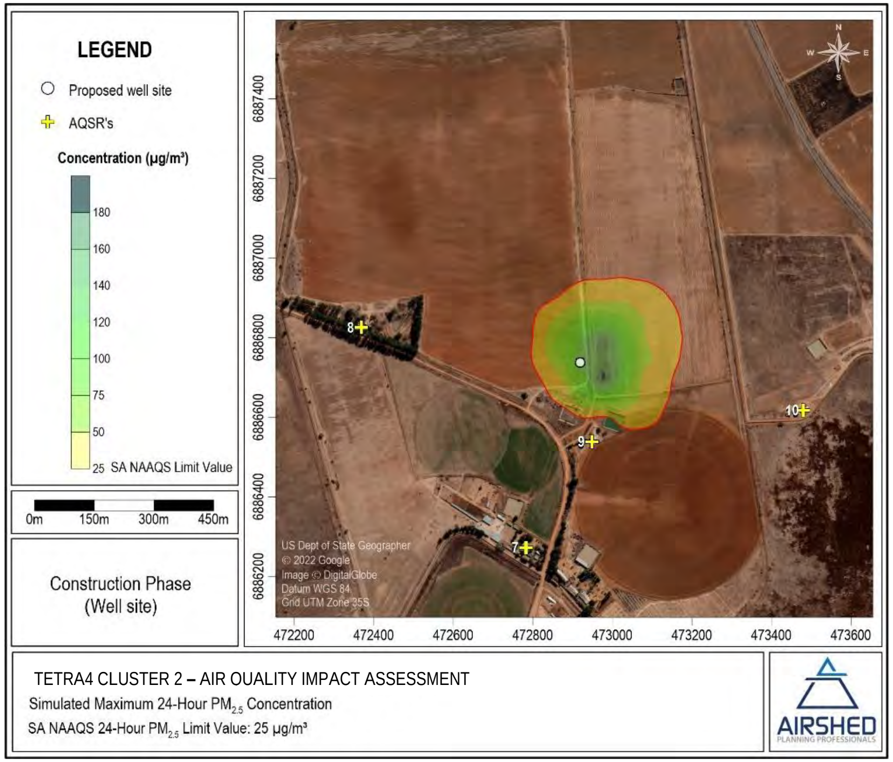

Figure 15: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed well construction emissions (single exceedance of NAAQS limit up to 300 m beyond well site indicated as red line)

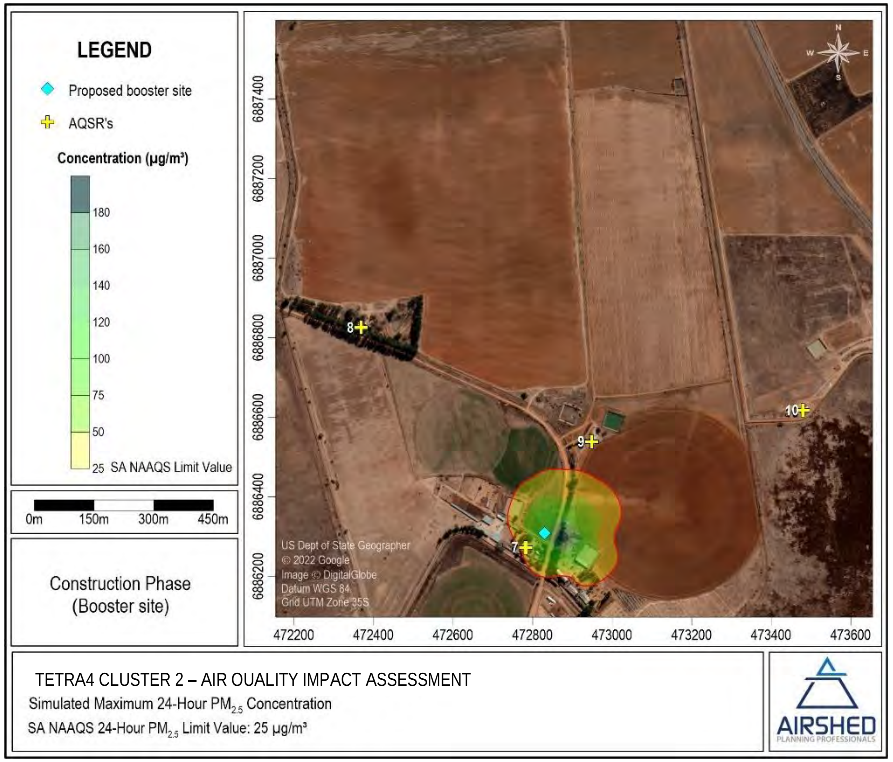

Figure 16: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed booster station construction emissions (single exceedance of NAAQS limit up to 180 m beyond booster site indicated as red line)

4.3.1.1.3 NO_2 GLC's

Maximum hourly GLCs depicting worst-case NO_2 impacts during the construction of proposed wells and booster stations are shown in Figure 18 and Figure 19 respectively. From Figure 17 simulated NO_2 GLCs exceed the NAAQS hourly limit up to 750 m beyond the well site and up to 500 m beyond the booster station. Simulated NO_2 GLCs did not exceed the NAAQS limit at any AQSRs for the well site (Figure 18) but did exceed at AQSR 7 and AQSR 9 for the booster station (Figure 19). However, it must be kept in mind that worst case impacts are not anticipated to occur over long intervals since peak activities will not be consistent over the construction period and will only last short-term.

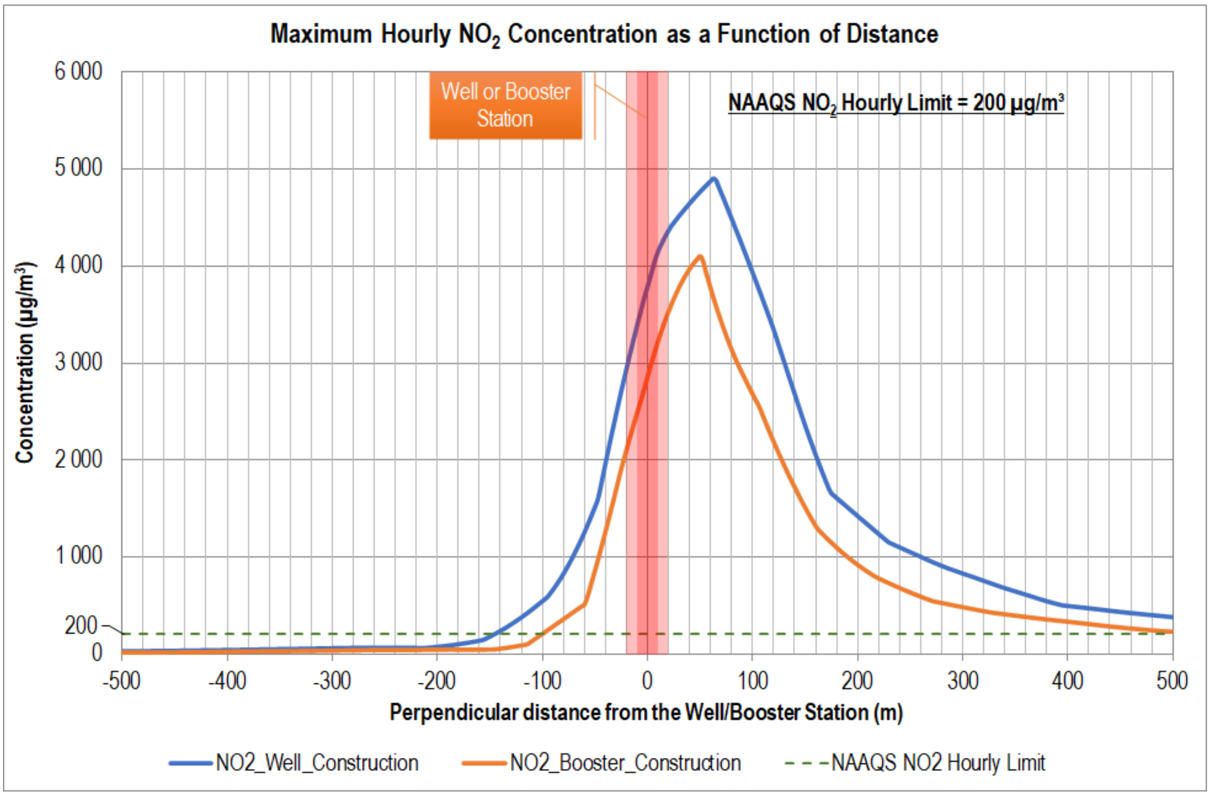

Figure 17: Simulated maximum hourly NO_2 GLCs due to well/booster station construction emissions (exceedances of NAAQS limit up to 500 m perpendicular distance from booster station and 750 m from well were simulated)

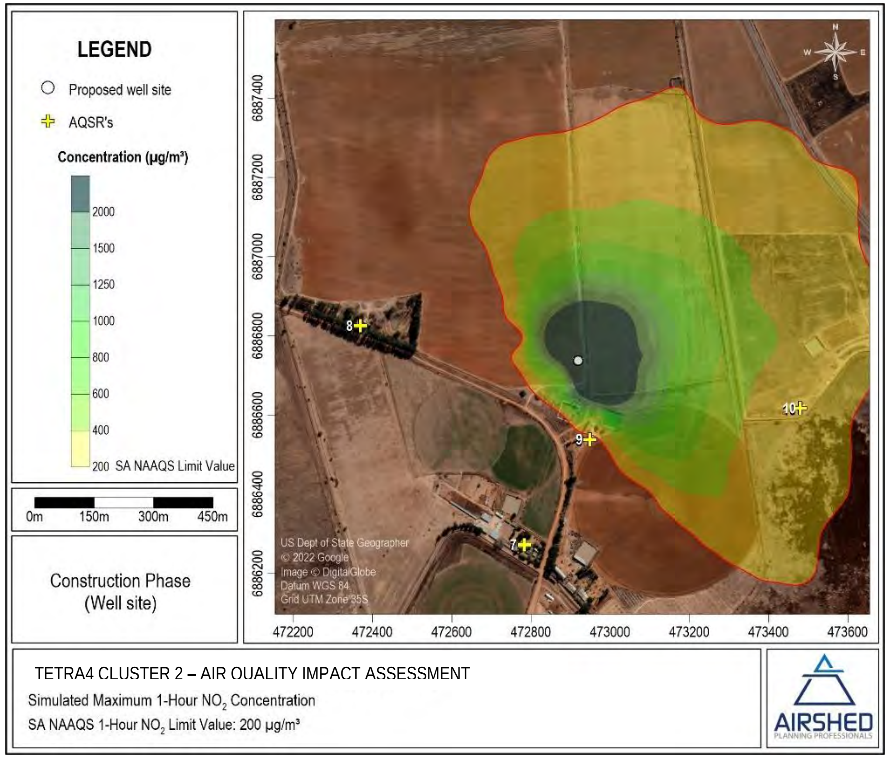

Figure 18: Simulated maximum 1-hour NO_2 GLCs due to proposed well construction emissions (single exceedance of NAAQS limit up to 750 m beyond well site indicated as red line)

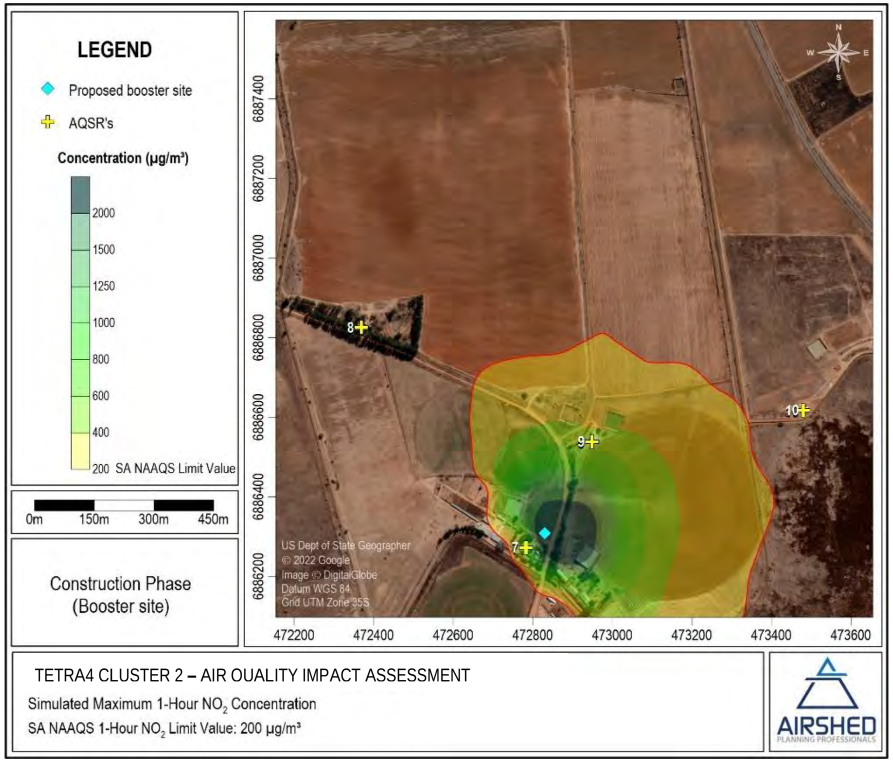

Figure 19: Simulated maximum 1-hour NO_2 GLCs due to proposed booster station construction emissions (single exceedance of NAAQS limit up to 500 m beyond booster site indicated as red line)

4.3.1.1.4 SO_2 GLC's

Simulated hourly GLCs depicting worst-case SO_2 construction impacts as a function of perpendicular distance from the proposed wells and booster stations are shown in Figure 20. Figure 20 illustrates that simulated SO_2 GLCs are very low and are not expected to exceed the NAAQS hourly limit (350 µg/m³) during well/booster station construction.

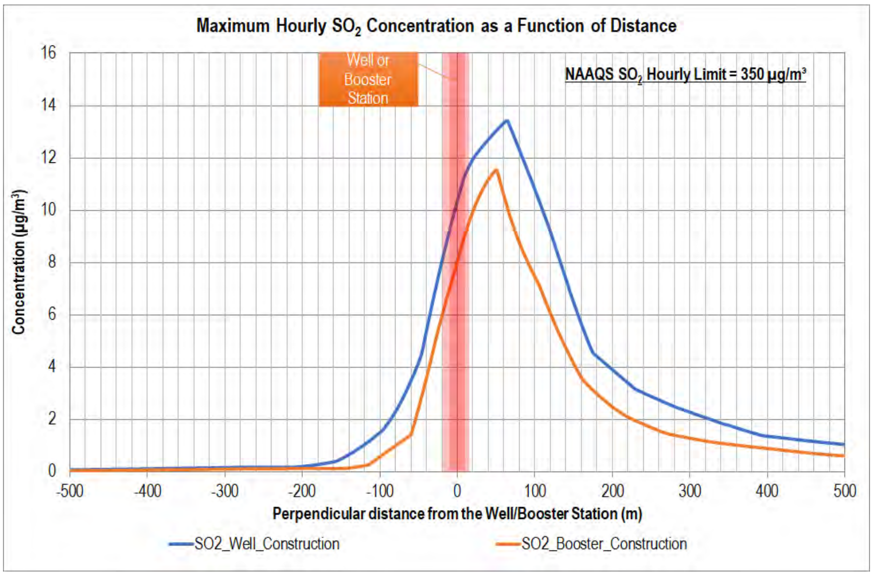

Figure 20: Simulated maximum hourly SO_2 GLCs due to well/booster station construction emissions (the NAAQS limit is not exceeded)

4.3.1.1.5 CO GLC's

Simulated hourly GLCs depicting worst-case CO construction impacts as a function of perpendicular distance from the proposed wells and booster stations are shown in Figure 21. Figure 21 illustrates that simulated CO GLCs are not expected to exceed the NAAQS hourly limit (30 000 µg/m³) during the construction of wells and booster stations.

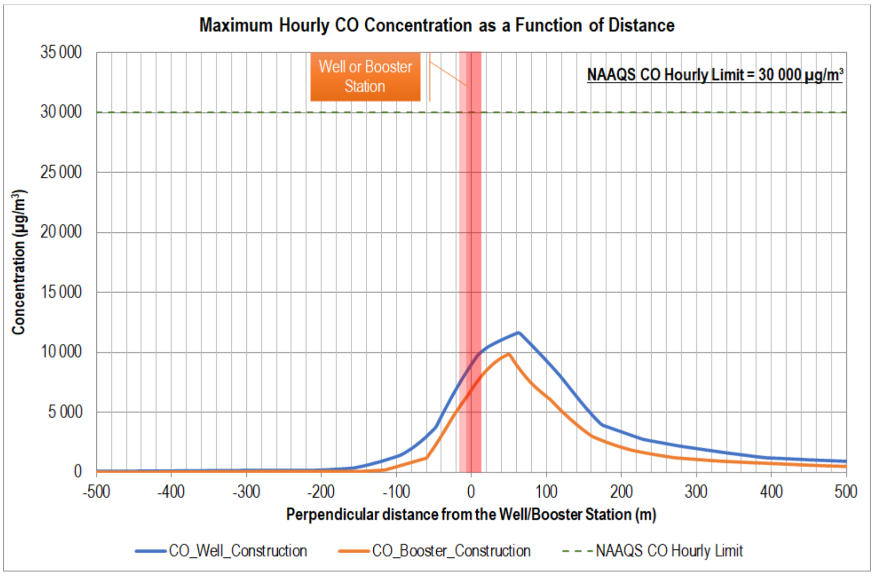

Figure 21: Simulated maximum hourly CO GLCs due to well/booster station construction emissions (the NAAQS limit is not exceeded)

4.3.1.1.6 VOC GLC's

Maximum simulated hourly VOC GLCs due to construction activities as a function of perpendicular distance from the well and booster station are illustrated in Figure 22. From Figure 22 hourly VOC GLCs exceed the TCEQ Effects Screening Level (ESL) of 1 000 µg/m³ up to 170 m beyond the well site and up to 130 m beyond the booster station, but not at any AQSRs (see Figure 23 and Figure 24).

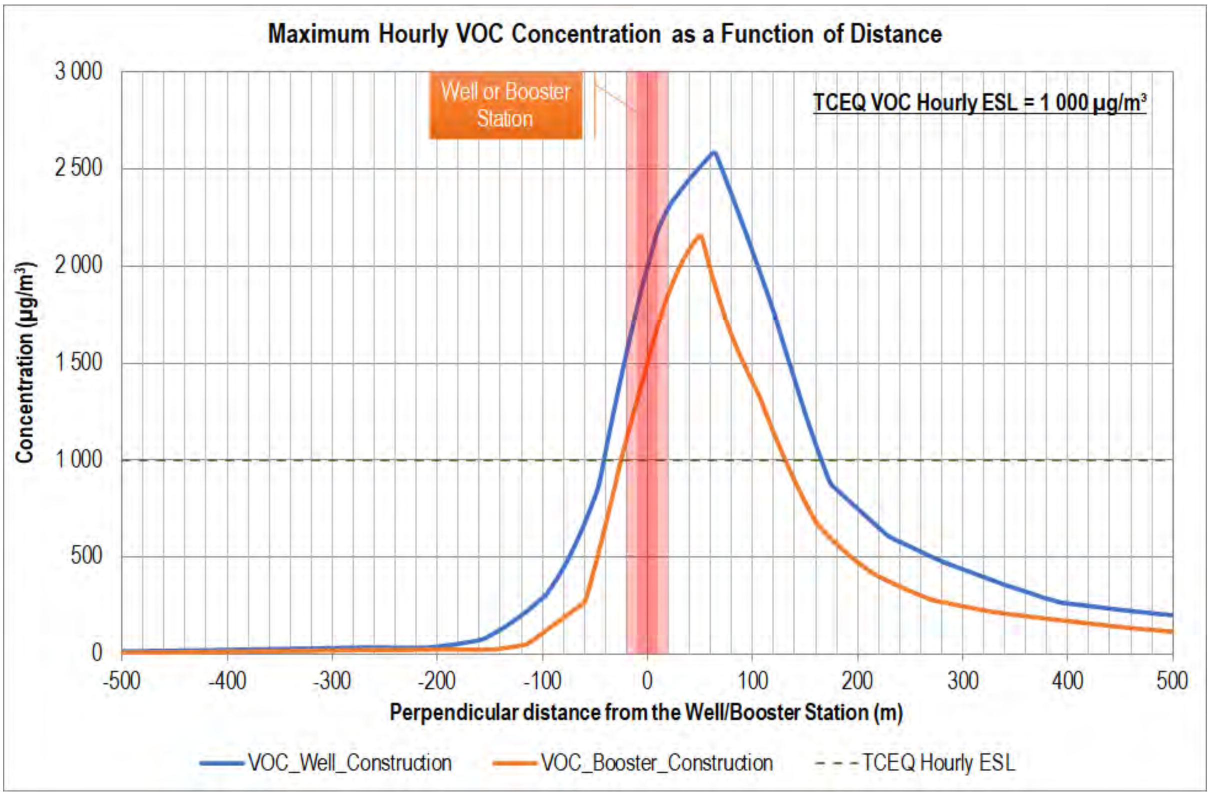

Figure 22: Simulated maximum hourly VOC GLCs due to well/booster station construction emissions (exceedances of TCEQ ESL up to 130 m perpendicular distance from booster station and 170 m from well were simulated)

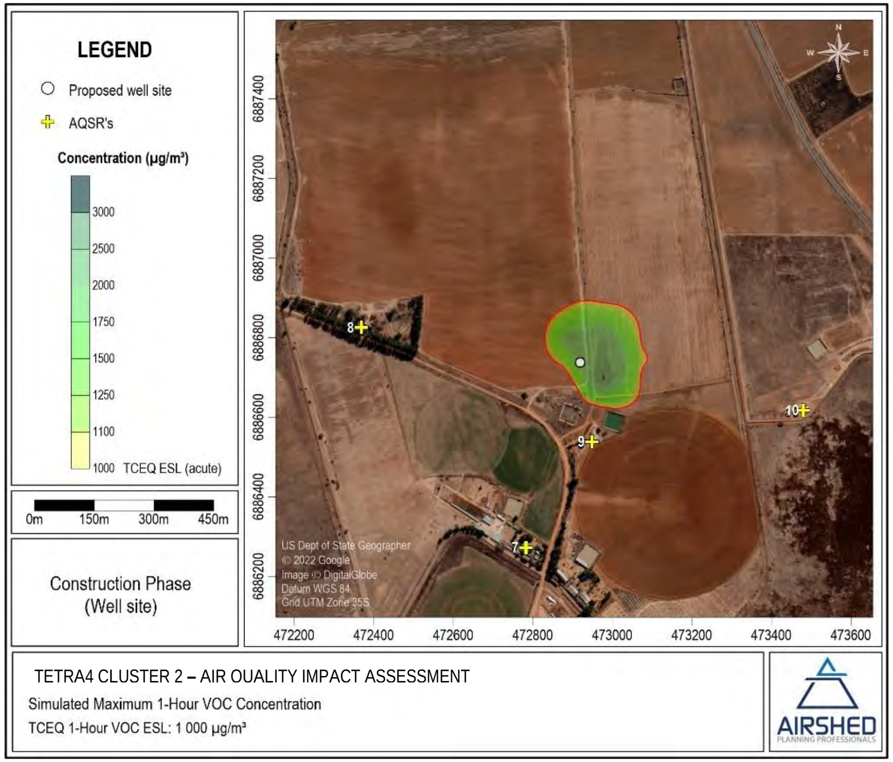

Figure 23: Simulated maximum 1-hour VOC GLCs due to proposed well construction emissions (single exceedance of TCEQ ESL up to 170 m beyond well site indicated as red line)

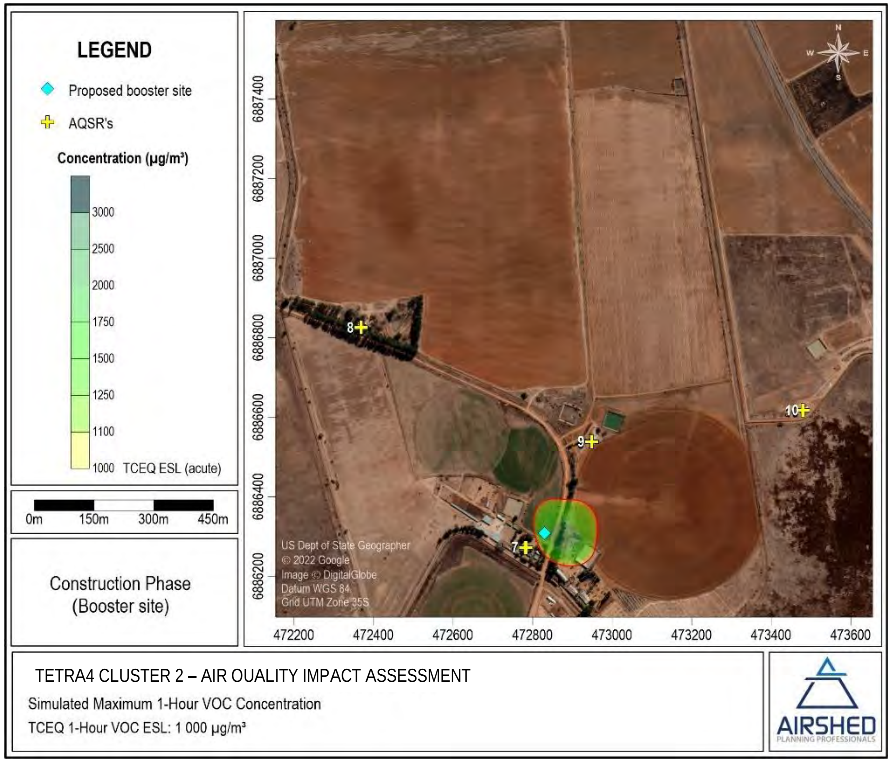

Figure 24: Simulated maximum 1-hour VOC GLCs due to proposed booster station construction emissions (single exceedance of TCEQ ESL up to 130 m beyond booster site indicated as red line)

4.3.1.1.7 Dustfall Deposition Rates

Maximum simulated daily dustfall deposition rates as a result of well and booster station construction emissions are shown in Figure 25 as a function of perpendicular distance from the well and booster station. From Figure 25 simulated daily dustfall deposition rates do not exceed the NDCR residential limit of 600 mg/m²/day.

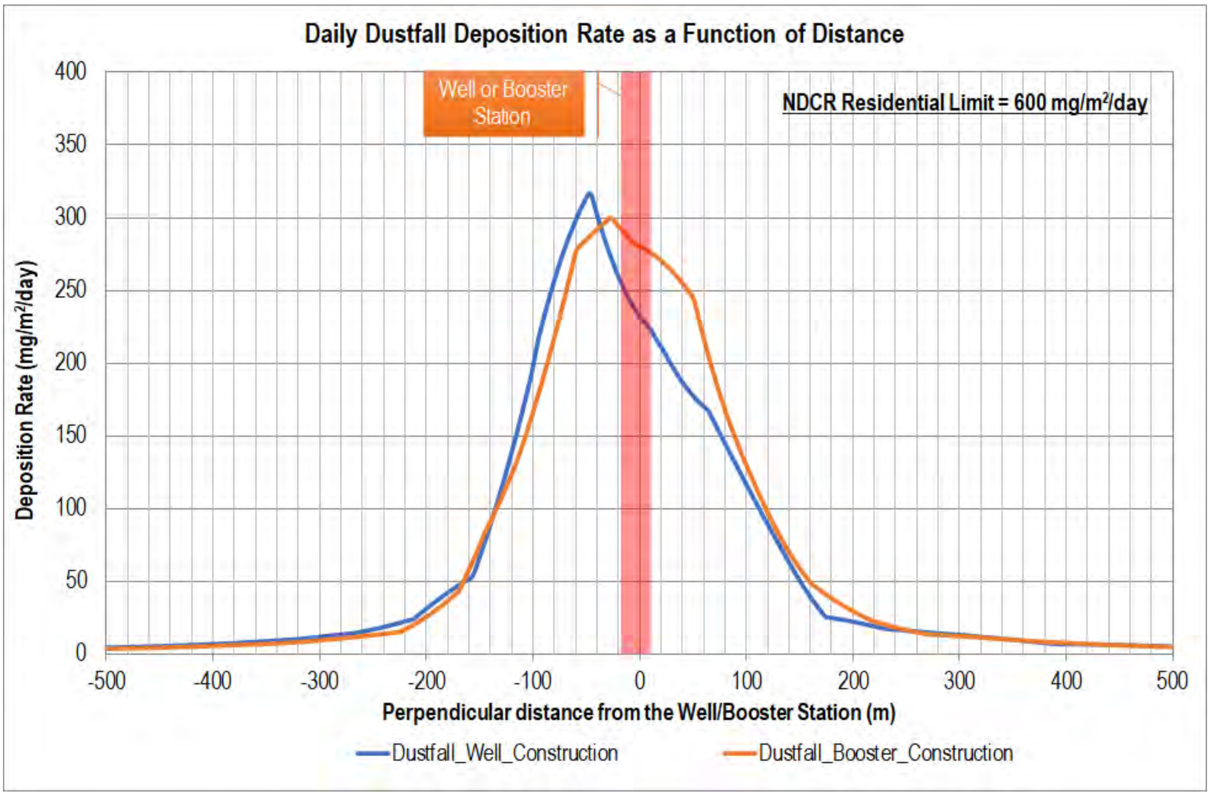

Figure 25: Simulated daily dustfall deposition rates due to well/booster station construction emissions (the NDCR residential limit is not exceeded)

4.3.1.2 Roads/Pipeline Construction

Simulated maximum GLCs and deposition rates depicting worst-case air quality impacts during the construction of roads[3] and pipeline are discussed in the below sections for PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, VOCs and dustfall.

4.3.1.2.1 PM_{10} GLC's

Simulated maximum daily PM_{10} GLCs due to road and pipeline construction emissions are shown in Figure 27 and Figure 28 respectively. Simulated maximum daily PM_{10} GLCs due to road construction emissions exceed the PM_{10} NAAQS limit up to 95 m perpendicular distance from the centre of the road, while maximum daily PM_{10} GLCs due to pipeline construction emissions exceed the PM_{10} NAAQS limit up to 100 m perpendicular distance from the pipeline (Figure 26). Worst case impacts are not anticipated to occur over long intervals since road construction will only last a few days per 500 m stretch and peak activities will not be consistent over that specified period.

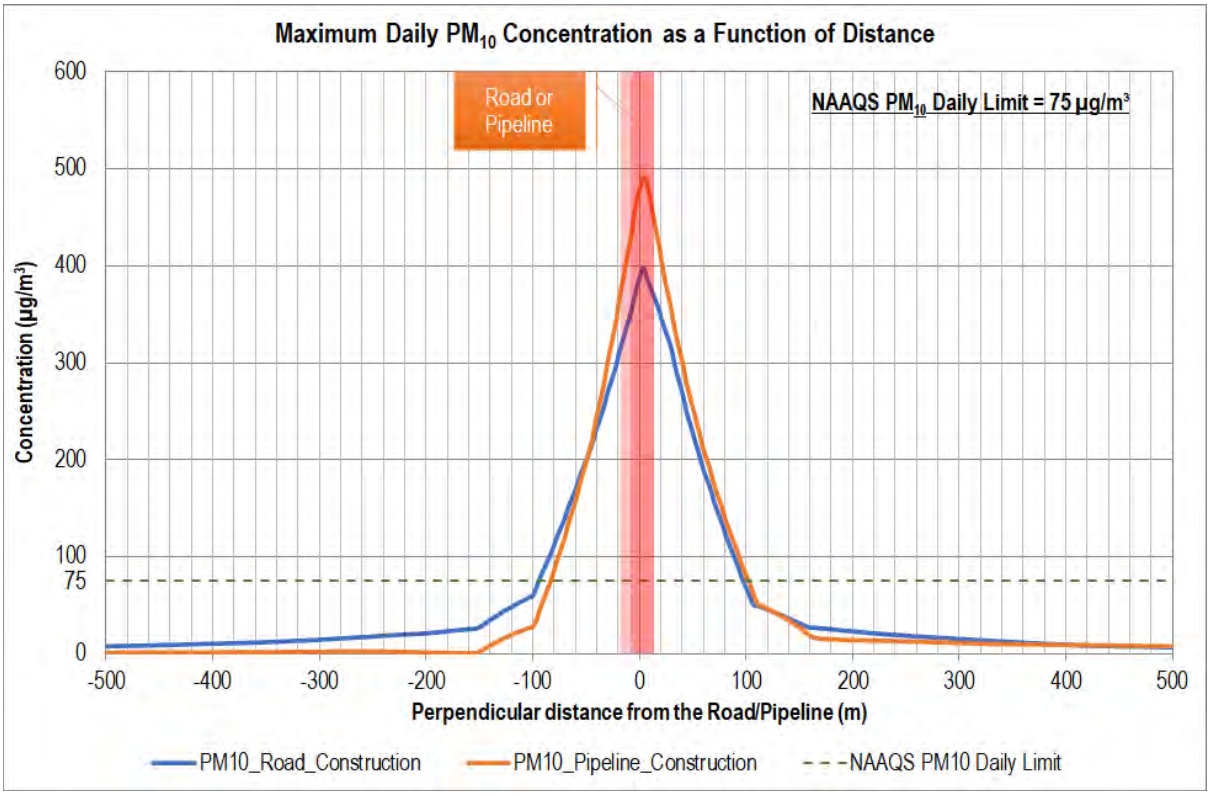

Figure 26: Simulated maximum daily PM_{10} GLCs due to road/pipeline construction emissions (exceedances of NAAQS limit up to 95 m perpendicular distance from the road and 100 m from the pipeline were simulated)

[3] The access road to the plant was modelled as an unpaved road. The results are representative of any new unpaved roads that may be constructed as part of the Project.

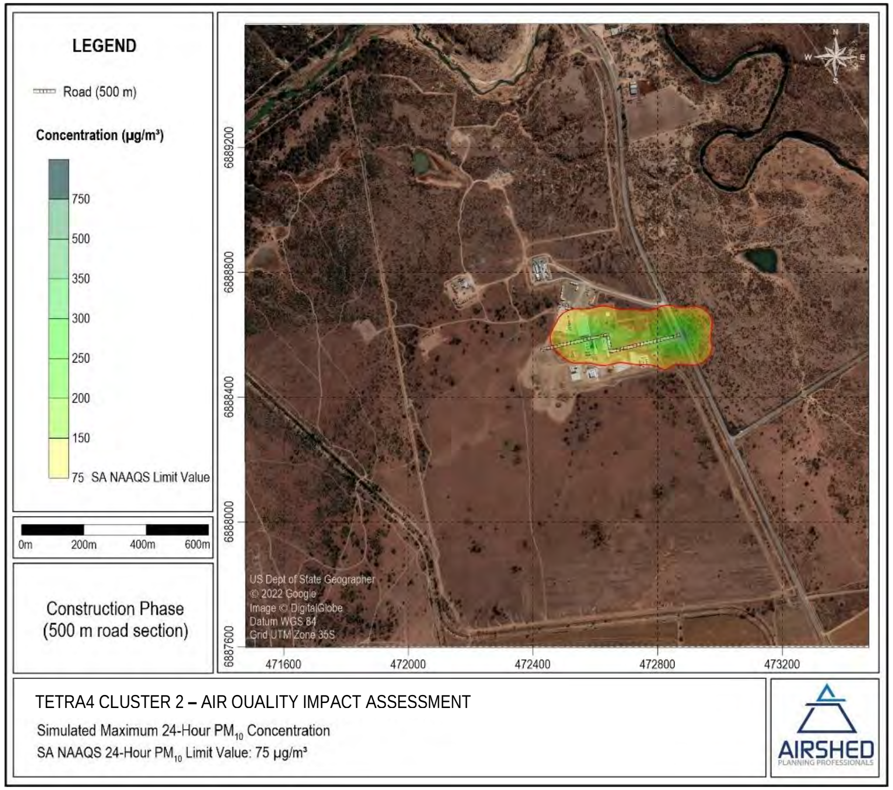

Figure 27: Simulated maximum 24-hour PM_{10} GLCs due to proposed road construction emissions (single exceedance of NAAQS limit up to 95 m beyond road indicated as red line)

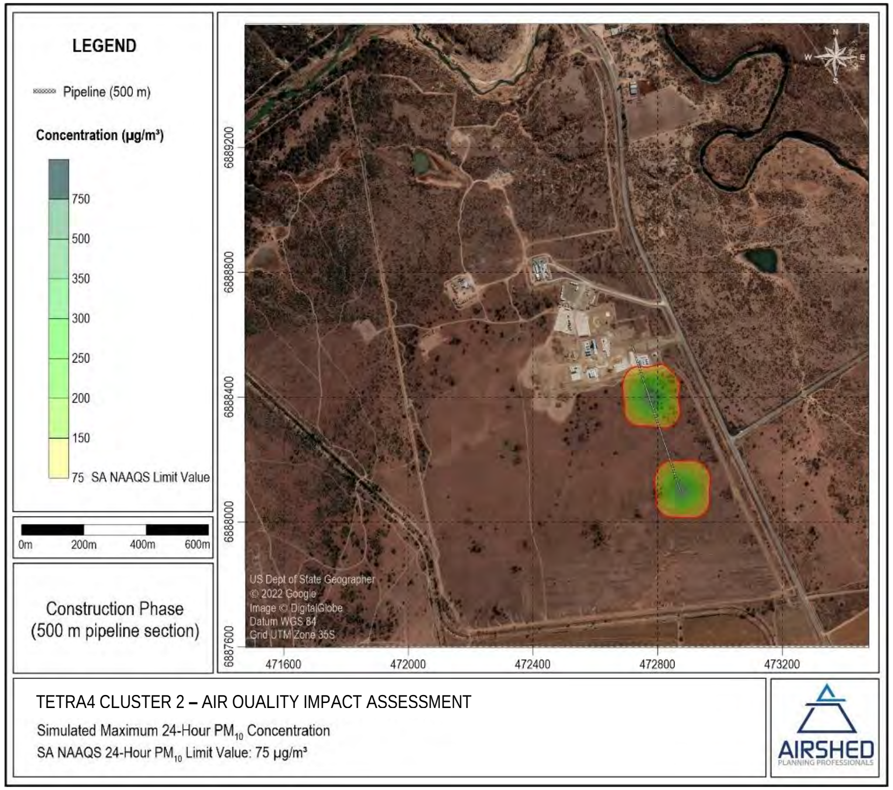

Figure 28: Simulated maximum 24-hour PM_{10} GLCs due to proposed pipeline construction emissions (single exceedance of NAAQS limit up to 100 m beyond pipeline indicated as red line)

4.3.1.2.2 $PM_{2.5}$ GLC's

Simulated maximum daily $PM_{2.5}$ GLCs due to road and pipeline construction emissions are shown in Figure 30 and Figure 31 respectively. Simulated maximum daily $PM_{2.5}$ GLCs due to road construction emissions exceed the $PM_{2.5}$ NAAQS limit up to 80 m perpendicular distance from the centre of the road, while maximum daily $PM_{2.5}$ GLCs due to pipeline construction emissions exceed the $PM_{2.5}$ NAAQS limit up to 100 m perpendicular distance from the pipeline (Figure 29).

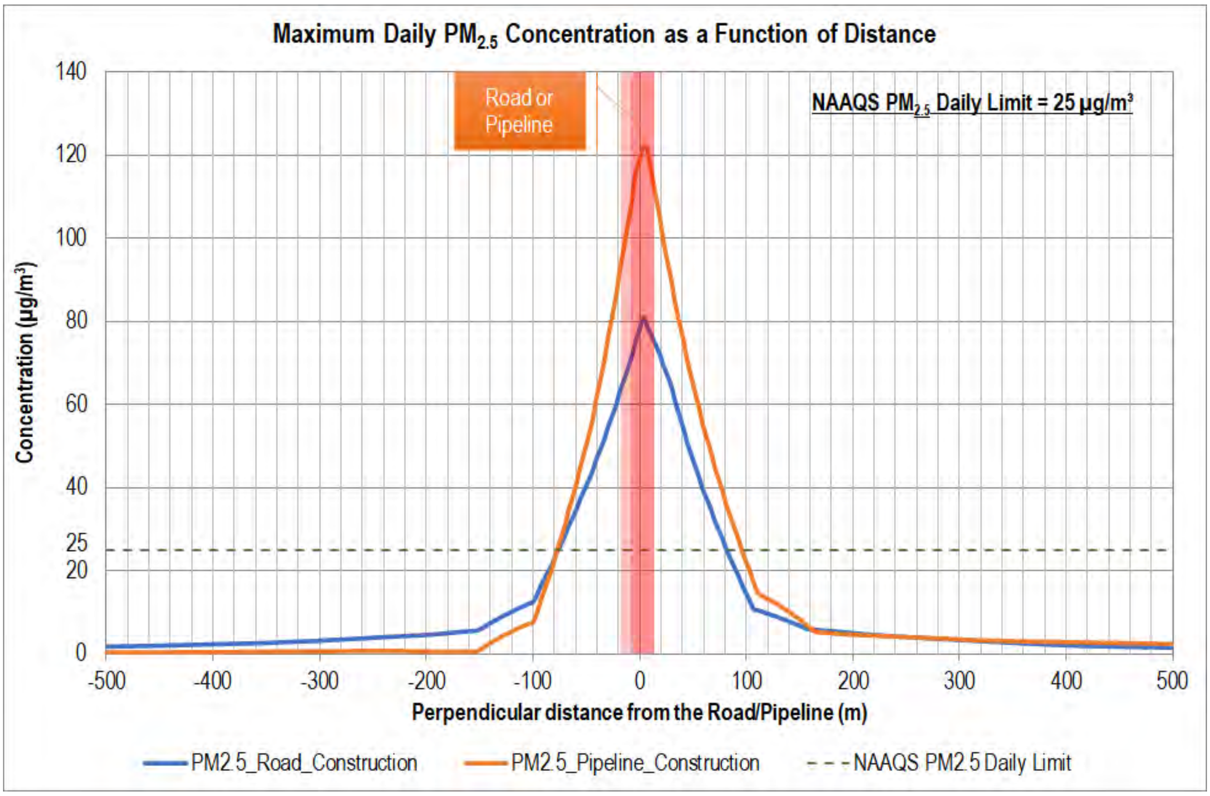

Figure 29: Simulated maximum daily $PM_{2.5}$ GLCs due to road/pipeline construction emissions (exceedances of NAAQS limit up to 80 m perpendicular distance from the road and 100 m from the pipeline were simulated)

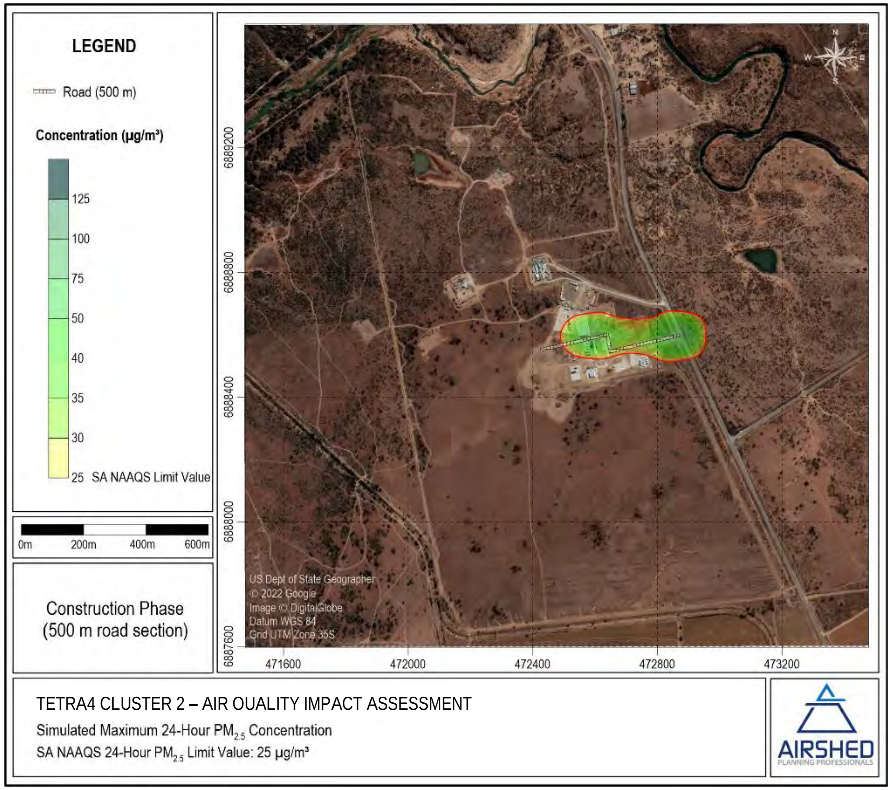

Figure 30: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed road construction emissions (single exceedance of NAAQS limit up to 80 m beyond road indicated as red line)

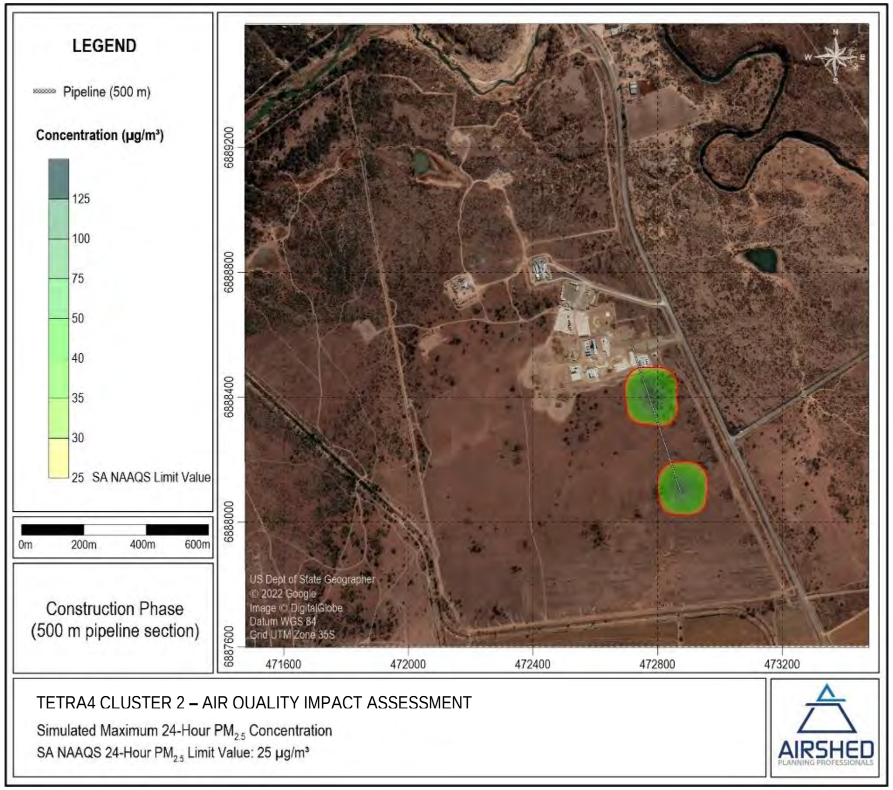

Figure 31: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed pipeline construction emissions (single exceedance of NAAQS limit up to 100 m beyond pipeline indicated as red line)

4.3.1.2.3 NO_2 GLC's

Simulated maximum hourly NO_2 GLCs due to road and pipeline construction emissions are shown in Figure 33 and Figure 34 respectively. Simulated maximum hourly NO_2 GLCs due to road/pipeline construction emissions exceed the NO_2 NAAQS limit up to 150 m perpendicular distance from both the centre of the road and the pipeline (Figure 32).

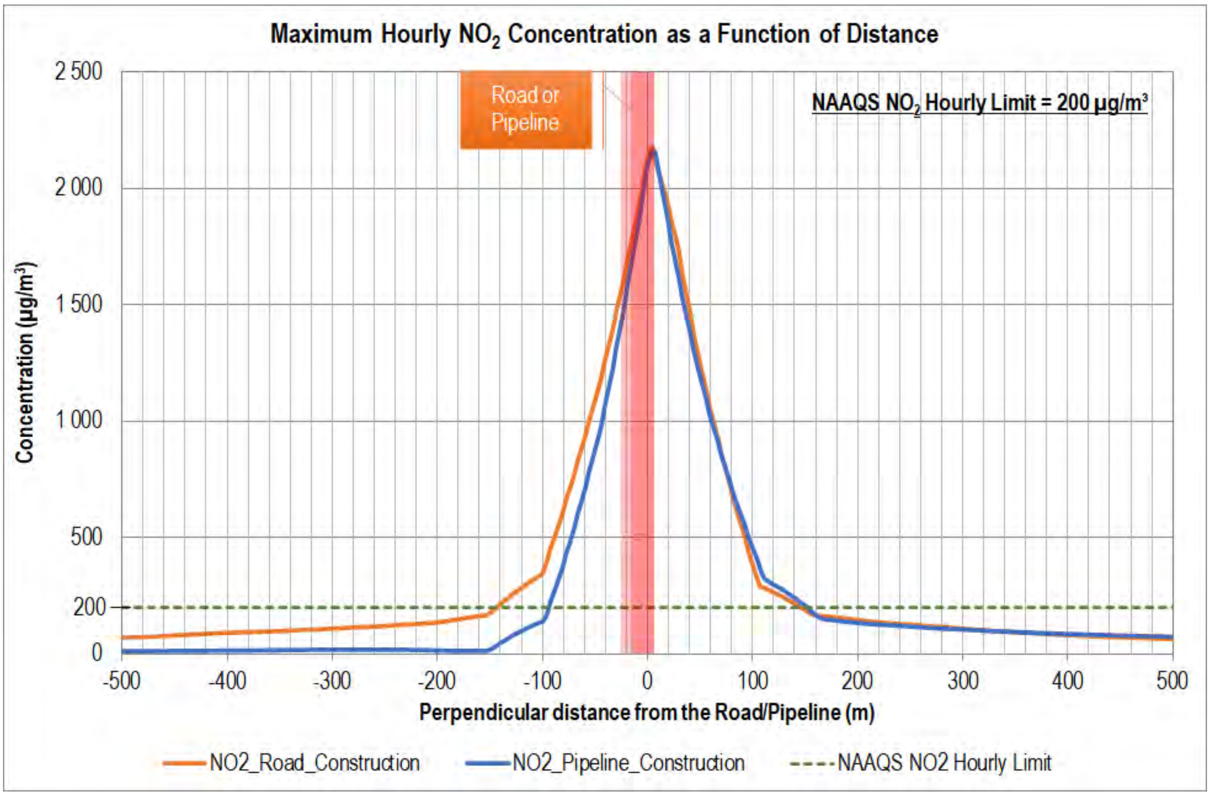

Figure 32: Simulated maximum hourly NO_2 GLCs due to road/pipeline construction emissions (exceedances of NAAQS limit up to 150 m perpendicular distance from the road and pipeline were simulated)

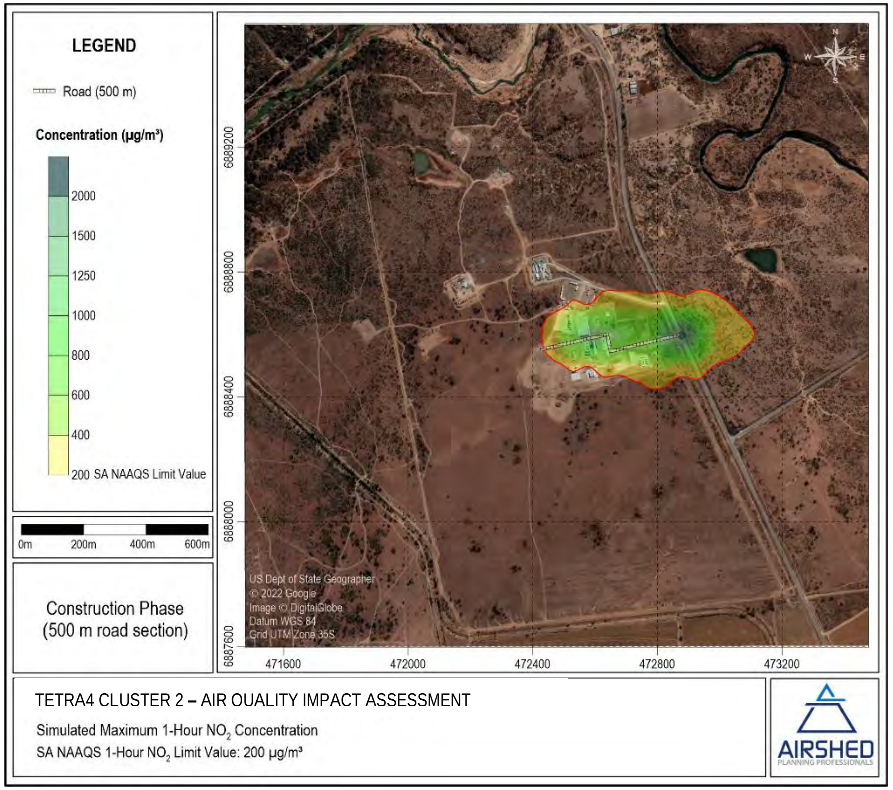

Figure 33: Simulated maximum 1-hour NO_2 GLCs due to proposed road construction emissions (single exceedance of NAAQS limit up to 150 m beyond road indicated as red line)

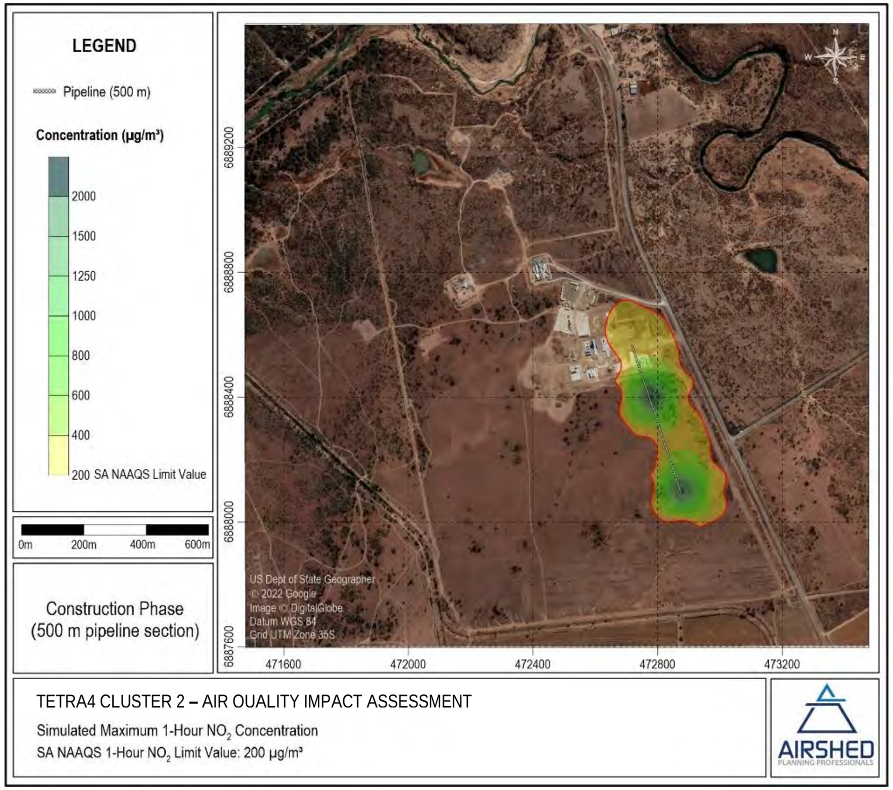

Figure 34: Simulated maximum 1-hour NO_2 GLCs due to proposed pipeline construction emissions (single exceedance of NAAQS limit up to 150 m beyond pipeline indicated as red line)

4.3.1.2.4 SO_2 GLC's

Simulated hourly GLCs depicting worst-case SO_2 construction impacts as a function of perpendicular distance from the proposed road and pipeline are shown in Figure 35. Figure 35 illustrates that simulated SO_2 GLCs are very low and are not expected to exceed the NAAQS hourly limit (350 µg/m³) during road/pipeline construction.

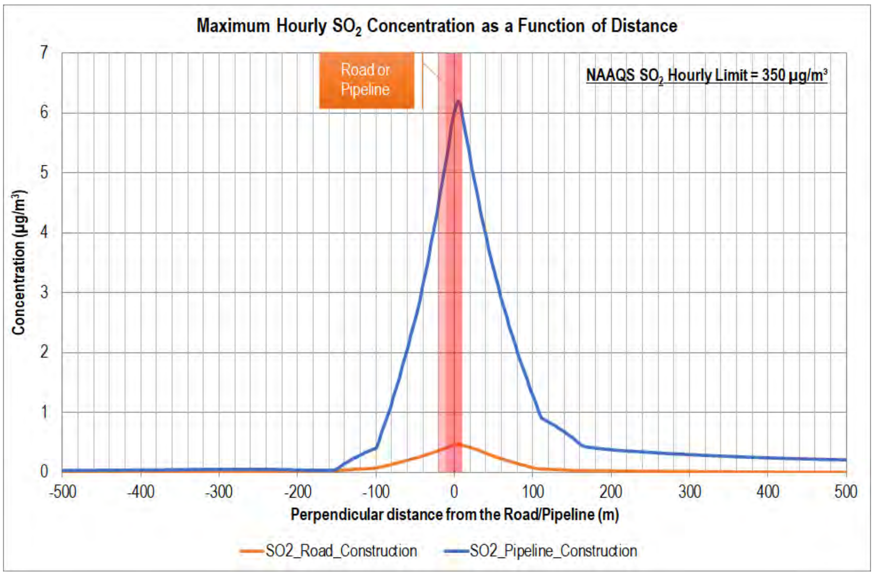

Figure 35: Simulated maximum hourly SO_2 GLCs due to road/pipeline construction emissions (the NAAQS limit is not exceeded)

4.3.1.2.5 CO GLC's

Simulated hourly GLCs depicting worst-case CO construction impacts as a function of perpendicular distance from the proposed road and pipeline are shown in Figure 36. Figure 36 illustrates that simulated CO GLCs are not expected to exceed the NAAQS hourly limit (30 000 µg/m³) during road/pipeline construction.

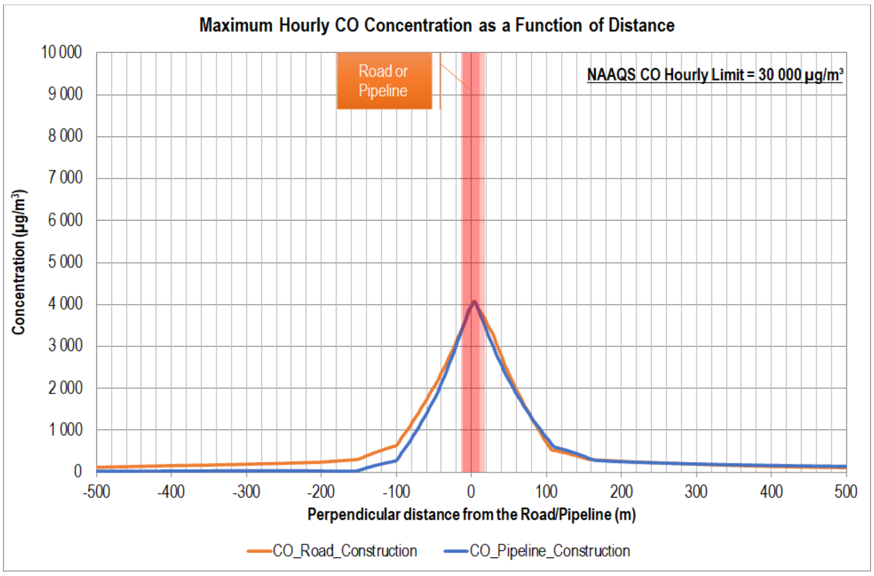

Figure 36: Simulated maximum hourly CO GLCs due to road/pipeline construction emissions (the NAAQS limit is not exceeded)

4.3.1.2.6 VOC GLC's

Maximum simulated hourly VOC GLCs due to construction activities as a function of perpendicular distance from the road and pipeline are illustrated in Figure 37. From Figure 37 hourly VOC GLCs do not exceed the TCEQ ESL of 1 000 µg/m³.

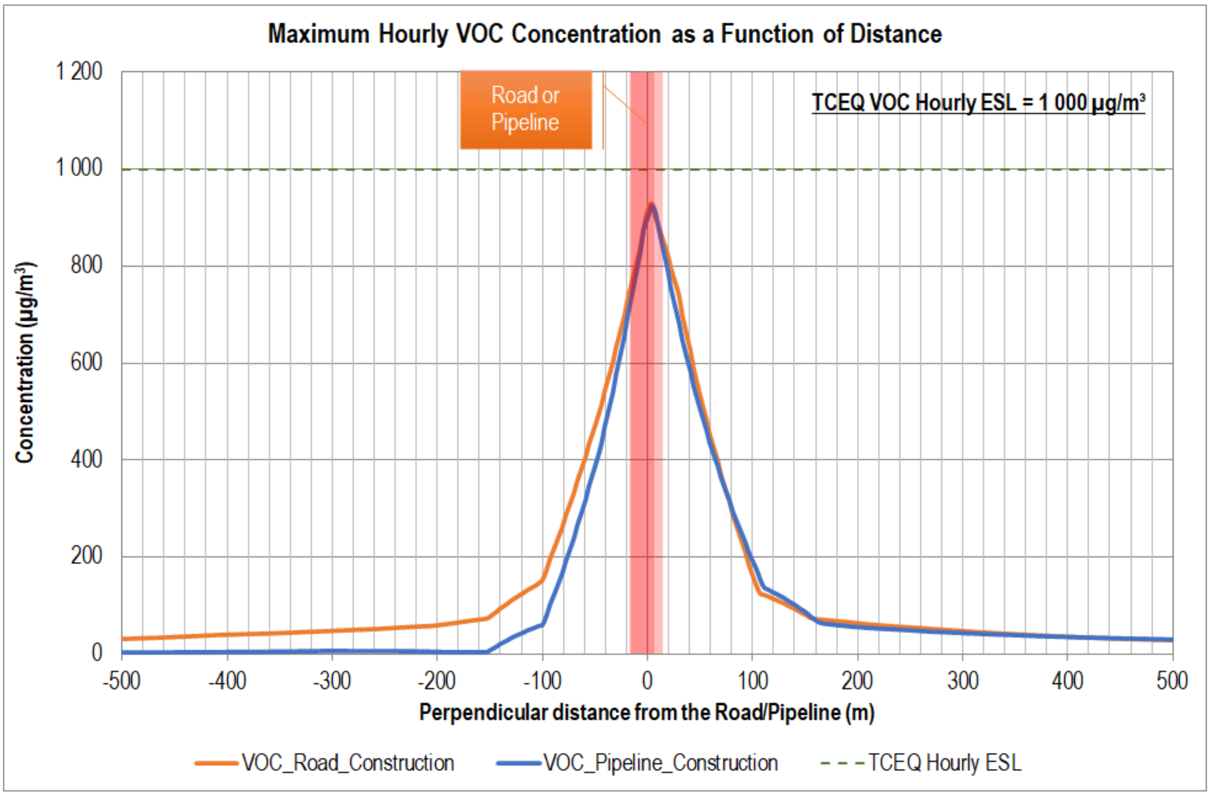

Figure 37: Simulated maximum hourly VOC GLCs due to road/pipeline construction emissions (the TCEQ ESL is not exceeded)

4.3.1.2.7 Dustfall Deposition Rates

Maximum simulated daily dustfall deposition rates as a result of road and pipeline construction emissions are shown in Figure 38 as a function of perpendicular distance from each type of infrastructure. From Figure 38 simulated daily dustfall deposition rates exceed the NDCR residential limit of 600 mg/m²/day up to 50 m and 40 m beyond the road and pipeline respectively (see Figure 39 and Figure 40).

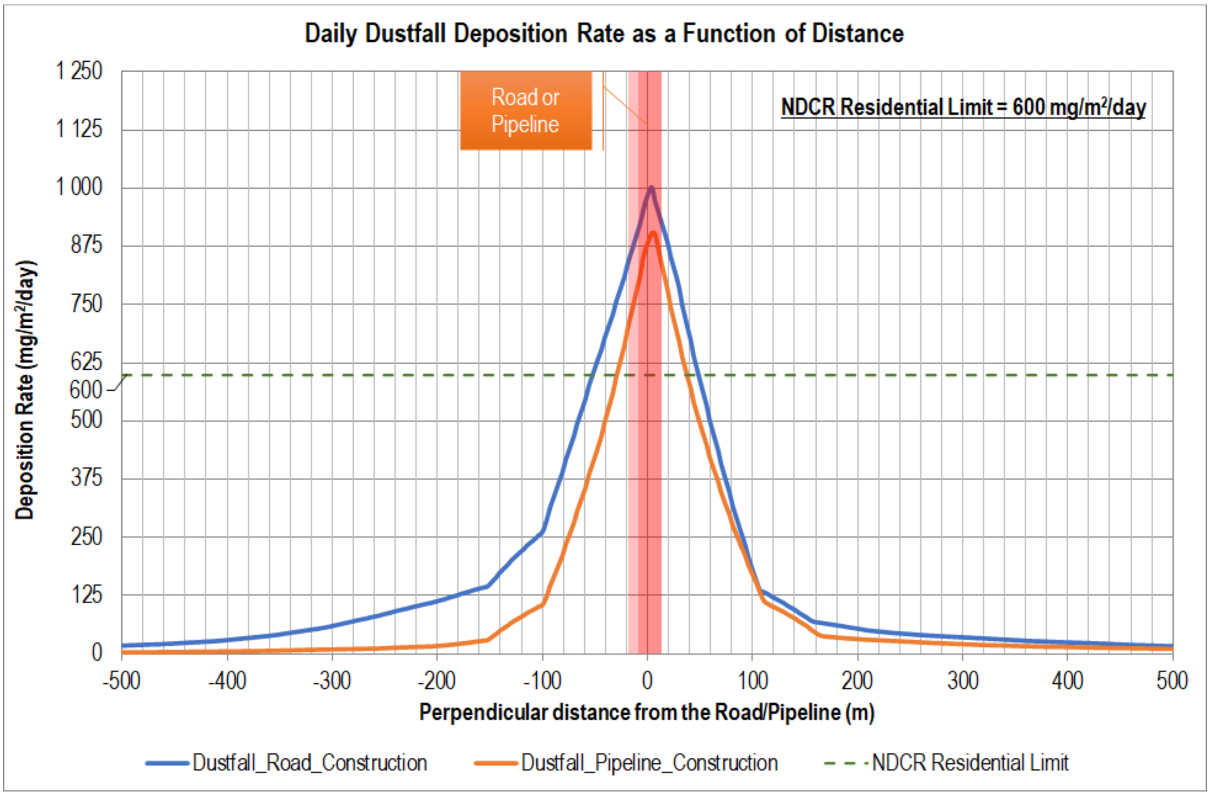

Figure 38: Simulated daily dustfall deposition rates due to road/pipeline construction emissions (exceedances of the NDCR residential limit up to 50 m perpendicular distance from road and 40 m from pipeline were simulated)

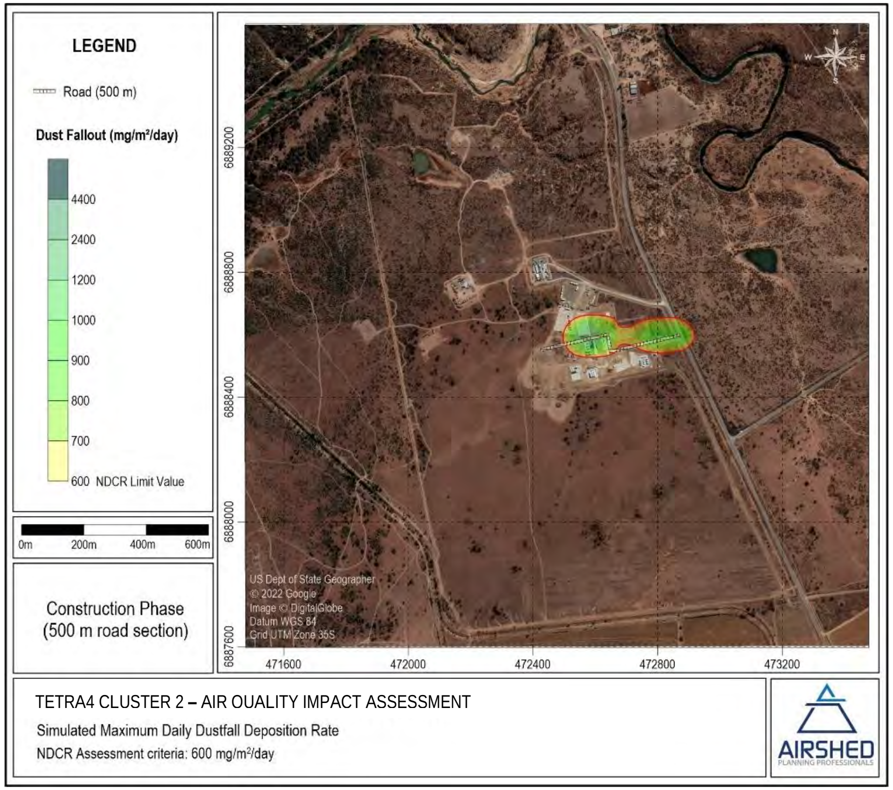

Figure 39: Simulated maximum daily dustfall deposition rates due to proposed road construction emissions (single exceedance of the NDCR residential limit up to 50 m beyond road indicated as red line)

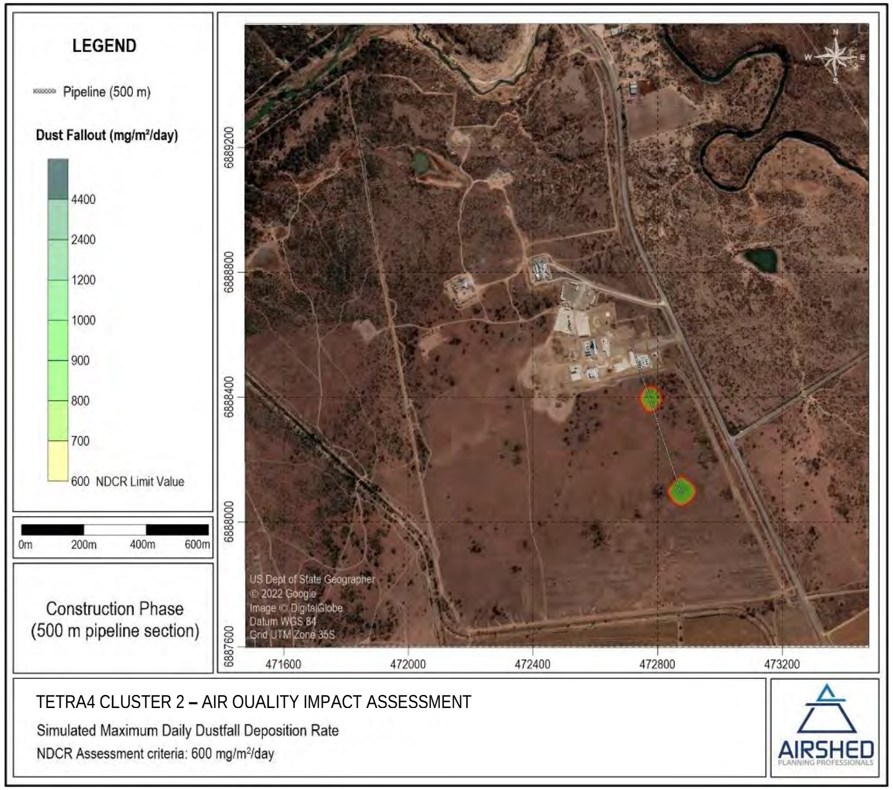

Figure 40: Simulated maximum daily dustfall deposition rates due to proposed pipeline construction emissions (single exceedance of the NDCR residential limit up to 40 m beyond pipeline indicated as red line)

4.3.1.3 Plant/Compressor Site Construction

Simulated maximum GLCs and deposition rates depicting worst-case air quality impacts during the construction of compressor stations and plant are discussed in the below sections for PM_{10}, $PM_{2.5}$, NO_2, SO_2, CO, VOCs and dustfall.[4]

4.3.1.3.1 PM_{10} GLC's

Simulated maximum daily GLCs depicting worst-case air quality impacts during construction as a function of perpendicular distance from plant and compressor stations are shown in Figure 41. From Figure 41 simulated PM_{10} GLCs exceed the NAAQS daily limit up to 500 m beyond the plant boundary and up to 200 m beyond the compressor station (also see Figure 42). Isopleth contours representing maximum daily PM_{10} GLCs and frequency of exceedance of the daily NAAQS limit due to plant construction emissions are shown in Figure 43. Figure 43 shows that although PM_{10} GLCs exceed the NAAQS daily limit up to 500 m from the plant boundary, the footprint of exceedance of more than the allowable 4 days per year extends only 270 m beyond the plant boundary.

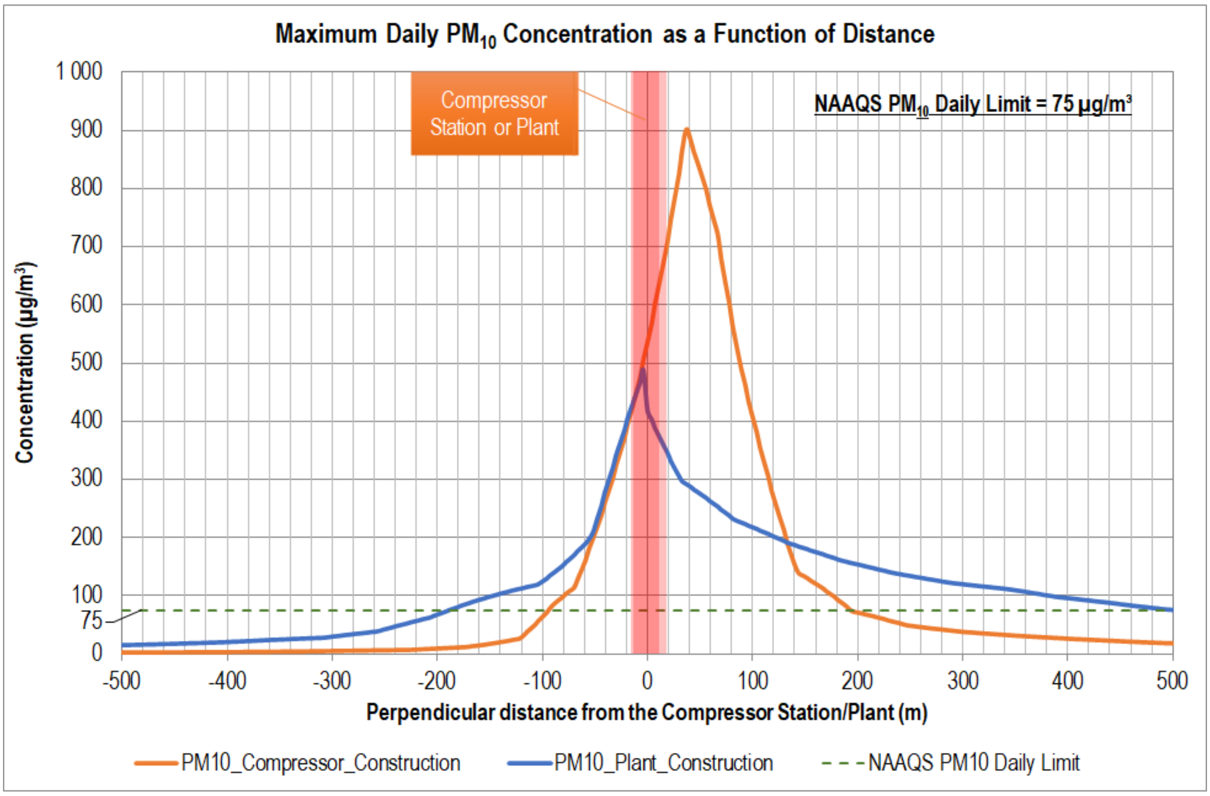

Figure 41: Simulated maximum daily PM_{10} GLCs due to compressor station/plant construction emissions (exceedances of NAAQS limit up to 200 m perpendicular distance from compressor station and 500 m from plant site were simulated)

[4] Three compressor stations are proposed: Compressor Station 1 (CS1), Compressor Station 2 (CS2) and Compressor Station 3 (CS3). There are two potential sites for CS3: the preferred site ~500 m south of CS2 and an alternative site ~4500 m south of CS2. Potential air quality impacts due to construction activities were assessed at CS1 location. The impact at CS1 will be representative of the impacts expected at CS2, CS3 and the other alternative location to CS3.

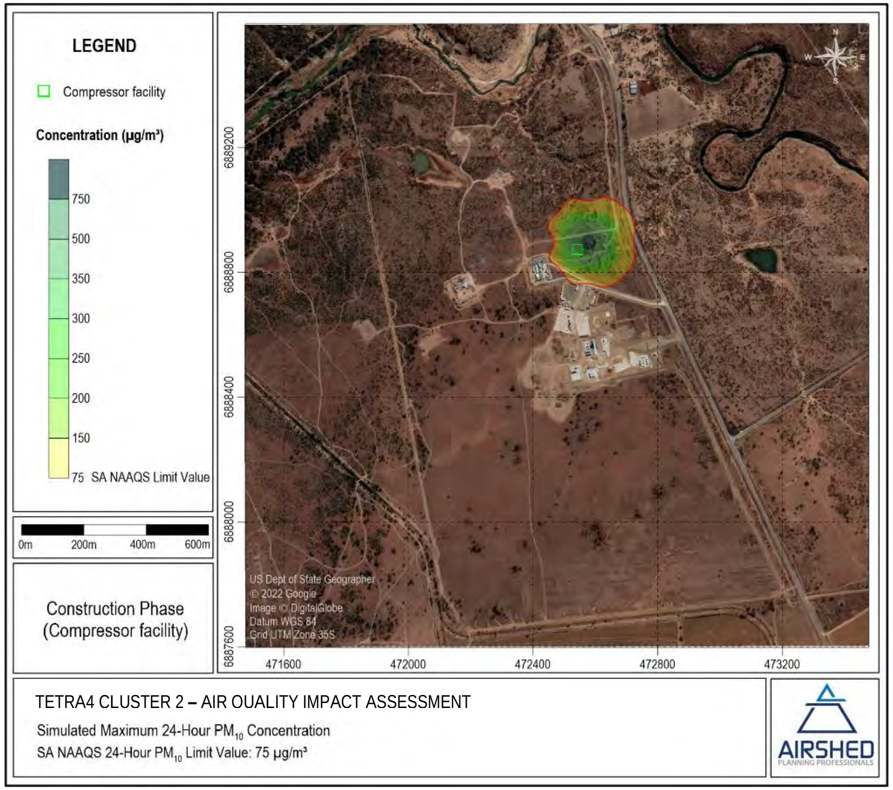

Figure 42: Simulated maximum 24-hour PM_{10} GLCs due to proposed compressor station construction emissions (single exceedance of the NAAQS limit up to 200 m beyond compressor station site indicated as red line)

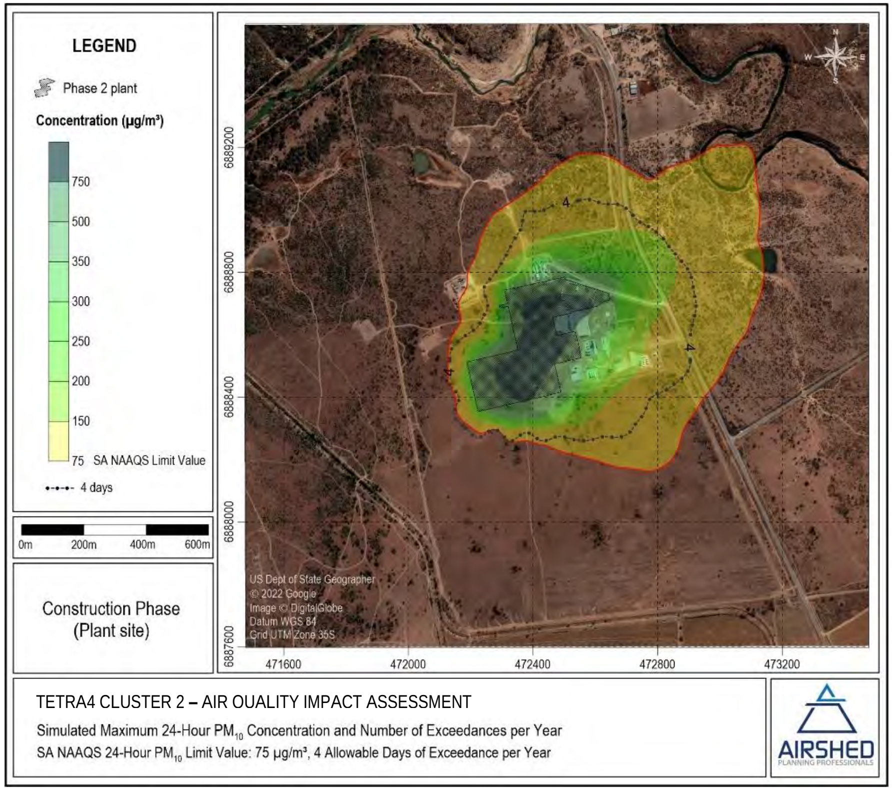

Figure 43: Simulated maximum 24-hour PM_{10} GLCs and frequency of exceedance due to proposed plant construction emissions (single exceedance of NAAQS limit and allowable frequency of exceedance up to 500 m and 270 m respectively beyond plant site)

4.3.1.3.2 $PM_{2.5}$ GLC's

Simulated maximum daily GLCs depicting worst-case $PM_{2.5}$ impacts during construction as a function of perpendicular distance from plant and compressor stations are shown in Figure 44. Isopleth contours representing maximum daily $PM_{2.5}$ GLCs due to construction of the compressor station and plant are shown in Figure 45 and Figure 46 respectively. From Figure 44 simulated $PM_{2.5}$ GLCs exceed the NAAQS daily limit up to 180 m beyond the plant boundary and up to 150 m beyond the compressor station. From Figure 46 the footprint of exceedance of more than the allowable 4 days per year extends 85 m beyond the plant boundary.

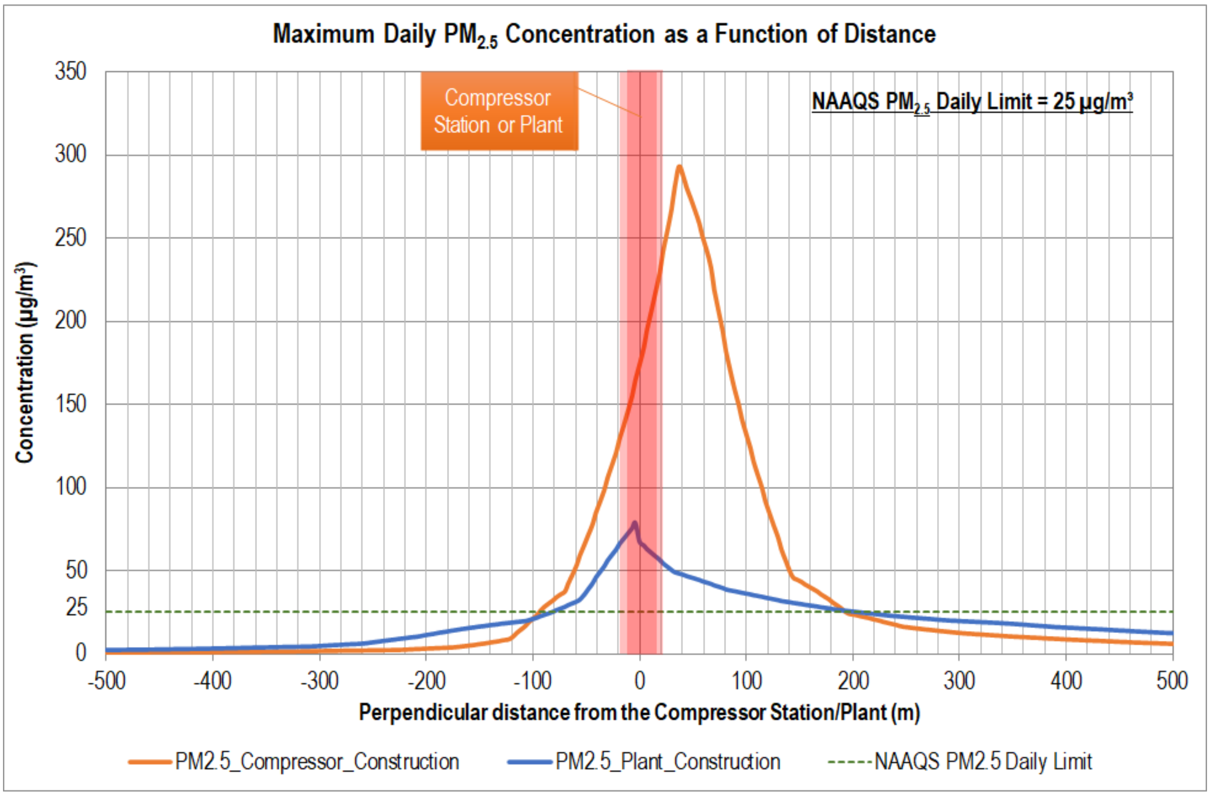

Figure 44: Simulated maximum daily $PM_{2.5}$ GLCs due to compressor station/plant construction emissions (exceedances of NAAQS limit up to 150 m perpendicular distance from compressor station and 180 m from plant site were simulated)

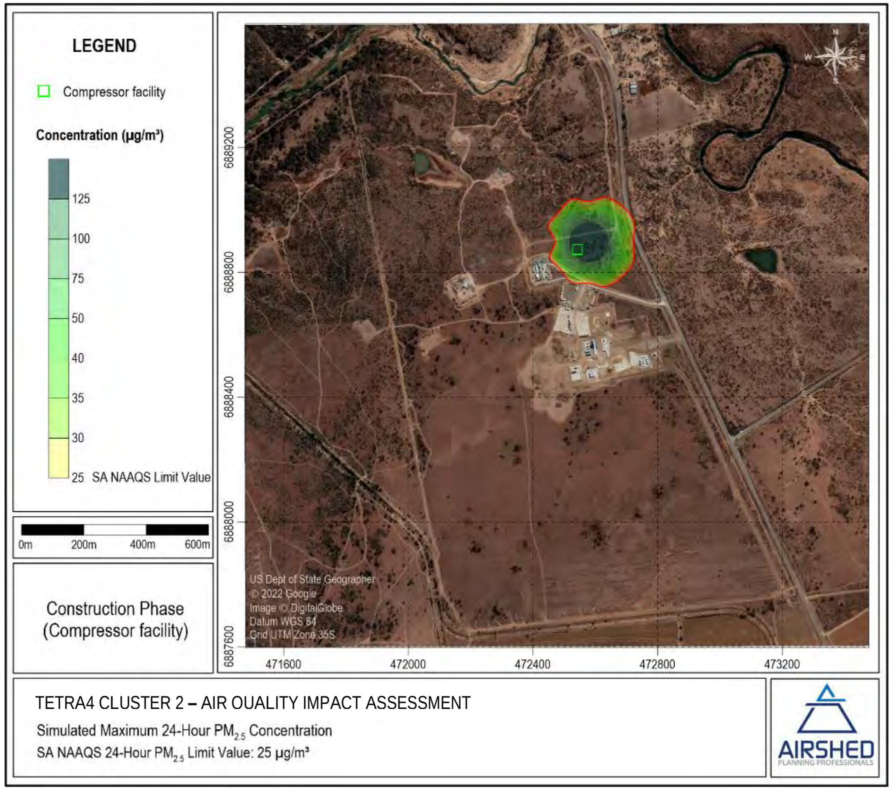

Figure 45: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed compressor station construction emissions (single exceedance of NAAQS limit up to 150 m beyond compressor station site indicated as red line)

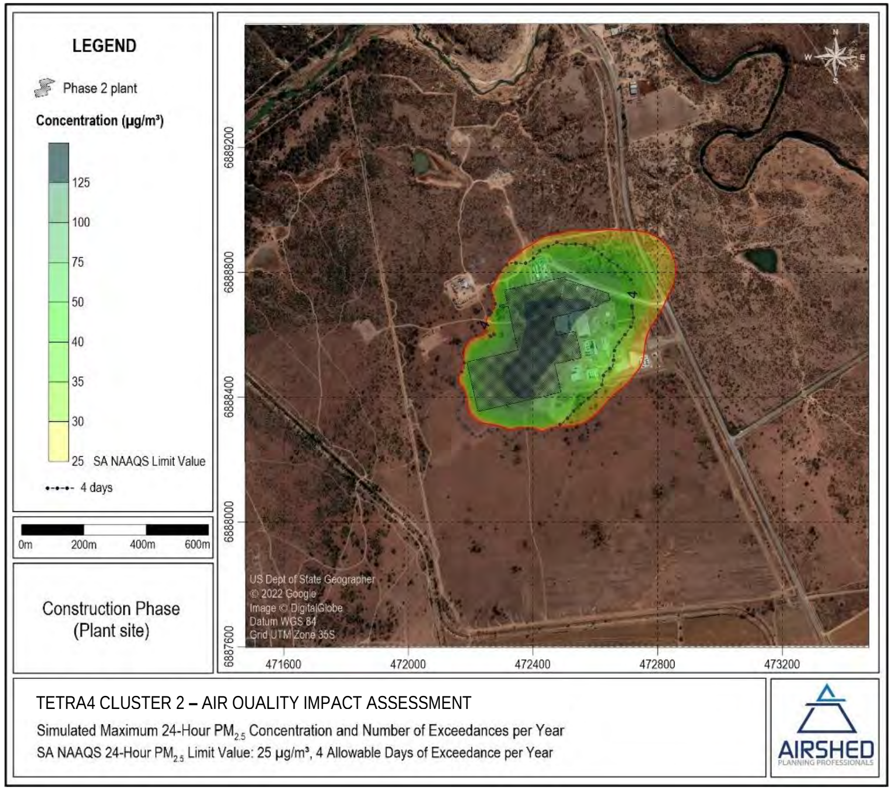

Figure 46: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to proposed plant construction emissions (single exceedance of NAAQS limit and allowable frequency of exceedance up to 180 m and 85 m respectively beyond plant site)

4.3.1.3.3 NO_2 GLC's

Simulated maximum hourly GLCs depicting worst-case NO_2 impacts during construction as a function of perpendicular distance from plant and compressor stations are shown in Figure 47. Isopleth contours representing maximum hourly NO_2 GLCs and frequency of exceedance of the NAAQS hourly limit are shown in Figure 48 and Figure 49 for compressor and plant construction respectively. From Figure 47 and Figure 48 simulated NO_2 GLCs exceed the NAAQS hourly limit up to 500 m beyond the compressor station. From Figure 49 simulated maximum hourly NO_2 GLCs exceed the NAAQS hourly limit up to 700 m beyond the plant boundary. The footprint of exceedance on more than the allowable 88 hours per year extends 140 m beyond the compressor station (Figure 48) and 60 m beyond the plant boundary (Figure 49) respectively.

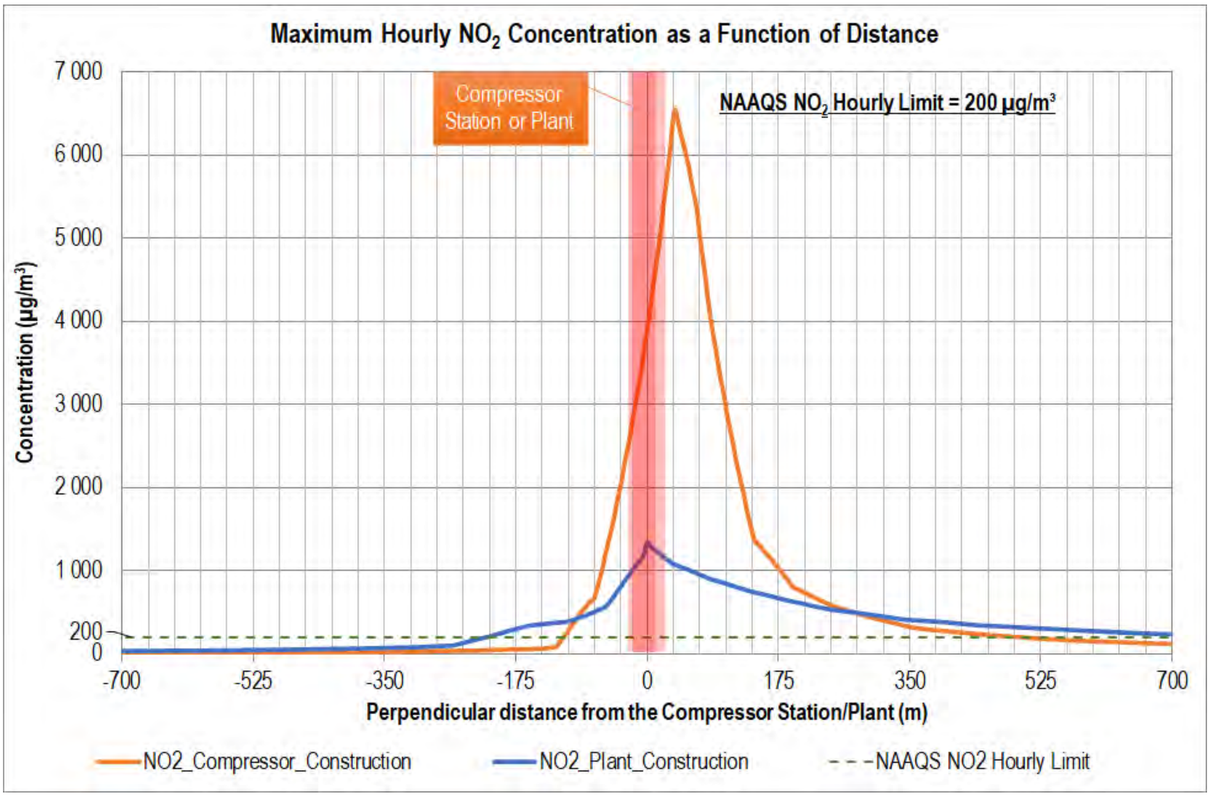

Figure 47: Simulated maximum hourly NO_2 GLCs due to compressor station/plant construction emissions (exceedances of NAAQS limit up to 500 m perpendicular distance from compressor station and 800 m from plant site were simulated)

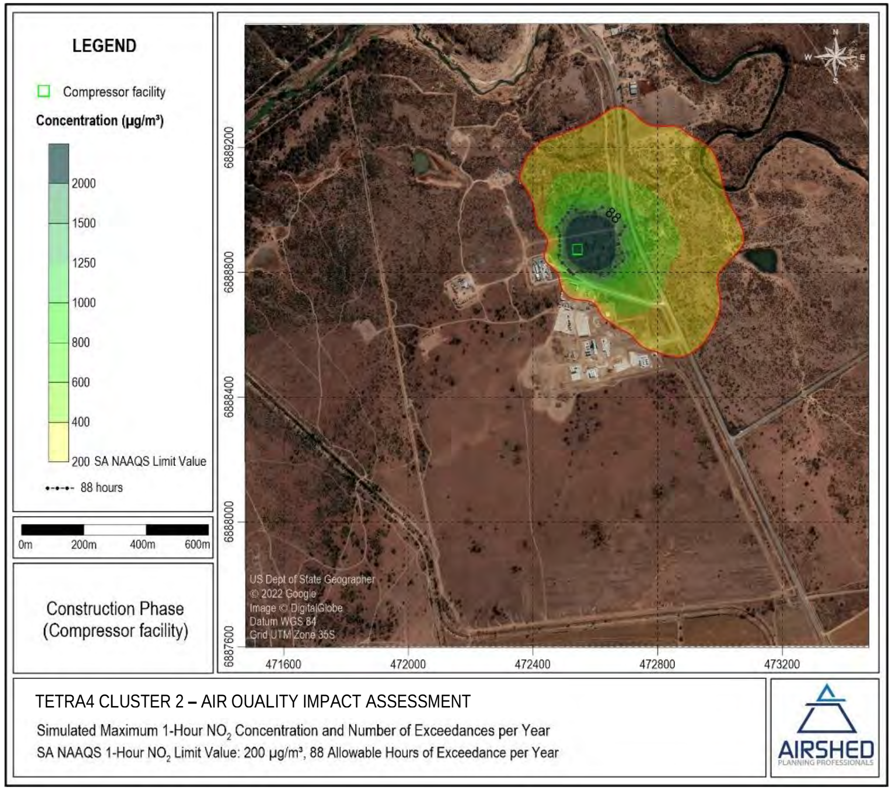

Figure 48: Simulated maximum 1-hour NO_2 GLCs due to proposed compressor station construction emissions (single exceedance of NAAQS limit and allowable frequency of exceedance up to 500 m and 140 m respectively beyond compressor site)

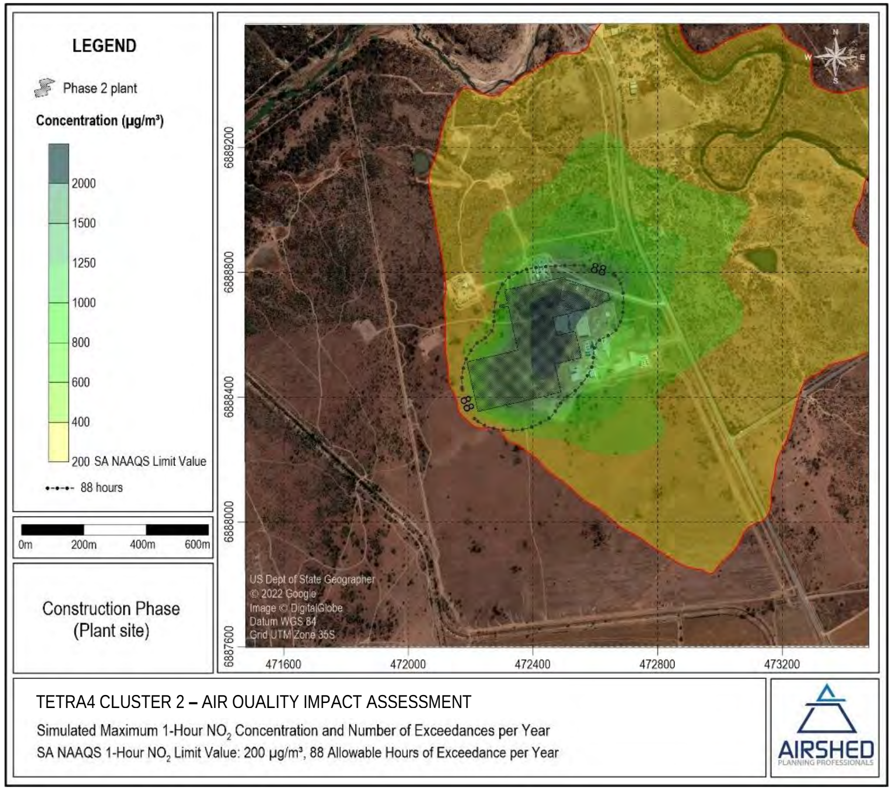

Figure 49: Simulated maximum 1-hour NO_2 GLCs due to proposed plant construction emissions (single exceedance of NAAQS limit and allowable frequency of exceedance up to 800 m and 60 m respectively beyond plant site)

4.3.1.3.4 SO_2 GLC's

Simulated hourly GLCs depicting worst-case SO_2 construction impacts as a function of perpendicular distance from the proposed compressor station and plant are shown in Figure 50. Figure 50 illustrates that simulated SO_2 GLCs are very low and are not expected to exceed the NAAQS hourly limit (350 µg/m³) during compressor station/plant construction.

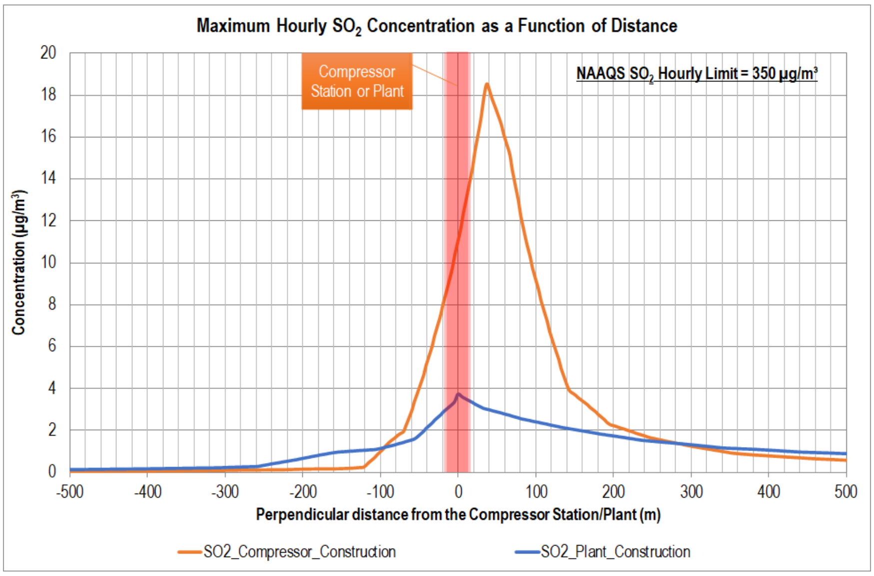

Figure 50: Simulated maximum hourly SO_2 GLCs due to compressor station/plant construction emissions (the NAAQS limit is not exceeded)

4.3.1.3.5 CO GLC's

Simulated hourly GLCs depicting worst-case CO construction impacts as a function of perpendicular distance from the proposed compressor station and plant are shown in Figure 51. Figure 51 illustrates that simulated CO GLCs are not expected to exceed the NAAQS hourly limit (30 000 µg/m³) during the construction of compressor stations or plant.

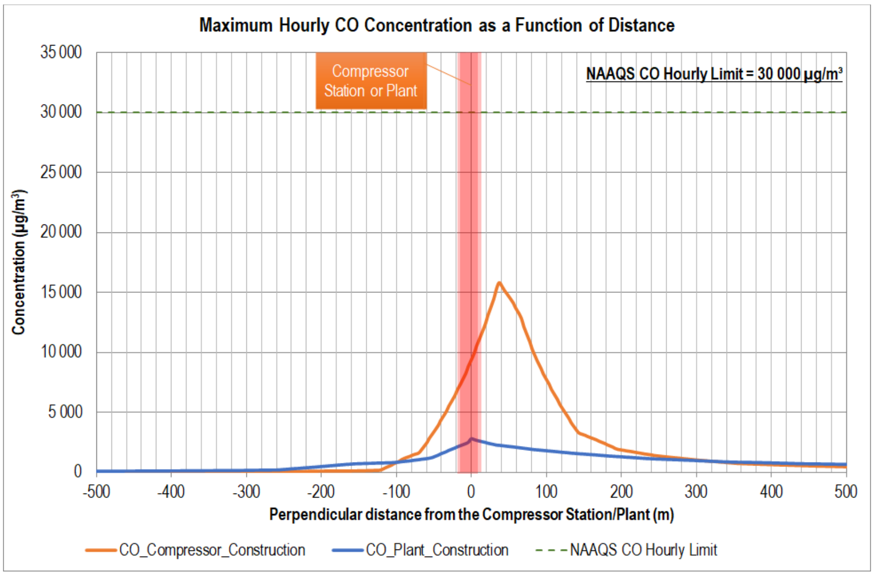

Figure 51: Simulated maximum hourly CO GLCs due to compressor station/plant construction emissions (the NAAQS limit is not exceeded)

4.3.1.3.6 VOC GLC's

Maximum simulated hourly VOC GLCs due to construction activities as a function of perpendicular distance from the compressor station and plant are illustrated in Figure 52. From Figure 52 and Figure 53 hourly VOC GLCs exceed the TCEQ Effects Screening Level (ESL) of 1 000 µg/m³ up to 130 m beyond the compressor station site. From Figure 54 the area of exceedance due to plant construction activities is confined to the plant site and no exceedances are expected beyond the plant boundary.

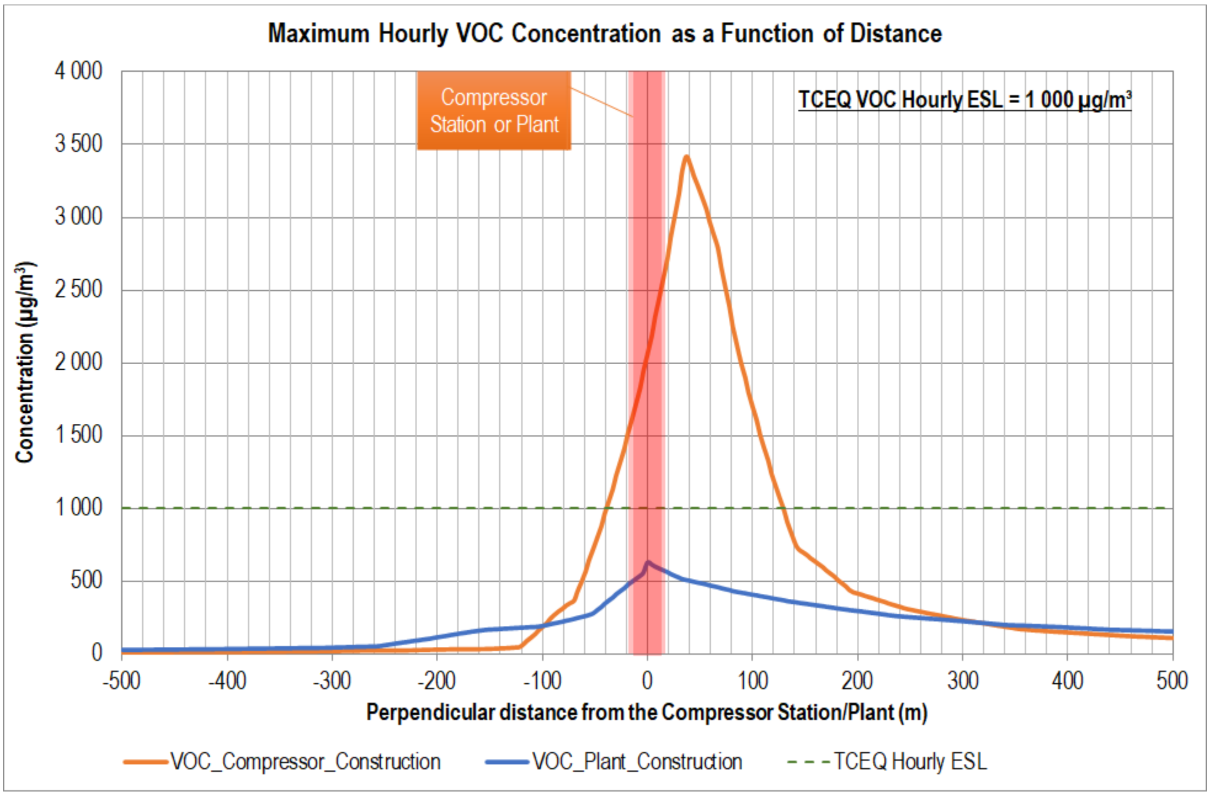

Figure 52: Simulated maximum hourly VOC GLCs due to compressor station/plant construction emissions (exceedance of TCEQ ESL up to 130 m perpendicular distance from compressor station was simulated; no exceedances of TCEQ ESL beyond plant boundary)

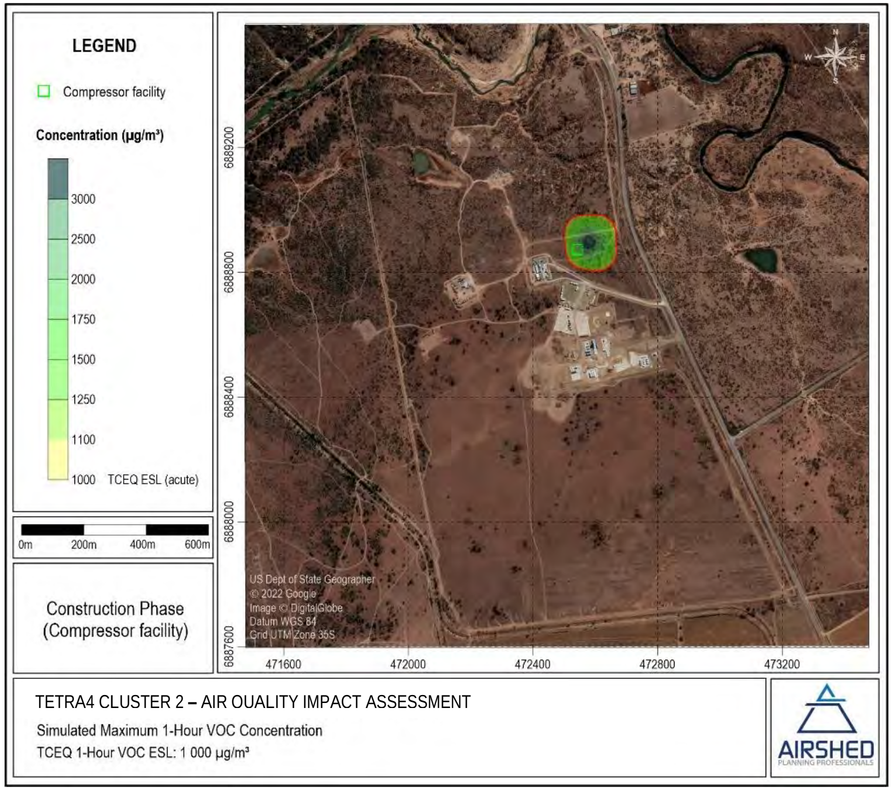

Figure 53: Simulated maximum 1-hour VOC GLCs due to proposed compressor station construction emissions (single exceedance of TCEQ ESL up to 130 m beyond compressor station site indicated as red line)

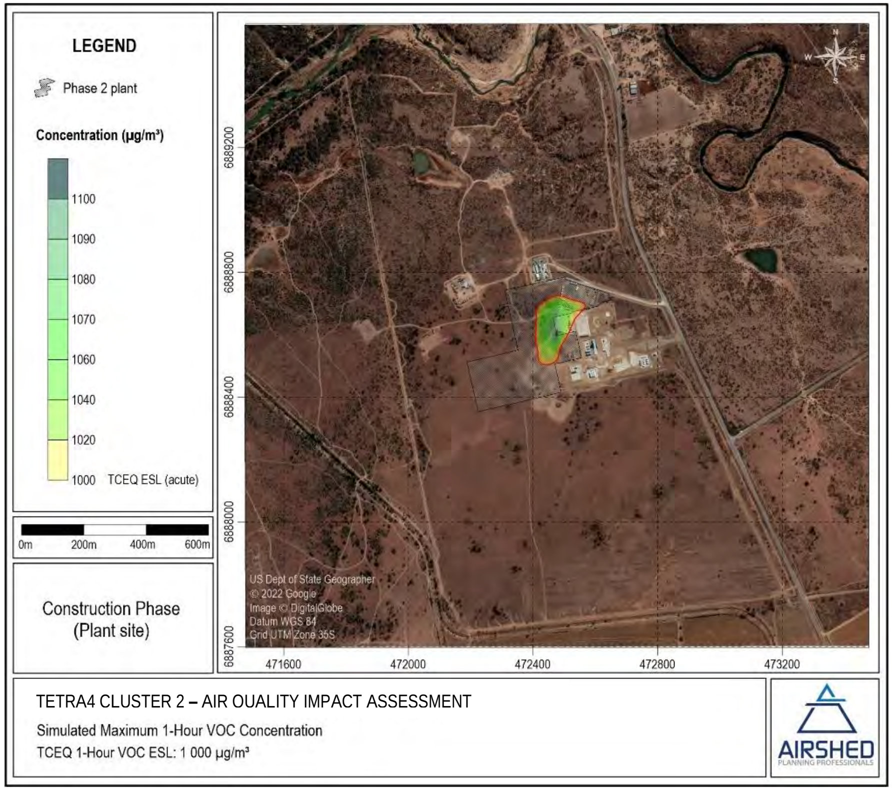

Figure 54: Simulated maximum 1-hour VOC GLCs due to proposed plant construction emissions (no exceedance of TCEQ ESL beyond plant boundary)

4.3.1.3.7 Dustfall Deposition Rates

Maximum simulated daily dustfall deposition rates as a result of compressor station and plant construction emissions are shown in Figure 55 as a function of perpendicular distance from each type of infrastructure. From Figure 55 simulated daily dustfall deposition rates exceed the NDCR residential limit of 600 mg/m²/day up to 60 m and 90 m beyond the compressor station and plant respectively (see Figure 56 and Figure 57).

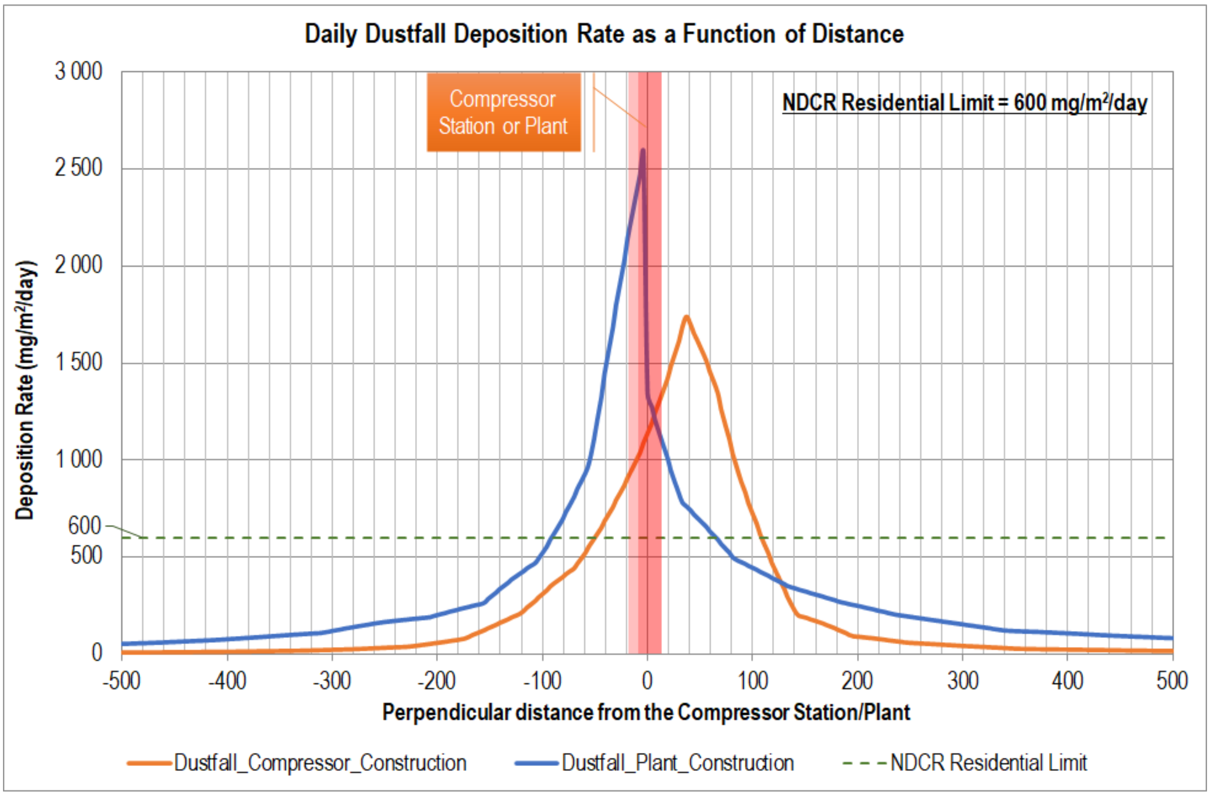

Figure 55: Simulated daily dustfall deposition rates due to compressor station/plant construction emissions (exceedances of the NDCR residential limit up to 60 m perpendicular distance from compressor station and 90 m from plant were simulated)

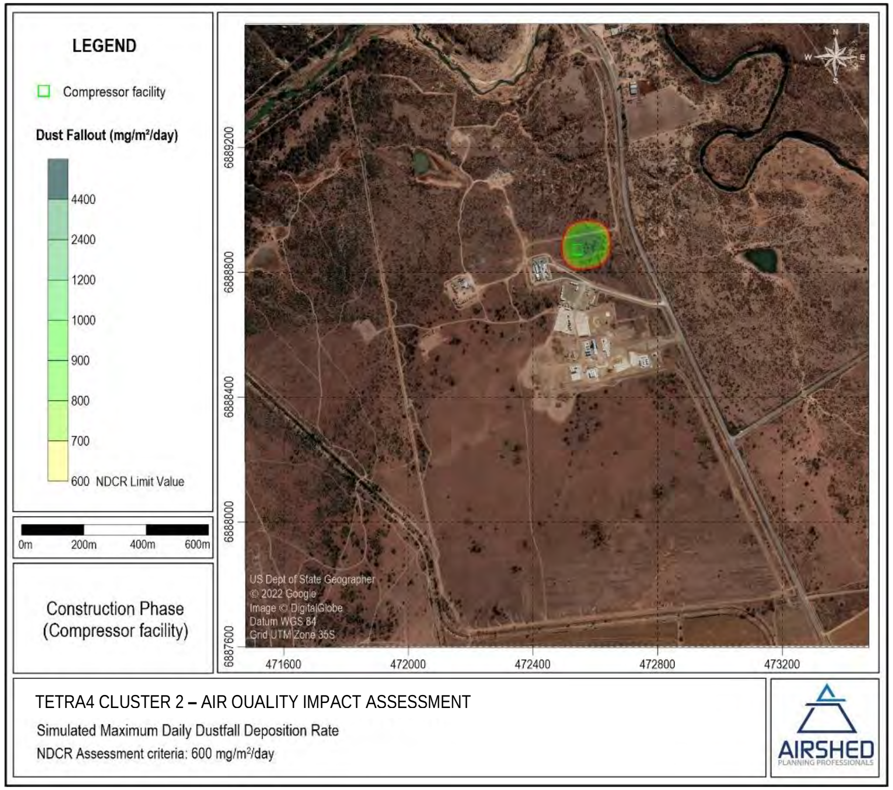

Figure 56: Simulated maximum daily dustfall deposition rates due to proposed compressor station construction emissions (single exceedance of the NDCR residential limit up to 60 m beyond compressor station indicated as red line)

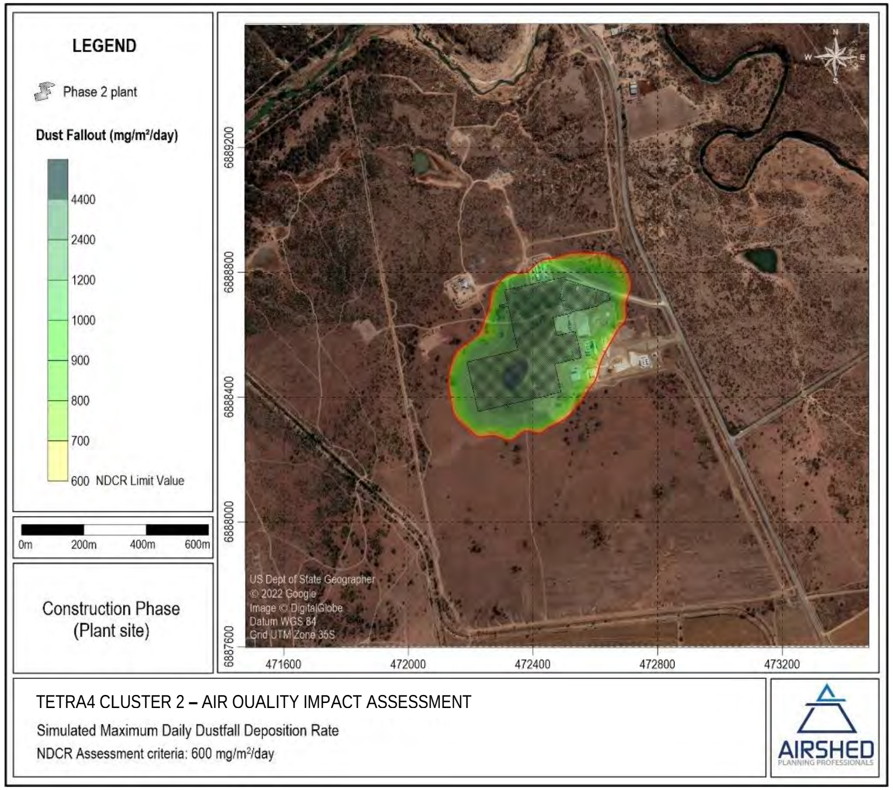

Figure 57: Simulated maximum daily dustfall deposition rates due to plant construction emissions (single exceedance of the NDCR residential limit up to 90 m beyond plant boundary indicated as red line)

4.3.2 Operational Phase Results

4.3.2.1 Routine or Normal operations

Sources of emission and associated pollutants for the operational phase and included in the dispersion model are:

- Combined LNG/LHe plant flaring emissions – CO, NO_X and VOCs
- Generator emissions at booster stations – $PM_{2.5}$, PM_{10}, CO, SO_2, NO_X and VOCs
- Entrained PM from unpaved roads – $PM_{2.5}$, PM_{10}, and TSP.

Isopleth plots are provided for all pollutants where exceedances of the relevant NAAQSs were simulated. Isopleth plots reflect the incremental GLCs and deposition rates over the 5 km by 5 km modelling domain for all pollutants assessed. The modelling domain was selected such that all sources of project emissions are contained in it, to give a good representation of air quality related impacts because of the proposed project on air quality sensitive receptors.

4.3.2.1.1 PM_{10} GLC's

Isopleth plots showing simulated maximum daily and annual average PM_{10} GLCs due to operational phase emissions are presented in Figure 58 and Figure 59 respectively. Maximum daily GLCs representing worst-case PM_{10} impacts at AQSRs during the operational phase are provided in Table 22. From Table 22 simulated PM_{10} concentrations were low and well below the NAAQS for both 24-hour averages and annual averages, at all AQSRs.

Table 22: Simulated PM_{10} GLCs at AQSRs due to operational phase emissions (all sources)

AQSR	Annual average (µg/m³)		24-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	GLCs	NAAQS Limit	Number of days	NAAQS Limit
1	0.03	40	0.35	75	0	4
2	0.04	40	0.31	75	0	4
3	0.04	40	0.42	75	0	4
4	0.06	40	0.48	75	0	4
5	0.05	40	0.28	75	0	4
6	0.03	40	0.32	75	0	4
7	2.77	40	5.85	75	0	4
8	0.08	40	0.48	75	0	4
9	0.54	40	4.07	75	0	4
10	0.11	40	0.82	75	0	4
Max (grid)	88.40	–	310.99	–	226	–

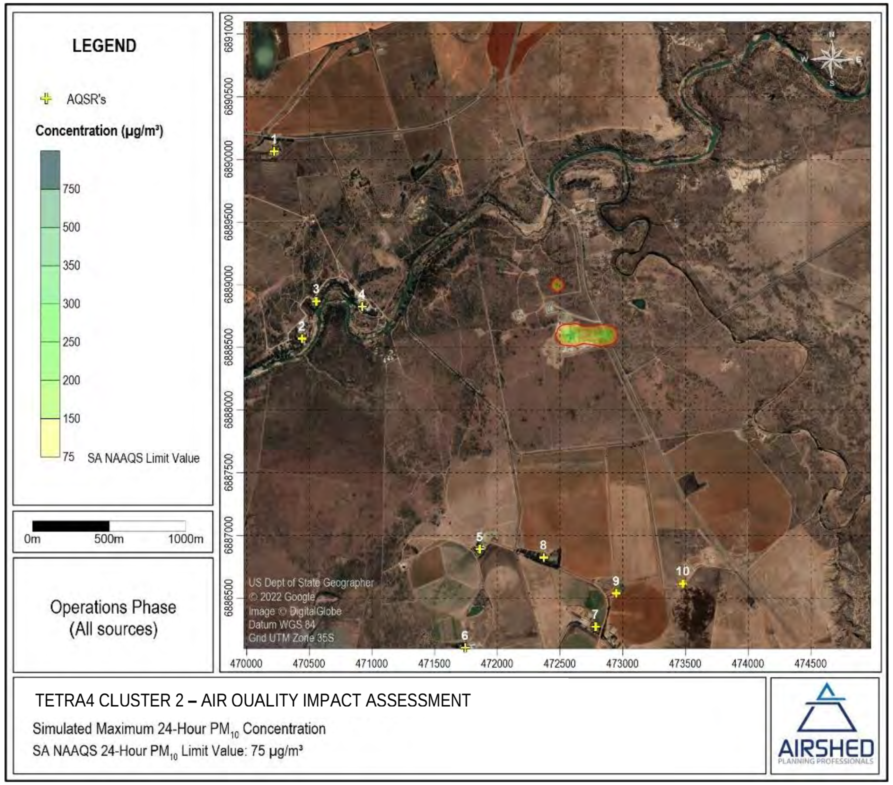

Figure 58: Simulated maximum 24-hour PM_{10} GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 80 m beyond public road and 60 m beyond booster station, indicated as red line)

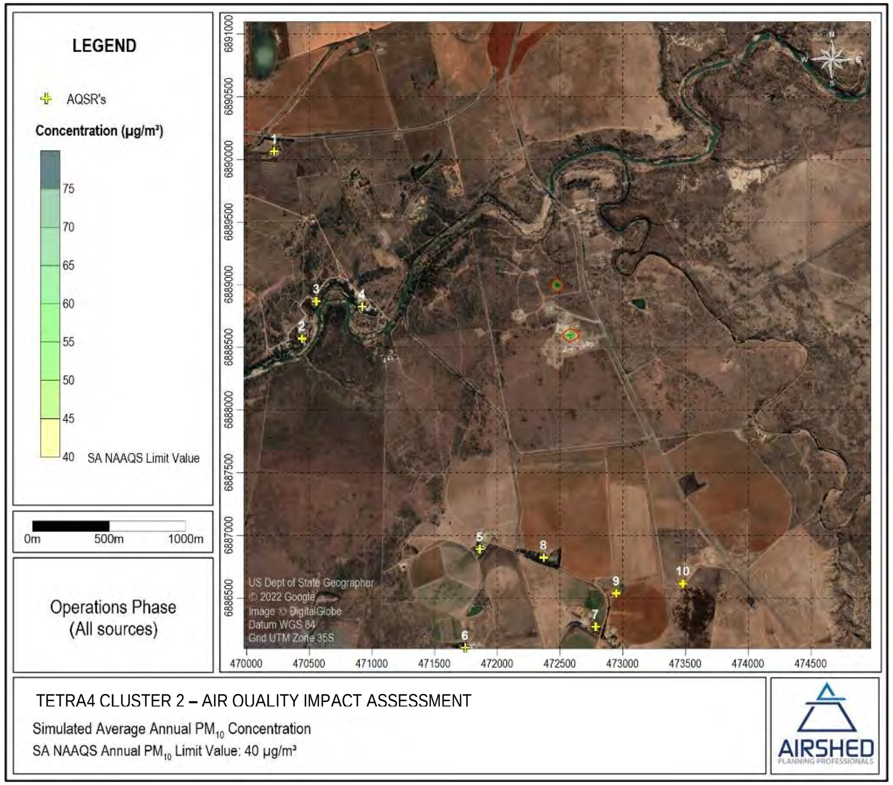

Figure 59: Simulated annual average PM_{10} GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 55 m beyond booster station indicated as red line)

4.3.2.1.2 $PM_{2.5}$ GLC's

Isopleth plots showing simulated maximum daily and annual average $PM_{2.5}$ GLCs due to operational phase emissions are presented in Figure 60 and Figure 61 respectively. Maximum daily GLCs representing worst-case $PM_{2.5}$ impacts at AQSRs during the operational phase are provided in Table 23. From Table 23 simulated $PM_{2.5}$ concentrations were low and well below the NAAQS for both 24-hour averages and annual averages, at all AQSRs.

Table 23: Simulated $PM_{2.5}$ GLCs at AQSRs due to operational phase emissions

AQSR	Annual average (µg/m³)		24-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	GLCs	NAAQS Limit	Number of days	NAAQS Limit
1	0.01	15	0.08	25	0	4
2	0.01	15	0.05	25	0	4
3	0.01	15	0.06	25	0	4
4	0.02	15	0.09	25	0	4
5	0.02	15	0.07	25	0	4
6	0.02	15	0.08	25	0	4
7	2.70	15	5.72	25	0	4
8	0.05	15	0.42	25	0	4
9	0.52	15	3.99	25	0	4
10	0.10	15	0.81	25	0	4
Max (grid)	85.69	–	164.09	–	333	–

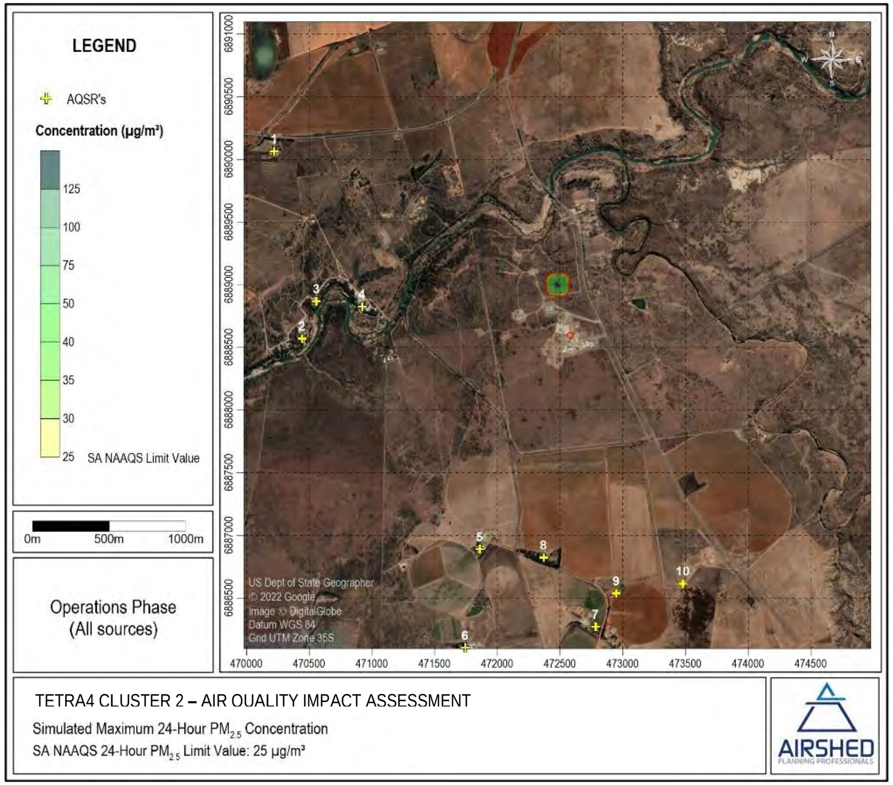

Figure 60: Simulated maximum 24-hour $PM_{2.5}$ GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 100 m beyond booster station indicated as red line)

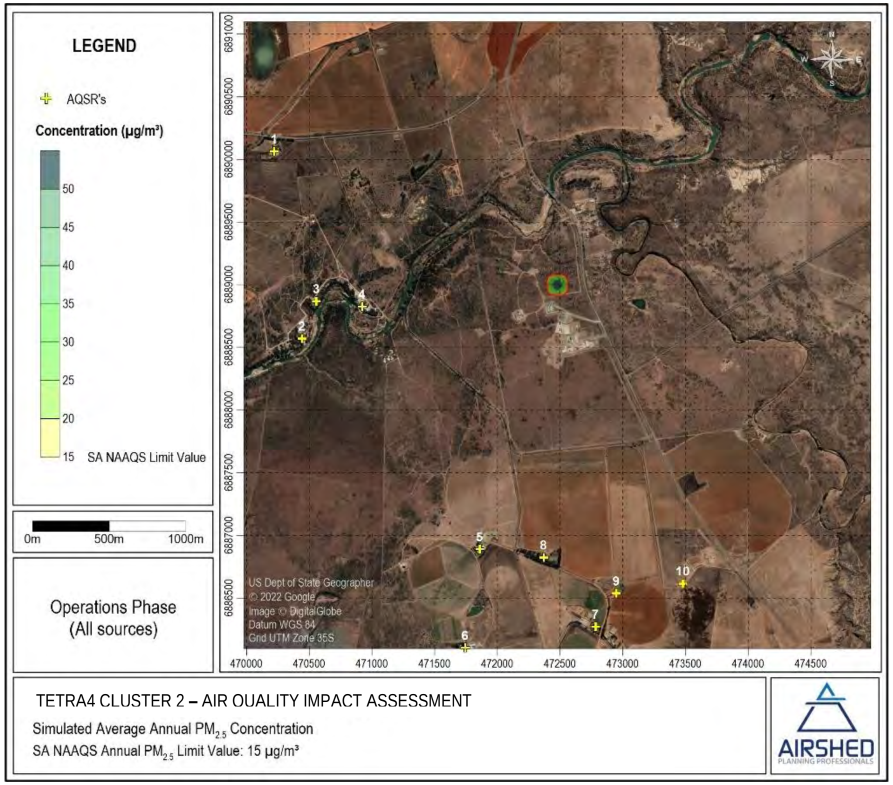

Figure 61: Simulated annual average $PM_{2.5}$ GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 90 m beyond booster station indicated as red line)

4.3.2.1.3 NO_2 GLC's

Isopleth plots showing simulated maximum hourly and annual average NO_2 GLCs due to operational phase emissions are presented in Figure 62 and Figure 63 respectively. Maximum hourly GLCs representing worst-case NO_2 impacts at AQSRs during the operational phase are provided in Table 24. From Table 24 simulated NO_2 concentrations were well below the NAAQS for both 24-hour averages and annual averages, at all AQSRs. The highest hourly concentrations were simulated at AQSRs 7 and 9 due to their close proximity to the booster station (where a diesel generator is operated).

Table 24: Simulated NO_2 GLCs at AQSRs due to operational phase emissions

AQSR	Annual average (µg/m³)		1-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	GLCs	NAAQS Limit	Number of hours	NAAQS Limit
1	0.02	40	1.73	200	0	88
2	0.03	40	1.37	200	0	88
3	0.03	40	1.30	200	0	88
4	0.04	40	2.98	200	0	88
5	0.04	40	2.36	200	0	88
6	0.04	40	2.00	200	0	88
7	7.78	40	36.90	200	0	88
8	0.14	40	17.49	200	0	88
9	1.49	40	79.15	200	0	88
10	0.28	40	28.86	200	0	88
Max (grid)	247.19	–	724.86	–	4 449	–

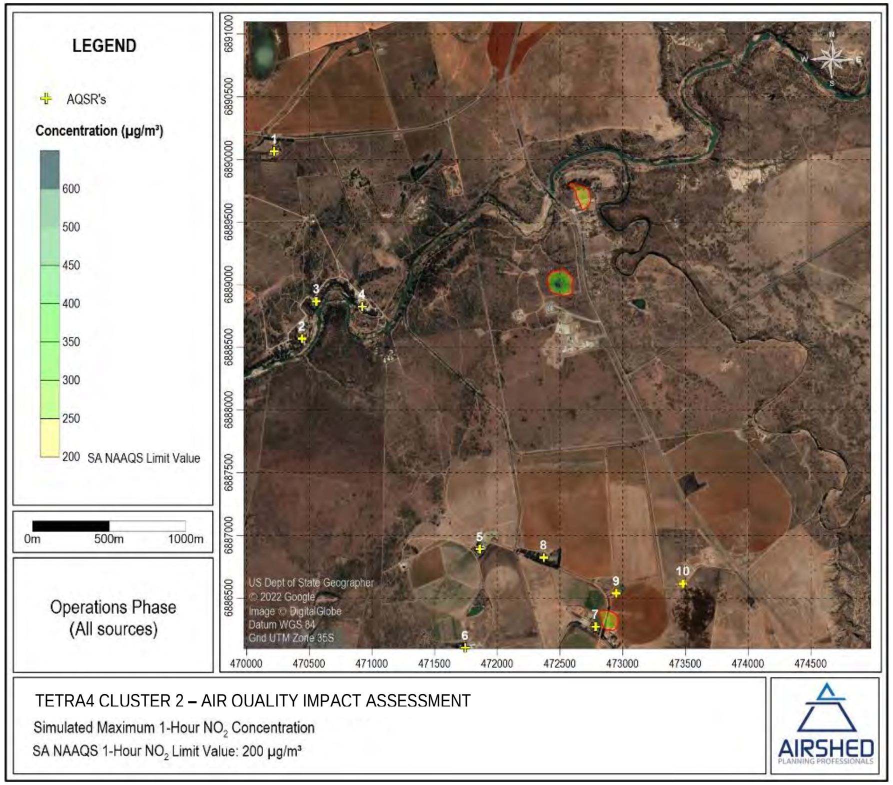

Figure 62: Simulated maximum 1-hour NO_2 GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 100 m beyond booster station indicated as red line)

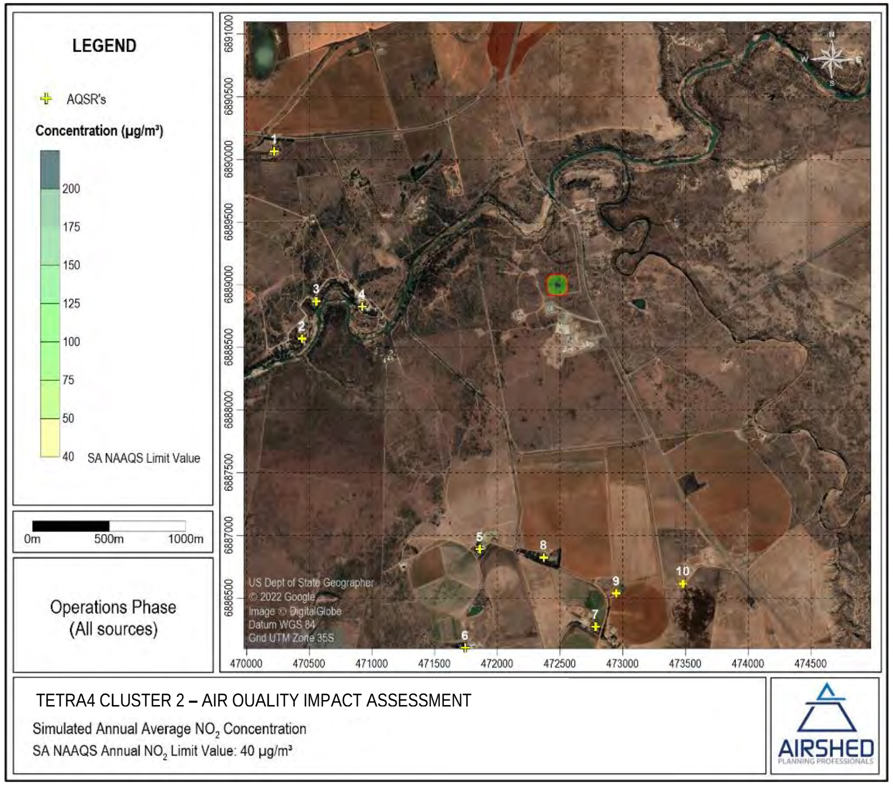

Figure 63: Simulated annual average NO_2 GLCs due to operational phase emissions (single exceedance of NAAQS limit up to 90 m beyond booster station indicated as red line)

4.3.2.1.4 SO_2 GLC's

Maximum hourly GLCs representing worst-case SO_2 impacts at AQSRs during the operational phase are provided in Table 25. The concentrations were well below the NAAQS for both 1-hour averages and annual averages, at all AQSRs.

Table 25: Simulated SO_2 GLCs at AQSRs due to operational phase emissions

AQSR	Annual average (µg/m³)		1-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	GLCs	NAAQS Limit	Number of hours	NAAQS Limit
1	0.000	50	0.002	350	0	88
2	0.000	50	0.001	350	0	88
3	0.000	50	0.001	350	0	88
4	0.000	50	0.003	350	0	88
5	0.000	50	0.002	350	0	88
6	0.000	50	0.002	350	0	88
7	0.009	50	0.042	350	0	88
8	0.000	50	0.020	350	0	88
9	0.002	50	0.089	350	0	88
10	0.000	50	0.033	350	0	88
Max (grid)	0.022	–	0.374	–	0	–

4.3.2.1.5 CO GLC's

Maximum hourly GLCs representing worst-case CO impacts at AQSRs during the operational phase are provided in Table 26. The concentrations were well below the NAAQS for 1-hour averages, at all AQSRs.

Table 26: Simulated CO GLCs at AQSRs due to operational phase emissions

AQSR	1-hr (µg/m³)		Frequency of exceedance	
	GLCs	NAAQS Limit	Number of hours	NAAQS Limit
1	1.86	30 000	0	88
2	1.48	30 000	0	88
3	1.39	30 000	0	88
4	3.20	30 000	0	88
5	2.54	30 000	0	88
6	2.16	30 000	0	88
7	39.66	30 000	0	88
8	18.80	30 000	0	88
9	85.07	30 000	0	88
10	31.02	30 000	0	88
Max (grid)	779.10	–	0	–

4.3.2.1.6 VOC GLC's

Maximum hourly GLCs representing worst-case VOC impacts at AQSRs during the operational phase are provided in Table 27. The concentrations were well below the TCEQ ESL for both 1-hour averages and annual averages, at all AQSRs.

Table 27: Simulated VOC GLCs at AQSRs due to operational phase emissions

AQSR	Annual (µg/m³)		1-hr (µg/m³)	
	GLCs	TCEQ ESL (chronic)	GLCs	TCEQ ESL (acute)
1	0.01	100	0.63	1 000
2	0.01	100	0.50	1 000
3	0.02	100	0.47	1 000
4	0.02	100	1.08	1 000
5	0.02	100	0.86	1 000
6	0.02	100	0.73	1 000
7	2.82	100	13.38	1 000
8	0.05	100	6.34	1 000
9	0.54	100	28.70	1 000
10	0.10	100	10.46	1 000
Max (grid)	89.63	–	262.83	–

4.3.2.1.7 Dustfall Deposition Rates

An isopleth plot showing simulated maximum 30-day average dustfall deposition rates due to operational phase emissions are presented in Figure 64. Maximum dustfall rates at AQSRs during the operational phase are provided in Table 28. From Table 28 the deposition rates were well below the NDCR residential limit at all AQSRs and higher dustfall rates were limited to the plant site (Figure 64).

Table 28: Simulated daily dustfall deposition rates at AQSRs due to operational phase emissions

AQSR	Maximum daily (mg/m²/day)	
	Deposition Rates	NDCR Residential Limit
1	5.45	600
2	4.56	600
3	5.67	600
4	7.88	600
5	4.91	600
6	2.94	600
7	19.71	600
8	3.89	600
9	2.72	600
10	1.85	600
Max (grid)	6 783.57	–

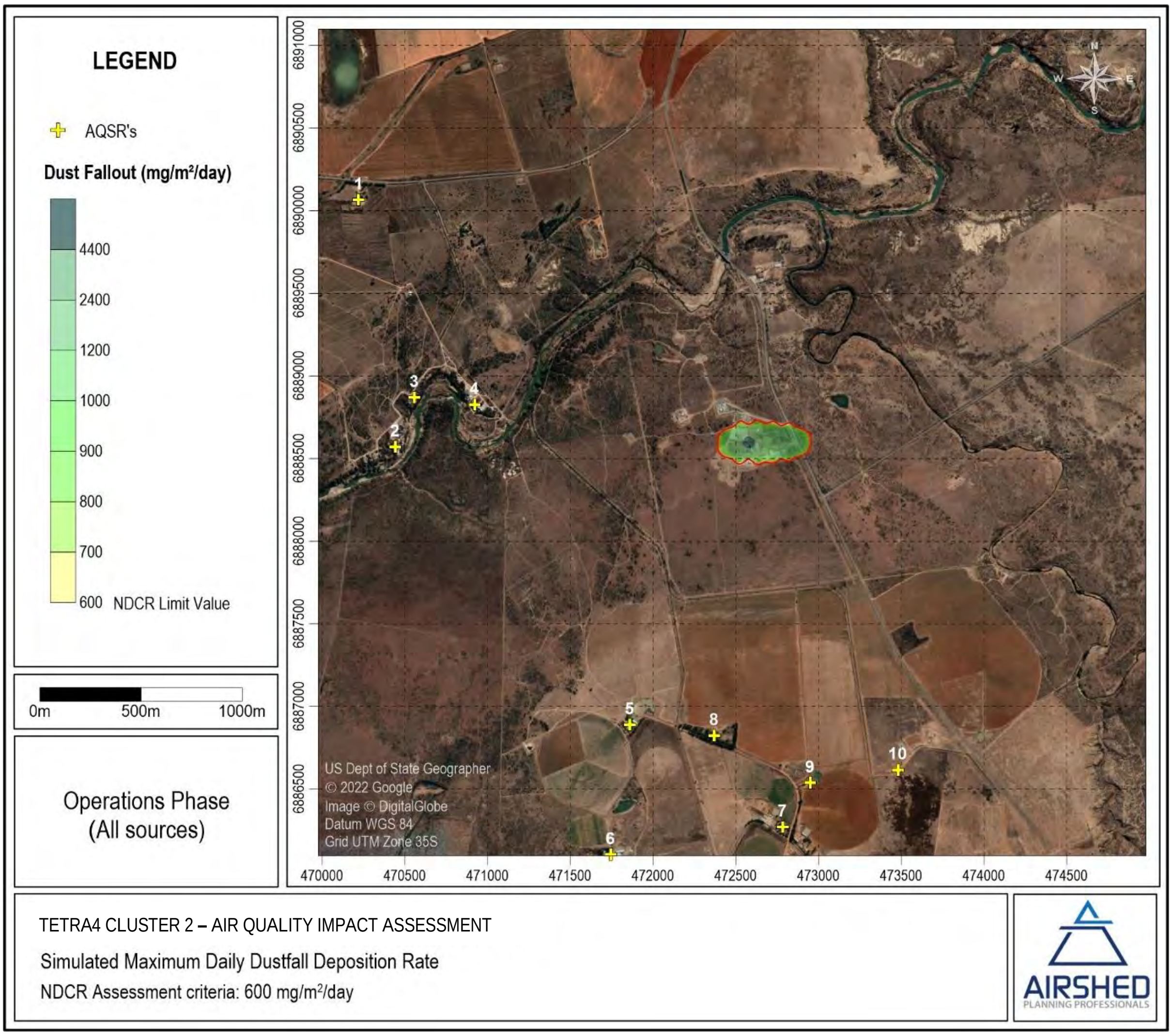

Figure 64: Simulated maximum daily dustfall deposition rates due to operational phase emissions (single exceedance of the NDCR residential limit up to 75 m beyond public road indicated as red line)

4.3.2.2 Emergency or Upset conditions

The impacts of flaring due to short-term emergency or upset conditions during operational phase were assessed based on description and assumptions published in Section 4.1.2.2. Maximum GLCs for each pollutant assessed are shown in Table 29 and are extremely low for flaring under routine conditions. Simulated NO_2 and CO GLCs due to upset conditions (warm or cold flares) fall below the respective NAAQS limits, but simulated VOC GLCs due to upset conditions exceed the TCEQ hourly screening criteria.

Table 29: Simulated maximum GLCs due to flaring during routine versus upset conditions

Pollutant	Routine Conditions (Flare)		Upset Conditions (Warm Flare)		Upset Conditions (Cold Flare)	
	GLCs (µg/m³)	NAAQS Limit	GLCs (µg/m³)	NAAQS Limit	GLCs (µg/m³)	NAAQS Limit
NO_2	0.06	200	119.33	200	33.91	200
CO	1.70	30 000	3 456.27	30 000	984.75	30 000
VOC	2.93	1 000[(a)]	5 947.12	1 000[(a)]	1 695.33	1 000[(a)]

Notes:

(a) TCEQ hourly ESL for VOCs

4.3.3 Proposed Setback Distances

Set back distances represent separations between a construction or project site and any adjacent residential areas or sensitive developments. The width of the setback distances is informed by the results from the dispersion modelling results presented in Sections 4.3.1 and 4.3.2. Since construction will only be for short durations, and operations are only likely to result in single exceedances of the NAAQSs, the setback distances are seen not as exclusion zones, but as management zones where the potential for air quality impacts can be mitigated and managed.

Table 30: Simulated setback distances (approximate)

Construction Phase							
Sources	Setback distance (m)						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NO_2	CO	SO_2
Well construction site	290	180	–	170	750[(a)]	–	–
Booster station site	200	150	–	130	500[(a)]	–	–
Pipeline construction site	100	100	40	–	150[(a)]	–	–
Road construction site	80	95	50	–	150[(a)]	–	–
Compressor station construction site	150	200	60	130	140[(b)]	–	–
Plant construction site	85 [(c)]	270 [(c)]	90	–	60[(b)]	–	–
Operations Phase							
Sources	Setback distance (m)						
	$PM_{2.5}$	PM_{10}	TSP	VOC	NO_2	CO	SO_2
Booster station	100	60	–	–	100	–	–
Unpaved road	–	80	75	–	–	–	–
Plant[(d)]	–	–	–	–	–	–	–

Notes:

(a) This setback distance represents a single exceedance of the NO_2 hourly NAAQS limit of 200 µg/m³. The distance at which more than the allowable 88 hours of exceedance is expected to occur will be much smaller (see (b))

(b) This setback distance represents the distance at which the simulated frequency of exceedance is in non-compliance with the hourly NO_2 NAAQS.

(c) This setback distance represents the distance at which the simulated frequency of exceedance is in non-compliance with the daily PM_{10} and $PM_{2.5}$ NAAQS

(d) No PM impacts, assuming no smoking flares that give off soot

5 IMPACT SIGNIFICANCE RATING

The significance of environmental noise impacts was assessed according to the methodology adopted by EIMS (Appendix A).

5.1 Construction

The assumption is that construction activities would be during day-time hours only.

Given the nature of construction activities for the roads/pipeline, wells and booster stations (where the location may vary depending on the gas reserves in the area) the air quality impacts (due to dust and vehicle exhaust gas) at the nearest residential receptors to the construction areas may exceed the respective short-term NAAQS's for residential areas. If there are exceedances of the standards, however, it would be of short duration. The negative air quality impacts are therefore considered to be of medium significance without mitigation and low significance with mitigation at the nearest receptors due to construction activities for roads/pipeline sections (Table 31) and construction of wells/booster stations (Table 32).

Table 31: Significance rating for potential noise impacts due to the construction of the road/pipeline

Impact Name	Increase in air quality impacts due to construction of the road/pipeline				
Alternative	NA				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	1	1	Probability	4	3
Environmental Risk (Pre-mitigation)					-9.00
Mitigation Measures					
As construction will only take place during day-time hours and will be of limited duration, AQSRs within 150 m of the road/pipeline construction site should be notified of the activities and potential disturbance durations prior to construction taking place. Additional mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-6.75
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-7.59

Table 32: Significance rating for potential noise impacts due to the construction of the wells and booster stations

Impact Name	Increase in air quality impacts due to construction of the wells and booster stations				
Alternative	NA				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	1	1	Probability	4	3
Environmental Risk (Pre-mitigation)					-10.00
Mitigation Measures					
As construction will only take place during day-time hours and will be of limited duration, AQSRs within 300 m radius of all well construction sites and 200 m from booster station construction sites should be notified of the activities and potential disturbance durations prior to construction taking place. Additional mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-6.75
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-7.59

Unlike the roads/pipeline, wells or booster stations (where the location may vary depending on the gas reserves in the area) the locations of the three compressor stations and plant have been fixed. The construction period for the plant is also longer (i.e. more than 1 year). The air quality impacts (due to dust and vehicle tailpipe emissions) at the nearest residential receptors to the construction areas may exceed the respective short-term NAAQS's for residential areas. These exceedances, should they occur, would be of short duration as the construction activities will be intermittent in nature and not part of routine operations. The negative air quality impacts are therefore considered to be of medium significance without mitigation and low significance with mitigation at the nearest receptors (Table 33).

Table 33: Significance rating for potential noise impacts due to the construction of the plant and compressor stations (assuming the preferred location for CS3)

Impact Name	Increase in air quality impacts due to construction of the plant and compressor stations				
Alternative	Assuming preferred location for CS3				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-8.44

Table 34: Significance rating for potential noise impacts due to the construction of the plant and compressor stations (assuming the alternative location for CS3)

Impact Name	Increase in air quality impacts due to construction of the plant and compressor stations				
Alternative	Assuming the alternative location for CS3				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-8.44

5.2 Operation

The operational activities would take place during day- and night-time conditions.

Given the location of the plant and the compressor stations and their potential air quality impacts, it is unlikely that the respective NAAQS's and NDCR limits for residential areas will be exceeded at AQSRs due to plant or compressor operations.

The operation of vehicles on unpaved roads, and specifically the plant access road, even under mitigated conditions, could result in single exceedances of the respective NAAQS's and NDCR limits for residential areas at AQSRs. The negative air quality impacts are therefore considered to be of medium significance at the nearest receptors but will reduce to low significance should the roads be paved (Table 35).

The air quality impacts due to booster station (generator) operations are likely to exceed the long-term NAAQS's for residential areas up to 90 m from the operations. Care should be taken to site the booster stations at least 100 m from all AQSRs. With careful siting, NAAQSs for residential areas should not be exceeded at AQSRs. The negative air quality impacts are therefore considered to be of medium significance (given the possible impact zone of 90 m) but will reduce to low significance at the nearest receptors with mitigation measures in place (Table 36).

The air quality impacts due to plant (flaring) operations are not likely to exceed the long-term NAAQS's. The negative air quality impacts are therefore considered to be of low significance at the nearest receptors (Table 37).

Table 35: Significance rating for potential air quality impacts due to the operation of vehicles on unpaved roads

Impact Name	Increase in air quality impacts due to the operation of vehicles on unpaved roads				
Alternative	NA				
Phase	Operations				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	4	3
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Ground level concentrations and dust fallout due to vehicle operations on unpaved roads are likely to exceed the PM_{10} NAAQS limit and NDCR limit for residential areas up to 80 m from the operations. Care should be taken to apply mitigation measures to unpaved roads located near AQSRs. Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.13
Final Significance					-8.44

Table 36: Significance rating for potential air quality impacts due to the operation of the booster stations

Impact Name	Increase in air quality impacts due to operation of the booster stations				
Alternative	NA				
Phase	Operations				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	4	3
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Air quality impacts due to booster station operations are likely to exceed the $PM_{2.5}$ and NO_2 NAAQS for residential areas up to 100 m from the operations. Care should be taken to site the booster stations at least 100 m from all AQSRs. Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-8.25
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-8.25

Table 37: Significance rating for potential air quality impacts due to the operation of the plant

Impact Name	Increase in air quality impacts due to operation of the plant				
Alternative	NA				
Phase	Operations				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	2	2
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	3	3
Environmental Risk (Pre-mitigation)					-7.50
Mitigation Measures					
Air quality impacts due to routine plant operations are not likely to exceed the limits for criteria pollutants, dustfall or VOCs. Mitigation measures are detailed in Section 5.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-7.50

5.3 Decommissioning and Closure

The assumption is that decommissioning would be during day-time hours only. Given the nature of decommissioning activities, and the extent of the process, NAAQS limits for residential areas may be exceeded sporadically at AQSRs. Mitigation measures, however, can be implemented to reduce emissions due to fugitive dust. The negative air quality impacts are therefore considered to be of medium significance without mitigation and low significance with mitigation at the nearest receptors (Table 38).

Table 38: Significance rating for potential noise impacts due to the decommissioning and closure phase of the project

Impact Name	Increase in air quality impacts due to decommissioning and closure				
Alternative	NA				
Phase	Decommissioning				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-7.50

6 Recommended Air Quality Management Measures

In the quantification of air emissions and simulation of impacts as a result of the project, it was found that environmental air quality evaluation criteria for residential, educational, and institutional receptors will be met at all off-site air quality sensitive receptors.

The measures discussed in this section are measures typically applicable to industrial sites and are considered good practice. It should be noted that not all mitigation measures are to be implemented, but should the need arise the mitigation measures as discussed in this section can be considered.

The mitigation measured discussed also takes into account the existing management measures utilised for the existing Cluster 1 Environmental Management Programme (EIMS, 2019). The approach adopted for this section is as follows:

- If the current mitigation measures for a particular impact are considered adequate, reference will be made to the existing mitigation measures (using the mitigation reference numbers provided in the 2019 Environmental Management Programme (EMPr));
- If the current mitigation measures are inadequate, amendments will be provided; and,
- If additional mitigation measures are required, these will be highlighted as additional to the existing approved EMPr.

6.1 Proposed Mitigation Measures and Target Control Efficiencies

The following air quality measures are recommended during construction, operational, decommissioning and rehabilitation and closure phases of the Project:

- The existing EMPr (nr 39) states that in controlling vehicle entrained PM during construction, it is recommended that water (at an application rate of 2 litre/m^2-hour), be applied on all unpaved road sections to ensure a minimum of 50% control efficiency (CE), and that binding agents or chemical suppressants (such as "Dust-A-Side" or "Dustex") should be considered for application on all unpaved road sections (emissions reduction efficiency of more than 80%). This should be amended to also be applicable during the operational phase.
- Additionally, for construction/operation, it is recommended to pave the access road between the plant and the R30 provincial road. This would result in a control efficiency of between 87% and 92% (US EPA, 2006).
- For topsoil management during construction and rehabilitation, the existing EMPr (nr 35) should be amended to include the recommendation that exposed areas must be ensured to remain moist through water spraying during dry, windy periods (CE 50%).
- During all phases, material transfers are to be controlled through the use of water sprays resulting in 50% control efficiency.
- The following good practice should be followed during all phases of the project: In order to ensure lower exhaust emissions from vehicles and machinery, equipment suppliers or contractors should be required to ensure compliance with appropriate emission standards for production fleets. Also, maintenance and repair of diesel engines should be carried out as prescribed by manufacturer in order to maximize combustion and reduce gaseous emissions.
- Fuel efficient driving practices on site, during all phases of the Project, may also help lower exhaust emissions from vehicles and machinery, such as stipulating a maximum speed on all unpaved roads. In addition, other fuel-efficient practices that may lower exhaust emissions include limiting idling of machinery, driving in an upper gear rather than a lower gear as much as possible, ensuring tire pressure are always adequate etc.
- Products, liquid fuels, and chemicals should be stored in areas where there are provisions for containment of spills.

- The project proponent has indicated that all infrastructure and facilities will be designed, installed and maintained according to best industry practices to control fugitive and unintended methane emissions as prescribed in (US EPA, 2015). In addition, the following actions are recommended:
    - o If applicable, the implementation of a leak detection and repair (LDAR) program, which include identifying equipment, leak definition, monitoring equipment, repairing equipment, and recordkeeping; and
    - o Regular check (monthly or quarterly) and reporting of exploration well, booster and compressor facility installations, as well as pipelines portions close to ground surface or those that have potential to be vandalized.

In addition, the following are suggestions for consideration in the design of the combined Helium and LNG plant:

- If applicable, the use of low–NOx burners in combustion systems should be considered for operation of the combined LNG/LHe plant; and
- The implementation of vapour recovery systems, for storage tanks and/or other applicable units, to control losses of VOCs and achieve over 90% recovery, should be considered.

6.2 Air Quality Monitoring

The existing EMPr subsection 11.4 on Air Quality Monitoring contains references to emissions monitoring (11.4.1) and ambient air quality monitoring (11.4.2). The air quality monitoring programme for Tetra4 is specified in Table 11.

The air quality monitoring programme reference to monthly dustfall sampling during construction (Table 11) can be amended to say that "monthly dustfall sampling should be conducted at the four main wind directions (north; east; south and west) during the construction of the plant to assess cumulative deposition rates".

6.3 Impact Zones

The impact zones in the existing EMPr can be amended to include distances for air quality impacts, due to various activities, as indicated in Table 39. These are conservative buffer zones in consideration of cumulative air quality impacts in the Project region. Therefore, these are seen as management zones where the potential for air quality impacts can be mitigated and managed.

Table 39: Recommended setback distances

Project phase		Setback distance (m)	Indicator Pollutant	Description
Construction	Well construction site	750	NO_2	Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit, where the distance will be significantly less based on the allowable frequency of exceedance.
	Booster station site	500		
	Pipeline construction site	150		
	Road construction site	150		
	Compressor station construction site	200	PM_{10}	
	Plant construction site	270		Based on exceedance of NAAQ daily limit.
Operational	Booster station	100	PM_{10} and NO_2	Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit and of the daily PM_{10} NAAQS limit, where the distance will be less based on the allowable frequency of exceedance.
	Unpaved road	80	PM_{10}	
	Plant	none	none	The flare is an intermittent source with no exceedances

7 CONCLUSIONS AND RECOMMENDATIONS

A quantitative air quality impact assessment was conducted for the planning and design, construction, operation, decommissioning, rehabilitation and closure phase activities of the Tetra4 Cluster 2 Project. The assessment included an estimation of atmospheric emissions, the simulation of pollutant levels and determination of the significance of impacts. This section summarises the main findings of the impact assessment.

The conclusions and recommendations of the assessment are summarised below:

- The receiving environment:
  - The area is dominated by winds from the north-northeast and northeast, followed by northerly and easterly winds with an average wind speed of 3.7 m/s.
  - Ambient air pollutant levels in the project area are currently affected by the following sources of emission: agricultural activities, gold mining and ore processing, fugitive and process emissions, vehicle tailpipe emissions, household fuel combustion, biomass burning and windblown dust from exposed areas.
  - AQSRs such as residences and farm holdings are located within and beyond the project boundary. Nearby towns include Welkom, Virginia, Bronville, Harmony and Theunissen.

- Impact of the Project:
  - Planning, design and construction phase impacts:
    - Construction activities for the roads/pipeline, wells and booster stations (where the location may vary depending on the gas reserves in the area) vehicle and equipment (vehicle entrainment and vehicle exhaust gas), three compressor stations and the plant might include land clearing, topsoil removal, material loading, bulk services construction, hauling, excavation, back-filling, road construction (where necessary) and traffic, rig-move/drilling, pipeline installation, and wind erosion of exposed areas.
    - Resulting potential air quality health and nuisance impacts at the nearest residential receptors resulted in a medium significance without mitigation and low significance with mitigation. Worst-case simulated construction impacts are not anticipated to occur over long intervals since construction activities will only last a few weeks and peak activities will not be consistent over the specified period.

  - Operational phase impacts:
    - Potential air quality impacts, including health and nuisance impacts, as a result of operational phase activities such as operation of the well pad, roads, pipelines, compression station, booster station and combined LNG/LHe plant, as well as associated emissions from movement of trucks and other vehicles, flaring (if applicable), and gas processing as well as operation of heavy machinery.
    - Vehicles on unpaved roads, and specifically the plant access road, even under mitigated conditions are likely to result in medium significance at the nearest receptors but will reduce to low significance should the road be paved.
    - Air quality impacts due to booster station (generator) operations of medium significance but low significance at the nearest receptors with mitigation measures in place.
    - Plant (flaring) operations are unlikely to result in exceedances of the respective NAAQS's and are therefore considered to be of low significance at the nearest receptors.

- o Decommissioning, rehabilitation and closure phase impacts:
  - Potential air quality impacts, including health impacts as a result of decommissioning, rehabilitation and closure phase activities such as decommissioning/ removal of all berms, trenches and other storm water infrastructure, stationary infrastructure, pipeline infrastructure, and wastes.
  - The environmental risk was assigned a score of low significance due to localised impacts of the various emissions, their temporary nature, and the likelihood that these activities will not occur concurrently at all portions of the site.

In conclusion, it is the specialist opinion that the project may be authorised provided that the recommended air quality management measures are implemented. These air quality management measures include:

- o Source emissions monitoring and reporting;
- o Ambient air quality monitoring;
- o Mitigation measures aimed at reducing emissions at source;
- o Paving of the unpaved road from plant to provincial R30 road; and
- o The delineation of management zones around production wells, pipeline routes, compressor and booster stations and the plant site. As a conservative approached the following setback distances are recommended, where these are seen as management zones where the potential for air quality impacts can be mitigated and managed:

Project phase		Setback distance (m)	Indicator Pollutant	Description
Construction	Well construction site	750	NO_2	Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit, where the distance will be significantly less based on the allowable frequency of exceedance.
	Booster station site	500		
	Pipeline construction site	150		
	Road construction site	150		
	Compressor station construction site	200	PM_{10}	
	Plant construction site	270		Based on exceedance of NAAQ daily limit.
Operational	Booster station	100	PM_{10} and NO_2	Setback distance represents a single exceedance of the NO_2 hourly NAAQS limit and of the daily PM_{10} NAAQS limit, where the distance will be less based on the allowable frequency of exceedance.
	Unpaved road	80	PM_{10}	
	Plant	none	none	The flare is an intermittent source with no exceedances

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9 Appendix A – Impact Significance Rating Methodology

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

Determination of Environmental Risk:

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \frac{(E+D+M+R)}{4} \times N$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 40.

Table 40: Criteria for determining impact consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).

Aspect	Score	Definition
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P (Table 42). Probability is rated/scored as per Table 41.

Table 41: Probability scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur)

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

$$ER = C \times P$$

Table 42: Determination of environmental risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 43.

Table 43: Significance classes

Environmental Risk Score	
Value	Description
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation:

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition, it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision-making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 44: Criteria for determining prioritisation

Public response (PR)	Low (1)	Issue not raised in public response.
	Medium (2)	Issue has received a meaningful and justifiable public response.
	High (3)	Issue has received an intense meaningful and justifiable public response.
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 44. The impact priority is therefore determined as follows:

$$\text{Priority} = PR + CI + LR$$

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (refer to Table 45).

Table 45: Determination of prioritisation factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring (Table 46). The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 46: Final environmental significance rating

Environmental Significance Rating	
Value	Description
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).

Aquatic Baseline & Risk Assessment for the proposed Tetra4 Cluster 2 Project

Virginia, Free State Province

April 2022

CLIENT

Prepared by:

The Biodiversity Company

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Report Name	Aquatic Baseline & Risk Assessment for the proposed Tetra4 Cluster 2 Project
Submitted to	EIMS Environmental Impact Management Services
Report / Fieldwork and Writer	Christian Fry
	Christian Fry has obtained an MSc in Aquatic Health from the University of Johannesburg and is a registered Professional Scientist (Pr. Sci. Nat: 119082). Christian has 9 years of experience conducting basic assessments, biomonitoring and EIAs for various sectors.
Reviewer	Andrew Husted
	Andrew Husted is Pr Sci Nat registered (400213/11) in the following fields of practice: Ecological Science, Environmental Science and Aquatic Science. Andrew is an Aquatic, Wetland and Biodiversity Specialist with more than 12 years' experience in the environmental consulting field. Andrew has completed numerous wetland training courses, and is an accredited wetland practitioner, recognised by the DWS, and also the Mondi Wetlands programme as a competent wetland consultant.
Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2014 (as amended). We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than to provide a professional service within the constraints of the project (timing, time and budget) based on the principles of science.

Declaration

I, Christian Fry declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Christian Fry

Freshwater Ecologist

The Biodiversity Company

April 2022

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Figures

1 Introduction

The modification of land use within a river catchment has the potential to degrade local water resources (Wepener *et al*., 2005). Primary activities such as mining thus have the potential to negatively impact on local water resources and ecosystem services. In order to effectively manage the potential impacts to watercourses, the establishment of the baseline condition of a watercourse is required.

The Biodiversity Company was appointed by Environmental Impact Management Services (EIMS) to conduct an aquatic baseline and impact (risk) assessment for the proposed Tetra4 Cluster 2 gas exploration project in Virginia, Free State Province. A single wet season survey was conducted from the 14th of March 2022 to 18th of March 2022 by a freshwater ecologist.

1.1 Background

The following information was provided by EIMS:

In 2012, a Production Right (Ref: 12/4/1/07/2/2) was granted which spans approximately 187 000 hectares for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within the approval of the Production Right, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1-1).

The activities in the Production Right include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original EIA and approved EMPr).

On 21 September 2017, the Department of Mineral Resources and Energy (DMRE) issued an integrated environmental authorisation (“Cluster 1 EA”) (reference: 12/04/07) to Tetra4 in terms of the NEMA. The Cluster 1 EA (as amended by Cluster 1 EA amendments dated 26 August 2019 and 1 September 2020) authorises the development of “Cluster 1” of the Project. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and LNG Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Furthermore, the following licences have been issued to Tetra4 in respect of Cluster 1 of the Project:

- Provisional Atmospheric Emission Licence (PAEL) dated 4 August 2017 (reference: LDM/AEL/YMK/014) for the Storage and Handling of Petroleum Products [Category 2: Subcategory 2.4 of the Listed Activities (Government Notice 893, as amended) published under the National Environmental Management: Air Quality Act 39 of 2004 (NEMAQA)] by the Lejweleputswa District Municipality. A final atmospheric emission licence will be issued after operation of the plant which is currently under construction; and
- Water Use Licence (WUL) dated 22 January 2019 (reference: 08/C42K/CI/8861) for the construction of pipelines for the Project in terms of section 21(c&i) water uses of the National Water Act 36 of 1998 (NWA) by the Department of Water and Sanitation (DWS).

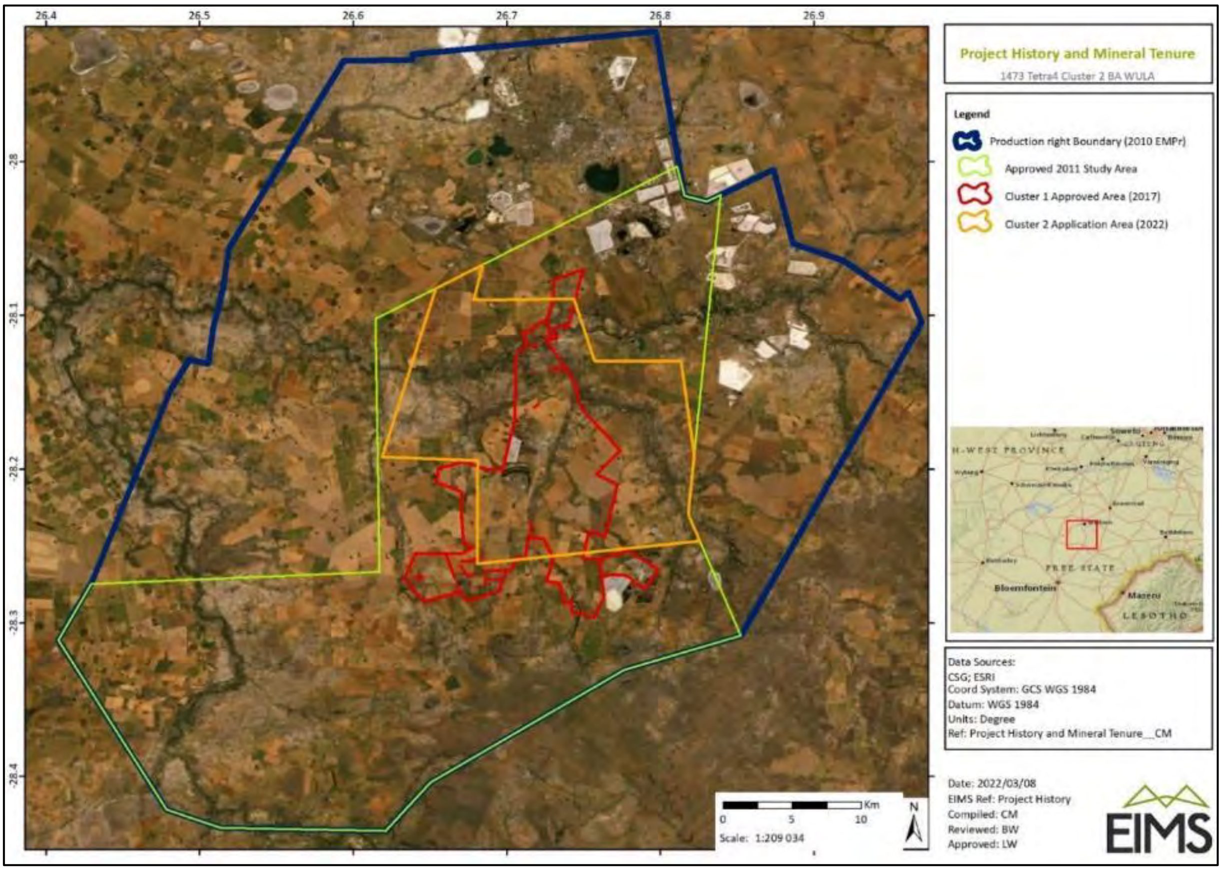

Figure 1-1 Project history and mineral tenure.

The following information is as provided by EIMS:

"Tetra 4 has a natural gas production right over a very large area in the Free State Province, near Virginia. They also have an existing environmental authorisation and associated water use licence for their current production activities (referred to as Cluster 1 above). Tetra 4 wishes to expand their current production operations onto other areas which still fall within the approved Production Right, but outside of the areas approved in the EA and WUL. The planned expansions will include the following (Figure 1-2):

- Expansions to the current LNG and Helium production plant located on the Farm Mond van Doorn Rivier. The planned expansions will be to increase the helium and LNG production capacities significantly (~30 fold increase) and increase the footprint of the existing approved plant by approximately 10ha.
- The drilling of new gas wells ~300 wells spread over a total study area (Cluster 2) of approximately 27500ha.
- The installation of trenched pipelines connecting the wells to localised booster compressors and then to in-field compressor stations (~3 sites) and subsequently the compressor stations to the main plant area.
- There will be a requirement to have short powerline and water connections to the compressor sites."

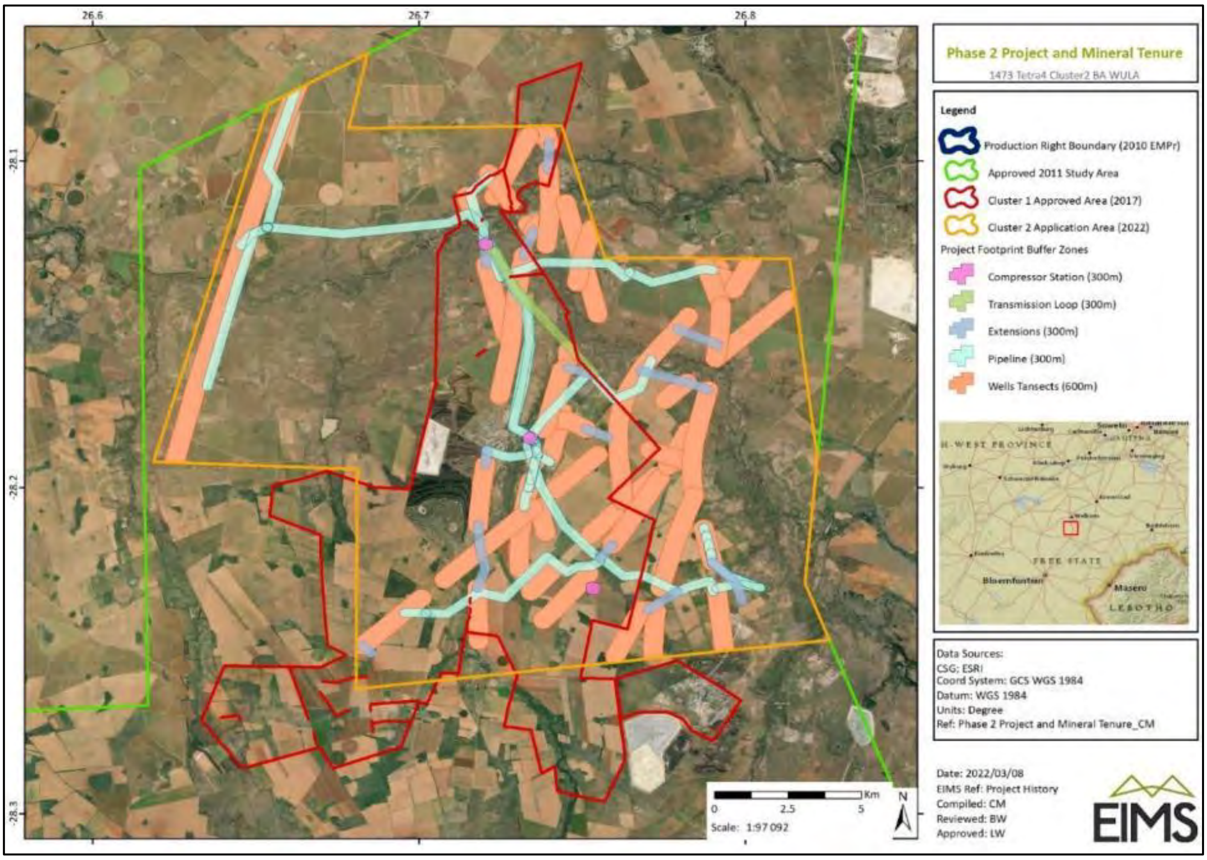

Figure 1-2 Cluster 2 study area and proposed infrastructure footprint buffer zones

This assessment was conducted in accordance with the amendments to the Environmental Impact Assessment Regulations. 2014 (GNR 326, 7 April 2017) of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA). The approach has taken cognisance of the recently published Government Notices (GN) 320 (20 March 2020): "Procedures for the Assessment and Minimum Criteria for Reporting on Identified Environmental Themes in terms of Sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998, when applying for Environmental Authorisation" (Reporting Criteria). The National Web based Environmental Screening Tool has characterised the aquatic sensitivity of the project area as "Very High" (Figure 1-3), and therefore an aquatic biodiversity specialist assessment was completed for the proposed project.

The purpose of the specialist study is to provide relevant input into the basic assessment process and provide a report for the proposed activities associated with the project. This report, after taking into consideration the findings and recommendations provided by the specialist herein, should inform and guide the Environmental Assessment Practitioner (EAP) and regulatory authorities, enabling informed decision making, as to the ecological viability of the proposed project.

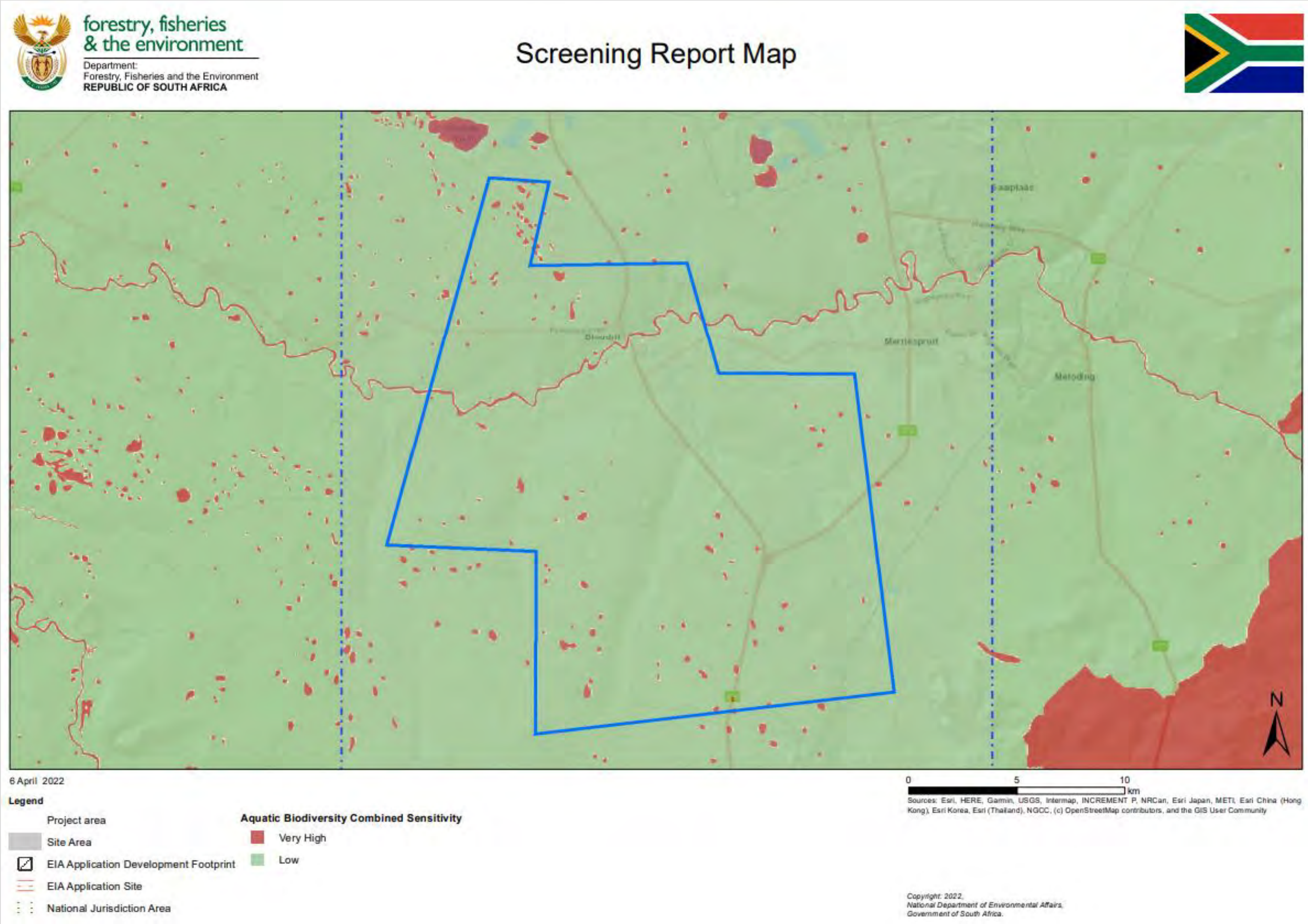

Figure 1-3 Sensitivity of aquatic biodiversity features for the project area

1.2 Terms of Reference

The following tasks were completed in fulfilment of the terms of reference for this assessment:

- Review of existing desktop information;
- The determination of the baseline Present Ecological Status (PES) of the associated watercourses, their instream and riparian condition – using appropriate survey methods;
- The delineation and identification of sensitive riverine areas;
- Conduct risk assessments relevant to the proposed activity;
- Recommendations relevant to associated impacts; and
- Report compilation detailing the baseline findings.

2 Project Area

Tetra4 Cluster 2 is located approximately 17 km south of Welkom and 11 km west of Virginia in the Free State Province (Figure 2-1). The project area is approximately 28,000 ha and falls within the Matjhabeng Local Municipality. The project area is drained by several ephemeral and perennial watercourses, which fall within the C42J, C42L and C42K quaternary catchments, and Vaal Water Management Area (WMA5). The easter portion of the project area falls within the C42K quaternary catchment and ephemeral systems drain into the Boschluisspruit and Doring Rivers which eventuate into the Sand River at the catchment boundary. The eastern portion of the project area falls within the C42L quaternary catchment and consists of several small ephemeral systems which drain into the Sand River. The Sand River flows west into the Vet River, which has its confluence with the Vaal River 87 km west within the Bloemhof Dam. The elevation ranges between 1338 meters above sea level (masl) in the upper reaches of the Doring River to 1282 masl on the Sand River at the outlet of the project area. The spatial framework for the PES assessment of the watercourses falls within the Vaal WMA and includes the Boschluispruit, Doring River and Sand River, as well as several unnamed tributaries.

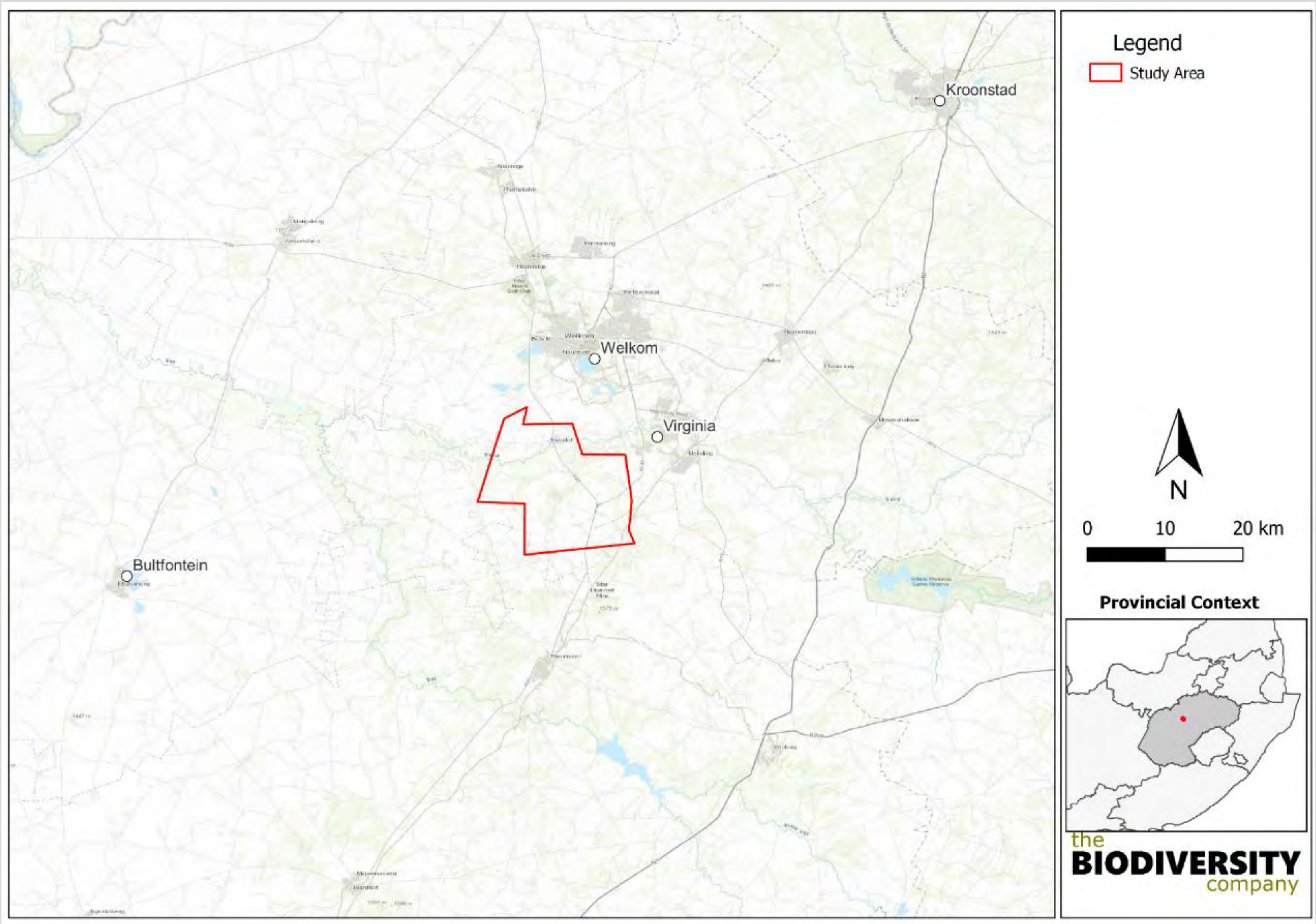

Figure 2-1 Locality of the project area

3 Key Legislative Requirements

3.1 National Water Act (NWA, 1998)

The Department Water and Sanitation (DWS) is the custodian of South Africa's water resources and therefore assumes public trusteeship of water resources, which includes watercourses, surface water, estuaries, or aquifers. The National Water Act (Act No. 36 of 1998) (NWA) allows for the protection of water resources, which includes:

- The maintenance of the quality of the water resource to the extent that the water resources may be used in an ecologically sustainable way;
- The prevention of the degradation of the water resource; and
- The rehabilitation of the water resource.

A watercourse is defined in the NWA as:

- A river or spring;
- A natural channel in which water flows regularly or intermittently;
- A wetland, lake or dam into which, or from which, water flows; and
- Any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its bed and banks.

The NWA recognises that the entire ecosystem and not just the water in isolation, and any given water resource constitutes the resource and as such needs to be conserved. No activity may therefore take place within a watercourse unless it is authorised by the DWS. Any area within a wetland or riparian zone is therefore excluded from development unless authorisation is obtained from the DWS in terms of Section 21 (c) and (i).

3.1.1 National Water Act, 1998 – General Notice 704 (1999)

Restrictions on locality; no person in control of a mine or activity may – except in relation to a matter contemplated in regulation 10, carry on any underground or opencast mining, prospecting or any other operation or activity under or within the 1:50 year flood-line or within a horizontal distance of 100 m from any watercourse or estuary, whichever is greatest.

3.1.2 National Water Act, 1998 – Section 21: (c) and (i) water uses for General Authorisation – GN 509 of 26 August 2016

The DWS, is of the view that any activity within the 500 m Regulated Area or radius from the boundary (temporary zone) of any wetland or pan, or within the outer edge of the 1 in 100 year flood line or riparian habitat measured from the middle of the watercourse from both banks, requires a risk assessment to determine whether a Water Use Licence (WUL) or General Authorisation (GA) for a section 21(c) and (i) water use is required (DWS, 2016a).

3.2 National Environmental Management Act (NEMA, 1998)

The National Environmental Management Act (NEMA) (Act 107 of 1998) and the associated EIA Regulations as amended in November 2017, states that prior to any development taking place within a wetland or riparian area, an environmental authorisation process needs to be followed. This could follow either the Basic Assessment Report (BAR) process or the Scoping and Environmental Impact Reporting (S&EIR) process depending on the scale of the impact.

4 Methodology

4.1 Approach and Methodology

A single aquatic sampling survey was conducted on the 14th of March 2022 to 18th of March 2022. The survey constituted a wet season/ high flow/ summer assessment. Standard methods were implemented to establish the baseline conditions of the considered river reaches. Details pertaining to the specific methodologies applied are provided in the relevant sections below.

A total of 11 sites were assessed during the study, with emphasis placed on the systems within the project area and a downstream receiving environment on the Sand River. Figure 4-1 illustrates the sampling points for the study, and Table 4-1 presents site photographs, Global Positioning System (GPS) coordinates. It should be noted that several sites were dry and access to two sites was limited.

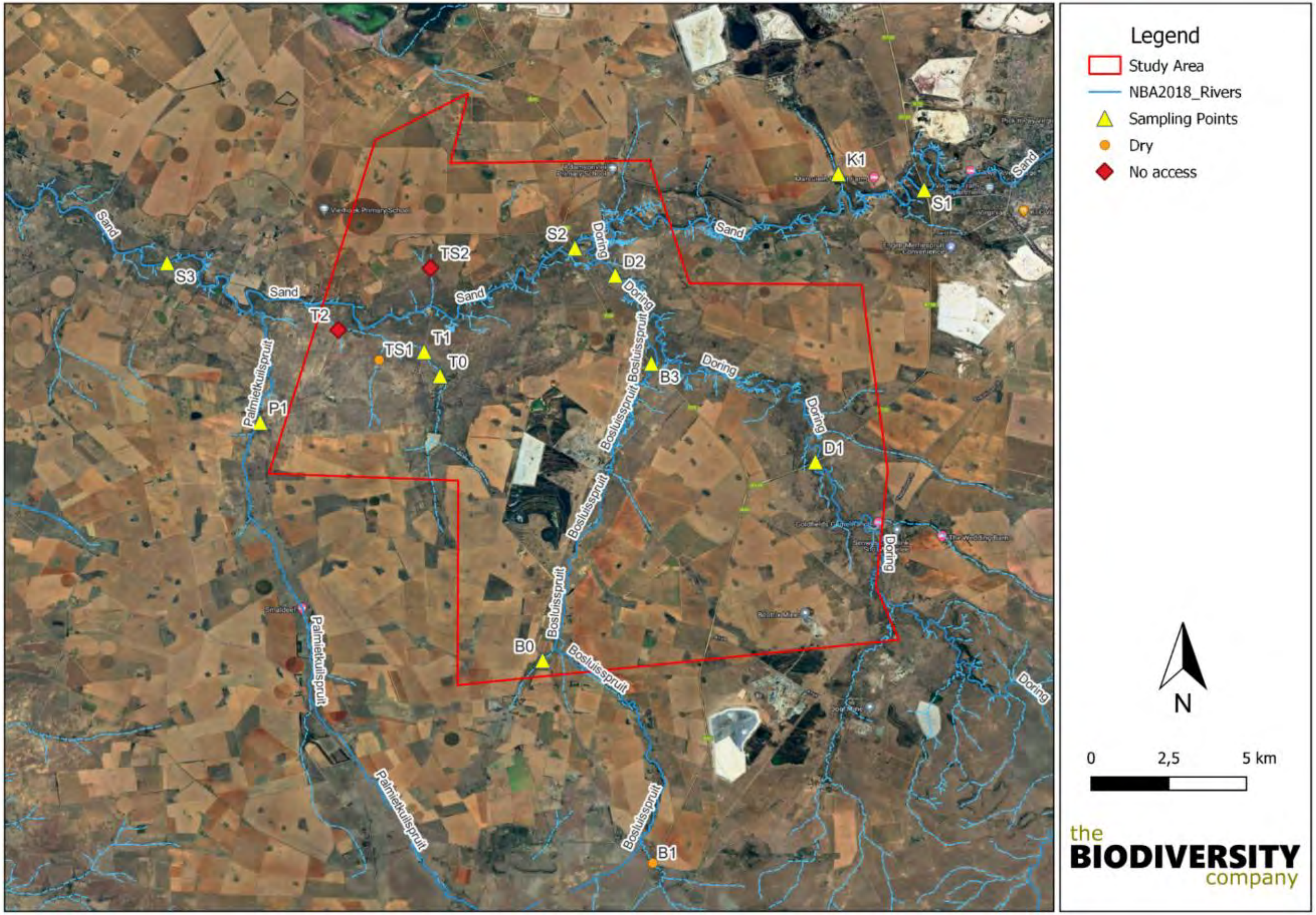

Figure 4-1 Study sampling points

Table 4-1 Investigation site photographs and coordinates (March 2022)

Site	Upstream	Downstream
Sand River		
S1		
Comments	Upstream Sand River site. Substrate dominated by sand and scattered stones of current. Debris within the channel provides cover features for aquatic biota. Flooding conditions during sampling.	
GPS-coordinates	28° 5'55.27"S 26°50'2.40"E	
S2		
Comments	Midstream Sand River site. Flooding conditions during sampling. Substrate dominated by sand and portions of bedrock.	
GPS-coordinates	28° 7'4.26"S 26°43'9.48"E	
S3		
Comments	Downstream Sand River site. Flooding conditions during sampling. Instream habitat limited, predominantly sand substrate.	
GPS-coordinates	28° 7'21.92"S 26°35'7.29"E	

Site	Upstream	Downstream
	Doring River	
D1		
Comments	Upstream Doring River site. Limited instream habitat diversity and hydraulic biotopes.	
GPS-coordinates	28°11'17.45"S 26°47'53.81"E	
D2		
Comments	Downstream Doring River site. Limited instream habitat diversity and hydraulic biotopes.	
GPS-coordinates	28° 7'36.76"S 26°43'57.13"E	
	Palmietkuilspruit	
P1		
Comments	Reference site on the Palmietkuilspruit. Diverse habitat including stones and marginal vegetation.	
GPS-coordinates	28°10'30.53"S 26°36'57.33"E	

Site	Upstream	Downstream
Boschluispruit		
B0		
Comments	Upstream site on Boschluispruit, characteristic of wetland system.	
GPS-coordinates	28°15'12.51"S 26°42'31.37"E	
B3		
Comments	Wetland system in downstream reaches of Boschluispruit	
GPS-coordinates	28° 9'20.92"S 26°44'39.94"E	
Ephemeral Tributaries		
K1		
Comments	Site downstream of mining activities, outside of project area. Flows into the Sand River upstream of project area.	
GPS-coordinates	28° 5'36.28"S 26°48'20.94"E	

Site	Upstream	Downstream
T0		
Comments	Ephemeral tributary. Site limited to a standing pool.	
GPS-coordinates	28° 9'35.66"S 26°40'29.93"E	
T1		
Comments	Ephemeral tributary with limited surface water	
GPS-coordinates	28° 9'6.98"S 26°40'11.16"E	

4.1.1 Water Quality

Water quality was measured in situ using a handheld calibrated Extech® DO700 multi-meter. The constituents considered that were measured included: pH, electrical conductivity (µS/cm), temperature (°C) and Dissolved Oxygen (DO) in mg/l.

4.1.2 Aquatic Habitat Integrity

The Intermediate Habitat Integrity Assessment (IHIA) as described in the Procedure for Rapid Determination of Resource Directed Measures for River Ecosystems (Section D), 1999 was used to define the ecological status of the considered river reaches. The method is based on Kleynhans (1996).

The IHIA model will be used to assess the integrity of the habitats from a riparian and in-stream perspective. The habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale which are comparable to the characteristics of natural habitats of the region (Kleynhans, 1996). This model compares current conditions with reference conditions that are expected to have been present. Specification of the reference condition follows an impact based approach where the intensity and extent of anthropogenic changes are used to interpret the impact on the habitat integrity of the system. To accomplish this, information on abiotic changes that can potentially influence river habitat integrity are obtained from surveys or available data sources. These changes are all related and interpreted in terms of modification of the drivers of the system, namely hydrology, geomorphology and physico-chemical conditions and how these changes would impact on the natural riverine habitats. The criteria and ratings utilised in the assessment of habitat integrity in the current study are presented in Table 4-2 and Table 4-3 respectively.

Table 4-2 Criteria used in the assessment of habitat integrity (Kleynhans, 1996)

Criterion	Relevance
Water abstraction	Direct impact on habitat type, abundance and size. Also implicated in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction or regulation by impoundments. Changes in temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain habitat types or water at the start of the breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment. Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation is also included.
Channel modification	May be the result of a change in flow, which may alter channel characteristics causing a change in marginal instream and riparian habitat. Purposeful channel modification to improve drainage is also included.
Water quality modification	Originates from point and diffuse point sources. Measured directly or alternatively agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in the volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences water quality and the movement of sediments.
Exotic macrophytes	Alteration of habitat by obstruction of flow and may influence water quality. Dependent upon the species involved and scale of infestation.
Exotic aquatic fauna	The disturbance of the stream bottom during feeding may influence the water quality and increase turbidity. Dependent upon the species involved and their abundance.
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also, a general indication of the misuse and mismanagement of the river.
Indigenous vegetation removal	Impairment of the buffer the vegetation forms to the movement of sediment and other catchment runoff products into the river. Refers to physical removal for farming, firewood and overgrazing.
Exotic vegetation encroachment	Excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochtonous organic matter input will also be changed. Riparian zone habitat diversity is also reduced.
Bank erosion	Decrease in bank stability will cause sedimentation and possible collapse of the riverbank resulting in a loss or modification of both instream and riparian habitats. Increased erosion can be the result of natural vegetation removal, overgrazing or exotic vegetation encroachment.

Table 4-3 Descriptions used for the ratings of the various habitat criteria

Impact Category	Description	Impact Score
None	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small.	1-5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.	6-10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11-15

Impact Category	Description	Impact Score
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16-20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21-25

4.1.3 Aquatic Macroinvertebrate Assessment

Macroinvertebrate assemblages are good indicators of localised conditions because many benthic macroinvertebrates have limited migration patterns or a sessile mode of life. They are particularly well-suited for assessing site-specific impacts (upstream and downstream studies) (Barbour *et al.,* 1999). Benthic macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects (Barbour *et al.,* 1999). The assessment and monitoring of benthic macroinvertebrate communities forms an integral part of the monitoring of the health of an aquatic ecosystem.

4.1.3.1 Macroinvertebrate Habitat

The invertebrate habitat at the site was assessed using the South African Scoring System version 5 (SASS5) biotope rating assessment. A rating system of 0 to 5 was applied, 0 being not available or absent, while 5 was abundant and diverse. The weightings for lowland rivers (slope class F) were used to categorize biotope ratings (Rowntree *et al.,* 2000; Rowntree & Ziervogel, 1999).

4.1.3.2 South African Scoring System

The South African Scoring System version 5 (SASS5) is the current index being used to assess the status of riverine macroinvertebrates in South Africa. According to Dickens and Graham (2002), the index is based on the presence of aquatic invertebrate families and the perceived sensitivity to water quality changes of these families. Different families exhibit different sensitivities to pollution, these sensitivities range from highly tolerant families (e.g. Chironomidae) to highly sensitive families (e.g. Perlidae). SASS results are expressed both as an index score (SASS score) and the Average Score Per recorded Taxon (ASPT value).

Sampled invertebrates were identified using the “Aquatic Invertebrates of South African Rivers” Illustrations book, by Gerber and Gabriel (2002). Identification of organisms was made to family level (Fry, 2022; Thirion *et al.,* 1995; Dickens and Graham, 2002; Gerber and Gabriel, 2002).

All SASS5 and ASPT scores are compared with the SASS5 Data Interpretation Guidelines (Dallas, 2007) for the Highveld Lower - Ecoregion (Figure 4-2). This method seeks to develop biological bands depicting the various ecological states and is derived from data contained within the Rivers Database and supplemented with other data not yet in the database.

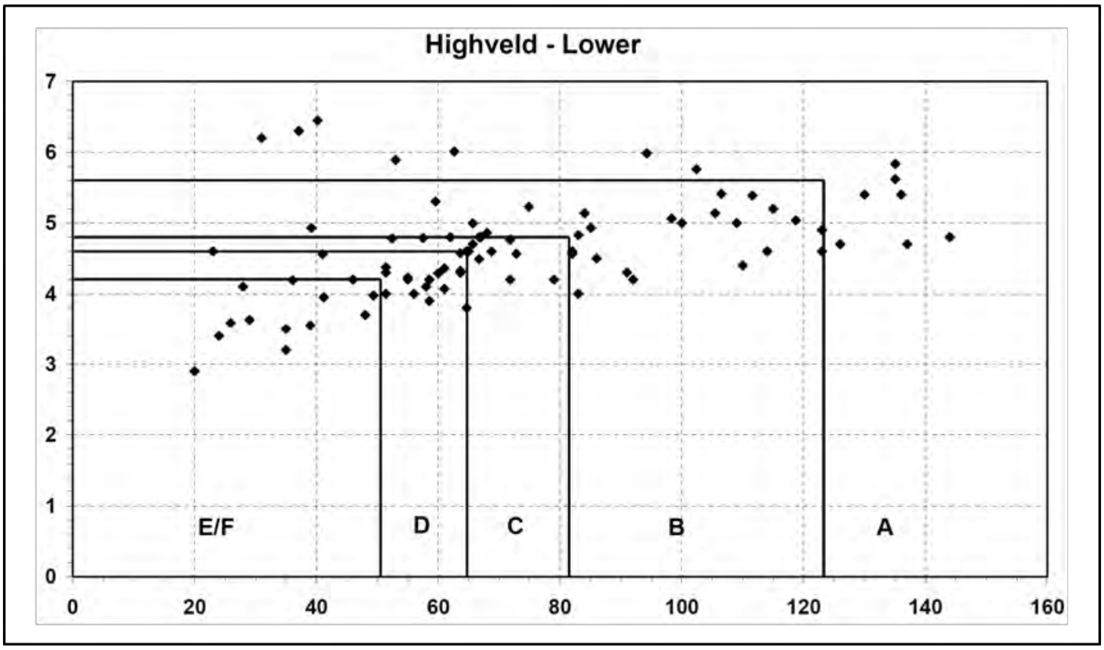

Figure 4-2 Biological Bands for the Highveld Lower - Ecoregion, calculated using percentiles

4.2 Macroinvertebrate Response Assessment Index

The Macroinvertebrate Response Assessment Index (MIRAI) was used to provide a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic invertebrate community from the calculated reference conditions for the SQR. This does not preclude the calculation of SASS5 scores if required (Thirion, 2007). The four major components of a stream system that determine productivity for aquatic macroinvertebrates are as follows:

- Flow regime;
- Physical habitat structure;
- Water quality; and
- Energy inputs from the watershed Riparian vegetation assessment.

The results of the MIRAI will provide an indication of the current ecological category and therefore assist in the determination of the PES. This was conducted for the Doring, Boschluispruit and Sand River.

4.3 Fish Presence

Fish were sampled through electroshocking (Figure 4-3). All fish were identified in the field and released at the point of capture, in order not to cross fish populations. Fish species were identified using the guide Freshwater Fishes of Southern Africa (Skelton, 2001). The identified fish species were compared to those expected to be present for the quaternary catchment. The expected fish species list for the project area was developed from a literature survey to compare to the sampled species at site. Different fish species represent different sensitivities to water chemistry, habitat and flow which considered as part of the Fish Response Assessment Index (FRAI) (Kleynhans *et al*., 2007 and Skelton 2001).

Figure 4-3 Example of methodology used to catch fish species (KZN, 2019).

4.4 Present Ecology Status Classification

Ecological classification refers to the determination and categorisation of the integrity of the various selected biophysical attributes of ecosystems compared to the natural or close to natural reference conditions (Kleynhans and Louw, 2007). For the purpose of this study, ecological classifications have been determined for biophysical attributes for the associated watercourses. This was completed using the river ecoclassification manual by Kleynhans and Louw (2007). The areas considered in the PES assessment are outlined in the description of the project area section.

4.5 Determining Buffer Requirements

The “Preliminary Guideline for the Determination of Buffer Zones for Rivers, Wetlands and Estuaries” (Macfarlane *et al.*, 2014) was used to determine the appropriate buffer zone for the proposed activity.

4.6 Limitations

The following limitations are applicable:

- Results for the study are based on a single high flow survey and therefore no ecological trends are included in this report;
- Standard rapid assessment protocols were applied during the study, and therefore a low confidence is provided in the assessment of the biotic community and a snapshot of water quality conditions. As the survey protocols are rapid, it is likely that the biotic community is underestimated, and that additional studies would yield additional species. Despite the rapid nature of the survey, the results do provide informative data of the general biotic community;
- Flooding conditions within the Sand River reduced the efficacy of sampling instream habitat for aquatic biota. Additionally, water quality results do not reflect stable conditions within the region; and
- Access to several sites was limited during the survey, and therefore no sampling was conducted at sites T2, TS2, and limited access to S3. Additionally, several ephemeral systems were dry. These sites remain critical to ecosystem services and are regarded as highly sensitive.

5 Desktop Baseline Assessment

5.1 Hydrological Setting

The spatial framework for the PES assessment of the watercourses falls within the Vaal WMA and includes the perennial systems Boschluispruit, Doring River and Sand River, as well as several unnamed ephemeral tributaries. The Sand River is classified as a lowland river, with a low gradient alluvial fine bed and meandering channel. A distinctive macro-channel is visible with sand and silt deposits occurring throughout the reach. Riparia zone is well developed. The upper reaches of the Boschluispruit are characteristic of upper foothills geoclass, and develop into lower foothills. The riparian zone is poorly defined and wetland delineations provide a more robust delineation of the watercourse. The Doring River is classed as lower foothills, with incised channels, limiting the lateral movement of water.

The Sand River is represented by two Sub-Quaternary Reaches (SQRs), namely the C42J-2716 and C42L-2690. The Doring is represented by the C42K-2754 and C42K-2744 SQRs. The Boschluispruit is represented by a single SQR, C42K- 2764. The Present Ecological State (PES) of the rivers range from largely natural (class B) to moderately modified (class C) within the region. Impacts to the watercourses are attributed to runoff from mining, agricultural activities, urban areas (Virginia) and flow modifications. The activities have contributions to water quality perturbations and impacts to instream habitat, erosion of channel and banks, and proliferation of alien vegetation.

A summary of the PES, stream orders, and Ecological Importance (EI) and Ecological Sensitivity (ES) for the relevant SQRs are presented in Table 5-1 and the PES are illustrated in Figure 5-1. The freshwater features within the region are presented in Figure 5-2 and additional water source points are in Figure 5-3.

Table 5-1 Desktop Ecological summary for the relevant quaternary catchments

SQR	Stream order	Length (km)	PES (DWS, 2014)	ES	EI	Default Ecological Category
Sand River						
C42J-2578	3	27	E	High	Moderate	C
PES-EIS Justification		Large impacts to instream habitat and connectivity. Serious water quality perturbations and large flow modifications. Low to moderate instream and wetland integrity class. Moderate to high sensitivity of aquatic biota to changes in flow and physicochemical modifications. Impacts include urban runoff from Virginia, mining, roads and instream dams, Waste Water Treatment Works (WWTW), and slimes dams.				
C42L-2690	3	16	C	Moderate	High	B
PES-EIS Justification		Moderate to large impacts to instream habitat and connectivity. Serious water quality perturbations and moderate flow modifications. Moderate instream and wetland integrity class. High sensitivity of aquatic biota to changes in flow and physicochemical modifications. Impacts include urban runoff from agriculture, instream weirs and low water crossings.				
Doring River						
C42K-2754	2	32	B	Moderate	High	B
PES-EIS Justification		Minor impacts to instream habitat and connectivity, water quality and flow modifications are small. Very high instream and wetland integrity class and connectivity. Moderate to High sensitivity of aquatic biota to changes in flow and physicochemical modifications. Impacts within the reach are attributed to mining, slimes dams, agriculture, small dams, and roads.				
C42K-2744	2	6	C	Moderate	Moderate	C
PES-EIS Justification		Small to moderate impacts to the ecological state of the system, with moderate impacts to water quality and instream habitat. High instream migration link class, and very high instream habitat integrity. Moderate to high intolerance of aquatic biota to flow and water quality modifications. Roads and weirs contribute to modifications to ecological state.				
Boschluispruit						
C42K- 2764	1	28	C	Moderate	Moderate	C
PES-EIS Justification		.Small to moderate modifications to instream and riparian habitat and moderate impacts to water quality. Very high migration class, and high riparian habitat integrity class. Moderate to high sensitivity of aquatic biota to changes in flow and water quality. Impacts within the reach include mining, chicken farm, agriculture and roads.				

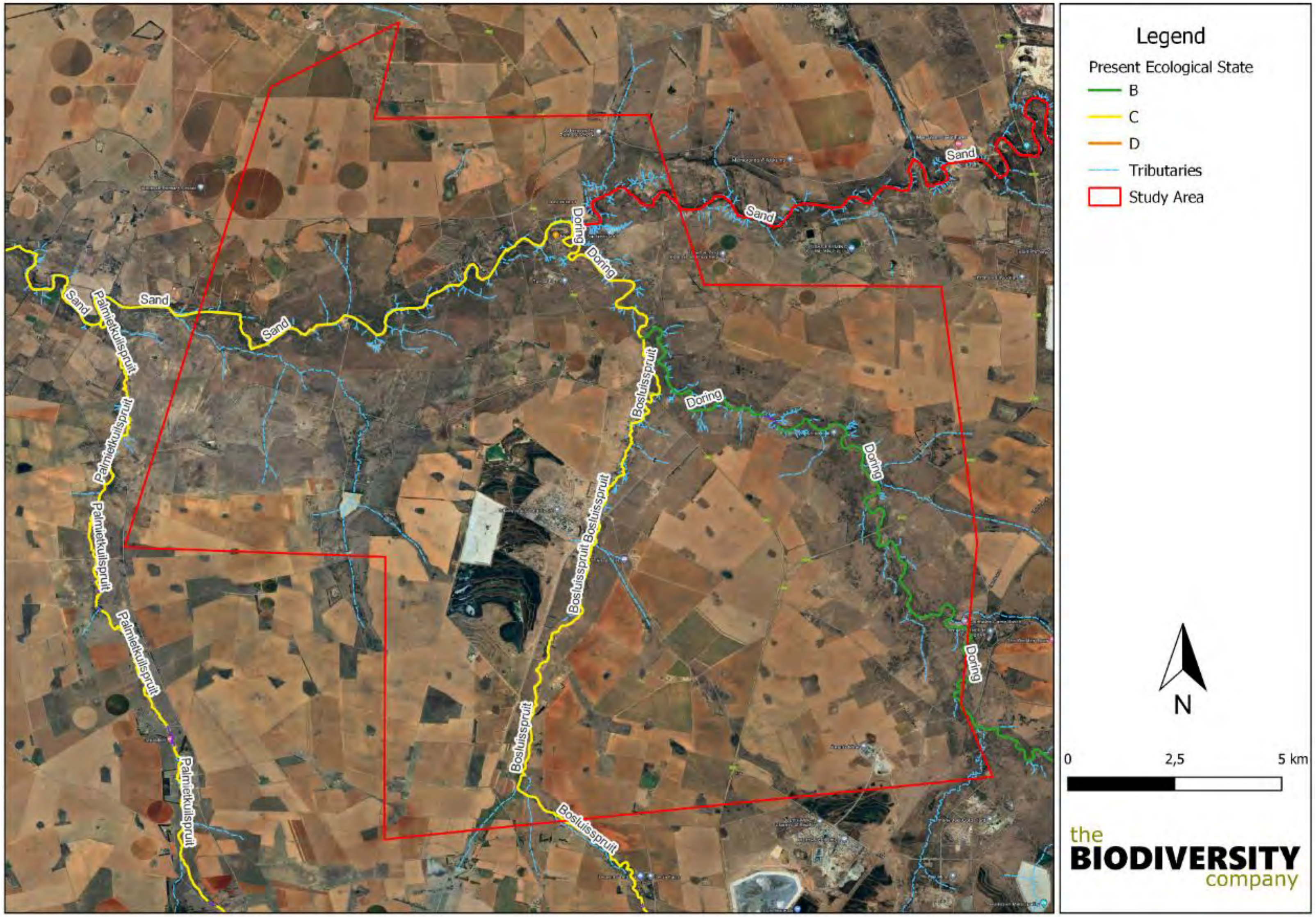

Figure 5-1 Illustration of the Present Ecological State within the relevant catchments (DWS, 2014)

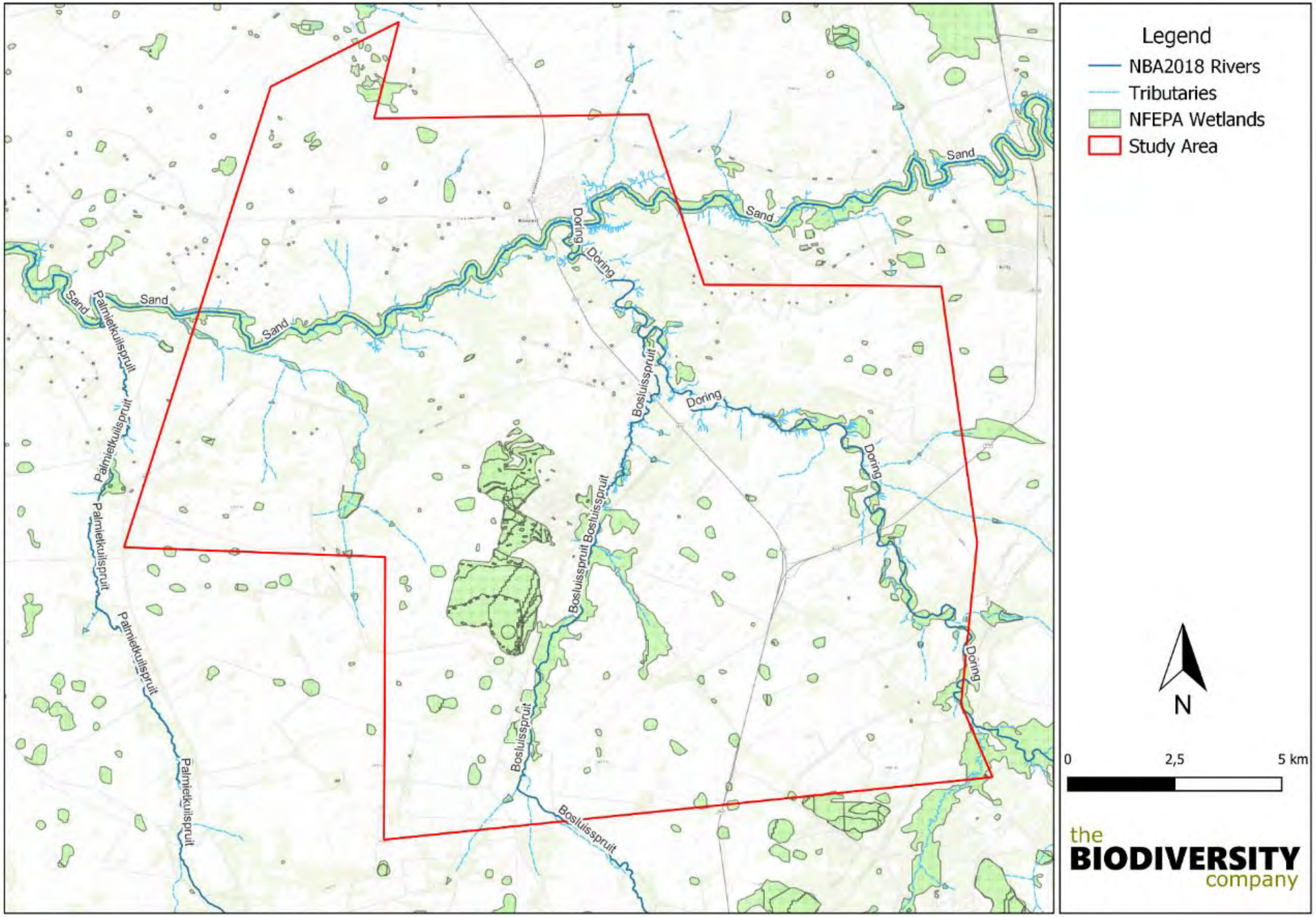

Figure 5-2 Illustration of the water resources associated with the project area

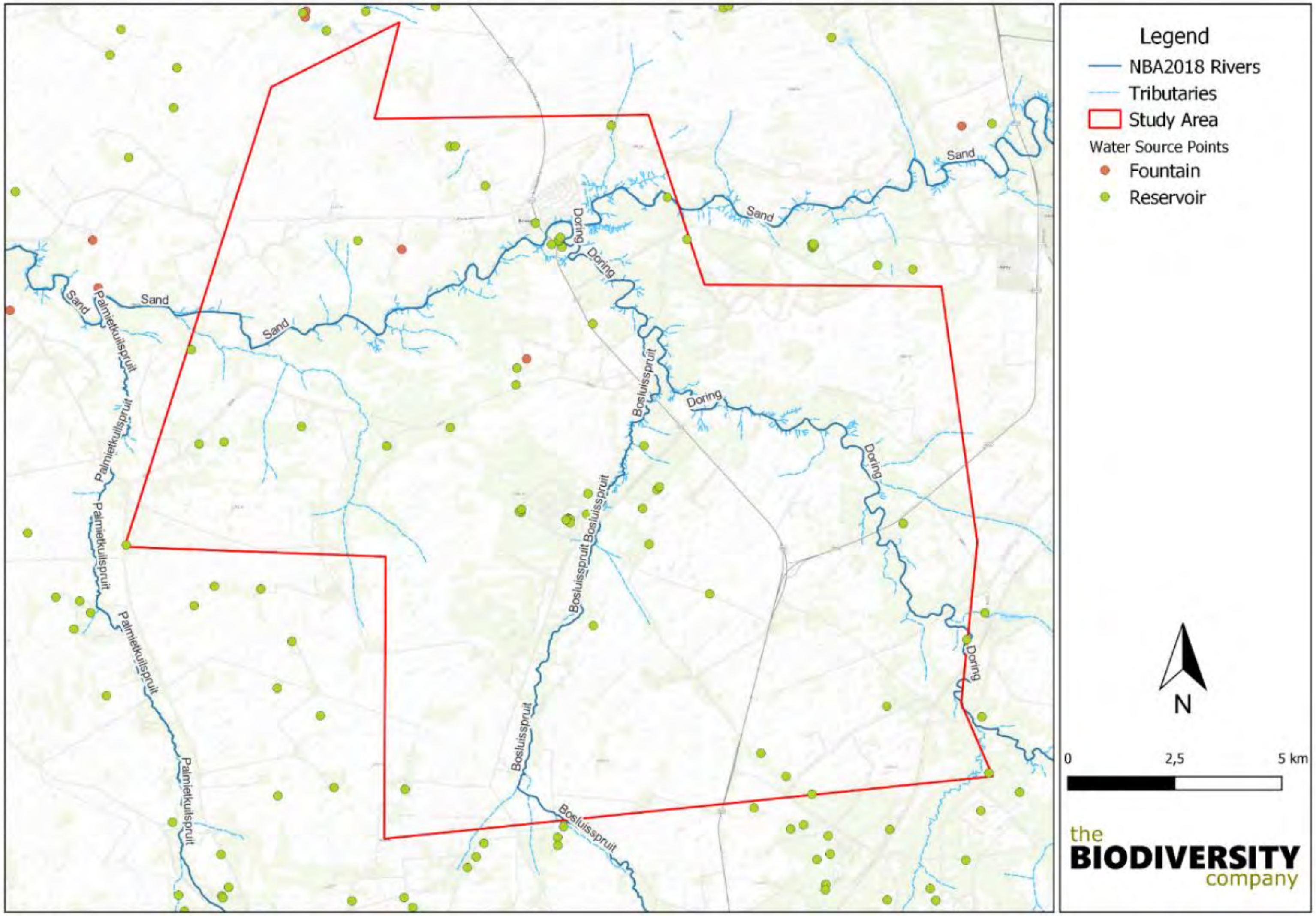

Figure 5-3 Illustration of the water source points associated with the project area

5.2 Climate

The region has seasonal rains, with rainfall occurring during the summer months of October to April (Figure 5-4) and Mean annual precipitation (MAP) of 530 mm (Mucina & Rutherford, 2006). High summer temperatures are common for this region with severe frost occurring throughout the winter (on average 37 days per year).

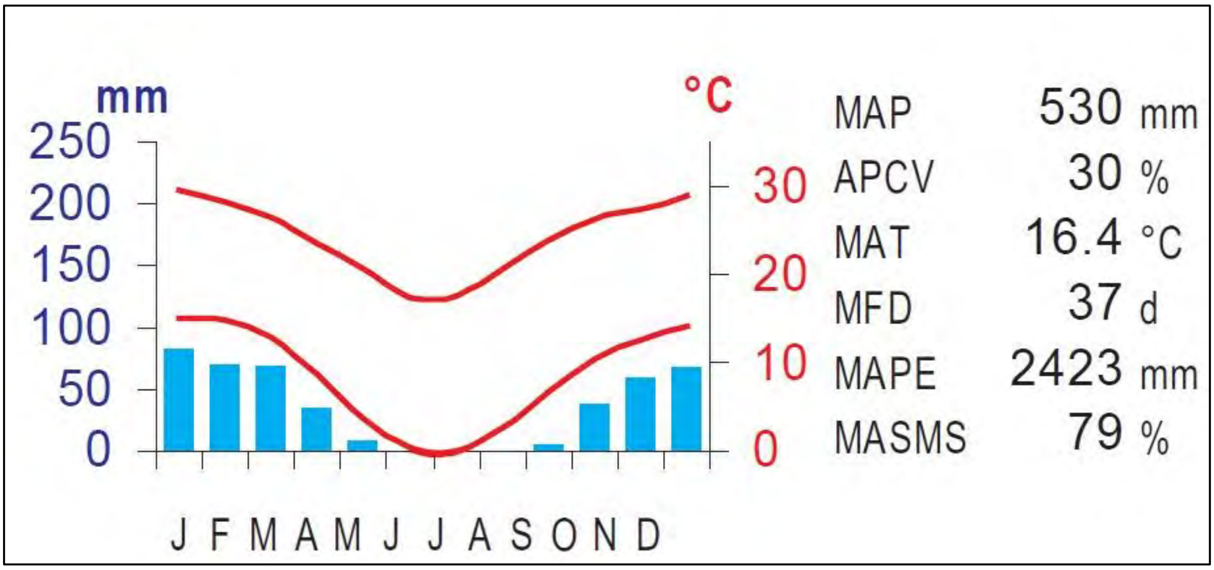

Figure 5-4 Climate for the Vaal-Vet Sandy Grassland (Mucina & Rutherford, 2006).

5.3 Land Use

The land use in the catchment area associated with the project consisted largely of commercial annuals crops rain-fed / dryland / non-irrigated (Table 5-2 and Figure 5-5). Natural grasslands predominantly occur along the various watercourses, particularly along the middle to lower reaches of the Boschluispruit, Doring River and Sand River.

Table 5-2 Major land uses within the catchment

Land Use	Hectares
Commercial Annuals Crops Rain-Fed / Dryland / Non-Irrigated	3409
Natural Grassland	385
Commercial Annuals Pivot Irrigated	410
Fallow Land & Old Fields (Grass)	229

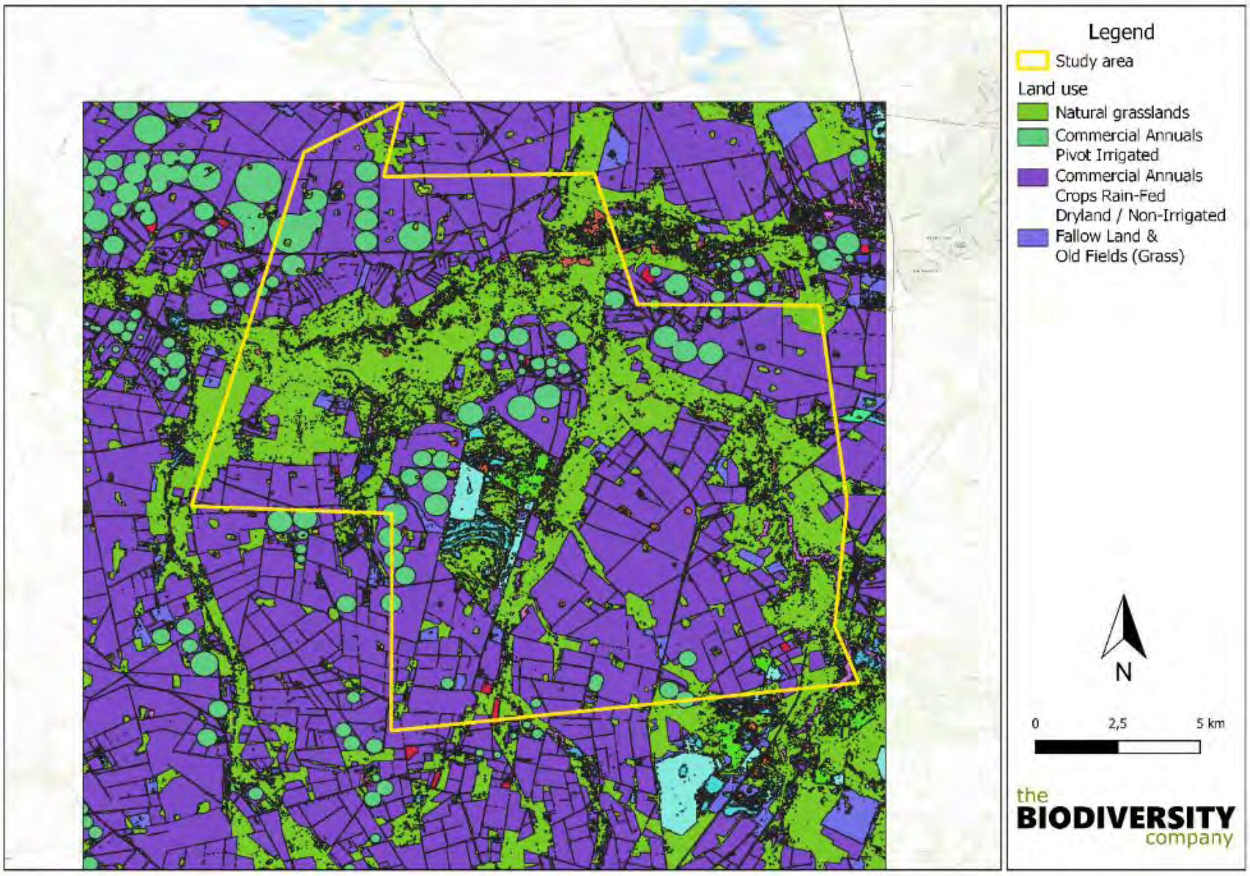

Figure 5-5 Land use within the catchment associated with the project area

5.4 Ecological Setting

The study area is located across a single Freshwater Ecoregion, the Southern Temperate Highveld (Figure 5-6), with the rivers eventuating into the Vaal River. The aquatic fauna of the Southern Temperate Highveld Freshwater Ecoregion, in comparison to northern African river systems is “lacking in diversity” with (Abel *et al.,* 2008). The ecoregion is known to have increased flow rates during the spring and summer seasons (September to March) and the indigenous fish species breed during this period. Notable aquatic ecology in these basins include the several endemic Cyprinid species. According to the expected fish species list, a total of 9 indigenous species are expected within the system. The species assemblage expected within the study area are typically widely distributed over a large geographic range.

The study area predominantly falls within the Highveld ecoregion [Kleynhans, Thirion and Moolman (2005)]. The ecoregion is characterised by plains with moderate to low relief and dry sandy grasslands and limited mixed bushveld.

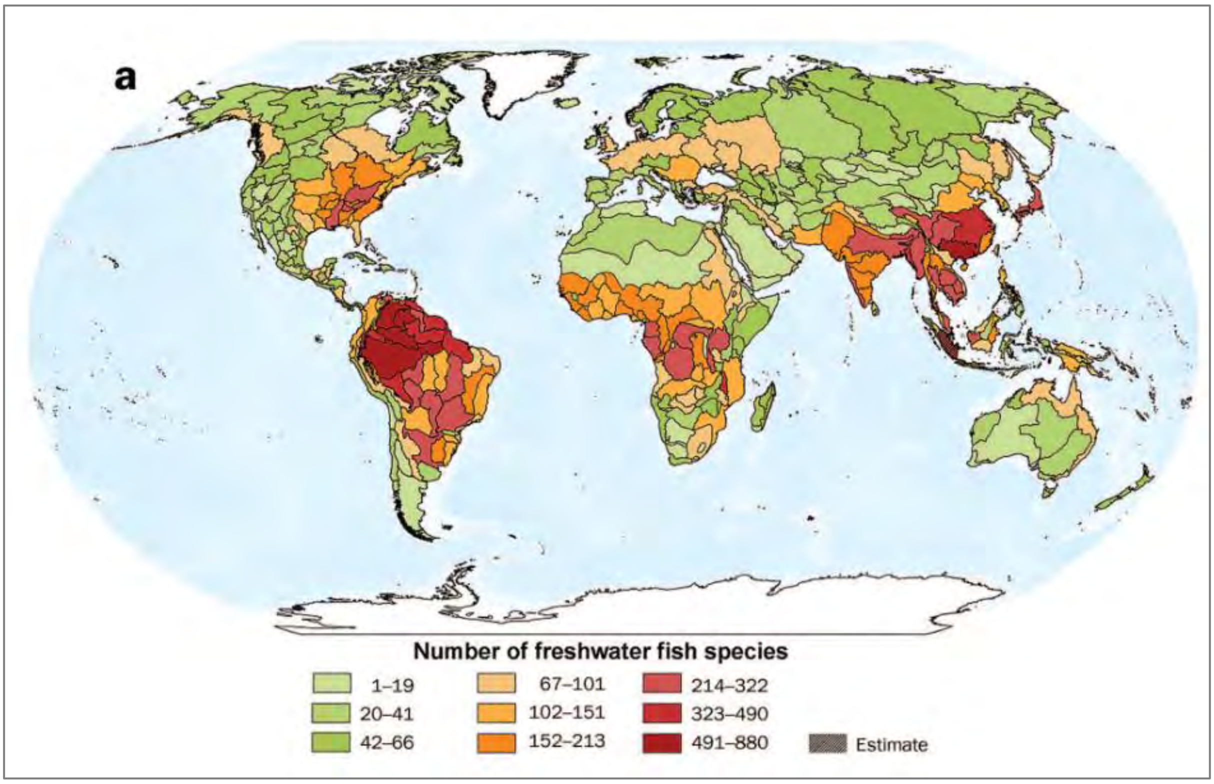

Figure 5-6 Freshwater Ecoregions of the World (Abell et al., 2008)

5.5 National Freshwater Ecosystem Priority Areas (NFEPA)

The National Freshwater Ecosystem Priority Areas (NFEPA) database forms part of a comprehensive approach to the sustainable and equitable development of South Africa's scarce water resources. This database provides guidance on how many rivers, wetlands and estuaries, and which ones, should remain in a natural or near-natural condition to support the water resource protection goals of the National Water Act (Act 36 of 1998). This directly applies to the National Water Act, which feeds into Catchment Management Strategies, water resource classification, reserve determination, and the setting and monitoring of resource quality objectives (Nel *et al.,* 2011). The NFEPAs are intended to be conservation support tools and envisioned to guide the effective implementation of measures to achieve the National Environment Management Biodiversity Act's biodiversity goals (NEM:BA) (Act 10 of 2004), informing both the listing of threatened freshwater ecosystems and the process of bioregional planning provided for by this Act (Nel *et al*., 2011).

The project area falls across five SQRs with several NFEPAs listed within the project area (Table 5-3). These FEPAs are associated with wetland type ecosystems and no aquatic biodiversity FEPAs are designated to the watercourses within the project area (Figure 5-7 and Figure 5-8).

Conserving the water quality, riverine and wetland habitat and associated ecological functioning within the project area and associated SQRs, will aid in the protection of riverine habitat supporting fish species occurring within the entire catchment and water quality for the aquatic and terrestrial biota downstream of the project area. The SQR's in which human activities occur need to be managed to maintain water quality and prevent further degradation of downstream water resources in order to contribute to national biodiversity goals and support sustainable use of water resources.

Table 5-3 NFEPAs listed for the project area

Type of FEPA map category	Biodiversity features
Doring River C42K-2754	

Type of FEPA map category	Biodiversity features
Wetland ecosystem type	3 WetCluster FEPAs
Wetland ecosystem type	Dry Highveld Grassland Group 3_Channelled valley-bottom wetland
Wetland ecosystem type	Dry Highveld Grassland Group 3_Depression
Wetland ecosystem type	Dry Highveld Grassland Group 3_Flat
Wetland ecosystem type	Dry Highveld Grassland Group 3_Seep
Wetland ecosystem type	Dry Highveld Grassland Group 3_Unchannelled valley-bottom wetland
Wetland ecosystem type	Dry Highveld Grassland Group 4_Channelled valley-bottom wetland
Wetland ecosystem type	Dry Highveld Grassland Group 4_Flat
Wetland ecosystem type	Dry Highveld Grassland Group 4_Seep
Wetland ecosystem type	Dry Highveld Grassland Group 4_Unchannelled valley-bottom wetland
Wetland ecosystem type	Dry Highveld Grassland Group 4_Valleyhead seep
Boschluispruit C42K- 2764	
Wetland ecosystem type	Dry Highveld Grassland Group 3_Channelled valley-bottom wetland
Wetland ecosystem type	Dry Highveld Grassland Group 3_Depression
Wetland ecosystem type	Dry Highveld Grassland Group 3_Flat
Wetland ecosystem type	Dry Highveld Grassland Group 3_Seep

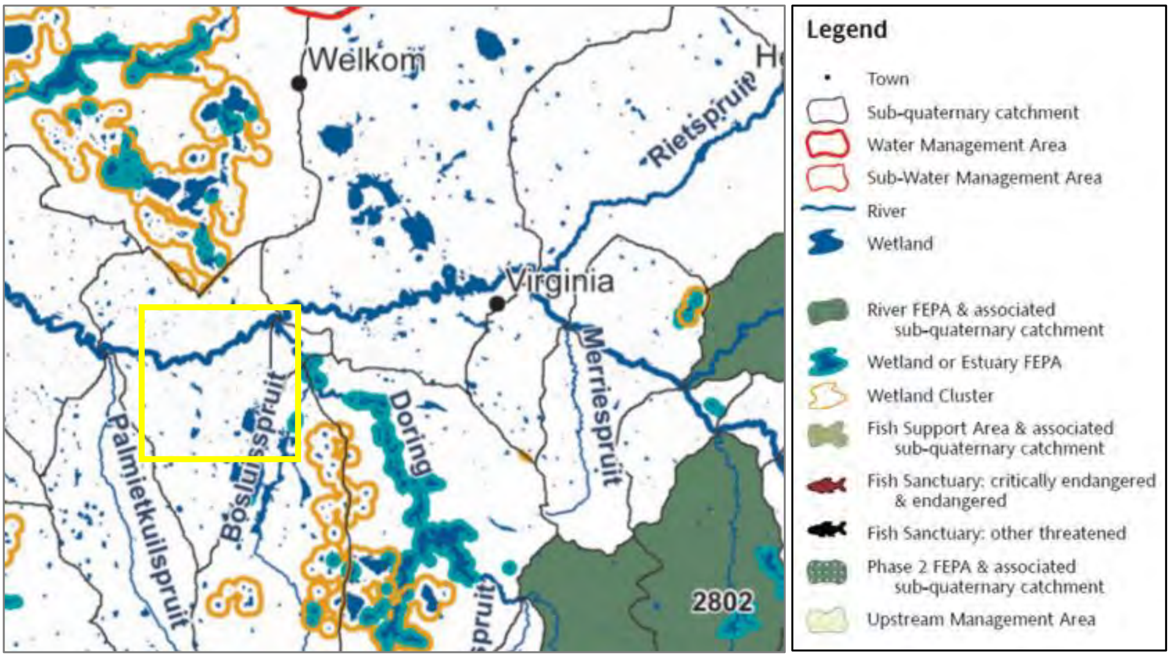

Figure 5-7 Map illustrating fish and river FEPAs for the project area, the project area is represented by the yellow square (Nel et al., 2011)

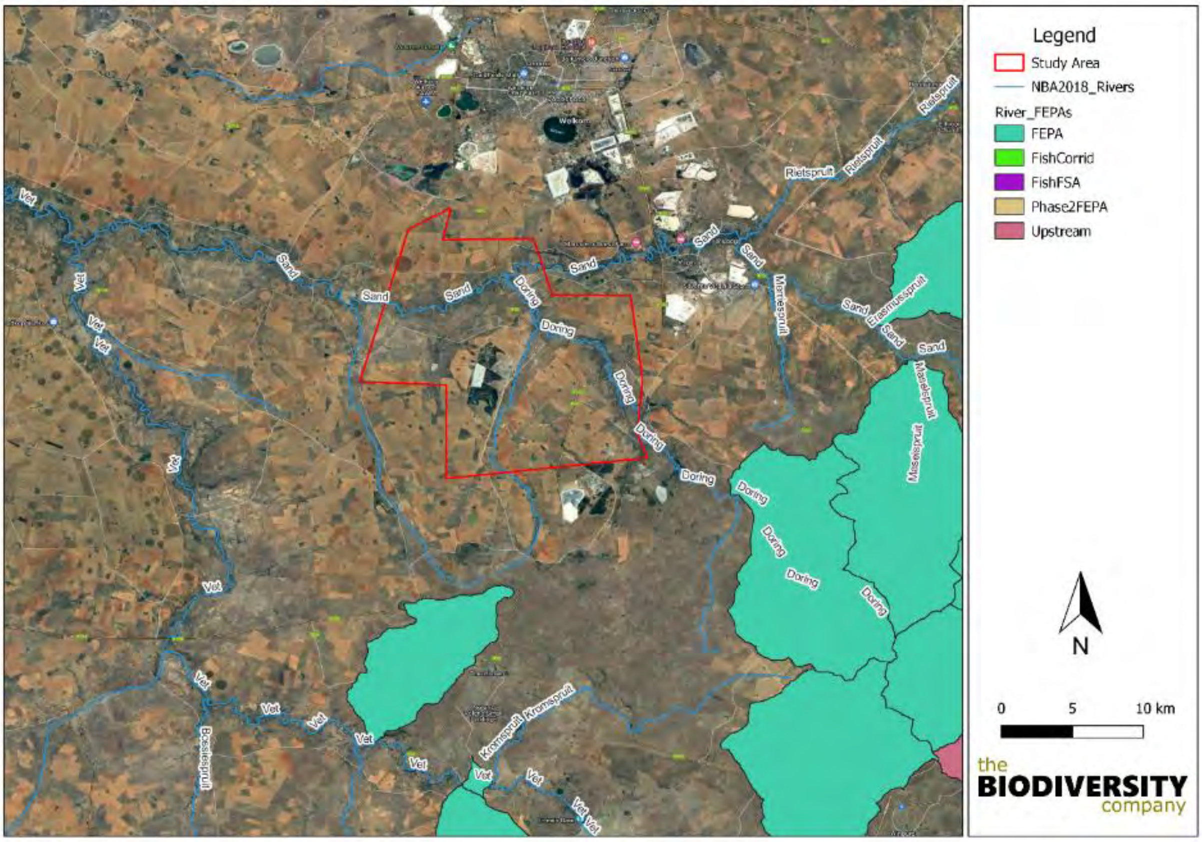

Figure 5-8 Aquatic FEPAs associated with the project area

5.6 Strategic Water Source Areas

Strategic Water Source Areas are areas that supply a disproportionate amount of mean annual runoff to a geographical region of interest. The areas supplying ≥ 50% of South Africa's water supply (which were represented by areas with a mean annual runoff of ≥ 135 mm/year) represent national Strategic Water Source Areas (SANBI, 2013). According to the Strategic Water Source Areas (SWSAs) of South Africa, Lesotho and Swaziland, the project area is not located within the SWSAs with all SWSA aligned along the coast. The project area is considered warm and temperate climate that receives limited rainfall (annual 530 mm) with an average annual temperature in the region of 16.4°C and does not fall within a SWSA.

5.7 Freshwater Critical Biodiversity Area

Critical Biodiversity Areas (CBAs) are terrestrial and aquatic areas of the landscape that need to be maintained in a natural or near-natural state to ensure the continued existence and functioning of species and ecosystems and the delivery of ecosystem services. CBAs are areas of high biodiversity value and need to be kept in a natural state, with no further loss of habitat or species (MTPA, 2014). Thus, if these areas are not maintained in a natural or near natural state then biodiversity targets cannot be met. Maintaining an area in a natural state can include a variety of biodiversity compatible land uses and resource uses (SANBI, 2017).

According to Collins (2016), no aquatic CBA have been designated for the Free State Province, however, terrestrial CBAs are provided in Figure 5-9. These should be taken into consideration with the freshwater systems due to ecosystem services provided by the watercourses in the region. Additionally, it was recommended by Collins (2016) to treat all NFEPA wetlands as Ecological Support Areas (ESA) within the region.

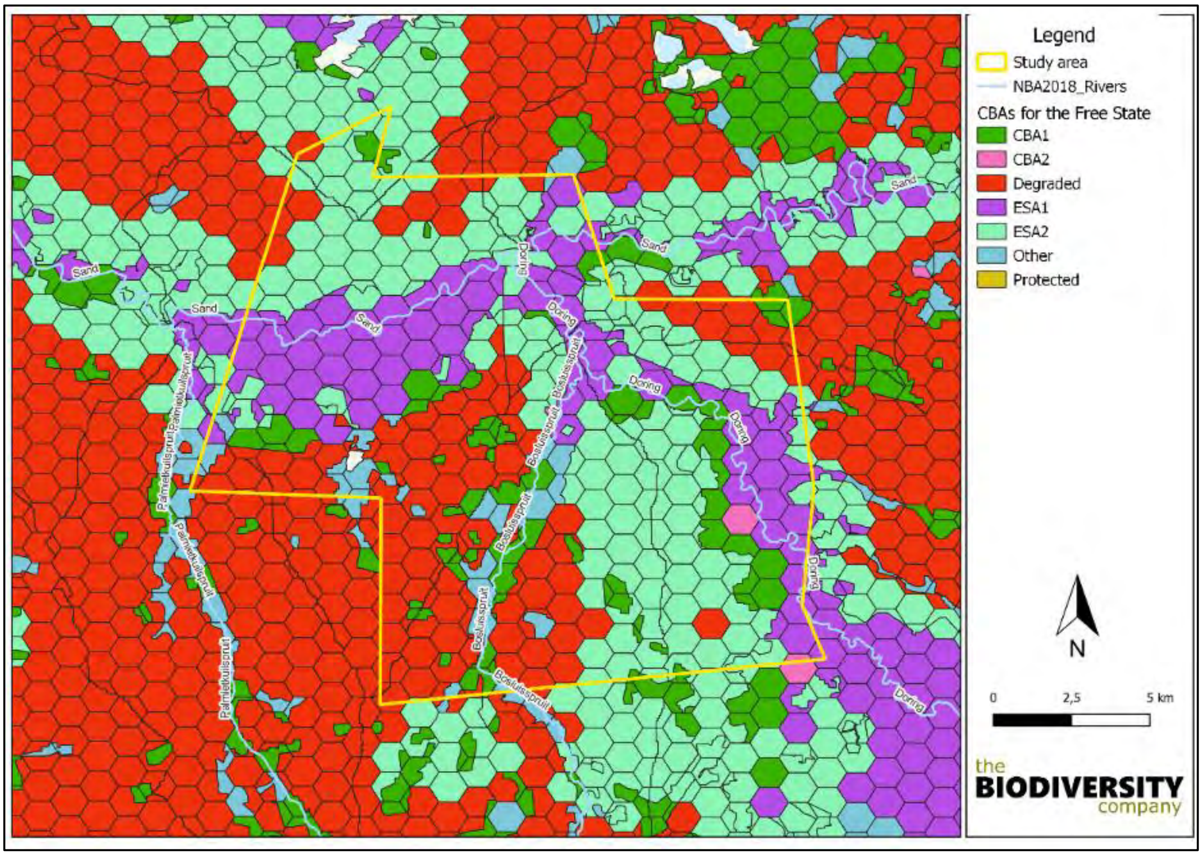

Figure 5-9 Illustration of the Terrestrial Critical Biodiversity Areas within the project area (Collins, 2016)

5.8 Ecosystem Threat Status

Ecosystem threat status outlines the degree to which ecosystems are still intact or alternatively losing vital aspects of their structure, function and composition, on which their ability to provide ecosystem services ultimately depends (Skowno *et al*., 2019).

Ecosystem types are categorised as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Least Threatened (LT), based on the proportion of each ecosystem type that remains in good ecological condition (Skowno *et al*., 2019). The Ecosystem Threat Status (ETS) of each river assessed was based on the extent to which the system had been modified from its natural condition (SANBI, 2022). According to the South African Inventory of Inland Aquatic Ecosystems (SAIIAE) released with the National Biodiversity Assessment (NBA) of rivers, the rivers which were superimposed on the aquatic ecosystem threat status indicate that the project area falls across an interconnected CR ecosystem (Figure 5-10).

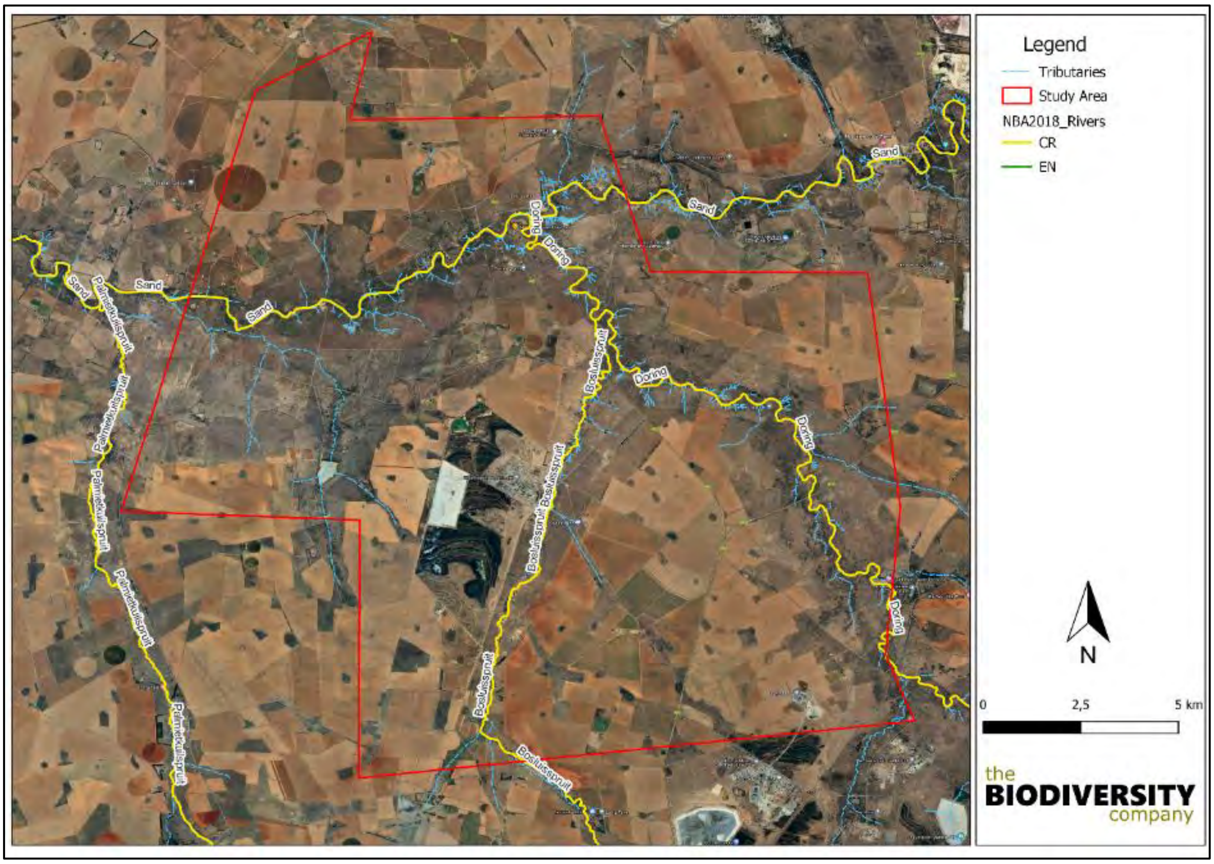

Figure 5-10 Illustration of the Ecosystem Threat Status of the project area (SANBI, 2022)

5.9 Ecosystem Protection Level

Ecosystem protection level tells us whether ecosystems are adequately protected or under-protected. Ecosystem types are categorised as not protected, poorly protected, moderately protected or well protected, based on the proportion of each ecosystem type that occurs within a protected area recognised in the Protected Areas Act (Skowno *et al*., 2019). The Ecosystem Protection Level (EPL) of each river assessed was based on the extent (expressed as a percentage) to which the system has their biodiversity target located within protected areas and are in a natural or near-natural ecological condition. Rivers in protected areas need to be in good condition (A or B ecological category) to be considered as protected. Well protected rivers have 100% located within protected areas, while moderately protected and poorly protected river ecosystem types have at least 50% and 5% of their biodiversity target in protected areas, respectively. Not protected rivers form less than 5% (SANBI, 2022).

The project area was superimposed on the ecosystem protection level map to assess the protection status of aquatic ecosystems associated with the development (Figure 5-11). This indicates that the aquatic ecosystems associated with the project area are predominantly rated as *poorly protected* with portions of the Boschluisspruit rated as *not protected*.

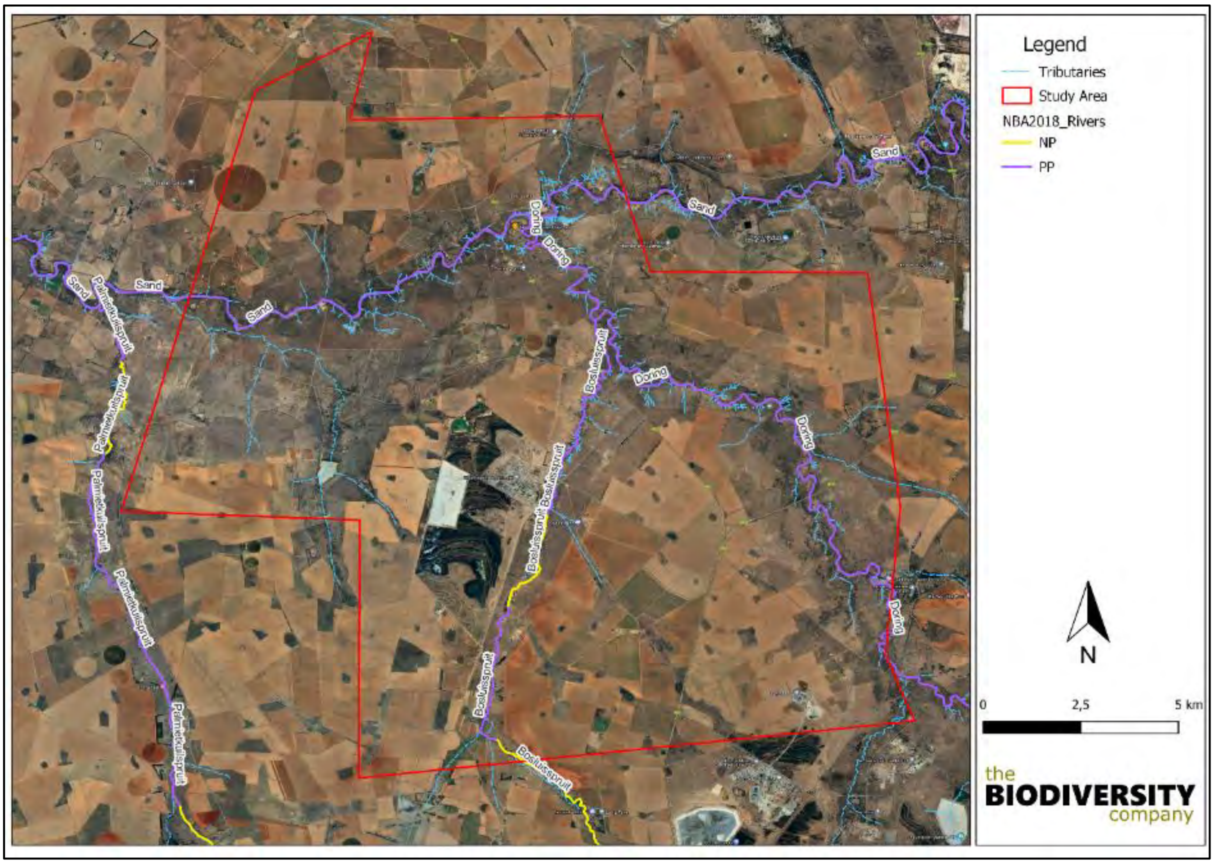

Figure 5-11 Illustration of the Ecosystem Protection Level of the project area (NBA, 2022)

5.10 Spatially Sensitive Mapping

This approach has also taken cognisance of the recently published Government Notice 320 in terms of NEMA dated March 2020: “Procedures for the Assessment and Minimum Criteria for Reporting on Identified Environmental Themes in terms of Sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998, when applying for Environmental Authorisation” (DWS, 2020). The National Web Based Environmental Screening Tool (NWBEST) has characterised the aquatic sensitivity of the project area as “very high” - requiring an assessment (Figure 5 1). The freshwater ecology of the immediate project area and further downstream areas are considered sensitive to disturbance from a hydrological and biological perspective. This will include all watercourses within the project area which are considered sensitive due to their relatively small spatial scale when compared to terrestrial habitat with a large demand for the ecosystem services which they provide. Construction and operation activities must take cognizance of this, and avoid any unnecessary disturbance of the watercourses and adjacent habitat.

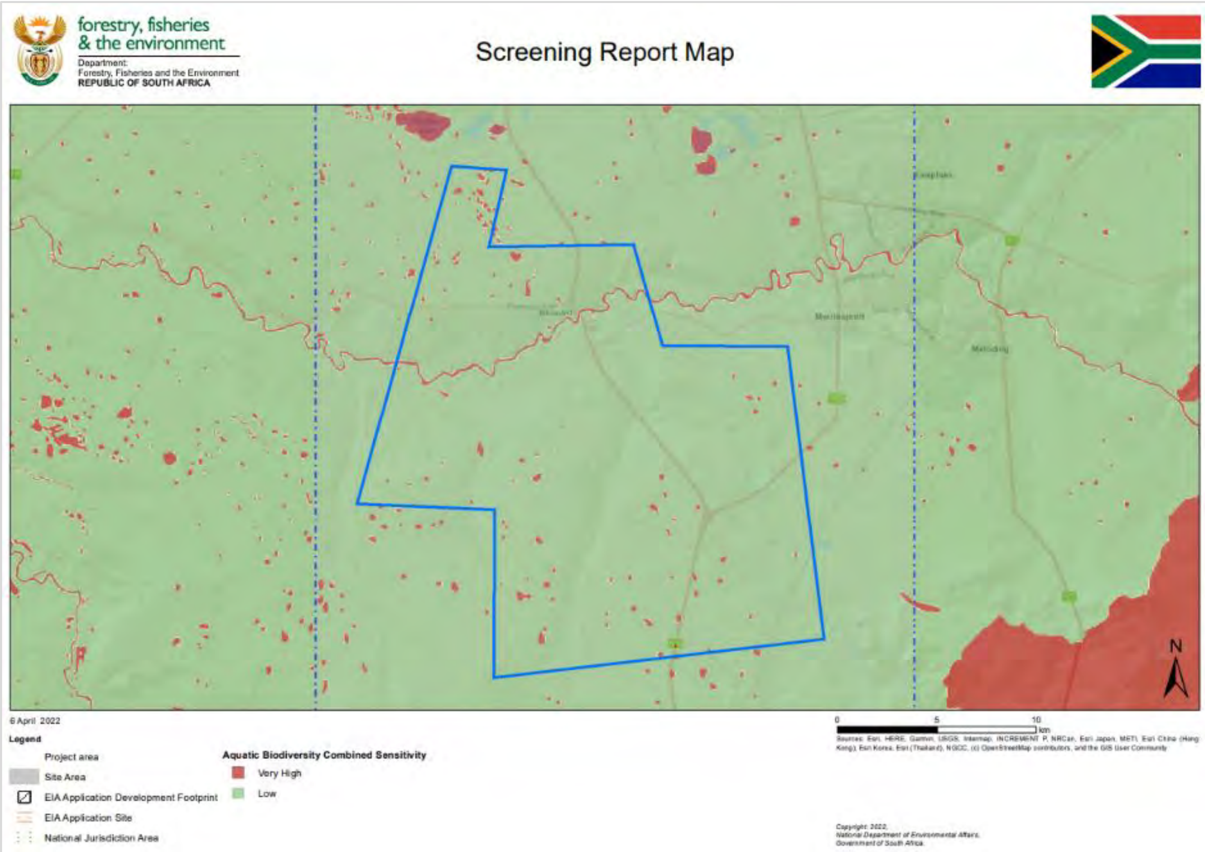

Figure 5-12 Aquatic Biodiversity Combined Sensitivity (National Web based Environmental Screening Tool)

5.11 Expected Fish Species

An expected species list was generated from DWS (2014), and Skelton (2011) for the C23H-01653 SQR's. A total of 10 fish species are expected to occur in the Sand River region which are presented in Table 5-4. The conservational status of fish species was assessed against the latest IUCN database (IUCN, 2022).

The expected species are generated on a reach basis, and the occurrence of all species in the system is unlikely as different species are specialists of different habitats which are present along a reach. The Sand River reach does however have limited habitat diversity and cover features which would likely limit the diversity of the fish community. A single species of conservational concern is expected within the reach and downstream systems, *Labeobarbus kimberleyensis* (Largemouth yellowfish) which is listed as Near Threatened (NT). The species is on decreasing population trend and is threatened by deterioration in water quality including eutrophication (nutrient enrichment through poor farming practices and inefficient wastewater treatment), loss of habitat and habitat fragmentation due to weirs and dams, loss of spawning grounds due to instream sedimentation (related to erosion), flow modifications due to drought and dam releases, and threats from exotic species, namely Common Carp (*Cyprinus carpio*) and Grass Carp (*Ctenopharyngodon idella*) (IUCN, 2022).

Table 5-4 Expected fish species for the SQRs sampled for the project

Species	Common Name	IUCN (2022)	C42L-2690 (Sand)	C42K-2754 (Doring)	C42K- 2764 (Boschluispruit)
Austroglanis sclateri	Rock-catfish	LC	1	1	
Clarias gariepinus	Sharptooth catfish	LC	1	1	
Enteromius anoplus	Chubby head barb	LC	1	1	1
Enteromius paludinosus	Straightfin barb	LC	1	1	1
Labeo capensis	Mudfish	LC	1	1	1
Labeo umbratus	Moggel	LC	1	1	1
Labeobarbus aeneus	Smallmouth yellowfish	LC	1	1	1
Labeobarbus kimberleyensis	Largemouth yellowfish	NT	1	1	
Pseudocrenilabrus philander	Southern mouthbrooder	LC	1	1	
Tilapia sparrmanii	Banded tilapia	LC	1	1	
Total expected species	10		10	10	5

LC - Least concern
NT - Near Threatened
NA - Not assessed

5.12 Resource Quality Objectives

Results from the aquatic assessment are compared to the Resource Quality Objectives (RQOs) for the Vaal WMA, Integrated Unit of Analysis MD2 Lower Sand, Resource Unit LS3 (DWS, 2016). The Resource Units (RU) are presented in Table 5-5 and the RQOs for the units are presented in Table 5-6. The stipulated RQOs should be considered for the Environmental Management Plan and monitoring protocols should EA be granted for this project. Each aspect of the aquatic assessment will be presented along with relevant RQOs.

Table 5-5 Summary of resources assigned RQOs for the relevant Sand River region

Integrated Unit of Analysis (IUA)	RU	Water Resource Class for IUA	Quaternary Catchment	Mean Annual Runoff (MAR)	Present Ecological State	Recommended Ecological Category
Lower Sand River (MD2)	LS3	III	C42L	180.27	C	C

Table 5-6 Resource Quality Objectives for the sand River Resource Unit (RU) LS3

<table>
<tr><th>RU</th><th>Quaternary Catchment</th><th>Component</th><th>Component Sub-</th><th>Resource Quality Objective</th><th>Indicator/measure</th><th colspan="2">Numerical limit</th></tr>
<tr><td rowspan="13">LS3</td><td rowspan="13">C42K, C42L, C43B</td><td>Quantity</td><td>Low flows</td><td>The maintenance low flows and drought flows must be attained to support a healthy condition for the ecosystem and users.</td><td>Total Ecological Water Requirement (node MD 2.3) = 43.933 million cubic metres/annum (24.37% of the Virgin Mean Annual Runoff) Maintenance flows (percentage value of naturalised flow distribution) Drought flows (percentage value of naturalised flow distribution)</td><td colspan="2">
<table>
<tr><td>Month</td><td>Maintenance Low Flows</td><td>Drought Flows</td><td></td><td></td></tr>
<tr><td>cubic metres/ second</td><td>Per cen tile</td><td>cubic metres/ second</td><td>Per cen tile</td><td></td></tr>
<tr><td>Oct</td><td>0.4014</td><td>70</td><td>0.0523</td><td>99</td></tr>
<tr><td>Nov</td><td>0.7481</td><td>80</td><td>0.0270</td><td>99</td></tr>
<tr><td>Dec</td><td>0.8658</td><td>80</td><td>0.0187</td><td>99</td></tr>
<tr><td>Jan</td><td>1.2769</td><td>80</td><td>0.1792</td><td>99</td></tr>
<tr><td>Feb</td><td>1.5828</td><td>80</td><td>0.1819</td><td>99</td></tr>
<tr><td>Mar</td><td>1.5177</td><td>80</td><td>0.1120</td><td>99</td></tr>
<tr><td>Apr</td><td>1.0849</td><td>70</td><td>0.0849</td><td>99</td></tr>
<tr><td>May</td><td>0.6440</td><td>40</td><td>0.0933</td><td>99</td></tr>
<tr><td>Jun</td><td>0.3306</td><td>50</td><td>0.0849</td><td>99</td></tr>
<tr><td>Jul</td><td>0.1404</td><td>80</td><td>0.0448</td><td>99</td></tr>
<tr><td>Aug</td><td>0.1493</td><td>90</td><td>0.0493</td><td>99</td></tr>
<tr><td>Sep</td><td>0.2986</td><td>60</td><td>0.0876</td><td>99</td></tr>
</table>
</td></tr>
<tr><td rowspan="12">Quality</td><td rowspan="3">Nutrients</td><td rowspan="3">Instream concentration of nutrients must be improved to sustain aquatic ecosystem health and ensure the prescribed ecological category is met.</td><td>Dissolved Inorganic Nitrogen as Nitrogen</td><td colspan="2">≤ 1.5 milligrams/litre (50th percentile)</td></tr>
<tr><td>Nitrate & Nitrite as Nitrogen</td><td colspan="2">≤ 1.0 milligrams/litre (50th percentile)
≤ 6 milligrams/litre (95th percentile)</td></tr>
<tr><td>Orthophosphate as Phosphorus</td><td colspan="2">≤ 0.058 milligrams/litre (50th percentile)</td></tr>
<tr><td>Salts</td><td>Salinity levels are significantly high. Instream salinity must be improved to support the aquatic ecosystem and the water quality requirements of the water users.</td><td>Electrical conductivity</td><td colspan="2">≤ 85 milliSiemens/metre (95th percentile)</td></tr>
<tr><td rowspan="7">Toxics</td><td rowspan="7">The concentrations of toxins should not be at a level that is toxic to aquatic organisms and a threat to human health.</td><td colspan="2">Cyanide (free)</td><td>≤ 0.045 milligrams/litre (95th percentile)</td></tr>
<tr><td colspan="2">Aluminium</td><td>≤ 0.1 milligrams/litre (95th percentile)</td></tr>
<tr><td colspan="2">Manganese</td><td>≤ 0.25 milligrams/litre (95th percentile)</td></tr>
<tr><td colspan="2">Iron</td><td>≤ 0.3 milligrams/litre (95th percentile)</td></tr>
<tr><td colspan="2">Uranium</td><td>≤ 0.03 milligrams/litre (95th percentile)</td></tr>
<tr><td colspan="2">Ammonia as Nitrogen</td><td>≤ 0.072 milligrams/litre (95th percentile)</td></tr>
<tr><td colspan="3">A screening level whole effluent toxicity test should be conducted at four trophic levels and should the results show toxicity greater than 1 (limited to not acutely toxic) further definitive tests are required</td></tr>
</table>

LS3	Lower Sand (C42J) (Downstream Rietspruit tributary to confluence with the Vet River)	Quality	Pathogens	The presence of pathogens should pose a low risk to human health.	Escherichia coli	≤ 130 counts/100 millilitres (95th percentile)
			System variables	pH must be maintained at present state.	pH range	6.5 (5 percentile) th percentile) and 9.2 (95^{th})
				A baseline assessment to determine the present state instream turbidity is required.	Turbidity	A 10% variation from background concentration is allowed.
		Habitat	Instream Habitat	Instream and Riparian habitat must be in a moderately modified condition or better.	The Rapid Habitat Assessment Method must be implemented.	Instream and Riparian habitat Integrity category ≥ C (≥ 62)
		Biota	Fish	Instream biota must be in moderately modified condition or better through maintenance of habitat, flows, water quality.	A baseline assessment to determine the integrity and health of the fish community should be conducted to determine the current state and potential impacts to the population. Fish Response Assessment Index (FRAI) must be utilized.	Fish ecological category: ≥ C (≥ 62) Macro-invertebrate ecological category:≥ C (≥ 62) Instream Ecostatus category ≥ C (≥ 62) Hydrological category ≥ C (≥ 62) With monthly flow requirements as specified. Water Quality category: ≥ C (≥ 62)
			Aquatic Invertebrates	The integrity of the macroinvertebrate community within the system must be maintained.	The integrity of the invertebrate community should be determined using the Macroinvertebrate Response Assessment Index. Conduct aquatic biomonitoring annually using the South African scoring System 5 methodology.	Maintain the D ecological category by ensuring that the Average Score Per Taxon is >5 4.0.

6 Results

6.1 *In situ* Water Quality

In situ water quality analysis was conducted during the study at multiple points along the watercourses in the project area which contained water. Results have been compared to limits stipulated in the Target Water Quality Range (TWQR) for aquatic ecosystems (DWAF, 1996). The results of the March 2022 assessment are presented in Table 6-1.

Table 6-1 In situ surface water quality results (March 2022)

Site	pH	Conductivity (µS/cm)	DO (mg/l)	Temperature (°C)
RQOs* TWQR**	6.5-9.2*	850*	>5.00 mg/l**	5-30**
Palmietkuilspruit				
P1	7,0	1305	9,1	20.0
Sand River				
S1	6,6	342	5,3	20,6
S2	6,4	736	6,3	22,5
S3	6,6	735	5,4	23,8
Boschluispruit				
BO	6,9	833	4,3	19,3
B1	Dry			
B3	7,02	411	6,7	19,5
Doring River				
D1	7,1	1495	7,2	21,1
D2	6,8	1845	6,5	22,8
Ephemeral Tributaries				
K1	6,9	313	4,5	20,6
TS1	Dry			
T2	No access			
TS2	No access			
T1	6,0	346	4,8	19,3
TO	6,3	434	7,7	19,4

*TWQR – Target Water Quality Range (DWAF, 2006); ** Resource Quality Objective (DWS, 2016); Levels exceeding guideline levels are indicated in red

Water quality results indicate pH levels within the catchment fall largely into RQOs and the TWQR, and range from 6.0 at site T1 to 7.1 at site D1. Sites in the Sand River were acidic, ranging from 6.4 to 6.6 within the assessed reach. Additionally, acidic pH levels were recorded at sites on the unnamed tributary (T0 and T1). The low pH levels recorded at several sites would contribute to adverse conditions for local aquatic biota. Marked changes in pH levels within the catchment would further contribute to adverse conditions, limiting the abundances and diversity of sensitive aquatic biota.

The concentrations of dissolved solids as measured in Electrical Conductivity (EC) were found to range from 313 µS/cm at site K1 to 1845 µS/cm. The elevated EC levels within the Doring and Palmietkuilspruit would limit the diversity of local aquatic biota. The contributions of dissolved solids from the Doring into the Sand River increase EC levels by 46%. This marked increase would contribute to adverse conditions, interfering with osmotic balances in metabolism and respiration. Mining activities within the Doring River, and agricultural runoff contribute to the elevated levels.

Low Dissolved Oxygen (DO) levels were recorded within the tributaries (K1 and T1), and the upper reaches of the Boschluispruit. Sites T1 and B0 presented limited surface water and flow, reducing oxygen replenishment into the system. Chronically low DO levels would limit the diversity and abundances of sensitive aquatic biota. Water temperatures fell within expected ranges for the highveld ecoregion during the summer rainfall period.

6.2 Habitat Integrity Assessment

The IHIA was completed for the Sand River, Doring River and Boschluispruit as described in the IHIA methodology component of this study. The spatial framework of which constitutes a 5 km reach of the each of the systems was used to complete the IHIA and represented in Table 6-2.

Table 6-2 The Intermediate Habitat Integrity Assessment results for the various perennial watercourses

Instream	Sand River	Boschluispruit	Doring River
Water abstraction	8	10	10
Flow modification	10	15	19
Bed modification	11	16	19
Channel modification	14	15	15
Water quality	10	10	17
Inundation	10	12	10
Exotic macrophytes	10	5	5
Exotic fauna	5	5	5
Solid waste disposal	5	5	5
Total Instream	61	55	48
Category	C	D	D
Riparian	Sand River	Boschluispruit	Doring River
Indigenous vegetation removal	10	16	15
Exotic vegetation encroachment	10	8	10
Bank erosion	15	12	16
Channel modification	12	16	15
Water abstraction	10	10	10
Inundation	5	12	10
Flow modification	8	16	15
Water quality	5	15	17
Total Riparian	62	47	45
Category	C	D	D

The results of the instream and riparian habitat assessments in the Boschluispruit and Doring River indicated class D or largely modified habitat condition in all watercourses. The lowered ecological condition of the watercourses was derived to be below the recommended class C (moderately modified) or >62 condition of the RQOs for the C42K catchment. While these RQOs are not specific for these two rivers, the deterioration of these catchments below class C contributes to the deterioration of the downstream Sand River. The Sand River instream and riparian ecological integrity was rated as class

C, falling within the RQOs. The relatively low intensity of anthropogenic activities within the reach contributes to moderate modifications to the riparian and instream habitat integrity.

The watersheds considered in this study have modified land use, which is dominated by dryland agriculture and livestock land uses. Groundwater abstraction (boreholes) is anticipated to have impacted on the baseflow of the watercourses, whilst altered landcover has resulted in the increased flood-peaks of low duration. Direct discharges to surface water in the study area are also known to occur, whereby discharge or treated sewage water from upstream urban areas on the Sand River and Doring River and is considered a key source of water in the catchments with associated water quality issues (dissolved salt loads and eutrophication). Additionally, discharge of water from mines on the Doring catchment contribute to flow and water quality modifications, increasing dissolved solid concentration.

Instream habitat modifications within the catchment was noted at all sites, and particularly increased sediment deposits within the Doring and Sand Rivers. The source of the increased sediment yield can be attributed to the erosion of channel edges within the Doring and Sand River catchments, compounded by dryland agricultural activities (Figure 6-1 and Figure 6-2). The soils observed within the river banks was noted to be composed of highly erodible soils which is further contributing towards the erosion and sedimentation in the watercourses. The erosion of bed and banks results in channelisation and reduced lateral movement of water into the riparian zone. The reduced lateral flow of water and physical disturbance of the riparian zone due to erosion has compromised the riparian zone integrity within the catchment.

Figure 6-1 Erosion within the Doring River catchment (Google Earth, 2021)

Figure 6-2 Erosion within the Sand River catchment (Google Earth, 2021)

Similar aspects covered in the instream habitat assessment indicated above, the observation of woody invasive species (*Tamarix* sp.) were also observed in the bank-top vegetation which further contributed to the deteriorated ecological state (Figure 6-3). Additionally, anthropogenic activities within the riparian zone have contributed to a deteriorated ecological state, including residential areas and mining activities (Figure 6-4).

Figure 6-3 Illustration of Tamarix sp. in the bank-top vegetation of the Doring River

Figure 6-4 Illustration of mining activities along the Sand River bank (Google Earth, 2021)

6.3 Aquatic Macroinvertebrate Assessment

6.3.1 Macroinvertebrate Habitat

Biological SASS5 assessments were completed at representative sites in the considered river reaches. The results of the biotope assessment are provided in Table 6-3.

Table 6-3 Biotope availability at the sites in 2022 (Rating 0-5)

Biotope	Weighting (Lowland River)	P1	S2	B3	D1
Stones in current	18	3,5	3	0	3
Stones out of current	12	4	3	0	3
Bedrock	3	2	2,5	0	1
Aquatic Vegetation	1	1	1	1	0
Marginal Vegetation In Current	2	1	2	2	1
Marginal Vegetation Out Of Current	2	2	1,5	2	2
Gravel	4	3	3	1	1
Sand	2	3	4	1	2
Mud	1	3	1	2	3
Biotope Score		22,5	21	9	16
Weighted Biotope Score (%)		64	56	8	49
Biotope Category (Tate and Husted, 2015)		B	C	F	D

The biotope rating assessment indicated diverse habitat at sites P1, with diverse instream substrate including stones in and out of current, gravel, sand and mud substrate. Limited marginal and aquatic vegetation were recorded at all sites, reducing the expected macroinvertebrate orders from Odonata, Hemiptera and Coleoptera. Site S2 on the Sand River presented moderate biotope diversity, with substrate dominated by sand substrate with patches of stones in and out of current (Figure 6-5). Sedimentation and erosion have reduced the availability of stones in and out of current biotopes due to instream smothering. Poor habitat diversity was sampled at site B3, however, the site was naturally low in biotope diversity due to wetland nature of the system (Figure 6-6 and Figure 6-7). The low habitat diversity would limit the diversity and abundances of macroinvertebrate taxa with preferences to flow and stones biotopes. Moderate biotope diversity was sampled at site D1 on the Doring River, with substrate dominated by stones in and out of current, and mud substrate. No aquatic vegetation was sampled.

All sites bar B3 are considered to have habitat types capable of supporting a moderate diversity of macroinvertebrates and is therefore considered a hindrance on a highly diverse assemblage.

Figure 6-5 Habitat sampled at site S2 on the Sand River (March 2022)

Figure 6-6 Illustration of the reach type within the Boschluispruit (B3, March 2022)

Figure 6-7 Typical marginal vegetation within the Boschluispruit (B3, March 2022)

6.3.2 South African Scoring System

The SASS5 score and SASS5 ecological classes obtained for each site sampled during the surveys are presented in Table 6-4. According to RQOs, the ASPT for the Sand River must above 5 for the Sand River.

Table 6-4 Macroinvertebrate assessment results recorded during the survey (March 2022)

Site	SASS5	Taxa	ASPT*	**Class (Dallas, 2007)
Sand River				
S2	96	16	6.0	B
Palmietkuilspruit				
P1	72	16	4.5	C
Doring River				
D1	94	14	6.7	B
Boschluispruit				
B3	42	11	3.8	E/F

*ASPT: Average score per taxon; ** Highveld Lower - Ecoregion

The results of the high flow 2022 SASS5 assessment indicated total sensitivity scores ranging from 42 at B3 to 96 at S2. The diversity of taxa observed ranged from 11 at B3 to 16 at P1 and S2. The derived ASPT value (average sensitivity score) for the sites ranged from 3.8 at B3 to 6.7 at D1. The ecological classes obtained ranged from class E/F at B3 to class B at sites S2 and D1. The ASPT at site B3 indicated largely tolerant taxa were collected within the reach. Moderately tolerant taxa collected include Gerridae, Ceratopogonidae, and Dytiscidae. A total of 5 of the 11 taxa were air breathers at site B3 which allow these taxa to survive within the low DO waters at the site.

Moderately tolerant taxa were collected within the Palmietkuilspruit during the survey as indicated by the ASPT of 4.5. Flow sensitive taxa were collected within the system, including Hydropsychidae and more than 2 spp. of Baetidae. Moderately sensitive taxa collected include Ancylidae and Atyidae.

Site S2 presented a moderately diverse macroinvertebrate community and the biotic integrity was rated as largely natural. The ASPT score indicated a moderately tolerant community collected (ASPT of 6.0). Sensitive taxa collected include Elmidae, Atyidae, and Ecnomidae. The ASPT recorded was above the stipulated ASPT value within the RQOs of 5.

The ASPT recorded within the Doring River indicated moderately intolerant taxa collected within the reach (ASPT of 6.7). The biotic integrity of the site was rated at largely natural. Modifications to instream habitat and water quality contributed to the modifications to the macroinvertebrate community.

An illustration of selected macroinvertebrates is illustrated in Figure 6-8.

Figure 6-8 Examples of Atyidae on the left and Aeshnidae on the right

6.4 Macroinvertebrate Response Assessment Index

The MIRAI methodology was conducted according to Thirion (2007). Data collected from the SASS5 method was applied to the MIRAI model. The MIRAI model provides a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic macroinvertebrate community (assemblage) from the reference condition (unmodified river). The MIRAI results provide a more robust interpretation of the macroinvertebrate community structure compared to the SASS5 biological bands. It should be noted that the MIRAI score for Sand River should be interpreted with caution due to flooding conditions during the survey. Additionally, due to access limitations, MIRAI scores were determined from single sites on the reach, reducing the confidence of the scores. The reference condition for the study sites was selected based on the geomorphological setting and longitudinal zonation of the watercourses considered in the study. As derived from the SASS5 results the aquatic macroinvertebrate community observed in the study sites consisted of tolerant taxa, with highly sensitive species being absent from the samples. The results of the MIRAI are presented in Table 6-5.

Table 6-5 MIRAI Score for the various watercourses

Invertebrate Metric Group	Doring River	Sand River	Boschluispruit
Flow Modifications	52,2	37,0	47,0
Habitat	44,1	42,0	47,4
Water Quality	48,6	43,7	41,2
Ecological Score	48	41	45
Category	D	D/E	D
RQOs	-	C	-

The results of the MIRAI completed in the watercourses for the study period indicates largely modified conditions within the Doring and Boschluispruit systems. Modifications to habitat and water quality drivers were the largest contributors to modified macroinvertebrate communities within the Doring River, with flow modifications further contributing to the modified community.

The invertebrate community was largely dominated by species adapted to the vegetation biotopes where diverse groups of Hemiptera, Diptera and Coleoptera were observed. Several sensitive taxa observed included Scirtidae (previously Helodidae), Dixidae, and Elmidae. Several taxa were absent, including tolerant and water quality sensitive taxa such as Heptageniidae and Leptophlebiidae. The absence of the water quality sensitive taxa was anticipated due to the eutrophic nature of the watercourses compounded by the elevated salinity. The absence of the tolerant taxa could be attributed to instream habitat modification in the Doring River, whilst biotopes were found to be smothered in the Boschluispruit.

The results of the MIRAI confirm the ecological condition of the watercourses and effectively depict the current level of instream habitat modification. The ecological classification of the Sand River (class D/E) was below the stipulated RQOs of class C. As previously mentioned, due to flooding, these results should be interpreted with caution.

6.5 Fish Communities

Sampling for fish was conducted at sites S2, P1, B3 and D1 during the study. A total of nine of the eleven native species were observed during the survey, with the highest representation of the fish community observed at sites S2, with 73% of the expected community, and 50% at sites P1 and D1 of the expected fish community were collected. A summary of expected species and fish collected is presented in Table 6-6 and illustrated in Table 6-8. No fish were collected within the Boschluispruit.

It should be noted that *Enteromius trimaculatus* was collected within the Sand River at site S2, which is not expected in the reach according to DWS (2014), Skelton (2011) or IUCN (2022), and likely represents a new distribution record for the species. The species is listed as Least Concern (LC) and is not a species of conservational concern.

Habitat sampled within the Sand River was considered moderately diverse, however, the presence of a weir artificially increased habitat diversity. The fish community largely consisted of cyprinids from the genera *Enteromius* sp., *Labeo* sp., and *Labeobarbus* sp. which are moderately intolerant to moderately tolerant to flow modifications, and moderately tolerant to modified to physico-chemical parameters (Table 6-9).

Cover features sampled within the Doring and Palmietkuilspruit were limited and would contribute to the absence of several species. The presence of instream impoundments within the Boschluispruit would limit migration and the presence of several species in the upper reaches. Additional surveys are required to improve the confidence of the fish community assessment. No species of conservational concern were collected within the sampled sites.

The results of the Fish Response Assessment Index (FRAI) are presented in Table 6-7. Results indicate the fish community within the Sand River is moderately modified, which is attributed o the presence of 73% of the expected fish community. The absence of *Labeobarbus kimberleyensis* and *Austroglanis sclateri* contribute to the lowered ecological state, however, the results of this survey do not discount the presence of these species within the reach. The FRAI score indicated the stipulated RQOs of class C for the fish community were met within the Sand River.

The Palmietkuilspruit and Doring were classed as moderately to largely modified. The diversity of hydraulic biotopes and cover features were limited within both systems and were a limiting factor to the fish community. Water quality perturbations within the Doring further reduced the biotic integrity.

Table 6-6 Presence/absence of fish species for the sampled sites

Species	IUCN (2022)	S2	P1	B3	D1
Austroglanis sclateri	LC	0	0	0	0
Clarias gariepinus	LC	1	1	0	1
Enteromius anoplus	LC	0	1	0	1
Enteromius paludinosus	LC	1	1	0	0

Species	IUCN (2022)	S2	P1	B3	D1
Enteromius trimaculatus (not expected within the catchment)	LC	1	0	0	0
Labeo capensis	LC	1	0	0	0
Labeo umbratus	LC	1	0	0	0
Labeobarbus aeneus	LC	1	0	0	0
Labeobarbus kimberleyensis	NT	0	0	0	0
Pseudocrenilabrus philander	LC	1	1	0	1
Tilapia sparrmanii	LC	1	1	0	1
Expected		11	10	5	10
Total		8	5	0	5

Table 6-7 FRAI results for the various watercourses

FRAI	Doring River	Sand River	Boschluispruit	Palmietkuilspruit
Adjusted Score	61,75	76.86	23.0	59,32
Category	**C/D**	C	E/F	**C/D**
RQOs	-	C	-	

Table 6-8 Illustration of fish species observed

Species/Site	Photograph
Clarias gariepinus	
Enteromius anoplus	
Enteromius paludinosus	
Enteromius trimaculatus	

Species/Site	Photograph
Pseudocrenilabrus philander	
Tilapia sparrmanii	

Table 6-9 Hydraulic biotope preferences and water quality intolerances for expected and collected species

	Velocity-depth preference				Flow intolerance				Cover preference					Tolerance: modified physico-chem			
Scientific Names	Fast deep	Fast shallow	Slow deep	Slow shallow	Intolerant: no-flow (>4)	Moderately intolerant: no flow(>3-4)	Moderately tolerant: no flow (>2-3)	tolerant: no flow (1-2)	Overhanging vegetation: high->very high (>3)	Bank undercut: high->very high (>3)	Substrate: high->very high (>3)	Aquatic macrophytes: high->very high (>3)	Water column: high->very high (>3)	Intolerant: modified wq (>4)	Moderately intolerant: modified wq (>3-4)	Moderately tolerant (>2-3): modified wq	Tolerant: modified wq (1-2)
Austroglanis sclateri	0	3,80	3,40	0	0	3,20	0	0	0	3,50	4,40	0	0	0	0	2,60	0
Clarias gariepinus	0	0	4,30	3,40	0	0	0	1,70	0	0	0	0	0	0	0	0	1,00
Enteromius anoplus	0	0	4,10	4,30	0	0	2,30	0	4,00	0	0	3,20	0	0	0	2,60	0
Enteromius paludinosus	0	0	3,90	3,90	0	0	2,30	0	4,20	0	0	3,60	3,50	0	0	0	1,80
Enteromius trimaculatus	0	0	3,90	3,20	0	0	2,70	0	3,90	0	0	0	0	0	0	0	1,80
Labeo capensis	3,30	0	4,20	0	0	3,50	0	0	0	0	4,20	0	3,20	0	0	2,80	0
Labeo umbratus	0	0	4,50	0	0	0	2,70	0	0	0	4,20	0	0	0	0	0	1,60
Labeobarbus aeneus	3,50	4,00	3,50	0	0	3,30	0	0	0	0	4,00	0	4,00	0	0	2,50	0
Labeobarbus kimberleyensis	4,30	3,80	3,70	0	0	3,80	0	0	0	0	0	0	3,30	0	3,60	0	0
Pseudocrenilabrus philander	0	0	0	4,30	0	0	0	1,00	4,50	3,20	0	0	0	0	0	0	1,40
Tilapia sparrmanii	0	0	0	4,30	0	0	0	0,90	4,50	0	0	3,60	0	0	0	0	1,40

6.6 Present Ecological Status

The PES assessment for the Sand River, Doring River, and Boschluispruit are based on the collective data collected based on the March 2022 survey. The spatial, temporal, and flooding limitations experienced during the field survey. The results are provided in Table 6-10 and Table 6-11, respectively.

Table 6-10 Present Ecological Status of the Sand River (March 2022)

Aspect Assessed	Survey Results	RQOs
Instream Ecological Category	C	C
Riparian Ecological Category	C	C
Aquatic Invertebrate Ecological Category	D/E	C
Fish Community	C	
Ecostatus	C	C

The results of the PES assessment in the Sand River derived a moderately modified status in 2022. The anthropogenic activities within the reach have resulted in moderate modifications to the riparian and instream habitat integrity of the reach. However, upstream activities have contributed to erosion of the Sand River banks and riparian zones resulting in instream sedimentation, increased water quality perturbations from urban, agricultural and mining activities, reducing the biotic integrity of the reach. Despite upstream activities and deterioration to the system, the Sand River has achieved the RQOs of class C within the project area. Any proposed activities within the catchment should not further contribute to the deterioration of the instream and riparian zones as this will compromise the ecological integrity of the reach and RQOs may not be achieved.

Table 6-11 Present Ecological Status of the Doring River (March 2022)

Aspect Assessed	Score
Instream Ecological Category	48
Riparian Ecological Category	45
Aquatic Invertebrate Ecological Category	48
Fish Community	62
Ecostatus	class D

The ecological status of the Doring River during the 2022 survey was determined to be largely modified (class D). The modified nature of the watercourse was driven by diffuse agricultural runoff, discharges and runoff from mining activities, which have resulted in water quality perturbations that reduce the biotic integrity of the system. The erosion of banks and riparian zone have resulted in largely modified riparian and instream habitat integrity. The high erodibility of soils within the catchment have high risks to additional activities within the reach.

Table 6-12 Present Ecological Status of the Boschluispruit River (March 2022)

Aspect Assessed	Score
Instream Ecological Category	55
Riparian Ecological Category	47
Aquatic Invertebrate Ecological Category	45
Ecostatus	class D

The results of the Boschluispruit indicated largely modified ecological conditions within the reach. Modifications to the reach were attributed to erosion, instream impoundments within the upper reaches and influxes of poor water quality from agricultural and mining activities.

The baseline assessment indicated catchment wide impacts to the watercourses associated with the project area. Impacts have resulted in deterioration of drivers, namely water quality, habitat, and flow. The modification of these drivers have resulted in a modified biotic communities within the various watercourses. Despite direct modifications to the Sand River, and contributions of sediments and poor water quality from the Doring and Boschluispruit, the RQOs for the reach have been achieved. However, due to the sensitivity of soils to erosion within the reach, an increase in anthropogenic activities poses a risk to the ecological integrity of the watercourses. Given the findings of this assessment, no pristine or natural waterbodies were observed or expected in any of the project right areas.

6.7 Sensitivity Assessment

As noted in the geomorphological description of the project area, the watercourses considered in this assessment represented characteristic source zone waterbodies with wetlands. As can be observed in Figure 6-9, riparian vegetation was limited to features characteristic of wetlands. Given the wetland nature of the riparian vegetation, and relationships between wetland integrity within catchments and stable riverine conditions, the delineated wetlands as identified in TBC (2022) were used to derive the sensitive habitats. Riparian zones within the lower foothills of the Doring and Sand River were well defined and comprised of woody species Figure 6-10.

Figure 6-9 Typical headwater zone in the upper reaches of the Boschluispruit

Figure 6-10 Typical lower foothills zone and well defined riparian zone within the Sand River

The ecological sensitivity of the watercourses was determined to be largely uniform across the project area. Limited presence sensitive riverine biota was noted during the assessment, which is attributed to water quality and habitat degradation. Overall, the macroinvertebrate communities were made up of tolerant taxa with limited sensitivities. Taxa such as Atyidae (Freshwater shrimp), Hydropsychidae, Elmidae (Riffle beetles), and Ecnomidae (caddis fly) were determined to be the most sensitive aquatic invertebrates observed during the baseline assessment. Ichthyofauna communities were also found to be dominated by tolerant/adaptable taxa and largely consisted of cyprinids from the genera *Enteromius* sp., *Labeo* sp., and *Labeobarbus* sp. which are moderately intolerant to moderately tolerant to flow modifications, and moderately tolerant to modified to physico-chemical parameters.

Given the assessments that have been conducted in the region, the above taxa are likely to occur only in isolated populations. Considering the presence of such taxa, the watercourses in the project area are regarded as sensitive environments in relation to changes in flow and water quality.

In-line with GN704, the delineated floodline of 1:50 year or within a horizontal distance of 100 m from a watercourse, whichever is greatest should be considered a no-go area. According to the National Water Act, Section 21 (c) and (i), the term "wetland" is included in the legal definition of a watercourse. The legal definition of the extent of a watercourse is defined in the amendment of the General Authorisation for section 21 (c) and (i) water uses in terms of GN509 of 2016 (DWS, 2016a). The extent of the watercourse is defined as:

- A river, spring or natural channel in which water flows regularly or intermittently "within the outer edge of the 1 in 100 year floodline or riparian habitat measures from the middle of the watercourse from both banks" and for:
- Wetlands and pans: the delineated boundary (outer temporary zone) of any wetland or pan.

Given the varied geomorphological features of the watercourses, the delineated areas proposed in the wetland assessment for this project (TBC, 2022) are utilised to define the watercourse extent within the headwaters of the Boschluispruit, unchanneled valley bottoms and depressions, and the lower foothill riparian zones were delineated by identifying vegetation features on aerial imagery. An example of the proposed watercourse extent as well as where appropriate buffer areas are provided in Figure 6-11 and Figure 6-12. The various layouts and their respective delineated sensitive areas are depicted in Figure 6-13.

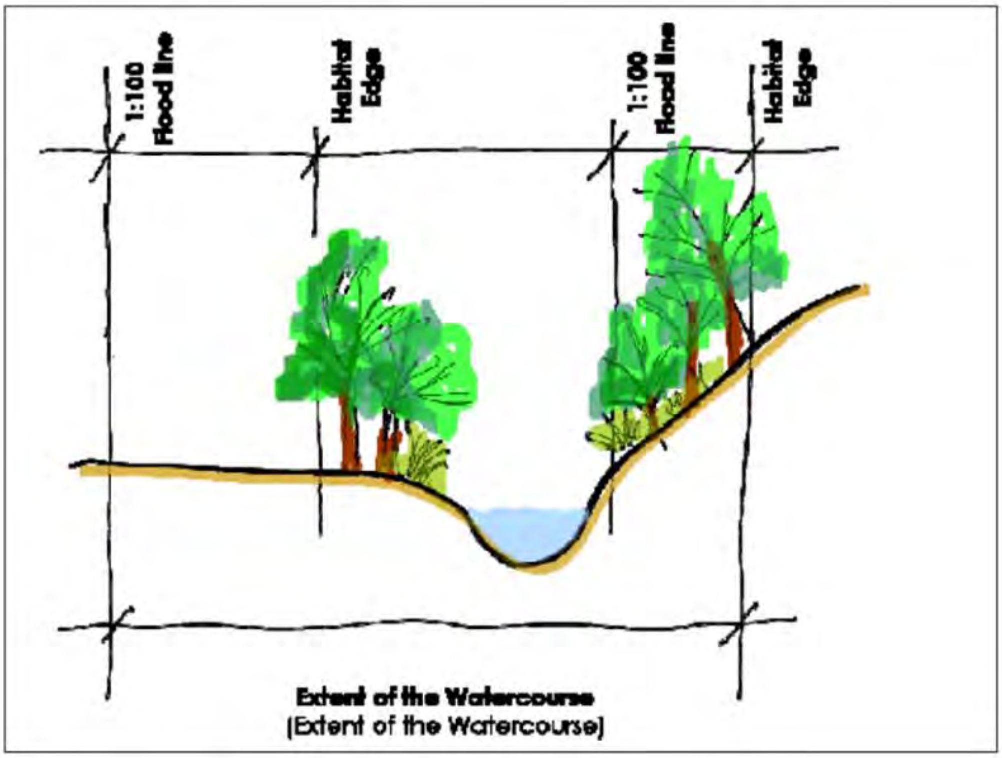

Figure 6-11 Illustration of the extent of a watercourse (DWA, 2012)

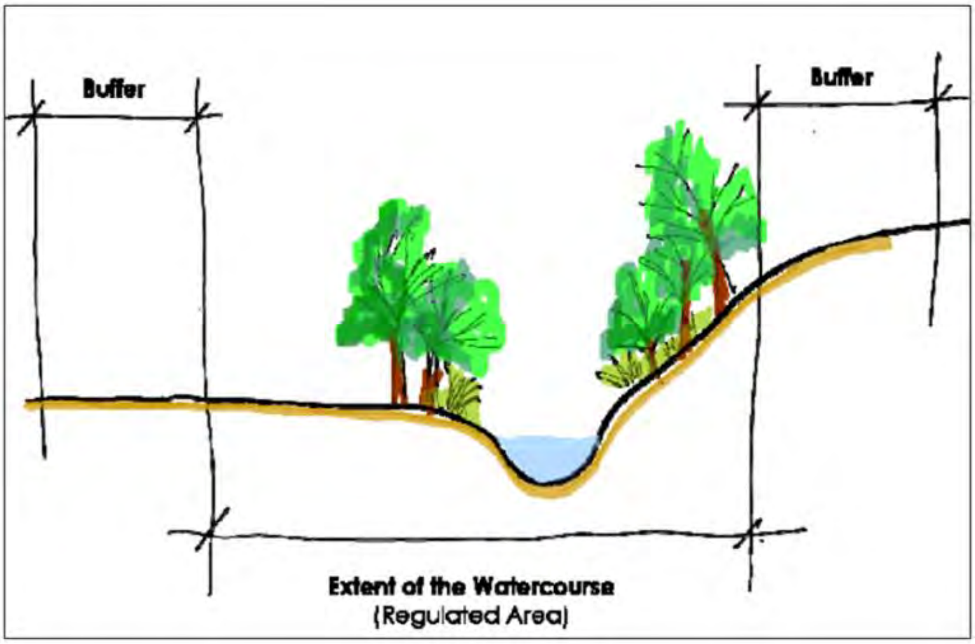

Figure 6-12 Illustration of the extent of a watercourse and the Regulated Area (DWA, 2012)

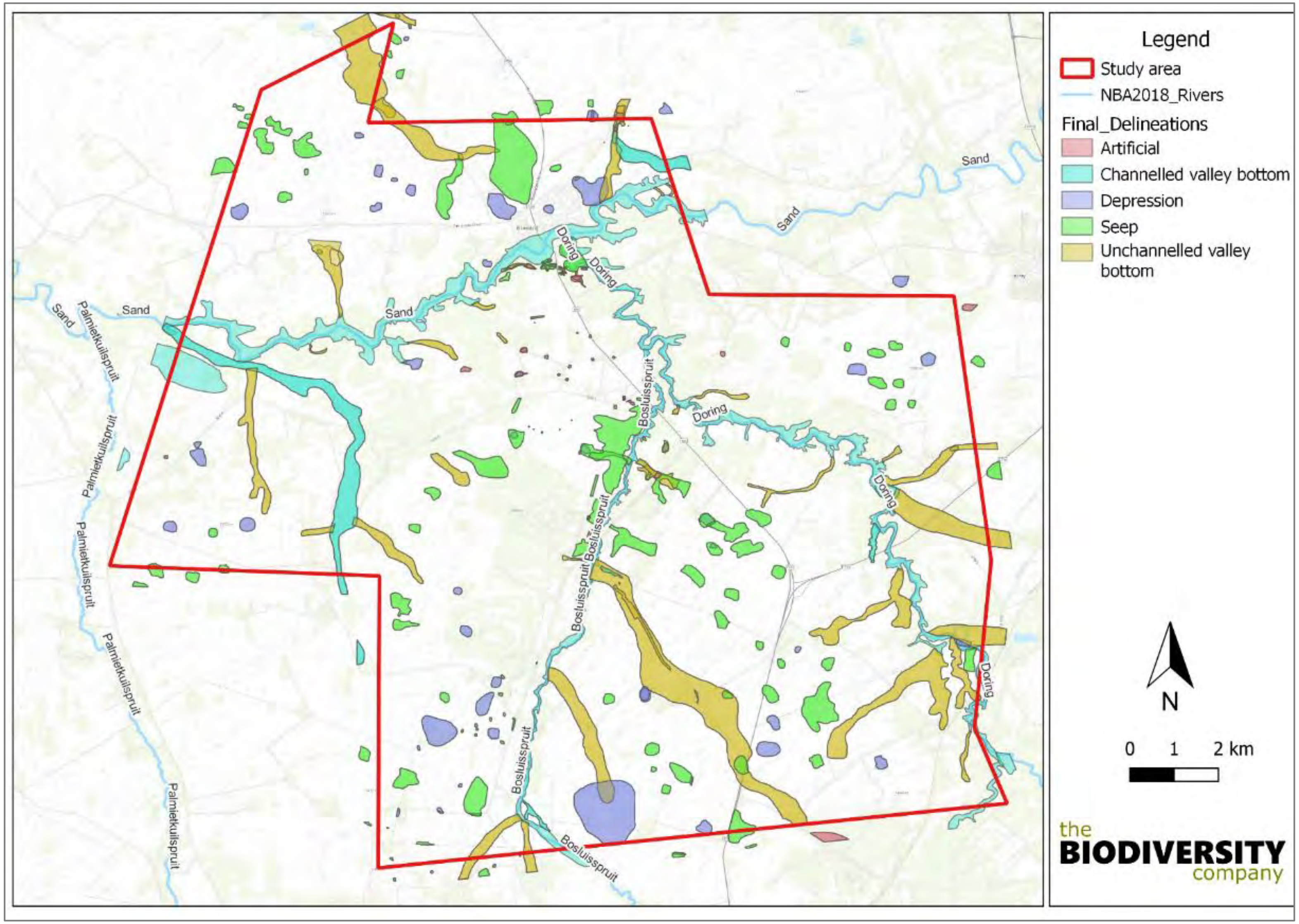

Figure 6-13 Tetra4 Cluster 2 project area and associated sensitive freshwater resources (TBC, 2022)

The overall Ecological Importance and Sensitivity (EIS) of the river reaches in this study were assessed according to Kleynhans (1999). The results of the EIS assessment are provided in the table below (Table 6-13). The results of the EIS assessment derived a moderate EIS for the river reaches assessed in this study from the Vaal WMA.

Table 6-13 Ecological Importance and Sensitivity Ratings for the Watercourses in the project area located Sand River and Doring River

Biological Determinants		
Determinant	Rating	Comment
Rare and endangered biota	3	More than one taxon rare or endangered at a local scale
Unique biota	2	The aquatic fauna are distributed widely throughout the Middle Vaal WMA
Intolerant biota	2	Source zone conditions make the presence of flowing water rare. Therefore, flow intolerant taxa make up only a small portion of the aquatic fauna
Species richness	2	On a local scale the species richness is moderate
Habitat Determinants		
Diversity of aquatic habitat	2	Impacted system, most of which are permanent impacts (erosion)
Refuge value of habitat types	2	Limited refuge areas
Sensitivity of habitat to flow modification	2	Moderate sensitivity to flow modifications
Sensitivity to flow related water quality changes	1	Low number of impoundments within the project area
Migration route corridor for instream and riparian biota	1	The watercourses are in the mid to upper reaches of the river systems
National parks and wilderness areas	0	No NFEPA listing and no nature reserves associated with the watercourses.
Mean	1.7	
EIS class	Moderate	

6.7.1 Buffer Requirements

The "Preliminary Guideline for the Determination of Buffer Zones for Rivers, Wetlands and Estuaries" (Macfarlane et al. 2014) was used to determine the appropriate buffer zone for the proposed activity. The buffer size for the delineated water resources has been calculated according to the various water resources, and are as follows:

- Riparian zones of lower foothill rivers – 50 m; and
- Wetlands, non-perennial systems and drainage lines – 35 m.

Buffers and sensitive receptors are presented in Figure 6-14 to Figure 6-17. Linear infrastructure includes pipelines and, river crossings, and non-linear infrastructure includes compressor stations that intersect with riparian zones and buffers. Alternatives have been provided and are illustrated in Figure 6-14 to Figure 6-17. The re-aligned compressor stations are preferred due to avoidance of sensitive areas. The allocated buffers consider the high erodibility of the soils within the catchment. Areas associated with the watercourses that are eroded should be avoided or stabilised to minimise additional channel and bank erosion and subsequent sedimentation to downstream systems.

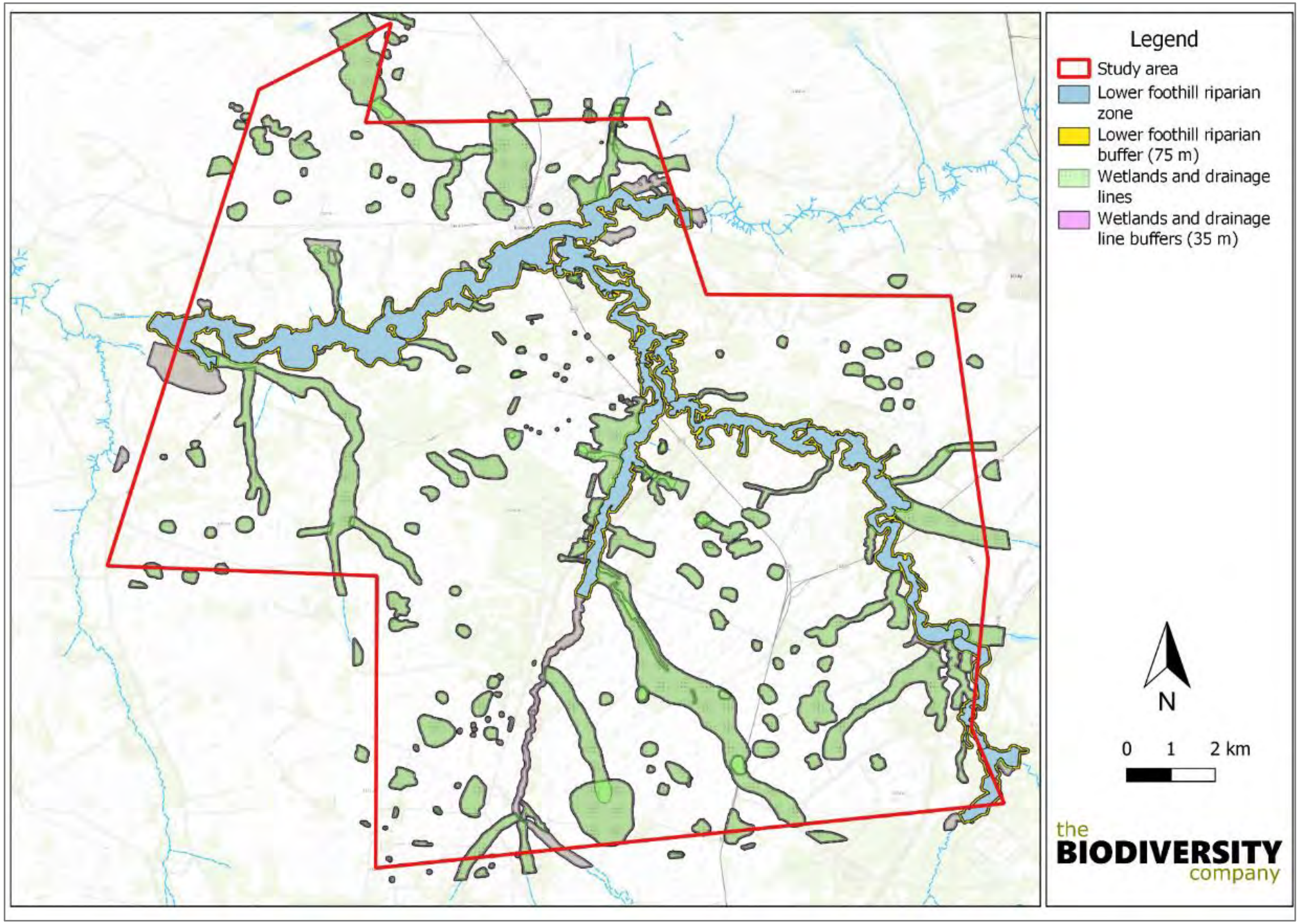

Figure 6-14 Sensitive freshwater resources and buffers

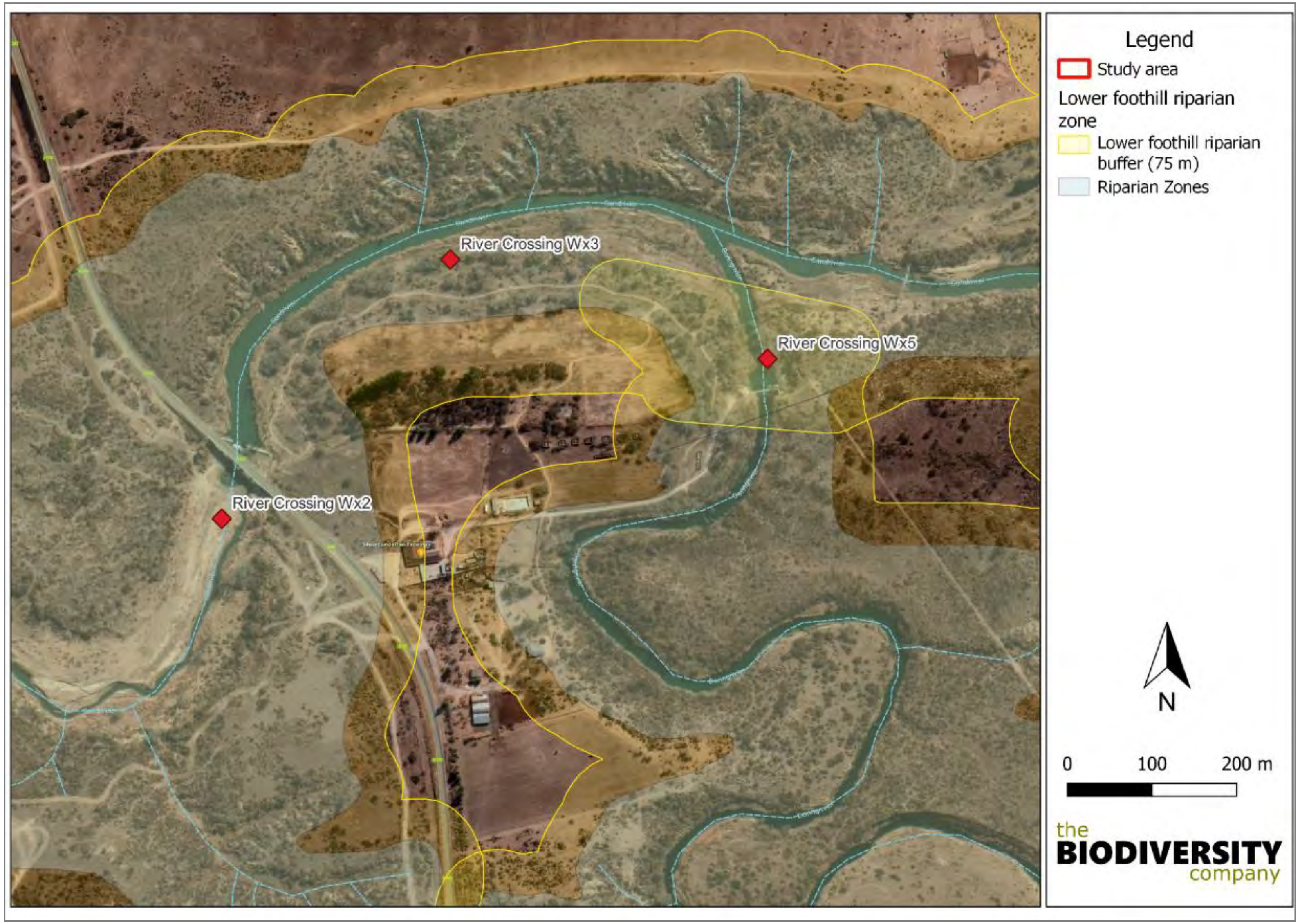

Figure 6-15 Sensitive freshwater resources and buffers and proposed Sand and Doring River crossings

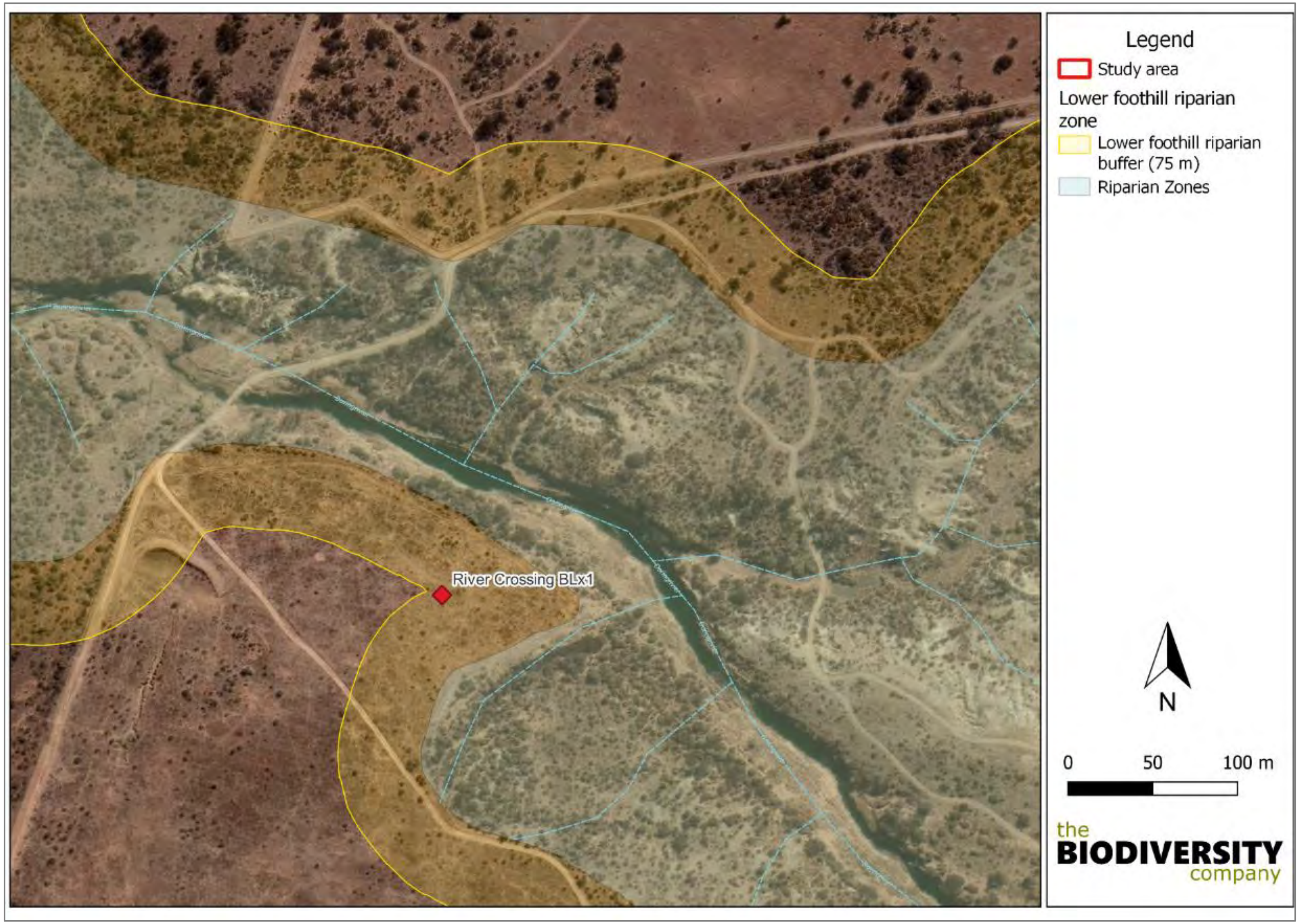

Figure 6-16 Sensitive freshwater resources and buffers and proposed Doring River crossing

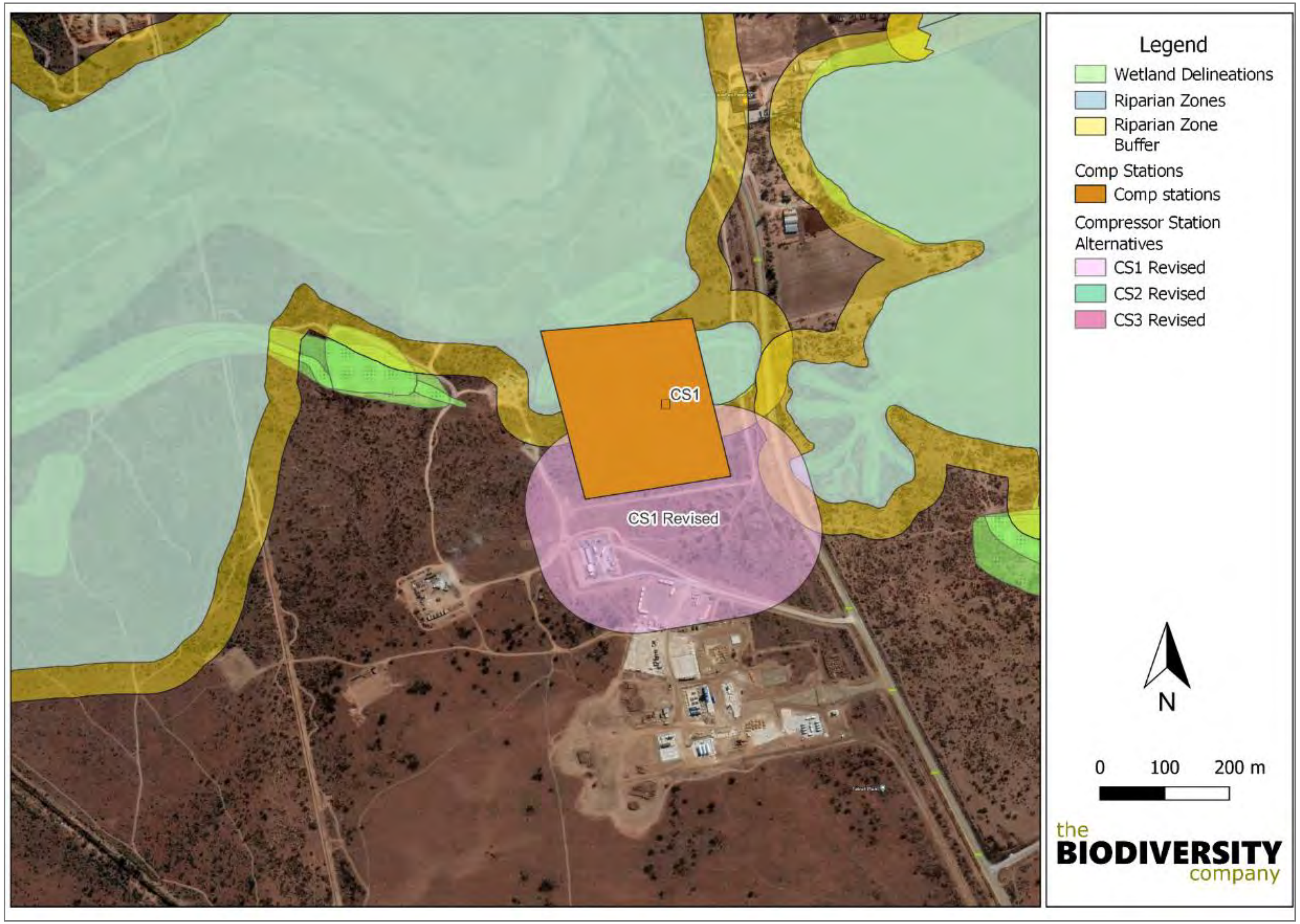

Figure 6-17 Illustration of proposed compressor station CS1 and CS1 Alternative within the water resource and buffer

7 Impact Assessment

The sections below serve to outline and summarise the types of perceived impacts from the proposed activities on the aquatic ecosystems, as well as responses to the concerns raised by stakeholders. The associated significance of each impact is evaluated as relevant to the local biodiversity and the likely project activities.

7.1 Anticipated Activities

It is evident from the figure that the following may have a negative effect on more sensitive water resources, most impacts involve the water resources and the habitats connected to these:

- Expansions to the current LNG and Helium production plant located on the Farm Mond van Doorn Rivier. The planned expansions will be to increase the helium and LNG production capacities significantly (~30 fold increase) and increase the footprint of the existing approved plant by approximately 10 ha;
- The drilling of new gas wells ~300 wells spread over a total study area (Cluster 2) of approximately ~27 500 ha;
- The installation of trenched pipelines connecting the wells to localised booster compressors and then to in-field compressor stations (~3 sites) and subsequently the compressor stations to the main plant area; and
- There will be a requirement to have short powerlines (132kV and 33kV) and water connections to the compressor sites."

7.2 Stakeholder Comments

Highlighted concerns/comments from stakeholders relevant are represented and discussed in Table 7-1 below.

Table 7-1 Stakeholder considerations relevant to the report

Comment	Tetra4 EIA formal response	Specialist Response
The impact of erosion, construction and operational phases. (Seen from cluster 1's 'rehabilitation')	The majority of erosion concerned have been on areas that has minimal or no vegetation, such as access road. Tetra4 has and implements and erosion and stormwater management plan to continuously monitor and address these areas of concern	Continuous monitoring is required to assess whether revegetation efforts are successful to reduce erosion, particularly prior to the wet season. Stormwater management plan needs to include energy dissipation measures to reduce the probability of erosion.
Alien and invader plant species, all phases. (Viewed from Cluster 1)	Tetra4 has and implement an alien and invasive plant species management plan and continuously monitors and applies control measures as required. It has been noted that the areas of most concern, is areas where the background site is already predominated by these species.	As indicated in the terrestrial study: Fourteen (14) IAP species listed under the Alien and Invasive Species List 2020, Government Gazette No. GN1003 as Category 1b were recorded within the project area. As per the Tetra4 response, due to the predominant land uses (agriculture), the AIP are numerous and have proliferated Due to this the infestation will require tedious and long during management and control. Any landowner is responsible for any Category 1b species within their 'property' and must be controlled by implementing an IAP Management Programme, in compliance of section 75 of the NEMBA

7.3 Review of Cluster 1 EIA and EMPr

Several impacts were identified for the aquatic ecology and wetland assessment completed by Imperata Consulting CC (2017), which were also considered for the Cluster 2 gas exploration project. The impacts and mitigation measures from Cluster 1 that are still relevant/adequate are represented and discussed in Table 7-2 below.

Table 7-2 Cluster 1 Environmental Impacts and EMPr

Ref #	Activities	Impact/ Aspect	Management/ Mitigation Measures	Planned Outcomes and/or Targets
1	All	Water quality baseline	The pre-production condition of the water resources must be utilised as the target for post-production closure objectives. All necessary measures must be taken to ensure that the post-production water quality as the same as pre-production baseline levels. In order to achieve this relevant water pre-construction water sampling must be undertaken to determine the baseline.	Reliable baseline data
2	All	Management of sensitive areas	Any drill sites or infrastructure routes located inside medium, high or very high sensitive sites on the sensitivity /constraint map require a site-specific pre-commencement assessment. The pre-commencement assessment must address the sensitive aspects on site, as identified in the overall sensitivity / constraint map. The pre-commencement assessment must be compiled by the site Environmental Officer (EO) with a suitable environmental qualification and experience. All recommendations of the pre-commencement assessment must be implemented on site. The completeness and adequacy of the pre-commencement assessment in respect of identifying and managing on site sensitivities must be included in the monthly ECO reports and annual independent audit. [Amendment 2019/05].	Avoidance and/or management / mitigation of sensitive environmental areas.
15	All	Loss of watercourse habitat	Locate pipeline/ trunkline alignments/ compressors outside of buffered watercourses (sensitive watercourse habitat) as far as possible. Buffered watercourses within proximity to the construction footprints should be demarcated on site for the entire construction process to help indicate sensitive areas and prevent unauthorized access. Unavoidable crossings should ideally be located perpendicular to the direction of flow at the shortest possible crossing distances. Long crossings along the length of wetlands, rivers and drainage lines should be avoided as far as practically possible. Aboveground pipeline watercourse crossings that are suspended on plinths are recommended as opposed to the excavation, lowering and infilling of pipelines in watercourses. Tetra4 should make provision in the design phase for permanent access tracks/ roads that will be required for the maintenance of the pipeline. A construction method statement should be prepared by the contractor with input from a watercourse specialists prior to the start of construction.	Avoid or minimise damage to watercourse habitats.
20	All	Disruption of watercourse hydrology	Pipeline crossings through wetlands and other watercourses should ideally be raised aboveground on plinths to prevent preferential flow along their length. In areas where this is not possible, trench breakers with a low hydrological conductivity should be used to reduce water movement in bedding and padding material along the buried pipeline in wetlands and other watercourses. Long and/or steep approaches that border watercourses (specifically wetlands) should receive trench breakers that will help to restrict the desiccation impact on wetlands due to preferential drainage. It is recommended that input be obtained from a geotechnical specialist or geohydrologist regarding the use and positioning of trench breakers along buried sections of the pipeline. Other crossings through depression (pan) and flat wetland require trench-breakers or other forms of underground barriers/plugs to prevent preferential drainage along the pipeline/trunkline alignment.	Ensure continued watercourse integrity and functionality.
21	Processing facilities	Decrease in surface water quality	Design and implement a site specific stormwater management plan for the compressor and helium/LNG plant that will enable dispersed release of runoff at outlets, with outlets located outside (upslope) of buffered watercourses (where possible). ensure separation of clean and dirty water and provide for adequate dirty water containment. Ensure that sufficient ablution facilities are available on site and that septic tanks are located outside of buffered watercourses. Stabilise new channels that form as a result of headcut erosion or other forms of erosion once they are recorded [Amendment 2019/05].	Minimise pollution and sedimentation of water resources and minimise and control erosion.
36	Exploration/ Production drilling	Water pollution and waste management	<u>To mitigate the effluent from long term drilling sites (>3 years)</u>: Separation pits (sumps) for wastewater and grease and oil polluted fluids should be excavated and constructed to treat wastewater; Where excavating these pits, topsoil and subsoil should be stored separately; Sump areas should be lined with PVC to prevent seepage; In order to contain non-biodegradable oil and fuel spills, drip pans or PVC lining should be provided for mobile pans and drip pans; For stationary drill rigs, thin concrete slabs and/or with PVC lining should be installed before the stationary drill rigs are erected; Sump	Control effluent and waste to minimise impact on environment.

			areas must be designed to accommodate the 1:100 year flood event. Clean and dirty water streams must be separated. Sump areas must be designed to accommodate the 1:100 year flood event. Clean and dirty water streams must be separated. The location and design of the sumps must be in accordance with the applicable GN 704 conditions [Amendment 2019/05]; and Sump areas should be constructed in such a way that clean water (stormwater) is diverted away from these areas. <u>To mitigate effluent from short term drillings sites (<3 years):</u> The topsoil layer of the surface area required for the drill should be excavated and stored according to accepted topsoil management practices; A contiguous impervious PVC layer (e.g. large silage sheets) is placed under the drill (within the excavated area) to collect any spills; Spills of hazardous substances should be collected and disposed of according to the approved EMPR requirements at a suitably licensed facility; Collected spills from the drill must not be allowed to contaminate the soils and/or the closed water system utilised for the drilling fluids; and It is recommended that where possible, closed, above ground tanks are utilised for future drilling as opposed to sumps/pits.	
37	Construction areas	Stormwater control and management	All clean water should be diverted away from the site. Minimize the area that is disturbed during production activities in order to minimize the potential stormwater disturbance and to reduce the sediment loads to receiving water courses. Adequate drainage and erosion protection in the form of cut-off berms or trenches should be provided where necessary.	Minimise pollution and sedimentation of water resources and minimise and control erosion.
48	All	Disruption of aquatic communities	Ideally, no vehicle access tracks/roads should transect through watercourses. Access tracks/roads should be designed in such a way to minimise overlap with watercourses. Use existing access roads/tracks as far as possible. Construction and unavoidable access tracks/roads through wetlands, rivers and other watercourses must provide habitat connectivity between upstream and downstream reaches (e.g. flume pipes and/or culverts) and to reduce the risk of scour erosion and channel incision within the watercourse. . No unauthorised driving should be allowed through watercourses. Driving can only occur on specially designed tracks/roads that minimised the risk of erosion and surface flow concentration. No perched flumes should be present in temporary construction running tracks and/or permanent access tracks. In the case of aboveground pipelines, the pipeline should not be located 'flush' along the surface profile of the watercourse with no gap between the natural ground level and the pipeline. Aboveground pipelines should rather be suspended on plinths of a sufficient height that will allow the free movement of indigenous fauna present within the study area, such as tortoises, as recorded in the Bosluisspruit channel near existing well SPG3.	Ensure continued aquatic habitat and community integrity.
49	All	Watercourse erosion	Prevent the use of only one or two flume pipes in access/running tracks located in watercourses, specifically unchannelled valley bottom wetland and seep wetlands where concentrated flows can result in headcut development and the formation of a channel. Surface flows should also be spread out in channelled watercourse crossings though the use of several flume pipes to prevent channel incision and scour erosion. Access tracks should be maintained during the entire construction process and removed once construction is completed. Flume pipes should be monitored and kept free of blockages. Construction in watercourses should ideally occur during the dry season. Any new erosion features identified should be stabilised during the construction process (soft interventions such as hay bales, rock packs, runoff control berms and 'bio-socks' are recommended). Erosion control features should be maintained. Keep vegetation clearing to a minimum on the adjacent slopes to prevent erosion on approaches bordering watercourses. Small temporary contour berms may be used to help control runoff on approaches should it be required. Drainage furrows that may be required to create dry working conditions should ideally be avoided as they can easily erode during high flow events. Development of a watercourse monitoring plan before the onset of the construction phase, and the development and implementation of a watercourse rehabilitation plan during the latter half of the construction phase to ensure the eroded wetlands and other watercourses are stabilised and rehabilitated. Dewatering discharges at construction sites should be done in a silt bay to prevent erosion and sedimentation in adjacent watercourses. Runoff from the construction footprint should be controlled on site to prevent concentrated point releases of water into downslope watercourses. Care needs to be taken not to initiate or aggravate erosion in watercourses.	Ensure continued watercourse services and functionality.

55	All	Increase sediment loads	Progressive rehabilitation of disturbed land should be carried out to minimize the amount of time that bare soils are exposed to the erosive effects of rain and subsequent runoff. Traffic and movement over stabilised areas should be controlled (minimised and kept to certain paths), and damage to stabilised areas should be repaired timeously and maintained. The total footprint area to be cleared for drilling should be kept to a minimum by demarcating the drilling areas and restricting removal of vegetation to these areas only.	Avoid sediment build-up from exposed soil. Ensure timely rehabilitation of disturbed areas.
56	Exploration/ Production drilling	Spillage of oils, fuel and chemicals	The placement of drip trays under the drilling rigs should be implemented and recorded to minimize the contamination of waste oil from the drilling rig. Drilling fluids should be biodegradable and should be kept in a lined mud pit or surface container. Proper rehabilitation and off site removal of excess fluids should take place. Oil recovered from the drilling rigs and any vehicle on site should be collected, stored and disposed of at licenced facilities or provided to accredited vendors for recycling.	Avoid, minimise and remediate pollution.
57	All	Increased soil erosion	Ensure that topsoil (0-30 cm approx.) and subsoil (30 cm +) are stored separately during excavation, so they can be replaced in the correct order. Ensure that pipeline route is re-vegetated as soon as possible after construction and that soil surface is in good condition.	Avoid, minimise, and remediate erosion.
59	All	Spill response and pollution clean-up	All necessary measures should be taken to prevent spills from occurring on site. However, should a spill occur, the following procedure must be followed: A spill response kit should be available on site at all times. Where potential contaminants are transported along access roads, emergency containment and mitigation measures must be developed to minimize impacts should accidental spills occur. Any spillage will be investigated and immediate action must be taken. In the event of a significant spill (>35 litres) of any hazardous substance, these must also be recorded and reported to the PASA, DWA (DWS) and the local/provincial authority where necessary. Depending on the nature and the extent of the spill, contaminated soil must be either excavated or treated on-site. The EO should determine the exact method of treatment. Clean up should be immediate and to the satisfaction of the EO. A register of the treatment method and clean up close out report must be kept and be made available reviewed by the ECO during independent audits [Amendment 2019/05]. Treatment could include the use of absorbent material or hydrocarbon-digesting substances. It is therefore, recommended that a spill kit and hydrocarbon digesting substance should be kept on site at all times. Clean up should be immediate and to the satisfaction of the ECO. Excavation of contaminated soil must involve careful removal of soil using appropriate tools/machinery to storage containers until treated or disposed of at a licensed hazardous landfill site. Materials used for the remediation of spills must be used according to product specification and guidance for use. A record of all spills and actions taken to remediate the spills should be kept at all times. Proper and frequent maintenance should be done to minimise spillage risk.	Avoid, minimise and remediate pollution.
64	All	Decrease in surface water quality in watercourses	Store all hazardous materials (Incl. hydrocarbons) in a bunded area, outside of buffered watercourses. Stripped and excavated subsoil and topsoil stockpiles should be stored outside of buffered wetland areas and be protected from erosion. This may not be possible for long wetland crossings in seep and other wetlands, in which case topsoil can be stored on low berms within the wetland on geotextile material. Topsoil and subsoil should however be protected from erosion. Approaches that border watercourses, particularly those along steep and long slopes, should receive runoff control measures to prevent siltation and concentrated flow into watercourses. Inspect vehicles for leaks and repair all leaks immediately. Any generators used in watercourses should be used with a functional drip tray. Ensure that sufficient ablution facilities are available on site and that they are located outside of buffered watercourses. Stabilise new channels that form as a result of headcut erosion or other forms of erosion once they are recorded. Sediment deposition should be prevented in watercourses and especially watercourse channels through the following measures: Implementing stormwater control measures around construction areas; and Dewatering during excavation activities in watercourses should be released in a silt bay with sufficient capacity that filters and retains sediment before the water is released into the watercourses. Sediment deposition events into watercourses should be evaluated by an experienced ECO/ wetland specialist and based on the magnitude of the impact recommendations can be made regarding the removal of deposited material.	Ensure continued watercourse services and functionality.

75	All	Watercourse erosion	Use existing access roads as far as possible. Unavoidable new permanent access roads/tracks in watercourses should be designed to prevent erosion downstream of the crossings by using several flume pipes, preferably culverts, or other structures, such as concrete fords. All temporary and permanent vehicle access tracks/roads in watercourses will require approval from DWS in the form of a Water Use License. New permanent access roads/tracks should be located along existing infrastructure footprints as far as possible and at areas that will enable the shortage crossing distance through watercourses. Long crossings along the length of watercourses (parallel to its flow direction) should be avoided. Remnant erosion features that remain after the rehabilitation phase should be addressed until full rehabilitation and closure is achieved. Rehabilitation interventions should be considered with care and not worsen erosion once implemented [Amendment 2019/05]. Identified permanent access tracks should be maintained during the entire operational phase of the project and blockages should be removed, while erosion features should be repaired once observed. Concrete fords (low water bridges) are preferred as crossing structures in larger watercourse channels, compared to culverts and flume pipes, which are more likely to result in erosion and require more regular maintenance. The Helium plant should receive stormwater mitigation measures at its outlets that will prevent concentrated flow. Stormwater mitigation measures and flow outlets should be located outside of buffered watercourses.	Ensure continued watercourse services and functionality.
77	Exploration/ Production drilling and Processing facilities	Pollution prevention and usage of water sources	All contaminated water and spillage will be drained from the containment area into primary and secondary fully lined sumps. Drilling water should be kept in closed circuit and re-circulated to the drilling machine. Water condensate from the gas polishing process (Dehydration) should be treated to remove volatile compounds, before evaporation. Make up water will be introduced when required. All domestic effluent water from the site should be collected and disposed of in an appropriate and legal manner such as a French drain system which is situated not closer than 100 metres from any streams, rivers, pans, dams or boreholes. Do not exceed the water abstraction permit and General Authorisation (GA) limits for water use for drilling activities. All LNG processing facilities and storage vessels must include adequate (at least 110% containment volume) secondary liquid containment areas (e.g. bunds). [Amendment 2019/05].	Minimise pollution of water resources. No wasting of water, usage to be within licensed thresholds.
93	All	Water abstraction	The necessary DWS permits should be obtained if it is expected that DWS abstraction limits will be triggered before water abstraction is undertaken. Obtain agreement from landowner to abstract water from existing boreholes. If required, abstraction of water should be kept within the permit limits as issued to the landowner by DWA. Water may only be obtained from approved sources. [Amendment 2019/05].	Legal Compliance
102	All	Loss of watercourse habitat/ Alterations of the river banks and river bed	Locate pipeline/trunkline alignments outside of buffered watercourses (sensitive watercourse habitat) as far as possible. Buffered watercourses should be demarcated on site for the entire construction process to help indicate sensitive areas and prevent unauthorised access. Mitigation for pipeline construction primarily includes the avoidance of watercourse crossings. Where crossings are unavoidable, crossings should be located along existing infrastructure features, such as roads, dam walls and existing pipelines. Unavoidable crossings should ideally be located perpendicular to the direction of flow at the shortest possible crossing distances. Long crossings along the length of wetlands, rivers and drainage lines should be avoided as far as practically possible. Horizontal directional drilling is recommended for the Sand River and Bosluisspruit crossings, as opposed to the clearing, temporary damming, excavation, lowering and infilling of pipelines in these river watercourses. Vegetation clearing, topsoil stripping, trenching and infilling to bury the pipeline, are considered to be an acceptable approach in other types of watercourse crossings. The construction servitude should however not remain bare (stripped for longer than a month at a time), while trenches should not remain open for more than five days. It is therefore recommended that the pipeline be completely constructed in sections, rather than removing all of the topsoil and creating open trenches across the entire study area for prolonged periods of time. The servitude width should be restricted in watercourse crossings to reduce the footprint of the impact. Topsoil material should only be stripped in the area where trench excavation is required, while the surrounding area in the servitude is only cleared of vegetation. Limited topsoil stripping is conditional on the prevention of soil compaction by heavy motorised vehicles (HMVs) through the use and maintenance of running tracks. Examples of running tracks include bogmats or rock aggregate combined with geotextile fabric and flume	Avoid or minimise damage to watercourse habitats.

			pipes. Alternatively topsoil across the entire width of the construction servitude (often referred to as the right of way) can be stripped and stored separately outside of buffered watercourses. Removed topsoil and subsoil should be sorted separately in stockpiles and protected from erosion when required. Additional erosion protection measures should be implemented for stockpiles that are to be stored for an extended duration [Amendment 2019/05].	
103	All	Loss of watercourse habitat/ Alterations of the river banks and river bed	A construction method statement should be prepared by the contractor prior to the start of construction. Conditions stated in the water use license should also be implemented. The use of old and new quarry sites for bedding and padding material, as well as other needs (e.g. the discard of spoil material) should not be located within wetlands and other watercourse types. Watercourse crossings and construction methods affecting watercourse must comply with the approved water use licence and associated DWS approved method statements [Amendment 2019/05]. The use of sites outside the study are will also be subject to environmental authorisation. Provision should be made in the design phase for permanent access tracks/roads that will be required for the maintenance of the pipeline. After completion of the construction phase, the reinstatement of the original topography of the watercourse (its geomorphological template) should be undertaken followed by re-vegetation activities. The following mitigation measures are recommended: Limit the construction activities to the smallest area possible; Reinstate the geomorphological template of the watercourse crossing using subsoil material, followed by topsoil material on top. This should be done as soon as possible after completion of construction activities; During the reinstatement of watercourse profiles to the pre-construction profile, entrenched gullies and channels may have to be cut back to create a lower gradient that will not be susceptible to erosion; Once the crossing has been shaped and topsoil reintroduced to stripped areas, biojute can be applied according to specification to avoid rill formation and undercutting below biojute material. During the start of the growing season the annual grass *Eragrostis tef* can be introduced through manual broadcasting on reinstated watercourse surfaces. Rehabilitated areas within watercourse boundaries must be protected from overgrazing. Protection methods must be identified in consultation with the respective landowners [Amendment 2019/05].	Avoid or minimise damage to watercourse habitats.
105	All	Contamination of alluvial and sand aquifers	Implement good housekeeping practices, regular inspections as well as sound environmental training. An emergency response protocol must be implemented at the operations that are aimed at early detection and swift reaction speed. Where possible and reasonable daily inspections (focused on detecting leaks and spills) of drilling pads, pipelines, compressors and the helium plant must be implemented. An on-site communication system must be put in place to ensure that instructions are given and carried out with efficiency. In the event of a spill occurring, a method statement must be completed that describes how, where and when clean-ups will be undertaken. The on-site communication system must make provision for continual review and improvement of spill management. The necessary equipment and personal protection equipment (PPE) must be kept on site to clean spills up and leaks. Tetra4 personnel must receive adequate training on the use of the equipment and the disposal of waste material generated during a spill. All such wastes must be treated as hazardous. The waste must be placed in a dedicated sealed container on site, which must be disposed of to a licensed facility. All on-site vehicle and equipment maintenance must be undertaken within an area of secondary containment, such as a bund or over a drip tray, to prevent accidental soil contamination. Oil and diesel stored on site must be placed within a suitably sized bund. The dispensing of hydrocarbons must be undertaken with due care to prevent or contain spills. All hazardous waste generated must be contained and stored in suitably sealed, bunded and protected areas to avoid spills and leaks. Waste must be collected and disposed of off site in a responsible manner so as to prevent groundwater contamination off site.	Avoid and control pollution of water resources.
108	All	Encroachment/ invasion of alien plants (specifically into watercourses)	Restrict the clearing of watercourse vegetation as far as possible. Areas that have been cleared should be re-vegetated with indigenous species or other suitable plant species, such as *Eragrostis tef*, after construction and initial rehabilitation work (reinstatement of the geomorphological template) is completed. Compile and implement an alien plant control program with a particular focus on alien control in watercourses (including wetlands) during the rehabilitation phase of the project. Rehabilitate disturbed areas as soon as possible. Restrict new footprints to disturbed areas as far as possible. Regular monitoring should be undertaken in the watercourses to check any possible invasion by alien vegetation so that they can be weeded out before they grow and spread out.	Avoid, minimise and remediate invasion by alien plants particularly in watercourses.

7.4 Riverine Impact Assessment

Infrastructure within the study area assigned to riverine systems include compressor stations, gas pipelines, well heads and a transmission loop. The compressor stations are located within water resources, however, alternative localities have been provided with are preferable as they avoid sensitive areas. Should the alternatives be considered and adequate mitigation measures be implemented, the potential impacts to the water resources are predominantly low. However, some indirect impacts can still affect the water resources. Linear infrastructure including pipelines are expected to traverse the water resources and avoidance is not possible. The linear structures (Pipeline and Transmission Loop) will be assessed as one and the compressor station and wells will be assessed as one.

Potential impacts to the water resources associated with the proposed activities include loss of riparian vegetation due to erosion or direct loss through clearing; water quality deterioration through contamination from waste water and waste materials, spills and leaks from heavy machinery, and sanitation facilities; instream habitat loss due to sedimentation from erosion of channel banks and terrestrial areas within the catchment; altered flow dynamics due to increased runoff from hardened surfaces; and subsequent impacts to environmental responders including disturbances to the biotic communities.

Risks expected for the construction activities are associated with vegetation and topsoil removal, which is attributed to the locality of the selected structures within the riparian zone and delineated wetlands. Additionally, waste management is considered due to the potential of spills and leaks of contaminated water and sludge. As the infrastructure is linear, the watercourses cannot be avoided and therefore mitigation measures to reduce the risks to the watercourse should be prioritised. Alternatives to the river crossings type include Open Trenches or Horizontal Directional Drilling (HDD), however, due to the sensitivity of the watercourses, HDD is the preferred crossing methodology. Well placements fall outside of the water resources and respective buffers.

The additional impacts associated with the proposed activities, which weren't considered covered in the existing approved Cluster 1 EIA and EMPr, are considered in this section. No 'new' impacts are expected for the Cluster 2 gas exploration project, except for the powerlines (132kVand 33kV) (Figure 7-1).

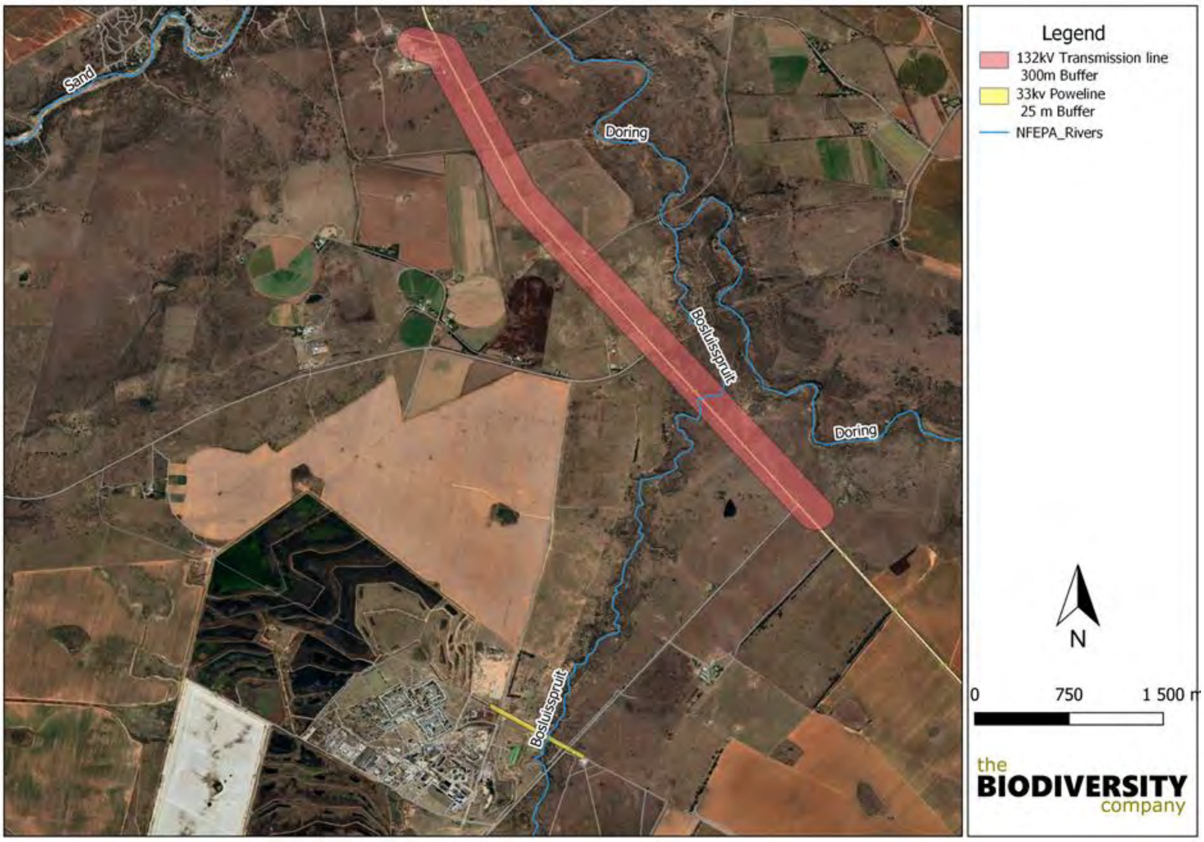

Figure 7-1 Proposed 33kVand 132kVPowerlines

The proposed powerline construction is regarded as low risk to the water resources should construction occur outside of the delineated areas as the footprint area is limited to the pylon base. However, the increase in traffic along the servitude is likely to increase erosion of channels and banks along drainage lines, larger riverine systems and wetland areas. Existing powerlines are currently in place on the proposed route and span across watercourses. Should pylon placement be within the riparian areas impacts would be considered moderate. The powerlines pose low risks to the watercourse during the operational phase should the pylons be constructed outside of the delineated water resources.

For the proposed powerline crossing points, mitigation measures are largely associated with avoiding the delineated watercourse areas and implementing recommended buffer zones, therefore the anticipated impacts and mitigation measures for the two powerlines are expected to be similar. Impacts are associated with the construction of pylons. The impact table for the 33kVpowerline construction is presented in Table 7-3 and for the 132kVin Table 7-4. The impact table for the powerline construction is presented in Table 7-4.

Table 7-3 Impact assessment for the proposed 33kVpowerline

Impact	Phase	Pre-mitigation ER	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Final score
Powerlines - Habitat	Construction	-5.5	-3	High	1	1	-3
Powerlines - Water Quality	Construction	-2	-1.25	High	1	1	-1
Powerlines - Flow	Construction	-2.5	-1.25	High	1	1	-1

Powerlines - Habitat	Operation	-5	-3.5	High	1	1	-4
Powerlines - Water Quality	Operation	-1	-1	High	1	1	-1
Powerlines - Flow	Operation	-1	-1.25	High	1	1	-1
Powerlines - Habitat	Decommissioning	-5	-3	High	1	1	-3
Powerlines - Water Quality	Decommissioning	-2	-1.25	High	1	1	-1
Powerlines - Flow	Decommissioning	-2.5	-1.25	High	1	1	-1

Table 7-4 Impact assessment for the proposed 132kVpowerline

Impact	Phase	Pre-mitigation ER	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Final score
Powerlines - Habitat	Construction	-5.5	-3	High	1	1	-3
Powerlines - Water Quality	Construction	-2	-1.25	High	1	1	-1
Powerlines - Flow	Construction	-2.5	-1.25	High	1	1	-1
Powerlines - Habitat	Operation	-5	-3.5	High	1	1	-4
Powerlines - Water Quality	Operation	-1	-1	High	1	1	-1
Powerlines - Flow	Operation	-1	-1.25	High	1	1	-1
Powerlines - Habitat	Decommissioning	-5	-3	High	1	1	-3
Powerlines - Water Quality	Decommissioning	-2	-1.25	High	1	1	-1
Powerlines - Flow	Decommissioning	-2.5	-1.25	High	1	1	-1

7.4.1 Mitigation Measures

The following mitigation measures are applicable for the powerline:

- Keep the number of towers in the wetland to a feasible minimum. The placement of towers in the assigned buffer (of 35 m) is preferred to minimise the number of towers placed within the wetland;
- Construction activities should be scheduled for the least sensitive periods, in order to avoid the migration, nesting and breeding seasons of SCC as far as practical;
- Locate powerline alignment outside of buffered watercourses (sensitive watercourse habitat) as far as possible;
- Buffered watercourses should be demarcated on site for the entire construction process to help indicate sensitive areas and prevent unauthorised access;
- The route should be located along existing infrastructure features, such as roads, dam walls and existing pipelines. Unavoidable crossings should ideally be located perpendicular to the direction of flow at the shortest possible crossing distances;
- The servitude width should be restricted in watercourse crossings to reduce the footprint of the impact;
- A construction method statement should be prepared by the contractor with input from a watercourse specialists prior to the start of construction. Conditions stated in the water use license should also be implemented; and
- Make provision in the design phase for permanent access tracks/roads that will be required for the maintenance of the powerline.

7.4.2 No-Go and Cumulative Impacts

The impacts of projects are often assessed by comparing the post-project situation to a pre-existing baseline. Where projects can be considered in isolation this provides a good method of assessing a project's impact. However, in areas where baselines have already been affected, or where future development will continue to add to the impacts in an area or region, it is appropriate to consider the cumulative effects of development. This is similar to the concept of shifting baselines, which describes how the environmental baseline at a point in time may represent a significant change from the original state of the system. This section describes the potential impacts of the project that are cumulative for the aquatic resources.

The area within the project area has previously and presently been impacted directly due to agricultural and mining activities, and urban runoff from Virginia. The activities have resulted in water quality perturbations and direct modifications to riverine habitats. The modifications have resulted in the Sand River being classed as moderately modified, and the Doring and Boschluispruit as largely modified.

Due to the nature of the proposed activities, particularly construction activities adjacent or within the delineated riparian zone and its buffers, and the pipeline crossings through the Sand and Doring Rivers, the cumulative impact of the project to habitat integrity was rated as moderate should the project go ahead due to the sensitivity of soils to erosion and locality of activities to the various affected water resources (Table 7-5).

Minor cumulative impacts are expected to water quality deterioration should the proposed activities proceed (Table 7-6). The proposed activities should contribute significant potential contaminants to the water resources should adequate mitigation measures be implemented and correct handling, storage and disposal of any solid or liquid waste/hazardous materials.

Table 7-5 Cumulative Impacts to habitat integrity of the project area

Nature of the impact: Habitat Quality Deterioration within the project area		
	Cumulative impact should the project not go ahead	Cumulative impacts should the project go ahead
Extent	Regional	Regional
Duration	Long term	Life of project
Magnitude	Medium	Medium
Probability	Definite	Definite
Calculated Significance Rating	Minor / Moderate	Moderate
Impact Status:	Negative	Negative/Positive
Reversibility:	Reversible	Reversible
Irreplaceable loss of resources:	No	Potentially
Can impacts be enhanced:	Yes	Yes

Table 7-6 Cumulative Impact to water quality within the project area

Nature of the impact: Water Quality Deterioration within the project area		
	Cumulative impact should the project not go ahead	Cumulative impacts should the project go ahead
Extent	Regional	Regional
Duration	Long term	Life of project
Magnitude	Medium	Minor
Probability	Definite	Possible
Calculated Significance Rating	Minor / Moderate	Minor
Impact Status:	Negative	Negative
Reversibility:	Reversible	Reversible
Irreplaceable loss of resources:	No	No
Can impacts be enhanced:	Yes	Yes

7.5 Recommendations

The following recommendations are provided for the project:

- No mitigation measures have been prescribed for the decommissioning phase of the project. It is recommended that the closure plan and objective be reviewed, and appropriate measures be included for the local water resources;
- Implement the “Working in Sensitive Areas” (document number T4-PP-SHERQ-051) detailed in the operating procedures document;
- Implement the “Erosion Control and Storm Water Management” (document number T4-PP-SHERQ-043) detailed in the operating procedures document;
- Once the pipeline has been installed, the disturbed area must be cleaned up in accordance with the Environmental Management Plan, and in accordance to the Tetra4 Rehabilitation Plan and Procedure; and
- All activities related to these works shall comply with all applicable Environmental Laws, Tetra4’s approved Environmental Management Programme (EMPR) and Tetra4’s Environmental Procedures when undertaking any works.

7.6 Monitoring programme

Based on the outcomes of this assessment, the further actions are recommended. The monitoring programme proposed is presented in Table 7-7.

Table 7-7 Proposed monitoring activities

Location	Monitoring objectives	Frequency of monitoring	Parameters to be monitored
Current sites used in this assessment and additional up and downstream monitoring points	Overall PES	Bi-annual	Standard River Ecosystem Monitoring Programme (Ecostatus) methods
Current sites used in this assessment and additional up and downstream monitoring points	Determine if water quality deterioration is occurring.	Bi-annual	SASS5 scores should not decrease as and be related to mining activities.
Site used in this assessment and the surface water assessment	Determine if water quality deterioration is occurring.	Monthly	Standard water quality monitoring, as per the surface water specialist report.
Current sites used in this assessment and additional up and downstream monitoring points	Determine if water/habitat quality deterioration is occurring.	Bi-annual	Monitor for presence of fish.

Based on the outcomes of this study, further actions are recommended:

- Annual auditing of the recommended mitigation actions for the project infrastructure must be conducted;
- Following completion of the construction activities, an audit should be completed to assess whether there will be requirements for the installation of sediment traps or other alterations to the stormwater drainage of the infrastructure footprint areas;
- An annual alien invasive vegetation assessment must be conducted in accordance with the floral component of this overall application;
- Bio-Monitoring:
    - Bi-annual aquatic biomonitoring must be conducted once during the construction phase and once following the completion of the construction phase; and
    - Riverine aquatic biomonitoring along with the implementation of the Rapid Habitat Assessment Method must be completed on a bi-annual basis during the operational phase. The aim of the study will be to assess and monitor the long terms trends and implications of the potential dewatering and water quality deterioration.

The further assessment of *L. kimberleyensis* within the study area is recommended. Should the species be present a management plan should be derived. It is noted that the mitigation actions provided in this assessment must make use of the proposed mitigation actions as an Environmental Management Plan. The outcome based management plan for riverine resources is presented in Table 7-8.

Table 7-8 Outcome Based Management Plan

Outcome	Action	Timeframe
Limit riverine habitat degradation	Implement buffer and no-go areas;	Project lifespan
	Implement stormwater management plan	Project lifespan
	Implement mitigation actions to reduce dewatering/provide ecological reserve	Project lifespan
	Implement erosion control measures such as energy dissipation	Project lifespan
	Implement alien invasive plan removal and monitoring programme	Project lifespan
	Revegetate disturbed areas	Construction and Decommissioning
Limit water quality degradation	Implement buffer and no-go areas;	Project lifespan
	Implement stormwater management plan	Project lifespan
	Implement erosion control measures such as energy dissipation	Project lifespan
	Revegetate disturbed areas	Project lifespan
	Implement alien invasive plan removal and monitoring programme	Project lifespan
	Implement stockpile and waste management strategies whereby exposure to direct runoff can be reduced	Project lifespan
	Implement water treatment for mine water decant	Decommissioning and closure
Effective Water Resource Management	Implement water quality and aquatic biomonitoring studies	Project lifespan

8 Conclusion

The baseline assessment established three main watercourses within the project area, namely the Sand River, Doring River, and Boschluispruit, and a single system outside the project boundary, the Palmietkuilspruit. Additionally, numerous ephemeral systems and wetlands occur throughout the project area. The ecological assessment of the watercourses indicated moderate to large modifications attributed to varying land use, namely agriculture, mining, and urban activities upstream of the project area on the Sand River (Virginia). The land use activities have cumulatively resulted in a moderate deterioration in water quality, flow, and instream habitat, and subsequently to the biotic communities within the systems. Despite modifications, the Sand River met the Resource Quality Objectives for the reach, and all the water resources associated with the project area are considered sensitive. Given the findings of this assessment, no pristine or natural waterbodies were observed or expected in any of the project right areas, with the Doring River being classed as largely modified (class D), the Boschluispruit as largely modified (class D), and the Sand River as moderately modified (class C).

The upper reaches of the Boschluispruit and several tributaries within the project area are characteristic of wetland systems, and riparian zones and buffers were applied according to the wetland report (TBC, 2022). The Sand, Doring and lower reaches of the Boschluispruit presented well defined riparian zones consisting of woody vegetation. The soils along the watercourses are highly susceptible to erosion and considered sensitive to any potential anthropogenic activities along these systems which could potentially compromise the ecological integrity of the watercourses.

The water resources are poorly protected, and the ecosystems are critically endangered. Additionally, no Freshwater Priority Areas are assigned to them. *Labeobarbus kimberleyensis* (Largemouth Yellowfish) is expected within the Sand River and is the only species of conservational concern within the catchment and red listed as Near Threatened due to habitat fragmentation and water quality deterioration. The species was not collected during the survey, however, despite the absence of the species during the survey, the precautionary approach would assume the species to be within the project area and would likely be collected with increased sampling effort. The poorly protected nature of the systems indicates that strict mitigation measures should be adhered to ensure no further deterioration of the watercourses should the project proceed.

The buffers determined for the lower foothill systems was calculated at 50 m, and for the ephemeral systems, drainage lines and wetlands a buffer of 35 m.

The impact assessment considered both direct and indirect impacts, to the water resources. According to the layout provided and the delineated riparian zones and applicable buffers, the compression station, and pipeline crossings intersect with the water resources. Considering the pipelines are linear infrastructure, avoidance of the watercourses is not possible, strict mitigation implementation is required to ensure the minimisation of erosion and additional deterioration of the water resources are negated. The locality of compressor station CS1 falls within the riparian zone and buffer of the Sand River. This poses a moderate risk to the watercourse and alternative sites should be selected as erosion of the banks is likely. The position of compressor stations CS2 and CS3 are located within delineated wetlands and are addressed in the wetland specialist assessment.

Risks associated with the proposed infrastructure range from low to moderate, with the majority of moderate risks being reduced to low with the implementation of adequate mitigation measures, however, activities within the buffers and water resources remain moderate.

8.1 Specialist Recommendation

It is the specialist's opinion that no fatal flaws have been identified for the proposed activities, The alternative positioning of the compressor stations are preferred due to the avoidance of water resource sensitive areas. The soils within the catchment are prone to erosion and care is required to ensure proposed activities do not exacerbate erosion within the catchment. Monitoring of the aquatic resources is required during construction and operational activities.

A competent Environmental Control Officer (ECO) must oversee the construction activities and associated concurrent rehabilitation measures undertaken, with watercourse areas as a priority. Two follow up ECO assessments/audits must be carried out in the first and sixth months of operation. The ECO must be supplied with a copy of this and the other specialists reports and must be familiar with the mitigation and recommendations prior to construction.

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10 Appendix A Specialist Declaration

Climate Change Assessment Report for Cluster 2 of the Gas Gathering Project in Virginia, South Africa

Project done on behalf of EIMS (Pty) Ltd

Report Compiled by:
H Liebenberg-Enslin
R Bornman
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Report No: 22EIM03 | Date: October 2022

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Report Details

Project Name	Climate Change Assessment Report for Phase 2 of the Gas Gathering Project in Virginia, South Africa
Client	Environmental Impact Management Services (EIMS) (Pty) Ltd
Report Number	23EIM03
Report Version	Final Rev 3
Prepared by	Hanlie Liebenberg-Enslin, PhD (University of Johannesburg) Rochelle Bornman, MPhil. GIS and Remote Sensing (University of Cambridge) Gillian Petzer, (Pr. Eng.), BEng Chemical (University of Pretoria)
Reviewed by	Terri Bird (Pr. Sci. Nat.), PhD (University of Witwatersrand) Hanlie Liebenberg-Enslin, PhD (University of Johannesburg)
Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in air quality and environmental noise impact assessments. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
Declaration	I, Hanlie Liebenberg-Enslin, as authorised representative of Airshed Planning Professionals (Pty) Ltd, hereby confirm my independence as a specialist and declare that neither I nor Airshed Planning Professionals (Pty) Ltd have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of which Airshed Planning Professionals (Pty) Ltd was appointed as air quality specialists in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998); other than fair remuneration for worked performed, specifically in connection with the assessment summarised in this report. I also declare that I have expertise in undertaking the specialist work as required, possessing working knowledge of the acts, regulations and guidelines relating to the application. I further declare that I am able to perform the work relating to the application in an objective manner, even if this result in views and findings that is not favourable to the application; and that I am confident in the results of the studies undertaken and conclusions drawn as a result of it – as is described in this report.
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Revision Record

Revision Number	Date	Reason for Revision
Draft Rev 0	13 July 2022	For client review
Final Rev 1	18 July 2022	Addressed client comments
Final Rev 2	25 October 2022	Included Scope 3 GHG emissions
Final Rev 3	27 October 2022	Addressed client comments

Competency Profiles

Report author and Project Manager: H Liebenberg-Enslin, PhD Geography (University of Johannesburg).
After earning her master's degree in science from the University of Johannesburg (formerly RAU) in Geography and Environmental Management. Hanlie Liebenberg-Enslin began her professional career in air quality management in 2000 when she joined Environmental Management Services (EMS). The same department at the University of Johannesburg awarded her a PhD in June 2014 with a focus on aeolian dust transport. She is one of the founding members of Airshed Planning Professionals and served as a director of the organization until May 2013, when she assumed the role of managing director.

She has worked across Africa and has considerable experience in the many aspects of air quality management, including impact- and health risk screening assessments, dispersion modelling simulations, and emissions quantification for a variety of source types. Hanlie has been involved in a few United Nations Environmental Programme (UNEP) projects and served as the project manager on numerous innovative air quality management plan (AQMP) developments. She also participates actively in the National Association for Clean Air (NACA) and the International Union of Air Pollution Prevention and Environmental Protection Associations (IUAPPA). She served as an external examiner for various MSc and PhD dissertations and lectured at air quality management courses.

Report author: R Bornman (M.Phil in GIS and Remote Sensing, University of Cambridge)
Rochelle Bornman started her professional career in Air Quality in 2008 when she joined Airshed Planning Professionals (Pty) Ltd after having worked in malaria research at the Medical Research Council in Durban. Rochelle has worked on several air quality specialist studies between 2008 and 2022. She has experience on the various components including emissions quantification for a range of source types, simulations using a range of dispersion models, impacts assessment and health risk screening assessments. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to air quality. Whilst most of his working experience has been in South Africa, a number of investigations were made in countries elsewhere, including Mozambique, Namibia, Saudi Arabia and Mali.

Report author: Gillian Petzer, (Pr. Eng.), BEng Chemical (University of Pretoria)
Gillian has been with Airshed since 2003. She holds a bachelor's degree in chemical engineering from the University of Pretoria. Her experience in air quality started in 2000 with the "Indoor Air Quality" division of Building Research Establishment (BRE) in the UK. Over the last two decades she has been actively involved in the development of atmospheric dispersion modelling and its applications, air pollution compliance assessments, health risk assessments, mitigation measures, development of air quality management plans, as well as meteorological and air quality monitoring programmes. She registered as a professional engineer in 2017. Whilst most of her working experience has been in South Africa, a number of investigations were made in countries throughput Africa as well as recent countries such as Afghanistan and Armenia.

Report reviewer: Dr Theresa (Terri) Bird, Pr. Sci. Nat., PhD (University of the Witwatersrand)
Dr Terri Bird holds a PhD from the School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, Johannesburg. The focus of her doctoral research was on the impact of sulfur and nitrogen deposition on the soil and waters of the Mpumalanga Highveld. Since March 2012 she has been employed at Airshed Planning Professionals (Pty) Ltd. In this time, she has been involved in air quality impact assessments for various mining operations (including coal, mineral sand, diamond and platinum mines) as well as coal-fired power station ash disposal facilities. She has been a team member on the development of Air Quality Management Plans, both provincial and for specific industries. Recent projects include assessing the impact of Postponement and/or Exemption of Emission Standards for various Listed Activities.

Executive Summary

Tetra4 wishes to expand the natural gas operations within the approved production right area and around the Cluster 1 project. This planned expansion to the existing approved production activities will involve up to 300 new production wells, gas transmission pipelines and associated infrastructure, three (3) compressor stations and an additional new combined Liquid Natural Gas (LNG) and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure.

A Climate Change Assessment (CCA) was conducted to determine the potential long term climate change impacts as a result of the Tetra4 Cluster 2 operations. Greenhouse gas (GHG) emissions for the project were calculated based on the Department of Forestry, Fisheries and Environment (DFFE) 2022 Methodological guidelines for quantification of GHG emissions which are based on the Intergovernmental Panel on Climate Change (IPCC) emission factors. This study considered Scope1, Scope 2 and Scope 3 emissions, where Scope 1 are the emissions directly attributable to the project and Scope 2 emissions are the emissions associated with bought-in electricity. Scope 3 emissions consider the "embedded" carbon in bought-in materials and transport as well as the use of exported materials. Only Scope 1 emissions need to be quantified to be in line with the DFFE guidelines; the addition of Scope 2 would place the assessment in line with the guidelines provided by the International Finance Corporation (IFC).

The conclusions and recommendations of the assessment are summarised below:

- The region around Welkom and Virginia where Tetra4 Cluster 2 project is proposed to be developed is likely to experience increased temperatures and extreme weather-related events in the future. Climate change impacts will disproportionately affect under-developed communities that lack the physical and financial resources to cope with the physical effects of climate change, such as droughts, floods and increases in diseases.
- Scope- 1, 2 and 3 emissions were estimated based on emission factors and expected production rates or raw material use. The main construction activities attributing to GHG emissions are well drilling, well testing and well servicing followed by off-road mobile equipment. During operations, the electricity bought from ESKOM (Scope 2) is the main source, followed by road transportation and gas process venting (Scope 1). The main source of Scope 3 GHG emissions would be the end use of the LNG, but as LNG will be replacing other fuels already in use, it will result in a reduction of 14.6% in indirect GHG emissions.
- Construction- and operational-related GHG emissions from the proposed Tetra4 Cluster 2 project cannot be attributed directly to any particular climate change effects, and, when considered in isolation, will have a Low to Medium impact on the National GHG inventory total. The main GHG impact is associated with downstream use of the LNG, i.e. Scope 3. GHG emissions per unit of gas combusted, however, is less than per unit coal.
- Since climate change is a global challenge, there is a collective responsibility to address climate change and Tetra4 has an individual responsibility to minimise its own negative contribution to the issue. It is recommended that renewable energy (such as photovoltaic solar panels) be considered to replace/ reduce the reliance on ESKOM electricity which is likely to reduce the significance from the Tetra4 Cluster 2 project from Medium to Low, since ESKOM's contribution to the operational phase is the main source of GHG emissions. Also, the use of LNG instead of diesel will reduce the GHG footprint further. Maintenance of vehicles and machinery, the implementation of a leak-detection program, and the minimisation of flaring and venting would reduce the potential for GHG emissions.
- Once operational, it is recommended records be kept of actual fuel usage for transport of materials and products, energy requirements, production rates, flare and venting rates and raw material consumption for GHG reporting purposes and refinement of the emissions inventory.

Based on Tetra4 Cluster 2 Scope 1, 2 and 3 GHG emissions, it is the specialist opinion that the project may be authorised due to its low to medium impact significance.

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Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
AR5	IPCC Fifth Assessment Report
CCRA	Climate Change Reference Atlas
CCS	Carbon Capture and Sequestration (or Carbon Capture and Storage)
COP	Conference of the Parties
DEA	Department of Environmental Affairs (now DEFF)
DEFRA	United Kingdom's Department of Environment, Food and Rural Affairs
DFFE	Department of Forestry, Fisheries and Environment (previously DEA)
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
ETF	Enhanced transparency framework
FOLU	Forestry and Other Land Use
GCMs	Global Climate Change Models
GHGIP	National Greenhouse Gas Improvement Programme
GWP	Global Warming Potential
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
IPPU	Industrial Processes and Other Product Use
IRP	Integrated Resource Plan
LT-LEDS	Long-term low greenhouse gas emission development strategies
NAEIS	National Atmospheric Emissions Inventory System
NCCRP	National Climate Change Response Plan
NDC	Nationally Determined Contribution
NDCR	National Dust Control Regulations
NEMAQA	National Environmental Management Air Quality Act
PPP	Pollution Prevention Plan
RCPs	Representative Concentration Pathways
SAAELIP	South African Atmospheric Emission Licencing and Inventory Portal
SAAQIS	South African
SAGERS	South African Greenhouse Gas Emission Reporting System
SAWS	South African Weather Services
UNFCCC	United Nations Framework Convention on Climate Change

Symbols and Units

°C	Degree Celsius
C_6H_6	Benzene
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent
ha	Hectare
HFC	Hydrofluorocarbons
kg	Kilograms
1 kilogram	1 000 grams
km	Kilometre
m	Metres
mm	Millimetres
mamsl	Metres above mean sea level
m/s	Metres per second
mm	Millimetres
NO	Nitrogen oxide
N_2O	Nitrous oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
O_3	Ozone
Pb	Lead
PFC	Perfluorocarbons
$PM_{2.5}$	Inhalable particulate matter (aerodynamic diameter less than 2.5 µm)
PM_{10}	Thoracic particulate matter (aerodynamic diameter less than 10 µm)
SF6	Sulfur hexafluoride
SO_2	Sulfur dioxide (1)
tpa	Tonnes per annum
1 ton	1 000 000 grams

Notes:

The spelling of "sulfur" has been standardised to the American spelling throughout the report. The International Union of Pure and Applied Chemistry, the international professional organisation of chemists that operates under the umbrella of UNESCO, published, in 1990, a list of standard names for all chemical elements. It was decided that element 16 should be spelled "sulfur". This compromise was to ensure that in future searchable data bases would not be complicated by spelling variants. (IUPAC. Compendium of Chemical Terminology, 2nd ed. (the "Gold Book"). Compiled by A. D. McNaught and A. Wilkinson. Blackwell Scientific Publications, Oxford (1997). XML on-line corrected version: http://goldbook.iupac.org (2006) created by M. Nic, J. Jirat, B. Kosata; updates compiled by A. Jenkins. ISBN 0-9678550-9-8.doi: 10.1351/goldbook)"

1 INTRODUCTION

Tetra4 holds the first and only onshore petroleum production right in South Africa, making Tetra4 the front runner in domestic natural gas distribution. A Production Right (Ref: 12/4/1/07/2/2) was granted in 2012, spanning approximately 187 000 hectares (ha) for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within this approval, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1). Activities within the Production Right areas include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500 km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original Environmental Impact Assessment (EIA) and approved EMPr).

An integrated environmental authorisation (EA) for the first phase gas field production referred to as Cluster 1, in terms of the National Environmental Management Act (NEMA), was issued on 21 September 2017 by the Department of Mineral Resources and Energy (DMRE) to Tetra4 ("Cluster 1 EA", reference: 12/04/07) and amended on 26 August 2019 and 1 September 2020. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and Liquid Natural Gas (LNG) Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Tetra4 now plans to expand the natural gas operations (referred to as Cluster 2) to be located within the approved production right area and around the Cluster 1 project (Figure 2). This planned expansion to the existing approved production activities will include:

- Drilling and establishment of further production wells (up to 300 new production wells);
- Installation of gas transmission pipelines and associated infrastructure;
- Installation of three (3) compressor stations;
- An additional new combined LNG and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure, and
- Establishment of powerlines as part of the Cluster 2 expansion of the Project in order to meet the future production requirements.

Airshed Planning Professionals (Pty) Ltd (Airshed) was appointed by Environmental Impact Management Services (EIMS) (Pty) Ltd to conduct a Climate Change Assessment (CCA) for the project. The main objective is to quantify the greenhouse gasses (GHG) associated with the project and the potential long term climate change impacts as a result.

1.1 Study Objective

The main objective of the CCA is to quantify the greenhouse gasses (GHG) associated with the project and to determine the significance of potential climate change impacts as a result.

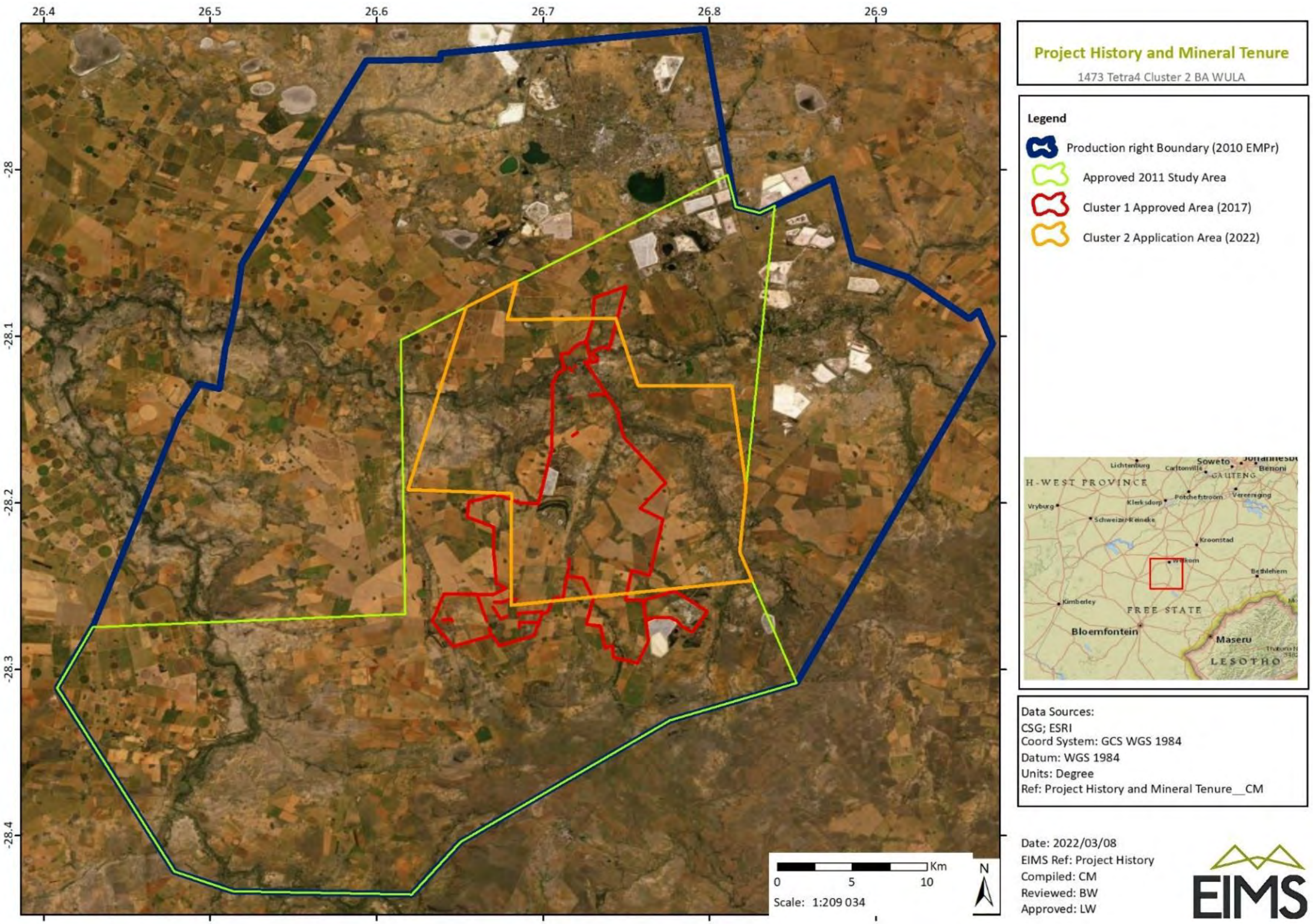

Figure 1: Project history and mineral tenure

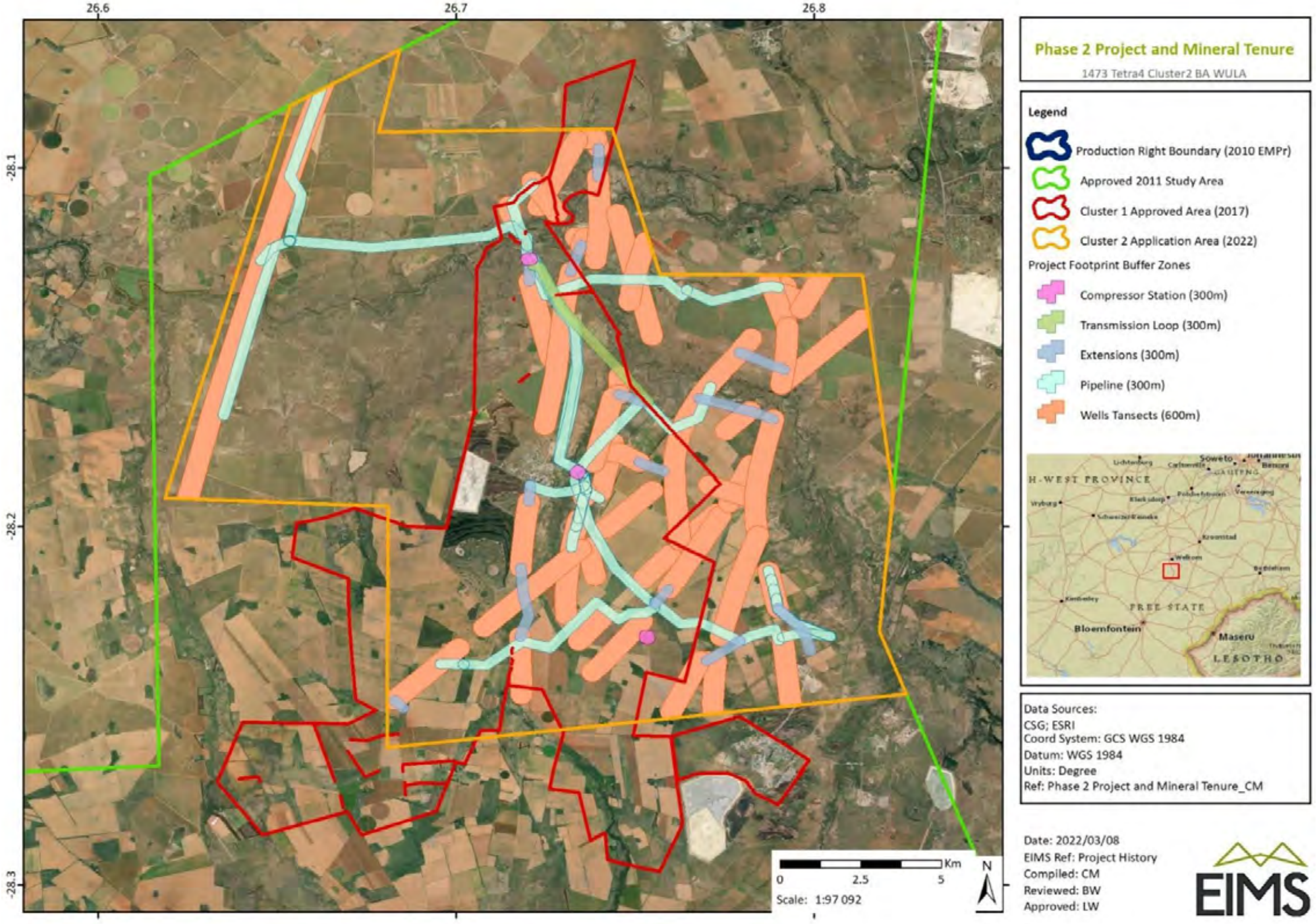

Figure 2: Cluster 2 study area and proposed infrastructure footprint buffer zones

1.2 Scope of Work

The tasks proposed as part of the scope of work for the CCA for the Construction and Operational Phases of the project, are:

- Identification of the Transitional and Physical Risks associated with the project (as per the Task Force on Climate-related Financial Disclosures).
- GHG emissions during the construction and operation of the project covering Scope1, Scope 2 and Scope 3 emissions.
- Comparison of GHG emissions to the global and national emission inventories, and to international benchmarks for the project.
- The robustness of the project in terms of forecasted climate change impacts to the area over the lifetime of the project.
- The vulnerability of communities in the immediate vicinity of the project to climate change.
- Proposed management and mitigation strategies.
- Compile a report that complies with the requirements of Appendix 6 of the EIA Regulations, 2014 (Government Notice (GN) R 982 of 2014, as amended); and/or
- The Department of Forestry, Fisheries and Environment (DFFE) "Protocols for the assessment and minimum report content requirements of environmental impacts" (GN 320 of 2020 and GN 1150 of 2020); and/or
- Any other applicable sector-specific guidelines and protocols.

1.3 Study Approach and Methodology

GHG emissions for the project were calculated and compared to the global and national emission inventory and compared to international benchmarks for the project.

1.3.1 Project and Information Review

A review of the project from an air quality perspective in order to identify sources of GHG emission was conducted. In the review the following documents were referenced:

- Project information supplied by EIMS, including the AQIA conducted in 2017 (Akinshipe, 2017); and
- Section 21 of the National Environmental Management: Air Quality Act (NEMAQA).

1.3.2 Carbon Footprint Calculation

The Carbon Footprint is an indication of the GHGs estimated to be emitted directly and/or indirectly by an organisation, facility, or product. It can be estimated from

$$Carbon\ emissions = Activity\ information * emission\ factor * GWP$$

where

- *Activity information* relates to the activity that causes the emissions.
- *emission factor* refers to the amount of GHG emitted per unit of activity.
- *GWP* or global warming potential is the potential of an emitted gas to cause global warming relative to carbon dioxide (CO_2). This converts the emissions of all GHGs to the equivalent amount of CO_2 or CO_2-e.

For combustion processes, the emission factor is often calculated from a carbon mass balance, where the combustion of each unit mass of carbon in the fuel leads to an equivalent emission of 3.67 mass units of CO_2 (from 44/12, the ratio of molecular weight of CO_2 to that of carbon).

GWPs from the recently published DFFE guideline on quantification of GHG emissions (based on the IPCC Third Assessment Report, 2001) were applied in this study. These GWPs are compliant with UNFCCC Reporting Requirements. The 100-year GWPs were used: 23 for methane (CH_4) and 296 for nitrous oxide (N_2O).

In the quantification of Scope 1 emissions, the recently published DFFE guideline on quantification of GHG emissions (DFFE, 2022) was used. Scope 3 emissions were estimated using the United Kingdom's Department of Environment, Food and Rural Affairs (UK DEFRA) 2022 emission factors (https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022). A summary of the emission factors applied is provided in Appendix A.

1.3.3 Scope of Carbon Footprint

The three broad scopes for estimating GHG are:

- Scope 1: All direct GHG emissions.
- Scope 2: Indirect GHG emissions from consumption of purchased electricity, heat, or steam.
- Scope 3: Other indirect emissions, such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2, outsourced activities, waste disposal, etc.

In this study, Scope 1 emissions are the emissions directly attributable to the project and Scope 2 emissions are the emissions associated with bought-in electricity. Scope 3 emissions consider the "embedded" carbon in bought-in materials and transport as well as the use of exported materials. Only Scope 1 emissions need to be quantified to be in line with the DFFE guidelines; the addition of Scope 2 would place the assessment in line with the guidelines provided by the International Finance Corporation (IFC, 2012).

1.3.4 Impact Assessment Methodology

As the emission of greenhouse gases has a global impact, it is not feasible to follow the normal impact assessment methodology viz. comparing the state of the physical environment after implementation of the project to the condition of the physical environment prior to its implementation. Instead, this study assessed the following:

(i) The GHG emissions during the construction, operation and decommissioning of the project compared to the global and South African emission inventory and to international benchmarks for the project.

(ii) The impact of climate change over the lifetime of the project taking the robustness of the project into account.

(iii) The vulnerability of communities in the immediate vicinity of the project to climate change.

1.4 Project Description

1.4.1 Construction

The construction phase comprises activities, such as drilling and construction of new wells, construction of access roads, installation of pipelines, construction of the helium and LNG plant, as well as site clearing or upgrade activities on existing wells. Each of these operations has its own duration and GHG emission potential with typical activities land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, well drilling etc. It is anticipated therefore that the extent of GHG emissions would vary substantially from day to day depending on the level of activity and the specific operations.

1.4.2 Operations

The operational phase of the Project will include mainly the combined LNG/LHe plant with continuous and emergency flares, three electrically powered compressor stations and booster stations that would require natural gas generators. Nitrogen (N_2) will be trucked to the plant, and the LNG and LHe products will be exported by truck from the plant via road. In addition, maintenance vehicles and equipment will operate as needed.

1.5 Assumptions and Limitations

The following important limitation applies to the study and should be noted:

- Project information required to calculate GHG emissions for proposed operations were provided by Tetra4 via EIMS. Where necessary, assumptions were made based on common industry practice and experience.
- The compressor stations were assumed to be electrically powered, whereas the booster stations were assumed to use natural gas generators.
- The methodological guidelines for quantification of GHG emissions (DFFE, 2022), published in October 2022, have been used to estimate the Scope 1 GHG emissions. The 100-year GWPs were used.
- GHG emissions from the well drilling[1], well testing[2], and well servicing[3] were based on measurements provided by the client, and not calculated using emission factors. These activities were included under construction operations.
- Scope 3 emissions were estimated using the UK DEFRA (2022) emission factors (https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022).
- The following Scope 3 categories are excluded since these are not regarded applicable to the project:
    - Category 2: Capital Goods
    - Category 8: Upstream Leased Assets
    - Category 10: Processing of Sold Products
    - Category 12: End-of-Life Treatment of Sold Products
    - Category 13: Downstream Leased Assets
    - Category 14: Franchises
    - Category 15: Investments.
- The following assumptions apply to the Scope 3 assessment:
    - Raw materials needed for the wells and plant was assumed to be 100 980 tonne concrete, 26 060 tonne metal and 9 000 tonne HDPE.
    - It was assumed that the raw materials would be transported by truck to site (450 km).
    - Industrial waste to be sent to a landfill was assumed to be 31 428 tpa.
    - Business travel was assumed to be 6 people travelling to USA and Europe per year.
    - It was assumed that contractors and permanent staff (total 1 254 people) would have the following split for employee commuting to work (2.8% diesel car, 4.6% petrol car, 19.6% taxi and 73% bus). It was assumed that the return trip per day was 60 km.
    - It was assumed that 60% of the LNG (~ 90 000 tpa) would be shipped by sea tanker to China.
    - It was assumed that the Helium (1 825 tpa) would be transported by truck to Durban (600 km), and then by ship (cargo ship average bulk carrier) to either Europe, Asia or North America (average 14 461 km).
    - It was assumed that the LNG (~ 160 000 tpa) would be combusted (end use of product).

[1] Data obtained from kestrel flow meter while drilling and extrapolated for duration of exploration drilling in gas bearing units.
[2] Data obtained from flow testing and flaring of existing exploration wells.
[3] Data obtained from fugitive monitoring of both existing production and exploration wells.

2 Regulatory Requirements

2.1 Introduction

2.1.1 The Greenhouse Effect

Greenhouse gases (GHG) are "those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the GHG effect. Water vapour (H_2O), CO_2, nitrous oxide (N_2O), methane (CH_4) and O_3 are the primary greenhouse gases in the earth's atmosphere. Moreover, there are a number of entirely human-made GHG gases in the atmosphere, such as the halocarbons and other chlorine and bromine containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) (IPCC, 2007). Human activities since the beginning of the Industrial Revolution (taken as the year 1750) have produced a 40% increase in the atmospheric concentration of carbon dioxide, from 280 ppm in 1750 to 406 ppm in early 2017 (NOAA, 2017). This increase has occurred despite the uptake of a large portion of the emissions by various natural "sinks" involved in the carbon cycle (NOAA, 2017). Anthropogenic CO_2 emissions (i.e., emissions produced by human activities) come from combustion of fossil fuels, principally coal, oil, and natural gas, along with deforestation, soil erosion and animal agriculture (IPCC, 2007).

2.1.2 IFC Literature on GHG

The International Finance Corporation (IFC) lists methods that countries and projects can reduce GHG impacts. These include carbon financing; improvement of energy efficiency; GHG sinks and reservoir protection and improvements; that environmentally friendly agriculture and forestry be encouraged; the increased use of renewable energy methods; implementation of carbon capture and sequestration methods; and, improved waste management (recovery and use of methane emissions) as well as reducing GHG emissions from vehicle use and industrial, construction and energy production processes (IFC, 2007). Carbon financing may have much potential in developing countries as well as sustainable agriculture and forestry practices (IFC, 2012), and when supported by governments may be a way of reducing the country's GHG impacts, where projects receive carbon credits and financing for reducing GHG emissions and installing more environmentally friendly alternatives. Because different industries contribute various amounts of GHG emissions, the IFC performance standards suggests that for industrial processes the CO_2-equivalent (CO_2-e) emissions per year do not exceed 100 000 tonnes, this including direct (Scope 1) and indirect (Scope 2) sources (IFC, 2012).

2.1.3 International Agreements

In 1992, countries joined an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC) as a framework for international cooperation to combat climate change by limiting average global temperature increases and the resulting climate change, and coping with impacts that were, by then, inevitable.

By 1995, countries launched negotiations to strengthen the global response to climate change, and, two years later, adopted the Kyoto Protocol. The Kyoto Protocol legally binds developed country parties to emission reduction targets. The Protocol's first commitment period started in 2008 and ended in 2012. As agreed in Doha in 2012, the second commitment period began on 1 January 2013 and would end in 2020 (UNFCCC, 2017) but due to lack of ratification has not come into force.

The Paris Agreement was adopted by 196 Parties at Conference of the Parties (COP) 21 in Paris, on 12 December 2015 and commenced 4 November 2016. The Paris Agreement (2016) builds upon the Convention and – for the first time – brings all nations into a common cause to undertake ambitious efforts to combat climate change and adapt to its effects, with enhanced support to assist developing countries to do so. As such, it charts a new course in the global climate effort.

The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change. To reach these ambitious goals, appropriate financial flows, a new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives.

The Paris Agreement is founded on the idea of countries improving on their climate change strategies in 5-year cycles. The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs) and to strengthen these efforts in the years ahead. This includes requirements that all Parties report regularly on their emissions and on their implementation efforts.

The Paris Agreement proposes that Parties submit long-term low greenhouse gas emission development strategies (LT-LEDS) by 2020 but this was not mandatory.

Parties will take stock of the collective efforts in relation to progress towards the goal set in the Paris Agreement and to inform the preparation of NDCs. There will also be a global stocktake every 5 years to assess the collective progress towards achieving the purpose of the Agreement and to inform further individual actions by Parties. Ethiopia submitted their first NDC to the UNFCCC secretariat and ratified the Paris agreement on 9 March 2017. Existing Parties were expected to submit their updated NDC in 2020; and new Parties their original NDCs. Parties are to submit updated NDCs every 5 years. As of May 2021, there are 192 parties that have submitted their NDCs and 8 parties that have submitted their second NDC. There are only 191 Parties to the Paris Agreement; Eritrea has not become a Party to the Paris Agreement but has submitted its first NDC.

Countries as part of the Paris agreement established an enhanced transparency framework (ETF). ETF is to start in 2024 and all countries will need to openly report on all activities untaken and progress in climate change mitigation, adaptation measures as well as any support provided or received. ETF also sets out a procedure for reviewing submitted reports. The information provided as part of the ETF will be used as an input for the global stocktake which will assess the collective progress towards the long-term climate goals.

2.1.4 Global GHG Emission Inventory

The proposed Cluster 2 operations would most likely fall under the category of "energy" for the global GHG inventory. According to the "mitigation of climate change" document as part of the Intergovernmental Panel on Climate Change (IPCC) fifth Assessment Report (AR5) (IPCC, 2014) the 2010 global GHG emissions were 49 (±4.5) Gt CO_2-e, of which 35% (17 Gt CO_2-e) was a result of the energy sector. The World Resources Institute Climate Watch global GHG emissions from the "industrial processes" sector were 2.7711 Gt CO_2-e in 2016 (6% of total anthropogenic GHG emissions).

2.2 South Africa's Status in terms of Climate Change and Quantification of Greenhouse Gases

2.2.1 Paris Agreement - Nationally Determined Contribution

South Africa ratified the UNFCCC in August 1997 and acceded to the Kyoto protocol in 2002, with effect from 2005. However, since South Africa is an Annex 1 country it implies no binding commitment to cap or reduce GHG emissions. The South African Intended Nationally Determined Contribution (INDC) was completed in 2015 and submitted to the UNFCCC[4] on 1 November 2016. This was undertaken to comply with decision 1/CP.19 and 1/CP.20 of the Conference of the Parties to the UNFCC. This document describes South Africa's INDC on adaptation, mitigation and finance and investment necessities to undertake the resolutions.

As part of the adaption portion the following goals have been assembled:

1. Goal 1: Development and implementation of a National Adaption Plan. The implementation of this will also result in the implementation of the National Climate Change Response Plan (NCCRP) per the 2011 policy.
2. Goal 2: In the development of national, sub-national and sector strategy framework, climate concerns must be taken into consideration.
3. Goal 3: An official institutional function for climate change response planning and implementation needs to be assembled.
4. Goal 4: The creation of an early warning, vulnerability, and adaptation monitoring system
5. Goal 5: Develop policy regarding vulnerability assessment and adaptation needs.
6. Goal 6: Disclosure of undertakings and costs with regards to past adaptation strategies.

As part of the mitigation portion the following have been, or can be, implemented at National level:

- The approval of 79 (5 243 MW) renewable energy Independent Power Producer (IPP) projects as part of a Renewable Energy Independent Power Producer Procurement Programme (REI4P). An additional 6 300 MW is being deliberated.
- A "Green Climate Fund" has been created to back green economy initiatives. This fund will be increased in the future to sustain and improve successful initiatives.
- It is intended that by 2050 electricity will be decarbonised.
- Carbon Capture and Sequestration (or Carbon Capture and Storage) (CCS).
- To support the use of electric and hybrid electric vehicles.
- Reduction of emissions can be achieved through the use of energy efficient lighting; variable speed drives and efficient motors; energy efficient appliances; solar water heaters; electric and hybrid electric vehicles; solar photovoltaic; wind power; CCS; and advanced bioenergy.

A draft update of the first NDC was published for public comment[5] on the 30th of March 2021 and the final updated of the first NDC was published and submitted to the UNFCCC[6] on the 27th of September 2021 in preparation for the 26th Conference of the Parties (to held in Glasgow, Scotland in November 2021). The final update of the first NDC South Africa has not submitted its second NDC to UNFCCC. The draft document describes South Africa's NDC on adaptation, mitigation and finance and investment necessities to undertake the resolutions with updated revisions to the adaptation goals and mitigation targets.

[4] https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx
[5] https://www.environment.gov.za/mediarelease/creecy_indc2021draftlaunch_climatechangecop26
[6] https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx

As part of the updated adaption portion the following goals have been assembled:

1. Goal 1: Enhance climate change adaptation governance and legal framework.
2. Goal 2: Develop an understanding of the impacts on South Africa of 1.5 and 2°C global warming and the underlying global emission pathways through geo-spatial mapping of the physical climate hazards, and adaptation needs in the context of strengthening the key sectors of the economy. This will provide the scientific basis for strengthening the national and provincial governments' readiness to respond to climate risk.
3. Goal 3: Implementation of National Climate Change Adaptation Strategy (NCCAS) adaptation interventions for the period 2021 to 2030, where priority sectors have been identified as biodiversity and ecosystems; water; health; energy; settlements (coastal, urban, rural); disaster risk reduction, transport infrastructure, mining, fisheries, forestry and agriculture.
4. Goal 4: Mobilise funding for adaptation implementation through multilateral funding mechanisms.
5. Goal 5: Quantification and acknowledgement of the national adaptation and resilience efforts.

As part of the mitigation portion the following have been, or can be, implemented at National level:

- The approval of 79 (5 243 MW) renewable energy Independent Power Producer projects as part of a Renewable Energy Independent Power Producer Procurement Programme. An additional 6 300 MW is being deliberated.
- A "Green Climate Fund" has been created to back green economy initiatives. This fund will be increased in the future to sustain and improve successful initiatives.
- It is intended that by 2050 electricity will be decarbonised.
- CCS.
- To support the use of electric and hybrid electric vehicles.
- Reduction of emissions can be achieved through the use of energy efficient lighting; variable speed drives and efficient motors; energy efficient appliances; solar water heaters; electric and hybrid electric vehicles; solar photovoltaic (PV); wind power; CCS; and advanced bioenergy.
- Updated targets based on revised 100-year global warming potential (GWP) factors (published in the Annex to decision 18/CMA.1 of the IPCC 5th assessment report) and based on exclusion of land sector emissions arising from natural disturbance. The updated NDC mitigation targets, consistent with South Africa's fair share, are presented in Table 1.

Table 1: **South Africa's NDC mitigation targets**

Year	Target	Corresponding period
2025	South Africa's annual GHG emissions will be in a range between 398 - 510 Mt CO_2-e.	2021-2025
2030	South Africa's annual GHG emissions will be in a range between 398 - 440 Mt CO_2-e.	2026-2030

2.2.2 National Climate Change Response Policy

The National Climate Change Response White Paper stated that in responding to climate change, South Africa has two objectives: to manage the inevitable climate change impacts and to contribute to the global effort in stabilising GHG emissions at a level that avoids dangerous anthropogenic interference with the climate system. The White Paper proposes mitigation actions, especially a departure from coal-intensive electricity generation, be implemented in the short- and medium-term to match the GHG trajectory range. Peak GHG emissions are expected between 2020 and 2025 before a decade long plateau period and subsequent reductions in GHG emissions.

The White Paper also highlighted the co-benefit of reducing GHG emissions by improving air quality and reducing respiratory diseases by reducing ambient particulate matter, ozone and SO_2 concentrations to levels in compliance with NAAQS by 2020.

In order to achieve these objectives, the Department of Forestry, Fisheries and Environment (DFFE) has appointed a service provider to establish a national GHG emissions inventory, which will report through SAAQIS.

The draft Climate Change Bill was published for comment on the 8th of June 2018 and introduced to parliament on the 18th of February 2022 (B9-2022). The Bill is aligned with international policies guidelines and South Africa's Nationally Determined Contribution and aim to reduce GHG emissions as primary driver to anthropogenic climate change. The aim of the Bill is to achieve an effective climate change response through a long-term just transition to a low carbon economy that is climate resilient and allows for sustainable development of South Africa. When in force, the Bill will:

- Establish provincial and municipal forums on climate change which will be responsible for coordinating climate change response actions in each province.
- Strengthen the establishment of the Presidential Climate Change Coordinating Commission (4PC). Although, the 4PC has already been established and has been working for the Government since December 2020, however, its establishment only carries legal force after the Bill becomes an Act.
- Within one year of the coming into force of the Act, establish a National Adaptation Strategy. This strategy will guide South Africa's adaptation to the impacts of climate change and develop adaptation scenarios which anticipate the likely impacts over the short, medium, and long term.
- Determine a national GHG emissions trajectory, which must be reviewed every five years, and which indicates an emissions reduction objective.
- Put in place a 5-yearly sectoral emission targets for identified sectors and sub-sectors. The sectoral targets must be aligned with the national GHG emissions trajectory and include quantitative and qualitative GHG emission reduction goals.
- Bring into force the carbon budget allocation mechanism, which will replace the current National Pollution Prevention Plan mechanism which is enforced under the National Environmental Management: Air Quality Act (NEM:AQA). The carbon budget will be linked to the Carbon Tax Act, in relation to carbon tax rates which will be charged on emissions above the carbon budget.

The Bill is nearing the end of its parliamentary process having been passed by the National Council of Provinces and been returned to the National Assembly for concurrence. It is likely to be enacted during the operational lifetime of the Tetra4 Cluster 2, if not before.

2.2.3 Greenhouse Gas Emissions Reporting

Regulations pertaining to GHG reporting using the National Atmospheric Emissions Inventory System (NAEIS) were published in 2017 (Republic of South Africa, 2017) (as amended by GN R994, 11 September 2020). The South African mandatory reporting guidelines focus on the reporting of Scope 1 emissions only.

The South African Greenhouse Gas Emission Reporting System (SAGERS) web-based monitoring and reporting system will be used to collect GHG information in a standard format for comparison and analyses. The system forms part of the national atmospheric emission inventory component of South African Atmospheric Emission Licensing and Inventory Portal (SAAELIP). Tetra4 operations will have to report their GHG emissions to SAGERS since there is no threshold for annual GHG emissions reporting for the Natural Gas producers as per the amended GHG reporting guidelines (GG43712, 7 September 2020).

The DFFE is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the IPCC default emission figures may be used to populate the SAAQIS GHG emission factor database. These country specific emission factors will replace some of the default IPCC emission factors. Methodological guidelines for quantification of GHG emissions (DFFE, 2022), published in October 2022, have been issued to estimate emissions.

Also, the Carbon Tax Act (No 15 of 2019) (Republic of South Africa, 2019) includes details on the imposition of a tax on the CO_2-e of GHG emissions. Certain production processes indicated in Annexure A of the Declaration of Greenhouse Gases as Priority Pollutants (Republic of South Africa, 2017) with GHG more than 0.1 mega tonnes (Mt) or million metric tonnes, measured as CO_2-e, are required to submit a pollution prevention plan to the Minister for approval.

2.2.4 National GHG Emissions Inventory

South Africa is perceived as a global climate change contributor and is undertaking steps to mitigate and adapt to the changing climate. DFFE is categorised as the lead climate change institution and is required to coordinate and manage climate related information such as development of mitigation, monitoring, adaption, and evaluation strategies (DEA, 2019). This includes the establishment and updating of the National GHG Inventory. The National Greenhouse Gas Improvement Programme (GHGIP) has been initiated; it includes sector specific targets to improve methodology and emission factors used for the different sectors as well as the availability of data.

The 2000 to 2017 National GHG Inventory (https://bit.ly/3kkaCco) was prepared using the 2006 IPCC Guidelines (IPCC, 2006) based on updated sector information and emission estimation techniques. According to the 4th Biennial Update Report to the UNFCCC (DFFE, 2021), the total GHG emissions in 2017 were estimated at approximately 512.66 million metric tonnes CO_2-e (excluding Forestry and Other Land Use [FOLU]). This was a 14.2% increase from the 2000 total GHG emissions (excluding FOLU) and 2.8% decrease from the 2015 total GHG emissions (excluding FOLU). FOLU is estimated to be a net carbon sink which reduces the 2017 GHG emissions to 482.02 million metric tonnes CO_2-e. The estimated GHG emissions (excluding FOLU) for 2017 showed the Industrial Processes and Product Use (IPPU) sector contributed 6.3% to the total GHG emissions (excluding FOLU), which relates to 32.08 million metric tonnes. The estimated CO_2-e emissions (excluding FOLU) for 2017 for the Energy sector is 410.64 million metric tonnes, which is 80% of the total GHG emissions.

2.2.5 Draft National Guideline for Consideration of Climate Change in Development Applications, June 2021

The DFFE has, on 25 June 2021, published a Notice under the NEMA requesting public comment on the *Draft National Guideline for the consideration of climate change implications in applications for environmental authorisation, atmospheric emission licences and waste management licences*.

The Draft National Guideline has been developed to support the inclusion of climate change considerations into the EIA process, and to create a consistent approach for such incorporation, which will help proponents to assess:

- how a proposed development will likely exacerbate climate change;
- the impact of a development on features (natural and built) that are crucial for climate change adaptation and resilience; and
- the sustainability of a development in the context of climate change projection.

The Guideline puts forward “a consistent approach in providing interested and affected parties (e.g. proponents, EAPs and specialists) with the minimum requirements to consider when undertaking a climate change assessment, which forms part of an application for environmental authorisation (EA), an atmospheric emissions licence (AEL) and/or waste management licence (WML)”.

One of the impact requirements for a climate change assessment is an estimation of the GHG emissions, direct and indirect (including upstream GHG emissions) that will be released into the atmosphere annually throughout the impact related to the activity.

3 CLIMATE CHANGE BASELINE

3.1 Physical Risks of Climate Change on the Region

In 2017 the South African Weather Service (SAWS) published an updated Climate Change Reference Atlas (CCRA) based on Global Climate Change Models (GCMs) projections (SAWS, 2017). It must be noted that as with all atmospheric models there is the possibility of inaccuracies in the results as a result of the model's physics and accuracy of input data; for this reason, an ensemble of models' projections is used to determine the potential change in near-surface temperatures and rainfall depicted in the CCRA. The projections are for 30-year periods described as the near future (2036 to 2065) and the far future (2066 to 2095). Projected changes are defined relative to a historical 30-year period (1976 to 2005). The Rossby Centre regional model (RCA4) was used in the predictions for the CCRA which included the input of nine GCMs results. The RCA4 model was used to improve the spatial resolution to 0.44° x 0.44°- the finest resolution GCMs in the ensemble were run at resolutions of 1.4° x 1.4° and 1.8° x 1.2°.

Two trajectories are included based on the four Representative Concentration Pathways (RCPs) discussed in the IPCC's fifth assessment report (AR5) (IPCC, 2013). RCPs are defined by their influence on atmospheric radiative forcing in the year 2100. RCP4.5 represents an addition to the radiation budget of 4.5 W/m^2 as a result of an increase in GHGs. The two RCPs selected were RCP4.5 representing the medium-to-low pathway and RCP8.5 representing the high pathway. RCP4.5 is based on a CO_2 concentration of 560 ppm and RCP8.5 on 950 ppm by 2100. RCP4.5 is based on the expectation that current interventions will reduce GHG emissions and that it will be sustained (after 2100 the concentration is expected to stabilise or even decrease). RCP8.5 is based on no interventions implemented to reduce GHG emissions (then after 2100 the concentration is expected to continue to increase).

3.1.1 RCP4.5 Trajectory

Based on the median, for the region in which the proposed facility and communities are situated, the annual average near surface temperatures (2 m above ground) are expected to increase by between 1.5°C and 2.0°C for the near future and between 2.0°C and 2.5°C for the far future. The seasonal average temperatures are expected to increase for all seasons, in the same order as the annual average increases, with slightly larger temperature increases in autumn (March to May) and larger increases in spring (September to November). The total annual rainfall is expected to increase by between 5 mm and 10 mm for the near future and decrease by up to 20 mm in the far future. Seasonal rainfall is expected to increase in summer (December to February) up to 30mm in the near- and far future, while other seasons are likely to show decreases between 5 and 10 mm.

3.1.2 RCP8.5 Trajectory

Based on the median, the region in which the proposed facility and communities are situated, the annual average near surface temperatures (2 m above ground) are expected to increase by between 2.0°C and 2.5°C for the near future and between 5.0°C and 5.5°C for the far future. The seasonal average temperatures are expected to increase for all seasons in similar ranges to the annual average temperature, with higher increases in spring, summer, and autumn. The total annual rainfall change is likely to increase by between 20 and 30 mm, while it is more uncertain for the far future with potential decrease up to 5 mm. Seasonal rainfall changes could see an increase of 5 mm in spring and summer in the near future with decreased up to 10 mm in autumn and winter. In the far future, the seasonal the rainfall changes are similar to the near future, except in summer where increased rainfall could be up to 50 mm.

3.1.2.1 Water Stress and Extreme Events

South Africa is known to be a water stressed country (Kusangaya, Shekede, & Mbengo, 2017), but Welkom/Virginia falls within a low water- stress and depletion zone. It falls in a Low-Medium interannual variability but with a Medium-High seasonal variability, leading to a Medium-High drought risk[7]. Climate change, through elevated temperatures, is likely to increase evaporation rates and decrease water volumes available for dryland and irrigated agriculture (Davis-Reddy & Vincent, 2017). Commercial agriculture (crop and livestock farming) is the predominant agricultural land-use in the vicinity of Welkom and Virginia.

Extreme weather events affecting southern Africa, including heat waves, flooding due to intensified rainfall due to large storms and drought, have been shown to increase in number since 1980 (Davis-Reddy & Vincent, 2017). Projections indicate (Davis-Reddy & Vincent, 2017):

- with high confidence, that heat wave and warm spell duration are likely to increase while cold extremes are likely to decrease, where up to 80 days above 35°C are projected by the end of the century under the RCP4.5 scenario;
- with medium confidence, that droughts are likely to intensify due to reduced rainfall and/or an increase in evapotranspiration; and
- with low confidence, that heavy rainfall events (more than 20 mm per 24 hours) will increase.

[7] https://www.wri.org/applications/aqueduct/water-risk-atlas/#/?advanced=false&basemap=hydro&indicator=w_awr_def_tot_cat&lat=30&lng=-80&mapMode=view&month=1&opacity=0.5&ponderation=DEF&predefined=false&projection=absolute&scenario=optimistic&scope=baseline&timeScale=annual&year=baseline&zoom=3

4 IMPACT ASSESSMENT: THE PROJECT'S CARBON FOOTPRINT

4.1 Scope 1 GHG Emission Sources

4.1.1 Clearing and Rehabilitation – Carbon Sequestration and Carbon Sink

Accounting for the uptake of carbon by plants, soils and water is referred to as *carbon sequestration* and these sources are commonly referred to as *carbon sinks*. Quantifying the rate of carbon sequestration is however not a trivial task requiring detailed information on the geographical location, climate (specifically temperature and humidity) and species dominance (Ravin & Raine, 2007).

Photosynthesis is the main sequestration process in forests and in soils. Carbon is absorbed as fixed carbon into the roots, trunk, branches, and leaves and during the shedding of leaves, but is emitted – although at a reduced percentage – from foliage and when biomass decays. Several factors also determine the amount of carbon absorbed by trees such as species, size, and age. Mature trees, for example, will absorb more carbon than saplings (Ravin & Raine, 2007).

Aspects required to calculate the carbon stack change in the pool (in tons of carbon per year) include the climate, the type of forest or vegetation removed and the type to be re-introduced, and management measures. Soil type also has different absorption and release ratios that need to be included. "Decomposition of soil organic matter in drained inland grassland" was used to the carbon losses from the cleared areas. It should be noted that carbon losses apply to the replacement of vegetation with built infrastructure, except where temporary clearing activities could have long-term impacts on water resources, including rivers, aquifers, streams, and wetlands, or water infrastructure (for example dams and storm water systems) (Government Gazette No. 44761, Notice 559, 25 June 2021), where in this case, vegetation may recover over the pipeline areas.

The areas to be cleared were accounted for as indicated in Table 2.

Table 2: Tetra4 Cluster 2 land clearance during construction

Construction Activity	Description of Area	Area (m^2) (unit area)	No of units	Total area (m^2)
Land Clearance	Road construction	5 000	1	5 000
	Pipeline construction [(a)]	2 500	139	346 530
	Well construction	900	300	270 000
	Booster station construction	3 600	30	108 000
	Compressor station construction	3 600	3	10 800
	Plant construction	93 979	1	93 979
			Area (m^2)	834 309
			Area (ha)	83.43

Notes: [(a)] This is a conservative approach since vegetation may recover over the pipeline areas.

4.1.2 Construction fuel combustion

There will be an initial carbon sink loss due to the vegetation removal for the new and expansion Cluster 2 areas. GHG will also be emitted through operating diesel-powered mobile and stationary equipment, as listed in Table 3.

Table 3: Tetra4 Cluster 2 construction fuel combustion

Mobile Diesel Equipment	Total kWh	Stationary Equipment	Total kWh
Plant	11 799 841	Natural gas generator	210 287
Pipeline	854 684		
Wells	1 275 986		
Booster Stations	1 275 986		
Compressor Stations	1 275 986		
Drilling	862 682		

4.1.3 *Construction well drilling, testing, and servicing*

There will be fugitive emissions (excluding venting and flaring) from gas well drilling, drill stem testing and well completions during construction. Emission factors are provided in Appendix A and emissions are calculated in Gg per 10^3m^3 total production. Gas processing was given as 203 786.67 10^3m^3 and assumed to apply to raw gas feed and gas production.

4.1.4 *Operations*

The main sources of GHG due to the proposed operations are the mobile (trucking) and stationary equipment (generators) (Table 4), emissions from gas processing (fugitives, flaring and raw CO_2 venting) (calculated in Gg per 10^6m^3 raw gas feed – see Table 5) and emissions from transmission and storage (calculated in Gg/year/km and Gg/year/m^3 respectively – see Table 6)

Table 4: Tetra4 Cluster 2 operational phase fuel combustion per year

Road transportation (diesel)	Total tonne-km per year	Stationary Equipment	Total kWh
Trucking	187 091 100 [(a)]	Natural gas generator	36 842 352

Notes: [(a)] Total tonne-km per year = assumed 155 909 tpa trucked over 1 200 km

Table 5: Tetra4 Cluster 2 gas processing during an operational year

Gas processed	Volume (10^3 m^3)
Raw gas processed [(a)]	203 786.67

Notes: [(a)] Latest figures provided

Table 6: Tetra4 Cluster 2 transmission (pipeline fugitives and venting) and storage during an operational year

Gas transmission	Length (km)	Storage per year	Volume (m^3/year)	Product (tpa)	Density (kg/m^3)
Pipeline length	120	Product	232 558.14	100 000 [(a)]	430

Notes: [(a)] Maximum product storage per annum provided as 100 000 tpa; product density 430 kg/m^3

4.1.5 *Decommissioning*

As operations progress, the previously cleared areas that form part of the project will be rehabilitated resulting in a carbon sink gain. Even assuming rehabilitation uses the same indigenous vegetation, the carbon balance will not be completely restored. There may also be potential soil degradation due to stockpiling. However, there is insufficient data at this point to determine the decommissioning GHG emissions. This is likely to be equivalent or less than the construction phase, with the reestablishment of a carbon sink in the revegetation of the site.

4.2 Scope 2 GHG Emissions

Scope 2 GHG emissions apply to consumption of purchased electricity, heat, or steam. Tetra 4 Cluster 2 will make use of ESKOM electricity supply for some operations as listed in Table 7.

Table 7: Tetra4 Cluster 2 ESKOM electricity supply during construction and operations

Project phase	Activity	MW	No of hours/ year	Total MWh
Construction	Gas gathering			
	Plant	0.16	5 278	844
Operations	Gas gathering	9.72	8 322	80 890
	Plant	23.06	8 322	191 905

A summary of the calculated GHG emissions for the construction and operational phases is provided in Table 8 and the emission factors used provided in Appendix A.

Table 8: Tetra4 Cluster 2 Scope 1 and 2 GHG emission summary

Emission summary					
Construction	Activities	CO_2 (as tCO_2-e)	CH_4 (as tCO_2-e)	N_2O (as tCO_2-e)	Total CO_2-e (tonnes/year)
Scope 1 emissions	Land clearance	509			509
	Off-road mobile equipment	4 627	6	529	5 162
	Generators	42	0.09	0.02	43
	Well drilling	10 716			10 716
	Well testing	14 517			14 517
	Well servicing	1 534			1 534
Total Scope 1 emissions	Land clearance, heavy construction, generators, well drilling, well testing and well servicing	32 479			32 479
Total Scope 2 emissions	Electricity bought from ESKOM	861			861
				Total emissions	33 341
Operations	Activities	CO_2 (as tCO_2-e)	CH_4 (as tCO_2-e)	N_2O (as tCO_2-e)	Total CO_2-e (tonnes/year)
Scope 1 emissions	Road transportation	19 858			19 858
	Generators	7 441	15	4	7 460
	Gas processing (fugitives)	65	4 828		4 893
	Gas processing (flaring)	367	6	2	374
	Gas processing (CO_2 venting)	8 151			8 151
	Gas storage		12		12
	Gas transmission (pipeline fugitives)	2	6 900		6 902
	Gas transmission (pipeline venting)	1	2 760		2 761
Total Scope 1 emissions	Road transportation, gas processing, transmission and storage, generators	50 411			50411
Total Scope 2 emissions	Electricity bought from ESKOM	278 251			278 251
				Total emissions	328 662

The total CO_2eq emission rate from the Tetra4 Cluster 2 construction phase is 32 479 tpa (Scope 1) and 861 tpa (Scope 2). For a single operational year, the Scope 1 GHG emissions are 50 411 tpa, with Scope 2 accounting for the largest part at 278 251 tpa.

4.3 Scope 3 GHG Emissions

Scope 3 GHG emissions are listed in Table 9.

Table 9: Tetra4 Cluster 2 GHG Scope 3 emission summary

Scope 3 sector	Activities	Total CO_2-e (tonnes/year)
Total Scope 3 emissions – Transportation	Category 4 – Upstream transportation and distribution	6 498
	Category 6 – Business travel	26
	Category 7 – Employee commuting	2 297
	Category 9 – Downstream transportation and distribution	17 962
Total Scope 3 emissions – Products used	Category 1 – Purchased goods and services	147 442
Total Scope 3 emissions – Use of products	Category 11 – Use of sold products	398 391
Total Scope 3 emissions – Other sources	Category 5 – Generated in operations	14 677
	Total emissions	587 293

The main source of scope 3 emissions would be the end use of the LNG. As LNG will be replacing other fuels already in use, there will be a reduction in indirect GHG emissions as shown in Table 10. By using LNG, indirect GHG emissions would be reduced by 85 960 tpa.

Table 10: Tetra4 Cluster 2 GHG scope 3 use of sold products to replace other fuels currently in use

Scope 3 sector	Activities	Total CO_2-e (tonnes/year)
Total Scope 3 emissions – Use of products currently (diesel)	Category 11 – Use of sold products	289 531
Total Scope 3 emissions – Use of products currently (LPG)	Category 11 – Use of sold products	122 476
Total Scope 3 emissions – Use of products currently (HFO)	Category 11 – Use of sold products	72 345
Total Scope 3 emissions **–** Use of products currently (Total)	Category 11 **–** Use of sold products	484 352
Total Scope 3 emissions **–** Use of products in future	Category 11 **–** Use of sold products	398 391
	Total emissions reduction	85 960

4.4 **The Project's** GHG Emissions Impact

4.4.1 Impact on the National Inventory

The operational phase of Tetra4 Cluster 2 will likely result in an increase in Scope 1 & 2 emissions. The annual operational CO_2-e emissions from the Tetra4 Cluster 2 operations would contribute approximately 0.08% to the South African "energy" sector total (410.64 million metric tonnes $CO_{2\text{-e}}$, excluding FOLU) and represent a contribution of 0.064% to the National GHG inventory total (512.66 million metric tonnes $CO_{2\text{-e}}$, excluding FOLU), based on the published 2017 National GHG Inventory (DFFE, 2021) (see Section 2.2.4). The annual CO_2-e emissions from the construction phase would contribute approximately 0.008% to the South African "energy" sector total and represent a contribution of 0.007% to the National GHG inventory total (DFFE, 2021).

4.4.2 Alignment with national policy

Regulations pertaining to GHG reporting using the NAEIS were published in 2017 (Republic of South Africa, 2017) (as amended by GN R994, 11 September 2020) where mandatory reporting guidelines focus on reporting of Scope 1 emissions only. The DFFE is working together with local sectors to develop country specific emissions factors in certain areas; however, in the interim the IPCC default emission figures may be used to populate the SAAQIS GHG emission factor database. With the operational Scope 1 CO_2-e emissions below 100 000 t/a, Tetra4 does not have to report on SAGERS, calculate its Carbon Tax nor compile a pollution prevention plan (PPP).

4.4.3 Physical Risks of Climate Change on the Project's Construction and Operations

4.4.3.1 Temperature

With the increase in temperature, including heat waves, there is the likelihood of an increase in discomfort, possibility of heat related illness (such as heat exhaustion, heat cramps, and heat stroke). Both these have the potential to negatively affect staff process performance and productivity.

From a process point of view, elevated ambient temperatures (up to 45°C) may slightly reduce the fuel requirements needed to meet the generating capacity required. However, water use as a dust control measure during construction, may increase.

4.4.3.2 Rainfall, Water Stress, and Extreme Events

Rainfall decreases in autumn, winter and spring could result in constrained water supply outside of summer months. During drought conditions water supply could decline and intended use of reclaimed water and boreholes/wellpoints should be investigated to secure long-term supplies.

The impact of intense rainfall events on the LNG/LHe Plant cannot be ruled out, where the frequency of intense rainfall events could increase from the long-term baseline. These events could affect production capacity during intense rainfall (unless fully protected from rain and wind), flooding affecting site access, safe operation of equipment, delivery of fuel; collection of compressed gas product, as well as physical damage to infrastructure during high wind speed events associated with intense storms.

4.4.4 Impact Assessment: Potential Effect of Climate Change on the Community

4.4.4.1 Temperature

With the increase in temperature, including heat waves, there is the likelihood of an increase in discomfort and possibility of heat related illness (such as heat exhaustion, heat cramps, and heat stroke). There is also the possibility of increased evaporation which in conjunction with the decrease in rainfall can result in water shortage. This does not only negatively affect the community's water supply but can reduce the crop yields and affect livestock resulting in compromised food security.

4.4.4.2 Rainfall, Water Stress, and Extreme Events

As discussed above the decrease in rainfall can result in the following effects:

- Reduced water supply of reduced water quality; and,
- A negative impact on food security.

The impact of intense rainfall events on the local communities cannot be ruled out, where the frequency of these event could increase from the long-term baseline. These events could affect road access within the area due to flooding, and physical damage to public and private infrastructure through flooding and high wind speeds.

4.5 Project adaptation and mitigation measures

Climate change management includes both mitigation and adaptation. The main aim of mitigation is to stabilise or reduce GHG concentrations as a result of anthropogenic activities. This is achievable by lessening sources (emissions) and/or enhancing sinks through human intervention. Mitigation measures are typically the focus of the energy, transport, and industry sectors (Thambiran & Naidoo, 2017). Adaptation measures focus on the minimising the impact of climate change, especially on vulnerable communities and sectors. Inclusion of the climate change adaptation in business strategic implementation plans is one of the outcomes defined in the Draft National Climate Change Adaptation Strategy (Government Gazette No.42466:644, May 2019).

Additional support infrastructure can reduce the climate change impact on the staff and project, for example the improving thermal and electrical efficiency of buildings to reduce electricity consumption, ensuring adequate water supply for staff and reducing on-site water usage as much as possible. A community development program could be initiated to assist communities near the Tetra4 project site that are vulnerable to climate change impacts, such as thermal and electrically efficient buildings (to minimise electricity needs for heating and cooling), energy efficient stoves (to minimise the use of coal and woody biomass), or small-scale renewable energy innovations suitable for use in homes.

Project specific mitigation measures, may include:

- GHG emissions from vehicles and equipment:
  - Maintain vehicles and machinery in accordance with manufacturers standard specifications; and
  - A leak-detection program to be implemented to reduce product loss.
- GHG emissions from flaring, venting and fugitives:
  - Emissions of GHG should be limited as much as possible to reduce the global impact;
  - Flaring and venting of GHG should be minimised; and
  - Prudent operations and reductions in plant upsets would lead to fewer maintenance, startup, and shutdown events that cause flare and blowdown emissions, with the added benefit of retaining more product.
- GHG from National Grid:
  - The implementation and use of renewable energy such as solar photovoltaic (PV) units to replace/ reduce the reliance on ESKOM electricity would reduce the Tetra4 Cluster 2 GHG emissions significantly since ESKOM's contribution to the operational phase is the main source of GHG emissions; and
  - The use of LNG instead of diesel for generators and other stationary equipment would reduce the Project's GHG footprint further.

5 IMPACT SIGNIFICANCE RATING

The significance of climate change impacts was based on Scope 1, 2 and 3 GHG emissions and assessed according to the methodology provided by EIMS (Appendix A). Since climate change is a global phenomenon, the criterion is not fully applicable to an assessment of the impacts of GHG emissions on climate change. However, the criterion is currently the best tool for the climate change impact analysis.

5.1 Construction

Given the nature of construction activities for the roads/pipeline, wells and booster stations (where the location may vary depending on the gas reserves in the area) the negative climate change impacts are considered to be of Low significance without mitigation and Low significance with mitigation (Table 11).

Table 11: Significance rating for potential Climate Change impacts due to the construction activities

Impact Name	Climate Change risk due to Scope 1 & 2 construction				
Alternative	NA				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	2	1
Extent of Impact	-	-	Reversibility of Impact	5	5
Duration of Impact	1	1	Probability	3	3
Environmental Risk (Pre-mitigation)					-8.0
Mitigation Measures					
As construction will be of limited duration. Develop and implement management programs and procedures.					
Environmental Risk (Post-mitigation)					-7.0
Degree of confidence in impact prediction:					Low
Impact Prioritisation					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-8.17

Note: [a] The extent of climate change impact is always national or wider and therefore can result in an overly conservative significance, and since the overall consequence and significance are not influenced by the extent, but rather by the intensity of emissions, "extent" was not included in the significance rating.

5.2 Operation

Vehicle and trucks, natural gas generators, the processing and flaring of gas, fugitive releases, and indirect upstream and downstream emissions could result in Medium significance on climate change and could reduce, although still Medium significance with mitigation and adaptation measures in place (Table 12).

Table 12: Significance rating for potential climate change impacts due to the Project operations

Impact Name	Climate Change risk due to the operational phase of the project				
Alternative	NA				
Phase	Operations				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	-	-	Reversibility of Impact	5	5
Duration of Impact	4	4	Probability	3	3
Environmental Risk (Pre-mitigation)					-12.0
Mitigation Measures					
Emissions of GHG should be limited as much as possible to reduce the global impact. Flaring and venting of GHG should be minimised. A leak-detection program to be implemented to reduce product loss. Replacing ESKOM electricity supply with renewable energy. Using LNG instead of diesel in equipment and machinery.					
Environmental Risk (Post-mitigation)					-11.0
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.33
Final Significance					-14.67

Note: [(a)] The extent of climate change impact is always national or wider and therefore can result in an overly conservative significance, and since the overall consequence and significance are not influenced by the extent, but rather by the intensity of emissions, "extent" was not included in the significance rating.

5.3 Alternative Significance Rating

Other literature (Murphy & Gillam, 2013) suggests use of thresholds (Table 13) presented as tonnes of CO_2e per year, as basis for specific consideration of the specific elements to be assessed in the EIA, as guidance states that the contribution of an individual project to climate change cannot be measured.

Table 13: GHG and Climate in EIA – Elements to consider

GHG emissions (tonnes CO_2e/year)	Qualitative rating	Elements of assessment to consider
GHGs < 25 000	Very Low	Quantify GHG
25 000 < GHGs < 100 000	Low	Look at possible mitigation, quantify GHG, place in context
100 000 < GHGs < 1 000 000	Medium	As above and prepare management plan, describe existing climate conditions, consider how changes in climate may affect project and surroundings
GHGs > 1 000 000	High	As above and consider adaptation analyses

Based on the suggested thresholds from Table 13, the construction phase Scope1 GHG emissions would result in Low significance, and Scope 2 Very Low, with a combined significance of Low. The operational phase would result in Low significance for Scope 1 emissions, and Medium for Scope 2 emissions, where the combined (Scope 1 and Scope 2) significance would be Medium. The contribution of Scope 3 to GHG emissions would result in a Medium significance.

6 CONCLUSION

The region around Welkom and Virginia where Tetra4 Cluster 2 project is proposed to be developed is likely to experience increased temperatures and extreme weather-related events in the future. Climate change impacts will disproportionately affect under-developed communities that lack the physical and financial resources to cope with the physical effects of climate change, such as droughts, floods and increases in diseases.

Scope- 1, 2 and 3 emissions were estimated based on emission factors and expected production rates or raw material use. The main construction activities attributing to GHG emissions are well drilling, well testing and well servicing followed by off-road mobile equipment. During operations, the electricity bought from ESKOM (Scope 2) is the main source, followed by road transportation and gas process venting (Scope 1). The main source of Scope 3 GHG emissions would be the end use of the LNG, but as LNG will be replacing other fuels already in use, it will result in a reduction of 14.6% in indirect GHG emissions.

Construction- and operational-related GHG emissions from the proposed Tetra4 Cluster 2 project cannot be attributed directly to any particular climate change effects, and, when considered in isolation, will have a Low to Medium impact on the National GHG inventory total. The main GHG impact is associated with downstream use of the LNG, i.e. Scope 3. GHG emissions per unit of gas combusted, however, is less than per unit coal.

Climate change is a global challenge and there is a collective responsibility to address the global challenge of climate change and Tetra4 has an individual responsibility to minimise its own negative contribution to the issue. It is therefore recommended that:

- Renewable energy (such as PV Solar) be considered to replace/ reduce the reliance on ESKOM electricity – this is likely to reduce the significance from the Tetra4 Cluster 2 project from Medium to Low, since ESKOM's contribution to the operational phase is the main source of GHG emissions.
- Also, the use of LNG instead of diesel will reduce the GHG footprint further.
- Maintenance of vehicles and machinery, the implementation of a leak-detection program, and the minimisation of flaring and venting would reduce the potential for GHG emissions.

Once operational, it is recommended records be kept of actual fuel usage for transport of materials and products, energy requirements, production rates, flare and venting rates and raw material consumption for GHG reporting purposes and refinement of the emissions inventory.

Based on Tetra4 Cluster 2 Scope 1, 2 and 3 GHG emissions, it is the specialist opinion that the project may be authorised due to its low to medium impact significance.

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8 Appendix A – Emission Factors

IPCC Category	Description	Emission source	Fuel/material	Emission factors CO_2	Emission factors CH_4	Emission factors N_2O	Unit	Source	Notes
	Scope 1 - Direct Emissions								
1.A.3.e.ii	Mobile combustion	Off-road mobile equipment	Diesel	74100	4.15	28.6	kg per TJ	2006 IPCC default	
1.A.3.b		Road transportation	Diesel	0.10614			kg CO_2e per tonne.km	2022 UK DEFRA	All HGVs. Average laden. Assumed 155 909 tpa trucked 1 200 km.
1.A.4.a	Stationary combustion	Generator	Diesel	74100	3	0.6	kg per TJ	2006 IPCC default	
			Natural gas	56100	1	0.1	kg per TJ	2006 IPCC default	
1.B.2.b.ii	Natural gas flaring and venting	Well drilling	Natural gas	1E-04	0.000033	ND	Gg/10^3 m^3 total gas production	SA 2022 Methodological guidelines for quantification of GHG emissions	Provided gas processing 203 786 67 m^3.
		Well testing	Natural gas	9E-03	5.1E-05	6.8E-08	Gg/10^3 m^3 total gas production		
		Well servicing	Natural gas	1.9E-06	1.1E-04	ND	Gg/10^3 m^3 total gas production		
1.B.2.b.iii.3	Gas processing	Fugitives	Gas	1.5E-04 to 3.2E-04	4.8E-04 to 1.03E-03	NA	Gg/10^6 m^3 raw gas feed	SA 2022 Methodological guidelines for quantification of GHG emissions	Sweet gas plants. Assumed raw gas feed 203 786 67 m^3.
1.B.2.b.ii		Flaring	Gas	1.8E-03	1.2E-06	2.5E-08	Gg/10^6 m^3 raw gas feed		
1.B.2.b.i		Raw CO_2 venting	Gas	0.04	NA	NA	Gg/10^6 m^3 raw gas feed		Default. Assumed raw gas feed 203 786 67 m^3.
1.B.2.b.iii.4	Gas transmission and storage	Transmission - fugitives	Gas	1.6E-05	2.5E-03	n/a	Gg/year/km	SA 2022 Methodological guidelines for quantification of GHG emissions	Assume 120 km.
1.B.2.b.i		Transmission - venting	Gas	8.5E-06	1E-03		Gg/year/km		
1.B.2.b.iii.4		Storage	Gas		2.32E-09		Gg/year/m^3		Assumed storage of 100 000 tonne.
3.B.3.b	Decomposition of soil organic matter in drained inland grassland	Land clearance	Grassland	6.1	n/a	n/a	tonnes CO_2-C/ha/yr	1996 & 2006 IPCC default	

IPCC Category	Description	Emission source	Fuel/materia l	Emission factors			Unit	Source	Notes
				CO_2	CH_4	N_2O			
	Scope 2 - Indirect Emissions								
	ESKOM energy grid	Electricity generation	Coal	1.02	n/a	n/a	tonnes CO_2 per MWh	Median value from Eskom Integrated Reports (2016-2021)	
	Scope 3 - Indirect Emissions								
	Transportation	Category 4 - Upstream transportation and distribution	Plant, pipeline and overhead line goods.	0.10614			kg CO_2e per tonne.km	2022 UK DEFRA	All HGVs. Average laden. Assumed 125 540 tonne/year trucked from (450 km)
			Well casing goods.	0.10614			kg CO_2e per tonne.km	2022 UK DEFRA	All HGVs. Average laden. Assumed 10 500 tonne/year trucked from (450 km)
		Category 6 - Business travel	Air	0.18362			kg CO_2e per passenger.km	2022 UK DEFRA	International. Average passenger. Assumed 14 400 km (USA) – 2 trips, 3 people. Assumed 9 500 km (Europe) – 2 trips, 3 people.
		Category 7 - Employee commuting	Car petrol	0.17048			kg CO_2e per km	2022 UK DEFRA	Average car. Assumed 58 people 60km/day.
			Car diesel	0.170824			kg CO_2e per km	2022 UK DEFRA	Average car. Assumed 35 60km/day.
			Taxi	0.02136			kg CO_2e per passenger.km	Toyota Quantum specifications	299g CO_{2e}/km, assumed 14 passengers. Assumed 246 people 60km/day.
			Bus	0.0965			kg CO_2e per passenger.km	2022 UK DEFRA	Average local bus. Assumed 915 people 60km/day.

IPCC Category	Description	Emission source	Fuel/materia l	Emission factors			Unit	Source	Notes
				CO_2	CH_4	N_2O			
		Category 9 - Downstream transportation and distribution	He	0.10614			kg CO_2e per tonne.km	2022 UK DEFRA	All HGVs. Average laden. Assumed He trucked to Durban (600 km).
			He	0.003539			kg CO_2e per tonne.km	2022 UK DEFRA	Cargo ship. Average bulk carrier. Assumed He shipped to Asia, Europe and USA (14 461 km average).
			LNG	0.011548			kg CO_2e per tonne.km	2022 UK DEFRA	Sea tanker. Assumed 445 tonne/day produced, 350 days/year. Assumed % 60 LNG shipped to China (16 433 km).
	Products used	Category 1 – Purchased goods and services	Concrete	131.751			kg CO_2e per tonne	2022 UK DEFRA	Assumed tonne/year concrete: 5 940 (wells) + 95 040 (plant, pipeline and overhead line).
			Metal	4018.003			kg CO_2e per tonne	2022 UK DEFRA	Assumed tonne/year metal: 4 560 (wells) + 21 500 (plant, pipeline and overhead line).
			HDPE	3269.839			kg CO_2e per tonne	2022 UK DEFRA	Assumed tonne/year HDPE: 9 000 (pipeline).
	Use of products	Category 11 –	LNG	2559.17			kg CO_2e per tonne	2022 UK DEFRA	Assumed 445 tonne/day

IPCC Category	Description	Emission source	Fuel/materia l	Emission factors			Unit	Source	Notes
				CO_2	CH_4	N_2O			
		Use of sold products							produced, 350 days/year.
	Other sources	Category 5 - Waste generated n operations	Waste	467.0084			kg CO_2e per tonne	2022 UK DEFRA	Industrial waste. Landfill. Assumed 31 428 tonne/year waste.
	Conversion Factors								
	Global Warming Potential (GWP) (100 year time horizon)			1	23	296	tonne CO_2e/tonne	Annexure G (DFFE, 2022)	

9 APPENDIX B – IMPACT SIGNIFICANCE RATING METHODOLOGY

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

Determination of Environmental Risk:

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \frac{(E+D+M+R)}{4} \times N$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 14.

Table 14: Criteria for determining impact consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).

Aspect	Score	Definition
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P (Table 16). Probability is rated/scored as per Table 15.

Table 15: Probability scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur)

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

$$ER = C \times P$$

Table 16: Determination of environmental risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 17.

Table 17: Significance classes

Environmental Risk Score	
Value	Description
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation:

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition, it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision-making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 18: Criteria for determining prioritisation

Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 18. The impact priority is therefore determined as follows:

$$\text{Priority} = PR + CI + LR$$

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (refer to Table 19).

Table 19: Determination of prioritisation factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring (Table 20). The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 20: Final environmental significance rating

Environmental Significance Rating	
Value	Description
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).

26 September 2022

Cluster 2Economic Impact Assessment: Tetra4 (Pty) Ltd Cluster 2 Expansion

CLUSTER 2ASSESSMENT OF THE ECONOMIC NEED AND DESIRABILITY FOR TETRA4'S CLUSTER 2 EXPANSION FOR ENVIRONMENTAL AUTHORISATION PURPOSES

GERRIE MULLER

STRATEGY4GOOD | 17 Barkly Road, Parktown

1 CONTENT

Acronyms

CAGR
Compound Annual Growth Rate, 22, 25
CNG
Compressed Natural Gas, 5
COP
Conference of Parties, 11, 36
ECIA
Economic Impact Assessment, 41
EIA
Environmental Management Programme, 7, 8
GDP
Gross Domestic Product, 12, 14, 15, 16, 17, 18, 19, 29, 38, 39, 40, 43, 53, 60
GGP
Gross Geographical Product, 2, 12, 43, 50, 51, 53, 68, 78, 88, 98, 99
GHG
Greenhouse Gases, 11, 13, 23, 34, 36, 37
GTL
Gas-to-Liquids, 31
IDP
Integrated Development Plan, 48, 50
IRP
Integrated Resource Plan, 11
LED
Local Economic Development, 48, 60
LNG
Liquefied Petroleum Gas, 5, 7, 11
MRI
Magnetic Resonance Imaging, 21
MW
Megawhatt, 11
NDP
National Development Plan, 9
OECD
Organisation for Economic Cooperation and Development, 56
PIC
Public Investment Commission, 14
SARB
South African Reserve Bank, 38
SLP
Social and Labour Plan, 59, 108
VAT
Value Added Tax, 58, 59

2 DECLARATION OF INDEPENDENCE BY SG MULLER T/A STRATEGY4GOOD (‘S4G”)

The following report has been compiled by SG Muller t/a Strategy4Good. Strategy4Good endeavoured to record the economic need and desirability aspects independently and faithfully, and hereby declares they have no commercial interest in the proposed development. Although the applicant is ultimately responsible for paying Strategy4Good’s fees, Strategy4Good is contracted to Environmental Impact Management Services (EIMS), which is an independent Environmental Assessment Practitioner, thus ensuring that the applicant is in no position to effect any undue influence on Strategy4Good’s findings.

Where Strategy4Good reports on the findings of other sources or specialists, or where S4G restates the Applicant’s own views, it is clearly stated.

S4G is a specialist strategy and economic development consultant and has undertaken in excess of fifty economic impact assessments in support of obtaining licenses to operate in the minerals and petroleum sectors. The author, SG Muller, holds a B Admin MBA from the University of Stellenbosch and had undertaken numerous independent socio-economic impact assessments during his career.

SG Muller

3 BACKGROUND TO THE PROJECT

Renergen is an emerging producer of helium and liquefied natural gas (LNG), with existing production and sales of compressed natural gas (CNG). Tetra4 (Pty) Ltd ("Tetra4"), is a wholly owned subsidiary of Renergen Ltd ("Renergen"), a company listed on various stock exchanges. Renergen's major asset is Tetra4, and the latter is the only holder of an onshore petroleum production right in South Africa. Tetra4 is also the first helium developer with proven reserves in SA.[1]

The Group focus on the commercialisation of the Virginia Gas Project, which is comprised of an executed and granted production right for 187 000 hectares of gas-fields across Welkom, Virginia and Theunissen in the Free State. It is understood that he source of the Virginia Gas Project's methane is primarily microbial, originating from deep within the Witwatersrand Supergroup. The methane find is remarkable as the resource had been in existence for millions of years and lay undiscovered deep within Earth's crust (the methane is released because of bacteria in the water). This means that Tetra4's methane is largely biogenic and, as such, could be regarded as a continuous regenerative resource (i.e. renewable).

The above-mentioned resource is being developed in phases and Tetra4 had already completed Cluster 1, which comprised of an investment thus far of just under R1 billion (referred to as cluster 1).

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[1] https://www.renergen.co.za/renergen-rockets-as-it-reports-sevenfold-jump-in-proved-helium-reserves/#:~:text=The%20gas%20group%20said%20on,much%20as%2018%25%20to%20R41.

To view its recent activities, as reported by Renergen dated 30 September 2021, see the below inset from its quarterly report.

Figure 1: Update of Renergen Group Activities to September 2021

Note 1: Source https://www.renergen.co.za/asx-quarterly-activity-report-september-2021/

Tetra4 is in the process of developing the gas field using the existing wells – known as the Cluster 1 project – in conjunction with a drilling programme for future wells. Construction of the Cluster 1 gas gathering pipeline is now underway and due to be completed shortly while the LNG and LHe processing facility is currently being commissioned.

It is Tetra4's objective to expand its existing production capabilities through the implementation of the Cluster 2 LNG/LHe processing facility. The overall project consists of two main components namely, gas gathering, and the LNG/LHe process plant.

IN THIS ASSESSMENT WE TREATED THE LIQUIFIED NATURAL GAS "PRODUCT" ECONOMICALLY AS PART OF THE NATURAL GAS SECTOR IN ORDER TO PUT THE PRODUCT IN A WIDER ECONOMIC PERSPECTIVE, AND WE FOLLOWED THE SAME PRINCIPLE WITH THE "LIQUIFIED HELIUM" PRODUCT – BY GROUPING IT UNDER HELIUM.

As is commonly known liquified gasses can be degassed, and thus by liquifying natural gas Renergen makes it possible to enter the global LNG market. Natural gas in liquid form is compressed almost 600 times, enhancing the economic viability of transportation of this commodity.

4 LEGISLATIVE AND POLICY BACKGROUND

4.1 REGULATORY ENVIRONMENT PERTAINING TO IMPACT ASSESSMENTS

4.1.1 SUSTAINABILITY REGULATIONS

The following sets of South African Government regulations give context to the economic impact assessment.

a. First, as part of the Environmental Impact Assessment (EIA) /Environmental Management Programme (EMPr) process, an alternative economic land use analysis needs to be undertaken to determine whether a proposed development in the energy sector is to the net benefit of the economy. The requirement of this analysis is encapsulated in Regulation 50(c)[2], which has two distinct components - the first being a straight analysis of the economic value of land between a mining or gas production project and the predominant alternative land-use; and the second being an opinion

[2] Guideline For The Compilation Of An Environmental Impact Assessment And An Environmental Management Programme To Be Submitted With Applications For A Mining Right In Terms Of The Mineral And Petroleum Resources Development Act, 2002, (Act No. 28 Of 2002) (The Act)". Regulation 50.

on the sustainable development quality of the project relative to the alternative land-use;

b. Second, the Guideline On Need And Desirability In Terms Of The Environmental Impact Assessment (EIA) Regulations, Notice 819 of 2014, provides a number of key economic aspects that an EIA has to cover in order to illustrate the need and desirability of a proposed development;

c. Third, National Environmental Management Act (NEMA – Act No. 107 of 1998) itself specifies in its Preamble that "*sustainable development requires the integration of social, economic and environmental factors in the planning, implementation and evaluation of decisions to ensure that development serves present and future generations".* It furthermore states that *"the social, economic and environmental impacts of activities, including disadvantages and benefits must be considered assessed and evaluated, and decisions must be appropriate in the light of such consideration and assessment*.

4.1.2 GAS ACT, 2001

The objectives of the amended Gas Act of 2001 strongly support the development of gas projects such as that of Tetra4. The objectives are to:

- Provide for the promotion of the orderly development of the gas industry;
- Enhance the national regulatory framework;
- Promote broad-based black economic empowerment;
- Provide for socio-economic and environmentally sustainable development;
- Provide for new developments and changing technologies in the gas sector;
- Facilitate gas infrastructure development and investment;
- Provide for cooperation between the private and public sectors in the gas industry;
- Strengthen enforcement and improve compliance;
- And to provide for matters connected therewith.

4.1.3 GAS MASTER PLAN

Adding to the above sustainability regulatory section, the Gas Master Plan for SA is an important consideration and a short paragraph that indicates its relevance to SA is given below.

The SA Government has published a Gas Master Plan in December 2021 for comments from the public. The background to the Master Plan is the following (quoted directly from the plan): "The National

Development Plan (NDP) envisions that by 2030 South Africa will have an energy sector that promotes economic growth and development through adequate investment in energy infrastructure. At just 2.6% of the country's total energy mix, South Africa's natural gas market is small, but with all its inherent benefits, it has the potential to completely change the economy by stimulating economic growth and development, stability, and job creation. The meaningful addition of natural gas to the country's energy mix will rejuvenate an overburdened, out-dated energy infrastructure and reduce cyclical energy shortfalls. Perhaps even more importantly, it will stimulate the economy by allowing business and industry to lower their energy and operational spend while also creating significant numbers of new jobs and skills development opportunities. Considering that nearly 90% of South Africa's existing natural gas demand is supplied by a single entity, namely Sasol Gas, the associated economic and employment risks of limited supply options, development and sourcing of alternative natural gas resources are high. It is imperative to ensure economic and employment stability within the natural gas sector by introducing more suppliers. Southern Africa's gas potential has been revealed by major discoveries that, when developed, widen options for greater regional energy trade. South Africa's unconventional gas potential remains to be quantified but raises the prospect of possible domestic production in the longer term. Globally the natural gas industry has moved into a supply surplus, favouring a larger role for gas as a clean fossil fuel in many countries' energy policies. A challenge in developing the gas sector is to bring gas demand and supply on stream at the same time and spread geographically to stimulate broader localized demand through South Africa. Without such localized gas demand, it is difficult to develop distributed gas supply and without such distributed gas supply it is difficult to develop localized gas demand. One way of breaking this impasse is to create significant "anchor" gas demand through the development of a gas-to-power programme. In pursuit of adding generating capacity, lowering carbon emissions, enhancing energy security and supporting industrial development, South Africa has taken the first steps in a gas-to-power programme to be executed under the Integrated Resource Plan 2019, aiming to increase the national energy mix natural gas contribution from 2.6% to 15.7% by 2030."

4.1.4 REGULATORY CONCLUSION

As with any large-scale development that triggers an Environmental Impact Assessment, Tetra4 must comply with a broad scope of laws and regulations. The above short paragraphs were not intended to do justice to all the regulations, but is stated here as acknowledgement that this report need to comply with these regulations.

In the case of this report the critical issues from a compliance perspective are the following:

a) Stating the positives of the economic development to juxtapose the potential harmful impacts on society and the environment.

b) Stating whether current economic interests may be negatively impacted.

c) Stating whether the current land-use is not better economically as it stands.

5 NEED AND DESIRABILITY SECTION

As shown in the section immediately preceding, a need and desirability assessment is required for the Tetra4 expansion.

5.1 EXECUTIVE SUMMARY

Renergen is Tetra4's holding company and the group is an emerging helium and domestic natural gas producer. Renergen holds the rights to natural gas fields in the Free State, South Africa, and it is important to note that these gas fields have unusually high helium concentrations.

The necessity for this economic need and desirability assessment is triggered by Tetra4's proposed Cluster 2 expansion in terms of South Africa's regulatory requirements to obtain an environmental authorisation for the planned activities. Tetra4's Cluster 2 expansion is the result of the company desiring to expand its existing helium and methane gas production and beneficiation within its existing Production Right area.

The probable and proven natural gas reserves as put forward by Renergen is of significant volumes, and thus the proposed expansion could be viewed as one of the more strategic investments in South Africa at present from an energy perspective. It certainly has the potential of being one of the largest business expansions in the Matjhabeng Municipality in recent years.

Table 1: Renergen Resources and Reserves

In Billion Cubic Feet		Mar-19	Sep-21	% Change	
Methane *Proven*	Phase - 1P	40.8	215.1	***427%***	BCF
	Phase - 2P	**138.9**	**407.0**	***193%***	
	Phase - 3P	284.2	600.1	***111%***	
Helium *Proven*	Phase - 1P	1.0	7.2	***610%***	BCF
	Phase - 2P	**3.4**	**13.6**	***298%***	
	Phase - 3P	6.9	20.0	***192%***	

Source 1: Tetra4 provided information

Theoretically, if 600 billion cubic feet of gas (see phase 3P above) is converted over 100 years to electricity it could cover SA's current installed capacity of approximately 60 Gwh with ease. However, this is theoretically only as the process of conversion poses its own challenges.

The key positive findings in favour of the need and desirability of Tetra4's expansion are the following:

1. **Domestically sourced gas.** The value of an own sourced gas plant cannot be over-emphasized. The biggest criticism of most nascent gas projects aiming to alleviate South Africa's electricity crises is that the input costs (thus imported gas) may be exorbitantly expensive and is an obvious inflationary risk to SA. In the case of the Tetra4 development the gas is captured from local geological sources thus avoiding the disadvantage of being a price-taker. However, cognisance is taken that gas may well be sold at international commodity prices, but a locally sourced gas can give SA the flexibility around pricing.
2. **The establishment of a self-sufficient helium industry in SA.** As is known SA imports all its helium, and therefore this development could result in the establishment of a self-sustaining helium industry in the country which have several benefits, one of which is the considerable foreign exchange savings, the other becoming a major exporter of helium. This is significant considering that helium is a scarce resource and whilst the gas' demand continues to rise, it's global supply could be under threat. (See sections below for discussion on the demand and supply for Helium).
3. **The contribution to a more competitive natural gas sector in SA.** It is discussed in the sections below that for historic reasons the gas sector in SA is small and uncompetitive. Based on the consideration that the establishment of a gas sector in SA is viewed by many as a necessary step to meet SA's COP 26 GHG emissions reductions, then it follows that Tetra4's expansion ought to be seen as very needed and desirable. (Natural gas is a better energy source than coal due to gas' lower CO_2 emission rates). There is every reason to believe that with Tetra4's methane resources and reserves, it could be a significant contributor to the competitiveness in SA's natural gas sector.
4. **Potential for cleaner power generation.** The LNG to be processed by Tetra4 could also be used as a source of power generation in South Africa. The significance of this is that the Government of South Africa in the various versions of its integrated resource planning has made it clear that natural gas as a source of power generation is highly desirable. In particular, the various IRP documents highlight the necessity of generating almost 6000 MW of the national grid from gas technologies soon. The discovery of the gas fields in the Free State, and the subsequent exploitation thereof by Tetra4 could therefore be seen as opportune for the SA economy.

5. **Significant positive economic impacts.** Econometrically, there is no doubt that Cluster 2 will contribute significant additions to GDP and employment in the local economy. Cluster 2's GDP contributions from the Tetra4 expansion after multipliers are potentially up to 13% relative to the Matjhabeng GGP, and employment is nearly 5.8% of that base. (Note that these ratios are *relative to* Matjhabeng because much of these benefits will leak out of the local economy). Captured as an addition *within* the Matjhabeng economy it is likely to be 6.9% of GGP and 1.5% of current employment.

   In addition to the aforementioned, Tetra4 is planning on investing approximately R13 billion in South Africa over its Cluster 2 investment period of 2 years. After considering the potential leakages through exports of the Cluster 2 investment, and adding in investment multipliers, it is estimated that the project's investment amount relative to Matjhabeng' total gross geographic fixed capital formation (new investment plus depreciation) would amount to 57%. This is a significant increase, and its positive impact cannot be overstated.

   A further positive economic aspect is that of the contribution to SA's current account in its balance of payments. The significance of this aspect is that without earning hard-currency through exports South Africa would not be able to import goods and services without depleting its foreign exchange resources. South Africa over the last 10 years has had a negative current account of approximately R127 billion per annum on average. Therefore, the estimated turnover of R6 billion per annum of Tetra4 could contribute strongly to the current account of the country given that most of this turnover would either be exports or import substitution.

6. Furthermore, **the likelihood of future expansions** remains, and these increases will add further value to the economy.

<u>The argument against, or perhaps in the neutral category is the following:</u>

Detractors of prioritising natural gas over "green" renewable energy point out two arguments against natural gas over green energy:

1. Natural gas still emits CO_2, and hence the problem of mostly eradicating greenhouse gas emissions globally remains unresolved[3] if natural gas continues to be a source of energy.
2. In addition to this, natural gas is composed of 70-90% methane, a potent greenhouse gas and major contributor to global warming. The argument is put forward that 2-3% of methane escapes during processing, transmission, and distribution. These fugitive emissions add to global warming.

Proponents of cleaner energy in South Africa have vociferously proposed that the country bypasses natural gas developments in its entirety and concentrates only on renewables like solar, wind and hydro. (It must be noted that helium is NOT((a GHG because if anything, it will cool the earth's atmosphere, and due to its lightweight properties, it escapes into space and does not trap heat in the atmosphere.)

Despite the above concerns, the overall conclusion based on this assessment is that the economic need and desirability of Tetra4's expansion is significantly high. The main reasons are: 1) The establishment of an onshore natural gas and helium processing facility, 2) the urgent need to replace coal as a source of energy in SA, and 3) the significant economic benefits proposed.

5.2 ASSESSMENT OF THE ECONOMIC NEED AND DESIRABILITY OF TETRA4 EXPANSION

5.2.1 LIMITATIONS AND ASSUMPTIONS OF ECONOMIC IMPACT ASSESSMENTS

Prior to stating the findings of this economic assessment, several limitations and assumptions to the statistics presented below in Table 2 below need to be mentioned:

a. Although Tetra4's Cluster 1 production is in progress (thus there is direct evidence that the enterprise is operational and viable), the Cluster 2 economic impact is based on an intent, namely Tetra4's intent to generate the output and employment as is discussed below. The

Pounds of CO2 emitted per million British thermal units (Btu) of energy for various fuels

Coal (anthracite)	228.6
Coal (bituminous)	205.7
Diesel fuel and heating oil	161.3
Gasoline (without ethanol)	157.2
Propane	139.0
Natural gas	117.0

Source: eia.gov

3

eventuation of these benefits is reliant on an economically viable Tetra4, an assumption that is made in this report.

b. As a sub-section of the economic viability, it is assumed that Tetra4 will be fully funded for its Cluster 2 project. (News of the PIC willing to invest R1billion has surfaced in April 2022, which is a vote of confidence by the PIC in the Tetra4 expansion.)

c. Accepting of the above assumption, the next limitation is the ratios and multipliers used in the economic valuation. Although care was taken to use acceptable economic science, there is always a risk that some of the estimates may not eventuate in practice, and hence that the actualised economic and employment benefits may be much less. This is a limitation over which no assessment has control but needs to be mentioned.

d. A further important limitation is that multipliers on a national level are different compared to a municipal level. This is due to the "leakages" from a local economy, for example income earned by a mine is often distributed to a region outside the enterprise's' municipality, or procurement if from outside the region, or salaries and wages are not always spent in a local economy. For this reason the direct impact is used as a barometer of impacts on the local economy and when multipliers were included those ratios were stated as *relative to* the local economy. However, despite this limitation the economy-wide benefits compared to the local base is instructive as it allows a competent authority a better perspective of the total local and national benefits relative to the local base.

e. The gas multipliers for a well-established gas driven economy will be different to that of SA and for this reason, where possible, multipliers were adjusted to assume a more mature gas industry in SA.

f. The economic impacts are calculated on the supply side of the economy in an optimal year. Thus, GDP is calculated as the sum of salaries and wages, depreciation and gross operating profit for the optimal year.

g. For a long-term project such as Tetra4 the net present value of economic benefits could also have been used, but it has been shown that using the optimal year methodology (which we use), is equally correct, and easier to understand for the lay reader.

h. The investment of the project is used separately as year 1 and 2 increases in GDP.

i. As the world had experienced, outlier events such as the impact of Covid-19 are not included in this assessment.

5.3 FACTORS IN FAVOUR OF THE ECONOMIC NEED AND DESIRABILITY

5.3.1 POSITIVE ECONOMIC IMPACTS

This section outlines the positive economic impacts of Cluster 2 based on an analysis of the potential economic output of the expansion.

5.3.1.1 Assessment of the economic data in Table 2 below

The economic impact is based on the optimum production year principle, which is one specific year. In this regard, we selected 6 years from today, namely 2028. The basis for selection is that in that year Tetra4 will be in full production as is anticipated in the Cluster 2 expansion.

Table 2: Economic impact assessment basis of assessment

Phase 2		Row #
Assume steady state date	2028 Total	
Daily Volume - 1000 Standard Cubic Feet	44 000	1
Yearly Volume - 1000 Standard Cubic Feet - 265 workdays	9 900 000	2
US Dollar Price per 1000scf	#N/A	3
Turnover in US Dollars (incl maint days) pa	360 000 000	4
Rand:USD Exchange (2028)	18.4	5
Turnover in Rand pa - Rand million	6 641	6
% GDP:Turnover - Estmated natural gas	55%	7
GDP (Economic Value Added by Tetra 4) pa Rand Million	3 653	8
Add GDP Multiplier	1.87	9
National GDP Addition - R Million	6 822	10
Estimated Direct Employment	1 218	11
Employment Multiplier	3.80	12
Total Employment	4 623	13
GGP Matjhabeng - 2028 Est (Rand Million)	53 221	14
% relative to GGP including mulitpliers	12.8%	15
Estimated Employment in Matjhabeng	80 211	16
% Additional employment relative to Matjhabeng	5.8%	17
New Investment over 2 years (Rounded off) - Rand Million	13 000	18
Deduct for imports (Equipment, Fabrication and Installation)	6 500	19
Annualise (Above investment over two years)	3 250	20
Estimated national investment multiplier	1.87	21
New investment after leakage and added multipliers per annum	6 078	22
Average investment in Matjabeng per annum	10 644	23
% New Investment relative to Matjabeng Economy pa	57%	24
Average Current Account last 10 years	(127 176)	25
Tetra4 potential Mitigation to Current Account	6000	26
Tetra4 potential Mitigation to Current Account %	5%	27

Source 2: OWN CALCULATIONS

Please note that the mix of LNG to Helium may change from time to time depending on demand. The current mix of the resource is circa 4% Helium and 96% Methane/LNG.

The key findings are outlined below.

- In row 8 in Table 2 above we show that in an optimal year for Cluster 2, Tetra4 could add an additional R3.65 billion to the local economy. Including multipliers, this additional GDP could increase to R6.8 billion. Relative to the Matjhabeng economy, this is a 13% addition to GDP. Subject to economic multiplier leakage, this is a significant additional amount to the local economy.

- Row 11 shows that an additional 1 218 jobs could be created, and after multipliers this could amount to 4 623 jobs throughout the country. Relative to the local economy, this is an addition of just over 5% and needs to be considered as a significantly positive impact.
- The employment multiplier is higher than the GDP multiplier because the gas and helium industry is capital intensive, meaning its cost per job created is high, and as the cost per job in downstream industries are lower, thus the multiplier is in favour of job-creation downstream. In simple terms this means that one job created by Tetra4 has the potential of creating almost 4x as many formal jobs.
- A further factor is that the project could save SA R6.6 billion in foreign exchange per annum – foreign exchange earnings in a stable currency are important for a country as it is an indication of wealth – the more stable currency a country possesses, the higher the quality of its financial standing in the world which results in better trading relations and less expensive cost of capital.

Cognisant of the assumptions and limitations, there cannot be any doubt that the Cluster 2 Expansion can only be significantly positive from an economic perspective, thus the perspective of quantitative economics benefits.

5.3.1.2 EXPLANATION OF NOTES IN ABOVE TABLE

1. The estimated volume of processing per day is shown in the first row. This information is sourced from a presentation made by Renergen and the link is included in the graphic below.

Source 3: https://www.renergen.co.za/virginia-gas-project-reserves-resources-update/

2. This row was simply multiplying the day's output by the days of the year, after making provision for break-downs and maintenance days, to result in the annual volumes. This is obviously done as an economic analysis is done on an annual basis.
3. The prices for methane and helium in 2028 is conservative as these are today's prices as indicated by Tetra4 presentations. The prices used were US Dollar Price per 1000 scf of 15 and 250 for LNG and helium respectively.
4. This is simply volume x unit prices.
5. In this row we project the rand to weaken by 3% per annum against the US Dollar. The basis is simply the expected inflation differential between SA and the United States (even though at the time of writing this report there seems to be an aberration in inflation rates due to Covid's impacts.)
6. In this row we simply state the potential Rand Turnover in 2028.
7. This row is the estimated percentage of GDP to Turnover. The GDP of an enterprise (on the supply side) is in short, the sum of EBITDA and Salaries and Wages. Why is GDP the equivalent of EBITDA and Salaries and Wages? This is because procurement from an external enterprise, be that electricity or insurance services, is recorded as income to that third party and if

included in a GDP total it would amount to double counting in an economy. For a large economy, of which SA is one, a GDP:Turnover statistic is stable over years due to the inherent structure of such an economy. Because Tetra4 is not in full production it would be difficult to estimate its "GDP" (note a company's "GDP" is also very similar to its Economic Value Add). Thus, using historical GDP:Turnover[4] ratios would yield good enough results to evaluate this project's economic need and desirability. However, because SA does not a well-established natural gas sector (this sector is combined with the electricity sector in SA's economic data), we relied on our own calculations[5] to determine a GDP:Turnover ratio appropriate for this assessment. (We combined data from the United States of America and South Africa.) We concluded that a 55% GDP:Turnover ratio is an acceptable ratio for the purposes of this assessment.

8. This row returns the potential GDP produced by Tetra4 to be added to the SA economy.
9. This row adds an estimated multiplier to the direct increase in GDP produced by Tetra4. The multiplier works on the basis that as the GDP in an industry increases, there will be knock-on demand from other sectors (e.g. Tetra4 will procure goods and services), which leads to an indirect increase in GDP. The additional salaries and wages then earned throughout the economy will result in increased consumption in the economy, and hence what is termed an "induced" impact is put into effect. Together the direct, indirect and induced impacts are the economic-wide impacts. We concluded that a 1.87 is an acceptable GDP multiplier for the purpose of this economic need and desirability study.[i]
10. This row is the product of the GDP multiplier and the direct GDP added by Tetra4.
11. This row is the estimated number of direct jobs that could be created by Tetra4. We estimated the number of jobs by dividing the additional GDP with a GDP per employee in the gas sector. This resulted in an average number of jobs created. Working with estimated number of employees based on industry averages is preferred to employment estimates by Tetra4 for the simple reason that when working with a steady state mining statistic, it is best to work with industry averages rather than projected actual numbers due to a potential mismatch between a specific project estimate and tried and tested estimates based on a larger economic structure. Over the long term, individual enterprises have a strong tendency to approximate

[4] Please note that in economics the term "Gross Output" is a proxy for "Turnover" and although these two economic quantalities are slightly different, we use the economic GDP:Gross Output as a proxy for GDP:Turnover.

[5] We used the published multipliers in South Africa for the electricity and gas sector. It turned out that the GDP:Turnover ratio in the SA Gas and Electricity Sector is very similar to the ratio of the Gas Sector in the USA. Perhaps this is coincidence.

industry averages. From an evaluation perspective, using these average statistics tend to result in a better assessment.

12. This row shows the employment multiplier and the same principles outlined in row 9 are applicable here.
13. This is the product of the direct employment and employment multiplier.
14. This is this report's own estimate of Matjhabeng's GDP in 2028.
15. The result in this row is the division between the increased GDP of the project and the Matjhabeng GDP.
16. Estimated employment in Matjhabeng in 2028.
17. The division between the potential additional employment generated and the Matjhabeng employment.
18. This row shows the estimated investment amount of Cluster 2 that is being planned for the expansion.
19. This row shows the estimated investment after a 50% reduction for potential imports of equipment and services during the investment phase.
20. This row shows the Tetra4 local investment divided by two as the investment will take place over two years.
21. This row shows the estimated national investment multiplier.
22. This row is the product of the net local investment and the national investment multiplier.
23. This row shows the average gross domestic fixed investment of the local economy based on our own estimate as derived from national averages from the SA Reserve Bank. Using National statistics, we estimate that at present the gross domestic fixed investment (read gross investment) for the local economy amounts to R10 billion.
24. This row simply shows the division between rows 22 and 23.
25. This row shows the *average* amount of SA's Current Account – this amounted to a negative average of R127 billion for the last 10 years.
26. This row shows the potential foreign exchange earnings that could be generated by Tetra4 during optimal processing.
27. This row shows the potential mitigation that could result because of the Tetra4 expansion.

5.3.2 THE DEMAND FOR HELIUM

The demand for a product or service is defined as a consumer's desire to purchase goods and services and willingness to pay a price for such goods or services. The processing of helium is a high priority for Tetra4 and the demand for this gas is important for the assessment of this expansion. Assuming the reader of this report may well not be an scientist or engineer, the below definition of helium is tendered.

5.3.2.1 What is helium?

Helium is the second most abundant element in the universe after hydrogen. It is a colourless and odourless inert[6] gas that has unique properties.

5.3.2.2 What makes helium so unique?

Of all the elements, helium is the most stable; it will not burn or react with other elements. Helium has the lowest melting and boiling points. It exists as a gas, except under extreme conditions. At temperatures near *absolute* zero, helium is a liquid; most materials are solid when cooled to such low temperatures. Helium is therefore one of the most important cooling agents on the planet.

5.3.2.3 Where does helium come from?

Helium is a non-renewable natural resource that is most recovered from natural gas deposits. Thus, helium is mostly a by-product of natural gas fields. It is important to note that helium is found in recoverable quantities in only a few locations around the world, many of which are being depleted.

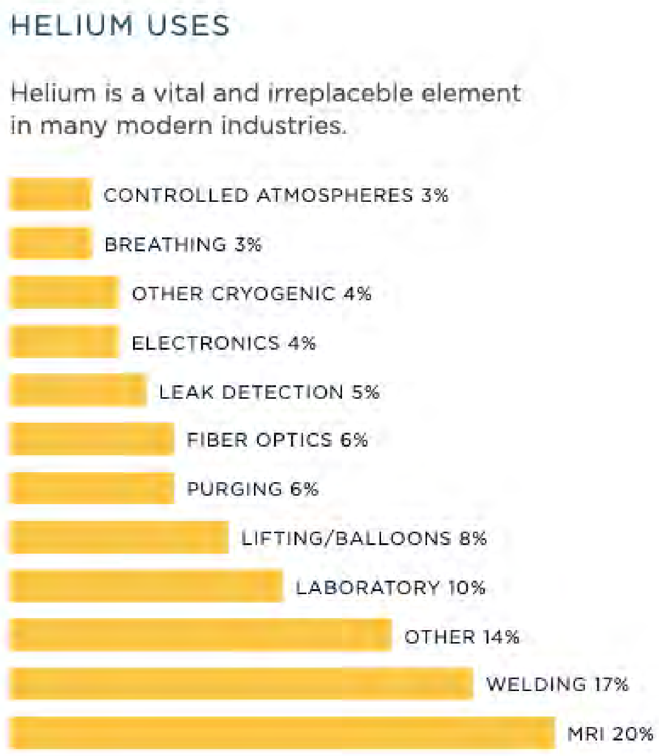
In the gas fields of Virginia in the Free State, the source of helium for this study is indicated as being unique given the *high* helium content in the gas field. This makes this development a potential "game changer" in the helium industry in that Tetra4 could produce helium as its prime product, with methane potentially being a by-product. This is a different strategy to how helium is currently recovered worldwide. The uniqueness of this situation is that as pressure increases on reducing gas production worldwide, helium production will also decline. However, in the case of Tetra4, as said, this status quo is reversed, meaning that the Virginia Gas fields may well become a significant strategic helium resource in the world.

5.3.2.4 What is helium used for, and why is it a strategic natural resource?

Perhaps the most familiar use of helium is as a safe, non-flammable gas to fill party and parade balloons. However, helium is a critical component in many fields, including scientific research, medical technology, high-tech manufacturing, space exploration, and national defence.

[6] An inert gas is a gas that does not undergo chemical reactions under a set of given conditions. The noble gases often do not react with many substances and were historically referred to as the inert gases. Inert gases are used generally to avoid unwanted chemical reactions degrading a sample. These undesirable chemical reactions are often oxidation and hydrolysis reactions with the oxygen and moisture in air. The term inert gas is context-dependent because several of the noble gases can be made to react under certain conditions.

Figure 2: Uses of helium



As can be seen in the graph to the left, the largest use of helium is in magnetic resonance imaging (MRI). Liquid helium is the ideal temperature to maintain superconducting magnets in MRI's and help them work at their full potential. The ideal temperature for the highest resolution images is 4,15 Kelvin, which is -269 degrees Celsius. Using liquid helium for MRI machines will ensure the best imaging results and safety.

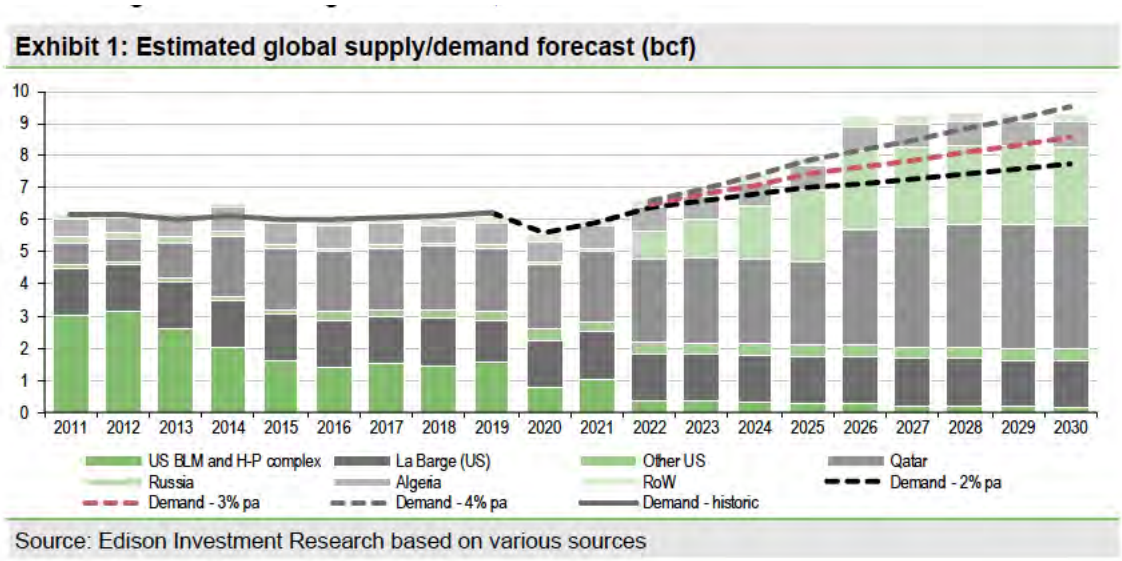
Other uses of helium, in no particular order, is as an inert-gas for welding metals such as aluminium; in rocket propulsion (to pressurize fuel tanks, especially those for liquid hydrogen, because only helium is still a gas at liquid-hydrogen temperature); in meteorology (as a lifting gas for instrument-carrying balloons); in cryogenics (as a coolant because liquid helium is the coldest substance); and in high-pressure breathing operations (mixed with oxygen, as in scuba diving and caisson work, especially because of its low solubility in the bloodstream).

When looking at the future uses of helium, there is overwhelming evidence that this element with its rare properties will continue to be in demand. Research is showing that helium is increasingly used in the health industry, and as a coolant in the military and rocket industries. In addition, helium is targeted as a coolant in the potential new nuclear energy generators using fusion, as opposed to fission. In addition, increasing consumption of helium in the electronics and semiconductor industry is expected.

5.3.2.5 Demand predictions for Helium

The importance of the demand for helium is that an economic need and desirability would be low if a sufficient demand now, or in the future, could not be established. In this regard, all indications are that the demand for helium is strong and sustainable, thus contributing strongly to the economic need and desirability of this expansion.

Figure 3: Global Demand and Supply of helium – Billion Cubic Feet



Note 2: Source Edison Investment Research

The above graph was sourced from the Edison Research Group as published on Renergen's website. It shows a possible slight oversupply of helium in next few years, but thereafter demand is likely to outstrip supply (all things being equal).

A few independent forecasts for the global growth in demand for helium are mentioned below:

- Energy Industry Review, an energy magazine in Europe, predicts a 4% CAGR between 2019 and 2027.
- Mordor Intelligence, an independent research company, also predicted growth at 4% CAGR between 2021 and 2026.
- Global Newswire, an independent market analyst reporting on listed investments, predicts the growth to be 4.5% to 2030.
- Various other sources put the growth rate of helium much higher than the three sources above - at between 5-11% CAGR based on the continued increase in scientific and technological innovation.

The conclusion about the demand for helium is that every source on the internet that we scanned predicts a healthy growth in the demand for helium. It can therefore be concluded that helium is in strong demand globally, which is a positive factor for the economic need and desirability of the Tetra4 expansion.

5.3.3 THE DEMAND FOR NATURAL GAS IN THE ECONOMY[ii]

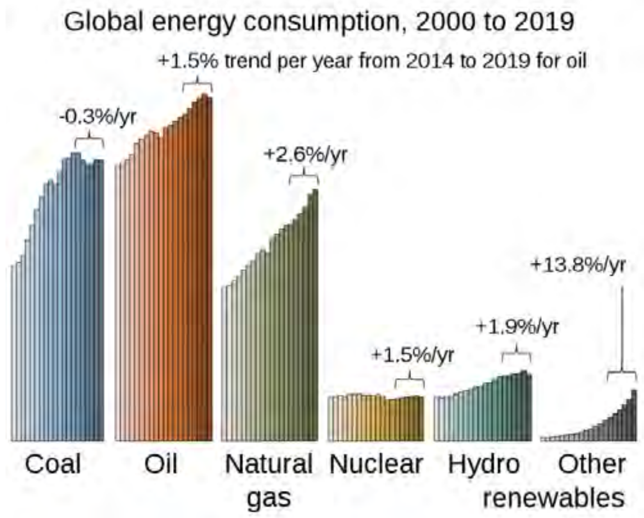
In this and the section below, the need for natural gas is discussed. Note that natural gas is largely composed of methane, and the gas fields under discussion yields methane as its primary gas. Thus, in discussing natural gas, a discussion of methane is implicit.

The self-evident nature of the need for natural gas is stated in the list of items below (not an exhaustive list):

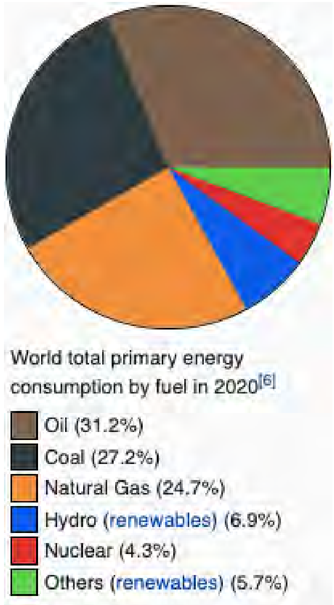
- The electric power sector uses natural gas to generate electricity. For example, natural gas accounted for 40% of U.S. electricity generation in 2020, as opposed to 3% in SA.
- The industrial sector uses natural gas as a fuel for heating, as a feedstock to produce chemicals, fertilizer and hydrogen, and many other applications.
- The residential sector uses natural gas for heating, cooking and other applications.
- The commercial sector needs natural gas to heat buildings and water, to operate refrigeration and cooling equipment, to cook, to dry clothes, and to provide outdoor lighting. Some consumers in the commercial sector also use natural gas as a fuel in combined heat and power systems.
- The transportation sector uses natural gas as a fuel to operate compressors that move natural gas through pipelines and as a vehicle fuel in the form of compressed natural gas and liquefied natural gas.

In the insets following below, we show some statistics and trends on the growth and demand for natural gas. At the end of this section, and at the end of the report the contradiction in the use of natural gas ought to be clear – it's regarded as a bridging source of energy by most responsible governments today because it emits less GHG's than coal, but its long-term usage will continue to be under pressure as it remains a fossil fuel.

Figure 4: Global Energy Composition and Growth

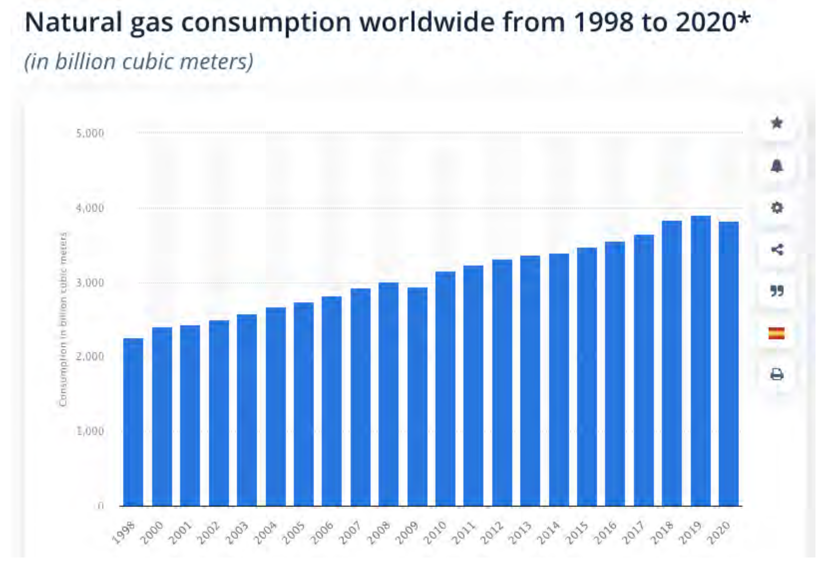


The figure to the left shows that natural gas is growing second only to renewables (2.6%), and it makes up, as can be seen below 24.7% of energy consumption globally.



Source: 1: https://en.wikipedia.org/wiki/World_energy_supply_and_consumption#/media/File:Global_Energy_Consumption.svg

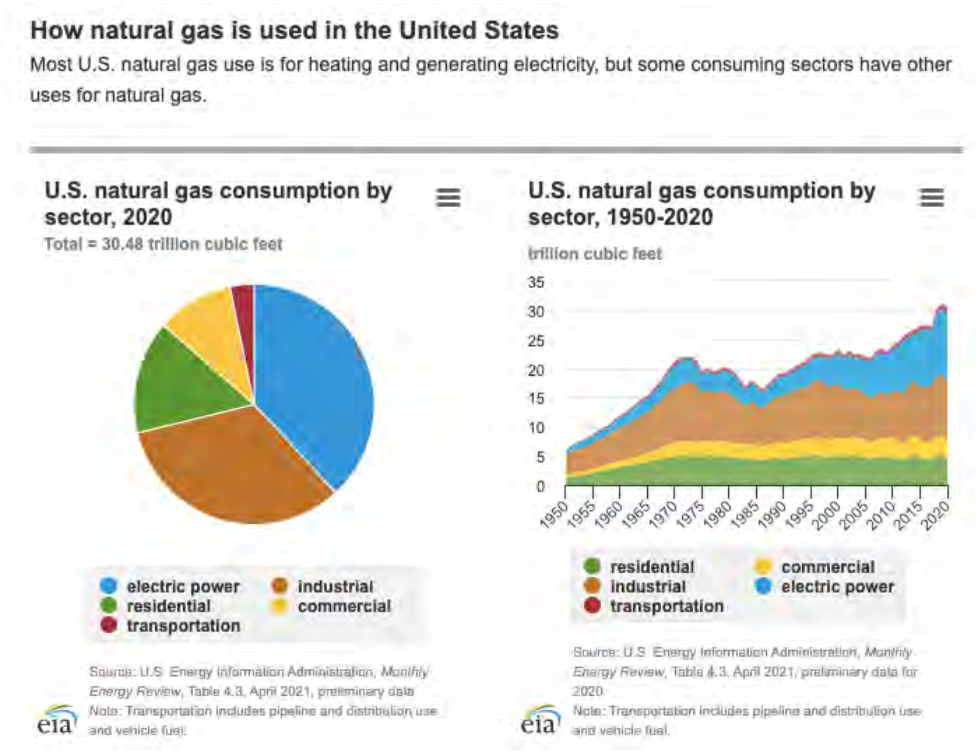
Figure 5: 2.4% CAGR in Natural Gas Consumption



The figure to the left shows the growth in natural gas usage globally. The trend is continually upward, and as indicated above, at 2.6% by volume annually.

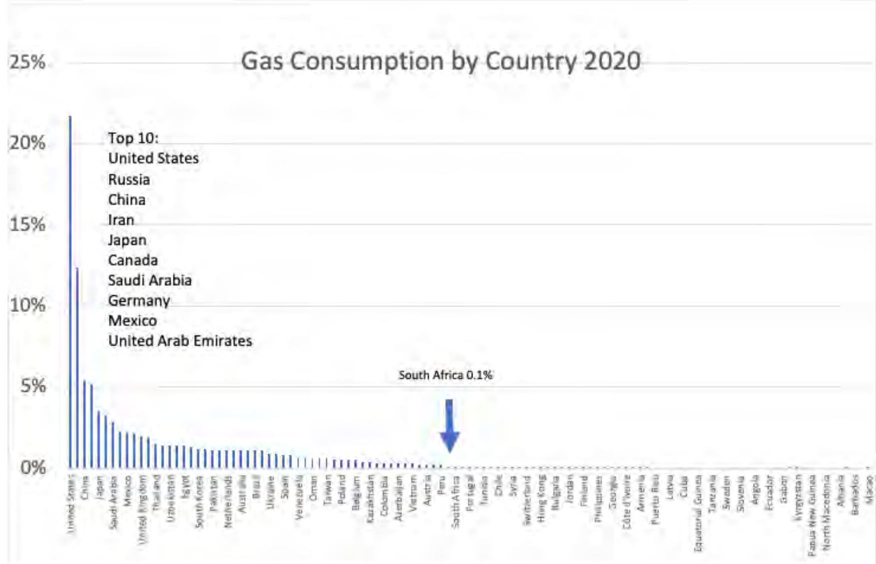
Source: 2 https://www.statista.com/statistics/282717/global-natural-gas-consumption/

Figure 6: Graphic illustration of the use of natural gas by one country, USA



Note 3: https://www.eia.gov/energyexplained/natural-gas/use-of-natural-gas.php

Figure 7: Gas Consumption in South Africa

	As could be expected, South Africa makes up a small market for gas consumption globally.

Source: 3: https://www.worldometers.info/gas/gas-consumption-by-country/

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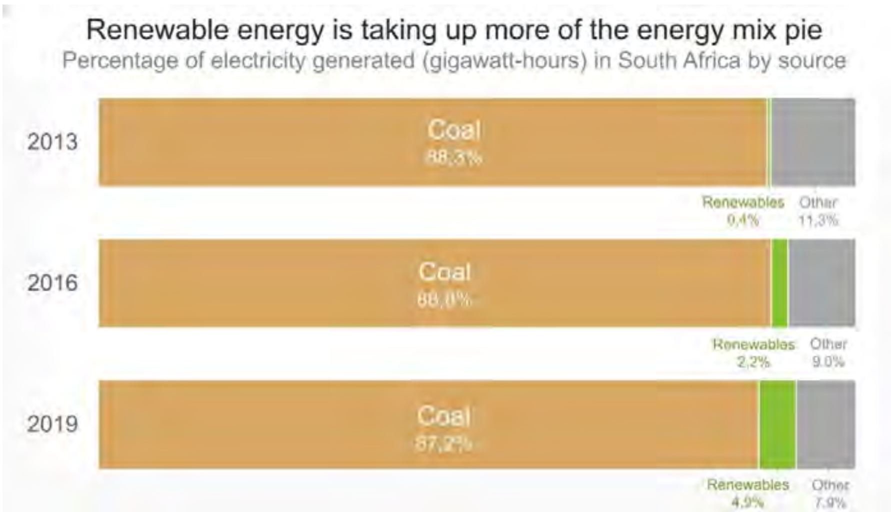
Figure 8: Electricity generation sources in SA - Gas is under "Other".



Source 4: StatsSA

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South Africa is slowly moving away from coal. In 1996, 96% of the country's electricity was generated from coal. Today this proportion is decreasing towards 85%. Given the pressure coal is under, this shift is likely to continue.

Gas comprised only 3% of SA's electricity generation.

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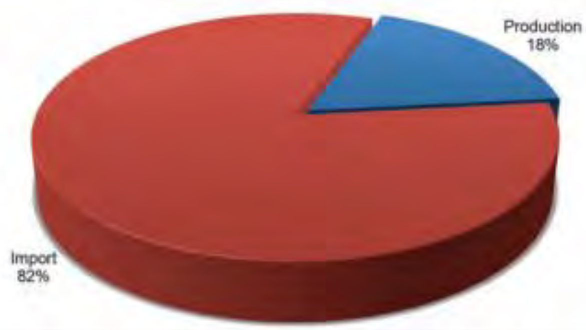
Figure 9: Production and Imports of Natural Gas in South Africa



Source 5: http://www.energy.gov.za/files/media/explained/2019-South-African-Energy-Sector-Report.pdf SA Dept of Energy Balances in a 2019 Report

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As is probably expected, the majority of SA's natural gas is imported.

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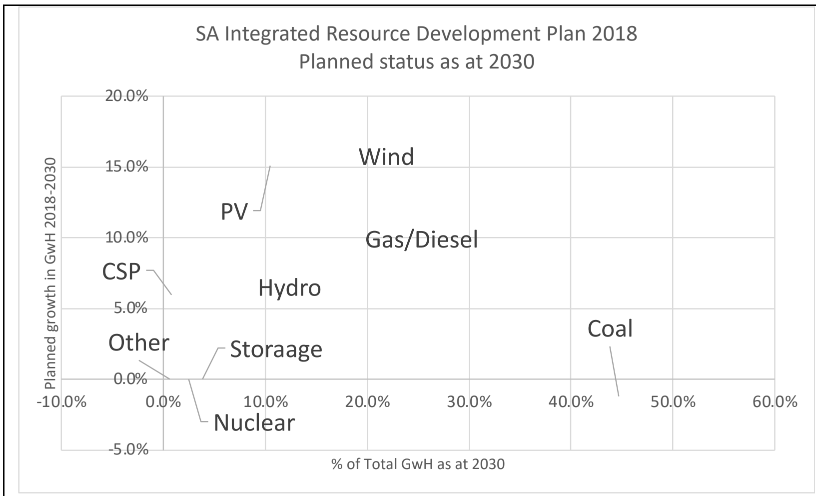
 **Source 6: Source SA Integrated Resource Plan 2018 for 2030**	Estimated gas use by 2030 in SA. Note that natural gas had moved from 5% to 15% of the mix.

5.3.3.1 Conclusion on demand for natural gas in the world and South Africa

From the above it can be concluded that at present gas still plays a significant role in the production of energy in the world. We showed above that gas makes up 25% of the world's electricity production. In addition, the growth in the demand for gas seems stable.

In South Africa, natural gas plays a relatively small part in contributing to electricity generation. Gas is not regarded as a cleaner energy than "green energy" sources, for example solar, water and wind, but is undoubtedly "cleaner" than coal. As a "bridging" source of energy, there is sufficient cause to rate gas as economically needed and desirable, however, this statement is subject to the views of more qualified scientists and engineers. As an economist, one would favour gas processing in SA in the short and medium term, however, it is very likely that at some future point targets will be set to reduce gas production (note not helium) in the same manner as targets are being set to reduce coal production today.

5.3.4 A SUSTAINABLE AND COMPETITIVE LOCAL GAS AND HELIUM INDUSTRY IN SA IS NEEDED

A further factor in favour of Tetra4's expansion application is the potential for the development of a sustainable and competitive gas and helium industry in South Africa.

5.3.4.1 Why is a competitive gas and/or helium industry important for South Africa?

To answer the above question, one must visit the study of economic comparative advantages and the importance of innovation and productivity for an economy. When a country has a comparative advantage economically, such as gold for example historically in SA, that advantage creates economic wealth that then translates into a better quality of life for that country's citizens. Since the advent of the use of oil and gas worldwide, SA has had a comparative disadvantage as it did not possess those natural resources. That meant SA had to (and still does) import most of its oil and gas, which meant that foreign reserves had to be used to pay for such imports. That in itself not only resulted in a decrease in GDP, it also caused a reduction in the country's foreign reserves.

It can be argued that even though SA had been blessed with significant mineral resources, the lack of oil and gas had been the country's Achilles heel. The historic increase in the cost of gas and oil and weakening of the SA Rand had brought about a persistent "imported" inflation to the SA economy for many decades, and unless SA creates its own less expensive and clean energy, the country will remain less economically competitive than it could be.

Ironically, the commodity that SA has in abundance, coal, is today considered as an undesirable commodity because of its effect on warming the earth. Thus, SA faces ominous comparative disadvantages in the generation of future energy - the lack of natural gas, the small amount of energy that can be produced from green energy in the foreseeable future, and the undesirable nature of coal as an energy source.

There is thus a strong case to be made for a much stronger natural gas industry in South Africa.

5.3.4.2 How will the Tetra4 expansion assist with an increase in the Gas and Helium Sector competitiveness?

To answer this question, the competitiveness framework developed by Michael Porter, an eminent economist and strategy consultant, can be applied. We describe his competitiveness framework below and in each section we highlight how Tetra4 can potentially enhance the SA natural gas and helium industry.

An important note, as had been indicated in many sections in this assessment, SA historically did not have a helium producer, and to that extent the advent of Tetra4's helium production is in fact the establishment of a helium industry in this country. Thus, starting from a zero base for helium, one could therefore argue that the need and desirability of the advent of a helium sector in SA is beyond significantly high.

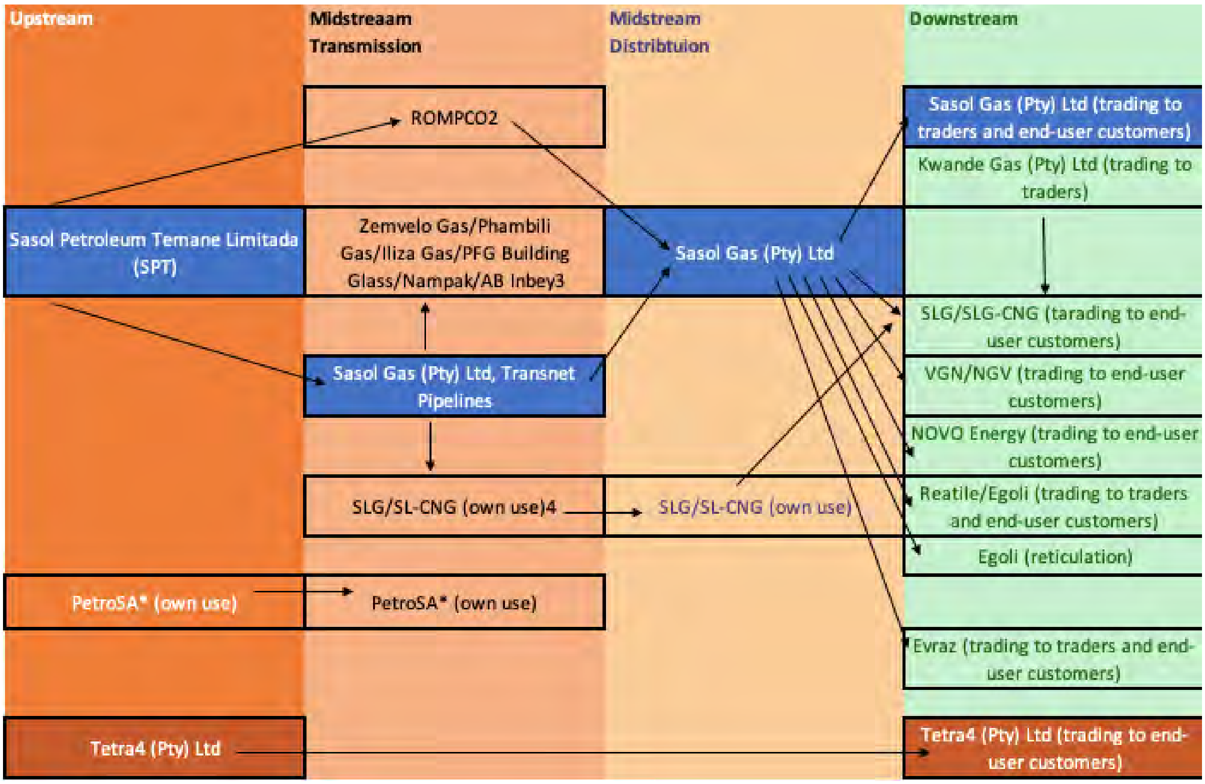
For the reason above, thus accepting that the competitiveness of the helium industry starts from a zero base and hence the establishment of this industry has a high economic need and desirability, we elaborate below only on the increase in competitiveness of the gas sector in SA.

5.3.4.3 Explaining the structure of the SA gas sector

Prior to discussing how Renergen could increase the competitiveness in the SA natural gas sector, a quick overview of the SA gas sector is provided.

The inset below gives a snapshot of the natural gas sector in SA. As indicated below, the supply chain of the piped-gas industry is broadly categorised into three levels, namely upstream, mid-stream and downstream. The upstream level of the piped-gas industry includes gas exploration and production activities. The midstream level comprises transmission and distribution of gas, while the downstream level consists of gas reticulation and trading activities.

Figure 10: SA Natural Gas Sector



Source 7: Nersa 25 February 2021 Report

Based on the above figure, it can be gleaned that Sasol Gas is the dominant gas enterprise in South Africa. From this figure it plays a major role in production, transmission and distribution. Because there are not that many rivals, even in the downstream activities, it follows logically that there can't be lots of rivalry in this sector. It follows further, by mere inference that the SA natural gas sector may not be as efficient a sector as in countries with robust competition.

Prior to Tetra4, there were only two suppliers of gas. The first is Sasol Gas that imports natural gas from the Pande and Temane gas fields in Mozambique to Secunda via the transmission pipeline owned by the Republic of Mozambique Pipeline Investing Company (ROMPCO). (This is a joint venture company comprised of the South African Gas Development Company (Pty) Ltd, and Companhia Mocambicana de Gasoduto S.A.R.L, nominated by their respective governments as the designated shareholders, with a 25% shareholding each. The third shareholder, Sasol Gas Holdings (Pty) Ltd, has a 50% shareholding.) The transmission pipeline is 865 kilometres long with a 26-inch diameter, and a capacity of 147 million Gigajoules per annum.

Sasol Synfuels, which is a coal-based synthetic fuels manufacturing facility, produces methane-rich gas in its plant in Secunda. Synthetic gas is produced through coal gasification and natural gas reforming through the utilisation of Sasol's proprietary technologies.

The other supplier, PetroSA, is a state-owned entity, owned by the Central Energy Fund, and was the only producer of indigenous natural gas. Its offshore producing gas field is in the Bredasdorp basin, and provides feedstock for PetroSA's Gas-to-Liquids (GTL) plant. It produces for its own exclusive use. However, this field is close to being depleted, and further developments of the field have been undertaken to supply feedstock for the GTL plant. In 2011, PetroSA was granted approval to explore additional gas reserves of the coast of Mossel Bay, in which drilling activities have been ongoing.

Sasol Gas is the only supplier of piped-gas in South Africa, given that PetroSA is not a supplier of piped-gas as it uses its production for its GTL plant.

There are two transmission pipeline operators in South Africa – Sasol Gas which owns and operates the gas transmission facilities in the Gauteng, Mpumalanga and Free State Provinces and Transnet Pipelines which owns and operates a gas transmission pipeline, known as the 'Lily' pipeline, from Secunda in Mpumalanga to Durban South in KwaZulu-Natal.

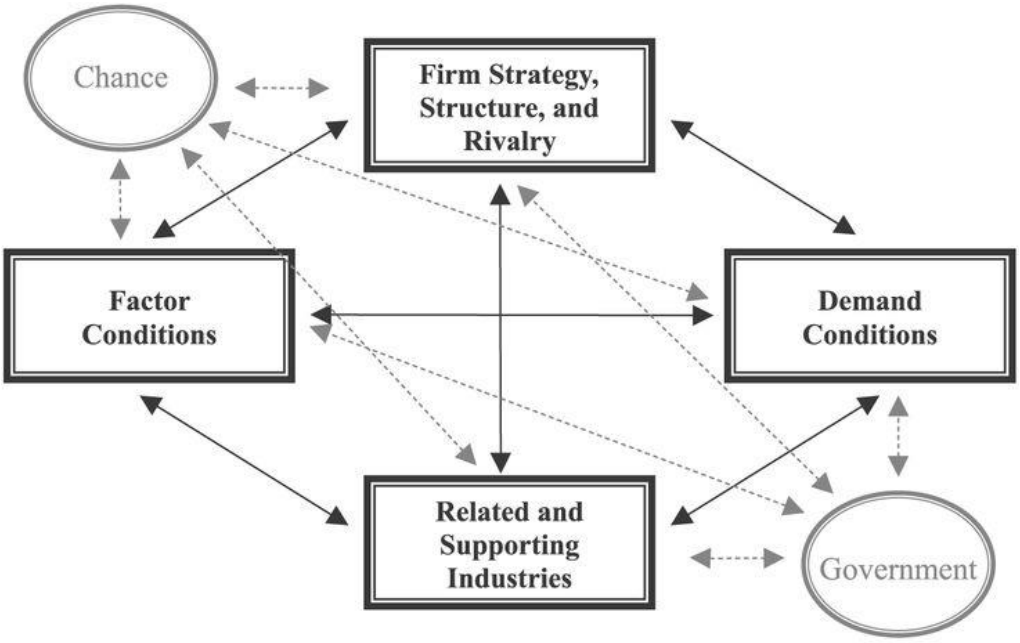
The transmission pipelines owned by Sasol Gas in the Gauteng/Mpumalanga/Free State Provinces have a combined length of approximately 903 kilometres, and a compressor station exists in Komatipoort, Mpumalanga, which facilitates the natural gas delivery from Mozambique into South Africa. These compressor stations are fuelled by the natural gas from the pipelines.

The 'Lily' pipeline is approximately 600 kilometres long, and transports a portion of the methane rich gas from Sasol's Secunda plant to KwaZulu-Natal. The Transnet pipeline extends to Newcastle, Richards Bay and Durban South.

From the above brief overview of the gas sector in SA, the need and desirability of a further gas supplier to increase the competitiveness of the SA gas sector is undoubted. In this regard the economic need and desirability of the Tetra4 expansion becomes even more evident.

To elaborate further on the significance of a competitive gas sector in SA, and why Tetra4 is needed and desirable, the country and industry competitiveness framework of Michael Porter is applied in the section below.

5.3.5 COUNTRY AND INDUSTRY ECONOMIC COMPETITIVENESS



Source: Porter (1990)

Country and industry competitiveness can be described using the following aspects as outlined by Michael Porter in his book *The Competitive Advantage of Nations*.

- Factor conditions – this is the degree of development in a country's basic production factors in a particular industry, being entrepreneurial, labour, physical, intellectual, land and infrastructure, and capital factors.
  - With respect to factor conditions, Tetra4 thus far has shown itself to be entrepreneurial and able to conjoint labour, land and capital to spearhead a new and significant enterprise in the natural gas industry. There is an equally strong argument that the enterprise could prioritise helium over natural gas. However, on the assumption that it equally wants to focus on methane, the project is needed and desirable as it will add greatly to the development of SA's factor conditions.

- Demand conditions - the degree to which national firms create a competitive advantage is dependent on home buyers demanding local firms to innovate and create more advanced products.
    - As an opening remark, the demand conditions for natural gas had historically been poor in SA. One could argue because of the limited usage of natural gas in the SA economy historically, there are not sufficient sophisticated consumers to drive competitiveness. If one compares for example the rivalry and demand conditions of internet data transfer, one will find a large consumer market and many competitors. It is also easy to switch from one supplier to another. Compared to that industry, the gas industry obviously does not have that kind of rivalry and neither does it have that type of consumer sophistication. The reason for this comparison is that for an industry to enhance its competitiveness, it requires many rivals and sophisticated consumers.
    - It is possible that Tetra4's increase in supply of methane may stimulate demand for the product, and this may educate consumers to become more sophisticated, but it is not foreseen that Tetra4 will contribute to a major improvement in gas consumption sophistication in SA in the short to medium future.
- Related and supporting industries – the degree to which these industries assist with important inputs for innovation and internationalisation determines the competitiveness of industries in a country. These industries provide cost-effective inputs, but they also participate in the upgrading process, thus stimulating other companies in the chain to innovate.
    - As a first comment it is important to note that the gas industry is strongly integrated with the electricity generation industry. As showed above, 40% if the United States' electricity is generated by gas and therefore the technology and services that underpin the process of gas-to-powerplant are well established. If Renergen choses to focus on gas-to-power plants then the integration of these two industries in SA are likely to improve the country's gas to power competitiveness.
    - When looking at the related and supporting industries to the natural gas industry, it becomes interesting to note that the finance, insurance, and services industries are the ones that are most inter-related with the natural gas industry (see page 39). The educational and research industries are particularly well integrated with the gas sector in countries with robust gas industries.
    - There is every possibility that Tetra4 would stimulate the supply and sophistication of products and services in related industries, for example more research and education in the natural gas sector, or more technical engineering knowledge and better capital

markets for gas projects. Stimulating the related industries would certainly improve SA's competitiveness in the gas sector.

- Government can influence each of the four determinants of competitiveness. Clearly government can influence the supply conditions of key production factors, demand conditions in the home market, and competition between firms. Government interventions can occur at local, regional, national or multi-national level.
    - All indications are that the current SA Government is gas development positive, and media statements of Government officials indicate that gas is seen as the bridging energy source to achieve sustainable energy supply and reduce GHG emissions in SA.
    - SA furthermore has the Gas Act (Act 48 of 2001) which has as its goal the promotion and orderly development of the piped gas industry.
    - Thus, overlapping the SA Gas Act with that of the Tetra4 expansion plans, where both have as their goal the development of a natural gas sector, every indication is that this determinant ought to improve the competitiveness in the gas sector.
- Chance events are occurrences that are outside of the control of a firm. They are important because they create discontinuities in which some gain competitive positions and other may lose.
    - The significance of chance in the development of the Virginia Gas Fields cannot be under-estimated. The history of the discovery of the gas field is worth reading and is explained on the Renergen website. (www.renergen.co.za)
    - One can argue that it was indeed chance, more than anything else, that brought the opportunity of exploiting a major gas field in a traditionally gold mine and maize pfarm area.
    - Like gold, this is a chance factor that ought to be exploited, all things being equal.
- Role of multinationals – this aspect was added to the Porter model by commentators who indicated that Porter's single home-based diamond approach is incomplete regarding smaller and emerging economies. It is indicated that multinationals make an important contribution to national competitiveness.
    - One of the factors that often short-cuts the increase in competitiveness, is the transfer of technology from international firms. From press statements, it is clear that Tetra4 has aligned itself with numerous multi-nationals that will assist it in achieving operational efficiencies. The benefit of the transfer of technology from leading multi-nationals to an economy such as SA, cannot be underestimated in its value. Over and above chance, one could argue that technology transfer from international

multinationals to Tetra4 are probably the two most important factors in increasing the SA gas sector competitiveness.

- Firm strategy, structure and rivalry is a further determinant of competitiveness. The way in which companies are created, set goals and managed are important for success. The presence of intense rivalry in the home base is also important as it creates pressure to upgrade competitiveness.
  - In can be asserted that that the SA gas sector is one of the sectors with the least rivalry in SA. In the SA gas sector, there are only two producers at present, Sasol and PetroSA - and it cannot be argued that these two companies compete. For that reason, Nersa plays a decisive role in regulating piped gas prices.
  - The entry of Renergen may be a spark that will add to competitiveness in the SA gas sector. For example, if there are sufficient resources, what is to stop Renergen from supplying domestic gas supplies to municipalities for household consumer use?
  - A new entrant to the gas market can only increase competitiveness because competition in an economy drives efficiencies. To this extent, this expansion project could be of great value to the SA economy.

5.3.6 CONCLUSION OF FACTORS IN FAVOUR OF THE NEED AND DESIRABILITY

The above section shows clearly that both the economic quantitative and qualitative factors ought to be considered as positive for the SA economy.

5.4 ARGUMENTS NEUTRAL OR AGAINST THE NATURAL GAS SECTOR'S NEED AND DESIRABILITY

5.4.1 NEGATIVE FACTORS

5.4.1.1 Climate Change Impacts

5.4.1.1.1 Natural gas

In as much as some may consider a discussion of climate change as outside the study of economics, most modern economist would agree that the challenges of climate change today are of such importance that few sciences are unaffected by it, and neither should they be unaffected. There is consensus that global warming is the number one challenge on earth and given that fossil fuels are large contributors to global warming, this topic deserves mentioning, even if as brief as in the few paragraphs below.

The context is that there is more consensus than ever that GHG'es cause global warming. In this regard, SA at COP 26 had pledged to reduce its GHG emissions by reducing its dependence on coal as a source of energy in favour of renewable energy sources. In addition to this, economically, SA runs the risk of being sanctioned by the international community should it persist with an intransigence regarding the use of coal.

Natural gas is therefore seen by many in the country as a "bridging" source of energy because it emits almost 50% less CO_2 than coal. Considering only tailpipe emissions, natural gas is 15-30% cleaner than fuel when it is burned. Thus, if SA converts its coal fired stations to natural gas tomorrow, it will save a considerable amount of GHG emissions.

Thus, based on the above, natural gas is certainly a cleaner energy source than coal, and therefore relative to coal, must be considered as more desirable in this context.

However, detractors of prioritising natural gas over "green" renewable energy point out two particular arguments against natural gas over green energy:

1. Natural gas still emits CO_2, and hence the problem of mostly eradicating greenhouse gas emissions globally remains unresolved[7] if natural gas continues to be a source of electricity.
2. In addition to this, natural gas is composed of 70-90% methane, a potent greenhouse gas and major contributor to global warming. The argument is put forward that 2-3% of methane escapes during processing, transmission and reticulation. These fugitive emissions add to global warming.

Proponents of cleaner energy in South Africa have advocated that the country bypasses natural gas developments in its entirety and concentrate on renewables like solar, wind and water.

7

Pounds of CO2 emitted per million British thermal units (Btu) of energy for various fuels

Coal (anthracite)	228.6
Coal (bituminous)	205.7
Diesel fuel and heating oil	161.3
Gasoline (without ethanol)	157.2
Propane	139.0
Natural gas	117.0

Source: eia.gov

A further interesting observation is that a plethora of gas operators seem to want to enter the SA gas market, and although that could be of major benefit in the reduction of the use of coal, at some future point the debate will intensify regarding the emissions of GHG emissions in the gas industry vs that of other cleaner energy sources.

Economically, common sense does indicate that natural gas offers an interim solution for the climate change target challenges in SA in the short to medium term. In the long term, it is very possible that even natural gas usage becomes an undesirable commodity, as is the case with coal at present. That stated, an economic need and desirability assessment must consider the current generation, and although not discounting future generations, the economics of gas production in SA at present has a strong case.

5.4.1.1.2 Helium

Where the Tetra4 expansion is different from the typical gas producer is in the concentrations of helium in its gas reserves. Whereas an economic cut-off as low as 0.05% helium in natural gas has been proven to be economically viable, Tetra4 has indicated that its helium concentrations are high – between 2-14%. When one considers that helium is NOT a GHG because When the vital use of helium in an economy is furthermore considered, then one has to conclude that the weight of the need and desirability of this project, because of the high helium content, must be rated as high.

As is observed elsewhere in this assessment, because of the pressure on the reduction of gas production, helium may become an ever-scarcer commercially available commodity on earth. Thus, the helium find in the Free State will not only provide in SA's own helium needs, but it also has the potential of contributing significantly to the supply of helium globally.

6 ECONOMIC IMPACT ASSESSMENT SECTION

6.1 RECEIVING ENVIRONMENT

6.1.1 NATIONAL ECONOMY

The national economy, thus the broader receiving environment, is under much stress and in a receiving environment of this nature it would be commonplace to observe that all desirable economic development would be urgent for SA. In this regard, all things being equal, the Tetra4 expansion ought to be viewed as a significant benefit to the SA economy.

The summary below of the SA economy is based on a PWC document referenced below. Paragraphs in italics are directly quoted from the report.[8] (Our own summary in bold and italics in the notes below.)

- "Statistics South Africa (Stats SA) reported on March 8 that real gross domestic product (GDP) increased by 1.2% q-o-q and 1.8% y-o-y during the fourth quarter of 2021. This was in line with expectations. The latest data indicated that real GDP increased by 4.9% last year following the pandemic-induced 6.4% decline in activity during 2020. This was a healthy bounce-back — and the highest annual growth number since 2007 — due to the base effects from the 2020 recession. Following the 2021 expansion, the South African economy entered 2022 at about 1.7% smaller compared to the end of 2019. However, over the same period, the local population also increased by 2.5% — resulting in a net decline of 4.2% in real GDP per capita during 2020-2021."
    - ***The population of SA keeps becoming poorer, and the outlook for economic growth that could improve average wealth creation per capita is challenging.***
- "Local inflation outlook deteriorates as international commodity prices rise following invasion of Ukraine. Consumer price inflation moderated from 5.9% y-o-y in December 2021 to 5.7% y-o-y in both January and February 2022 — though the latest numbers remained near the top end of the 3%-6% range targeted by the South African Reserve Bank (SARB)."
    - ***A decline in the GDP per capita coupled with high inflation is a breeding ground for social unrest in South Africa.***

[8] https://www.pwc.co.za/en/assets/pdf/economic-outlook/economic-outlook-local-impacts-from-disruptions-in-central-eastern-europe.pdf

- ***A high inflation has the risk of budget over-runs for the Tetra4 expansion. There is a strong possibility of increases in salaries and wages and other input costs into the Tetra4 expansion.***
- ***On the upside increases in commodity prices is positive for the SA economy.***

- "Global shipping costs surge and commodity prices jump as conflict constrains exports. For some years there has been concern about increasing polarisation in society. In our view, polarisation is characterised by a breakdown in the global consensus and a fracturing world, with growing nationalism and populism. In this environment, a new nationalism is taking hold, with many countries prioritising their own interests. As seen in Central and Eastern Europe right now, there could be an accompanied increase in international conflict, insecurity, migration, and tensions in cross-border business. The World Economic Forum (WEF) Global Risks Report 2022 reflected that in 23 out of 124 economies (18.5%) surveyed, interstate conflict was identified by business executives amongst the top five risks that pose a critical threat to their country in the next two years. For Ukrainian business leaders, this factor placed joint third on the list, while it was the number one factor for Russian businesses."

A further useful description of the outlook to the SA economy is the following quoted section from the *African Development Bank*.

- "South Africa's real GDP growth was 0.2% in 2019. The pandemic and the containment measures to curb the spread of the virus further damaged the economy. Real GDP contracted by 8.2% in 2020, the result of a decline in construction, transport and communication, manufacturing, and mining. On the demand side, all components declined, with the largest contraction, 32.4%, recorded in investment. The Reserve Bank of South Africa cut the policy rate by a cumulative 300 basis points in 2020, from 6.5% to 3.5%, to support businesses and households affected by the pandemic. Inflation was estimated to decline to 3.4% in 2020, within the reserve bank target of 3%–6%. The budget deficit was estimated to widen significantly to more than 14% of GDP, mainly due to spending pressures to contain the economic impact of the pandemic. The country will, however, record its first current account surplus in 2020, estimated at about 1% of GDP, because of the high price of the gold it exports, a low bill for fuel imports, and increased agricultural exports. Despite the pandemic, the South African banking sector remains sound, with a capital ratio of 16.3%, which is above the 10% regulatory requirement. Domestic credit to private sector reached $280 billion in November 2020, an increase of 3.5% from December 2019, when it was 139% of GDP. Lingering economic weaknesses prompted the three major credit rating agencies to downgrade South Africa's local and foreign currency credit rating to subinvestment grade. Nevertheless, real private investment expanded by 33.2% in the third quarter of 2020. Social indicators are likely to remain weak due to the severity of the pandemic and legacy issues of low human development. About 2.6 million people have lost their jobs since March 2020, bringing the unemployment rate to 30.8% in September 2020 from 23.3% in December 2019.

Real GDP growth is projected to rebound to 3.0% in 2021, but the pace of the recovery will slow to 1.6% in 2022 due to continued structural constraints such as unreliable electricity supply and job regulations. The inflation rate is projected at 4.2% in 2021 and is expected to stay within the reserve banks' target range of 3%–6% for 2022. The current account surplus is expected to erode, since a recovery in oil prices could raise the import bill. Public debt could reach more than 90% of GDP in the medium term, with projections that it will stabilize at 95% in 2026. The 2020 Medium Term Budget Policy Statement (MTBPS) in October 2020 projected a significantly larger budget deficit and slower debt consolidation in the medium term. These projections will raise risks due to the high debt-service costs and deteriorating balance sheets of state-owned enterprises and the continued weaknesses of the financial position of municipalities.

The 2020 Medium Term Budget Policy Statement proposed steps to reduce the public service wage bill and investment driven by state-owned companies in order to narrow the fiscal deficit and stabilize the debt-to-GDP ratio over a five-year period. The treasury expects to reduce the wage bill—the major driver of the fiscal deficit—by nearly $1.8 billion through 2023–24. The proposal has already raised the risk of widespread strikes by the 1.3 million public sector workers. Also, calls for debt guaranteed by the government to support higher levels of capital investment will be discouraged. This could push South African Airways into liquidation and the electric utility Eskom to adopt tariffs that reflects its costs, which would be efficient but unpopular. In 2020, the South Africa government committed itself to investment in public utilities through strong private sector participation. South Africa's gross international reserves increased slightly from $52.4 billion at the end of March 2020, covering 6.9 months of imports, to $53.8 billion at the end of November 2020, covering 8.3 months of imports. This progress mainly reflects foreign borrowings received on behalf of the government from multilateral banks, including the African Development Bank, to cope with the pandemic crisis."

- ***The key points from the above are the following:***
    - ***The SA Government will endeavour to reduce its budget deficit through a "right-sizing" of its public sector wages and salaries. The State intends to reduce its debt dramatically and will be looking towards the private sector***

for public-private joint ventures. Tetra4 being in the energy space, may well benefit on levels not anticipated at present.

- ***SA's foreign reserves are healthy which means Tetra4 ought to be able to source international funding as international investors need certainty that they can withdraw funds in hard currency again.***
- ***2.6 million people lost their jobs due to the pandemic and the current unemployment rate is 34%. (Other sources indicate an unemployment rate of 40%.) Socio-economic indicators will continue to decline and hence Tetra4 and its suppliers can expect a disproportionate amount of job applications, which means that it would have to be vigilant on the fairness of its recruitment process.***

6.1.2 *MINNG CITY EDGE ECONOMIES*: MATJHABENG ECONOMY

The project area covers a large part of the Free State gold fields, and hence an understanding of the afore-mentioned economic baseline is important to finalise this Economic Impact Assessment (ECIA). The immediate receptor area is the population of Matjhabeng Municipality, which is one of five local municipalities in Lejweleputswa District in the Free State. The major towns located in Matjhabeng are Allanridge, Hennenman, Odendaalsrus, Ventersburg, Virginia and Welkom.

As is to be expected in any economic observation of Matjhabeng, gold production and the mining industry loom large. The wellbeing of the Matjhabeng economy is therefore interwoven with the state of its mining industry. In the past two decades this industry has unfortunately declined in output, affecting employment especially. Interestingly though, the decline in economic value added (thus the money side of the economy) of the mining industry has not been as severe as that of the job losses in the industry. This can be ascribed to 1) higher commodity process and 2) more mechanisation.

The Matjhabeng economy can be described as a mining city edge economy (a phrase coined by this report). These kinds of economies are pervasive in SA and particularly in Gauteng. Good examples of city edge economies are areas like Rustenburg, Emalahleni and Matjhabeng itself. These economies tend to have S-curve economies – meaning with the advent of mining the local economies grow at an exponential rate, then plateau and inevitably experience long declines. The long declines is an aspect that few have found sustainable solutions for and it is not in the soope of this report to address these wider socio-economic challenges.

Returning to the mining city edge economies the following observations are worth making:

a) Mining edge economies owe their development to the growth of the mining sectors in their economies.
b) They are vulnerable to commodity price declines and ore depletion, and hence these economies often are inextricably linked to the performance of its mining sector.
c) Of all the economic sectors in the edge areas the mining and tertiary sectors tend to be largest given that the one is a propulsive industry and the other is a service sector to mining. The more important economic sector, namely manufacturing, is often underweight in these areas which means that upon mining output declines other propulsive industries do not exist to buffer economic downturns. Thus, these edge economies' fortunes fluctuate alongside the fortunes of the mining industry.
d) This author's experience is that relatively little is being done in the growth and stability periods of the edge economies to counter their inevitable economic decline. "Decline" needs to be qualified though as the base of the edge economies are much larger than the baseline prior to when the mining industry invested. Thus, the declines come from a larger base than the original baseline and even after mine closures these local economies are larger than what they would have been had it not been for the mining sector. Even so, the declines are significantly negatively to edge economies.
e) Moving from the capital markets to the labour markets, these edge economies attract large amounts of in-migrants looking for jobs when mining commences often leading to the oversupply of labour. This then result in large informal settlements which then adds pressure to local governments to provide social services.
f) When mining declines in an edge economy, the legacy footprint that the sector leaves behind is extensive with often very negative visual impacts and unattractive landscapes, resulting in significant obstacles to re-generate a better sense of place.
g) Despite the above negative observations, the edge economies undoubtedly play an important role in economic development of SA as they have comparative advantages that when exploited lead to wealth generation that is to the advantage of the whole country.
h) The challenge is to retain that wealth creation in the local ("mining edge") economies when mine-closure occurs.

Following from the above observations, Renergen's investment in the Matjhabeng economy is considered to be different to a typical mining investment as it is derived that its gas resource has a "life of mine" that could exceed 50 years. An economic generation is 25-30 years which means that Tetra4's operations are likely to span two economic generations. This type of longevity allows local economies to step up their economies over a long period of time that ought to create stronger buffers against downscaling.

Moving from a discussion of “edge economies” to the local economic receiving area, the graphs below assist in portraying the salient aspects of Matjhabeng.

The total GGP of the Matjhabeng municipality is estimated at R45 billion at present and this can be considered as a large economy by size in South Africa. SA’s GDP is just under R5 000 billion rand and although Matjhabeng’s economy is only ~1 % of that amount, it needs to be compared to the 0,2% of the average municipality in SA. Thus, Matjhabeng’s economy is 5 times larger than the average municipality in SA and hence could be considered as a relatively big economy in the country. The significance of this is that the local area has a reasonable economic base that could sustain itself and as a rule ought to provide in some of Tetra4’s supplier and procurement needs.

The graphs below show that the local economy’s GDP growth rates had been mostly negative between 2005-2014. As the data for the local economy’s performance was not available after 2014, a look at the SA GDP growth rate shows that nationally there were no signs to indicate that the economy was improving. One could therefore assume that the local economy may also *not* have experienced strong growth, albeit that higher commodity prices may have had a positive impact locally in 2021 (that year’s statistic not in the graph.)

From the graphs below it can also be seen that the mining industry made up 56% of the local economy in 2014. (Compare this to national mining contribution to GDP of less than 10%). The Government sector, which is not a propulsive industry, is the next biggest economic sector in Matjhabeng.. The critical sector for economic success namely the manufacturing sector is very small in that economy.

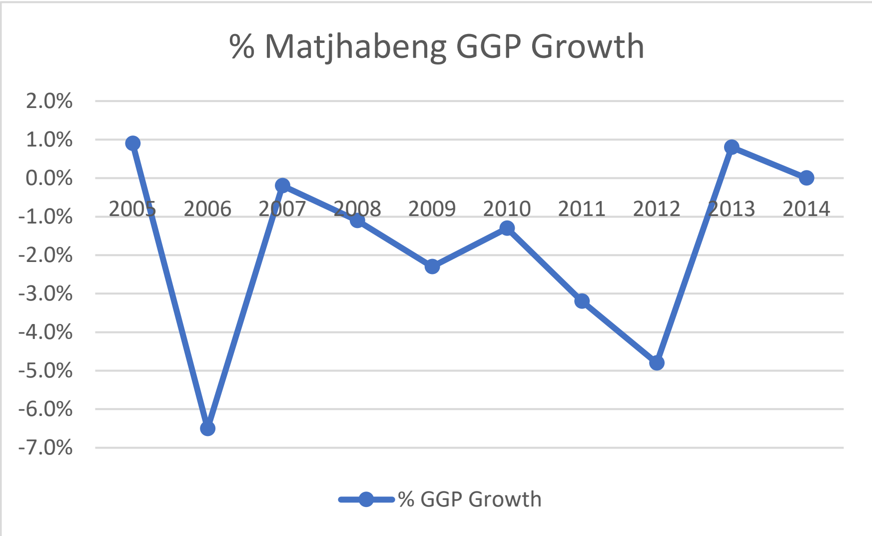
Mining output in the local economy is showing a downward trend at a rate of 1.5% per year. From the graphs below Matjhabeng had been hit hard by declining gold production. Its workforce had been halved since the golden years of the 1990’s and this had led to high unemployment rates.

The area’s population is large with well over 400 000 inhabitants. The population growth rate in Matjhabeng was estimated at 0,5% in the last decade, compared to 1,5% in SA, which indicates that the Gold Fields is not a major in-migration area at present. This can only be ascribed to the area’s inability to absorb job-seekers in the economy prompting less people to in-migrate.

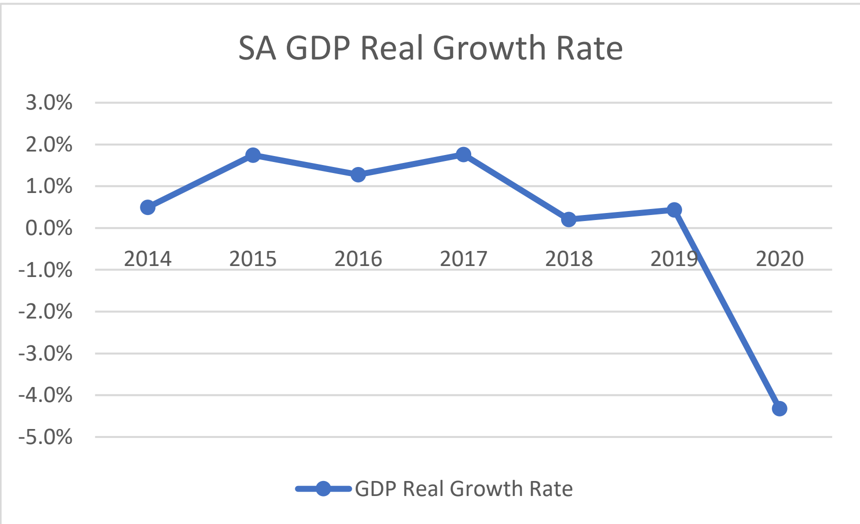
As is the case in the rest of South Africa, the Matjhabeng unemployment rate is high, bordering on 40%.

Due to the urbanised nature of Matjhabeng its Agricultural Sector is small contributing less than 2% to its economy. The agricultural sector in the region is much larger as is expected in the Free State, averaging 5% of GDP.

Figure 11: Key Economic Graphs

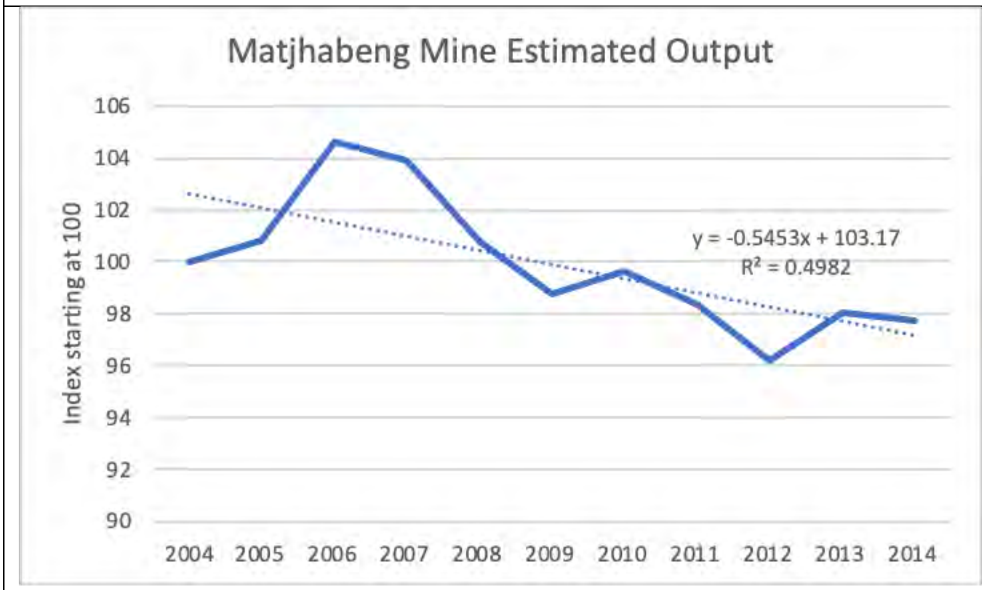


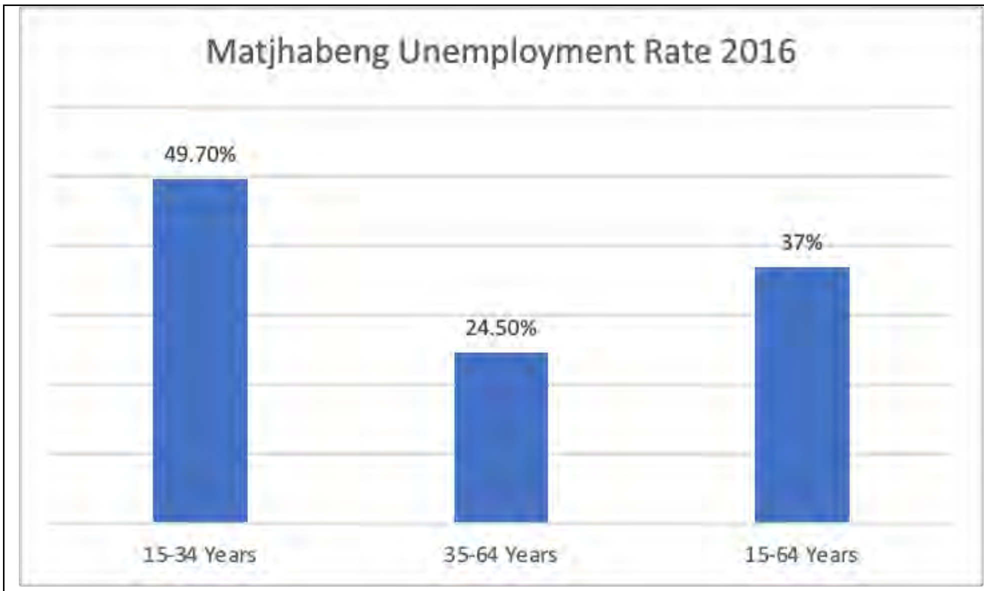
Source 8: Matjhabeng IDP



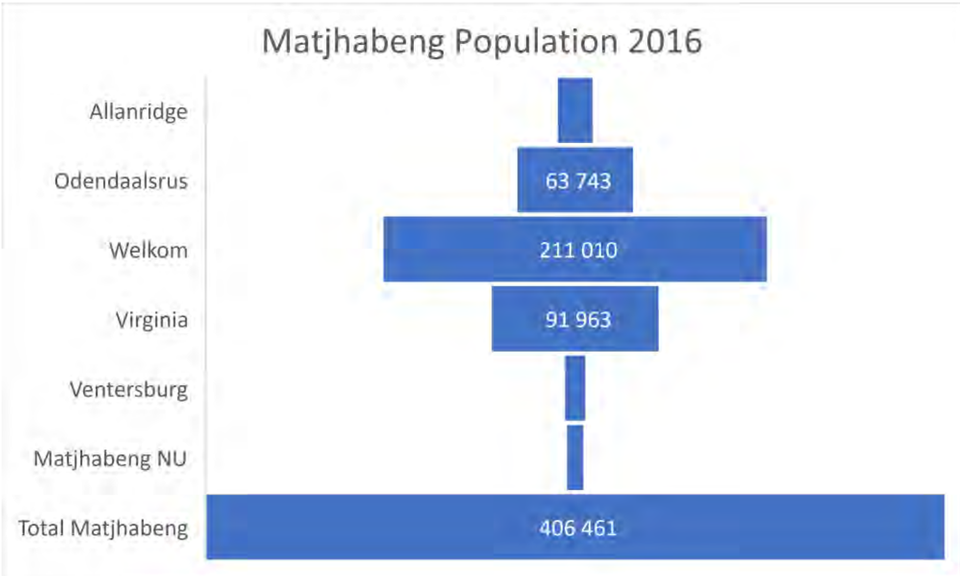
Source 9: Reserve Bank Statistics

Figure 12 :Structure of Matjhabeng economy by economic output 2014





Note 4: Population in 2020 estimated at 430 000 people



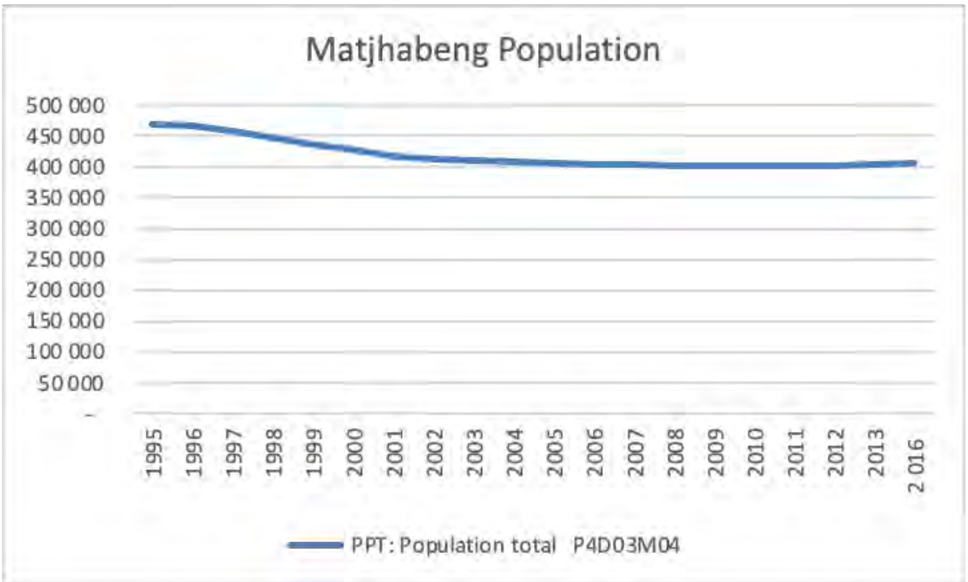
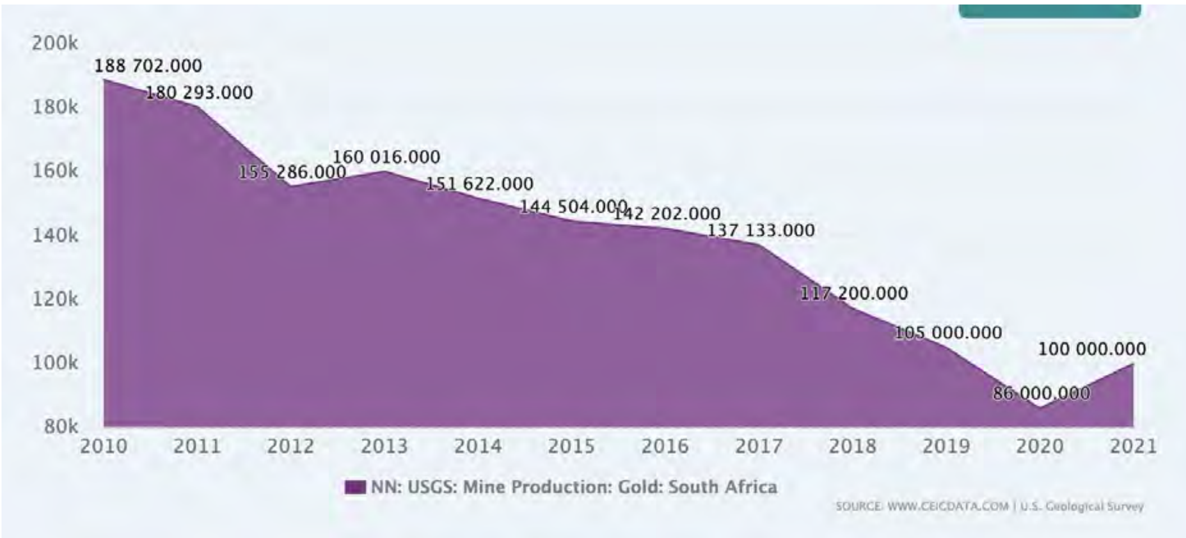
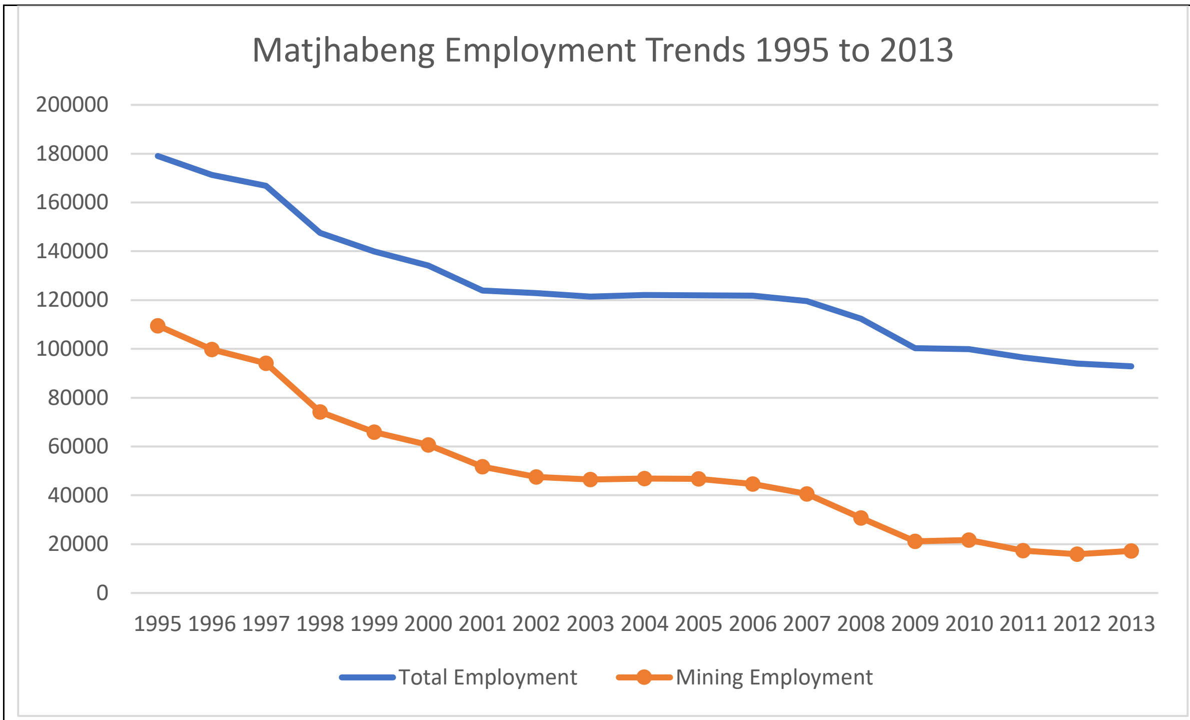


Figure 13: SA Gold Production



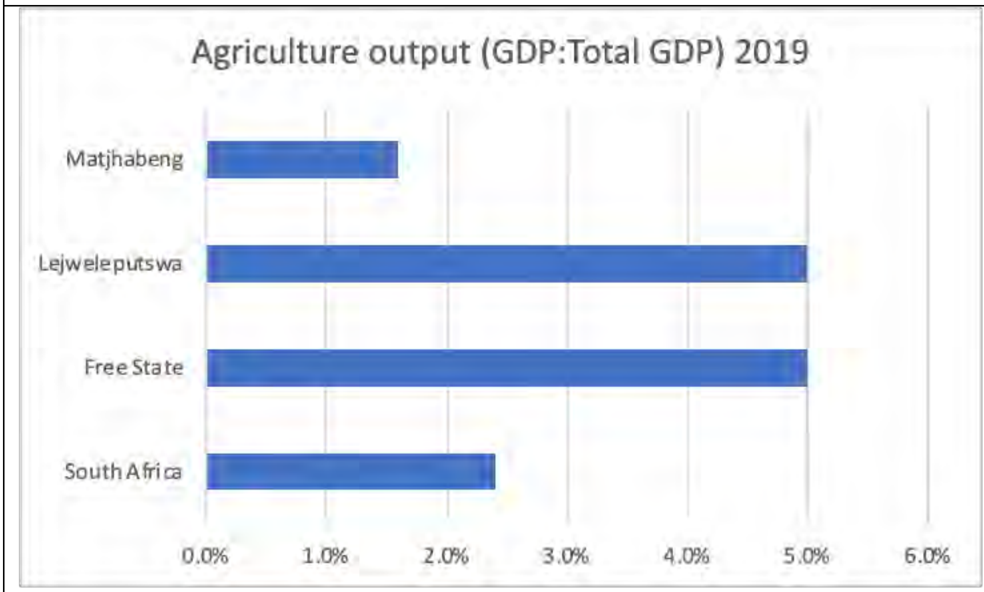
Source 10: Independent Source www.ceicdata.com



Employment	South Africa				Free State				Lejweleputswa				Matjhabeng			
	2009		2019		2009		2019		2009		2019		2009		2019	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Formal sector: Skilled	11987	19%	13866	19%	532	15%	551	16%	105	15%	112	15%	73	16%	82	15%
Formal sector: Semi-Skilled	34614	54%	39915	56%	1875	54%	1921	55%	356	52%	363	50%	242	52%	273	51%
Formal sector: Low Skilled	9178	14%	10033	14%	592	17%	642	18%	122	18%	160	22%	86	19%	123	23%
Informal	8606	13%	7989	11%	480	14%	399	11%	104	15%	91	13%	62	13%	61	11%

Source: Quantec, 2019

Source 11: Matjhabheng LED Report 2019



Source 12: Unless otherwise stated source of information aboce is the Matjhabeng 20/21 Draft IDP

6.1.3 LOCAL ECONOMIC NEWS MATJHABENG

We include two items of local economic news in order to weave more threads into the tapestry of the local economy for the purposes of this report.

05 Sep 2021: https://www.news24.com/news24/SouthAfrica/News/matjhabeng-municipality-rampant-looting-illegal-mining-and-theft-could-wipe-out-ailing-entity-20210905 Matjhabeng municipality: Rampant looting, illegal mining and theft could wipe out ailing municipal infrastructure. Unemployment and Covid-19 have severely affected Matjhabeng municipality. The Free State municipality is dealing with theft and vandalism of its properties and infrastructure. Illegal mining activities and cable theft are on the rise too. Unemployment and closure of businesses in the Free State's mining towns has left one municipality with a burden of problems resting on its shoulders. The Matjhabeng local municipality servicing Allanridge, Odendaalsrus, Welkom, and Virginia, is now grappling with increasing unemployment. Matjhabeng is the Sesotho name for a place where people of different races meet. The area is home to locals and foreigners from Lesotho, Zimbabwe, and Mozambique, who were attracted to the area by the gold mines. The municipality is also battling rampant looting and the destruction of its infrastructure and properties. Among those targeted are municipal buildings and theft of municipal fences, electricity cables, and other valuables. Looting takes place in both towns and in townships. The most ailing towns are Meloding, Virginia, Thabong, and Welkom. Two weeks ago, thieves struck "gold" when they stole electricity cables worth R5 million. Cemeteries are not spared either.
08:11 Sun, 13 Mar 2022 https://www.ofm.co.za/article/centralsa/314016/businesses-community-commits-to-rebuild-matjhabeng- It is time that the business community starts lending a helping hand to the Matjhabeng Municipality in the Free State. This, according to local businessman, Jakes Jooste, during the the launch of the Matjhabeng Community Forum. The event, hosted by the local business community and the Executive Mayor of Matjhabeng, Thanduxolo Khalipha, was attended by roughly 300 businessmen and women across Matjhabeng. Jooste, in an interview with OFM News, said it's high time the local community gets involved - as it is the only way to rejuvenate local economy. Mayor Khalipa also pledged his support to the initiative, adding Matjhabeng's people must unite to rebuild the city of Welkom Meanwhile, Khalipha confirmed an amount of R1.8 billion has been received from the National Treasury, of which R64 million will be set aside to renew water and sewage treatment around Matjhabeng. Philip van der Merwe tabled their plan and gave the business model they will use to achieve this vision. He also said the benefits of the project include that Matjhabeng will have

clean towns, fewer potholes, security in the residential areas to curb criminal activities, and that the business community will be involved in the Integrated Development Plan of the Municipality.

6.1.4 SUMMARY OF THE LOCAL ECONOMY

6.1.4.1 Strengths of the local economy

The local economy is considered to have the following strong points:

- Matjhabeng has a relatively large GGP compared to other municipalities, which ought to leverage possibilities for further development in the area.
- The road infrastructure from Matjhabeng that connects it to both the Johannesburg markets and Durban ports is of a very high quality, which makes import and export linkages more efficient than for many other municipalities in the country.
- Barring further mine closures, Matjhabeng may be finding a new economic equilibrium which ought to increase business confidence and investment in the area.
- The 2014/15 IDP indicates that the average household income has increased, which ought to contribute to social stability.
- The IDP also states that educational levels in the area have improved substantially, and a better-educated population is crucial for economic development.
- The IDP furthermore states that Matjhabeng has a Human Development Index (HDI) of 0.66, which is one of the highest in the Free State and just above the average SA HDI. However, the country's HDI is still low compared to that of developed countries, and it requires much improvement before Matjhabeng could be a significantly competitive economy.

6.1.4.2 Weaknesses of the local economy

- As was described in the section on the 'mining edge economies', Matjhabeng is dependent on one propulsive industry, namely mining. With an undiversified economy it is thus vulnerable to the prospects of mining.
- The Matjhabeng municipality itself does not seem to have a strong set of financial statements. Its current liabilities exceed its current assets by a large margin and it has been recording deficits (losses) for the last few years. In addition to this, it also had qualified audits which does not bode well for the financial management of the municipality.
- Other weaknesses are in alignment with what most of SA is experiencing at present:
    - Long term decline in business confidence;
    - Unreliable electricity supply;

- Low growth economic environment;
- Generally low investment environment;
- High unemployment;
- Unplanned urbanisation;
- Crime;
- Apparent government inefficiencies.

Figure 14: SA Long term business confidence

6.1.5 CONCLUSION ON THE LOCAL ECONOMY

Matjhabeng has a relatively large economy compared to that of other SA municipalities, but its GGP has been declining for years. Although the local economy still has a measure of critical mass that could provide continued private consumption expenditure which could sustain it for quite some time, it requires new investments to sustain itself.

The Matjhabeng economy is by all accounts finding a new equilibrium – an economy that is adjusting to declines in mining employment and a stagnating population. The increase in government expenditure and perennial agricultural activities are keeping the municipality's decline in check, but if more mines close down its GGP and formal employment is set to decline more. At present it is not sure what the impact of higher commodity prices are on the local economy.

An investment such as that of Renergen will undoubtedly improve the economic prospects for the local economy.

7 ECONOMIC IMPACTS

7.1 HIGH LEVEL ASSESSMENT RATING

The table below is based on the environmental assessor's impact assessment methodology. An indicators of +25 score means absolutely positive and a -25 means an absolutely negative impact. A zero is in fact a neutral impact and hence any impact above zero is positive.

From the table below most of the significant economic impacts are rated as very positive.

Figure 15: Impact Assessment Rating

No of Impact	Impact Description	Phase	Average of Pre-mitigation ER	Average of Post-mitigation ER
⊟ A	⊟ GGP Impact	Construction	16.0	16.0
A	GGP Impact	Operation	23.8	23.8
⊟ B	⊟ Employment Impacts	Construction	13.0	13.0
B	Employment Impacts	Operation	17.0	17.0
⊟ C	⊟ Forex savings	Construction	(9.8)	(9.8)
C	Forex savings	Operation	18.0	18.0
⊟ D	⊟ Fiscal Income	Construction	12.0	12.0
D	Fiscal Income	Operation	17.0	17.0
⊟ E	⊟ Economic development per capita	Construction	15.0	15.0
E	Economic development per capita	Operation	17.0	17.0
⊟ F	⊟ Country and Industry Competitiveness	Construction	16.0	16.0
F	Country and Industry Competitiveness	Operation	20.0	20.0
⊟ G	⊟ Black Economic Transformation	Construction	14.0	14.0
G	Black Economic Transformation	Operation	16.0	16.0
⊟ H	⊟ Alternative Land-use	Construction	8.8	8.8
H	Alternative Land-use	Operation	11.3	11.3
⊟ H2	⊟ Impact on individual farmland values	Construction	(7.5)	(7.5)
H2	Impact on individual farmland values	Operation	(9.0)	(9.0)
⊟ I	⊟ Need and Desirability	Construction	15.0	15.0
I	Need and Desirability	Operation	20.0	20.0
Grand Total			**12.2**	**12.2**

Source 13: Own Calculation

7.2 GGP IMPACT

GGP is the acronym for Gross Geographical Product and is the same as GDP, except that the latter is for the country and the former for a province, district or municipality, in this case for Matjhabeng. (GDP, GGP and GVA [Gross Value Added] are often used interchangeably.) For the layman the GDP is the most common economic indicator as it is most reported on. From an impact perspective the GDP or GGP on the demand side is the sum of investments, private consumption expenditure, government expenditure, and net exports. On the flipside, GDP from the supply side is the sum of salaries and wages, gross operating surplus and depreciation. The GDP/GGP statistic, is the quantum that pulls it all together.

We described in paragraph 5.3.1 page 15 in the paragraph headed "Positive economic impacts" how we arrived at the GGP that Tetra4 will be creating.

As described there, assuming an annual *direct* GGP contribution from Tetra4 of R3,6 billion and R6,6 billion after multipliers *(direct, indirect and induce*), the additional GGP relative to the Matjhabeng economy is 6,9% and 12,8% respectively. This ratio is very high given that most economies increase in a boom year by 5%. Relative to the Matjhabeng economy does not mean all the economic benefits will occur within the Matjhabeng economy due to economic leakages. Calculating the exact GGP addition is possibly an exercise in futility as it would be difficult to follow the leakages. The direct increase in GGP is estimated at 6,9% and this is considered as significantly high.

7.2.1 INPUT-OUTPUT STATUS OF GAS IN STRONG GAS PRODUCING ECONOMIES

Given that SA is not a mature gas economy we outline the input and output relationships between gas and other economic sectors based on an "average gas producing hypothetical country" – in the case of this report it is the average input-output relationship of gas within the economies of the United Kingdom, United States of America and Russia. Please note that the extraction of gas is categorized under mining activities in international industry classifications, and the processing of gas falls under the electricity and gas supply sector. For ease of reference we give the economic categorisations of the economic sectors below.

The definitions of industries are based on international standard industrial classifications:

B. Mining and quarrying (***note the extraction of crude oil and natural gas fall under this category).***

05 – Mining of coal and lignite

06 – Extraction of crude petroleum and natural gas

07 – Mining of metal ores

08 – Other mining and quarrying

09 – Mining support service activities

D - Electricity, gas, steam and air conditioning supply ***(note that the manufacture of gas and supply fall in this category).***

35 - Electricity, gas, steam and air conditioning supply

351 - Electric power generation, transmission and distribution

352 - Manufacture of gas; distribution of gaseous fuels through mains

353 - Steam and air conditioning supply.

We also provide further definitions of industries below.

Figure 16: Industrial Classifications of Industries

Division	Group	Class	Description
Division 05			**Mining of coal and lignite**
	051	0510	Mining of hard coal
	052	0520	Mining of lignite
Division 06			**Extraction of crude petroleum and natural gas**
	061	0610	Extraction of crude petroleum
	062	0620	Extraction of natural gas

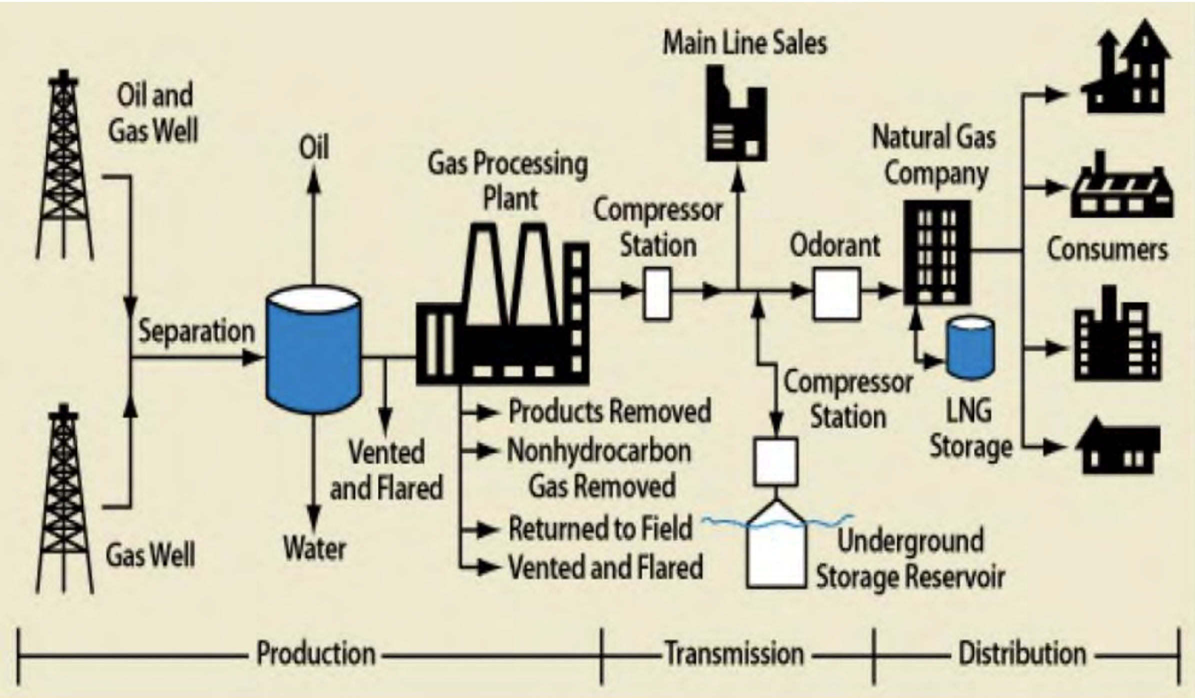
Division 20			**Manufacture of chemicals and chemical products**
	201		Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms
		2011	Manufacture of basic chemicals
		2012	Manufacture of fertilizers and nitrogen compounds
		2013	Manufacture of plastics and synthetic rubber in primary forms
	202		Manufacture of other chemical products
		2021	Manufacture of pesticides and other agrochemical products
		2022	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
		2023	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
		2029	Manufacture of other chemical products n.e.c.
	203	2030	Manufacture of man-made fibres

Division 24			**Manufacture of basic metals**
	241	2410	Manufacture of basic iron and steel
	242	2420	Manufacture of basic precious and other non-ferrous metals
	243		Casting of metals
		2431	Casting of iron and steel
		2432	Casting of non-ferrous metals

Division 33			Repair and installation of machinery and equipment
	331		Repair of fabricated metal products, machinery and equipment
		3311	Repair of fabricated metal products
		3312	Repair of machinery
		3313	Repair of electronic and optical equipment
		3314	Repair of electrical equipment
		3315	Repair of transport equipment, except motor vehicles
		3319	Repair of other equipment
	332	3320	Installation of industrial machinery and equipment

Division 68			Real estate activities
	681	6810	Real estate activities with own or leased property
	682	6820	Real estate activities on a fee or contract basis

Figure 17: The natural gas supply chain

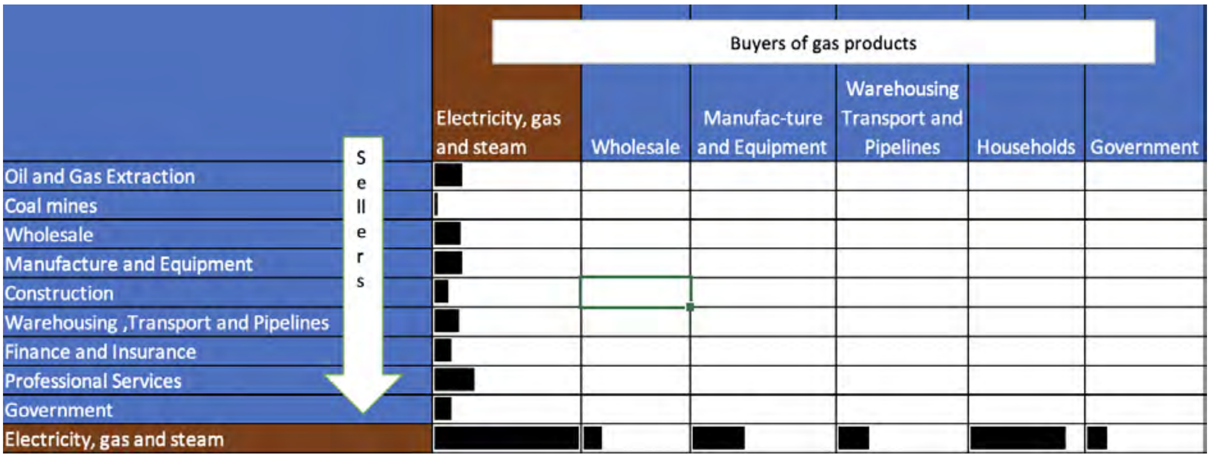


Source 14: https://apps.dtic.mil/sti/pdfs/AD1080502.pdf

Applying the above to Tetra4 it can be gleaned that it has the potential of establishing a robust gas supply chain in the Free State (and potentially Gauteng). The inset above clearly shows the division between production, transmission and distribution, with the various components comprising those divisions.

From an economics supply chain perspective, the table below shows the relative monetary values from production to consumption. The first observation is that the gas industry obtains most of its inputs, and provides most of its outputs, from and to itself. For example, gas is used to generate electricity at power plants which in itself powers the gas processing plants. After the industry itself, most of the outputs of gas feed into households which indicate that Tetra4 could provide gas to the wholesale and retail sector should it wish to adopt such a business model. Equally a large amount of gas outputs find its way to the other sectors indicated below, namely wholesale, manufacture and transport. Therefore Tetra4 has many strategic options for the use of its gas.

Table 3 : Input output by major industry to and from Gas Manufacturing Sector based on average of UK, USA and Russian input-output



Note 5: The bars above are indicative of the monetary value in each segment (block). (No monetary values provided as these values are in US Dollars based on the average of the UK, USA and Russia.)

Source 15: OECD Input Output Tables and own calculations

Figure 18: Detailed Input-Output table for average UK<USA and Russian economies

Sum of Avg UK,USA and Russia	Column Labels	
Row Labels	Inputs	Outputs
Agriculture and Fishing	0.2%	0.6%
Basic and Fabricated Metals	0.8%	2.5%
Changes in inventories	0.0%	0.0%
Chemical and Chemical Products	0.5%	1.7%
Coal miinng and oil extraction	18.2%	0.9%
Coke and refined petroleum products	5.7%	0.9%
Construction	3.1%	0.9%
Educationa and Social Services	0.3%	4.7%
Electricity, gas, steam and air conditioning supply	30.9%	16.5%
Exports	0.0%	-0.7%
Finance and insurance	3.5%	0.8%
Gross Fixed Capital Formation	0.0%	0.6%
Hospitality	0.5%	3.1%
Imports	0.0%	0.6%
ITC	1.6%	0.7%
Land transport and transport via pipelines	2.9%	1.0%
Other Manufacturing	1.7%	4.8%
Other mining	0.4%	0.6%
Professional, scientific and technical activities	8.6%	2.4%
Public Administration and Defence	3.3%	1.6%
Publishing and broadcasting	0.2%	0.2%
Real estate activities	1.2%	11.7%
Repain and intallastion of machinery and equipment	0.6%	0.3%
Sales directly to Government	0.0%	0.4%
Sales directly to households	0.0%	34.0%
Taxes to foreign countries	0.0%	0.0%
Taxes to own country	6.1%	0.0%
Transport Equipment	0.1%	0.2%
Warehousing and other transport	2.4%	1.5%
Water and waste management	1.2%	0.4%
Wholesale and retail trade; repair of motor vehicles	6.0%	7.0%
Grand Total	**100.0%**	**100.0%**

7.3 NEW INVESTMENT

New investment is an important catalyst for economic growth and in this regard the planned R13 billion investments of Renergen would be a significant economic contribution to Matjhabeng and SA.

Possibly the best manner to describe the significance of the Renergen investment is to compare it to the average government and private investment quantum's in SA today. To this end, the Nedbank's Capital Expenditure Project Listing[9] for 2021 shows a total of 28 new projects worth R117.7 billion that

[9]https://www.nedbank.co.za/content/dam/nedbank/site-assets/AboutUs/Economics_Unit/Research/EconomicResearch/Nedbank%20Capital%20Expenditure%20Project%20Listing%20July%202021%20Full%20report.pdf

were announced during the first half of that year. (These are large, noteworthy projects.) On an annualised basis, this translates to 56 projects valued at R235.4 billion. Ergo, the average value per project amounts to R4,2 billion. The Renergen investment of nearly R13 billion is much higher than this average and denotes its significance.

7.4 HOUSEHOLD INCOME/ POVERTY ALLEVIATION

Private consumption expenditure and household income are flip-sides to the same main economic driver, namely remuneration of employees. Appreciably, it is understood that private consumption expenditure can exceed household income due to household borrowing, welfare, pension and retirement incomes.

This report's calculations indicate that the addition of 1 218 jobs from Tetra4 and its direct contractors is estimated to amount remuneration of R1,1 billion per annum and this is 3,4% of the current R31,8 billion estimated household income in Matjhabeng. This is a significant increase.

The direct employment at a gas plant will be overweight on skilled employees due to the complexities of gas processing technology. This is to some extent corroborated by the employment profiles in the table immediately below where it can be gleaned that South Africa's Electricity and Gas Sector uses much less semi-and unskilled workers pro-rata to total SA. Therefore, it can be concluded that Tetra4 ought *not* to be viewed as a direct, major employer of semi- and unskilled workers.

However, the above stated, the dependency ratio in South Africa of population to formally employed now stands at 6:1. In Matjhabeng this ratio is 5:1. This means on average that 6 090 local citizens could have an improvement of quality of life because of Tetra4's and it's contractors' direct employment of 1 218. When one considers that economy-wide job creation after multipliers may be as high as 4 600, and multiplying that by the SA 6:1 dependency ratio, then the amount of people that could benefit from the cumulative job creation could be as high as 28 000. Cognisance is taken that there is not always a direct link of financial aid between direct employment and statistical dependents, (e.g. an employee may not have an extended family and even if such and employee did have such a family, that person may not always share income with others.)

Regarding poverty alleviation in general, it can be stated that the SA Government is likely to establish an unemployment welfare payment system to the underprivileged in the country. It is estimated that Tetra4's economic value add may well be R3 billion per annum, thus a total VAT contribution of R450 million could be expected per fiscal year. (R3 billion x 15%). Based on this one could posit that Tetra4's expansion could cover a SA Government social grant of R350 pm for over 100 000 South Africans. Although there is no direct link between government income collections and a particular expenditure budget item, stating that an economic benefit such as the proposed expansion could cover the social grants of 100 000 citizens in SA is used only to show the significance of such benefits.

Table 4: Employment by skills level

	SA Total	Mining	Electricity and Gas
IS100: Formal employment by skill: Highly skilled - Toral (Number)	18%	5%	36%
IS200: Formal employment by skill: Skilled - Total (Number)	43%	19%	35%
IS300: Formal employment by skill: Semi- and unskilled (Number)	40%	75%	29%
Grand Total	**100%**	**100%**	**100%**

Source 16: Quantec Data

7.4.1 GOVERNMENT INCOME

In the paragraph above it had been shown that Tetra4 may well add R450 million per annum in an optimal production year to the SA fiscus in net VAT payments alone. (Note that economy wide the amount of increased VAT received by the SA fiscus would be approximately double as input-and output VAT would cancel out.) In addition to this, assuming an average employee income tax rate of 25%, then this tax group may well add an additional R275 million. Corporate tax may well not be paid in the foreseeable future given high depreciation allowances on investments, but after allowances had depleted it is not impossible that Renergen may well pay upwards of R250 million in corporate tax per annum.

At full potential production, total direct and indirect taxes (including SLP and other mandatory contributions), it is not farfetched to estimate that this project's total contribution to the fiscal coffers may well be R1 billion a year.

7.4.2 EXPORTS AND IMPORTS

SA Reserve Bank data shows that SA imports on average R1,2 trillion worth of goods and services and exports on average a very similar amount. In the last 9 years SA's net trade account is positive by R15 billon on average. The significance of these statistics is that Tetra4 is likely to import substitute a total of R6 billion a year at full production, and this is 38% of the average trade surplus of the last 9 years. This is a significant contribution to the trade account of SA.

Table 5: SA Imports and Exports

Year	Imports R million	Exports R million	Trade deficit
2011	896 247	921 530	25 283
2012	1 014 404	967 887	(46 517)
2013	1 179 768	1 097 889	(81 879)
2014	1 260 788	1 198 849	(61 939)
2015	1 282 606	1 225 163	(57 443)
2016	1 318 643	1 340 104	21 461
2017	1 330 275	1 388 381	58 106
2018	1 447 581	1 472 740	25 159
2019	1 502 601	1 532 539	29 938
2020	1 289 107	1 533 645	244 538
Avearge	1 252 202	1 267 873	15 671

Source 17: SA Reserve Bank

7.5 EMPLOYMENT IMPACTS

It is well-known that unemployment in SA is rampant and the causes for such high unemployment are many, which discussion is outside the scope of this report. Gas plants are very capital intensive and as a rule the cost of a job created is high relative to other economic sectors. However, gas plants are propulsive entities, meaning it has strong multiplier effects.

We showed the bases of our employment generation statistics in paragraph 5.3.1 page 15 in the paragraph headed “Positive economic impacts”.

A R3m GDP per employee was used to estimate the number of direct and contractor’s jobs for the Tetra4 expansion which is much higher than South Africa’s GDP per employee of R500k. This shows that the GDP created per direct employee in the Tetra4 expansion is 6x more.

Note we did not use Tetra4’s organogram because of outsourcing and out-contracting difficulties in calculating the correct number.

The estimated direct employment is set at 1 218 and at a multiplier of 3.80 this amounts to total estimated job creation of 4 623 in the national economy. Calculated as relative to the Matjhabeng’s total employment in 2016 of 80 211 employees, it amounts to a 5,8% increase. It is undoubted that this will be a major increase.

It needs to be stressed that a high ration of job creation will be in the highly-skilled category (possibly 40%).

It is important to note that Matjhabeng’s electricity and gas sector employed a total of 539 in 2019 compared to 463 people in 2009. (Matjhabeng LED Plan 2019) The direct employment at Tetra4 and its direct contractors of 1 218 employees is clearly a major increase from the 539 in 2019.

A further analysis worth indicating is shown in the table below. As an introduction, it must be stated that the "bars" below are based on the economic structures of gas economies, not SA. The average of UK, USA and Russian input-output tables were used. This table shows the high employment propulsive impacts of employment creation of a gas plant. Note the high creation of jobs in wholesale and retail (e.g. distribution centres and companies), followed by manufacturing (e.g. manufacturing of gas equipment), professional services, construction and financial services. Pipelines fall under warehousing and other transport and due to the low job requirements for pipelines this sector does not create that many jobs.

This analysis shows that should Tetra4 drive its methane business as hard as its helium business, it could create an eco-system much like high gas economies. Renergen's proven methane resource is estimated at 600 billion cubic feet as in September 2021, which means that over a 100- year period it would have a resource of 6 billion cubic feet per annum, or 0,5 billion cubic feet per month. This report works on an assessment of 40 million cubic feet of gas per month. Thus, using these numbers it can be stated that the life of mine could be more than a 100 years. When considering that it is speculated that the United States has 90 years of gas resources left, it gives an indication of the scope and scale the Tetra4 expansion may achieve in SA.

Table 6: Indicate direct and indirect employment

Sum of Avg UK,USA and Russia	Direct Employment	Indirect Employmen
Wholesale and retail trade		57%
Manufacturing		51%
Professional, scientific and technical activities		45%
Electricity, gas and steam	100%	35%
Industry Other		25%
Construction		22%
Finance and insurance		19%
Government		13%
Transport		9%
Warehousing and other transport		8%
Other mining		2%
Coke and refined petroleum products		2%
Water and waste management		2%

Source 18: Own Calculations

7.6 FOREX SAVINGS

US Dollar Foreign Reserves of any country (excluding the United States itself), is of paramount importance when measuring a country's financial strength, and for international trading purposes. Tetra4 will likely replace all helium imports and in addition also export helium. In addition to this its natural gas will result in savings of gas importation. Thus, its entire revenue per annum could be considered as a forex saving for South Africa.

As indicate above, the average net current account balance of SA in the last 10 years amounted to just over R15 billion, thus should the optimal turnover of Tetra4's sales be considered as a forex saving, then the impact could be 38% positive. This is a significant percentage, but it must be borne in mind the numerator is divided by the denominator of net trade, not total exports.

7.7 COUNTRY AND INDUSTRY COMPETITIVENESS

We discuss country and industry competitiveness in the need and desirability section of this report. Please refer to par 5.3.5 on page 33 of this report.

7.8 BLACK ECONOMIC TRANSFORMATION

The Gas Act makes provision for black economic transformation and the provisions thereof is described in the BBBEE Act. This project will need to comply with these provisions which compliance will have an obvious positive impact on economic transformation.

7.9 ALTERNATIVE LAND-USE ANALYSIS / FOOD SECURITY

The likely amount of hectares of directly impacted is set at 7 500 hectares based on a GIS survey undertaken by specialists of the environmental assessor. The stated hectares can be considered as the size of an average farm in the area and hence from a macro-economic viewpoint the Tetra4 development is a significant better land-use for South Africa.

8 FARMLAND VALUES

It is likely that farmland values would be impacted because of establishing wells, pump stations and gas-pipes across a wide area of farmland. For this reason we set as a mitigation, in line with the social impact assessment, that Tetra4 (or it's proxy) needs to negotiate with each individual farmer where there is clear evidence of land value losses (which losses could be a result of either productivity losses or general land value losses).

9 SITE SENSITIVITIES

From an economic perspective, the areas to avoid are productive farmland because this would decrease farming output.

10 SITE CONSTRAINTS

There were no site constraints noted while visiting the site, and there are economically no site constraints to optimising economic output.

10.1 IMPACT RATINGS

1. GGP Impact -					
Impact Name	**GGP Impact**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	5	5
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					16.00
Mitigation Measures					

Table 7: GDP Impact

Mitigation #	Mitigation Title	Mitigation Description
19	Loss of agricultural land	Ensure that as much of the infrastructure as possible is sited away from agricultural lands. Utilize servitudes, farm roads and any other routes to avoid sensitive areas. Ensure that pipelines are buried at sufficient depth (>1 m minimum) to avoid interference with arable agriculture activities.
23	Influx of people looking for economic opportunities	Communication to stakeholders about the nature and extent of economic opportunities should be undertaken. No unrealistic expectations should be created and the recruitment policy giving preference to local labour should be communicated from the beginning of the project. The local area of influence should be agreed with stakeholders early on in the process.
28	Landowner Consultations	Landowners must be consulted and all reasonable requests complied with. A written landowner agreement should be negotiated and concluded prior to commencement. Should this not be possible, a record should be kept of reasonable negotiations with the land owners.
32	Impacts on land-use	The pipelines will be buried in accordance with the schedule as agreed upon with landowners to minimise disturbance to farming operations [Amendment 2019/05].
40	Loss of farm labour to the Cluster 1 project	If any farm labourers apply for positions at Tetra4 or one of its contractors, Tetra4 or the contractor must ensure that the labourer is aware that the position may only be temporary and what the long term consequences of taking the position are.
41	Potential for conflict between local residents and newcomers about economic opportunities.	Preference for employment should be given to the local community. The recruitment policy must be communicated openly and made available to the public if requested.

51	Potential opportunity for education, skills development, and training	Tetra4 should liaise with local training institutions or service providers to determine whether there are any opportunities to offer internships and practical experience for their students. Tetra4 must ensure that skills development requirements form part of their contracts with sub-consultants as prescribed in the SLP. The skills development requirements and bursaries for local learners as discussed in their Social and Labour Plan (SLP) must be implemented.
94	Interference with existing land uses/livelihoods	Tetra4 must appoint a CLO that deals with the affected landowners throughout the life of the project. If existing activities will be affected negatively Tetra4 must enter into negotiations with the affected parties as soon as reasonably achievable to ensure the affected parties are compensated fairly or can make additional arrangements. Interference with existing livelihoods should be avoided if possible. If any new activities are planned for a property, Tetra4 must consult with the landowner and take reasonable steps to obtain his consent to execute the activity on his/her land. A system to arrange access to properties must be devised and formalised. All reasonable efforts must be taken to obtain agreement on the system with the landowners and it must be formalised. Access must be arranged at least 24 hours prior, except in emergencies, when the landowners should also be informed immediately. If routine access is required, the landowners must be provided with a roster indicating dates and approximate times that access will be required. Tetra4 must compensate the landowners for any damage to property or goods if it was due to behaviour of their contractors. Sub-contractors must be made aware of this and a clause spelling out their liability should be included in their contracts. All contractors should sign a code of conduct as part of their induction process. Induction must explicitly include aspects such as closing gates and littering. Toolbox talks must be designed to include social and environmental aspects. A fining system must be put in place for any transgressions affecting the landowners.

100	Employment opportunities	Contractors should be required to make use of a certain proportion of local labour - it is acknowledged that not all skills will be available locally. Jobs should be advertised in a way that is accessible to all members of society and labour desks (labour registration stations) should be in accessible areas. No unrealistic expectations should be created and the recruitment policy giving preference to local labour should be communicated from the beginning of the project. The local area of influence should be agreed with the stakeholders early on in the process.
106	Secondary economic opportunities e.g. transport, domestic services, catering, etc.	Procurement targets to be in line with the existing Social Labour Plan (SLP). [Amendment 2019/05]

Environmental Risk (Post-mitigation)	16.00
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.13
Final Significance	18.00

2. Employment Impacts -					
Impact Name	**Employment Impacts**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	5	5
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					13.00
Mitigation Measures					

Table 8: Employment Impact

Mitigation #	Mitigation Title	Mitigation Description
23	Influx of people looking for economic opportunities	Communication to stakeholders about the nature and extent of economic opportunities should be undertaken. No unrealistic expectations should be created and the recruitment policy giving preference to local labour should be communicated from the beginning of the project. The local area of influence should be agreed with stakeholders early on in the process.
41	Potential for conflict between local residents and newcomers about economic opportunities.	Preference for employment should be given to the local community. The recruitment policy must be communicated openly and made available to the public if requested.
51	Potential opportunity for education, skills development, and training	Tetra4 should liaise with local training institutions or service providers to determine whether there are any opportunities to offer internships and practical experience for their students. Tetra4 must ensure that skills development requirements form part of their contracts with sub-consultants as prescribed in the SLP. The skills development requirements and bursaries for local learners as discussed in their Social and Labour Plan (SLP) must be implemented.
94	Interference with existing land uses/livelihoods	Tetra4 must appoint a CLO that deals with the affected landowners throughout the life of the project. If existing activities will be affected negatively Tetra4 must enter into negotiations with the affected parties as soon as reasonably achievable to ensure the affected parties are compensated fairly or can make additional arrangements. Interference with existing livelihoods should be avoided if possible. If any new activities are planned for a property, Tetra4 must consult with the landowner and take reasonable steps to obtain his consent to execute the activity on his/her land. A system to arrange access to properties

		must be devised and formalised. All reasonable efforts must be taken to obtain agreement on the system with the landowners and it must be formalised. Access must be arranged at least 24 hours prior, except in emergencies, when the landowners should also be informed immediately. If routine access is required, the landowners must be provided with a roster indicating dates and approximate times that access will be required. Tetra4 must compensate the landowners for any damage to property or goods if it was due to behaviour of their contractors. Sub-contractors must be made aware of this and a clause spelling out their liability should be included in their contracts. All contractors should sign a code of conduct as part of their induction process. Induction must explicitly include aspects such as closing gates and littering. Toolbox talks must be designed to include social and environmental aspects. A fining system must be put in place for any transgressions affecting the landowners.
100	Employment opportunities	Contractors should be required to make use of a certain proportion of local labour - it is acknowledged that not all skills will be available locally. Jobs should be advertised in a way that is accessible to all members of society and labour desks (labour registration stations) should be in accessible areas. No unrealistic expectations should be created and the recruitment policy giving preference to local labour should be communicated from the beginning of the project. The local area of influence should be agreed with the stakeholders early on in the process.

Environmental Risk (Post-mitigation)	13.00
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	

Prioritisation Factor	1.13
Final Significance	14.63

3. Forex savings -

Impact Name	**Forex savings**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	1	1
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	2	2	Probability	3	3
Environmental Risk (Pre-mitigation)					-9.75
Mitigation Measures					
No mitigation foreseen.					
Environmental Risk (Post-mitigation)					-9.75
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					

Prioritisation Factor	1.13
Final Significance	-10.97

4. Fiscal Income -

Impact Name	**Fiscal Income**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	1	1
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	1	1	Probability	4	4
Environmental Risk (Pre-mitigation)					12.00
Mitigation Measures					
No mitigation foreseen.					
Environmental Risk (Post-mitigation)					12.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2

The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.13
Final Significance	13.50

5. Economic development per capita -

Impact Name	**Economic development per capita**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					15.00
Mitigation Measures					
See Table 7 above.					
Environmental Risk (Post-mitigation)					15.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2

The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.13
Final Significance	16.88

6. Country and Industry Competitiveness -

Impact Name	**Country and Industry Competitiveness**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	4	4
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					16.00
Mitigation Measures					
No mitigation foreseen.					
Environmental Risk (Post-mitigation)					16.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					

Degree of potential irreplaceable loss of resources	2
The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.13
Final Significance	18.00

7. Black Economic Transformation -

Impact Name	**Black Economic Transformation**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	4	4
Extent of Impact	5	5	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					14.00
Mitigation Measures					
No mitigation foreseen.					
Environmental Risk (Post-mitigation)					14.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					

Degree of potential irreplaceable loss of resources	2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.13
Final Significance	15.75

8. Alternative Land-use -

Impact Name	**Alternative Land-use**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	1	1
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	5	5
Environmental Risk (Pre-mitigation)					8.75
Mitigation Measures					

Table 9: Alternative land-use

Mitigation #	Mitigation Title	Mitigation Description
19	Loss of agricultural land	Ensure that as much of the infrastructure as possible is sited away from agricultural lands. Utilize servitudes, farm roads and any other routes to avoid sensitive areas. Ensure that pipelines are buried at sufficient depth (>1 m minimum) to avoid interference with arable agriculture activities.
28	Landowner Consultations	Landowners must be consulted and all reasonable requests complied with. A written landowner agreement should be negotiated and concluded prior to commencement. Should this not be possible, a record should be kept of reasonable negotiations with the land owners.
32	Impacts on land-use	The pipelines will be buried in accordance with the schedule as agreed upon with landowners to minimise disturbance to farming operations [Amendment 2019/05].
40	Loss of farm labour to the Cluster 1 project	If any farm labourers apply for positions at Tetra4 or one of its contractors, Tetra4 or the contractor must ensure that the labourer is aware that the position may only be temporary and what the long term consequences of taking the position are.
41	Potential for conflict between local residents and newcomers about economic opportunities.	Preference for employment should be given to the local community. The recruitment policy must be communicated openly and made available to the public if requested.
94	Interference with existing land uses/livelihoods	Tetra4 must appoint a CLO that deals with the affected landowners throughout the life of the project. If existing activities will be affected negatively Tetra4 must enter into negotiations with the affected parties as soon as reasonably achievable to ensure the affected parties are compensated fairly or can make additional arrangements. Interference with existing livelihoods should be avoided if possible. If any new

		activities are planned for a property, Tetra4 must consult with the landowner and take reasonable steps to obtain his consent to execute the activity on his/her land. A system to arrange access to properties must be devised and formalised. All reasonable efforts must be taken to obtain agreement on the system with the landowners and it must be formalised. Access must be arranged at least 24 hours prior, except in emergencies, when the landowners should also be informed immediately. If routine access is required, the landowners must be provided with a roster indicating dates and approximate times that access will be required. Tetra4 must compensate the landowners for any damage to property or goods if it was due to behaviour of their contractors. Sub-contractors must be made aware of this and a clause spelling out their liability should be included in their contracts. All contractors should sign a code of conduct as part of their induction process. Induction must explicitly include aspects such as closing gates and littering. Toolbox talks must be designed to include social and environmental aspects. A fining system must be put in place for any transgressions affecting the landowners.	

Environmental Risk (Post-mitigation)	8.75
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.13
Final Significance	9.84

9. Need and Desirability -					
Impact Name	**Need and Desirability**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	5	5
Extent of Impact	4	4	Reversibility of Impact	4	4
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					15.00
Mitigation Measures					
See Table 7 above.					
Environmental Risk (Post-mitigation)					15.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.13
Final Significance					16.88

10. Impact on individual farmland values -					
Impact Name	**Impact on individual farmland values**				
Alternative	**0**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	3	3
Environmental Risk (Pre-mitigation)					-7.50
Mitigation Measures					
See Table 9 Above.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Low
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.13
Final Significance					-8.44

11. GGP Impact -

Impact Name	**GGP Impact**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	5	5
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	4	4	Probability	5	5
Environmental Risk (Pre-mitigation)					23.75
Mitigation Measures					
See Table 7 above.					
Environmental Risk (Post-mitigation)					23.75
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.38
Final Significance					32.66

12. Employment Impacts -					
Impact Name	**Employment Impacts**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	4	4	Probability	4	4
Environmental Risk (Pre-mitigation)					17.00
Mitigation Measures					
See Table 8 above.					
Environmental Risk (Post-mitigation)					17.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.38
Final Significance					23.38

13. Forex savings -

Impact Name	**Forex savings**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	4	4
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	4	4	Probability	4	4
Environmental Risk (Pre-mitigation)					18.00
Mitigation Measures					
No mitigation required.					
Environmental Risk (Post-mitigation)					18.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.38
Final Significance					24.75

14. Fiscal Income -

Impact Name	**Fiscal Income**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	3	3
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	4	4	Probability	4	4
Environmental Risk (Pre-mitigation)					17.00
Mitigation Measures					
No mitigation required.					
Environmental Risk (Post-mitigation)					17.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.38
Final Significance					23.38

15. Economic development per capita -					
Impact Name	**Economic development per capita**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	4	4	Probability	4	4
Environmental Risk (Pre-mitigation)					17.00
Mitigation Measures					
See Table 7 above.					
Environmental Risk (Post-mitigation)					17.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.38
Final Significance					23.38

16. Country and Industry Competitiveness -

Impact Name	Country and Industry Competitiveness				
Alternative	0				
Phase	Operation				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	5	5
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	4	4
Environmental Risk (Pre-mitigation)					20.00
Mitigation Measures					
See Table 7 above.					
Environmental Risk (Post-mitigation)					20.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.38

Final Significance	27.50

17. Black Economic Transformation -

Impact Name	**Black Economic Transformation**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	4	4
Extent of Impact	5	5	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	4	4
Environmental Risk (Pre-mitigation)					16.00
Mitigation Measures					
No mitigation required.					
Environmental Risk (Post-mitigation)					16.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					

Prioritisation Factor	1.38
Final Significance	22.00

18. Alternative Land-use -

Impact Name	**Alternative Land-use**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	1	1
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	5	5
Environmental Risk (Pre-mitigation)					11.25
Mitigation Measures					
See Table 9 above.					
Environmental Risk (Post-mitigation)					11.25
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2

The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.38
Final Significance	15.47

19. Need and Desirability -

Impact Name	**Need and Desirability**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	5	5
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	4	4
Environmental Risk (Pre-mitigation)					20.00
Mitigation Measures					
See Table 7 above.					
Environmental Risk (Post-mitigation)					20.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					2

The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.38
Final Significance	27.50

20. Impact on individual farmland values -

Impact Name	**Impact on individual farmland values**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	3	3
Environmental Risk (Pre-mitigation)					-9.00
Mitigation Measures					
See Table 9 above.					
Environmental Risk (Post-mitigation)					-9.00
Degree of confidence in impact prediction:					0
Impact Prioritisation					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.					

Degree of potential irreplaceable loss of resources	2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.38
Final Significance	-12.38

21. GGP Impact -					
Impact Name	**GGP Impact**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					-13.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-13.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					

Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-13.00

22. Employment Impacts -

Impact Name	**Employment Impacts**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					-13.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-13.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					1

Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-13.00

23. Forex savings -

Impact Name	**Forex savings**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	5	5
Environmental Risk (Pre-mitigation)					-22.50
Mitigation Measures					
No mitigation required.					
Environmental Risk (Post-mitigation)					-22.50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					1

Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-22.50

24. Fiscal Income -

Impact Name	**Fiscal Income**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	5	5
Environmental Risk (Pre-mitigation)					-22.50
Mitigation Measures					
No mitigation required.					
Environmental Risk (Post-mitigation)					-22.50
Degree of confidence in impact prediction:					High
Impact Prioritisation					

Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-22.50

25. Economic development per capita -

Impact Name	**Economic development per capita**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					-13.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-13.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					

Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-13.00

26. Country and Industry Competitiveness -

Impact Name	**Country and Industry Competitiveness**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	5	5	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	4	4
Environmental Risk (Pre-mitigation)					-18.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-18.00
Degree of confidence in impact prediction:					Medium

Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-18.00

27. Black Economic Transformation -

Impact Name	Black Economic Transformation				
Alternative	0				
Phase	Decommissioning				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	4	4
Environmental Risk (Pre-mitigation)					-16.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-16.00
Degree of confidence in impact prediction:					Medium

Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-16.00

28. Alternative Land-use -

Impact Name	**Alternative Land-use**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	2	2	Reversibility of Impact	4	4
Duration of Impact	2	2	Probability	5	5
Environmental Risk (Pre-mitigation)					-15.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-15.00

Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-15.00

29. Need and Desirability -

Impact Name	**Need and Desirability**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	5
Extent of Impact	4	4	Reversibility of Impact	4	4
Duration of Impact	2	2	Probability	4	4
Environmental Risk (Pre-mitigation)					-15.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-15.00

Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-15.00

30. Impact on individual farmland values -

Impact Name	**Impact on individual farmland values**				
Alternative	**0**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	3	3
Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	3	3
Environmental Risk (Pre-mitigation)					8.25
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					

Environmental Risk (Post-mitigation)	8.25
Degree of confidence in impact prediction:	0
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	8.25

31. GGP Impact -

Impact Name	**GGP Impact**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	5	5
Environmental Risk (Pre-mitigation)					-22.50
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					

Environmental Risk (Post-mitigation)	-22.50
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-22.50

32. Employment Impacts -					
Impact Name	**Employment Impacts**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	5	5
Environmental Risk (Pre-mitigation)					-22.50
Mitigation Measures					

Comply with downscaling regulations of the DMRE.	
Environmental Risk (Post-mitigation)	-22.50
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-22.50

33. Forex savings -					
Impact Name	**Forex savings**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	5	5
Environmental Risk (Pre-mitigation)					-22.50

Mitigation Measures	
No mitigation required.	
Environmental Risk (Post-mitigation)	-22.50
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-22.50

34. Fiscal Income -

Impact Name	**Fiscal Income**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	5	5

Environmental Risk (Pre-mitigation)	-22.50
Mitigation Measures	
No mitigation required.	
Environmental Risk (Post-mitigation)	-22.50
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-22.50

35. Economic development per capita -

Impact Name	**Economic development per capita**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	4	4	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	5	5

Environmental Risk (Pre-mitigation)	-22.50
Mitigation Measures	
Comply with downscaling regulations of the DMRE.	
Environmental Risk (Post-mitigation)	-22.50
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-22.50

36. Country and Industry Competitiveness -

Impact Name	**Country and Industry Competitiveness**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	5	5	Reversibility of Impact	2	2

Duration of Impact	5	5	Probability	4	4
Environmental Risk (Pre-mitigation)					-15.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-15.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-15.00

37. Black Economic Transformation -

Impact Name	**Black Economic Transformation**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	3

Extent of Impact	3	3	Reversibility of Impact	5	5
Duration of Impact	5	5	Probability	4	4
Environmental Risk (Pre-mitigation)					-16.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-16.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-16.00

39. Need and Desirability -

Impact Name	**Need and Desirability**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**

Nature of Impact	-1	-1	Magnitude of Impact	5	5
Extent of Impact	4	4	Reversibility of Impact	4	4
Duration of Impact	5	5	Probability	4	4
Environmental Risk (Pre-mitigation)					-18.00
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					-18.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-18.00

40. Impact on individual farmland values -

Impact Name	**Impact on individual farmland values**				
Alternative	**0**				
Phase	**Rehab and closure**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	1	1	Magnitude of Impact	3	3

Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	3	3
Environmental Risk (Pre-mitigation)					8.25
Mitigation Measures					
Comply with downscaling regulations of the DMRE.					
Environmental Risk (Post-mitigation)					8.25
Degree of confidence in impact prediction:					0
Impact Prioritisation					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					8.25

11 MITIGATION

See the above section for the mitigation measures.

12 ADDENDUM 1

Although this is a relatively old study (2013), it gives a very good example of the structure of multipliers in the USA. Although the multipliers are not in fact calculated in the table below, these ratios are easy to calculate. Suffice to say, this study was undertaken by a reputable organization and its ratios are comparable to this evaluation's own estimates. Keep in mind yet again that the gas sector in SA is slightly under-recorded and SA's gas multipliers are combined with the Electricity Sector.

Sector Description	Employment*	Labor Income ($ million)**	Value Added ($ million)
Direct Impact of the Oil and Natural Gas Industry	**2,590,700**	**$203,591**	**$551,018**
Indirect and Induced Impact on Other Industries	**7,242,600**	**$394,024**	**$658,372**
Operational Impact	***5,854,500***	***$311,777***	***$522,535***
Agriculture	84,700	$2,591	$3,978
Mining	13,700	$1,064	$2,749
Utilities	24,600	$3,256	$12,950
Construction	430,000	$23,762	$25,822
Manufacturing	380,200	$26,826	$46,883
Wholesale and retail trade	777,600	$33,179	$54,430
Transportation and warehousing	228,900	$11,869	$16,159
Information	101,700	$10,432	$20,710
Finance, insurance, real estate, rental and leasing	721,200	$37,435	$144,867
Services	2,829,100	$142,602	$172,764
Other	262,700	$18,761	$21,221
Capital Investment Impact	***1,388,100***	***$82,247***	***$135,837***
Agriculture	17,400	$592	$876
Mining	3,700	$282	$699
Utilities	4,000	$525	$2,165
Construction	20,900	$1,170	$1,390
Manufacturing	221,800	$17,941	$28,886
Wholesale and retail trade	218,000	$11,497	$19,450
Transportation and warehousing	57,600	$3,073	$4,342
Information	35,200	$3,810	$7,950
Finance, insurance, real estate, rental and leasing	155,000	$8,091	$26,553
Services	640,500	$34,270	$42,575
Other	13,900	$997	$953
Total Economic Impact	**9,833,200**	**$597,615**	**$1,209,389**

Source: PwC calculations using the IMPLAN modeling system (2011 database).
Details may not add to totals due to rounding.
* Employment is defined as the number of payroll and self-employed jobs, including part-time jobs.
** Labor income is defined as wages and salaries and benefits as well as proprietors' income.

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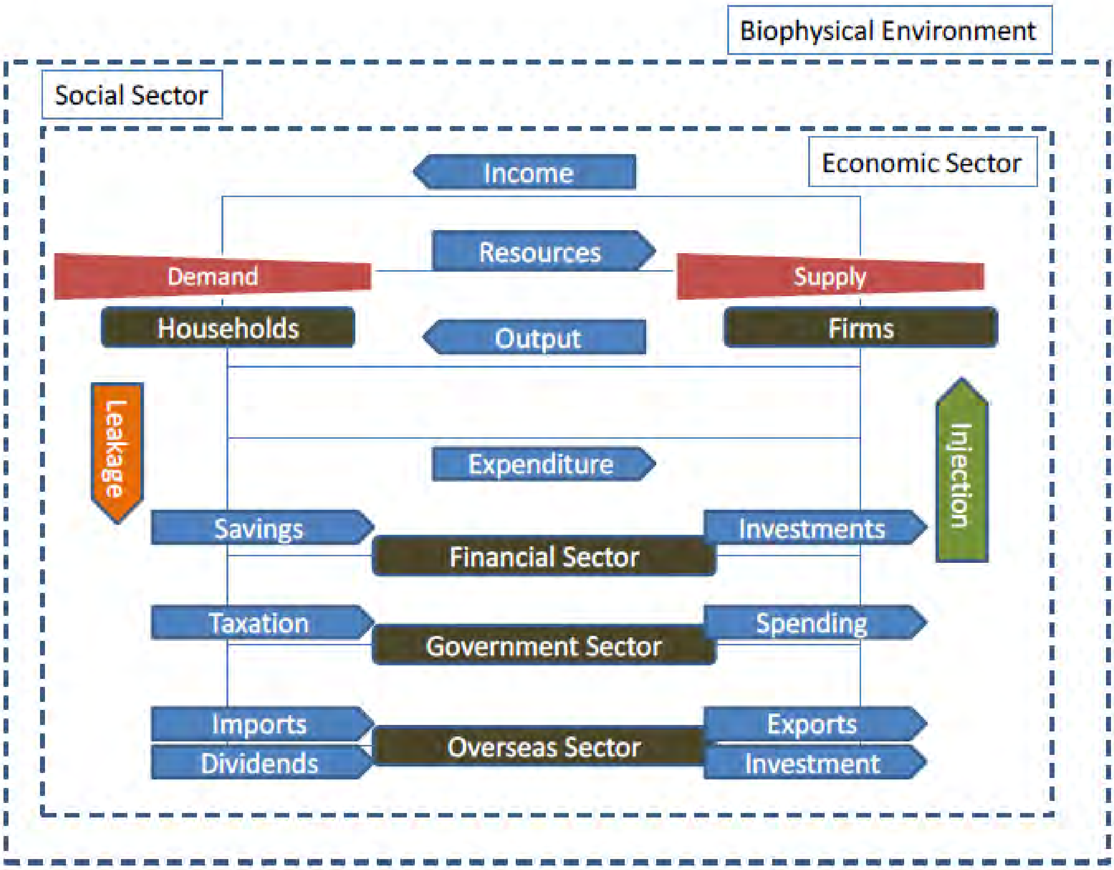
[i] https://www.api.org/~/media/files/policy/jobs/economic_impacts_ong_2011.pdf


Biophysical Environment
Social Sector
Economic Sector
Income
Resources
Demand
Supply
Households
Output
Firms
Leakage
Injection
Expenditure
Savings
Financial Sector
Investments
Taxation
Government Sector
Spending
Imports
Dividends
Overseas Sector
Exports
Investment

Document Number
HG-R-22-004-V3

TETRA 4 GAS PRODUCTION CLUSTER 2 EIA HYDROGEOLOGICAL BASELINE INVESTIGATION AND GROUNDWATER IMPACT ASSESSMENT

October 2022

Conducted on behalf of:
Environmental Impact Management Services (Pty) Ltd

Compiled by:
JFW Mostert (M.Sc. Hydrogeology, *Pr.Sci.Nat.*)

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DOCUMENT HISTORY

Report no	Date	Version	Status
HG-R-22-004-V1	May 2022	1.0	Draft
HG-R-22-004-V2	July 2022	2.0	Draft
HG-R-22-004-V3	October 2022	3.0	Draft
HG-R-22-004-V3	October 2022	3.0	Final

REPORT REVIEW AND SIGN OFF

Report undertaken by:	JFW Mostert
Signature:	
Designation:	Hydrogeologist (Pr.Sci.Nat.40057/14 – Water Resource Science)
Reference Number:	HG-R-22-004-V3
Date:	12 October 2022

INDEMNITY AND SPECIALIST DECLARATION

The findings, results, observations, conclusions and recommendations given in this report are based on the author's best scientific and professional knowledge as well as available information. The report is based on assessment techniques, which are limited by information available, time and budgetary constraints relevant to the type and level of investigation undertaken and Gradient Consulting (Pty) Ltd reserve the right to modify aspects of the report including the recommendations if and when new information may become available from ongoing research, monitoring, further work in this field, or pertaining to the investigation.

Although Gradient Consulting (Pty) Ltd exercises due care and diligence in rendering services and preparing documents, Gradient Consulting (Pty) Ltd accepts no liability, and the client, by receiving this document, indemnified Gradient Consulting (Pty) Ltd against all actions, claims, demands, losses, liabilities, costs, damages and expenses arising from or in connection with the services rendered, directly or indirectly by Gradient Consulting (Pty) Ltd and by the use of the information contained in this document.

This report has been drafted as per the latest requirements for specialist reports as set by the Department of Environmental Affairs and listed in Government Gazette No. 40713, dated 24 March 2017 and Government Gazette No. 40772 dated 07 April 2017 in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA). We realise that a false declaration is an offence in terms of regulation 48 of the Environmental Impact Assessment Regulations, 2014 (as amended) promulgated in terms of the National Environmental Management Act, 107 of 1998 (NEMA) and is punishable in terms of section 49B of the NEMA.

I, JFW Mostert, hereby declare that:

- I act as the independent specialist in this application.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity.
- I will comply with the Act, Regulations and all other applicable legislation.
- I have not, and will not engage in, conflicting interests in the undertaking of the activity.
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.
- All the particulars furnished by me in this form are true and correct.

JFW Mostert (Hydrogeologist)

M.Sc. Hydrogeology, Pr.Sci.Nat.

Executive summary

Gradient Consulting (Pty) Ltd was appointed by Environmental Impact Management Services (Pty) Ltd to conduct a hydrogeological baseline investigation and groundwater impact assessment to be conducted to support an Environmental Impact Assessment (EIA) and Water Use Licence Application (WULA) authorisation process to be followed. The project entails expansion of the existing Tetra 4 natural gas production development and will include a combined helium and liquid natural gas (LNG) plant, gas wells and the associated pipelines and compressor infrastructure.

The objective of this investigation is to determine the status quo of the regional groundwater system and aim to quantify and qualify potential impacts of the proposed expansion project on sensitive environmental and groundwater receptors.

The gas production right and greater study area covers a total area of ~187 000ha and falls within the Free State Province of South Africa.

The topography of the greater study area is generally flat and can be classified as a central interior plain or plateau. The lowest topographical elevation on-site is recorded as ~1280.0mamsl which is situated towards the western and eastern borders where the Sandrivier enters and exists the gas production right boundary and form part of the on-site drainage system. The highest topographical point recorded on site is approximately 1405.0mamsl and form part of the quaternary catchment boundary and groundwater/ surface water divide to the southern and south-western portion of the study area.

The greater study is situated in primary catchment (C) of the Vaal River drainage system which falls under the Vaal Water Management Area. The project area is situated within quaternary catchments C42K and C42L.

The hydrology of the region is characterised by predominately perennial watercourses with the regional drainage occurring in a general west to north-western direction via the Sandrivier and Doringrivier both of which are traversing the study area from east to west (Sandrivier) and southeast to northwest (Doringrivier). A non-perennial drainage, Bosluisspruit, also traverse the study area and generally drain the catchment in a northern direction.

The study area's rainfall is strongly seasonal, and the weather pattern reflects a typical summer rainfall region, with > 80.0% of precipitation occurring as convective thunderstorms from October to March. The calculated mean annual precipitation (MAP) for this rainfall zone is 521.0mm/a, with the 5th percentile of the data set (roughly equivalent to a 1:20 year drought period) calculated at 343.38mm/a while the 95th percentile (representing a 1:20 flood period) is calculated at 752.43mm/a. The mean annual evaporation (s-pan) ranging between 1600mm/a to 1680mm/a, more than threefold the annual precipitation.

The project area's surficial geology comprises mostly aeolian sands, quaternary deposits and isolated outcrops of the Karoo Supergroup i.e., dolerite and sandstone/ shales, while the greater study area is generally also underlain by rocks of the Witwatersrand Supergroup as well as the Ventersdorp Supergroup. Isolated patches within the study area are also covered by alluvial sand deposits which is mainly associated with the Sand and Doringriver floodplains and constrained by drainage patterns and riparian zones. The primary source of gas

originates from the Witwatersrand Supergroup as well as the shallower Karoo sediments.

According to the DWS Hydrogeological map the site is predominantly underlain by an intergranular and fractured aquifer system (d2) with the aquifer media consisting mainly of fractured and weathered compact argillaceous strata. According to Vegter's groundwater regions delineated (2000) the study area can be classified as falling under the North-eastern Pan Belt region.

For the purposes of this investigation, four main hydrostratigraphic units/aquifer systems can be inferred in the saturated zone:

i. **A shallow quaternary and recent types of sediments** (unconfined) are characteristically a primary porosity aquifer associated with alluvium material deposited in flood plains of the main rivers traversing the study area. These aquifers cover a large portion of the study area and are limited to a zone of variable width and depth. The alluvial aquifer is specifically vulnerable to contamination as it there is a direct connectivity with rivers and streams and associated high permeability.

ii. **A shallow, intergranular aquifer** (unconfined to semi-confined) occurring in the transitional soil and weathered bedrock formations of the Karoo Supergroup rocks underlain by more consolidated bedrock. Groundwater flow patterns usually follow the topography, discharging as natural springs at topographic low-lying areas. Usually, this aquifer can be classified as a secondary porosity aquifer and is generally unconfined with phreatic water levels. Due to higher effective porosity (*n)* this aquifer is most susceptible to impacts from contaminant sources.

iii. **An intermediate, fractured aquifer** (semi-confined to confined) where pores are well-cemented and do not allow any significant flow of water. Groundwater flow is dictated by transmissive secondary porosity structures such as bedding plane fractures, faults, contact zones as well as fracture zones that occur in the relatively competent Karoo Supergroup host rock. Fractured sandstones, mudstones and shales sequences are considered as fractured rock aquifers holding water in storage in both pore spaces and fractures. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. Although generally low yielding, this aquifer is important to local groundwater users as it form the sole source of water supply in the region (Lea, 2017).

iv. **A deeper, fractured aquifer** (semi-confined to confined) where pores are well-cemented and do not allow any significant flow of water. Groundwater flow is dictated by transmissive secondary porosity structures such as bedding plane fractures, faults and contact zones fracture zones that occur in the relatively competent Ventersdorp and Witwatersrand Supergroups host rock. Volcanic formations of the Ventersdorp lavas can also act as aquicludes, restricting the vertical movement of groundwater. Fractured quartzites of the Witwatersrand Supergroup are considered as fractured rock aquifers holding water in storage in both pore spaces and fractures. Groundwater yields, although more heterogeneous, can be expected to be higher than the weathered zone aquifer. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position.

The water in the deep aquifers is naturally saline due to their marine depositional history. It should be noted that the shallow potable Karoo aquifers are separated from deep aquifer systems associated with the Ventersdorp and Witwatersrand Supergroup formations by the 30.0m thick dolerite sill (which may act as an aquitard) that extends across the study area and by the 65.0m thick Dwyka Tillite sedimentary deposit acting as an aquiclude. It should furthermore be noted that, under natural conditions, there is very limited hydraulic connectivity between the deep, fractured and shallow, intergranular aquifers.

The hydraulic conductivity of sedimentary formations such as evident on site can range from $10E^{-6}$ – $10E^{-2}$ m/d. Historical aquifer tests results confirm that the permeability of the shales is very low ($9E^{-4}$m/d). The hydraulic conductivity of fractured igneous rocks (i.e., dolerite) varies between $10E^{-6}$ – $10E^{-1}$ m/d, while conductivity values for un-fractured igneous rocks (i.e., fresh dolerite sill) ranges between $10E^{-9}$ – $10E^{-6}$ m/d. The hydraulic conductivity of quaternary deposits and alluvial pockets associated with the drainage system i.e., riverbed aquifers can be orders higher and can vary between $10E^{-2}$ – $10E^{1}$ m/d.

An approximation of recharge for the study area is estimated at ~4.0% of MAP i.e., ~21.69mm/a.

A total of 78 groundwater receptors i.e., boreholes, artesian wells, wind pumps as well as surface water features were visited as part of the hydrocensus user survey which are largely applied for livestock watering and domestic water supply purposes. Of the boreholes recorded, the majority are in use (>78.0%) while ~17.0% are not currently being utilized.

The unsaturated zone within the study area is in the order of 0 (fully saturated to surface) to >26.0m with a mean thickness of approximately ~9.0m. It should be noted that due to the argillaceous nature of the host aquifer(s) the shallow water levels observed at some of the borehole localities can be attributed to clay/silt lenses and be indicative of perched aquifer conditions and not necessarily represent the vadose zone.

Artesian conditions were observed at three of the boreholes visited namely HBH31, 21B as well as 8B which can be indicative of semi-confined to confined aquifer conditions present or perched aquifer conditions. The minimum water level was recorded at 0.0mbgl, while the deepest water level was measured at borehole locality Mon-HDR1 (26.71mbgl).

It is noted that most water levels suggest a decrease in water levels and recovering trend. The latter can be attributed the onset of the wet cycle and above average rainfall events experienced with rainfall recharge replenishing aquifer storage. It can be observed that there is a definite a relatively quick response to rainfall, suggesting that recharge of the shallow, intergranular aquifer takes place without a prolonged lag effect. Statistical analyses of the water level trends furthermore suggest that the local groundwater system is in quasi-steady state conditions.

Analysed data indicate that the surveyed water levels correlate very well to the topographical elevation (R^2 <0.98). Accordingly, it can be assumed that the regional groundwater flow direction is dictated by topography. Bayesian interpolation was used to interpolate the groundwater levels throughout the study area.

The inferred groundwater flow direction will be towards the lower laying drainage system(s) traversing the project area from where groundwater will discharge as baseflow. The groundwater flow direction within the southern catchment of the Sandrivier and Doringrivier, also in the vicinity of the proposed plant expansion footprint, will be in a general northern direction, whereas the groundwater flow direction within the northern catchment of the study area will be mostly in a south to southwestern direction.

The average groundwater gradient (i) of the shallow, weathered aquifer in the vicinity of the proposed plant expansion footprint is relatively flat and calculated at a mean of 0.002, with a maximum of 0.003 in a south to north orientation and a minimum of 0.001 in a general southeast to northwest orientation.

The expected seepage rate from contamination originating at the proposed plant expansion footprint as well as associated infrastructure is estimated at an average of approximately 1.26m/a, with a maximum distance of ~2.20m/a in a southern to northern direction.

Under natural conditions this area exhibits certain regions where there is pronounced interaction between surface and groundwater and regional drainages can be generally classified as influent or gaining stream systems. The alluvial associated with the floodplains of the Sand - and Doringrivier forms a primary aquifer and is directly connected with surface water resources, especially during high flow conditions.

The hydrochemical results of the hydrocensus boreholes water samples analysed suggest the overall ambient groundwater quality is good with most macro and micro determinants falling within or below the SANS 241:2015 limits. Groundwater can be described as neutral, saline to very saline and hard to very hard. The groundwater quality is impacted by the geological formations, which were deposited in shallow marine environments and are therefore naturally saline.

It is observed that most of the boreholes indicate elevated Nitrate (NO_3) concentrations. The latter may be attributed to the agricultural land-use activities dominating the greater study area with elevated NO_3 concentrations potentially derived from leachate of fertilizer to the local aquifer. It is noted that borehole localities with elevated NO_3 concentrations are situated within or directly down-gradient of planted crop areas as well as near surface water features.

Surface water quality can be classified as moderate to good with Aluminum (Al) and Iron (Fe) being slightly elevated. It should be noted that there is not a significant change in the downstream water quality compared to the upstream quality with an increase in Aluminum (Al), however all surface water samples analysed suggest elevated heavy metal concentrations i.e., Al and Fe.

Three distinct categories can be observed, Category A: Calcium-Bi-carbonate dominance which suggest a recently recharged and unimpacted groundwater environment (majority of samples), Category B: Calcium-Magnesium-Chloride dominance which indicate a static and disordinate environment as well as Category C: Sodium-Potassium-Bi-carbonate dominance which indicate an area of dynamic groundwater environments.

The surface water samples analysed can be categorized as having Calcium-Magnesium-Chloride dominance which indicate a static and disordinate environment, one would except a more Calcium-Bi-carbonate signature from an unpolluted surface water source, however baseflow discharge present from the saline groundwater resource will have an impact on the salinity of the surface water resources as is evident.

Comparison of different hydrochemical signatures observed suggest on-site boreholes to target a shallow, intergranular aquifer unit as well as a deeper (possibly intermediate, fractured aquifer unit) being more saline.

The Sodium-Potassium-Chloride dominance of the deep, fractured aquifer groundwater suggests extremely saline conditions as expected.

According to the aquifer classification map of South Africa the project area is underlain by a “Minor aquifer”. It should however be noted that the shallow, intergranular aquifer is important to local groundwater users as it forms the sole source of water supply in the region. Furthermore, the primary riparian zone aquifer is classified as a major aquifer system due to its highly permeable nature as well as good water quality.

A GQM Index = 4 was calculated for the local aquifer system and according to this estimate, a “Medium” level groundwater protection is required for this aquifer system. According to the DRASTIC index methodology applied, the existing/proposed activities and associated infrastructure’s risk to groundwater pollution of the shallow, intergranular aquifer is rated as “Moderate”, Di = 109.

A numerical groundwater flow and mass transport migration model was developed and calibrated in steady state based on gathered site characterisation information which was applied as initial hydrogeological conditions for transient simulations.

A scenario was simulated representing point source pollution plume migration of saline groundwater emanating from leaking boreholes targeting the deep, fractured aquifer for the operational phase (20-year period). The TDS pollution plume extend covers a total area of approximately 414.06ha in the Karoo formations, reaching a maximum distance of ~80.0m in a radial pattern from the gas production borehole(s), and approximately 251.60ha in the alluvial deposits, reaching a maximum distance of ~200.0m in a radial pattern from the gas production borehole(s) after a simulation period of 20-years. The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH63, HBH72, HBH73 and HBH74.

It can be noted that the pollution plume migration in the denser Karoo formations is sluggish while movement in the unconsolidated alluvial deposits of the riparian zone suggest a larger flux.

It is evident that source term mass load contribution to existing neighbouring borehole situated near the gas production borehole(s) does not exceed ~800.0mg/l and ranges between 600mg/l to 700.0mg/l.

A scenario was simulated representing point source pollution plume migration of stray methane (CH_4) gas emanating from leaking boreholes targeting the deep, fractured aquifer for the operational phase (20-year period). The CH_4 pollution plume extend covers a total area of approximately 162.74ha in the Karoo formations, reaching a maximum distance of ~50.0m in a radial pattern from the gas production borehole(s), and approximately 62.83ha in the alluvial deposits, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole(s) after a simulation period of 20-years. The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH63, HBH72, HBH73 and Tetra4 monitoring borehole 11A.

It is noted that the source term mass load contribution to existing neighbouring borehole situated near the gas production borehole(s) remains below the EPA safety threshold (2011) of 10.0mg/l and ranges between 0.01mg/l to 1.50mg/l.

A scenario was simulated with a pollution plume migration from the plant footprint areas for the operational phase. The TDS pollution plume extend covers a total area of approximately 48.80ha reaching a maximum distance of ~110.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 20-years. The simulation indicates that no neighbouring boreholes or local drainages are expected to be impacted on during the operational phase.

It is evident that the TDS mass load contribution to down-gradient receptors increase to a concentration of between 200.0 – 800.0 mg/l, however, remains below the SANS 241:2015 limit of 1200.0mg/l for the duration of the simulation period.

It can be noted that the mass transport of the pollution plume is mostly limited to the shallow, intergranular aquifer.

A scenario was simulated representing point source pollution plume migration of saline groundwater emanating from leaking boreholes targeting the deep, fractured aquifer for the post-closure phase. The TDS pollution plume extend covers a total area of approximately 643.70ha in the Karoo formations, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole(s), and approximately 392.70ha in the alluvial deposits, reaching a maximum distance of ~250.0m in a radial pattern from the gas production borehole(s) after a simulation period of 50-years. The TDS pollution plume extend covers a total area of approximately 1 456.42ha in the Karoo formations, reaching a maximum distance of ~150.0m in a radial pattern from the gas production borehole(s), and approximately 769.70ha in the alluvial deposits, reaching a maximum distance of ~350.0m in a radial pattern from the gas production borehole(s) after a simulation period of 100-years. The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH48, HBH50, HBH63, HBH72, HBH73, HBH74 as well as Tetra4 monitoring boreholes Mon 2057 and 11A.

It is noted that source term mass load contribution to existing neighbouring and monitoring boreholes situated near the gas production boreholes ranges between 650.0mg/l to >1200.0mg/l. Furthermore, it is observed that the SANS241:2015 limit is exceeded at borehole localities HBH63 and Mon 2057.

A scenario was simulated representing point source pollution plume migration of stray methane (CH_4) gas emanating from leaking boreholes targeting the deep, fractured aquifer for the post-closure phase. The CH_4 pollution plume extend covers a total area of approximately 414.06ha in the Karoo formations, reaching a maximum distance of ~80.0m in a radial pattern from the gas production borehole(s), and approximately 141.37ha in the alluvial deposits, reaching a maximum distance of ~150.0m in a radial pattern from the gas production borehole(s) after a simulation period of 50-years. The CH_4 pollution plume extend covers a total area of approximately 643.70ha in the Karoo formations, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole(s,) and approximately 392.70ha in the alluvial deposits, reaching a maximum distance of ~250.0m in a radial pattern from the gas production borehole(s) after a simulation period of

100-years. The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH48, HBH49, HBH63, HBH72, HBH73 as well as Tetra4 monitoring boreholes Mon 2057 and 11A.

It is evident that source term mass load contribution to existing neighbouring and monitoring boreholes situated near the gas production boreholes ranges between 0.50mg/l to ~2.0mg/l, however, remains below the EPA safety threshold (2011) of 10.0mg/l.

A scenario was simulated with a pollution plume migration from the plant footprint areas for the post-closure phase. The TDS pollution plume extend covers a total area of approximately 54.8ha reaching a maximum distance of ~170.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 50-years and covers a total area of approximately 71.20ha reaching a maximum distance of ~300.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 100-years. It is evident that the pollution plume potentially reaches the local drainages system down-gradient of the plant footprint during the post-closure phase.

It is observed that the TDS mass load contribution to down-gradient receptors increase to a concentration above the SANS 241:2015 limit of 1200.0mg/l for the post-closure simulation period. It is noted that the TDS mass load contribution increases to a percentage of ~10.0% to the Sandrivier where the mass load contribution to the Doringrivier increase to a percentage of ~2.0% for the duration of the post-closure simulation period.

It should be noted that vast areas within the study area have been subjected to historical mining activities and, as such, reflect modified to highly modified present ecological status. A total number of >15 000 historical exploration wells have been drilled throughout the study area, some of which remain uncased and unsealed. The latter may act as preferential pathways and conduits for groundwater flow and contaminant transport mechanisms. As mentioned earlier an impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human and/or other related activities. Accordingly, this already highly modified zones should form part of the impact significance rating and risk approach. During the construction phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium negative** without implementation of remedial measures and **low negative** with implementation of proposed mitigation measures. The main impacts associated with the construction phase activities include the following:

- Groundwater deterioration and siltation due to contaminated stormwater run-off from the construction area.
- Poor quality leachate may emanate from the construction camp which may have a negative impact on groundwater quality.
- Mobilisation and maintenance of heavy vehicles and machinery on-site may cause hydrocarbon contamination of groundwater resources.
- Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution.

During the operational phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium** to **high negative** without implementation of remedial measures and **low** to **medium negative** with implementation of proposed mitigation measures. The main impacts associated with the operational phase activities include the following:

- Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.
- Migration of stray methane (CH_4) gas from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.
- Groundwater pollution because of wastewater spills and seepage from the evaporation dams.
- Poor quality leachate may emanate from the plant footprint area which may have a negative impact on groundwater quality.
- Mobilisation and maintenance of heavy vehicle and machinery on-site may cause hydrocarbon contamination of groundwater resources.
- Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution.
- Leakage of harmful substances from tanks, pipelines or other equipment may cause groundwater pollution.
- Leachate of contaminants used in the drilling mud sump(s) to the intergranular, potable aquifer(s) during the operational phase.

During the decommissioning and post-closure phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium negative** without implementation of remedial measures and **low** to **medium negative** with implementation of proposed mitigation measures. The main impacts associated with the post-closure and decommissioning phase activities include the following:

- Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the borehole closure and decommissioning phase.
- Migration of stray methane (CH_4) gas from the deep, fractured aquifer to the overlying, potable aquifer(s) borehole closure and decommissioning phase.
- Groundwater pollution because of wastewater spills and seepage from the evaporation dams.
- Poor quality leachate may emanate from the plant footprint area which may have a negative impact on groundwater quality.
- De-mobilisation of heavy vehicle and machinery as part of the decommissioning phase on-site may cause hydrocarbon contamination of groundwater resources.

The most significant impact of the project on the regional groundwater regime is deterioration of the potable Karoo aquifer water quality as well as modification of the riparian zone primary porosity aquifer associated with alluvium material deposited in flood plains. Groundwater is the sole water resource to the landowners and rural communities within the study area and can thus be classified as a sole source aquifer. It can be concluded that, should the prescribed mitigation and management measures, as stipulated in the groundwater management plan, be implemented and honoured, the impacts associated with the project phases can be minimised. It is important that an integrated groundwater monitoring program be developed and applied serving as an early warning and detection mechanism to implement mitigation measures. The calibrated groundwater flow model should be applied as groundwater management tool for future scenario predictions.

The following recommendations are proposed following this investigation:

i. Mitigation and management measures as set out in the groundwater management plan should be implemented as far as practically possible. It should be noted that the mitigation and management measures recommended in this report should be incorporated into the existing EMPr groundwater management plan and do not substitute the existing mitigation measures, but rather supplement them.

ii. Any development and/or drilling which takes place within the primary porosity aquifer associated with alluvium material deposited in flood plains must be avoided where possible and restricted if it cannot be avoided.

iii. The identified hydrogeological sensitive areas and buffer zones delineated as part of this assessment must be adhered to during the construction and operational phase activities. It is recommended that a localised hydrocensus user survey be performed within a 500.0m radius of each proposed gas production borehole situated within the riparian zone(s) and 350.0m radius of each proposed gas production borehole situated within the Karoo formations in order to identify the presence of other sensitive groundwater receptors and/or private boreholes. Accordingly, the gas production well design must take the results of the hydrocensus into consideration, specifically with regard to the planning and placement of boreholes as part of future drilling programmes.

iv. Additional monitoring boreholes should be established down-gradient of the existing and proposed plant expansion footprints to evaluate the mass load contribution to sensitive environmental and groundwater receptors. Drilling localities should be determined by means of a geophysical survey to target lineaments and weathered zones acting as preferred groundwater flow pathways and contaminant transport mechanisms.

v. It is recommended that the revised monitoring program as set out in this report should be implemented and adhered to. It is imperative that monitoring be conducted to serve as an early warning and detection system. Monitoring results should be evaluated on a bi-annual basis by a suitably qualified person for interpretation and trend analysis and submitted to the Regional Head: Department of Water and Sanitation.

vi. The numerical groundwater flow modelling assumptions should be verified and confirmed. The calibrated groundwater flow model should be updated on a biennial basis as newly gathered monitoring results become available to be applied as groundwater management tool for future scenario predictions.

vii. All preferred groundwater flow pathways which are in direct connection with surface topography such as decommissioned gas production boreholes as well as historical mining exploration boreholes should be sealed off and rehabilitated according to best practise guidelines.

List of Abbreviations

ASTM	**American Society for Testing Materials**
Avg	**Average**
BH	**Borehole**
CMB	**Chloride Mass Balance**
CNG	**Compressed Natural Gas**
CV	**Coefficient of Variation**
b	**Saturated Thickness**
DMR	**Department of Environmental Affairs**
DEM	**Digital Elevation Model**
DRASTIC	**DI Index**
DWS	**Department of Water Affairs and Sanitation**
EC	**Electrical Conductivity (mS/m)**
EA	**Environmental Authorisation**
EIA	**Environmental Impact Assessment**
EMPr	**Environmental Management Programme**
E.N.	**Electro Neutrality**
EPA	**United States Environmental Protection Agency**
ha	**Hectares**
GIS	**Geographic Information Systems**
GN	**Government Notice**
GQM	**Groundwater Quality Management**
i	**Hydraulic gradient (dimensionless)**
I& AP	**Interested and Affected Party**
ICP-OES	**Inductively coupled plasma optical emission spectrometer**
ICP-MS	**Inductively coupled plasma mass spectrometry**
IWULA	**Integrated Water Use License Application**
ISP	**Internal Strategic Perspective**
K	**Hydraulic Conductivity (m/d)**
l/s	**Litre per second**
LNG	**Liquid Natural Gas**
m^3/d	**Cubic meters per day**
MAE	**Mean Annual Evaporation OR Mean Absolute Error**
mamsl	**Metres Above Mean Sea Level**
MAP	**Mean Annual Precipitation**
MAR	**Mean Annual Runoff**
mbgl	**Metres Below Ground Level**
mcm	**Million Cubic Metres**
ME	**Mean Error**
meq/L	**Mili-equivalents per litre**
mg/l	**Milligrams per litre**
mm/a	**Millimetre per annum**
n	**Porosity**
NAWL	**No Access to Water Level**
NGA	**National Groundwater Archive**
NGDB	**National Groundwater Database**

NRMSD	**Normalised Root Mean Square Deviation**
NWA	**National Water Act (Act 36 of 1998)**
REV	**Representative Elementary Value**
RMSE	**Root Mean Square Error**
S	**Storage coefficient**
Sc	**Specific Storage**
SoW	**Scope of Work**
SANAS	**South African National Accreditation System**
SANS	**South African National Standards**
T	**Transmissivity (m^2/d)**
TDS	**Total Dissolved Solids**
UNESCO	**The United Nations Educational, Scientific and Cultural Organisation**
USGS	**United States Geological Survey**
WGS	**World Geodetic System**
WM	**With Mitigation**
WOM	**Without Mitigation**
WULA	**Water Use Licence Application**

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1. INTRODUCTION

1.1. Project background

Gradient Consulting (Pty) Ltd was appointed by Environmental Impact Management Services (Pty) Ltd (hereafter referred to as EIMS) to conduct a hydrogeological baseline investigation and groundwater impact assessment to be conducted to support an Environmental Impact Assessment (EIA) and Water Use Licence Application (WULA) authorisation process to be followed.

The project entails the Tetra 4 natural gas production development which operates under an existing production right (PASA Ref. 12/4/1/07/2/2) as well as environmental authorisation and associated water use licence for their current gas production activities (referred to as Cluster 1). The Tetra 4 Cluster 2 natural gas production project entails the expansion of the existing natural gas production and will include a combined helium and liquid natural gas (LNG) plant, gas wells and the associated pipelines and compressor infrastructure.

This report focuses on the status quo of the regional groundwater system and aims to quantify and qualify potential impacts of the proposed expansion project on sensitive environmental and groundwater receptors.

1.2. Objectives

The objective of this investigation is to:

i. Establish site baseline and background conditions and identify sensitive environmental receptors.

ii. Determine the current status quo of the regional groundwater system including aquifer classification, aquifer unit delineation and vulnerability.

iii. Development of a conceptual groundwater flow model.

iv. Development of a numerical groundwater flow and mass transport model to quantify and qualify the potential impact of the gas extraction as well as simulate potential saline water migration towards the shallow aquifer.

v. Hydrogeological impact assessment and risk matrix.

vi. Recommendations on best practise mitigation and management measures to be implemented.

vii. Compilation of an integrated groundwater monitoring network and protocol.

1.3. Terms of reference

The investigation is based on the terms of reference and scope of work (SoW) as detailed in proposal ref.no. HG-P-21-055-V1, submitted in September 2021. This project plan and scope of work was compiled based on the following guidelines and regulations:

i. Government Notice NO. R. 267: Regulations regarding the procedural requirements for water use licence applications.

ii. Government Gazette No. 40713, dated 24 March 2017 and Government Gazette No. 40772 dated 07 April 2017 in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998)

(NEMA).

iii. Best Practice Guidelines (BPG4 – Impact Prediction) as published by the former Department of Water Affairs and Sanitation (DWS, 2008).

1.3.1. Phase A: Desk study and gap analysis

Phase A will entail the following activities:

i. Information gathering and data acquisition.

ii. Desk study and review of historical groundwater baseline information, existing specialist reports as well as DWS supported groundwater databases i.e., national groundwater archive (NGA).

iii. Fatal flaw and gap analysis.

1.3.2. Phase B: Hydrogeological baseline assessment - hydrocensus user survey, hydrochemical analysis and aquifer classification

Phase B will entail the following activities:

will entail the following activities:

i. Hydrocensus user survey to evaluate and verify existing surface and groundwater uses, local and neighbouring borehole locations and depths, spring localities and seepage zones, regional water levels, abstraction volumes, groundwater application as well as environmental receptors in the vicinity of the proposed gas exploration area.

ii. Sampling of existing boreholes and surface water bodies according to best practise guidelines and analyses of water samples to determine the macro and micro inorganic chemistry and hydraulic connections based on hydrochemistry (analyses at SANAS accredited laboratory).

iii. Assess the structural geology and geometry of the aquifer systems with respect to hydraulic interactions and compartmentalisation.

iv. Data interpretation aiding in aquifer classification, delineation and vulnerability ratings. Development of a scientifically defendable hydrogeological baseline.

v. Compilation of geological, hydrogeological and hydrochemical thematic maps summarising the aquifer system(s), indicating aquifer delineation, groundwater piezometric map, depth to groundwater, groundwater flow directions as well as regional geology.

1.3.3. Phase C: Numerical groundwater flow and contamination transport model update

Phase C will entail the following activities:

i. Development of a conceptual hydrogeological model in conjunction with interpreted geology data and gathered site characterisation information.

ii. Development of a regional numerical groundwater flow model by applying the Finite Element Flow

(FEFLOW) modelling software. Model domain to include proposed infrastructure and gas exploration footprint as well as associated activities.

iii. Calibration of groundwater flow model using site specific data including hydrocensus geosites information.

iv. Development of a numerical mass transport model utilizing the calibrated groundwater flow model as basis.

v. The calibrated model will be used to simulate management scenario's as follows:

a. Steady state groundwater flow directions, hydraulic gradient and flow velocities.

b. Seepage potential from waste facilities and mass transport plume migration with time.

c. Hydrochemical migration of deeper, saline water towards the shallow aquifer and plume propagation with time.

d. Migration of dissolved gas within the aquifer units and plume migration with time.

e. Post-closure scenarios.

f. Water management alternatives and best practice mitigation measures.

1.3.4. Phase D: Hydrogeological impact assessment update and reporting

Phase D will entail the following activities:

i. Compilation of a detailed hydrogeological specialist investigation update report with conclusions and recommendations on the following aspects:

a. Fatal flaw and gap analyses.

b. Site baseline characterisation.

c. Field work summary and interpretation.

d. Aquifer classification and vulnerability.

e. Numerical groundwater flow and mass transport model development, calibration and simulations.

f. Formulation of an impact assessment and risk matrix of proposed activities.

g. Recommendation on best practise mitigation and management measures to be implemented.

ii. Development of an integrated surface water and groundwater monitoring program for implementation.

1.4. Details and expertise of the author

Ferdinand Mostert is a consulting hydrogeologist and specializes in providing hydrogeological advisory and supporting services. He holds a M.Sc. in Hydrogeological from the Institute of Groundwater Studies (IGS) at the

University of the Free State and is a registered Professional Scientist in the Water Resource Sciences field. His experience of 13⁺ years include environmental impact and risk assessments, hydrogeological baseline assessments, aquifer sustainability studies contamination risk assessments, numerical groundwater flow and mass transport modeling, mine dewatering designs, groundwater due diligence studies, groundwater resource development, integrated groundwater and surface water management as well as practical implementation and decision-making approaches. He also has thorough knowledge and understanding of the National Water Act (Act 36 of 1998) and has in excess of 10 years' experience in compliance auditing focusing mainly on external water use licence audits. He has worked in all provinces throughout South Africa as well as sub-Saharan Africa countries, and his experience includes commodities such as iron ore, gold, coal and platinum. The details of the author(s) who prepared this report are summarised in Table 1-1 below.

Table 1-1 Details of the authors.

Author	Ferdinand Mostert
Highest qualification	M.Sc. Hydrogeology
Years' experience	13^{+}
Professional registration	SACNASP Member (Reg. No 40057/14 – Water Resource Science). Member of the Groundwater Division of the Geological Society of South Africa (MGSSA).

1.5. Available information

The following information was available and used in this investigation:

i. Aquiworx software. 2016. Version 2.5.2.0. Centre for Water Sciences and Management at the North-West University.
ii. Barnard, H. C., 2000. An explanation of the 1:500 000 general Hydrogeological Map. Kroonstad 2726.
iii. Chief Directorate. Surveys and Mapping. 2003. Cape Town, 2826BA, 2826BB, 2826BC, 2826BD [Map]. Edition 9. Scale 1:50,000. Mowbray, South Africa: Chief Directorate of Surveys and Mapping.
iv. Council of Geoscience geological map sheet 2826: Winburg (1:250 000).
v. Department of Water Affairs: Directorate Hydrological Services, 2012. Aquifer classification of South Africa.
vi. Department of Water Affairs: Directorate Hydrological Services, 2012. Aquifer susceptibility of South Africa.
vii. Department of Water Affairs: Directorate Hydrological Services, 2012. Aquifer vulnerability of South Africa.
viii. Department of Water Affairs and Forestry, South Africa. 2004. Internal Strategic Perspective: Middle Vaal Water Management Area. Prepared by PDNA, WMB and WRP on behalf of the Directorate National Water Resources Planning. Report no. 09/000/00/0304.
ix. ESRI basemaps, 2022.
x. Google Earth, 2022. 6.0.12032 Beta.
xi. i.lEH. 2017. *Tetra 4 Cluster 1 Production Right EIA Hydrogeological Specialist Report.* Report No iLEH-EIMS MOL-1 05-15.
xii. Lynch, S.D., Reynders, A.G. and Schulze, R.E., 1994: A DRASTIC approach to groundwater vulnerability mapping in South Africa. SA Jour. Sci., Vol. 93, pp 56 - 60.

i. JR Vegter, DWS and WRC, 1995. Groundwater Resources of the Republic of South Africa.
ii. Parsons, R, 1995. A South African Aquifer System Management Classification, Water Research Commission, WRC Report No KV 77/95.
iii. Tetra 4. 2021/2022. Monthly Groundwater Monitoring Data.
iv. van Tonder and Xu, 2000. Program to estimate groundwater recharge and the Groundwater Reserve.
v. Water Research Commission (WRC), 2012. Water Resources of South Africa.

1.6. Project assumptions and limitations

Data limitations were addressed by following a conservative approach and assumptions include the following:

i. The scale of the investigation was set at 1:50 000 resolutions in terms of topographic and spatial data, a lower resolution of 1:250 000 scale for geological data and a 1: 500 000 scale resolution for hydrogeological information.
ii. The Digital Elevation Model (DEM) data was interpolated with a USGS grid spacing of 25.0m intervals.
iii. Rainfall data and other climatic data was sourced from the WR2012 database.
iv. Water management and catchment-based information was sourced from the GRDM and Aquiworx databases.
v. The concept of representative elementary volumes (REV) has been applied i.e., a scale has been assumed so that heterogeneity within a system becomes negligible and thus can then be treated as a homogeneous system. The accuracy and scale of the assessment will result in deviations at point e.g. individual boreholes.
vi. The investigation relied on data collected as a snapshot of field surveys and existing monitoring data. Further trends should be verified by continued monitoring as set out in the monitoring program.
vii. Stratigraphical units, as delineated from surface geology within the model domain, are assumed to occur throughout the entire thickness of the model and were incorporated as such.
viii. The geological structures (fault zones and dyke contact zones) were modelled as permeable linear zones.
ix. The model basement i.e., competent Karoo basement or Dwyka tillite/diamictite is assumed to generally be impermeable and serves to isolate the fractured Karoo aquifer from the fractured pre-Karoo aquifer units.
x. Model calibration was achieved by assigning a ratio of 1:1 for Hydraulic Conductivity (K) in x and y directions, with a ratio of 1:10 in the z direction i.e., anisotropic aquifer (except for alluvial deposits which were assigned at a 1:1 ratio).
xi. Perennial rivers within the model domain have been treated as gaining type streams. As such groundwater is lost from the system via baseflow to local drainages.
xii. Groundwater divides have been assumed to align with surface water divides and it is assumed that groundwater cannot flow across this type of boundaries.
xiii. The numerical groundwater flow model was developed considering site specific information. It should be stated that influences from neighbouring mining developments were not taken into consideration

as part of this investigation.

xiv. Prior to development, the system is in equilibrium and therefore in steady state.

xv. Where data was absent or insufficient, values were assumed based on literature studies and referenced accordingly[1]

2. METHODOLOGY

The groundwater impact assessment was undertaken by applying the methodologies as summarised below.

2.1. Desk study and review

This task entails the review of available geological and hydrogeological information including DWS supported groundwater databases (NGA/ Aquiworx), existing specialist reports, development plans as well as climatic and other relevant groundwater data. Data collected was used to delineate various aquifer and hydrostratigraphic units, establish the vulnerability of local aquifers, aquifer classification as well as aquifer susceptibility.

2.2. Evaluation of potential environmental receptors

A hydrocensus user survey was conducted in February 2022 in which high-risk environmental receptors have been identified. The hydrocensus user survey will evaluate and verify existing surface and groundwater uses, local and neighbouring borehole locations and depths, spring localities and seepage zones, regional water levels, abstraction volumes, groundwater application as well as environmental receptors in the vicinity of the existing gas production operations.

2.3. Hydrochemical analysis

Water samples collected were submitted at a SANAS accredited laboratory to determine the macro and micro inorganic chemistry and potential hydraulic connections present. SANS 241:2015 Drinking Water Standards was applied and used a guideline for all water quality analysis.

2.4. Hydrogeological baseline description

Based on the gathered groundwater and site characterisation data a baseline description of the current status quo of the regional groundwater system including aquifer classification, aquifer unit delineation and vulnerability is formulated.

2.5. Development of a conceptual hydrogeological model

The hydrogeological conceptual model consists of a set of assumptions, which will aid in reducing the problem statement to a simplified and acceptable version. Data gathered during the desk study and site investigation has been incorporated to develop a conceptual understanding of the regional hydrogeological system.

[1] Where model assumptions were made or reference values used, a conservative approach was followed. Data gaps identified should be addressed as part of the model update.

2.6. Numerical groundwater flow and mass transport model development

A numerical groundwater flow and mass transport model was developed based on the defined groundwater conceptual model. The latter will serve as a tool to evaluate various water management options and different scenarios will be applied to quantify and qualify potential groundwater impacts.

2.7. Groundwater impact assessment

Identification of preliminary and potential impacts and ratings related to new developments and/or listed activities are defined based on outcomes of the investigation. An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human and/or other related activities. Risk assessment involves the calculation of the magnitude of potential consequences (levels of impacts) and the likelihood (levels of probability) of these consequences to occur. Mitigation measures were recommended to render the significance of impacts identified.

3. LEGAL FRAMEWORK AND REGULATORY REQUIREMENTS

The following water management legislation should be adhered to:

3.1. The National Water Act (Act 36 of 1998) as amended

The purpose of the National Water Act, 36 of 1998 ("NWA") as set out in Section 2, is to ensure that the country's water resources are protected, used, developed, conserved, managed, and controlled, in a way which inter alia considers the reduction, prevention and degradation of water resources. The NWA states in Section 3 that the National Government is the public trustee of the Nation's water resources. The National Government must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons and in accordance with its constitutional mandate. Section 22 of the NWA states that a person may only use water without a license if such water use is: permissible under Schedule 1, if that water use constitutes as a continuation of an existing lawful water use, or if that water use is permissible in terms of a general authorization issued under Section 39. Permissible water use furthermore includes water use authorised by a license issued in terms of the NWA or alternatively without a license if the responsible authority dispensed with a license requirement under subsection 3. Section 21 of the National Water Act indicates that water use includes the following:

a. taking water from a water resource (section 21(a));
b. storing water (section 21(b));
c. impeding or diverting the flow of water in a water course (section 21(c));
d. engaging in a stream flow reduction activity contemplated in section 3649 (section 21(d));
e. engaging in a controlled activity which has either been declared as such or is identified in section 37(1)50 (section 21(e));
f. discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit (section 21(f));
g. disposing of waste in a manner which may detrimentally impact on a water resource (section 21(g);

h. disposing in any manner of water which contains waste from, or which has heated in, any industrial or power generation process (section 21 (h));
i. altering the bed, banks, course or characteristics of a water course (section 21(i));
j. removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people (section 21(j)); and
k. using water for recreational purposes (section 21(k)).

3.2. National Environmental Management Act (Act 107 of 1998) as amended

The National Environmental Management Act 107 of 1998 intends:

i. to provide for co-operative, environmental governance by establishing principles for decision-making on matters affecting the environment, institutions that will promote co-operative governance and procedures for co-ordinating environmental functions exercised by organs of state; and
ii. to provide for matters connected therewith.

3.3. Mineral and Petroleum Resources Development Act (Act 28 of 2002) as amended

The Mineral and Petroleum Resources Development Act 28 of 2002 intends to

i. to make provision for equitable access to and sustainable development of the nation's mineral and petroleum resources; and
ii. to provide for matters connected therewith.

4. STUDY AREA AND LISTED ACTIVITIES

4.1. Regional setting and site locality

The project area is situated on the farm Mond van Doornrivier 38 which is located between Welkom (16.7km SSW), Virginia (14.4km SWW), and Theunissen (30.0km N). The gas production right and greater study area covers a total area of ~187 000ha and falls within the Free State Province of South Africa. The site is accessible via the R30 secondary route from the north as well as the southeast. General site coordinates are listed in Table 4-1 and a map indicating an aerial extent of the greater study area is indicated in Figure 4-1 with the project boundary and topo-cadastral map depicted in Figure 4-2.

Table 4-1 General site coordinates (Coordinate System: Geographic, Datum: WGS84).

Latitude	-28.129°
Longitude	26.718°

4.2. Project description and proposed infrastructure

The Tetra 4 Gas Production Project entails a natural gas production facility within an existing Production Right (PASA Ref. 12/4/1/07/2/2). The extracted gas is compressed and reticulated via pipelines to further infield compressors. From here the gas is piped to a combined helium and liquid natural gas (LNG) plant for processing. The final products (helium and LNG) will be stored temporarily in tankers on site and then trucked away for sale to the end users (EIMS, 2016a). The current development includes a combined helium and LNG plant, gas wells as well as associated pipelines and compressor infrastructure. Refer to Figure 4-3 for an infrastructure and layout map indicating the proposed drilling priorities as well expansion footprints. The planned expansions will include the following:

i. Expansions to the current liquid natural gas (LNG) and Helium production plant located on the Farm Mond van Doorn River. The planned expansions will be to increase the helium and LNG production capacities significantly (~30fold increase) and increase the footprint of the existing approved plant by approximately 10ha.

ii. The drilling of new gas wells ~300 wells spread over a total study area (referred to as Cluster 2) of approximately 27 500ha.

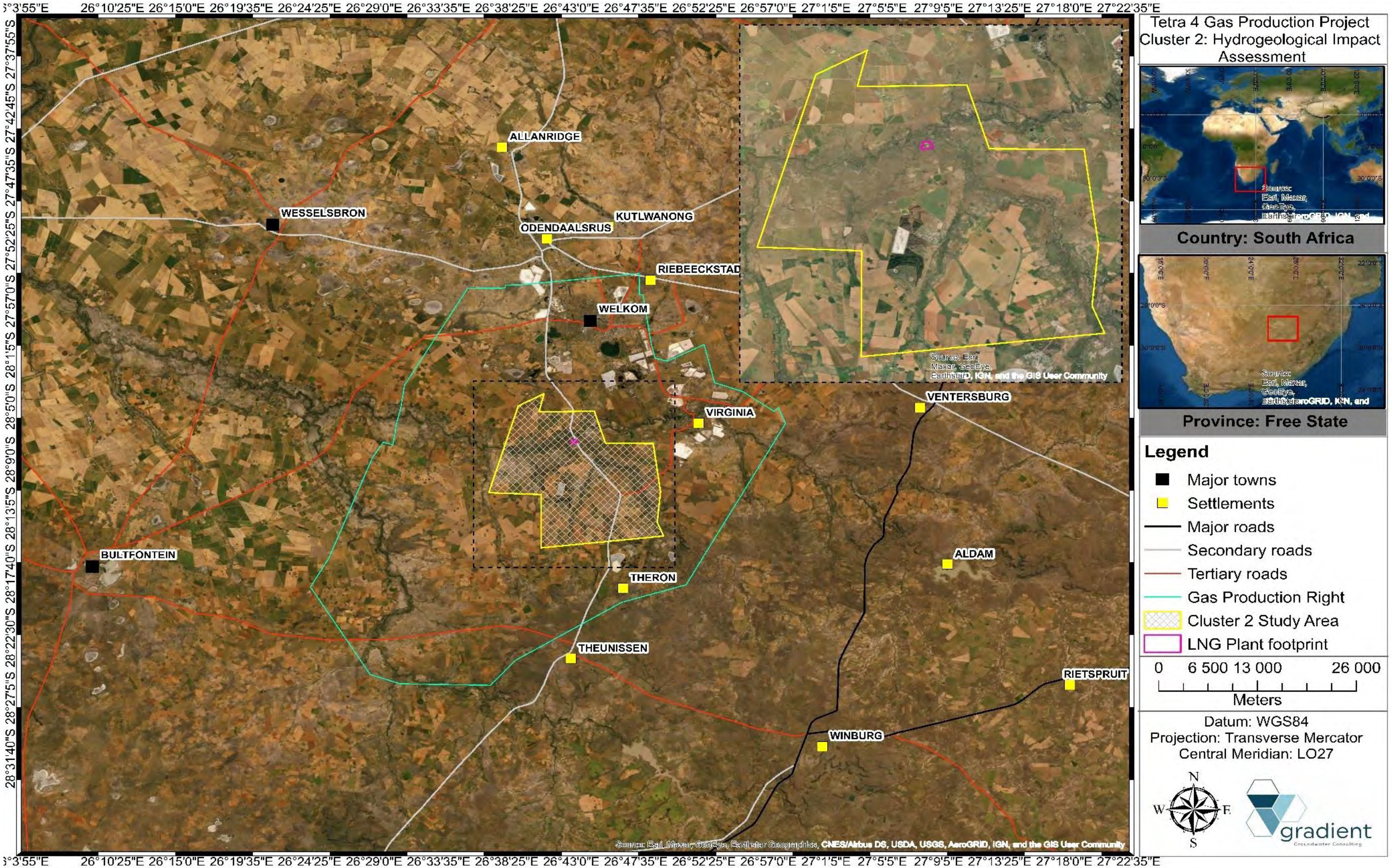


Figure 4-1 **Aerial extent and greater study area.**

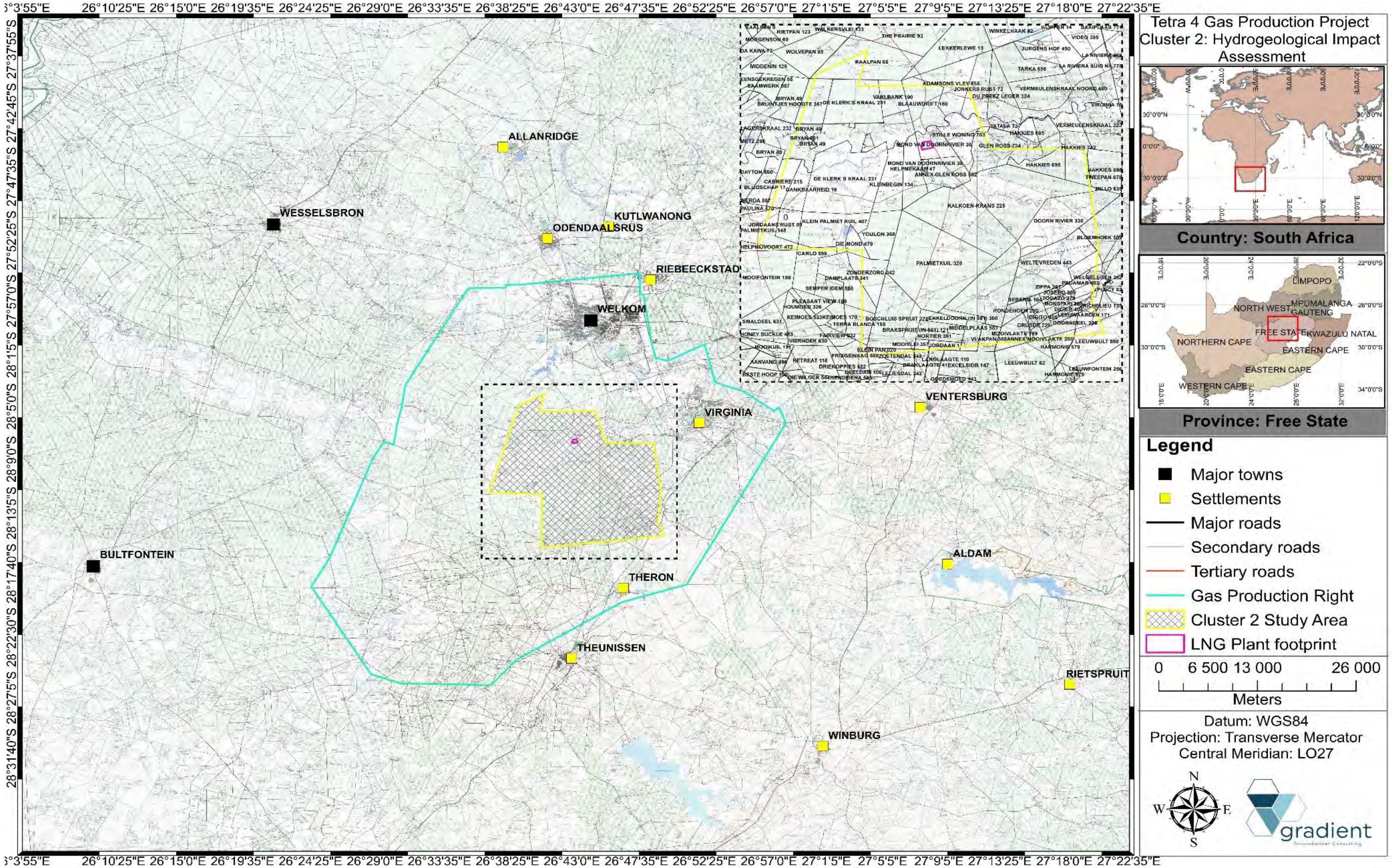


Figure 4-2 **Greater study area (1:50 000 topographical mapsheet 2826BA).**

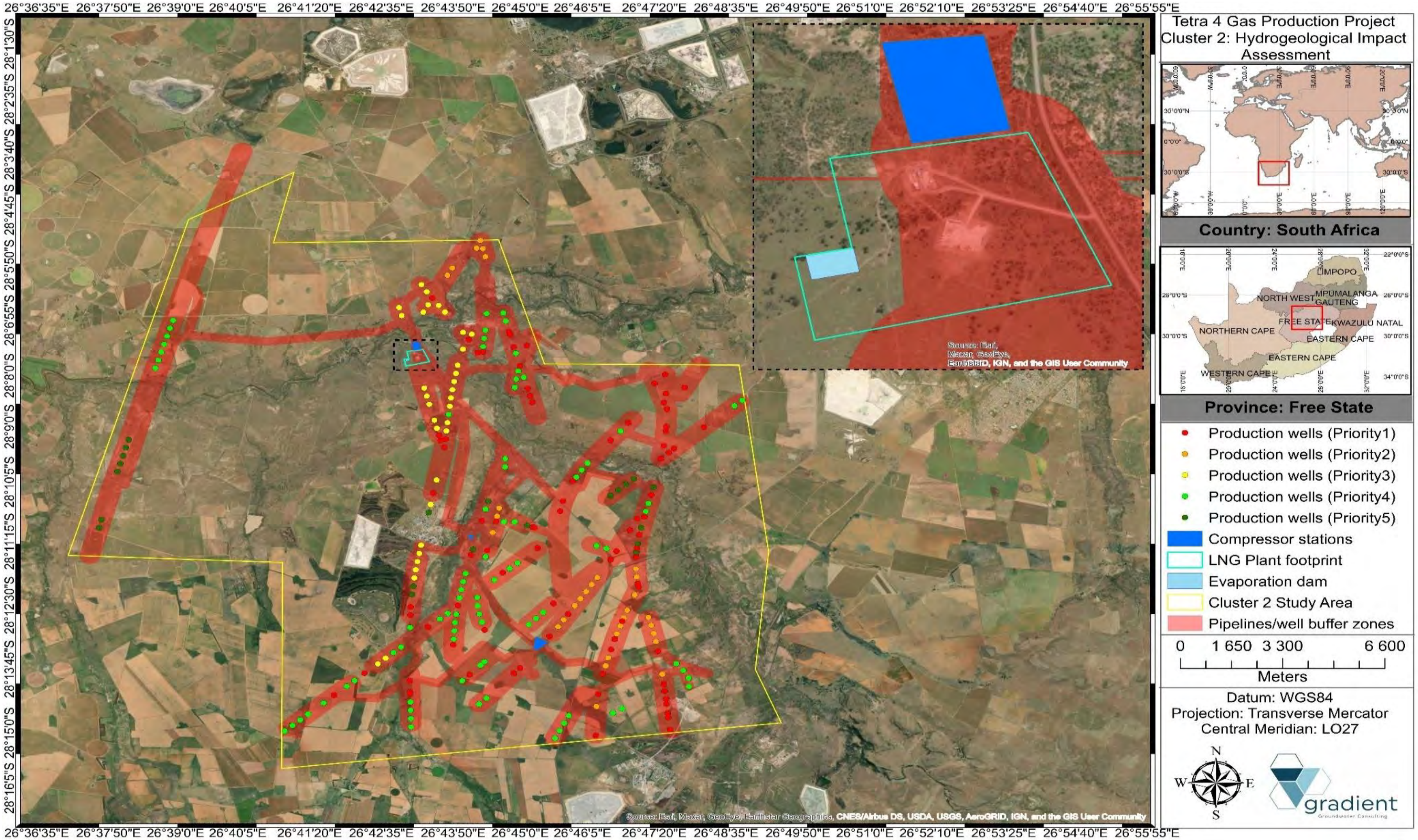


Figure 4-3 **Layout and infrastructrure map.**[2]

[2] It should be note that the indicated production borehole localities is based on a high level of uncertainty and is subject to change. Borehole positions will however not fall outside of the proposed buffer zone(s).

5. PHYSIOGRAPHY

The following sub-sections evaluate the physiography of the study area.

5.1. Topography

The topography of the greater study area is generally flat and can be classified as a central interior plain or plateau. Large dolerite intrusions are observed throughout the study area and because of its relative resistance to erosion, the Karoo dolerite sheets generally give rise to very prominent high-standing topographic features (DWAF, 2004). The relief of the area varies between 0 – 130.0m. The landscape gradually flattens out towards the lower laying drainage system in the north-west (approximate elevation low of 1250.0mamsl), while the southern and south-eastern perimeters are shaped by scattered outcrops with a regional topographical high point recorded as 1540.0mamsl.

The lowest topographical elevation on-site is recorded as ~1280.0mamsl which is situated towards the western and eastern borders where the Sandrivier enters and exists the gas production right boundary and form part of the on-site drainage system. The highest topographical point recorded on site is approximately 1405.0mamsl and form part of the quaternary catchment boundary and groundwater/ surface water divide to the southern and south-western portion of the study area. On-site gradients are variable, but generally gentle with the average slope calculated at ~0.80% and an elevation loss of 130.0 m over a lateral distance of 16.0km in a north-south orientation whereas an average slope of ~0.40% and elevation loss of 70.0m over a lateral distance of 17.50km is calculated in an east- west orientation. Figure 5-1 depicts a topographical cross-section (south-western aspect) of the greater study area while Figure 5-2 shows the regional topographical contours and setting.

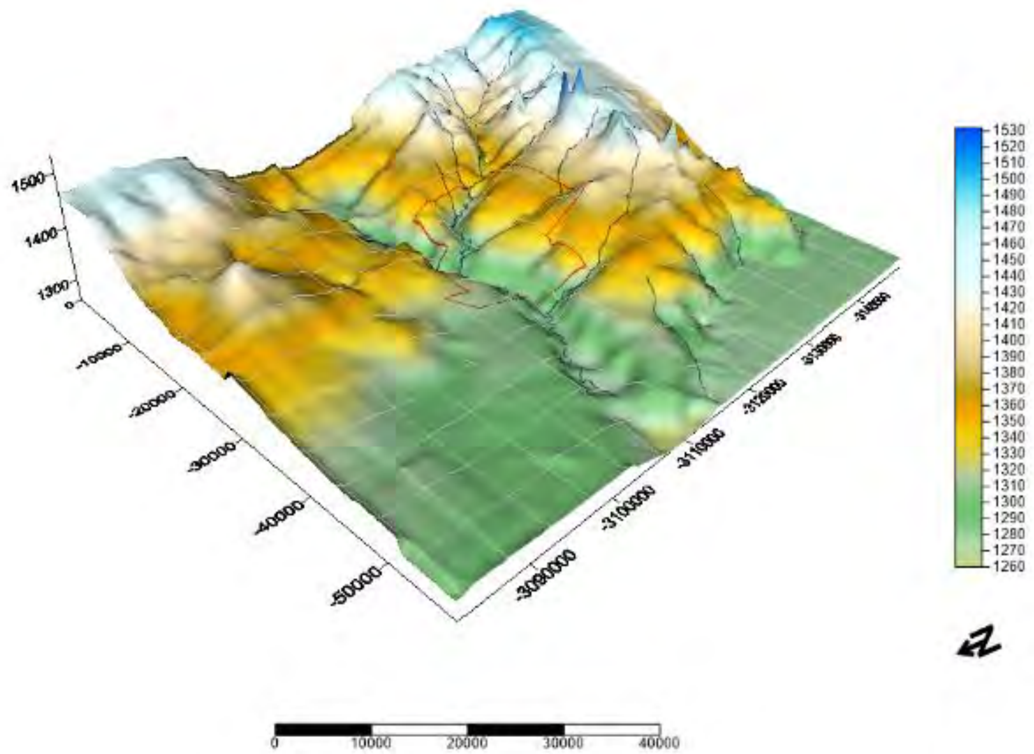


Figure 5-1 **Topographical cross-sections of the greater project area.**

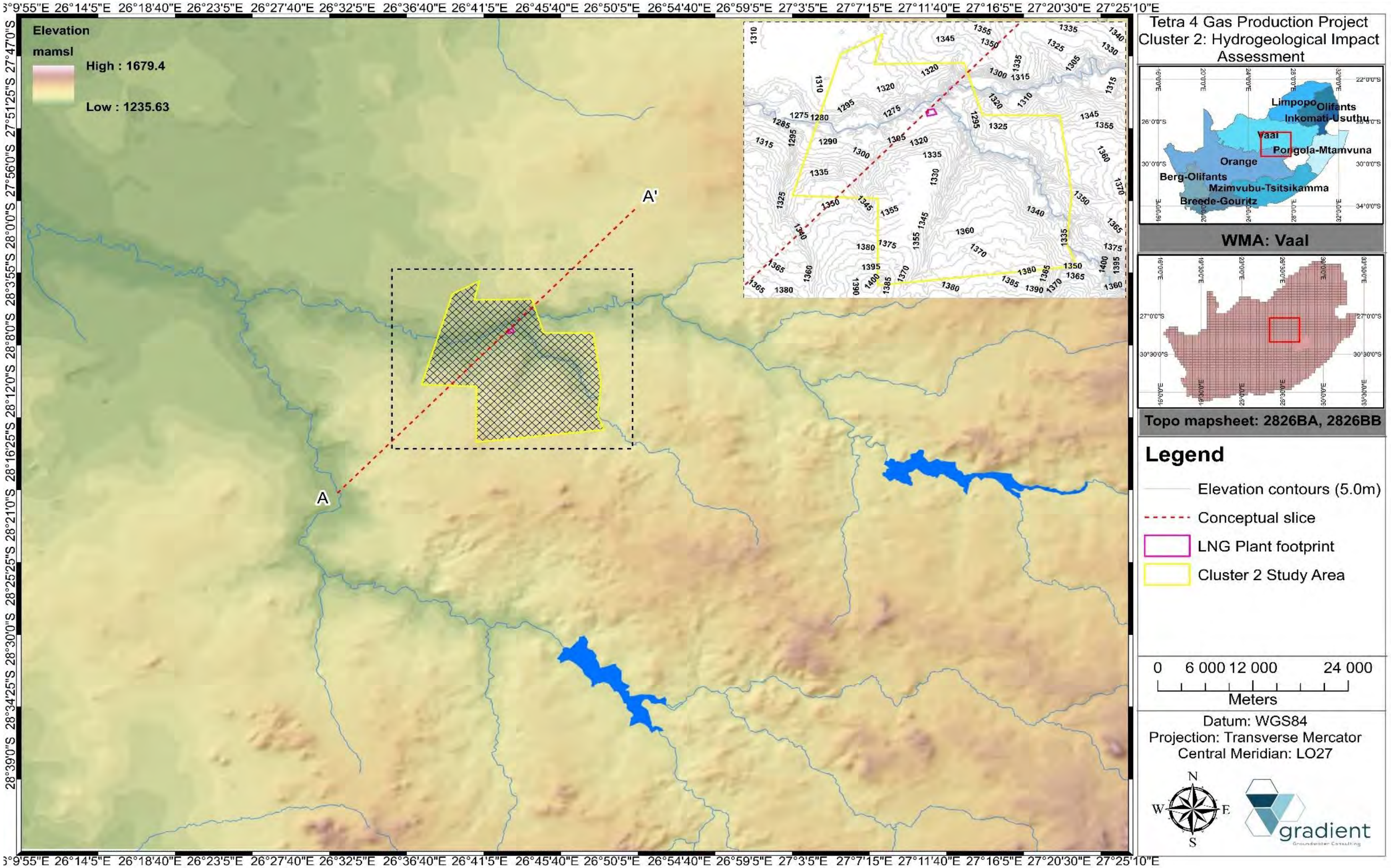


Figure 5-2 **Regional topography and conceptual slice (Refer to Figure 11-2).**

5.2. Drainage and catchment

The greater study is situated in primary catchment (C) of the Vaal River drainage system which covers a total area of approximately 246 674.5km^2. The resource management falls under the Vaal Water Management Area (WMA5) which spans portions of the North West Province, northern Free State as well northern sections of the Northern Cape.

The project area is situated within quaternary catchments C42K (nett surface area of 668.0km^2) and C42L (nett surface area of 510.8km^2), falls within hydrological zone E and has an estimated mean annual runoff (MAR) of between 10.0 to 13.0mcm (million cubic metres) (WR 2012).

The hydrology of the region is characterised by predominately perennial watercourses with the regional drainage occurring in a general west to north-western direction via the Sandrivier and Doringrivier both of which are traversing the study area from east to west (Sandrivier) and southeast to northwest (Doringrivier). A non-perennial drainage, Bosluisspruit, also traverse the study area and generally drain the catchment in a northern direction. The Doringrivier convergences with the Sandrivier approximately 1.30km to the northeast of the study area from where it flows in a general westerly direction before joining the Vetrivier roughly ~ 30.0km downstream of the project area. Major surface water features being fed by the drainage system(s) of this quaternary catchment include the Bloemhof Dam situated <100.0 km to the northwest. Table 5-1 provides a summary of relevant climatological and hydrogeological information for the relevant quaternary catchments.

Table 5-1 Quaternary catchment information.

Attribute	C42K	C42L
Water Management Area (WMA)	Vaal	Vaal
Primary catchment	C	C
Secondary catchment	C4	C4
Tertiary catchment	C42	C42
Quaternary catchment	C42K	C42L
Major rivers	Sandrivier, Vetrivier and Doringrivier	Sandrivier, Vetrivier and Doringrivier
Hydro-zone	E	E
Rainfall zone	C4C	C4D
Area (km^2)	668.0	510.8
Mean annual rainfall (mm)	521.2	505.9
Mean annual evaporation (mm)	1600.0	1680.0
Mean annual runoff (mm)	23.8	22.7
Baseflow	2.9	2.5
Total groundwater use (l/s)	27.9	22.7
Present Eco Status Category	Category C	Category C
Recharge (mm)	15 - 25	15 - 25
Average water level (mbgl)	39.3	23.0
Soil type	SaClLm-SaCl	SaClLm-SaCl
Groundwater General Authorization	75m^3/ha/a	75m^3/ha/a

Note: Catchment based information sourced from Aquiworx 2014

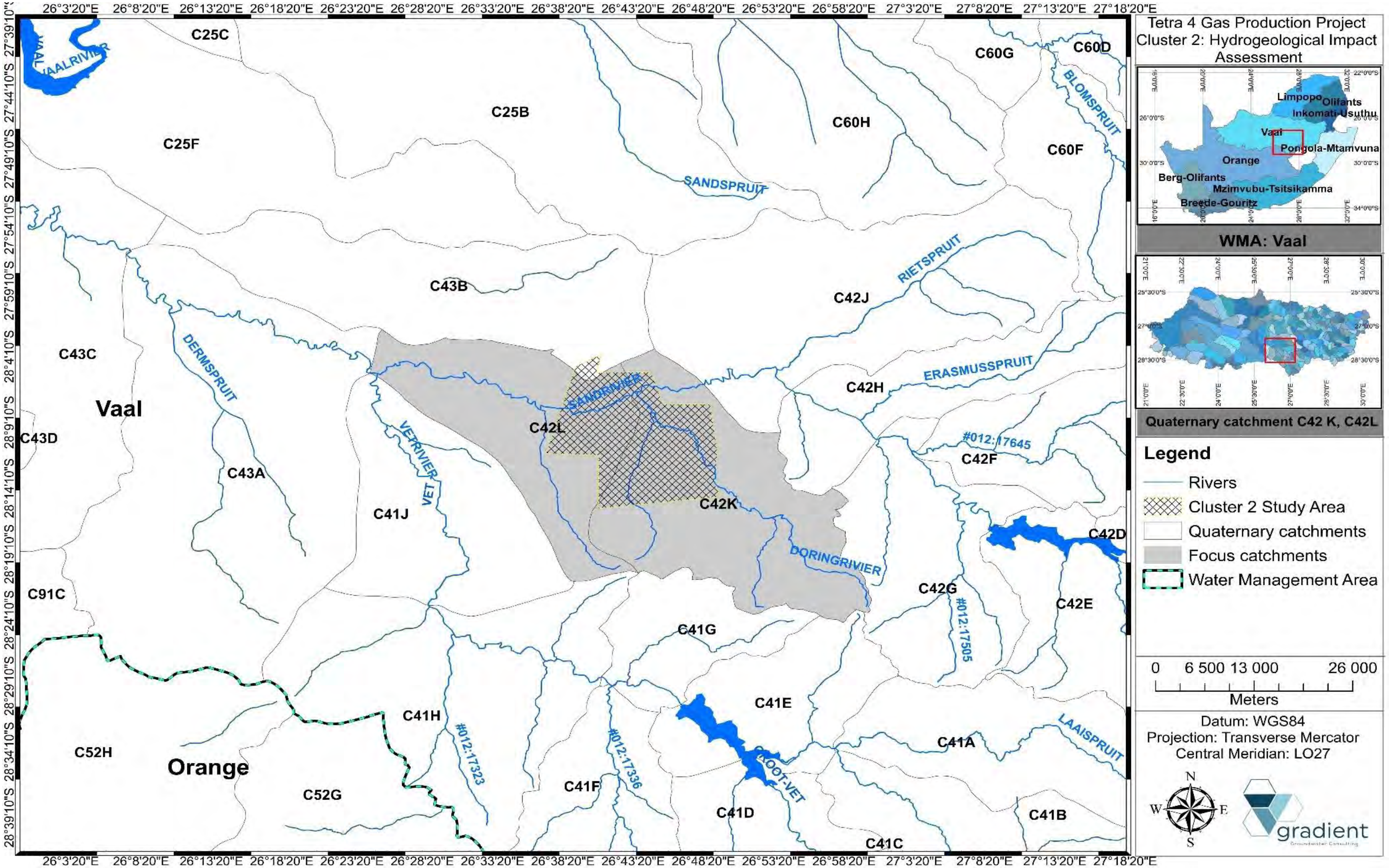


Figure 5-3 **Quaternary catchments and water management area.**

5.3. Climate

The study area's rainfall is strongly seasonal, and the weather pattern reflects a typical summer rainfall region, with > 80.0% of precipitation occurring as convective thunderstorms from October to March. Patched rainfall and evaporation data were sourced from the WR2012 database (Rainfall zone 4C4) and span a period of some 90 years (1920 – 2009). Refer to Appendix A for time-series rainfall data tables.

The calculated mean annual precipitation (MAP) for this rainfall zone is 521.0mm/a, with the 5th percentile of the data set (roughly equivalent to a 1:20 year drought period) calculated at 343.38mm/a while the 95th percentile (representing a 1:20 flood period) is calculated at 752.43mm/a. The highest MAP for the 90 years of rainfall data was recorded as 860.30mm (1942) while the lowest MAP of 264.0mm was recorded during 2006.

Both catchment areas are categorised under evaporation zone 19C which have a mean annual evaporation (s-pan) ranging between 1600.0mm/a to 1680.0mm/a. The highest evaporation is usually experienced in December (215.0mm) while the lowest evaporation is in June (61.0mm). Figure 5-4 depicts a bar chart of the yearly rainfall distributions with Figure 5-5indicating monthly rainfall patterns. It is evident that the peak rainfall months are December and January. Figure 5-6 compares monthly precipitation volumes with monthly evaporation volumes. It is noted that the annual evaporation volumes are more than threefold the annual precipitation.

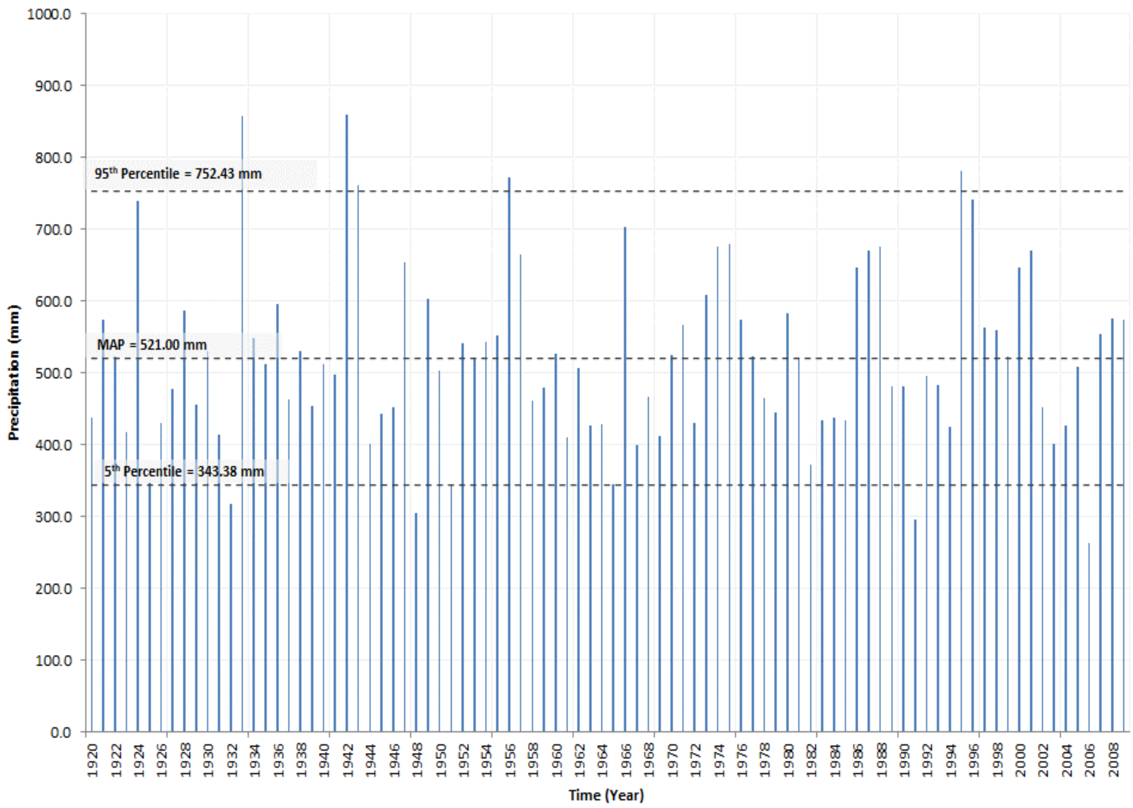


Figure 5-4 **Bar chart indicating yearly rainfall distribution for rainfall zone V3B (WR2012).**

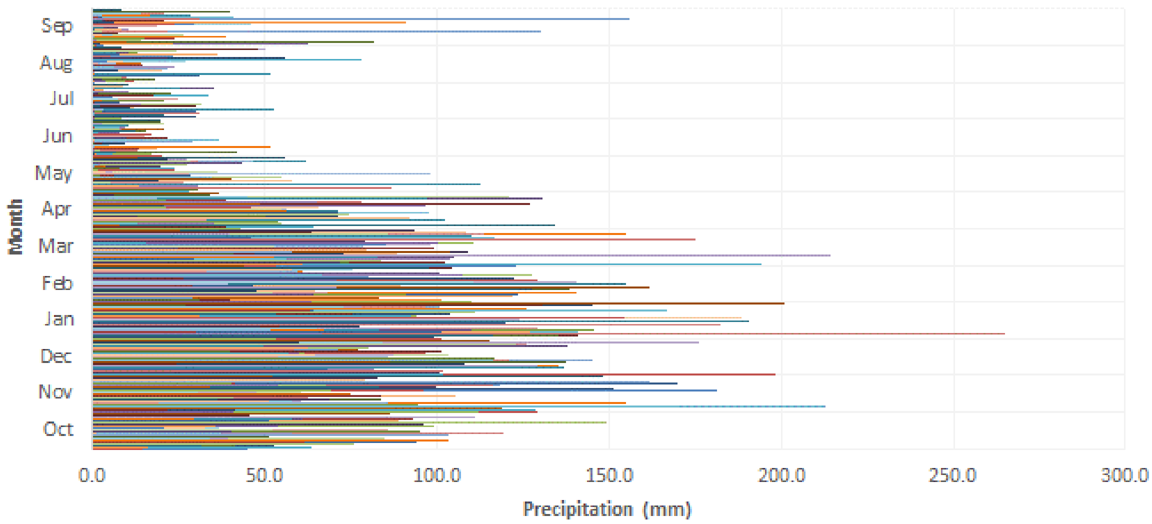


Figure 5-5 **Bar chart indicating monthly rainfall distribution for rainfall zone 4C4 (WR2012).**

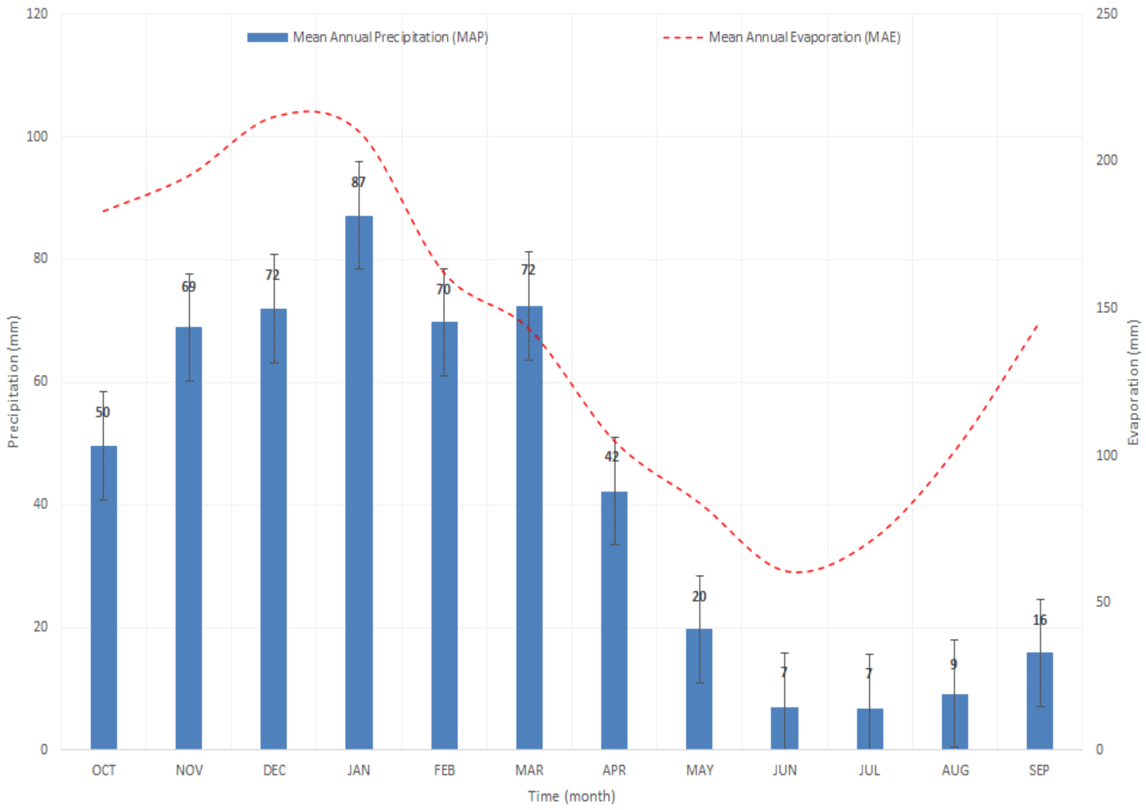


Figure 5-6 **Bar chart and curve comparing monthly rainfall and evaporation distribution for rainfall zone 4C4 (WR2012).**

5.4. Geological setting

The following sections summarises the regional and local geology.

5.4.1. Regional geology

Although the project area's surficial geology comprises mostly aeolian sands, quaternary deposits and isolated outcrops of the Karoo Supergroup i.e., dolerite and sandstone/ shales, the greater study area is generally also underlain by rocks of the Witwatersrand Supergroup as well as the Ventersdorp Supergroup. The primary source of gas originates from the Witwatersrand Supergroup as well as the shallower Karoo sediments (Lea, 2017). Figure 5-7 represents a regional geological cross section (Shango, 2016). It can be inferred from exploration borehole geological logs that the estimated depth of the unconsolidated material on-site is approximately 11.0m (Lea, 2017).

The Witwatersrand Supergroup is a sedimentary deposition across the stable granite-gniess basement which commenced around 3 billion years ago. In stratigraphic terms the Witwatersrand sequence is divided into two divisions, the lower dominantly marine, slate rich West Rand Group and the upper dominantly alluvial sandstone rich Central Rand Group (Johnson, 2006). The Witwatersrand Supergroup depth within the study area was inferred from exploration borehole geological logs and is estimated at an average depth of >1600.0mbgl (Lea, 2017).

The Ventersdorp Supergroup uncomformably overlies the Witwatersrand Supergroup. This Group is very thick, more than 4500.0m. The lower Kliprivierberg Group is mafic lava and tuff while the upper Platberg Group is conglomerates and breccia on top of Kliprivierberg, with intermediate and felsic lava higher, with quartzite, shale and siltstone layers in between (Johnson, MR. Anhauser, CR., Thomas, RJ., 2006). The Ventersdorp Supergroup depth within the study area was inferred from exploration borehole geological logs and is estimated at an average depth of >1120.0mbgl. Gas will be extracted from deep-seated fracture zones associated with the Ventersdorp lavas and Witwatersrand quartzites (Lea, 2017).

The Karoo Super Group is the largest stratigraphic unit in Southern Africa covering almost two thirds of the land surface. The supergroup consists of a sequence of units, mostly of nonmarine origin, deposited between the Late Carboniferous and Early Jurassic, a period of about 120 million years. The Karoo Supergroup consist of argillaceous rocks of the Beaufort Group i.e. lower Adelaide Subgroup (Late Permian) and an upper Tarkastad Subgroup, the Permian Ecca Group which consist largely of shales and sandstones as well as the Dwyka Group (Late Carboniferous to Early Permian) which consists mainly of diamictite (tillite). The Ecca Group underlies the Beaufort Group in all known outcrops and exposures and follows conformably after the Dwyka Group in certain sections, however in some localities overlies unconformably over older basement rocks (Schlüter and Thomas, 2008). The Karoo Supergroup (which include the Beaufort as well as Ecca Groups) depth within the study area was inferred from exploration borehole geological logs and is estimated at an average depth of 300.0mbgl.

5.4.2. Local geology

According to the 1:250 000 geological maps (2826: Winburg), a large portion of the study area's surficial geology comprises aeolian sands and quaternary deposits. Isolated patches within the study area are also covered by alluvial sand deposits which is mainly associated with the Sand and Doringriver floodplains and constrained by drainage patterns and riparian zones. The site is underlain by the Adelaide Subgroup (Vpa) consisting of alternating layers of bluish-grey, greenish-grey or greyish-red mudrock and grey, very fine to medium-grained, lithofeldspathic sandstone, the Vryheid Formation (Pv) which consists mainly of fine grained mudstone, carbonaceous shale with alternating and coarse grained, bioturbated immature sandstones respectively as well as the Volksrust Formation (PVo) which consists of grey to black, silty shale with thin, usually bioturbated, siltstone or sandstone lenses and beds, particularly towards its upper and lower boundaries. The Dwyka Group consists mainly of diamictite (tillite) which is generally massive with little jointing, but it may be stratified in places.

5.4.3. Structural geology

Large dolerite intrusions in the form of dykes and sills are observed throughout the study area. The Karoo sediments in this portion of the WMA are much intruded by sub accordant sheets, and to a lesser extent by near-vertical dykes of Karoo dolerite (DWAF, 2004). The Karoo Basin is characterised by a vast network of post-Karoo intrusive dolerite (Jd) sills and dykes that rapidly intruded at 183.0 to 182.3Ma (Svensen et al., 2012). The intrusive Karoo dolerite suite represents a shallow feeder system which occurs as an interconnected network of dykes, sills as well as sheets which typically form resistant caps of hills compromising softer sedimentary strata (Chevallier and Woodford, 1999). Exploration data evaluated suggest dykes are relatively thin, usually not wider than 5.0m while sills may be as thick as 100.0m. On a regional scale various dykes can be observed which may have an impact on the local hydrogeological regime as it can serve as potential preferred pathways for groundwater flow and contaminant transport. Deep fault zones that will be targeted for gas production are associated with the Central Rand Group and Ventersdorp lavas.

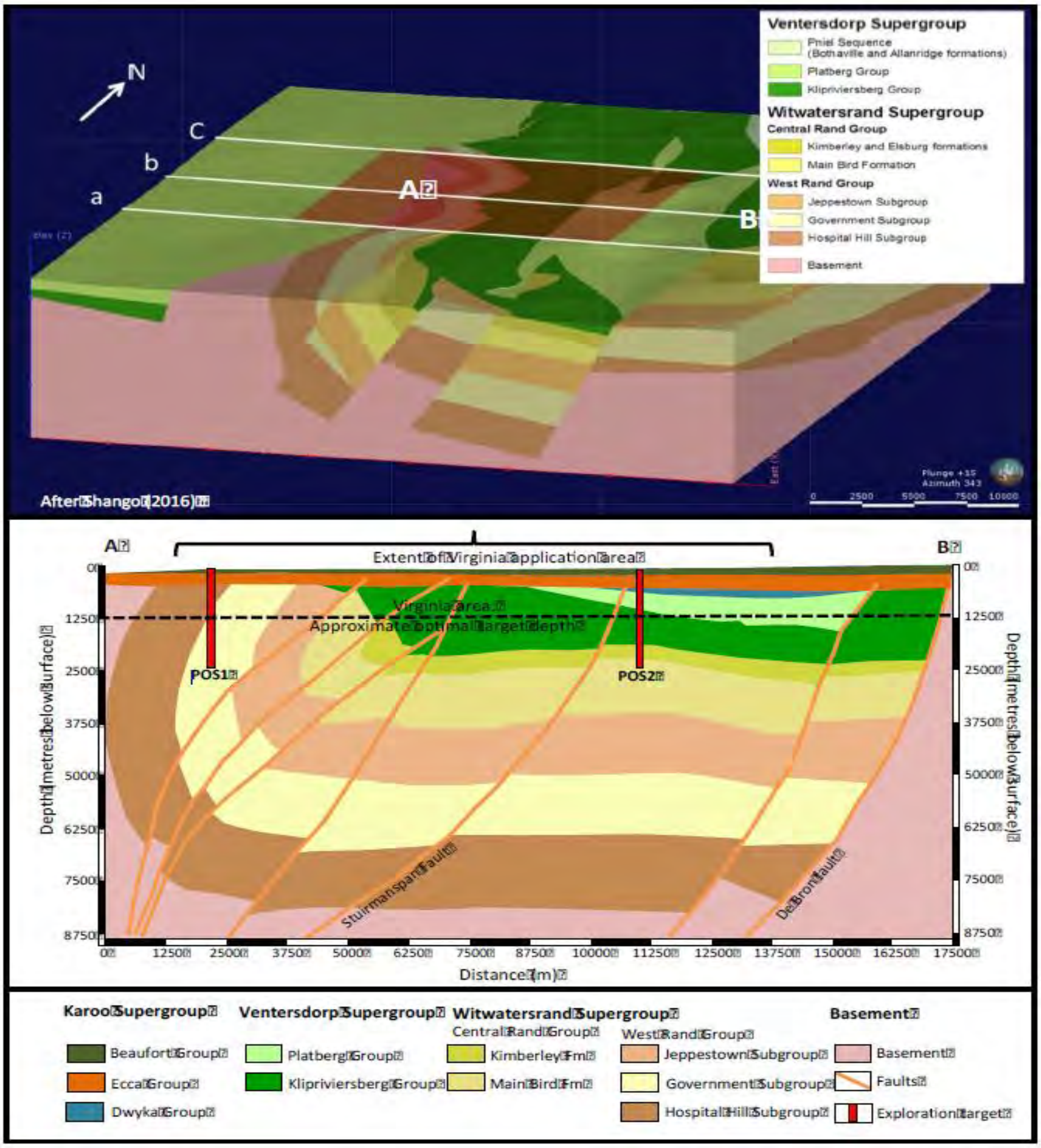


Figure 5-7 **Cross section of the regional geology (after Shango, 2016).**

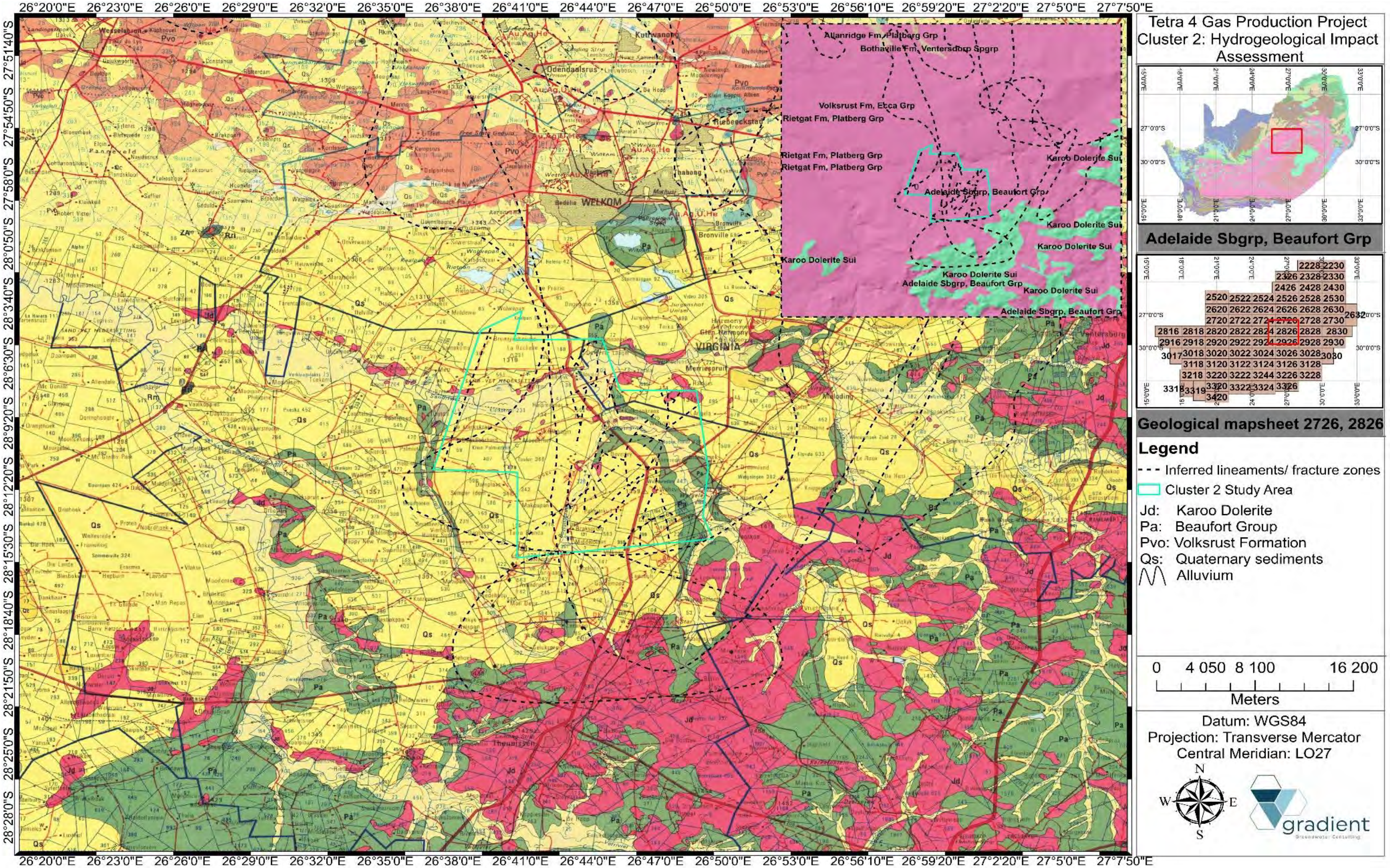


Figure 5-8 **Regional geology and stratigraphy (Geological map sheet 2826: Winburg).**

6. HYDROGEOLOGICAL BASELINE ASSESSMENT

The following sections summarises the regional and site-specific hydrogeology.

6.1. Regional hydrogeology

The Department have characterised South African aquifers based on host-rock formations in which it occurs together with its capacity to transmit water to boreholes drilled into relative formations. The water bearing properties of respective formations can be classified into four aquifer classes defined below. Each of these classes is further subdivided into groups relating to the capacity of an aquifer to transmit water to boreholes, typically measured in l/s. The groups therefore represent various ranges of borehole yields:

a. **Class A:** Intergranular Aquifers associated either with loose and unconsolidated formations such as sands and gravels or with rock that has weathered to only partially consolidated material.
b. **Class B:** Fractured Aquifers associated with hard and compact rock formations in which fractures, fissures and/or joints occur that are capable of both storing and transmitting water in useful quantities.
c. **Class C:** Karst Aquifers associated with carbonate rocks such as limestone and dolomite in which groundwater is predominantly stored in and transmitted through cavities that can develop in these rocks.
d. **Class D:** Intergranular and fractured Aquifers that represent a combination of Class A and B aquifer types. This is a common characteristic of South African aquifers. Substantial quantities of water are stored in the intergranular voids of weathered rock but can only be tapped via fractures penetrated by boreholes drilled into it.

According to the DWS Hydrogeological map (DWS Hydrogeological map series 2726 Kroonstad) the site is predominantly underlain by an intergranular and fractured aquifer system (d2) (refer to Figure 6-1) with the aquifer media consisting mainly of fractured and weathered compact argillaceous strata (refer to Figure 6-2). According to Vegter's groundwater regions delineated (2000) the study area can be classified as falling under the North-eastern Pan Belt region. Most hard-rock aquifers are secondary in nature with groundwater associated with fracturing, fault zones as well as contact zones of the dolerite intrusions.

The geometry of argillaceous rock aquifers is complicated by the lateral migration of meandering streams over a floodplain. Aquifers in the Beaufort Group will thus not only be multi-layered, but also multi-porous with variable thicknesses. The contact plane between two different sedimentary layers will cause a discontinuity in the hydraulic properties of the composite aquifer. The Ecca Group aquifers consists mainly of shales and sandstones that are very dense with permeability usually very low due to poorly sorted matrices. The aquifer has a low development potential (Botha *et al*., 1998) with borehole yields ranging from 0.1 – 0.5l/s, however higher yielding boreholes (>5.0l/s) may occur along intruding dyke contact zones and other structural features i.e., fault zones etc. (Barnard, 2000).

The maximum aquifer thickness (i.e., shallow, intergranular aquifer system) is 20m with water stored mainly in decomposed/partly decomposed rock and water bearing fractures principally restricted to a shallow zone below the static groundwater level.

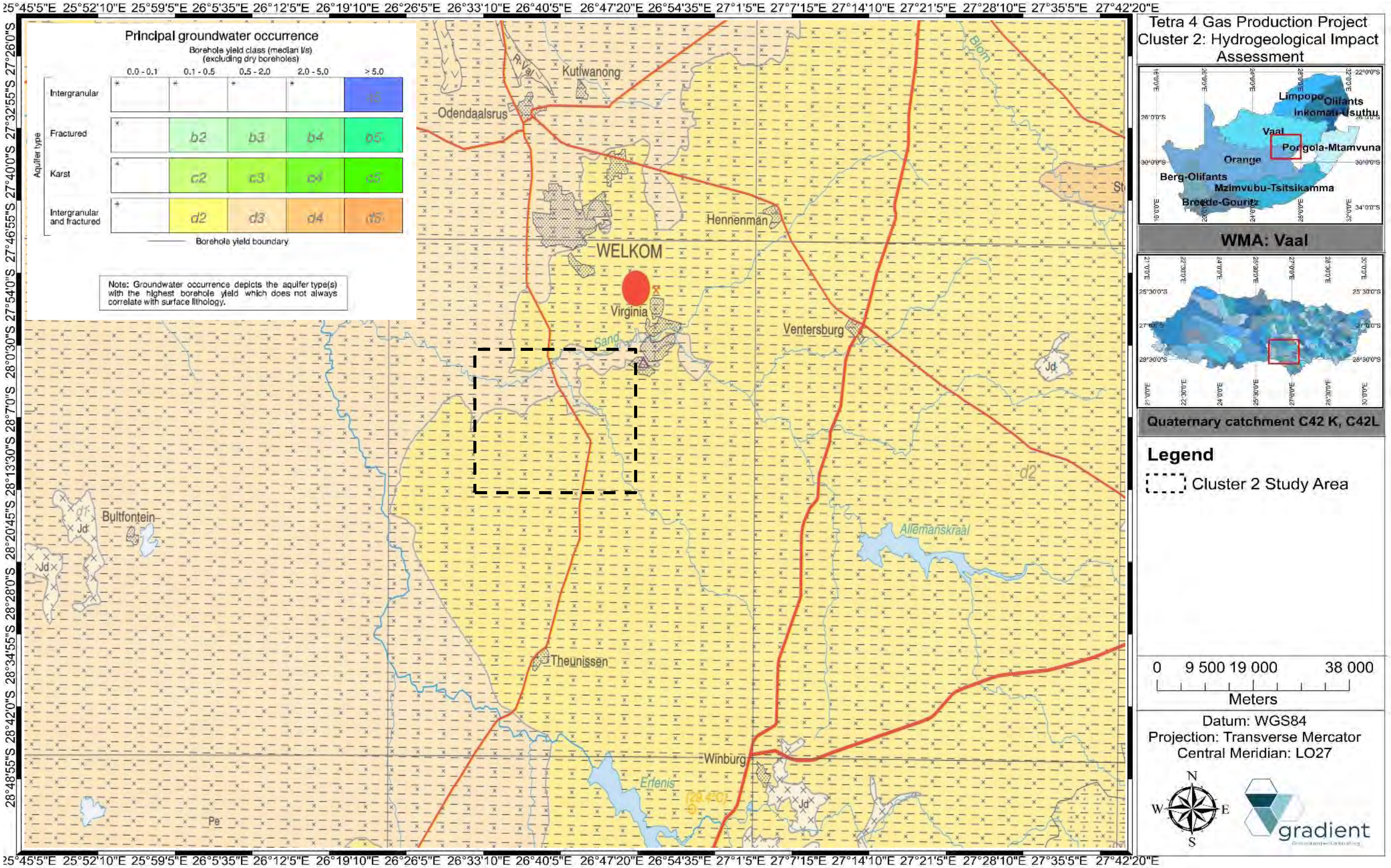


Figure 6-1 **Hydrogeological map illustrating the typical groundwater occurr ence for the study area (2726 Kroonstad).**

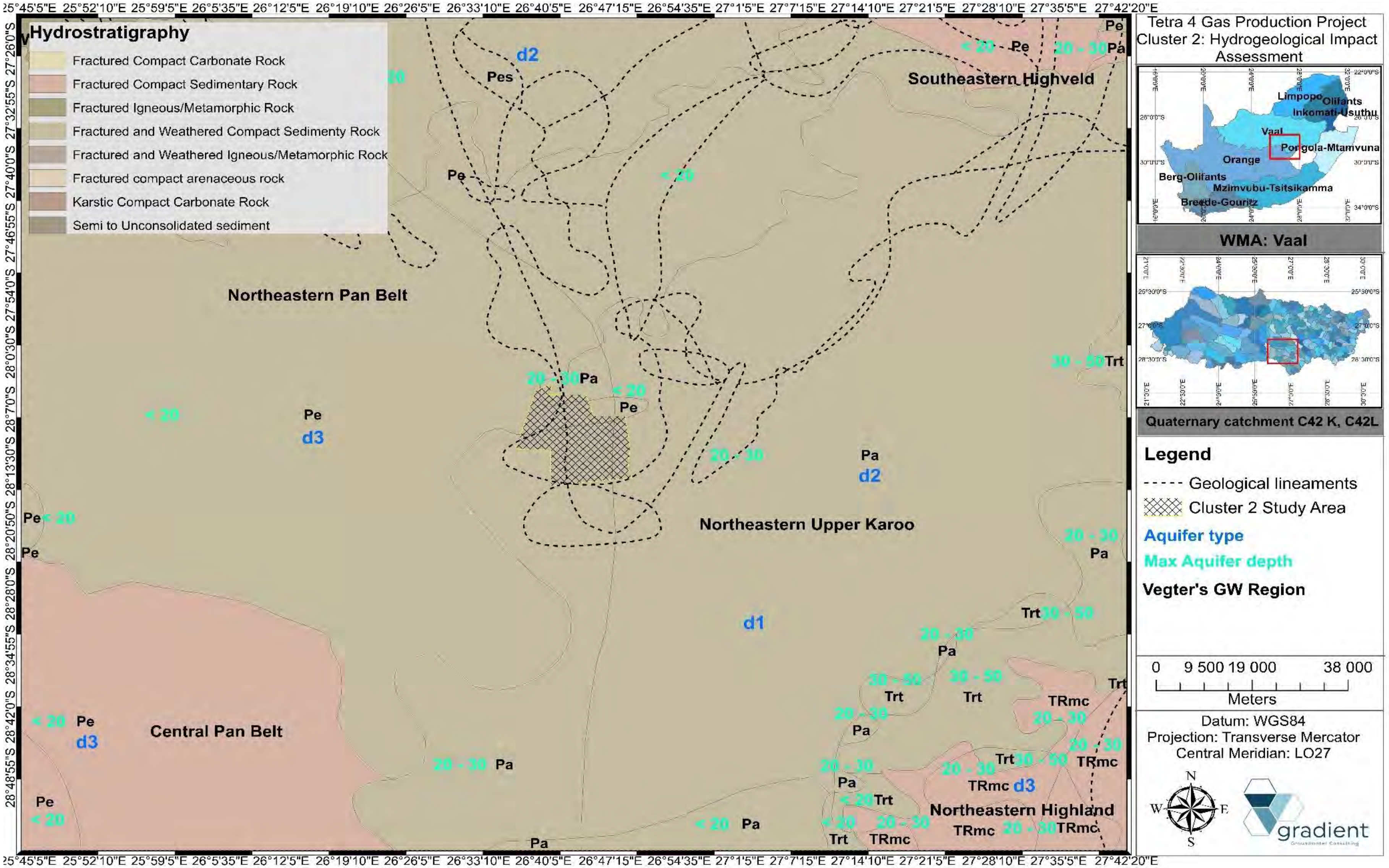


Figure 6-2 **Hydrogeological map illustrating the typical groundwater occurrence for the study region (2726 Kroonstad).**

6.2. Local hydrostratigraphic units

For the purposes of this investigation, four main hydrostratigraphic units/aquifer systems can be inferred in the saturated zone:

i. **A shallow quaternary and recent types of sediments** (unconfined) are characteristically a primary porosity aquifer associated with alluvium material deposited in flood plains of the main rivers traversing the study area. These aquifers cover a large portion of the study area and are limited to a zone of variable width and depth. The alluvial aquifer is specifically vulnerable to contamination as it there is a direct connectivity with rivers and streams and associated high permeability.

ii. **A shallow, intergranular aquifer** (unconfined to semi-confined) occurring in the transitional soil and weathered bedrock formations of the Karoo Supergroup rocks underlain by more consolidated bedrock. Groundwater flow patterns usually follow the topography, discharging as natural springs at topographic low-lying areas. Usually, this aquifer can be classified as a secondary porosity aquifer and is generally unconfined with phreatic water levels. Due to higher effective porosity (*n)* this aquifer is most susceptible to impacts from contaminant sources.

iii. **An intermediate, fractured aquifer** (semi-confined to confined) where pores are well-cemented and do not allow any significant flow of water. Groundwater flow is dictated by transmissive secondary porosity structures such as bedding plane fractures, faults, contact zones as well as fracture zones that occur in the relatively competent Karoo Supergroup host rock. Fractured sandstones, mudstones and shales sequences are considered as fractured rock aquifers holding water in storage in both pore spaces and fractures. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. Although generally low yielding, this aquifer is important to local groundwater users as it forms the sole source of water supply in the region (Lea, 2017).

iv. **A deeper, fractured aquifer** (semi-confined to confined) where pores are well-cemented and do not allow any significant flow of water. Groundwater flow is dictated by transmissive secondary porosity structures such as bedding plane fractures, faults and contact zones fracture zones that occur in the relatively competent Ventersdorp and Witwatersrand Supergroups host rock. Volcanic formations of the Ventersdorp lavas can also act as aquicludes, restricting the vertical movement of groundwater. Fractured quartzites of the Witwatersrand Supergroup are considered as fractured rock aquifers holding water in storage in both pore spaces and fractures. Groundwater yields, although more heterogeneous, can be expected to be higher than the weathered zone aquifer. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. The water in the deep aquifers is naturally saline due to their marine depositional history. Below a depth of 300.0m, groundwater quality deteriorates, and the permeability of the water-bearing formations decreases by orders of magnitude and consequently these aquifers are not used for water supply or private water use (Steyl et al, 2012). It should be noted that the shallow potable Karoo aquifers are separated from deep aquifer systems associated with the Ventersdorp and Witwatersrand Supergroup formations by the 30.0m thick dolerite sill (which may act as an aquitard) that extends across the study area and by the 65.0m thick Dwyka Tillite sedimentary deposit acting as an aquiclude (Lea, 2017). It should furthermore be noted that, under natural conditions, there is very limited hydraulic connectivity between the deep, fractured and shallow, intergranular aquifers (Steyl et al, 2012).

6.3. Hydraulic parameters

To follow is a brief overview of aquifer hydraulic parameters based on published literature for similar hydrogeological conditions as well as historical reports.

6.3.1. Hydraulic conductivity and Transmissivity

Hydraulic conductivity is the constant of proportionality in Darcy's Law which states that the rate of flow through a porous medium is proportional to the loss of head, and inversely proportional to the length of the flow path as indicated in the following equation:

Equation 6-1 Hydraulic Conductivity (Darcy's Law).

$$\boldsymbol{K} = \frac{\boldsymbol{Q}}{\boldsymbol{A}\left(\frac{\boldsymbol{dh}}{\boldsymbol{dl}}\right)}$$

where:

K = Hydraulic Conductivity (m/d).

Q = Flow of water per unit of time (m^3/d).

dh/dl = Hydraulic gradient.

A = is the cross-sectional area, at a right angle to the flow direction, through which the flow occurs (m^2)

The hydraulic conductivity of sedimentary formations such as evident on site can range from $10E^{-6} – 10E^{-2}$ m/d. Historical aquifer tests results confirm that the permeability of the shales is very low ($9E^{-4}$m/d). The hydraulic conductivity of fractured igneous rocks (i.e. dolerite) varies between $10E^{-6} – 10E^{-1}$ m/d, while conductivity values for un-fractured igneous rocks (i.e. fresh dolerite sill) ranges between $10E^{-9}$ – $10E^{-6}$ m/d. The hydraulic conductivity of quaternary deposits and alluvial pockets associated with the drainage system i.e., riverbed aquifers can be orders higher and can vary between $10E^{-2}$ – $10E^{1}$ m/d as depicted in Figure 6-3 (Freeze and Cherry, 1979).

Transmissivity can be expressed as the product of the average hydraulic conductivity (K) and thickness (b) of the saturated portion of an aquifer and expressed by:

Equation 6-2 Transmissivity.

$$T = Kb$$

where:

T = Transmissivity (m^2/d).

K = Hydraulic Conductivity (m/d).

b = Saturated aquifer thickness.

From historical aquifer tests conducted it is calculated that the average transmissivity for the shallow, weathered aquifer ranges between 0.12 m/d^2 to 0.6m^2/d depending on the saturated thickness of the aquifer targeted[3].

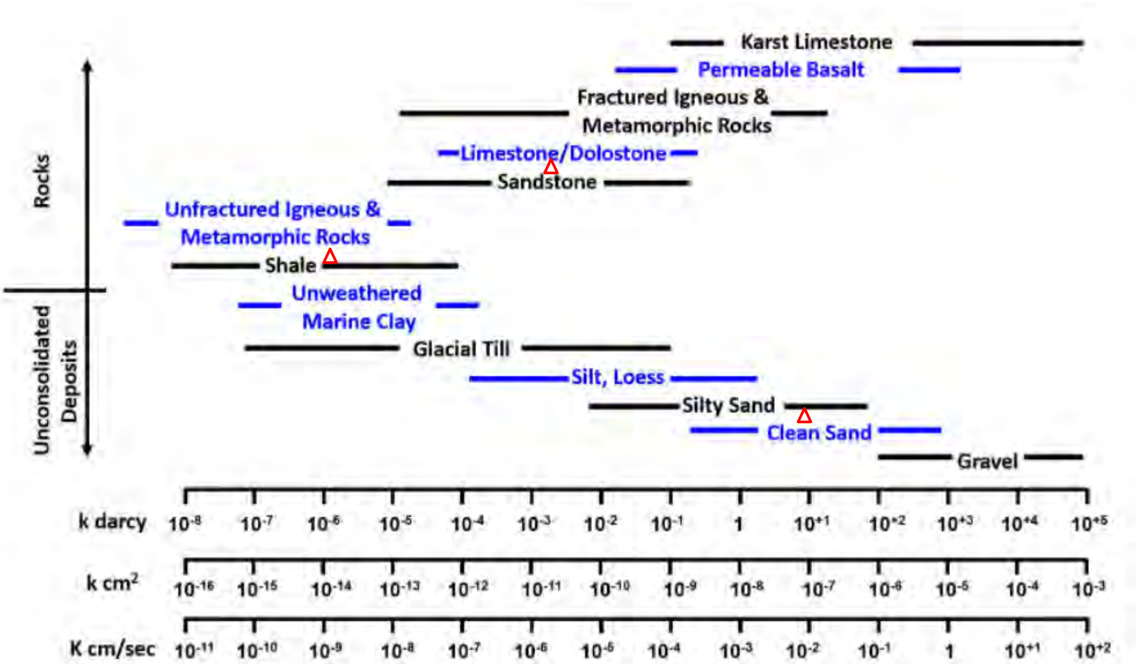


Figure 6-3 Typical hydraulic conductivity values for on-site hydrostratigraphical units.

3 It should be noted that no additional aquifer tests were conducted as part of this investigation.

6.3.2. Storativity

Storativity refers to the volume of water per volume of aquifer released as a result of a change in head. For a confined aquifer, the storage coefficient is equal to the product of the specific storage and aquifer thickness. Typical storativity values for fractured rock systems is in the order of $10E^{-5}$ – $10E^{-3}$ (Freeze and Cherry, 1979). Storativity values of the shallow, weathered aquifer will be slightly higher i.e., $10E^{-2}$.

6.3.3. Porosity

Porosity is an intrinsic value of seepage velocity and hence contamination migration. Porosity is an intrinsic value of seepage velocity and hence contamination migration. The porosity of fractured sedimentary formations ranges between 3% – 10%, while porosity of weathered formations can range between 10% to 15% depending on the nature and state of weathering. The intrinsic porosity of primary aquifers i.e., alluvial deposits can be as high as 20% depending on the nature of sorting (Freeze and Cherry, 1979).

6.3.4. Recharge

An approximation of recharge for the study area is estimated at ~4.0% of MAP i.e., ~21.69 mm/a as summarised in Table 6-1. Groundwater recharge was calculated using the RECHARGE Program1 (van Tonder and Xu, 2000), which includes using qualified guesses as guided by various schematic maps. The following methods/sources were used to estimate the recharge: (i) Chloride (Cl) method (Figure 6-4) (ii) Geology (iii) Vegter Groundwater Recharge Map (Figure 6-5) (iv) Harvest Potential (Figure 6-6) (v) Baseflow as a minimum of recharge (vi) Qualified opinion and, (vii) Literature review.

Table 6-1 Recharge estimation (after van Tonder and Xu, 2000).

Recharge method/ Reference	Recharge (mm/a)	Recharge (% of MAP)	Weighted Average (High = 5; Low = 1)
Chloride	15.40	2.96	4.00
Geology	21.60	4.15	2.00
Vegter	32.00	6.14	3.00
Harvest Potential	25.00	4.80	2.00
Baseflow	25.00	4.80	2.00
Qualified Opinion	18.24	3.50	4.00
Literature	14.58	2.80	3.00
Weighted average	**21.69**	**4.01**	**20.00**

Notes: Recharge per annum were calculated using a MAP of 521.0 mm/a.

Chloride Method Summary

Welkom	
Average annual rainfall (mm)=	521
Cl in rain (mg/l) =	1.04
Dry deposition Cl (mg/l) =	0.104
Cl in gw or unsat. zone (mg/l) =	38.7
Average annual recharge (mm) =	**15.40**
Percentage recharge =	**2.96**

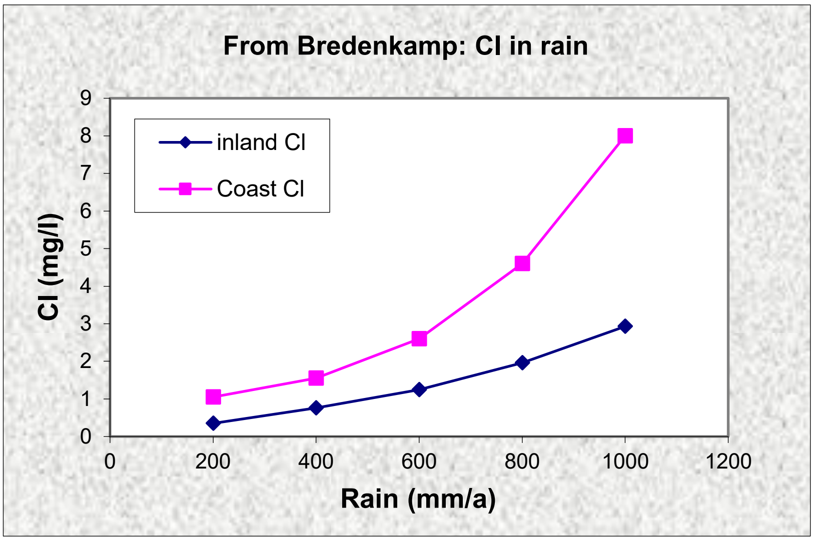


Figure 6-4 **Chloride method summary.**

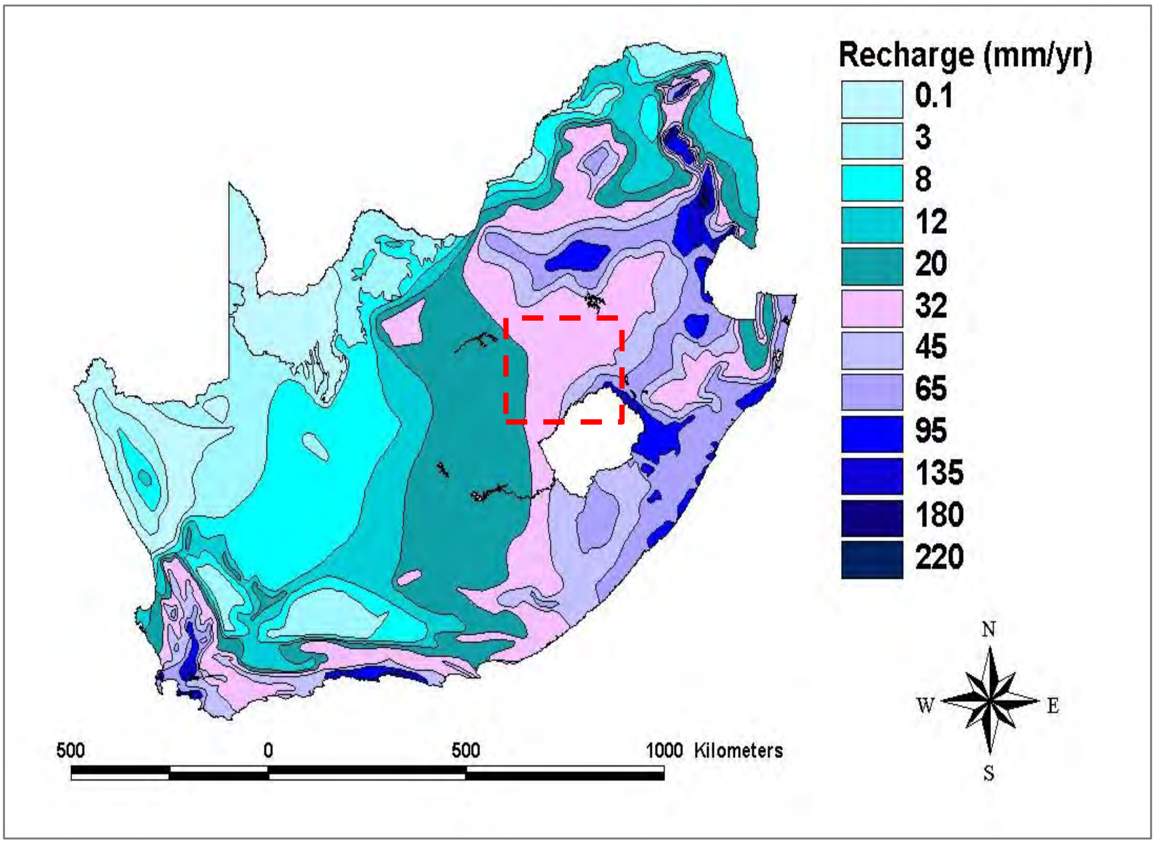


Figure 6-5 Groundwater recharge distribution in South Africa (After Vegter, 1995).

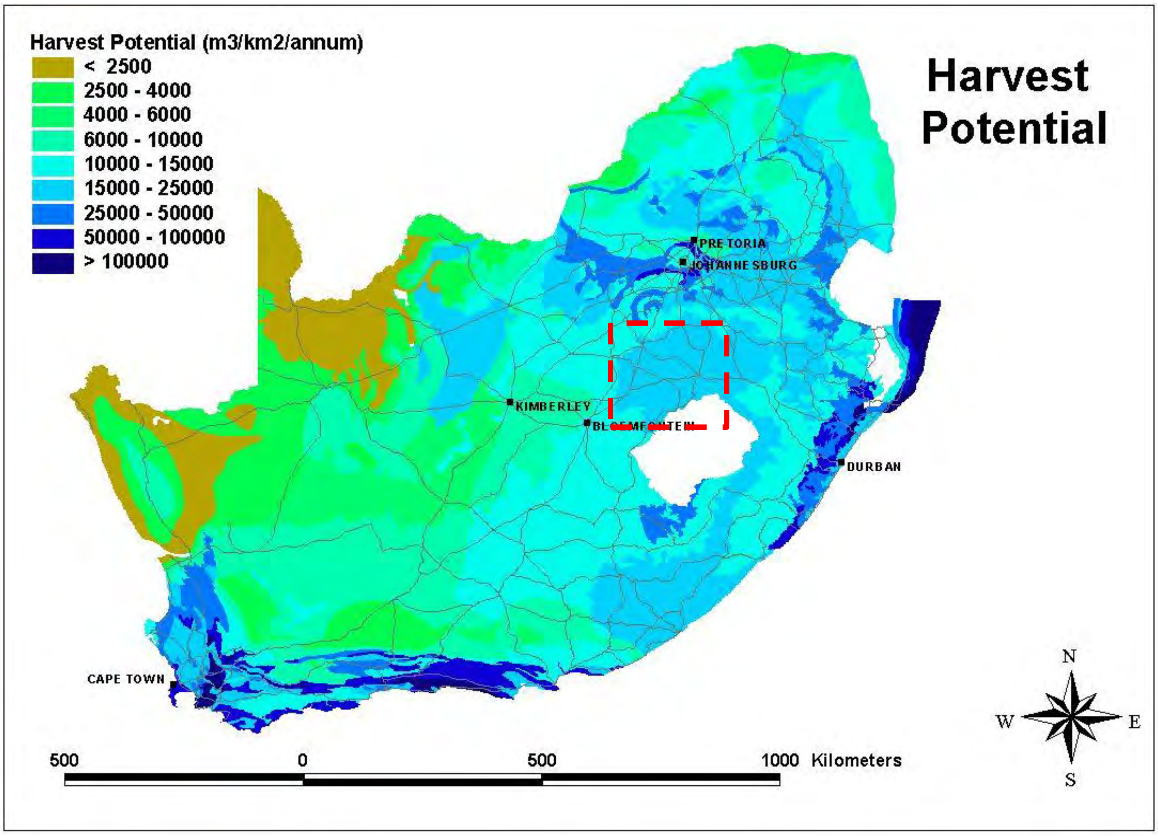


Figure 6-6 Harvest potential distribution in South Africa (DWS, 2013).

7. SITE INVESTIGATION

7.1. Hydrocensus user survey

A hydrocensus user survey within the greater study area was conducted during February and March 2022[4] where relevant hydrogeological baseline information was gathered. The aim of the hydrocensus survey is to determine the ambient and background groundwater conditions and applications and to identify potential sensitive environmental receptors i.e., groundwater users in the direct vicinity of the gas production operations. A total of 78 groundwater receptors i.e., boreholes, artesian wells, wind pumps as well as surface water features were visited as part of the hydrocensus user survey which are largely applied for livestock watering and domestic water supply purposes. Relevant hydrocensus information is summarised in Table 7-1 while a spatial distribution map is shown in Figure 7-5.

7.1.1. Groundwater status

Of the boreholes recorded, the majority are in use (>78.0%) while ~17.0% are not currently being utilized. Approximately 4.0% of boreholes allocated could not be visited due to access challenges. Refer to Figure 7-2 for a summary of the groundwater status quo.

7.1.2. Groundwater application

Most boreholes recorded are being applied for livestock watering and domestic water supply purposes (~45.0%) while domestic and household purposes which is combined with either irrigation or livestock purposes account for >18.0%. A small number of boreholes are also being applied for either monitoring or industrial purposes (~5.0%) while ~17.0% of boreholes do not have an application and are not currently being utilized. Refer to Figure 7-3 for a summary of groundwater applications. According to the Middle Vaal ISP (DWAF, 2004), most boreholes are being applied for irrigation and small-town water supply.

7.1.3. Borehole equipment

Most boreholes visited are equipped with submersible pumps and account to 57.0%, while 15.0% of boreholes were fitted either with a wind pump, mono pump (4.0%), handpump (1.0%) or solar pump (1.0%). An average of 18.0% of boreholes are not equipped as indicated in Figure 7-4.

[4] It should be noted that relevant site information gathered will be representative of wet season contribution.

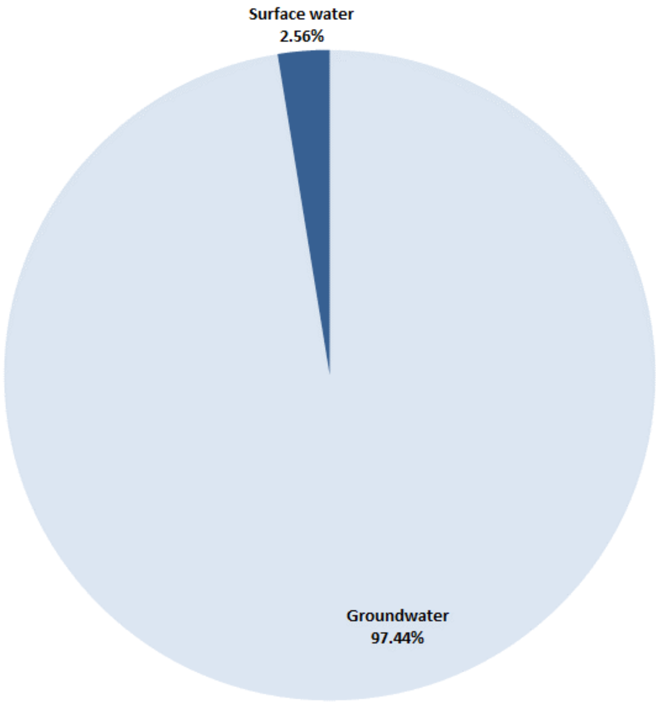


Figure 7-1 Hydrocensus user survey: Geosite type.

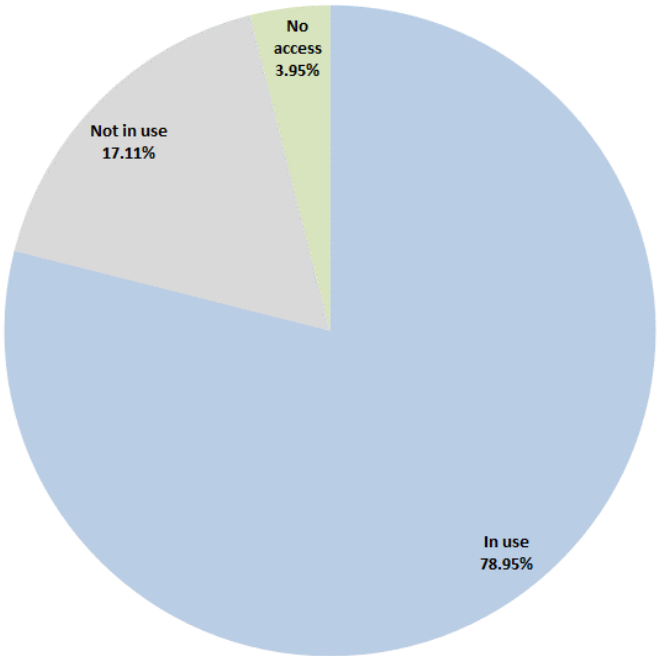


Figure 7-2 Hydrocensus user survey: Groundwater status.

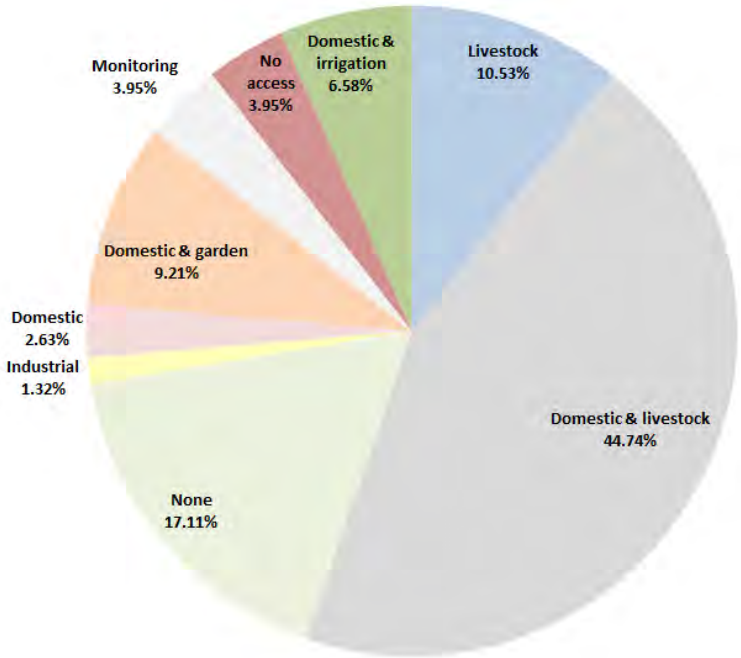


Figure 7-3 **Hydrocensus user survey: Groundwater application.**

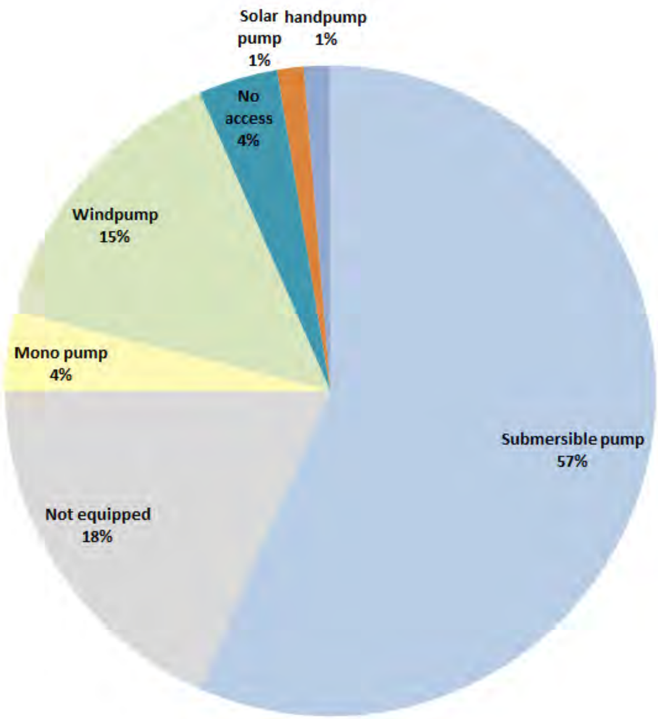


Figure 7-4 **Hydrocensus user survey: Equipment type.**

Table 7-1 Hydrocensus user survey: relevant geosite information.

Site ID	Latitude	Longitude	Water level (mbgl)	Borehole depth (mbgl)	Site type	Site status	Equipment	Water application	Field notes
HBH1	-28.14362	26.80863	NAWL		Borehole	In use	Submersible pump	Livestock	Flooded Area
HBH2	-28.12872	26.80516	NAWL		Borehole	In use	Windpump	Domestic & livestock	
HBH3	-28.12768	26.80522	NAWL		Borehole	In use	Submersible pump	Domestic & livestock	ROCLA
HBH4	-28.12407	26.80630	NAWL		Borehole	In use	Submersible pump	Domestic & livestock	ROCLA
HBH5	-28.11982	26.80036	NAWL		Borehole	In use	Submersible pump	Domestic & livestock	ROCLA
HBH6	-28.12005	26.79521	1.52	30	Borehole	In use	Submersible pump	Domestic & garden	
HBH7	-28.12940	26.77388	NAWL		Borehole	Not in use	No access	None	Blocked
HBH8	-28.15651	26.79403	NAWL		Borehole	In use	Submersible pump	Livestock	
HBH9	-28.15477	26.78428	10.87	30	Borehole	In use	Submersible pump	Livestock	
HBH10	-28.11906	26.81375	NAWL		Borehole	In use	Submersible pump	Industrial	ROCLA
HBH11	-28.11540	26.81199	NAWL		Borehole	In use	Submersible pump	Domestic	
HBH12	-28.13337	26.76153	13.65	30	Borehole	In use	Submersible pump	Domestic & livestock	
HBH13	-28.13200	26.76094	12.35	70	Borehole	In use	Submersible pump	Domestic & livestock	
HBH14	-28.12823	26.75381	16.65		Borehole	In use	Submersible pump	Domestic & livestock	
HBH15	-28.12852	26.75373	17.74		Borehole	In use	Submersible pump	Domestic & livestock	
HBH16	-28.13105	26.75641	25.40	45	Borehole	In use	Submersible pump	Domestic & livestock	
HBH17	-28.12700	26.75455	11.55	40	Borehole	In use	Submersible pump	Domestic & livestock	
HBH18	-28.13405	26.75741	16.47	40	Borehole	Not in use	Not equipped	None	Open
HBH19	-28.13356	26.75760	NAWL		Borehole	In use	Submersible pump	Domestic & livestock	
HBH20	-28.08584	26.75406	1.10	70	Borehole	In use	Submersible pump	Domestic & livestock	
HBH21	-28.09424	26.73133	2.67		Borehole	Not in use	Not equipped	None	Open
HBH22	-28.11837	26.71244	NAWL		Borehole	Not in use	Not equipped	None	Closed
HBH23	-28.10725	26.70513	3.16	18	Borehole	Not in use	Not equipped	None	Open
HBH24	-28.11683	26.70197	8.50		Borehole	In use	Submersible pump	Domestic & livestock	
HBH25	-28.11792	26.68013	24.20		Borehole	In use	Submersible pump	Domestic & livestock	
HBH26	-28.12714	26.65699	NAWL		Borehole	Not in use	Not equipped	None	Closed
HBH27	-28.12845	26.65437	1.40		Borehole	In use	Submersible pump	Domestic & livestock	
HBH28	-28.06977	26.66653	5.02	40	Borehole	In use	Submersible pump	Domestic	
HBH29	-28.07050	26.66551	NAWL		Borehole	In use	Mono pump	Livestock	
HBH30	-28.07475	26.67059	NAWL		Borehole	In use	Submersible pump	Livestock	
HBH31	-28.10189	26.64343	0.00		Borehole	In use	Not equipped	Domestic & garden	Artesian
HBH32	-28.09055	26.65710	NAWL		Borehole	In use	Mono pump	Domestic & garden	
HBH33	-28.11279	26.63522	15.70		Borehole	In use	Submersible pump	Domestic & garden	

Site ID	Latitude	Longitude	Water level (mbgl)	Borehole depth (mbgl)	Site type	Site status	Equipment	Water application	Field notes
HBH34	-28.12682	26.69912	26.04	60	Borehole	In use	Submersible pump	Domestic & livestock	
HBH35	-28.11991	26.69965	3.70	20	Borehole	In use	Submersible pump	Domestic & garden	
HBH36	-28.06441	26.66184	2.66	18	Borehole	In use	Submersible pump	Domestic & garden	
HBH37	-28.06606	26.66227	3.18	20	Borehole	In use	Submersible pump	Domestic & garden	
HBH38	-28.18060	26.64045	2.94	50	Borehole	In use	Submersible pump	Livestock	
HBH39	-28.16963	26.63504	8.26	40	Borehole	In use	Submersible pump	Domestic & livestock	
HBH40	-28.16964	26.63456	8.75	16	Borehole	Not in use	Not equipped	None	Open
HBH41	-28.14747	26.72413	NAWL	80	Borehole	In use	Submersible pump	Domestic & irrigation	
HBH42	-28.14750	26.72416	NAWL	80	Borehole	In use	Submersible pump	Domestic & irrigation	
HBH43	-28.15102	26.72540	NAWL		Borehole	Not in use	Not equipped	None	No access
HBH44	-28.15038	26.72384	8.46	50	Borehole	In use	Submersible pump	Domestic & livestock	
HBH45	-28.15055	26.72382	8.40	50	Borehole	In use	Submersible pump	Domestic & livestock	
HBH46	-28.14817	26.72182	14.50		Borehole	In use	Submersible pump	Domestic & livestock	
HBH47	-28.14472	26.73037	NAWL		Borehole	In use	Solar pump	Domestic & livestock	
HBH48	-28.17827	26.74558	11.03		Borehole	In use	Submersible pump	Domestic & livestock	
HBH49	-28.17886	26.74621	7.12		Borehole	In use	Submersible pump	Domestic & livestock	
HBH50	-28.18372	26.74679	NAWL		Borehole	In use	No access	Domestic & livestock	No access
HBH51	-28.19216	26.72884	NAWL		Borehole	In use	No access	Monitoring	No access
HBH52	-28.18767	26.73012	1.08	10	Borehole	In use	Not equipped	Monitoring	Open
HBH53	-28.18655	26.73110	2.80	5	Borehole	In use	Not equipped	Monitoring	Open
HBH54	-28.24539	26.71029	7.98		Borehole	In use	Submersible pump	Domestic & livestock	
HBH55	-28.24598	26.71291	NAWL		Borehole	In use	Submersible pump	Domestic & livestock	
HBH56	-28.21266	26.69929	1.79	30	Borehole	Not in use	Not equipped	None	Open
HBH57	-28.25142	26.74366	NAWL		Borehole	Not in use	Not equipped	None	Blocked
HBH58	-28.25125	26.74377	7.95		Borehole	In use	Submersible pump	Domestic & livestock	
HBH59	-28.25111	26.74382	8.35		Borehole	In use	Submersible pump	Domestic & irrigation	
HBH60	-28.24983	26.74353	12.90		Borehole	In use	Submersible pump	Domestic & irrigation	
HBH61	-28.24970	26.74315	12.55		Borehole	In use	Submersible pump	Domestic & irrigation	
HBH62	-28.22459	26.80767	12.70	30	Borehole	In use	Windpump	Livestock	
HBH63	-28.20166	26.78398	NAWL		Borehole	In use	Windpump	Livestock	
HBH64	-28.21076	26.78479	NAWL		Borehole	No access	Windpump	No access	
HBH65	-28.21203	26.79141	NAWL		Borehole	No access	Windpump	No access	
HBH66	-28.21220	26.78951	NAWL		Borehole	No access	Windpump	No access	
HBH67	-28.21859	26.75478	NAWL		Borehole	Not in use	Not equipped	None	Open. Bees.
HBH68	-28.22435	26.75422	NAWL		Borehole	In use	Windpump	Domestic & livestock	

Site ID	Latitude	Longitude	Water level (mbgl)	Borehole depth (mbgl)	Site type	Site status	Equipment	Water application	Field notes
HBH69	-28.22273	26.75010	1.67		Borehole	In use	Submersible pump	Domestic & livestock	
HBH70	-28.22878	26.74097	3.10		Borehole	In use	Windpump	Domestic & livestock	
HBH71	-28.19508	26.74163	NAWL		Borehole	In use	Windpump	Domestic & livestock	
HBH72	-28.19312	26.73970	1.75		Borehole	Not in use	Not equipped	None	Open
HBH73	-28.19301	26.73964	1.63		Borehole	In use	Mono pump	Domestic & livestock	
HBH74	-28.22959	26.80025	NAWL		Borehole	In use	Windpump	Domestic & livestock	
HBH75	-28.23077	26.80533	NAWL		Borehole	In use	Windpump	Domestic & livestock	
HBH76	-28.09771	26.73687	NAWL		Borehole	Not in use	Handpump	None	
SRD	-28.12263	26.70925	N/A		Surface water	N/A	N/A	N/A	Sand River downstream point
SRU	-28.10651	26.73623	N/A		Surface water	N/A	N/A	N/A	Sand River upstream point

N/A: Not applicable

NAWL: No access to water level

Figure 7-5 **Spatial distribution of hydrocensus user survey geosites.**

8. GROUNDWATER FLOW EVALUATION

The following sub-sections outline the groundwater flow dynamics of the study area.

8.1. Unsaturated zone

The thickness of the unsaturated or vadose zone was determined by subtracting the undisturbed static water level elevation from corresponding surface topography. The latter will govern the infiltration rate, as well as effective recharge of rainfall to the aquifer. Furthermore, the nature of the formation(s) forming the unsaturated zone will significantly influence the mass transport of surface contamination to the underlying aquifer(s). The unsaturated zone within the study area is in the order of 0 (fully saturated to surface) to >26.0m with a mean thickness of approximately ~9.0m. It should be noted that due to the argillaceous nature of the host aquifer(s) the shallow water levels observed at some of the borehole localities can be attributed to clay/silt lenses and be indicative of perched aquifer conditions and not necessarily represent the vadose zone.

8.2. Depth to groundwater

A distribution of borehole water levels recorded as part of the hydrocensus user survey conducted as well as monitoring borehole water levels measured were considered and used to interpolate local groundwater elevation and hydraulic head contours as summarised in Table 8-1 and depicted in Figure 8-1. Artesian conditions were observed at three of the boreholes visited namely HBH31, 21B as well as 8B which can be indicative of semi-confined to confined aquifer conditions present or perched aquifer conditions. The minimum water level was recorded at 0.0mbgl, while the deepest water level was measured at borehole locality Mon-HDR1 (26.71mbgl)[5]. The average water level is calculated at 8.91mbgl which is much shallower than the regional average water level of ~23.0mbgl (Aquiworx, 2014).

Figure 8-2 summarises time-series water levels within the existing Tetra 4 monitoring boreholes by comparing water levels representative of the dry-cycle contribution vs water levels representative of the wet cycle contribution. It is noted that most water levels suggest a decrease in water levels and recovering trend. The latter can be attributed the onset of the wet cycle and above average rainfall events experienced with rainfall recharge replenishing aquifer storage. It can be observed that there is a definite a relatively quick response to rainfall, suggesting that recharge of the shallow, intergranular aquifer takes place without a prolonged lag effect. The average change in most water levels is <5.0%, which accounts to less than 0.5m, while the relatively low Coefficient of Variation (CV) values derived from statistical analyses suggest that the local groundwater system is in quasi-steady state conditions.

[5] It should be noted that due to this borehole currently being applied for supply purposes, it can be assumed that this water level represents a dynamic water level.

Table 8-1 Regional water level summary.

Site ID	Topographical Elevation (mamsl)	Water level (mbgl)	Groundwater Elevation (mamsl)
HBH6	1308.35	1.52	1306.83
HBH9	1314.33	10.87	1303.46
HBH12	1317.12	13.65	1303.47
HBH13	1317.12	12.35	1304.77
HBH14	1306.16	16.65	1289.51
HBH15	1306.16	17.74	1288.42
HBH16	1311.92	25.40	1286.52
HBH17	1306.16	11.55	1294.61
HBH18	1312.93	16.47	1296.46
HBH20	1341.47	1.10	1340.37
HBH21	1316.68	2.67	1314.01
HBH23	1313.61	3.16	1310.45
HBH24	1296.78	8.50	1288.28
HBH25	1306.46	24.20	1282.26
HBH27	1300.84	1.40	1299.44
HBH28	1312.85	5.02	1307.83
HBH31	1308.76	0.00	1308.76
HBH33	1303.06	15.70	1287.36
HBH34	1282.46	26.04	1256.42
HBH35	1293.51	3.70	1289.81
HBH36	1311.04	2.66	1308.38
HBH37	1311.33	3.18	1308.15
HBH38	1338.24	2.94	1335.30
HBH39	1312.52	8.26	1304.26
HBH40	1312.52	8.75	1303.77
HBH44	1318.93	8.46	1310.47
HBH45	1318.93	8.40	1310.53
HBH46	1314.70	14.50	1300.20
HBH48	1325.03	11.03	1314.00
HBH49	1325.03	7.12	1317.91
HBH52	1323.97	1.08	1322.89
HBH53	1323.97	2.80	1321.17
HBH54	1363.06	7.98	1355.08
HBH56	1358.94	1.79	1357.15
HBH58	1373.57	7.95	1365.62
HBH59	1373.57	8.35	1365.22
HBH60	1371.99	12.90	1359.09
HBH61	1371.99	12.55	1359.44
HBH62	1337.84	12.70	1325.14
HBH69	1358.14	1.67	1356.47
HBH70	1360.24	3.10	1357.14
HBH72	1332.90	1.75	1331.15
HBH73	1332.90	1.63	1331.27
15E	1380.01	2.20	1377.81
21A (BH05)	1281.21	12.48	1268.74
21B	1281.21	0.00	1281.21
21D	1280.00	16.09	1263.91
22A	1282.95	10.64	1272.31
22D (BH09)	1281.21	8.33	1272.89
23C	1373.57	5.42	1368.16
25B	1404.66	9.39	1395.27
8B	1325.03	0.00	1325.03
BD52	1381.39	0.73	1380.66
BH01	1283.95	23.33	1260.63

Site ID	Topographical Elevation (mamsl)	Water level (mbgl)	Groundwater Elevation (mamsl)
BH02	1308.60	10.07	1298.53
BH07	1281.69	16.97	1264.73
Mon-2057	1320.23	3.09	1317.14
Mon-F1	1290.60	21.46	1269.14
Mon-F3	1304.74	7.74	1297.00
Mon-F4	1319.62	7.69	1311.93
Mon-HDR1	1283.95	26.71	1257.24
OB	1364.24	0.70	1363.54
Geometric Mean	**1321.87**	**8.91**	**1312.88**
Minimum	**1280.00**	**0.00**	**1256.42**
Maximum	**1404.66**	**26.71**	**1395.27**
Standard deviation	**30.02**	**7.17**	**33.46**
Correlation		**0.98**	

Notes: Boreholes highlighted in red represent the current Tetra 4 monitoring localities.

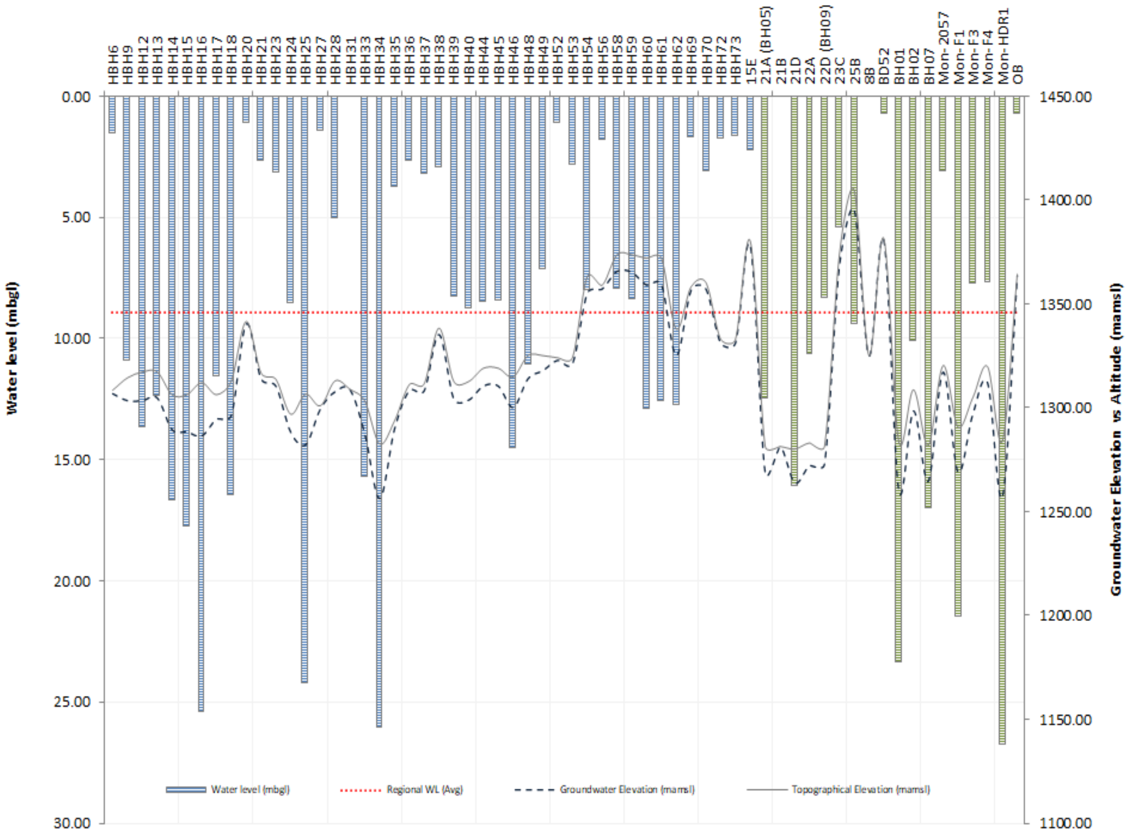


Figure 8-1 **Bar chart indicating regional water level summary.**

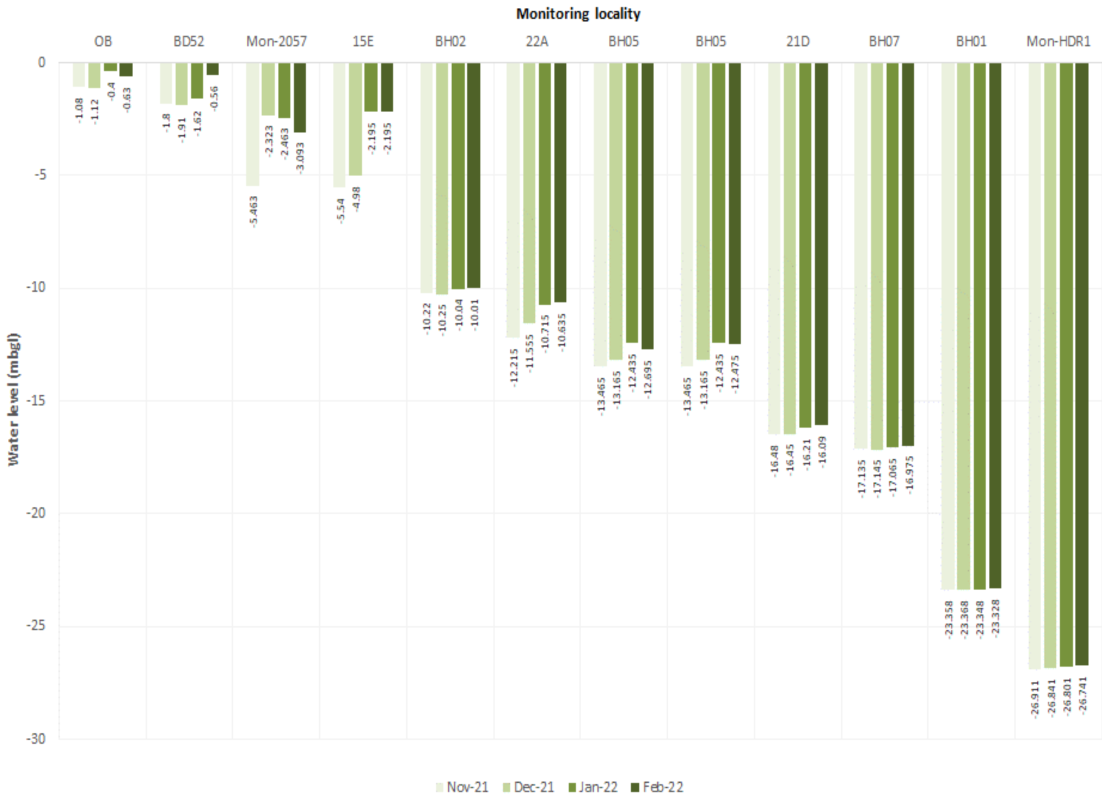


Figure 8-2 **Bar chart indicating time-series water level comparison of the Tetra 4 monitoring boreholes.**

8.3. Groundwater flow direction and hydraulic gradients

Analysed data indicate that the surveyed water levels correlate very well to the topographical elevation (R^2 <0.98) (Figure 8-3). Accordingly, it can be assumed that the regional groundwater flow direction is dictated by topography. Bayesian interpolation was used to interpolate the groundwater levels throughout the study area. The inferred groundwater flow direction will be towards the lower laying drainage system(s) traversing the project area from where groundwater will discharge as baseflow. The groundwater flow direction within the southern catchment of the Sandrivier and Doringrivier, also in the vicinity of the proposed plant expansion footprint, will be in a general northern direction, whereas the groundwater flow direction within the northern catchment of the study area will be mostly in a south to southwestern direction as depicted in Figure 8-4.

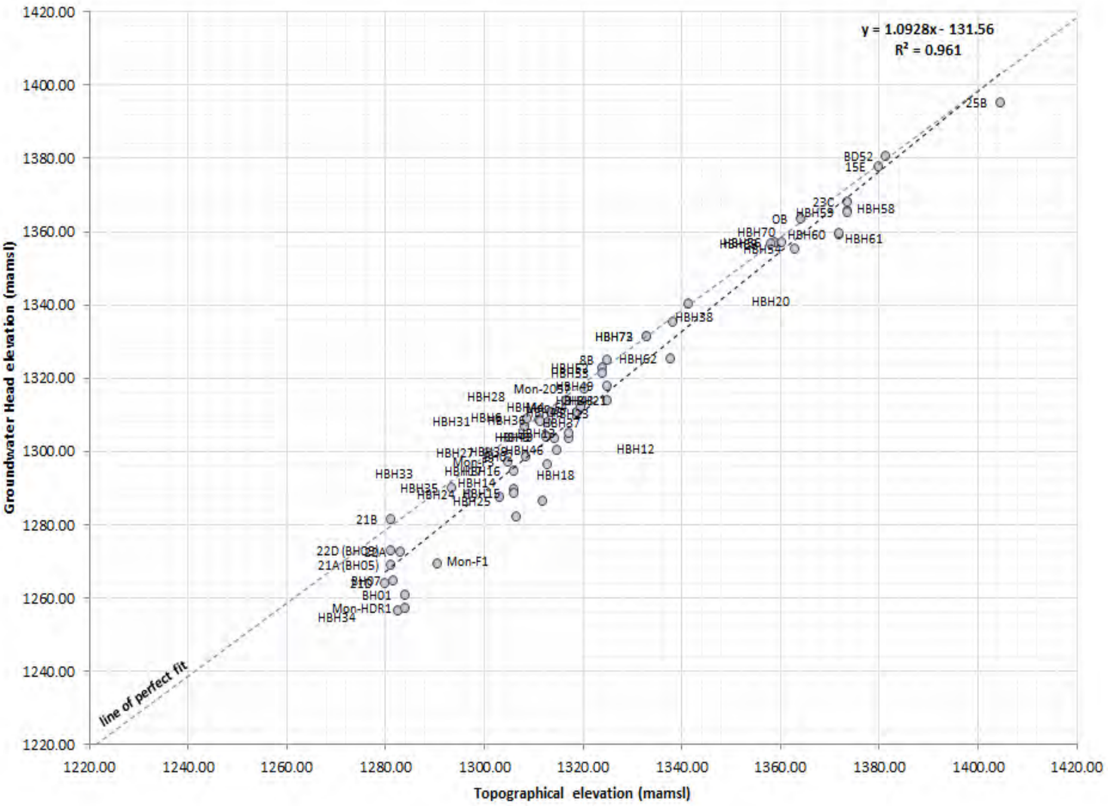


Figure 8-3 **Topographical elevation vs. groundwater elevation correlation graph.**

Groundwater flow path lines are lines perpendicular to groundwater contours, flow generally occurs faster where contours are closer together and gradients are thus steeper. The groundwater or hydraulic gradient is the change in the hydraulic head over a certain distance, mathematically it is the difference in hydraulic head over a distance along the flow path between two points. The latter provides an indication of the direction of groundwater flow. The following equation can be applied:

Equation 8-1 **Hydraulic gradient.**

$$i = \frac{dh}{dl}$$

where:

i = Hydraulic gradient (dimensionless).

dh = Is the head loss between two observation wells.

dL = Horizontal distance between two observation points...

The average groundwater gradient (i) of the shallow, weathered aquifer in the vicinity of the proposed plant expansion footprint is relatively flat and calculated at a mean of 0.002, with a maximum of 0.003 in a south to north orientation and a minimum of 0.001 in a general southeast to northwest orientation as summarised in Table 8-2 below.

Table 8-2 Inferred groundwater gradient and seepage direction.

Inferred seepage direction	Hydraulic gradient (i)
S to N	0.003
E to W	0.001
SW to NE	0.001
SE to NW	0.002
Minimum	**0.001**
Maximum	**0.003**
Standard deviation	**0.001**
Geometric Mean	**0.002**

8.4. Darcy flux and groundwater flow velocity

The Darcy flux (or velocity) is a function of the hydraulic conductivity (K) and the hydraulic gradient as suggested by Equation 8-2 whereas the seepage velocity can be defined as the Darcy flux divided by the effective porosity[6] (Equation 8-3). This is also referred to as the average linear velocity and can be calculated by applying the following equations (Fetter 1994).

Equation 8-2 Darcy flux.

$$\boldsymbol{v} = \boldsymbol{Ki}$$

Equation 8-3 Seepage velocity.

$$\boldsymbol{v} = \frac{\boldsymbol{Ki}}{\emptyset}$$

where:

v = flow velocity (m/d).

K = hydraulic conductivity (m/d).

i = hydraulic gradient (dimensionless).

ø = effective porosity.

The expected seepage rate from contamination originating at the proposed plant expansion footprint as well as associated infrastructure is estimated at an average of approximately 1.26m/a, with a maximum distance of ~2.20m/a in a southern to northern direction as summarised in Table 8-3 below.

[6] It should be noted that effective porosity percentages have been assumed and in situ tests have not been conducted to confirm these ratios.

Table 8-3 Darcy flux and seepage rates[7].

Shallow, intergranular aquifer	Hydraulic gradient (i)	Hydraulic conductivity (K)	Darcy flux (m/d)	Effective porosity	Seepage velocity (m/d)	Seepage velocity (m/a)
S to N	0.003	0.188	0.00060	0.100	0.006	2.202
E to W	0.001	0.188	0.00023	0.100	0.002	0.825
SW to NE	0.001	0.188	0.00025	0.100	0.002	0.908
SE to NW	0.002	0.188	0.00035	0.100	0.003	1.264
Minimum	**0.001**	**0.188**	**0.0002**	**0.100**	**0.002**	**0.825**
Maximum	**0.003**	**0.188**	**0.0006**	**0.100**	**0.006**	**2.202**
Standard deviation	**0.001**	**0.000**	**0.0001**	**0.000**	**0.001**	**0.546**
Geometric Mean	**0.002**	**0.188**	**0.0003**	**0.100**	**0.003**	**1.202**

8.5. Groundwater-surface water interaction

Groundwater and surface water interaction is an essential component of the hydrological cycle. The hyporheic zone (stream bed) is the zone of most interaction (Adams et. al.,2012). According to records documented by Van Tonder and Dennis (2003), under natural conditions this area exhibits certain regions where there is pronounced interaction between surface and groundwater. The two regimes are therefore well-linked and should be integrated to manage any water related issues in these catchments. Regional drainages can be generally classified as influent or gaining stream systems as the groundwater head elevation of the water table in the vicinity of the stream is higher than the altitude of the stream bed and, accordingly, there definitely exists groundwater discharge as baseflow to local drainages. The alluvial associated with the floodplains of the Sand - and Doringrivier forms a primary aquifer and is directly connected with surface water resources, especially during high flow conditions (Lea, 2017).

[7] This estimate does however not take into account all known or suspected zones in the aquifer like preferential flow paths formed by faults and fracture zones or igneous contact zones like the intrusive dykes that have higher transmissivities than the general aquifer matrix. Such structures may cause flow velocities to increase several meters or even tens of meters per year under steady state conditions. Under stressed conditions such as at groundwater abstraction areas the seepage velocities could increase another order of magnitude.

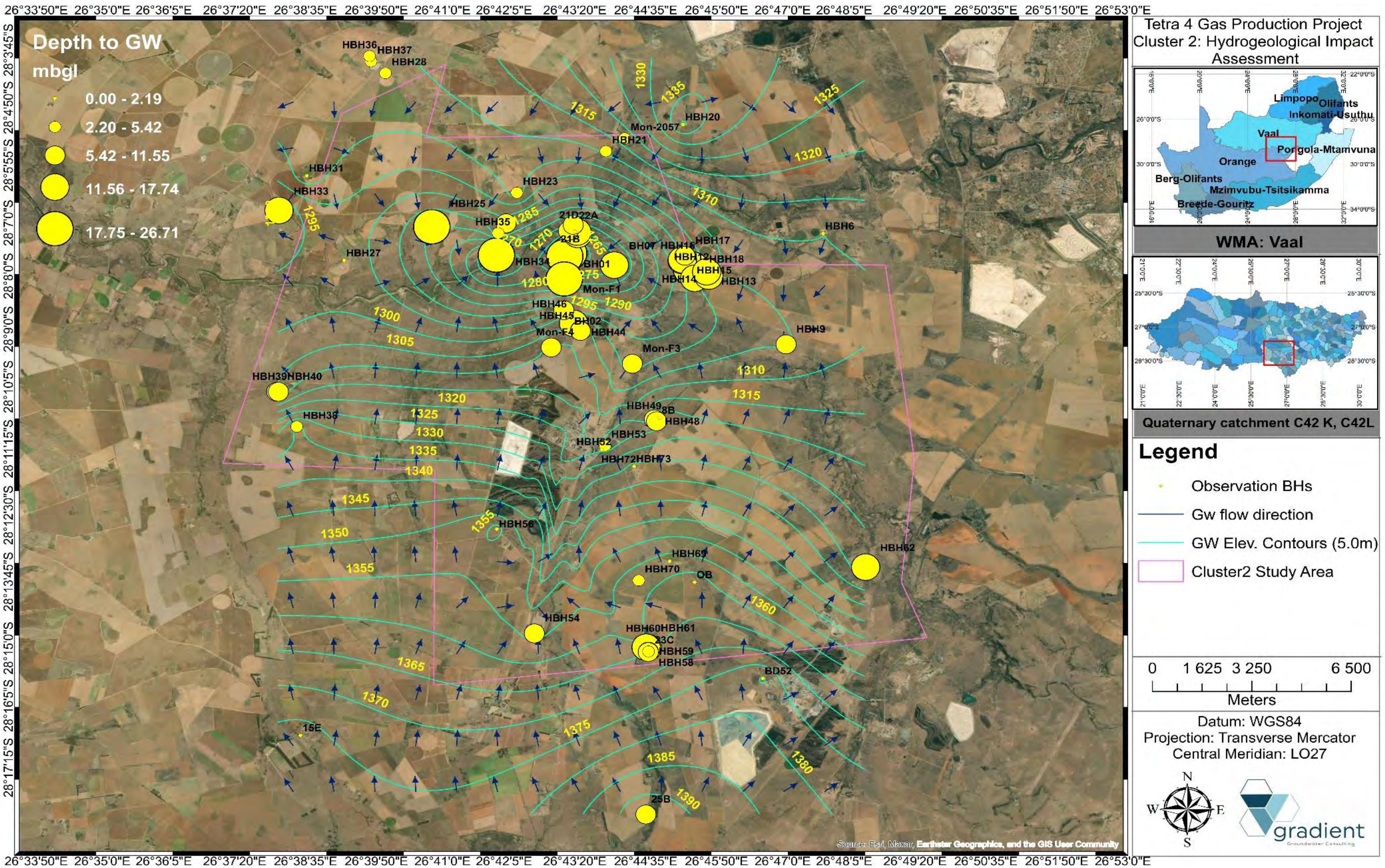


Figure 8-4 **Regional groundwater flow direction and depth to groundwater.**

9. HYDROCHEMISTRY

To assess future impacts of the proposed gas production activities on the groundwater regime, it is necessary to develop a baseline/background to be applied as benchmark prior to onset. The following section serves to characterise ambient groundwater quality and develop a relevant baseline for future reference.

9.1. Water quality analysis

The South African National Standards (SANS 241: 2015) have been applied to assess the water quality within the project area. The standards specify a maximum limit based on associated risks for constituents (Refer to Table 9-1). Water samples were submitted for analysis at a SANAS accredited laboratory for inorganic analysis. Parameters exceeding the stipulated SANS 241:2015 thresholds are highlighted in red (acute health), elemental concentrations above this range are classed as unsuitable for domestic consumption without treatment whereas yellow highlighted cells indicate parameters above aesthetic limits. These standards were selected for use as the current and future water uses in the area are primarily domestic application and/or livestock watering.

Table 9-1 SANS 241:2015 risks associated with constituents occurring in water.

Risk	Effect
Aesthetic	Determinant that taints water with respect to taste, odour and colour and that does not pose an unacceptable health risk if present at concentration values exceeding the numerical limits specified.
Operational	Determinant that is essential for assessing the efficient operation of treatment systems and risks to infrastructure.
Acute Health – 1	Routinely quantifiable determinant that poses an immediate health risk if consumed with water at concentration values exceeding the numerical limits specified.
Acute Health – 2	Determinant that is presently not easily quantifiable and lacks information pertaining to viability and human infectivity which, however, does pose immediate unacceptable health risks if consumed with water at concentration values exceeding the numerical limits specified.
Chronic Health	Determinant that poses an unacceptable health risk if ingested over an extended period if present at concentration values exceeding the numerical limits specified.

Table 9-2 SANS 241:2015 physical aesthetic, operational and chemical parameters.

Parameter	Risk	Unit	Standard limits [a]
Physical and aesthetic determinants			
Electrical conductivity (EC)	Aesthetic	mS/m	≤170
Total Dissolved Solids (TDS)	Aesthetic	mg/l	≤1200
Turbidity [b]	Operational	NTU	≤1
	Aesthetic	NTU	≤5
pH [c]	Operational	pH units	≥5 to ≤9,7
Chemical determinants – macro			
Nitrate as N[d]	Acute health	mg/l	≤11
Sulphate as SO_4^{-2}	Acute health	mg/l	≤500
	Aesthetic	mg/l	≤250
Fluoride as F	Chronic health	mg/l	≤1.5
Ammonia as N	Aesthetic	mg/l	≤1.5
Chloride as Cl^-	Aesthetic	mg/l	≤300
Sodium as Na	Aesthetic	mg/l	≤200
Zinc as Zn	Aesthetic	mg/l	≤5
Chemical determinants – micro			
Antimony as Sb	Chronic health	mg/l	≤0.02
Arsenic as As	Chronic health	mg/l	≤0.010
Cadmium as Cd	Chronic health	mg/l	≤0.003
Total chromium as Cr	Chronic health	mg/l	≤0.050
Copper as Cu	Chronic health	mg/l	≤2.0
Iron as Fe	Chronic health	mg/l	≤2.0
	Aesthetic	mg/l	≤0.30
Lead as Pb	Chronic health	mg/l	≤0.010
Manganese as Mn	Chronic health	mg/l	≤0.50
	Aesthetic	mg/l	≤0.10
Mercury as Hg	Chronic health	mg/l	≤0.006
Nickel as Ni	Chronic health	mg/l	≤0.07
Selenium as Se	Chronic health	mg/l	≤0.010
Uranium as U	Chronic health	mg/l	≤0.015
Vanadium as V	Chronic health	mg/l	≤0.2
Aluminium as Al	Operational	mg/l	≤0.3

a The health-related standards are based on the consumption of 2 L of water per day by a person of a mass of 60 kg over a period of 70 years.

b Values in excess of those given in column 4 may negatively impact disinfection.

c Low pH values can result in structural problems in the distribution system.

d This is equivalent to nitrate at 50 mg/l NO_3^-.

9.2. Data validation

The laboratory precision was validated by employing the plausibility of the chemical analysis, electro neutrality (E.N.) which is determined according to Equation 10-1, below. An error of less than 5.0% is an indication that the analysis results are of suitable precision for further evaluation. All water samples analysed indicate a good plausibility (<5.0%) and data can be considered as accurate and correct (Table 9-3).

Equation 9-1 Electro-neutrality.

$$E.N. = \frac{\sum cations\left[\frac{meq}{L}\right] + \sum anions\left[\frac{meq}{L}\right]}{\sum cations\left[\frac{meq}{L}\right] - \sum anions\left[\frac{meq}{L}\right]} .100\% < 5.0\%$$

Table 9-3 Laboratory precision and data validity.

Sample Localities	Σ Major cations (meq/l)	Σ Major anions (meq/l)	Electro-Neutrality [E.N.] %
HBH 2	10.059	10.210	-0.75%
HBH 9	7.701	8.017	-2.01%
HBH 12	9.023	9.401	-2.05%
HBH 15	7.072	7.356	-1.97%
HBH 16	9.304	9.647	-1.81%
HBH 19	11.087	11.471	-1.70%
HBH 21	12.503	12.595	-0.37%
HBH 23	3.118	3.238	-1.89%
HBH 24	8.057	8.363	-1.86%
HBH 25	13.868	13.865	0.01%
HBH 27	12.578	12.225	1.42%
HBH 31	6.659	6.955	-2.18%
HBH 32	8.917	9.245	-1.81%
HBH 34	11.112	11.473	-1.60%
HBH 35	9.681	9.871	-0.97%
HBH 38	6.811	7.078	-1.93%
HBH 42	8.578	8.858	-1.61%
HBH 44	15.226	15.754	-1.70%
HBH 46	10.424	10.775	-1.66%
HBH 48	26.369	26.526	-0.30%
HBH 49	13.933	14.434	-1.77%
HBH 55	7.981	8.271	-1.79%
HBH 56	5.985	6.212	-1.86%
HBH 63	9.392	9.699	-1.61%
HBH 68	9.863	9.480	1.98%
HBH 69	12.426	12.921	-1.95%
HBH 70	11.028	11.473	-1.98%
HBH 73	11.682	12.043	-1.52%
HBH 74	19.709	20.530	-2.04%
HBH 75	21.617	22.267	-1.48%
HBH 76	16.525	17.199	-2.00%
SRD	8.764	9.039	-1.55%
SRU	10.504	10.822	-1.49%

Note: E.N. < 5.0% generally reflect an accurate laboratory analysis.

Table 9-4, Table 9-5 as well as Table 9-6 below classify water quality according to pH, salinity as well as hardness.

Table 9-4 Hydrochemical classification according to pH-values.

pH Values used to indicate alkalinity or acidity of water	
pH: > 8.5	Alkaline/Basic
pH: 6.0- 8.5	Neutral
pH: < 6	Acidic

Table 9-5 Hydrochemical classification according to salinity.

TDS Concentrations to indicate the salinity of water	
TDS < 450 mg/l	Non-saline
TDS 450 - 1 000 mg/l	Saline
TDS 1 000 - 2 400 mg/l	Very saline
TDS 2 400 - 3 400 mg/l	Extremely saline

Table 9-6 Hydrochemical classification according to hardness.

Hardness concentrations to indicate softness or hardness of water	
Hardness < 50 mg/l	Soft
Hardness 50 – 100 mg/l	Moderately soft
Hardness 100 – 150 mg/l	Slightly hard
Hardness 150 – 200 mg/l	Moderately hard
Hardness 200 – 300 mg/l	Hard
Hardness 300 – 600 mg/l	Very hard
Hardness > 600mg/l	Extremely hard

9.3. Water quality

The hydrochemical results of the hydrocensus boreholes water samples analysed suggest the overall ambient groundwater quality is good with most macro and micro determinants falling within or below the SANS 241:2015 limits. Groundwater can be described as neutral, saline to very saline and hard to very hard. The groundwater quality is impacted by the geological formations, which were deposited in shallow marine environments and are therefore naturally saline (Lea, 2017).

It is observed that most of the boreholes indicate elevated Nitrate (NO_3) concentrations. The latter may be attributed to the agricultural land-use activities dominating the greater study area with elevated NO_3 concentrations potentially derived from leachate of fertilizer to the local aquifer. It should be noted that elevated nitrate concentrations were also recorded in most of the hydrocensus boreholes identified during the initial groundwater study of 2017. It is noted that the TDS concentration increases towards the northern section of the study area as well as near the drainages present. This can most likely be attributed to the geology within these sections, however, should be confirmed. Refer to Figure 9-4 for a spatial distribution map of nitrate concentrations per borehole locality analysed. It is noted that borehole localities with elevated NO_3 concentrations are generally situated within or directly down-gradient of planted crop areas as well as near surface water features.

Isolated sampling localities also suggest elevated Calcium (Ca)/Magnesium (Mg)/Sodium (Na)-Chloride (Cl) concentrations which may be indicative of the intermediate, fractured aquifer unit being targeted by the respective borehole(s), sourcing more stagnant groundwater. The latter may also be indicative of over-abstraction of the respective boreholes which result in more saline matrix water being sourced due to turbulent flow conditions instead of water being sourced from fractures via laminar flow conditions.

Surface water samples include an upstream (SRU) and down-stream (SRD) water sample which were collected from the Sandrivier passing down-gradient of the existing and proposed plant expansion footprint area. The surface water quality can be classified as moderate to good with Aluminum (Al) and Iron (Fe) being slightly elevated. It should be noted that there is not a significant change in the downstream water quality compared to the upstream quality with an increase in Aluminum (Al), however all surface water samples analysed suggest elevated heavy metal concentrations i.e., Al and Fe.

The hydrochemical results of the monitoring boreholes water samples analysed suggest the overall ambient groundwater quality to be moderate with a higher salt load being observed. Groundwater can be described as neutral, saline to very saline and hard to very hard. Most samples analysed suggest elevated Calcium/Magnesium-Chloride concentrations with isolated boreholes (BH04 and BH05) indicating elevated concentrations of Manganese (Mn).

Table 9-7, Table 9-8 and Table 9-9 summarises water quality analysis for the hydrocensus samples analysed whereas Table 9-10 tabulates the monitoring borehole water samples analysed. Figure 9-1 (hydrocensus boreholes) and Figure 9-2 (monitoring boreholes) depicts a bar-chart of the major anion and cation composition while Figure 9-3 indicate a spatial distribution map of hydrochemical composition per sampling locality. It is evident that borehole localities HBH44, HBH48, HBH74, HBH75, BH01, BH04, BH05 and BH08 indicate a higher salt load compared to the other sampling localities which may be indicative of a different, potentially deeper, aquifer unit being targeted, however this should be confirmed be evaluation of borehole drilling logs and construction. Below is a short summary of water quality per sampling locality.

9.3.1. Borehole locality HBH2

Water quality can be described as neutral, saline and hard:

- pH of 7.60.
- TDS of 537.38mg/l.
- Total Hardness ($CaCO_3$/l) of 375.86mg/l.

9.3.2. Borehole locality HBH9

Water quality can be described as neutral, non-saline and hard:

- pH of 7.51.
- TDS of 449.27mg/l.
- Total Hardness ($CaCO_3$/l) of 236.78mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 16.03mg/l.

9.3.3. Borehole locality HBH12

Water quality can be described as neutral, saline and very hard:

- pH of 7.33.
- TDS of 511.56mg/l.
- Total Hardness ($CaCO_3$/l) of 361.56mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 12.80 mg/l.

9.3.4. Borehole locality HBH15

Water quality can be described as neutral, non-saline and hard:

- pH of 7.55.
- TDS of 420.78mg/l.
- Total Hardness ($CaCO_3$/l) of 219.26mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 18.80mg/l.

9.3.5. Borehole locality HBH16

Water quality can be described as neutral, saline and very hard:

- pH of 7.48.
- TDS of 539.41mg/l.
- Total Hardness ($CaCO_3$/l) of 323.10mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 16.90mg/l.

9.3.6. Borehole locality HBH19

Water quality can be described as neutral, saline and very hard:

- pH of 7.44.
- TDS of 646.73mg/l.
- Total Hardness ($CaCO_3$/l) of 417.83mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 21.70mg/l.

9.3.7. Borehole locality HBH21

Water quality can be described as neutral, saline and very hard:

- pH of 7.24.
- TDS of 686.31mg/l.
- Total Hardness ($CaCO_3$/l) of 430.64mg/l.

9.3.8. Borehole locality HBH23

Water quality can be described as neutral, non-saline and moderately soft:

- pH of 8.32.
- TDS of 174.51mg/l.
- Total Hardness ($CaCO_3$/l) of 70.0mg/l.

9.3.9. Borehole locality HBH24

Water quality can be described as neutral, non-saline and hard:

- pH of 7.52.
- TDS of 462.11mg/l.
- Total Hardness ($CaCO_3$/l) of 258.30mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 14.30mg/l.

9.3.10. Borehole locality HBH25

Water quality can be described as neutral, saline and very hard:

- pH of 7.40.
- TDS of 747.67mg/l.
- Total Hardness ($CaCO_3$/l) of 360.76mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NH_3 of 3.89mg/l.

9.3.11. Borehole locality HBH27

Water quality can be described as neutral, saline and very hard:

- pH of 7.47.
- TDS of 671.76mg/l.
- Total Hardness ($CaCO_3$/l) of 390.20mg/l.

9.3.12. Borehole locality HBH31

Water quality can be described as neutral, non-saline and moderately hard:

- pH of 7.47.
- TDS of 410.94mg/l.
- Total Hardness ($CaCO_3$/l) of 189.05mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 26.20mg/l.

9.3.13. Borehole locality HBH32

Water quality can be described as neutral, saline and hard:

- pH of 7.52.
- TDS of 528.42mg/l.
- Total Hardness ($CaCO_3$/l) of 249.77mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 24.60mg/l.

9.3.14. Borehole locality HBH34

Water quality can be described as neutral, saline and soft:

- pH of 8.17.
- TDS of 635.87mg/l.
- Total Hardness ($CaCO_3$/l) of 7.48mg/l.

9.3.15. Borehole locality HBH35

Water quality can be described as neutral, saline and hard:

- pH of 7.37.
- TDS of 546.79mg/l.
- Total Hardness ($CaCO_3$/l) of 281.13mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 14.50mg/l.

9.3.16. Borehole locality HBH38

Water quality can be described as neutral, non-saline and hard:

- pH of 7.12.
- TDS of 417.21mg/l.
- Total Hardness ($CaCO_3$/l) of 205.38mg/l.

9.3.17. Borehole locality HBH42

Water quality can be described as neutral, saline and hard:

- pH of 7.23.
- TDS of 478.99mg/l.
- Total Hardness ($CaCO_3$/l) of 291.82mg/l.

9.3.18. Borehole locality HBH44

Water quality can be described as neutral, saline and very hard:

- pH of 7.40.
- TDS of 848.64mg/l.
- Total Hardness ($CaCO_3$/l) of 491.49mg/l.

9.3.19. Borehole locality HBH46

Water quality can be described as neutral, saline and very hard:

- pH of 7.62.
- TDS of 613.93mg/l.
- Total Hardness ($CaCO_3$/l) of 333.20mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 21.10mg/l.

9.3.20. Borehole locality HBH48

Water quality can be described as neutral, saline and extremely hard:

- pH of 7.05.
- TDS of 1558.04mg/l.
- Total Hardness ($CaCO_3$/l) of 946.03mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- TDS of 1558.04mg/l.
- Electrical Conductivity 255.0mS/m.
- Cl of 523.0mg/l.
- NO_3 of 53.5mg/l.
- Ca of 272.0mg/l.

9.3.21. Borehole locality HBH49

Water quality can be described as neutral, saline and very hard:

- pH of 7.72.
- TDS of 806.77mg/l.
- Total Hardness ($CaCO_3$/l) of 444.52mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 19.70mg/l.

9.3.22. Borehole locality HBH55

Water quality can be described as neutral, saline and moderately hard:

- pH of 7.91.
- TDS of 462.33mg/l.
- Total Hardness ($CaCO_3$/l) of 178.29mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 12.80mg/l.

9.3.23. Borehole locality HBH56

Water quality can be described as neutral, non-saline and hard:

- pH of 8.47.
- TDS of 354.36mg/l.
- Total Hardness ($CaCO_3$/l) of 208.12mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 14.80mg/l.

9.3.24. Borehole locality HBH63

Water quality can be described as neutral, saline and hard:

- pH of 7.78.
- TDS of 530.94mg/l.
- Total Hardness ($CaCO_3$/l) of 288.56mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 13.0mg/l.

9.3.25. Borehole locality HBH68

Water quality can be described as neutral, saline and very hard:

- pH of 7.58.
- TDS of 527.78mg/l.
- Total Hardness ($CaCO_3$/l) of 310.88mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 13.80mg/l.

9.3.26. Borehole locality HBH69

Water quality can be described as neutral, saline and very hard:

- pH of 7.40.
- TDS of 698.14mg/l.
- Total Hardness ($CaCO_3$/l) of 387.80mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 15.70mg/l.

9.3.27. Borehole locality HBH70

Water quality can be described as neutral, saline and very hard:

- pH of 8.17.
- TDS of 630.74mg/l.
- Total Hardness ($CaCO_3$/l) of 323.66mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 19.90mg/l.

9.3.28. Borehole locality HBH73

Water quality can be described as neutral, saline and very hard:

- pH of 7.83.
- TDS of 664.41mg/l.
- Total Hardness ($CaCO_3$/l) of 351.60mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 14.90mg/l.

9.3.29. Borehole locality HBH74

Water quality can be described as neutral, very saline and extremely hard:

- pH of 7.56.
- TDS of 1132.04mg/l.
- Total Hardness ($CaCO_3$/l) of 782.31mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- Electrical Conductivity 189.0mS/m.
- Cl of 477.0mg/l.
- NO_3 of 26.30mg/l.
- Ca of 216.0mg/l.

9.3.30. Borehole locality HBH75

Water quality can be described as neutral, very saline and very hard:

- pH of 7.83.
- TDS of 1230.35mg/l.
- Total Hardness ($CaCO_3$/l) of 479.80mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- Electrical Conductivity 208.0mS/m.
- TDS of 1230.35mg/l.
- Cl of 598.0mg/l.

9.3.31. Borehole locality HBH76

Water quality can be described as neutral, saline and extremely hard:

- pH of 7.49.
- TDS of 942.94mg/l.
- Total Hardness ($CaCO_3$/l) of 669.22mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- NO_3 of 30.20mg/l.

9.3.32. Surface water locality SRU

Water quality can be described as neutral, saline and hard:

- pH of 7.38.
- TDS of 613.94mg/l.
- Total Hardness ($CaCO_3$/l) of 290.92mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- Fe of 1.05mg/l.

9.3.33. Surface water locality SRD

Water quality can be described as neutral, saline and hard:

- pH of 7.42.
- TDS of 506.36mg/l.
- Total Hardness ($CaCO_3$/l) of 235.90mg/l.

The following chemical variable concentrations exceeded SANS 241-1: 2015:

- Al of 1.18mg/l.
- Fe of 0.94mg/l.

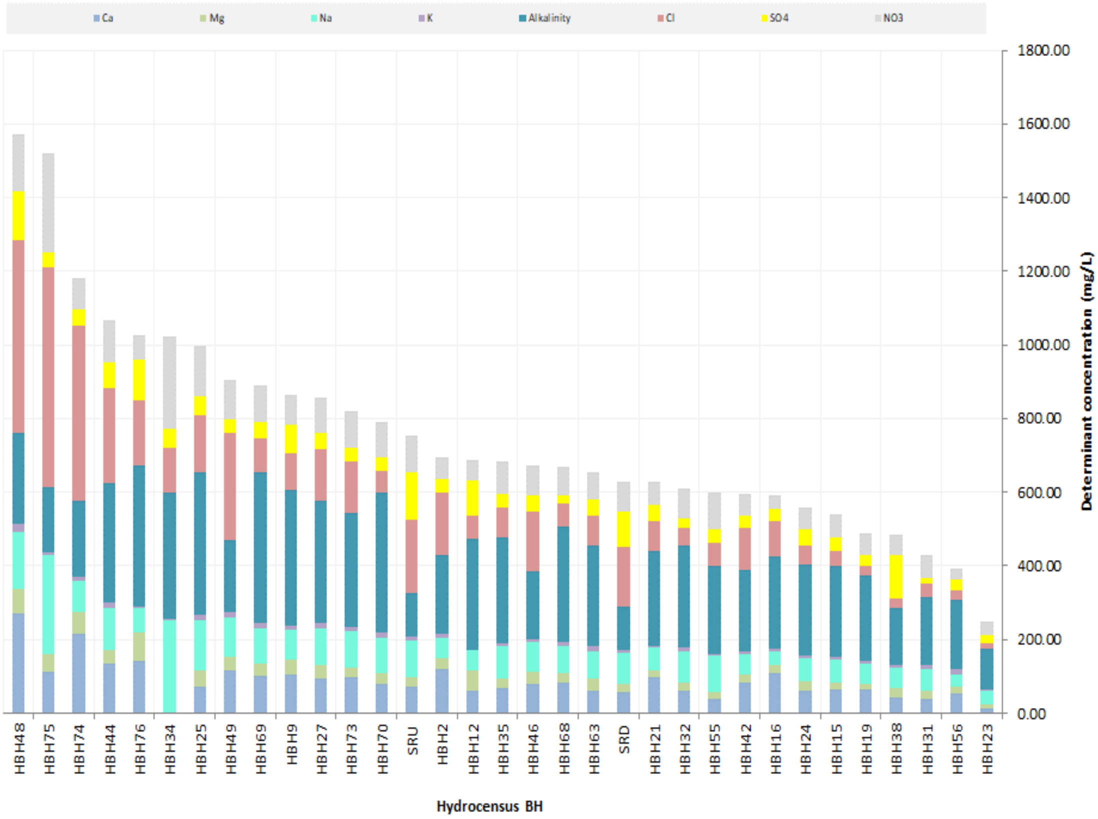


Figure 9-1 **Hydrochemistry: Composite bar-chart indicating groundwater major anion cation composition of hydrocensus samples analysed.**

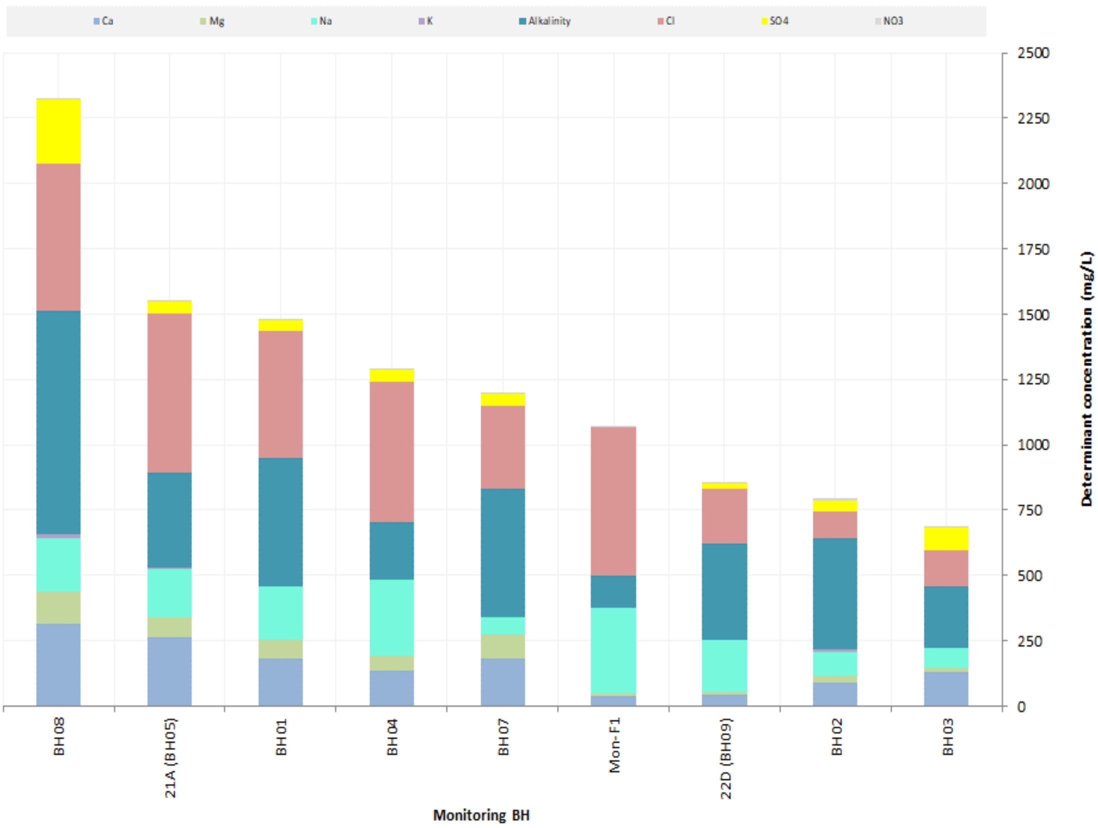


Figure 9-2 **Hydrochemistry: Composite bar-chart indicating groundwater major anion cation composition of monitoring borehole samples analysed.**

Table 9-7 Hydrochemistry: Groundwater quality evaluation of hydrocensus samples analysed.

Determinant	Unit	Risk	SANS 241:2015 limits	HBH 2	HBH 9	HBH 12	HBH 15	HBH 16	HBH 19	HBH 21	HBH 23	HBH 24	HBH 25	HBH 27
Physical determinants														
Colour	-	-	-	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Temperature	°C	-	-	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00
General parameters														
pH	-	Operational	≥5.0 ≤ 9.5	7.60	7.51	7.33	7.55	7.48	7.44	7.24	8.32	7.52	7.40	7.47
EC	mS/m	Aesthetic	≤170.0	92.80	75.20	88.30	67.80	89.30	126.00	116.00	32.80	74.70	136.00	120.00
TDS		Aesthetic	≤ 1 200.0	537.38	449.27	511.56	420.78	539.41	646.73	686.31	174.51	462.11	747.67	671.76
Total Alkalinity	CaCO3/l	-	-	301.00	246.00	250.00	232.00	256.00	216.00	367.00	112.00	248.00	389.00	330.00
Total Hardness	mg/l	-	-	375.86	236.78	361.56	219.26	323.10	417.83	430.64	70.00	258.30	360.76	390.20
Anions														
Cl	mg/l	Aesthetic	≤300.0	61.10	40.70	97.70	25.10	84.00	167.00	98.50	13.80	52.50	152.00	141.00
SO_4	mg/l	Acute health	≤500.0	95.70	36.40	33.20	31.30	43.50	39.60	77.80	22.80	42.10	53.90	42.40
F	mg/l	Acute health	≤1.50	0.13	0.14	<0.09	<0.09	<0.09	<0.09	<0.09	0.25	<0.09	<0.09	<0.09
NO_3< N	mg/l	Acute health	≤12.0	6.16	**16.30**	**12.80**	**18.80**	**16.90**	**21.70**	11.40	1.59	**14.30**	8.06	9.92
PO_4	mg/l	Acute health	≤5.0	<0.03	<0.03	<0.03	<0.03	0.11	<0.03	<0.03	<0.03	<0.03	0.39	<0.03
NH_3	mg/l	Acute health	≤1.5	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	**3.89**	<0.45
Cations and metals														
Na	mg/l	Aesthetic	≤200.0	55.20	63.20	36.50	57.10	61.20	55.90	80.10	36.70	60.80	135.00	98.60
K	mg/l	Aesthetic	≤50.0	2.88	6.69	6.20	5.95	4.92	9.60	12.60	4.10	7.86	15.90	15.90
Ca	mg/l	Aesthetic	≤150.0	58.50	62.50	110.00	63.40	97.40	120.00	106.00	13.90	60.40	70.10	93.60
Mg	mg/l	Operational	70.0	55.80	19.60	21.10	14.80	19.40	28.70	40.30	8.57	26.10	45.10	38.00
Al	mg/l	Operational	0.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	mg/l	Acute health	2.0	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01	0.06	<0.01	<0.01	0.03
Mn	mg/l	Operational	0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
As	mg/l	Acute health	0.01	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
CN	mg/l	Acute health	0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	mg/l	Acute health	5.0	<0.01	<0.01	<0.01	0.44	0.01	<0.01	<0.01	<0.01	0.02	0.01	0.04

Note: "- " indicate that no limits have been provided by the SANS 2015:241 guidelines.
"<" below detection limit
Shaded cells exceed SANS 241:2015 drinking water guidelines.

Table 9-8 Hydrochemistry: Groundwater quality evaluation of hydrocensus samples analysed (Cont.).

Determinant	Unit	Risk	SANS 241:2015 limits	HBH 31	HBH 32	HBH 34	HBH 35	HBH 38	HBH 42	HBH 44	HBH 46	HBH 48	HBH 49	HBH 55
Physical determinants														
Colour	-	-	-	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Temperature	°C	-	-	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00
General parameters														
pH	-	Operational	≥5.0 ≤ 9.5	7.47	7.52	8.17	7.37	7.12	7.23	7.40	7.62	7.05	7.72	7.91
EC	mS/m	Aesthetic	≤170.0	65.30	85.20	119.00	95.00	67.60	87.50	149.00	103.00	**255.00**	133.00	75.70
TDS		Aesthetic	≤ 1 200.0	410.94	528.42	635.87	546.79	417.21	478.99	848.64	613.93	**1558.04**	806.77	462.33
Total Alkalinity	CaCO3/l	-	-	184.00	276.00	345.00	284.00	153.00	219.00	324.00	182.00	246.00	195.00	238.00
Total Hardness	mg/l	-	-	189.05	249.77	7.48	281.13	205.38	291.82	491.49	333.20	946.03	444.52	178.29
Anions														
Cl	mg/l	Aesthetic	≤300.0	35.80	50.30	120.00	81.20	25.20	114.00	259.00	162.00	**523.00**	292.00	61.10
SO_4	mg/l	Acute health	≤500.0	17.80	25.20	52.80	39.40	119.00	35.90	70.40	46.60	135.00	36.70	39.60
F	mg/l	Acute health	≤1.50	<0.09	<0.09	0.49	<0.09	0.42	<0.09	<0.09	<0.09	<0.09	<0.09	0.11
NO_3< N	mg/l	Acute health	≤12.0	**26.20**	**24.60**	<0.35	**14.50**	11.10	6.58	5.19	**21.10**	**53.50**	**19.70**	**12.80**
PO_4	mg/l	Acute health	≤5.0	0.06	<0.03	<0.03	0.10	<0.03	<0.03	0.35	0.26	0.21	0.16	0.15
NH_3	mg/l	Acute health	≤1.5	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Cations and metals														
Na	mg/l	Aesthetic	≤200.0	59.80	81.70	**251.00**	86.50	56.50	57.60	113.00	78.90	154.00	107.00	96.70
K	mg/l	Aesthetic	≤50.0	9.34	12.60	1.19	9.72	8.14	7.48	15.50	10.20	23.60	12.10	6.67
Ca	mg/l	Aesthetic	≤150.0	39.10	58.80	1.61	67.40	43.00	82.40	134.00	80.50	**272.00**	117.00	37.10
Mg	mg/l	Operational	70.0	22.20	25.00	0.84	27.40	23.80	20.90	38.10	32.10	64.80	37.00	20.80
Al	mg/l	Operational	0.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Fe	mg/l	Acute health	2.0	0.08	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Mn	mg/l	Operational	0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01
As	mg/l	Acute health	0.01	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
CN	mg/l	Acute health	0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	mg/l	Acute health	5.0	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Note: "- " indicate that no limits have been provided by the SANS 2015:241 guidelines.
"<" below detection limit
Shaded cells exceed SANS 241:2015 drinking water guidelines.

Table 9-9 Hydrochemistry: Groundwater quality evaluation of hydrocensus samples analysed (Cont.).

Determinant	Unit	Risk	SANS 241:2015 limits	HBH 56	HBH 63	HBH 68	HBH 69	HBH 70	HBH 73	HBH 74	HBH 75	HBH 76	SRD	SRU
Physical determinants														
Colour	-	-	-	Clear	Brownish	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Brownish	Clear
Temperature	°C	-	-	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00	21.00
General parameters														
pH	-	Operational	≥5.0 ≤ 9.5	8.47	7.78	7.58	7.40	8.17	7.83	7.56	7.83	7.49	7.42	7.38
EC	mS/m	Aesthetic	≤170.0	54.50	89.90	93.90	114.00	97.50	108.00	**189.00**	**208.00**	143.00	85.50	105.00
TDS		Aesthetic	≤ 1 200.0	354.36	530.94	527.78	698.14	630.74	664.41	1132.04	**1230.35**	942.94	506.36	613.94
Total Alkalinity	CaCO3/l	-	-	189.00	273.00	312.00	409.00	379.00	308.00	204.00	174.00	384.00	116.00	119.00
Total Hardness	mg/l	-	-	208.12	288.56	310.88	387.80	323.66	351.60	782.31	479.80	669.22	235.90	290.92
Anions														
Cl	mg/l	Aesthetic	≤300.0	23.90	82.00	61.50	94.20	58.50	140.00	**477.00**	**598.00**	175.00	162.00	196.00
SO_4	mg/l	Acute health	≤500.0	29.10	46.20	23.60	44.30	38.10	39.10	44.90	42.70	112.00	96.10	131.00
F	mg/l	Acute health	≤1.50	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	<0.09	1.20	0.38	0.13	0.10
NO_3< N	mg/l	Acute health	≤12.0	**14.80**	**13.00**	**13.80**	**15.70**	**19.90**	**14.90**	**26.30**	10.30	**30.20**	0.92	1.22
PO_4	mg/l	Acute health	≤5.0	0.84	<0.03	<0.03	<0.03	<0.03	<0.03	0.04	<0.03	0.03	0.09	0.13
NH_3	mg/l	Acute health	≤1.5	<0.45	0.60	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45	<0.45
Cations and metals														
Na	mg/l	Aesthetic	≤200.0	31.60	74.00	76.00	97.50	95.10	98.90	82.30	268.00	65.00	82.30	98.60
K	mg/l	Aesthetic	≤50.0	16.30	11.90	10.70	13.60	13.90	11.60	13.60	9.13	4.76	9.58	11.40
Ca	mg/l	Aesthetic	≤150.0	53.86	61.80	80.80	99.40	78.00	97.60	**216.00**	112.00	143.00	57.20	70.00
Mg	mg/l	Operational	70.0	17.88	32.60	26.50	33.90	31.30	26.20	59.00	48.60	**75.80**	22.60	28.20
Al	mg/l	Operational	0.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	**1.18**	<0.01
Fe	mg/l	Acute health	2.0	0.02	<0.01	0.06	<0.01	<0.01	<0.01	0.02	<0.01	<0.01	**0.94**	**1.05**
Mn	mg/l	Operational	0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.06	0.03	0.04
As	mg/l	Acute health	0.01	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009	<0.009
CN	mg/l	Acute health	0.2	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Zn	mg/l	Acute health	5.0	<0.01	0.03	0.04	0.02	<0.01	<0.01	<0.01	<0.01	2.43	<0.01	<0.01

Note: "- " indicate that no limits have been provided by the SANS 2015:241 guidelines.
"<" below detection limit
Shaded cells exceed SANS 241:2015 drinking water guidelines.

Table 9-10 Hydrochemistry: Groundwater quality evaluation of monitoring samples analysed.

Determinant	Unit	Risk	SANS 241:2015 limits	BH01	BH02	BH04	21A (BH05)	BH07	BH08	22D (BH09)	Mon-F1
General parameters											
pH	**-**	**Operational**	**≥5.0 ≤ 9.5**	7.14	7.22	7.50	7.05	6.97	7.05	7.88	8.26
EC	**mS/m**	**Aesthetic**	**≤170.0**	**328.00**	117.10	**325.00**	**398.00**	**286.10**	**505.00**	126.20	**214.90**
TDS		**Aesthetic**	**≤ 1 200.0**	**1653.00**	676.00	**1662.00**	**2140.00**	**1511.00**	**2559.00**	697.00	1098.00
Total Alkalinity	**CaCO3/l**	**-**	**-**	488.00	427.00	216.60	366.00	488.00	854.00	366.00	122.00
Total Hardness	**mg/l**	**-**	**-**	739.00	328.00	571.00	983.00	826.00	1280.00	147.00	127.00
Anions											
Cl	**mg/l**	**Aesthetic**	**≤300.0**	**488.00**	101.00	**540.00**	**609.00**	**318.00**	**566.00**	210.00	**568.00**
SO_4	**mg/l**	**Acute health**	**≤500.0**	39.00	43.00	43.00	44.00	48.00	246.00	23.00	0.29
F	**mg/l**	**Acute health**	**≤1.50**	0.06	0.04	0.11	0.07	0.04	0.04	0.88	0.12
NO_3< N	**mg/l**	**Acute health**	**≤12.0**	3.80	6.40	0.02	0.02	0.02	6.60	0.02	0.02
NH_3	**mg/l**	**Acute health**	**≤1.5**	0.01	0.04	1.20	1.10	0.07	0.01	0.17	0.52
Cations and metals											
Na	**mg/l**	**Aesthetic**	**≤200.0**	**205.00**	93.00	**288.00**	183.00	67.00	**208.00**	200.00	**327.00**
K	**mg/l**	**Aesthetic**	**≤50.0**	3.00	9.00	4.20	3.90	2.90	12.00	1.90	2.70
Ca	**mg/l**	**Aesthetic**	**≤150.0**	**183.00**	87.00	137.00	**262.00**	**181.00**	**315.00**	43.00	40.00
Mg	**mg/l**	**Operational**	**70.0**	69.00	27.00	56.00	**80.00**	**91.00**	**121.00**	9.70	6.80
Al	**mg/l**	**Operational**	**0.3**	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Fe	**mg/l**	**Acute health**	**2.0**	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Mn	**mg/l**	**Operational**	**0.4**	0.01	0.10	**1.20**	**5.10**	0.11	0.02	0.05	0.09
As	**mg/l**	**Acute health**	**0.01**	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Zn	**mg/l**	**Acute health**	**5.0**	0.54	0.04	0.01	0.04	0.04	0.18	0.04	0.04

Note: "- " indicate that no limits have been provided by the SANS 2015:241 guidelines.
"<" below detection limit
Shaded cells exceed SANS 241:2015 drinking water guidelines.

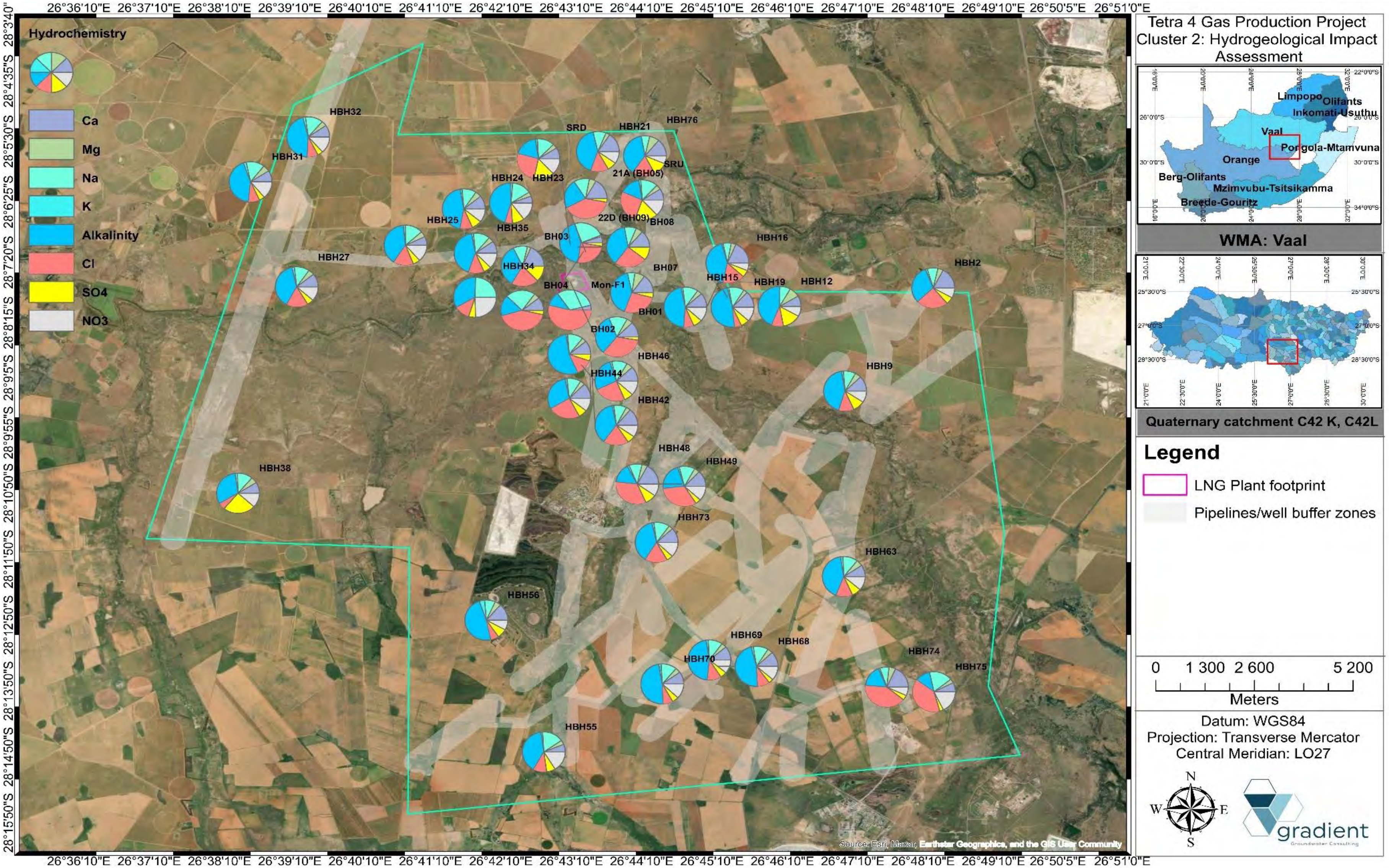


Figure 9-3 **Hydrochemical analysis spatial distribution (mg/l).**

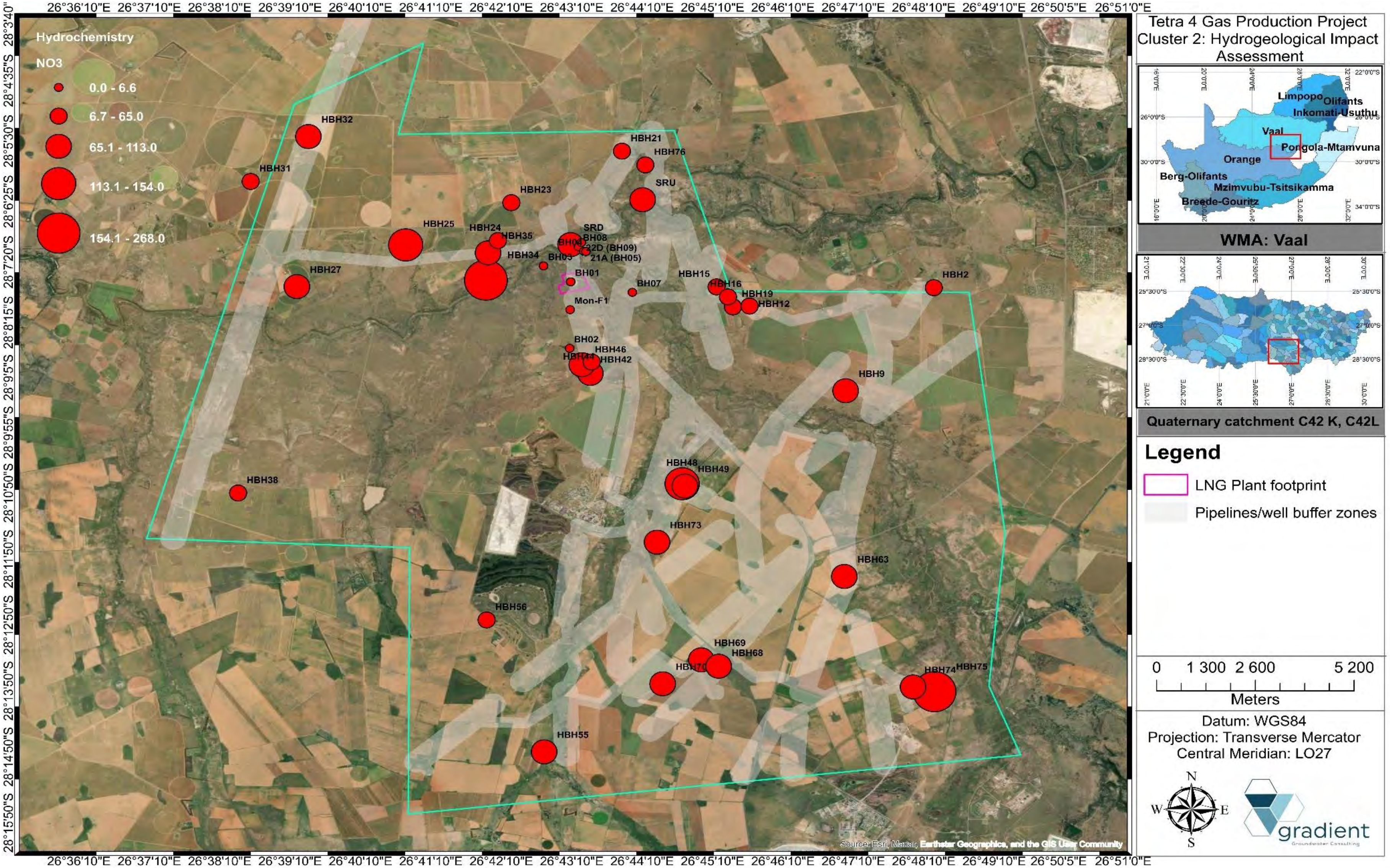


Figure 9-4 **Nitrate (NO_3) spatial distribution (mg/l).**

9.4. Hydrochemical signature

The hydrochemical signature of the samples analysed were evaluated by means of diagnostic plots. The latter aids to get an understanding of various environments and sources from where groundwater and surface water originates. Three types of diagnostic plots were used to characterise analysed water samples based on hydrochemistry.

9.4.1. Piper diagrams

A piper diagram is a diagnostic representation of major anions and cations as separate ternary plots as summarised in Figure 9-5. Different water types derived from different environments plot in diagnostic areas. The upper half of the diamond normally contains water of static and disordinate regimes, while the middle area generally indicates an area of dissolution and mixing. The lower triangle of this diamond shape indicates an area of dynamic and coordinated regimes. Figure 9-6 depicts a piper diagram developed from the water quality analysis results. Most water samples analysed suggest no cation dominance while the dominant anion is either chloride (sodium or chloride enrichment) or carbonate/bicarbonate (recently recharged water). Accordingly, three distinct categories can be observed, Category A: Calcium-Bi-carbonate dominance which suggest a recently recharged and unimpacted groundwater environment (majority of samples), Category B: Calcium-Magnesium-Chloride dominance which indicate a static and disordinate environment (HBH48, HBH49, HBH74 and HBH75) as well as Category C: Sodium-Potassium-Bi-carbonate dominance which indicate an area of dynamic groundwater environments (HBH34 and BH09).

The surface water samples analysed can be categorized as having Calcium-Magnesium-Chloride dominance which indicate a static and disordinate environment, one would except a more Calcium-Bi-carbonate signature from an unpolluted surface water source, however baseflow discharge present from the saline groundwater resource will have an impact on the salinity of the surface water resources as is evident. Figure 9-7 indicate a piper diagram comparison of major anions and cations of the deep vs shallow aquifer(s) and the Sodium-Potassium-Chloride dominance of the deep, fractured aquifer groundwater suggest extremely saline conditions as expected.

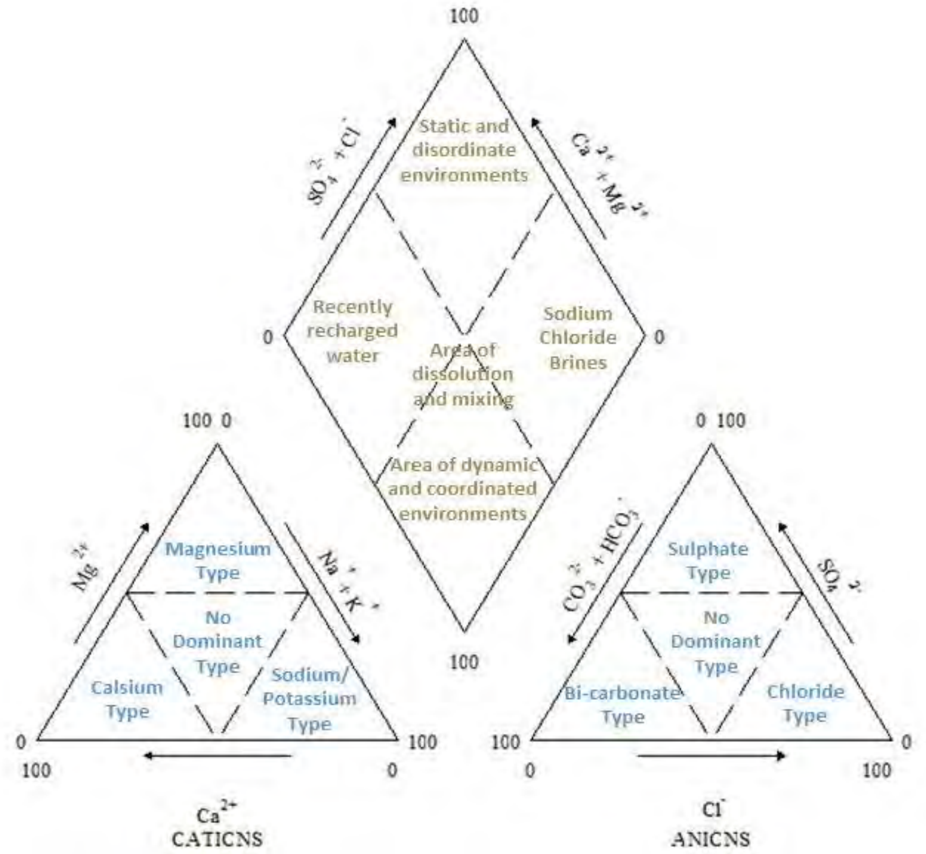


Figure 9-5 **Piper diagram indicating classification for anion and cation facies in terms of ion percentages**

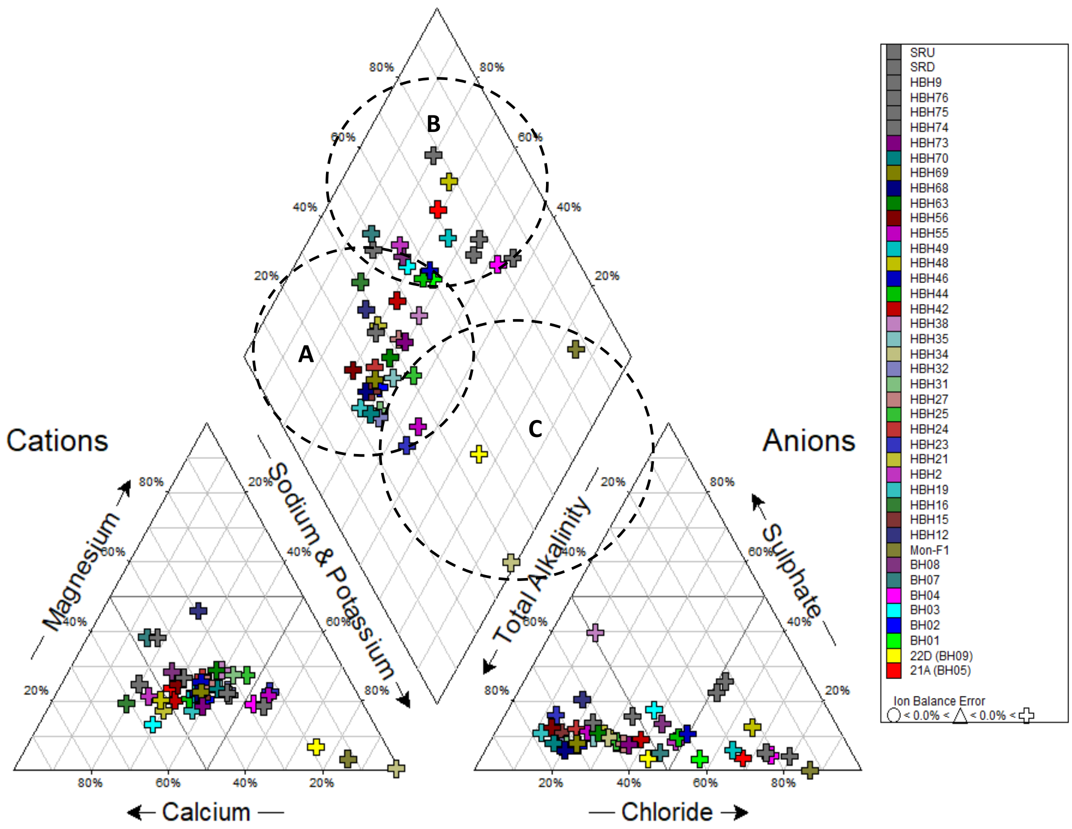


Figure 9-6 **Piper diagram indicating major anions and cations of water samples analysed.**

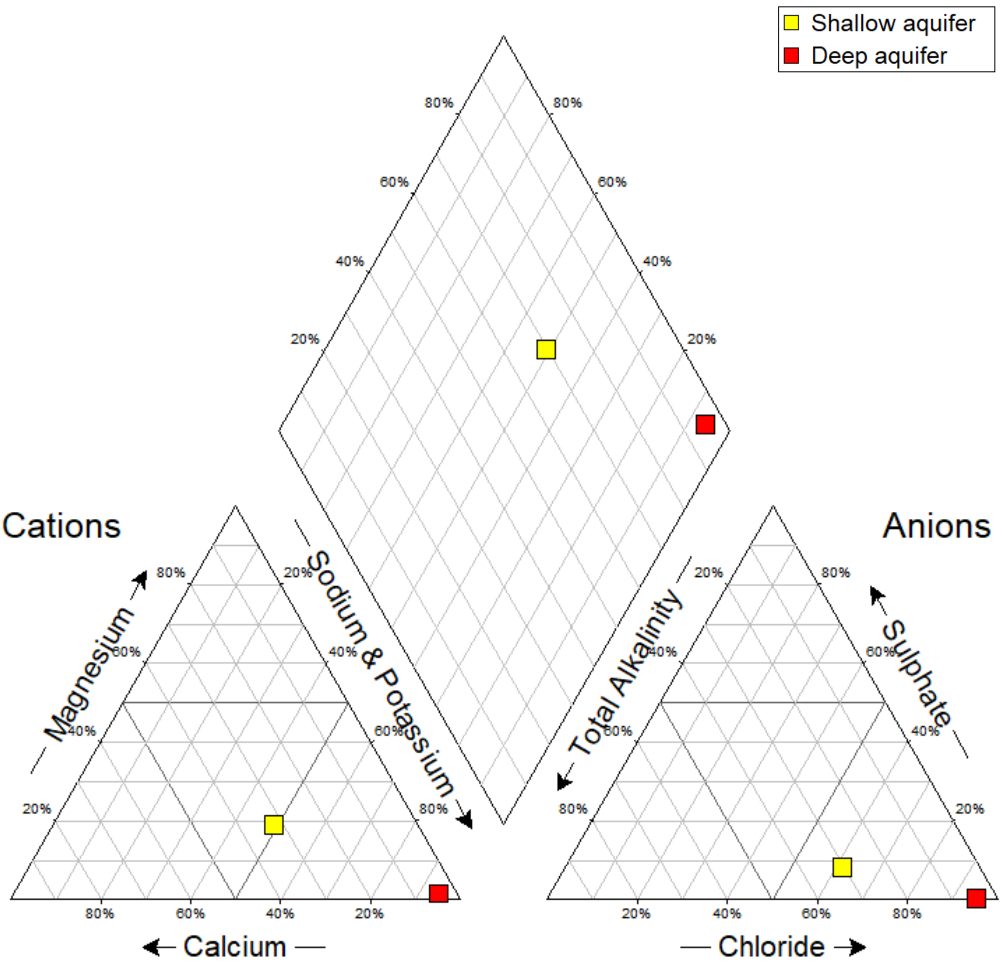


Figure 9-7 **Piper diagram indicating a comparison of major anions and cations of the deep vs shallow aquifer(s).**

9.4.2. Stiff diagrams

A Stiff diagram, or Stiff pattern, is a graphical representation of chemical analyses and major anions and cations, first developed by H.A. Stiff in 1951. STIFF diagrams plot the equivalent concentrations of major anions and cations on a horizontal scale on opposite sides of a vertical axis. The plot point of each parameter is linked to the adjacent point creating a polygon around the vertical axis. Water with similar major ion ratios will show similar geometries. Figure 9-8 and Figure 9-9 depicts Stiff diagrams compiled from the hydrocensus groundwater sampling analysis while Figure 9-10 indicate Stiff diagrams compiled from the monitoring water quality data evaluated. It is evident that borehole localities HBH48, HBH49, HBH74 and HBH75indicate a different ion composition and geometry compared the other groundwater sampling localities and suggest two different aquifer or hydrostratigraphical units being targeted, possibly a deeper, more stagnant water source. Monitoring localities BH04, BH05, BH09 also suggests a higher salt load with sodium-chloride enrichment and may also represent a deeper aquifer unit being targeted. Figure 9-11 indicate a Stiff diagram comparison of major anions and cations of the deep vs shallow aquifer(s) and the Sodium-Potassium-Chloride dominance of the deep, fractured aquifer groundwater show extremely saline conditions.

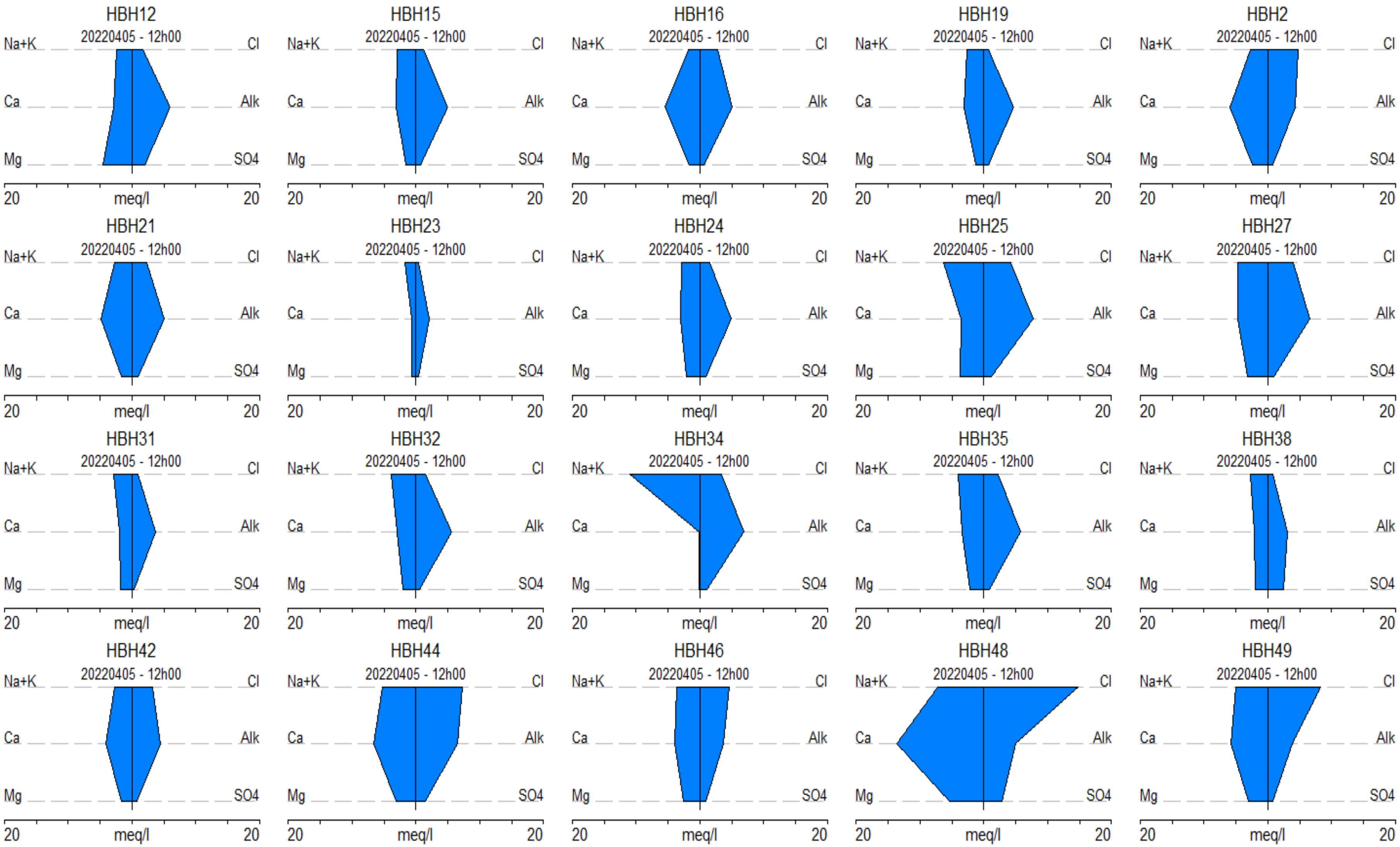


Figure 9-8 Stiff diagrams representing the hydrocensus groundwater sampling localities analysed.

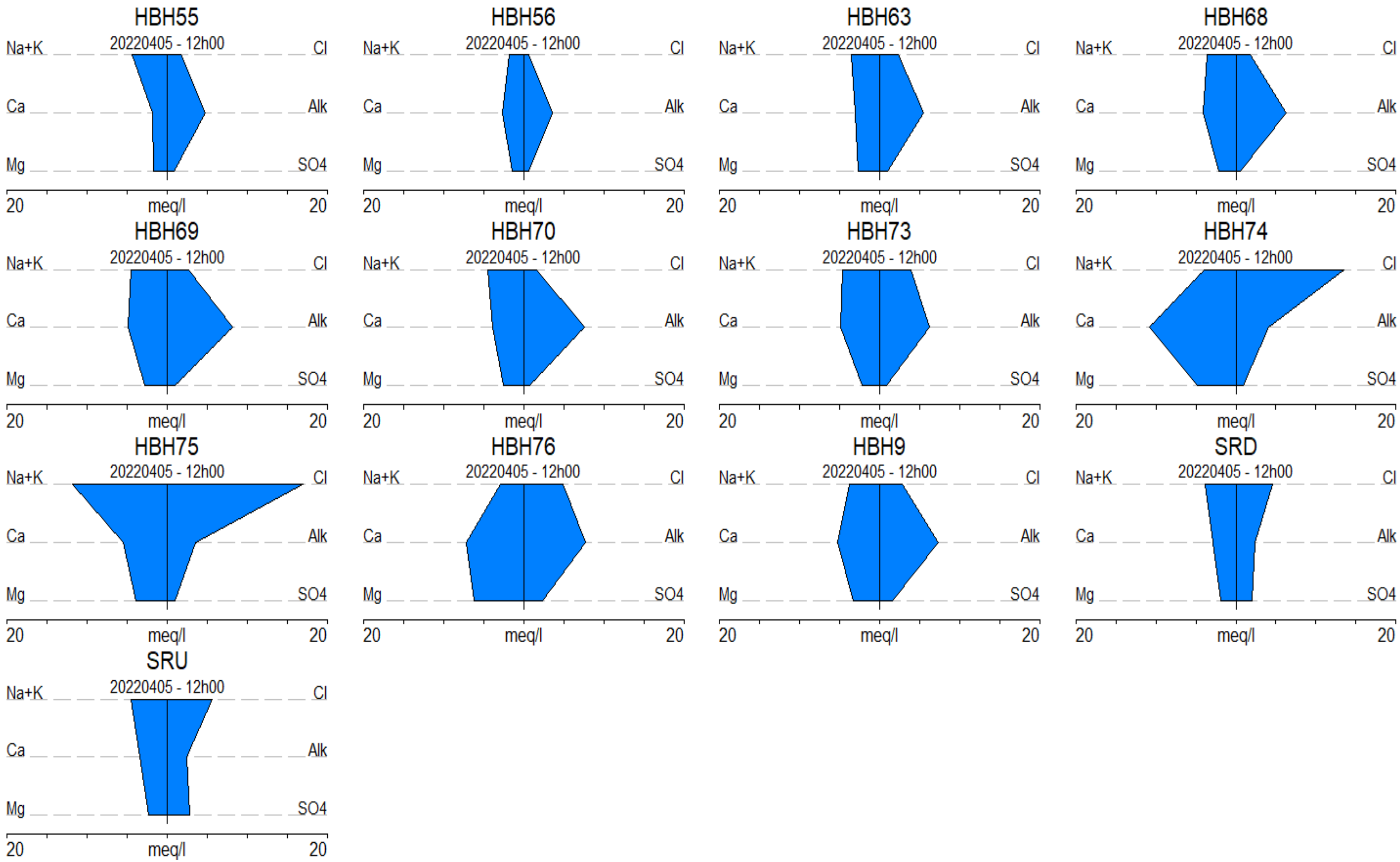


Figure 9-9 **Stiff diagrams representing the hydrocensus groundwater sampling localities analysed.**

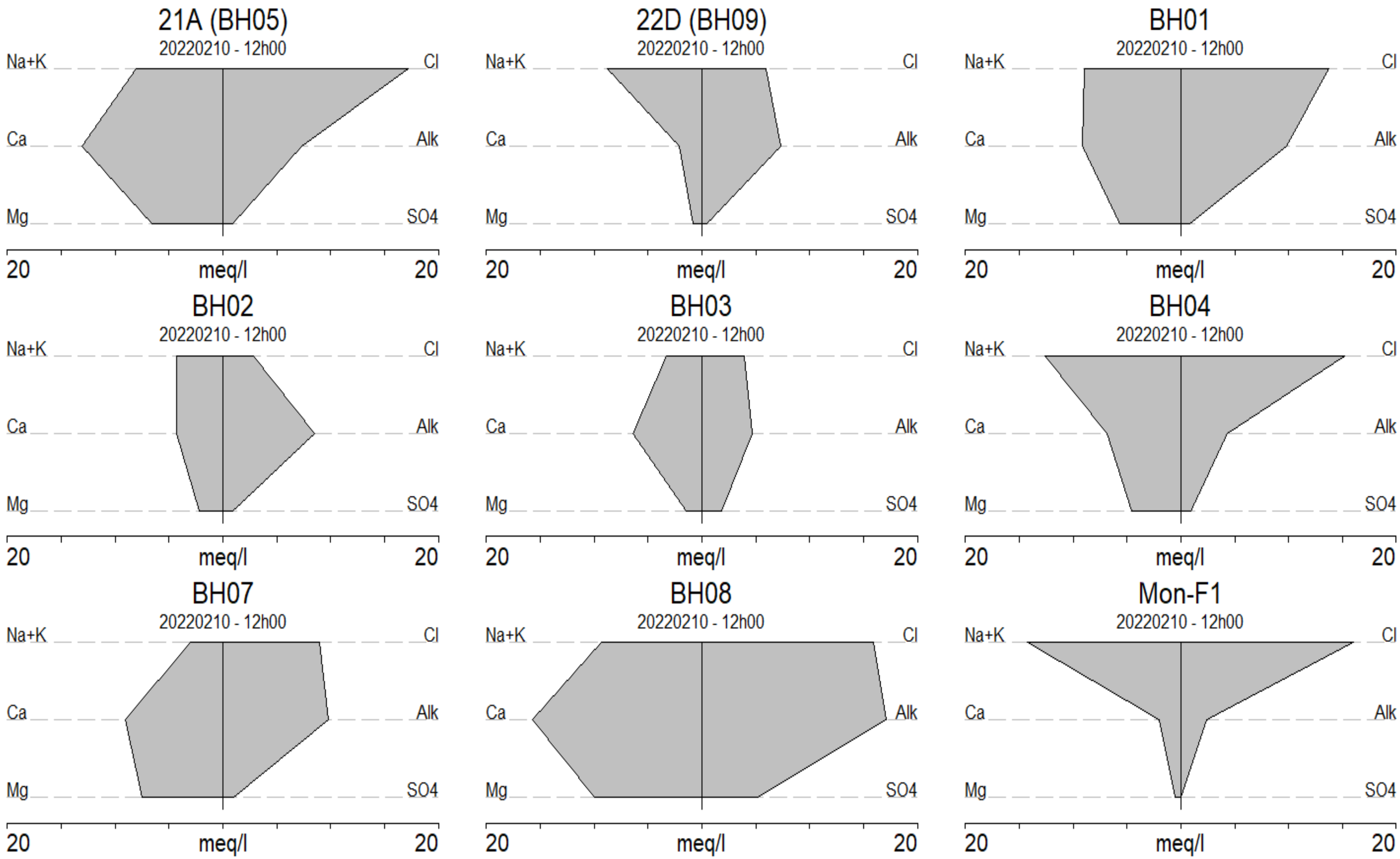


Figure 9-10 Stiff diagrams representing the monitoring borehole groundwater sampling localities analysed.

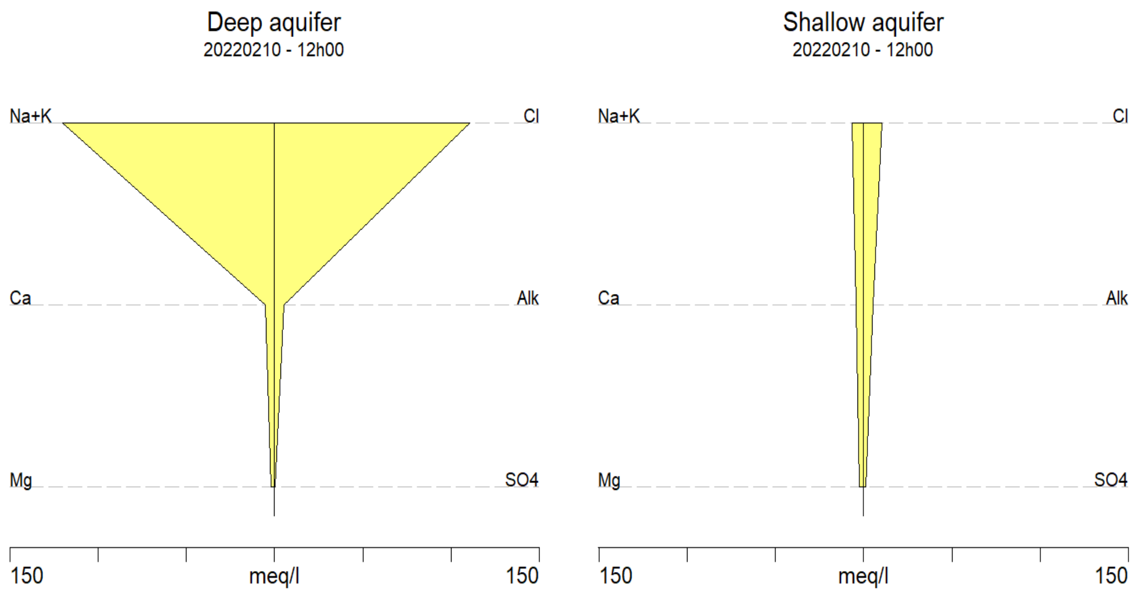


Figure 9-11 **Stiff diagrams indicating a comparison in major ion composition of the deep vs shallow aquifer(s).**

9.4.3. Expanded Durov diagram

The expanded Durov diagram is used to show hydrochemical processes occurring within different hydrogeological systems as depicted in Figure 9-12. Different fields of the diagram could be summarised as follows:

Field 01: Water (mostly fresh, clean and recently recharged) with HCO_3- and CO_3 as dominant anion and Ca as dominant cation.

Field 02: Water (mostly fresh, clean, and relatively young) that also has an Mg signature, often found in dolomitic terrain.

Field 03: Often associated with Na ion exchange between groundwater and aquifer material (sometimes in Na-enriched granites or other felsic rocks) or because of contamination effects from a source rich in Na.

Field 04: Often associated with mining related SO_4 contamination.

Field 05: Groundwater that is usually a mix of different types – either clean water from fields 1 and 2 that has undergone SO_4 and NaCl mixing/contamination or old stagnant NaCl dominated water that has mixed with clean water.

Field 06: Groundwater from field 5 that has been in contact with a source rich in Na or old stagnant NaCl dominated water that resides in Na rich host rock/material.

Field 07: Water rarely plots in this field that indicates NO_3 or Cl enrichment or dissolution.

Field 08: Groundwater that is usually a mix of different types, for example water from 2 that has undergone Cl mixing/contamination or old stagnant NaCl-dominated water that has mixed with water richer in Mg.

Field 09: Seawater or very old stagnant water that has reached the end of the geohydrological cycle (deserts, salty pans etc.), or water that has moved a long time and/or distance through the aquifer and has undergone significant ion exchange.

Most groundwater samples analysed can be classified as either Field01/ Field 02 i.e., mostly fresh, clean and relatively young with HCO3- and CO3 dominance evident indicative of an unimpacted groundwater environment or Field 03 (often associated with Na ion exchange between groundwater and aquifer material). Borehole localities BH07, BH08, HBH38, HBH44 and HBH46 can be classified as Field05, suggesting old stagnant NaCl dominated water that has mixed with clean water. Borehole localities HBH48, HBH74 can be classified as Field07 (that indicates NO_3 or Cl), BH01, BH05 and BH49 as Field08 (old stagnant NaCl-dominated water) or Mon-F1, BH04 and BH75 as Field09 (very old stagnant water). The latter suggest more stagnant and older water which may indicate a deeper aquifer or hydrostratigraphical units being targeted (Figure 9-13).

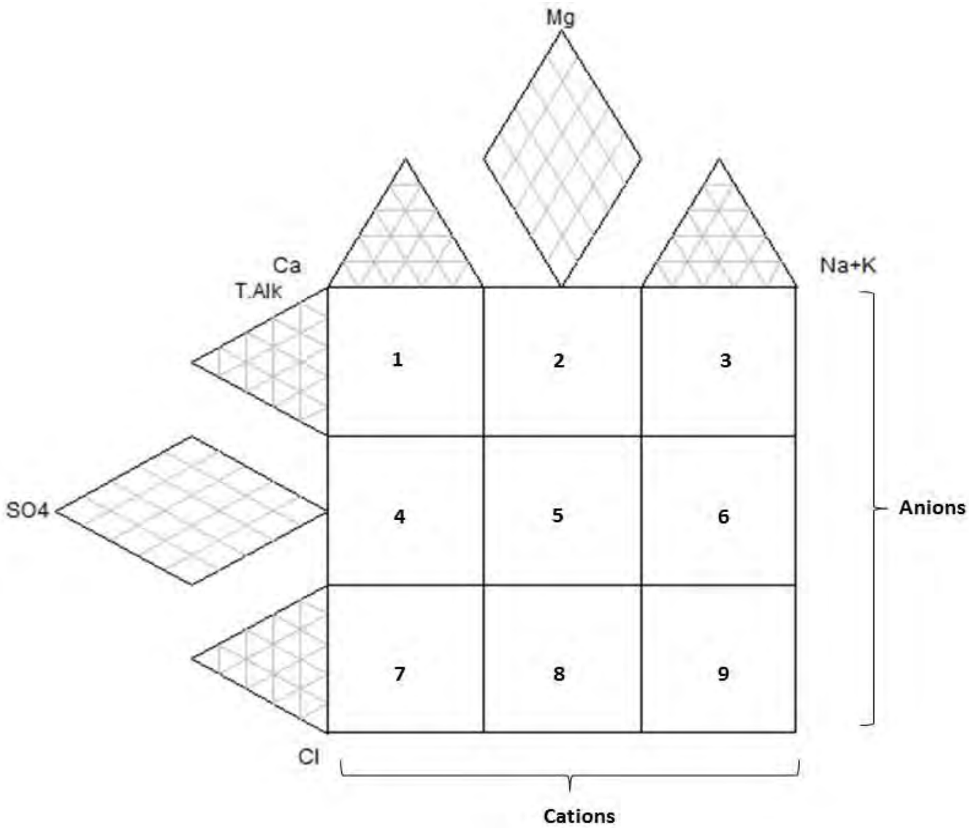


Figure 9-12 Extended Durov diagramindicating major anions and cations.

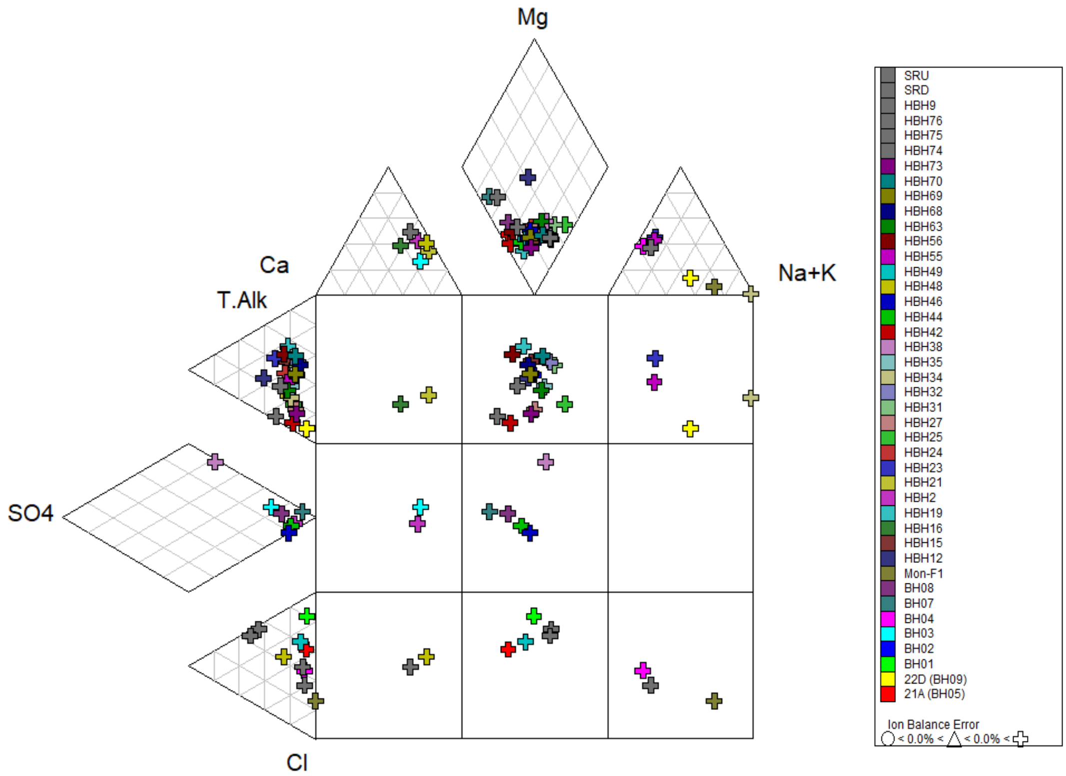


Figure 9-13 **Extended Durov diagram of water samples analysed.**

Figure 9-14 indicates a Schoeller diagram of the water samples analysed and highlights the main hydrochemical species as being Sodium-Chloride.

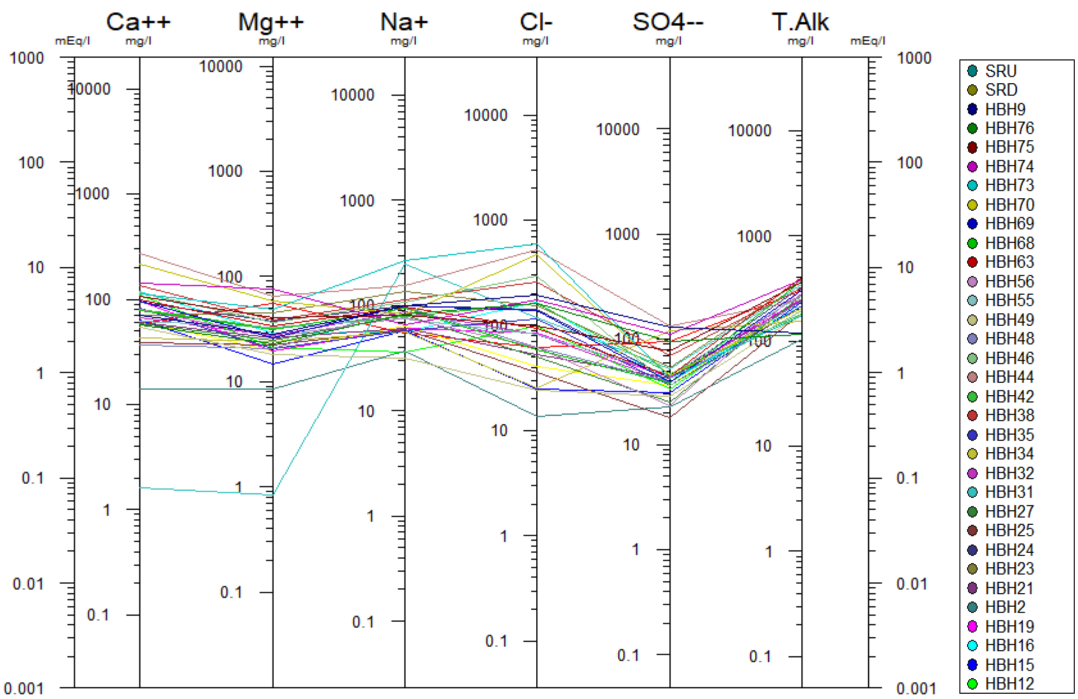


Figure 9-14 **Schoeller diagram of water samples analysed.**

10. AQUIFER CLASSIFICATION AND GROUNDWATER MANAGEMENT INDEX

The most widely accepted definition of groundwater contamination is defined as the introduction into water of any substance in undesirable concentration not normally present in water e.g., microorganisms, chemicals, waste or sewerage, which renders the water unfit for its intended use (UNESCO, 1992). The objective of this study is to formulate a risk-based framework from geological and hydrogeological information obtained as part of this investigation. Two approaches were followed in an estimation of the risk of groundwater contamination as discussed below. As part of the aquifer classification, a Groundwater Quality Management (GQM) Index is used to define the level of groundwater protection required. The GQM Index is obtained by multiplying the rating of the aquifer system management and the aquifer vulnerability. A **GQM Index = 4** was calculated for the local aquifer system and according to this estimate, a "**Medium**" level groundwater protection is required for this aquifer system.

Equation 10-1 GMQ Index.

$$\textit{GQM Index} = \boldsymbol{Aquifer\ system\ management\ x\ Aquifer\ vulnerability}$$

10.1. Aquifer classification

The aquifer classification was guided by the principles set out in South African Aquifer System Management Classification (Parsons, 1995). Aquifer classification forms a very useful planning tool which can be applied to guide the management of groundwater systems. According to the aquifer classification map of South Africa the project area is underlain by a "**Minor aquifer**" (DWS, 2013). It should however be noted that the shallow, intergranular aquifer is important to local groundwater users as it forms the sole source of water supply in the region (Lea, 2017). Furthermore, the primary riparian zone aquifer is classified as a major aquifer system due to its highly permeable nature as well as good water quality. The classifications and definitions for each aquifer system are summarised in Table 10-1.

Table 10-1 Aquifer System Management Classes (After Parsons , 1995).

Sole source aquifer	An aquifer which is used to supply 50% or more of domestic water for a given area, and for which there are no reasonable available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
Major aquifer system	Highly permeable formations, usually with a known probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (less than 150 mS/m).
Minor aquifer system	These can be fractured or potentially fractured rocks, which do not have a high primary permeability, or other formations of variable permeability. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and supplying base flow to rivers.
Non aquifer system	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer as unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.
Special aquifer system	An aquifer designated as such by the Minister of Water Affairs, after due process.

10.2. Aquifer vulnerability

Aquifer vulnerability can be defined as the tendency or likelihood for contamination to reach a specified position in the groundwater system after introduction at some location above the uppermost aquifer. According to the aquifer vulnerability map of South Africa the project area is underlain by an aquifer system with a "**Moderate**" vulnerability rating (DWS, 2013).

10.3. Aquifer susceptibility

Aquifer susceptibility is a qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities. According to the Aquifer susceptibility map of South Africa the project area is underlain by an aquifer system with a "**Medium**" susceptibility rating (DWS, 2013).

Table 10-2 Groundwater Quality Management Index.

Aquifer system Management qualification Class		Points	Aquifer vulnerability Classification Class	Points
Sole Source Aquifer System		6	High	3
Major Aquifer System		4	**Moderate**	**2**
Minor Aquifer System		**2**	Low	1
Non-Aquifer System		0		
Special Aquifer System		0-6		
GQM INDEX	**Level of protection**			
<1	Limited Protection			
1 to 3	Low Level Protection			
3 to 6	**Medium Level Protection**			
6 to 10	High Level Protection			
>10	Strictly Non- Degradation			
GQM INDEX				**4**

10.4. Groundwater contamination risk assessment

The concept of groundwater vulnerability to contamination by applying the DRASTIC methodology was introduced by Aller et al. (1987) and refined by the US EPA (United States Environmental Protection Agency). DRASTIC is an acronym for a set of parameters that characterise the hydrogeological setting and combined evaluated vulnerability: Depth to water level, Nett Recharge, Aquifer media, Soil media, Topography, Impact of the vadose zone and Hydraulic Conductivity. This method provides a basis for evaluating the vulnerability to pollution of groundwater resources based on hydrogeological parameters. Lynch et al (1994) suggests a considerable variation in terms of hydraulic conductivity in hard rock aquifers and revised this methodology to accommodate local aquifer conditions accordingly. Parameters used as part of the index are summarised in Table 10-3. The DRASTIC index (DI) can be computed using the following formula.

Equation 10-2 DRASTIC Index (Di).

$$\mathrm{Di} = \boldsymbol{DrD\lambda + RrR\lambda + ArA\lambda + Sr\,S\lambda + TrT\lambda + IrI\lambda}$$

where:

D = Depth to Water Table

R = Recharge

A = Aquifer media.

S = Soil media.

T = Topographic aspect.

I = Impact of vadose zone media.

C = Conductivity.

Table 10-3 DRASTIC Index.

Risk/ Vulnerability	DRASTIC Index (Di)
Low	50-87
Moderate	87-109
High	109-183

Where **D, R, A, S, T, I**, and **C** are the parameters, r is the rating value, and λ the constant weight assigned to each parameter as summarised in Table 10-4 below (Lynch et al, 1994).

Table 10-4 Ratings assigned to groundwater vulnerability parameters (Lynch et al, 1994).

Depth to groundwater (D_R)

Range (m)	Rating
0 – 5	10
5 – 15	7
15 – 30	3
> 30	1

Net Recharge (R_R)

Range (mm)	Rating
0 – 5	1
5 – 10	3
10 – 50	6
50 – 100	8
> 100	9

Aquifer Media (A_R)

Range	Rating
Dolomite	10
Intergranular	8
Fractured	6
Fractured and weathered	3

Topography (T_R)

Range (% slope)	Rating
0 – 2	10
2 – 6	9
6 – 12	5
12 – 18	3
> 18	1

Soil Media (S_R)

Range	Rating
Sand	8 – 10
Shrinking and/or aggregated clay	7 - 8
Loamy sand	6 - 7
Sandy loam	5 - 6
Sandy clay loam and loam	4 - 5
Silty clay loam, sandy clay and silty loam	3 - 4
Clay loam and silty clay	2 – 3

Impact of the vadose zone (I_R)

Range	Rating
Gneiss,Namaqua metamorphic rocks	3
Ventersdorp, Pretoria, Griqualand West, Malmesbury, Van Rhynsdorp, Uitenhage, Bokkeveld, Basalt, Waterberg, Soutspansberg, Karoo (northern), Bushveld, Olifantshoek	4
Karoo (southern)	5
Table Mountain, Witteberg, Granite, Natal, Witwatersrand, Rooiberg, Greenstone, Dominion, Jozini	6
Dolomite	9
Beach sands and Kalahari	10

According to the DRASTIC index methodology applied, the proposed activities and associated infrastructure's risk to groundwater pollution of the aquifer system(s), is rated as "**Moderate**", **Di = 109**, (refer to Table 10-5).

Table 10-5 DRASTIC weighting factors: Shallow, intergranular aquifer.

Parameter	Range	Rating	Description	Relative weighting
Depth to water (D) (mbgl)	0 - 5	10	Refers to the depth to the water surface in an unconfined aquifer. Deeper water table levels imply lesser chance for contamination to occur. Depth to water is used to delineate the depth to the top of a confined aquifer.	5
	5 -15	**7**		
	15 - 30	3		
	> 30	1		
Net recharge (R) (mm/a)	0-5	1	Indicates the amount of water per unit area of land which penetrates the ground surface and reaches the water table. Recharge water is available to transport a contaminant vertically to the water table, horizontal with in an aquifer.	3
	5-10	**3**		
	10-50	**6**		
	50-100	8		
	> 100	9		
Aquifer media (A)	Dolomite	10	Refers to the consolidated or unconsolidated medium which serves as an aquifer. The larger the grain size and more fractures or openings within an aquifer, leads to higher permeability and lower attenuation capacity, hence greater the pollution potential.	4
	Intergranular	8		
	Fractured	6		
	Fractured and weathered	**3**		
Soil media (S)	Sand	10	Refers to the uppermost weathered portion of the vadose zone characterised by significant biological activity. Soil has a significant impact on the amount of recharge.	2
	Shrinking and/or aggregated clay	8		
	Loamy sand	6		
	Sandy loam	**5**		
	Sandy clay	4		
	Silty loam	3		
	Silty clay and clay loam	2		
Topography (T) (Slope %)	0 - 2	10	Refers to the slope of the land surface. It helps a pollutant to runoff or remain on the surface in an area long enough to infiltrate it.	1
	2 - 6	**9**		
	6 - 12	5		
	12 - 18	3		
	> 18	1		
Impact of vadose zone (I)	Gneiss, Namaqua metamorphic rocks	3	Is defined as unsaturated zone material. The significantly restrictive zone above an aquifer forming the confining layers is used in a confined aquifer, as the type of media having the most significant impact.	5
	Ventersdorp, Pretoria, Griekwaland West, Malmesbury, Van Rhynsdorp, Uitenhage, Bokkeveld, Basalt, Waterberg, Soutpansberg, Karoo (Northern), Bushveld, Olifantshoek	4		
	Karoo (Southern)	**5**		
	Table Mountain, Witteberg Granite, Natal, Witwatersrand, Rooiberg, Greenstone, Dominion, Jozini	6		
	Dolomite	9		
	Beach sands and Kalahari	10		
DRASTIC Index (Di) = 109				

10.5. Source-pathway-receptor evaluation

In order to evaluate the risk of groundwater contamination, potential sources of contamination should be identified, as well as potential pathways and receptors. The pollution linkage concept relies on the identification of a potential pollutant (i.e., source) on-site which is likely to have the potential to cause harm on a receptor by means of a pathway by which the receptor may be exposed to the contaminant (Figure 10-1).

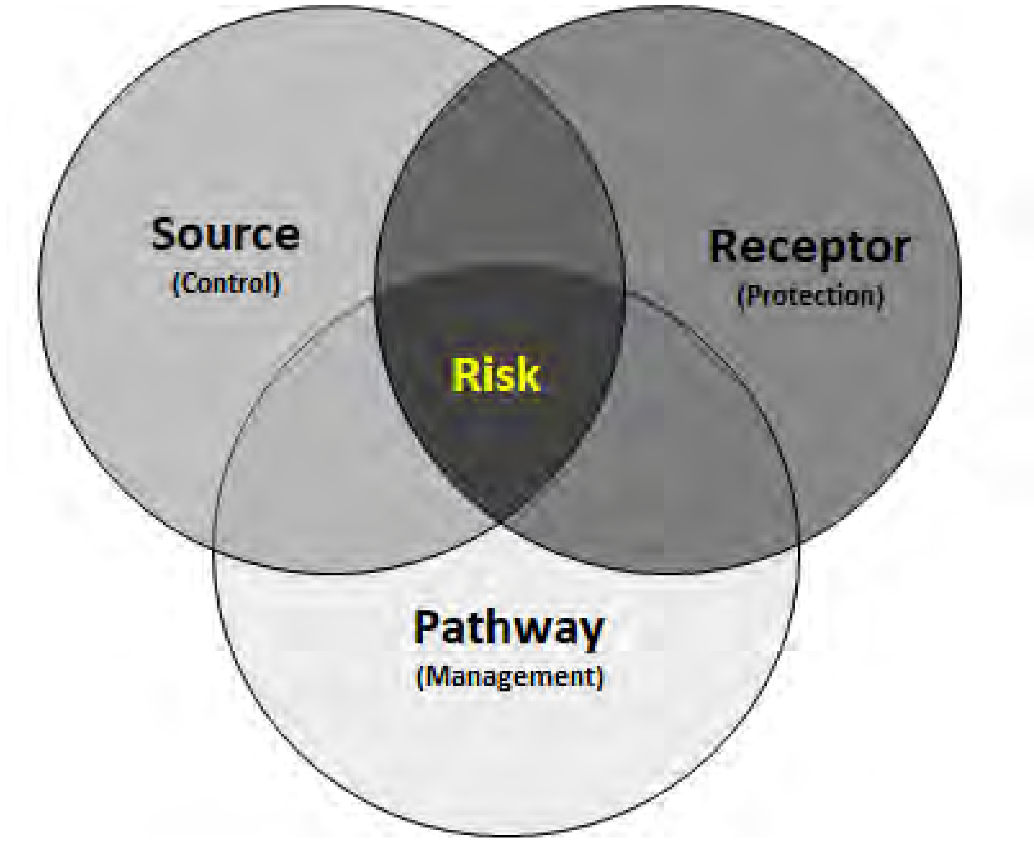


Figure 10-1 Source pathway receptor principle.

10.5.1. Potential sources

The following potential sources have been identified:

i. Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.

ii. Migration of stray gas from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.

iii. Migration of contaminants from the plant expansion waste facilities and associated infrastructure into local water resources and host aquifers.

10.5.2. Potential pathways

The following aquifer pathways have been identified:

i. Vertical flow through the unsaturated/vadose zone as well as saturated zone to the underlying intergranular and fractured rock aquifers. The rate at which seepage will take place is governed by the permeability of sub-surface soil layers and host-rock formations.

ii. Preferential flow-paths include the contact between the depth of weathering and fresh un-weathered rock, fractures, faults, joints and bedding planes. Secondary fractures may also potentially act as transport mechanisms.

iii. If not adequately sealed and suitably mitigated, gas exploration and production wells will form preferential flow paths and serve as a direct connection between the deeper, fractured aquifer and shallow, potable aquifer unit(s).

10.5.3. Potential receptors

The following receptors were identified:

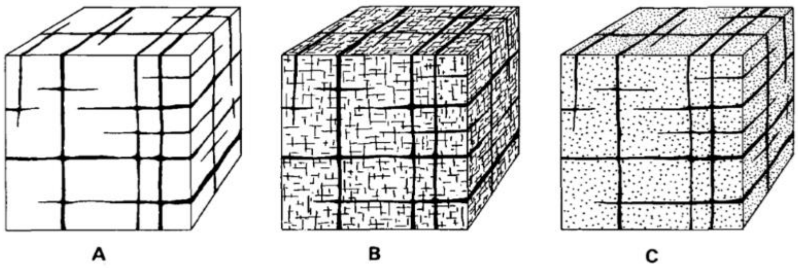
i. Shallow, inter-granular as well as the intermediate, fractured aquifer units situated within the plume migration footprint(s).

ii. Down-gradient drainages and streams including associated riparian zone aquifer system(s) and baseflow contribution.

iii. Private or neighbouring boreholes associated with relevant fracture zones and/or structures(s)if intercepted by the pollution plume migration footprint.

11. HYDROGEOLOGICAL CONCEPTUAL MODEL

The hydrogeological conceptual model consists of a set of assumptions, which will aid in reducing the problem statement to a simplified and acceptable version. Data gathered during the desk study and site investigation has been incorporated to develop a conceptual understanding of the regional hydrogeological system. Figure 11-1 depicts a generalised hydrogeological conceptual model for similar environments and illustrate the concept of primary porous media aquifers and secondary fractured rock media aquifers. In porous aquifers, flow occurs through voids between unconsolidated rock particles whereas in double porosity aquifers, the host rock is partially consolidated, and flow occurs through the pores as well as fractures in the rock. In secondary aquifers the host rock is consolidated, and porosity is generally restricted to fractures that have formed after consolidation of the rock. The weathered zone aquifer and secondary rock aquifer in the area could be classified as double porosity aquifers. Figure 11-2 depicts southeast-northwest cross section of the study area (construction phase) while Figure 11-3 depicts southeast-northwest cross section of the study area (operational phase). Refer to Figure 5-2 for spatial reference.



A: Primary porosity aquifer **B: Double porosity aquifer** **C: Secondary porosity aquifer**

Figure 11-1 Generalised conceptual hydrogeological model (after Kruseman and de Ridder, 1994).

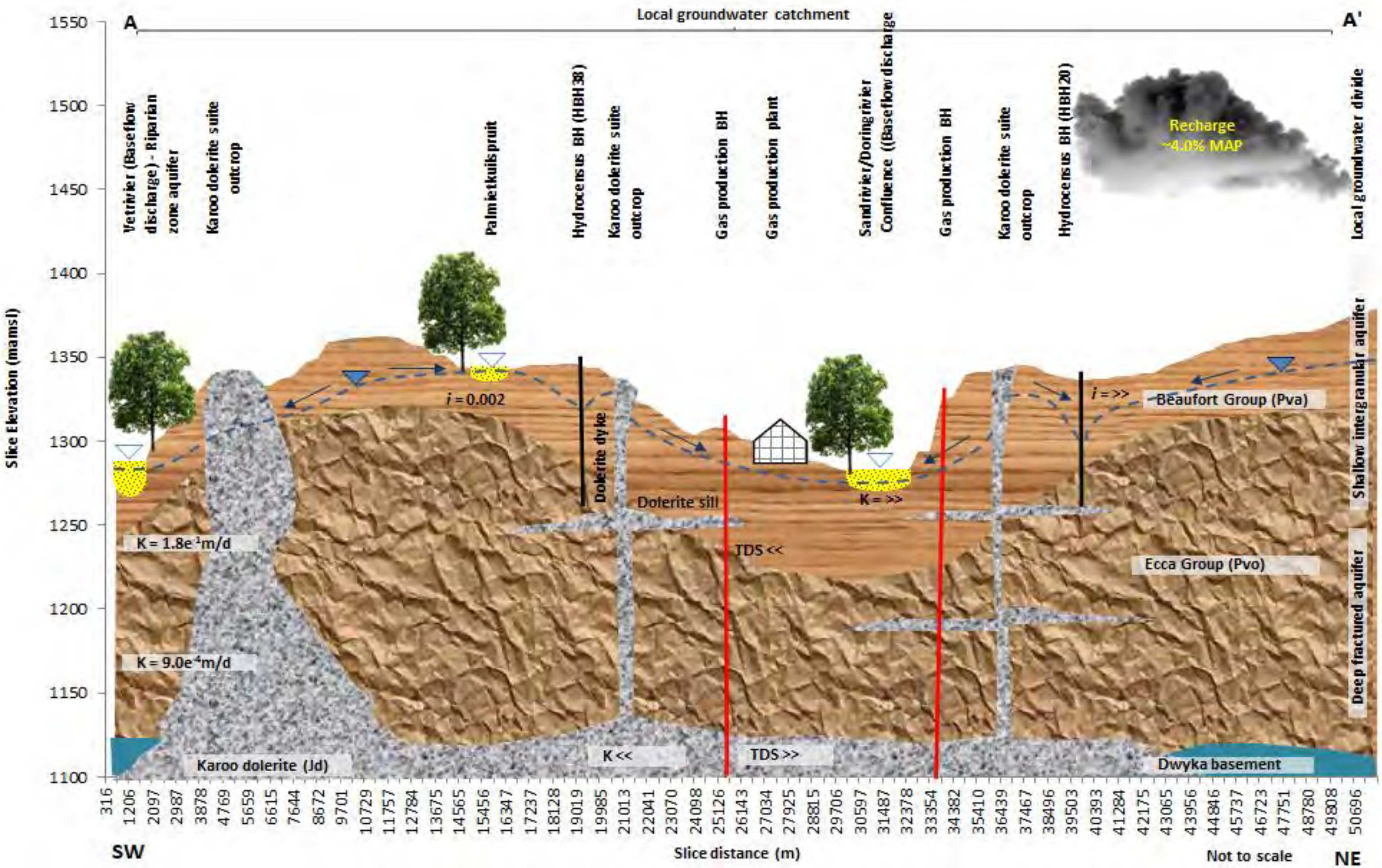


Figure 11-2 **Hydrogeological conceptual model: Southwest- Northeast cross section – Construction Phase (A-A') (Figure 5-2).**

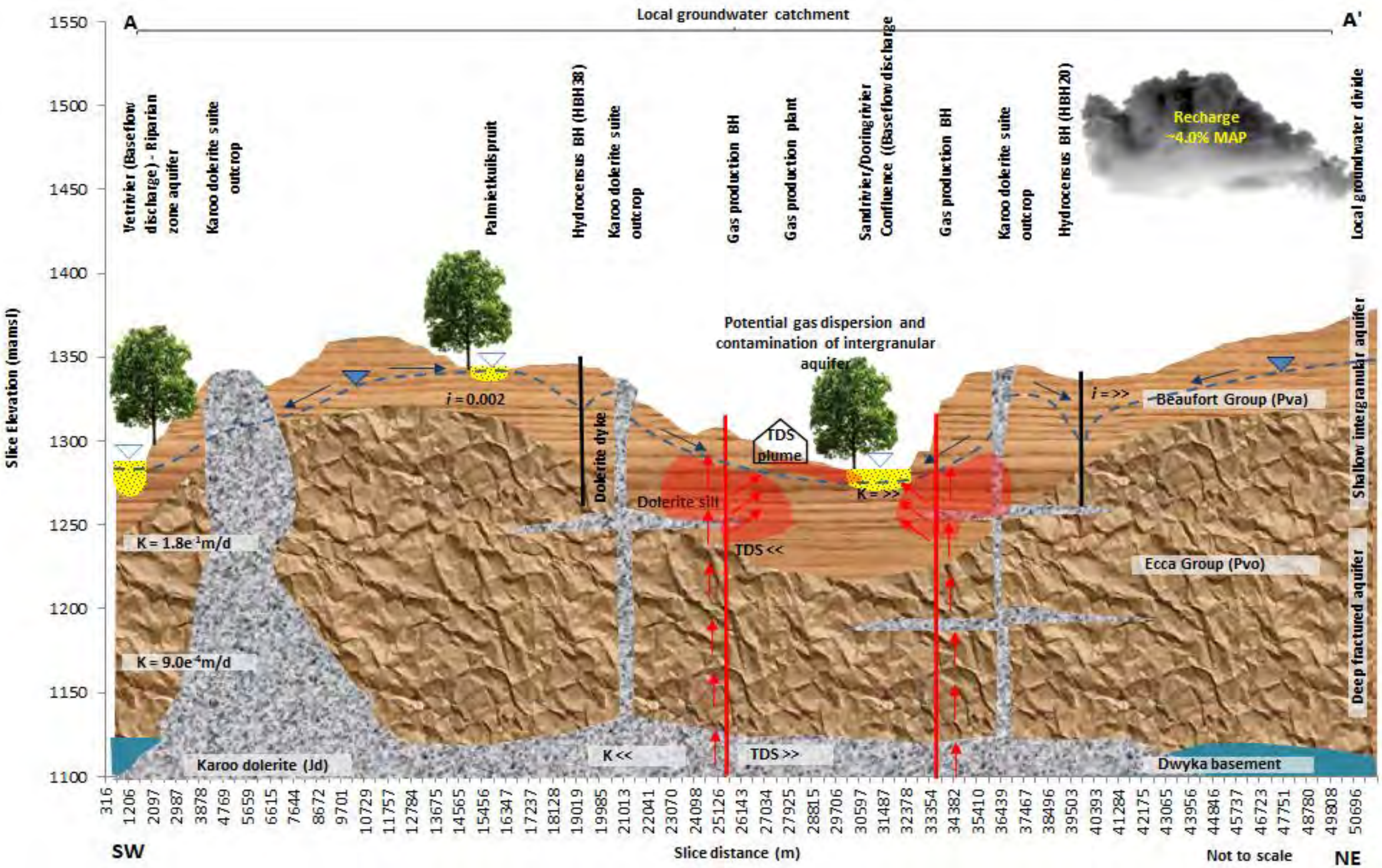


Figure 11-3 **Hydrogeological conceptual model: Southwest- Northeast cross section – Operational Phase (A-A') (Figure 5-2).**

12. NUMERICAL GROUNDWATER FLOW AND CONTAMINANT TRANSPORT MODEL

The purpose of a groundwater model is to serve as a tool to evaluate various water management options and scenarios.

12.1. Approach to modeling

The typical workflow and modelling approach employed is summarised in Figure 12-1 below and encompass a conceptualisation phase, calibration phase as well as a prediction phase.

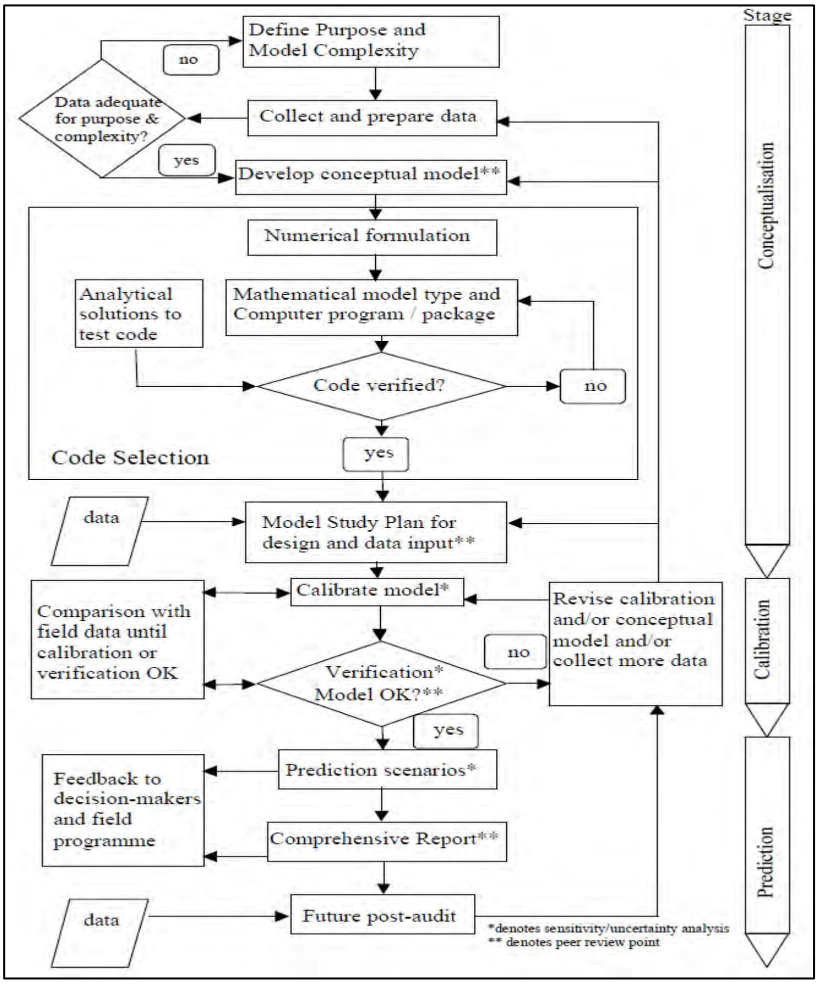


Figure 12-1 Workflow numerical groundwater flow model development.

In natural steady-state conditions, the net groundwater inflow from recharge is balanced by base flow and losses. The groundwater balance is given by:

Equation 12-1 Simplified groundwater balance.

$$Q_{Recharge} - Q_{Baseflow} + Q_{Losses} = 0$$

where:

$Q_{Recharge}$ = Groundwater inflow from rainfall recharge (m^3/d).

$Q_{Baseflow}$ = Groundwater outflow as baseflow (m^3/d).

Q_{Losses} = Groundwater outflow from other losses (m^3/d).

The piezometric gradient, which can be measured from site characterization and monitoring boreholes are known and the boreholes can be pump tested to determine the transmissivity and hydraulic conductivity. The outflow per unit length (L) of aquifer are given by Darcy's law as, q=K dh/dL where q is the Darcy flux in m/d (or $m^3/m^2/d$) and K is the hydraulic conductivity, D the aquifer thickness and dh/dl the piezometric gradient. Since K, D and the head gradient can be measured, a steady-state model can be calibrated by changing the recharge value until the measured and simulated head gradients have a small error (usually <10.0 % of the aquifer thickness).

12.2. Software application

A dynamic flow model was developed by applying the modelling package FEFLOW (Finite Element Flow) and interface (Diersch, 1979). This modelling software has been developed by WASY and is based on the partial differential equation principle. The finite element method is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations.

12.3. Model development

12.3.1. Model domain

A model grid was created with global origin X: -27483.94[m] and Y: -3112580.59[m] using triangular prism type of elements. The model has a width of 57938.3[m], height of 66653.0[m], depth of 613.44[m] and spans an area of $2.36e^{+9}m^2$ with a volume of ~$7.34e^{+11}m^3$. The model domain was delineated based on regional drainages as well as topographical highs i.e., discharge zones and no-flow zones (Figure 12-2). Figure 12-4 shows the model finite element mesh (FEM) construction while Figure 12-6 depicts a respective cross section on which the hydrogeological conceptual model is based on.

12.3.2. Model construction

The model was constructed from FEM and consist of two layers i.e., three slices, 351 905 triangular prism elements per layer, a total of 703 810 elements for the model domain, with 177 480 nodes per slice a total of 532 440 nodes for the model domain. The mesh quality is acceptable and summarised below:

- Delaunay violating triangle: 0.70%.
- Interior holes: 0.
- Obtuse angled triangles: 0.50% > 120°, 6.40% > 90°.

Figure 12-2 **Model domain: Aerial extent.**

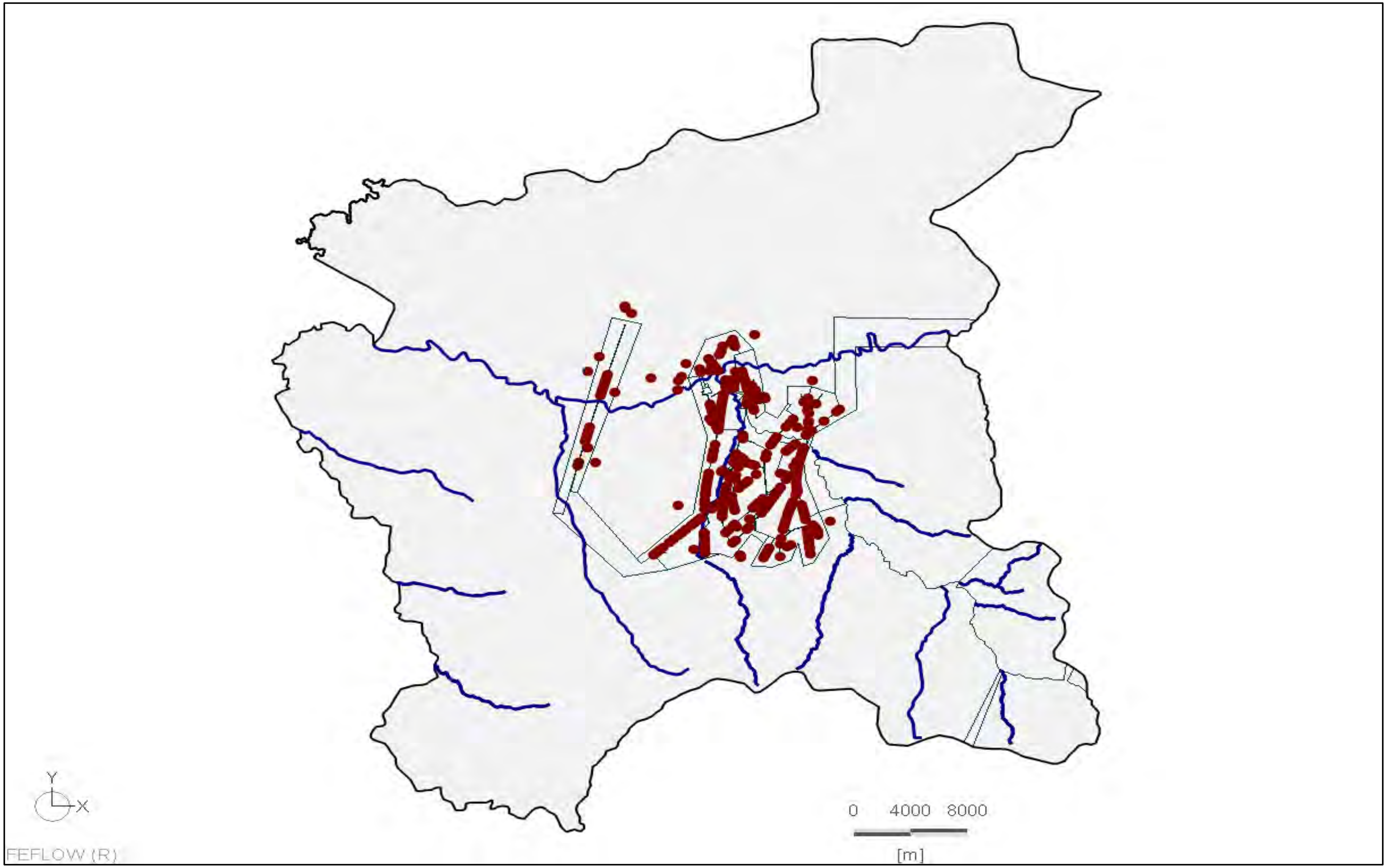


Figure 12-3 **Model domain: Supermesh view.**

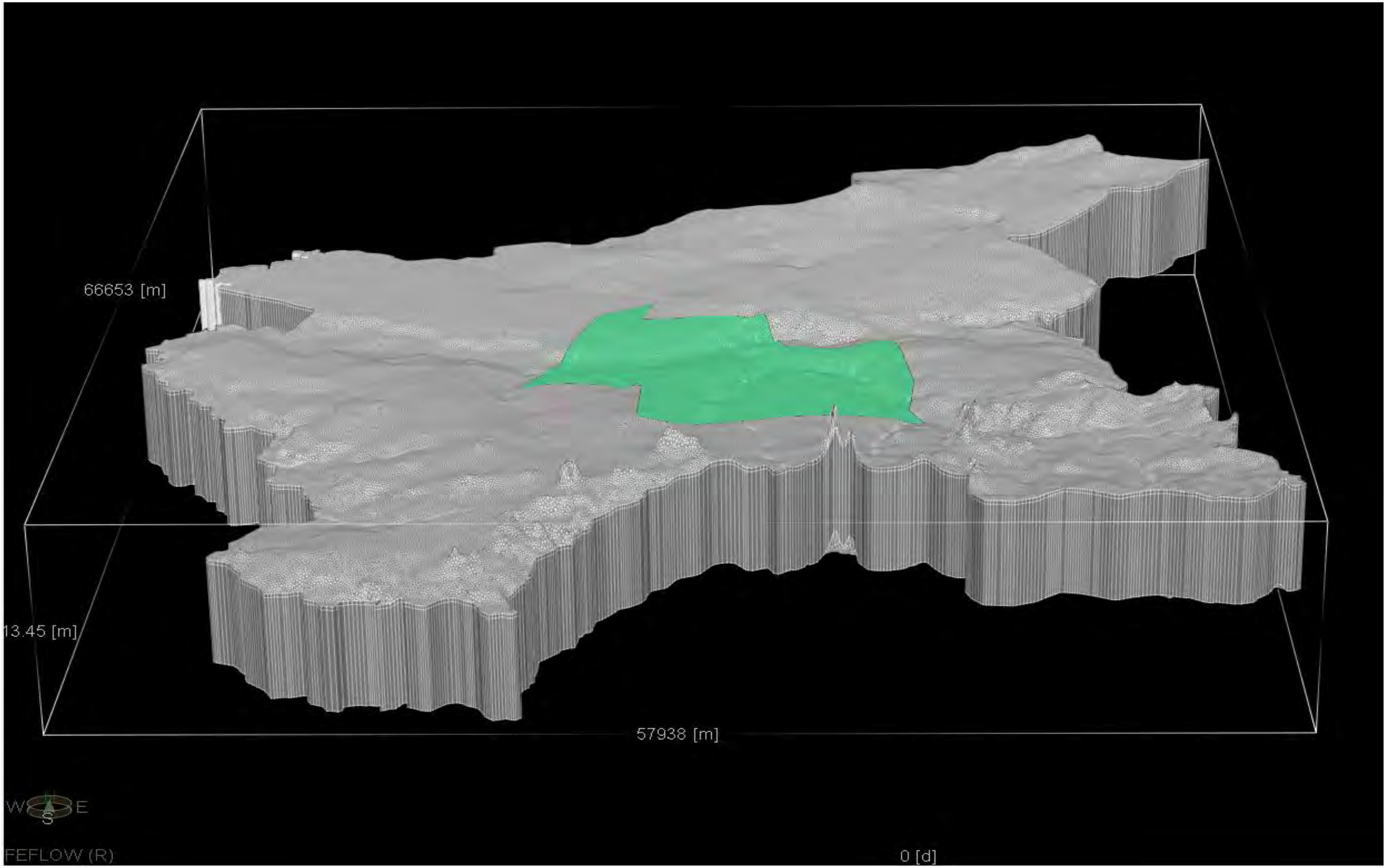


Figure 12-4 Model domain 3-D FEM mesh view depicting a plan-view south-north orientation.

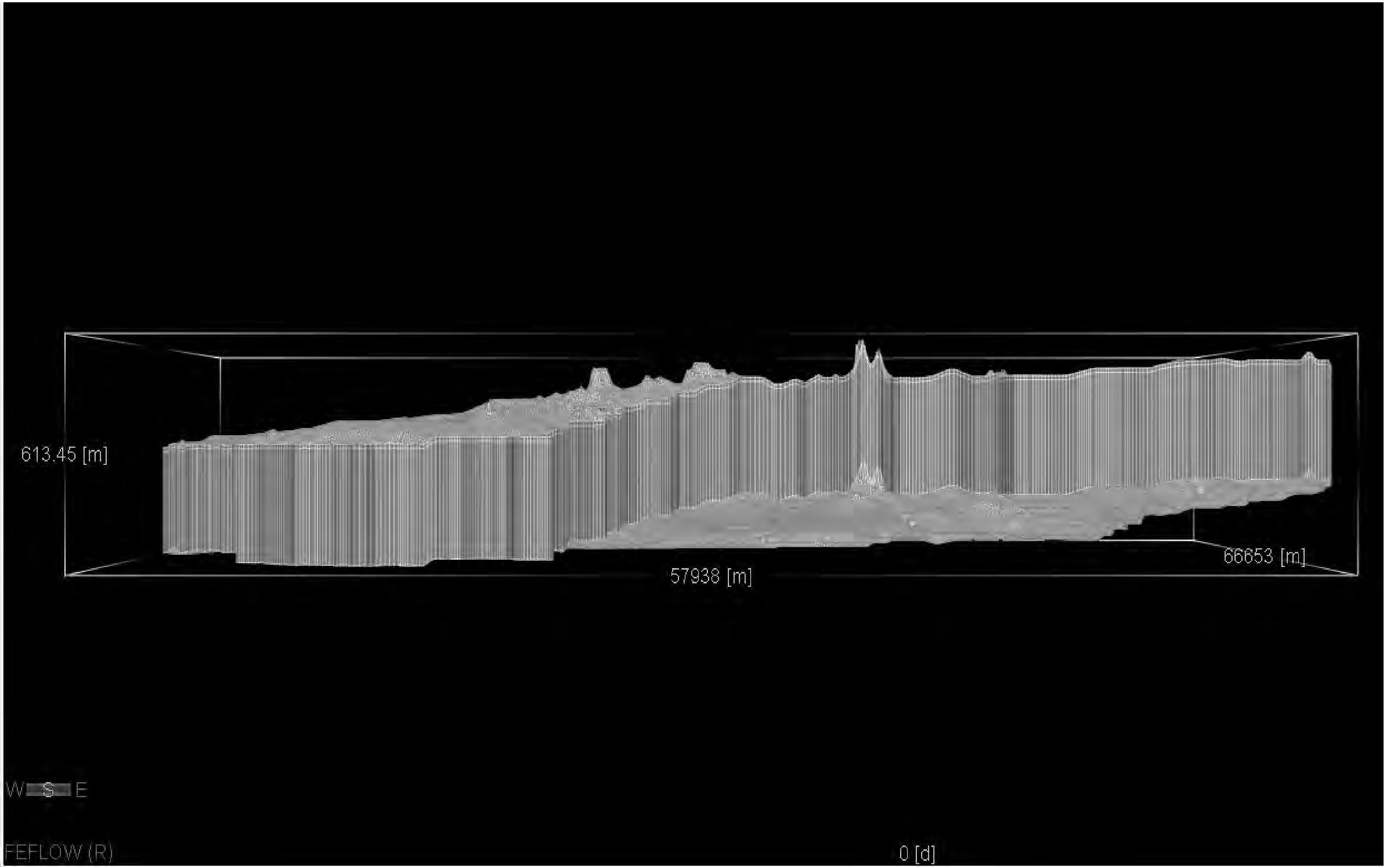


Figure 12-5 **Model domain 3-D FEM mesh view depicting a plan-view south-north orientation.**

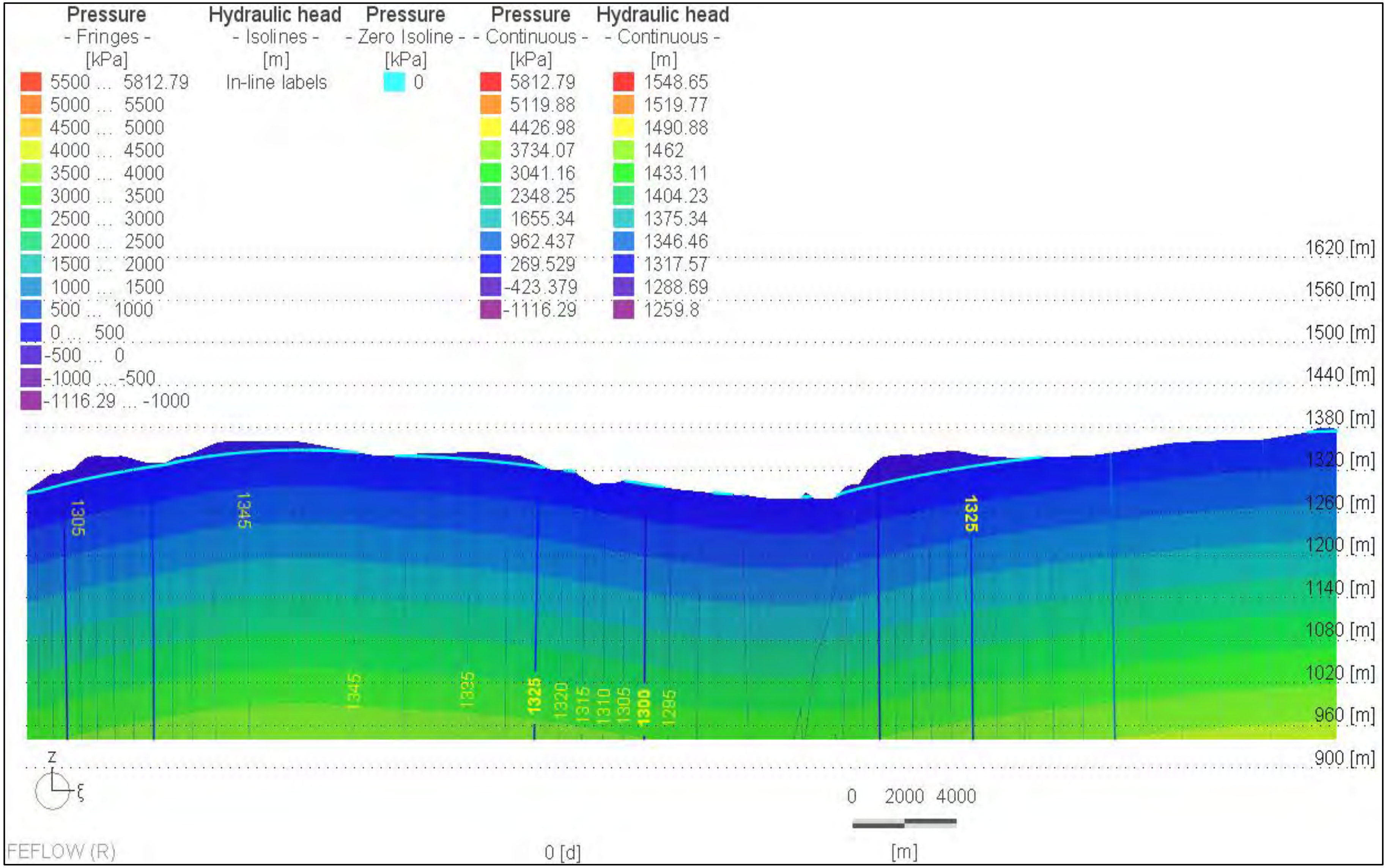


Figure 12-6 **Model domain 3-D FEM mesh view (cross sectional view southwest-northeast orientation of conceptual slice A-A').**

12.3.3. Model layers

The groundwater model consists of two layers, representing identified hydrostratigraphical units. The top layer was based on surface topography with succeeding layers developed horizontally parallel to this layer. Layer sequence and average thickness are listed below (Table 12-1):

i. Layer 01: A shallow, intergranular zone aquifer occurring in the transitional soil and weathered bedrock formations of the Beaufort Group host rock including quaternary deposits (Average thickness = 11.0m).

ii. Layer 02: A deep fractured aquifer where groundwater flow will be dictated by transmissive fracture zones that occur in the relatively competent host rock of the Ecca Group as well as Karoo dolerite Suite (Average thickness = ~300.0m).

12.3.4. Boundary conditions

For the purposes of this model, it is assumed that the lower perimeter of the model domain i.e., competent Karoo basement or Dwyka tillite/diamictite which is generally impermeable and serves to isolate the fractured Karoo aquifer from the fractured pre-Karoo aquifer units. Accordingly, this boundary is represented numerically as a “no-flow” boundary condition and was assigned as such. Topographical high perimeters (groundwater divides) were assigned as no-flow boundaries while major rivers i.e., Vetrivier, Sandrivier as well as Doringrivier were assigned as specific head boundary conditions (Dirichlet Type I) with a maximum constraint set where baseflow discharge from the model domain[8]. Figure 12-1 indicates different boundary conditions assigned within the model domain.

12.4. Model hydraulic properties

The following sections provide a brief overview of the model hydraulic parameters assigned as part of the model development and calibration.

12.4.1. Hydraulic Conductivity

Hydraulic conductivity (K) values were sourced from historical aquifer characterisation data as well as literature values published for similar hydrogeological environments. The model calibration was also used to guide refinement of aquifer parameter values[9]. Hydraulic conductivity values range from $7.50E^{-1}$m/d for alluvial deposits, $1.88E^{-1}$m/d for the weathered Beaufort Group formations and $3.750E^{-2}$m/d for the more competent Karoo dolerite formations. Hydraulic conductivity values were assigned to all major hydrostratigraphic units within the model domain as depicted in Figure 12-12 and Figure 12-7. A ratio of 1:1 for hydraulic conductivity (K) in x and y directions have been assigned, with a 1:10 ratio in the z direction i.e., anisotropic aquifer. Table 12-1 provides a summary of parameter values per layer.

[8] Refer to “gaining stream” assumption.

[9] It should be noted that hydraulic parameters assigned for various hydrostratigraphical units correlate well to historical models and literature values published for similar geological environments.

12.4.2. Sources and sinks

The primary source to groundwater is through recharge. An approximation of recharge for the model domain is estimated at between ~10.0mm/a assigned for denser Karoo dolerite formations to 21.96mm/a assigned to alluvial deposits including riparian zones as listed in Table 12-1 and indicated in Figure 12-8 below. Sinks in the model domain include groundwater abstraction from privately owned and community boreholes[10] as well as groundwater discharge to baseflow.

12.4.3. Storativity and specific storage

Specific storage values were assigned per hydrostratigraphical units and ranges between $1.00E^{-5}$ to $1.00E^{-1}$ as listed in Table 12-1 below.

12.4.4. Porosity

A porosity value ranging from 15.0% (alluvial deposits) to 5.0% (Weathered aquifer unit) to 1.0% (denser Karoo matrix of the deeper aquifer) was assigned per model layer as listed in Table 12-1 below.

12.4.5. Longitudinal and Transversal Dispersivities

A longitudinal dispersivity value of 5.0m was specified for the simulations (Spitz and Moreno, 1996). Bear and Verruijt (1992) estimated the average transversal dispersity to be 10 to 20 times smaller than the longitudinal dispersity. An average value of 0.5m was selected for this parameter during the simulations.

[10] The volume of groundwater abstraction from boreholes is based on data recorded during the hydrocensus as well an assumption for the entire model catchment.

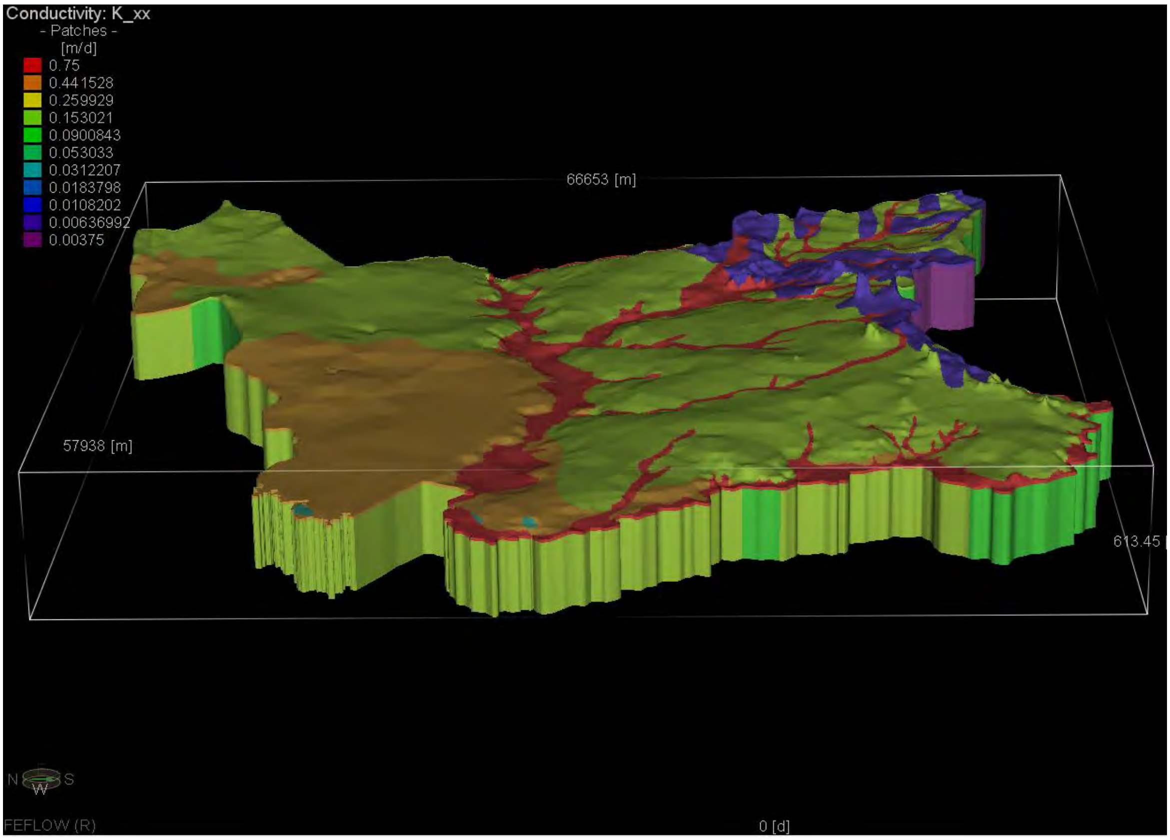


Figure 12-7 **Model development: Numerical groundwater flow model: Hydraulic conductivity distribution.**

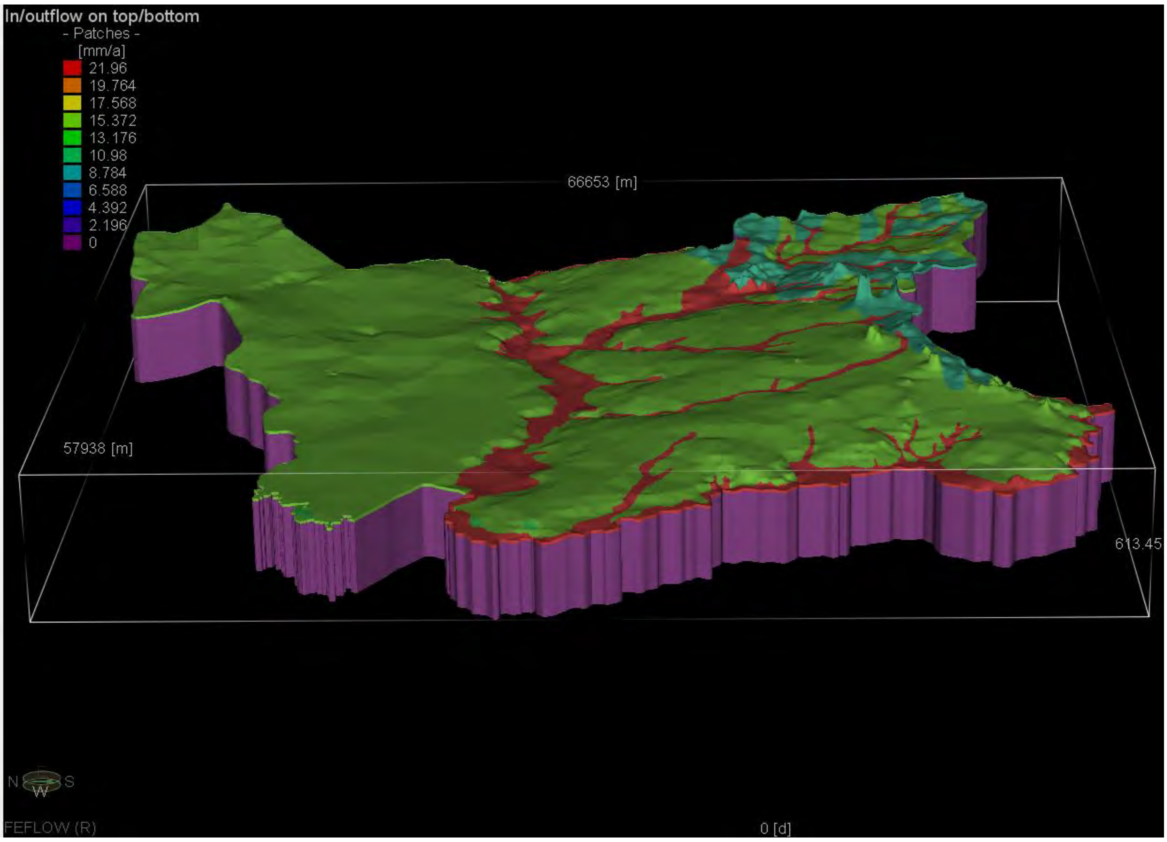


Figure 12-8 **Model development: Numerical groundwater flow model: Recharge distribution.**

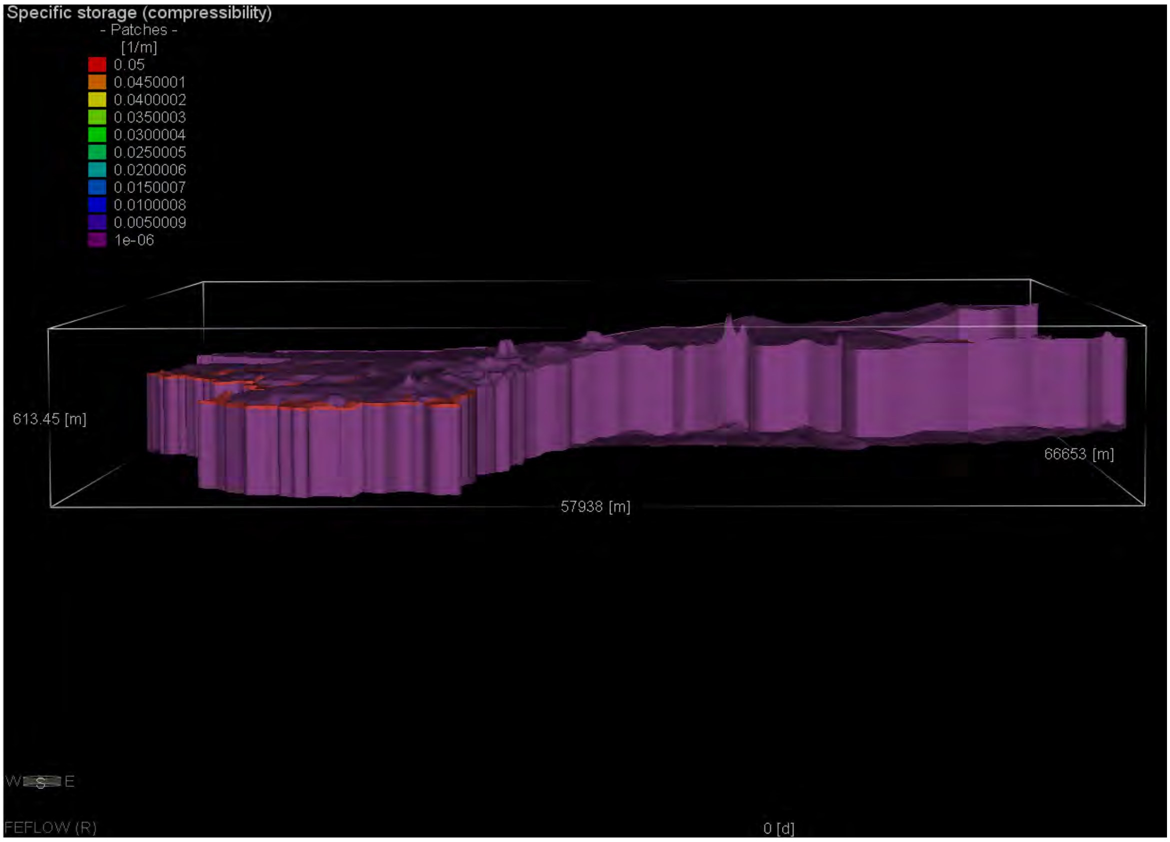


Figure 12-9 **Model development: Numerical groundwater flow model: Specific storage distribution.**

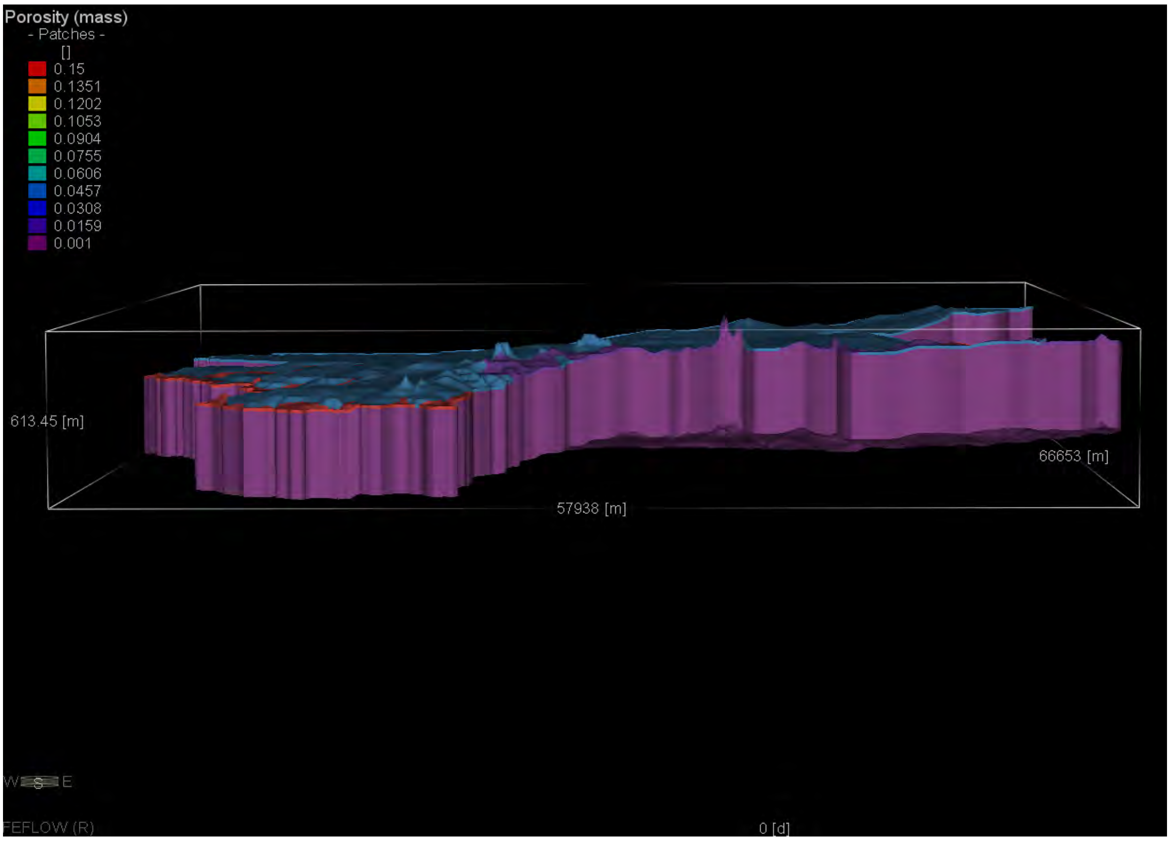


Figure 12-10 **Model development: Numerical groundwater flow model: Porosity distribution.**

Table 12-1 Model set-up: Hydraulic Parameters.

Model Layer	Hydrostratigraphic unit	Layer thickness (m)	Hydraulic Conductivity (K)		Recharge (Re)	Specific storage (Sc)	Porosity (n)
			Kx,y 1:1 (m/d)	Kz 1:10 (m/d)*	In/Outflow on top/bottom (mm/a)	Sc (1/m)	
Layer 01	Alluvial deposits	11.00	7.50E-01	7.50E-01	2.20E+01	1.00E-01	1.50E-01
	Volksrust Formation		3.75E-01	3.75E-02	1.50E+01	1.00E-03	5.00E-02
	Beaufort Group		1.88E-01	1.88E-02	1.50E+01	1.00E-03	5.00E-02
	Karoo Dolerite		7.50E-03	7.50E-04	1.00E+01	1.00E-05	1.00E-02
	Rietgat Formation		3.75E-02	3.75E-03	1.25E+01	1.00E-03	3.00E-02
Layer 02	Volksrust Formation	300.00	1.88E-01	1.88E-02	0.00E+00	1.00E-04	5.00E-03
	Beaufort Group		9.30E-02	9.30E-03		1.00E-04	5.00E-03
	Karoo Dolerite		3.75E-03	3.75E-04		1.00E-06	1.00E-03
	Rietgat Formation		1.88E-02	1.88E-03		1.00E-04	3.00E-03

***Note: Anisotropy of the alluvial, riparian zone aquifer was set at a 1:1 ratio**

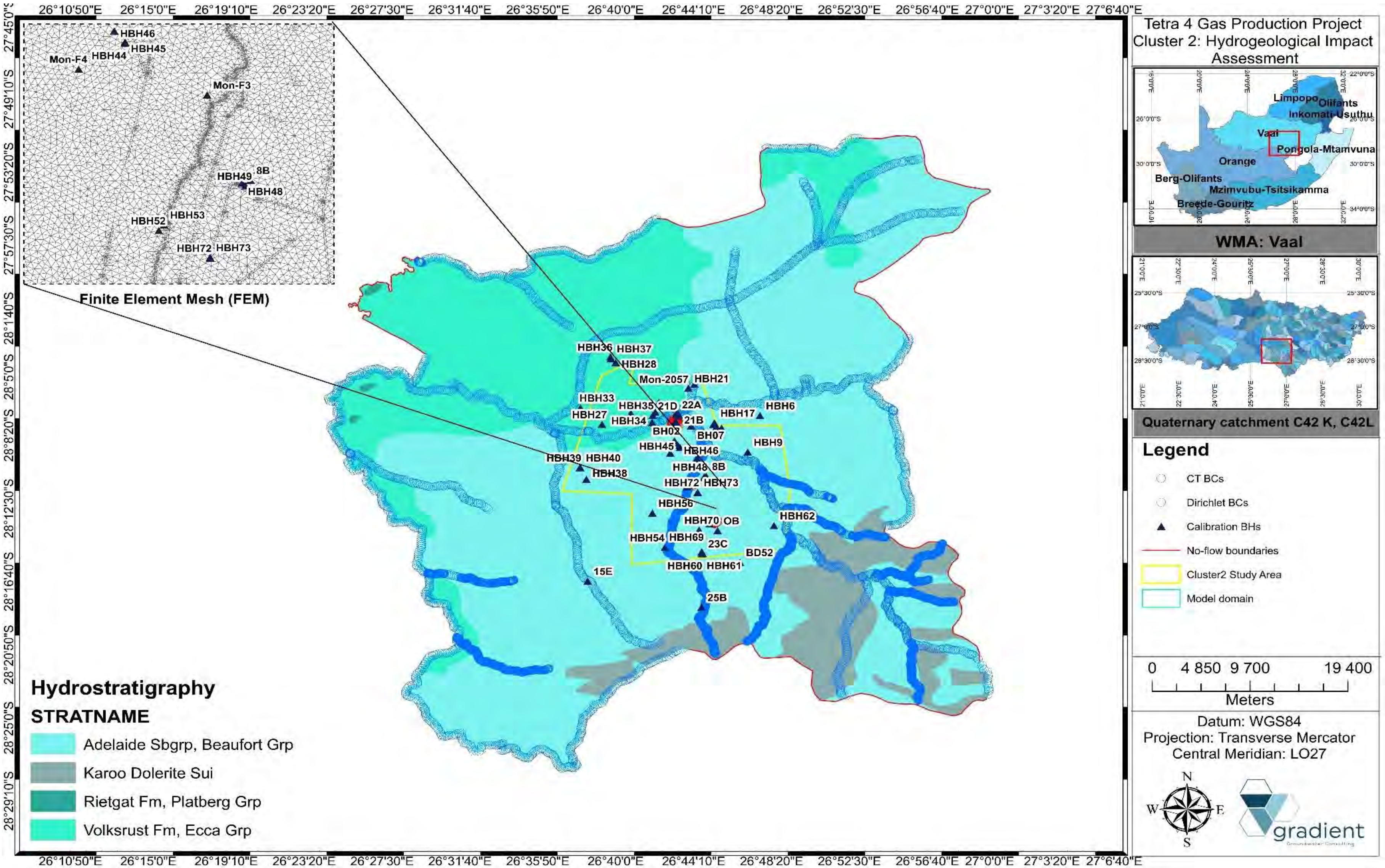


Figure 12-11 **Hydrostratigraphic units and model boundary conditions.**

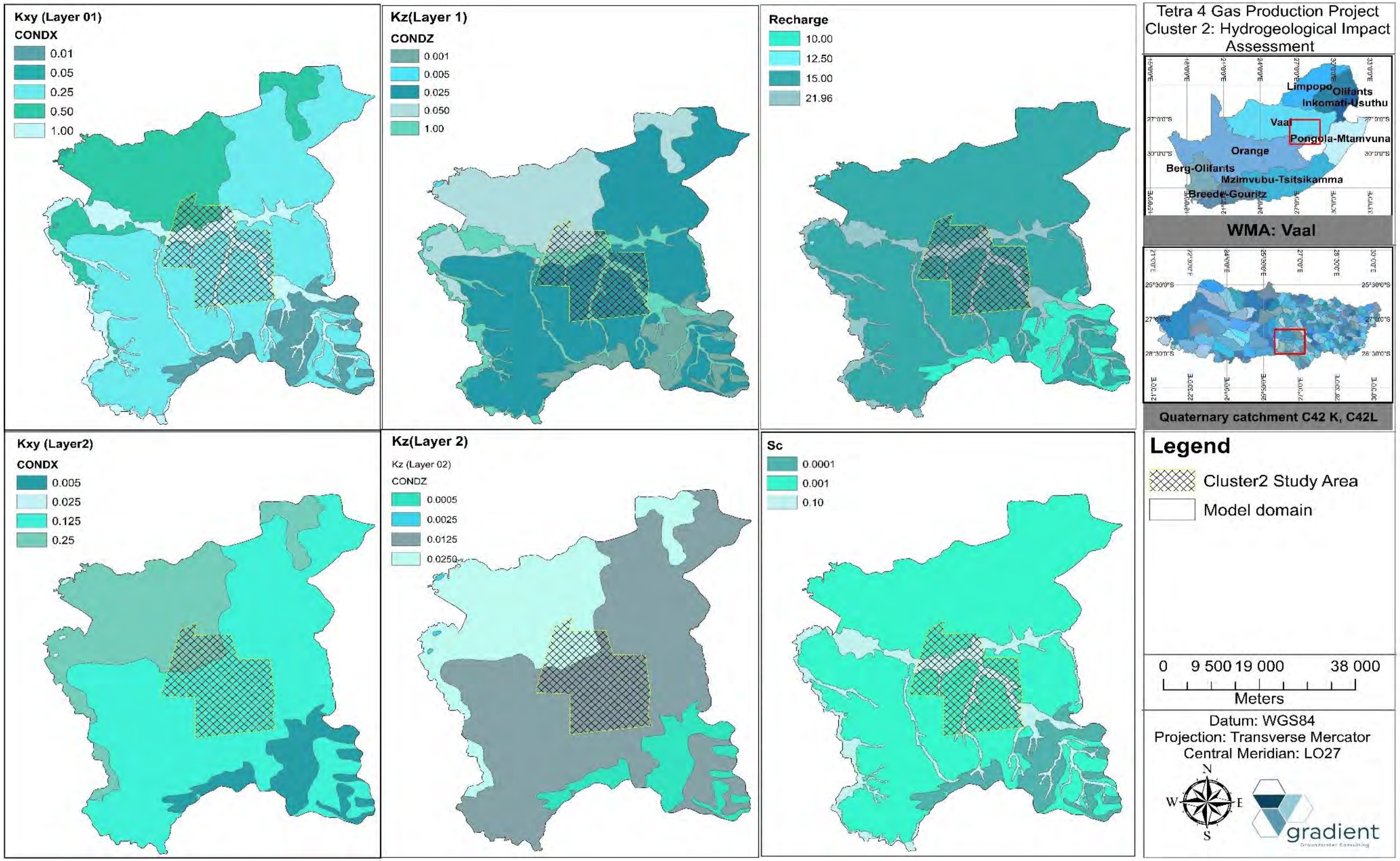


Figure 12-12 **Numerical groundwater flow model: Hydraulic properties.**

12.5. Model calibration

12.5.1. Steady state calibration (∞)

A steady state groundwater flow model was developed to simulate equilibrium conditions, i.e., pre-development conditions, which will be used as initial hydrogeological conditions for transient simulations. The model was standardised by applying the American Society for Testing Materials (ASTM) guidelines (1993), as well as methods presented in Anderson and Woesner (1992) and Spitz and Moreno (1996) case studies. Under steady state conditions, the groundwater flow equation is reduced to exclude storativity. Groundwater levels of gathered observation boreholes were simulated by varying aquifer parameters (hydraulic conductivity and recharge) until an acceptable fit between the measured and simulated hydraulic heads was obtained as summarised in Table 12-2. Observed groundwater levels were plotted against measured water levels and a correlation of ~0.95 was obtained (refer to Figure 12-13, Figure 12-14 and Figure 12-15) while Figure 12-16 indicate calibration error margin per borehole observation locality. Figure 12-17 depicts steady state hydraulic head contours and groundwater flow directions. A good correlation indicates that the developed groundwater model will accurately represent on-site conditions. The residual calibration error is expressed through the calculated; mean error (ME), mean absolute error (MAE) as well as the root mean squared error (RMSE) of the observed versus simulated heads. The RMSE was evaluated as a ratio of the total saturated thickness across the model domain and calculated errors are summarised below:

i. Mean Error (ME): -1.27m.

ii. Mean Absolute Error (MAE): 8.23m.

iii. Normalised Root Mean Square Deviation (NRMSD): 7.83% i.e., represents the deviation between observed and calibration water levels across the model domain.

Table 12-2 Steady State Model Calibration – Statistical Summary.

Calibration BH	Topographical Elevation (mamsl)	Water Level (mbgl)	Measured head elevation (mamsl)	Simulated head elevation (mamsl)	Mean Error (m)	Mean Absolute Error (m)	Root Mean Square Error (m)
HBH6	1308.35	1.52	1306.83	1302.18	4.65	4.65	21.65
HBH9	1314.33	10.87	1303.46	1305.66	-2.20	2.20	4.85
HBH12	1317.12	13.65	1303.47	1295.93	7.54	7.54	56.90
HBH13	1317.12	12.35	1304.77	1295.16	9.61	9.61	92.41
HBH14	1306.16	16.65	1289.51	1290.99	-1.47	1.47	2.17
HBH15	1306.16	17.74	1288.42	1291.06	-2.63	2.63	6.94
HBH16	1311.92	25.40	1286.52	1293.15	-6.64	6.64	44.08
HBH17	1306.16	11.55	1294.61	1290.82	3.80	3.80	14.43
HBH18	1312.93	16.47	1296.46	1294.76	1.69	1.69	2.87
HBH20	1341.47	1.10	1340.37	1309.66	30.71	30.71	942.80
HBH21	1316.68	2.67	1314.01	1299.86	14.15	14.15	200.14
HBH23	1313.61	3.16	1310.45	1294.19	16.26	16.26	264.32
HBH24	1296.78	8.50	1288.28	1288.69	-0.41	0.41	0.17
HBH25	1306.46	24.20	1282.26	1292.15	-9.89	9.89	97.79
HBH27	1300.84	1.40	1299.44	1287.57	11.87	11.87	140.83
HBH28	1312.85	5.02	1307.83	1310.99	-3.16	3.16	9.97
HBH31	1308.76	0.00	1308.76	1298.25	10.51	10.51	110.42
HBH33	1303.06	15.70	1287.36	1292.32	-4.96	4.96	24.59
HBH34	1282.46	26.04	1256.42	1282.22	-25.80	25.80	665.69
HBH35	1293.51	3.70	1289.81	1287.34	2.47	2.47	6.10

Calibration BH	Topographical Elevation (mamsl)	Water Level (mbgl)	Measured head elevation (mamsl)	Simulated head elevation (mamsl)	Mean Error (m)	Mean Absolute Error (m)	Root Mean Square Error (m)
HBH36	1311.04	2.66	1308.38	1311.39	-3.01	3.01	9.05
HBH37	1311.33	3.18	1308.15	1311.17	-3.02	3.02	9.13
HBH38	1338.24	2.94	1335.30	1318.63	16.67	16.67	277.76
HBH39	1312.52	8.26	1304.26	1307.12	-2.86	2.86	8.19
HBH40	1312.52	8.75	1303.77	1306.99	-3.22	3.22	10.38
HBH44	1318.93	8.46	1310.47	1300.07	10.41	10.41	108.28
HBH45	1318.93	8.40	1310.53	1300.18	10.35	10.35	107.21
HBH46	1314.70	14.50	1300.20	1298.69	1.51	1.51	2.29
HBH48	1325.03	11.03	1314.00	1315.69	-1.69	1.69	2.87
HBH49	1325.03	7.12	1317.91	1316.45	1.46	1.46	2.14
HBH52	1323.97	1.08	1322.89	1320.93	1.95	1.95	3.82
HBH53	1323.97	2.80	1321.17	1320.16	1.01	1.01	1.02
HBH54	1363.06	7.98	1355.08	1363.98	-8.90	8.90	79.14
HBH56	1358.94	1.79	1357.15	1349.15	8.00	8.00	63.95
HBH58	1373.57	7.95	1365.62	1373.53	-7.90	7.90	62.46
HBH59	1373.57	8.35	1365.22	1373.45	-8.22	8.22	67.63
HBH60	1371.99	12.90	1359.09	1372.66	-13.57	13.57	184.20
HBH61	1371.99	12.55	1359.44	1372.54	-13.10	13.10	171.69
HBH62	1337.84	12.70	1325.14	1342.98	-17.84	17.84	318.27
HBH69	1358.14	1.67	1356.47	1354.77	1.70	1.70	2.89
HBH70	1360.24	3.10	1357.14	1358.74	-1.60	1.60	2.55
HBH72	1332.90	1.75	1331.15	1328.33	2.82	2.82	7.96
HBH73	1332.90	1.63	1331.27	1328.21	3.06	3.06	9.36
15E	1380.01	2.20	1377.81	1374.98	2.83	2.83	8.03
21A (BH05)	1281.21	12.48	1268.74	1281.33	-12.59	12.59	158.48
21B	1281.21	0.00	1281.21	1281.19	0.02	0.02	0.00
21D	1280.00	16.09	1263.91	1281.68	-17.77	17.77	315.95
22A	1282.95	10.64	1272.31	1280.01	-7.70	7.70	59.27
22D (BH09)	1281.21	8.33	1272.89	1280.04	-7.15	7.15	51.19
23C	1373.57	5.42	1368.16	1373.42	-5.26	5.26	27.67
25B	1404.66	9.39	1395.27	1403.97	-8.70	8.70	75.69
8B	1325.03	0.00	1325.03	1315.64	9.39	9.39	88.19
BD52	1381.39	0.73	1380.66	1377.11	3.55	3.55	12.62
BH01	1283.95	23.33	1260.63	1284.80	-24.17	24.17	584.33
BH02	1308.60	10.07	1298.53	1295.69	2.84	2.84	8.06
BH07	1281.69	16.97	1264.73	1283.23	-18.51	18.51	342.47
Mon-2057	1320.23	3.09	1317.14	1303.70	13.45	13.45	180.79
Mon-F1	1290.60	21.46	1269.14	1288.23	-19.10	19.10	364.73
Mon-F3	1304.74	7.74	1297.00	1301.27	-4.27	4.27	18.22
Mon-F4	1319.62	7.69	1311.93	1304.28	7.65	7.65	58.51
Mon-HDR1	1283.95	26.71	1257.24	1284.40	-27.16	27.16	737.45
OB	1364.24	0.70	1363.54	1359.60	3.94	3.94	15.50
Average	**1322.21**	**8.91**	**1313.30**	**1314.57**	**-1.27**	**8.23**	**118.20**
Minimum	**1280.00**	**0.00**	**1256.42**	**1280.01**	**-27.16**	**0.02**	**0.00**
Maximum	**1404.66**	**26.71**	**1395.27**	**1403.97**	**30.71**	**30.71**	**942.80**
Correlation			**0.95**				
∑					**-78.62**	**510.36**	**7328.51**
1/n					**-1.27**	**8.23**	**118.20**
Root Mean Square Deviation (RMSD)					**1.13**	**2.87**	**10.87**
Normalised Root Mean Square Deviation (NRMSD) (% of water level range)							**7.83**

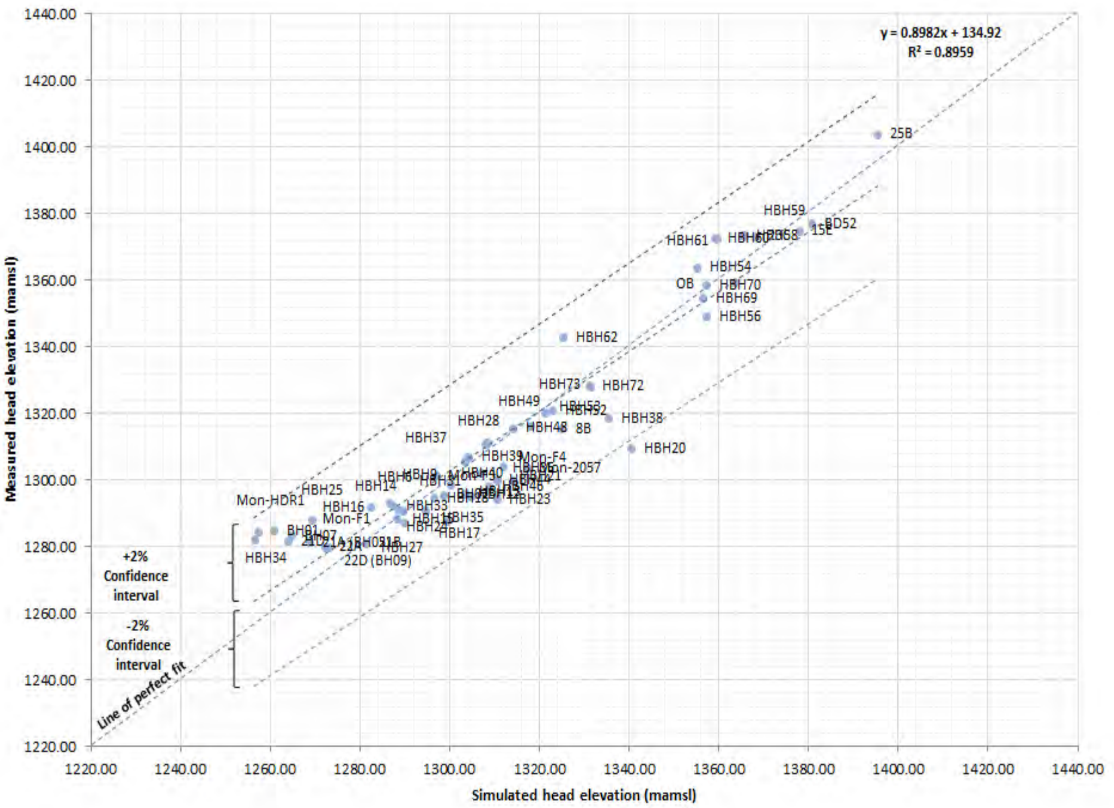


Figure 12-13 Model steady state calibration: Scatter plot of simulated vs. measured hydraulic head elevation.

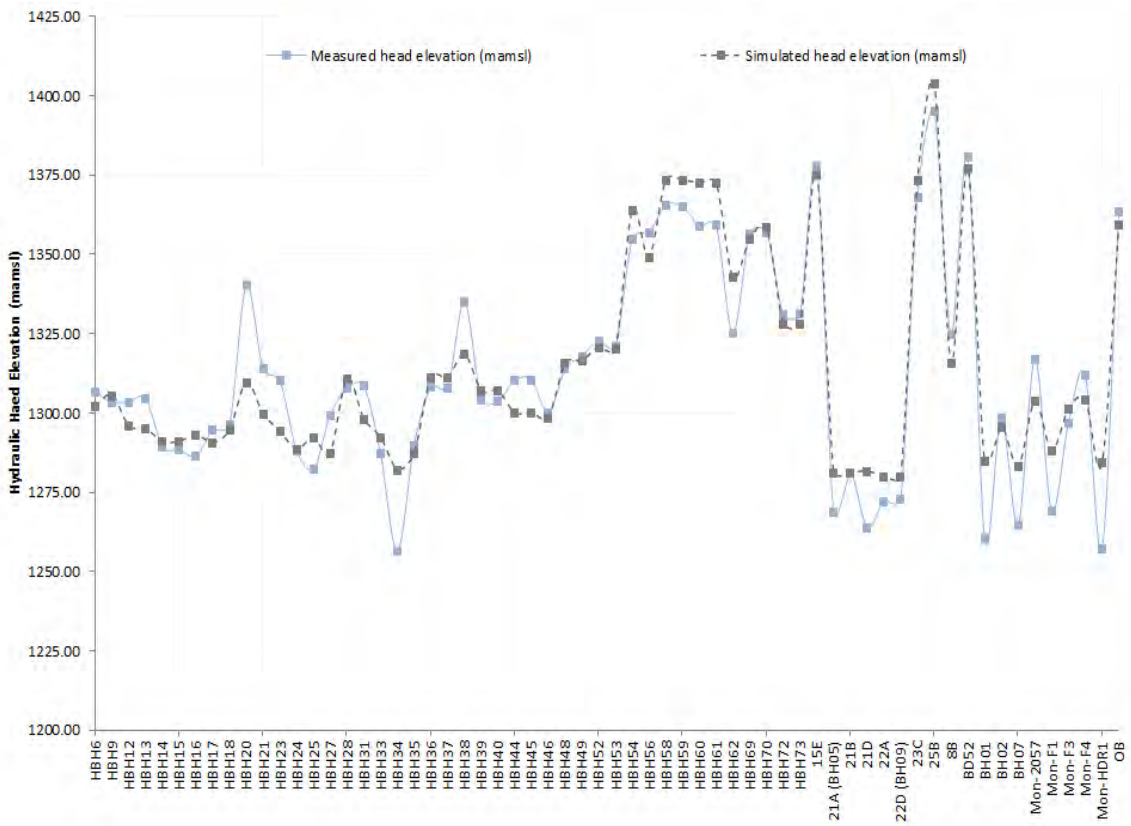


Figure 12-14 Model steady state calibration: curve of simulated vs. measured hydraulic head elevation.

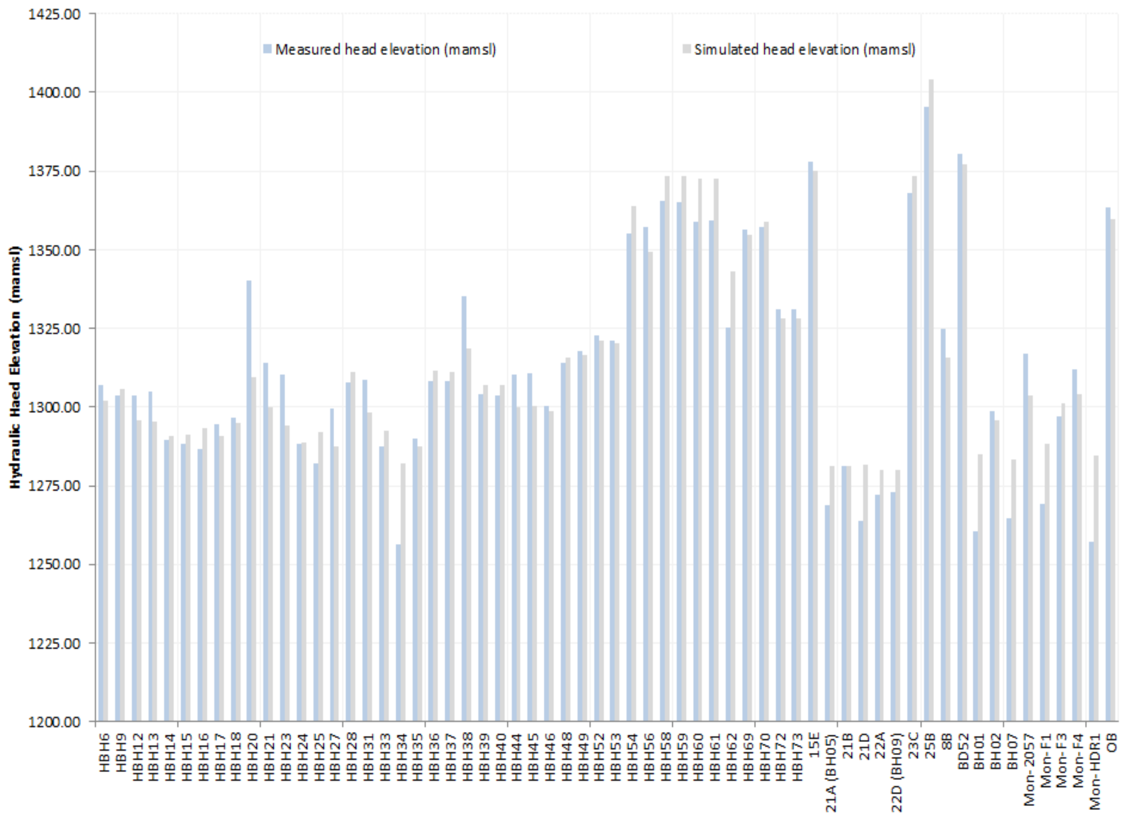


Figure 12-15 Model steady state calibration: Bar chart of simulated vs. measured hydraulic head elevation.

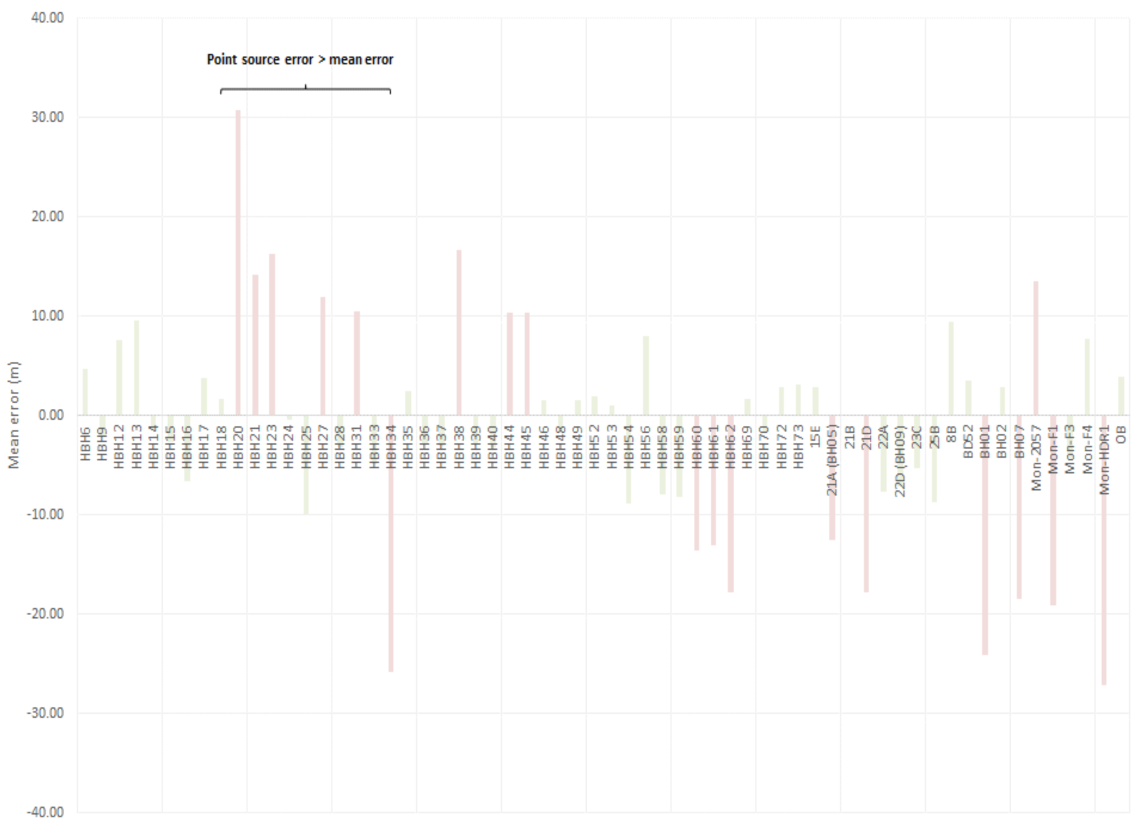


Figure 12-16 Model steady state calibration: Bar-chart of simulated vs. measured hydraulic head elevation.

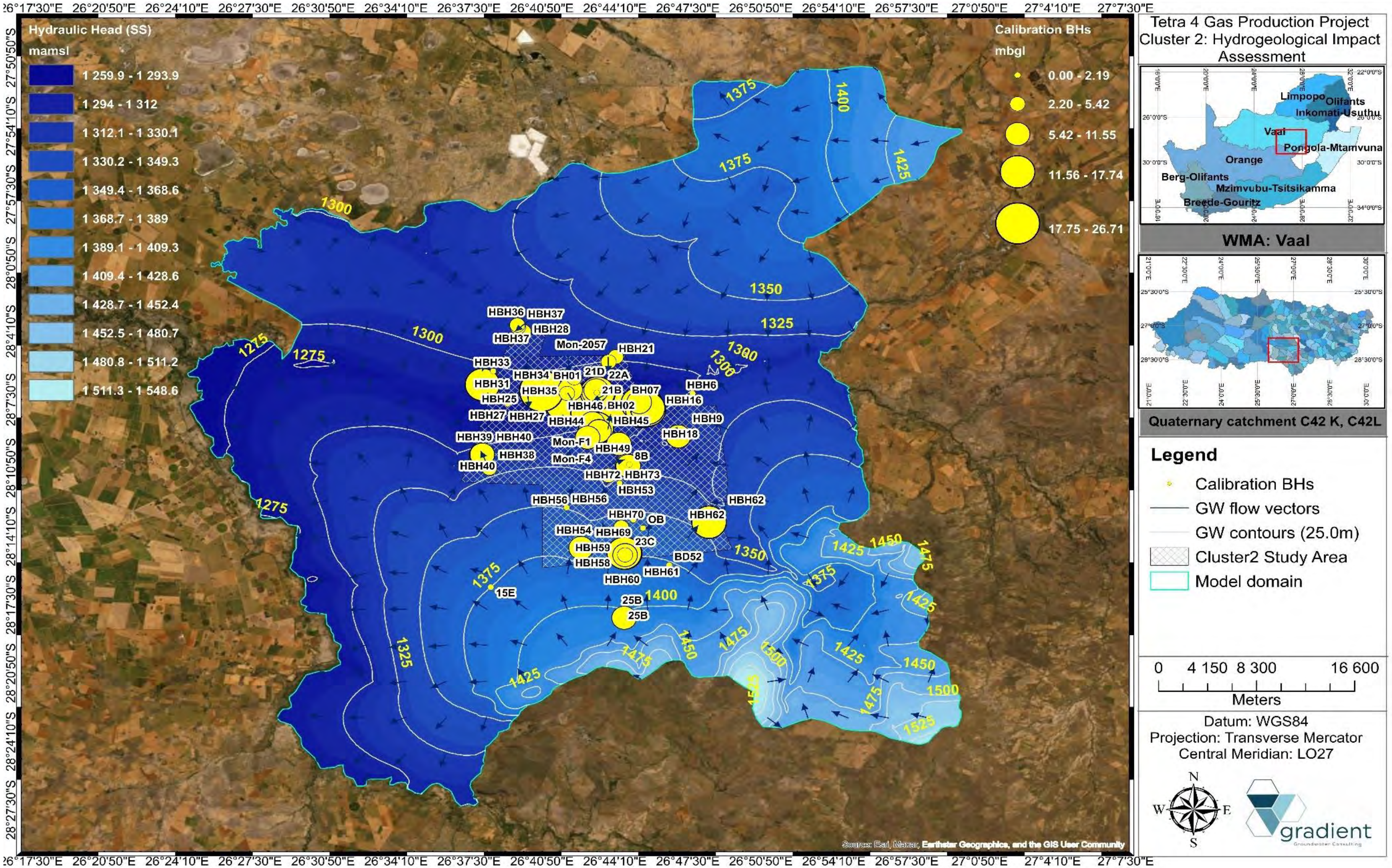


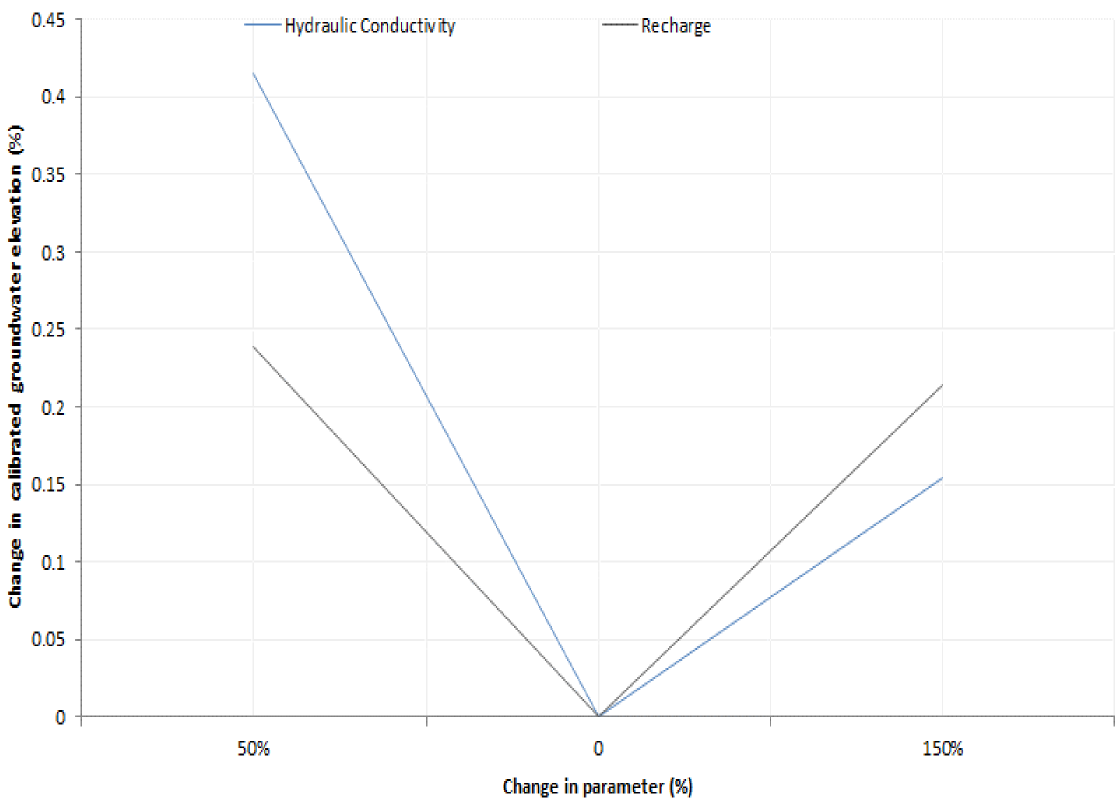
Figure 12-17 **Model calibration: steady state hydraulic heads and groundwater flow direction.**

12.5.2. Model sensitivity analysis

Sensitivity analysis is the study of how the uncertainty in the output of a mathematical model or system (numerical or otherwise) can be apportioned to different sources of uncertainty in its inputs (Saltelli, 2002). The process of recalculating outcomes under alternative assumptions to determine the impact of a variable under sensitivity analysis can increase the understanding of the relationships between input and output variables in a system or model as well as reduce the model uncertainty (Pannell, 1997). In order to verify the sensitivity of the calibrated model in terms of hydraulic stresses, aquifer parameters (i.e., recharge and transmissivity) were adjusted while the impact on the hydraulic head elevation evaluated at relevant on-site borehole localities. As summarised in Table 12-2 it is noted that the model tends to be more sensitive to variations in recharge, especially a downward adjustment (Figure 12-18, Figure 12-19 and Figure 12-20)[11].

Table 12-3 Steady State Model Calibration – Sensitivity analysis.

Parameter	Scenario: Base Case	Scenario: 90% of calibrated K-value	Scenario: 110% of calibrated K-value	Scenario: 90% of calibrated recharge	Scenario: 110% of calibrated recharge
Correlation	0.95	0.96	0.94	0.94	0.95
Mean Error	-1.27	-7.27	1.49	3.95	-4.42
Mean Abs Error	8.23	9.71	8.68	10.00	8.44
RMSD	10.87	12.27	11.58	12.85	11.09
NRMSD	7.83%	8.83%	8.34%	9.26%	7.99%



[11]Recharge remains an uncertain parameter and it is difficult to estimate groundwater recharge accurately. The accurate quantification of natural recharge uncertainty is critical for groundwater management.

Figure 12-18 Model steady state calibration: sensitivity analysis for monitoring locality HBH09.

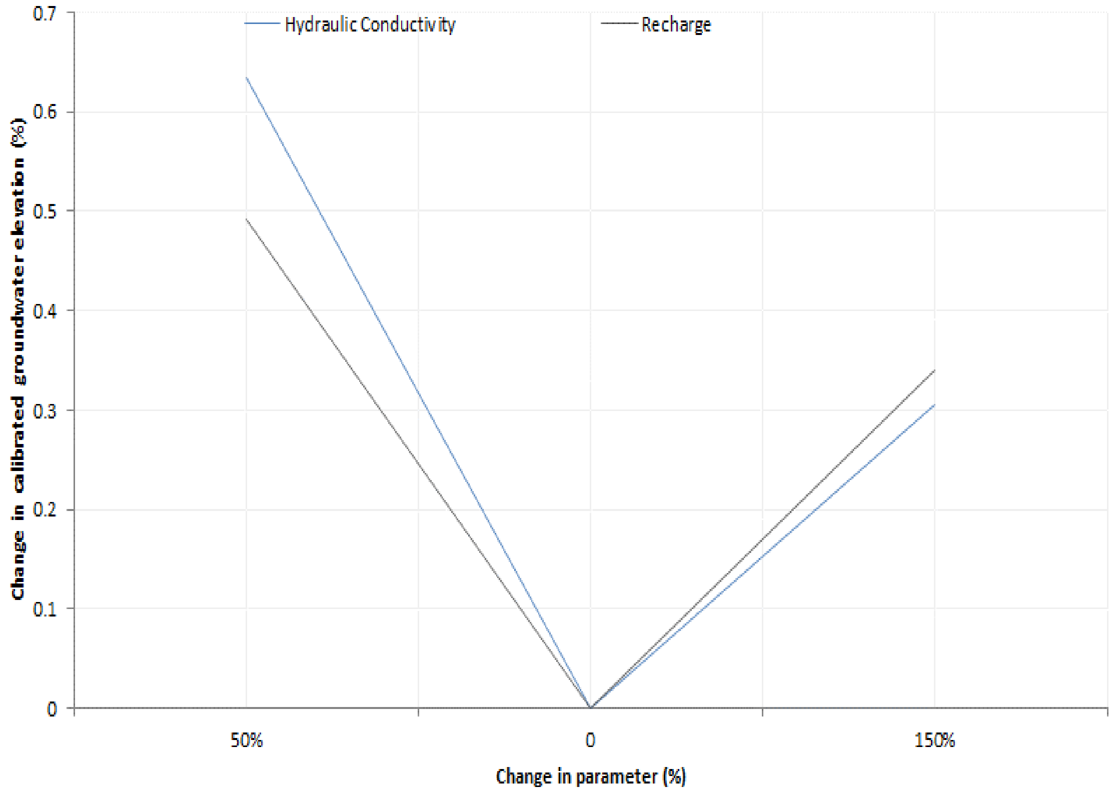


Figure 12-19 Model steady state calibration: sensitivity analysis for monitoring locality HBH28.

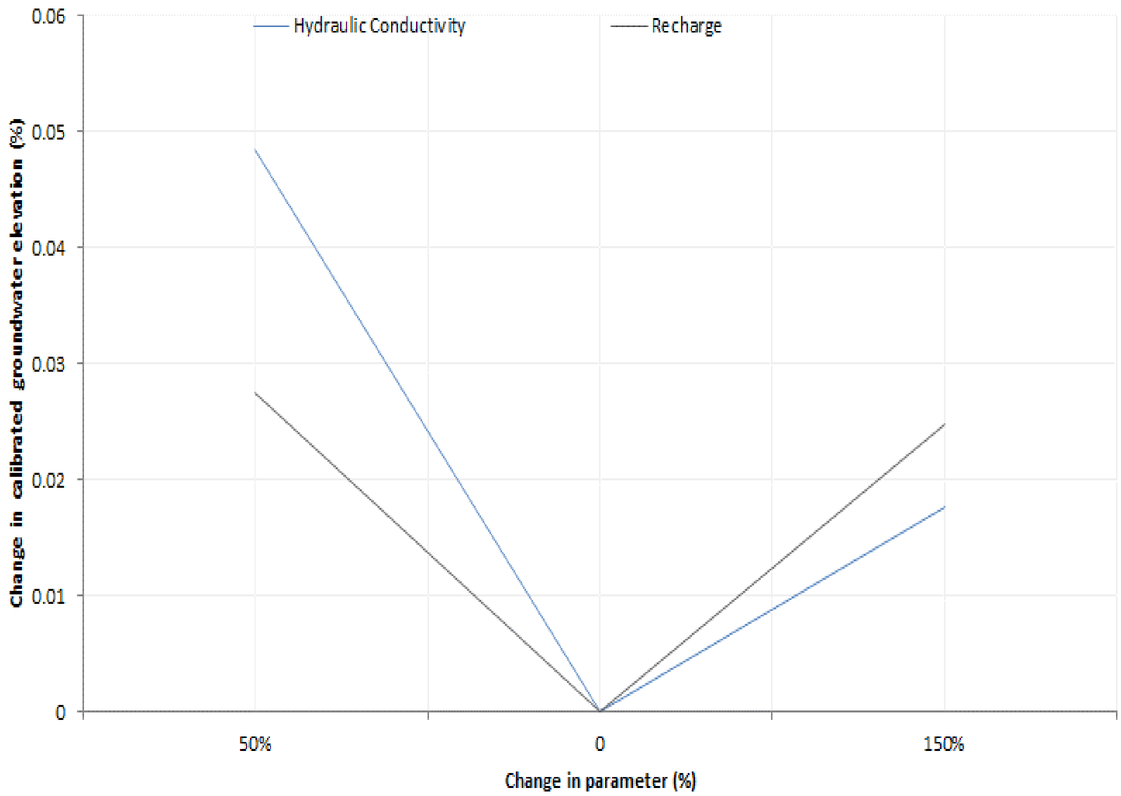


Figure 12-20 Model steady state calibration: sensitivity analysis for monitoring locality 21B.

12.6. Numerical groundwater flow model

The groundwater model is based on three-dimensional groundwater flow and may be described by the following equation (Darcy, 1856):

Equation 12-2 Groundwater flow.

$$\frac{\partial}{\partial x}(K_x \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_y \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_z \frac{\partial h}{\partial z}) \pm W = S\frac{\partial h}{\partial t}$$

where:

h = hydraulic head [L]

Kx,Ky,Kz = Hydraulic Conductivity [L/T]

S = storage coefficient

t = time [T]

W = source (recharge) or sink (pumping) per unit area [L/T]

x,y,z = spatial co-ordinates [L]

12.7. Numerical mass transport model

The mass balance equation (Bear and Verruijt, 1992) (advection-dispersion equation) of a pollutant can be expressed as follows:

Equation 12-3 Advection-dispersion.

$$\frac{\delta nc}{\delta t} = - \Delta \bullet q_{c,total} - f + n\rho\Gamma - P_c + R_c$$

where:

nc = mass of pollutant per unit volume of porous medium;

n = porosity of saturated zone;

c = concentration of pollutant (mass of pollutant per unit volume of liquid (water));

$\Delta \bullet q_{c,total}$ = excess of inflow of a considered pollutant over outflow, per unit volume of porous medium, per unit time;

f = quantity of pollutant leaving the water (through adsorption, ion exchange etc.);

$n\rho\Gamma$ = mass of pollutant added to the water (or leaving it) as a result of chemical interactions among species inside the water, or by various decay phenomena[12];

Γ = rate at which the mass of a pollutant is added to the water per unit mass of fluid;

p = density of pollutant;

Pc = total quantity of pollutant withdrawn (pumped) per unit volume of porous medium per unit time;

Rc = total quantity of pollutant added (artificial recharge) per unit volume of porous medium per unit time.

[12] This investigation and contaminant transport model are based on a “worst-case” scenario and as such, it is assumed that no decay and/or retardation are taking place in the aquifer.

Advection and hydrodynamic dispersion are the major processes controlling transport through a porous medium. Advection is the component of contaminant movement described by Darcy's Law. If uniform flow at a velocity V takes place in the aquifer, Darcy's law calculates the distance (x) over which a labelled water particle migrates over a time period t as x = Vt. Hydrodynamic dispersion refers to the stretching of a solute band in the flow direction during its transport by an advecting fluid and comprises mechanical dispersion as well as molecular diffusion. Contaminant transport scenarios serve as tool for management purposes and the simulation results indicate the expected plume migration. The latter can be used to establish additional monitoring points to be applied as transient input for model updates and re-calibration.

It should be noted that the contaminant transport scenarios serve as a tool for management purposes with advective transport simulating the potential leachate concentrations from waste facilities, however, does not include biochemical breakdown and cation/anion exchange reactions which will further retard plume migration.

Various source terms and contaminant proxies were applied as part of the mass transport migration simulations and include saline groundwater emanating from the deep, fractured aquifer from leaking gas production boreholes (TDS = 7 832.0 mg/l - based on hydrochemical analysis of water samples representing this aquifer unit) as well as contaminated water emanating at the plant footprint and evaporation dam(s) (TDS = 2000.0 mg/l).

A contaminant transport scenario was conducted simulating stray methane gas (CH_4) from leaking gas production boreholes. The drilling and operation of gas production wells could result in the migration of stray gas from the deep-seated fracture zones to formations higher up in the geological sequence. This impact has been recorded in the US where hydraulic fracturing, dewatering or a combination of these has occurred (Jackson et al, 2013). It should be stated that Tetra4 does not intend to undertake hydraulic fracturing or any well stimulation and the existing dataset suggests that no dewatering of produced water will be required. Accordingly, the risk of stray gas migration is therefore expected to be low. It should be noted that this scenario is highly unlikely under natural conditions as the production zone(s) is separated from the shallow and potable Karoo aquifer by very low permeability shale formations which will act as an aquitard towards any groundwater and stray gas migration. This is however provided that well construction, including cementation and the installation of steel casing, is sound. As such, the impact assessment evaluated represents a worst-case scenario and simulates the eventual occurrence once stray gas does reach the shallow aquifer. The mechanisms by which stray gas can migrate into the shallower potable Karoo aquifer include (*iLEH*, 2017):

- Leakage of stray gas along poorly sealed gas production wells;
- Gas leakage because of an overpressure event and barrier (casing and cementation) failure; and
- Migration of gas from deep-seated fracture zones along fractures and faults.

As methane gas reaches saturation in water at 28 milligrams per litre (mg/L) at atmospheric pressure (Eltschlager and others, 2001), this concentration was applied as source term for this scenario. According to the U.S. Environmental Protection Agency (EPA, 2011) as well as U.S. Department of the Interior, Office of Surface Mining (2011), methane concentrations below 10 mg/L are generally considered safe.

Various management scenarios were modelled for the purposes of planning and decision making with stress periods listed in Table 12-4:

i. **Scenario 01:** Steady state water balance (∞).
ii. **Scenario 02a:** Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the operational gas production phase.
iii. **Scenario 02b:** Migration of stray methane (CH_4) gas emanating from the deep, fractured aquifer to the overlying, potable aquifer(s) during the operations gas production phase.
iv. **Scenario 03:** Migration of the TDS pollution plume emanating from the plant footprint area during the operational gas production phase.
v. **Scenario 04a:** Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the post-closure and decommissioning phase (50-year and 100-year scenarios).
vi. **Scenario 04b:** Migration of stray methane (CH_4) gas emanating from the deep, fractured aquifer to the overlying, potable aquifer(s) during the post-closure and decommissioning phase (50-year and 100-year scenarios).
vii. **Scenario 05:** Migration of the TDS pollution plume emanating from the plant footprint area during the post-closure and decommissioning phase (50-year and 100-year scenarios).

Table 12-4 Summary of model stress-periods.

Stress period	Description
Year01 – Year20	Gas production operational phase
Year 21 – Year 71	50-years post closure
Year 72 – Year 121	100-years post closure

12.7.1. Scenario 01: Steady state baseline water balance (∞)

Table 12-5 summarises the groundwater catchment water balance representing baseline steady state conditions. Recharge is assumed the only source of inflow to the system and has been simulated at 1.03E^{+05} m^3/d, while the largest loss to the groundwater system is via baseflow, 1.02E^{+04} m^3/d. The imbalance of the delineated aquifer unit, ignoring internal transfer, is calculated at 1.90E^{+3}m^3/d.

Table 12-5 Catchment water balance: Scenario 01 – Steady state baseline water balance.

Scenario 01 – Steady State Catchment Groundwater Balance			
Parameter	**Inflow (m³/d)**	**Outflow (m³/d)**	**Balance (m³/d)**
Recharge (m³/d)	1.03E+05	0.00E+00	1.03E+05
GW component of baseflow/ Dirichlet boundary conditions (m³/d)	1.02E+03	1.02E+05	-1.01E+05
Storage Capture(-)/Release(+)(m³/d)	2.11E+01	1.86E+01	2.50E+00
Imbalance ignoring internal transfer (m³/d)	0.00E+00	1.99E+03	0.00E+00
Total (m³/d)	**1.04E+05**	**1.04E+05**	**0.00E+00**

12.7.2. Scenario 02a: Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the operational gas production phase

This scenario summarises the simulated point source pollution plume migration of saline groundwater emanating from the deep, fractured aquifer should the integrity of the gas production boreholes be jeopardised i.e., leaking boreholes for the operational phase (20-year period). The TDS pollution plume extend covers a total area of approximately 414.06ha in the Karoo formations, reaching a maximum distance of ~80.0m in a radial pattern from the gas production borehole(s), and approximately 251.60ha in the alluvial deposits, reaching a maximum distance of ~200.0m in a radial pattern from the gas production borehole after a simulation period of 20-years (refer to Figure 12-23). The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH63, HBH72, HBH73 and HBH74. It is noted that the pollution plume does extend beyond the project boundary. Figure 12-22 indicates the expected flow pathways of particles derived from the source points and it is evident that the pollution plume migration in the denser Karoo formations is sluggish while movement in the unconsolidated alluvial deposits of the riparian zone suggest a larger flux.

Figure 12-21 summarises a time-series graph of the TDS mass load contribution to down-gradient receptors. It is evident that source term mass load contribution to existing neighbouring borehole situated near the gas production boreholes does not exceed ~800.0mg/l and ranges between 600mg/l to 700.0mg/l.

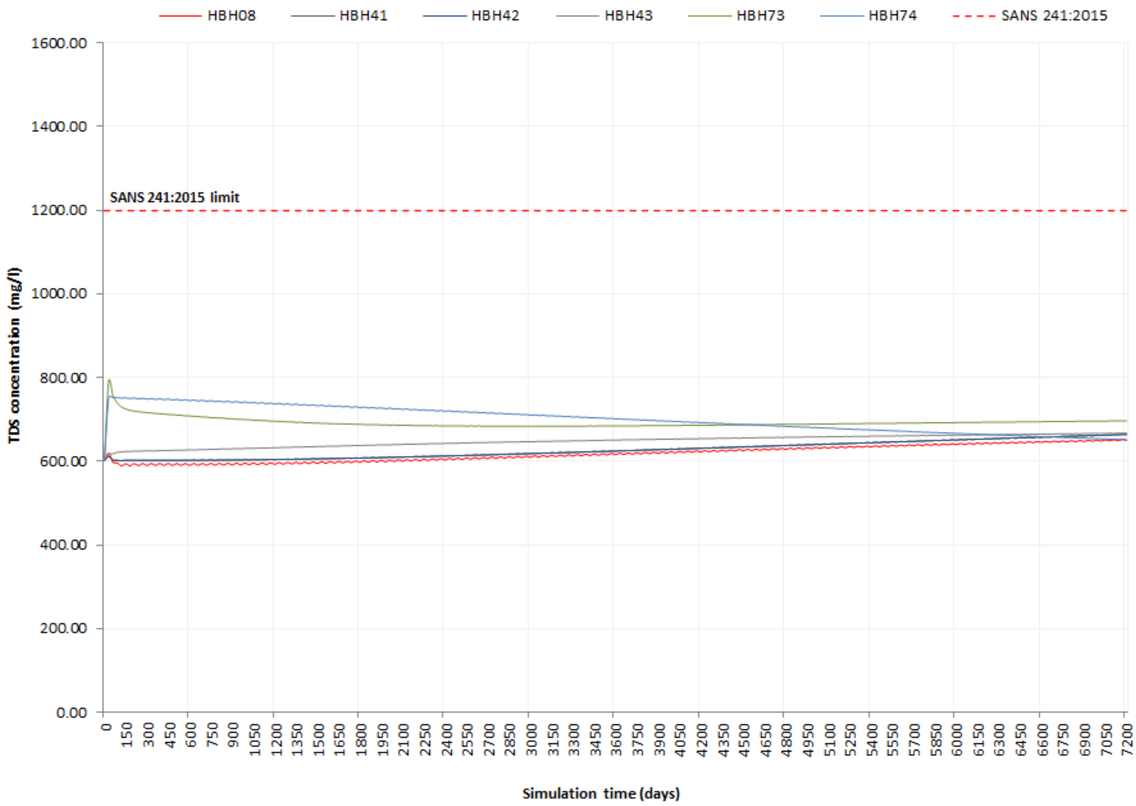


Figure 12-21 **Scenario 02a: Time-series graph indicating the TDS mass load contribution of deeper, fractured and saline aquifer on observation boreholes targetting the potable shallow, intergranular aquifer (Operational phase).**

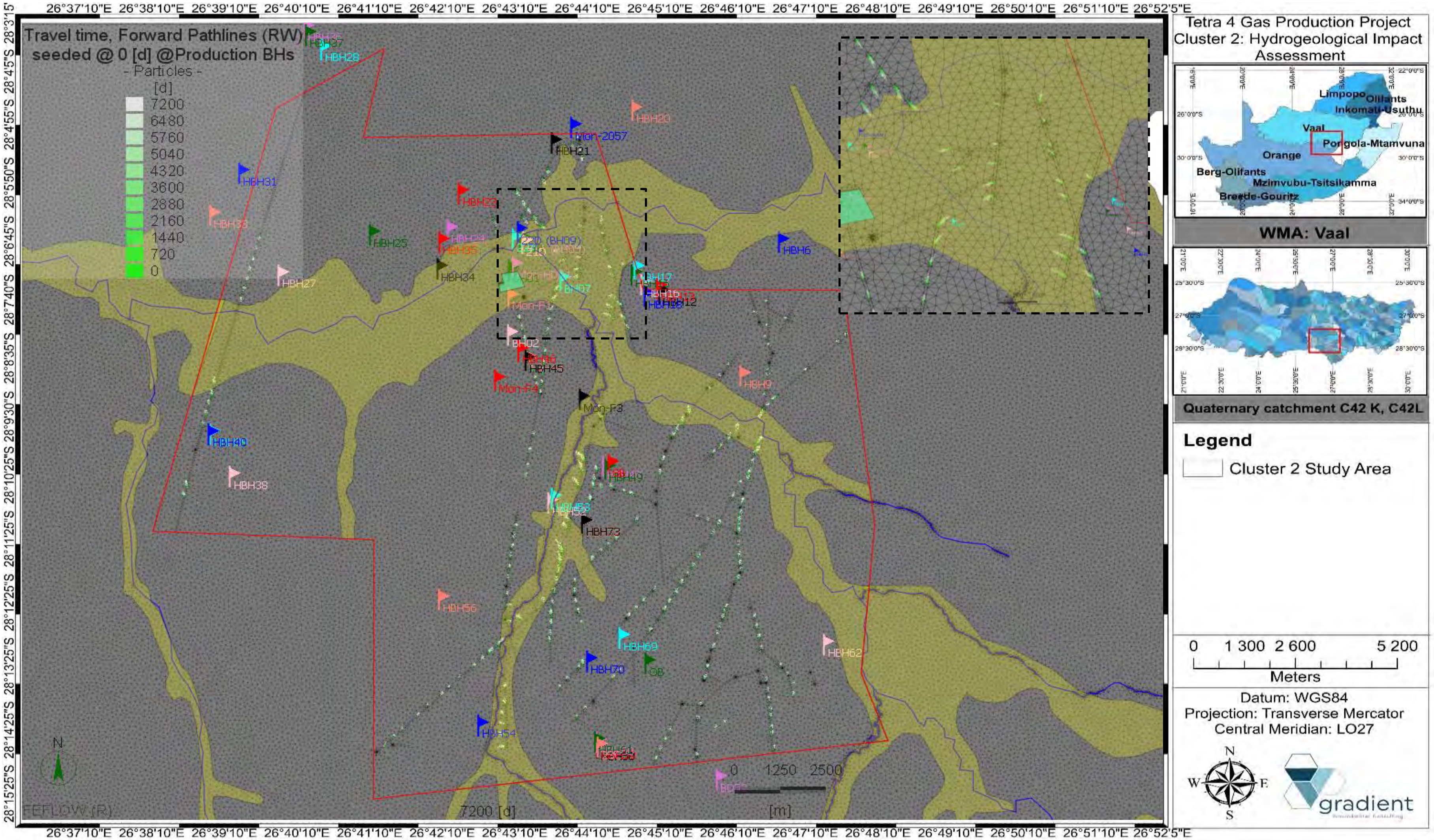


Figure 12-22 **Scenario 02: Simulated particle tracking of contaminants originating from the deeper, fractured aquifer migrating from leaking boreholes within the intergranular aquifer (Operational phase).**

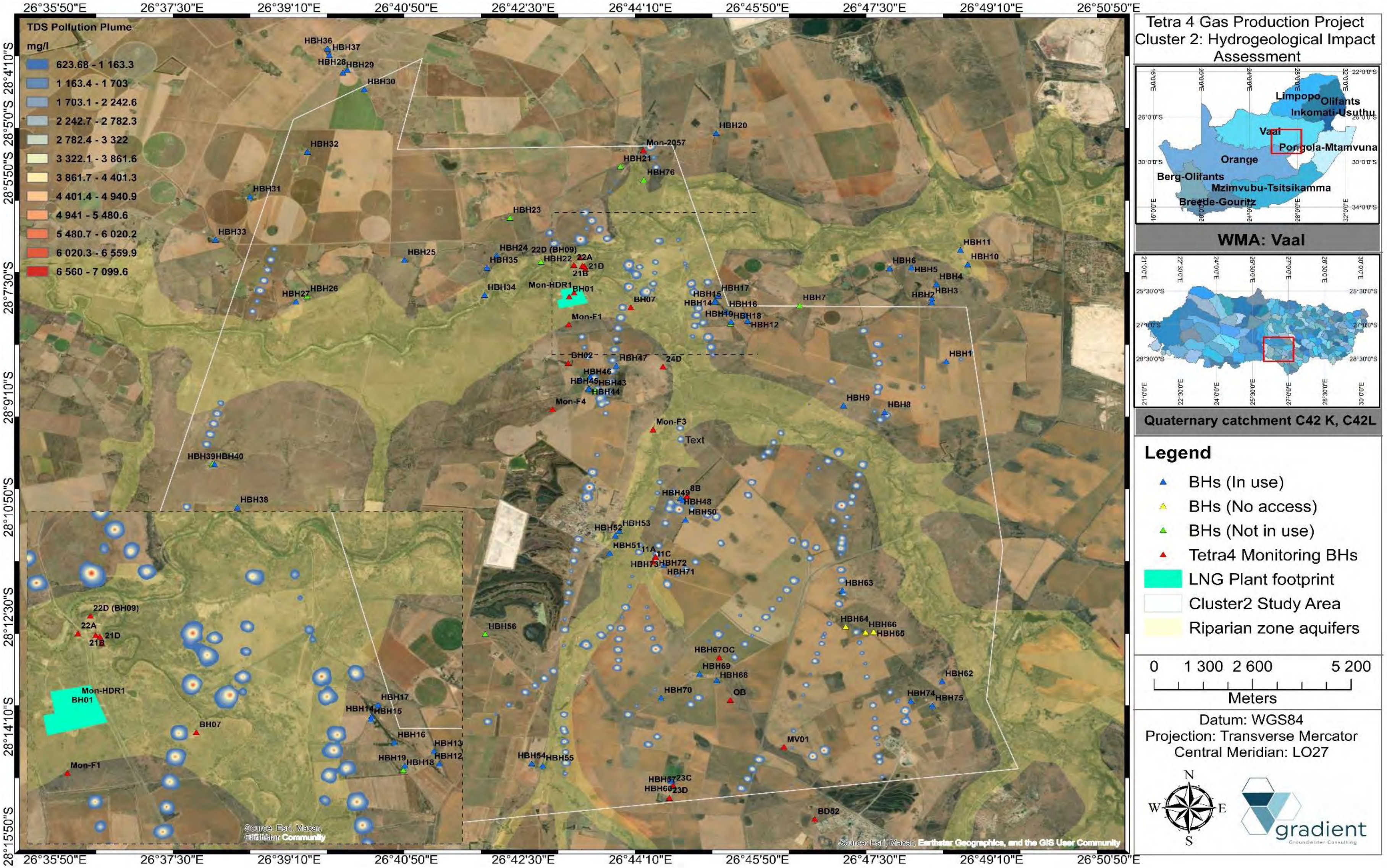


Figure 12-23 **Scenario 02a: TDS pollution plume migration of contaminants originating from the deeper, fractured aquifer migrating through the intergranular aquifer (Operational phase).**

12.7.3. Scenario 02b: Migration of stray methane (CH_4) gas emanating from the deep, fractured aquifer to the overlying, potable aquifer(s) during the operational gas production phase

This scenario summarises the simulated point source pollution plume migration of stray methane (CH_4) gas emanating from the deep, fractured aquifer should the integrity of the gas production boreholes be jeopardised i.e., leaking boreholes. The CH_4 pollution plume extend covers a total area of approximately 162.74ha in the Karoo formations, reaching a maximum distance of ~50.0m in a radial pattern from the gas production borehole(s), and approximately 62.83ha in the alluvial deposits, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole after a simulation period of 20-years (refer to Figure 12-25). The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH63, HBH72, HBH73 and Tetra4 monitoring borehole 11A. It is noted that the pollution plume does not extend beyond the project boundary.

Figure 12-24 summarises a time-series graph of the CH_4 mass load contribution to down-gradient receptors. It is evident that source term mass load contribution to existing neighbouring borehole situated near the gas production boreholes remains below the EPA safety threshold (2011) of 10.0mg/l and ranges between 0.01mg/l to 1.50mg/l.

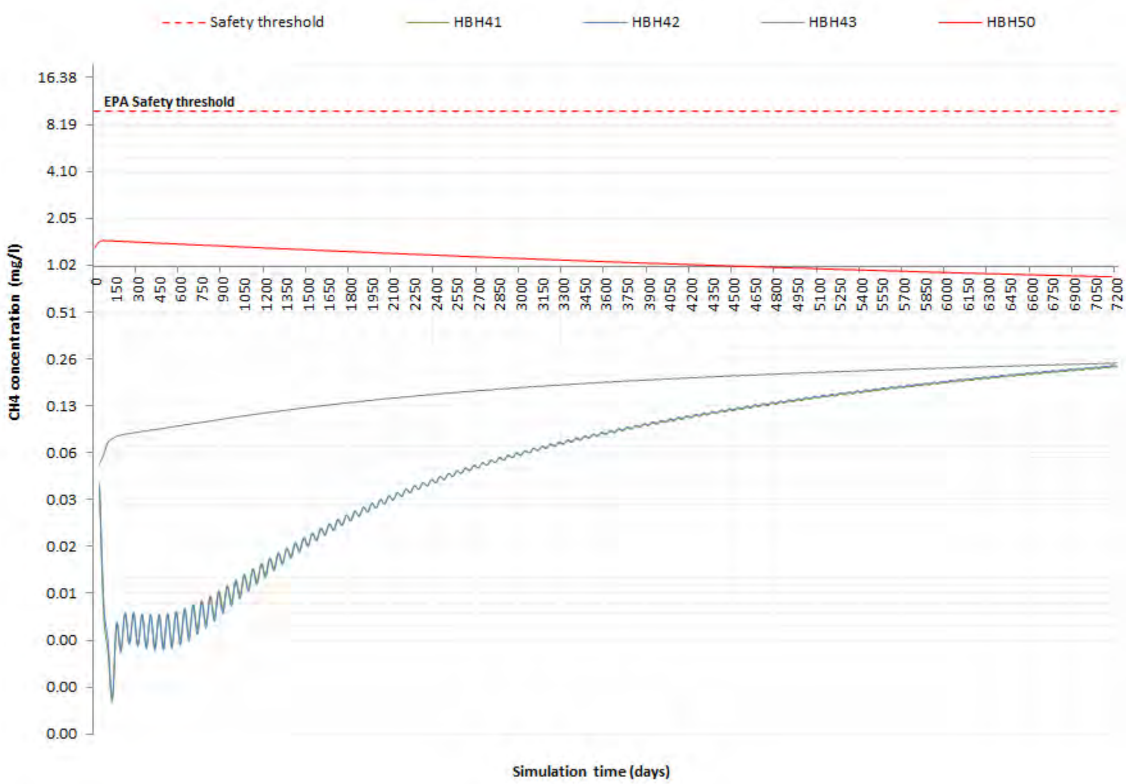


Figure 12-24 **Scenario 02b: Time-series graph indicating the CH_4 mass load contribution of deeper, fractured aquifer on observation boreholes targetting the potable shallow, intergranular aquifer (Operational phase).**

Figure 12-25 Scenario 02b: CH_4 pollution plume migration of contaminants originating from the deeper, fractured aquifer migrating through the intergranular aquifer (Operational phase).

12.7.4. Scenario 03: Migration of the TDS pollution plume emanating from the plant footprint area during the operational gas production phase

This scenario summarises the simulated pollution plume migration from the plant footprint areas for the operational phase. The TDS pollution plume extend covers a total area of approximately 48.80ha reaching a maximum distance of ~110.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 20-years as depicted in Figure 12-29. The simulation indicates that no neighbouring boreholes or local drainages are expected to be impacted on during the operational phase.

Figure 12-26 summarises a time-series graph of the TDS mass load contribution to down-gradient receptors[13]. It is evident that the TDS mass load contribution to down-gradient receptors increase to a concentration of between 200.0 – 800.0 mg/l, however, remains below the SANS 241:2015 limit of 1200.0mg/l for the duration of the simulation period.

Figure 12-27 depicts a model cross section of the pollution plume migration within the simulated aquifer. It is evident that the mass transport of the pollution plume is mostly limited to the shallow, intergranular aquifer.

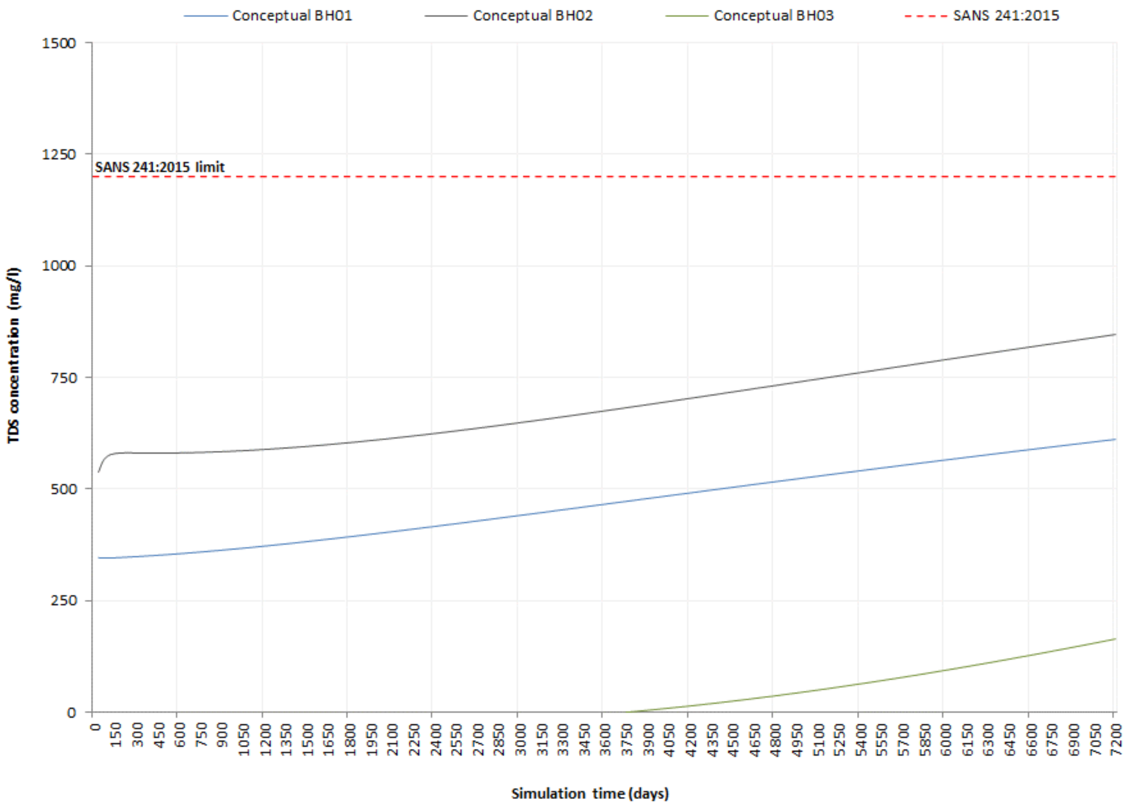


Figure 12-26 **Scenario 03: Time-series graph indicating the TDS mass load emenating from the plant footprint on down-gradient observation boreholes targetting the potable shallow, intergranular aquifer (Operational phase).**

[13] Conceptual boreholes were used as receptors as no boreholes are situated in the direct down-gradient vicinity of the plant footprint.

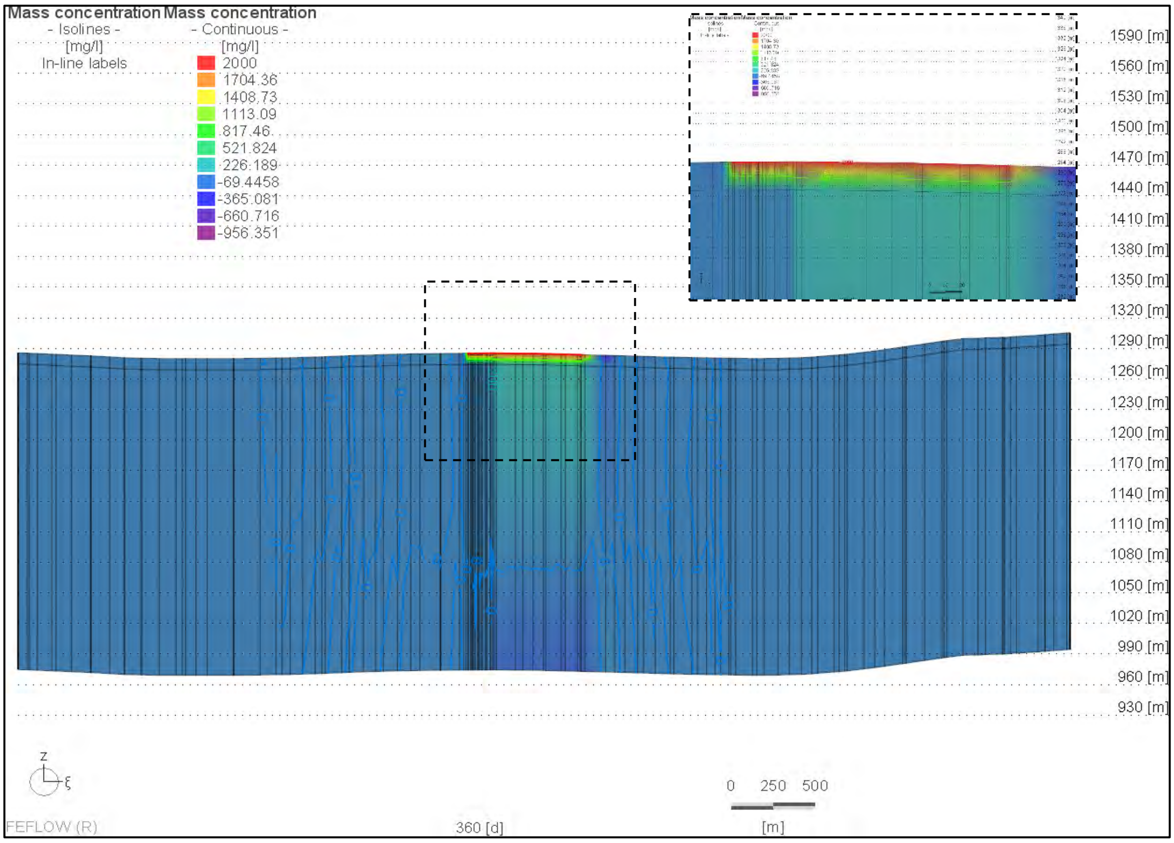


Figure 12-27 **Scenario 03: Model domain 3-D FEM mesh view (cross sectional view soutwest-northeast orientation A-A') of the TDS pollution plume originating at the plant footprint (Operational phase).**

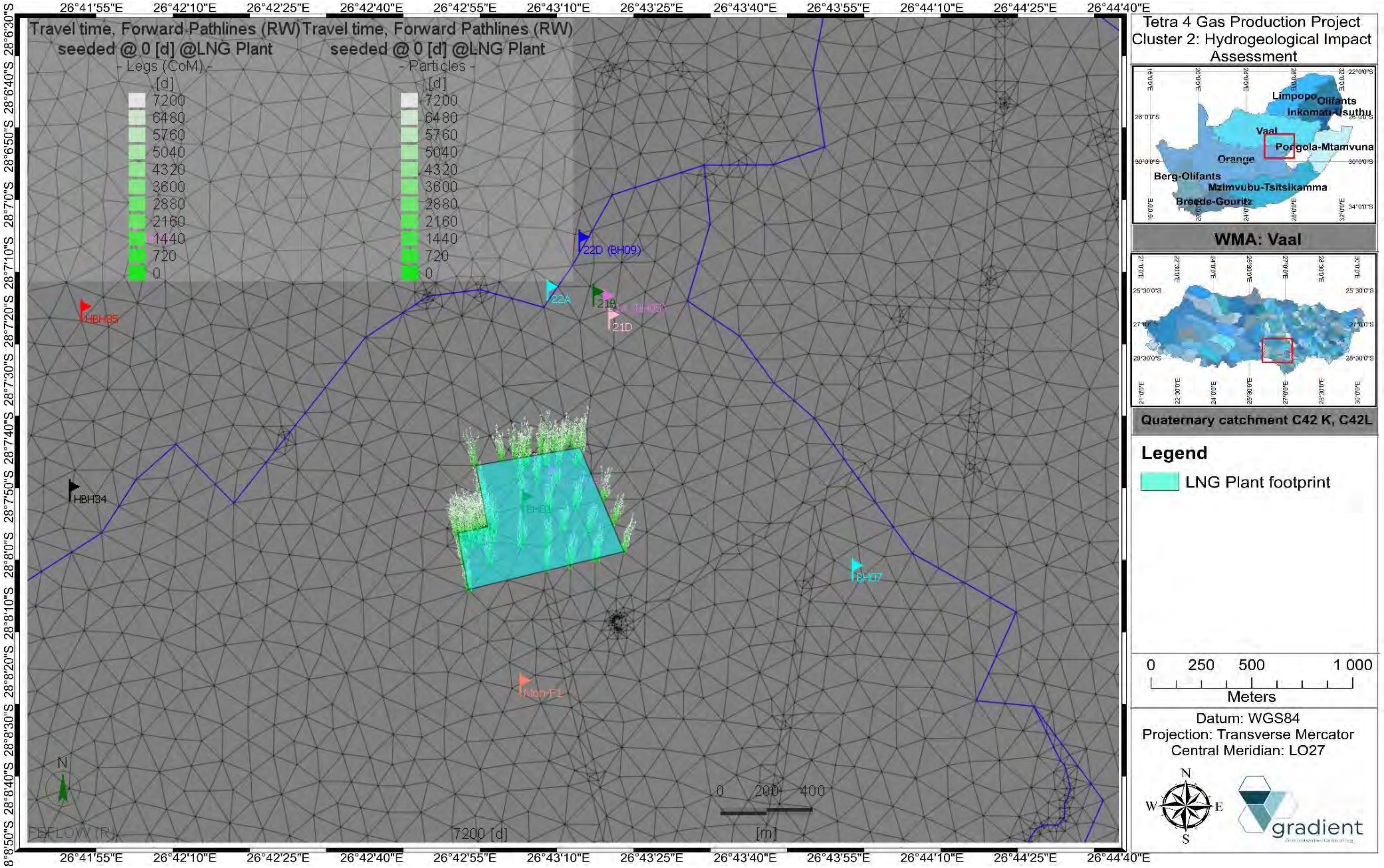


Figure 12-28 **Scenario 03: Simulated particle tracking of contaminants originating from the plant footprint within the intergranular aquifer (Operational phase).**

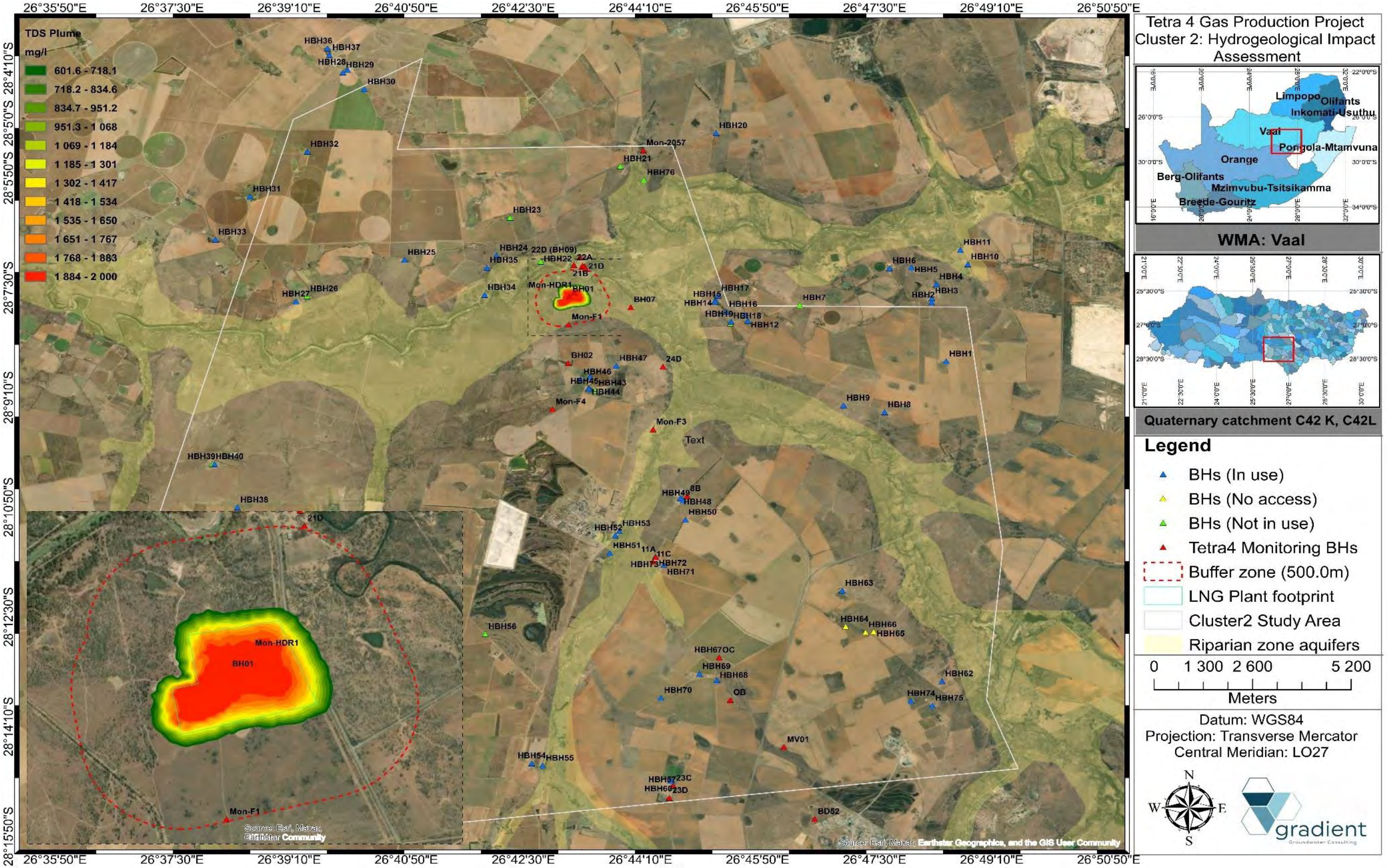


Figure 12-29 **Scenario 03: TDS pollution plume migration of contaminants originating from the plant footprint within the intergranular aquifer (Operational phase).**

12.7.5. Scenario 04a: Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the post-closure and decommissioning phase (50-year and 100-year scenarios)

This scenario summarises the simulated point source pollution plume migration of saline groundwater emanating from the deep, fractured aquifer should the integrity of the gas production boreholes be jeopardised i.e., leaking boreholes for the post-closure phase. The TDS pollution plume extend covers a total area of approximately 643.70ha in the Karoo formations, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole(s), and approximately 392.70ha in the alluvial deposits, reaching a maximum distance of ~250.0m in a radial pattern from the gas production borehole(s) after a simulation period of 50-years.

The TDS pollution plume extend covers a total area of approximately 1 456.42ha in the Karoo formations, reaching a maximum distance of ~150.0m in a radial pattern from the gas production borehole(s), and approximately 769.70ha in the alluvial deposits, reaching a maximum distance of ~350.0m in a radial pattern from the gas production borehole(s) after a simulation period of 100-years (refer to Figure 12-32). The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH48, HBH50, HBH63, HBH72, HBH73, HBH74 as well as Tetra4 monitoring boreholes Mon 2057 and 11A. It is noted that the pollution plume does not extend beyond the project boundary.

Figure 12-31 indicates the expected flow pathways of particles derived from the source points and as noted earlier, it is evident that the pollution plume migration in the denser Karoo formations is sluggish while movement in the unconsolidated alluvial deposits of the riparian zone suggest a larger flux. Figure 12-21 summarises a time-series graph of the TDS mass load contribution to down-gradient receptors. It is evident that source term mass load contribution to existing neighbouring and monitoring boreholes situated near the gas production boreholes ranges between 650.0mg/l to >1200.0mg/l. It is noted that the SANS241:2015 limit is exceeded at borehole localities HBH63 and Mon 2057.

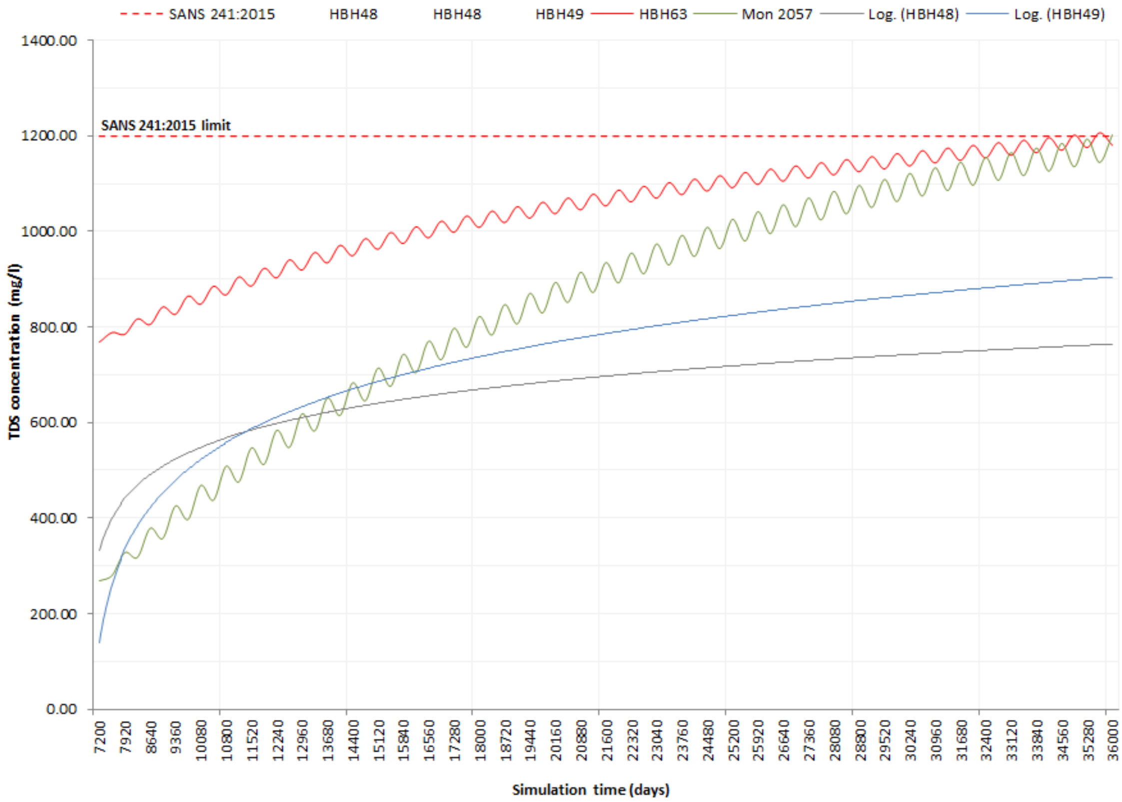


Figure 12-30 **Scenario 04a: Time-series graph indicating the TDS mass load contribution of deeper, fractured and saline aquifer on observation boreholes targetting the potable shallow, intergranular aquifer (Post-closure phase).**

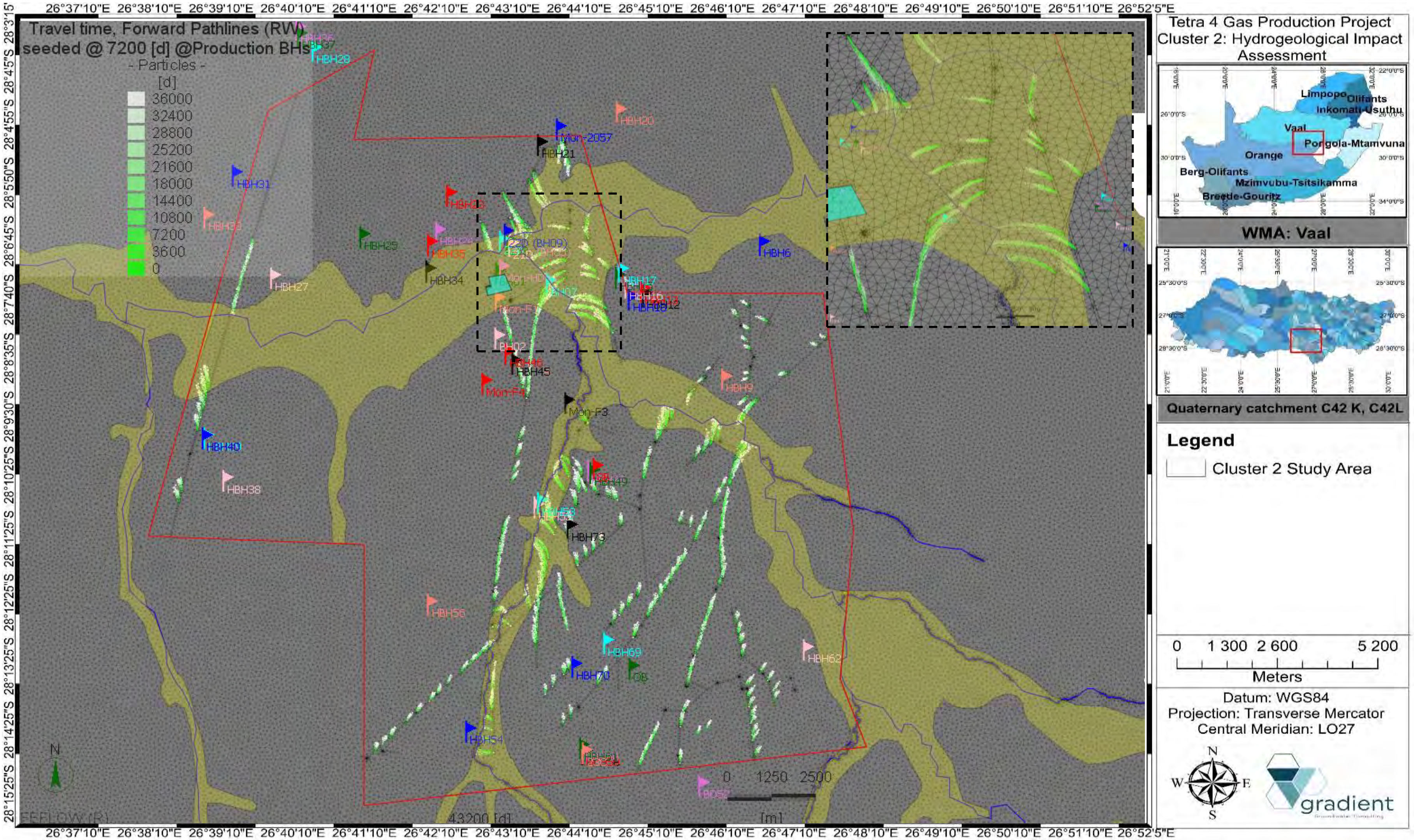


Figure 12-31 **Scenario 04: Simulated particle tracking of contaminants originating from the deeper, fractured aquifer migrating from leaking boreholes within the intergranular aquifer (Post-closure phase).**

Figure 12-32 **Scenario 04a: TDS pollution plume migration of contaminants originating from the deeper, fractured aquifer migrating through the intergranular aquifer (Post-closure phase).**

12.7.6. Scenario 04b: Migration of stray methane (CH_4) gas emanating from the deep, fractured aquifer to the overlying, potable aquifer(s) during the post-closure and decommissioning phase (50-year and 100-year scenarios)

This scenario summarises the simulated point source pollution plume migration from of stray methane (CH_4) gas emanating from the deep, fractured aquifer should the integrity of the gas production boreholes be jeopardised i.e., leaking boreholes for the post-closure phase. The CH_4 pollution plume extend covers a total area of approximately 414.06ha in the Karoo formations, reaching a maximum distance of ~80.0m in a radial pattern from the gas production borehole(s), and approximately 141.37ha in the alluvial deposits, reaching a maximum distance of ~150.0m in a radial pattern from the gas production borehole(s) after a simulation period of 50-years.

The CH_4 pollution plume extend covers a total area of approximately 643.70ha in the Karoo formations, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole(s), and approximately 392.70ha in the alluvial deposits, reaching a maximum distance of ~250.0m in a radial pattern from the gas production borehole(s) after a simulation period of 100-years (refer to Figure 12-34). The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH48, HBH49, HBH63, HBH72, HBH73 as well as Tetra4 monitoring boreholes Mon 2057 and 11A. It is noted that the pollution plume does not extend beyond the project boundary.

Figure 12-33 summarises a time-series graph of the CH_4 mass load contribution to down-gradient receptors. It is evident that source term mass load contribution to existing neighbouring and monitoring boreholes situated near the gas production boreholes ranges between 0.50mg/l to ~2.0mg/l, however, remains below the EPA safety threshold (2011) of 10.0mg/l.

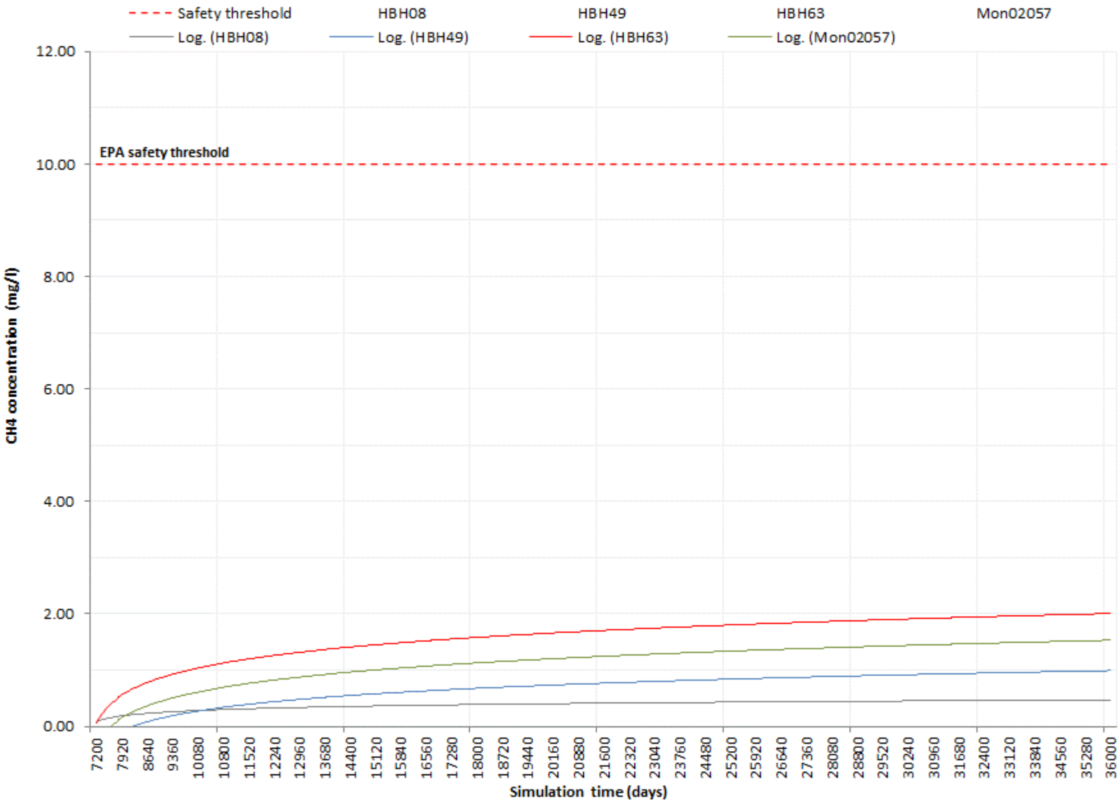


Figure 12-33 **Scenario 04b: Time-series graph indicating the CH_4 mass load contribution of waste facilities on down-gradient receptors.**

Figure 12-34 **Scenario 04b: CH_4 pollution plume migration of contaminants originating from the deeper, fractured aquifer migrating through the intergranular aquifer (Post-closure phase).**

12.7.7. Scenario 05: Migration of the TDS pollution plume emanating from the plant footprint area during the post-closure and decommissioning phase (50-year and 100-year scenarios)

This scenario summarises the simulated pollution plume migration from the plant footprint areas for the post-closure phase. The TDS pollution plume extend covers a total area of approximately 54.8ha reaching a maximum distance of ~170.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 50-years and covers a total area of approximately 71.20ha reaching a maximum distance of ~300.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 100-years as depicted in Figure 12-39.

Figure 12-37 and Figure 12-38 indicates the expected flow pathways of particles for the 50- and 100-years simulation periods respectively, and it is evident that the pollution plume potentially reaches the local drainages system down-gradient of the plant footprint during the post-closure phase.

Figure 12-35 summarises a time-series graph of the TDS mass load contribution to down-gradient receptors. It is evident that the TDS mass load contribution to down-gradient receptors increase to a concentration above the SANS 241:2015 limit of 1200.0mg/l for the post-closure simulation period.

Figure 12-36 summarises a time-series graph of the TDS mass load percentage contribution to down-gradient river receptors of the Sandrivier and Doringrivier. It is evident that the TDS mass load contribution increases to a percentage of ~10.0% to the Sandrivier where the mass load contribution to the Doringrivier increase to a percentage of ~2.0% for the duration of the post-closure simulation period.

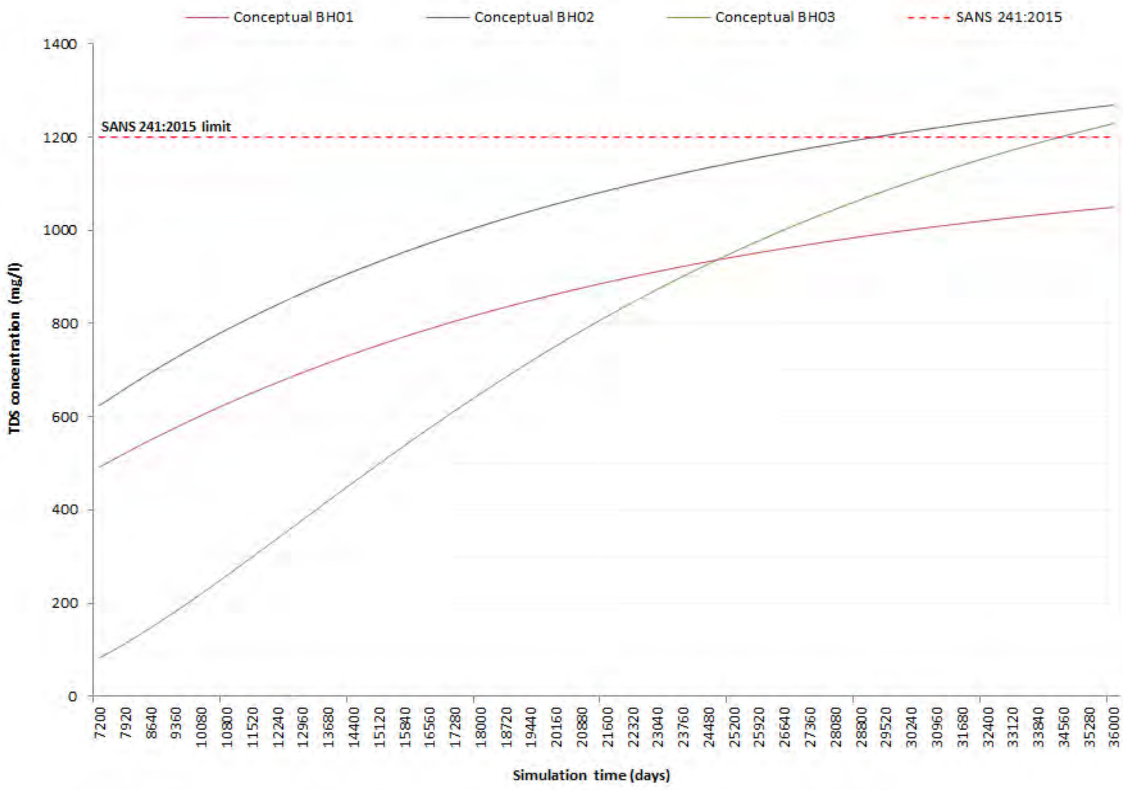


Figure 12-35 **Scenario 05: Time-series graph indicating the TDS mass load emenating from the plant footprint on down-gradient observation boreholes targetting the potable shallow, intergranular aquifer (Post-closure phase).**

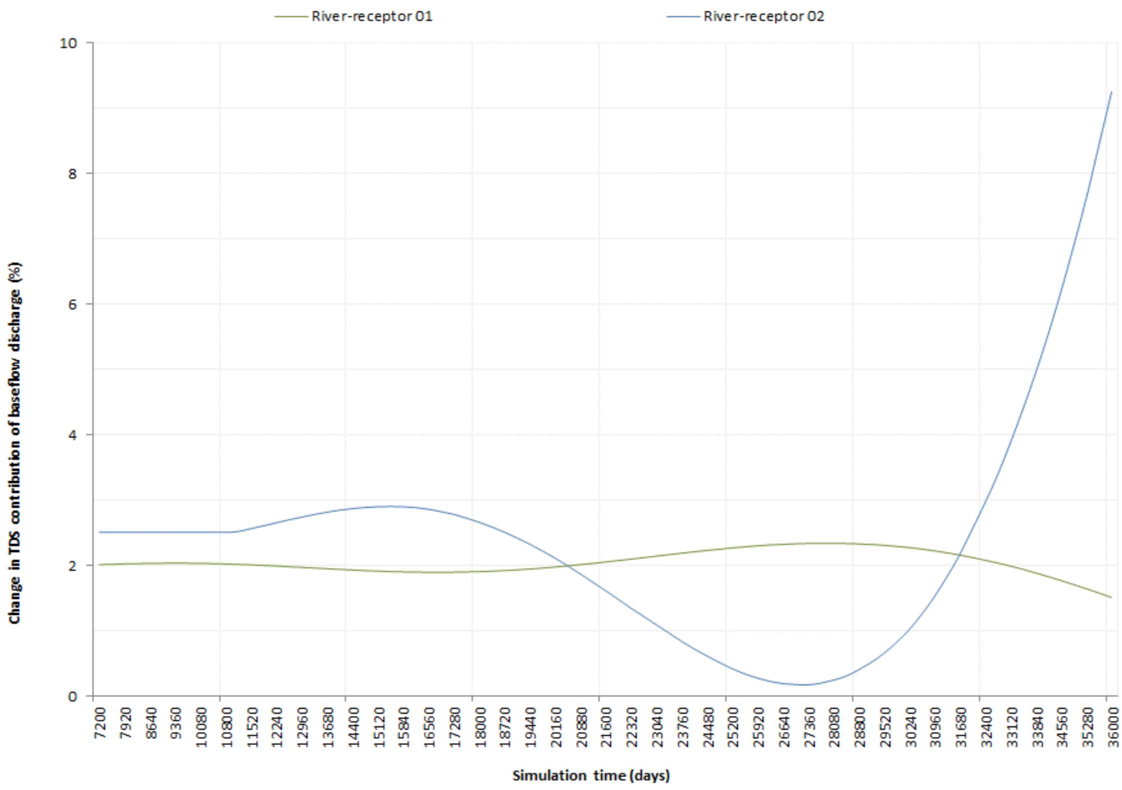


Figure 12-36 **Scenario 05: Time-series graph indicating the TDS mass load emenating from the plant footprint on down-gradient river receptors expressed as the percentage change in salt load (Post-closure phase).**

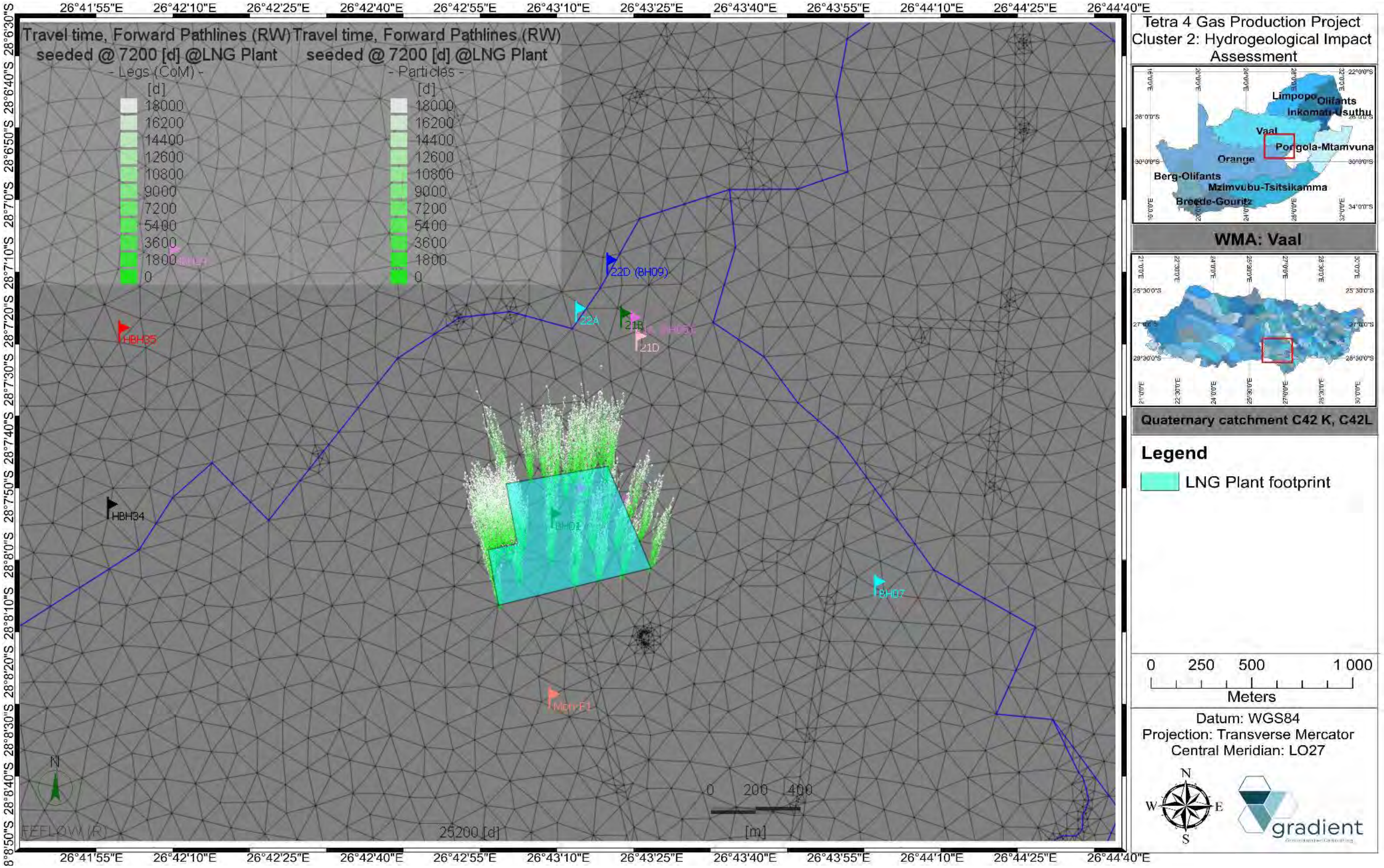


Figure 12-37 **Scenario 05: Simulated particle tracking of contaminants originating from the plant footprint within the intergranular aquifer (50-years post-closure).**

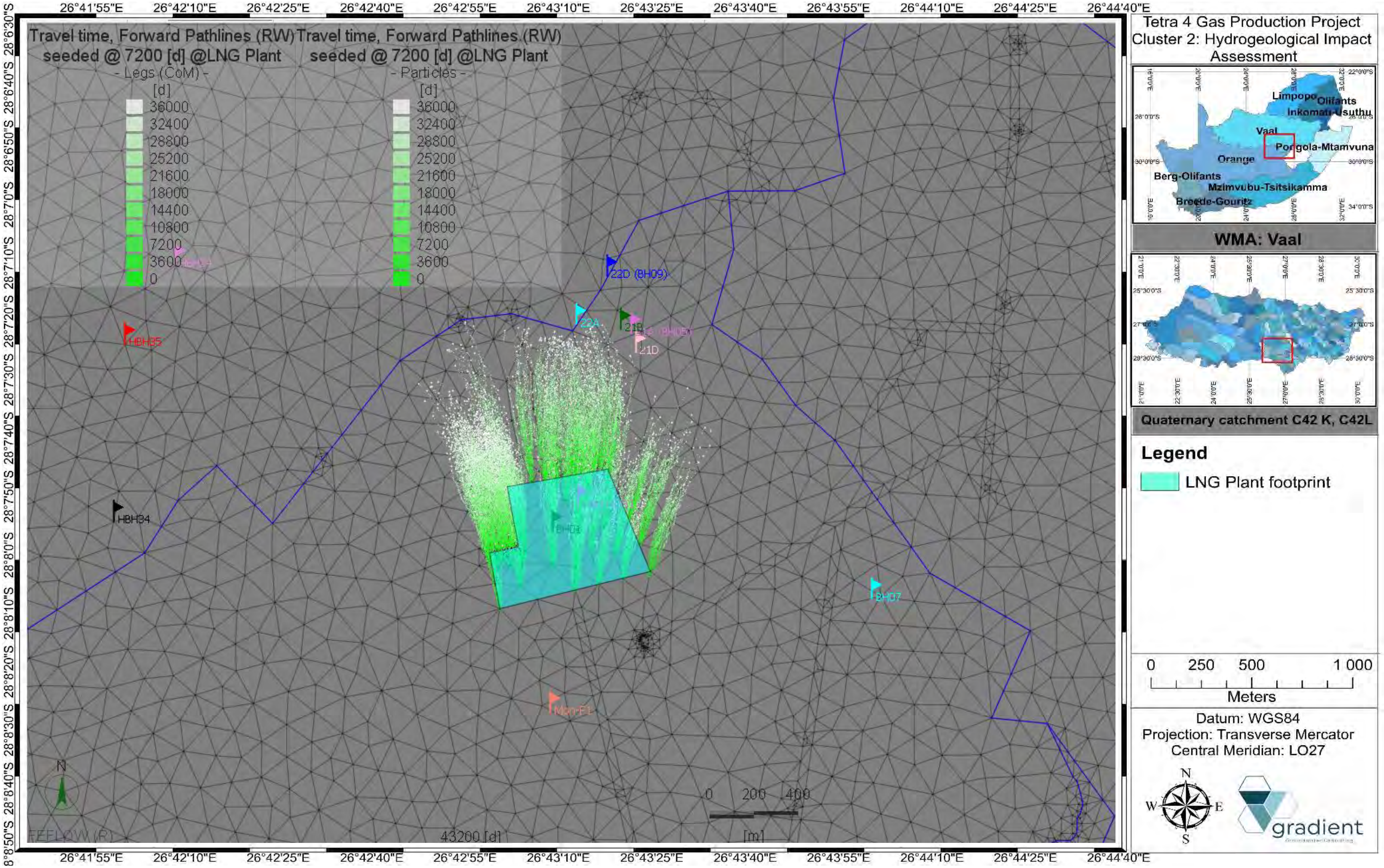


Figure 12-38 **Scenario 05: Simulated particle tracking of contaminants originating from the plant footprint within the intergranular aquifer (100-years post-closure).**

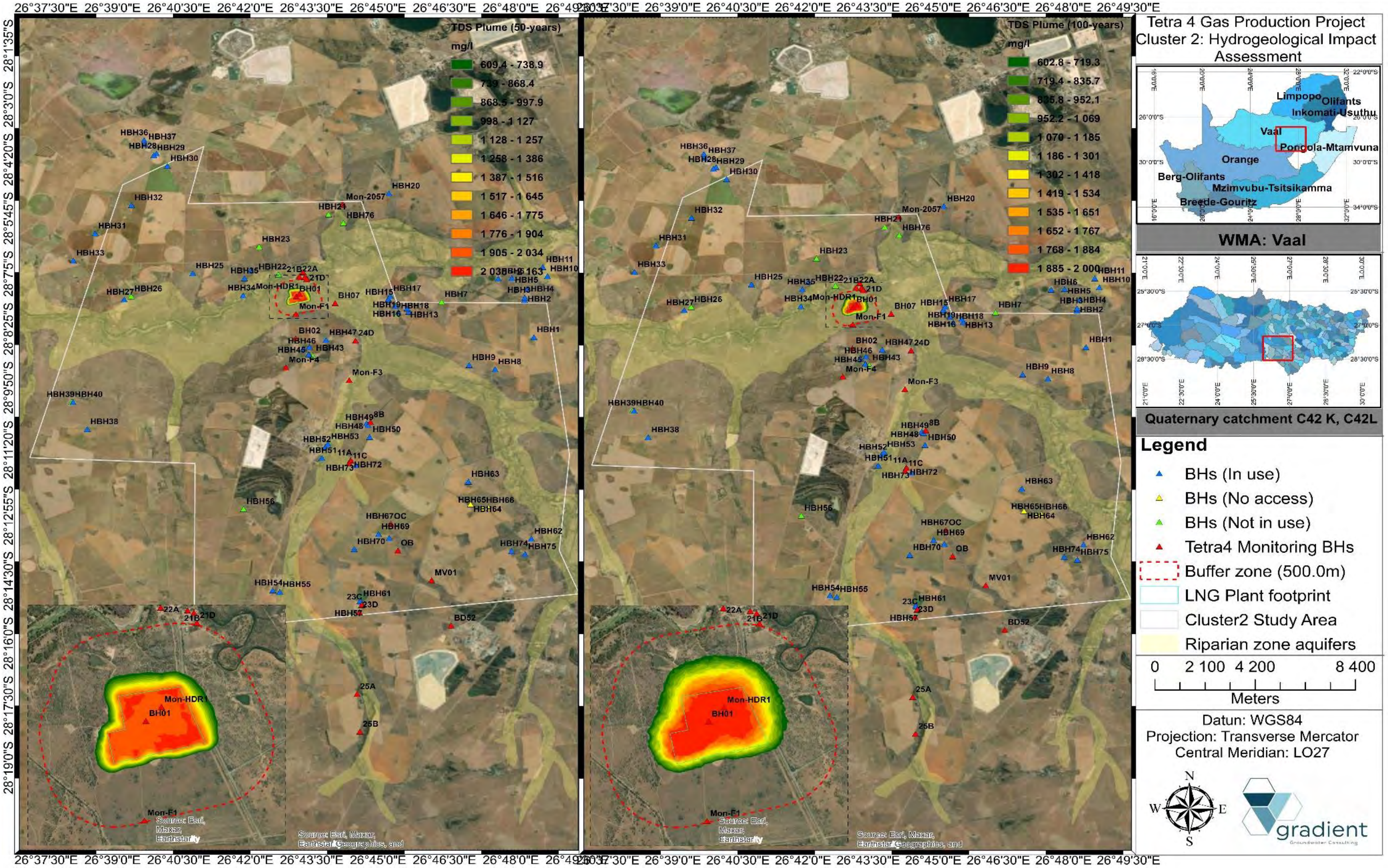


Figure 12-39 **Scenario 05: TDS pollution plume migration of contaminants originating from the plant footprint within the intergranular aquifer (Post-closure phase).**

13. ENVIRONMENTAL IMPACT ASSESSMENT

Identification of potential impacts and ratings related to the proposed activities are briefly discussed below.

13.1. Methodology

An impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human and/or other related activities. The impact significance rating methodology is guided by the requirements of the NEMA EIA Regulations 2014 (as amended). The broad approach to the significance rating methodology is to determine the environmental risk (**ER**) by considering the consequence (**C**) of each impact (comprising **N**ature, **E**xtent, **D**uration, **M**agnitude, and **R**eversibility) and relate this to the probability/ likelihood (**P**) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (**PF**) which is applied to the **ER** to determine the overall significance (**S**). The impact assessment will be applied to all identified alternatives. Where possible, mitigation measures will be recommended for impacts identified.

13.2. Determination of Environmental Risk

The significance (**S**) of an impact is determined by applying a prioritisation factor (**PF**) to the environmental risk (**ER**). The environmental risk is dependent on the consequence (**C**) of the particular impact and the probability (**P**) of the impact occurring. Consequence is determined through the consideration of the Nature (**N**), Extent (**E**), Duration (**D**), Magnitude (**M**), and reversibility (**R**) applicable to the specific impact. For the purpose of this methodology the consequence of the impact is represented by the following equation:

Equation 13-1 Impact Consequence.

$$\mathbf{C} = (\boldsymbol{E} + \boldsymbol{D} + \boldsymbol{M} + +\boldsymbol{R})(\boldsymbol{N}\mathbf{4})$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 13-1 below with Table 13-2 summarising the probability scorings.

Table 13-1 Criteria for Determining Impact Consequence.

Aspect	Description	Weight
Nature	Likely to result in a negative/ detrimental impact.	-1
	Likely to result in a positive/ beneficial impact.	1
Extend	Activity (i.e., limited to the area applicable to the specific activity)	1
	Site (i.e., within the development property boundary)	2
	Local (i.e., the area within 5 km of the site)	3
	Regional (i.e., extends between 5 and 50 km from the site)	4
	Provincial/ National (i.e., extends beyond 50 km from the site)	5
Duration	Immediate (< 1 year)	1
	Short term (1 – 5 years)	2
	Medium term (6 – 15 years)	3
	Long term (the impact will cease after the operational life span of the project)	4
	Permanent (no mitigation measure of natural process will reduce the impact after construction).	5
Magnitude	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected)	1
	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected)	2
	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way)	3
	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or	4
	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).	5
Reversibility	Impact is reversible without any time and cost	1
	Impact is reversible without incurring significant time and cost	2
	Impact is reversible only by incurring significant time and cost	3
	Prohibitively high time and cost	4
	Irreversible	5

Table 13-2 Probability scoring.

Probability	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%)	1
	Low probability (there is a possibility that the impact will occur; >25% and <50%)	2
	Medium probability (the impact may occur; >50% and <75%)	3
	High probability (it is most likely that the impact will occur- > 75% probability) or	4
	Definite (the impact will occur)	5

The result is a qualitative representation of relative **ER** associated with the impact. **ER** is therefore calculated by applying the following equation:

Equation 13-2 Impact Consequence.

$$\mathrm{ER} = \boldsymbol{C} \,.\, \boldsymbol{P}$$

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25 as summarised in Table 13-4. These **ER** scores are then grouped into respective classes as described in Table 13-4.

Table 13-3 Determination of Environmental Risk.

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5

Table 13-4 Significance classes.

Environmental Risk Score	Low (i.e., where this impact is unlikely to be a significant environmental risk)	< 9
	Medium (i.e., where the impact could have a significant environmental risk)	≥ 9 - <17
	High (i.e., where the impact will have a significant environmental risk)	≥ 17

The impact **ER** will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

13.3. Impact prioritization

Further to the assessment criteria presented in the section above, it is necessary to assess each potentially significant impact in terms of:

i. Cumulative impacts; and

ii. The degree to which the impact may cause irreplaceable loss of resources.

To ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented. The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 13-5.

Table 13-5 Criteria for Determining Prioritisation.

Cumulative Impact (C)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change	Low (1)
	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change	Medium (2)
	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/ definite that the impact will result in spatial and temporal cumulative change	High (3)
Irreplaceable loss of Resource (LR)	Where the impact is unlikely to result in irreplaceable loss of resources	Low (1)
	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited	Medium (2)
	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions)	High (3)

The impact priority is therefore determined as follows:

Equation 13-3 Impact Consequence.

$$\text{Priority } = \boldsymbol{CI + LR}$$

The result is a priority score which ranges from 3 to 9 and a consequent **PF** ranging from 1 to 2 (Refer to Table 13-6 below).

Table 13-6 Determination of Prioritisation Factor.

Priority	Ranking	Prioritisation factor
2	Low	1
3	Medium	1.125
4	Medium	1.25
5	Medium	1.375
6	High	1.5

In order to determine the final impact significance (Table 13-7), the **PF** is multiplied by the **ER** of the post mitigation scoring. The ultimate aim of the **PF** is an attempt to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e., if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 13-7 Final Environmental Significance Rating.

Value	Description
≤ -20	High negative (i.e., where the impact must have an influence on the decision process to develop in the area).
> -20 ≤ -10	Medium negative (i.e., where the impact could influence the decision to develop in the area).
> -10	Low negative (i.e., where this impact would not have a direct influence on the decision to develop in the area).
0	No impact
< 10	Low positive (i.e., where this impact would not have a direct influence on the decision to develop in the area).
≥ 10 < 20	Medium positive (i.e., where the impact could influence the decision to develop in the area).
≥ 20	High positive (i.e., where the impact must have an influence on the decision process to develop in the area).

The significance ratings and additional considerations applied to each impact will be used to provide a quantitative comparative assessment of the alternatives being considered. In addition, professional expertise and opinion of the specialists and the environmental consultants will be applied to provide a qualitative comparison of the alternatives under consideration. This process will identify the best alternative for the proposed project.

13.4. Impact Identification and significance ratings

It should be noted that vast areas within the study area have been subjected to historical mining activities and, as such, reflect modified to highly modified present ecological status. A total number of >15 000 historical exploration wells have been drilled throughout the study area, some of which remain uncased and unsealed. The latter may act as preferential pathways and conduits for groundwater flow and contaminant transport mechanisms. As mentioned earlier an impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human and/or other related activities. Accordingly, this already highly modified zones should form part of the impact significance rating and risk approach. Impacts and significant ratings associated different project phases are briefly discussed below.

13.4.1. Construction phase: Associated activities and impacts

Refer to Table 13-8 for a summary of the impact risk matrix and significance ratings for the construction phase. During the construction phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium negative** without implementation of remedial measures and **low negative** with implementation of proposed mitigation measures. The main impacts associated with the construction phase activities include the following:

1. Groundwater deterioration and siltation due to contaminated stormwater run-off from the construction area (Table 13-9).
2. Poor quality leachate may emanate from the construction camp which may have a negative impact on groundwater quality (Table 13-10).
3. Mobilisation and maintenance of heavy vehicle and machinery on-site may cause hydrocarbon contamination of groundwater resources (Table 13-11).
4. Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution (Table 13-12).

Table 13-8 Impact assessment and significant rating: Construction phase summary.

Imp act	IMPACT DESCRIPTION	PRE - MITIGATION							POST - MITIGATION							IMPACT PRIORITISATION	
No.	Impact	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Priority Factor	Final score
Construction phase																	
1	Groundwater deterioration and siltation due to contaminated stormwater run-off from the construction area.	-1	2	2	2	2	2	-4.00	-1	2	2	1	2	1	-1.75	1.00	-1.75
2	Poor quality leachate may emanate from the construction camp which may have a negative impact on groundwater quality.	-1	3	2	3	3	3	-8.25	-1	2	2	2	3	2	-4.50	1.25	-5.63
3	Mobilisation and maintenance of heavy vehicle and machinery on-site may cause hydrocarbon contamination of groundwater resources.	-1	3	5	4	4	3	-12.00	-1	2	5	4	4	2	-7.50	1.25	-9.38
4	Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution.	-1	3	2	3	3	3	-8.25	-1	2	2	2	3	2	-4.50	1.25	-5.63

Table 13-9 Risk assessment matrix and significant scoring: Construction phase impact 01.

Impact Name	**Groundwater deterioration and siltation due to contaminated stormwater run-off from the construction area.**				
Alternative	**Alternative 1**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	2	1
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	2	1
Environmental Risk (Pre-mitigation)					-4.00
Mitigation Measures					
Mitigation Measures	i. Develop a stormwater management plan in accordance with GN704 in order to separate dirty/contact water from clean water circuits. All water retention structures, process water dams; storm water dams, retention ponds etc. should be constructed to have adequate freeboard to be able to contain water from 1:50 year rain events. ii. All construction should take place during the dry season, as far as possible. iii. Location of construction camps must be carefully considered and within the approved area to ensure that the site does not impact on sensitive areas identified during the Environmental Assessment phase or field work. iv. Sites must be located, where possible, on previously disturbed areas. v. Every effort must be made to keep the footprint as small as possible.				
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikley that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-1.75

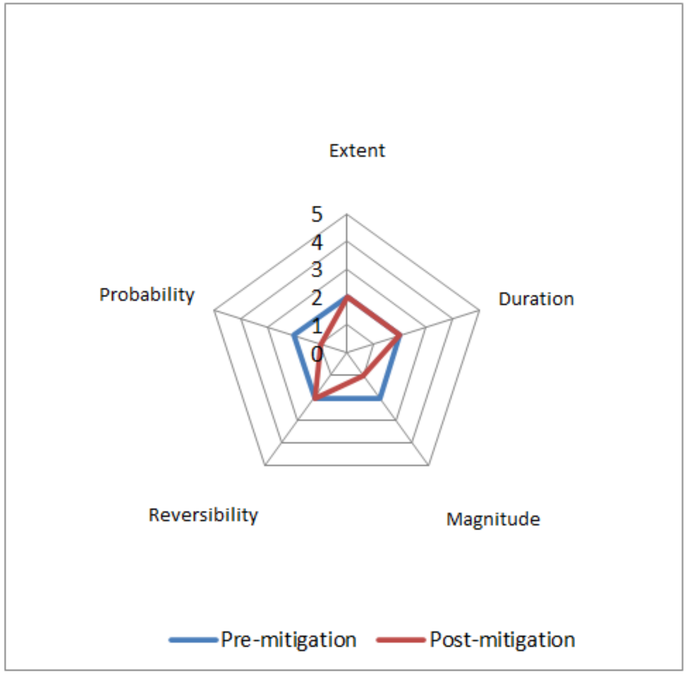


Table 13-10 Risk assessment matrix and significant scoring: Construction phase impact 02.

Impact Name	**Poor quality leachate may emanate from the construction camp which may have a negative impact on groundwater quality.**				
Alternative	**Alternative 1**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	3	2
Environmental Risk (Pre-mitigation)					-8.25
Mitigation Measures					
Mitigation Measures	i. Develop a stormwater management plan in accordance with GN704 in order to separate dirty/contact water from clean water circuits. All water retention structures, process water dams; storm water dams, retention ponds etc. should be constructed to have adequate freeboard to be able to contain water from 1:50 year rain events. ii. All construction should take place during the dry season, as far as possible. iii. Location of construction camps must be carefully considered and within the approved area to ensure that the site does not impact on sensitive areas identified during the Environmental Assessment phase or field work. iv. Sites must be located, where possible, on previously disturbed areas. v. Any excess sand, stone and cement must be removed or reused from site on completion of the construction period and disposed at a registered disposal facility. Certificates of safe disposal for general and recycled waste must be maintained and retained on file.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-5.63

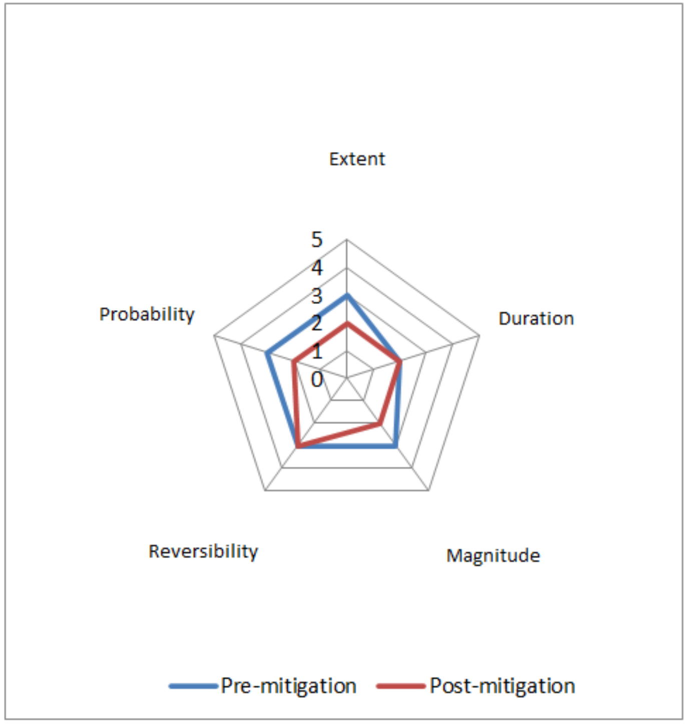


Table 13-11 Risk assessment matrix and significant scoring: Construction phase impact 03.

Impact Name	**Mobilisation and maintenance of heavy vehicle and machinery on-site may cause hydrocarbon contamination of groundwater resources.**				
Alternative	**Alternative 1**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	3	2	Reversibility of Impact	4	4
Duration of Impact	5	5	Probability	3	2
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Mitigation Measures	i. Construction vehicles and machinery must be serviced and maintained regularly in order to ensure that oil spillages are limited. Spill trays must be provided if refuelling of operational vehicles is done on site. Further to this spill kits must be readily available in case of accidental spillages with regular spot checks to be conducted. ii. During servicing of vehicles or equipment, especially where emergency repairs are effected outside the workshop area, a suitable drip tray must be used to prevent spills onto the soil. iii. Leaking equipment must be repaired immediately or be removed from site to facilitate repair. iv. Workshop areas must be monitored for oil and fuel spills. v. An appropriate number of spill kits must be available and must be located in all areas where activities are being undertaken.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-9.38

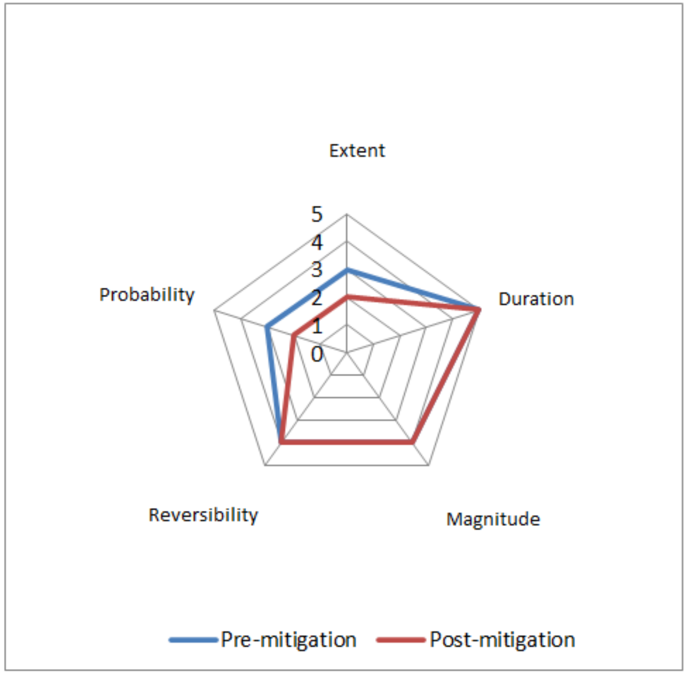
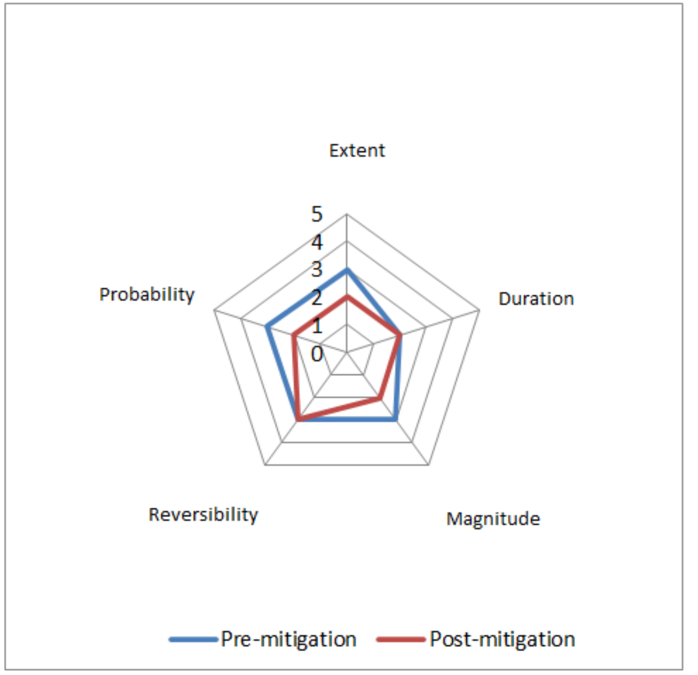


Table 13-12 Risk assessment matrix and significant scoring: Construction phase impact 04.

Impact Name	**Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution.**				
Alternative	**Alternative 1**				
Phase	**Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	3	2
Environmental Risk (Pre-mitigation)					-8.25
Mitigation Measures					
Mitigation Measures	i. All hazardous substances used on-site should have an applicable Material Safety Data Sheet (MSDS) to provide information regarding the hazards, emergency response, protective measures and correct storage methodology. ii. Hazardous substance containment facilities to be used during operational phase should comply with the relevant hazardous substance storage legislation in order to ensure spillages are contained. iii. All hazardous substances and material used on-site should be stored in a dedicated, closed-off facility with an impervious floor and bunded area to prevent seepage and/or run-off in case of accidental spills.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-5.63



13.4.2. Operational phase: Associated activities and impacts

Refer to Table 13-13 for a summary of the impact risk matrix and significance ratings for the construction phase. During the operational phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium** to **high negative** without implementation of remedial measures and **low** to **medium negative** with implementation of proposed mitigation measures. The main impacts associated with the operational phase activities include the following:

1. Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase (Table 13-14).
2. Migration of stray methane (CH_4) gas from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase. (Table 13-15).
3. Groundwater pollution as a result of wastewater spills and seepage from the evaporation dams (Table 13-16).
4. Poor quality leachate may emanate from the plant footprint area which may have a negative impact on groundwater quality (Table 13-17).
5. Mobilisation and maintenance of heavy vehicle and machinery on-site may cause hydrocarbon contamination of groundwater resources (Table 13-18).
6. Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution (Table 13-19).
7. Leakage of harmful substances from tanks, pipelines or other equipment may cause groundwater pollution (Table 13-20).
8. Leachate of contaminants used in the drilling mud sump(s) to the intergranular, potable aquifer(s) during the operational phase (Table 13-21).

Table 13-13 Impact assessment and significant rating: Operational phase summary.

Imp act	IMPACT DESCRIPTION	PRE - MITIGATION							POST - MITIGATION							IMPACT PRIORITISATION	
No.	Impact	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Priority Factor	Final score
Operational phase																	
1	Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.	-1	3	5	5	5	4	-18.00	-1	3	5	4	4	3	-12.00	1.25	-15.00
2	Migration of stray gas from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.	-1	3	5	5	5	4	-18.00	-1	3	5	4	4	3	-12.00	1.25	-15.00
3	Groundwater pollution as a result of wastewater spills and seepage from the evaporation dams.	-1	3	5	4	4	3	-12.00	-1	2	5	4	4	2	-7.50	1.25	-9.38
4	Poor quality leachate may emanate from the plant footprint area which may have a negative	-1	3	5	4	4	3	-12.00	-1	2	5	4	4	2	-7.50	1.25	-9.38

Impact	IMPACT DESCRIPTION	PRE - MITIGATION							POST - MITIGATION							IMPACT PRIORITISATION	
No.	Impact	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Priority Factor	Final score
	impact on groundwater quality.																
5	Mobilisation and maintenance of heavy vehicle and machinery on-site may cause hydrocarbon contamination of groundwater resources.	-1	3	2	3	3	3	-8.25	-1	2	2	2	3	2	-4.50	1.25	-5.63
6	Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution.	-1	3	5	4	4	3	-12.00	-1	2	5	4	4	2	-7.50	1.25	-9.38
7	Leakage of harmful substances from tanks, pipelines or other equipment may cause groundwater pollution.	-1	3	5	4	4	3	-12.00	-1	2	5	4	4	2	-7.50	1.25	-9.38
8	Leachate of contaminants used in the drilling mud sump(s) to the intergranular, potable aquifer(s)	-1	2	3	3	4	4	-12.00	-1	1	3	2	3	3	-6.75	1.00	-6.75

Impact	IMPACT DESCRIPTION	PRE - MITIGATION							POST - MITIGATION							IMPACT PRIORITISATION	
No.	Impact	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Priority Factor	Final score
	during the operational phase.																

Table 13-14 Risk assessment matrix and significant scoring: Operational phase impact 01.

Impact Name	**Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	4
Extent of Impact	3	3	Reversibility of Impact	5	4
Duration of Impact	5	5	Probability	4	3
Environmental Risk (Pre-mitigation)					-18.00
Mitigation Measures					
Mitigation Measures	i. All exploration wells should be sealed-off with a combination of casing and grouting to ensure isolation of the saline water from the host-aquifer(s). ii. Development and implementation of an integrated groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures. iii. Monitoring results should be evaluated and reviewed on a biannual basis by a registered hydrogeologist for interpretation and trend analysis for submission to the Regional Head of Department. Based on the water quality results, the monitoring network should be refined and updated every three to five years based on hydrochemical results obtained to ensure optimisation and adequacy of the proposed localities. iv. The calibrated groundwater flow model should be updated on a bi-annual basis as newly gathered monitoring results become available in order to be applied as groundwater management tool for future scenario predictions.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-15.00

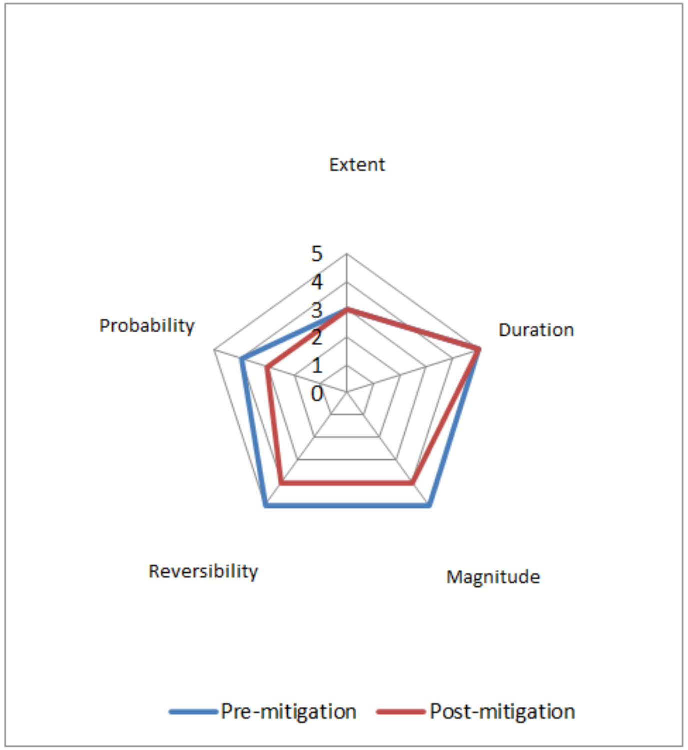


Table 13-15 Risk assessment matrix and significant scoring: Operational phase impact 02.

Impact Name	**Migration of stray gas from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	4
Extent of Impact	3	3	Reversibility of Impact	5	4
Duration of Impact	5	5	Probability	4	3
Environmental Risk (Pre-mitigation)					-18.00
Mitigation Measures					
Mitigation Measures	i. All exploration wells should be sealed-off with a combination of casing and grouting to ensure isolation of the gas from the host-aquifer(s). ii. Development and implementation of an integrated groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures. iii. Monitoring results should be evaluated and reviewed on a biannual basis by a registered hydrogeologist for interpretation and trend analysis for submission to the Regional Head of Department. Based on the water quality results, the monitoring network should be refined and updated every three to five years based on hydrochemical results obtained to ensure optimisation and adequacy of the proposed localities. iv. The calibrated groundwater flow model should be updated on a bi-annual basis as newly gathered monitoring results become available in order to be applied as groundwater management tool for future scenario predictions.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-15.00

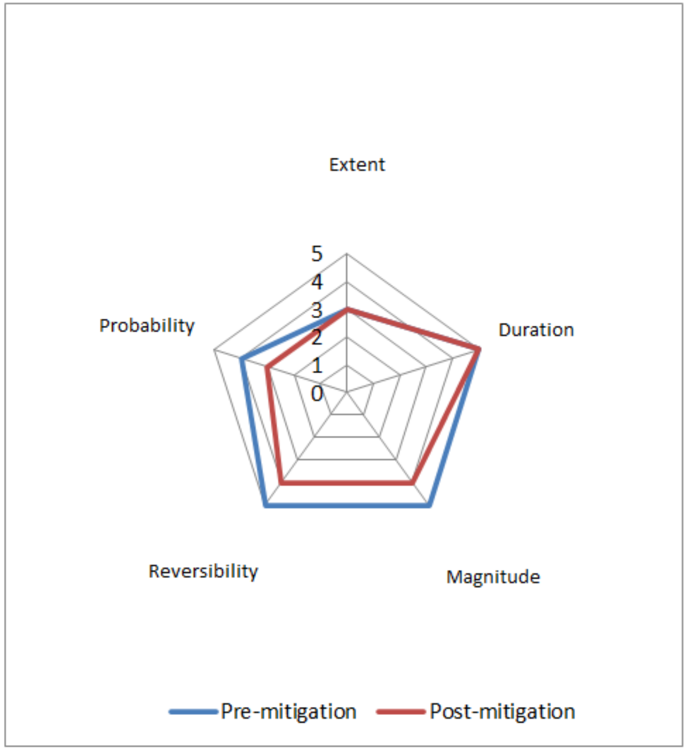


Table 13-16 Risk assessment matrix and significant scoring: Operational phase impact 03.

Impact Name	**Groundwater pollution as a result of wastewater spills and seepage from the evaporation dams.**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	3	2	Reversibility of Impact	4	4
Duration of Impact	5	5	Probability	3	2
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Mitigation Measures	i. Develop a stormwater management plan in accordance with GN704 in order to separate dirty/contact water from clean water circuits. All water retention structures, process water dams; storm water dams, retention ponds etc. should be constructed to have adequate freeboard to be able to contain water from 1:50 year rain events. ii. Development and implementation of an integrated groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures. iii. An appropriately sized spill kit must kept onsite and available at all times. The spill kit size must be relevant to the scale of the activities involving the use of hazardous substances. iv. An appropriate number of spill kits must be available and must be located in all areas where activities are being undertaken. v. The responsible operator must have the required training to make use of the spill kit in emergency situations.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-9.38

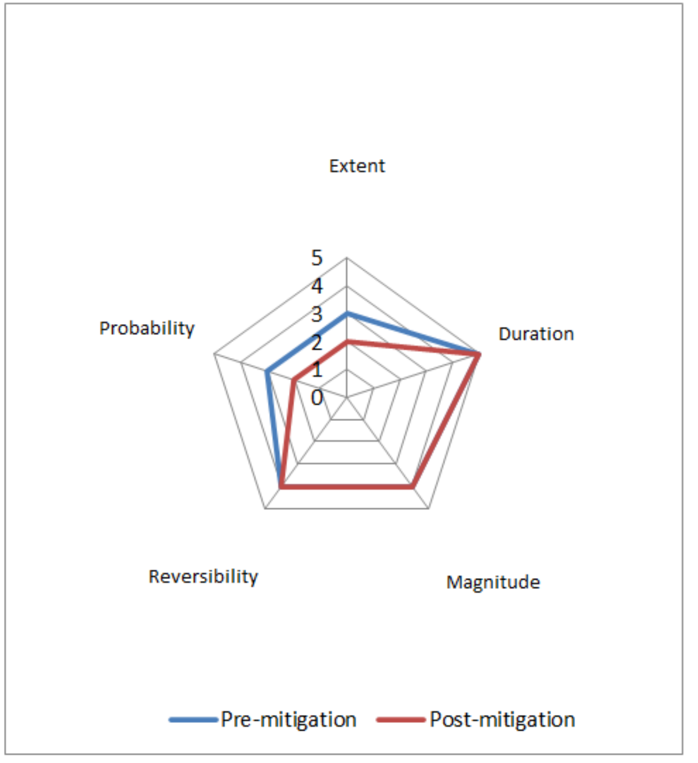


Table 13-17 Risk assessment matrix and significant scoring: Operational phase impact 04.

Impact Name	**Poor quality leachate may emanate from the plant footprint area which may have a negative impact on groundwater quality.**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	3	2	Reversibility of Impact	4	4
Duration of Impact	5	5	Probability	3	2
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Mitigation Measures	i. Develop a stormwater management plan in accordance with GN704 in order to separate dirty/contact water from clean water circuits. All water retention structures, process water dams; storm water dams, retention ponds etc. should be constructed to have adequate freeboard to be able to contain water from 1:50 year rain events. ii. Plant areas must be fitted with a containment facility for the collection of dirty water. This facility must be impervious to prevent soil and groundwater contamination. Ii. iii. The plant area must have a concrete slab that is sloped to facilitate runoff into a collection sump.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-9.38

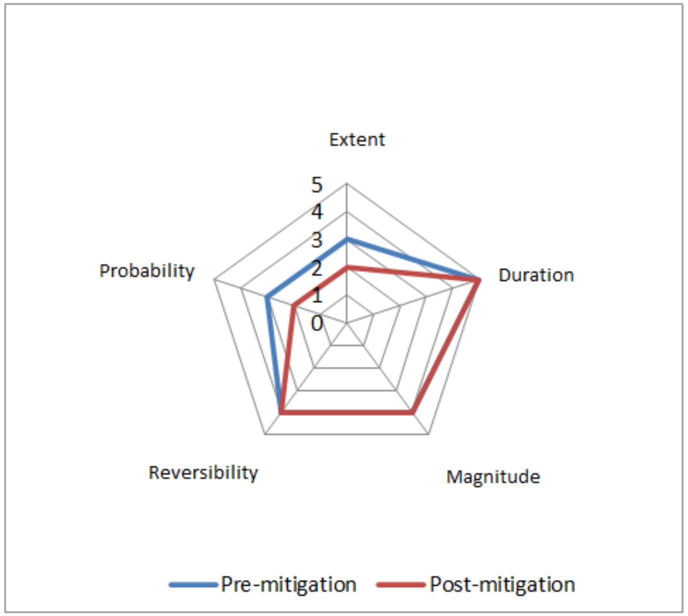


Table 13-18 Risk assessment matrix and significant scoring: Operational phase impact 05.

Impact Name	**Mobilisation and maintenance of heavy vehicle and machinery on-site may cause hydrocarbon contamination of groundwater resources.**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	3	2
Environmental Risk (Pre-mitigation)					-8.25
Mitigation Measures					
Mitigation Measures	i. Operational vehicles and machinery must be serviced and maintained regularly in order to ensure that oil spillages are limited. Spill trays must be provided if refuelling of operational vehicles is done on site. Further to this spill kits must be readily available in case of accidental spillages with regular spot checks to be conducted. ii. During servicing of vehicles or equipment, especially where emergency repairs are effected outside the workshop area, a suitable drip tray must be used to prevent spills onto the soil. iii. Leaking equipment must be repaired immediately or be removed from site to facilitate repair. iv. Workshop areas must be monitored for oil and fuel spills, and a suitable oil/water separator should be in place where maintenance work on vehicles and equipment can be performed. . v. An appropriate number of spill kits must be available and must be located in all areas where activities are being undertaken.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-5.63

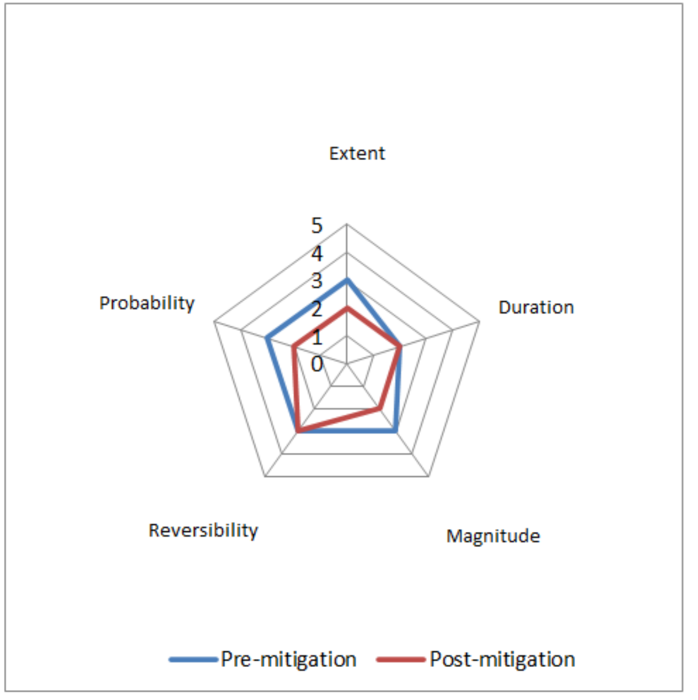


Table 13-19 Risk assessment matrix and significant scoring: Operational phase impact 06.

Impact Name	**Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution.**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	3	3
Duration of Impact	2	2	Probability	3	2
Environmental Risk (Pre-mitigation)					-8.25
Mitigation Measures					
Mitigation Measures	i. All hazardous substances used on-site should have an applicable Material Safety Data Sheet (MSDS) to provide information regarding the hazards, emergency response, protective measures and correct storage methodology. ii. Hazardous substance containment facilities to be used during operational phase should comply with the relevant hazardous substance storage legislation in order to ensure spillages are contained. iii. All hazardous substances and material used on-site should be stored in a dedicated, closed-off facility with an impervious floor and bunded area to prevent seepage and/or run-off in case of accidental spills. iv. An appropriately sized spill kit must kept onsite and available at all times. The spill kit size must be relevant to the scale of the activities involving the use of hazardous substances. v. The responsible operator must have the required training to make use of the spill kit in emergency situations.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-5.63

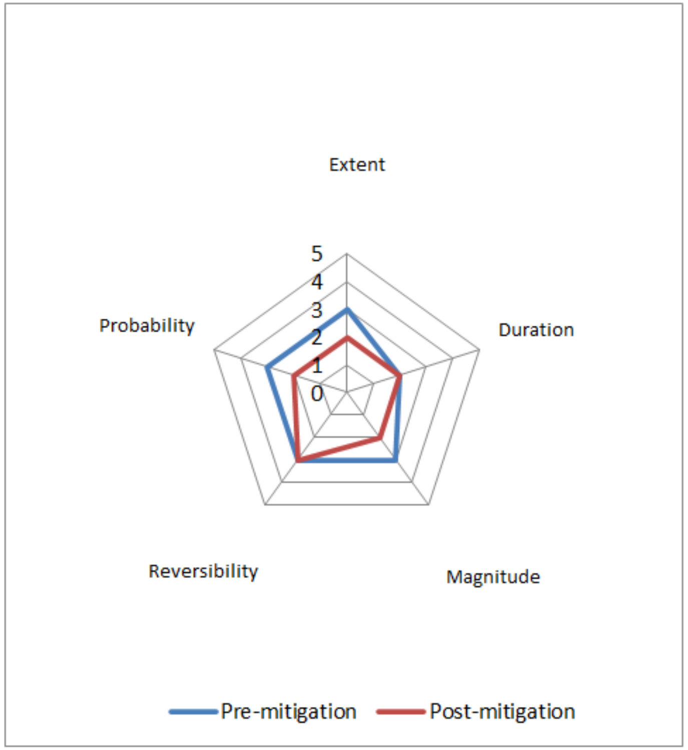


Table 13-20 Risk assessment matrix and significant scoring: Operational phase impact 07.

Impact Name	**Leakage of harmful substances from tanks, pipelines or other equipment may cause groundwater pollution.**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	4
Extent of Impact	3	2	Reversibility of Impact	4	4
Duration of Impact	5	5	Probability	3	2
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Mitigation Measures	i. Leaking equipment must be repaired immediately or be removed from site to facilitate repair. ii. Annual external audits should be conducted to ensure that pipelines and waste facilities are maintained and functioning effective and according to licence conditions. iii. The Licensee shall appoint a suitably qualified and responsible person to give effect to all recommendations as stipulated in specialist reports to ensure compliance to licence conditions pertaining to activities in order to ensure that potential impact(s) are minimised, and mitigation measures proposed are functioning effectively. iv. Development and implementation of an integrated groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures. v. Monitoring results should be evaluated and reviewed on a biannual basis by a registered hydrogeologist for interpretation and trend analysis for submission to the Regional Head of Department. Based on the water quality results, the monitoring network should be refined and updated every three to five years based on hydrochemical results obtained to ensure optimisation and adequacy of the proposed localities.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-9.38

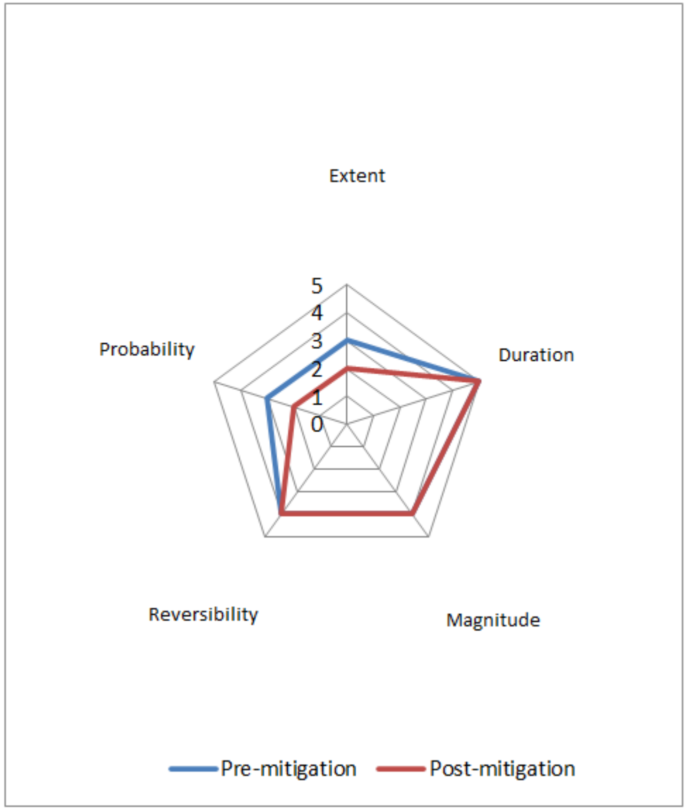
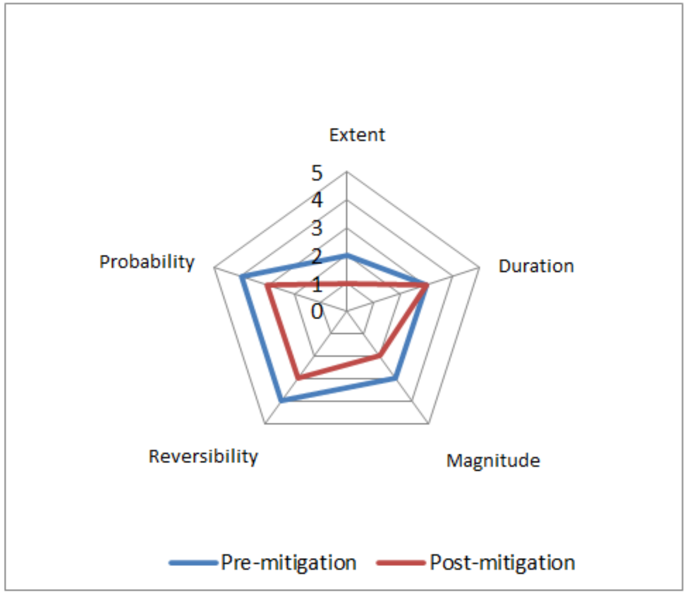


Table 13-21 Risk assessment matrix and significant scoring: Operational phase impact 08.

Impact Name	**Leachate of contaminants used in the drilling mud sump(s) to the intergranular, potable aquifer(s) during the operational phase.**				
Alternative	**Alternative 1**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	2	1	Reversibility of Impact	4	3
Duration of Impact	3	3	Probability	4	3
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Mitigation Measures	i. All actively used drill mud sumps should be adequately liner with an appropriate barrier system in order to isolate and prevent seepage of contaminants from the host aquifer. Furthermore, a biodegradeable polymer should be used as drilling lubricant. i. A rehabilitation plan must be developed based on site-specific issues and performed in accordance to best practise guidelines and guided by the closure and rehabilitation plans. ii. An ECO must be appointed to oversee the rehabilitation phase, and ensure least possible harm to biodiversity and ensure compliance to the rehabilitation plan.				
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikley that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-6.75



13.4.3. Post-operational and decommissioning phase: Associated activities and impacts

Refer to Table 13-22 for a summary of the impact risk matrix and significance ratings for the construction phase. During the decommissioning and post-closure phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium negative** without implementation of remedial measures and **low** to **medium negative** with implementation of proposed mitigation measures. The main impacts associated with the post-closure and decommissioning phase activities include the following:

1. Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the borehole closure and decommissioning phase (Table 13-23).
2. Migration of stray methane (CH_4) gas from the deep, fractured aquifer to the overlying, potable aquifer(s) borehole closure and decommissioning phase (Table 13-24).
3. Groundwater pollution as a result of wastewater spills and seepage from the evaporation dams (Table 13-25).
4. Poor quality leachate may emanate from the plant footprint area which may have a negative impact on groundwater quality (Table 13-26).
5. De-mobilisation of heavy vehicle and machinery as part of the decommissioning phase on-site may cause hydrocarbon contamination of groundwater resources (Table 13-27).

Table 13-22 Impact assessment and significant rating: Decommissioning and closure phase summary.

Impact	IMPACT DESCRIPTION	PRE - MITIGATION							POST - MITIGATION							IMPACT PRIORITISATION	
No.	Impact	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Priority Factor	Final score
Decommissioning phase																	
1	Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the borehole closure and decommissioning phase.	-1	3	3	5	5	4	-16.00	-1	2	2	4	4	3	-9	1.25	-11.25
2	Migration of stray gas from the deep, fractured aquifer to the overlying, potable aquifer(s) borehole closure and decommissioning phase.	-1	3	3	5	5	4	-16.00	-1	2	2	4	4	3	-9	1.25	-11.25
3	Groundwater pollution as a result of wastewater spills and seepage from the evaporation dams.	-1	3	3	3	4	2	-6.50	-1	2	2	2	3	1	-2.25	1.13	-2.53

Impact	IMPACT DESCRIPTION	PRE - MITIGATION							POST - MITIGATION							IMPACT PRIORITISATION	
No.	Impact	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Priority Factor	Final score
4	Poor quality leachate may emanate from the plant footprint area which may have a negative impact on groundwater quality.	-1	3	3	3	4	2	-6.50	-1	2	2	2	3	1	-2.25	1.13	-2.53
5	De-mobilisation of heavy vehicle and machinery as part of the decommissioning phase on-site may cause hydrocarbon contamination of groundwater resources.	-1	3	3	3	4	2	-6.50	-1	2	2	2	3	1	-2.25	1.13	-2.53

Table 13-23 Risk assessment matrix and significant scoring: Decommissioning and closure phase impact 01.

Impact Name	**Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the borehole closure and decommissioning phase.**				
Alternative	**Alternative 1**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	4
Extent of Impact	3	2	Reversibility of Impact	5	4
Duration of Impact	3	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-16.00
Mitigation Measures					
Mitigation Measures	i.Contractor to prepare a consolidated site-specific closure/sealing plan to be submitted for approval. The plan should include a detailed description of the following aspects: -Calliper Logging should be conducted to identify and investigate potential blockages/cavities within well. -Cement Bond Logging should be performed to investigate the current integrity of the casing and cementation. -Contractor to determine the most suitable and appropriate closure, sealing and rehabilitation strategy with specific focus on the plugging method to ensure no vertical gas and/or fluid movements within the well. -Develop cement formulation for cementing the entire well annulus. -Develop cement formulation to top-up "no bond" or "poor bond" cemented sections between casing and formation walls – ensure cement seals and does not disperse into porous formations. -Cement formulations and volumetric calculations to be approved by well engineer/cement specialist. -Contractor must ensure cement mixture seals the entire well length along the well annulus. -Cement plugs must be stacked along the full length and diameter of the well to surface (open hole section above the packer as well as the upper casing) to ensure efficient redundancy. -All plugs must be tagged to ensure successful placement. -Cementation extent: Should be from end of hole (bottom of well) to surface. -Cementation technique: Squeeze technique - this displacement method minimizes the contamination of the cement by being able to displace fluid within the well, thus allowing for a more stable well plug. Contractor must also make use of wiper plugs for cement displacement. -Contractor to conduct cement top-ups along the annulus and existing cemented sections showing "no bond" or "poor bond" from logging results. -A surface / shallow cement plug (+/ 50m below ground Level) must be set, and the well casing must be cut and capped 1 m below ground level to remove the wellhead and all casing above this point. -Integrity of the plugs must be confirmed by setting weight down on the upper most plug (using the drill string) as well as a differential pressure test for 4 hours at determined pressure with less than 10% bleed over the period. Pressure test data to be captured in 15-minute intervals for the entire 4-hour testing period. ii. Development and implementation of a post-closure groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-11.25

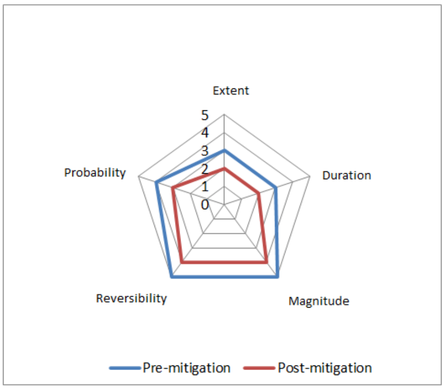


Table 13-24 Risk assessment matrix and significant scoring: Decommissioning and closure phase impact 02.

Impact Name	**Migration of stray gas from the deep, fractured aquifer to the overlying, potable aquifer(s) borehole closure and decommissioning phase.**				
Alternative	**Alternative 1**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	4
Extent of Impact	3	2	Reversibility of Impact	5	4
Duration of Impact	3	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-16.00
Mitigation Measures					
Mitigation Measures	i.Contractor to prepare a consolidated site-specific closure/sealing plan to be submitted for approval. The plan should include a detailed description of the following aspects: -Calliper Logging should be conducted to identify and investigate potential blockages/cavities within well. -Cement Bond Logging should be performed to investigate the current integrity of the casing and cementation. -Contractor to determine the most suitable and appropriate closure, sealing and rehabilitation strategy with specific focus on the plugging method to ensure no vertical gas and/or fluid movements within the well. -Develop cement formulation for cementing the entire well annulus. -Develop cement formulation to top-up "no bond" or "poor bond" cemented sections between casing and formation walls – ensure cement seals and does not disperse into porous formations. -Cement formulations and volumetric calculations to be approved by well engineer/cement specialist. -Contractor must ensure cement mixture seals the entire well length along the well annulus. -Cement plugs must be stacked along the full length and diameter of the well to surface (open hole section above the packer as well as the upper casing) to ensure efficient redundancy. -All plugs must be tagged to ensure successful placement. -Cementation extent: Should be from end of hole (bottom of well) to surface. -Cementation technique: Squeeze technique - this displacement method minimizes the contamination of the cement by being able to displace fluid within the well, thus allowing for a more stable well plug. Contractor must also make use of wiper plugs for cement displacement. -Contractor to conduct cement top-ups along the annulus and existing cemented sections showing "no bond" or "poor bond" from logging results. -A surface / shallow cement plug (+/ 50m below ground Level) must be set, and the well casing must be cut and capped 1 m below ground level to remove the wellhead and all casing above this point. -Integrity of the plugs must be confirmed by setting weight down on the upper most plug (using the drill string) as well as a differential pressure test for 4 hours at determined pressure with less than 10% bleed over the period. Pressure test data to be captured in 15-minute intervals for the entire 4-hour testing period. ii. Development and implementation of a post-closure groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures.				
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.25
Final Significance					-11.25

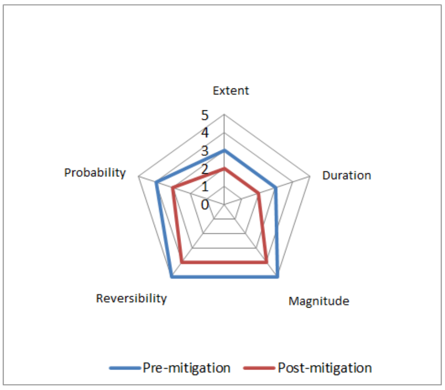


Table 13-25 Risk assessment matrix and significant scoring: Decommissioning and closure phase impact 03.

Impact Name	**Groundwater pollution as a result of wastewater spills and seepage from the evaporation dams.**				
Alternative	**Alternative 1**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	4	3
Duration of Impact	3	2	Probability	2	1
Environmental Risk (Pre-mitigation)					-6.50
Mitigation Measures					
Mitigation Measures	i. Develop a stormwater management plan in accordance with GN704 in order to separate dirty/contact water from clean water circuits. All water retention structures, process water dams; storm water dams, retention ponds etc. should be constructed to have adequate freeboard to be able to contain water from 1:50 year rain events. ii. Development and implementation of a post-closure groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures. iv. A rehabilitation plan must be developed based on site-specific issues and performed in accordance to best practise guidelines and guided by the closure and rehabilitation plans. v. An ECO must be appointed to oversee the rehabilitation phase, and ensure least possible harm to biodiversity and ensure compliance to the rehabilitation plan.				
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikley that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.13
Final Significance					-2.53

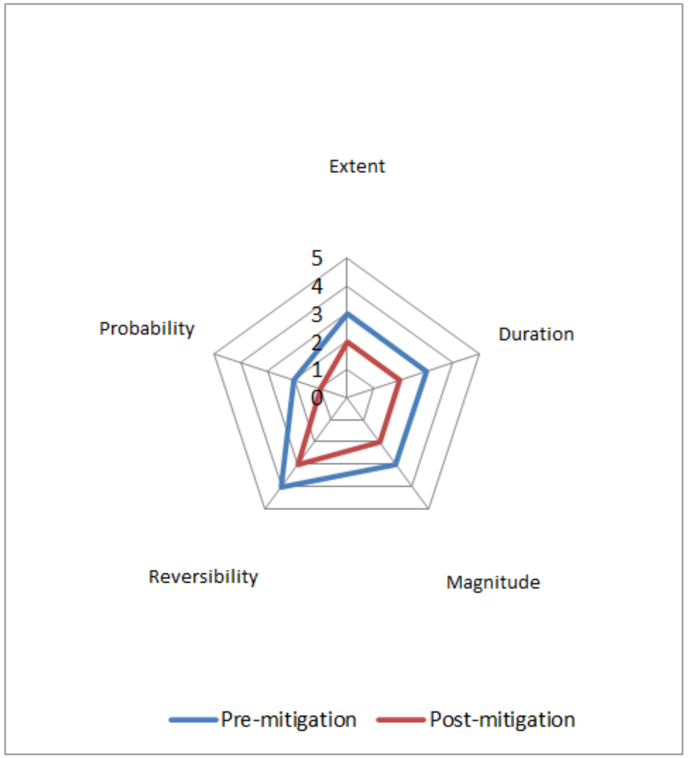


Table 13-26 Risk assessment matrix and significant scoring: Decommissioning and closure phase impact 04.

Impact Name	**Poor quality leachate may emanate from the plant footprint area which may have a negative impact on groundwater quality.**				
Alternative	**Alternative 1**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	4	3
Duration of Impact	3	2	Probability	2	1
Environmental Risk (Pre-mitigation)					-6.50
Mitigation Measures					
Mitigation Measures	i. Develop a stormwater management plan in accordance with GN704 in order to separate dirty/contact water from clean water circuits. All water retention structures, process water dams; storm water dams, retention ponds etc. should be constructed to have adequate freeboard to be able to contain water from 1:50 year rain events. ii. Development and implementation of a post-closure groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures. iv. A rehabilitation plan must be developed based on site-specific issues and performed in accordance to best practise guidelines and guided by the closure and rehabilitation plans. v. An ECO must be appointed to oversee the rehabilitation phase, and ensure least possible harm to biodiversity and ensure compliance to the rehabilitation plan.				
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikley that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.13
Final Significance					-2.53

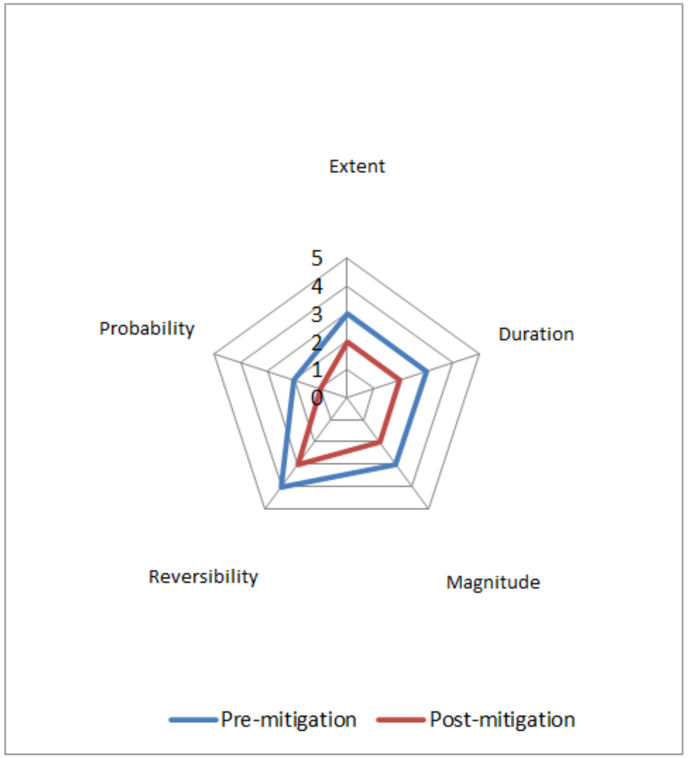
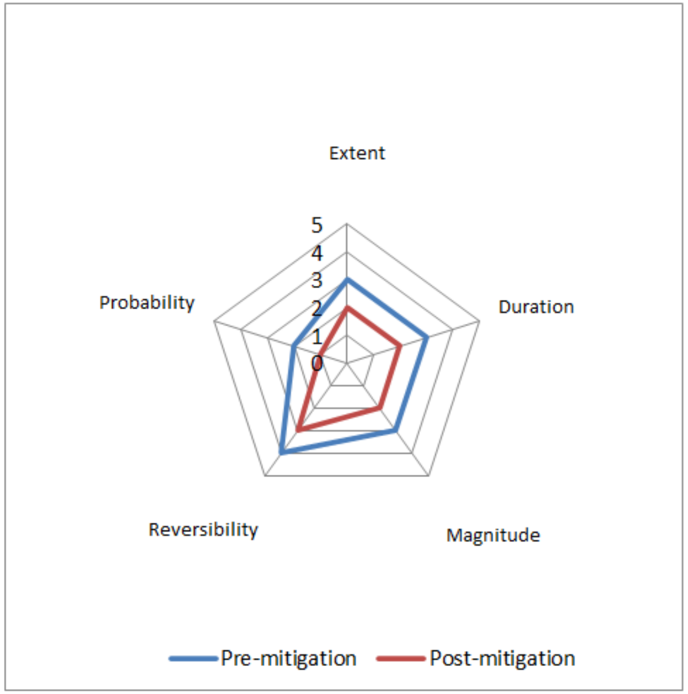


Table 13-27 Risk assessment matrix and significant scoring: Decommissioning and closure phase impact 05.

Impact Name	**De-mobilisation of heavy vehicle and machinery as part of the decommissioning phase on-site may cause hydrocarbon contamination of groundwater resources.**				
Alternative	**Alternative 1**				
Phase	**Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	2	Reversibility of Impact	4	3
Duration of Impact	3	2	Probability	2	1
Environmental Risk (Pre-mitigation)					-6.50
Mitigation Measures					
Mitigation Measures	i. Operational vehicles and machinery must be serviced and maintained regularly in order to ensure that oil spillages are limited. Spill trays must be provided if refuelling of operational vehicles is done on site. Further to this spill kits must be readily available in case of accidental spillages with regular spot checks to be conducted. ii. During servicing of vehicles or equipment, especially where emergency repairs are effected outside the workshop area, a suitable drip tray must be used to prevent spills onto the soil. iii. Leaking equipment must be repaired immediately or be removed from site to facilitate repair. iv. Workshop areas must be monitored for oil and fuel spills, and a suitable oil/water separator should be in place where maintenance work on vehicles and equipment can be performed. . v. An appropriate number of spill kits must be available and must be located in all areas where activities are being undertaken.				
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikley that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or subsitituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.13
Final Significance					-2.53



13.5. Hydrogeological sensitivity

Based on the findings of this investigation and outcomes of the impact assessment a hydrogeological sensitivity map was generated, highlighting groundwater zones which will be sensitive to contamination and should form part of the monitoring protocol. Refer to Table 13-28 for a summary of identified hydrogeological sensitive areas with a spatial representation depicted in Figure 13-1.

Table 13-28 Hydrogeological sensitivity rating (after EIMS).

Sensitivity rating	Description	Hydrogeological component identified	Motivation	Weighting
Low	The inherent feature status and sensitivity is already degraded. The proposed development will not affect the current status and/or may result in a positive impact. These features would be the preferred alternative for mining or infrastructure placement.	All areas not included in either the moderately of highly sensitive zones as identified.	This area excludes groundwater receptors or sensitive areas identified as part of the assessment.	-1
Moderate	The proposed development will negatively influence the current status of the feature to a moderate degree of modification.	A zone of 450m around the proposed gas production wells situated within the primary porosity aquifer associated with alluvium material deposited in flood plains. A zone of 250m around the proposed gas production wells situated within the Karoo formations. A buffer zone of 50m along identified fault zones traverse the project area.	These aquifers cover a substantial portion of the study area and are limited to a zone of variable width and depth. The alluvial aquifer is specifically vulnerable to contamination as it there is a direct connectivity with rivers and streams and associated high permeability. This aquifer is moderately susceptible to impacts from contaminant sources originating within this buffer zone as point source pollution. The intergranular Karoo aquifer can be classified as a secondary porosity aquifer and is generally unconfined with phreatic water levels. Due to higher effective porosity (n) this aquifer is most susceptible to impacts from contaminant sources. This aquifer is moderately susceptible to impacts from contaminant sources originating within this buffer zone as point source pollution. Fault zones targeted as part of the gas production operation can serve as potential preferred pathways for groundwater flow and contaminant transport.	+1

Sensitivity rating	Description	Hydrogeological component identified	Motivation	Weighting
High	The proposed development will negatively influence the current status of the feature to a high degree of modification.	A zone of 350m around the proposed gas production wells situated within the riparian zone primary porosity aquifer associated with alluvium material deposited in flood plains. A zone of 150m around the proposed gas production wells situated within the Karoo formations.	These aquifers cover a substantial portion of the study area and are limited to a zone of variable width and depth. The alluvial aquifer is specifically vulnerable to contamination as it there is a direct connectivity with rivers and streams and associated high permeability. This aquifer is highly susceptible to impacts from contaminant sources originating within this buffer zone as point source pollution. The intergranular Karoo aquifer can be classified as a secondary porosity aquifer and is generally unconfined with phreatic water levels. Due to higher effective porosity (n) this aquifer is highly susceptible to impacts from contaminant sources originating within this buffer zone as point source pollution.	+1

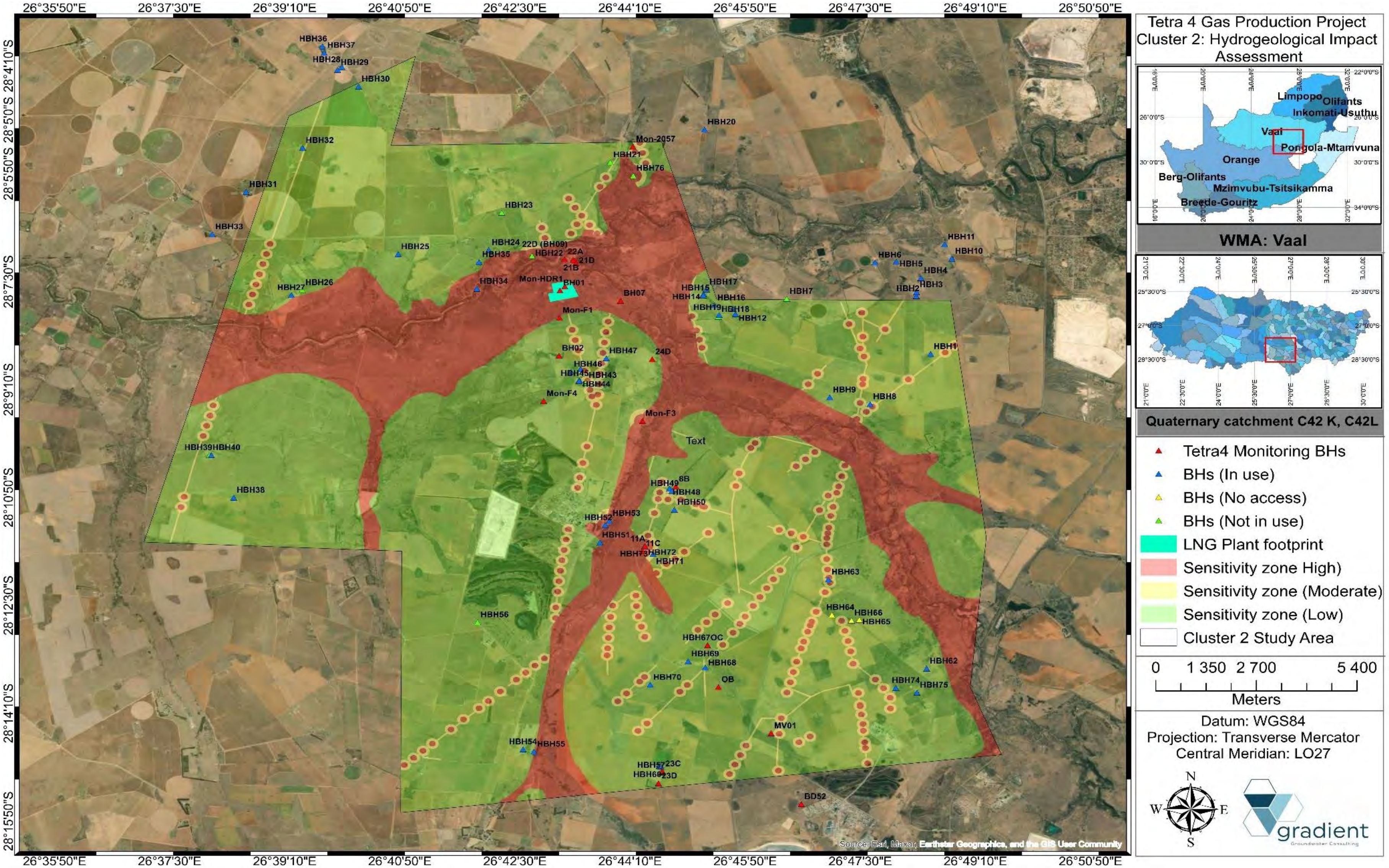


Figure 13-1 **Hydrogeological sensitivity map.**

14. GROUNDWATER MANAGEMENT PLAN

The purpose of the groundwater management plan is to provide a guideline and framework for the applicant to identify, mitigate and minimize potential impacts of the proposed operations on sensitive environmental and groundwater receptors. This management plan is applicable to the construction, operational and decommissioning/ post-closure phases of the project.

14.1. Potential impacts and associated risks

The following main impacts and associated risks have been identified as part of the groundwater impact assessment:

i. Contamination of the shallow, intergranular aquifer caused by migration of saline water and/or stray methane gas from the deep, fractured aquifer. If the gas wells are constructed and sealed off to protect the shallow potable Karoo aquifers, the impacts associated with the project can be minimised.

ii. Groundwater pollution as a result of wastewater spills and seepage from the plant footprint area as well as potential leachate from hazardous chemical substances on-site.

iii. Leakage of harmful substances from tanks, pipelines or other equipment may cause groundwater pollution.

iv. Hydrocarbon contamination of groundwater resources caused by heavy vehicle and machinery on-site.

v. Leachate of contaminants used in the drilling mud sump(s) to the intergranular, potable aquifer(s) during the operational phase.

14.2. Key responsibilities

The following management and mitigation measures should be implemented as part of the integrated groundwater management plan. The applicant will be responsible for compliance with the proposed groundwater management plan. Operational staff should implement the following measures:

i. The Licensee shall appoint a suitably qualified and responsible person to give effect to all recommendations as stipulated in specialist reports to ensure compliance to licence conditions pertaining to activities to ensure that potential impact(s) are minimised, and mitigation measures proposed are functioning effectively.

ii. An ECO must be appointed to oversee the rehabilitation phase and ensure least possible harm to biodiversity and ensure compliance to the rehabilitation plan.

iii. Compile annual reports that will be submitted to the applicable regulatory authorities.

iv. Annual external audits should be conducted to ensure that waste facilities are maintained and functioning effectively and according to licence conditions.

v. Any water use activity exercised in terms of Section 21 of the National Water Act (Act 36 of 1998) should be authorised.

vi. Listed environmental activities should be authorised in terms of the National Environmental Management Act (Act 107 of 1998).

14.3. Mitigation and management

To follow is a brief description of mitigation and management measures to be implemented per phase.

14.3.1. Construction phase: Management and mitigation measures

Mitigation and management measures associated with the construction phase activities include the following:

i. Areas where vegetation has been cleared shall be rehabilitation as soon as possible to minimise erosion. Erosion control measures should be put in place where it is deemed necessary.

ii. Clean surface water runoff to be diverted around disturbed areas and discharged to the downstream catchment zones.

iii. Develop and implement a stormwater management plan in accordance with GN704 to separate dirty/contact water from clean water circuits.

iv. Location of construction camps must be carefully considered and within the approved area to ensure that the site does not impact on sensitive areas identified during the Environmental Assessment phase or field work.

v. Sites must be located, where possible, on previously disturbed areas and e very effort must be made to keep the footprint as small as possible.

vi. All construction should take place during the dry season, as far as possible.

vii. Any excess sand, stone and cement must be removed or reused from site on completion of the construction period and disposed at a registered disposal facility. Certificates of safe disposal for general and recycled waste must be maintained and retained on file.

viii. Hazardous substance containment facilities to be used during construction phase should comply with the relevant hazardous substance storage legislation to ensure spillages are contained.

ix. All hazardous substances used on-site should have an applicable Material Safety Data Sheet (MSDS) to provide information regarding the hazards, emergency response, protective measures and correct storage methodology.

x. All hazardous substances and material used on-site should be stored in a dedicated, closed-off facility with an impervious floor and bunded area to prevent seepage and/or run-off in case of accidental spills.

xi. The use of all materials, fuels and chemicals which could potentially leach into groundwater must be controlled.

xii. Construction vehicles and machines must be serviced and maintained regularly to ensure that oil spillages are limited.

xiii. Workshop areas must be monitored for oil and fuel spills.

xiv. Spill trays must be provided if refuelling of construction vehicles is done on site. Further to this spill kits must be readily available in case of accidental spillages.

xv. Employees must be trained in terms of emergency response towards bulk chemical and hydrocarbon spillages.

xvi. An appropriate number of spill kits must be available and must be in all areas where activities are being undertaken.

xvii. Leaking equipment must be repaired immediately or be removed from site to facilitate repair.

xviii. An integrated groundwater water monitoring program should be developed and implemented to ensure that groundwater monitoring is conducted and to formulate groundwater baseline conditions to be used as benchmark for future comparison.

14.4. Operational phase: Management and mitigation measures

Mitigation and management measures associated with the operational phase activities include the following:

i. All exploration wells should be sealed-off with a combination of casing and grouting to ensure isolation of the gas from the host-aquifer(s). Well design will be undertaken according to designs developed by a qualified well engineer.

ii. Daily inspections of drilling pads, pipelines, compressors and the helium plant must be implemented.

iii. Development and implementation of an integrated groundwater monitoring program evaluating hydrochemistry as well as water levels will serve as early warning mechanism to implement mitigation measures.

iv. The existing groundwater flow model should be recalibrated with time-series monitoring data on a biennial basis to be applied as water management tool. Scenario predictions and model simulations should be conducted and interpreted by an external and independent specialist.

v. Mining vehicles and machinery must be serviced and maintained regularly to ensure that oil spillages are limited. Spill trays must be provided if refuelling of operational vehicles is done on site. Further to this spill kits must be readily available in case of accidental spillages with regular spot checks to be conducted.

vi. Plant areas must be fitted with a containment facility for the collection of dirty water. This facility must be impervious to prevent soil and groundwater contamination.

vii. The plant area must have a concrete slab that is sloped to facilitate runoff into a collection sump.

viii. Hazardous substance containment facilities to be used during operational phase should comply with the relevant hazardous substance storage legislation to ensure spillages are contained.

ix. Develop and implement a stormwater management plan in accordance with GN704 to separate dirty/contact water from clean water circuits. All water retention structures, process water dams; storm water dams, retention ponds etc. should be constructed to have adequate freeboard (0.8m below overflow level) to be able to contain water from 1:50 year rain events.

x. Leaking equipment must be repaired immediately or be removed from site to facilitate repair.

xi. A rehabilitation plan must be developed based on site-specific issues and requirements including soft and hard engineering interventions and revegetation.

xii. All actively used drill mud sumps should be adequately liner with an appropriate barrier system to isolate and prevent seepage of contaminants from the host aquifer. Furthermore, a biodegradable polymer should be used as drilling lubricant.

xiii. A rehabilitation plan must be developed based on site-specific issues and performed in accordance to best practise guidelines and guided by the closure and rehabilitation plans.

xiv. Monitoring results should be evaluated on a quarterly basis by a suitably qualified person for interpretation and trend analysis and submitted to the Regional Head: Department of Water and Sanitation. Based on the water quality results, the monitoring network should be refined and updated every three to five years based on hydrochemical results obtained to ensure optimisation and adequacy of the proposed localities.

14.5. Post-operational and decommissioning phase: Management and mitigation measures

Mitigation and management measures associated with the post-operational and decommissioning phase activities include the following:

i. In the event that the casing and/or cementation in a well failure, the well can become a high-permeability conduit for saline water and stray gas from deep-seated formations to the overlying shallow Karoo aquifers. All exploration wells should be sealed-off with a combination of casing and grouting to ensure isolation of the gas from the host-aquifer(s).

ii. The contractor should prepare a consolidated site-specific closure/sealing plan to be submitted for approval. The plan should include a detailed description of the following aspects:

   - Calliper Logging should be conducted to identify and investigate potential blockages/cavities within well.
   - Cement Bond Logging should be performed to investigate the current integrity of the casing and cementation.
   - Contractor to determine the most suitable and appropriate closure, sealing and rehabilitation strategy with specific focus on the plugging method to ensure no vertical gas and/or fluid movements within the well.
   - Contractor to prepare a consolidated site-specific closure/sealing plan to be submitted for approval.
   - Develop cement formulation for cementing the entire well annulus.

- Develop cement formulation to top-up “no bond” or “poor bond” cemented sections between casing and formation walls – ensure cement seals and does not disperse into porous formations.
- Cement formulations and volumetric calculations to be approved by well engineer/cement specialist.
- Contractor must ensure cement mixture seals the entire well length along the well annulus. Cement plugs must be stacked along the full length and diameter of the well to surface (open hole section above the packer as well as the upper casing) to ensure efficient redundancy.
- All plugs must be tagged to ensure successful placement.
- Cementation extent: Should be from end of hole (bottom of well) to surface.
- Cementation technique: Squeeze technique - this displacement method minimizes the contamination of the cement by being able to displace fluid within the well, thus allowing for a more stable well plug. Contractor must also make use of wiper plugs for cement displacement.
- Contractor to conduct cement top-ups along the annulus and existing cemented sections showing “no bond” or “poor bond” from logging results.
- A surface / shallow cement plug (+/ 50m below ground Level) must be set, and the well casing must be cut and capped 1 m below ground level to remove the wellhead and all casing above this point.
- Integrity of the plugs must be confirmed by setting weight down on the upper most plug (using the drill string) as well as a differential pressure test for 4 hours at determined pressure with less than 10% bleed over the period. Pressure test data to be captured in 15-minute intervals for the entire 4-hour testing period.
- Contractor to prepare a comprehensive project report containing the following:
    - o Calliper and CBL logging results;
    - o Cement formulations and Material Safety Datahseets of all additives;
    - o Cementation methodology and photographs;
    - o Recorded pressure test data;
    - o Well tagging photographs and coordinates;
    - o Surface rehabilitation photographs.

iii. Well-specific plugging requirements should be implemented to protect the shallow potable Karoo aquifers at closure. The integrity of the seals will be pressure tested before the well decommissioning can be signed-off.

iv. A surface casing vent flow test should be conducted to determine whether gas or liquid or a combination thereof is escaping from the casing. If gas is detected during this test, additional seals should be designed and implemented.

v. Development and implementation of a post-closure groundwater monitoring program evaluating hydrochemistry will serve as early warning and detection mechanism to implement mitigation measures.

vi. A rehabilitation plan must be developed based on site-specific issues and performed in accordance to best practise guidelines and guided by the closure and rehabilitation plans.

vii. All preferred groundwater flow pathways which are in direct connection with surface topography i.e., unrehabilitated mine exploration boreholes should be sealed off and rehabilitated according to best practise guideline.

viii. It is expected that post-closure the generated pollution plume and local groundwater contamination footprint will decay and be diluted by rainfall recharge, however the lasting effect and subsequent impact on neighbouring borehole qualities should be monitored with alternative water supply sources or compensation measures available for nearby users if impacted on.

15. MONITORING

A monitoring program consists of taking regular measurements of the quantity and/or quality of a water resource at specified intervals and at specific locations to determine the chemical, physical and biological nature of the water resource and forms the foundation on which water management is based. Monitoring programmes are site-specific and need to be tailored to meet a specific set of needs or expectations. DWAF Best Practice Guideline – G3: Water Monitoring Systems (DWA, 2006), as illustrated in Figure 15-1 used as guideline for the development of this water monitoring program.

1. DESIGNING OF MONITORING PROGRAM

1.1 Define the management actions of interest.
1.2 Define objectives of the intended management actions.
1.3 Define data requirements that support objectives.
1.4 Define location of monitoring points.
1.5 Define parameters to be measured.
1.6 Define frequency of measurements.
1.7 Define data/information reporting requirements.

Monitoring objectives

2. PROVIDE DETAILED IMPLEMENTATION PROCEDURES

2.1 Develop detailed data/sampling collection procedure.
2.2 Develop quality assurance program.

3. DEVELOP DATA MANAGEMENT SYSTEM

3.1 Develop appropriate databases and data manipulation techniques.
3.2 Develop reporting formulas and procedures.

4. AUDIT THE MONITORING PROGRAM

4.1 Undertake internal/external audits of monitoring systems/programme.
4.2 Review/revise the design of the monitoring systems/programme.

Figure 15-1 Monitoring programme (DWA, 2006).

15.1. Monitoring Objectives

Monitoring, measuring, evaluating and reporting are key activities of the monitoring programme. These actions are designed to evaluate possible changes in the physical and chemical nature of the aquifer and geo-sphere to detect potential impacts on the groundwater. This will ensure that management is timely warned of problems and unexpected impacts that might occur and can be positioned to implement mitigation measures at an early stage. Key objectives of monitoring are:

i. To provide reliable groundwater data that can be used for management purposes.

ii. The early detection of changes in groundwater quality and quantity.

iii. Provide an on-going performance record on the efficiency of the Water Management Plan.

iv. Obtain information that can be used to redirect and refocus the Water Management Plan.

v. Determine compliance with environmental laws, standards and the water use licence and other environmental authorizations.

15.2. Monitoring network

Tetra4 does have an existing monitoring protocol and network in place which was implemented das part of the phase I operations. It is recommended that additional monitoring boreholes be established down-gradient of the plant expansion footprint to evaluate the expected mass load contribution to environmental and groundwater receptors. Drilling localities for the two proposed new boreholes should be determined by means of a geophysical survey to target lineaments and weathered zones acting as preferred groundwater flow pathways and contaminant transport mechanisms. Table 15-1 summarises the proposed updated and revised monitoring network and program, with relevant information depicted in Figure 15-2. Privately owned, neighbouring boreholes situated within high impact risk areas have been included into the existing monitoring network on a bi-annual basis (after the wet and dry rainy seasons) whereas all other borehole identified as part of the hydrocensus user survey should be visited and analsyed on an annual basis. In the event that monitoring of gas production wells indicates gas leaks, casing or cementation failure and the frequency of hydrocensus boreholes are increased to monthly, the analysis must include the full set of elements.

15.3. Determinants for analysis

Baseline and background water quality results should be evaluated to set a site-specific limit per parameter and applied as benchmark for monitoring purposes. Supplementary guidelines i.e., Water Use Licence (WUL) conditions as well as WMA Resource Quality Objectives (RQO) should also be considered as part of the monitoring protocol. All monitoring localities should be subjected to an initial comprehensive water quality analysis to evaluate hydrochemical composition and identify potentially elevated parameters going forward[14]. Chemical variables to form part of the sampling run are listed below. Groundwater monitoring boreholes should be analysed for the following chemical constituents:

i. ***Physical and aesthetic determinants:*** pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Total Hardness.

ii. ***Macro determinants:*** Total Alkalinity (MAlk), Sulphate (SO_4), Nitrate (NO_3), Chloride (Cl), Fluoride (F), Calcium (Ca), Magnesium (Mg), Potassium (K) and Sodium (Na).

iii. ***Micro determinants:*** Aluminium (Al), Iron (Fe), Manganese (Mn), Cadmium (Cd), Total Chromium (Cr), Chromium (VI), Arsenic (As), Copper (Cu), Uranium (U), Nickel (Ni), Lead (Pb), Cobalt (Co) and Zinc (Zn), dissolved Methane (CH_4), dissolved Ethane (C_2H_6).

iv. ***Organic determinants:*** Total Oil and Grease, Dissolved Organic Carbon (DOC), Total Organic Carbon (TOC), TPH GRO C6-C10, TPH C28-C40.

15.4. Water levels

Water levels should be monitored to evaluate the impact of existing groundwater abstraction on aquifer storage and replenishment including privately owned, neighbouring boreholes.

[14] It is recommended that a comprehensive water quality analysis be repeated annually. Also note that should additional parameters be requested in existing permits/licence conditions, these should be adhered to.

15.5. Monitoring frequency

Groundwater monitoring, i.e., water level measurements and quality analysis should be conducted on a quarterly basis at existing Tetra4 boreholes (included newly proposed monitoring localities down-gradient of the plant area) whereas water level and water quality monitoring at privately owned boreholes should be conducted on a bi-annual basis. Water quality reports summarising monitoring results should be submitted to the Regional Head of the Department within timeframes as stipulated in the WUL conditions.

15.6. Sampling procedure

The sampling procedure for groundwater should be done according to the protocol by Weaver, 1992. The actions can be summarised as follows:

1. Calibrate the field instruments before every sampling run. Read the manufacturers manual and instructions carefully before calibrating and using the instrument.
2. Bail the borehole.
3. Sample for chemical constituents – remove the cap of the plastic 1 litre sample bottle, but do not contaminate inner surface of cap and neck of sample bottle with hands. Fill the sample bottle without rising.
4. Leave sample air space in the bottle (at least 2.5 cm) to facilitate mixing by shaking before examination.
5. Replace the cap immediately.
6. Complete the sample label with a water-resistant marker and tie the label to the neck of the sample bottle with a string or rubber band. The following information should be written on the label.
   - A unique sample number and description
   - The date and time of sampling
   - The name of the sampler
7. Place sample in a cooled container (e.g., cool box) directly after collection. Try and keep the container dust-free and out of any direct sunlight. Do not freeze samples.
8. Complete the data sheet for the borehole.

See to it that the sample gets to the appropriate laboratory as soon as possible, samples for chemical analysis should reach the laboratory preferably within seven days.

Table 15-1 Revised monitoring network and programme.

Monitoring locality	Latitude	Longitude	Locality description	Monitoring frequency		Parameters
				Water quality	Water level	
Existing monitoring boreholes						
11A	-28.193137	26.739703	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	As in Section 15.3
11C	-28.194320	26.739080	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
15E	-28.277361	26.641556	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
21A (BH05)	-28.119556	26.722806	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
21B	-28.119389	26.722333	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
21D	-28.120278	26.723028	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
22A	-28.119194	26.720306	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
22D (BH09)	-28.117306	26.721722	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
23C	-28.251048	26.743863	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
23D	-28.254167	26.742944	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
24D	-28.144972	26.741444	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
25A	-28.287028	26.742056	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
25B	-28.302167	26.743083	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
8B	-28.177728	26.747135	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
BD52	-28.259487	26.777427	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
BH01	-28.127231	26.719194	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
BH02	-28.144047	26.718938	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
BH07	-28.129905	26.733792	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
Mon-2057	-28.090217	26.736790	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
Mon-F1	-28.134285	26.719059	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
Mon-F3	-28.160855	26.739085	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
Mon-F4	-28.155733	26.715230	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
Mon-HDR1	-28.126232	26.720356	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
MV01	-28.241273	26.770132	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
OB	-28.229342	26.757408	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
OC	-28.218611	26.754778	Existing Tetra4 Monitoring borehole	Quarterly	Quarterly	
Existing boreholes in private use						
HBH01	-28.156508	26.794027	Borehole in private use for livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	As in Section 15.3
HBH08	-28.156508	26.794027	Borehole in private use for livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	

Monitoring locality	Latitude	Longitude	Locality description	Monitoring frequency		Parameters
				Water quality	Water level	
HBH27	-28.128449	26.654374	Borehole in private use for domestic and livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH39	-28.169627	26.635037	Borehole in private use for domestic and livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH41	-28.147466	26.724128	Borehole in private use for domestic and irrigation purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH42	-28.147499	26.724159	Borehole in private use for domestic and irrigation purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH43	-28.151021	26.725400	Borehole not in use. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH48	-28.178267	26.745580	Borehole in private use for domestic and livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH49	-28.178856	26.746212	Borehole in private use for domestic and livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH50	-28.183719	26.746794	Borehole in private use for domestic and livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH63	-28.201657	26.783977	Borehole in private use for livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH66	-28.212197	26.789505	Borehole in private use for livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH72	-28.193122	26.739700	Borehole not in use. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH73	-28.193009	26.739636	Borehole in private use for domestic and livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
HBH74	-28.229587	26.800249	Borehole in private use for domestic and livestock purposes. Monitoring pollution plume migration from gas production boreholes	Bi-annually	Bi-annually	
Newly proposed monitoring boreholes						
Mon BH01	-28.123973	26.721958	New monitoring borehole down-gradient of the production plant serving as Doringrivier receptor	Quarterly	Quarterly	As in Section 15.3
Mon BH02	-28.124473	26.717889	New monitoring borehole down-gradient of the production plant serving as Sandrivier receptor	Quarterly	Quarterly	

Notes: All remaining boreholes as identified during the hydrocensus user survey conducted, should be included into the monitoring network on an annual basis.

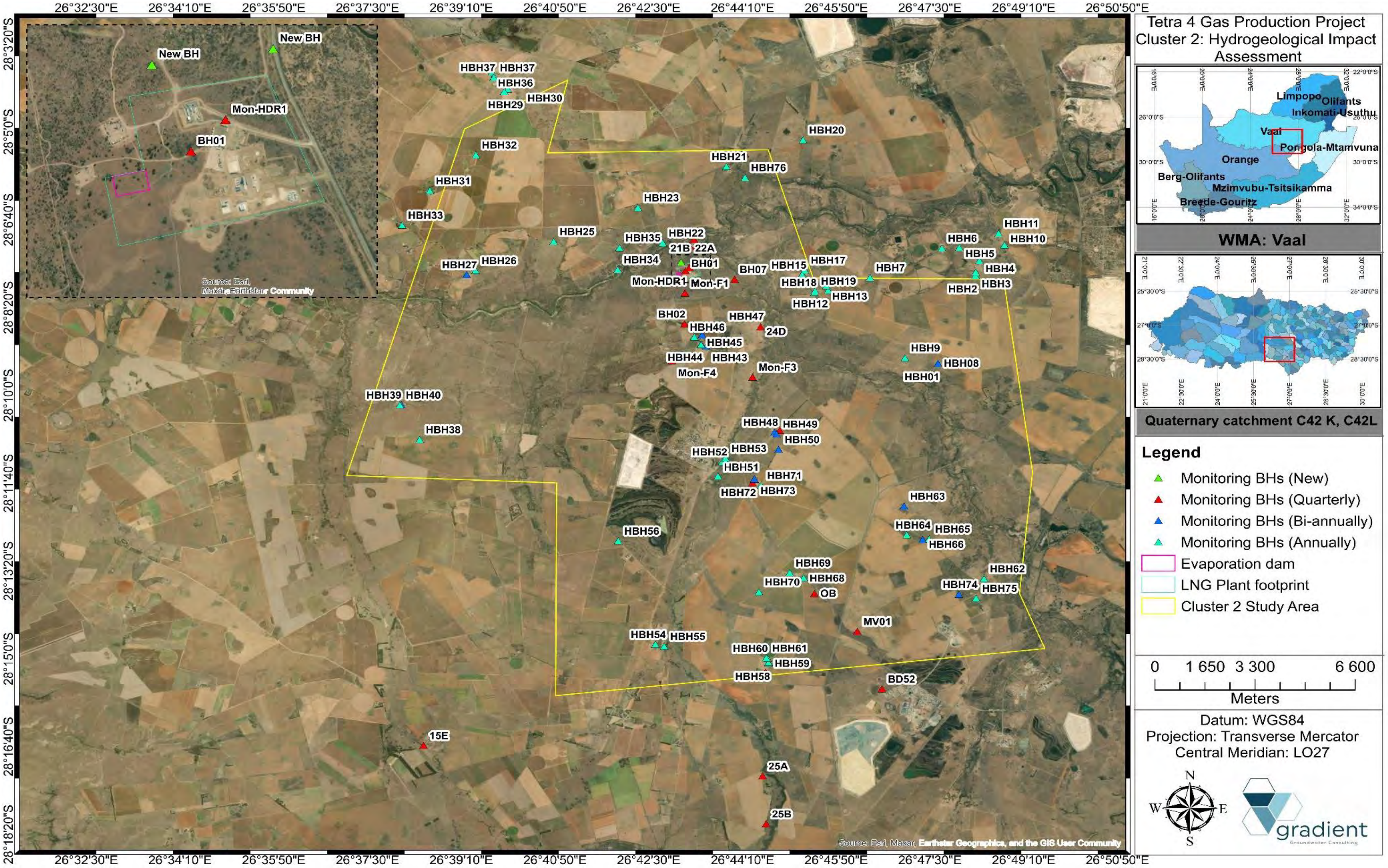


Figure 15-2 **Updated integrated groundwater monitoring network.**

16. CONCLUSIONS

The following conclusions were derived from the outcomes of this investigation:

The project area's surficial geology comprises mostly aeolian sands, quaternary deposits and isolated outcrops of the Karoo Supergroup i.e., dolerite and sandstone/ shales, while the greater study area is generally also underlain by rocks of the Witwatersrand Supergroup as well as the Ventersdorp Supergroup. Isolated patches within the study area are also covered by alluvial sand deposits which is mainly associated with the Sand and Doringriver floodplains and constrained by drainage patterns and riparian zones. The primary source of gas originates from the Witwatersrand Supergroup as well as the shallower Karoo sediments.

The site is predominantly underlain by an intergranular and fractured aquifer system (d2) with the aquifer media consisting mainly of fractured and weathered compact argillaceous strata. According to Vegter's groundwater regions delineated (2000) the study area can be classified as falling under the North-eastern Pan Belt region.

For the purposes of this investigation, four main hydrostratigraphic units/aquifer systems can be inferred in the saturated zone:

i. **A shallow quaternary and recent types of sediments** (unconfined) are characteristically a primary porosity aquifer associated with alluvium material deposited in flood plains of the main rivers traversing the study area. These aquifers cover a large portion of the study area and are limited to a zone of variable width and depth. The alluvial aquifer is specifically vulnerable to contamination as it there is a direct connectivity with rivers and streams and associated high permeability.

ii. **A shallow, intergranular aquifer** (unconfined to semi-confined) occurring in the transitional soil and weathered bedrock formations of the Karoo Supergroup rocks underlain by more consolidated bedrock. Groundwater flow patterns usually follow the topography, discharging as natural springs at topographic low-lying areas. Usually, this aquifer can be classified as a secondary porosity aquifer and is generally unconfined with phreatic water levels. Due to higher effective porosity (*n)* this aquifer is most susceptible to impacts from contaminant sources.

iii. **An intermediate, fractured aquifer** (semi-confined to confined) where pores are well-cemented and do not allow any significant flow of water. Groundwater flow is dictated by transmissive secondary porosity structures such as bedding plane fractures, faults, contact zones as well as fracture zones that occur in the relatively competent Karoo Supergroup host rock. Fractured sandstones, mudstones and shales sequences are considered as fractured rock aquifers holding water in storage in both pore spaces and fractures. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. Although generally low yielding, this aquifer is important to local groundwater users as it forms the sole source of water supply in the region (Lea, 2017).

iv. **A deeper, fractured aquifer** (semi-confined to confined) where pores are well-cemented and do not allow any significant flow of water. Groundwater flow is dictated by transmissive secondary porosity structures such as bedding plane fractures, faults and contact zones fracture zones that occur in the relatively competent Ventersdorp and Witwatersrand Supergroups host rock. Volcanic formations of the Ventersdorp lavas can also act as aquicludes, restricting the vertical movement of groundwater. Fractured quartzites of the Witwatersrand Supergroup are considered as fractured rock aquifers holding water in storage in both pore spaces and fractures. Groundwater yields, although more heterogeneous, can be expected to be higher than the weathered zone aquifer. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position.

The water in the deep aquifers is naturally saline due to their marine depositional history. It should be noted that the shallow potable Karoo aquifers are separated from deep aquifer systems associated with the Ventersdorp and Witwatersrand Supergroup formations by the 30.0m thick dolerite sill (which may act as an aquitard) that extends across the study area and by the 65.0m thick Dwyka Tillite sedimentary deposit acting as an aquiclude. It should furthermore be noted that, under natural conditions, there is very limited hydraulic connectivity between the deep, fractured and shallow, intergranular aquifers.

The hydraulic conductivity of sedimentary formations such as evident on site can range from $10E^{-6} – 10E^{-2}$ m/d. Historical aquifer tests results confirm that the permeability of the shales is very low ($9E^{-4}$m/d). The hydraulic conductivity of fractured igneous rocks (i.e., dolerite) varies between $10E^{-6} – 10E^{-1}$ m/d, while conductivity values for un-fractured igneous rocks (i.e., fresh dolerite sill) ranges between $10E^{-9} – 10E^{-6}$ m/d. The hydraulic conductivity of quaternary deposits and alluvial pockets associated with the drainage system i.e., riverbed aquifers can be orders higher and can vary between $10E^{-2} – 10E^{1}$ m/d.

An approximation of recharge for the study area is estimated at ~4.0% of MAP i.e., ~21.69mm/a.

A total of 78 groundwater receptors i.e., boreholes, artesian wells, wind pumps as well as surface water features were visited as part of the hydrocensus user survey which are largely applied for livestock watering and domestic water supply purposes. Of the boreholes recorded, the majority are in use (>78.0%) while ~17.0% are not currently being utilized.

The unsaturated zone within the study area is in the order of 0 (fully saturated to surface) to >26.0m with a mean thickness of approximately ~9.0m. It should be noted that due to the argillaceous nature of the host aquifer(s) the shallow water levels observed at some of the borehole localities can be attributed to clay/silt lenses and be indicative of perched aquifer conditions and not necessarily represent the vadose zone.

Artesian conditions were observed at three of the boreholes visited namely HBH31, 21B as well as 8B which can be indicative of semi-confined to confined aquifer conditions present or perched aquifer conditions. The minimum water level was recorded at 0.0mbgl, while the deepest water level was measured at borehole locality Mon-HDR1 (26.71mbgl).

It is noted that most water levels suggest a decrease in water levels and recovering trend. The latter can be attributed the onset of the wet cycle and above average rainfall events experienced with rainfall recharge replenishing aquifer storage. It can be observed that there is a definite a relatively quick response to rainfall, suggesting that recharge of the shallow, intergranular aquifer takes place without a prolonged lag effect.

Statistical analyses of the water level trends furthermore suggest that the local groundwater system is in quasi-steady state conditions.

Analysed data indicate that the surveyed water levels correlate very well to the topographical elevation (R^2 <0.98). Accordingly, it can be assumed that the regional groundwater flow direction is dictated by topography. Bayesian interpolation was used to interpolate the groundwater levels throughout the study area. The inferred groundwater flow direction will be towards the lower laying drainage system(s) traversing the project area from where groundwater will discharge as baseflow. The groundwater flow direction within the southern catchment of the Sandrivier and Doringrivier, also in the vicinity of the proposed plant expansion footprint, will be in a general northern direction, whereas the groundwater flow direction within the northern catchment of the study area will be mostly in a south to southwestern direction.

The average groundwater gradient (i) of the shallow, weathered aquifer in the vicinity of the proposed plant expansion footprint is relatively flat and calculated at a mean of 0.002, with a maximum of 0.003 in a south to north orientation and a minimum of 0.001 in a general southeast to northwest orientation.

The expected seepage rate from contamination originating at the proposed plant expansion footprint as well as associated infrastructure is estimated at an average of approximately 1.26m/a, with a maximum distance of ~2.20m/a in a southern to northern direction.

Under natural conditions this area exhibits certain regions where there is pronounced interaction between surface and groundwater and regional drainages can be generally classified as influent or gaining stream systems. The alluvial associated with the floodplains of the Sand - and Doringrivier forms a primary aquifer and is directly connected with surface water resources, especially during high flow conditions.

The hydrochemical results of the hydrocensus boreholes water samples analysed suggest the overall ambient groundwater quality is good with most macro and micro determinants falling within or below the SANS 241:2015 limits. Groundwater can be described as neutral, saline to very saline and hard to very hard. The groundwater quality is impacted by the geological formations, which were deposited in shallow marine environments and are therefore naturally saline.

It is observed that most of the boreholes indicate elevated Nitrate (NO_3) concentrations. The latter may be attributed to the agricultural land-use activities dominating the greater study area with elevated NO_3 concentrations potentially derived from leachate of fertilizer to the local aquifer. It is noted that borehole localities with elevated NO_3 concentrations are generally situated within or directly down-gradient of planted crop areas as well as near surface water features.

Surface water quality can be classified as moderate to good with Aluminium (Al) and Iron (Fe) being slightly elevated. It should be noted that there is not a significant change in the downstream water quality compared to the upstream quality with an increase in Aluminium (Al), however all surface water samples analysed suggest elevated heavy metal concentrations i.e., Al and Fe.

Three distinct categories can be observed, Category A: Calcium-Bi-carbonate dominance which suggest a recently recharged and unimpacted groundwater environment (majority of samples), Category B: Calcium-

Magnesium-Chloride dominance which indicate a static and disordinate environment as well as Category C: Sodium-Potassium-Bi-carbonate dominance which indicate an area of dynamic groundwater environments.

The surface water samples analysed can be categorized as having Calcium-Magnesium-Chloride dominance which indicate a static and disordinate environment, one would except a more Calcium-Bi-carbonate signature from an unpolluted surface water source, however baseflow discharge present from the saline groundwater resource will have an impact on the salinity of the surface water resources as is evident.

Comparison of different hydrochemical signatures observed suggest on-site boreholes to target a shallow, inter-granular aquifer unit as well as a deeper (possibly intermediate, fractured aquifer unit) being more saline.

The Sodium-Potassium-Chloride dominance of the deep, fractured aquifer groundwater suggest extremely saline conditions as expected.

According to the aquifer classification map of South Africa the project area is underlain by a “Minor aquifer”. It should however be noted that the shallow, intergranular aquifer is important to local groundwater users as it form the sole source of water supply in the region. Furthermore, the primary riparian zone aquifer is classified as a major aquifer system due to its highly permeable nature as well as good water quality.

A GQM Index = 4 was calculated for the local aquifer system and according to this estimate, a “Medium” level groundwater protection is required for this aquifer system. According to the DRASTIC index methodology applied, the existing/proposed activities and associated infrastructure’s risk to groundwater pollution of the shallow, intergranular aquifer is rated as “Moderate”, Di = 109.

A numerical groundwater flow and mass transport migration model was developed and calibrated in steady state based on gathered site characterisation information which was applied as initial hydrogeological conditions for transient simulations.

A scenario was simulated representing point source pollution plume migration of saline groundwater emanating from leaking boreholes targeting the deep, fractured aquifer for the operational phase (20-year period). The TDS pollution plume extend covers a total area of approximately 414.06ha in the Karoo formations, reaching a maximum distance of ~80.0m in a radial pattern from the gas production borehole(s), and approximately 251.60ha in the alluvial deposits, reaching a maximum distance of ~200.0m in a radial pattern from the gas production borehole(s) after a simulation period of 20-years. The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH63, HBH72, HBH73 and HBH74.

It can be noted that the pollution plume migration in the denser Karoo formations is sluggish while movement in the unconsolidated alluvial deposits of the riparian zone suggest a larger flux.

It is evident that source term mass load contribution to existing neighbouring borehole situated near the gas production borehole(s) does not exceed ~800.0mg/l and ranges between 600mg/l to 700.0mg/l

A scenario was simulated representing point source pollution plume migration of stray methane (CH_4) gas emanating from leaking boreholes targeting the deep, fractured aquifer for the operational phase (20-year period). The CH_4 pollution plume extend covers a total area of approximately 162.74ha in the Karoo formations, reaching a maximum distance of ~50.0m in a radial pattern from the gas production borehole(s), and approximately 62.83ha in the alluvial deposits, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole(s) after a simulation period of 20-years. The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH63, HBH72, HBH73 and Tetra4 monitoring borehole 11A.

It is noted that the source term mass load contribution to existing neighbouring borehole situated near the gas production borehole(s) remains below the EPA safety threshold (2011) of 10.0mg/l and ranges between 0.01mg/l to 1.50mg/l.

A scenario was simulated with a pollution plume migration from the plant footprint areas for the operational phase. The TDS pollution plume extend covers a total area of approximately 48.80ha reaching a maximum distance of ~110.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 20-years. The simulation indicates that no neighbouring boreholes or local drainages are expected to be impacted on during the operational phase.

It is evident that the TDS mass load contribution to down-gradient receptors increase to a concentration of between 200.0 – 800.0 mg/l, however, remains below the SANS 241:2015 limit of 1200.0mg/l for the duration of the simulation period.

It can be noted that the mass transport of the pollution plume is mostly limited to the shallow, intergranular aquifer.

A scenario was simulated representing point source pollution plume migration of saline groundwater emanating from leaking boreholes targeting the deep, fractured aquifer for the post-closure phase. The TDS pollution plume extend covers a total area of approximately 643.70ha in the Karoo formations, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole(s), and approximately 392.70ha in the alluvial deposits, reaching a maximum distance of ~250.0m in a radial pattern from the gas production borehole(s) after a simulation period of 50-years. The TDS pollution plume extend covers a total area of approximately 1 456.42ha in the Karoo formations, reaching a maximum distance of ~150.0m in a radial pattern from the gas production borehole(s), and approximately 769.70ha in the alluvial deposits, reaching a maximum distance of ~350.0m in a radial pattern from the gas production borehole(s) after a simulation period of 100-years. The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH48, HBH50, HBH63, HBH72, HBH73, HBH74 as well as Tetra4 monitoring boreholes Mon 2057 and 11A.

It is noted that source term mass load contribution to existing neighbouring and monitoring boreholes situated near the gas production boreholes ranges between 650.0mg/l to >1200.0mg/l. Furthermore, it is observed that the SANS241:2015 limit is exceeded at borehole localities HBH63 and Mon 2057.

A scenario was simulated representing point source pollution plume migration of stray methane (CH_4) gas emanating from leaking boreholes targeting the deep, fractured aquifer for the post-closure phase. The CH_4

pollution plume extend covers a total area of approximately 414.06ha in the Karoo formations, reaching a maximum distance of ~80.0m in a radial pattern from the gas production borehole(s), and approximately 141.37ha in the alluvial deposits, reaching a maximum distance of ~150.0m in a radial pattern from the gas production borehole(s) after a simulation period of 50-years. The CH_4 pollution plume extend covers a total area of approximately 643.70ha in the Karoo formations, reaching a maximum distance of ~100.0m in a radial pattern from the gas production borehole(s,) and approximately 392.70ha in the alluvial deposits, reaching a maximum distance of ~250.0m in a radial pattern from the gas production borehole(s) after a simulation period of 100-years. The simulation indicates that the following neighbouring boreholes will potentially be intercepted by the simulated pollution plume HBH08, HBH41, HBH42, HBH43, HBH48, HBH49, HBH63, HBH72, HBH73 as well as Tetra4 monitoring boreholes Mon 2057 and 11A.

It is evident that source term mass load contribution to existing neighbouring and monitoring boreholes situated near the gas production boreholes ranges between 0.50mg/l to ~2.0mg/l, however, remains below the EPA safety threshold (2011) of 10.0mg/l.

A scenario was simulated with a pollution plume migration from the plant footprint areas for the post-closure phase. The TDS pollution plume extend covers a total area of approximately 54.8ha reaching a maximum distance of ~170.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 50-years and covers a total area of approximately 71.20ha reaching a maximum distance of ~300.0m in a general north-northwest direction towards the lower laying drainage system(s) after a simulation period of 100-years. It is evident that the pollution plume potentially reaches the local drainages system down-gradient of the plant footprint during the post-closure phase.

It is observed that the TDS mass load contribution to down-gradient receptors increase to a concentration above the SANS 241:2015 limit of 1200.0mg/l for the post-closure simulation period. It is noted that the TDS mass load contribution increases to a percentage of ~10.0% to the Sandrivier where the mass load contribution to the Doringrivier increase to a percentage of ~2.0% for the duration of the post-closure simulation period.

It should be noted that vast areas within the study area have been subjected to historical mining activities and, as such, reflect modified to highly modified present ecological status. A total number of >15 000 historical exploration wells have been drilled throughout the study area, some of which remain uncased and unsealed. The latter may act as preferential pathways and conduits for groundwater flow and contaminant transport mechanisms. As mentioned earlier an impact can be defined as any change in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human and/or other related activities. Accordingly, this already highly modified zones should form part of the impact significance rating and risk approach.

During the construction phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium negative** without implementation of remedial measures and **low negative** with implementation of proposed mitigation measures. The main impacts associated with the construction phase activities include the following:

i. Groundwater deterioration and siltation due to contaminated stormwater run-off from the construction area.
ii. Poor quality leachate may emanate from the construction camp which may have a negative impact on groundwater quality.
iii. Mobilisation and maintenance of heavy vehicles and machinery on-site may cause hydrocarbon contamination of groundwater resources.
iv. Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution.

During the operational phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium** to **high negative** without implementation of remedial measures and **low** to **medium negative** with implementation of proposed mitigation measures. The main impacts associated with the operational phase activities include the following:

i. Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.
ii. Migration of stray methane (CH_4) gas from the deep, fractured aquifer to the overlying, potable aquifer(s) during the gas production phase.
iii. Groundwater pollution because of wastewater spills and seepage from the evaporation dams.
iv. Poor quality leachate may emanate from the plant footprint area which may have a negative impact on groundwater quality.
v. Mobilisation and maintenance of heavy vehicle and machinery on-site may cause hydrocarbon contamination of groundwater resources.
vi. Poor storage and management of hazardous chemical substances on-site may cause groundwater pollution.
vii. Leakage of harmful substances from tanks, pipelines or other equipment may cause groundwater pollution.
viii. Leachate of contaminants used in the drilling mud sump(s) to the intergranular, potable aquifer(s) during the operational phase.

During the decommissioning and post-closure phase the environmental significance rating of groundwater quality impacts on down-gradient receptors are rated as **medium negative** without implementation of remedial measures and **low** to **medium negative** with implementation of proposed mitigation measures. The main impacts associated with the post-closure and decommissioning phase activities include the following:

i. Migration of saline groundwater from the deep, fractured aquifer to the overlying, potable aquifer(s) during the borehole closure and decommissioning phase.
ii. Migration of stray methane (CH_4) gas from the deep, fractured aquifer to the overlying, potable aquifer(s) borehole closure and decommissioning phase.
iii. Groundwater pollution because of wastewater spills and seepage from the evaporation dams.
iv. Poor quality leachate may emanate from the plant footprint area which may have a negative impact on

groundwater quality.

v. De-mobilisation of heavy vehicle and machinery as part of the decommissioning phase on-site may cause hydrocarbon contamination of groundwater resources.

The most significant impact of the project on the regional groundwater regime is deterioration of the potable Karoo aquifer water quality as well as modification of the riparian zone primary porosity aquifer associated with alluvium material deposited in flood plains. Groundwater is the sole water resource to the landowners and rural communities within the study area and can thus be classified as a sole source aquifer. It can be concluded that, should the prescribed mitigation and management measures, as stipulated in the groundwater management plan, be implemented and honoured, the impacts associated with the project phases can be minimised. It is important that an integrated groundwater monitoring program be developed and applied serving as an early warning and detection mechanism to implement mitigation measures. The calibrated groundwater flow model should be applied as groundwater management tool for future scenario predictions.

17. RECCOMMENDATIONS

The following recommendations are proposed following this investigation:

i. Mitigation and management measures as set out in the groundwater management plan should be implemented as far as practically possible. It should be noted that the mitigation and management measures recommended in this report should be incorporated into the existing EMPr groundwater management plan and do not substitute the existing mitigation measures, but rather supplement them.

ii. Any development and/or drilling which takes place within the primary porosity aquifer associated with alluvium material deposited in flood plains must be avoided where possible and restricted if it cannot be avoided.

iii. The identified hydrogeological sensitive areas and buffer zones delineated as part of this assessment must be adhered to during the construction and operational phase activities. It is recommended that a localised hydrocensus user survey be performed within a 500.0m radius of each proposed gas production borehole situated within the riparian zone(s) and 350.0m radius of each proposed gas production borehole situated within the Karoo formations in order to identify the presence of other sensitive groundwater receptors and/or private boreholes. Accordingly, the gas production well design must take the results of the hydrocensus into consideration, specifically with regard to the planning and placement of boreholes as part of future drilling programmes.

iv. Additional monitoring boreholes should be established down-gradient of the existing and proposed plant expansion footprints to evaluate the mass load contribution to sensitive environmental and groundwater receptors. Drilling localities should be determined by means of a geophysical survey to target lineaments and weathered zones acting as preferred groundwater flow pathways and contaminant transport mechanisms.

v. It is recommended that the revised monitoring program as set out in this report should be implemented and adhered to. It is imperative that monitoring be conducted to serve as an early warning and detection system. Monitoring results should be evaluated on a bi-annual basis by a suitably qualified person for interpretation and trend analysis and submitted to the Regional Head: Department of Water and Sanitation.

vi. The numerical groundwater flow modelling assumptions should be verified and confirmed. The calibrated groundwater flow model should be updated on a biennial basis as newly gathered monitoring results become available to be applied as groundwater management tool for future scenario predictions.

vii. All preferred groundwater flow pathways which are in direct connection with surface topography such as decommissioned gas production boreholes as well as historical mining exploration boreholes should be sealed off and rehabilitated according to best practise guidelines.

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19. APPENDIX A: RAINFALL DATA (RAINFALL ZONE 4C4)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1920	45.0	34.3	57.4	48.7	62.9	123.0	31.7	31.1	0.1	0.0	0.2	3.1	437.5
1921	14.7	129.2	198.3	101.3	19.0	53.2	1.4	24.4	20.4	0.0	11.8	1.3	575.0
1922	32.6	112.4	79.8	53.0	109.8	29.2	42.9	27.3	17.2	8.4	9.4	0.7	522.7
1923	36.9	40.7	14.1	72.8	63.8	107.6	11.3	3.9	0.2	0.1	3.9	62.4	417.6
1924	63.6	128.4	101.9	99.0	36.7	194.4	64.0	27.8	6.0	0.1	0.3	16.6	738.9
1925	16.1	17.0	34.2	72.8	101.4	61.1	17.6	2.5	1.0	0.1	0.4	23.3	347.6
1926	53.0	41.2	60.6	99.0	36.1	91.9	14.0	0.1	0.1	30.2	3.0	2.1	431.2
1927	39.2	22.0	66.3	141.2	40.1	102.3	38.8	0.9	0.7	0.1	4.2	21.9	477.5
1928	41.3	50.6	42.8	135.5	30.9	74.6	19.4	30.6	42.0	19.6	18.1	81.5	587.0
1929	10.7	73.7	100.8	71.6	61.1	71.8	39.1	13.8	4.0	4.7	2.9	1.3	455.5
1930	31.8	31.2	48.5	116.3	74.5	65.2	134.1	0.1	6.7	20.9	0.8	1.1	531.1
1931	73.9	119.0	32.2	26.4	83.4	58.6	8.1	1.1	1.3	0.1	0.2	9.7	413.9
1932	10.4	62.4	97.3	12.0	29.1	52.2	40.4	3.3	3.4	0.1	0.8	7.0	318.4
1933	18.0	147.8	102.0	264.8	57.4	72.6	49.0	86.7	13.1	31.3	9.9	6.1	858.7
1934	76.1	125.8	68.9	36.1	63.8	83.9	54.6	14.8	2.3	0.1	8.4	14.3	549.2
1935	20.7	95.6	81.9	66.8	75.9	104.0	35.1	30.8	0.1	0.1	0.1	0.9	511.8
1936	41.8	212.6	38.6	141.1	71.5	56.3	13.0	3.6	0.1	0.4	0.5	15.9	595.3
1937	1.5	24.2	64.1	127.2	122.1	20.6	48.1	13.3	18.8	7.6	12.5	3.0	463.1
1938	94.0	13.6	68.4	101.4	123.7	29.6	5.5	25.7	2.7	30.1	31.0	4.6	530.3
1939	61.5	85.0	27.0	30.0	68.8	88.7	44.7	10.0	13.7	0.2	0.7	23.7	453.7
1940	2.8	94.5	68.5	145.9	91.1	37.7	53.8	0.2	0.2	2.7	0.2	14.9	512.3
1941	59.6	9.8	24.9	110.0	63.9	104.7	62.5	11.1	0.1	0.1	43.9	6.7	497.1
1942	87.2	68.4	137.1	83.3	71.0	82.5	102.3	112.4	0.1	52.6	51.8	11.7	860.3
1943	103.1	155.2	135.1	67.2	140.4	52.9	0.7	16.5	51.7	0.1	0.2	38.8	761.9
1944	60.4	86.0	12.5	51.5	55.3	112.7	5.7	13.3	0.1	3.2	0.2	0.7	401.6
1945	14.3	19.2	28.0	129.3	68.0	121.8	33.3	26.6	0.1	0.1	0.1	2.0	442.6
1946	84.8	34.1	53.4	54.0	52.0	58.6	72.9	5.5	0.1	10.5	0.3	26.4	452.4
1947	39.3	60.4	129.0	86.1	38.9	214.2	67.1	15.2	0.1	0.1	0.1	4.1	654.5
1948	34.1	57.8	11.6	64.9	31.9	55.8	15.0	10.1	4.9	3.6	8.8	5.7	304.2
1949	38.1	51.0	106.5	65.1	64.8	88.2	92.0	58.1	4.9	12.2	20.1	2.9	603.9
1950	39.8	37.0	107.9	77.5	47.5	72.8	71.2	19.1	9.2	10.8	7.2	4.0	504.0
1951	45.6	18.2	24.2	54.1	91.2	47.3	21.3	0.7	2.4	30.0	0.4	7.2	342.6
1952	51.2	83.9	137.4	22.2	138.2	40.8	50.3	6.9	0.1	0.1	8.4	1.3	540.9
1953	72.4	68.5	50.1	48.6	125.3	108.8	13.1	14.8	14.0	1.6	0.1	2.4	519.8

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1954	7.5	36.3	67.9	159.4	127.7	32.1	71.0	27.2	10.6	2.0	0.2	1.9	543.9
1955	38.9	50.6	86.2	35.1	161.7	103.9	15.5	40.5	0.5	0.1	0.1	19.7	552.8
1956	103.3	51.0	145.3	132.6	43.3	58.1	33.7	2.6	29.0	21.3	21.6	130.3	772.2
1957	119.3	62.5	121.1	182.5	33.4	47.6	48.6	27.6	0.4	0.0	0.1	21.9	665.0
1958	22.6	40.6	99.1	54.8	41.0	37.6	74.2	54.7	1.4	31.7	0.1	2.8	460.5
1959	57.7	49.7	79.5	37.3	70.9	75.9	50.4	7.7	3.0	14.1	24.0	10.3	480.3
1960	37.5	39.4	116.1	69.1	37.3	45.3	97.7	34.7	36.6	4.5	6.5	2.3	527.1
1961	1.3	105.6	37.9	38.6	89.4	79.6	46.2	2.5	0.1	0.0	1.1	8.4	410.6
1962	35.0	61.5	51.9	119.9	46.7	65.0	71.5	28.4	18.8	8.0	0.0	0.7	507.3
1963	34.5	83.5	51.4	48.0	29.0	99.4	36.7	6.4	21.7	0.1	14.7	1.5	426.8
1964	94.9	20.0	116.7	83.2	12.6	17.5	44.4	1.9	8.4	20.7	0.2	7.5	427.9
1965	40.2	53.5	20.9	108.8	69.9	25.1	6.9	1.4	10.2	0.1	0.3	7.3	344.3
1966	36.6	45.1	73.8	190.8	155.0	76.4	71.5	49.4	0.7	0.2	1.3	3.2	704.1
1967	52.8	75.0	34.5	22.4	15.2	68.8	56.5	56.0	0.0	2.6	14.0	1.3	399.0
1968	31.7	27.8	85.8	31.9	39.5	78.6	56.4	98.4	6.5	0.0	6.6	4.0	467.2
1969	85.8	26.9	53.9	72.4	38.1	23.9	22.1	27.9	15.1	25.1	1.7	18.6	411.4
1970	52.0	60.5	103.3	105.3	59.9	52.9	54.9	36.0	0.0	0.5	0.1	0.0	525.3
1971	31.9	47.6	87.3	123.8	140.4	98.2	22.4	5.8	8.9	0.1	0.0	0.0	566.3
1972	36.9	30.6	17.8	56.0	110.5	44.3	51.8	1.6	0.0	7.3	27.1	46.1	430.0
1973	32.8	51.8	64.4	188.4	102.3	84.3	65.8	3.7	0.4	0.0	8.8	5.2	607.9
1974	20.8	181.2	71.5	128.7	94.0	85.1	37.7	16.0	2.2	5.7	4.3	29.6	676.8
1975	22.8	95.9	96.8	154.3	129.0	69.7	46.1	23.7	17.2	0.0	0.4	24.0	679.9
1976	99.0	69.2	61.4	94.1	50.8	110.6	21.3	1.5	0.6	0.0	2.4	62.9	573.9
1977	53.9	26.5	59.8	76.1	70.9	100.2	96.7	0.0	7.7	0.5	8.2	21.9	522.5
1978	30.0	41.7	56.7	92.5	70.1	15.7	10.0	23.9	1.7	33.9	78.2	9.8	464.2
1979	35.6	92.0	42.8	31.2	79.1	55.1	11.6	4.5	0.0	0.3	1.2	90.8	444.2
1980	5.1	151.4	49.4	103.8	122.2	55.3	21.0	6.5	5.7	0.0	55.7	6.3	582.5
1981	38.3	61.5	101.3	75.7	26.5	48.8	126.9	0.9	3.7	17.9	0.0	20.7	522.2
1982	91.1	50.4	39.6	41.3	52.5	22.4	25.7	8.0	15.4	22.7	0.3	2.9	372.2
1983	95.9	99.6	31.8	47.7	22.1	79.1	10.4	19.6	0.3	1.9	21.8	3.5	433.8
1984	67.1	83.1	52.7	53.1	78.8	78.9	7.9	1.5	12.5	0.0	0.1	2.8	438.4
1985	76.9	34.2	77.2	73.0	12.8	58.6	48.6	3.5	20.6	0.0	18.0	10.0	433.3
1986	62.6	118.4	71.4	45.2	80.0	46.8	33.3	0.3	0.1	8.9	23.4	156.0	646.5
1987	25.6	116.1	58.2	29.2	117.1	174.9	78.3	23.5	8.1	3.2	5.3	31.2	670.7
1988	149.5	67.9	80.2	111.2	127.6	54.8	46.8	27.5	7.6	0.8	2.4	0.5	676.8
1989	42.9	53.8	51.4	43.8	107.6	88.9	65.3	2.1	9.6	10.4	2.7	3.0	481.4

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1990	17.5	25.8	30.8	166.8	66.7	116.7	5.4	1.5	8.0	0.5	0.0	41.0	480.7
1991	88.8	37.6	62.7	21.3	16.0	16.4	14.4	0.0	0.0	3.4	36.1	0.1	296.8
1992	51.4	170.0	39.9	64.3	82.7	46.2	27.0	3.7	0.6	0.0	7.9	2.9	496.5
1993	92.9	41.5	94.1	62.9	97.9	52.2	38.9	0.0	0.3	0.2	0.0	1.7	482.7
1994	31.6	40.5	46.8	84.0	42.9	101.6	21.3	39.1	0.4	0.0	13.1	3.8	425.1
1995	61.0	75.5	137.8	90.7	100.7	71.1	130.6	43.6	0.0	35.3	10.6	23.9	780.8
1996	58.0	129.4	49.6	124.4	39.6	110.3	97.0	61.8	10.4	25.4	6.6	28.5	740.9
1997	29.5	72.3	90.2	126.2	61.1	154.9	12.3	0.5	0.0	0.0	0.2	16.6	563.9
1998	25.3	161.7	103.5	100.7	59.4	41.3	18.5	46.5	0.5	0.0	0.1	2.6	560.1
1999	53.6	19.5	125.9	96.7	33.3	113.5	25.7	30.6	3.1	0.1	0.1	20.7	522.8
2000	95.1	54.9	123.1	41.7	45.5	85.9	120.8	28.7	20.6	3.1	24.4	3.6	647.4
2001	111.0	76.0	175.9	78.2	62.1	40.1	37.7	27.3	2.7	0.1	50.1	10.2	671.3
2002	24.4	32.9	84.2	72.9	75.2	88.7	45.1	7.4	0.0	0.0	7.6	14.3	452.6
2003	21.2	79.3	26.3	50.3	57.7	108.5	24.2	0.0	12.3	9.1	5.8	5.9	400.6
2004	11.6	31.9	60.1	145.2	72.6	48.3	31.5	21.8	2.7	0.0	0.0	0.7	426.4
2005	45.5	61.1	26.2	130.8	104.5	63.4	11.5	7.2	0.0	0.0	48.3	10.0	508.4
2006	30.3	40.8	43.6	26.8	22.2	4.6	34.2	2.3	19.5	0.0	0.0	39.8	264.1
2007	86.2	82.9	74.2	137.0	21.4	93.7	6.3	48.3	4.0	0.0	0.0	0.0	554.1
2008	59.1	148.2	41.7	85.7	97.6	36.5	4.9	56.0	19.6	10.4	8.3	8.6	576.6
2009	86.2	52.0	115.5	201.1	44.1	25.6	36.7	13.2	0.0	0.0	0.0	0.0	574.4
Geometric mean	**49.6**	**69.0**	**72.0**	**87.2**	**69.8**	**72.4**	**42.3**	**19.8**	**7.0**	**6.8**	**9.3**	**15.9**	**521.0**
Minimum	**1.3**	**9.8**	**11.6**	**12.0**	**12.6**	**4.6**	**0.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**264.1**
Maximum	**149.5**	**212.6**	**198.3**	**264.8**	**161.7**	**214.2**	**134.1**	**112.4**	**51.7**	**52.6**	**78.2**	**156.0**	**860.3**
Standard deviation	**30.3**	**42.5**	**37.8**	**47.5**	**35.7**	**37.5**	**30.8**	**22.1**	**9.7**	**11.0**	**14.8**	**25.8**	**121.5**

20. APPENDIX B: WATER QUALITY ANALYSIS LABORATORY CERTIFICATES

21. APPENDIX C: SPECIALIST CURICULUM VITAE

THE PROPOSED TETRA4 CLUSTER 2 GAS PRODUCTION PROJECT, BETWEEN WELKOM, VIRGINIA AND THEUNISSEN, FREE STATE PROVINCE

Heritage Impact Assessment

Issue Date:	29 June 2022
Revision No.:	0.2
Project No.:	580HIA

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Waverley, Pretoria,
South Africa

Directors: HS Steyn, PD Birkholtz, W Fourie

Declaration of Independence

I, Nikki Mann, declare that –

1. General declaration:
2. I act as the independent heritage practitioner in this application
3. I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant
4. I declare that there are no circumstances that may compromise my objectivity in performing such work;
5. I have expertise in conducting heritage impact assessments, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
6. I will comply with the Act, Regulations and all other applicable legislation;
7. I will take into account, to the extent possible, the matters listed in section 38 of the NHRA when preparing the application and any report relating to the application;
8. I have no, and will not engage in, conflicting interests in the undertaking of the activity;
9. I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
10. I will ensure that information containing all relevant facts in respect of the application is distributed or made available to interested and affected parties and the public and that participation by interested and affected parties is facilitated in such a manner that all interested and affected parties will be provided with a reasonable opportunity to participate and to provide comments on documents that are produced to support the application;
11. I will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not
12. All the particulars furnished by me in this form are true and correct;
13. I will perform all other obligations as expected from a heritage practitioner in terms of the Act and the constitutions of my affiliated professional bodies; and
14. I realise that a false declaration is an offence in terms of regulation 71 of the Regulations and is punishable in terms of section 24F of the NEMA.

Disclosure of Vested Interest

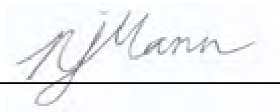
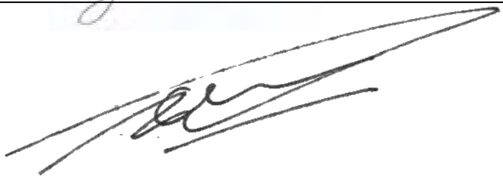
15. I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remuneration for work performed in terms of the Regulations;

<u>HERITAGE CONSULTANT:</u> PGS Heritage (Pty) Ltd

<u>CONTACT PERSON:</u> Nikki Mann - Archaeologist
Tel: +27 (0) 12 332 5305
Email: nikki@pgsheritage.co.za

<u>SIGNATURE:</u> NJ Mann

Report Title	*THE PROPOSED TETRA4 CLUSTER 2 GAS PRODUCTION PROJECT, BETWEEN WELKOM, VIRGINIA AND THEUNISSEN, FREE STATE PROVINCE*

Control	Name	Signature	Designation
Author	Nikki Mann		Archaeologist – PGS Heritage
Reviewed	Wouter Fourie		Senior Heritage Specialist/ Project Manager – PGS Heritage
Reviewed			EIMS

<u>DETAILS OF CLIENT</u>:

CLIENT: Environmental Impact Management Services (Pty) Ltd (EIMS)

CONTACT PERSON:

EXECUTIVE SUMMARY

PGS Heritage (Pty) Ltd (PGS) was appointed by Environmental Impact Management Services Consulting (Pty) Ltd (EIMS) to undertake a Heritage Impact Assessment (HIA), which forms part of the environmental process for the proposed Tetra4 Cluster 2 Gas Production Project, located within the Matjhabeng and Masilonyana Local Municipalities, between Welkom, Virginia and Theunissen, Free State Province.

This HIA aims to evaluate the possible impacts on heritage resources present within the proposed development footprint of the Tetra4 Cluster 2 Gas Production Project. Immediate and direct impacts on archaeological and palaeontological resources were addressed through the HIA.

Site Name and Location

The proposed Tetra4 Cluster 2 Gas Production Project is located within Matjhabeng and Masilonyana Local Municipalities, between Welkom, Virginia and Theunissen, Free State Province.

Coordinates for Study Area	Northernmost point: S -28.07716 E 26.66416	Easternmost point: S -28.23105 E 26.80612
	Southernmost point: S -28.23972 E 26.69567	Westernmost point: S -28.16878 E 26.63364

General Desktop Study

An archival and historical desktop study was undertaken to provide a historic framework for the project area and surrounding landscape. This was augmented by a study of available historical and archival maps and an assessment of previous archaeological and heritage studies completed for the area. The desktop study revealed that the surroundings of the study area are characterised by a long and significant history, whereas previous archaeological and heritage studies from this area have revealed several archaeological and heritage sites from the surroundings.

Several archaeological and heritage surveys have been undertaken within the region. In 2016 and 2017, fieldwork was conducted by Polke Birkholtz (2017a, 2017b), an archaeologist of PGS. **Thirty-five** (35) of the **heritage finds** identified during this fieldwork, fall within the current study area. These were classified as either cemeteries, historic structures believed to be older than 100 years, historic structures believed to be older than 60 years, historical buildings of low significance, historic to recent sites with possible stillborn baby graves and possible grave sites.

There were ten (10) graves and burial grounds (**TET 1, TET 7-8, TET 11, TET 15, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19**), eleven (11) structures (**TET 2-3, TET 9, TET 27, SSL/BET/25-26, SSL/BET/36, SITE 1A, SITE 1B, SITE 20-21**), fourteen (14) historic to recent sites with possible graves (**TET 4-6, TET 13-14,TET 25a, TET 25b, TET 26**, **SSL/BET/37-39, SSL/BET/53**, **SSL/BET/60, SSL/BET/66**).

Palaeontology

Elize Butler of Banzai Environmental (Pty) Ltd was commissioned to undertake a two-day Palaeontological Impact Assessment. Her report and findings are attached in full in Appendix B.

Butler found that the study area is " by Quaternary sediments as well as Permian aged sandstone and shale of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup). According to the PalaeoMap of the South African Heritage Resources Information System (SAHRIS) the Palaeontological Sensitivity of Quaternary sediments in this area is Moderate, while that of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup) is Very High."

Fieldwork

The fieldwork component of the study was aimed at identifying tangible remains of archaeological, historical and heritage significance.

The fieldwork was undertaken by way of intensive walkthroughs of the proposed development footprint areas. It is important to note that although as intensive a fieldwork coverage as possible was undertaken, sections of the study area are in areas which are more densely overgrown and/or disturbed (crops: maize, sunflowers, soya beans; ploughed areas) or have restricted access, which limited visibility in those areas of the study area. Therefore, the walkthroughs were focused on those areas that are not disturbed, as the potential for identifying archaeological and heritage sites in the more undisturbed components of the study area are much higher. As a result, only limited fieldwork was undertaken in those components of the study area that are entirely disturbed.

The fieldwork was undertaken by three archaeologists from PGS (Nikki Mann, Michelle Sachse, Nicholas Fletcher) on 14-24 February 2022. Throughout the fieldwork, hand-held GPS devices were used to record tracklogs showing the routes followed by the fieldwork team.

Recent fieldwork undertaken resulted in the identification of a total of **forty-one** (41) **heritage sites** (four of which were previously recorded; see footnotes below).

These sites comprised the following:

- Seven (7) sites containing burial grounds and graves. See sites **T0003, T0009, T0010, T0012[1], T0013, T0024, T0029**.
- Nine (9) sites historic to recent sites with possible graves. See sites **T0007, T0008, T0011, T0015, T0023, T0026, T0027, T0028, T0035[2]**.
- Twenty-five (25) structures. See sites **T0001, T0002, T0004, T0005, T0006[3], T0014, T0016, T0017, T0018, T0019, T0020, T0021, T0022, T0025, T0030, T0031, T0032[4], T0033, T0034, T0036, T0037, T0038, T0039, T0040, T0041.**

Impact Assessment

Burial grounds and graves

A total of fourteen (14) burial grounds and graves (**TET 1, TET 7-8, TET 11, TET 15**[1]**, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19** and **T0003, T0009, T0024, T0029**) were identified within the proposed development areas. Burial grounds and graves have high heritage significance and are given a IIIA significance rating in accordance with the system described in Section 4 of this document.

Burial grounds and graves are protected under Section 36 of the NHRA 25 of 1999. Thus, the sites are provisionally rated as having a high heritage significance with a heritage rating of IIIA. All graves have high levels of emotional, religious and in some cases historical significance. It is also important to understand that the identified graves could have significant heritage value to the relevant families.

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

Historic to recent sites with possible graves

A total of fourteen (14) possible grave sites (**TET 4-6, TET 13**[2]**, TET 14, TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**) were identified within the proposed development area. Burial grounds and graves have high heritage significance and are given a IIIA significance rating in accordance with the system described in Section 4 of this document.

[1] Note that site T0012 identified during the field assessment is the same site as TET15 identified in the 2016/2017 heritage assessment.

[2] Note that site T0035 identified during the field assessment is the same site as TET13 identified in the 2016/2017 heritage assessment.

[3] Note that site T0006 identified during the field assessment is the same site as SITE 1B identified in the 2016/2017 heritage assessment.

[4] Note that site T0032 identified during the field assessment is the same site as TET3 identified in the 2016/2017 heritage assessment.

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

Structures

A total of thirty-one (31) structures (**TET 2, TET3**[4]**, TET 9, TET 27, SSL/BET/25-26, SSL/BET/36, SITE 1A, SITE 1B**[3]**, SITE 20-21**and **T0001, T0002, T0004, T0005, T0017, T0018, T0019, T0020, T0021, T0025, T0030, T0031, T0033, T0034, T0036, T0037, T0038, T0039, T0040, T0041**) were identified within the proposed development area.

Twenty-one (21) of the heritage sites (**TET27, SSL/BET/25, SSL/BET/26, SSL/BET/36, T0001, T0002, T0004, T0005, T0017, T0018, T0019, T0020, T0025, T0030, T0031, T0033, T0034, T0036, T0037, T0038, T0039**) are assessed to have a low heritage significance are not included in the impact assessment. The reason for this is that sites of low significance will not require mitigation.

Structures older than 60 years fall under the protection of Section 34(1) of the National Heritage Resources Act 25 of 1999. Additionally, in terms of Section 35(4) of the National Heritage Resources Act (25 of 1999), man-made features and artefacts older than 100 years are defined as being archaeological. In the same section, the act also states that such archaeological sites and objects may not be disturbed, altered, modified or destroyed without a suitable permit from the South African Heritage Resources Agency (SAHRA).

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

Palaeontology

No visible evidence of fossiliferous outcrops was found in the development footprint and thus an overall medium palaeontological significance is allocated to the development footprint. It is therefore considered that the proposed development will not lead to detrimental impacts on the palaeontological reserves of the area and construction of the development may be authorised in its whole extent.

Mitigation measures

The following mitigation measures are listed in the table below.

Area and site no.	Mitigation Measures
General project area	▪ Implement a chance find procedures in case where possible heritage finds are uncovered.

Area and site no.	Mitigation Measures
Burial Grounds and Graves (**TET 1, TET 7-8, TET 11, TET 15**[1], **TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19** and **T0003, T0009, T0024, T0029**) that were located within the proposed development area and were rated as high local heritage significance and had a heritage grading of IIIA.	▪ The graves should be demarcated with a **50-meterbuffer** and should be avoided and left in situ. ▪ A Grave Management Plan should be developed for the graves which also need to be approved by SAHRA BGG. ▪ If the site is going to be impacted and the graves need to be removed a grave relocation process as per the Heritage Management Plan for the site is recommended as a mitigation and management measure. This will involve the necessary social consultation and public participation process before grave relocation permits can be applied for with the SAHRA BGG under the NHRA and National Health Act regulations.
Burial Grounds and Graves (**T0010, T0013**) that were located outside of the proposed development area.	▪ No mitigation required.
Historic to recent sites with possible grave sites (**TET 4-6, TET 13**[2]**, TET 14, TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**) that were located within the proposed development area and were rated as high local heritage significance and had a heritage grading of IIIA.	▪ Apply for the test excavation and/or GPR permit to determine if the site contains graves. ▪ If human remains are discovered a grave relocation process is recommended as a mitigation and management measure. This will involve the necessary social consultation and public participation process before grave relocation permits can be applied for with the SAHRA BGG under the NHRA and National Health Act regulations. ▪ When graves are discovered/uncovered the site should be demarcated with a **50-meterno-go-buffer-zone** and the grave should be avoided. ▪ If, during test excavations, it is determined that the site does not contain graves, no further mitigation will be required.
Historic to recent sites with possible grave sites (**T0015, T0023, T0026, T0027, T0028**) that were located outside of the proposed development area and were rated as high local heritage significance and had a heritage grading of IIIA.	▪ No mitigation required.
Structures (**TET2, TET3**[4]**, TET9, SITE 1A, SITE 1B**[3]**, SITE 20,**	▪ It is recommended that a no-go-buffer-zone of at least **30m** is kept to the closest infrastructure.

Area and site no.	Mitigation Measures
SITE 21, T0021, T0040, T0041) that were located within the proposed development area and were rated as medium local heritage significance and had a heritage grading of IIIB.	▪ If development occurs within 30m of the site, the structure will need to be satisfactorily studied and recorded before impact occurs. ▪ Recording of the site i.e. (a) map indicating the position and footprint of the structure (b) photographic recording of the structure (c) measured drawings of the floor plans of the structure. ▪ Submission of permit application to SAHRA to allow for the disturbance to the site. A Phase 2 Heritage Report must accompany the permit.
Structures (**T0014**) that were located outside of the proposed development area and were rated as medium local heritage significance and had a heritage grading of IIIB.	▪ No mitigation is required.
Structures (**TET27, SSL/BET/25, SSL/BET/26, SSL/BET/36, T0017, T0018, T0019, T0020, T0025, T0037, T0038**) that were located within the proposed development area and were rated as low local heritage significance and had a heritage grading of IIIC.	▪ No mitigation is required. The documentation of the site in the HIA report is sufficient and the site can be destroyed without a permit but with the approval of this report.
Structures (**T0016, T0022**) that were located outside of the proposed development area and were rated as low local heritage significance and had a heritage grading of IIIC.	▪ No mitigation is required.
Structures (**T0001, T0002, T0004, T0005, T0030, T0031, T0033, T0034, T0036, T0039)** that were located within the proposed development area and were rated to have no research potential or other cultural significance and had a heritage	▪ No mitigation is required.

Area and site no.	Mitigation Measures
grading of not conservation worthy (NCW).	
Palaeontology	• The ECO for this project must be informed that the Adelaide Subgroup (Beaufort Group, Karoo Supergroup) has a **Very High Palaeontological Sensitivity**. • If Palaeontological Heritage is uncovered during surface clearing and excavations the **Chance find Protocol** attached should be implemented immediately. Fossil discoveries ought to be protected and the ECO/site manager must report to South African Heritage Resources Agency (SAHRA) (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Tel: 021 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) so that mitigation (recording and collection) can be carried out. • Before any fossil material can be collected from the development site the specialist involved would need to apply for a collection permit from SAHRA. Fossil material must be housed in an official collection (museum or university), while all reports and fieldwork should meet the minimum standards for palaeontological impact studies proposed by SAHRA (2012). • These recommendations should be incorporated into the Environmental Management Plan for the Tetra4 Development.

General

It is the considered opinion of the authors of this report that the overall impact of the proposed Tetra4 Cluster 2 Gas Production Project on heritage resources will be Low. Provided that the general recommendations and mitigation measures outlined in this report are implemented, the impact would be acceptably Low or could be totally mitigated to the degree that the project could be approved from a heritage perspective. The management and mitigation measures as described in section 8 of this report have been developed to minimise the project impact on heritage resources.

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TERMINOLOGY AND ABBREVIATIONS

Archaeological resources

This includes:

- material remains resulting from human activity which are in a state of disuse and are in or on land and which are older than 100 years including artefacts, human and hominid remains and artificial features and structures;
- rock art, being any form of painting, engraving or other graphic representation on a fixed rock surface or loose rock or stone, which was executed by human agency, and which is older than 100 years, including any area within 10m of such representation;
- wrecks, being any vessel or aircraft, or any part thereof, which was wrecked in South Africa, whether on land, in the internal waters, the territorial waters or in the maritime culture zone of the republic as defined in the Maritimes Zones Act, and any cargo, debris or artefacts found or associated therewith, which is older than 60 years or which SAHRA considers to be worthy of conservation; and
- features, structures and artefacts associated with military history which are older than 75 years and the site on which they are found.

Cultural significance

This means aesthetic, architectural, historical, scientific, social, spiritual, linguistic or technological value or significance

Development

This means any physical intervention, excavation, or action, other than those caused by natural forces, which may in the opinion of the heritage authority in any way result in a change to the nature, appearance or physical nature of a place or influence its stability and future well-being, including:

- construction, alteration, demolition, removal or change in use of a place or a structure at a place;
- carrying out any works on or over or under a place;
- subdivision or consolidation of land comprising a place, including the structures or airspace of a place;
- constructing or putting up for display signs or boards;
- any change to the natural or existing condition or topography of land; and
- any removal or destruction of trees, or removal of vegetation or topsoil.

Early Stone Age

The archaeology of the Stone Age between 700 000 and 3 300 000 years ago.

Fossil

Mineralised bones of animals, shellfish, plants and marine animals. A trace fossil is the track or footprint of a fossil animal that is preserved in stone or consolidated sediment.

Heritage

That which is inherited and forms part of the National Estate (historical places, objects, fossils as defined by the National Heritage Resources Act 25 of 1999).

Heritage resources

This means any place or object of cultural significance and can include (but is not limited to) the following list as outlined under Section 3 of the National Heritage Resources Act (NHRA):

- places, buildings, structures, and equipment of cultural significance;
- places to which oral traditions are attached or which are associated with living heritage;
- historical settlements and townscapes;
- landscapes and natural features of cultural significance;
- geological sites of scientific or cultural importance;
- archaeological and palaeontological sites;
- graves and burial grounds, and
- sites of significance relating to the history of slavery in South Africa;

Holocene

The most recent geological time which commenced 10 000 years ago.

Late Stone Age

The archaeology of the last 30 000 years associated with fully modern people.

Late Iron Age (Early Farming Communities)

The archaeology of the last 1000 years up to the 1800's, associated with iron-working and farming activities such as herding and agriculture.

Middle Iron Age

The archaeology of the period between 900-1300AD, associated with the development of the Zimbabwe culture, defined by class distinction and sacred leadership.

Middle Stone Age

The archaeology of the Stone Age between 30 000-300 000 years ago, associated with early modern humans.

Palaeontology

Any fossilised remains or fossil trace of animals or plants which lived in the geological past, other than fossil fuels or fossiliferous rock intended for industrial use, and any site which contains such fossilised remains or trace.

Site

Site in this context refers to a place where a heritage resource is located and not a proclaimed heritage site as contemplated under s27 of the NHRA.

Table 1 - List of abbreviations used in this report

Abbreviations	Description
AIA	Archaeological Impact Assessment
ASAPA	Association of South African Professional Archaeologists
CRM	Cultural Resource Management
DEA	Department of Environmental Affairs
EAP	Environmental Assessment Practitioner
ECO	Environmental Control Officer
EIA	Environmental Impact Assessment
EIMS	Environmental Impact Management Services (Pty) Ltd
EMPr	Environmental Management Programme
ESA	Earlier Stone Age
FSHRA	Free State Heritage Resources Authority
GPS	Global Positioning System
HIA	Heritage Impact Assessment
I&AP	Interested & Affected Party
LCTs	Large Cutting Tools
LSA	Late Stone Age
LIA	Late Iron Age
LOM	Life of Mine
MPRDA	Mineral and Petroleum Resources Development Act 28 of 2002
MSA	Middle Stone Age
MIA	Middle Iron Age
NEMA	National Environmental Management Act, 1998 (Act No 107 of 1998)
NHRA	National Heritage Resources Act, 1999 (Act No 25 of 1999)
PGS	PGS Heritage (Pty) Ltd
PHRA	Provincial Heritage Resources Authority
PIA	Palaeontological Impact Assessment
PSSA	Palaeontological Society of South Africa
SAHRA	South African Heritage Resources Agency
SAHRIS	South African Heritage Resources Information System

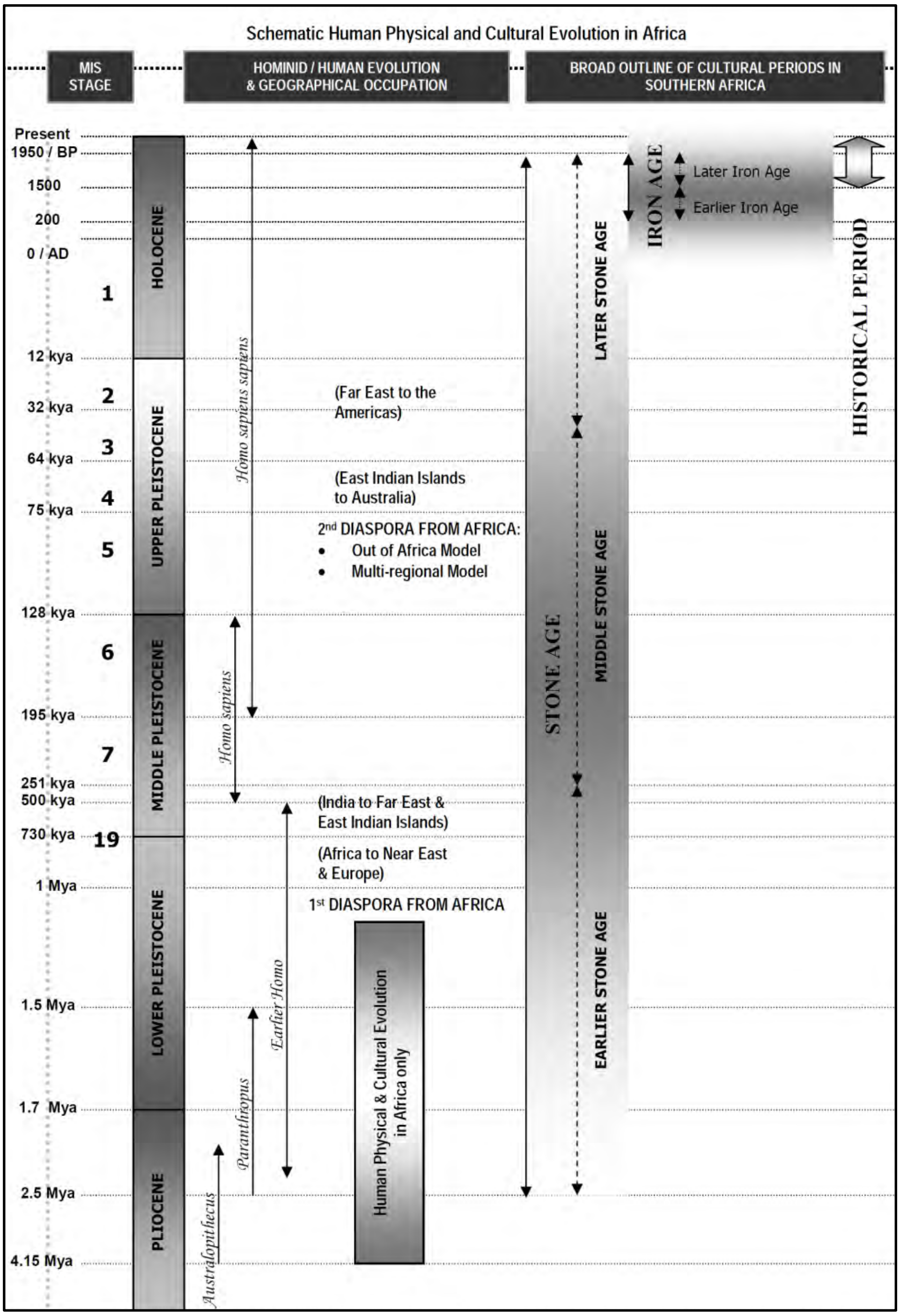


Figure 1 - Human and Cultural Timeline in Africa (Morris, 2008).

1 INTRODUCTION

PGS Heritage (Pty) Ltd (PGS) was appointed by Environmental Impact Management Services Consulting (Pty) Ltd (EIMS) to undertake a undertake a Heritage Impact Assessment (HIA), which forms part of the environmental process for the proposed Tetra4 Cluster 2 project. The project proposes to extend natural gas production operations within an existing Production Right (PASA Reference: 12/4/1/07/2/2), within the Matjhabeng and Masilonyana Local Municipalities, located between Welkom, Virginia and Theunissen. The study area is approximately 25 000ha in extent in the Free State Province.

Apart from the overall study area, which was assessed by the desktop study, a development footprint was provided by EIMS to assess as part of this HIA.

1.1 SCOPE OF THE STUDY

The aim of the study is to identify possible heritage sites and finds that may occur in the proposed development area. The HIA aims to inform the EIA in the development of a comprehensive EMPr to assist the project applicant in responsibly managing the identified heritage resources to protect, preserve, and develop them within the framework provided by the National Heritage Resources Act (Act 25 of 1999) (NHRA).

1.2 SPECIALIST QUALIFICATIONS

This HIA was compiled by PGS.
The staff at PGS has a combined experience of nearly 90 years in the heritage consulting industry. PGS and its staff have extensive experience in managing HIA processes. And will only undertake heritage assessment work where they have the relevant expertise and experience to undertake that work competently.

The following individuals were involved with this study:

- Wouter Fourie, the Project Coordinator, is registered with the ASAPA as a Professional Archaeologist and is accredited as a Principal Investigator; he is further an Accredited Professional Heritage Practitioner with the Association of Professional Heritage Practitioners (APHP).

- Nikki Mann, the author of this report, is registered as a Professional Archaeologist with the Association of Southern African Professional Archaeologists (ASAPA). She has 4 years of experience in the heritage assessment field and holds a Master's degree (MSc) in Archaeology from the University of Cape Town.

- Michelle Sachse, the co-author of this report, is registered with the Association of Southern African Professional Archaeologists (ASAPA) as a Professional Archaeologist. She holds a MA in Archaeology and a BA (Hons) in Archaeology
- Nicholas Fletcher is a field archaeologist. He holds a BA (Hons) in Archaeology.

1.3 ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations regarding this study and report exist:

- Not detracting in any way from the comprehensiveness of the fieldwork undertaken, it is important to realise that the heritage resources located during the fieldwork do not necessarily represent all the possible heritage resources present within the area. Various factors account for this, including the subterranean nature of some archaeological sites, as well as the dense vegetation cover and disturbance found in some areas (crops: maize, sunflowers, soya bean; ploughed land).
- There was also restricted access to certain farm properties (BLAAUWDRIFT No.188 (Portion 3), BRUINTJE HOOGTE No.367 (Portion 2, 3), BRYAN No.561 (Portion 10, 21, 28, 29, 30, 31, 38), GLEN ROSS No.734 (Portion 4, 5, 6, 7, 18, 20), JONKERS RUST No.72, KALKOENKRANS No.225 (Portion 3), MOND VAN DOORNRIVIER No.38 (Portion 2), MOOIFONTEIN No.639, PALMIETJUIL No.548 (Portion 1), STILLE WONING no.703, VLAKPAN No.358) due to farm owners not giving permission to access their properties, flooded roads and dangerous game life on the properties.
- As such, should any heritage features and/or objects not included in the present inventory be located or observed, a heritage specialist must immediately be contacted. Such observed or located heritage features and/or objects may not be disturbed or removed in any way until such time that the heritage specialist has been able to make an assessment as to the significance of the site (or material) in question. This applies to graves and cemeteries as well. In the event that any graves or burial places are located during the development, the procedures and requirements pertaining to graves and burials will apply as set out below.
- The study area boundaries and development footprints depicted in this report were provided by the client. As a result, these were the areas assessed during the fieldwork. Should any additional development footprints located outside of these study area boundaries be required, such additional areas will have to be assessed in the field by an experienced archaeologist/heritage specialist long before construction starts.

1.4 IDENTIFICATION OF POLICIES, LEGISLATION, STANDARDS & GUIDELINES

The identification, evaluation and assessment of any cultural heritage site, artefact or find in the South

African context is required and governed by the following legislation:

1.4.1 STATUTORY FRAMEWORK: THE NATIONAL HERITAGE RESOURCES (ACT 25 OF 1999)

The NHRA is utilised as the basis for the identification, evaluation and management of heritage resources, and in the case of Cultural Resource Management (CRM), those resources specifically impacted by the development as stipulated in Section 38 of NHRA.

The National Heritage Resources Act (Act No 25 of 1999, Art 3) outlines the following types and ranges of heritage resources that qualify as part of the National Estate, namely:

a) places, buildings structures and equipment of cultural significance;
b) places to which oral traditions are attached or which are associated with living heritage;
c) historical settlements and townscapes;
d) landscapes and natural features of cultural significance;
e) geological sites of scientific or cultural importance;
f) archaeological and palaeontological sites;
g) graves and burial grounds including-
    (i) ancestral graves;
    (ii) royal graves and graves of traditional leaders;
    (iii) graves of victims of conflict;(iv) graves of individuals designated by the Minister by notice in the Gazette;
    (iv) (v) historical graves and cemeteries; and
    (v) (vi) other human remains which are not covered by in terms of the Human Tissues Act, 1983 (Act No 65 of 1983);
h) sites of significance relating to the history of slavery in South Africa;
i) movable objects, including -
j) objects recovered from the soil or waters of South Africa, including archaeological and palaeontological objects and material, meteorites and rare geological specimens;
    (i) objects to which oral traditions are attached or which are associated with living heritage;
    (ii) ethnographic art and objects;
    (iii) military objects;
    (iv) objects of decorative or fine art;
    (v) objects of scientific or technological interest; and
    (vi) books, records, documents, photographs, positives and negatives, graphic, film or video material
    (vii) or sound recordings, excluding those that are public records as defined in section 1(xiv) of the National Archives of South Africa Act, 1996 (Act No 43 of 1996).

The NHRA (Act No 25 of 1999) also distinguishes nine criteria for places and objects to qualify as 'part of the national estate if they have cultural significance or other special value'. These criteria are:

3) Without limiting the generality of subsections (1) and (2), a place or object is to be considered part of the national estate if it has cultural significance or other special value because of—

a) its importance in the community, or pattern of South Africa's history;
b) its possession of uncommon, rare or endangered aspects of South Africa's
c) natural or cultural heritage;
d) its potential to yield information that will contribute to an understanding of
e) South Africa's natural or cultural heritage;
f) its importance in demonstrating the principal characteristics of a particular
g) class of South Africa's natural or cultural places or objects;
h) its importance in exhibiting particular aesthetic characteristics valued by a
i) community or cultural group;
j) its importance in demonstrating a high degree of creative or technical
k) achievement at a particular period;
l) its strong or special association with a particular community or cultural group
m) for social, cultural or spiritual reasons;
n) its strong or special association with the life or work of a person, group or
o) organisation of importance in the history of South Africa; and
p) sites of significance relating to the history of slavery in South Africa.

1.4.1.1 SECTION 34 – STRUCTURES

According to Section 34 of the NHRA, no person may alter, damage or destroy any structure that is older than 60 years, and which forms part of the built environment of the sites, without the necessary permits from the relevant provincial heritage authority.

1.4.1.2 SECTION 35 – ARCHAEOLOGY, PALAEONTOLOGY AND METEORITES

According to Section 35 (Archaeology, Palaeontology and Meteorites) and Section 38 (Heritage Resources Management) of the NHRA, PIAs and AIAs are required by law in the case of developments in areas underlain by potentially fossiliferous (fossil-bearing) rocks, especially where substantial bedrock excavations are envisaged, and where human settlement is known to have occurred during prehistory and the historic period.

1.4.1.3 SECTION 36 – BURIAL GROUNDS & GRAVES

A Section 36 permit application is made to the SAHRA or the competent provincial heritage authority which protects burial grounds and graves that are older than 60 years and must conserve and generally care for burial grounds and graves protected in terms of this section, and it may make such arrangements for their conservation as it sees fit. SAHRA must also identify and record the graves of victims of conflict and any other graves which it deems to be of cultural significance and may erect memorials associated with these graves and must maintain such memorials. A permit is required under the following conditions:

Permit applications for burial grounds and graves older than 60 years should be submitted to the South African Heritage Resources Agency:

- destroy, damage, alter, exhume or remove from its original position or otherwise disturb the grave of a victim of the conflict, or any burial ground or part thereof which contains such graves.
- destroy, damage, alter, exhume, remove from its original position or otherwise disturb any grave or burial ground older than 60 years which is situated outside a formal cemetery administered by a local authority; or
- bring onto or use at a burial ground or grave referred to in paragraph (a) or (b) any excavation equipment, or any equipment which assists in the detection or recovery of metals.
- SAHRA or a provincial heritage resources authority may not issue a permit for the destruction or damage of any burial ground or grave referred to in subsection (3)(a) unless it is satisfied that the applicant has made satisfactory arrangements for the exhumation and re-interment of the contents of such graves, at the cost of the applicant.

1.4.1.4 SECTION 38 - HIA AS A SPECIALIST STUDY WITHIN THE EIA IN TERMS OF SECTION 38(8)

A NHRA Section 38 (Heritage Impact Assessments) application is required when the proposed development triggers one or more of the following activities:

a) the construction of a road, wall, power line, pipeline, canal or other similar form of linear development or barrier exceeding 300m in length;
b) the construction of a bridge or similar structure exceeding 50 m in length;
c) any development or other activity which will change the character of a site,
    i. exceeding 5 000 m2 in extent; or
    ii. involving three or more existing erven or subdivisions thereof; or
    iii. involving three or more erven or divisions thereof which have been consolidated within the past five years; or

iv. the costs of which will exceed a sum set in terms of regulations by SAHRA or a provincial heritage resources authority;

d) the re-zoning of a site exceeding 10 000 m2 in extent; or
e) any other category of development provided for in regulations by SAHRA or a provincial heritage resources authority

In this instance, the heritage assessment for the property is to be undertaken as a component of the EIA for the project. Provision is made for this in terms of Section 38(8) of the NHRA, which states that:

- An HIA report is required to identify, and assess archaeological resources as defined by the NHR Act, assess the impact of the proposal on the said archaeological resources, review alternatives and recommend mitigation (see methodology above).

Section 38 (3) Impact Assessments are required, in terms of the statutory framework, to conform to basic requirements as laid out in Section 38(3) of the NHRA. These are:

- The identification and mapping of heritage resources in the area affected;
- The assessment of the significance of such resources;
- The assessment of the impact of the development on the heritage resources;
- An evaluation of the impact on the heritage resources relative to sustainable socio/economic benefits;
- Consideration of alternatives if heritage resources are adversely impacted by the proposed development;
- Consideration of alternatives; and
- Plans for mitigation.

1.4.2 NATIONAL ENVIRONMENTAL MANAGEMENT ACT, 1998 (ACT NO. 107 OF 1998)

The cultural environment in South Africa is managed through Section 24 of the National Environmental Management Act (NEMA), No. 107 of 1998. The NEMA creates the legal framework by which cultural heritage can be managed.

Furthermore, under Section 2(4)(a) of the NEMA:

2 (4) (a) Sustainable development requires the consideration of all relevant factors including the following:

(iii) the disturbance of landscapes and sites that constitute the nation's cultural heritage must be avoided, or where it cannot be altogether avoided, is minimised and remedied.

1.4.3 NOTICE 648 OF THE GOVERNMENT GAZETTE 45421

Although minimum standards for archaeological (2007) and palaeontological (2012) assessments were published by SAHRA (2016), Government Notice (GN) 648 of 2019 requires sensitivity verification for a site selected on the national web-based environmental screening tool for which no specific assessment protocol related to any theme has been identified. The requirements for this GN are listed in **Table 2** and the applicable section in this report noted.

Table 2 - Reporting requirements for GN 648 of 2019

GN 648	Relevant section in report	Where not applicable
2.2 (a) a desktop analysis, using satellite imagery	Section 5	-
2.2 (b) a preliminary on-site inspection to identify if there are any discrepancies with the current use of land and environmental status quo versus the environmental sensitivity as identified on the national web-based environmental screening tool, such as new developments, infrastructure, indigenous/pristine vegetation, etc.	Section 3	-
2.3(a) confirms or disputes the current use of the land and environmental sensitivity as identified by the national web-based environmental screening tool	Section 1 and 5	-
2.3(b) contains a motivation and evidence (e.g. photographs) of either the verified or different use of the land and environmental sensitivity	Section 3 provides a description of the current use and confirms the status in the screening report	-

An assessment of the Environmental Screening tool provides the following sensitivity rating for archaeological and heritage resources that fall within the proposed area as Low (**Figure 2**), while palaeontological resources are rated as Medium to Very High (**Figure 3**). Based on the fieldwork findings the screening tool for the archaeological and cultural heritage layer mapped the known historical sites in the central portion of the study area as well as those within the towns adjacent to the study area. However, parts of the study area contain numerous archaeological sites not listed on the database of the screening tool.

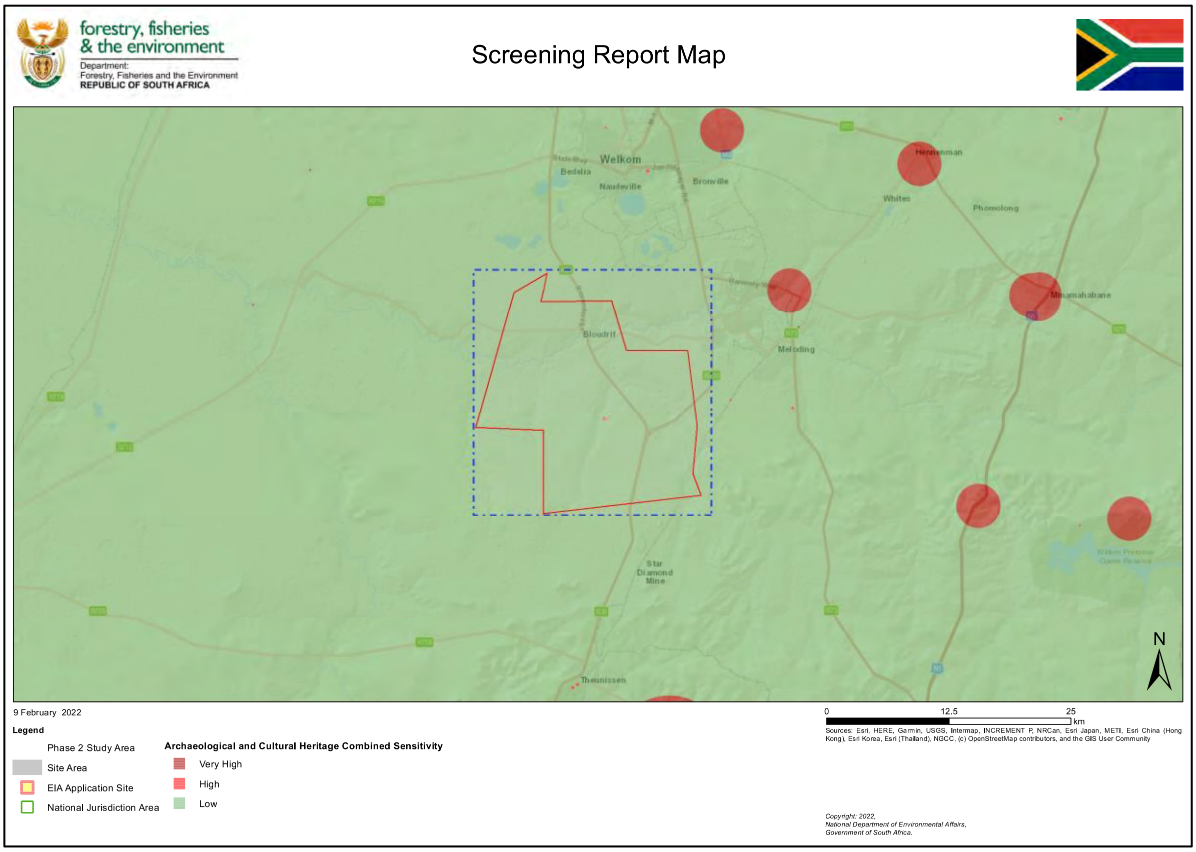


Figure 2 - Environmental screening tool's depiction of the archaeological and heritage sensitivity of the study area and surroundings.

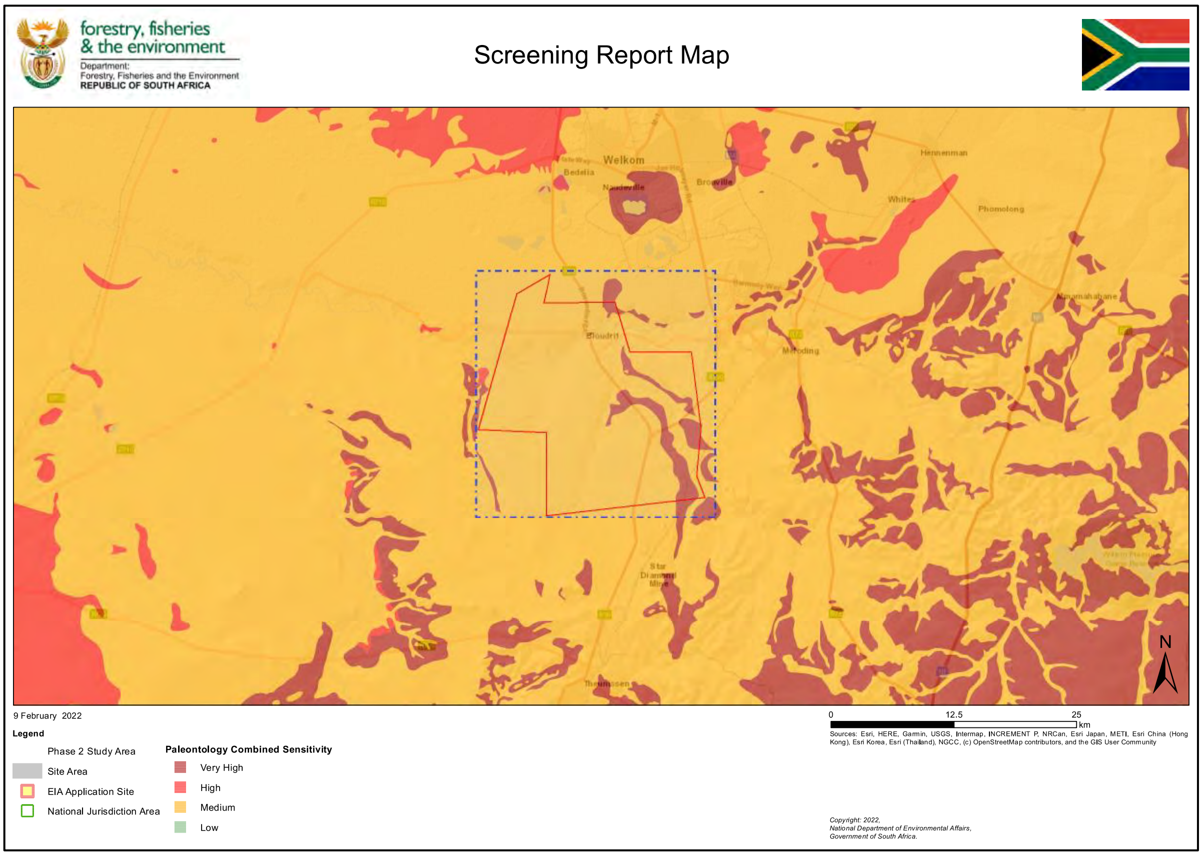


Figure 3 - Environmental screening tool's depiction of the palaeontological sensitivity of the study area and surroundings.

1.4.4 NEMA – APPENDIX 6 REQUIREMENTS

The HIA report has been compiled considering the National Environmental Management Act (Act No. 107 of 1998) (NEMA) and Environmental Impact Assessment (EIA) Regulations (2014, and as amended in 2017) (

Table 3).

The table below sets out the relevant sections as listed in Appendix 6 of the EIA Regulations (2017), which describes the requirements for specialist reports. For ease of reference, the table provides cross-references to the report sections where these requirements have been addressed. It is important to note that where something is not applicable to this HIA, this has been indicated in the table below.

Table 3 - Reporting requirements as per NEMA Appendix 6 for specialist reports

Requirements of Appendix 6 – GN R326 EIA Regulations of 7 April 2017	Relevant section in report	Comment where not applicable
1.(1) (a) (i) Details of the specialist who prepared the report	Page ii of Report – Contact details and company	-
(ii) The expertise of that person to compile a specialist report including a curriculum vita	Section 1.2 – refer to **Appendix A**	-
(b) A declaration that the person is independent in a form as may be specified by the competent authority	Page ii of the report	-
(c) An indication of the scope of, and the purpose for which, the report was prepared	Section 1.1	-
(cA) An indication of the quality and age of base data used for the specialist report	Section 4	-
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 5 and 6	-
(d) The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 3, 4	-
(e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Section 4	-
(f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Sections 3, 5	-
(g) An identification of any areas to be avoided, including buffers	Section 8	-
(h) A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 6	-
(i) A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 1.3	-
(j) A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Executive Summary, Sections 6, 7, 8	-
(k) Any mitigation measures for inclusion in the EMPr	Executive Summary, Sections 8	-
(l) Any conditions for inclusion in the environmental authorisation	Executive Summary, Sections 8, 9	-
(m) Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Executive Summary, Sections 8, 9	-
(n)(i) A reasoned opinion as to whether the proposed activity, activities or portions thereof should be authorised and	Executive Summary; Section 10	-

Requirements of Appendix 6 – GN R326 EIA Regulations of 7 April 2017	Relevant section in report	Comment where not applicable
(n)(iA) A reasoned opinion regarding the acceptability of the proposed activity or activities; and		-
(n)(ii) If the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Executive summary, Sections 8 and 9	-
(o) A description of any consultation process that was undertaken during the course of carrying out the study		Not applicable. A public consultation process was handled as part of the environmental process.
(p) A summary and copies if any comments that were received during any consultation process		Not applicable. To date no comments regarding heritage resources that require input from a specialist have been raised.
(q) Any other information requested by the competent authority.		Not applicable.
(2) Where a government notice by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	NEMA Appendix 6 and GN648 SAHRA guidelines on HIAs, PIAs and AIAs	

1.4.5 MPRDA 2002 (ACT NO. 28 OF 2002)

As per the NEMA no 107 of 1998, and the NEMA EIA Regulations, any activity requiring a prospecting right, mining right, mining permit, production right or exploration right, triggers the Mineral and Petroleum Resources Development Act, 28 of 2002 (MPRDA). The MPRDA Act 28 of 2002 intends to make provision for sustainable development of South Africa's mineral and petroleum resources.

Under Section 5(4) no person may prospect for or remove, mine, conduct technical co-operation operations, reconnaissance operations, explore for and produce any mineral or petroleum or commence with any work incidental thereto on any area without

(a) an approved environmental management programme or approved environmental management plan, as the case may be.

Furthermore, Chapter 8 of the MPRDA, as amended in 2015, states that the principles of the NEMA No. 107 of 1998 apply to all mining-related activities. It also serves as guidelines for the interpretation, administration and implementation of all the needed environmental requirements and authorizations of the MPRDA. In conjunction with the NEMA, the MPRDA makes provision that mining companies need to comply with other South African legislation regulating the impacts of mining-related projects on the natural and cultural environment, including the National Environmental Management Protected Areas Act (No. 57 of 2003) and the NHRA No. 25 of 1999.

Section 86 for EIA of the Regulations for Petroleum Exploration and Production (2015) of the MPRDA states that:

(1) The exploration and production activities related to petroleum are subject to the requirements of the NEMA and any relevant specific environmental management Act;

(2) Before exploration and production activities related to petroleum may commence, the holder must be in possession of an Environmental Authorisation (EA) issued in terms of the EIA Regulations, 2014.

(3) When submitting an application in terms of the EIA Regulations an applicant must comply with the minimum information requirement, guidance document or decision support tool as identified by the competent authority.

(4) The designated agency, the Council of Geosciences and the Council for Scientific Research must be identified as interested and affected parties for the purposes of the public participation to be undertaken as part of the EIA process.

2 SITE LOCATION AND DESCRIPTION

2.1 LOCALITY AND SITE DESCRIPTION

<table>
<tr><td rowspan="2">Coordinates for Study Area</td><td>Northernmost point:
S -28.07716
E 26.66416</td><td>Easternmost point:
S -28.23105
E 26.80612</td></tr>
<tr><td>Southernmost point:
S -28.23972
E 26.69567</td><td>Westernmost point:
S -28.16878
E 26.63364</td></tr>
<tr><td>Location</td><td colspan="2">The proposed development area is located west and east of the R30. It is located approximately 10km south of Welkom, approximately 3.6km west of Virginia and approximately 16km north of Theunissen. The Sand River flows west-east through the study area (Figure 4).</td></tr>
<tr><td>Property</td><td colspan="2">The proposed application area comprises portions of the following farms:
<table>
<tr><td>ADAMSONS VLEY No. 655</td><td>JORDAANS RUST No. 59</td></tr>
<tr><td>ANNEX GLEN ROSS No. 562</td><td>KAALPAN No. 65</td></tr>
<tr><td>ANNEX GRUSDE No. 474</td><td>KALKOENKRANS No. 225</td></tr>
<tr><td>BLAAUWDRIFT No. 188</td><td>KOVNO No. 235</td></tr>
<tr><td>BLAAUWDRIFT No. 188</td><td>LEEUWAARDEN No. 171</td></tr>
<tr><td>BOSCHLUIS SPRUIT No. 278</td><td>LEEUWBULT No. 52</td></tr>
<tr><td>BRAKSPRUIT No. 121</td><td>MIDDELPLAAS No. 583</td></tr>
<tr><td>BRUINTJES HOOGTE No. 367</td><td>MOND VAN DOORNRIVIER No. 38</td></tr>
<tr><td>BRYAN No. 561</td><td>MOOIFONTEIN No. 639</td></tr>
<tr><td>CABRIERE No. 215</td><td>MOOIVLAKTE No. 199</td></tr>
<tr><td>DANKBAARHEID No. 16</td><td>NORTIER No. 361</td></tr>
<tr><td>DE KLERKS KRAAL No. 231</td><td>PALMIETKUIL No. 328</td></tr>
<tr><td>DIGITO No. 642</td><td>PAULINA No. 470</td></tr>
<tr><td>DOORN RIVER No. 330</td><td>RONDEHOEK No. 200</td></tr>
<tr><td>DOORNDEEL No. 236</td><td>STILLE WONING No. 703</td></tr>
<tr><td>ENKELDOORN No. 360</td><td>TERRA BLANDA No. 155</td></tr>
<tr><td>GLEN ROSS No. 734</td><td>VLAKPAN No. 358</td></tr>
<tr><td>GRUSDE No. 229</td><td>WALKERSVLEI 133/0</td></tr>
<tr><td>HAKKIES No. 695</td><td>WELTEVREDE No. 638</td></tr>
<tr><td>HAKKIES No. 742</td><td>WELTEVREDEN No. 443</td></tr>
<tr><td>HARMONIE No. 579</td><td>WOLVEPAN No. 85</td></tr>
<tr><td>JONKERS RUST No. 72</td><td></td></tr>
</table></td></tr>
<tr><td>Topographical Map</td><td colspan="2">2826BA Blaauwdrift and 2826BB Virginia</td></tr>
</table>

Extent	Tetra4 has a production right for natural gas over a large area ~300 000ha.

The following infrastructure is encountered in the areas surveyed:

- Provincial roads (R30)
- Farmsteads
- Schools
- Mining infrastructure
- Power lines
- Local roads (tar and informal)
- Existing pipelines

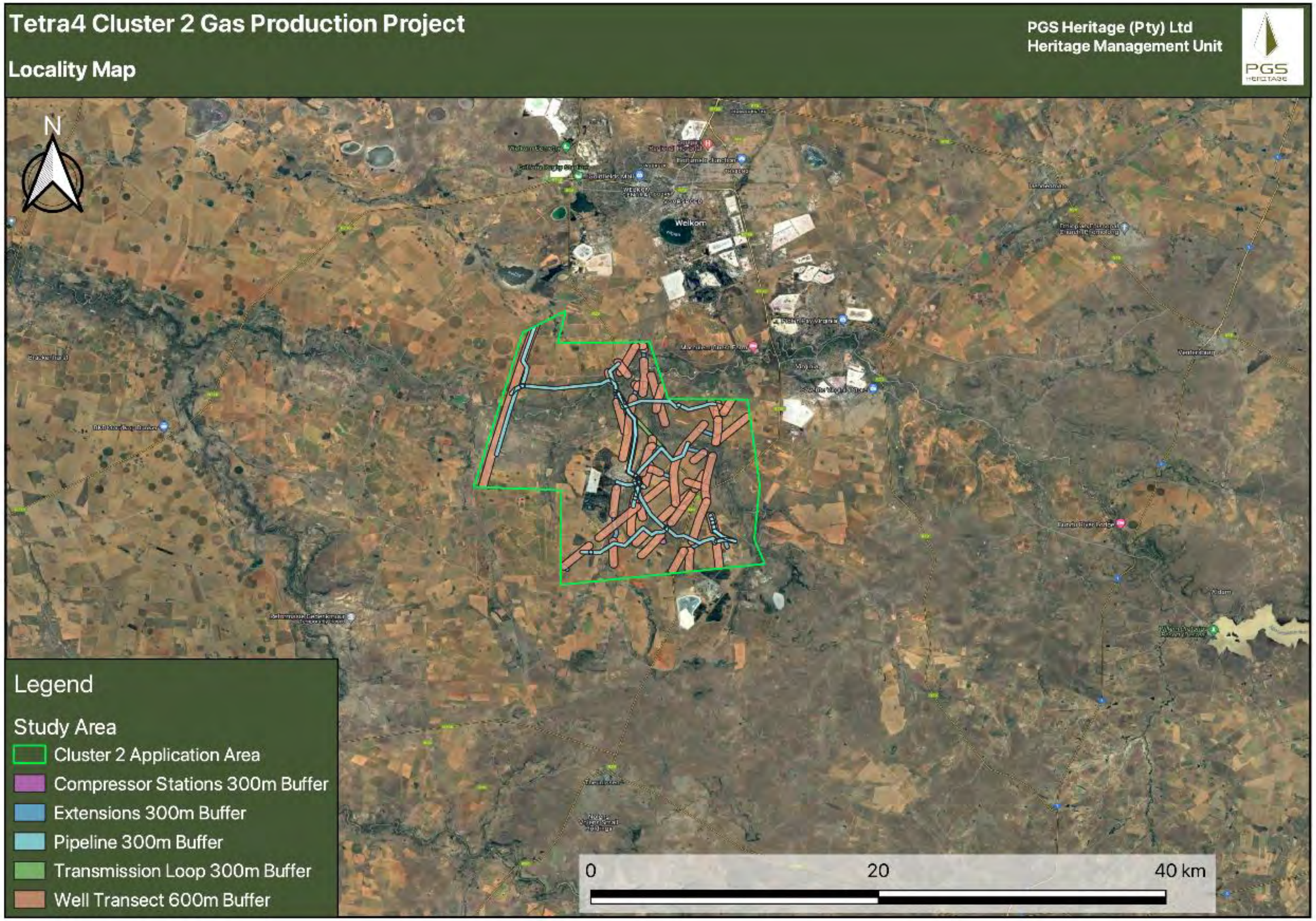


Figure 4 - Locality map depicting the regional context of the study area.

2.2 TECHNICAL PROJECT DESCRIPTION

The following project description for the project has been supplied by EIMS.

2.2.1 PROPOSED CLUSTER 2 PROJECT

Tetra4 now wishes to expand the natural gas operations, to be located within the approved production right area and around the Cluster 1 project (**Figure 5**). This planned expansion to the existing approved production activities will involve up to 300 new production wells, gas transmission pipelines and associated infrastructure, 3 compressor stations and an additional new combined Liquid Natural Gas (LNG) and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure, as well as powerlines as part of the Cluster 2 expansion of the Project in order to meet the future production requirements. The Cluster 2 study area and infrastructure buffer zones are presented in **Figure 6**.

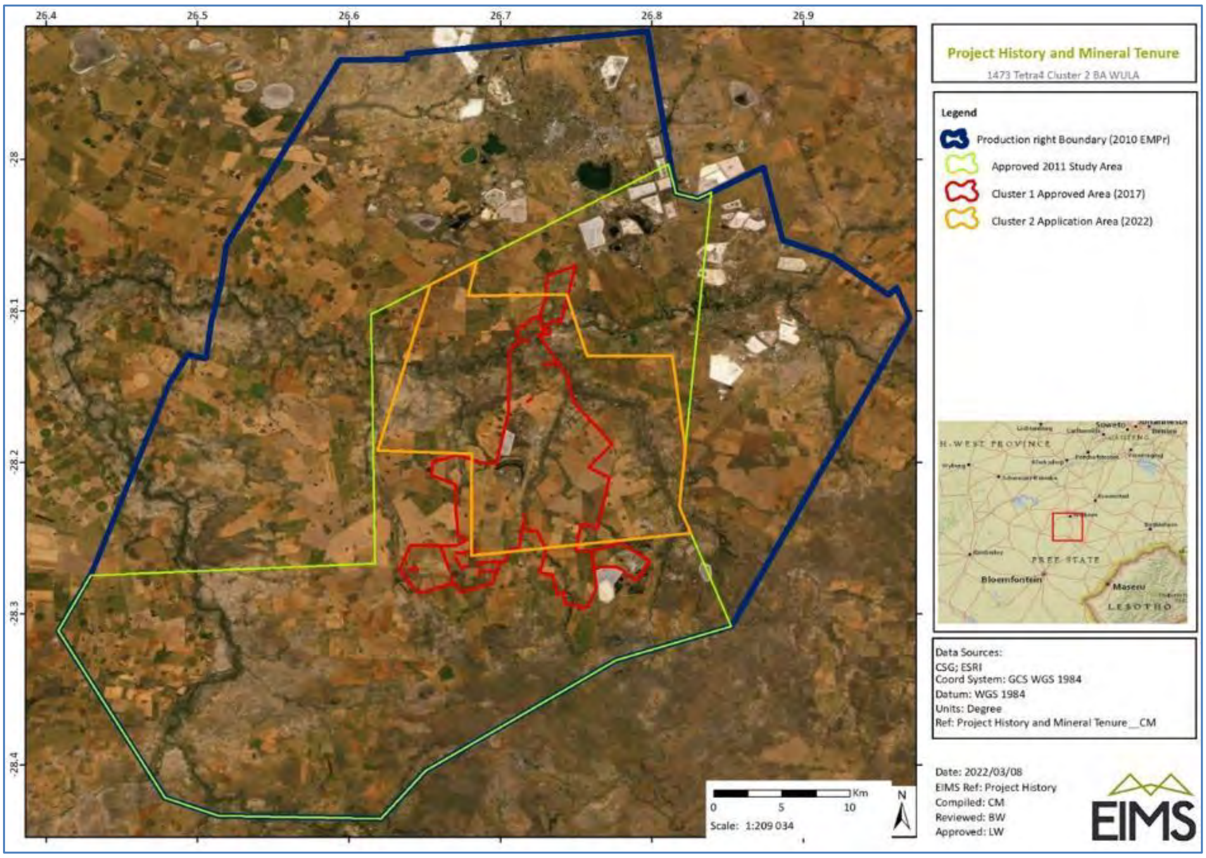


Figure 5 - Project history and mineral tenure.

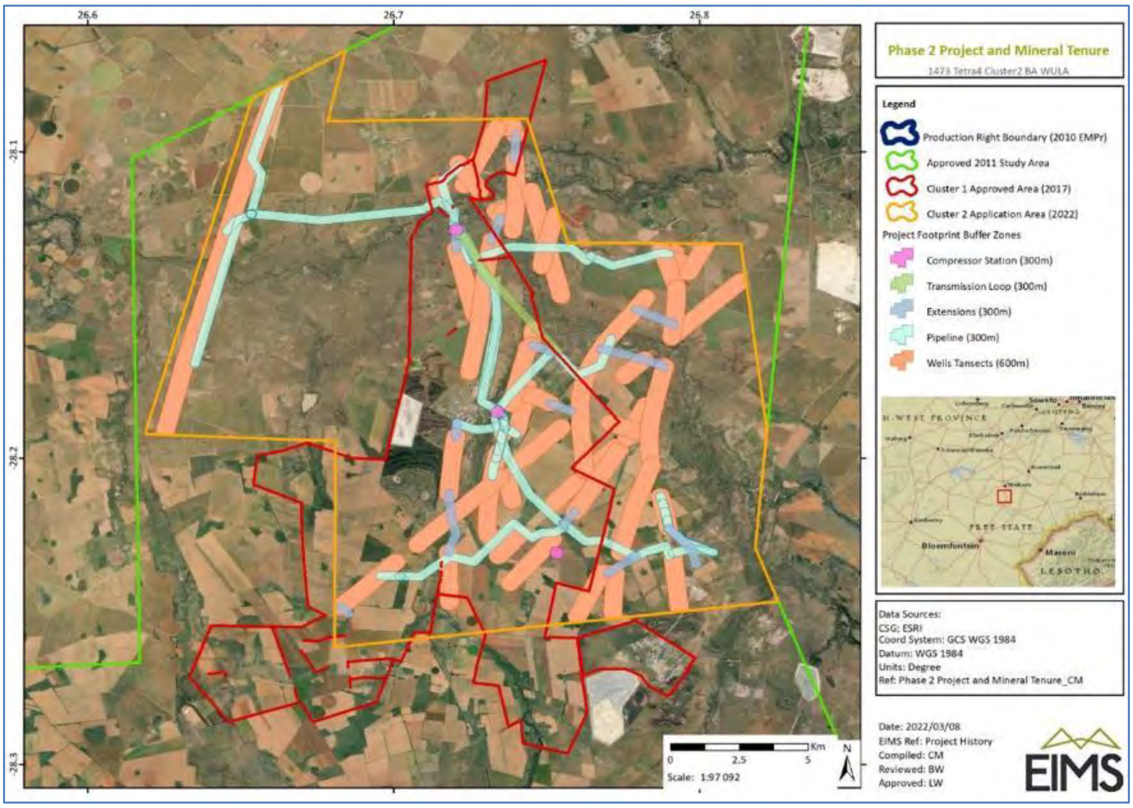


Figure 6 – Cluster 2 study area and proposed infrastructure footprint buffer zones.

2.2.1.1 THE GAS RESOURCE

The Tetra4 Production Right is located within the Sand River Play or Virginia Gas Field. Despite not being clearly defined, the field is composed predominantly of Karoo, Ventersdorp and Witwatersrand Supergroup lithologies complete with younger dolerite intrusions. Major fault systems associated with closely spaced zones of fractures and joints provide for preferential pathways for a combination of abiogenic and biogenic gas to reach the surface.

As such, the resulting gas at the surface is a direct emission from the major fault or from minor secondary faults linked to a major fault. In this regard, it is thought that the primary source of gas originates from the Witwatersrand Supergroup or shallower Karoo. As an unconventional resource, the gas is presumed to be a mix of both abiogenic from the mantle and biogenic hydrocarbons originating from ancient fissure waters, coal beds of the Ecca Group of the Karoo Supergroup as well as ancient algal mats within the shallow marine/lacustrine Witwatersrand Supergroup deposits. Once the gas target areas are intersected, the feed gas will flow passively out of the wells at a low pressure of ~0.4 barg[5] (gauge pressure) and with a temperature in the range between 10 º and 30 ºC. The feed gas will be compressed upstream of the helium process units by 3 inline compressor stations which will be located at strategic points along the gas pipeline routes. A gas pre-treatment will remove condensate

[5] Barg: a unit of gauge pressure, i.e. pressure in bars above ambient or atmospheric pressure.

as well as traces of sulphur, mercury and C3+ gas components (e.g. propanes, butanes, pentanes) which could cause possible damage to the downstream process equipment.

2.2.1.2 GAS PRODUCTION METHOD

Gas production encompasses the exploration for gas resources with specific focus on existing geological fractures followed by the extraction of gas through production wells. From the production wells, a gas gathering network of pipes, booster stations, metering stations, pigging stations and compressor stations transports the gas to the LNG/LHe Plant where gas processing, storage and distribution is undertaken.

Gas production is accomplished by extracting gas occurring in fractures, fissures and faults within the Ventersdorp and Witwatersrand supergroups located at depths of between approximately 380 to 880 meters (m). Construction of the gas gathering pipelines for Cluster 1 is well underway and the LNG/LHe processing facility is currently in the construction phase. Once Cluster 1 is complete, Tetra4 will begin producing up to 50 tons of LNG and 375 kg of LHe per day.

Cluster 2 of the project aims to expand upon Cluster 1 production by increasing natural gas production. This is achieved through the expansion of the existing gas sources, gas gathering and the production capacities. The project consists of two components namely, gas gathering and the LNG/LHe processing plant. The targeted total feed gas flow from Cluster 2 production wells is estimated at 44 million-standard cubic feet per day (MMSCFD) by 2026. From experience in Cluster 1 the helium composition will be between approximately 2% and 4% to the LNG/LHe process plant and the ability to recover at least 95% methane and helium from the gas wells before supplying to the plant.

The gas is to be collected from a group of wells located in the well transects and transported to a single feed point whereafter it is piped to the processing plant (LNG/LHe plant). Each group of gas wells will feed into a common booster station. From the booster stations the gas will be fed into a dual gathering pipeline (trunkline) towards a compressor station. The compressor stations' outlets will then be combined through a trunkline into the single tie-in feed point within the proximity of the Plant.

The Cluster 2 project entails a total of ~ 300 production wells with a 0.17 MMSCFD flowrate per well to get a total of 44.37 MMSCFD. The wells will be located within the identified zones with the number of wells informed by the total gas requirements and expected well gas capacity. The current plan is to drill vertical or incline wells ~300m apart along the fault lines and withing the identified and assessed well transect areas.

The Cluster 2 gas field will have 3 x ~15MMSCFD zones each with one compressor station. Approximately 10 production wells will be grouped and will be routed to a common booster station and thereafter feed to a compressor station. Power to the booster stations will be provided from nearby existing Eskom power sources or alternatively a gas engine.

The gas gathering network will comprise primarily of HDP pipelines buried at least 1.5m below plough level in order to ensure minimal disruption to existing agricultural activities. Sensitive environmental features, land-uses and infrastructure will be avoided as far as practically possible. However, it is practically impossible to avoid all sensitive features (including tar road crossings and river crossings). In the case where the pipeline will cross dirt roads an open cut trench technique will be used. To ensure integrity of tar roads is not compromised, horizontal directional drilling (HDD) will be used to lay the pipe underneath the road. Similarly, horizontal directional drilling (HDD) will be used for river crossings to lay the pipeline approximately 6m underneath the riverbeds.

2.2.1.3 EXPLORATION DRILLING

Exploration wells will be drilled and, if successful, converted into production wells. As the exact location of exploration well drilling cannot be identified at this stage, this study has followed the approach of assessing well corridors (600m wide or 300m on either side of known target fault lines). Exploration drilling entails the use of a truck, trailer or skid mounted percussion or diamond drill rig to drill to varying depths (~380m to ~880m) along known fault lines in order to strike the gas reserve.

Percussion and diamond drills typically require temporary clearance of an area of 30 m x 30 m in order to set up the rig and begin drilling activities. All exploration boreholes to be drilled and cased in accordance with applicable international standards and best practice guidelines[6], and will be sealed with a combination of casing and grouting to ensure vertical isolation of the gas from both the surrounding geology and hydrological regime. In addition to the drill rig, lined sumps will be required to store and recirculate water for the drilling process. A maximum of 6000 litres per day is required for drilling purposes and will be sourced from the municipality.

In the event that an exploration borehole proves unsuccessful it will be sealed and cased (in accordance with the EMPr) and the area rehabilitated. In the event that an exploration borehole proves successful it will be converted into a production well (as described below) and added to the network of gas producing wells for Cluster 2. The drilling of exploration boreholes is a temporary and short-lived activity and the equipment to be used during drilling activities includes a truck/trailer or skid mounted diamond drill rig, excavator, dozer, grader water cart, light motor vehicle for transport of personnel and chemical toilets.

2.2.1.4 WELL SITE CONNECTION

All wells that are drilled and used for production purposes are strengthened with a combination of casing and grouting to average depths of 300 m to prevent any interplay between deep and shallow aquifers. The casing and grouting ensure that the gas is isolated from surrounding geology and promotes the preferential flow of gas from the formation through the well and up to the surface. As the gas is naturally lighter than air, it rises naturally to the surface and no well stimulation is required. The combination of

[6] Internationally accepted best practice should be applied and reference should be made to the relevant British Oil and Gas and/or the API guidelines and standards.

casing and grouting also serves to ensure that gas is isolated and prevented from interacting with the geohydrological regime.

Due to low gas pressures in the wells, groups of ~10 wells will be included as an inlet to a booster station to provide vacuum suction. The booster stations will be connected via pipelines to centralised infield reciprocating gas compressor stations. Pipelines will be a combination of high-pressure steel as well as low-pressure high-density polyethylene (HDPE) and is installed at a minimum depth of 1.5m below the plough line. The pipeline will be installed using a back-actor and TLB. Where piping (e.g. for the compressors and driers) will be brought to surface, a 110 mm steel piping of approximately 10 m – 30 m will be utilised instead.

Production wells will be placed within a secured precast well chamber with manhole for access. Minimal mechanical infrastructure will be placed within the precast well chamber other than the wellhead, connecting pipeline, an isolation valve and sample point. The surface infrastructure for the manhole would be 1,4m x 1,1m and the manhole surface height will be 0,25m.

2.2.1.5 GAS INLINE STATIONS

In order to transport gas via pipelines from the wellheads to the Plant, various inline infrastructure is required to monitor, measure and control gas flow through the pipelines and this includes booster stations, pigging stations and compressor stations.

Localised inline gas booster stations will be installed for each cluster of 7-10 wells which will feed pressurised gas via pipelines from the production wells to the compressor stations. The booster stations will occupy an area of 10 m x 14m and a total of 28 booster stations may be constructed.

Inline pigging stations (**Figure 7**) are installed to allow for regular cleaning and inspection of the pipelines. The pigging stations allow for insertion of probes or cleaning pigs (plugs) at regular intervals in order to perform regular maintenance.

Figure 7 - View of an existing pigging station constructed as part of Cluster 1.

Raw gas received at the compressor stations will be filtered to remove dust and moisture through the use of a combination of water filter and an activated carbon filter that absorbs dust and unwanted organic compounds. Once filtered, the gas from the compressors will be dried to 7 pounds per MMSCF adjacent to the compressor stations, and then piped for final processing to the LNG/LHe Plant. The footprint for a compressor station including the gas drier station will be approximately 60 m x 60 m (**Figure 8**).

Figure 8 - Example of Compressor Station just recently constructed as part of Cluster 1.

2.2.1.6 COMBINED HELIUM AND LIQUID NATURAL GAS PLANT

Feed gas from the centralised reciprocating infield compressor stations will be discharged into the combined LNG/LHe Plant. The LNG/LHe facility is a modularized facility to convert the Feed Gas into LNG, LHe and to provide fuel gas for future power generation. The power generation will be a separate project and is not included in this application process.

The Cluster 2 LNG/LHe Plant will be constructed directly adjacent to the Cluster 1 plant which is currently under construction on the remaining extent of the farm Mond Van Doornrivier 38. The LNG and LHe products will be loaded to trucks for distribution to users.

The LNG/LHe plant comprises of the following process units:

- Gas Treatment and Boosting System;
- Helium Separation Unit;
- Gas Liquefaction System;
- LHe Storage (~2x100m^3);
- LNG Storage (~11x300m^3); and
- LHe and LNG loading bays.

The area occupied by the proposed Cluster 2 LNG/LHe plant in the operational phase is approximately 9ha while additional areas are required during the construction phase for various contractor laydown areas, offices, parking, etc.

The plant will include a small sewage treatment works as well as stormwater infrastructure to divert potentially dirty water into an evaporation pond of approximately 1005 m^3. Treated effluent from the sewage treatment plant will also be directed to the evaporation pond from where water will be pumped into a reverse osmosis plant and then stored in the fire water and service water tanks for reuse. The fire water and service water tanks are linked and therefore, recirculating to service water tank is taken off for use in the system. The fire water tank is maintained at a minimum level to ensure fire water availability. No discharge of polluted water will take place and all waste products from the sewage treatment works (sludge) and the reverse osmosis plant will be collected by a registered waste contractor for offsite disposal at a suitably licenced facility.

2.2.1.7 SURFACE INFRASTRUCTURE

The proposed Cluster 2 project expansion requires various surface infrastructure as listed below:

- Access roads;
- Pipelines and powerlines;
- Coalescer filter or knockout drum at each booster station;
- Pipe markers (approximately every 100 m of the pipeline, where feasible);
- Wellheads;
- Booster pumps (where required);
- Inline booster compressors or infield reciprocating compressors;
- Gas driers;
- Fencing and security (limited to gas producing wells, compressor stations and LNG/LHe Plant infrastructure);
- Combined helium and LNG plant;
- LNG/LHe storage and dispensing units;
- Chemical storage;
- Temporary hazardous waste storage (including but not limited to waste water recirculation at drill sites and waste containing hydrocarbons such as used oil and filters, diesel, lubricants, grease, etc.);
- Temporary general waste storage;
- Contractors' laydown areas around the LNG/LHe Plant area; and
- Permanent offices, storage areas and workshops.

In broad summary, infrastructure required for the Cluster 2 gas field development is broadly split between:

a) <u>Gas Gathering Network</u>: infrastructure required for gas extraction and transport at well sites (including compressor stations); and

b) <u>Gas Processing</u>: infrastructure required for gas processing and transport of final product.

3 CURRENT STATUS QUO

3.1 SITE DESCRIPTION

A site visit was conducted by three archaeologists from PGS on 14th-24th February 2022. The proposed development area is located within Matjhabeng and Masilonyana Local Municipalities, located between Welkom, Virginia and Theunissen, in the Free State Province.

Significant components of the study area are characterized by extensive farming activities in the form of extensive agricultural fields. For the most part maize production is undertaken within this area, although other crops such as sunflowers and soya beans are also grown. In the northern section of the study area, there is mining of sediment along the Sand River. Whilst the central and south-eastern components of the study area are associated with mines and mining activities of the Beatrix Mine of Sibanye Gold. The likelihood of finding in-situ heritage resources within these particular regions of the study area is lessened due to these facts. Therefore, the walkthroughs were focused on those areas that are not disturbed, as the potential for identifying archaeological and heritage sites in the more undisturbed components of the study area are much higher. As a result, only limited fieldwork was undertaken in those components of the study area that are entirely disturbed. There was also restricted access to certain farm properties (BLAAUWDRIFT No.188 (Portion 3), BRUINTJE HOOGTE No.367 (Portion 2, 3), BRYAN No.561 (Portion 10, 21, 28, 29, 30, 31, 38), GLEN ROSS No.734 (Portion 4, 5, 6, 7, 18, 20), JONKERS RUST No.72, KALKOENKRANS No.225 (Portion 3), MOND VAN DOORNRIVIER No.38 (Portion 2), MOOIFONTEIN No.639, PALMIETJUIL No.548 (Portion 1), STILLE WONING no.703, VLAKPAN No.358) due to flooded roads, game life on the properties or farm owners not giving permission to access their properties.

In terms of the topography, the study area comprises relatively level portions of land. Ephemeral streams and the Sand River cut across some of the components within the application area. Several man-made dams and reservoirs are also located within this area. In terms of the geology, the study area comprises: Karoo Dolerite Suite (Dolerite and minor ultrabasic rocks), Balfour Formation (Greenish- to bluish-grey and greyish-red mudstone, siltstone and subordinate sandstone) and alluvium.

The study area is serviced by the R30 road, provincial gravel roads and farm roads. Existing infrastructure includes mine infrastructure, electricity transmission lines, telephone lines, fences, schools, and other buildings and structures. In terms of buildings and structures, several farmsteads are located within the study area. These farmsteads can be expected to comprise farmhouses of varying ages as well as farm worker accommodation, sheds, barns, silos, livestock enclosures etc. Photographs of the general study area are provided below.

Figure 9 – Typical dense vegetation observed during the field assessment.

Figure 10 – View of a wetland observed within the study area.

Figure 11 – View of overgrown farm track.

Figure 12 – General view of soya bean crops.

Figure 13 – View of sunflower fields.

Figure 14 – Typical ploughed land.

Figure 15 – View of muddy farm roads.

Figure 16 – View of flooded road after rainfall.

3.2 SITE VEGETATION

Significant sections of the undisturbed components of the study area comprise open grassland, interposed by scattered pockets of trees. Planted vegetation, which includes exotic trees (*Eucalyptus*) and plants, are found in proximity to farmsteads and human occupation areas. Lanes of such planted exotic trees were also strategically planted as wind-breaks and are found all over the study area. There is also secondary grassland which is associated with areas of cultivation/grazing.

In terms of region's vegetation, the study area is characterised by two vegetation types: The Vaal-Vet Sandy Grassland and the Highveld Alluvial Vegetation (Mucina and Rutherford, 2006).

"The Vaal-Vet Sandy Grassland is characterised by Aeolian and colluvial sand overlying sandstone, mudstone and shale of the Karoo Supergroup (mostly the Ecca Group). An important feature of the vegetation type is the dominance of *Themeda triandra*. In areas where heavy grazing and/or erratic rainfall occurs low cover of *T. triandra* associated with an increase in *Elionurus muticus, Cymbopogon pospischii* and *Aristida congesta* is evident."

Highveld Alluvial Vegetation "occurs within a flat topography supporting riparian thickets, which are mostly dominated by *Vachellia karroo*, accompanied by seasonally flooded grassland and distributed herb lands that are often dominated by alien plants. It is characterised by deep sand to clayey (but mostly coarse sand) alluvial soils developed over Quaternary alluvial (fluviatile) sediments."

4 ASSESSMENT METHODOLOGY

The section below outlines the assessment methodologies utilised in the study. This report was compiled by PGS for the proposed Tetra4 Cluster 2 Production Project. The applicable maps, tables and figures, are included as stipulated in the NHRA (no 25 of 1999) and the NEMA (no 107 of 1998). The HIA process consisted of three steps:

Step I – Desktop Study: A detailed archaeological and historical overview of the study area and surroundings was undertaken. This work was augmented by an assessment of reports and data contained on the South African Heritage Resources Information System (SAHRIS). Additionally, an assessment was made of the available historic topographic maps. All these desktop study components were undertaken to support the fieldwork.

Step II – Field Survey: The fieldwork component of the study was aimed at identifying tangible remains of archaeological, historical and heritage significance. The fieldwork was undertaken by way of intensive walkthroughs of the proposed development footprint areas.

The fieldwork was undertaken by three archaeologists (Nikki Mann, Michelle Sachse, Nicholas Fletcher) on 14-24 February 2022. Throughout the fieldwork, hand-held GPS devices were used to record the track logs showing the routes followed by the fieldwork team.

Step III – Report: The final step involved the recording and documentation of relevant archaeological resources, the assessment of resources in terms of the HIA criteria and report writing, as well as mapping and constructive recommendations.

The significance of heritage sites was based on four main criteria:

- Site integrity (i.e. primary vs. secondary context),
- Amount of deposit, range of features (e.g., stonewalling, stone tools and enclosures),
- Density of scatter (dispersed scatter)
    - Low-<10/50m2
    - Medium - 10-50/50m2
    - High - >50/50m2
- Uniqueness; and
- Potential to answer present research questions.

Management actions and recommended mitigation, which will result in a reduction in the impact on the sites, will be expressed as follows:

A - No further action necessary;

B - Mapping of the site and controlled sampling required;

C - No-go or relocate development activity position;

D - Preserve site, or extensive data collection and mapping of the site; and

E - Preserve site.

Impacts on these sites by the development will be evaluated as follows:

4.1.1 SITE SIGNIFICANCE

Site significance classification standards use is based on the heritage classification of s3 in the NHRA and developed for implementation keeping in mind the grading system approved by SAHRA for archaeological impact assessments. The update classification and rating system as developed by Heritage Western Cape (2016) is implemented in this report

Site significance classification standards prescribed by the Heritage Western Cape Guideline (2016), were used for the purpose of this report (**Table 4** and **Table 5**).

Table 4 - Rating system for archaeological resources

Grading	Description of Resource	Examples of Possible Management Strategies	Heritage Significance
I	Heritage resources with qualities so exceptional that they are of special national significance. Current examples: Wonderwerk Cav), Cradle of Humankind	May be declared as a National Heritage Site managed by SAHRA. Specific mitigation and scientific investigation can be permitted in certain circumstances with sufficient motivation.	Highest Significance
II	Heritage resources with special qualities which make them significant, but do not fulfil the criteria for Grade I status. Current examples: Blombos, Paternoster Midden.	May be declared as a Provincial Heritage Site managed by Free State Heritage Resources Authority (FSHRA). Specific mitigation and scientific investigation can be permitted in certain circumstances with sufficient motivation.	Exceptionally High Significance
III	Heritage resources that contribute to the environmental quality or cultural significance of a larger area and fulfils one of the criteria set out in section 3(3) of the Act but that does not fulfil the criteria for Grade II status. Grade III sites may be formally protected by placement on the Heritage Register.		
IIIA	Such a resource must be an excellent example of its kind or must be sufficiently rare. Current examples: Varschedrift; Peers Cave; Brobartia Road Midden at Bettys Bay	Resource must be retained. Specific mitigation and scientific investigation can be permitted in certain circumstances with sufficient motivation.	High Significance
IIIB	Such a resource might have similar significances to those of a Grade III A resource, but to a lesser degree.	Resource must be retained where possible where not possible it must be fully investigated and/or mitigated.	Medium Significance
IIIC	Such a resource is of contributing significance.	Resource must be satisfactorily studied before impact. If the recording already done (such as in an HIA or permit application) is not sufficient, further recording or even mitigation may be required.	Low Significance
NCW	A resource that, after appropriate investigation, has been determined	No further actions under the NHRA are required. This must be	No research potential or

Grading	Description of Resource	Examples of Possible Management Strategies	Heritage Significance
	to not have enough heritage significance to be retained as part of the National Estate.	motivated by the applicant or the consultant and approved by the authority.	other cultural significance

Table 5 - Rating system for built environment resources

Grading	Description of Resource	Examples of Possible Management Strategies	Heritage Significance
I	Heritage resources with qualities so exceptional that they are of special national significance. Current examples: Robben Island	May be declared as a National Heritage Site managed by SAHRA.	Highest Significance
II	Heritage resources with special qualities which make them significant in the context of a province or region, but do not fulfil the criteria for Grade I status. Current examples: 8 Ventershoek Street,Colesberg	May be declared as a Provincial Heritage Site managed by FSHRA.	Exceptionally High Significance
II	Such a resource contributes to the environmental quality or cultural significance of a larger area and fulfils one of the criteria set out in section 3(3) of the Act but that does not fulfil the criteria for Grade II status. Grade III sites may be formally protected by placement on the Heritage Register.		
IIIA	Such a resource must be an excellent example of its kind or must be sufficiently rare. These are heritage resources which are significant in the context of an area.	This grading is applied to buildings and sites that have sufficient intrinsic significance to be regarded as local heritage resources; and are significant enough to warrant that any alteration, both internal and external, is regulated. Such buildings and sites may be representative, being excellent examples of their kind, or may be rare. In either case, they should receive maximum protection at local level.	High Significance
IIIB	Such a resource might have similar significances to those of a Grade III A resource, but to a lesser degree. These are heritage resources which are significant in the context of a townscape, neighbourhood, settlement or community.	Like Grade IIIA buildings and sites, such buildings and sites may be representative, being excellent examples of their kind, or may be rare, but less so than Grade IIIA examples. They would receive less stringent protection than Grade IIIA buildings and sites at local level.	Medium Significance
IIIC	Such a resource is of contributing significance to the environs. These are heritage resources which are significant in the context of a streetscape or direct neighbourhood.	This grading is applied to buildings and/or sites whose significance is contextual, i.e., in large part due to its contribution to the character or significance of the environs. These buildings and sites should, as a consequence,	Low Significance

Grading	Description of Resource	Examples of Possible Management Strategies	Heritage Significance
		only be regulated if the significance of the environs is sufficient to warrant protective measures, regardless of whether the site falls within a Conservation or Heritage Area. Internal alterations should not necessarily be regulated.	
NCW	A resource that, after appropriate investigation, has been determined to not have enough heritage significance to be retained as part of the National Estate.	No further actions under the NHRA are required. This must be motivated by the applicant and approved by the authority. Section 34 can even be lifted by HWC for structures in this category if they are older than 60 years.	No research potential or other cultural significance

4.2 ARCHAEOLOGICAL SPECIFIC METHODOLOGY

Additional to the preceding methodological description the archaeological methodology included fulfilling the requirements of the NHRA (section 35 and 36) that protects the following features in the landscape:

- Material remains resulting from human activity which are in a state of disuse and are in or on land and which are older than 100 years, including artefacts, human and hominid remains and artificial features and structures;
- Rock art, being any form of painting, engraving or other graphic representation on a fixed rock surface or loose rock or stone, which was executed by human agency and which is older than 100 years, including any area within 10m of such representation;
- Graves and burial grounds, including ancestral graves, royal graves, graves of traditional leaders, graves of victims of conflict, historical graves and cemeteries, and other human remains not covered by the Human Tissue Act (1983) (Act No 65 of 1983).

5 HISTORICAL AND ARCHAEOLOGICAL OVERVIEW OF THE STUDY AREA

5.1 OVERVIEW OF THE STUDY AREA AND SURROUNDING LANDSCAPE

The high-level archival research focused on available information sources that were used to compile a general background history of the study area and surrounds.

The Free State has a rich archaeological and historical history going back millions of years and includes significant aspects such as Later Stone Age rock art, Battlefields and Iron Age stonewalled enclosures. The general surroundings of the study area became a melting pot of contact and conflict as it represents one of many frontiers where San hunter- gatherers, Nguni and Sotho-Tswana agro-pastoralists, Dutch Voortrekkers and British Colonists all came together. The ravages of war also swept across these plains, and in particular the South African War (1899-1902) as well as the Boer Rebellion (1914-1915).

It must be noted that such an overview, which is based on available literature and archival research, would necessarily reflect a bias toward a traditional white history of the region as this would have been the focus of publications and archival documents during the last 150 years.

Table 6 – Archaeological and Historical Overview of the Study Area and Surrounding Landscape

DATE	DESCRIPTION
The Study Area during the Stone Age	
Very little is known about the Stone Age archaeology of the study area and its immediate surroundings. In the wider surroundings, probably the most significant Stone Age is at Florisbad, located roughly 78 km south-west of the present study area. Closer to the study area, a number of Middle and Later Stone Age material in associated with mammal fossil remains have been identified in erosion gullies along the Sand, Doring and Vet Rivers between Virginia and Theunissen (De Ruiter *et. al.* 2011). See also Rossouw (n.d.).	
2.5 million to 250 000 years ago	The Earlier Stone Age (ESA) is the first and oldest phase identified in South Africa's archaeological history and comprises two technological phases. The earliest of these is known as Oldowan and is associated with crude flakes and hammer stones. It dates to approximately 2 million years ago. The second technological phase is the Acheulian and comprises more refined and better made stone artefacts such as the cleaver and bifacial hand axe. The Acheulian dates back to approximately 1.5 million years ago. No information regarding ESA sites from the study area and surroundings was found.
>250 000 to 40 000 years ago	The Middle Stone Age (MSA) is associated with flakes, points and blades manufactured by means of the prepared core technique. This phase is furthermore associated with modern humans and complex cognition (Wadley, 2013). During research fieldwork by the National Museum in Bloemfontein, ten sites were recorded where Middle Stone Age and/or Later Stone Age lithics were identified in association with mammal fossil remains from erosion gullies along the Sand, Vet and Doring Rivers (De Ruiter *et. al.* 2011). While almost all of these sites are located within a distance of 20 km of the present study area, one site is located immediately adjacent to the study area. This site is named Kalkoenkrans 225 and is located no more than 500 m north-east of the study area.

DATE	DESCRIPTION
	During the fieldwork undertaken during the Heritage Scoping, a Middle Stone Age site was identified within the study area on the northern bank of the Sand River (see Site 33 (Birkholtz, 2017a)).

Figure 17 – Photograph of the archaeological field survey as published in De Ruiter et. al. (2011).

40 000 years ago to c. 1800s	The Later Stone Age (LSA) is the third archaeological phase identified and is characterised by an abundance of very small stone tools known as microliths as well many rock art sites across the country. This period is associated with hunter-gatherers (San) as well as early pastoralists (Khoekhoe) and lasted up until - and in many cases a considerable number of years after – the arrival of Iron Age and European communities. Apart from the occurrence of Later Stone Age lithics along the Sand, Vet and Doring Rivers (see above), no other Later Stone Age sites are known from the surroundings of the study area. Similarly, no known rock art sites are known from the study area or its wider surroundings.

The Study Area during the Iron Age

The arrival of early farming communities during the first millendium, heralded in the start of the Iron Age for South Africa. The Iron Age is that period in South Africa's archaeological history associated with pre-colonial farming communities associated with agricultural and pastoralsit farming activites, metal working, cultural customs such as lobola as well as the tangible representation of the significance of cattle imprinted on their settlement layouts (known as the Central Cattle Pattern) (Huffman, 2007).
According to the distribution map for Iron Age settlements on the Southern Highveld as published in Maggs (1976), the study area is located to the west of the known distribution of such Late Iron Age sites. It is therefore unlikely for any Late Iron Age sites to be located within the study area or its immediate surroundings. This surmise is largely supported by the distribution maps as published by Huffman (2007), albeit these latter distribution maps (which are based on known archaeological information) indicate that the study area is located very close to the periphery of two Iron Age facies. For the sake of completeness, these two Iron Age facies, known as Thabeng and Makgwareng, will be presented here.

DATE	DESCRIPTION
AD 1700 – AD 1840	The Thabeng facies of the Moloko Branch of the Urewe Tradition is one of the facies identified within the study area. The decoration on the ceramics associated with this facies is characterised by incised triangles, coloured chevrons and arcades. The Tlhaping at Dithakong, Rolong at Platberg and the Kubung from the Free State form a Southwestern Sotho-Tswana cluster that is associated with this Thabeng facies pottery and Type Z settlement layouts (Huffman, 2007). The Type Z settlements are one of the Late Iron Age stonewalled settlement types identified by Tim Maggs during his extensive archaeological research project on the Iron Age of the southern Highveld, which includes the present study area (Maggs, 1976). These sites are characterised by large primary enclosures enclosed by a ‘discontinuous ring’ of characteristic bilobial dwellings. Each of these bilobial dwellings comprises a hut at its front with a semi-circular courtyard at the back. With the area in front of the hut enclosed by a low stone wall and the courtyard at the back similarly enclosed by a smaller enclosure, the layout plan of these huts comprise two lobes, one larger than the other. The huts are defined by a ring of upright stones and are usually paved with flat stones. Unlike Type V settlements (see below), corbelled hut are rarely associated with these Type Z settlements, and appear to be the result of contact with the Type V settlements located to the east. While a number of Type Z sites are located within the study area, one of the more prominent ones is OXF1, located roughly 34.7 km east-by-northeast of the present study area and a short distance north-west of the town of Ventersburg. This site was excavated by Tim Maggs during the 1970s as part of his overall research project alluded to above (Maggs, 1976). In his conclusions on the history of his entire study area, Maggs (1976:317) states that “*…the conclusion seems inescapable that the Kubung were the builders of Type Z. This conclusion could be put forward on the typological evidence alone, for the Kubung are the only known off-shoot of the Rolong to have settled in our area, and the Type Z industry was clearly the work of a group related to the Rolong*.”

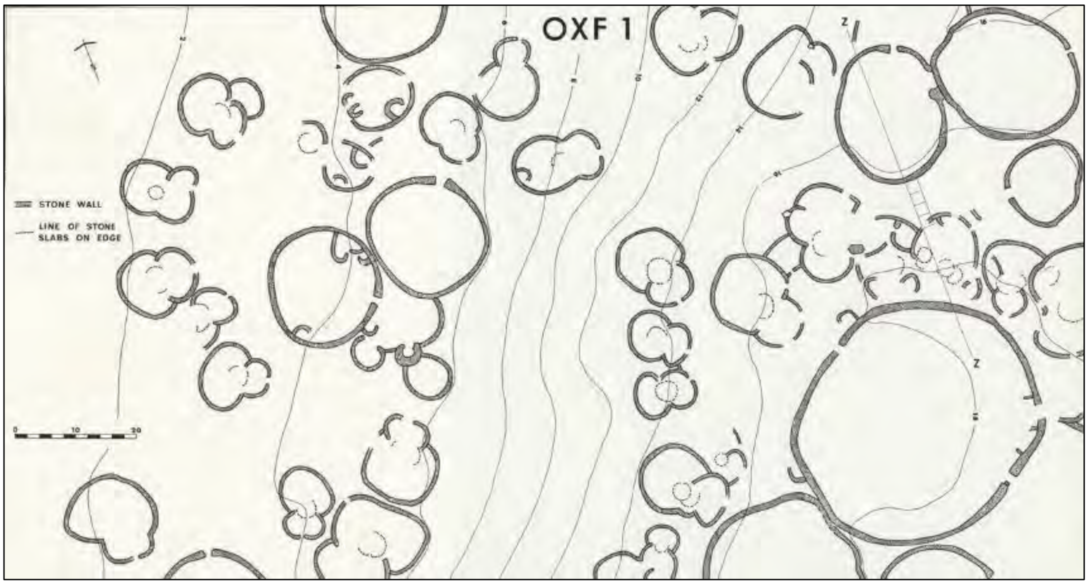


Figure 18 - This plan depicts the settlement layout of a typical Type Z site, and was recorded at site OXF 1 (Maggs, 1976:233).

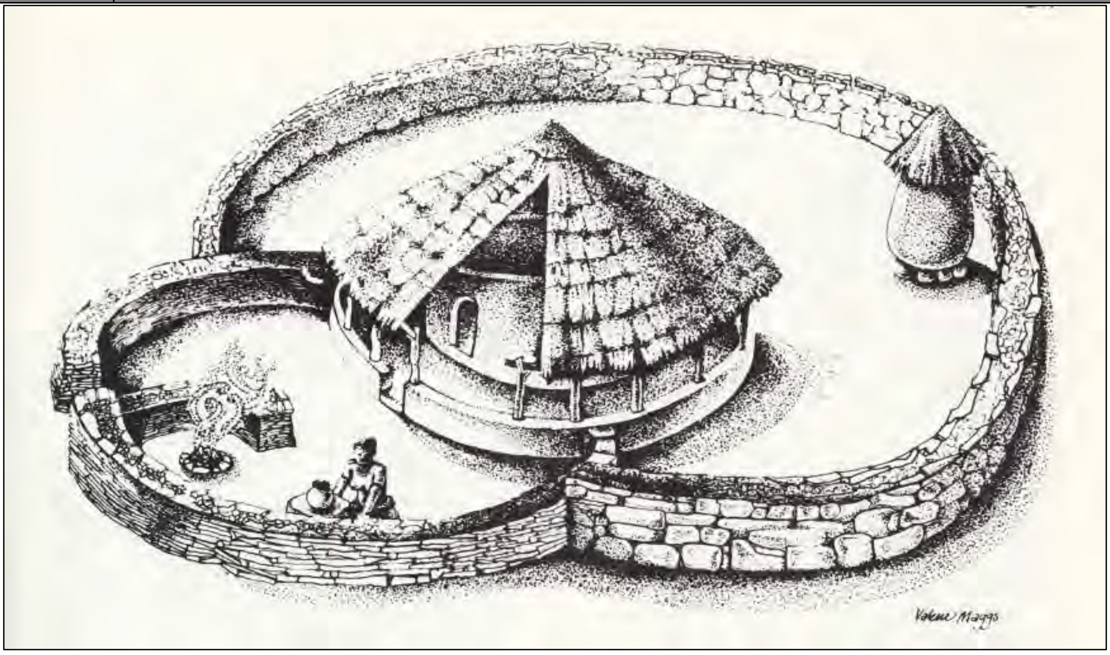
DATE	DESCRIPTION
	 *Figure 19 – Artist's impression of a bilobial dwelling at site OXF 1. These bilobial dwellings represent a characteristic element of Type Z settlements (Maggs, 1976:241).*
AD 1700 – AD 1820	The Makgwareng facies of the Blackburn Branch of the Urewe Ceramic Tradition represents the next known Iron Age period within the surroundings of the study area. The decoration on the ceramics from this facies is characterised by finely stamped triangles, rim notching and appliqué (Huffman, 2007). This facies developed from Ntsuanatsatsi south of the Vaal River and can be associated with the Type V stone walling settlement type (Huffman, 2007), the name of which is derived from Vegkop (Maggs, 1976). Van Riet Lowe (1927) was one of the first to record these structures. Dreyer (1990) also conducted excavations on Type V Late Iron Age stonewalled settlements located a short distance south-west of Winburg. The Type V settlements comprise a core of cattle enclosures surrounded by beehive huts. Corbelled stone huts are associated with this walling type, and can be seen as characteristic. They are low stone huts located at the edge of the cattle enclosures and were where the boys herding the cattle often lived (Huffman 2007). As suggested by Huffman (2007), the corbelled huts were in fact beehive huts made of stone rather than grass and reeds. Furthermore, the presence of beehive huts at these sites necessarily indicates a Nguni association or origin with these settlements. Based in information presently avaiable, the best known site of this type found within the surroundings of the study area, comprises a so-called "Early Sotho Settlement, Waterval, Sandrivierhoogte" that was originally declared a National Monument and which is now registered as a Provincial Heritage Site. The site is located 27.3 km east of the present study area. The site was proclaimed a national monument by virtue of a notice in the Government Gazette on 17 December 1982. In the declaration, the site is described as a 'Leghoya Village' comprising corbelled huts and stonewalls. The site has since been declared a Provincial Heritage Site in terms of the National Heritage Resources Act (www.sahra.org.za).

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Figure 20 – Corbelled stone huts associated with a Type V settlement (Huffman, 2007:39).

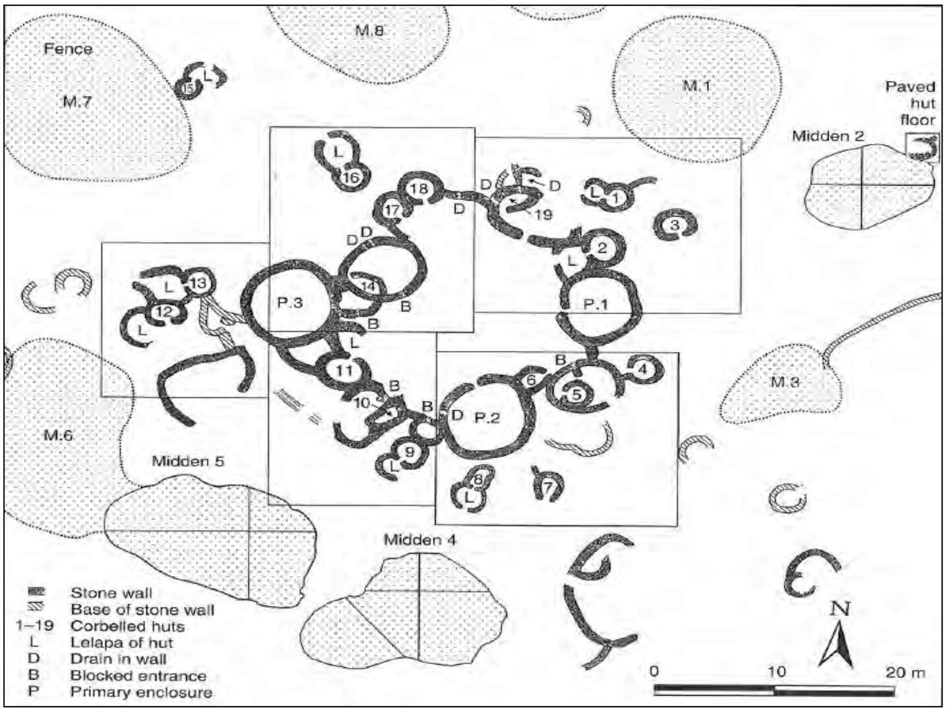

Figure 21 – Layout of a Type V Settlement (Huffman, 2007:38).

</td></tr>
<tr><td>1820s</td><td>Across the Southern Highveld, this period was characterised by warfare and unrest. Known as the Mfecane, these years of upheaval originated primarily in the migration of three Nguni groups from present day Kwazulu-Natal into the present day Free State as a result of the conquests of the Zulu under King Shaka. The three Nguni groups were the Hlubi of Mpangazitha, the Ngwane of Matiwane and the Khumalo Ndebele (Matabele) of Mzilikazi.
In c. 1821, the Hlubi migrated across the Drakensberg Mountains in a westerly direction (Maggs, 1976) and attacked the Tlokwa of MaNthatisi along the banks of the Wilge River. This river has its source near Harrismith and flows into the Vaal River where the Vaal Dam is located today. While it is not exactly certain where MaNthatisi's settlements would have been located (in all likelihood further south), the Tlokwa fled</td></tr>
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DATE	DESCRIPTION
	westward as a result of the Hlubi attack and in turn attacked other groups in its path. This started a period of unrest and warfare, which rippled across the Highveld on both sides of the Vaal River (Legassick, 2010) (Lye and Murray, 1980). The Ngwane followed closely on the Hlubi and further augmented the unrest and warfare along the southern Highveld (Legassick, 2010). Although the effects of the migrations of the Hlubi and Ngwane would certainly have had a profound impact on the northern Free State, this was also the case in terms of the Khumalo Ndebele who would have played a significant role in the surroundings of the study area during this time. The Khumalo Ndebele (also known as the Matabele) were also forced to leave Kwazulu-Natal and between 1823 and 1827 settled along the central Vaal River (Bergh, 1999). Mzilikazi attacked a number of Sotho-Tswana groups and settlements and incorporated them into his kingdom. As a result, his activities would have had a definite impact on the northern Free State at the time.

Figure 22 - King Mzilikazi of the Matabele. This illustration was made by Captain Cornwallis Harris in c. 1838 (www.sahistory.org.za).

The Early Colonial Period

<table>
<tr><th>DATE</th><th>DESCRIPTION</th></tr>
<tr><td colspan="2">The early Colonial Period within the study area and surroundings was characterised by the arrival of newcomers to the Transoraniga. The first arrivals were the Griqua followed by white Trekboers, who for the most part practiced a nomadic pastoralist way of life and were small in number. During the 1830s a mass migration of roughly 2 540 Afrikaner families (comprising approximately 12 000 individuals) from the frontier zone of the Cape Colony to the interior of Southern Africa took place. The people who took part in this Great Trek were later to be known as Voortrekkers (Visagie, 2011).</td></tr>
<tr><td>1804</td><td>The Griqua were of European and Khoikhoi descent, and although they had been present on the Orange River for some time, they only established themselves permanently north of the river in 1804 when they settled near present-day Danielskuil (Reader’s Digest, 1994).</td></tr>
<tr><td>Early 1800s</td><td>During the early 1800s, frequent droughts forced white farmers from the Cape Colony to move with their livestock across the Orange River to look for better grazing. Initially, these Trekboers first obtained permission from the Cape authorities before departing across the frontier, however with time, increasing numbers of Trekboers moved across this river into the Transorangia (as it became known) without any prior permission (Schoeman, 1980).</td></tr>
<tr><td>Early 1836</td><td>The first Voortrekker party of some 70 wagons crossed over the Orange River during early 1836. More groups followed and in terms of the surroundings of the study area, established themselves along the Vet River (Schoeman, 1980). Meintjies (1973) mentions that a Voortrekker party under Hendrik Potgieter arrived along the Vet River during this time. The grazing around the Vet River was not enough for all the livestock and animals of the Voortrekkers, so they split into smaller groups with one group establishing itself in May 1836 at Blaaudrift, on the Zand River. This farm is located within the study area. Apart from this historic event, the closest known tangible evidence for the Voortrekkers to the study area was a fort which they built on the northern bank of the Zand River on the farm Du Preez Leger. The farm Du Preez Leger is located 1.7 km east of the present study area.</td></tr>
<tr><td>1837 - 1843</td><td>In 1841 the town of Winburg was established on the banks of the Vet river. After the annexation of Natal by the British in 1843 and the subsequent dissolution of the Voortrekker Republic of Natalia, Winburg became the capital of the Voortrekkers in what is today known as the Free State (Erasmus, 2004). Winburg is located 34 km south-east of the study area.
On 10 October 1968, an extensive Voortrekker Monument was opened near Winburg (www.artefacts.co.za).</td></tr>
<tr><td colspan="2">
Figure 23 – Depiction of an ox wagon crossing a river during the Great Trek (Reader’s Digest, 1994:116).</td></tr>
<tr><td colspan="2">The Mid to Late Nineteenth Century</td></tr>
</table>

DATE	DESCRIPTION
3 February 1848	The Orange River Sovereignty was proclaimed over the Transorangia by Great Britain and had its capital at the newly established town of Bloemfontein (www.wikipedia.org). The sovereignty came about after one-sided agreements that favoured the British Government had been reached between Great Britain on the one hand and King Moshesh of the Basotho and Adam Kok III of the Griqua on the other. Those Voortrekkers present in the Transorangia were completely by-passed by these agreements, which led to serious dismay and disappointment amongst them. In terms of the surroundings of the study area, the response of the Voortrekkers was to force the British magistrate at Winburg, one Thomas Biddulph, out of town and proclaim the Republic of Winburg (Reader's Digest, 1994).
16 January 1852	On 16 January 1852 the Sand River Convention was signed between the British Government and the Transvaal Boers. The British Government was represented by British Assistant Commissioners W.S. Hogge and C.M. Owen, whereas the Transvaal Boers were under the leadership of the Voortrekker hero of Blood/Ncome River, General Andries Pretorius. This convention formally recognised the existence and independence of the Boer Republic north of the Vaal River by the British Government. As a result, this agreement allowed for the creation of a Boer Republic, namely the *Zuid-Afrikaansche Republiek* (South African Republic) (Oberholster, 1972). The *Zuid-Afrikaansche Republiek* remained in existence until the end of the South African War in 1902. The site where the signing of the convention took place, was declared a monument and for many years was marked by a stone cairn and plaque (Oberholster, 1972). The present condition of the monument is not known. The site is located near the bridge where the N1 highway passes over the Sand River, and is located approximately 29 km east of the present study area.
23 February 1854	The Orange River Convention was signed by representatives of Great Britain and the Boers, and resulted in the proclamation of the Boer Republic of the Orange Free State. The convention was signed at Bloemfontein (www.wikipedia.org). As with the proclamation of the Soverignty, the Orange River Convention was again one-sided and did not obtain the blessing or inputs of all the major role-players in the Free State. While the Voortrekkers were excluded in 1848, the signing of the Orange River Convention in 1854 did the same to the Basotho and Griqua. For the next 48 years, the study area fell within the boundaries of the Boer Republic of the Orange Free State. Incidentally, the Orange River Convention is sometimes referred to as the Bloemfontein Convention.
1872	The town of Ventersburg was laid out on the farm Kromfontein in 1872. Kromfontein had originally belonged to one of the early Voortrekker leaders, namely Field-Cornet P.A. Venter. After his death in 1857, his son B.G. Venter allowed church services to be held in his father's homestead. The second Gereformeerde (Dopper) church north of the Orange River was also established at Kromfontein in 1859. The use of the farm for church services led to the establishment of a town. The new town was named after Field-Cornet P.A. Venter, and formal proclamation for Ventersburg took place in 1876 (Erasmus, 2004). Ventersburg is located 37.23 km east of the present study boundaries.
1890	Erasmus (2004) states that two American engineers were responsible for the original survey of sections of the proposed railway line between Bloemfontein and Johannesburg. On the farm Merriespruit they chiselled the name 'Virginia' on a boulder, presumably in honour of the American State of Virginia. When the railway line was built a few years later, the nearby railway siding was named Virginia and some years later, in 1954, the town of Virginia was also established. The Virginia railway siding is located 13.5 km east of the present study area. The exact position of the chiselled boulder, if it still exists today, is not presently known.

DATE	DESCRIPTION
Early 1890s	The railway line between Bloemfontein and Johannesburg was built during the early 1890s, and eventually reached Johannesburg during September 1891 and Pretoria in January 1892 (Schoeman, 1980). In terms of the study area, this railway line passed to its east and in this area was built from Smaldeel (present day Theunissen) to Theron, Welgelegen and Virginia.
9 November 1892 – 1899	The Driekopjes Diamond Mining Company was registered. One of the founding directors of the company was the man who would become synomynous with South African diamond mining and diamonds, Sir Thomas Major Cullinan. The "Driekopjes" in the name of the company referred to a farm of that name north-west of Kroonstad, where diamond mining was taking place. In June 1894 the Driekopjes Diamond Mining Company also acquired an interest in the farm Welgegund from the Van Rensburg Diamond Mining Syndicate. The farm Welgegund was located within the study area, and is presently known as the farm Driekoppies 422. No information could be found on this syndicate. However, the fact that the Driekopjes Company acquired an interest from the Van Rensburg syndicate, suggests that diamond prospecting and possibly mining activities had taken place within the study area before this transfer took place. A large number of diamonds were subsequently recovered from Welgegund. However all mining activities came to a halt with the South African War (1899 – 1902) (Helme, 1974).
Mid 1890s	During the mid 1890s two men arrived on the farm Aandenk to undertake prospecting work. Alexander Edward King Donaldson was a prospector and his associate Herbert Hinds an engineer. They excavated an 18-meter-deep shaft and took samples from their excavations for further testing and analysis. On their return journey to England, both men died when their ship, the Drummond Castle, wrecked at Ushant off France, and with it the samples they had brought from the Free State (www.sahra.org.za) (Felstar Publishers, 1968). The activities of these two men laid the foundation for the discovery and development of the Free State Goldfields. The farm Aandenk is located immediately south of Allanridge today, some 35 km north by north-west of the present study area.
1899	The town of Odendaalsrust was officially established in 1899 when the Dutch Reformed Church chose the farm Kalkkuil for its new parish. The town was proclaimed a municipality in 1912. At the time, it only had about 40 houses, three shops and a hotel (Mayhew, 1982).
The South African War (1899 – 1902)	
The South African War was fought between the Boer Republics of the Transvaal and Free State on the one side and Great Britain on the other, but is referred to as the South African War as the victims and participants of the war were not excluded to Britain or Boer alone. As will be discussed in more detail below, the march of Lord Roberts from Bloemfontein to Pretoria in May and June 1900 was especially significant in terms of the study area. In particular, the so-called Battle of Zand River (7 – 10 May 1900) was fought very close to the study area, with at least the movement of troops during the battle taking place across the study area.	
13 March 1900 – 6 May 1900	Bloemfontein, the capital of the Boer Republic of the Orange Free, was occupied by the British Army under Lord Roberts on 13 March 1900. The Boer Republic of the Orange Free State was renamed the Orange River Colony. With the Republican forces of the Transvaal and Free State retreating northwards from Bloemfontein, Lord Roberts's eyes drifted further north, where the greatest prize of the war lay waiting, Pretoria. Lord Roberts and his staff strongly believed that once the capital of the *Zuid-Afrikaansche Republiek* fell, the war would be over. However, the success of the British Army required all focus on the immediate front, as the land between Bloemfontein and Pretoria was bisected by a myriad of rivers, dongas

DATE	DESCRIPTION
	and hills, all strategically significant obstacles from where the Boer forces could implement a solid defence. The Boer forces standing between Lord Roberts and Transvaal capital were estimated by British Intelligence to comprise two main groups namely a force of between 5 000 to 6 000 burghers with 18 guns under General Louis Botha and a similarly large force in the surroundings of Kroonstad (Maurice & Grant, 1906). After departing from Bloemfontein, Lord Roberts's force was involved in a couple of successful actions on their way to Pretoria, including Brandfort (3 May 1900) and Vet River (4 - 6 May 1900). With the successful conclusion of the battle of Vet River, Lord Robers and almost his entire army crossed over the river successfully, and by the evening of 6 May 1900 bivouacked at the small railway siding known as Smaldeel. The town of Theunissen is located here today and is roughly 12 km south of the present study area (Maurice & Grant, 1906). A short distance to the north lay the next, and far more daunting, obstacle on Lord Roberts's march to Pretoria, the Zand (or Sand) River. It was here, at this river, that General Louis Botha, the commanders-in chief of the Transvaal republican forces, was determined to halt Lord Roberts's march on Pretoria.

Figure 24 – Lord Frederick Sleigh Roberts (left) and General Louis Botha (right). These two officers commanded the opposing forces at the Battle of Zand River (Changuion, 2001:77 & 117)

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7 – 10 May 1900	On 7 May 1900 a reconnaissance of the Zand River by General Edward Hutton indicated that the northern bank of the river was held by a force of roughly 6 000 Boers supported by two heavy and eight light pieces of artillery. These estimates provided by General Hutton allowed Lord Robers to draw up a battle plan (Maurice & Grant, 1906). On the 9th of May 1900, Lord Roberts moved his army forward and established his headquarters at the Welgelegen Station, roughly 6 km east of the study area. The movement of the British Army under Lord Roberts from a position a short distance south of the study area at

DATE	DESCRIPTION
	Smaldeel to a position a short distance east of it, suggests that the main component of Lord Roberts's force followed the railway line and in this way skirted around the study area. However, in view of the closeness of this railway line to the present study area, sections of his force would almost certainly have crossed over the study area as well. Lord Roberts's battle plan focussed on securing significant drifts that provides safe crossing of his infantry over the Zand River, and especially so Junction Drift (23.5 km east of the study area), Merriespruit (16.6 km east of the study area), Du Preez Leger Drift (located within the study area where the bridge on the road between Theunissen and Welkom crosses the river) and De Klerks Kraal Drift (940 m west of the present study area). For the purposes of this discussion, the events associated with the latter two of these drifts will be discussed in more detail below. On the morning of 9 May 1900, Lieutenant-Colonel Thomas William Porter with the 1s Cavalry Brigade departed from Smaldeel to reconnoitre the two drifts at Du Preez Leger and De Klerks Kraal. They were assisted in this task by Major-General J.B.B. Dickson with the 4th Cavalry Brigade. Meanwhile, at 11 am, Major-General John French with his advance guard reached Kalkoenkrans, a section of which farm is located within the present study area. At Kalkoenrkans, French received word from the reconnaissance units on the river that the Du Preez Leger Drift was not held by the enemy. Seizing the opportunity to outflank the Boer positions, French immediately ordered a squadron of the Scots Greys forward to take possession of the drift, and ordered the remainder of the 1st Cavalry Brigade to follow and assist in this task. The 4th Cavalry Brigade was left at Kalkoenkrans in support. By 15h30 that afternoon the Du Preez Leger Drift was occupied by the British force, with the De Klerks Kraal Drift was taken shortly thereafter. Incidentally, the other significant drifts on the river had also been taken with similar ease. On the morning of 10 May 1900, Lord Roberts's army advanced on the river. On its left flank (and the side closest to the study area) General French with the 1st Cavalry Brigade, the 4th Cavalry Brigade as well as Hutton's Mounted Infantry, crossed over the Du Preez Leger Drift from where they moved in a north-eastern direction. On the left centre of the front, the 3rd Cavalry Brigade and Henry's Mounted Infantry crossed over the drift at the railway line in proximity to present-day Virginia, some 16.6 km to the east of the study area. The northern bank was occupied by 8 am that same morning. The crossing of the drifts further to the east was achieved with more difficulty, but the northern banks were also occupied a mere half an hour after the crossing over the Merriespruit Drift near the railway line. This meant that Lord Roberts's front comprising cavalry and mounted infantry units had successfully crossed over the Zand River early on the morning of 10 May 1900, without meeting any significant resistance. However, the fortunes of war were about to change for Lord Roberts. A patrol sent out by General French ran into a large Boer force of between 2 000 and 3 000 burghers moving down onto the centre of Lord Roberts's front at the Virginia Station. French ordered an attack by one squadron each from the 6th Inniskilling Dragoons, Scots Greys and Australian Horse and two troops from the 6th Dragoon Guards (Carabiniers). Their attack was focussed on the centre of the advancing Boer force on a ridge located on the farm Vredes Verdrag. This farm is situated some 21.3 km north-east of the present study area and as a result this part of the battle will not be discussed in any detail. Suffice to say that the battle raged for some time and the outcome was not at all clear until 14h00 that afternoon when the Boers abandoned the field of battle, allowing the British to occupy the ridge and proceed forward (Maurice & Grant, 1906).

DATE	DESCRIPTION
	Further battles and actions took place to the east, near Junction Drift. However, by the afternoon of 10 May 1900, all the drifts had been successfully cleared and occupied to allow for the crossing of the Zand River by Lord Roberts's infantry (Maurice & Grant, 1906).

Figure 25 – Lord Roberts's infantry crossing the Zand River at the conclusion of the Battle of Zand River. This photograph was in all likelihood taken during the afternoon of 10 May 1900, after all the significant drifts across the river had been cleared by the cavalry and other units. The crossing and surrounding landscape are monitored by an observation balloon (see top right). It is not possible to identify the exact drift where this crossing took place, although the remnants of a bridge foundation structure can be seen in the river bed (Raath, 2007:351).

DATE	DESCRIPTION
	 *Figure 26 - Two of the British officers at the Battle of the Zand River who were closely associated with the events within the study area, namely the occupation of the Du Preez Leger Drift on 9 May 1900 as well as the crossing of the drift on the morning of 10 May 1900. General John French (left) (Changuion, 2001:77) and Colonel Thomas William Porter (www.nzetc.victoria.ac.nz).*
	After the fall of Pretoria on 5 June 1900 and the subsequent battles of Diamond Hill (11-12 June 1900) and Bergendal (21-27 August 1900), the Boer generals decided that the only way to proceed with the war would be the implementation of a completely different strategy, a strategy based on mobility by using smaller commandos to attack and harass the British on all fronts in what was to become known as guerrilla warfare. This style of warfare had significant successes, and extended the war for nearly another two years. However, these successes also came with significant losses as the war increasingly dragged the civilian population of the Boer Republics into the carnage of war. No skirmishes or battles associated with the guerrilla war are known from within the study area or its immediate surroundings. This said, the study area and surroundings, as with almost the entire South Africa, experienced the effects of guerrilla warfare. In retaliation to the new form of warfare, the British High Command devised a strategy of building extensive blockhouse lines across the country as a way of hindering the mobility of the Boer commandoes. By December 1900, points along the railway line north of Bloemfontein had been fortified with hastily constructed trenches shaded by roofs and defended by razor wire. The closest of these defensive works to the present study area was at Virginia, 13.5 km to the east. Shortly thereafter, a number of key positions along the railway line north of Bloemfontein were significantly strengthened with the construction of multi-storey blockhouses. At Virginia, for example, a double storey stone blockhouse as well as one corrugated iron blockhouse were built (Hattingh & Wessels, 1997). Lord Kitchener, in particular, also implemented a strategy that was to become known as scorched earth whereby the Boer farms were burnt to the ground and the civilian population (both white and black) remaining on these farms forced into concentration camps. No details regarding the destruction of farms from within the study area are presently known. However, the destruction of farms during the guerrilla phase of the war would certainly have taken place within the study area as well. While no concentration camps existed within the study area, a surprising large number of such camps were located in the surroundings of the study area. Black concentration camps were located at Smaldeel, Virginia, Welgelegen and Winburg (Warwick, 1983). Of these,

DATE	DESCRIPTION
	Welgelegen is the closest at a distance of 6 km east of the present study area. The closest white concentration camp to the study area was at Winburg, roughly 34 km south-east of the study area (www.angloboerwar.com). Untold hardship ensued in these concentration camps, and many women and children died as a result of exposure, inadequate nutrition and poor medical facilities. These camps resulted in the deaths of 27 926 white and 14 154 black people (www.sahistory.org.za).
The Early Twentieth Century (1902 – 1913)	
October 1902 – November 1904	In October 1902, some months after the end of the South African War, the name of the Driekopjes Diamond Mining Company was changed to the New Driekopjes Diamond Mining Company, which still had Thomas Major Cullinan as one of its directors. Although work at the Driekopjes Mine north-west of Kroonstad resumed on a small scale during 1903 (in all likelihood work at Welgegund also continued), all work at the mine was permanently halted by November 1904. This was due to disappointing yields and as a result the company was liquidated shortly thereafter (Helme, 1974).

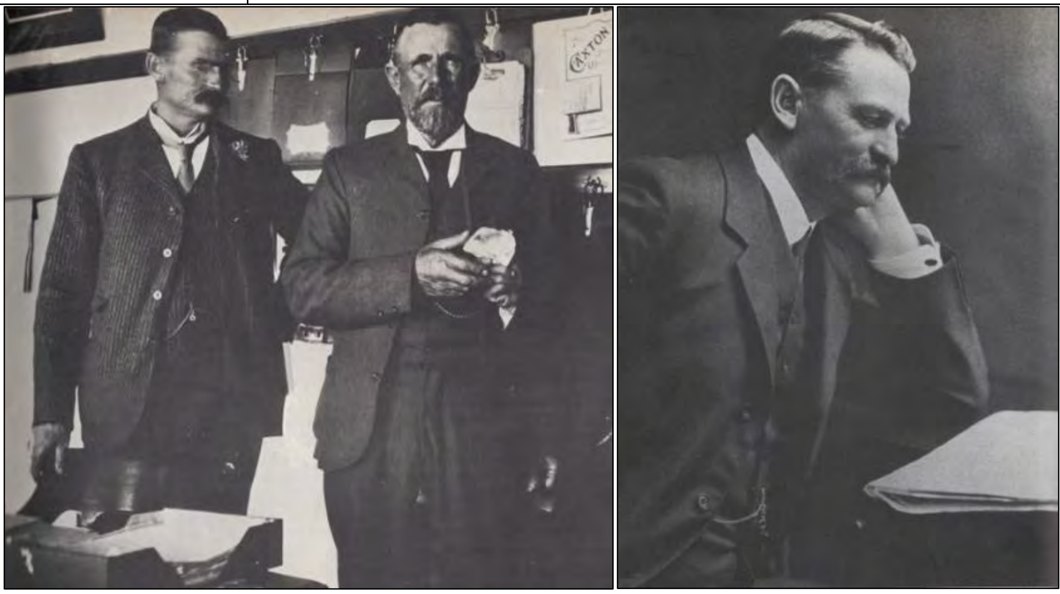


Figure 27 – Sir Thomas Major Cullinan was one of the founding directors of the Driekopjes Diamond Mining Company, which acquired an interest in the farm Welgegund in 1894. In the historic photograph on the left he is shown shortly after the discovery of the Cullinan diamond (which is held by F. Wells) at the Premier Diamond Mining Company, of which he was the chairman. The photograph on the right depicts Cullinan in 1929 (Helme, 1974: 75 & 146).

1904	After the South African War, renewed efforts were made to carry out gold prospecting work in the area. In 1904, a prospector named Archibald Megson arrived on the farm Aandenk, and the farmer showed him the trench where Alexander Edward King Donaldson and Herbert Hinds had looked for gold. It had been more than a decade since these two pioneers had prospected the same farm. Megson opened up the old trench and continued with the excavations. At a depth of 30 meters, he found indications of gold and took a number of samples.

DATE	DESCRIPTION
	Megson returned to Johannesburg with his samples and attempted to gain the interest of various mining houses and investors on the rand. However, with the rapid development and expansion of the Witwatersrand gold mining industry attracting all of the attention, no one seemed interested in possible gold discoveries so far away from Johannesburg (www.sahra.org.za).

Figure 28 – Archibald Megson standing in the prospecting trench on the farm Aandenk (Felstar Publications, 1968).

August 1907	In August 1907, the town of Theunissen was proclaimed. This proclamation followed on a petition by farmers living in proximity to Smaldeel Siding. The town was named in honour of Commandant Helgaardt Theunissen, who led the petition and had also been the leader of the local commando during the South African War. The town of Theunissen became a municipality in 1912 (Erasmus, 2004). Theunissen is located 2.5 km from the study area.
1910	At the time, the Driekoppies Diamond Mine at Welgegund comprised 50 claims (Johnson, 1910). Although no detailed information on these syndicates and companies could be obtained, it would appear that by this time the farm was prospected and mined by at least the Magnus Diamond Syndicate Limited as well as the Triumph Diamond Mining Company Limited. Based on this information, it would appear that the Magnus and Triumph entities in all likelihood took over at Welgegund after the liquidation of the New Driekopjes Mining Company in 1904.
25 November 1911	The Drie Koppie Diamond Mine Limited was formed on 25 November 1911 by W.G. Griffiths to acquire from the Magnus Diamond Syndicate Limited and the Triumph Diamond Mining Company Limited the farm Welgegund in the Winburg District (The Mining Manual and Mining Year Book, 1914). The later history of the diamond mine and mining activities at Welgegund could not be revealed by way of the desktop study. However, based on the remains of the mine property observed during the field, it would appear that a diamond mine was operated here into the relatively recent past.

The Boer Rebellion (1914 – 1918)

At the end of the South African War (1899 – 1902), the Transvaal and Orange Free State republics lost their independence to the British Empire. In 1910, the Union of South Africa was established consisting of the Cape Colony, Natal, the Transvaal Colony and the Orange River Colony. General Louis Botha was appointed the Union's first prime minister and believed that South Africa's future would be best served as part of the British Commonwealth. In 1914, the South African government under General Louis Botha decided to assist Great Britain in its war with Germany. A number of

DATE	DESCRIPTION
Boer leaders were not happy about this turn of events, and when General Koos de la Rey was killed at a roadblock in Johannesburg, emotions reached a boiling point and rebellion broke out across the former Boer republics. This rebellion saw more than 11 000 Boer men under the leadership of some of the former Boer War generals such as De Wet, Maritz, Kemp and Beyers rebelling against the South African government and its armed forces under the leadership of former Boer War generals Louis Botha and Jan Smuts.	
16 November 1914	In terms of the study area, the most notable event relating to the Boer Rebellion was the battle that occurred between the commando of General De Wet and the Government forces under the command of Colonel Enslin at the Virginia railway station on 16 November 1914. This battle followed on the defeat of De Wet's rebels at Mushroom Valley, south-east of Winburg, at the hands of General Louis Botha. De Wet and 2 000 rebels managed to escape from Mushroom Valley and followed the railway line north-eastwards towards the Virginia Station on the Zand River. De Wet wanted to cross over the railway line, and as a result, a fight ensued with Colonel Enslin's forces stationed at Virginia Station. General De Wet suffered a number of casualties and 50 of his men were also taken prisoner. After the battle, De Wet and his men followed the Zand River in a western direction and crossed over the river into the Transvaal Colony in proximity to Hoopstad (Union of South Africa, 1916). The Virginia Station is located 13.5 km east of the study area, and as a result the battle would have taken place outside the study area boundaries. However, the movement of De Wet and his commando after the battle would have taken them through the present study area.


Figure 29 –The hardships experienced by General C.R. de Wet during the rebellion can be seen on these photographs. The one on the left shows De Wet shortly after the South African War (Van Schoor, 2007) with the image on the right depicting the general in the Bloemfontein prison after his capture late in 1914 (Raath & Langner, 2014:119).

The Remainder of the Twentieth Century (1915 – Present Day)	
1929 - 1933	Nearly 25 years after finding the first indications of gold on the farm Aandenk, Archibald Megson finally managed to raise the interests of possible investors in Johannesburg. In 1929, during a chance encounter with Joseph Freedman, Megson found a more welcoming response. Freedman introduced the prospector to Johannesburg attorney, Emmanuel Jacobson, and his friend Allan Roberts, a dental technician. Despite being interested in what the prospector had to say, it took almost

DATE	DESCRIPTION
	four years before Jacobson, Roberts and Megson travelled to the Free State (Shorten, 1970). Allan Roberts, who was an amateur prospector, was able to trace a conglomerate outcrop all along the farm Aandenk, and incorrectly identified it as part of the Upper Witwatersrand series. The two friends returned to Johannesburg and formed a syndicate comprising themselves, F.L. Marx, Dr. E.B. Woolf, Samuel Potter and Joseph Freedman. Freedman represented the interests of the old prospector Archibald Megson in the syndicate (Shorten, 1970). The syndicate acquired prospecting options on 31 farms in the area and the company Wit. Extensions Limited was established by the syndicate. On 23 October 1933, drilling commenced at a point roughly 80 m from Megson's trench on the same farm Aandenk. However, by February 1935 the drilling work had to be halted due to a lack of funds without any evidence for gold-bearing reefs identified. Many years later, it was estimated that if the two friends had only managed to deepen the hole by another 400 feet, they would have become very rich men and the discoverers of the Free State goldfields. Sadly, this was not to be their fate. Allan Roberts died in such poverty in 1939 and his friends had to pay for his funeral whereas Emmanuel Jacobson had to sell all his assets to survive (Shorten, 1970). Today, the town of Allanridge (named after Allan Roberts) and a monument to the west of the road between Welkom and Bothaville are all that is left of the dreams and expectations of these two mining pioneers.
 *Figure 30 - The first gold prospecting borehole in the Free State was sunk on the farm Aandenk between October 1933 and February 1935. The arrows indicate the positions of Allan Roberts and his wife (Felstar Publications, 1968:11).*	
1935	After the failure of Wit. Extensions Limited, an agreement was reached with the Anglo-French Exploration Company to continue prospecting work at Aandenk. However, instead of continuing deeper on the same borehole, the Anglo-French Exploration Company decided to rather deflect the borehole and no results were achieved. It was later estimated that if either one of these companies had deepened the borehole by only another 400 feet, payable gold would have been discovered (Shorten, 1970). The agreement between Wit. Extensions Limited and Anglo-French Exploration Company came to an end and the famous geologist Dr. Hans Merensky acquired an interest in Wit. Extensions Limited. He subsequently carried out extensive prospecting work including the drilling

DATE	DESCRIPTION
	of further boreholes. However, even these more extensive attempts by Merensky to find the Free State goldfields also failed (Shorten, 1970). Machens (2009) indicates that when news broke that the famous discoverer of inter alia South Africa's platinum reserves owned options in a company working on the Free State goldfields, the interest from investors and mining companies to this part of the Free State was further awakened.
 *Figure 31 –The famous geologist Dr. Hans Merensky, who had his role to play in the discovery of the Free State goldfields (Machens, 2009).*	
1 February 1937 – April 1939	After failing to discover any payable gold, Merensky sold his shares in Wit. Extensions to the Anglo American Corporation, who on 1 February 1937 established the West Rand Investment Trust. The trust also carried out an extensive drilling operation. The activities and interest of the Anglo American Corporation in this part of the Free State attracted the interest of other mining houses and investment companies, and prospecting options were taken out on a large number of farms from this area (Shorten, 1970).
	Despite all this interest, the first payable gold in the Free state was only identified in March 1939 during drilling operations by the African and European Investment Company on the farm Uitsig at a depth of 2 701 feet (Felstar Publishers, 1968). One month later, during April 1939, another discovery of payable gold was made on the farm St. Helena at a depth of 1 143 feet (Shorten, 1970). The discoveries of payable gold at Uitsig and St. Helena created significant excitement amongst mining companies and investors, and increasing numbers of prospecting options and eventually mines were acquired and developed. The Free State gold rush had begun. The farm Uitsig is located 10.3 km north by north-east of the present study area with the farm St. Helena roughly 2.9 km to the north.
1941	The first gold mining lease in the Free State was granted by the government of the Union of South Africa for the farm St. Helena in 1941, and the St. Helena Gold Mining Company was established to mine and develop the property (Felstar Publishers, 1968). A number of other gold mining companies were also established in a relatively short spate of time, including the Welkom Gold Mining Company, President Steyn Gold Mining Company and the President Brand Gold Mining Company.

DATE	DESCRIPTION
 *Figure 32 –The first mine shaft ever sunk along the Free State goldfields, namely the No. 3 Incline Shaft at the St. Helena Gold Mine (Felstar Publishers, 1968:151).*	
16 April 1946	The borehole of the Blinkpoort Gold Syndicate Limited on the boundary of the farms Geduld and Friedenheim, reached payable gold in 1946. On 16 April 1946 it was announced that the gold-bearing material retrieved at a depth of 3 922 feet from this borehole assayed at an impressive 1 252 dwts per ton which was unique in the history of golf prospecting and mining in South Africa, with averages usually in the region of 250 dwts per ton. This discovery led to further interest in the Free State goldfields (Felstar Publishers, 1968).
11 July 1946 – 15 April 1947	On 11 July 1946 an application was made by the land company of Sir Ernest Oppenhaimer's Anglo American Corporation, namely the South African Township and Mining and Finance Corporation, for the establishment of a new town called Welkom. After some legal and procedural processes and debate between the township applicants and its opponents (including the Odendaalsrus Town Council), the application for the establishment of the town of Welkom was approved on 15 April 1947 (Felstar Publishers, 1968). William Backhouse designed the town as a garden city with a commercial centre built around a town square and traffic circles rather than stop streets or traffic lights. More than a million trees were also planted (Erasmus 2014).

DATE	DESCRIPTION
	 *Figure 33 –This photograph of Welkom was taken during the 1960s, roughly ten years after its establishment (Felstar Publications, 1968:171).*
1953	After gold was discovered in the area, Odendaalsrus became a prominent town in the Free State. A railway line was built from Allanridge to Odendaalsrus in 1953 and served the two Freddie's mines (Nienaber et al. 1982).
1954	Three of the six mines surrounding Welkom had reached production stage by 1954. These were the Welkom, Western Holdings and St. Helena Mines. During the same year, the town of Virginia was laid out on the banks of the Zand River. As indicated elsewhere, the name of this town was derived from the nearby railway station, which in turn was named this after two American engineers working on the line in 1890 had carved the name "Virginia" on a boulder from a nearby hill (Erasmus 2014). Virginia is located 13.5 km east of the present study area.
1981 - 1987	Beisa Shaft (now the Beatrix West Section) was commissioned in 1981 to exploit uranium. The sinking of Beatrix 1 and 2 Shafts (now the Beatrix South Section) were also started at the time (www.sibanyegold.co.za). In 1984, the Beisa Uranium Mine was closed due to the low price of uranium at the time. In 1985 the Beatrix 1 and 2 Shafts were commissioned and exploration work commenced in proximity to the Beisa Mine on the farm Kalkoenkrans (www.sibanyegold.co.za). The sinking of two sub-vertical shafts and a ventilation shaft commenced at the Beisa Mine in 1987. During the same year this mine was renamed the Oryx Mine (www.sibanyegold.co.za). The Beisa (Oryx) Mine is located within the study area on the farm Palmietkuil.

5.2 HERITAGE SENSITIVITY AS REVEALED IN THE HISTORICAL AND ARCHAEOLOGICAL OVERVIEW

It is clear that the historical and archaeological overview revealed various aspects relating to the surroundings of the study area. While this assists with reconstructing the historical landscape, it does however provide some indication of the relatively limited historical significance of the study area as a whole. The following historical events and sites can be directly associated with the study area:

- During archaeological research undertaken by the National Museum in Bloemfontein, a total of 10 Middle Stone Age and Later Stone Age sites were identified in association with mammal fossil bones in drainage gullies along the Vet, Doring and Sand Rivers. It is important to note that this research was not focussed on identifying Stone Age sites without the associated presence of mammal fossil bones. The chances for finding more Stone Age sites along these rivers are therefore high. The prevalence of such sites along the banks of rivers was supported during the fieldwork when a previously unrecorded Middle Stone Age site was identified within the boundaries of the study area on the northern bank of the Sand River (see Site 33).
- The historical and archaeological review has revealed that the study area is located outside of the known distribution of Late Iron Age stonewalled settlements as published by Maggs (1976). This observation is largely supported by the distribution maps of known Iron Age sites as published by Huffman (2007). This said, it is always still possible for Iron Age sites to be located within the study area, and especially sites associated with the Thabeng and Makgwareng facies.
- In May 1836, a Voortrekker party under the leadership of Hendrik Potgieter arrived in the wider surroundings of the study area. Due to limited grazing the party decided to splinter into smaller groups. One of these groups established themselves at the present-day farm Blaauwdrift, located within the study area (Meintjies, 1976).
- Diamond prospecting and mining activities had been undertaken on the farm Welgegund since at least the early 1890s. These early activities appear to have been undertaken by the Van Rensburg Diamond Mining Syndicate. In June 1894 an interest in the farm Welgegund was acquired by the Driekopjes Diamond Mining Company, a founding director of which was the famous diamond magnate Sir Thomas Major Cullinan. While mining activities were undertaken in earnest during the remainder of the decade, the outbreak of the South African War in 1899 brought all work to a halt. After the war, mining activities continued at Welgegund. With time other mining companies also acquired claims on the farm, including the Magnus Diamond Mining Company, Triumph Diamond Mining Company, Welgegund Diamond Mining Company as well as the Drie Koppies Diamond Mining Company. This latter company appears to have still existed by 1931. The farm Welgegund was located within the study area, and is presently known as the farm Driekoppies 422.
- The South African War (1899-1902) had a significant impact across the country, and also within the study area. During the Battle of Zand River (7 – 10 May 1900), the most significant drifts across the river were earmarked for attention by Lord Robers in his attack, including the Du Preez Leger Drift as well as De Klerks Kraal Drift. While the latter drift is located outside of the study area, the

available land deed information has revealed that the farms Blaauwdrift and Adamson's Vley located within the present study area, were subdivided from the farm Du Preez Leger after the war. It is evident that at the time of the battle, the drift located within the study area on the farm Blaauwdrift, was in fact located on the farm Du Preez Leger. This means that the actions and events associated with this drift during the battle, would have taken place within the study area.

- During the Boer Rebellion (1914 -1915) a battle took place between the commando of General De Wet and government forces under Colonel Enslin at the Virginia railway station on 16 November 1914. While this battle was located some distance east of the study area, it is important to note that after the battle De Wet and his commando followed the Zand River in a westerly direction towards Hoopstad, and as a result crossed through the study area.
- In March and April 1939 and 16 April 1946 significant discoveries of payable gold were made during prospecting drilling operations on the farms Uitsig, St. Helena and Geduld. These discoveries led to the rapid development of the Free State goldfields which significantly changed the entire landscape, including the present study area.
- In 1981 the Beisa Shaft was commissioned. This shaft is located within in the study area, and is where the Beatrix 4 Shaft is still located today.

5.3 EXAMINATION OF ARCHIVAL AND HISTORICAL MAPS

The examination of historical data and cartographic resources represents a critical tool for locating and identifying heritage resources and in determining the historical and cultural context of the study area. Relevant topographic maps and satellite imagery were studied to identify structures, possible burial grounds or archaeological sites present in the footprint area.

Historical topographic maps (1:50 000) for various years (1945, 1954, 1975, 1997, 2007) were available for utilisation in the background study. These maps were assessed to observe the development of the area, as well as the location of possible historical structures and burial grounds. The study area was overlain on the map sheets to identify structures or graves situated within or immediately adjacent to the study area that could possibly be older than 60 years and thus protected under Section 34 and 36 of the NHRA.

5.3.1 FIRST EDITION OF THE 2826BA BLAAUWDRIFT AND 2826BB VIRGINIA TOPOGRAPHICAL MAP DATED TO 1945

The 2826BA Blaauwdrift map sheet was surveyed in 1945 by 45 Survey Company U.D.F and drawn by the Trigonometrical Survey Office, 1945. The 2826BB Virginia map sheet was surveyed in 1945 and drawn by the Trigonometrical Survey Office, 1945.

As the study area extends over a significant portion of land, the discussion that follows will be done on a section-by-section basis. These map sheets show several structures (incl. farmsteads and kraals), ruins, homesteads and graves within the vicinity of the study area. If these heritage sites still exist today, they would be at least 77 years old. Overlays of the study area components over this map sheet are provided in the section below.

First Edition of the 2826BA Topographical Sheet:

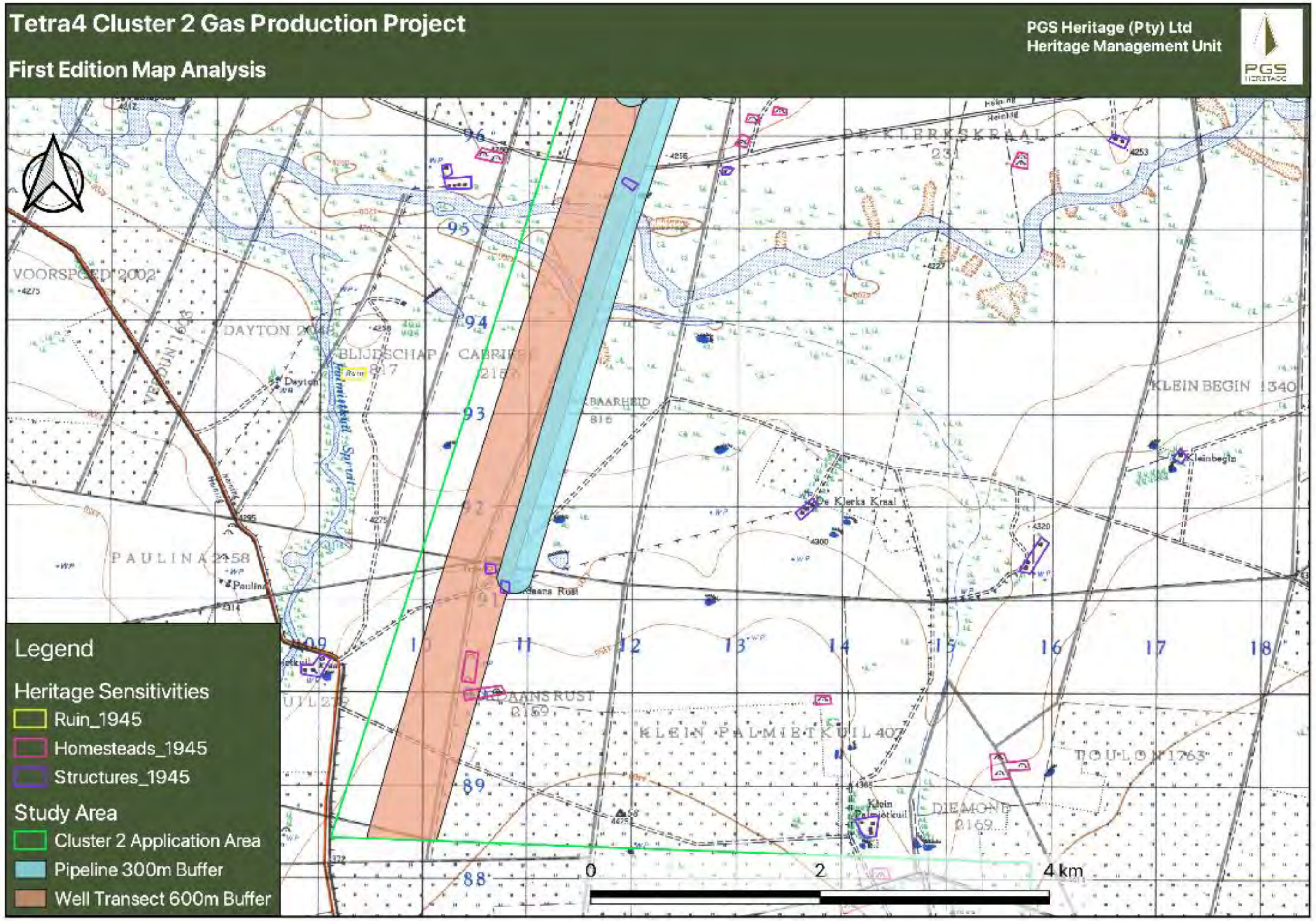


Figure 34 - Section of First Edition of the 2826BA Topographical Map, showing several heritage features. These comprise structures (purple polygon), ruins (yellow polygon) and historical Black Homesteads (red polygons) located within the immediate vicinity of the proposed development.

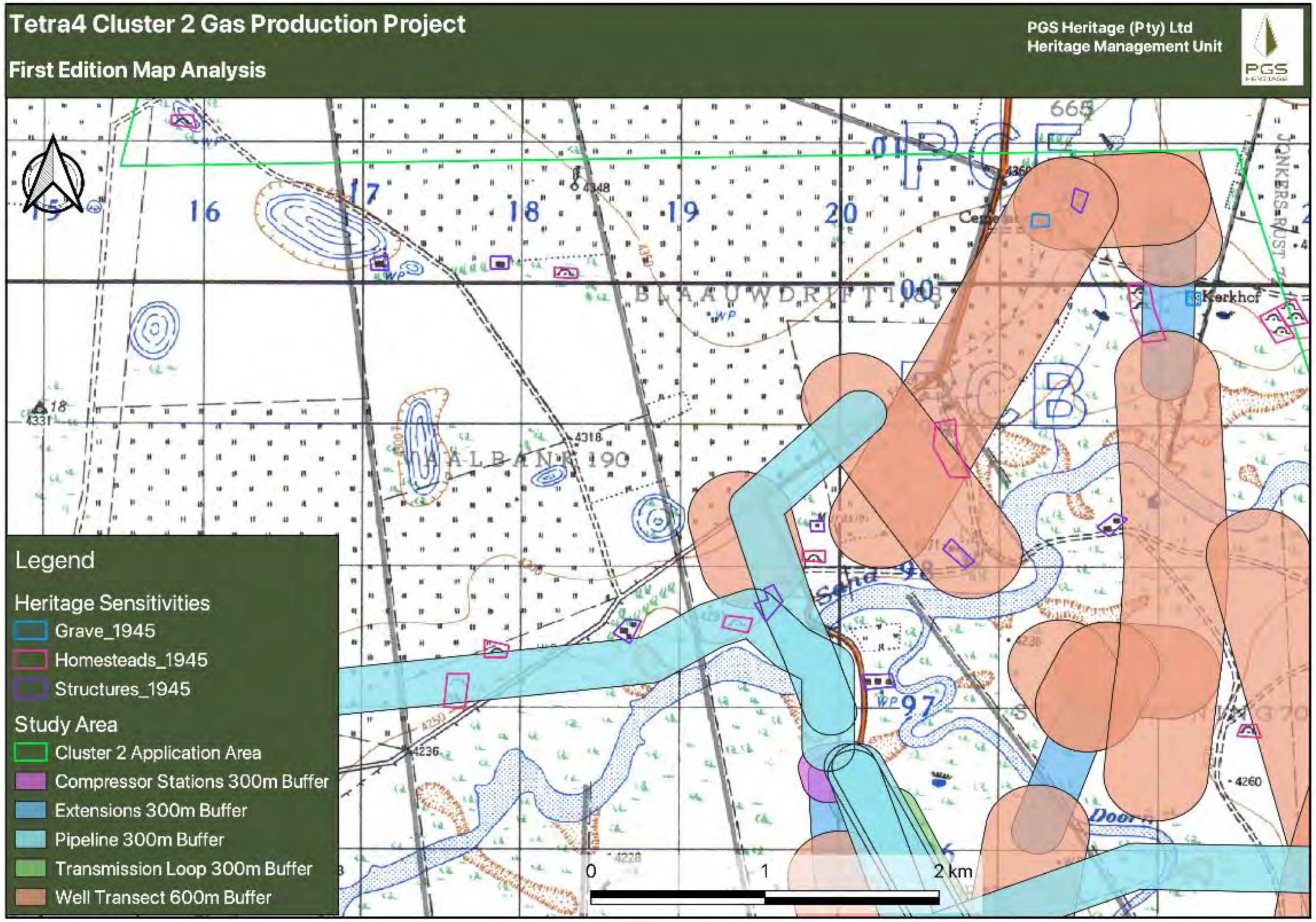


Figure 35 – Second section of First Edition of the 2826BA Topographical Map, showing several heritage features. These comprise structures (purple polygon), graves (blue polygon) and historical Black Homesteads (red polygons) located within the immediate vicinity of the proposed development.

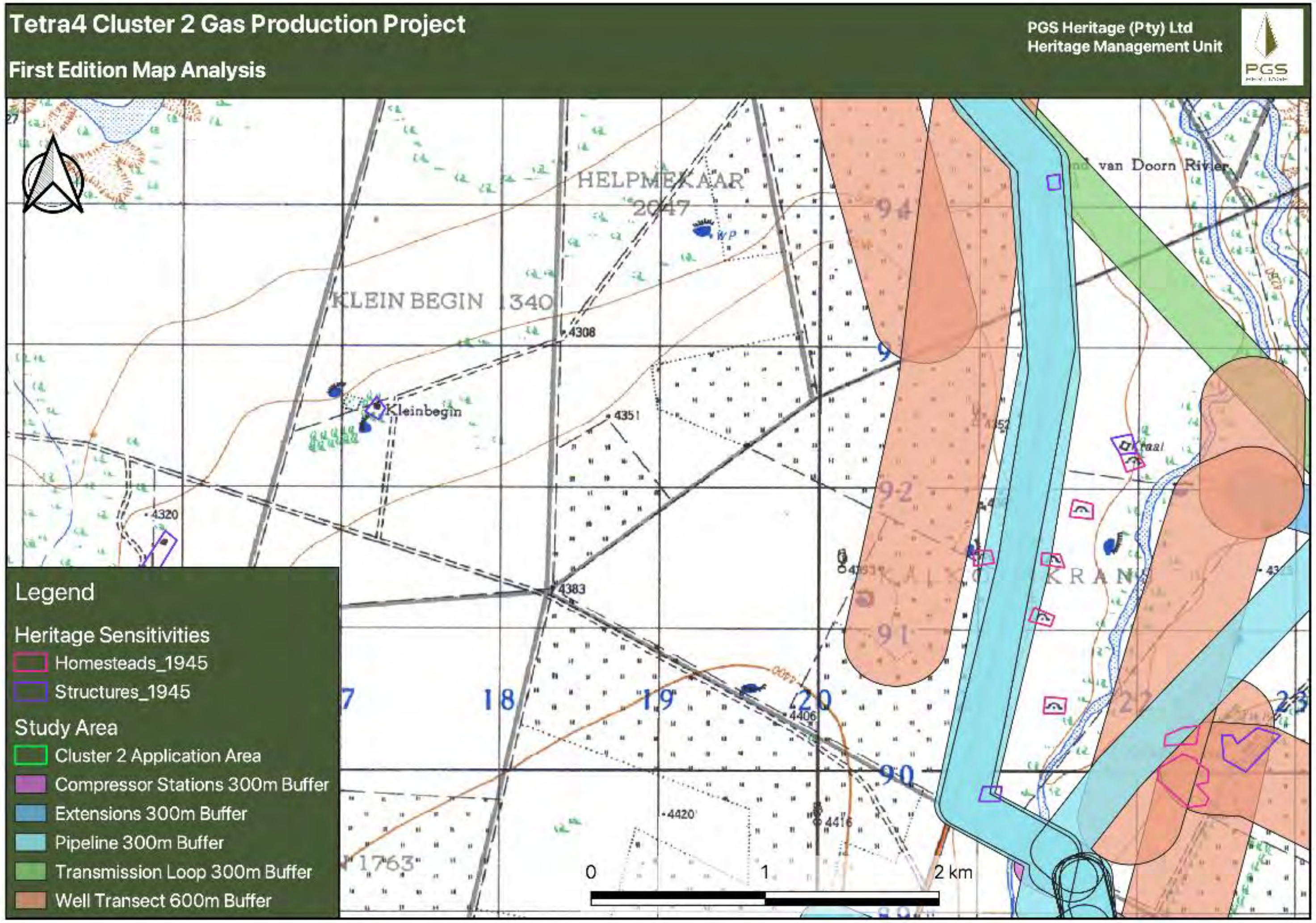


Figure 36 – Third section of First Edition of the 2826BA Topographical Map, showing several heritage features. These comprise structures (purple polygon) and historical Black Homesteads (red polygons) located within the immediate vicinity of the proposed development.

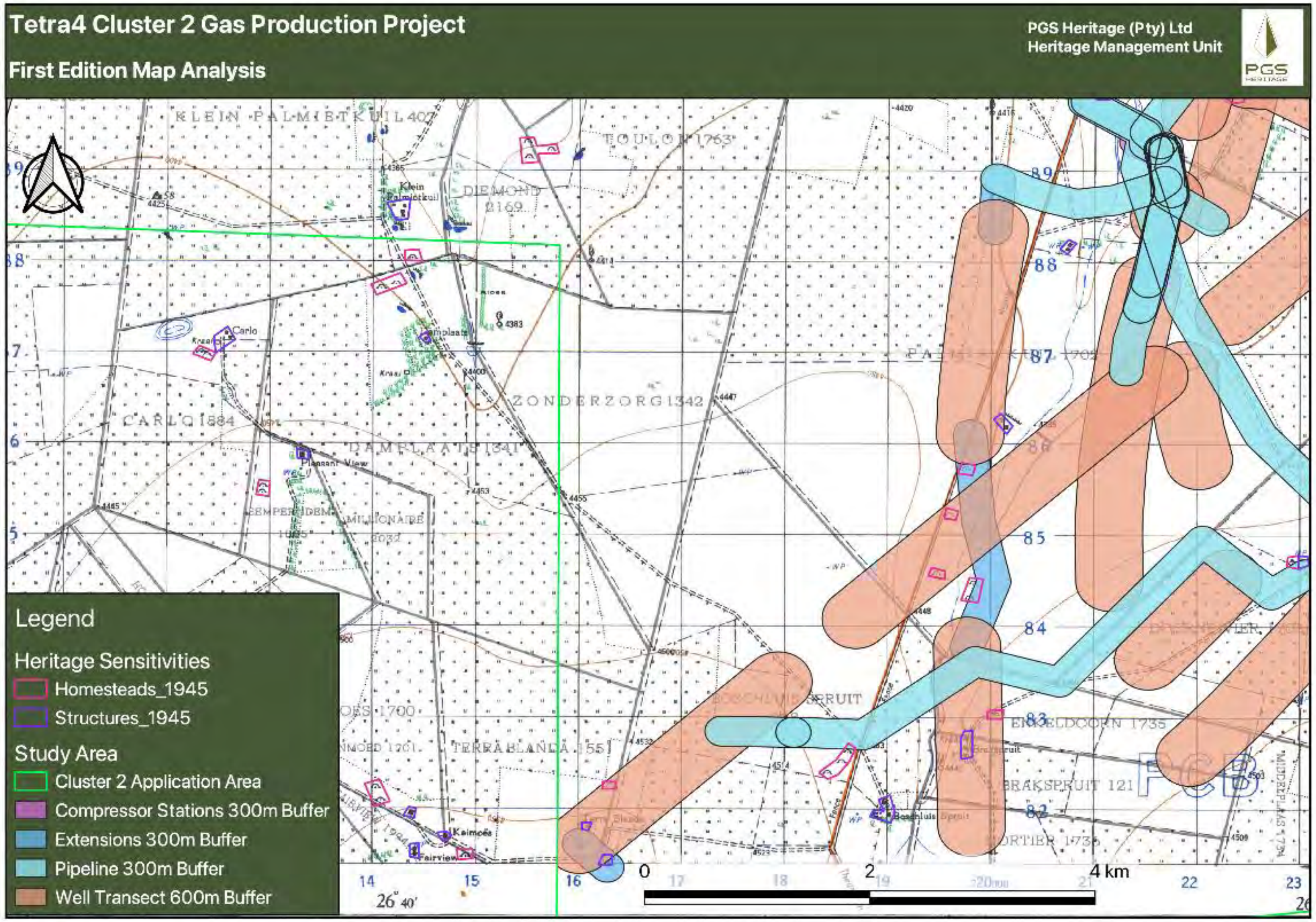


Figure 37 – Fourth section of First Edition of the 2826BA Topographical Map, showing several heritage features. These comprise structures (purple polygon) and historical Black Homesteads (red polygons) located within the immediate vicinity of the proposed development.

First Edition of the 2826BB Topographical Sheet:

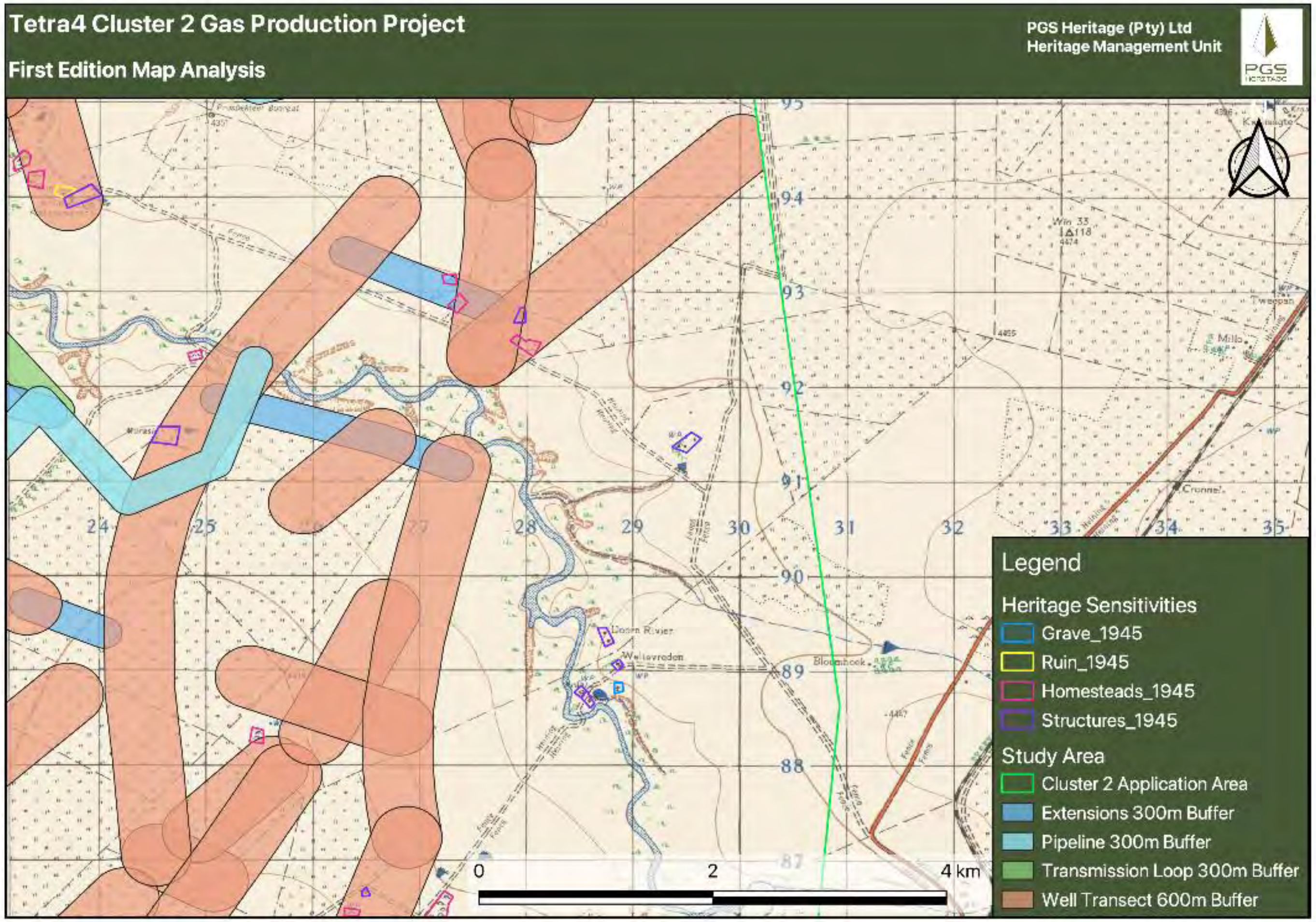


Figure 38 - Section of First Edition of the 2826BB Topographical Map, showing several heritage features. These comprise structures (purple polygon), ruin (yellow polygon), historical Black Homesteads (red polygons) and graves (blue polygon) located within the vicinity of the proposed development.

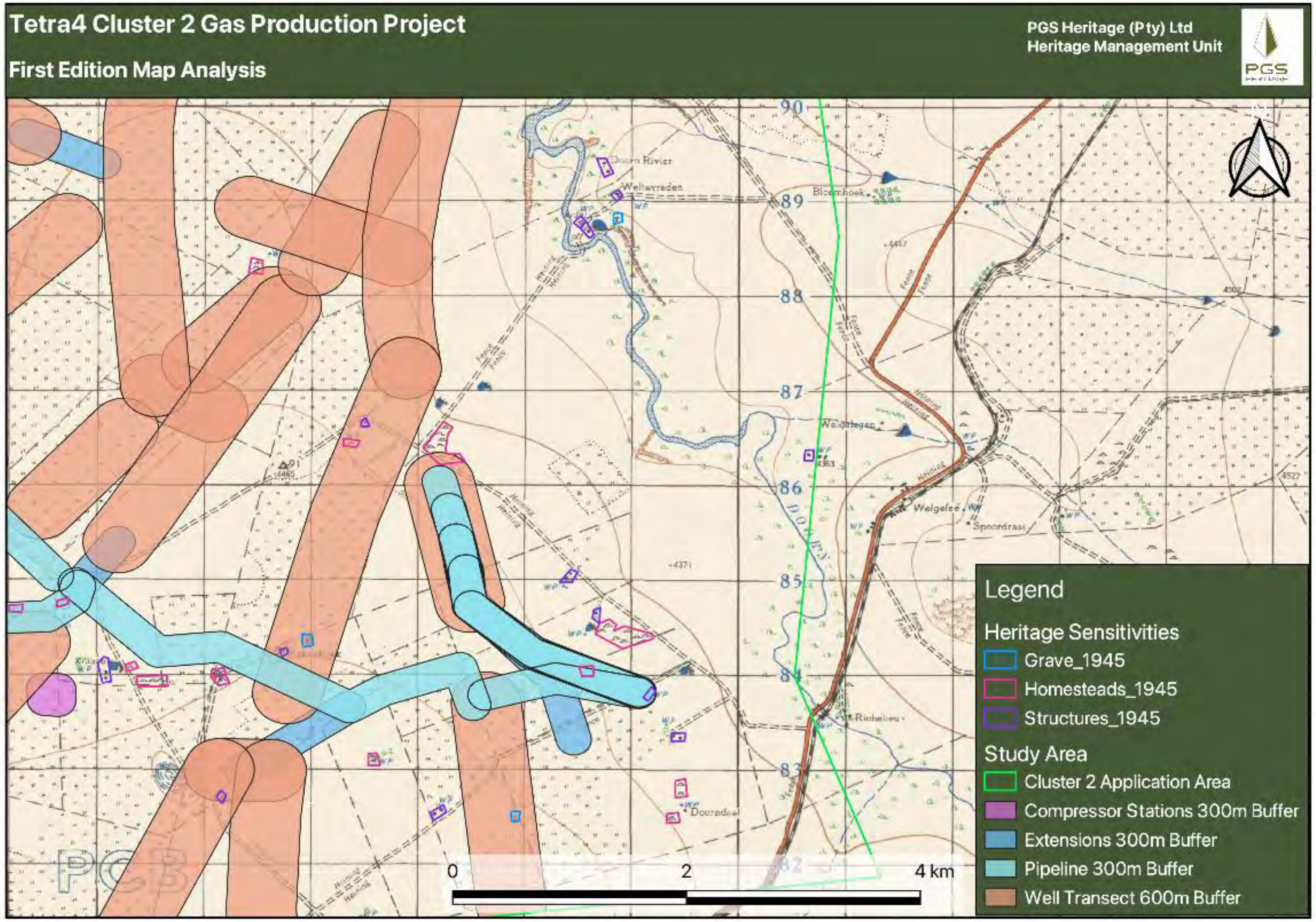


Figure 39 – Second section of First Edition of the 2826BB Topographical Map, showing several heritage features. These comprise structures (purple polygon), historical Black Homesteads (red polygons) and graves (blue polygon) located within the vicinity of the proposed development.

5.3.2 SECOND EDITION OF THE 2826BA AND 2826BB TOPOGRAPHICAL MAP DATED TO 1954

The 2826BA Bloudrif map sheet was based on aerial photography carried out in 1952, was surveyed in 1954 and drawn in 1957 by the Trigonometrical Survey Office. The 2826BB Virginia map sheet was based on aerial photography carried out in 1952, was surveyed in 1954 and drawn in 1957 by the Trigonometrical Survey Office.

As the study area extends over a significant portion of land, the discussion that follows will be done on a section-by-section basis. These map sheets show several structures (incl. farmsteads and kraals), homesteads and graves within the vicinity of the study area. If these heritage sites still exist today, they would be at least 68 years old. Overlays of the study area components over this map sheet are provided in the section below.

Second Edition of the 2826BA Topographical Sheet:

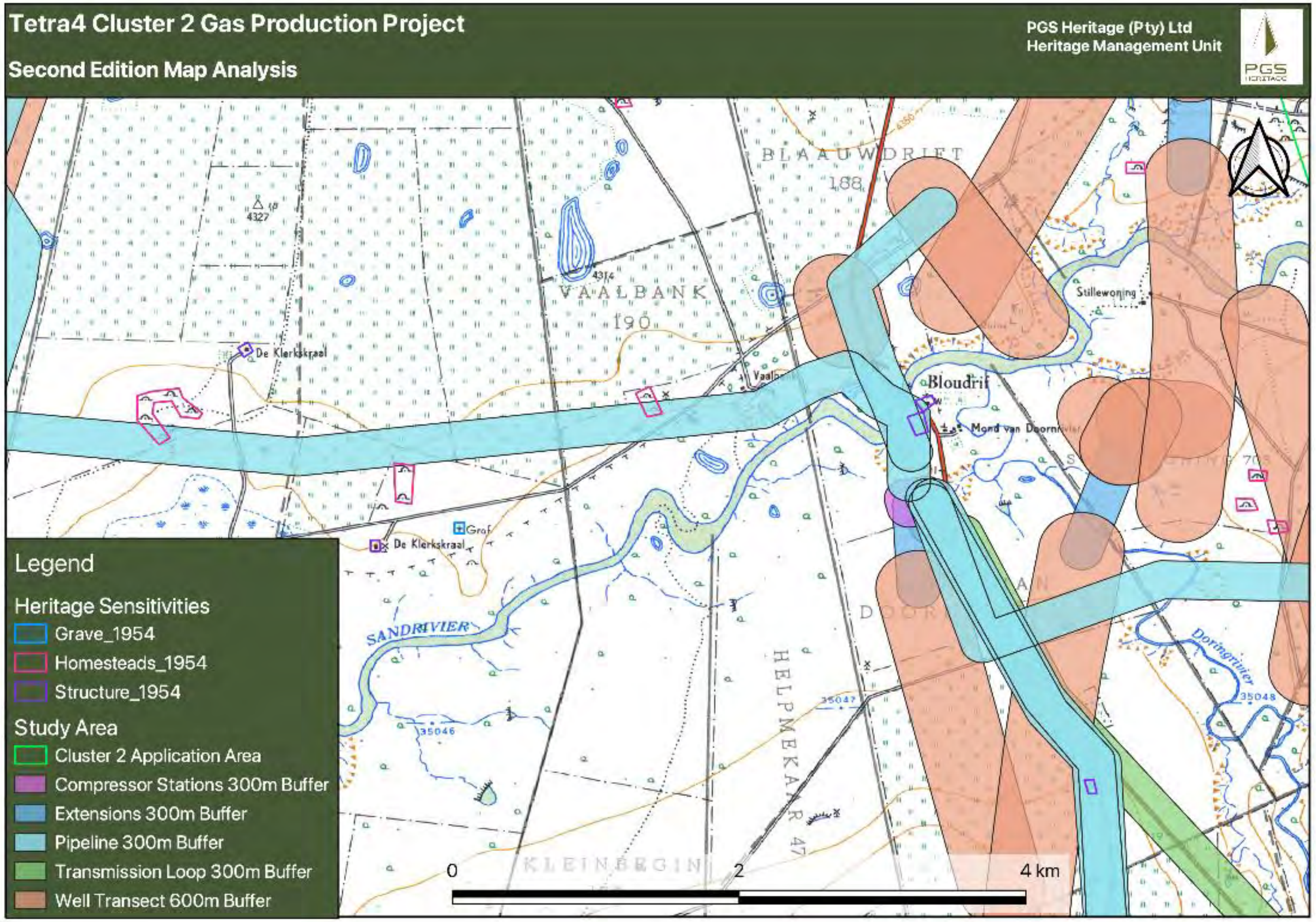


Figure 40 - Section of Second Edition of the 2826BA Topographical Map, showing several heritage features. These comprise structures (purple polygon), historical Black Homesteads (red polygons) and graves (blue polygon) located within the vicinity of the proposed development.

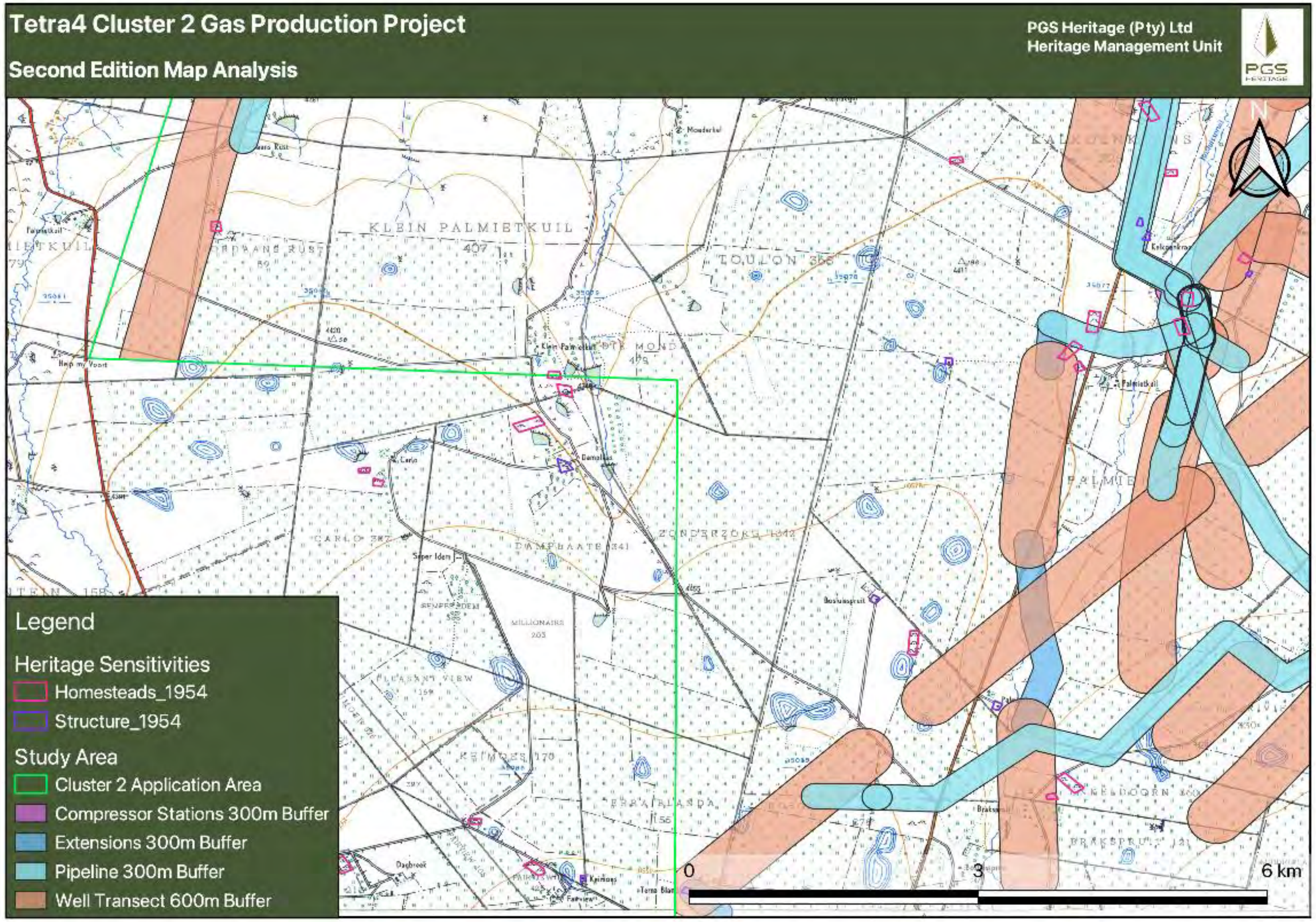


Figure 41 – Second section of Second Edition of the 2826BA Topographical Map, showing several heritage features. These comprise structures (purple polygon) and historical Black Homesteads (red polygons) located within the vicinity of the proposed development.

<u>Second Edition of the 2826BB Topographical Sheet:</u>

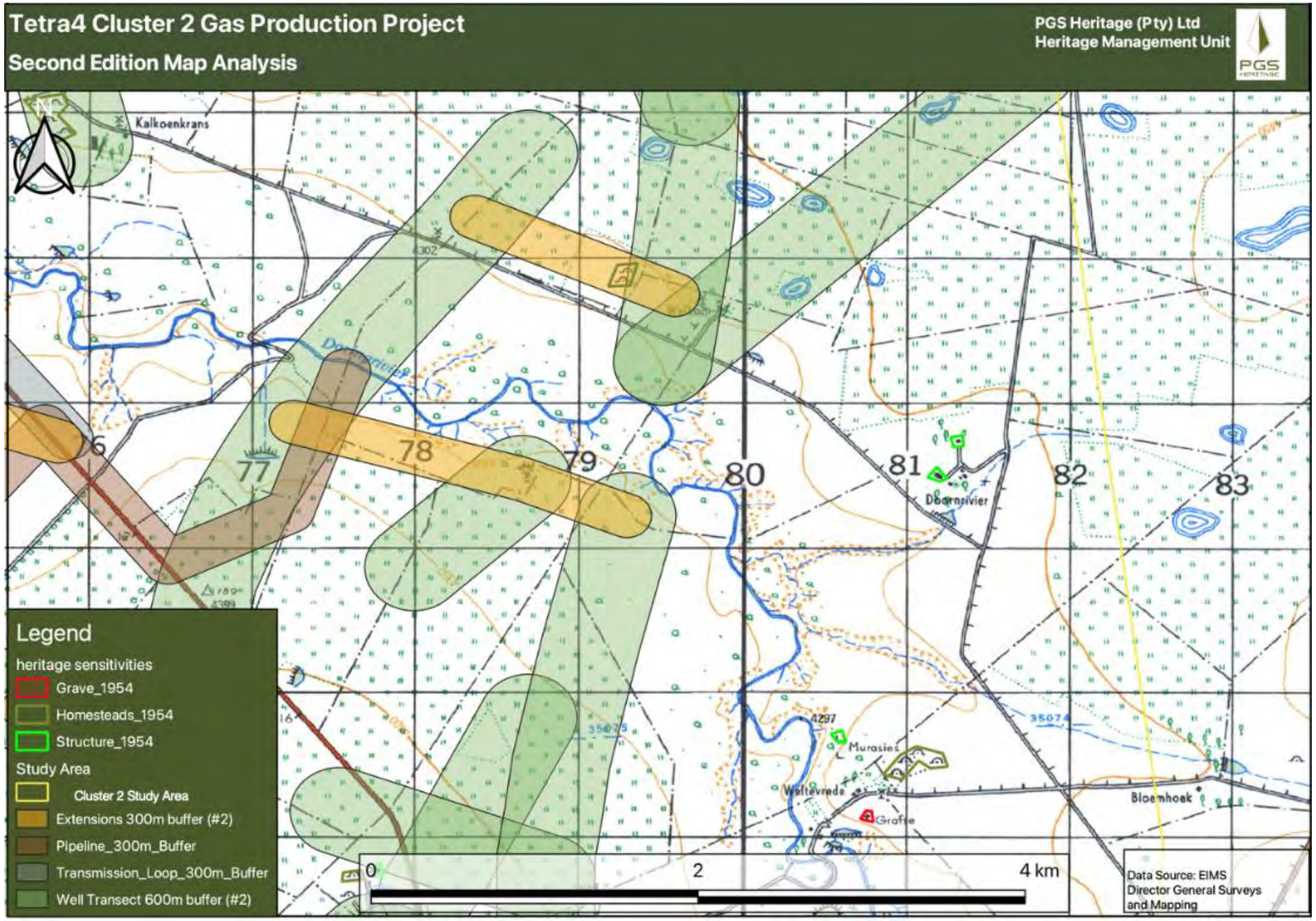


Figure 42 - Section of Second Edition of the 2826BB Topographical Map, showing several heritage features. These comprise structures (bright green polygon), historical Black Homesteads (dark green polygons) and graves (red polygon) located within the vicinity of the proposed development.

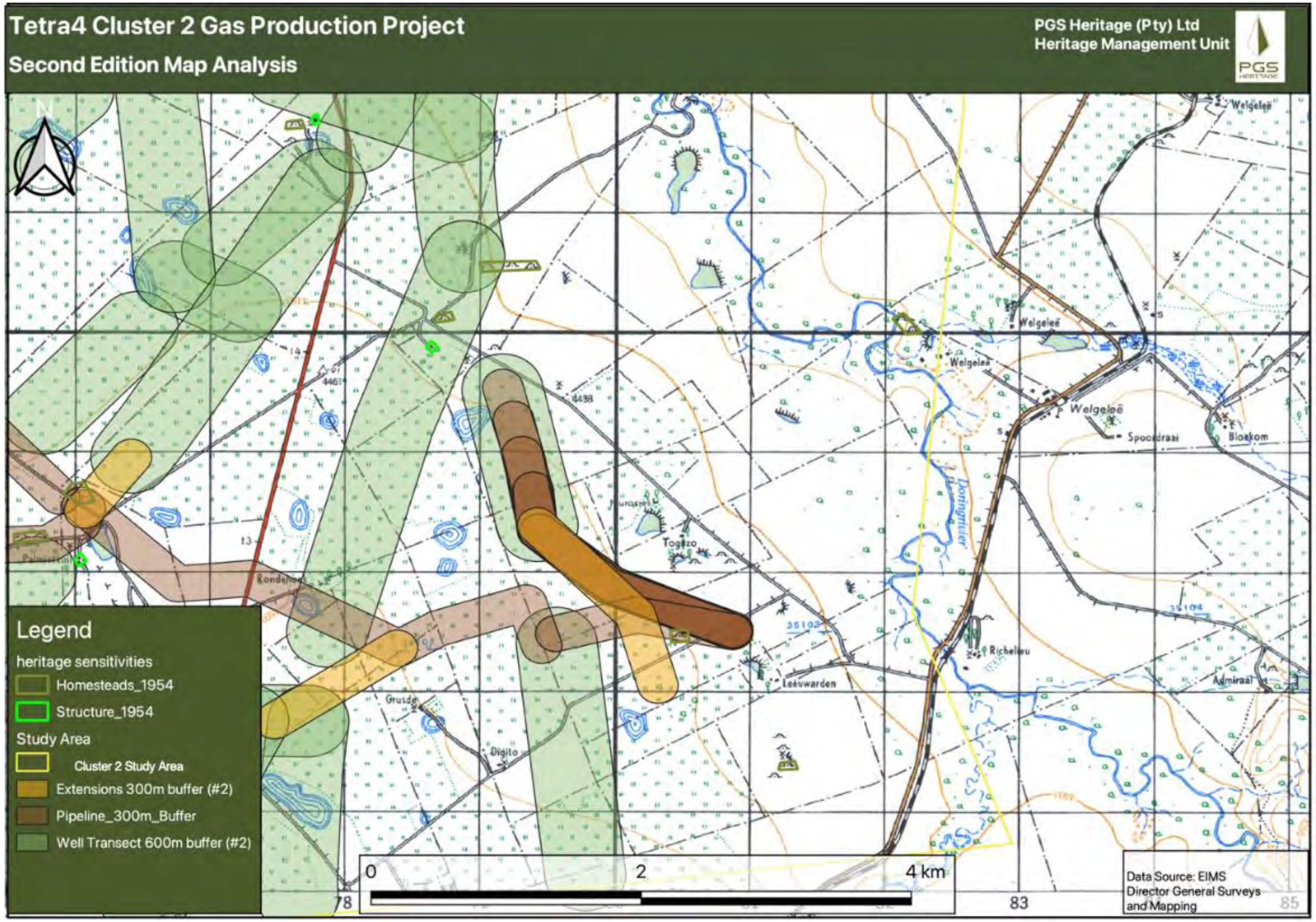


Figure 43 – Second section of Second Edition of the 2826BB Topographical Map, showing several heritage features. These comprise structures (bright green polygon) and historical Black Homesteads (dark green polygons) located within the vicinity of the proposed development.

5.3.3 THIRD EDITION OF THE 2826BB TOPOGRAPHICAL MAP DATED TO 1975

The 2826BB Virginia map sheet was remapped in 1975 by the Director – General of Surveys.

As the study area extends over a significant portion of land, the discussion that follows will be done on a section-by-section basis. This map sheet shows several structures (incl. farmsteads and kraals), graves and ruins within the vicinity of the study area. If these heritage sites still exist today, they would be at least 47 years old. Overlays of the study area components over this map sheet are provided in the section below.

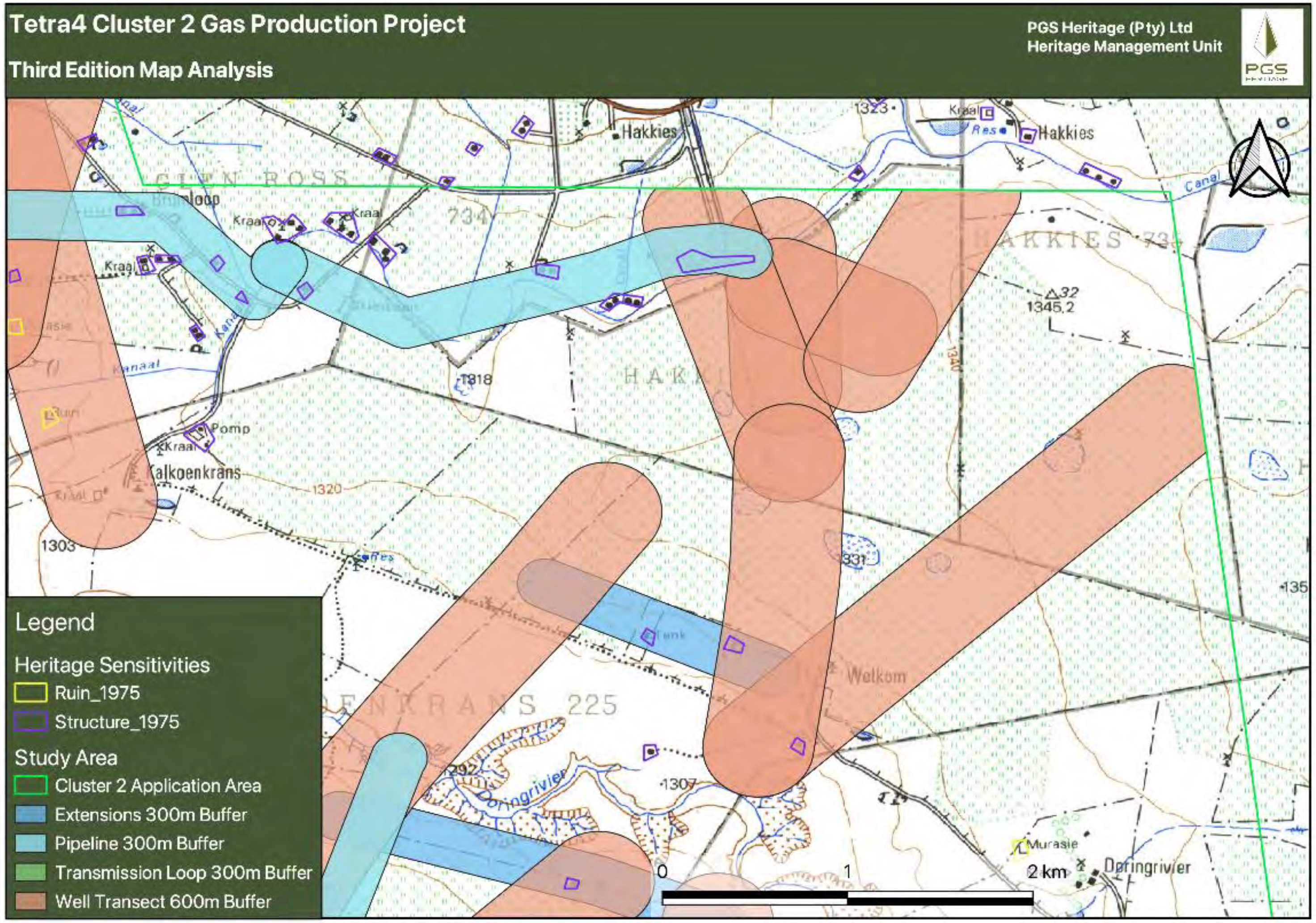


Figure 44 - Section of Third Edition of the 2826BB Topographical Map, showing several heritage features. These comprise structures (purple polygon) and ruins (yellow polygon) located within the vicinity of the proposed development.

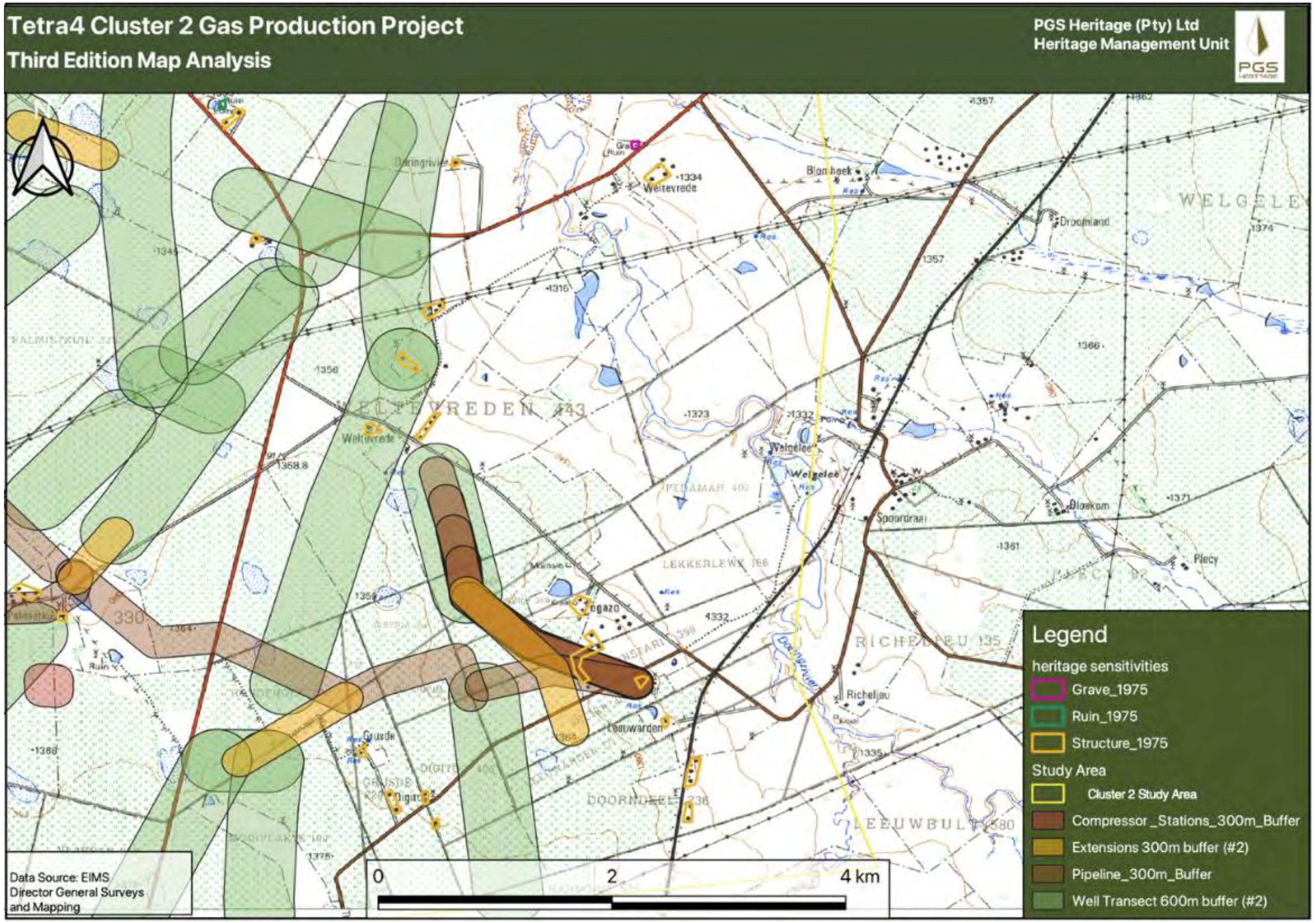


Figure 45 – Second section of Third Edition of the 2826BB Topographical Map, showing several heritage features. These comprise structures (orange polygon), ruins (dark green polygon) and graves (red polygon) located within the vicinity of the proposed development.

5.3.4 FOURTH EDITION OF THE 2826BA TOPOGRAPHICAL MAP DATED TO 1997

The 2826BA Bloudrif map sheet was remapped and published by the Chief Directorate: Surveys and Mapping, copyright 2001.

As the study area extends over a significant portion of land, the discussion that follows will be done on a section-by-section basis. This map sheet shows several graves within the vicinity of the study area. If these heritage sites still exist today, they would be at least 25 years old. Overlays of the study area components over this map sheet are provided in the section below.

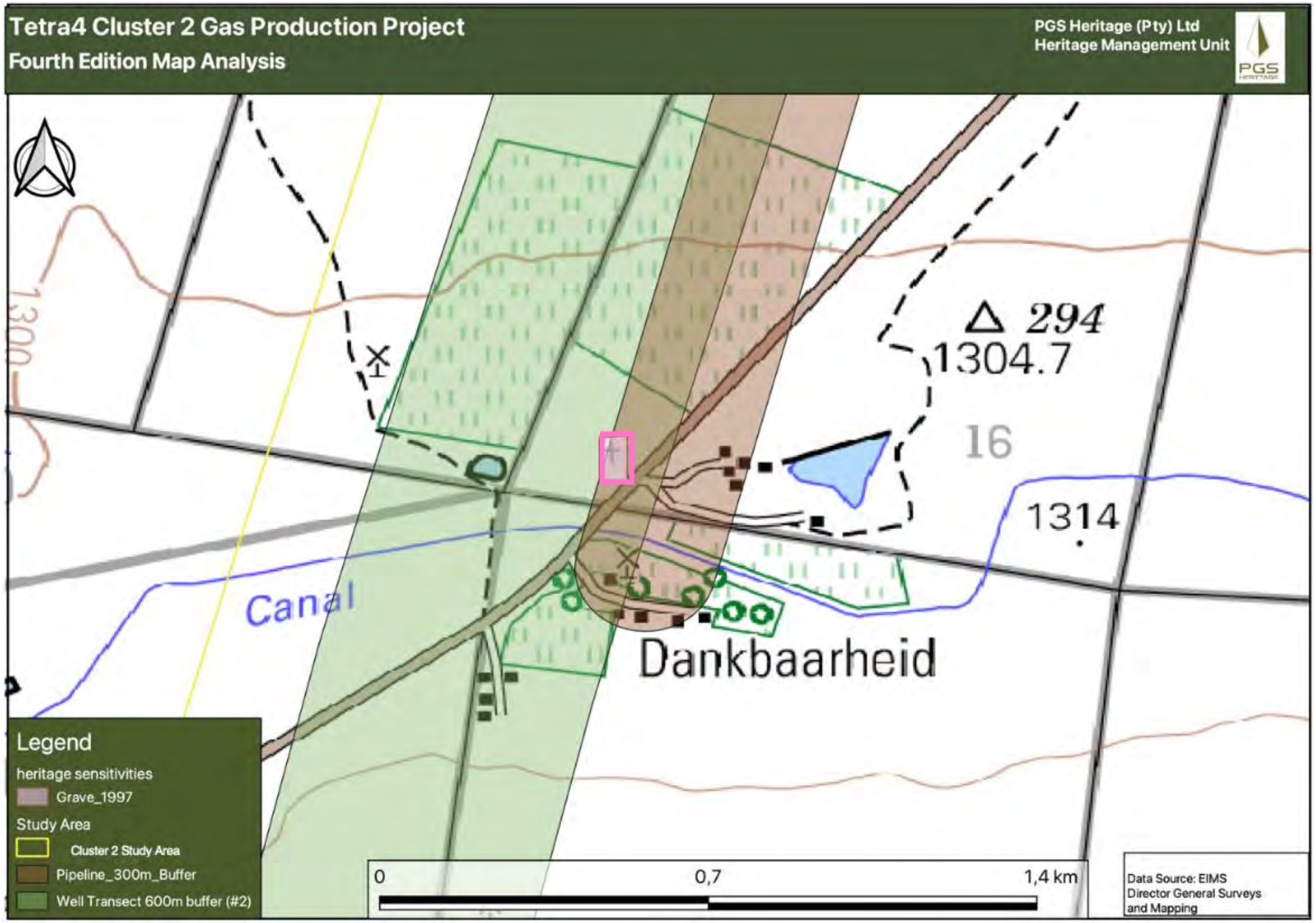


Figure 46 – A section of Fourth Edition of the 2826BA Topographical Map, showing several heritage features. These comprise graves (pink polygon) located within the vicinity of the proposed development.

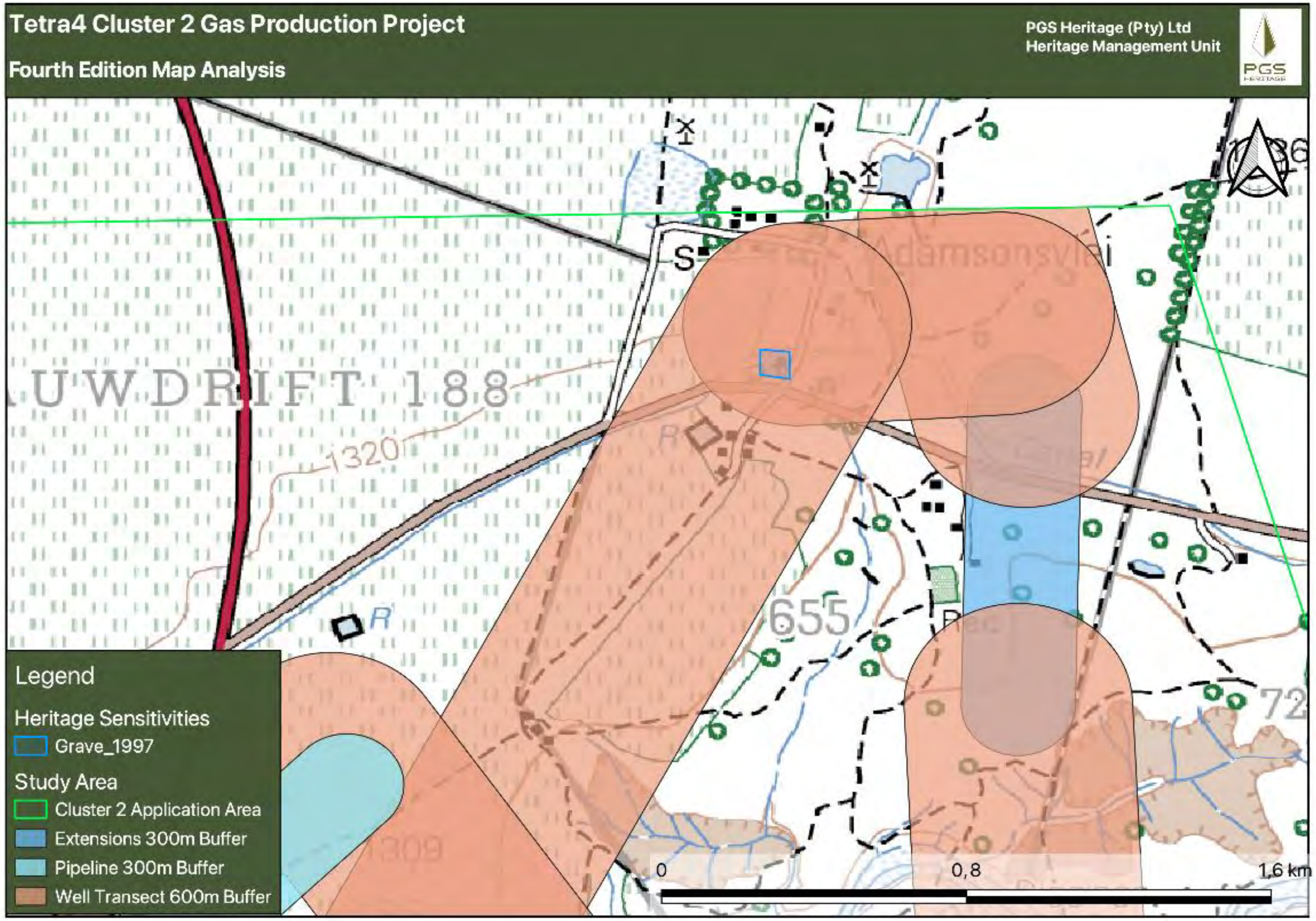


Figure 47 – Second section of Fourth Edition of the 2826BA Topographical Map, showing several heritage features. These comprise graves (blue polygon) located within the vicinity of the proposed development.

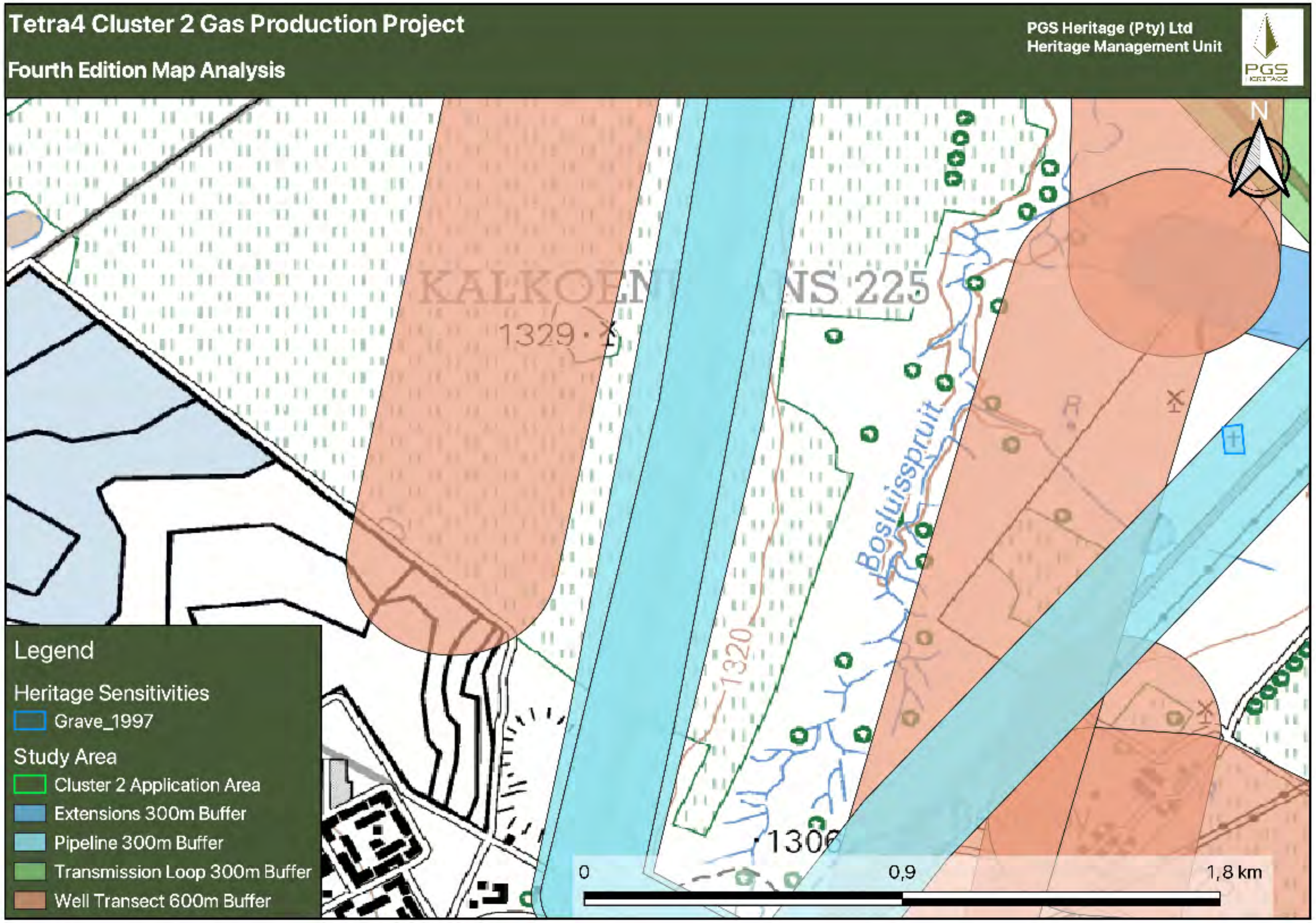


Figure 48 – Third section of Fourth Edition of the 2826BA Topographical Map, showing several heritage features. These comprise graves (blue polygon) located within the vicinity of the proposed development.

5.4 PREVIOUS ARCHAEOLOGICAL AND HERITAGE RESEARCH FROM WITHIN THE STUDY AREA AND SURROUNDINGS

A search of the South African Heritage Resources Information System (SAHRIS) database revealed that several previous archaeological and heritage impact assessments had been undertaken within the surroundings of the study area. In each case, the results of each study are shown in bold. These previous studies are listed below in ascending chronological order:

- Dreyer, C. 2004a. First Phase Heritage/Archaeological Assessment of the Proposed Powerline Route at Phakisa Mine, Welkom, Free State. **The survey was conducted approximately 20km north of the current study area. No archaeological, cultural, or historical material was identified during the survey.**

- Dreyer, C. 2004b. Archaeological and Historical Investigation of the Graves at the Proposed Housing Developments near Thabong, Welkom, Free State. **The survey was conducted approximately 22km north-east of the current study area. One grave and several other stones protruding from the ground suggested that it was an old graveyard.**

- Dreyer, C. 2005. Archaeological and Historical Investigation of the Proposed New Filling Station at Virginia, Free State. **The survey was conducted approximately 11.5km north-east of the current study area. No archaeological, cultural, or historical material was identified during the survey.**

- Dreyer, C. 2007. First Phase Archaeological and Cultural Heritage Assessment of the Proposed New MTN Cell Phone Mast at Pumlani Cemetery, Thabong, Welkom, Free State. **The survey was conducted approximately 22km north-east of the current study area. No archaeological, cultural or historical material was identified during the survey.**

- Coetzee, F. 2008. Cultural Heritage Survey of the Proposed Phakisa Housing Development, Welkom, Free State. **The survey was conducted approximately 16km north-north-east of the current study area. No Stone Age or Iron Age settlements, structures, features, or artefacts were recorded during the survey. One site that consisted of a mine shaft and various associated buildings and structures that probably older than 60 years were identified. No impact on the site was envisaged.**

- Dreyer, C. 2008. First Phase Archaeological and Heritage Investigation of the proposed Oppenheimer Park Golf Estate, Welkom, Free State. **The survey was conducted approximately**

11km north-east of the current study area. No archaeological, cultural, or historical material was identified during the survey due to the surface disturbance.

- Dreyer, C. 2011. First Phase Archaeological and Heritage Investigation of the proposed Chicken Egg Production Developments at Mooidoorns 319, Welkom, Free State. **The survey was conducted approximately 26km north-north-east of the current study area. No archaeological, cultural, or historical material was identified during the survey due to the surface disturbance (ploughed fields).**

- Van Ryneveld, K. 2013. Phase 1 Archaeological Impact Assessment for the Lebone Solar Farm, Onvewag RE/728 and Vaalkranz 2/220, Welkom, Free State, South Africa. Prepared for Enviroworks. **The survey was conducted approximately 19km north-east of the current study area. The report identified five sites: colonial period farming infrastructure, farmstead, cultural landscape, structure remains and railway bridge.**

- van Schalkwyk, J. 2014. Cultural Heritage Impact Assessment Report for the Proposed SANRAL Thabong Interchange Development, Welkom Region, Free State Province. **The survey was conducted approximately 16km north-north-east of the current study area. No archaeological, cultural, or historical material was identified during the survey.**

- Fourie, W. 2021. Heritage Impact Assessment for The Proposed Harmony FSS6 Reclamation Pipeline, Welkom, Free State Province. **The survey was conducted approximately 11km north-east of the current study area. No archaeological, cultural, or historical material was identified during the survey.**

- Kruger, N. 2021a. Archaeological Impact Assessment (AIA) On Portions Of The Farms Bloemhoek 509, Welgelegen 382, Mooi Uitzig 352, Florida 633, Le Roux 717 And Detente 744 For The Proposed Virginia Solar Park Power Lines Ba Project, Lejweleputswa District Municipality, Free State Province. **The survey was conducted approximately 12km north-east of the current study area. The study noted the remains of a later Historical Period settlement (possibly a farmworkers compound of houses). The site was poorly preserved and of medium to low significance.**

- Kruger, N. 2021b. Archaeological Impact Assessment (AIA) On Portions Of The Farm Blomskraal 216 For The Proposed Virginia 1, 2 & 3 Solar Parks Eia Project, Lejweleputswa District Municipality, Free State Province. **The survey was conducted approximately 20km east of the current study area. The study noted the remains of a large Iron Age occupation, several Historical Period settlements, and farmsteads, and three burial sites.**

5.4.1 PREVIOUS ARCHAEOLOGICAL AND HERITAGE STUDIES FROM WITHIN THE STUDY AREA

A previous archaeological and heritage surveys was undertaken within the immediate vicinity of the study area.

- Van der Walt, J. 2013a. Archaeological Scoping Report for the Proposed Oryx Solar Energy Facility. Prepared for Savannah Environmental (Pty) Ltd.

  The study was conducted on Portion 2 of the farm Kalkoenkrans 225. This farm portion is located on the eastern end of the present study area.

- Van der Walt, J. 2013b. Archaeological Impact Assessment for the Proposed Oryx Solar Energy Facility. Prepared for Savannah Environmental (Pty) Ltd.

  The survey was conducted on Portion 2 of the farm Kalkoenkrans 225. This farm portion is located on the eastern end of the present study area. **The report identified three sites: informal cemetery and two derelict structures younger than 60 years and of little architectural value.**

- Birkholtz, P.D. 2017a. Heritage Impact Assessment for the Proposed Tetra4 Cluster 1 Gas Production Project. Prepared for EIMS.

  Fieldwork was undertaken during both the Heritage Scoping and HIA Phases. During the Heritage Scoping Phase, the fieldwork focused on the Cluster 1 study area. The fieldwork undertaken during the HIA Phase focused on the assessing the proposed development footprints for the pipeline and surface infrastructure and their alternatives.

  In March 2016, a field survey was conducted for the Heritage Scoping Phase. The fieldwork resulted in the identification of 45 sites (Site 1 to Site 45) and of these, 36 were confirmed heritage sites. In December 2016, a field survey was conducted as part of the HIA. A total of 18 heritage sites were identified (TET1 – TET18). A second fieldwork component was undertaken in February 2017. A total of 9 heritage sites were identified (TET19 – TET27).

  These identified sites comprise the following: cemeteries, Stone Age sites, historic structures believed to be older than 100 years, historic structures believed to be older than 60 years, historical buildings of low significance, historic to recent sites with possible stillborn baby graves, possible grave sites and a site comprising a single lower grinder.

- Birkholtz, P.D. 2017b. Heritage Audit Report for the Beatrix Mining Areas of Sibanye Gold, Between Welkom and Theunissen, Lejweleputswa District, Orange Free State Province. Prepared for Sibanye Gold (Pty Ltd).

  The purpose of the Heritage Audit was to compile a database of known heritage resources within a particular area as the foundation block for the management of such identified resources. The fieldwork was undertaken during June, July and August 2017.

  A total of 66 heritage sites were identified within the total study area (Site 001 to Site 066). These identified heritage sites comprise 9 graves or burial grounds, 30 historical structures believed to be older than 60 years, of which 11 are believed to be older than 100 years, and 12 archaeological (Stone Age) sites. Sites where possible unmarked (infant) graves could occur were also identified (15). These sites include the remains of black homesteads. In terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents.

5.5 FINDINGS OF THE HISTORICAL DESKTOP STUDY

This archival and historical desktop study has revealed important aspects about the history of the area. The findings of the historical desktop study can be compiled as follows and have been combined to produce a heritage sensitivity map for the project based on the desktop assessment (refer **Figure 49**).

5.5.1 HERITAGE SCREENING

A heritage screening report was compiled by the Department of Environmental Affairs National Web-based Environmental Screening Tool as required by Regulation 16(1)(v) of the Environmental Impact Assessment Regulations 2014, as amended. According to the heritage screening report, the project area has a Low Heritage Sensitivity (**Figure 2**). The field work that was conducted in the study area demonstrates that there were numerous archaeological and historical sites of heritage significance that warrant conservation. Therefore, in the case of this study area, the DFFE screening tool sensitivity map is not supported based on the findings of this fieldwork.

5.5.2 HERITAGE SENSITIVITY

Analysis of maps and satellite imagery enabled the identification of possible heritage sensitive areas. By superimposition and analysis, it was possible to rate these structures according to age and thus their level of protection under NHRA. **Table 7** lists the possible tangible heritage sites identified in the vicinity of the study area and the relevant legislative protection.

Table 7 - Tangible heritage site in the study area.

Name	Description	Legislative protection
Archaeology	Older than 100 years	NHRA Sections 3 and 35
Structures	Possibly older than 60 years	NHRA Sections 3 and 34
Burial grounds	Graves	NHRA Sections 3 and 36 and MP Graves Act

Additionally, evaluation of satellite imagery has indicated the following areas that may be sensitive from a heritage perspective. The analysis of the studies conducted in the area assisted in the development of the following landform type to heritage find matrix (**Table 8**).

Table 8 - Landform type to heritage find matrix

LANDFORM TYPE	HERITAGE TYPE
Crest and foot hill	LSA and MSA scatters, LIA settlements
Crest of small hills	Small LSA sites – scatters of stone artefacts, ostrich eggshell, pottery and beads
Water holes/pans/rivers	MSA and LSA sites, LIA settlements
Farmsteads	Historical archaeological material
Ridges and drainage lines	LSA sites, LIA settlements

The heritage sensitivity map (**Figure 49**) was used during the fieldwork to assist in identifying and assessing any heritage resources in the landscape.

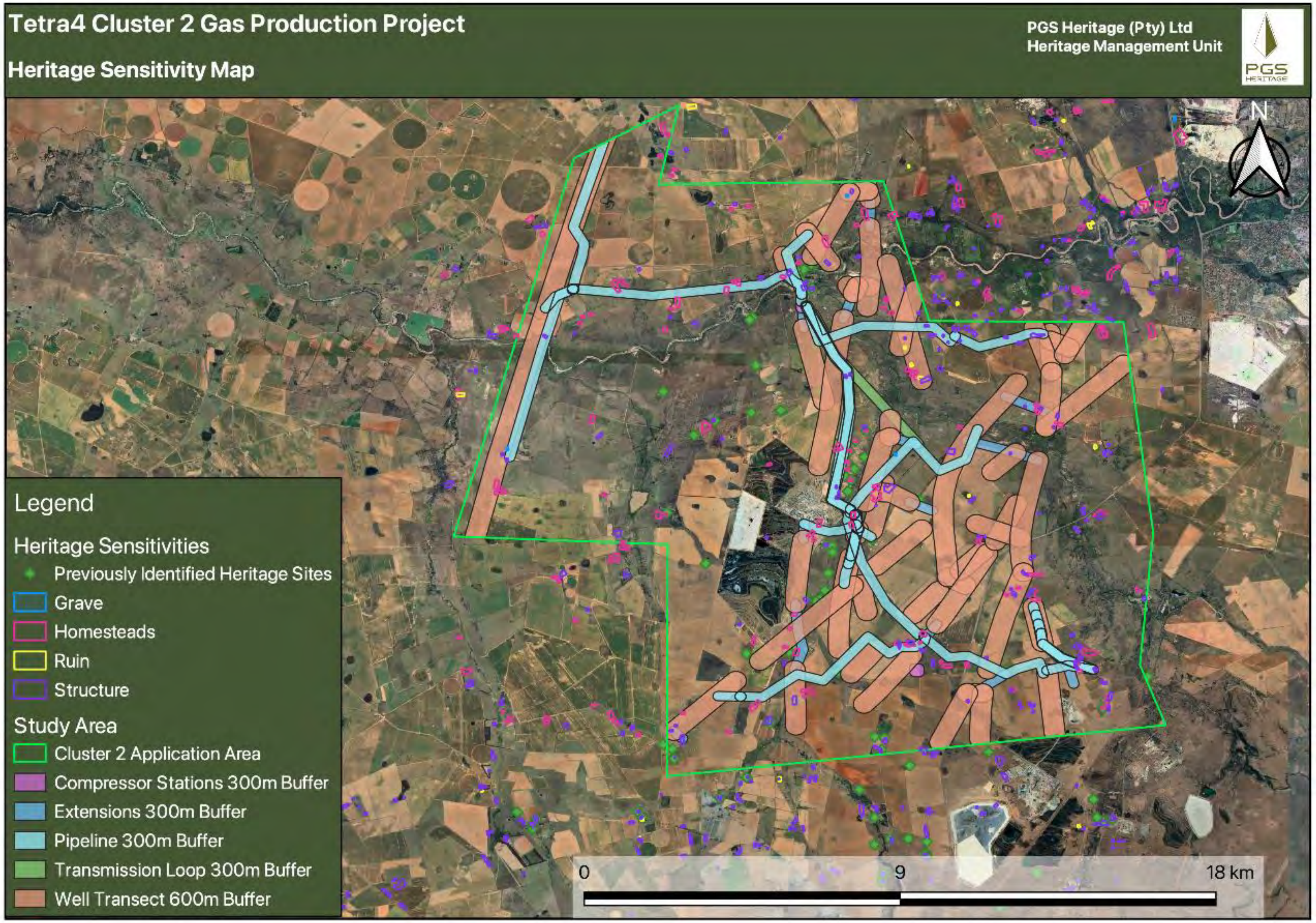


Figure 49 - Heritage Sensitivity Map indicating possible sensitive areas within and adjacent to the proposed development areas.

6 FIELDWORK AND FINDINGS

6.1 HERITAGE SITES PREVIOUSLY IDENTIFIED WITHIN THE STUDY AREA

Several archaeological and heritage studies were previously conducted within the region of the current study area (Birkholtz, 2017a, 2017b; **Figure 50**).

Thirty-five (35) heritage sites were identified within the footprint areas of the current proposed Tetra4 Cluster 2 Gas Production Project study area (**Figure 51** to **Figure 54**). There were 10 graves and burial grounds (**TET 1, TET 7-8, TET 11, TET 15, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19**), 11 structures (**TET 2-3, TET 9, TET 27, SSL/BET/25-26, SSL/BET/36, SITE 1A, SITE 1B, SITE 20-21**), 14 historic to recent sites with possible graves (**TET 4-6, TET 13-14,TET 25a, 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**).

The 35 heritage sites will be discussed individually below (Birkholtz, 2017a, 2017b).

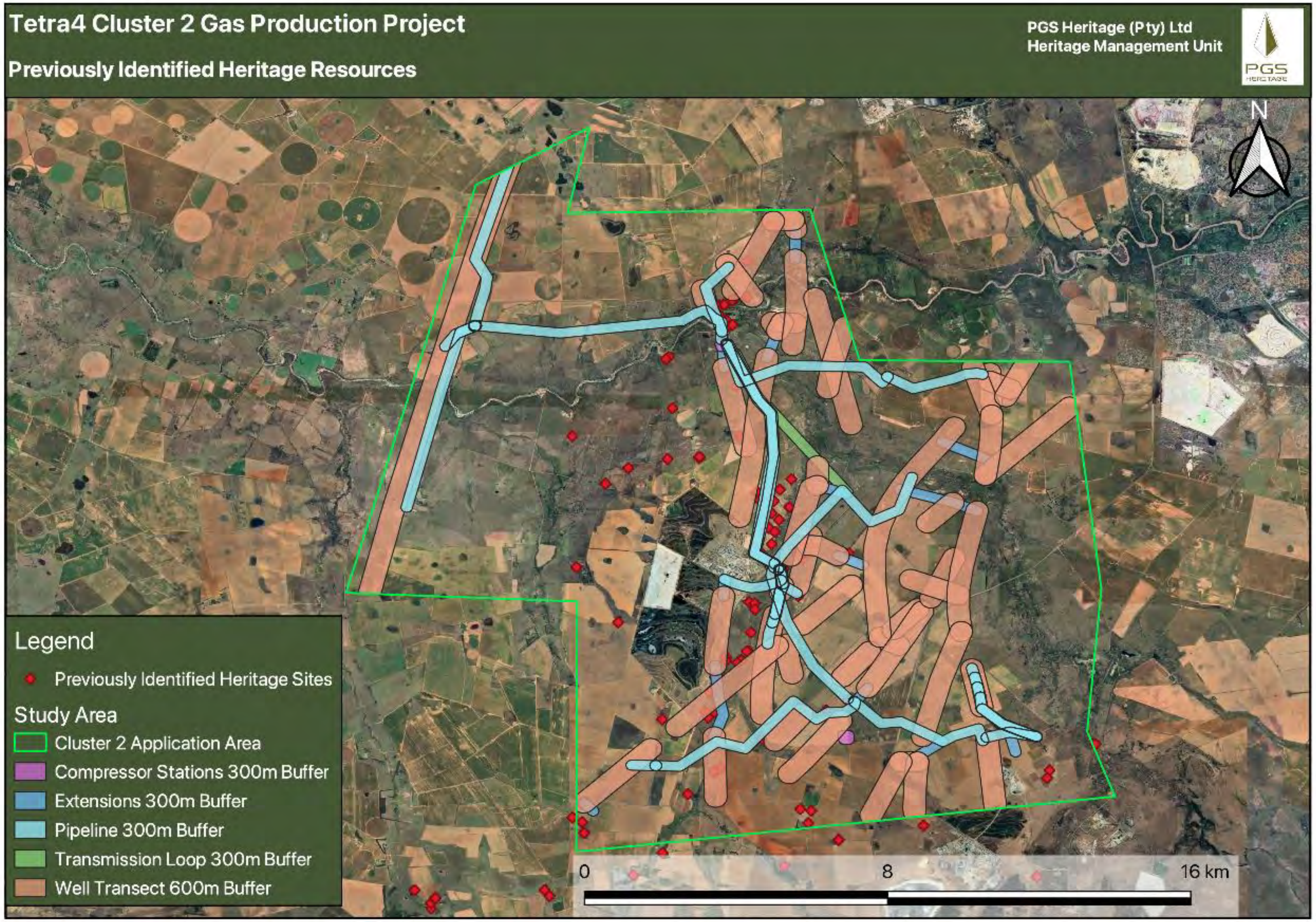


Figure 50 – Map depicting the distribution of the previously identified sites in the region.

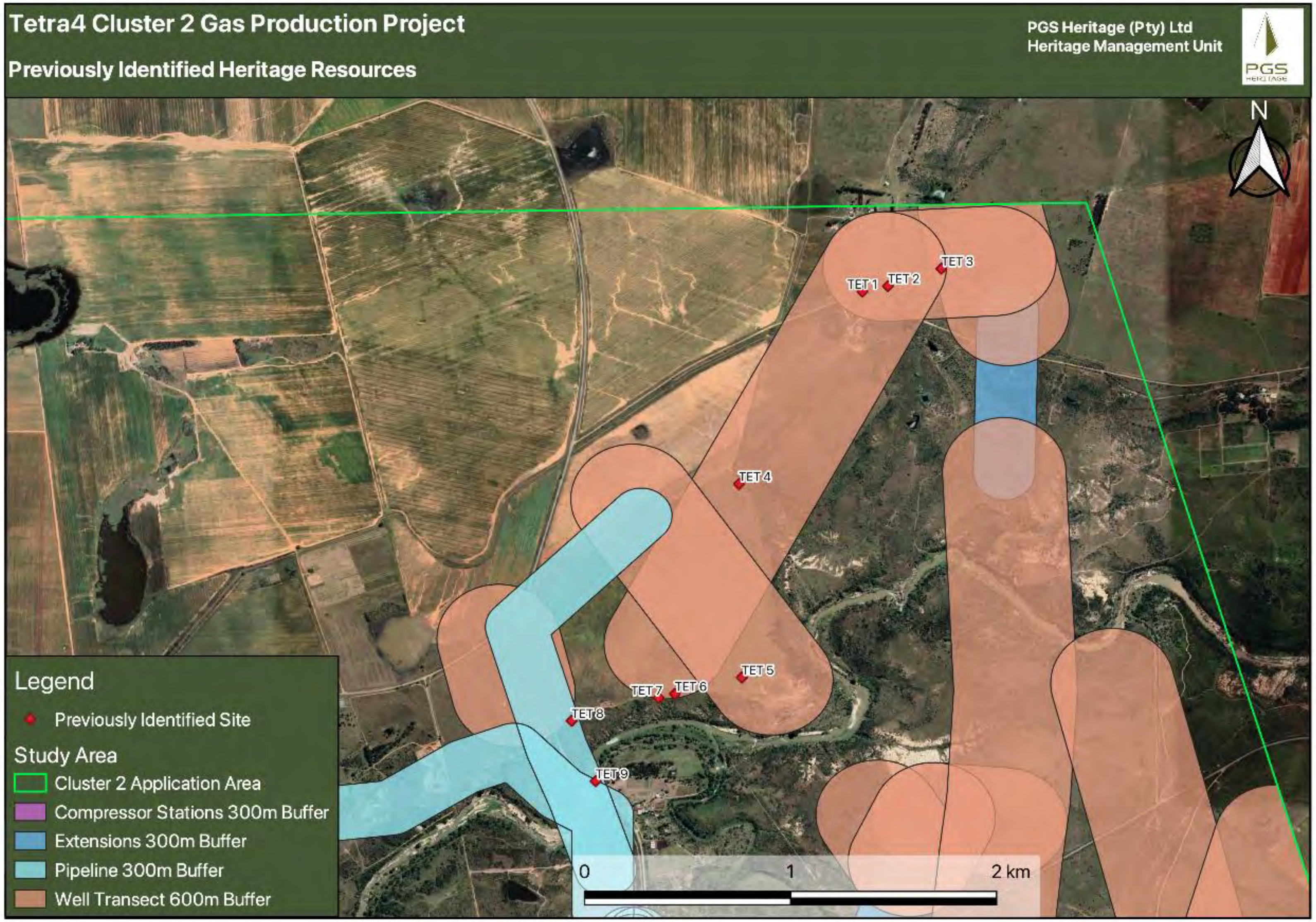


Figure 51 – Closer view of the previously identified sites recorded within the buffer zones in the northern section of the current study area.

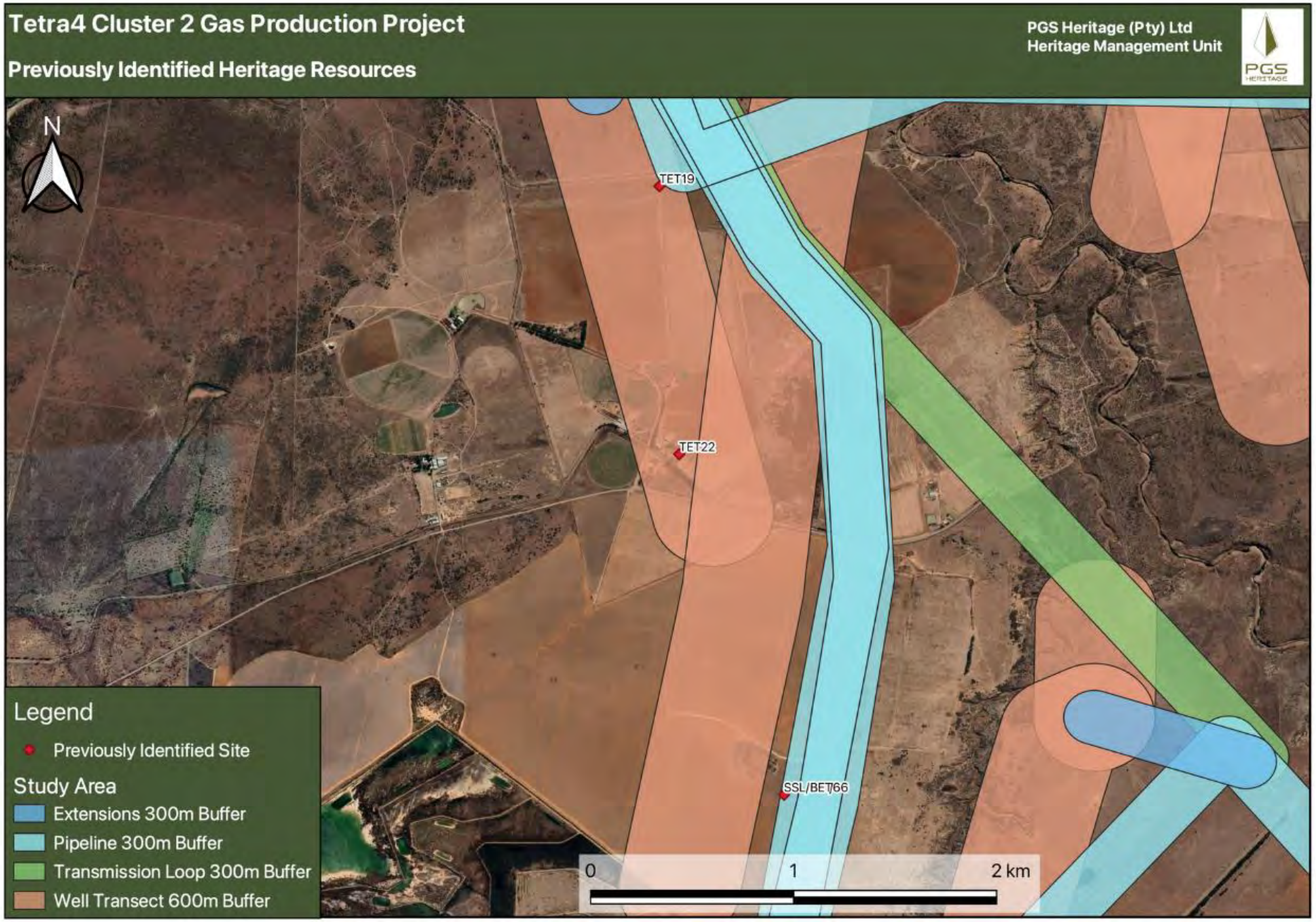


Figure 52 – Closer view of the previously identified sites recorded within the buffer zones in the central section of the current study area.

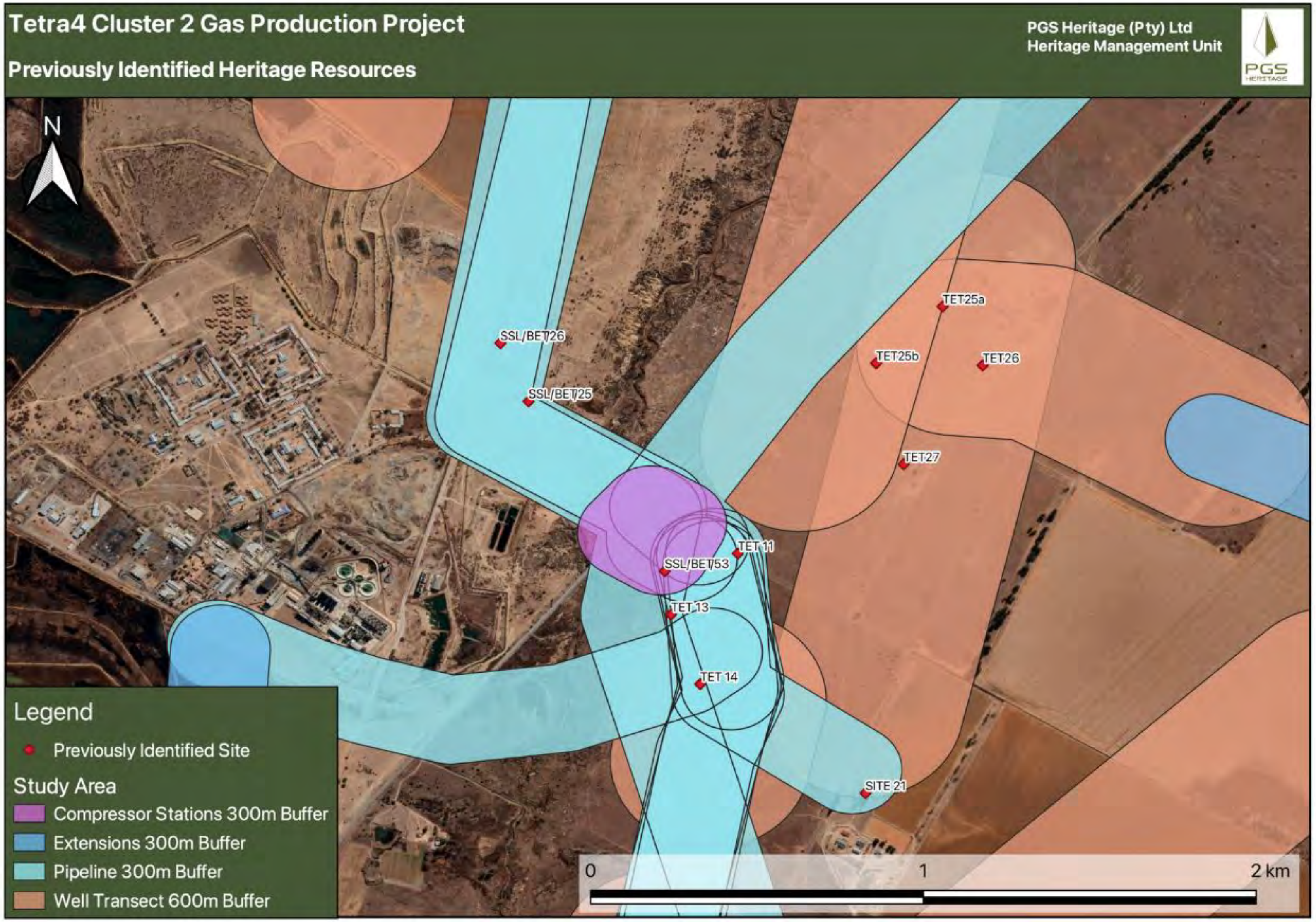


Figure 53 – Closer view of the previously identified sites recorded within the buffer zones near one of the proposed compressor stations.

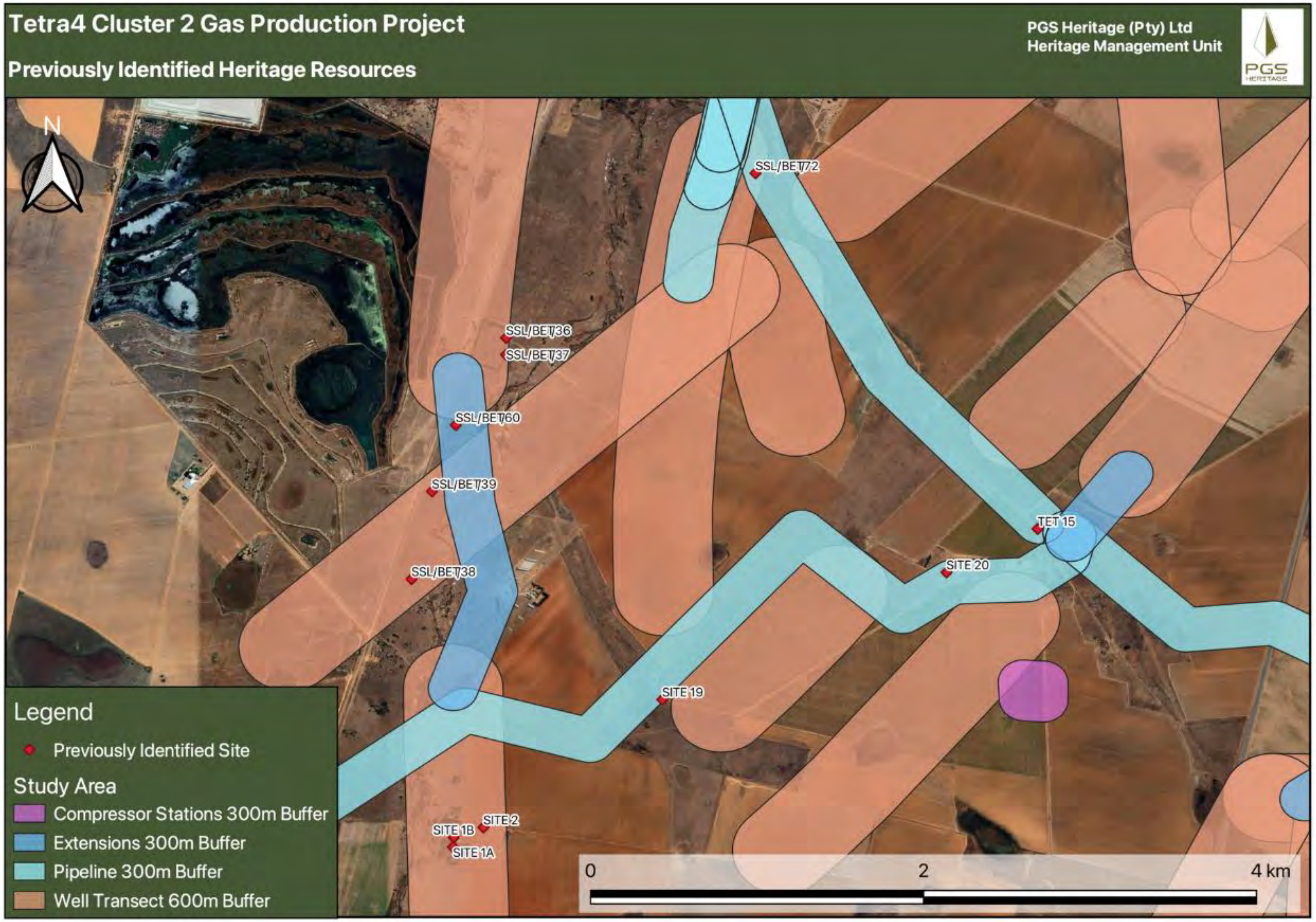


Figure 54 - Closer view of the previously identified sites recorded within the buffer zones in the Southern section of the current study area.

Table 9: Sites previously identified in the study area

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
TET 1	-28.09339°S	26.73264°E	The site comprised an informal cemetery comprising 37 graves was identified in a clump of trees on the farm Adamsonsvlei 655. All the graves from the cemetery are orientated along the east-west axis. The following dressing types were identified: ▪ Upright formal marked headstone at the head of the grave (n = 1) ▪ Upright unmarked stone at the head of the grave (n = 2) ▪ Stone packed grave dressing some with upright unmarked stone as headstone (n = 33) ▪ Rectangular dressing comprising vertically packed stones (n = 1) Only the one grave comprising a single upright formal headstone contained details of the particular deceased (**Figure 56**). The inscription from this headstone revealed that two individuals were buried here. It reads as follows: *"IN SACRED MEMORY* *OF* *JOHN ADAMSON* *DIED 27 FEBRUARY 1913* *AND* *EMMA YOUNG ADAMSON* *DIED … 1903"* The inscription on this grave makes it clear that this cemetery can be associated with Adamson family who gave the farm Adamsonsvlei 655 its name. At least sections of the cemetery are at least 100 years old. **Extent:** Approximately 70m x 40m. As TET 1 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 55 - General view of the cemetery at TET 1.

Figure 56 – Close up view of the headstone on the grave of John Adamson and his wife Emma Young Adamson (Scale is in 10cm increments).

Figure 57 – One of the stone packed graves from TET 1 (Scale is in 10cm increments).

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
TET 2	-28.09312°S	26.73390°E	The site comprises a stone packed terrace wall located approximately 130m from the historic cemetery where John Adamson lies buried. Apart from its function of a terrace wall, the structure may also have formed part of the livestock enclosures on the farm. It seems likely that the wall forms part of the meagre tangible remains associated with John Adamson that still exists today as well as the early history of the farm Adamsonsvlei. Although the exact age of the structure is not presently known, it is certainly older than 60 years and more than likely older than 100 years as well. As TET 2 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium Significance	IIIB
 *Figure 58 – View of a section of TET 2. The cemetery at TET 1 can be seen at the trees in the back (Scale is in 10cm increments).*					
TET 3	-28.09226°S	26.73654°E	The site comprises an extensive rectangular stone walled-enclosure which is sub-divided into two main sections. The rectangular shape of the stone-walled enclosure indicates that it dates from the Historic Period rather than the Late Iron Age. It seems more than likely that this rectangular structure was the main cattle enclosure for the original farmstead of John Adamson.	Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			The walls of the structure are in a poor state of preservation. Although the foundations and lower wall sections are still *in situ*, the remainder of these stone walls appear to have been deliberately damaged. Although this is not certain, it is possible that these upper wall sections were bulldozed at an unknown point in time. The presence of vegetation growth on disturbed wall sections indicates that this mechanical disturbance is not a recent event. Although the exact age of the structure is not presently known, it is certainly older than 60 years and more than likely older than 100 years as well. **Extent**: Approximately 60m x 60m. As TET 3 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Figure 59 – General view of a section of the site (Scale is in 10cm increments).

Figure 60 – This view along the southern wall of the structure depicts the disturbance which had taken place at the site. Although the original foundation of the wall is located on left, the dispersed stones from the actual stone wall itself can be seen on the right (Scale is in 10cm increments).

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
TET 4	-28.10289°S	26.72654°E	The site comprises the poorly preserved remains of farm worker accommodation on both sides of the fence between the farms Adamsonsvlei and Blaauwdrift. The remains of structures and associated rubbish heaps were observed. The site has been abandoned for a number of years and as a result was found to be quite overgrown by vegetation. The exact age of the site is not known. However, based on the artefacts observed at the various middens from the site, it is not very old. These middens revealed a significant number of recent and modern items, including plastics. It is therefore quite clear that the site is not older than 60 years. Although the structures and cultural material located at this site is of little heritage significance, the possibility does exist for unmarked stillborn graves to be located at this site. Until such time that the presence of graves at the site has been tested, the site must be viewed as containing stillborn graves. As TET 4 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium-High Significance	IIIA

<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td colspan="3">
Figure 61 – General view of TET 4 (Scale is in 10cm increments).</td><td colspan="3">
Figure 62 - One of the poorly preserved structures from TET 4 (Scale is in 10cm increments).</td></tr>
<tr><td>TET 5</td><td>-28.11244°S</td><td>26.72668°E</td><td>The site comprises three irregularly shaped stone concentrations associated with a low-density scatter of cultural material of different ages. The stone concentrations can presently be viewed as possible graves only. The cultural material observed in proximity to the stone concentrations include Later Stone Age lithics as well as a hammerstone, undecorated potsherds that may be associated with either the Late Iron Age or Historic Period as well as glass artefacts from the Historic Period. The site is located within an agricultural field. As a result, the context of the artefacts observed here is not known.

Extent: Approximately 30m x 30m.

Although the structures and cultural material located at this site is of little heritage significance, the possibility does exist for unmarked stillborn graves to be located at this site. Until such time that the presence of graves at the site has been tested, the three stone concentrations must be viewed as containing graves.</td><td>Medium-High Significance</td><td>IIIA</td></tr>
</table>

<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td></td><td></td><td></td><td>As TET 5 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.</td><td></td><td></td></tr>
<tr><td colspan="3">
Figure 63 – One of the stone concentrations identified at TET 5 (Scale is in 10cm increments).</td><td colspan="3">
Figure 64 – The lithics and hammerstone identified at TET 5 (Scale is in 1cm increments).</td></tr>
<tr><td>TET 6</td><td>-28.11325°S</td><td>26.72337°E</td><td>The site comprises a rectangular stone concentration that is orientated along the east-west axis. The rectangular structure is approximately 1.6m long and 1m wide. Despite the absence of a formal headstone and grave goods, the structure does have the appearance of a grave.

Two irregularly shaped stone concentrations were observed 5m and 8m respectively west of the rectangular stone concentration described first. These stone concentrations may also be graves.

Extent: Approximately 20m x 20m.</td><td>Medium-High Significance</td><td>IIIA</td></tr>
</table>

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			The cultural material identified at the site is of low significance. Until such time that the presence of graves at the site has been tested, the stone concentrations must be viewed as containing graves. As TET 6 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.		
 *Figure 65 – General view of the rectangular stone concentration identified at TET 6 (Scale is in 10cm increments).*					
TET 7	-28.11344°S	26.72257°E	The site comprises a loose pile of stones and headstones. One of these headstones is firmly placed in the ground in an upright position, with the remainder of the headstones that could be observed at the site scattered around. All the headstones from the site were found to be broken. It is not presently known whether the site represents the original position of a cemetery comprising roughly four graves, or whether disturbed graves from another site had been dumped here. This said, the fact that at least one of the	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			headstone fragments was found to be still firmly placed in the ground, suggest that this site represents the original location of the cemetery. The following headstones could be identified: ▪ Loose broken cement headstone on which the name ELISA can still be read. This stone was lying flat and was partially covered by soil; ▪ Loose upper section of a broken gothic-shaped cement headstone containing the name DICK SWAR(?). The headstone does contain a date of death, but this was illegible; ▪ Base of broken cement headstone that was still firmly placed in the ground in an upright position. Only the date of death section could be read from the headstone, namely DIED 8 – 9 – 35; and ▪ Two broken cement headstone fragments found lying next to each other. The following sections could be read from the two headstone fragments: LYDIA…THLAHO 1923…HLOKAHALA…10 SEPTEMBER 1933 ROBALE KA KHOTSO. In terms of this headstone, the only component of the name that could be deciphered is LYDIA. The remaining words have reference to aspects such as Born (Date of Birth), Died (Date of Death) and Rest in Peace. From this it is clear that a 10 year old girl named Lydia was buried here. It is clear from the dates appearing on two of the headstones, namely 1933 and 1935, that these graves appear to date from the 1930s and are as a result certainly older than 60 years. **Extent:** Approximately 10m x 10m. As TET 7 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 66 - General view of the cemetery at TET 7. The positions of three of the four headstones identified at the site which can be seen on this image are marked with red arrows (Scale is in 10cm increments).

Figure 67 - One of the broken headstones at the cemetery at TET 7 (Scale is in 10cm increments).

Figure 68 – Another view of one of the broken headstones from the cemetery at TET 7 (Scale is in 10cm increments).

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
TET 8	-28.11458°S	26.71827°E	An informal cemetery comprising eight graves is located here. One grave has a granite headstone with a granite-lined dressing, six of the graves have soil heaps with small upright stones at the head and foot whereas the remaining grave has a stone packed dressing. The inscription on the granite grave dressing reads as follows: "*NOHASI* *11.01.1966* *26.05.2005* *IN LOVING MEMORY* *OF* *OUR BELOVED MOTHER* *+ GRANDMOTHER* *NOBANTU* *REST IN PEACE*" The cemetery may be associated with the small settlement located 140m to the west. **Extent:** Approximately 25m x 25m. As TET 8 is located within a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 69 - General view of the cemetery at TET 8.

Figure 70 – Closer view of one of the graves at TET 8 (Scale is in 10cm increments).

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 71 - Close up view of the granite headstone.*			 *Figure 72 – Closer view of one of the graves at TET 8. This grave dressing consists of a soil heap with small upright stones marking the head and foot of the grave (Scale is in 10cm increments).*		
TET 9	-28.11755°S	26.71946°E	The site comprises the concrete drift and adjacent bridge over the Sand River at Blaauwdrift. According to information obtained during the desktop study, this drift was also known as the Du Preez Leger Drift. The drift pre-dates the bridge and was embedded by two rocks. The drift is depicted on the First Edition of the 2826BA Topographical Sheet that was surveyed in 1945, whereas the concrete bridge is depicted for the first time on the Second Edition of the 2826BA Topographical Sheet that was surveyed in 1954. As a result, both structures are older than 60 years. As revealed during the archival and historical desktop study, the following historic events associated with the Battle of Zand River can be associated with the Du Preez Leger Drift:	Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			• On the morning of 9 May 1900, Lieutenant-Colonel Thomas William Porter with the 1s Cavalry Brigade departed from Smaldeel to reconnoitre the two drifts at Du Preez Leger and De Klerks Kraal. They were assisted in this task by Major-General J.B.B. Dickson with the 4th Cavalry Brigade; • At 11 am, Major-General John French with his advance guard reached Kalkoenkrans, a section of which farm is located within the present study area. Here he received word from the reconnaissance units on the river that the Du Preez Leger Drift was not held by the enemy. Seizing the opportunity to outflank the Boer positions, French immediately ordered a squadron of the Scots Greys forward to take possession of the drift, and ordered the remainder of the 1st Cavalry Brigade to follow and assist in this task; and • By 15h30 that afternoon the Du Preez Leger Drift was occupied by the British force. The site possesses moderate levels of historic and architectural significance. Although events associated with the Battle of Zand River appears to have taken place at the drift where the site is located, the drift was not held by the Boer forces and as a result no shots were actually fired here. **Extent**: Approximately 100m x 50m. As TET 9 is in a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 Figure 73 – General view of TET 9, with the older drift visible on the right and the modern concrete bridge dominating the landscape on the left.			 Figure 74 – View along the older drift with the more modern concrete bridge on the left.		
TET 11	-28.18559°S	26.73656°E	An extensive cemetery comprising 112 graves of black people is located here. The cemetery is located on the boundary fence between the farms Palmietkuil 328 and Kalkoenkrans 225, and is situated in its entirety within the latter farm's property. The cemetery was included in a previous heritage report undertaken by Van der Walt (2013). The cemetery had been fenced and is located 26m from Eskom power line pylons. The cemetery is not maintained and a number of headstones were seen in a fallen-down state. Eight different grave dressing types could be identified at the cemetery. For the most part, these grave dressing were orientated along the east-west axis. The following grave dressings were identified at the cemetery: ▪ Upright stones at the head and foot of the grave (n = 57) ▪ Stone packed grave dressing with upright unmarked stone as headstone (n = 39) ▪ Stone packed grave dressing with metal marker as headstone (n = 1) ▪ Rectangular brick-line dressing with granite headstone (n = 6) ▪ Rectangular brick-lined dressing with cement headstone (n = 2)	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			▪ Rectangular granite-lined dressing with granite headstone (n = 1) ▪ Metal marker without any other dressing components (n = 4) ▪ Cement headstone without any other dressing components (n = 2) The oldest date that could be identified on any of the graves from the cemetery, is 1956. Of course, this does not mean that 1956 can be considered the *terminus post quem* for the site. A large number of graves from the site do not possess any inscriptions or details of the deceased. It is therefore quite likely for the cemetery to be considerably older than the 1950s. The extensive size of the cemetery suggests that it was associated with a reasonably large community. Approximately 340m south-east of the cemetery the remains of an old farm school is located. It seems more than likely that the school and cemetery were associated with the same reasonably large farm worker community residing on the farm Kalkoenkrans. **Extent:** Approximately 60m x 60m. As TET 11 is located within a pipeline buffer zone, adjacent to a proposed compressor station, it is possible that the site may be impacted upon by the proposed development.		

<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td colspan="3">
Figure 75 - General view of the cemetery at TET 11. The boundary fence between the farms Kalkoenkrans (left of the fence) and Palmietkuil (right of the fence) can clearly be seen.</td><td colspan="3">
Figure 76 – General view of some of what is believed to be some of the older graves from the cemetery comprising stone concentrations with unmarked upright stones as headstones (Scale is in 10cm increments).</td></tr>
</table>

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 77 – Granite headstone from one of the graves with a brick-lined dressing and granite headstone (Scale is in 10cm increments).*					
TET 13	-28.18746°S	26.73452°E	The site comprises the poorly preserved remains of farm worker accommodation on the farm Palmietkuil 328. All that remains of the farm worker accommodation is a rectangular stone foundation (5m x 3m) and four stone corner posts of a small camp (5m x 5m). Cultural material in the form of glass, metal and imported ceramic fragments were identified in association with the rectangular foundation structure.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			As indicated above, the four stone posts appear to be all that remains of a small camp, possibly for the keeping of livestock. Only one of the stone posts are still in an upright position, with another one leaning over and the remaining two posts lying flat on the ground. The exact age of the site is not known. However, the only time that huts are depicted in proximity to this site on the available topographical map sheets, is on the Second Edition of the 2826BA sheet that was surveyed in 1954. The site may be just older than 60 years with some remnants of its stone structures remaining. The cultural material identified here is not older than 100 years and as a result not protected by the available heritage legislation. However, the risk does exist for stillborn babies to have been buried here. Until the presence of such possible graves at the site has been proven or disproven, a worst case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. **Extent**: Approximately 70m x 50m. As TET 13 is in a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

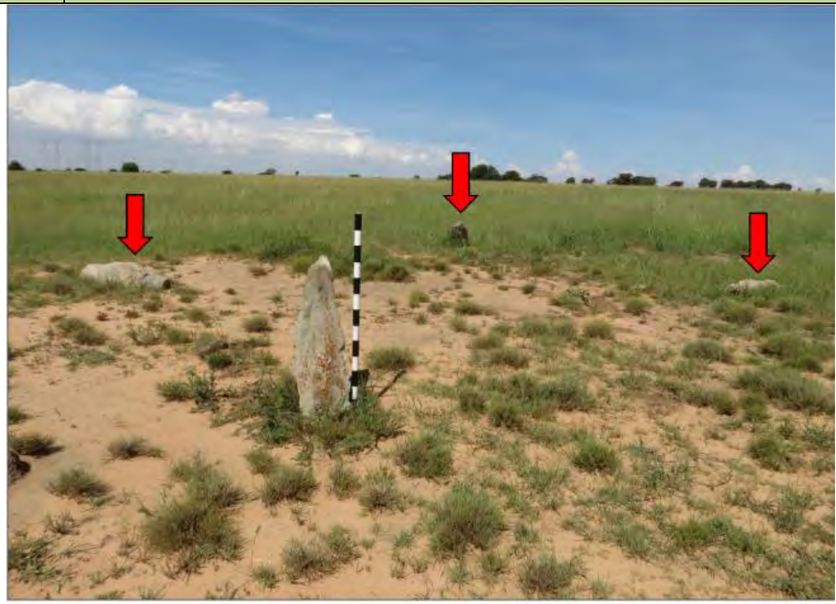


Figure 78– View of the remnants of what appears to have been a livestock camp. Apart from the upright corner post visible in the front, the positions of the corner posts are marked with red arrows (Scale is in 10cm increments).

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 79 - General view of the remains of the structure (Scale is in 10cm increments).*			 *Figure 80 – Another view of the remains of the structure (Scale is in 10cm increments).*		
TET 14	-28.18959°S	26.73541°E	The site comprises the poorly preserved remains of farm worker accommodation on the farm Palmietkuil 328. All that remains of the farm worker accommodation are scatters of cultural material such as glass and metal fragments. The extent of the site is approximately 120m x 70m. The exact age of the site is not known. However, the only time that huts are depicted in proximity to this site on the available topographical map sheets, is on the Second Edition of the 2826BA sheet that was surveyed in 1954. Although the site may be just older than 60 years, none of the structures have remained preserved. Furthermore, the cultural material identified here is not older than 100 years and as a result not protected by the available heritage legislation. However, the risk does exist for stillborn babies to have been buried here. Until the presence of such possible graves at the site has been proven or disproven, a worst case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. As TET 14 is in a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium-High Significance	IIIA

<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td colspan="3">
Figure 81 – General view of TET 14 (Scale is in 10cm increments).</td><td colspan="3">
Figure 82 – Cultural material in the form of glass and metal fragments were found across the surface of TET 14 (Scale is in 10cm increments).</td></tr>
<tr><td>TET 15</td><td>-28.22097°S</td><td>26.75365°E</td><td>An informal cemetery comprising two black graves is located immediately adjacent to a farm road. The cemetery is enclosed by a fence.

The two graves are located adjacent to each other and their dressings are both orientated along the east-west axis. One of the graves has a granite headstone with a granite lined dressing. The second grave is stone packed with a metal plaque. From the information found on the granite headstone, it is evident that the graves from this cemetery include the deceased of the Mokati family. This grave dates to 1978. The site may have been a small farmworker cemetery.

Extent: Approximately 5m x 5m.

As TET 15 is located within a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.</td><td>High Significance</td><td>IIIA</td></tr>
</table>

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 83 - General view of the cemetery at TET 15.*			 *Figure 84 - Closer view of one of the graves at TET15.*		
TET 19	-28.13652°S	26.72375°E	An informal cemetery comprising approximately 26 black graves is located here. The cemetery is situated along a boundary fence. All the grave dressings from this cemetery are orientated along the East-West axis. Six of the grave dressings are stone concentrations, with unmarked upright stones on their western ends. Two of the grave dressings have cement brick linings, one has a clay baked lining with a cement headstone and one grave dressing has a brick lining with a granite headstone. The only surface markings on the remainder of the graves are small upright stones or concrete fragments. From information found on the headstones, it is evident that the graves from this cemetery include the deceased of the Nhlapo and Nondela families. The site appears to have been a farmworker cemetery. **Extent:** Approximately 40m x 20m.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			As TET 19 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Figure 85 – One of the graves from the cemetery at TET 19

(Scale is in 10cm increments).

Figure 86 - Another view of one of the graves from the cemetery at TET19.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
TET 22	-28.14997°S	26.72474°E	The site comprises the burial place for the ashes of Mr. Lourens Lourens snr. The burial site is located in the garden of the deceased's son, Mr. Lourens Lourens (jnr.). The place where the ashes were buried is marked with a cross. **Extent:** Approximately 5m x 5m. As TET 22 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 87 – General view of TET 22.*			 *Figure 88 – Closer view of the cross at TET 22.*		
TET 25a and 25b	-28.17803°S/ -28.17977°S	26.74283°E/ 26.74080°E	The site comprises the poorly preserved remains of farm worker accommodation on the farm Kalkoenkrans 225. All that remains of the farm worker accommodation are scatters of cultural material such as glass and metal fragments that were identified between the two waypoints shown above. This cultural material was observed over a corridor roughly 400m. While the exact age of the site is not known, a number of huts are depicted in this area on both the First and Second Editions of the 2826BA topographical sheets surveyed in 1945 and 1954 respectively. Although the site may be just older than 60 years, none of the structures have remained preserved. Furthermore, the cultural material identified here is not older than 100 years and as a result not protected by the available heritage legislation. However, the risk does exist for stillborn babies to have been buried here. Until the presence of such possible graves at the site has been proven	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			or disproven, a worst case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. As TET 25a and 25b are in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Figure 89 – General view of a section of the area where cultural material was identified.

Figure 90 – Cultural material in the form of glass and metal fragments is found across the surface of the site. Scale is in 1cm and 5cm increments.

TET 26	-28.17983°S	26.74406°E	The site comprises the poorly preserved remains of farm worker accommodation on the farm Kalkoenkrans 225. All that remains of the farm worker accommodation at the site is a poorly preserved structure of mud and baked red clay bricks. Only three of the walls of this structure still remains preserved, with no roof present. The poorly preserved structure is located within a cluster of modern farm worker accommodation units. The exact age of the structure is not known. However, huts are depicted in proximity to this structure on both the First and Second Editions of the 2826BA topographical sheets that were surveyed in	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			1945 and 1954 respectively. It seems likely therefore for the site to be potentially older than 60 years. While the structure itself is too poorly preserved to have any heritage significance, the risk does exist for stillborn babies to have been buried here. Until the presence of such possible graves at the site has been proven or disproven, a worst case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. **Extent:** Approximately 20m x 20m. As TET 26 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Figure 91 – General view of the structure at TET 26.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
TET 27	-28.18286°S	26.74164°E	A poorly preserved east-facing farm dwelling is located here. The building originally had a hipped roof construction, and it was built out of cement bricks. Most of the roof and all the window and door frames missing and sections of the walling are also disintegrating. A brick reservoir is associated with the building. Although the exact age of the structure is not presently known, a building is depicted for the first time here on the Second Edition of the 2826BA that was surveyed in 1954. This building is not depicted on the First Edition of the same topographical sheet that was surveyed in 1945. As a result, it would appear that the building is between 77 and 68 years old. **Extent:** Approximately 60m x 60m. As TET 27 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Low Significance	IIIC

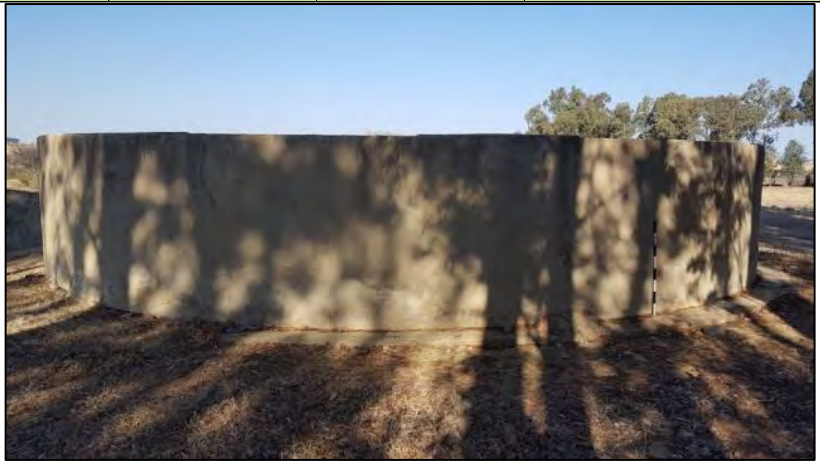
Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 92 – General view of a section of the building.*			 *Figure 93 – View of a section of the interior of the building.*		
SSL/BET/25	-28.18093°S	26.730159°E	The site comprises a concrete and brick foundation of an old farmhouse and an outbuilding. It was located on the farm Kalkoenkrans 225 (Portion 1). The remains of the walling on the farmhouse indicates that a brick-laying technique known as header bond was used in the construction of the building. This brick-laying technique results in 11-inch thick internal walls and is typical of the period before the 1940s. The remains of linoleum flooring and earthenware piping also indicate that the structure was probably built in the 1930s. A possible midden was also identified in the area. Although the structure is not depicted on the 1940 topographical map, it is, in all likelihood, between 60 and 100 years old. As most of the structures have been demolished, the site is of low heritage significance.	Low Significance	IIIC

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			Extent: Farmhouse: approximately 20 square meters; an outbuilding: approximately 10 square meters. As SSL/BET/25 is in a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Figure 94 – General view of remains of the farmhouse at SSL/BET/25.

Figure 95 – Example of the linoleum flooring within the old farmhouse at SSL/BET/25 (Scale is in 10cm increments).

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 Figure 96 - The foundation remains of the outbuilding at site SSL/BET/25.			 Figure 97 - Fragments of earthenware piping (Scale is in 10cm increments).		
SSL/BET/26	-28.179151°S	26.729295°E	The site consists of an old reservoir with an associated furrow located between several trees. It most likely supplied water to the farmhouse identified at site 023. The brick used in its construction was a baked red brick of imperial dimensions with large holes to facilitate the pouring of cement. This brick design was used before the 1940s. **Extent:** Approximately 5m x 5m As SSL/BET/26 is in a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	Low Significance	IIIC

<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td colspan="3">
Figure 98 – General view of the reservoir identified at SSL/BET/26 (Scale is at 10cm increments).</td><td colspan="3">
Figure 99 - Closer view of one of the bricks with which the reservoir was built.</td></tr>
<tr><td>SSL/BET/36</td><td>-28.209272°S</td><td>26.721111°E</td><td>The site consists of the remains of a southwest facing, small building (8x8m) which is surrounded by an extensive Blue gum tree wind-break (6000m^2). The building has baked clay brick walls with concrete lintels, a concrete foundation and steel door frames. It may be the remains of farmworker accommodation. It is depicted as two buildings on an early topographic map sheet surveyed during the 1940s.

In addition to this main structure, the site contains the remains of several other structures:
▪ A brick reservoir with a diameter of approximately 10m.
▪ An old, corrugated reservoir situated north-west of the brick reservoir, which had been used as a relatively recent midden containing a large amount of beer bottles and cans dating to the 1960s/1970s.
▪ Two boreholes and a windmill situated north-east of the brick dam.
Extent: Approximately 300m x 200m.

As SSL/BET/36 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.</td><td>Low Significance</td><td>IIIC</td></tr>
</table>

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 100 – Front view of the building at SSL/BET/36. The concrete lintels are visible.

Figure 101 – Rear view of the same building. The steel doorframes can be seen.

Figure 102 – Remains of an old brick reservoir at SSL/BET/36.

Figure 103 – Remains of an old corrugated reservoir.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
SSL/BET/37	-28.210306°S	26.721111°E	This site is located just outside a Blue gum wind break and is, in all likelihood, the remains of labourers' accommodation associated with Site SSL/BET/36. An upright stone fence post as well as two rectangular stone foundations (6x3m and 8x3m) were identified here. It must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. **Extent:** Approximately 70 m x20 m. As SSL/BET/37 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 104 – Upright stone fence post at SSL/BET/37 (Scale is in increments of 10cm).*			 *Figure 105 - Visible remains of stone foundation of the 8x3m structure (Scale is in increments of 10cm).*		
SSL/BET/38	-28.224040°S	26.715320°E	The site was depicted as a hut on an early topographic map sheet surveyed in the 1940s. The remains identified in the field consist of a 3x12m dressed, packed-stone foundation. Although the exact age of the structure is not known, it is certainly older than 60 years. A nearby electricity pylon may have disturbed sections of the site. It must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. **Extent:** Approximately 10 m x 5 m.	Medium-High Significance	IIIA

<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td></td><td></td><td></td><td>As SSL/BET/38 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.</td><td></td><td></td></tr>
<tr><td colspan="3">

Figure 106 – General view of SSL/BET/38, showing the Eskom pylon (Scale is in increments of 10cm).</td><td colspan="3">

Figure 107 - Visible remains of structure foundation (Scale is in increments of 10cm).</td></tr>
<tr><td>SSL/BET/39</td><td>-28.218674°S</td><td>26.716572°E</td><td>The site was depicted as a single hut on an early topographic map sheet surveyed during the 1940s. The remains of the site identified in the field consist of a stone and mud wall which is approximately 40cm long. Although the exact age of the structure is not known, it is certainly older than 60 years.
It must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here.</td><td>Medium-High Significance</td><td>IIIA</td></tr>
</table>

<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td></td><td></td><td></td><td>Extent: Approximately 5 m x 4m.

As SSL/BET/39 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.</td><td></td><td></td></tr>
<tr><td colspan="6">

Figure 108–General view of the remains of the stone and mud wall at SSL/BET/39.

</td></tr>
<tr><td>SSL/BET/53</td><td>-28.18613°S</td><td>26.73433°E</td><td>The site comprises the poorly preserved remains of farm worker accommodation on the farm Palmietkuil 328. All that remains of the farm worker accommodation at this site are two rectangular stone foundations (050a & 050b) associated with cultural material in the form of glass and metal fragments. A concentration of cultural material in the form of a midden (050c) is also located nearby.

The three components of the site can be described as follows:</td><td>Medium-High Significance</td><td>IIIA</td></tr>
</table>

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			050a) comprises the remnants of a rectangular stone foundation that is located close to an Eskom pylon. As indicated above, glass and metal fragments were found associated with this structure; 051b) comprises a rectangular stone foundation (5m x 4m) with glass and metal fragments found associated with the structure. Two of these glass fragments are from the same clear container and have embossed letters on them. One of these glass fragments contains the embossed word section "…EUR…" and the second fragment the word section "…ON…" It is not presently possible to identify the particular bottle or brand; and 051c) represents a midden located roughly 5m from the previous structure. The fragments observed on the surface of the site include the lid of a Consol glass jar, a writing slate fragment as well as the shoulder, neck and rim of a small brown medicine bottle. The exact age of the site is not known. However, the only time that huts are depicted in proximity to this site on the available topographical map sheets, is on the Second Edition of the 2826BA sheet that was surveyed in 1954. It seems likely therefore for the site to be potentially just older than 60 years. Furthermore, the presence of a Consol glass item provides a *terminus post quem* for this section of the midden in that Consolidated Glass Works was started in May 1946 (www.consol.co.za). The cultural material identified here is not older than 100 years and as a result not protected by the available heritage legislation. It must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. **Extent:** Approximately 70 m x 70m. As SSL/BET/53 is in a compressor station buffer zone, it is possible that the site may be impacted upon by the proposed development.		

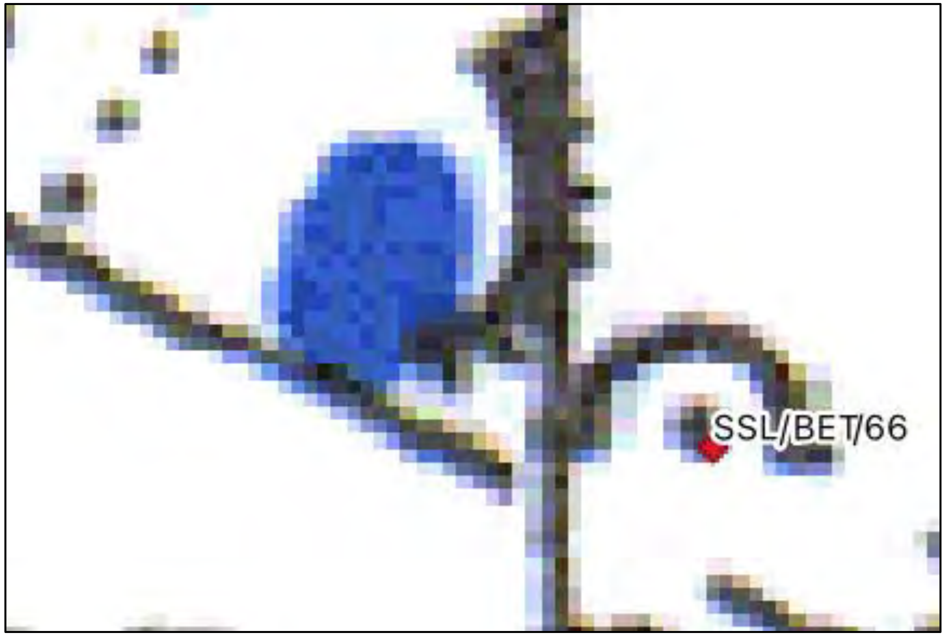
Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 109–General view of the structure observed at SSL/BET/53 (Scale is in 10cm increments).

Figure 110 - Three of the glass fragments observed in proximity to Site 050a (Scale is in 1cm increments).

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 Figure 111 - General view of the structure at Site 050b (Scale is in 10cm increments).			 Figure 112 - The midden identified at Site 051c (Scale is in 10cm increments).		
SSL/BET/60	-28.214607°S	26.718030°E	The site was depicted as a single hut on an early topographic map sheet surveyed during the 1940s. No structural remains of the site were identified in the field. However, it must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. As such, this must be considered as a sensitive area and must be given a buffer. As SSL/BET/60 is in an extension buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 113– Section of the1945 topographical map showing a hut at SSL/BET/60.*					
SSL/BET/66	-28.1670611°S	26.730000°E	The site was depicted as a single hut on an early topographic map sheet surveyed during the 1940s. However, the site was not visited during the fieldwork survey. Due to the risk of unmarked stillborn graves, it is included in the inventory. It is clear from satellite imagery that there will be no surface remains as the site lies in an agricultural field and has been heavily ploughed. However, it must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. As such, this must be considered as a sensitive area and must be given a buffer. As SSL/BET/66 is in a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 114– Section of the 1945 topographical map showing a hut at SSL/BET/66.*					
SSL/BET/72	-28.19919°S	26.73638°E	The site comprises one grave, with a metal marker, with no inscription. According to local tradition, a number of graves are buried at this location. While only one grave dressing could be observed, the position of the site on a farm boundary fence supports oral history. The site may have been a small farmworker cemetery. As SSL/BET/72 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 115 – General views of grave observed at SSL/BET/72.*					
SITE 1A	-28.24045°S	26.71786°E	The site comprises an old farmhouse with at least two identifiable construction phases; the core comprises a multi-roomed structure built with clay sundried bricks and mortar which is built in an English bond style. Largely enclosing the core is a kiln baked brick veranda on the northern and eastern sides as well as other additions. Associated structures include a water tank foundation, brick and cement reservoir and brick meat-processing room. The site was depicted as a single structure on an early topographic map sheet surveyed during the 1940s. As no additional information was available, the site is provisionally rated as IIIB with medium heritage significance. As SITE 1A is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 116 – General views of SITE 1A.

Figure 117 – Section of the 1945 topographical map showing a structure at SITE 1A.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
SITE 1B	-28.23986°S	26.71790°E	The site comprises an old wagon shed is located here. Its southern aspect is dressed sandstone and is joined to the stone built eastern façade with coining. The structure is divided via three internal walls of mud bricks and stone with room added to the northern side of the structure. All corners of the structure are joined with coined sandstone blocks. The site was depicted as a single structure on an early topographic map sheet surveyed during the 1940s. The wagon shed is certainly older than 60 years and in all likelihood is older than 100 years as well. Considering its age, the structure is in a moderate state of preservation. As no additional information was available, the site is provisionally rated as IIIB with medium heritage significance. **Extent:** Approximately 11 m x20 m. As SITE 1B is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium Significance	IIIB

Figure 118–General views of SITE 1B.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 119– Section of the 1945 topographical map showing a structure at SITE 1B.*					
SITE 2	-28.23925°S	26.71972°E	The site comprises the Jordaan and Pienaar cemetery comprising at least four graves, three of which have headstones. While the area around the graves is reasonably well kept, the headstones and grave dressings are damaged. The position of this cemetery so close to the buildings and structures identified at Site 1, suggests that the two sites are associated with one another. As SITE 2 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
  *Figure 120– View of headstones observed at SITE 2.*					
SITE 19	-28.23142°S	26.73067°E	The site comprises five graves, of which two are fenced soil heaps, with one upright stone. The other three graves are outside the fenced area, with soil heaps. Two of these latter graves have stones and one has a metal marker. No information could be obtained from the headstones or dressings. However, it seems likely that the site is a small farmworker cemetery. As SITE 19 is in a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 121–General view of the two fenced off graves observed at SITE 19.*					
SITE 20	-28.22363°S	26.74807°E	The site comprises the original farm house of the farm, which has now been repurposed as a shed. It has a hipped roof with metal tie rods on the eastern aspect. The original window sills have been bricked up and a double door added to the one facade. It is evident that the building is currently being used as a shed. The farmhouse is older than 60 years but has been extensively modified over the years and is currently used as a shed. **Extent:** Approximately 13 m x 12m. As SITE 20 is in a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	Low-Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			  *Figure 122–General views of SITE 20.*		
SITE 21	-28.19293°S	26.74047°E	The site comprises a farmhouse. According to the landowner, Mr. Oosthuizen, this farmhouse was built in 1955. The house has since then been extensively modified by the three generations that have resided here. Mr. Oosthuizen kindly provided old photographs of the original house. A comparison between these historic photographs and the contemporary view of the dwelling today, clearly shows the significant modifications which have taken place here. The farmhouse is older than 60 years, but has been extensively modified. As SITE 21 is in a pipeline and well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Low-Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 123 – General view of SITE 21.

Figure 124 - Historical photographs of the farmhouse at SITE 21.

6.2 HERITAGE SITES IDENTIFIED DURING THE CURRENT FIELD ASSESSMENT

The fieldwork component of the study was aimed at identifying tangible remains of archaeological, historical and heritage significance. The fieldwork was conducted by three archaeologists from PGS (Nikki Mann, Michelle Sachse and Nicholas Fletcher) on 14-24 February 2022. The fieldwork comprised a controlled exclusive survey of the proposed development footprint areas. The fieldwork team recorded track logs with their hand-held GPS devices. These track logs are depicted in yellow in **Figure 256** and show the areas assessed by the archaeologists during the fieldwork.

For the most part, the archaeological visibility of the area was not ideal for surveying due to the dense grass cover and disturbance found in some areas (crops: maize, sunflowers, soya beans; ploughed land). Therefore, the walkthroughs were focused on those areas that are not disturbed, as the potential for identifying archaeological and heritage sites in the more undisturbed components of the study area are much higher. As a result, only limited fieldwork was undertaken in those components of the study area that are entirely disturbed. Furthermore, none of the currently occupied farmhouses are expected to be impacted upon by the proposed development and as such were not documented in this report to respect the owner's privacy.

There was also restricted access to certain farm properties (BLAAUWDRIFT No.188 (Portion 3), BRUINTJE HOOGTE No.367 (Portion 2, 3), BRYAN No.561 (Portion 10, 21, 28, 29, 30, 31, 38), GLEN ROSS No.734 (Portion 4, 5, 6, 7, 18, 20), JONKERS RUST No.72, KALKOENKRANS No.225 (Portion 3), MOND VAN DOORNRIVIER No.38 (Portion 2), MOOIFONTEIN No.639, PALMIETJUIL No.548 (Portion 1), STILLE WONING no.703, VLAKPAN No.358) due to flooded roads, game life on the properties or farm owners not giving permission to access their properties.

The fieldwork identified heritage finds that were then classified as either structures, ruins or graves and burial grounds. The fieldwork completed for the HIA component has confirmed the presence of 7 burial ground sites (**T0003, T0009, T0010, T0012[7], T0013, T0024, T0029**), 9 historic to recent sites with possible graves (**T0007, T0008, T0011, T0015, T0023, T0026, T0027, T0028, T0035[8]**) and 25 structures (**T0001, T0002, T0004, T0005, T0006[9], T0014, T0016, T0017, T0018, T0019, T0020, T0021, T0022, T0025, T0030, T0031, T0032[10], T0033, T0034, T0036, T0037, T0038, T0039, T0040, T0041**)

[7] Note that the site T0012 identified during the field assessment is the same site as TET15 identified in the 2016/2017 heritage assessment.
[8] Note that the site T0035 identified during the field assessment is the same site as TET13 identified in the 2016/2017 heritage assessment
[9] Note that site T0006 identified during the field assessment is the same site as SITE 1B identified in the 2016/2017 heritage assessment.

[10] Note that site T0032 identified during the field assessment is the same sites as TET3 identified in the 2016/2017 heritage assessment.

that may be affected by the proposed development. The position and distribution of the sites are illustrated in **Figure 126** to **Figure 133.**

The most recently identified sites were also combined with the previously identified sites (Birkholtz, 2017a, 2017b). See **Figure 134.**

Only additional photos or comments will be provided for the previously recorded sites as their descriptions are provided in **Section 6.1** (see SITE 1B, TET 15, TET 3, TET 13).

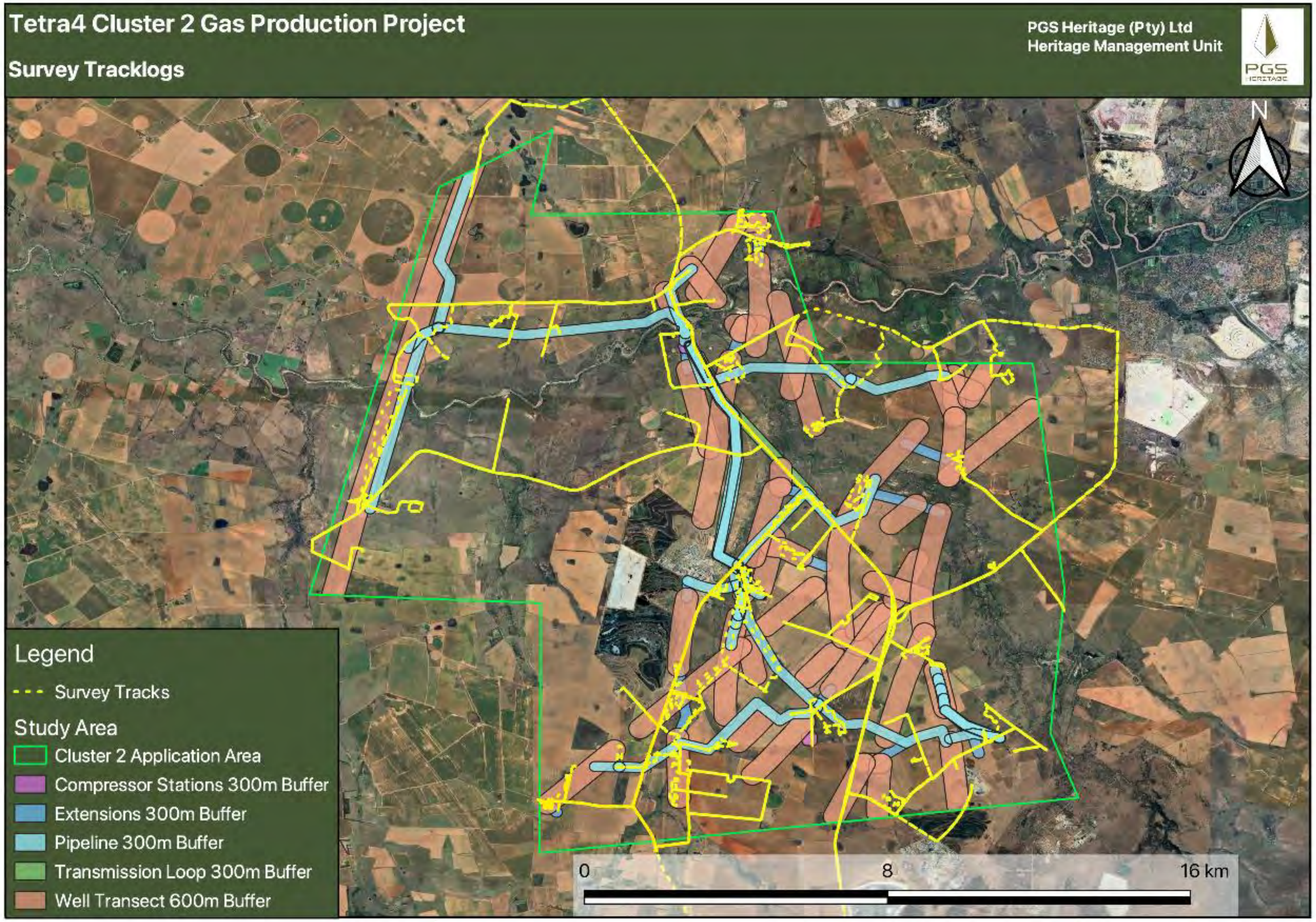


Figure 125 - Survey Tracklogs.

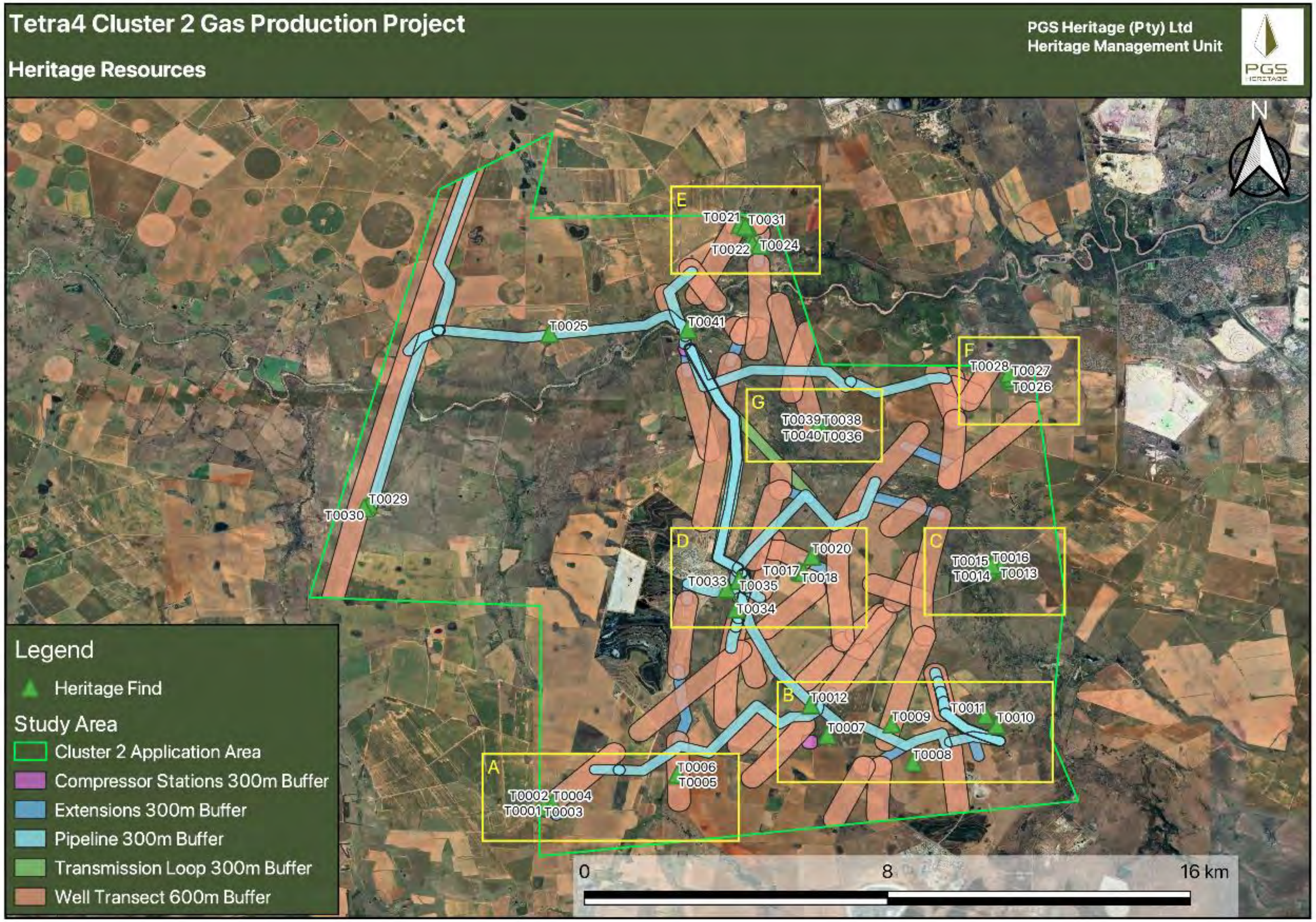


Figure 126 - Heritage Resources identified during the fieldwork. See insets below.

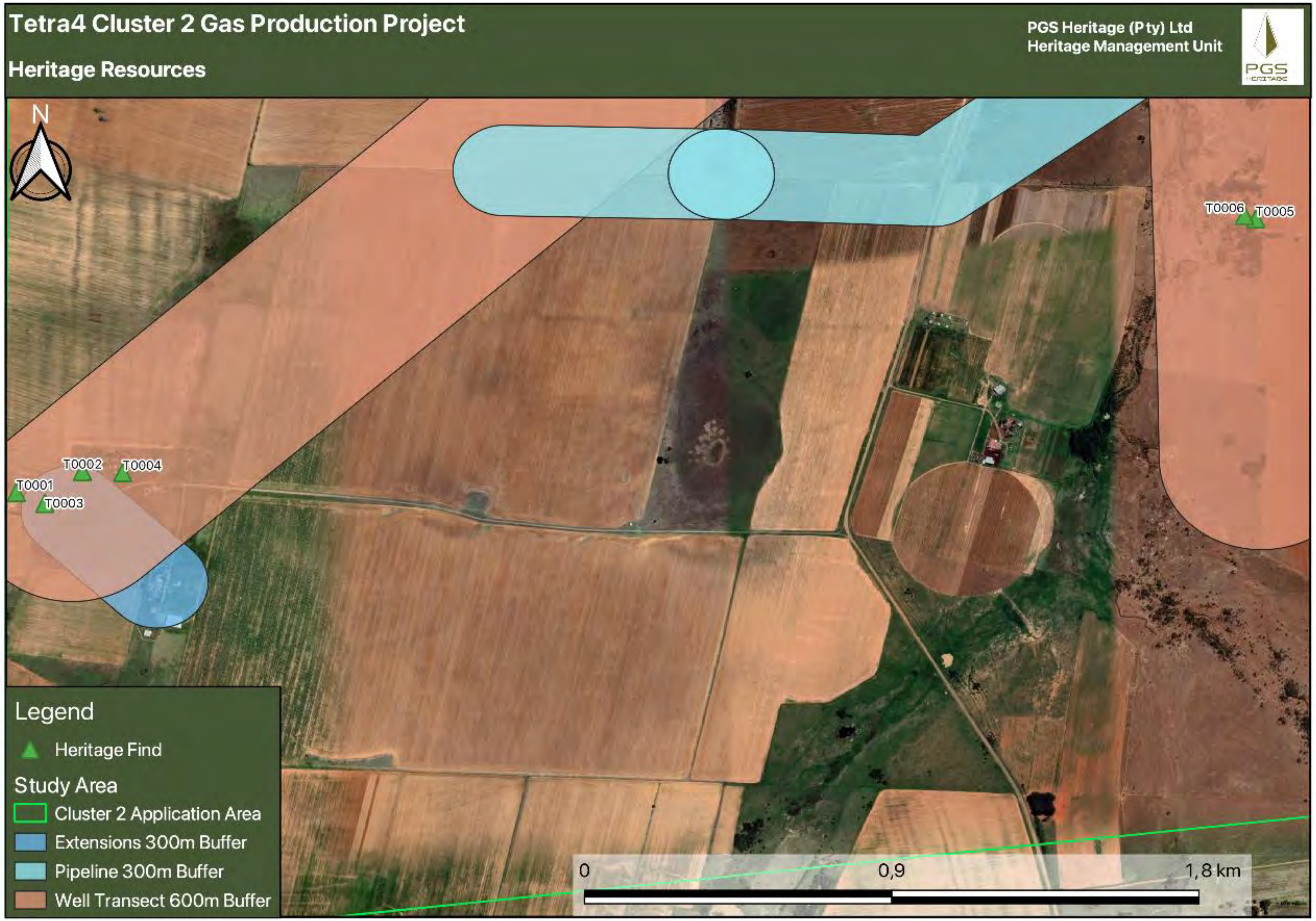


Figure 127 – Heritage Resources identified during the fieldwork. Inset A.

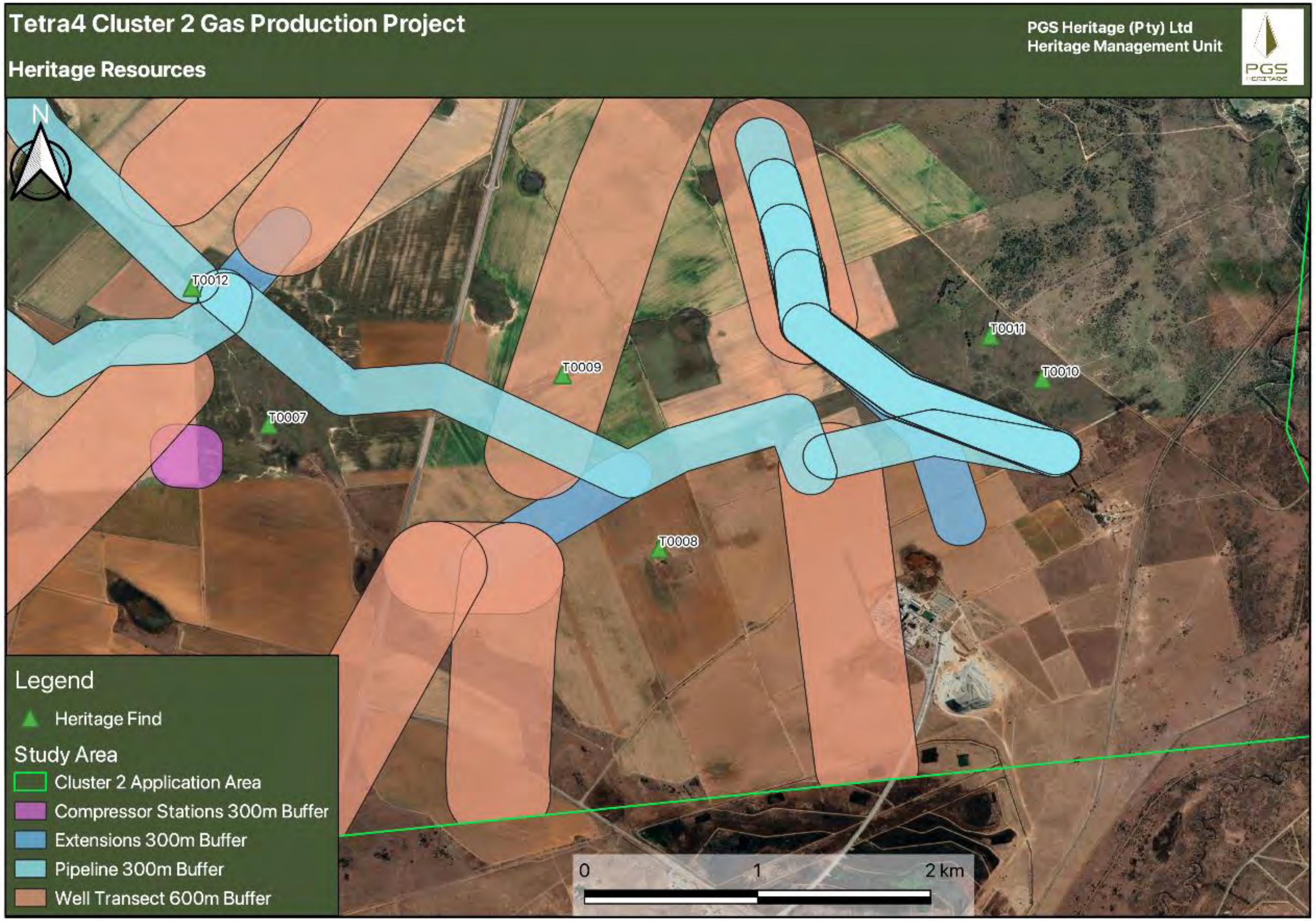


Figure 128 - Heritage Resources identified during the fieldwork. Inset B.

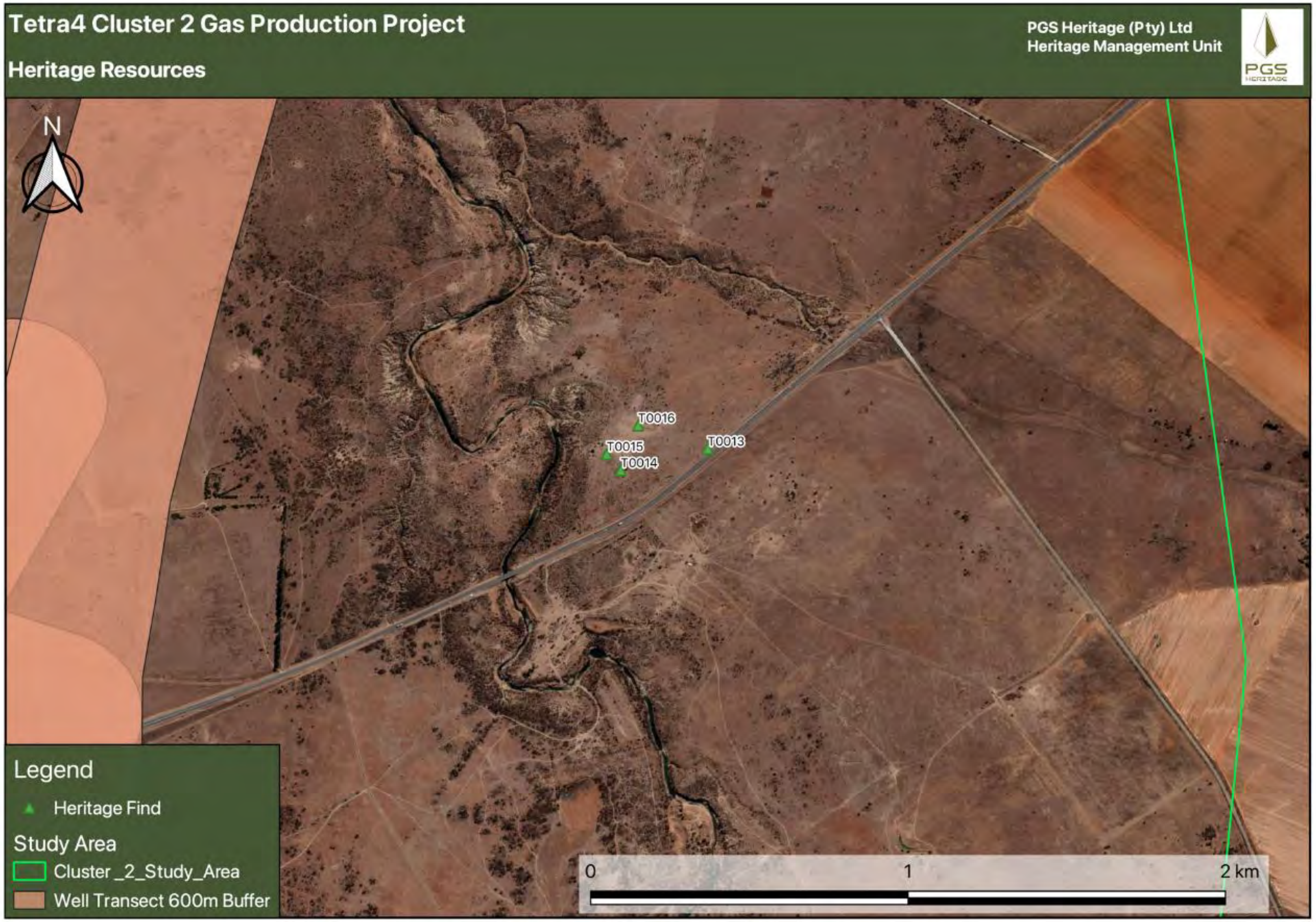


Figure 129 - Heritage Resources identified during the fieldwork. Inset C.

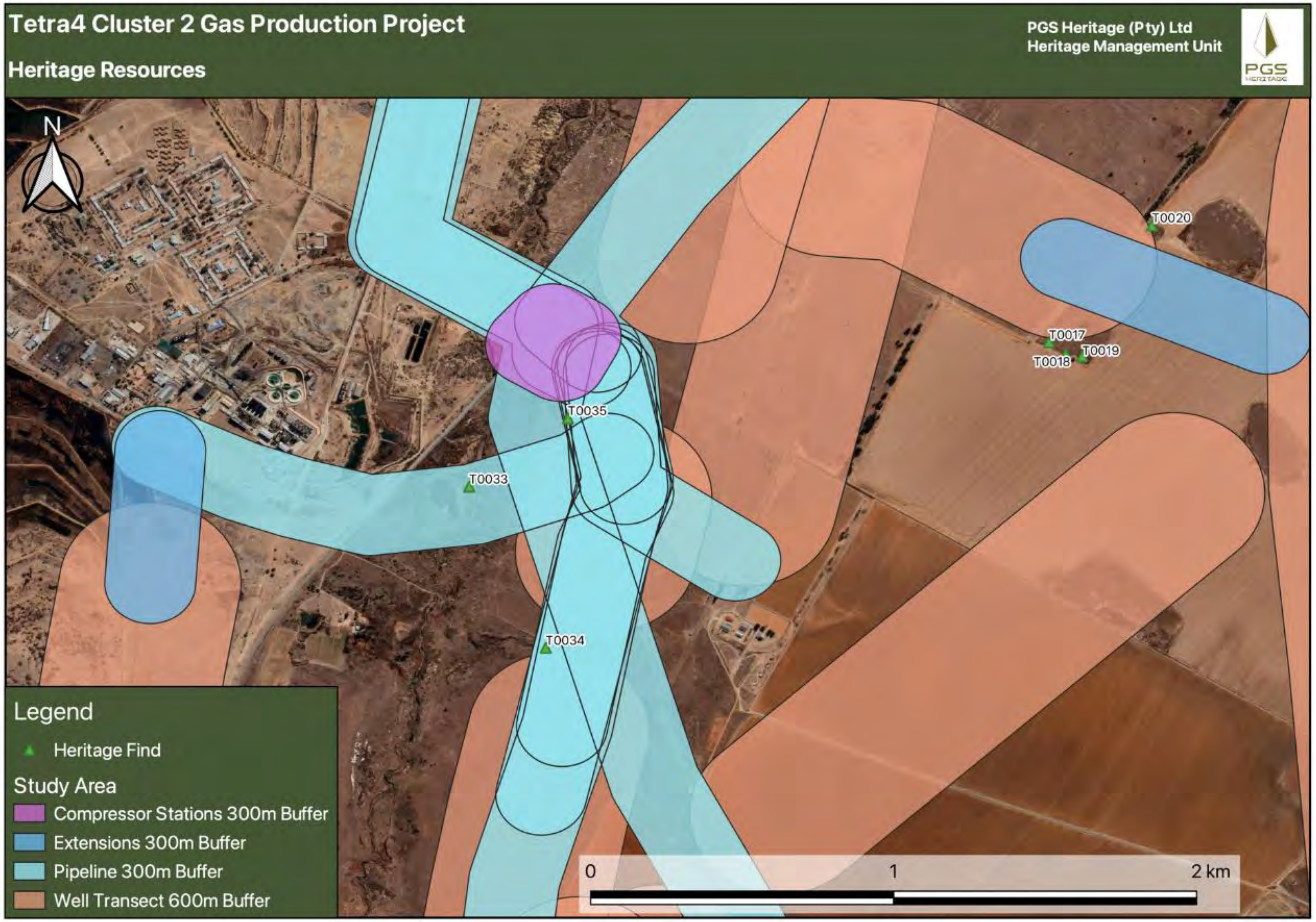


Figure 130 - Heritage Resources identified during the fieldwork. Inset D.

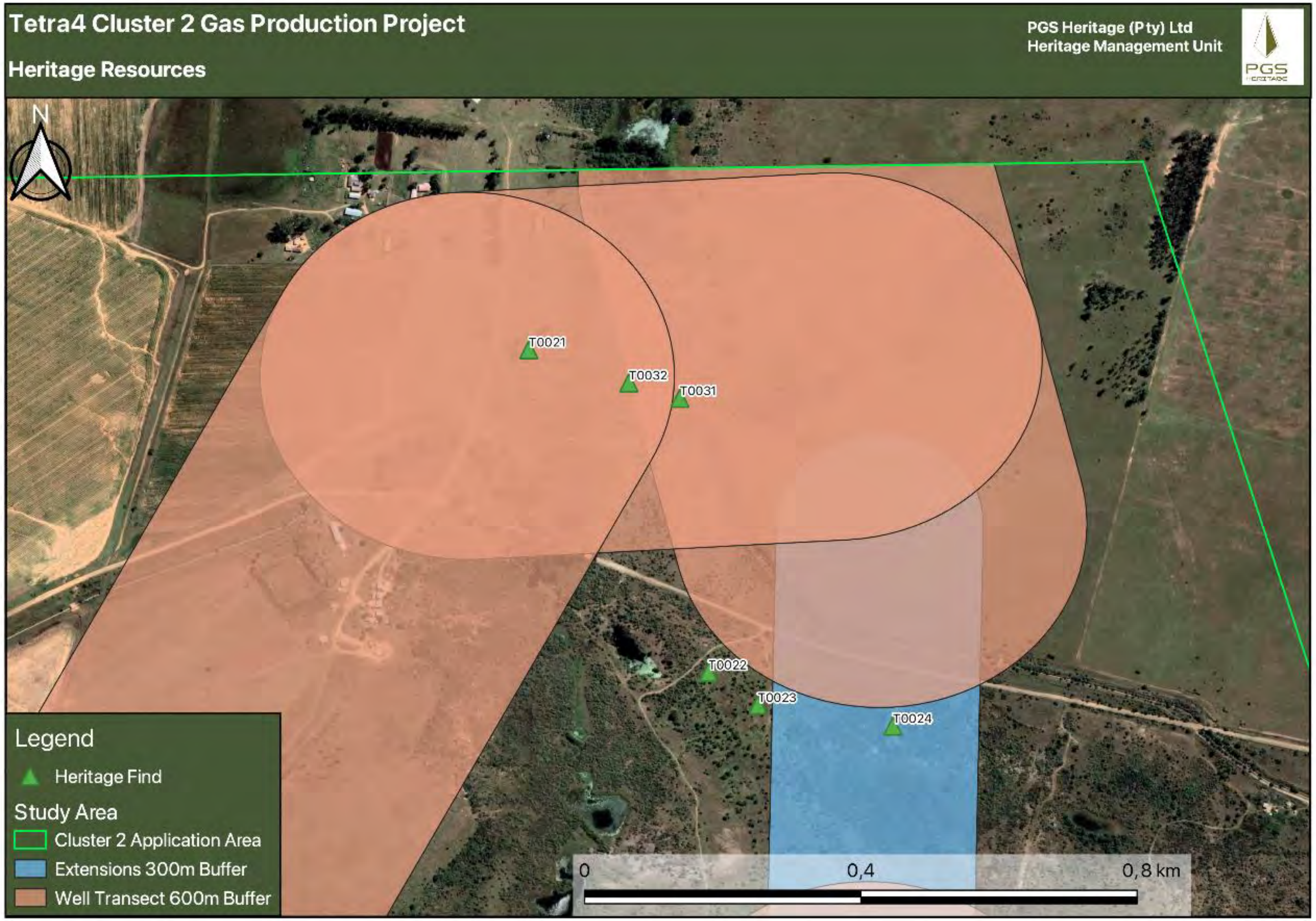


Figure 131 - Heritage Resources identified during the fieldwork. Inset E.

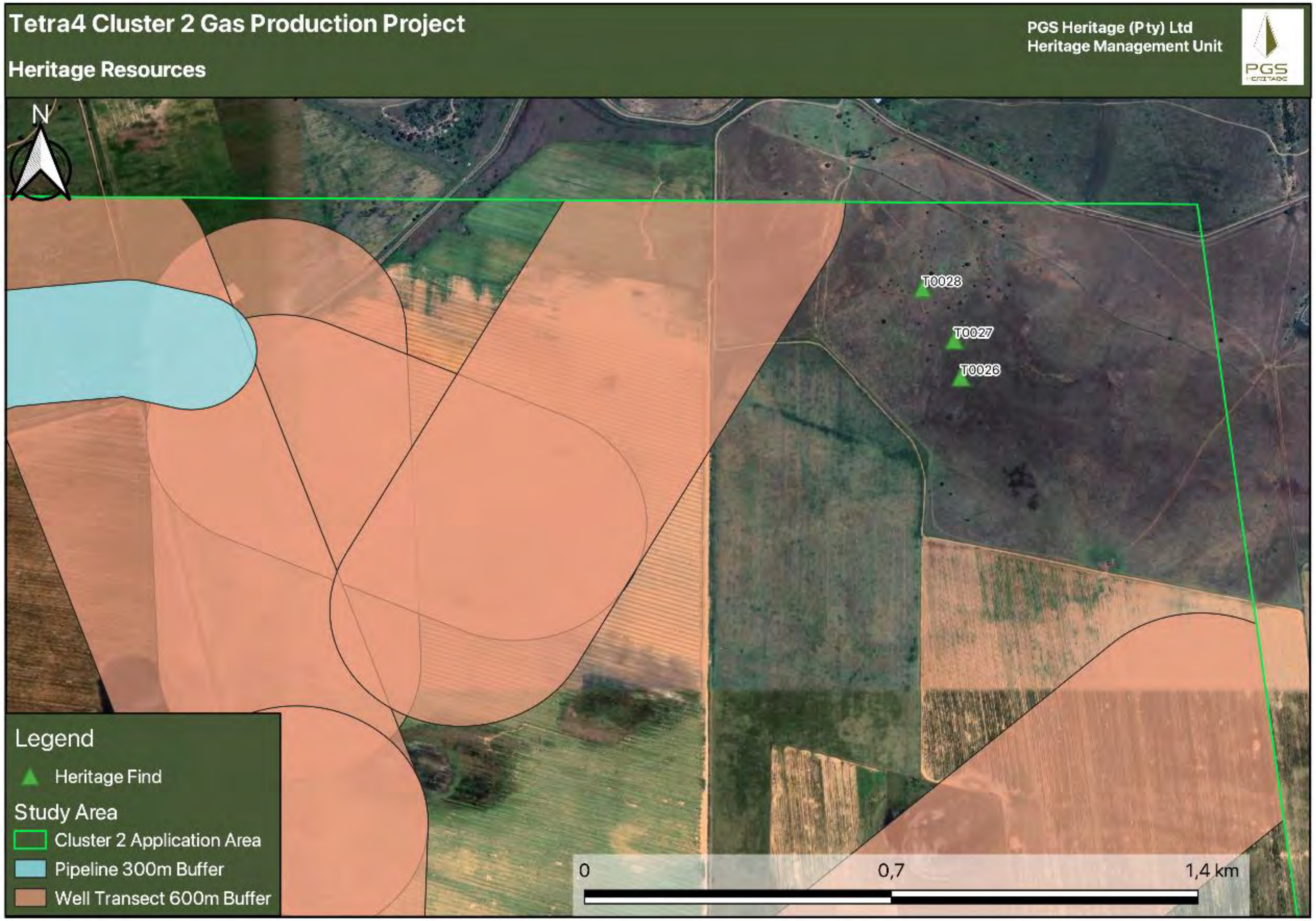


Figure 132 - Heritage Resources identified during the fieldwork. Inset F.

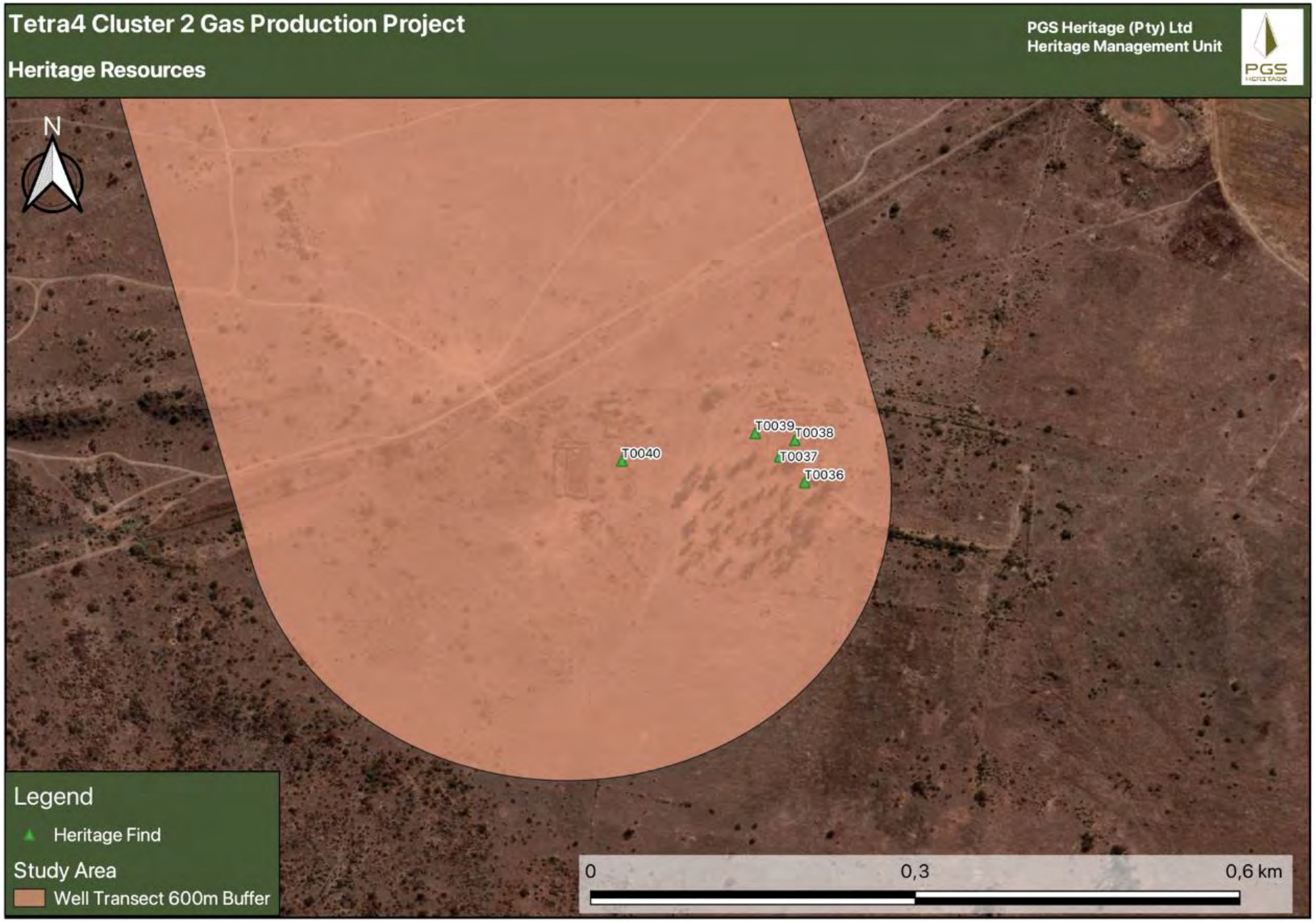


Figure 133 - Heritage Resources identified during the fieldwork. Inset G.

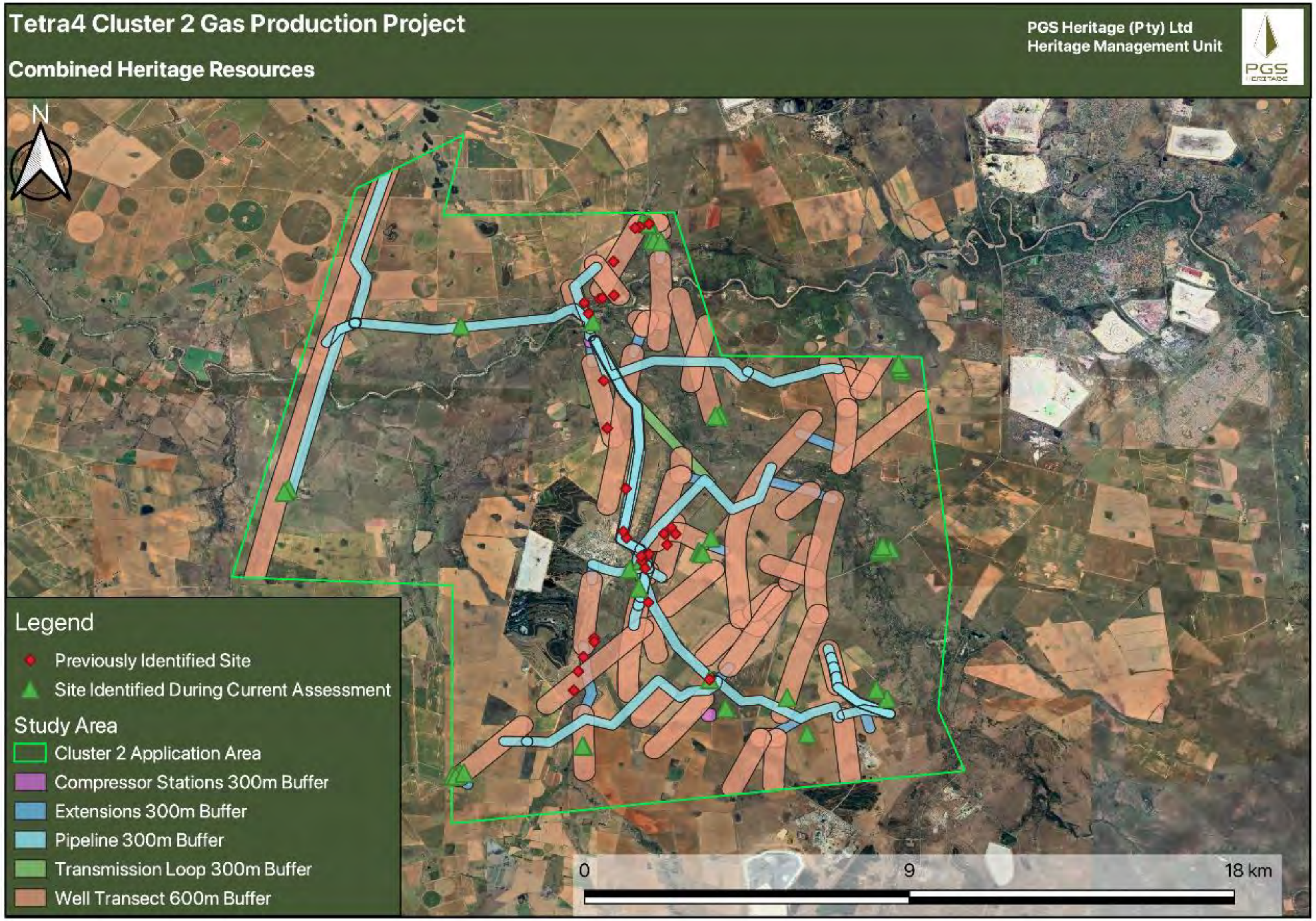


Figure 134 - Heritage Resources identifies during previous and current field assessments.

Table 10 - Sites identified during the heritage survey

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0001	-.28.247976°S	26.681095°E	The site comprises a fenced-off maize storage facility. It is located on the farm Terra Blanda No.155 in the south-western portion of the proposed development area. Two structures are located adjacent to existing maize fields. The structures had brick walls and one of the structures had a corrugated iron roof. The other structure's roof was missing. The construction materials and technique are consistent with modern building methods. No other cultural material was identified around the site. **Extent**: Approximately 95m x 150m fenced property. The structures were approx. 10m x 15m and 15 x 20m. The site was not depicted at this locality on the 2826BA topographical sheet dating to 1945 or 1954. Two structures were depicted at this locality on the 2826BA topographical sheet dating to 1997. The site is therefore younger than 60 years and is of no heritage significance. The site is rated as NCW. T0001 is located within a well transect buffer. It is possible that the proposed development will impact on the site.	No research potential or other cultural significance	NCW

Figure 135 – General views of the two structures at T0001.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0003	-.28.248300°S	26.681945°E	A single grave site was found at T0003. It is located within a fenced-off property (T0001) on the farm Terra Blanda No.155. The grave site which may mark the burial place of ashes is marked by an engraved granite block with palisade fencing around it. The inscription on the granite grave dressing reads as follows: "DANIE MEINTJES ★ 05.02.1974 † 12.06.2015 GELIEFDE BROER EN VRIEND TOT ONS WEER SIEN" T0003 is located within an extension buffer. It is possible that the proposed development will impact on the site.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 136 – General views of T0003.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0002	-28.247349.°S	26.683071°E	The site comprises an animal pen and loading ramp. It is located adjacent to maize fields on the farm Terra Blanda No.155. The site is rated as NCW as it has no research potential or is of other cultural significance. T0002 is located within an extension buffer. It is possible that the proposed development will impact on the site.	No research potential or other cultural significance	NCW
  *Figure 137 – General views of T0002.*					
T0004	-.28.247385°S	26.684274°E	The site comprises five brick labourer dwellings. It is located within an overgrown fenced-off property located adjacent to maize fields on the farm Terra Blanda No.155. The construction materials and technique are consistent with modern building methods. No other cultural material was identified around the site. The site was not depicted at this locality on the 2826BA topographical sheet dating to 1945 or 1954. The site is therefore younger than 60 years. As. No	No research potential or other cultural significance	NCW

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			additional information was available, the site is provisionally rated as NCW as it has no research potential or is of other cultural significance. T0004 is located within a well transect buffer. It is possible that the proposed development will impact on the site.		



Figure 138 – General views of T0004.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0005	-.28.239803°S	26.718104°E	The site comprises a brick and corrugated iron structure. It is located adjacent to maize fields on the farm Brakspruit No.121 in the south-western portion of the proposed development area. The structure has concrete brick walls and the roof is missing. The construction materials and technique are consistent with modern building methods. No other cultural material was identified around the site. **Extent**: Approximately 15m x 20m. The site is rated as NCW as it has no research potential or is of other cultural significance. T0005 is located within a well transect buffer. It is possible that the proposed development will impact on the site.	No research potential or other cultural significance	NCW

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
  *Figure 139 – General views of T0005.*					
T0006	-.28.239696°S	26.717768°E	**Please note that T006 was already recorded in the 2017 assessments as SITE 1B**. As such it was described in **Table 9**.	Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 140 – Satellite image illustrating that T0006 was previously recorded as SITE 1B.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 141 – General views of T0006 in an overgrown environment.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0007	-.28.229026°S	26.758204°E	The site comprises the poorly preserved remains of a structure on the farm Doorn River 330 (Portion 2). It is located in an overgrown partially waterlogged area and all that remains of the structure at the site are a few baked red clay bricks and stone blocks. The exact age of the structure is not known. However, two structures are depicted in proximity to this structure on both the First and Second Editions of the 2826BB topographical sheets that were surveyed in 1945 and 1954 respectively. It seems likely therefore for the site to be potentially older than 60 years. While the structure itself is too poorly preserved to have any heritage significance, the risk does exist for stillborn babies to have been buried here. Until the presence of such possible graves at the site has been proven or disproven, a worst case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. **Extent:** Approximately 20m x 20m. As T0007 is located outside the proposed development area, no mitigation is required, as no impact is expected.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 142 - General views of T0007.

Figure 143 - Sample of building materials observed at T0007.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 144 - 2826BB topographical sheet surveyed in 1945 depicts two structures at T0007.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0008	-28.236338°S	26.781216°E	The site comprises the poorly preserved remains of several structures (historical farmstead), on the farm Grusde 229. It is located in an overgrown area adjacent to cultivated fields. All that remains of the structure at the site are baked red clay bricks, stone blocks and chunks of foundation (rubble). There is also refuse scattered around the site. The exact age of the structure is not known. However, two huts are depicted in proximity to this structure on the First Edition of the 2826BB topographical sheet that was surveyed in 1945. A structure and a wind pump were depicted at this location on the Second Edition of the 2826BB topographical sheet that was surveyed in 1954. Several structures and a wind pump were depicted at this location on the Third Edition of the 2826BB topographical sheet that was surveyed in 1975.It seems likely therefore for the site to be potentially older than 60 years. While the structure itself is too poorly preserved to have any heritage significance, the risk does exist for stillborn babies to have been buried here. Until the presence of such possible graves at the site has been proven or disproven, a worst case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. **Extent:** Approximately 80m x 80m. As T0008 is located outside the proposed development area, no mitigation is required, as no impact is expected.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 145 - General view of T0008.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 146 - Rubble observed at T0008.

Figure 147 - Sample of refuse observed at T0008.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 148 - View of a water trough at T0008.

Figure 149 - 2826BB topographical sheet surveyed in 1945 depicts two huts at T0008.

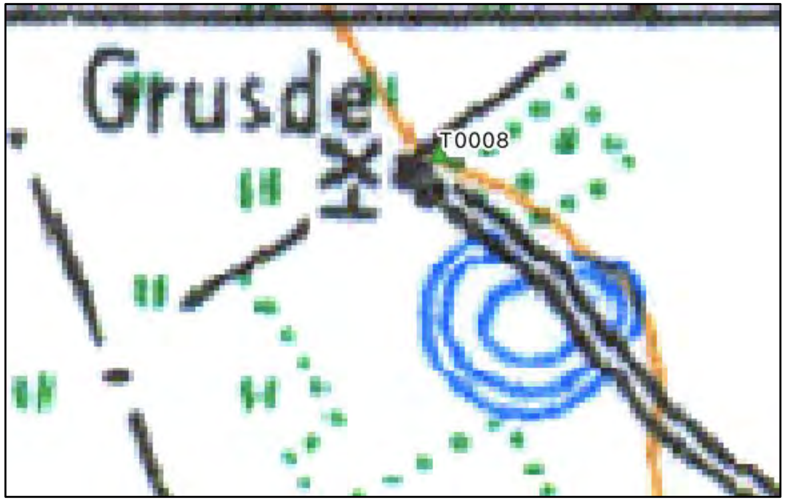
<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td colspan="3">

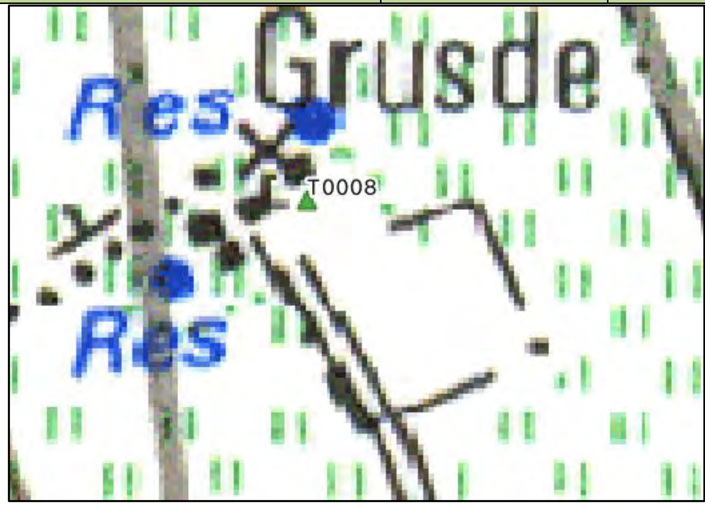
Figure 150 - 2826BB topographical sheet surveyed in 1954 depicts a structure and windpump at T0008.</td><td colspan="3">

Figure 151 - 2826BB topographical sheet surveyed in 1975 depicts several structures at T0008.</td></tr>
<tr><td>T0009</td><td>-28.226073°S</td><td>26.775525°E</td><td>The site comprises a single grave located adjacent to a farm track, within maize field, on the farm Rondehoek N.200. The grave is not maintained and the ground has been partially eroded away. The grave is marked by an engraved sandstone headstone. The inscription on the granite grave dressing is weathered by the grave dates to 1937.

A grave is depicted at this location on the First Edition of the 2826BB topographical sheet that was surveyed in 1945.

T0009 is located within a well transect buffer zone. It is possible that the site may be impacted upon by the proposed development.</td><td>High Significance</td><td>IIIA</td></tr>
</table>

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 152 - Views of the grave at T0009.*					

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 153 - Closer view of the grave at T0009.

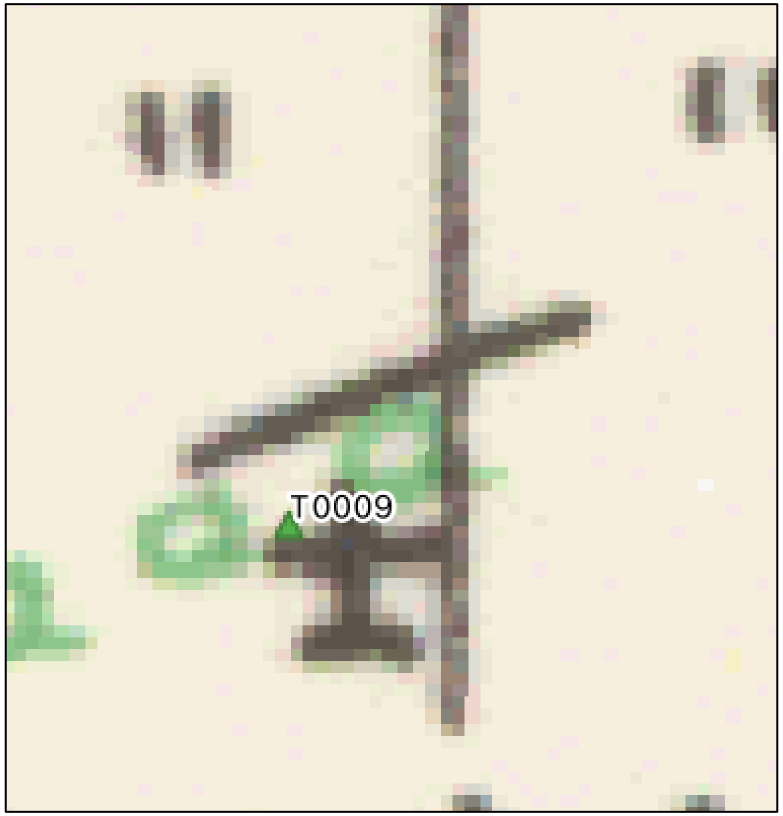


Figure 154 - 2826BB topographical sheet surveyed in 1945 depicts a grave at T0009.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0010	-28.226324°S	26.803788°E	The site comprises an extensive burial ground with both formal and informal graves. It is located approximately 170m west of a farm track on the farm Digito No. 642. The area is very overgrown but it is estimated that at least fifty graves are located at this site. The burial ground is not maintained and a number of headstones were dislodged. There were several types of grave dressing types identified at the burial ground. For the most part, these grave dressings were orientated along the east-west axis. The following grave dressings were identified at the cemetery: ▪ Upright stones at the head and foot of the grave ▪ Stone packed grave dressing with unmarked stone as headstone ▪ Stone packed grave dressing with marked stone headstone ▪ Metal marker without any other dressing components ▪ Stone packed grave dressing with granite headstone ▪ Rectangular brick-line dressing with granite headstone Several huts are depicted in proximity to this burial ground on the First Edition of the 2826BB topographical sheet that was surveyed in 1945. The extensive size of the cemetery suggests that it was associated with a reasonably large community. As T0010 is located outside the proposed development area, no impact is expected.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 155 - General view of T0010.*					

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 156 – View of grave with metal marker at T0010.

Figure 157 - Rectangular brick-line dressing with granite headstone at T0010.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 158 – View of overgrown stone packed grave dressing at T0010.

Figure 159 - View of overgrown stone packed grave dressing with unmarked stone as headstone at T0010.

Figure 160 – Engraved stone headstone at T0010.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 161 – Overgrown grave with granite headstone at T0010.

Figure 162 - View of stone headstone at T0010.

Figure 163 - 2826BB topographical sheet surveyed in 1945 depicts several huts at T0010.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0011	-28.223779°S	26.800728°E	The site comprises the remains of historical structure adjacent to an avenue of trees. It is located in an overgrown area approximately 210m south of a farm track on the farm Digito No. 642. All that remains of the structure at the site are baked red clay bricks, stone and cement blocks (rubble). The exact age of the structure is not known. However, a structure is depicted at this location on the First Edition of the 2826BB topographical sheet that was surveyed in 1945. It seems likely therefore for the site to be potentially older than 60 years. While the structure itself is too poorly preserved to have any heritage significance, the risk does exist for stillborn babies to have been buried here. Until the presence of such possible graves at the site has been proven or disproven, a worst case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. **Extent:** Approximately 80m x 80m. As T0011 is located outside the proposed development area, no mitigation is required, as no impact is expected.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 164 - General view of T0011.

Figure 165 - View of rubble at T0011.

Figure 166 - Closer view of rubble at T0011.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			 *Figure 167 - 2826BB topographical sheet surveyed in 1945 depicts a structure and avenue of trees at T0011.*		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0012	-28.220937°S	26.753686°E	**Please note that T012 was already recorded in the 2017 assessments as TET 15**. As such it was described in **Table 9**. At the time of the field assessment the two graves were overgrown and waterlogged.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

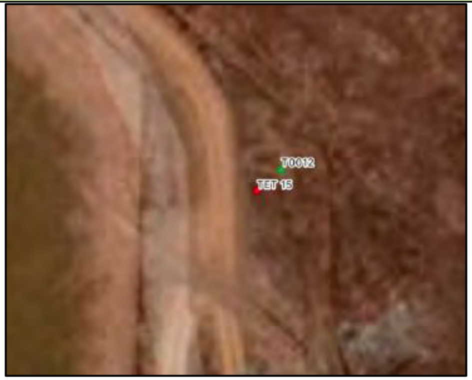


Figure 168 – Satellite image illustrating that T0012 was previously recorded as TET 15.

Figure 169 – General views of the overgrown and waterlogged graves at T0012.

<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td>T0013</td><td>-28.184090°S</td><td>26.804759°E</td><td>The site comprises a fenced-off burial ground with five graves (two formal, three informal). It is located adjacent to a tar road (R730) on the farm Doorn River No.330 (Portion 5). Graves of the Human family were found here.

The area is very overgrown and is not maintained. There were several types of grave dressing types identified at the burial ground. For the most part, these grave dressings were orientated along the east-west axis. The following grave dressings were identified at the cemetery:

▪ Stone packed grave dressing with unmarked stone as headstone
▪ Rectangular brick-line dressing with granite headstone

The inscription on the one granite grave dressing reads as follows:
“IN MEMORIAM
HIER RUS ONS DIERBARE EGGENOTE EN MOEDER
SUSANNA ELIZABETH HUMAN (GEE. MARAIS)
GEB. 9 JULIE 1872 - OVERL. 22 NOV 1928
STILLE RUST PLAATS VAN GOD’S DOGTER…”

A grave is depicted in proximity to this burial ground on the Third Edition of the 2826BB topographical sheet that was surveyed in 1975.

As T0013 is located outside the proposed development area, no impact is expected.</td><td>High Significance</td><td>IIIA</td></tr>
</table>

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 170 - General view of the graves at T0013.

Figure 171 - View of an overgrown stone packed grave at T0013.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 172 – Views of the two granite headstones observed at T0013.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 173 - 2826BB topographical sheet surveyed in 1975 depicts a grave at T0013.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0014	-28.184780°S	26.801970°E	The site comprises the remains of a historical structure. adjacent to a tar road (R730) on the farm Doorn River No.330 (Portion 5). It is likely that the graves at T0013 are associated with T0014. The materials used in the construction indicate a mix of local stone and modern plastered brick, which suggests modification and additions through time. There is also refuse (incl. a horse shoe) scattered around the site. **Extent**: Approximately 9m x 12m. Two structures were depicted at this locality on the 2826BB topographical sheet dating to 1945 and 1954. It seems likely therefore for the site to be potentially older than 60 years. As no additional information was available, the site is provisionally rated as IIIB with medium heritage significance. T0014 is located outside of the proposed development areas. It is unlikely that the proposed development will impact on the site.	Medium Significance	IIIB



Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 174 - General views of the ruin at T0014.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 175 - Horse shoe identified at T0014.

Figure 176 - 2826BB topographical sheet surveyed in 1945 depicts a grave at T0014.

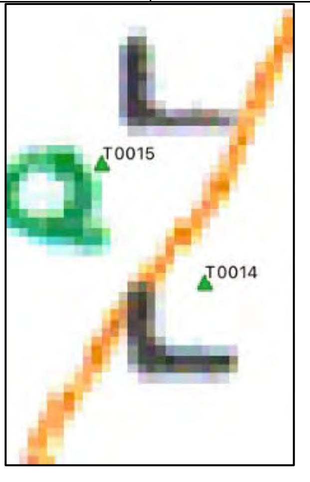


Figure 177 - 2826BB topographical sheet surveyed in 1954 depicts a grave at T0014.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0015	-28.184260°S	26.801520°E	The site is a possible grave situated adjacent to T0014. The only indication that it is possibly a grave is the stones at the head and foot. T0015 is located outside of the proposed development areas. It is unlikely that the proposed development will impact on the site.	High Significance	IIIA

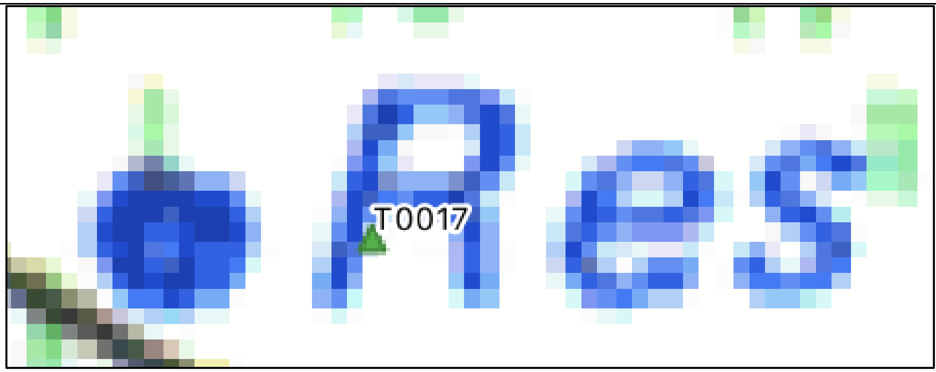
Figure 178 - General view of T0015.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0016	-28.183344°S	26.802529°E	The site comprises a stone kraal which is divided into a large and smaller enclosure. It is likely that the graves (T0013) and ruin (T0014) are associated with this site. No other cultural material was identified around the site. **Extent:** approximately 15m x 42m and 8m x 15m	Low Significance	IIIC

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			As no additional information was available, the site is provisionally rated as IIIC with low heritage significance. T0016 is located outside of the proposed development areas. It is unlikely that the proposed development will impact on the site.		

Figure 179 - General views of the stone kraals at T0016.

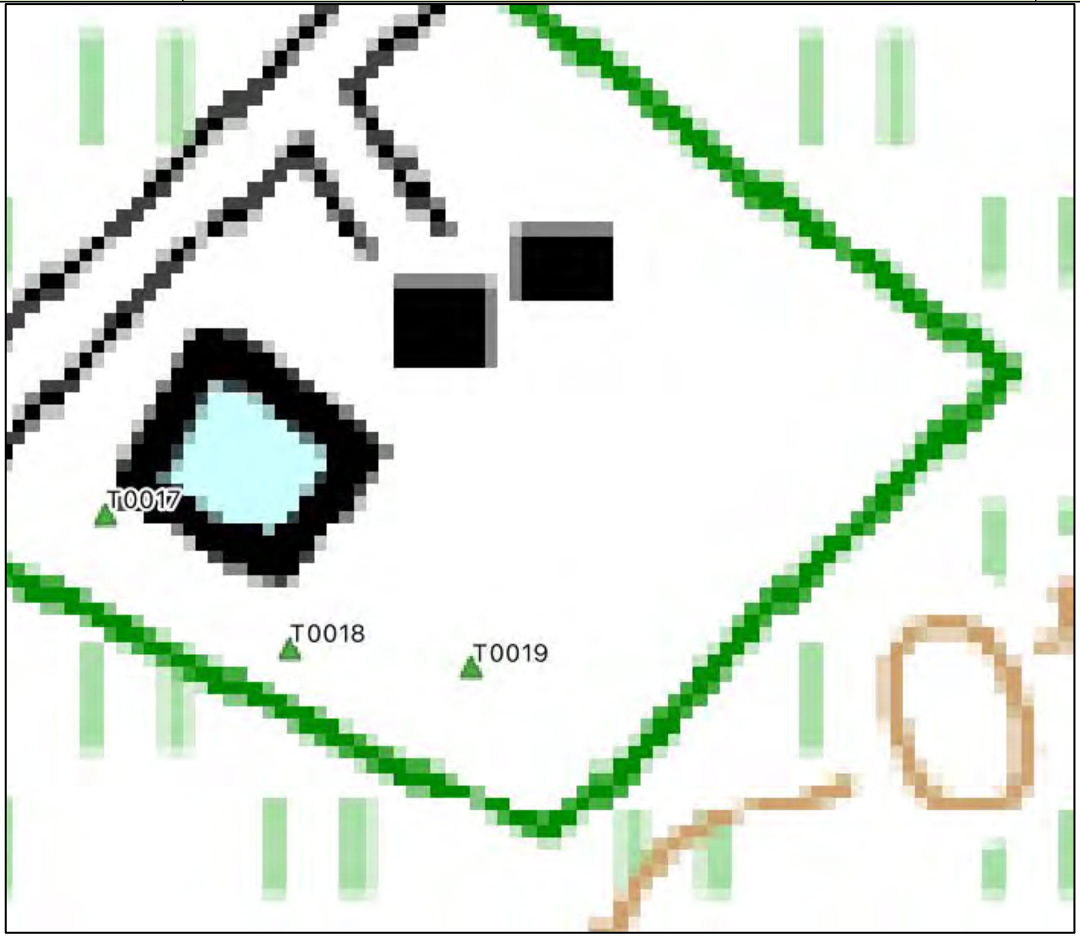
Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0017	-28.184868°S	26.750606°E	The site comprises a historical reservoir which is located adjacent to ploughed fields in a very overgrown area. It is situated on the farm Kalkoenkrans No. 225 (Portion 2). **Extent:** approximately 50m x 58m A reservoir was depicted at this locality on the 2826BB topographical sheet dating to 1975. As no additional information was available, the site is provisionally rated as IIIC with low heritage significance. T0017 is located within a well transect buffer. It is possible that the proposed development will impact on the site.	Low Significance	IIIC

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
  Figure 180 - General views of T0017.					
 Figure 181 - 2826BB topographical sheet surveyed in 1975 depicts a grave at T0017.					

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0018 and T0019	-28.185277°S/ -28.185337°S	26.751167°E/ 26.751725°E	The site comprises numerous concrete foundations of structures which are located in a very overgrown area. It is situated on the farm Kalkoenkrans No. 225 (Portion 2). A possible midden was also identified in the area. Several structures were depicted at this locality on the 2826BB topographical sheet dating to 1997. As no additional information was available, and all the structures have been demolished, the site is provisionally rated as IIIC with low heritage significance. The site is located within a well transect buffer. It is possible that the proposed development will impact on the site.	Low significance	IIIC




Figure 182 - General views of T0018 and T0019.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			 Figure 183 - 2826BB topographical sheet surveyed in 1997 depicts two structures in the vicinity of T0018 and T0019.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0020	-28.180938°S	26.7544069°E	The site comprises the remains of a core yard which are located in a very overgrown area. It is situated on the farm Kalkoenkrans No. 225 (Portion 2). A possible midden was also identified in the area. As no additional information was available, the site is provisionally rated as IIIC with low heritage significance. The site is located within a well transect buffer. It is possible that the proposed development will impact on the site.	Low significance	IIIC
 *Figure 184 - General views of T0020.*					
T0021	-28.091772°S	26.734648°E	The site comprises the remains of a historical farm complex. adjacent to a farm track, approximately 300m south-east of the existing farm house on the farm Adamsonsvlei 655. It is likely that the sites at is also associated with TET 1, TET 2 and TET 3. The materials used in the construction indicate a mix of local stone, baked red clay bricks and concrete, which suggests modification and additions through time. There is also the remains of a stone fountain and an anti-erosional wall. **Extent**: Approximately 40m x 50m. Two structures were depicted at this locality on the 2826BA topographical sheet dating to 1945 and multiple structures were depicted at this locality on	Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			the 2826BA topographical sheet dating to 1954. It seems likely therefore for the site to be potentially older than 60 years. As no additional information was available, the site is provisionally rated as IIIB with medium heritage significance. T0021 is located within a well transect buffer. It is possible that the proposed development will impact on the site.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 185 - General views of the historical farmstead ruin at T0021.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating


Figure 186 - Views of the different building materials and methods observed at T0021.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 187 - View of the remnants of walling at T0021.

Figure 188 - Views of foundations observed at T0021.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 189 - View of the stone fountain at T0021.

Figure 190 - View of anti-erosion walling at T0021.

Figure 191 - 2826BA topographical sheet surveyed in 1945 depicts two structures in the vicinity of T0021.

Figure 192 - 2826BA topographical sheet surveyed in 1954 depicts several structures and an anti-erosion wall in the vicinity of T0021.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0022	-28.096527°S	26.737295°E	The site comprises two ruins located adjacent to a farm track on the farm Adamsonsvlei 655. The structures were made out of clay sundried bricks, stone and wood. No other cultural material was identified around the site. Several structures were depicted at this locality on the 2826BA topographical sheet dating to 1997. As no additional information was available, the site is provisionally rated as IIIC with low heritage significance. T0022 is located approx. 50m outside of a proposed well transect buffer . It is unlikely that the proposed development will impact on the site.	Low Significance	IIIC

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 193 - General view of the ruins at T0022.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 194 - Closer view of the construction materials used at T0021.

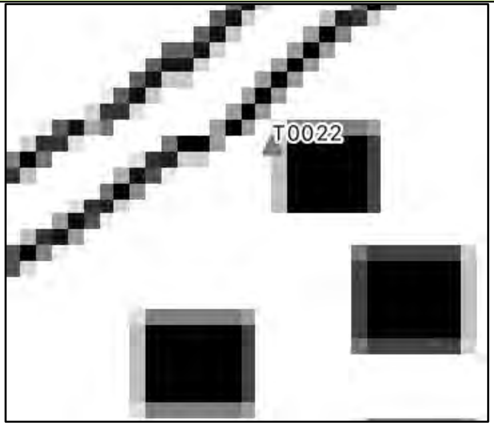
<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td colspan="6">

Figure 195 - 2826BA topographical sheet surveyed in 1997 depicts several structures in the vicinity of T0021.</td></tr>
<tr><td>T0023</td><td>-28.097008°S</td><td>26.738023°E</td><td>The site was depicted as a several huts, on the farm Adamsonsvlei No. 655, on an early topographic map sheet surveyed during the 1940s and 1950s. The remains of the site identified in the field consist of a stone and brick rubble.

Although the exact age of the structure is not known, it is certainly older than 60 years. The Primrose bricks observed at the site may date back to the 1930s-40s. The bricks were made by hand, sun-dried and kiln-baked.

Several huts were depicted at this locality on the 2826BA topographical sheet dating to 1945 and 1954. It must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here.

As T0023 is approx. 20m adjacent to a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.</td><td>Medium-High Significance</td><td>IIIA</td></tr>
</table>

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 196 - General view of T0023.

Figure 197 - View of stone and brick rubble observed at T0023.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 198 - Section of the1945 topographical map showing two huts in the vicinity of T0023.

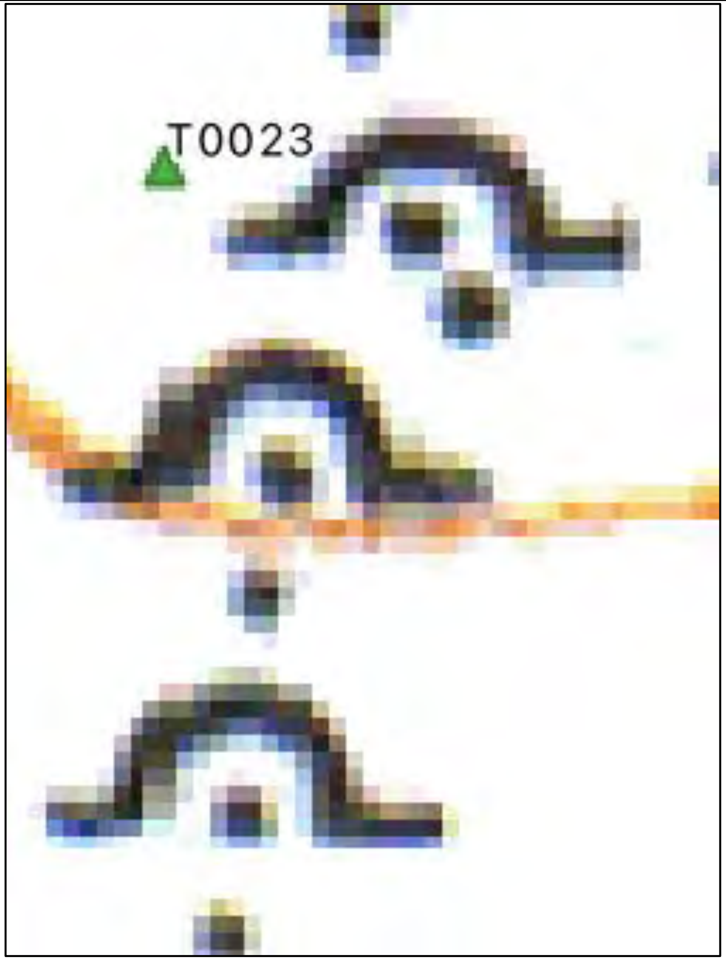


Figure 199 - Section of the1954 topographical map showing three huts in the vicinity of T0023.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0024	-28.097317°S	26.740014°E	An extensive cemetery comprising at least 100 formal and informal graves is located on the farm Adamsonsvlei No. 655. The cemetery is very overgrown and not maintained, and as such the exact number of graves could not be determined. It is evident that the cemetery is still being used as more recent grave sites were observed. A number of headstones were seen in a fallen-down state and some grave sites were being eroded out. Several different grave dressing types could be identified at the cemetery. For the most part, these grave dressing were orientated along the east-west axis. The following grave dressings were identified at the cemetery: ▪ Upright stones at the head and foot of the grave ▪ Stone packed grave dressing with upright unmarked stone as headstone ▪ Stone packed grave dressing with metal marker as headstone ▪ Rectangular brick-line dressing with granite headstone ▪ Rectangular brick-lined dressing with cement headstone ▪ Rectangular granite-lined dressing with granite headstone ▪ Metal marker without any other dressing components ▪ Cement headstone without any other dressing components A churchyard was depicted at this locality on the 2826BA topographical sheet dating to 1945. The extensive size of the cemetery suggests that it was associated with a reasonably large community and that several generations of families have been buried at this site. **Extent:** Approximately 55m x 75m. As T0024 is located within an extension buffer zone, it is possible that the site may be impacted upon by the proposed development.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating


Figure 200 - Views of the signage and access gate to T0024.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 201 – One of the formal graves observed at T0024.

Figure 202 – View of a cement headstone at T0024.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 203 – One of the stone packed grave dressings at T0024.

Figure 204 – View of a metal grave marker at T0024.

Figure 205 - Section of the1945 topographical map showing a churchyard in the proximity of T0024.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0025	-28.121075°S	26.683404°E	The site comprises a ruin and stone wall reservoir. It is located adjacent to a farm track on the Farm De Klerks Kraal No.231 (portion 7). The structure was made out of bricks and cement. No other cultural material was identified around the site. No structure was depicted on any of the topographical maps but a reservoir was depicted adjacent to this locality on the 2826BA topographical sheet dating to 1997. As no additional information was available, the site is provisionally rated as IIIC with low heritage significance. As T0025 is located within a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	Low Significance	IIIC

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating


Figure 206 - General views of the ruin at T0025.

Figure 207 - General view of the overgrown stone wall reservoir at T0025.

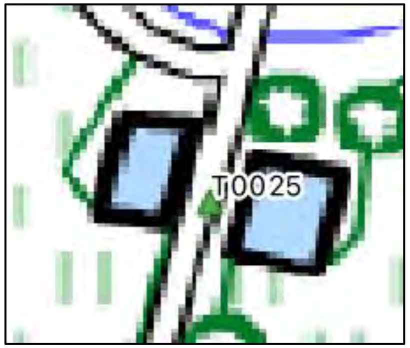


Figure 208 - Section of the1997 topographical map showing a reservoir at T0025.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0026	-28.133914°S	26.807963°E	The site comprises the remains of homestead in a very overgrown field on the Farm Hakkies No. 742.The site was depicted as a single hut on the 2826BB topographic map sheet surveyed during the 1940s. Several huts were depicted on the topographical map sheet surveyed during the 1950s. The remains of the site identified in the field consist of a line of stones. Although the exact age of the structure is not known, it is certainly older than 60 years. It must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. As T0026 is not located within the proposed development area, it is unlikely that the site may be impacted upon.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

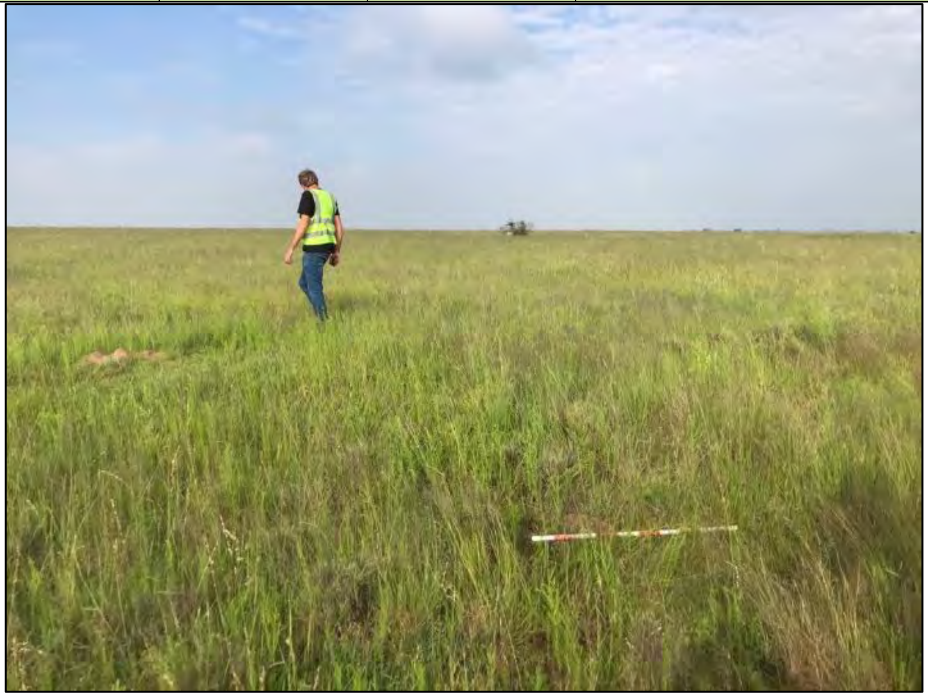
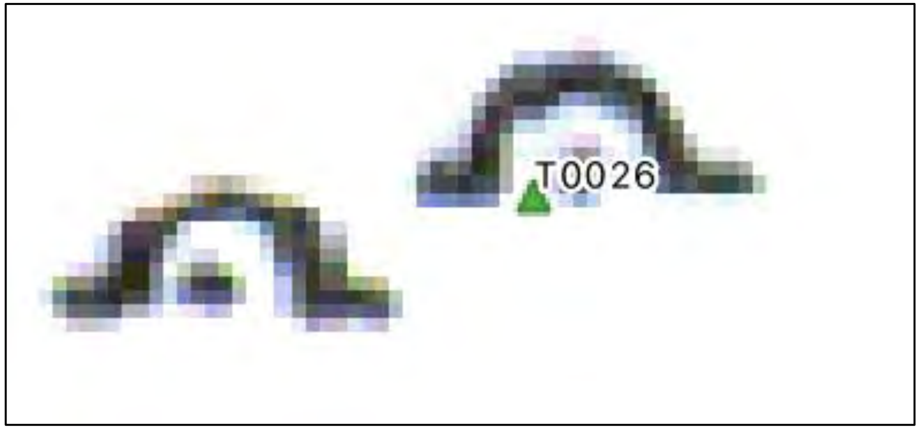


Figure 209 - General view of T0026.

Figure 210 - View of the line of stones observed at T0026.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 211 - Section of the1945 topographical map showing a single hut at T0026.*			 *Figure 212 - Section of the1954 topographical map showing several huts in the proximity of T0026.*		
T0027	-28.133049°S	26.807810°E	The site comprises the remains of homestead in a very overgrown field on the Farm Hakkies No. 742.The site was depicted as a single hut on the 2826BB topographic map sheet surveyed during the 1940s. Several huts were depicted on the topographical map sheet surveyed during the 1950s. The remains of the site identified in the field consist of a few lines of stones and fragments of ceramics, glass and metal. Although the exact age of the structure is not known, it is certainly older than 60 years. It must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			As T0027 is not located within the proposed development area, it is unlikely that the site may be impacted upon.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 213 - General view of T0027.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 214 - Sample of ceramic fragments observed at T0027.

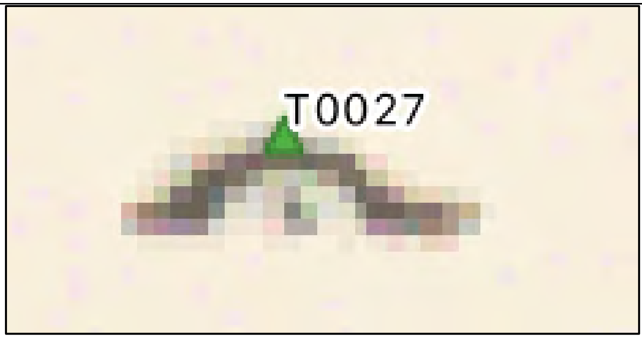


Figure 215 - Section of the1945 topographical map showing a single hut at T0027.

Figure 216 - Section of the1954 topographical map showing several huts in the proximity of T0027.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0028	-28.131855°S	26.807071°E	The site comprises the remains of homestead in a very overgrown field on the Farm Hakkies No. 742.The site was depicted as a single hut on the 2826BB topographic map sheet surveyed during the 1940s. Several huts were depicted on the topographical map sheet surveyed during the 1950s. The remains of the site identified in the field consist of lines of stones and fragments of ceramics, glass and metal. Although the exact age of the structure is not known, it is certainly older than 60 years. It must be noted that in terms of black African tradition, stillborn babies were often buried in unmarked graves underneath or adjacent to the homesteads of their parents. Until the presence of such possible graves at the site has been proven or disproven, a worst-case scenario will be adopted within which it is assumed that such stillborn baby graves are indeed located here. As T0028 is not located within the proposed development area, it is unlikely that the site may be impacted upon.	Medium-High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			  Figure 217 - Views of stone lines at T0028.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 218 - Fragments of metal and glass observed at T0028.

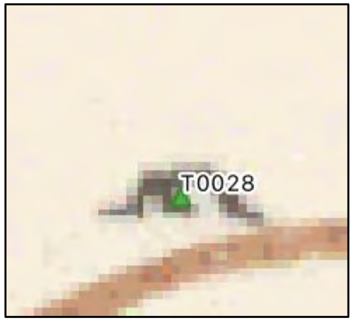


Figure 219 - Section of the1945 topographical map showing a single hut at T0028.

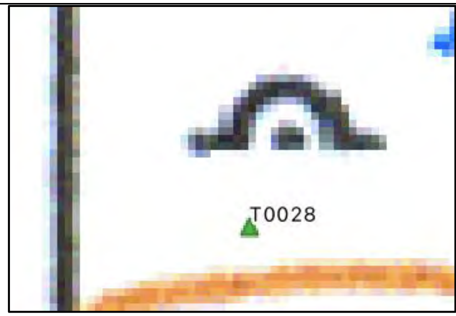


Figure 220 - Section of the1954 topographical map showing a single hut in proximity to T0028.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0029	-28.167103°S	26.634733°E	The site comprises a grave on the farm Dankbaarheid No. 16. The area is very overgrown and the fenced off grave is not maintained. It is possible that additional unmarked graves are located within the vicinity of the site. The inscription on the granite grave dressing reads as follows: "BOTHMA HIER RUS ONS VADER JACOBUS JOHANNES CEB. 20.3.1875 – OORL.16.1.1910 GOD IS LIEFDE" A single grave is depicted at this locality on the 2826BA topographical sheet dating to 1997. T0029 is located within a pipeline and well transect buffer. It is therefore possible that the site will be impacted upon by the proposed development.	High Significance	IIIA

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			 Figure 221 - General view of T0029.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 222 - Views of the grave observed at T0029.

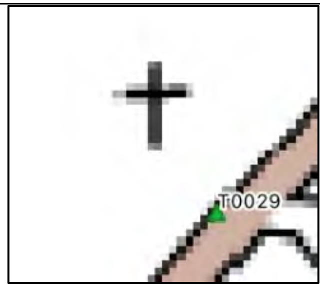


Figure 223 - Section of the1997 topographical map showing a grave in proximity to T0029.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0030	-28.168002°S	26.633488°E	The site comprises the remains of stone walling on the Farm Jordaans Rust No.59 The site possibly represents the remnants of a kraal that was depicted at this locality on the 2826BA topographical sheet dating to 1945. The kraal was associated with the main farmstead but the construction of a farm road in the area destroyed the site. T0030 is located within a well transect buffer, but due to its current state the possible impact of the proposed development will be negligible.	No research potential or other cultural significance	NCW

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 224 - Views of the T0030.

Figure 225 - Section of the1945 topographical map showing a kraal within the vicinity of T0030.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0031	-28.092487°S	26.736873°E	The site comprises a small concentration of stones. It is located within an overgrown field on the Farm Adamsonsvlei 655. No other cultural material was identified around the site. A structure was not depicted at this locality on any of the 2826BA topographical sheets. However on the topographical sheet dating to 1997, a farm track is depicted at this locality. It is possible that the stones may associated with the farm track. As no additional information is available, the site is provisionally rated as NCW. As T0031 is in a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	No research potential or other cultural significance	NCW

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating


Figure 226 - Views of the stones at T0031.

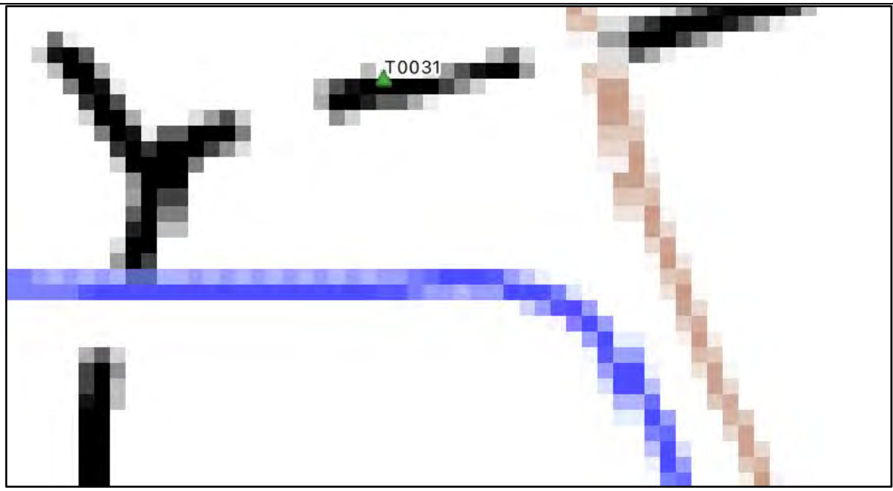


Figure 227 - Section of the1997 topographical map showing a farm track within the vicinity pf T0031.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0032	-28.092260°S	26.736122°E	**Previously recorded as TET 3 in the 2017 assessments**. As such it was described in **Table 9**.	Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

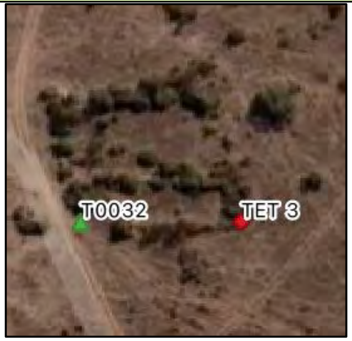
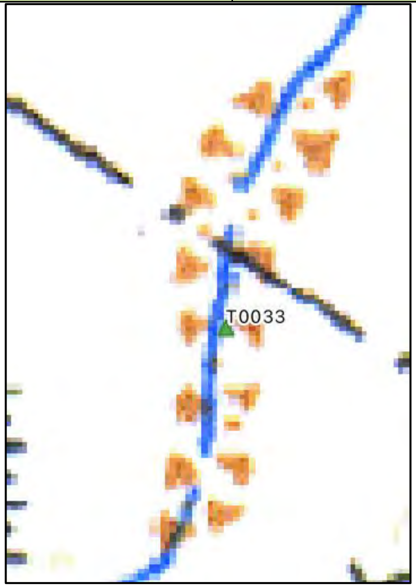


Figure 228 – Satellite image illustrating that T0032 was previously recorded as TET 3

Figure 229 - Views of the overgrown site at T0032.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0033	-28.189717°S	26.731113°E	The site comprises a 25m long packed low stone walling located adjacent to an ephemeral stream on the farm Palmiet No.328 (Portion 6). The area is very overgrown and no other cultural material was identified around the site. A terrace is depicted at this locality on the 2826BA topographical sheet dating to1954. As no additional information was available, the site is provisionally rated as NCW. As T0033 is located within a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	No research potential or other cultural significance	NCW

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 230 - General view of T0033.*			 *Figure 231 - Section of the1954 topographical map showing a terrace at T0033.*		
T0034	-28.195137°S	26.733686°E	The site comprises the remains of a concentration of stones and a dam. It is located adjacent to a farm track on the farm Palmiet No.328 (RE/328). No structures are depicted at this locality on any of the 2826BA topographical sheets. It is likely that the stones were related to the construction of the dam. As no additional information was available, the site is provisionally rated as NCW. As T0034 is located within a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	No research potential or other cultural significance	NCW

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 Figure 232 – View of the dam at T0034.			 Figure 233 – View of the stones at T0034.		
T0035	-28.187420°S	26.734432°E	The site was previously recorded as **TET13.** As T0035 is located within a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium-High Significance	IIIA

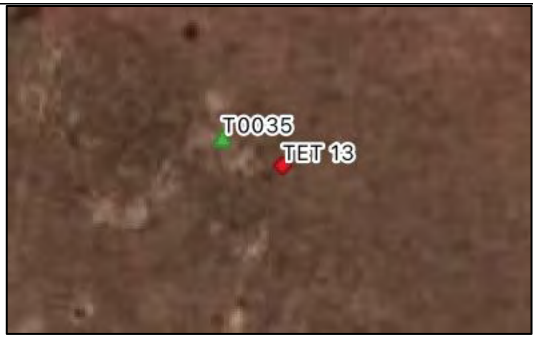


Figure 234 – Satellite image illustrating that T0035 was previously recorded as TET 13.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0036	-28.146731°S	26.756982°E	The site comprises an outhouse. It is located on the farm Kalkoenkrans No.225 (RE/225). The structure is constructed from bricks and cement. As no additional information was available, the site is provisionally rated as NCW. As T0036 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	No research potential or other cultural significance	NCW

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			 *Figure 235 - Views of T0036.*		
T0037	-28.146489°S	26.756746°E	The site comprises a two roomed ruin. It is located on the farm Kalkoenkrans No.225 (RE/225). There are the remains of walling. The materials used in the construction indicate a mix of sun-baked and cemented modern brick which suggests modification and additions through time. A structure is depicted within the vicinity of this locality on the 2826BB topographical sheet dating to 1945. The site is therefore older than 60 years. As no additional information was available, the site is provisionally rated as IIIC with low heritage significance. As T0037 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Low Significance	IIIC

Figure 236 - View of the structure at T0037.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 237 – Additional view of the structure at T0037.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 238 – Closer view of the building materials and techniques observed at T0037.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 239 - Section of the1945 topographical map showing a structure at T0037.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0038	-28.146335°S	26.756890°E	The site comprises a large ruin. It is located on the farm Kalkoenkrans No.225 (RE/225). There are the remains of walling. The materials used in the construction indicate a mix of sun-baked and cemented modern brick which suggests modification and additions through time. A structure is depicted within the vicinity of this locality on the 2826BB topographical sheet dating to 1945 and 1954. The site is therefore older than 60 years. As no additional information was available, the site is provisionally rated as IIIC with low heritage significance. As T0038 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Low Significance	IIIC

Figure 240 - Views of the ruin at T0038.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 241 – Additional views of the ruin at T0038.

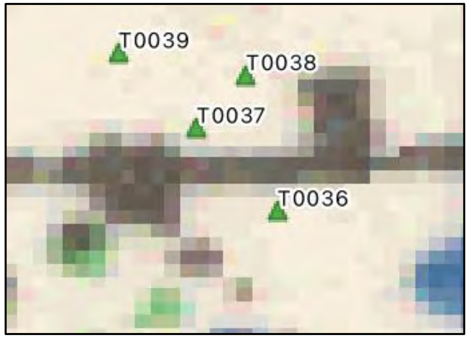
<table>
<tr><th>Site number</th><th>Lat</th><th>Lon</th><th>Description</th><th>Heritage Significance</th><th>Heritage Rating</th></tr>
<tr><td colspan="3">

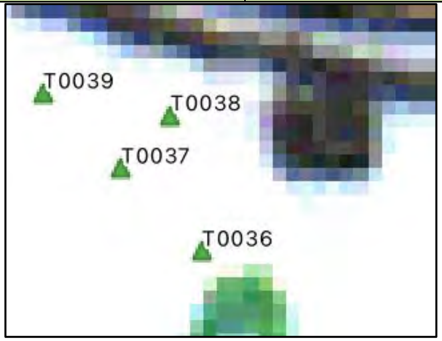
Figure 242 - Section of the1945 topographical map showing a structure within the vicinity of T0038.</td><td colspan="3">

Figure 243 - Section of the1954 topographical map showing a structure within the vicinity of T0038.</td></tr>
<tr><td>T0039</td><td>-28.146270°S</td><td>26.756518°E</td><td>The site comprises a ruin and rubble debris. It is located on the farm Kalkoenkrans No.225 (RE/225). It is likely associated with T0037 and T0038.

A structure is depicted within the vicinity of this site on the 2826BB topographical sheet dating to 1975. The site is therefore younger than 60 years. As no additional information was available, the site is provisionally rated as NCW.

As T0039 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.</td><td>No research potential or other cultural significance</td><td>NCW</td></tr>
</table>

Figure 244 - Views of T0039.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			 *Figure 245 - Section of the1975 topographical map showing a structure at T0039.*		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
T0040	-28.146529°S	26.755262°E	The site comprises a complex of stone kraals. It is located on the farm Kalkoenkrans No.225 (RE/225). A kraal is depicted within the vicinity of this site on the 2826BB topographical sheet dating to 1945. The site is therefore older than 60 years. As no additional information was available, the site is provisionally rated as IIIB. **Extent**: Approx. 30m x 60m As T0040 is located within a well transect buffer zone, it is possible that the site may be impacted upon by the proposed development.	Medium Significance	I|IIB

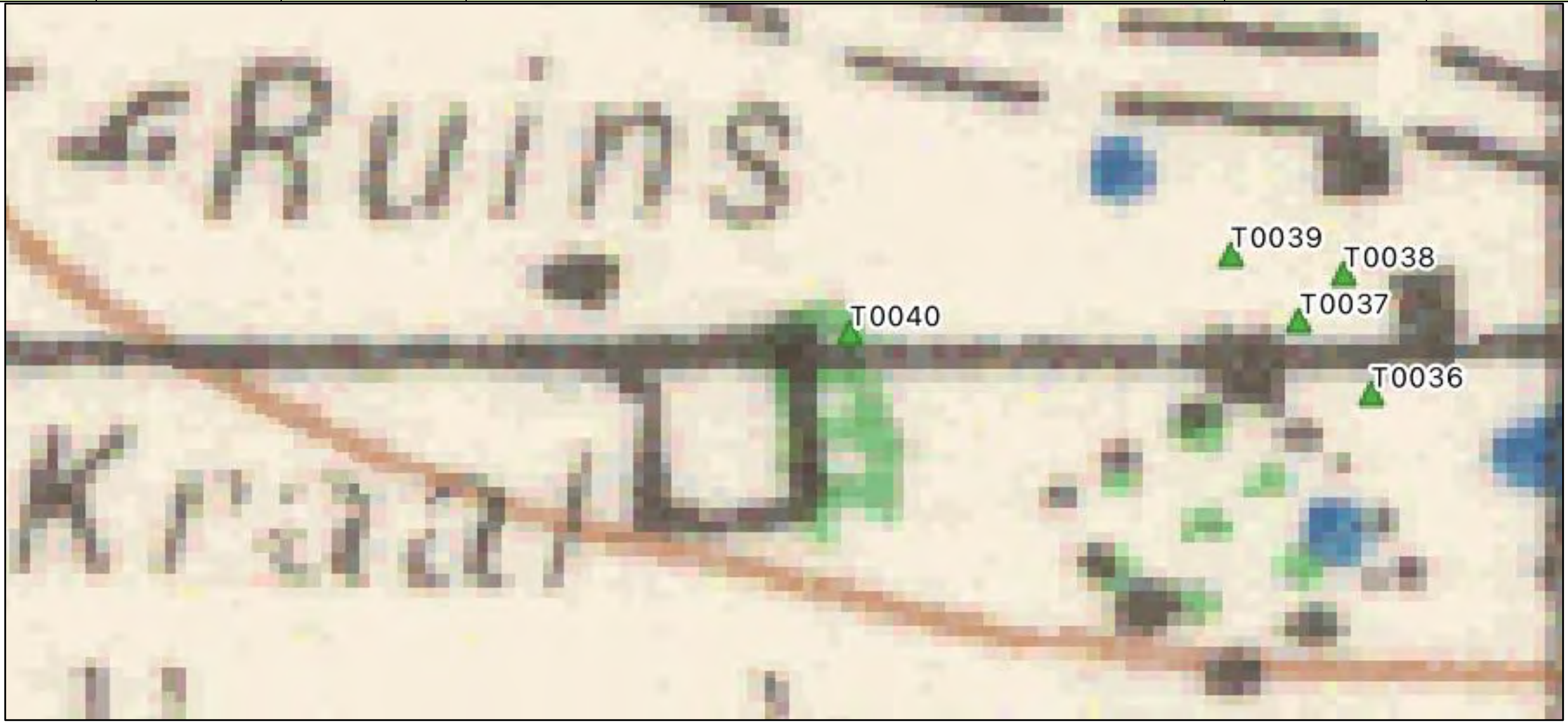
Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 246 - Views of T0040.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

Figure 247 - Closer view of the stone kraal walling at T0040.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			 Figure 248 - Closer view of the building materials used at T0040.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
 *Figure 249 - Section of the1945 topographical map showing a kraal at T0040.*					
T0041	-28.119933°S	26.720693°E	The site comprises a complex of structures on the farm Mond Van Doornrivier No.38. It is located within a very overgrown and neglected area, next to the R30 adjacent to a farm track. There is a two-roomed structure, a smaller structure, one possible animal stable, two towers and a reservoir.	Medium Significance	IIIB

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			Several structures are depicted at this locality on the 2826BA topographical sheet dating to 1954. The site is therefore older than 60 years. As no additional information was available, the site is provisionally rated as IIB. As T0041 is located within a pipeline buffer zone, it is possible that the site may be impacted upon by the proposed development.		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			 *Figure 250 - General view of T0041.*		

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating

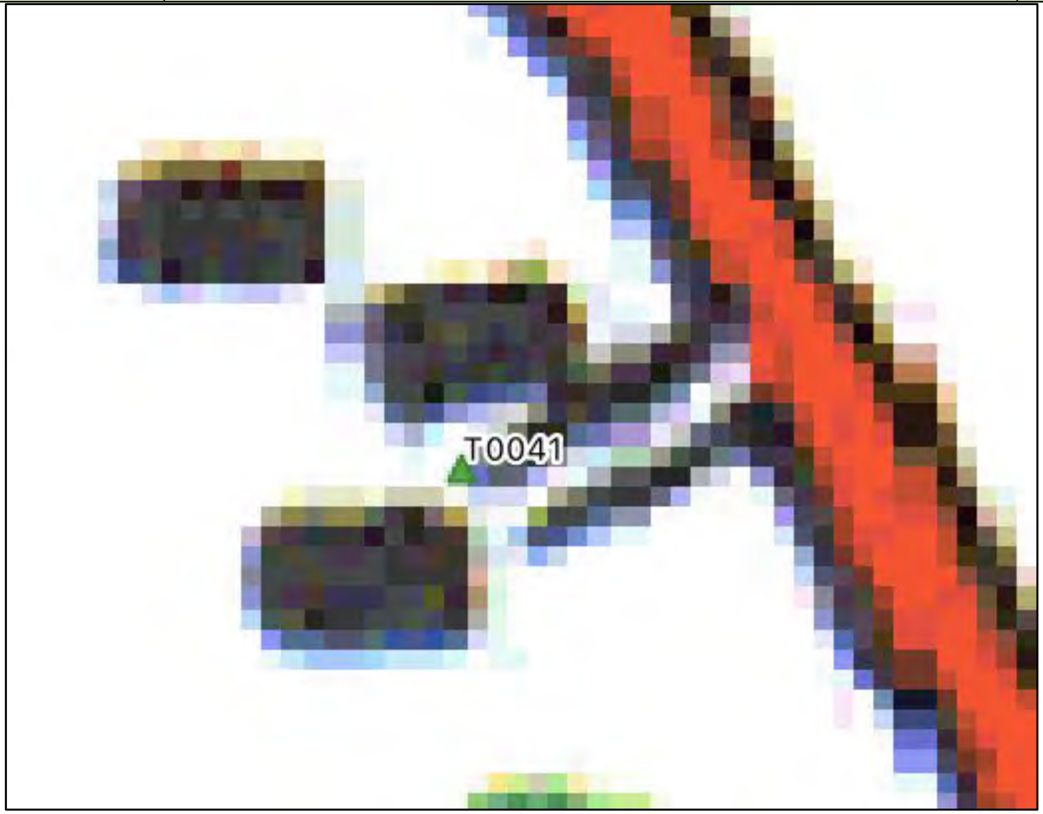

Figure 251 - Views of the two-roomed structure at T0041.

Figure 252 - View of an additional structure at T0041.

Figure 253 - Views of the possible stable at T0041.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating


Figure 254 - Views of the towers at T0041.

Site number	Lat	Lon	Description	Heritage Significance	Heritage Rating
			 *Figure 255 - Section of the1954 topographical map showing several structures at T0041.*		

6.3 SENSITIVITY ASSESSMENT OUTCOME

Thirty-five (35) heritage sites which were previously identified for a 2016/2017 assessment, fall within the footprint areas of the current proposed Tetra4 Cluster 2 Gas Production Project. There were 10 graves and burial grounds (**TET 1, TET 7-8, TET 11, TET 15, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19**), 11 structures (**TET 2-3, TET 9, TET 27, SSL/BET/25-26, SSL/BET/36, SITE 1A, SITE 1B, SITE 20-21**), 14 historic to recent sites with possible graves (**TET 4-6, TET 13-14,TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**).

During the current field assessment, a further **thirty-seven** (37) **heritage sites** were recorded. There were six (6) sites containing burial grounds and graves (**T0003, T0009, T0010, T0013, T0024, T0029**), eight (8) sites historic to recent sites with possible graves (**T0007, T0008, T0011, T0015, T0023, T0026, T0027, T0028**) and twenty-three (23) structures (**T0001, T0002, T0004, T0005, T0014, T0016, T0017, T0018, T0019, T0020, T0021, T0022, T0025, T0030, T0031, T0033, T0034, T0036, T0037, T0038, T0039, T0040, T0041**).

Thirty-seven (37) sites were rated as having high heritage significance (IIIA): **TET 1, TET 7-8, TET 11, TET 15, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19, TET 4-6, TET 13-14,TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66, T0003, T0009, T0010, T0013, T0024, T0029, T0007, T0008, T0011, T0015, T0023, T0026, T0027, T0028.**

Twelve (12) sites were rated as having medium heritage significance (IIIB): **TET 2, TET 3, TET 9, SITE 1A, SITE 1B, SITE 20, SITE 21, T0014, T0015, T0021, T0040, T0041**

Thirteen (13) sites were rated as having low heritage significance (IIIC): **TET 27, SSL/BET/25, SSL/BET/26, SSL/BET/36, T0016, T0017, T0018, T0019, T0020, T0022, T0025, T0037, T0038**

Ten (10) sites were rated as having no research potential or other cultural significance (NCW): **T0001, T0002, T0004, T0005, T0030, T0031, T0033, T0034, T0036, T0039**

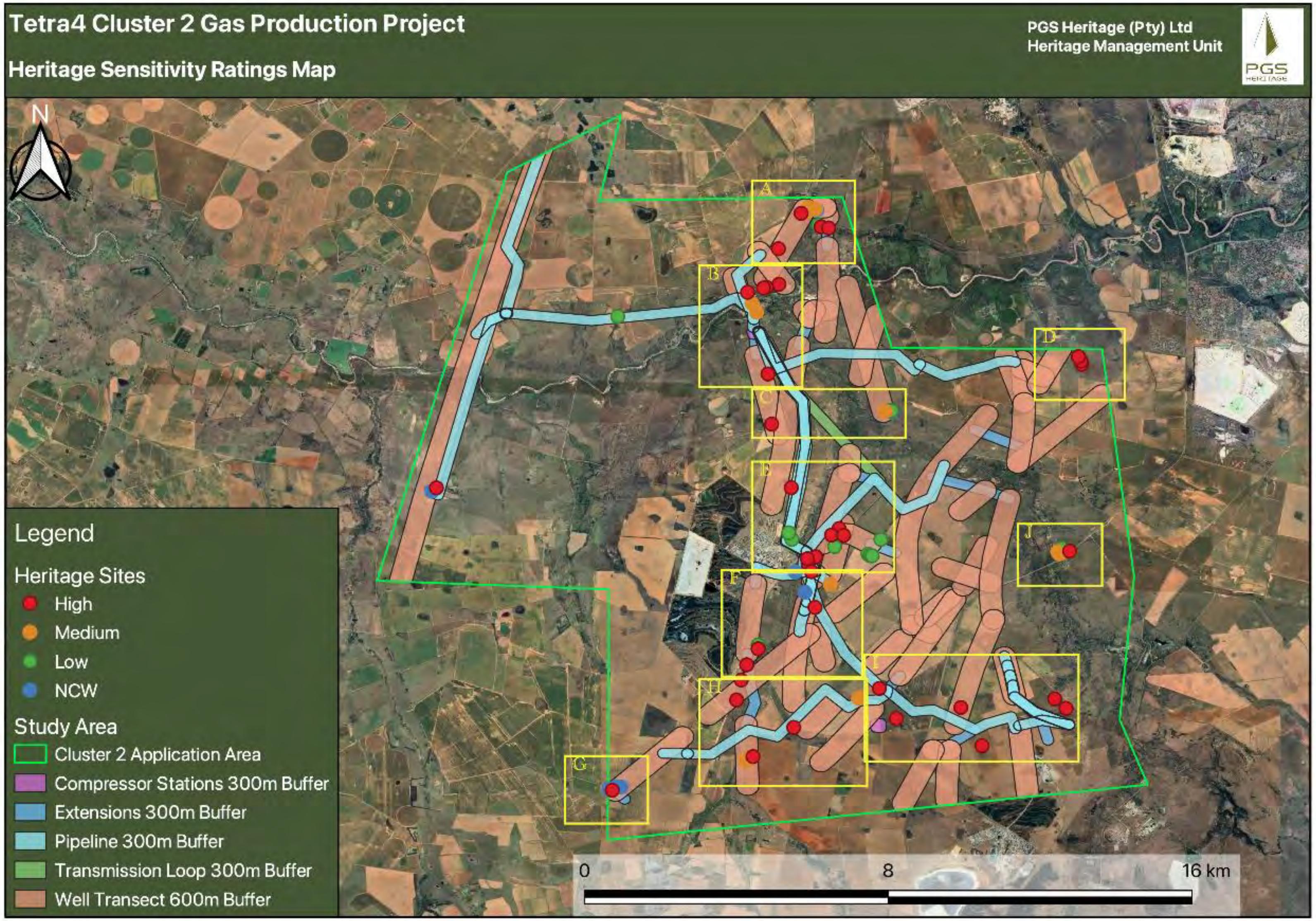


Figure 256 - Map showing heritage sensitivity rating of identified heritage resources. See insets below.

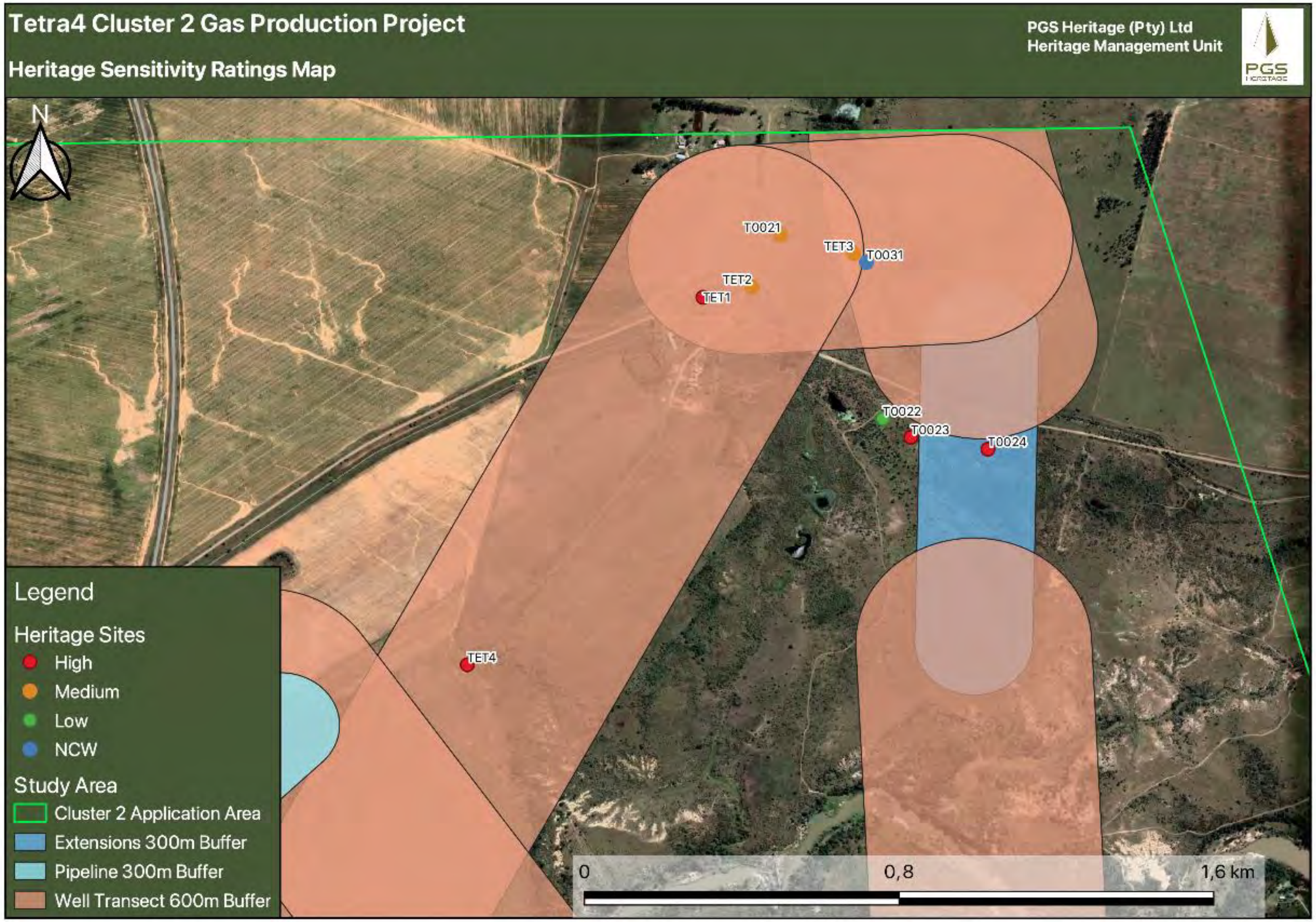


Figure 257 - Heritage sensitivity rating of identified heritage resources. Inset A.

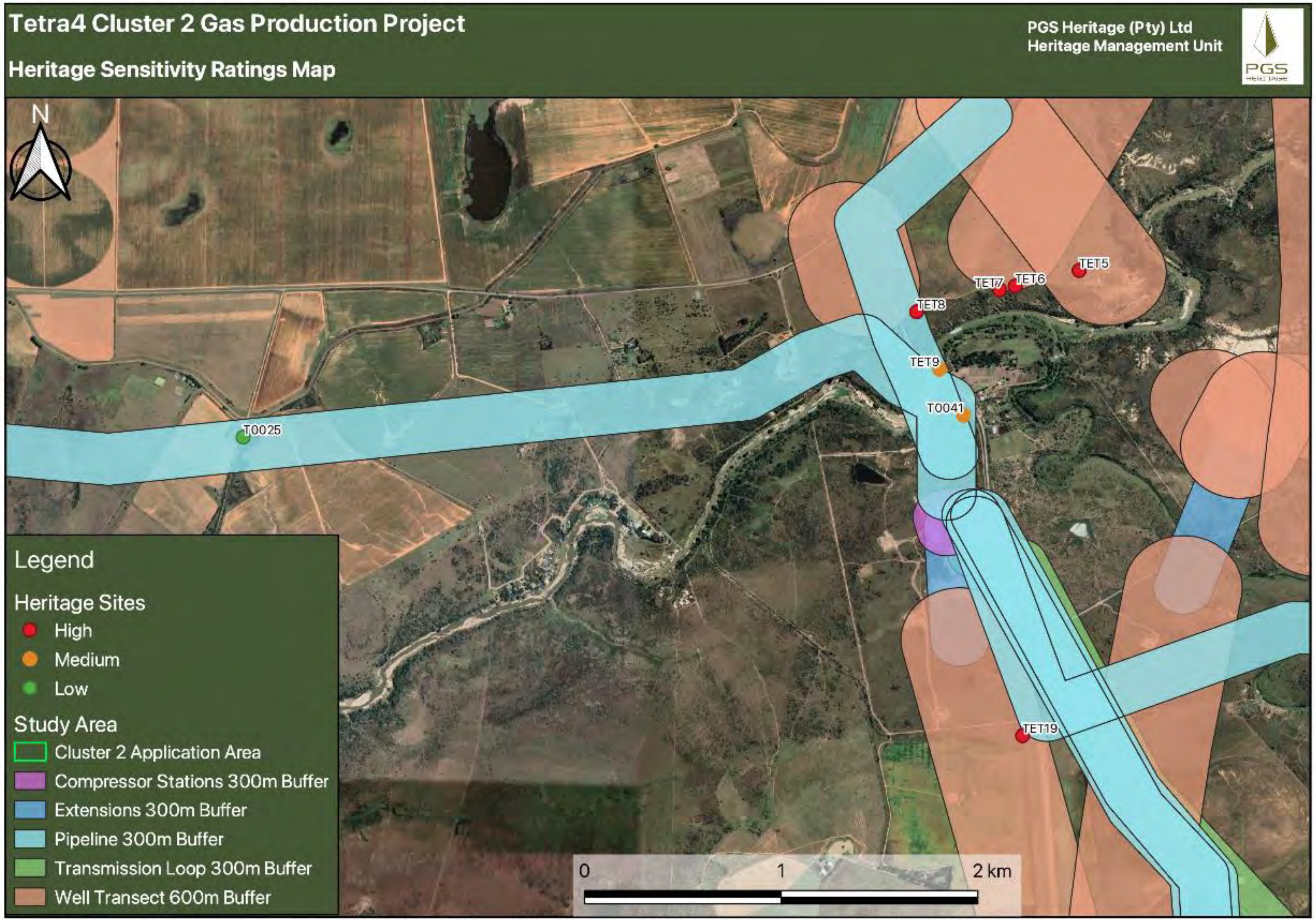


Figure 258 - Heritage sensitivity rating of identified heritage resources. Inset B.

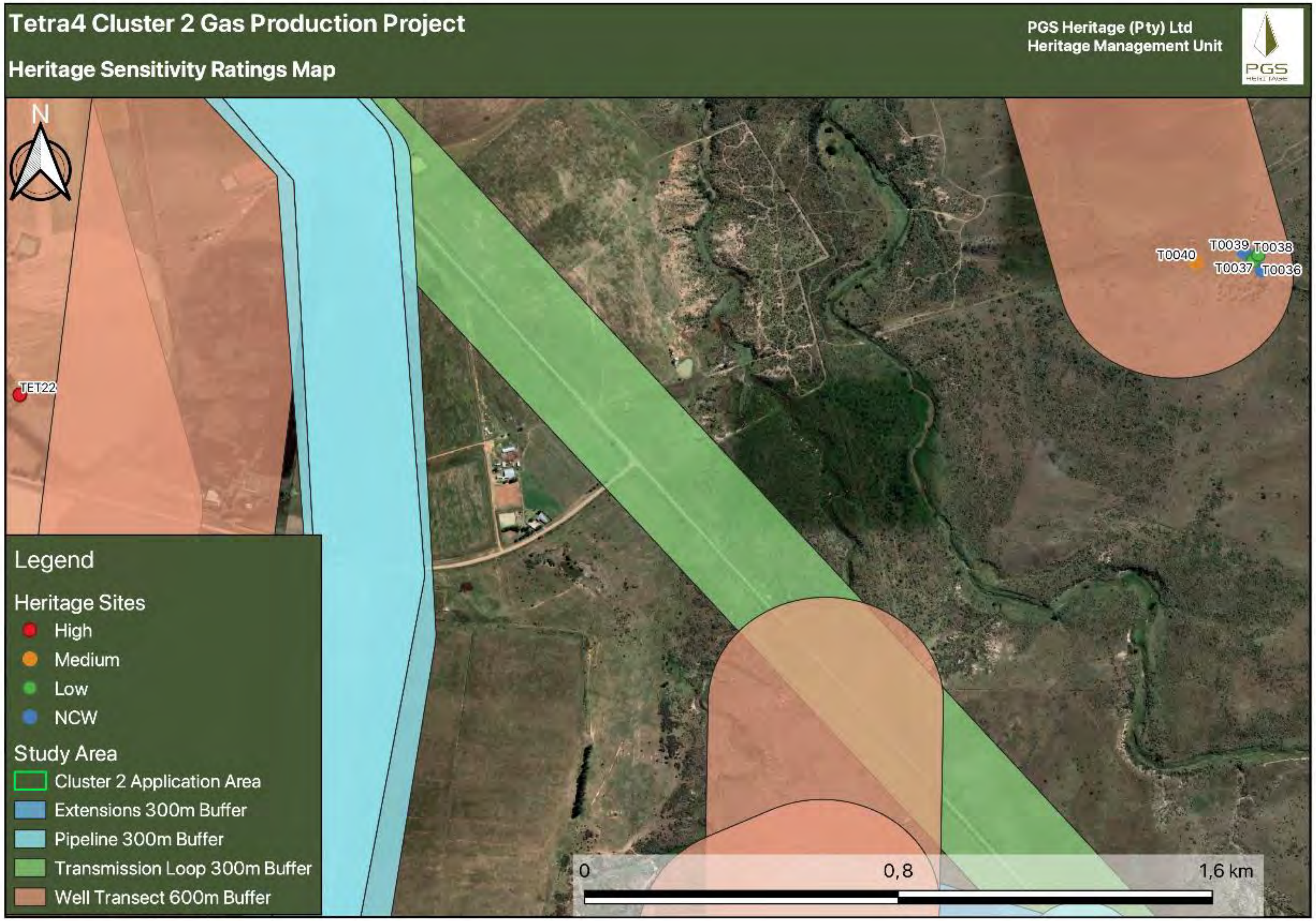


Figure 259 - Heritage sensitivity rating of identified heritage resources. Inset C.

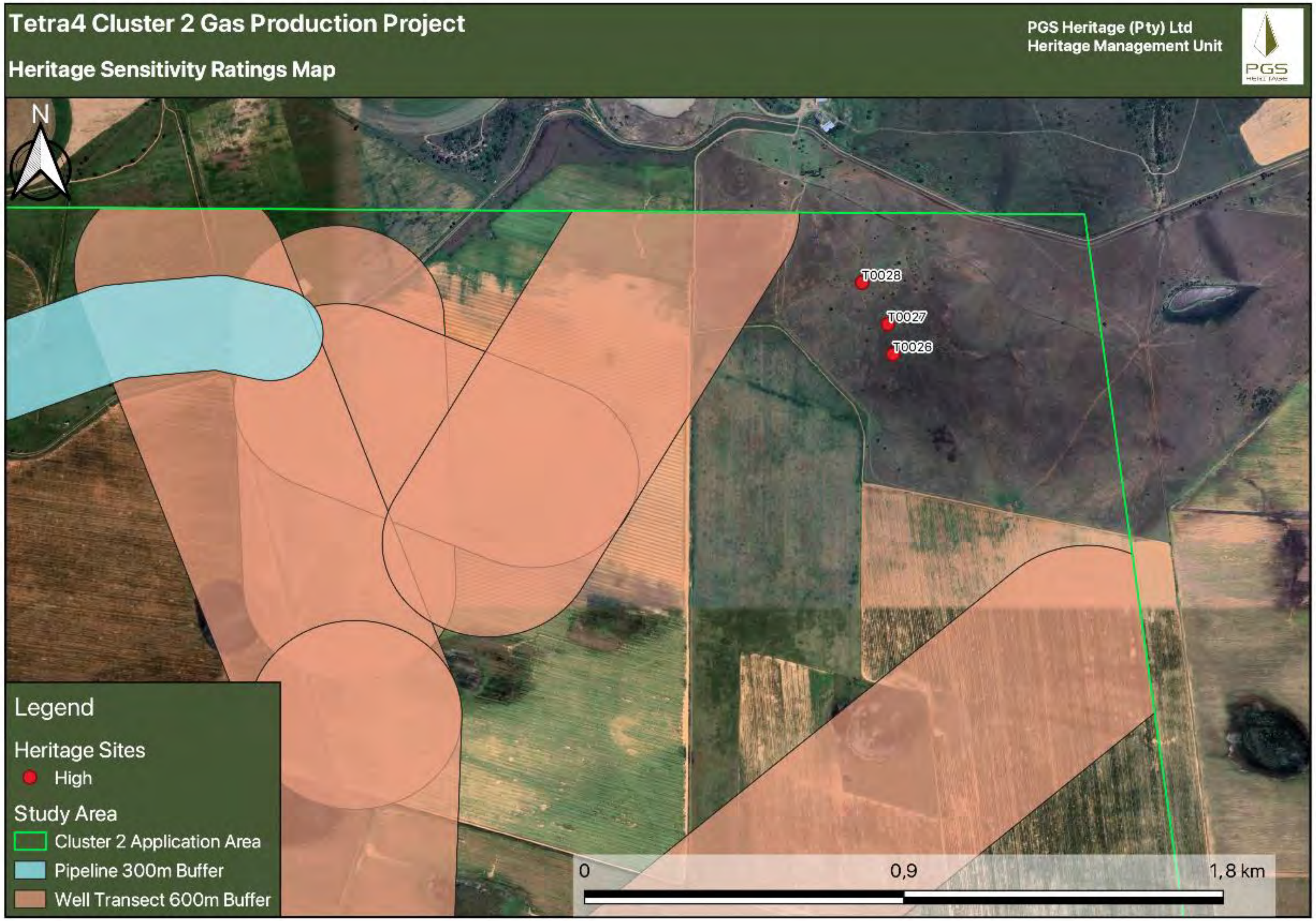


Figure 260 - Heritage sensitivity rating of identified heritage resources. Inset D.

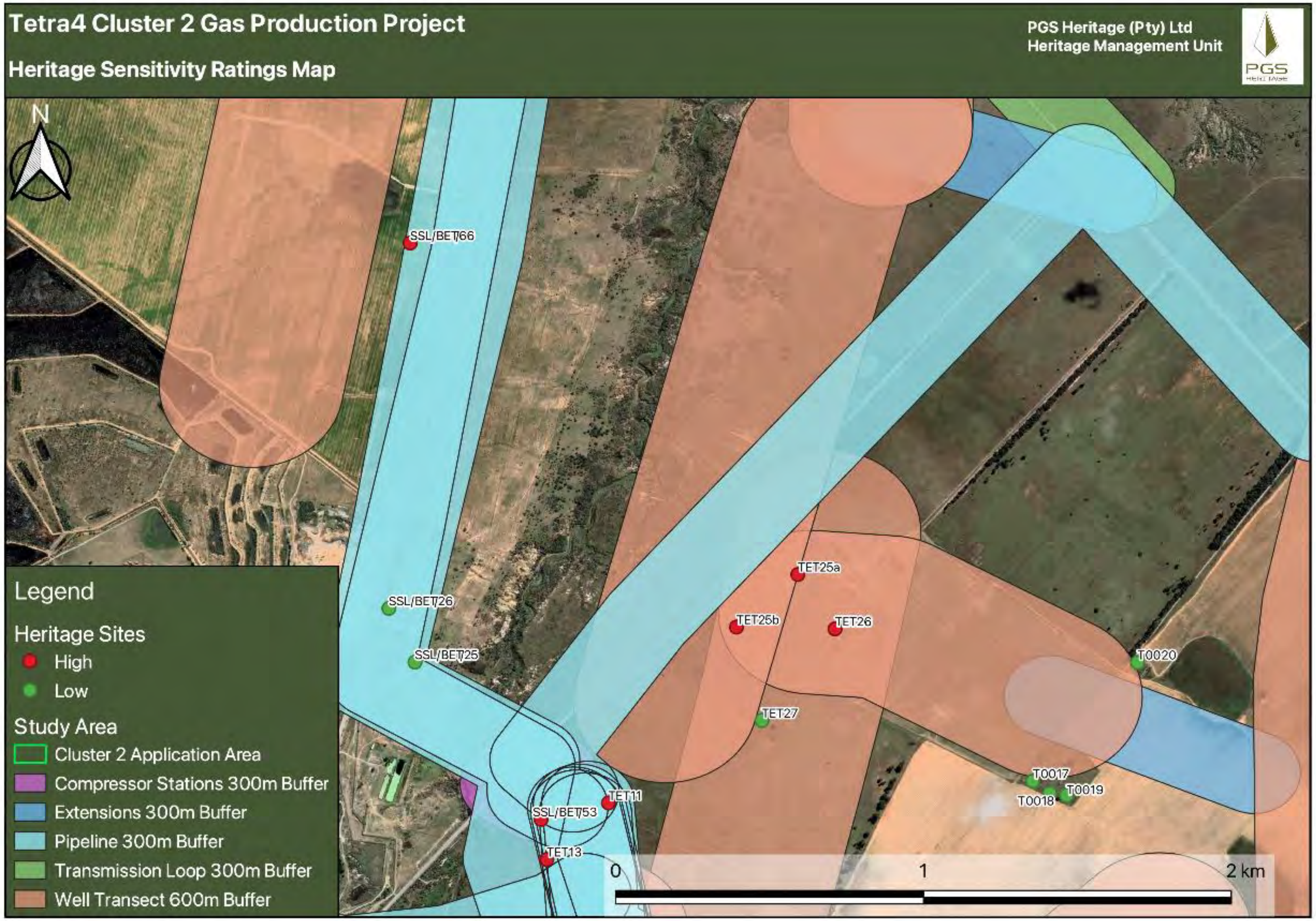


Figure 261 - Heritage sensitivity rating of identified heritage resources. Inset E.

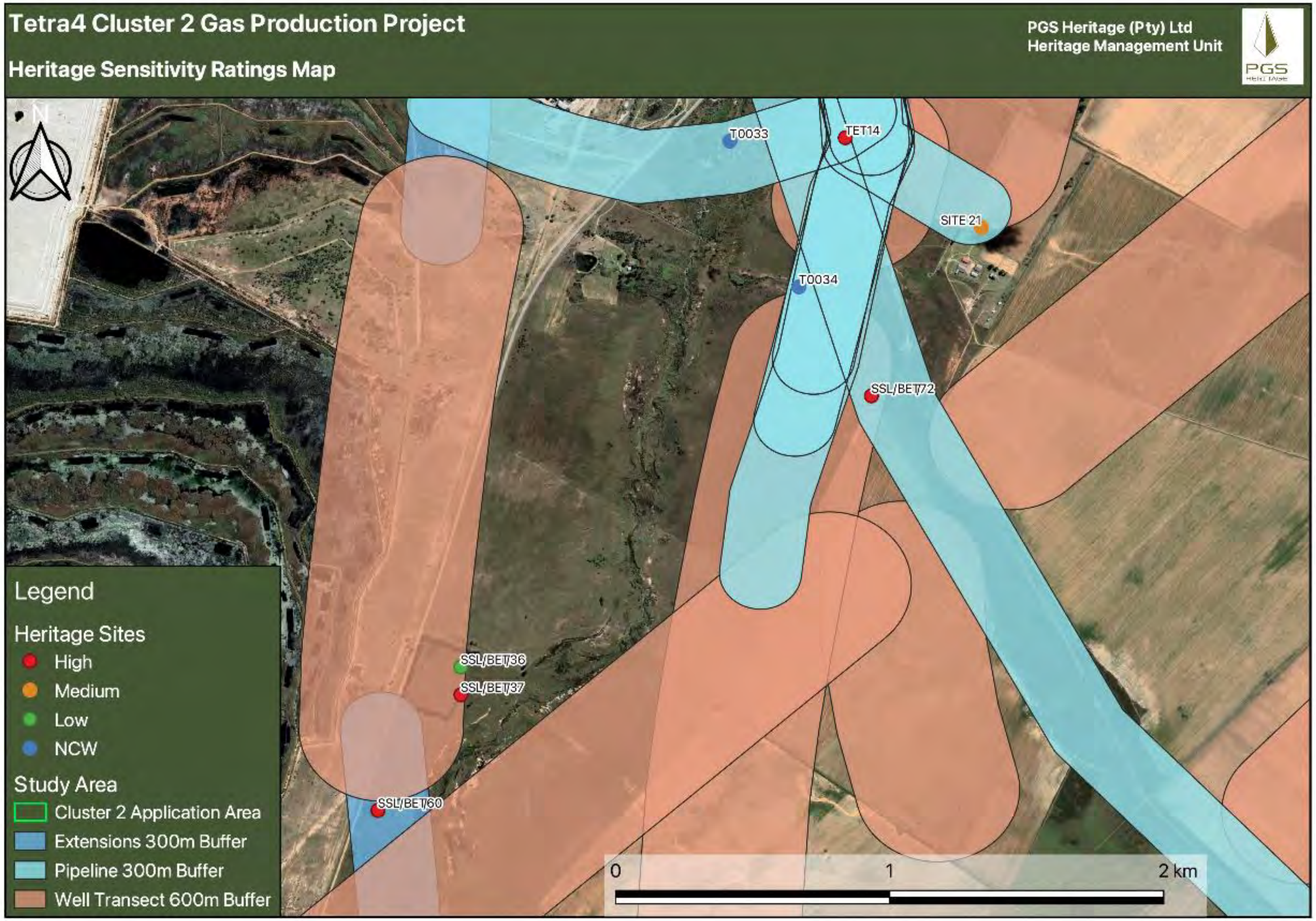


Figure 262 - Heritage sensitivity rating of identified heritage resources. Inset F.

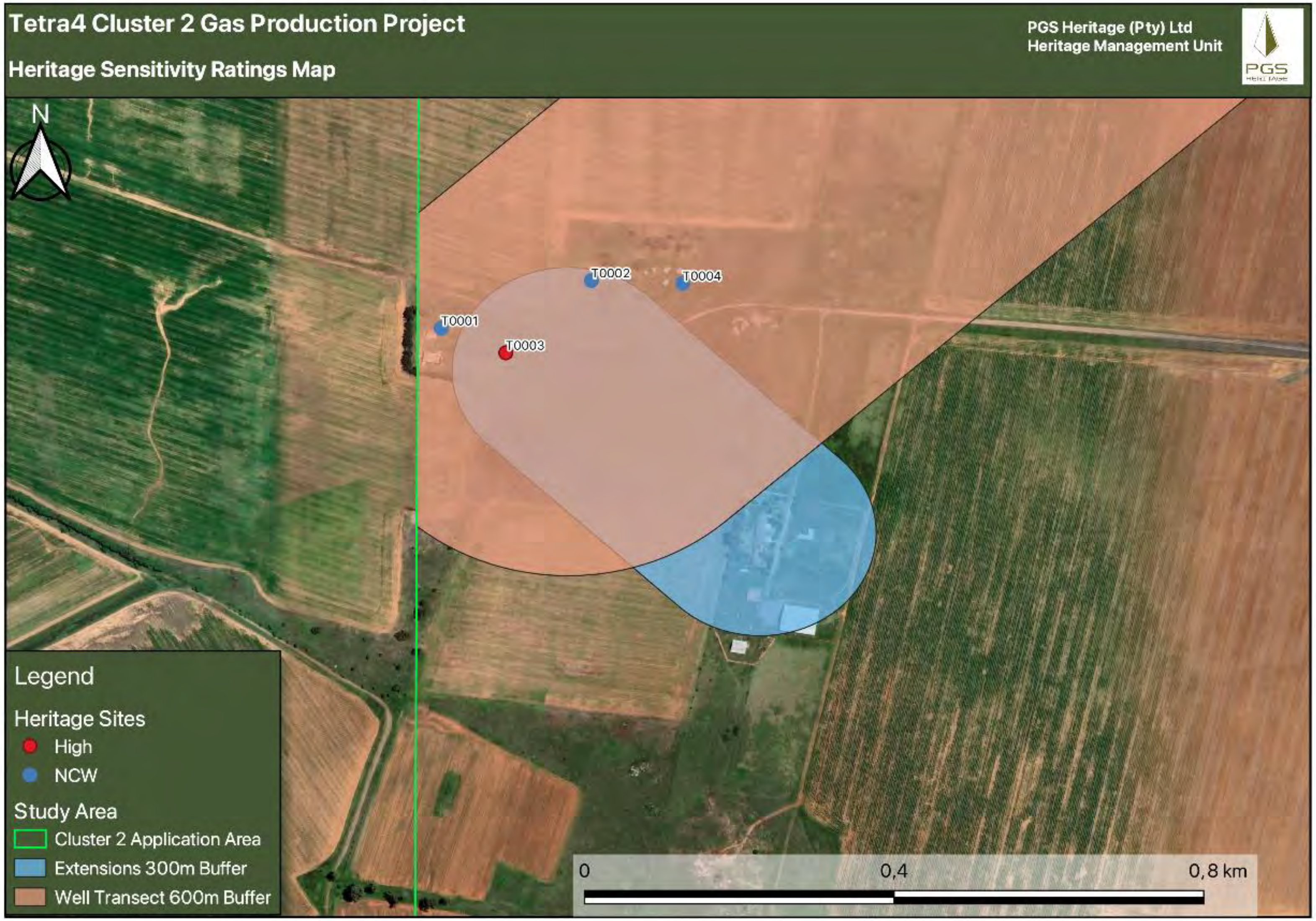


Figure 263 - Heritage sensitivity rating of identified heritage resources. Inset G.

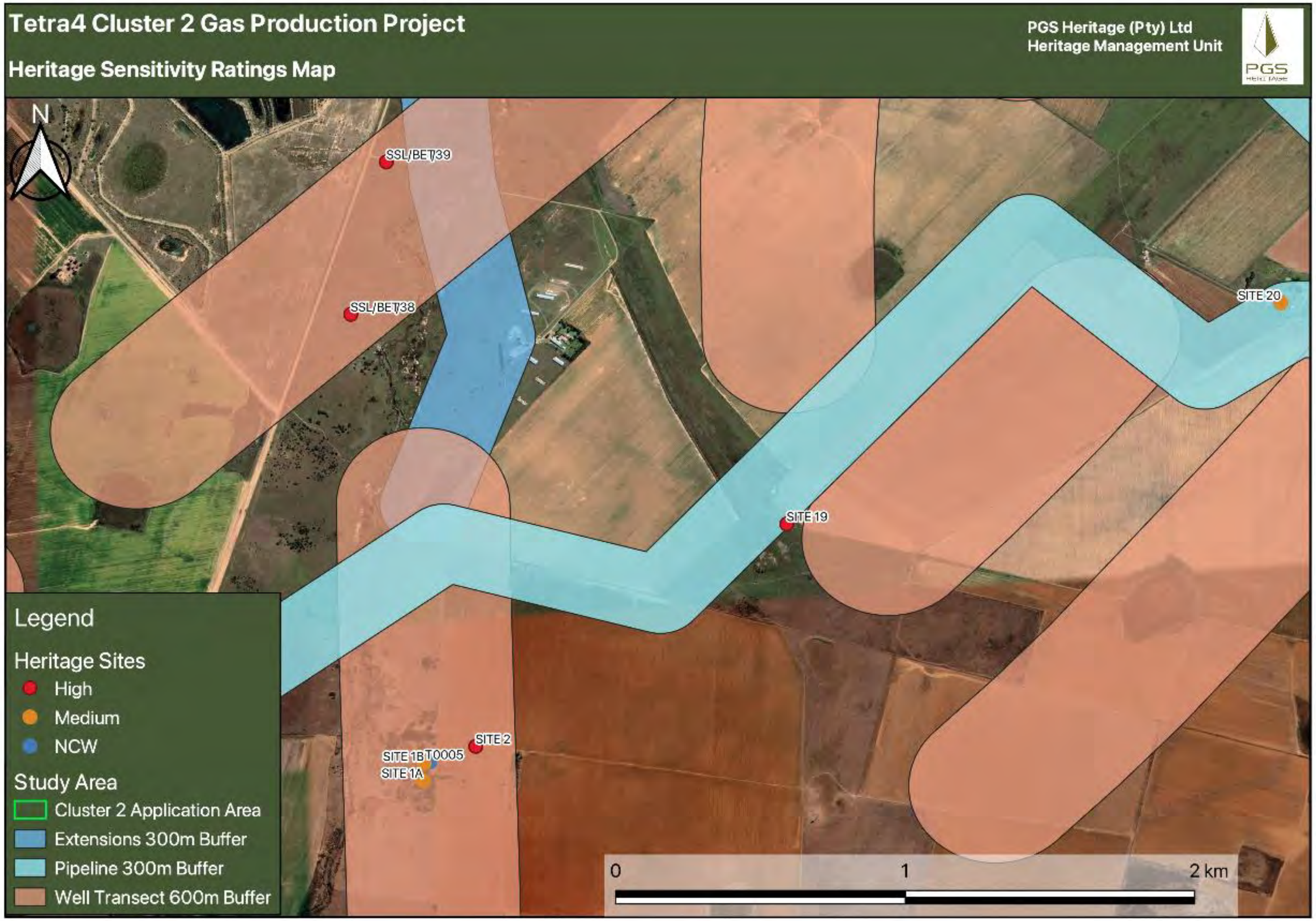


Figure 264 - Heritage sensitivity rating of identified heritage resources. Inset H.

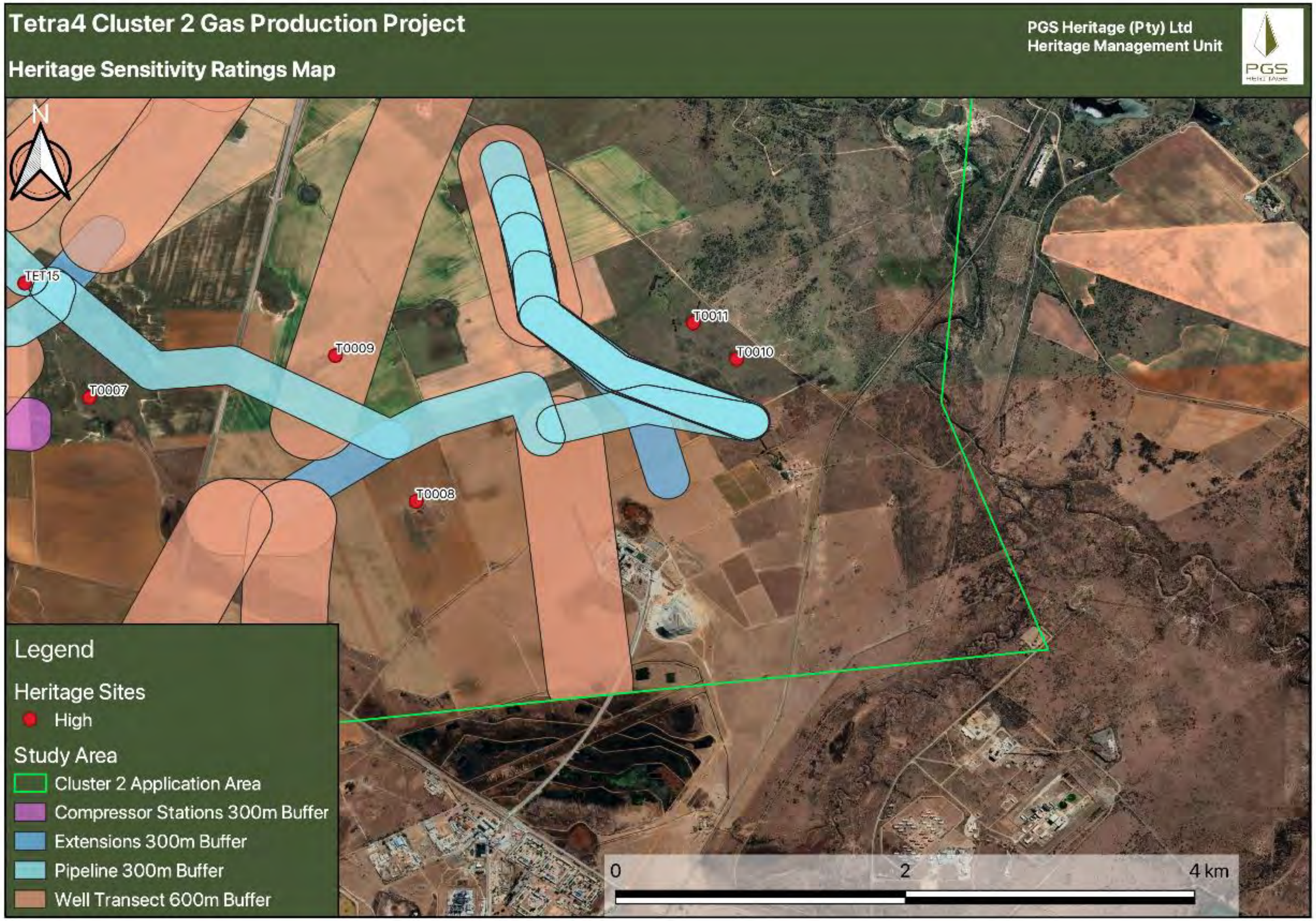


Figure 265 - Heritage sensitivity rating of identified heritage resources. Inset I.

Figure 266 - Heritage sensitivity rating of identified heritage resources. Inset J.

7 PALEONTOLOGY

The Palaeontological study completed by Elize Butler (February 2022) indicates the proposed Tetra4 development is underlain by Quaternary sediments as well as Permian aged sandstone and shale of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup). According to the PalaeoMap of the South African Heritage Resources Information System (SAHRIS) the Palaeontological Sensitivity of Quaternary sediments in this area is Moderate, while that of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup) is Very High.

A 2-day site-specific field survey of the development footprint was conducted on foot and by a motor vehicle on 26 to 27 February 2021. No visible evidence of fossiliferous outcrops was found in the development footprint and thus an overall medium palaeontological significance is allocated to the development footprint. It is therefore considered that the proposed development will not lead to detrimental impacts on the palaeontological reserves of the area and construction of the development may be authorised in its whole extent.

8 IMPACT ASSESSMENT

The following section provides an analysis of the proposed development on heritage resources within the study area.

The impact significance rating methodology, as provided by EIMS, is guided by the requirements of the NEMA EIA Regulations 2014 (as amended). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/ likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S). possible, mitigation measures will be recommended for the impacts identified.

8.1 DETERMINATION OF ENVIRONMENTAL RISK

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. The consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology, the consequence of the impact is represented by:

$$\boldsymbol{C} = \frac{(\boldsymbol{E}+\boldsymbol{D}+\boldsymbol{M}+\boldsymbol{R}) \times \boldsymbol{N}}{\mathbf{4}}$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in **Table 11** below.

Table 11 - Criteria for Determining Impact Consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),

Aspect	Score	Definition
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined, the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/ scored as per Table 12.

Table 12 - Probability Scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur)

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

ER= C x P

Table 13 - Determination of Environmental Risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
	0	1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in **Table 14**.

Table 14 - Significance Classes

Environmental Risk Score	
Value	**Description**
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk).
≥9 - <17	Medium (i.e. where the impact could have a significant environmental risk),
≥17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post-implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

8.2 IMPACT PRIORITISATION

Further to the assessment criteria presented in the section above, it is necessary to assess each potentially significant impact in terms of:

1. Cumulative impacts; and
2. The degree to which the impact may cause irreplaceable loss of resources.

To ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 15 - Criteria for Determining Prioritisation

Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/ definite that the impact will result in spatial and temporal cumulative change.
	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.

Irreplaceable Loss of Resources (LR)	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 16. The impact priority is therefore determined as follows:

Priority = CI + LR

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (Refer to **Table 16**).

Table 16 - Determination of Prioritisation Factor

Priority	Ranking	Prioritisation Factor
2	Low	**1**
3	Medium	**1.125**
4	Medium	**1.25**
5	Medium	**1.375**
6	High	**1.5**

In order to determine the final impact significance, the PF is multiplied by the ER of the post-mitigation scoring. The ultimate aim of the PF is an attempt to increase the post-mitigation environmental risk rating by a full ranking class if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential and significant potential for irreplaceable loss of resources, then the net result would be too upscale the impact to a high significance).

Table 17 - Final Environmental Significance Rating

Environmental Significance Rating	
Value	**Description**
< -17	High negative (i.e. where the impact must have an influence on the decision process to develop in the area).
≥ -17 ≤ -9	Medium negative (i.e. where the impact could influence the decision to develop in the area).
> -9, <0	Low negative (i.e. where this impact would not have a direct influence on the decision to develop in the area).
0	No impact
<0, <9	Low positive (i.e. where this impact would not have a direct influence on the decision to develop in the area).

Environmental Significance Rating	
Value	**Description**
≥ 19 ≤ 17	Medium positive (i.e. where the impact could influence the decision to develop in the area).
≥ 217	High positive (i.e. where the impact must have an influence on the decision process to develop in the area).

The significance ratings and additional considerations applied to each impact will be used to provide a quantitative comparative assessment of the alternatives being considered. In addition, professional expertise and opinion of the specialists and the environmental consultants will be applied to provide a qualitative comparison of the alternatives under consideration. This process will identify the best alternative for the proposed project.

8.3 HERITAGE IMPACTS

8.3.1 GENERAL OBSERVATIONS

- Thirty-five (35) of the previously identified sites are located within the proposed development buffer areas.
- Heritage sites assessed to have a low heritage significance are not included in these impact assessment calculations. The reason for this is that sites of low significance will not require mitigation. These sites are **TET27, SSL/BET/25, SSL/BET/26, SSL/BET/36, T0001, T0002, T0004, T0005, T0017, T0018, T0019, T0020, T0025, T0030, T0031, T0033, T0034, T0036, T0037, T0038, T0039.**

8.3.2 BURIAL GROUNDS AND GRAVES

A total of fourteen (14) burial grounds and graves (**TET 1, TET 7-8, TET 11, TET 15**[1]**, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19** and **T0003, T0009, T0024, T0029**) were identified within the proposed development areas. Burial grounds and graves have high heritage significance and are given a IIIA significance rating in accordance with the system described in Section 4 of this document.

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

8.3.2.1 MITIGATION MEASURES

- The sites should be demarcated with a 50-meterno-go-buffer-zone and the graves should be avoided.

- A Grave Management Plan should be developed for the graves which also needs to be approved by SAHRA BGG.
- If the site is going to be impacted upon, then a grave relocation process is recommended as a mitigation and management measure. This will involve the necessary social consultation and public participation process before grave relocation permits can be applied for with the SAHRA BGG under the NHRA and National Health Act regulations.

8.3.3 HISTORIC TO RECENT SITES WITH POSSIBLE GRAVES

A total of fourteen (14) possible grave sites (**TET 4-6, TET 13**[2]**, TET 14, TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**) were identified within the proposed development area. Burial grounds and graves have high heritage significance and are given a IIIA significance rating in accordance with the system described in Section 4 of this document.

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

8.3.3.1 MITIGATION MEASURES

- Mitigation measures would include applying for the test excavation and/or GPR permit to determine if the site contains graves.
- If human remains are discovered a grave relocation process is recommended as a mitigation and management measure. This will involve the necessary social consultation and public participation process before grave relocation permits can be applied for with the SAHRA BGG under the NHRA and National Health Act regulations.
- When graves are discovered/uncovered the site should be demarcated with a 50-meterno-go-buffer-zone and the grave should be avoided.
- If, during test excavations, it is determined that the site does not contain graves, no further mitigation will be required.

8.3.4 STRUCTURES

A total of ten (10) structures (**TET 2, TET3**[4]**, TET 9, SITE 1A, SITE 1B**[3]**, SITE 20-21**and **T0021, T0040, T0041**) that have medium heritage significance (IIIB significance rating) were identified within the proposed development area.

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

8.3.4.1 MITIGATION MEASURES

- It is recommended that a no-go-buffer-zone of at least **30m** is kept to the closest infrastructure.
- If development occurs within 30m of the site, the structure will need to be satisfactorily studied and recorded before impact occurs.
- Recording of the site i.e. (a) map indicating the position and footprint of the structure (b) photographic recording of the structure (c) measured drawings of the floor plans of the structure.
- Submission of permit application to SAHRA to allow for the disturbance to the site. A Phase 2 Heritage Report must accompany the permit.

Table 18 illustrates the impact rating for heritage resources and **Table 19** illustrates the impact rating for palaeontological resources. The possibility of chance finds of unidentified heritage resources, can be mitigated through the proposed management measures contained in the next section of this report.

Table 18 - Impact rating for heritage resources

IMPACT DESCRIPTION			**Pre-Mitigation**							**Post Mitigation**								**Priority Factor Criteria**			
Identifier	Impact	Nature	Extent	Duration		Magnitude	Reversibilit	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibilit	Probability	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score
10.1.1	Impact on unidentified heritage resources	-1	1	5		1	5	1	-3	-1	1	4	2	4	2	-5.5	Medium	2	3	1.375	-7.56
10.1.2	Impact on burial grounds and graves	-1	2	4		5	5	4	-16	-1	1	4	2	5	2	-6	Medium	2	3	1.375	-8.25
10.1.3	Impact on historic to recent sites with possible graves	-1	2	4		4	5	3	-11.25	-1	1	4	2	5	2	-6	Medium	1	3	1.25	-7.5
10.1.4	Impact on structures of medium heritage significance	-1	1	5		3	5	3	-10.5	-1	1	3	3	3	2	-5	Medium	2	2	1.25	-6.25

Table 19 - Impact rating for palaeontological resources

IMPACT DESCRIPTION			**Pre-Mitigation**							**Post Mitigation**								**Priority Factor Criteria**			
Identifier	Impact	Nature	Extent	Duration		Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score
10.1.1	Impact on palaeontology	-1	4	5		4	5	4	-18	-1	4	5	2	5	2	-8	Medium	2	3	1.375	-11

9 MANAGEMENT RECOMMENDATIONS AND GUIDELINES

9.1 CONSTRUCTION PHASE

The project will encompass a range of activities during the Construction Phase, including disturbance to the soil surface and small-scale infrastructure development associated with the project.

It is always possible that cultural material may be exposed during construction and may be recoverable, keeping in mind delays can be costly during construction and as such must be minimised. Development surrounding mining and construction results in significant disturbance; however, any excavation work offers a window into the past, and it thus may be possible to rescue some of the data and materials. It is also possible that substantial alterations will be implemented during this phase of the project, and these must be catered for. Temporary infrastructure developments, such as construction camps and laydown areas, are often changed or added to the project as required. In general, these are low impact developments as they are superficial, resulting in little alteration of the land surface, but still need to be catered for.

During the Construction Phase, it is important to recognize any significant material being unearthed, making the correct judgment on which actions should be taken. It is recommended that the following chance find procedure should be implemented.

9.2 CHANCE FIND PROCEDURE

- A heritage practitioner / archaeologist should be appointed to develop a heritage induction program and conduct training for the ECO as well as team leaders in the identification of heritage resources and artefacts.
- An appropriately qualified heritage practitioner / archaeologist must be identified to be called upon if any possible heritage resources or artefacts are identified.
- Should an archaeological site or cultural material be discovered during construction (or operation), the area should be demarcated, and construction activities halted.
- The qualified heritage practitioner / archaeologist will then need to come out to the site and evaluate the extent and importance of the heritage resources and make the necessary recommendations for mitigating the find and the impact on the heritage resource.
- The contractor therefore should have some sort of contingency plan so that operations could move elsewhere temporarily while the materials and data are recovered.
- Construction can commence as soon as the site has been cleared and signed off by the heritage practitioner / archaeologist.

9.3 POSSIBLE FINDS DURING CONSTRUCTION PHASES

The study area occurs within a greater historical and archaeological context as identified during the desktop and fieldwork phase. Soil clearance may uncover the following:

- Unmarked graves.
- High density concentrations of stone artefacts

9.4 TIMEFRAMES

It must be kept in mind that mitigation and monitoring of heritage resources discovered during construction activity will require permitting for collection or excavation of heritage resources and lead times must be worked into the construction time frames. The table below gives guidelines for lead times on permitting.

Table 20 - Lead times for permitting and mobilisation

Action	Responsibility	Timeframe
Preparation for field monitoring and finalisation of contracts	The contractor and service provider	1 month
Application for permits to do necessary mitigation work	Service provider – Archaeologist and SAHRA	3 months
Documentation, excavation and archaeological report on the relevant site	Service provider – Archaeologist	3 months
Handling of chance finds – Graves/Human Remains	Service provider – Archaeologist and SAHRA	2 weeks
Relocation of burial grounds or graves in the way of construction	Service provider – Archaeologist, SAHRA, local government and provincial government.	6 months

9.5 HERITAGE MANAGEMENT PLAN FOR EMPR IMPLEMENTATION

Table 21: Heritage Management Plan for EMPr implementation

Area and site no.	Mitigation measures	Phase	Timeframe	The responsible party for implementation	Monitoring Party (frequency)	Target	Performance indicators (monitoring tool)
General project area	Implement a chance find procedures in case where possible heritage finds (incl. unmarked graves) are uncovered.	Planning, Construction	Prior to construction and ongoing.	Applicant ECO Heritage Specialist	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report
Grave and burial ground sites (TET 1, TET 7-8, TET 11, TET 15[1]**, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19** and **T0003, T0009, T0024, T0029)** that were located within the proposed development area and were rated as high local heritage significance and had a heritage grading of IIIA.	▪ The graves should be demarcated with a **50-meterbuffer** and should be avoided and left in situ. ▪ A Grave Management Plan should be developed for the graves which also need to be approved by SAHRA BGG. ▪ If the site is going to be impacted and the graves need to be removed a grave relocation process as per the Heritage Management Plan for the site is recommended as a mitigation and management measure. This will involve the necessary social consultation and public participation process before grave relocation permits can be applied for with the SAHRA BGG under the NHRA and National Health Act regulations.	Planning, Construction	Prior to construction and ongoing.	Applicant ECO Heritage Specialist	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report
Burial Grounds and Graves (**T0010, T0013**) that were located	▪ No mitigation required.	Planning, Construction	Prior to construction and ongoing.	Applicant ECO	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations	ECO Monthly Checklist/Report

Area and site no.	Mitigation measures	Phase	Timeframe	The responsible party for implementation	Monitoring Party (frequency)	Target	Performance indicators (monitoring tool)
outside of the proposed development area.						from SAHRA under Section 34-36 and 38 of NHRA	
Historic to recent sites with possible grave sites (**TET 4-6, TET 13**[2]**, TET 14, TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**) that were located within the proposed development area and were rated as high local heritage significance and had a heritage grading of IIIA.	▪ Mitigation measures would include applying for the test excavation and/or GPR permit to determine if the site contains graves. ▪ If human remains are discovered a grave relocation process is recommended as a mitigation and management measure. This will involve the necessary social consultation and public participation process before grave relocation permits can be applied for with the SAHRA BGG under the NHRA and National Health Act regulations. ▪ When graves are discovered/uncovered the site should be demarcated with a 50-meterno-go-buffer-zone and the grave should be avoided. ▪ If, during test excavations, it is determined that the site does not contain graves, no further mitigation will be required.	Planning, Construction	Prior to construction and ongoing.	Applicant ECO Heritage Specialist	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report
Historic to recent sites with possible grave sites (**T0015, T0023, T0026, T0027, T0028**) that were located outside of the proposed	▪ No mitigation required.	Planning, Construction	Prior to construction and ongoing.	Applicant ECO	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report

Area and site no.	Mitigation measures	Phase	Timeframe	The responsible party for implementation	Monitoring Party (frequency)	Target	Performance indicators (monitoring tool)
development area and were rated as high local heritage significance and had a heritage grading of IIIA.							
Structures (**TET2, TET3**[4]**, TET9, SITE 1A, SITE 1B**[3]**, SITE 20, SITE 21, T0021, T0040, T0041**) that were located within the proposed development area and were rated as medium local heritage significance and had a heritage grading of IIIB.	▪ It is recommended that a no-go-buffer-zone of at least **30m** is kept to the closest infrastructure. ▪ If development occurs within 30m of the site, the structure will need to be satisfactorily studied and recorded before impact occurs. ▪ Recording of the site i.e. (a) map indicating the position and footprint of the structure (b) photographic recording of the structure (c) measured drawings of the floor plans of the structure. ▪ Submission of permit application to SAHRA to allow for the disturbance to the site. A Phase 2 Heritage Report must accompany the permit.	Construction	Prior to construction and ongoing.	Applicant ECO Heritage Specialist	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report
Structures (**T0014**) that were located outside of the proposed development area and were rated as medium local heritage significance and had a heritage grading of IIIB.	▪ No mitigation is required.	Construction	Prior to construction and ongoing.	Applicant ECO	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report

Area and site no.	Mitigation measures	Phase	Timeframe	The responsible party for implementation	Monitoring Party (frequency)	Target	Performance indicators (monitoring tool)
Structures (**TET27, SSL/BET/25, SSL/BET/26, SSL/BET/36, T0017, T0018, T0019, T0020, T0025, T0037, T0038**) that were located within the proposed development area and were rated as low local heritage significance and had a heritage grading of IIIC.	▪ No mitigation is required. The documentation of the site in the HIA report is sufficient and the site can be destroyed without a permit but with the approval of this report.	Construction	Prior to construction and ongoing.	Applicant ECO	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report
Structures (**T0016, T0022**) that were located outside of the proposed development area and were rated as low local heritage significance and had a heritage grading of IIIC.	▪ No mitigation required.	Construction	Prior to construction and ongoing.	Applicant ECO	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report
Structures (**T0001, T0002, T0004, T0005, T0030, T0031, T0033, T0034, T0036, T0039)** that were located within the proposed development area	▪ No mitigation required.	Construction	Prior to construction and ongoing.	Applicant ECO	ECO (monthly / as or when required)	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 34-36 and 38 of NHRA	ECO Monthly Checklist/Report

Area and site no.	Mitigation measures	Phase	Timeframe	The responsible party for implementation	Monitoring Party (frequency)	Target	Performance indicators (monitoring tool)
and were rated to have no research potential or other cultural significance and had a heritage grading of not conservation worthy (NCW).							
Palaeontological finds	▪ The ECO for this project must be informed that the Adelaide Subgroup (Beaufort Group, Karoo Supergroup) has a **Very High Palaeontological Sensitivity**. ▪ If fossil remains are discovered during any phase of construction, either on the surface or exposed by fresh excavations the Chance Find Protocol must be implemented by the ECO in charge of these developments.	Construction	During construction	Applicant ECO Palaeontologist	Monthly	Ensure compliance with relevant legislation and recommendations from SAHRA under Section 35 of NHRA	Final report to be used by the develop to apply for a destruction permit under s35 of the NHRA.

10 CONCLUSIONS

PGS Heritage (Pty) Ltd (PGS) was appointed by Environmental Impact Management Services Consulting (Pty) Ltd (EIMS) to undertake a Heritage Impact Assessment (HIA), which forms part of the environmental process for the proposed Tetra4 Cluster 2 Gas Production Project, located within the Matjhabeng and Masilonyana Local Municipalities, between Welkom, Virginia and Theunissen, Free State Province.

This HIA aims to evaluate the possible impacts on heritage resources present within the proposed development footprint of the Tetra4 Cluster 2 Gas Production Project. Immediate and direct impacts on archaeological and palaeontological resources were addressed through the HIA.

The HIA has shown that the study area has a multitude of heritage resources situated within the proposed development boundaries.

10.1 GENERAL DESKTOP STUDY

An archival and historical desktop study was undertaken to provide a historic framework for the project area and surrounding landscape. This was augmented by a study of available historical and archival maps and an assessment of previous archaeological and heritage studies completed for the area. The desktop study revealed that the surroundings of the study area are characterised by a long and significant history, whereas previous archaeological and heritage studies from this area have revealed several archaeological and heritage sites from the surroundings.

Several archaeological and heritage surveys have been undertaken within the region. In 2016 and 2017, fieldwork was conducted by Polke Birkholtz (2017a, 2017b), an archaeologist of PGS. **Thirty-five** (35) of the **heritage finds** identified during this fieldwork, fall within the current study area. These were classified as either cemeteries, historic structures believed to be older than 100 years, historic structures believed to be older than 60 years, historical buildings of low significance, historic to recent sites with possible stillborn baby graves and possible grave sites.

There were ten (10) graves and burial grounds (**TET 1, TET 7-8, TET 11, TET 15, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19**), eleven (11) structures (**TET 2-3, TET 9, TET 27, SSL/BET/25-26, SSL/BET/36, SITE 1A, SITE 1B, SITE 20-21**), fourteen (14) historic to recent sites with possible graves (**TET 4-6, TET 13-14,TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**).

10.2 PALAEONTOLOGY

Elize Butler of Banzai Environmental (Pty) Ltd was commissioned to undertake a two-day Palaeontological Impact Assessment. Her report and findings are attached in full in Appendix B.

Butler found that the study area is " by Quaternary sediments as well as Permian aged sandstone and shale of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup). According to the PalaeoMap of the South African Heritage Resources Information System (SAHRIS) the Palaeontological Sensitivity of Quaternary sediments in this area is Moderate, while that of the Adelaide Subgroup (Beaufort Group, Karoo Supergroup) is Very High."

10.3 FIELDWORK

The fieldwork component of the study was aimed at identifying tangible remains of archaeological, historical and heritage significance. The fieldwork was undertaken by way of intensive walkthroughs of the proposed development footprint areas. The fieldwork was conducted by three archaeologists from PGS (Nikki Mann, Michelle Sachse and Nicholas Fletcher) on 12 November 2021. It is important to note that although as intensive a fieldwork coverage as possible was undertaken, sections of the study area are in areas which are more densely overgrown and/or disturbed (crops: maize, sunflowers, soya beans; ploughed areas) or have restricted access, which limited visibility in those areas of the study area. Therefore, the walkthroughs were focused on those areas that are not disturbed, as the potential for identifying archaeological and heritage sites in the more undisturbed components of the study area are much higher. As a result, only limited fieldwork was undertaken in those components of the study area that are entirely disturbed.

Recent fieldwork undertaken resulted in the identification of a total of **forty-one** (41) **heritage sites** (four of which were previously recorded; see footnotes below).

These sites comprised the following:

- Seven (7) sites containing burial grounds and graves. See sites **T0003, T0009, T0010, T0012[11], T0013, T0024, T0029**.
- Nine (9) sites historic to recent sites with possible graves. See sites **T0007, T0008, T0011, T0015, T0023, T0026, T0027, T0028, T0035[12]**.

[11] Note that site T0012 identified during the field assessment is the same site as TET15 identified in the 2016/2017 heritage assessment.

[12] Note that site T0035 identified during the field assessment is the same site as TET13 identified in the 2016/2017 heritage assessment.

- Twenty-five (25) structures. See sites **T0001, T0002, T0004, T0005, T0006**[13]**, T0014, T0016, T0017, T0018, T0019, T0020, T0021, T0022, T0025, T0030, T0031, T0032**[14]**, T0033, T0034, T0036, T0037, T0038, T0039, T0040, T0041.**

10.4 IMPACT ASSESSMENT

10.4.1 BURIAL GROUNDS AND GRAVES

A total of fourteen (14) burial grounds and graves (**TET 1, TET 7-8, TET 11, TET 15**[1]**, TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19** and **T0003, T0009, T0024, T0029**) were identified within the proposed development areas. Burial grounds and graves have high heritage significance and are given a IIIA significance rating in accordance with the system described in Section 4 of this document.

Burial grounds and graves are protected under Section 36 of the NHRA 25 of 1999. Thus, the sites are provisionally rated as having a high heritage significance with a heritage rating of IIIA. All graves have high levels of emotional, religious and in some cases historical significance. It is also important to understand that the identified graves could have significant heritage value to the relevant families.

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

10.4.2 HISTORIC TO RECENT SITES WITH POSSIBLE GRAVES

A total of fourteen (14) possible grave sites (**TET 4-6, TET 13**[2]**, TET 14, TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**) were identified within the proposed development area. Burial grounds and graves have high heritage significance and are given a IIIA significance rating in accordance with the system described in Section 4 of this document.

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

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[13] Note that site T0006 identified during the field assessment is the same site as SITE 1B identified in the 2016/2017 heritage assessment.

[14] Note that site T0032 identified during the field assessment is the same site as TET3 identified in the 2016/2017 heritage assessment.

10.4.3 STRUCTURES

A total of thirty-one (31) structures (**TET 2, TET3**[4]**, TET 9, TET 27, SSL/BET/25-26, SSL/BET/36, SITE 1A, SITE 1B**[3], **SITE 20-21**and **T0001, T0002, T0004, T0005, T0017, T0018, T0019, T0020, T0021, T0025, T0030, T0031, T0033, T0034, T0036, T0037, T0038, T0039, T0040, T0041**) were identified within the proposed development area.

Twenty-one (21) of the heritage sites (**TET27, SSL/BET/25, SSL/BET/26, SSL/BET/36, T0001, T0002, T0004, T0005, T0017, T0018, T0019, T0020, T0025, T0030, T0031, T0033, T0034, T0036, T0037, T0038, T0039**) are assessed to have a low heritage significance are not included in the impact assessment. The reason for this is that sites of low significance will not require mitigation.

Structures older than 60 years fall under the protection of Section 34(1) of the National Heritage Resources Act 25 of 1999. Additionally, in terms of Section 35(4) of the National Heritage Resources Act (25 of 1999), man-made features and artefacts older than 100 years are defined as being archaeological. In the same section, the act also states that such archaeological sites and objects may not be disturbed, altered, modified or destroyed without a suitable permit from the South African Heritage Resources Agency (SAHRA).

The pre-mitigation impact significance is rated as **MEDIUM**, but with the implementation of the required mitigation measures the post-mitigation impact will be **LOW**. The overall Environmental significance will be Low negative.

10.4.4 PALAEONTOLOGY

No visible evidence of fossiliferous outcrops was found in the development footprint and thus an overall medium palaeontological significance is allocated to the development footprint. It is therefore considered that the proposed development will not lead to detrimental impacts on the palaeontological reserves of the area and construction of the development may be authorised in its whole extent.

10.5 MITIGATION MEASURES

The following mitigation measures are listed in the table below.

Area and site no.	Mitigation Measures
General project area	▪ Implement a chance find procedures in case where possible heritage finds are uncovered.
Burial Grounds and Graves (**TET 1, TET 7-8, TET 11, TET 15**[1], **TET 19, TET 22, SSL/BET/72, SITE 2, SITE 19** and **T0003, T0009, T0024, T0029**) that were located within the proposed development area and were rated as high local heritage significance and had a heritage grading of IIIA.	▪ The graves should be demarcated with a **50-meterbuffer** and should be avoided and left in situ. ▪ A Grave Management Plan should be developed for the graves which also need to be approved by SAHRA BGG. ▪ If the site is going to be impacted and the graves need to be removed a grave relocation process as per the Heritage Management Plan for the site is recommended as a mitigation and management measure. This will involve the necessary social consultation and public participation process before grave relocation permits can be applied for with the SAHRA BGG under the NHRA and National Health Act regulations.
Burial Grounds and Graves (**T0010, T0013**) that were located outside of the proposed development area.	▪ No mitigation required.
Historic to recent sites with possible grave sites (**TET 4-6, TET 13**[2], **TET 14, TET 25a, TET 25b, TET 26, SSL/BET/37-39, SSL/BET/53, SSL/BET/60, SSL/BET/66**) that were located within the proposed development area and were rated as high local heritage significance and had a heritage grading of IIIA.	▪ Apply for the test excavation and/or GPR permit to determine if the site contains graves. ▪ If human remains are discovered a grave relocation process is recommended as a mitigation and management measure. This will involve the necessary social consultation and public participation process before grave relocation permits can be applied for with the SAHRA BGG under the NHRA and National Health Act regulations. ▪ When graves are discovered/uncovered the site should be demarcated with a **50-meterno-go-buffer-zone** and the grave should be avoided. ▪ If, during test excavations, it is determined that the site does not contain graves, no further mitigation will be required.
Historic to recent sites with possible grave sites (**T0015, T0023, T0026,**	▪ No mitigation required.

Area and site no.	Mitigation Measures
T0027, T0028) that were located outside of the proposed development area and were rated as high local heritage significance and had a heritage grading of IIIA.	
Structures (**TET2, TET3**[4]**, TET9, SITE 1A, SITE 1B**[3]**, SITE 20, SITE 21, T0021, T0040, T0041**) that were located within the proposed development area and were rated as medium local heritage significance and had a heritage grading of IIIB.	▪ It is recommended that a no-go-buffer-zone of at least **30m** is kept to the closest infrastructure. ▪ If development occurs within 30m of the site, the structure will need to be satisfactorily studied and recorded before impact occurs. ▪ Recording of the site i.e. (a) map indicating the position and footprint of the structure (b) photographic recording of the structure (c) measured drawings of the floor plans of the structure. ▪ Submission of permit application to SAHRA to allow for the disturbance to the site. A Phase 2 Heritage Report must accompany the permit.
Structures (**T0014**) that were located outside of the proposed development area and were rated as medium local heritage significance and had a heritage grading of IIIB.	▪ No mitigation is required.
Structures (**TET27, SSL/BET/25, SSL/BET/26, SSL/BET/36, T0017, T0018, T0019, T0020, T0025, T0037, T0038**) that were located within the proposed development area and were rated as low local heritage significance and	▪ No mitigation is required. The documentation of the site in the HIA report is sufficient and the site can be destroyed without a permit but with the approval of this report.

Area and site no.	Mitigation Measures
had a heritage grading of IIIC.	
Structures (**T0016, T0022**) that were located outside of the proposed development area and were rated as low local heritage significance and had a heritage grading of IIIC.	▪ No mitigation is required.
Structures (**T0001, T0002, T0004, T0005, T0030, T0031, T0033, T0034, T0036, T0039)** that were located within the proposed development area and were rated to have no research potential or other cultural significance and had a heritage grading of not conservation worthy (NCW).	▪ No mitigation is required.
Palaeontology	• The ECO for this project must be informed that the Adelaide Subgroup (Beaufort Group, Karoo Supergroup) has a **Very High Palaeontological Sensitivity**. • If Palaeontological Heritage is uncovered during surface clearing and excavations the **Chance find Protocol** attached should be implemented immediately. Fossil discoveries ought to be protected and the ECO/site manager must report to South African Heritage Resources Agency (SAHRA) (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Tel: 021 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) so that mitigation (recording and collection) can be carried out.

Area and site no.	Mitigation Measures
	• Before any fossil material can be collected from the development site the specialist involved would need to apply for a collection permit from SAHRA. Fossil material must be housed in an official collection (museum or university), while all reports and fieldwork should meet the minimum standards for palaeontological impact studies proposed by SAHRA (2012). • These recommendations should be incorporated into the Environmental Management Plan for the Tetra4 Development.

10.6 GENERAL

It is the considered opinion of the authors of this report that the overall impact of the proposed Tetra4 Cluster 2 Gas Production Project on heritage resources will be **Low**. Provided that the general recommendations and mitigation measures outlined in this report are implemented, the impact would be acceptably Low or could be totally mitigated to the degree that the project could be approved from a heritage perspective. The management and mitigation measures as described in **Section 8** of this report have been developed to minimise the project impact on heritage resources.

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11.2 HISTORIC TOPOGRAPHIC MAPS

All historic topographic maps used in this report were obtained from the Directorate: National Geo-spatial Information of the Department of Rural Development and Land Reform in Cape Town.

11.3 INTERNET

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www.nzetc.victoria.ac.za
www.sahistory.org.za

www.sahra.org.za
www.sanbi.org
www.wikipedia.org

11.4 GOOGLE EARTH

All the aerial depictions and overlays used in this report are from Google Earth.

Appendix A

CURRICULUM VITAE

WOUTER FOURIE

Professional Heritage Specialist and Professional Archaeologist and Director PGS Heritage

Summary of Experience

Specialised expertise in Archaeological Mitigation and excavations, Cultural Resource Management and Heritage Impact Assessment Management, Archaeology, Anthropology, Applicable survey methods, Fieldwork and project management, Geographic Information Systems, including *inter alia* -

Involvement in various grave relocation projects (some of which relocated up to 1000 graves) and grave "rescue" excavations in the various provinces of South Africa

Involvement with various Heritage Impact Assessments, within South Africa, including -

- Archaeological Walkdowns for various projects
- Phase 2 Heritage Impact Assessments and EMPs for various projects
- Heritage Impact Assessments for various projects
- Iron Age Mitigation Work for various projects, including archaeological excavations and monitoring
- Involvement with various Heritage Impact Assessments, outside South Africa, including -
- Archaeological Studies in Democratic Republic of Congo
- Heritage Impact Assessments in Mozambique, Botswana and DRC
- Grave Relocation project in DRC

Key Qualifications

BA [Hons] (Cum laude) - Archaeology and Geography - 1997

BA - Archaeology, Geography and Anthropology - 1996

Professional Archaeologist - Association of Southern African Professional Archaeologists (ASAPA) - Professional Member

Accredited Professional Heritage Specialist – Association of Professional Heritage Practitioners (APHP)

CRM Accreditation (ASAPA) -

- Principal Investigator - Grave Relocations
- Field Director – Iron Age
- Field Supervisor – Colonial Period and Stone Age
- Accredited with Amafa KZN

Key Work Experience

2003- current - Director – Professional Grave Solutions (Pty) Ltd

2007 – 2008 - Project Manager – Matakoma-ARM, Heritage Contracts Unit, University of the Witwatersrand

2005-2007 - Director – Matakoma Heritage Consultants (Pty) Ltd

2000-2004 - CEO– Matakoma Consultants

1998-2000 - Environmental Coordinator – Randfontein Estates Limited. Randfontein, Gauteng

1997-1998 - Environmental Officer – Department of Minerals and Energy. Johannesburg, Gauteng

Worked on various heritage projects in the SADC region including, Botswana, Mozambique, Malawi, Mauritius, Zimbabwe and the Democratic Republic of the Congo

CURRICULUM VITAE FOR NIKKI MANN

Professional Archaeologist for PGS Heritage

Name:	Nikki Mann
Profession:	Archaeologist
Date of birth:	1992-10-13
Parent Firm:	PGS Heritage (Pty) Ltd
Position at Firm:	Archaeologist
Years with firm:	2
Years of experience:	7
Nationality:	South African
HDI Status:	White

EDUCATION:

Name of University or Institution	**:**	University of Cape Town
Degree obtained	**:**	BSc
Major subjects	**:**	Archaeology, Environmental and Geographical Sciences
Year	**:**	2013

Name of University or Institution	**:**	University of Cape Town
Degree obtained	**:**	BSc [Hons]
Major subjects	**:**	Archaeology
Year	**:**	2014

Name of University or Institution	:	University of Cape Town
Certificate obtained	:	MSc – Archaeology (phytolith analysis)
Year	:	2017

Professional Qualifications:

Professional Archaeologist - Association of Southern African Professional Archaeologists - Professional Member – No 472

Languages:

English

French

KEY QUALIFICATIONS

- 3 years of work in the heritage consulting field;
- 7 years working experience in archaeological excavations;
- Proven experience in report writing and report deliverables;

HERITAGE IMPACT ASSESSMENTS

South African

Harmony Kareerand Pipelines Project. Between Klerkdorp and Potchefstroom, North West Province. EIMS. **Position**: Heritage Specialist

Black Mountain PV. Northern Cape. Uvuna. **Position**: Heritage Specialist

Proposed amendment of existing mining activities for Kolomela Mine. South-west of Postmasburg, Northern Cape. EXM. **Position**: Heritage Specialist.

Proposed amendment of existing mining activities for Kudumane Mine. Hotazel, Northern Cape. SRK. **Position**: Heritage Specialist.

10MW Chelsea Solar PV. Gqeberha, Eastern Cape. SLR. **Position:** Heritage Specialist.

Koup 1 and Koup 2 WEF. Beaufort West, Western Cape. SiVEST. **Position:** Heritage Specialist.

Victoria West Pipelines. Victoria West, Northern Cape. iXEng. – **Position:** Heritage Specialist.

East Orchards Poultry Farm Project. Delmas, Mpumalanga. EcoSphere. – **Position:** Heritage Specialist.

Gunstfontein WEF and OHL. Sutherland, Northern Cape. Savannah– **Position:** Heritage Specialist.

Overhead power line for Oya PV Facility. Sutherland, Northern Cape. SiVEST– **Position:** Heritage Specialist.

Infrastructure for Kudusberg WEF. Sutherland, Northern Cape. SiVEST– **Position:** Heritage Specialist.

Proposed SKA fibre optic cable, between Beufort West and Carnarvon, Northern and Western Cape. **Position:** Heritage Specialist.

Proposed SANSA Space Operations. Matjiesfontein, Western Cape. **Position:** Heritage Specialist

Pienaarspoort WEF 1 and 2. North-west of Matjiesfontein, Western Cape. Savannah- **Position:** Heritage Specialist.

Swellendam WEF. Swellendam, Western Cape. – **Position:** Heritage Specialist.

Matjiesfontein Road Extension Project. Matjiesfontein, Western Cape. **Position:** Heritage Specialist.

MITIGATION WORK

2020 – Coega Zone 10, Coega IDZ, Eastern Cape Province. Colonial Period Phase 2 Mitigation Archaeological Excavation. ***Archaeologist.***

2019 **–** 2020 **- Lesotho Highland Development Authority – Polihali Dam Project - Heritage Management Plan development and Implementation.** Mokhotlong, Kingdom of Lesotho. ***Archaeologist***.

2018- Proposed development of boreholes and associated pipelines for the Langebaan Aquifer within the Hopefield Private Nature Reserve, Hopefield, Western Cape. **Archaeologist.**

POSITIONS HELD

2021 – current: Archaeologist - PGS (Pty) Ltd

2019 – 2020: Archaeologist - PGS (Pty) Ltd Lesotho

2018 – 2020: Contract Archaeologist – CTS Heritage

REFERENCES

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SMEC INTERNAL REF. JH0049

Draft Report

Tetra4 Gas Hydrological Assessment

Prepared for EIMS (Pty) Ltd

14 November 2022

Document Control

Document	Tetra4 Gas Hydrological Assessment
File Location	Z:\Projects\JH0049 Tetra4 Gas Floodlines\3_Working\3-5_DivW\05 Reports
Project Name	Tetra4 Gas Floodlines
Project Number	JH0049
Revision Number	C

Revision History

Revision No.	Date	Prepared By	Reviewed By	Approved for Issue By
C	14/11/2022	Rendani Thovhakale	Neil Meyer	Viren Gajathar

Issue Register

Distribution List	Date Issued	Number of Copies
EIMS (Pty) Ltd	7/06/2022	1
EIMS (Pty) Ltd	15/09/2022	1

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Important Notice

This report is confidential and is provided solely for the purposes of **Hydrological Study for Tetra4 Gas**. This report is provided pursuant to a Consultancy Agreement between **SMEC South Africa Pty Limited ("SMEC")** and **EIMS (Pty) Ltd**, under which SMEC undertook to perform a specific and limited task for **EIMS**. This report is strictly limited to the matters stated in it and subject to the various assumptions, qualifications and limitations in it and does not apply by implication to other matters. SMEC makes no representation that the scope, assumptions, qualifications and exclusions set out in this report will be suitable or sufficient for other purposes nor that the content of the report covers all matters which you may regard as material for your purposes.

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The report supersedes all previous draft or interim reports, whether written or presented orally, before the date of this report. This report has not and will not be updated for events or transactions occurring after the date of the report or any other matters which might have a material effect on its contents, or which come to light after the date of the report. SMEC is not obliged to inform you of any such event, transaction or matter nor to update the report for anything that occurs, or of which SMEC becomes aware, after the date of this report.

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Declaration of Independence:

I, Rendani Thovhakale and Neil Meyer, representing SMEC South Africa (PTY) Ltd., hereby declare that I am an independent consultant appointed to provide specialist input for the hydrological component of an Environmental Impact Assessment (EIA) study for the proposed Gas Cluster 2 project. I confirm that I have no personal financial interest other than the remuneration of the EIA study itself, neither I nor SMEC South Africa (Pty) Ltd will benefit in any other away from the outcomes of the Gas Cluster 2 project. I further declare that opinions expressed in this report have been formulated in an objective manner without interference from any third party.

Rendani Thovhakale

Name

Signature

Neil Meyer

Name

Signature

27-July-2022

Date

Summary of Expertise:

Rendani Thovhakale

Rendani is a registered ECSA Candidate Civil Engineer with 6 years of experience in undertaking Hydrological impact assessments. He has specialist skills in hydrological analysis and hydraulic modelling. Rendani has worked on similar hydrological projects based in 6 different countries including Lesotho, Mauritius, South Africa, Eswatini, Guinea and Mali. He has undertaken Environmental Impact Assessment (EIA) studies in the hydrology specialist area with adherence to relevant legislation and guidelines including the National Water Act, Act 36 of 1998 (NWA) aimed at the protection of water resources.

Neil Meyer

Neil is a registered ECSA professional Civil Engineer with 20 year of experience in the design and project management of various projects both in South Africa and internationally, plus design and project management of bulk and municipal water, sanitation and drainage infrastructure including water and wastewater treatment projects. He has completed his MSc. Eng at the University of Stellenbosch from 2000 to 2001 and his MSc. Eng HEM/DIC at the University of London, United Kingdom from 2001 to 2002.

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List of Abbreviations

Abbreviation	Description
EIA	Environmental Impact Assessment
EA	Environmental Authorisation
EMPr	Environmental Management Programme
km^2	Square kilometres
m	meters
m^3/s	cubic meters per second
m/s	meters per second
Ml	megaliters
SWMP	Storm Water Management Plan
WUL	Water Use Licence

1 Introduction

SMEC South Africa (Pty) Ltd. was appointed by EIMS to undertake a Hydrological Study for the proposed Tetra4 Gas Cluster 2 located in the Free State, South Africa. Tetra4 (Pty) Ltd aims to extend its natural gas operations inside the project area indicated in Figure 1-1. The purpose of this hydrological study is to serve as a component of the Environmental Impact Assessment (EIA) study. The objectives of this EIA phase are to determine the overall impacts and potential mitigation measures, on the hydrological environment, in order to ensure environmental legal compliance and efficient, cost-effective surface water management. The project area is situated approximately 10 kilometres (km) south of Welkom, as shown in Figure 1-1, below. The approximate geographical coordinates of the centre of project area are:

- Latitude - 28°10'00"S
- Longitude - 26°44'00"E

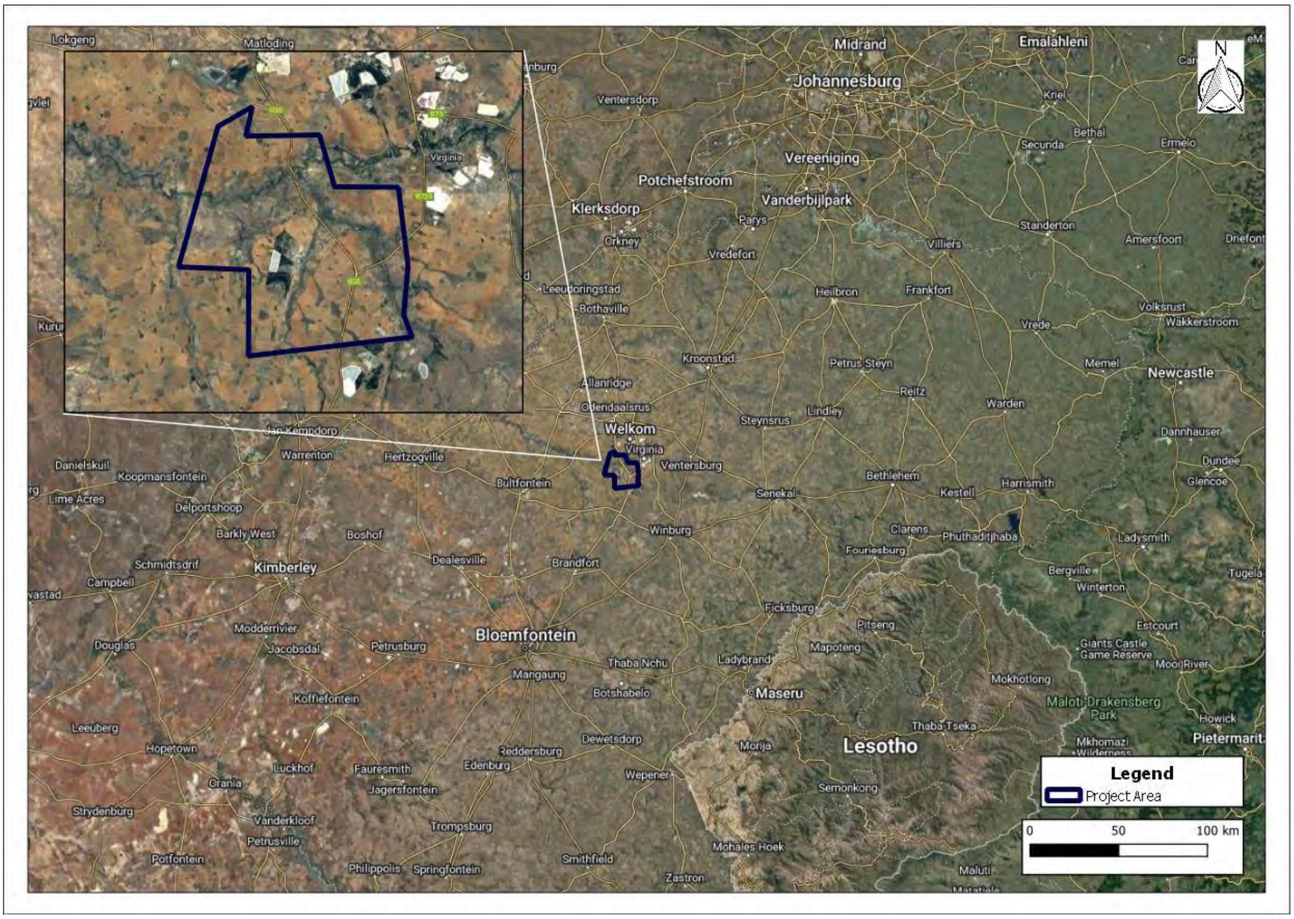

Figure 1-1: Project area location

The extent of the Project area boundary is shown below. The area of the site is approximately 27 500 Hectares.

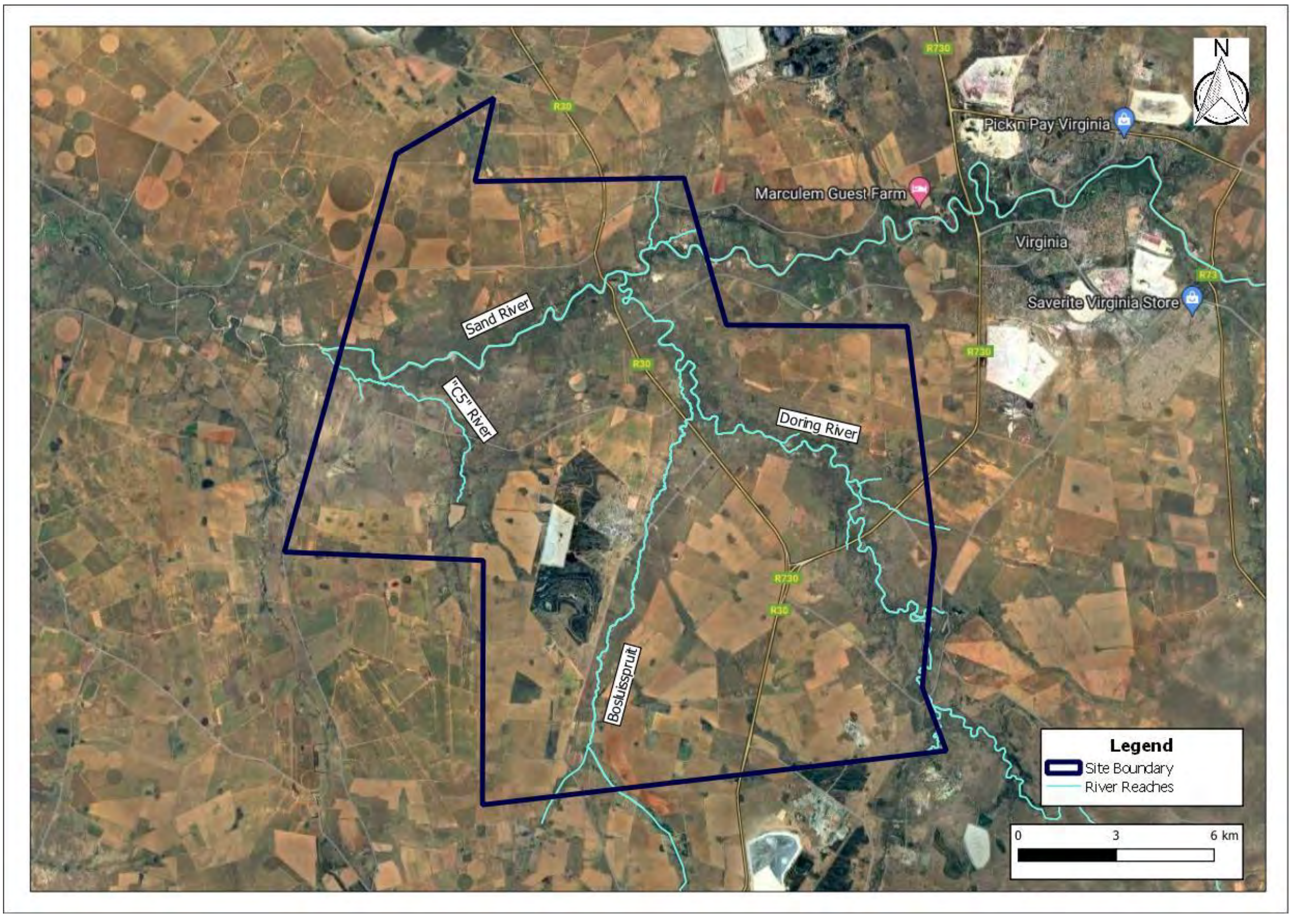

Figure 1-2: Project area Boundary

2 Scope of Work

The Scope of Work for the Hydrological Impact Assessment can be summarised as follows:

1. Desktop Assessment:
   - A description of the hydrological baseline receiving environment was prepared based on publicly available data;
   - Identification and description of surface water drainage systems that occur in the study area, and the manner in which these may be affected by the proposed activities were undertaken.
2. Site Visit:
   - A site visit was conducted on 12th and 13th of April 2022 to measure the hydraulic structure located within the rivers crossing the site and to verify findings of the desktop assessment.
3. Hydrology:
   - The catchment size was assessed, and run-off factors and catchment characteristics were determined.
   - Historical daily rainfall records for the area were sourced.
   - Time of concentration was calculated for each catchment along its longest watercourse, using methods and formulae appropriate to the hydrological method selected.
   - 1:100-year flood peaks were calculated using the most appropriate hydrological methods for each catchment.
4. Hydraulic Modelling:
   - A 1D river hydraulic model was compiled for each of the identified rivers using GeoHEC-RAS river modelling software.
   - Appropriate boundary conditions were selected based on the likely hydraulic regime.
   - The model geometry was based on topographic survey data to be provided by the Client.
   - Roughness factors were determined through an assessment of site and aerial photos.
5. Floodlines:
   - Delineate the floodlines on a map, with respect to any known locations of pipe routes, well locations and plant areas.
6. Risk Assessment:
   - A description of all surface water impacts and proposed mitigation measures, using EIMS' standard EIA Risk and Mitigation methodology.
   - Site sensitivities and relevant potential surface water constraints to the project were identified.
7. Reporting:
   - Recommendations on required hydrological management and mitigation measures will be provided

3 Legal Framework

The EIA study was conducted by EIMS to comply with relevant legislation and policies. The direct applicable guiding legislation is the following:

- **National Water Act (Act 36 of 1998)**

  The National Water Act, 1998 (Act No. 36 of 1998) (NWA) is the principal legal instrument relating to water resource management in South Africa. As guardian and trustee of the nation's water resources, the Government (specifically the Department of Water and Sanitation) must ensure that water is protected, used, developed, conserved, managed and controlled in a sustainable and equitable manner for the benefit of all persons and in accordance with its constitutional mandate.

  In accordance with GN509 of 2016 as it relates to the National Water Act, 1998 (Act No. 36 of 1998), a regulated area of a watercourse in terms of water uses as listed in Section 21c and 21i is defined as:

  - The outer edge of the 1 in 100-year floodline and/or delineated riparian habitat, whichever is the greatest distance, measured from the middle of the watercourse of a river, spring, natural channel, lake or dam;
  - in the absence of a determined 1 in 100-year floodline or riparian area the area within 100 m from the edge of a watercourse where the edge of the watercourse is the first identifiable annual bank fill flood bench: or
  - A 500m radius from the delineated boundary (extent) of any wetland or pan in terms of this regulation.

- **National Environmental Management Act (Act 107 of 1998)**

  The National Environmental Management Act, 1998 (Act No. 107 of 1998) and the associated Regulations as amended in 2017, states that prior to any development taking place within a wetland or riparian area, an environmental authorisation process needs to be followed. This could follow either the Basic Assessment Report (BAR) process or the Environmental Impact Assessment (EIA) process depending on the scale of the impact. Provincial regulations must also be considered.

- **The Constitution of South Africa, 1996**

  The environment and the health and well-being of people are safeguarded under the Constitution of the Republic of South Africa, 1996 by way of section 24. Section 24(a) guarantees a right to an environment that is not harmful to human health or well-being and to environmental protection for the benefit of present and future generations. Section 24(b) directs the state to take reasonable legislative and other measures to prevent pollution, promote conservation, and secure the ecologically sustainable development and use of natural resources (including water and mineral resources) while promoting justifiable economic and social development. Section 27 guarantees every person the right of access to sufficient water, and the state is obliged to take reasonable legislative and other measures within its available resources to achieve the progressive normalization of this right. Section 27 is defined as a socio-economic right and not an environmental right. However, read with section 24 it requires of the state to ensure that water is conserved and protected and that sufficient access to the resource is provided. Water regulation in South Africa places a great emphasis on protecting the resource and on providing access to water for everyone.

4 Hydrological Characteristics

The project area is located within the 42K, 42L and 43K quaternary catchment areas as defined by Water resources of South Africa, 2005 study (WR 2005). The main drainage features traversing the project area include the Bosluisspruit River, Doring River and the Sand River, of which the Sand River is the major system originating in the area of east and draining south-west past Welkom and the Project site.

Based on the observations made from Google Earth Pro satellite imagery (Google Earth, 2022) and the site visit that was conducted on the 13th of April 2022, the project area comprises mostly of farmlands with some bush areas in-between. In general, based on the available topographic survey data, the project area is generally flat (<10% slope). According to the "SANRAL Drainage Manual, 6th Edition", the soils in the project area have a moderately low to moderately high internal drainage capacity and generalised SCS soil grouping classification for South Africa. Soils that are well drained produce a lower stormflow response than poorly drained soils.

The delineation of catchment areas draining to the above-mentioned rivers was undertaken using the topography of the area defined by SRTM DEM data. A catchment area is generally defined as that area from which all rainfall will drain into a drainage system through surface flow, to a common point.

The focus of the reporting on this section is on the major points of the major rivers, however, the project area has multiple small tributaries that drain into the major rivers at multiple points along the major rivers; these were individually considered as flow change locations in the river modelling so that the peak flow at the downstream end of a river doesn't represent the entire river. The catchment areas are shown below:

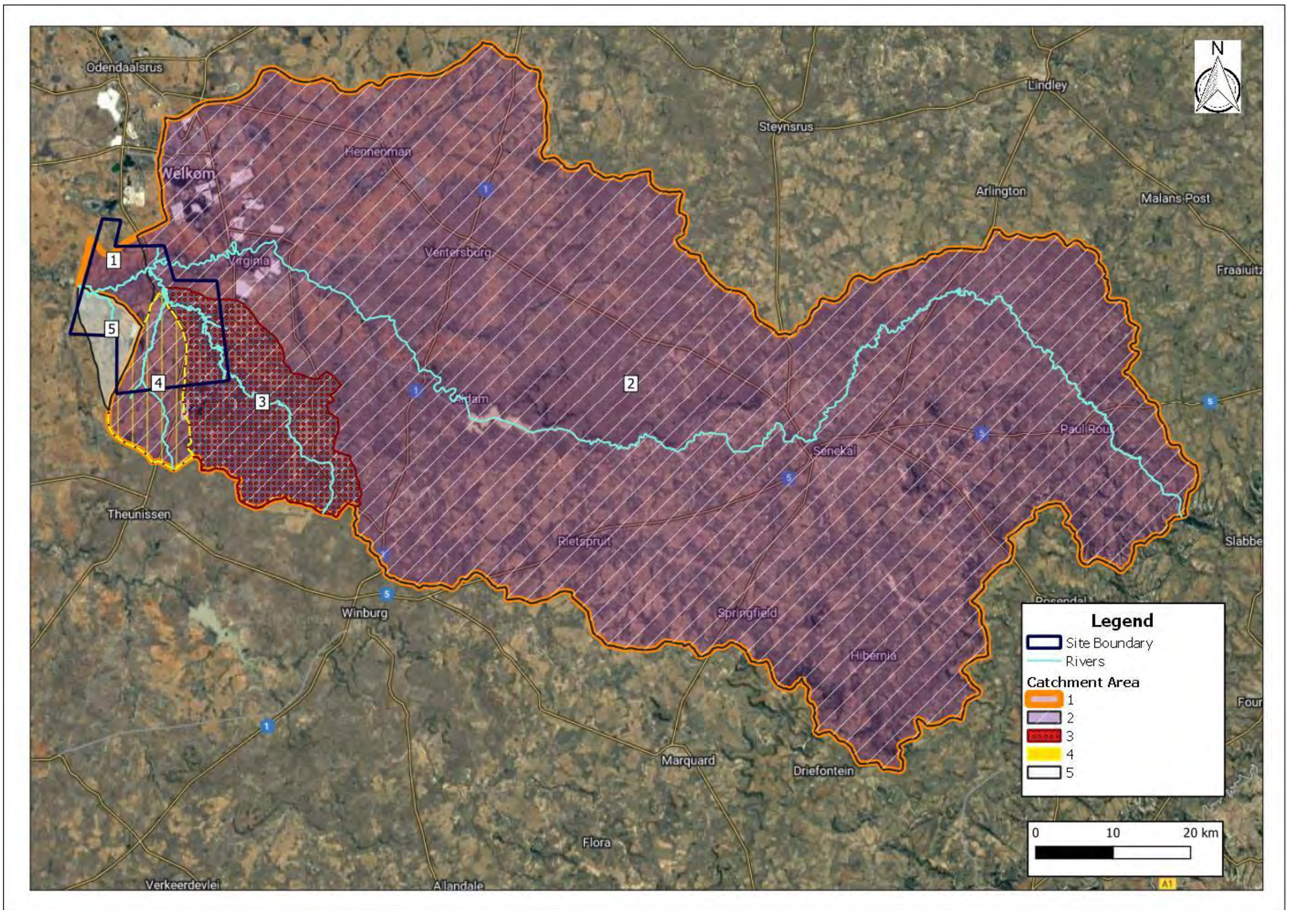

Figure 4-1: Catchment Areas

The physical properties of the various catchment areas shown in Figure 4-1 are summarized in Table 4-1.

Table 4-1: Catchment Area Physical Properties

Description	Unit	1	2	3	4	5
Size of Catchment Area	km^2	7118	7054	442	155	68
Hydraulic length of Catchment	km	251	217	58	29	20
Average Stream Slope	m/m	0.0013	0.0012	0.0032	0.0055	0.0079

5 Hydrological Analysis

5.1 Methodology

The following methodology was used in the hydrological analysis to determine flood peaks:

- Five flood estimation methods were selected as being relevant to the catchment areas under consideration, being the Standard Design Flood Method (SDF), Rational Method (RM), Alternative Rational Method (ARM), Unit Hydrograph Method (UHM) and the Empirical Method developed by Midgley and Pitman.
- Input data for these three methods was developed as follows:
  - Design rainfall depths were obtained from Water Research Commission Project Number K5/1060 (2002) for Welkom/Sandvet Station (South African Weather Bureau (SAWB) Number 0328308A) for the majority of small catchment areas inside the project area. For the larger catchment areas (1 and 2) that fall within multiple rainfall stations, an average of the MAPs was considered. The considered rainfall stations are:
    - (i) Paul Roux (SAWB No. 0330797W) with MAP of 614mm;
    - (ii) Senekal (SAWB No. 0553762 W) with MAP of 625mm;
    - (iii) Ventersberg (SAWB No. 0329215W) with MAP of 546mm; and the
    - (iv) Welkom/Sandvet (SAWB No. 0328308A) with MAP of 496mm.
    - (v) These stations have an average record of 80 years between them.
  - The catchment area was delineated using the 30 m SRTM DEM topographical data, using QGIS software.
  - The project area is located in SDF Basin number 7, Veld type zone 4 and Kovács region K4.
  - The design flood peaks for various return periods were then estimated both methods using the above inputs. The Utility Programs for Drainage Software (from University of Pretoria) was used to calculate the flood peaks. The program was developed specifically for South African rainfall conditions.

5.2 Topographical Data

The client provided a topographic survey of the project area. The water depth maps provided in this study are only as accurate as the quality of the topographical data provided, however SMEC took all the necessary steps to apply best engineering judgment to produce the flood maps as accurately as possible. The survey data that was provided for this project was 1 m contours data. The name of the data file used was "Tetra_Virginia_20211102_All Contours" and was received on the 1st of February 2022.

5.3 Climate Data

The climate of the study area is characterised by dry winters and wet summers. The warmest periods are usually noted between November and February and the coldest periods are usually seen between May and August. Average annual maximum temperature is approximately 28 ^{0}C per annum, according to the National Centre for Environmental Information (NCEI). The main characteristics are shown in Table 5-1 below:

Table 5-1: Climate Data

Month	Max. Temp (^{0}C)	Min. Temp (^{0}C)
Jan	32	17
Feb	32	17
Mar	30	15
Apr	27	11
May	24	6
Jun	20	3

Month	Max. Temp (^oC)	Min. Temp (^oC)
Jul	20	2
Aug	24	5
Sep	28	9
Oct	30	13
Nov	31	14
Dec	32	16
Average	**28**	**11**

The Witbank/Sandvet rainfall station is located approximately 8 km north from the centre of the project area. The Mean Annual Precipitation (MAP) for the project area is 496 mm based on the Witbank/Sandvet rainfall station data. This station has a 60 year record. This station was applied to peak flow calculations involving the smaller catchment areas (3, 4 and 5) nearest to the station. Catchment areas 1 and 2 fall within multiple rainfall stations, therefore an average MAP (580 mm) and rainfall depth was applied between all the relevant stations (See Section 5.1). The 24-hour storm rainfall depths for various return periods at the stations are presented in Table 5-2.

Table 5-2: Design Rainfall – 24-hour Rainfall Depths at Rainfall Stations within the Project Area (mm)

Rainfall Station	Return Period (years)					
	2	5	10	20	50	100
Paul Roux	52	69	81	93	100	123
Senekal	48	64	76	87	103	115
Ventersberg	48	64	76	88	104	117
Welkom/Sandvet	51	69	82	94	111	124
Average	**50**	**67**	**79**	**91**	**105**	**120**

5.4 Peak Flow Volumes

The peak flows used for floodline determination were calculated using 5 standard methods applied in South Africa shown in Table 5-3. Based on the legislation adopted for this study, peak flows resulting from the 1:100-year event were used in floodline modelling. A summary of the calculated peak flows, for the various catchment areas are presented below and are based on the calculations and inputs indicated in Section 5.1. The peak flow volumes are indicated in Table 5-3.

Table 5-3: 1:100-year peak flow rates (m^3/s)

Flood Estimation Method	Catchment Areas (km^2)				
	1	2	3	4	5
Standard Design Flood (SDF)	**3045**	**3022**	**745**	**502**	**325**
Rational Method (RM)	1493	1000	285	188	112
Alternative Rational Method (ARM)	1397	933	242	185	139
Unit Hydrograph Method (UHM)	1267	1258	424	229	134
Midgley and Pitman Empirical Method (EM)	2111	2086	356	213	134

The calculated SDF method flows are generally higher than the other methods. The SDF method was chosen to represent the 1:100-year flood peak at the site. The SDF method resulted in the highest peak flows being estimated for most catchment areas, making its application a conservative approach. The SDF method is designed for South African conditions and is one of the most widely used and accepted methods in South Africa (SANRAL, 2013). The method can also be used accurately for catchment areas of any size.

6 Floodline Modelling

The river hydraulics were modelled using the GeoHEC-RAS software suite, developed by CivilGEO Engineering Software. The software utilises the widely used one-dimensional HEC-RAS river hydraulics engine, developed by the US Army Corps of Engineers. The floodlines are based on static flow conditions and do not reflect any additional water rise, due to possible dam break events, in the upstream catchment area. Flood modelling was undertaken for the sections of the above-mentioned rivers that lie within project area boundary.

6.1 Channel Roughness

Channel roughness values are physical parameters describing the unevenness of the surface within a particular stream/river that impacts the water depth, velocity and therefore energy and momentum of water moving from upstream to a downstream location.

Manning's Roughness coefficient/values (n) were estimated using a visual assessment of Google Earth aerial photograph maps and site photographs. They were based on the description obtained from the SANRAL Drainage manual, 6th Edition as well as the following equation developed by Cowan (1956), to estimate the Manning's Roughness Coefficient/values (n) for the channel.

$$n = (nb + n1 + n2 + n3 + n4) \times m$$

Where:

nb = a base value of n for a straight, uniform, smooth channel in natural materials
n1 = a correction factor for the effect of surface irregularities
n2 = a value for variations in shape and size of the channel cross section
n3 = a value for obstructions
n4 = a value for vegetation and flow conditions
m = a correction factor for meandering of the channel

Table 6-1: Manning's Roughness Coefficient/values

Parameter	Left Bank	Channel	Right Bank
Sand River	0.111	0.036	0.079
Doring River	0.101	0.040	0.084
Bosluisspruit River	0.099	0.039	0.073
"Catchment 5" River	0.078	0.037	0.078

The values above represent the average Manning's roughness values across the rivers inside the project area. Generally, every section along a natural river has a different manning's roughness due to its irregular nature. The following figures indicate the channel characteristics at each of the rivers.

Figure 6-1: Sand River Channel Characteristic

Figure 6-2: Doring River Channel Characteristics

Figure 6-3: Bosluisspruit Channel Characteristics

Figure 6-4: "Catchment 5" River Channel Characteristics

6.2 River Hydraulic Model

A site visit of the culverts and bridges was conducted on the 12th and 13th of April 2022 by SMEC. During this site visit, the dimensions for bridges and culvert structures, considered/included in the model, were measured. Weir structures/ dams were not included in the analysis since they could not be measured. The model accuracy relies on this data and can be deemed fairly inaccurate on the near upstream side of any potential dams located within the rivers of the study area. Figure 6-5 indicates the hydraulic structures that were measured:

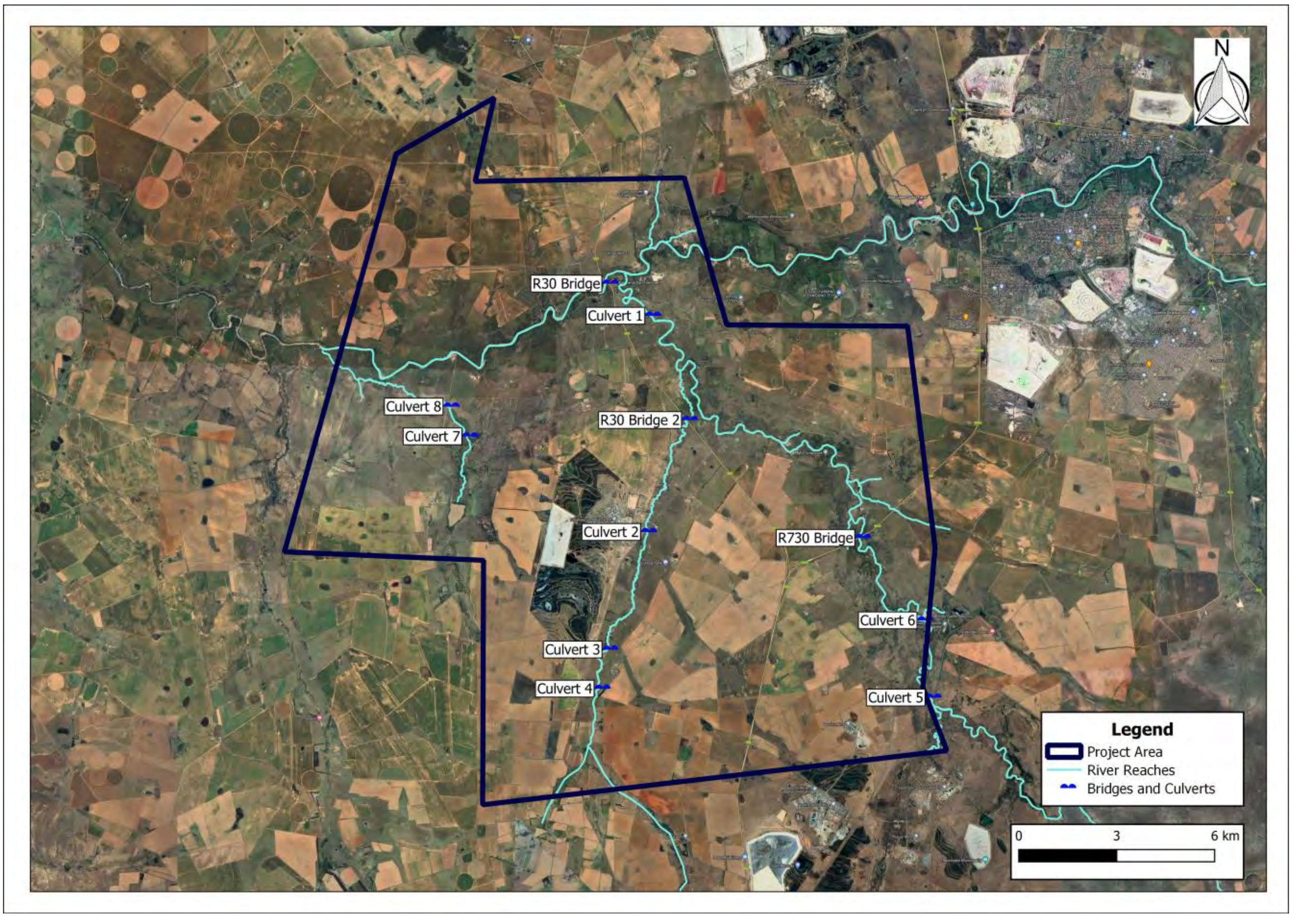

Figure 6-5: Bridges and Culverts Locations

6.2.1 Boundary Conditions

The normal depth condition was used as the downstream and upstream hydraulic controls / boundaries. In general, the boundary condition assumption had little to no effect on the flood depth, near the project area. It did however make a difference on the downstream boundary of the Sand River. Increasing or reducing the slope affects the position of floodlines. The average slope of the river was assumed as the downstream boundary. The downstream boundary slope used was the average slope of the river inside the project area.

6.3 Results

The peak flows estimated by the SDF method as presented in Section 5.4 were used to simulate the floodlines of the rivers running through the Tetra4 Gas project area. The floodlines are indicated in Figure 6-6, below.

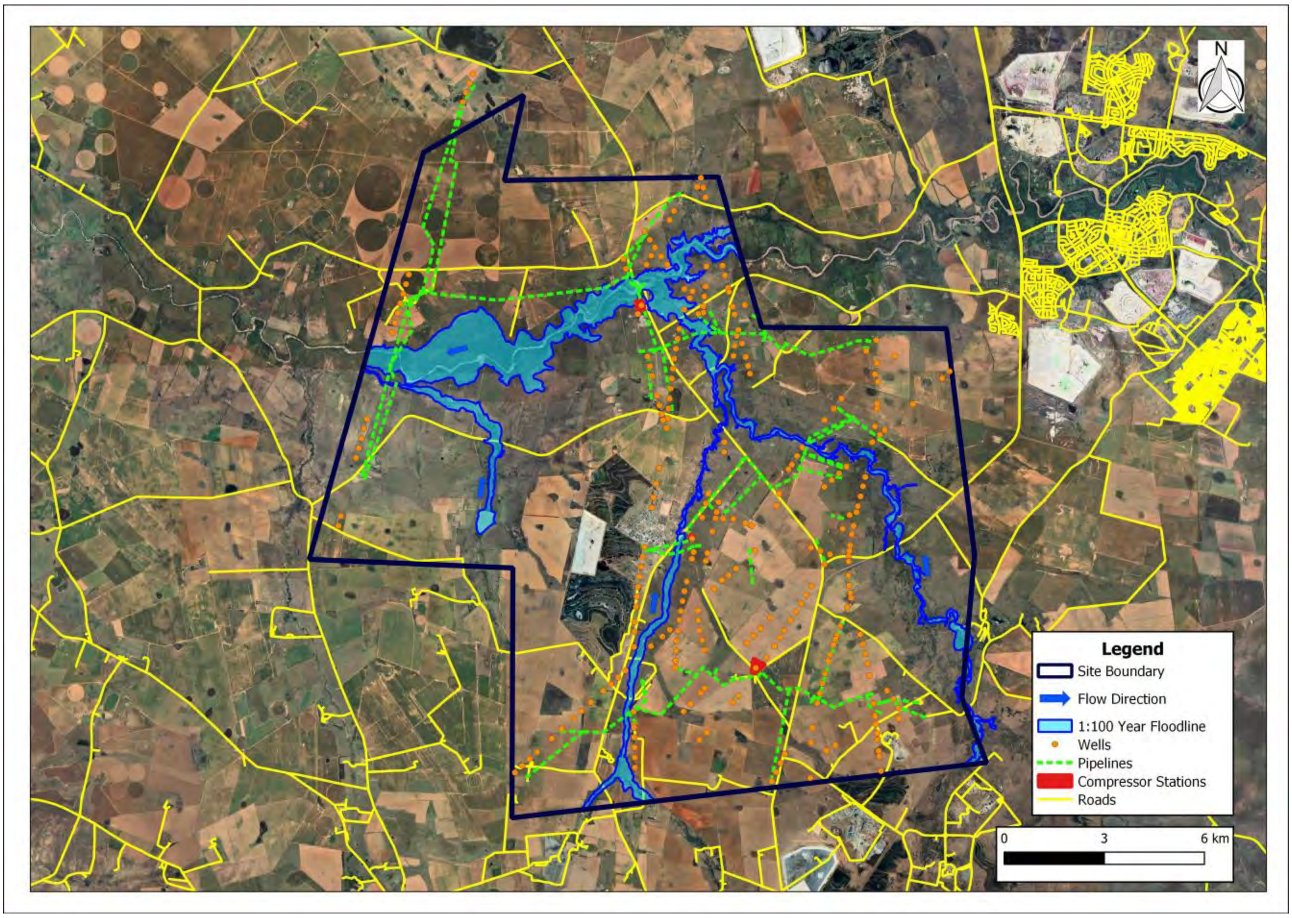

Figure 6-6: 100-year floodlines

7 Site Sensitivities

The sensitivities and constraints at the Tetra4 Cluster 2 Gas project site were assessed in accordance with the National Water Act Regulations (GN509, 2016) and the EIMS sensitivity assessment methodologies. Based on the National Water Act (GN509, 2016) described in Section 3, the area within the 1:100-year floodline is considered to be the regulated area of a watercourse. Any activities within the 1:100-year floodline will require the appropriate water use authorisation by the DWS. Figure 7-1 indicates a sensitivity map which was developed to assist in identifying sensitive features in relation to the 1:100-year flood within the project area.

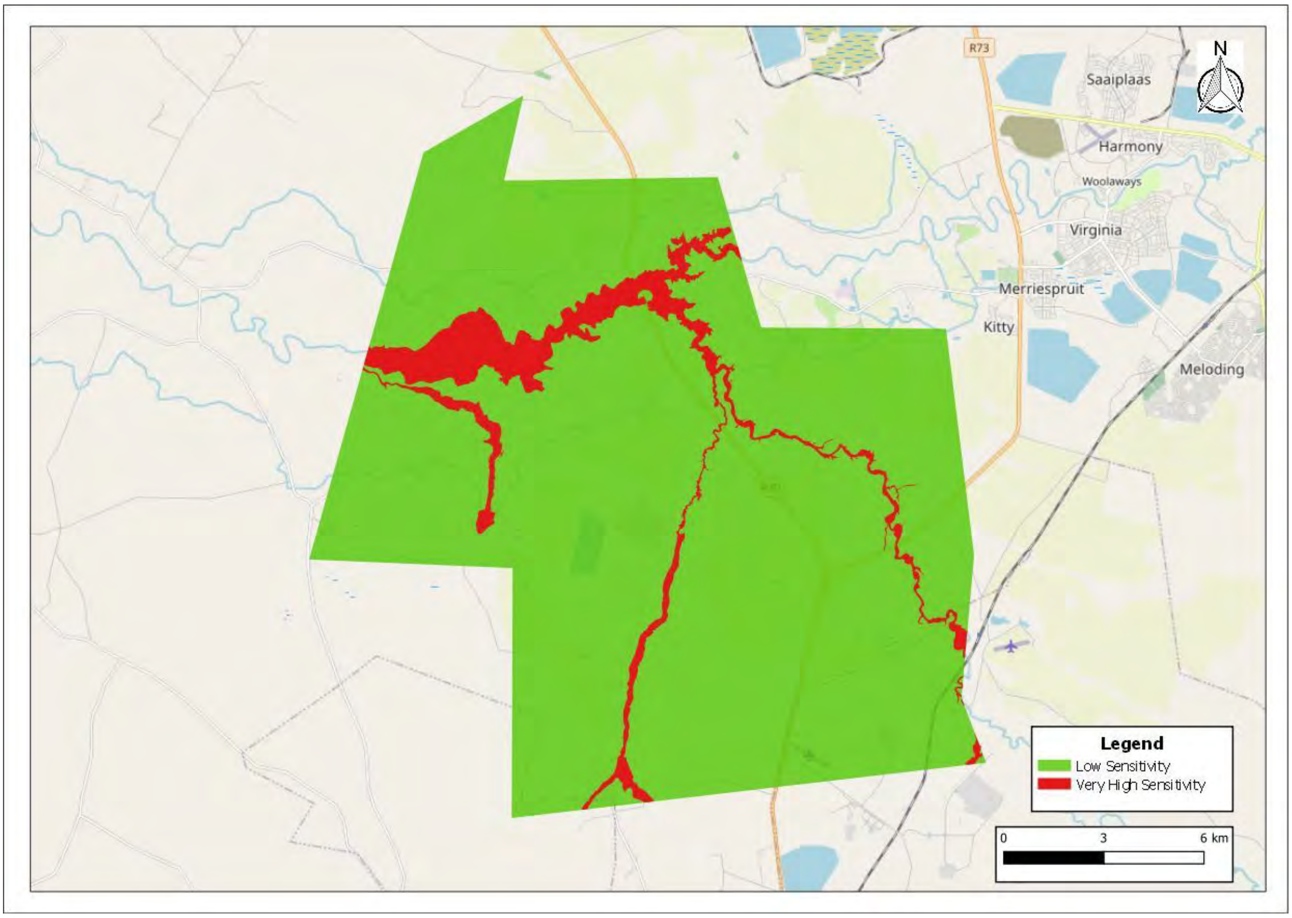

Figure 7-1: Hydrology Sensitivity Map

8 Potential Impacts and Mitigation

This section presents the flowing:

- Potential impacts on the ecology of the identified watercourses associated with the proposed development;
- Recommended mitigation measures needed to minimise the perceived impacts of the proposed development.

Most impacts are considered to be easily detectable and the considered mitigation measures are easily practicable therefore the risks associated with the development are considered to be low.

8.1 Construction Phase Impacts

During the construction phase, pipes connecting the new wells to the compressor stations and helium plant will be laid down. Construction work for laying of pipes across rivers or parallel to them may involve the excavation of riverbed material and restoring the river to a near-natural state thereafter. Horizontal Directional Drilling (HDD) will be the method generally used on site to lay pipes so that the impact is minimal/negligible.

Table 8-1: Construction Phase Impacts and Mitigation Measures

• Potential Impacts	Mitigation Measures
Exposure of soil, leading to increased runoff, and erosion, and thus increased sedimentation of the watercourses.	Ensure total footprint area is kept to a minimum.
	Traffic and movement of machinery should be minimised and restricted to certain paths.
	Progressive rehabilitation of disturbed land should be carried out.
Soil and stormwater contamination by oils and hydrocarbons spills, originating from construction vehicles	Construction waste must be collected and stored safely for disposal in accordance with the relevant waste regulations, protocols, and product specifications. Care must be taken not to leave any waste on project area that can lead to future contamination of the project area or the downstream area.
Increase in the number of alien and/or invasive vegetation as a result of disturbances.	Monitoring for the project area for alien and invasive vegetation species must be undertaken, specifically for access roads through or along the watercourses. Should alien and invasive plan species be identified, they must be removed and disposed of as per an alien and invasive species control plan and the area must be revegetated with suitable indigenous vegetation.
Alterations of the river banks and river bed due to movement near the drainage lines.	The reaches of all watercourses where no construction activities are planned to occur must be considered no-go areas.

8.2 Operational Phase Impacts

The activities expected during the operational phase involve the operation of the well pad, pipelines, compression station and LNG/LHe beneficiation plant, movement of trucks and other vehicles, general and hazardous waste management, gas processing as well as operation of Road tankers for gas distribution. The potential environmental impacts and mitigation measures during the operational phase are listed below.

Table 8-2: Operational Phase Impacts and Mitigation Measures

Potential Impacts	Mitigation Measures
Disturbance to soil and ongoing erosion as a result of periodic maintenance activities.	No movement of construction equipment through the watercourses may be permitted during standard operational activities or maintenance activities. Use must be made of the existing and/or approved watercourse crossings only.
	Regular conditional inspections of all stormwater infrastructure are required. Inspection data must be recorded and accumulated for tracking purposes. Regular reporting should be scheduled management task.
	Specific attention must be given to inspection during and after any rain and/or flood event to kerb any damage that may have occurred.
Altered water quality as a result of increased availability of pollutants.	Oil recovered from construction vehicles and machinery should be collected, stored and disposed of by accredited vendors for recycling.
Potential increase in the number of alien and/or invasive vegetation as a result of floods or people who visit the site.	Monitoring for the project area for alien and invasive vegetation species must be undertaken, specifically for access roads through or along the watercourses. Should alien and invasive plan species be identified, they must be removed and disposed of as per an alien and invasive species control plan and the area must be revegetated with suitable indigenous vegetation.

8.3 Decommissioning Phase Impacts

The decommissioning phase involves the removal of all berms, trenches and other storm water infrastructure, stationary infrastructure, pipeline infrastructure and wastes.

Potential Impacts	Mitigation Measures
Increased erosion due to construction vehicles movement.	Topsoil removed during construction must be stored on site for rehabilitation and re-vegetation. The soil must be stabilised using materials such as netting or geotextiles where necessary.
	The site shall be re-instated to its original condition as far as possible. No foreign material generated / deposited during construction shall remain on site.
	Rehabilitate disturbance areas as soon as construction in an area is completed.
Stormwater Contamination resulting from spillages of polluted groundwater from wells	All wells should be capped to prevent the spilling of contaminated groundwater.
Potential increase in the number of alien and/or invasive vegetation as a result of floods or people who visit the site.	Monitoring for the project area for alien and invasive vegetation species must be undertaken, specifically for access roads through or along the watercourses. Should alien and invasive plan species be identified, they must be removed and disposed of as per an alien and invasive species control plan and the area must be revegetated with suitable indigenous vegetation.

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Appendix A: Hydrological Calculations

Flood frequency analysis : Standard Design Flood method

Project name	= Tetra4 Gas Floodline
Analysed by	= Rendani Thovhakale
Name of river	= Reach 1
Description of site	= Catchment 1
Date	= 2022/02/10
Catchment characteristics:	
Area of catchment	= 7118 km²
Length of longest watercourse	= 251 km
1085 height difference	= 251 m
Average slope	= 0.0013 m/m
Drainage basin characteristics:	
Drainage basin number	= 7
Mean annual daily max rain	= 49 mm
Days on which thunder was heard	= 39 days
Runoff coefficient C2	= 15 %
Runoff coefficient C100	= 60 %
Basin mean annual precipitation	= 510 mm
Basin mean annual evaporation	= 1700 mm
Basin evaporation index MAE/MAP	= 3.33

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site. The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 328726 @ OLIVINE
Point mean annual precipitation = 510 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	32	39	49	57	64
.50 h	19	32	41	51	64	74	84
1 h	23	39	51	63	79	91	103
2 h	27	46	61	75	94	108	122
4 h	32	54	70	87	109	125	142
1 day	49	68	82	96	118	137	157
2 days	62	87	107	128	158	184	213
3 days	68	94	115	136	167	193	221
7 days	84	118	144	172	211	243	279

Runoff coefficients C2 = 15 % C100 = 60 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m³/s)
1:2	59.75	48.8	79.8	39.0	15.0	193.56
1:5	59.75	82.4	79.8	65.7	31.2	679.70
1:10	59.75	107.7	79.8	86.0	39.7	1131.06
1:20	59.75	133.1	79.8	106.2	46.7	1642.05
1:50	59.75	166.6	79.8	133.0	54.6	2404.59
1:100	59.75	192.0	79.8	153.3	60.0	3045.14
1:200	59.75	217.4	79.8	173.5	64.8	3724.94

Calculated using Utility Programs for Drainage 1.1.0

Flood frequency analysis : Standard Design Flood method

```
Project name                             = Tetra4 Gas Floodlines
Analysed by                              = Rendani Thovhakale
Name of river                            =
Description of site                      = Catchment 2
Date                                     = 2022/02/10
Catchment characteristics:
Area of catchment                        = 7054 km²
Length of longest watercourse            = 239 km
1085 height difference                   = 217 m
Average slope                            = 0.0012 m/m
Drainage basin characteristics:
Drainage basin number                    = 7
Mean annual daily max rain               = 49 mm
Days on which thunder was heard          = 39 days
Runoff coefficient C2                    = 15 %
Runoff coefficient C100                  = 60 %
Basin mean annual precipitation          = 510 mm
Basin mean annual evaporation            = 1700 mm
Basin evaporation index MAE/MAP          = 3.33
```

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site. The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 328726 @ OLIVINE
Point mean annual precipitation = 510 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	32	39	49	57	64
.50 h	19	32	41	51	64	74	84
1 h	23	39	51	63	79	91	103
2 h	27	46	61	75	94	108	122
4 h	32	54	70	87	109	125	142
1 day	49	68	82	96	118	137	157
2 days	62	87	107	128	158	184	213
3 days	68	94	115	136	167	193	221
7 days	84	118	144	172	211	243	279

Runoff coefficients C2 = 15 % C100 = 60 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m³/s)
1:2	59.72	48.8	79.9	39.0	15.0	192.06
1:5	59.72	82.4	79.9	65.8	31.2	674.43
1:10	59.72	107.7	79.9	86.0	39.7	1122.29
1:20	59.72	133.1	79.9	106.3	46.7	1629.31
1:50	59.72	166.6	79.9	133.1	54.6	2385.94
1:100	59.72	192.0	79.9	153.4	60.0	3021.53
1:200	59.72	217.4	79.9	173.6	64.8	3696.06

Calculated using Utility Programs for Drainage 1.1.0

Utility Programs for Drainage
Flood calculations

Sinotech

Project name: Tetra4 Gas Floodlines
Analysed by: Rendani Thovhakale
Name of river:
Description of site: Catchment 3
Filename: C:\Users\rt2704930\OneDrive - Surbana Jurong Private Limited\Desktop\Desktop\Manager\Tetra4 Gas\Hydrology\Junction 1 (Catchment 3).fld
Date: 10 February 2022

Flood frequency analysis : Standard Design Flood method

Project name	= Tetra4 Gas Floodlines
Analysed by	= Rendani Thovhakale
Name of river	=
Description of site	= Catchment 3
Date	= 2022/02/10
Catchment characteristics:	
Area of catchment	= 442 km²
Length of longest watercourse	= 58 km
1085 height difference	= 134 m
Average slope	= 0.0031 m/m
Drainage basin characteristics:	
Drainage basin number	= 7
Mean annual daily max rain	= 49 mm
Days on which thunder was heard	= 39 days
Runoff coefficient C2	= 15 %
Runoff coefficient C100	= 60 %
Basin mean annual precipitation	= 510 mm
Basin mean annual evaporation	= 1700 mm
Basin evaporation index MAE/MAP	= 3.33

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site. The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 328726 @ OLIVINE
Point mean annual precipitation = 510 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	32	39	49	57	64
.50 h	19	32	41	51	64	74	84
1 h	23	39	51	63	79	91	103
2 h	27	46	61	75	94	108	122
4 h	32	54	70	87	109	125	142
1 day	49	68	82	96	118	137	157
2 days	62	87	107	128	158	184	213
3 days	68	94	115	136	167	193	221
7 days	84	118	144	172	211	243	279

Runoff coefficients C2 = 15 % C100 = 60 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m³/s)
1:2	14.01	39.7	90.6	36.0	15.0	47.36
1:5	14.01	67.0	90.6	60.7	31.2	166.31
1:10	14.01	87.6	90.6	79.4	39.7	276.75
1:20	14.01	108.3	90.6	98.1	46.7	401.78
1:50	14.01	135.6	90.6	122.9	54.6	588.36
1:100	14.01	156.2	90.6	141.6	60.0	745.09
1:200	14.01	176.8	90.6	160.3	64.8	911.43

Calculated using Utility Programs for Drainage 1.1.0

Utility Programs for Drainage
Flood calculations

Project name: Tetra4 Gas Floodline
Analysed by: Rendani Thovhakale
Name of river:
Description of site: Catchment 4
Filename: C:\Users\rt2704930\OneDrive - Surbana Jurong Private Limited\Desktop\Desktop\Manager\Tetra4 Gas\Hydrology\Junction 2 (Catchment 4).fld
Date: 10 February 2022

Flood frequency analysis : Standard Design Flood method

Project name = Tetra4 Gas Floodline
Analysed by = Rendani Thovhakale
Name of river =
Description of site = Catchment 4
Date = 2022/02/10
Catchment characteristics:
Area of catchment = 155 km²
Length of longest watercourse = 29 km
1085 height difference = 117 m
Average slope = 0.0054 m/m
Drainage basin characteristics:
Drainage basin number = 7
Mean annual daily max rain = 49 mm
Days on which thunder was heard = 39 days
Runoff coefficient C2 = 15 %
Runoff coefficient C100 = 60 %
Basin mean annual precipitation = 510 mm
Basin mean annual evaporation = 1700 mm
Basin evaporation index MAE/MAP = 3.33

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site. The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 328726 @ OLIVINE
Point mean annual precipitation = 510 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	32	39	49	57	64
.50 h	19	32	41	51	64	74	84
1 h	23	39	51	63	79	91	103
2 h	27	46	61	75	94	108	122
4 h	32	54	70	87	109	125	142
1 day	49	68	82	96	118	137	157
2 days	62	87	107	128	158	184	213
3 days	68	94	115	136	167	193	221
7 days	84	118	144	172	211	243	279

Runoff coefficients C2 = 15 % C100 = 60 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m³/s)
1:2	6.63	35.0	93.4	32.7	15.0	31.89
1:5	6.63	59.1	93.4	55.2	31.2	111.97
1:10	6.63	77.3	93.4	72.2	39.7	186.33
1:20	6.63	95.5	93.4	89.2	46.7	270.51
1:50	6.63	119.5	93.4	111.6	54.6	396.13
1:100	6.63	137.7	93.4	128.6	60.0	501.66
1:200	6.63	155.9	93.4	145.6	64.8	613.65

Calculated using Utility Programs for Drainage 1.1.0

Utility Programs for Drainage
Flood calculations

Project name: Tetra4 Gas Floodline
Analysed by:
Name of river:
Description of site: Catchment 5
Filename: C:\Users\rt2704930\OneDrive - Surbana Jurong Private Limited\Desktop\Desktop\Manager\Tetra4 Gas\Hydrology\Downstream 2 (Catchment 5).fld
Date: 10 February 2022


```
Flood frequency analysis : Standard Design Flood method

Project name                             = Tetra4 Gas Floodline
Analysed by                              =
Name of river                            =
Description of site                      = Catchment 5
Date                                     = 2022/02/10
Catchment characteristics:
Area of catchment                        = 68.2 km²
Length of longest watercourse            = 20.5 km
1085 height difference                   = 117 m
Average slope                            = 0.0076 m/m
Drainage basin characteristics:
Drainage basin number                    = 7
Mean annual daily max rain               = 49 mm
Days on which thunder was heard          = 39 days
Runoff coefficient C2                    = 15 %
Runoff coefficient C100                  = 60 %
Basin mean annual precipitation          = 510 mm
Basin mean annual evaporation            = 1700 mm
Basin evaporation index MAE/MAP          = 3.33

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall
is from the Department of Water Affair's publication TR102 for the representative site.
The modified Hershfield equation is used for durations up to four hours. Linear
interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 328726 @ OLIVINE
Point mean annual precipitation =  510  mm
```

Dur:	RP =2	5	10	20	50	100	200
.25 h	14	24	32	39	49	57	64
.50 h	19	32	41	51	64	74	84
1 h	23	39	51	63	79	91	103
2 h	27	46	61	75	94	108	122
4 h	32	54	70	87	109	125	142
1 day	49	68	82	96	118	137	157
2 days	62	87	107	128	158	184	213
3 days	68	94	115	136	167	193	221
7 days	84	118	144	172	211	243	279

Runoff coefficients C2 = 15 %   C100 = 60 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m³/s)
1:2	4.44	32.5	96.2	31.3	15.0	20.03
1:5	4.44	54.8	96.2	52.8	31.2	70.35
1:10	4.44	71.7	96.2	69.0	39.7	117.06
1:20	4.44	88.6	96.2	85.3	46.7	169.94
1:50	4.44	110.9	96.2	106.8	54.6	248.86
1:100	4.44	127.8	96.2	123.0	60.0	315.16
1:200	4.44	144.7	96.2	139.3	64.8	385.51

Calculated using Utility Programs for Drainage 1.1.0

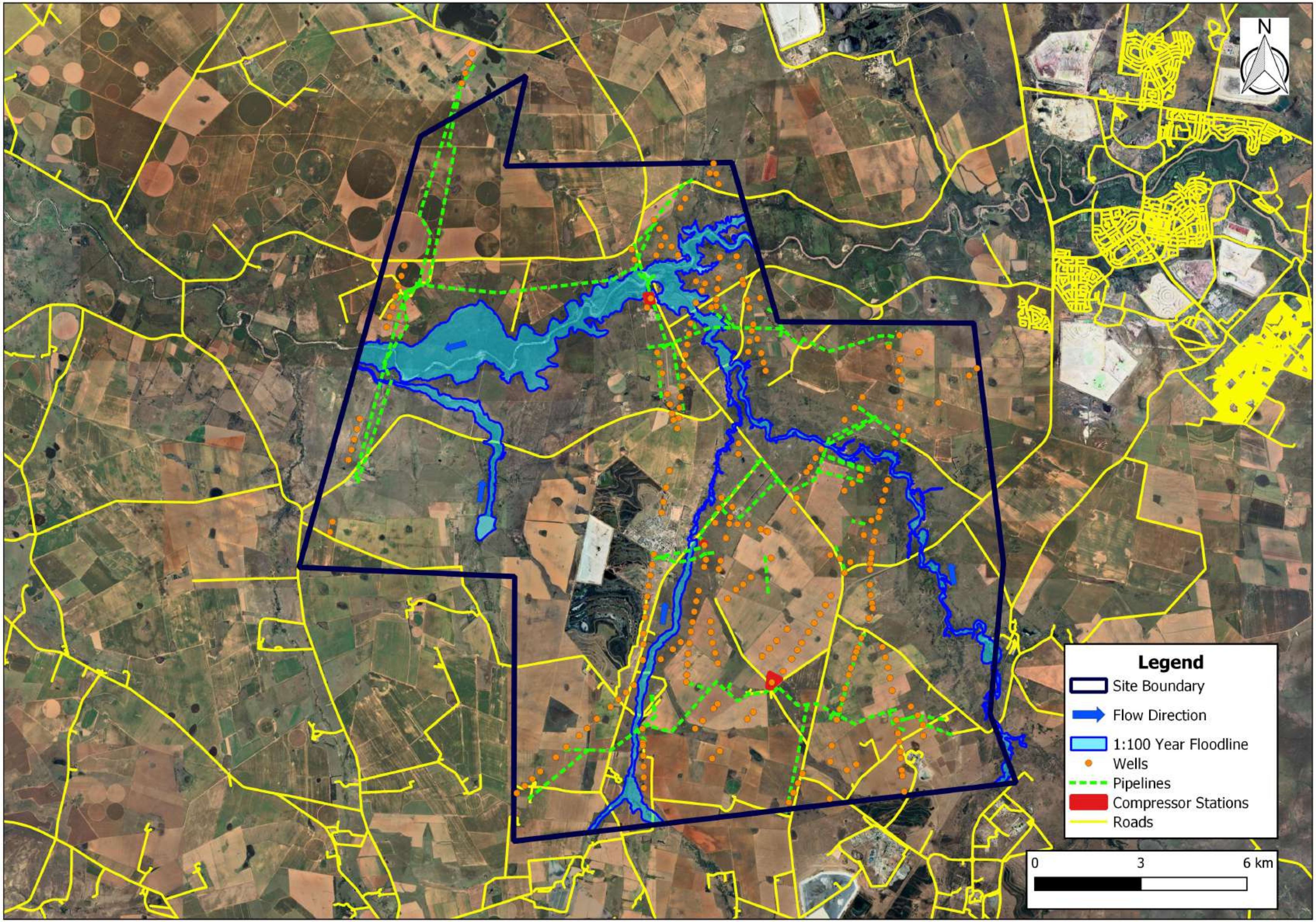
Appendix B: Impact Significance Ratings

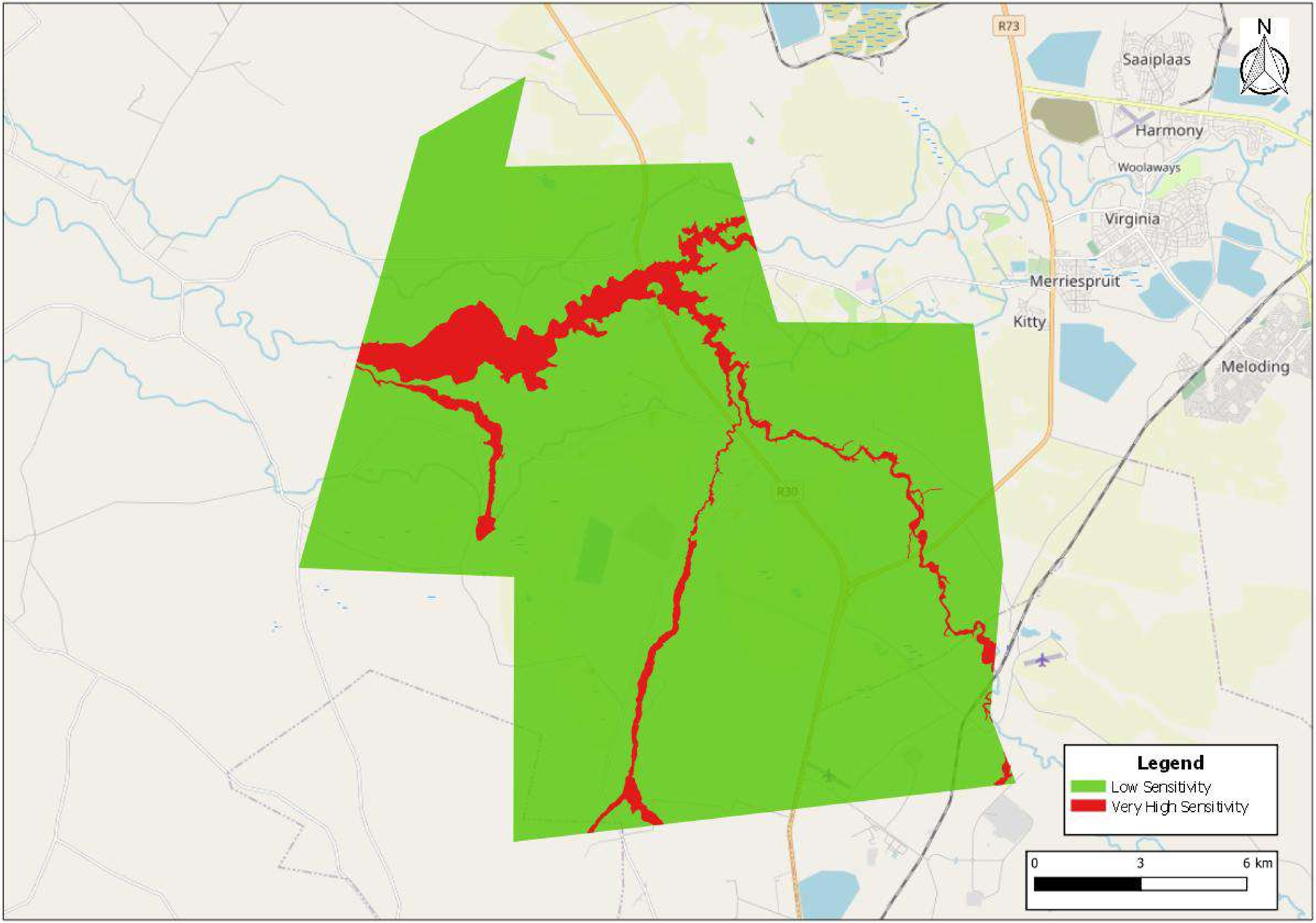
IMPACT DESCRIPTION			Pre-Mitigation						
Identifier	Impact	Phase	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER
10.1.1	Loss of watercourse vegetation	Construction	-1	2	1	1	2	2	-3
10.1.2	Erosion	Construction	-1	1	2	1	2	4	-6
10.1.3	Stormwater contamination	Construction	-1	1	2	2	2	4	-7
10.1.4	Alien and/or Invasive Vegetation	Construction	-1	3	4	3	3	2	-6.5
10.1.5	Alterations of the river banks and river bed	Construction	-1	2	2	2	3	3	-6.75
10.1.6	Erosion	Operation	-1	2	4	3	2	2	-5.5
10.1.7	Stormwater contamination	Operation	-1	3	3	3	3	3	-9
10.1.8	Alien and/or Invasive Vegetation	Operation	-1	3	4	3	3	3	-9.75
10.1.9	Erosion	Decommissioning	-1	2	3	3	2	2	-5
10.1.10	Stromwater contamination	Decommissioning	-1	3	3	3	3	3	-9
10.1.11	Alien and/or Invasive Vegetation	Decommissioning	-1	3	4	3	3	2	-6.5

IMPACT DESCRIPTION			Post Mitigation						
Identifier	Impact	Phase	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER
10.1.1	Loss of watercourse vegetation	Construction	-1	2	1	1	2	1	-1.5
10.1.2	Erosion	Construction	-1	1	1	2	2	2	-3
10.1.3	Stormwater contamination	Construction	-1	1	1	2	2	2	-3
10.1.4	Alien and/or Invasive Vegetation	Construction	-1	2	2	1	2	1	-1.75
10.1.5	Alterations of the river banks and river bed	Construction	-1	2	2	1	2	2	-3.5
10.1.6	Erosion	Operation	-1	2	4	3	2	1	-2.75
10.1.7	Stormwater contamination	Operation	-1	2	2	1	2	2	-3.5
10.1.8	Alien and/or Invasive Vegetation	Operation	-1	2	2	1	3	2	-4
10.1.9	Erosion	Decommissioning	-1	2	3	3	2	1	-2.5
10.1.10	Stromwater contamination	Decommissioning	-1	2	2	1	2	2	-3.5
10.1.11	Alien and/or Invasive Vegetation	Decommissioning	-1	2	2	1	2	1	-1.75

IMPACT DESCRIPTION				Priority Factor Criteria			
Identifier	**Impact**	**Phase**	**Confidence**	**Cumulative Impact**	**Irreplaceable loss**	**Priority Factor**	**Final score**
10.1.1	Loss of watercourse vegetation	Construction	Low	2	1	1.13	-1.6875
10.1.2	Erosion	Construction	Low	2	1	1.13	-3.375
10.1.3	Stormwater contamination	Construction	Medium	2	1	1.13	-3.375
10.1.4	Alien and/or Invasive Vegetation	Construction	Low	2	1	1.13	-1.96875
10.1.5	Alterations of the river banks and river bed	Construction	Medium	2	2	1.25	-4.375
10.1.6	Erosion	Operation	Low	2	2	1.25	-3.4375
10.1.7	Stormwater contamination	Operation	Medium	2	2	1.25	-4.375
10.1.8	Alien and/or Invasive Vegetation	Operation	Medium	2	2	1.25	-5
10.1.9	Erosion	Decommissioning	Low	2	2	1.25	-3.125
10.1.10	Stromwater contamination	Decommissioning	Medium	2	2	1.25	-4.375
10.1.11	Alien and/or Invasive Vegetation	Decommissioning	Low	2	1	1.13	-1.96875

Appendix C: Maps


N
Legend
Site Boundary
Flow Direction
1:100 Year Floodline
Wells
Pipelines
Compressor Stations
Roads
0
3
6 km



R73
Saaiplaas
Harmony
Woolaways
Virginia
Merriespruit
Kitty
Meloding
R30
N
Legend
Low Sensitivity
Very High Sensitivity
0
3
6 km

Appendix D: NEMA Reporting Requirements Checklist

Reporting requirements as per NEMA Appendix 6 for specialist reports. Requirements of Appendix 6 – GN R326 EIA Regulations of 7 April 2017	Relevant section in report	Comment where not applicable
1.(1) (a) (i) Details of the specialist who prepared the report	Page i of Report – Contact details and company	-
(ii) The expertise of that person to compile a specialist report including a curriculum vita	Page iii – refer to Appendix E	-
(b) A declaration that the person is independent in a form as may be specified by the competent authority	Page ii of the report	-
(c) An indication of the scope of, and the purpose for which, the report was prepared	Section 1	-
(cA) An indication of the quality and age of base data used for the specialist report	Section 5.3	-
(cB) a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 8	-
(d) The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 6.2	-
(e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used	Section 5 and 6	-
(f) details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Sections 7	-
(g) An identification of any areas to be avoided, including buffers	Section 7	-
(h) A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 6.3	-
(i) A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 6.2	-
(j) A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Sections 6.3, 7, 8	-
(k) Any mitigation measures for inclusion in the EMPr	Sections 8	-
(l) Any conditions for inclusion in the environmental authorisation	Sections 8	-
(m) Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Sections 8	-
(n)(i) A reasoned opinion as to whether the proposed activity, activities or portions thereof should be authorised and	Section 8	-
(n)(iA) A reasoned opinion regarding the acceptability of the proposed activity or activities; and		-
(n)(ii) If the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Sections 8	-
(o) A description of any consultation process that was undertaken during the course of carrying out the study	-	Not applicable. A public consultation process will be handled as part of the environmental process.
(p) A summary and copies if any comments that were received during any consultation process	-	Not applicable. To date no comments regarding

		Stormwater that require input from a specialist have been raised.
(q) Any other information requested by the competent authority.		Not applicable.
(2) Where a government notice by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	NEMA Appendix 6 and GN648 SAHRA guidelines.	

Appendix E: CVs

Neil Meyer

Technical Principal: Water Infrastructure

SMEC South Africa
Member of the Surbana Jurong Group

Personal information
- ID no.: 760810 5061 082
- South African

Years of Industry Experience
- 20+ years

Countries of Experience
- South Africa
- Rwanda
- Zambia
- Gabon
- Malawi
- Sierra Leone
- Saudi Arabia
- Lesotho

Qualifications and Memberships
- University of London, Imperial College for Science, Technology and Medicine UK, MSc HEM (Hydrology for Environmental Management), 01/11/2001
- Master of Science Engineering (cum laude) (Civil), University of Stellenbosch 08/12/2000
- Bachelor of Engineering (cum laude) (Civil), University of Stellenbosch, 02/12/1998
- Professional Engineer (Pr. Eng), Engineering Council of South Africa (ECSA), 20060199, 14/08/2006
- Member: South African Institution of Civil Engineering (SAICE), Member, 980108, 15/01/2010
- Professional: Institute of Municipal Engineering of South Africa (IMESA) No M3362 10/02/2010
- South African National Commission on Large Dams (SANCOLD)

Key Skills and Competencies
- Project Management
- Master Planning
- Hydraulic Design
- Hydrological Analysis
- Basic WTW Design
- Basic WWTW Design

Professional Overview

Neil joined SMEC South Africa in 2013.

He has 20 years' experience in the design and project management of various projects both in South Africa and internationally, plus the design and project management of bulk water, sanitation/wastewater and drainage/stormwater infrastructure including water and wastewater treatment projects.

Neil is proficient with the use of numerous software packages for the planning, design and implementation of water, wastewater and stormwater projects. Neil has also developed spreadsheet models used to simplify and optimize water, sanitation and stormwater/drainage calculations, master planning assessments and evaluations of various infrastructure and treatment related projects.

Neil completed his MSc. Eng at the University of Stellenbosch from 2000 to 2001 and his MSc. Eng HEM/DIC at the University of London, United Kingdom from 2001 to 2002.

Relevant Project Experience

C1859 | Temporary Works on High-Speed Rail Network 2 (HS2), United Kingdom | GBP +500 Billion

Client: Sub-consultant to Robert Bird Group (RBG), United Kingdom on behalf of Effage, Kier, Ferrovial Construction and BAM Nuttal (EKFB), United Kingdom

Client Contact Details: Lisa Rapson; Director, Robert Bird Group; Tel: +44 20 7633 2880; Email: lisa.rapson@robertbird.com

Description: The temporary works contractor, EKFB, was appointed to conduct Temporary Works along the future High Speed 2 Rail Network (HS2) between London and Birmingham. The temporary works consist of Civil, Structural and Road works. RBG appointed SMEC to assist with Civil designs for the temporary works. To date a total of ten (10) earthwork design packages have been delivered.

Role and Responsibilities: Design lead for stormwater design and innovative drainage solutions for various excavations for temporary works. Design involvement included stormwater collection, routing, attenuation, silt management and pumping of stormwater. Hydraulic modelling of attenuation structures prepared using EPASWMM.

C1881 - Ernest Robertson Dam Dam Safety Evaluation, Western Cape, South Africa | R 92,366 Fees

Client: Mossel Bay Local Municipality | **Dates:** April 2022 – June 2022

Client Contact Details: Catherine Koelman; Project Manager; +27 (0)44 606 5269

Description: The 5th dam Safety Evaluation (DSE) for the Ernest Robertson Dam was undertaken in 2013. The 6th DSE was due, as required by the Department of Water and Sanitation (DWS) in terms of Regulations 35 of the Regulations regarding safety of dams published in government notice R.139 dated February 2012. SMEC was tasked with undertaking the 6th DSE. The scope of services of the Dam Safety Evaluation were as follows:

- Dam Inspection: Undertake the dam safety inspection and state the condition of indicators including the dam wall, dam crest and spillway, outlet works, reservoir basin slopes and monitoring instruments.
- Evaluation and Reporting: Review dam monitoring data to identify any issues; confirm flood hydrology and spillway capacity values remain applicable; prepare and submit draft Dam Safety

Evaluation Report with recommendations and action plan; Update and submit final Dam Safety Evaluation Report following receipt of comments from the client.

Role: Technical Lead.

Responsibilities: Review of Flood hydrology calculations, spillway capacity calculations, and report.

JH0049 - Tetra4 Gas Floodlines, Free State, South Africa | R 348 000 Fees

Client: EIMS | **Dates:** January 2022 – Ongoing

Client Contact Details: Brian Whitfield; Project Manager; +27 (0)82 688 9850

Description: SMEC was engaged by EIMS to prepare a Hydrological Impact Assessment that will be required to assist with the application of a Water Use License and Environmental Authorization for the Tetra4 Gas Production Project located in Welkom, Free State province.

Several hydrological methods, including Rational Method, Alternative Rational Method and SDF method were considered to calculate peak flood discharges for various return periods.

River hydraulics were modelled using the GeoHECRAS software suite developed by CivilGEO Engineering Software. The geometric information for the model was obtained from local topographic survey and roughness coefficients estimated from site surveys, based on the HEC-RAS hydraulic reference manual descriptions.

A flood hazard map and hydrological study report was prepared as input to various regulatory approval applications.

Role: Technical Lead.

Responsibilities: Review of Hydrological Analysis, Hydraulic Analysis, and the Hydrological assessment report.

Jh0051 - Mogalakwena PV Hydrological Study, Limpopo, South Africa | R250 917 Fees

Client: EDF Renewables | **Involvement Period:** April 2022 – July 2022

Client Contact Details: Martin Zietsman; Project Manager; +27 (0)83 69 13701

Description: SMEC was engaged by EDF Renewables to prepare a Hydrological Impact Assessment for a PV plant located in the Limpopo province of South Africa. This Hydrological Impact Assessment deals with the following aspects:

- Hydrological Analysis.
- Hydraulic Modelling.
- Floodline Delineation; and
- Flood impacts on infrastructure and flood mitigation measures.

The project also involved the design of a conceptual stormwater management plan. The scope of work was the design of a drainage layout, the sizing of drainage channels and detention basins, and erosion protection measures.

Role: Project manager and Design Engineer.

Responsibilities: Review of Hydrological Analysis, Hydraulic Analysis, Hydrology report and the stormwater management plan.

JH0050 - UMSO PV Hydrological Study, Northern Cape, South Africa | R 276 766 Fees

Client: EDF Renewables | **Dates:** January 2022 - Ongoing

Client Contact Details: Bradley Rabbitte; Project Manager; +27 (0)72 855 3420

Description: SMEC was engaged by EDF Renewables to prepare a Hydrological Impact Assessment for 5 PV plants located in the Northern Cape province of South Africa. This Hydrological Impact Assessment deals with the following aspects:

- Hydrological Analysis.
- Hydraulic Modelling.
- Floodline Delineation; and
- Flood impacts on infrastructure and flood mitigation measures.

Role: Technical Lead.

Responsibilities: Review of Hydrological Analysis, Hydraulic Analysis, and the Hydrology report.

DM0226: Replacement of AC/Mains for eThekwini Water and Sanitation, Phase II, Durban, KwaZulu-Natal, South Africa | R200 million

Client: eThekwini Municipality | Date: 2022 – Ongoing

Client Contact Details: Devashan Govender; Project Manager; Contact details: devashan.govender@durban.gov.za

Description: Replacement project comprising 12 months of intense field work and analysis to identify and select critical reservoir zones based on multi parameter optimization algorithms using GIS tools as part of the EWS water master plan and asset replacement programme for 2015/2030. A total of 80km of water mains to be designed already identified under phase I of the project. Prepare specification and tender documents for 40km of water mains in eThekwini Water Supply area.

Role and Responsibilities: Project Engineer, Lead Design Engineer. Technical advisor to field and data analysis teams in developing strategies to prioritize critical reservoir zones based on key KPI's. Lead the design work, prepare tender documentation, specification and project coordination of 2 construction contracts.

XL0048: NEOM Trojena, Stages 3B,3C,3D - Saudi Arabia | R 25 million (fees)

Client: Surbana Jurong (SJ) | **Date**: March 2022 – Ongoing

Contact Details: Sybille Tildsley - sybille.tildsley@smec.com

Description: SMEC International signed a sub-consultant agreement with Surbana Jurong (Holding Company) for the design of a futuristic city and freshwater lake in the NEOM mountains of Saudi Arabia. The project comprises all disciplines of stormwater, water, foul water, irrigation, recycled water and all the associated treatment processes. The harsh terrain required the teams to develop innovative solutions to provide wet services while managing the water quality of an artificial lake with challenges of high evaporation, lake seepage through designed liners etc. The project comprised confirming the master planning, developing the concept design through detailed design to tender and construction supervision.

Role and Responsibilities: Water Design Expert. Responsible for design development of bulk water systems for lake filling, lake recirculation and lake water treatment. Coordinating technical input required from potable water, foul water, recycled water, and treated water systems to ensure Lake water levels and quality is ensured through the correct sizing and placement of associated wet utility services around the lake and within the site-wide mountain assets as planned. Responsible to coordinate the design of stormwater and stormwater treatment systems impacting the Lake Water Quality.

Ferreira Canal, ESwatini | USD 27,000 (fees)

Client: eSwatini Electricity Company | **Date**: January to March 2022

Client Contact Details: Charles Coleman, Power Stations Manager, +268 550 2611, charles.coleman@sec.co.sz

Description: The Edwaleni Hydropower Station receives water from the Little Usutu and the Great Usutu rivers via two canals; the Main Canal and the Ferreira Canal respectively. This project entails the design of improvements to the Ferreira Canal (approximately 7.2 km in length and predominantly unlined) to increase the flow capacity to 6m³/s, by enlarging and lining.

Role and Responsibilities: Technical Hydraulic Design Support and Peer Review. Review hydraulic models, advise on sizing/position of sediment traps, junction boxes/stilling basins and inlet/outlet structures. High level input to quantities and cost to preliminary design levels, input with regards to constructability to the Preliminary Design Report.

C1847: Juba-Rumbek Road Upgrade – Hydrological Study Review, South Sudan | R 0.1 million (fees)

Client: SMEC International | **Date**: Jan 2021 – March 2021

Client Contact Details: Daniel Kamau Daniel.Kamau@smec.com +254 20 444 1541/2/3

Description: The upgrade of the 63 km road from Juba to Rumbek in South-Sudan has been prioritized by the Ministry of Roads and Transport to address severe flooding. The project comprises the upgrading of at least 5 large bridges and up to 60 culverts along the route for which flood modelling and hydraulic capacity calculations were reviewed**.**

Role and Responsibilities: Specialist Hydrologist / Hydraulic Engineer. Responsible for review of hydrological calculations of the 1:50 and 1:100-year events, including hydraulic capacity reviews of structures**.**

XL0022: Consulting Engineering Services for the Upgrading of the Mpiti to Sehlaba Thebe Road Project – Hydrological Study Review, Lesotho | R 0.1 million

Client: Ministry of Public Works & Transport, Lesotho| **Date**: Nov 2020 - 2021

Client Contact Details: SA Thamae: +266 22 324191

Description: Hydraulic capacity reviews of 20 key culverts along the 90 km length of road, including full hydrological modelling of mountain catchments using various flood estimation methods. Advising on culvert upgrades.

Role and Responsibilities: Specialist Hydrologist / Hydraulic Engineer. Responsible for review of hydrological calculations of the 1:20 and 1:50 year events including hydraulic capacity reviews of existing structures.

XL0048: Neom Mountain Lake and Village, Stage 3A - Saudi Arabia | R 13 million (fees)

Client: Bureu Proberts | **Date**: Oct 2020 – June 2021

Contact Details: skyer@bureauproberts.com.au

Description: SMEC International signed a Contract with an international architect (name undisclosed – under NDA) who won a design competition for the design of a Lake and Lake village located within mountain resort project. SMEC South Africa is required to provide input to the Feasibility and Concept Design for various Infrastructure, Dam, Geology, Hydrology, Power & Urban Infrastructure of the Lake and Village.

Role and Responsibilities: Water Engineer / Stormwater Engineer. Responsible for undertaking Lake water balances, determining bulk water requirements, lake filling times, lake management energy requirements and costs, lake catchment stormwater conceptual designs, flood calculations and development and sizing of stormwater treatment options. Conceptualizing and sizing and Desalination of Lake Water and management of brine.

XL0049: Consultancy Services for Freetown Water Supply and Sanitation Master Plan and Medium-Term Investment Project Proposal. GVWC, Freetown, Sierra Leone | R5.67 million (fees)

Client: Guma Valley Water Company – Sub-Consultant to COBA, Portugal| **Date**: 2020 - Ongoing

Client Contact Details: Francis H Lahai PE MSLIE, Contact Nr. +232 78781396, Contact Nr. ++232 30642872; Julio Arsenio (COBA); Contact Nr: +351 210 125 000

Description: The project addresses the water and sanitation master planning for Freetown with a population of 1.5 million people where dilapidated water and infrastructure forced authorities to plan ahead for the identification of short, medium- and long-term investment projects.

Role and Responsibilities: External Water & Sanitation Master Plan Reviewer. Responsible to direct and review inputs from a team with Sanitary Expert, Drainage Expert, Water Resources Expert, Financial Expert, Groundwater Expert and RAP/Environmental Expert. Directing master planning and design related philosophies, approaches and guidelines.

DM0020: Review of the Ndumo A Irrigation Scheme, Jozini, South Africa | R 0.5 million (fees)

Client: Department of Treasury, KwaZulu-Natal, South Africa | | **Date:** 2020

Client Contact Details: Nolwazi Maduma/ Rob Kempen, Project Managers, Contact Nr. +27 33 897 4496 / +27 82 651 3898; Nolwazi.Maduma@kzntreasury.gov.za / Rob.Kempen@kzntreasury.gov.za

Description: The project aimed to identify various alternative pumping main routes from the Pongola and other rivers to service the Ndumo A Irrigation Scheme more effectively and sustainability. The project concluded deficiencies in the original design and assisted the client to make informed discussion to rectify and approve the pumping system to ensure a sustainable overall scheme.

Role and Responsibilities: Hydraulic Modelling Expert. Responsible for the review of existing river abstraction works on the Pongola River and rising mains, storage reservoir hydraulic modelling as well as option development and hydraulic modelling for alternative irrigation bulk water supply options to the Ndumo A Irrigation Scheme. Development of review comments, reporting to the Project Manager.

XL0037: Master Plan of Proposed Airport City in Nkok, Gabonese Republic | R2.1 million

Client: DP Architects PTE LTD, Singapore | **Date:** 2018 - 2019

Client Contact Details: Djoko Prihanto, Project Manager, Contact Nr. + +65 6338 3988 & Dave Duke; +27 31 277 6600 dparchitects@dpa.com.sg

Description: Stormwater and flood modelling for Airport City with primary focus to confirm 1:50 and 1:100-year drainage lines to guide Town Planning process to ensure most suitable and efficient positioning of roads, stands and major infrastructure.

Role and Responsibilities: Hydrologist. Technical advisor on rainfall and runoff generation and stormwater/flood modelling using HEC-RAS 2D software. Services provided to SMEC South African team developing overall master plan for Airport City.

DH874: Investigations in the Improvements for Autumn Drive Dam, Umhlanga as Multipurpose Facility, KwaZulu-Natal, South Africa | R0.065 million

Client: Tongaat Hulett Developments | **Date:** 2016 - 2018

Client Contact Details: Lawrence Kirkman; PM; Contact Nr. +27 31 560 1900

Description: Hydrological & Hydraulic modelling of stormwater systems, dam and spillway to optimize re-use potential of dam considering both applications for retention and aesthetics.

Role and Responsibilities: Project Director. Liaise with client's representative, oversee modelling work in PCSWMM and review technical reports.

DT0001: Flood Calculations for Farm Dam SANRAL N1-17 at km 13.600, KwaZulu-Natal, South Africa

Client: SANRAL | **Date:** 2018

Client Contact Details: Zandile Nene; PM; Contact Nr. +27 33 392 8139

Description: Culvert hydraulics and river flood level modelling

Role and Responsibilities: Hydraulics Engineer. The Hydraulic Engineer undertook flood calculations for a river section at SANRAL's N1 Bridge at chainage 13.6km to ascertain a suitable flood outlet level for a farm dam downstream of the N1 Bridge to evaluate back-water effects on the N1 river bridge.

PE243: Heuningness Estuary, Western Cape Province, South Africa | R0.4 million

Client: Western Cape Nature Conservation | **Date:** 2016 - 2017

Client Contact Details: Pierre de Villiers; Programme Manager; Contact Nr. +27 21 866 8000 estuaries@capenature.co.za

Description: Undertake hydrological and hydrodynamic modelling to predict water (flood) levels under feasible system and mouth management scenarios for a big an area as possible of the Heuningnes Estuary and catchment. Provide recommendations and substantiated motivations for a mouth management regime/s that best balances ecological and human needs for the foreseeable future.

Role and Responsibilities: Project Manager. Project management and technical assistance to flood modelling, flood peak arrival

DH874: Investigations in the Improvements for Autumn Drive Dam, Umhlanga as Multipurpose Facility, Durban, KwaZulu-Natal, South Africa | R0.065 million

Client: Tongaat Hulett Developments | **Date:** 2016

Client Contact Details: Lawrence Kirkman; PM; Contact Nr. +27 31 560 1900

Description: Hydrological & Hydraulic modelling of stormwater systems, dam and spillway to optimize re-use potential of dam considering both applications of retention and aesthetics.

Role and Responsibilities: Project Director. Liaise with client's representative, oversee modelling work in PCSWMM and review technical reports.

DM0113: Cwaka Environmental Impact Assessment and Formalization, KwaZulu-Natal, South Africa | R1 million

Client: LDM Consulting | **Date:** 2016

Client Contact Details: Trivi Arjunan; PM; Contact Nr. +27 31 207 1340

Description: Floodline delineation and report.

Role and Responsibilities: Design Engineer, Hydraulic modelling Oversight. Hydraulic modelling and floodline delineation of 100-year floodlines for two major rivers in the Cwaka area using HEC-RAS software, drafting and reporting

DM0120: Rukwa Coal Project – Flood Analysis, Rukwa, Tanzania | R0.3 million

Client: Shangoni Management Services | **Date:** 2016

Client Contact Details: Dawie Maree, Contact Nr. +27 73 330 5815

Description: Hydrological flood modelling with UPFD software and hydraulic routing and mapping with HEC-RAS.

Role and Responsibilities: Project Manager. Oversee and project management of floodline and flood volume assessment for three major rivers for Rukwa Coal Mine.

PK270: Polokwane Wastewater Treatment Works Flood Line Analysis, Polokwane, South Africa | R 8 million

Client: Polokwane Municipality | **Date:** 2017

Client Contact Details: Vonani Mathebula, Director, Contact Nr. 072 153 3175

Description: Flood line delineation and report for the construction of a new wastewater treatment works.

Role and Responsibilities: Hydraulic Modelling Reviewer. Oversee hydrological study for two rivers' catchments (the Bloed River and the Sand Riviera) for the purposes of delineating the 1:20, 1:50 and 1:100-year floods. Review hydraulic modelling of the rivers for delineation of flood lines for the various storm events using HEC-RAS modelling software. The results were reported for the purposes of positioning the wastewater treatment works appropriately.

DD0081: Upgrade of KwaNqetho Inlet 300mm Ø Steel Pipe Watermain, Durban, KwaZulu-Natal, South Africa | R 10 million

Client: eThekwini Water and Sanitation | **Date:** 2016

Client Contact Details: Devashan Govender PM (Leisel Bowes); Contact Nr. +27 31 311 8796

Description: In the execution of eThekwini's water master plan and wider drive for asset renewal, the project considered the investigation and pipe replacement of a problematic section of water main in a challenging (steep topography) with a high historic frequency of bursts.

Role and Responsibilities: Lead Hydraulic Modeller, Design Review, Technical Advisor. Hydraulic modelling of existing water distribution system to determine cause of failure using Bentley WaterGEMS hydraulic modelling software, analysing pressure and flow data, modelling of proposed system with new connectivity to optimise break-pressure tank positions, design of proposed upgrade (diameters). Provide technical advice and design review to EWS on related matters such as valve selection, erosion protection and connectivity.

DD451 Developing a Stormwater Flood Risk Assessment Tool, Phoenix, KwaZulu-Natal, South Africa | R60k

Client: eThekwini Municipality, Coastal Stormwater & Catchment Management | **Date:** Jan 2015 – Feb 2015

Client Contact Details: Kiyash CherrSha, Contact Nr. 031 311 7323

Description: Pilot study to develop a storm water flood risk assessment tool. The assignment involved hydrological and hydraulic modelling (using PCSWMM software) of an urban catchment in Phoenix to the north-west of Durban comprising 479 sub-catchments, 18,400m of storm water pipes with diameters ranging from 225mm to 2,000mm.

Role and Responsibilities: Project Manager. Oversee and project management, Review of hydrological and hydraulic modelling. PCSWMM software.

DM0089: Pre-Feasibility Investigation, Water, Sewage & Effluent requirements, HEBEI Iron & Steel Industry, Richards Bay, KwaZulu-Natal, South Africa | R 1.3 billion

Client: Richards Bay Infrastructure Development Zone (IDZ) | **Date:** 2015

Client Contact Details: Brenda Mabaso; Research, Marketing Intelligence Manager; Contact Nr. +27 35 788 0571

Description: Feasibility studies, water & sewer services for planned Steel Smelter in Richards Bay.

Role and Responsibilities: Design Engineer / Support to Project Manager. Prepare high level feasibility studies on bulk water and sanitation supply for planned Steel Smelter in Richards Bay, analysis included various technical options and costs comparison's to ultimately inform decision makers on investment options and key timeframes.

DM0035: DUT Riverside and Indumiso Campus Storm Water Management Plan (Planning), Pietermaritzburg, KwaZulu-Natal Province, South Africa | R1.2 million

Client: Durban University of Technology | **Date:** Aug 2013 – Feb 2017

Client Contact Details: Tom McKune, Contact Nr. +27 (0)86 010 3194

Description: Civil and structural engineering services for the infrastructure upgrade at the Riverside campus of DUT in Pietermaritzburg. New engineering building, lecture halls, library and computer centre. Determination and delineation of 1:50 and 1:100 flood lines for the Msunduzi River at the Durban University of Technology (DUT) Riverside Campus.

Role and Responsibilities: Hydrological/Hydraulic Engineer. Hydrological calculations and Hydraulic Modelling of the Msunduzi River for delineation of 1:50 and 1:100-year flood lines including sensitivity analysis of building structures in the 1:100-year floodplain.

Rehabilitation of Centurion Lake, Pretoria, South Africa | R10 million

Client: City of Tshwane, Roads & Stormwater | **Date:** 2013

Client Contact Details: Gawie Janse van Vuuren; PM; Contact Nr. +27 21 358 9999

Description: Hydraulic capacity calculations.

Role and Responsibilities: Design Engineer. Project management and coordination of specialist river rehabilitation and flood hydrology studies. Hydraulic optimization of proposed drainage and diversion structures in support of the rehabilitation of the Centurion Lake suffering from toxic sedimentation pollution. Hydraulic investigations were undertaken for the Hennops River which included the SANRAL N1 road bridge section in Centurion. HEC-RAS software was used following hydrological inputs from XP-SWMM software.

Flood overtopping of N11 between Amersfoort and Ermelo, Mpumalanga, South Africa | part of R350 million project

Client: South African National Roads Agency | **Date:** 2008 - 2011

Client Contact Details: Willem van der Merwe, Contact Nr: +27 12 426 6200

Description: Hydraulic capacity calculations.

Role and Responsibilities: Hydraulics Engineer. The Hydraulic Engineer working for SCIP Engineering Group undertook flood calculations following flooding of a section of the N11 which involved hydrological calculations and culvert capacity assessments based on photo evidence and high-water levels observed during the flood event.

Professional History

- **2013 – Present | SMEC South Africa**

  2013 – Present | Technical Principal, Water Infrastructure
- **2003 – 2013 | SCIP Engineering Group (Pty) Ltd, Witbank**

  2003 – 2013 | Director
- **2001 – 2003 | Group 5 Roads & Earthworks (Pty) Ltd**

  2001 – 2003 | Site Agent
- **2000 – 2001 | Post graduate studies, University of London**

  2000 – 2001 | Student
- **1998 – 2000 | Post Graduate studies, Sigma Beta/Water Resources Commission, University of Stellenbosch**

  1998 – 2000 | Student

Courses and Conferences Attended

2020	IMESA	Site visit to 20 MLD Rosetta Water Treatment Works
2019	University of Cape Town	Permeable Pavements and Bio Retention Cells
2019	WISA	Getting Control Valves Right
2017	WISA	Energy recovery in pipelines – micro turbines
2016	WRC, University of Pretoria	Biofilm n water mains
2016	WISA	Water Institute South Africa – 2016 Conference
2015	University of Cape Town	Report Writing
2015	University of Cape Town	Sustainable Drainage Systems (SuDS)
2014	WISA	CFD & Pipe/Earth interaction
2014	Wolf Weidemann Pr Eng.	Finances for Built Environment Profession
2013	WISA Conference	Annual Conference
2013	University of Pretoria/SINOTECH	Conduit Hydropower
2013	Kaytech	Filtration & pipe material

Publications and Papers Presented

2000	MSc Thesis on Flood Measurement Techniques using Bridge Structures – University of Stellenbosch
2001	MSc HEM Thesis on Groundwater Recharge to Coastal Plains, Aden/Southern Yemen – University of London

Language Skills

Mother Tongue:	Afrikaans		
Languages	**Speak**	**Read**	**Write**
English	Excellent	Excellent	Excellent
Afrikaans	Excellent	Excellent	Excellent

Rendani Byven Thovhakale

Water Engineer

Years of Industry Experience

- 6 years

Personal Information

- Cell Number: +27 78 041 1701
- Email: rendanitb@yahoo.com
- Nationality: South African

Qualifications

- Bachelor of Engineering (Civil), University of Johannesburg, 2015

Key Skills and Competencies

- Hydrological analysis
- River hydraulics modelling
- Floodline delineation
- Surface Drainage
- Pipeline and Pump station design
- Erosion protection structures
- Energy dissipation structures
- Stormwater ponds
- AutoCAD Civil 3D
- AutoCAD
- GeoHEC-RAS
- QGIS
- Microsoft Excel

Professional History

- 2019 – Present | Engineer
- 2016 – 2019 | Graduate Engineer

Referees

Dawid van Coller, Senior Water Engineer, vancollerd@gmail.com, +44 7748 176 086

Roshuma Makhado, Classmate, roshumamakhado@gmailcom, +27 79 251 9246

Professional Overview

Rendani is a Water Engineer with 6 years of experience in the civil engineering industry, during which time he has developed varied technical expertise, primarily in the water sector. He is highly proficient in Hydrology and River hydraulic modelling and related studies having completed numerous hydrological and floodline studies on several international projects, most notably for the Lesotho Highlands Water project. Often the design of erosion protection measures or river rehabilitation work also form part of these projects. My expertise also extends to the detailed design of hydraulic components associated with river systems such as weirs, canals, and erosion protection structures.

Some of the projects he has been involved in include the feasibility design and planning of steel and concrete pipelines and pump stations.

Relevant Project Experience

Ernest Robertson Dam DSE, Western Cape, South Africa | US$ 5 621

Client: Mossel Bay Local Municipality | **Dates:** April 2022 – June 2022

Client Contact Details: Catherine Koelman; Project Manager; +27 (0)44 606 5269

Description: The 5th dam Safety Evaluation (DSE) for the Ernest Robertson Dam was undertaken in 2013. The 6th DSE was due, as required by the Department of Water and Sanitation (DWS) in terms of Regulations 35 of the Regulations regarding safety of dams published in government notice R.139 dated February 2012. SMEC was tasked with undertaking the 6th DSE. The scope of services of the Dam Safety Evaluation were as follows:

Dam Inspection: Undertake the dam safety inspection and state the condition of indicators including the dam wall, dam crest and spillway, outlet works, reservoir basin slopes and monitoring instruments.

Evaluation and Reporting: Review dam monitoring data to identify any issues; confirm flood hydrology and spillway capacity values remain applicable; prepare and submit draft Dam Safety Evaluation Report with recommendations and action plan; Update and submit final Dam Safety Evaluation Report following receipt of comments from the client.

Role: Design Engineer.

Responsibilities: Flood hydrology calculations, checking of spillway capacity, and preparation of report.

Tetra4 Gas Floodlines, Free State, South Africa | US$ 21 178 Fees

Client: EIMS | **Dates:** January 2022 – Ongoing

Client Contact Details: Brian Whitfield; Project Manager; Ph +27 (0)82 688 9850

Description: SMEC was engaged by EIMS to prepare a Hydrological Impact Assessment that will be required to assist with the application of a Water Use License and Environmental Authorization for the Tetra4 Gas Production Project located in Welkom, Free State province.

Several hydrological methods, including Rational Method, Alternative Rational Method and SDF method were considered to calculate peak flood discharges for various return periods.

River hydraulics were modelled using the GeoHECRAS software suite developed by CivilGEO Engineering Software. The geometric information for the model was obtained from local topographic survey and roughness coefficients estimated from site surveys, based on the HEC-RAS hydraulic reference manual descriptions.

A flood hazard map and hydrological study report was prepared as input to various regulatory approval applications.

Role: Project manager and Design Engineer.

Responsibilities: Review of Hydrological Analysis, Review Hydraulic Analysis, Floodline delineation and preparing the Hydrological assessment report.

Rendani Byven Thovhakale

Water Engineer

Mogalakwena PV Hydrological Study, Limpopo, South Africa | US$ 15 270

Client: EDF Renewables | **Involvement Period:** April 2022 – July 2022

Client Contact Details: Martin Zietsman; Project Manager; Ph +27 (0)83 691 3701

Description: SMEC was engaged by EDF Renewables to prepare a Hydrological Impact Assessment for a PV plant located in the Limpopo province of South Africa. This Hydrological Impact Assessment deals with the following aspects:

- Hydrological Analysis;
- Hydraulic Modelling;
- Floodline Delineation; and
- Flood impacts on infrastructure and flood mitigation measures.

The project also involved the design of a conceptual stormwater management plan. The scope of work was the design of a drainage layout, the sizing of drainage channels and detention basins, and erosion protection measures.

Role: Project manager and Design Engineer.

Responsibilities: Review of Hydrological Analysis, Hydraulic Analysis, Floodline delineation and preparing the Hydrology report. Design of stormwater management plan.

UMSO PV Hydrological Study, Northern Cape, South Africa | US$ 16 843 Fees

Client: EDF Renewables | **Dates:** January 2022 - Ongoing

Client Contact Details: Bradley Rabbitte; Project Manager; Ph +27 (0)72 855 3420

Description: SMEC was engaged by EDF Renewables to prepare a Hydrological Impact Assessment for 5 PV plants located in the Northern Cape province of South Africa. This Hydrological Impact Assessment deals with the following aspects:

- Hydrological Analysis;
- Hydraulic Modelling;
- Floodline Delineation; and
- Flood impacts on infrastructure and flood mitigation measures.

Role: Project manager and Design Engineer.

Responsibilities: Review of Hydrological Analysis, Hydraulic Analysis, Floodline delineation and preparing the Hydrology report.

Kaalspruit Climate Resilient Catchment Management Plan, Gauteng Province, South Africa | US$ 105 246 Fees

Client: Gauteng Department of Agriculture and Rural Development (GDARD) | **Dates:** August 2021 - Ongoing

Client Contact Details: Gerson Nethavhani; Project Manager; Ph +27 (0)11 240 3435

Description: The assignment entailed the development of a climate-resilient Catchment Management Plan (CMP) for the Kaalspruit catchment to the east of Johannesburg. The 1st step in developing the CMP was to identify the diverse stakeholders in the catchment and to prepare a Stakeholder Engagement Plan. This was followed by stakeholder engagement and literature review leading to a description of the catchment status quo in the form of a Situational Assessment Report. This step included development of a base case hydrological and hydraulic model using PCSWMM software. Planned future steps were identification of potential catchment interventions and testing of these in the model to assess physical benefits, further stakeholder engagement, and ultimately the development of the CMP.

Role: Project Manager and Design Engineer

Responsibility: Hydrological and Hydraulic analysis.

Calitzdorp Spa Dam, Northern Cape Province, South Africa | US$ 7647 Fees

Client: Calitzdorp Export Agri Hub | **Dates:** April 2021 - July 2021

Client Contact Details: Gerhard Meyer; Project Manager; Ph +27 (0)82 802 7138

Description: Execution of a Water Resource Study to investigate the feasibility of the proposed Calitzdorp Spa Dam. The primary purpose of the Study was to ascertain whether there is sufficient water available in the catchment over the long-term for the intended water use, at a sufficiently high assurance of supply. Four potential dam sites were assessed using the Water Resources Simulation Model (WRSM/Pitman), taking environmental water requirements into account. The Study had a positive outcome, and the following investigations were scoped for execution subject to funding availability.

Role: Design Engineer

Responsibility: Water resources modelling

Pandora Water Extraction, North West Province, South Africa | US$ 41 000 Fees

Client: Eastern Platinum Limited | **Dates:** November 2020- April 2021

Client Contact Details: Andre Laubscher; Project Manager; Ph +27 (0)82 228 7069

Description: To supplement water supply to the Marikana Platinum Mine, Sibanye Stillwater have secured an allocation from the Hartbeestpoort Dam Irrigation System. The project will entail the detail design of the following components: Extraction point from the West Canal Hartbeespoort Dam Irrigation System; gravity feed pipeline/canal from the offtake to a new holding dam with a transfer capacity of 10 million litres per day; 30 million litre (3 days) holding dam adjacent to the irrigation canal; and pump station fed from the holding dam and delivering into an existing 315mm diameter pipeline which is connected to the mine's water reticulation/distribution system.

Role: Design Engineer

Responsibility: Preliminary design of Pump Station and 5.3km HDPE pipeline

Mokopane Treated Wastewater Pipeline, Limpopo, South Africa | US$ 91 500

Client: Anglo American Platinum | Date: August 2020 - December 2020

Client Contact Details: Chiedza Mnguni; Project Manager; Chiedza.mnguni@angoamerican.com

Anglo American Platinum intends to improve the current 30km long, 250mm and 300mm diameter steel pipeline's capacity. The pipe is intended to deliver 6Ml/day which is an improvement over the 4.42Ml/day that it delivers currently in 2020. SMEC was assigned to investigate the possible options for improving the current pipe system. These options included analysing: various pipe sizes for pipe replacement; lining options for refurbishing the current pipe; required pump station capacity; and cost models for all options.

Role: Design Engineer

Analysed the capacity of the existing pump station and Pipeline; Designed options for improving the pipe system capacity; and prepared the feasibility study and cost models

Steynsrus Water Supply Scheme, Free State, South Africa | US$ 38 000

Client: MIB Infrastructure Development | Date: May 2020 - July 2020

Client Contact Details: Papi Wessie; Project Manager; Ph (+27) 12 942 4450

The existing Steynsrus Water Supply Scheme sources water from the Vals River and supplies the towns of Steynsrus and Matlwangtlwang. The scheme comprises an abstraction weir and pump station on the Vals River, which pumps raw water via a 400 mm diameter low pressure asbestos-cement (AC) pipeline into the off-channel Morgenzon Dam. Water is stored in the dam and pumped from there by a high lift pump station via a booster pump station and balancing reservoir to the water treatment works (WTW), from whence treated water is supplied to Steynsrus and Matlwangtlwang. These towns regularly suffer from water shortages. This feasibility study investigated options to augment the supply to the town. A raising of the dam in combination with an upgrade of the pump station was the recommended option.

Role: Design Engineer

Performed the Water Resource Study, Analysed the capacity of the existing pump station and Pipeline and prepared the feasibility study

Steenkoolspruit Hydrodynamic Modelling, Mpumalanga, South Africa | US$ 9 500 Fees

Client: Anglo American Coal South Africa | Date: April 2020 - May 2020

Client Contact Details: Marthinus van Wyk; Project Manager; Ph +27 (0)17 620 2714

SMEC was engaged by the Anglo American Coal South Africa to undertake a Hydrological and Flood Risk Assessment at the Isibonelo Colliery which is located 9 km to the north of Secunda, Mpumalanga Province. The objective of this study was to investigate the impacts of removing the Isibonelo Attenuation Dam on flood levels on the farmlands upstream, and on the mining area downstream. A 1D hydrodynamic HEC-RAS model was used to determine flood levels of various flood events in combination with a flood routing model to take into account the attenuation effects of the existing dam.

Role: Design Engineer

Review of Hydrological Analysis, Hydraulic Analysis, Floodline delineation and preparing the Hydrology report.

Polokwane Waste Water Treatment Works, Limpopo, South Africa | US$ 50 000 000m

Client: Mafumu Consulting (Pty) Ltd | Date: March 2020 - March 2021

Client Contact Details: Terrence Mathebula; Manager; Ph +27 72 153 3175

Development of the new Polokwane Regional Wastewater Treatment Works with an ultimate capacity of 40ML/day. The scope of SMEC's appointment entails design, documentation and procurement, construction monitoring and contract administration. The works are being implemented in two contracts, namely an earthworks contract and a main works contract.

Role: Design Engineer

Design of a 1m diameter and 100m long concrete pipe and the design of an energy dissipation structure. Design of stormwater drains. Site Supervision

Lesotho Highlands Water Project Delivery Tunnel North Maintenance Shutdown, Free State Province, South Africa | US$ 710 000

Client: Trans Caledon Tunnel Authority (TCTA) | **Date**: Oct 2019 – Feb 2020

Client Contact Details: David Keyser, Project Manager; Ph +27 12 683 1203

Description: The 4,6m diameter and 22km long Delivery Tunnel North which is part of the Lesotho Highlands Water Project was constructed in the 1990s to transfer water to the Gauteng Provence of South Africa. SMEC undertook a planned inspection of the tunnel during a 9week system outage to identify the repair and maintenance requirements. Other works that were undertaken during that period involved the inspection of the Ash River to assess erosion and deposition conditions along the river and to assess the status of existing structures along the river. SMEC procured a contractor and repairs and maintenance of tunnel lining and valves were executed, all within the outage period.

Role: Design Engineer and Inspector

Responsibilities: Inspection of the Ash River, Hydraulic modelling, preparing the Ash River Inspection report.

Isibonelo Dam Inspections, Mpumalanga Province, South Africa| US$ 6 700

Client: Anglo American Coal South Africa | **Date**: December 2019

Client Contact Details: Marthinus van Wyk, Project Manager; Ph +27 17 620 2714

Description: SMEC South Africa (SMEC) was appointed by Anglo American Coal South Africa (AACSA) to carry out an annual safety inspection for five dams at their Isibonelo Colliery including:

- Attenuation Dam (Category II 11.5m high earthfill embankment with Armco Culvert Spillway)
- Diversion Dam (Category II 10.5m high earthfill embankment with side channel and auxiliary culvert spillway)
- Farm Dam (Uncategorized approximately 5m high earthfill embankment with side channel spillway)
- Montedi Dam (Uncategorized approximately 5m high earthfill embankment with side channel spillway)
- Vaskop Dam (Category II 13.5m high earthfill embankment with side channel spillway)

The main purpose of the dam inspection was to assess the condition of each of the following indicators: Wall embankment; Inlet; Outlet; Spillway; Pump station; Leak detectors; and Safety and security.

Role: Dam Inspector

Responsibilities: Dam inspections and preparing the dam inspection reports.

Emalahleni Discard Dump Floodlines, Mpumalanga Province, South Africa| US$ 4 000

Client: Shangoni Management Services | **Date**: November 2019

Client Contact Details: Christiaan Schutte, Project Manager; Ph +27 82 784 2942

Description: SMEC was engaged by Shangoni Management Services to undertake a floodline study for the proposed discard dump in Emalahleni, Mpumalanga Province.
This study report documents the results of the floodline study which deals with the following aspects:

- Hydrological Analysis
- Hydraulic Modelling
- Flood routing
- Floodline Delineation; and

Several hydrological methods, including Rational Method, Alternative Rational Method and SDF method were considered to calculate peak flood discharges for various return periods.
River hydraulics were modelled using the GeoHECRAS software suite developed by CivilGEO Engineering Software. The geometric information for the model was obtained from local topographic survey and roughness coefficients estimated from site surveys, based on the HEC-RAS hydraulic reference manual descriptions.

A floodline map and hydrological study report was prepared as input to various regulatory approval applications.

R**ole:** Design Engineer

Responsibilities: Hydrological analysis, Hydraulic modelling, Floodline delineation and preparing the Hydrology report.

Greefspan 2 Solar Farm Hydrology, Northern Cape Province, South Africa | US$ 2 500

Client: Grupo Gransolar | **Date**: October 2019

Client Contact Details: Manuel Bolano, Project Manager; Ph +34 917 364 248

Description: SMEC was engaged by Gransolar to undertake a Hydrological and Flood Risk Assessment for the proposed Greefspan 2 Photovoltaic Solar plant in Northern Cape, South Africa. The objective of the hydrological study is to determine the external flows that will enter the site for various return periods.
Several hydrological methods, including Rational Method and SCS method were considered to calculate peak flood discharges for various return periods.
Whilst there are no defined watercourses traversing the site, local storm water will still need to be managed when the site infrastructure is developed. The input parameters generated in this hydrological study will be used to size any storm water drainage infrastructure using similar methods presented in this report.

Role: Design Engineer

Responsibilities: Hydrological analysis and preparing the Hydrology report.

Mambia PV Plant Hydrological Study, Kindia, Guinea| US$ 5 500

Client: Phanes Group | **Date**: August 2019

Client Contact Details: Guillaume Aryal, project Manager; Ph +971 55660 3166

Description: SMEC was engaged by Phanes Group to undertake a Hydrological and Flood Risk Assessment for the proposed Mambia Photovoltaic Solar Plant in Guinea, covering the following aspects:

- Hydrological Analysis
- Hydraulic Modelling
- Floodline Delineation; and
- Flood Risk Assessment.

Several hydrological methods, including Rational Method and SCS method were considered to calculate peak flood discharges for various return periods.

River hydraulics were modelled using the GeoHECRAS software suite developed by CivilGEO Engineering Software. The geometric information for the model was obtained from a drone based photogrammetric survey and roughness coefficients estimated from site surveys, based on the HEC-RAS hydraulic reference manual descriptions.

A floodline map and flood risk report was prepared as input to Environmental Authorisation process with the flood risk assessment considering the following: Depth of floodwaters; Erosion/siltation; Period of Flooding; Potential damage to infrastructure; Loss of vegetation and Loss of Life.

Role: Design Engineer

Responsibility: Hydrological analysis, Hydraulic modelling, Floodline delineation, Flood Risk Assessment and preparing the Hydrology report.

Mohale's Hoek Solar Farm, Mohale's Hoek, Lesotho | US$ 8 600

Client: Phanes Group | **Date**: July 2019

Client Contact Details: Valerio Massimo Bu, Project Manager, Ph +971 4558 7450

Description: SMEC was appointed by Phanes Group to undertake a Hydrology and Flood Risk Assessment for the proposed Mohale's Hoek Photovoltaic Solar Plant in Lesotho. The objectives of the Hydrology and Flood Risk Assessment include: Collection of historical precipitation data; Determination of design or peak floods using empirical methods, statistical/probabilistic methods and deterministic methods; Hydraulic modelling for the 10 and 100 year recurrence interval floods; Determination of 10 and 100 year floodlines using a hydraulic model; Description and determination of flood risk based on flood hazards (based on floodlines) and vulnerabilities (location of proposed critical civil, mechanical and electrical infrastructure, power stations, dwelling units, offices and solar installations); and recommendation of flood mitigation and protection measures.

Role: Design Engineer

Responsibilities: Hydrological analysis, Hydraulic modelling, Floodline delineation and preparing the Hydrology report.

Touna-Bla PV Plant, Bamako, Mali | US$ 7 500

Client: Phanes Group | **Date**: June 2019 – July 2020

Client Contact Details: Guillaume Ayral, Project Development Manager; Ph +971 55660 3166

Description: SMEC was appointed by Phanes Group to undertake a Hydrology and Flood Risk Assessment for the proposed Touna-Bla Photovoltaic Solar Plant in Mali. The objectives of the Hydrology and Flood Risk Assessment Study include: Estimation of pre-development flood magnitudes and flood hydrographs for various design recurrence intervals using at least 3 international recognised methods; Estimation of post development flood magnitudes and flood hydrographs for various design recurrence intervals using at least 3 international recognised methods; 1D Hydraulic modelling for the estimated flood peaks in order to establish the extents of the flood lines for the desired recurrence intervals, along the areas at risk of flooding.; Description and determination of flood risk based on flood hazards (based on floodlines) and vulnerabilities (location of proposed critical civil, mechanical and electrical infrastructure, power stations, dwelling units, offices and solar installations); and recommendation of flood mitigation and protection measures.

Role: Design Engineer

Responsibilities: Hydrological analysis, Hydraulic modelling, Floodline delineation and preparing the Hydrology report.

Polihali Transfer Tunnel, Polihali, Lesotho | US$ 514 000 000

Client: Lesotho Highlands Development Authority | **Date**: May 2018 – Ongoing

Client Contact Details: John Sawyer, Deputy Executive Manager; Ph +266 5225 2271

Description: Design and construction supervision of approximately 38km of water tunnels, majority TBM excavation and minority drill and blast excavation, to transfer water from the new Polihali Dam to the existing Katse Dam, all as part of Phase 2 of the Lesotho Highlands Water Project (LHWP).

Role: Design Engineer

Responsibilities: Hydrological analysis, Hydraulic modelling, Floodline delineation, Concrete Pipes Design, Drainage Channel, AutoCAD Drawings and preparing the Hydrology report.

Henrietta Photovoltaic project, Henrietta, Mauritius| US$ 6 000

Client: Bouygues Construction | **Date**: March 2018 – May 2018

Client Contact Details: Claire Sina, Project Manager; Ph +337 6399 0948

Description: The project focused on developing an Operation and Maintenance Management Plan for the proactive implementation of routine maintenance tasks and providing the municipality with a baseline for cost planning and scheduling resources. The project includes the development and implementation of the plan.

Role: Design Engineer

Responsibilities: Hydrological analysis, Hydraulic modelling Floodline delineation, and preparing the report.

AKS 100MW Photovoltaic Project, Kaduna, Nigeria | US$ 14 000

Client: Sky Power| **Date**: October 2017 – December 2017

Client Contact Details: Giorgio Mauro, Director; giorgiom@skypower.com

Description: Consultancy Services for Technical Pre-Feasibility Studies
on 100MW Solar Photovoltaic PV Plant in Kaduna. The overall scope of consultancy services includes the following studies: Geotechnical study, Topographic survey, Water management study and a transport study.

Role: Design Engineer

Responsibilities: Hydrological analysis, Hydraulic modelling, Floodline delineation and preparing the water management study report.

Gamsberg Mine SWMP, Northern Cape Province, South Africa | US$ 1 175 000

Client: Black Mountain Mining | **Date**: Oct2017 – March 2018

Client Contact Details: Avinash Mamtora, Manager; Ph +27 82 881 8761

Description: Preparation of a Storm Water Management Plan for a zinc mine in the Northern Cape province of South Africa. Various measured are required to deal with storm water run-off, both clean and contaminated. These measures include drainage channels, earthen bund walls, pollution control dams, pipelines and pump stations.

Role: Design Engineer

Responsibilities: Hydrological analysis, pipeline and pump station design, Design of stormwater ponds and drainage channel designs, and preparing the design report.

Douglasdale River Improvements Phase 2, Gauteng Province, South Africa | US$ 38 900 Construction Value

Client: Douglasdale Retirement Village | **Date**: March 2017 – July 2017

Client Contact Details: Rob Fraser, Manager; Ph +27 71 863 5183

Description: After assessment of an existing dam situated within the Douglasdale Retirement Village, it was concluded that its spillway capacity was inadequate with a high risk of overtopping the earth-fill embankment. A design was prepared for the upgrade of the spillway to increase its discharge capacity. The watercourse upstream of the dam is prone to erosion. To prevent further erosion of the riverbanks, several erosion control measures were investigated. An erosion control weir was proposed as the most suitable rehabilitation and prevention measure.

Role: Design Engineer

Responsibility: River hydraulics modelling and detailed design of erosion control weirs, and preparing the report.

Loopspruit Floodlines, Gauteng Province, South Africa | US$ 7 000

Client: Shangoni Management Services (Pty) Ltd

Client Contact Details: Nico Brits Manager; Ph +27 12 807 7036

Description: Determination of 1:50 and 1:100-year floodlines for a 2.5 km reach along the Loopspruit River as part of a Water Use Licence Application for a mine.

Role: Design Engineer

Responsibility: Hydrological analysis, river hydraulics modelling and preparing the report.

Verref Pollution Control Dam, Gauteng Province, South Africa | US$ 6 000

Client: Shangoni Management Services | **Date**: May 2017 – November 2017

Client Contact Details: Dawie Marre, Manager; Ph +27 12 807 7036

Description: Assessment of an existing Pollution Control Dam (PCD) to check compliance with the sizing requirements of Regulation No. 704 of the National Water Act, 1998 (Act No. 36 of 1998) which regulates the use of water for mining and related activities aimed at the protection of water resources.

Role: Design Engineer

Responsibility: Hydrological analysis of the dam using a water balance model and the concept design of a new pollution control dam; and preparing the report.

Vorna Valley River Hydraulics Management, Gauteng Province, South Africa | US$ 1 400 000

Client: Johannesburg Roads Agency (JRA) | **Date**: Sep 2016 – April 2018

Client Contact Details: Andre Nel, Planning Manager; Ph +27 82 492 2363

Description: The Vorna Valley watercourse in Midrand regularly floods adjacent properties and has eroded severely in some areas. The project aims to investigate these problems and to implement measures to address them.

Role: Design Engineer

Responsibility: Hydrological analysis, surveying, determining the flood lines and the feasibility of various proposed solutions using GeoHECRAS, designing the flood protection berms, designing gabions for erosion control as well as flood protection, and designing various riprap-lined channels, stilling basins and groynes.

Douglasdale River Improvements Phase 1, Gauteng Province, South Africa | US$ 42 800 Construction Value

Client: Douglasdale Retirement Village | **Date**: Feb 2016 – Nov 2016

Client Contact Details: Rob Fraser, Manager; Ph +27 71 863 5183

Description: Civil Engineering designs on the Stormwater stream running through Douglasdale Retirement Village were required. These designs included: Gabion designs and Rockfill sand trap design (weir).

Role: Design Engineer

Responsibility: Producing the hydrology flood estimation, gabion designs for bank erosion protection and the weir design, site surveying, site monitoring and BOQ.

Tharisa Rail Project, North West Province, South Africa | US$ 35 000 00

Client: Transnet and Tharisa Minerals | **Date**: Feb 2016 – March 2016

Client Contact Details: Lazarus Rapetswa, Manager; Ph +27 12 315 2525

Description: Transnet freight rail and Tharisa Minerals entered a Public Private Partnership to construct a new link line into Tharisa mine, near Marikana, providing access to a new load-out station that will be capable of loading a 150-wagon train.

Role: Hydrologist

Responsibility: Hydrological analysis.

Devland Community Education Campus, Gauteng Province, South Africa | US$ 376 000

Client: Growing up Africa | **Date**: Nov 2017 – Dec 2017

Client Contact Details: Deborah Terhune, CEO; Ph +27 82 826 2237

Description: Growing Up Africa (GUA), A non-profit organization based in the USA is building a multi-purpose community centre in the Devland community located in Soweto. The centre is a single storey educational facility.

Role: Construction Monitor

Responsibility: Responsible for site monitoring as well as land surveying on site.

Courses & Conferences attended

2016:	SAICE Ingula Pumped Storage Scheme (1 day site visit)
2017:	The CAD Corporation AutoCAD Essentials course (4 days)
2017:	CESA Technical and Business report writing (3 days)
2017:	The CAD Corporation Civil 3D Essentials course (4 days)
2017:	CoJ Stormwater By Laws training workshop (2 days)
2017:	CESA YPF BBBEE debate (1 day)
2018:	SAICE 2017 Infrastructure Report Card Breakfast workshop (1 day)
2018:	SARF Drainage Manual course (2 days)

Appendix F: Site Visit

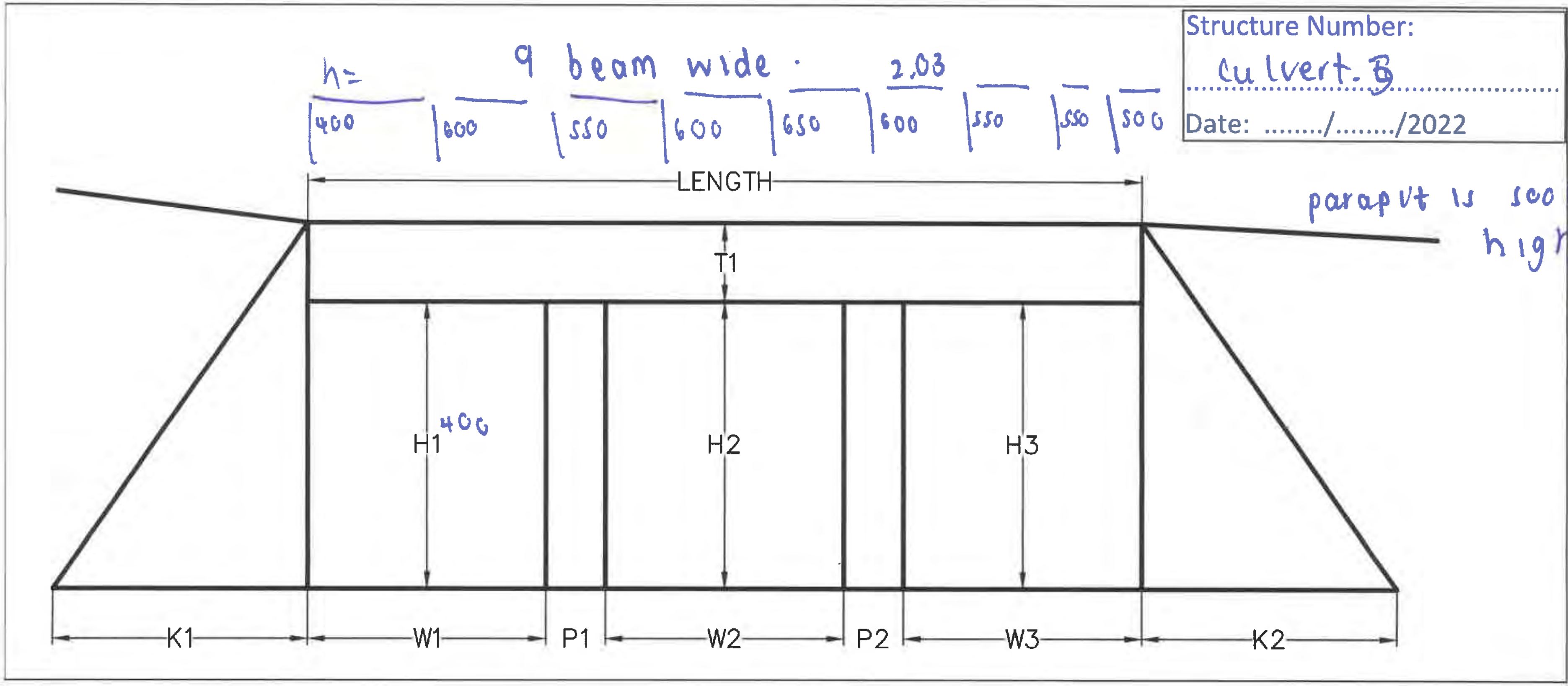

Untitled Map
Write a description for your map.
Legend
Feature 1
Reach
Welkom
R730
R30
R73
Virginia
R30 Bridge
Culvert 1
He/LNG Plant Expansion
Culvert 8
Culvert 7
R30 Bridge 2
Tetra4
Culvert 2
R720 Bridge
Culvert 6
Culvert 3
Culvert 4
Culvert 5
Google Earth
Image © 2022 Maxar Technologies
Image © 2022 CNES / Airbus
10 km
N

2.03×0.2

~~2.03~~ 5 1,02

Structure Number: Culvert. B

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ____
H2 = ____
H3 = ____
H4 = ____
T1 = 200mm

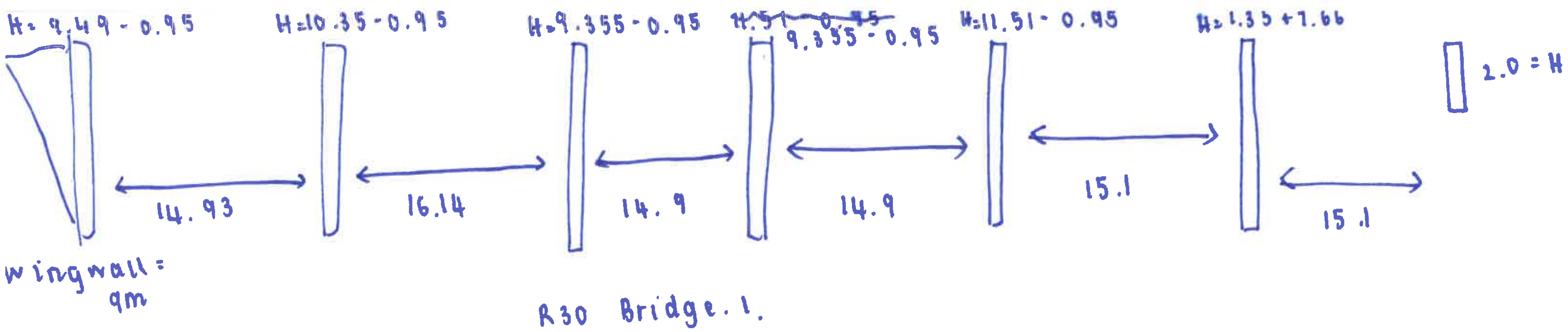
P1 = ____
P2 = ____
P3 = ____
P4 = ____
L = ~~5.47m~~ 18,45

W1 = 2,03 m
W2 = 2.03m
W3 = ____
W4 = ____
W5 = ____

K1u/s = ____
K1d/s = ____
K2u/s = ____
K1u/s = ____
R = 5,47

Comments:

Most of the bays/openings are overgrown.

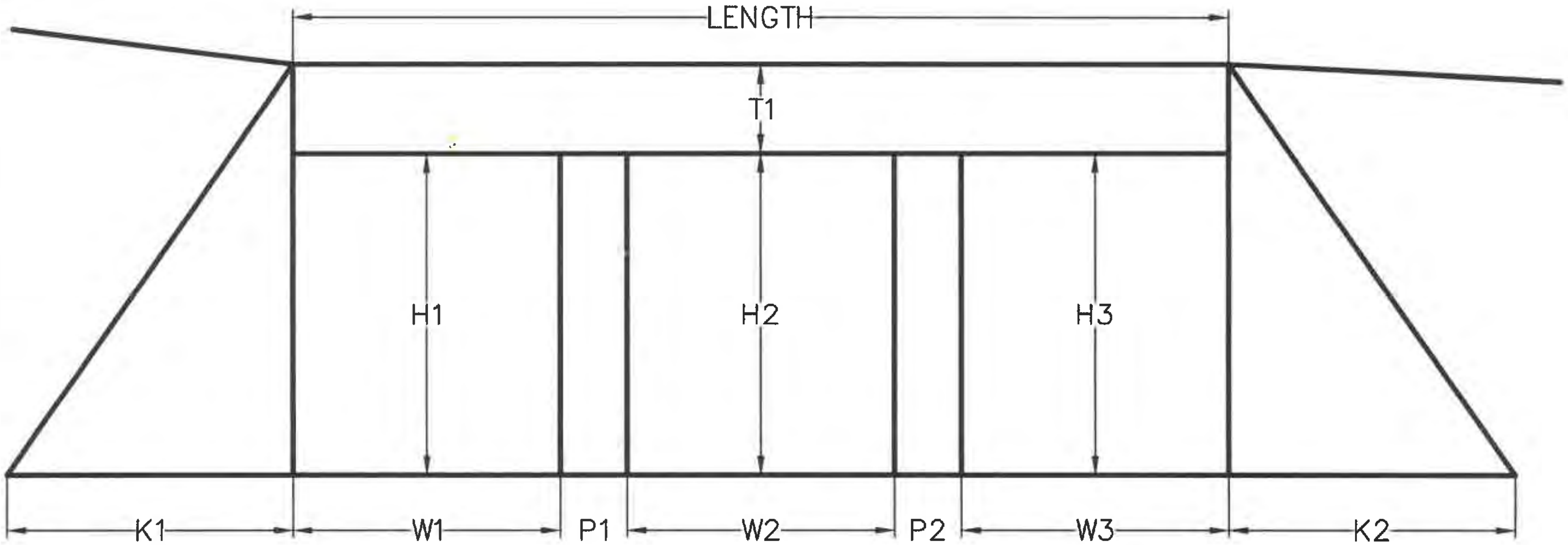


083 2764847
Mirna

450mm pipe - 300/400mm cover

Structure Number: Culvert 8.

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ____________
H2 = ____________
H3 = ____________
H4 = ____________
T1 = ____________

P1 = ____________
P2 = ____________
P3 = ____________
P4 = ____________
L = ____________

W1 = ____________
W2 = ____________
W3 = ____________
W4 = ____________
W5 = ____________

K1u/s = ____________
K1d/s = ____________
K2u/s = ____________
K1u/s = ____________
R = ____________

Comments:

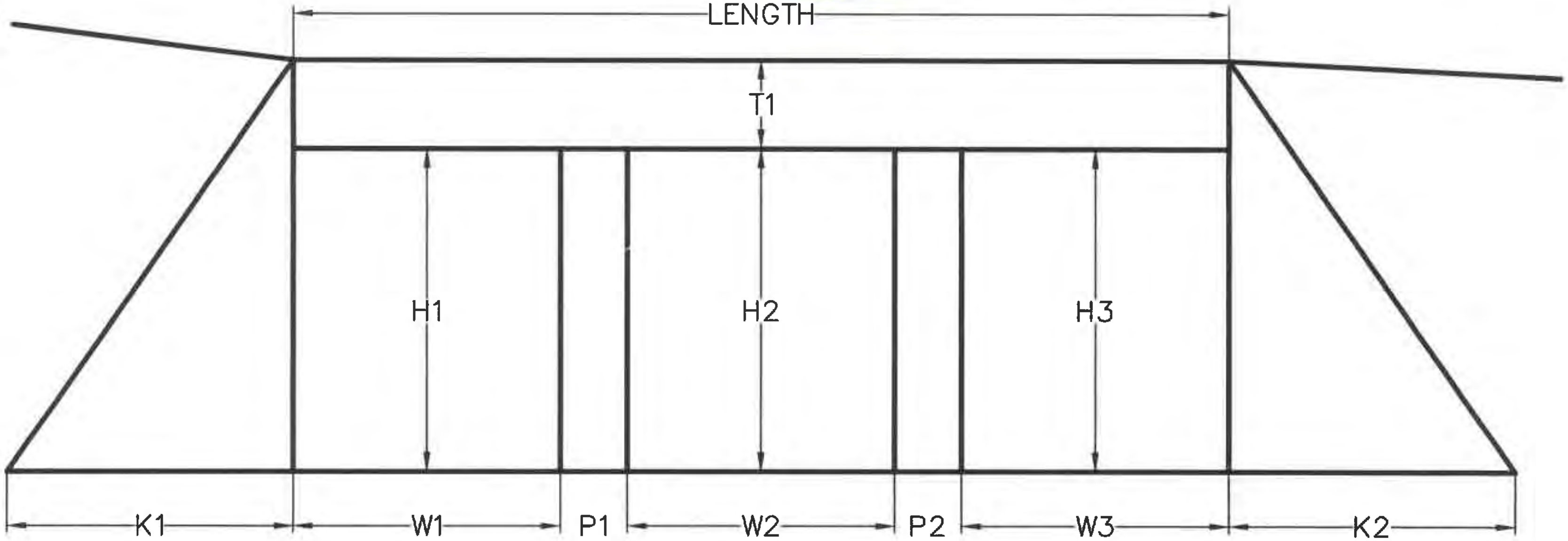
....

....

450 (model both)
~~600mm~~ pipe with a 400/500mm cover.

Structure Number: Culvert 7

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ______
H2 = ______
H3 = ______
H4 = ______
T1 = ______

P1 = ______
P2 = ______
P3 = ______
P4 = ______
L = ______

W1 = ______
W2 = ______
W3 = ______
W4 = ______
W5 = ______

K1u/s = ______
K1d/s = ______
K2u/s = ______
K1u/s = ______
R = 1.6m

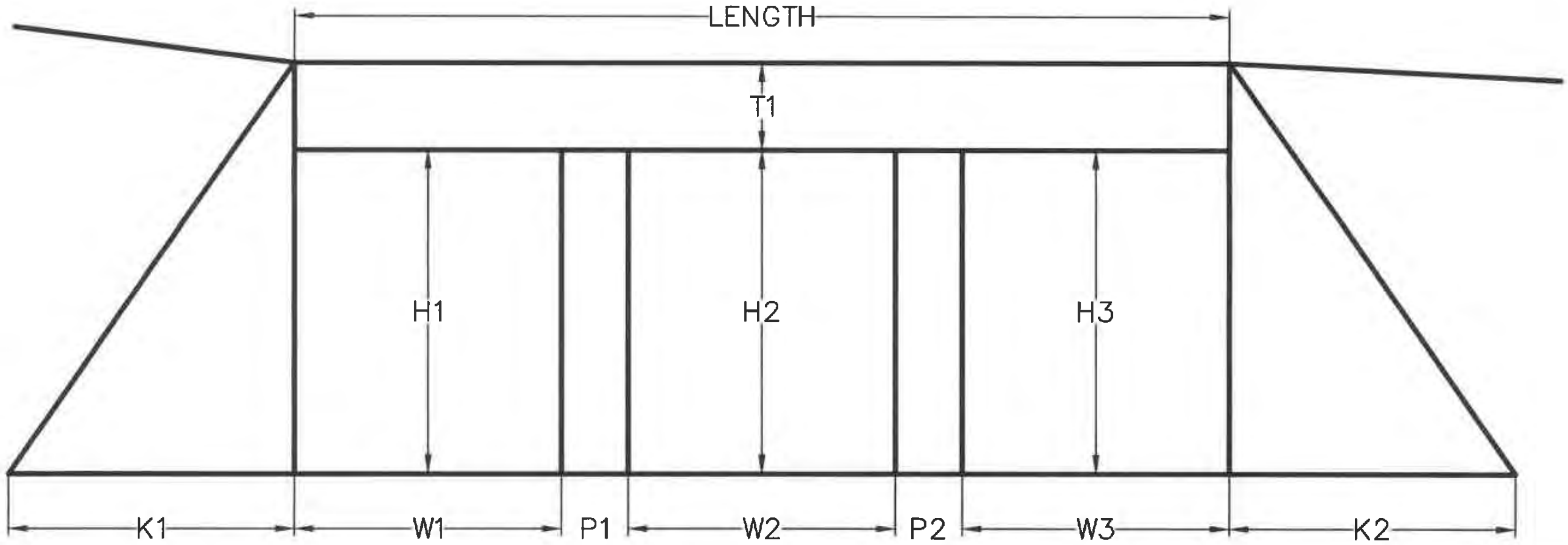
Comments:

....

....

Structure Number:
culvert. ff

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ____
H2 = ____
H3 = ____
H4 = ____
T1 = ____

P1 = ____
P2 = ____
P3 = ____
P4 = ____
L = ____

W1 = ____
W2 = ____
W3 = ____
W4 = ____
W5 = ____

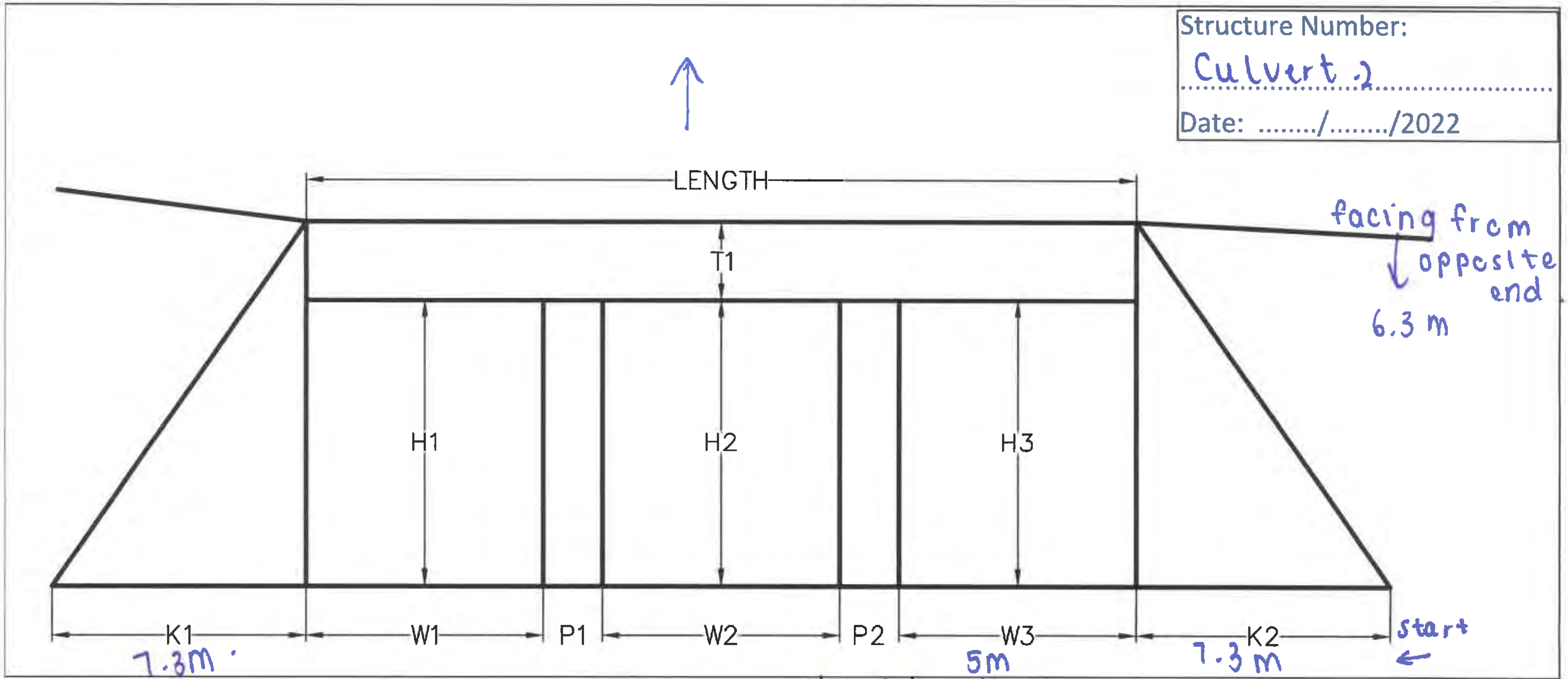
K1u/s = ____
K1d/s = ____
K2u/s = ____
K1u/s = ____
R = ____

Comments:
culvert pipe abandonned / broken, ~~area~~ has been replaced with building rubble.

Bridge No: 1695/19 81

Structure Number: Culvert 2

Date: ..../......../2022



culvert length: 27.4m

H	= Height of opening
T	= Thickness of bridge deck
P	= Thickness of bridge pier
W	= Width of opening
K	= Width of bridge wing
L	= Length of bridge
R	= Road width

H1 =	~~3.42~~ 3.6
H2 =	~~3.42~~ 2.65
H3 =	3.42
H4 =	
T1 =	0.85m

P1 =	~~0.5m~~ 0.475
P2 =	0.475
P3 =	0.475
P4 =	
L =	12.5m

W1 =	5.02
W2 =	5m
W3 =	5 m
W4 =	
W5 =	

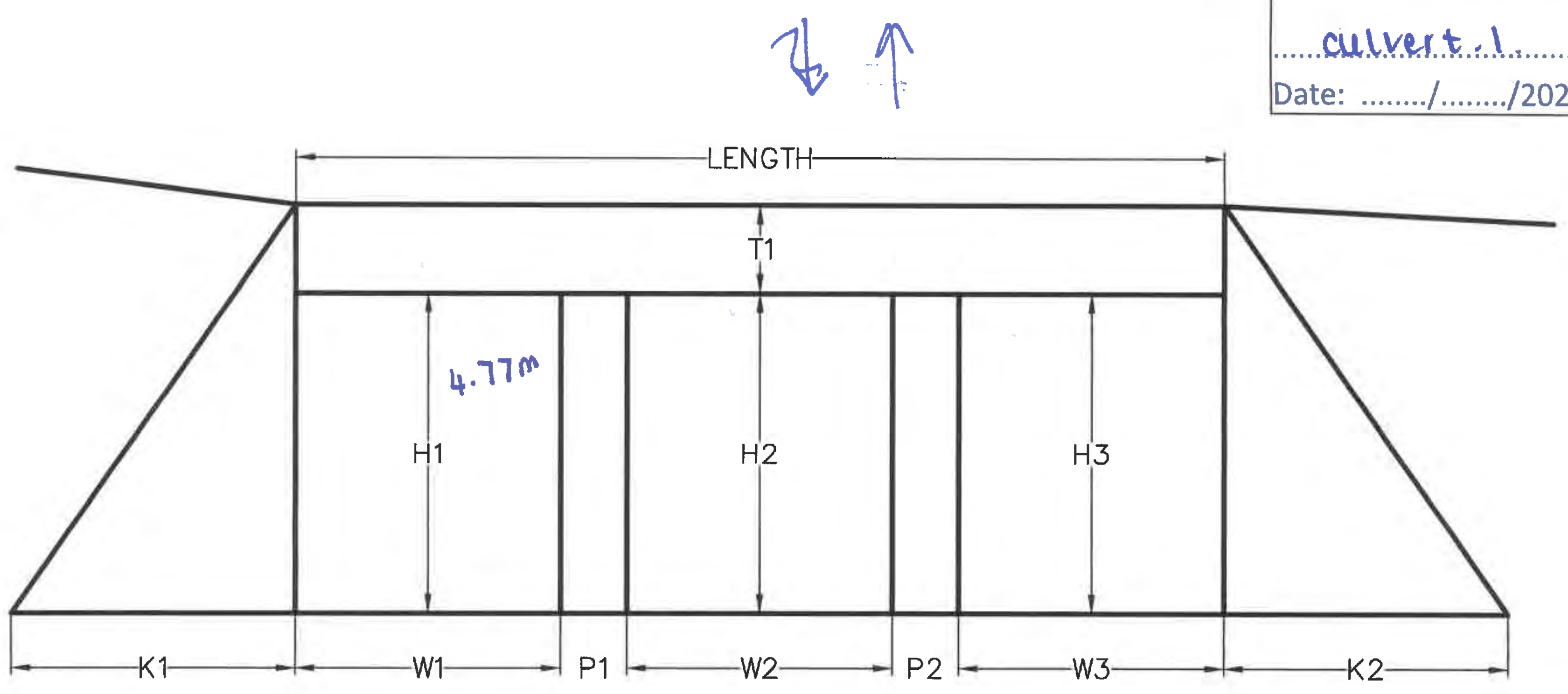
K1u/s =	
K1d/s =	
K2u/s =	
K1u/s =	
R =	

Comments:

Deck thickness and 1m Road cover

Structure Number: culvert.1

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ______
H2 = ______
H3 = ______
H4 = ______
T1 = 1.3m

P1 = ______
P2 = ______
P3 = ______
P4 = ______
L = 42.85

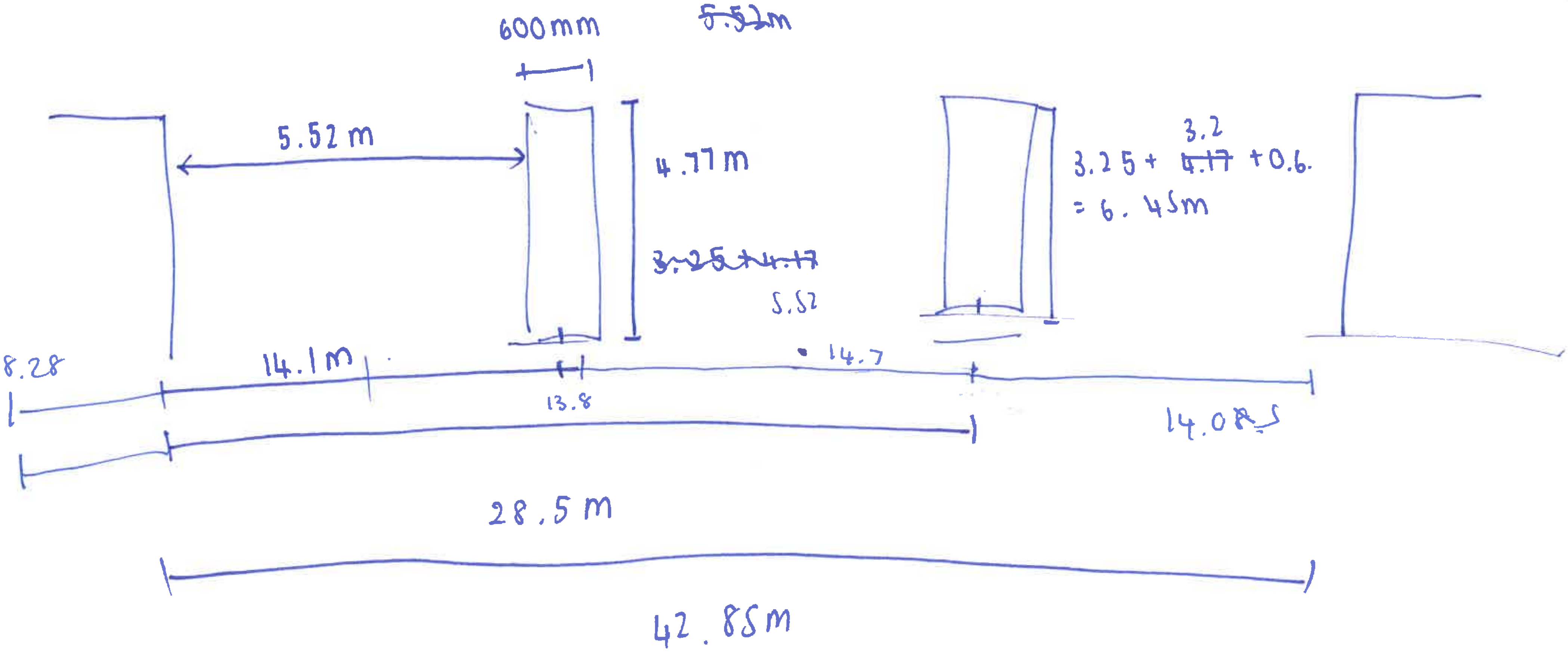
W1 = ______
W2 = ______
W3 = ______
W4 = ______
W5 = ______

K1u/s = ______
K1d/s = ______
K2u/s = ______
K1u/s = ______
R = 9.9m

Comments:

....

....



2 weirs are water affairs

(*) DWS website → look @ historical data for flows @ culvert.1.

→ for report.

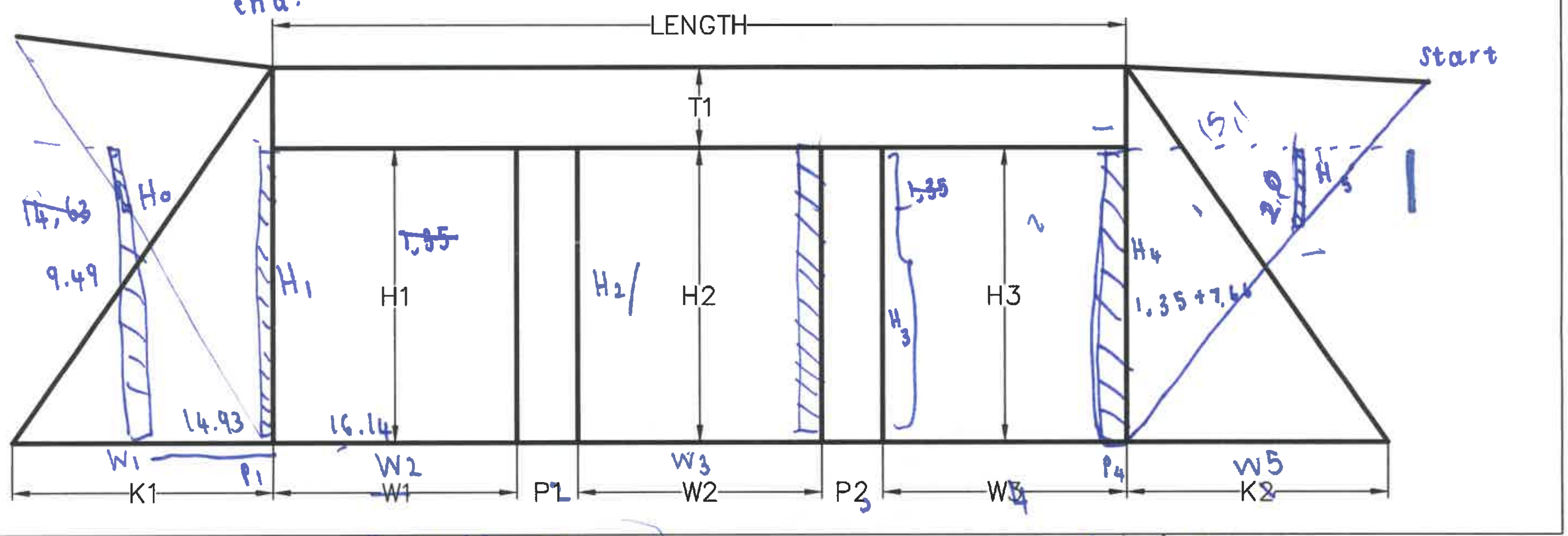
6piers legi

55km Say

Habee

Structure Number: R30 Bridge.1

Date: ..../......../2022



Ho ~~14.63~~ 9.49-0.95

width of bridge = 10.3m

H1 = ~~1,35~~ ~~8.41~~ ~~9.07~~ 10.35 - 0.95	P1 =	W1 = 15,12m / 15,2	K1u/s =
H2 = 9.355 - ~~1,2~~ 0,95	P2 =	W2 =	K1d/s =
H3 = 11,51 - ~~1,2~~ 0,95	P3 = 1,5m	W3 = 14.9	K2u/s =
H4 = 1,35 + 7,88 6,6 ~~-1,2~~	P4 =	W4 = 15,1	K1u/s =
T1 = [1,4m]	L = 99 m	W5 = 15,1	R = 10.3 m

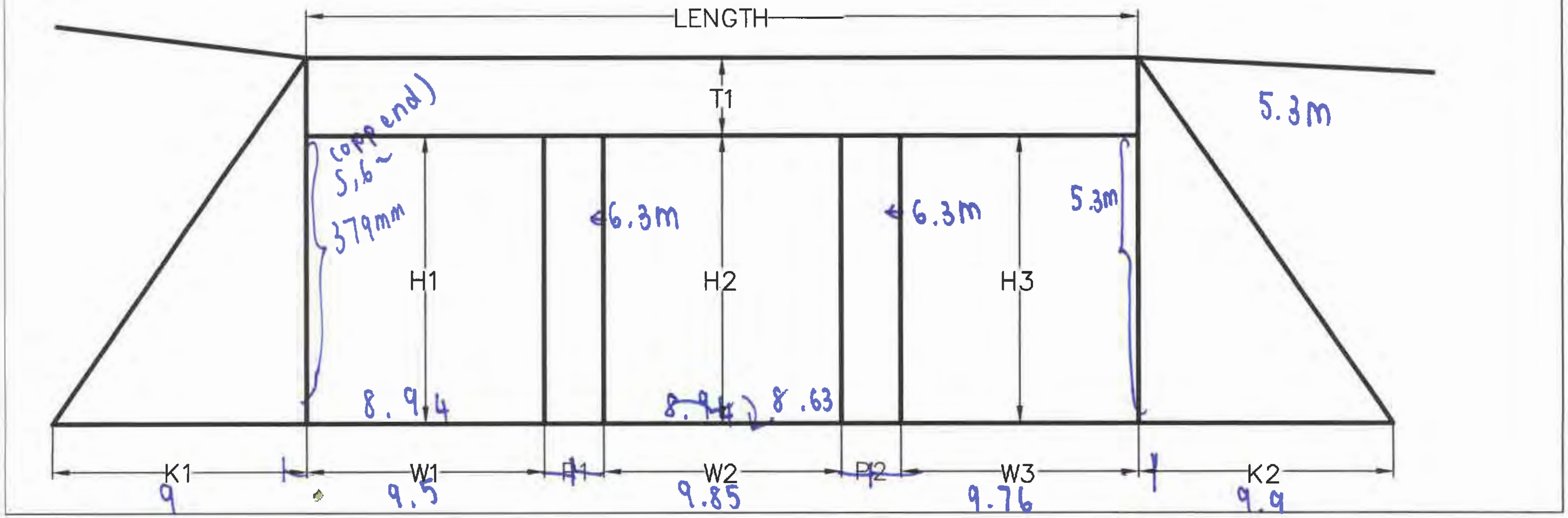
H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

Comments:

Use T1, L, R from here. Refer to map for dimension.

Structure Number: R30 bridge.2

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = 6.3
H2 = 6.3
H3 = 6.3
H4 =
T1 = 650mm

P1 = 1.25m
P2 =
P3 =
P4 =
L = ~~26.9~~ 29.5

W1 =
W2 =
W3 =
W4 =
W5 =

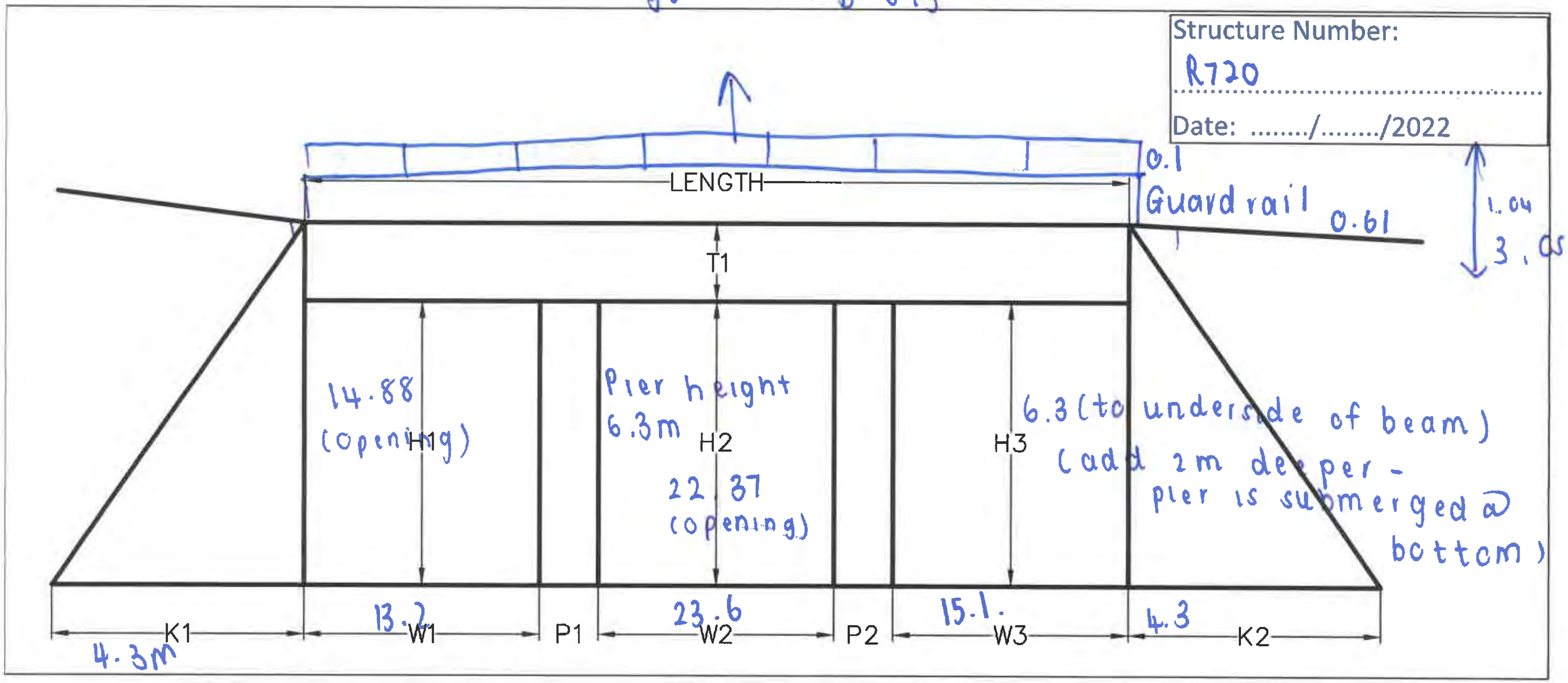
K1u/s =
K1d/s =
K2u/s =
K1u/s =
R = 0.85

Comments:

Bridge : B 875

Structure Number: R720

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 =
H2 =
H3 =
H4 =
T1 =

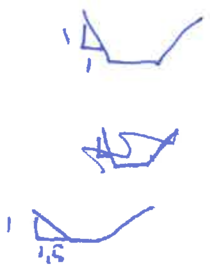
P1 = 1.26m
P2 = 1.26 m
P3 =
P4 =
L =

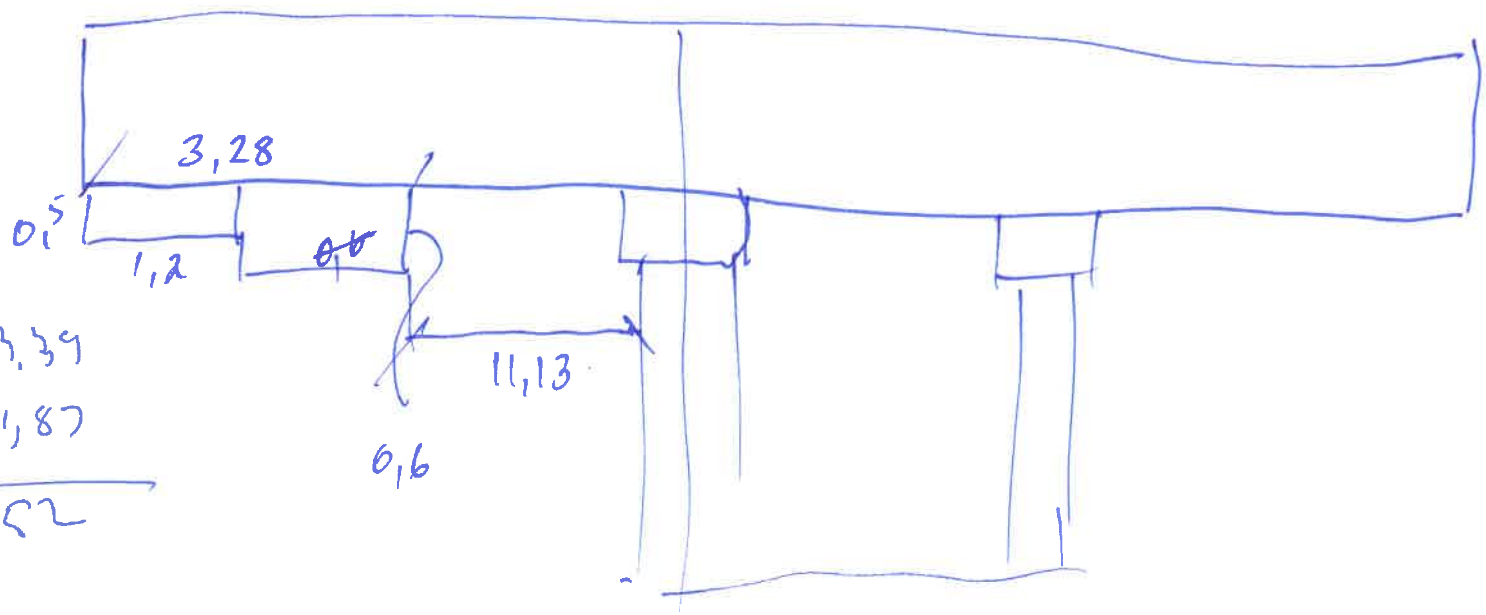
W1 =
W2 =
W3 =
W4 =
W5 =

K1u/s =
K1d/s =
K2u/s =
K1u/s =
R = 13.45

Comments:

1309.6 - 1309.8



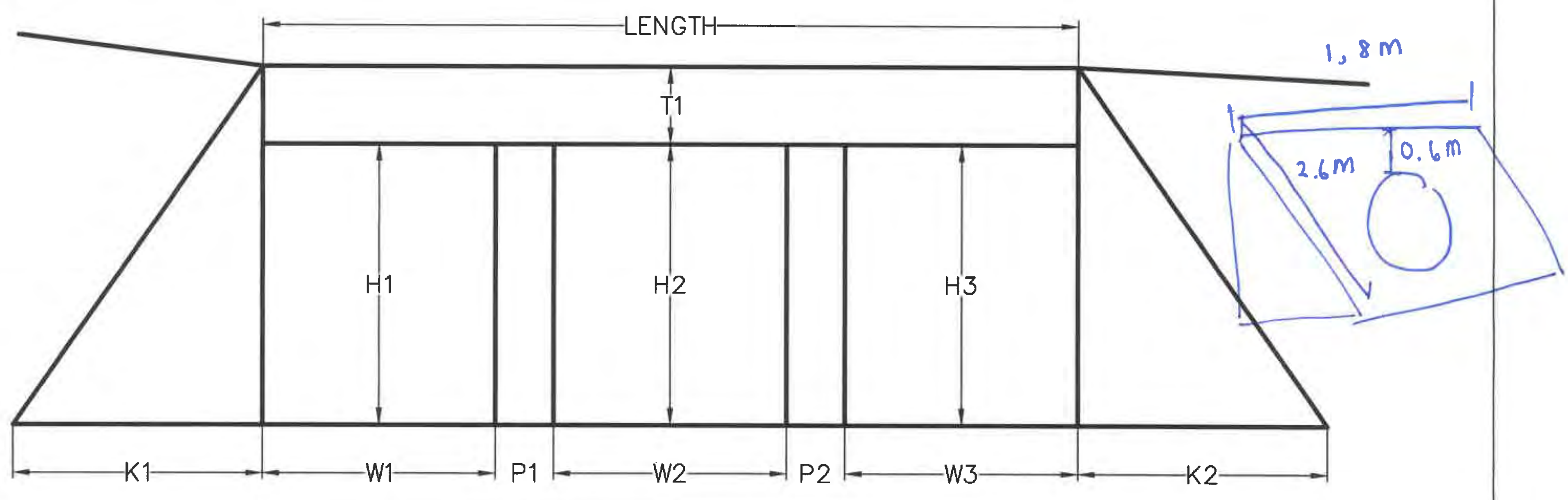


17,79	603,39
16,30	601,87
1,49	1,52

Slope is reno matteresses

Rockler culvert →
1,05m diameter (further research)

Structure Number:
Culvert 6.
Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 =	P1 =	W1 =	K1u/s =
H2 =	P2 =	W2 =	K1d/s =
H3 =	P3 =	W3 =	K2u/s =
H4 =	P4 =	W4 =	K1u/s =
T1 =	L =	W5 =	R = 5 m

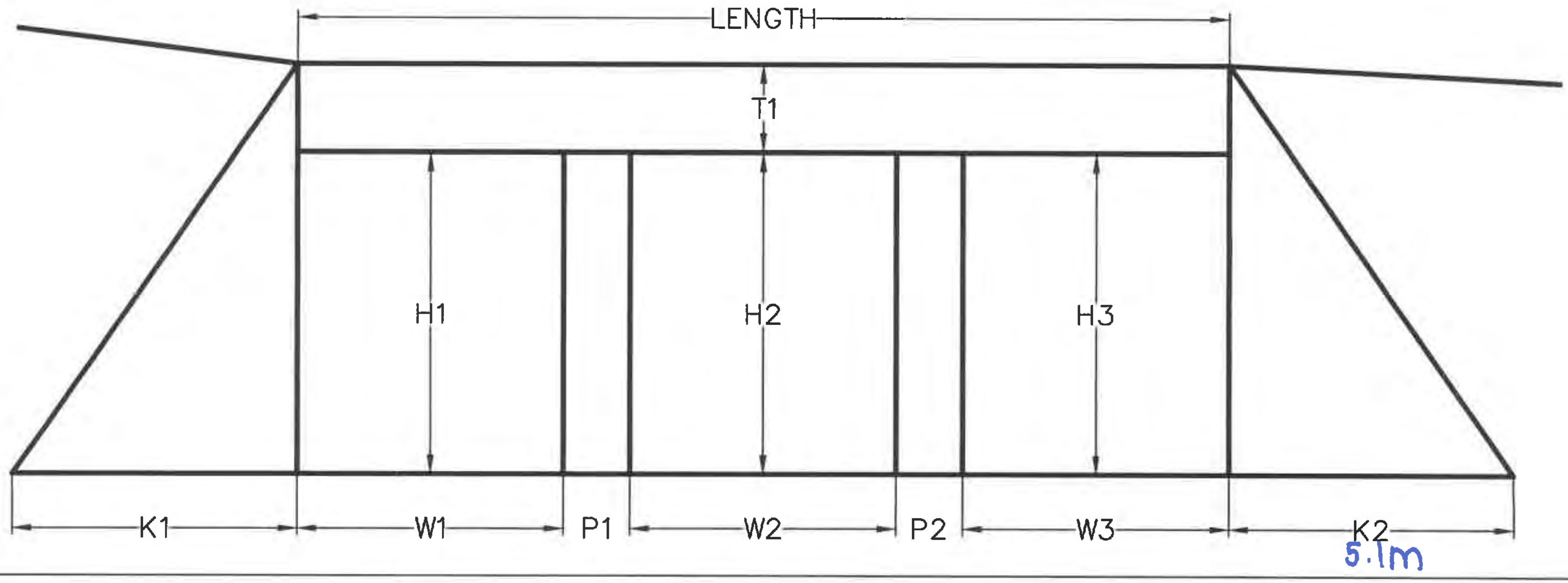
Comments:

....

....

Structure Number:
culverts

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ____
H2 = ____
H3 = ____
H4 = ____
T1 = 0.45 m

P1 = ____
P2 = ____
P3 = ____
P4 = ____
L = 25.1.

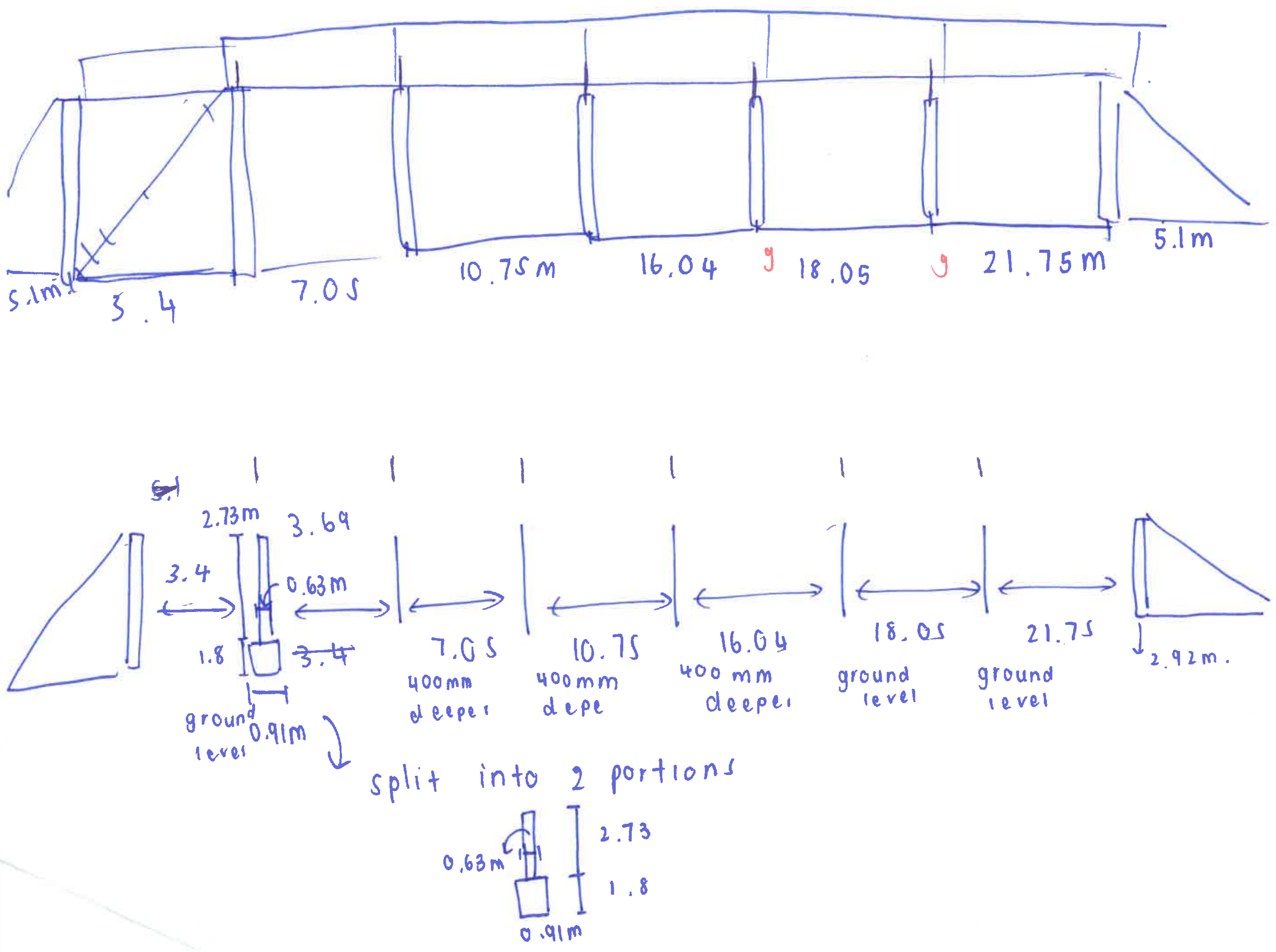
W1 = ____
W2 = ____
W3 = ____
W4 = ____
W5 = ____

K1u/s = ____
K1d/s = ____
K2u/s = ____
K1u/s = ____
R = ____

Comments:

....

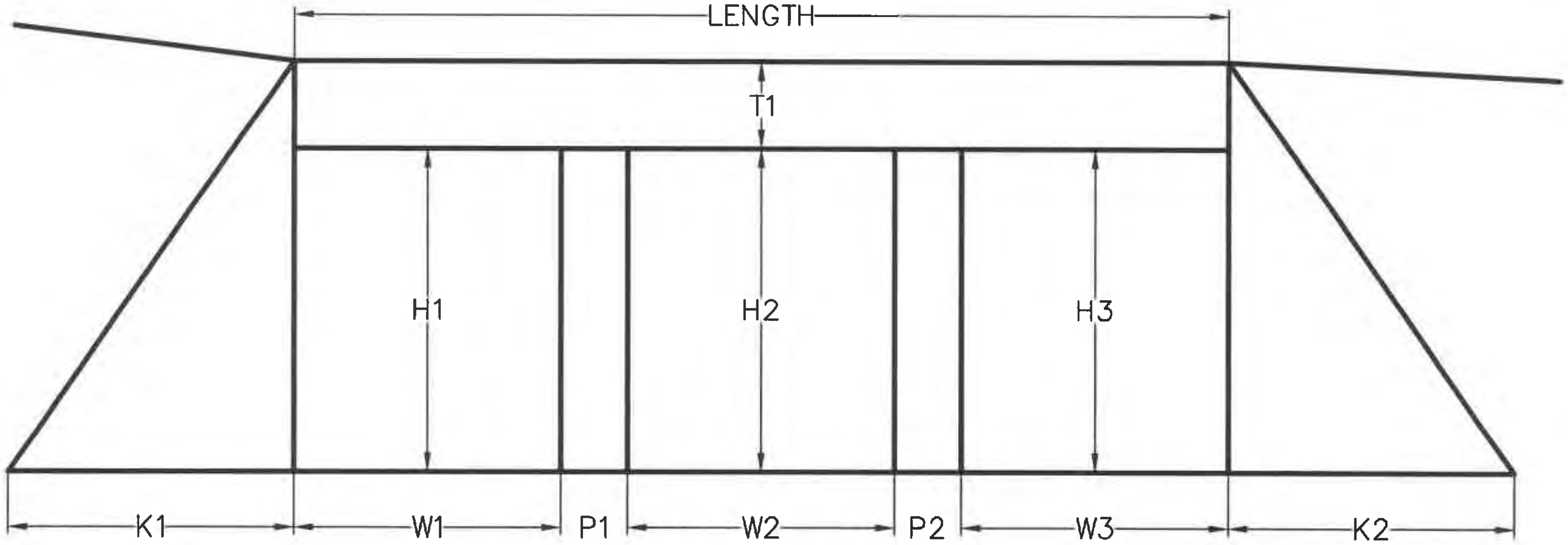
....


5.1m
3.4
7.05
10.75m
16.04
9
18.05
9
21.75m
5.1m
2.73m
3.69
3.4
0.63m
1.8
~~3.4~~
ground level
0.91m
7.05
400mm deeper
10.75
400mm depe
16.04
400 mm deeper
18.05
ground level
21.75
ground level
2.92m.
split into 2 portions
0.63m
2.73
1.8
0.91m

Structure Number:

....

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ____________
H2 = ____________
H3 = ____________
H4 = ____________
T1 = ____________

P1 = ____________
P2 = ____________
P3 = ____________
P4 = ____________
L = ____________

W1 = ____________
W2 = ____________
W3 = ____________
W4 = ____________
W5 = ____________

K1u/s = ____________
K1d/s = ____________
K2u/s = ____________
K1u/s = ____________
R = ____________

Comments:

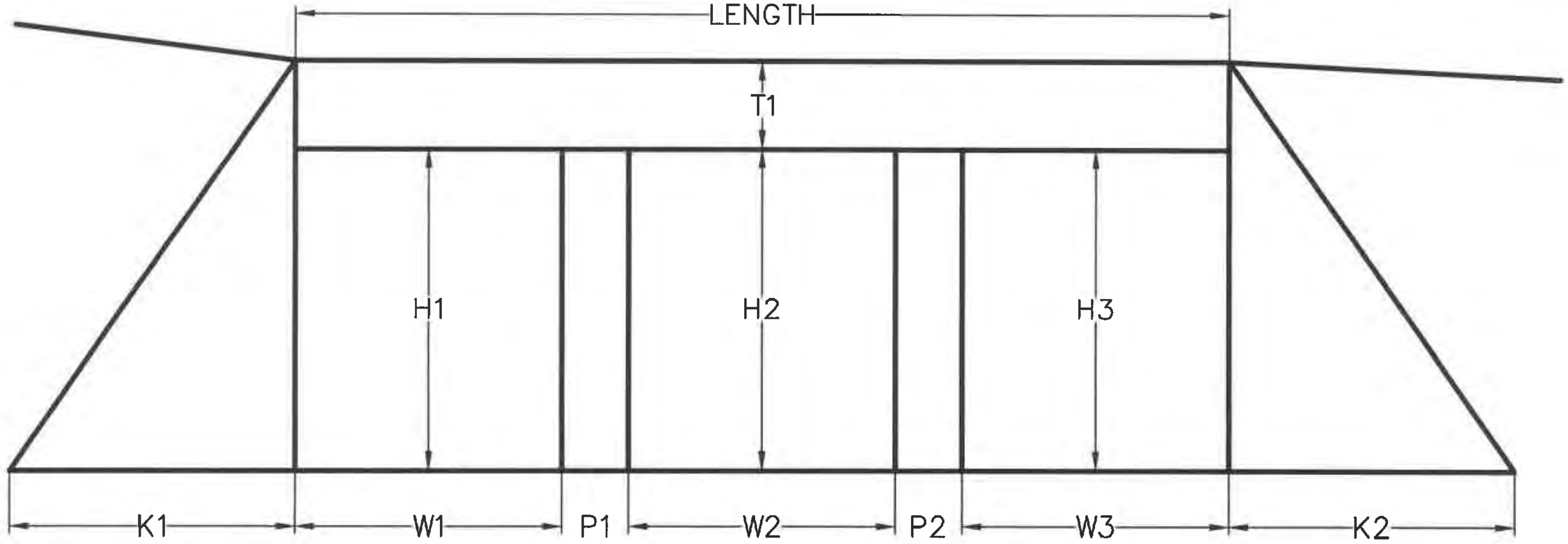
....

....

Structure Number:

....

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ____________

H2 = ____________

H3 = ____________

H4 = ____________

T1 = ____________

P1 = ____________

P2 = ____________

P3 = ____________

P4 = ____________

L = ____________

W1 = ____________

W2 = ____________

W3 = ____________

W4 = ____________

W5 = ____________

K1u/s = ____________

K1d/s = ____________

K2u/s = ____________

K1u/s = ____________

R = ____________

Comments:

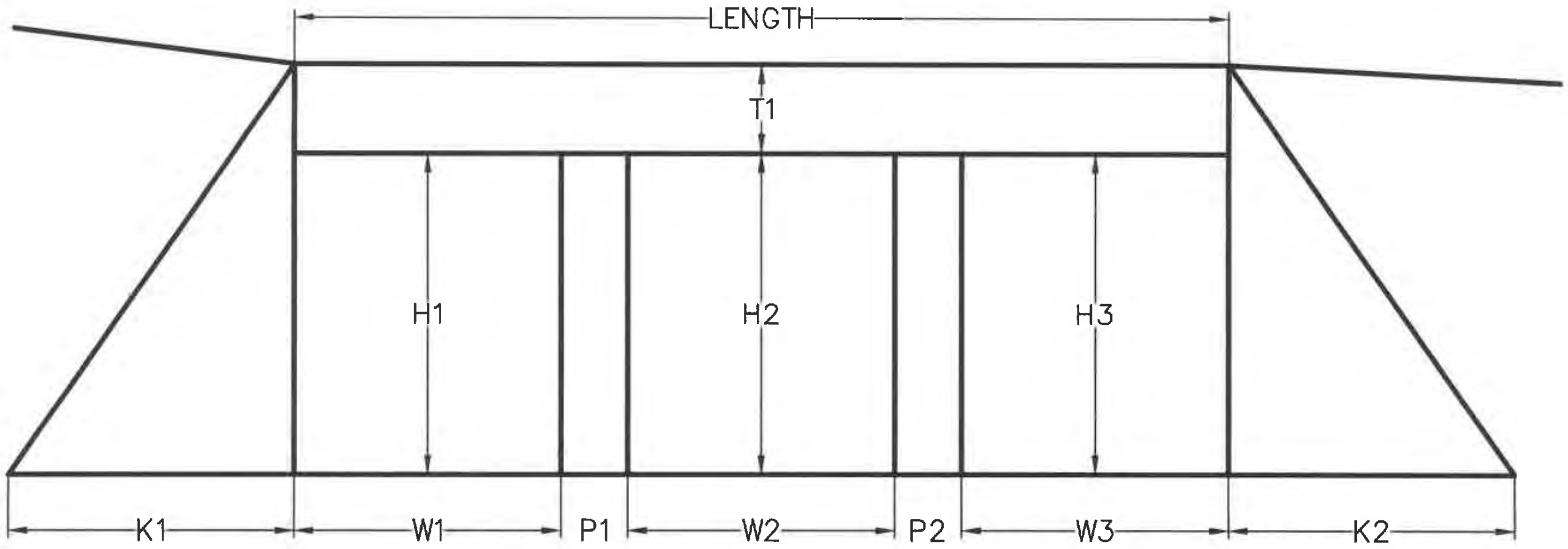
....

....

Structure Number:

....

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ____________
H2 = ____________
H3 = ____________
H4 = ____________
T1 = ____________

P1 = ____________
P2 = ____________
P3 = ____________
P4 = ____________
L = ____________

W1 = ____________
W2 = ____________
W3 = ____________
W4 = ____________
W5 = ____________

K1u/s = ____________
K1d/s = ____________
K2u/s = ____________
K1u/s = ____________
R = ____________

Comments:

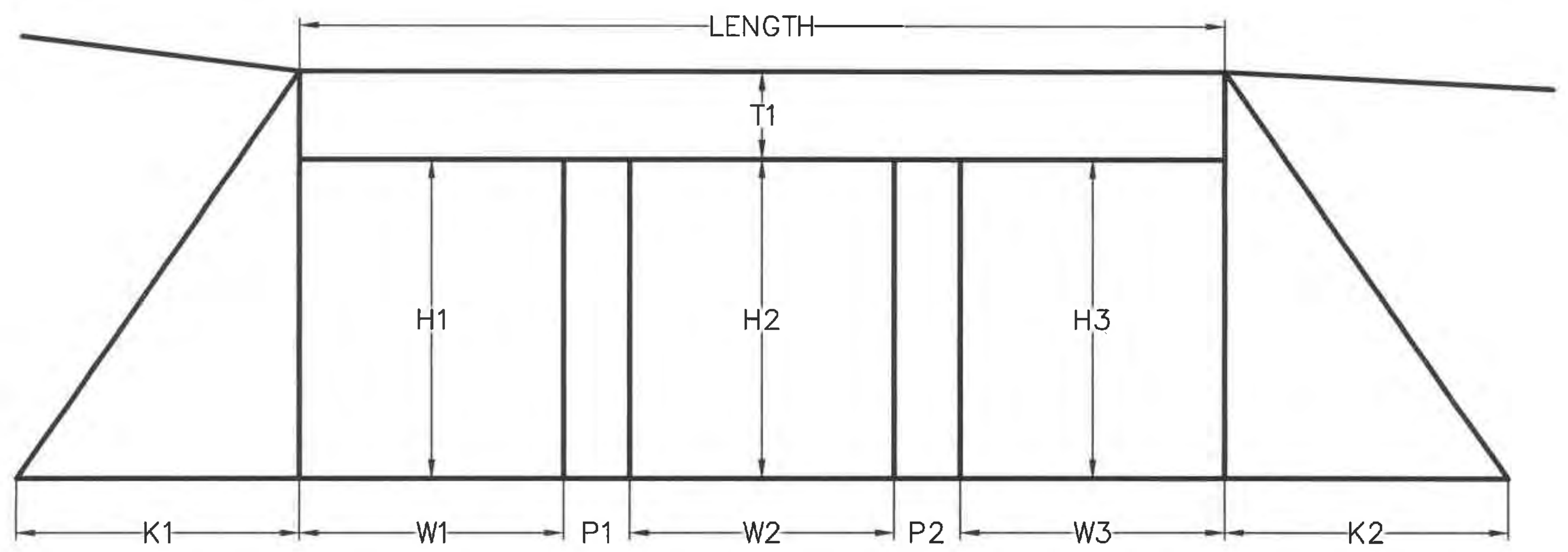
....

....

Structure Number:

....

Date: ..../......../2022



H = Height of opening
T = Thickness of bridge deck
P = Thickness of bridge pier
W = Width of opening
K = Width of bridge wing
L = Length of bridge
R = Road width

H1 = ____	P1 = ____	W1 = ____	K1u/s = ____
H2 = ____	P2 = ____	W2 = ____	K1d/s = ____
H3 = ____	P3 = ____	W3 = ____	K2u/s = ____
H4 = ____	P4 = ____	W4 = ____	K1u/s = ____
T1 = ____	L = ____	W5 = ____	R = ____

Comments:

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Environmental Noise Impact Assessment for the Tetra4 Cluster 2 Gas Production Project

Project done for EIMS (Pty) Ltd

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Report Details

Report Title	Environmental Noise Impact Assessment for the Tetra4 Cluster 2 Gas Production Project
Client	EIMS (Pty) Ltd
Report Number	21EIM08
Report Version	Rev 0.3
Date	September 2022
Prepared by	Reneé von Gruenewaldt (Pr. Sci. Nat), MSc (University of Pretoria)
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Revision Record

Version	Date	Comments
Rev 0	April 2022	For client's review
Rev 0.1	April 2022	Editorial changes
Rev 0.2	June 2022	Incorporation of client's comments
Rev 0.3	September 2022	Amendment of section 6 to include current mitigation measres

Glossary and Abbreviations

Airshed	Airshed Planning Professionals (Pty) Ltd
dB	Descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure.
dBA	Descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure that has been A-weighted to simulate human hearing.
DMRE	Department of Mineral Resources and Energy
EA	Environmental Authorisation
EAR	Enviro Acoustic Research
EC	European Commission
EHS	Environmental, Health, and Safety (IFC)
EIA	Environmental Impact Assessment
EIMS	EIMS (Pty) Ltd
EMPr	Environmental Management Programme
GN	Government Notice
Hz	Frequency in Hertz
IEC	International Electro Technical Commission
IFC	International Finance Corporation
ISO	International Standards Organisation
Kn	Noise propagation correction factor
K1	Noise propagation correction for geometrical divergence
K2	Noise propagation correction for atmospheric absorption
K3	Noise propagation correction for the effect of ground surface;
K4	Noise propagation correction for reflection from surfaces
K5	Noise propagation correction for screening by obstacles
kW	Power in kilowatt
L_{Aeq} (T)	The A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured) (in dBA)
L_{AIeq} (T)	The impulse corrected A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured) (in dBA)
$L_{Req,d}$	The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the day-time period, i.e. from 06:00 to 22:00.
$L_{Req,n}$	The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the night-time period, i.e. from 22:00 to 06:00.
L_{A90}	The A-weighted 90% statistical noise level, i.e. the noise level that is exceeded during 90% of the measurement period. It is a very useful descriptor which provides an indication of what the L_{Aeq} could have been in the absence of noisy single events and is considered representative of background noise levels (L_{A90}) (in dBA)
L_{AFmax}	The A-weighted maximum sound pressure level recorded during the measurement period
L_{AFmin}	The A-weighted minimum sound pressure level recorded during the measurement period
LNG	Liquid Natural Gas

L_P	Sound pressure level (in dB)
Ltd	Limited
L_W	Sound Power Level (in dB)
m^2	Area in square metres
m/s	Speed in metres per second
NA	Not applicable
NACA	National Association for Clean Air
NEMA	National Environmental Management Act
NEMAQA	National Environmental Management Air Quality Act
NEMWA	National Environmental Management: Waste Act 59 of 2008
NSR	Noise sensitive receptor
p	Pressure in Pa
Pa	Pressure in Pascal
µPa	Pressure in micro-pascal
p_{ref}	Reference pressure, 20 µPa
Pty	Proprietary
SABS	South African Bureau of Standards
SACNASP	South African Council for Natural Scientific Professions
SANS	South African National Standards
SAWS	South African Weather Services
SLM	Sound Level Meter
SoW	Scope of Work
STRM	Shuttle Radar Topography Mission
USGS	United States Geological Survey
WHO	World Health Organisation

Executive Summary

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by EIMS (Pty) Ltd (EIMS) to undertake a specialist environmental noise impact study for Tetra4 Cluster 2 expansion (hereafter referred to as the project).

The main objective of the noise specialist study was to determine the significance of impacts on the acoustic environment and noise receptors (NSRs) given noise generated by activities proposed as part of the project.

To meet the above objective, the following tasks were included in the Scope of Work (SoW):

1. A review of technical project information.
2. A review of the legal requirements and applicable environmental noise guidelines.
3. A study of the receiving (baseline) acoustic environment, including:
    a. The identification of NSRs from available maps and field observations;
    b. A study of environmental noise attenuation potential by referring to available weather records, land use, and topography; and
    c. A short-term baseline noise survey.
4. An impact assessment, including:
    a. A source inventory for operations and activities proposed as part of the project.
    b. Noise propagation simulations to determine environmental noise levels over the selected study area and at NSRs as a result of the project.
    c. The screening of simulated noise levels against environmental noise criteria.
5. The identification and recommendation of suitable noise management measures and monitoring requirements.
6. Determining impact significance.
7. The preparation of a comprehensive specialist noise impact assessment report.

In the assessment of sampled and simulated noise levels, reference was made to the International Finance Corporation (IFC) noise level guidelines for residential, institutional and educational receptors (55 dBA during the day and 45 dBA during the night) since these are applicable to nearby NSRs. Annoyance was assessed according to the South African National Standard (SANS) 10103 (2008) scale.

The baseline acoustic environment was described in terms of the location of NSRs, the ability of the environment to attenuate noise over long distances, as well as existing background and baseline noise levels. The following was found:

- NSRs:
    - Include places of residence and areas where members of the public may be affected by noise generated by proposed activities.
    - Potential noise sensitive receptors within the study area include individual homesteads and industrial and residential areas.
- Atmospheric conditions are more conducive to noise attenuation during the day.

- On average, noise impacts are expected to be slightly more notable to the southwest and southeast (day-time) and southwest (night-time) of the project activities.
- All the measurements indicated a site with a very complex sound character. Areas away from busy roads and mining activities are very quiet, with measurement locations closer to houses, busy roads and mining activities indicating higher sound levels. Vegetation growth closer to dwellings creates habitat, attracting birds and insects, which in turn make sounds that increases the ambient sound levels. The vegetation also increased wind-induced noises. The larger part of the study area, away from roads, dwellings and mining activities can be rated as Rural as per the SANS 10103:2008 criteria.

A source inventory was developed for the project. A detailed list of equipment, pumps and compressors was provided. Noise levels for the equipment were obtained from a combination of sources available in the BSI Standards: code of practice for noise and vibration control on construction and open sites (BSI, 2008), a noise source level database for similar operations (based on source measurements carried out in accordance with the procedures specified in SANS 10103) and calculations using the L_W predictive equations for mobile equipment as per the Handbook of Acoustics, Chapter 69, by Bruce and Moritz (1998).

The source inventory, local meteorological conditions and information on topography and local land use were used to populate the noise propagation model (CadnaA, ISO 9613). The propagation of noise was calculated over an area of 25.5 km east-west by 27 km north-south. The area was divided into a grid matrix with a 50-m resolution. The model was set to calculate L_P's (L_{Aeq}) at each grid and discrete receptor point at a height of 1.5 m above ground level.

A summary of simulated noise levels due to project construction and operational activities area as follows:

- Construction activities:
  - Activities were specified to take place during day-time hours only
  - Exceedances of the day-time IFC noise guidelines for residential, educational, and institutional areas (55 dBA) were as follows:
    - Wells: Up to 400 m from activities.
    - Pipeline: Up to 90 m from activities.
    - Blower Stations: Up to 600 m from activities (this is a conservative estimate as topography was not taken into account for these predictions).
    - Plant: Up to 420 m from Plant area.
    - Compressor Stations: Up to 380 m from Compressor Station areas.
- Operational activities:
  - Activities were assumed to take place continuously (24 hours per day)
  - Exceedances of the night-time IFC noise guidelines for residential, educational, and institutional areas (45 dBA) were as follows:
    - Blower Stations: Up to 150 m from activities (this is a conservative estimate as topography was not taken into account for these predictions).
    - Plant: Up to 600 m from Plant area.
    - Compressor Stations: Up to 120 m from Compressor Station areas.

It is recommended that general good practice measures for managing noise as set out in this report, be adopted as part of the facility's Environmental Management Plan. In the event that noise related complaints are received short term (30-min to 24-hours in duration) ambient noise measurements should be conducted as part of investigating the complaints. The results of the measurements should be used to inform any follow up interventions.

The significance of environmental noise impacts was assessed according to the methodology adopted by EIMS. The significance of project activities was found to be as follows:

- Construction activities:
    - Wells, Blower Stations and pipeline: Significance rating was medium without mitigation and low with mitigation.
    - Compressor Stations and plant: Significance rating was low without and with mitigation.
- Operational activities:
    - Blower Stations, Compressor Stations and plant: Significance was low without and with mitigation
- Decommissioning activities: Significance rating was medium without mitigation and low with mitigation.

Based on the findings of the assessment and provided the recommended general "good practice" management and mitigation measures are in place, it is the specialist opinion that the project may be authorised.

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1 Introduction

In 2012, a Production Right (Ref: 12/4/1/07/2/2) was granted which spans approximately 187 000 hectares for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within the approval of the Production Right, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1-1).

The activities in the Production Right include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500 km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original Environmental Impact Assessment (EIA) and approved EMPr).

On 21 September 2017, the Department of Mineral Resources and Energy (DMRE) issued an integrated environmental authorisation ("Cluster 1 EA") (reference: 12/04/07) to Tetra4 in terms of the National Environmental Management Act (NEMA). The Cluster 1 EA (as amended by Cluster 1 EA amendments dated 26 August 2019 and 1 September 2020) authorises the development of "Cluster 1" of the Project. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and Liquid Natural Gas (LNG) Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Tetra4 now wishes to expand the natural gas operations, to be located within the approved production right area and around the Cluster 1 project (Figure 1-1). This planned expansion to the existing approved production activities will involve up to 300 new production wells, gas transmission pipelines and associated infrastructure, 3 compressor stations and an additional new combined LNG and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure, as well as powerlines as part of the Cluster 2 expansion of the Project in order to meet the future production requirements. The Cluster 2 study area and infrastructure buffer zones are presented in Figure 1-2.

Airshed Planning Professionals (Pty) Ltd (Airshed) was commissioned by EIMS (Pty) Ltd (EIMS) to undertake a specialist environmental noise impact study for Cluster 2 expansion (hereafter referred to as the project).

1.1 Study Objective

The main objective of the noise specialist study was to determine the significance of impacts on the acoustic environment and potential noise sensitive receptors (NSRs) given noise generated by activities proposed as part of the project.

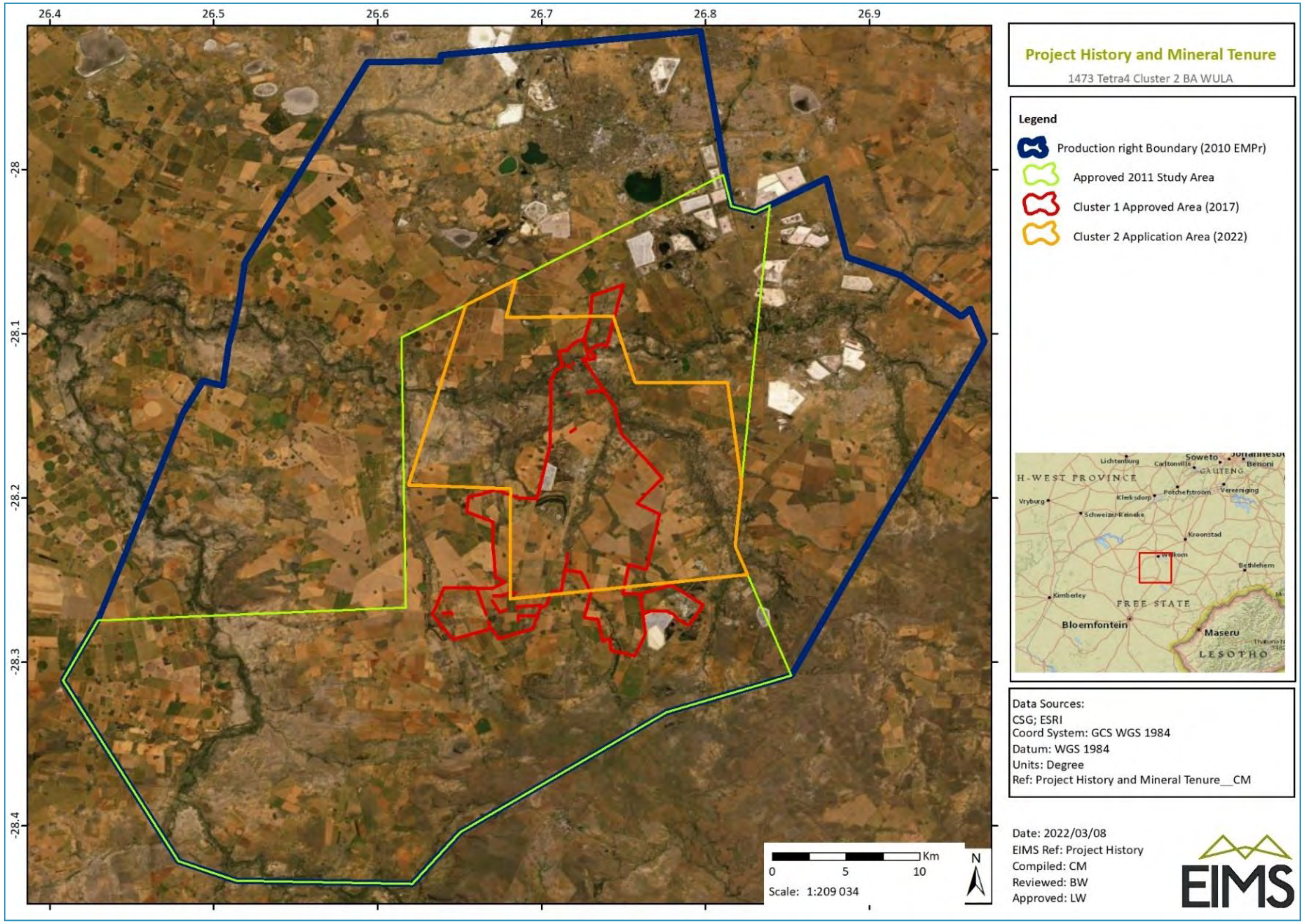


Figure 1-1: Project history and mineral tenure

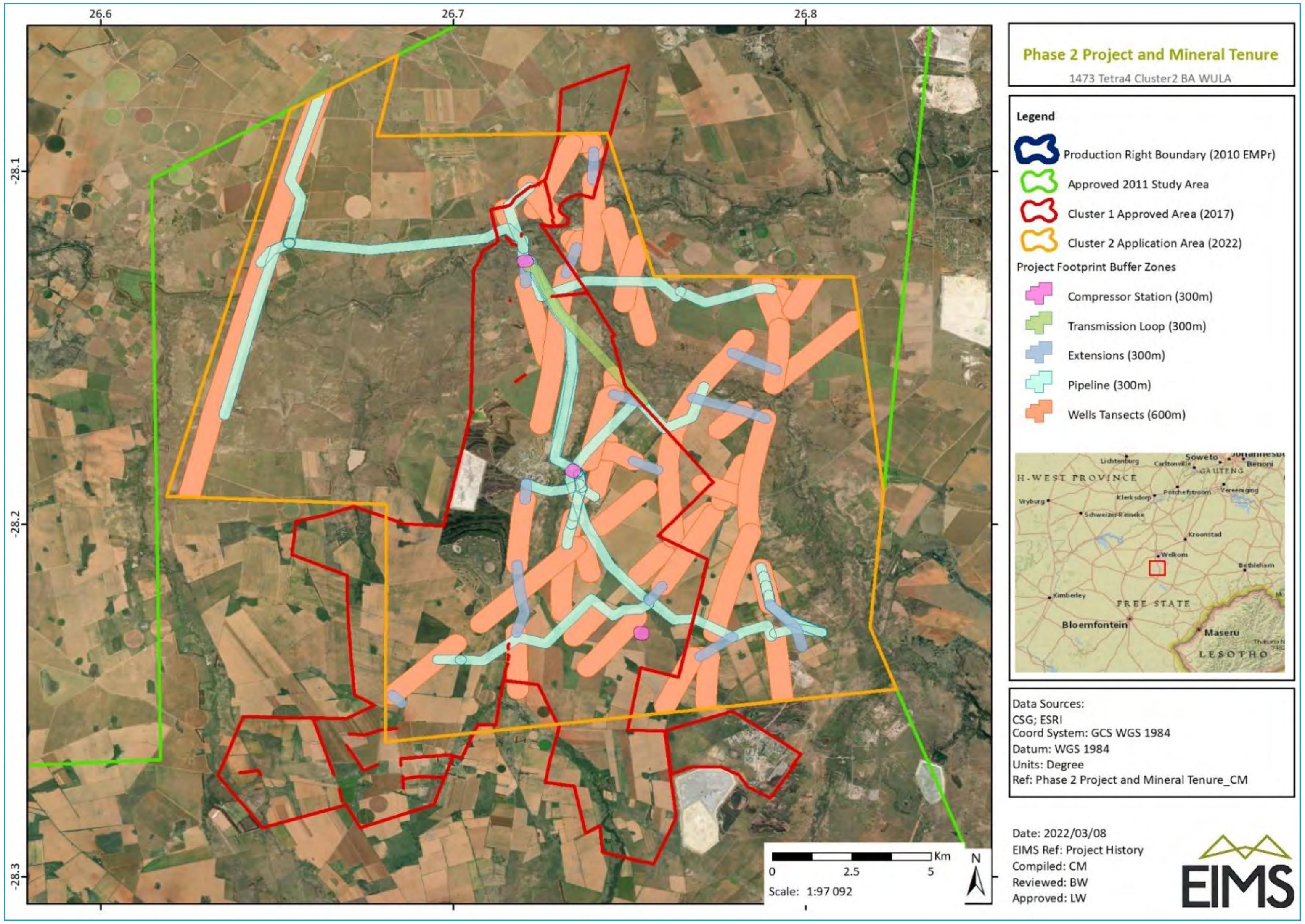


Figure 1-2: Cluster 2 study area and proposed infrastructure footprint buffer zones

1.2 Scope of Work

To meet the above objective, the following tasks were included in the Scope of Work (SoW):

1. A review of technical project information.
2. A review of the legal requirements and applicable environmental noise guidelines.
3. A study of the receiving (baseline) acoustic environment, including:
    a. The identification of NSRs from available maps and field observations;
    b. A study of environmental noise attenuation potential by referring to available weather records, land use, and topography; and
    c. A short-term baseline noise survey.
4. An impact assessment, including:
    a. A source inventory for operations and activities proposed as part of the project.
    b. Noise propagation simulations to determine environmental noise levels over the selected study area and at NSRs as a result of the project.
    c. The screening of simulated noise levels against environmental noise criteria.
5. The identification and recommendation of suitable noise management measures and monitoring requirements.
6. Determining impact significance.
7. The preparation of a comprehensive specialist noise impact assessment report.

1.3 Specialist Details

1.3.1 Specialist Details

Airshed is an independent consulting firm with no interest in the project other than to fulfil the contract between the client and the consultant for delivery of specialised services as stipulated in the terms of reference.

1.3.2 Competency Profile of Specialist

Reneé von Gruenewaldt is a Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP) and a member of the National Association for Clean Air (NACA).

Following the completion of her bachelor's degree in atmospheric sciences in 2000 and honours degree (with distinction) with specialisation in Environmental Analysis and Management in 2001 at the University of Pretoria, her experience in air pollution started when she joined Environmental Management Services (now Airshed Planning Professionals) in 2002. Reneé von Gruenewaldt later completed her master's degree (with distinction) in Meteorology at the University of Pretoria in 2009.

Reneé von Gruenewaldt became a partner of Airshed Planning Professionals in September 2006. Airshed Planning Professionals is a technical and scientific consultancy providing scientific, engineering, and strategic air pollution impact assessment and management services and policy support to assist clients in addressing a wide variety of air pollution and environmental noise related assessments.

She has experience on the various components of environmental noise assessments from 2015 to present. Her project experience range over various countries in Africa, providing her with an inclusive knowledge base of international legislation and requirements pertaining to noise impacts.

A comprehensive curriculum vitae of Reneé von Gruenewaldt is provided in Appendix A.

The declaration of independence for Reneé von Gruenewaldt is provided in Appendix B.

1.4 Description of Activities from a Noise Perspective

1.4.1 Construction

Noise generating sources during construction include equipment used for activities such as land clearing, site preparation, excavation, drilling, clean-up, and landscaping.

Construction can be described or divided into distinct categories. These are earthmoving equipment, materials handling equipment, stationary equipment, impact equipment, and other types of equipment. The first three categories include machines that are powered by internal combustion engines. Machines in the latter two categories are powered pneumatically, hydraulically, or electrically. Additionally, exhaust noise tends to account for most of the noise emitted by machines in the first three categories (those that use internal combustion engines) whereas engine-related noise is usually secondary to the noise produced by the impact between impact equipment and the material on which it acts (Bugliarello, et al., 1976).

Construction and diesel mobile mining equipment generally produce noise in the lower end of the frequency spectrum. Reverse, or moving beeper alarms emit at higher frequency ranges and are often heard over long distances.

Noise generated during construction activities is highly variably since it is characterised by variations in the power expended by equipment. Besides having daily variations in activities, construction is accomplished in several different phases where each phase has a specific equipment mix depending on the work to accomplished during that phase.

1.4.2 Operation

Sound fields in an industrial setting, are usually complex due to the participation of many sources: propagation through air (air-borne noise), propagation through solids (structure-borne noise), diffraction at the machinery boundaries, reflection from the floor, wall, ceiling and machinery surface, absorption on the surfaces, etc. High noise levels can therefore be present in the vicinity of operating machinery. The project will include pumps, compressors, motors, cooling towers, trucks and generators. For a given machine, the sound pressure levels depend on the part of the total mechanical or electrical energy that is transformed into acoustical energy.

Piping noise associated with the movement of the LNG from blower stations and compressors to the plant are usually very localised and not considered significant.

1.4.3 Operational Hours

The construction activities were provided to take place during day-time hours (07:00 to 18:00). Project activities have been assumed to take place 24 hours per day.

1.5 Background to Environmental Noise and the Assessment Thereof

Before more details regarding the approach and methodology adopted in the assessment is given, the reader is provided with some background, definitions and conventions used in the measurement, calculation and assessment of environmental noise.

Noise is generally defined as unwanted sound transmitted through a compressible medium such as air. Sound in turn, is defined as any pressure variation that the ear can detect. Human response to noise is complex and highly variable as it is subjective rather than objective.

A direct application of linear scales (in pascal (Pa)) to the measurement and calculation of sound pressure leads to large and unwieldy numbers. And, as the ear responds logarithmically rather than linearly to stimuli, it is more practical to express acoustic parameters as a logarithmic ratio of the measured value to a reference value. This logarithmic ratio is called a decibel or dB. The advantage of using dB can be clearly seen in Figure 1-3. Here, the linear scale with its large numbers is converted into a manageable scale from 0 dB at the threshold of hearing (20 micro-pascals (μPa)) to 130 dB at the threshold of pain (~100 Pa) (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

As explained, noise is reported in dB. “dB” is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities that have the same units, in this case sound pressure. The relationship between sound pressure and sound pressure level is illustrated in this equation.

$$L_p = 20 \cdot \log_{10}\left(\frac{p}{p_{ref}}\right)$$

Where:

L_p is the sound pressure level in dB;

p is the actual sound pressure in Pa; and

p_{ref} is the reference sound pressure (p_{ref} in air is 20 μPa).

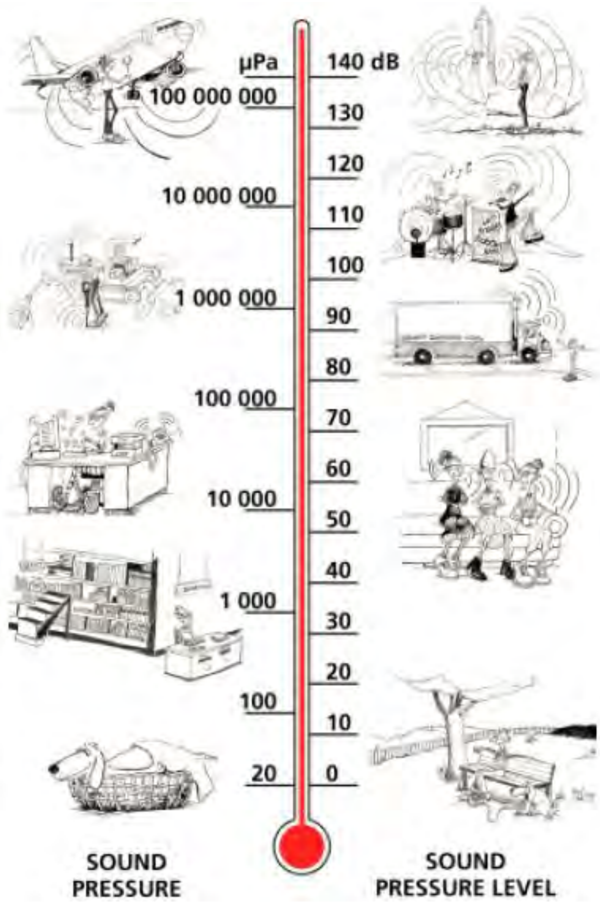


Figure 1-3: The decibel scale and typical noise levels (Brüel & Kjær Sound & Vibration Measurement A/S, 2000)

1.5.1 Perception of Sound

Sound has already been defined as any pressure variation that can be detected by the human ear. The number of pressure variations per second is referred to as the frequency of sound and is measured in hertz (Hz). The hearing frequency of a young, healthy person ranges between 20 Hz and 20 000 Hz.

In terms of L_P, audible sound ranges from the threshold of hearing at 0 dB to the pain threshold of 130 dB and above. Even though an increase in sound pressure level of 6 dB represents a doubling in sound pressure, an increase of 8 to 10 dB is required before the sound subjectively appears to be significantly louder. Similarly, the smallest perceptible change is about 1 dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

1.5.2 Frequency Weighting

Since human hearing is not equally sensitive to all frequencies, a ‘filter’ has been developed to simulate human hearing. The ‘A-weighting’ filter simulates the human hearing characteristic, which is less sensitive to sounds at low frequencies than at high frequencies (Figure 1-4). “dBA” is the descriptor that is used to indicate 10 times a logarithmic ratio of quantities, that have the same units (in this case sound pressure) that has been A-weighted.

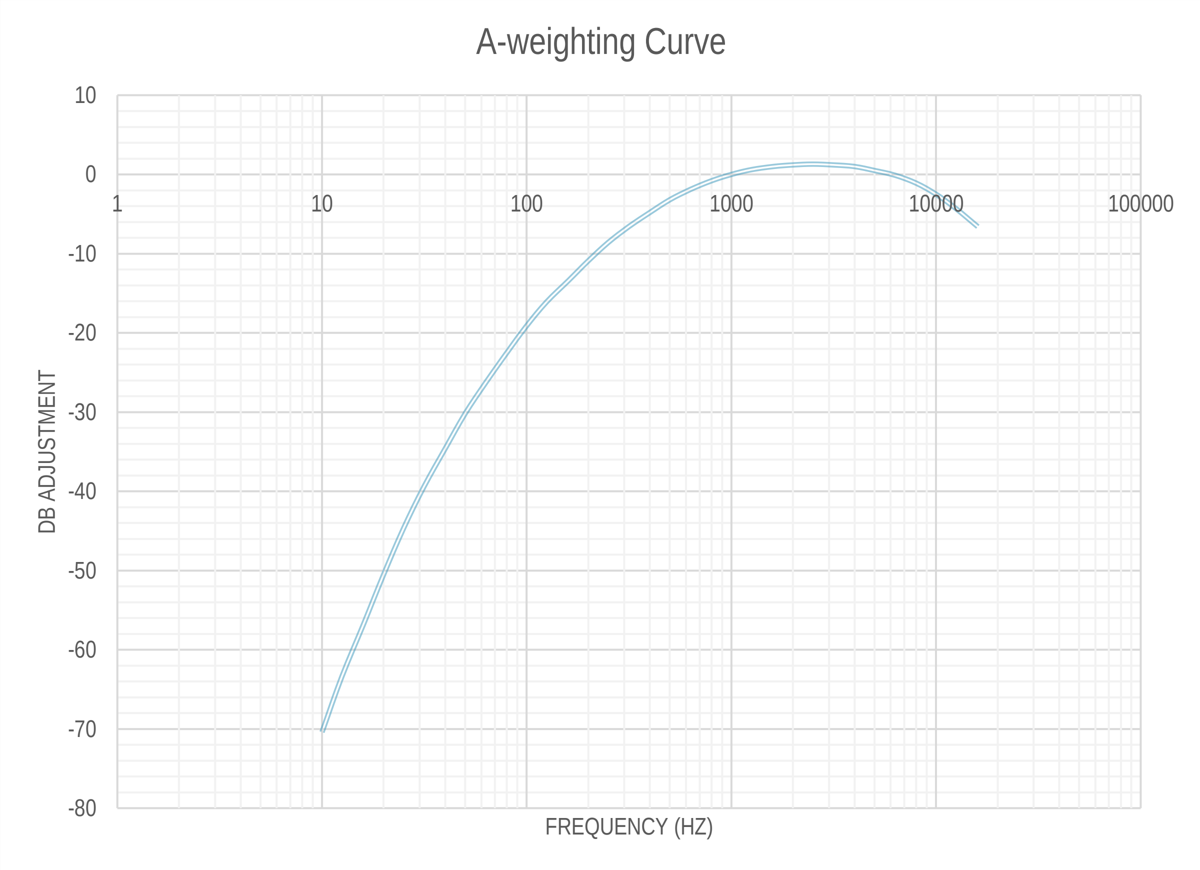


Figure 1-4: A-weighting curve

1.5.3 Adding Sound Pressure Levels

Since sound pressure levels are logarithmic values, the sound pressure levels as a result of two or more sources cannot just simply be added together. To obtain the combined sound pressure level of a combination of sources such as those at an industrial plant, individual sound pressure levels must be converted to their linear values and added using:

$$L_{p\_combined} = 10 \cdot \log\left(10^{\frac{L_{p1}}{10}} + 10^{\frac{L_{p2}}{10}} + 10^{\frac{L_{p3}}{10}} + \cdots 10^{\frac{L_{pi}}{10}}\right)$$

This implies that if the difference between the sound pressure levels of two sources is nil the combined sound pressure level is 3 dB more than the sound pressure level of one source alone. Similarly, if the difference between the sound pressure levels of two sources is more than 10 dB, the contribution of the quietest source can be disregarded (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

1.5.4 Environmental Noise Propagation

Many factors affect the propagation of noise from source to receiver. The most important of these are:

- The type of source and its sound power (L_W);
- The distance between the source and the receiver;
- Atmospheric conditions (wind speed and direction, temperature and temperature gradient, humidity etc.);
- Obstacles such as barriers or buildings between the source and receiver;
- Ground absorption; and
- Reflections.

To arrive at a representative result from either measurement or calculation, all these factors must be taken into account (Brüel & Kjær Sound & Vibration Measurement A/S, 2000).

1.5.5 Environmental Noise Indices

In assessing environmental noise either by measurement or calculation, reference is made to the following indices:

- L_{Aeq} (T) – The A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured).
- L_{AIeq} (T) – The impulse corrected A-weighted equivalent sound pressure level, where T indicates the time over which the noise is averaged (calculated or measured). In the South African Bureau of Standards' (SABS) South African National Standard (SANS) 10103 of 2008 for *'The measurement and rating of environmental noise with respect to annoyance and to speech communication'* prescribes the sampling of L_{AIeq} (T).
- $L_{Req,d}$ – The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the day-time period, i.e. from 06:00 to 22:00.
- $L_{Req,n}$ – The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the night-time period, i.e. from 22:00 to 06:00.
- L_{A90} – The A-weighted 90% statistical noise level, i.e., the noise level that is exceeded during 90% of the measurement period. It is a very useful descriptor which provides an indication of what the L_{Aeq} could have been in the absence of noisy single events and is considered representative of background noise levels.
- L_{AFmax} – The maximum A-weighted noise level measured with the fast time weighting. It's the highest level of noise that occurred during a sampling period.
- L_{AFmin} – The minimum A-weighted noise level measured with the fast time weighting. It's the lowest level of noise that occurred during a sampling period.

1.6 Approach and Methodology

The assessment included a study of the legal requirements pertaining to environmental noise impacts, a study of the physical environment of the area surrounding the project and the analyses of existing noise levels in the area. The impact assessment focused on the estimation of L_W's (noise 'emissions') and L_P's (noise impacts) associated with the operational phase. The findings of the assessment components informed recommendations of management measures, including mitigation and monitoring. Individual aspects of the noise impact assessment methodology are discussed in more detail below.

1.6.1 Information Review

The following information was supplied for inclusion in the study:

- Layout maps;
- Process description;
- List of equipment and related power ratings;
- Throughputs;
- Energy balance; and,
- Flare parameters.

1.6.2 Review of Assessment Criteria

In South Africa, provision is made for the regulation of noise under the National Environmental Management Air Quality Act (NEMAQA) (Act. 39 of 2004) but environmental noise limits have yet to be set. It is believed that when published, national criteria will make extensive reference to SANS 10103 of 2008 '*The measurement and rating of environmental noise with respect to annoyance and to speech communication*'. This standard has been widely applied in South Africa and is frequently used by local authorities when investigating noise complaints. These guidelines, together with those published by the IFC in their *General Environmental Health and Safety (EHS) Guidelines* (IFC 2007) and World Health Organisation (WHO) *Guidelines for Community Noise* (WHO 1999), were considered in the assessment.

1.6.3 Noise Propagation Simulations

The propagation of noise from project activities was simulated with the DataKustic CadnaA software. Use was made of the International Organisation for Standardization's (ISO) 9613 module for outdoor noise propagation from industrial noise sources.

ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation outdoors in order to predict the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level under meteorological conditions favourable to propagation from sources of known sound emission. These conditions are for downwind propagation or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night.

The method also predicts an average A-weighted sound pressure level. The average A-weighted sound pressure level encompasses levels for a wide variety of meteorological conditions. The method specified in ISO 9613 consists specifically of octave-band algorithms (with nominal midband frequencies from 63 Hz to 8 kHz) for calculating the attenuation of sound which originates from a point sound source, or an assembly of point sources. The source (or sources) may be moving or stationary. Specific terms are provided in the algorithms for the following physical effects; geometrical divergence, atmospheric absorption, ground surface effects, reflection and obstacles. A basic representation of the model is given in the equation below:

$$L_P = L_W - \sum [K_1, K_2, K_3, K_4, K_5, K_6]$$

Where;

L_P is the sound pressure level at the receiver;

L_W is the sound power level of the source;

K_1 is the correction for geometrical divergence;

K_2 is the correction for atmospheric absorption;

K_3 is the correction for the effect of ground surface;

K_4 is the correction for reflection from surfaces; and

K_5 is the correction for screening by obstacles.

This method is applicable in practice to a great variety of noise sources and environments. It is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources.

To apply the method of ISO 9613, several parameters need to be known with respect to the geometry of the source and of the environment, the ground surface characteristics, and the source strength in terms of octave-band sound power levels for directions relevant to the propagation.

If the dimensions of a noise source are small compared with the distance to the listener, it is called a point source. All sources of noise were quantified as point sources or areas/lines represented by point sources. The sound energy from a point source spreads out spherically, so that the sound pressure level is the same for all points at the same distance from the source and decreases by 6 dB per doubling of distance. This holds true until ground and air attenuation noticeably affect the level. The impact of an intruding industrial noise on the environment will therefore rarely extend over more than 5 km from the source and is therefore always considered “local” in extent.

The propagation of noise was calculated over an area of 25.5 km east-west by 27 km north-south. The area was divided into a grid matrix with a 50-m resolution. The model was set to calculate L_P’s (L_{Aeq}) at each grid and discrete receptor point at a height of 1.5 m above ground level.

1.6.4 Study of the Receiving Environment

NSRs generally include private residences, community buildings such as schools, hospitals and any publicly accessible areas outside an industrial facility’s property. Homesteads and residential areas included in the assessment as NSRs were identified from available maps and satellite imagery.

The ability of the environment to attenuate noise as it travels through the air was studied by considering local meteorology, land use, and terrain data. Atmospheric attenuation potential was described based on measured meteorological data obtained from the Welkom South African Weather Services (SAWS) station. Data for the period January 2015 to January 2022 was considered.

Readily available terrain data was obtained from the United States Geological Survey (USGS) web site (https://earthexplorer.usgs.gov/) in January 2022. A study was made of Shuttle Radar Topography Mission (STRM) 1 arc-sec data.

1.6.5 Noise Survey

The extent of noise impacts as a result of an intruding noise depends largely on existing noise levels in an area. Higher ambient noise levels will result in less noticeable noise impacts and a smaller impact area. The opposite also holds true. Increases in noise will be more noticeable in areas with low ambient noise levels. The data from a baseline noise survey conducted by Enviro Acoustic Research (2016) and Airshed (2022) was used.

The survey methodology that Airshed applied, which closely followed guidance provided by the IFC (2007) and SANS 10103 (2008), is summarised below:

- The survey was designed and conducted by a trained specialist.
- Sampling was carried out using a Type 1 sound level meter (SLM) that meet all appropriate International Electrotechnical Commission (IEC) standards and is subject to calibration by an accredited laboratory (Appendix C). Equipment details are included in Table 1-1.
- The acoustic sensitivity of the SLM was tested with a portable acoustic calibrator before and after each sampling session.
- Samples representative and sufficient for statistical analysis were taken with the use of the portable SLM capable of logging data continuously over the sampling time period. Samples representative of the day- and night-time acoustic environment were taken. SANS 10103 defines day-time as between 06:00 and 22:00 and night-time between 22:00 and 06:00 (SANS 10103, 2008).
- L_{Aleq} (T), L_{Aeq} (T); L_{AFmax}; L_{AFmin}; L_{Zeq} (T), L_{90} and 3rd octave frequency spectra were recorded.
- The SLM was located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface.
- SANS 10103 states that one must ensure (as far as possible) that the measurements are not affected by the residual noise and extraneous influences, e.g., wind, electrical interference and any other non-acoustic interference, and that the instrument is operated under the conditions specified by the manufacturer.
- A detailed log and record were kept. Records included site details, weather conditions during sampling and observations made regarding the acoustic environment of each site.

Table 1-1: Sound level meter details

Equipment	Serial Number	Purpose	Last Calibration Date
Svantek 977 sound level meter	S/N 36183	Noise sampling.	1,2 March 2021
Svantek 7052E ½" microphone	S/N 78692		
Svantek SV 12L ½" pre-amplifier	S/N 40659		
SVANTEK SV33 Class 1 Acoustic Calibrator	S/N 43170	Testing of the acoustic sensitivity before and after each daily sampling session.	2 March 2021

Equipment	Serial Number	Purpose	Last Calibration Date
Kestrel 4000 Pocket Weather Tracker	S/N 559432	Determining wind speed, temperature and humidity during sampling.	Not Applicable

SANS 10103 (2008) prescribes the method for the calculation of the equivalent continuous rating level ($L_{Req,T}$) from measurement data. $L_{Req,T}$ is the equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$) during a specified time interval, plus specified adjustments for tonal character, impulsiveness of the sound and the time of day; and derived from the applicable equation:

$$L_{Req,T} = L_{Aeq,T} + C_i + C_t + K_n$$

Where

- $L_{Req,T}$ is the equivalent continuous rating level;
- $L_{Aeq,T}$ is the equivalent continuous A-weighted sound pressure level, in decibels;
- C_i is the impulse correction;
- C_t is the correction for tonal character; and
- K_n is the adjustment for the time of day (or night), 0 dB for daytime and +10 dB for night-time.

1.6.6 Source Inventory

To determine the change in noise impacts associated with the project, a source inventory had to be developed. A detailed list of equipment was provided and used to compile the source inventory. L_W's for construction equipment were obtained from BSI Standards Publication for construction equipment (BSI, 2008). The L_W's for operational equipment were calculated using predictive equations for industrial machinery as per the Handbook of Acoustics, Chapter 69, by Bruce and Moritz (1998).

Decommissioning activities are expected to result in noise impacts similar to impacts associated with the construction phase. A source inventory was therefore only developed for the construction and operational phase of the project.

1.6.7 Presentation of Results

Results are presented in tabular and isopleth form. An isopleth is a line on a map connecting points at which a given variable (in this case sound pressure, L_P) has a specified constant value. This is analogous to contour lines on a map showing terrain elevation. In the assessment of environmental noise, isopleths present lines of constant noise level as a function of distance.

Simulated noise levels were assessed according to guidelines published in SANS 10103 and by the IFC. To assess annoyance at nearby places of residence, the increase in noise levels above the baseline at NSRs were calculated and compared to guidelines published in SANS 10103.

1.6.8 Recommendations of Management and Mitigation

The findings of the noise specialist study informed the recommendation of suitable noise management and mitigation measures.

1.6.9 Impact Significance Assessment

The significance of environmental noise impacts was assessed according to the methodology provided by EIMS. Refer to Appendix F of this report for the methodology.

1.7 Management of Uncertainties

The following limitations and assumptions should be noted:

- The quantification of sources of noise was limited to the construction and operational phase of the project. Impacts due to closure phase activities are expected to be similar to construction activities and its impacts only assessed qualitatively. Noise impacts will cease post-closure.
- The source power levels were calculated based on information provided by EIMS. The assumption is that this information is correct and reflects the routine construction and operational phase of the project.
- Structural obstacles were not included in the propagation modelling of the project noise sources. This is a conservative approach as the simulated noise impacts would not be attenuated by structural obstacles.
- Process activities were assumed to be 24 hours per day, 7 days per week.
- Although other existing sources of noise within the area were identified during the survey, such sources were not quantified but were taken into account during the baseline sampling.
- The environmental noise assessment focuses on the evaluation of impacts for humans.
- The scope of work did not include a vibration assessment.

2 Legal Requirements and Noise Level Guidelines

2.1 National Noise Control Regulations

The 1992 Noise Control Regulations (The Republic of South Africa, 1992) published in terms of Section 25 of the Environment Conservation Act (Act no. 73 of 1989) defines a "disturbing noise" as a noise level which exceeds the zone sound level or, if no zone sound level has been designated, a noise level which exceeds the ambient sound level at the same measuring point by 7 dBA or more.

The Noise Control Regulations were revised under Government Notice Number R. 55 of 14 January 1994 to make it obligatory for all authorities to apply the regulations. The Free State Province did promulgate provincial regulations in 1998.

2.2 Free State Provincial Noise Control Regulations (PN 24 of 1998)

The control of noise in the Free State Province is legislated in the form of Noise Control Regulations promulgated in terms of Section 25 of the Environment Conservation Act (Act no. 73 of 1989).

These regulations provide the following definitions:

1. "ambient sound level" - the reading on an integrating impulse sound level meter taken at a measuring point in the absence of any alleged disturbing noise at the end of a total period of at least 10 minutes after such meter was put into operation;

2. "disturbing noise" - a noise level that exceeds the ambient sound level measured continuously at the same measuring point by 5 dBA or more.

3. "noise level" - the reading on an integrating impulse sound level meter taken at a measuring point in the presence of any alleged disturbing noise at the end of a total period of at least 10 minutes after such meter was put into operation, and, if the alleged disturbing noise has a discernible pitch, for example, a whistle, buzz, drone or music, to which 5 dBA has been added;

In addition, the regulations also provide the following stipulations:

1. In terms of Regulation 2 (d):
   "A local authority may –
   before changes are made to existing facilities or existing uses of land or buildings, or before new buildings are erected, in writing require that noise impact assessments or tests be conducted to the satisfaction of that local authority by the owner, developer, tenant or occupant of the facilities, land or buildings and that reports or certificates relating to the noise impact to the satisfaction of that local authority be submitted by the owner, developer, tenant or occupant to the local authority";

2. In terms of Regulation 3 (c):

"No person shall –

make changes to existing facilities or existing uses of land or buildings or erect new buildings, if it shall in the opinion of a local authority house or cause activities which shall, after such change or erection, cause a disturbing noise, unless precautionary measures to prevent the disturbing noise have been taken to the satisfaction of the local authority";

3. In terms of Regulation 4 of the Noise Control Regulations:
   "No person shall make, produce or cause a disturbing noise, or allow it to be made, produced or caused by any person, machine, device or apparatus or any combination thereof".

2.3 South African National Standards

In South Africa, provision is made for the regulation of noise under the National Environmental Management Air Quality Act (NEMAQA) (Act. 39 of 2004) but legally enforceable environmental noise limits have yet to be set. It is believed that when published, national criteria will make extensive reference to the South African Bureau of Standards (SABS) standard SANS 10103 (2008) *'The measurement and rating of environmental noise with respect to annoyance and to speech communication'.* This standard has been widely applied in South Africa and is frequently used by local authorities when investigating noise complaints. The standard is also fully aligned with the WHO guidelines for Community Noise (WHO, 1999). It should be noted that the values given in Table 2-1 are typical rating levels for different districts specified.

Table 2-1: Typical rating levels for outdoor noise

Type of district	Equivalent Continuous Rating Level ($L_{Req,T}$) for Outdoor Noise		
	Day/night $L_{R,dn}$[(c)] (dBA)	Day-time $L_{Req,d}$[(a)] (dBA)	Night-time $L_{Req,n}$[(b)] (dBA)
Rural districts	45	45	35
Suburban districts with little road traffic	50	50	40
Urban districts	55	55	45
Urban districts with one or more of the following: business premises; and main roads.	60	60	50
Central business districts	65	65	55
Industrial districts	70	70	60

Notes

(a) $L_{Req,d}$ =The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the day-time period, i.e. from 06:00 to 22:00.

(b) $L_{Req,n}$ =The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the night-time period, i.e. from 22:00 to 06:00.

(c) $L_{R,dn}$ =The L_{Aeq} rated for impulsive sound and tonality in accordance with SANS 10103 for the period of a day and night, i.e. 24 hours, and wherein the $L_{Req,n}$ has been weighted with 10dB in order to account for the additional disturbance caused by noise during the night.

SANS 10103 also provides a useful guideline for estimating community response to an increase in the general ambient noise level caused by intruding noise. If Δ is the increase in noise level, the following criteria are of relevance:

- "$\Delta \leq 0$ dB: There will be no community reaction;
- 0 dB < $\Delta \leq$ 10 dB: There will be 'little' reaction with 'sporadic complaints';
- 5 dB < $\Delta \leq$ 15 dB: There will be a 'medium' reaction with 'widespread complaints'. Δ = 10 dB is subjectively perceived as a doubling in the loudness of the noise;
- 10 dB < $\Delta \leq$ 20 dB: There will be a 'strong' reaction with 'threats of community action'; and
- Δ > 15 dB: There will be a 'very strong' reaction with 'vigorous community action'.

The categories of community response overlap because the response of a community does not occur as a stepwise function, but rather as a gradual change.

2.4 International Finance Corporation Guidelines on Environmental Noise

The IFC General Environmental Health and Safety Guidelines on noise address impacts of noise beyond the property boundary of the facility under consideration and provides noise level guidelines.

The IFC states that noise impacts should not exceed the levels presented in Table 2-2, or result in a maximum increase above background levels of 3 dBA at the nearest receptor location off-site (IFC, 2007). For a person with average hearing acuity an increase of less than 3 dBA in the general ambient noise level is not detectable. Δ = 3 dBA is, therefore, a useful significance indicator for a noise impact.

It is further important to note that the IFC noise level guidelines for residential, institutional and educational receptors correspond with the SANS 10103 guidelines for urban districts.

Table 2-2: IFC noise level guidelines

Area	One Hour L_{Aeq} (dBA) 07:00 to 22:00	One Hour L_{Aeq} (dBA) 22:00 to 07:00
Industrial receptors	70	70
Residential, institutional and educational receptors	55	45

2.5 Summary of Assessment Criteria

Simulated noise levels were assessed according to guidelines published by the IFC. To assess annoyance at nearby places of residence, the increase in noise levels above the baseline at NSRs were calculated and compared to guidelines published in SANS 10103.

2.6 Regulations Regarding Report Writing

This report complies with the requirements of the National Environmental Management Act, 1998 (NEMA, No. 107 of 1998) and the Environmental Impact Assessment (EIA) regulations (Government Notice [GN] R982 as amended by GN 326 of 7 April 2017; GN 706 of 13 July 2018 and GN 320 of 20 March 2020). The table below provides a summary of the requirements, with cross references to the report sections where these requirements have been addressed.

Table 2-3: Specialist report requirements in terms of Appendix 6 of the EIA Regulations (Government Notice [GN] R982 as amended by GN 326 of 7 April 2017; GN 706 of 13 July 2018 and GN 320 of 20 March 2020).

A specialist report prepared in terms of the Environmental Impact Regulations must contain:	Relevant section in report
Details of the specialist who prepared the report	Section 1.3
The expertise of that person to compile a specialist report including a curriculum vitae	Section 1.3.2 Appendix A
A declaration that the person is independent in a form as may be specified by the competent authority	Section 1.3.1 Appendix B
An indication of the scope of, and the purpose for which, the report was prepared	Section 1.2
An indication of the quality and age of base data used for the specialist report;	Section 3.2 Section 3.3
A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 3.3 Section 4
The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment	Section 3.3 Section 4
A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 1.6
Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternative;	Section 3.1
An identification of any areas to be avoided, including buffers	Section 3.1 Section 4
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 4
A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 1.7
A description of the findings and potential implications of such findings on the impact of the proposed activity or activities	Section 4
Any mitigation measures for inclusion in the EMPr	Section 6
Any conditions for inclusion in the environmental authorisation	Section 6
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 6
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised	Section 7
Regarding the acceptability of the proposed activity or activities; and	Section 4
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Section 4 Section 6 Section 7
A description of any consultation process that was undertaken during the course of carrying out the study	Not applicable

A specialist report prepared in terms of the Environmental Impact Regulations must contain:	Relevant section in report
A summary and copies if any comments that were received during any consultation process	None received
Any other information requested by the competent authority.	None received

2.7 Procedures for the Assessment

This report complies with protocols for the assessment and minimum report content in terms of sections 24(5)(a), (h) and 44 of the National Environmental Management Act, 1998 (NEMA, No. 107 of 1998) (Government Gazette No. 43110) published on 20 March 2020. The table below provides a summary of the requirements, with cross references to the report sections where these requirements have been addressed.

Table 2-4: Specialist assessment requirements in terms of Government Gazette No. 43110 (2020)

Assessment and Reporting on Noise Impacts	Section in Report
The assessment must be undertaken by a noise specialist	Section 1.3 and Appendix A
The assessment must be undertaken based on a site inspection as well as applying the noise standards and methodologies stipulated in SANS 10103:2008 and SANS 10328:2008 (or latest versions) for residential and non -residential areas as defined in these standards.	Section 2, Section 3.3 and Section 4
A baseline description must be provided of the potential receptors and existing ambient noise levels. The receptors could include places of residence or tranquillity that have amenity value associated with low noise levels. As a minimum, this description must include the following:	
• current ambient sound levels recorded at relevant locations (e.g., receptors and proposed new noise sources) over a minimum of two nights and that provide a representative measurement of the ambient noise climate, with each sample being a minimum of ten minutes and taken at two different times of the night (such as early evening and late at night) on each night, in order to record typical ambient sound levels at these different times of night;	Section 3.3
• records of the approximate wind speed at the time of the measurement;	Section 3.3
• mapped distance of the receiver from the proposed development that is the noise source; and	Section 3.1
• discussion on temporal aspects of baseline ambient conditions.	Section 3.3
Assessment of impacts done in accordance with SANS 10103:2008 and SANS 10328:2008 (or latest versions) must include the following aspects which must be considered as a minimum in the predicted impact of the proposed development:	
• characterisation and determination of noise emissions from the noise source, where characterization could include types of noise, frequency, content, vibration and temporal aspects;	Section 4
• projected total noise levels and changes in noise levels as a result of the construction, commissioning and operation of the proposed development for the nearest receptors using industry accepted models and forecasts; and,	Section 4
• desired noise levels for the area.	Section 4 and Section 5
The findings of the Noise Specialist Assessment must be written up in a Noise Specialist Report that must contain as a minimum the following information:	
• details and relevant qualifications and experience of the noise specialist preparing the assessment including a curriculum vitae;	Section 1.3 and Appendix A

Assessment and Reporting on Noise Impacts	Section in Report
• a signed statement of independence by the specialist;	Appendix B
• the duration and date of the site inspection and the relevance of the season and weather conditions to the outcome of the assessment;	Section 3.2 and Section 3.3
• a description of the methodology used to undertake the on-site assessment inclusive of the equipment and models used, as relevant, together with results of the noise assessment;	Section 1.6.3, Section 1.6.4 and Section 4
• a map showing the proposed development footprint (including supporting infrastructure) with a 50m buffered development envelope;	Figure 1-2
• confirmation from the specialist that all reasonable measures have been considered, or not, in the micro- siting of the proposed development to minimise disturbance of receptors;	Section 3.3
• a substantiated statement from the specialist on the acceptability, or not, of the proposed development and a recommendation on the approval, or not, of the proposed development;	Section 7
• any conditions to which this statement is subjected;	Section 6 and Section 7
• the assessment must identify alternative development footprints within the preferred site which would be of a "low" sensitivity as identified by the screening tool and verified through the site sensitivity verification and which were not considered;	Section 4.
• a motivation must be provided if there were development footprints identified as per paragraph 2.5.9. above that were identified as having a "low" noise sensitivity and that were not considered appropriate;	Not applicable
• where identified, proposed impact management outcomes, mitigation measures for noise emissions during the construction and commissioning phases that may be of relative short duration, or any monitoring requirements for inclusion in the Environmental Management Programme (EMPr); and,	Section 6
• a description of the assumptions made and any uncertainties or gaps in knowledge or data.	Section 1.7

3 Description of the Receiving Environment

This chapter provides details of the receiving acoustic environment which is described in terms of:

- Local NSRs;
- The local environmental noise propagation and attenuation potential; and
- Current noise levels and the existing acoustic climate.

3.1 Noise Sensitive Receptors

NSRs generally include places of residence and areas where members of the public may be affected by noise generated by proposed activities.

Potential noise sensitive receptors within the study area (Figure 3-1) include individual homesteads and industrial and residential areas (i.e., Virginia).

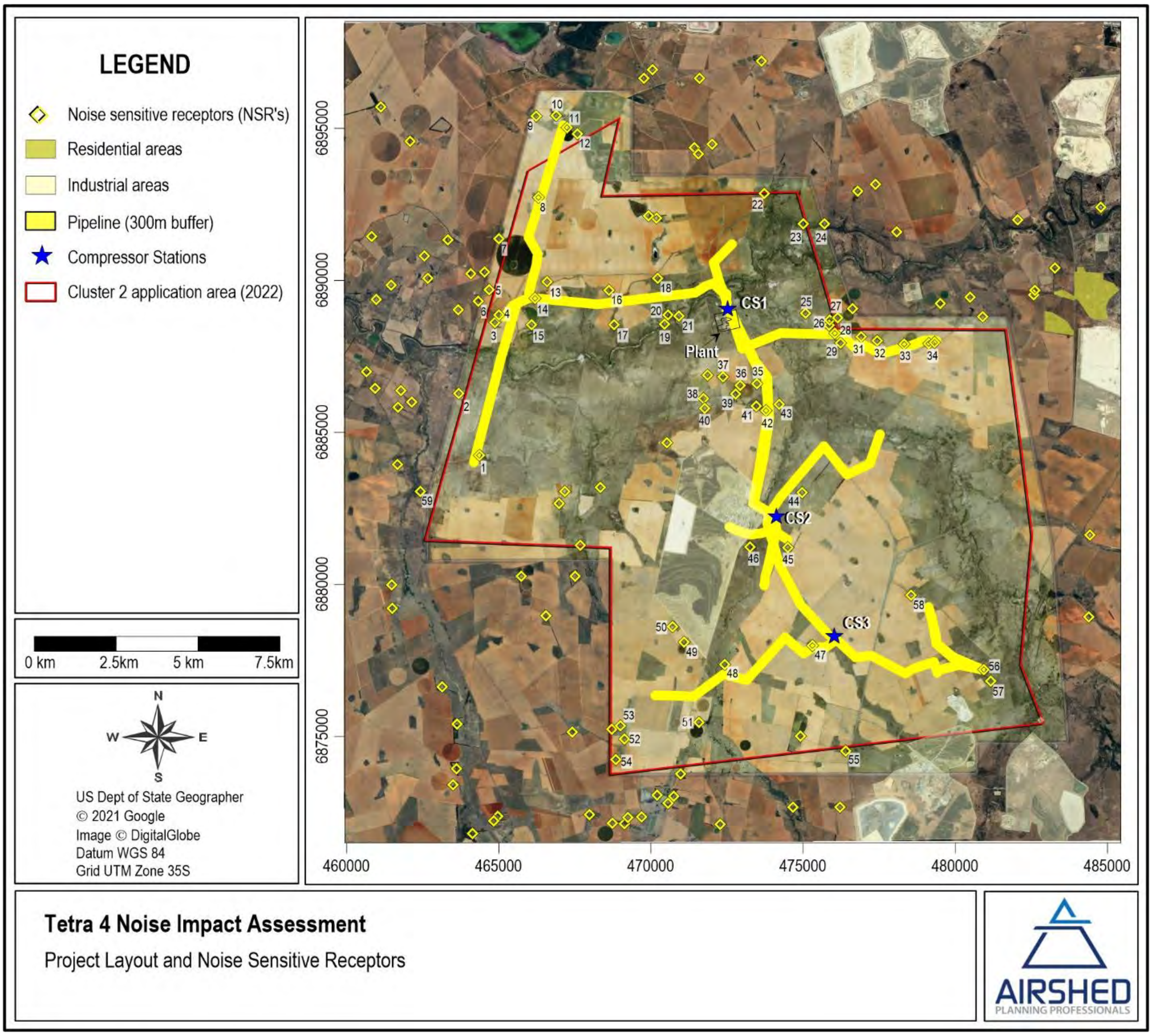


Figure 3-1: Sensitive receptors within the study area

3.2 Environmental Noise Propagation and Attenuation Potential

3.2.1 Atmospheric Absorption and Meteorology

Atmospheric absorption and meteorological conditions have already been mentioned with regards to their role in the propagation on noise from a source to receiver (Section 1.5.4). The main meteorological parameters affecting the propagation of noise include wind speed, wind direction and temperature. These along with other parameters such as relative humidity, air pressure, solar radiation and cloud cover affect the stability of the atmosphere and the ability of the atmosphere to absorb sound energy.

Wind speed increases with altitude. This results in the 'bending' of the path of sound to 'focus' it on the downwind side and creating a 'shadow' on the upwind side of the source. Depending on the wind speed, the downwind level may increase by a few dB but the upwind level can drop by more than 20 dB (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). It should be noted that at wind speeds of more than 5 m/s, ambient noise levels are mostly dominated by wind generated noise.

The wind field of an area can be presented using wind roses. Wind roses represent wind frequencies for the 16 cardinal wind directions. Frequencies are indicated by the length of the shaft when compared to the circles drawn to represent a frequency of occurrence. Wind speed classes are assigned to illustrate the frequencies with high and low winds occurring for each wind vector. The frequencies of calms, defined as periods for which wind speeds are below 1 m/s, are also indicated.

Reference was made to meteorological data from the South African Weather Services (SAWS) operated station located in Welkom, for the period January 2015 to January 2022. The measured data set indicates wind flow primarily from the northeastern sector (Figure 3-2 (a)) during the day with winds also frequent from the northwestern and southwestern sectors. At night, the wind field is mostly from a northeastern sector (Figure 3-2 (b)). Calm conditions occur 2.96% of time during the day and 3.11% during the night. On average, noise impacts are expected to be slightly more notable to the southeast and southwest of the project activities during the day and to the southwest of the project activities during the night.

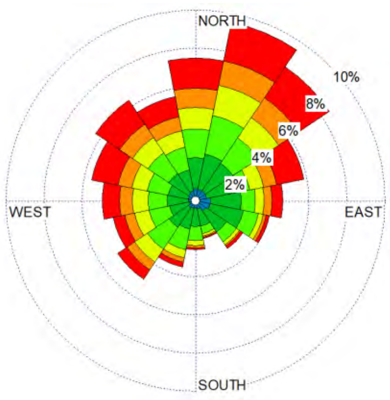
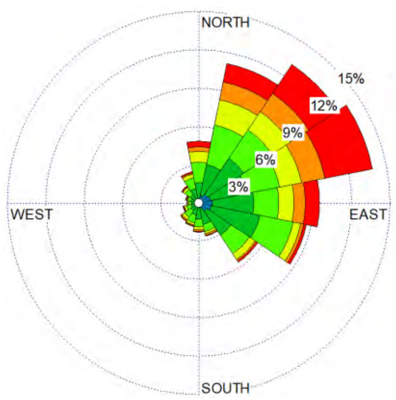
<table>
<tr><th>Day-time wind field (06:00 to 22:00)</th><th>Night-time wind field (22:00 to 06:00)</th><th></th></tr>
<tr><td>
</td><td>
</td><td>WIND SPEED (m/s)
>= 6.00
5.00 - 6.00
4.00 - 5.00
3.00 - 4.00
2.00 - 3.00
1.00 - 2.00</td></tr>
</table>

Figure 3-2: Wind rose for SAWS data, January 2015 to January 2022

Temperature gradients in the atmosphere create effects that are uniform in all directions from a source. On a sunny day with no wind, temperature decreases with altitude and creates a 'shadowing' effect for sounds. On a clear night, temperatures may increase with altitude thereby 'focusing' sound on the ground surface. Noise impacts are therefore generally more notable during the night (Figure 3-3). CadnaA requires the definition of both temperature and humidity. An average temperature of 18°C and a humidity of 70% were applied in simulations.

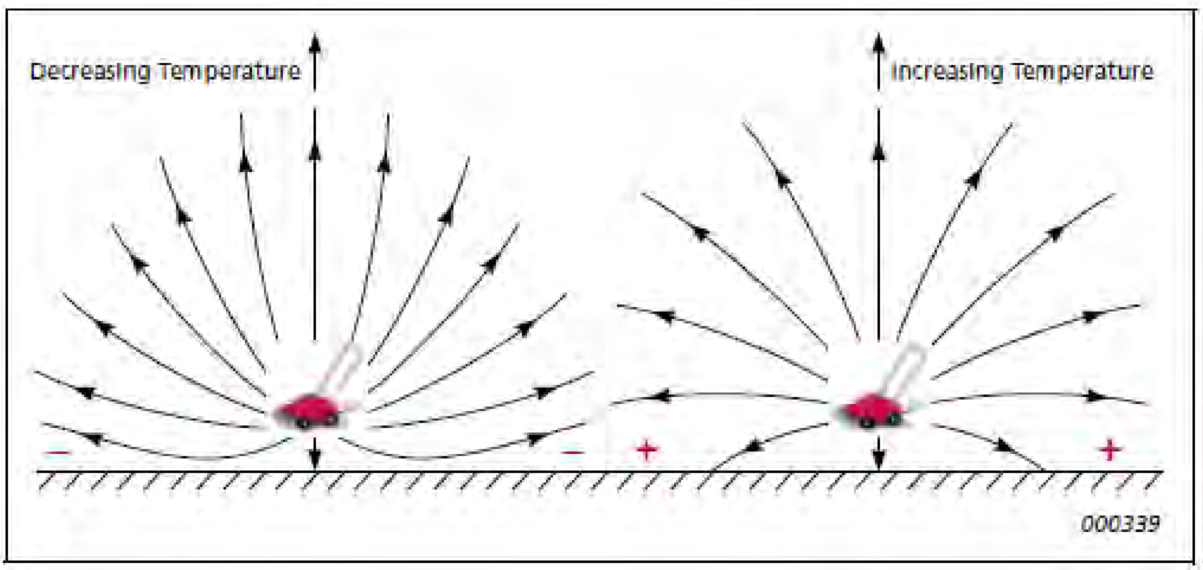


Figure 3-3: Bending the path of sound during typical day time conditions (image provided on the left) and night-time conditions (image provided on the right)

3.2.2 Terrain, Ground Absorption and Reflection

Noise reduction caused by a barrier (i.e., natural terrain, installed acoustic barrier, building) feature depends on two factors namely the path difference of a sound wave as it travels over the barrier compared with direct transmission to the receiver and the frequency content of the noise (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). The topography[1] for the study area is provided in Figure 3-4.

Sound reflected by the ground interferes with the directly propagated sound. The effect of the ground is different for acoustically hard (e.g., concrete or water), soft (e.g., grass, trees or vegetation) and mixed surfaces. Ground attenuation is often calculated in frequency bands to take into account the frequency content of the noise source and the type of ground between the source and the receiver (Brüel & Kjær Sound & Vibration Measurement A/S, 2000). Based on observations, ground cover was found to be acoustically mixed.

[1] SRTM1 from the United States Geological Survey at https://earthexplorer.usgs.gov

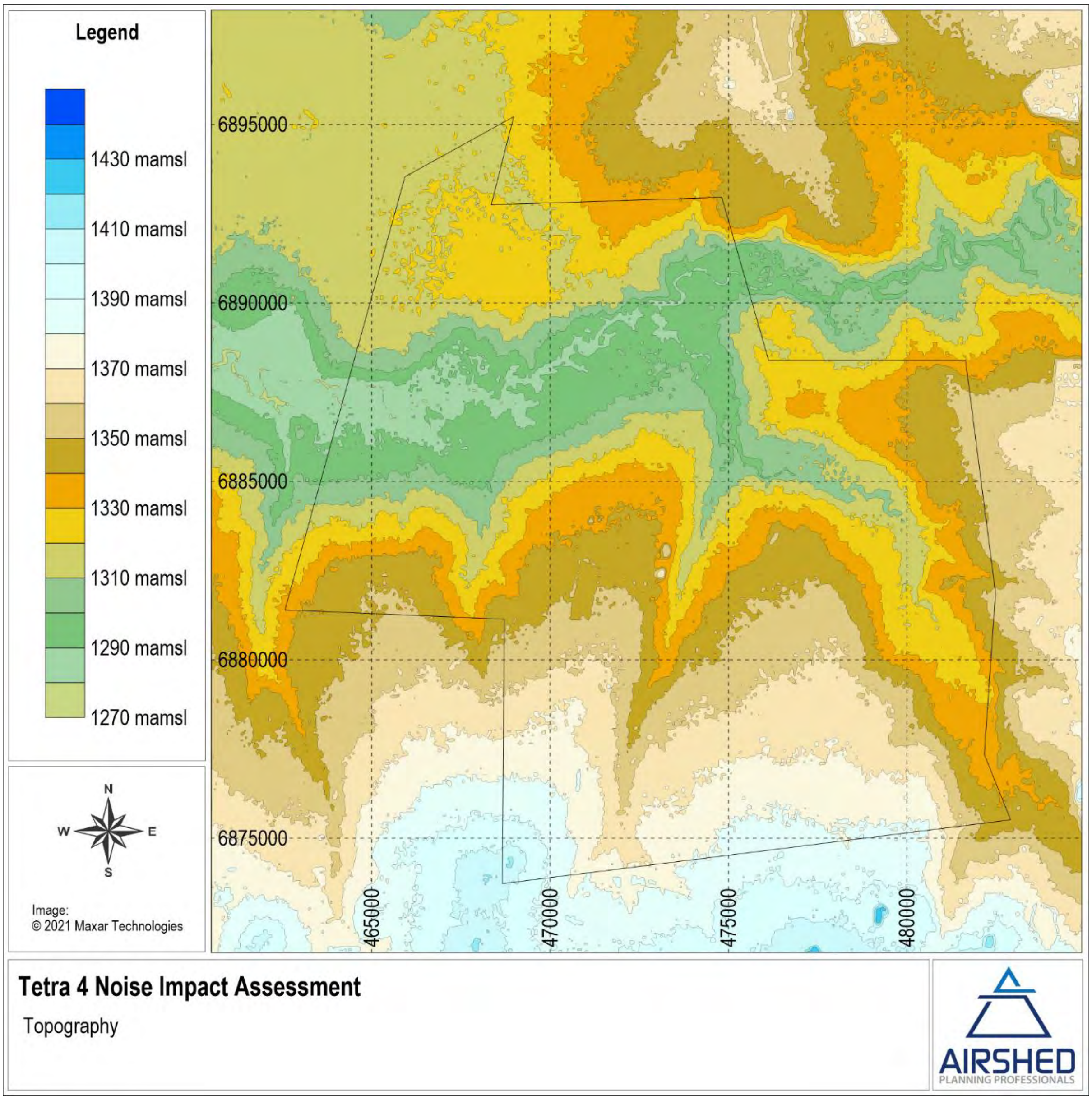


Figure 3-4: Topography for the study area

3.3 Noise Survey and Results

Sampling points for the noise survey conducted by Airshed in 2022 were selected based on proposed project activities, position of sensitive receptors and noise survey locations selected for the baseline campaign conducted in 2016 (Figure 3-5).

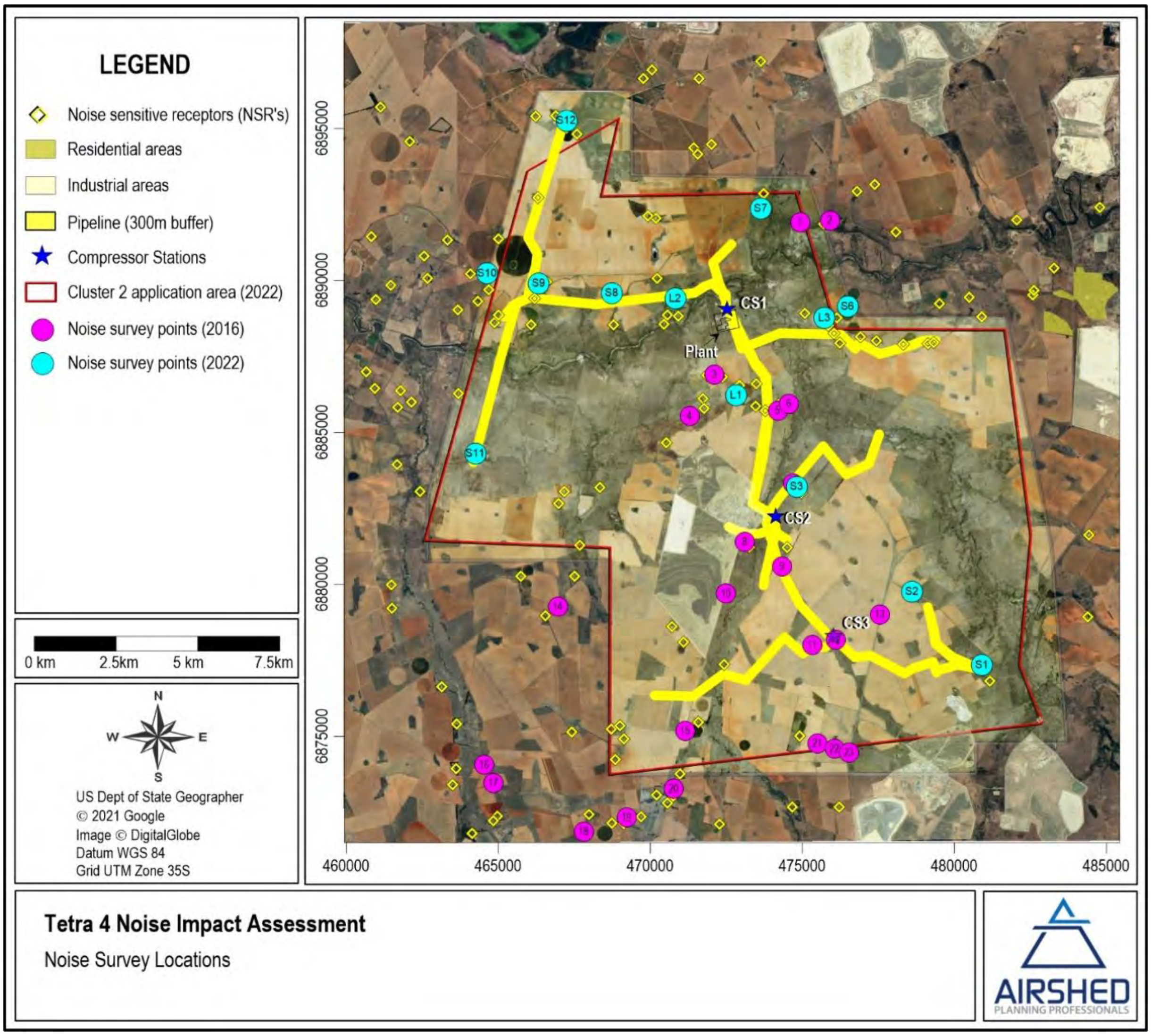


Figure 3-5: Baseline noise survey sites

3.3.1 Baseline Noise Survey Undertaken in 2016

A summary of the baseline noise levels within the study area, as measured by Enviro Acoustic Research (EAR) during March 2016 (with the exception of Site 11 which was sampled in June 2016) (De Jager, 2016), is provided in Table 3-1.

Table 3-1: Summary of noise measurements conducted in 2016 by EAR

Measurement Location	Day-time	Night-time	Comment
	L_{Aeq} (dBA)	L_{Aeq} (dBA)	
1	22		Birds and insects. Some birds fly over second measurement. Naturally quiet.
	23		
	23		
2	47		

Measurement Location	Day-time L_{Aeq} (dBA)	Night-time L_{Aeq} (dBA)	Comment
	22		Naturally quiet location. Birds and insects. First measurement LDV and voices.
3	27		Birds and insects dominant sound. Fans or low rumble barely audible.
	25		
4	24		Typical bushveld appearance. Bird calls at times. Quite quiet. Fans audible in background. Insects audible. Impulsive sounds just audible.
	23		
5	56		Next to corrugated gravel road. Traffic on tar road clearly audible but passing cars dominating sound levels (during passing). Birds dominating during quiet periods. Wind noises with a banging noise audible in distance. Measurement 1: 6 cars (5 slow, 1 very fast). Cars generally driving slow due to condition of road, Measurement 2: 1 car racing.
	54		
6	69		Insects and birds with traffic dominating. Some wind noises. Measurement 1: 36 cars and a bus, Measurement 2: 34 cars and 3 trucks.
	70		
7	61		Fans from Beatrix shaft constant background noise. Road noises dominate with passing though few cars. Bird sounds dominant in quiet periods. Measurement 1: 16 cars in 10 min. Measurement 2: 14 cars and 1 bus.
	65		
8	44		Next to road, close to process plant. Plant fans and pumps dominant. Sounds of vehicles audible at times. Birds audible.
	44		
9	54		Next to gas borehole. Dominating sound of beeping alarm with constant sound similar to leaking gas.
	54		
	54		
10	31		Large stand of bluegums. Birds dominate but low rumbling coming from mining area.
11	48	46	A number of 10 minute measurements were collected over a period of 2 nights from the evening of 9 to 11 June 2016.Bird and water sprayers dominated the soundscape, likely masking noise from traffic on the R30.
12	36		Light wind. Birds and insects dominating. Vehicular noise from R30 constant and quite dominating. Sound of wind though maize barely audible.
	37		
13	78		Road noises dominate. Measurement 1: 110 cars and 9 trucks, Measurement 2: 134 cars and 8 trucks.
	79		
14	29		Bird sounds dominate. TLB working in distance but inaudible. Cricket or similar insect.
15	24		Quiet with little activities in area. Bird sounds audible in area at times. Insects and possibly wind noises. Sound of tractor working on farmland just audible about 1000 m away. Cattle mooing in far distance.
	26		
16	30		Very quiet location close to road. Area quiet due to insufficient habitat for animals. Light wind. Bird sounds in distance. Insects. Possible wind induced noises later in measurement. Ldv passing at speed 3 min in measurement. Cows in area calling/mooing. Cow mooing max
	33		

Measurement Location	Day-time L_{Aeq} (dBA)	Night-time L_{Aeq} (dBA)	Comment
			sound second measurement. Sound levels 20 - 25 dBA in quiet periods.
17	27		Directly under powerline. Constant corona discharge audible. Insects and bird sounds. Light wind with gust at times.
	27		
	26		
	27		
18	27		Bird sounds dominate. Insects. Farming equipment in area just audible.
	26		
19	26		Birds. Some wind induced noises. Insects. Farming equipment just audible at times for undefined area.
	24		
20	34		Birds dominating but sound of farming equipment audible at times. Dove very dominant at times.
	35		
21	30		Open field around 1000 m from road. Birds dominating. Insects clearly audible. Vehicles audible during passing. Typical quiet rural area. Trucks clearly audible and distinguishable during passing.
	33		
22	37		Location around 500 m from road. No trees close. Birds' constant background sound. Vehicle sounds clearly audible and distinguishable during passing. Maximum sounds relate to bird sounds. Insect sounds at times.
	36		
23	73		10 m from road. 2 measurements. Windless. Lots of bird sounds a constant background. A large number of massive blue gums in vicinity (20 to 30 m). Measurement 1: 45 cars and 7 trucks. Measurement 2: 46 cars and 3 trucks.
	72		

3.3.2 Baseline Noise Survey Undertaken in 2022

Survey results for the campaign undertaken on the 15 to 17 February 2022 are summarised in Table 3-2.

The study area, given the baseline measurements, can generally be rated as rural as per the SANS 10103:2008 criteria. The baseline noise measurements for the area near L3 and S6 is generally higher than the quieter surrounding farm areas where farm activities such as tractors and mining were audible. The measured day-time baseline at L3 and S6 were more typical of urban and suburban districts respectively (as per the SANS 10103:2008 criteria). Higher night-time noise measurements were observed at sites L1, L2 and L3 on 15 February where night-time patrols were more prevalent. Night-time noise measurements undertaken at these three sites on 16 February were lower and more in line with rural districts (as per the SANS 10103:2008 criteria).

For detailed time-series, frequency spectra and statistical results, the reader is referred to Appendix E.

Table 3-2: Summary of noise measurements conducted in 2022

Sampling point	Visual and acoustic observations	General weather conditions	Time of day	Start date and time	Duration	LAFmax (dBA)	LAFmin (dBA)	LAeq (dBA)	LAIeq (dBA)	LA90 (dBA)
Site L1	Noise sources include birds, insects, dogs and vehicle traffic.	Winds of 0.6 m/s from the NW 25°C 69% humidity 70% cloud cover	Day	2022/02/15 19:01	00:15:01	54.0	34.1	40.1	45.1	37.9
		Winds of 1.4 m/s from the NW 24°C 69% humidity 60% cloud cover	Day	2022/02/16 18:35	00:15:02	61.4	27.6	39.4	44.4	30.4
		Winds of 0.8 m/s from the N 21°C 70% humidity 60% cloud cover	Night	2022/02/15 23:15	00:15:01	53.2	46.2	51.2	51.2	48.1
		Winds of 0.9 m/s from the NW 20°C 72% humidity 60% cloud cover	Night	2022/02/16 23:35	00:15:01	55.0	24.0	37.9	42.9	29.5
Site L2	Noise sources include birds, insects, farm animals and activities and vehicle traffic.	Winds of 0.7 m/s from the NW 25°C 68% humidity 70% cloud cover	Day	2022/02/15 18:29	00:15:02	53.3	35.0	41.1	46.1	37.9

Sampling point	Visual and acoustic observations	General weather conditions	Time of day	Start date and time	Duration	LAFmax (dBA)	LAFmin (dBA)	LAeq (dBA)	LAIeq (dBA)	LA90 (dBA)
		Winds of 1.7 m/s from the NW 25°C 69% humidity 60% cloud cover	Day	2022/02/16 18:06	00:15:03	63.8	27.6	47.4	52.4	36.5
		21°C 70% humidity 70% cloud cover	Night	2022/02/15 22:40	00:15:02	67.5	58.3	64.9	68.3	61.1
		Winds of 1.1 m/s from the NW 22°C 70% humidity 60% cloud cover	Night	2022/02/16 22:03	00:15:02	59.5	23.0	43.5	56.5	29.6
Site L3	Noise sources include birds, insects, dogs and tractor activities.	Winds of 0.3 m/s from the N24°C68% humidity80% cloud cover	Day	2022/02/15 19:37	00:15:01	59.5	52.3	57.0	57.0	55.5
		Winds of 1.2 m/s from the NW 23°C 70% humidity 60% cloud cover	Day	2022/02/16 19:32	00:15:01	74.5	32.6	51.9	51.9	36.4
		23°C 69% humidity 70% cloud cover	Night	2022/02/15 22:03	00:15:01	60.5	55.6	58.3	58.3	56.5
		Winds of 1 m/s from the NW 20°C 72% humidity 60% cloud cover	Night	2022/02/16 22:57	00:15:01	64.7	23.9	42.4	47.4	29.5

Sampling point	Visual and acoustic observations	General weather conditions	Time of day	Start date and time	Duration	LAFmax (dBA)	LAFmin (dBA)	LAeq (dBA)	LAIeq (dBA)	LA90 (dBA)
Site S1	Noise sources include birds, insects, farm animals and activities and vehicle traffic.	Winds of 3.4 m/s from the NW 26°C 50% humidity 40% cloud cover	Day	2022/02/16 09:44	00:10:02	62.4	32.4	40.2	45.2	35.7
Site S2	Noise sources include birds and insects.	Winds of 2.4 m/s from the NW 24°C 50% humidity 20% cloud cover	Day	2022/02/16 10:16	00:10:01	55.4	33.9	41.5	46.5	37.6
Site S3	Noise sources include birds, insects, vehicle traffic and mining activities.	Winds of 3.1 m/s from the NW 25°C 57% humidity 40% cloud cover	Day	2022/02/16 11:01	00:10:01	67.3	32.2	43.5	48.5	34.5
Site S6	Noise sources include birds and vehicle traffic.	Winds of 3.5 m/s from the NW 30°C 58% humidity 60% cloud cover	Day	2022/02/16 11:55	00:10:01	71	38.9	47.9	47.9	41.4
Site S7	Noise sources include birds, insects and farm animals.	Winds of 3.7 m/s from the NW 30°C 58% humidity 70% cloud cover	Day	2022/02/16 12:28	00:10:01	56.9	33.8	41.3	46.3	36
Site S8	Noise sources include birds.	Winds of 2.8 m/s from the NW 31°C 68% humidity 70% cloud cover	Day	2022/02/16 12:58	00:10:03	66.3	29.3	39	44	33.3

Sampling point	Visual and acoustic observations	General weather conditions	Time of day	Start date and time	Duration	LAFmax (dBA)	LAFmin (dBA)	LAeq (dBA)	LAleq (dBA)	LA90 (dBA)
Site S9	Noise sources include birds and children.	Winds of 3.7 m/s from the NW 27°C 60% humidity 70% cloud cover	Day	2022/02/16 13:27	00:10:01	69.9	27.1	42.2	47.2	30.7
Site S10	Noise sources include birds, vehicle traffic and people talking.	Winds of 1.4 m/s from the NE 24°C 58% humidity	Day	2022/02/17 07:37	00:10:05	61.9	32.5	46	51	38.8
Site S11	Noise sources include birds, insects, farm animals and vehicle traffic.	Winds of 1.8 m/s from the NE 25°C 59% humidity 10% cloud cover	Day	2022/02/17 08:10	00:10:27	63.3	28.8	40.7	45.7	31.1
Site S12	Noise sources include birds, farm animals and farm activities.	Winds of 1.2 m/s from the NE 29°C 54% humidity	Day	2022/02/17 08:59	00:10:02	67.3	33.1	45.3	50.3	36

3.3.3 General Noise Survey Conclusions

All the measurements indicated a site with a very complex sound character. Areas away from busy roads and mining activities are very quiet, with measurement locations closer to houses, busy roads and mining activities indicating higher sound levels. Vegetation growth closer to dwellings creates habitat, attracting birds and insects, which in turn make sounds that increases the ambient sound levels. The vegetation also increased wind-induced noises. The larger study area, away from roads, dwellings and mining activities can be rated as Rural as per the SANS 10103:2008 criteria.

4 Impact Assessment

The noise source inventory, noise propagation modelling and results for the construction and operational phase of the project are discussed in the following section.

4.1 Construction Phase

Construction activities will take place during day-time hours only (07:00 to 18:00) with a one-hour lunch break.

4.1.1 Noise Sources and Sound Power Levels

The list of construction equipment was provided for the current assessment (Table 4-1). Source noise levels for construction equipment were obtained from a combination of sources available in the BSI Standards: code of practice for noise and vibration control on construction and open sites (BSI, 2008), a noise source level database for similar operations (based on source measurements carried out in accordance with the procedures specified in SANS 10103) and calculations using the L_W predictive equations for mobile equipment (Bruce & Moritz, 1998).

The source noise levels obtained from the BSI standards (at a distance of 10 m) are provided in Table 4-2 with the equivalent noise source levels at source provided in Table 4-3.

Table 4-1: List of noise sources for the project construction activities

Area	Description	No. of units
Construction of Wells	Dozer	1
	Tracked excavator	1
	Grader	1
	Water bowser discharging	1
	Tractor towing water bowser	1
	Truck with trailer	1
	Cable percussion drilling rig	1
Construction of Pipeline	Back-actor	1
	Truck mounted crane (high-up)	1
	Compactor	1
	Tracked excavator	1
	Grader	1
	Ditcher/Digging wheel	1
	Backhoe (TLB)	2
Construction of Plant	Dozer	2
	Tracked excavator	4
	Grader	2
	Water bowser discharging	2
	Tractor towing water bowser	1

Area	Description	No. of units
	Hauling: Dump truck	2
	Backhoe (TLB)	4
	Truck mounted crane (high-up)	1
	Rough terrain / telescope crane	1
	Compactor	1
	Forklift	2
	Low-bed/flat-bed truck	2
	Pre-cast concrete piling – hydraulic hammer	1
	Concrete mixer truck	4
Construction of Compressor/ Blower Stations	Dozer	1
	Tracked excavator	1
	Grader	1
	Water bowser discharging	1
	Tractor towing water bowser	1
	Hauling: Dump truck	1
	Backhoe (TLB)	1
	Truck mounted crane (high-up)	1
	Rough terrain / telescope crane	1
	Compactor	1
	Forklift	1
	Low-bed/flat-bed truck	1
	Pre-cast concrete piling – hydraulic hammer	1
	Concrete mixer truck	1

Table 4-2: Sound level data for the construction equipment as obtained from the BSI standard (BSI, 2014)

Area	Description	Octave band sound pressure levels at 10m, Hz								A-weighted sound pressure level, $L_{Aeq, T}$, dB at 10m
		63	125	250	500	1k	2k	4k	8k	
Construction of Wells	Dozer	89	90	81	73	74	70	68	64	80
	Tracked excavator	75	84	78	74	70	68	64	61	77
	Grader	88	87	83	79	84	78	74	65	86
	Water bowser discharging	80	81	75	79	73	74	70	65	81
	Tractor towing water bowser	78	86	84	78	78	77	70	69	83*
	Truck with trailer	88	90	80	79	76	71	65	61	81
	Cable percussion drilling rig	77	77	67	66	70	68	62	56	74
Construction of Pipeline	Truck mounted crane (high-up)	87	86	77	73	75	72	67	59	79
	Compactor	81	76	72	73	72	72	68	63	78
	Tracked excavator	75	84	78	74	70	68	64	61	77
	Grader	88	87	83	79	84	78	74	65	86
	Backhoe (TLB)	68	67	63	62	62	61	54	47	67
Construction of Plant	Dozer	89	90	81	73	74	70	68	64	80
	Tracked excavator	75	84	78	74	70	68	64	61	77
	Grader	88	87	83	79	84	78	74	65	86
	Water bowser discharging	80	81	75	79	73	74	70	65	81
	Tractor towing water bowser	78	86	84	78	78	77	70	69	83
	Hauling: Dump truck	86	79	79	79	79	84	69	60	87
	Backhoe (TLB)	68	67	63	62	62	61	54	47	67
	Truck mounted crane (high-up)	87	86	77	73	75	72	67	59	79
	Rough terrain / telescope crane	78	69	67	64	62	57	49	40	67
	Compactor	81	76	72	73	72	72	68	63	78
	Pre-cast concrete piling – hydraulic hammer	82	82	82	89	83	78	75	70	89
	Concrete mixer truck	83	74	66	69	70	78	60	55	80
Construction of Compressor/ Blower Stations	Dozer	89	90	81	73	74	70	68	64	80
	Tracked excavator	75	84	78	74	70	68	64	61	77
	Grader	88	87	83	79	84	78	74	65	86
	Water bowser discharging	80	81	75	79	73	74	70	65	81

Area	Description	Octave band sound pressure levels at 10m, Hz								A-weighted sound pressure level, $L_{Aeq,T}$, dB at 10m
		63	125	250	500	1k	2k	4k	8k	
	Tractor towing water bowser	78	86	84	78	78	77	70	69	83
	Hauling: Dump truck	86	79	79	79	79	84	69	60	87
	Backhoe (TLB)	68	67	63	62	62	61	54	47	67
	Truck mounted crane (high-up)	87	86	77	73	75	72	67	59	79
	Rough terrain / telescope crane	78	69	67	64	62	57	49	40	67
	Compactor	81	76	72	73	72	72	68	63	78
	Pre-cast concrete piling – hydraulic hammer	82	82	82	89	83	78	75	70	89
	Concrete mixer truck	83	74	66	69	70	78	60	55	80

Table 4-3: Sound power level (L_w) estimates at source for the construction phase

Area	Description	Type	Octave band sound pressure levels, Hz								A-weighted sound pressure level, $L_{Aeq,T}$, dB at source	Source
			63	125	250	500	1k	2k	4k	8k		
Construction of Wells	Dozer	L_W	120	121	112	104	105	101	99	95	111.1	Calculated based on BSI (2014) at 10m
	Tracked excavator	L_W	106	115	109	105	101	99	95	92	107.9	Calculated based on BSI (2014) at 10m
	Grader	L_W	119	118	114	110	115	109	105	96	117.5	Calculated based on BSI (2014) at 10m
	Water bowser discharging	L_W	110	112	106	110	104	105	101	96	111.6	Calculated based on BSI (2014) at 10m
	Tractor towing water bowser	L_W	109	117	115	109	109	108	101	100	114.5	Calculated based on BSI (2014) at 10m
	Truck with trailer	L_W	119	121	111	110	107	102	96	92	112.4	Calculated based on BSI (2014) at 10m
	Cable percussion drilling rig	L_W	108	108	98	97	101	99	93	87	104.9	Calculated based on BSI (2014) at 10m
Construction of Pipeline	Back-actor	L_W	113	111.2	103.6	101.3	97.6	93.8	89		103.7	Measurement Database
	Truck mounted crane (high-up)	L_W	118	117	108	104	106	103	98	90	110.4	Calculated based on BSI (2014) at 10m

Area	Description	Type	Octave band sound pressure levels, Hz								A-weighted sound pressure level, $L_{Aeq,T}$, dB at source	Source
			63	125	250	500	1k	2k	4k	8k		
	Compactor	L_W	112	107	103	104	103	103	99	94	108.7	Calculated based on BSI (2014) at 10m
	Tracked excavator	L_W	106	115	109	105	101	99	95	92	107.9	Calculated based on BSI (2014) at 10m
	Grader	L_W	119	118	114	110	115	109	105	96	117.5	Calculated based on BSI (2014) at 10m
	Ditcher/Digging wheel	L_W	115.5	120.5	123.5	118.5	116.5	113.5	107.5	101.5	121.8	L_W Predictions (Bruce & Moritz, 1998)
	Backhoe (TLB)	L_W	99	98	94	93	93	92	85	78	97.8	Calculated based on BSI (2014) at 10m
Construction of Plant	Dozer	L_W	120	121	112	104	105	101	99	95	111.1	Calculated based on BSI (2014) at 10m
	Tracked excavator	L_W	106	115	109	105	101	99	95	92	107.9	Calculated based on BSI (2014) at 10m
	Grader	L_W	119	118	114	110	115	109	105	96	117.5	Calculated based on BSI (2014) at 10m
	Water bowser discharging	L_W	110	112	106	110	104	105	101	96	111.6	Calculated based on BSI (2014) at 10m
	Tractor towing water bowser	L_W	109	117	115	109	109	108	101	100	114.5	Calculated based on BSI (2014) at 10m
	Hauling: Dump truck	L_W	117	110	110	110	110	115	100	91	117.7	Calculated based on BSI (2014) at 10m
	Backhoe (TLB)	L_W	99	98	94	93	93	92	85	78	97.8	Calculated based on BSI (2014) at 10m
	Truck mounted crane (high-up)	L_W	118	117	108	104	106	103	98	90	110.4	Calculated based on BSI (2014) at 10m
	Rough terrain / telescope crane	L_W	111.8	116.8	119.8	114.8	112.8	109.8	103.8	97.8	118.1	L_W Predictions (Bruce & Moritz, 1998)
	Compactor	L_W	112	107	103	104	103	103	99	94	108.7	Calculated based on BSI (2014) at 10m
	Forklift	L_W	105.6	110.6	113.6	108.6	106.6	103.6	97.6	91.6	111.8	L_W Predictions (Bruce & Moritz, 1998)
	Low-bed/flat-bed truck	L_W	113.1	118.1	121.1	116.1	114.1	111.1	105.1	99.1	119.4	L_W Predictions (Bruce & Moritz, 1998)
	Pre-cast concrete piling – hydraulic hammer	L_W	113	113	113	120	114	109	106	101	119.7	Calculated based on BSI (2014) at 10m
	Concrete mixer truck	L_W	114	105	97	100	101	109	91	86	111	Calculated based on BSI (2014) at 10m
Construction of Compressor/ Blower Stations	Dozer	L_W	120	121	112	104	105	101	99	95	111.1	Calculated based on BSI (2014) at 10m
	Tracked excavator	L_W	106	115	109	105	101	99	95	92	107.9	Calculated based on BSI (2014) at 10m
	Grader	L_W	119	118	114	110	115	109	105	96	117.5	Calculated based on BSI (2014) at 10m
	Water bowser discharging	L_W	110	112	106	110	104	105	101	96	111.6	Calculated based on BSI (2014) at 10m
	Tractor towing water bowser	L_W	109	117	115	109	109	108	101	100	114.5	Calculated based on BSI (2014) at 10m
	Hauling: Dump truck	L_W	117	110	110	110	110	115	100	91	117.7	Calculated based on BSI (2014) at 10m

Area	Description	Type	Octave band sound pressure levels, Hz								A-weighted sound pressure level, $L_{Aeq,T}$, dB at source	Source
			63	125	250	500	1k	2k	4k	8k		
	Backhoe (TLB)	L_W	99	98	94	93	93	92	85	78	97.8	Calculated based on BSI (2014) at 10m
	Truck mounted crane (high-up)	L_W	118	117	108	104	106	103	98	90	110.4	Calculated based on BSI (2014) at 10m
	Rough terrain / telescope crane	L_W	111.8	116.8	119.8	114.8	112.8	109.8	103.8	97.8	118.1	L_W Predictions (Bruce & Moritz, 1998)
	Compactor	L_W	112	107	103	104	103	103	99	94	108.7	Calculated based on BSI (2014) at 10m
	Forklift	L_W	105.6	110.6	113.6	108.6	106.6	103.6	97.6	91.6	111.8	L_W Predictions (Bruce & Moritz, 1998)
	Low-bed/flat-bed truck	L_W	113.1	118.1	121.1	116.1	114.1	111.1	105.1	99.1	119.4	L_W Predictions (Bruce & Moritz, 1998)
	Pre-cast concrete piling – hydraulic hammer	L_W	113	113	113	120	114	109	106	101	119.7	Calculated based on BSI (2014) at 10m
	Concrete mixer truck	L_W	114	105	97	100	101	109	91	86	111	Calculated based on BSI (2014) at 10m

4.1.2 Noise Propagation and Simulated Noise Levels

The propagation of noise was calculated with CadnaA in accordance with ISO 9613. Meteorological and site-specific acoustic parameters as discussed in Section 3.2, along with source data discussed in Section 4.1.1, were applied in the model. Results are presented in tabular form at NSRs within the study area, as isopleths and as profile graphs were applicable.

4.1.2.1 Proposed Wells

The exact location of the wells will only be determined during the exploration phase as more data becomes available to guide the positioning of further wells. The construction site for the wells was assumed to be 30m x 30m for equipment movement and setup. The final size applied for now, after the noise impact assessment was completed, is 50m x 50m. The impact distance from construction site, however, will remain the same for both areas.

Simulated day-time noise levels due to well construction activities as a function of distance are shown in Figure 4-1. IFC day-time noise guidelines for residential areas (55 dBA) are exceeded up to 400 m from the well construction sites. As construction will only take place during day-time hours and will be of limited duration, NSRs within 400m radius of all well construction sites should be notified of the activities and potential disturbance durations prior to construction taking place.

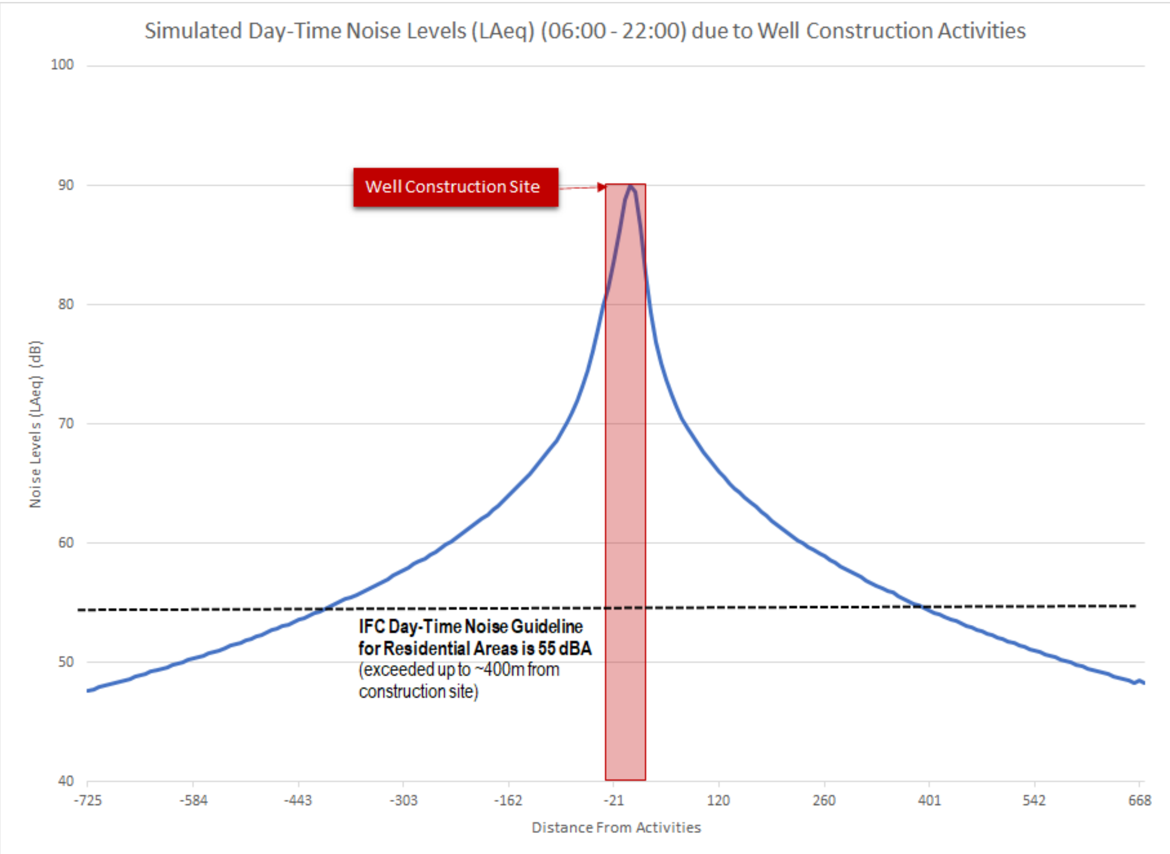


Figure 4-1: Profile for the simulated day-time noise levels (LAeq) due to well construction activities

4.1.2.2 Pipeline

Figure 4-2 provides an indication of the potential noise levels due to pipeline construction activities assuming the centreline of the 300 m buffer provided for this activity. The pipeline may however be located anywhere within the 300 m buffer.

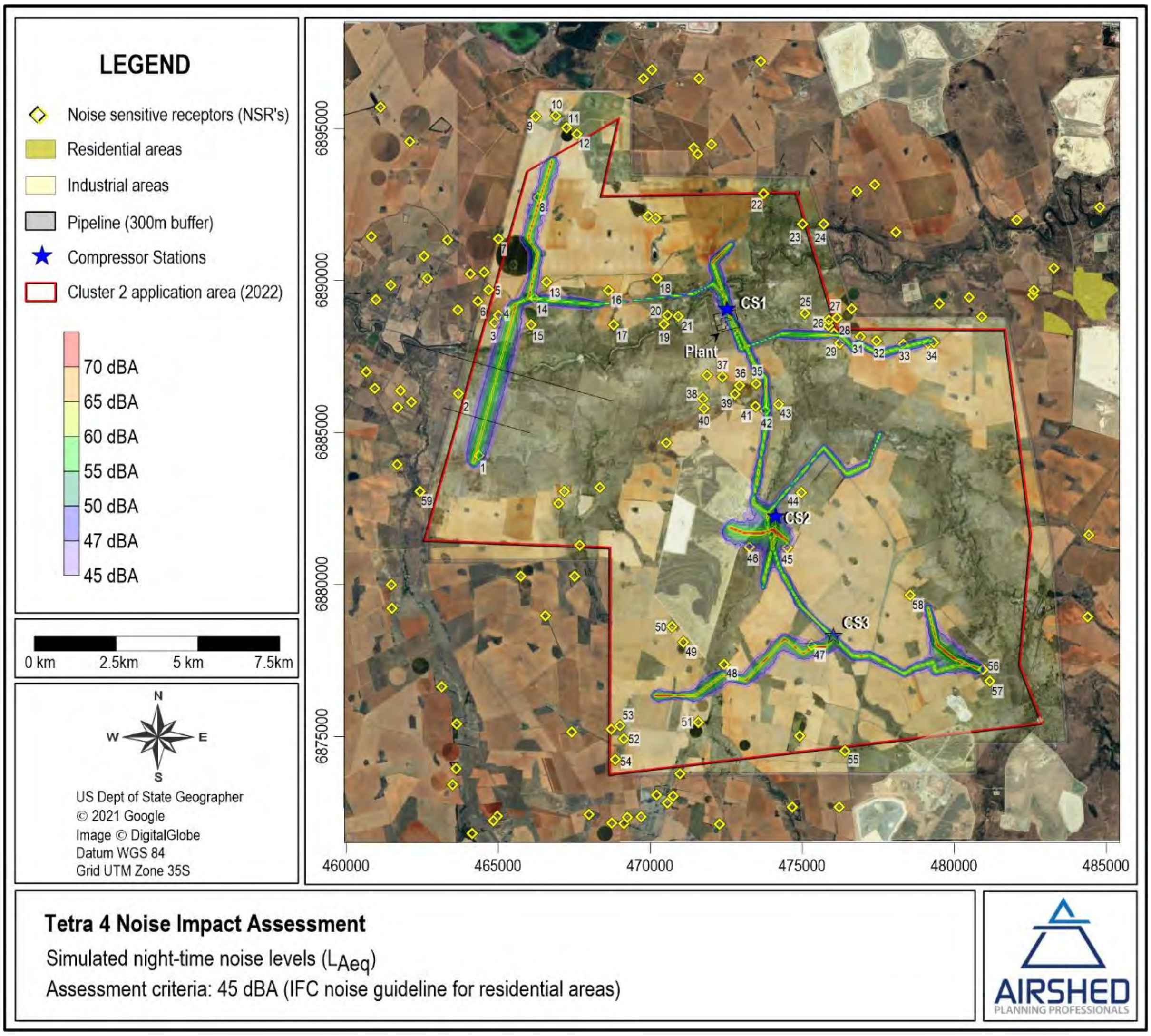


Figure 4-2: Isopleths indicating the simulated day-time noise levels (LAeq) due to pipeline construction activities

A profile of the simulated noise levels due to pipeline construction activities is provided in Figure 4-3. IFC day-time noise guidelines for residential areas (55 dBA) are exceeded up to 90 m from the pipeline construction site. Note, the dips in the profile are due to topography that was included in simulations for the pipeline.

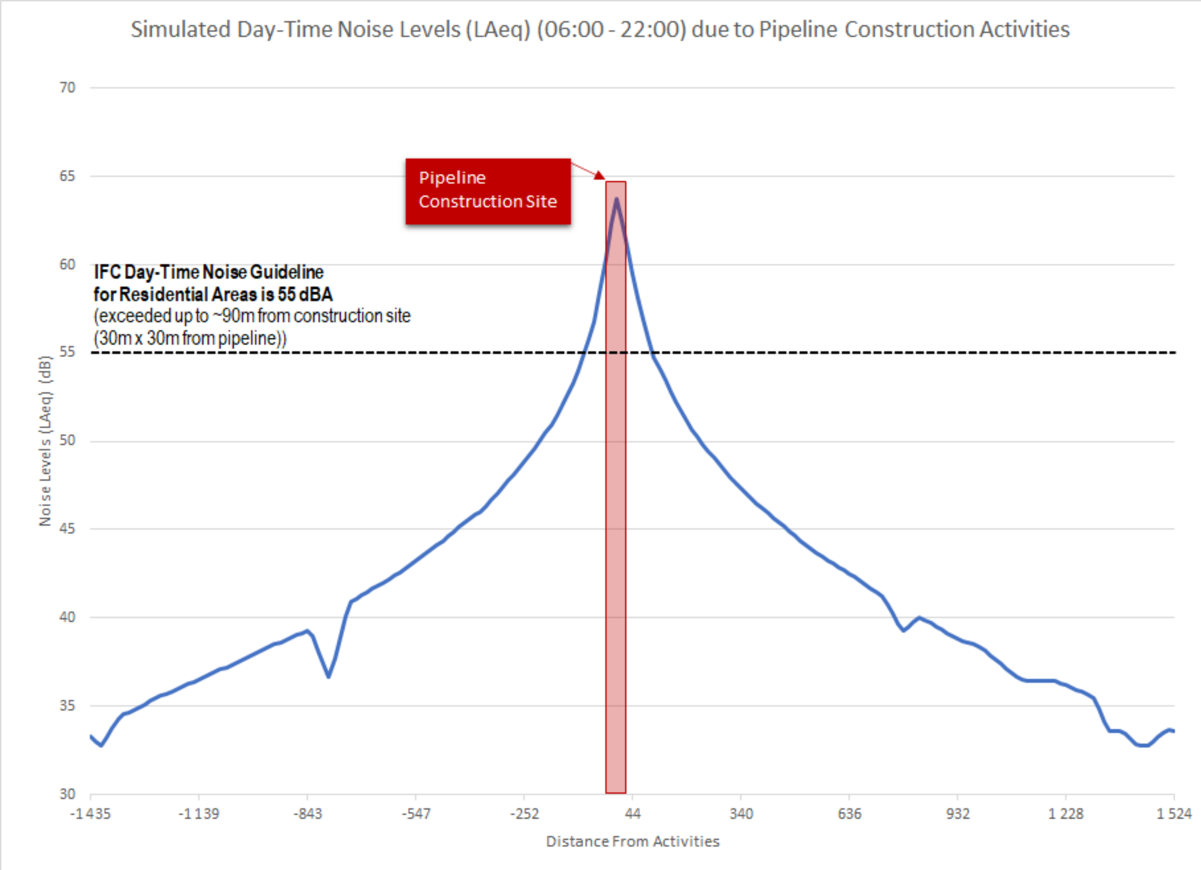


Figure 4-3: Profile for the simulated day-time noise levels (LAeq) due to pipeline construction activities

The maximum simulated day-time noise levels, due to pipeline construction, at potential NSRs within the study site is summarised in Table 4-4. This summary takes into account the potential shift in the pipeline alignment within the provided 300m buffer and is therefore conservative. For a person with average hearing acuity an increase of less than 3 dBA in the general ambient noise level is not detectable. The increase in noise levels above the baseline due to the construction of the pipeline (depending on its location within the 300 m buffer) may result in 'little' community reaction at NSR31, NSR34 and NSR56, 'medium' reaction at NSR8, NSR42, NSR45, and NSR47 and 'strong' community reaction at NSR14. With the exception of NSR56, the predicted increase in noise levels due to pipeline construction activities at all of the above listed NSRs are above 7 dBA (1992 Noise Control Regulations definition for "disturbing noise").

Table 4-4: Summary of simulated day-time noise levels (provided as dBA) due to the pipeline construction activities and baseline noise measurements at NSRs within the vicinity of the project

Noise Sensitive Receptor	Comments	Project operations (a)	Baseline	Increase Above Baseline (b)
NSR1	Baseline noise levels typical of rural districts	64.7	45.0	19.7
NSR2	Baseline noise levels typical of rural districts	38.8	45.0	0.9
NSR3	Baseline noise levels typical of rural districts	46.3	45.0	3.7
NSR4	Baseline noise levels typical of rural districts	45.8	45.0	3.4
NSR5	Baseline noise levels typical of rural districts	35.7	45.0	0.5
NSR6	Baseline noise levels typical of rural districts	36.0	45.0	0.5
NSR7	Baseline noise levels typical of rural districts	37.8	45.0	0.8
NSR8	Baseline noise levels typical of rural districts	57.3	45.0	12.5
NSR9	Baseline noise levels typical of rural districts	25.2	45.0	0.0
NSR10	Baseline noise levels typical of rural districts	25.1	45.0	0.0
NSR11	Baseline noise levels typical of rural districts	26.8	45.0	0.1
NSR12	Baseline noise levels typical of rural districts	27.4	45.0	0.1
NSR13	Baseline noise levels typical of rural districts	43.4	45.0	2.3
NSR14	Baseline noise levels typical of rural districts	62.1	45.0	17.2
NSR15	Baseline noise levels typical of rural districts	43.9	45.0	2.5
NSR16	Baseline noise levels typical of rural districts	34.8	45.0	0.4
NSR17	Baseline noise levels typical of rural districts	28.7	45.0	0.1
NSR18	Baseline noise levels typical of rural districts	28.8	45.0	0.1
NSR19	Baseline noise levels typical of rural districts	30.0	45.0	0.1
NSR20	Baseline noise levels typical of rural districts	38.4	45.0	0.9
NSR21	Baseline noise levels typical of rural districts	35.2	45.0	0.4
NSR22	Baseline noise levels typical of rural districts	16.1	45.0	0.0
NSR23	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR24	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR25	Baseline noise levels typical of urban districts (<550 m from road)	37.4	55.0	0.1
NSR26	Baseline noise levels assumed to be typical of rural districts	39.5	45.0	1.1
NSR27	Baseline noise levels typical of suburban districts (<1000 m from road)	33.4	50.0	0.1
NSR28	Baseline noise levels assumed to be typical of rural districts	43.5	45.0	2.3
NSR29	Baseline noise levels assumed to be typical of rural districts	44.4	45.0	2.7
NSR30	Baseline noise levels assumed to be typical of rural districts	29.9	45.0	0.1
NSR31	Baseline noise levels assumed to be typical of rural districts	53.6	45.0	9.2
NSR32	Baseline noise levels assumed to be typical of rural districts	44.5	45.0	2.8
NSR33	Baseline noise levels assumed to be typical of rural districts	47.1	45.0	4.2
NSR34	Baseline noise levels assumed to be typical of rural districts	52.0	45.0	7.8
NSR35	Baseline noise levels typical of urban districts (<500m from R30 road)	43.3	55.0	0.3
NSR36	Baseline noise levels typical of suburban districts (<1000m from R30)	36.7	50.0	0.2
NSR37	Baseline noise levels typical of rural districts	34.3	45.0	0.4
NSR38	Baseline noise levels typical of rural districts	25.3	45.0	0.0
NSR39	Baseline noise levels typical of rural districts	34.2	45.0	0.3
NSR40	Baseline noise levels typical of rural districts	19.6	45.0	0.0
NSR41	Baseline noise levels typical of suburban districts (<1000 m from R30)	44.8	50.0	1.1
NSR42	Baseline noise levels typical of suburban districts (<1000 m from R30)	64.0	50.0	14.2
NSR43	Baseline noise levels typical of urban districts (<500 m from R30 road)	40.4	55.0	0.1
NSR44	Baseline noise levels typical of rural districts	38.1	45.0	0.8
NSR45	Baseline noise levels typical of rural districts	56.3	45.0	11.6
NSR46	Baseline noise levels typical of rural districts	47.8	45.0	4.6
NSR47	Baseline noise levels typical of rural districts	59.1	45.0	14.3
NSR48	Baseline noise levels typical of rural districts	42.0	45.0	1.8
NSR49	Baseline noise levels typical of rural districts	28.8	45.0	0.1
NSR50	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR51	Baseline noise levels typical of rural districts	34.9	45.0	0.4
NSR52	Baseline noise levels typical of rural districts	23.9	45.0	0.0

Noise Sensitive Receptor	Comments	Project operations (a)	Baseline	Increase Above Baseline (b)
NSR53	Baseline noise levels typical of rural districts	21.6	45.0	0.0
NSR54	Baseline noise levels typical of rural districts	22.9	45.0	0.0
NSR55	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR56	Baseline noise levels typical of rural districts	49.5	45.0	5.8
NSR57	Baseline noise levels typical of rural districts	36.9	45.0	0.6
NSR58	Baseline noise levels typical of rural districts	34.7	45.0	0.4
NSR59	Baseline noise levels typical of rural districts	24.2	45.0	0.0

Notes:

(a) Exceedances of IFC guideline (55 dBA for day-time at residential areas) are provided in bold.

(b) Likely community response in accordance with the SANS 10103:

<3 dBA	<5 dBA	<10 dBA	<15 dBA	<20 dBA
Change imperceptible	*No reaction*	*'Little' reaction with sporadic complaints*	*'Medium' reaction with widespread complaints*	*'Strong' to 'very strong' reaction with threats of community action or vigorous community action.*

4.1.2.3 Blower Station

The exact location of the Blower Stations will be dependent on the well locations. It is proposed that a Blower Station for every 10 wells will be constructed.

Simulated day-time noise levels due to Blower Station construction activities as a function of perpendicular distance are shown in Figure 4-4.

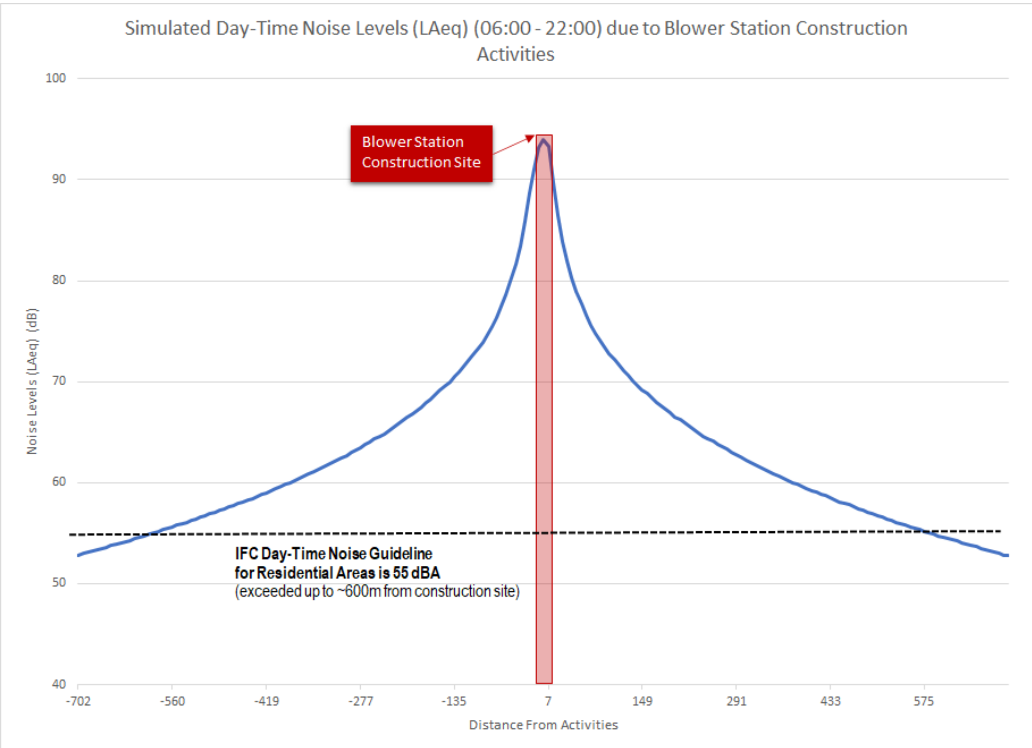


Figure 4-4: Profile for the simulated day-time noise levels (LAeq) due to Blower Station construction activities

IFC day-time noise guidelines for residential areas (55 dBA) are exceeded up to 600 m from the Blower Station sites. As construction will only take place during day-time hours and will be of limited duration, NSRs within 600 m radius of all Blower Station construction sites should be notified of the activities and potential disturbance durations prior to construction taking place. Care should be taken to minimise heavy machinery activity (where possible) in these areas and to switch off equipment when not in use.

4.1.2.4 Plant and Compressor Stations

Three compressor stations are proposed: Compressor Station 1 (CS1), Compressor Station 2 (CS2) and Compressor Station 3 (CS3). There are two potential sites for CS3: the preferred site ~500 m south of CS2 and an alternative site ~4500 m south of CS2. Potential noise levels due to construction activities were assessed at all site locations.

Figure 4-5 to Figure 4-9 provides an indication of the potential noise levels due to plant and Compressor Station construction activities. The IFC day-time noise guidelines for residential areas (55 dBA) are not exceeded at any of the identified NSRs within the study area due to Plant and Compressor Station construction activities.

The simulated day-time noise levels, due to Plant and Compressor Station construction at potential NSRs within the study site is summarised in Table 4-5 and Table 4-6. The increase in noise levels above the baseline due to the construction of the plant and Compressor stations are unlikely to be disturbing[2] at NSRs and should not result in community reaction.

[2] 1992 Noise Control Regulations define “disturbing noise” as increase noise levels above baseline of 7 dBA

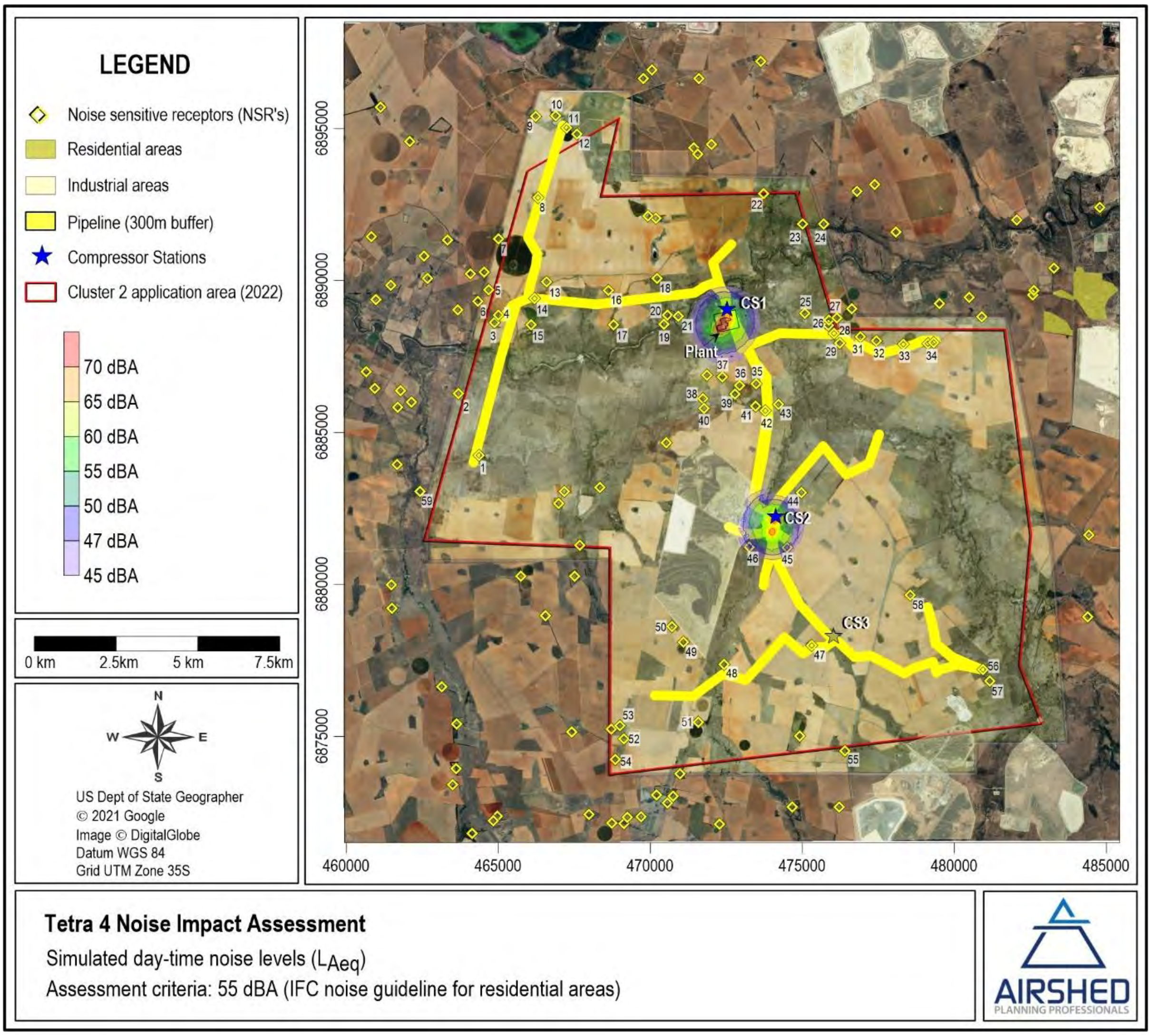


Figure 4-5: Isopleths indicating the simulated day-time noise levels (LAeq) due to Plant and Compressor Station construction activities (assuming the preferred CS3 location)

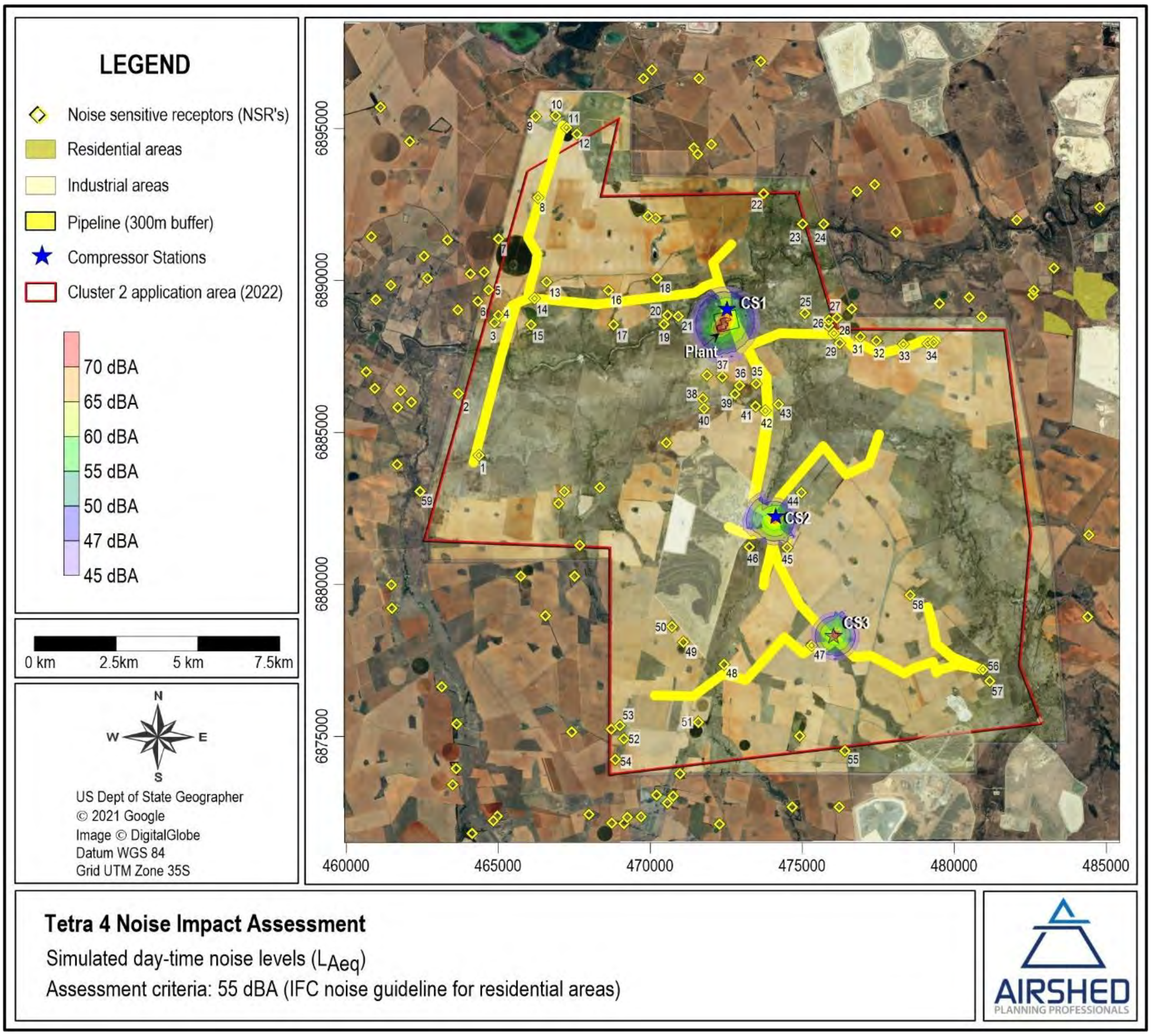


Figure 4-6: Isopleths indicating the simulated day-time noise levels (LAeq) due to Plant and Compressor Station construction activities (assuming the alternative CS3 location)

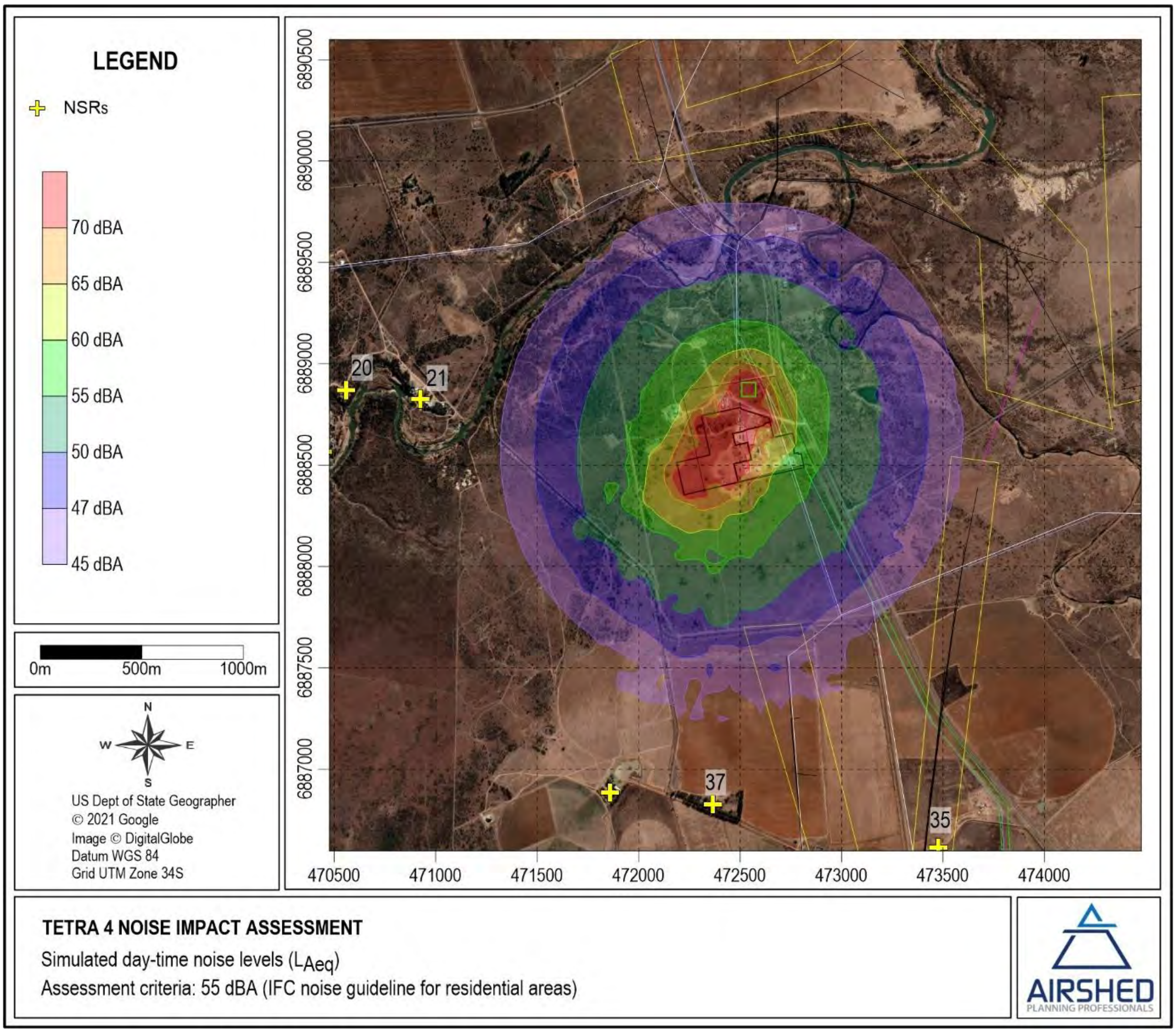


Figure 4-7: Isopleths indicating the simulated day-time noise levels (LAeq) due to Plant and Compressor Station construction activities at the Plant site

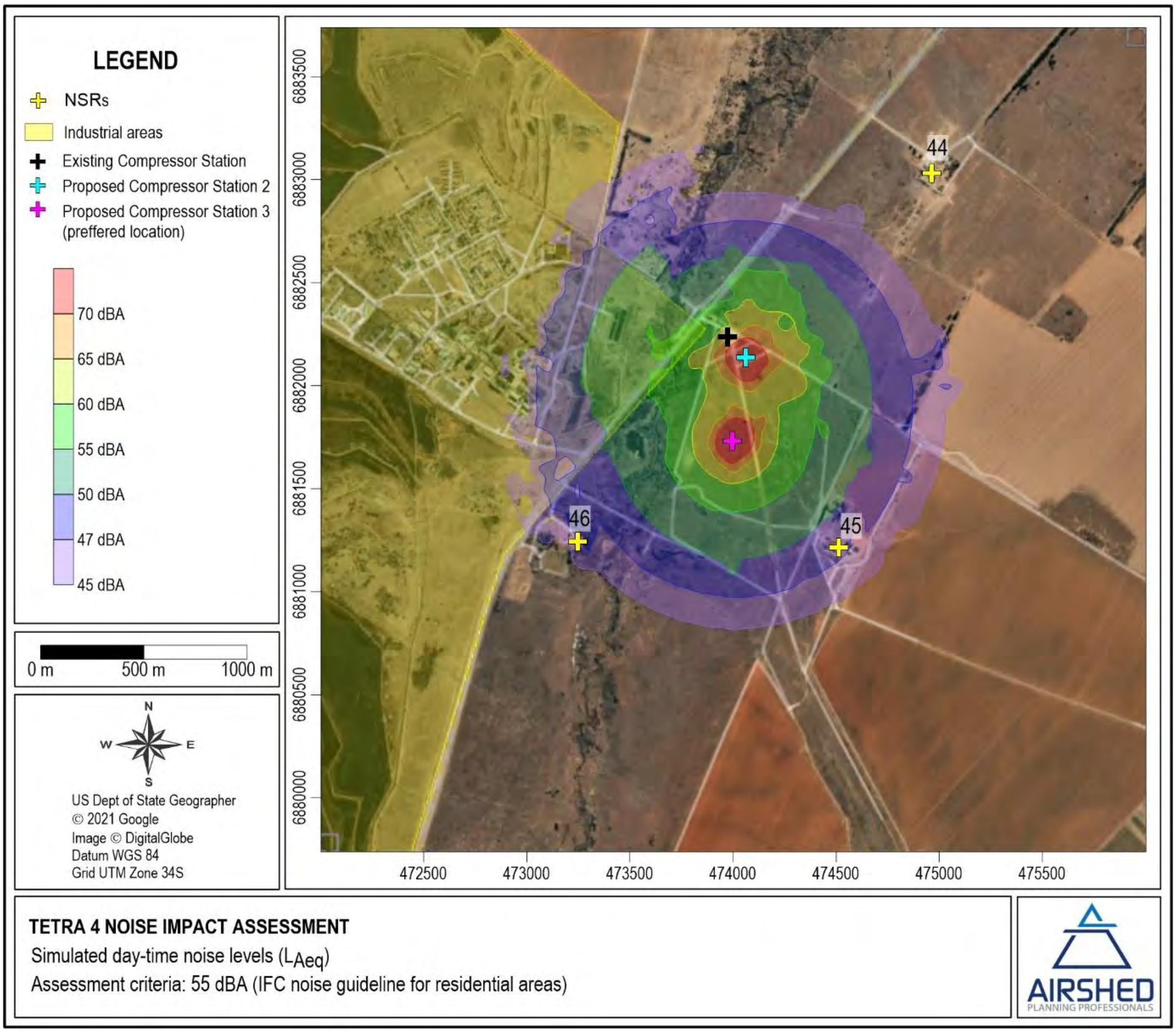


Figure 4-8: Isopleths indicating the simulated day-time noise levels (LAeq) due to Compressor Station construction activities at the CS2 site (assuming the preferred CS3 location)

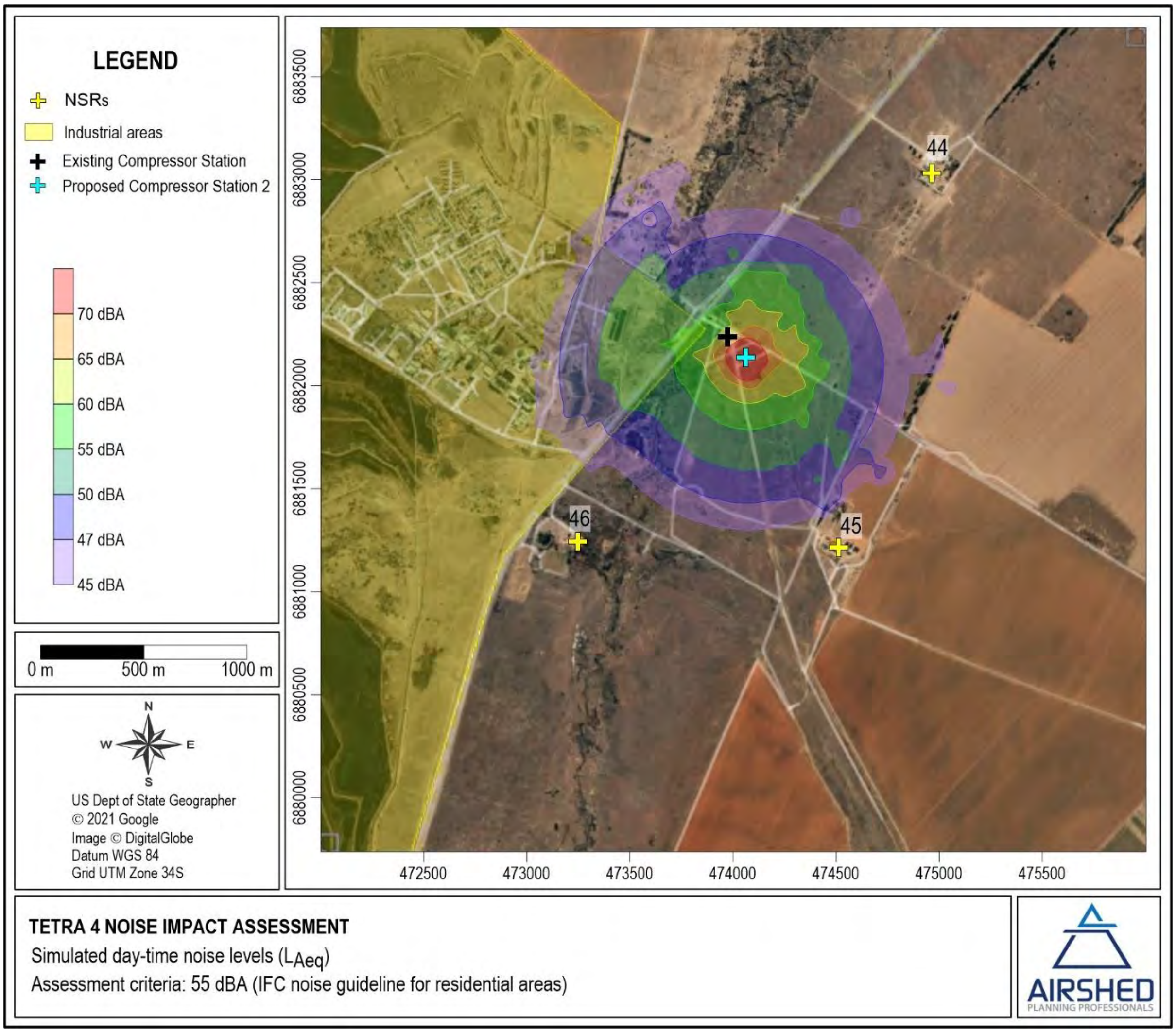


Figure 4-9: Isopleths indicating the simulated day-time noise levels (LAeq) due to Compressor Station construction activities at the CS2 site (assuming the alternative CS3 location)

Table 4-5: Summary of simulated day-time noise levels (provided as dBA) due to the Plant and Compressor Station construction activities (assuming preferred location for CS3) and baseline noise measurements at NSRs within the vicinity of the project

Noise Sensitive Receptor	Comment	Project operations [(a)]	Baseline	Increase Above Baseline [(b)]
NSR1	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR2	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR3	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR4	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR5	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR6	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR7	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR8	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR9	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR10	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR11	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR12	Baseline noise levels typical of rural districts	0.0	45.0	0.0

Noise Sensitive Receptor	Comment	Project operations (a)	Baseline	Increase Above Baseline (b)
NSR13	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR14	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR15	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR16	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR17	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR18	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR19	Baseline noise levels typical of rural districts	35.6	45.0	0.5
NSR20	Baseline noise levels typical of rural districts	38.2	45.0	0.8
NSR21	Baseline noise levels typical of rural districts	40.8	45.0	1.4
NSR22	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR23	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR24	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR25	Baseline noise levels typical of urban districts (<550m from road)	0.0	55.0	0.0
NSR26	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR27	Baseline noise levels typical of suburban districts (<1000m from road)	0.0	50.0	0.0
NSR28	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR29	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR30	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR31	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR32	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR33	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR34	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR35	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	55.0	0.0
NSR36	Baseline noise levels typical of suburban districts (<1000m from R30)	36.0	50.0	0.2
NSR37	Baseline noise levels typical of rural districts	42.1	45.0	1.8
NSR38	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR39	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR40	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR41	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	50.0	0.0
NSR42	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	50.0	0.0
NSR43	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	55.0	0.0
NSR44	Baseline noise levels typical of rural districts	40.1	45.0	1.2
NSR45	Baseline noise levels typical of rural districts	47.5	45.0	4.4
NSR46	Baseline noise levels typical of rural districts	45.1	45.0	3.1
NSR47	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR48	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR49	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR50	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR51	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR52	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR53	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR54	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR55	Baseline noise levels typical of rural districts	0.0	45.0	0.0

Noise Sensitive Receptor	Comment	Project operations (a)	Baseline	Increase Above Baseline (b)
NSR56	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR57	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR58	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR59	Baseline noise levels typical of rural districts	0.0	45.0	0.0

Notes:

(a) Exceedances of IFC guideline (55 dBA for day-time at residential areas) are provided in bold.

(b) Likely community response in accordance with the SANS 10103:

<3 dBA	<5 dBA	<10 dBA	<15 dBA	<20 dBA
Change imperceptible	*No reaction*	*'Little' reaction with sporadic complaints*	*'Medium' reaction with widespread complaints*	*'Strong' to 'very strong' reaction with threats of community action or vigorous community action.*

Table 4-6: Summary of simulated day-time noise levels (provided as dBA) due to the Plant and Compressor Station construction activities (assuming alternative location for CS3) and baseline noise measurements at NSRs within the vicinity of the project

Noise Sensitive Receptor	Comments	Project operations (a)	Baseline	Increase Above Baseline (b)
NSR1	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR2	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR3	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR4	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR5	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR6	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR7	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR8	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR9	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR10	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR11	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR12	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR13	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR14	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR15	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR16	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR17	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR18	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR19	Baseline noise levels typical of rural districts	35.6	45.0	0.5
NSR20	Baseline noise levels typical of rural districts	38.2	45.0	0.8
NSR21	Baseline noise levels typical of rural districts	40.8	45.0	1.4
NSR22	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR23	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR24	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR25	Baseline noise levels typical of urban districts (<550m from road)	0.0	55.0	0.0
NSR26	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR27	Baseline noise levels typical of suburban districts (<1000m from road)	0.0	50.0	0.0
NSR28	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR29	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0

Noise Sensitive Receptor	Comments	Project operations (a)	Baseline	Increase Above Baseline (b)
NSR30	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR31	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR32	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR33	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR34	Baseline noise levels assumed to be typical of rural districts	0.0	45.0	0.0
NSR35	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	55.0	0.0
NSR36	Baseline noise levels typical of suburban districts (<1000m from R30)	36.0	50.0	0.2
NSR37	Baseline noise levels typical of rural districts	42.1	45.0	1.8
NSR38	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR39	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR40	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR41	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	50.0	0.0
NSR42	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	50.0	0.0
NSR43	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	55.0	0.0
NSR44	Baseline noise levels typical of rural districts	38.4	45.0	0.9
NSR45	Baseline noise levels typical of rural districts	42.8	45.0	2.0
NSR46	Baseline noise levels typical of rural districts	39.9	45.0	1.2
NSR47	Baseline noise levels typical of rural districts	44.2	45.0	2.6
NSR48	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR49	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR50	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR51	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR52	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR53	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR54	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR55	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR56	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR57	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR58	Baseline noise levels typical of rural districts	0.0	45.0	0.0
NSR59	Baseline noise levels typical of rural districts	0.0	45.0	0.0

Notes:

(a) Exceedances of IFC guideline (55 dBA for day-time at residential areas) are provided in bold.

(b) Likely community response in accordance with the SANS 10103:

<3 dBA	<5 dBA	<10 dBA	<15 dBA	<20 dBA
Change imperceptible	*No reaction*	*'Little' reaction with sporadic complaints*	*'Medium' reaction with widespread complaints*	*'Strong' to 'very strong' reaction with threats of community action or vigorous community action.*

4.2 Operation Phase

Operational activities were assumed to take place 24 hour per day, 7 days per week.

4.2.1 Noise Sources and Sound Power Levels

The list of equipment was provided for the current assessment and source noise levels were using the L_W predictive equations (Bruce & Moritz, 1998). A summary of the calculated noise source levels is provided in Table 4-7.

The truck trips to transport materials to, and product from, the plant, were provided (Table 4-8). The tankers were assumed to travel at 40 km/hr onsite.

The sound power level for the elevated flare was calculated based on the German recognised Standard – VDI 3272 standard noise levels of flares:

$$Lwac = 112(\pm 6) + 17logQ$$

Where:

Lwac = A-weighted sound power level of the flare (dBA)

Q = flare gas mass flow (t/h)

Given that 32 kg/hr of flare header blanket gas and 4.4 kg/hr pilot gas is used, the sound power level was conservatively calculated to be 93.5 dBA at the flare tip. The height of the flare was provided as ranging between 9 m and 16 m. As the simulated noise levels using the upper and lower range of flare height had very little notable difference, only simulated results for the 9 m flare stack are provided. An exit velocity and exit temperature of 20 m/s and 1400°C respectively was assumed.

Table 4-7: Sound power level (L_W) estimates for the project operational phase

Area	Description	Type	L_W octave band frequency spectra (dB)									L_W (dB)	L_{WA} (dBA)	Source
			31.5	63	125	250	500	1000	2000	4000	8000			
Compressor Station	Cooling Tower Motors	L_W	70.9	70.9	73.9	75.9	78.9	78.9	77.9	72.9	64.9	85.2	83.6	L_W Predictions (Bruce & Moritz, 1998)
	Compressor Motors	L_W	88.0	90.0	92.0	93.0	93.0	93.0	98.0	88.0	81.0	102.1	101.0	L_W Predictions (Bruce & Moritz, 1998)
Blower Station	Blower	L_W	88.6	90.6	92.6	91.6	90.6	95.6	86.6	82.6	75.6	100.2	97.2	L_W Predictions (Bruce & Moritz, 1998)
	Cooling Tower	L_W	89.0	92.0	92.0	88.0	88.0	87.0	87.0	84.0	78.0	98.2	92.9	L_W Predictions (Bruce & Moritz, 1998)
	Centrifugal Pumps	L_W	72.1	73.1	74.1	76.1	76.1	79.1	76.1	72.1	66.1	84.6	82.7	L_W Predictions (Bruce & Moritz, 1998)
	Generators	L_W	84.5	87.5	88.5	88.5	88.5	86.5	84.5	81.5	76.5	95.8	91.7	L_W Predictions (Bruce & Moritz, 1998)
Plant	Pumps	L_W	84.6	85.6	86.6	88.6	88.6	91.6	88.6	84.6	78.6	97.1	95.2	L_W Predictions (Bruce & Moritz, 1998)
	Compressors	L_W	111.7	108.1	110.0	109.1	107.9	110.7	114.7	112.2	110.1	120.6	119.2	L_W Predictions (Bruce & Moritz, 1998)
	Motors	L_W	70.3	70.3	73.3	75.3	78.3	78.3	77.3	72.3	64.3	84.5	83.0	L_W Predictions (Bruce & Moritz, 1998)
	Tankers	L_W		113.4	118.4	121.4	116.4	114.4	111.4	105.4	99.4	125.0	119.6	L_W Predictions (Bruce & Moritz, 1998)

Table 4-8: Product and raw material transported via tankers to and from the plant and the total calculated truck trips

Detail	Quantity	Unit
LNG produced	465.3	tpd
N_2 brought in	25.2	tpd
Capacity of truck (LNG)	24	t
Capacity of truck (N_2)	46	t
Truck trips per day	19.9	

4.2.2 Noise Propagation and Simulated Noise Levels

The propagation of noise was calculated with CadnaA in accordance with ISO 9613. Meteorological and site-specific acoustic parameters as discussed in Section 3.2, along with source data discussed in 4.2.1, were applied in the model. Results are presented in tabular form at NSRs within the study area, as isopleths and as profile graphs were applicable.

4.2.2.1 Blower Station

The sound power levels for the Blower Station were conservatively calculated based on the equipment list provided. It has been stipulated that noise levels should not exceed 85 dBA at 1 m from the site. This will reduce the noise source levels from those calculated for the current assessment. Simulated noise levels due to Blower Station operational activities as a function of perpendicular distance are shown in Figure 4-10.

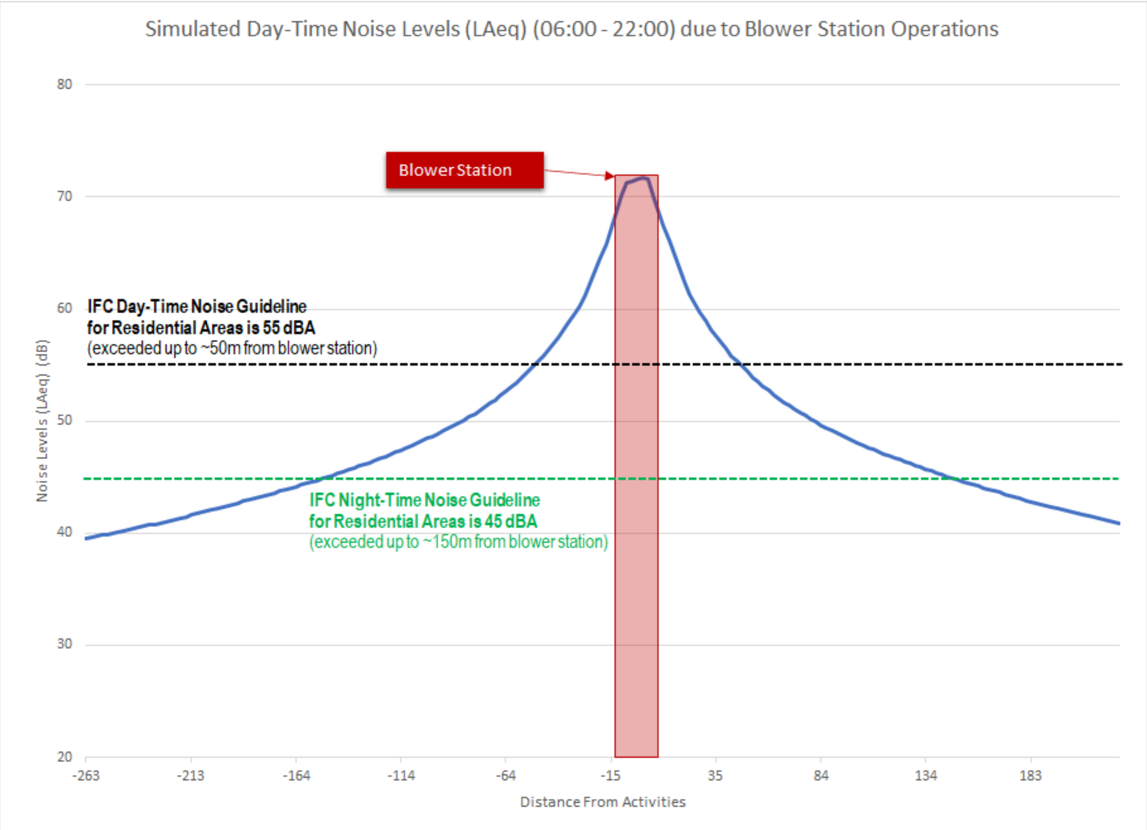


Figure 4-10: Profile for the simulated day-time noise levels (LAeq) due to Blower Station operational activities

IFC day-time (55 dBA) and night-time (45 dBA) noise guidelines for residential areas are exceeded up to 50 m and 150 m from the Blower Station sites respectively. Care should thus be taken to try to construct the Blower Stations at least 150 m from potential NSRs. If noise source levels can be reduced to 85 dBA at 1 m from the Station, IFC night-time noise guidelines (45 dBA) will only be exceeds up to 100 m from the Blower Station.

4.2.2.2 Plant and Compressor Stations

Figure 4-11 to Figure 4-22 provides an indication of the potential noise levels due to Plant and Compressor Station operational activities. The IFC day- (55 dBA) and night-time (45 dBA) noise guidelines for residential areas are not exceeded at any of the identified NSRs within the study area due to Plant and Compressor Station operational activities. It should be noted that the sound power levels were conservatively calculated based on equipment list provided. Using this information, the simulated noise levels due to Compressor Station operations exceeds the IFC night-time noise guidelines (45 dBA) up to 120 m from the operations. If noise source levels can be reduced to 85 dBA at 1 m from the Compressor Station, IFC night-time noise guidelines (45 dBA) will only be exceeded up to 100 m from the Compressor Stations.

The simulated day-time noise levels, due to Plant and Compressor Station operations, at potential NSRs within the study site is summarised in Table 4-9 to Table 4-11. The increase in noise levels above the baseline due to the operation of the Plant and Compressor Stations are unlikely to be disturbing[3] at NSRs and should not result in community reaction.

[3] 1992 Noise Control Regulations define "disturbing noise" as increase noise levels above baseline of 7 dBA

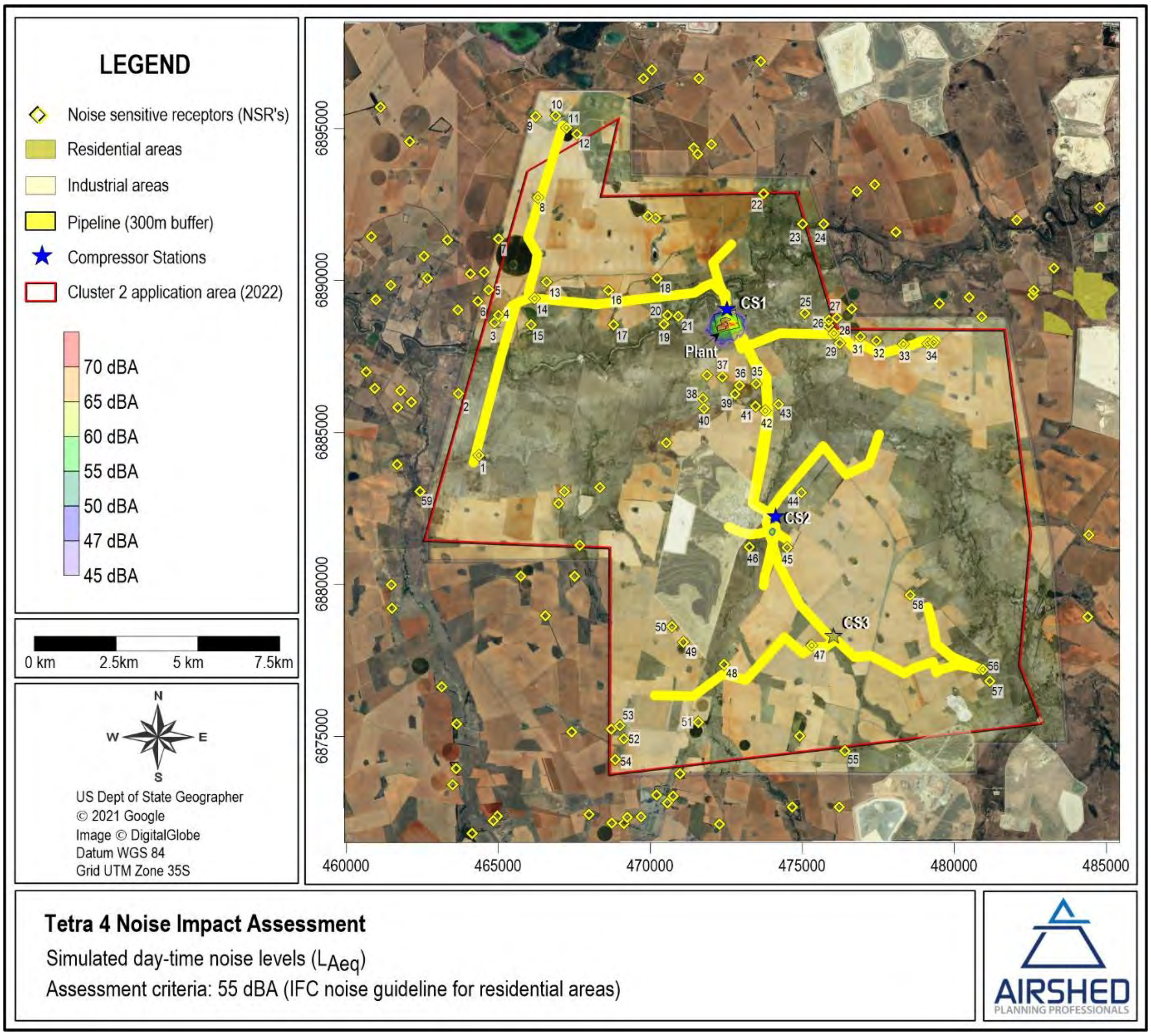


Figure 4-11: Isopleths indicating the simulated day-time noise levels (LAeq) due to Plant and Compressor Station operational activities (assuming the preferred CS3 location)

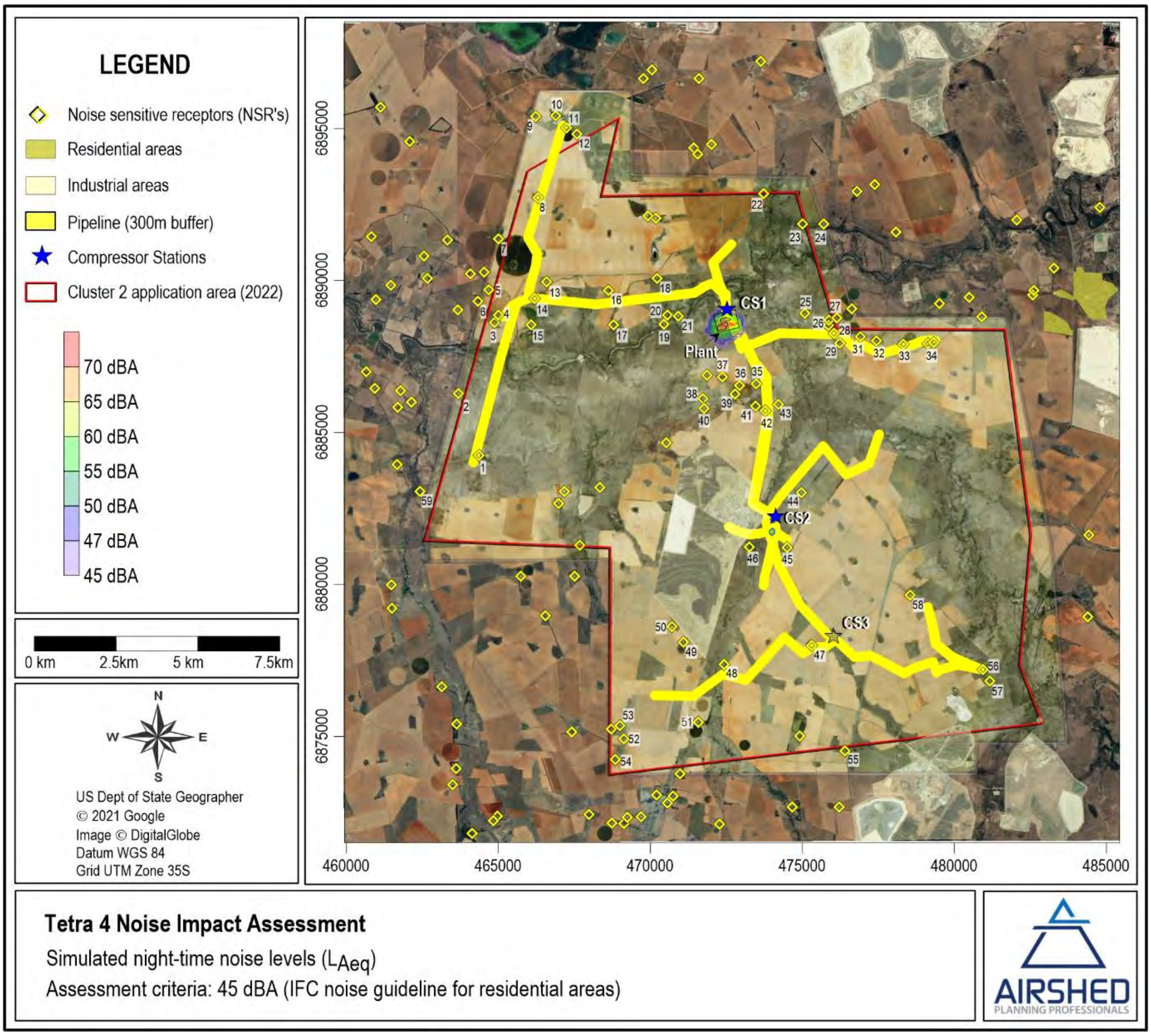


Figure 4-12: Isopleths indicating the simulated night-time noise levels (LAeq) due to Plant and Compressor Station operational activities (assuming the preferred CS3 location)

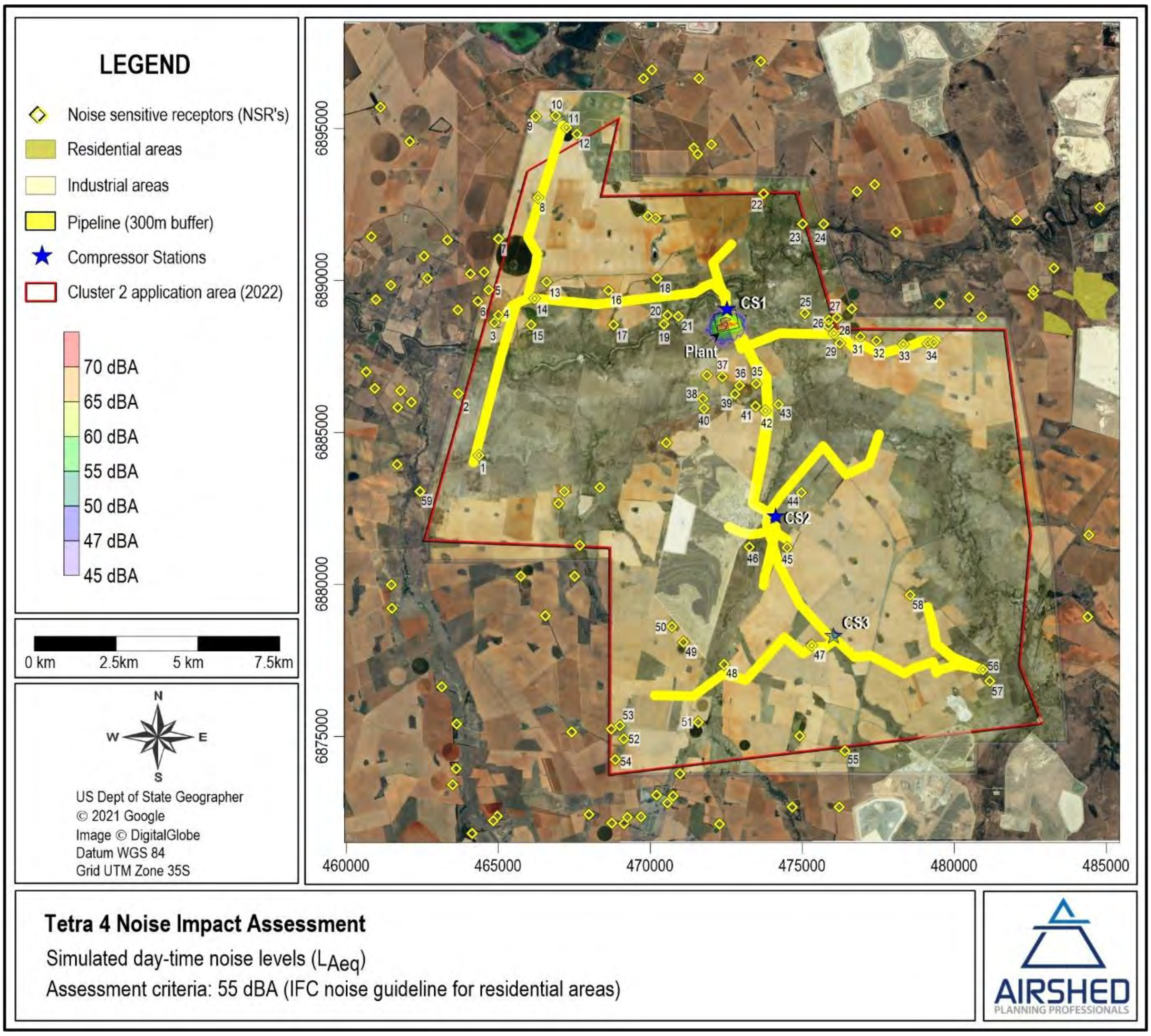


Figure 4-13: Isopleths indicating the simulated day-time noise levels (LAeq) due to Plant and Compressor Station operational activities (assuming the alternative CS3 location)

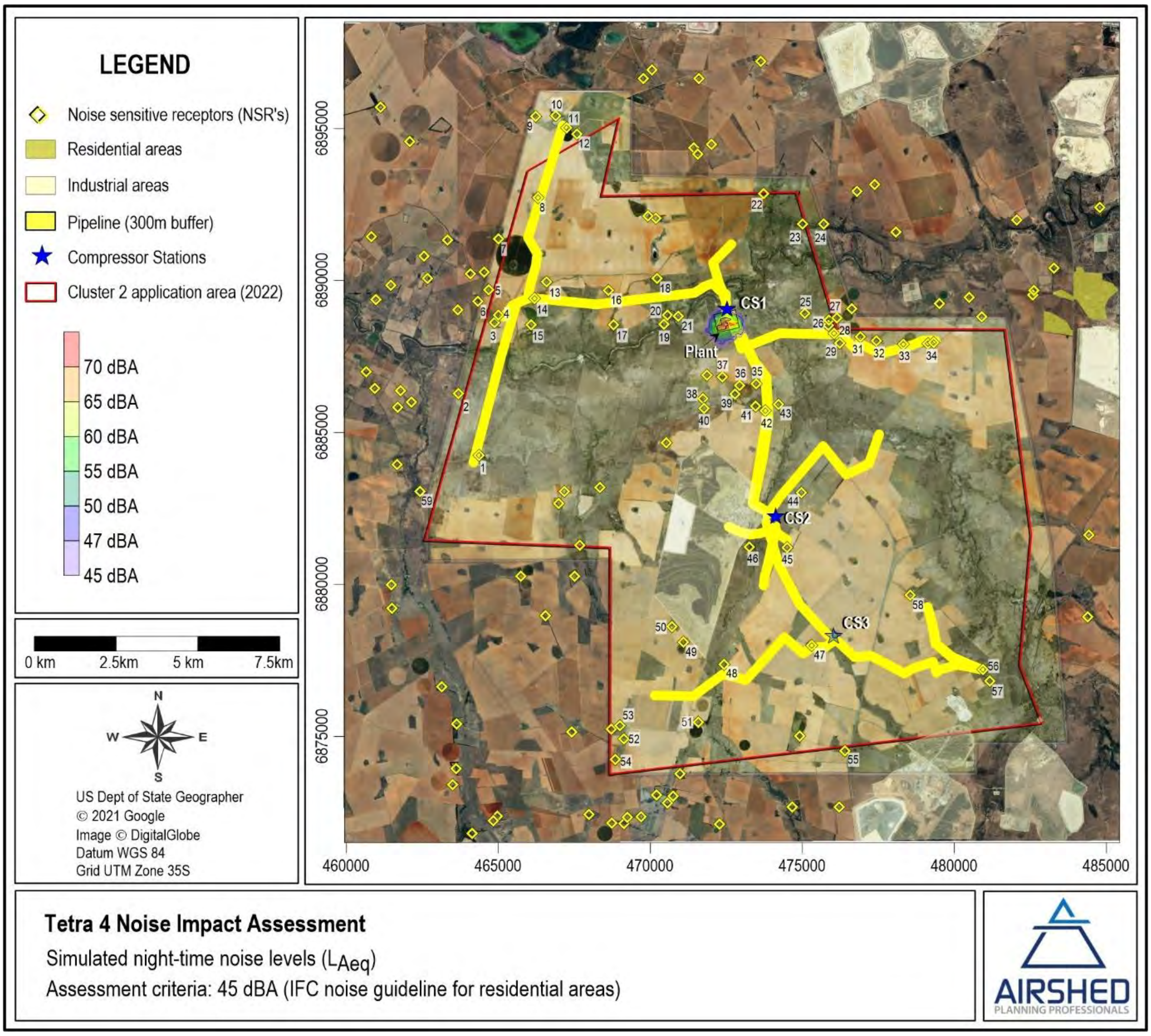


Figure 4-14: Isopleths indicating the simulated night-time noise levels (LAeq) due to Plant and Compressor Station operational activities (assuming the alternative CS3 location)

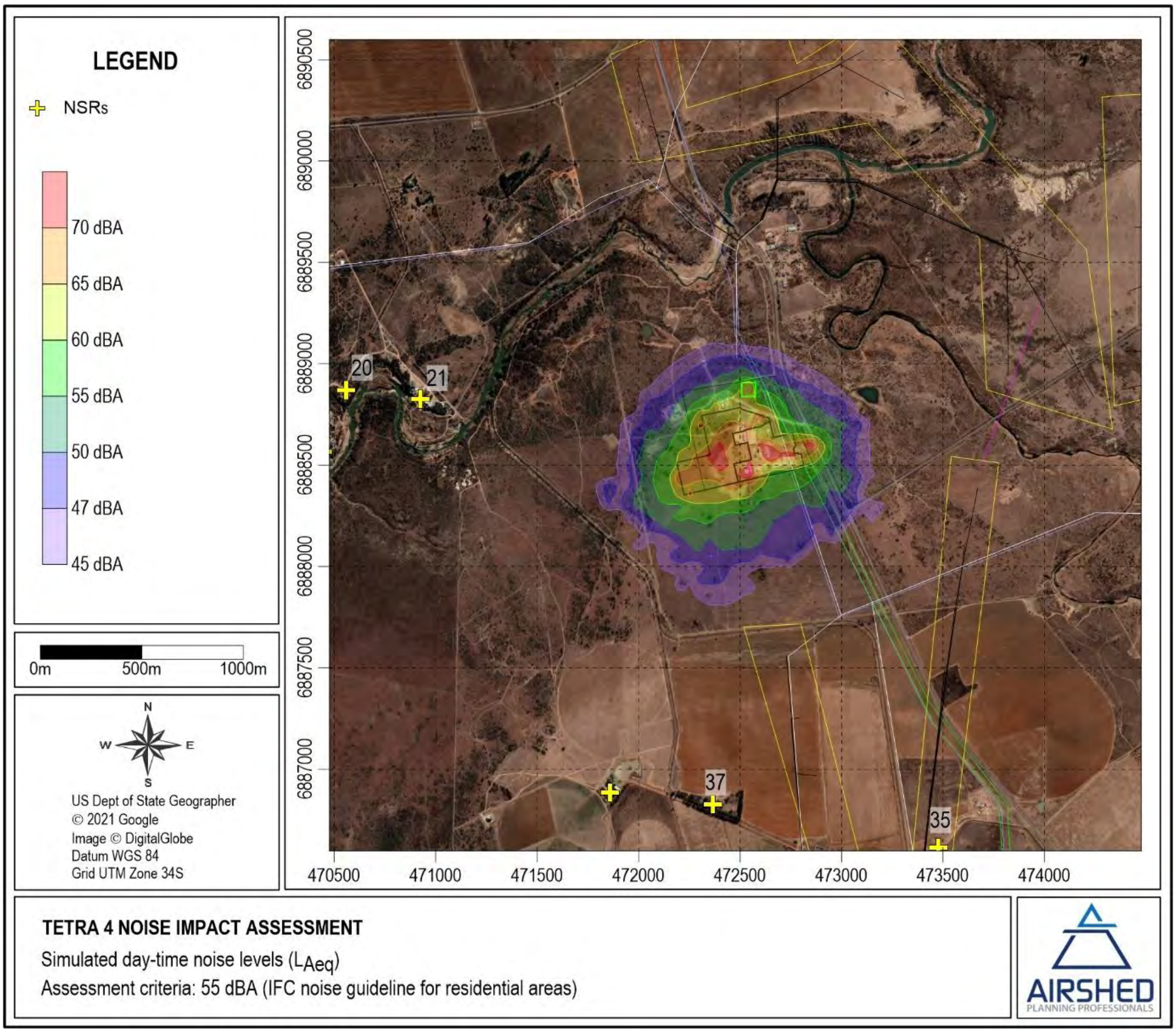


Figure 4-15: Isopleths indicating the simulated day-time noise levels (LAeq) due to Plant and Compressor Station operational activities at the plant site

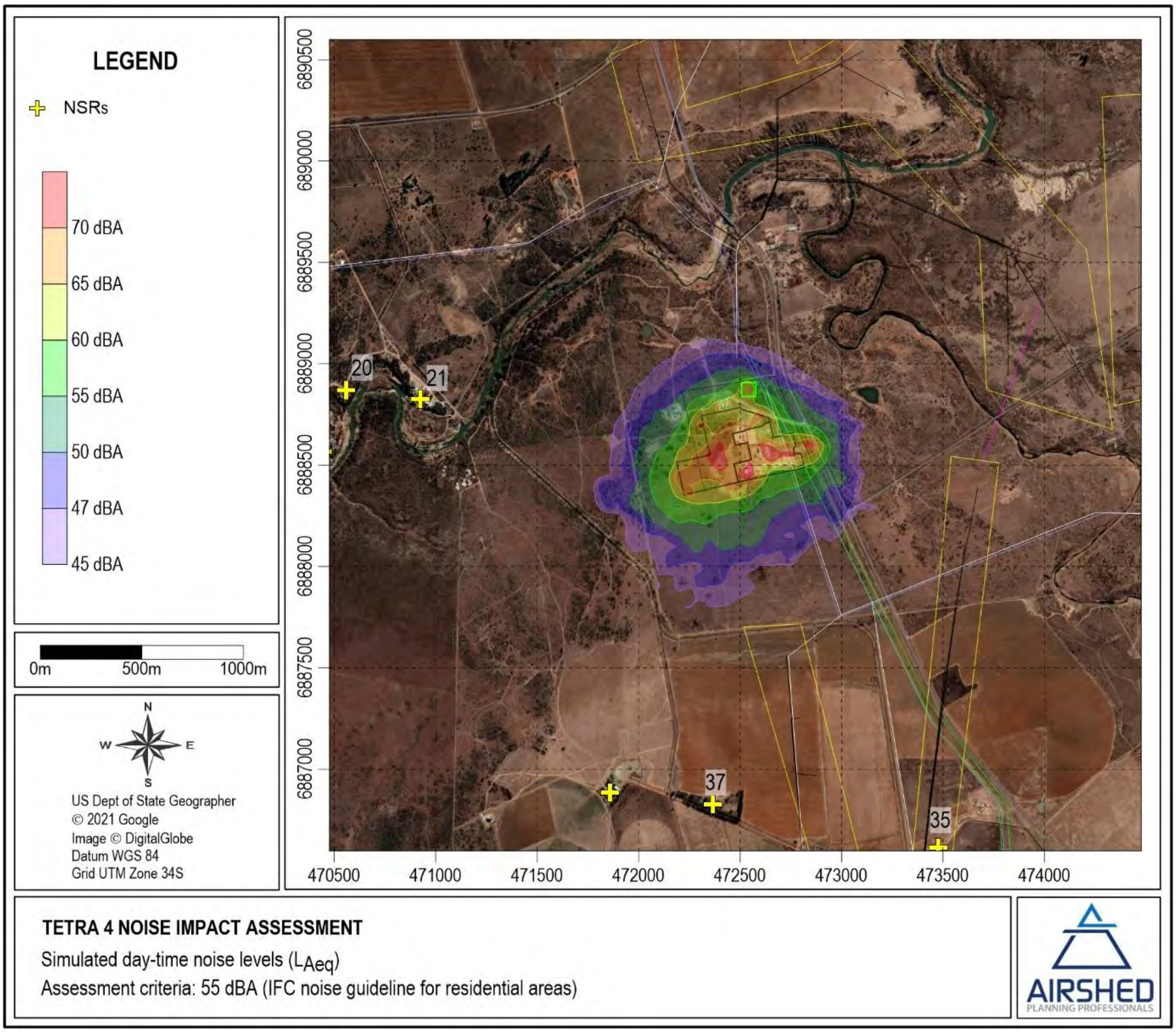


Figure 4-16: Isopleths indicating the simulated night-time noise levels (LAeq) due to Plant and Compressor Station operational activities at the plant site

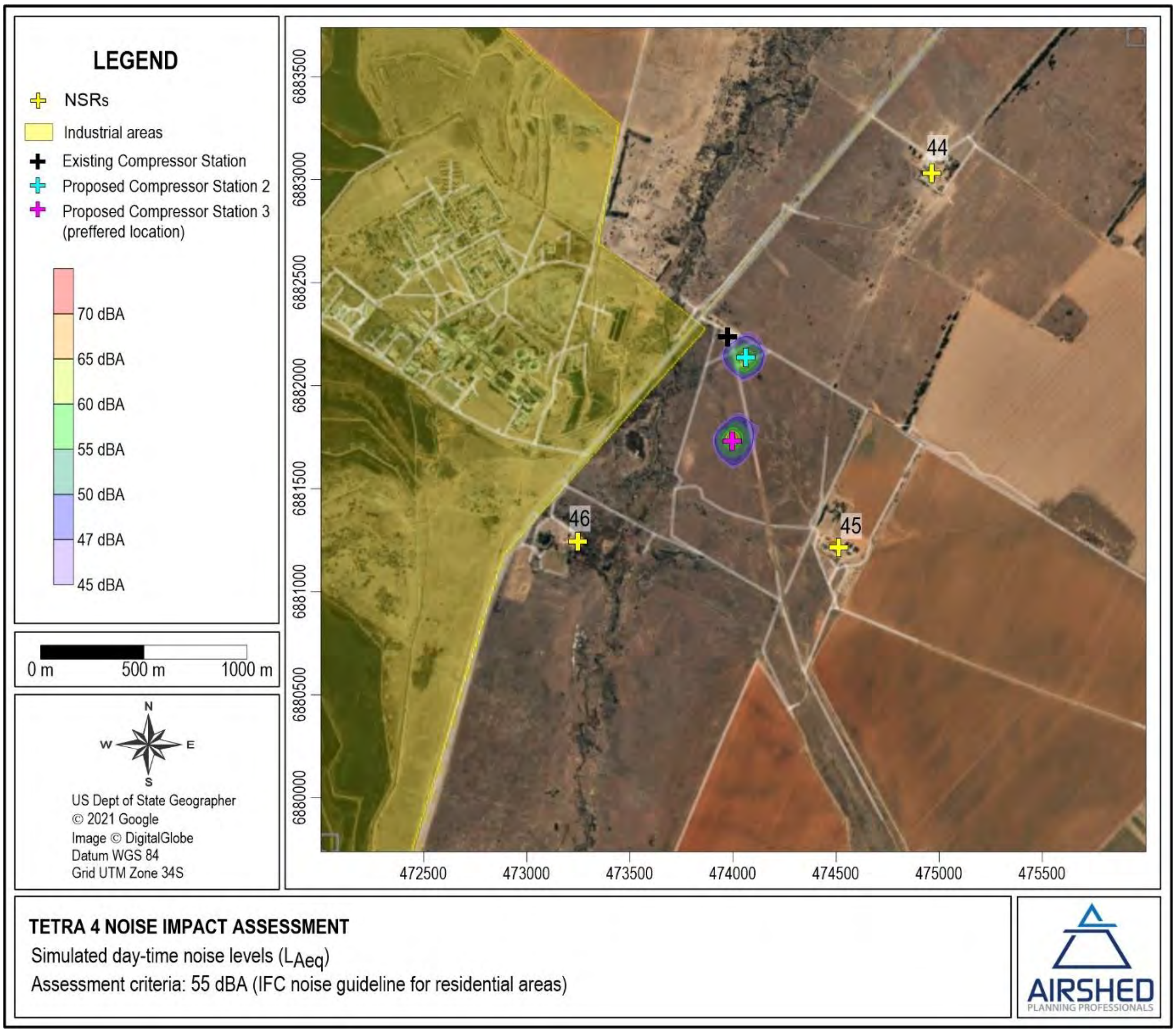


Figure 4-17: Isopleths indicating the simulated day-time noise levels (LAeq) due to Compressor Station operational activities at the CS2 site (assuming the preferred CS3 location)

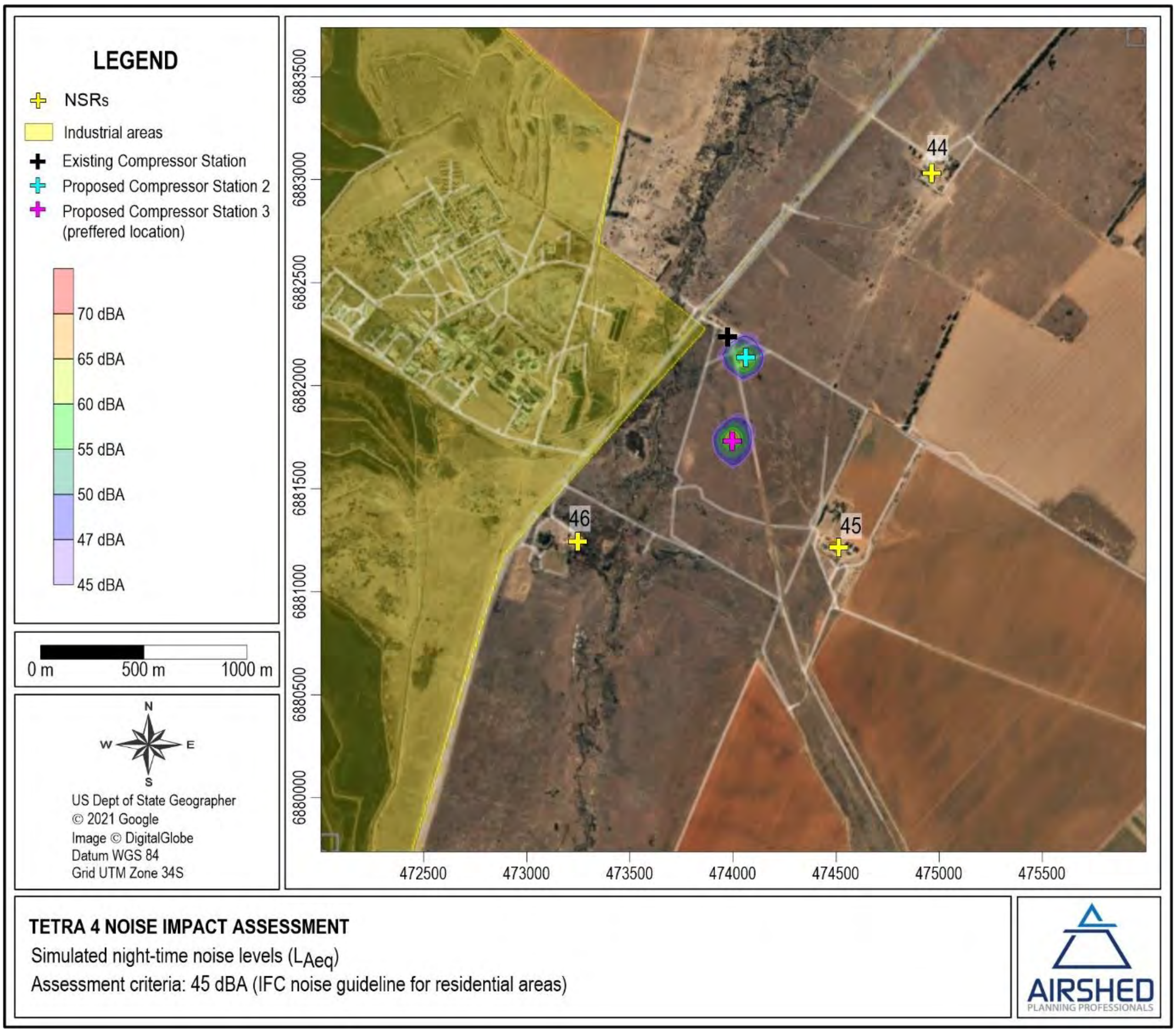


Figure 4-18: Isopleths indicating the simulated night-time noise levels (LAeq) due to Compressor Station operational activities at the CS2 site (assuming the preferred CS3 location)

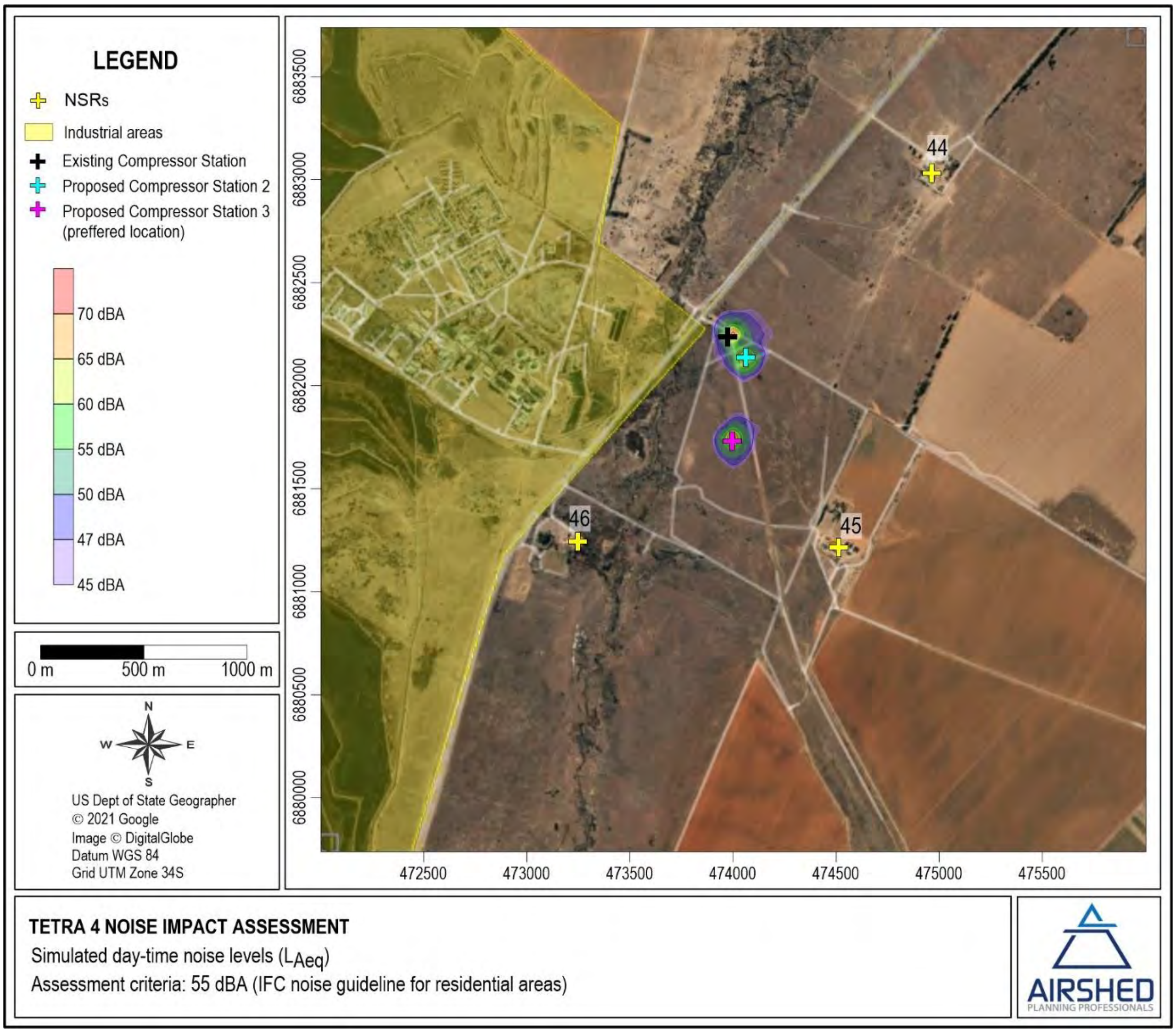


Figure 4-19: Isopleths indicating the simulated day-time noise levels (LAeq) due to cumulative Compressor Station operations (Compressor Stations for Cluster 1 and Cluster 2) at the CS2 site (assuming the preferred CS3 location)

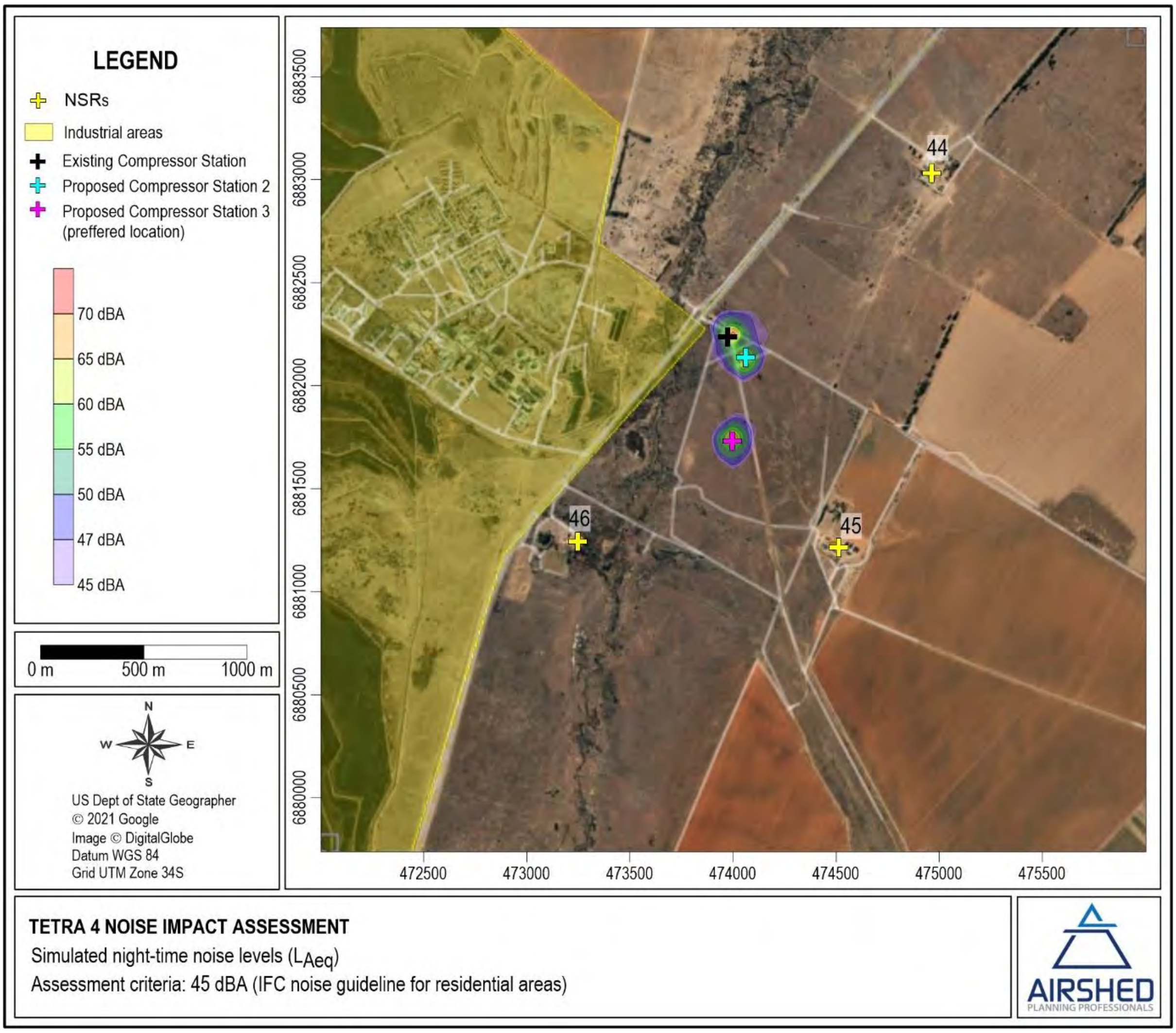


Figure 4-20: Isopleths indicating the simulated night-time noise levels (LAeq) due to cumulative Compressor Station operations (Compressor Stations for Cluster 1 and Cluster 2) at the CS2 site (assuming the preferred CS3 location)

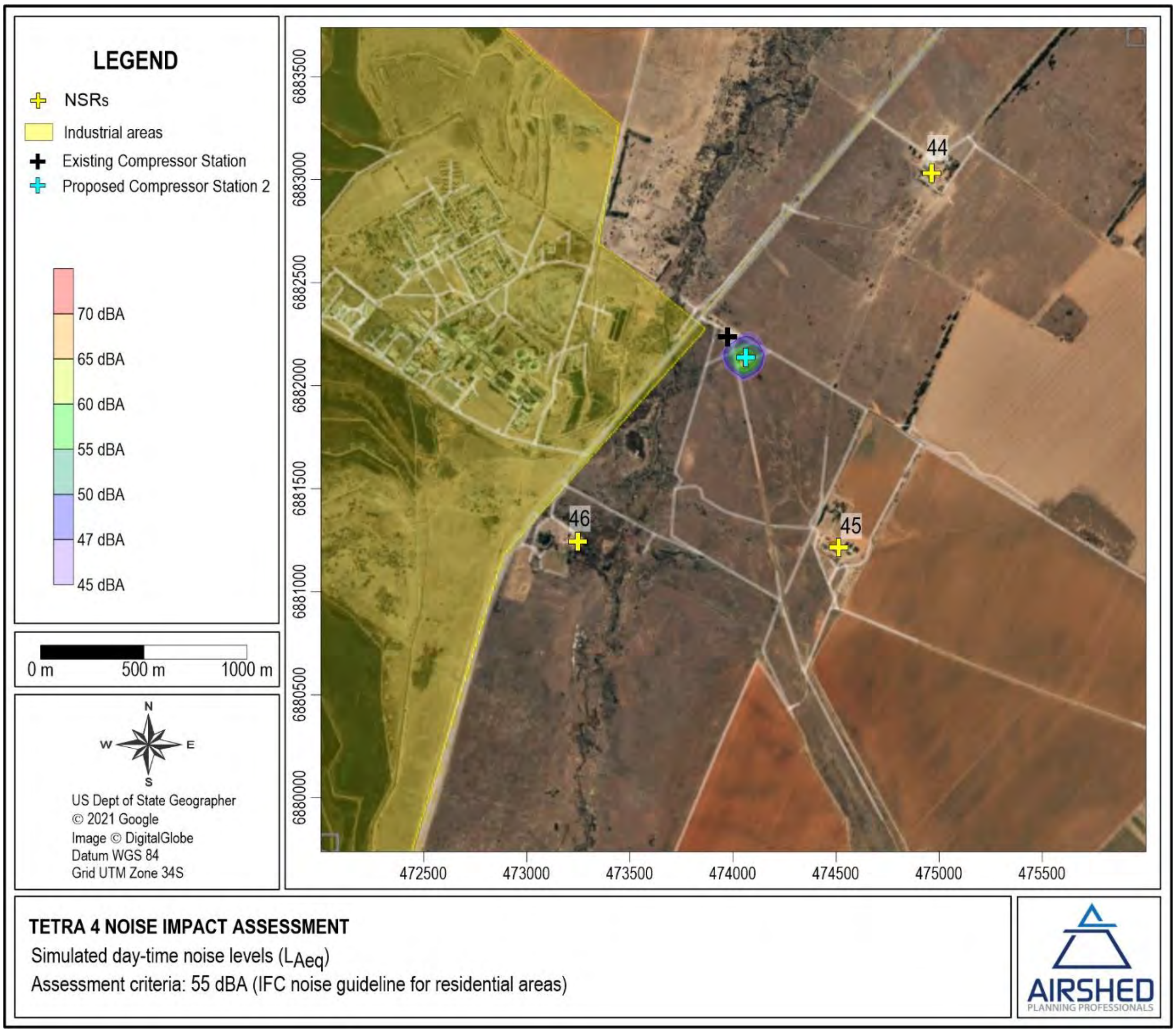


Figure 4-21: Isopleths indicating the simulated day-time noise levels (LAeq) due to Compressor Station operational activities at the CS2 site (assuming the alternative CS3 location)

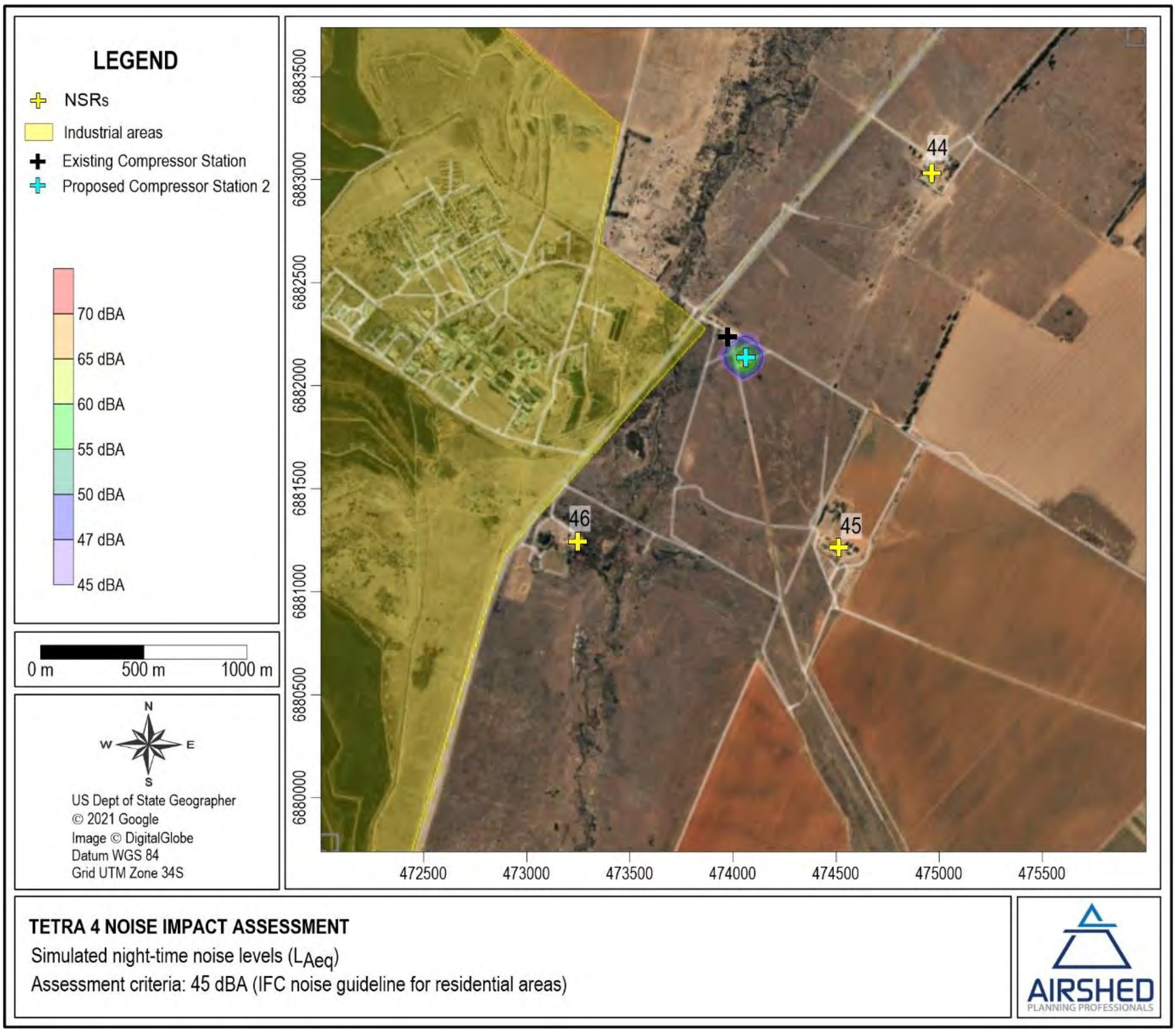


Figure 4-22: Isopleths indicating the simulated night-time noise levels (LAeq) due to Compressor Station operational activities at the CS2 site (assuming the alternative CS3 location)

Table 4-9: Summary of simulated day-time noise levels (provided as dBA) due to the Plant and Compressor Station operation activities (assuming preferred location for CS3) and baseline noise measurements at NSRs within the vicinity of the project

Noise Sensitive Receptor	Comments	Project operations (a)		Baseline		Increase Above Baseline (b)	
		Day	Night	Day	Night	Day	Night
NSR1	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR2	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR3	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR4	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR5	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR6	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR7	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR8	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR9	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR10	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR11	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR12	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0

Noise Sensitive Receptor	Comments	Project operations (a)		Baseline		Increase Above Baseline (b)	
		Day	Night	Day	Night	Day	Night
NSR13	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR14	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR15	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR16	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR17	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR18	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR19	Baseline noise levels typical of rural districts	23.8	25.0	45.0	35.0	0.0	0.4
NSR20	Baseline noise levels typical of rural districts	25.9	27.0	45.0	35.0	0.1	0.6
NSR21	Baseline noise levels typical of rural districts	30.7	31.8	45.0	35.0	0.2	1.7
NSR22	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR23	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR24	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR25	Baseline noise levels typical of urban districts (<550m from road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR26	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR27	Baseline noise levels typical of suburban districts (<1000m from road)	0.0	0.0	50.0	40.0	0.0	0.0
NSR28	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR29	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR30	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR31	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR32	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR33	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR34	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR35	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR36	Baseline noise levels typical of suburban districts (<1000m from R30)	28.8	28.6	50.0	40.0	0.0	0.3
NSR37	Baseline noise levels typical of rural districts	34.3	34.4	45.0	35.0	0.4	2.7
NSR38	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR39	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR40	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR41	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	0.0	50.0	40.0	0.0	0.0
NSR42	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	0.0	50.0	40.0	0.0	0.0
NSR43	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR44	Baseline noise levels typical of rural districts	13.4	12.2	45.0	35.0	0.0	0.0
NSR45	Baseline noise levels typical of rural districts	21.7	20.9	45.0	35.0	0.0	0.2
NSR46	Baseline noise levels typical of rural districts	19.0	19.8	45.0	35.0	0.0	0.1
NSR47	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR48	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR49	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR50	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR51	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR52	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR53	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR54	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR55	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0

Noise Sensitive Receptor	Comments	Project operations (a)		Baseline		Increase Above Baseline (b)	
		Day	Night	Day	Night	Day	Night
NSR56	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR57	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR58	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR59	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0

Notes:

(c) Exceedances of IFC guideline (55 dBA for day-time and 45 dBA for night-time at residential areas) are provided in bold.

(d) Likely community response in accordance with the SANS 10103:

<3 dBA	<5 dBA	<10 dBA	<15 dBA	<20 dBA
Change imperceptible	*No reaction*	*'Little' reaction with sporadic complaints*	*'Medium' reaction with widespread complaints*	*'Strong' to 'very strong' reaction with threats of community action or vigorous community action.*

Table 4-10: Summary of simulated day-time noise levels (provided as dBA) due to the Plant and Compressor Station operation activities (assuming alternative location for CS3) and baseline noise measurements at NSRs within the vicinity of the project

Noise Sensitive Receptor	Comments	Project operations (a)		Baseline		Increase Above Baseline (b)	
		Day	Night	Day	Night	Day	Night
NSR1	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR2	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR3	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR4	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR5	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR6	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR7	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR8	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR9	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR10	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR11	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR12	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR13	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR14	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR15	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR16	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR17	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR18	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR19	Baseline noise levels typical of rural districts	23.8	25.0	45.0	35.0	0.0	0.4
NSR20	Baseline noise levels typical of rural districts	25.9	27.0	45.0	35.0	0.1	0.6
NSR21	Baseline noise levels typical of rural districts	30.7	31.8	45.0	35.0	0.2	1.7
NSR22	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR23	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR24	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR25	Baseline noise levels typical of urban districts (<550m from road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR26	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR27	Baseline noise levels typical of suburban districts (<1000m from road)	0.0	0.0	50.0	40.0	0.0	0.0
NSR28	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR29	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0

Noise Sensitive Receptor	Comments	Project operations (a)		Baseline		Increase Above Baseline (b)	
		Day	Night	Day	Night	Day	Night
NSR30	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR31	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR32	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR33	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR34	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR35	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR36	Baseline noise levels typical of suburban districts (<1000m from R30)	28.8	28.6	50.0	40.0	0.0	0.3
NSR37	Baseline noise levels typical of rural districts	34.3	34.4	45.0	35.0	0.4	2.7
NSR38	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR39	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR40	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR41	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	0.0	50.0	40.0	0.0	0.0
NSR42	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	0.0	50.0	40.0	0.0	0.0
NSR43	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR44	Baseline noise levels typical of rural districts	11.9	10.6	45.0	35.0	0.0	0.0
NSR45	Baseline noise levels typical of rural districts	16.9	16.3	45.0	35.0	0.0	0.1
NSR46	Baseline noise levels typical of rural districts	13.6	14.3	45.0	35.0	0.0	0.0
NSR47	Baseline noise levels typical of rural districts	19.0	19.9	45.0	35.0	0.0	0.1
NSR48	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR49	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR50	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR51	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR52	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR53	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR54	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR55	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR56	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR57	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR58	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR59	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0

Notes:

(a) Exceedances of IFC guideline (55 dBA for day-time and 45 dBA for night-time at residential areas) are provided in bold.

(b) Likely community response in accordance with the SANS 10103:

<3 dBA	<5 dBA	<10 dBA	<15 dBA	<20 dBA
Change imperceptible	*No reaction*	*'Little' reaction with sporadic complaints*	*'Medium' reaction with widespread complaints*	*'Strong' to 'very strong' reaction with threats of community action or vigorous community action.*

Table 4-11: Summary of simulated day-time noise levels (provided as dBA) due to the Plant and cumulative Compressor Station operations (Compressor Stations for Cluster 1 and Cluster 2 operations) (assuming preferred location for CS3) and baseline noise measurements at NSRs within the vicinity of the project

Noise Sensitive Receptor	Comments	Project operations [(a)]		Baseline		Increase Above Baseline [(b)]	
		Day	Night	Day	Night	Day	Night
NSR1	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR2	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR3	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR4	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR5	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR6	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR7	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR8	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR9	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR10	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR11	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR12	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR13	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR14	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR15	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR16	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR17	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR18	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR19	Baseline noise levels typical of rural districts	23.8	25.0	45.0	35.0	0.0	0.4
NSR20	Baseline noise levels typical of rural districts	25.9	27.0	45.0	35.0	0.1	0.6
NSR21	Baseline noise levels typical of rural districts	30.7	31.8	45.0	35.0	0.2	1.7
NSR22	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR23	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR24	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR25	Baseline noise levels typical of urban districts (<550m from road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR26	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR27	Baseline noise levels typical of suburban districts (<1000m from road)	0.0	0.0	50.0	40.0	0.0	0.0
NSR28	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR29	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR30	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR31	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR32	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR33	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR34	Baseline noise levels assumed to be typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR35	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR36	Baseline noise levels typical of suburban districts (<1000m from R30)	28.8	28.6	50.0	40.0	0.0	0.3
NSR37	Baseline noise levels typical of rural districts	34.3	34.4	45.0	35.0	0.4	2.7
NSR38	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR39	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR40	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0

Noise Sensitive Receptor	Comments	Project operations (a)		Baseline		Increase Above Baseline (b)	
		Day	Night	Day	Night	Day	Night
NSR41	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	0.0	50.0	40.0	0.0	0.0
NSR42	Baseline noise levels typical of suburban districts (<1000m from R30)	0.0	0.0	50.0	40.0	0.0	0.0
NSR43	Baseline noise levels typical of urban districts (<500m from R30 road)	0.0	0.0	55.0	45.0	0.0	0.0
NSR44	Baseline noise levels typical of rural districts	15.9	14.6	45.0	35.0	0.0	0.0
NSR45	Baseline noise levels typical of rural districts	22.5	21.8	45.0	35.0	0.0	0.2
NSR46	Baseline noise levels typical of rural districts	20.0	20.8	45.0	35.0	0.0	0.2
NSR47	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR48	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR49	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR50	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR51	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR52	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR53	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR54	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR55	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR56	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR57	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR58	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0
NSR59	Baseline noise levels typical of rural districts	0.0	0.0	45.0	35.0	0.0	0.0

Notes:

(a) Exceedances of IFC guideline (55 dBA for day-time and 45 dBA for night-time at residential areas) are provided in bold.

(b) Likely community response in accordance with the SANS 10103:

<3 dBA	<5 dBA	<10 dBA	<15 dBA	<20 dBA
Change imperceptible	*No reaction*	*'Little' reaction with sporadic complaints*	*'Medium' reaction with widespread complaints*	*'Strong' to 'very strong' reaction with threats of community action or vigorous community action.*

5 Impact Significance Rating

The significance of environmental noise impacts was assessed according to the methodology adopted by EIMS (Appendix F).

5.1.1 Construction

The assumption is that construction activities would be during day-time hours only.

Given the nature of construction activities for the pipeline, wells and Blower Stations (where the location may vary depending on the gas reserves in the area) the noise levels at the nearest residential receptors to the construction areas may exceed IFC guidelines for residential areas (55 dBA). If there are exceedances of this guideline, it would be of short duration. The negative noise impacts are therefore considered to be of medium significance without mitigation and low significance with mitigation at the nearest receptors due to these activities (Table 5-1 and Table 5-2).

Table 5-1: Significance rating for potential noise impacts due to the construction of the pipeline

Impact Name	Increase in noise levels due to construction of the pipeline				
Alternative	NA				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
As construction will only take place during day-time hours and will be of limited duration, NSRs within 90 m of the pipeline construction site should be notified of the activities and potential disturbance durations prior to construction taking place. Additional mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-8.75

Table 5-2: Significance rating for potential noise impacts due to the construction of the wells and Blower Stations

Impact Name	Increase in noise levels due to construction of the wells and Blower Stations				
Alternative	NA				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	3	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
As construction will only take place during day-time hours and will be of limited duration, NSRs within 400 m radius of all well construction sites and 600 m from Blower Station construction sites should be notified of the activities and potential disturbance durations prior to construction taking place. The noise levels due to Blower Station operations is likely to exceed the IFC night-time noise guideline for residential areas up to 150 m from the operations. Care should be taken to site the Blower Stations at least 150 m from all NSRs. Additional mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-8.75

The noise levels at the nearest residential receptors due to the construction activities of the Plant and Compressor Stations are not likely to exceed day-time IFC guidelines for residential areas (55 dBA). The negative noise impacts are therefore considered to be of low significance without and with mitigation at the nearest receptors due to these activities (Table 5-3 and Table 5-4).

Table 5-3: Significance rating for potential noise impacts due to the construction of the plant and Compressor Stations (assuming the preferred location for CS3)

Impact Name	Increase in noise levels due to construction of the Plant and Compressor Stations				
Alternative	Assuming preferred location for CS3				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	3	3	Probability	3	3
Environmental Risk (Pre-mitigation)					-8.25
Mitigation Measures					
Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-8.75

Table 5-4: Significance rating for potential noise impacts due to the construction of the plant and Compressor Stations (assuming the alternative location for CS3)

Impact Name	Increase in noise levels due to construction of the Plant and Compressor Stations				
Alternative	Assuming the alternative location for CS3				
Phase	Construction				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	3	3	Probability	3	3
Environmental Risk (Pre-mitigation)					-8.25
Mitigation Measures					
Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					2
Issue has received a meaningful and justifiable public response					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-8.75

5.1.2 Operation

The operational activities would take place during day- and night-time conditions.

The noise levels due to Blower Station operations is likely to exceed the IFC night-time noise guideline for residential areas up to 150 m from the operations. Care should be taken to site the Blower Stations at least 150 m from all NSRs. With careful siting, IFC noise guidelines for residential areas should not be exceeded at NSRs. The negative noise impacts are therefore considered to be of low significance at the nearest receptors (Table 5-5).

Given the location of the Plant and the Compressor Stations and the potential noise levels due to operations, it is unlikely that IFC noise guidelines for residential areas will be exceeded at NSRs. The negative noise impacts are therefore considered to be of low significance at the nearest receptors (Table 5-6 and Table 5-7).

Table 5-5: Significance rating for potential noise impacts due to the operation of the Blower Stations

Impact Name	Increase in noise levels due to Blower Station operation				
Alternative	NA				
Phase	Operation				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	3	3
Environmental Risk (Pre-mitigation)					-9.75
Mitigation Measures					
The noise levels due to Blower Station operations is likely to exceed the IFC night-time noise guideline for residential areas up to 150 m from the operations. Care should be taken to site the Blower Stations at least 150 m from all NSRs. Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-9.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-9.00

Table 5-6: Significance rating for potential noise impacts due to the operation of the Plant and Compressor Stations (assuming the preferred location for CS3)

Impact Name	Increase in noise levels due to Plant and Compressor Station operation				
Alternative	Assuming preferred location for CS3				
Phase	Operation				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	3	3
Environmental Risk (Pre-mitigation)					-9.75
Mitigation Measures					
Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-9.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-9.00

Table 5-7: Significance rating for potential noise impacts due to the operation of the Plant and Compressor Stations (assuming the alternative location for CS3)

Impact Name	Increase in noise levels due to Plant and Compressor Station operation				
Alternative	Assuming the alternative location for CS3				
Phase	Operation				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	3	3	Reversibility of Impact	3	3
Duration of Impact	4	4	Probability	3	3
Environmental Risk (Pre-mitigation)					-9.75
Mitigation Measures					
Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-9.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-9.00

5.1.3 Decommissioning and Closure

The assumption is that decommissioning would be during day-time hours only. Given the nature of decommissioning activities, and the extent of the process, IFC noise guidelines for residential areas may be exceeded sporadically at NSRs. Attenuation measures, however, can be implemented to reduce noise levels. The negative noise impacts are therefore considered to be of medium significance without mitigation and low significance with mitigation at the nearest receptors (Table 5-8 and Table 5-9).

Table 5-8: Significance rating for potential noise impacts due to the decommissioning and closure phase of the project (assuming the preferred location for CS3)

Impact Name	Increase in noise levels				
Alternative	Assuming preferred location for CS3				
Phase	Decommissioning				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-7.50

Table 5-9: Significance rating for potential noise impacts due to the decommissioning and closure phase of the project (assuming the alternative location for CS3)

Impact Name	Increase in noise levels				
Alternative	Assuming the alternative location for CS3				
Phase	Decommissioning				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	4	3
Extent of Impact	3	3	Reversibility of Impact	2	2
Duration of Impact	2	2	Probability	4	3
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
Mitigation measures are detailed in Section 6.					
Environmental Risk (Post-mitigation)					-7.50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-7.50

6 Management Measures

In the quantification of noise emissions and simulation of noise levels as a result of the project, it was found that environmental noise evaluation criteria for residential, educational, and institutional receptors will be met at all off-site noise sensitive receptors.

The measures discussed in this section are measures typically applicable to industrial sites and are considered good practice by the IFC (2007) and British Standard BSI (2008).

It should be noted that not all mitigation measures are to be implemented, but should the need arise the mitigation measures as discussed in this section can be considered.

The mitigation measured discussed also takes into account the existing management measures utilised for the existing Cluster 1 Environmental Management Programme (EIMS, 2019). The approach adopted for this section is as follows:

- If the current mitigation measures for a particular impact are considered adequate, reference will be made to the existing mitigation measures (using the mitigation reference numbers provided in the 2019 Environmental Management Programme (EMPr));
- If the current mitigation measures are inadequate, amendments will be provided; and,
- If additional mitigation measures are required, these will be highlighted as additional to the existing approved EMPr.

6.1 Controlling Noise at the Source

6.1.1 General Good Practice Measures

Although the current EMPr (number 50) specifies complaints need to be registered it is recommended that the complaints register description be expanded (for number 50 and number 78) as follows:

- A complaints register, including the procedure which governs how complaints are received, managed and responses given, must be implemented, and maintained.

The existing EMPr specifies that construction activities should where possible be during day-time (number 50). It is recommended that this be expanded as follows (applying to all phases of the project):

- Unless it is an emergency situation, non-routine noisy activities such as construction, decommissioning, start-up and maintenance, should be limited to day-time hours.

6.1.2 Specifications and Equipment Design

It is recommended that the current EMPr include the following specifications for equipment (number 50 and number 78):

- Equipment to be employed should be reviewed to ensure the quietest available technology is used. Equipment with lower sound power levels must be selected in such instances and vendors/contractors should be required to guarantee optimised equipment design noise levels.

6.1.3 Enclosures

The existing EMPr specifies enclosures (number 50). The following additional information could be included:

- It should be noted that the effectiveness of partial enclosures and screens can be reduced if used incorrectly, e.g., noise should be directed into a partial enclosure and not out of it, there should not be any reflecting surfaces such as parked vehicles opposite the open end of a noise enclosure.

6.1.4 Use and Siting of Equipment and Noise Sources

The following good practice should be implemented (additional measures to be included in the EMPr (number 50 and number 78)):

a) Machines and mobile equipment used intermittently should be shut down between work periods or throttled down to a minimum and not left running unnecessarily. This will reduce noise and conserve energy.
b) Acoustic covers of engines should be kept closed when in use or idling.

6.1.5 Noise Impacts at Sensitive Receptors

The current EMPr (number 50) specifies that construction activities should not be within 500 m from sensitive receptors if occurring at night. Construction activities were specified for the current assessment to be taking place at night. The distance from sensitive receptors (day-time) can be amended to 600 m as this is the predicted noise impacts for construction of blower stations. Alternatively, distances for noise impacts, due to various activities, can be specified as follows:

- Construction (day-time):
    - Wells: 400 m
    - Pipeline: 90 m
    - Blower station: 600 m
    - Plant: 430 m
    - Compressors: 420 m
- Operation (day-time):
    - Blower station: 50 m
    - Plant: 170 m
    - Compressors: 80 m
- Operation (night-time):
    - Blower station: 150 m
    - Plant: 580 m
    - Compressors: 150 m

6.1.6 Maintenance

Regular and effective maintenance of equipment are included in the current EMPr (number 50). This should also be included for the operational phase (number 78).

6.2 Monitoring

In the event that noise related complaints are received, the existing EMPr makes provision for short term ambient noise measurements. The EMPr specifies that the noise levels should be co-ordinated with the 10-m wind speed. It should be noted that it is good practice to undertake noise measurements when wind speeds are less than 5 m/s and it is recommended that this description be ammended.

It is also recommended that the following procedure be adopted and included in the EMPr for all noise surveys (for complaints):

- Any surveys should be designed and conducted by a trained specialist.
- Sampling should be carried out using a Type 1 SLM that meets all appropriate IEC standards and is subject to annual calibration by an accredited laboratory.
- The acoustic sensitivity of the SLM should be tested with a portable acoustic calibrator before and after each sampling session.
- Samples sufficient for statistical analysis should be taken with the use of portable SLM's capable of logging data continuously over the time period. Samples, representative of the day- and night-time acoustic environment should be taken.
- The SLM should be located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface.
- Efforts should be made to ensure that measurements are not affected by the residual noise and extraneous influences, e.g. wind, electrical interference and any other non-acoustic interference, and that the instrument is operated under the conditions specified by the manufacturer. It is good practice to avoid conducting measurements when the wind speed is more than 5 m/s, while it is raining or when the ground is wet.
- A detailed log and record should be kept. Records should include site details, weather conditions during sampling and observations made regarding the acoustic environment of each site.

7 Conclusion

Based on the findings of the assessment and provided the recommended general "good practice" management and mitigation measures are in place, it is the specialist opinion that the project may be authorised.

8 References

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Appendix A – Specialist Curriculum Vitae

FULL CURRICULUM VITAE

Name of Firm	Airshed Planning Professionals (Pty) Ltd
Name of Staff	Reneé von Gruenewaldt (*nee* Thomas)
Profession	Air Quality and Environmental Noise Scientist
Date of Birth	13 May 1978
Years with Firm	19 years
Nationalities	South African

MEMBERSHIP OF PROFESSIONAL SOCIETIES

- Registered Professional Natural Scientist (Registration Number 400304/07) with the South African Council for Natural Scientific Professions (SACNASP)
- Member of the National Association for Clean Air (NACA)

KEY QUALIFICATIONS

Reneé von Gruenewaldt (Air Quality Scientist): Reneé joined Airshed Planning Professionals (Pty) Ltd (previously known as Environmental Management Services cc) in 2002. She has, as a Specialist, attained over nineteen (19) years of experience in the Earth and Natural Sciences sector in the field of Air Quality and eight (8) years of experience in the field of environmental noise assessments. As an environmental practitioner, she has provided solutions to both large-scale and smaller projects within the mining, minerals, and process industries.

She has developed technical and specialist skills in various air quality modelling packages including the AMS/EPA Regulatory Models (AERMOD and AERMET), UK Gaussian plume model (ADMS), EPA Regulatory puff-based model (CALPUFF and CALMET), puff-based HAWK model and line-based models. Her experience with air emission models includes Tanks 4.0 (for the quantification of tank emissions), WATER9 (for the quantification of wastewater treatment works) and GasSim (for the quantification of landfill emissions). Noise propagation modelling proficiency includes CONCAWE, South African National Standards (SANS 10210) for calculating and predicting road traffic noise and CadnaA for propagation of industrial, road and rail noise sources.

Having worked on projects throughout Africa (i.e., South Africa, Mozambique, Malawi, Kenya, Angola, Democratic Republic of Congo, Namibia, Madagascar and Egypt for Air Quality Impact Assessments and Mozambique, Namibia, Botswana, Kenya, Ghana, Suriname and Afghanistan for Environmental Noise Impact Assessments) Reneé has developed a broad experience base. She has a good understanding of the laws and regulations associated with ambient air quality and emission limits in South Africa and various other African countries, as well as the World Bank Guidelines, European Community Limits and World Health Organisation.

RELEVANT EXPERIENCE (AIR QUALITY)

Mining and Ore Handling

Reneé has undertaken numerous air quality impact assessments and management plans for coal, platinum, uranium, copper, cobalt, chromium, fluorspar, bauxite, manganese and mineral sands mines. These include: compilation of emissions databases for Landau and New Vaal coal collieries (SA), impact assessments and management plans for numerous mines over Mpumalanga (viz. Schoonoord, Belfast, Goedgevonden, Mbila, Evander South, Driefontein, Hartogshoop, Belfast, New Largo, Geluk, etc.), Mmamabula Coal Colliery (Botswana), Moatize Coal Colliery (Mozambique), Revuboe Coal Colliery (Mozambique), Toliera Sands Heavy Minerals Mine and Processing (Madagascar), Corridor Sands Heavy Minerals Mine monitoring assessment, El Burullus Heavy Minerals Mine and processing (Egypt), Namakwa Sands Heavy Minerals Mine (SA), Tenke Copper Mine and Processing Plant (DRC), Rössing Uranium (Namibia), Lonmin platinum mines including operations at Marikana, Baobab, Dwaalkop and Doornvlei (SA), Impala Platinum (SA), Pilannesburg Platinum (SA), Aquarius Platinum, Hoogland Platinum Mine (SA), Tamboti PGM Mine (SA), Sari Gunay Gold Mine (Iran), chrome mines in the Steelpoort Valley (SA), Mecklenburg Chrome Mine (SA), Naboom Chrome Mine (SA), Kinsenda Copper Mine (DRC), Kassinga Mine (Angola) and Nokeng Flourspar Mine (SA), etc.

Mining monitoring reviews have also been undertaken for Optimum Colliery's operations near Hendrina Power Station and Impunzi Coal Colliery with a detailed management plan undertaken for Morupule (Botswana) and Glencor (previously known as Xstrata Coal South Africa).

Air quality assessments have also been undertaken for mechanical appliances including the Durban Coal Terminal and Nacala Port (Mozambique) as well as rail transport assessments including BHP-Billiton Bauxite transport (Suriname), Nacala Rail Corridor (Mozambique and Malawi), Kusile Rail (SA) and WCL Rail (Liberia).

Metal Recovery

Air quality impact assessments have been carried out for Highveld Steel, Scaw Metals, Lonmin's Marikana Smelter operations, Saldanha Steel, Tata Steel, Afro Asia Steel and Exxaro's Manganese Pilot Plant Smelter (Pretoria).

Chemical Industry

Comprehensive air quality impact assessments have been completed for NCP (including Chloorkop Expansion Project, Contaminated soils recovery, C3 Project and the 200T Receiver Project), Revertex Chemicals (Durban), Stoppani Chromium Chemicals, Foskor (Richards Bay), Straits Chemicals (Coega), Tenke Acid Plant (DRC), and Omnia (Sasolburg).

Petrochemical Industry

Numerous air quality impact assessments have been completed for Sasol (including the postponement/exemption application for Synfuels, Infrachem, Natref, MIBK2 Project, Wax Project, GTL Project, re-commissioning of boilers at Sasol Sasolburg and Ekandustria), Engen Emission Inventory Functional Specification (Durban), Sapref refinery (Durban), Sasol (at Elrode) and Island View (in Durban) tanks quantification, Petro SA and Chevron (including the postponement/exemption application).

Pulp and Paper Industry

Air quality studies have been undertaken or the expansion of Mondi Richards Bay, Multi-Boiler Project for Mondi Merebank (Durban), impact assessments for Sappi Stanger, Sappi Enstra (Springs), Sappi Ngodwana (Nelspruit) and Pulp United (Richards Bay).

Power Generation

Air quality impact assessments have been completed for numerous Eskom coal fired power station studies including the ash expansion projects at Kusile, Kendal, Hendrina, Kriel and Arnot; Fabric Filter Plants at Komati, Grootvlei, Tutuka, Lethabo and Kriel Power Stations; the proposed Kusile, Medupi (including the impact assessment for the Flue Gas Desulphurization) and Vaal South Power Stations. Reneé was also involved and the cumulative assessment of the existing and return to service Eskom power stations assessment and the optimization of Eskom's ambient air quality monitoring network over the Highveld.

In addition to Eskom's coal fired power stations, various Eskom nuclear power supply projects have been completed including the air quality assessment of Pebble Bed Modular Reactor and nuclear plants at Duynefontein, Bantamsklip and Thyspunt.

Apart from Eskom projects, power station assessments have also been completed in Kenya (Rabai Power Station) and Namibia (Paratus Power Plant).

Waste Disposal

Air quality impact assessments, including odour and carcinogenic and non-carcinogenic pollutants were undertaken for the Waste Water Treatment Works in Magaliesburg, proposed Waterval Landfill (near Rustenburg), Tutuka Landfill, Mogale General Waste Landfill (adjacent to the Leipardsvlei Landfill), Cape Winelands District Municipality Landfill and the Tsoeneng Landfill (Lesotho). Air quality impact assessments have also been completed for the BCL incinerator (Cape Town), the Ergo Rubber Incinerator and the Ecorevert Pyrolysis Plant.

Cement Manufacturing

Impact assessments for ambient air quality have been completed for the Holcim Alternative Fuels Project (which included the assessment of the cement manufacturing plants at Ulco and Dudfield as well as a proposed blending platform in Roodepoort).

Management Plans

Reneé undertook the quantification of the baseline air quality for the first declared Vaal Triangle Airshed Priority Area. This included the establishment of a comprehensive air pollution emissions inventory, atmospheric dispersion modelling, focusing on impact area "hotspots" and quantifying emission reduction strategies. The management plan was published in 2009 (Government Gazette 32263).

Reneé has also been involved in the Provincial Air Quality Management Plan for the Limpopo Province.

RELEVANT EXPERIENCE (NOISE)

Mining

Reneé has undertaken numerous environmental noise assessments for mining operations. These include environmental noise impact assessments including baseline noise surveys for Balama (Mozambique), Masama Coal (Botswana), Lodestone (Namibia), Prieska (SA), Kolomela (SA) Heuningkranz (SA), Syferfontein (SA), South 32 (SA), Mamatwan and Marula Platinum Mine (SA).

Power Generation

Environmental noise assessments have been completed for numerous Eskom coal fired power station studies in SA including the Kriel Fabric Filter Plant, Kendal ash facility, Medupi ash facility. Apart from Eskom projects, power plant assessments have also been completed in Botswana (Morupule), Kenya (Or Power geothermal power plants), Suriname (EBS power plant) and SA (Richards Bay combined cycle power plant).

Process Operations

Environmental noise assessments have been undertaken for various process operations including waste disposal facilities (Bon Accord in Gauteng), bottling and drink facilities (Imali and Isanti Project in Gauteng) and Smelter (Gamsberg in Northern Cape).

Transport

An environmental noise assessment was completed for the Obetsebi road expansion and flyover project in Ghana.

Gas Pipelines

An environmental noise assessment is currently being undertaken for the Sheberghan gas pipeline in Afghanistan.

Baseline Noise Surveys

Baseline noise surveys have been undertaken for numerous mining and process operation activities (including Raumix quarries and Sibanye Stillwater Platinum Mines (SA)) in support of onsite Environmental Management Programmes.

OTHER EXPERIENCE (2001)

Research for B.Sc Honours degree was part of the "Highveld Boundary Layer Wind" research group and was based on the identification of faulty data from the Majuba Sodar. The project was THRIP funded and was a joint venture with the University of Pretoria, Eskom and Sasol (2001).

EDUCATION

M.Sc Earth Sciences	University of Pretoria, RSA, Cum Laude (2009) Title: *An Air Quality Baseline Assessment for the Vaal Airshed in South Africa*
B.Sc Hons. Earth Sciences	University of Pretoria, RSA, Cum Laude (2001) Environmental Management and Impact Assessments
B.Sc Earth Sciences	University of Pretoria, RSA, (2000) Atmospheric Sciences: Meteorology

ADDITIONAL COURSES

CALMET/CALPUFF	Presented by the University of Johannesburg, RSA (March 2008)
Air Quality Management	Presented by the University of Johannesburg, RSA (March 2006)
ARCINFO	GIMS, Course: Introduction to ARCINFO 7 (2001)

COUNTRIES OF WORK EXPERIENCE

South Africa, Mozambique, Botswana, Ghana, Suriname, Afghanistan, Malawi, Liberia, Kenya, Angola, Democratic Republic of Congo, Lesotho, Namibia, Madagascar, Egypt, Suriname and Iran.

EMPLOYMENT RECORD

January 2002 - Present

Airshed Planning Professionals (Pty) Ltd, (previously known as Environmental Management Services cc until March 2003), Principal Air Quality Scientist, Midrand, South Africa.

2001

University of Pretoria, Demi for the Geography and Geoinformatics department and a research assistant for the Atmospheric Science department, Pretoria, South Africa.

Department of Environmental Affairs and Tourism, assisted in the editing of the Agenda 21 document for the world summit (July 2001), Pretoria, South Africa.

1999 - 2000

The South African Weather Services, vacation work in the research department, Pretoria, South Africa.

CONFERENCE AND WORKSHOP PRESENTATIONS AND PAPERS

- Understanding the Synoptic Systems that lead to Strong Easterly Wind Conditions and High Particulate Matter Concentrations on The West Coast of Namibia, H Liebenberg-Enslin, R von Gruenewaldt, H Rauntenbach and L Burger. National Association for Clean Air (NACA) conference, October 2017.
- Topographical Effects on Predicted Ground Level Concentrations using AERMOD, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2011.
- Emission Factor Performance Assessment for Blasting Operations, R.G. von Gruenewaldt. National Association for Clean Air (NACA) conference, October 2009.
- Vaal Triangle Priority Area Air Quality Management Plan – Baseline Characterisation, R.G. Thomas, H Liebenberg-Enslin, N Walton and M van Nierop. National Association for Clean Air (NACA) conference, October 2007.
- A High-Resolution Diagnostic Wind Field Model for Mesoscale Air Pollution Forecasting, R.G. Thomas, L.W. Burger, and H Rautenbach. National Association for Clean Air (NACA) conference, September 2005.
- Emissions Based Management Tool for Mining Operations, R.G. Thomas and L.W. Burger. National Association for Clean Air (NACA) conference, October 2004.
- An Investigation into the Accuracy of the Majuba Sodar Mixing Layer Heights, R.G. Thomas. Highveld Boundary Layer Wind Conference, November 2002.

LANGUAGES

	Speak	Read	Write
English	Excellent	Excellent	Excellent
Afrikaans	Fair	Fair	Fair

CERTIFICATION

I, the undersigned, certify that to the best of my knowledge and belief, these data correctly describe me, my qualifications, and my experience.

Signature of staff member

24/05/2021

Date (Day / Month / Year)

Full name of staff member: Reneé Georgeinna von Gruenewaldt

Appendix B – Declaration of Independence

SPECIALIST DECLARATION

I, Reneé von Gruenewaldt, hereby declare that:

- I act as the independent specialist in this application.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant.
- I declare that there are no circumstances that may compromise my objectivity in performing such work.
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity.
- I will comply with the Act, Regulations and all other applicable legislation.
- I have not, and will not engage in, conflicting interests in the undertaking of the activity.
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority.
- All the particulars furnished by me in this form are true and correct.
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

21 June 2022

Appendix C – Sound Level Meter Calibration Certificates

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Calibration Laboratory
148
1302

M AND N ACOUSTIC SERVICES (Pty) Ltd
Co. Reg. No. 2012/113298/07 VAT NO: 4300255876 BEE Status: Level 4
P.O. Box 61713, Pierre van Ryneveld, 0045
No. 15, Mustang Avenue
Pierre van Ryneveld, 0045
Tel: 012 689-2007 (076 920 3070) • Fax: 086 211 4690
E-mail: admin@mnacoustics.co.za
Website: www.mnacoustics.co.za

CERTIFICATE OF CONFORMANCE

CERTIFICATE NUMBER	2021-AS-0246
ORGANISATION	AIRSHED PLANNING PROFESSIONALS (PTY) LTD
ORGANISATION ADDRESS	P.O. BOX 5260, HALFWAY HOUSE, 1685
CALIBRATION OF	ACOUSTIC CALIBRATOR
MANUFACTURER	SVANTEK
MODEL NUMBER	SV 33
SERIAL NUMBER	43170
DATE OF CALIBRATION	02 MARCH 2021
RECOMMENDED DUE DATE	--------------------
PAGE NUMBER	PAGE 1 OF 3

This certificate is issued in accordance with the conditions of approval granted by the South African National Accreditation System (SANAS). This Certificate may not be reproduced without the written approval of SANAS and M and N Acoustic Services.

Calibrations performed by this laboratory are in terms of standards, the accuracies of which are traceable to national measuring standards as maintained by NMISA.

The measurement results recorded in this certificate were correct at the time of calibration. The subsequent accuracy will depend on factors such as care, handling, frequency of use and the amount of different users. It is recommended that re-calibration should be performed at an interval, which will ensure that the instrument remains within the desired limits and/or manufacturer's specifications.

The South African National Accreditation System (SANAS) is member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org

Calibrated by:	Authorized/Checked by:	Date of Issue:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	M. NAUDÉ (SANAS TECHNICAL SIGNATORY)	02 MARCH 2021

Director: Marianka Naudé

Conditions under Which M and N Acoustic Services (Pty) Ltd Will Perform Work

In this document, reference to a service of services will include: calibration, measurement analysis or conformance work performed by M and N Acoustics on behalf of the Applicant.

1. Services are carried out at the discretion of M and N Acoustic Services, which reserves the right to decline any application for performance or services when deemed to be outside the scope of services of this Company.
2. Through acceptance of the original quotation, the Applicant agrees to the quoted fee and the conditions state herein. In cases where M and N Acoustic Services has not published the amount of the fee, M and N Acoustic Services will in good faith give estimates of the time and cost of the service based upon its previous experience.
3. Payment is strictly COD, or 30 days from the date of invoice, or as mutually agreed in writing between the Applicant and M and N Acoustic Services before the service is commenced. M and N Acoustic Services retains the right to ask for a deposit for services.
4. All instruments, items of equipment, etc. sent by the Applicant for performance of service shall be delivered and collected at the Applicant's own cost and risk.
5. M and N Acoustic Services cannot guarantee to complete the work within the estimated time and cost but will consult the Applicant of it becomes apparent that either estimate will be exceeded.
6. If a service is not completed because of defects or deficiencies in the item submitted by the applicant, an appropriate reduction in the fee may be allowed depending on the amount of work already performed. The normal practice will be to charge the fee in full.
7. The Applicant hereby consents that the legal liability of M and N Acoustic Services with regard to any damage whatsoever or a mistake made by M and N Acoustic Services in services performed for the Applicant will be limited to the original quoted fee.
8. Regarding certificates and reports:
   - A certificate or report will be furnished to the Applicant on completion of the service.
   - Additional certified copies of certificates, or re-issued certificates will be subjected to an additional fee, as determined on a case by case basis.
   - The values in the issued certificates are correct at the time of calibration. Subsequently the accuracy will depend on such factors as the care exercised in handling and use of the instrument and the frequency of use.
   - Re-calibration should be performed after a period which has been chosen to ensure that the instrument's accuracy remains within the desired limits.

1. PROCEDURE

The UUT was calibrated according to the procedures 1002/P/001 and also to the IEC 60942 specifications for Sound Level Calibrators as well as the manufacturer's specifications.

2. MEASURING EQUIPMENT

Keysight	34461A	Digital Multimeter	MY 53223905
Greysinger	80 CL	Environmental Logger	02304030/1/2
G.R.A.S	42 AP	Piston Phone	256092
G.R.A.S	26 AJ	½" Pre-Amplifier	188476
B&K	2363	Measuring Amplifier	1232647
G.R.A.S	40 AG	½" Microphone	19721
Leader	LDM-170	Distortion Meter	0100240
Svantek	SV 35	Acoustic Calibrator	58106
LG	FC-7015	Universal Counter	00022701
Agilent	34461A	Digital Multimeter	MY 53205694
G.R.A.S	42 AG	Multi-Frequency Calibrator	279025

3. RESULTS

3.1 The following parameters of the Calibrator were calibrated:

Output Level	IEC 60942: Section 5.2.3
Output Frequency	IEC 60942: Section 5.3.3
Selective Distortion	IEC 60942: Section A.4.9

The Calibrator output level was found to be 114,1 dB at 1 000 Hz.
No adjustment was made.

These results were corrected to the ambient condition of 1 013,25 Pa.

Conclusion: The Calibrator complied with the above-specified clauses of the IEC 60942 specification and requirements according to ARP 0109:2014. **Class 1**.

Calibrated by:	*Authorized/Checked by:*
W.S. SIBANYONI *(CALIBRATION TECHNICIAN)*	*M. NAUDE* *(SANAS TECHNICAL SIGNATORY)*

Director: Marianka Naude

4. REMARKS

4.1 The reported expanded uncertainties of measurements are based on a standard uncertainty multiplied by a coverage factor of $k=2$, providing a level of confidence of approximately 95,45 %, the uncertainties of measurements have been estimated in accordance with the principles defined in the GUM (Guide to Uncertainty of Measurement) ISO, Geneva, 1993.

4.2 The environmental conditions were: Temperature: (23 ± 2) °C
Relative Humidity: (50 ± 15) %RH

4.3 Calibration labels bearing cal date, due date (if requested), certificate number and serial number have been affixed to the instrument.

4.4 The above statement of conformance is based on the measurement values obtained, extended by the estimated uncertainty of measurement, being within the appropriate specification limits

4.5 The uncertainty of measurements was estimated as follows:

Acoustic Calibrator: ± 0,19 dB

4.6 The results on this Certificate relates only to the items and parameters calibrated.

------------SECTION 4.5 THE END OF CERTIFICATE-----------

Calibrated by:	Authorized/Checked by:
W.S. SIBANYONI *(CALIBRATION TECHNICIAN)*	*M. NAUDÉ* *(SANAS TECHNICAL SIGNATORY)*

Director: Marianka Naudé

M AND N ACOUSTIC SERVICES (Pty) Ltd

Co. Reg. No: 2012/123238/07 VAT NO: 4300255876 BEE Status: Level 4

P.O. Box 61713, Pierre van Ryneveld, 0045

No. 15, Mustang Avenue
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Tel: 012 689-2007 (076 920 3070) • Fax: 086 211 4690
E-mail: admin@mnacoustics.co.za
Website: www.mnacoustics.co.za

sanas Calibration Laboratory

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1302

CERTIFICATE OF CALIBRATION

CERTIFICATE NUMBER	2021-AS-0250
ORGANISATION	AIRSHED PLANNING PROFESSIONALS (PTY) LTD
ORGANISATION ADRESS	P.O. BOX 5260, HALFWAY HOUSE, 1685
CALIBRATION OF	SOUND & VIBRATION ANALYZER complete with built-in ⅓-OCTAVE/OCTAVE FILTER, ½" PRE-AMPLIFIER and ½" MICROPHONE
MANUFACTURERS	SVANTEK and ACO
MODEL NUMBERS	SVAN 977, SV 12L and 7052E
SERIAL NUMBERS	36183, 40659 and 78692
DATE OF CALIBRATION	01-02 MARCH 2021
RECOMMENDED DUE DATE	-------------------------
PAGE NUMBER	PAGE 1 OF 6

This certificate is issued in accordance with the conditions of approval granted by the South African National Accreditation System (SANAS). This Certificate may not be reproduced without the written approval of SANAS and M and N Acoustic Services.

The measurement results recorded in this certificate were correct at the time of calibration. The subsequent accuracy will depend on factors such as care, handling, frequency of use and the number of different users. It is recommended that re-calibration should be performed at an interval, which will ensure that the instrument remains within the desired limits and/or manufacturer's specifications.

The South African National Accreditation System (SANAS) is member of the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Arrangement (MRA). This arrangement allows for mutual recognition of technical test and calibration data by member accreditation bodies worldwide. For more information on the arrangement please consult www.ilac.org

Calibrated by:	Authorized/Checked by:	Date of Issue:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	M. NAUDÉ (SANAS TECHNICAL SIGNATORY)	03 MARCH 2021

Director: Marianka Naudé

Conditions under Which M and N Acoustic Services (Pty) Ltd Will Perform Work

In this document, reference to a service of services will include: calibration, measurement analysis or conformance work performed by M and N Acoustics on behalf of the Applicant.

1. Services are carried out at the discretion of M and N Acoustic Services, which reserves the right to decline any application for performance or services when deemed to be outside the scope of services of this Company.

2. Through acceptance of the original quotation, the Applicant agrees to the quoted fee and the conditions state herein. In cases where M and N Acoustic Services has not published the amount of the fee, M and N Acoustic Services will in good faith give estimates of the time and cost of the service based upon its previous experience.

3. Payment is strictly COD, or 30 days from the date of invoice, or as mutually agreed in writing between the Applicant and M and N Acoustic Services before the service is commenced. M and N Acoustic Services retains the right to ask for a deposit for services.

4. All instruments, items of equipment, etc. sent by the Applicant for performance of service shall be delivered and collected at the Applicant's own cost and risk.

5. M and N Acoustic Services cannot guarantee to complete the work within the estimated time and cost but will consult the Applicant of it becomes apparent that either estimate will be exceeded.

6. If a service is not completed because of defects or deficiencies in the item submitted by the applicant, an appropriate reduction in the fee may be allowed depending on the amount of work already performed. The normal practice will be to charge the fee in full.

7. The Applicant hereby consents that the legal liability of M and N Acoustic Services with regard to any damage whatsoever or a mistake made by M and N Acoustic Services in services performed for the Applicant will be limited to the original quoted fee.

8. Regarding certificates and reports:

   - A certificate or report will be furnished to the Applicant on completion of the service.
   - Additional certified copies of certificates, or re-issued certificates will be subjected to an additional fee, as determined on a case by case basis.
   - The values in the issued certificates are correct at the time of calibration. Subsequently the accuracy will depend on such factors as the care exercised in handling and use of the instrument and the frequency of use.
   - Re-calibration should be performed after a period which has been chosen to ensure that the instrument's accuracy remains within the desired limits.

1. PROCEDURE

The Integrating Sound Level Meter was calibrated according to procedure 1002/P/013 and to the IEC 61672-3:2006 specifications as well as the manufacturer's specifications.

The ½" Microphone was calibrated according to procedure 1002/P/002 and 1002/P/011 as well as the manufacturer's specifications.

The ⅓-Octave/Octave Filter was calibrated according to procedure 1002/P/008 and to the IEC 61260 specification as well as the manufacturer's specifications.

2. MEASURING EQUIPMENT

JFW	50BR-022	50 Ohm Step Attenuator	4610290708
Agilent	33522A	Function Generator	MY 50005443
Agilent	34461A	Digital Multimeter	MY 53224004
Onset	UX100-011	Environmental Logger	2047747
Majortech	MT669	Environmental Logger	150828469
Svantek	SV 35	Acoustical Calibrator	58106
Keysight	34461A	Digital Multimeter	MY 53223905
G.R.A.S	42 AP	Piston Phone	256092
G.R.A.S	26 AJ	½" Pre-Amplifier	188476
G.R.A.S	40 AG	½" Microphone	19721
B&K	4226	Multi-Functional Calibrator	3081642
Greysinger	80 CL	Data Logger	02304030/1/2
Gems	3500B0001A01B000	Pressure Sensor	1606-0204475
B&K	2829	4-Ch Microphone Power Supply	2329283

Calibrations performed by this laboratory are in terms of standards, the accuracies of which are traceable to national measuring standards as maintained by NMISA.

Calibrated by:	Authorized/Checked by:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	M. NAUDÉ (SANAS TECHNICAL SIGNATORY)

Director: Marianka Naudé

3. RESULTS - ACCORDING TO THE IEC 61672-3: 2006:

3.1 The following parameters of the Integrating Sound Level Meter were calibrated:

Parameter	Specification	Uncertainty of Measurement in dB
Calibration Check Frequency at 114,0 dB at 1 000 Hz at Nominal Range: High	IEC 61672-3: Clause 9	± 0,3
Self-Generated Noise: A-Weighted with Microphone 37,7 dB A-Weighted Electrical 1,1 dB C-Weighted Electrical 0,0 dB Z-Weighted Electrical 3,7 dB B-Weighted Electrical - 0,2 dB	IEC 61672-3: Clause 10	-------
Level Linearity at 8 000 Hz Nominal Range: High Reference Level at 114,0 dB: (59,3 dB to 148,9 dB)	IEC 61672-3: Clause: 14	± 0,3
Level Range Control at 1 000 Hz Reference Level at 114,0 dB Nominal Range: High Low Range	IEC 61672-3: Clause: 15	± 0,3
Frequency and Time Weightings at 1 000 Hz at 114,0 dB	IEC 61672-3: Clause 13	± 0,3
Tone Burst Response (Max. Fast, Max. Slow, LA_{eq} and SEL)	IEC 61672-3: Clause 16	± 0,3

Calibrated by:	Authorized/Checked by:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	M. NAUDE (SANAS TECHNICAL SIGNATORY)

Director: Marianka Naudé

Parameter	Specification	Uncertainty of Measurement in dB
A-Weighting Network (31,5 to 20 000) Hz	IEC 61672-3: Clause 12	± 0,3
C-Weighting Network (31,5 to 20 000) Hz	IEC 61672-3: Clause 12	± 0,3
Z- Weighting Network (31,5 to 20 000) Hz	IEC 61672-3: Clause 12	± 0,3
B- Weighting Network (31,5 to 20 000) Hz	IEC 61672-3: Clause 12	± 0,3
Peak, C Low Peak Range	IEC 61672-3: Clause 17	± 0,3

Conclusion: The Integrating Sound Level Meter complied with the above-specified clauses of the IEC 61672-3:2006 specifications and requirements according to ARP 0109:2014. **Class 1.**

3.2 The following parameters of the built-in ⅓-Octave/Octave Filter were calibrated:

Octave Frequency Response (31,5 to 16 000) Hz	IEC 61260: Sections 4.7 & 5.6
⅓-Octave Frequency response (25 to 20 000) Hz	IEC 61260: Sections 4.7 & 5.6

The uncertainty of measurement was estimated as follows: ± 0,3 dB

Conclusion: The built-in Octave Filter complied with the above-specified clauses of the IEC 61260 specification, **Class 1.**

Calibrated by:	Authorized/Checked by:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	*M. NAUDE (SANAS TECHNICAL SIGNATORY)*

Director: Marianka Naudé

3.3 The following parameters of the ½" Microphone were calibrated and the results were corrected to the ambient condition of 1 013,25 mBar:

Output Sensitivity at 250 Hz at 94,0 dB
Frequency Response (31,5 to 16 000) Hz

The uncertainty of measurements was estimated as follows: ± 0,3 dB

Conclusion: The parameters measured for the ½" Microphone, complied with the manufacturer's specification.

3.4 The ½" Microphone was calibrated Electroacoustic according to Clause 12 of IEC 61672-3: 2006 complete with Integrating Sound Level Meter and Svantek SV 12L ½" Pre-amplifier Serial No: 25686, free-field corrections were taken into consideration and the results were corrected to the ambient condition of 1 013,25 mBar:

FREQUENCY (Hz)	CALCULATED EXPECTED VALUE (dB)	MEASURED VALUE (dB)	DEVIATION (dB)	UoM (dB)
1 000 (Ref)	114,1	114,1	0,0	± 0,3
31,5	111,3	111,2	- 0,1	± 0,3
63	113,4	113,3	- 0,1	± 0,3
125	113,9	113,9	0,0	± 0,3
250	114,1	114,0	- 0,1	± 0,3
500	114,0	114,0	0,0	± 0,3
1 000	114,1	114,1	0,0	± 0,3
2 000	113,9	113,9	0,0	± 0,3
4 000	113,4	113,5	+ 0,1	± 0,3
8 000	109,4	109,2	- 0,2	± 0,3
12 500	106,5	106,9	+ 0,4	± 0,3
16 000	103,3	104,0	+ 0,7	± 0,3

Calibrated by:	Authorized/Checked by:
W.S. SIBANYONI (CALIBRATION TECHNICIAN)	*M. NAUDE (SANAS TECHNICAL SIGNATORY)*

Director: Marianka Naudé

4. REMARKS

4.1 The reported expanded uncertainties of measurements are based on a standard uncertainty multiplied by a coverage factor of $k=2$, providing a level of confidence of approximately 95,45 %, the uncertainties of measurements have been estimated in accordance with the principles defined in the GUM (Guide to Uncertainty of Measurement) ISO, Geneva, 1993

4.2 The environmental conditions during calibration of items in section 3 were:
Temperature: (23 ± 2) °C
Relative Humidity: (50 ± 15) %RH

4.3 Calibration labels bearing cal date, due date (if requested), certificate number and serial number have been affixed to the instrument.

4.4 The above statement of conformance is based on the measurement values obtained, extended by the estimated uncertainty of measurement, being within the appropriate specification limits

4.5 The microphone's frequency range determines the useful frequency range of the sound level meter and vice versa.

4.6 The results on this Certificate relates only to the items and parameters calibrated.

4.7 Abbreviation:
UoM = Uncertainty of Measurement

------------SECTION 4.7 THE END OF CERTIFICATE-----------

Calibrated by:	Authorized/Checked by:
W.S. SIBANYONI *(CALIBRATION TECHNICIAN)*	*M. NAUDÉ* *(SANAS TECHNICAL SIGNATORY)*

Director: Marianka Naudé

Appendix D – Survey Site Photos

Facing north

Facing east

Facing south

Facing west

Figure D-1: Photographs of environmental noise survey Site L2

Facing north

Facing east

Facing south

Facing west

Figure D-2: Photographs of environmental noise survey Site L1

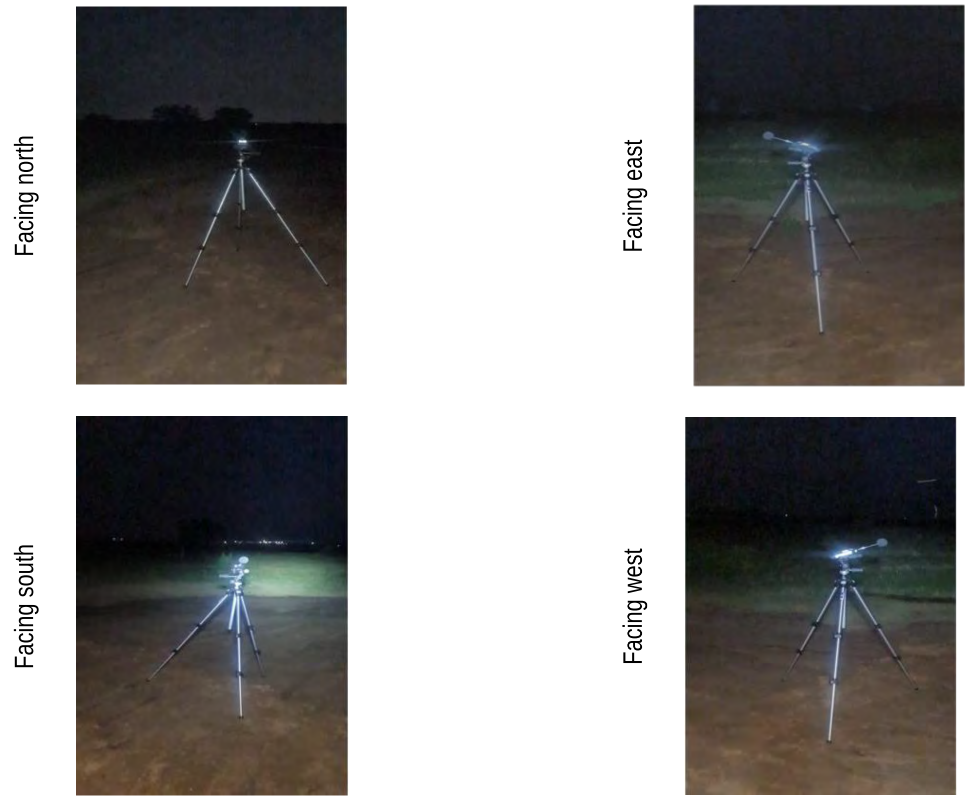


Figure D-3: Photographs of environmental noise survey Site L3

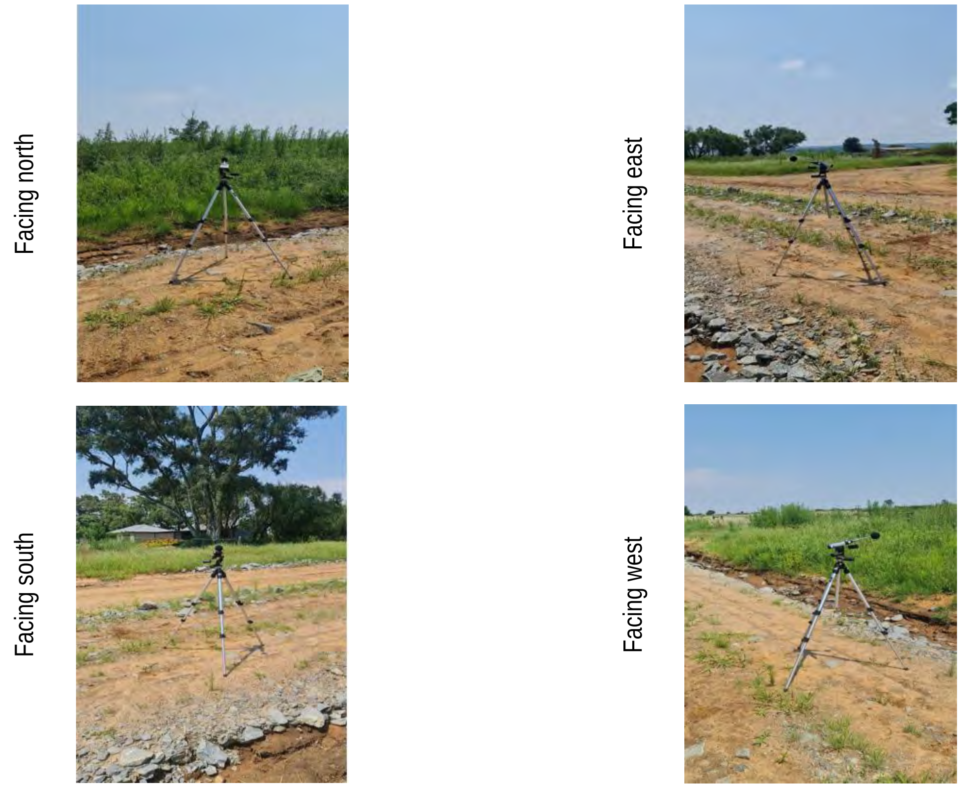


Figure D-4: Photographs of environmental noise survey Site S1

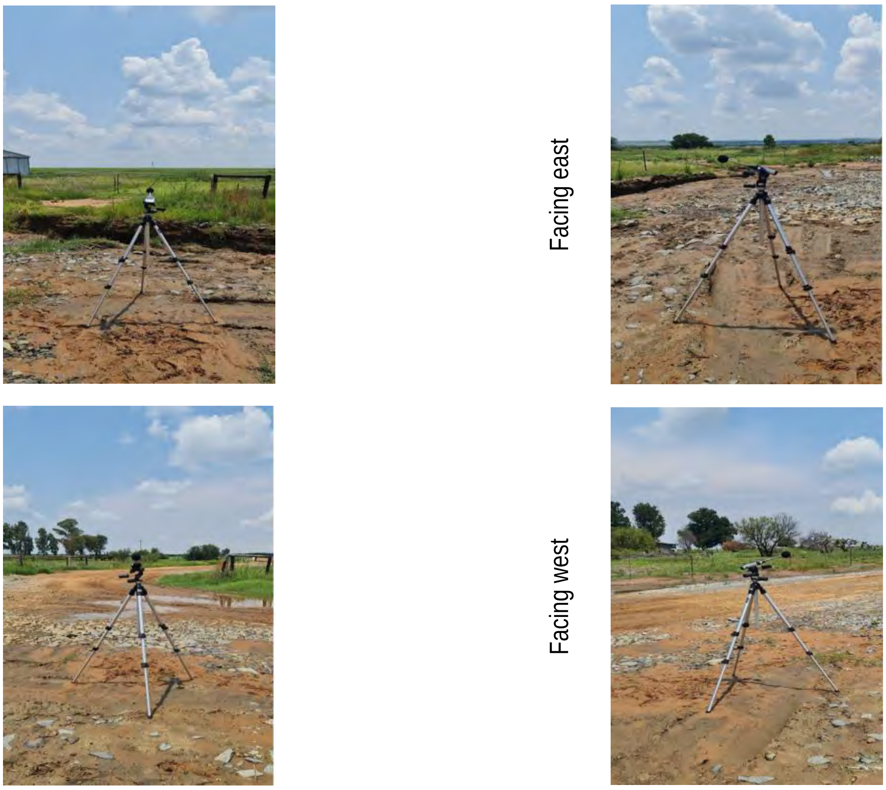


Figure D-5: Photographs of environmental noise survey Site S2

Figure D-6: Photographs of environmental noise survey Site S3

Facing north

Facing east

Facing south

Facing west

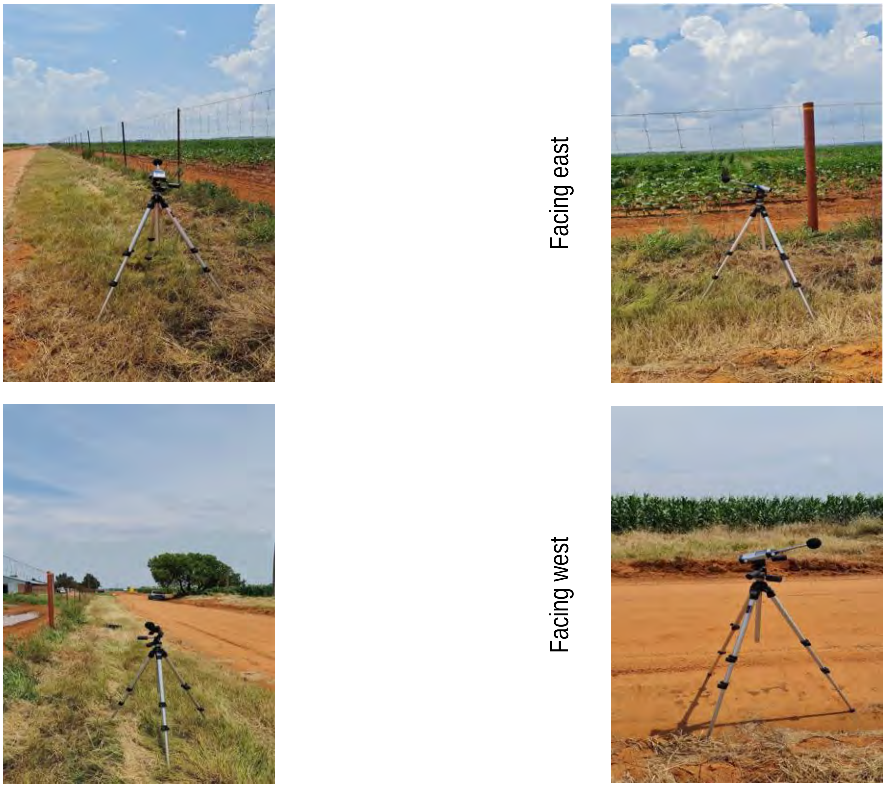


Figure D-7: Photographs of environmental noise survey Site S6

Facing north

Facing east

Facing south

Facing west

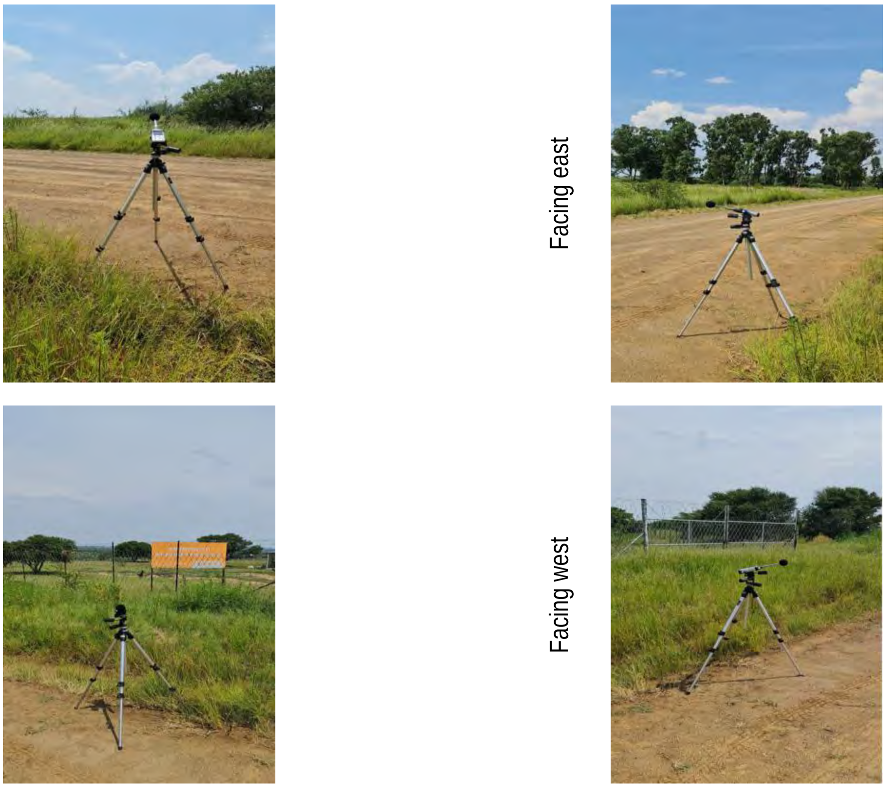


Figure D-8: Photographs of environmental noise survey Site S7

Facing north
Facing east
Facing south
Facing west

Figure D-9: Photographs of environmental noise survey Site S8

Facing north
Facing east
Facing south
Facing west

Figure D-10: Photographs of environmental noise survey Site S9

Facing north

Facing east

Facing south

Facing west

Figure D-11: Photographs of environmental noise survey Site S10

Facing north

Facing east

Facing south

Facing west

Figure D-12: Photographs of environmental noise survey Site S11

Facing north

Facing east

WFacing south

Facing west

Figure D-13: Photographs of environmental noise survey Site S12

Appendix E – Time-series, Statistical, and Frequency Spectrum Results

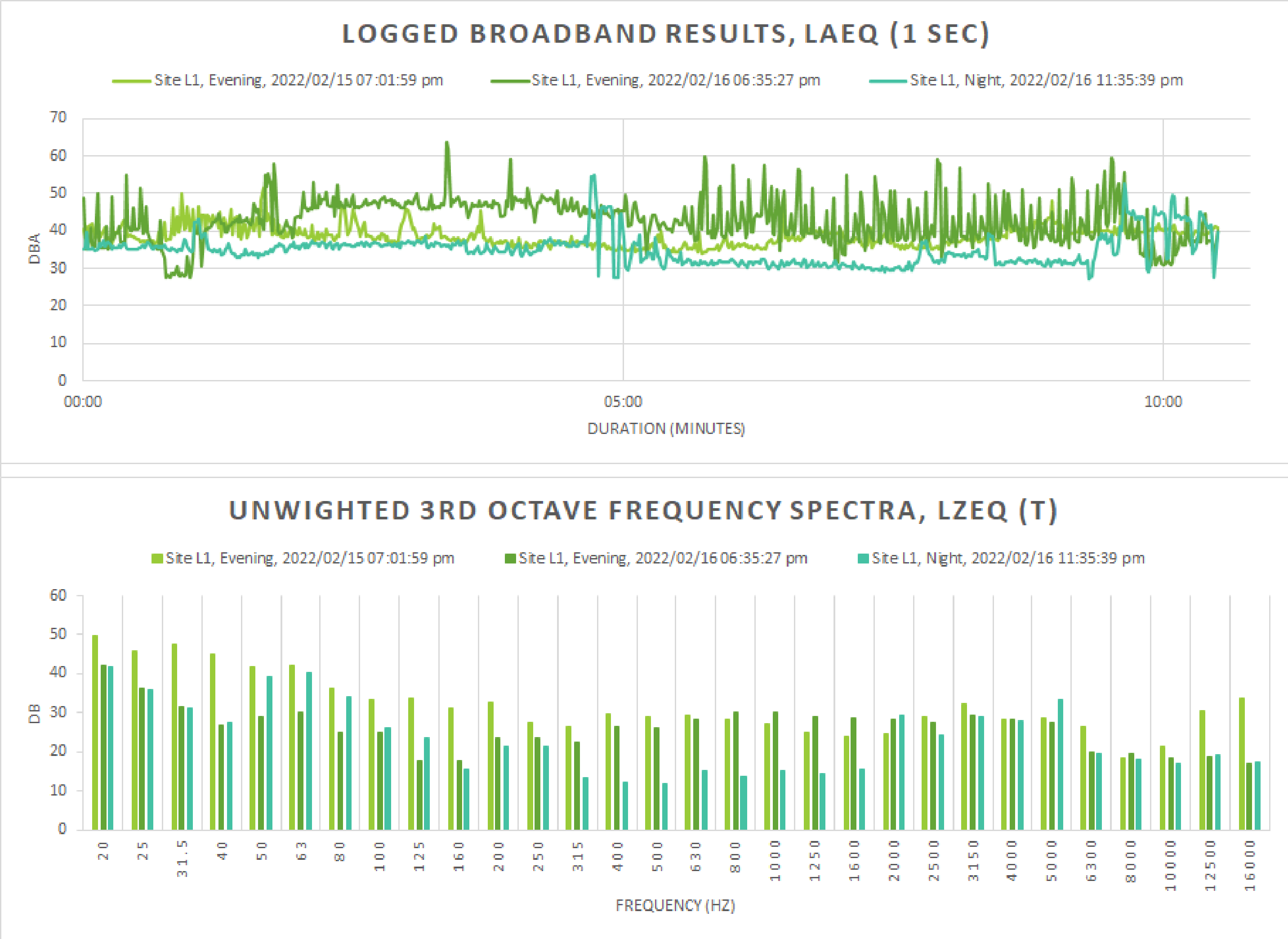


Figure E-1: Detailed day- and night-time survey results for Site L1

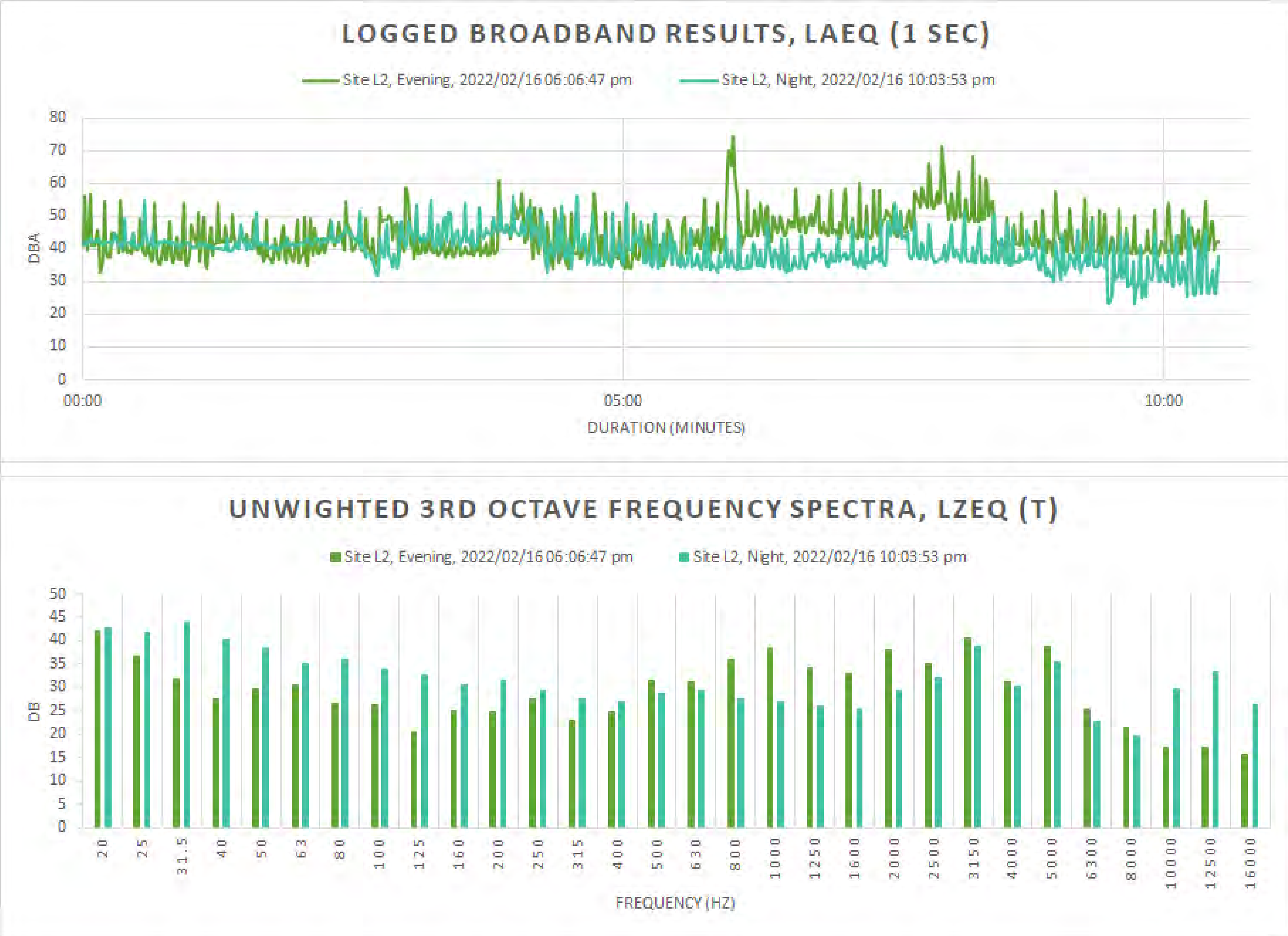
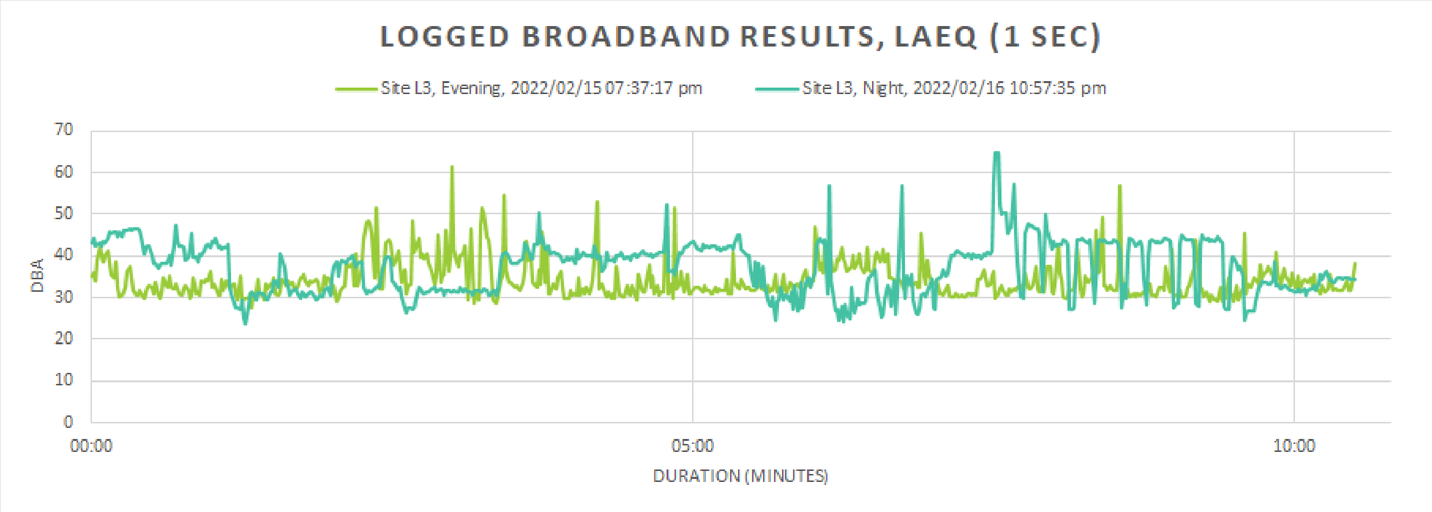


Figure E-2: Detailed day- and night-time survey results for Site L2



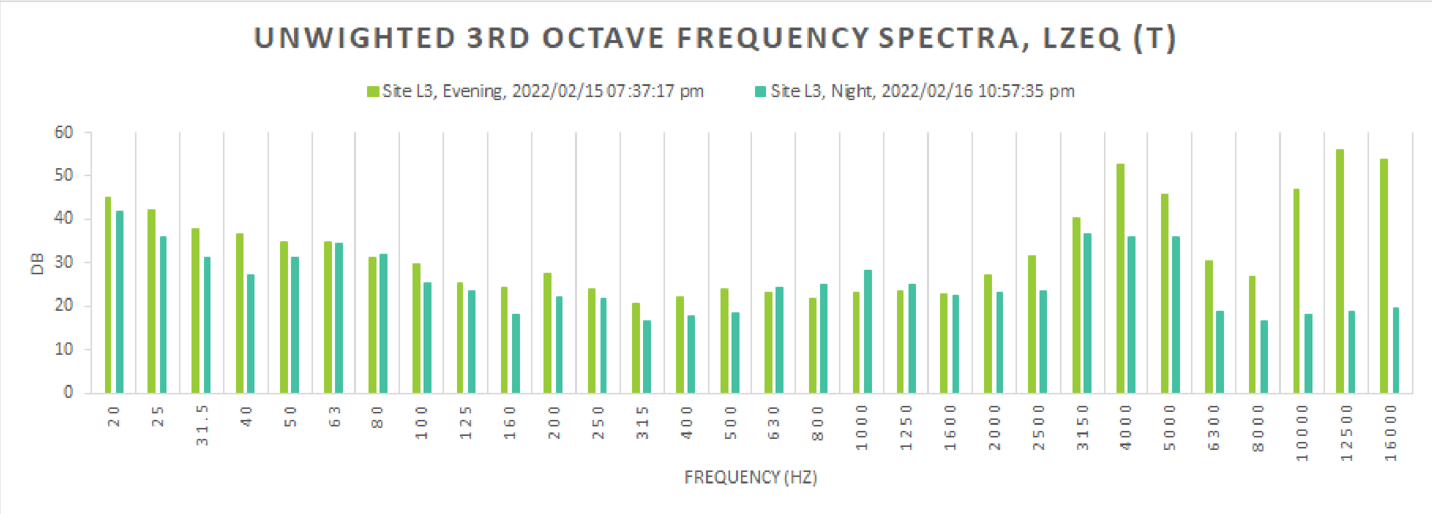
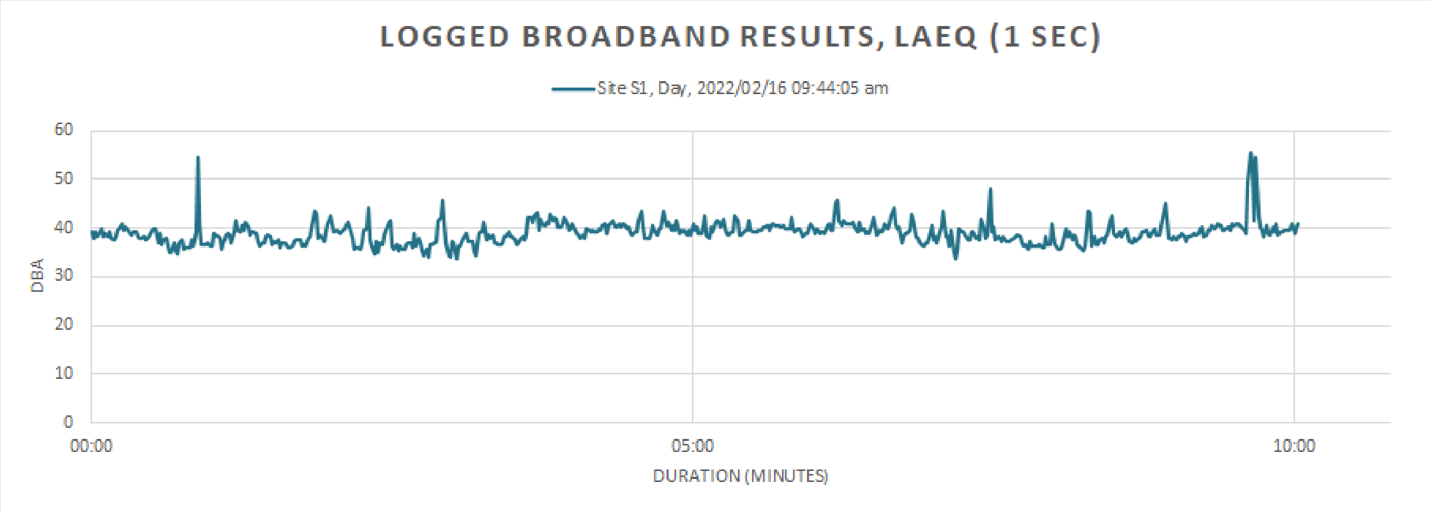


Figure E-3: Detailed day- and night-time survey results for Site L3



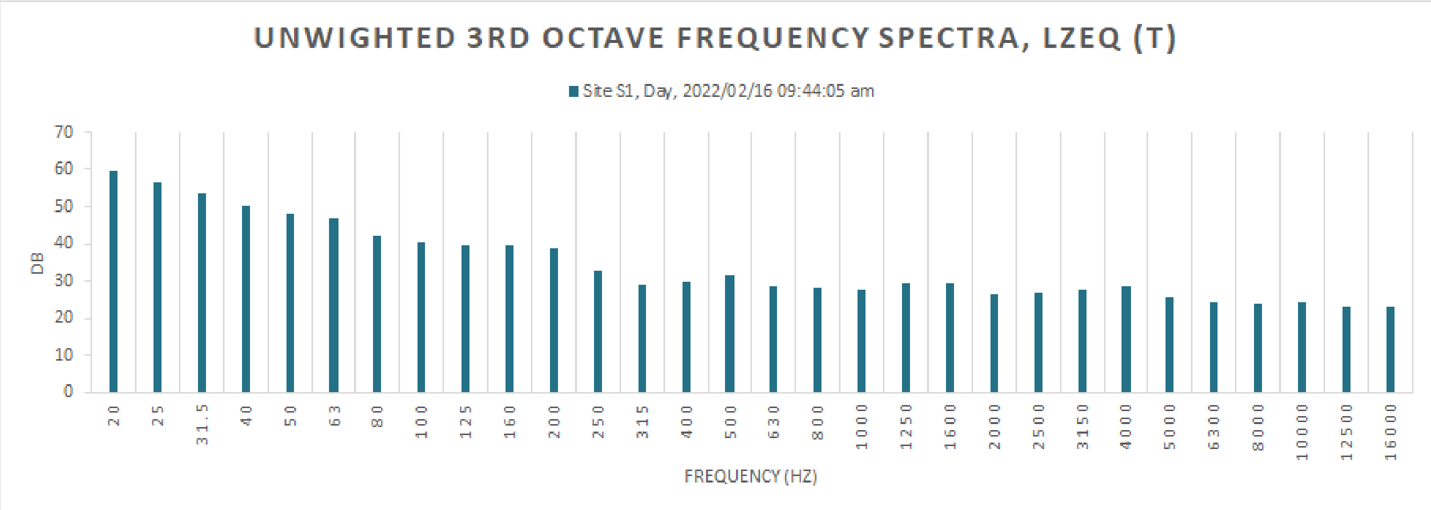


Figure E-4: Detailed day-time survey results for Site S1

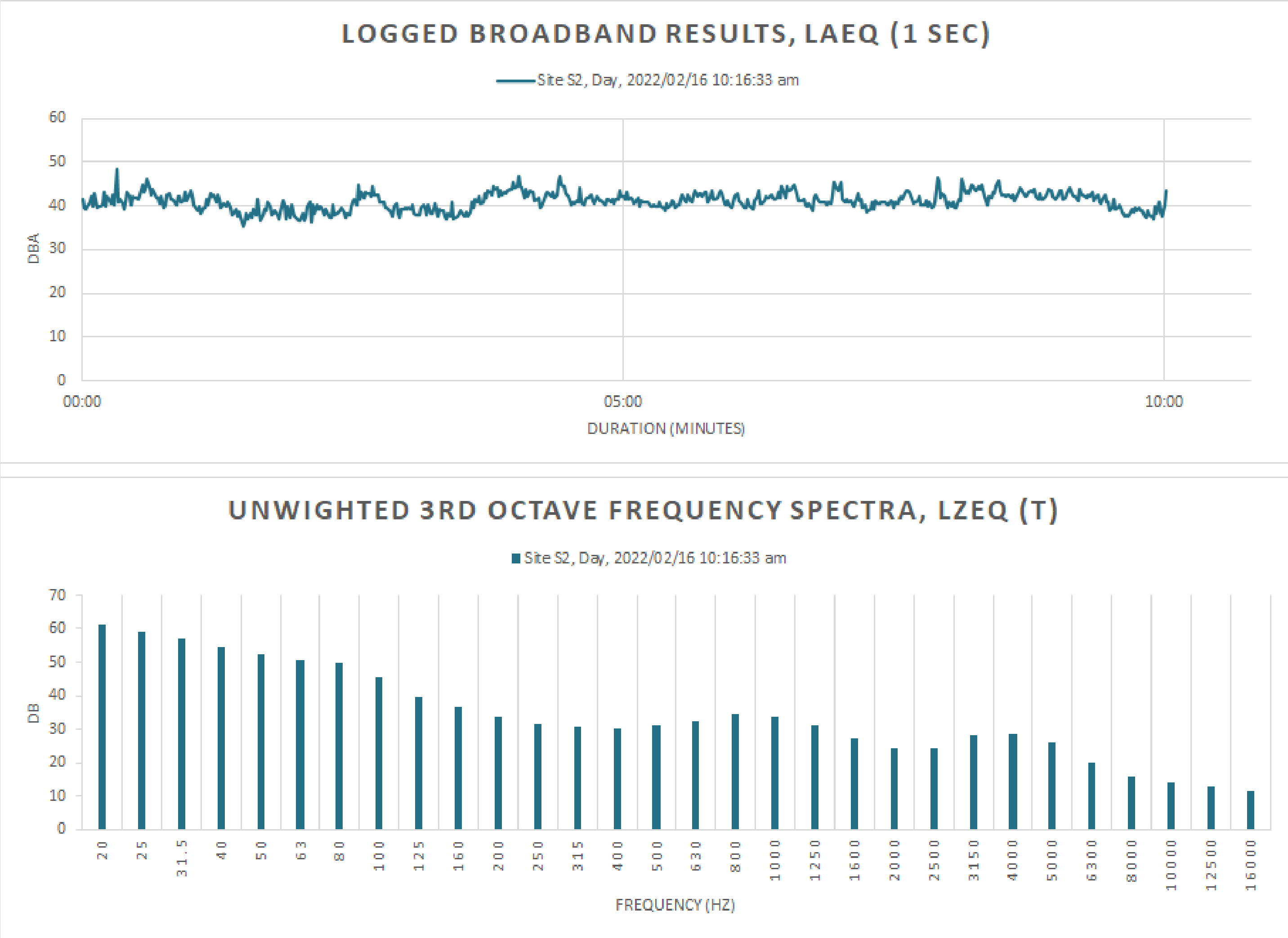


Figure E-5: Detailed day-time survey results for Site S2

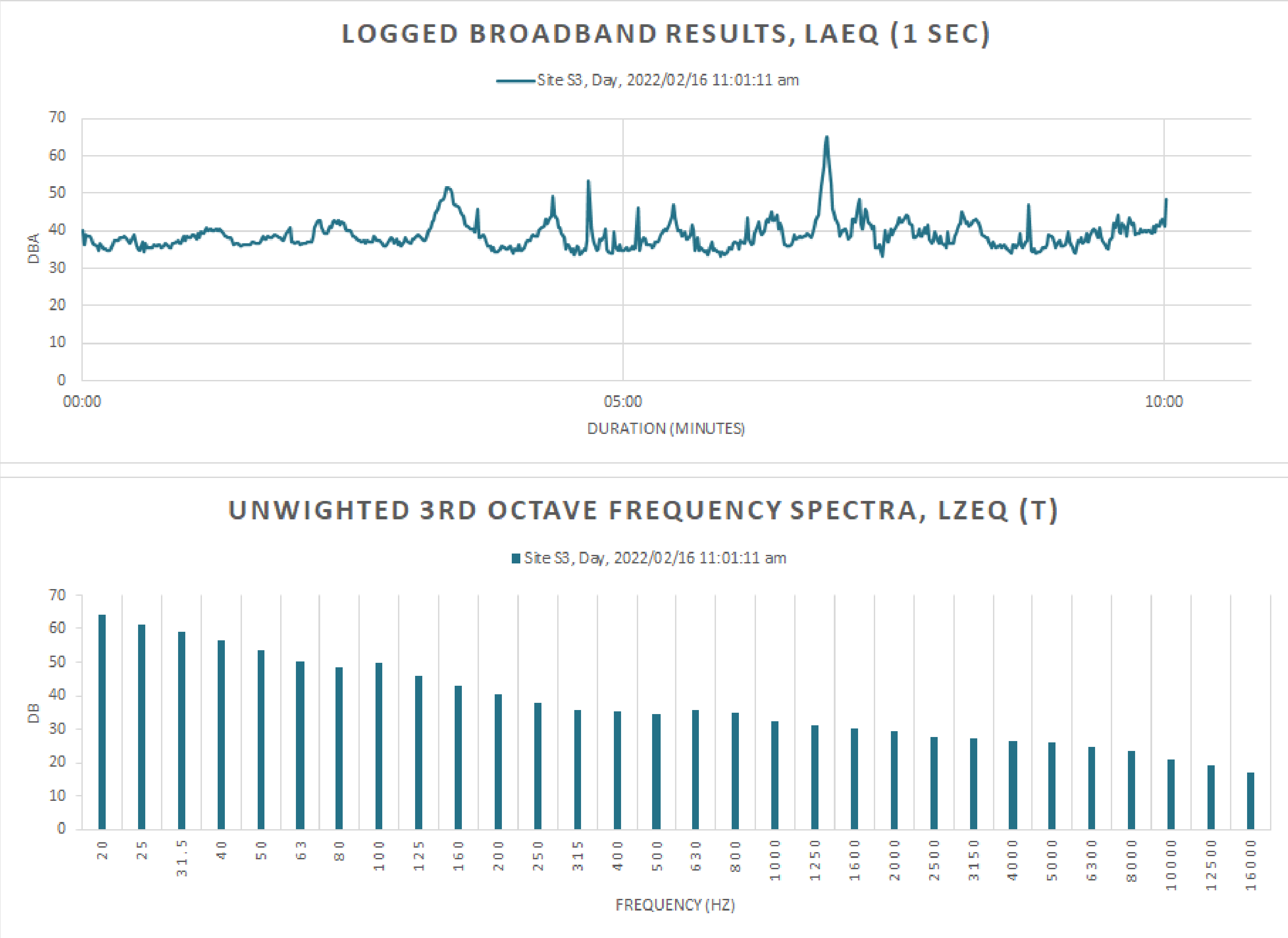


Figure E-6: Detailed day-time survey results for Site S3

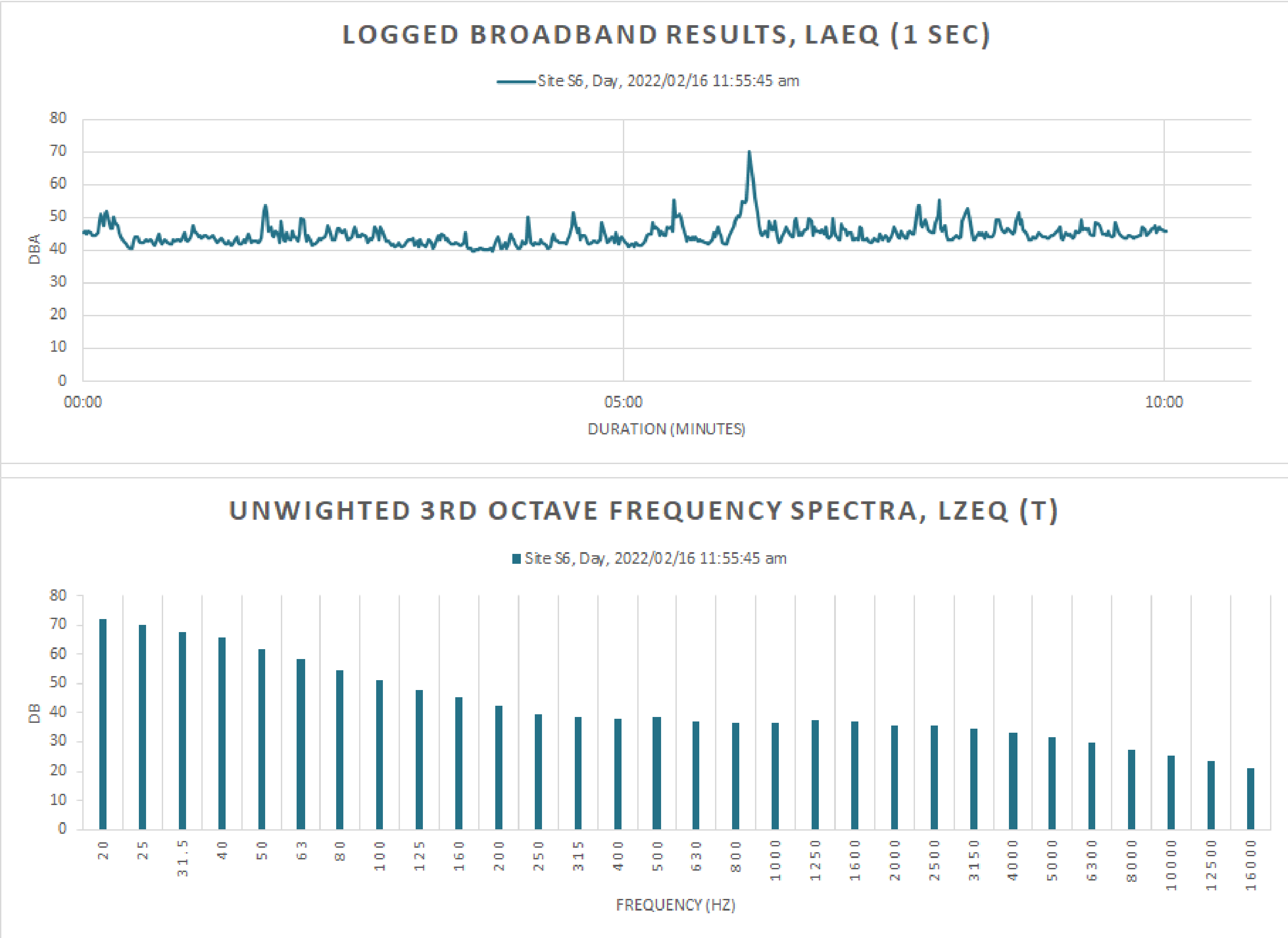
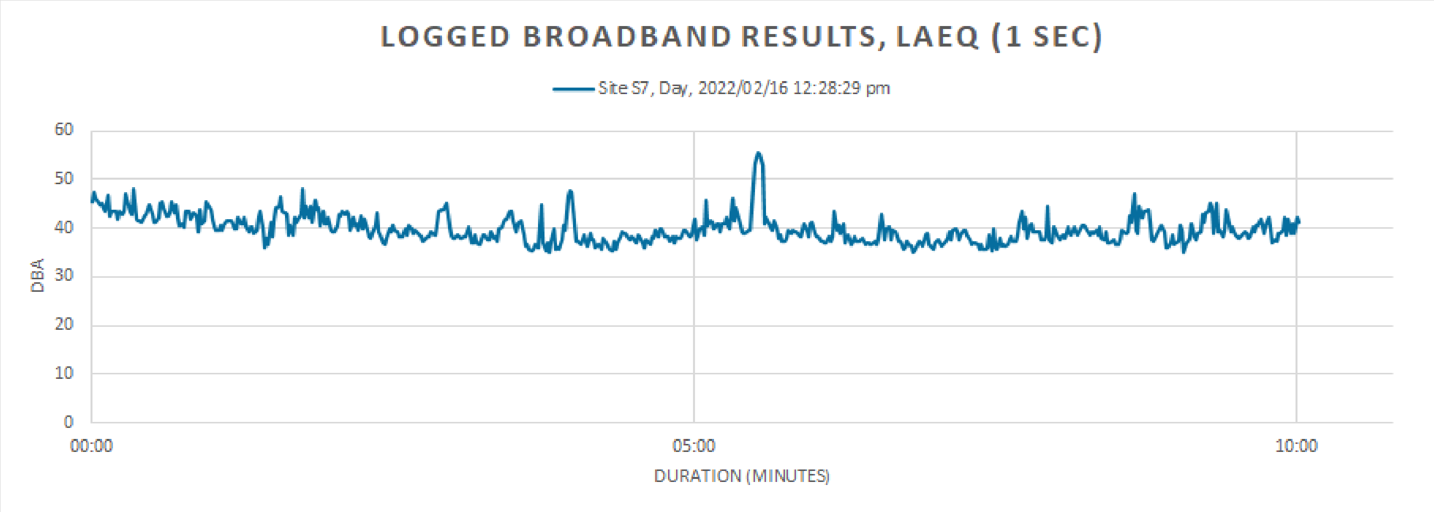


Figure E-7: Detailed day-time survey results for Site S6



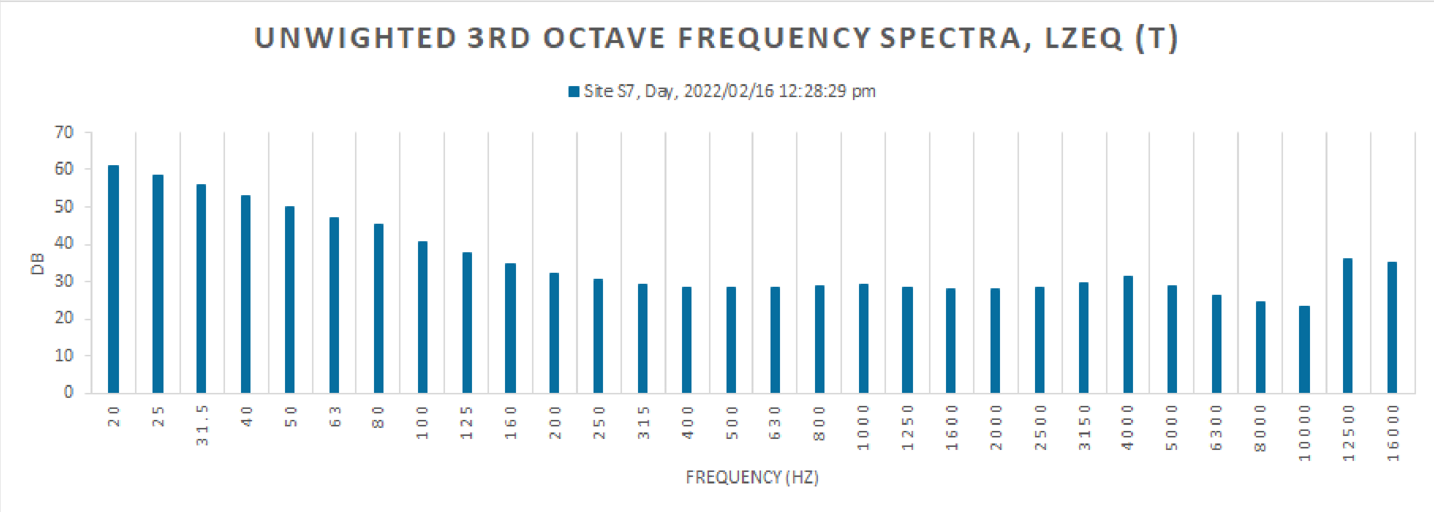
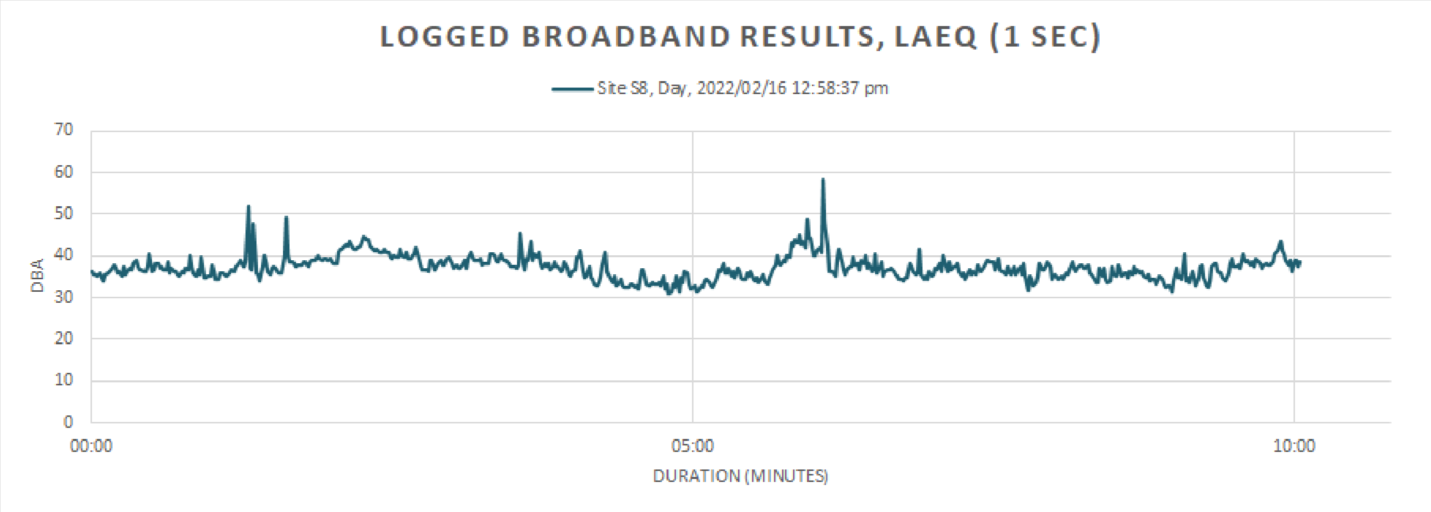


Figure E-8: Detailed day-time survey results for Site S7



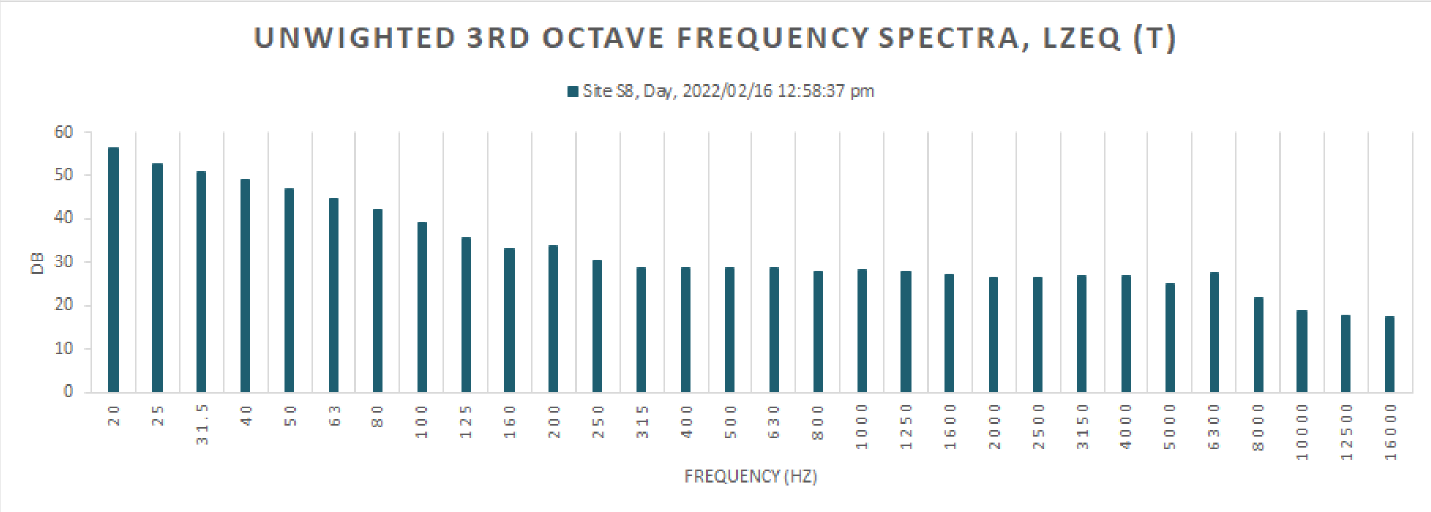


Figure E-9: Detailed day-time survey results for Site S8

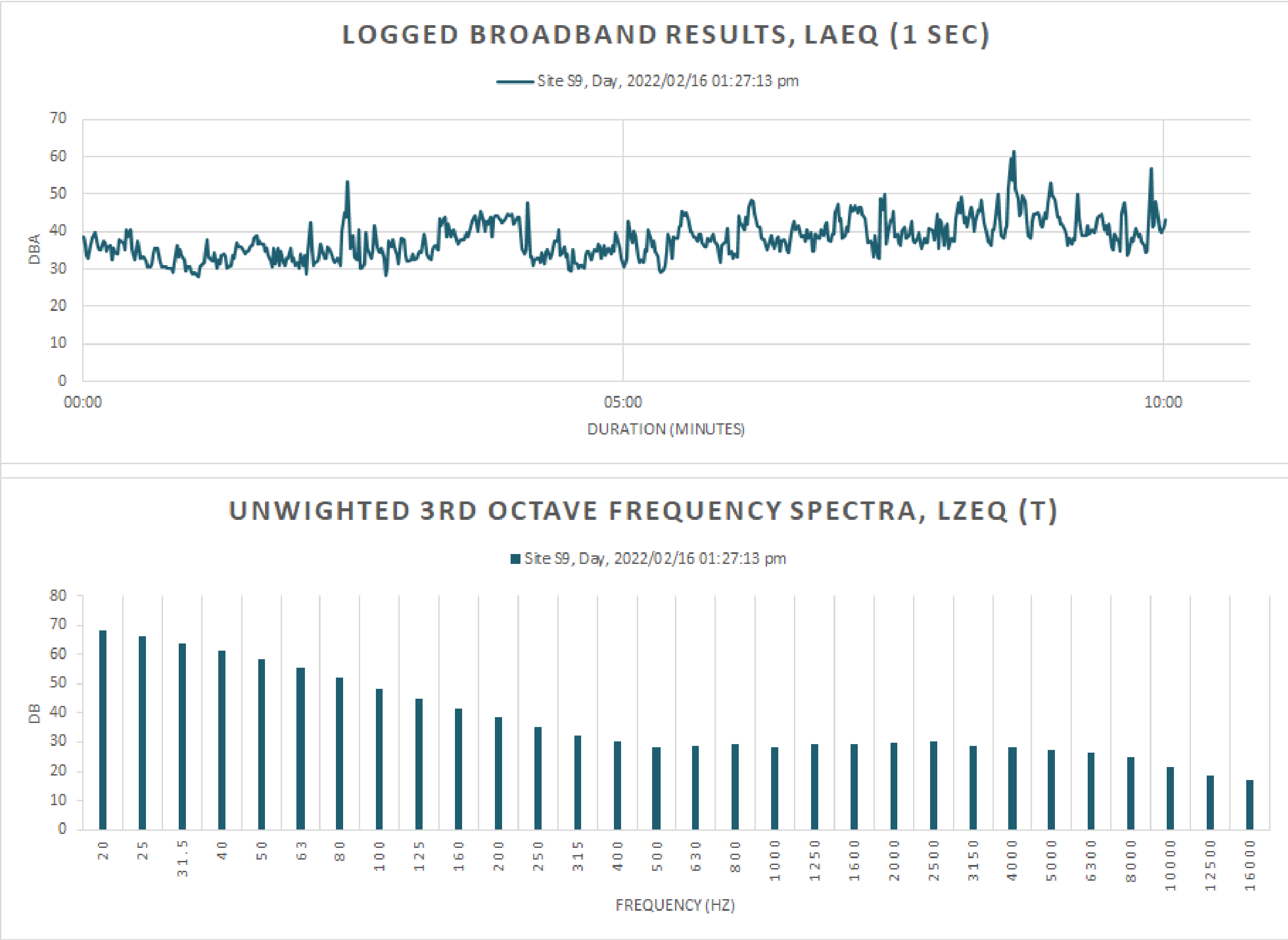


Figure E-10: Detailed day-time survey results for Site S9

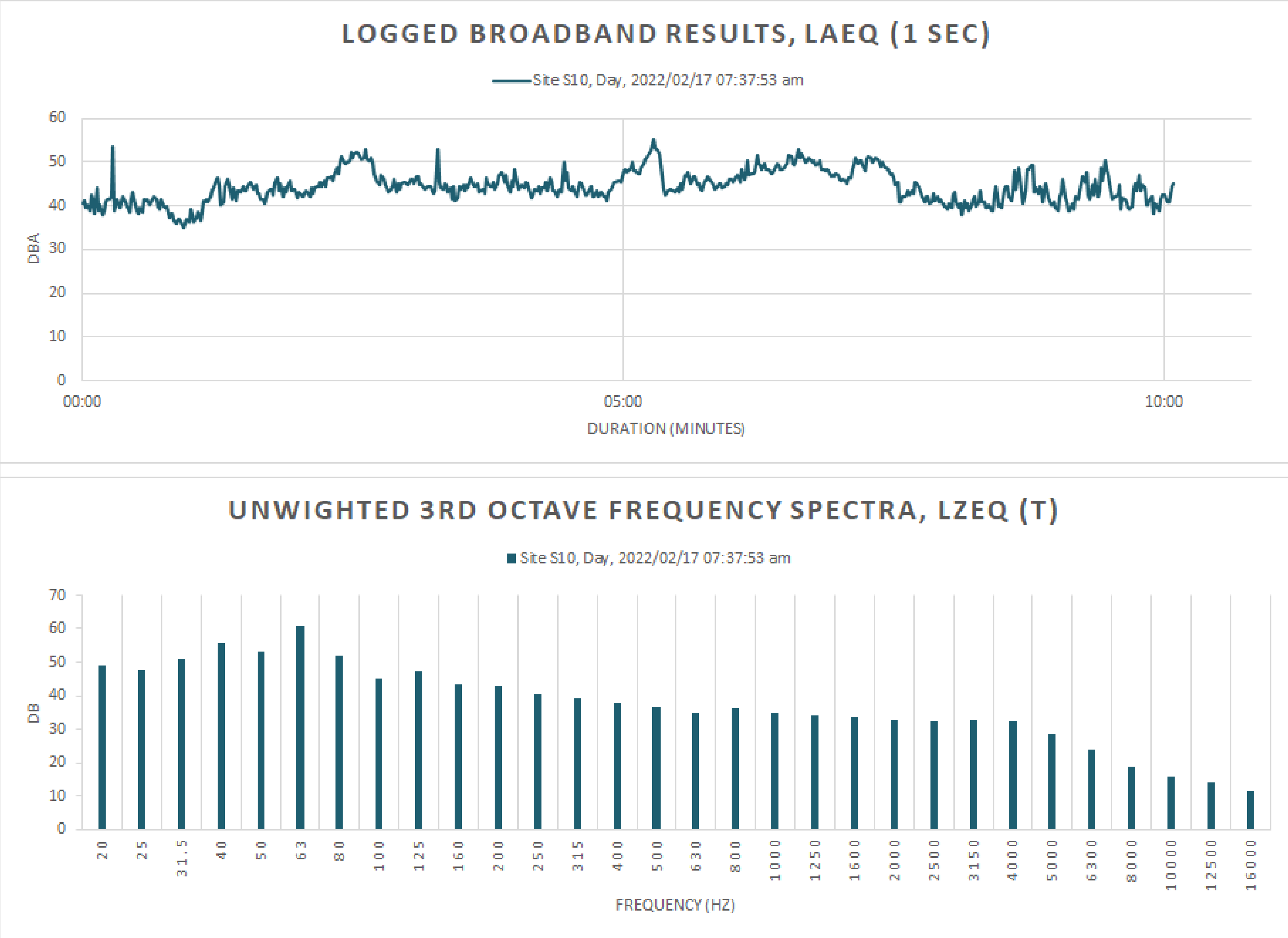
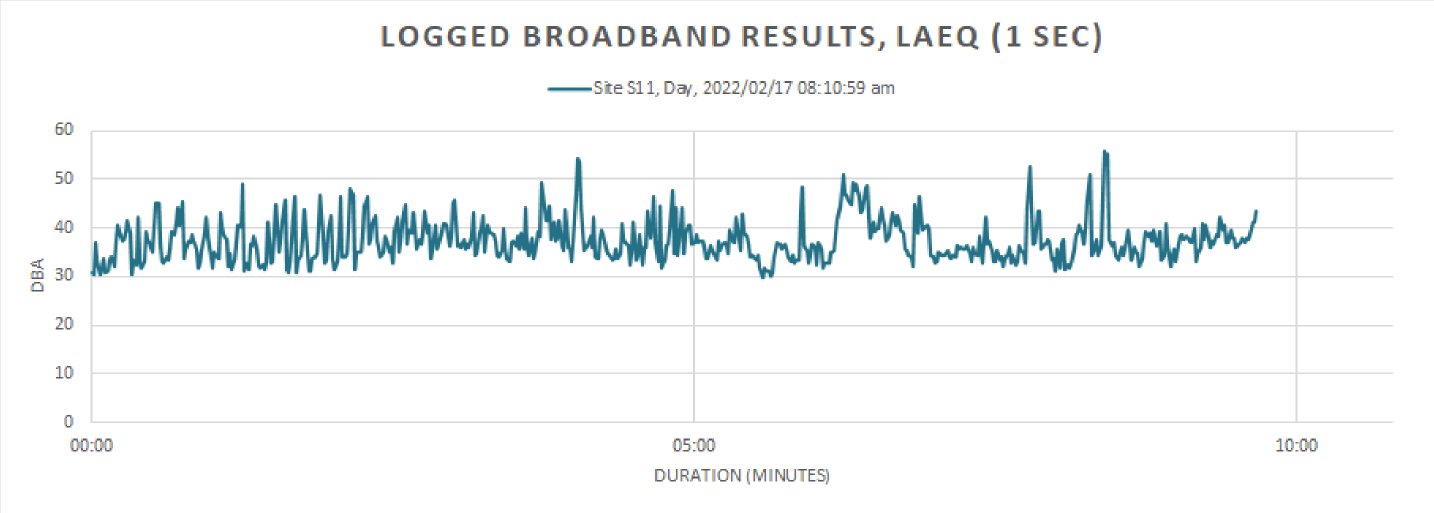


Figure E-11: Detailed day-time survey results for Site S10



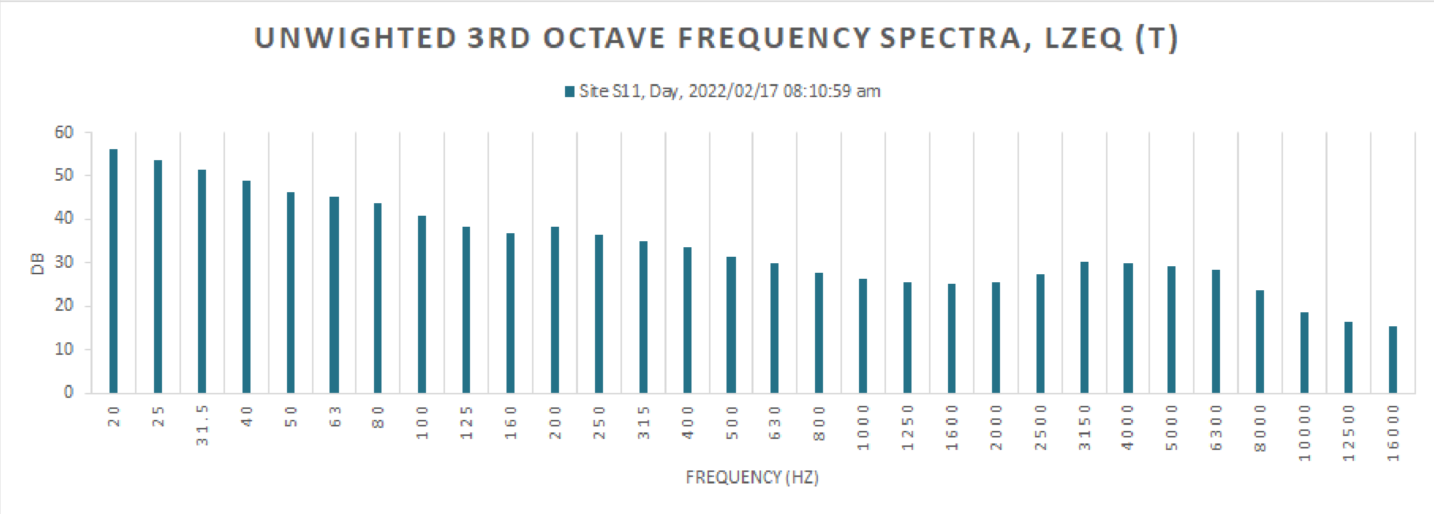
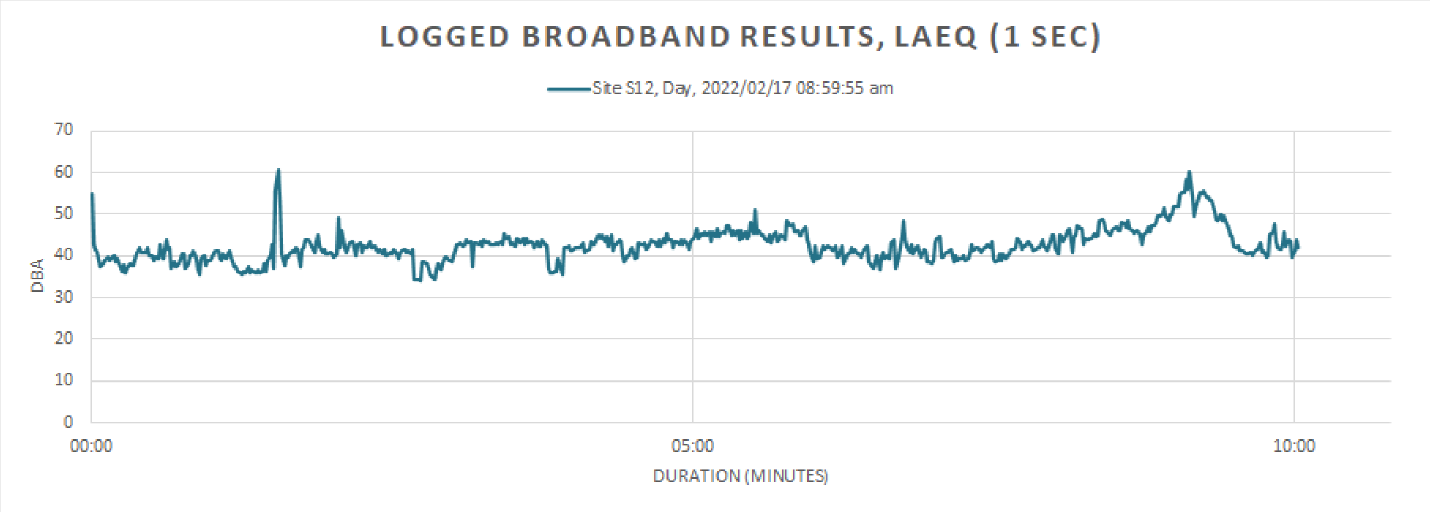


Figure E-12: Detailed day-time survey results for Site S11



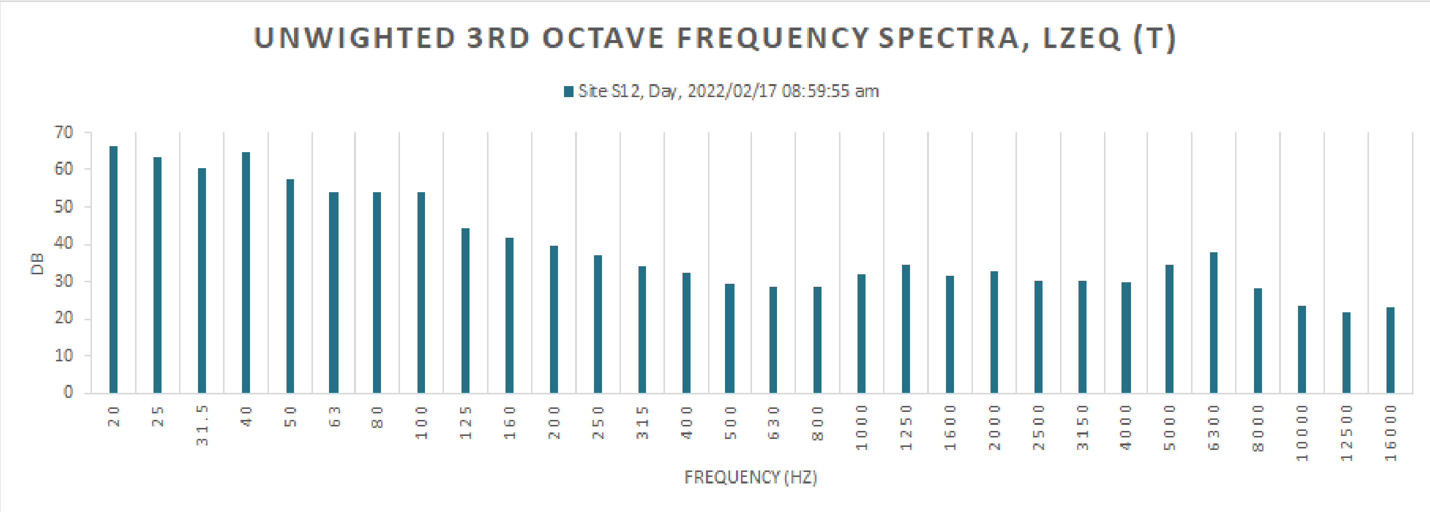


Figure E-13: Detailed day-time survey results for Site S12

Appendix F – Impact Significance Rating Methodology

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition, other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

Determination of Environmental Risk:

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER). The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \underline{(E+D+M+R)} \times N$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table F-1.

Table F-1: Criteria for determining impact consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or

Aspect	Score	Definition
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/scored as per Table F-2.

Table F-2: Probability scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur),

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

$$ER = C \times P$$

Table F-3: Determination of environmental risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table F-4.

Table F-4: Significance classes

Environmental Risk Score	
Value	Description
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

Impact Prioritisation:

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition, it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision-making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table F-5: Criteria for determining prioritisation

Public response (PR)	Low (1)	Issue not raised in public response.
	Medium (2)	Issue has received a meaningful and justifiable public response.
	High (3)	Issue has received an intense meaningful and justifiable public response.
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table F-5. The impact priority is therefore determined as follows:

$$\text{Priority} = PR + CI + LR$$

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (refer to Table F-6).

Table F-6: Determination of prioritisation factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table F-7: Final environmental significance rating

Environmental Significance Rating	
Value	Description
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).

Tetra4 Cluster 2 Gas Production Project

Social Impact Assessment

Prepared by:

Equispectives Research & Consulting Services

Contact person: Dr Ilse Aucamp

Prepared for:
EIMS

September 2022

Executive Summary

The purpose of this document is to provide a baseline description of the receiving socio-economic environment and to identify social impacts associated with the expansion of the Tetra4 natural gas operations project.

The receiving environment is located in the Masilonyana and Matjhabeng Local Municipalities that are located in the Lejweleputswa District Municipality in the Free State Province. The closest towns are Welkom, Virginia and Theunissen. The economy of the district relies heavily on the gold mining sector. Agriculture is also one of the key drivers of the economy.

The Cluster 1 project is in the process of being implemented. The proposed Cluster 2 project will impact on high quality agricultural soil which is used to grow crops that contribute to food security in South Africa. One of the most significant potential social impacts associated with the proposed project is the potential impacts on livelihoods of the farming community. There are high levels of uncertainty about exactly how the Cluster 2 project will unfold. Farmers fear that their land rights and property values will be affected. The project will require access to farms, and because of the current socio-political issues in South Africa, this is a sensitive matter. Farmers are concerned about the impact of the Cluster 2 project on their existing way of life, and on the infrastructure on their farms. Although they are appreciative of Tetra4's efforts to communicate with them, there has been instances where the communication was insufficient, of where some of the Tetra4 staff have not followed procedures that was agreed to.

A number of stakeholder groups will be affected by the proposed project, and the most affected groups are the farmers and farm workers. Although the Tetra4 project will have a positive economic impact in South Africa, the direct benefit for the local communities is limited. The job creation benefits, both primary and secondary are not significant. Therefore, it is of utmost importance that the local social impacts must be managed and monitored to the best of Tetra4's ability, since the parties who pay the social cost of the development will not be beneficiaries of the development.

Based on the findings of this study, the following key recommendations are made:

- There is a possibility that Tetra4's activities will cause economic displacement for some of the affected farmers. The actual impact on their livelihoods must be assessed by an agricultural economist and compensation must be done according to international best practice;
- There are several questions from the landowners that Tetra4 should respond to in writing before any contracting can proceed. These questions are related to timeframes and the construction phase;
- The impacts of servitudes on the land value of the affected properties must be considered and mitigated by means of negotiation. If the negotiation process is unsuccessful, it must be arbitrated by a lawyer with knowledge about environmental law, the MPRDA and property law. This should be a last resort;
- Farm safety must be a priority and the landowners and Tetra must agree on security measures;
- Tetra4 must consult with landowners about any new work or potential changes that may take place on their properties;
- Protocols on farm access, compensation, communication, and road maintenance must be agreed upon and be in place before construction commences. The affected landowners must have input in the development of these protocols;
- A grievance mechanism and claims procedure must be in place and shared with all the stakeholders before the construction commences; and
- A special meeting must be conducted with farm workers and other vulnerable parties, in their mother languages, to ensure that they understand the technical and safety aspects of the project.

The potential impact on the livelihoods of some of the directly affected farmers will be severe. This will have a spinoff impact on farm workers, food security and the local economy. Every possible measure must be implemented to ensure that the production of the farmers is not permanently impacted. The project can only be recommended if the livelihood impacts are mitigated and managed successfully.

Declaration of Independence

Equispectives Research and Consulting Services declare that:

- All work undertaken relating to the proposed project was done as independent consultants;
- They have the necessary required expertise to conduct social impact assessments, including the required knowledge and understanding of any guidelines or policies that are relevant to the proposed activity;
- They have undertaken all the work and associated studies in an objective manner, even if the findings of these studies were not favourable to the project proponent;
- They have no vested interest, financial or otherwise, in the proposed project or the outcome thereof, apart from remuneration for the work undertaken under the auspices of the above-mentioned regulations;
- They have no vested interest, including any conflicts of interest, in either the proposed project or the studies conducted in respect of the proposed project, other than complying with the relevant required regulations; and
- They have disclosed any material factors that may have the potential to influence the competent authority's decision and/or objectivity in terms of any reports, plans or documents related to the proposed project as required by the regulations.

Record of Experience

Ilse Aucamp and San-Marié Aucamp compiled this report.

Ilse Aucamp holds a D Phil degree in Social Work obtained from the University of Pretoria in 2015. She also has Masters' degree in Environmental Management (Cum Laude) from the Potchefstroom University for Christian Higher Education, which she obtained in 2004. Prior to that she completed a BA degree in Social Work at the University of Pretoria. She is frequently a guest lecturer in pre- as well as post-graduate programmes at various tertiary institutions. Her expertise includes social impact assessments, social management plans, social and labour plans, social auditing, training as well as public participation. She is a co-author of the *Social Impact Assessment: Guidance for assessing and managing the social impacts of projects* document published by the International Association for Impact Assessment.

San-Marié Aucamp is a registered Research Psychologist with extensive experience in both the practical and theoretical aspects of social research. She has more than 10 years' experience in social research, and she occasionally presents guest lectures on social impact assessment. Her experience includes social impact assessments, social and labour plans, training, group facilitation as well as social research. She is a past council member of the Southern African Marketing Research Association (SAMRA).

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1 Introduction

The project proponent wishes to expand their natural gas (helium and methane) operations, located within an approved production right area. The planned expansion to the existing approved production activities will involve up to 300 production wells, gas transmission pipelines and associated infrastructure, compressor stations and a Liquid Natural Gas (LNG) and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure (including powerlines) as part of the Cluster 2 expansion of the Project in order to meet the future production requirements.

The Cluster 2 project will comprise of two components namely (1) the gas gathering network and (2) the LNG/LHe Plant. Exploration drilling is approved in the Production Right and therefore does not fall within the scope of this application.

As the specific location of new production wells and subsequent pipelines and associated infrastructure can only be confirmed once exploration activities are undertaken, this application is focussing on infrastructure transects (buffer areas) in addition to a broad assessment of the entire study area. Through this process any potential no-go areas or highly sensitive areas will be delineated, and appropriate mitigation measures identified where relevant.

The full field well development will comprise 3 phases/groups of wells during which exploration and drilling will be undertaken. The first phase will target approximately 15 million Standard Cubic Feet per Day of gas (MMSCFD) followed by the second phase of approximately 30 MMSCFD and finally the third phase of approximately 45 MMSCFD. The construction of the gas gathering network (including pipelines, booster and compressor stations, etc) is planned to commence in May 2023 and be completed by December 2023. Construction of the LNG/LHe plant and associated infrastructure is planned to commence in March 2023 and be completed by February 2025. The operational (gas production) timeframe for the project is approximately 20 years (2025 to 2045).

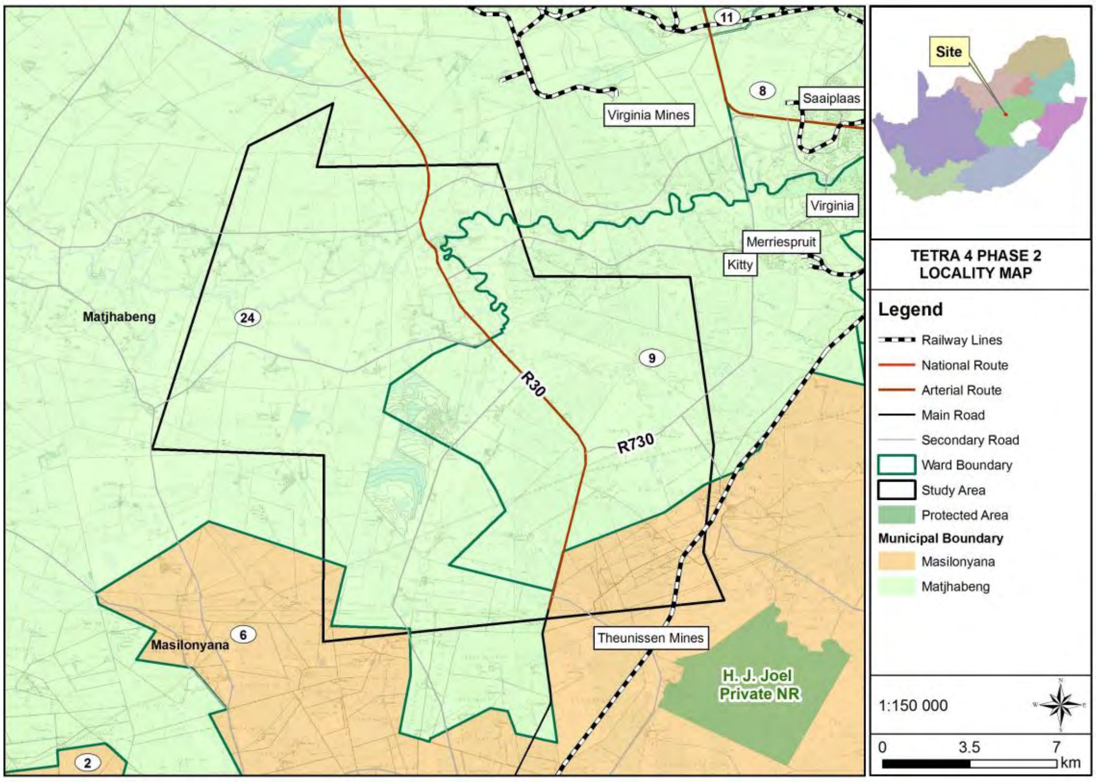
The proposed project falls within the Masilonyana and Matjhabeng Local Municipalities, in the Lejweleputswa District Municipality, Free State Province. The site boundary is 5km south west of the town of Virginia, 9km south the town of Welkom and 16km north of the town of Theunissen. The application area covers approximately 27 500 hectares, and the approximate centre point of the site is located at 28 10'20.47"S and 26 43'50.79"E.

The project covers various farm portions. Below is a list of parent farms of which certain portions of each are included under this application:

Adamsons Vley No. 655, Annex Glen Ross No. 562, Annex Grusde No. 474, Annex Mooivlakte No. 208, Blaauwdrift No. 188, Bloemhoek No. 509, Boschluis Spruit No. 278, Braklaagte No. 41, Brakspruit No. 121, Bruintjies Hoogte No. 367, Bryan No. 561, Cabriere No. 215, Carlo No. 596, Damplaats No. 341, Dankbaarheid No. 16, De Klerks Kraal No. 231, Die Mond No. 479, Digito No. 642, Doorn River No. 330, Doorndeel No. 236, Enkeldoorn No. 360, Frisgewaag No. 550, Glen Ross No. 734, Grusde No. 229, Hakkies No. 695, Hakkies No. 742, Harmonie No. 579, Helpmekaar No. 47, Jonkers Rust No. 72, Jordaan No. 1, Jordaans Rust No. 59, Kaalpan No. 65, Kalkoenkrans No. 225, Klein Palmiet Kuil No. 407, Klein Pan No. 320, Kleinbegin No. 134, Kovno No. 235, Langlaagte No. 110, Leeuwaarden No. 171, Leeuwbult No. 52, Leeuwbult No. 580, Lekkerlewe No. 643, Middelplaas No. 583, Mond Van Doornrivier No. 38, Mooifontein No. 639, Mooivlakte No. 199, Mooivlei No. 357, Nortier No. 361, Palmietkuil No. 548, Palmietkuil No. 328, Paulina No. 470, Richelieu No. 135, Rondehoek No. 200, Siberia No. 464, Spoorleggerswoning 54 No. 167, Stille Woning No. 703, Terra Blanda No. 155, Toulon No. 368, Vaalbank No. 190, Vlakpan No. 358, Welgelegen No. 382, Weltevrede No. 638, Weltevreden No. 443, Zoetendal No. 243, Zonderzorg No. 342, Zonderzorg No. 640

Figure 1 shows the proposed location for the project within municipal context.

Figure 1: Locality of proposed Tetra4 Cluster 2 project.



The purpose of this report is to provide baseline information regarding the socio-economic environment, to identify possible social and economic impacts and to suggest ways in which these impacts can be mitigated. This will assist decision-makers on the project in making informed decisions by providing information on the potential or actual consequences of their proposed activities. The process entailed the following:

- A baseline socio-economic description of the affected environment;
- Identification of potential social and economic change processes that may occur as a result of the project; and
- Identification of potential social and economic impacts.

One of the ways in which social risk can be managed is by conducting a social impact assessment (SIA). Such an assessment can assist with identifying possible social impacts and risks. Disregarding social impacts can alter the cost-benefit equation of development and in some cases even undermine the overall viability of a project. A proper social impact assessment can have many benefits for a proposed development (UNEP, 2002) such as:

- Reduced impacts on communities of individuals;
- Enhanced benefits to those affected;
- Avoiding delays and obstruction – helps to gain development approval (social license);
- Lowered costs;
- Better community and stakeholder relations; and
- Improved proposals.

More detail on the scope of each of these phases is included in the section below.

2 Scope of Work

The purpose of the SIA is to provide input in the Environmental Impact Assessment (EIA)/ Environmental Management Programme (EMPr) Report for the proposed gas production and ancillary service/activities that will take place on site.

3 Methodology

Scientific social research methods were used for this assessment. To clarify the process to the reader, this section will start with a brief explanation of the processes that have been used in this study.

3.1 Information base

The information used in this report was based on the following:

- A literature review (see list provided in the References);
- Data from Statistics South Africa;
- The public participation records provided by EIMS;
- Professional judgement based on experience gained with similar projects; and
- Consultation with affected stakeholders in April 2022.

3.2 Assumptions and limitations

The following assumptions and limitations were relevant:

1. Not every individual in the community could be interviewed therefore only key people in the community were approached for discussion. These key people include all the directly affected landowners. Additional information was obtained using existing data.

2. The social environment constantly changes and adapts to change, and external factors outside the scope of the project can offset social changes, for example changes in local political leadership, droughts or economic conditions. It is therefore difficult to predict all impacts to a high level of accuracy, although care has been taken to identify and address the most likely impacts in the most appropriate way for the current local context within the limitations. In addition, it is also important to manage social impacts for the life of the project, especially in the light of the changing social environment.

3. Social impacts can be felt on an actual or perceptual level, and therefore it is not always straightforward to measure the impacts in a quantitative manner.

4. Social impacts commence when the project enters the public domain. Some of these impacts will occur irrespective of whether the project continues or not, and other impacts have already started. These impacts are difficult to mitigate and some would require immediate action to minimise the risk.

5. There are different groups with different interests in the community, and what one group may experience as a positive social impact, another group may experience as a negative impact. This duality will be pointed out in the impact assessment phase of the report.

6. Social impacts are not site-specific, but take place in the communities surrounding the proposed development.

3.3 Social Impact Assessment Model

The theoretical model used for this impact assessment was developed by Slootweg, Vanclay and Van Schooten and presented in the *International Handbook of Social Impact Assessment* (Vanclay & Becker, 2003). This model identifies pathways by which social impacts may result from proposed projects. The model differentiates between social change processes and social impacts, where the social change process is the pathway leading to the social impact. Detail of how the model works is not relevant to this study, but it is important to understand the key concepts, which will be explained in the following paragraphs.

Social change processes are set in motion by project activities or policies. A social change process is a discreet, observable, and describable process that changes the characteristics of a society, taking place regardless of the societal context (that is, independent of specific groups, religions etc.) These processes may, in certain circumstances and depending on the context, lead to the experience of social impacts (Vanclay, 2003). If managed properly, however, these changes may not create impacts. Whether impacts are caused will depend on the characteristics and history of the host community, and the extent of mitigation measures that are put in place (Vanclay, 2003). Social change processes can be measured objectively, independent of the local context. Examples of social change processes are an increase in the population, relocation, or the presence of temporary workers.

For the purpose of this report, the following social change process categories were considered:

- Demographic processes;
- Economic processes;
- Geographic processes;
- Institutional and legal processes;
- Emancipatory and empowerment processes;
- Socio-cultural processes; and
- Other relevant processes.

The *International Association for Impact Assessment* (2003) states that Social Impact Assessment includes the processes of analysing, monitoring and managing the intended and unintended social consequences, both positive and negative, of planned interventions (policies, programs, plans, projects) and any social change processes invoked by these interventions. Its primary purpose is to bring about a more sustainable and equitable biophysical and human environment.

A social impact is something that is experienced or felt by humans. It can be positive or negative. Social impacts can be experienced in a physical or perceptual sense. Therefore, two types of social impacts can be distinguished:

- **Objective social impacts** – i.e. impacts that can be quantified and verified by independent observers in the local context, such as changes in employment patterns, in standard of living or in health and safety.
- **Subjective social impacts** – i.e. impacts that occur "in the heads" or emotions of people, such as negative public attitudes, psychological stress or reduced quality of life.

It is important to include subjective social impacts, as these can have far-reaching consequences in the form of opposition to, and social mobilisation against the project (Du Preez & Perold, 2005).

For the purpose of this SIA, the following Social Impact Assessment categories were investigated:

- Health and social well-being;
- Quality of the living environment;
- Economic impacts and material well-being;
- Cultural impacts;
- Family and community impacts;
- Institutional, legal, political and equity impacts; and
- Gender impacts.

Relevant criteria for selecting significant social impacts included the following:

- Probability of the event occurring;
- Number of people that will be affected;
- Duration of the impact;
- Value of the benefits or costs to the impacted group;
- Extent to which identified social impacts are reversible or can be mitigated;
- Likelihood that an identified impact will lead to secondary or cumulative impacts;
- Relevance for present and future policy decisions;
- Uncertainty over possible effects; and
- Presence or absence of controversy over the issue.

For the purpose of this study, the model was adapted to suit the South African context, and where processes and impacts were not relevant to the study, it was omitted. Each category has a number of sub-categories, which also have been investigated. The Equator Principles, International Finance Corporation Performance Standards and World Bank Environmental, Health and Safety guidelines were consulted in the writing of this report and the mitigation suggested adheres to these requirements.

3.4 Literature study

A literature search was undertaken to obtain secondary data for the baseline description of the socio-economic environment. The information in this report was acquired via statistical data obtained from Statistics South Africa, SIA literature (see References), previous SIA studies conducted in the area, EIMS's public consultation process and information from reputable sources on the World Wide Web.

3.5 Research approach

Traditionally there are two approaches to SIA, a technical approach, and a participatory approach. A technical approach entails that a scientist remains a neutral observer of social phenomena. The role of the scientist is to identify indicators, obtain objective measures relevant to the situation and provide an expert assessment on how the system will change (Becker, Harris, Nielsen & McLaughlin, 2004). A participatory approach uses the knowledge and experiences of individuals most affected by the proposed changes as the basis for projecting impacts. In this case the role of the scientist is facilitator of knowledge sharing, interpretation, and reporting of impacts (Becker et al, 2004). Both approaches were followed in this study.

3.6 Ethical issues

The most basic principle of research is that participants should not be harmed by participation in the research project. It is important that research not only does no harm, but also potentially contributes to the wellbeing of others. At times this might place a researcher in a difficult position – what is beneficial to one group may not be beneficial to another (Bless, Higson-Smith & Kagee, 2006). Furthermore, an individual has the autonomy to decide whether to participate in research or not. No person should be forced, either overtly or covertly, to participate in research. Other important principles include justice (based on the assumption that all people are equals), fidelity (keeping promises or agreements, specifically between the researcher and the participant) and respect for participants' rights and dignity. In addition to these overarching ethical principles, important ethical principles that should be met are informed consent, confidentiality, anonymity, and discontinuance. This is in line with international as well as national research practice such as the World Association for Market, Social and Opinion Researchers (ESOMAR) and Southern African Marketing Research Association (SAMRA) codes of conduct. The researcher has an ethical obligation to develop well-designed projects and execute them with care. Researchers are not allowed to change their data or observations and should report on technical shortcomings, failures, limits of the study, negative findings, and methodological constraints. The honest and accurate reporting of data is also an essential component of scientifically accurate and ethically legitimate research and conclusions should be supported by data.

4 Legislative and Policy Framework

Although there are no explicit acts referring directly to SIA, there are many acts and policies that require specific social outcomes that can be related to this project, and these are discussed in the section below.

4.1 The Constitution of the Republic of South Africa 1996

The current Constitution of the Republic of South Africa 1996 can be regarded as one of the most progressive constitutions in the world. Human rights are enshrined in the South African Constitution, which forms the basis of all the country's legislation. Chapter 2 consists of a Bill of Rights, which explicitly spells out the rights of every South African citizen. Human rights and dignity are fundamental to SIA and it recognises fundamental human rights and the prerogative to protect those rights as core values (Vanclay, 2003). The human rights relevant to the environmental management field that are safeguarded by the Constitution of the Republic of South Africa 1996 in the Bill of Rights, include:

- Right to a healthy environment;
- Right of access to land and to security of tenure; and
- Right to adequate housing and protection against evictions and demolitions.

The right to a protected biophysical environment, the promotion of social development and trans-generational equity is explicitly included in the Constitution of the Republic of South Africa 1996, which states:

"Everyone has the right -

1. To an environment that is not harmful to their health and wellbeing, and
2. *To* have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that*:*
    1. *Prevent pollution*
    2. *Promote conservation, and*

3. *Secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development."*

When considering an environment that is not harmful to peoples' health and wellbeing, it is important to reflect on the interconnectedness of biophysical, economic, and social aspects. The impact of development on people, and the true cost of development, as well as the consideration of "who pays the price?" versus "who reaps the benefits?" cannot be ignored in a discussion about human rights and the environment.

The right to a generally satisfactory environment is increasingly seen as a human right in Africa (Du Plessis, 2011), and South Africa's environmental legislation supports this.

4.1.1 The National Environmental Management Act 107 of 1998

The National Environmental Management Act (NEMA) 107 of 1998 states that the State must respect, protect, promote, and fulfil the **social**, economic, and environmental rights of everyone and strive to meet the needs of previously disadvantaged communities. It states further that sustainable development requires the integration of **social**, economic, and environmental factors in the planning, evaluation, and implementation of decisions to ensure that development serves present and future generations.

Chapter 1 of NEMA contains a list of principles and states clearly that environmental management must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, cultural, and social interests (NEMA, 1998). It states further that negative impacts on the environment and on peoples' environmental rights must be anticipated and prevented, and if they cannot be prevented, they should be minimised and remedied. It elaborates further on the equity of impacts, and the fact that vulnerable communities should be protected from negative environmental impacts. It refers to the principle that everyone should have equal access to environmental resources, benefits, and services to meet their basic human needs (NEMA, 1998). Therefore, there is a clear mandate for environmental and restorative justice in the act, something that must be considered in this project.

Another important aspect of NEMA is the principle of public participation. It states that people should be empowered to participate in the environmental governance processes, and that their capacity to do so should be developed if it does not exist. All decisions regarding the environment should take the needs, interest, and values of the public into account, including traditional and ordinary knowledge (NEMA, 1998). There are also specific environmental management acts that fall under NEMA, such as the National Environmental Management, Air Quality Act 39 of 2004 (NEM: AQA), and the National Environmental Management, Waste Act 59 of 2008 (NEM: WA). These acts require similar public participation processes to NEMA and the principles of NEMA also apply to them (Department of Environmental Affairs & Development Planning [DEA&DP], Provincial Government of the Western Cape, 2010).

Chapter 6 of NEMA elaborates on the public participation requirements. This is supplemented by the EIA regulations published in GN 982 of 4 December 2014, which contained requirements for public participation (GN 982 in GG 38282 of 4 December 2014). It provides requirements for the public participation, the minimum legal requirements for public participation processes, the generic steps of a public participation process, requirements for planning a public participation process and a description of the roles and responsibilities of the various role players. A compulsory Public Participation Guideline that was published in 2012 (GN 807 of 10 October 2012) in terms of section J of NEMA (NEMA, 1998) complements these requirements. According to the guidelines, public participation can be seen as one of the most important aspects of the environmental authorisation process. Public participation is the only requirement of the environmental impact assessment process for which exemption cannot be given, unless no rights are affected by an application. This stems from the requirement in NEMA that people have a right to be informed about potential decisions that may affect them and that they must be given an opportunity to influence those decisions.

The principles of the National Environmental Management Act 107 of 1998 declare further that community wellbeing and empowerment must be promoted through environmental education, the raising of environmental awareness, sharing of environmental knowledge and experience and any other appropriate means. It states that the social, environmental, and economic impacts of activities, including disadvantages and benefits, must be considered, assessed and evaluated, and decisions taken must be appropriate given the assessment and evaluation. NEMA 107 of 1998 recognises that the environment is held in public trust for the people, and therefore the beneficial use of environmental resources must serve the peoples' interest and protect the environment as the peoples' common heritage.

NEMA takes a holistic view of the environment, and promotes the consideration of social, economic, and biophysical factors to obtain sustainable development and achieve effective management of the biophysical environment.

4.1.2 The National Water Act 36 of 1998

Chapter 1 of the National Water Act (NWA) 36 of 1998 states that sustainability and equity are identified as central guiding principles in the protection, use, development, conservation, management, and control of water resources. It affirms that the guiding principles recognise the basic human needs of present and future generations and the need to promote social and economic development using water. Chapter 2 of the NWA states amongst others that the purpose of the act is to ensure that everyone has equitable access to water, and that the results of past racial and gender discrimination are redressed. It aims to promote the efficient, sustainable, and beneficial use of water in the public interest, and to facilitate social and economic development. The NWA recognises that the nations' water resources are held in public trust for the people, and therefore the sustainable, equitable and beneficial use of water resources must serve the peoples' interest.

4.1.3 The Mineral and Petroleum Resources Development Act 28 of 2002

The Mineral and Petroleum Resources Development Act (MPRDA) 28 of 2002 is the only environmental act that explicitly requires a social development output, in addition to a public participation process, in the form of a Social and Labour Plan (SLP). In the preamble to the Act, it recognises the need to promote local and rural development and the social upliftment of communities affected by resource development. In Section 2 it states that some of the objectives of the act are:

- To substantially and meaningfully expand opportunities for historically disadvantaged persons, including women, to enter the mineral and petroleum industries and to benefit from the exploitation of the nations' mineral and petroleum resources;
- To promote economic growth and mineral and petroleum resources development in the Republic;
- To promote employment and advance the social and economic welfare of all South Africans, and
- To ensure that holders of mining and production rights contribute towards the socio-economic development of the areas in which they are operating.

The MPRDA acknowledges that mineral and petroleum resources are the common heritage of all the people of South Africa and that the State is the custodian thereof for the benefit of all. It states that the Minister of Mineral Resources must ensure the sustainable development of South Africa's mineral and petroleum resources within a framework of national environmental policy, norms and standards while promoting economic and social development (MPRDA, 2002).

In Section 37 of the Mineral and Petroleum Resources Development Act 28 of 2002 it endorses the principles set out in Chapter 1 of the National Environmental Management Act 107 of 1998. In Section 39 of the MPRDA the act explicitly requires a social impact assessment as well as an environmental impact assessment when it states that applicants must:

"…investigate, assess, and evaluate the impact of his or her proposed prospecting or mining operations on:

(i) The environment;

(ii) The **socio-economic conditions of any person** who might be directly affected by the prospecting or mining operation…"

Section 3, Chapter 2, Part I, of the regulations (Government Notice 527, 23 April 2004) published under the MPRDA refers to the public participation process, which must be followed according to the Act. It includes advertising and an invitation to comment on the process.

Sections 40 to 46, Chapter 2, Part II, of the regulations published under the MPRDA deal with the Social and Labour Plan (SLP) requirements (Government Notice 527, 23 April 2004). The Department of Mineral Resources provided guidelines for the development of the SLP (Department of Mineral Resources, 2010). The guidelines specify the objectives of the SLP as:

- Promote economic growth and mineral and petroleum resources development in the Republic;
- Promoting employment and advancing the social and economic welfare of all South Africans;
- Ensuring that holders of mining or production rights contribute towards the socio-economic development of the areas in which they are operating as well as the areas from which the majority of the workforce is sourced, and
- To utilise and expand the existing skills base for the empowerment of Historically Disadvantaged South Africans and to serve the community (Department of Mineral Resources, 2010).

The crux of this section is that the SLP requires applicants for mining and production rights to develop and implement comprehensive Human Resources Development Programmes including Employment Equity Plans, Local Economic Development Programmes, and processes to save jobs and manage downscaling and/or closure (MPRDA 28 of 2002). According to the regulations, the above programmes are aimed at promoting employment and advancement of the social and economic welfare of all South Africans whilst ensuring economic growth and socio-economic development. The management of downscaling and/or closure is aimed at minimising the impact of commodity cyclical volatility, economic turbulence and physical depletion of the mineral or production resources on individuals, regions or local economies. All mines in South Africa are required to compile an SLP, and they must report compliance on a yearly basis (MPRDA, 2002). Compiling an SLP must be done in a participatory manner, and local economic development initiatives must be aligned with the municipal integrated development planning processes. An SLP is not a social impact management plan per se, although it does aim to manage some negative social impacts. The guideline is very clear about the fact that measures put in place for the mitigation of impacts cannot be seen as mine community development projects (Department of Mineral Resources, 2010).

4.1.4 The National Heritage Resources Act 25 of 1999

Although the National Heritage Resources Act (NHRA) 25 of 1999 is not an environmental act per se, it is relevant in the field of environmental management. The NHRA affirms that every generation has a moral responsibility to act as trustee of the national heritage for later generations and that the State is obliged to manage heritage resources in the interest of all South Africans. The general principles for heritage management in Chapter 5 of the Act state that in order to ensure that heritage resources are effectively managed, the skills and capacities of persons and communities involved in heritage resources management must be developed. The Act further elaborates on the fact that heritage resources form an important part of the history and beliefs of communities and must be managed in a way that acknowledges the right of affected communities to be consulted and to participate in their management.

The general principles (Chapter 5) state that the identification, assessment, and management of the heritage resources of South Africa must:

- Take account of all relevant cultural values and indigenous knowledge systems;
- Take account of material or cultural heritage value and involve the least possible alteration or loss of it;
- Promote the use and enjoyment of and access to heritage resources, in a way consistent with their cultural significance and conservation needs;
- Contribute to social and economic development, and

- Safeguard the options of present and future generations.

The National Heritage Resources Act 25 of 1999 therefore protects the cultural rights and heritage of the people of South Africa. It does not require explicit public participation or give any guidelines on how the public should participate. It does refer, like the National Environmental Management Act 107 of 1998 and the National Water Act 36 of 1998, to social and economic development. Public participation processes may be requested by the South African Heritage Resources Agency if it deems it necessary for a specific project.

4.1.5 Promotion of Administrative Justice Act 3 of 2000

The Bill of Rights in the Constitution of the Republic of South Africa 1996 states that everyone has the right to administrative action that is legally recognised, reasonable and procedurally just. The Promotion of Administrative Justice Act (PAJA) 3 of 2000 gives effect to this right. The PAJA applies to all decisions of all State organisations exercising public power or performing a public function in terms of any legislation that negatively affects the rights of any person. The Act prescribes what procedures an organ of State must follow when it takes decisions. If an organ of State implements a decision that impacts on an individual or community without giving them an opportunity to comment, the final decision will be illegal and may be set aside. The Promotion of Administrative Justice Act 3 of 2000 also forces State organisations to explain and give reasons for the manner in which they have arrived at their decisions and, if social issues were involved, and how these issues were considered in the decision-making process.

The Promotion of Administrative Justice Act 3 of 2000 therefore protects the rights of communities and individuals to participate in decision-making processes, especially if these processes affect their daily lives.

4.1.6 Gas related legislation

The introduction of natural gas into South Africa's mainstream energy supply is an important step in the fulfilment of one of the major objectives of the White Paper on Energy Policy.

The Department of Minerals and Energy has formulated:

The Gas Act 2001, Act 48 of 2001 and the Government / Sasol regulatory agreement referred to in section 36 of the Act, which aims to:

- Promote the orderly development of the piped gas industry;
- Establish a national regulatory framework; and
- Establish a National Gas Regulator as the custodian and enforcer of the national regulatory framework.

The Gas Regulator Levies Act 2002, Act 75 of 2002, which provides for the imposition of levies for the functioning of the national gas regulator and for matters connected therewith.

Piped Gas Regulations. After the establishment of the National Energy Regulator, the Department of Energy has promulgated the Piped Gas Regulations, 2007, to promote the orderly development of the piped gas industry.

4.2 Additional governance tools

Legislation is not the only tool that authorities can use to achieve sustainable development and social development outcomes. There are several tools, policies and strategic planning instruments that can contribute to this.

4.2.1 Integrated Development Plans

For the purpose of this project, Integrated Development Plan (IDP) documents of three municipalities need to be considered: the Lejweleputswa District Municipality; the Matjhabeng Local Municipality; and the Masilonyana Local Municipality.

The Lejweleputswa District Municipality IDP (2021/22) highlights that the purpose of municipal integrated development planning is to:

- Ensure sustainable provision of services;

- Promote social and economic development;
- Promote a safe and healthy environment;
- Give priority to the basic needs of communities; and
- Encourage involvement of communities.

Matjhabeng Local Municipality identified the following mayoral strategic priorities (IDP 2022/23):

- Road maintenance;
- Local economic development;
- Replacement of ageing infrastructure;
- Achieving housing accreditation;
- Build internal capacity;
- Develop climate change strategy, adaptation, and mitigation;
- Improve private-public partnerships for growth and development; and
- Economic corridors linking six towns.

The Masilonyana Local Municipality listed its strategic objectives as:

- Sustainable services to the community;
- Promotion of a sound environmental management system;
- Provision of sound governance for local communities; and
- Ensuring sound governance practices within the municipality.

4.2.2 Provincial Growth and Development Strategies

The Free State Provincial Growth and Development Strategy (FGDS) is based on six pillars, each with its own set of drivers (FSDF, 2012). The drivers and pillars are:

1. Inclusive economic growth and sustainable job growth creation
    a. Diversify and expand agricultural development and food security.
    b. Minimise the impact of the declining mining sector and ensure that existing mining potential is harnessed.

c. Expand and diversify manufacturing opportunities.
d. Capitalise on transport and distribution opportunities.
e. Harness and increase tourism potential and opportunities.

2. Education, innovation and skills development
   a. Ensure an appropriate skills base for growth and development.
3. Improved quality of life
   a. Curb crime and streamline criminal justice performance.
   b. Expand and maintain basic and road infrastructure.
   c. Facilitate sustainable human settlements.
   d. Provide and improve adequate health care for citizens.
   e. Ensure social development and social security services for all citizens.
   f. Integrate environmental limitations and change into growth and development planning.
4. Sustainable rural development
   a. Mainstream rural development into growth and development planning.
5. Build social cohesion
   a. Maximise arts, culture, sports and recreation opportunities and prospects for all communities.
6. Good governance
   a. Foster good governance to create a conducive climate for growth and development.

The Free State Provincial Spatial Development Framework (FSDF) supplements the FGDS as guidance document for the province to use resources in a way that will ensure sustainable outcomes based on provincial development needs and priorities (FSDF, 2012). The FSDF outlines Vision 2030, a collective response to the need for the province to describe and map its future destiny through long-term development planning, and to forge a common and shared development agenda across a wide spectrum of service delivery mechanisms. The Free State Vision 2030 envisages that, by 2030, *the Free State shall have a resilient, thriving and competitive economy that is inclusive, with immense prospects for human development anchored on the principles of unity, dignity, diversity, equality and prosperity for all* (FSDF, 2012).

Encouraged by this vision, the Free State of 2030 will be characterised by an economy that encourages the development of new growth sectors with emphasis on the knowledge-based industries and the green economy (FSGDS).

The Free State Vision 2030 furthermore envisages that, *by 2030, ownership and control patterns of the economy will be transformed, spatial under-development will be addressed, basic services such as healthcare, education, electricity, water and sanitation will be equitably accessed by the people of the province. In the quest for inclusive economic growth and development, the environment will be protected for future generations. Lasting responses to climate changes will be part of the landscape of the development of the province. Steeped within the democratic principles, the Provincial Government will be accountable, transparent, effective, efficient, responsive to people's needs, and corruption will be eliminated* (FSDF, 2012).

The Tetra4 project therefore aligns with at least the first two pillars of the FGDS that address economic development, job creation and skills development.

4.2.3 National Development Plan

On 11 November 2011 the National Planning Commission released the National Development Plan: Vision for 2030 (NPC, 2012) for South Africa and it was adopted as government policy in August 2012. The National Development Plan (NDP) was undertaken to envision what South Africa should look like in 2030 and what action steps should be taken to achieve this (RSA, 2013). The aim of the NDP is to eliminate poverty and reduce inequality by 2030. The report identifies nine central challenges to development in South Africa:

1. Too few people work.
2. The standard of education for most black learners is of poor quality.
3. Infrastructure is poorly located, under-maintained and insufficient to foster higher growth.
4. Spatial patterns exclude the poor from the fruits of development.
5. The economy is overly and unsustainably resource intensive.
6. A widespread disease burden is compounded by a failing public health system.
7. Public services are uneven and often of poor quality.
8. Corruption is widespread.
9. South Africa remains a divided society (NPC, 2012).

The plan focuses on creating an enabling environment for development and wants to shift from a paradigm of entitlement to a paradigm of development that promotes the development of capabilities, the creation of opportunities and the involvement of all citizens (NPC, 2012). The National Development Plan (NPC, 2012) wants to achieve the following:

1. An economy that will create more jobs.
2. Improving infrastructure.
3. Transition to a low-carbon economy.
4. An inclusive and integrated rural economy.
5. Reversing the spatial effects of apartheid.

6. Improving the quality of education, training and innovation.

7. Quality healthcare for all.

8. Social protection.

9. Building safer communities.

10. Reforming the public service.

11. Fighting corruption.

12. Transforming society and uniting the country.

Each of the points above is a chapter in the plan, and contains a range of targets and proposals. Some are general statements of policy intent, while others are specific policy proposals, actions or processes that should take place (NPC, 2012). Through its contribution to the economy, the Tetra4 project will assist with achieving the goal of creating an economy that will create more jobs.

4.2.4 Sustainable Development Goals

All 189 Members States of the United Nations, including South Africa, adopted the United Nations Millennium Declaration in September 2000 (UN, 2000). The commitments made by the Millennium Declaration are known as the Millennium Development Goals (MDGs), and 2015 was targeted as the year to achieve these goals. The United Nations Open Working Group of the General Assembly identified seventeen sustainable development goals, built on the foundation of the MDGs as the next global development target (UN, 2014). The sustainable development goals include aspects such as ending poverty, addressing food security, promoting health, wellbeing and education, gender equality, water and sanitation, economic growth and employment creation, sustainable infrastructure, reducing inequality, creating sustainable cities and human settlements, and addressing challenges in the physical environment such as climate change and environmental resources (UN, 2014). These aspects are included in the NPD, and it can therefore be assumed that South Africa's development path is aligned with the international development agenda. Tetra4 can assist with contributing to achieving goals such as economic growth and employment creation and promoting health, wellbeing and education through their SLP.

4.3 National and international standards

National and international industry standards aimed at sustainable development and social justice specifically have become abundant in the last decade. Many industries use these standards as indicators for best practice. The discussion below highlights only a few of these standards.

4.3.1 ISO 26000:2010/SANS 26000:2010

Performance standards have long been a voluntary tool used by industry to achieve certain outcomes. The first standard on social responsibility, ISO 26000 was published on 1 November 2010 (ISO, 2010). It was developed using a multi-stakeholder approach involving experts from more than 90 countries and 40 international or broadly based regional organisations involved in different aspects of social responsibility (ISO, 2010).

The South African Bureau of Standards (SABS), a statutory body that is mandated to develop, promote and maintain South African National Standards (SABS, [sa]) adopted the ISO 26000 Standard as a South African National Standard (SANS) 26000:2010.

Social responsibility is defined in the standard as the responsibility of an organisation for the impacts of its decisions and activities on society and the environment, through transparent and ethical behaviour that contributes to sustainable development, including health and welfare of society; takes into account the expectations of the stakeholders; complies with applicable law and is consistent with international behaviour norms, and is integrated throughout the organisation and practiced in its relationships (ISO, 2010).

The document identifies seven principles for social responsibility and seven core subjects that should be addressed by organisations. The seven principles for social responsibility are accountability, transparency, ethical behaviour, respect for stakeholder interests, respect for the rule of law, respect for international norms of behaviour and respect for human rights (ISO, 2010). The core subjects that should be addressed include organisational governance, human rights, labour practices, environment, fair operating practices, consumer issues and community involvement and development (ISO, 2010). Economic aspects, health and safety and the value chain are dealt with throughout the seven core subjects, and gender issues are considered.

ISO 26000 is a good introduction to what social responsibility is and what measures should be taken to move towards being a more socially responsible company. It deals with equity issues and can encourage social development initiatives by companies through activities such as social investment projects, employment creation, skills development and income creation. Any company operating in area where people are affected by their activities has a social responsibility towards the affected community, and as such it would be in the interest of Tetra4 to address the core subjects as suggested by ISO 26000:2010.

4.3.2 International Social Performance Standards/Initiatives

There is a profusion of global initiatives aiming at assisting companies to make their operations more sustainable. Human rights, environmental protection and social justice are gaining support from industry. The social agenda forms an important part of this trend. Only a few relevant initiatives will be mentioned in this section.

The Global Reporting Initiative (GRI) is a leading organisation in the sustainability field that promotes sustainability reporting as a way for companies to become more sustainable and contribute to sustainable development. A company publishes a sustainability report to report the economic, social and environmental impacts of its everyday activities, present its values and governance model and explain the link between its strategy and its commitment to sustainable development (GRI, [sa]). The GRI have strategic partnerships with the United Nations Environment Programme, the United Nations Global Compact, the Organisation for Economic Co-operation and Development and the International Organisation for Standardisation, amongst others (GRI, [sa]). The social category relates to the impact of the company on the social systems in which it operates. The social category consists of four subcategories namely labour practices and decent work; human rights; society; and product responsibility.

Each of the categories is unpacked by using a number of aspects that should be considered (GRI, [sa]). GRI Focal Points are national offices that drive the initiatives in particular countries and regions. On 26 February 2013 the GRI Focal Point South Africa was launched. South Africa is one of the countries with the largest number of GRI reporters in the world. The GRI Focal Point South Africa aims to work with multi-national companies to expand and share best practices across the continent (GRI, [sa]).

Many of the multi-lateral funding agencies such as the World Bank have social standards that they must uphold. The most frequently used in the EIA industry is the International Finance Corporation's (IFC) principles (IFC, 2012). The IFC is a member of the World Bank group, and as a part of their sustainability framework they created performance standards on environmental and social sustainability (IFC, 2012). The standards relevant to the social environment are the following:

1. Environmental and Social Standard 1. Assessment and Management of Environmental and Social Risks and Impacts
2. Environmental and Social Standard 2: Labour and Working Conditions
3. Environmental and Social Standard 4: Community Health and Safety
4. Environmental and Social Standard 5 Land Acquisition, Restrictions on Land Use and Involuntary Resettlement
5. Environmental and Social Standard 8: Cultural Heritage
6. Environmental and Social Standard 10. Stakeholder Engagement and Information Disclosure (World Bank, 2016)

Issues such as gender, climate change, water and human rights are addressed across the standards. A guidance note accompanies each standard (IFC, 2012:4). Environmental and social risks and impacts must be managed by using an Environmental and Social Management System. The standard applies to all the activities funded by the IFC for the duration of the loan period. A number of private banks adopted most of the IFC standards in an initiative known as the Equator Principles (Esteves, Franks & Vanclay, 2012).

4.3.3 International Principles for SIA

The practice of SIA is guided by a set of *International Principles* that defines the core values, fundamental principles for development and principles specific to SIA practice (Vanclay, 2003). When the *International Principles* are considered, it is clear that SIA aspires to more than just assessing the impact of development on people, and includes sustainable outcomes. The following specific principles refer to these sustainable outcomes (Vanclay, 2003):

1. Development projects should be broadly acceptable to the members of those communities likely to benefit from, or be affected by, the planned intervention.
2. The primary focus of all developments should be positive outcomes, such as capacity building, empowerment, and the realisation of human and social capital.
3. The term "environment" should be defined broadly to include social and human dimensions, and in such inclusion, care must be taken to ensure that adequate attention is given to the realm of the social.
4. Equity considerations should be a fundamental element of impact assessment and of development planning.
5. There should be a focus on socially sustainable development, with the SIA contributing to the determination of best development alternative(s) – SIA (and EIA) has more to offer than just being an arbiter between economic benefit and social cost.
6. In all planned interventions and their assessments, avenues should be developed to build the social and human capital of local communities and to strengthen democratic processes.
7. Local knowledge, experience and acknowledgement of different cultural values should be incorporated in any assessment.

8. Development processes that infringe the human rights of any section of society should not be accepted.

In addition to the *International Principles*, the international SIA community produced a document titled: *Social Impact Assessment: Guidance for assessing and managing the social impacts of projects* (Vanclay, Esteves, Aucamp & Franks, 2015) in April 2015. The purpose of this document is to provide advice to various stakeholders (including proponents) about good practice SIA and social impact management (Vanclay et al., 2015). This document aspires to provide a much-needed benchmark for SIA practice across the globe.

5 Receiving environment

According to the National Environmental Management Act (NEMA, 1998) environment refers to the surroundings in which humans exist. When viewing the environment from a socio-economic perspective the question can be asked what exactly the social environment is. Different definitions for social environment exist, but a clear and comprehensive definition that is widely accepted remains elusive. Barnett & Casper (2001) offers the following definition of human social environment:

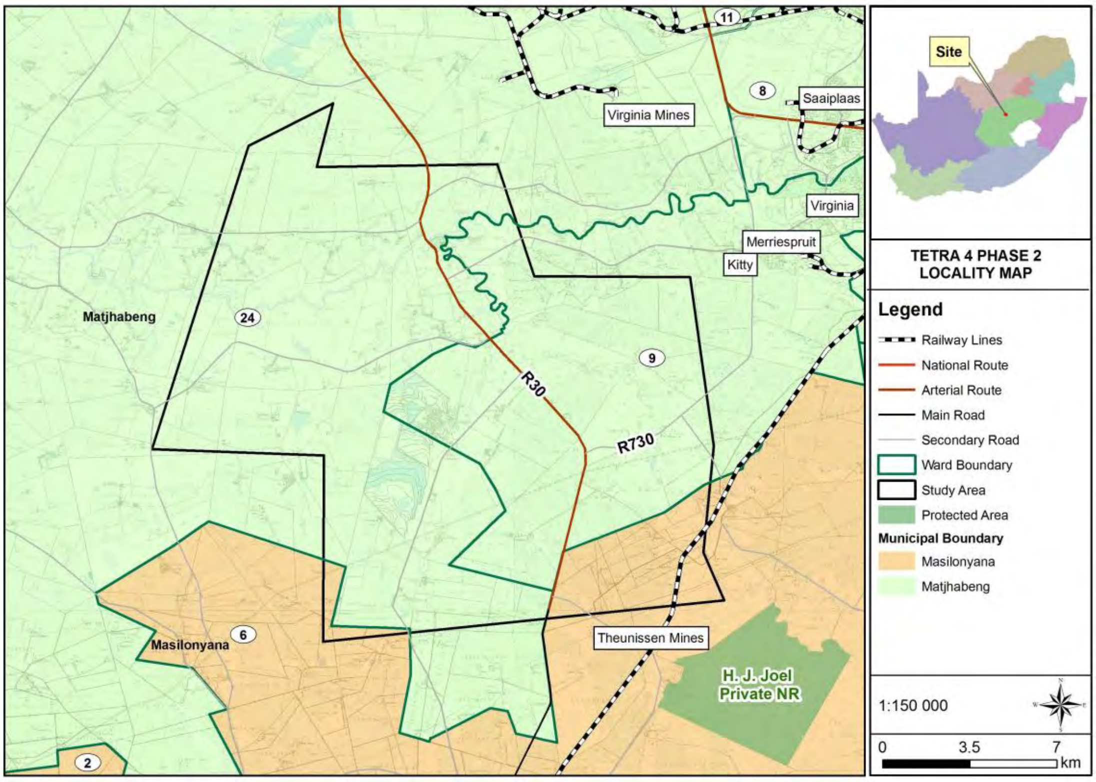
> *"Human social environments encompass the immediate physical surroundings, social relationships, and cultural milieus within which defined groups of people function and interact. Components of the social environment include built infrastructure; industrial and occupational structure; labour markets; social and economic processes; wealth; social, human, and health services; power relations; government; race relations; social inequality; cultural practices; the arts; religious institutions and practices; and beliefs about place and community. The social environment subsumes many aspects of the physical environment, given that contemporary landscapes, water resources, and other natural resources have been at least partially configured by human social processes. Embedded within contemporary social environments are historical social and power relations that have become institutionalized over time. Social environments can be experienced at multiple scales, often simultaneously, including households, kin networks, neighbourhoods, towns and cities, and regions. Social environments are dynamic and change over time as the result of both internal and external forces. There are relationships of dependency among the social environments of different local areas, because these areas are connected through larger regional, national, and international social and economic processes and power relations."*

Environment-behaviour relationships are interrelationships (Bell, Fisher, Baum & Greene, 1996). The environment influences and constrains the behaviour of people, but behaviour also leads to changes in the environment. The impacts of a project on people can only be truly understood if their environmental context is understood. The baseline description of the social environment will include a description of the area within a provincial, district and local context that will focus on the identity and history of the area as well as a description of the population of the area based on a number of demographic, social and economic variables.

5.1 Description of the area

The proposed site for the Cluster 2 project is located in Wards 9 and 24 of the Matjhabeng Local Municipality and Ward 6 of the Masilonyana Local Municipality that forms part of the Lejweleputswa District Municipality in the Free State Province. The baseline description of the environment will include these areas. Figure 2 shows the location of the proposed Cluster 2 project as well as social and physical infrastructure in the area.

Figure 2: Location of the proposed Cluster 2 Project.



5.1.1 Free State Province

The Free State province lies in the centre of South Africa between the Vaal River in the north and the Orange River in the south. The province borders on the Northern Cape, Eastern Cape, North-West, Mpumalanga, KwaZulu-Natal and the Gauteng province. It also shares a border with Lesotho. With a total area of 129 825 km^2, the Free State is the country's third-largest province but has the second-smallest population (www.municipalities.co.za).

The Free State is a rural province, and its economic activities are dominated by mining, agriculture and manufacturing. The province is the fifth-largest producer of gold in the world and is also home to Sasol, the large synthetic fuels company.

About 90% of the Free State is used for agricultural production (www.municipalities.co.za). About 34% of the total maize production of South Africa, 37% of wheat, 53% of sorghum, 33% of potatoes, 18% of red meat, 30% of groundnuts and 15% of wool is produced in the Free State.

Bloemfontein is the capital of the Free State and South Africa's judicial capital. The province is divided into one metropolitan municipality (Mangaung Metropolitan Municipality) and four district municipalities, namely Fezile Dabi, Lejweleputswa, Xhariep and Thabo Mofutsanyane. Other important towns in the Free State include Welkom, Kroonstad, Sasolburg and Bethlehem.

5.1.2 Lejweleputswa District Municipality

The Lejweleputswa District Municipality (LDM) is situated in the north western part of the Free State and borders the North West Province to the north; the Fezile Dabi and Thabo Mofutsanyane District Municipalities to the north-east and east respectively; the Xhariep District Municipality and Mangaung Metropolitan Municipality to the south; and the Northern Cape Province to the west. The LDM is accessible from Johannesburg, Cape Town, Klerksdorp and Kimberley through one of South Africa's main national roads, the N1. The district covers an area of 32 286 km^2 and make up almost a third of the Free State province. It consists of the Masilonyana, Matjhabeng, Nala, Tokologo and Tswelopele Local Municipalities (www.lejweleputswa.co.za).

The economy of the district relies heavily on the gold mining sector which is dominant in the Matjhabeng and Masilonyana Local Municipalities (Lejweleputswa DM IDP 2021/22). The mining sector is on a downward trend and many businesses that have traditionally depended on the mining sector have either closed down are in the process of closing down. The other municipalities are dominated by agriculture.

5.1.3 Matjhabeng Local Municipality

The main towns in the Matjhabeng Local Municipality are Welkom, Odendaalsrus, Virginia, Hennenman, Allanridge and Ventersburg (www.matjhabeng.fs.gov.za). The economy of the municipality is centred on mining activities in and around Welkom, Allanridge, Odendaalsrus and Virginia. Manufacturing aimed at the mining sector exists to a limited extent in the above towns, with other activities being limited. Other main economic sectors include manufacturing, tourism, agriculture, gold jewellery, transportation (logistics), and retail (Matjhabeng LM IDP 2022/2023).

5.1.4 Masilonyana Local Municipality

The main towns in the Masilonyana Local Municipality are Theunissen, Brandfort, Winburg, Verkeerdevlei and Soutpan (www.masilonyana.fs.gov.za). It is a semi-rural municipality that is dependent on agriculture and mining as the key drivers of its economy (Masilonyana LM IDP 2019/20). In 2016 the mining sector contributed about 52.4% to the municipality's economic output, but only about 8% of the employment in the municipality. With the decline in the mining sector the municipality plans to turn its focus on tourism. The municipality prides itself on its tourism destinations.

5.2 Description of the population

The baseline description of the population will take place on three levels, namely provincial, district and local. Impacts can only truly be comprehended by understanding the differences and similarities between the different levels. The baseline description will focus on the Matjhabeng Local Municipality and the Masilonyana Local Municipality in the Lejweleputswa District Municipality in the Free State Province (referred to in the text as the study area), as these are the areas that will be most affected by the proposed project. Where possible, the data will be reviewed on a ward level – Ward 9 and 24 of the Matjhabeng LM and Ward 6 of the Masilonyana LM. The data used for the socio-economic description was sourced from Census 2011. Census 2011 was a *de facto* census (a census in which people are enumerated according to where they stay on census night) where the reference night was 9-10 October 2011. The results should be viewed as indicative of the population characteristics in the area and should not be interpreted as absolute.

The following points regarding Census 2011 must be kept in mind (www.statssa.co.za):

- Comparisons of the results of labour market indicators in the post-apartheid population censuses over time have been a cause for concern. Improvements to key questions over the years mean that the labour market outcomes based on the post-apartheid censuses must be analysed with caution. The differences in the results over the years may be partly attributable to improvements in the questionnaire since 1996 rather than to actual developments in the labour market. The numbers published for the 1996, 2001, and 2011 censuses are therefore not comparable over time and are different from those published by Statistics South Africa in the surveys designed specifically for capturing official labour market results.
- For purposes of comparison over the period 1996–2011, certain categories of answers to questions in the censuses of 1996, 2001 and 2011, have either been merged or separated.
- The tenure status question for 1996 has been dropped since the question asked was totally unrelated to that asked thereafter. Comparisons for 2001 and 2011 do however remain.
- All household variables are controlled for housing units only and hence exclude all collective living arrangements as well as transient populations.
- When making comparisons of any indicator it must be considered that the time period between the first two censuses is five years and that between the second and third census is ten years. Although Census captures information at one given point in time, the period available for an indicator to change is different.

5.2.1 Population and household sizes

According to the Community Survey 2016, the population of South Africa is approximately 55,7 million and has shown an increase of about 7.5% since 2011. The household density for the country is estimated on approximately 3.29 people per household, indicating an average household size of 3-4 people (leaning towards 3) for most households, which is down from the 2011 average household size of 3.58 people per household. Smaller household sizes are in general associated with higher levels of urbanisation.

The greatest increase in population since 2011 has been on local level (Table 1), but still lower than the national average. Population density refers to the number of people per square kilometre and the population density on a national level has increased from 42.45 people per km^2 in 2011 to 45.63 people per km^2 in 2016. In the study area the population density has increased since 2011 with the highest density in the Matjabeng LM.

Table 1: Population density and growth estimates (sources: Census 2011, Community Survey 2016)

Area	Size in km^2	Population 2011	Population 2016	Population density 2011	Population density 2016	Growth in population (%)
Free State Province	129,825	2,745,590	2,834,714	21.15	21.83	3.25
Lejweleputswa DM	31,930	627,626	649,964	19.66	20.36	3.56
Matjhabeng LM	5,155	406,461	428,843	78.85	83.19	5.51
Masilonyana LM	6,796	63,334	66,084	9.32	9.72	4.34

The number of households in the study area has increased on all levels (Table 2). The proportionate increase in households were greater than the increase in population on all levels and exceeded the growth in households of 12.3% on a national level. The average household size has shown a decrease on all levels, which means there are more households, but with less members.

Table 2: Household sizes and growth estimates (sources: Census 2011, Community Survey 2016)

Area	Households 2011	Households 2016	Average household size 2011	Average household size 2016	Growth in households (%)
Free State Province	823,316	946,639	3.33	2.99	14.98
Lejweleputswa DM	183,163	219,014	3.43	2.97	19.57
Matjhabeng LM	123,195	149,021	3.30	2.88	20.96
Masilonyana LM	17,575	22,802	3.60	2.90	29.74

The total dependency ratio is used to measure the pressure on the productive population and refer to the proportion of dependents per 100 working-age population. As the ratio increases, there may be an increased burden on the productive part of the population to maintain the upbringing and pensions of the economically dependent. A high dependency ratio can cause serious problems for a country as the largest proportion of a government's expenditure is on health, social grants and education that are most used by the old and young population.

The total dependency ratio in the Masilonyana LM is higher than on district or provincial level (Table 3), while in the Matjhaneng LM the total dependency ratio is lower that on district or provincial level. The same trend applies to the youth, aged and employment dependency ratios. Employed dependency ratio refers to the proportion of people dependent on the people who are employed, and not only those of working age. The employed dependency ratio for the Matjhabeng LM is lower than on district and provincial level, while for the Masilonyana LM it is higher. This suggests high levels of poverty in the Masilonyana area.

Table 3: Dependency ratios (source: Census 2011).

Area	Total dependency	Youth dependency	Aged dependency	Employed dependency
Free State Province	52.88	44.48	8.39	76.34
Lejweleputswa DM	51.33	43.71	7.61	77.16
Matjhabeng LM	46.93	40.09	6.85	75.46
Ward 9	31.92	24.88	7.04	68.37
Ward 24	31.54	29.01	2.53	69.84
Masilonyana LM	54.99	45.99	9.00	82.14
Ward 6	40.36	33.35	7.01	88.18

Poverty is a complex issue that manifests itself in economic, social and political ways and to define poverty by a unidimensional measure such as income or expenditure would be an oversimplification of the matter. Poor people themselves describe their experience of poverty as multidimensional. The South African Multidimensional Poverty Index (SAMPI) (Statistics South Africa, 2014) assess poverty on the dimensions of health, education, standard of living and economic activity using the indicators child mortality, years of schooling, school attendance, fuel for heating, lighting and cooking, water access, sanitation, dwelling type, asset ownership and unemployment.

The poverty headcount refers to the proportion of households that can be defined as multi-dimensionally poor by using the SAMPI's poverty cut-offs (Statistics South Africa, 2014). The poverty headcount has increased on all levels since 2011 (Table 4), indicating an increase in the number of multi-dimensionally poor households.

The intensity of poverty experienced refers to the average proportion of indicators in which poor households are deprived (Statistics South Africa, 2014). The intensity of poverty has increased slightly on all levels. The intensity of poverty and the poverty headcount is used to calculate the SAMPI score. A higher score indicates a very poor community that is deprived on many indicators. The SAMPI score has increased in the Masilonyana LM area, indicating that households in this area might be getting poorer. In the Matjhabeng LM area the SAMPI score has decreased, suggesting an improvement in some respects relating to poverty in this area.

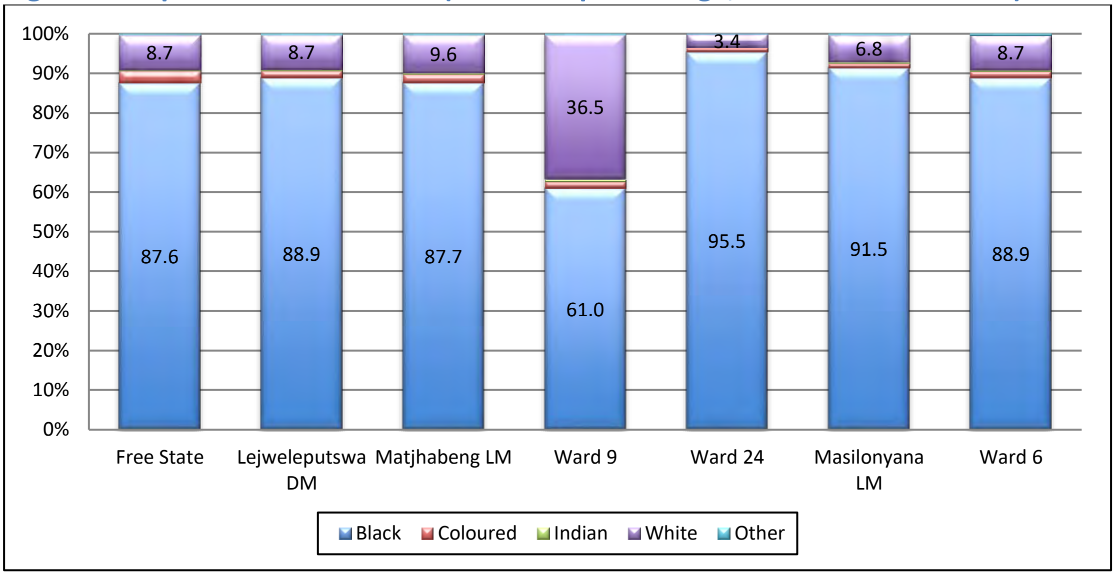
Table 4: Poverty and SAMPI scores (sources: Census 2011 and Community Survey 2016).

Area	Poverty headcount 2011 (%)	Poverty intensity 2011 (%)	SAMPI 2011	Poverty headcount 2016 (%)	Poverty intensity 2016 (%)	SAMPI 2016
Free State Province	5.5	42.2	0.023	5.5	41.7	0.023
Lejweleputswa DM	5.6	42.8	0.024	4.8	42.2	0.020
Matjhabeng LM	5.5	43.0	0.024	4.3	41.8	0.018
Masilonyana LM	5.3	41.8	0.022	6.5	41.8	0.027

5.2.2 Population composition, age, gender and home language

In all the areas under investigation, the majority of the population belongs to the Black population group (Figure 3), but the proportions differ. Ward 24 has the highest proportion of people belonging to the Black population group, while Ward 9 has the highest proportion of people belonging to the White population group.

Figure 3: Population distribution (shown in percentage, source: Census 2011)



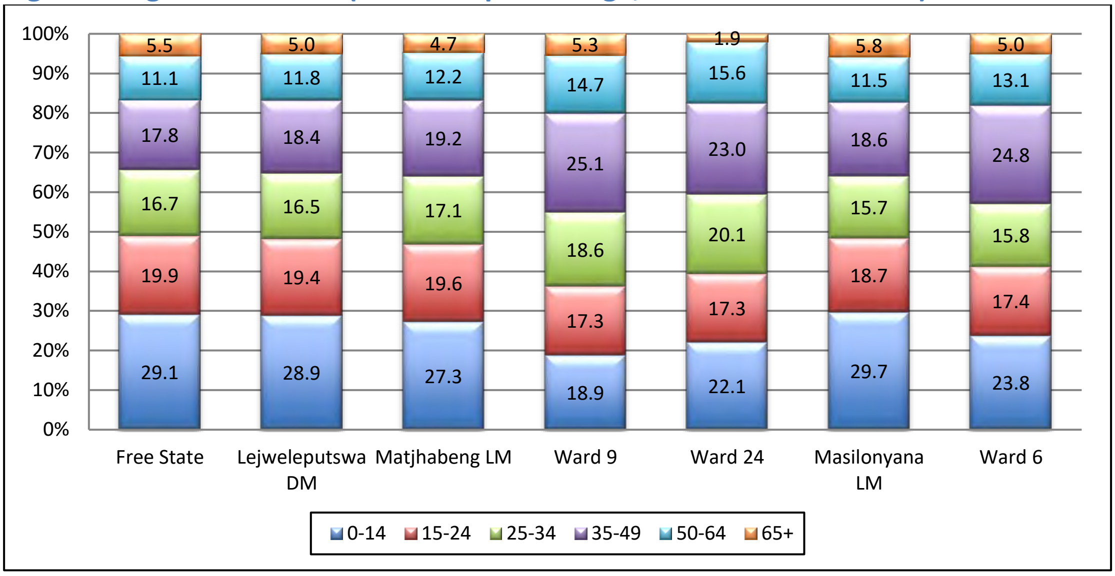
The average age on local level is higher than on district and provincial level (Table 5). The highest average age is in Ward 9 of the Matjhabeng LM.

Table 5: Average age (source: Census 2011).

Area	Average Age (in years)
Free State Province	28.38
Lejweleputswa DM	28.52
Matjhabeng LM	28.89
Ward 9	32.84
Ward 24	30.46
Masilonyana LM	28.73
Ward 6	31.21

The age distribution of the areas under investigation shows that the population in on a ward level tend to be older than on district or provincial level, with a greater proportion of people aged between 35 years to 64 years (Figure 4).

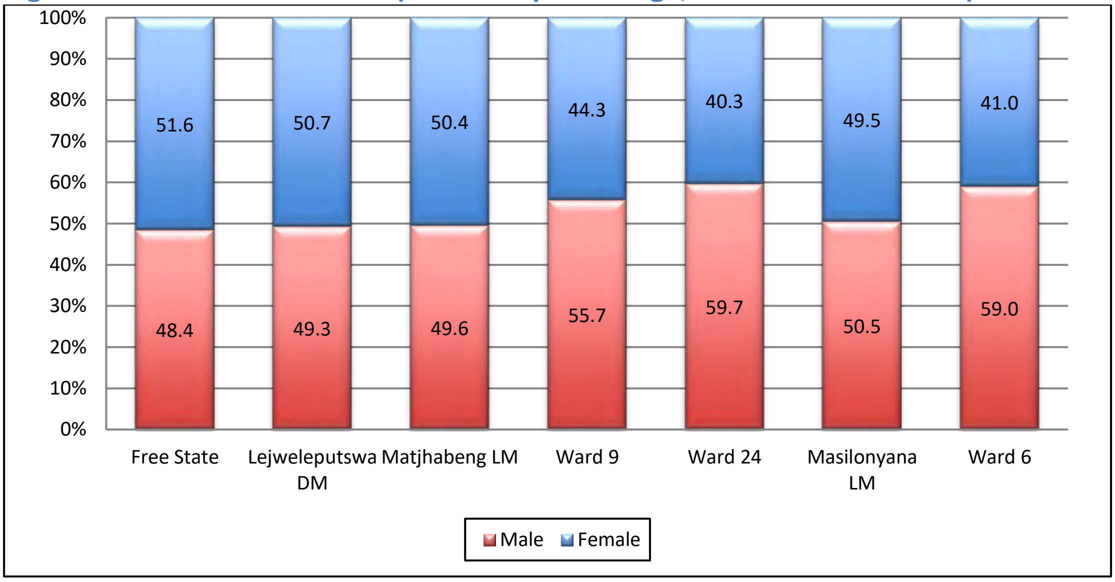
Figure 4: Age distribution (shown in percentage, source: Census 2011)



5.2.3 Gender

The gender distribution on provincial, district and local level is balanced (Figure 5), but on a ward level there is a bias towards males. A higher incidence of males is usually found in mining areas and all three the wards have mining areas that appear to have residences for mine workers.

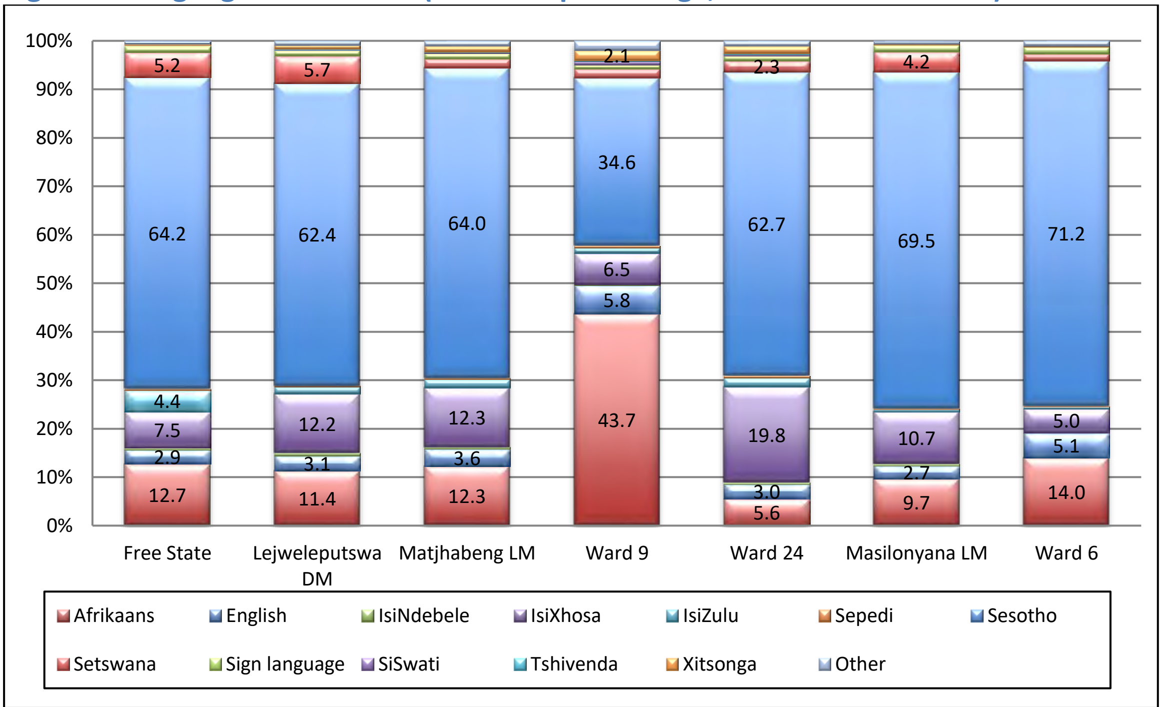
Figure 5: Gender distribution (shown in percentage, source: Census 2011)



5.2.4 Language

Almost two thirds of people in the area under investigation have Sesotho as home language (Figure 6), except in Ward 9 where it is only about a third of people. In Ward 9 more than 40% of people have Afrikaans as home language. Almost a fifth of people in Ward 24 has IsiXhosa as home language, suggesting a high incidence of migrant mine workers residing in this ward. Home language should be taken into consideration when communicating with the local communities and based on the profile of the area communication should take place in Sesotho, Afrikaans and English.

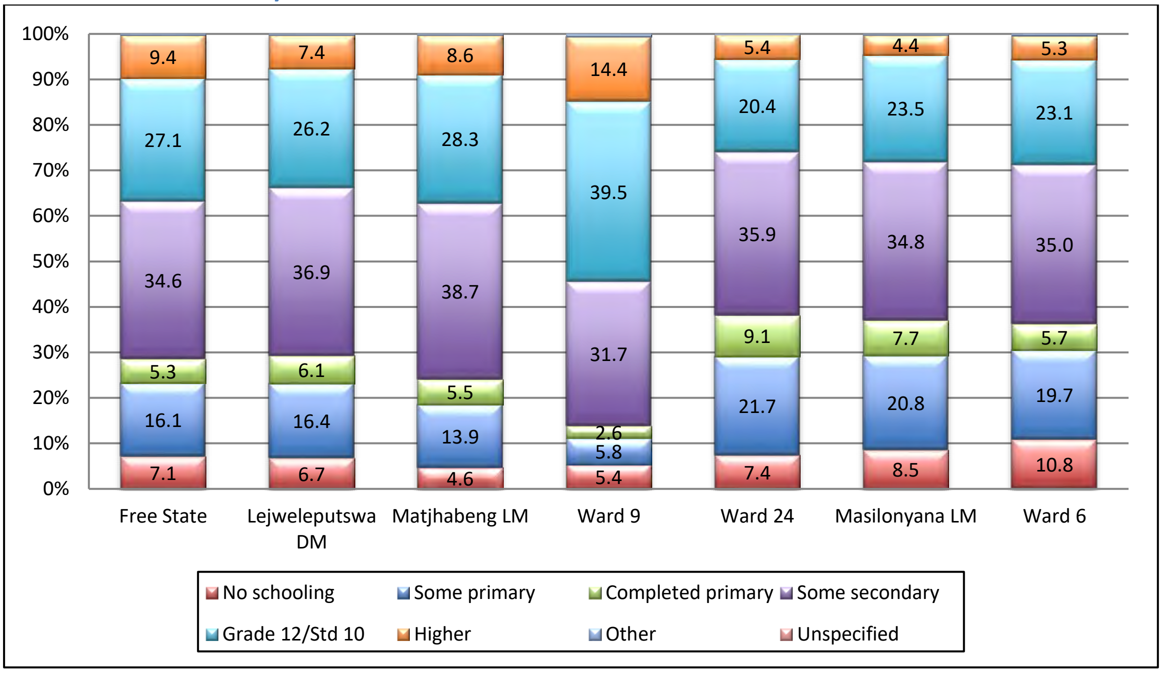
Figure 6: Language distribution (shown in percentage, source: Census 2011)



5.2.5 Education

Figure 7 shows the education profiles for the areas under investigation for those aged 20 years or older. Ward 9 has the highest proportion of people who have completed Grade 12 or higher, while more than 70% of people in Wards 6 and 24 have not completed secondary school.

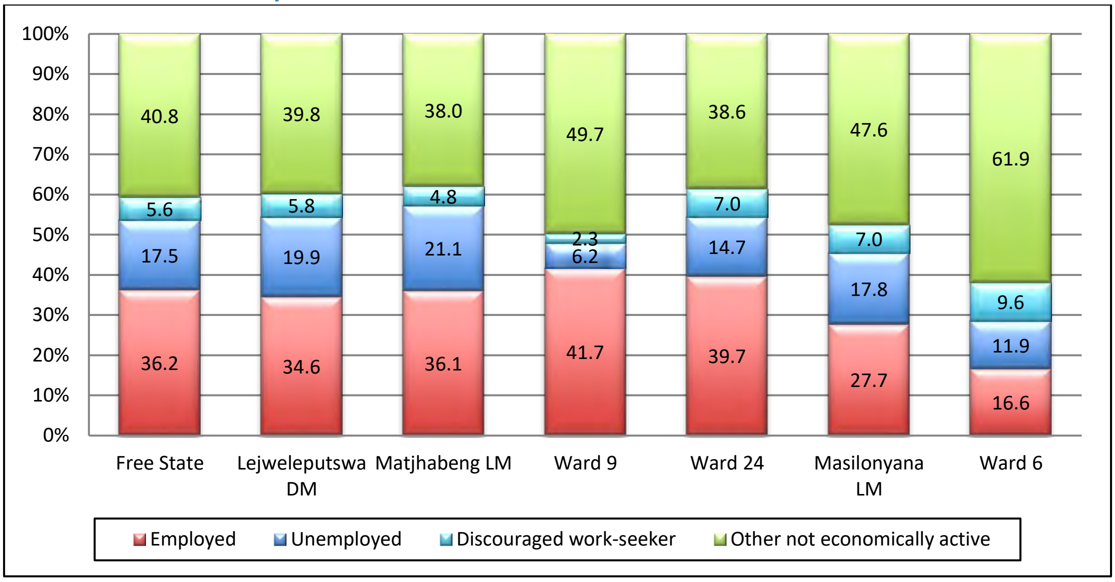
Figure 7: Education profiles (those aged 20 years or older, shown in percentage, source: Census 2011)



5.2.6 Employment

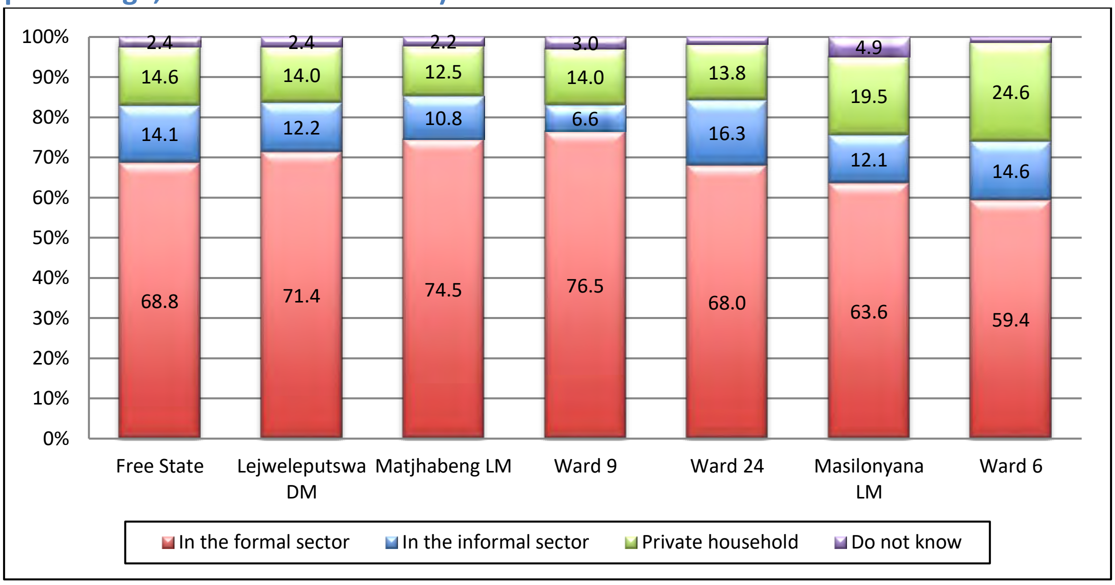
Ward 6 has the lowest proportion of people of economically active age (aged between 15 years and 65 years) that are employed (Figure 8), while Wards 9 and 24 have the highest proportions. Since 2010 employment in the gold mining industry showed a steady decline from 157 019 in 2010 to 94 399 in 2020 (www.mineralscouncil.org.za). As such the proportion unemployed people in the area are likely to have increased since 2011.

Figure 8: Labour status (those aged between 15 - 65 years, shown in percentage, source: Census 2011)



The majority of the employed people in the areas under investigation work in the formal sector (Figure 9). Ward 9 has the highest proportion of people working in the formal sector while Ward 6 has the highest proportion of people working for private households.

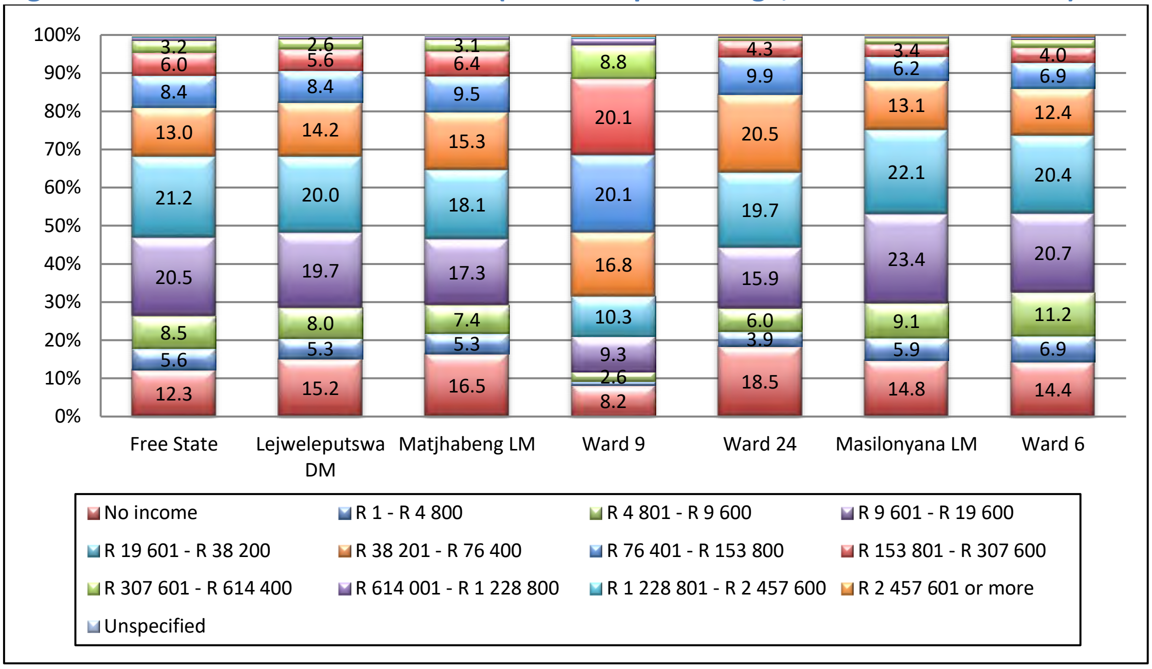
Figure 9: Employment sector (those aged between 15 - 65 years, shown in percentage, source: Census 2011)



5.2.7 Household Income

Ward 24 has the highest proportion of households that have no annual household income (Figure 10), while Ward 9 has the highest average household income.

Figure 10: Annual household income (shown in percentage, source: Census 2011)



5.2.8 Housing

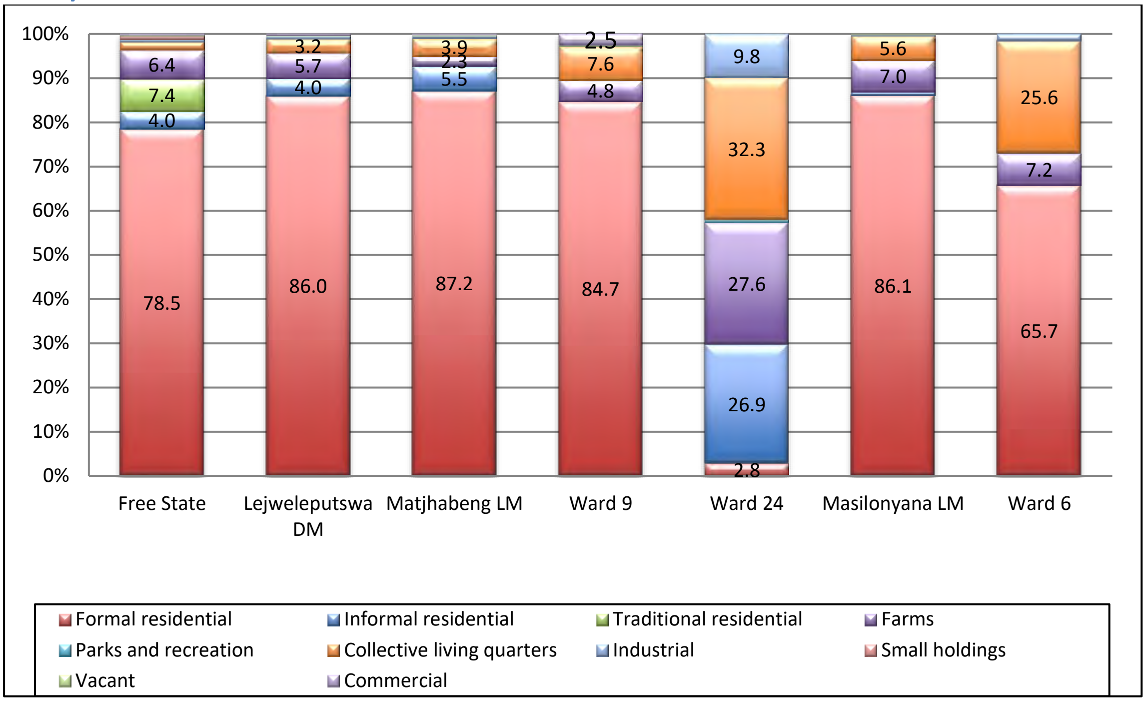
On a ward level the majority of households live in areas classified as urban. Wards 24 and 6 have the highest incidence of households living on farms. In Ward 24 almost a quarter of households live on farms. Ward 9 includes a large portion of the town of Virginia.

Table 6: Geotypes (source: Census 2011, households)

Area	Urban	Tribal/Traditional	Farm
Free State Province	84.5	8.8	6.7
Lejweleputswa DM	93.9	0.0	6.1
Matjhabeng LM	97.7	0.0	2.3
Ward 9	94.2	0.0	5.8
Ward 24	75.2	0.0	24.8
Masilonyana LM	91.4	0.0	8.6
Ward 6	87.4	0.0	12.6

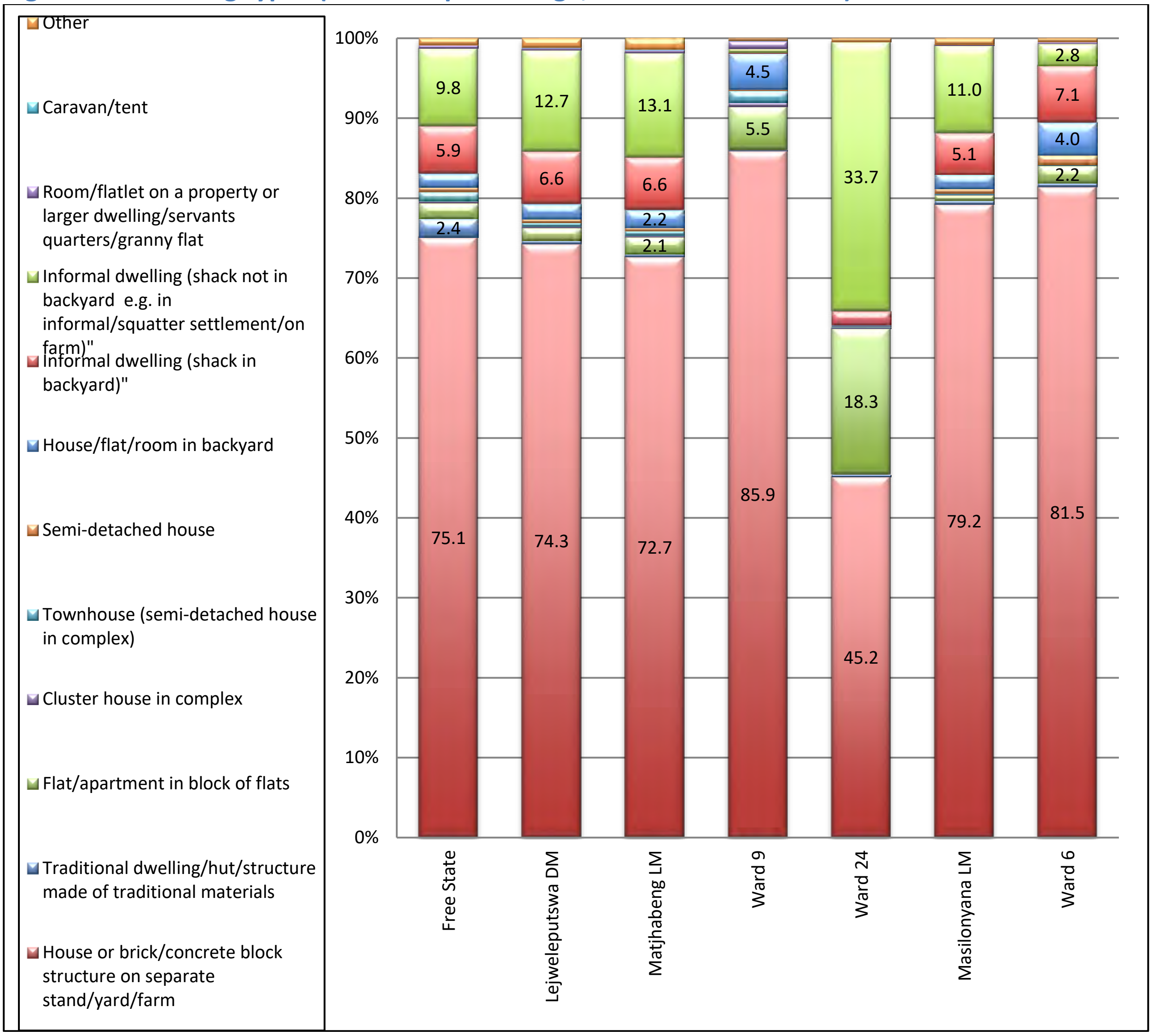
Most households live in formal residential areas (Figure 11), with about a quarter of households in Ward 6 and a third of households in Ward 24 residing in collective living quarters. Just over a quarter of households in Ward 24 live in informal residential areas.

Figure 11: Enumeration area types (persons, shown in percentage, source: Census 2011)



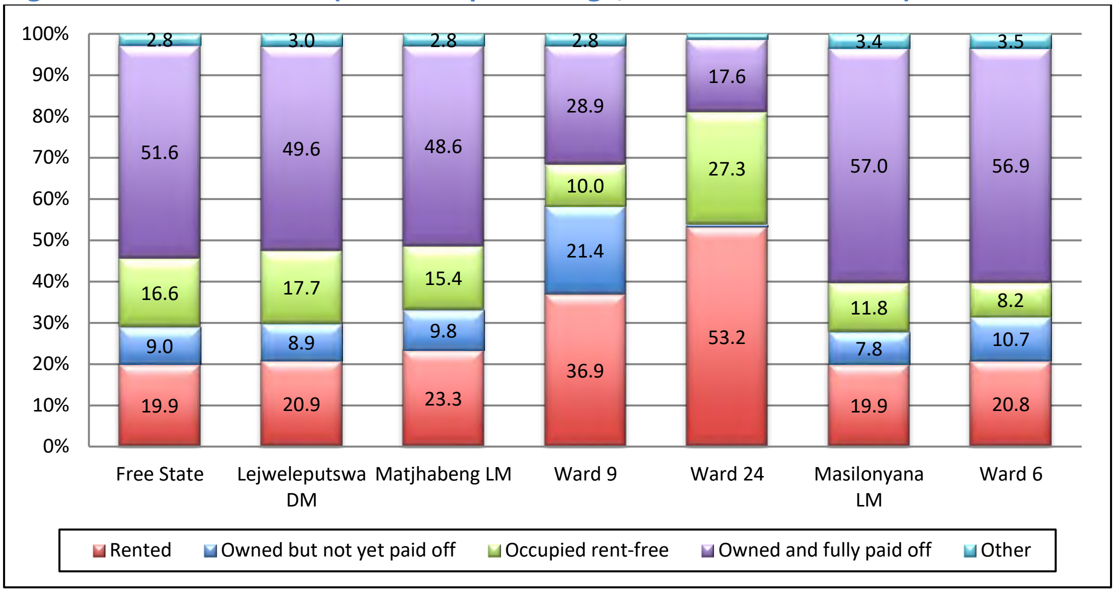
Most of the dwellings in the area are houses or brick/concrete block structures that are on a separate yard, stand or farm (Figure 12), except in Ward 24 where about a third of the dwellings are informal and a fifth live in a flat or an apartment in a block of flats.

Figure 12: Dwelling types (shown in percentage, source: Census 2011)



Ward 24 has the largest proportion of households that are renting their dwellings (Figure 13), with more than half of the households renting, while Ward 6 has the largest proportion of households that own their dwellings and have paid them off in full.

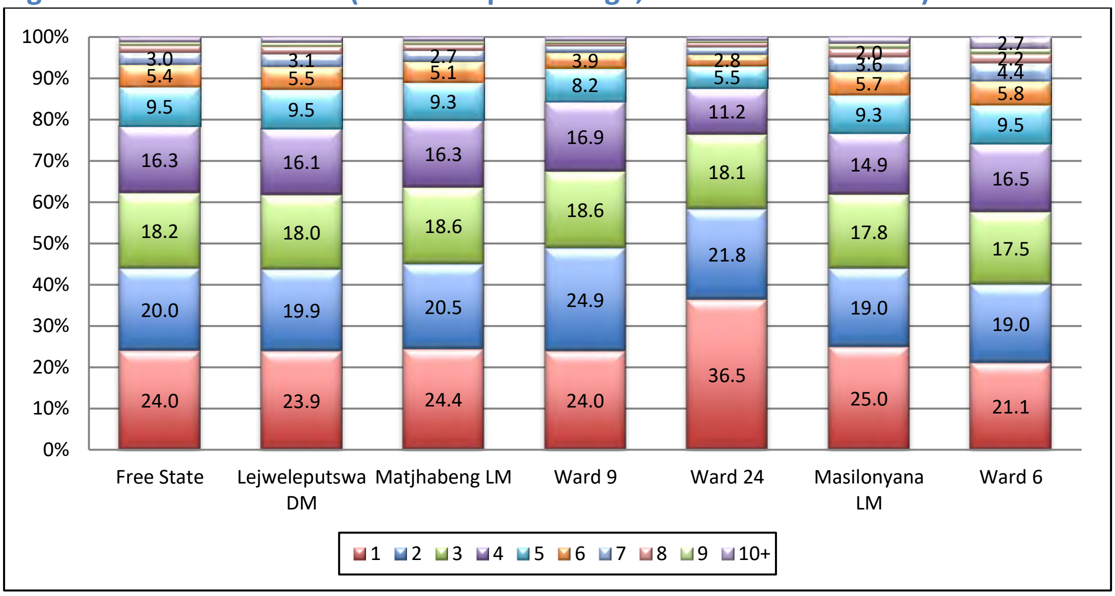
Figure 13: Tenure status (shown in percentage, source: Census 2011)



5.2.9 Household Size

Household sizes on a ward level in the Matjhabeng LM tend to be smaller than on local, district or provincial level (Figure 14), with approximately 50% or more of households on ward level consisting of one or two people, compared to just over 40% on local, district and provincial level. In Ward 6 of the Masilonyana LM households sizes tend to be larger than on local, district or provincial level.

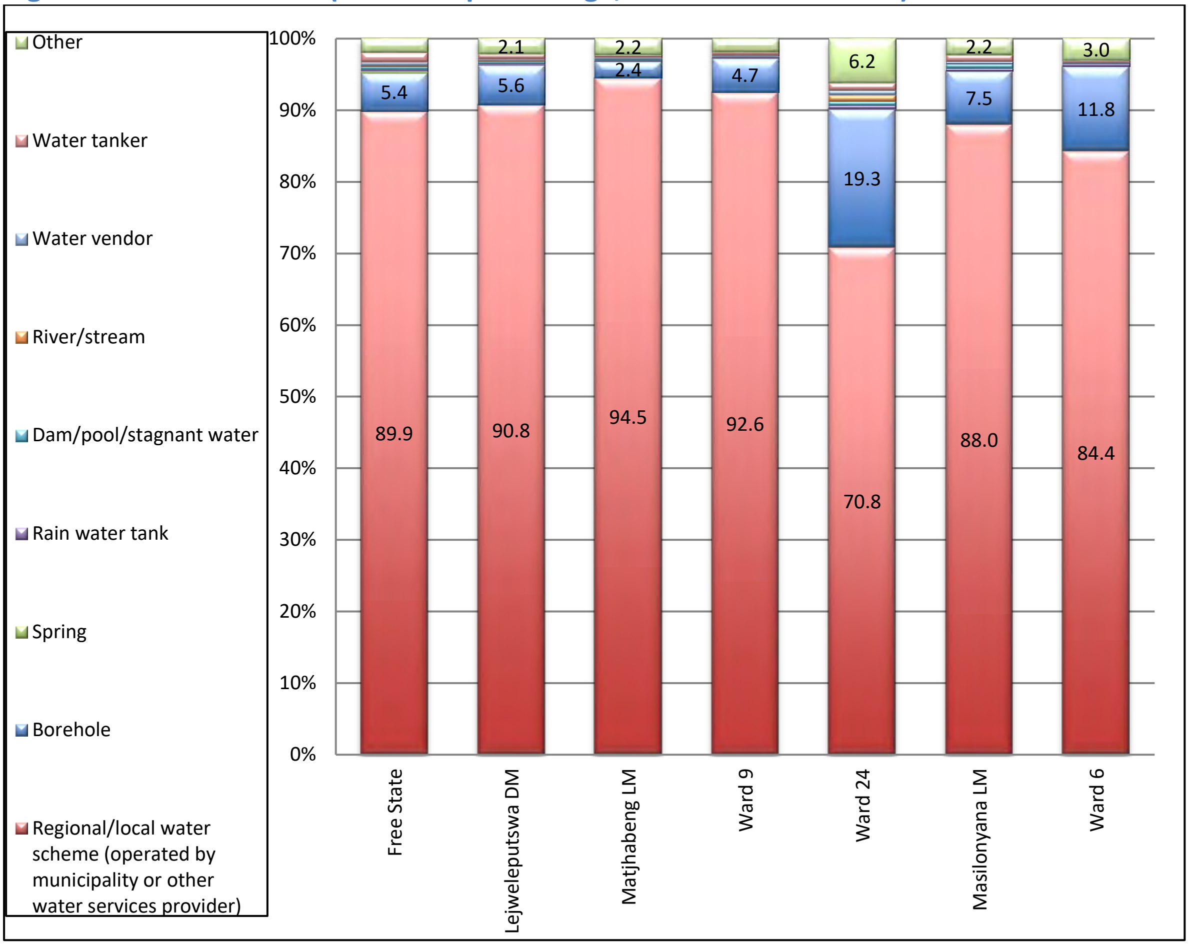
Figure 14: Household size (shown in percentage, source: Census 2011)



5.2.10 Access to water and sanitation

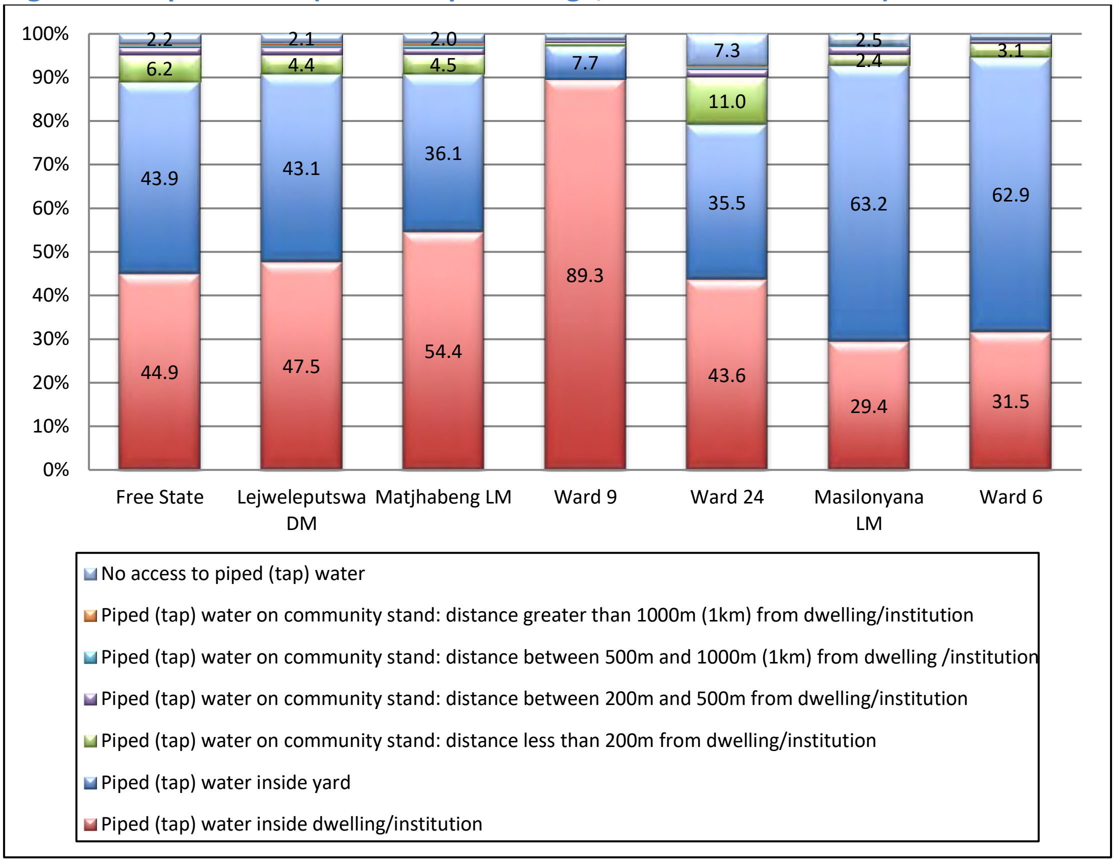
Ward 24 has the lowest incidence of households that access to water from a local or a regional water scheme, but the highest incidence of households that get their water from a borehole or another source (Figure 15).

Figure 15: Water source (shown in percentage, source: Census 2011)



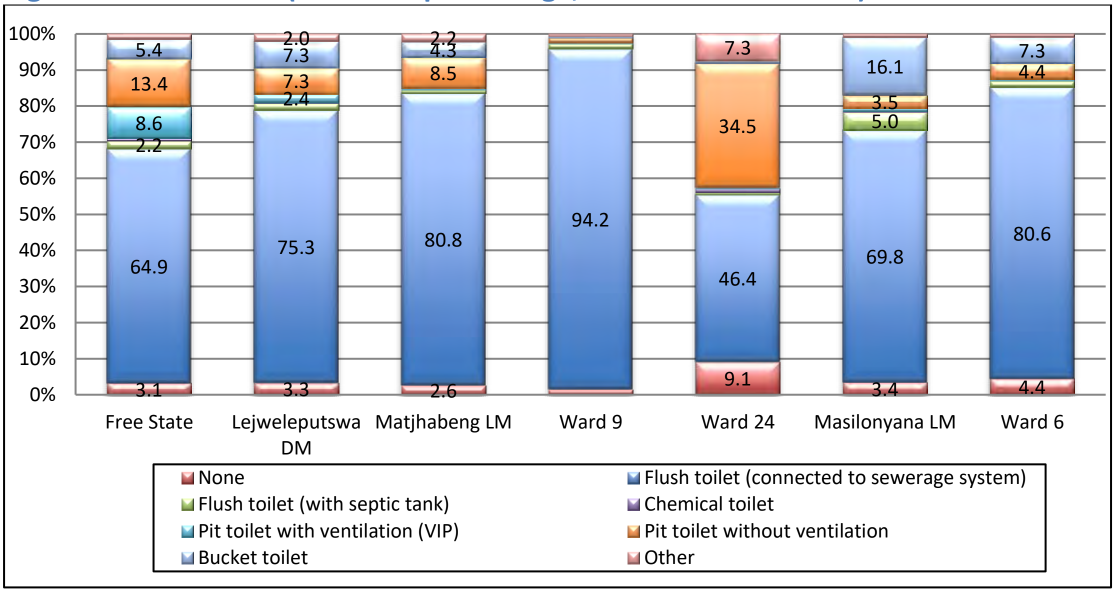
Access to piped water, electricity and sanitation relate to the domain of Living Environment Deprivation as identified by Noble et al (2006). Almost 90% of households in Ward 9 has access to piped water inside the dwelling (Figure 16). In Ward 6 more than 90% of households have access to water insider their dwelling or stand, compared to almost 80% in Ward 24.

Figure 16: Piped water (shown in percentage, source: Census 2011)



The highest incidence of households that do not have access to any sanitation services is in Ward 24 (Figure 17), with approximately a third of the households in the ward having access to pit toilets without ventilation.

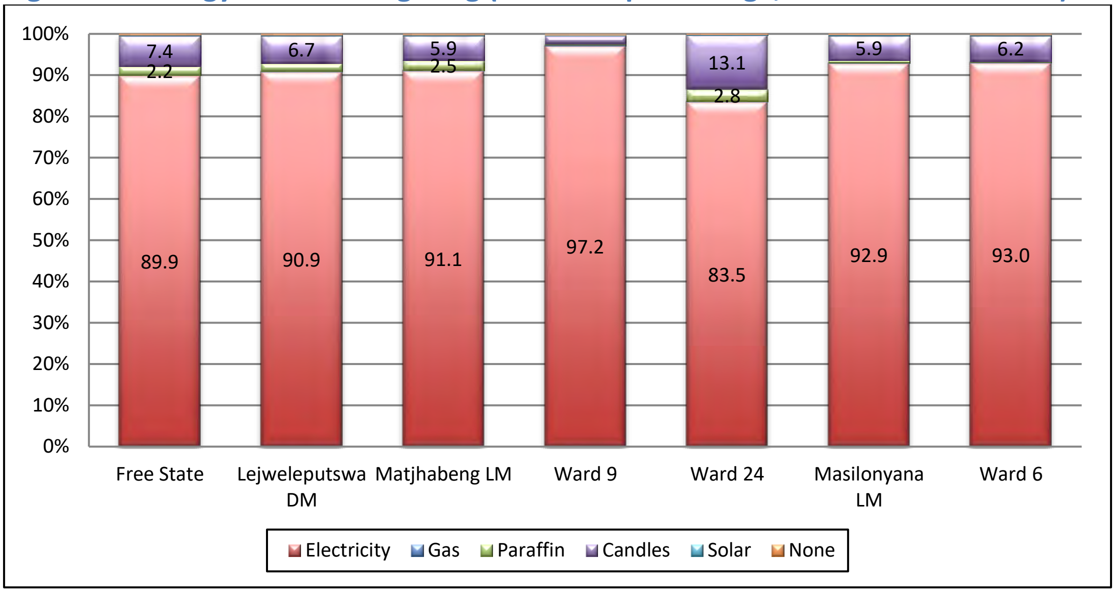
Figure 17: Sanitation (shown in percentage, source: Census 2011)



5.2.11 Energy

Electricity is seen as the preferred lighting source (Noble et al, 2006) and the lack thereof should thus be considered a deprivation. Even though electricity as an energy source may be available, the choice of energy for cooking may be dependent on other factors such as cost. More than 80% of households have access to electricity as energy source for lighting (Figure 18), with candles the second most used source.

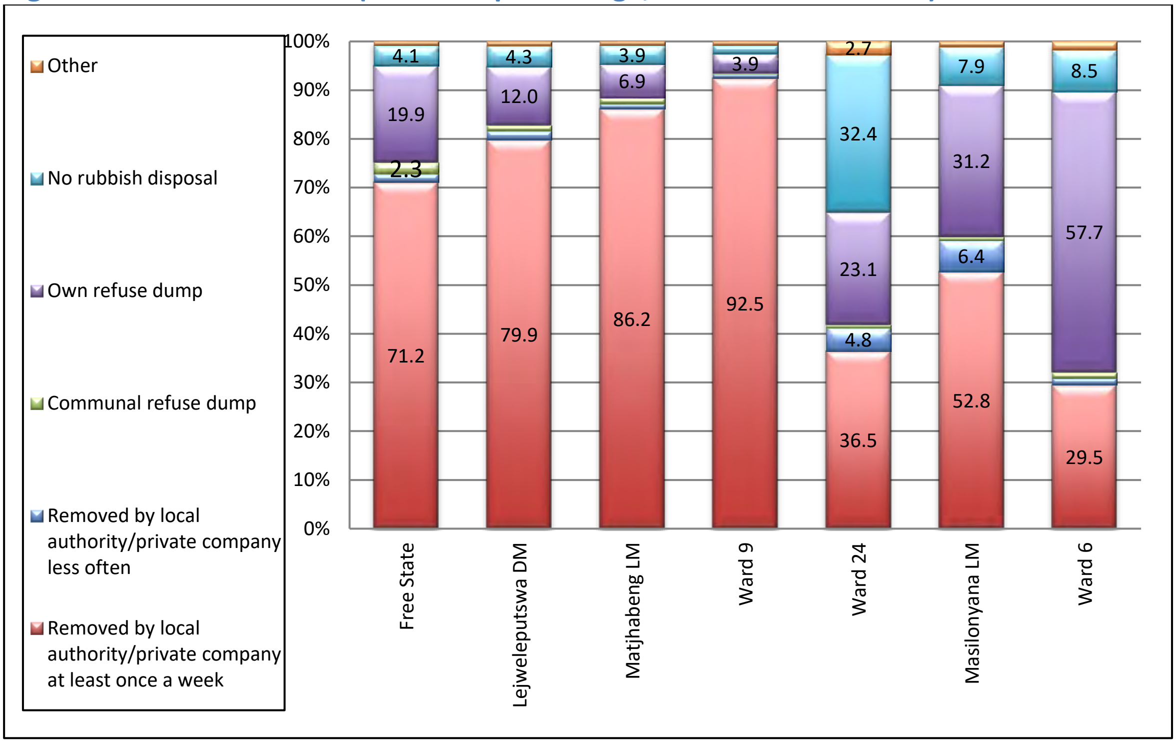
Figure 18: Energy source for lighting (shown in percentage, source: Census 2011)



5.2.12 Refuse removal

Wards 6 and 24 have the lowest incidence of households that have their refuse removed at least once a week by a local authority or private company (Figure 19), with almost a third of households in Ward 24 having no rubbish disposal.

Figure 19: Refuse removal (shown in percentage, source: Census 2011)



6 Stakeholder Identification and Analysis

6.1 Approach

Stakeholders include all individuals and groups who are affected by, or can affect, a given operation. Stakeholders consist of individuals, interest groups and organizations (Vanclay, Esteves, Aucamp & Franks, 2015). Stakeholder analysis is a deliberate process of identifying all stakeholders of a project - the individuals and groups that are likely to impact or be impacted by it - and understanding their concerns about the project and/or relationship with it (Vanclay et al, 2015). Stakeholder analysis assists the proponent with understanding the local cultural and political context. It is acknowledged that different stakeholder groups have different interests, and that there are individual differences within stakeholder groups. The purpose of this section of the report is to introduce the stakeholder groups that will be affected by the proposed projects. The following stakeholder groups were identified and their interest in the projects will be discussed briefly in the section below.

6.2 List of stakeholders

The following stakeholders that may have an interest in or affected by the proposed Tetra4 project have been identified:

Table 7: Detail of Stakeholder Groups.

Stakeholder Grouping	Organisation
Internal Stakeholders	
Renergen	Renergen Staff involved with the Tetra4 project
Tetra4 (Pty) Ltd	Tetra4 Management Team Employees of Tetra4
Government	
Governmental departments and directorates	• Free State Provincial Government • Petroleum Agency of South Africa • National Energy Regulator of South Africa (NERSA) • Department of Environment, Forestry and Fisheries • Free State Department of Economic, Small Business Development, Tourism and Environmental Affairs • Free State Department of Water and Sanitation • Free State Department of Police, Roads, and Transport • Department of Mineral Resources and Energy • Lejweleputswa District Municipality • Masilonyana Local Municipality • Matjhabeng Local Municipality

Stakeholder Grouping	Organisation
	• South African Heritage Resources Agency (SAHRA)
State-owned entities and regulators	• Eskom Distribution • Eskom Transmission • National Energy Regulator of South Africa (NERSA) • South African National Roads Agency Limited (SANRAL)
Business	
Local Businesses	Various in Virginia, Welkom, Thabong, Theunissen and Riebeeckstad Free State Goldfields Chamber of Business
Contractors / Suppliers	Contractors providing sub-contracting services to Tetra4 Suppliers of goods to Tetra4 Suppliers receiving agricultural produce from the farmers in the project affected area Suppliers of agricultural goods to farmers in the project affected area
Other industries	Sibanye Gold
Environmental	
Environmental Interest groups	Endangered Wildlife Trust WESSA Birdlife South Africa Centre for Environmental Rights
Societal	
Social Organizations	Community forums (e.g., employment, youth)
Residents/ Community	
Residents	Residents of informal settlements, homeowners/tenants Virginia, Welkom, Thabong, Theunissen and Riebeeckstad
Local farmers	Farmers and farm workers on directly affected by boreholes or other infrastructure and neighbouring properties Other farmers and farm workers in the area

The identified level of interest of each stakeholder helps assist with designing the stakeholder engagement strategy for the project, and to decide how much time to devote to engaging with each stakeholder or group. This is a qualitative analysis that should ideally be done by the stakeholder engagement team and revisited as needed, as the interest of stakeholders may change after the construction phase and in the operation phase. The engagement levels required for each group of stakeholders as revealed through this analysis may be more than consultation, for example they may include partnerships, involvement in community development plans or community monitoring, strategic planning, or any other activity. Knowing the needs, issues and expectations of affected stakeholders assist with building and retaining good relationships with them, and with managing their expectations.

Table 8 below plots the stakeholders according to their ability to influence the company's activities (horizontal axis) and the degree to which they are affected by the proposed Tetra4 activities, whether the impact is social, economic or environmental (vertical axis). In instances where the impact or influence is potentially significant individual stakeholder groups/organisations have been used. All other groupings are used in general.

Table 8: Stakeholder matrix.

Degree to which they are impacted on		Ability to influence company's activities: Low	Medium	High
	High	Local Businesses Contractors / Suppliers Directly affected farm workers	Contractors Directly affected farmers	
	Medium	Neighbouring farmers and farm workers	State-owned entities and regulators Environmental Interest groups	Governmental departments and directorates
	Low	Social organisations Local residents		

The stakeholders that will be impacted on most in both a positive and negative manner but have the least ability to influence the company's activities are local businesses, contractors, suppliers, and directly affected farmers. There are two groups of directly affected farmers. The first group have been affected by Tetra4 Phase 1 and will be affected by Phase 2 as well. The second group has not been impacted before and will experience the impacts for the first time. This means that the same impact will be a new impact for the one group, and a cumulative impact for the second group. The impact on the livelihoods of the farmers in the long term is a significant concern. The project is still in the negotiation phase about where infrastructure will be, and the relationship between Tetra4 and the landowners are mostly positive. Tetra4 is currently trying to accommodate the landowners' fears and issues, but there are high levels of uncertainty amongst the stakeholders. There is a power imbalance between Tetra4 and the landowners, and there is a risk that the precarious relationship can turn from a good social licence to operate to no social licence to operate. It is therefore of great importance that Tetra4 and the directly affected parties communicate frequently in an open and honest manner to avoid a standoff.

7 Description of potential impacts

7.1 Social Impact Assessment

> *"Almost all projects almost always cause almost all impacts. Therefore more important than predicting impacts is having on-going monitoring and adaptive management."* Frank Vanclay

Considering the statement above, it must be considered that some social impacts will not be discussed in detail and that the focus will be on the most severe impacts. A number of impacts have been identified during the scoping phase of the project. However, during the impact assessment phase of the project when the impacts were investigated in more detail, it was found that some of the impacts will not be significant, and therefore these have not been included in the final impact assessment report. A list of the impacts identified during the scoping phase is included in Section 7.3, and the impacts that require no further investigation at this stage are highlighted in red. Nevertheless, it must be considered that the social environment is dynamic and adapts to change and it is highly likely that impacts predicted in this report will change throughout the life of the project. This has been a major concern amongst many of the directly affected stakeholders. The focus should rather be on the active management of social impacts than on the prediction and once-off mitigation thereof. Successful mitigation and management of social impacts requires long-term commitment and involvement and should form part of the strategic planning and management of the project until decommissioning. Suggestions for the management of social impacts are included in the report in the form of a social impact management plan (SIMP). The implementation of the relevant management suggestions should start as soon as possible, since the social impacts of the project started when the project was announced. Another important consideration in this project is the social context in which it will be executed. Impacts are assessed from a community perspective, and where it will influence a specific group of stakeholders it will be indicated as such. An attempt was made to simplify the impact assessment and to focus on aspects that can aid the decision-making process.

Social impacts are the result of social change, and to fully understand the potential impacts it is important to know the impact pathways. A social change process is a discreet, observable and describable process that changes the characteristics of a society, taking place regardless of the societal context (that is, independent of specific groups, religions etc.). Social change processes can be measured objectively. The way in which social change processes are perceived, given meaning or valued, depend on the social context in which various societal groups act. Some groups in society are able to adapt quickly and exploit the opportunities of a new situation. Others (e.g. vulnerable groups) are less able to adapt, and will bear most of the negative consequences of change. These social change processes may, in certain circumstances and depending on the context, lead to the experience of social impacts. Social impacts are therefore completely context-dependent (Vanclay, 2003).

7.2 Impact assessment criteria

It must be stated that the impact tables and ratings were adapted from the environmental sciences and that it is not always possible to compartmentalise the social impacts. For the sake of consistency this has been attempted, but it is not innate to social sciences. Allowance for the changing and adaptive nature of social impacts should be made when interpreting the impact tables.

The rating criteria used in determining the significance ratings are summarised in the tables below:

Table 9: Criteria for determination of impact consequence.

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),

	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Table 10: Probability scoring.

Aspect	Score	Definition
	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur),

Table 11: Criteria for the determination of prioritisation.

Aspect	Score	Definition
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.

	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).
Degree of Confidence	Low	<30% certain of impact prediction
	Medium	>30% and <60% certain of impact prediction
	High	>60% certain of impact prediction

7.3 Social impacts and mitigation

In this section each impact will be described once, and the phases of the project where the impact will take place will be identified. Mitigation measures for each impact that are relevant through the specific phases will be discussed after each impact.

7.3.1 Impact on livelihoods specific to farming communities

Description of impact

A livelihood refers to the way of life of a person or household and how they make a living, in particular, how they secure the basic necessities of life, e.g., their food, water, shelter and clothing, and live in the community (Vanclay et al., 2015). The farming community in the area is close-knit, and the majority of stakeholders that will be affected by the project rely on farming as a livelihood, in many cases for generations. This includes vulnerable parties like farm workers. The farms are not only their homes, but their businesses. They generate their income from the land. Any aspect that impacts on the ability of a farmer to make a living from his/her land can be seen as an impact on his/her livelihood.

Tetra4 Cluster 2 will involve up to 300 production wells, gas transmission pipelines and associated infrastructure, compressor stations and a Liquid Natural Gas (LNG) and

Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure (including powerlines) in order to meet the future production requirements. Some of the grain farmers have central pivots that will be affected, and in some instances their most productive land is impacted. In order to be an effective grain farmer, you must cover as much ground as possible for sowing and harvesting purposes. The width and distance of the land that they can plough, treat of harvest contribute to the number of hectares that they cover every day. The tractors follow a specific pattern when the fields are prepared. The implements that the farmers use is enormous - harvesters are 12 meters wide, and crop sprayer booms varies between 24 and 36 meters (Figure 20). These implements cannot travel underneath power lines. The position of some of the wells are indicated as being right in the middle of some of the fields. This means that the fields are fragmented, and the farmers will be unable to utilise sections of the fields. It is important to the farmers that each piece of land remain an economic unit. Given the size of the equipment it is difficult to plough on fragmented pieces of land. Farming on fragmented pieces of land is much more labour and time intensive and will have a significant impact on the size of the harvest.

Figure 20: Size of farm equipment (shown with person for scale).

Cattle and game farmers may lose some of the grazing areas, and the noise and movement around the animals is not ideal. Cattle and game farmers are concerned about an increase in poaching incidents due to more movement over their properties. There is small game that occurs naturally in the area. Experience with similar projects has shown that poaching incidents increase when there are construction activities in an area. This is often done via snares and traps, which also pose a risk to livestock. Another concern for game farmers is the hunting season. Hunting forms part of their income, and if there are construction activities on the farms, they cannot accommodate hunters due to safety concerns.

Currently Tetra4 offered the farmers compensation of R18 000 per hectare of their properties that are affected by the servitude per year. If a field is affected by drilling and pipelines, and the farmer cannot produce crops on that field, the financial impact would be much higher since the compensation will only cover the servitude area and not the extra land where no crops can be grown. Drilling in a farmer's field can potentially sterilise the field for up to two years. The reason for this is that the drill will compact the land. The farmer will then need to loosen the ground again. The soil must also be prepared for the harvest. Farmers invest significant amounts in measuring soil chemistry and preparing the soil to get the best possible harvest. Farming is approached from a scientific perspective and a seasonal endeavour. If a farmer misses a planting season, he can only plant his crops again in the next season. Preparing, planting, fertilising, and harvesting activities means that the farmers work their land all year long – there are never times when it just lies fallow. Due to the lack of information and timeframes, the farmers are uncertain about how long their fields will be occupied and how permanent the impact will be. They will lose the income generated by the specific field, which in some instances where the farmers are impacted by a lot of wells and trenches, forms a significant part of their income. This meets the International Finance Corporation (IFC) definition of economic displacement. According to the IFC economic displacement is the loss of income streams or means of livelihood resulting from land acquisition or obstructed access to resources (land, water, or forest) resulting from the construction or operation of a project or its associated facilities (IFC,2002).

Renting fields from farmers does not yield a similar income to harvesting a field. If the farm is out of commission for an extended time due to Tetra4's activities, it will mean that some farm workers may lose their jobs and houses, as the farmers cannot afford to keep paying staff without generating income or having work for them to do. Farmers must also continue to pay for water and electricity rights, whether they use it or not.

Any negative impact on the livelihood of a farmer impacts on farmworkers, who are much less resilient. Many of the affected people have dependents such as elderly parents and young children, in addition to their workers. Impacts on livelihoods are seen as some of the most significant impacts from a social perspective, as the ripple effect of this impact can be felt on so many levels, and people always experience this impact severely on a personal level.

Table 12: Potential mitigation for impacts on existing livelihoods.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	The Tetra4 community liaison officer (CLO) must continue to deal with the affected landowners throughout the life of the project	All phases	Throughout the life of the project	Tetra4	The CLO must keep records of all the communication with affected landowners throughout the life of the project	Establish good relationships with the affected landowners and protect their interests	Communication register, social risk and incident register
2.	In cases where there the farmer does not agree with the compensation offered by Tetra4 related to loss of potential income due to exploration, construction or operational activities, Tetra 4 must appoint an agricultural economist at their cost to determine what the actual losses will be to the farmers due to the drilling and trenching activities on their properties. Farmers must be	Exploration phase Construction phase Operation phase	Periodically when a farmer's source of income is affected	Tetra4	Revised yearly as long as the impact exist.	Ensure that there is no loss of income for the affected farmers due to Tetra4's activities	Report from agricultural economist Economic displacement action plan.

	compensated for the actual losses for the entire period that they cannot use the land due to Tetra's activities. This may be one or two years, depending on when in the season the drilling and trenching take place, and how long the property is affected. The principles explained in the **IFC Handbook for Preparing a Resettlement Action Plan** must be followed. This includes a land use/land capability inventory; an asset register and physical asset survey; an income stream analysis and entitlement matrix. Compensation must be determined with input from the landowners.						
3.	If any existing livelihood activities will be affected negatively Tetra4 must enter into negotiations with the affected parties as soon as reasonably achievable to ensure	All phases	Before the construction phase or activity that will interfere with their	Tetra4 CLO	Ad hoc – CLO must keep records and produce on request	Protect the livelihoods of landowners against negative social impacts	Proof of communication about prospective activity (minutes of meeting, e-mail, SMS)

	the affected parties are compensated fairly or can make additional arrangements. Interference with existing livelihoods should be avoided if possible. If any new activities are planned for a property, Tetra4 must consult with the landowner and obtain his consent to execute the activity on his/her land.		livelihoods commence				Written agreements
4.	If any interference takes place and there are actual losses, the landowner should be compensated for their losses. Tetra4 must have a claims procedure that is communicated to all affected landowners. There must be specific timeframes dealing with response times and time it takes to close out complaints. In order to receive compensation, the claim forms must be submitted to the Tetra4 CLO Compensation should follow the IFC principles, which states that market related prices should be paid, and if anything is restored, it must be to the	All phases	Commence in the planning phase and continue throughout the life of the project	Tetra4 CLO	As required – claims received by CLO and records of all claims must be kept	Ensures that landowners do not suffer actual losses because of the project.	Claims procedure distributed to all land owners Claims register Completed claim forms

	same or better standards than before.						
5.	If areas are fenced, the fences must be checked for snares on a daily basis for the duration of the construction period. All incidences must be reported to the closest police station. Anti-poaching toolbox talks should form part of the induction process of all the fencing teams. Any contractor or employee caught poaching should be removed from site.	Construction	Throughout the construction period	Tetra4	Daily	To ensure no poaching events take place or harm is done to livestock	Record of inspections Toolbox talk records

7.3.2 Impact of servitudes on land values

Description of impact

Tetra4 plans to register servitudes for all the wells, pipelines and other infrastructure that is on the property of the farmers. The farmers are concerned about the impact of having numerous servitudes registered on your property on the value of their properties. They also commented that some of the Cluster 1 servitudes has not yet been registered at the Deeds office. Due to the fact that there is not clarity at the moment about where exactly wells will be drilled and where the pipes will be, the landowners are not keen to have a multitude of servitudes registered before Tetra4 has exact locations for the wells that they are definitely going to use. The farming community suggested that temporary access and rent arrangement should be made to access the land until there are certainty about which wells will be used.

A praedial servitude is registered against immovable property in favour of other immovable property. The real right therefore, attaches to the land itself and not a person. In this instance, you will have a servient tenement and a dominant tenement. The servient tenement is the land burdened by the servitude, and the dominant tenement is the land that benefits from the servitude. Common examples of praedial servitudes are right of way, right of aqueduct, right of conduction of electricity and right of grazing servitudes.

Table 13: Potential mitigation for impacts from servitudes.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	Servitudes should only be registered for the life of the operations or as long as the well and pipeline in use are productive. At the end of the life of operations, or when a well or pipeline is no longer productive od used, servitudes must be de-registered at the cost of Tetra4. Servitudes cannot be seen as access routes unless it has been specified as such and agreed on by both parties.	Pre-construction Decommission-ing	Negotiations must commence before any activities take place	Tetra4 Landowner	Servitude agreements must be revisited once a year to determine if it is still relevant and necessary	Protect the land values of the affected land owners.	Servitude agreements
2.	Temporary access and land arrangements must be made until there are more certainty on exactly where the wells will be. Servitudes should only be registered for productive wells.	Pre construction Operation	Before the drilling commence	Tetra4 Landowner	To be revisited whenever new wells are drilled or new infrastructure will be required.	Protect the land rights and property values of the landowners.	Temporary land agreement and access arrangement document.

7.3.3 Uncertainty

Description of impact

The farmers are the holders of the surface rights, whilst Tetra4 holds the production rights. This means, that according to the MPRDA, Tetra4 can give the land owner 21 days' notice, and then continue with their production activities, despite objections from the land owners. This is a cause of uncertainty and tension amongst the farmers, since they feel that they have no control over or say in what will happen on their property. Another source of uncertainty is how Tetra4 will implement the project and the way in which the contract with the landowners is structured. The farmers feel that the contract is too open, have few specifications, no explanation on exactly what they are agreeing too and no timelines. Since the impact on each individual landowner will be different, the farmers feel that there should be a basic contract which are then negotiated with the specific landowner.

The affected landowners would like to see a map of the project as a whole – it is difficult for them to see on the maps that only cover their property where the pipeline exit their property and enters their neighbour's property and what route is planned.

Farmers are also concerned about what the consequences will be if farmers or farm workers damage any Tetra4 property, for example when using large equipment such as tractors or harvesters. The farmers are unsure about who would be responsible to pay for the damages.

The land owners affected by Cluster 1 are especially concerned about the potential future expansion of the project. They are now affected by Cluster 2 as well, and fear that there may be more future expansion. They are concerned about their rights. Some of the landowners have lived on the properties for generations, and also see it as the future for their children. The uncertainty has a mental impact on the farmers as well and is a source of stress and worry.

Table 14: Potential mitigation for uncertainty

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	Tetra4 must provide detailed written information to the landowners to assist them with making informed decisions. The information must include: 1. Depth and route of the pipeline 2. Timeframe associated with the drilling and installation process – when will Cluster 2 start and end. 3. A3 or A2 maps of the entire project area for each affected landowner 4. Information about well heads and boreholes: How long does it take to drill a borehole? Can more than one borehole be drilled with the same drill point? What infrastructure are needed around the well heads and sketches of this infrastructure	All phases	Commence in the planning phase and continue throughout the life of the project	Tetra4	The CLO must keep records of all the communication with affected landowners throughout the life of the project	Establish good relationships with the affected landowners and protect their interests	Written information sheet Communication register, social risk and incident register

	Are all the drill points necessary? What will happen if there is a change in the infrastructure presented to the landowners? Can more than one wellhead be operated from one underground manhole? Will the boreholes be left open for a period of time after the holes were drilled? How are the wellheads connected to each other? What happens if no gas is found at a borehole? Will unproductive boreholes be investigated again later? 5. Positions of blowers, booster stations and compressors, if any. Sketches of all associated infrastructure. 6. Will there be overhead power lines or electric						

	cables? Will cables be buried? 7. What maintenance will be required, and how often will teams need access for maintenance? 8. Where will the condensation wells be? 9. How will condensation water be removed? The contract states it will be no more than once a week, but is it once a week per well, or once a week that the vehicle gets access? 10. Who will be responsible for damage to Tetra4 property?						
2.	Any future expansion plans must be communicated to any landowner that will be influenced by the expansion.	All phases	Before the construction phase or activity that will affect their land rights commence	Tetra4 CLO	Ad hoc – CLO must keep records and produce on request	Protect the land rights of the landowners	Proof of communication about prospective activity (minutes of meeting, e-mail, SMS) Written agreements

7.3.4 Nuisance factor due to increase in ambient dust and noise levels

Description of impact

Nuisance factors refers to aspects that may be within the legal limit, but still causes a nuisance or irritation to the receptors. The drilling and construction phase activities will create dust, especially if it is done in the dry season. This will mostly affect the stakeholders whose dwellings are close to where the work will be conducted. Another concern is the impact of the dust created by the drilling on the crops of the farmers.

Some of the new well sites are very close to dwellings. Drilling is an inherently noisy activity. The noise from the drilling will be worse than the noise from digging trenches. Although this is a temporary impact, it will create a major nuisance whilst happening.

Table 15: Potential mitigation nuisance factors.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	The relevant specialists will provide scientific mitigation measures for this aspect. Practical, visible solutions such as putting shade nets against fences close to dwellings during the construction phase should be investigated. No drilling or construction must take place on weekends or between sunset and sunrise.	Design and planning, construction, operation.	Commence in the planning phase and continue through to the operation phase of the project	Tetra4 EO CLO	As prescribed by specialists Meetings with affected landowners to discuss issues	Minimise the nuisance impact on affected landowners	Minutes of CLO meetings Monitoring results from relevant specialist studies. Practical solutions implemented by Tetra4 Minutes of meetings with affected landowners.

7.3.5 Change in travel patterns

Description of impact

Changes in travelling patterns can be experienced on different levels. People may need longer travelling times and need to change routes due to increase in traffic or lack of access. This may be especially relevant where people have more than one property and use internal roads to access their properties. Especially during the drilling and construction phase there may be instances where access routes will be obstructed, and people will need to change their existing movement patterns. This may have time and cost implications for the affected landowners. In some cases, they would need to construct new access routes, and in other instances they would need to incur costs to travel longer routes. Although construction is planned for a certain period, there are many external factors that can impact on construction plans, such as extreme weather events, labour unrest and changes in company structures. Should construction last much longer than intended, this impact will increase in severity. When considering access, the nature of the business that is operated from each property must be considered. Some properties need 24 hours access and any problem with accessing these properties will impact on the livelihoods of the residents. Mega-farm implements and their operating requirements must also be considered. There are also a few game farms in the area which farm with exotic game. The game is sensitive, expensive, and vulnerable to environmental stressors such as noise and movement. To support their livelihoods, farmers in the area have certain window periods when they need to cultivate their fields, especially during planting and harvesting time. During these periods they must be able to access their fields without any difficulties. At the end of the project access routes that provide access to land/ infrastructure that was cut-off by the project must be reinstated.

Table 16: Potential mitigation impacts on travel patterns.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	It may be unavoidable to change travel patterns. It is important to inform the affected stakeholders about the possibility of this impact as soon as possible. It will allow them time to get used to the idea and plan their activities accordingly. It is also important that locally affected parties give input in potential mitigation measures. Before construction and drilling commences Tetra4 must meet individually with each landowner to discuss their movement patterns and needs. Tetra4 must provide all the affected landowners with a construction and drilling schedule to ensure that they know when construction will take place on their properties. It is recommended that construction and drilling be done outside the peak planting and harvesting seasons. Any changes to the construction and drilling schedule must be communicated to the farmers at least a week in advance. As far as possible obstruction of access routes and sensitive areas must be avoided. If it cannot be avoided both parties must agree on	Design and planning, Construction, Operation, Decommission.	Commence in the planning phase and continue throughout the life of the project	Tetra4 CLO	Meetings with landowners Construction schedule communicated at least 7 days before construction commences.	Ensure that the access routes used by landowners are not affected by the project. If it is affected, to minimise disruption and costs	Minutes of meetings with landowners Construction schedule provided to landowners Proof of communication of changes in construction schedule. Written agreements in place where Tetra4 specify what costs they will carry if access routes need to change;

	alternative routes, and Tetra4 should carry the cost of implementing the alternatives. Industrial vehicles should not travel during peak traffic times. If practical and required by the landowner, access routes to land/infrastructure should be reinstated in the decommissioning phase. This must be done in conjunction with the landowners.						

7.3.6 Damage to farm roads, existing services, and infrastructure

Description of impact

Tetra4 is and will continue to use existing farm roads to access their infrastructure, and in some instances the infrastructure is and will be aligned with existing roads. There is a high possibility that the roads will be damaged during construction the process. Farmers maintain and construct their own roads. Road maintenance is especially tricky in the rainy season. The project area received unusual high rainfall during the past rainy season. The farmers acknowledge that Tetra4 is trying their best to accommodate farmers' requests to not access their land after heavy rains, but report that it still happens, despite them having asked explicitly that no one drive on the roads until it can be done without damage. The farmers feel that it is impossible for Tetra to control the movements of all the drivers at any given time. Some of the roads must be able to carry the weight of heavy farm implements or trucks that the farmers use in their daily tasks, but the farmers are still concerned about the drilling rigs and the potential damage it will cause to roads and fields. The roads are not very wide, and it may be problematic for big vehicles to pass each other on the roads – especially in the rainy season there is a high risk of getting stuck. The farmers reported that they had to help some of Tetra4's personnel who got stuck on the roads.

Landowners report that the trenches were not compacted properly during the Cluster 1 construction. As a result, some of the trenches formed ditches that lead to erosion and uneven road surfaces which made it challenging for the big farm equipment to traverse.

There are services such as electricity lines and water lines installed by the farmers that must be protected, since interruption in these services will have time and cost implications for the farmers. The damage of roads and services are a major concern of the farmers.

Table 17: Potential mitigation impacts on farm roads and existing infrastructure.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	If private roads are affected by project activities, it is the responsibility of Tetra4 to maintain these roads as long as they use it. Tetra4 should engage with the relevant farmers about road maintenance, as some of them have preferential ways in which the roads must be maintained, for example if roads are only graded and not built up it turns into rivers when there is heavy rain. The road maintenance agreements must be formalised before construction and drilling commences to ensure all parties involved are protected and know their rights and responsibilities. Tetra4 must make sure that all compacting and rehabilitating of trenches are done to the specifications in the Environmental Management Plan. It is recommended that construction and drilling be planned for the dry season. Tetra4 must provide all the affected landowners with a construction and drilling schedule to ensure that they know when construction will take place on their properties. Any changes to the construction and	Design and planning, Construction, Operation, Decommission.	Before construction commence, throughout the life of the project	Tetra4 CLO	Road inspections with landowners and CLO every 4 months	Ensure that Tetra4's activities does not impact negatively on existing roads at the cost of the affected landowners	Signed road maintenance agreements Construction schedule Proof of communication of changes in construction schedule (E-mail, SMS, minutes of meeting)

	drilling schedule must be communicated to the farmers at least a week in advance.						
2.	Before the project commences Tetra4 should compile an asset and infrastructure baseline of any landowner infrastructure such as fences, pipes, electricity lines, roads and troughs that may be affected by the project. Photographs and GPS co-ordinates of the infrastructure must be included in the baseline. A copy of the baseline affecting their property should be given to each landowner, who should sign off the document to ensure that it is accurate. Tetra4 should keep the master document. If any damage occurs it should be reinstated to its pre-project status. If the infrastructure must move, it must be done at Tetra4's cost. Tetra4 must ensure that the construction team has a copy of the asset and infrastructure baseline to guarantee that no infrastructure will be damaged due to ignorance during the construction phase of the project.	Construction Rehab and closure	Must be compiled before construction and drilling commences. At project closure landowners must sign land release agreement that states all infrastructure has been reinstated to its original status.	Tetra4 CLO	CLO and landowners must have copy. Landowner to sign copy to indicate assets and infrastructure has been recorded correctly	Ensure that landowners property are returned to him/her in a similar or better condition than before the project started	Asset and Infrastructure Baseline report Proof that copies of report has been distributed to all relevant parties Signed land release agreements

7.3.7 Impacts on livelihoods due to behaviour of contractors

Description of impact

Tetra4 may use contractors to do some of the work required, or to do specialised work on the project during different phases of the project. Seemingly innocent acts may have severe consequences for affected parties. Gates that are left open can lead to road accidents if livestock wander into roads. It can also cause damage if livestock enter cultivated fields and eat the crops, which could in some instances kill them, or damage the crops to such an extent that it reduces the potential profit. In addition, open gates can give access to opportunistic criminals. People driving off-road may cause erosion, get stuck or scare sensitive livestock. If contractors' litter, the livestock may eat some of the garbage such as plastic bags, which could kill them. It is also unsightly. Food waste may attract pests like rodents. Contractors defecating and urinating in the fields due to a lack of sanitation facilities may unknowingly spread diseases, as animals may eat the excretions. No contactor must enter any property without the knowledge of the landowner.

Table 18: Potential mitigation impacts due to behaviour of contractors.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	All contractors should sign a code of conduct as part of their induction process. Induction must explicitly include aspects such as closing gates and littering. Toolbox talks must be designed to include social and environmental aspects. A fining system must be put in place for any transgressions affecting the landowners. It is important to instil respect for the landowners and their livelihoods from the beginning of the project.	Design and planning, construction, operation	Before construction commence, throughout life of project for any new contractors	Tetra4 Sub-contractors	At least one toolbox talk a month should be dedicated to social and environmental matters	Ensure contractors and sub-contractors treat landowners with respect.	Toolbox talk records Fining system for transgressions

7.3.8 Impacts on safety and security of local residents

Description of impact

Safety and security are a major concern of all of the affected landowners. The current socio-economic and political conditions in South Africa are such that people living in isolated areas such as farms are extremely vulnerable to crime and violence. The project will introduce unfamiliar people into the area who will be able to share current conditions with outsiders or opportunistic criminals. The farmers are acutely aware and distrusting of any strangers or strange cars moving in the area. Any movement at night is unusual. In some instances, vulnerable parties such as women and children are alone on the farms from time to time (this includes the farm workers). It is important for the farming community to control who access their property. This includes access between neighbouring farms – some farmers have gates in the fence between themselves and their neighbours, and they also need to control who uses these gates. Some of the farmers installed their own security cameras. Their other security concerns include vandalism, stock theft and fires. Erfenis Veiligheid is the preferred security service provider of the farmers, as most of them uses Erfenis already and they have sorted out some issues that they had. The farmers think that security is acceptable at the moment but must be intensified during the construction phase. Farmers prefer that the AgriSA access protocol should be used to access their farms.

Table 19: Potential mitigation impacts on safety and security.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	Tetra4 should work with the preferred farmers' security group (Erfenis Veiligheid) and implement the AgriSA farm access protocol for everybody that need to access the properties. Pictures, make and registration numbers of all vehicles used by Tetra4 on site should be provided to the farmer's security group and distributed to all affected landowners to ensure that they will be able to identify these vehicles if they access their properties. For scheduled and maintenance work Tetra4 should give a roster to the farmers stating dates and approximate times that contractors will be on the farms. Farmers emphasised that they need to know of people accessing the farm ahead of time. It is too late to inform them when entering the property. All access arrangements should be made at least 24 hours before access is required. Tetra4 must meet with the landowners before the construction and drilling phase commence and formalise security arrangements. This should be done in writing and include the existing forums that the landowners	All phases	Commence in planning throughout the life of the project	Tetra4 Local security groups CLO	Security check-ins should be done on a monthly basis to ensure all aspects are attended to.	Ensure the safety and security of affected land owners.	Signed formalised security agreements with existing security groups. Construction and maintenance schedule distributed to farmers

	know and trust.						
2.	All contractors and employees need to wear photo identification cards. Vehicles should be marked as construction vehicles and should have Tetra4's logo clearly exhibited. Entry and exit points of the site should be controlled during the construction and drilling phase. Areas where materials are stockpiled must be fenced. The schedules of the security company should be communicated to the farmers, especially to those farmers that have Tetra4 infrastructure that need to be guarded. It must be considered that guards changing shifts contribute to the impact of strangers accessing properties, and therefore a system that consider the safety of both the Tetra4 infrastructure and the safety of the landowners must be implemented. The necessary sanitation facilities must be made available, and some form of shelter from the elements. The security guards must not be allowed to make fires for cooking or heating purposes.	All phases	Commence in planning throughout the life of the project	Tetra4 Local security groups CLO Health and Safety officer	Security check-ins should be done on a monthly basis to ensure all aspects are attended to.	Ensure the safety and security of affected land owners.	All contractors and employees issued with photo identification cards. All vehicles marked Access control on site Schedule of security company communicated to farmers. Sanitation facilities for security forces erected.
3.	A system to arrange access to properties must be devised and formalised. The landowners must agree to the system. Access must be arranged at least 24	All phases	Before construction commence,	Tetra4 Contractors Sub-contractors	Every time a new contractor works on the project	Ensure access to properties are controlled and	A formalised access control system Communication register

	hours prior, except in emergencies, when the landowners should also be informed immediately. Landowners have the right to refuse people access to their properties if it was not arranged in advance. If routine access is required, the landowners must be provided with a roster indicating dates and approximate times that access will be required. Tetra4 must compensate the landowners for any damage to property or goods if it was due to behaviour of their contractors. Sub-contractors must be made aware of this and a clause spelling out their liability should be included in their contracts		throughout life of project	Landowners	As required	landowners do not incur any losses as a result of the behaviour of sub-contractors and contractors	Claim forms for any losses Incident register Clauses included in sub-contractor agreements

7.3.9 Impacts on sense and spirit of place

Description of impact

Sense of place refers to an individual's personal relationship with his/her local environment, both social and natural, which the individual experiences in his/her everyday daily life (Vanclay et al, 2015). It is highly personal, and once it is affected, it cannot be restored. It is also difficult to quantify. Part of the sense of place is the emotional attachment that the farmers have to their properties, and the hopes that they have for it to serve future generations (their children). The environmental philosopher Glenn Albrecht noted a consistent theme of distress caused by coal mining in Australia by the assault on the people's sense of identity, place, belonging, control, and good health. He identified a melancholia from the loss of solace and comfort connected with their home which he termed 'solastalgia' – a form of homesickness that one gets when one is still at 'home' associated with the major project impacts they experienced (Albrecht et al, 2007). Social impacts can therefore range from significant health impacts to the loss of a cherished landscape and associated loss of a sense of place.

The spirit of place associated with an area is an important factor in tourism and hunting and the marketing of these activities. Spirit of place refers to the unique, distinctive, and cherished aspects of a place. Whereas 'sense of place' is the personal feelings an individual has about a place, spirit of place refers the inherent characteristics of the place (Vanclay et al, 2015). In this case the spirit of place includes the vast rural landscape.

Many things can impact on a person's perception of sense of place. The area in question will have high levels of dust in the planting season. This dust has significance for the people and contributes to the sense of place. Dust outside of the planting season will not have the same meaning and will be seen as a nuisance that changes the way in which people experience the area, as it will be associated with industrial activities. Farms are generally noisy places if one considers animal-sounds and farming activities. From the receptors' perspective, this kind of noise is acceptable and even attractive, because this is what living on a farm is all about. Noises associated with drilling, construction and trenching are not "normal" and disturb the sense of place and the value that people place on the auditory environment. Although lights are used as a security measure on farms, one of the things people values is the absence of bright lights and that they can see the stars. Lights for any other use than lightening up their direct environment is seen as invasive and disturbs the sense of place. Farmers affected by Cluster 1 that have infrastructure on their property commented on the extra lights and how difficult it is to get used to it. Farmers also commented on having to get used to people patrolling the infrastructure. Although it is encouraging that there are visible safety measures, farmers commented that they sometimes feel like they are trespassers on their own property when they are stopped at night and have flashlights pointing in their faces. Visual aspects are an important consideration in the experience of sense of place. If people are used to unspoiled vistas, or seeing open fields, the establishment of any buildings or infrastructure that they feel do not belong there can alter their sense of place. Game farmers are concerned about the markers on the pipeline, and do not want to see red beacons in their fields. The project will permanently alter the sense of place. Especially in the beginning this impact will be expressed in a severe manner, but as time goes on people will get used to the changing environment and adapt to it.

Table 20: Potential mitigation impacts as a result of sense of place.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	It is difficult to mitigate the impact on sense of place as it is experienced on a personal level. In general, the mitigation measures suggested in the visual, noise, ecological impact assessments and other relevant specialist studies should be adhered to. The relevant specialists will provide scientific mitigation measures for the aspects relevant to their studies. The direction and brightness of lights close to residences must be considered. Pipeline markers on game farms must be camouflaged by either painting it in a colour that blend in with the surrounding areas, or putting natural materials such as branches or wooden poles around it. This must be done in consultation with the affected landowners. Sense of place is a personal experience, but successful rehabilitation will go a long way in recreating a rural sense of place. The public perception would be negative or positive depending on the successful implementation of the rehabilitation.	Construction, Operation, Decommission.	Commence in construction phase, through the life of the project	Tetra4 CLO EO	As per the requirements of the relevant specialist	Minimise or soften the impact on the sense of place	Minutes of meetings with landowners about lights and beacons. Outcomes of environmental audits

7.3.10 Impacts on the social licence to operate

Description of impact

Social licence to operate (SLO) is a popular expression to imply that the acceptance of the community is also necessary for a project to be successful. Tetra4 has been working hard to build good relationships with the landowners and has mostly succeeded in keeping the relationship positive. Many of the landowners commented on the effectiveness of communication and especially the community liaison officer. However, despite this, there seem to be some things slipping through. A lot of the frustration is related to access issues, and changes to the project that has not been communicated to affected landowners. A number of new landowners will be affected by Cluster 2. It is important that Tetra4 continues with the positive relationships. The way in which landowner concerns are dealt with, and the time it takes to resolve issues will determine whether the SLO remains intact. The way in which the contracting issues will be dealt with can cause serious harm to the SLO if not handled with care.

Table 21: Potential mitigation impacts on social license to operate.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	Tetra4 has a dedicated person that communicate with the landowners with whom they have a positive relationship. It is important that this relationship is extended to the Cluster 2 landowners. Information sharing, frequent communication and quick responses to issues/complaints/enquiries will assist Tetra4 with maintaining their SLO	Construction, operation, decommission, closure and rehabilitation	Commence in construction phase and continue throughout the life of the project.	CLO		Optimise Tetra4's social license to operate	Communication registers

7.3.11 Increase in social pathologies

Description of impact

Cluster 2 of the Tetra4 project will include construction and drilling teams. The levels of activities on the farms and in the local areas will increase. People with access to more money and different value systems may mix with local community members. Given the high unemployment in the area, people may deploy livelihood strategies such as prostitution. Vulnerable parties such as young girls may also fall victim to sexual predators and there can be an increase in teenage pregnancies. Promiscuous behaviour can lead to an increase in the spread of sexually transmitted diseases. Especially in isolated areas there may be an increase in alcohol and substance abuse due to these things being more easily available.

Table 22: Potential mitigation impacts on social pathologies.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	Toolbox talks should include talks about the impact of promiscuous behaviour. Tetra4 should develop an in-house infectious diseases strategy to address health issues within the workforce. A workforce code of conduct should be developed to maximise positive employee behaviour in the local community, and optimise integration.	Construction	Align with the construction period	Tetra4	CLO to ensure strategy implemented in construction phase.	To create awareness about social pathologies and the spread if diseases	In-house infectious diseases strategy Voluntary testing and counselling events organised Trained peer educators Accepted workforce code of conduct

7.3.12 Public perceptions about safety associated with gas production

Affected phases: Operation

Description of impact

The landowners are aware of the fact that helium is not an explosive gas. They are concerned about the methane that is mixed with the helium. The landowners want to know where and how the two gasses will be separated and transported. They are concerned that pipelines under pressure close to residences may explode. Another concern is that leaks or explosions in the pipeline may cause veld fires.

Table 23: Potential mitigation impacts associated public perceptions.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	Tetra4 should compile a background information document (BID) explaining the process and potential risks in laymen terms. This should be distributed to local stakeholders. Special sessions to inform the farm workers in their native languages must be conducted. They can also consider a media awareness campaign on local radio stations and press statements to local papers.	Operation	Start campaign before project commence. Consider to expand to other phases if required	Tetra4	BID distributed once. Communication procedures ad hoc as required	Increase awareness and educate people about the project and associated risks	Background information document Press releases Newspaper articles Minutes/records of meetings Attendance registers from farm worker meetings
2.	Tetra4 must become a member of the local firefighting association. Access routes and procedures in case of any veld fire must be determined and shared with the firefighting association, farm owners and Tetra4 staff.	Construction Operation	Before construction and drilling commence, for the life of the project.	Tetra4 Land owners Firefighting association	Reviewed quarterly	Improve emergency preparedness and reaction time when there are veld fires	Written procedures in case of veld fires/explosions
3.	Wells and pipelines must be kept away from residences as far as possible	Construction	Before construction commence	Tetra4	Every time new infrastructure is considered	Address safety concerns of landowners and residents	Position of pipeline and wells relative to houses.

7.3.13 Contribution to economy of South Africa

Description of impact

The Tetra4 project is unique in South Africa and can potentially contribute significantly to the economy of South Africa through exports of helium gas. The project is the first and only natural gas project to have been awarded an onshore petroleum production right in South Africa. All the liquefied natural gas produced will be available for local market consumption. The helium produced will meet local demand, and the balance will be exported (Makay, 2019). The economic impacts are discussed in the economic impact assessment, but from a social perspective there are greater societal benefits associated with the project.

Table 24: Potential mitigation impacts on economy of South Africa.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	No mitigation or enhancement is required. This is a positive impact that will occur if the project proceed.						

7.3.14 Secondary economic opportunities

Description of impact

Apart from the direct economic impacts of the proposed project, as described in the economic impact assessment, there will also be secondary economic opportunities that can potentially benefit local service providers. Opportunities include transport, domestic services, catering, drilling, security and fencing amongst others. The use of local service providers will ensure that the local economy benefits directly from the proposed project. Since there will be limited direct local economic benefits, this impact can potentially assist with ensuring social license to operate and that the local communities feel as if the project benefits them in some way.

Table 25: Potential mitigation impacts on secondary economic opportunities and local economy.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	Tetra4 should ensure at least 70% of **secondary economic opportunities** are given to local contractors. Services and goods must be procured locally as far as reasonably possible. Aspects of this positive impact will occur by default when the construction force lives locally and they utilise local services and support local shops.	Construction, operation, decommission, closure and rehabilitation		Tetra4 Local business chamber	Review supplier list on a yearly basis	To ensure Tetra4 contribute to the local economy through secondary opportunities	Signed service provider agreements

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7.3.15 Potential opportunity for education, skills development, and training

Description of impact

Through their Social and Labour Plan Tetra4 have the opportunity to contribute to education, skills development, and training. This can be done through specific technical training related to their core business, or supportive training such as helping local schools. Through internships and practical experience, they can contribute to skills development.

Table 26: Potential mitigation impacts on education, skills development and training.

No	Mitigation Measures	Phase	Timeframe	Responsible party for implementation	Monitoring party (frequency)	Target	Performance indicators (monitoring tool)
1.	Tetra4 should liaise with local training institutions to determine whether there are any opportunities to offer internships and practical experience for their students. Tetra4 must ensure that skills development requirements form part of their contracts with sub-consultants. The skills development requirements in their Social and Labour Plan (SLP) must be implemented. Tetra4 can liaise with local schools to participate in science classes or bring science pupils to visit the facility once it is operational.	Construction, operation	Once construction commence, throughout operation phase of the project	Tetra4	Will be monitored as part of the SLP	To ensure Tetra4 contributes to local education, skills development and training	Requirements written into sub-consultant agreements Number of internships and on-the-job training opportunities offered Records of liaison with science classes.

7.4 Impact ratings

Impact	Phase	Pre-Mitigation							Post-Mitigation							Confidence	Impact Prioritisation		Priority Factor	Final Score
		Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER		Cumulative Impact	Irreplaceable Loss		
Impact on livelihoods specific to farming communities	Construction	-1	2	2	4	4	5	-15	-1	2	2	2	3	5	-11.25	High	2	2	1.25	-14.06
Impact on livelihoods specific to farming communities	Operation	-1	3	4	5	4	5	-18	-1	3	3	4	3	3	-13	High	2	2	1.25	-16.25
Impact of servitudes on land values	Operation	-1	3	5	5	4	5	-21.25	-1	3	4	3	3	4	-13	High	2	2	1.25	-16.25
Uncertainty	Planning	-1	3	3	4	3	5	-16.25	-1	3	2	3	3	3	-8.25	High	2	2	1.25	-10.31
Nuisance factor due to increase in ambient dust and noise levels	Construction	-1	2	2	3	3	5	-12.5	-1	2	2	3	3	4	-10	High	2	1	1.13	-11.25
Changes in travel patterns	Construction	-1	2	2	4	2	5	-12.5	-1	2	2	3	2	4	-9	High	2	1	1.13	-10.13
Damage to farm roads, existing services, and infrastructure	Construction	-1	2	2	5	3	5	-15	-1	2	2	4	2	4	-10	High	2	1	1.13	-11.25
Damage to farm roads, existing services, and infrastructure	Operation	-1	2	4	5	3	4	-14	-1	2	4	4	3	4	-13	High	3	1	1.25	-16.25
Impacts on livelihoods due to behaviour of contractors	Construction	-1	3	2	4	2	4	-11	-1	2	2	3	2	3	-6.75	High	2	1	1.13	-7.59

Impacts on safety and security of local residents	Construction	-1	3	2	5	3	4	-13	-1	3	2	3	3	4	-11	High	3	3	1.50	-16.50
Impacts on safety and security of local residents	Operation	-1	3	4	5	3	5	-18.75	-1	3	4	3	3	4	-13	High	2	2	1.25	-16.25
impacts on sense and spirit of place	Construction	-1	2	2	5	3	5	-15	-1	2	2	4	2	4	-10	High	3	2	1.38	-13.75
impacts on sense and spirit of place	Operation	-1	2	5	4	5	5	-20	-1	2	5	4	5	5	-20	High	3	2	1.38	-27.50
Impacts on the social licence to operate	Construction	-1	3	2	4	3	4	-12	1	2	2	4	3	4	11	Medium	2	2	1.25	13.75
Impacts on the social licence to operate	Operation	-1	3	4	5	3	4	-15	1	3	4	4	2	4	13	Medium	2	2	1.25	16.25
Increase in social pathologies	Construction	-1	3	2	3	3	4	-11	-1	3	2	3	2	4	-10	Medium	2	1	1.13	-11.25
Public perceptions about safety associated with gas production	Operation	-1	3	3	4	2	4	-12	-1	3	2	2	2	3	-6.75	Medium	1	1	1.00	-6.75
Contribution to economy of South Africa	Operation	1	5	4	4	5	5	22.5	1	5	4	5	5	5	23.75	High	2	1	1.13	26.72
Secondary economic opportunities	Construction	1	3	2	4	2	4	11	1	4	4	4	2	5	17.5	Medium	2	1	1.13	19.69
Secondary economic opportunities	Operation	1	3	4	4	2	4	13	1	4	4	4	3	5	18.75	Medium	2	1	1.13	21.09
Potential opportunity for education, skills development, and training	Operation	1	3	4	4	2	4	13	1	4	4	4	3	5	18.75	Medium	2	1	1.13	21.09

7.5 Social inputs as described in the Generic Environmental Management Plan for Gas Transmission Pipeline infrastructure in South Africa.

The following aspects included in the Generic Environmental Management Plan for Gas Transmission Pipeline infrastructure in South Africa (CSIR,2020) are relevant to the social environment:

7.5.1 Planning/design

Table 27: Agriculture

Impact management outcomes: To achieve a reduced amount of disturbance on productive agricultural land as a result of the implementation of the impact management actions.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Plan the fine-scale positioning of the gas pipeline, block valves, pigging stations, access roads, storage areas and construction camps to have minimal disturbance on agricultural activities and agricultural land. 2. Where possible the gas pipeline infrastructure must be positioned on existing boundaries or edges of agricultural units of land (fields) wherever possible, so as not to interfere with agricultural activities within a unit. 3. Avoid, wherever possible, the pipeline route from running through:						

a. areas that are utilised for and/or are suitable for deep rooted agricultural and forestry crops; and b. lands that have contour banks. 4. Where the above avoidance is not possible, ensure that the construction is undertaken in the least productive agricultural season or period to minimise the impact on agricultural processes. 5. Existing farm-based accommodation and settlements must be taken into consideration during the fine-scale positioning of the gas pipeline and associated infrastructure, as best as possible.						

Table 28: Settlement Planning, Disaster Management and Social Aspects

Impact management outcomes: To build local community capacity and municipal support, avoiding key areas (where possible) and providing decision support.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Use existing infrastructure servitudes where viable and agreed to. 2. Ensure that the gas transmission pipeline is sited						

so as avoid the need for resettlement. Where involuntary resettlement cannot be avoided, the relocation of affected households and/or compensation for economic displacement should be guided by national and/or international best practice (such as a Resettlement Action Plan) to manage the impact of resettlement. 3. Ensure a fair compensation process is implemented by the EA holder, where required, in line with the most recent and relevant Standards (such as the International Finance Corporation (IFC) Performance Standards). 4. Timeous negotiations and detailed studies must be undertaken to minimise negative impact in vulnerable communities such as farm workers. 5. Ensure transparency in decision-making to provide clarity and ensure clean processes. 6. All negotiations and planning process should ensure that the phasing is clear, that schedules for the construction is limited and clearly communicated to limit the impacts on the population and their livelihoods. 7. A servitude agreement must be drawn up and signed by the EA holder and landowner(s). The						

agreement must stipulate the requirements of the agreement, as well as the activities that may and may not be undertaken within the servitude, such as growth of deep-rooted plants. 8. Ensure that pipelines are designed and built according to international and national standards and in accordance with the surrounding land-use. 9. The pipeline design must consider the latest technology to prevent leaks and to monitor volumes of natural gas transmitted. This must include a suitable system to manage and monitor the transmission of the gas through the pipeline. 10. A Leak Detection Monitoring Plan must be compiled. 11. Pigging stations must be located in areas accessible to 24 hour emergency services. 12. Develop an emergency plan for implementation during the construction and operational phases, based on widespread consultation and awareness-raising. 13. Include municipalities and Fire Protection Associations in their disaster management planning procedures. 14. Ensure that a community emergency response						

plan is devised and coordinated with appropriate community representatives. This should include: 15. a. The warning signs of a possible gas leak, such as: • Dirt being blown or appearing to be thrown into the air; • A white vapour stream or mist-like cloud over the pipeline; • Dead or dying vegetation in an otherwise green area; • A dry area in a wet field; • Flames coming from the ground or appearing to burn above the ground; • Continuous bubbling in wet or flooded areas; • Unexpected frost or ice on the ground; • A roaring, blowing or hissing sound; • An unusual “rotten egg” odour (Natural gas has no smell, but gas producers add chemicals to create a smell, and this helps with identification of leaks). b. Important steps emergency responders can take during the initial stages of an incident: • If it is safe to do so, turn off any						

mechanized equipment and ignition sources in the vicinity of the suspected leak; • Secure the site and determine a plan to evacuate or sheltering place; • Monitor for hazardous atmospheres; • Control and redirect traffic; and • Provide immediate access to representatives from the pipeline company. c. The role of the local responders: • Handling traffic control and evacuation; • Securing the site; • Firefighting; • Making appropriate contacts if it appears other agencies, facilities or local authorities are impacted by the pipeline incident; • Handling search and rescue; and • Providing medical assistance. d. The emergency response plan should also include a continuing-education program for all first responders and the public residing adjacent to the pipeline.						

7.5.2 Construction phase

Table 29: Access roads

Impact management outcomes: To establish effective access and movement of vehicles within authorised areas on site in order to minimise resultant environmental impacts.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Access to the construction right of way, site camps, storage areas, and pigging station positions must be negotiated with the relevant landowner. Such access roads must fall within the assessed and authorised area. 2. An access agreement must be formalised and signed by the Project Manager (PM), Contractor and landowner before commencing with the construction activities. 3. The access roads to the construction right of way, site camps, storage areas, and pigging station positions must be signposted after access has been negotiated and before the commencement of the construction activities. 4. All contractors must be made aware of all these access routes. 5. Restrict all vehicle traffic within the authorised						

disturbance area. 6. Any access route deviation from that in the written agreement must be closed and re-vegetated immediately, at the expense of the Contractor. 7. Maximum use of both existing servitudes and existing roads must be made. 8. In circumstances where private roads must be used, the condition of such roads must be recorded prior to use and the condition thereof agreed by the landowner, the PM, and the Contractor. 9. All private roads used for access to the construction right of way and pigging station positions must be maintained and upon completion of the works, be left in at least the original condition. This must be agreed with the asset owner. 10. Access roads and bridges shall only be constructed where necessary at watercourses, on steep slopes or where boulders prohibit vehicular traffic 11. As far as possible, access roads must follow the contours in hilly areas, as opposed to winding down steep slopes.						

12. Access roads must be constructed in accordance with relevant design standards.						

Table 30: Fencing and gate instillation

Impact management outcomes: The erection of fencing and management of fencing is to be undertaken in accordance with relevant legislation.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Use existing gates available to gain access to all parts of the area authorised for development, where possible. 2. Existing and new gates are to be recorded and documented. 3. All gates must be fitted with locks and be kept locked at all times during the construction phase, unless otherwise agreed with the landowner. 4. At points where the pipeline routing crosses a fence in which there is no suitable gate within the extent of the construction right of way, on the instruction of the Project Manager (PM), a gate must be installed at the approval of the landowner. 5. Original tension must be maintained in the fence						

wires. 6. All gates installed in electrified fencing must be re-electrified. 7. All demarcation fencing and barriers must be maintained in good working order for the duration of the gas transmission pipeline construction activities. 8. Fencing must be erected around the construction site camp, batching plants, hazardous storage areas, and all designated No-Go and restricted areas, where appropriate and would not cause harm to sensitive flora and fauna. 9. Any temporary fencing to restrict the movement of livestock must only be erected with the permission of the landowner. 10. All fencing must be constructed with high quality, SABS approved, material. 11. The use of razor wire as fencing must be avoided. 12. Fenced areas with gate access must remain locked after hours, during weekends and on holidays if staff are away from site. Site security will be required at all times.						

Table 31: General Solid Waste Management

Impact management outcomes: To manage general solid waste in accordance with relevant national and provincial legislation and local by-laws.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. All measures regarding waste management must be undertaken using an integrated waste management approach. 2. Sufficient, covered waste collection bins (scavenger and weatherproof) must be provided. 3. A suitably positioned and clearly demarcated waste collection site must be identified and provided on site. 4. The waste collection site must be maintained in a clean and orderly manner. 5. Waste must be segregated into separate bins and clearly marked for each waste type for recycling and safe disposal. 6. Staff must be trained in waste segregation. 7. Recycling of waste types must be maximised. 8. Bins must be emptied regularly, and the resulting waste disposed of correctly. 9. General waste produced on site must be disposed of at a registered waste disposal sites or via a recycling company.						

10. Certificates of safe disposal for general and recycled waste must be maintained and retained on file. 11. Under no circumstances shall any waste be disposed of, burned or buried, on site.						

Table 32: Safety of the public

Impact management outcomes: All precautions are taken where possible to minimise the risk of injury, harm or complaints						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Identify fire hazards, demarcate and restrict public access to these areas as well as notify the local authority of any potential threats e.g. large brush stockpiles, fuels etc. 2. All unattended open excavations must be adequately fenced or demarcated. 3. Adequate protective measures must be implemented to prevent unauthorised access to and climbing of protective scaffolding. 4. Ensure structures vulnerable to high winds are secured. 5. Maintain an incidents and complaints register in						

which all incidents or complaints involving the public are logged. 6. Ensure that an awareness campaign is undertaken prior to the commencement of construction to inform surrounding landowners, land users and occupiers, as well as Interested and Affected Parties of the proposed construction, and inform them of the potential risks associated with prohibited activities within the gas pipeline servitude, such as illegal excavations. 7. Ensure that all surrounding Interested and Affected Parties have access to a contact number for the Contractor and Pipeline Operator for emergency situations.						

Table 33: Sanitation

Impact management outcomes: No pollution or disease arises on-site as a result of sanitation facilities or lack thereof.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Mobile chemical toilets must be installed on site if no other ablution facilities are available. 2. The use of ablution facilities and or mobile toilets						

must always be used and no indiscriminate use of the environment for the purposes of ablutions must be permitted under any circumstances. 3. Ablution facilities shall be located within 100 m of any workplace and must be sufficient enough to accommodate the workforce (minimum requirement of 1:15 workers on site). 4. Where mobile chemical toilets are required, the following must be ensured: a. Toilets are located no closer than 100 m to any watercourse or water body. b. Toilets are secured to the ground to prevent them from toppling due to wind or any other cause. c. No spillage occurs when the toilets are cleaned or emptied, and the contents are managed in accordance with the EMPr; d. Toilets are emptied before long weekends and workers holidays, and must be locked after working hours; and e. Toilets are serviced regularly, and the ECO must inspect toilets to ensure compliance to health standards. 5. A copy of the waste disposal certificates must be						

maintained.						

Table 34: Prevention of diseases

Impact management outcomes: The risk of the occurrence and spread of disease is minimised through the effective implementation of EMPr actions.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Undertake environmentally friendly pest control in the camp area. 2. Ensure that the workforce is sensitised to the effects of sexually transmitted diseases, especially HIV/AIDS, or other highly infectious viruses such as COVID-19. 3. The Contractor must ensure that information posters on HIV/AIDS and COVID-19 are displayed in the Contractor site camp area. 4. Information and education relating to sexually transmitted diseases and COVID-19 are to be made available to both construction workers and the local community, where applicable. 5. Free condoms at central points must be made available to all staff on site. 6. Medical support must be made available.						

7. Provide access to Voluntary HIV Testing and Counselling Services.						

Table 35: Noise

Impact management outcomes: Noise management is undertaken in accordance with SANS 10103 and requirements of the EMPr..						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. The Contractor must keep noise levels within acceptable limits. 2. Restrict the use of sound amplification equipment for communication and emergency only. 3. All vehicles and machinery must be fitted with appropriate silencing technology and must be properly maintained. 4. Any complaints received by the Contractor regarding noise must be recorded and communicated. Where possible or applicable, provide transport to and from the site on a daily basis for construction staff. 5. Develop a Code of Conduct for the construction phase in terms of behaviour of construction staff. 6. Operating hours during the construction phase as						

determined by the EA must be adhered to. Where not defined, it must be ensured that construction activities must still meet the impact management outcome related to noise management.						

Table 36: Fire prevention

Impact management outcomes: Fire prevention measures are carried out in accordance with relevant legislation and the EMPr, in order to prevent uncontrollable fires..						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Designate smoking areas where the fire hazard could be regarded as insignificant. 2. Open and unattended fires must not be allowed on site under any circumstances. 3. Educate workers on the dangers of open and/or unattended fires. 4. Firefighting equipment must be available on all vehicles located on site. 5. The local Fire Protection Agency (FPA) must be informed of construction activities. 6. Contact numbers for the FPA and emergency services must be communicated in the						

environmental awareness training and displayed at a central location on site. 7. The ECO must send the FPA their contact details and must also make a note of the FPA's contact details.						

Table 37: Agricultural Resources

Impact management outcomes: To maintain soil capability levels and to achieve reduced levels of erosion and disturbance on productive agricultural land as a result of the implementation of the impact management actions.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Implement an effective system of run-off control, using furrows and banks, wherever it is required, that collects and safely disseminates run-off water from all hardened and disturbed surfaces and prevents potential down slope erosion. Such a system is required wherever run-off water will tend to accumulate and then flow with the potential to cause erosion. 2. Apply soil surface stabilising measures in all areas that are highly susceptible to erosion or on which erosion occurs that cannot be controlled by the						

run-off control system. 3. If any contour banks are disturbed, fully restore their integrity and that of the run-off system of which they are a part, after disturbance. 4. Inspect the entire site for any evidence of erosion. Keep a record at each inspection of all occurrences of erosion with their GPS positions and photographs. If there are no occurrences of erosion, that must also be recorded. 5. Before excavation, the topsoil with its original vegetation, to a depth of 30 cm, must be stripped from the entire surface of the excavation area and stockpiled for re-spreading after backfilling. Underlying subsoil that is excavated must also be stockpiled, but separately from the topsoil. In addition, significantly different subsoil layers must also be stored in separate stockpiles from one another. 6. Topsoil stockpiles must be conserved against losses through erosion by establishing vegetation cover on them. 7. When backfilling, the separate soil layers must be backfilled in their same, original vertical sequence i.e. deepest soil layer at the bottom, and topsoil at						

the top. 8. Ensure that the trench is backfilled in a manner that allows the surface to be free draining and prevents erosion. Subsidence (and resultant channeling of run-off) can make the backfilled trench susceptible to erosion. 9. Erosion must be controlled, if necessary, on newly backfilled areas, which are likely to be susceptible to erosion. 10. Contractor and ECO must sign off after every backfilling event that soil has been backfilled in the correct order with topsoil at the surface, and that the backfilled area is higher than the surrounding surface. 11. Inspect the entire site for any evidence of erosion. Keep a record at each inspection of all occurrences of erosion with their GPS positions and photographs. If there are no occurrences of erosion, that must also be recorded.						

Table 38: Settlement Planning, Disaster Management and Social Aspects

Impact management outcomes: To build local community capacity and municipal support, avoiding key areas and providing decision support.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Ensure effective Disaster Management training capacity-building/awareness are established for municipalities. 2. Develop and implement communication strategies to facilitate public participation. 3. Develop and implement a collaborative and constructive approach to conflict resolution as part of the external stakeholder engagement process. 4. Sustain continuous communication and liaison with neighbouring owners and residents. 5. Ensure contractors implement a 'locals first' policy for construction jobs, specifically for semi and low-skilled job categories. 6. Develop a recruitment process and/or use a recruitment agency to advertise job and secure positions beforehand, thereby minimising the amount of job opportunities offered on-site during the construction phase. 7. Ensure that the number and availability of jobs is						

clearly mentioned and discussed during the awareness sessions that would be undertaken when the final alignment of a proposed section of the pipeline has been confirmed. 8. Develop a Code of Conduct for the construction phase. The code should identify which types of behaviour and activities are not acceptable, such as trespassing, hunting, stock theft etc. 9. The EA holder and/or the appointed contractor should provide transport to and from the site daily for construction workers. This will enable the contactor to effectively manage and monitor the movement of construction workers on and off the site. 10. Depending on the duration of the contract, the EA holder and or the contractor(s) should make the necessary arrangements for construction workers from outside the area to return home over weekends and/ or on a regular basis. This would reduce the risk posed to local family structures and social networks. 11. Where feasible, no construction workers, except for security personnel, should be permitted to stay over-night on the site. This would reduce the						

risk to local farmers. 12. Accommodation must be found in existing settlement, or the construction camp must be in or adjacent to existing settlements. 13. Ensure that construction camps do not remain permanent and should not be permanently occupied for more than 3 months. 14. Ensure that clear access to public facilities and public transport is maintained (e.g. detour less than 500 m (walking distance)), as well as clear 24 hour access to emergency services). 15. Ensure that competent personnel are appointed for welding operations.						

7.5.3 Decommissioning phase

Table 39: Settlement Planning, Disaster Management and Social Aspects

Impact management outcomes: To build local community capacity and municipal support.						
Impact management actions	**Implementation**			**Monitoring**		
	Responsible person	**Method of implementation**	**Timeframe for implementation**	**Responsible person**	**Frequency**	**Evidence of compliance**
1. Ensure maintenance is undertaken as per the required schedule and appropriate corrective actions implemented timeously. Normally, leaks						

are detected by abnormal pressure drops and a loss of transported volumes. Risk Based Inspection via scheduled intelligent pigging of the pipeline must be undertaken to set an initial baseline and thereafter monitor the condition of the pipeline. 2. Ensure that gas pipeline infrastructure is regularly inspected for signs of corrosion or any potential perforation of the pipeline walls that could result in gas leaks and subsequent explosions. 3. Ensure that the latest technology is used during integrity testing (to detect general corrosion, pitting corrosion, stress corrosion cracking, etc.) – for example automated ultrasonics, electromagnetic acoustic transducer (EMAT). 4. Ensure that risks to the pipeline due to any changes in the environmental conditions surrounding the pipeline (e.g. increase in moisture in the drainage line where the pipe is laid down) are considered. 5. Ensure that the location class of a section of existing pipeline is changed in the event of land use change. Where there are changes in land use planning (or existing land use) along the alignment						

of an existing pipeline, a safety assessment must be carried out and additional control measures determined to ensure that the risk associated with a rupture or leak is ALARP. 6. During a pipeline-related disaster, the key strategies that apply to all natural gas emergencies are to establish a command and safe staging area, secure the scene, evacuate at-risk occupants and bystanders, effect viable rescues, eliminate ignition sources, and co-operate with the local utility company. 7. Implement the community emergency response plan. 8. Plans should be developed for safeguarding critical infrastructure. 9. Training exercises of first responders must consider critical infrastructure. Preferably, joint exercises with providers of critical infrastructure services should be regularly scheduled.						

8 Stakeholder Engagement Plan

Social impacts already start in the planning phase of a project and as such it is imperative to start with stakeholder engagement as early in the process as possible. A stakeholder engagement plan will assist Tetra4 to outline their approach towards communicating in the most efficient way possible with stakeholders throughout the life of the project. Such a plan cannot be considered a once off activity and should be updated on a yearly basis to ensure that it stays relevant and to capture new information. Stakeholders must provide input in the Stakeholder Engagement Plan.

The Tetra4 Stakeholder Engagement Plan should have the following objectives:

- To identify and assess the processes and/or mechanisms that will improve the communication between local communities, the wider community and Tetra4.
- To improve relations between Tetra4 staff and the people living in the local communities.
- To provide a guideline for the dissemination of information crucial to the local communities in a timely, respectful, and efficient manner.
- To provide a format for the timely recollection of information from the local communities in such a way that the communities are included in the decision-making process.

The Stakeholder Engagement Plan should be compiled in line with International Finance Corporation (IFC) Guidelines and should consist of the following components:

- Stakeholder Identification and Analysis – time should be invested in identifying and prioritising stakeholders and assessing their interests and concerns.
- Information Disclosure – information must be communicated to stakeholders early in the decision-making process in ways that are meaningful and accessible, and this communication should be continued throughout the life of the project.

- Stakeholder Consultation – each consultation process should be planned out, consultation should be inclusive, the process should be documented and follow-up should be communicated.
- Negotiation and Partnerships – add value to mitigation or project benefits by forming strategic partnerships and for controversial and complex issues, enter into good faith negotiations that satisfy the interest of all parties.
- Grievance Management – accessible and responsive means for stakeholders to raise concerns and grievances about the project must be established throughout the life of the project.
- Stakeholder Involvement in Project Monitoring – directly affected stakeholders must be involved in monitoring project impacts, mitigation, and benefits. External monitors must be involved where they can enhance transparency and credibility.
- Reporting to Stakeholders – report back to stakeholders on environmental, social and economic performance, both those consulted and those with more general interests in the project and parent company.
- Management Functions – sufficient capacity within the company must be built and maintained to manage processes of stakeholder engagement, track commitments and report on progress.

It is of critical importance that stakeholder engagement takes place in each phase of the project cycle and it must be noted that the approach will differ according to each phase. The stakeholder analysis done in Section 6 of this report must inform the stakeholder engagement strategy.

9 Proposed Grievance Mechanism

In accordance with international good practice Tetra4 should establish a specific mechanism for dealing with grievances. A grievance is a complaint or concern raised by an individual or organisation that judges that they have been adversely affected by the project during any stage of its development. Grievances may take the form of specific complaints for actual damages or injury, general concerns about project activities, incidents and impacts, or perceived impacts. The IFC standards require Grievance Mechanisms to provide a structured way of receiving and resolving grievances. Complaints should be addressed promptly using an understandable and transparent process that is culturally appropriate and readily acceptable to all segments of affected communities and is at no cost and without retribution. The mechanism should be appropriate to the scale of impacts and risks presented by a project and beneficial for both the company and stakeholders. The mechanism must not impede access to other judicial or administrative remedies.

The grievance mechanism should be based on the following principles:

- Transparency and fairness;
- Accessibility and cultural appropriateness;
- Openness and communication regularity;
- Written records;
- Dialogue and site visits; and
- Timely resolution.

Based on the principles described above, the grievance mechanism process involves four stages:

- Receiving and recording the grievance;
- Acknowledgement and registration;

- Site inspection and investigation; and
- Response.

10 Conclusion and recommendations

The aim of this report is to identify potential social impacts associated with the proposed Tetra4 Cluster 2 project. The Cluster 1 project is in the process of being implemented. The proposed Cluster 2 project will impact on high quality agricultural soil which is used to grow crops that contribute to food security in South Africa. One of the most significant potential social impacts associated with the proposed project is the potential impacts on livelihoods of the farming community. There are high levels of uncertainty about exactly how the Cluster 2 project will unfold. Farmers fear that their land rights and property values will be affected. The project will require access to farms, and because of the current socio-political issues in South Africa, this is a sensitive matter. Farmers are concerned about the impact of the Cluster 2 project on their existing way of life, and on the infrastructure on their farms. Although they are appreciative of Tetra4's efforts to communicate with them, there has been instances where the communication was insufficient, of where some of the Tetra4 staff have not followed procedures that was agreed to.

A number of stakeholder groups will be affected by the proposed project, and the most affected groups are the farmers and farm workers. Although the Tetra4 project will have a positive economic impact in South Africa, the direct benefit for the local communities is limited. The job creation benefits, both primary and secondary are not significant. Therefore, it is of utmost importance that the local social impacts must be managed and monitored to the best of Tetra4's ability, since the parties who pay the social cost of the development will not be beneficiaries of the development.

Based on the findings of this study, the following key recommendations are made:

- There is a possibility that Tetra4's activities will cause economic displacement for some of the affected farmers. The actual impact on their livelihoods must be assessed by an agricultural economist and compensation must be done according to international best practice;

- There are a number of questions from the landowners that Tetra4 should respond to in writing before any contracting can proceed. These questions are related to timeframes and the construction phase;
- The impacts of servitudes on the land value of the affected properties must be considered and mitigated by means of negotiation. If the negotiation process is unsuccessful, it must be arbitrated by a lawyer with knowledge about environmental law, the MPRDA and property law. This should be a last resort;
- Farm safety must be a priority and the landowners and Tetra must agree on security measures;
- Tetra4 must consult with landowners about any new work or potential changes that may take place on their properties;
- Protocols on farm access, compensation, communication, and road maintenance must be agreed upon and be in place before construction commences. The affected landowners must have input in the development of these protocols;
- A grievance mechanism and claims procedure must be in place and shared with all the stakeholders before the construction commences; and
- A special meeting must be conducted with farm workers and other vulnerable parties, in their mother languages, to ensure that they understand the technical and safety aspects of the project.

The potential impact on the livelihoods of some of the directly affected farmers may be severe. This will have a spinoff impact on farm workers, food security and the local economy. Every possible measure must be implemented to ensure that the production of the farmers is not permanently impacted. The project can only be recommended if the livelihood impacts are mitigated and managed successfully.

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Soil Pedology Assessment for the proposed Tetra4 Cluster 2 Project

Virginia, Free State Province

April 2022

Client

Prepared by:

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Reference	Tetra 4 Cluster 2
Submitted to	EIMS Environmental Impact Management Services
Report Writer and Reviewer	Ivan Baker Ivan Baker is Pr. Sci Nat registered (119315) in environmental science with Cand. Sci. Nat recognition in geological science. Ivan is a wetland and soil specialist with vast experience in wetlands, pedology, hydropedology and land contamination and has completed numerous specialist studies ranging from basic assessments to EIAs. Ivan has carried out various international studies following FC standards. Ivan completed training in Tools for Wetland Assessments with a certificate of competence and completed his MSc in environmental science and hydropedology at the North-West University of Potchefstroom. Ivan is also affiliated with the Fertiliser Society of South Africa after the acquiring a certificate of competence following the completion of the FERTASA training course.
Report Writer and Fieldwork	Matthew Mamera Matthew Mamera is Candr. Sci Nat registered (116356) in natural and agricultural sciences with a Cand. Sci. Nat recognition in soil science. Matthew is a soil and hydropedology specialist with experience in soil, pedology, hydropedology, water and sanitation management and land contamination and has field experience and numerous peer reviewed scientific publications in international journals. Matthew completed his M.Sc. in soil science, hydropedology and water management at the University of Fort Hare, Alice. He is also a holder of a PhD in soil science, hydropedology, water and sanitation obtained at the University of the Free State, Bloemfontein. Matthew is also a member of the Soil Science Society of South Africa (SSSSA).
Report Contributor	Andrew Husted Andrew Husted is Pr Sci Nat registered (400213/11) in the following fields of practice: Ecological Science, Environmental Science and Aquatic Science. Andrew is an Aquatic, Wetland and Biodiversity Specialist with more than 13 years' experience in the environmental consulting field.
Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2017. We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than to provide a professional service within the constraints of the project (timing, time and budget) based on the principals of science.

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Document Guide

According to the Government Notice 320 dated 20 March 2020 and the procedures for the assessment and minimum criteria for reporting on identified environmental themes in terms of Sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998, when applying for environmental authorisation, the following criteria is applicable to that of an agricultural compliance statement;

Requirement	Reference
Specialist Details and CV	Appendix A
Locality of the proposed activity	Section 2
Sensitivity verification	Section 8.2
Acceptability of impacts towards agricultural production capability associated with proposed activities	Section 9
Declaration of specialist(s)	Page vi
Project components with 50 m regulated area superimposed to that of the agricultural sensitivities of the screening tool	Section 8.2
Confirmation from specialist that mitigation to avoid fragmentation has been considered	Section 9.1
Statement from specialist regarding the acceptability and approval of proposed activities	Section 9.2
Conditions to acceptability of proposed activities	
Probability of land being returned to current state after decommissioning	N/A
Monitoring requirements and/or any inclusions into EMPr	Section 9.1
Assumptions and uncertainties	Section 4

DECLARATION

I, **Matthew Mamera** declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Matthew Mamera

Soil Specialist

The Biodiversity Company

May 2022

1 Introduction

The Biodiversity Company was appointed to compile an agricultural compliance statement, as part of the environmental authorisation process for the proposed Tetra 4 Cluster 2 project in Virginia Free State (see Figure 2-1). The project area and the associated infrastructure is located approximately 17 km south-east of the town of Welkom and 25 km north of the Theuniseen town. The area is found along the R30 and R730 located in between the R710 and R73 roads.

1.1 Background

The following information was provided by EIMS:

In 2012, a Production Right (Ref: 12/4/1/07/2/2) was granted which spans approximately 187 000 hectares for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within the approval of the Production Right, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1-1).

The activities in the Production Right include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original EIA and approved EMPr).

On 21 September 2017, the Department of Mineral Resources and Energy (DMRE) issued an integrated environmental authorisation ("Cluster 1 EA") (reference: 12/04/07) to Tetra4 in terms of the NEMA. The Cluster 1 EA (as amended by Cluster 1 EA amendments dated 26 August 2019 and 1 September 2020) authorises the development of "Cluster 1" of the Project. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and LNG Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Furthermore, the following licences have been issued to Tetra4 in respect of Cluster 1 of the Project:

- Provisional Atmospheric Emission Licence (PAEL) dated 4 August 2017 (reference: LDM/AEL/YMK/014) for the Storage and Handling of Petroleum Products [Category 2: Subcategory 2.4 of the Listed Activities (Government Notice 893, as amended) published under the National Environmental Management: Air Quality Act 39 of 2004 (NEMAQA)] by the Lejweleputswa District Municipality. A final atmospheric emission licence will be issued after operation of the plant which is currently under construction; and
- Water Use Licence (WUL) dated 22 January 2019 (reference: 08/C42K/CI/8861) for the construction of pipelines for the Project in terms of section 21(c&i) water uses of the National Water Act 36 of 1998 (NWA) by the Department of Water and Sanitation (DWS).

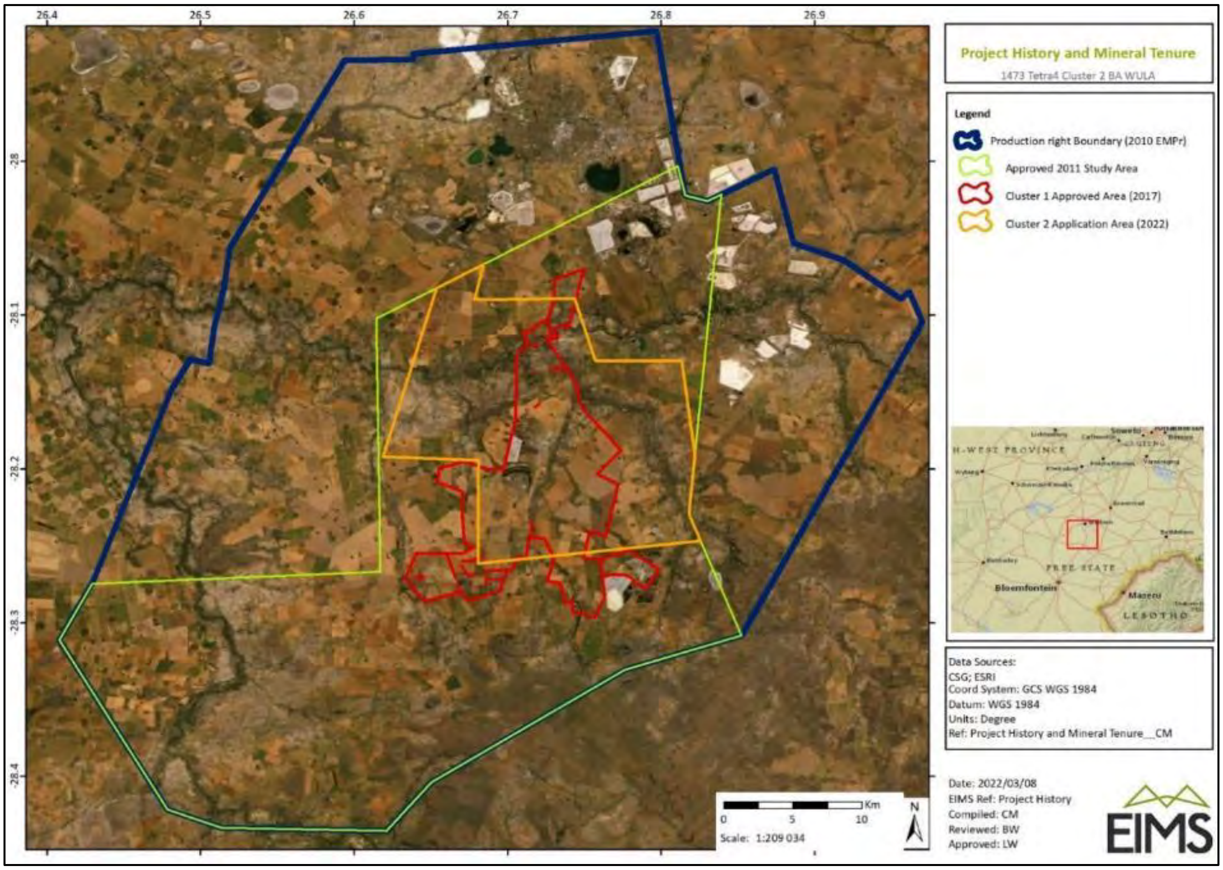

Figure 1-1 Project history and mineral tenure.

The following information is as provided by EIMS:

"Tetra 4 has a natural gas production right over a very large area in the Free State Province, near Virginia. They also have an existing environmental authorisation and associated water use licence for their current production activities (referred to as Cluster 1 above). Tetra 4 wishes to expand their current production operations onto other areas which still fall within the approved Production Right, but outside of the areas approved in the EA and WUL. The planned expansions will include the following (Figure 1-2):

- Expansions to the current LNG and Helium production plant located on the Farm Mond van Doorn Rivier. The planned expansions will be to increase the helium and LNG production capacities significantly (~30 fold increase) and increase the footprint of the existing approved plant by approximately 10ha.
- The drilling of new gas wells ~300 wells spread over a total study area (Cluster 2) of approximately 27500ha.
- The installation of trenched pipelines connecting the wells to localised booster compressors and then to in-field compressor stations (~3 sites) and subsequently the compressor stations to the main plant area.
- There will be a requirement to have short powerline and water connections to the compressor sites."

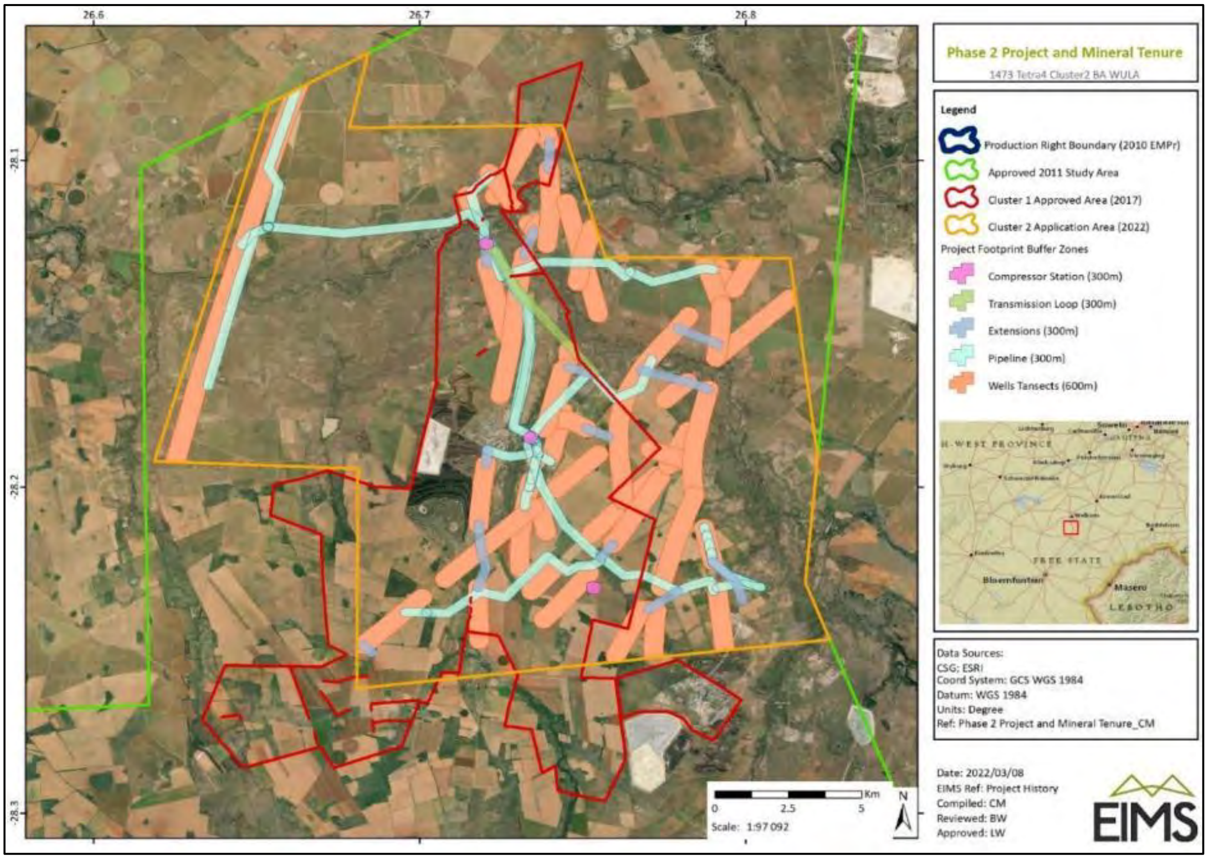

Figure 1-2 Cluster 2 study area and proposed infrastructure footprint buffer zones

The approach adopted for the assessments has taken cognisance of the recently published Government Notice 320 in terms of NEMA dated 20 March 2020: "Procedures for the Assessment and Minimum Criteria for Reporting on Identified Environmental Themes in terms of Sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998, when applying for Environmental Authorisation".

This report aims to present and discuss the findings from the soil resources identified within the regulated 50 m, the agricultural and land potential of these resources, the land uses within the regulated area and also the risk associated with the proposed structure.

1.2 Terms of Reference

According to the National Web based Environmental Screening Tool, the proposed development is located within a "Low" sensitivity land capability area. The protocols for minimum requirements (DEA, 2020)[1] stipulates that in the event that a proposed development is located within "Low" or "Medium" sensitivities, an agricultural compliance statement will be sufficient. It is worth noting that according to these protocols, a site inspection will still need to be conducted to determine the accuracy of these sensitivities. After acquiring baseline information pertaining to soil resources within the 50 m regulated areas, it is the specialist's opinion that the soil forms and associated land capabilities concur with the sensitivities stated by the screening tool. Therefore, only an agricultural compliance statement will be compiled. This includes:

[1] A site identified by the screening tool as being of 'High" or "Very High" sensitivity for agricultural resources must submit a specialist assessment unless the impact on agricultural resources is from an electricity pylon (item 1.1.2).

- The feasibility of the proposed activities;
- Confirmation about the “Low” and “Medium” sensitivities;
- The effects that the proposed activities will have on agricultural production in the area;
- A map superimposing the proposed footprint areas, a 50 m regulated area as well as the sensitivities pertaining to the screening tool;
- Confirmation that no agricultural segregation will take place and that all options have been considered to avoid segregation;
- The specialist’s opinion regarding the approval of the proposed activities; and
- Any potential mitigation measures described by the specialist to be included in the EMPr.

2 Project Area

The proposed Tetra 4 Cluster 2 gas production project is located in Virginia, Free State province. Virginia is a gold mining town located in the Lejweleputswa District Municipality and on goldfields of the Free State province in South Africa about 140 km northeast of Bloemfontein the provincial capital. The Tetra 4 Cluster 2 project is approximately 17 km south-east of the town of Welkom and 25 km north of the Theuniseen town (see Figure 2-1). The area is found along the R30 and R730 located in between the R710 and R73 roads. The Tetra4 Production Right is located within the Sand River Play or Virginia Gas Field. Despite not being clearly defined, the field is composed predominantly of Karoo, Ventersdorp and Witwatersrand Supergroup lithologies complete with younger dolerite intrusions. The surrounding land use predominantly includes agriculture (crop and grazing), game reserves and mining.

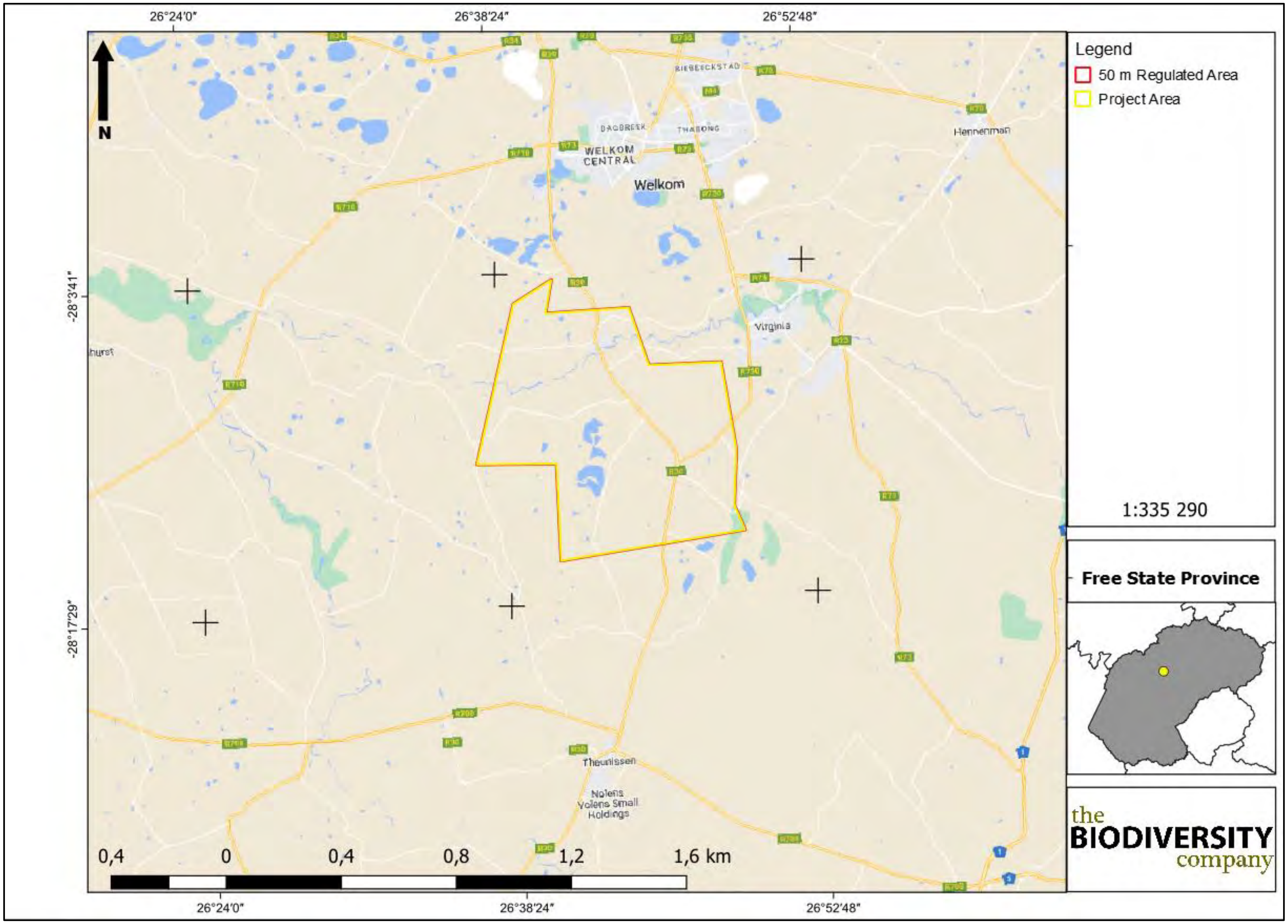

Figure 2-1 Locality map of the project area

3 Expertise of the Specialists

3.1 Ivan Baker

Ivan Baker is Pr. Sci Nat registered (119315) in environmental science with Cand. Sci. Nat recognition in geological science. Ivan is a wetland and soil specialist with vast experience in wetlands, pedology, hydropedology and land contamination and has completed numerous specialist studies ranging from basic assessments to EIAs. Ivan has carried out various international studies following FC standards. Ivan completed training in Tools for Wetland Assessments with a certificate of competence and completed his MSc in environmental science and hydropedology at the North-West University of Potchefstroom. Ivan is also affiliated with the Fertiliser Society of South Africa after the acquiring a certificate of competence following the completion of the FERTASA training course.

3.2 Matthew Mamera

Matthew Mamera is Cand. Sci Nat registered (116356) in natural and agricultural sciences with a Cand. Sci. Nat recognition in soil science. Matthew is a soil and hydropedology specialist with experience in soil pedology, hydropedology, water and sanitation management and land contamination and has field experience and numerous scientific publications in international peer reviewed journals. Matthew completed his MSc in soil science, hydropedology and water management at the University of Fort Hare, Alice. He is also a holder of a PhD in soil science, hydropedology, water and sanitation obtained at the University of the Free State, Bloemfontein. Matthew is also a member of the Soil Science Society of South Africa (SSSSA).

4 Methodology

4.1 Desktop Assessment

As part of the desktop assessment, baseline soil information was obtained using published South African Land Type Data. Land type data for the site was obtained from the Institute for Soil Climate and Water (ISCW) of the Agricultural Research Council (ARC) (Land Type Survey Staff, 1972 - 2006). The land type data is presented at a scale of 1:250 000 and comprises of the division of land into land types. In addition, a Digital Elevation Model (DEM) as well as the slope percentage of the area was calculated by means of the NASA Shuttle Radar Topography Mission Global 1 arc second digital elevation data by means of QGIS and SAGA software.

4.2 Field Survey

An assessment of the soils present within the project area was conducted during a field survey in March 2022. The site was traversed on foot. A soil auger was used to determine the soil form/family and depth. The soil was hand augured to the first restricting layer or 1,5 m. Soil survey positions were recorded as waypoints using a handheld GPS. Soils were identified to the soil family level as per the “Soil Classification: A Taxonomic System for South Africa” (Soil Classification Working Group, 2018). Landscape features such as existing open trenches were also helpful in determining soil types and depth.

4.3 Erosion Potential

Erosion has been calculated by means of the (Smith, 2006) methodology. The steps in calculating the Fb[2] ratings relevant to erosion potential is illustrated in Table 4-1 with the final erosion classes illustrated in Table 4-2.

[2] The soil erodibility index

Table 4-1 Fb ratings relevant to the calculating of erosion potential (Smith, 2006)

Step 1- Initial value, texture of topsoil horizon				
Light (0-15% clay)		Medium (15-35% clay)		Heavy (>35% clay)
Fine sand	Medium/coarse sand	Fine Sand	Medium/coarse sand	All sands
3.5	4.0	4.5	5.0	6.0
Step 2- Adjustment value (permeability of subsoil)				
Slightly restricted		Moderately restricted		Heavily restricted
-0.5		-1.0		-2.0
Step 3- Degree of leaching (excluding bottomlands)				
Dystrophic soils, medium and heavy textures		Mesotrophic soils		Eutrophic or calcareous soils, medium and heavy textures
+0.5		0		-0.5
Step 4- Organic Matter				
Organic topsoil			Humic Topsoil	
+0.5			+0.5	
Step 5- Topsoil limitations				
Surface crusting			Excessive sand/high swell-shrink/self-mulching	
-0.5			-0.5	
Step 6- Effective soil depth				
Very shallow (<250 mm)			Shallow (250-500 mm)	
-1.0			-0.5	

Table 4-2 Final erosion potential class

Erodibility	Fb Rating (from calculation)
Very Low	>6.0
Low	5.0 - 5.5
Moderate	3.5 – 4.5
High	2.5 – 3.0
Very High	<3.0

4.4 Land Capability

Given the nature of the compliance statement and the fact that baseline findings correlate with the screening tool’s sensitivities, land capability was solely determined by means of the National Land Capability Evaluation Raster Data Layer (DAFF, 2017). Land capability and land potential will also briefly be calculated to match to that of the screening tool to ultimately determine the accuracy of the land capability sensitivity from (DAFF, 2017).

Land capability and agricultural potential will briefly be determined by a combination of soil, terrain and climate features. Land capability is defined by the most intensive long-term sustainable use of land under rain-fed conditions. At the same time an indication is given about the permanent limitations associated with the different land use classes.

Land capability is divided into eight classes and these may be divided into three capability groups. Table 4-3 shows how the land classes and groups are arranged in order of decreasing capability and ranges of use. The risk of use increases from class I to class VIII (Smith, 2006).

Table 4-3 Land capability class and intensity of use (Smith, 2006)

Land Capability Class	Increased Intensity of Use									Land Capability Groups
I	W	F	LG	MG	IG	LC	MC	IC	VIC	Arable Land
II	W	F	LG	MG	IG	LC	MC	IC		
III	W	F	LG	MG	IG	LC	MC			
IV	W	F	LG	MG	IG	LC				
V	W	F	LG	MG						Grazing Land
VI	W	F	LG	MG						
VII	W	F	LG							
VIII	W									Wildlife
W - Wildlife		MG - Moderate Grazing			MC - Moderate Cultivation					
F- Forestry		IG - Intensive Grazing			IC - Intensive Cultivation					
LG - Light Grazing		LC - Light Cultivation			VIC - Very Intensive Cultivation					

The land potential classes are determined by combining the land capability results and the climate capability of a region as shown in Table 4-4. The final land potential results are then described in Table 4-5.

Table 4-4 The combination table for land potential classification

Land capability class	Climate capability class							
	C1	C2	C3	C4	C5	C6	C7	C8
I	L1	L1	L2	L2	L3	L3	L4	L4
II	L1	L2	L2	L3	L3	L4	L4	L5
III	L2	L2	L3	L3	L4	L4	L5	L6
IV	L2	L3	L3	L4	L4	L5	L5	L6
V	Vlei	Vlei	Vlei	Vlei	Vlei	Vlei	Vlei	Vlei
VI	L4	L4	L5	L5	L5	L6	L6	L7
VII	L5	L5	L6	L6	L7	L7	L7	L8
VIII	L6	L6	L7	L7	L8	L8	L8	L8

Table 4-5 The Land Potential Classes.

Land potential	Description of land potential class
L1	Very high potential: No limitations. Appropriate contour protection must be implemented and inspected.
L2	High potential: Very infrequent and/or minor limitations due to soil, slope, temperatures or rainfall. Appropriate contour protection must be implemented and inspected.

L3	Good potential: Infrequent and/or moderate limitations due to soil, slope, temperatures or rainfall. Appropriate contour protection must be implemented and inspected.
L4	Moderate potential: Moderately regular and/or severe to moderate limitations due to soil, slope, temperatures or rainfall. Appropriate permission is required before ploughing virgin land.
L5	Restricted potential: Regular and/or severe to moderate limitations due to soil, slope, temperatures or rainfall.
L6	Very restricted potential: Regular and/or severe limitations due to soil, slope, temperatures or rainfall. Non-arable
L7	Low potential: Severe limitations due to soil, slope, temperatures or rainfall. Non-arable
L8	Very low potential: Very severe limitations due to soil, slope, temperatures or rainfall. Non-arable

4.5 Limitations

- The information contained in this report is based on auger points taken and observations on site. There may be variations in terms of the delineation of the soil forms across the area;
- Due to the size of the proposed area only the key areas where infrastructure is located were focused on, the remaining areas were predominantly delineated through means of desktop; and
- The GPS used for delineations is accurate to within five meters. Therefore, the delineation plotted digitally may be offset by at least five meters to either side.

5 Project Area

5.1 Soils and Geology

According to the land type database (Land Type Survey Staff, 1972 - 2006) the assessment corridor to be focused on falls within the Ae40, Bd20, Dc8, Dc9 and Dc12 land types. The Ae land type mostly consist of apedal (yellow/red), duplex soils characterised with high clay contents and shallow profiles associated with partially weathered/ un-weathered material with the possibility of other soils occurring throughout. Lime is generally present in low-lying areas. The Bd land type consists of mostly apedal and duplex soils with miscellaneous land classes including rocky areas with Mispah and Oakleaf soils forms according to the SA soil classification working group (1990). The Dc land types is characterised with duplex, transitional young alluvial soil deposits with occasional red soils, some saturated profiles, shallow soils, and intrusive hard rocks. The terrain units and expected soils for the Ae40 land type is illustrated in Figure 5-1 and Table 5-1 respectively. Similarly, those for the Bd20 land type is depicted in Figure 5-2 and Table 5-2; Dc8 land type in Figure 5-3 and Table 5-3; Dc9 land type in Figure 5-4 and Table 5-4 and Dc12 in Figure 5-5 and Table 5-5 respectively.

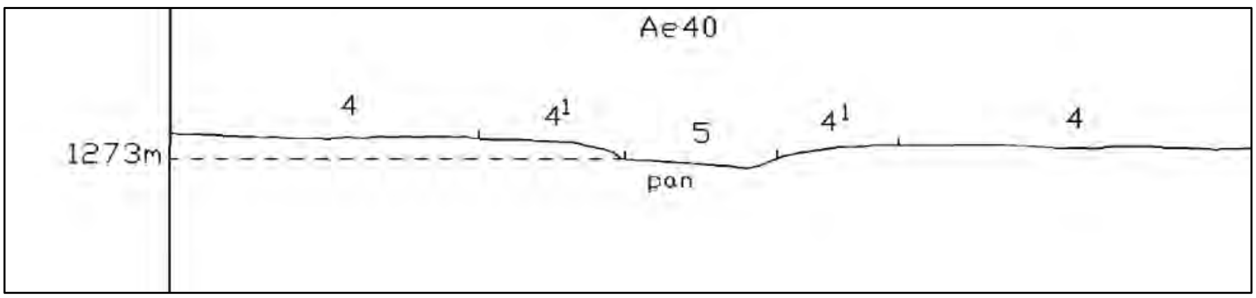

Figure 5-1 Illustration of land type Ae40 terrain unit (Land Type Survey Staff, 1972 - 2006)

Table 5-1 Soils expected at the respective terrain units within the Ae 40 land type (Land Type Survey Staff, 1972 - 2006)

4 (92%)		4 (1) (4%)		5 (4%)	
Hutton	89%	Swartland	25%	Katspruit, Rensburg	75%
Clovelly	7%	Mispah	50%	Swartland	25%
Bainsvlei	2%	Oakleaf	25%		
Avalon	2%				

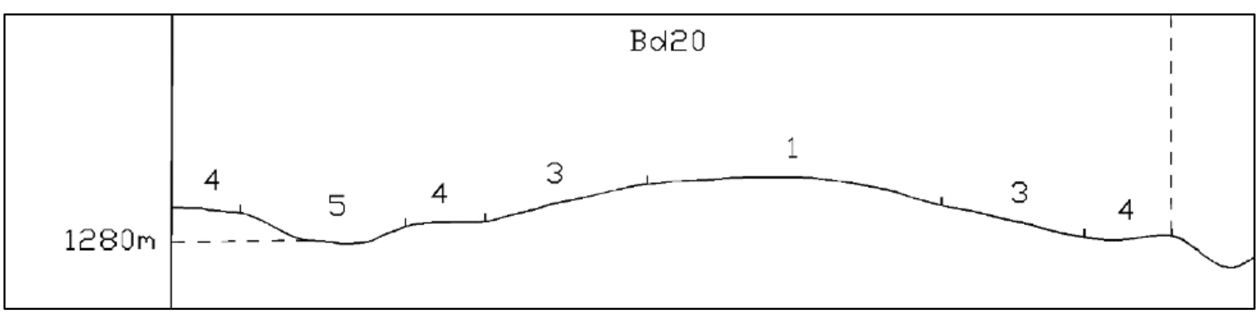

Figure 5-2 Illustration of land type Bd 20 terrain unit (Land Type Survey Staff, 1972 - 2006)

Table 5-2 Soils expected at the respective terrain units within the Bd 20 land type (Land Type Survey Staff, 1972 - 2006)

Terrain Units							
1 (55%)		3 (40%)		4 (3%)		5 (2%)	
Clovelly	65%	Clovelly	45%	Hutton	50%	Valsrivier	55%
Avalon	30%	Avalon	20%	Valsrivier	18%	Arcadia, Rensburg	30%
Arcadia, Rensburg	1%	Hutton	25%	Avalon	10%	Oakleaf	10%
Katspruit	1%	Valsrivier	8%	Clovelly	5%	Katspruit	10%
Valsrivier	3%	Arcadia, Rensburg	1%	Oakleaf	5%		
		Katspruit	1%	Arcadia, Rensburg	1%		

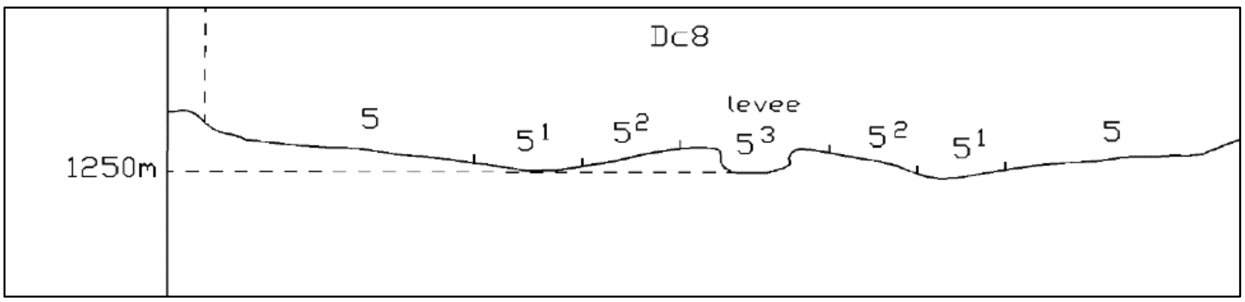

Figure 5-3 Illustration of land type Dc 8 terrain unit (Land Type Survey Staff, 1972 - 2006)

Table 5-3 Soils expected at the respective terrain units within the Dc 8 land type (Land Type Survey Staff, 1972 - 2006)

Terrain Units							
5 (44%)		5(1) (40%)		5 (2) 27%)		5 (3) (16%)	
Arcadia	42%	Arcadia	41%	Oakleaf	66%	Dundee	7%
Valsrivier	48%	Rensburg	59%	Valsrivier	32%	Stream beds	28%
Sterkspruit	6%			Stream beds	2%	Fernwood	22%
Katspruit	1%					Oakleaf	13%
Bonheim	4%						

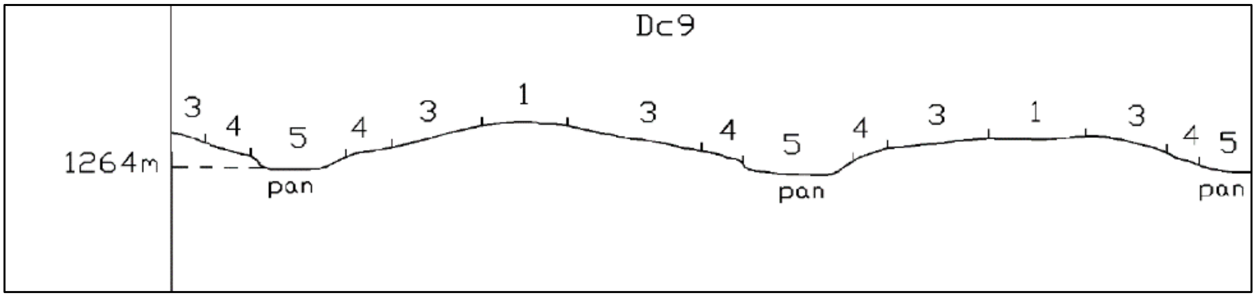

Figure 5-4 Illustration of land type Dc 9 terrain unit (Land Type Survey Staff, 1972 - 2006)

Table 5-4 Soils expected at the respective terrain units within the Dc 9 land type (Land Type Survey Staff, 1972 - 2006)

Terrain Units							
1 (10%)		3 (27%)		4 (41%)		5 (22%)	
Hutton	100%	Hutton	88%	Swartland	28%	Willowbrook	91%
		Clovelly	11%	Valsrivier	24%	Valsrivier	5%
		Oakleaf	1%	Oakleaf	23%	Arcadia	2%
				Sterkspruit	17%	Sterkspruit	1%
				Arcadia	4%	Mispah	1%
				Estcourt	3%		
				Mispah	1%		

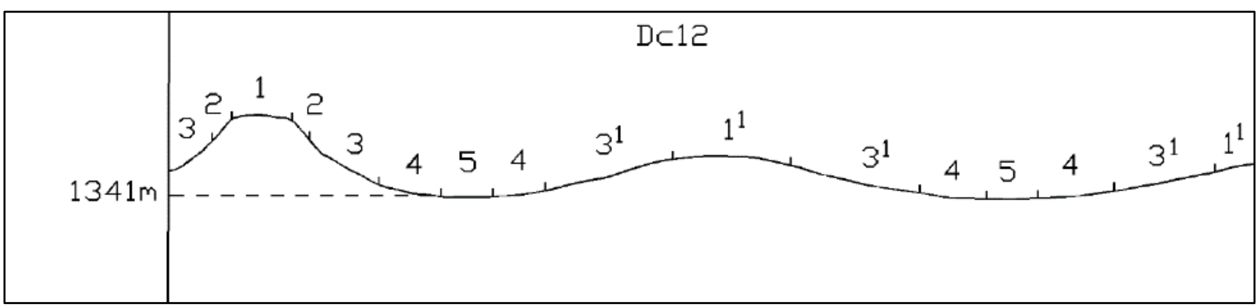

Figure 5-5 Illustration of land type Dc 12 terrain unit (Land Type Survey Staff, 1972 - 2006)

Table 5-5 Soils expected at the respective terrain units within the Dc 12 land type (Land Type Survey Staff, 1972 - 2006)

Terrain Units													
1 (3%)		1 (1) (20%)		2 (1%)		3 (6%)		3 (1) (38)		4 (24)		5 (8)	
Rocks	33%	Mispah	37%	Rocks	60%	Rocks	33%	Swartland	34%	Bonheim	29%	Oakleaf	41%
Mayo	23%	Swartland	19%	Mispah	30%	Mayo	25%	Mispah	18%	Swartland	27%	Katspruit	27%

Mispah	21%	Glenrosa	13%	Glenrosa	10%	Swartland	17%	Bonheim	14%	Valsrivier	15%	Stream beds	13%
Glenrosa	13%	Westleigh	12%			Mispah	17%	Valsrivier	9%	Arcadia	15%	Valsrivier	6%
Swartland	10%	Mayo	6%			Glenrosa	8%	Glenrosa	7%	Sterkspruit	4%	Bonheim	5%
		Bonheim	5%					Arcadia	7%	Mispah	4%	Glenrosa	4%
		Valsrivier	3%					Westleigh	5%	Mayo	3%	Mayo	4%
		Rocks	3%					Mayo	3%	Glenrosa	2%		
		Hutton	2%					Hutton	2%	Rocks	1%		

5.2 Terrain

The slope percentage of the project area has been calculated and is illustrated in Figure 5-6. The majority of the regulated area is characterised by a slope percentage between 0 and 20%, with some smaller patches within the project area characterised by a slope percentage above 40. This illustration indicates mostly a uniform area with few undulating slopes, mountainous areas and ridges. The Digital Elevation Model (DEM) of the project area (Figure 5-7) indicates an elevation of 1 272 to 1 410 Metres Above Sea Level (MASL).

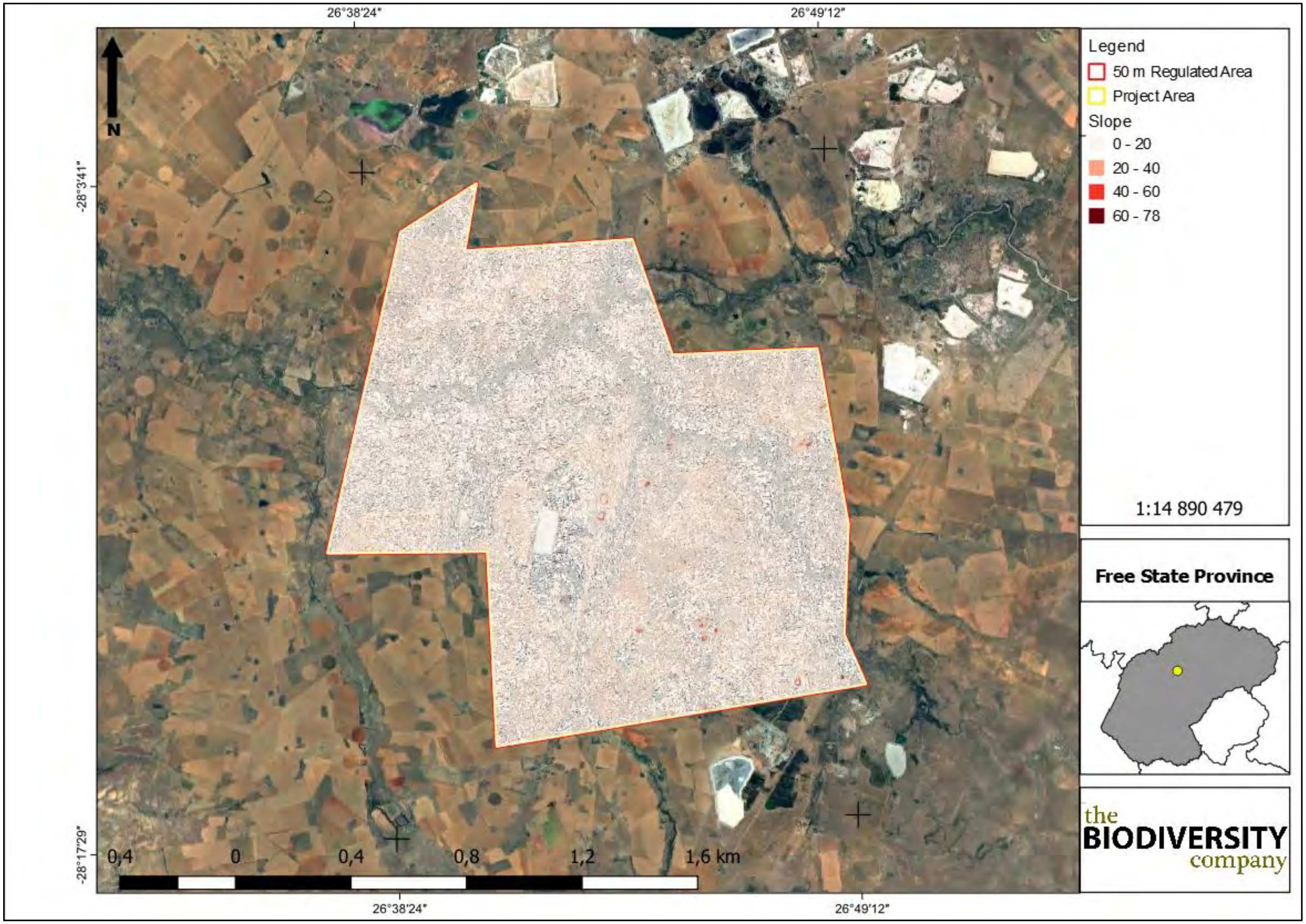

Figure 5-6 Slope percentage map for the assessment area

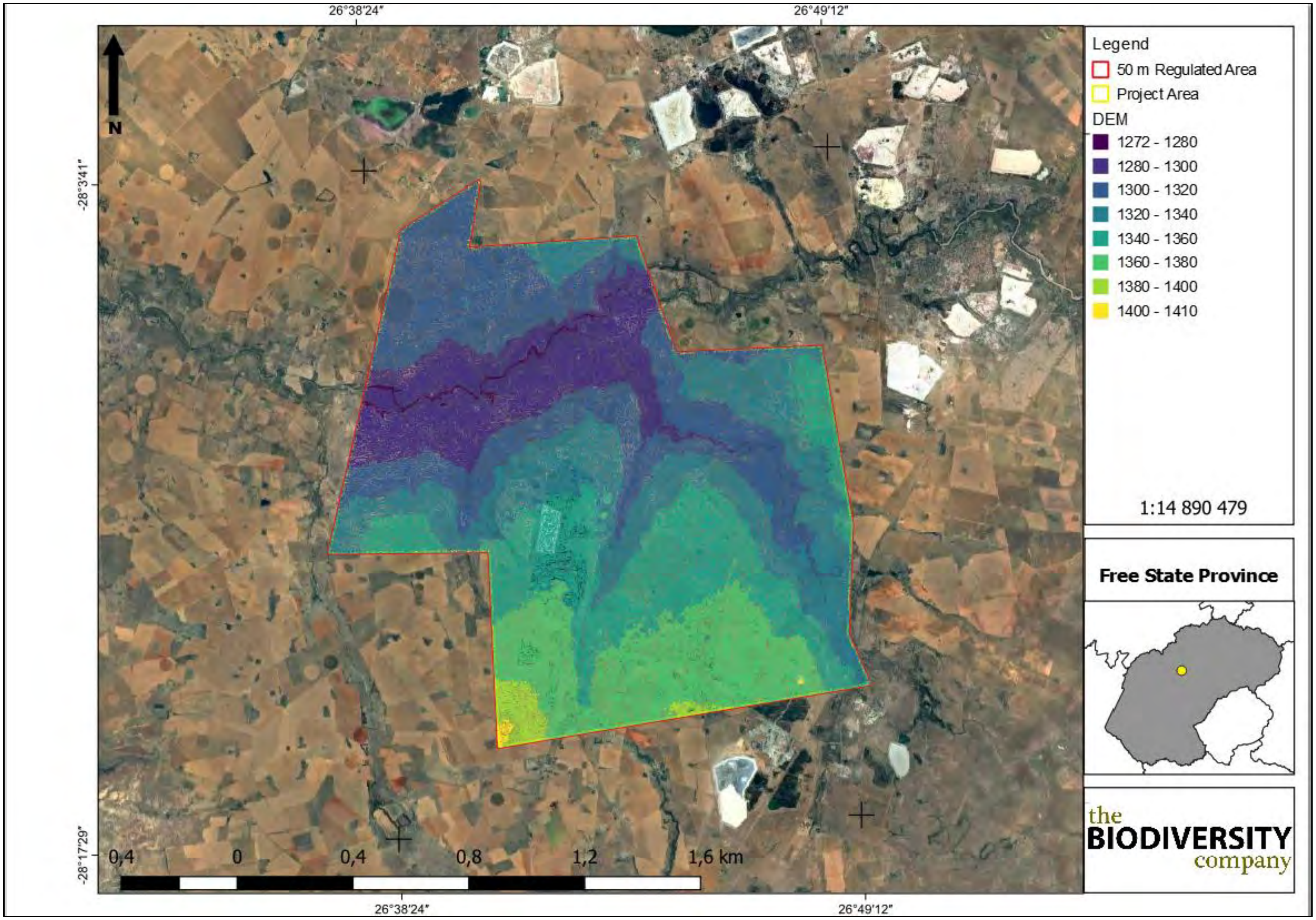

Figure 5-7 Elevation map for the assessment area

6 Results and Discussion

6.1 Description of Soil Profiles and Diagnostic Horizons

Soil profiles were studied up to a depth of 1.2 m to identify specific diagnostic horizons which are vital in the soil classification process as well as determining the agricultural potential and land capability. Considering the large scale of the project area, only the most sensitive soil forms have been considered. The following diagnostic horizons were identified during the site assessment (also see Figure 6-1):

- Orthic topsoil;
- Gley horizon;
- Soft Plinthic horizons;
- Lithocutanic horizon;
- Red apedal horizon; and
- Yellow-brown apedal horizon.

6.1.1 Orthic Topsoil

Orthic topsoils are mineral horizons that have been exposed to biological activities and varying intensities of mineral weathering. The climatic conditions and parent material ensure a wide range of properties differing from one Orthic A topsoil to another (i.e. colouration, structure etc) (Soil Classification Working Group, 2018).

6.1.2 Soft Plinthic Horizon

The accumulations of iron (and in some cases manganese) as hydroxides and oxides with the presence of high chroma striations and concretions with black matrixes are associated with the Soft Plinthic horizon. This diagnostic horizon forms due to fluctuating levels of saturation. The iron and manganese concentration result in soft marks within the soil matrix which transform in concretions with high consistencies (Soil Classification Working Group, 1991).

If this process continues for long enough periods, a massive continues impermeable layer of hard plinthite forms. A Soft Plinthic horizon and a Hard Plinthic horizon can be distinguished from one another by means of a simple spade test. A Soft Plinthic horizon can be penetrated by means of a spade in wet conditions whereas a Hard Plinthic horizon cannot (Soil Classification Working Group, 1991).

According to Soil Classification Working Group (2018), this horizon commonly occurs as a result of hillslope hydrology in flat, sandy landscapes. This horizon is known to have an apedal structure together with the presence of concretions.

6.1.3 Lithocutanic Horizon

For the lithocutanic horizon, i*n situ* weathering of rock underneath a topsoil results in a well-mixed soil-rock layer. The colour, structure and consistency of this material must be directly related to the parent material of the weathered rock. The Lithocutanic horizon is usually followed by a massive rock layer at shallow depths. Hard rock, permeable rock and horizontally layered shale usually is not associated with the weathering processes involved with the formation of this diagnostic horizon.

6.1.4 Gley Horizon

Gley horizons that are well developed and have homogenous dark to light grey colours with smooth transitions. Stagnant and reduced water over long periods is the main factor responsible for the formation of a Gley horizon and could be characterised by green or blue tinges due to the presence of a mineral called Fougerite which includes sulphate and carbonate complexes. Even though grey colours are dominant, yellow and/or red striations can be noticed throughout a gley horizon. The structure of a gley horizon mostly is characterised as strong pedal, with low hydraulic conductivities and a clay texture, although sandy gley horizons are known to occur. The gley soil form commonly occurs at the toe of hillslopes (or benches) where lateral water inputs (sub-surface) is dominant and the underlaying geology is characterised by a low hydraulic conductivity. The gley horizon usually is second in diagnostic sequence in shallow profiles yet is known to be lower down in sequence and at greater depths (Soil Classification Working Group, 2018).

6.1.5 Yellow-Brown Apedal Horizon

The yellow-brown apedal horizon is similar to that of the Red Apedal horizon in all aspects except for the colour and the iron-oxide processes involved with the colouration thereof. This diagnostic soil horizon rarely occurs in parent rock high in iron-oxides and will rather be associated with Quartzite, Sandstone, Shale and Granites.

6.1.6 Red Apedal Horizon

The red apedal diagnostic soil horizon has no well-formed peds, but rather small porous aggregates. The poor structure associated with this diagnostic profile is a result of weathering processes under well drained oxidising conditions. Iron-oxide precipitations form on the outside of soil particles (hence the red colour) and non-swelling clays dominate the clay particles. This diagnostic soil horizon is widely spread across South Africa and can be associated with any parent material expected (Soil Classification Working Group, 1991).

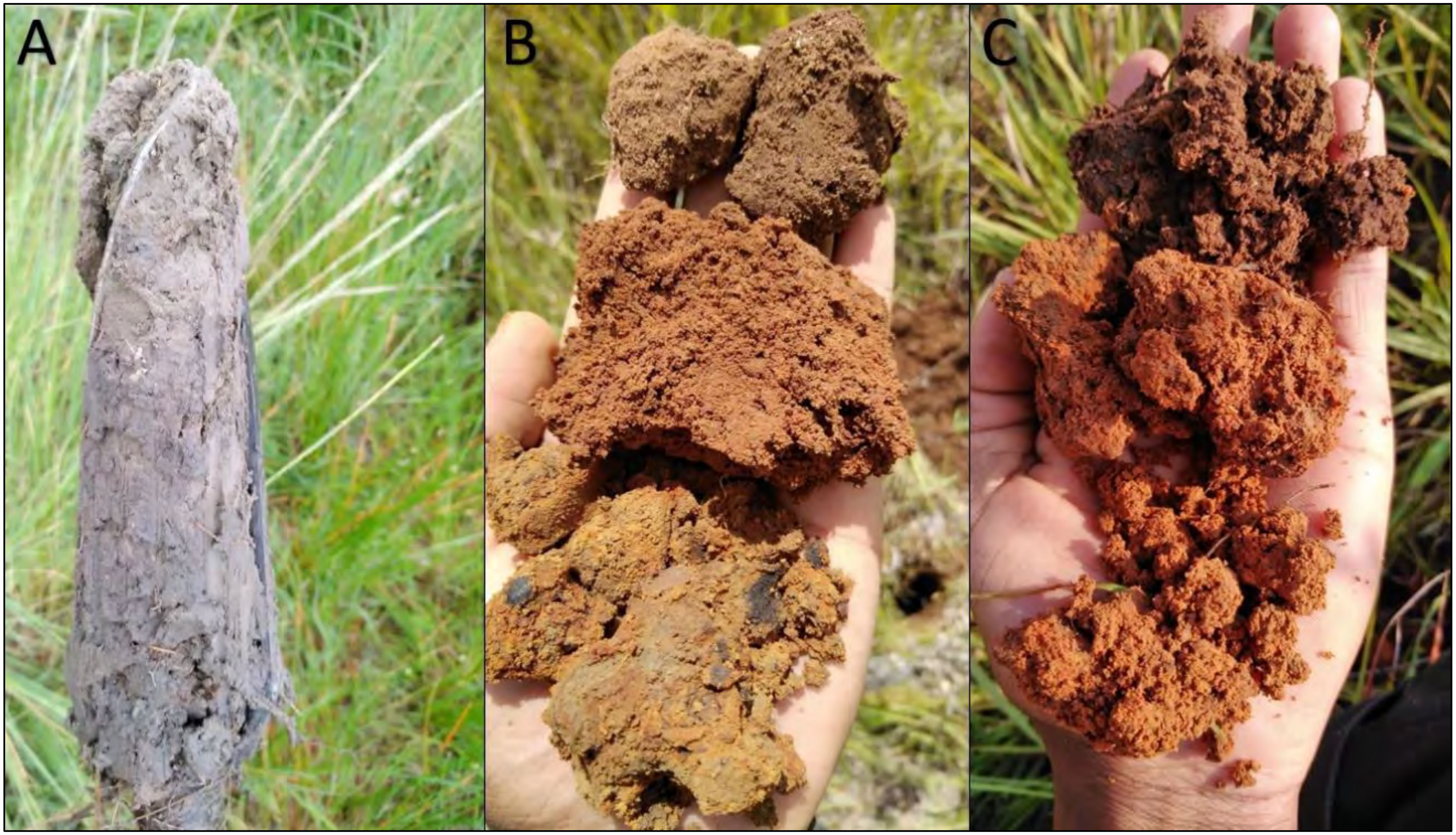

Figure 6-1 Dominant soils identified during the site assessment. A) Gley horizon. B) Orthic on top of yellow-brown apedal, underlined by soft-plinthite (Avalon). C) Orthic on top of red apedal horizon.

6.1.7 Description of Soil Forms and Soil Families

During the site assessment various soil forms were identified. These soil forms are described in Table 6-1 according to depth, clay percentage, indications of surface crusting, signs of wetness and percentage rock. The soil forms are followed by the soil family and in brackets the maximum clay percentage of the topsoil. Soil family characteristics are described in

Table 6-2.

Table 6-1 Summary of soils identified within the project area

	Topsoil					Subsoil A				Subsoil B			
	Depth (mm)	Clay (%)	Signs of wetness	Rock %	Surface crusting	Depth (mm)	Clay (%)	Signs of wetness	Rock %	Depth (mm)	Clay (%)	Signs of wetness	Rock %
Griffin 1120(15)	0-300	0-15	None	0	None	300-700	15-30	None	0	700-1200 (+)	15-30		
Avalon 1220(15)	0-300	0-15	None	0	None	300-700	15-35	None	0	700-1200 (+)	>35	Plinthic conditions	
Ermelo	0-300	0-15	None	0	None	300-1 200 (+)	0-15	None	0	N/A			
Hydromorphic	0-300	0-15	None	0	None	300- 800	0-15	None	0	N/A			

Table 6-2 Description of soil family characteristics

Soil Form/Family	Topsoil Colour	Base Status	Textural Contrast
Griffin 1120(15)	Dark Topsoil	Mesotrophic	Luvic
Avalon 1220(15)	Dark Topsoil	Mesotrophic	Luvic
Ermelo 1120(15)	Dark Topsoil	Mesotrophic	Luvic

6.2 Agricultural Potential

Agricultural potential is determined by a combination of soil, terrain and climate features. Land capability classes reflect the most intensive long-term use of land under rain-fed conditions.

The land capability is determined by the physical features of the landscape including the soils present. The land potential or agricultural potential is determined by combining the land capability results and the climate capability for the region.

6.2.1 Climate Capability

The climatic capability has been determined by means of the Smith (2006) methodology, of which the first step includes determining the climate capability of the region by means of the Mean Annual Precipitation (MAP) and annual Class A pan (potential evaporation) (see Table 6-3).

Table 6-3 Climatic capability (step 1) (Scotney et al., 1987)

Central Sandy Bushveld region				
Climatic Capability Class	Limitation Rating	Description	MAP: Class A pan Class	Applicability to site
C1	None to Slight	Local climate is favourable for good yields for a wide range of adapted crops throughout the year.	0.75-1.00	
C2	Slight	Local climate is favourable for a wide range of adapted crops and a year-round growing season. Moisture stress and lower temperature increase risk and decrease yields relative to C1.	0.50-0.75	
C3	Slight to Moderate	Slightly restricted growing season due to the occurrence of low temperatures and frost. Good yield potential for a moderate range of adapted crops.	0.47-0.50	
C4	Moderate	Moderately restricted growing season due to the occurrence of low temperatures and severe frost. Good yield potential for a moderate range of adapted crops but planting date options more limited than C3.	0.44-0.47	
C5	Moderate to Severe	Moderately restricted growing season due to low temperatures, frost and/or moisture stress. Suitable crops at risk of some yield loss.	0.41-0.44	
C6	Severe	Moderately restricted growing season due to low temperatures, frost and/or moisture stress. Limited suitable crops that frequently experience yield loss.	0.38-0.41	
C7	Severe to Very Severe	Severely restricted choice of crops due to heat and moisture stress.	0.34-0.38	
C8	Very Severe	Very severely restricted choice of crops due to heat and moisture stress. Suitable crops at high risk of yield loss.	0.30-0.34	✓

According to Smith (2006), the climatic capability of a region is only refined past the first step if the climatic capability is determined to be between climatic capability 1 and 6. Given the fact that the climatic capability has been determined to be “C8” for the project area, no further steps will be taken to refine the climate capability.

6.2.2 Land Capability

The land capability was determined by using the guidelines described in “The farming handbook” (Smith, 2006). The delineated soil forms were clipped into the four different slope classes (0-3%, 3-7%, 7-12% and

>12%) to determine the land capability of each soil form. Accordingly, the most sensitive soil forms associated with the project area are restricted to land capability 3, 4 and 5 classes.

Table 6-4 Land capability for the soils within the project area

Land Capability Class	Definition of Class	Conservation Need	Use-Suitability	Land Capability Group	Sensitivity
3	Moderate limitations. Some erosion hazard	Special conservation practice and tillage methods	Rotation crops and ley (50%)	Arable	High
4	Severe limitations. Low arable potential.	Intensive conservation practice	Long term leys (75%)	Arable	Moderate
5	Water course and land with wetness limitations	Protection and control of water table	Improved pastures, suitable for wildlife	Grazing	Low

6.3 Land Potential

The methodology in regard to the calculations of the relevant land potential levels are illustrated in Table 6-5 and Table 6-6. From the three land capability classes, two land potential levels have been determined by means of the Guy and Smith (1998) methodology. Land capability III and IV have been reduced to a land potential level L6 due to climatic limitations. The land capability V has been allocated a land potential "Vlei" considering its hydromorphic characteristics.

Table 6-5 Land potential from climate capability vs land capability (Guy and Smith, 1998)

Land Capability Class	Climatic Capability Class							
	C1	C2	C3	C4	C5	C6	C7	C8
LC1	L1	L1	L2	L2	L3	L3	L4	L4
LC2	L1	L2	L2	L3	L3	L4	L4	L5
LC3	L2	L2	L2	L2	L4	L4	L5	L6*
LC4	L2	L3	L3	L4	L4	L5	L5	L6*
LC5	Vlei	Vlei	Vlei	Vlei	Vlei	Vlei	Vlei	Vlei*
LC6	L4	L4	L5	L5	L5	L6	L6	L7
LC7	L5	L5	L6	L6	L7	L7	L7	L8
LC8	L6	L6	L7	L7	L8	L8	L8	L8

*Land potential level applicable to climatic and land capability

Table 6-6 Land potential for the soils within the project area (Guy and Smith, 1998)

Land Potential	Description of Land Potential Class	Sensitivity
6	Very restricted potential. Regular and/or severe limitations due to soil, slope, temperatures or rainfall. Non-arable.	Low
Vlei	Wetland (grazing and wildlife)	Low
Disturbed	N/A	None

6.4 Erosion Potential

The erosion potential of the identified soil forms has been calculated by means of the (Smith, 2006) methodology. In some cases, none of the parameters are applicable, in which case the step was skipped.

6.4.1 Griffin

Table 6-7 illustrates the values relevant to the erosion potential of the Griffin soil forms. The final erosion potential score has been calculated at 3.5, which indicates a "Moderate" potential for erosion.

Table 6-7 Erosion potential calculation for the Avalon soil forms

Step 1- Initial Value, Texture of Topsoil				
Light (0-15% Clay)		Medium (15-35% Clay)		Heavy (>35% Clay)
3.5	4.0	4.5	5.0	6.0
Step 2- Adjustment Value (Permeability of Subsoil)				
Slightly Restricted		Moderately Restricted		Heavily Restricted
-0.5		-1.0		-2.0
Step 3- Degree of Leaching (Excluding Bottomlands)				
Dystrophic Soils, Medium and Heavy Textures		Mesotrophic Soils		Eutrophic or Calcareous Soils, Medium and Heavy Textures
+0.5		0		-0.5
Step 4- Organic Matter				
Organic Topsoil			Humic Topsoil	
+0.5			+0.5	
Step 5- Topsoil Limitations				
Surface Crusting			Excessive Sand/High Shrink/Self-Mulching	
-0.5			-0.5	
Step 6- Effective Soil Depth				
Very Shallow (<250 mm)			Shallow (<250-500 mm)	
-1.0			-0.5	

6.4.2 Avalon

Table 6-8 illustrates the values relevant to the erosion potential of the Avalon soil forms. The final erosion potential score has been calculated at 4.0, which indicates a "Moderate" potential for erosion.

Table 6-8 Erosion potential calculation for the Hutton soil forms

Step 1- Initial Value, Texture of Topsoil				
Light (0-15% Clay)		Medium (15-35% Clay)		Heavy (>35% Clay)
3.5	4.0	4.5	5.0	6.0
Step 2- Adjustment Value (Permeability of Subsoil)				
Slightly Restricted		Moderately Restricted		Heavily Restricted
-0.5		-1.0		-2.0

Step 3- Degree of Leaching (Excluding Bottomlands)

Dystrophic Soils, Medium and Heavy Textures	Mesotrophic Soils	Eutrophic or Calcareous Soils, Medium and Heavy Textures
+0.5	0	-0.5

Step 4- Organic Matter

Organic Topsoil	Humic Topsoil
+0.5	+0.5

Step 5- Topsoil Limitations

Surface Crusting	Excessive Sand/High Shrink/Self-Mulching
-0.5	-0.5

Step 6- Effective Soil Depth

Very Shallow (<250 mm)	Shallow (<250-500 mm)
-1.0	-0.5

6.4.3 Ermelo

Table 6-9 illustrates the values relevant to the erosion potential of the Ermelo soil forms. The final erosion potential score has been calculated at 4.0, which indicates a “High” potential for erosion.

Table 6-9 Erosion potential calculation for the Dundee soil forms

Step 1- Initial Value, Texture of Topsoil

Light (0-15% Clay)		Medium (15-35% Clay)		Heavy (>35% Clay)
3.5	4.0	4.5	5.0	6.0

Step 2- Adjustment Value (Permeability of Subsoil)

Slightly Restricted	Moderately Restricted	Heavily Restricted
-0.5	-1.0	-2.0

Step 3- Degree of Leaching (Excluding Bottomlands)

Dystrophic Soils, Medium and Heavy Textures	Mesotrophic Soils	Eutrophic or Calcareous Soils, Medium and Heavy Textures
+0.5	0	-0.5

Step 4- Organic Matter

Organic Topsoil	Humic Topsoil
+0.5	+0.5

Step 5- Topsoil Limitations

Surface Crusting	Excessive Sand/High Shrink/Self-Mulching
-0.5	-0.5

Step 6- Effective Soil Depth

Very Shallow (<250 mm)	Shallow (250-500 mm)
-1.0	-0.5

6.4.4 Hydromorphic Soils

Table 6-10 illustrates the values relevant to the erosion potential of the hydromorphic soil forms. The final erosion potential score has been calculated at 5.5, which indicates a "Low" potential for erosion.

Table 6-10 Erosion potential calculation for the Katspruit soil forms

Step 1- Initial Value, Texture of Topsoil				
Light (0-15% Clay)		Medium (15-35% Clay)		Heavy (>35% Clay)
3.5	4.0	4.5	5.0	6.0
Step 2- Adjustment Value (Permeability of Subsoil)				
Slightly Restricted		Moderately Restricted		Heavily Restricted
-0.5		-1.0		-2.0
Step 3- Degree of Leaching (Excluding Bottomlands)				
Dystrophic Soils, Medium and Heavy Textures		Mesotrophic Soils		Eutrophic or Calcareous Soils, Medium and Heavy Textures
+0.5		0		-0.5
Step 4- Organic Matter				
Organic Topsoil			Humic Topsoil	
+0.5			+0.5	
Step 5- Topsoil Limitations				
Surface Crusting			Excessive Sand/High Shrink/Self-Mulching	
-0.5			-0.5	
Step 6- Effective Soil Depth				
Very Shallow (<250 mm)			Shallow (<250-500 mm)	
-1.0			-0.5	

6.5 Sensitivity Verification

The following land potential levels have been determined;

- Land potentials level 6 (these land potential levels are defined as having restricted to very restricted potentials. Regular, moderate and/or severe limitations due to soil, slope, temperatures or rainfall. Non-arable. The sensitivity of these land potentials are characterised by a "Low Sensitivity").

Fifteen land capabilities have been digitised by (DAFF, 2017) across South Africa, of which eight potential land capability classes are located within the proposed footprint area's assessment corridor, including;

- Land Capability 1 to 5 (very low to low);
- Land Capability 6 to 8 (moderately low to moderate); and
- Land Capability 8 to 10 (moderate to moderate high).

The baseline findings and the sensitivities as per the Department of Agriculture, Forestry and Fisheries (DAFF, 2017) national raster file concur with one another. It therefore is the specialist's opinion that the land capability and land potential of the resources in the regulated area is characterised by "Low" to "Moderate High" sensitivities (see Figure 6-2), which conforms to the requirements of an agricultural compliance statement only.

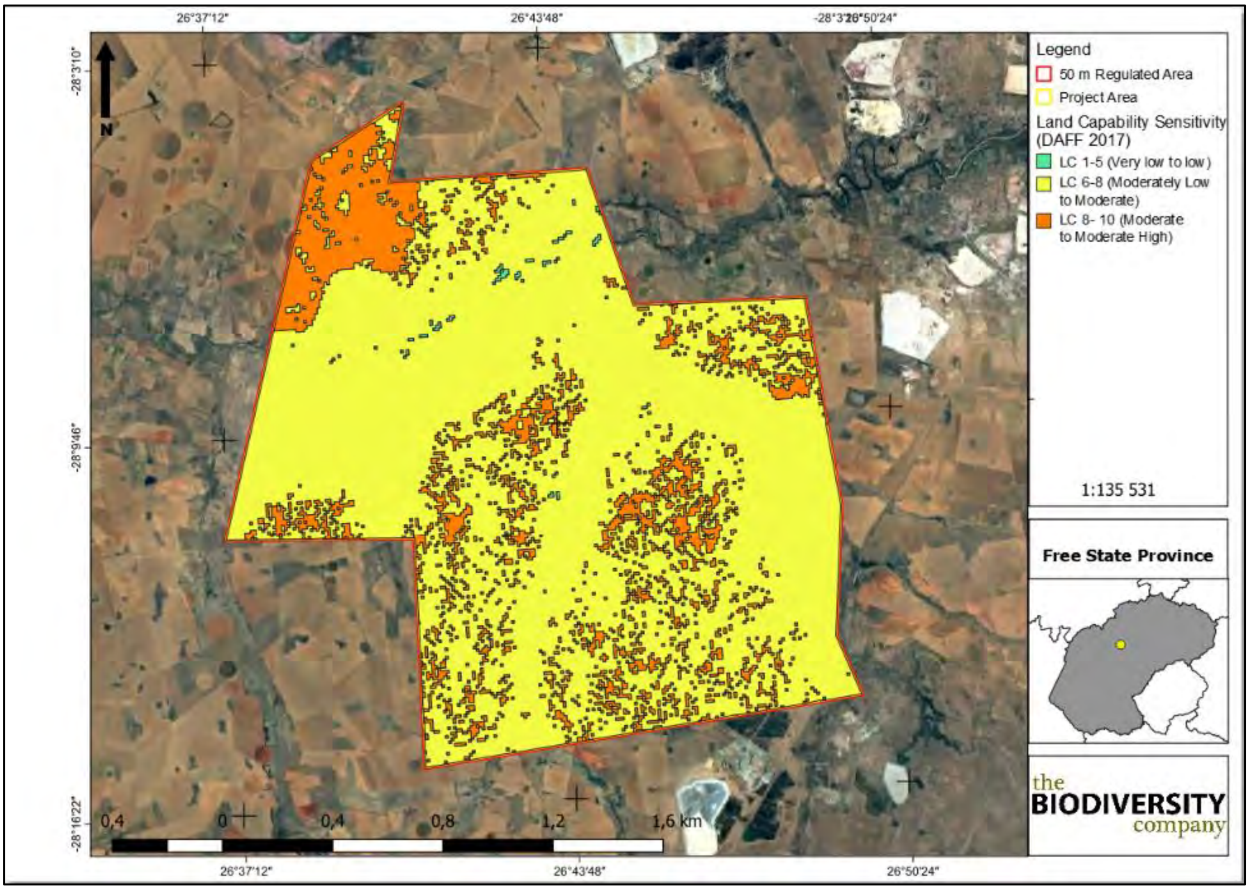

Figure 6-2 Land Capability Sensitivity (DAFF, 2017)

According to the DEA Screening Tool (2022) land capability was identified as very low to moderate high and the farming field crop sensitivity as high to very high in some areas (See Figure 6-3).

No "High" land capability sensitivities were identified within proximity to any of the proposed activities. However, for those components located within high and very high sensitivity agricultural land uses, stakeholder engagement with the landowners can be undertaken to compensate for the loss of any high-productivity crop fields. Furthermore, it is advisable to rearrange proposed components around high/very high sensitivity crop fields to ensure the conservation thereof where possible.

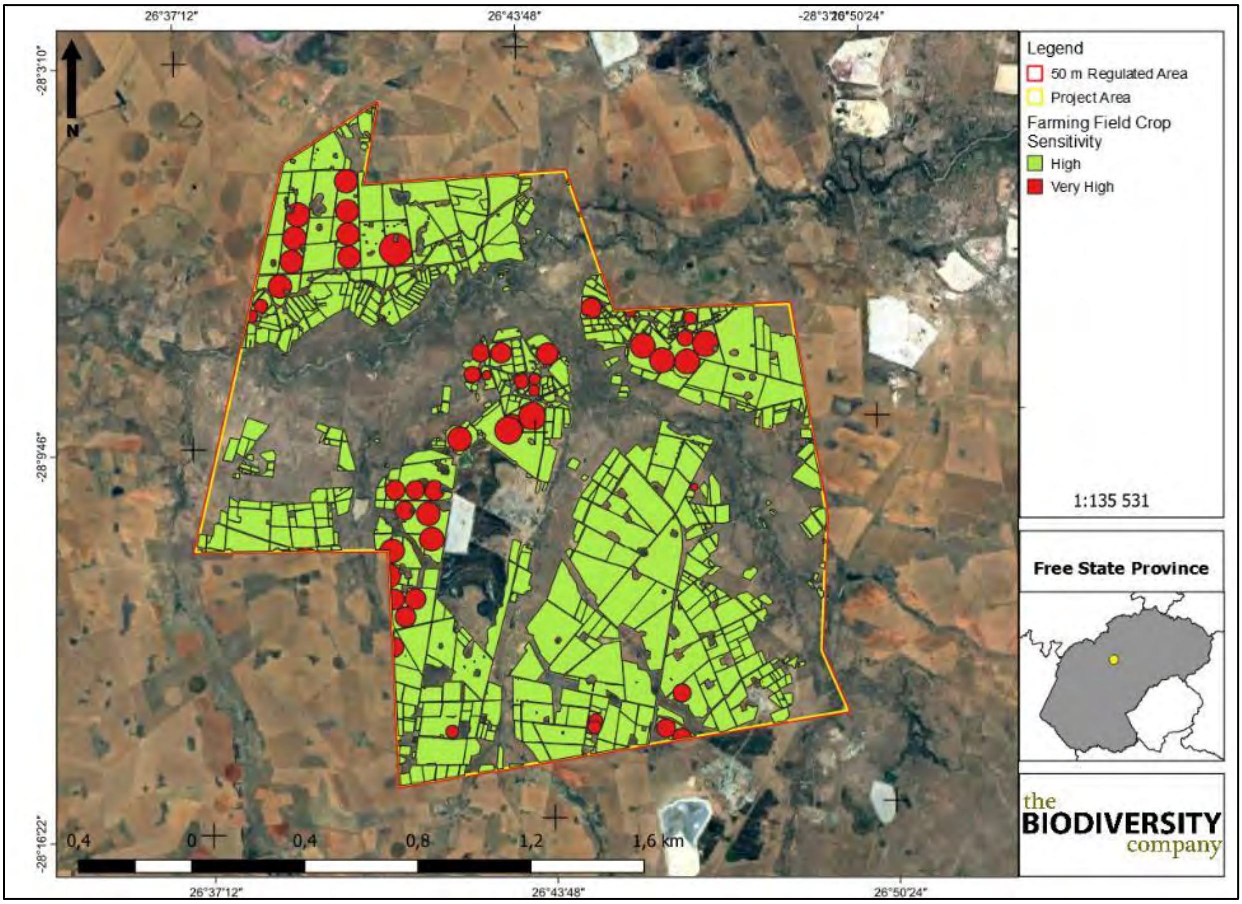

Figure 6-3 Farming Field crop Sensitivity (DEA, 2022)

7 Impact Assessment

Infrastructure within the study area includes compressor stations, gas pipelines, well heads and a transmission loop. The proposed activities often impede into “Very High” and “High” sensitivity crop fields. Even though these sensitivities aren’t associated with arable land potential conditions, high production agricultural activities will be impacted on.

Impacts were considered in terms of the construction/operational phases, with no impacts on the watercourse receiving environment being identified that will occur during the decommissioning phase of the project. Mitigation measures were only applied to impacts deemed relevant.

7.1 Anticipated Activities

The proposed activities associated with the expansion of gas production can be seen overlaid with the overall sensitivity (Figure 6-3). It is evident from the figure that the following may have a negative effect on more sensitive wetland features, most impacts involve the wetland and its associated buffer area:

- Expansions to the current LNG and Helium production plant located on the Farm Mond van Doorn Rivier. The planned expansions will be to increase the helium and LNG production capacities significantly (~30 fold increase) and increase the footprint of the existing approved plant by approximately 10 ha;
- The drilling of new gas wells ~300 wells spread over a total study area (Cluster 2) of approximately ~27 500 ha;
- The installation of trenched pipelines connecting the wells to localised booster compressors and then to in-field compressor stations (~3 sites) and subsequently the compressor stations to the main plant area; and
- There will be a requirement to have short powerlines (132kV and 33kV) and water connections to the compressor sites.”

7.2 Stakeholder Comments

No comments pertinent to wetlands were provided for a response.

Highlighted concerns/comments from stakeholders relevant are represented and discussed in Table 7-1 below.

Table 7-1 Stakeholder considerations relevant to the report

Comment	Tetra4 EIA formal response	Specialist Response
Here we are dealing with commercial agricultural land, game farms, livestock farms and retirement land. This is productive land that has been acquired through hard work and generates income for many families. It is an asset, in certain cases the only asset of the landowners and it is well looked after. It is a way of life, a privilege. Any interference from outside has an impact and the impact is always negative.	Thank you for this comment. As mentioned above, we wish to have open engagement with yourself and all affected landowners to discuss what (if any) realistic mitigation measures we can develop or improve upon, and which will be legally binding on Tetra4 to achieve an amicable outcome for all.	It is recommended he avoidance of active agricultural lands be prioritised. Where avoidance is not feasible, then rehabilitation objectives for the disturbed areas must be agreed between the applicant and land user. In the event disturbed areas cannot be suitably rehabilitated to achieve the agreed targets, compensation must be provided.

7.3 Review of Cluster 1 EIA and EMPr

Several impacts were identified for the soil and agricultural assessment completed by the ARC-Institute for Soil, Climate and Water (2017), which were also considered for the Cluster 2 gas exploration project. The impacts and mitigation measures from Cluster 1 that are still relevant/adequate are represented and discussed in Table 7-2.

Table 7-2 Cluster 1 Environmental Impacts and EMPr

#	Activities	Impact/ Aspect	Management/ Mitigation Measures	Suggested Amendment
3	Pipelines	Impacts on land-use	Infrastructure routes should follow existing servitudes and farm boundaries wherever possible. Where necessary pipelines should be laid underground below plough ripping level. In the event that surface pipelines are to be utilised, written approval must first be obtained from the relevant landowner. Pipelines that will be buried at a minimum of 1.5m below surface which is deeper than the rip-depth to ensure that the farmer has full utilization of their land.	
5	Exploration/ Production drilling	Impacts on land-use	The identified drill site should, where possible, not infringe on the landowners surface activities. Irrigation Pivot points should remain unaffected by infrastructure, and must be deviated around or buried to allow for continued pivot irrigation operation.	
12	Exploration/ Production drilling	Impacts on land-use	The location of the drilling site should be done so as to impact minimally on the daily activities of the landowner. The location of the site should be consulted with the landowner. Drilling site should not be situated near visually sensitive areas or residential areas. Steep areas should be avoided.	
19	All	Loss of agricultural land	Ensure that as much of the infrastructure as possible is sited away from agricultural lands. Utilize servitudes, farm roads and any other routes to avoid sensitive areas. Ensure that pipelines are buried at sufficient depth (>1 m minimum) to avoid interference with arable agriculture activities.	In the event agricultural lands cannot be avoided, rehabilitation of these disturbed areas must be agreed with the land user. In the event rehabilitation cannot be achieved, compensation must be provided.
32	Pipelines	Impacts on land-use	The pipelines will be buried in accordance with the schedule as agreed upon with landowners to minimise disturbance to farming operations.	
57	All	Increased soil erosion	Ensure that topsoil (0-30 cm approx.) and subsoil (30 cm +) are stored separately during excavation, so they can be replaced in the correct order. Ensure that pipeline route is re-vegetated as soon as possible after construction and that soil surface is in good condition.	In an event soil will not be returned to the profile, these soils can be used for rehabilitation efforts elsewhere. Avoid importing soils from 'outside' the project area for rehabilitation of affected areas.
82	ALL	Spill response and pollution clean-up	All necessary measures should be taken to prevent spills from occurring on site. However, should a spill occur, the following procedure must be followed: A spill response kit should be available on site at all times. Where potential contaminants are transported along access roads, emergency containment and mitigation measures must be developed to minimize impacts should accidental spills occur. Any spillage will be investigated and immediate action must be taken. In the event of a significant spill (>35 litres) of any hazardous substance, these must also be recorded and reported to the PASA, DWA (DWS) and the local/provincial authority where necessary. Depending on the nature and the extent of the spill, contaminated soil must be either excavated or treated on-site. The EO should determine	

			the exact method of treatment. Clean up should be immediate and to the satisfaction of the EO. A register of the treatment method and clean up close out report must be kept and be made available reviewed by the ECO during independent audits. Treatment could include the use of absorbent material or hydrocarbon-digesting substances. It is therefore, recommended that a spill kit and hydrocarbon digesting substance should be kept on site at all times. Clean up should be immediate and to the satisfaction of the ECO. Excavation of contaminated soil must involve careful removal of soil using appropriate tools/machinery to storage containers until treated or disposed of at a licensed hazardous landfill site. Materials used for the remediation of spills must be used according to product specification and guidance for use. A record of all spills and actions taken to remediate the spills should be kept at all times. Proper and frequent maintenance should be done to minimise spillage risk..	
85	Exploration/ Production drilling	Contamination from leakage and spillage	All wells should be capped to prevent the spilling of contaminated groundwater.	

7.4 Soil Impact Assessment

The development of the project will result in the loss of potentially productive agricultural land due to the establishment of infrastructure in these areas. This is notable for the high crop sensitivity areas and areas actively cultivated. The development in the area could also increase the potential for soil erosion because of the clearing of vegetation and creation of bare / open areas. Erosion risk is increased during high rainfall events and high winds. The results of such erosion being unchecked could include loss of topsoil, surface crusting/sealing and even rill or donga formation in the worst cases. Soil quality could also be impacted by spills and leaks from machinery, equipment and vehicles operating in the area. These pollutants would filter through the soil body, into underground water sources and even into watercourses.

The additional impacts associated with the proposed activities, which weren't considered covered in the existing approved Cluster 1 EIA and EMPr, are considered in this section. No 'new' impacts are expected for the Cluster 2 gas exploration project, except for a consideration of seismicity sensitivity. This is a consideration for soils that are prone to erosion, notably duplex soils or sodium rich soils would be more sensitive to seismic activity. The erosion risk for soils identified in the project area ranges from moderate to high, with high risks associated with the Hutton soil form. This soil form is not associated with a vertic horizon and is not a duplex form. Despite the high erosion risk of this soil form the associated seismicity risk is expected to be negligible for the area.

7.5 Recommendations

The following recommendations are provided for the project:

- No mitigation measures have been prescribed for the decommissioning phase of the project. It is recommended that the closure plan and objective be reviewed, and appropriate measures be included for the local water resources;
- Implement the "Erosion Control and Storm Water Management" (document number T4-PP-SHERQ-043) detailed in the operating procedures document;
- Once the pipeline has been installed, the disturbed area must be cleaned up in accordance with the Environmental Management Plan, and in accordance to the Tetra4 Rehabilitation Plan and Procedure;
- All activities related to these works shall comply with all applicable Environmental Laws, Tetra4's approved Environmental Management Programme (EMPR) and Tetra4's Environmental Procedures when undertaking any works; and
- The number and extent of 'bare' areas must be kept to a minimum. These bare areas must be ripped and vegetated. Compacted areas must also be ripped (in two directions) and re-vegetated to facilitate the establishment of ground cover. See below.

7.5.1 Ripping Compacted Areas

All areas outside of the footprint areas that will be degraded (by means of vehicles, laydown yards etc.) must be ripped where compaction has taken place. According to the Department of Primary Industries and Regional Development (Agriculture and Food) (2017), ripping tines must penetrate to just below the compacted horizons (approximately 300 – 400 mm) with soil moisture being imminent to the success of ripping. Ripping must take place within 1-3 days after seeding, and also following a rain event to ensure a higher moisture content.

To summarise;

- Rip all compacted areas outside of the developed areas that have been compacted;

- This must be done by means of a commercial ripper that has at least two rows of tines; and
- Ripping must take place between 1 and 3 days after seeding and following a rainfall event (seeding must therefore be carried out directly after a rainfall event).

7.5.2 Revegetate Degraded Areas

Vegetation within the footprint areas will be cleared to accommodate the excavation activities coupled with the proposed footprint areas' foundations. This impact will degrade soil resources, ultimately decreasing the land capability of resources and increasing erosion. According to Russell (2009), areas characterised by a loss of soil resources should be revegetated by means of vegetation with vigorous growth, stolons or rhizomes that more or less resembles the natural vegetation in the area.

It is recommended that all areas surrounding the development footprint areas that have been degraded by traffic, laydown yards etc. must be ripped and revegetated by means of indigenous grass species. Mixed stands or monocultures will work sufficiently for revegetation purposes. Mixed stands tend to blend in with indigenous vegetation species and are more natural. Monocultures however could achieve high productivity. In general, indigenous vegetation should always be preferred due to various reasons including the aesthetical presence thereof as well as the ability of the species to adapt to its surroundings.

Plant phase plants which are characterised by fast growing and rapid spreading conditions. Seed germination, seed density and seed size are key aspects to consider before implementing revegetation activities. The amount of seed should be limited to ensure that competition between plants are kept to a minimum. During the establishment of seed density, the percentage of seed germination should be taken into consideration. *E curvula* is one of the species recommended due to the ease of which it germinates. This species is also easily sown by means of hand propagation and hydro seeding.

The following species are recommended for rehabilitation purposes;

- *Eragrostis teff;*
- *Cynodon species (Indigenous and altered types);*
- *Chloris gayana;*
- *Panicum maximum;*
- *Digitaria eriantha;*
- *Anthephora pubescens; and*
- *Cenchrus ciliaris.*

8 Conclusion

Three main sensitive soil forms were identified within the assessment area, namely the Avalon, Ermelo and Griffin soil forms. The land capability sensitivities (DAFF, 2017) indicate land capabilities with "Low" and "Moderate high" sensitivities, which correlates with the findings from the baseline assessment.

The assessment area is associated with arable soils, due to the type of soils which the DEA Screening Tool (2022) also identified as high to very high sensitivity for field crops farming. However, the available climatic conditions of low annual rainfall and high evapotranspiration potential severely limits crop production significantly resulting in land capabilities with "Low" and "Moderate high" sensitivities. The land capabilities associated with the regulated area are suitable for cropping and grazing, which corresponds with the current land use.

8.1 Specialist Recommendation

The final results indicate “Insignificant” to “Very Low” post-mitigation significance ratings for the proposed components. It is therefore clear that the proposed activities are expected to have a minimal impact on land potential resources. It is worth noting that some “High” sensitivity crop field areas were identified by means of the DEA Screening tool (2022) which is not expected to be avoided throughout the life of the operation. Therefore, stakeholder engagement must be undertaken to compensate land owners for high crop field land use areas where necessary.

With this being considered, it is recommended that the proposed activities may proceed as have been planned.

9 References

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Terrestrial Ecology Assessment for the proposed Tetra 4 Cluster 2 Project

Virginia, Free State Province

May 2022

CLIENT

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Tables

Figures

1 Introduction

The Biodiversity Company was appointed to complete an ecological assessment, as part of the environmental authorisation process for the proposed Tetra 4 Cluster 2 project in Virginia Free State. The project area and the associated infrastructure is located approximately 17 km south-east of the town of Welkom and 25 km north of the Theuniseen town. The area is found along the R30 and R730 located in between the R710 and R73 roads.

1.1 Background

The following information was provided by EIMS:

In 2012, a Production Right (Ref: 12/4/1/07/2/2) was granted which spans approximately 187 000 hectares for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within the approval of the Production Right, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1-1).

The activities in the Production Right include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original EIA and approved EMPr).

On 21 September 2017, the Department of Mineral Resources and Energy (DMRE) issued an integrated environmental authorisation ("Cluster 1 EA") (reference: 12/04/07) to Tetra4 in terms of the NEMA. The Cluster 1 EA (as amended by Cluster 1 EA amendments dated 26 August 2019 and 1 September 2020) authorises the development of "Cluster 1" of the Project. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and LNG Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Furthermore, the following licences have been issued to Tetra4 in respect of Cluster 1 of the Project:

- Provisional Atmospheric Emission Licence (PAEL) dated 4 August 2017 (reference: LDM/AEL/YMK/014) for the Storage and Handling of Petroleum Products [Category 2: Subcategory 2.4 of the Listed Activities (Government Notice 893, as amended) published under the National Environmental Management: Air Quality Act 39 of 2004 (NEMAQA)] by the Lejweleputswa District Municipality. A final atmospheric emission licence will be issued after operation of the plant which is currently under construction; and
- Water Use Licence (WUL) dated 22 January 2019 (reference: 08/C42K/CI/8861) for the construction of pipelines for the Project in terms of section 21(c&i) water uses of the National Water Act 36 of 1998 (NWA) by the Department of Water and Sanitation (DWS).

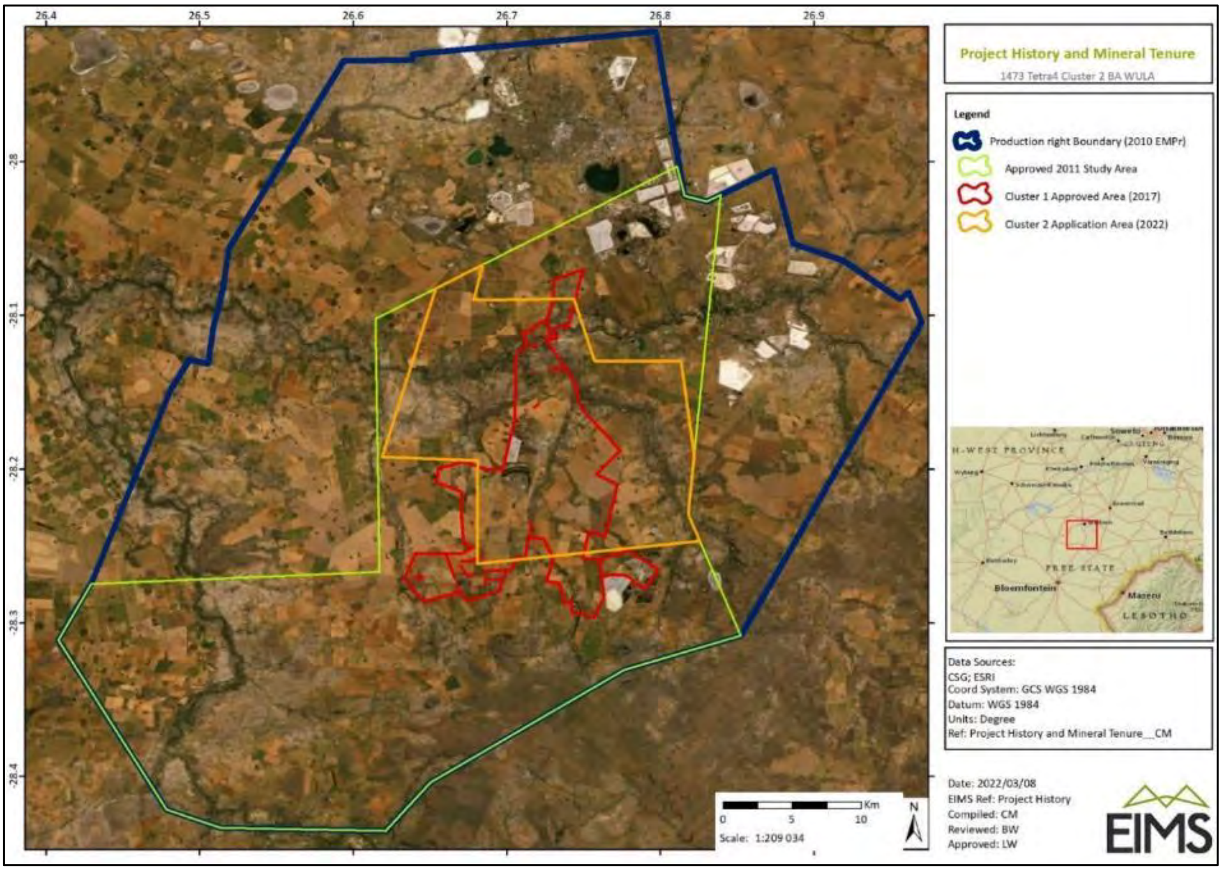


Figure 1-1 Project history and mineral tenure.

The following information is as provided by EIMS:

"Tetra 4 has a natural gas production right over a very large area in the Free State Province, near Virginia. They also have an existing environmental authorisation and associated water use licence for their current production activities (referred to as Cluster 1 above). Tetra 4 wishes to expand their current production operations onto other areas which still fall within the approved Production Right, but outside of the areas approved in the EA and WUL. The planned expansions will include the following (Figure 1-2):

- Expansions to the current LNG and Helium production plant located on the Farm Mond van Doorn Rivier. The planned expansions will be to increase the helium and LNG production capacities significantly (~30 fold increase) and increase the footprint of the existing approved plant by approximately 10ha.
- The drilling of new gas wells ~300 wells spread over a total study area (Cluster 2) of approximately 27500ha.
- The installation of trenched pipelines connecting the wells to localised booster compressors and then to in-field compressor stations (~3 sites) and subsequently the compressor stations to the main plant area.
- There will be a requirement to have short powerline and water connections to the compressor sites."

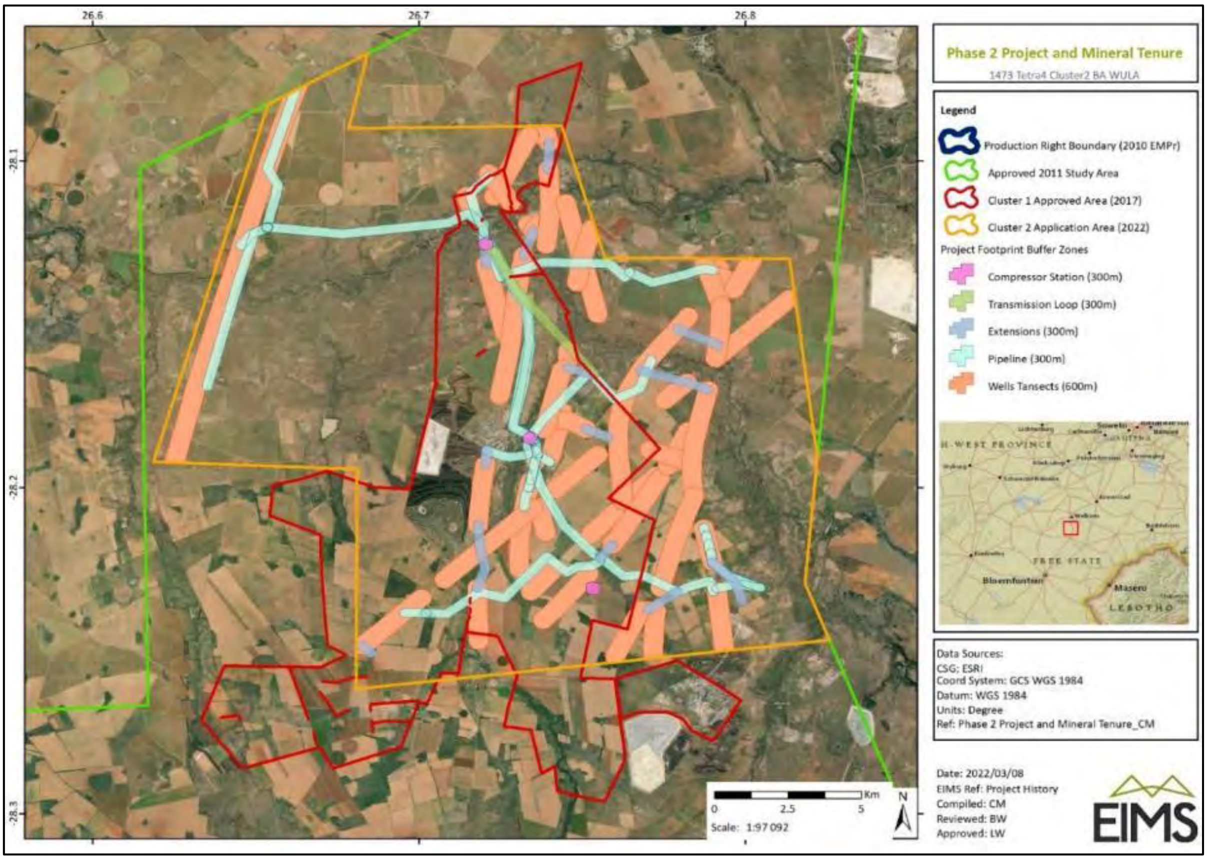


Figure 1-2 Cluster 2 study area and proposed infrastructure footprint buffer zones

This assessment was conducted per the amendments to the Environmental Impact Assessment Regulations. 2014 (GNR 326, 7 April 2017) of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA). The approach has taken cognisance of the recently published Government Notices (GN) 320 (20 March 2020): “Procedures for the Assessment and Minimum Criteria for Reporting on Identified Environmental Themes in terms of Sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998, when applying for Environmental Authorisation” (Reporting Criteria). The National Web-based Environmental Screening Tool has characterised the terrestrial sensitivity of the project area as “Very High”.

The purpose of the specialist studies is to provide relevant input into the environmental authorisation process. This report, after taking into consideration the findings and recommendations provided by the specialist herein, should inform and guide the Environmental Assessment Practitioner (EAP) and regulatory authorities, enabling informed decision making, as to the ecological viability of the project.

1.2 Terms of Reference

The Terms of Reference (ToR) included the following:

- Description of the baseline receiving environment specific to the field of expertise (general surrounding area as well as site specific environment);
- Identification and description of any desktop sensitive receptors in terms of relevant specialist disciplines (fauna and flora) that occur in the project area, and the manner in which these sensitive receptors may be affected by the project;
- Identify ‘significant’ desktop ecological, botanical and faunal features within the proposed project areas;

- Identification of conservation significant habitats around the project area which might be impacted;
- Screening to identify any critical issues (potential fatal flaws) that may result in project delays or rejection of the application;
- Provide a map to identify sensitive receptors in the project area, based on available maps and database information;

1.3 Project Description

Tetra 4 Cluster 2 is located some 11 km from Virginia in the Free State Province, within the Matjhabeng and Lejweleputswa District Municipality. The area surrounding the project area consists mainly of agricultural fields with interspersed mining activities and secondary roads. Natural areas include the Sand River and surrounds with natural fields occurring in certain areas. The project layout is shown in Figure 1-3.

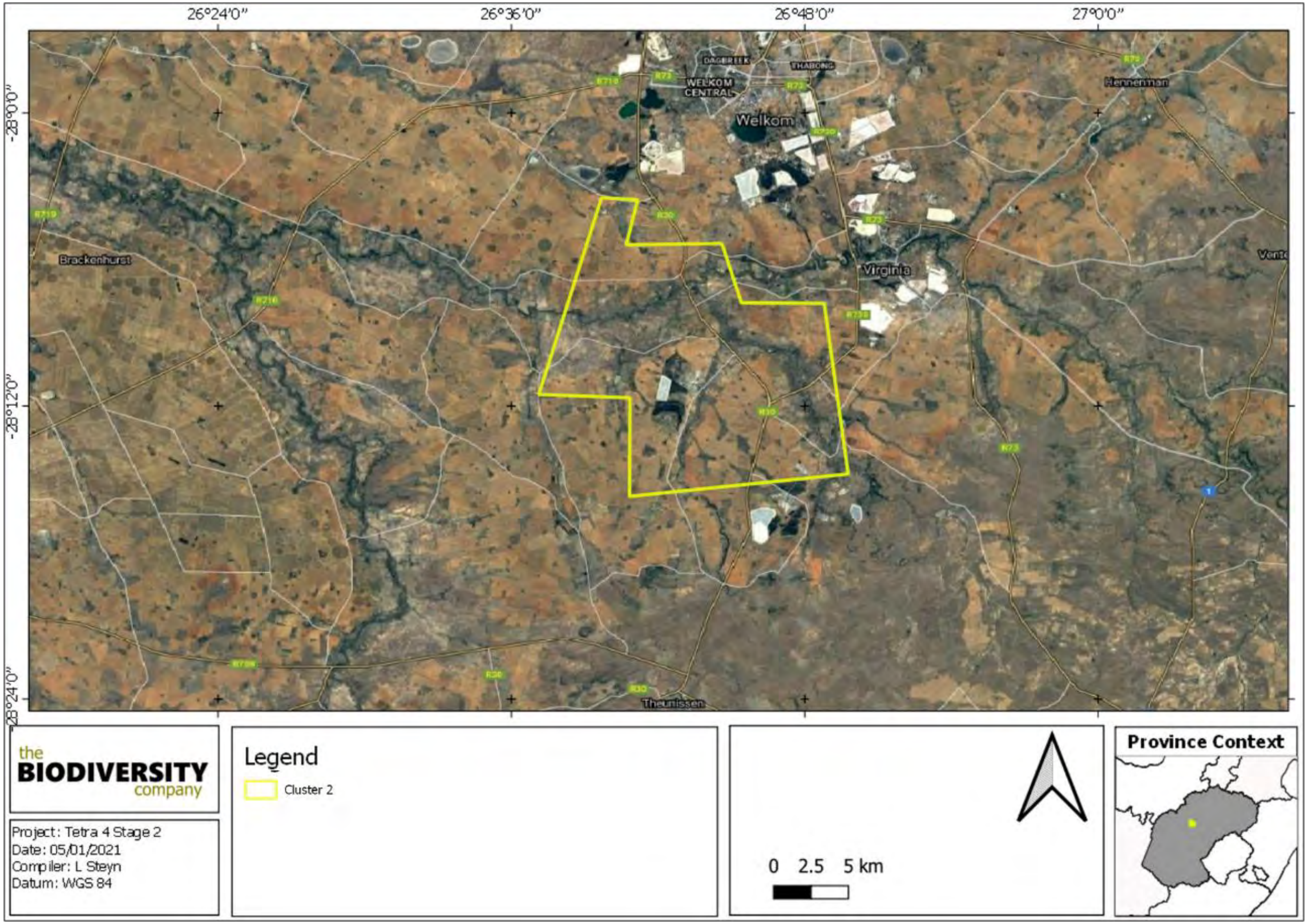


Figure 1-3 Project location on a regional scale

2 Specialist Details

Report Name	Terrestrial Ecology Assessment for the proposed Tetra 4 Cluster 2 Project COLLIERY
Submitted to	
Report Writer (Desktop)	Lindi Steyn Dr Lindi Steyn has completed her PhD in Biodiversity and Conservation from the University of Johannesburg. Lindi is a terrestrial ecologist with a special interest in ornithology. She has completed numerous studies ranging from Basic Assessments to Environmental Impact Assessments following IFC standards.
Report Writer and Fieldwork	Martinus Erasmus Martinus Erasmus obtained his B-Tech degree in Nature Conservation in 2016 at the Tshwane University of Technology. Martinus has been conducting EIAs, basic assessments and assisting specialists in field during his studies since 2015. Martinus is Cand. Sci. Nat. registered (118630) is a specialist terrestrial ecologist and botanist which conducts floral surveys faunal surveys which include mammals, birds, amphibians and reptiles.
Report Reviewer	Andrew Husted Andrew Husted is Pr Sci Nat registered (400213/11) in the following fields of practice: Ecological Science, Environmental Science and Aquatic Science. Andrew is an Aquatic, Wetland and Biodiversity Specialist with more than 12 years' experience in the environmental consulting field. Andrew has completed numerous wetland training courses, and is an accredited wetland practitioner, recognised by the DWS, and also the Mondi Wetlands programme as a competent wetland consultant.
Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2017. We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than to provide a professional service within the constraints of the project (timing, time and budget) based on the principals of science.

3 Key Legislative Requirements

The legislation, policies and guidelines listed below are applicable to the current project in terms of biodiversity and ecological support systems. The list below, although extensive, is not exhaustive and other legislation, policies and guidelines may apply in addition to those listed below (Table 3-1).

Table 3-1 A list of key legislative requirements relevant to biodiversity and conservation in Free State

Region	Legislation
National	Constitution of the Republic of South Africa (Act No. 108 of 2006)
	The National Environmental Management Act (NEMA) (Act No. 107 of 1998)
	The National Environmental Management Protected Areas Act (Act No. 57 of 2003)
	The National Environmental Management Biodiversity Act (Act No. 10 of 2004)
	The National Environmental Management Act (NEMA) (Act No. 107 of 1998) Section 24 , No 42946 (January 2020)
	The National Environmental Management Act (NEMA) (Act No. 107 of 1998) Section 24 , No 43110 (March 2020)
	The National Environmental Management: Waste Act, 2008 (Act 59 of 2008);
	The Environment Conservation Act (Act No. 73 of 1989) and associated EIA Regulations
	National Protected Areas Expansion Strategy (NPAES)
	Environmental Conservation Act (Act No. 73 of 1983)
	Natural Scientific Professions Act (Act No. 27 of 2003)
	National Biodiversity Framework (NBF, 2009)
	National Forest Act (Act No. 84 of 1998)
	National Veld and Forest Fire Act (101 of 1998)
	National Spatial Biodiversity Assessment (NSBA)
	World Heritage Convention Act (Act No. 49 of 1999)
	National Heritage Resources Act, 1999 (Act 25 of 1999)
	Municipal Systems Act (Act No. 32 of 2000)
	Alien and Invasive Species Regulations, 2014
	South Africa's National Biodiversity Strategy and Action Plan (NBSAP)
	Conservation of Agricultural Resources Act, 1983 (Act 43 of 1983)
	Sustainable Utilisation of Agricultural Resources (Draft Legislation).
	White Paper on Biodiversity
Provincial	Boputhatswana Nature Conservation Act 3 of 1973
	Free State Nature Conservation Ordinance 8 of 1969

4 Methods

4.1 Desktop Assessment

The desktop assessment was principally undertaken using a Geographic Information System (GIS) to access the latest available spatial datasets to develop digital cartographs and species lists. These datasets and their date of publishing are provided below.

4.1.1 Ecologically Important Landscape Features

Existing ecologically relevant data layers were incorporated into a GIS to establish how the proposed development might interact with any ecologically important entities. Emphasis was placed around the following spatial datasets:

- National Biodiversity Assessment 2018 (Skowno *et al*, 2019) - The purpose of the National Biodiversity Assessment (NBA) is to assess the state of South Africa's biodiversity based on the best available science, with a view to understanding trends over time and informing policy and decision-making across a range of sectors. The NBA deals with all three components of biodiversity: genes, species and ecosystems; and assesses biodiversity and ecosystems across terrestrial, freshwater, estuarine and marine environments. The two headline indicators assessed in the NBA are:
    - Ecosystem Threat Status – an indicator of an ecosystem's wellbeing, based on the level of change in structure, function or composition. Ecosystem types are categorised as Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT) or Least Concern (LC), based on the proportion of the original extent of each ecosystem type that remains in good ecological condition.
    - Ecosystem Protection Level – an indicator of the extent to which ecosystems are adequately protected or under-protected. Ecosystem types are categorised as Well Protected (WP), Moderately Protected (MP), Poorly Protected (PP), or Not Protected (NP), based on the proportion of the biodiversity target for each ecosystem type that is included within one or more protected areas. Not Protected, Poorly Protected or Moderately Protected ecosystem types are collectively referred to as under-protected ecosystems.
- Protected areas:
    - South Africa Protected Areas Database (SAPAD) (DEA, 2020) – The South African Protected Areas Database (SAPAD) contains spatial data for the conservation of South Africa. It includes spatial and attributes information for both formally protected areas and areas that have less formal protection. SAPAD is updated continuously and forms the basis for the Register of Protected Areas which is a legislative requirement under the National Environmental Management: Protected Areas Act, Act 57 of 2003.
    - National Protected Areas Expansion Strategy (NPAES) (SANBI, 2010) – The National Protected Area Expansion Strategy (NPAES) provides spatial information on areas that are suitable for terrestrial ecosystem protection. These focus areas are large, intact and unfragmented and are, therefore, of high importance for biodiversity, climate resilience and freshwater protection.
- The Free State Critical Biodiversity Areas (CBA) map accounts for terrestrial fauna and flora only. The inclusion of the aquatic component was limited to the Freshwater Ecosystem Priority Areas (FEPA) catchments (included in the cost layer and for the identification of Ecological Support Areas (ESAs)) and wetland clusters (included in the ESAs only). The areas are subdivided as Critical Biodiversity Areas (CBA1), CBA2, Degraded, ESA1, ESA2, Other and Protected:
    - Critical Biodiversity Areas (CBAs) –Areas considered critical for meeting biodiversity targets and thresholds, and which are required to ensure the persistence of viable populations of species and the functionality of ecosystems.
    - Ecological Support Areas (ESAs) - Areas are required to support and sustain the ecological functioning of Critical Biodiversity Areas (CBAs). For terrestrial and aquatic environments, these areas are functional but are not necessarily pristine natural areas.

They are however required to ensure the persistence and maintenance of biodiversity patterns and ecological processes within the CBAs, and which also contributes significantly to the maintenance of Ecological Infrastructure.

- Important Bird and Biodiversity Areas (BirdLife South Africa, 2015) – Important Bird and Biodiversity Areas (IBAs) constitute a global network of over 13 500 sites, of which 112 sites are found in South Africa. IBAs are sites of global significance for bird conservation, identified through multi-stakeholder processes using globally standardised, quantitative and scientifically agreed criteria; and

- Hydrological Setting:

    - South African Inventory of Inland Aquatic Ecosystems (SAIIAE) (Van Deventer *et al,* 2018) – A South African Inventory of Inland Aquatic Ecosystems (SAIIAE) was established during the National Biodiversity Assessment of 2018. It is a collection of data layers that represent the extent of river and inland wetland ecosystem types as well as pressures on these systems.

    - Strategic Water Source Areas (SWSAs) (Le Maitre *et al*, 2018) – SWSAs are defined as areas of land that supply a quantity of mean annual surface water runoff in relation to their size and therefore, contribute considerably to the overall water supply of the country. These are key ecological infrastructure assets and the effective protection of surface water SWSAs areas is vital for national security because a lack of water security will compromise national security and human wellbeing.

    - National Freshwater Ecosystem Priority Areas (NFEPA) – The NFEPA spatial data has been incorporated in the above mentioned SAIIAE spatial data set. However, to ensure that this data sets are considered we included it as the Freshwater Ecosystem Priority Areas (FEPAs) (Driver *et al*., 2011) are intended to be conservation support tools and are envisioned to guide the effective implementation of measures to achieve the National Environment Management Biodiversity Act (NEM:BA) biodiversity goals (Nel *et al.,* 2011).

4.1.2 Desktop Flora Assessment

The Vegetation of South Africa, Lesotho and Swaziland (Mucina & Rutherford, 2006) was used to identify the vegetation type that would have occurred under natural or pre-anthropogenically altered conditions. Furthermore, the Plants of Southern Africa (POSA) database was accessed to compile a list of expected flora species within the proposed development area and surrounding landscape. The Red List of South African Plants (Raimondo *et al.,* 2009; SANBI, 2020) was utilized to provide the most current national conservation status of flora species.

Relevant field guides and texts consulted for identification purposes in the field during the surveys included the following:

- Field Guide to the Wild Flowers of the Highveld (Van Wyk & Malan, 1997);
- A field guide to Wild flowers (Pooley, 1998);
- Guide to Grasses of Southern Africa (Van Oudtshoorn, 1999);
- Orchids of South Africa (Johnson & Bytebier, 2015);
- Guide to the Aloes of South Africa (Van Wyk & Smith, 2014);
- Mesembs of the World (Smith *et al*., 1998);

- Medicinal Plants of South Africa (Van Wyk *et al*., 2013);
- Freshwater Life: A field guide to the plants and animals of southern Africa (Griffiths & Day, 2016); and
- Identification guide to southern African grasses. An identification manual with keys, descriptions and distributions (Fish *et al*., 2015).

Additional information regarding ecosystems, vegetation types, and Species of Conservation Concern (SCC) included the following sources:

- The Vegetation of South Africa, Lesotho and Swaziland (Mucina & Rutherford, 2012); and
- Red List of South African Plants (Raimondo *et al*., 2009; SANBI, 2016).

The field work methodology included the following survey techniques:

- Timed meanders;
- Sensitivity analysis based on structural and species diversity; and
- Identification of floral red-data species.

4.1.3 Desktop Faunal Assessment

The faunal desktop assessment comprised the following:

- Compilation of expected species lists;
- Identification of any Red Data or SCC potentially occurring in the area; and
- Emphasis was placed on the probability of occurrence of species of provincial, national and international conservation importance.

Mammal distribution data was obtained from the following information sources:

- The Mammals of the Southern African Subregion (Skinner & Chimimba, 2005);
- Bats of Southern and Central Africa (Monadjem *et al*., 2010);
- The 2016 Red List of Mammals of South Africa, Lesotho and Swaziland (www.ewt.org.za) (EWT, 2016); and
- Animal Demography Unit (ADU) - MammalMap Category (MammalMap, 2019) (mammalmap.adu.org.za).

While the Avifauna distribution, and other pertinent data, was obtained from:

- Southern African Bird Atlas Project 2 (SABAP2, 2019);
- Birdlife South Africa (2015);
- Birdlife. (2017). Important Bird Areas Factsheets;
- Checklist of the Birds of the World (Del Hoyo *et al*., 1996);
- Book of birds of South Africa, Lesotho and Swaziland (Taylor *et al*., 2015); and
- Roberts – Birds of Southern Africa (Hockey *et al*., 2005).

A herpetofauna desktop assessment of the possible species in the area was undertaken and attention was paid to the SCCs, sources used included the IUCN (2017) and ADU (2019). Herpetofauna distributional data was obtained from the following information sources:

- South African Reptile Conservation Assessment (SARCA) (sarca.adu.org);

- A Guide to the Reptiles of Southern Africa (Alexander & Marais, 2007);
- Field guide to Snakes and other Reptiles of Southern Africa (Branch, 1998);
- Atlas and Red list of Reptiles of South Africa, Lesotho and Swaziland (Bates *et al*., 2014);
- A Complete Guide to the Frogs of Southern Africa (du Preez & Carruthers, 2009);
- Animal Demography Unit (ADU) - FrogMAP (frogmap.adu.org.za);
- Atlas and Red Data Book of Frogs of South Africa, Lesotho and Swaziland (Mintner *et al*., 2004); and
- Ensuring a future for South Africa's frogs (Measey, 2011).

4.2 Biodiversity Field Assessment

A single field survey was undertaken in March from the 14th till the 18th of March (Summer) 2022, which is a dry-season survey, to determine the presence of SCC. Effort was made to cover all the different habitat types within the limits of time and access, focus being placed on areas where proposed infrastructure was going to be placed, referred to as the study area.

4.2.1 Flora Survey

The fieldwork and sample sites were placed within targeted areas (i.e. target sites) perceived as ecologically sensitive based on the preliminary interpretation of satellite imagery (Google Corporation) and GIS analysis (which included the latest applicable biodiversity datasets) available prior to the fieldwork. The focus of the fieldwork was therefore to maximise coverage and navigate to each target site in the field to perform a vegetation and ecological assessment. Emphasis was placed on sensitive habitats, especially those overlapping with the proposed opencast areas.

Homogenous vegetation units were subjectively identified using satellite imagery and existing land cover maps. The floristic diversity and search for flora SCC were conducted through timed meanders within representative habitat units delineated during the scoping fieldwork. Emphasis was placed mostly on sensitive habitats overlapping with the proposed project areas.

The timed random meander method is a highly efficient method for conducting floristic analysis, specifically in detecting flora SCC and maximising floristic coverage. In addition, the method is time and cost effective and highly suited for compiling flora species lists and therefore gives a rapid indication of flora diversity. The timed meander search was performed based on the original technique described by Goff *et al.* (1982). Suitable habitat for SCC were identified according to Raimondo *et al.* (2009) and targeted as part of the timed meanders.

At each sample site notes were made regarding current impacts (e.g. livestock grazing, erosion etc.), subjective recording of dominant vegetation species and any sensitive features (e.g. wetlands, outcrops etc.). In addition, opportunistic observations were made while navigating through the project area.

4.2.2 Fauna Survey

The faunal assessment within this report pertains to herpetofauna (amphibians and reptiles) avifauna and mammals. The field survey component of the assessment utilised a variety of sampling techniques including, but not limited to, the following:

- Visual and auditory searches - This typically comprised of meandering and using binoculars to view species from a distance without them being disturbed as well as listening to species calls;
- Motion Camera trapping;
- Identification of tracks and signs; and

- Utilization of local knowledge.

Site selection for trapping focussed on the representative habitats within the project area. Sites were selected based on GIS mapping and Google Earth imagery and then the final selection was confirmed through ground-truthing during the surveys.

The herpetofauna field assessment was conducted in each habitat or vegetation type within the project area, as identified from the desktop assessment, with a focus on those areas which will be most impacted by the proposed development (i.e. the infrastructure development and waste dumping areas). The herpetological field survey comprised the following techniques:

- Hand searching is used for reptile species that shelter in or under particular habitats. Visual searches, typically undertaken for species which activities occur on surfaces or for species that are difficult to detect by hand-searches or trap sampling. Active hand-searches - are used for species that shelter in or under particular micro-habitats (typically rocks, exfoliating rock outcrops, fallen trees, leaf litter, bark etc.).

4.3 Terrestrial Site Ecological Importance

The different habitat types within the project area were delineated and identified based on observations during the field assessment, and available satellite imagery. These habitat types were assigned Ecological Importance (EI) categories based on their ecological integrity, conservation value, the presence of species of conservation concern and their ecosystem processes.

Site Ecological Importance (SEI) is a function of the Biodiversity Importance (BI) of the receptor (e.g., SCC, the vegetation/fauna community or habitat type present on the site) and Receptor Resilience (RR) (its resilience to impacts) as follows.

BI is a function of Conservation Importance (CI) and the Functional Integrity (FI) of the receptor as follows. The criteria for the CI and FI ratings are provided in Table 4-1 and Table 4-2, respectively.

Table 4-1 Summary of Conservation Importance (CI) criteria

Conservation Importance	Fulfilling Criteria
Very High	Confirmed or highly likely occurrence of Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Extremely Rare or CR species that have a global extent of occurrence (EOO) of < 10 km^2. Any area of natural habitat of a CR ecosystem type or large area (> 0.1% of the total ecosystem type extent) of natural habitat of an EN ecosystem type. Globally significant populations of congregatory species (> 10% of global population).
High	Confirmed or highly likely occurrence of CR, EN, VU species that have a global EOO of > 10 km^2. IUCN threatened species (CR, EN, VU) must be listed under any criterion other than A. If listed as threatened only under Criterion A, include if there are less than 10 locations or < 10 000 mature individuals remaining. Small area (> 0.01% but < 0.1% of the total ecosystem type extent) of natural habitat of EN ecosystem type or large area (> 0.1%) of natural habitat of VU ecosystem type. Presence of Rare species. Globally significant populations of congregatory species (> 1% but < 10% of global population).
Medium	Confirmed or highly likely occurrence of populations of Near Threatened (NT) species, threatened species (CR, EN, VU) listed under Criterion A only and which have more than 10 locations or more than 10 000 mature individuals. Any area of natural habitat of threatened ecosystem type with status of VU. Presence of range-restricted species. > 50% of receptor contains natural habitat with potential to support SCC.
Low	No confirmed or highly likely populations of SCC. No confirmed or highly likely populations of range-restricted species. < 50% of receptor contains natural habitat with limited potential to support SCC.
Very Low	No confirmed and highly unlikely populations of SCC. No confirmed and highly unlikely populations of range-restricted species. No natural habitat remaining.

Table 4-2 Summary of Functional Integrity (FI) criteria

Functional Integrity	Fulfilling Criteria
Very High	Very large (> 100 ha) intact area for any conservation status of ecosystem type or > 5 ha for CR ecosystem types. High habitat connectivity serving as functional ecological corridors, limited road network between intact habitat patches. No or minimal current negative ecological impacts, with no signs of major past disturbance.
High	Large (> 20 ha but < 100 ha) intact area for any conservation status of ecosystem type or > 10 ha for EN ecosystem types. Good habitat connectivity, with potentially functional ecological corridors and a regularly used road network between intact habitat patches. Only minor current negative ecological impacts, with no signs of major past disturbance and good rehabilitation potential.
Medium	Medium (> 5 ha but < 20 ha) semi-intact area for any conservation status of ecosystem type or > 20 ha for VU ecosystem types. Only narrow corridors of good habitat connectivity or larger areas of poor habitat connectivity and a busy used road network between intact habitat patches. Mostly minor current negative ecological impacts, with some major impacts and a few signs of minor past disturbance. Moderate rehabilitation potential.
Low	Small (> 1 ha but < 5 ha) area. Almost no habitat connectivity but migrations still possible across some modified or degraded natural habitat and a very busy used road network surrounds the area. Low rehabilitation potential. Several minor and major current negative ecological impacts.
Very Low	Very small (< 1 ha) area. No habitat connectivity except for flying species or flora with wind-dispersed seeds. Several major current negative ecological impacts.

BI can be derived from a simple matrix of CI and FI as provided in Table 4-3.

Table 4-3 Matrix used to derive Biodiversity Importance (BI) from Functional Integrity (FI) and Conservation Importance (CI)

Biodiversity Importance (BI)		Conservation Importance (CI)				
		Very high	High	Medium	Low	Very low
Functional Integrity (FI)	Very high	Very high	Very high	High	Medium	Low
	High	Very high	High	Medium	Medium	Low
	Medium	High	Medium	Medium	Low	Very low
	Low	Medium	Medium	Low	Low	Very low
	Very low	Medium	Low	Very low	Very low	Very low

The fulfilling criteria to evaluate RR are based on the estimated recovery time required to restore an appreciable portion of functionality to the receptor, as summarised in Table 4-4.

Table 4-4 Summary of Resource Resilience (RR) criteria

Resilience	Fulfilling Criteria
Very High	Habitat that can recover rapidly (~ less than 5 years) to restore > 75% of the original species composition and functionality of the receptor functionality, or species that have a very high likelihood of: (i) remaining at a site even when a disturbance or impact is occurring, or (ii) returning to a site once the disturbance or impact has been removed.
High	Habitat that can recover relatively quickly (~ 5–10 years) to restore > 75% of the original species composition and functionality of the receptor functionality, or species that have a high likelihood of: (i) remaining at a site even when a disturbance or impact is occurring, or (ii) returning to a site once the disturbance or impact has been removed.
Medium	Will recover slowly (~ more than 10 years) to restore > 75% of the original species composition and functionality of the receptor functionality, or species that have a moderate likelihood of: (i) remaining at a site even when a disturbance or impact is occurring, or (ii) returning to a site once the disturbance or impact has been removed.
Low	Habitat that is unlikely to be able to recover fully after a relatively long period: > 15 years required to restore ~ less than 50% of the original species composition and functionality of the receptor functionality, or species that have a low likelihood of: (i) remaining at a site even when a disturbance or impact is occurring, or (ii) returning to a site once the disturbance or impact has been removed.
Very Low	Habitat that is unable to recover from major impacts, or species that are unlikely to: (i) remain at a site even when a disturbance or impact is occurring, or (ii) return to a site once the disturbance or impact has been removed.

Subsequent to the determination of the BI and RR, the SEI can be ascertained using the matrix as provided in Table 4-5.

Table 4-5 Matrix used to derive Site Ecological Importance from Receptor Resilience (RR) and Biodiversity Importance (BI)

Site Ecological Importance		Biodiversity Importance (BI)				
		Very high	High	Medium	Low	Very low
Receptor Resilience (RR)	Very Low	Very high	Very high	High	Medium	Low
	Low	Very high	Very high	High	Medium	Very low
	Medium	Very high	High	Medium	Low	Very low
	High	High	Medium	Low	Very low	Very low
	Very High	Medium	Low	Very low	Very low	Very low

Interpretation of the SEI in the context of the project is provided in Table 4-6.

Table 4-6 Guidelines for interpreting Site Ecological Importance in the context of the development activities

Site Ecological Importance	Interpretation in relation to development activities
Very High	Avoidance mitigation – no destructive development activities should be considered. Offset mitigation not acceptable/not possible (i.e., last remaining populations of species, last remaining good condition patches of ecosystems/unique species assemblages). Destructive impacts for species/ecosystems where persistence target remains.
High	Avoidance mitigation wherever possible. Minimisation mitigation – changes to project infrastructure design to limit the amount of habitat impacted, limited development activities of low impact acceptable. Offset mitigation may be required for high impact activities.
Medium	Minimisation and restoration mitigation – development activities of medium impact acceptable followed by appropriate restoration activities.
Low	Minimisation and restoration mitigation – development activities of medium to high impact acceptable followed by appropriate restoration activities.
Very Low	Minimisation mitigation – development activities of medium to high impact acceptable and restoration activities may not be required.

The SEI evaluated for each taxon can be combined into a single multi-taxon evaluation of SEI for the assessment area. Either a combination of the maximum SEI for each receptor should be applied, or the SEI may be evaluated only once per receptor but for all necessary taxa simultaneously. For the latter, justification of the SEI for each receptor is based on the criteria that conforms to the highest CI and FI, and the lowest RR across all taxa.

5 Limitations

The following assumptions and limitations are applicable for this assessment:

- The assessment area was based on the area provided by the client and any alterations to the area and/or missing GIS information pertaining to the assessment area would have affected the area surveyed;
- Only a single season survey will be conducted for the respective studies, this would constitute a wet season survey with its limitations;
- Access to certain portions within the study area was not possible due to the fact that the land owner did not give the go-ahead;
- Whilst every effort is made to cover as much of the site as possible, representative sampling is completed and by its nature it is possible that some plant and animal species that are present on site were not recorded during the field investigations; and
- The GPS used in the assessment has an accuracy of 5 m and consequently any spatial features may be offset by 5 m.

6 Results and discussion

6.1 Desktop Baseline

6.1.1 Ecologically Important Landscape Features

The following features describe the general area and habitat, this assessment is based on spatial data that are provided by various sources such as the provincial environmental authority and SANBI. The desktop analysis and their relevance to this project are listed in Table 6-1.

Table 6-1 Desktop spatial features examined

Desktop Information Considered	Relevant/Irrelevant	Section
Critical Biodiversity Area	Relevant – Intersects CB1, CBA2, ESA1 and ESA2	6.1.2
Ecosystem Threat Status	Relevant – Located within an Endangered and Least Concerned ecosystem	6.1.3.1
Ecosystem Protection Level	Relevant – Located within a Not Protected and a Poorly Protected ecosystem	6.1.3.2
Protected Areas	Relevant – Within 5km of a protected area	6.1.4
National Protected Area Expansion Strategy	Relevant –Overlap any NPAES areas	6.1.4
Important Bird and Biodiversity Areas	Irrelevant – Does not overlap IBA, is 29,5 km from the Willem Pretorius Nature Reserve IBA	
South African Inventory of Inland Aquatic Ecosystems	Relevant – overlaps with three CR rivers and numerous unclassified wetlands.	6.1.6
National Freshwater Ecosystem Priority Areas	Relevant – overlaps with a true FEPA wetland and an unclassified river.	6.1.6.1
Strategic Water Source Areas	Irrelevant – Not located within a SWSA, closest SWSA is 122 km away	-

6.1.2 Biodiversity Spatial Plan (BSP)

Conservation of CBAs is crucial, in that if these areas are not maintained in a natural or near-natural state, biodiversity conservation targets cannot be met. Maintaining an area in a natural state can include a variety of biodiversity compatible land uses and resource uses (SANBI-BGIS, 2017). The proposed development overlaps with an area regarded as CBA1, CBA2, ESA1, ESA2, Other, and Degraded The project area falls across both a CBA2 and an ESA1 classified area (Figure 6-1). The Power line, water pipeline, roads and return water corridor falls across the ESA1 areas.

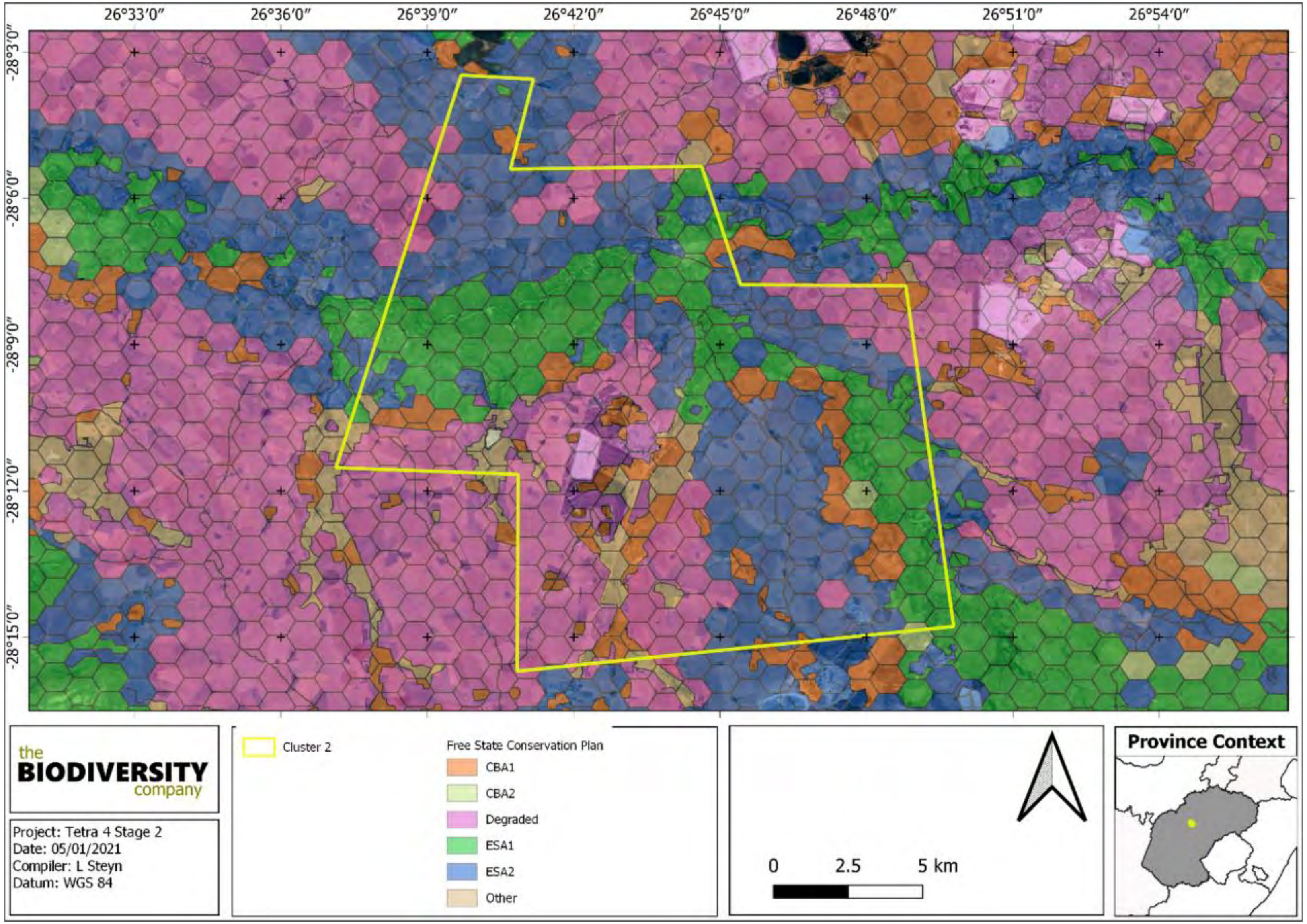


Figure 6-1 Project area superimposed on the Free State BSP.

6.1.3 The National Biodiversity Assessment

The National Biodiversity Assessment (NBA) was completed as a collaboration between the SANBI, the DEA and other stakeholders, including scientists and biodiversity management experts throughout the country over a three-year period (Skowno *et al*., 2019).

The purpose of the NBA is to assess the state of South Africa's biodiversity with a view to understanding trends over time and informing policy and decision-making across a range of sectors (Skowno *et al*., 2019).

The two headline indicators assessed in the NBA are *ecosystem threat status* and *ecosystem protection level* (Skowno *et al*., 2019).

6.1.3.1 Ecosystem Threat Status

Ecosystem threat status outlines the degree to which ecosystems are still intact or alternatively losing vital aspects of their structure, function and composition, on which their ability to provide ecosystem services ultimately depends (Skowno *et al*., 2019).

Ecosystem types are categorised as Critically Endangered (CR), Endangered (EN), Vulnerable (VU) or Least Threatened (LT), based on the proportion of each ecosystem type that remains in good ecological condition (Skowno *et al*., 2019).

The project area was superimposed on the terrestrial ecosystem threat status (Figure 6-2). According to the spatial dataset the proposed development overlaps with LC and EN ecosystems.

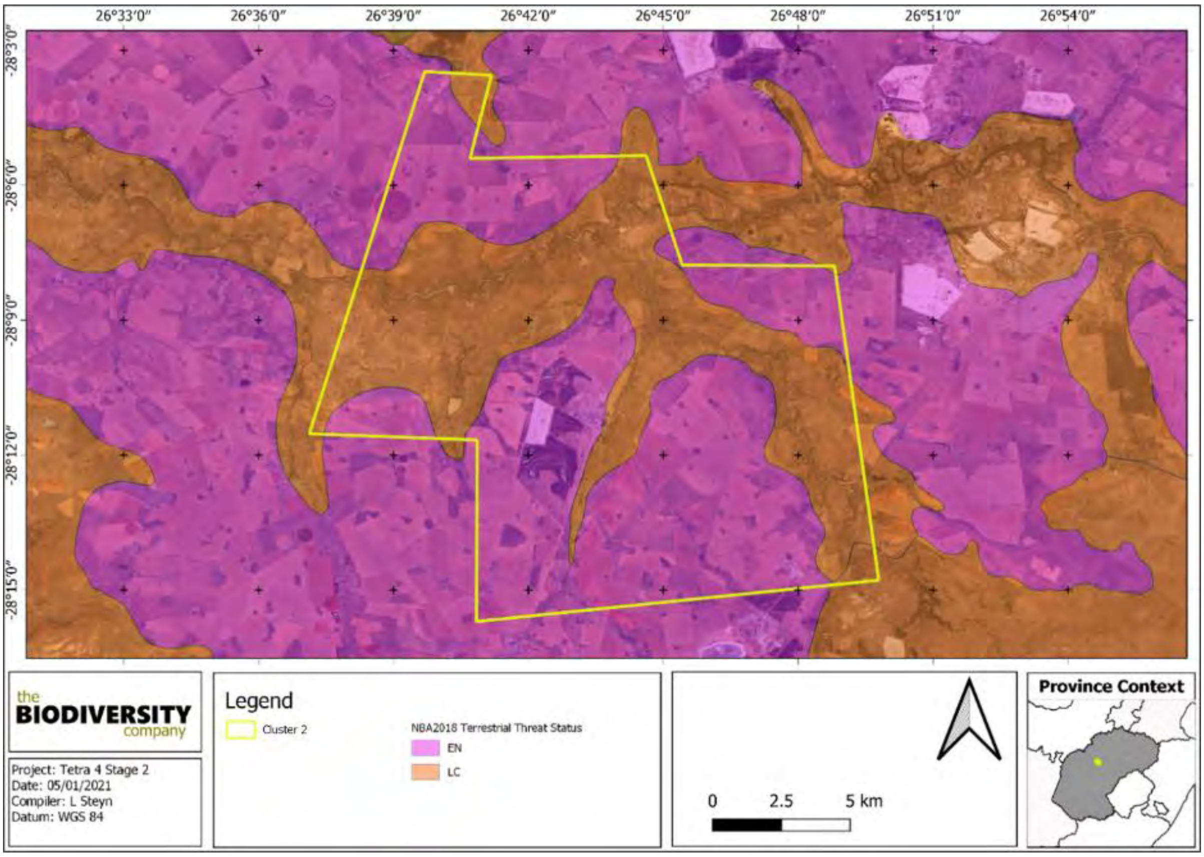


Figure 6-2 The project area showing the regional ecosystem threat status of the associated terrestrial ecosystems (NBA, 2018)

6.1.3.2 Ecosystem Protection Level

Ecosystem protection level tells us whether ecosystems are adequately protected or under-protected. Ecosystem types are categorised as not protected, poorly protected, moderately protected or well protected, based on the proportion of each ecosystem type that occurs within a protected area recognised in the Protected Areas Act (Skowno *et al*., 2019).

The project area was superimposed on the ecosystem protection level map to assess the protection status of terrestrial ecosystems associated with the development (Figure 6-3). The proposed development overlaps with NP and PP ecosystems

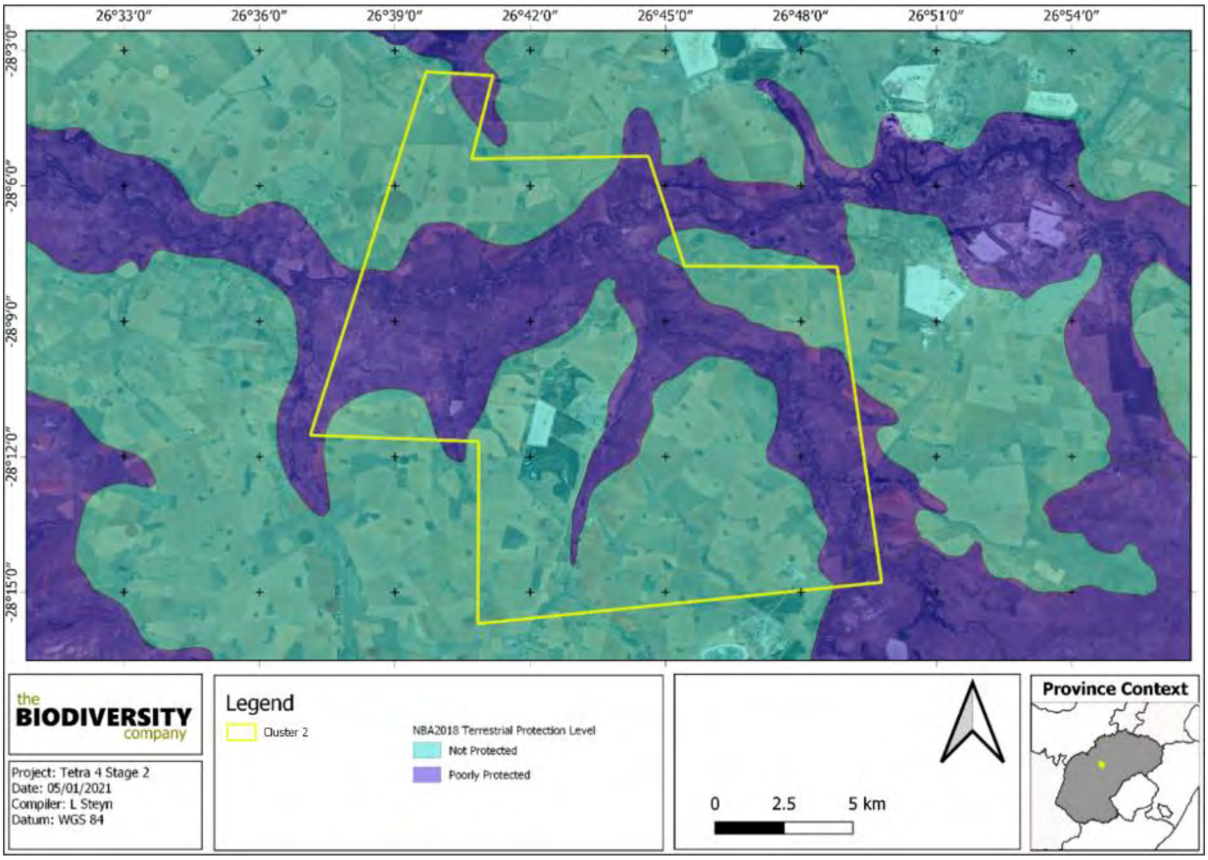


Figure 6-3 The project area showing the regional level of protection of terrestrial ecosystems (NBA, 2018)

6.1.4 Protected Areas

According to the protected area spatial datasets, the proposed development does not occur within any protected area but does overlap with an NPAES area and is within the 5 km buffer of protected areas. The H.J Joel Private Nature Reserve is found 876 m from the project area (Figure 6-4). The south-eastern corner of the project area overlaps with a NPAES priority focus area (Figure 6-5).

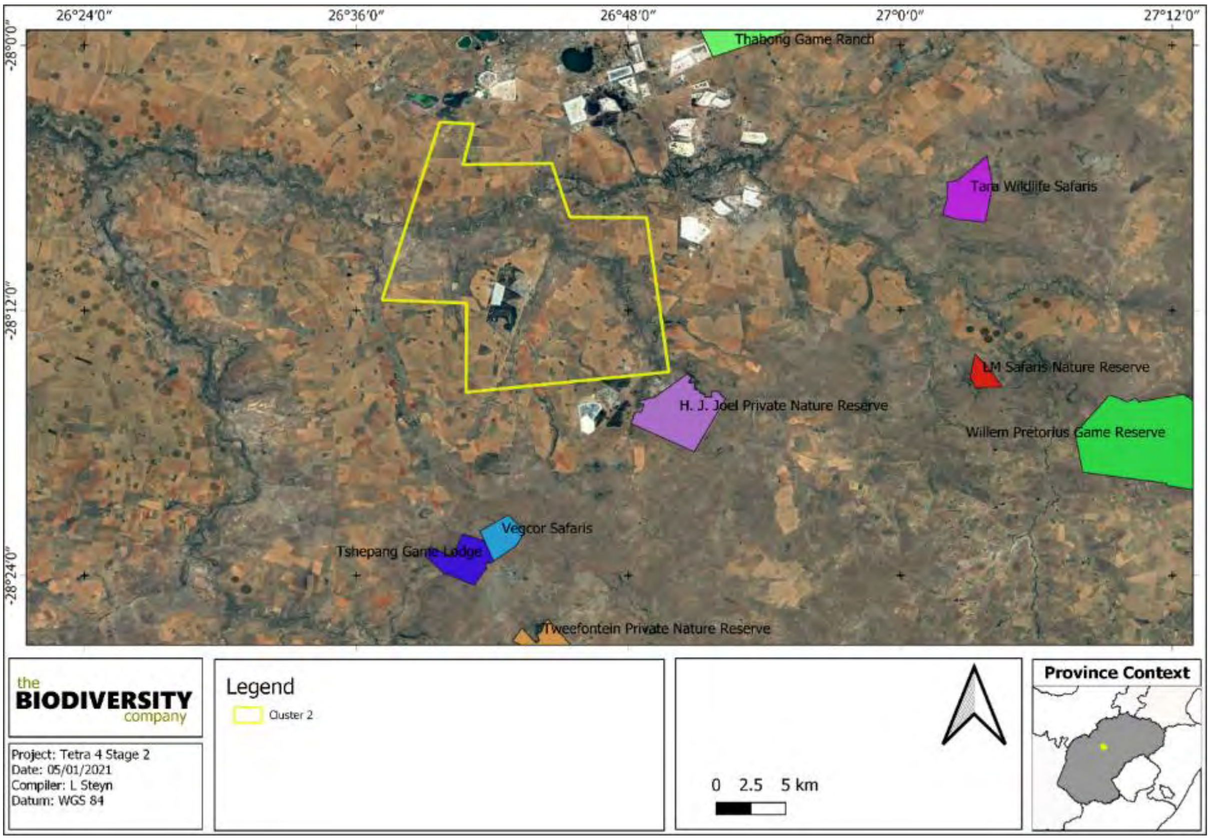


Figure 6-4 Map illustrating the location of protected areas proximal to the assessment area

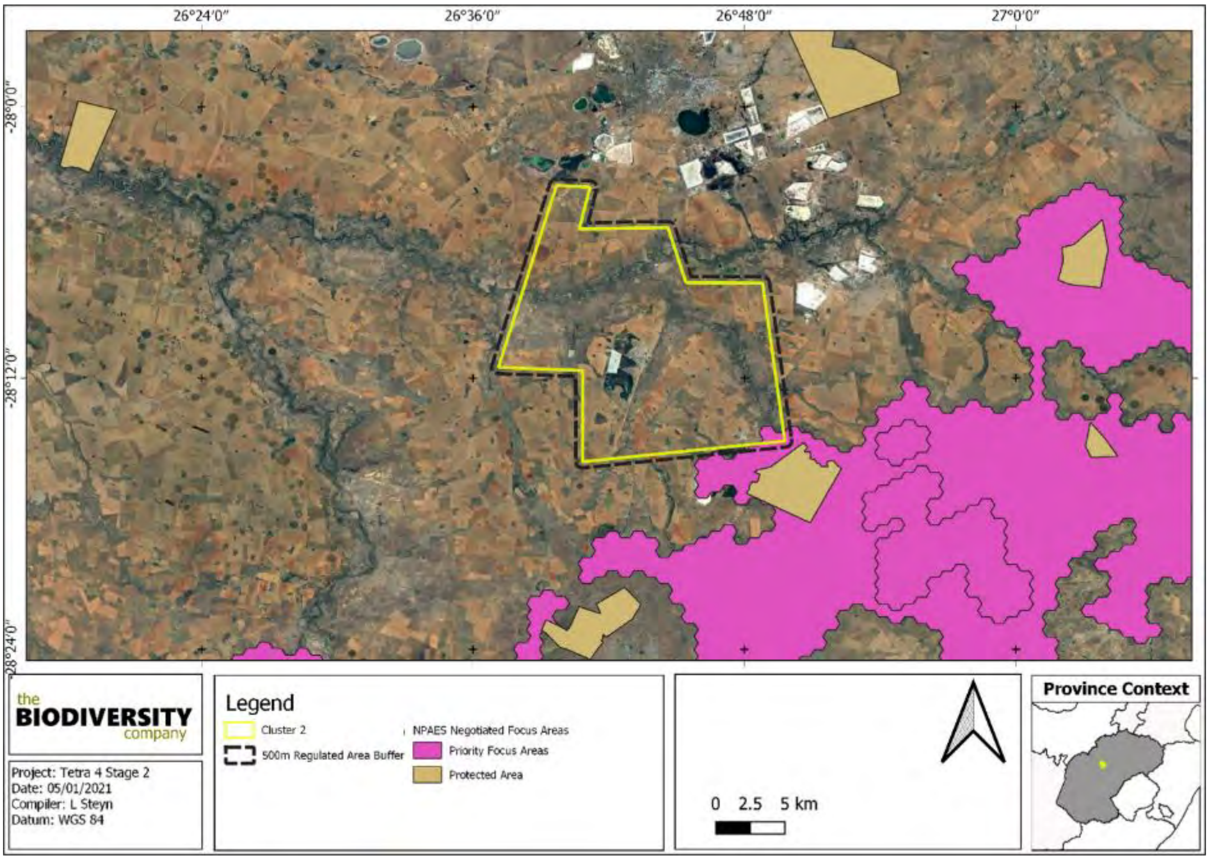


Figure 6-5 Map illustrating the location of NPAES proximal to the assessment area

6.1.5 Important Bird and Biodiversity Areas (IBAs)

The proposed development does not overlap any IBA (Figure 6-6). The closest IBA, the Willem Pretorius Nature Reserve, is located approximately 29.5 km to the east.

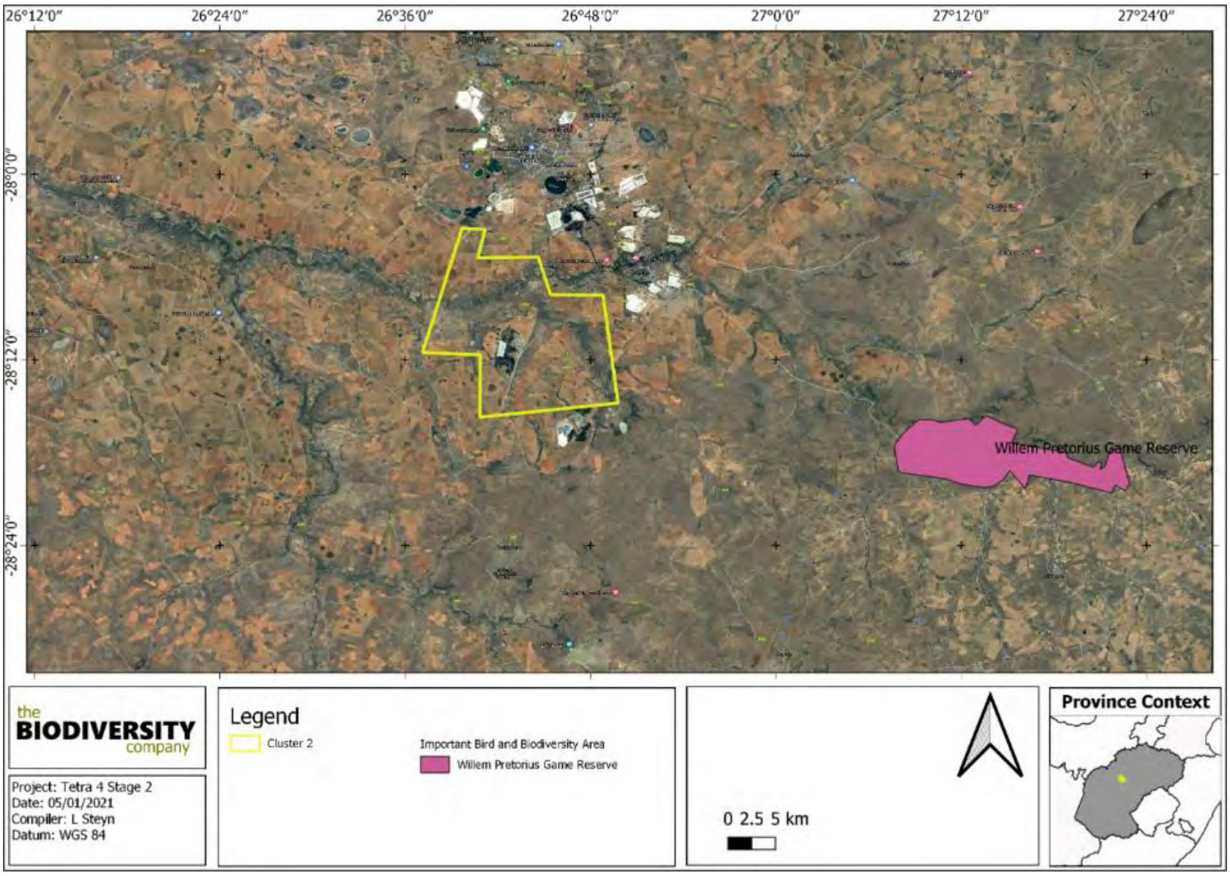


Figure 6-6 Map illustrating the location of Important Bird and Biodiversity Areas (IBAs) in relation to the assessment area

6.1.6 Hydrological Setting

Three major river systems assessed as part of the South African Inventory of Inland Aquatic Ecosystems (SAIIAE) overlap with the proposed development area (Sand River, Doring River and Bosluisspruit) (Figure 6-7).

The threat status, protection level and condition of South African rivers and wetlands were released with the National Biodiversity Assessment (NBA) 2018. Ecosystem Threat Status (ETS) are based on the extent to which each type had been altered from its natural condition. Ecosystem types are categorised as CR, EN, VU or LC. Critically Endangered, EN and VU ecosystem types are collectively referred to as 'threatened' (Van Deventer *et al*, 2019; Van Niekerk *et al*, 2019; Skowno *et al,* 2019). The rivers were all classed as CR, while the wetlands were not evaluated as part of NBA 2018.

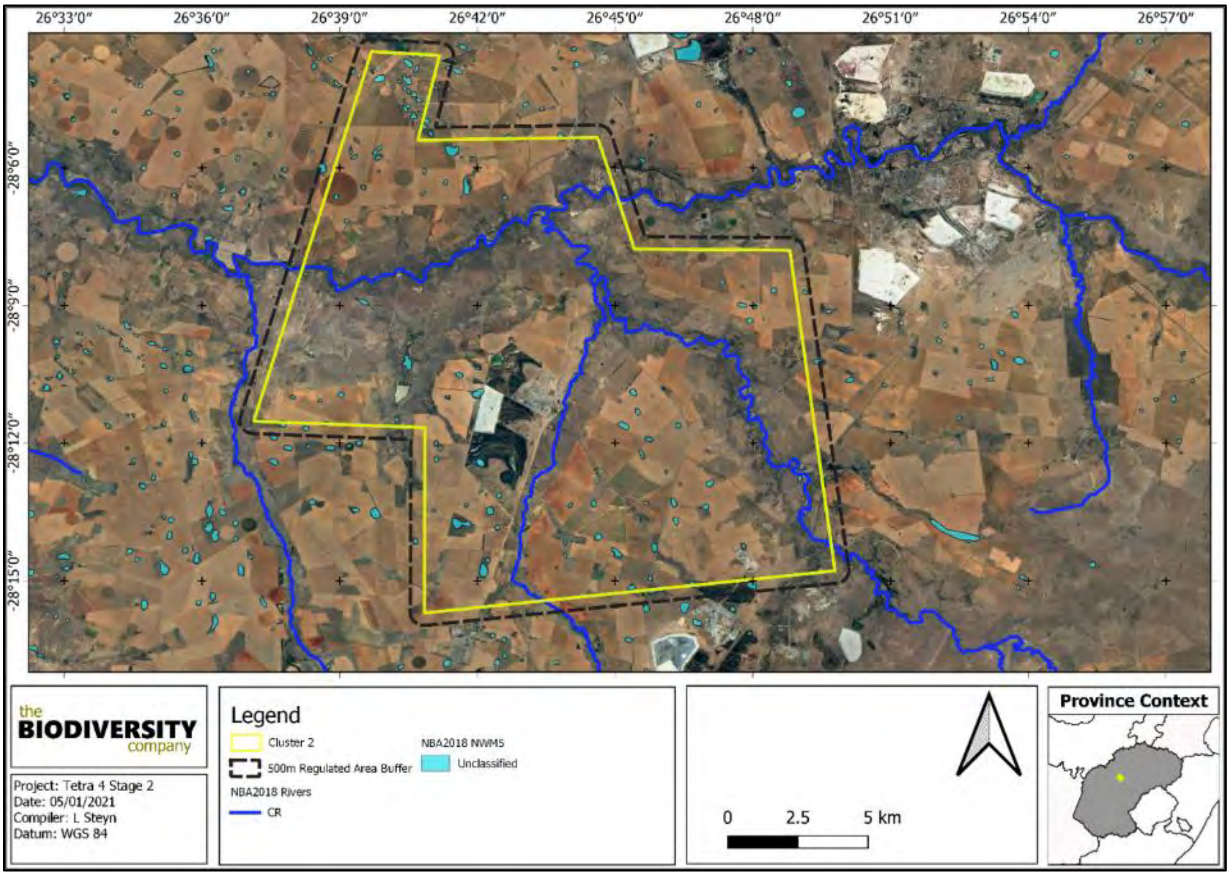


Figure 6-7 Map illustrating the hydrological context of the assessment area based on the NBA spatial dataset (2018)

6.1.6.1 National Freshwater Ecosystem Priority Areas

Freshwater Ecosystem Priority Areas (FEPAs) (Driver *et al*., 2011) are intended to be conservation support tools and are envisioned to guide the effective implementation of measures to achieve the National Environment Management Biodiversity Act (NEM:BA) biodiversity goals (Nel *et al.*, 2011). Figure 6-8 shows the assessment area overlaps with a true FEPA wetland and an unclassified river.

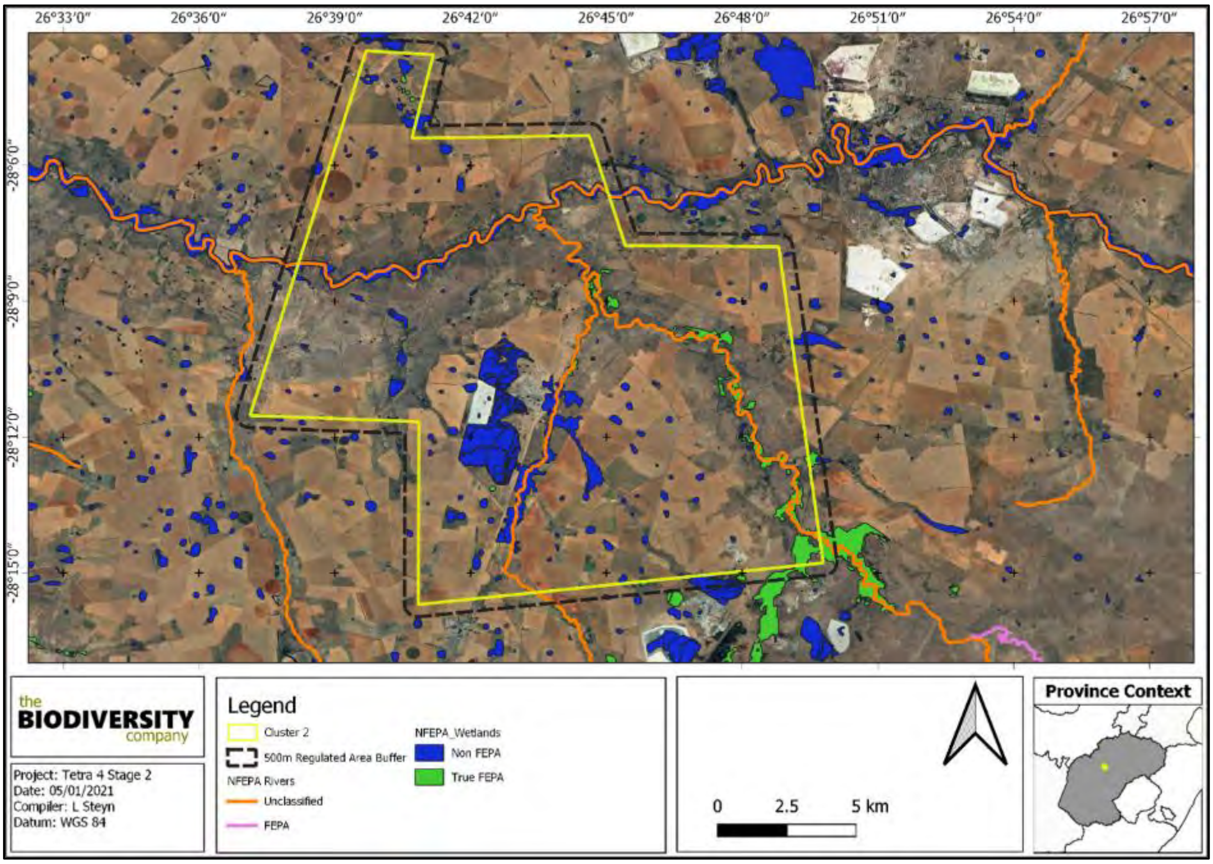


Figure 6-8 Map illustrating the hydrological context of the assessment area based on the NFEPA spatial dataset (2011)

6.1.7 Desktop Vegetation Baseline

This section is divided into a description of the vegetation type expected under natural conditions and the expected flora species.

6.1.7.1 Vegetation Types

The project area is situated within the Grassland biome. This biome is centrally located in southern Africa, and adjoins all except the desert, fynbos and succulent Karoo biomes (Mucina & Rutherford, 2006). Major macroclimatic traits that characterise the grassland biome include:

a) Seasonal precipitation; and

b) The minimum temperatures in winter (Mucina & Rutherford, 2006).

The grassland biome is found chiefly on the high central plateau of South Africa, and the inland areas of KwaZulu-Natal and the Eastern Cape. The topography is mainly flat and rolling but includes the escarpment itself. Altitude varies from near sea level to 2 850 m above sea level.

Grasslands are dominated by a single layer of grasses. The amount of cover depends on rainfall and the degree of grazing. The grassland biome experiences summer rainfall and dry winters with frost (and fire), which are unfavourable for tree growth. Thus, trees are typically absent, except in a few localized habitats. Geophytes (bulbs) are often abundant. Frosts, fire and grazing maintain the grass dominance and prevent the establishment of trees.

On a fine-scale vegetation type, the project area overlaps with Highveld Alluvial Vegetation and Vaal Vet Sandy Grassland, with 2 smaller portions overlapping with Western Free State Clay Grassland and Central Free State Grassland respectively (Figure 6-9). The two major vegetation types are discussed.

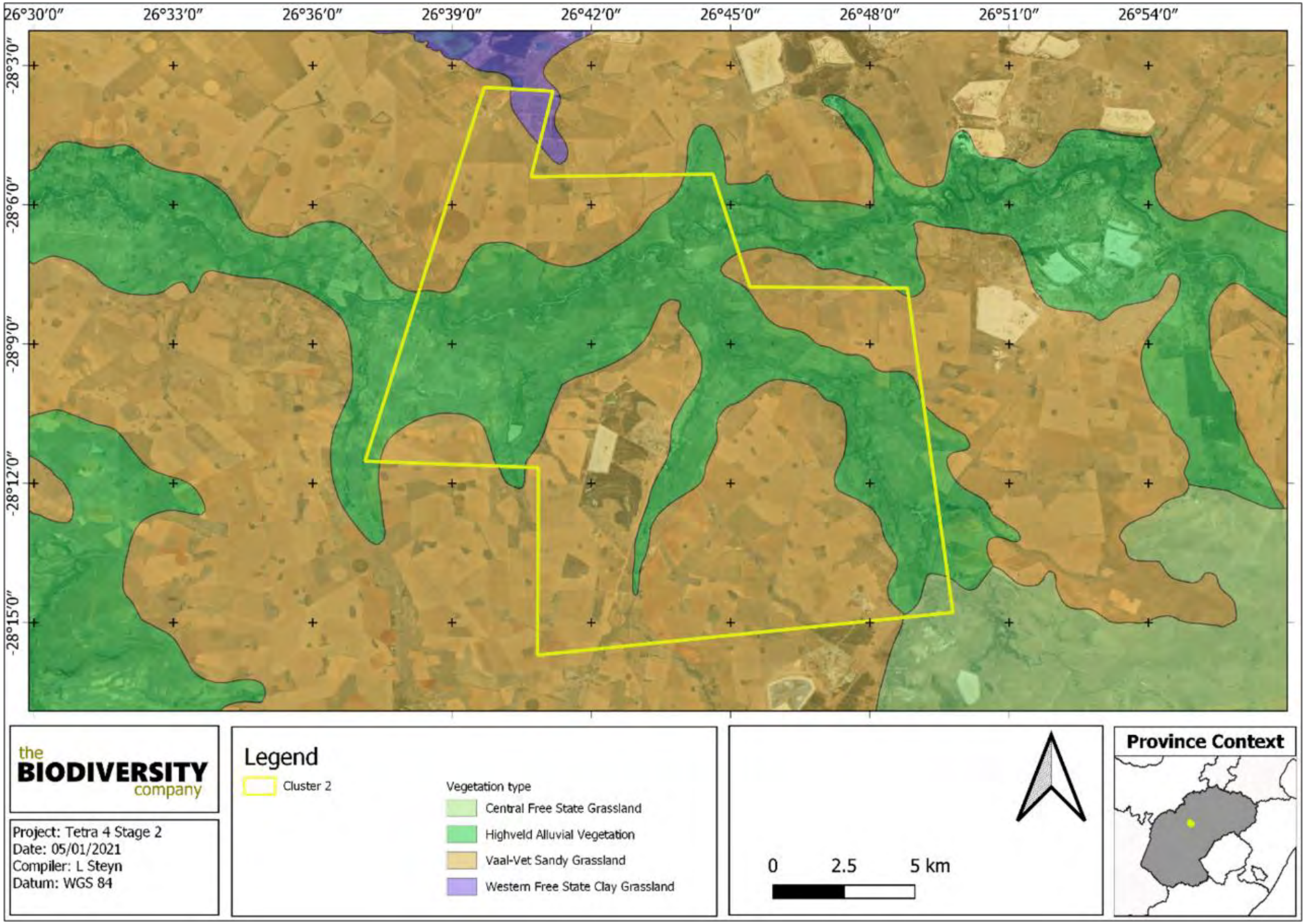


Figure 6-9 *The project area showing the vegetation type based on the Vegetation Map of South Africa, Lesotho & Swaziland (BGIS, 2018)*

6.1.7.1.1 Highveld Alluvial Vegetation

The highveld alluvial vegetation type is characterised by flat topography supporting riparian thickets dominated by *Acacia karroo.* This vegetation type can be found in the Free State, North West, Mpumalanga and Gauteng Province. It is embedded in the Grassland and Savanna biomes.

Important Taxa:

The important taxa are divided into the main growth areas namely: Riparian thicket, Reed Beds, Flooded grasslands & herblands and Open water.

Riparian thickets

Small Trees: *Acacia karroo*, *Salix mucronata* subsp. *mucronata*, *S. mucronata* subsp. *woodii* (d, within subescarpment grasslands of KwaZulu-Natal), *Ziziphus mucronata*, *Celtis africana*, *Rhus lancea*.

Tall Shrubs: *Gymnosporia buxifolia*, *Rhus pyroides*, *Diospyros lycioides*, *Ehretia rigida*, *Grewia flava*.

Low Shrubs: *Asparagus laricinus*, *A. suaveolens*.

Woody Climber: *Clematis brachiata*.

Succulent Shrub: *Lycium hirsutum*

Graminoids: *Setaria verticillata*, *Panicum maximum*.

Herb: *Pollichia campestris*.

Reed beds

Megagraminoid: *Phragmites australis*

Flooded grasslands & herblands

Low Shrubs: *Gomphocarpus fruticosus*, *Felicia muricata*.

Succulent Shrub: *Salsola rabieana*.

Graminoids: *Agrostis lachnantha*, *Andropogon eucomus*, *Chloris virgata*, *Cynodon dactylon*, *Eragrostis plana*, *Hemarthria altissima*, *Imperata cylindrica*, *Ischaemum fasciculatum*, *Miscanthus junceus*, *Paspalum distichum*, *Andropogon appendiculatus*, *Brachiaria marlothii, Cyperus denudatus*, *C. longus*, *Echinochloa holubii*, *Eragrostis obtusa*, *E. porosa*, *Fimbristylis ferruginea, Panicum coloratum*, *Pycreus mundii*, *Sporobolus africanus*, *S. fimbriatus*, *Themeda triandra*, *Urochloa panicoides*.

Herbs: *Persicaria lapathifolia*, *Alternanthera sessilis*, *Barleria macrostegia*, *Corchorus asplenifolius*, *Equisetum ramosissimum*, *Galium capense*, *Hibiscus pusillus*, *Lobelia angolensis, Nidorella resedifolia*, *Persicaria amphibia, P. hystricula*, *Pseudognaphalium oligandrum*, *Pulicaria scabra, Rorippa fluviatilis* var. *fluviatilis*, *Senecio inornatus*, *Stachys hyssopoides*, *Vahlia capensis*.

Geophytic Herbs: *Crinum bulbispermum*, *Haplocarpha lyrata*.

Open water

Aquatic Herb: *Myriophyllum spicatum*.

Conservation Status

According to Mucina & Rutherford (2006), this vegetation type is classified as LT. The national target for conservation protection for both these vegetation types is 31%, with nearly 10% statutorily conserved in the Barberspan (a Ramsar site), Bloemhof Dam, Christiana, Faan Meintjes, Sandveld, Schoonspruit, Soetdoring and Wolwespruit Nature Reserves.

6.1.7.1.2 Vaal Vet Sandy Grassland

This vegetation type is a plains-dominated landscape with some scattered, slightly undulating plains and hills. Mainly low-tussock grasslands with an abundant karroid element occurs here. Dominance of *Themeda triandra* is an important feature of this vegetation unit. Locally low cover of *T. triandra* and the associated increase in *Elionurus muticus*, *Cymbopogon pospischilii* and *Aristida congesta* is attributed to heavy grazing and/or erratic rainfall (Mucina & Rutherford, 2006).

Important Taxa

Important plant taxa are those species that have a high abundance, a frequent occurrence or are prominent in the landscape within a particular vegetation type (Mucina & Rutherford, 2006).

The following species are important in the Vaal Vet Sandy Grassland vegetation type:

Graminoids: *Anthephora pubescens* (d), *Aristida congesta* (d), *Chloris virgata* (d), *Cymbopogon caesius* (d), *Cynodon dactylon* (d), *Digitaria argyrograpta* (d), *Elionurus muticus* (d), *Eragrostis chloromelas* (d), *E. lehmanniana* (d), *E. plana* (d), *E. trichophora* (d), *Heteropogon contortus* (d), *Panicum gilvum* (d), *Setaria sphacelata* (d), *Themeda triandra* (d), *Tragus berteronianus* (d), *Brachiaria serrata*, *Cymbopogon pospischilii*, *Digitaria eriantha*, *Eragrostis curvula*, *E. obtusa*, *E. superba*, *Panicum coloratum*, *Pogonarthria squarrosa*, *Trichoneura grandiglumis*, *Triraphis andropogonoides*.

Herbs: *Stachys spathulata* (d), *Barleria macrostegia*, *Berkheya onopordifolia* var. *onopordifolia*, *Chamaesyce inaequilatera*, *Geigeria aspera* var. *aspera*, *Helichrysum caespititium*, *Hermannia depressa*, *Hibiscus pusillus*, *Monsonia burkeana*, *Rhynchosia adenodes*, *Selago densiflora*, *Vernonia oligocephala*.

Geophytic Herbs: *Bulbine narcissifolia*, *Ledebouria marginata*. Succulent Herb: *Tripteris aghillana* var. *integrifolia*.

Low Shrubs: *Felicia muricata* (d), *Pentzia globosa* (d), *Anthospermum rigidum* subsp. *pumilum*, *Helichrysum dregeanum*, *H. paronychioides*, *Ziziphus zeyheriana*.

Endemic Taxon

Herb: *Lessertia phillipsiana*.

Conservation status

This vegetation type is classified as Endangered according to Mucina and Rutherford (2006). The conservation target for this vegetation type is 24% with only 0.3% statutorily conserved in the Bloemhof Dam, Schoonspruit, Sandveld, Faan Meintjies, Wolwespruit and Soetdoring Nature Reserves. More than 63%has been transformed for cultivation (ploughed for commercial crops) and the rest under strong grazing pressure from cattle and sheep.

6.1.7.2 Plant Species of Conservation Concern

Based on the Plants of Southern Africa (BODATSA-POSA, 2022) database, 463 plant species have the potential to occur in the project area and its surroundings (Figure 6-10) and can be seen in (Appendix B). Of these 463 plant species, no species are listed as being Species of Conservation Concern (SCC).

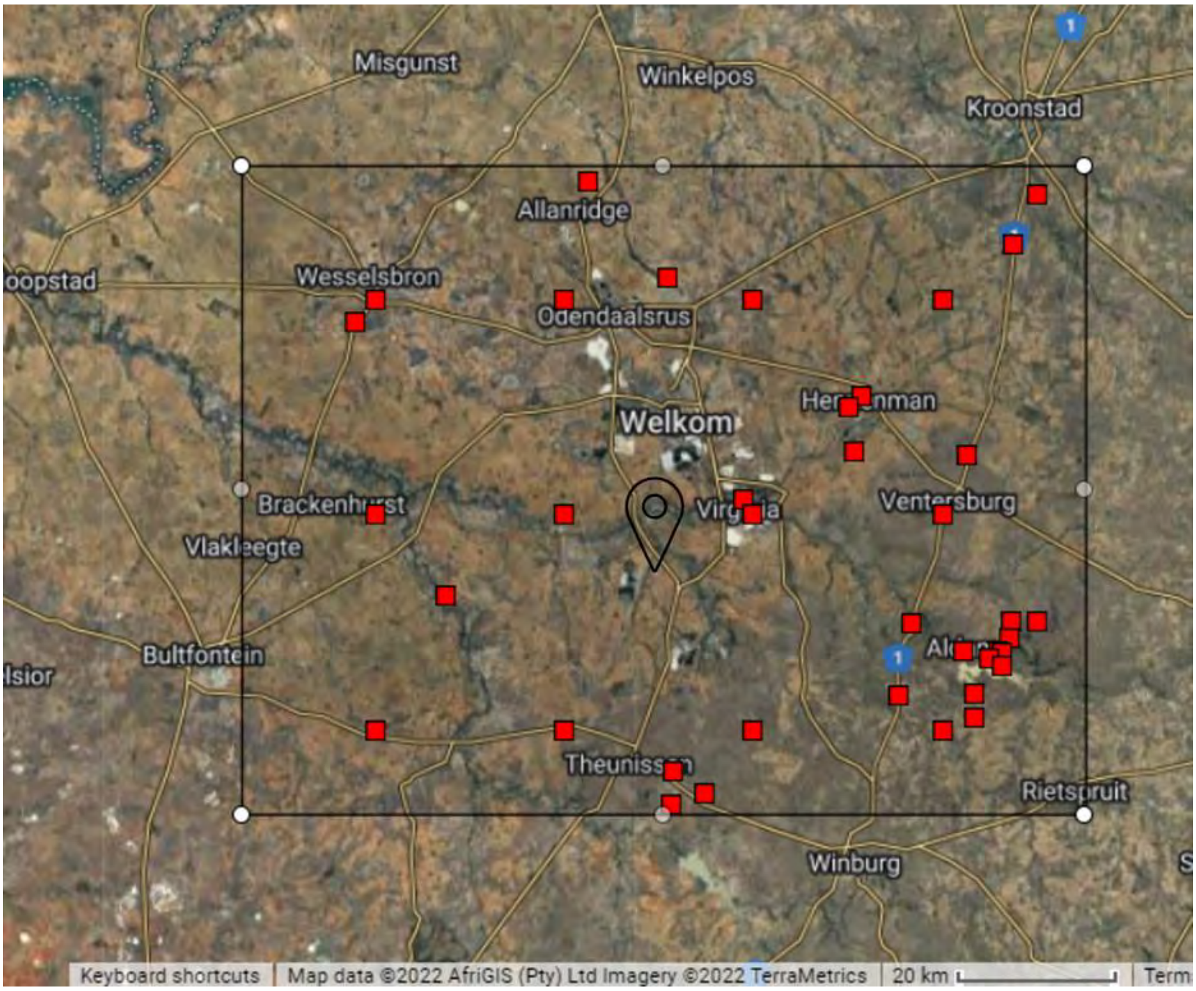


Figure 6-10 Map showing the grid drawn in order to compile an expected plant species list (BODATSA-POSA, 2022.) The red squares are cluster markers of botanical records as per POSA data. The icon indicates the centre of the project area.

6.1.8 Desktop Faunal Baseline

6.1.8.1.1 Avifauna

Based on the South African Bird Atlas Project, Version 2 (SABAP2) database, 236 bird species have the potential to occur in the vicinity of the project area. The full list of potential bird species is provided in Appendix C. The SCC expected can be seen in Table 6-2; and nine of these have a moderate-high likelihood of occurrence based on the suitable habitat and food sources present in the project area. Two species were confirmed during the field assessment.

Table 6-2 List of bird species of regional or global conservation importance that are expected to occur in close vicinity to the project area

Species	Common Name	Conservation Status		Likelihood of occurrence
		Regional (SANBI, 2016)	IUCN (2021)	
Calidris ferruginea	Sandpiper, Curlew	LC	NT	High
Charadrius pallidus	Plover, Chestnut-banded	NT	NT	Moderate
Ciconia abdimii	Stork, Abdim's	NT	LC	Low
Ciconia nigra	Stork, Black	VU	LC	Low

Eupodotis caerulescens	Korhaan, Blue	LC	NT	High
Falco biarmicus	Falcon, Lanner	VU	LC	Moderate
Gyps africanus	Vulture, White-backed	CR	CR	Moderate
Mycteria ibis	Stork, Yellow-billed	EN	LC	Moderate
Oxyura maccoa	Duck, Maccoa	NT	VU	Confirmed
Phoeniconaias minor	Flamingo, Lesser	NT	NT	High
Phoenicopterus roseus	Flamingo, Greater	NT	LC	Confirmed
Rostratula benghalensis	Painted-snipe, Greater	NT	LC	High
Sagittarius serpentarius	Secretarybird	EN	EN	Confirmed

Calidris ferruginea (Curlew Sandpiper) is migratory species which breeds on slightly elevated areas in the lowlands of the high Arctic and may be seen in parts of South Africa during winter. During winter, the species occurs at the coast, but also inland on the muddy edges of marshes, large rivers and lakes (both saline and freshwater), irrigated land, flooded areas, dams and saltpans (IUCN, 2017). Due to the presence of these habitat types within the project area the likelihood of occurrence of this species was rated as high.

Eupodotis caerulescens (Blue Korhaan) is listed as NT according to the IUCN (2017). Their moderately rapid decline is accredited to habitat loss that is a result of intensive agriculture. They are found in high grassveld in close proximity to water, usually above an altitude of 1 500m (del Hoyo *et al.,* 1996). The specie nests in bare open ground, situated in thick grass or cropland. Based on the required habitat the likelihood of occurrence of this species is rated as high.

Falco biarmicus (Lanner Falcon) is native to South Africa and inhabits a wide variety of habitats, from lowland deserts to forested mountains (IUCN, 2017). They may occur in groups up to 20 individuals but have also been observed solitary. Their diet is mainly composed of small birds such as pigeons and francolins. The likelihood of incidental records of this species in the project area is rated as high due to the presence of many bird species on which Lanner Falcons may predate.

Falco chicquera (Red-necked Falcon) is classed as NT on a global scale. This species was recently split from its Indian counterpart *Falco chicquera chicquera*. The African species is mostly found in semi-dessert and savanna areas with some trees for perching. The number of this species is declining due to ongoing habitat degradation. The likelihood of occurrence in the project area is rated as high due to the availability of suitable habitat.

Gyps africanus (White-backed Vulture) has a large range and only occurs throughout sub-Saharan Africa. Primarily a lowland species of open wooded savanna, particularly areas of *Acacia* (*Vachellia*). It requires tall trees for nesting. According to the IUCN (2017) this species faces similar threats to other African vultures, being susceptible to habitat conversion to agro-pastoral systems, loss of wild ungulates leading to a reduced availability of carrion, hunting for trade, persecution, and poisoning. The likelihood of suitably large trees for nesting for this species is low at the project site, but due to the relatively degraded nature of certain areas in the project area and the abundance of game farms, the likelihood of occurrence for the species is moderate.

Mycteria ibis (Yellow-billed Stork) is listed as EN on a regional scale and LC on a global scale. This species is migratory and has a large distributional range which includes much of sub-Saharan Africa. It is typically associated with freshwater ecosystems, especially wetlands and the margins of lakes and dams (IUCN, 2017). The presence of water bodies within the project area creates a high possibility that this species may occur there.

Oxyura maccoa (Maccoa Duck) has a large northern and southern range, South Africa is part of its southern distribution. During the species' breeding season, it inhabits small temporary and permanent inland freshwater lakes, preferring those that are shallow and nutrient-rich with extensive emergent vegetation such as reeds (*Phragmites* spp.) and cattails (*Typha* spp.) on which it relies for nesting (IUCN, 2017). The species was confirmed present[1] in the area during the March 2022 field assessment.

Phoeniconaias minor (Lesser Flamingo) is listed as NT on a global and regional scale whereas *Phoenicopterus roseus* (Greater Flamingo) is listed as NT on a regional scale only. Both species have similar habitat requirements, and the species breed on large undisturbed alkaline and saline lakes, salt pans or coastal lagoons, usually far out from the shore after seasonal rains have provided the flooding necessary to isolate remote breeding sites from terrestrial predators and the soft, muddy material for nest building (IUCN, 2017). *Phoenicopterus roseus* was confirmed during the March 2022 field assessment.

Rostratula benghalensis (Greater Painted-snipe) shows a preference for recently flooded areas in shallow lowland freshwater temporary or permanent wetland, it has a wide range of these freshwater habitats which they occur in, in this case, sewage pools, reservoirs, mudflats overgrown with marsh grass which may possibly exist within the project area, thus the likelihood of occurrence is high.

Sagittarius serpentarius (Secretarybird) occurs in sub-Saharan Africa and inhabits grasslands, open plains, and lightly wooded savanna. It is also found in agricultural areas and sub-desert (IUCN, 2017). The species was confirmed present[2] in the area during the March 2022 field assessment.

6.1.8.1.2 Mammals

The IUCN Red List Spatial Data and the MammalMap database lists 89 mammal species that could be expected to occur within the area (Appendix D). This list excludes large mammal species that are normally limited to protected areas, however still included in the appendices. Ten (10) of these expected species are regarded as SCC.

Table 6-3 List of mammal species of conservation concern that may occur in the project area as well as their global and regional conservation statuses

Species	Common Name	Conservation Status		Likelihood of occurrence
		Regional (SANBI, 2016)	IUCN (2021)	
Aonyx capensis	Cape Clawless Otter	NT	NT	Confirmed
Atelerix frontalis	South Africa Hedgehog	NT	LC	Moderate
Eidolon helvum	African Straw-colored Fruit Bat	LC	NT	Low
Felis nigripes	Black-footed Cat	VU	VU	Moderate
Hydrictis maculicollis	Spotted-necked Otter	VU	NT	Moderate
Leptailurus serval	Serval	NT	LC	High
Mystromys albicaudatus	White-tailed Rat	VU	EN	Low
Panthera pardus	Leopard	VU	VU	Low
Parahyaena brunnea	Brown Hyaena	NT	NT	Confirmed
Poecilogale albinucha	African Striped Weasel	NT	LC	Moderate

Aonyx capensis (Cape Clawless Otter) is the most widely distributed otter species in Africa (IUCN, 2017). This species is predominantly aquatic, and it is seldom found far from water. The species was confirmed present[3] in the area during the March 2022 field assessment.

[1] Confirmed photo by Mike Adam,Martinus Erasmus

[2] Confirmed observation by Martinus Erasmus

[3] Confirmed track by Martinus Erasmus

Atelerix frontalis (South African Hedgehog) has a tolerance of a degree of habitat modification and occurs in a wide variety of semi-arid and sub-temperate habitats (IUCN, 2017). Based on the Red List of Mammals of South Africa, Lesotho and Swaziland (2016), *A. frontalis* populations are decreasing due to the threats of electrocution, veld fires, road collisions, predation from domestic pets and illegal harvesting. Although the species is cryptic and therefore not often seen, there is suitable habitat in the project area and therefore the likelihood of occurrence is rated as moderate.

Felis nigripes (Black-footed cat) is endemic to the arid regions of southern Africa. This species is naturally rare, has cryptic colouring is small in size and is nocturnal. These factors have contributed to a lack of information on this species. Given that the highest densities of this species have been recorded in the more arid Karoo region of South Africa, the habitat in the project area can be considered to be suitable for the species and the likelihood of occurrence is rated as moderate.

Panthera pardus (Leopard) has a wide distributional range across Africa and Asia, but populations have become reduced and isolated, and they are now extirpated from large portions of their historic range (IUCN, 2017). Impacts that have contributed to the decline in populations of this species include continued persecution by farmers, habitat fragmentation, increased illegal wildlife trade, excessive harvesting for ceremonial use of skins, prey base declines and poorly managed trophy hunting (IUCN, 2017). Although known to occur and persist outside of formally protected areas, the densities in these areas are considered to be low. The likelihood of occurrence in the project area which is in such close proximity to an urban area, and where they are likely to be persecuted, is regarded as low.

Parahyaena brunnea (Brown Hyaena) is endemic to southern Africa. This species occurs in dry areas, generally with annual rainfall less than 100 mm, particularly along the coast, semi-desert, open scrub and open woodland savanna. Given its known ability to persist outside of formally protected areas the likelihood of occurrence of this species in the project area is moderate to good. Prey species are most likely absent for the project area and as such the likelihood of occurrence is rated as low. The species was confirmed present[4] in the area during the March 2022 field assessment.

Poecilogale albinucha (African Striped Weasel) is usually associated with savanna habitats, although it probably has a wider habitat tolerance (IUCN, 2017). Due to its secretive nature, it is often overlooked in many areas where it does occur. There is sufficient habitat for this species in the project area and the likelihood of occurrence of this species is therefore considered to be moderate.

6.1.8.1.3 Herpetofauna (Reptiles & Amphibians)

Based on the IUCN Red List Spatial Data and the ReptileMAP database, 48reptile species are expected to occur within the area (Appendix E). Three (3) are regarded as SCC (Table 6-4).

Table 6-4 Threatened reptile species that are expected to occur within the project area

Species	Common Name	Conservation Status		Likelihood of Occurrence
		Regional (SANBI, 2016)	IUCN (2021)	
Homoroselaps dorsalis	Striped Harlequin Snake	NT	LC	Moderate
Psammophis leightoni	Cape Sand Snake	VU	LC	Unlikely
Smaug giganteus	Giant Dragon Lizard	VU	VU	Confirmed

Homoroselaps dorsalis (Striped Harlequin Snake) is partially fossorial and known to inhabit old termitaria in grassland habitat (IUCN, 2017). Most of its range is at moderately high altitudes, reaching 1,800 m in Mpumalanga and Swaziland, but it is also found at elevations as low as about 100 m in KwaZulu-Natal. The likelihood of occurrence was rated as moderate.

[4] Confirmed track by Martinus Erasmus

Smaug giganteus (Giant Dragon Lizard) is categorised as VU on both a regional and an international scale. It is endemic to South Africa, where it is found only in the grasslands of the northern Free State and the southwestern parts of Mpumalanga (IUCN, 2017). Habitat loss due to agriculture is a continuing threat. Large portions of the grassland habitat are underlain by coal beds of varying quality and extent, and exploitation of coal for fuel has and will result in further habitat loss. The species was confirmed present[5] in the project area during the field assessment.

Based on the IUCN Red List Spatial Data (IUCN, 2017) and the AmphibianMap database provided by the Animal Demography Unit (ADU, 2019) 15 amphibian species have the potential to occur in the project area (Appendix F Amphibian expected in the project area). No amphibian SCCs are expected to occur in the project area.

Based on the IUCN Red List Spatial Data and AmphibianMap, 17 amphibian species are expected to occur within the area (Appendix B). One of the species are SCCs (Table 6-5).

Table 6-5 Threatened amphibian species that are expected to occur within the project area

Species	Common Name	Conservation Status		Likelihood of Occurrence
		Regional (SANBI, 2016)	IUCN (2021)	
Pyxicephalus adspersus	Giant Bullfrog	NT	LC	Confirmed

The Giant Bull Frog (*Pyxicephalus adspersus*) is a species of conservation concern that may potentially occur in the project area. The Giant Bull Frog is listed as NT on a regional scale. It is a species of drier savannahs. It is fossorial for most of the year, remaining buried in cocoons. They emerge at the start of the rains, and breed in shallow, temporary waters in pools, pans and ditches (IUCN, 2017). The species was confirmed present[6] in the project area during the field assessment.

6.2 Field Survey

The following sections provide the results from the field survey for the proposed development that was undertaken during the March 2022.

6.2.1 Flora Assessment

This section is divided into the following sections:

- Indigenous flora;
    - Protected plant species; and
- Invasive Alien Plants (IAPs).

6.2.1.1 Indigenous Flora

The vegetation assessment was conducted throughout the extent of the project area. A total of 122 tree, shrub, herbaceous and graminoid plant species were recorded in the project area during the field assessment (Table 6-6). Plants listed as Category 1 alien or invasive species under the NEMBA appear in green text. Plants listed in Category 2 or as 'not indigenous' or 'naturalised' according to NEMBA, appear in blue text. Some of the plant species recorded can be seen in Figure 6-11.

The list of plant species recorded is by no means comprehensive, and repeated surveys during different phenological periods not covered may likely yield up to 20% additional flora species for the project area. However, floristic analysis conducted to date is regarded as a sound representation of the local flora for the project area.

[5] Confirmed dens and scale by Mike Adams and Martinus Erasmus
[6] Confirmed individual by Mike Adams

Table 6-6 Trees, shrub and herbaceous plant species recorded in the project area

Family	*Scientific Name*	Threat Status (SANBI, 2017)	SA Endemic	Alien Category
Acanthaceae	*Blepharis squarrosa*	LC	Endemic	
Acanthaceae	*Crabbea angustifolia*	LC	Endemic	
Agavaceae	*Chlorophytum cooperi*	LC	Not Endemic	
Aizoaceae	*Delosperma herbeum*	LC	Not Endemic	
Amaranthaceae	*Achyranthes aspera*			Naturalized exotic
Amaranthaceae	*Gomphrena celosioides*			Naturalized exotic
Amaryllidaceae	*Ammocharis coranica*	LC-Schedule 6 Protected	Not Endemic	
Amaryllidaceae	*Boophone disticha*	LC Schedule -6 Protected	Not Endemic	
Anacardiaceae	*Schinus terebinthifolius*			Naturalized exotic
Anacardiaceae	*Searsia lancea*	LC	Not Endemic	
Anacardiaceae	*Searsia pyroides var. pyroides*	LC	Not Endemic	
Apocynaceae	*Nerium oleander*			NEMBA Category 1b.
Asclepiadaceae	*Gomphocarpus fruticosus subsp. fruticosus*	LC	Indigenous	
Asparagaceae	*Asparagus cooperi*	LC	Not Endemic	
Asparagaceae	*Asparagus laricinus*	LC	Not Endemic	
Asparagaceae	*Eucomis autumnalis*	LC -Schedule 6 Protected	Not Endemic	
Asphodelaceae	*Aloe dominella*	Near Threatened B1ab(ii,iii,v) (-Schedule 6 Protected)	Endemic	
Asteraceae	*Artemisia afra*	LC	Not Endemic	
Asteraceae	*Berkheya onopordifolia var. onopordifolia*	LC	Not Endemic	
Asteraceae	*Berkheya pinnatifida*	LC	Not Endemic	
Asteraceae	*Bidens pilosa*			Naturalized exotic weed
Asteraceae	*Cirsium vulgare*			NEMBA Category 1b.
Asteraceae	*Conyza bonariensis*			Naturalized exotic

Asteraceae	*Cotula anthemoides*	LC	Not Endemic	
Asteraceae	*Felicia muricata subsp. muricata*	LC	Not Endemic	
Asteraceae	*Geigeria burkei*	LC	Not Endemic	
Asteraceae	*Hilliardiella elaeagnoides*	LC	Not Endemic	
Asteraceae	*Macledium zeyheri*	LC	Not Endemic	
Asteraceae	*Nidorella anomala*	LC	Not Endemic	
Asteraceae	*Schkuhria pinnata*			Naturalized exotic
Asteraceae	*Senecio inornatus*	LC	Not Endemic	
Asteraceae	*Stoebe plumosa*	LC	Not Endemic	
Asteraceae	*Tagetes minuta*			Naturalized exotic
Asteraceae	*Xanthium stramonium*			NEMBA Category 1b.
Asteraceae	*Zinnia peruviana*			Naturalized exotic
Cactaceae	*Opuntia ficus-indica*			NEMBA Category 1b.
Cactaceae	*Opuntia stricta*			NEMBA Category 1b.
Campanulaceae	*Wahlenbergia undulata*	LC	Not Endemic	
Cannabaceae	*Celtis africana*	LC	Not Endemic	
Caryophyllaceae	*Pollichia campestris*	LC	Not Endemic	
Commelinaceae	*Commelina africana*	LC	Not Endemic	
Commelinaceae	*Commelina erecta*	LC	Not Endemic	
Commelinaceae	*Cyanotis speciosa*	LC	Not Endemic	
Convolvulaceae	*Cuscuta campestris*			Naturalized exotic
Cucurbitaceae	*Cucumis zeyheri*	LC	Not Endemic	
Ebenaceae	*Diospyros austro-africana*	LC	Not Endemic	
Fabaceae	*Chamaecrista mimosoides*	LC	Not Endemic	
Fabaceae	*Robinia pseudoacacia*			NEMBA Category 1b.

Fabaceae	*Vachellia karroo*	LC	Not Endemic	
Geraniaceae	*Monsonia angustifolia*	LC	Not Endemic	
Hyacinthaceae	*Dipcadi longifolium*	LC	Not Endemic	
Hyacinthaceae	*Ledebouria marginata*	LC	Not Endemic	
Hyacinthaceae	*Schizocarphus nervosus*	LC-Schedule 6 Protected		
Hypoxidaceae	*Hypoxis hemerocallidea*	LC	Not Endemic	
Hypoxidaceae	*Hypoxis iridifolia*	LC	Not Endemic	
Iridaceae	*Gladiolus crassifolius*	LC-Schedule 6 Protected	Not Endemic	
Iridaceae	*Gladiolus permeabilis*	LC-Sched 6 Protected	Endemic	
Malvaceae	*Hermannia depressa*	LC	Not Endemic	
Malvaceae	*Hibiscus trionum*	LC	Not Endemic	
Malvaceae	*Hibiscus trionum*			Naturalized exotic
Malvaceae	*Malva neglecta*			Naturalized exotic
Meliaceae	*Melia azedarach*			NEMBA Category 1b.
Moraceae	*Morus alba*			NEMBA Category 3
Myrtaceae	*Eucalyptus camaldulensis*			NEMBA Category 1b
Oxalidaceae	*Oxalis depressa*	LC	Not Endemic	
Pentzia Globosa	*Pentzia globosa*	LC	Not Endemic	
Pinaceae	*Pinus pinaster*			NEMBA Category 2
Poaceae	*Aristida adscensionis*	LC	Not Endemic	
Poaceae	*Aristida canescens subsp. canescens*	LC	Not Endemic	
Poaceae	*Aristida congesta subsp. barbicollis*	LC	Not Endemic	
Poaceae	*Aristida congesta subsp. congesta*	LC	Not Endemic	
Poaceae	*Arundo donax*			NEMBA Category 1b.
Poaceae	*Bambusa sp*			Naturalized exotic

Poaceae	*Bewsia biflora*	LC	Not Endemic	
Poaceae	*Cenchrus ciliaris*	LC	Not Endemic	
Poaceae	*Chloris gayana*	LC	Not Endemic	
Poaceae	*Cortaderia selloana*			NEMBA Category 1b.
Poaceae	*Cymbopogon caesius*	LC	Not Endemic	
Poaceae	*Cynodon dactylon*	LC	Not Endemic	
Poaceae	*Digitaria eriantha*	LC	Not Endemic	
Poaceae	*Eleusine coracana*			Naturalized exotic
Poaceae	*Eragrostis chloromelas*	LC	Not Endemic	
Poaceae	*Eragrostis curvula*	LC	Not Endemic	
Poaceae	*Eragrostis gummiflua*	LC	Not Endemic	
Poaceae	*Eragrostis obtusa*	LC	Not Endemic	
Poaceae	*Eragrostis superba*	LC	Not Endemic	
Poaceae	*Fingerhuthia africana*	LC	Not Endemic	
Poaceae	*Heteropogon contortus*	LC	Not Endemic	
Poaceae	*Hyparrhenia hirta*	LC	Not Endemic	
Poaceae	*Hyperthelia dissoluta*	LC	Not Endemic	
Poaceae	*Melinis repens*	LC	Not Endemic	
Poaceae	*Microchloa caffra*	LC	Not Endemic	
Poaceae	*Panicum maximum*	LC	Not Endemic	
Poaceae	*Paspalum dilatatum*	LC	Indigenous	
Poaceae	*Pennisetum clandestinum*			NEMBA Category 1b.
Poaceae	*Phragmites australis*	LC	Not Endemic	
Poaceae	*Pogonarthria squarrosa*	LC	Not Endemic	
Poaceae	*Setaria pumila*	LC	Not Endemic	

Poaceae	*Setaria sphacelata var. Sericea*	LC	Not Endemic	
Poaceae	*Setaria sphacelata var. sphacelata*	LC	Not Endemic	
Poaceae	*Setaria sphacelata var. torta*	LC	Not Endemic	
Poaceae	*Setaria verticillata*	LC	Not Endemic	
Poaceae	*Sporobolus africanus*	LC	Not Endemic	
Poaceae	*Themeda triandra*	LC	Not Endemic	
Poaceae	*Trachypogon spicatus*	LC	Not Endemic	
Poaceae	*Trichoneura grandiglumis*	LC	Not Endemic	
Poaceae	*Urochloa mosambicensis*	LC	Not Endemic	
Polygonaceae	*Persicaria lapathifolia*			Naturalized exotic
Rhamnaceae	*Ziziphus mucronata subsp. mucronata*	LC	Not Endemic	
Rosaceae	*Prunus persica*			Naturalized exotic
Salicaceae	*Populus alba*			NEMBA Category 2
Salicaceae	*Populus deltoides*			Naturalized exotic
Salicaceae	*Salix babylonica*			Naturalized exotic
Scrophulariaceae	*Jamesbrittenia aurantiaca*	LC	Not Endemic	
Scrophulariaceae	*Selago densiflora*	LC	Not Endemic	
Solanaceae	*Datura ferox*			NEMBA Category 1b.
Solanaceae	*Solanum lichtensteinii*	LC	Not Endemic	
Tamaricaceae	*Tamarix chinensis*			NEMBA Category 1b.
Typhaceae	*Typha capensis*	LC	Not Endemic	
Verbenaceae	*Verbena astrigera*			Naturalized exotic
Verbenaceae	*Verbena bonariensis*			NEMBA Category 1b.
Zygophyllaceae	*Tribulus terrestris*	LC	Not Endemic	

Figure 6-11 Some of the plants recorded in the project area: A) Blepharis squarrosa, B) Aloe dominella (NT), C) Dipcadi longifolium, D) Berkheya onopordifolia var. onopordifolia and E) Gladiolus permeabilis

6.2.1.1.1 Protected plant species

Several individuals of protected plant species that are protected by the Free State Nature Conservation Ordinance 8 of 1969 were observed in various parts of the project area. According to the list of protected species under Schedule, if any individuals of these plant species are to be disturbed, permits must be obtained from the Free State Department of Economic, Small Business Development, Tourism and Environmental Affairs (FSDESTEA).

6.2.1.2 Invasive Alien Plants

Invasive Alien Plants (IAPs) tend to dominate or replace indigenous flora, thereby transforming the structure, composition and functioning of ecosystems. Therefore, it is important that these plants are controlled by means of an eradication and monitoring programme. Some invader plants may also degrade ecosystems through superior competitive capabilities to exclude native plant species.

NEMBA is the most recent legislation pertaining to alien invasive plant species. In August 2014, the list of Alien Invasive Species was published in terms of the NEMBA. The Alien and Invasive Species Regulations were published in the Government Gazette No. 44182, 24th of February 2021. The legislation calls for the removal and / or control of AIP species (Category 1 species). In addition, unless authorised thereto in terms of the NWA, no land user shall allow Category 2 plants to occur within 30 meters of the 1:50 year flood line of a river, stream, spring, natural channel in which water flows regularly or intermittently, lake, dam or wetland. Category 3 plants are also prohibited from occurring within proximity to a watercourse. Below is a brief explanation of the three categories in terms of the NEMBA:

- *Category 1a*: Invasive species requiring compulsory control. Remove and destroy. Any specimens of Category 1a listed species need, by law, to be eradicated from the environment. No permits will be issued.
- *Category 1b*: Invasive species requiring compulsory control as part of an invasive species control programme. Remove and destroy. These plants are deemed to have such a high invasive potential that infestations can qualify to be placed under a government sponsored invasive species management programme. No permits will be issued.
- *Category 2*: Invasive species regulated by area. A demarcation permit is required to import, possess, grow, breed, move, sell, buy or accept as a gift any plants listed as Category 2 plants. No permits will be issued for Category 2 plants to exist in riparian zones.
- *Category 3*: Invasive species regulated by activity. An individual plant permit is required to undertake any of the following restricted activities (import, possess, grow, breed, move, sell, buy or accept as a gift) involving a Category 3 species. No permits will be issued for Category 3 plants to exist in riparian zones.

Note that according to the Alien and Invasive Species Regulations, a person who has under his or her control a category 1b listed invasive species must immediately:

- Notify the competent authority in writing
- Take steps to manage the listed invasive species in compliance with:
  - Section 75 of the NEMBA;
  - The relevant invasive species management programme developed in terms of regulation 4; and
  - Any directive issued in terms of section 73(3) of the NEMBA.

Fourteen (14) IAP species were recorded within the project area. These species are listed under the Alien and Invasive Species List 2020, Government Gazette No. GN1003 as Category 1b. Category 1b species must be controlled by implementing an IAP Management Programme, in compliance of section 75 of the NEMBA, as stated above.

6.2.2 Faunal Assessment

Avifauna, Mammal and Herpetofauna observations and recordings fall under this section.

6.2.2.1 Avifauna

Eighty-nine (89) (37.7 % of expected) species were recorded in the project area during the survey based on either direct observation, vocalisations, or the presence of visual tracks & signs, (Table 6-7) (Figure 6-12). Four (4) (red text) species are rated as SCC, whereas 75 were listed as protected provincially.

Table 6-7 A list of avifaunal species recorded for the project area

Species	Common Name	Conservation Status		Free State Nature Conservation Ordinance 8 of 1969
		Regional (SANBI, 2016)	IUCN (2021)	
Acridotheres tristis	Myna, Common	Unlisted	LC	-
Afrotis afraoides	Korhaan, Northern Black	Unlisted	LC	Schedule 1 Protected
Alopochen aegyptiaca	Goose, Egyptian	Unlisted	LC	Schedule 1/2 Protected
Amadina erythrocephala	Finch, Red-headed	Unlisted	LC	Schedule 1 Protected
Anas erythrorhyncha	Teal, Red-billed	Unlisted	LC	Schedule 1 Protected
Anas sparsa	Duck, African Black	Unlisted	LC	Schedule 1 Protected
Anas undulata	Duck, Yellow-billed	Unlisted	LC	Schedule 1/2 Protected
Anhinga rufa	Darter, African	Unlisted	LC	Schedule 1 Protected
Apus apus	Swift, Common	Unlisted	LC	Schedule 1 Protected
Ardea cinerea	Heron, Grey	Unlisted	LC	Schedule 1 Protected
Ardea intermedia	Egret, Yellow-billed (Intermediate)	Unlisted	LC	Schedule 1 Protected
Ardea melanocephala	Heron, Black-headed	Unlisted	LC	Schedule 1 Protected
Ardea purpurea	Heron, Purple	Unlisted	LC	Schedule 1 Protected
Ardeola ralloides	Heron, Squacco	Unlisted	LC	Schedule 1 Protected
Asio capensis	Owl, Marsh	Unlisted	LC	Schedule 1 Protected
Bostrychia hagedash	Ibis, Hadeda	Unlisted	LC	Schedule 1 Protected
Bubulcus ibis	Egret, Cattle	Unlisted	LC	Schedule 1 Protected
Burhinus capensis	Thick-knee, Spotted	Unlisted	LC	Schedule 1 Protected
Buteo buteo	Buzzard, Common (Steppe)	Unlisted	LC	Schedule 1 Protected
Buteo rufofuscus	Buzzard, Jackal	Unlisted	LC	Schedule 1 Protected
Charadrius tricollaris	Plover, Three-banded	Unlisted	LC	Schedule 1 Protected
Chlidonias hybrida	Tern, Whiskered	Unlisted	LC	Schedule 1 Protected
Chlidonias leucopterus	Tern, White-winged	Unlisted	LC	Schedule 1 Protected
Chrysococcyx caprius	Cuckoo, Diderick	Unlisted	LC	Schedule 1 Protected
Circus macrourus	Harrier, Pallid	NT	NT	Schedule 1 Protected
Columba livia	Dove, Rock	Unlisted	LC	-
Coracias caudatus	Roller, Lilac-breasted	Unlisted	LC	Schedule 1 Protected
Corvus albus	Crow, Pied	Unlisted	LC	-
Corythornis cristatus	Kingfisher, Malachite	Unlisted	Unlisted	Schedule 1 Protected

Cursorius temminckii	Courser, Temminck's	Unlisted	LC	Schedule 1 Protected
Dendrocygna viduata	Duck, White-faced Whistling	Unlisted	LC	Schedule 1 Protected
Egretta ardesiaca	Heron, Black	Unlisted	LC	Schedule 1 Protected
Egretta garzetta	Egret, Little	Unlisted	LC	Schedule 1 Protected
Elanus caeruleus	Kite, Black-shouldered	Unlisted	LC	Schedule 1 Protected
Estrilda astrild	Waxbill, Common	Unlisted	LC	Schedule 1 Protected
Euplectes afer	Bishop, Yellow-crowned	Unlisted	LC	-
Euplectes ardens	Widowbird, Red-collared	Unlisted	LC	-
Euplectes orix	Bishop, Southern Red	Unlisted	LC	-
Euplectes progne	Widowbird, Long-tailed	Unlisted	LC	-
Falco amurensis	Falcon, Amur	Unlisted	LC	Schedule 1 Protected
Falco rupicolus	Kestrel, Rock	Unlisted	LC	Schedule 1 Protected
Fulica cristata	Coot, Red-knobbed	Unlisted	LC	Schedule 1 Protected
Himantopus himantopus	Stilt, Black-winged	Unlisted	LC	Schedule 1 Protected
Hirundo dimidiata	Swallow, Pearl-breasted	Unlisted	LC	Schedule 1 Protected
Lamprotornis bicolor	Starling, Pied	Unlisted	LC	-
Lanius collaris	Fiscal, Common (Southern)	Unlisted	LC	Schedule 1 Protected
Lanius minor	Shrike, Lesser Grey	Unlisted	LC	Schedule 1 Protected
Lybius torquatus	Barbet, Black-collared	Unlisted	LC	Schedule 1 Protected
Melierax canorus	Goshawk, Southern Pale Chanting	Unlisted	LC	Schedule 1 Protected
Merops apiaster	Bee-eater, European	Unlisted	LC	Schedule 1 Protected
Microcarbo africanus	Cormorant, Reed	Unlisted	LC	Schedule 1 Protected
Mirafra africana	Lark, Rufous-naped	Unlisted	LC	Schedule 1 Protected
Myrmecocichla formicivora	Chat, Anteating	Unlisted	LC	Schedule 1 Protected
Netta erythrophthalma	Pochard, Southern	Unlisted	LC	Schedule 1 Protected
Numida meleagris	Guineafowl, Helmeted	Unlisted	LC	Schedule 1/2 Protected
Nycticorax nycticorax	Night-Heron, Black-crowned	Unlisted	LC	Schedule 1 Protected
Oena capensis	Dove, Namaqua	Unlisted	LC	Schedule 1 Protected
Oxyura maccoa	Duck, Maccoa	NT	VU	Schedule 1 Protected
Passer domesticus	Sparrow, House	Unlisted	LC	-
Phoenicopterus roseus	Flamingo, Greater	NT	LC	Schedule 1 Protected
Phoeniculus purpureus	Wood-hoopoe, Green	Unlisted	LC	Schedule 1 Protected
Platalea alba	Spoonbill, African	Unlisted	LC	Schedule 1 Protected
Plectropterus gambensis	Goose, Spur-winged	Unlisted	LC	Schedule 1/2 Protected
Plegadis falcinellus	Ibis, Glossy	Unlisted	LC	Schedule 1 Protected
Plocepasser mahali	Sparrow-weaver, White-browed	Unlisted	LC	-
Ploceus velatus	Masked-weaver, Southern	Unlisted	LC	-
Podiceps nigricollis	Grebe, Black-necked	Unlisted	LC	Schedule 1 Protected

Prinia flavicans	Prinia, Black-chested	Unlisted	LC	Schedule 1 Protected
Pternistis swainsonii	Spurfowl, Swainson's	Unlisted	LC	Schedule 1/2 Protected
Rhinoptilus africanus	Courser, Double-banded	Unlisted	LC	Schedule 1 Protected
Sagittarius serpentarius	Secretarybird	VU	EN	Schedule 1 Protected
Saxicola torquatus	Stonechat, African	Unlisted	LC	Schedule 1 Protected
Spatula hottentota	Teal, Hottentot	Unlisted	LC	Schedule 1 Protected
Spatula smithii	Shoveler, Cape	Unlisted	LC	Schedule 1 Protected
Spilopelia senegalensis	Dove, Laughing	Unlisted	LC	-
Sporopipes squamifrons	Finch, Scaly-feathered	Unlisted	LC	-
Streptopelia capicola	Turtle-dove, Cape	Unlisted	LC	-
Sturnus vulgaris	Starling, Common	Unlisted	LC	Schedule 1 Protected
Tachybaptus ruficollis	Grebe, Little	Unlisted	LC	Schedule 1 Protected
Telophorus zeylonus	Bokmakierie, Bokmakierie	Unlisted	LC	Schedule 1 Protected
Trachyphonus vaillantii	Barbet, Crested	Unlisted	LC	Schedule 1 Protected
Tringa stagnatilis	Sandpiper, Marsh	Unlisted	LC	Schedule 1 Protected
Tyto alba	Owl, Barn	Unlisted	LC	Schedule 1 Protected
Upupa africana	Hoopoe, African	Unlisted	LC	Schedule 1 Protected
Uraeginthus angolensis	Waxbill, Blue	Unlisted	LC	Schedule 1 Protected
Urocolius indicus	Mousebird, Red-faced	Unlisted	LC	Schedule 1 Protected
Vanellus armatus	Lapwing, Blacksmith	Unlisted	LC	Schedule 1 Protected
Vanellus coronatus	Lapwing, Crowned	Unlisted	LC	Schedule 1 Protected
Vidua macroura	Whydah, Pin-tailed	Unlisted	LC	Schedule 1 Protected

Figure 6-12 Some of the avifaunal species recorded; A) Heron, Black (Egretta ardesiaca) , B) Bokmakierie (Telophorus zeylonus) and C) Duck, Maccoa (Oxyura maccoa)(NT), D) Stilt, Black-winged (Himantopus Himantopus), E) Courser, Double-banded (Rhinoptilus africanus), F) Kingfisher, Malachite (Corythornis cristatus) and G) Dove, Namaqua (Oena capensis).

6.2.2.2 Mammals

Twenty-two (22) mammal species were observed during the survey of the project area (Table 6-8) based on either direct observation or the presence of visual tracks and signs (Figure 6-13). Three (3) (in red text) of the species recorded are regarded as SCC. Four (4) mammal species are considered 'captive' species as these were only present within the game farm areas, marked in blue text.

Table 6-8 Summary of mammal species recorded within the project area

Species	Common Name	Conservation Status		Free State Nature Conservation Ordinance 8 of 1969
		Regional (SANBI, 2016)	IUCN (2021)	
Antidorcas marsupialis	Springbok	LC	LC	Schedule 2-Protected
Aonyx capensis	Cape Clawless Otter	NT	NT	-
Atilax paludinosus	Water Mongoose	LC	LC	-
Canis mesomelas	Black-backed Jackal	LC	LC	-
Chlorocebus pygerythrus	Vervet Monkey	LC	LC	-
Connochaetes taurinus	Blue Wildebeest	LC	LC	Schedule 2-Protected
Cryptomys hottentotus	Southern African Mole-rat	LC	LC	-
Cynictis penicillata	Yellow Mongoose	LC	LC	-
Damaliscus pygargus	Blesbok	LC	LC	Schedule 2-Protected
Genetta genetta	Small-spotted Genet	LC	LC	-
Giraffa camelopardalis	Giraffe	LC	VU	Schedule 2-Protected
Herpestes sanguineus	Slender Mongoose	LC	LC	-
Hystrix africaeaustralis	Cape Porcupine	LC	LC	-
Kobus leche	Lechwe	Unlisted	NT	-
Leptailurus serval	Serval	NT	LC	-
Lepus saxatilis	Scrub Hare	LC	LC	Schedule 2-Protected
Micaelamys namaquensis	Namaqua Rock Mouse	LC	LC	-
Parahyaena brunnea	Brown Hyaena	NT	NT	-
Raphicerus campestris	Steenbok	LC	LC	Schedule 2-Protected
Sylvicapra grimmia	Common Duiker	LC	LC	Schedule 2-Protected
Tragelaphus strepsiceros	Greater Kudu	LC	LC	Schedule 2-Protected
Xerus inauris	South African Ground Squirrel	LC	LC	-

Figure 6-13 Photograph illustrating some of the mammal species recorded in the project area. A) Small-spotted Genet (Genetta genetta), B) Water Mongoose (Atilax paludinosus), C) Vervet Monkey (Chlorocebus pygerythrus), D) Yellow Mongoose (Cynictis penicillata), E) Slender Mongoose (Herpestes sanguineus) and F) Cape Porcupine (Hystrix africaeaustralis).

Figure 6-14 Photograph illustrating some of the mammal species recorded in the project area. A) Scrub Hare scat (Lepus saxatilis), B) Black-backed Jackal spoor (Canis mesomelas) and C) Brown Hyaena spoor (Parahyaena brunnea) (NT) and D) Cape Clawless Otter spoor (Aonyx capensis)

6.2.2.3 Herpetofauna

6.2.2.3.1 Reptiles

Eleven (11) species of reptiles were recorded in the project area during survey period. (Table 6-9) (Figure 6-15). One SCC, namely *Smaug giganteus* (Sungazer/Giant Dragon Lizard) was recorded during the field assessment. However, there is the possibility of more species being present, as certain reptile species are secretive and require long-term surveys to ensure capture.

Smaug giganteus (Sungazer/Giant Dragon Lizard) is categorised as VU on both a regional and an international scale. Additionally, the species is listed on the Convention on International Trade in Endangered Species (CITES) Appendix II, as well as a Threatened or Protected Species (TOPS). It is endemic to South Africa, where it is found only in the grasslands of the northern Free State and the southwestern parts of Mpumalanga with an estimated EOO (km²) of 37 617 (Alexander *et al.*, 2018). The species is considered to be a habitat specialist, that is highly philopatric (tending to return to or remain near a particular site or area) for burrowing sites. Sungazers/Giant Dragon Lizards also won't easily disperse across the landscape to make new burrows should its habitat be destroyed (Alexander *et al.*, 2018)

Habitat loss due to agriculture is a continuing threat. Large portions of the grassland habitat are underlain by coal beds of varying quality and extent, and exploitation of coal for fuel has and will result in further habitat loss. Another substantial threat to the species is illegal collection for the pet trade to an extent that it is one of the most exported species from South Africa with 1 194 individuals exported between 1985 and 2014 for pet trade (Parusnath *et al*, 2017; UNEP-WCMC, 2017).

A collection of burrows was observed during the field survey (Figure 6-15), it is however presumed that there are several additional burrows. Due to the sensitivity of this species, especially in regard to its illegal collection, no waypoints will be displayed or provided in this report.

Table 6-9 Summary of reptile species recorded within the project area

Species	Common Name	Conservation Status		Free State Nature Conservation Ordinance 8 of 1969
		Regional (SANBI, 2016)	IUCN (2021)	
Crotaphopeltis hotamboeia	Red-lipped Snake	LC	LC	-
Dasypeltis scabra	Rhombic Egg-eater	LC	LC	-
Smaug giganteus	Sungazer	VU	VU	Schedule 1 Protected
Boaedon capensis	Brown House Snake	LC	LC	-
Pseudaspis cana	Mole Snake	LC	LC	-
Leptotyphlops scutifrons	Peters' Thread Snake	LC	LC	-
Lygodactylus capensis	Common Dwarf Gecko	LC	LC	-
Panaspis wahlbergii	Wahlberg's Snake-eyed Skink	LC	LC	-
Trachylepis punctatissima	Speckled Rock Skink	LC	LC	-
Rhinotyphlops lalandei	Delalande's Beaked Blind Snake	LC	LC	-
Varanus niloticus	Nile Monitor	LC	LC	-

Figure 6-15 Some of the reptile species recorded in the project area: A) Red-lipped Snake (Crotaphopeltis hotamboeia); B) Brown House Snake (Boaedon capensis); C) Sungazer (Smaug giganteus) burrow; D) Speckled Rock Skink (Trachylepis punctatissima); E) Delalande's Beaked Blind Snake (Rhinotyphlops lalandei); F) Mole Snake (Pseudaspis cana); and G) Sungazer (Smaug giganteus) habitat.

6.2.2.3.2 Amphibians

Four (4) amphibian species were recorded in the project area (Table 6-10and Figure 6-16). One species recorded species recorded was a SCCs.

Table 6-10 Summary of amphibian species recorded within the project area

Species	Common Name	Conservation Status		Free State Nature Conservation Ordinance 8 of 1969
		Regional (SANBI, 2016)	IUCN (2021)	
Amietia quecketti	Common River Frog	LC	LC	-
Cacosternum boettgeri	Common Caco	LC	LC	-
Pyxicephalus adspersus	Giant Bullfrog	NT	LC	-
Sclerophrys gutturalis	Guttural Toad	LC	LC	-

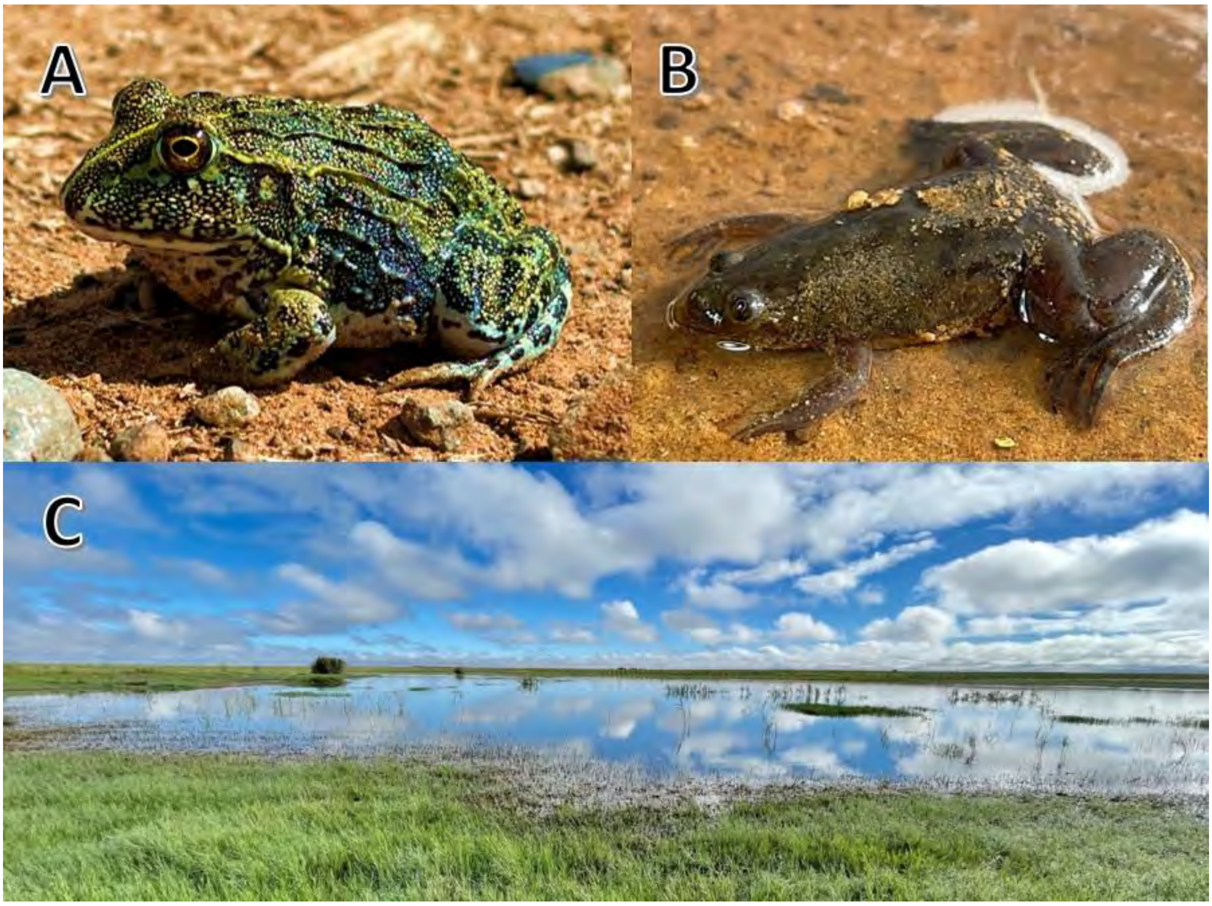


Figure 6-16 Some of the amphibian species recorded in the project area: A) Juvenile Giant Bullfrog (Pyxicephalus adspersus); B) Common Platanna (Xenopus laevis); and C) One of several temporary pans and wetlands within the project area which provide ideal breeding sites for Pyxicephalus adspersus.

6.2.3 Habitat Assessment and Site Ecological Importance

6.2.3.1 Habitat Assessment

The main habitat types identified across the project area were initially identified largely based on aerial imagery. These main habitat types were refined based on the field coverage and data collected during the survey; the delineated habitats can be seen in Figure 6-17 and Figure 6-18. Emphasis was placed on limiting timed meander searches along the proposed area within the natural habitats and therefore habitats with a higher potential of hosting SCC

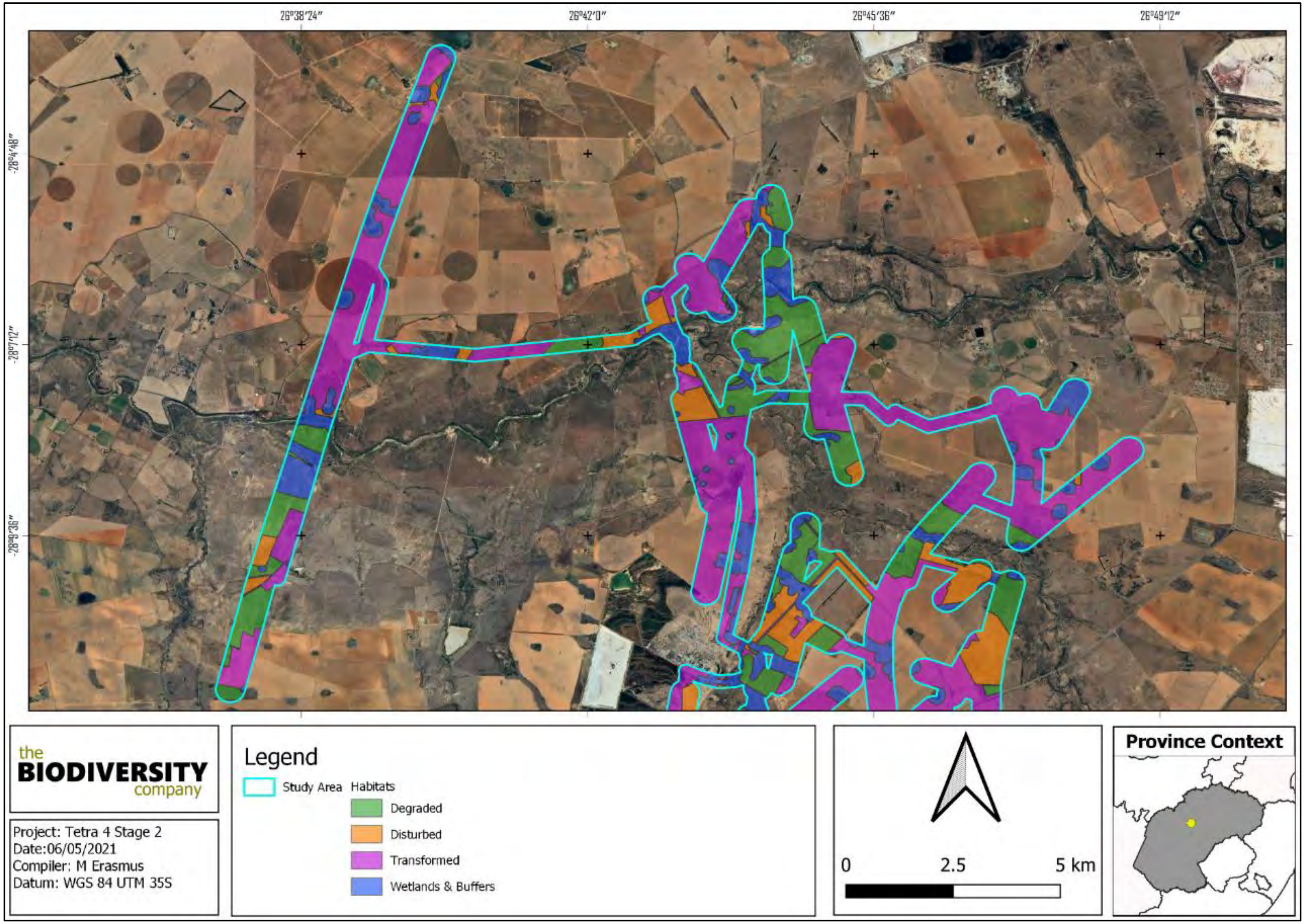


Figure 6-17 Habitats identified within the project area.

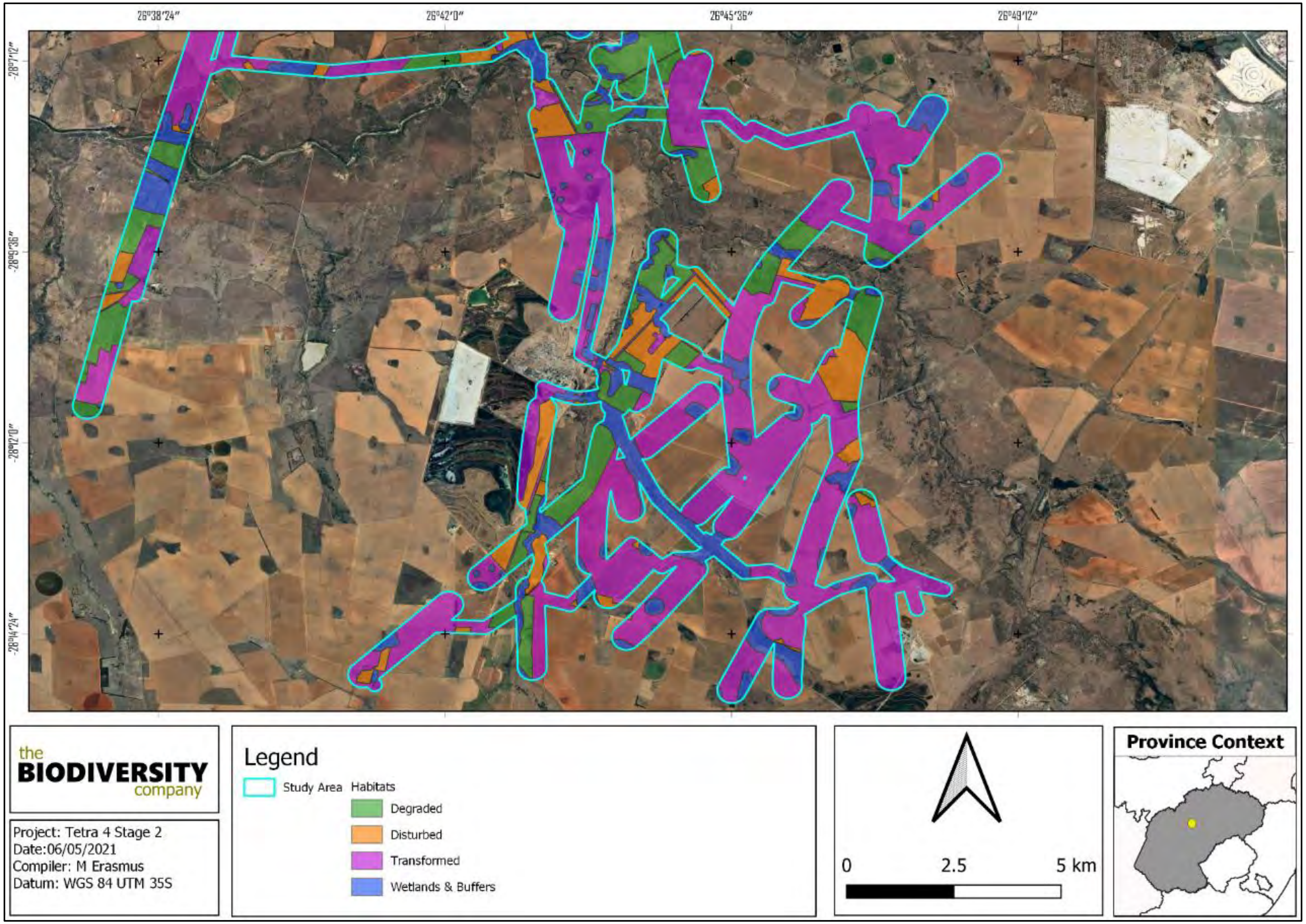


Figure 6-18 *Habitats identified within the project area.*

Degraded Habitat (Vaal Vet Sandy Grassland and Alluvial Vegetation)

The degraded habitat includes areas that are connected to and play a crucial role regarding the water resource habitats present. This habitat type is regarded as semi-natural, but disturbed due to fragmentation, grazing by livestock and also human infringement in areas close to roads (Figure 6-19 and Figure 6-20).

Generally, this habitat unit has intact ecological functioning attributed to faunal communities found in this habitat. The current ecological condition of this habitat, regarding the driving forces, are inconsistent due to the different land uses. Portions of these areas have been disturbed by the historic and current grazing pressure. Additionally, the presence of some disturbances such as AIP presence or edge effect impacts on floral communities have resulted in decreased habitat integrity. The condition difference within this habitat depends on the extent of the disturbance in some areas being more severe, usually related to one being more overgrazed than the other.

Although the habitat unit is not entirely disturbed, ongoing and historic disturbances have resulted in the plant community no longer being fully representative of the reference vegetation. However, the habitat indicators that are known to show ‘unhealthy’ Dry Highveld Grassland such as grassland dominated by karroid shrubs, or the absence of endangered animal species.

The main ecological characteristics of dry highveld grasslands, which the Vaal Vet Sandy Grassland, is classified as, (SANBI, 2013):

- Climate; fundamentally different from any other grassland systems due to the significant difference in climate. This grassland experiences cold (frost) winters, but a defining difference is the low and highly variable summer rainfall that affects the grassland productivity, due to water being the main factor affecting growth, and not the duration or temperature of the season;
- Fire; plays a role in maintaining these grasslands, however not as important as grazing. Due to its slow growing nature, the grassland recovers slowly from fire events;
- Grazing, a slow growing sweetveld grassland being able to support animal production for most of the year, grazing is an important driver in these systems. and this is the most important ecosystem process that can be managed to maintain biodiversity and productivity in these ecosystems;
- Life-history strategies; due to the environmental conditions, driven primarily by adaptation to drought, the plants persist mainly through being long-lived, perennial plants replacing themselves through seeds or vegetative reproduction;
- Encroachment by invasive woody species; due to the factors limiting encroachment (fire, rainfall and frost) being variable in this grassland, if the biomass is reduced by grazing or decreased fire intensity, bush encroachment by trees such as *Vachellia karoo*, or woody karroid shrubs (such as *Pentzia* and *Felicia* species) can occur.
- Geology; The underlying geology is an important determinant of the biodiversity patterners and processes. Especially dolerite sheets that correlates to high levels of plant species richness and endemism.

The portions of this remaining habitat unit can thus be regarded as incredibly important, not only within the local landscape, but also regionally; it acts as a greenland, used for habitat, foraging area and movement corridors for fauna (including the SCC recorded). The habitat sensitivity of the degraded habitat is regarded as high/very high, mainly due to the role of this habitat to biodiversity within a very fragmented local landscape, not to mention the various ecological datasets.

The management and spatial guidelines for the land use of these grasslands that are relevant to this project area include (SANBI,2013);

- Avoid habitat loss in threatened grassland vegetation types: Threatened vegetation types such as Vaal-Vet Sandy Grassland are highly fragmented and there should be no further habitat loss, or ploughing, in these vegetation types without proper impact assessments.

Figure 6-19 Examples of degraded habitat (grassland) from the project area.

Figure 6-20 Examples of degraded habitat (alluvial vegetation) from the project area.

Water resources (Wetlands, rivers and riparian zones)

This habitat unit represents the water resource habitats with the adjacent vegetation that it is connected to (Figure 6-21 & Figure 6-22). The riparian habitat unit or riparian zone represents areas associated with the Sand River as well as a small tributary to the river. Although the stream and associated dams are in a relatively modified poor condition with the presence of invasive species, bank erosion and overgrazing/trampling adjacent to the stream, the riparian vegetation serves an important ecological function with high conservation value. Riparian areas have high conservation value and can be considered the most important part of a watershed for a wide range of values and resources. They provide important habitat for a large volume of wildlife and often forage for domestic animals. The vegetation they contain are an important part of the water balance for the hydrological cycle through evapotranspiration. The wetlands (and riparian zones) habitat unit is considered to be of very high ecological sensitivity due to the contribution of the various wetland (and riparian) features to faunal migratory connectivity, ecoservices provision and the unique habitat provided for faunal and floral species. The wetland habitats have been provided by the wetland specialist, and the accompanying wetland report must be consulted for the relevance and sensitivity of these systems which have been included within this report.

Even though somewhat disturbed, the ecological integrity, importance, and functioning of these areas play a crucial role as a water resource system and an important habitat for various fauna and flora, including the SCC recorded. The preservation of this system is an important aspect to consider for the proposed development, even more so due to the high sensitivity of the area according to the various ecological datasets. This habitat needs to be protected and improved due to the role of this habitat as a water resource.

Figure 6-21 A photo of the Water resource (Sand River and riparian) habitat in the project area.

Figure 6-22 A photo of the Water resource (wetland) habitat the project area.

Disturbed Habitat

The disturbed habitat is regarded as areas that has been impacted by edge effects of transformed areas as well as direct impacts from historic and ongoing overgrazing, dumping and infringement (Figure 6-23 & Figure 6-24). This area has been disturbed and modified from its natural state, it represents habitat that is more disturbed than the ‘degraded habitat’ area, but not as disturbed as the ‘transformed’ area. This habitat is regarded as areas that have been impacted more by historic overgrazing, mismanagement, and harmful land use (historic agriculture). These habitats aren't entirely transformed but in a constant disturbed state as they can't recover to a more natural state due to ongoing disturbances and impacts it receives from grazing and mismanagement. These areas are considered to have a medium sensitivity due to the fact that the areas may be used as a movement corridor and in many cases form a barrier between the more degraded bushveld and the transformed areas.

Figure 6-23 A photo of the disturbed habitat in the project area.

Figure 6-24 A photo of the disturbed habitat the project area.

Transformed Habitat

The transformed habitat unit, which is the largest of the habitat units, represents areas where vegetation cover has been significantly impacted by current and historical mining and agricultural activities as well as through infrastructure associated with the mining/agricultural activities (Figure 6-25 & Figure 6-26). This habitat unit has no conservation value from an ecological perspective.

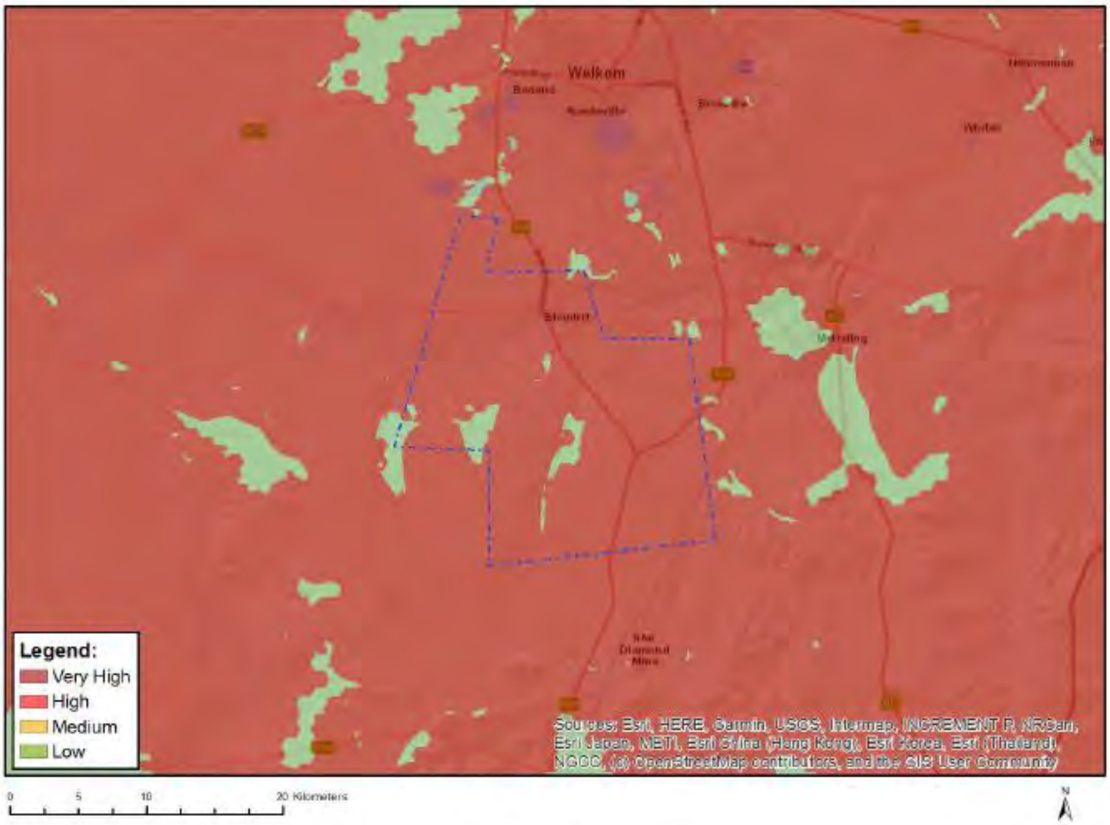
Figure 6-25 A illustration of transformed habitat the project area.

Figure 6-26 A illustration of transformed habitat the project area.

6.2.3.2 Site Ecological Importance

The biodiversity theme sensitivity as indicated in the screening report was derived to be *Very High* (Figure 6-27). This was based on the CBA 1, ESA 1 & 2 areas as well as the NPAES area. The animal sensitivity was rated as *Medium*, while the plant sensitivity was rated as *Low*.

MAP OF RELATIVE TERRESTRIAL BIODIVERSITY THEME SENSITIVITY



Very High sensitivity	High sensitivity	Medium sensitivity	Low sensitivity
X			

Sensitivity Features:

Sensitivity	Feature(s)
Low	Low Sensitivity
Very High	Critical biodiveristy area 1
Very High	Critical biodiveristy area 2
Very High	Ecological support area 1
Very High	Ecological support area 2
Very High	Endangered ecosystem
Very High	Protected Areas Expansion Strategy

Figure 6-27 Biodiversity Theme Sensitivity, Screening Report

As per the terms of reference for the project, GIS sensitivity maps are required in order to identify sensitive features in terms of the relevant specialist discipline/s within the project area. The sensitivity scores identified during the field survey for each terrestrial habitat are mapped. The location and extent of these habitats are illustrated in Figure 6-28 and Figure 6-29. Based on the criteria provided in Section 4.3 of this report, all habitats within the assessment area of the proposed project were allocated a sensitivity category (Table 6-11). The sensitivities of the habitat types delineated are illustrated in 'Very High/High Sensitivity' areas are due to the following, and the guidelines can be seen in Table 6-12:

- All habitats within the assessment area were observed to be utilised by threatened (local classification) species during the field survey, these species comprised of:

  - One flora species;
  - Four (4) avifaunal species;
  - Three (3) mammal species;
  - One (1) reptile species; and
  - One (1) amphibian species.
- Unique, important (EN Ecosystem CBA1/ESA 1& 2) and very low resilience habitats (water resource); and
- Habitat that is regarded as crucial to the survival of a threatened species.

Table 6-11 Summary of habitat types delineated within the field assessment area of the project area

Habitat	Conservation Importance	Functional Integrity	Biodiversity Importance	Receptor Resilience	Site Ecological Importance
Degraded (Sensitive Species)	High	High	Medium	Low	Very High
Degraded	High	Medium	Medium	Low	High
Water Resource	High	Medium	Medium	Very Low	High
Disturbed	Medium	Medium	Medium	Medium	Medium
Transformed	Very Low	Very Low	Very Low	Medium	Very Low

Table 6-12 Guidelines for interpreting Site Ecological Importance in the context of the proposed development activities

Site Ecological Importance	Interpretation in relation to development activities
Very High	Avoidance mitigation – no destructive development activities should be considered. Offset mitigation not acceptable/not possible (i.e., last remaining populations of species, last remaining good condition patches of ecosystems/unique species assemblages). Destructive impacts for species/ecosystems where persistence target remains.
High	Avoidance mitigation wherever possible. Minimisation mitigation – changes to project infrastructure design to limit the amount of habitat impacted, limited development activities of low impact acceptable. Offset mitigation may be required for high impact activities.
Medium	Minimisation and restoration mitigation – development activities of medium impact acceptable followed by appropriate restoration activities.
Very Low	Minimisation mitigation – development activities of medium to high impact acceptable and restoration activities may not be required.

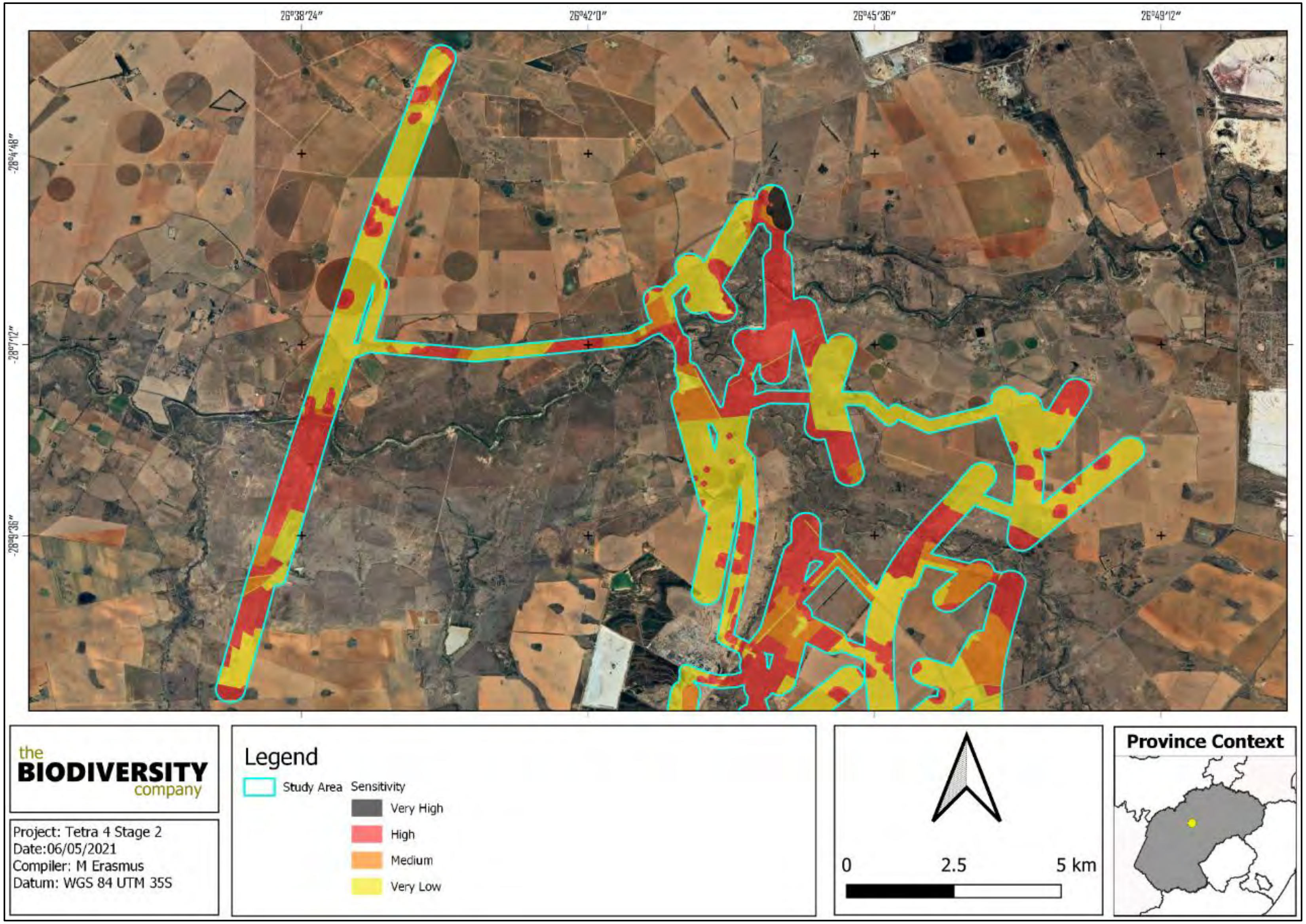


Figure 6-28 The study area superimposed over the sensitivities in the area

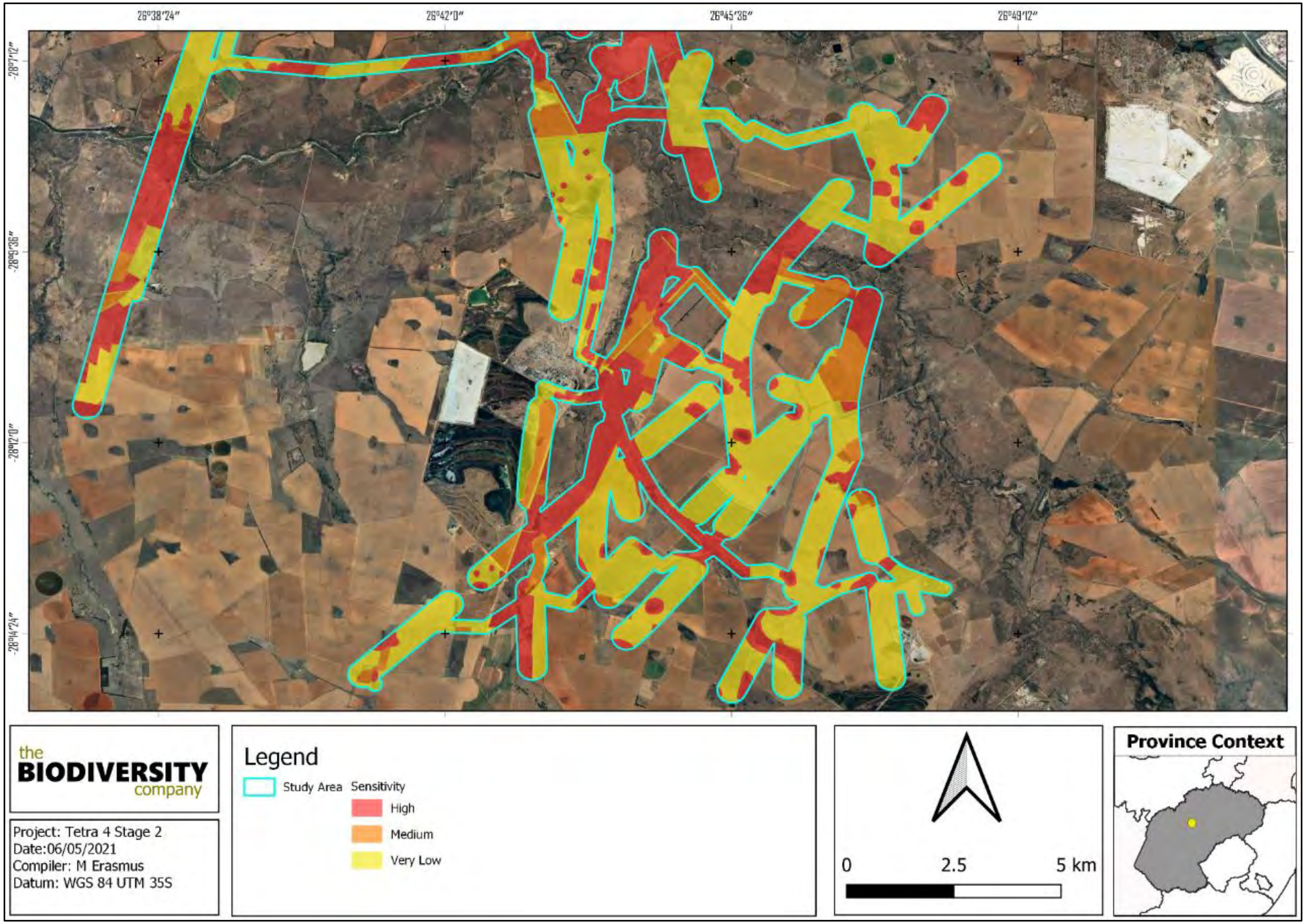


Figure 6-29 The study area superimposed over the sensitivities in the area

7 Impact Assessment

The sections below serve to outline and summarise the types of perceived impacts from the proposed activities on the terrestrial biodiversity and ecology of the project, as well as responses to the concerns raised by stakeholders. The associated significance of each impact is evaluated as relevant to the local biodiversity and the likely project activities.

7.1 Anticipated Activities

The proposed activities associated with the expansion of gas mining can be seen overlaid with the overall sensitivity (Figure 6-28 and Figure 6-29). It is evident from the figure that the following may have a negative effect on more sensitive water resources, most impacts involve the water resources and the habitats connected to these:

- Expansions to the current LNG and Helium production plant located on the Farm Mond van Doorn Rivier. The planned expansions will be to increase the helium and LNG production capacities significantly (~30 fold increase) and increase the footprint of the existing approved plant by approximately 10 ha;
- The drilling of new gas wells ~300 wells spread over a total study area (Cluster 2) of approximately ~27 500 ha;
- The installation of trenched pipelines connecting the wells to localised booster compressors and then to in-field compressor stations (~3 sites) and subsequently the compressor stations to the main plant area; and
- There will be a requirement to have short powerline and water connections to the compressor sites."

7.2 Stakeholder Comments

Highlighted concerns/comments from stakeholders relevant are represented and discussed in Table 7-1 below.

Table 7-1 Stakeholder considerations relevant to the report

Comment	Tetra4 EIA formal response	Specialist Response
Alien and invader plant species, all phases. (Viewed from Cluster 1)	Tetra4 has and implement an alien and invasive plant species management plan and continuously monitors and applies control measures as required. It has been noted that the areas of most concern, is areas where the background site is already predominated by these species.	Fourteen (14) IAP species listed under the Alien and Invasive Species List 2020, Government Gazette No. GN1003 as Category 1b were recorded within the project area. As per the Tetra4 response, due to the predominant land uses (agriculture), the AIP are numerous and have proliferated Due to this the infestation will require tedious and long during management and control. Any landowner is responsible for any Category 1b species within their 'property' and must be controlled by implementing an IAP Management Programme, in compliance of section 75 of the NEMBA
Disturbance of wildlife, (Construction and operational phases)	Disturbance of wildlife - to be assessed by specialist during EIA	Assuming this mainly pertains to the numerous game farm areas. Even though many of these could not be assessed due to access limitations, these will be addressed in the sections below.

Visual impact and landscape character, Vegetation.	Visual impact and landscape character, Vegetation. - to be assessed by specialist during EIA and should be noted that this is very subjective	Assuming this mainly pertains to the general landscape and not natural areas specifically, the impact in habitats and vegetation however be addressed in the sections below.

7.3 Review of Cluster 1 EIA and EMPr

The impacts and mitigation measures from Cluster 1 that are still relevant/adequate are represented and discussed in Table 7-2 below.

Table 7-2 Cluster 1 Environmental Impacts and EMPr

Ref #	Activities	Impact/ Aspect	Management/ Mitigation Measures	Suggested Amendment
2	All	Management of sensitive areas	Any drill sites or infrastructure routes located inside medium, high or very high sensitive sites on the sensitivity /constraint map require a site-specific pre-commencement assessment. The pre-commencement assessment must address the sensitive aspects on site, as identified in the overall sensitivity / constraint map. The pre-commencement assessment must be compiled by the site Environmental Officer (EO) with a suitable environmental qualification and experience. All recommendations of the pre-commencement assessment must be implemented on site. The completeness and adequacy of the pre-commencement assessment in respect of identifying and managing on site sensitivities must be included in the monthly ECO reports and annual independent audit. [Amendment 2019/05].	Plan the placement of infrastructure in such a way that areas identified as Very High are avoided. If avoidance is not possible, suitable engineering solutions must be used to traverse these areas. Development in High sensitivity areas must be minimised as much is feasible. The infrastructure should be realigned to prioritise development within very low sensitivity areas. Mitigated development in medium sensitivity areas is permissible.
9	Exploration/ Production drilling	Management of sensitive areas	Once prospective drilling sites are identified, a suitably trained EO must undertake a site-specific pre-commencement assessment to assess the site for any potential environmental sensitivities prior to commencement. Should environmental sensitivities be identified, the relevant Tetra4 Response or Action Plan Procedures must be adhered to [Amendment 2019/05].	A site walk through is recommended by a suitably qualified ecologist prior to any construction activities, preferably during the wet season and any SSC should be noted. In situations where the threatened and protected plants must be removed, the proponent may only do so after the required permission/permits have been obtained in accordance with national and provincial legislation. In the abovementioned situation the development of a search, rescue and recovery program is suggested for the protection of these species. Should animals not move out of the area on their own relevant specialists must be contacted to advise on how the species can be relocated
11	All	Management of sensitive areas	After any site-specific assessment, the Environmental Management Programme must be amended to include any site specific requirements. The site assessment must include a survey of the preferred footprint area (including access routes) to identify any potential sensitive/ red data species (flora and fauna).	
15	All	Loss of watercourse habitat	Locate pipeline/ trunkline alignments/ compressors outside of buffered watercourses (sensitive watercourse habitat) as far as possible. Buffered watercourses within proximity to the construction footprints should be demarcated on site for the entire construction process to help indicate sensitive areas and prevent unauthorized access. Unavoidable crossings should ideally be located perpendicular to the direction of flow at the shortest possible crossing distances. Long crossings along the length of wetlands, rivers and drainage lines should be avoided as far as practically possible. Aboveground pipeline watercourse crossings that are suspended on plinths are recommended as opposed to the excavation, lowering and infilling of pipelines in watercourses. Tetra4 should make provision in the design phase for permanent access tracks/ roads that will be required for the maintenance of the pipeline. A construction method statement should be prepared by the	

			contractor with input from a watercourse specialist prior to the start of construction.	
17	All	Flora and fauna direct and indirect mortality	Search and rescue of species of concern. Obtain permits for disturbance/destruction of any listed/protected species found on site. Where possible, undertake activities in previously disturbed areas and/or habitats with lower sensitivity. Where possible, locate activities on the boundaries of existing disturbance. Use existing access roads as much as possible.	Appropriate speed humps, enforcing of speed limits and mitre drains must be constructed along the access roads (every three metres of elevation) in order to slow the flow of water run-off from the road surface, if this does not already exist. Reducing the dust generated by the listed activities above, especially the earth moving machinery, through wetting the soil surface (with "dirty water") and putting up signs to enforce speed limit as well as speed bumps built to force slow speeds. Any excavations or holes must be conducted in a progressive manner. Should the holes/excavations stay open overnight they must be covered temporarily, to ensure no small fauna species fall in. • Equip open trenches with suitable ramps or steps every 50 m so that trapped animals can escape. In areas where there is high animal activity, fine-mesh fences should be laid out around the open section of trenches and secured to minimise the likelihood of animals falling in. • Conduct daily patrols to rescue any animals trapped in the pipeline trench. Schedule activities and operations during least sensitive periods, to avoid migration, nesting and breeding seasons. • Driving on access roads at night should be limited or if possible avoided in order to reduce or prevent wildlife road mortalities which occur more frequently during this period. Once the development layout has been confirmed, the open areas must be fenced off appropriately pre-construction in order to allow animals to move or be moved into these areas before breaking ground activities occur. Construction activities must take place systemically, especially in relation to the game farm areas. These particularly pertains for Game Farm Areas. The design of the proposed OHLs must be of a type or similar structure as endorsed by the Eskom-EWT Strategic Partnership on Birds and Energy, considering the mitigation guidelines recommended by Birdlife South Africa (Jenkins *et al.*, 2015). Any OHLs must be of a design that minimizes electrocution risk by using adequately insulated 'bird friendly' monopole structures, with clearances between live components of 2 m or greater. Monitoring of the OHL route must be undertaken to detect bird carcasses, to enable the identification of any potential areas of high impact to be marked with bird flappers if not already done so. Monitoring should be undertaken at least once a month for the first year of operation. OHLs, especially over the

				water resource areas, must be fitted with bird diverters throughout the whole area and not just the portions adjacent to the poles
21	Processing facilities	Decrease in surface water quality	Design and implement a site specific stormwater management plan for the compressor and helium/LNG plant that will enable dispersed release of runoff at outlets, with outlets located outside (upslope) of buffered watercourses (where possible). ensure separation of clean and dirty water and provide for adequate dirty water containment. Ensure that sufficient ablution facilities are available on site and that septic tanks are located outside of buffered watercourses. Stabilise new channels that form as a result of headcut erosion or other forms of erosion once they are recorded [Amendment 2019/05].	
30	All	Management of sensitive species	If sensitive species occur within the preferred footprint, the first option should be to relocate the proposed footprint followed by the alternative of preparing a relocation plan (prepared by a suitably qualified specialist).	
36	Exploration/ Production drilling	Water pollution and waste management	To mitigate the effluent from long term drilling sites (>3 years): Separation pits (sumps) for wastewater and grease and oil polluted fluids should be excavated and constructed to treat wastewater; Where excavating these pits, topsoil and subsoil should be stored separately; Sump areas should be lined with PVC to prevent seepage; In order to contain non-biodegradable oil and fuel spills, drip pans or PVC lining should be provided for mobile pans and drip pans; For stationary drill rigs, thin concrete slabs and/or with PVC lining should be installed before the stationary drill rigs are erected; Sump areas must be designed to accommodate the 1:100 year flood event. Clean and dirty water streams must be separated. Sump areas must be designed to accommodate the 1:100 year flood event. Clean and dirty water streams must be separated. The location and design of the sumps must be in accordance with the applicable GN 704 conditions [Amendment 2019/05]; and Sump areas should be constructed in such a way that clean water (stormwater) is diverted away from these areas. To mitigate effluent from short term drillings sites (<3 years): The topsoil layer of the surface area required for the drill should be excavated and stored according to accepted topsoil management practices; A contiguous impervious PVC layer (e.g. large silage sheets) is placed under the drill (within the excavated area) to collect any spills; Spills of hazardous substances should be collected and disposed of according to the approved EMPR requirements at a suitably licensed facility; Collected spills from the drill must not be allowed to contaminate the soils and/or the closed water system utilised for the drilling fluids; and It is recommended that where possible, closed, above ground tanks are utilised for future drilling as opposed to sumps/pits.	
37	Construction areas	Stormwater control and management	All clean water should be diverted away from the site. Minimize the area that is disturbed during production activities in order to minimize the potential stormwater disturbance and to reduce the sediment loads to receiving water courses. Adequate drainage and erosion protection in the form of cut-off berms or trenches should be provided where necessary.	Keep the surface & sub-surface water as well as storm water away that may run off from the construction areas from the low laying areas, such as drainage lines as well as the surrounding areas, from leaving the project area in an uncontrolled manner.

38	All	Noise, vibration, visual and dust impacts	The contractor must prevent labourers form loitering in the area and causing noise disturbance. Ensure that all equipment is in a good working condition to ensure that no additional noise is admitted from them. Light impact should be kept to a minimum (e.g. use of full cut-off lighting fixtures if necessary). Retain vegetation were possible to maintain its natural noise and visual screening function. Reduce speed limit on gravel roads to reduce noise generation.	Noise must be kept to an absolute minimum during the evenings and at night to minimize all possible disturbances to amphibian species and nocturnal mammals. Outside lighting should be designed and limited to minimize impacts on fauna. Fluorescent and mercury vapor lighting should be avoided and sodium vapor (yellow) lights should be used wherever possible.
42	All	Loss / destruction of natural habitat	Where possible, locate infrastructure in previously disturbed places and/or habitats with a lower sensitivity score. Rehabilitate disturbed areas as soon as possible. Control alien plants.	The areas to be developed must be specifically demarcated to prevent movement into surrounding environments, especially wetlands and watercourses. Areas of indigenous vegetation, even secondary communities outside of the direct project footprint, should under no circumstances be fragmented or disturbed further. Clearing of vegetation should be minimized and avoided where possible.
48	All	Disruption of aquatic communities	Ideally, no vehicle access tracks/roads should transect through watercourses. Access tracks/roads should be designed in such a way to minimise overlap with watercourses. Use existing access roads/tracks as far as possible. Construction and unavoidable access tracks/roads through wetlands, rivers and other watercourses must provide habitat connectivity between upstream and downstream reaches (e.g. flume pipes and/or culverts) and to reduce the risk of scour erosion and channel incision within the watercourse. . No unauthorised driving should be allowed through watercourses. Driving can only occur on specially designed tracks/roads that minimised the risk of erosion and surface flow concentration. No perched flumes should be present in temporary construction running tracks and/or permanent access tracks. In the case of aboveground pipelines, the pipeline should not be located 'flush' along the surface profile of the watercourse with no gap between the natural ground level and the pipeline. Aboveground pipelines should rather be suspended on plinths of a sufficient height that will allow the free movement of indigenous fauna present within the study area, such as tortoises, as recorded in the Bosluisspruit channel near existing well SPG3.	
49	All	Watercourse erosion	Prevent the use of only one or two flume pipes in access/running tracks located in watercourses, specifically unchannelled valley bottom wetland and seep wetlands where concentrated flows can result in headcut development and the formation of a channel. Surface flows should also be spread out in channelled watercourse crossings though the use of several flume pipes to prevent channel incision and scour erosion. Access tracks should be maintained during the entire construction process and removed once construction is completed. Flume pipes should be monitored and kept free of blockages. Construction in watercourses should ideally occur during the dry season. Any new erosion features identified should be stabilised during the construction process (soft interventions such as hay bales, rock packs, runoff control berms and 'bio-socks' are recommended). Erosion control features should be maintained. Keep vegetation clearing to a minimum on the adjacent slopes to prevent erosion on approaches bordering watercourses. Small temporary contour	

			berms may be used to help control runoff on approaches should it be required. Drainage furrows that may be required to create dry working conditions should ideally be avoided as they can easily erode during high flow events. Development of a watercourse monitoring plan before the onset of the construction phase, and the development and implementation of a watercourse rehabilitation plan during the latter half of the construction phase to ensure the eroded wetlands and other watercourses are stabilised and rehabilitated. Dewatering discharges at construction sites should be done in a silt bay to prevent erosion and sedimentation in adjacent watercourses. Runoff from the construction footprint should be controlled on site to prevent concentrated point releases of water into downslope watercourses. Care needs to be taken not to initiate or aggravate erosion in watercourses.	
50	All	Noise impacts from construction activities	The use of smaller/quieter equipment when operating near receptors. Ensuring that equipment is well maintained and fitted with the correct and appropriate noise abatement measures. Engine bay covers over heavy equipment could be pre-fitted with sound absorbing material. Heavy equipment that fully encloses the engine bay should be considered, ensuring that the seam gap between the hood and vehicle body is minimised. Where possible only undertake construction activities during the day. If night-time activities are required, do not operate closer than 500 m from any sensitive receptors. Ensure a good working relationship between the developer and all potentially noise-sensitive receptors. Communication channels should be established to ensure prior notice to the sensitive receptor if work is to take place close to them (especially if work is to take place within 500 m from them at night). Information that should be provided to potentially sensitive receptor(s) includes: Proposed working dates, the duration that work will take place in an area, and working times; The reason why the activity is taking place; The construction methods that will be used; and Contact details of a responsible person where any complaints can be lodged should there be an issue of concern. When simultaneous noise emitting activities are to take place close to potential noise-sensitive receptors, co-ordinate the working time with periods when the receptors are not at home.	
53	All	Establishment of informal settlements close to the project area	No informal settlers should be allowed on private property within the development area. If any person erects an illegal structure the landowner and police should be informed immediately and asked to remove the structure.	
56	Exploration/ Production drilling	Spillage of oils, fuel and chemicals	The placement of drip trays under the drilling rigs should be implemented and recorded to minimize the contamination of waste oil from the drilling rig. Drilling fluids should be biodegradable and should be kept in a lined mud pit or surface container. Proper rehabilitation and off site removal of excess fluids should take place. Oil recovered from the drilling rigs and any vehicle on site should be collected, stored and disposed of at licenced facilities or provided to accredited vendors for recycling.	A hydrocarbon spill management plan must be put in place to ensure that should there be any chemical spill out or over that it does not run into the surrounding areas. The Contractor shall be in possession of an emergency spill kit that must always be complete and available on site. Drip trays or any form of oil absorbent material must be placed underneath vehicles/machinery and equipment when not in use. No servicing of equipment on site unless necessary. All contaminated soil / yard stone shall be treated in situ or

				removed and be placed in containers. Appropriately contain any generator diesel storage tanks, machinery spills (e.g., accidental spills of hydrocarbons oils, diesel etc.) in such a way as to prevent them leaking and entering the environment.
57	All	Increased soil erosion	Ensure that topsoil (0-30 cm approx.) and subsoil (30 cm +) are stored separately during excavation, so they can be replaced in the correct order. Ensure that pipeline route is re-vegetated as soon as possible after construction and that soil surface is in good condition.	
62	All	Blockage of floral and faunal seasonal and dispersal movements	Where possible, undertake activities in previously disturbed areas and/or habitats with lower sensitivity. Where possible, locate activities on the boundaries of existing disturbance. Use existing access roads as much as possible. Rehabilitate disturbed areas as soon as possible.	
63	All	Pollution of wetland habitats	Control all waste sources emanating from proposed activities. Maintain minimum distances from aquatic and wetland habitats, where possible. Undertake activities in previously disturbed areas and/or habitats with lower sensitivity.	
64	All	Decrease in surface water quality in watercourses	Store all hazardous materials (Incl. hydrocarbons) in a bunded area, outside of buffered watercourses. Stripped and excavated subsoil and topsoil stockpiles should be stored outside of buffered wetland areas and be protected from erosion. This may not be possible for long wetland crossings in seep and other wetlands, in which case topsoil can be stored on low berms within the wetland on geotextile material. Topsoil and subsoil should however be protected from erosion. Approaches that border watercourses, particularly those along steep and long slopes, should receive runoff control measures to prevent siltation and concentrated flow into watercourses. Inspect vehicles for leaks and repair all leaks immediately. Any generators used in watercourses should be used with a functional drip tray. Ensure that sufficient ablution facilities are available on site and that they are located outside of buffered watercourses. Stabilise new channels that form as a result of headcut erosion or other forms of erosion once they are recorded. Sediment deposition should be prevented in watercourses and especially watercourse channels through the following measures: Implementing stormwater control measures around construction areas; and Dewatering during excavation activities in watercourses should be released in a silt bay with sufficient capacity that filters and retains sediment before the water is released into the watercourses. Sediment deposition events into watercourses should be evaluated by an experienced ECO/ wetland specialist and based on the magnitude of the impact recommendations can be made regarding the removal of deposited material.	
71	All	Displacement of faunal species	Where possible, undertake activities in previously disturbed places and/or habitats with a lower sensitivity score. Rehabilitate disturbed areas as soon as possible.	The duration of the construction should be minimized to as short term as possible, to reduce the period of disturbance on fauna

				• The schedule and progression of the construction work must be planned and designed in a manner in which any area is only disrupted for a short period
72	All	Increase in poaching incidents	If areas are fenced, the fences must be checked for snares on a daily basis for the duration of the construction period. All incidences must be reported to the closest police station. Anti-poaching toolbox talks should form part of the induction process of all the fencing teams. Any contractor or employee caught poaching should be removed from site.	
75	All	Watercourse erosion	Use existing access roads as far as possible. Unavoidable new permanent access roads/tracks in watercourses should be designed to prevent erosion downstream of the crossings by using several flume pipes, preferably culverts, or other structures, such as concrete fords. All temporary and permanent vehicle access tracks/roads in watercourses will require approval from DWS in the form of a Water Use License. New permanent access roads/tracks should be located along existing infrastructure footprints as far as possible and at areas that will enable the shortage crossing distance through watercourses. Long crossings along the length of watercourses (parallel to its flow direction) should be avoided. Remnant erosion features that remain after the rehabilitation phase should be addressed until full rehabilitation and closure is achieved. Rehabilitation interventions should be considered with care and not worsen erosion once implemented [Amendment 2019/05]. Identified permanent access tracks should be maintained during the entire operational phase of the project and blockages should be removed, while erosion features should be repaired once observed. Concrete fords (low water bridges) are preferred as crossing structures in larger watercourse channels, compared to culverts and flume pipes, which are more likely to result in erosion and require more regular maintenance. The Helium plant should receive stormwater mitigation measures at its outlets that will prevent concentrated flow. Stormwater mitigation measures and flow outlets should be located outside of buffered watercourses.	
77	Exploration/ Production drilling and Processing facilities	Pollution prevention and usage of water sources	All contaminated water and spillage will be drained from the containment area into primary and secondary fully lined sumps. Drilling water should be kept in closed circuit and re-circulated to the drilling machine. Water condensate from the gas polishing process (Dehydration) should be treated to remove volatile compounds, before evaporation. Make up water will be introduced when required. All domestic effluent water from the site should be collected and disposed of in an appropriate and legal manner such as a French drain system which is situated not closer than 100 metres from any streams, rivers, pans, dams or boreholes. Do not exceed the water abstraction permit and General Authorisation (GA) limits for water use for drilling activities. All LNG processing facilities and storage vessels must include adequate (at least 110% containment volume) secondary liquid containment areas (e.g. bunds). [Amendment 2019/05].	

82	Exploration/ Production drilling	Contamination from leakage and spillage	The pipeline needs to be inspected regularly to find and fix any leakages. A water quality monitoring plan needs to be produced and implemented to determine any changes in the water quality. Any water (Incl. condensate) generated at the conventional and unconventional well heads need to be captured in some form of dirty water storage facility. This water can be tested and treated (if needed) and used for irrigation or discharge into the environment if found to be suitable. Should the water be found to be unsuitable for irrigation or discharge into the environment, the contaminated water will be disposed of at a suitable licenced facility.	
83	All	Pollution of habitats	Control all waste sources emanating from operations activities. A defined waste management system must be implemented according to the hierarchy of waste management (avoid, reduce, reuse, recycle, dispose). All wastes generated must be stored and disposed of according to relevant legal requirements.	
85	Exploration/ Production drilling	Contamination from leakage and spillage	All wells should be capped to prevent the spilling of contaminated groundwater. The water quality monitoring plan should be implemented in this phase to monitor any deterioration of the water quality.	
89	All	Environmental Awareness	All personnel should undergo environmental awareness and induction training. A register should be kept of all attendees. Toolbox talks should be scheduled to ensure continuous environmental awareness training. Emergency procedures should be communicated and displayed prominently on the site. A copy of the EMPr should be available on the work site at all times. Appointed sub-contractors must be made aware of their obligations under this EMPr.	
91	All	Management of flora and fauna	Vegetation should be retained as far as possible. Establish an alien invasive plant eradication programme for the control of weed species. This must be monitored for a period of time following rehabilitation to ensure that alien invasive plants do not establish themselves. Unnecessary damage or disturbance to vegetation should be prevented. No trees or shrubs should be felled or damaged for the purpose of obtaining firewood, unless otherwise agreed to with the landowner. Areas outside the footprint (including all infrastructure) should be considered as no-go areas. No faunal species are allowed to be purposefully killed. Any potential protected or sensitive areas should be clearly demarcated and noted as no-go areas.	
93	All	Water abstraction	The necessary DWS permits should be obtained if it is expected that DWS abstraction limits will be triggered before water abstraction is undertaken. Obtain agreement from landowner to abstract water from existing boreholes. If required, abstraction of water should be kept within the permit limits as issued to the landowner by DWA. Water may only be obtained from approved sources. [Amendment 2019/05].	
101	All	Habitat fragmentation and edge effects	Undertake activities in previously disturbed areas and/or habitats with lower sensitivity where possible. Locate activities on the boundaries of existing disturbance where possible. Use existing access roads as much as possible. Rehabilitate disturbed areas as soon as possible.	

102	All	Loss of watercourse habitat/ Alterations of the river banks and river bed	Locate pipeline/trunkline alignments outside of buffered watercourses (sensitive watercourse habitat) as far as possible. Buffered watercourses should be demarcated on site for the entire construction process to help indicate sensitive areas and prevent unauthorised access. Mitigation for pipeline construction primarily includes the avoidance of watercourse crossings. Where crossings are unavoidable, crossings should be located along existing infrastructure features, such as roads, dam walls and existing pipelines. Unavoidable crossings should ideally be located perpendicular to the direction of flow at the shortest possible crossing distances. Long crossings along the length of wetlands, rivers and drainage lines should be avoided as far as practically possible. Horizontal directional drilling is recommended for the Sand River and Bosluisspruit crossings, as opposed to the clearing, temporary damming, excavation, lowering and infilling of pipelines in these river watercourses. Vegetation clearing, topsoil stripping, trenching and infilling to bury the pipeline, are considered to be an acceptable approach in other types of watercourse crossings. The construction servitude should however not remain bare (stripped for longer than a month at a time), while trenches should not remain open for more than five days. It is therefore recommended that the pipeline be completely constructed in sections, rather than removing all of the topsoil and creating open trenches across the entire study area for prolonged periods of time. The servitude width should be restricted in watercourse crossings to reduce the footprint of the impact. Topsoil material should only be stripped in the area where trench excavation is required, while the surrounding area in the servitude is only cleared of vegetation. Limited topsoil stripping is conditional on the prevention of soil compaction by heavy motorised vehicles (HMVs) through the use and maintenance of running tracks. Examples of running tracks include bogmats or rock aggregate combined with geotextile fabric and flume pipes. Alternatively topsoil across the entire width of the construction servitude (often referred to as the right of way) can be stripped and stored separately outside of buffered watercourses. Removed topsoil and subsoil should be sorted separately in stockpiles and protected from erosion when required. Additional erosion protection measures should be implemented for stockpiles that are to be stored for an extended duration [Amendment 2019/05].	
103	All	Loss of watercourse habitat/ Alterations of the river banks and river bed	A construction method statement should be prepared by the contractor prior to the start of construction. Conditions stated in the water use license should also be implemented. The use of old and new quarry sites for bedding and padding material, as well as other needs (e.g. the discard of spoil material) should not be located within wetlands and other watercourse types. Watercourse crossings and construction methods affecting watercourse must comply with the approved water use licence and associated DWS approved method statements [Amendment 2019/05]. The use of sites outside the study are will also be subject to environmental authorisation. Provision should be	

			made in the design phase for permanent access tracks/roads that will be required for the maintenance of the pipeline. After completion of the construction phase, the reinstatement of the original topography of the watercourse (its geomorphological template) should be undertaken followed by re-vegetation activities. The following mitigation measures are recommended: Limit the construction activities to the smallest area possible; Reinstate the geomorphological template of the watercourse crossing using subsoil material, followed by topsoil material on top. This should be done as soon as possible after completion of construction activities; During the reinstatement of watercourse profiles to the pre-construction profile, entrenched gullies and channels may have to be cut back to create a lower gradient that will not be susceptible to erosion; Once the crossing has been shaped and topsoil reintroduced to stripped areas, biojute can be applied according to specification to avoid rill formation and undercutting below biojute material. During the start of the growing season the annual grass *Eragrostis tef* can be introduced through manual broadcasting on reinstated watercourse surfaces. Rehabilitated areas within watercourse boundaries must be protected from overgrazing. Protection methods must be identified in consultation with the respective landowners [Amendment 2019/05].	
108	All	Encroachment/ invasion of alien plants (specifically into watercourses)	Restrict the clearing of watercourse vegetation as far as possible. Areas that have been cleared should be re-vegetated with indigenous species or other suitable plant species, such as *Eragrostis tef*, after construction and initial rehabilitation work (reinstatement of the geomorphological template) is completed. Compile and implement an alien plant control program with a particular focus on alien control in watercourses (including wetlands) during the rehabilitation phase of the project. Rehabilitate disturbed areas as soon as possible. Restrict new footprints to disturbed areas as far as possible. Regular monitoring should be undertaken in the watercourses to check any possible invasion by alien vegetation so that they can be weeded out before they grow and spread out.	

7.4 Biodiversity Risk Assessment

7.4.1 Impact Assessment Considerations and Procedure

The project activities will have a negative effect on the natural environment of the area. Anthropogenic activities drive habitat destruction leading to the displacement of fauna and flora and possibly causing direct mortality. Land clearing destroys local wildlife habitat and can lead to the loss of local breeding grounds, foraging and nesting sites, and wildlife movement corridors such as rivers, streams and drainage lines, or other locally important features. The removal of natural vegetation is likely to reduce the habitat available for all types of fauna species and hence reduce animal populations and species compositions within the area.

The additional impacts associated with the proposed activities, which weren't considered covered in the existing approved Cluster 1 EIA and EMPr, are considered in this section. The first additional impact that was not considered, was the impact to the recorded Sungazer (*Smaug giganteus*). In the context of Cluster 1, the species was not recorded, even though the project areas overlap (Figure 7-1).

Figure 7-1 Illustration of the project area from Cluster 1 (left) and Cluster 2 (right). Red circle indicates area overlap for Cluster 1

The species environmental guidelines SANBI (2020) indicate that specific directives contained within a Biodiversity Management Plan (BMP) must take precedence as mitigation measures. According to the guidelines, SANBI (2020), there is a BMP currently in development for the IUCN VU Sungazer (*Smaug giganteus*) that specifically states that: 'Destruction of intact habitat with extant Sungazer populations is not permitted'. Therefore, avoidance mitigation and not minimisation mitigation would be applicable in such a case. Additionally, the protocols advise a minimum buffer of 250 meters, to up to 400 m buffer to be applied around the periphery of Sungazer colonies, which in this case represent the Very High sensitivity area. There are no mitigation measures that can described in this report that will reduce the significance of the risk to an acceptable level, and hence no impact significance rating will be conducted. The development within these Very High Sensitivity areas is considered 'No-Go". In order to guide the development, mitigations regarding the species can be seen in Table 7-3 below

Table 7-3 Mitigations for Sensitive species

Activities	Impact/ Aspect	Management/ Mitigation Measures
All	Management of sensitive area.	Very High sensitivity area to be avoided and declared a No-go area. The Medium and High sensitivity area in relation to this area must be avoided, as these act as buffers for the population. If possible, all livestock (including cattle, pigs, goats, domestic dogs and cats) must be kept out of the area at all times.
All	Loss / destruction of natural habitat	The areas to be developed must be specifically demarcated to prevent movement into surrounding environments, especially grassland surrounding the Very High Sensitivity area. Areas of indigenous vegetation, even secondary communities outside of the direct project footprint, should under no circumstances be fragmented or disturbed further. Clearing of vegetation should be minimized and avoided where possible.

All	Fauna direct and indirect mortality. Possibility of poaching incidents	Any and all information within this report and additional reports pertaining to the locality of the species, must not divulged or made available to the public. Due to the sensitivity of this species, especially in regard to its illegal collection, no locality data should be displayed or provided to the public. Any person during the application process should treat the information with the necessary confidentially. Any large lizard mortalities should be cross checked to confirm the identification. Traffic and car movement
All	Environmental Awareness	All personnel should undergo environmental awareness and induction training regarding the species and their sensitivity. Stakeholder engagement with landowners must be conducted to assist in the presence/absence of the species Sungazer (Smaug giganteus) or “Ou Volk”.
All, Especially Planning Phase	Management of fauna	Consultation and communication with the lead or implementing agent for the species, Endangered Wildlife Trust (EWT), must be implemented before any construction within or close to the specific area. Monitoring and Management of the species will be crucial throughout the lifetime of the project and must be discussed and implemented by the EWT.

The second additional impacts pertain to the 33kV and 132kV powerlines. The powerlines in relation to the biodiversity sensitivity can be seen in Figure 7-2 and Figure 7-3. From a biodiversity perspective, the main concern for the activity pertains to water resources, as most of the area is very low sensitivity. All mitigation regarding linear infrastructure, especially in relation to water resources, thus apply, including the suggested amendments.

Figure 7-2 Illustration of the 33kV powerline in relation to the sensitivity.

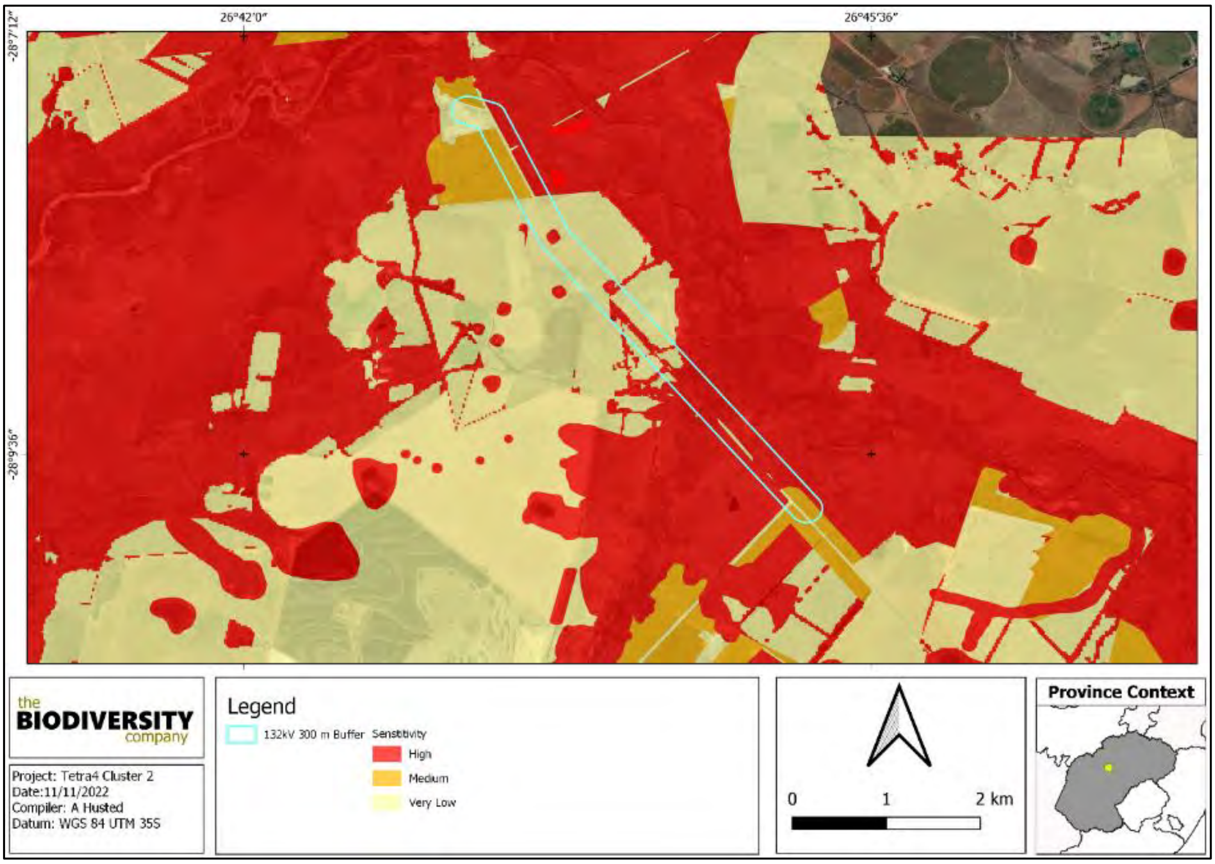


Figure 7-3 Illustration of the 132kV powerline in relation to the sensitivity.

8 Conclusion

The aim of this Biodiversity Assessment was to provide information to guide the risk of the proposed activity to the ecosystems and their inherent fauna and flora within the project area.

Based on the latest available ecologically relevant spatial datasets, the following information is pertinent to the degraded and water resource habitats in the project area:

- It is recognised as a CBA 1 and ESA 1& 2 as per the Free State Conservation Plan; and
- Categorised as intact constituents of an EN ecosystem or CR river as identified by the National Biodiversity Assessment.

The ecological integrity, importance, and functioning of these terrestrial biodiversity areas provide a variety of ecological services that are considered beneficial, with one key service being the maintenance of biodiversity. The preservation of these systems is the most important aspect to consider for the proposed project. Thus, if these areas are not maintained in a natural or near natural state, destroyed or fragmented, then meeting targets for biodiversity features will not be achieved.

Observation and species records during the field survey denote that certain habitats within the assessment area were utilised by threatened flora and fauna species, comprising of:

- One flora species;
- Four (4) avifaunal species;
- Three (3) mammal species;
- One (1) reptile species; and
- One (1) amphibian species.

The completion of a comprehensive desktop study, in conjunction with the results from the field survey, suggest there is a high confidence in the information provided. The survey ensured that there was a suitable groundtruth coverage of the assessment area and major habitats and ecosystems were assessed to obtain a general species (fauna and flora) overview and the major current impacts were observed.

The developer is urged to provide a layout or design which represents a compromise between the needs of the development and the environmental concerns at the site, especially in regard to the very high/high sensitivity areas. A potential suggested alternative could be to make use of the existing agricultural areas within the surrounds.

The existence and importance of these habitats is regarded as crucial, due to the fauna species recorded as well as the role of this intact unique habitat to biodiversity within a very fragmented and disturbed local landscape, not to mention the sensitivity according to various ecological datasets.

8.1 Recommendations

The following recommendation are provided to ensure that the ecosystem and biodiversity is adequately protected:

- A follow up survey to more accurately determine the population size and extent of *Smaug giganteus* (Sungazer/Giant Dragon Lizard) is strongly recommened.

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10 Appendices

10.1 Appendix A Specialist declarations

DECLARATION

I, Martinus Erasmus, declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Martinus Erasmus

Terrestrial Ecologist

The Biodiversity Company

May 2022

DECLARATION

I, Lindi Steyn, declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Lindi Steyn

Terrestrial Ecologist

The Biodiversity Company

May 2022

DECLARATION

I, Andrew Husted, declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Andrew Husted

Wetland Ecologist

The Biodiversity Company

May 2022

10.2 Appendix B Flora species expected in the project area and surrounds

Family	Taxon	Author	IUCN	Ecology
Malvaceae	*Abutilon galpinii*	A.Meeuse	LC	Indigenous
Malvaceae	*Abutilon sp.*			
Cucurbitaceae	*Acanthosicyos naudinianus*	(Sond.) C.Jeffrey	LC	Indigenous
Amaranthaceae	*Achyranthes aspera var. aspera*	L.		Not indigenous; Naturalised
Amaranthaceae	*Achyranthes aspera var. sicula*	L.		Indigenous
Cyperaceae	*Afroscirpoides dioeca*	(Kunth) Garcia-Madr.		Indigenous; Endemic
Poaceae	*Agrostis lachnantha var. lachnantha*	Nees	LC	Indigenous
Amaranthaceae	*Alternanthera sessilis*	(L.) DC.		Not indigenous; Naturalised; Invasive
Amaranthaceae	*Amaranthus hybridus subsp. hybridus*	L.		Not indigenous; Naturalised
Amaranthaceae	*Amaranthus thunbergii*	Moq.	LC	Indigenous
Anacampserotaceae	*Anacampseros filamentosa subsp. filamentosa*	(Haw.) Sims		Indigenous; Endemic
Anacampserotaceae	*Anacampseros ustulata*	E.Mey. ex Fenzl	LC	Indigenous; Endemic
Boraginaceae	*Anchusa riparia*	A.DC.	LC	Indigenous; Endemic
Poaceae	*Andropogon appendiculatus*	Nees	LC	Indigenous
Poaceae	*Andropogon schirensis*	Hochst. ex A.Rich.	LC	Indigenous
Poaceae	*Anthephora pubescens*	Nees	LC	Indigenous
Rubiaceae	*Anthospermum sp.*			
Menispermaceae	*Antizoma angustifolia*	(Burch.) Miers ex Harv.	LC	Indigenous; Endemic
Aponogetonaceae	*Aponogeton junceus*	Lehm.	LC	Indigenous
Scrophulariaceae	*Aptosimum elongatum*	(Hiern) Engl.	LC	Indigenous; Endemic
Asteraceae	*Arctotis stoechadifolia*	P.J.Bergius	LC	Indigenous; Endemic
Poaceae	*Aristida adscensionis*	L.	LC	Indigenous
Poaceae	*Aristida bipartita*	(Nees) Trin. & Rupr.	LC	Indigenous
Poaceae	*Aristida canescens subsp. canescens*	Henrard	LC	Indigenous
Poaceae	*Aristida congesta subsp. barbicollis*	Roem. & Schult.	LC	Indigenous
Poaceae	*Aristida congesta subsp. congesta*	Roem. & Schult.	LC	Indigenous
Poaceae	*Aristida diffusa subsp. burkei*	Trin.	LC	Indigenous
Poaceae	*Aristida junciformis subsp. junciformis*	Trin. & Rupr.	LC	Indigenous; Endemic
Poaceae	*Aristida meridionalis*	Henrard	LC	Indigenous
Poaceae	*Aristida stipitata subsp. graciliflora*	Hack.	LC	Indigenous
Asteraceae	*Artemisia afra var. afra*	Jacq. ex Willd.	LC	Indigenous
Apocynaceae	*Asclepias meyeriana*	(Schltr.) Schltr.	LC	Indigenous; Endemic
Asparagaceae	*Asparagus laricinus*	Burch.	LC	Indigenous
Asparagaceae	*Asparagus setaceus*	(Kunth) Jessop	LC	Indigenous
Asparagaceae	*Asparagus suaveolens*	Burch.	LC	Indigenous

Apocynaceae	*Aspidoglossum interruptum*	(E.Mey.) Bullock	LC	Indigenous
Aspleniaceae	*Asplenium adiantum-nigrum var. adiantum-nigrum*	L.	LC	Indigenous
Aspleniaceae	*Asplenium aethiopicum*	(Burm.f.) Bech.	LC	Indigenous
Aspleniaceae	*Asplenium capense*	(Kunze) Bir, Fraser-Jenk. & Lovis	LC	Indigenous
Asteraceae	*Aster sp.*			
Amaranthaceae	*Atriplex nummularia subsp. nummularia*	Lindl.		Not indigenous; Naturalised; Invasive
Amaranthaceae	*Atriplex semibaccata*	R.Br.		Not indigenous; Naturalised; Invasive
Amaranthaceae	*Atriplex suberecta*	I.Verd.	LC	Not indigenous; Naturalised; Invasive
Iridaceae	*Babiana hypogaea*	Burch.	LC	Indigenous
Acanthaceae	*Barleria macrostegia*	Nees	LC	Indigenous
Amaranthaceae	*Bassia indica*	(Wight) A.J.Scott		Not indigenous; Naturalised
Elatinaceae	*Bergia sp.*			
Asteraceae	*Berkheya onopordifolia var. onopordifolia*	(DC.) O.Hoffm. ex Burtt Davy	LC	Indigenous; Endemic
Asteraceae	*Berkheya pinnatifida subsp. stobaeoides*	(Thunb.) Thell.	LC	Indigenous; Endemic
Asteraceae	*Bidens pilosa*	L.		Not indigenous; Naturalised
Acanthaceae	*Blepharis squarrosa*	(Nees) T.Anderson	LC	Indigenous; Endemic
Fabaceae	*Bolusia acuminata*	(DC.) Polhill	LC	Indigenous; Endemic
Amaryllidaceae	*Boophone disticha*	(L.f.) Herb.	LC	Indigenous
Poaceae	*Brachiaria eruciformis*	(Sm.) Griseb.	LC	Indigenous
Poaceae	*Brachiaria nigropedata*	(Ficalho & Hiern) Stapf	LC	Indigenous
Poaceae	*Brachiaria serrata*	(Thunb.) Stapf	LC	Indigenous
Poaceae	*Bromus catharticus*	Vahl	NE	Not indigenous; Naturalised; Invasive
Poaceae	*Bromus leptoclados*	Nees	LC	Indigenous
Poaceae	*Bromus sp.*			
Amaryllidaceae	*Brunsvigia radulosa*	Herb.	LC	Indigenous; Endemic
Bryaceae	*Bryum argenteum*	Hedw.		Indigenous
Bryaceae	*Bryum dichotomum*	Hedw.		Indigenous
Asphodelaceae	*Bulbine abyssinica*	A.Rich.	LC	Indigenous
Asphodelaceae	*Bulbine narcissifolia*	Salm-Dyck	LC	Indigenous; Endemic
Cyperaceae	*Bulbostylis hispidula subsp. pyriformis*	(Vahl) R.W.Haines	LC	Indigenous
Apiaceae	*Bupleurum mundtii*	Cham. & Schltdl.	LC	Indigenous; Endemic
Fabaceae	*Calpurnia sericea*	Harv.	LC	Indigenous; Endemic
Cyperaceae	*Carex glomerabilis*	V.I.Krecz.	LC	Indigenous; Endemic
Cyperaceae	*Carex spartea*	Wahlenb.		Indigenous
Cyperaceae	*Carex uhligii*	K.Schum. ex C.B.Clarke		Indigenous
Cannabaceae	*Celtis africana*	Burm.f.	LC	Indigenous
Poaceae	*Cenchrus sphacelatus*	(Nees) Morrone	LC	Indigenous
Apocynaceae	*Ceropegia differens subsp. grata*	Bruyns		Indigenous; Endemic

Solanaceae	*Cestrum aurantiacum*	Lindl.		Not indigenous; Naturalised; Invasive
Scrophulariaceae	*Chaenostoma neglectum*	J.M.Wood & M.S.Evans	LC	Indigenous; Endemic
Scrophulariaceae	*Chaenostoma patrioticum*	(Hiern) Kornhall	LC	Indigenous; Endemic
Verbenaceae	*Chascanum pinnatifidum var. pinnatifidum*	(L.f.) E.Mey.	LC	Indigenous
Aizoaceae	*Chasmatophyllum musculinum*	(Haw.) Dinter & Schwantes	LC	Indigenous; Endemic
Pteridaceae	*Cheilanthes eckloniana*	(Kunze) Mett.	LC	Indigenous
Poaceae	*Chloris gayana*	Kunth	LC	Indigenous
Poaceae	*Chloris pycnothrix*	Trin.	LC	Indigenous
Poaceae	*Chloris virgata*	Sw.	LC	Indigenous
Apiaceae	*Choritaenia capensis*	Benth.	LC	Indigenous; Endemic
Asteraceae	*Chrysocoma sp.*			
Asteraceae	*Cirsium vulgare*	(Savi) Ten.		Not indigenous; Naturalised; Invasive
Cleomaceae	*Cleome rubella*	Burch.	LC	Indigenous
Peraceae	*Clutia natalensis*	Bernh.	LC	Indigenous; Endemic
Peraceae	*Clutia pulchella var. pulchella*	L.	LC	Indigenous
Commelinaceae	*Commelina africana var. africana*	L.	LC	Indigenous
Commelinaceae	*Commelina africana var. lancispatha*	L.	LC	Indigenous
Commelinaceae	*Commelina livingstonii*	C.B.Clarke	LC	Indigenous
Commelinaceae	*Commelina subulata*	Roth	LC	Indigenous
Nyctaginaceae	*Commicarpus pentandrus*	(Burch.) Heimerl	LC	Indigenous
Convolvulaceae	*Convolvulus boedeckerianus*	Peter	LC	Indigenous; Endemic
Asteraceae	*Conyza podocephala*	DC.		Indigenous; Endemic
Malvaceae	*Corchorus aspleniifolius*	Burch.	LC	Indigenous
Malvaceae	*Corchorus schimperi*	Cufod.	LC	Indigenous
Apocynaceae	*Cordylogyne globosa*	E.Mey.	LC	Indigenous; Endemic
Rubiaceae	*Cordylostigma virgatum*	(Willd.) Groeninckx & Dessein		Indigenous
Caryophyllaceae	*Corrigiola litoralis subsp. litoralis*	L.	NE	Indigenous
Asteraceae	*Cotula anthemoides*	L.	LC	Indigenous; Endemic
Acanthaceae	*Crabbea angustifolia*	Nees	LC	Indigenous; Endemic
Acanthaceae	*Crabbea hirsuta*	Harv.	LC	Indigenous
Asteraceae	*Crassothonna protecta*	(Dinter) B.Nord.	LC	Indigenous; Endemic
Crassulaceae	*Crassula corallina subsp. corallina*	Thunb.	LC	Indigenous; Endemic
Crassulaceae	*Crassula lanceolata subsp. transvaalensis*	(Eckl. & Zeyh.) Endl. ex Walp.	LC	Indigenous
Crassulaceae	*Crassula nudicaulis var. nudicaulis*	L.	LC	Indigenous; Endemic
Crassulaceae	*Crassula sp.*			
Crassulaceae	*Crassula tabularis*	Dinter	LC	Indigenous; Endemic
Fabaceae	*Crotalaria burkeana*	Benth.	LC	Indigenous

Fabaceae	*Crotalaria sphaerocarpa subsp. sphaerocarpa*	Perr. ex DC.	LC	Indigenous
Fabaceae	*Crotalaria virgulata subsp. grantiana*	Klotzsch	LC	Indigenous
Cucurbitaceae	*Cucumis myriocarpus subsp. myriocarpus*	Naudin	LC	Indigenous
Asteraceae	*Curio radicans*	(L.f.) P.V.Heath	LC	Indigenous; Endemic
Convolvulaceae	*Cuscuta campestris*	Yunck.		Not indigenous; Naturalised; Invasive
Araliaceae	*Cussonia paniculata subsp. sinuata*	Eckl. & Zeyh.	LC	Indigenous; Endemic
Commelinaceae	*Cyanotis speciosa*	(L.f.) Hassk.	LC	Indigenous
Amaranthaceae	*Cyathula uncinulata*	(Schrad.) Schinz	LC	Indigenous
Poaceae	*Cymbopogon caesius*	(Hook. & Arn.) Stapf	LC	Indigenous
Poaceae	*Cymbopogon marginatus*	(Steud.) Stapf ex Burtt Davy	LC	Indigenous; Endemic
Poaceae	*Cymbopogon pospischilii*	(K.Schum.) C.E.Hubb.	NE	Indigenous
Apocynaceae	*Cynanchum viminale subsp. viminale*	(L.) L.		Indigenous
Poaceae	*Cynodon dactylon*	(L.) Pers.	LC	Indigenous
Poaceae	*Cynodon incompletus*	Nees	LC	Indigenous; Endemic
Poaceae	*Cynodon transvaalensis*	Burtt Davy	LC	Indigenous
Cyperaceae	*Cyperus capensis*	(Steud.) Endl.	LC	Indigenous; Endemic
Cyperaceae	*Cyperus decurvatus*	(C.B.Clarke) C.Archer & Goetgh.	LC	Indigenous; Endemic
Cyperaceae	*Cyperus denudatus*	L.f.	LC	Indigenous
Cyperaceae	*Cyperus difformis*	L.	LC	Indigenous
Cyperaceae	*Cyperus eragrostis*	Lam.		Not indigenous; Naturalised
Cyperaceae	*Cyperus esculentus var. esculentus*	L.	LC	Indigenous
Cyperaceae	*Cyperus fastigiatus*	Rottb.	LC	Indigenous; Endemic
Cyperaceae	*Cyperus laevigatus*	L.	LC	Indigenous
Cyperaceae	*Cyperus longus var. tenuiflorus*	L.	NE	Indigenous
Cyperaceae	*Cyperus marginatus*	Thunb.	LC	Indigenous
Cyperaceae	*Cyperus semitrifidus*	Schrad.	LC	Indigenous; Endemic
Cyperaceae	*Cyperus usitatus*	Burch.	LC	Indigenous
Lobeliaceae	*Cyphia triphylla*	E.Phillips	LC	Indigenous; Endemic
Amaranthaceae	*Cyphocarpa angustifolia*	(Moq.) Lopr.	LC	Indigenous
Poaceae	*Dactyloctenium aegyptium*	(L.) Willd.	LC	Indigenous
Aizoaceae	*Delosperma sp.*			
Asteraceae	*Denekia capensis*	Thunb.	LC	Indigenous
Apiaceae	*Deverra burchellii*	(DC.) Eckl. & Zeyh.	LC	Indigenous
Caryophyllaceae	*Dianthus basuticus subsp. basuticus*	Burtt Davy	NE	Indigenous; Endemic
Caryophyllaceae	*Dianthus micropetalus*	Ser.	LC	Indigenous; Endemic
Acanthaceae	*Dicliptera leistneri*	K.Balkwill	LC	Indigenous; Endemic
Asteraceae	*Dicoma anomala subsp. anomala*	Sond.	LC	Indigenous
Urticaceae	*Didymodoxa caffra*	(Thunb.) Friis & Wilmot-Dear	LC	Indigenous

Poaceae	*Digitaria argyrograpta*	(Nees) Stapf	LC	Indigenous
Poaceae	*Digitaria eriantha*	Steud.	LC	Indigenous
Poaceae	*Digitaria sanguinalis*	(L.) Scop.	NE	Not indigenous; Naturalised
Poaceae	*Digitaria tricholaenoides*	Stapf	LC	Indigenous; Endemic
Poaceae	*Diheteropogon amplectens var. amplectens*	(Nees) Clayton	LC	Indigenous
Asteraceae	*Dimorphotheca zeyheri*	Sond.	LC	Indigenous; Endemic
Ebenaceae	*Diospyros austroafricana var. microphylla*	De Winter	LC	Indigenous; Endemic
Ebenaceae	*Diospyros lycioides subsp. lycioides*	Desf.	LC	Indigenous
Hyacinthaceae	*Dipcadi longifolium*	(Ker Gawl.) Baker	LC	Indigenous
Fabaceae	*Dolichos angustifolius*	Eckl. & Zeyh.	LC	Indigenous; Endemic
Fabaceae	*Dolichos linearis*	E.Mey.	LC	Indigenous; Endemic
Hyacinthaceae	*Drimia elata*	Jacq. ex Willd.	DD	Indigenous
Hyacinthaceae	*Drimia sp.*			
Dryopteridaceae	*Dryopteris inaequalis*	(Schltdl.) Kuntze	LC	Indigenous; Endemic
Iridaceae	*Duthiastrum linifolium*	(E.Phillips) M.P.de Vos	LC	Indigenous; Endemic
Amaranthaceae	*Dysphania multifida*	(L.) Mosyakin & Clemants		Not indigenous; Naturalised; Invasive
Poaceae	*Echinochloa crus-galli*	(L.) P.Beauv.	LC	Indigenous
Poaceae	*Echinochloa holubii*	(Stapf) Stapf	LC	Indigenous
Poaceae	*Ehrharta erecta var. natalensis*	Lam.	LC	Indigenous; Endemic
Cyperaceae	*Eleocharis limosa*	(Schrad.) Schult.	LC	Indigenous
Poaceae	*Eleusine coracana subsp. africana*	(L.) Gaertn.	LC	Indigenous
Poaceae	*Eleusine indica*	(L.) Gaertn.	LC	Indigenous
Poaceae	*Elionurus muticus*	(Spreng.) Kunth	LC	Indigenous
Poaceae	*Enneapogon desvauxii*	P.Beauv.	LC	Indigenous
Poaceae	*Enneapogon scoparius*	Stapf	LC	Indigenous
Poaceae	*Eragrostis barrelieri*	Daveau	NE	Not indigenous; Naturalised
Poaceae	*Eragrostis bicolor*	Nees	LC	Indigenous
Poaceae	*Eragrostis biflora*	Hack. ex Schinz	LC	Indigenous
Poaceae	*Eragrostis capensis*	(Thunb.) Trin.	LC	Indigenous
Poaceae	*Eragrostis chloromelas*	Steud.	LC	Indigenous; Endemic
Poaceae	*Eragrostis cilianensis*	(All.) Vignolo ex Janch.	LC	Indigenous
Poaceae	*Eragrostis curvula*	(Schrad.) Nees	LC	Indigenous
Poaceae	*Eragrostis gummiflua*	Nees	LC	Indigenous
Poaceae	*Eragrostis lappula*	Nees	LC	Indigenous
Poaceae	*Eragrostis lehmanniana var. lehmanniana*	Nees	LC	Indigenous
Poaceae	*Eragrostis mexicana subsp. virescens*	(Hornem.) Link	NE	Not indigenous; Naturalised
Poaceae	*Eragrostis micrantha*	Hack.	LC	Indigenous
Poaceae	*Eragrostis nindensis*	Ficalho & Hiern	LC	Indigenous
Poaceae	*Eragrostis obtusa*	Munro ex Ficalho & Hiern	LC	Indigenous; Endemic

Poaceae	*Eragrostis plana*	Nees	LC	Indigenous
Poaceae	*Eragrostis planiculmis*	Nees	LC	Indigenous; Endemic
Poaceae	*Eragrostis pseudobtusa*	De Winter	NE	Indigenous; Endemic
Poaceae	*Eragrostis racemosa*	(Thunb.) Steud.	LC	Indigenous
Poaceae	*Eragrostis remotiflora*	De Winter	LC	Indigenous; Endemic
Poaceae	*Eragrostis sp.*			
Poaceae	*Eragrostis stapfii*	De Winter	LC	Indigenous
Poaceae	*Eragrostis superba*	Peyr.	LC	Indigenous
Poaceae	*Eragrostis tef*	(Zuccagni) Trotter	NE	Not indigenous; Naturalised
Poaceae	*Eragrostis trichophora*	Coss. & Durieu	LC	Indigenous
Poaceae	*Eriochloa fatmensis*	(Hochst. & Steud.) Clayton	LC	Indigenous
Brassicaceae	*Erucastrum strigosum*	(Thunb.) O.E.Schulz	LC	Indigenous; Endemic
Ebenaceae	*Euclea crispa subsp. crispa*	(Thunb.) Gurke	LC	Indigenous
Euphorbiaceae	*Euphorbia clavarioides*	Boiss.	LC	Indigenous; Endemic
Euphorbiaceae	*Euphorbia inaequilatera*	Sond.	LC	Indigenous
Euphorbiaceae	*Euphorbia pulvinata*	Marloth	LC	Indigenous; Endemic
Euphorbiaceae	*Euphorbia rhombifolia*	Boiss.	LC	Indigenous; Endemic
Euphorbiaceae	*Euphorbia spartaria*	N.E.Br.	LC	Indigenous
Euphorbiaceae	*Euphorbia striata*	Thunb.	LC	Indigenous; Endemic
Asteraceae	*Euryops empetrifolius*	DC.	LC	Indigenous; Endemic
Asteraceae	*Euryops sp.*			
Poaceae	*Eustachys paspaloides*	(Vahl) Lanza & Mattei	LC	Indigenous
Asteraceae	*Felicia burkei*	(Harv.) L.Bolus	LC	Indigenous; Endemic
Cyperaceae	*Fimbristylis dichotoma subsp. dichotoma*	(L.) Vahl	LC	Indigenous
Poaceae	*Fingerhuthia africana*	Lehm.	LC	Indigenous; Endemic
Phyllanthaceae	*Flueggea virosa subsp. virosa*	(Roxb. ex Willd.) Royle	LC	Indigenous
Frankeniaceae	*Frankenia pulverulenta*	L.	LC	Indigenous
Cyperaceae	*Fuirena pubescens var. pubescens*	(Poir.) Kunth	LC	Indigenous
Rubiaceae	*Galium capense subsp. garipense*	Thunb.	NE	Indigenous; Endemic
Asteraceae	*Garuleum pinnatifidum*	(Thunb.) DC.	LC	Indigenous; Endemic
Asteraceae	*Gazania krebsiana subsp. krebsiana*	Less.	LC	Indigenous
Asteraceae	*Geigeria aspera var. aspera*	Harv.	LC	Indigenous; Endemic
Asteraceae	*Geigeria burkei subsp. burkei*	Harv.	NE	Indigenous
Iridaceae	*Gladiolus dalenii subsp. dalenii*	Van Geel	LC	Indigenous
Iridaceae	*Gladiolus ecklonii*	Lehm.	LC	Indigenous; Endemic
Iridaceae	*Gladiolus permeabilis subsp. edulis*	D.Delaroche	LC	Indigenous
Verbenaceae	*Glandularia aristigera*	(S.Moore) Tronc.		Not indigenous; Naturalised; Invasive
Asteraceae	*Gnaphalium filagopsis*	Hilliard & B.L.Burtt	LC	Indigenous
Thymelaeaceae	*Gnidia sp.*			

Scrophulariaceae	*Gomphostigma virgatum*	(L.f.) Baill.	LC	Indigenous
Malvaceae	*Grewia flava*	DC.	LC	Indigenous
Malvaceae	*Grewia occidentalis var. occidentalis*	L.	LC	Indigenous
Celastraceae	*Gymnosporia buxifolia*	(L.) Szyszyl.	LC	Indigenous
Amaryllidaceae	*Haemanthus humilis subsp. humilis*	Jacq.	LC	Indigenous; Endemic
Asteraceae	*Haplocarpha scaposa*	Harv.	LC	Indigenous
Asteraceae	*Helichrysum cerastioides var. cerastioides*	DC.	LC	Indigenous
Asteraceae	*Helichrysum nudifolium var. nudifolium*	(L.) Less.	LC	Indigenous
Asteraceae	*Helichrysum paronychioides*	DC.	LC	Indigenous; Endemic
Asteraceae	*Helichrysum pumilio subsp. pumilio*	(O.Hoffm.) Hilliard & B.L.Burtt	LC	Indigenous; Endemic
Asteraceae	*Helichrysum zeyheri*	Less.	LC	Indigenous; Endemic
Rhamnaceae	*Helinus integrifolius*	(Lam.) Kuntze	LC	Indigenous
Brassicaceae	*Heliophila carnosa*	(Thunb.) Steud.	LC	Indigenous
Boraginaceae	*Heliotropium lineare*	(A.DC.) Gurke	LC	Indigenous
Poaceae	*Hemarthria altissima*	(Poir.) Stapf & C.E.Hubb.	LC	Indigenous
Malvaceae	*Hermannia bicolor*	Engl. & Dinter	LC	Indigenous; Endemic
Malvaceae	*Hermannia depressa*	N.E.Br.	LC	Indigenous
Malvaceae	*Hermannia sp.*			
Asteraceae	*Hertia ciliata*	(Harv.) Kuntze	LC	Indigenous; Endemic
Apiaceae	*Heteromorpha arborescens var. abyssinica*	(Spreng.) Cham. & Schltdl.	LC	Indigenous
Poaceae	*Heteropogon contortus*	(L.) Roem. & Schult.	LC	Indigenous
Malvaceae	*Hibiscus calyphyllus*	Cav.	LC	Indigenous
Malvaceae	*Hibiscus microcarpus*	Garcke	LC	Indigenous
Malvaceae	*Hibiscus pusillus*	Thunb.	LC	Indigenous
Malvaceae	*Hibiscus trionum*	L.		Not indigenous; Naturalised
Asteraceae	*Hilliardiella capensis*	(Houtt.) H.Rob., Skvarla & V.A.Funk		Indigenous
Apocynaceae	*Huernia sp.*			
Poaceae	*Hyparrhenia anamesa*	Clayton	LC	Indigenous
Poaceae	*Hyparrhenia dregeana*	(Nees) Stapf ex Stent	LC	Indigenous
Poaceae	*Hyparrhenia hirta*	(L.) Stapf	LC	Indigenous
Hypericaceae	*Hypericum lalandii*	Choisy	LC	Indigenous
Asteraceae	*Hypochaeris microcephala var. albiflora*	(Sch.Bip.) Cabrera		Not indigenous; Naturalised
Fabaceae	*Indigofera alternans var. alternans*	DC.	LC	Indigenous
Fabaceae	*Indigofera daleoides var. daleoides*	Benth. ex Harv.	NE	Indigenous
Fabaceae	*Indigofera filipes*	Benth. ex Harv.	LC	Indigenous
Fabaceae	*Indigofera sessilifolia*	DC.	LC	Indigenous; Endemic
Fabaceae	*Indigofera torulosa var. angustiloba*	E.Mey.	LC	Indigenous; Endemic
Fabaceae	*Indigofera zeyheri*	Spreng. ex Eckl. & Zeyh.	LC	Indigenous; Endemic

Convolvulaceae	*Ipomoea oblongata*	E.Mey. ex Choisy	LC	Indigenous
Convolvulaceae	*Ipomoea oenotheroides*	(L.f.) Raf. ex Hallier f.	LC	Indigenous; Endemic
Convolvulaceae	*Ipomoea simplex*	Thunb.	LC	Indigenous
Acanthaceae	*Isoglossa woodii*	C.B.Clarke	LC	Indigenous; Endemic
Scrophulariaceae	*Jamesbrittenia albiflora*	(I.Verd.) Hilliard	LC	Indigenous; Endemic
Scrophulariaceae	*Jamesbrittenia atropurpurea subsp. atropurpurea*	(Benth.) Hilliard	LC	Indigenous
Scrophulariaceae	*Jamesbrittenia aurantiaca*	(Burch.) Hilliard	LC	Indigenous
Scrophulariaceae	*Jamesbrittenia stricta*	(Benth.) Hilliard	LC	Indigenous; Endemic
Juncaceae	*Juncus rigidus*	Desf.	LC	Indigenous
Acanthaceae	*Justicia orchioides subsp. glabrata*	L.f.	LC	Indigenous; Endemic
Crassulaceae	*Kalanchoe thyrsiflora*	Harv.	LC	Indigenous; Endemic
Achariaceae	*Kiggelaria africana*	L.	LC	Indigenous
Poaceae	*Koeleria capensis*	(Steud.) Nees	LC	Indigenous
Cyperaceae	*Kyllinga alata*	Nees	LC	Indigenous
Cyperaceae	*Kyllinga alba*	Nees	LC	Indigenous
Verbenaceae	*Lantana rugosa*	Thunb.	LC	Indigenous
Iridaceae	*Lapeirousia plicata subsp. foliosa*	(Jacq.) Diels		Indigenous; Endemic
Araceae	*Lemna gibba*	L.	LC	Indigenous
Fabaceae	*Leobordea adpressa subsp. adpressa*	(N.E.Br.) B.-E.van Wyk & Boatwr.	LC	Indigenous; Endemic
Brassicaceae	*Lepidium bonariense*	L.		Not indigenous; Naturalised
Poaceae	*Leptochloa fusca*	(L.) Kunth	LC	Indigenous
Fabaceae	*Lessertia depressa*	Harv.	LC	Indigenous; Endemic
Fabaceae	*Lessertia frutescens subsp. microphylla*	(L.) Goldblatt & J.C.Manning	LC	Indigenous; Endemic
Fabaceae	*Lessertia stricta*	L.Bolus	LC	Indigenous; Endemic
Linaceae	*Linum thunbergii*	Eckl. & Zeyh.	LC	Indigenous
Fabaceae	*Listia heterophylla*	E.Mey.	LC	Indigenous
Fabaceae	*Listia marlothii*	(Engl.) B.-E.van Wyk & Boatwr.	LC	Indigenous; Endemic
Boraginaceae	*Lithospermum hirsutum*	E.Mey. ex A.DC.	LC	Indigenous; Endemic
Boraginaceae	*Lithospermum scabrum*	Thunb.	LC	Indigenous; Endemic
Lobeliaceae	*Lobelia erinus*	L.	LC	Indigenous
Lobeliaceae	*Lobelia sonderiana*	(Kuntze) Lammers	LC	Indigenous
Lobeliaceae	*Lobelia thermalis*	Thunb.	LC	Indigenous
Fabaceae	*Lotononis divaricata*	(Eckl. & Zeyh.) Benth.	NE	Indigenous; Endemic
Solanaceae	*Lycium arenicola*	Miers	LC	Indigenous
Solanaceae	*Lycium cinereum*	Thunb.	LC	Indigenous; Endemic
Solanaceae	*Lycium hirsutum*	Dunal	LC	Indigenous; Endemic
Solanaceae	*Lycium horridum*	Thunb.	LC	Indigenous; Endemic
Malvaceae	*Malva neglecta*	Wallr.		Not indigenous; Naturalised

Malvaceae	*Malva pusilla*	Sm.		Not indigenous; Naturalised
Scrophulariaceae	*Manulea parviflora var. limonioides*	Benth.	LC	Indigenous; Endemic
Hyacinthaceae	*Massonia jasminiflora*	Burch. ex Baker	LC	Indigenous; Endemic
Celastraceae	*Maytenus undata*	(Thunb.) Blakelock	LC	Indigenous
Poaceae	*Melica decumbens*	Thunb.	LC	Indigenous; Endemic
Poaceae	*Melica racemosa*	Thunb.	LC	Indigenous; Endemic
Poaceae	*Melinis nerviglumis*	(Franch.) Zizka	LC	Indigenous
Poaceae	*Melinis repens subsp. repens*	(Willd.) Zizka	LC	Indigenous
Lamiaceae	*Mentha longifolia subsp. capensis*	(L.) Huds.	LC	Indigenous
Lamiaceae	*Mentha longifolia subsp. polyadena*	(L.) Huds.	LC	Indigenous; Endemic
Aizoaceae	*Mestoklema arboriforme*	(Burch.) N.E.Br. ex Glen	LC	Indigenous; Endemic
Poaceae	*Microchloa caffra*	Nees	LC	Indigenous
Mniaceae	*Mielichhoferia subnuda*	Sim		Indigenous
Phrymaceae	*Mimulus gracilis*	R.Br.	LC	Indigenous
Iridaceae	*Moraea pallida*	(Baker) Goldblatt	LC	Indigenous; Endemic
Myrsinaceae	*Myrsine africana*	L.	LC	Indigenous
Scrophulariaceae	*Nemesia fruticans*	(Thunb.) Benth.	LC	Indigenous
Rubiaceae	*Nenax microphylla*	(Sond.) T.M.Salter	LC	Indigenous; Endemic
Amaryllidaceae	*Nerine laticoma*	(Ker Gawl.) T.Durand & Schinz	LC	Indigenous
Asteraceae	*Nolletia ciliaris*	(DC.) Steetz	LC	Indigenous; Endemic
Asteraceae	*Oedera humilis*	(Less.) N.G.Bergh		Indigenous; Endemic
Onagraceae	*Oenothera indecora*	Cambess.		Not indigenous; Naturalised; Invasive
Onagraceae	*Oenothera tetraptera*	Cav.		Not indigenous; Naturalised; Invasive
Rubiaceae	*Oldenlandia herbacea*	(L.) Roxb.		Indigenous
Oleaceae	*Olea europaea subsp. cuspidata*	L.		Indigenous
Resedaceae	*Oligomeris dregeana*	(Mull.Arg.) Mull.Arg.	LC	Indigenous; Endemic
Ophioglossaceae	*Ophioglossum polyphyllum var. polyphyllum*	A.Braun	LC	Indigenous
Poaceae	*Oropetium capense*	Stapf	LC	Indigenous
Asteraceae	*Osteospermum leptolobum*	(Harv.) Norl.	LC	Indigenous; Endemic
Asteraceae	*Osteospermum muricatum subsp. muricatum*	E.Mey. ex DC.	LC	Indigenous
Asteraceae	*Osteospermum scariosum var. scariosum*	DC.	NE	Indigenous; Endemic
Santalaceae	*Osyris lanceolata*	Hochst. & Steud.	LC	Indigenous
Poaceae	*Panicum coloratum*	L.	LC	Indigenous
Poaceae	*Panicum deustum*	Thunb.	LC	Indigenous
Poaceae	*Panicum maximum*	Jacq.	LC	Indigenous
Poaceae	*Panicum schinzii*	Hack.	LC	Indigenous
Poaceae	*Panicum sp.*			
Poaceae	*Panicum stapfianum*	Fourc.	LC	Indigenous; Endemic

Papaveraceae	*Papaver aculeatum*	Thunb.	LC	Indigenous; Endemic
Poaceae	*Paspalum dilatatum*	Poir.	NE	Not indigenous; Naturalised; Invasive
Poaceae	*Paspalum distichum*	L.	LC	Not indigenous; Naturalised; Invasive
Geraniaceae	*Pelargonium dolomiticum*	R.Knuth	LC	Indigenous; Endemic
Pteridaceae	*Pellaea calomelanos var. calomelanos*	(Sw.) Link	LC	Indigenous
Asteraceae	*Pentzia globosa*	Less.	LC	Indigenous; Endemic
Polygonaceae	*Persicaria lapathifolia*	(L.) Delarbre		Not indigenous; Naturalised; Invasive
Poaceae	*Phragmites australis*	(Cav.) Steud.	LC	Indigenous
Phyllanthaceae	*Phyllanthus maderaspatensis*	L.	LC	Indigenous
Asteraceae	*Platycarphella parvifolia*	(S.Moore) V.A.Funk & H.Rob.	LC	Indigenous; Endemic
Poaceae	*Pogonarthria squarrosa*	(Roem. & Schult.) Pilg.	LC	Indigenous
Polygalaceae	*Polygala hottentotta*	C.Presl	LC	Indigenous
Portulacaceae	*Portulaca quadrifida*	L.	LC	Indigenous
Potamogetonaceae	*Potamogeton pectinatus*	L.	LC	Indigenous
Rosaceae	*Potentilla supina*	L.		Indigenous
Fabaceae	*Prosopis glandulosa var. glandulosa*	Torr.	NE	Not indigenous; Naturalised
Pedaliaceae	*Pterodiscus speciosus*	Hook.	LC	Indigenous
Ranunculaceae	*Ranunculus trichophyllus*	Chaix	LC	Indigenous
Apocynaceae	*Raphionacme dyeri*	Retief & Venter	LC	Indigenous; Endemic
Resedaceae	*Reseda lutea subsp. lutea*	L.	NE	Not indigenous; Naturalised; Invasive
Rhamnaceae	*Rhamnus prinoides*	L'Her.	LC	Indigenous
Vitaceae	*Rhoicissus tridentata subsp. cuneifolia*	(L.f.) Wild & R.B.Drumm.	NE	Indigenous
Fabaceae	*Rhynchosia adenodes*	Eckl. & Zeyh.	LC	Indigenous; Endemic
Fabaceae	*Rhynchosia pentheri var. pentheri*	Schltr. ex Zahlbr.	LC	Indigenous; Endemic
Fabaceae	*Rhynchosia totta var. totta*	(Thunb.) DC.	LC	Indigenous
Ricciaceae	*Riccia albolimbata*	S.W.Arnell		Indigenous
Ricciaceae	*Riccia albovestita*	O.H.Volk		Indigenous
Ricciaceae	*Riccia argenteolimbata*	O.H.Volk & Perold		Indigenous
Ricciaceae	*Riccia atropurpurea*	Sim		Indigenous
Ricciaceae	*Riccia cavernosa*	Hoffm.		Indigenous
Ricciaceae	*Riccia okahandjana*	S.W.Arnell		Indigenous
Ricciaceae	*Riccia pottsiana*	Sim		Indigenous; Endemic
Ricciaceae	*Riccia simii*	Perold		Indigenous
Ricciaceae	*Riccia volkii*	S.W.Arnell		Indigenous
Rosaceae	*Rosa rubiginosa*	L.		Not indigenous; Naturalised; Invasive
Rubiaceae	*Rubia petiolaris*	DC.	LC	Indigenous
Aizoaceae	*Ruschia indurata*	(L.Bolus) Schwantes	LC	Indigenous; Endemic
Aizoaceae	*Ruschia rigens*	L.Bolus	LC	Indigenous; Endemic

Aizoaceae	*Ruschia sp.*			
Salicaceae	*Salix babylonica var. babylonica*	L.		Not indigenous; Naturalised
Amaranthacea e	*Salsola aphylla*	L.f.	LC	Indigenous
Amaranthacea e	*Salsola glabrescens*	Burtt Davy	LC	Indigenous; Endemic
Amaranthacea e	*Salsola kali*	L.		Not indigenous; Naturalised; Invasive
Lamiaceae	*Salvia repens var. repens*	Burch. ex Benth.	LC	Indigenous; Endemic
Lamiaceae	*Salvia repens var. transvaalensis*	Burch. ex Benth.	LC	Indigenous; Endemic
Lamiaceae	*Salvia runcinata*	L.f.	LC	Indigenous
Lamiaceae	*Salvia verbenaca*	L.	LC	Not indigenous; Naturalised; Invasive
Asteraceae	*Schistostephium crataegifolium*	(DC.) Fenzl ex Harv.	LC	Indigenous
Asteraceae	*Schkuhria pinnata*	(Lam.) Kuntze ex Thell.		Not indigenous; Naturalised
Cyperaceae	*Schoenoplectus corymbosus*	(Roth ex Roem. & Schult.) J.Raynal	LC	Indigenous
Cyperaceae	*Schoenoplectus muricinux*	(C.B.Clarke) J.Raynal	LC	Indigenous
Cyperaceae	*Schoenoxiphium sp.*			
Salicaceae	*Scolopia zeyheri*	(Nees) Harv.	LC	Indigenous
Anacardiaceae	*Searsia burchellii*	(Sond. ex Engl.) Moffett	LC	Indigenous; Endemic
Anacardiaceae	*Searsia ciliata*	(Licht. ex Schult.) A.J.Mill.	LC	Indigenous; Endemic
Anacardiaceae	*Searsia dentata*	(Thunb.) F.A.Barkley	LC	Indigenous
Anacardiaceae	*Searsia lancea*	(L.f.) F.A.Barkley	LC	Indigenous
Anacardiaceae	*Searsia leptodictya forma leptodictya*	(Diels) T.S.Yi, A.J.Mill. & J.Wen	NE	Indigenous
Anacardiaceae	*Searsia pyroides var. pyroides*	(Burch.) Moffett	LC	Indigenous
Anacardiaceae	*Searsia tridactyla*	(Burch.) Moffett	LC	Indigenous; Endemic
Convolvulacea e	*Seddera capensis*	(E.Mey. ex Choisy) Hallier f.	LC	Indigenous
Asteraceae	*Senecio achilleifolius*	DC.	LC	Indigenous; Endemic
Asteraceae	*Senecio affinis*	DC.	LC	Indigenous; Endemic
Asteraceae	*Senecio consanguineus*	DC.	LC	Indigenous; Endemic
Asteraceae	*Senecio coronatus*	(Thunb.) Harv.	LC	Indigenous
Asteraceae	*Senecio hastatus*	L.	LC	Indigenous; Endemic
Amaranthacea e	*Sericorema remotiflora*	(Hook.f.) Lopr.	LC	Indigenous
Fabaceae	*Sesbania notialis*	J.B.Gillett	LC	Indigenous; Endemic
Poaceae	*Setaria incrassata*	(Hochst.) Hack.	LC	Indigenous
Poaceae	*Setaria nigrirostris*	(Nees) T.Durand & Schinz	LC	Indigenous
Poaceae	*Setaria pumila*	(Poir.) Roem. & Schult.	LC	Indigenous
Poaceae	*Setaria sp.*			
Poaceae	*Setaria sphacelata var. sphacelata*	(Schumach.) Stapf & C.E.Hubb. ex M.B.Moss	LC	Indigenous
cccccc	*Setaria sphacelata var. torta*	(Schumach.) Stapf & C.E.Hubb. ex M.B.Moss	LC	Indigenous
Poaceae	*Setaria verticillata*	(L.) P.Beauv.	LC	Indigenous
Malvaceae	*Sida dregei*	Burtt Davy	LC	Indigenous

Caryophyllaceae	*Silene undulata*	Aiton		Indigenous
Brassicaceae	*Sisymbrium capense*	Thunb.	LC	Indigenous; Endemic
Solanaceae	*Solanum campylacanthum*	Hochst. ex A.Rich.		Indigenous
Solanaceae	*Solanum retroflexum*	Dunal	LC	Indigenous; Endemic
Poaceae	*Sporobolus discosporus*	Nees	LC	Indigenous
Poaceae	*Sporobolus fimbriatus*	(Trin.) Nees	LC	Indigenous
Poaceae	*Sporobolus ioclados*	(Trin.) Nees	LC	Indigenous
Poaceae	*Sporobolus ludwigii*	Hochst.	LC	Indigenous; Endemic
Poaceae	*Sporobolus sp.*			
Lamiaceae	*Stachys spathulata*	Burch. ex Benth.	LC	Indigenous
Apocynaceae	*Stapelia grandiflora var. grandiflora*	Masson	LC	Indigenous; Endemic
Poaceae	*Stipagrostis uniplumis var. neesii*	(Licht.) De Winter	LC	Indigenous
Aizoaceae	*Stomatium ermininum*	(Haw.) Schwantes	LC	Indigenous; Endemic
Orobanchaceae	*Striga bilabiata subsp. bilabiata*	(Thunb.) Kuntze	LC	Indigenous
Orobanchaceae	*Striga sp.*			
Asteraceae	*Tagetes minuta*	L.		Not indigenous; Naturalised; Invasive
Tamaricaceae	*Tamarix chinensis*	Lour.		Not indigenous; Naturalised; Invasive
Asteraceae	*Tarchonanthus camphoratus*	L.	LC	Indigenous
Asteraceae	*Tarchonanthus minor*	Less.	LC	Indigenous; Endemic
Poaceae	*Tarigidia aequiglumis*	(Gooss.) Stent	LC	Indigenous; Endemic
Fabaceae	*Tephrosia capensis var. capensis*	(Jacq.) Pers.	LC	Indigenous
Fabaceae	*Tephrosia sp.*			
Poaceae	*Themeda triandra*	Forssk.	LC	Indigenous
Santalaceae	*Thesium resedoides*	A.W.Hill	LC	Indigenous
Asphodelaceae	*Trachyandra asperata var. asperata*	Kunth	LC	Indigenous; Endemic
Poaceae	*Tragus berteronianus*	Schult.	LC	Indigenous
Poaceae	*Tragus koelerioides*	Asch.	LC	Indigenous
Poaceae	*Tragus racemosus*	(L.) All.	LC	Indigenous
Aizoaceae	*Trianthema parvifolia var. parvifolia*	E.Mey. ex Sond.	LC	Indigenous
Aizoaceae	*Trianthema salsoloides var. transvaalensis*	Fenzl ex Oliv.	LC	Indigenous
Zygophyllaceae	*Tribulus terrestris*	L.	LC	Indigenous
Boraginaceae	*Trichodesma angustifolium subsp. angustifolium*	Harv.	LC	Indigenous
Poaceae	*Trichoneura grandiglumis*	(Nees) Ekman	LC	Indigenous
Pottiaceae	*Trichostomum brachydontium*	Bruch		Indigenous
Poaceae	*Triraphis andropogonoides*	(Steud.) E.Phillips	LC	Indigenous; Endemic
Poaceae	*Trisetopsis imberbis*	(Nees) Roser, A.Wolk & Veldkamp		Indigenous; Endemic
Poaceae	*Urochloa panicoides*	P.Beauv.	LC	Indigenous
Fabaceae	*Vachellia hebeclada subsp. hebeclada*	(DC.) Kyal. & Boatwr.	LC	Indigenous; Endemic

Fabaceae	*Vachellia karroo*	(Hayne) Banfi & Galasso	LC	Indigenous
Verbenaceae	*Verbena bonariensis*	L.		Not indigenous; Naturalised; Invasive
Santalaceae	*Viscum rotundifolium*	L.f.	LC	Indigenous
Campanulaceae	*Wahlenbergia albens*	(Spreng. ex A.DC.) Lammers	LC	Indigenous; Endemic
Campanulaceae	*Wahlenbergia androsacea*	A.DC.	LC	Indigenous
Xyridaceae	*Xyris gerrardii*	N.E.Br.	LC	Indigenous
Apocynaceae	*Xysmalobium undulatum var. undulatum*	(L.) W.T.Aiton	LC	Indigenous
Rhamnaceae	*Ziziphus mucronata subsp. mucronata*	Willd.	LC	Indigenous
Fabaceae	*Zornia capensis subsp. capensis*	Pers.	LC	Indigenous

10.3 Appendix C Avifauna species expected in the project area

Species	Common Name	Conservation Status	
		Regional (SANBI, 2016)	IUCN (2021)
Apalis thoracica	Apalis, Bar-throated	Unlisted	LC
Recurvirostra avosetta	Avocet, Pied	Unlisted	LC
Tricholaema leucomelas	Barbet, Acacia Pied	Unlisted	LC
Lybius torquatus	Barbet, Black-collared	Unlisted	LC
Trachyphonus vaillantii	Barbet, Crested	Unlisted	LC
Batis pririt	Batis, Pririt	Unlisted	LC
Merops apiaster	Bee-eater, European	Unlisted	LC
Merops bullockoides	Bee-eater, White-fronted	Unlisted	LC
Euplectes orix	Bishop, Southern Red	Unlisted	LC
Euplectes afer	Bishop, Yellow-crowned	Unlisted	LC
Ixobrychus minutus	Bittern, Little	Unlisted	LC
Telophorus zeylonus	Bokmakierie, Bokmakierie	Unlisted	LC
Pycnonotus nigricans	Bulbul, African Red-eyed	Unlisted	LC
Emberiza tahapisi	Bunting, Cinnamon-breasted	Unlisted	LC
Buteo buteo	Buzzard, Common (Steppe)	Unlisted	LC
Buteo rufofuscus	Buzzard, Jackal	Unlisted	LC
Crithagra atrogularis	Canary, Black-throated	Unlisted	LC
Crithagra flaviventris	Canary, Yellow	Unlisted	LC
Myrmecocichla formicivora	Chat, Anteating	Unlisted	LC
Oenanthe familiaris	Chat, Familiar	Unlisted	LC
Emarginata sinuata	Chat, Sickle-winged	Unlisted	LC
Cisticola textrix	Cisticola, Cloud	Unlisted	LC
Cisticola aridulus	Cisticola, Desert	Unlisted	LC
Cisticola tinniens	Cisticola, Levaillant's	Unlisted	LC
Cisticola chiniana	Cisticola, Rattling	Unlisted	LC
Cisticola juncidis	Cisticola, Zitting	Unlisted	LC
Petrochelidon spilodera	Cliff-swallow, South African	Unlisted	LC
Fulica cristata	Coot, Red-knobbed	Unlisted	LC
Microcarbo africanus	Cormorant, Reed	Unlisted	LC
Phalacrocorax lucidus	Cormorant, White-breasted	Unlisted	LC
Centropus burchellii	Coucal, Burchell's	Unlisted	Unlisted
Rhinoptilus africanus	Courser, Double-banded	Unlisted	LC
Cursorius temminckii	Courser, Temminck's	Unlisted	LC
Zapornia flavirostra	Crake, Black	Unlisted	LC
Corvus albus	Crow, Pied	Unlisted	LC
Chrysococcyx caprius	Cuckoo, Diderick	Unlisted	LC
Clamator jacobinus	Cuckoo, Jacobin	Unlisted	LC

Chrysococcyx klaas	Cuckoo, Klaas's	Unlisted	LC
Cuculus solitarius	Cuckoo, Red-chested	Unlisted	LC
Anhinga rufa	Darter, African	Unlisted	LC
Spilopelia senegalensis	Dove, Laughing	Unlisted	LC
Oena capensis	Dove, Namaqua	Unlisted	LC
Streptopelia semitorquata	Dove, Red-eyed	Unlisted	LC
Columba livia	Dove, Rock	Unlisted	LC
Anas sparsa	Duck, African Black	Unlisted	LC
Dendrocygna bicolor	Duck, Fulvous	Unlisted	LC
Oxyura maccoa	Duck, Maccoa	NT	VU
Thalassornis leuconotus	Duck, White-backed	Unlisted	LC
Dendrocygna viduata	Duck, White-faced Whistling	Unlisted	LC
Anas undulata	Duck, Yellow-billed	Unlisted	LC
Hieraaetus pennatus	Eagle, Booted	Unlisted	LC
Bubo africanus	Eagle-owl, Spotted	Unlisted	LC
Bubulcus ibis	Egret, Cattle	Unlisted	LC
Ardea alba	Egret, Great	Unlisted	LC
Egretta garzetta	Egret, Little	Unlisted	LC
Ardea intermedia	Egret, Yellow-billed (Intermediate)	Unlisted	LC
Falco amurensis	Falcon, Amur	Unlisted	LC
Falco biarmicus	Falcon, Lanner	VU	LC
Falco peregrinus	Falcon, Peregrine	Unlisted	LC
Amadina erythrocephala	Finch, Red-headed	Unlisted	LC
Sporopipes squamifrons	Finch, Scaly-feathered	Unlisted	LC
Lagonosticta rhodopareia	Firefinch, Jameson's	Unlisted	LC
Lagonosticta senegala	Firefinch, Red-billed	Unlisted	LC
Lanius collaris	Fiscal, Common (Southern)	Unlisted	LC
Haliaeetus vocifer	Fish-eagle, African	Unlisted	LC
Phoenicopterus roseus	Flamingo, Greater	NT	LC
Phoeniconaias minor	Flamingo, Lesser	NT	NT
Stenostira scita	Flycatcher, Fairy	Unlisted	LC
Melaenornis silens	Flycatcher, Fiscal	Unlisted	LC
Muscicapa striata	Flycatcher, Spotted	Unlisted	LC
Scleroptila gutturalis	Francolin, Orange River	Unlisted	LC
Anser anser	Goose, Domestic	Unlisted	LC
Alopochen aegyptiaca	Goose, Egyptian	Unlisted	LC
Plectropterus gambensis	Goose, Spur-winged	Unlisted	LC
Micronisus gabar	Goshawk, Gabar	Unlisted	LC
Melierax canorus	Goshawk, Southern Pale Chanting	Unlisted	LC
Podiceps nigricollis	Grebe, Black-necked	Unlisted	LC

Podiceps cristatus	Grebe, Great Crested	Unlisted	LC
Tachybaptus ruficollis	Grebe, Little	Unlisted	LC
Chlorocichla flaviventris	Greenbul, Yellow-bellied	Unlisted	LC
Tringa nebularia	Greenshank, Common	Unlisted	LC
Numida meleagris	Guineafowl, Helmeted	Unlisted	LC
Chroicocephalus cirrocephalus	Gull, Grey-headed	Unlisted	LC
Larus dominicanus	Gull, Kelp	Unlisted	LC
Scopus umbretta	Hamerkop, Hamerkop	Unlisted	LC
Polyboroides typus	Harrier-Hawk, African	Unlisted	LC
Egretta ardesiaca	Heron, Black	Unlisted	LC
Ardea melanocephala	Heron, Black-headed	Unlisted	LC
Ardea goliath	Heron, Goliath	Unlisted	LC
Ardea cinerea	Heron, Grey	Unlisted	LC
Ardea purpurea	Heron, Purple	Unlisted	LC
Ardeola ralloides	Heron, Squacco	Unlisted	LC
Indicator indicator	Honeyguide, Greater	Unlisted	LC
Upupa africana	Hoopoe, African	Unlisted	LC
Lophoceros nasutus	Hornbill, African Grey	Unlisted	LC
Threskiornis aethiopicus	Ibis, African Sacred	Unlisted	LC
Plegadis falcinellus	Ibis, Glossy	Unlisted	LC
Bostrychia hagedash	Ibis, Hadeda	Unlisted	LC
Vidua funerea	Indigobird, Dusky	Unlisted	LC
Vidua chalybeata	Indigobird, Village	Unlisted	LC
Actophilornis africanus	Jacana, African	Unlisted	LC
Falco rupicoloides	Kestrel, Greater	Unlisted	LC
Falco naumanni	Kestrel, Lesser	Unlisted	LC
Falco rupicolus	Kestrel, Rock	Unlisted	LC
Halcyon albiventris	Kingfisher, Brown-hooded	Unlisted	LC
Megaceryle maxima	Kingfisher, Giant	Unlisted	Unlisted
Corythornis cristatus	Kingfisher, Malachite	Unlisted	Unlisted
Ceryle rudis	Kingfisher, Pied	Unlisted	LC
Elanus caeruleus	Kite, Black-shouldered	Unlisted	LC
Eupodotis caerulescens	Korhaan, Blue	LC	NT
Afrotis afraoides	Korhaan, Northern Black	Unlisted	LC
Vanellus armatus	Lapwing, Blacksmith	Unlisted	LC
Vanellus coronatus	Lapwing, Crowned	Unlisted	LC
Mirafra fasciolata	Lark, Eastern Clapper	Unlisted	LC
Calandrella cinerea	Lark, Red-capped	Unlisted	LC
Mirafra africana	Lark, Rufous-naped	Unlisted	LC
Calendulauda sabota	Lark, Sabota	Unlisted	LC

Chersomanes albofasciata	Lark, Spike-heeled	Unlisted	LC
Macronyx capensis	Longclaw, Cape	Unlisted	LC
Riparia paludicola	Martin, Brown-throated	Unlisted	LC
Ptyonoprogne fuligula	Martin, Rock	Unlisted	Unlisted
Ploceus velatus	Masked-weaver, Southern	Unlisted	LC
Gallinula chloropus	Moorhen, Common	Unlisted	LC
Urocolius indicus	Mousebird, Red-faced	Unlisted	LC
Colius striatus	Mousebird, Speckled	Unlisted	LC
Colius colius	Mousebird, White-backed	Unlisted	LC
Acridotheres tristis	Myna, Common	Unlisted	LC
Cisticola fulvicapilla	Neddicky, Neddicky	Unlisted	LC
Nycticorax nycticorax	Night-Heron, Black-crowned	Unlisted	LC
Struthio camelus	Ostrich, Common	Unlisted	LC
Tyto alba	Owl, Barn	Unlisted	LC
Asio capensis	Owl, Marsh	Unlisted	LC
Rostratula benghalensis	Painted-snipe, Greater	NT	LC
Cypsiurus parvus	Palm-swift, African	Unlisted	LC
Terpsiphone viridis	Paradise-flycatcher, African	Unlisted	LC
Vidua paradisaea	Paradise-whydah, Long-tailed	Unlisted	LC
Anthoscopus minutus	Penduline-tit, Cape	Unlisted	LC
Columba guinea	Pigeon, Speckled	Unlisted	LC
Anthus cinnamomeus	Pipit, African	Unlisted	LC
Anthus leucophrys	Pipit, Plain-backed	Unlisted	LC
Charadrius pallidus	Plover, Chestnut-banded	NT	NT
Charadrius hiaticula	Plover, Common Ringed	Unlisted	LC
Pluvialis squatarola	Plover, Grey	Unlisted	LC
Charadrius pecuarius	Plover, Kittlitz's	Unlisted	LC
Charadrius tricollaris	Plover, Three-banded	Unlisted	LC
Netta erythrophthalma	Pochard, Southern	Unlisted	LC
Prinia flavicans	Prinia, Black-chested	Unlisted	LC
Pytilia melba	Pytilia, Green-winged	Unlisted	LC
Coturnix coturnix	Quail, Common	Unlisted	LC
Ortygospiza atricollis	Quailfinch, African	Unlisted	LC
Quelea quelea	Quelea, Red-billed	Unlisted	LC
Rallus caerulescens	Rail, African	Unlisted	LC
Acrocephalus baeticatus	Reed-warbler, African	Unlisted	Unlisted
Acrocephalus arundinaceus	Reed-warbler, Great	Unlisted	LC
Cossypha caffra	Robin-chat, Cape	Unlisted	LC
Coracias caudatus	Roller, Lilac-breasted	Unlisted	LC
Calidris pugnax	Ruff	Unlisted	LC

Actitis hypoleucos	Sandpiper, Common	Unlisted	LC
Calidris ferruginea	Sandpiper, Curlew	LC	NT
Tringa stagnatilis	Sandpiper, Marsh	Unlisted	LC
Tringa glareola	Sandpiper, Wood	Unlisted	LC
Rhinopomastus cyanomelas	Scimitarbill, Common	Unlisted	LC
Cercotrichas paena	Scrub-robin, Kalahari	Unlisted	LC
Cercotrichas coryphoeus	Scrub-robin, Karoo	Unlisted	LC
Sagittarius serpentarius	Secretarybird	VU	EN
Tadorna cana	Shelduck, South African	Unlisted	LC
Spatula smithii	Shoveler, Cape	Unlisted	LC
Lanius minor	Shrike, Lesser Grey	Unlisted	LC
Lanius collurio	Shrike, Red-backed	Unlisted	LC
Gallinago nigripennis	Snipe, African	Unlisted	LC
Passer melanurus	Sparrow, Cape	Unlisted	LC
Passer domesticus	Sparrow, House	Unlisted	LC
Passer diffusus	Sparrow, Southern Grey-headed	Unlisted	LC
Accipiter melanoleucus	Sparrowhawk, Black	Unlisted	LC
Eremopterix leucotis	Sparrowlark, Chestnut-backed	Unlisted	LC
Plocepasser mahali	Sparrow-weaver, White-browed	Unlisted	LC
Platalea alba	Spoonbill, African	Unlisted	LC
Pternistis natalensis	Spurfowl, Natal	Unlisted	LC
Pternistis swainsonii	Spurfowl, Swainson's	Unlisted	LC
Lamprotornis nitens	Starling, Cape Glossy	Unlisted	LC
Sturnus vulgaris	Starling, Common	Unlisted	LC
Lamprotornis bicolor	Starling, Pied	Unlisted	LC
Onychognathus morio	Starling, Red-winged	Unlisted	LC
Creatophora cinerea	Starling, Wattled	Unlisted	LC
Himantopus himantopus	Stilt, Black-winged	Unlisted	LC
Calidris minuta	Stint, Little	LC	LC
Saxicola torquatus	Stonechat, African	Unlisted	LC
Ciconia abdimii	Stork, Abdim's	NT	LC
Ciconia nigra	Stork, Black	VU	LC
Ciconia ciconia	Stork, White	Unlisted	LC
Mycteria ibis	Stork, Yellow-billed	EN	LC
Chalcomitra amethystina	Sunbird, Amethyst	Unlisted	LC
Cinnyris fuscus	Sunbird, Dusky	Unlisted	LC
Cinnyris talatala	Sunbird, White-bellied	Unlisted	LC
Hirundo rustica	Swallow, Barn	Unlisted	LC
Cecropis cucullata	Swallow, Greater Striped	Unlisted	LC
Hirundo dimidiata	Swallow, Pearl-breasted	Unlisted	LC

Cecropis semirufa	Swallow, Red-breasted	Unlisted	LC
Hirundo albigularis	Swallow, White-throated	Unlisted	LC
Porphyrio madagascariensis	Swamphen, African Purple	Unlisted	Unlisted
Acrocephalus gracilirostris	Swamp-warbler, Lesser	Unlisted	LC
Apus barbatus	Swift, African Black	Unlisted	LC
Tachymarptis melba	Swift, Alpine	Unlisted	LC
Apus apus	Swift, Common	Unlisted	LC
Apus affinis	Swift, Little	Unlisted	LC
Apus caffer	Swift, White-rumped	Unlisted	LC
Tchagra australis	Tchagra, Brown-crowned	Unlisted	LC
Anas capensis	Teal, Cape	Unlisted	LC
Spatula hottentota	Teal, Hottentot	Unlisted	LC
Anas erythrorhyncha	Teal, Red-billed	Unlisted	LC
Chlidonias hybrida	Tern, Whiskered	Unlisted	LC
Chlidonias leucopterus	Tern, White-winged	Unlisted	LC
Burhinus capensis	Thick-knee, Spotted	Unlisted	LC
Turdus smithi	Thrush, Karoo	Unlisted	LC
Melaniparus cinerascens	Tit, Ashy	Unlisted	LC
Curruca subcoerulea	Tit-babbler, Chestnut-vented	Unlisted	Unlisted
Streptopelia capicola	Turtle-dove, Cape	Unlisted	LC
Gyps africanus	Vulture, White-backed	CR	CR
Motacilla capensis	Wagtail, Cape	Unlisted	LC
Phylloscopus trochilus	Warbler, Willow	Unlisted	LC
Brunhilda erythronotos	Waxbill, Black Cheecked	Unlisted	LC
Uraeginthus angolensis	Waxbill, Blue	Unlisted	LC
Estrilda astrild	Waxbill, Common	Unlisted	LC
Amandava subflava	Waxbill, Orange-breasted	Unlisted	Unlisted
Granatina granatina	Waxbill, Violet-eared	Unlisted	LC
Oenanthe pileata	Wheatear, Capped	Unlisted	LC
Myrmecocichla monticola	Wheatear, Mountain	Unlisted	LC
Zosterops virens	White-eye, Cape	Unlisted	LC
Zosterops pallidus	White-eye, Orange River	Unlisted	LC
Vidua macroura	Whydah, Pin-tailed	Unlisted	LC
Vidua regia	Whydah, Shaft-tailed	Unlisted	LC
Euplectes progne	Widowbird, Long-tailed	Unlisted	LC
Euplectes albonotatus	Widowbird, White-winged	Unlisted	LC
Phoeniculus purpureus	Wood-hoopoe, Green	Unlisted	LC
Dendropicos fuscescens	Woodpecker, Cardinal	Unlisted	LC
Jynx ruficollis	Wryneck, Red-throated	Unlisted	LC

10.4 Appendix D Mammals expected in the project area

Species	Common Name	Conservation Status	
		Regional (SANBI, 2016)	IUCN (2021)
Aethomys ineptus	Tete Veld Rat	LC	LC
Aethomys namaquensis	Namaqua rock rat	LC	LC
Antidorcas marsupialis	Sclater's Shrew	LC	LC
Aonyx capensis	Cape Clawless Otter	NT	NT
Atelerix frontalis	South Africa Hedgehog	NT	LC
Atilax paludinosus	Water Mongoose	LC	LC
Canis mesomelas	Black-backed Jackal	LC	LC
Caracal caracal	Caracal	LC	LC
Chlorocebus pygerythrus	Vervet Monkey	LC	LC
Crocidura cyanea	Reddish-grey Musk Shrew	LC	LC
Crocidura fuscomurina	Tiny Musk Shrew	LC	LC
Cynictis penicillata	Yellow Mongoose	LC	LC
Desmodillus auricularis	Short-tailed Gerbil	LC	LC
Eidolon helvum	African Straw-colored Fruit Bat	LC	NT
Elephantulus myurus	Eastern Rock Sengi	LC	LC
Eptesicus hottentotus	Long-tailed Serotine Bat	LC	LC
Felis nigripes	Black-footed Cat	VU	VU
Felis silvestris	African Wildcat	LC	LC
Genetta genetta	Small-spotted Genet	LC	LC
Gerbilliscus brantsii	Highveld Gerbil	LC	LC
Gerbilliscus leucogaster	Bushveld Gerbil	LC	LC
Herpestes sanguineus	Slender Mongoose	LC	LC
Hydrictis maculicollis	Spotted-necked Otter	VU	NT
Hystrix africaeaustralis	Cape Porcupine	LC	LC
Ichneumia albicauda	White-tailed Mongoose	LC	LC
Ictonyx striatus	Striped Polecat	LC	LC
Leptailurus serval	Serval	NT	LC
Lepus capensis	Cape Hare	LC	LC
Lepus saxatilis	Scrub Hare	LC	LC
Lepus victoriae	African Savanna Hare	LC	LC
Malacothrix typica	Gerbil Mouse	LC	LC
Mastomys coucha	Multimammate Mouse	LC	LC
Mellivora capensis	Honey Badger	LC	LC
Mus musculus	House Mouse	Unlisted	LC
Mus orangiae	Free State Pygmy Mouse	NE	Unlisted
Myotis welwitschii	Welwitsch's Hairy Bat	LC	LC
Mystromys albicaudatus	White-tailed Rat	VU	EN

Neoromicia capensis	Cape Serotine Bat	LC	LC
Neoromicia zuluensis	Aloe Bat	LC	LC
Orycteropus afer	Aardvark	LC	LC
Otocyon megalotis	Bat-eared Fox	LC	LC
Otomys irroratus	Vlei Rat (Fynbos type)	LC	LC
Panthera pardus	Leopard	VU	VU
Papio ursinus	Chacma Baboon	LC	LC
Parahyaena brunnea	Brown Hyaena	NT	NT
Pedetes capensis	Springhare	LC	LC
Phacochoerus africanus	Common Warthog	LC	LC
Poecilogale albinucha	African Striped Weasel	NT	LC
Procavia capensis	Rock Hyrax	LC	LC
Proteles cristata	Aardwolf	LC	LC
Raphicerus campestris	Steenbok	LC	LC
Rattus rattus	House Rat	Exotic (Not listed)	LC
Rhabdomys pumilio	Xeric Four-striped Mouse	LC	LC
Rhinolophus clivosus	Geoffroy's Horseshoe Bat	LC	LC
Rhinolophus darlingi	Darling's Horseshoe Bat	LC	LC
Saccostomus campestris	Pouched Mouse	LC	LC
Scotophilus dinganii	Yellow House Bat	LC	LC
Steatomys krebsii	Krebs's Fat Mouse	LC	LC
Suncus varilla	Lesser Dwarf Shrew	LC	LC
Suricata suricatta	Suricate	LC	LC
Sylvicapra grimmia	Common Duiker	LC	LC
Tadarida aegyptiaca	Egyptian Free-tailed Bat	LC	LC
Thryonomys swinderianus	Greater Cane Rat	LC	LC
Vulpes chama	Cape Fox	LC	LC
Xerus inauris	Cape Ground Squirrel	LC	LC

10.5 Appendix E Reptiles species expected in the project area

Species	Common Name	Conservation Status	
		Regional (SANBI, 2016)	IUCN (2021)
Acontias gracilicauda	Thin-tailed Legless Skink	LC	LC
Afroedura nivaria	Drankensberg Flat Gecko	LC	LC
Agama aculeata distanti	Eastern Ground Agama	LC	LC
Agama atra	Southern Rock Agama	LC	LC
Agama hispida	Southern Spiny Agama	LC	LC
Aparallactus capensis	Black-headed Centipede-eater	LC	LC
Bitis arietans arietans	Puff Adder	LC	Unlisted
Boaedon capensis	Brown House Snake	LC	LC
Chamaeleo dilepis	Common Flap-neck Chameleon	LC	LC
Crotaphopeltis hotamboeia	Red-lipped Snake	LC	Unlisted
Dasypeltis scabra	Rhombic Egg-eater	LC	LC
Elapsoidea sundevallii	Sundevall's Garter Snake	LC	Unlisted
Gerrhosaurus flavigularis	Yellow-throated Plated Lizard	LC	Unlisted
Hemachatus haemachatus	Rinkhals	LC	LC
Homopus femoralis	Greater Dwarf Tortoise	LC	LC
Homoroselaps dorsalis	Striped Harlequin Snake	NT	LC
Karusasaurus polyzonus	Southern Karusa Lizard	LC	LC
Lamprophis aurora	Aurora House Snake	LC	LC
Leptotyphlops scutifrons scutifrons	Peters' Thread Snake	LC	Unlisted
Lycophidion capense capense	Cape Wolf Snake	LC	Unlisted
Lygodactylus capensis	Common Dwarf Gecko	LC	Unlisted
Monopeltis capensis	Cape Worm Lizard	LC	LC
Naja nivea	Cape Cobra	LC	Unlisted
Nucras holubi	Holub's Sandveld Lizard	LC	Unlisted
Nucras intertexta	Spotted Sandveld Lizard	LC	Unlisted
Pachydactylus capensis	Cape Gecko	LC	Unlisted
Pachydactylus mariquensis	Common Banded Gecko	LC	LC
Panaspis wahlbergi	Wahlberg's Snake-eyed Skink	LC	Unlisted
Pedioplanis burchelli	Burchell's Sand Lizard	LC	LC
Pedioplanis lineoocellata lineoocellata	Spotted Sand Lizard	LC	Unlisted
Pelomedusa galeata	South African Marsh Terrapin	Not evaluated	Unlisted
Prosymna ambigua	Angolan Shovel-snout	Unlisted	LC
Prosymna sundevallii	Sundevall's Shovel-snout	LC	LC
Psammobates oculifer	Serrated Tent Tortoise	LC	Unlisted
Psammophis crucifer	Cross-marked Grass Snake	LC	LC
Psammophis leightoni	Cape Sand Snake	VU	LC
Psammophylax rhombeatus	Spotted Grass Snake	LC	Unlisted

Psammophylax tritaeniatus	Striped Grass Snake	LC	LC
Pseudaspis cana	Mole Snake	LC	Unlisted
Rhinotyphlops lalandei	Delalande's Beaked Blind Snake	LC	Unlisted
Smaug giganteus	Giant Dragon Lizard	VU	VU
Stigmochelys pardalis	Leopard Tortoise	LC	LC
Trachylepis capensis	Cape Skink	LC	Unlisted
Trachylepis punctatissima	Speckled Rock Skink	LC	LC
Trachylepis punctulata	Speckled Sand Skink	LC	Unlisted
Trachylepis varia	Variable Skink	LC	LC
Varanus albigularis albigularis	Southern Rock Monitor	LC	Unlisted
Varanus niloticus	Water Monitor	LC	Unlisted

10.6 Appendix F Amphibian expected in the project area

Species	Common Name	Conservation Status	
		Regional (SANBI, 2016)	IUCN (2021)
Amietia delalandii	Delalande's River Frog	LC	Unlisted
Amietia fuscigula	Cape River Frog	LC	LC
Amietia poyntoni	Poynton's River Frog	LC	LC
Cacosternum boettgeri	Common Caco	LC	LC
Kassina senegalensis	Bubbling Kassina	LC	LC
Phrynobatrachus natalensis	Snoring Puddle Frog	LC	LC
Poyntonophrynus vertebralis	Southern Pygmy Toad	LC	LC
Pyxicephalus adspersus	Giant Bullfrog	NT	LC
Sclerophrys capensis	Raucous Toad	LC	LC
Sclerophrys gutturalis	Guttural Toad	LC	LC
Sclerophrys poweri	Power's Toad	LC	LC
Tomopterna cryptotis	Tremelo Sand Frog	LC	LC
Tomopterna natalensis	Natal Sand Frog	LC	LC
Tomopterna tandyi	Tandy's Sand Frog	LC	LC
Xenopus laevis	Common Platanna	LC	LC

THE PROPOSED DEVELOPMENT OF PHASE 2 OF THE TETRA NATURAL GAS PROJECT NEAR VIRGINIA IN THE FREESTATE PROVINCE

LANDSCAPE & VISUAL IMPACT ASSESSMENT REPORT

OCTOBER 2022

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1 INTRODUCTION

1.1 GENERAL

In 2012, a Production Right (Ref: 12/4/1/07/2/2) was granted which spans approximately 187 000 hectares for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within the approval of the Production Right, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area.

The activities in the Production Right include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original EIA and approved EMPr).

On 21 September 2017, the Department of Mineral Resources and Energy (DMRE) issued an integrated environmental authorisation ("Cluster 1 EA") (reference: 12/04/07) to Tetra4 in terms of the NEMA. The Cluster 1 EA (as amended by Cluster 1 EA amendments dated 26 August 2019 and 1 September 2020) authorises the development of "Cluster 1" of the Project.

Tetra4 now wishes to expand the natural gas operations, to be located within the approved production right area and around the Cluster 1 project. Cluster 2 gas production activities are now under consideration.

This Landscape and Visual Impact Assessment Report forms part of the Environmental Impact Assessment process that is being undertaken for the proposed Tetra4 Cluster 2 proposal which consists of and extension of the existing Phase 1 Gas Field and Production Plant.

The Environmental Impact Assessment process is being undertaken by Environmental Management Services (Pty) Ltd.

1.2 PROJECT LOCATION

The proposed Cluster 2 development will take place over approximately ~25 000ha. This area overlaps with Cluster 1 which is approximately ~17 000ha

The approximate geographic coordinates of the centre of the proposed Phase 2 development area are;

South	28^0	09′	52.31″
East	26^0	44′	11.01″

No site alternatives are under consideration, however there is flexibility in the development layout to take account of physical and social environmental factors.

Refer to Map 1, Project Area and Map 2 for an indication of how the currently proposed Project Cluster 2 area relates to the authorised Cluster 1.

1.3 BACKGROUND OF SPECIALIST

Jon Marshall (Pr. LArch, CMLI, Dip LA) qualified as a Landscape Architect in 1978. He has been a Chartered Member of the Landscape Institute (UK) since 1986. He is also a registered Landscape Architect and has extensive experience of environmental impact assessment in South Africa.

During the early part of his career (1981 – 1990) he worked with Clouston (now RPS) in Hong Kong and Australia. During this period he was called on to undertake visual impact assessment input to numerous environmental assessment processes for major infrastructure projects. This work was generally based on photography with line drawing superimposed to illustrate the extent of development visible.

He worked in the United Kingdom (1990 – 1995) for major supermarket chains including Sainsbury's and prepared CAD based visual impact assessments for public enquiry for new store development. He also prepared the VIA input to the environmental statement for the Cardiff Bay Barrage for consideration by the UK Parliament in the passing of the Barrage Bill (1993).

His more recent VIA work in Africa (1995 to present) includes a combination of CAD and GIS based work for a new international airport to the north of Durban, new heavy industrial operations, overhead electrical transmission lines, mining operations, a number of commercial and residential developments as well as numerous renewable energy projects.

VIA work undertaken during the last eighteen months includes assessments for several proposed tourism developments in National Parks, numerous solar power projects, as well as two wind energy projects.

A brief CV is attached as Appendix I for information.

1.4 BRIEF AND RELEVANT GUIDELINES

The brief is to determine the sensitivity of the affected landscape and review the possible nature of landscape and visual impacts that the proposed project could result in and specifically to;

- Characterise the affected landscape;
- Identify potential sensitive landscapes and receptors that may be impacted by the proposed facility and the types of impacts that are most likely to occur; and
- Provide sensitivity mapping identifying 'No-Go' areas, and areas for development that will minimise landscape and visual impacts.

Work has been undertaken in accordance with the following guideline documents;

a. The Government of the Western Cape Guideline for Involving Visual and Aesthetic Specialists in EIA Processes (Western Cape Guideline), which is the only local relevant guideline, setting various levels of assessment subject to the nature of the proposed development and surrounding landscape, and

b. The Landscape Institute and Institute of Environmental Management and Assessment (UK) Guidelines for Landscape and Visual Impact Assessment which provides detail of international best practice (UK Guidelines).

Refer to Appendix II for the Western Cape Guideline.

This specialist report and assessment has been undertaken in accordance with Appendix 6 of the EIA Regulations, as amended (GN No. 326 of 7 April 2017).

1.5 LIMITATIONS AND ASSUMPTIONS

The following limitations and assumptions should be noted:

A site visit was undertaken over a two day period (21st and 22nd February 2022).

The timing of photography was planned to ensure that the sun was as far as possible behind the photographer to ensure that as much detail as possible was recorded in the photographs.

GIS data sets used in the assessment are either available on line to the public or have been sourced from relevant government departments.

Photographs were taken with a Canon EOS M50 camera fitted with a 22mm lens.

The following GIS data sets were used in undertaking and presenting the assessments:

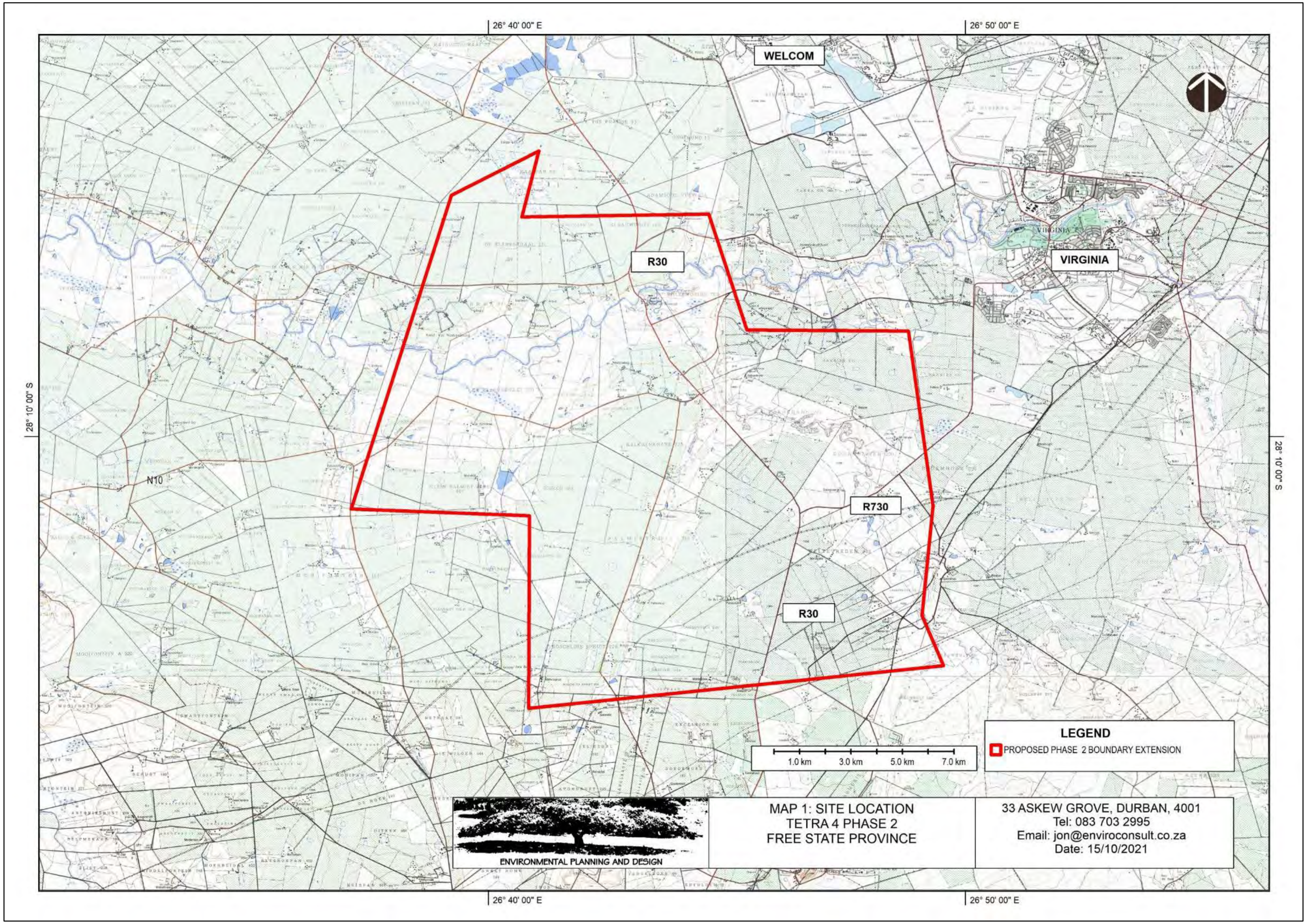
DATA SET	SOURCE	YEAR
South Africa Protected Areas Database (SAPAD)	Department of Environmental Affairs	2021
SRTM Worldwide Elevation Data	CIAT-CCAFS	2018
World Imagery	ESRI	2009 (updated 2021)
SA NLC (National Land Cover)	Department of Environmental Affairs	2018
1:50,000 raster mapping	Chief Directorate National Geo-Spatial Information of South Africa	Unknown
South African rivers in drainage region ALL	Department of Water Affairs	2012
Free State Cadastral	Chief Surveyor-General, Department of Rural Development and Land Reform	August 2021 (last updated)
Update of vegm2009	South African National Biodiversity Institute	2015
South Africa /Lesotho Roads	Open Street Map	2014

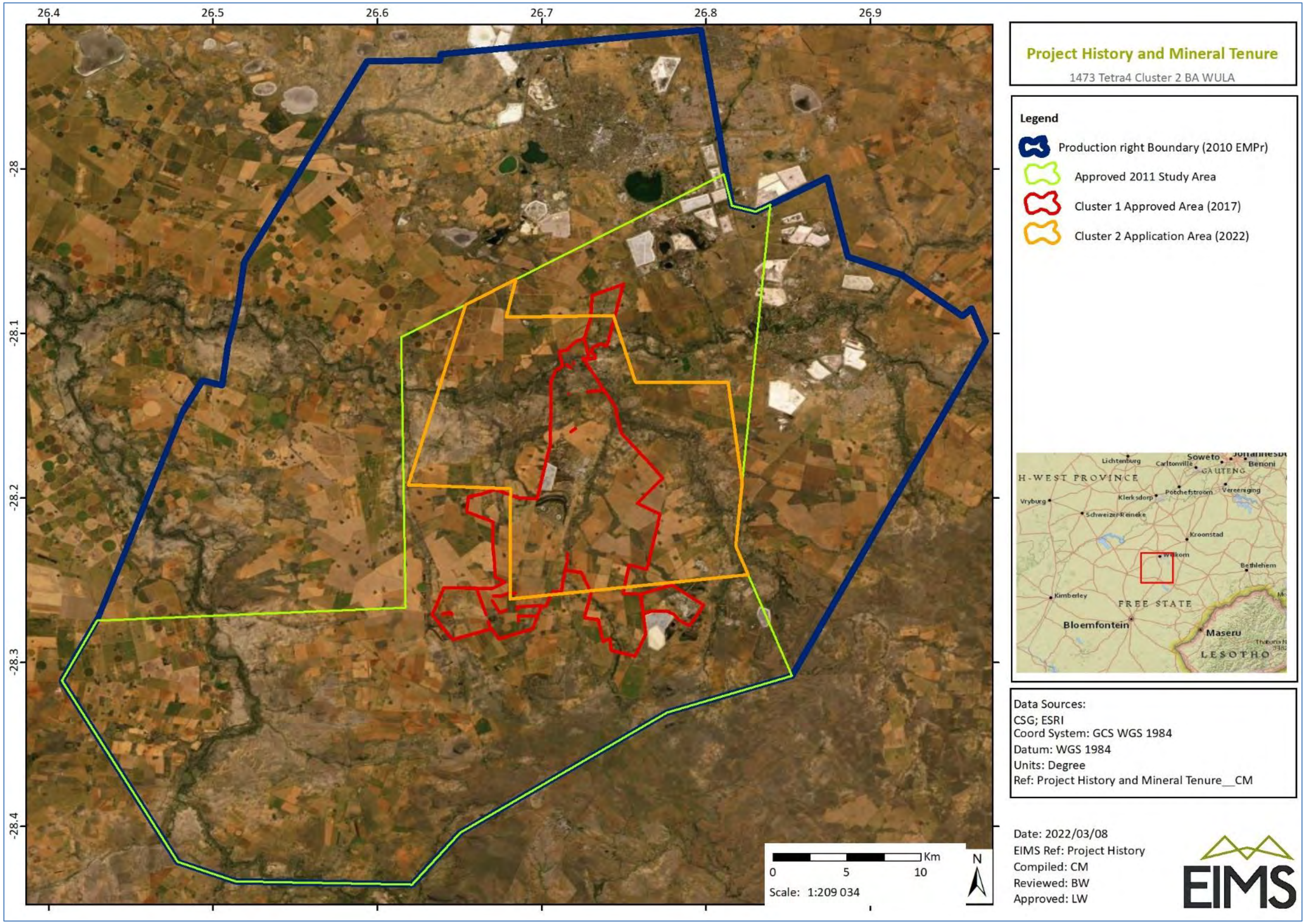
Visibility of the proposed facilities has been assessed using the Global Mapper Viewshed tool.

The majority of data sets have been used for assessment context. These have largely been sourced from government departments. Whilst these have been mainly mapped at national scale they were found to be largely sufficient to provide context for the assessment. Where additional detail was required, such as the location of local roads and homesteads, this was mapped on site and / or captured from online mapping.

The visibility assessments were based on terrain data that has been derived from satellite imagery (STRM Worldwide Elevation Data). This data was originally prepared by NASA and is freely available on the CIAT-CCAFS website (http://www.cgiar-csi.org). This data has been ground truthed using a GPS as well as online mapping. This is the key data on which the definition of possible affected landscapes and receptors was based and is considered sufficient for this purpose.

Calculation of visibility is based purely on the Digital Elevation Model and does not take into account the screening potential of vegetation or other development.


26° 40' 00" E
26° 50' 00" E
28° 10' 00" S
WELCOM
VIRGINIA
R30
R730
R30
N10
LEGEND
PROPOSED PHASE 2 BOUNDARY EXTENSION
1.0 km
3.0 km
5.0 km
7.0 km
ENVIRONMENTAL PLANNING AND DESIGN
MAP 1: SITE LOCATION
TETRA 4 PHASE 2
FREE STATE PROVINCE
33 ASKEW GROVE, DURBAN, 4001
Tel: 083 703 2995
Email: jon@enviroconsult.co.za
Date: 15/10/2021



MAP 2 – AUTORISED CLUSTER 1 AND PROPOSED CLUSTER 2

2. PROJECT DESCRIPTION

A detailed project description is included within EIMS documentation. Extracts from the detailed project description that relate to either location or description of elements that could contribute to landscape and / or visual impact are included in this document.

2.1 PROJECT OVERVIEW

Gas production encompasses the exploration for gas resources with specific focus on existing geological fractures followed by the extraction of gas through production wells. From the production wells, a gas gathering network of pipes, booster stations, metering stations, pigging stations and compressor stations transports the gas to the LNG/LHe Plant where gas processing, storage and distribution is undertaken.

Tetra4 is authorized to develop the following as part of Cluster 1:

- 19 wells;
- A CNG / Helium gas production plant; and
- Interconnecting pipelines.

This section of the project is nearing completion and is soon to be commissioned.

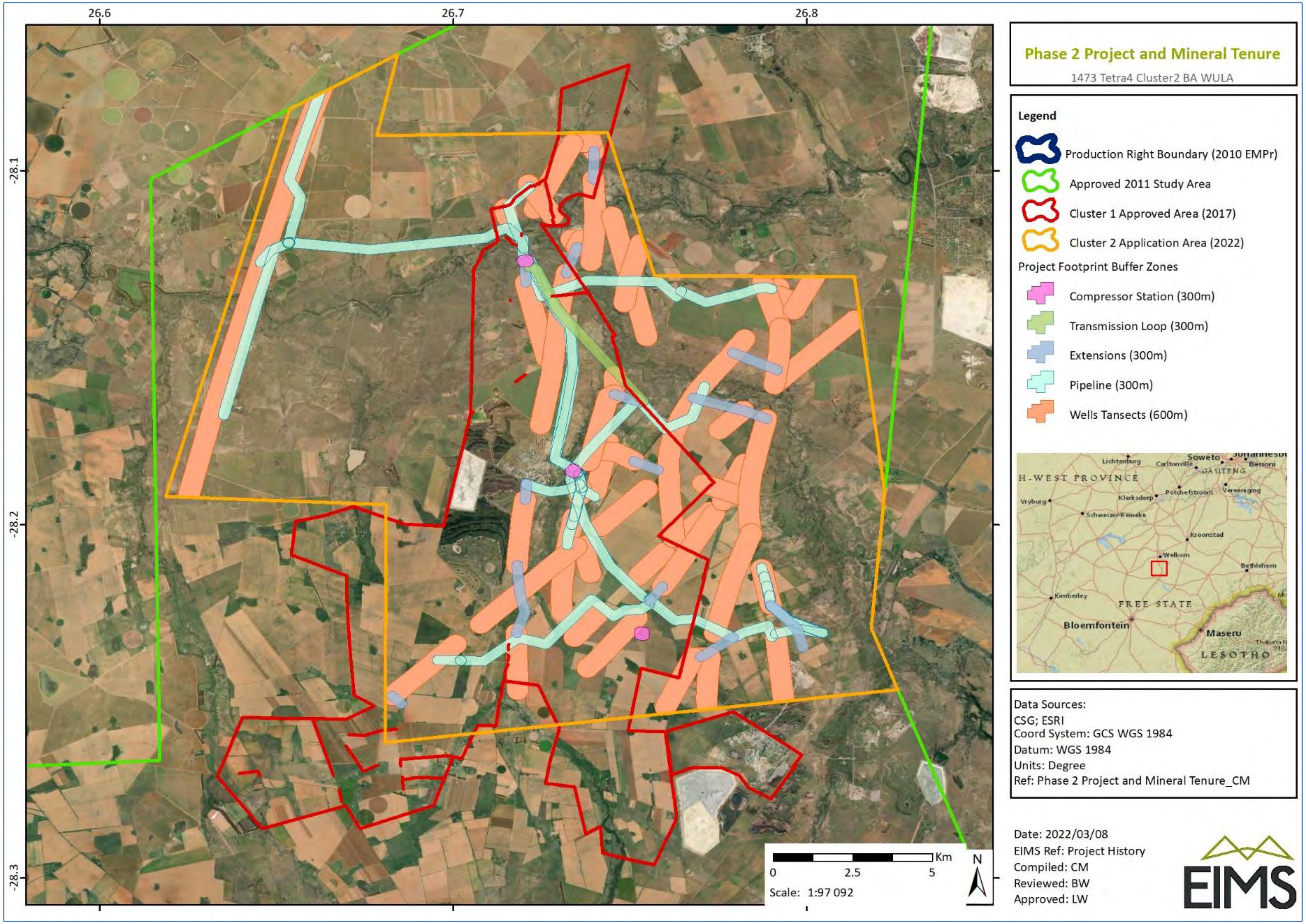
The planned Cluster 2 expansion to the existing approved production activities will involve up to 300 new production wells, gas transmission pipelines and associated infrastructure, 3 compressor stations and an additional new combined Liquid Natural Gas (LNG) and Liquid Helium (LHe) plant ("LNG/LHe Plant") and associated infrastructure, as well as powerlines as part of the Cluster 2 expansion of the Project in order to meet the future production requirements.

Because the final layout will be subject to the well location which will be subject to how exploratory drilling intercepts the gas bearing fault lines, the exact location of the various elements can not be confirmed. In order to accommodate the necessary layout flexibility therefore, buffer areas within which the necessary infrastructure will be developed have been defined.

The following buffer widths are considered:

- Wells – 600m;
- Compressor Stations – 300m;
- Pipelines – 300m; and
- Transmission Loop – 300m.

The Cluster 2 study area and infrastructure buffer zones are presented overleaf.



MAP 3 –CLUSTER 2, PROJECT FOOTPRINT AND BUFFER ZONES

2.2 EXPLORATION BOREHOLES AND WELLS

Exploration wells will be drilled and, if successful, converted into production wells. As the exact location of exploration well drilling cannot be identified at this stage, this study has followed the approach of assessing well corridors (600m wide or 300m on either side of known target fault lines). Exploration drilling entails the use of a truck, trailer or skid mounted percussion or diamond drill rig to drill to varying depths (~380m to ~880m) along known fault lines in order to strike the gas reserve.

A drilling rig will be used to sink exploration boreholes. These may be vertical or inclined boreholes subject to the relative location of the anticipated fault line.

In the event that an exploration borehole proves unsuccessful it will be sealed and cased and the area rehabilitated. In the event that an exploration borehole proves successful it will be converted into a production well and added to the network of gas producing wells for Cluster 2.

Due to low gas pressures in the wells, groups of ~10 wells will be included as an inlet to a booster station to provide vacuum suction. The booster stations will be connected via pipelines to centralised infield reciprocating gas compressor stations.

Three compressor stations are proposed (CS1, CS2 and CS3). An alternative location is under consideration for CS3.

The drilling operation during exploration will disturb an area of approximately 50m x 50m.

When developed, the production well footprint will cover an relatively small area.

Production wells will be placed within a secured precast well chamber with manhole for access. Minimal mechanical infrastructure will be placed within the precast well chamber other than the wellhead, connecting pipeline, an isolation valve and sample point. The surface infrastructure for the manhole would be 1,4m x 1,1m and the manhole surface height will be 0,25m.

Wells will not require fencing and will not be lit.

PLATE 1 – TYPICAL AREA OF DISTURBANCE FOLLOWING DRILLING OF EXPLORATION BOREHOLE
Image sourced from EIMS

PLATE 2 – TYPICAL CLUSTER 2 WELL INSTALLATION
Image sourced from EIMS

2.2 PIPELINES

Due to low gas pressures in the wells, groups of ~10 wells will be included as an inlet to a booster station to provide vacuum suction. The booster stations will be connected via pipelines to centralised infield reciprocating gas compressor stations. Pipelines will be a combination of high-pressure steel as well as low-pressure high-density polyethylene (HDPE) and is installed at a minimum depth of 1.5m below the plough line. The pipeline will be installed using a back-actor and TLB. Where piping (e.g. for the compressors and driers) will be brought to surface, a 110 mm steel piping of approximately 10 m – 30 m will be utilised instead.

Servitude corridors will be maintained free of woody plants in order to prevent disturbance by root growth and ensure access by Tetra4 personnel for regular inspection and infrequent maintenance.

Pipelines will be marked with concrete markers and will have inspection chambers at strategic locations for testing and pipeline maintenance.

Low point drains will also be installed as required. These are comprised of inspection chambers that allow for maintenance.

PLATE 3 – TYPICAL PIPELINE SERVITUDE
Image sourced from EIMS

PLATE 4 – LOW POINT DRAIN
Image sourced from EIMS

2.3 GAS INLINE STATIONS

In order to transport gas via pipelines from the wellheads to the Plant, various inline infrastructure is required to monitor, measure and control gas flow through the pipelines and this includes booster stations, pigging stations and compressor stations.

Localised inline gas booster stations will be installed for each cluster of 7-10 wells which will feed pressurised gas via pipelines from the production wells to the compressor stations. The booster stations will occupy an area of approximately 10 m x 14m and a total of 28 booster stations may be constructed.

Inline pigging stations are installed to allow for regular cleaning and inspection of the pipelines. The pigging stations allow for insertion of probes or cleaning pigs (plugs) at regular intervals in order to perform regular maintenance.

PLATE 5 – VIEW OF EXISTING CLUSTER 1 PIGGING STATION
Image sourced from EIMS

PLATE 6 – VIEW OF EXISTING CLUSTER 1 COMPRESSOR STATION
Image sourced from EIMS

2.4 COMBINED HELIUM AND LIQUID NATURAL GAS PLANT

Feed gas from the centralised reciprocating infield compressor stations will be discharged into the combined LNG/LHe Plant. The LNG/LHe facility is a modularized facility to convert the Feed Gas into LNG, LHe and to provide fuel gas for future power generation. The power generation will be a separate project and is not included in this application process.

The Cluster 2 LNG/LHe Plant will be constructed directly adjacent to the Cluster 1 plant which is currently under construction on the remaining extent of the farm Mond Van Doornrivier 38.

The LNG and LHe products will be loaded to trucks for distribution to users.

The LNG/LHe plant comprises of the following process units:

- Gas Treatment and Boosting System;
- Helium Separation Unit;
- Gas Liquefaction System;
- LHe Storage (~2x100m^3);
- LNG Storage (~11x300m^3); and
- LHe and LNG loading bays.

The area occupied by the proposed Cluster 2 LNG/LHe plant in the operational phase is approximately 9ha while additional areas are required during the construction phase for various contractor laydown areas, offices, parking, etc. Approximately 19.9Ha will be required for various laydown areas of which approximately 10.3Ha will be temporary for use during the construction period only and 9.6Ha will be permanent.

PLATE 7 – EXISTING PHASE 1 TETRA 4 COMBINED HELIUM AND LIQUID NATURAL GAS PLANT

As the plant is operational 24 hours a day, lighting will illuminate the facility throughout hours of darkness.

The tallest elements within the proposed facility are likely to be in the order of approximately 16m high. The buildings will be approximately 10m high.

2.5 POWER SUPPLY

For the Cluster 2 LNG/LHe Plant, electrical power will be obtained from a new dedicated overhead powerline. A new 132kV dual loop-in-loop-out powerline of approximately 4km in length to the Theseus-Oryx 132kV Line will be required and will likely be a 247 (double circuit) tower structure (FIGURE 1). Figure 1 indicates that the proposed 132kV power line towers will be in the order of 31.15m high.

The proposed powerline will feed into a new 40MVA substation at the LNG/LHe Plant. This proposed 132kV power line will be constructed in the powerline corridor.

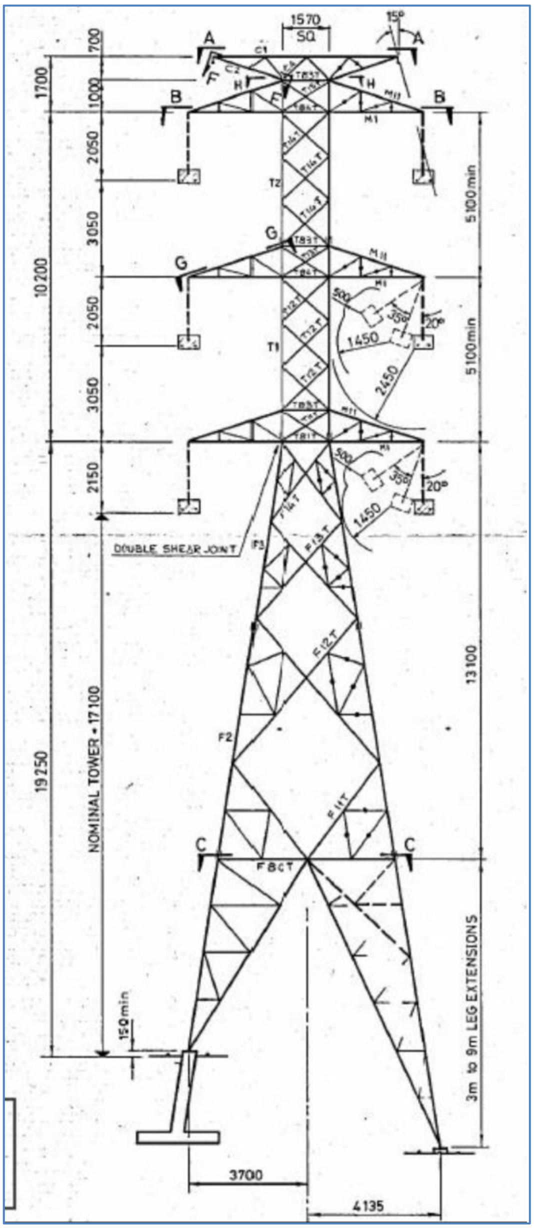


FIGURE 1: 247 TOWER OUTLINE DRAWING

The compressor stations will require a medium voltage substation connection from existing Municipal/Eskom lines (6.6kV/3.3kV switchboard to a 400V switchboard). The booster stations will require 220V (low voltage) and will be powered by either solar PV, LNG generator or municipal pole mounted transformers.

3 DESCRIPTION OF RECEIVING ENVIRONMENT AND POSSIBLE RECEPTORS

3.1 THE STUDY AREA

The study area is comprised of the area over which the proposed development may be visible.

The Approximate Limit of Visibility (ALV) is dictated by height and visual mass of the proposed development, surrounding landscape and built features such as vegetation, ridgelines and buildings as well as the curvature of the earth.

As the terrain is relatively flat, the vegetation relatively low and existing built elements few and far between, the height of the highest proposed elements and the earth's curvature have been used to set the initial study area.

Whilst final layout information was not available due to the possibility of layout adjustment as indicated in Section 4, in order to define an initial study area, it was assumed that, the tallest elements on site will be in the order of 10m high with and Approximate Limit of Visibility of 11.3km.

The initial study area was therefore set at a distance of 11.3km from the proposed site boundary (indicated in red on map 2).

The initial study area was used purely to focus on site survey and data capture work. It is not envisaged that impacts will extend over the entire area, it is however considered to be a sufficient study area to ensure that all likely impacts will fall within it.

3.2 LANDSCAPE CHARACTER

Landscape Character is a composite of a number of influencing factors including:
- Landform and drainage;
- Development and landuse; and
- Vegetation patterns.

From the initial desk top exercise and a subsequent site visit the following characteristics have been identified.

3.2.1 LANDFORM AND DRAINAGE

Topography is comprised of a generally flat landform that is bisected by shallow valleys.

There are three main perennial water courses that cross the proposed development area. They include the Sand River and two of its tributaries, the Doring and Bosluisspruit. Valley slopes are relatively steep rising in the order of 30m from the edge of water course channels.

The landform outside the valley system gently rises to the north and south from the Sand river channel. Gradients generally vary from 1:60 to 1:200.

In visual terms, the undulating landform provides limited screening ability. Should development be located on the minor ridgelines and higher areas this is likely to increase visibility whereas within the valley systems visibility is likely to be limited.

Refer to Map 4 (Landform and Drainage).

PLATE 8 – RELATIVELY FLAT AND GENTLY UNDULATING LANDFORM

PLATE 9 – SHALLOW SAND RIVER VALLEY

3.2.2 LAND COVER

Land cover can broadly be divided into three categories, including:

- Cultivation which occurs largely on the higher, flatter areas of the study area above the minor valleys.
- Natural areas which are generally located within the valley systems. Vegetation is comprised of indigenous grassland which is the natural vegetation type. However, much of this landcover type has been invaded by woody species much of which is comprised of invasive weed species; and

- Major mining operations are highly conspicuous throughout the development area due to extensive stockpiles and infrastructure;
- Settlement that occurs in the form of isolated and small groups of agricultural related homesteads. There are no major areas of settlement within the development area.

Local roads in the area include:

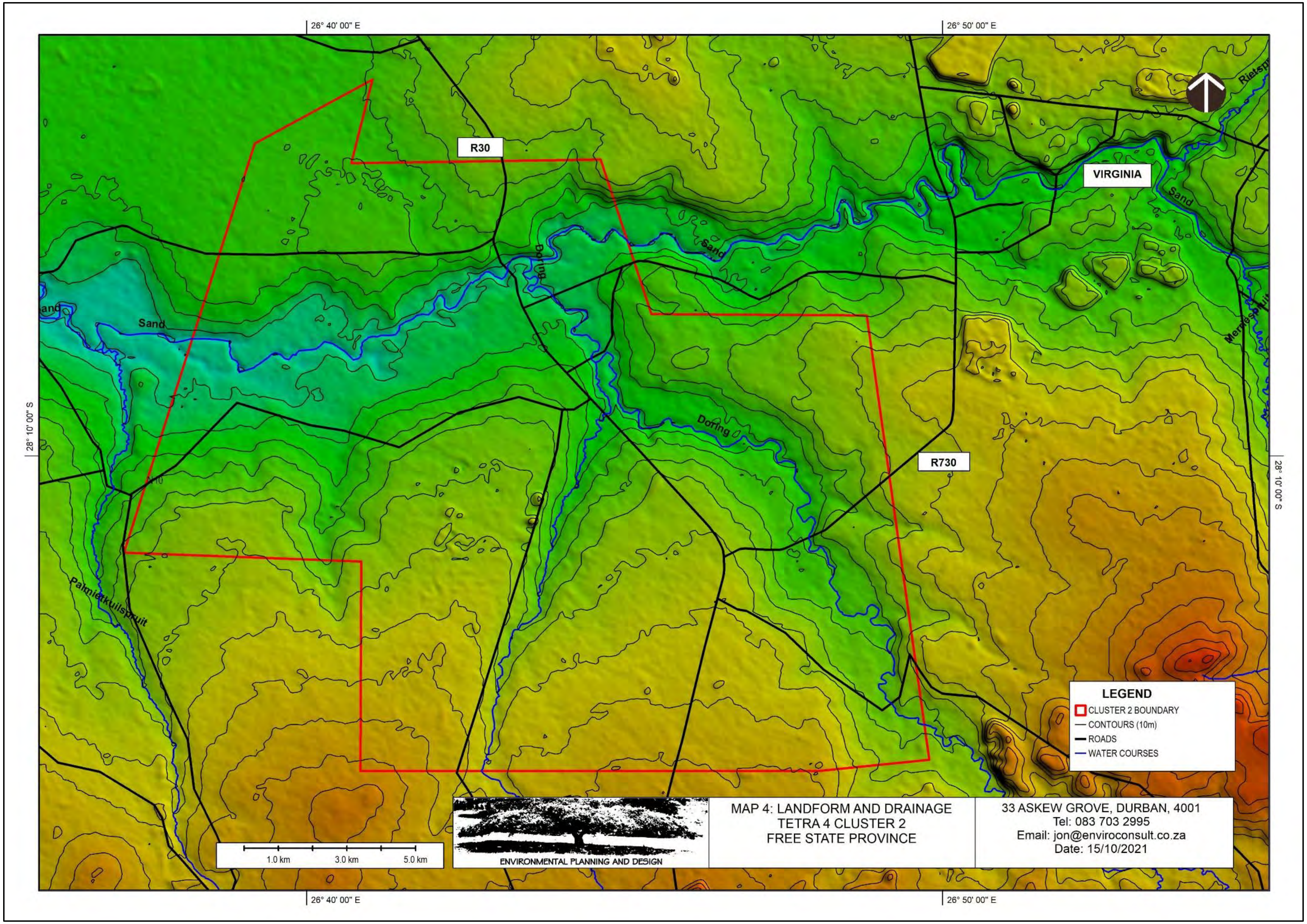
- The R30 and R730 both of which pass through the development area and links Virginia and areas to the north with Theunissen and Branfort to the south. These are both busy local distributors that appear to be largely used by local people and business related traffic including traffic associated with local mines;
- The R710 which links Virginia and Welkom with Bultfontein to the west. Like the R30 and R730, the R710 also appears to be used largely by local people and business related traffic. The R710 does not pass through the proposed development area, at its closest it runs approximately 8.5km to the north; and
- The R73 which links Virginia with the N1 and Winburg to the south east. . Like the R30 and R730, the R710 also appears to be used largely by local people and business related traffic. The R73 does not pass through the proposed development area, at its closest it runs approximately 7.2km to the east.
- A number of unsurfaced local roads that largely service the immediate rural community and mining operations. These roads generally run in an east - west direction providing links with the generally north – south running more major roads.

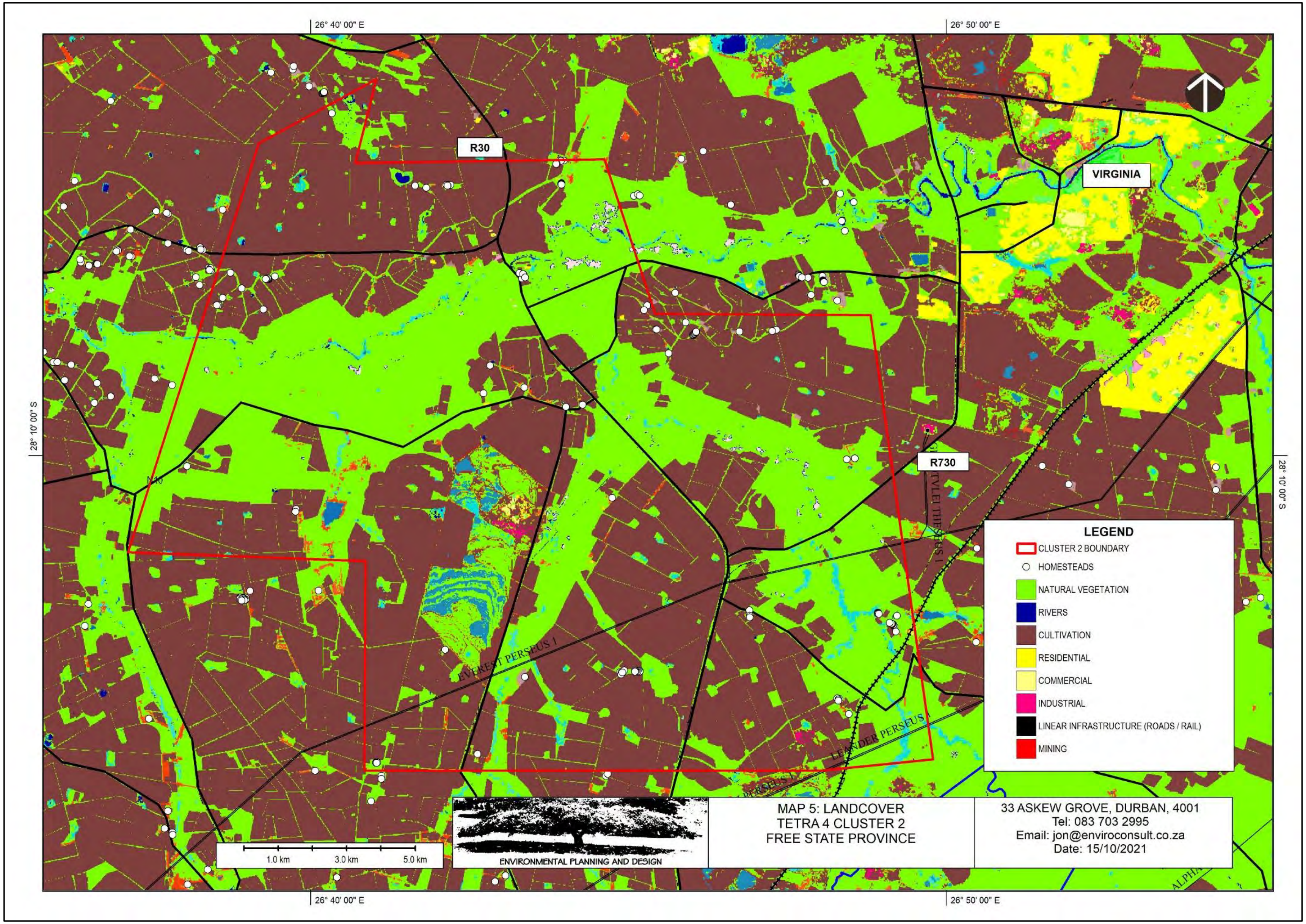
Electrical infrastructure including Eskom's Leander Perseus 1 and Perseus Theseus 1 high voltage (400Kv) overhead power lines are a common sight in the area.

There are no protected areas within the proposed Phase 2 project area. The H. J. Joel Private Nature Reserve is located approximately 1.2km to the south east and the Thabong Game Ranch is located approximately 14.8km to the north-east of the proposed project area. Both of these protected areas are gazetted Nature Reserves.

Refer to Map 5, Landcover.

PLATE 10, CULTIVATION WHICH OCCURS LARGELY ON THE HIGHER, FLATTER AREAS


26° 40' 00" E
26° 50' 00" E
28° 10' 00" S
R30
VIRGINIA
R730
Sand
Doring
Palmietkuilspruit
Rietspruit
LEGEND
CLUSTER 2 BOUNDARY
CONTOURS (10m)
ROADS
WATER COURSES
1.0 km
3.0 km
5.0 km
ENVIRONMENTAL PLANNING AND DESIGN
MAP 4: LANDFORM AND DRAINAGE
TETRA 4 CLUSTER 2
FREE STATE PROVINCE
33 ASKEW GROVE, DURBAN, 4001
Tel: 083 703 2995
Email: jon@enviroconsult.co.za
Date: 15/10/2021


26° 40' 00" E
26° 50' 00" E
28° 10' 00" S
R30
VIRGINIA
R730
N10
EVEREST PERSEUS 1
LEANDER PERSEUS
PERSEUS 1
ALPHA
LEGEND
CLUSTER 2 BOUNDARY
HOMESTEADS
NATURAL VEGETATION
RIVERS
CULTIVATION
RESIDENTIAL
COMMERCIAL
INDUSTRIAL
LINEAR INFRASTRUCTURE (ROADS / RAIL)
MINING
1.0 km
3.0 km
5.0 km
ENVIRONMENTAL PLANNING AND DESIGN
MAP 5: LANDCOVER
TETRA 4 CLUSTER 2
FREE STATE PROVINCE
33 ASKEW GROVE, DURBAN, 4001
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Email: jon@enviroconsult.co.za
Date: 15/10/2021

PLATE 11, NATURAL AREAS WHICH ARE GENERALLY LOCATED WITHIN THE VALLEY SYSTEMS

PLATE 12, MAJOR MINING OPERATIONS ARE HIGHLY CONSPICUOUS THROUGHOUT THE DEVELOPMENT AREA

PLATE 13, ISOLATED AND SMALL GROUPS OF HOMESTEADS ARE THE MAIN SETTLEMENT TYPE

PLATE 14, THE R30 IS ONE OF TWO REGIONAL ROADS RUNNING THROUGH THE DEVELOPMENT AREA

PLATE 15, LOCAL UNSURFACED ROADS LARGELY SERVICING LOCAL PEOPLE

3.2.3 VEGETATION PATTERNS

The following vegetation types are evident within the study area;

a) Natural vegetation that is generally associated with the shallow valley lines;
b) Agricultural vegetation that is comprised of cultivated fields and vegetation which is largely comprised of alien trees and shrubs around homesteads and on field boundaries.

a) Natural Vegetation

Mucina and Rutherford[1] indicate that the predominant vegetation type of the study area is comprised of Vaal-Vet Sandy Grassland, Central Free State Grassland and Highveld Alluvial Vegetation.

Highveld Alluvial Vegetation is described as Flat topography supporting riparian thickets mostly dominated by *Acacia karroo*, accompanied by seasonally flooded grasslands and disturbed herblands often dominated by alien plants. From a superficial overview it appears that this vegetation type is generally located on lower valley slopes and is largely comprised of alien vegetation.

Vaal-Vet Sandy Grassland, Central Free State Grassland generally occupy the upper valley slopes.

The Highveld Alluvial Grassland provides a degree of screening. The open grassland vegetation however provides no screening.

b) Agricultural Vegetation

[1] The Vegetation of South Africa, Lesotho and Swaziland

Agriculture in the study area is largely focused on cultivation including maize and sunflowers.

Within the agricultural pattern there are small patches of alien species including gum trees on field edges, along roads and around homesteads. There are also patches of woody vegetation along main drainage lines.

In visual terms, general crop areas have produced a relatively open landscape.

3.2.4 LANDSCAPE CHARACTER AREAS, VISUAL ABSORPTION CAPACITY (VAC) AND SIGNIFICANCE

Landscape Character Areas (LCAs) are defined as "single unique areas which are the discrete geographical areas of a particular landscape type".

The overriding character differentiating factors within the subject landscape appear to be landform /drainage and vegetation cover.

The landform appears to divide the landscape into Four discrete areas including;

a) Cultivated Rural Landscape Character Area. This area has gently undulating topography and a predominance of cultivated fields that are generally separated by areas of natural grassland. This is a relatively open landscape with little VAC which is only provided by minor ridgelines and alien vegetation;
b) Natural Landscape Character Area. This area is comprised of the shallow valleys surrounding watercourses and is generally covered in Natural Vegetation including grassland and woody alien species that occur in alluvial areas. VAC within these areas is generally moderate due to the fact that much of the woody vegetation extends above eye level;
c) Mining Landscape Character Area. This area includes all mining operations and the extensive stockpiles and infrastructure that associated with them; and
d) The Urban / Residential LCA. This area is comprised entirely of the urban areas of Virginia and Welkom. VAC is generally high within these areas due to the extent of structures and urban vegetation. Also due to distance (minimum 2.7km) surrounding rural vegetation and mining activities are likely to provide an effective screen.

Refer to Map 6, LCAs and Receptors.

3.3 VISUAL RECEPTORS

3.3.1 DEFINITION

Visual Receptors are defined as "individuals and / or defined groups of people who have the potential to be affected by the proposal".

The significance of a change in a view for a visual receptor is likely to relate to use.

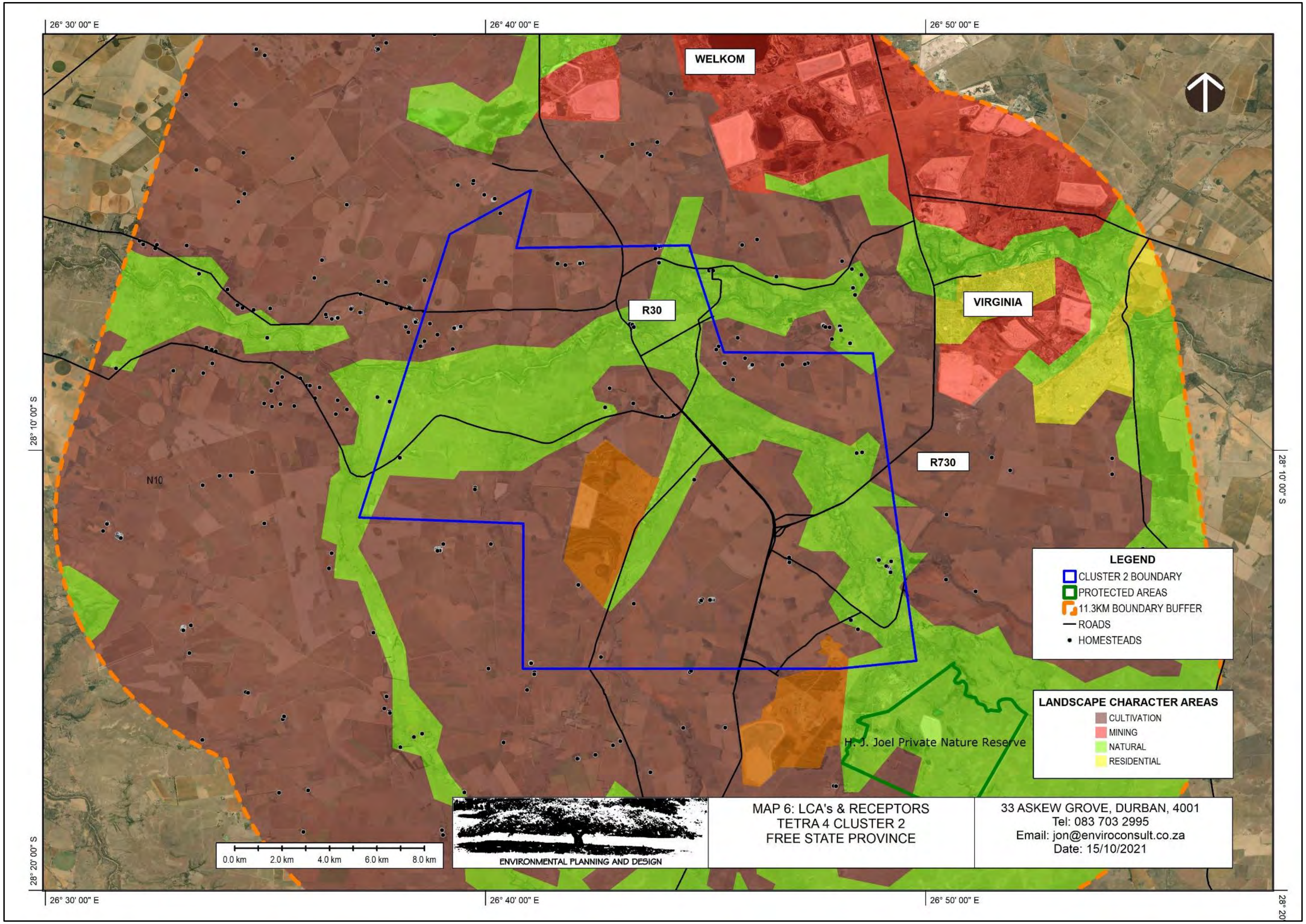
Uses such as guest houses, recreation and tourism related areas are likely to rely on the maintenance of an outlook for successfully attracting guests and users. Residential areas could depend on outlook for the enjoyment of the area by residents and for maintaining property values. A route that is particularly important for tourism may also be dependent on outlook for the maintenance of a suitable experience for users.

3.3.2 IDENTIFIED VISUAL RECEPTORS

Receptors within the affected landscape that due to use could be sensitive to landscape change are indicated below.

- Area Receptors may include;
    - Urban areas within the towns of Virginia and Welkom which are located approximately 2.7km to the east and 7.3km north of the proposed Cluster 2 Boundary Extension respectively; and
    - The H Joel Private Nature Reserve which, at its closest, is located approximately 1.0km to the south of the proposed Phase 2 Extension area.
- Point Receptors that include;
    - There are a number of Local Farmsteads and Homesteads located both within the surrounding landscape. From the site visit it appears that the farmsteads within the proposed site have a primarily agricultural use.
- Linear Receptors or routes through the area that include;
    - The R30, the R730 and the unsurfaced local roads that that run through the proposed Phase 2 Extension area. All of these are used mainly by local people with little or no tourism / recreational importance.

Refer to Map 6, LCAs and Receptors.


26° 30' 00" E
26° 40' 00" E
26° 50' 00" E
28° 10' 00" S
28° 20' 00" S
WELKOM
VIRGINIA
R30
R730
N10
H. J. Joel Private Nature Reserve
LEGEND
CLUSTER 2 BOUNDARY
PROTECTED AREAS
11.3KM BOUNDARY BUFFER
ROADS
HOMESTEADS
LANDSCAPE CHARACTER AREAS
CULTIVATION
MINING
NATURAL
RESIDENTIAL
0.0 km
2.0 km
4.0 km
6.0 km
8.0 km
ENVIRONMENTAL PLANNING AND DESIGN
MAP 6: LCA's & RECEPTORS
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4 THE NATURE OF POTENTIAL VISUAL IMPACTS

4.1 GENERAL

Impacts could include general degradation of the Landscape Character Areas due to the development that may detract from the existing character as well as change of view for affected people and / or activities;

a. General landscape change or degradation. This is particularly important for protected areas where the landscape character might be deemed to be exceptional or rare. However it can also be important in non-protected areas particularly where landscape character is critical to a specific broad scale use such as tourism areas or for general enjoyment of an area. This is generally assessed by the breaking down of a landscape into components that make up the overall character and understanding how proposed elements may change the balance of the various elements. The height, mass, form and colour of new elements all help to make new elements more or less obvious as does the structure of an existing landscape which can provide screening ability or texture that helps to assimilate new elements. This effect is known as visual absorption capacity.
b. Change in specific views within the affected area from which the character of a view may be important for a specific use or enjoyment of the area.
    - Visual intrusion is a change in a view of a landscape that reduces the quality of the view. This can be a highly subjective judgement. Subjectivity has however been removed as far as is possible by classifying the landscape character of each area and providing a description of the change in the landscape that will occur due to the proposed development. The subjective part of the assessment is to define whether the impact is negative or positive. Again to make the assessment as objective as possible, the judgement is based on the level of dependency of the use in question on existing landscape characteristics.
    - Visual obstruction is the blocking of views or foreshortening of views. This can generally be measured in terms of extent.

Due to the nature of the proposed development, visual impacts are expected to relate largely to intrusion.

4.2 THE NATURE OF LIKELY VIEWS OF THE DEVELOPMENT

4.2.1 EXPLORATION AND WELL CONSTRUCTION

During the exploration phase, the drilling rigs that will be used to sink boreholes are likely to be significantly taller (approximately 10m) than permanent works (approximately 2.5m – 3.0m). It is likely therefore that the proposed project will be visible over a wider area during exploration and construction phases than the operational and decommissioning phases.

However, it is likely that a limited number of drilling rigs will be used with each rig being moved to a new drill location on completion of each exploration borehole (approximately 3-5 days subject to the nature of material being drilled).

It is also likely that plant and storage of materials around drilling sites will be more extensive during exploration and construction of wells than during the operational phase. The working area around the drilling operation will be in the order of 100m x 100m. The nature of a typical drilling area can be seen in Plate 14. Once drilling and well construction is complete, well infrastructure will be below ground and all that will be visible is an access manhole. It is unlikely that the manhole will be visible for more than 300m.

it is expected that traffic will be slightly increased as trucks will be required to transport materials and equipment to the site during exploration. However, apart from the occasional delivery of equipment for maintenance.

Following the construction of wells, pipeline and compressor plant construction will be undertaken.

PLATE 16, DRILLING OPERATIONS UNDERWAY DURING PHASE 1 EXPLORATION

PLATE 17, PHASE 2 BELOW GROUND WELL
All that will be visible when complete is a concrete cover to the bunker and a manhole cover for access.

4.2.2 PIPELINES

Proposed pipelines will be buried approximately 1.5m below plough level. Inspection chambers will be installed. Inspection chambers will allow access for pipeline pigging which enables cleaning and inspection to be undertaken.

Pipelines will be constructed using appropriate excavation equipment, part backfilling with pipe bedding material to ensure that it is laid on an even grade, placing the pipe and backfilling with material that was originally excavated from the trench.

Following backfilling of the trenches, a bare section of soil will remain above the pipeline until grass and other surrounding vegetation re-colonises the area. When this has happened however all that will be visible will be pipeline markers and inspection chambers. These are relatively small elements that are necessary for pipeline maintenance. They are only likely to be visible from their immediate vicinity.

PLATE 18, PHASE 1 OPERATIONAL GAS PIPELINE
Note: the pipeline is only obvious due to the pipeline marker in the foreground and the inspection chamber in the middle distance.

4.2.3 COMPRESSOR STATIONS

Visually compressor stations are similar to wells in that they will be comprised of compressor plant enclosed by a mesh security fence in the order of 2.5m high. They will differ from well sites in that the enclosed area is smaller and the plant within the enclosure is smaller. However, like the well sites they will largely be visible from the immediate vicinity and should be easily screened.

Compressor stations are likely to be more obvious during construction than during the operational phase due to the nature of construction activities. Once construction is complete however, and subject to where they are located, compressor stations are likely to be easily missed by the casual observer particularly if they are some distance from receptors or if they are screened by vegetation.

Compressor stations will require a medium voltage substation connection from existing Municipal/Eskom lines (6.6kV/3.3kV switchboard to a 400V switchboard). Eskom MV mini-substations are comprised of closed structures in the order of 3.0m long, 1.2m wide and 1.2m high[2]. These are therefore likely to be relatively small elements that will be located close to the compressor stations.

PLATE 19, PHASE 1 OPERATIONAL PIGGING STATION

4.2.4 PROPOSED 132KV OVERHEAD POWERLINE

Plates 20 and 21 indicates a views along the line of 132kV overhead power lines. The views are taken during a period of good visibility along the line of towers which have a spacing of +/- 250m. In total 9 towers are visible along the line indicated in Figure 18 before it connects to another line at approximately right angles. The last tower in the line which is a solid pole structure is just visible at +/-2.5km.

From this review it is obvious that whilst the theoretical distance that a 31.15m high 132kV power line may be visible from is 19.9km in reality and in the majority of conditions it is unlikely to be obvious at distances greater than 2-3km.

It is possible that either lattice or mono pole towers could be used for the development. Due to the fact that from close views lattice towers tend to read as a more solid structure and the cross section of pole used for a monopole is significantly smaller than the cross section of a lattice tower, monopoles tend to be less imposing from close up. From a distance, however, lattice towers are more visually permeable and the more solid monopole structure is generally more obvious. Despite the observations above, the potential visibility of monopole and lattice towers is likely to be similar.

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[2] ESKOM SPECIFICATION FOR MEDIUM VOLTAGE MINIATURE SUBSTATIONS

The following visual limits have been drawn from these observations:

a) Due to the matt grey colour of the galvanised steel from which it is constructed, visibility of overhead power line structures reduces significantly with distance.

b) The visual mass of the overhead power line is unlikely to be visually obvious from distances greater than 3km.

PLATE 20 - A VIEW ALONG THE LINE OF A 132KV OVERHEAD POWER LINE WITH MONOPOLE TOWERS

PLATE 21 - A VIEW ALONG THE LINE OF AN EXISTING SIMILAR OVERHEAD POWER LINE WITH STEEL LATTICE TOWERS

4.2.5 SECURITY LIGHTING

The proposed production plant is the only section of the proposed project that will be lit throughout the night. This is likely to make the plant obvious during hours of darkness.

Other elements including compressor stations may be lit during night time maintenance operations. They are therefore only likely to infrequently be obvious during the hours of darkness.

4.2.6 SITE ACCESS ROADS

Existing surfaced and unsurfaced roads will be used to access the various sites.

Where a new road is required this will take the form of an unsurfaced road that will be sufficiently wide to allow access for delivery of equipment and access for maintenance. When not in use, new roads are unlikely to be visually obvious outside their general vicinity. When in use however, they are likely to be obvious due to the traffic using them. Due to their likely lite use they are unlikely to be highly obvious.

4.2.7 COMBINED HELIUM AND LIQUID NATURAL GAS PLANT AND 40MVA SUBSTATION

This is a relatively large industrial operation. It will be viewed from the R30 which passes to the east of the proposed plant.

The plant is proposed within a shallow valley and so from this road motorists will have an acute overview of the plant as well as an elevational view as the motorist travels through the valley.

The majority of elements within the plant are relatively low. However, elements such as gas storage tanks may be in the order of 10m high.

The proposed 40MVA substation will either be located within the proposed within the proposed Combined Helium and Liquid Natural Gas or immediately outside it. The substation will be located within a fenced enclosure.

Table 1 - Sub-station components and their functions

Equipment	Function
Circuit breakers	Automatic switching during normal or abnormal conditions
Feeder bay	Steelwork housing for circuits
Reactors	Equipment for the efficient operation of long transmission power lines as they compensate the voltage on power lines to avoid uncontrolled voltage rise, especially on lightly loaded lines
Isolators	Equipment for de-energising a circuit for maintenance and repair
Bus bars	Incoming and outgoing circuits of the same voltage tie into a common node called a busbar, which consists of a number of tubular conductors made of aluminium
Loop-in lines	Incoming power lines (connected to busbars)
Loop-out lines	Outgoing power lines (connected to busbars)
Telecommunication mast	Equipment used for remote communication with the sub-station
Buildings	Administrative office, control room, ablution blocks, equipment and storage areas

Lighting	For safety and security as well as for night-time emergency operations and maintenance

There will be a 16m high stack for flaring excess gas. There will be no permanent flame or pilot flame. There is an ignition source in the event that the flare is needed and the flare does not burn unless there is an uncontrolled release which is likely to be a very rare occurrence, or emergency maintenance has to be undertaken which requires some venting/flaring which again is likely to be a very rare occurrence.

The highest elements within a substation are generally the bus bars that facilitate the transfer of electrical current from the transformers to the downstream power line. These are likely to be in the order of 10m high.

4.2.8 SUMMARY

It is anticipated that the exploration and the construction period will overlap because as the flow of gas is proven in each borehole, well infrastructure is likely to be installed.

Landscape and visual impacts during exploration and construction are likely to be significantly larger both in terms of extent and nature of impacts, than during the operational phase. However, these larger impacts are likely to be local and will be short term and temporary.

When construction is complete and because a large proportion of elements will be located some distance from receptors and / or may be screened by vegetation or landform, it is likely that a large proportion of the various elements may not be obvious to the casual observer.

For many receptors therefore the links between various elements is unlikely to be clear and it will not be obvious that they are part of a larger project.

The exception to this is likely to be in situations where the receptor has a clear view along a line of wells in which case the link between the elements is likely to be clear and the project will read as a more significant development.

5 LANDSCAPE, RECEPTORS AND SITE SENSITIVITY

5.1 GENERAL

Due to the general flatness of the surrounding topography and the low nature and small scale and isolated nature of the majority of the proposed elements within the project, it is unlikely that it will affect areas extending significantly further than their immediate vicinity.

Exceptions to this are likely to include:

- Well drilling operations when the +/- 10m high drill rigs may be visible for up to 11.3km; and
- The Production plant, which could also have tanks and plant up to 10m high which could also be visible for up to 11.3km.

The key considerations include:

- The drill rigs will be in place on a temporary short term basis. The drilling rigs are also likely to be comprised of relatively slender structures and because of this are unlikely to be visible to the full extent of their theoretical limit of visibility.
- It is also likely that many of the boreholes will be inclined which means that the drill rigs will also be inclined thus reducing their overall height;
- The production plant will be in place on a long term basis. It is also likely that the visual mass of the plant is likely to be such that it could be visible to its theoretical limit of visibility.
- The limited height and visual mass of the proposed wells and compressor stations is likely to be such that these elements should be easily screened by natural vegetation. Their visibility is also likely to be mitigated with distance.
- Pipelines are only likely to have any significant impact during construction and then it is likely to be the construction plant and pipeline storage that will be most obvious. Once construction is complete, the only items that will be visible are likely to be pipeline markers and inspection chambers;
- The LV overhead power line is unlikely to have any significant impact at distances greater than 2.5km.

5.2 SENSITIVITY

Site (Landscape) sensitivity (Map 6) is largely related to the way that the site fits into the surrounding landscape i.e. is it an important component.

The sensitivity of potential receptors generally relates to whether views are important to support current or potential usage. However, they also relate to nuisance and whether for instance a proposed use could impose on and make an existing use uncomfortable or even untenable.

The landscape within which the proposed projects is located is not highly sensitive. It has largely been transformed by large scale mining operations and commercial agriculture.

The topography and vegetation patterns are also such that there is little VAC, receptors are therefore to a large degree affected by views of mining operations.

However, the development proposal is likely to result in a finer grain industrial character which could mean that even though the majority of individual elements are relatively small they will be considerably closer to the majority of potential receptors.

5.2.1 NO GO AREAS

Due to the fact that the affected landscape is highly transformed by both agriculture and mining and because protected areas are highly unlikely to be affected, there are no potentially affected areas where development should not happen due to potential landscape or visual impacts.

5.2.2 AREAS WITH HIGH SENSITIVITY

There are potentially affected areas that could be sensitive to potential development, these include:

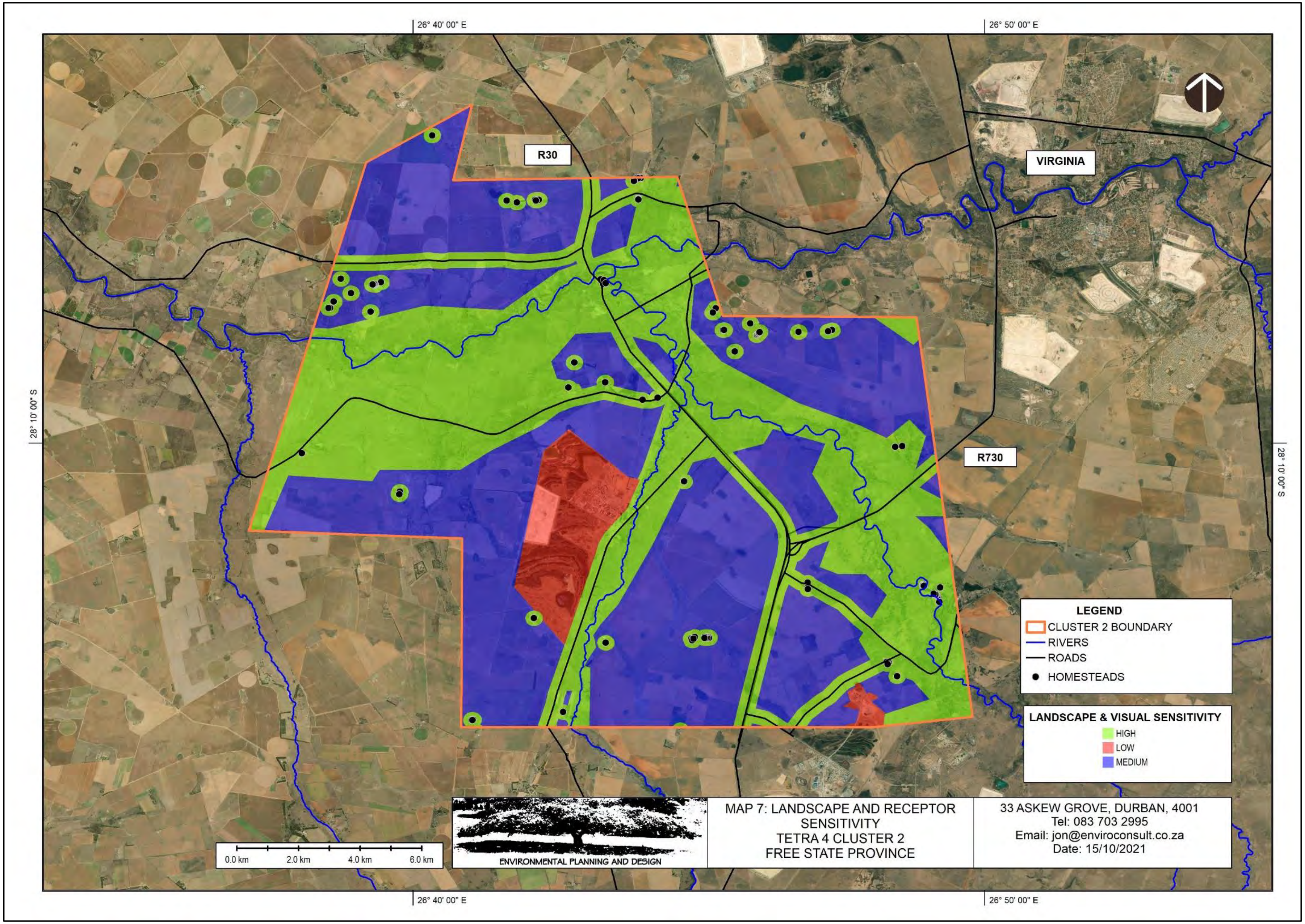
- All Natural areas that are largely located within the shallow river valleys. These areas have largely survived in a natural state due to their unsuitability for large scale mining and agriculture, they are therefore relatively intact. In addition to the provision of key environmental services such as attenuation of storm run-off, they provide visual buffers between intensive agriculture and mining operations. There are therefore sound reasons to maintain the integrity of these areas. From a landscape and visual perspective however, it is likely that the location of wells, compressor stations and pipelines might occur within these areas with minimal impact. However, this is subject to minimal disturbance and appropriate mitigation to ensure that the natural landscape character remains intact;
- All areas within close proximity to homesteads. Currently there are views from many homesteads of large scale mining operations. However, there are very few homesteads that have close range views over industrial operations. It is possible that the development of the various elements associated with the proposed project could be located in close proximity to homesteads and, subject to distance, these could dominate views of residents. Due to the small scale of the majority of proposed elements, he screening ability of natural areas in which many of the proposed elements are located, a 250m buffer has been indicated around homesteads. It is not proposed that development in these areas is prevented, however, development must be undertaken in a way that views from affected homesteads are not dominated by views of the elements, appropriate mitigation is undertaken and appropriate consultation is undertaken with residents.
- All areas within close proximity to roads. Views from the main "R" roads that pass through the affected area are currently largely comprised of large scale arable agriculture in the foreground and middle distance backed by large scale mining operations. These views are punctuated by natural landscape areas as the motorist crosses the shallow river valleys. Subject to distance, the majority of proposed elements are such that their location within the current large scale open agricultural landscape is unlikely to be highly obvious. Due to their scale, a well, compressor station or LV overhead power line located 250m away from a road is unlikely to the highly visible from the road. A pipeline at any distance from the road, as long as appropriate rehabilitation is undertaken, is unlikely to be highly visible.

5.2.3 AREAS WITH MEDIUM SENSITIVITY

Areas with medium sensitivity to development include all arable agricultural areas outside 250m from homesteads and roads.

5.2.4 NON-SENSITIVE AREAS

All non-sensitive areas including mining areas outside 250m from homesteads and roads.


26° 40' 00" E
26° 50' 00" E
R30
VIRGINIA
R730
28° 10' 00" S
LEGEND
CLUSTER 2 BOUNDARY
RIVERS
ROADS
HOMESTEADS
LANDSCAPE & VISUAL SENSITIVITY
HIGH
LOW
MEDIUM
0.0 km
2.0 km
4.0 km
6.0 km
ENVIRONMENTAL PLANNING AND DESIGN
MAP 7: LANDSCAPE AND RECEPTOR SENSITIVITY
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6 VISIBILITY

6.1 ZONES OF THEORETICAL VISIBILITY

Zones of Theoretical Visibility (ZTV) are defined as "a map usually digitally produced showing areas of land within which a development is theoretically visible"[3].

ZVTs of the proposed development have been assessed using Global Mapper GIS.

The ZTV has been calculated from terrain data only, existing vegetation and / or other development could have a modifying effect on the areas indicated.

The main elements that will have visual implications include:

- A series of compressor stations with structures up to 3.0m high.
- The proposed Combined Helium and Liquid Natural Gas Plant (CHLNGP); and
- The proposed 132kV overhead power line.

It should be noted that production well structures will be below ground and so will not be visible in the landscape.

ZTV analysis have been undertaken in order to provide an indication of visibility of these elements.

The temporary landscape and visual impact of construction operations and in particular drilling rigs has been discussed in Section 4.

The approximate limit of visibility of the main elements that are likely to contribute to landscape and visual impacts has been derived using a universally accepted navigational formula has been used to calculate the likely distance that the proposed structures might be visible over (Appendix III). This indicates that in a flat landscape the proposed structures may be visible for the following distances;

Table 2 - Approximate limit of Visibility (ALV)

ELEMENT	APPROXIMATE LIMIT OF VISIBILITY
Compressor Stations including MV substations, up to 3.0m high.	6.2 kilometres
The CHLNGP including 40MV substation, up to 10m high.	11.3 kilometres
132kV Overhead Power Line up to 31.25m high	19.9 kilometres

6.2 LIKELY VISIBILITY OF WELLS AND COMPRESSOR STATIONS

The ZTV analysis indicates these elements could be visible throughout the proposed Cluster 2 Extension area including all identified Landscape Character Areas. The ZTV also indicates that compressor plant are likely to be more visible in a north to south running band through the study area.

There are approximately 11 homesteads in close proximity to compressor stations that could be negatively impacted.

[3] UK Guidelines

There are also seven areas where compressor plant appear to be located in close proximity to roads.

Whilst these elements may be visible over a distance of up to 6.2km, they are relatively low with much of the higher sections including fencing likely to be relatively transparent. This means that visibility should be relatively successfully mitigated with distance and will also be relatively easily screened in areas with taller vegetation as long as disturbance is minimised.

Therefore, where these elements are located within the Natural LCA, as long as disturbance is minimised and rehabilitation undertaken, they are unlikely to be visually obvious.

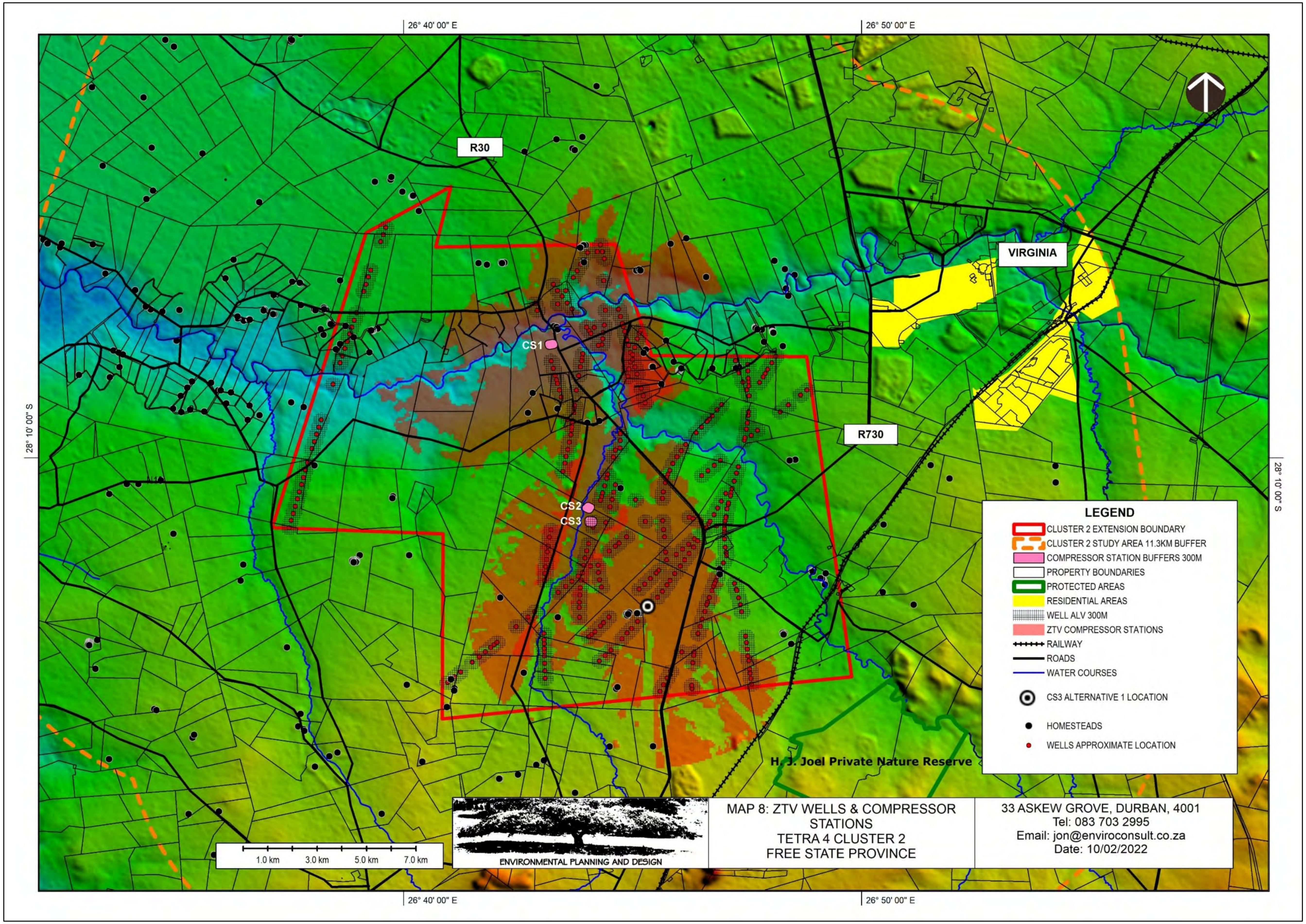
Within open landscape areas and particularly the wide open and relatively flat Agricultural LCA, having these elements organised in relatively straight lines along geological faults, could make them relatively obvious. It is likely that closely located grouping of these elements could also make them more obvious.

When assessing likely landscape and visual impacts, it has to be considered that the Agricultural LCA is a working landscape and whilst the proposed development could have a slight negative impact on agricultural production, it will not dominate or create an overall landscape change. They will therefore be viewed within a large scale agricultural landscape which will still dominate landscape character.

It is noted that there are two alternative locations for Compressor Station 3 under consideration. The preferred location is close to Compressor Station 2 and also within 1km of a local road whereas the alternative location is within 400m of a group of eight homesteads and 1.3km of the R30. Whilst impacts associated with both alternatives are likely to be relatively low, the developer's preferred alternative is preferred from a landscape and visual perspective due to the lower potential to impact on residential homesteads.

Because the proposed wells will be located underground and will only be visible as a manhole at the surface, they will not be visible outside their immediate vicinity. An arbitrary 300m ALV buffer is indicated on the map but in reality, they are unlikely to be visually obvious for more than 200m.

PLATE 22, OPEN AND FLAT AGRICULTURAL LANDSCAPE WITHIN WHICH COMPRESSOR PLANTS ARE LIKELY TO BE VISUALLY OBVIOUS


26° 40' 00" E
26° 50' 00" E
28° 10' 00" S
R30
VIRGINIA
R730
CS1
CS2
CS3
H. J. Joel Private Nature Reserve
LEGEND
CLUSTER 2 EXTENSION BOUNDARY
CLUSTER 2 STUDY AREA 11.3KM BUFFER
COMPRESSOR STATION BUFFERS 300M
PROPERTY BOUNDARIES
PROTECTED AREAS
RESIDENTIAL AREAS
WELL ALV 300M
ZTV COMPRESSOR STATIONS
RAILWAY
ROADS
WATER COURSES
CS3 ALTERNATIVE 1 LOCATION
HOMESTEADS
WELLS APPROXIMATE LOCATION
1.0 km
3.0 km
5.0 km
7.0 km
ENVIRONMENTAL PLANNING AND DESIGN
MAP 8: ZTV WELLS & COMPRESSOR STATIONS
TETRA 4 CLUSTER 2
FREE STATE PROVINCE
33 ASKEW GROVE, DURBAN, 4001
Tel: 083 703 2995
Email: jon@enviroconsult.co.za
Date: 10/02/2022

6.3 LIKELY VISIBILITY OF THE COMBINED HELIUM AND LIQUID NATURAL GAS PLANT INCLUDING A 40MV SUBSTATION AND GAS FLARE

The ZTV analysis indicates that the proposed CHLNGP will largely be visible from within the shallow Sand River Valley. The CHLNGP is therefore likely to be largely screened by landform from agricultural landscape areas to the north and south.

As it will be located immediately adjacent to the existing plant, it is likely that both facilities will be visible over the same general area.

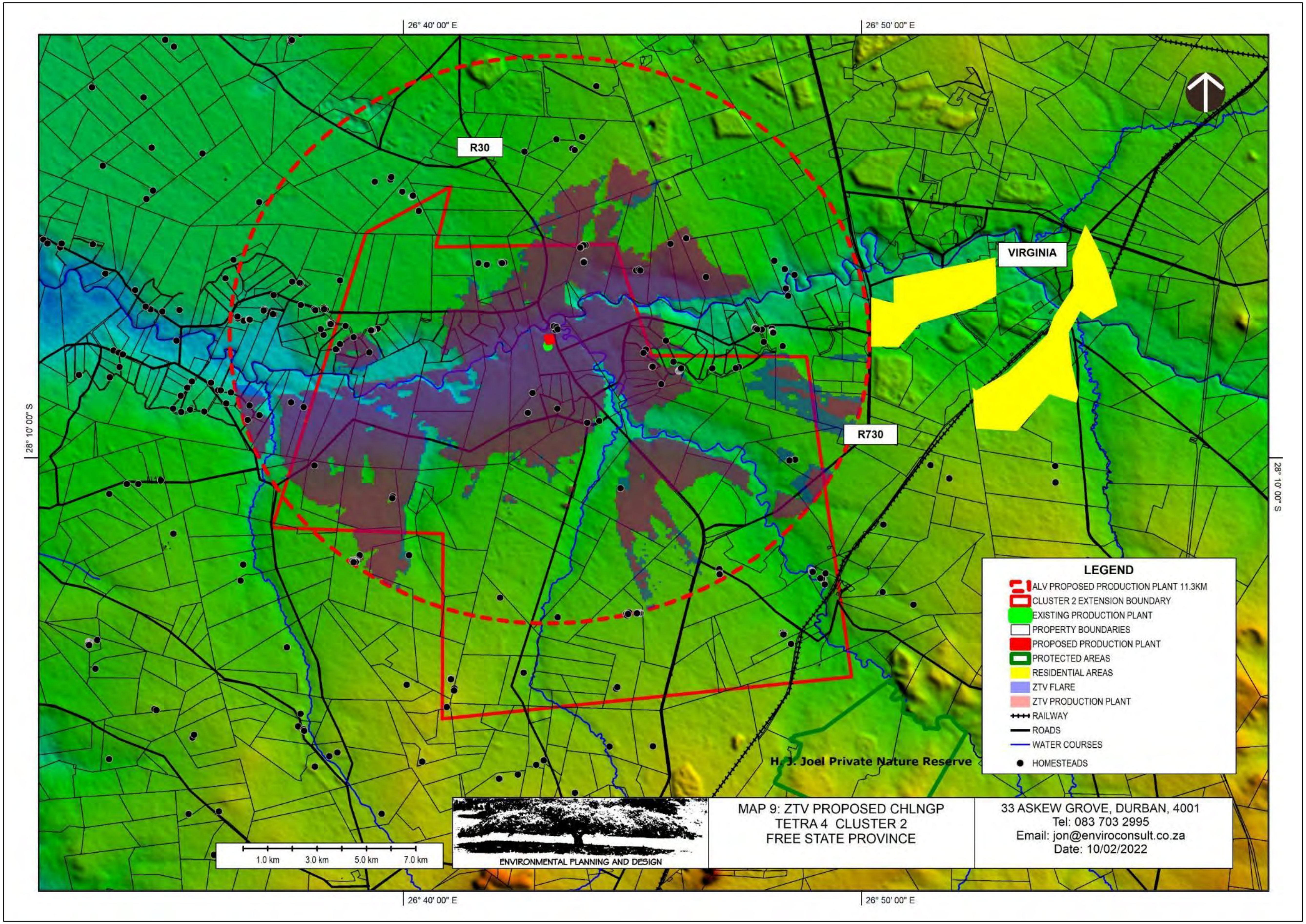
The facility could be highly obvious from the R30 as it crossed the valley. Whilst Cluster 1 plant is closest to the road, Cluster 2 plant is likely to add to the impact. It is noted however, that little rehabilitation has been undertaken to screen the existing plant.

The proposed CHLNGP is located approximately 220m from the closest private buildings and could be visible from a group of buildings some of which are used for residential use. These buildings are part of the Moerkands Pan which is a local bar. The buildings are lower than the road and trees between them and the proposed CHLNGP are likely to largely screen the plant.

Map 9 indicates that the likely extent of visibility of the plant including the 16m high stack which is likely to be visible from a similar area as the structures associated with the proposed plant.

PLATE 23, VIEW OF THE EXISTING CHLNGP IN THE SAND RIVER VALLEY.
THE CLUSTER 2 CHLNGP WILL BE LOCATED IMMIDIATELY ADJACENT TO THE EXISTING PLANT.

PLATE 24, MOERKANDSPAN WHICH IS A LOCAL BAR LOCATED ON THE OPPOSITE SIDE OF THE R30 TO THE PROPOSED CHLNGP


26° 40' 00" E
26° 50' 00" E
28° 10' 00" S
R30
VIRGINIA
R730
H. J. Joel Private Nature Reserve
LEGEND
ALV PROPOSED PRODUCTION PLANT 11.3KM
CLUSTER 2 EXTENSION BOUNDARY
EXISTING PRODUCTION PLANT
PROPERTY BOUNDARIES
PROPOSED PRODUCTION PLANT
PROTECTED AREAS
RESIDENTIAL AREAS
ZTV FLARE
ZTV PRODUCTION PLANT
RAILWAY
ROADS
WATER COURSES
HOMESTEADS
1.0 km
3.0 km
5.0 km
7.0 km
ENVIRONMENTAL PLANNING AND DESIGN
MAP 9: ZTV PROPOSED CHLNGP
TETRA 4 CLUSTER 2
FREE STATE PROVINCE
33 ASKEW GROVE, DURBAN, 4001
Tel: 083 703 2995
Email: jon@enviroconsult.co.za
Date: 10/02/2022

6.4 LIKELY VISIBILITY OF THE PROPOSED 132KV OVERHEAD POWER LINE

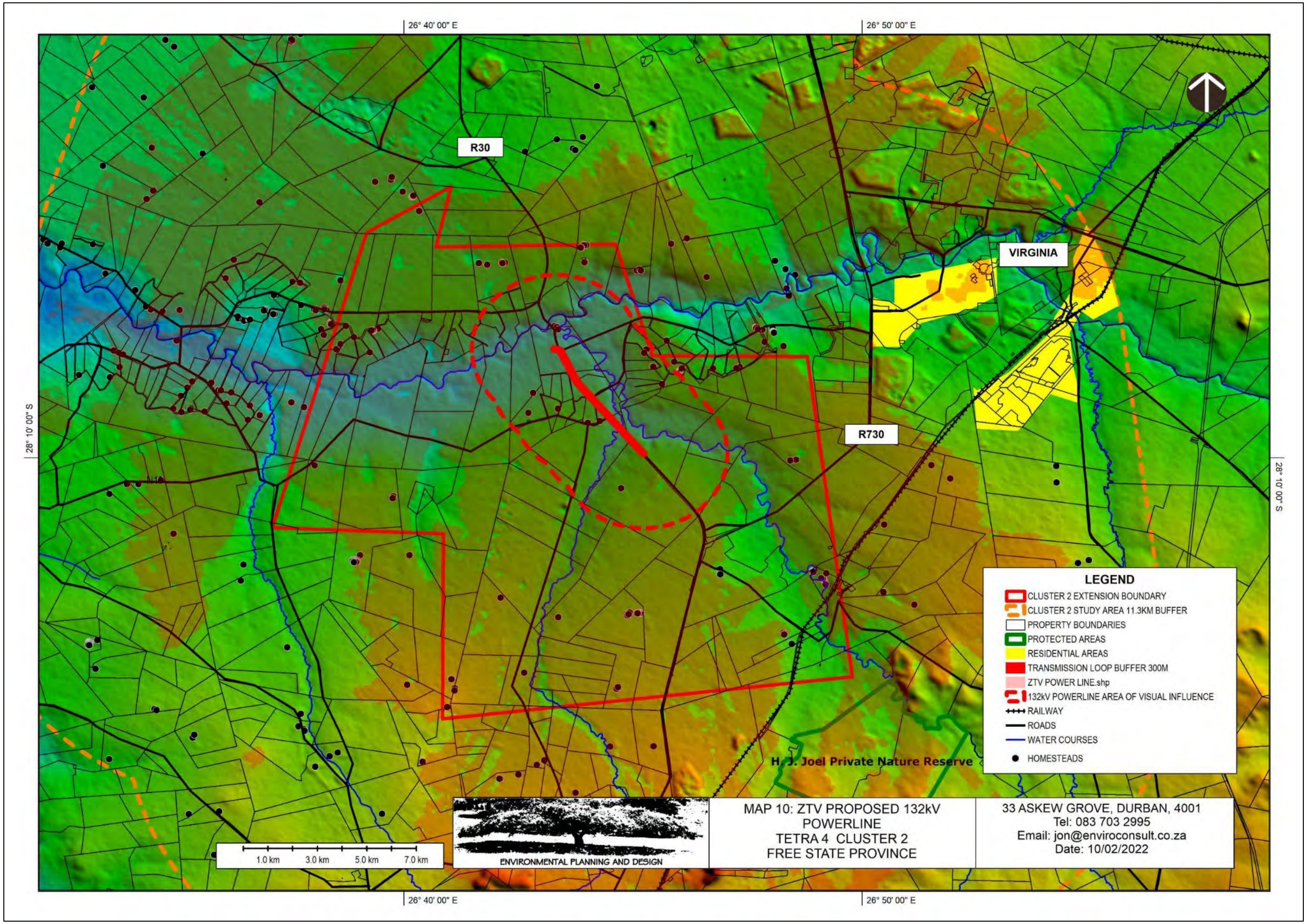
Due to the height of the proposed power line, it is potentially visible over an extensive area. However, due to the colouring and relative transparency of the power line, visibility is rapidly mitigated with distance to the extent that at a distance of approximately 2.5-3.0km, the power line is unlikely to be visually obvious.

The proposed power line will run parallel to the section of the R30 pictured in Plate 23.

The proposed power line will add an industrial element that will be highly obvious from the road. However, impacts are likely to be limited to approximately 10.8km of the R30.

The view of overhead power lines is a common site within the vicinity of the affected section of the R30.

PLATE 25, VIEW OF THE EXISTING EVEREST PERSEUS 275KV OVERHEAD POWER LINE FROM THE R30


26° 40' 00" E
26° 50' 00" E
28° 10' 00" S
R30
R730
VIRGINIA
H. J. Joel Private Nature Reserve
LEGEND
CLUSTER 2 EXTENSION BOUNDARY
CLUSTER 2 STUDY AREA 11.3KM BUFFER
PROPERTY BOUNDARIES
PROTECTED AREAS
RESIDENTIAL AREAS
TRANSMISSION LOOP BUFFER 300M
ZTV POWER LINE.shp
132kV POWERLINE AREA OF VISUAL INFLUENCE
RAILWAY
ROADS
WATER COURSES
HOMESTEADS
1.0 km 3.0 km 5.0 km 7.0 km
ENVIRONMENTAL PLANNING AND DESIGN
MAP 10: ZTV PROPOSED 132kV POWERLINE
TETRA 4 CLUSTER 2
FREE STATE PROVINCE
33 ASKEW GROVE, DURBAN, 4001
Tel: 083 703 2995
Email: jon@enviroconsult.co.za
Date: 10/02/2022

7 ASSESSMENT

7.1 GENERAL

The previous section of the report identified specific areas where visual impacts may occur as well as their likely nature. This section will quantify these potential visual impacts in their respective geographical locations and in terms of the identified issues.

7.2 LANDSCAPE AND VISUAL ISSUES

7.2.1 URBAN RESIDENTIAL AREAS

From the site visit, due to distance and topography, it was obvious that the proposed project would not be visible from either the urban area of Virginia or Welkom. This has been confirmed by the ZTV analysis with none of the assessments indicating that elements are likely to be visible from urban areas.

7.2.2 H J JOEL PRIVATE NATURE RESERVE

This reserve is located within and around the Joel Mine that is located to the south east of the proposed Cluster 2 Extension Area (Figure 2). From within the reserve the Joel mine and stockpiles are obvious.

The closest elements associated with the project are potential well locations that are located approximately 2.8km to the north-west. Between the possible well locations and the reserve there are facilities associated with the Joel Mine as well as the Beatrix Mine. It is therefore highly unlikely that the proposed wells will be visible from within the reserve whereas it is highly likely that existing mining operations will be visible.

7.2.3 LANDSCAPE AND VISUAL ISSUES TO BE ASSESSED

The following list of possible landscape and visual impacts were confirmed as being likely during the site visit;

a) The proposed development could change the character and sense of place of the landscape setting;
b) The proposed development could change the character of the landscape as seen from the local roads;
c) The proposed development could change the character of the landscape as seen from local homesteads;
d) Lighting impacts.

As indicated, landscape change and change in the views of receptors are likely to be greatest during exploration and construction. When storage and working areas are cleared, rehabilitation is undertaken and natural vegetation regenerates, areas and the nature of impacts are likely to reduce significantly to the extent that some elements are unlikely to be obvious to the casual observer.

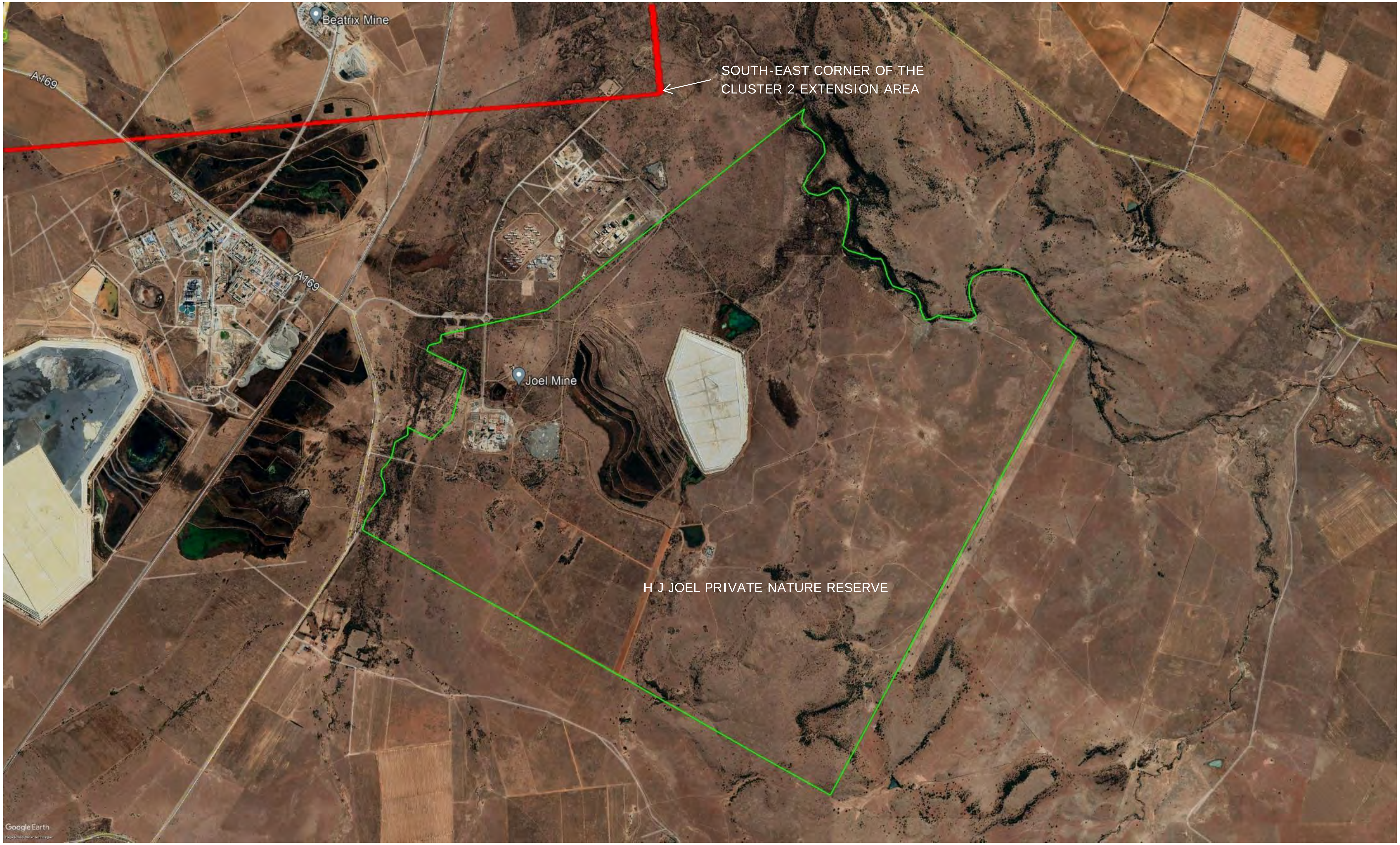


FIGURE 2, GOOGLE EARTH OVERVIEW OF THE H J JOEL PRIVATE NATURE RESERVE

From the overview it is clear that the Nature Reserve is within and around the Joel Mine and that mine facilities are located between the reserve and the proposed Cluster 2 Extension Area

7.3 DETAILED METHODOLOGY

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S). Please note that the impact assessment must apply to the identified Sub Station alternatives as well as the identified Transmission line routes.

7.3.1 DETERMINATION OF ENVIRONMENTAL RISK

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER).

The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \frac{(E+D+M+R)}{4} \times N$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table .

Table 3: Criteria for Determining Impact Consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),

Aspect	Score	Definition
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/scored as per Table .

Table 4: Probability Scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur),

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

ER= C x P

Table 5: Determination of Environmental Risk

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table .

Table 6: Significance Classes

Environmental Risk Score	
Value	Description
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

7.3.3 IMPACT PRIORITISATION

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 7: Criteria for Determining Prioritisation

Public response (PR)	Low (1)	Issue not raised in public response.
	Medium (2)	Issue has received a meaningful and justifiable public response.
	High (3)	Issue has received an intense meaningful and justifiable public response.
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the

		impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 11. The impact priority is therefore determined as follows:

Priority = PR + CI + LR

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (Refer to Table).

Table 8: Determination of Prioritisation Factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 9: Final Environmental Significance Rating

Environmental Significance Rating	
Value	Description
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),

Environmental Significance Rating	
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).

7.4 LANDSCAPE AND VISUAL IMPACT ASSESSMENT

Due to the scale elements, mitigation measures are generally likely to be significant in reducing levels of visual impact.

For the sake of the assessment the construction phase has been taken as including the initial exploration works;

7.4.1 THE PROPOSED FACILITY COULD IMPACT ON THE RURAL AGRICULTURAL LANDSCAPE CHARACTER AREA

a) Nature of Impact

In general terms the proposed project could industrialise this Landscape Character Area. Large scale mining operations are currently visible from within this landscape. The proposed project will see drilling operations occurring throughout the area during exploration and construction. However when this is complete, there will be up to 300 production well, compressor plants and a 4km long 132kV overhead power line within the landscape. These are relatively small infrastructure elements. The large scale agricultural nature of the landscape will remain very evident. A degree of industrialisation will therefore occur however, the existing landscape character will still dominate.

b) Impact Assessment

In terms of determining prioritisation, public response, cumulative effects and the possible irreplaceable loss of resources have to be considered.

As consultation has not been undertaken it is impossible to confirm public response, however, given the extent of mining in the vicinity and the fact that landscape is not protected and not of high quality, it seems unlikely that the issue will be raised as a significant concern.

In terms of cumulative effects, the proposed project will not significantly change the character of views. It will however combine with large scale mining operations including stockpiles and plant during the construction and operational phases to intensify current impacts on landscape character.

After decommissioning, visual impacts will reduce due to the removal of operational plant.

Due to the fact that the affected landscape is relatively flat and open, no mitigation is feasible.

7.4.2 IMPACT ASSESSMENT TABLES

Table 10 - Impact on Existing Agricultural Landscape Character, Assessment Table

Impact Name	**Change of Agricultural Landscape Character**
Phase	**10A - Construction**
Environmental Risk	

Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature of Impact	-1	-1	Magnitude of Impact	3	3
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	1	1	Probability	4	4
Environmental Risk (Pre-mitigation)					-8.00
Mitigation Measures					
No effective mitigation possible.					
Environmental Risk (Post-mitigation)					-8,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-9.36

Impact Name	**Change of Agricultural Landscape Character**				
Phase	**10B - Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	1	1
Extent of Impact	1	1	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	2	2
Environmental Risk (Pre-mitigation)					-3.50
Mitigation Measures					
• Rehabilitate disturbed area and reinstate agricultural usage					
Environmental Risk (Post-mitigation)					-3,50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-4,095

Impact Name	**Change of Agricultural Landscape Character**				
Phase	**10C - Decommissioning**				
Nature of Impact	-1	-1	Magnitude of Impact	2	1

Extent of Impact	2	1	Reversibility of Impact	2	1
Duration of Impact	4	1	Probability	4	1
Environmental Risk (Pre-mitigation)					-10,00
Mitigation Measures					
• Remove all above ground infrastructure; and • Return land to agricultural use.					
Environmental Risk (Post-mitigation)					-1,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-1.17

Table 11 - Impact on Existing Natural Landscape Character, Assessment Table

Impact Name	**Change of Natural Landscape Character**				
Phase	**11A - Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	3	2
Extent of Impact	2	1	Reversibility of Impact	2	2
Duration of Impact	1	1	Probability	4	2
Environmental Risk (Pre-mitigation)					-8.00
Mitigation Measures					
• Minimise disturbance of the natural landscape; and • Undertake rehabilitation and screen planting					
Environmental Risk (Post-mitigation)					-3,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-3.51

Impact Name	**Change of Natural Landscape Character**
Phase	**11- B Operation**
Environmental Risk	

Impact Name	Change of Natural Landscape Character				
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	2	1
Extent of Impact	2	1	Reversibility of Impact	2	1
Duration of Impact	4	4	Probability	3	2
Environmental Risk (Pre-mitigation)					-7.50
Mitigation Measures					
• Minimise disturbance of the natural landscape; and • Undertake rehabilitation and screen planting.					
Environmental Risk (Post-mitigation)					-3,50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-4,095

Impact Name	Change of Natural Landscape Character				
Phase	**11 C - Decommissioning**				
Nature of Impact	-1	-1	Magnitude of Impact	2	1
Extent of Impact	2	1	Reversibility of Impact	2	1
Duration of Impact	1	1	Probability	3	2
Environmental Risk (Pre-mitigation)					-5.25
Mitigation Measures					
• Remove all above ground infrastructure; • Rehabilitate disturbed areas.					
Environmental Risk (Post-mitigation)					-2,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-2,34

Table 12, The visual impact on views from local roads

Impact Name	Change of Natural of Views from Local Roads
Phase	**12A - Construction**

<table>
<tr><td colspan="6">Environmental Risk</td></tr>
<tr><td>Attribute</td><td>Pre-mitigation</td><td>Post-mitigation</td><td>Attribute</td><td>Pre-mitigation</td><td>Post-mitigation</td></tr>
<tr><td>Nature of Impact</td><td>-1</td><td>-1</td><td>Magnitude of Impact</td><td>3</td><td>2</td></tr>
<tr><td>Extent of Impact</td><td>2</td><td>2</td><td>Reversibility of Impact</td><td>2</td><td>2</td></tr>
<tr><td>Duration of Impact</td><td>1</td><td>1</td><td>Probability</td><td>4</td><td>3</td></tr>
<tr><td colspan="5">Environmental Risk (Pre-mitigation)</td><td>-8.00</td></tr>
<tr><td colspan="6">Mitigation Measures</td></tr>
<tr><td colspan="6">• Locate wells and compressor stations a minimum 250m from the edge of local roads;
• Undertake rehabilitation;
• Return disturbed agricultural land to agricultural use; and
• Undertake screen planting between the R30 and the proposed production plant.</td></tr>
<tr><td colspan="5">Environmental Risk (Post-mitigation)</td><td>-5,25</td></tr>
<tr><td colspan="5">Degree of confidence in impact prediction:</td><td>Medium</td></tr>
<tr><td colspan="6">Impact Prioritisation</td></tr>
<tr><td colspan="5">Public Response</td><td>1</td></tr>
<tr><td colspan="6">Low: Issue not raised in public responses</td></tr>
<tr><td colspan="5">Cumulative Impacts</td><td>2</td></tr>
<tr><td colspan="6">Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.</td></tr>
<tr><td colspan="5">Degree of potential irreplaceable loss of resources</td><td>1</td></tr>
<tr><td colspan="6">The impact is unlikely to result in irreplaceable loss of resources.</td></tr>
<tr><td colspan="5">Prioritisation Factor</td><td>1.17</td></tr>
<tr><td colspan="5">Final Significance</td><td>-6.14</td></tr>
</table>

<table>
<tr><td>Impact Name</td><td colspan="5">Change of Natural of Views from Local Roads</td></tr>
<tr><td>Phase</td><td colspan="5">12B - Operation</td></tr>
<tr><td colspan="6">Environmental Risk</td></tr>
<tr><td>Attribute</td><td>Pre-mitigation</td><td>Post-mitigation</td><td>Attribute</td><td>Pre-mitigation</td><td>Post-mitigation</td></tr>
<tr><td>Nature of Impact</td><td>-1</td><td>-1</td><td>Magnitude of Impact</td><td>2</td><td>1</td></tr>
<tr><td>Extent of Impact</td><td>1</td><td>1</td><td>Reversibility of Impact</td><td>2</td><td>2</td></tr>
<tr><td>Duration of Impact</td><td>4</td><td>4</td><td>Probability</td><td>3</td><td>2</td></tr>
<tr><td colspan="5">Environmental Risk (Pre-mitigation)</td><td>-6.75</td></tr>
<tr><td colspan="6">Mitigation Measures</td></tr>
<tr><td colspan="6">• Locate compressor stations a minimum 250m from the edge of local roads;
• Undertake rehabilitation;
• Return disturbed agricultural land to agricultural use; and
• Undertake screen planting between the R30 and the proposed production plant.</td></tr>
<tr><td colspan="5">Environmental Risk (Post-mitigation)</td><td>-4,00</td></tr>
<tr><td colspan="5">Degree of confidence in impact prediction:</td><td>Medium</td></tr>
<tr><td colspan="6">Impact Prioritisation</td></tr>
<tr><td colspan="5">Public Response</td><td>1</td></tr>
<tr><td colspan="6">Low: Issue not raised in public responses</td></tr>
<tr><td colspan="5">Cumulative Impacts</td><td>2</td></tr>
<tr><td colspan="6">Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.</td></tr>
<tr><td colspan="5">Degree of potential irreplaceable loss of resources</td><td>1</td></tr>
<tr><td colspan="6">The impact is unlikely to result in irreplaceable loss of resources.</td></tr>
</table>

Impact Name	Change of Natural of Views from Local Roads				
Prioritisation Factor					1.17
Final Significance					-4,68

Impact Name	Change of Natural of Views from Local Roads				
Phase	**12C - Decommissioning**				
Nature of Impact	-1	-1	Magnitude of Impact	3	1
Extent of Impact	2	1	Reversibility of Impact	2	1
Duration of Impact	3	1	Probability	4	1
Environmental Risk (Pre-mitigation)					-10,00
Mitigation Measures					
• Remove all above ground infrastructure; • Rehabilitate disturbed natural areas and • Return disturbed agricultural land to agricultural use.					
Environmental Risk (Post-mitigation)					-1,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1
Final Significance					-1.00

Table 13, The visual impact on views from local homesteads

Impact Name	Change of Natural of Views from Homesteads				
Phase	**13 A - Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	1
Extent of Impact	2	2	Reversibility of Impact	2	2
Duration of Impact	4	1	Probability	4	3
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
• Locate wells and compressor stations a minimum 250m from homesteads; • Rehabilitate disturbed natural areas; and • Return disturbed agricultural land to agricultural use; and • Undertake screen planting between the R30 and the proposed production plant.					
Environmental Risk (Post-mitigation)					-4,50
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2

Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.17
Final Significance	-5.26

Impact Name	**Change of Natural of Views from Homesteads**				
Phase	**13B - Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	2	1
Extent of Impact	1	1	Reversibility of Impact	2	2
Duration of Impact	4	4	Probability	3	2
Environmental Risk (Pre-mitigation)					-6.75
Mitigation Measures					
• Locate wells and compressor stations a minimum 250m from homesteads; • Undertake rehabilitation; • Re-establish agricultural uses; and • Undertake screen planting between the R30 and the proposed production plant.					
Environmental Risk (Post-mitigation)					-4,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.17
Final Significance					-4,68

Impact Name	**Change of Natural of Views from Homesteads**				
Phase	**13C - Decommissioning**				
Nature of Impact	-1	-1	Magnitude of Impact	3	1
Extent of Impact	2	1	Reversibility of Impact	2	1
Duration of Impact	3	1	Probability	4	1
Environmental Risk (Pre-mitigation)					-10,00
Mitigation Measures					
• Remove all above ground infrastructure; • Rehabilitate disturbed natural areas and • Return disturbed agricultural land to agricultural use.					
Environmental Risk (Post-mitigation)					-1,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1

Low: Issue not raised in public responses	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1
Final Significance	-1.00

Table 14, The visual impact of Lighting

Impact Name	**Lighting Impacts**				
Phase	**14A - Construction**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	1
Extent of Impact	2	1	Reversibility of Impact	1	1
Duration of Impact	1	1	Probability	4	1
Environmental Risk (Pre-mitigation)					-8.00
Mitigation Measures					
• Ensure that temporary lighting is of sufficient power to ensure safety but not so powerful that it creates glare that could cause danger for drivers or nuisance for neighbours; • Ensure that temporary lighting minimises light spill outside the area that it is intended to light.					
Environmental Risk (Post-mitigation)					-1,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-4.00

Impact Name	**Lighting Impacts**				
Phase	**14B - Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	1
Extent of Impact	2	1	Reversibility of Impact	1	1
Duration of Impact	4	4	Probability	4	1
Environmental Risk (Pre-mitigation)					-11.00
Mitigation Measures					
• Ensure that temporary lighting is of sufficient power to ensure safety but not so powerful that it creates glare that could cause danger for drivers or nuisance for neighbours;					

Environmental Risk (Post-mitigation)	-1.75
Degree of confidence in impact prediction:	Medium
Impact Prioritisation	
Public Response	1
Low: Issue not raised in public responses	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-1.75

Impact Name	**Lighting Impacts**				
Phase	**14C - Decommissioning**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	1
Extent of Impact	2	1	Reversibility of Impact	1	1
Duration of Impact	1	1	Probability	4	1
Environmental Risk (Pre-mitigation)					-8.00
Mitigation Measures					
• Ensure that temporary lighting is of sufficient power to ensure safety but not so powerful that it creates glare that could cause danger for drivers or nuisance for neighbours; • Ensure that temporary lighting minimises light spill outside the area that it is intended to light.					
Environmental Risk (Post-mitigation)					-1,00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is possible that the impact will result in spatial and temporal cumulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-4.00

8 CONCLUSION

8.1 AREAS AND NATURE OF LIKELY VISUAL IMPACTS

The assessment indicates that the development of the proposed facility is highly unlikely to impact on sensitive or protected landscape areas.

The proposed project is likely to be visible over the widest area and have the largest impact during exploration and construction than during the operational and decommissioning phases. This is due to:

- The necessary use of drilling rigs, which, because of their height (10.0m), will be visible over a significantly larger distance than elements associated with the final development the majority of which will be significantly lower (3.0m); and
- Because exploration and construction sites require significantly larger working and storage areas than the final development footprints.

By way of mitigation, drill rigs are likely to be in each location for a relatively short period

During the operational phase:

- Within the Natural LCA, due to limited height and the extent of taller vegetation, production wells compressor plant, pigging stations and other pipeline infrastructure is unlikely to be visually obvious as long as disturbance is minimised;
- Within the Agricultural LCA, due to the openness of the landscape, compressor plants, pigging stations and other pipeline infrastructure is likely to be relatively visible. However, their low height and small footprint is likely to make them less obvious with distance. The underground wells are only likely to impact during construction.
- Visibility of the proposed Combined Helium and Liquid Natural Gas Plant will be limited due to its location within the shallow Sand River Valley. This landform will mean that the plant is unlikely to be visible from outside the Valley. Visibility may also be limited by woody vegetation within the valley. It is important however, that disturbance of vegetation is minimised during construction.

8.2 IMPACT ON LANDSCAPE CHARACTER

Key Landscape Character Areas that could be affected include:

- The Agricultural LCA which is largely comprised of higher and relatively flat areas of the affected area that are used for commercial arable agriculture. Views within this LCA however are also backed by large scale mining operations. It is likely that a proportion of the production wells compressor plant, pigging stations and other pipeline infrastructure will be obvious, however, visibility of these elements will diminish with distance. Their presence will introduce new industrial elements however, they will not change the overall agricultural landscape character.

  Even with the low level of Visual Absorption Capacity due to the openness of the landscape, due to the fact that lines of wells marching across the landscape are all underground, they likely to make even distant structures more obvious during construction but during operation the impact will be limited. This impact on landscape character was assessed as likely to have a medium significance even with mitigation during construction. During operation and decommissioning the impact significance reduces to low.

- The Natural LCA which is largely comprised of the landscape within the shallow valleys that bisect the affected area. It is also generally covered by relatively low woody vegetation and grassland. Where woody vegetation exists, the majority lower development elements are unlikely to be visually obvious and so will not affect the perceived landscape character. However, due to its size, there is potential for the Combined Helium and Liquid Natural Gas Plant to introduce an obvious industrial element into this LCA. To a degree, this is inevitable as it will be seen from higher valley slopes from where it will be obvious as well as from within lower sections of the valley from where it could be largely screened by vegetation.

  Because of the relatively large level of Visual Absorption Capacity within this LCA, with mitigation, the significance of impact was assessed as likely to be low throughout the project cycle.

Whilst these Landscapes will be affected and they are no doubt important as they provide relatively green buffers between industry and urban areas, they are not unique or protected. The predominant character will also remain in place.

8.3 IMPACT ON RECEPTORS

Receptors that were identified as potentially being sensitive include:

- Local road users; and
- People living in local homesteads.

Potential views for both of these groups of receptors were assessed as likely to have a medium significance during construction. However, the significance is likely to reduce to a low level throughout the rest of the project cycle.

Mitigation should include:

- Ensuring that a minimum distance of 250m is included between proposed development and receptors;
- Minimising disturbance of the landscape; and
- Undertaking landscape rehabilitation.

8.4 ALTERNATIVES

An alternative location in addition to the proposed location of Compressor Station 3 has been considered.

The preferred location is close to Compressor Station 2 and also within 1km of a local road whereas the alternative location is within 400m of a group of eight homesteads and 1.3km of the R30. Whilst impacts associated with both alternatives are likely to be relatively low, the developer’s preferred alternative is preferred from a landscape and visual perspective due to the lower potential to impact on residential homesteads. However, as long as recommended mitigation measures are undertaken, there is no reason from a Landscape and Visual Impact perspective why either alternative should not be used.

8.5 RECOMMENDATION

Because the affected landscape areas are neither unique or protected and due to the fact that mitigation measures should generally be effective in minimising landscape impacts and visual impact experienced by potential receptors, there is no reason from a landscape and visual impact perspective that the project should not proceed as long as listed mitigation measures are implemented.

REFERENCES

Guidelines for involving visual and aesthetic specialists in EIA processes, Author; Bernard Oberhozer. Published by the Provincial Government of the Western Cape: Department of Environmental Affairs and Development Planning, 2005

Guidelines for landscape and visual impact assessment (third edition), authors; the Landscape Institute and Institute of Environmental Assessment and Management, published by E & FN Spon, 2013.

The vegetation of South Africa, Lesotho and Swaziland(Strelitzia series; no. 19), Mucina, L. & Rutherford, M.C. (eds.), 2006, South African National Biodiversity Institute, Pretoria.

Appendix 6, EIA Regulations (2014) as amended, promulgated under section 24 of the National Environmental Management Act, 107 of 1998. Department of Forestry Fisheries and the Environment.

APPENDIX II

ASSESSOR'S CURRICULUM VITAE

ENVIRONMENTAL PLANNING AND DESIGN

Name	JONATHAN MARSHALL
Nationality	British
Year of Birth	1956
Specialisation	Landscape Architecture / Landscape & Visual Impact Assessment / Environmental Planning / Environmental Impact Assessment.
Qualifications	
<u>Education</u>	Diploma in Landscape Architecture, Gloucestershire College of Art and Design, UK (1979) Environmental Law, University of KZN (1997)
<u>Professional</u>	Registered Professional Landscape Architect (SACLAP) Chartered Member of the Landscape Institute (UK) Member of the International Association of Impact Assessment, South Africa
Languages	<u>English</u> - Speaking - Excellent - Reading - Excellent - Writing - Excellent
Contact Details	Post: 13 Askew Grove Glenwood Durban 4001 Cell: +27 83 7032995

General

Jon qualified as a Landscape Architect (Dip LA) at Cheltenham (UK) in 1979. He has been a chartered member of the Landscape Institute UK since 1986. He is also a Registered Landscape Architect and has had extensive experience as an Environmental Assessment Practitioner within South Africa.

During the early part of his career (1981 - 1990) He worked with Clouston (now RPS) in Hong Kong and Australia. During this period he was called on to undertake visual impact assessment (VIA) input to numerous environmental assessment processes for major infrastructure projects. This work was generally based on photography with line drawing superimposed to illustrate the extent of development visible.

He has worked in the United Kingdom (1990 - 1995) for major supermarket chains including Sainsbury’s and prepared CAD based visual impact assessments for public enquiries for new store development. He also prepared the VIA input to the environmental statement for the Cardiff Bay Barrage for consideration by the UK Parliament in the passing of the Barrage Act (1993).

His more recent VIA work (1995 to present) includes a combination of CAD and GIS based work for a new international airport to the north of Durban, new heavy industrial operations, overhead electrical transmission lines, mining operations in West Africa and numerous commercial and residential developments.

VIA work undertaken during the last twelve months includes wind energy projects, numerous solar plant projects (CSP and PV) and electrical infrastructure.

Select List of Visual Impact Assessment Projects

- **Geelkop Solar PV projects –** Landscape and Visual Impact Assessment for seven proposed solar PV projects near Upington in the Northern Cape Province for Atlantic Renewable Energy Partners.
- **Makapanstad Agri- Hub –** Landscape and Visual Impact Assessment for proposed Agri-Hub development at Makapanstad in the North West Province for the Department of Rural Development and Land Reform.
- **Madikwe Sky Bubble -** Landscape and Visual Impact Assessment for proposed development of up-market accommodation at the Molori concession within the Madikwe Game Reserve.
- **Hartebeest Wind Energy Facility** – Landscape and Visual Impact Assessment Addendum Report for the proposed upgrading of turbine specifications for an authorised WEF near Mo0rreesburg in the Western Cape Province for a private client.
- **Selati Railway Bridge** - Landscape and Visual Impact Assessment for proposed development of up-market accommodation on a railway bridge at Skukuza in the Kruger Park.
- **Kangala Mine Extension -** Landscape and Visual Impact Assessment for a proposed extension to the Kangala Mine in Mpumalanga for Universal Coal.
- **Khunab Solar Developments** – Landscape and Visual Impact Assessment for four proposed solar PV projects near Upington in the Northern Cape Province for a private client.
- **Sirius Solar Developments** – Landscape and Visual Impact Assessment for four proposed solar PV projects near Upington in the Northern Cape Province for Sola Future Energy.
- **Aggeneys Solar Developments** – Landscape and Visual Impact Assessment for two proposed solar PV projects near Aggeneys in the Northern Cape Province for a private client.
- **Hyperion Solar Developments** – Landscape and Visual Impact Assessment for four proposed solar PV projects near Kathu in the Northern Cape Province for Building Energy South Africa.
- **Eskom Combined Cycle Power Plant** - Landscape and Visual Impact Assessment for proposed gas power plant in Richards Bay, KwaZulu Natal Province.
- **N2 Wild Coast Toll Road, Mineral Sources and Auxiliary Roads –** VIA for the Pondoland Section of this project for the South African National Roads Agency.
- **Mpushini Park Ashburton –** VIA for a proposed amendment to an authorised development plan which included residential, office park and light industrial uses to logistics and warehousing.
- **Moedeng PV Solar Project -** VIA for a solar project near Vrybury in the North West Province for a private client.
- **Establishment of Upmarket Tourism Accommodation on the Selati Bridge, Kruger National Park** – Assessment of visual implications of providing tourism accommodation in 12 railway carriages on an existing railway bridge at the Skukuza Rest Camp in the Kruger Park.
- **Jozini TX Transmission Tower** – Assessment of visual implications of a proposed MTN transmission tower on the Lebombo ridgeline overlooking the Pongolapoort Nature reserve and dam.
- **Bhangazi Lake Development** – Visual Impact Assessment for a proposed tourism development within the iSimangaliso Wetlend Park World Heritage Site.
- **Palesa Power Station** - VIA for a new 600MW power station near Kwamhlanga in Mpumalanga for a private client.
- **Heuningklip PV Solar Project** – VIA for a solar project in the Western Cape Province for a private client.
- **Kruispad PV Solar Project** – VIA for a solar project in the Western Cape Province for a private client.
- **Doornfontein PV Solar Project** – VIA for a solar project in the Western Cape Province for a private client.
- **Olifantshoek Power Line and Substation** – VIA for a new 10MVA 132/11kV substation and 31km powerline, Northern Cape Province, for Eskom.
- **Noupoort Concentrating Solar Plants -** Scoping and Visual Impact Assessments for two proposed parabolic trough projects.

- **Drakensberg Cable Car –** Preliminary Visual Impact Assessment and draft terms of reference as part of the feasibility study.
- **Paulputs Concentrating Solar Plant (tower technology)** – Visual Impact Assessment for a new CSP project near Pofadder in the Northern Cape.
- **Ilanga Concentrating Solar Plants 1, 2, 3, 4 & 5** – Scoping and Visual Impact Assessments for the proposed extension of five authorised CSP projects including parabolic trough and tower technology within the Karoshoek Solar Valley near Upington in the Northern Cape.
- **Ilanga Concentrating Solar Plants 1, 2, 3, 4 & 5 Shared Infrastructure** –Visual Impact Assessment for the necessary shared infrastructure including power lines, substation, water pipeline and roads for these projects.
- **Ilanga Concentrating Solar Plants 7, 8 & 9** - Scoping and Visual Impact Assessments for three new CSP projects including parabolic trough and tower technology within the Karoshoek Solar Valley near Upington in the Northern Cape.
- **Sol Invictus Solar Plants** - Scoping and Visual Impact Assessments for three new Solar PV projects near Pofadder in the Northern Cape.
- **Gunstfontein Wind Energy Facility** – Scoping and Visual Impact Assessment for a proposed WEF near Sutherland in the Northern Cape.
- **Moorreeesburg Wind Energy Facility** – Visual Impact Assessment for a proposed WEF near Moorreeesburg in the Western Cape.
- **Semonkong Wind Energy Facility** - Visual Impact Assessment for a proposed WEF near Semonkong in Southern Lesotho.
- **Great Karoo Wind Energy Facility** – Addendum report to the Visual Impact Assessment Report for amendment to this authorised WEF that is located near Sutherland in the Northern Cape. Proposed amendments included layout as well as rotor diameter.
- **Perdekraal East Power Line** – Visual Impact Assessment for a proposed power line to evacuate power from a wind energy facility near Sutherland in the Northern Cape.
- **Tshivhaso Power Station** – Scoping and Visual Impact Assessment for a proposed new power station near Lephalale in Limpopo Province.
- **Saldanha Eskom Strengthening** – Scoping and Visual Impact Assessment for the upgrading of strategic Eskom infrastructure near Saldanha in the Western Cape.
- **Eskom Lethabo PV Installation** - Scoping and Visual Impact Assessment for the development of a solar PV plant within Eskom's Lethabo Power Station in the Free State.
- **Eskom Tuthuka PV Installation** - Scoping and Visual Impact Assessment for the development of a solar PV plant within Eskom's Thutuka Power Station in Mpumalanga.
- **Eskom Majuba PV Installation** - Scoping and Visual Impact Assessment for the development of a solar PV plant within Eskom's Majuba Power Station in Mpumalanga.
- **Golden Valley Power Line** - Visual Impact Assessment for a proposed power line to evacuate power from a wind energy facility near Cookhouse in the Eastern Cape.
- **Mpophomeni Shopping Centre** – Visual impact assessment for a proposed new shopping centre close to the southern shore of Midmar Dam in KwaZulu Natal.
- **Rheeboksfontein Power Line** - Addendum report to the Visual Impact Assessment Report for amendment to this authorised power line alignment located near Darling in the Western Cape.
- **Woodhouse Solar Plants** – Scoping and Visual Impact Assessment for two proposed solar PV projects near Vryburg in the North West Province.
- **AngloGold Ashanti, Dokyiwa (Ghana)** – Visual Impact Assessment for proposed new Tailings Storage Facility at a mine site working with SGS as part of their EIA team.
- **Gateway Shopping Centre Extension (Durban)** – Visual Impact Assessment for a proposed shopping centre extension in Umhlanga, Durban.
- **Kouroussa Gold Mine (Guinea)** – Visual impact assessment for a proposed new mine in Guinea working with SGS as part of their EIA team.

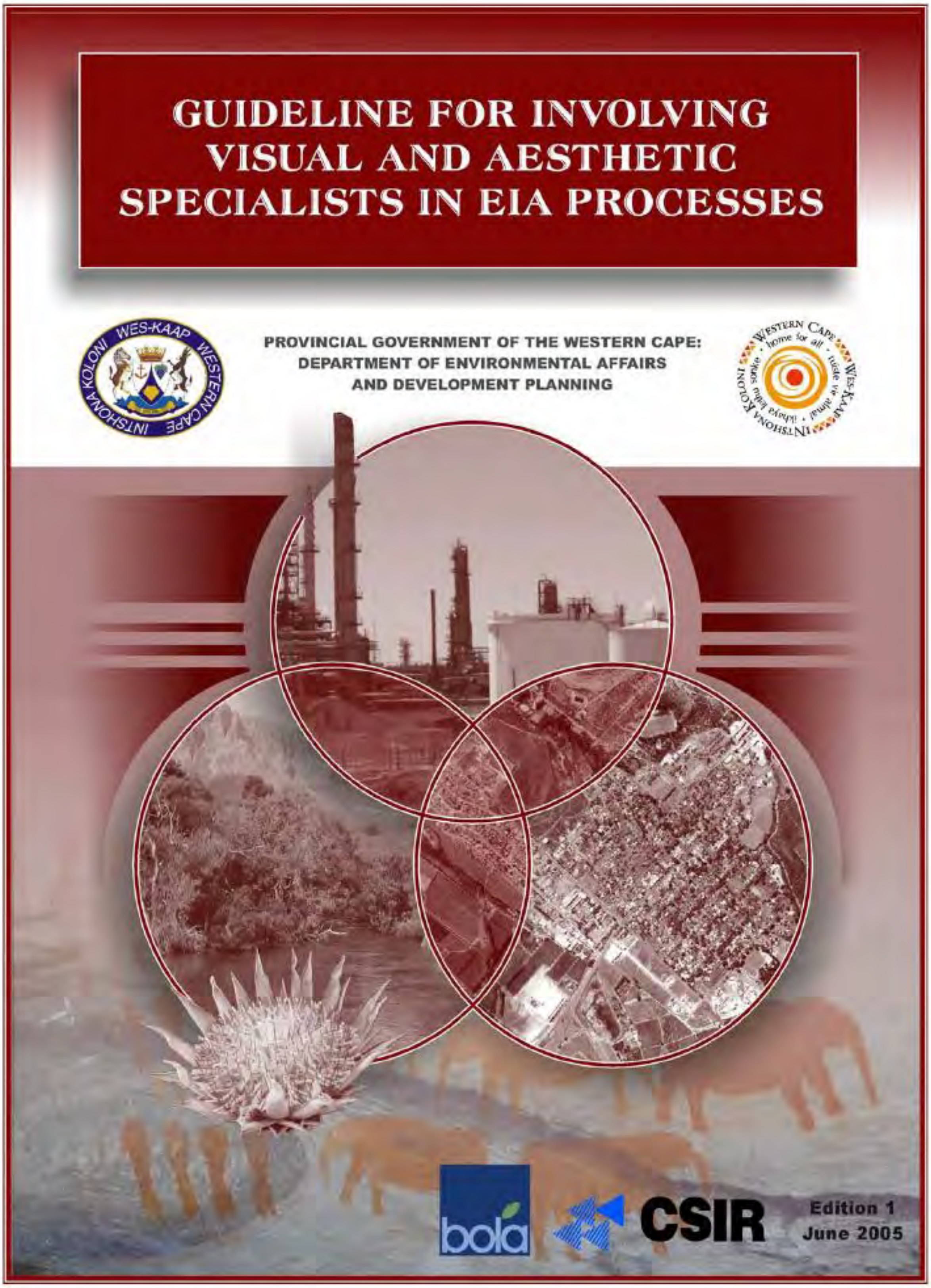
- **Mampon Gold Mine (Ghana)** - Visual impact assessment for a proposed new mine in Ghana working with SGS as part of their EIA team.
- **Telkom Towers** – Visual impact assessments for numerous Telkom masts in KwaZulu Natal.
- **Eskom Isundu Substation** – Visual Impact Assessment for a proposed major new Eskom substation near Pietermaritzburg in KwaZulu Natal.
- **Eskom St Faiths Power Line and Substation** – Visual Impact Assessment for a major new substation and associated power lines near Port Shepstone in KwaZulu Natal.
- **Eskom Ficksburg Power Line** – Visual Impact Assessment for a proposed new power line between Ficksburg and Cocolan in the Free State.
- **Eskom Matubatuba to St Lucia Power Line** – Visual Impact Assessment for a proposed new power line between Mtubatuba and St Lucia in KwaZulu Natal.
- **Dube Trade Port, Durban International Airport** – Visual Impact Assessment
- **Sibaya Precinct Plan** – Visual Impact Assessment as part of Environmental Impact Assessment for a major new development area to the north of Durban.
- **Umdloti Housing** – Visual Impact Assessment as part of Environmental Impact Assessment for a residential development beside the Umdloti Lagoon to the north of Durban.
- **Tata Steel Ferrochrome Smelter** - Visual impact assessment of proposed new Ferrochrome Smelter in Richards Bay as part of EIA undertaken by the CSIR.
- **Durban Solid Waste Large Landfill Sites –** Visual Impact Assessment of proposed development sites to the North and South of the Durban Metropolitan Area. The project utilised 3d computer visualisation techniques.
- **Hillside Aluminium Smelter, Richards Bay -** Visual Impact Assessment of proposed extension of the existing smelter. The project utilised 3d computer visualisation techniques.
- **Estuaries of KwaZulu Natal Phase 1 –** Visual character assessment and GIS mapping as part of a review of the condition and development capacity of eight estuary landscapes for the Town and Regional Planning Commission. The project was extended to include all estuaries in KwaZulu Natal.
- **Signage Assessments** – Numerous impact assessments for proposed signage developments for Blast Media.
- **Signage Strategy** – Preparation of an environmental strategy report for a national advertising campaign on National Roads for Visual Image Placements.
- **Zeekoegatt, Durban** - Computer aided visual impact assessment. EDP acted as advisor to the Province of KwaZulu Natal in an appeal brought about by a developer to extend a light industrial development within a 60 metre building line from the National N3 Highway.
- **La Lucia Mall Extension** - Visual impact assessment using three dimensional computer modelling / photo realistic rendering and montage techniques for proposed extension to shopping mall for public consultation exercise.
- **Redhill Industrial Development** - Visual impact assessment using three dimensional computer modelling / photo realistic rendering and montage techniques for proposed new industrial area for public consultation exercise.
- **Avondale Reservoir** - Visual impact assessment using three dimensional computer modelling / photo realistic rendering and montage techniques for proposed hilltop reservoir as part of Environmental Impact Assessment for Umgeni Water.
- **Hammersdale Reservoir** - Visual impact assessment using three dimensional computer modelling / photo realistic rendering and montage techniques for proposed hilltop reservoir as part of Environmental Impact Assessment for Umgeni Water.
- **Southgate Industrial Park, Durban** - Computer Aided Visual Impact Assessment and Landscape Design for AECI.
- **Sainsbury's Bryn Rhos** - Computer Aided Visual Impact Assessment/ Planning Application for the development of a new store within the Green Wedge North of Swansea.
- **Ynyston Farm Access** - Computer Aided Impact Assessment of visual intrusion of access road to proposed development of Cardiff for the Land Authority for Wales.

- **Cardiff Bay Barrage** – Preparation of the Visual Impact Statement for inclusion in the Impact Statement for debate by parliament (UK) prior to the passing of the Cardiff Bay Barrage Bill.
- **A470, Cefn Coed to Pentrebach** - Preparation of landscape frameworks for the assessment of the impact of the proposed alignment on the landscape for The Welsh Office.
- **Sparkford to Illchester Bye Pass -** The preparation of the landscape framework and the draft landscape plan for the Department of Transport.
- **Green Island Reclamation Study** - Visual Impact Assessment of building massing, Urban Design Guidelines and Masterplanning for a New Town extension to Hong Kong Island.
- **Route 3** - Visual Impact Assessment for alternative road alignments between Hong Kong Island and the Chinese Border.
- **China Border Link** - Visual Impact Assessment and initial Landscape Design for a new border crossing at Lok Ma Chau.
- **Route 81, Aberdeen Tunnel to Stanley** - Visual Impact Assessment for alternative highway alignments on the South side of Hong Kong Island.

APPENDIX II

GUIDELINES FOR INVOLVING VISUAL AND AESTHETIC SPECIALISTS IN EIA PROCESSES

(Preface, Summary and Contents for full document go to the Provincial Government of the Western Cape, Department of Environmental Affairs and Development Planning web site, http://eadp.westerncape.gov.za/your-resource-library/policies-guidelines)


GUIDELINE FOR INVOLVING VISUAL AND AESTHETIC SPECIALISTS IN EIA PROCESSES
PROVINCIAL GOVERNMENT OF THE WESTERN CAPE:
DEPARTMENT OF ENVIRONMENTAL AFFAIRS
AND DEVELOPMENT PLANNING
bola
CSIR
Edition 1
June 2005

GUIDELINE FOR INVOLVING VISUAL AND AESTHETIC SPECIALISTS IN EIA PROCESSES

Edition 1

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This guideline should be cited as:

Oberholzer, B. 2005. *Guideline for involving visual & aesthetic specialists in EIA processes: Edition 1*. CSIR Report No ENV-S-C 2005 053 F. Republic of South Africa, Provincial Government of the Western Cape, Department of Environmental Affairs & Development Planning, Cape Town.

ACKNOWLEDGEMENTS

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Stakeholders engaged in the guideline development process:

These guidelines were developed through a consultative process and have benefited from the inputs and comments provided by a wide range of individuals and organizations actively working to improve EIA practice. Thanks are due to all who took the time to engage in the guideline development process.

In particular, thanks are due to Jan Glazewski (University of Cape Town), Keith Wiseman (City of Cape Town), Paul Britton (SANPARKS), Graham Young (University of Pretoria), Lisa Parkes (Ninham Shand) and Paul Claassen (Environomics) for providing useful information and in-depth comments.

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PREFACE

The purpose of an Environmental Impact Assessment (EIA) is to provide decision-makers (be they government authorities, the project proponent or financial institutions) with adequate and appropriate information about the potential positive and negative impacts of a proposed development and associated management actions in order to make an informed decision whether or not to approve, proceed with or finance the development.

For EIA processes to retain their role and usefulness in supporting decision-making, the involvement of specialists in EIA needs to be improved in order to:

- Add greater value to project planning and design;
- Adequately evaluate reasonable alternatives;
- Accurately predict and assess potential project benefits and negative impacts;
- Provide practical recommendations for avoiding or adequately managing negative impacts and enhancing benefits;
- Supply enough relevant information at the most appropriate stage of the EIA process to address adequately the key issues and concerns, and effectively inform decision-making in support of sustainable development.

It is important to note that not all EIA processes require specialist input; broadly speaking, specialist involvement is needed when the environment could be significantly affected by the proposed activity, where that environment is valued by or important to society, and/or where there is insufficient information to determine whether or not unavoidable impacts would be significant.

The purpose of this series of guidelines is to improve the efficiency, effectiveness and quality of specialist involvement in EIA processes. The guidelines aim to improve the capacity of roleplayers to anticipate, request, plan, review and discuss specialist involvement in EIA processes. Specifically, they aim to improve the capacity of EIA practitioners to draft appropriate terms of reference for specialist input and assist all roleplayers in evaluating whether or not specialist input to the EIA process is appropriate for the type of development and environmental context. Furthermore, they aim to ensure that specialist inputs support the development of effective, practical Environmental Management Plans where projects are authorised to proceed (refer to *Guideline for Environmental Management Plans*).

The guidelines draw on best practice in EIA in general, and within specialist fields of expertise in particular, to address the following issues related to the timing, scope and quality of specialist input. The terms "specialist involvement" and "input" have been used in preference to "specialist assessment" and "studies" to indicate that the scope of specialists' contribution (if required) depends on the nature of the project, the environmental context and the amount of available information and does not always entail detailed studies or assessment of impacts.

The guidelines draw on best practice in EIA in general, and within specialist fields of expertise in particular, to address the following issues related to the timing, scope and quality of specialist input. The terms "specialist involvement" and "input" have been used in preference to "specialist

assessment" and "studies" to indicate that the scope of specialists' contribution depends on the nature of the project, the environmental context and the amount of available information.

	ISSUES
TIMING	▪ When should specialists be involved in the EIA process; i.e. at what stage in the EIA process should specialists be involved (if at all) and what triggers the need for their input?
SCOPE	▪ Which aspects must be addressed through specialist involvement; i.e. what is the purpose and scope of specialist involvement? ▪ What are appropriate approaches that specialists can employ? ▪ What qualifications, skills and experience are required?
QUALITY	▪ What triggers the review of specialist studies by different roleplayers? ▪ What are the review criteria against which specialist inputs can be evaluated to ensure that they meet minimum requirements, are reasonable, objective and professionally sound?

The following guidelines form part of this first series of guidelines for involving specialists in EIA processes:

- Guideline for determining the scope of specialist involvement in EIA processes
- Guideline for the review of specialist input in EIA processes
- Guideline for involving biodiversity specialists in EIA processes
- Guideline for involving hydrogeologists in EIA processes
- Guideline for involving visual and aesthetic specialists in EIA processes
- Guideline for involving heritage specialists in EIA processes
- Guideline for involving economists in EIA processes

The *Guideline for determining the scope of specialist involvement in EIA processes* and the *Guideline for the review of specialist input in EIA processes* provide generic guidance applicable to any specialist input to the EIA process and clarify the roles and responsibilities of the different roleplayers involved in the scoping and review of specialist input. It is recommended that these two guidelines are read first to introduce the generic concepts underpinning the guidelines which are focused on specific specialist disciplines.

Who is the target audience for these guidelines?

The guidelines are directed at authorities, EIA practitioners, specialists, proponents, financial institutions and other interested and affected parties involved in EIA processes. Although the guidelines have been developed with specific reference to the Western Cape province of South Africa, their core elements are more widely applicable.

What type of environmental assessment processes and developments are these guidelines applicable to?

The guidelines have been developed to support project-level EIA processes regardless of whether they are used during the early project planning phase to inform planning and design decisions (i.e. during pre-application planning) or as part of a legally defined EIA process to obtain statutory approval for a proposed project (i.e. during screening, scoping and/or impact assessment). Where specialist input may be required the guidelines promote early, focused and appropriate involvement of specialists in EIA processes in order to encourage proactive consideration of potentially significant impacts, so that negative impacts may be avoided or effectively managed and benefits enhanced through due consideration of alternatives and changes to the project.

The guidelines aim to be applicable to a range of types and scales of development, as well as different biophysical, social, economic and governance contexts.

What will these guidelines not do?

In order to retain their relevance in the context of changing legislation, the guidelines promote the principles of EIA best practice without being tied to specific legislated national or provincial EIA terms and requirements. They therefore do not clarify the specific administrative, procedural or reporting requirements and timeframes for applications to obtain statutory approval. They should, therefore, be read in conjunction with the applicable legislation, regulations and procedural guidelines to ensure that mandatory requirements are met.

It is widely recognized that no amount of theoretical information on how best to plan and coordinate specialist inputs, or to provide or review specialist input, can replace the value of practical experience of coordinating, being responsible for and/or reviewing specialist inputs. Only such experience can develop sound judgment on such issues as the level of detail needed or expected from specialists to inform decision-makers adequately. For this reason, the guidelines should not be viewed as prescriptive and inflexible documents. Their intention is to provide best practice guidance to improve the quality of specialist input.

Furthermore, the guidelines do not intend to create experts out of non-specialists. Although the guidelines outline broad approaches that are available to the specialist discipline (e.g. field survey, desktop review, consultation, modeling), specific methods (e.g. the type of model or sampling technique to be used) cannot be prescribed. The guidelines should therefore not be used indiscriminately without due consideration of the particular context and circumstances within which an EIA is undertaken, as this influences both the approach and the methods available and used by specialists.

How are these guidelines structured?

The specialist guidelines have been structured to make them user-friendly. They are divided into six parts, as follows:

- **Part A**: Background;
- **Part B**: Triggers and key issues potentially requiring specialist input;
- **Part C**: Planning and coordination of specialist inputs (drawing up terms of reference);
- **Part D**: Providing specialist input;
- **Part E**: Review of specialist input; and
- **Part F**: References.

Part A provides grounding in the specialist subject matter for all users. It is expected that authorities and peer reviewers will make most use of Parts B and E; EIA practitioners and project proponents Parts B, C and E; specialists Part C and D; and other stakeholders Parts B, D and E. Part F gives useful sources of information for those who wish to explore the specialist topic.

SUMMARY

This guideline document, which deals with specialist visual input into the EIA process, is organised into a sequence of interleading sections. These follow a logical order covering the following:

- the background and context for specialist visual input;
- the triggers and issues that determine the need for visual input;
- the type of skills and scope of visual inputs required in the EIA process;
- the methodology, along with information and steps required for visual input;
- finally, the review or evaluation of the visual assessment process.

Part A is concerned with defining the visual and aesthetic component of the environment, and with principles and concepts relating to the visual assessment process. The importance of the process being logical, holistic, transparent and consistent is stressed in order for the input to be useful and credible.

The legal and planning context within which visual assessments take place indicate that there are already a number of laws and bylaws that protect visual and scenic resources. These resources within the Western Cape context have importance for the economy of the region, along with the proclaimed World Heritage Sites in the Province.

The role and timing of specialist visual inputs into the EIA process are outlined, with the emphasis being on timely, and on appropriate level of input, from the early planning stage of a project, through to detailed mitigation measures and management controls at the implementation stage.

Part B deals with typical factors that trigger the need for specialist visual input to a particular project. These factors typically relate to:
(a) the nature of the receiving environment, in particular its visual sensitivity or protection status;
(b) the nature of the project, in particular the scale or intensity of the project, which would result in change to the landscape or townscape.

The correlation between these two aspects are shown in a table, in order to determine the varying levels of visual impact that can be expected, i.e. from little or no impact, to very high visual impact potential.

Part C deals with the choice of an appropriate visual specialist, and the preparation of the terms of reference (TOR) for the visual input. Three types of visual assessment are put forward, each requiring different expertise, namely:
Type A: assessments involving large areas of natural or rural landscape;
Type B: assessments involving local areas of mainly built environment;
Type C: assessments involving smaller scale sites with buildings, or groups of buildings.

The scope of the visual input would in summary relate to the following:

- the issues raised during the scoping process;
- the time and space boundaries, i.e. the extent or zone of visual influence;

- the types of development alternatives that are to be considered;
- the variables and scenarios that could affect the visual assessment;
- the inclusion of direct, indirect and cumulative effects.

Approaches to the visual input relate to the level of potential impact and range from minimal specialist input, to a full visual impact assessment (VIA). A list of the typical components of a visual assessment is given, and the integration with other studies forming part of the EIA process is discussed.

Part D provides guidance for specialist visual input, and on the information required by specialists. Notes on predicting potential visual impacts are given, along with suggested criteria for describing and rating visual impacts. The assessment of the overall significance of impacts, as well as thresholds of significance are discussed.

Further aspects that need to be considered by visual specialists in EIA processes include:

- affected parties who stand to benefit or lose,
- risks and uncertainties related to the project,
- assumptions that have been made, and their justification,
- levels of confidence in providing the visual input or assessment,
- management actions that can be employed to avoid or mitigate adverse effects and enhance benefits, and
- the best practicable environental option from the perspective of the visual issues and impacts.

Finally, pointers for the effective communication of the findings are given.

Part E lists specific evaluation criteria for reviewing visual input by a specialist, where this becomes necessary. Further guidance on this is given in the document on *Guideline for the review of specialist input in EIA processes.*

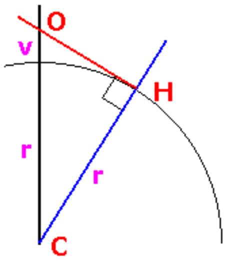
CONTENTS

APPENDIX III

FORMULA FOR DERIVING THE APPROXIMATE VISUAL HORIZON

The Mathematics behind this Calculation

This calculation should be taken as a guide only as it assumes the earth is a perfect ball 6378137 metres radius. It also assumes the horizon you are looking at is at sea level. A triangle is formed with the centre of the earth (C) as one point, the horizon point (H) is a right angle and the observer (O) the third corner. Using Pythagoras's theorem we can calculate the distance from the observer to the horizon (OH) knowing CH is the earth's radius (r) and CO is the earth's radius (r) plus observer's height (v) above sea level.



Sitting in a hotel room 10m above sea level a boat on the horizon will be 11.3km away. The reverse is also true, whilst rowing across the Atlantic, the very top of a mountain range 400m high could be seen on your horizon at a distance of 71.4 km assuming the air was clear enough.

Wetland Baseline & Impact Assessment for the proposed Tetra4 Cluster 2 Project

Virginia, Free State Province

April 2022

CLIENT

EIMS | ENVIRONMENTAL IMPACT MANAGEMENT SERVICES

Prepared by:

The Biodiversity Company

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Report Name	Wetland Baseline & Impact Assessment for the proposed Tetra4 Cluster 2 Project
Submitted to	EIMS ENVIRONMENTAL IMPACT MANAGEMENT SERVICES
Report Fieldwork and Writer	Rian Pienaar
	Rian Pienaar is an aquatic ecologist (Cand. Sci. Nat. 135544) with experience in wetland identification and delineations. Rian completed his M.Sc. in environmental science at the North-West University Potchefstroom Campus. Rian have been part of wetland studies for road and culvert upgrades, power station and dam construction.
Reviewer	Andrew Husted
	Andrew Husted is Pr Sci Nat registered (400213/11) in the following fields of practice: Ecological Science, Environmental Science and Aquatic Science. Andrew is an Aquatic, Wetland and Biodiversity Specialist with more than 13 years' experience in the environmental consulting field. Andrew has completed numerous wetland training courses, and is an accredited wetland practitioner, recognised by the DWS, and also the Mondi Wetlands programme as a competent wetland consultant.
Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2014 (as amended). We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than to provide a professional service within the constraints of the project (timing, time and budget) based on the principles of science.

Declaration

I, Rian Pienaar declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

RPienaar

Rian Pienaar

Wetland Ecologist

The Biodiversity Company

April 2022

Table of Contents

Tables

Figures

1 Introduction

The Biodiversity Company was appointed by Environmental Impact Management Solutions (EIMS) to conduct a wetland baseline and impact (risk) assessment for the proposed Tetra 4 Cluster 2 gas exploration project in Virginia, Free State Province (see Figure 1-3).

1.1 Background

The following information was provided by EIMS:

In 2012, a Production Right (Ref: 12/4/1/07/2/2) was granted which spans approximately 187 000 hectares for the development of natural gas (Helium and Methane) production operations around the town of Virginia in the Free State Province. Within the approval of the Production Right, the 2010 Environmental Management Programme (EMPr) was approved which is applicable to a large portion of the Production Right area (Figure 1-1).

The activities in the Production Right include:

- Continued exploration activities;
- Drilling and establishment of further production wells throughout the entire production area (260 production wells);
- Installation of intra-field pipelines throughout the entire production area (~500km);
- Installation of boosters and main compressors; and
- Central gas processing plant (not approved in the original EIA and approved EMPr).

On 21 September 2017, the Department of Mineral Resources and Energy (DMRE) issued an integrated environmental authorisation ("Cluster 1 EA") (reference: 12/04/07) to Tetra4 in terms of the NEMA. The Cluster 1 EA (as amended by Cluster 1 EA amendments dated 26 August 2019 and 1 September 2020) authorises the development of "Cluster 1" of the Project. In this EA approval, various new wells and pipelines, booster and compressor stations, a Helium and LNG Facility and associated infrastructure was approved which comprises the first gas field for development within the approved Production Right area. The Cluster 1 EA also authorises certain waste management activities as per the List of Waste Management Activities (Government Notice 921, as amended) published under the National Environmental Management: Waste Act 59 of 2008 (NEMWA).

Furthermore, the following licences have been issued to Tetra4 in respect of Cluster 1 of the Project:

- Provisional Atmospheric Emission Licence (PAEL) dated 4 August 2017 (reference: LDM/AEL/YMK/014) for the Storage and Handling of Petroleum Products [Category 2: Subcategory 2.4 of the Listed Activities (Government Notice 893, as amended) published under the National Environmental Management: Air Quality Act 39 of 2004 (NEMAQA)] by the Lejweleputswa District Municipality. A final atmospheric emission licence will be issued after operation of the plant which is currently under construction; and
- Water Use Licence (WUL) dated 22 January 2019 (reference: 08/C42K/CI/8861) for the construction of pipelines for the Project in terms of section 21(c&i) water uses of the National Water Act 36 of 1998 (NWA) by the Department of Water and Sanitation (DWS).

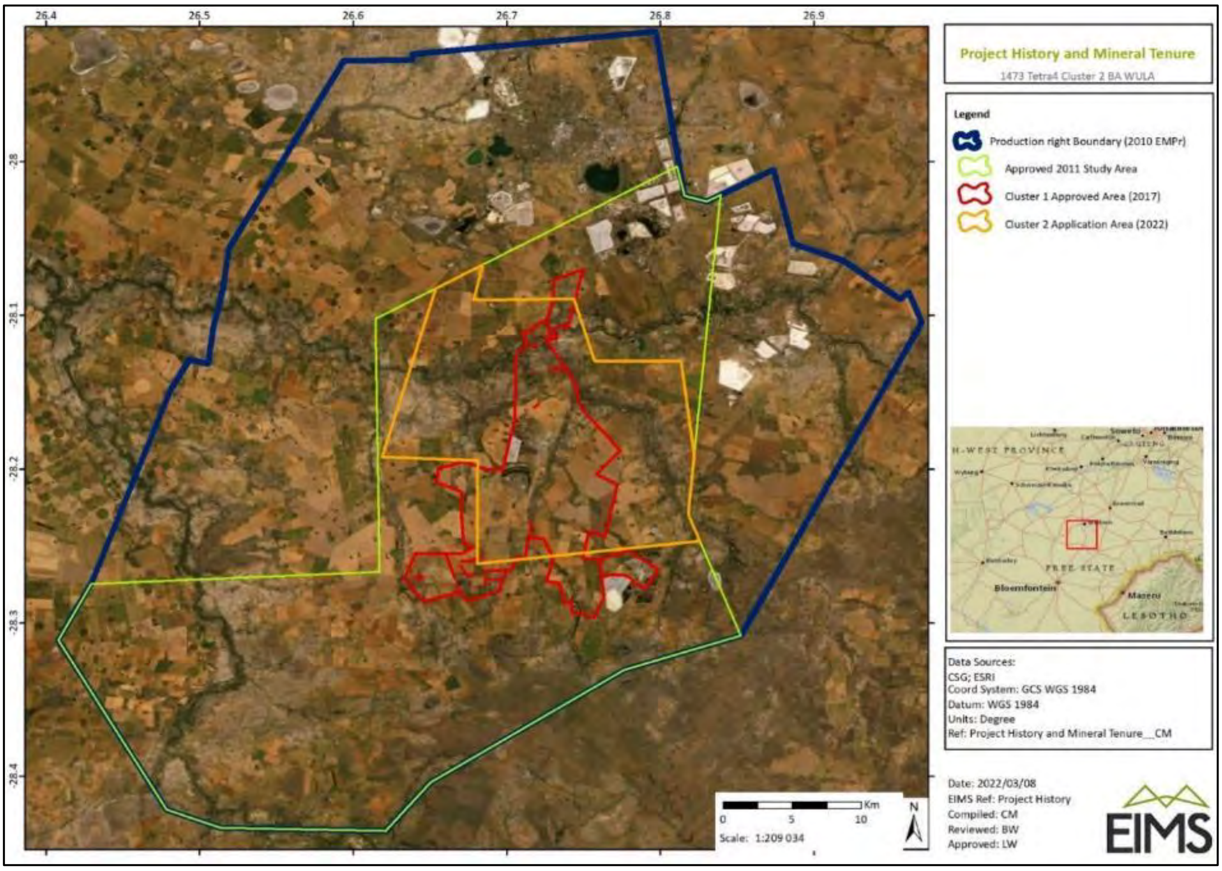

Figure 1-1 Project history and mineral tenure.

The following information is as provided by EIMS:

"Tetra 4 has a natural gas production right over a very large area in the Free State Province, near Virginia. They also have an existing environmental authorisation and associated water use licence for their current production activities (referred to as Cluster 1 above). Tetra 4 wishes to expand their current production operations onto other areas which still fall within the approved Production Right, but outside of the areas approved in the EA and WUL. The planned expansions will include the following (Figure 1-2):

- Expansions to the current LNG and Helium production plant located on the Farm Mond van Doorn Rivier. The planned expansions will be to increase the helium and LNG production capacities significantly (~30 fold increase) and increase the footprint of the existing approved plant by approximately 10ha.
- The drilling of new gas wells ~300 wells spread over a total study area (Cluster 2) of approximately 27500ha.
- The installation of trenched pipelines connecting the wells to localised booster compressors and then to in-field compressor stations (~3 sites) and subsequently the compressor stations to the main plant area.
- There will be a requirement to have short powerline and water connections to the compressor sites."

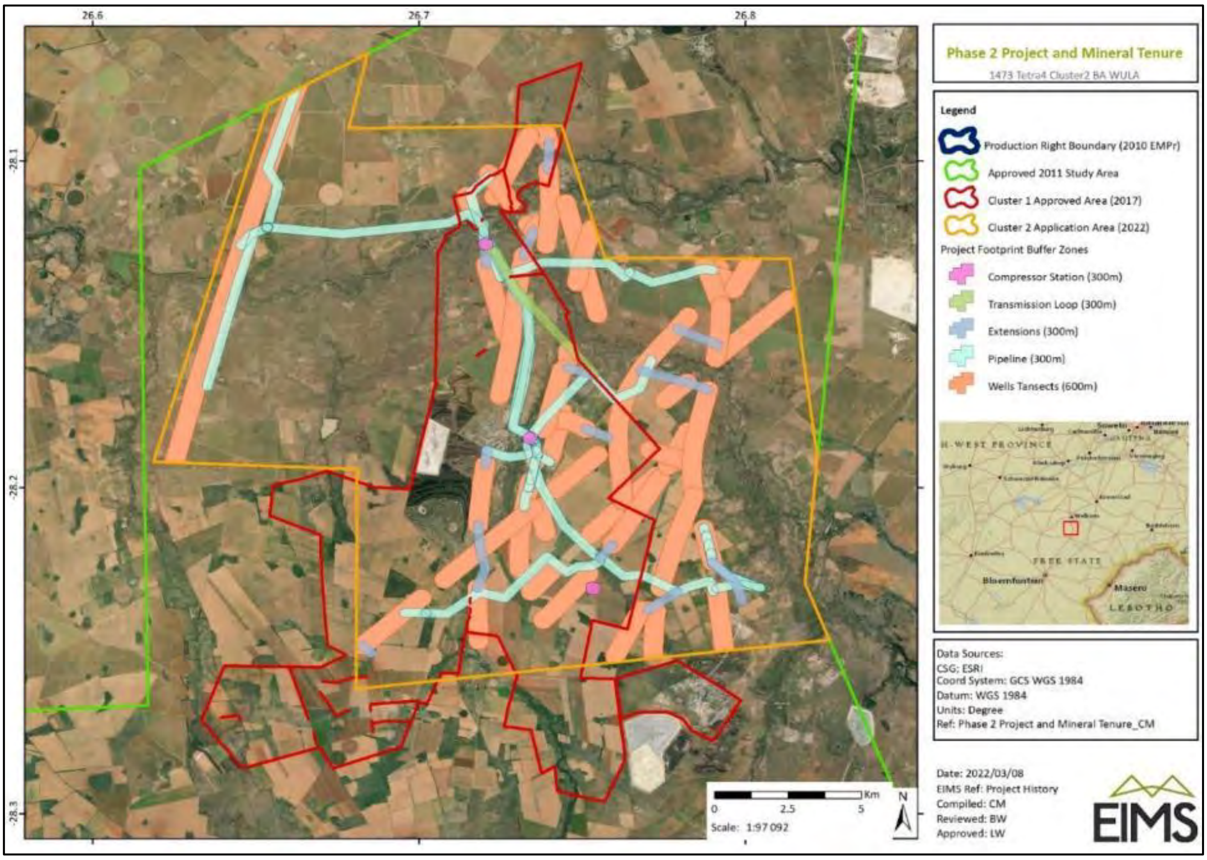

Figure 1-2 Cluster 2 study area and proposed infrastructure footprint buffer zones

A wet season wetland survey was conducted from the 14th of March 2022 to 18th of March 2022 by a freshwater ecologist. Furthermore, the identification and description of any sensitive receptors were recorded across the project area, and the manner in which these sensitive receptors may be affected by the activity was also investigated.

This report, after taking into consideration the findings and recommendations provided by the specialist herein, should inform and guide the Environmental Assessment Practitioner (EAP), enabling informed decision making as to the ecological viability of the proposed development and to provide an opinion on whether or not environmental authorisation processes or licensing is required for the proposed development.

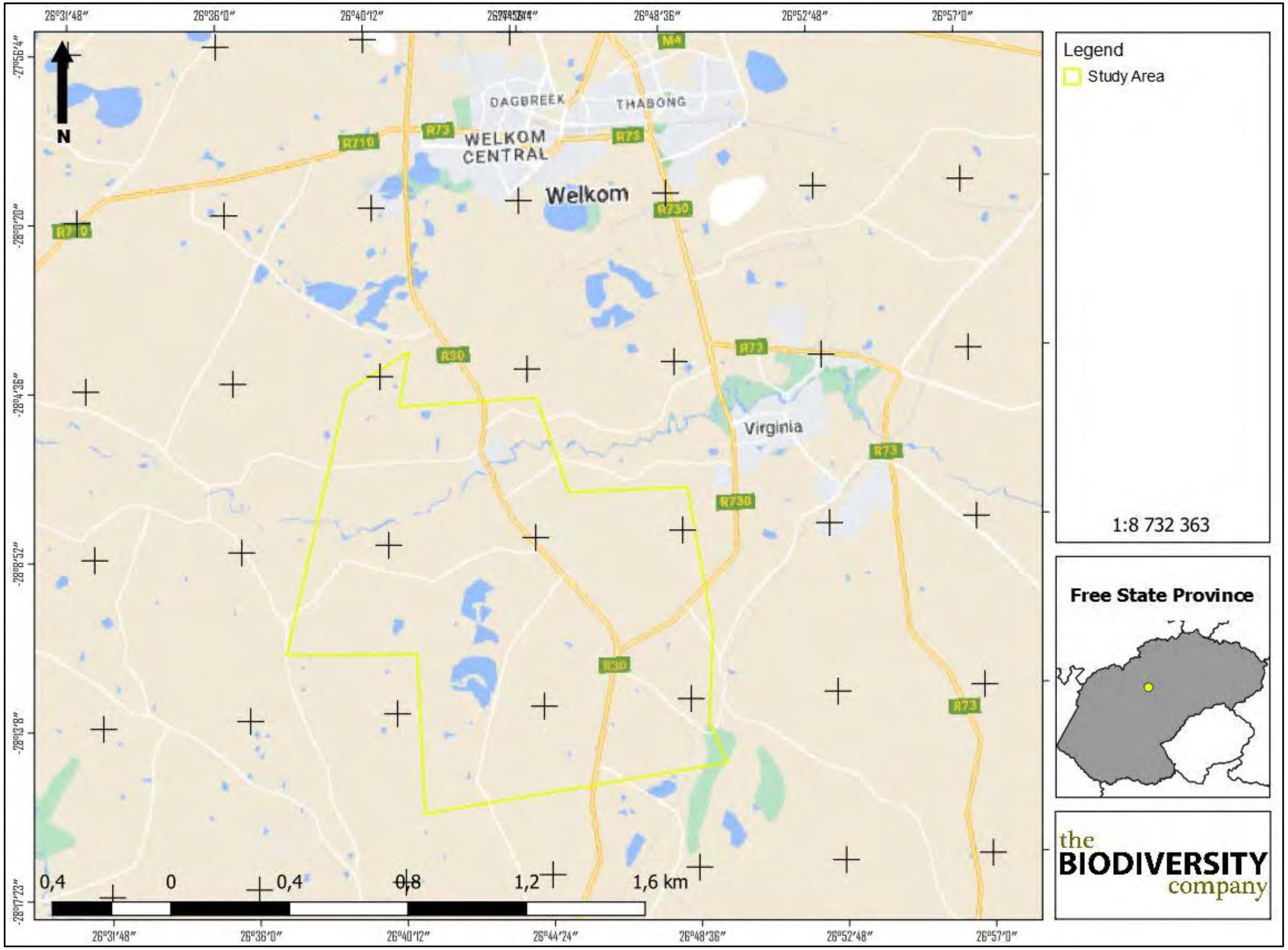

Figure 1-3 Map illustrating the location of the proposed Tetra 4 Cluster 2 project

1.2 Terms of Reference

The following tasks were completed in fulfilment of the terms of reference for this assessment:

- The delineation, classification and assessment of wetlands within 500 m of the project area;
- Conduct risk assessments relevant to the proposed activity;
- Recommendations relevant to associated impacts; and
- Report compilation detailing the baseline findings.

2 Key Legislative Requirements

2.1 National Water Act (NWA, 1998)

The Department Water and Sanitation (DWS) is the custodian of South Africa's water resources and therefore assumes public trusteeship of water resources, which includes watercourses, surface water, estuaries, or aquifers. The National Water Act (Act No. 36 of 1998) (NWA) allows for the protection of water resources, which includes:

- The maintenance of the quality of the water resource to the extent that the water resources may be used in an ecologically sustainable way;
- The prevention of the degradation of the water resource; and
- The rehabilitation of the water resource.

A watercourse is defined in the NWA as:

- A river or spring;
- A natural channel in which water flows regularly or intermittently;
- A wetland, lake or dam into which, or from which, water flows; and
- Any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its bed and banks.

The NWA recognises that the entire ecosystem and not just the water in isolation, and any given water resource constitutes the resource and as such needs to be conserved. No activity may therefore take place within a watercourse unless it is authorised by the DWS. Any area within a wetland or riparian zone is therefore excluded from development unless authorisation is obtained from the DWS in terms of Section 21 (c) and (i).

2.1.1 National Water Act, 1998 – General Notice 704 (1999)

Restrictions on locality; no person in control of a mine or activity may – except in relation to a matter contemplated in regulation 10, carry on any underground or opencast mining, prospecting or any other operation or activity under or within the 1:50 year flood-line or within a horizontal distance of 100 m from any watercourse or estuary, whichever is greatest.

2.1.2 National Water Act, 1998 – Section 21: (c) and (i) water uses for General Authorisation – GN 509 of 26 August 2016

The DWS, is of the view that any activity within the 500 m Regulated Area or radius from the boundary (temporary zone) of any wetland or pan, or within the outer edge of the 1 in 100 year flood line or riparian habitat measured from the middle of the watercourse from both banks, requires a risk assessment to determine whether a Water Use Licence (WUL) or General Authorisation (GA) for a section 21(c) and (i) water use is required (DWS, 2016a).

2.2 National Environmental Management Act (NEMA, 1998)

The National Environmental Management Act (NEMA) (Act 107 of 1998) and the associated EIA Regulations as amended in November 2017, states that prior to any development taking place within a wetland or riparian area, an environmental authorisation process needs to be followed. This could follow either the Basic Assessment Report (BAR) process or the Scoping and Environmental Impact Reporting (S&EIR) process depending on the scale of the impact.

3 Methodologies

3.1 Desktop assessment

The following information sources were considered for the desktop assessment;

- Aerial imagery (Google Earth Pro);
- LiDar imagery;
- Vegetation and climate information (Mucina & Rutherford, 2006);
- Land Type Data (Land Type Survey Staff, 1972 - 2006);
- The inland water dataset;
- Topographical river line data;
- The South African Inventory of Inland Aquatic Ecosystems (SAIIAE) (Van Deventer *et al*., 2018); and
- Contour data (5 m).

3.2 Identification and Mapping

The wetland areas are delineated in accordance with the DWAF (2005) guidelines, a cross section is presented in Figure 3-1. The outer edges of the wetland areas were identified by considering the following four specific indicators:

- The Terrain Unit Indicator helps to identify those parts of the landscape where wetlands are more likely to occur;
- The Soil Form Indicator identifies the soil forms, as defined by the Soil Classification Working Group (1991), which are associated with prolonged and frequent saturation.
    - The soil forms (types of soil) found in the landscape were identified using the South African soil classification system namely; Soil Classification: A Taxonomic System for South Africa;
- The Soil Wetness Indicator identifies the morphological "signatures" developed in the soil profile as a result of prolonged and frequent saturation; and
- The Vegetation Indicator identifies hydrophilic vegetation associated with frequently saturated soils.

Vegetation is used as the primary wetland indicator. However, in practise the soil wetness indicator tends to be the most important, and the other three indicators are used in a confirmatory role.

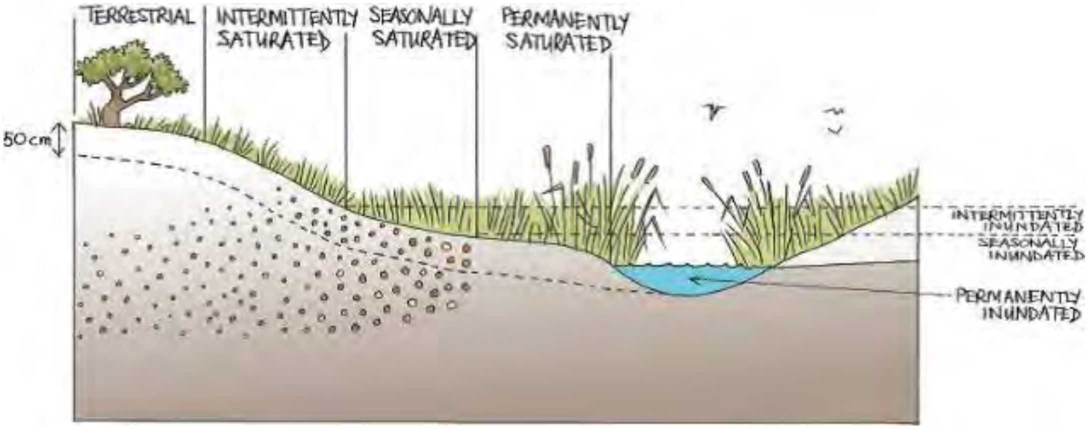

Figure 3-1 Cross section through a wetland, indicating how the soil wetness and vegetation indicators change (Ollis et al. 2013)

3.3 Delineation

The wetland indicators described above are used to determine the boundaries of the wetlands within the project area. These delineations are then illustrated by means of maps accompanied by descriptions.

3.4 Functional Assessment

Wetland functionality refers to the ability of wetlands to provide healthy conditions for the wide variety of organisms found in wetlands as well as humans. EcoServices serve as the main factor contributing to wetland functionality.

The assessment of the ecosystem services supplied by the identified wetlands was conducted per the guidelines as described in WET-EcoServices (Kotze et al. 2008). An assessment was undertaken that examines and rates the following services according to their degree of importance and the degree to which the services are provided (Table 3-1).

Table 3-1 Classes for determining the likely extent to which a benefit is being supplied

Score	Rating of likely extent to which a benefit is being supplied
< 0.5	Low
0.6 - 1.2	Moderately Low
1.3 - 2.0	Intermediate
2.1 - 3.0	Moderately High
> 3.0	High

3.5 Present Ecological Status

The overall approach is to quantify the impacts of human activity or clearly visible impacts on wetland health, and then to convert the impact scores to a Present Ecological Status (PES) score. This takes the form of assessing the spatial extent of impact of individual activities/occurrences and then separately assessing the intensity of impact of each activity in the affected area. The extent and intensity are then combined to determine an overall magnitude of impact. The Present State categories are provided in Table 3-2.

Table 3-2 The Present Ecological Status categories (Macfarlane, et al., 2009)

Impact Category	Description	Impact Score Range	PES
None	Unmodified, natural	0 to 0.9	A
Small	Largely Natural with few modifications. A slight change in ecosystem processes is discernible and a small loss of natural habitats and biota may have taken place.	1.0 to 1.9	B
Moderate	Moderately Modified. A moderate change in ecosystem processes and loss of natural habitats has taken place, but the natural habitat remains predominantly intact.	2.0 to 3.9	C
Large	Largely Modified. A large change in ecosystem processes and loss of natural habitat and biota has occurred.	4.0 to 5.9	D
Serious	Seriously Modified. The change in ecosystem processes and loss of natural habitat and biota is great, but some remaining natural habitat features are still recognizable.	6.0 to 7.9	E
Critical	Critical Modification. The modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	8.0 to 10	F

3.6 Ecological Importance and Sensitivity

The method used for the EIS determination was adapted from the method as provided by DWS (1999) for floodplains. The method takes into consideration PES scores obtained for WET-Health as well as function and service provision to enable the assessor to determine the most representative EIS category for the wetland feature or group being assessed. A series of determinants for EIS are assessed on a scale of 0 to 4, where 0 indicates no importance and 4 indicates very high importance. The mean of the determinants is used to assign the EIS category as listed in Table 3-3 (Rountree et al., 2012).

Table 3-3 Description of Ecological Importance and Sensitivity categories

EIS Category	Range of Mean	Recommended Ecological Management Class
Very High	3.1 to 4.0	A
High	2.1 to 3.0	B
Moderate	1.1 to 2.0	C
Low Marginal	< 1.0	D

3.7 Ecological Classification and Description

The National Wetland Classification Systems (NWCS) developed by the South African National Biodiversity Institute (SANBI) will be considered for this study. This system comprises a hierarchical classification process of defining a wetland based on the principles of the hydrogeomorphic (HGM) approach at higher levels, and then also includes structural features at the lower levels of classification (Ollis et al. 2013).

3.8 Determining Buffer Requirements

The "Preliminary Guideline for the Determination of Buffer Zones for Rivers, Wetlands and Estuaries" (Macfarlane et al. 2014) was used to determine the appropriate buffer zone for the proposed activity.

3.9 Limitations

The following limitations are applicable:

- Areas characterised by external wetland indicators have been focussed on for this study. Areas lacking these characteristics, i.e. disturbed areas, developed areas etc. have not been focussed on;
- Due to the size of the proposed area only the key areas where infrastructure is located were focused on, the remaining areas were predominantly delineated through means of desktop; and
- The GPS used for water resource delineations is accurate to within five meters. Therefore, the wetland delineation plotted digitally may be offset by at least five meters to either side

4 Project Area

4.1 Vegetation Types

The proposed development overlap with four vegetation types, Vaal-Vet Sandy Grassland, Highveld Alluvial Vegetation, Central Free State Grassland and Western Free State Clay Grassland (Figure 4-1). The threat status and conservation targets of each vegetation type is shown in Table 4-1.

Table 4-1 The Threat Status and Conservation Targets of each vegetation type (EN= Endangered, LC =Least Concerned, VU= Vulnerable)

Vegetation Type	Mucina and Rutherford Conservation Status (2007)	NBA Threat Status (2018)	Conservation Target (NBA, 2018)
Vaal-Vet Sandy Grassland	EN	EN	24%
Highveld Alluvial Vegetation	LC	LC	31%
Central Free State Grassland	VU	LC	24%
Western Free State Clay Grassland	LC	LC	24%

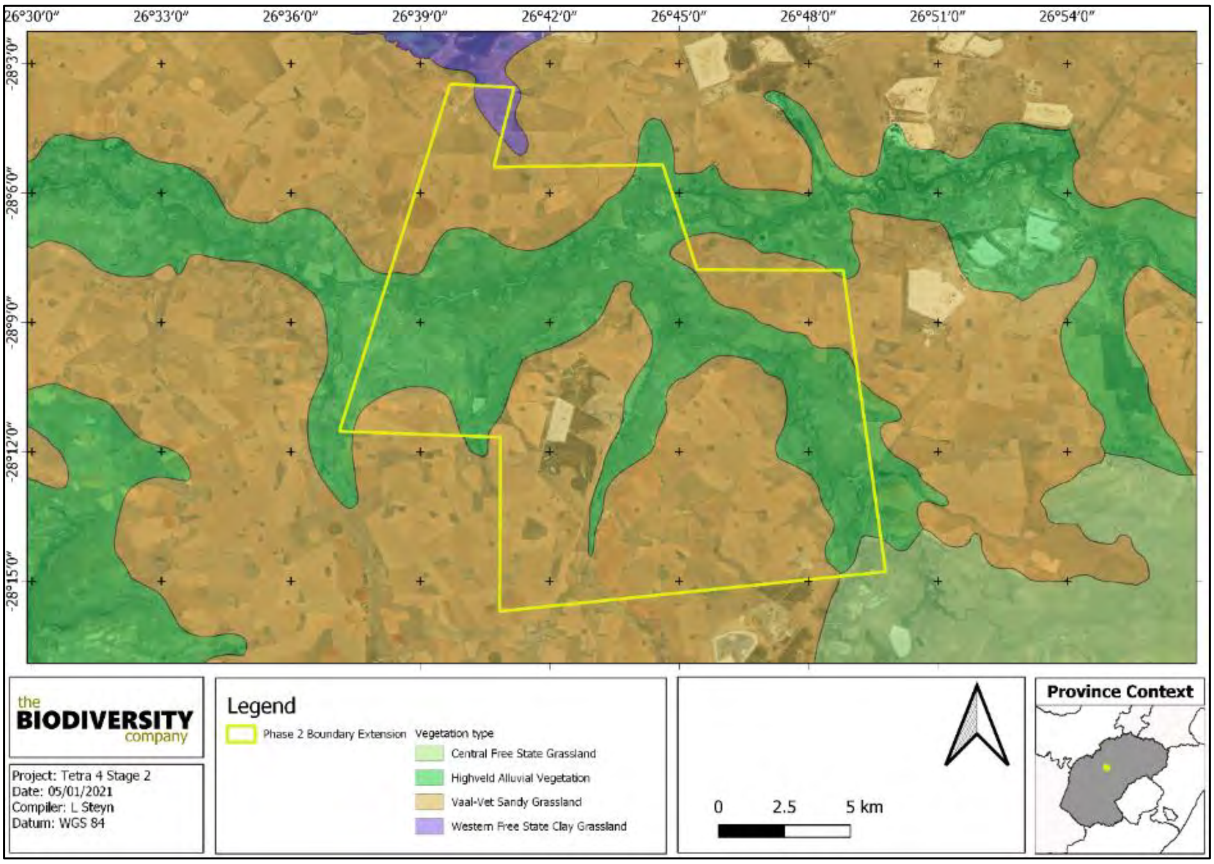

Figure 4-1 Map illustrating the vegetation type associated with the assessment area

4.2 Soils and Geology

According to the land type database (Land Type Survey Staff, 1972 - 2006), the project area is characterised by the Bd20 and the Dc8 land type. The Bd20 land type is characterized by plinthic catena as well as upland duplex and margalitic soils which rarely occur. Eutrophic, red soils are not widespread without the project area. As for the Dc8 land type, the soils within this land type are characterised by prismacutanic and/or pedocutanic diagnostic horizons with the addition of one or more of the following; Vertic, melanic and red structured diagnostic horizons.

The geology of this area is characterised by aeolian and colluvial sand which overlies mudstone, sandstone and shale of the Karoo Supergroup. Older Ventersdorp Supergroup basement gneiss and andesite is located to the north. Soil forms associated with the project area includes the Bd, Bc, Ae and Ba land types, which correlates with the findings from the land type database (Mucina & Rutherford, 2006).

4.3 Climate

This region is characterised by a warm-temperate summer rainfall climate with the average annual precipitation being approximately 530 mm (see Figure 4-2). High summer temperatures are common for this region with severe frost occurring throughout the winter (on average 37 days per year) (Mucina & Rutherford, 2006).

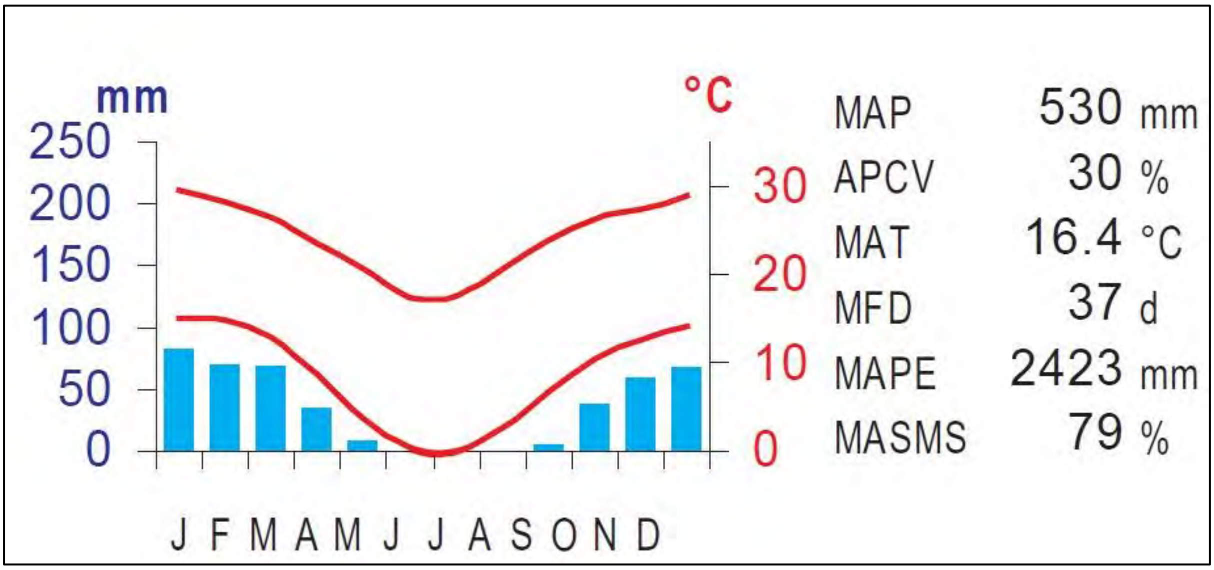

Figure 4-2 Climate for the Vaal-Vet Sandy Grassland (Mucina & Rutherford, 2006)

4.4 Topographical Inland Water and River Line Data

Multiple perennial and non-perennial streams have been identified within the proposed project area by means of the "2826" quarter degree square topographical river line data set. Multiple inland water areas ranging from natural dams to sewerage works has also been identified within the 500 m regulated area (see Figure 4-3).

4.5 NFEPA Wetlands

Seven types of NFEPA wetlands were identified within the study area, namely channelled valley bottom, depression, flat, floodplain, seep, unchannelled valley bottoms as well as valley head seep wetlands (see Figure 4-4).

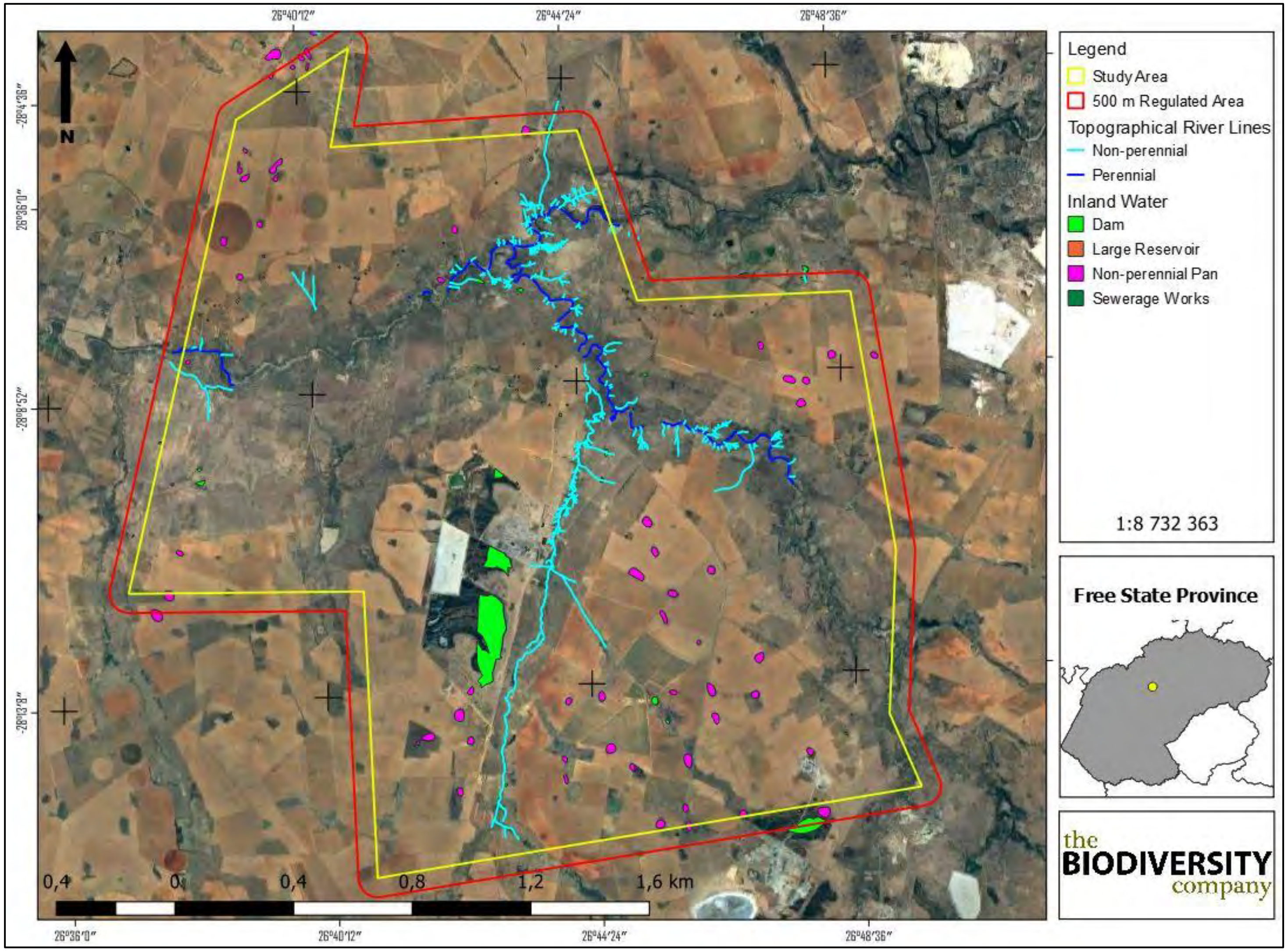

Figure 4-3 Illustration of topographical river lines and the inland water area located within the study area

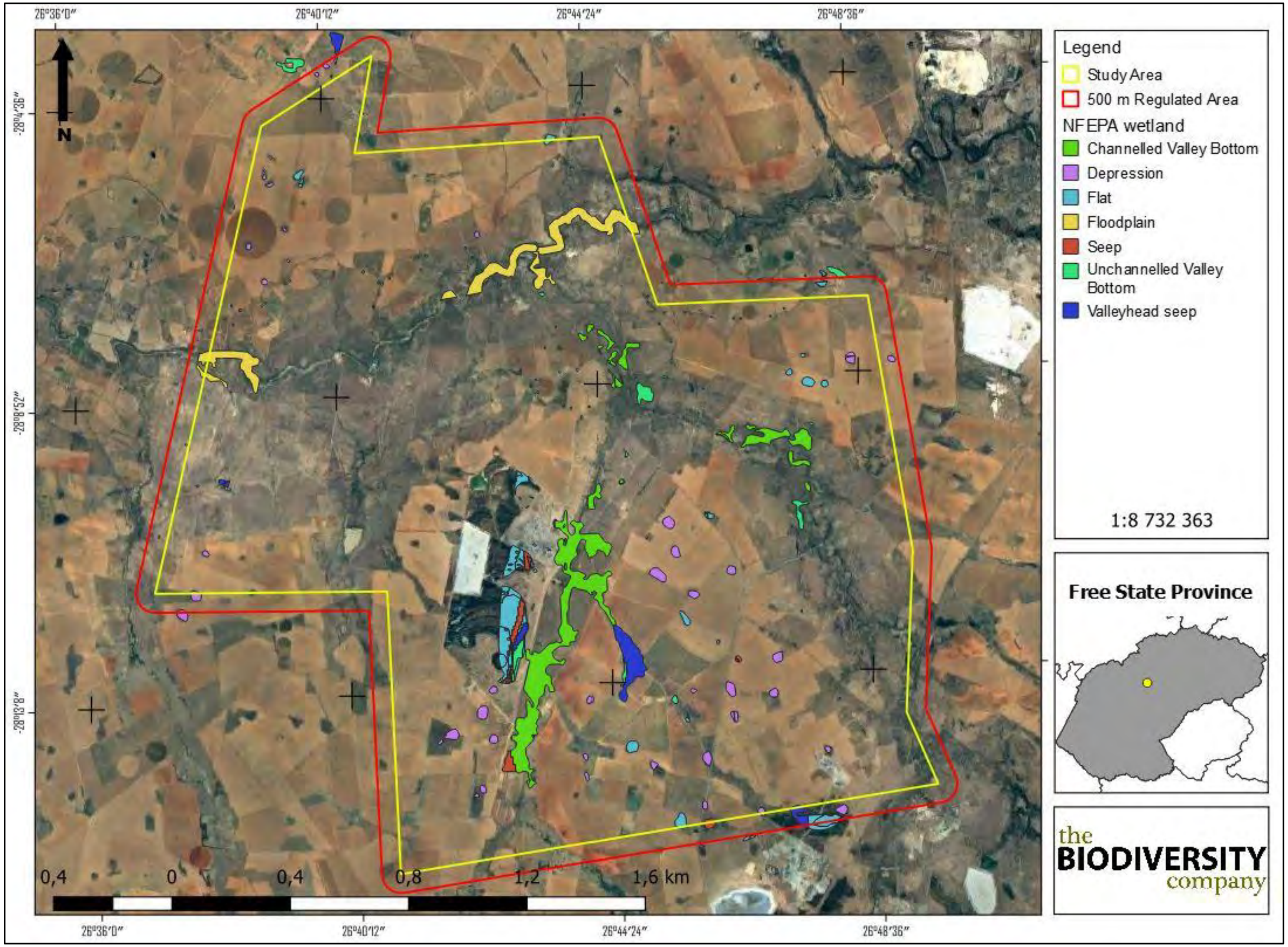

Figure 4-4 NFEPA wetlands within the project area and its surroundings

4.6 Terrain

The terrain of the 500 m regulated area has been analysed to determine potential areas where wetlands are more likely to accumulate (due to convex topographical features, preferential pathways or more gentle slopes).

4.6.1 Digital Elevation Model

A Digital Elevation Model (DEM) has been created to identify lower laying regions as well as potential convex topographical features which could point towards preferential flow paths. The 500 m regulated area ranges from 1272 to 1410 MASL. The lower laying areas (generally represented in dark blue) represent area that will have the highest potential to be characterised as wetlands (see Figure 4-5).

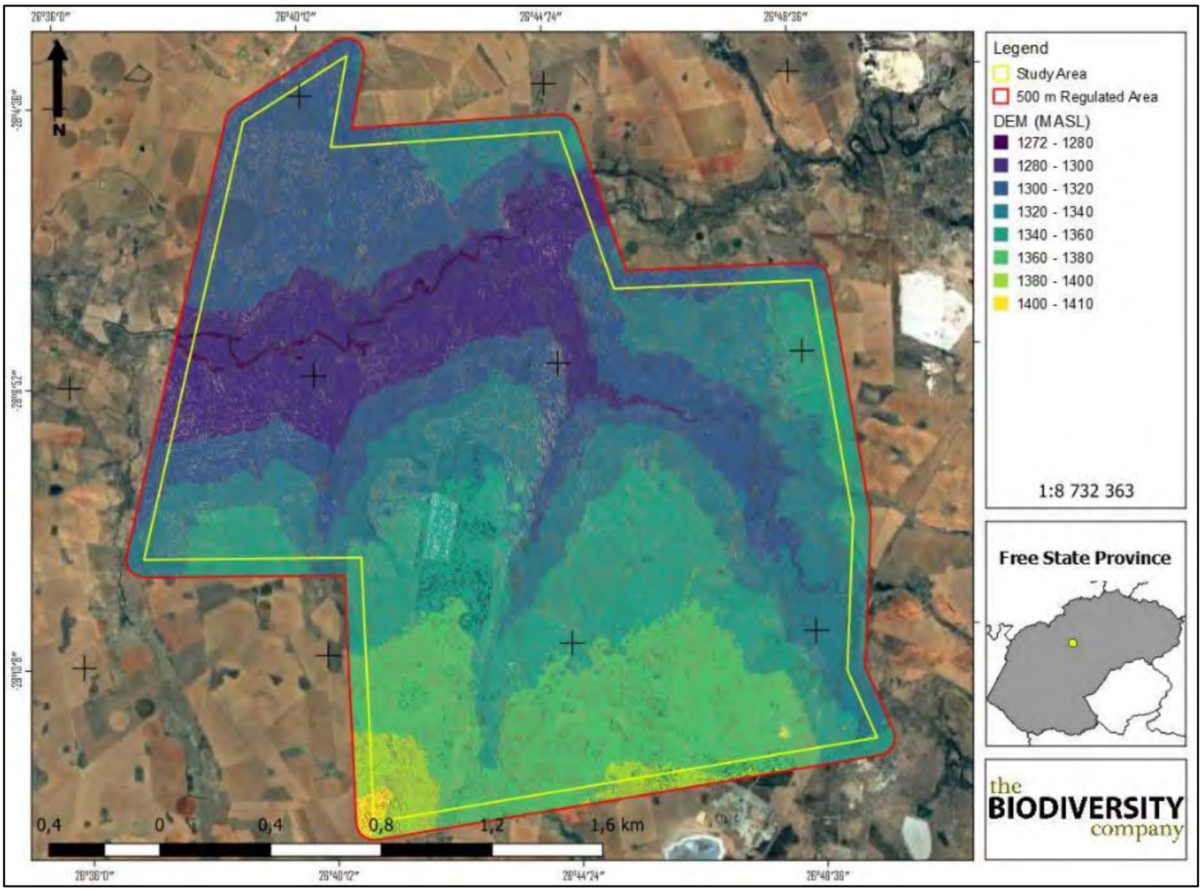

Figure 4-5 Digital Elevation Model of the 500 m regulated area

5 Results & Discussion

5.1 Delineation and Description

During the site visit four different wetland types were delineated in accordance with the DWAF (2005) guidelines. The four different types were classified as being channelled valley bottoms, unchannelled valley bottoms, hillslope seeps and depression wetlands.

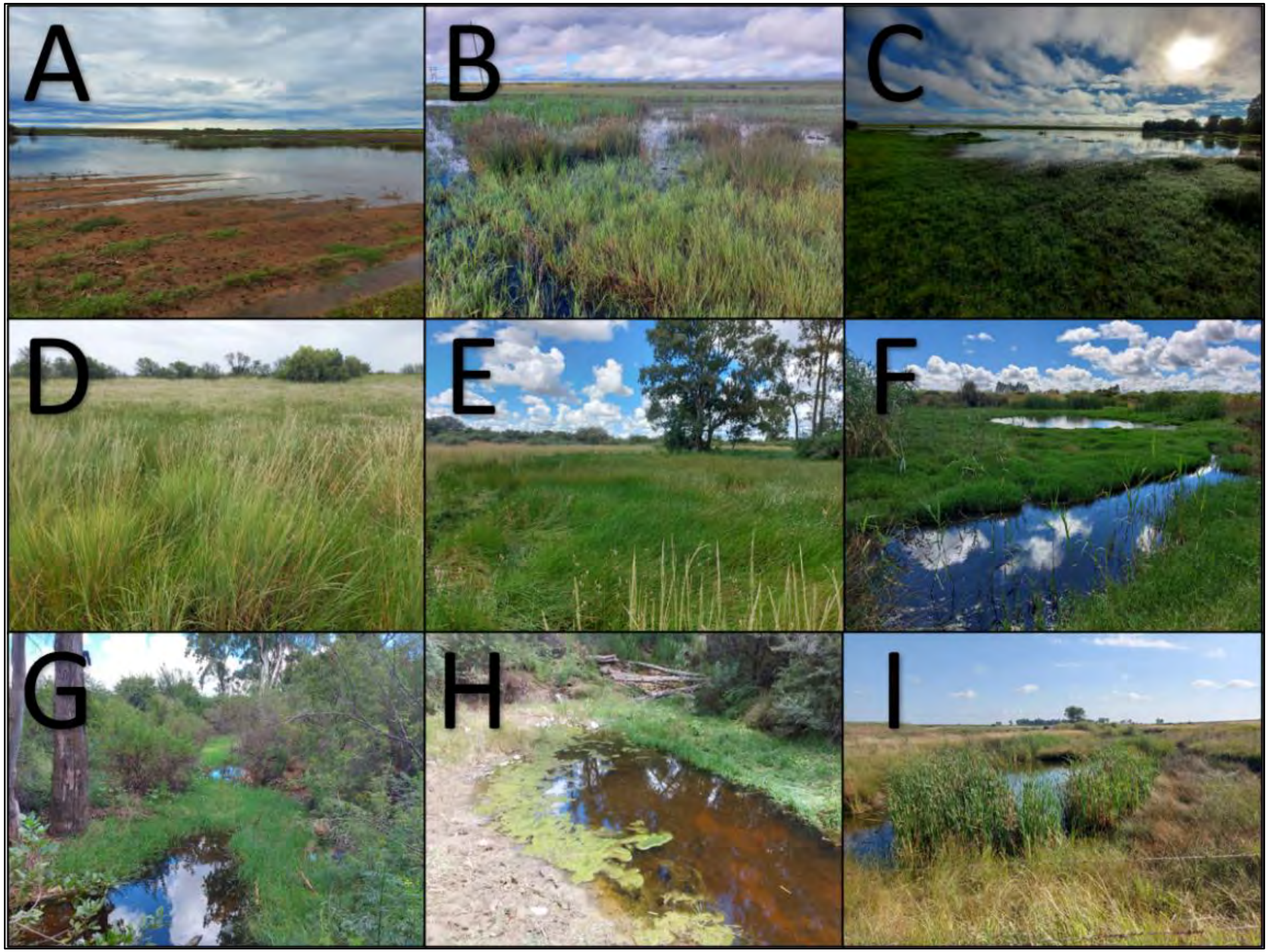

Figure 5-1 Photographical evidence of identified wetlands, A, B & C) depressions, D) Unchannelled valley bottom, E) seep and G, H & I) channelled valley bottoms

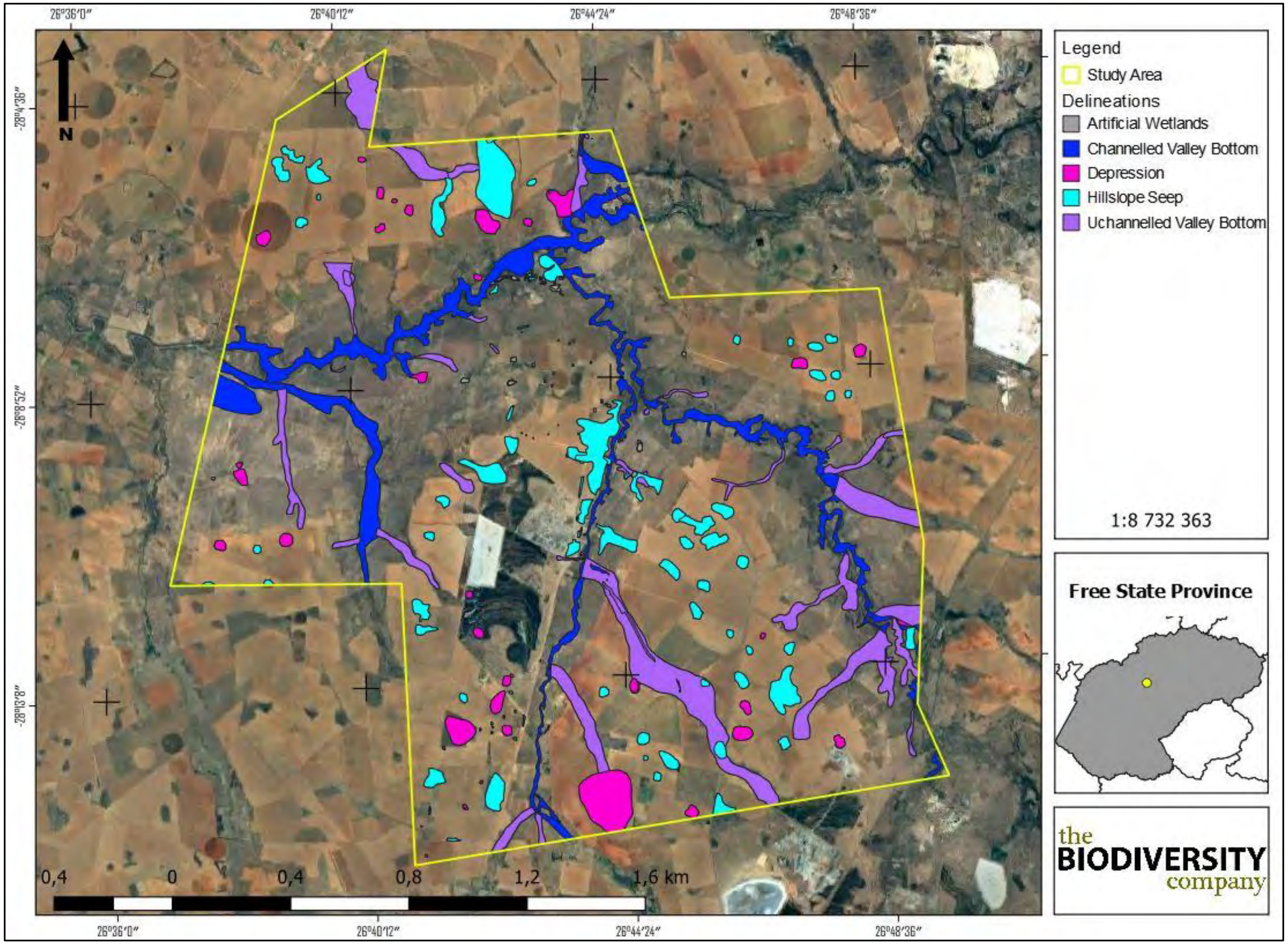

Figure 5-2 Delineation of wetlands within the study area

5.2 Unit Setting

The channelled valley bottom wetland is located on the “valley floor” landscape unit. Channelled valley bottom wetlands are typically found on valley-floors with a clearly defined, finite stream channel and lacks floodplain features, referring specifically to meanders. Channelled valley bottom wetlands are known to undergo loss of sediment in cases where the wetlands’ slope is high and the deposition thereof in cases of low relief. Figure 5-3 illustrates a diagram of the channelled valley bottom wetland, showing the dominant movement of water into, through and out of the system.

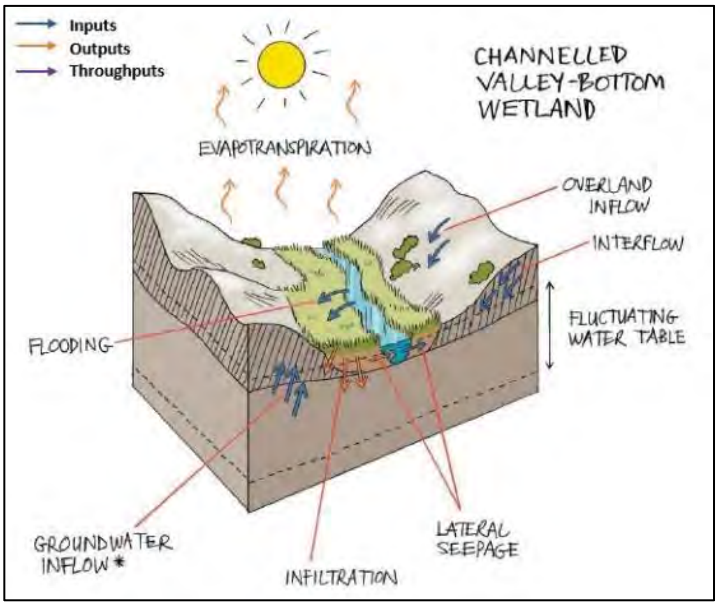

Figure 5-3 Amalgamated diagram of a typical channelled valley bottom wetland, highlighting the dominant water inputs, throughputs and outputs, SANBI guidelines (Ollis et al. 2013)

Depression wetlands are typically located on the “valley-floor” landscape unit. Depressions are inward draining basins with an enclosing topography which allows for water to accumulate within the system. Depressions, in some cases, are also fed by lateral sub-surface flows in cases where the dominant geology allows for these types of flows. Figure 5-4 illustrates a diagram of a depression, showing the dominant movement of water into, through and out of the system.

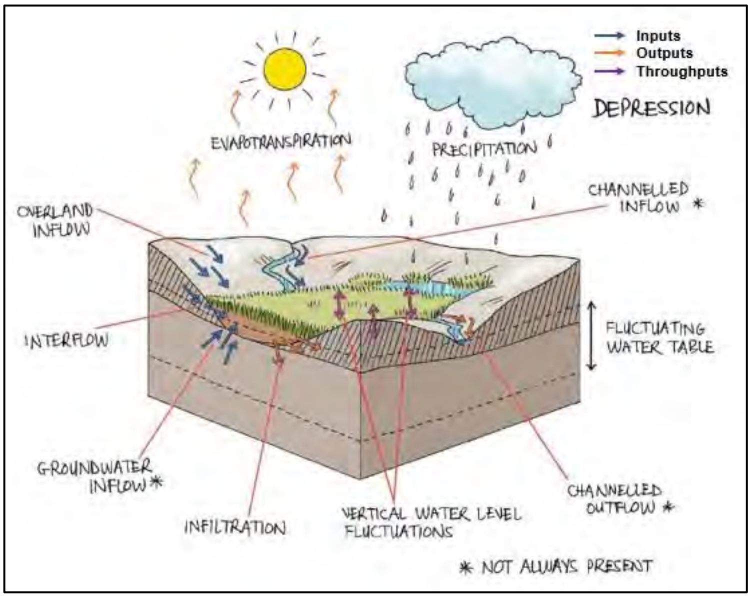

Figure 5-4 Amalgamated diagram of a typical depression wetland, highlighting the dominant water inputs, throughputs and outputs, SANBI guidelines (Ollis et al. 2013)

Hillslope seeps are located within slopes, as mentioned in Figure 5-5. Isolated hillslope seeps are characterised by colluvial movement of material. These systems are fed by very diffuse sub-surface flows which seeps out at very slow rates, ultimately ensuring that no direct surface water connects this wetland with other water courses within the valleys. Figure 5-5 illustrates a diagram of the hillslope seeps, showing the dominant movement of water into, through and out of the system.

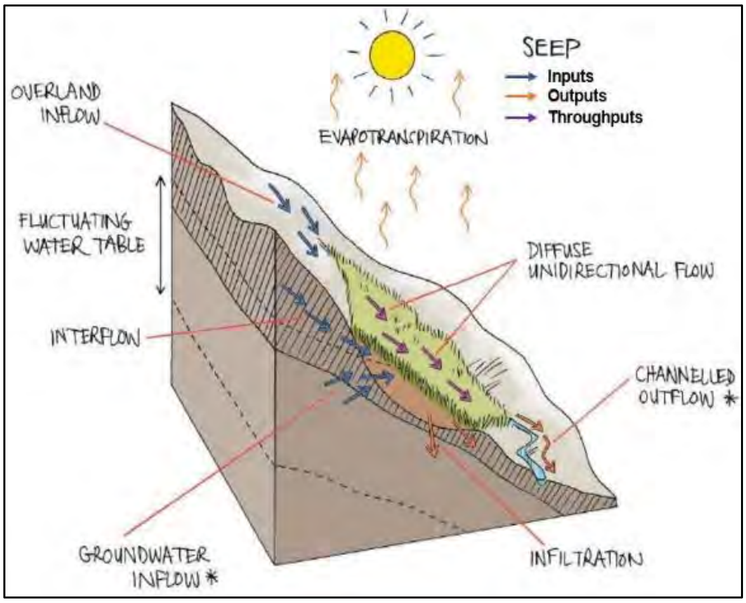

Figure 5-5 Amalgamated diagram of a typical hillslope seep wetland, highlighting the dominant water inputs, throughputs and outputs, SANBI guidelines (Ollis et al. 2013)

The unchannelled valley bottom is located on the “valley floor” landscape unit. Unchannelled valley bottom wetlands are typically found on valley-floors where the landscape does not allow high energy flows. Figure 5-6 illustrates a diagram of a typical unchannelled valley bottom, showing the dominant movement of water into, through and out of the system.

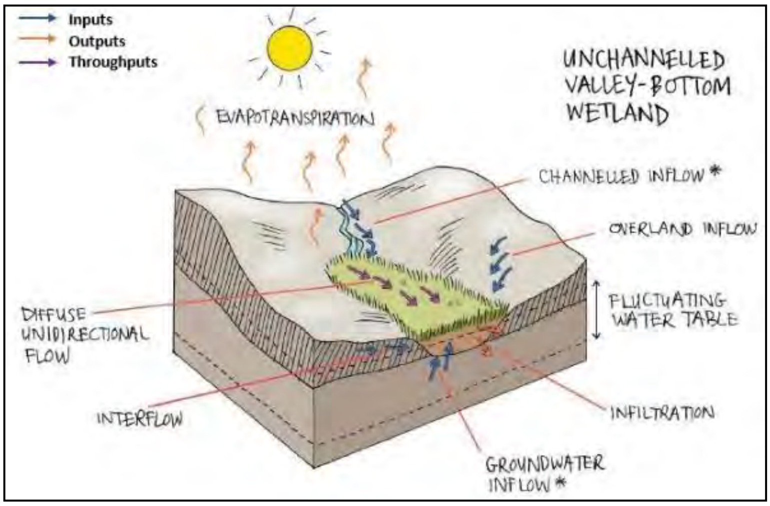

Figure 5-6 Amalgamated diagram of a typical unchannelled valley bottom wetland, highlighting the dominant water inputs, throughputs and outputs, SANBI guidelines (Ollis et al. 2013)

5.3 Indicators

According to (DWAF, 2005), a combination of hydromorphic soils and hydrophytic plants must be used to identify and accurately delineate wetland areas.

5.3.1 Hydromorphic Soils

According to (DWAF, 2005), soils are the most important characteristic of wetlands in order to accurately identify and delineate wetland areas. Five dominant soil forms were identified within the identified wetland, namely the Katspruit, Kroonstad, Longlands, Westleigh and Mispah soil forms (see Figure 5-7) (Soil Classification Working Group, 2018).

The Katspruit soil form consists of an orthic topsoil on top of a gleyic horizon. The “2210” family group is applicable to this soil form given the grey colours, the firm texture and structure of the soil form and the absence of lime.

The Kroonstad soil form consists of an Orthic topsoil on top of an Albic horizon, which in turn is underlain by a Gleyic horizon. The soil family group identified for the Kroonstad soil form is “1110” due to the gleyed colour of the topsoil, the Albic horizon’s grey colours when in a wet condition as well as the non-calcareous nature of the soil.

The Longlands soil form consists of an orthic topsoil on top of an albic horizon. The soil family group identified for the Longlands soil form on-site has been classified as the “1000” soil family due to the grey colour of the soil in wet conditions.

The Westleigh soil form consists of an Orthic A-horizon on top of a Soft Plinthic B-horizon. The soil family group identified for the Westleigh soil form on-site has been classified as the Helena (1000) soil family given the lack of evidence pertaining to luvic processes.

The Mispah soil form consists of an orthic topsoil on top of a hard rock layer. The soil family group identified for the Mispah soil form on-site is that of *2120* due to the chromic properties of the topsoil, the absence of lime as well as the solid structure of the bedrock.

Orthic topsoils are mineral horizons that have been exposed to biological activities and varying intensities of mineral weathering. The climatic conditions and parent material ensure a wide range of properties differing from one orthic topsoil to another (i.e. colouration, structure etc) (Soil Classification Working Group, 2018).

Albic horizons are often characterised by uniform white-greyish colours from the residual clay and quartz particles making up the matrix of the horizon. The main characteristic of this diagnostic horizon is a bleached colouration, which is a resultant product of distinct redox and ferrolysis pedological processes combined with eluvial processes. According to the Soil Classification Working Group (2018), albic horizons often receive lateral sub-surface flows from hillslope processes.

Gley horizons that are well developed and have homogenous dark to light grey colours with smooth transitions. Stagnant and reduced water over long periods is the main factor responsible for the formation of a gley horizon and could be characterised by green or blue tinges due to the presence of a mineral called Fougerite which includes sulphate and carbonate complexes. Even though grey colours are dominant, yellow and/or red striations can be noticed throughout a gley horizon. The structure of a gley horizon mostly is characterised as strong pedal, with low hydraulic conductivities and a clay texture, although sandy gley horizons are known to occur. The gley soil form commonly occurs at the toe of hillslopes (or benches) where lateral water inputs (sub-surface) are dominant and the underlaying geology is characterised by a low hydraulic conductivity. The gley horizon usually is second in diagnostic sequence in shallow profiles yet is known to be lower down in sequence and at greater depths (Soil Classification Working Group, 2018).

The accumulations of iron (and in some cases manganese) as hydroxides and oxides with the presence of high chroma striations and concretions with black matrixes are associated with the Soft Plinthic horizon. This diagnostic horizon forms due to fluctuating levels of saturation. The iron and manganese concentration result in soft marks within the soil matrix which transform in concretions with high consistencies (Soil Classification Working Group, 1991).

If this process continues for long enough periods, a massive continues impermeable layer of hard plinthite forms. A Soft Plinthic horizon and a Hard Plinthic horizon can be distinguished from one another by means of a simple spade test. A Soft Plinthic horizon can be penetrated by means of a spade in wet conditions whereas a Hard Plinthic horizon cannot (Soil Classification Working Group, 1991).

According to Soil Classification Working Group (2018), this horizon commonly occurs as a result of hillslope hydrology in flat, sandy landscapes. This horizon is known to have an apedal structure together with the presence of concretions.

The hard rock layer disallows infiltration of water or root systems and occur in shallow profiles. Horizontally layered, hard sediments without evidence of vertical seems fall under this category.

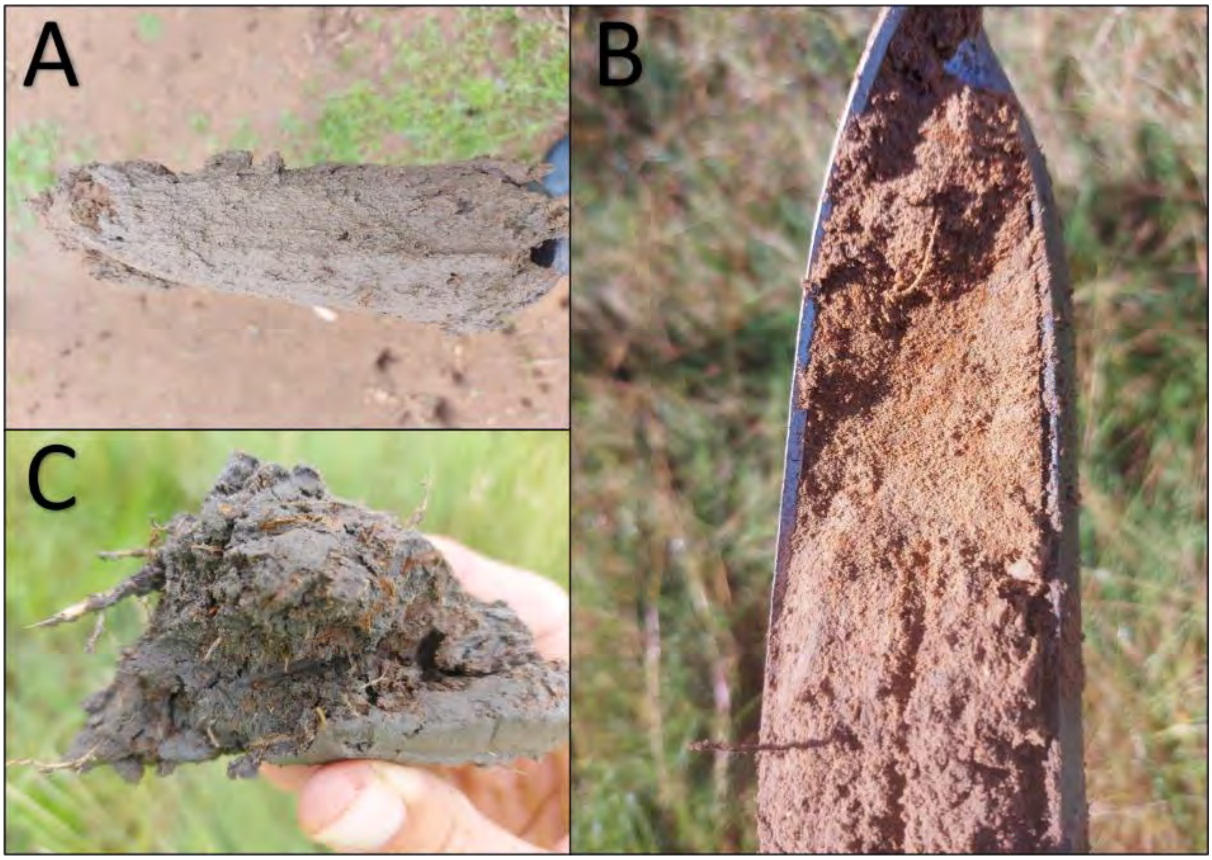

Figure 5-7 Different soils identified within the study area, A) Gley horizon, B) Orthic topsoil with signs of wetness, C) Orthic topsoil with mottles

5.3.2 Hydrophytes

Vegetation plays a considerable role in identifying, classifying and accurately delineating wetlands (DWAF, 2005). During the site visit, various hydrophytic species were identified (including facultative species). Examples include *Cyperus spp. Persicaria* spp., *Typha Capensis* (See Figure 5-8).

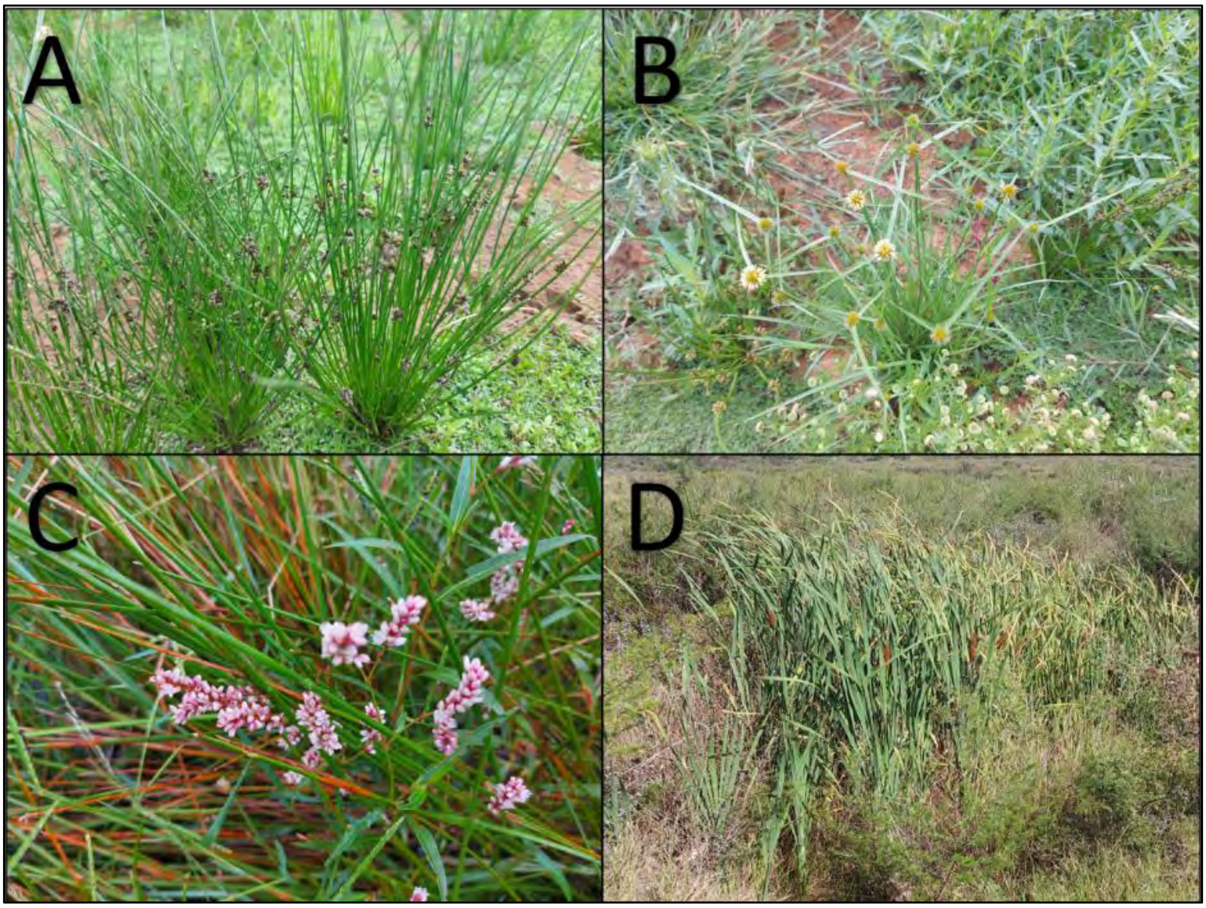

Figure 5-8 Hydrophytic vegetation identified within delineated watercourses. A) Cyperus spp. B) Kyllinga brevifolia C) Persicaria spp. D) Typha Capensis

5.4 General Functional Description of Wetland Types

Channelled valley bottom wetlands tend to contribute less to sediment trapping and flood attenuation than other systems. Channelled valley bottom wetlands are well known to improve the assimilation of toxicants, nitrates and sulphates, especially in cases where sub-surface flows contribute to the system's water source (Kotze et al., 2009).

The generally impermeable nature of depressions and their inward draining features are the main reasons why the streamflow regulation ability of these systems is mediocre. Regardless of the nature of depressions in regard to trapping all sediments entering the system, sediment trapping is another Eco Service that is not deemed as one of the essential services provided by depressions, even though some systems might contribute to a lesser extent. The reason for this phenomenon is due to winds picking up sediments within pans during dry seasons which ultimately leads to the removal of these sediments and the deposition thereof elsewhere. The assimilation of nitrates, toxicants and sulphates are some of the higher rated Eco Services for depressions. This latter statement can be explained the precipitation as well as continues precipitation and dissolving of minerals and other contaminants during dry and wet seasons respectively, (Kotze et al., 2009).

Hillslope seeps are well documented by (Kotze et al., 2009) to be associated with sub-surface ground water flows. These systems tend to contribute to flood attenuation given their diffuse nature. This attenuation only occurs while the soil within the wetland is not yet fully saturated. The accumulation of organic material and sediment contributes to prolonged levels of saturation due to this deposition slowing down the sub-surface movement of water. Water typically accumulates in the upper slope (above the seep). The accumulation of organic matter additionally is essential in the denitrification process involved with nitrate assimilation. Seeps generally also improve the quality of water by removing excess nutrient and inorganic pollutants originating from agriculture, industrial or mine activities. The diffuse nature of flows ensures the assimilation of nitrates, toxicants and phosphates with erosion control being one of the Eco Services provided very little by the wetland given the nature of a typical seep's position on slopes.

Unchanneled valley bottoms are characterised by sediment deposition, a gentle gradient with streamflow generally being spread diffusely across the wetland, ultimately ensuring prolonged saturation levels and high levels of organic matter. The assimilation of toxicants, nitrates and phosphates are usually high for unchanneled valley-bottom wetlands, especially in cases where the valley is fed by sub-surface interflow from slopes. The shallow depths of surface water within this system adds to the degradation of toxic contaminants by means of sunlight penetration.

It is however important to note that the descriptions of the above-mentioned functions are merely typical expectations. All wetland systems are unique and therefore, the ecosystem services rated high for these systems on site might differ slightly to those expectations.

5.5 Ecological Functional Assessment

The ecosystem services provided by the wetland units identified on site were assessed and rated using the WET-EcoServices method (Kotze *et al.,* 2008). Due to the high number of wetlands identified within the study area the wetlands have not been classified into HGM units. The wetland ecosystem services scores ranges from "Moderately High" to "Moderately Low". Ecosystem services contributing to these scores include flood attenuation, streamflow regulation, sediment trapping, phosphate assimilation, nitrate assimilation, toxicant assimilation, erosion control, biodiversity maintenance and tourism and recreation.

The wetlands that scored "Moderately High" ecosystem services were mostly the channelled valley bottoms where water drains into from the catchment areas. The catchments of these systems are predominantly used for agricultural fields were pesticides and herbicides are used to help maintain crop yields These pesticides and herbicides are taken out of the watercourses through the wetlands to help provide cleaner drinking water for the people downstream. The channels also help with streamflow regulation to prevent erosion within the wetlands as well as to regulate flood attenuation. The channelled valley bottoms also have water throughout the year providing important habitat and resources all year round.

The majority of wetlands scored "Intermediate" ecosystem services scores within the project area. The reason for this score is due to the fact that the areas around the wetlands are predominately used for agriculture which will release pesticide and herbicides into the wetlands but toxicants from anthropogenic activities are minimal. The wetlands scored "Intermediate" instead of "Moderately High" due to the fact that the wetland have less vegetation cover and is also more temporarily wet. The lack of water during the dry season as well as the lack of vegetation cover take away habitat for species as well as resources for humans. The wetlands do however play a vital role in sediment trapping, streamflow regulation as well as flood attenuation and was thus score higher than some of the wetlands.

The wetlands that scored the lowest ecosystem services score in this project area of "Moderately Low" were predominantly depression and seep wetlands. Seeps and Depression wetlands do not play a major role in streamflow regulation, flood attenuation and sediment trapping and thus scores lower ecosystem services in general. During the site visit this was evident as well. The depression wetland situated inside the crop fields have little to no hydrophyte vegetation which limits their ability to accumulate toxicants out the water. The lack of vegetation also hinders the wetlands' ability to provide habitat for charismatic species and limits the available resources for human use.

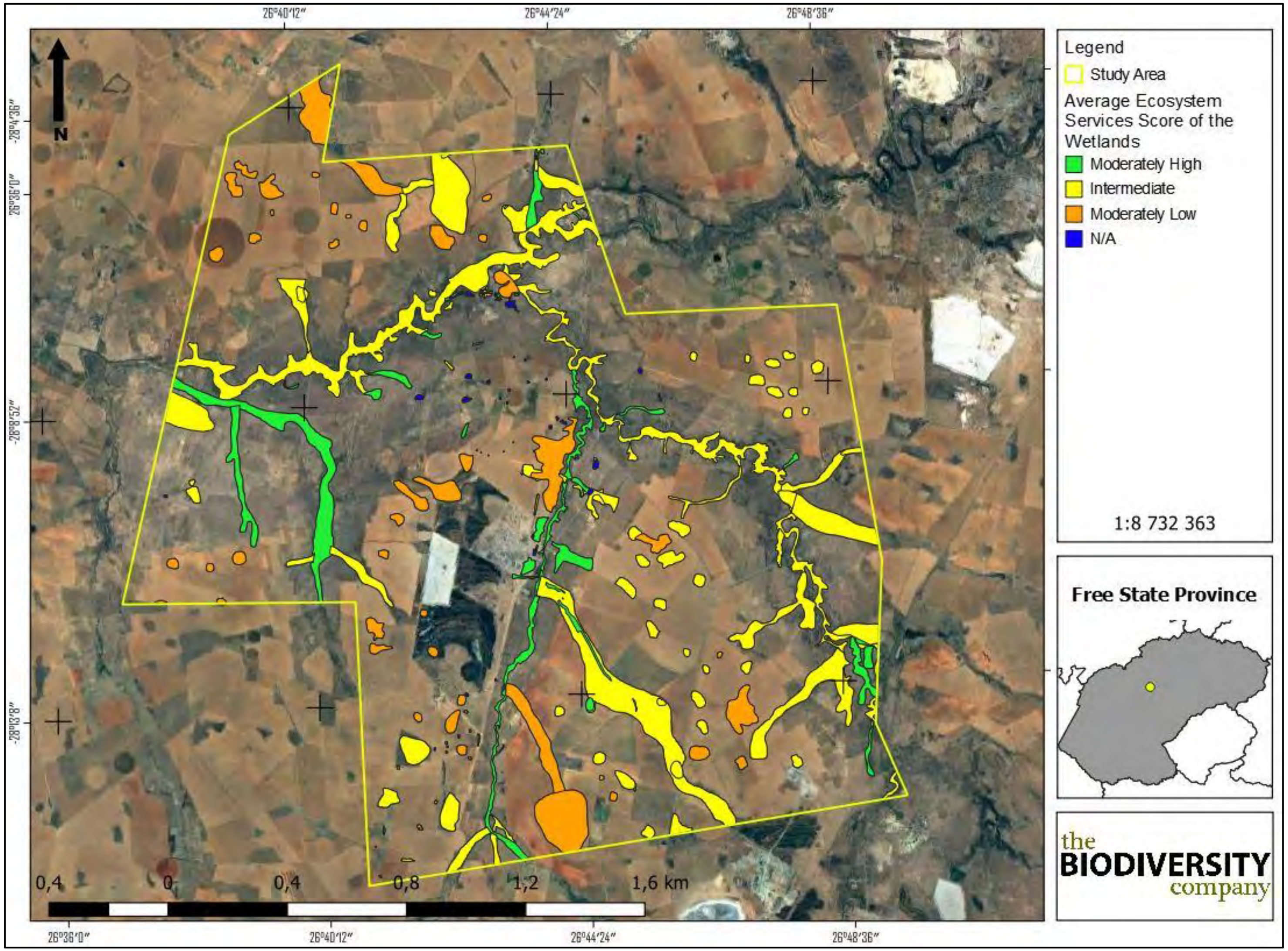

Figure 5-9 Average ecosystem service scores for the delineated wetland systems

5.6 Ecological Health Assessment

The PES for the assessed wetlands is presented in Figure 5-10. The delineated wetland systems have been scored overall PES ratings ranging of “Moderately Modified” (class C) to “Seriously Modified” (Class E). The wetlands were scored “Seriously Modified” due to multiple agricultural activities inside the wetlands. Many of the wetlands have been stripped of all vegetation and planting have taken place inside the wetland. The agricultural activities in the catchment areas of the wetlands which increased the overland flow of water and increase the possibility of flooding and erosion taking place. Multiple gravel roads, pipes and fences transverse through some of the wetlands modifying the water movement inside the wetlands.

The wetlands that scored “Moderately Modified” PES scores were located within the more natural areas of the study area. The wetlands are not subjected to agricultural activities and is thus in better ecological state. Although no agricultural activities take place inside the wetlands catchment the wetlands are still modified by human impacts. The largest modification will be through overgrazing by wildlife on the game farms. There are also roads and fences crossing through the wetlands and some anthropogenic activities taking place inside the wetlands.

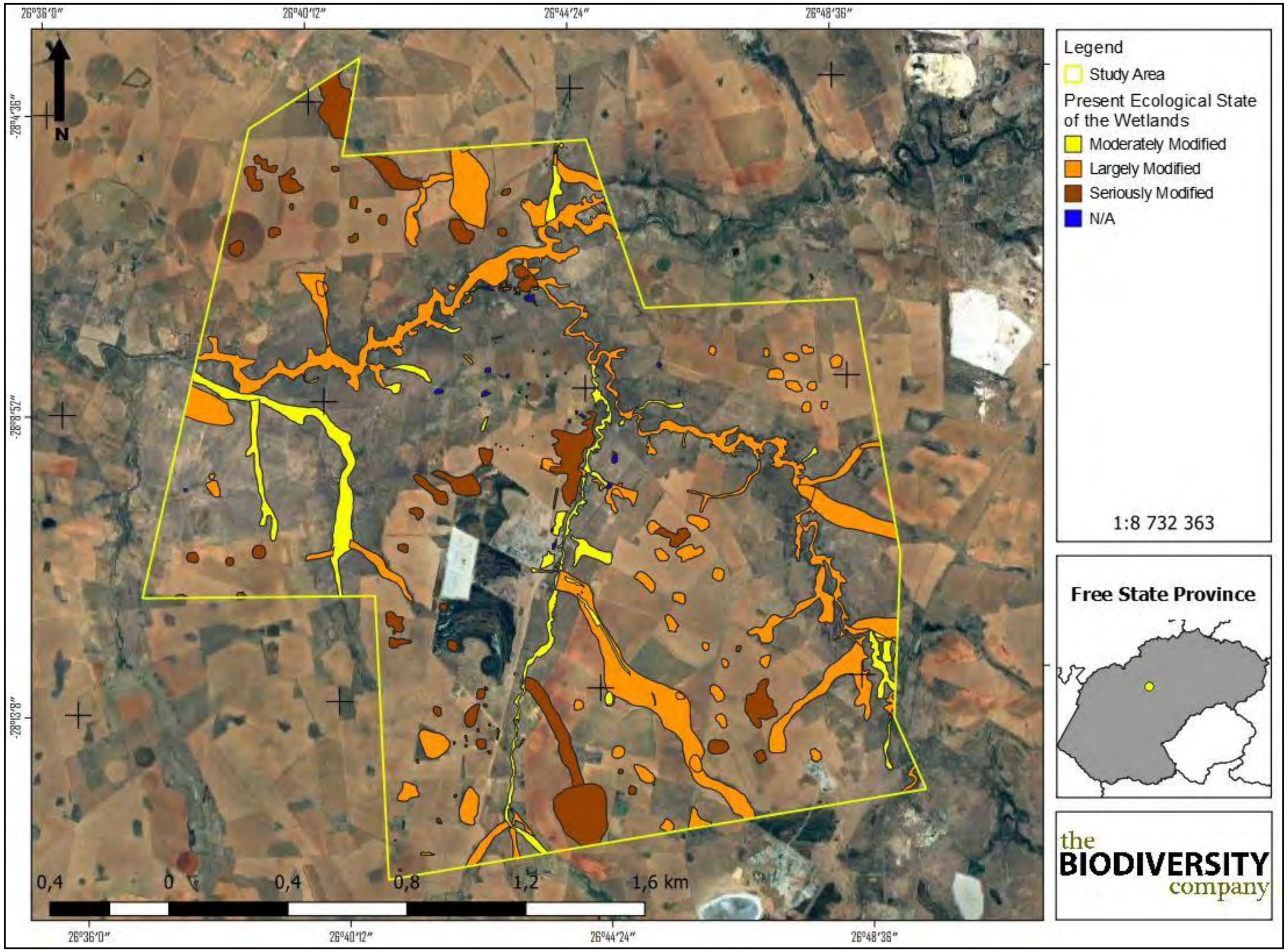

Figure 5-10 Overall present ecological state of delineated wetlands

5.7 Importance & Sensitivity Assessment

The results of the ecological IS assessment are shown in Table 5-1. Various components pertaining to the protection status of a wetland is considered for the IS, including Strategic Water Source Areas (SWSA), the NFEPA wet veg protection status and the protection status of the wetland itself considering the NBA wetland data set. The IS for all the different wetland types have been calculated to be "Moderate", which combines the relatively high protection status of the wet veg type and the low protection status of the wetland itself.

Table 5-1 The IS results for the delineated HGM unit

HGM Type	Wet Veg			NBA Wetlands			SWSA (Y/N)	Calculated IS
	Type	Ecosystem Threat Status	Ecosystem Protection Level	Wetland Condition	Ecosystem Threat Status 2018	Ecosystem Protection Level		
Channelled Valley Bottom	Dry Highveld Grassland Group 3	Least Threatened	Not Protected	D/E/F Seriously Modified	Critical	Not Protected	N	Moderate
Depression	Dry Highveld Grassland Group 3	Least Threatened	Not Protected	D/E/F Seriously Modified	Least Concern	Poorly Protected	N	Moderate
Hillslope Seep	Dry Highveld Grassland Group 3	Endangered	Not Protected	D/E/F Seriously Modified	Critical	Poorly Protected	N	High
Unchannelled Valley Bottom	Dry Highveld Grassland Group 3	Least Threatened	Not Protected	D/E/F Seriously Modified	Critical	Not Protected	N	Moderate

5.8 Buffer Requirements

The "Preliminary Guideline for the Determination of Buffer Zones for Rivers, Wetlands and Estuaries" (Macfarlane et al. 2014) was used to determine the appropriate buffer zone for the proposed activities. After taking into consideration the different activities the buffer size for the delineated wetlands were calculated as 35 m (see Figure 5-11 and Table 5-2).

Table 5-2 Threats posed during the construction- and operational phase for the delineated wetlands

	Threat Posed by the proposed land use / activity	Specialist Rating	Refined Class
Construction Phase	Alteration to surface runoff flow volumes	N/A	N/A
	Alteration of patterns of flows (increased flood peaks)	Very Low	Very Low
	Increase in sediment inputs & turbidity	Low	Low
	Increased nutrient inputs	Very Low	Very Low
	Inputs of toxic organic contaminants	Very Low	Very Low
	Inputs of toxic heavy metal contaminants	Low	Low
	Alteration of acidity (pH)	Very Low	Very Low
	Increased inputs of salts (salinization)	N/A	N/A
	Change (elevation) of water temperature	Low	Low

	Pathogen inputs (i.e. disease-causing organisms)	Very Low	Very Low
Operational Phase	Alteration to flow volumes	Low	Low
	Alteration of patterns of flows (increased flood peaks)	Low	Low
	Increase in sediment inputs & turbidity	Low	Low
	Increased nutrient inputs	Very Low	Very Low
	Inputs of toxic organic contaminants	Low	Low
	Inputs of toxic heavy metal contaminants	Low	Low
	Alteration of acidity (pH)	Low	Low
	Increased inputs of salts (salinization)	Low	Low
	Change (elevation) of water temperature	Low	Low
	Pathogen inputs (i.e. disease-causing organisms)	Very Low	Very Low

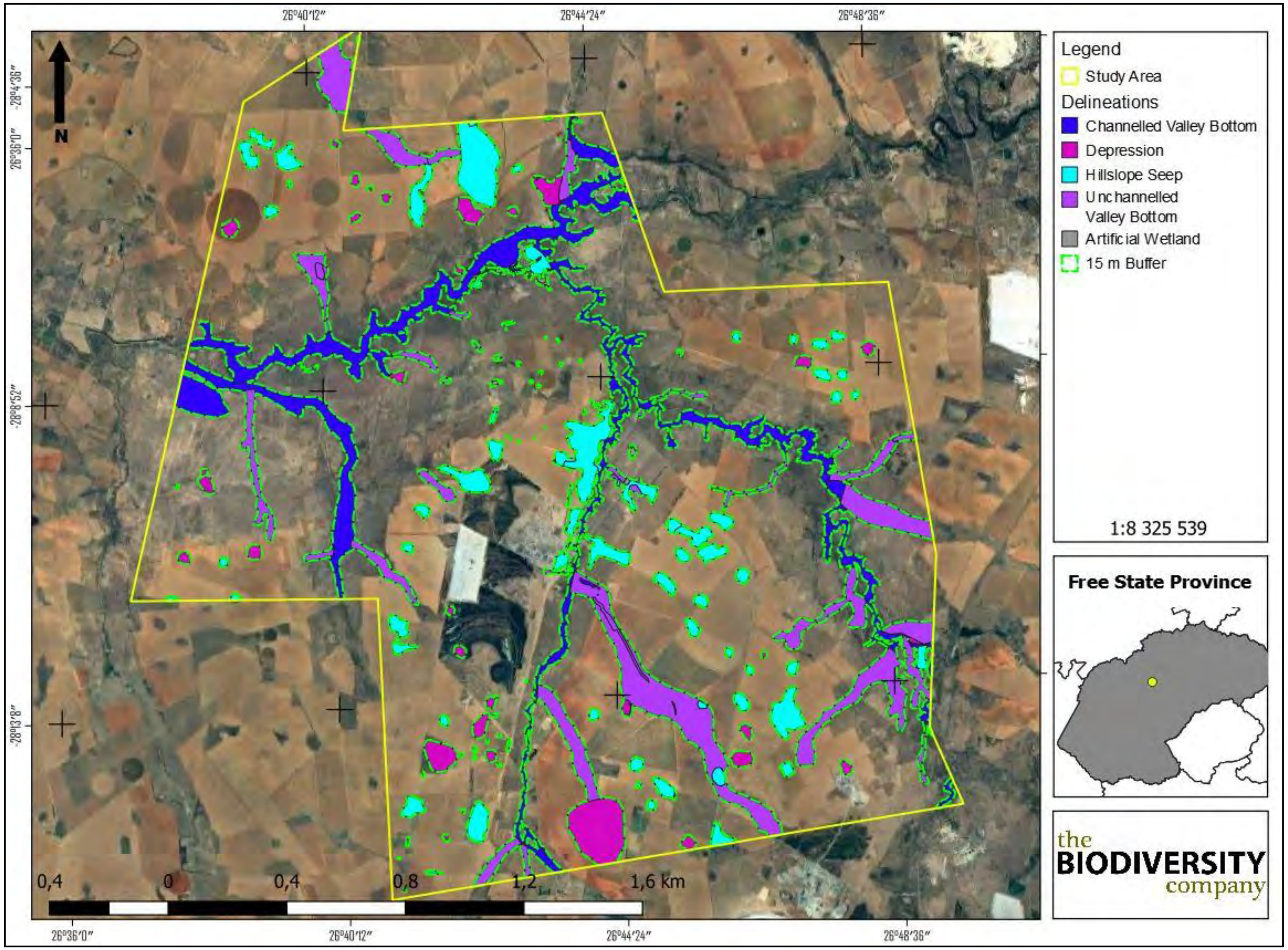

Figure 5-11 Extent of recommended buffer zones

6 Impact Assessment

Infrastructure within the study area includes compressor stations, gas pipelines, well heads and a transmission loop. The compressor stations are located outside of the wetland buffers but some indirect impacts can still affect the wetlands. The pipelines are expected to traverse the wetland systems. The well heads buffer will also impede into the wetlands but the well can be moved to stay clear of the wetland buffers, indirect impacts are still expected. The transmission loop will also transverse the wetlands. The linear structures (pipeline and transmission loop) will be assessed as one and the compressor station and wells will be assessed as one.

Impacts were considered in terms of the construction/operational phases, with no impacts on the watercourse receiving environment being identified that will occur during the decommissioning phase of the project. Mitigation measures were only applied to impacts deemed relevant.

6.1 Anticipated Activities

It is evident from the figure that the following may have a negative effect on more sensitive water resources, most impacts involve the water resources and the habitats connected to these:

- Expansions to the current LNG and Helium production plant located on the Farm Mond van Doorn Rivier. The planned expansions will be to increase the helium and LNG production capacities significantly (~30 fold increase) and increase the footprint of the existing approved plant by approximately 10 ha;
- The drilling of new gas wells ~300 wells spread over a total study area (Cluster 2) of approximately ~27 500 ha;
- The installation of trenched pipelines connecting the wells to localised booster compressors and then to in-field compressor stations (~3 sites) and subsequently the compressor stations to the main plant area; and
- There will be a requirement to have short powerline and water connections to the compressor sites."

6.2 Stakeholder Comments

No comments pertinent to wetlands were provided for a response.

6.3 Review of Cluster 1 EIA and EMPr

Several impacts were identified for the aquatic ecology and wetland assessment completed by Imperata Consulting CC (2017), which were also considered for the Cluster 2 gas exploration project. The impacts and mitigation measures from Cluster 1 that are still relevant/adequate are represented and discussed in Table 6-1.

Table 6-1 Cluster 1 Environmental Impacts and EMPr

#	Activities	Impact/ Aspect	Management/ Mitigation Measures	Suggested Amendment
15	All	Loss of watercourse habitat	Locate pipeline/ trunkline alignments/ compressors outside of buffered watercourses (sensitive watercourse habitat) as far as possible. Buffered watercourses within proximity to the construction footprints should be demarcated on site for the entire construction process to help indicate sensitive areas and prevent unauthorised access. Unavoidable crossings should ideally be located perpendicular to the direction of flow at the shortest possible crossing distances. Long crossings along the length of wetlands, rivers and drainage lines should be avoided as far as practically possible. Aboveground pipeline watercourse crossings that are suspended on plinths are recommended as opposed to the excavation, lowering and infilling of pipelines in watercourses. Tetra4 should make provision in the design phase for permanent access tracks/ roads that will be required for the maintenance of the pipeline. A construction method statement should be prepared by the contractor with input from a watercourse specialist prior to the start of construction.	The method statement must be reviewed on an annual basis, and here necessary, updated.
20	All	Disruption of watercourse hydrology	Pipeline crossings through wetlands and other watercourses should ideally be raised aboveground on plinths to prevent preferential flow along their length. In areas where this is not possible, trench breakers with a low hydrological conductivity should be used to reduce water movement in bedding and padding material along the buried pipeline in wetlands and other watercourses. Long and/or steep approaches that border watercourses (specifically wetlands) should receive trench breakers that will help to restrict the desiccation impact on wetlands due to preferential drainage. It is recommended that input be obtained from a geotechnical specialist or geohydrologist regarding the use and positioning of trench breakers along buried sections of the pipeline. Other crossings through depression (pan) and flat wetland require trench-breakers or other forms of underground barriers/plugs to prevent preferential drainage along the pipeline/trunkline alignment.	The cumulative loss of wetlands must be determined in consultation with a wetland ecologist. Should it be established that a notable loss is associated with the project, a wetland offset strategy must be produced for the project. This may include onsite rehabilitation of affected systems to provide suitable compensation. This strategy should be completed in association with land users who have contributed to the deterioration of the wetlands, and that can also contribute to the effective implementation of the strategy.
21	Processing facilities	Decrease in surface water quality	Design and implement a site-specific stormwater management plan for the compressor and helium/LNG plant that will enable dispersed release of runoff at outlets, with outlets located outside (upslope) of buffered watercourses (where possible). ensure separation of clean and dirty water and provide for adequate dirty water containment. Ensure that sufficient ablution facilities are available on site and that septic tanks are located outside of buffered watercourses. Stabilise new channels that form because of headcut erosion or other forms of erosion once they are recorded.	Implement a surface water monitoring programme.

48	All	Disruption of aquatic communities	Ideally, no vehicle access tracks/roads should transect through watercourses. Access tracks/roads should be designed in such a way to minimise overlap with watercourses. Use existing access roads/tracks as far as possible. Construction and unavoidable access tracks/roads through wetlands, rivers and other watercourses must provide habitat connectivity between upstream and downstream reaches (e.g. flume pipes and/or culverts) and to reduce the risk of scour erosion and channel incision within the watercourse. No unauthorised driving should be allowed through watercourses. Driving can only occur on specially designed tracks/roads that minimised the risk of erosion and surface flow concentration. No perched flumes should be present in temporary construction running tracks and/or permanent access tracks. In the case of aboveground pipelines, the pipeline should not be located 'flush' along the surface profile of the watercourse with no gap between the natural ground level and the pipeline. Aboveground pipelines should rather be suspended on plinths of a sufficient height that will allow the free movement of indigenous fauna present within the study area, such as tortoises, as recorded in the Bosluisspruit channel near existing well SPG3.	
49	All	Watercourse erosion	Prevent the use of only one or two flume pipes in access/running tracks located in watercourses, specifically unchannelled valley bottom wetland and seep wetlands where concentrated flows can result in headcut development and the formation of a channel. Surface flows should also be spread out in channelled watercourse crossings though the use of several flume pipes to prevent channel incision and scour erosion. Access tracks should be maintained during the entire construction process and removed once construction is completed. Flume pipes should be monitored and kept free of blockages. Construction in watercourses should ideally occur during the dry season. Any new erosion features identified should be stabilised during the construction process (soft interventions such as hay bales, rock packs, runoff control berms and 'bio-socks' are recommended). Erosion control features should be maintained. Keep vegetation clearing to a minimum on the adjacent slopes to prevent erosion on approaches bordering watercourses. Small temporary contour berms may be used to help control runoff on approaches should it be required. Drainage furrows that may be required to create dry working conditions should ideally be avoided as they can easily erode during high flow events. Development of a watercourse monitoring plan before the onset of the construction phase, and the development and implementation of a watercourse rehabilitation plan during the latter half of the construction phase to ensure the eroded wetlands and other watercourses are stabilised and rehabilitated. Dewatering discharges at construction sites should be done in a silt bay to prevent erosion and sedimentation in adjacent watercourses. Runoff from the construction footprint should be controlled on site to prevent	Watercourses should be monitored on an annual basis for signs of erosion. Any signs of erosion must be addressed to be prevent the worsening of the headcut.

			concentrated point releases of water into downslope watercourses. Care needs to be taken not to initiate or aggravate erosion in watercourses.	
55	All	Increase sediment loads	Progressive rehabilitation of disturbed land should be carried out to minimize the amount of time that bare soils are exposed to the erosive effects of rain and subsequent runoff. Traffic and movement over stabilised areas should be controlled (minimised and kept to certain paths), and damage to stabilised areas should be repaired timeously and maintained. The total footprint area to be cleared for drilling should be kept to a minimum by demarcating the drilling areas and restricting removal of vegetation to these areas only.	
63	All	Pollution of wetland habitats	Control all waste sources emanating from proposed activities. Maintain minimum distances from aquatic and wetland habitats, where possible. Undertake activities in previously disturbed areas and/or habitats with lower sensitivity.	
64	All	Decrease in surface water quality in watercourses	Store all hazardous materials (Incl. hydrocarbons) in a bunded area, outside of buffered watercourses. Stripped and excavated subsoil and topsoil stockpiles should be stored outside of buffered wetland areas and be protected from erosion. This may not be possible for long wetland crossings in seep and other wetlands, in which case topsoil can be stored on low berms within the wetland on geotextile material. Topsoil and subsoil should however be protected from erosion. Approaches that border watercourses, particularly those along steep and long slopes, should receive runoff control measures to prevent siltation and concentrated flow into watercourses. Inspect vehicles for leaks and repair all leaks immediately. Any generators used in watercourses should be used with a functional drip tray. Ensure that sufficient ablution facilities are available on site and that they are located outside of buffered watercourses. Stabilise new channels that form as a result of headcut erosion or other forms of erosion once they are recorded. Sediment deposition should be prevented in watercourses and especially watercourse channels through the following measures: Implementing stormwater control measures around construction areas; and Dewatering during excavation activities in watercourses should be released in a silt bay with sufficient capacity that filters and retains sediment before the water is released into the watercourses. Sediment deposition events into watercourses should be evaluated by an experienced ECO/ wetland specialist and based on the magnitude of the impact recommendations can be made regarding the removal of deposited material.	
75	All	Watercourse erosion	Use existing access roads as far as possible. Unavoidable new permanent access roads/tracks in watercourses should be designed to prevent erosion downstream of the crossings by using several flume pipes, preferably culverts, or other structures, such as concrete fords. All temporary and permanent vehicle access tracks/roads in watercourses will require	

			approval from DWS in the form of a Water Use License. New permanent access roads/tracks should be located along existing infrastructure footprints as far as possible and at areas that will enable the shortage crossing distance through watercourses. Long crossings along the length of watercourses (parallel to its flow direction) should be avoided. Remnant erosion features that remain after the rehabilitation phase should be addressed until full rehabilitation and closure is achieved. Rehabilitation interventions should be considered with care and not worsen erosion once implemented [Amendment 2019/05]. Identified permanent access tracks should be maintained during the entire operational phase of the project and blockages should be removed, while erosion features should be repaired once observed. Concrete fords (low water bridges) are preferred as crossing structures in larger watercourse channels, compared to culverts and flume pipes, which are more likely to result in erosion and require more regular maintenance. The Helium plant should receive stormwater mitigation measures at its outlets that will prevent concentrated flow. Stormwater mitigation measures and flow outlets should be located outside of buffered watercourses.	
108	All	Encroachment/ invasion of alien plants (specifically into watercourses)	Restrict the clearing of watercourse vegetation as far as possible. Areas that have been cleared should be re-vegetated with indigenous species or other suitable plant species, such as *Eragrostis tef*, after construction and initial rehabilitation work (reinstatement of the geomorphological template) is completed. Compile and implement an alien plant control program with a particular focus on alien control in watercourses (including wetlands) during the rehabilitation phase of the project. Rehabilitate disturbed areas as soon as possible. Restrict new footprints to disturbed areas as far as possible. Regular monitoring should be undertaken in the watercourses to check any possible invasion by alien vegetation so that they can be weeded out before they grow and spread out.	

6.4 Wetland Impact Assessment

The development of the project will result in the loss of watercourse habitats where infrastructure traverses or is placed. The clearing topsoil and vegetation will be required for the installation and placement of infrastructure. The development across and/or within watercourses can also cause a disruption to the biotic community structure due to the fragmentation and deterioration of habitat. Thus, the loss, fragmentation and/or deterioration of wetland habitat will reduce the level of ecosystem service benefit provide by the affected systems. The development of the area in proximity of the watercourses would also create erosion hotspots which could contribute to the sedimentation of any receiving watercourses. Infrastructure in proximity to watercourses and located on a suitable slope could create preferential flow paths, causing increased surface run-off volumes and velocities causing erosion to the area. Sunken pipelines could also impede interflow, resulting in a decrease in water reporting to the downslope watercourse. Sedimentation of the watercourses will impede the ability of the system to provided beneficial ecosystem services which might include water quality improvement, habitat maintenance but also water availability. Water quality could also be impacted by spills and leaks from machinery, equipment and vehicles operating in proximity to wetlands. Any contaminants entering the system/s could contribute to the deterioration in water quality. Poor water quality will have a resulting impact on biota and vegetation dependent on the affected system as a water source.

The additional impacts associated with the proposed activities, which weren't considered covered in the existing approved Cluster 1 EIA and EMPr, are considered in this section. No 'new' impacts are expected for the Cluster 2 gas exploration project, except for the powerlines. Two powerlines have been considered for this assessment, specifically the 33kV (Figure 6-1) and 132kV (Figure 6-2) routes. The two powerlines both traverse channelled valley bottom (CVB) wetlands and are also adjacent to seepage (SEEP) systems. Similar impacts are expected for both powerlines.

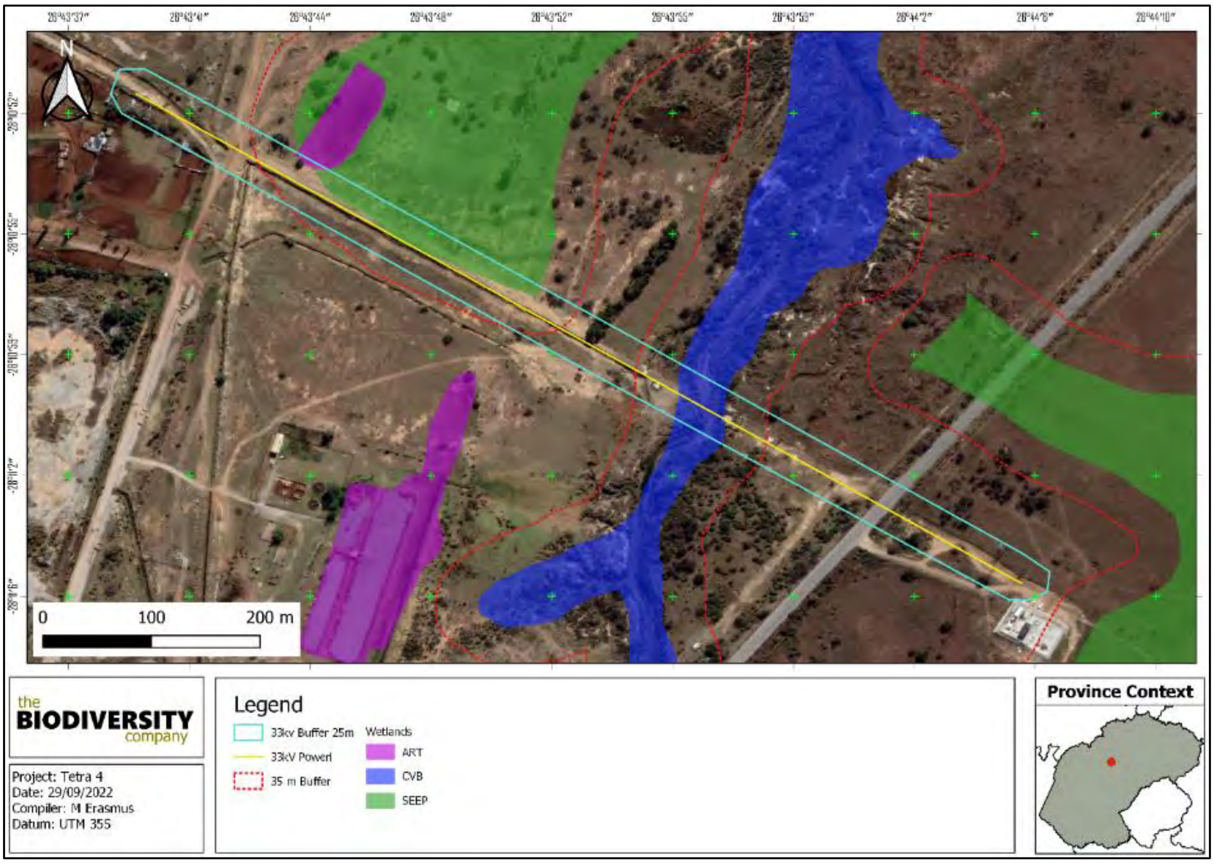

Figure 6-1 The location of the powerline in relation to the delineated water resources

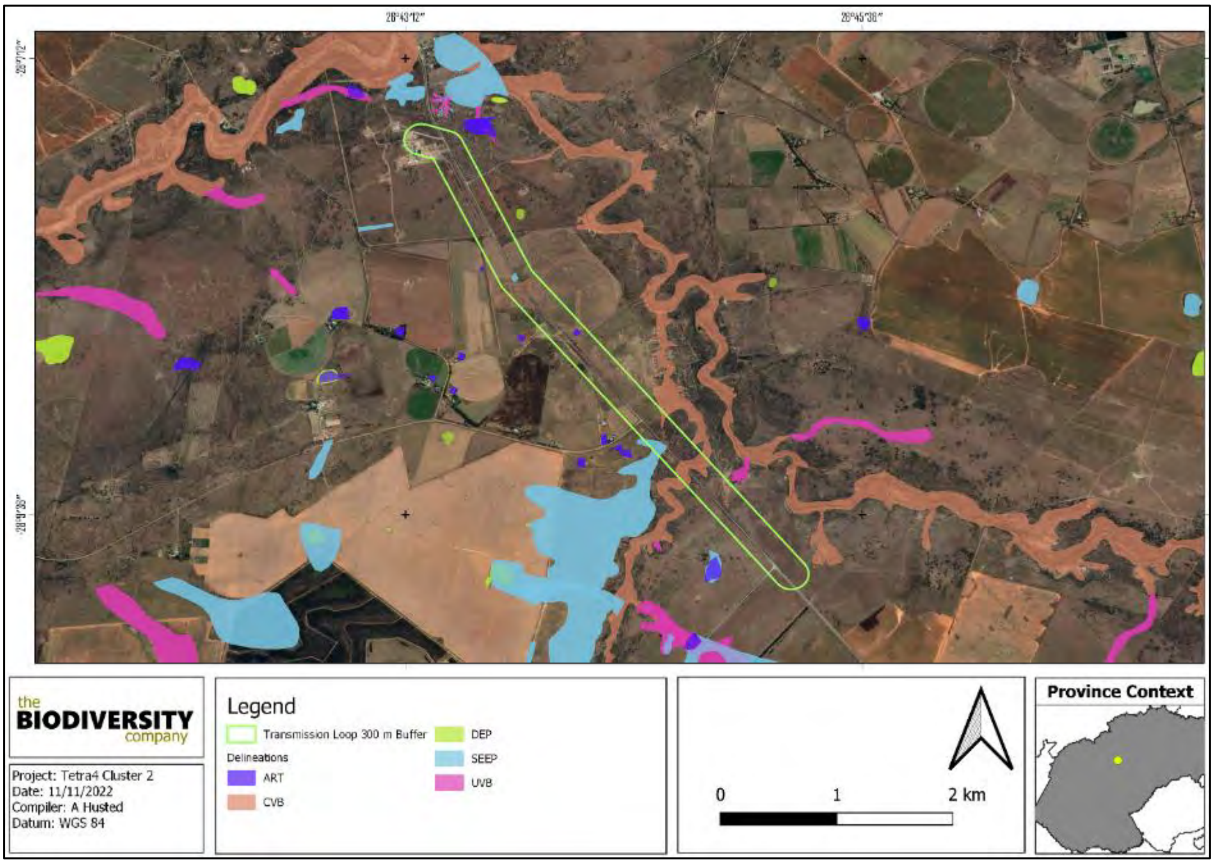

Figure 6-2 The location of the powerline in relation to the delineated water resources

Table 6-2 Impact assessment for the proposed 33kV and 132kV powerline

Impact	Phase	Pre-mitigation ER	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Final score
Powerlines - Habitat	Construction	-5.5	-3	High	1	1	-3
Powerlines - Water Quality	Construction	-2	-1.25	High	1	1	-1
Powerlines - Flow	Construction	-2.5	-1.25	High	1	1	-1
Powerlines - Habitat	Operation	-5	-3.5	High	1	1	-4
Powerlines - Water Quality	Operation	-1	-1	High	1	1	-1
Powerlines - Flow	Operation	-1	-1.25	High	1	1	-1
Powerlines - Habitat	Decommissioning	-5	-3	High	1	1	-3
Powerlines - Water Quality	Decommissioning	-2	-1.25	High	1	1	-1
Powerlines - Flow	Decommissioning	-2.5	-1.25	High	1	1	-1

6.4.1 Mitigation Measures

The following mitigation measures are applicable for the powerline:

- Keep the number of towers in the wetland to a feasible minimum. The placement of towers in the assigned buffer (of 35 m) is preferred to minimise the number of towers placed within the wetland;

- Construction activities should be scheduled for the least sensitive periods, in order to avoid the migration, nesting and breeding seasons of SCC as far as practical;
- Locate powerline alignment outside of buffered watercourses (sensitive watercourse habitat) as far as possible;
- Buffered watercourses should be demarcated on site for the entire construction process to help indicate sensitive areas and prevent unauthorised access;
- The route should be located along existing infrastructure features, such as roads, dam walls and existing pipelines. Unavoidable crossings should ideally be located perpendicular to the direction of flow at the shortest possible crossing distances;
- The servitude width should be restricted in watercourse crossings to reduce the footprint of the impact;
- A construction method statement should be prepared by the contractor with input from a watercourse specialists prior to the start of construction. Conditions stated in the water use license should also be implemented; and
- Make provision in the design phase for permanent access tracks/roads that will be required for the maintenance of the powerline.

6.5 Recommendations

The following recommendations are provided for the project:

- No mitigation measures have been prescribed for the decommissioning phase of the project. It is recommended that the closure plan and objective be reviewed, and appropriate measures be included for the local water resources;
- Implement the “Working in Sensitive Areas” (document number T4-PP-SHERQ-051) detailed in the operating procedures document;
- Implement the “Erosion Control and Storm Water Management” (document number T4-PP-SHERQ-043) detailed in the operating procedures document;
- Once the pipeline has been installed, the disturbed area must be cleaned up in accordance with the Environmental Management Plan, and in accordance to the Tetra4 Rehabilitation Plan and Procedure; and
- All activities related to these works shall comply with all applicable Environmental Laws, Tetra4’s approved Environmental Management Programme (EMPR) and Tetra4’s Environmental Procedures when undertaking any works.

6.6 Monitoring Plan

The following monitoring programme is recommended.

Table 6-3 The recommended monitoring programme

Location	Monitoring objectives	Frequency of monitoring	Parameters to be monitored
The wetlands area (Area of Interest), prioritising wetlands within 50 m of land disturbance	Wetland Present Ecological State, Functioning & Ecological	Bi-annual for 2-years as a minimum, thereafter to be determined by the wetland specialist in agreement	Wetland WET-Series

	Importance & Sensitivity	with the relevant Department.	
	Determine if habitat quality deterioration is occurring.		Monitor for presence erosion, alien vegetation, wetland rehabilitation succession, and sedimentation
	Determine if water quality deterioration is occurring.	To be determined by the surface water monitoring programme	-

7 Conclusion

Natural wetlands classified as being channelled valley bottoms, depressions, hillslope seeps and unchannelled valley bottom as well as artificial systems were identified within the study area. The Present Ecological State (PES) of the wetlands ranges from “Seriously Modified” to ‘Moderately Modified”. The majority of modifications to wetlands in the study area is from agricultural activities taking place in the wetland and their respective catchments.

The Ecosystem Services of the wetlands range from “Moderately High” to “Moderately Low” for the study area. The valley bottom scored overall higher ecosystem services scores due to their ability to regulate streamflow, prevent flooding and helps with erosion control. The vegetation cover within the wetlands plays a major role in the ecosystem services scores. All the wetlands delineated within the study area were rate to be “Moderately” sensitive due to the relatively high protection status of the wet veg type and the low protection status of the wetland itself.

The buffer zone calculated for the delineated wetlands is 35 m. This buffer zone will ensure the conservation of the delineated wetlands from the proposed activities.

The impact assessment considered both direct and indirect impacts, to the water resources. It is evident that the pipeline and the transmission loop will encroach into the delineated wetland areas. The buffers around the wells and compressors also encroach into the wetland buffers but impacts can be avoided with the mitigation provided.

Although all of the risks were considered low (post-mitigation). No moderate post-mitigation risks are anticipated to occur for the proposed project. Overall, the impacts associated with this service development are unlikely to negatively impact water resources to any appreciable level provided that the suggested mitigations measures are effectively implemented. Additionally, the project focusses on conveying gas, thus risks associated with leaks are considered low.

7.1 Specialist Recommendation

It is the specialist’s opinion that no fatal flaws have been identified, and that the proposed activities may proceed as have been planned. Given the fact that “Low” post-mitigation significance ratings were determined for various aspects of the proposed project, it’s the specialist’s opinion that a General Authorisation could be applied for.

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