REPORT

Central Térmica de Temane Project - Air Quality Impact Assessment Report

Moz Power Invest, S.A. and Sasol New Energy Holdings (Pty) Ltd.

Submitted to:

Ministry of Land, Environment and Rural Development (MITADER)

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Executive Summary

Moz Power Invest, S.A. (MPI), a company to be incorporated under the laws of Mozambique and Sasol New Energy Holdings (Pty) Ltd (SNE) in a joint development agreement is proposing the construction and operation of a gas to power facility, known as the Central Térmica de Temane (CTT) project. MPI's shareholding will be comprised of Electricidade de Mozambique E.P. (EDM) and Temane Energy Consortium (Pty) Ltd (TEC). The CTT project will use natural gas as feedstock and electrical power produced by the facility will be sold to EDM, which will then distribute the power to the electricity grid. The CTT plant with generation capacity of 450MW will include a facility with a power generation block, an outside battery limit and the plant infrastructure. The final selection of technology that will form part of the power generation block of the CTT project has not been determined at this stage. The two power technology options that are currently being evaluated are, closed cycle gas turbines (CCGT) or open cycle gas engines and generator sets (OCGE).

The preferred site for CTT project is located approximately 500 m south of the Sasol Central Processing Facility (CPF). The site is located approximately 40 km northwest of the town of Vilanculos and 30km southwest of the town of Inhassoro. The Govuro River lies 8 km east of the proposed CTT site.

Scope of study

The scope of this Air Quality Impact Assessment (AQIA) includes an assessment of the impact of the project on air quality in communities around the CTT site resulting from the proposed construction and operation of a gas to power plant, specifically:

- Baseline:
  - Verify consistency of Sasol CPF weather database;
  - Develop emissions inventory;
  - Map population density within 5 km of the plant; and
  - Assemble baseline air quality data (existing data collected over the past 8 years around the CPF and additional field measurements of selected criteria pollutants measured by CPF – Fine particulate matter (PM_{10}), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon monoxide (CO), Hydrogen Sulphide (H_2S) and Volatile Organic Carbons (VOC's).
- Impact Assessment:
  - Model dispersion of pollutants using the United States Environmental Protection Agency (US EPA) approved AERMOD software;
  - Assess impacts by comparing results with Mozambique and other relevant standards and guidelines, set out in the CPF oEMP as well as IFC / WHO guidelines;
  - Include assessment of Cumulative impacts such as adjacent CPF, EDM power plant and any other point sources in the study area as applicable; and
  - Recommend any necessary mitigation measures.

Conclusions – Gas Engines

The following was concluded for the gas engine option based on the configurations described in Section 7.0:

- Construction phase impacts for the gas engine were predicted to be of low significance;

- Operational phase impacts are anticipated to be of low significance for PM_{10} and SO_2, but moderate for NO_2; and
- Decommissioning phase impacts are anticipated to be of low significance.

Conclusions – Gas Turbines

The following was concluded for the gas turbine option based on the configurations described in Section 7.0:

- Construction phase impacts are anticipated to be of low significance;
- Operational phase impacts are anticipated to be of low significance; and
- Decommissioning phase impacts are anticipated to be of low significance.

Cumulative impacts

To assess the cumulative impacts of the proposed project, the process contributions of the proposed activities should be superimposed on the ambient baseline concentrations to determine if these contributions will result in a significant degeneration of the ambient air quality.

Considering that the current air quality in the project area is not degraded[1] as defined by the IFC / WHO, the cumulative impact of the process contributions from the gas engines through all three project phases is unlikely to lead to a significant degeneration of the ambient air quality. Similarly, the cumulative impact of the process contributions from the gas turbines through all three project phases is unlikely to lead to a significant degeneration of the ambient air quality.

Specialist recommendation

The two technologies can be configured to have similar impacts. Total potential pollutant emissions from the gas engines are higher than for those for gas turbines for the same power output, therefore gas turbines are recommended.

[1] An airshed should be considered as having poor air quality if nationally legislated air quality standards or WHO Air Quality Guidelines are exceeded significantly (IFC, 2007).

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ACRONYMS

Chemical Formulae	
As	Arsenic
BTEX	Benzene, Ethylbenzene, Toluene & Xylene
C_4H_8O	Methyl Ethyl Ketone
C_6H_6	Benzene
C_7H_8	Toluene
C_8H_{10}	Ethylbenzene
C_8H_{10}	Xylene
CaO	Calcium Oxide / Lime
CaOH	Calcium Hydroxide
Cd	Cadmium
CH_2Cl_2	Dichloromethane
CH_3-S-CH_3	Dimethyl Sulphide
CH_3S-H	Methyl Mercaptan
CH_3-S-S-CH_3	Dimethyl Disulphide
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
Cu	Copper
H_2SO_3	Sulphurous Acid
H_2SO_4	Sulphuric Acid
Na_2CO_3	Sodium Bicarbonate
NaOH	Sodium Hydroxide / Caustic Soda / Soda Ash
Ni	Nickel
NO	Nitrogen Oxide
NO_2	Nitrogen Dioxide
NO_X	Nitrogen Oxides
PAH	Polycyclic Aromatic Compounds
Pb	Lead
PM_{10}	Particulates with an aerodynamic diameter of less than 10 µm
$PM_{2.5}$	Particulates with an aerodynamic diameter of less than 2.5 µm
SiO_2	Silicon Dioxide
SO_2	Sulphur Dioxide
TRS	Total Reduced Sulphur
TSP	Total Suspended Particulates
VOC	Volatile Organic Compounds
Countries	
EU	European Union
RSA	Republic of South Africa
UK	United Kingdom
US	United States
Direction	
N	North

NNE	North-North-East
NE	North-East
ENE	East-North-East
E	East
ESE	East-South-East
SE	South-East
SSE	South-South-East
S	South
SSW	South-South-West
SW	South-West
WSW	West-South-West
W	West
WNW	West-North-West
NW	North West
NNW	North-North-West
Environmental management	
AQIA	Air Quality Impact Assessment
AQMP	Air Quality Management Plan
AQMPr	Air Quality Management Programme
CS	Concept Study
DMP	Dust Management Plan
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
PFS	Prefeasibility Study
S&SD	Safety and Sustainable Development
S&EIA	Social and Environmental Impact Assessment
Equipment	
PiD	Photo Ionisation Detector
Health	
COHb	Carboxyhaemoglobin
LOAEL	Lowest Observed Adverse Effect Level
NOAEL	No Observed Adverse Effect Level
MSDS	Material safety data sheets
Measurement	
amsl	Above mean sea level
asl	Above sea level
BDL	Below detection limit
°	Degrees
°C	Degrees Celsius
g/s	Grams per second
K	Kelvin
km	Kilometre
km/h	Kilometre per hour

m	Metres
m/s	Metres per second
µg	Microgram
µg/m^3	Micrograms per cubic meter
mg	Milligrams
mg/m^3	Milligrams per cubic meter
mg/m^2/day	Milligrams per meter squared per day
ppb	Parts per billion
tpa	Tons per annum
t/day	Tons per day
t/hr	Tons per hour
Organisations	
EA-NPI	Environment Australia - National Pollutant Inventory
EC	European Commission
IFC	International Finance Corporation
SANAS	South African National Accreditation System
UE-EA	United Kingdom - Environmental Agency
UK-EA	European Union - Environmental Agency
US-EPA	United States - Environmental Protection Agency
WHO	World Health Organisation

1.0 INTRODUCTION

The Mozambican economy is one of the fastest growing economies on the African continent with electricity demand increasing by approximately 6-8% annually. In order to address the growing electricity demand faced by Mozambique and to improve power quality, grid stability and flexibility in the system, Moz Power Invest, S.A. (MPI), a company to be incorporated under the laws of Mozambique and Sasol New Energy Holdings (Pty) Ltd (SNE) in a joint development agreement is proposing the construction and operation of a gas to power facility, known as the Central Térmica de Temane (CTT) project. MPI's shareholding will be comprised of EDM and Temane Energy Consortium (Pty) Ltd (TEC). The joint development partners of MPI and SNE will hereafter be referred to as the Proponent. The Proponent propose to develop the CTT, a 450MW natural gas fired power plant.

The proposed CTT project will draw gas from the Sasol Exploration and Production International (SEPI) gas well field via the phase 1 development of the PSA License area, covering gas deposits in the Temane and Pande well fields in the Inhassoro District and the existing Central Processing Facility (CPF). Consequently, the CTT site is in close proximity to the CPF. The preferred location for the CTT is approximately 500 m south of the CPF. The CPF, and the proposed site of the CTT project, is located in the Temane/Mangugumete area, Inhassoro District, Inhambane Province, Mozambique; and approximately 40 km northwest of the town of Vilanculos. The Govuro River lies 8 km east of the proposed CTT site. The estimated footprint of the CTT power plant is approximately 20 ha (see Figure 1).

Associated infrastructure and facilities for the CTT project will include:

1) Electricity transmission line (400 kV) and servitude; from the proposed power plant to the proposed Vilanculos substation over a total length of 25 km running generally south to a future Vilanculos substation. [Note: the development of the substation falls outside the battery limits of the project scope as it is part of independent infrastructure authorised separately (although separately authorised, the transmission line will be covered by the Project ESMP, and the Vilanculos substation is covered under the Temane Transmission Project (TTP) Environmental and Social Management Plans). Environmental authorisation for this substation was obtained under the STE/CESUL project. (MICOA Ref: 75/MICOA/12 of 22nd May 2012)];

2) Piped water from one or more borehole(s) located either on site at the power plant or from a borehole located on the eastern bank of the Govuro River (this option will require a water pipeline approximately 11km in length);

3) Access road; over a total length of 3 km, which will follow the proposed water pipeline to the northeast of the CTT to connect to the existing Temane CPF access road;

4) Gas pipeline and servitude; over a total length of 2 km, which will start from the CPF high pressure compressor and run south on the western side of the CPF to connect to the power plant;

5) Additional nominal widening of the servitude for vehicle turning points at points to be identified along these linear servitudes;

6) A construction camp and contractor laydown areas will be established adjacent to the CTT power plant footprint; and

7) Transhipment and barging of equipment to a temporary beach landing site and associated logistics camp and laydown area for the purposes of safe handling and delivery of large oversized and heavy equipment and infrastructure to build the CTT. The transhipment consists of a vessel anchoring for only approximately 1-2 days with periods of up to 3-4 months between shipments over a maximum 15 month period early in the construction phase, in order to offload heavy materials to a barge for beach landing. There are 3 beach landing site options, namely SETA, Maritima and Briza Mar (Figura 7). The SETA site is considered to be

the preferred beach landing site it therefore shall be selected unless it is found to be not feasible for any reason;

8) Temporary bridges and access roads or upgrading and reinforcement of existing bridges and roads across sections of the Govuro River where existing bridges are not able to bear the weight of the equipment loads that need to be transported from the beach landing site to the CTT site. Some new sections of road may need to be developed where existing roads are inaccessible or inadequate to allow for the safe transport of equipment to the CTT site. The northern transport route via R241 and EN1 is considered as the preferred transport route (Figura 8) on terrestrial impacts; however, until the final anchor point is selected, and the barge route confirmed, the marine factors may still have an impact on which is deemed the overall preferable route.

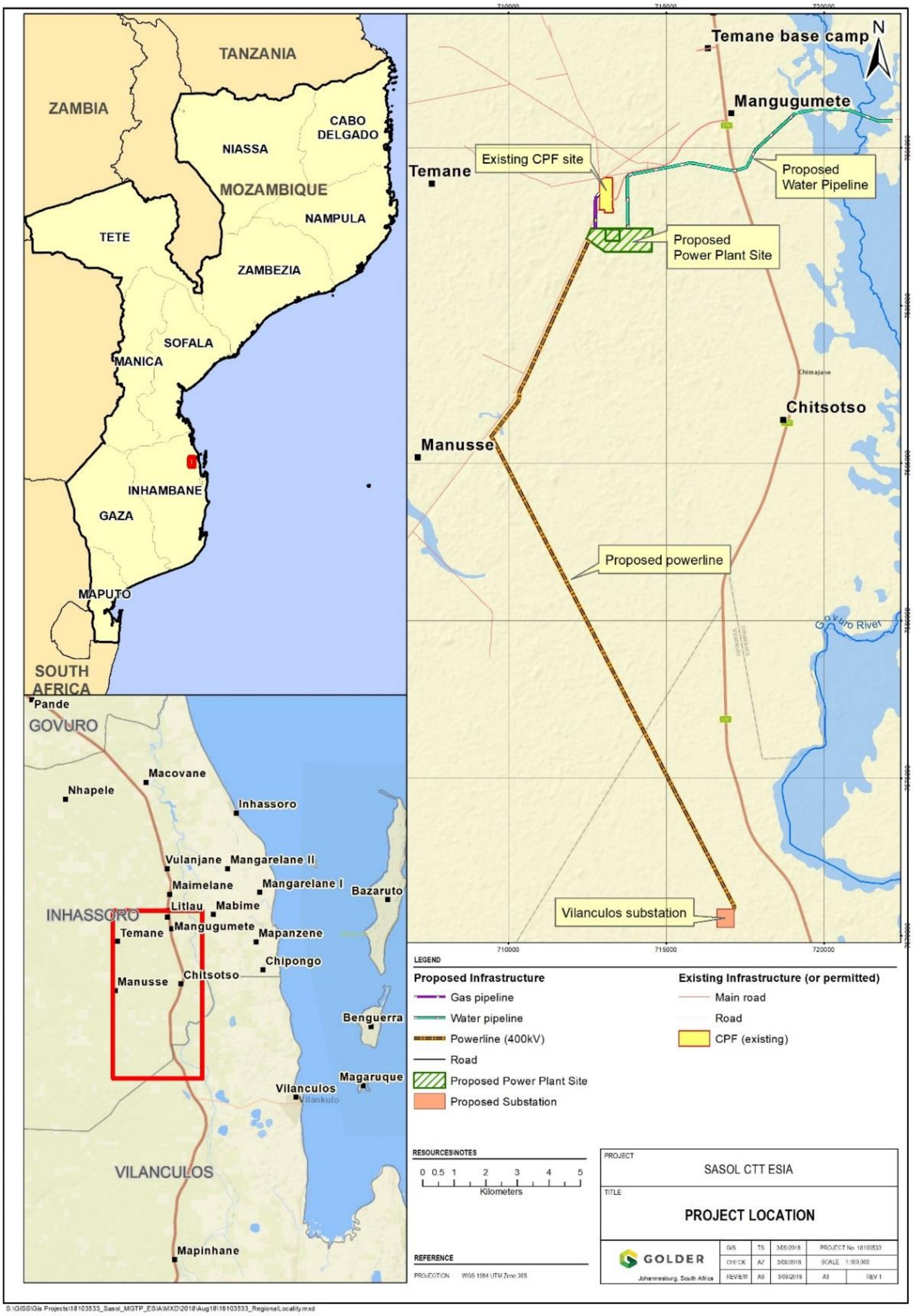

Figure 1: Project Location

Figure 2: The three beach landing site options and route options at Inhassoro

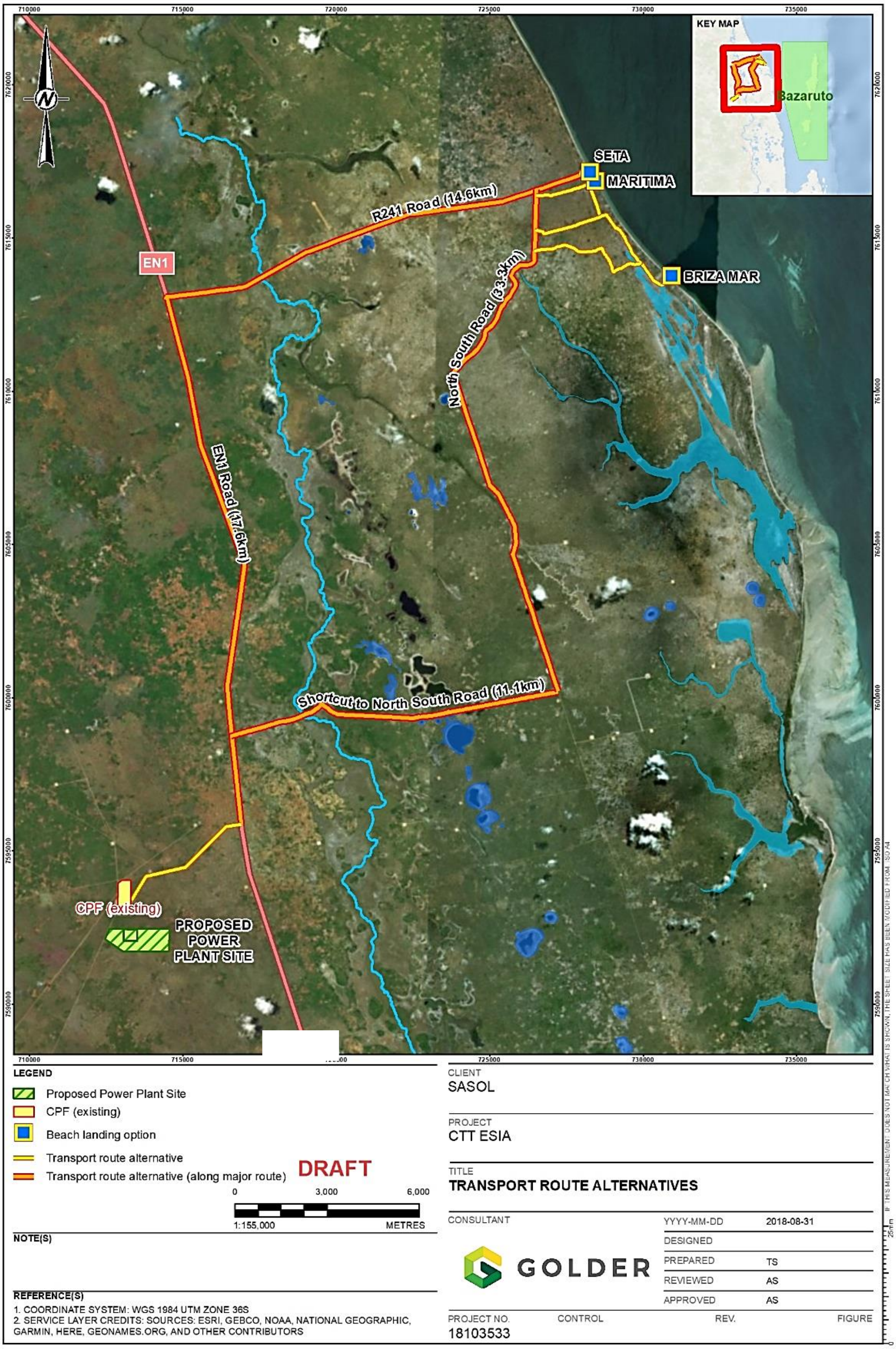

Figure 3: The two main transportation route alternatives from the beach landing sites to the CTT site

2.0 DESCRIPTION OF THE KEY PROJECT COMPONENTS

The CTT project will produce electricity from natural gas in a power plant located 500 m south of the CPF. The project will consist of the construction and operation of the following main components:

- Gas to Power Plant with generation capacity of 450 MW;
- Gas pipeline (±2 km) that will feed the Power Plant with natural gas from the CPF;
- 400kV Electrical transmission line (± 25 km) with a servitude that will include a fire break (vegetation control) and a maintenance road to the Vilanculos substation. The transmission line will have a partial protection zone (PPZ) of 100 m width. The transmission line servitude will fall inside the PPZ;
- Water supply pipeline from one or more borehole(s) located either on site or at boreholes located east of the Govuro River;
- Surfaced access road to the CTT site and gravel maintenance roads within the transmission line and pipeline servitudes;
- Temporary beach landing structures at Inhassoro for the purposes of delivery of equipment and infrastructure to build the power plant. This will include transhipment and barging activities to bring equipment to the beach landing site for approximately 1-2 days with up to 3-4 months between shipments over a period of approximately 8-15 months;
- Construction camp and contractor laydown areas adjacent to the CTT power plant site; and
- Temporary bridge structures across Govuro River and tributaries, as well possible new roads and/or road upgrades to allow equipment to be safely transported to site during construction.

The final selection of technology that will form part of the power generation component of the CTT project has not been determined at this stage. The two power generation technology options that are currently being evaluated are:

- Combined Cycle Gas Turbine (CCGT); and
- Open Cycle Gas Engines (OCGE).

Please refer to Chapter 4 of the main ESIA document for further details on the technology option.

At this early stage in the project a provisional layout of infrastructure footprints, including the proposed linear alignments is indicated in Figure 1. A conceptual layout of the CTT plant site is shown below in Figure 4. Figure 5 provides two typical examples of gas to power plants.

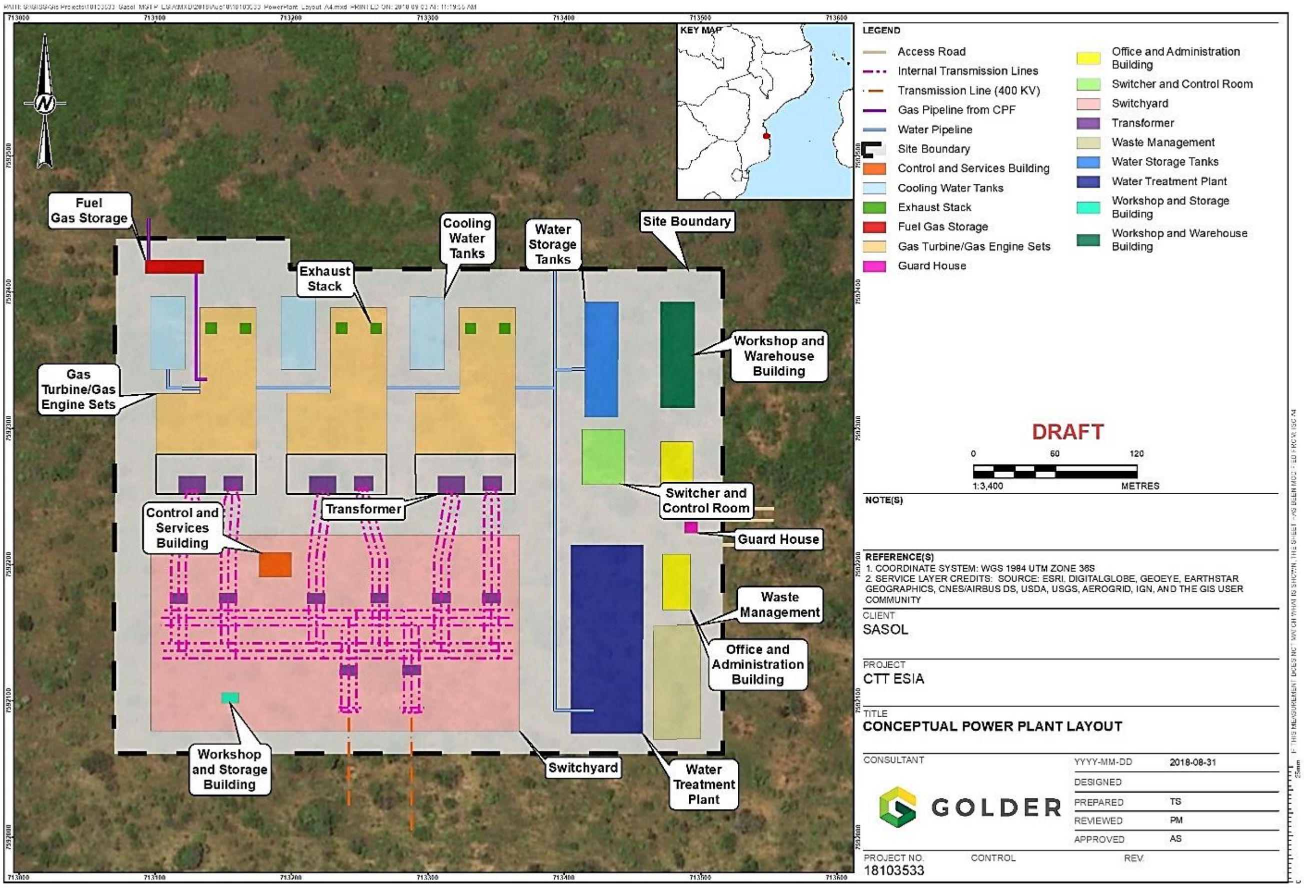

Figure 4: Conceptual layout of CTT plant site

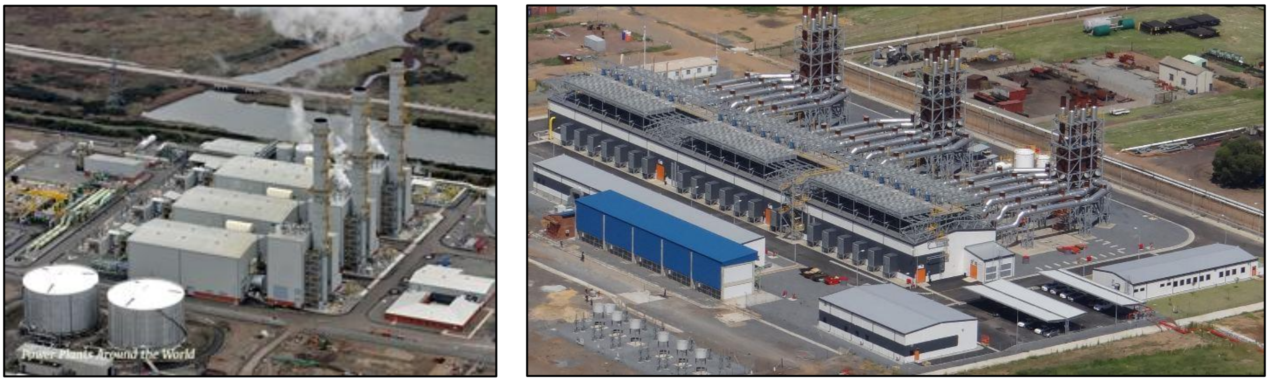

Figure 5: Examples of gas to power plant sites (source: www.industcards.com and www.wartsila.com)

2.1 Ancillary Infrastructure

The CTT project will also include the following infrastructure:

- Maintenance facilities, admin building and other buildings;
- Telecommunications and security;
- Waste (solid and effluent) treatment and/or handling and disposal by third party;
- Site preparation, civil works and infrastructure development for the complete plant;
- Construction camp (including housing/accommodation for construction workers); and

- Beach landing laydown area and logistics camp.

The heavy equipment and pre-fabricated components of the power plant will be brought in by ship and transferred by barge and landed on the beach near Inhassoro. The equipment and components will be brought to site by special heavy vehicles capable of handling abnormally heavy and large dimension loads. Figure 6, Figure 7 and Figure 8 show examples of the activities involved with a temporary beach landing site, offloading and transporting of large heavy equipment by road to site.

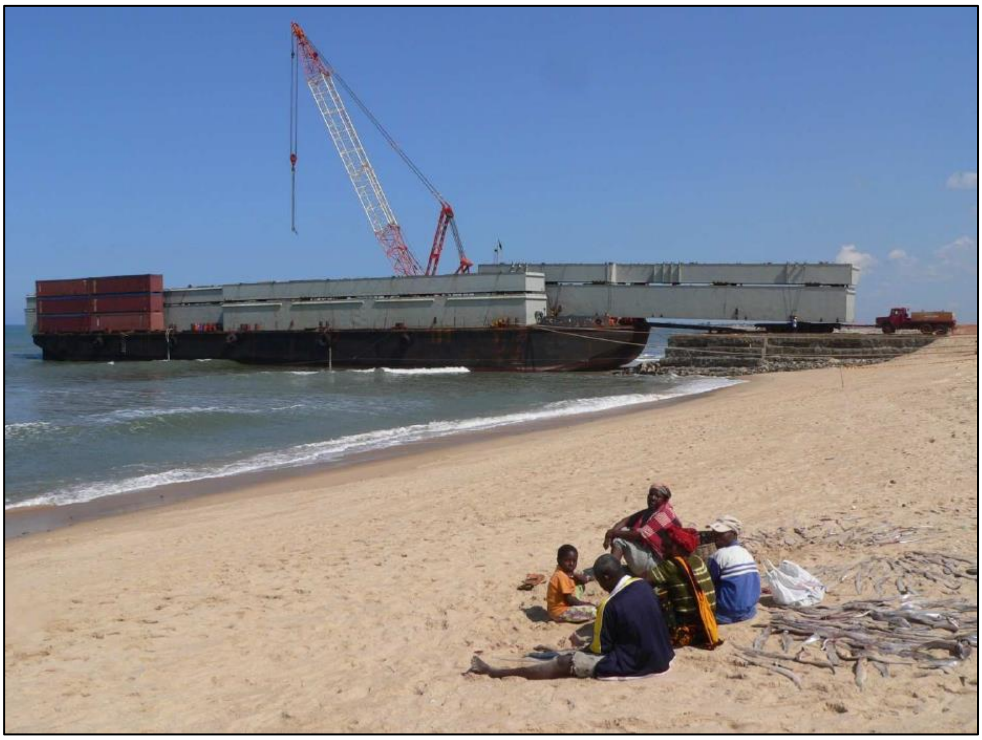

Figure 6: Typical beach landing site with barge offloading heavy equipment (source: Comarco)

Figure 7: Example of large equipment being offloaded from a barge. Note the levels of the ramp, the barge and the jetty (source: SUBTECH)

Figure 8: Heavy haulage truck with 16-axle hydraulic trailer transporting a 360 ton generator (source: ALE)

2.2 Water and electricity consumption

The type, origin and quantity of water and energy consumption are still to be determined based on the selected technology to construct and operate the CTT plant. At this stage it is known that water will be sourced from existing boreholes located on site or east of the Govuro River for either of the technology options below:

- Gas Engine: ± 12 m^3/day; or
- Gas Turbine (Dry-Cooling): ± 120 – 240 m^3/day.

2.3 Temporary Beach Landing Site and Transportation Route Alternative

As part of the CTT construction phase it was considered that large heavy equipment and materials would need to be brought in by a ship which would remain anchored at sea off the coast of Inhassoro. Equipment and materials would be transferred to a barge capable of moving on the high tide into very shallow water adjacent to the beach to discharge its cargo onto a temporary off-loading jetty (typically containers filled with sand) near the town of Inhassoro. As the tide changes, the barge rests on the beach and off-loading of the equipment commences.

Currently, the SETA beach landing site is the preferred beach landing site together with the road route option to be used in transporting equipment and materials along the R241 then the EN1 then via the existing CPF access road to the CTT site near the CPF. Figure 2 and Figure 3 indicate the beach landing site and route transportation option. The alternative beach landing sites of Maritima and Briza Mar are still being evaluated as potential options, as well as the southern transport route, which would also require road upgrades and a temporary bridge construction across the Govuro at the position of the existing pipe bridge. As part of the transportation route, the Govuro River bridge may need to be upgraded / strengthened to accommodate the abnormal vehicle loads. Alternatively, a temporary bypass bridge will be constructed adjacent to the existing bridge.

3.0 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

The proposed project has been determined as 'Category A' in terms of Mozambique's environmental law (Decree 54/2015 of 31 December, which has been in force since April 2016). For 'Category A' projects, an Environmental and Social Impact Assessment (ESIA) must be prepared by independent consultants as a basis for whether or not environmental authorisation of the project is to be granted, and if so, under what conditions. The final decision maker is the Ministry of Land, Environment and Rural Development (Ministério da Terra, Ambiente e Desenvolvimento Rural (MITADER) through the National Directorate of Environmental Impact Assessment (DNAIA). MITADER consults with other relevant government departments prior to deciding.

This document represents the Air Quality Impact Assessment undertaken to support the ESIA. This study is undertaken in terms of Mozambican legislation and policies as well as the World Bank Group operational policies and general environmental health and safety guidelines. In particular, the World Bank Performance Standards (OP 4.03), has been considered and incorporated throughout this assessment:

- International Finance Corporation (IFC) Environmental, Health, and Safety Guidelines, General EHS Guidelines: Environmental Air Emissions and Ambient Air Quality (IFC, 2007);
- IFC Environmental, Health, and Safety Guidelines for Onshore Oil and Gas Development (IFC, 2007);
- IFC Environmental, Health, and Safety Guidelines for Thermal Power Plants (IFC, 2008);
- IFC Performance Standards on Environmental and Social Sustainability (IFC, 2012); and
- World Health Organisation (WHO) Air Quality Guidelines for Particulate Matter, Ozone, Nitrogen Dioxide and Sulphur Dioxide (WHO, 2005).

3.1 Applicable Air Quality Standards, Legislation, and Guidelines

Mozambique air quality standards are framed within the Regulations on the Emission of Effluents and Environmental Quality Standards (Decree no. 18/2004 dated June 2) and Decree no. 67/2010, dated December 31 (amendments to Appendix I and inclusion of Appendices 1A and 1B to Decree 18/2004).

As per the International Finance Corporation (IFC) requirements and stated on the IFC Environmental Health and Safety (EHS) Guideline website:

*"When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment"***[1]**.

Therefore, when two or more emission and effluent limit or environmental standards have been identified for the same activity or environmental component, the most restrictive of these values should be adopted. This approach has been adopted for this assessment. The following project applicable standards are indicated in Table 1.

[1] http://www1.ifc.org/wps/wcm/connect/Topics_Ext_Content/IFC_External_Corporate_Site/IFC+Sustainability/Risk+Management/Sustainability+Framework/Sustainability+Framework+-+2006/Environmental,+Health,+and+Safety+Guidelines/

Table 1 : Ambient Air Quality Standards (µg/m³)

Pollutant	Averaging period	Project applicable standards	Mozambican Regulation[a]	IFC Guideline	World Health Organisation[b][c]			
					Guideline	Interim Target 1	Interim Target 2	Interim Target 3
CO	8 hours	10,000	10,000	10,000	-	-	-	-
	1 hour	40,000	40,000	30.000	-	-	-	-
	30 minutes	60,000	60,000	-	-	-	-	-
	15 minutes	100,000	100,000	-	-	-	-	-
Lead	Annual	0.5 – 1.5	0.5 – 1.5	-	-	-	-	-
	1 hour	3	3	-	-	-	-	-
O_3	Annual	70	70	-	-	-	-	-
	24 hours	50	50	-	-	-	-	-
	8 hours	120	120	-	-	-	-	-
	1 hour	160	160	-	-	-	-	-
TSP	Annual	60	60	80				
	24 hours	150	150	230	-	-	-	-
PM_{10}	Annual	20	-	50	20	70	50	30
	Maximum 24 hour	50	-	150	50	150	100	75
$PM_{2.5}$	Annual	10	-	-	10	35	25	15
	Maximum 24 hour	25	-	-	25	75	50	37.5
NO_2	Annual	10	10	100	40	-	-	-
	Maximum 24 hour	200	200	150	-	-	-	-
	Maximum 1 hour	190	190	-	200	-	-	-
SO_2	Annual	80	80	80	-	-	-	-
	Maximum 24 hour	20	365	150	20	125	50	-
	Maximum 1 hour	800	800	-	-	-	-	-
	10 minutes	500	500	500	-	-	-	-

a) *Regulation on Environmental Quality and Effluent Emissions Standards Decree 18/2004 – Appendix I Air Quality Standards*

b) *WHO Global Update (2005)*

c) *IFC EHS Air Emissions and Ambient Air Quality refer to the WHO guidelines*

Dust fallout is one of the main causes of complaint regarding air pollution from construction and operational sites. Coarse dust with an aerodynamic diameter of less than 10 µm generally poses little risk to human and ecological health, but is regarded as a nuisance due to its soiling nature. No local Mozambique and/or internationally recognised standard currently exists for fallout dust or dust deposition. To address this gap, the Project is required to adopt a suitable set of international dust fallout guidelines.

Considering that the Project site is located in Southern Africa, and that Mozambique and South Africa are both developing African countries, it is recommended that the project adopts the National Environmental Management: Air Quality Act (Act No. 39 of 2004): National dust control regulations (GN R.827 1 November 2013) prescribe the allowable dust fallout levels, which are not to be exceeded during a specified time period in a defined area (Table 2). Any person who has exceeded the dustfall rates set out in Table 2 must, within three months after submission of the dustfall monitoring report to the respective regulator, develop and submit a dust management plan to the applicable air quality management regulator for approval.

Table 2: National dust fallout regulations acceptable dust fall rates

Restriction areas	Dust rate (D) (mg/m2/day, 30 days average)	Permitted frequency of exceeding dust fallout rate
Residential areas	D< 600	Two within a year, not sequential months
Non-residential areas	600<D<1200	Two within a year, not sequential months

Source: National dust control regulations (GN R.827 1 November 2013)

4.0 STUDY APPROACH AND METHODOLOGY

4.1 Scope of Study

The scope of this Air Quality Impact Assessment (AQIA) includes an assessment of the impact of the project on air quality in communities around the CTT site resulting from the proposed construction and operation of a gas to power plant, specifically:

- Baseline:
  - Verify consistency of Sasol CPF weather database;
  - Develop emissions inventory;
  - Map population density within 5 km of the plant; and
  - Assemble baseline air quality data (existing data collected over the past 8 years around the CPF and additional field measurements of selected criteria pollutants measured by CPF – Fine particulate matter (PM_{10}), Sulphur Dioxide (SO_2), Nitrogen Dioxide (NO_2), Carbon monoxide (CO), Hydrogen Sulphide (H_2S) and Volatile Organic Carbons (VOC's).
- Impact Assessment:
  - Model dispersion of pollutants using the United States Environmental Protection Agency (US EPA) approved AERMOD software;
  - Assess impacts by comparing results with Mozambique and other relevant standards and guidelines, set out in the CPF oEMP as well as IFC / WHO guidelines;
  - Include assessment of Cumulative impacts such as adjacent CPF, EDM power plant and any other point sources in the study area as applicable; and
  - Recommend any necessary mitigation measures.

4.2 Method

The methodology used in this study is illustrated in summary in Figure 9. And discussed further in the following subsections.

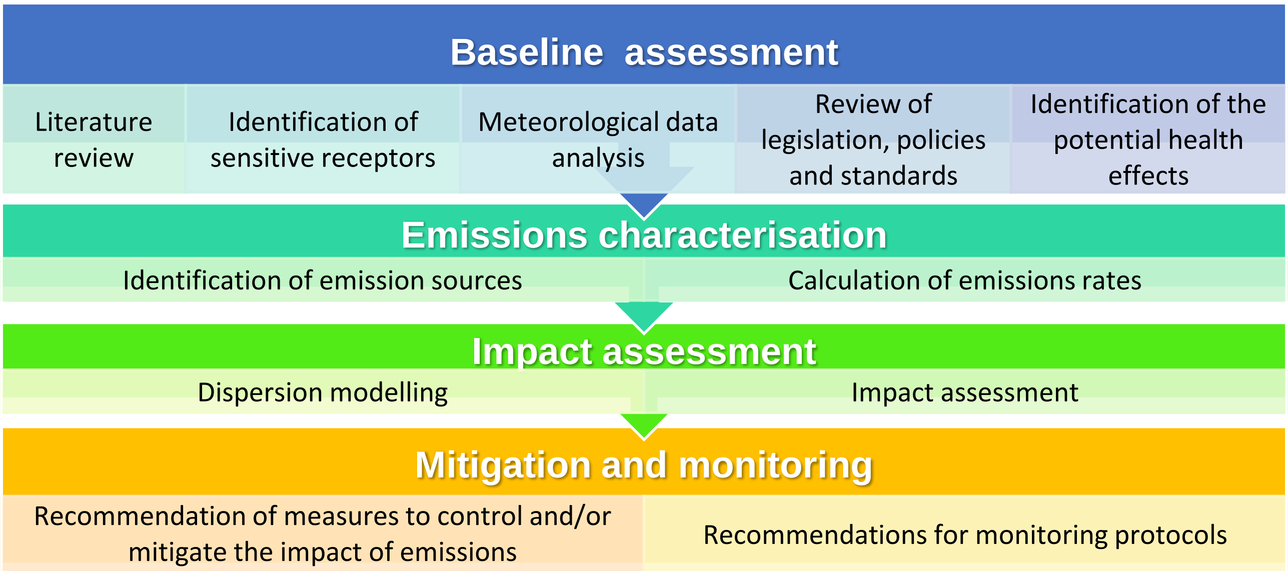

Figure 9: Process followed in the determination of the air quality impacts

4.3 Background literature review

A background literature review was conducted of various project related doccuments to gain an overview of the proposed project, and the typical regional climate and expected meteorological conditions. The following documents were reviewed:

- Sasol Technology Mozambique Gas to Power Plant Open Cycle Gas Engine Conceptual Design Study, Mozambique Temane Area (FW, 2014);
- Sasol Technology Mozambique Gas to Power Plant Closed Cycle Gas Turbine Conceptual Design Study, Mozambique Temane Area (FW, 2014);
- Air Quality Baseline Assessment - Mozambique Gas to Power Project (GAA, 2015);
- Environmental Impact Assessment for Sasol PSA And LPG Project - Air Quality Impact Assessment (Airshed Planning Professionals, 2014); and
- Future Exploration, Appraisal and Development Activities in the Sasol License Areas, Revision 7 (GAA, 2017).

During the background literature review, available monitoring data was sourced for the local area. This data was determined via the following field study methodologies:

- American Society for Testing and Materials, Designation: D1739 – 98 (Reapproved 2017) Standard Test Method for Collection and Measurement of Dust Fall (Settleable Particulate Matter) (ASTM, 2017);
- American Society for Testing and Materials, Designation: D1739 – 98 (Reapproved 2010) Standard Test Method for Collection and Measurement of Dust Fall (Settleable Particulate Matter) (ASTM, 2010);
- MetOne Instruments E-sampler Particulate Analyser (MetOne Instruments, 2018); and
- Radiello Passive Diffusive Air Sampling System (Sigma-Aldrich, 2007).

4.4 Baseline Assessment

The assessment of the ambient air quality is based on available ambient air quality information and baseline air quality monitoring data identified in the literature review and modelled MM5 meteorological data.

The baseline air quality assessment included:

- A review of applicable legislation, policy and standards;
- The analysis of site-specific modelled meteorological (MM5[2]) data;
- The identification of local emission sources; and
- The identification and discussion of the potential health effects associated with applicable atmospheric emissions.

4.5 Predictive emission factor estimations

Dispersion modelling is an effective tool in predicting the ambient atmospheric concentration of pollutants emitted to the atmosphere from a variety of processes, including power generation. Similarly, modelling is effective at determining the distribution of concentrations from existing sources. Based on the configuration of the existing sources adjacent to the proposed Project, a model capable of dealing with a range of area, volume and point sources will be required for the assessment.

The ICS-AERMOD modelling software code was used to determine likely ambient air pollutant concentrations from the proposed power plant, for comparison against the relevant ambient air quality standards. The AERMET pre-processor was used to process MM5 modelled regional meteorological data for input to ISC-AERMOD. The ISC-AERMOD software code calculates likely changes in dispersion plume trajectory and concentrations in response to changes in local terrain and meteorology. Input into a dispersion model includes prepared meteorological data, source data, information on the nature of the receptor grid and emissions input data. Model inputs are verified before the model is executed.

The establishment of a comprehensive emissions inventory forms the basis for the assessment of the impacts of the proposed project's emissions on the receiving environment. The establishment of an emissions inventory comprises the identification of sources of emission, and the quantification of each source's contribution to ambient air pollution concentrations.

Air pollution emissions may typically be obtained using actual sampling at the point of emission, estimating it from mass and energy balances or emission factors which have been established at other, similar operations. Sasol Petroleum International (SPI) provided locally derived emission factors for the proposed Project which were used in the simulations.

4.6 Dispersion Modelling

This assessment is considered to be a Level 2[3] assessment therefore a steady state Gaussian Plume model is required in order to gain an understanding of the distribution of the pollutant concentrations in time and space.

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[2] The MM5 (short for Fifth-Generation Penn State/NCAR Meso-scale Model) is a regional meso-scale model used for creating weather forecasts and climate projections. It is a community model maintained by Penn State University and the National Centre for Atmospheric Research (PSU-NCAR, 2015).

[3] The level of assessment depends on the technical factors to be considered in the modelling exercise such as the geophysical, emissions and meteorological conditions. The assessment must also depend on the level of risk associated with the emissions and hence the level of detail and accuracy required from a model (US-EPA, 2017) (RSA-NEMAQA, 2014).

The approved AERMOD View 9.5.0 modelling software was therefore chosen to determine the potential impacts. AERMOD View is an air dispersion modelling package which incorporates the following US EPA air dispersion models into one integrated interface:

- AERMOD;
- ISCST3; and
- ISC-PRIME.

These US EPA air dispersion models are used extensively internationally to assess pollution concentration and deposition from a wide variety of sources.

The AERMET[4] View 9.5.0 pre-processor was used to process MM5 modelled regional meteorological data for information on the nature of the receptor grid (Table 7) and emissions input data.

Dispersion models are limited in their inability to account for highly complex rapidly varying spatial and temporal meteorological systems such as calms and mountain and valley winds, especially where complex terrain is involved. The US EPA considers the range of uncertainty to be -50% to 200% for models applied to gently rolling terrain. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions. Dispersion modelling results can be compared with monitored values in order to improve the accuracy of, or “calibrate” models.

4.7 Impact Assessment Methodology and Rating Criteria

Potential impacts are assessed according to the direction, intensity (or severity), duration, extent and probability of occurrence of the impact. These criteria are discussed in more detail below:

Direction of an impact may be positive, neutral or negative with respect to the particular impact. A positive impact is one which is considered to represent an improvement on the baseline or introduces a positive change. A negative impact is an impact that is considered to represent an adverse change from the baseline or introduces a new undesirable factor.

Intensity / Severity is a measure of the degree of change in a measurement or analysis (e.g. the concentration of a metal in water compared to the water quality guideline value for the metal), and is classified as none, negligible, low, moderate or high. The categorisation of the impact intensity may be based on a set of criteria (e.g. health risk levels, ecological concepts and/or professional judgment). The specialist study must attempt to quantify the intensity and outline the rationale used. Appropriate, widely-recognised standards are used as a measure of the level of impact.

Duration refers to the length of time over which an environmental impact may occur: i.e. transient (less than 1 year), short-term (1 to 5 years), medium term (6 to 15 years), long-term (greater than 15 years with impact ceasing after closure of the project) or permanent.

Scale/Geographic extent refers to the area that could be affected by the impact and is classified as site, local, regional, national, or international. The reference is not only to physical extent but may include extent in a more abstract sense, such as an impact with regional policy implications which occurs at local level.

Probability of occurrence is a description of the probability of the impact actually occurring as improbable (less than 5% chance), low probability (5% to 40% chance), medium probability (40 % to 60 % chance), highly probable (most likely, 60% to 90% chance) or definite (impact will definitely occur).

[4] AERMET is a pre-processor that organizes and processes meteorological data and estimates the necessary boundary layer parameters for dispersion calculations in AERMOD

Impact significance will be rated using the scoring system shown in Table 3 below. The significance of impacts is assessed for the two main phases of the project: i) construction ii) operations. While a somewhat subjective term, it is generally accepted that significance is a function of the magnitude of the impact and the likelihood (probability) of the impact occurring. Impact magnitude is a function of the extent, duration and severity of the impact, as shown in Table 3.

Table 3: Scoring system for evaluating impacts

Severity	Duration	Extent	Probability
10 (Very high/don't know)	5 (Permanent)	5 (International)	5 (Definite/don't know)
8 (High)	4 (Long-term – longer than 15 years and impact ceases after closure of activity)	4 (National)	4 (Highly probable)
6 (Moderate)	3 (Medium-term – 6 to 15 years)	3 (Regional)	3 (Medium probability)
4 (Low)	2 (Short-term – 1 to 5 years)	2 (Local)	2 (Low probability)
2 (Minor)	1 (Transient – less than 1 year)	1 (Site)	1 (Improbable)
1 (None)			0 (None)

After ranking these criteria for each impact, a significance rating was calculated using the following formula:

SP (significance points) = (severity + duration + extent) x probability.

The maximum value is 100 significance points (SP). The potential environmental impacts were then rated as of High (SP >75), Moderate (SP 46 – 75), Low (SP ≤15 - 45) or Negligible (SP < 15) significance, both with and without mitigation measures in accordance with Table 4.

Table 4: Impact significance rating

Value	Significance	Comment
SP >75	Indicates **high** environmental significance	Where an accepted limit or standard may be exceeded, or large magnitude impacts occur to highly valued/sensitive resource/receptors. Impacts of high significance would typically influence the decision to proceed with the project.
SP 46 - 75	Indicates **moderate** environmental significance	Where an effect will be experienced, but the impact magnitude is sufficiently small and well within accepted standards, and/or the receptor is of low sensitivity/value. Such an impact is unlikely to have an influence on the decision. Impacts may justify significant modification of the project design or alternative mitigation.
SP 15 - 45	Indicates **low** environmental significance	Where an effect will be experienced, but the impact magnitude is small and is within accepted standards, and/or the receptor is of low sensitivity/value or the probability of impact is extremely low. Such an impact is unlikely to have an influence on the decision although impact should still be reduced as low as possible, particularly when approaching moderate significance.
SP < 15	Indicates **negligible** environmental significance	Where a resource or receptor will not be affected in any material way by a particular activity or the predicted effect is deemed to be imperceptible or is indistinguishable from natural background levels. No mitigation is required.
+	**Positive impact**	Where positive consequences / effects are likely.

In addition to the above rating criteria, the terminology used in this assessment to describe impacts arising from the current project are outlined in Table 5 below. To fully examine the potential changes that the project might produce, the project area can be divided into Areas of Direct Influence (ADI) and Areas of Indirect Influence (AII).

- Direct impacts are defined as changes that are caused by activities related to the project and they occur at the same time and place where the activities are carried out (i.e. within the ADI).
- Indirect impacts are those changes that are caused by project-related activities but are felt later in time and outside the ADI. The secondary indirect impacts are those resulting from activities outside of the ADI.

Table 5: Types of impact

Term for Impact Nature	Definition
Direct impact	Impacts that result from a direct interaction between a planned project activity and the receiving environment/receptors (i.e. between an effluent discharge and receiving water quality).
Indirect impact	Impacts that result from other activities that happen as a consequence of the Project (i.e., pollution of water placing a demand on additional water resources).
Cumulative impact	Impacts that act together with other impacts (including those from concurrent or planned activities) to affect the same resources and/or receptors as the Project.

5.0 RECEPTORS

A total of 10,809 receptors were considered including, including nine sensitive receptors[5], 16 residential areas (5 km to 40 km from the site), 18 industrial areas and 1,939 individual structures (Table 6, **Figure 10**).

Table 6: Sensitive receptors and points of interest.

#	Type	Receptor	UTM 36 K X (m)	UTM 36 K Y (m)
1	Sensitive	Health Centre - Mangungumete	716678	7596975
2		Health Centre - Temane	708403	7594925
3		Orphanage	713951	7594566
4		Primary school - Mangugumete	717059	7596101
5		Primary School - Temane	707567	7593872
6		Primary school - Chitsotso	718704	7586374
7		School - Litlau	716490	7599301
8		School - Manusse	707125	7585185
9		School - Temane Base Camp	716319	7598164
10	Residential	Chipongo	733081	7588874
11		Chitsotso	718703	7586373

[5] Sensitive receptors include, but are not limited to, hospitals, schools, day-care facilities, elderly housing and convalescent facilities. These are areas where the occupants are more susceptible to the adverse effects of exposure to toxic chemicals, pesticides, and other pollutants. Extra care must be taken when dealing with contaminants and pollutants in close proximity to areas recognized as sensitive receptors.

#	Type	Receptor	UTM 36 K X (m)	UTM 36 K Y (m)
12		Inhassoro	728432	7616428
13		Litlau	716489	7599300
14		Mabime	724375	7598565
15		Macovane	712561	7621798
16		Maimelane	716715	7602127
17		Mangarelane I	732540	7602476
18		Mangarelane II	726915	7606638
19		Mangugumete	717058	7596101
20		Manusse	707124	7585184
21		Mapanzene	731881	7593751
22		Temane	707566	7593872
23		Temane Base Camp	716319	7598164
24		Vilanculos	738891	7566447
25		Vulanjane	716275	7606606
26	Industrial / AQ monitoring	T-03 Well Pad	715875	7598067
27		T-04 Well Pad	710139	7587132
28		T-05 Well Pad	712686	7595239
29		T-06 Well Pad	705906	7596210
30		T-07 Well Pad	711231	7598913
31		T-10 Well Pad	710866	7597158
32		T-12 Well Pad	715408	7595830
33		T-13 Well Pad	716227	7599871
34		T-15 Well Pad	713449	7593189
35		T-16 Well Pad	707703	7598230
36		T-23 Well Pad	717065	7593814
37	Industrial	CTT	713149	7591987
38		CPF	713078	7593356
39		Proposed Well Pad	708543	7595056

#	Type	Receptor	UTM 36 K X (m)	UTM 36 K Y (m)
40		Proposed Well Pad	709134	7588475
41		Electricidade de Moçambique	713937	7594344
42		Proposed Well Pad	706425	7582122
43		Proposed Well Pad	709363	7578786

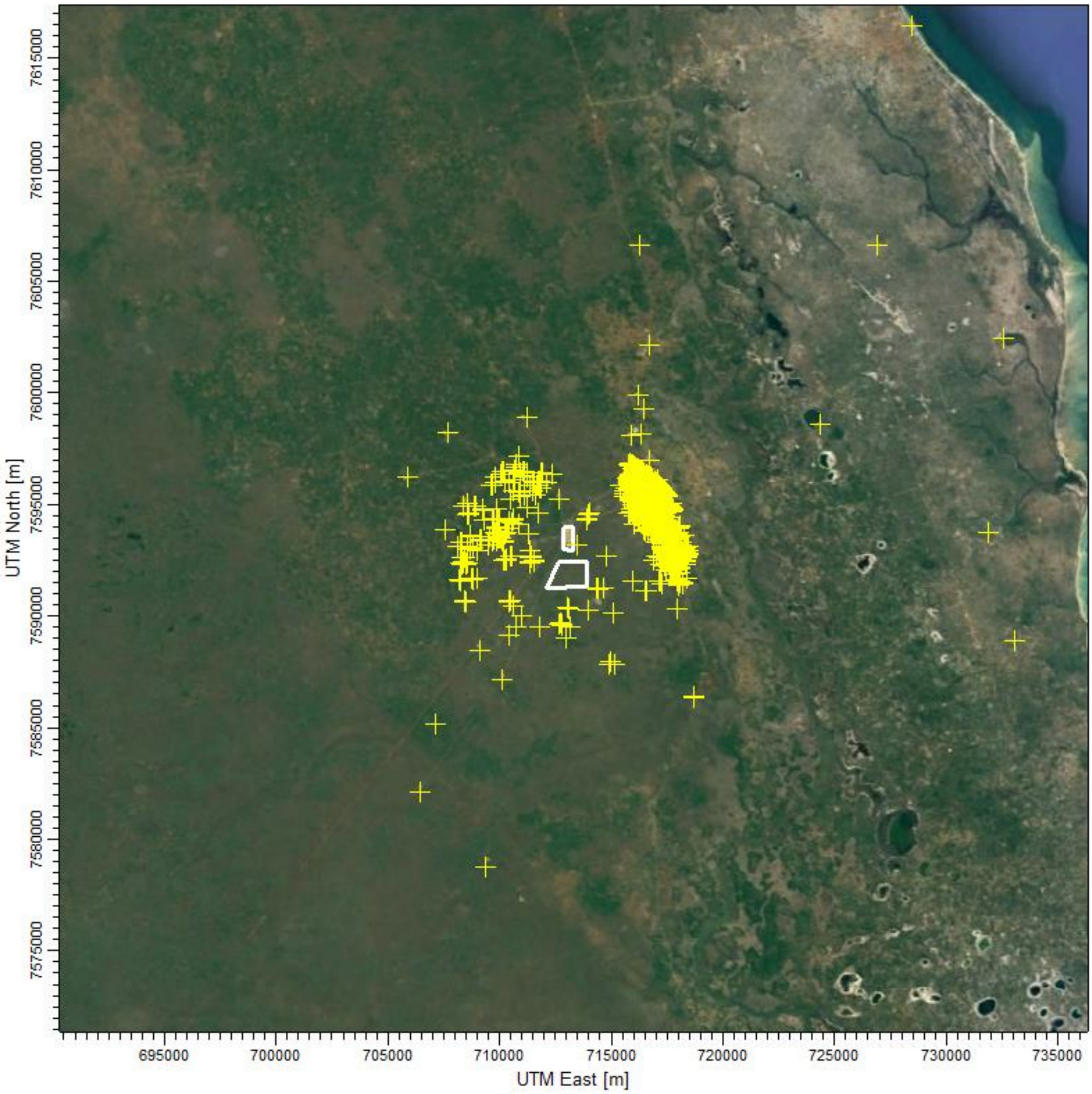
A 50 x 50 km modelling domain was considered using a multitiered receptor grid centred on the site (UTM Zone 36K, X 713158 m, Y 7592494 m).

Table 7: Receptor grid.

Tier	Distance Site Centre (m)	Tier Spacing (m)
1	1500	50
2	2500	100
3	5000	200
4	10000	500
5	>10000	1000

PROJECT TITLE:

Central Térmica de Temane
Sensitive Receptors & Points of Interest



COMMENTS:	SOURCES:	COMPANY NAME:	
White polygons - existing CPF and proposed Project area. Yellow crosses - Points of interest and sensitive receptors.	6	Golder Associates	
	RECEPTORS: 12771	MODELER: Lance Coetzee	GOLDER
		SCALE: 1:235,000 (0 – 5 km)	
		DATE: 2018-09-21	PROJECT NO.: 18103533

Figure 10: Points of interest and sensitive receptors (Scale 1:235,000).

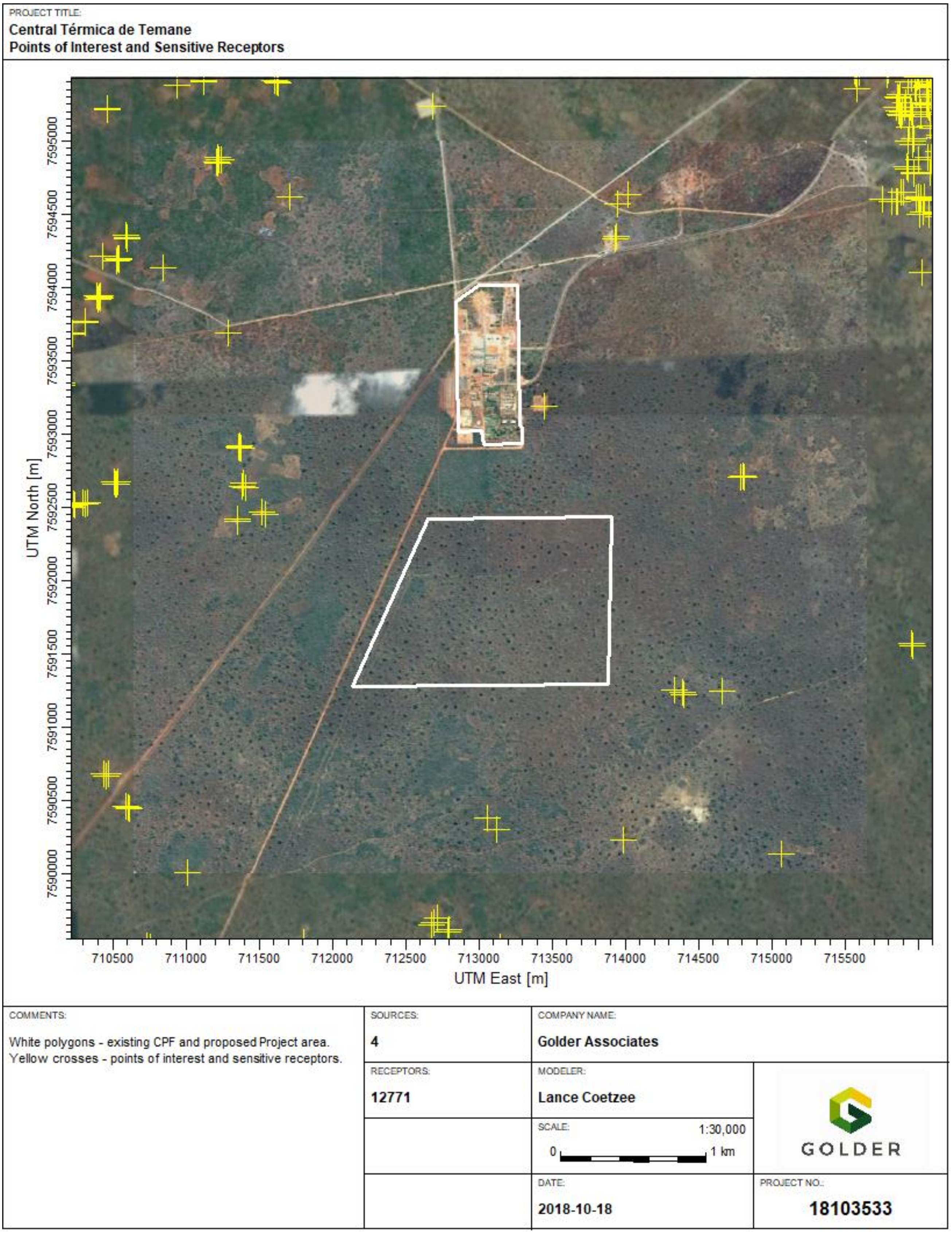


Figure 11: Points of interest and sensitive receptors (Scale 1:30,000).

6.0 BASELINE CONDITIONS

In characterising the baseline air quality, reference is made to details concerning atmospheric dispersion potential of the study area and other potential sources of atmospheric emissions in the area. The consideration of the existing air quality is important so as to facilitate the assessment of the potential for cumulative air pollutant concentrations arising due to proposed developments.

6.1 Topography

The study area is situated along the coastal plain of Mozambique, approximately 20 km inland of the coastline and about 30 m above mean sea level. The terrain surrounding the CTT site is level to very slightly undulating. There are local seasonal drainage lines to the immediate South of the preferred site which limit extension of the site in a southerly direction. From the CTT site there is a gentle gradient of <1% eastward towards the Govuro River, followed by a slight rise in elevation to a watershed that trends roughly north to south between Inhassoro and Vilanculos, about 6 km's inland.

Initially for this study a modelling domain of 50 km by 50 km centred on the proposed site was considered.

6.2 Land cover and use

The general CTT site can be described as a flat area covered by Mixed Woodland and Thicket Mosaic vegetation units. These areas have seen limited human activity due to inaccessibility; however, there are areas where some human influences can be seen (i.e. timber harvesting and agricultural subsistence practices). There are very few surface water features near the CTT site and some non-perennial drainage channels are evident to the south of the CTT footprint and further south along the transmission line servitude.

6.3 Atmospheric Dispersion Potential

Meteorological characteristics of a site govern the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume "stretching". The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction and the variability in wind direction, determine the general path pollutants will follow, and the extent of cross-wind spreading.

Pollution concentration levels fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field. Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales. Atmospheric processes at macro-scales and meso-scales need therefore be considered in order to accurately parameterise the atmospheric dispersion potential of a particular area.

Parameters that need to be considered in the characterisation of meso-scale ventilation potentials include wind speed, wind direction, extent of atmospheric turbulence, ambient air temperature and mixing depth (Pasquill, Smith (1983), Godish (1990)).

6.4 Boundary Layer Properties and Atmospheric Stability

The atmospheric boundary layer constitutes the first few hundred metres of the atmosphere and is directly affected by the earth's surface. The earth's surface affects the boundary layer through the retardation of air flow created by frictional drag, created by the topography, or as result of the heat and moisture exchanges that take place at the surface.

During the day, the atmospheric boundary layer is characterised by thermal heating of the earth’s surface, converging heated air parcels and the generation of thermal turbulence, leading to the extension of the mixing layer to the lowest elevated inversion. These conditions are normally associated with elevated wind speeds, hence a greater dilution potential for the atmospheric pollutants.

During the night, radiative flux divergence is dominant due to the loss of heat from the earth’s surface. This usually results in the establishment of ground-based temperature inversions and the erosion of the mixing layer. As a result, night-time is characterised by weak vertical mixing and the predominance of a stable layer. These conditions are normally associated with low wind speeds, hence less dilution potential.

The mixed layer ranges in depth from a few metres during night times to the base of the lowest elevated inversion during unstable, daytime conditions. Elevated inversions occur for a variety of reasons, however typically the lowest elevated inversion occurs at night during winter months when atmospheric stability is typically at its maximum. Atmospheric stability is frequently categorised into one of six stability classes, these are briefly described in Table 8.

The atmospheric boundary layer is normally unstable during the day as a result of the turbulence due to the sun's heating effect on the earth's surface. The thickness of this mixing layer depends predominantly on the extent of solar radiation, growing gradually from sunrise to reach a maximum at about 5-6 hours after sunrise. This situation is more pronounced during the winter months due to strong night-time inversions and a slower developing mixing layer. During the night a stable layer, with limited vertical mixing, exists. During windy and/or cloudy conditions, the atmosphere is normally neutral.

Table 8: Atmospheric stability classes

Designation	Stability Class	Atmospheric Condition
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

For elevated releases, the highest ground level concentrations would occur during unstable, daytime conditions. The wind speed resulting in the highest ground level concentration depends on the plume buoyancy. If the plume is considerably buoyant (high exit gas velocity and temperature) together with a low wind, the plume will reach the ground relatively far downwind. With stronger wind speeds, on the other hand, the plume may reach the ground closer, but due to the increased ventilation, it would be more diluted. A wind speed between these extremes would therefore be responsible for the highest ground level concentrations. In contrast, the highest concentrations for ground level, or near-ground level releases would occur during weak wind speeds and stable (night-time) atmospheric conditions.

6.5 Climate

Mozambique is located on the eastern coast of southern Africa at latitude of 11˚ to 26° south of the equator and has a tropical to sub-tropical climate which is moderated by the influence of mountainous topography in the north-west of the country. Seasonal variations in temperature are around 5°C between the coolest months (June, July and August) and the warmest months (December, January and February). Geographically, temperatures are warmer near to the coast, and in the southern, lowland regions compared with the inland regions of higher elevation. Average temperatures in these lowland parts of the country are around 25-27°C in the summer and 20-25°C in winter. The inland and higher altitude northern regions of Mozambique experience cooler average temperatures of 20-25°C in the summer, and 15-20°C in winter.

The wet season lasts from November to April, coinciding with the warmer months of the year. The Inter-tropical Convergence Zone (ITCZ) is positioned over the north of the country at this time of year, bringing 150-300mm of rainfall per month whilst the south receives 50-150mm per month. Topographical influences, however, cause local variations to this north-south rainfall gradient with the highest altitude regions receiving the highest rainfalls. Mozambique's coastal location means that it lies in the path of cyclones that occur during the wet season. The heavy rainfall associated with these events contributes a significant proportion of wet season rainfall over a period of a few days. Inter-annual variability in the wet-season rainfall in Mozambique is also strongly influenced by Indian Ocean sea surface temperatures, which can vary from one year to another due to variations in patterns of atmospheric and oceanic circulation. The most well documented cause of this variability is the El Niño Southern Oscillation (ENSO) which causes warmer and drier than average conditions in the wet season of eastern southern Africa in its warm phase (El Niño) and relatively cold and wet conditions in its cold phase (La Niña) (McSweeney, New, & Lizcano, 2010).

6.6 Meteorology

Wind direction and speed

Wind roses were constructed using onsite hourly surface wind data as well as the MM5 data for the same location. Wind roses comprise 16 spokes, which represent the directions from which winds blow during a specific period. The colours used in the wind roses below reflect the different wind speed categories. The dotted circles provide information regarding the frequency of occurrence of wind speed and wind direction. The frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s are indicted above the respective wind roses. The comparison of wind roses based on measurement at the CPF (Figure 12) shows fair correlation with the MM5 data (Figure 13 and Figure 14. The wind field is characterised by dominant southerly and easterly winds.

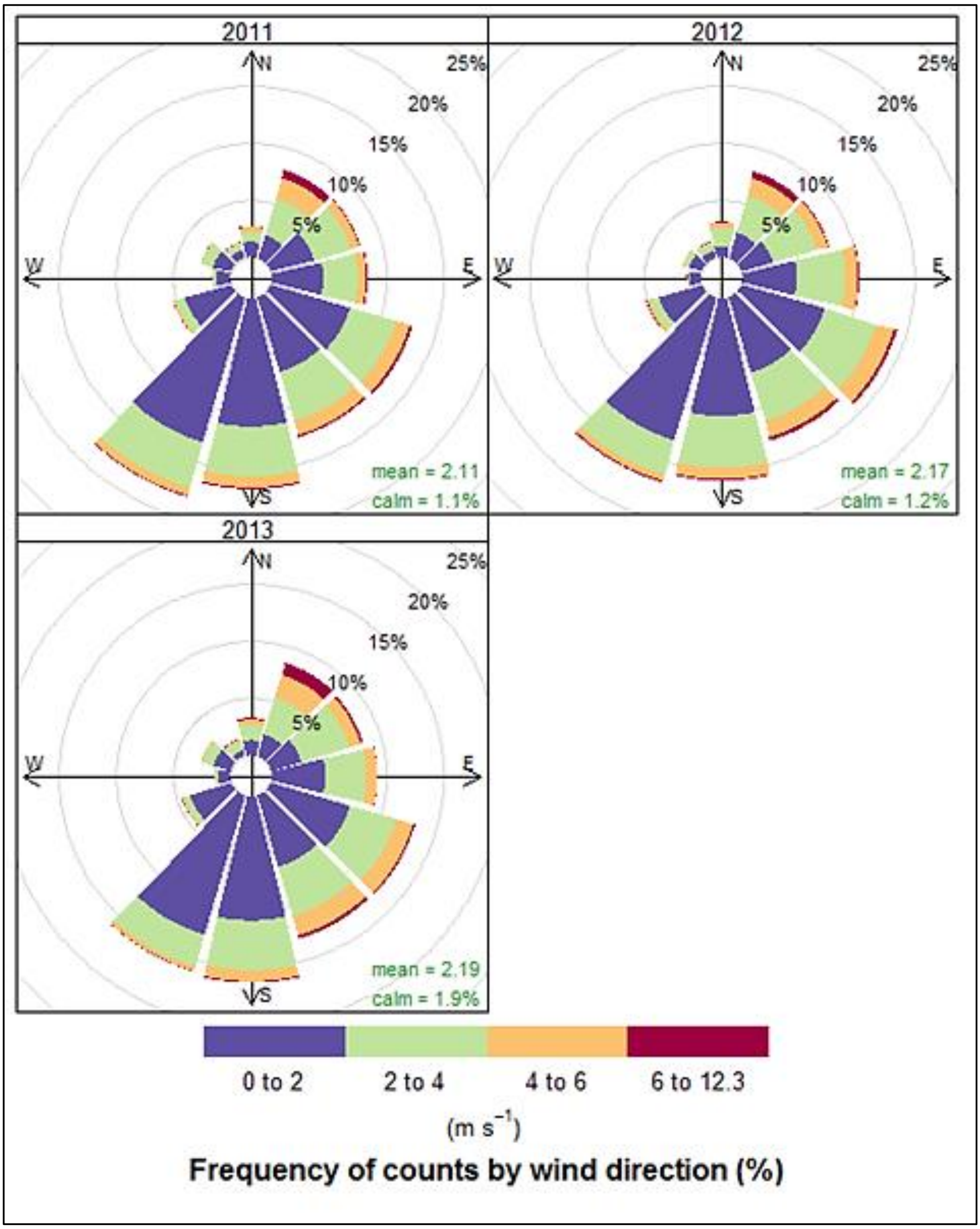
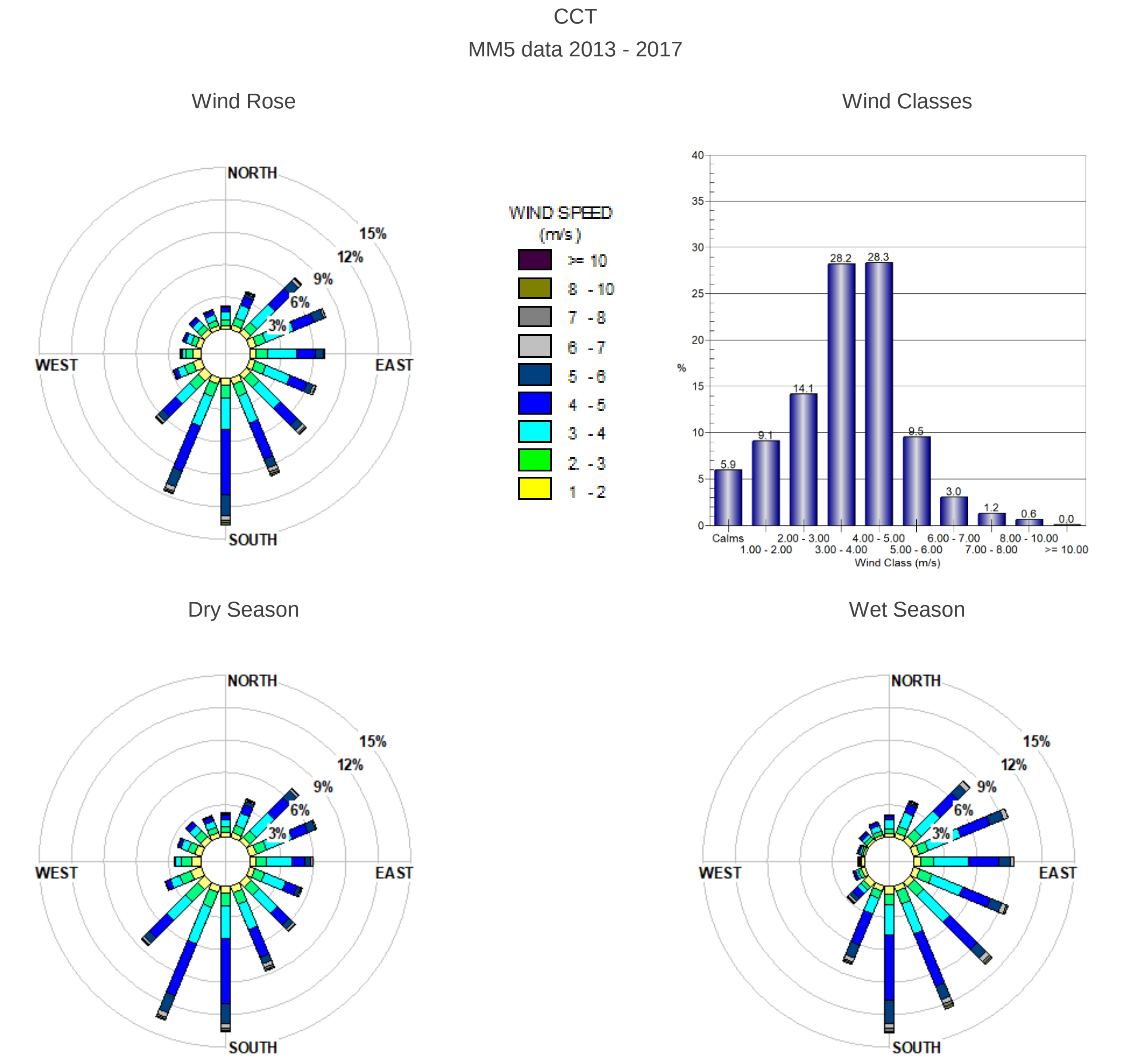
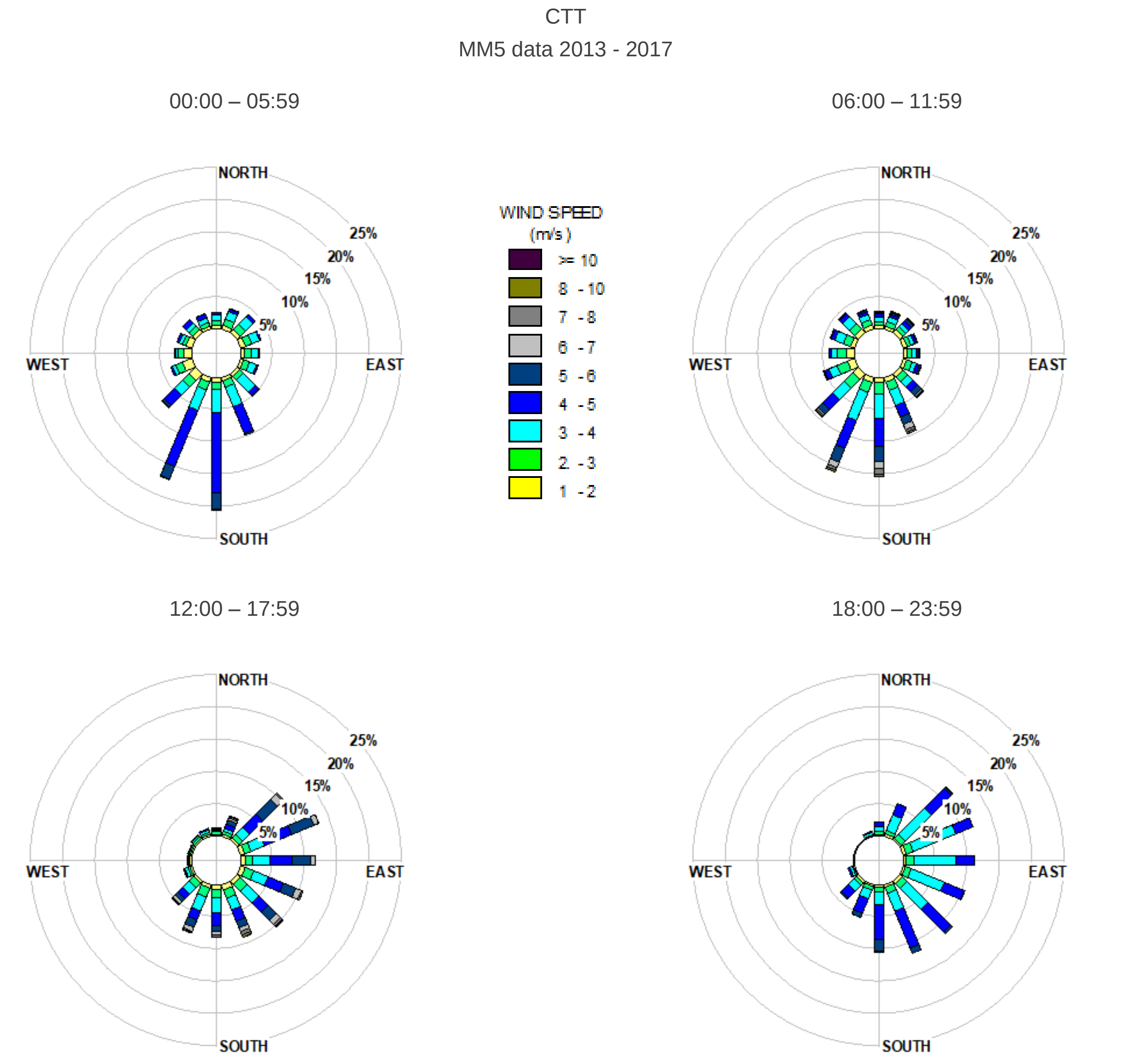


Figure 12: Period wind roses for the CPF (2011-2013)



Month	Wind Speed	Dominant Sector		Dominant Sector		Calms	Missing
2013 - 2017	3.5 m/s	NE-SW	82%	0	0%	6%	0%
Wet (Dec - Mar)	3.7 m/s	NE-SSW	85%	0	0%	5%	0%
Dry (Apr-Nov)	3.4 m/s	NE-ENE	14%	SE-WSW	53%	6%	0%

Figure 13: CTT period and seasonal wind roses (2013-2017)



Month	Wind Speed	Dominant Sector		Dominant Sector		Calms	Missing
00-05	3.1 m/s	SSE-SW	59%	0	0%	8%	0%
06-11	3.6 m/s	SSE-SW	54%	0	0%	8%	0%
12-17	3.9 m/s	NE-SSW	84%	0	0%	5%	0%
18-23	3.5 m/s	NE-S	80%	0	0%	3%	0%

Figure 14: CTT diurnal wind roses (2013-2017)

Temperature

Air temperature is important, both for determining the effect of plume buoyancy (the larger the temperature difference between the plume and the ambient air, the higher the plume is able to rise) and determining the development of the mixing and inversion layers. The diurnal and monthly temperature trend is presented in Figure 15.

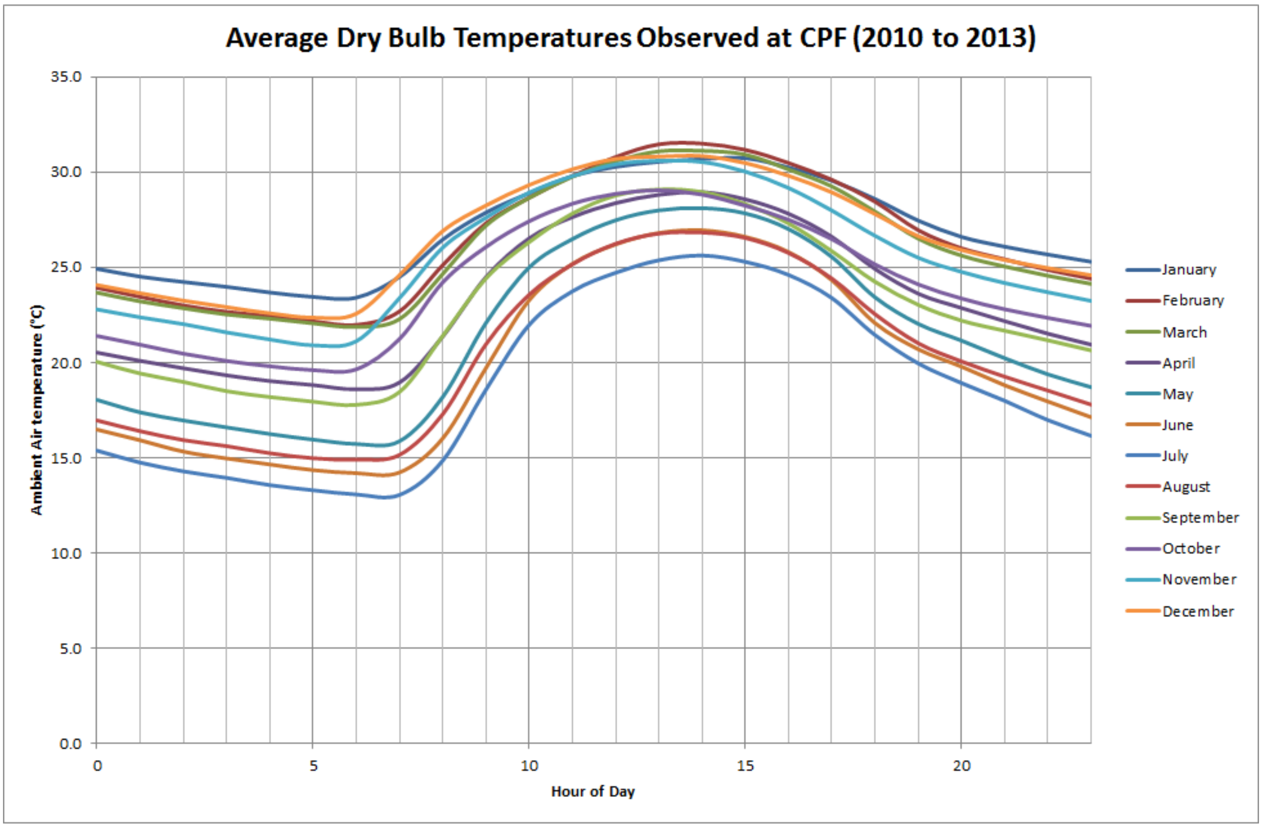


Figure 15: Monthly and Diurnal temperature profile (CPF site 2010 to 2013)

Table 9 shows the maximum, minimum and average monthly temperature profile for the site for the period January 2009 to December 2011. Temperatures typically range between 20°C and 28°C. The highest temperatures occur from December to April (Golder Associates Africa, Mark Wood Consulting and Airshed (2014)).

Table 9: Minimum, maximum and mean temperature (CPF site 2010 to 2013)

Temperature	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum	19.2	19.0	17.9	14.0	10.6	4.9	7.7	8.8	9.7	13.8	14.9	17.2
Average	27.0	26.4	26.2	23.3	21.4	19.9	18.8	20.3	22.9	24.1	25.6	26.6
Maximum	35.0	36.1	35.4	32.9	33.8	32.3	31.0	32.5	37.1	35.3	37.3	35.6

Rainfall

Precipitation is important to air pollution studies since it represents an effective removal mechanism for atmospheric pollutants and inhibits dust generation. Figure 16 shows the monthly average rainfall data as observed at the CPF for the period 2010 (October) to 2013. Rainfall in the region occurs mostly during the summer months of December to April, with approximately 82% of rainfall occurring during this period. Mean annual precipitation (MAP) for the period 2011-2013 was 782 mm (Golder Associates Africa, Mark Wood Consulting and Airshed (2014)).

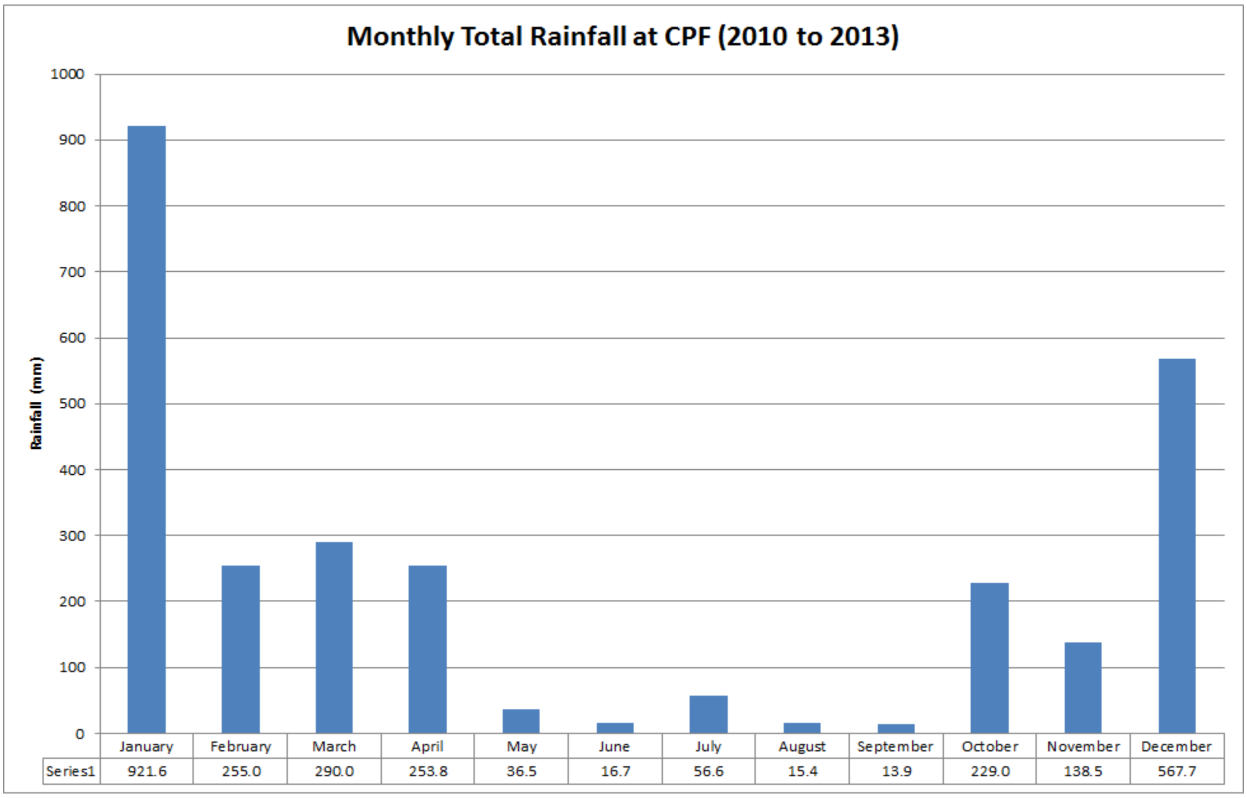


Figure 16: Rainfall data (CPF site 2010 to 2013)

6.7 Emission sources within the airshed

Potential activities and sources of air pollution which may impact on the ambient air quality within the airshed[6] include:

- Agricultural activities;
- Mining activities (sand and aggregate);
- Oil and gas extraction and processing;
- Domestic fuel burning;
- Biomass burning;
- Vehicle emissions (tailpipe and entrained emissions);
- Paved roads; and
- Unpaved roads.

Initially for this study a modelling domain of 50 km by 50 km centred on the proposed site was considered.

Agricultural activities

Emissions from agricultural activities are difficult to control due to the seasonality of emissions and the large surface area producing emissions (USEPA, 1995). Most of the agricultural activities in the Project region appear to be of a subsistence nature thus emissions are not anticipated to significantly influence the air quality in the

[6] A geographical area within which the air frequently is confined or channelled, with all parts of the area thus being subject to similar conditions of air pollution.

area although particulate emissions may increase during drier periods, then fields are ploughed in preparation for planting and/or due to seasonal wild fires on fallow farmlands.

Mining activities

Dust emissions from typical mining operations is commonly generated by wind erosion from waste rock dumps, tailings facilities (slimes dams, ash dumps etc.), open mining pits, unpaved mine access roads and other exposed areas. Dust emissions occur when the threshold wind speed is exceeded (Cowherd *et al*., 1988). Factors which influence the rate of wind erosion include surface compaction, moisture content, vegetation, shape of storage pile, particle size distribution, wind speed and rain. Dust generated by these sources is termed 'fugitive dust' as it is not emitted to the atmosphere in a confined flow stream (USEPA, 1995). These emissions are often difficult to quantify as they are very diffuse, variable and intermittent (Ministry of the Environment, 2001).

Mining activity within the Project area is limited and is not expected to have a significant impact on air quality, as mining is artisanal in nature (i.e. sand and stone/aggregate extraction).

Oil, Gas Extraction and Refining

The proposed Project will draw gas from either the Sasol Petroleum International (SPI) gas well field via the existing Central Processing Facility (CPF) or from an alternative gas source. The CPF is located approximately 500m north of the CTT and is viewed as a potential key source of atmospheric emissions resulting from the hydrocarbon refining activities. The following atmospheric pollutants are anticipated:

- Criteria air pollutants (CAP), these include:
  - Sulphur Dioxide (SO_2);
  - Nitrogen Oxides (NO_X);
  - Carbon Monoxide (CO);
  - Particulate Matter (PM_{10}, $PM_{2.5}$ and TSP); and
  - Ozone (O_3).
- Toxic air contaminants (TAC), that cause or may cause cancer or other serious health effects, such as:
  - Hydrogen Sulphide (H_2S);
  - Volatile Organic Compounds (VOC's) (such as Benzene, Toluene, Ethyl benzene and Xylene – BTEX);
  - Greenhouse gases (GHG), including:
    - Methane (CH_4); and,
    - Carbon Dioxide (CO_2).

Domestic fuel burning

Domestic fuel burning of coal emits a large amount of gaseous and particulate pollutants including: SO_2, heavy metals, particulate matter (PM_{10}, $PM_{2.5}$ and TSP), NO_2, CO, polycyclic aromatic hydrocarbons (PAH), and benzo(a) pyrene. Pollutants arising due to the combustion of wood include: particulate matter (PM_{10}, $PM_{2.5}$ and TSP), inorganic ash, polycyclic aromatic hydrocarbons (PAH), benzo(a) pyrene, NO_2, CO, and formaldehyde. The main pollutants emitted from the combustion of paraffin include: particulate matter (PM_{10}, $PM_{2.5}$ and TSP), CO, polycyclic aromatic hydrocarbons (PAH), and NO_2. Most of the housing within the project area is informal and thus it is highly likely that most households within the communities are likely to use coal, wood and paraffin for space heating and/or cooking purposes. Emissions from these communities are anticipated to impact the ambient air quality however as the density of households is not significant the impacts are likely to be limited and disbursed.

Biomass burning

Biomass burning may be described as the incomplete combustion process of natural plant matter with CO, Methane (CH_4) and NO_2 being emitted during the process. During the combustion process, approximately 40% of the nitrogen in biomass is emitted as nitrogen, 10% remains in the ashes and it is assumed that 20% of the nitrogen is emitted as higher molecular weight nitrogen compounds. In comparison to the nitrogen emissions, only small amount of SO_2 and sulphate aerosols are emitted. With all biomass burning, visible smoke plumes are typically generated. These plumes are created by the aerosol content of the emissions and are often visible for many kilometres from the actual source of origin.

The extent of emissions liberated from biomass burning is controlled by several factors, including:

- The type of biomass material;
- The quantity of material available for combustion;
- The quality of the material available for combustion;
- The fire temperature; and
- Rate of fire progression through the biomass body.

Crop-residue burning and general wild fires in the study area represent significant sources of combustion-related emissions associated with these agricultural areas. Given that the region is dominated by subsistence farming rather than large scale commercial farming, it is anticipated that general wild fires are likely to be more important than controlled burning related to the agricultural activities as emission sources.

Vehicle emissions

Air pollution generated from vehicle engines (including motorised boats) may be grouped into primary and secondary pollutants. Primary pollutants are those emitted directly to the atmosphere as tail-pile emissions whereas, secondary pollutants are formed in the atmosphere from atmospheric chemical reactions, such as hydrolysis, oxidation, or photochemical reactions. The primary pollutants emitted typically include CO_2, CO, hydrocarbons (including benzene, 1.2-butadiene, aldehydes and polycyclic aromatic hydrocarbons), SO_2, NO_x and particulates. Secondary pollutants formed in the atmosphere typically include NO_2, photochemical oxidants such as ozone, hydrocarbons, sulphur acid, sulphates, nitric acid, sulphates and nitrate aerosols.

The quantity of pollutants emitted by vehicles depend on specific vehicle related factors such as vehicle weight, speed and age; fuel-related factors such as fuel type (petroleum or diesel), fuel formulation (oxygen, sulphur, benzene and lead replacement agents) and environmental factors such as altitude, humidity and temperature.

Paved Roads

Particulate emissions occur whenever vehicles travel over a paved surface such as a road or parking lot, these emissions are due to direct emissions from vehicles in the form of exhaust, brake wear and tire wear emissions and re-suspension of loose material on the road surface. In general terms, re-suspended particulate emissions originate from, and result in, the depletion of loose material present on the roads surface (i.e., the surface loading). In turn, surface loading is continuously replenished from other sources. At industrial sites, surface loading is replenished by spillage of material and track-out dust from unpaved roads and staging areas. Various field studies have found that public streets and highways, as well as roadways at industrial facilities, can be major sources of the atmospheric particulate matter within an area.

Because the total coverage of tarmac road infrastructure in the area is limited vehicle entrainment of particulates from paved roads is anticipated to be insignificant.

Unpaved Roads

When vehicles travel on unpaved roads; 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 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.

Vehicle entrainment of particulates from unpaved roads is anticipated to be one of the dominant sources of particulate emissions in the region. Special attention regarding mitigation of such emissions will have to be undertaken to prevent the deterioration of ambient air quality due to increased traffic volumes.

6.8 Key Atmospheric Pollutant and Associated Health Effects

Key atmospheric pollutants are solid particles, liquid droplets, and/or gases in the air that could, when in high enough concentration, cause the degeneration of health in animals, humans, vegetation, and/or soil, contaminate and/or damage materials. Key atmospheric pollutants may be released from the proposed Project activities and/or from emission sources within the airshed. Key atmospheric pollutants applicable to the propose project and emission sources within the airshed are envisioned to include:

- Sulphur Dioxide (SO_2);
- Nitrogen Oxides (NO_X); and
- Particulate Matter (mainly PM_{10})

Associated health effects of these pollutants are discussed below.

Other atmospheric pollutants are also envisioned however at concentrations which are unlikely to be significant: CO, polycyclic aromatic hydrocarbons (PAH), benzo(a) pyrene, formaldehyde, O_3, H_2S, VOC's (such as Benzene, Toluene, Ethyl benzene and Xylene – BTEX), CH_4, and CO_2. Associated health effects of these pollutants are provided in Appendix A for reference purposes only.

Particulates

Particles can be classified by their aerodynamic properties into coarse particles, PM_{10} (particulate matter with an aerodynamic diameter of less than 10 µm) and fine particles, $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than 2.5 µm) (Harrison and van Grieken, 1998). The fine particles contain the secondarily formed aerosols such as combustion particles, sulphates, nitrates, and recondensed organic and metal vapours. The coarse particles contain earth crust materials and fugitive dusts from roads and industries (Fenger, 2002).

The impact of particles on human health is largely dependent on the particle characteristics, particle size, chemical composition, the duration, frequency and magnitude of the exposure/s. Typically, particulate air pollution is associated with respiratory complaints (WHO, 2000). Particle size is important because it controls where in the respiratory system a given particle deposits. Fine particles are thought to be more damaging to human health than coarse particles as larger particles are less respirable in that they do not penetrate deep into the lungs, compared to smaller particles (Manahan, 1991). Larger particles are deposited into the extra-thoracic part of the respiratory tract, while smaller particles are deposited into the smaller airways leading to the respiratory bronchioles (WHO, 2000).

Acute exposure

Studies have proven that acute exposure to particulate matter at both high and low concentrations is associated with health effects. Various studies undertaken during the 1980s to 1990s have investigated the relationship between daily fluctuations in particulate matter and mortality at low levels of acute exposure. Pope *et al* (1992) studied daily mortality in relation to PM_{10} concentrations in the Utah Valley during 1985 to 1989. A maximum daily average concentration of 365 µg/m^3 was recorded with effects on mortality observed at concentrations below 100 µg/m^3. The increase in total daily mortality was 13% per 100 µg/m^3 increase in the 24-hour average. Schwartz's 1993 studies in Birmingham, recorded daily concentrations of 163 µg/m^3 and noted that an increase in daily mortality was experienced with increasing PM_{10} concentration levels. Relative risks for chronic lung disease and cardiovascular deaths were higher than deaths from other causes.

Overall, exposure-response can be described as curvilinear, with small absolute changes in exposure at the low end of the curve having similar effects on mortality to large absolute changes at the high end (WHO, 2000). Morbidity effects associated with acute exposures to particulates include increases in lower respiratory symptoms, medication use and small reductions in lung functioning. Pope and Dockery (1992) studied groups of children in Utah Valley in winter during the period 1990 to 1991. Daily PM_{10} concentrations ranged between 7 to 251 µg/m^3. Peak Expiratory Flow was decreased, and respiratory symptoms increased when PM_{10} concentrations increased. Pope and Kanner (1993) utilised lung function data obtained from smokers with mild to moderate chronic obstructive pulmonary disease in Salt Lake City. The estimated effect was a 2% decline in the forced expiratory volume over one second for each 100 µg/m^3 increase in the daily PM_{10} average.

Chronic exposure

Chronic exposure to low concentrations of particulates is associated with mortality and other chronic effects such as increased rates of bronchitis and reduced lung functioning (WHO, 2000). An association between lung function and chronic respiratory disease and airborne particles has been indicated through several studies. Chestnut et al (1991) found that forced vital capacity decreases with increasing annual average particulate levels with an apparent threshold of 60 µg/m^3. Using chronic respiratory disease data, Schwartz (1993) determined that the risk of chronic bronchitis increased with increasing particulate concentrations, with no apparent threshold.

Few studies have been undertaken documenting the morbidity effects of chronic exposure to particulates. Recently, the Harvard Six Cities Study showed increased respiratory illness rates among children exposed to increasing particulate, sulphate and hydrogen ion concentrations. Relative risk estimates suggest an 11% increase in cough and bronchitis rates for each 10 µg/m^3 increase in annual average particulate concentrations.

Sulphur Dioxide

Health effects associated with exposure to SO_2 are mainly associated with the respiratory system. Being highly soluble, SO_2 is readily absorbed by the mucous membranes of the nose and upper respiratory tract (Maroni *et al*., 1995).

Acute exposure

Most information on the acute effects of SO_2 is derived from short-term exposures in controlled chamber experiments. These experiments have demonstrated a wide range of sensitivity amongst individuals, as SO_2 concentrations can lead to severe bronchio constriction in some individuals, while others remain completely unaffected. Response to SO_2 inhalation is rapid, with the maximum effect experienced within a few minutes. Continued exposure does not increase the response. Effects of SO_2 exposure were short-lived, with lung function returning to normal within a few minutes to hours (WHO, 2000).

Epidemiological studies have been used to determine the effects of exposure/s, averaged over 24 hour periods. Studies of the health impact of emissions from the inefficient burning of coal in domestic appliances have shown that when SO_2 concentrations exceed 250 µg/m^3 in the presence of particulate matter, an exacerbation of symptoms is observed in sensitive patients. Recent studies of health impacts in ambient air polluted by industrial and vehicular activities have demonstrated low level effects on mortality and increases in hospital admissions. In these studies, no obvious SO_2 threshold level was identified (WHO, 2000).

Chronic exposure

Chronic exposure to SO_2 has been found to be associated with an increase in respiratory symptoms and a small (or no) reduction in lung function in children. In adults, respiratory symptoms such as wheeze and cough are increased. Assessments during the coal burning period in Europe determined the lowest observed adverse effects to be at an annual average of 100 µg/m^3, together with particulate matter. Recent studies have shown adverse effects below this level in the presence of industrial air pollution. A closer relationship between mortality and particulate matter, rather than SO_2 concentrations has been found (WHO, 2000).

Nitrogen Dioxide

NO_x is a primary pollutant emitted from the combustion of stationary point sources and from motor vehicles. Nitrogen dioxide is formed through the oxidation of nitric oxide in the atmosphere.

Acute exposure

Acute exposures at concentration level of 1880 µg/m^3 and above, lead to observable changes in the pulmonary function of adults. Normal healthy people exposed at rest or with light exercise for less than 2 hours to concentrations above 4700 µg/m^3, experience pronounced decreases in pulmonary function. Asthmatics are the most sensitive subjects although various studies of the health effects on asthmatics have been inconclusive. The lowest concentration causing effects on pulmonary function was reported from two laboratories that exposed mild asthmatics for 30 to 110 minutes to 565 µg/m^3 during intermittent exercise (WHO, 2000).

Chronic exposure

Animal studies have shown that exposure to 1 880 µg/m^3 over a period of several weeks to months, causes effects in the lung, spleen and liver. The effects may be reversible or irreversible. NO_x exposure can lead to structural changes include a change in cell type in the tracheo-bronchial (levels above 640 µg/m^3) and pulmonary regions to emphysema like effects. Nitrogen dioxide concentrations, as low as 940 µg/m^3, can increase the lungs susceptibility to bacterial and viral infections (WHO, 2000).

Epidemiological studies have been undertaken on the indoor use of gas cooking appliances and health effects. Studies on adults and children under two years found no association between the use of gas cooking appliances and respiratory effects. Children aged five to 12 years have a 20% increased risk for respiratory symptoms and disease for each increase of 28 µg/m^3 NO_2 concentration, where the weekly average concentrations are in the range of 15 to 128 µg/m^3 (WHO, 2000).

Outdoor studies consistently indicate that children with chronic ambient NO_2 exposures exhibit increased respiratory symptoms that are of a longer duration. However, no evidence is provided for the association of long-term exposures with health effects in adults (WHO, 2000).

Summary of Key Pollutants and Associated Health Effects

Table 10 provides a summary of the health effects posed by common atmospheric pollutants.

Table 10: Pollutants and associated health effects

Pollutant	Acute exposure	Chronic exposure
Particulate matter	▪ Airway allergic inflammatory reactions and a wide range of respiratory problems ▪ Increase in medication usage related to asthma, nasal congestion and sinuses problems	▪ Increase in lung problems with lower respiratory symptoms ▪ Reduction in lung function in children and adults ▪ Increase in chronic obstructive pulmonary disease

Pollutant	Acute exposure	Chronic exposure
	■ Adverse effects on the cardiovascular system ■ Increase in hospital admissions ■ Increase in mortality	■ Reduction in life expectancy ■ Reduction in lung function development
Sulphur dioxide	■ Reduction in lung function ■ Respiratory symptoms (wheeze and cough) ■ Increase in hospital admissions ■ Increase in mortality	■ Increase in respiratory symptoms ■ Reduction in lung function, especially in asthmatics and children ■ Reduction in life expectancy ■ Increase in mortality
Nitrogen dioxide	■ Effects on pulmonary function, especially in asthmatics ■ Increase in airway allergic inflammatory reactions ■ Increase in hospital admissions ■ Increase in mortality	■ Reduction in lung function ■ Increased probability of respiratory symptoms ■ Reduction in life expectancy ■ Increase in mortality

6.9 Ambient Air Quality Monitoring

Baseline air quality monitoring was conducted in the area by Golder in 2014; the campaign lasted for 3 months (April to June) with monitoring at 11 locations as shown in Figure 17 and Table 11. Dust fallout and passive diffuse samplers (NO_2, SO_2, H_2S and BTEX) were installed at all sampling locations and particulate samplers at Well Pads T-12 and T-16. It is Golders opinion that current air quality in the region is similar to that of the 2014 study, since activities in the area seem to have remained largely unchanged.

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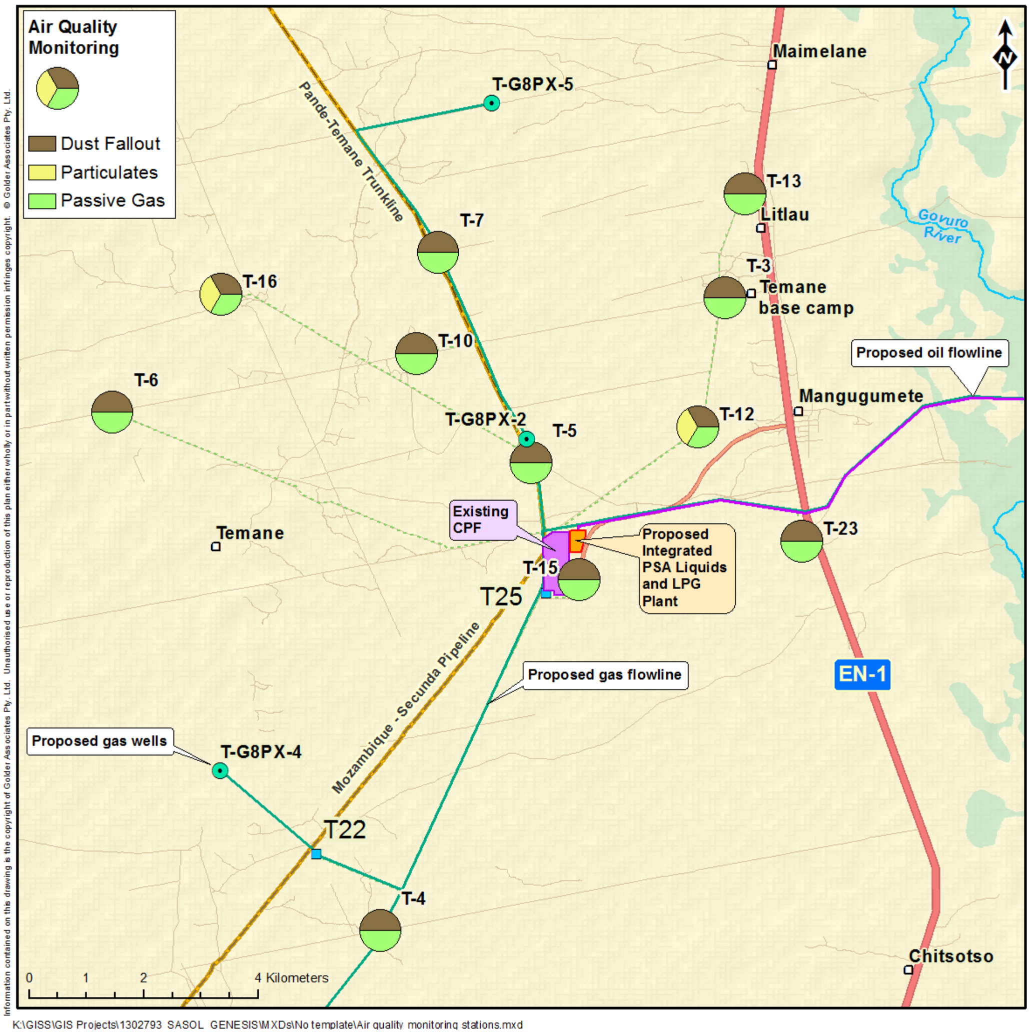


Figure 17: Sampling locations (April and June 2014)

Table 11: Sampling Locations

Site	Well Pad	Particulates	Dust Fallout	Passive Gas	South (°)	East (°)
1	T03		x	x	-21.70750	35.08681
2	T04		x	x	-21.80690	35.03278
3	T05		x	x	-21.73340	35.05636
4	T06		x	x	-21.72540	34.99072
5	T07		x	x	-21.70040	35.04183
6	T10		x	x	-21.71630	35.03853
7	T12	x	xx[a]	xx[a]	-21.72780	35.08258
8	T13		x	x	-21.69120	35.08997
9	T15		x	x	-21.75180	35.06400
10	T16	x	xx[a]	xx[a]	-21.70700	35.00783
11	T23		x	x	-21.74580	35.09886

Notes: [a] Duplicate sampling for dust fallout and gasses (NO_2, SO_2, H_2S and BTEX) was conducted at Well Pad 12 and 16.

Dust Fallout

Dust fallout samples were collected in accordance with the standard test method for collection and measurement of dust fallout (settleable particulate matter), ASTM D1739. Monthly dust deposition rates, expressed as milligrams per square metre per day (mg/m^2/day), were determined for each of the sampling locations.

The results of the dust fallout monitoring are presented as follows:

- April 2014 (Figure 18);
- May 2014 (Figure 19); and
- June 2014 (Figure 20).

Dust fallout levels did not exceed 200 mg/m^2/day, the RSA residential standard is 600 mg/m^2/day.

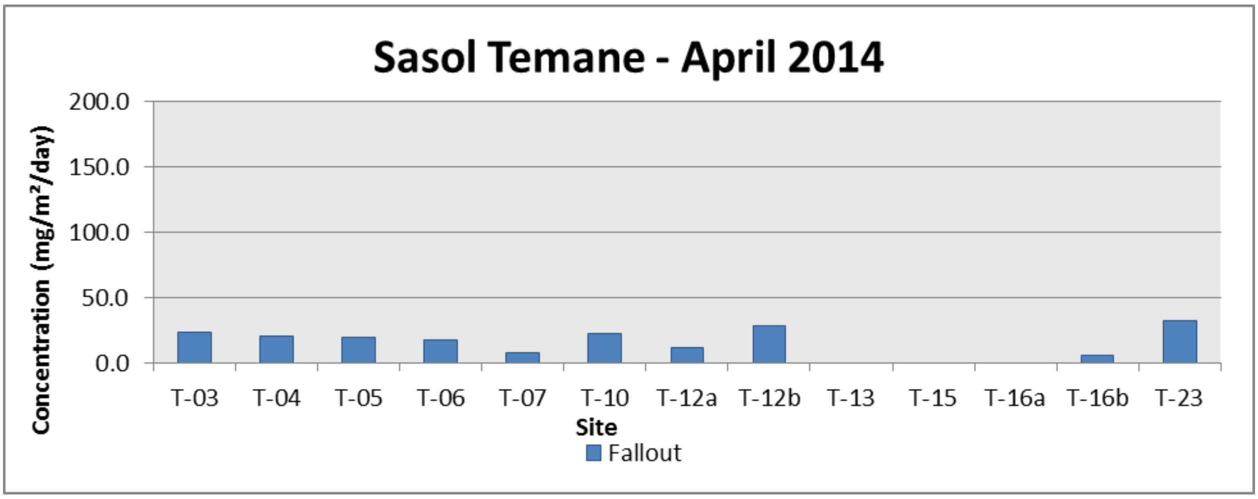


Figure 18: Dust fallout monitoring at Sasol Temane – April 2014

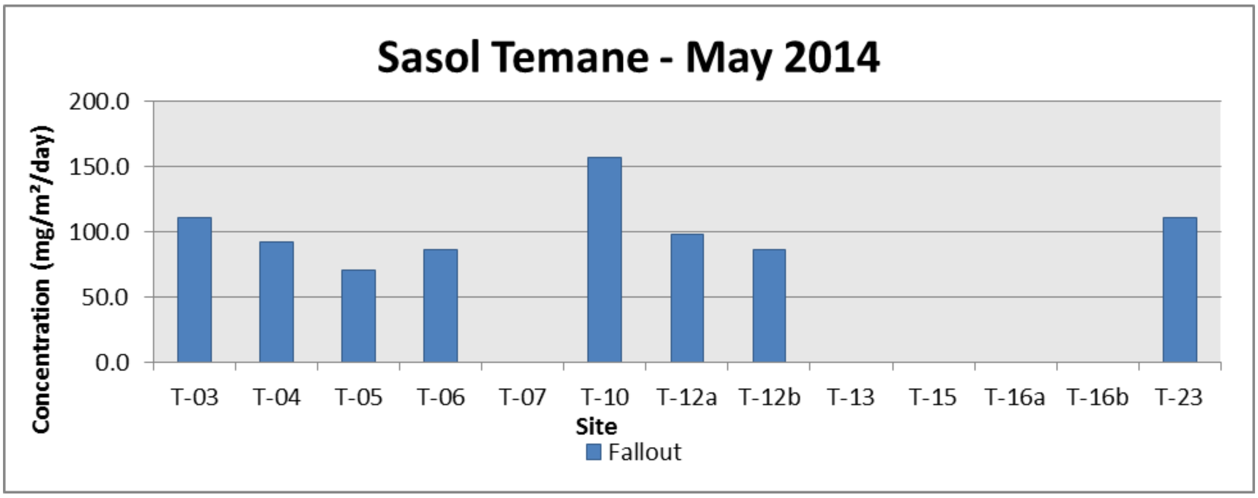


Figure 19: Dust fallout monitoring at Sasol Temane – May 2014

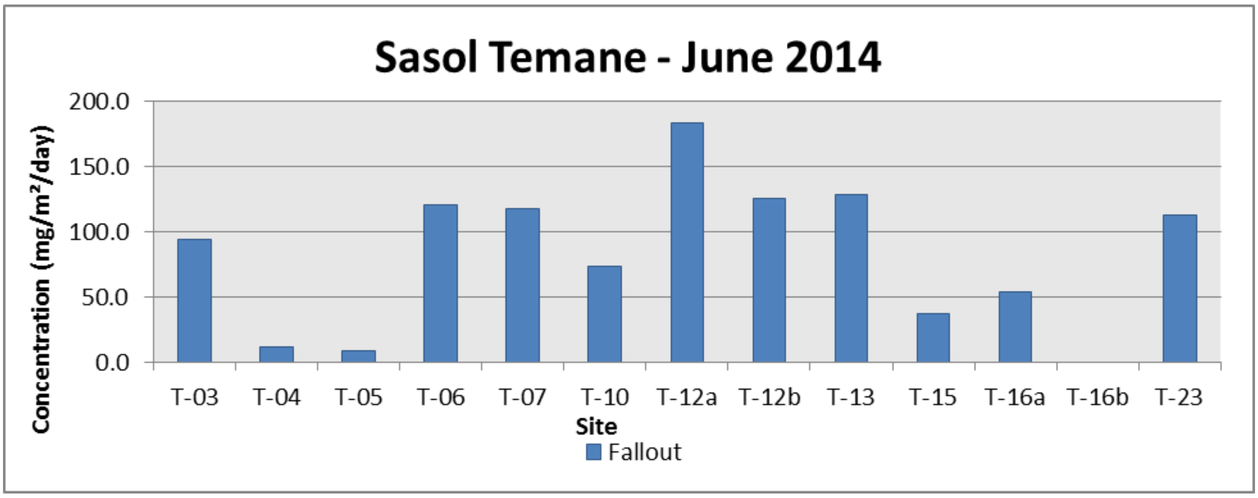


Figure 20: Dust fallout monitoring at Sasol Temane – June 2014

Particulates (PM_{10})

PM_{10} sampling was conducted at the CPF by means of MetOne E-samplers and the monitored concentrations were verified gravimetrically. Figure 21 and Figure 22 summarise the measured PM_{10} concentration during the monitoring campaign. Particulate levels did not exceed the IFC daily guideline (50 µg/m³).

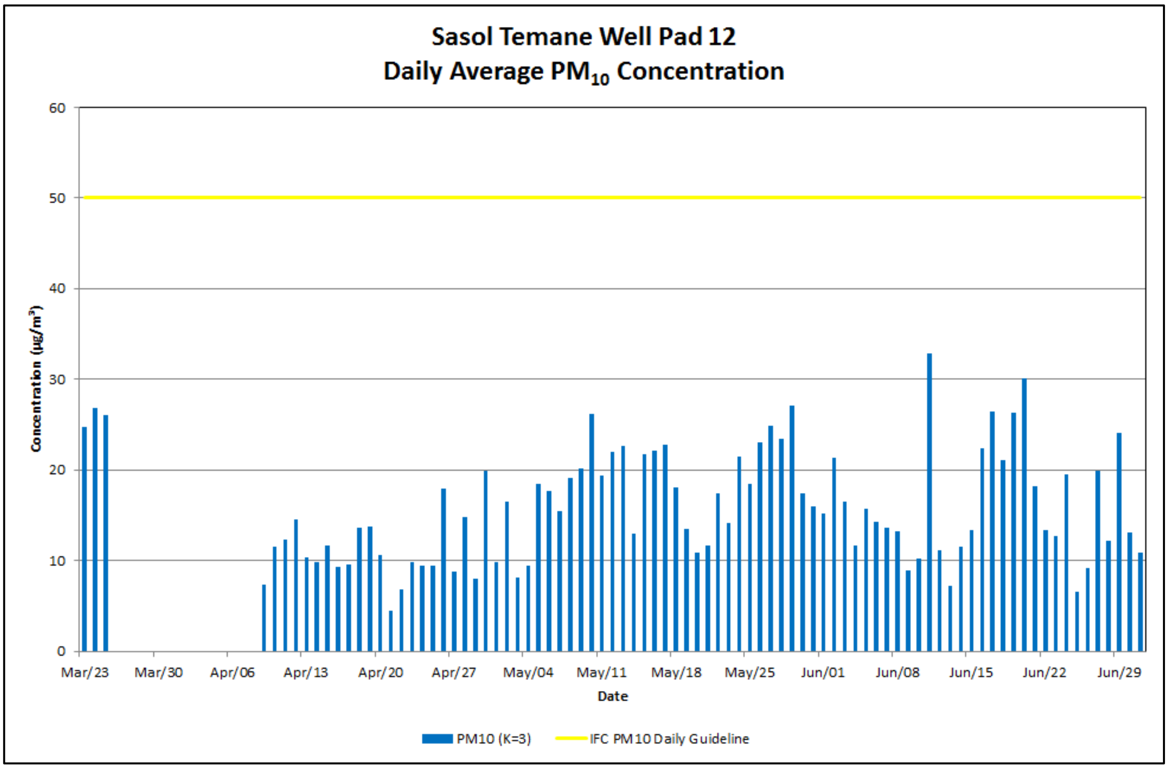


Figure 21: PM_{10} monitoring at Sasol Temane – Well Pad 12

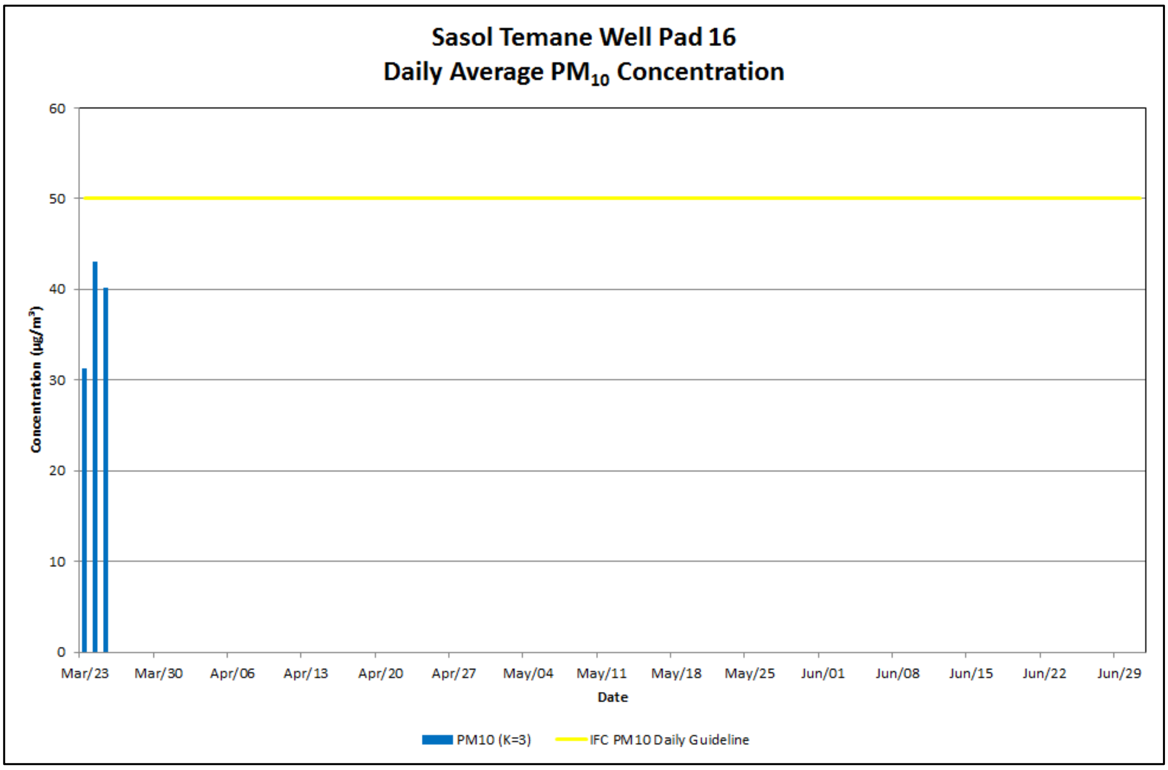


Figure 22: PM_{10} monitoring at Sasol Temane – Well Pad 16

Sulphur Dioxide and Nitrogen Dioxide (SO_2 and NO_2)

Radiello passive sampling tubes were used for SO_2 and NO_2 measurement, the results of the monitoring are presented as follows:

- April 2014 (Figure 23);
- May 2014 (Figure 24); and
- June 2014 (Figure 25).

NO_2 concentrations did not exceed the IFC annual guideline (40 µg/m³). SO_2 concentrations did not exceed the IFC daily (20 µg/m³); this is also the IFC annual guideline.

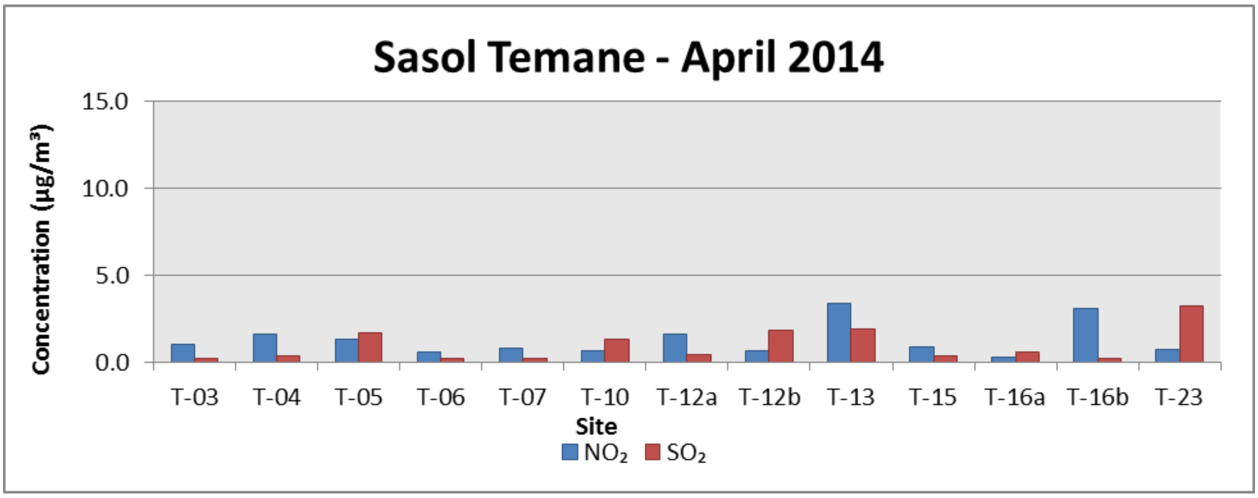


Figure 23: NO_2 and SO_2 monitoring at Sasol Temane – April 2014

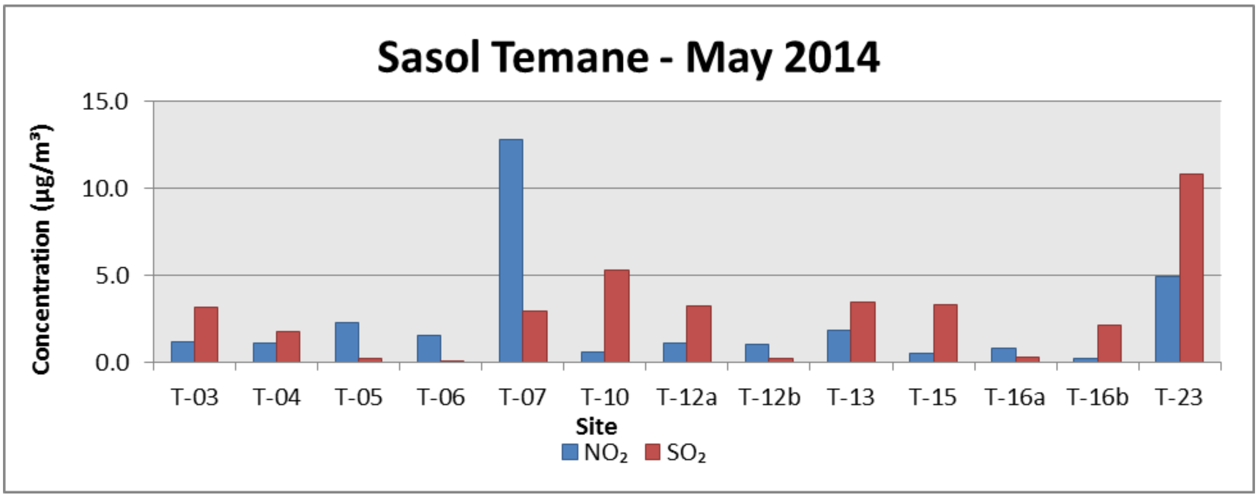


Figure 24: NO_2 and SO_2 monitoring at Sasol Temane – May 2014

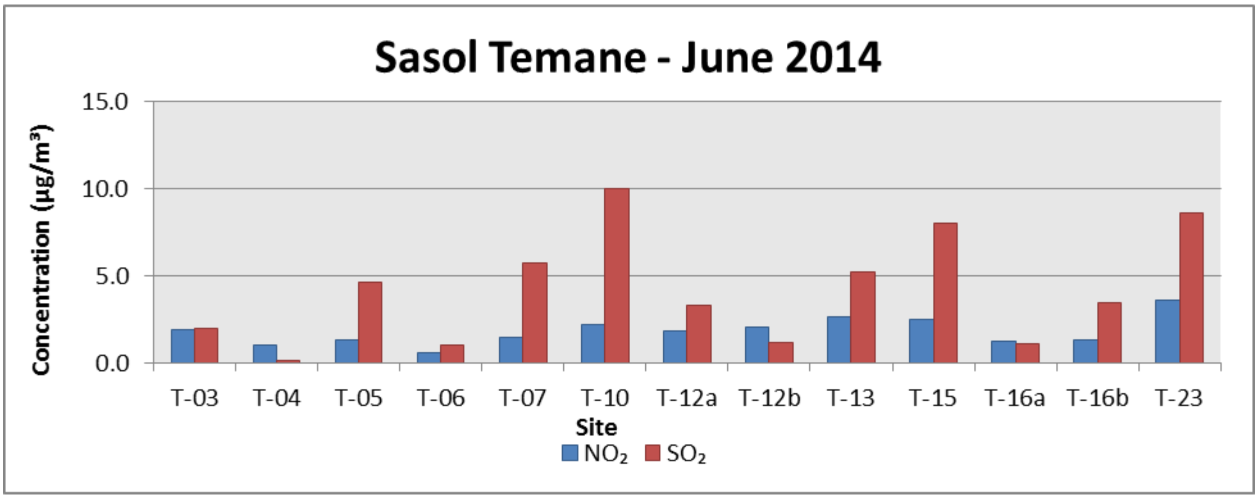


Figure 25: NO_2 and SO_2 monitoring at Sasol Temane – June 2014

Hydrogen Sulphide (H_2S)

Radiello passive sampling tubes were used to measure H_2S; all measurements were below the detection limit for the method (0.01 µg/m³).

Volatile Organic Compounds (VOC's)

Radiello passive sampling tubes were used to measure VOC's (Benzene, Toluene, Ethylbenzene and Xylene) the results of the monitoring are presented as follows:

- April 2014 (Figure 26);
- May 2014 (Figure 27); and
- June 2014 (Figure 28).

None of the parameters measured exceeded the EU annual Benzene guideline (5 µg/m³), guidelines for Toluene (1910 µg/m³), Ethylbenzene (4410 µg/m³) and Xylene (4410 µg/m³) are significantly less stringent. The Toluene spike at T-07 during April is therefore not significant.

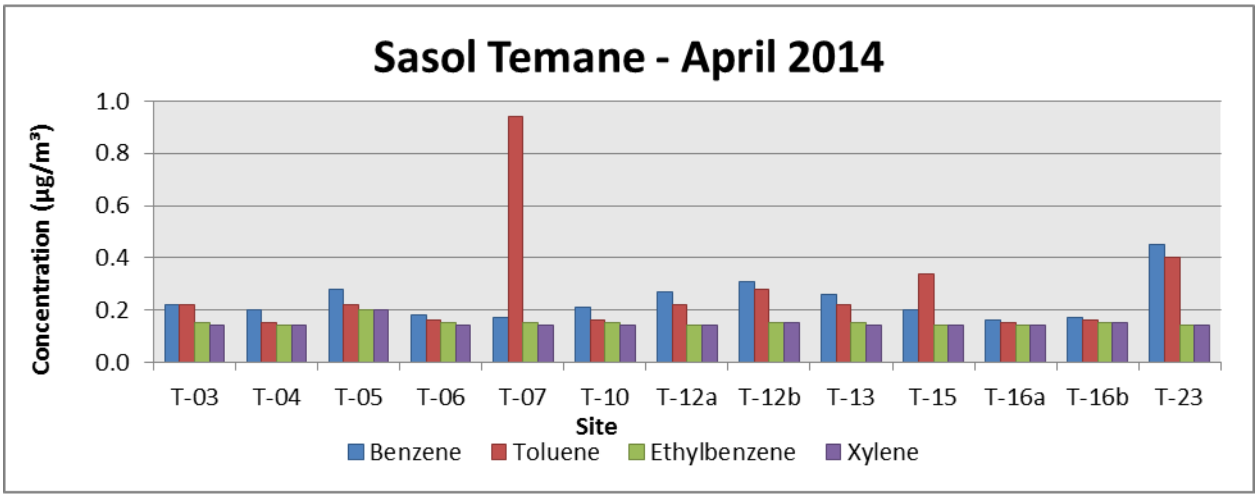


Figure 26: BTEX monitoring at Sasol Temane – April 2014

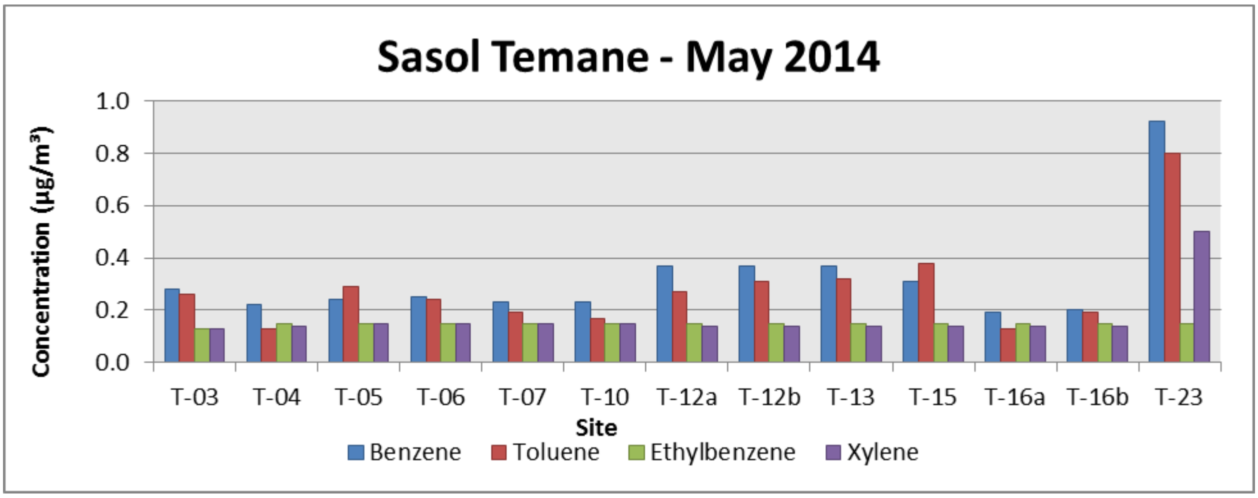


Figure 27: BTEX monitoring at Sasol Temane – May 2014

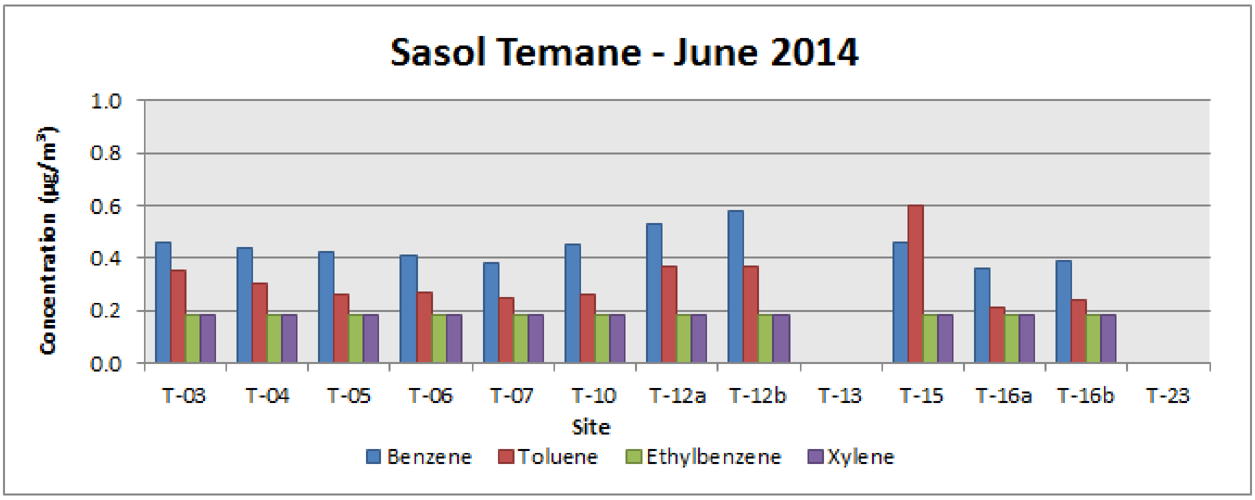


Figure 28: BTEX monitoring at Sasol Temane – June 2014

Summary of the regional air quality

Current air quality was assessed based on:

- Local sources identified and the anticipated emissions thereof, as well as
- Ambient air quality monitoring conducted in the area.

The conclusion of this assessment is that that current air quality in the project area is not degraded and thus the project is not within a degraded airshed as defined by the IFC.

7.0 IMPACT ASSESSMENT

7.1 Identified impacts - Open Cycle Gas Engines

Construction Phase Impacts

Air quality impacts during this phase are associated with the construction of the key project components, ancillary infrastructure and preparation of the temporary beach landing sites and various route alternative. Specific activities that would generate impacts include earthworks, terracing, refurbishing of old, and erection of new surface infrastructure, blasting, vehicle usage and backup power generation.

Table 12: OCGE construction phase impacts assessment matrix

	Pre-mitigation					Post-mitigation				
Indicator of potential impact	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Impact of PM_{10}	4	2	2	5	Low 40	2	2	2	5	Low 30
Impact of NO_2	4	2	2	5	Low 40	2	2	2	5	Low 30
Impact of SO_2	4	2	2	5	Low 40	2	2	2	5	Low 30

Construction phase impacts are anticipated to be of low significance and mitigation measures may however be implemented to further reduce impacts, such measures include:

- Particulates (PM_{10}):
  - Wet suppression (wet misting during material handling activities);
  - Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation;
  - Progressive rehabilitation and re-vegetation of areas when operationally available;
  - Reduction in unnecessary traffic volumes;
  - Routine inspections to identify areas of unpaved roads that are increasingly dusty;
  - Maintenance work to be undertaken on these areas including watering, application of dust suppressants, compaction, dust removal and/or utilisation of soil aggregate; and
  - Vehicles and machinery to be serviced regularly to reduce the generation of black tailpipe smoke;
  - Speed control and the institution of traffic calming measures; and
  - No burning of waste onsite
- Trace Gasses (NO_2 / SO_2):
  - Maintain and service all vehicles, backup power generation and other equipment regularly to ensure that emissions are kept to a minimum;
  - Where possible, use low sulphur fuels to reduce SO_2 emissions;
  - Vehicles and machinery should be turned off when not in use to avoid unnecessary idling (i.e. idling should be limited to a maximum of three minutes on site); and
  - No burning of waste onsite.

Operational Phase Impacts

This OCGE configuration is characterized by 24 Gas Engines with a N+1 sparing philosophy and provides large flexibility to meet any power plant load maintaining high efficiency (FW, 2014). The plant will be designed having four identical modules, each module containing six gas engines, all feeding into a common stack per module. Emission parameters and rates for normal operation (23 gas engines at base load 100%) are presented in Table 13.

Table 13: OCGE Emission parameters

Item	Value	Units
Stack Height	30	m
Stack Diameter	1.6	m
Stack Exit Velocity	28	m/s
Stack Exit Temperature	644	K
Carbon Monoxide (CO)	7374	tpa
Nitrogen Dioxide (NO_2)	4490	tpa
Particulates < 10 µm (PM_{10})	198	tpa
Sulphur Dioxide (SO_2)	23	tpa

The impacts associated with the above configuration were simulated and plots are provided for:

OCGE operations:

- Maximum daily PM_{10} concentration (Figure 30);
- Maximum annual PM_{10} concentration (Figure 31);
- Maximum daily NO_2 concentration (Figure 32;
- Maximum annual NO_2 concentration (Figure 33); and,
- Maximum daily PM_{10} concentration (Figure 34).

The plots are colour coded according to the air quality index (AQI) shown in Figure 29. The colour scale ranges from blue (indicating a low concentration relative to the standard / guideline), to red (indicating an exceedance of the standard / guideline). Table 14 contains a summary of impacts on various sensitive receptors, points of interest. Figure 35 indicates the locations of structures with a significant NO_2 impacts (hourly average NO_2 concentration exceeding 25% of the IFC guideline 200 µg/m^3).

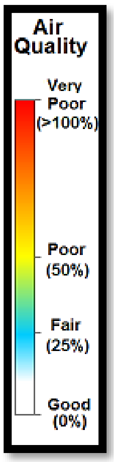
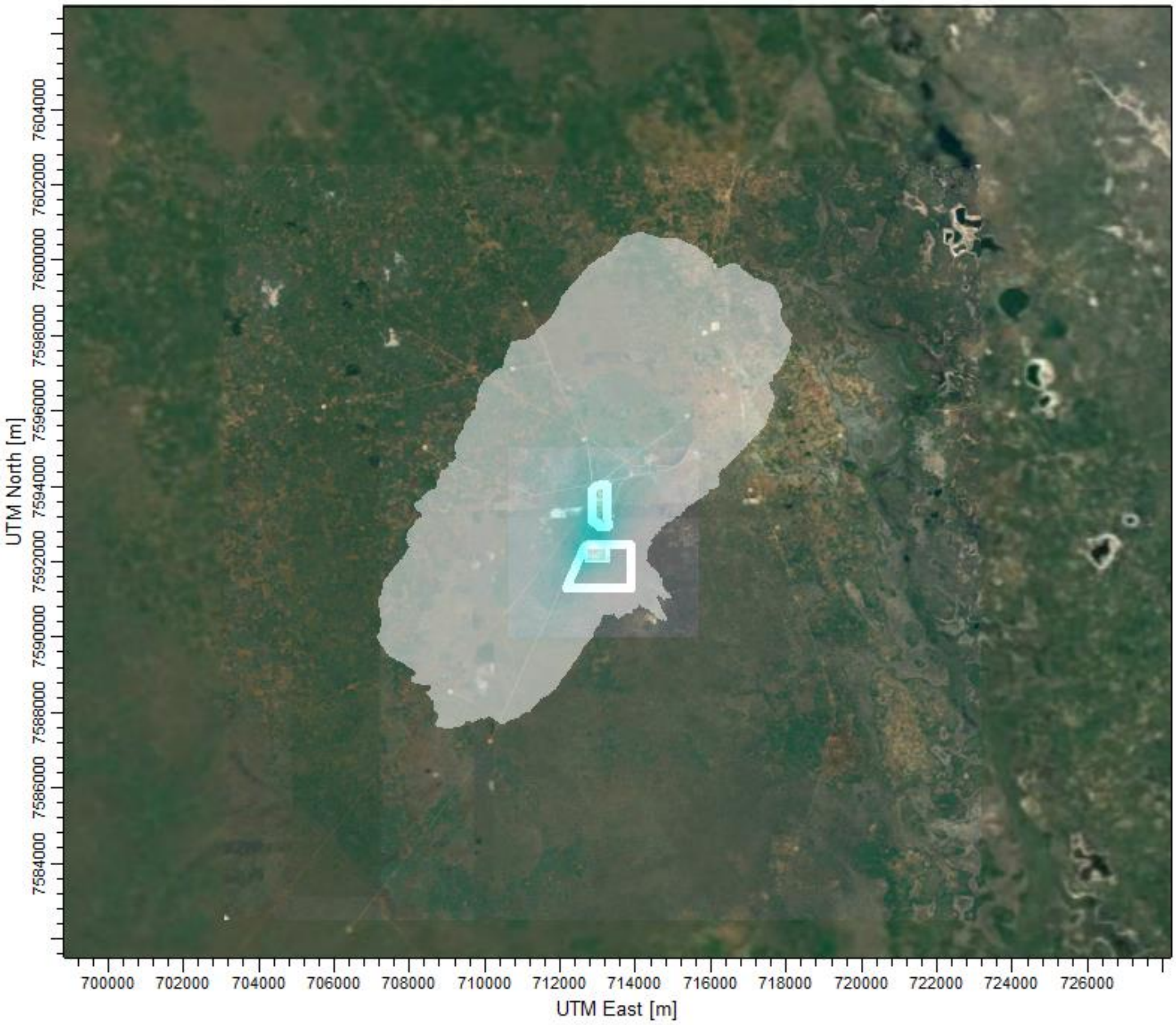


Figure 29: Air quality index

PROJECT TITLE:

Central Térmica de Temane
Open Cycle Gas Engines (OCGE)



IFC Daily PM10 Guideline (50 µg/m³) µg/m³

Maximum Daily PM10 Concentration (99th Percentile)

0 1 5 25 50

COMMENTS:	SOURCES:	COMPANY NAME:	
White polygons - existing CPF and proposed project area.	**4**	**Golder Associates**	
	RECEPTORS: **12771**	MODELER: **Lance Coetzee**	GOLDER
	OUTPUT TYPE: **Concentration**	SCALE: 1:150,000 (0 – 5 km)	
	MAX: **7 µg/m³**	DATE: **2018-09-27**	PROJECT NO.: **18103533**

Figure 30: OCGE maximum daily PM_{10} (99th percentile) concentration

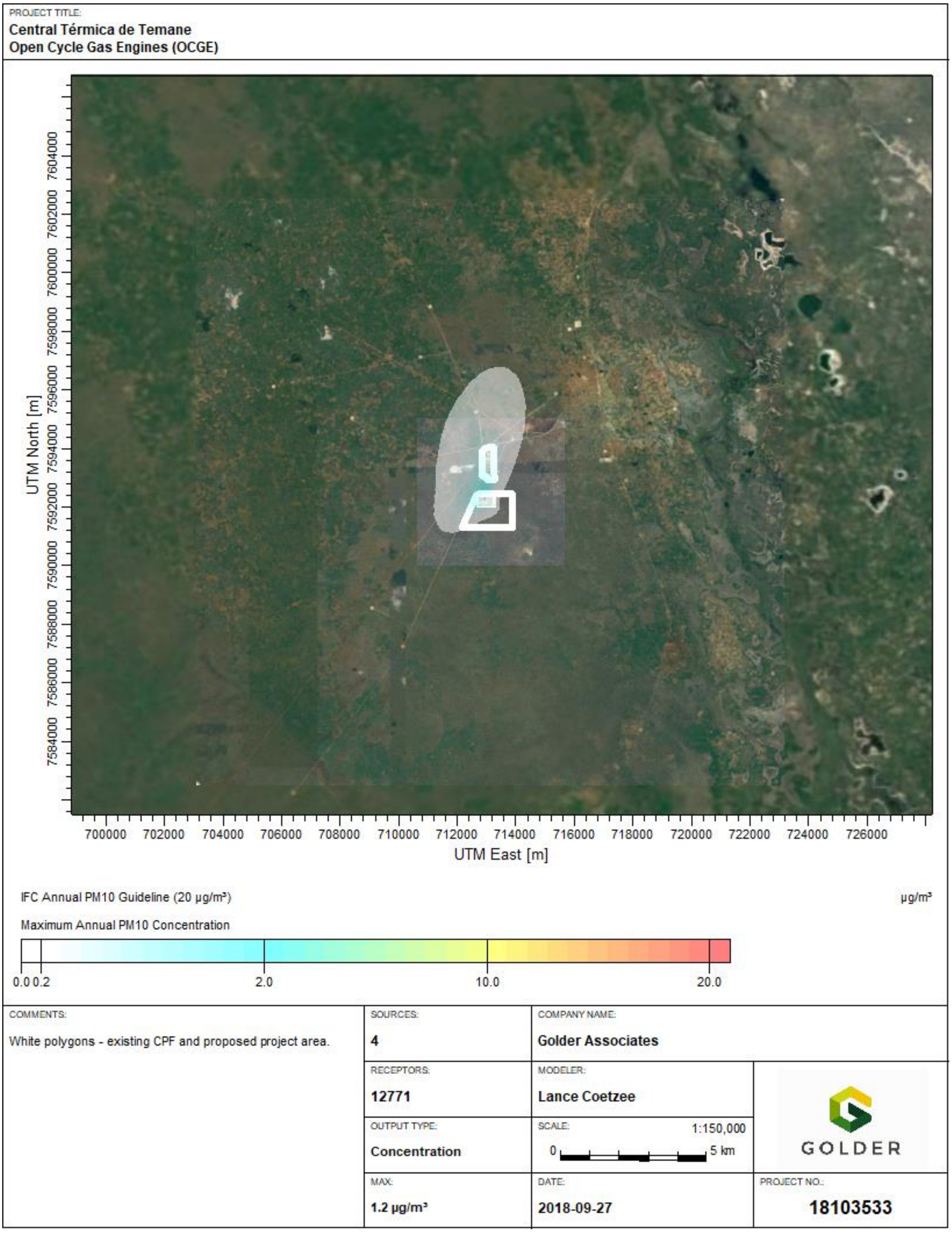


Figure 31: OCGE maximum annual PM_{10} concentration

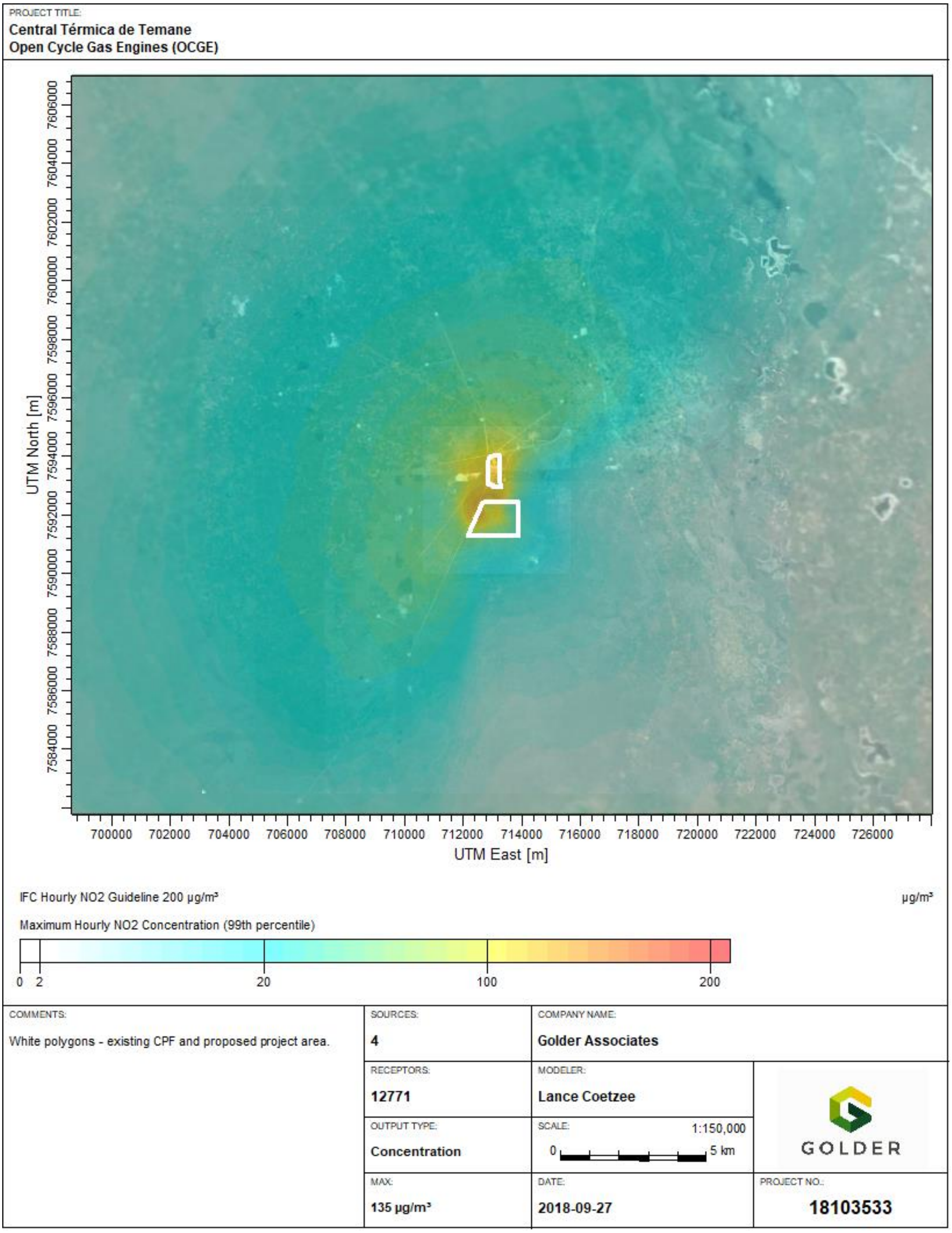


Figure 32: OCGE maximum daily NO_2 (99th percentile) concentration

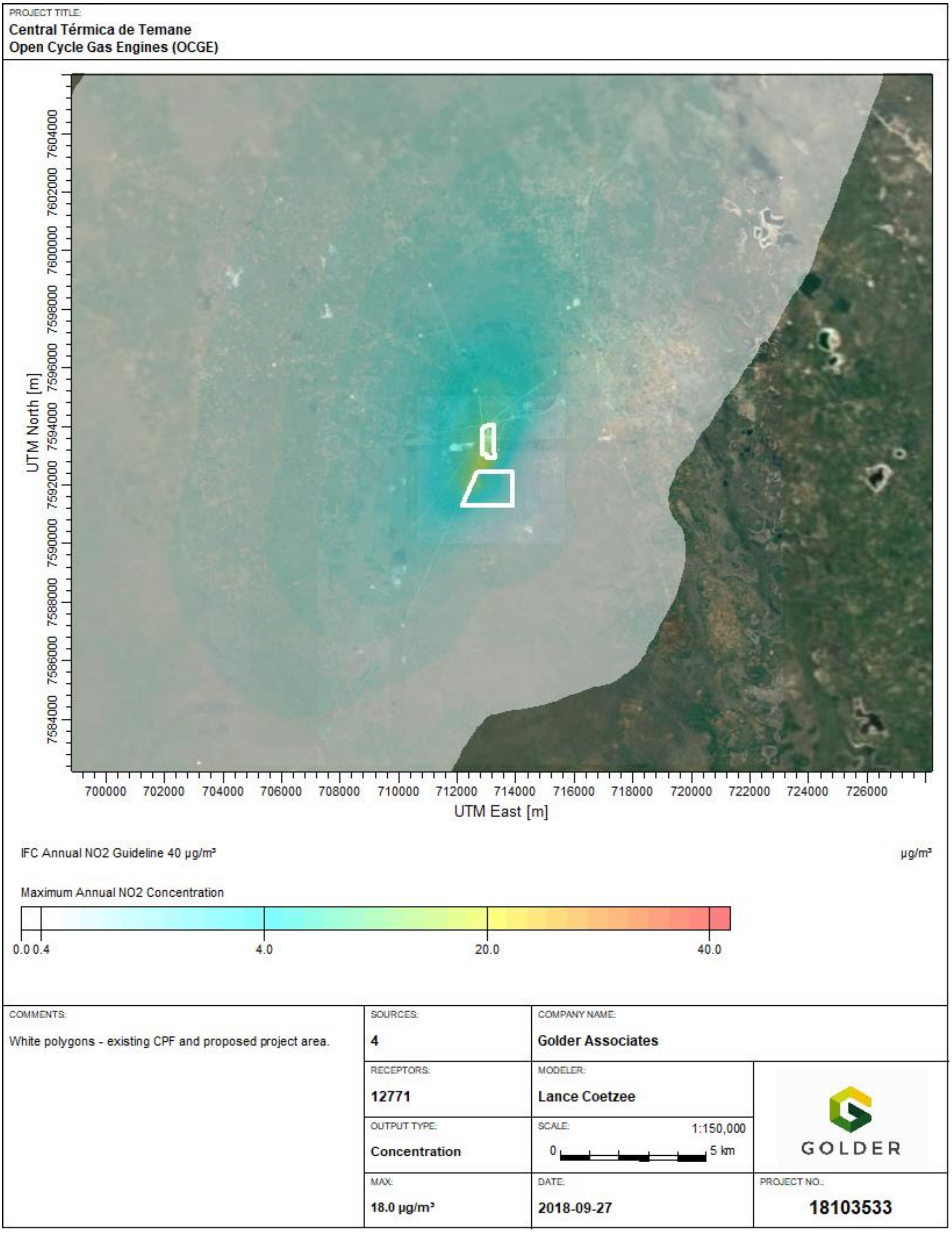
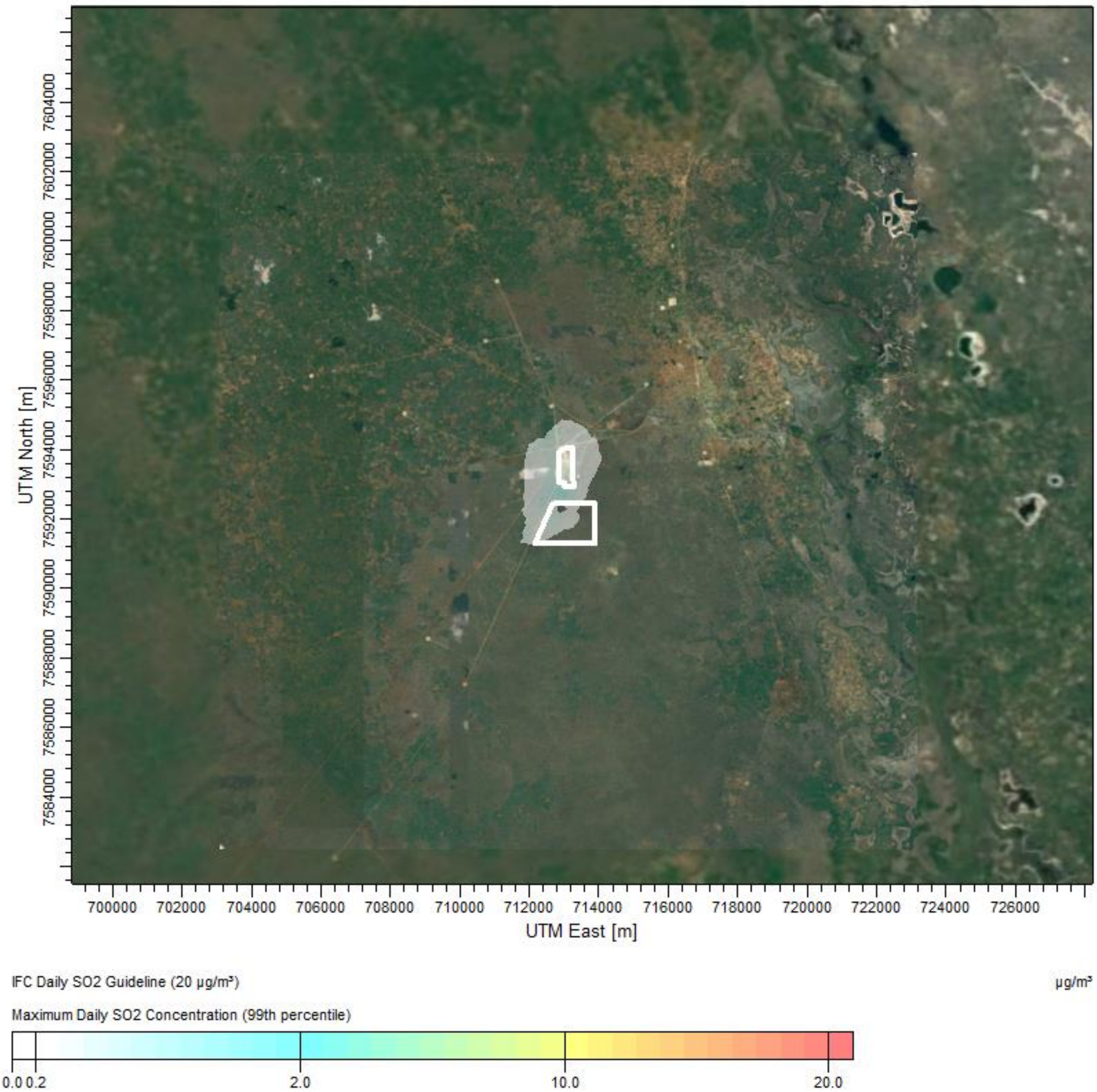


Figure 33: OCGE maximum annual NO_2 concentration

PROJECT TITLE:

Central Térmica de Temane
Open Cycle Gas Engines (OCGE)



COMMENTS:	SOURCES:	COMPANY NAME:	
White polygons - existing CPF and proposed project area.	**4**	**Golder Associates**	
	RECEPTORS: **12771**	MODELER: **Lance Coetzee**	GOLDER
	OUTPUT TYPE: **Concentration**	SCALE: 1:150,000 0 — 5 km	
	MAX: **0.8 µg/m³**	DATE: **2018-09-27**	PROJECT NO.: **18103533**

Figure 34: OCGE maximum annual SO_2 (99th percentile) concentration

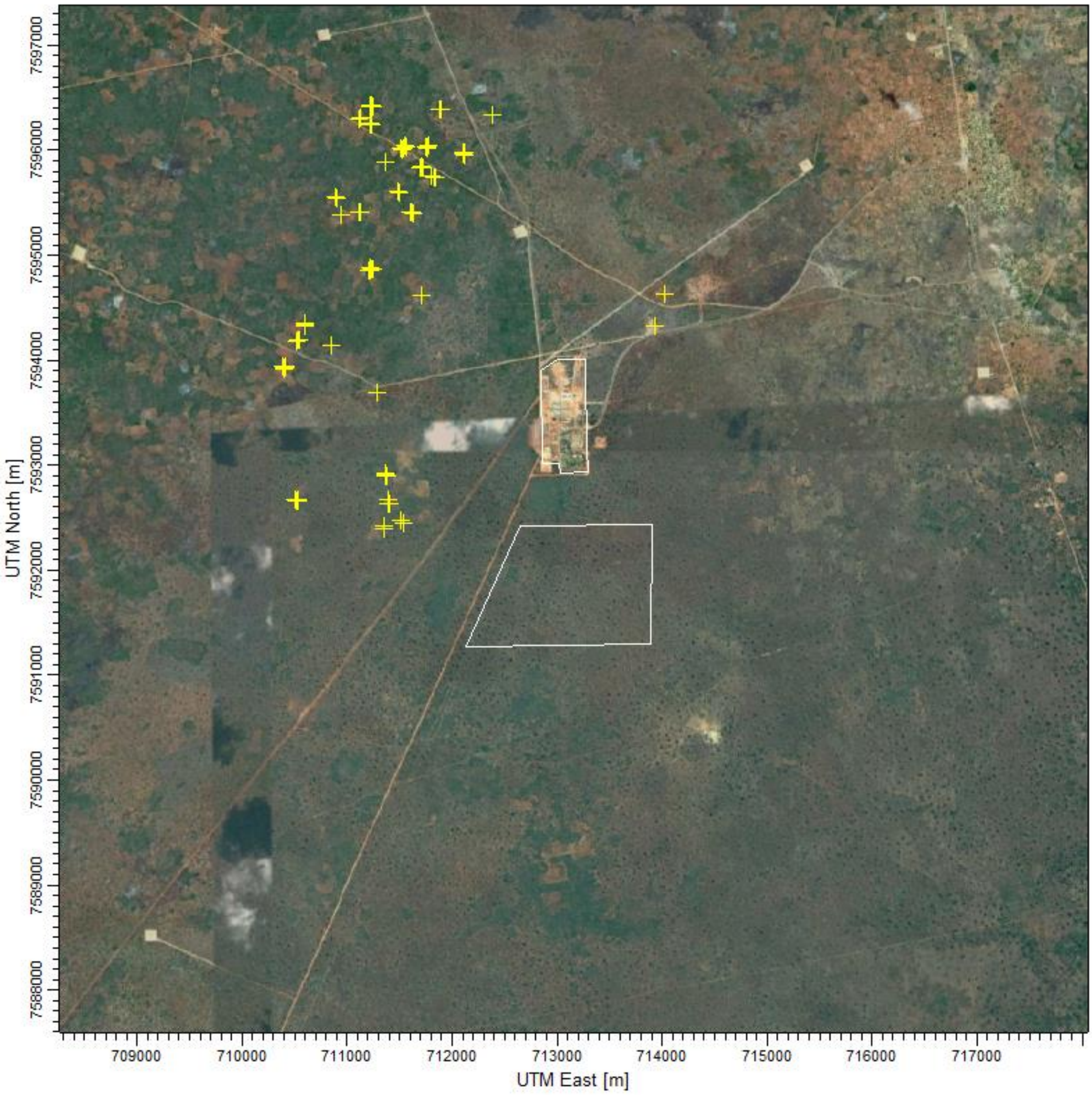
Table 14: OCGE summary of impacts on sensitive receptors and points of interest

#	Receptor	Daily Maximum		Annual Maximum		Hourly Maximum		Annual Maximum		Daily Maximum	
		PM_{10} (µg/m³)	% of IFC Standard (50 µg/m³)	PM_{10} (µg/m³)	% of IFC Standard (20 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (200 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (40 µg/m³)	SO_2 (µg/m³)	% of IFC Standard (20 µg/m³)
1	Health Centre - Mangungumete	1	1%	0	0%	34	17%	2	4%	0	0%
2	Health Centre - Temane	0	1%	0	0%	36	18%	2	4%	0	0%
3	Orphanage	2	3%	0	1%	74	37%	5	13%	0	1%
4	Primary school - Mangugumete	1	1%	0	0%	30	15%	1	3%	0	0%
5	Primary School - Temane	0	1%	0	0%	34	17%	1	3%	0	0%
6	Primary school -Chitsotso	0	0%	0	0%	7	4%	0	1%	0	0%
7	School - Litlau	1	1%	0	0%	29	15%	2	4%	0	0%
8	School - Manusse	0	1%	0	0%	22	11%	1	2%	0	0%
9	School - Temane Base Camp	1	1%	0	0%	32	16%	2	5%	0	0%
10	Chipongo	0	0%	0	0%	3	1%	0	0%	0	0%
11	Chitsotso	0	0%	0	0%	7	4%	0	1%	0	0%
12	Inhassoro	0	0%	0	0%	7	3%	0	1%	0	0%
13	Litlau	1	1%	0	0%	29	15%	2	4%	0	0%
14	Mabime	0	0%	0	0%	9	4%	0	1%	0	0%
15	Macovane	0	0%	0	0%	5	3%	0	1%	0	0%
16	Maimelane	0	1%	0	0%	22	11%	1	4%	0	0%
17	Mangarelane I	0	0%	0	0%	5	2%	0	1%	0	0%
18	Mangarelane II	0	0%	0	0%	9	5%	0	1%	0	0%
19	Mangugumete	1	1%	0	0%	30	15%	1	3%	0	0%
20	Manusse	0	1%	0	0%	22	11%	1	2%	0	0%

#	Receptor	Daily Maximum		Annual Maximum		Hourly Maximum		Annual Maximum		Daily Maximum	
		PM_{10} (µg/m³)	% of IFC Standard (50 µg/m³)	PM_{10} (µg/m³)	% of IFC Standard (20 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (200 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (40 µg/m³)	SO_2 (µg/m³)	% of IFC Standard (20 µg/m³)
21	Mapanzene	0	0%	0	0%	3	2%	0	0%	0	0%
22	Temane	0	1%	0	0%	34	17%	1	3%	0	0%
23	Temane Base Camp	1	1%	0	0%	32	16%	2	5%	0	0%
24	Vilanculos	0	0%	0	0%	2	1%	0	0%	0	0%
25	Vulanjane	0	1%	0	0%	15	8%	1	3%	0	0%
26	T-03 Well Pad	1	1%	0	1%	34	17%	2	5%	0	0%
27	T-04 Well Pad	0	1%	0	0%	29	15%	1	3%	0	0%
28	T-05 Well Pad	1	3%	0	1%	68	34%	6	14%	0	1%
29	T-06 Well Pad	0	1%	0	0%	23	12%	1	2%	0	0%
30	T-07 Well Pad	0	1%	0	0%	31	15%	2	5%	0	0%
31	T-10 Well Pad	1	1%	0	1%	39	19%	2	6%	0	0%
32	T-12 Well Pad	1	2%	0	1%	44	22%	2	6%	0	1%
33	T-13 Well Pad	0	1%	0	0%	28	14%	2	5%	0	0%
34	T-15 Well Pad	3	6%	0	2%	103	52%	9	21%	0	2%
35	T-16 Well Pad	0	1%	0	0%	25	12%	1	3%	0	0%
36	T-23 Well Pad	0	1%	0	0%	14	7%	1	2%	0	0%
37	CTT	3	6%	0	2%	110	55%	6	16%	0	2%
38	CPF	4	8%	1	3%	122	61%	12	31%	0	2%
39	Proposed Well Pad	0	1%	0	0%	36	18%	2	4%	0	0%
40	Proposed Well Pad	1	1%	0	0%	37	18%	2	4%	0	0%
41	Electricidade de Moçambique	2	3%	0	1%	77	39%	5	14%	0	1%

#	Receptor	Daily Maximum		Annual Maximum		Hourly Maximum		Annual Maximum		Daily Maximum	
		PM_{10} (µg/m³)	% of IFC Standard (50 µg/m³)	PM_{10} (µg/m³)	% of IFC Standard (20 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (200 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (40 µg/m³)	SO_2 (µg/m³)	% of IFC Standard (20 µg/m³)
42	Proposed Well Pad	0	0%	0	0%	15	7%	1	1%	0	0%
43	Proposed Well Pad	0	0%	0	0%	9	4%	0	1%	0	0%

PROJECT TITLE:
Central Térmica de Temane
Open Cycle Gas Engines (OCGE)



COMMENTS:	SOURCES:	COMPANY NAME:	
White polygons - existing CPF and proposed Project area. Yellow crosses - structures affected by NO2.	4	Golder Associates	
	RECEPTORS: 10874	MODELER: Lance Coetzee	GOLDER
		SCALE: 1:50,000 (0 – 2 km)	
		DATE: 2018-09-21	PROJECT NO.: 18103533

Figure 35: OCGE structures with significant NO_2 impacts (>25% of the hourly IFC guideline)

Table 15: OCGE - operational phase impact assessment matrix

	Pre-mitigation					Post-mitigation				
Indicator of potential impact	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Impact of PM_{10}	2	4	2	5	Low 40	2	4	2	5	Low 40
Impact of NO_2	4	4	2	5	Mod 50	2	4	2	5	Low 40
Impact of SO_2	2	4	2	5	Low 40	2	4	2	5	Low 40

Operational phase impacts are anticipated to be of low significance for PM_{10} and SO_2, additional mitigation will not be required for these parameters. Impacts for NO_2 were predicted to be moderate.

Measures aimed at reducing or mitigating NO_2 impacts from reciprocating gas engines include:

- An increase in stack height; and,
- Control Technologies:
  - Low NO_X burners;
  - Homogeneous Charge Compression Ignition (HCI); and
  - Flue-Gas Recirculation (FGR).

Decommissioning Phase Impacts

Air quality impacts during this phase are associated with the decommissioning of the key project components, ancillary infrastructure and preparation of the temporary beach landing sites and various route alternative. Specific activities that would generate impacts include earthworks, terracing, demolition of infrastructure, blasting, vehicle usage and backup power generation.

Table 16: OCGE decommissioning phase impact assessment matrix

	Pre-mitigation					Post-mitigation				
Indicator of potential impact	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Impact of PM_{10}	4	2	2	5	Low 40	2	2	2	5	Low 30
Impact of NO_2	4	2	2	5	Low 40	2	2	2	5	Low 30
Impact of SO_2	4	2	2	5	Low 40	2	2	2	5	Low 30

Decommissioning phase impacts are anticipated to be of low significance mitigation measures may be implemented to further reduce impacts, such measures include:

- Particulates (PM_{10}):
  - Wet suppression (wet misting during material handling activities);
  - Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation;
  - Progressive rehabilitation and re-vegetation of areas when operationally available;
  - Reduction in unnecessary traffic volumes;
  - Routine inspections to identify areas of unpaved roads that are increasingly dusty;
  - Maintenance work to be undertaken on these areas including watering, application of dust suppressants, compaction, dust removal and/or utilisation of soil aggregate; and
  - Vehicles and machinery to be serviced regularly to reduce the generation of black tailpipe smoke;
  - Speed control and the institution of traffic calming measures; and
  - No burning of waste onsite
- Trace Gasses (NO_2 / SO_2):
  - Maintain and service all vehicles, backup power generation and other equipment regularly to ensure that emissions are kept to a minimum;
  - Where possible, use low sulphur fuels to reduce SO_2 emissions;
  - Vehicles and machinery should be turned off when not in use to avoid unnecessary idling (i.e. idling should be limited to a maximum of three minutes on site); and,
  - No burning of waste onsite.

7.2 Identified impacts - Combined Cycle Gas Turbine

Construction Phase Impacts

Air quality impacts during this phase are associated with the construction of the key project components, ancillary infrastructure and preparation of the temporary beach landing sites and various route alternative. Specific activities that would generate impacts include earthworks, terracing, refurbishing of old, and erection of new surface infrastructure, blasting, vehicle usage and backup power generation.

Table 17: CCGT construction phase impacts assessment matrix.

	Pre-mitigation					Post-mitigation				
Indicator of potential impact	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Impact of PM_{10}	4	2	2	5	Low 40	2	2	2	5	Low 30
Impact of NO_2	4	2	2	5	Low 40	2	2	2	5	Low 30

	Pre-mitigation					Post-mitigation				
Impact of SO_2	4	2	2	5	Low 40	2	2	2	5	Low 30

Construction phase impacts are anticipated to be of low significance mitigation measures may be implemented to further reduce impacts, such measures include:

- Particulates (PM_{10}):
  - Wet suppression (wet misting during material handling activities);
  - Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation;
  - Progressive rehabilitation and re-vegetation of areas when operationally available;
  - Reduction in unnecessary traffic volumes;
  - Routine inspections to identify areas of unpaved roads that are increasingly dusty;
  - Maintenance work to be undertaken on these areas including watering, application of dust suppressants, compaction, dust removal and/or utilisation of soil aggregate; and
  - Vehicles and machinery to be serviced regularly to reduce the generation of black tailpipe smoke;
  - Speed control and the institution of traffic calming measures; and
  - No burning of waste onsite
- Trace Gasses (NO_2 / SO_2):
  - Maintain and service all vehicles, backup power generation and other equipment regularly to ensure that emissions are kept to a minimum;
  - Where possible, use low sulphur fuels to reduce SO_2 emissions;
  - Vehicles and machinery should be turned off when not in use to avoid unnecessary idling (i.e. idling should be limited to a maximum of three minutes on site); and,
  - No burning of waste onsite.

Operational Phase Impacts

The CCGT configuration is characterized by a high number of power generators (9 in total) and provides large flexibility to meet any power plant load maintaining high efficiency. It is based on three modules for electric power generation, each one constituted by the following main equipment in Table 18, the balance of plant units is common to the three-generation modules, providing all the utilities necessary for appropriate and safe operation of the Plant. (FW, 2014). Emission parameters and rates for normal operation (gas turbines at base load 100%) are presented in Table 19.

Table 18: CCGT modules

Item	Value	Units
Modules (identical)	3	unit/s
Gas turbines per module (heavy duty)	2	unit/s
Heat recovery steam generators per module	2	unit/s

Item	Value	Units
Steam turbines per module (condensing, no steam extraction)	1	unit/s
Air cooled condenser	1	unit/s
Stacks per module	2	unit/s

Table 19: CCGT emission parameters

Item	Value	Units
Stack Height	50	m
Stack Diameter	3.2	m
Stack Exit Velocity	17	m/s
Stack Exit Temperature	380	K
Carbon Monoxide (CO)	694	tpa
Nitrogen Dioxide (NO_2)	694	tpa
Particulates < 10 µm (PM_{10})	229	tpa
Sulphur Dioxide (SO_2)	19	tpa

The impacts associated with the above configuration were simulated and plots are provided for:

CCGT operations:

- Maximum daily PM_{10} concentration (Figure 37);
- Maximum annual PM_{10} concentration (Figure 38);
- Maximum daily NO_2 concentration (Figure 39;
- Maximum annual NO_2 concentration (Figure 40); and,
- Maximum daily PM_{10} concentration (Figure 41).

The plots are colour coded according to the air quality index (AQI) shown in Figure 36. The colour scale ranges from blue (indicating a low concentration relative to the standard / guideline), to red (indicating an exceedance of the standard / guideline). Table 20 contains a summary of impacts on various sensitive receptors and points of interest.

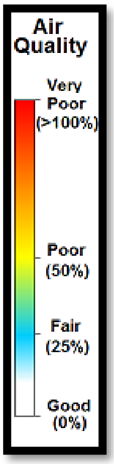


Figure 36: Air quality index

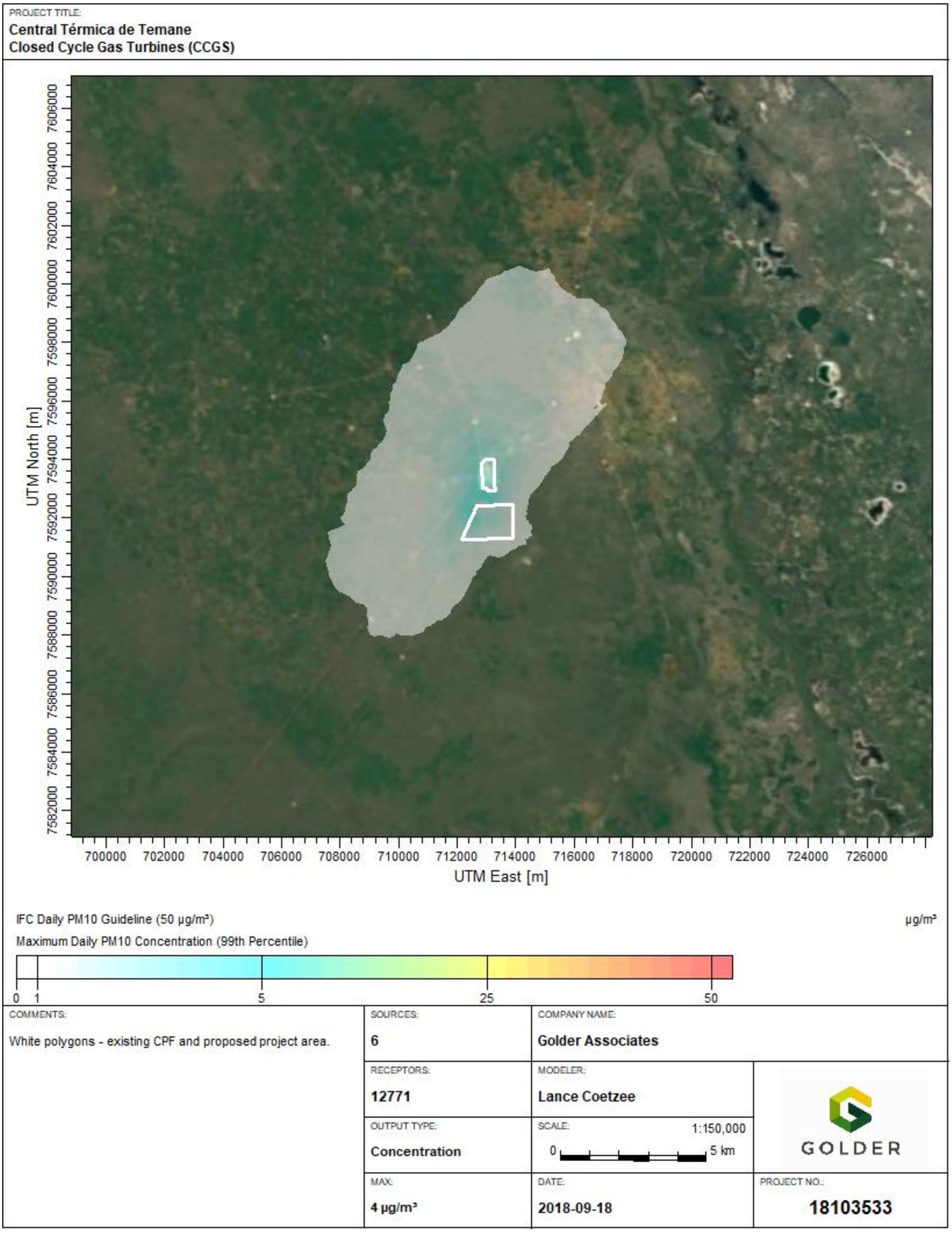


Figure 37: CCGT maximum daily PM_{10} (99th percentile) concentration

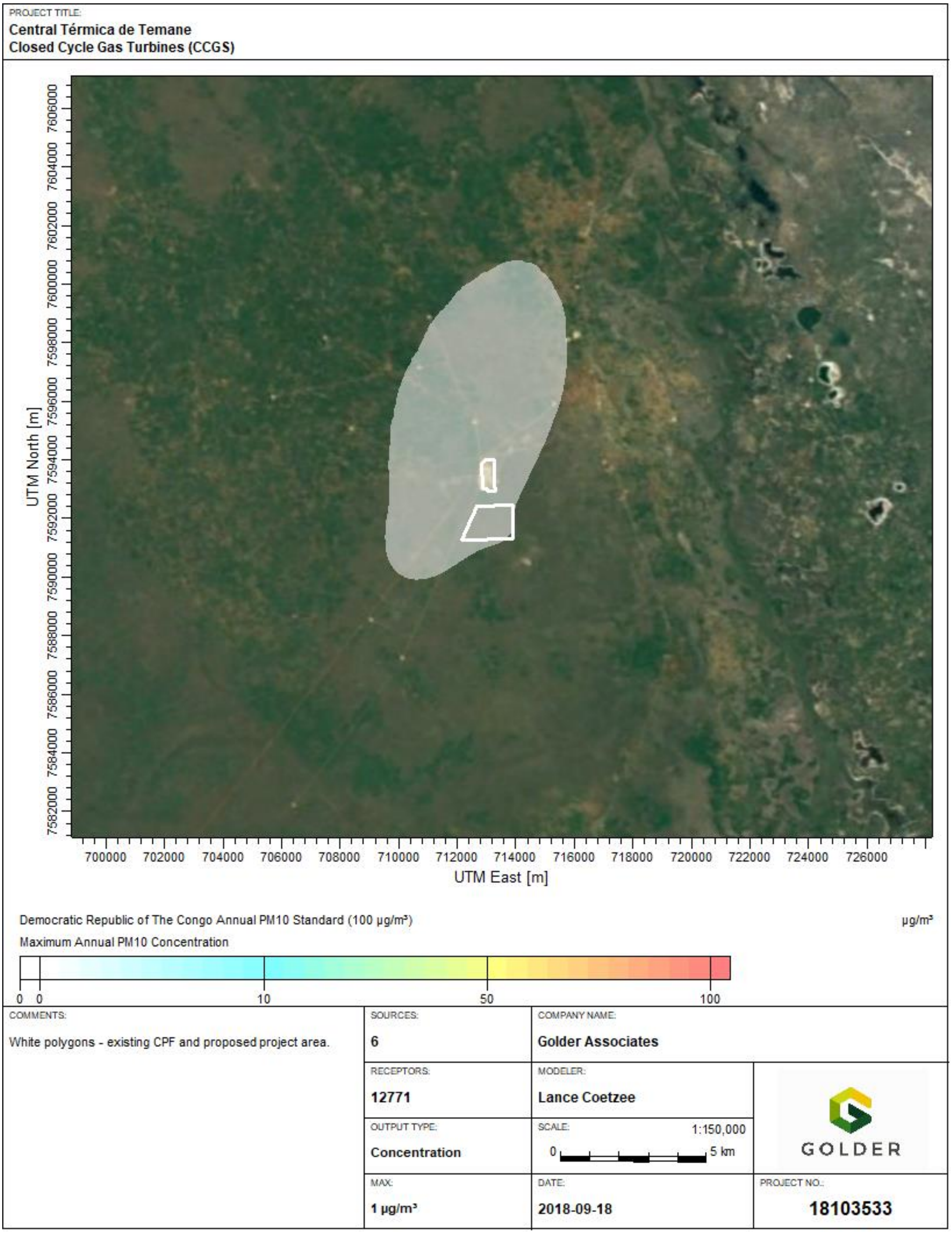


Figure 38: CCGT maximum annual PM_{10} concentration

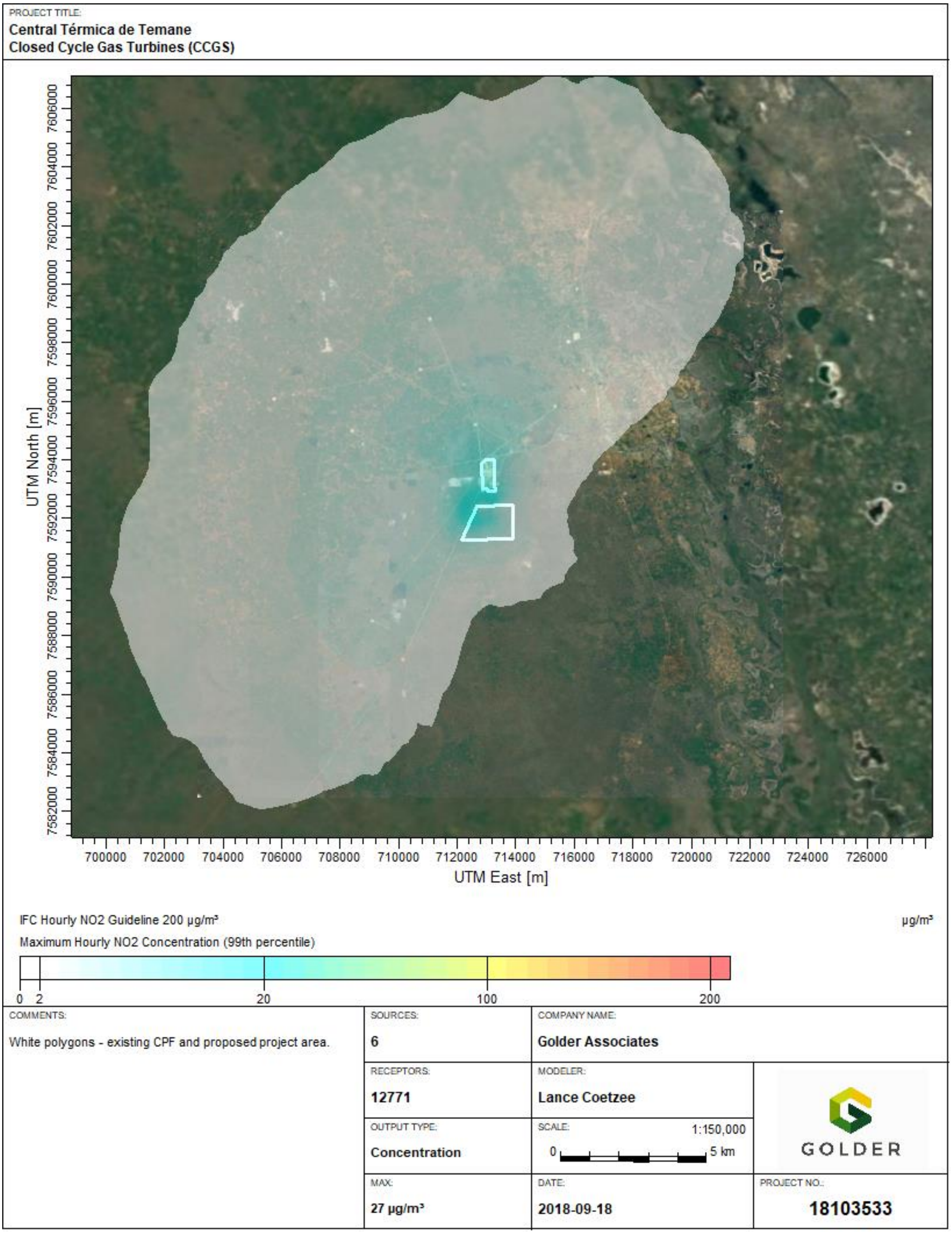


Figure 39: CCGT maximum hourly NO_2 (99th percentile) concentration

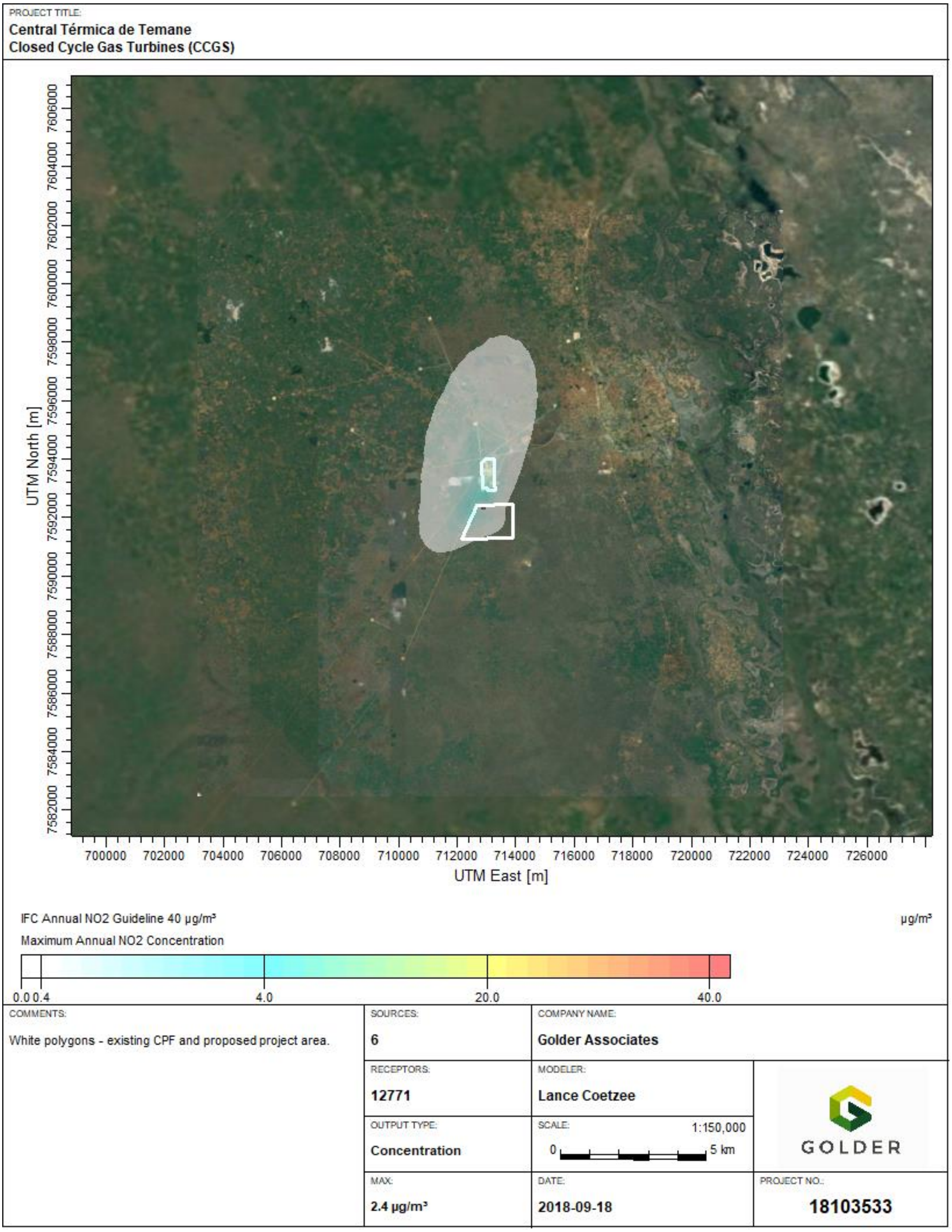


Figure 40: CCGT maximum annual NO_2 concentration

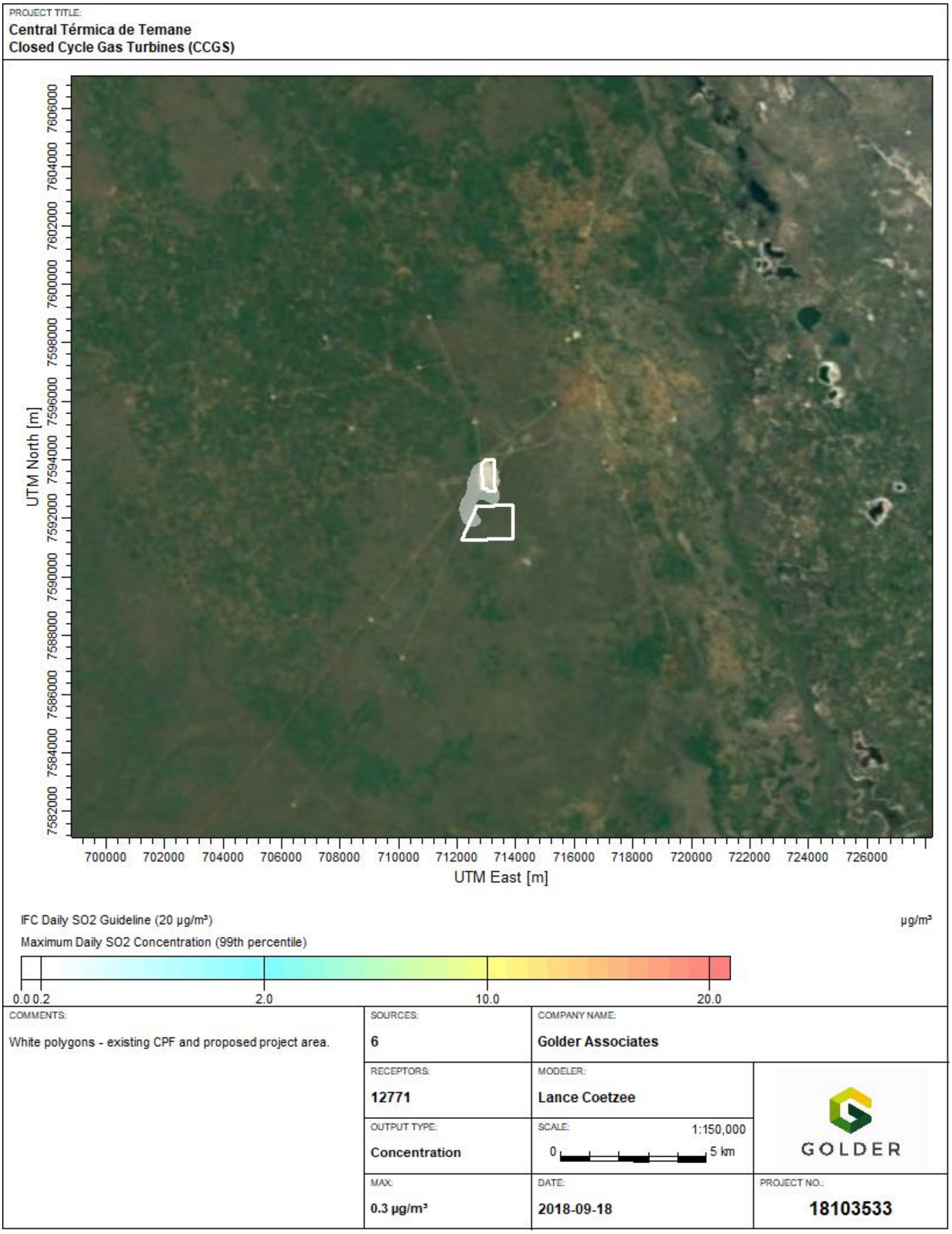


Figure 41: CCGT maximum annual SO_2 (99th percentile) concentration

Table 20: CCGT summary of impacts on sensitive receptors and points of interest

#	Receptor	Daily Maximum		Annual Maximum		Hourly Maximum		Annual Maximum		Daily Maximum	
		PM_{10} (µg/m³)	% of IFC Standard (50 µg/m³)	PM_{10} (µg/m³)	% of IFC Standard (20 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (200 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (40 µg/m³)	SO_2 (µg/m³)	% of IFC Standard (20 µg/m³)
1	Health Centre - Mangungumete	1	1%	0	0%	4	2%	0	0%	0	0%
2	Health Centre - Temane	0	1%	0	0%	4	2%	0	0%	0	0%
3	Orphanage	1	3%	0	0%	9	4%	1	2%	0	1%
4	Primary school - Mangugumete	0	1%	0	0%	3	2%	0	0%	0	0%
5	Primary School - Temane	0	1%	0	0%	4	2%	0	0%	0	0%
6	Primary school -Chitsotso	0	0%	0	0%	1	1%	0	0%	0	0%
7	School - Litlau	1	1%	0	0%	4	2%	0	1%	0	0%
8	School - Manusse	0	1%	0	0%	3	1%	0	0%	0	0%
9	School - Temane Base Camp	1	1%	0	0%	4	2%	0	1%	0	0%
10	Chipongo	0	0%	0	0%	0	0%	0	0%	0	0%
11	Chitsotso	0	0%	0	0%	1	1%	0	0%	0	0%
12	Inhassoro	0	0%	0	0%	1	0%	0	0%	0	0%
13	Litlau	1	1%	0	0%	4	2%	0	1%	0	0%
14	Mabime	0	0%	0	0%	1	1%	0	0%	0	0%
15	Macovane	0	0%	0	0%	1	0%	0	0%	0	0%
16	Maimelane	0	1%	0	0%	3	1%	0	0%	0	0%
17	Mangarelane I	0	0%	0	0%	1	0%	0	0%	0	0%
18	Mangarelane II	0	0%	0	0%	1	1%	0	0%	0	0%
19	Mangugumete	0	1%	0	0%	3	2%	0	0%	0	0%
20	Manusse	0	1%	0	0%	3	1%	0	0%	0	0%

#	Receptor	Daily Maximum		Annual Maximum		Hourly Maximum		Annual Maximum		Daily Maximum	
		PM_{10} (µg/m³)	% of IFC Standard (50 µg/m³)	PM_{10} (µg/m³)	% of IFC Standard (20 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (200 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (40 µg/m³)	SO_2 (µg/m³)	% of IFC Standard (20 µg/m³)
21	Mapanzene	0	0%	0	0%	0	0%	0	0%	0	0%
22	Temane	0	1%	0	0%	4	2%	0	0%	0	0%
23	Temane Base Camp	1	1%	0	0%	4	2%	0	1%	0	0%
24	Vilanculos	0	0%	0	0%	0	0%	0	0%	0	0%
25	Vulanjane	0	1%	0	0%	2	1%	0	0%	0	0%
26	T-03 Well Pad	1	1%	0	0%	4	2%	0	1%	0	0%
27	T-04 Well Pad	0	1%	0	0%	3	2%	0	0%	0	0%
28	T-05 Well Pad	1	3%	0	0%	9	4%	1	2%	0	1%
29	T-06 Well Pad	0	1%	0	0%	3	2%	0	0%	0	0%
30	T-07 Well Pad	0	1%	0	0%	4	2%	0	1%	0	0%
31	T-10 Well Pad	1	1%	0	0%	5	3%	0	1%	0	0%
32	T-12 Well Pad	1	2%	0	0%	5	3%	0	1%	0	0%
33	T-13 Well Pad	0	1%	0	0%	4	2%	0	1%	0	0%
34	T-15 Well Pad	2	5%	0	0%	13	7%	1	3%	0	1%
35	T-16 Well Pad	0	1%	0	0%	3	2%	0	0%	0	0%
36	T-23 Well Pad	0	0%	0	0%	2	1%	0	0%	0	0%
37	CTT	2	4%	0	0%	16	8%	1	2%	0	1%
38	CPF	3	6%	0	0%	15	7%	1	4%	0	1%
39	Proposed Well Pad	0	1%	0	0%	4	2%	0	1%	0	0%
40	Proposed Well Pad	1	1%	0	0%	4	2%	0	0%	0	0%
41	Electricidade de Moçambique	1	3%	0	0%	9	4%	1	2%	0	1%

#	Receptor	Daily Maximum		Annual Maximum		Hourly Maximum		Annual Maximum		Daily Maximum	
		PM_{10} (µg/m³)	% of IFC Standard (50 µg/m³)	PM_{10} (µg/m³)	% of IFC Standard (20 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (200 µg/m³)	NO_2 (µg/m³)	% of IFC Standard (40 µg/m³)	SO_2 (µg/m³)	% of IFC Standard (20 µg/m³)
42	Proposed Well Pad	0	0%	0	1%	2	1%	0	0%	0	0%
43	Proposed Well Pad	0	0%	0	1%	1	1%	0	0%	0	0%

Table 21: CCGT operational phase impact assessment matrix

	Pre-mitigation					Post-mitigation				
Indicator of potential impact	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Impact of PM_{10}	2	4	2	5	Low 40	2	4	2	5	Low 40
Impact of NO_2	2	4	2	5	Low 40	2	4	2	5	Low 40
Impact of SO_2	2	4	2	5	Low 40	2	4	2	5	Low 40

Operational phase impacts are anticipated to be of low significance.

Measures aimed at further reducing or mitigating NO_2 impacts from gas turbines engines include:

- An increase in stack height; and
- Control Technologies:
  - Selective catalytic reduction (SCR);
  - Selective non-catalytic reduction (SNCR);
  - Catalytic combustion; and
  - Wet Low Emissions (WLE).

Decommissioning Phase Impacts

Air quality impacts during this phase are associated with the decommissioning of the key project components, ancillary infrastructure and preparation of the temporary beach landing sites and various route alternative. Specific activities that would generate impacts include earthworks, terracing, demolition of infrastructure, blasting, vehicle usage and backup power generation.

Table 22: CCGT decommissioning phase impact assessment matrix

	Pre-mitigation					Post-mitigation				
Indicator of potential impact	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Impact of PM_{10}	4	2	2	5	Low 40	2	2	2	5	Low 30
Impact of NO_2	4	2	2	5	Low 40	2	2	2	5	Low 30
Impact of SO_2	4	2	2	5	Low 40	2	2	2	5	Low 30

Decommissioning phase impacts are anticipated to be of low significance mitigation measures may be implemented to further reduce impacts, such measures include:

- Particulates (PM_{10}):
  - Wet suppression (wet misting during material handling activities);
  - Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation;
  - Progressive rehabilitation and re-vegetation of areas when operationally available;
  - Reduction in unnecessary traffic volumes;
  - Routine inspections to identify areas of unpaved roads that are increasingly dusty;
  - Maintenance work to be undertaken on these areas including watering, application of dust suppressants, compaction, dust removal and/or utilisation of soil aggregate; and
  - Vehicles and machinery to be serviced regularly to reduce the generation of black tailpipe smoke;
  - Speed control and the institution of traffic calming measures; and
  - No burning of waste onsite
- Trace Gasses (NO_2 / SO_2):
  - Maintain and service all vehicles, backup power generation and other equipment regularly to ensure that emissions are kept to a minimum;
  - Where possible, use low sulphur fuels to reduce SO_2 emissions;
  - Vehicles and machinery should be turned off when not in use to avoid unnecessary idling (i.e. idling should be limited to a maximum of three minutes on site); and,
  - No burning of waste onsite.

7.3 Cumulative Impacts

To assess the cumulative impacts of the proposed project, the process contributions of the proposed activities should be superimposed on the ambient baseline concentrations to determine if these contributions will result in a significant degeneration of the ambient air quality.

The ambient monitoring data collected by SGS Environmental during the campaign of 2011, 2012 and 2013 point to an area that is non-degraded from an air quality perspective. The moderate PM_{10} concentrations measured during the most recent campaign are related to background sources as well as to emissions from the CPF facility. Average recorded PM_{10} concentrations were generally well below the Sasol Temane standard and the most recent dust fall out rates were well below the SA NDCR limit of 1 200 mg/m^2/day for non-residential areas. Current operations have not resulted in any significant increase in background SO_2 and NO_2 concentrations based on the passive sampling campaign results (Airshed Planning Professionals, 2014). The study predicted that for the 5th gas train (to be built in future to process additional gas):

- SO_2 ground level concentrations would essentially remain the same;
- A decrease in NO_x and CO ground level concentrations due to one of the existing power generators (with conventional burners) being placed on standby and the replacement of two MAN HP compressor turbines

with Lo-NO_x turbines. One of the existing HP compressors will also be placed on standby. These reductions are in spite of the additional five LP compressors, one HP compressor and one power generator; and

- Both PM_{10} and VOC ground level concentrations were predicted to increase; with the most significant increase for the 5th Gas Train and PSA Liquids & LPG Plant option. However, maximum PM_{10} concentrations resulting from both the current operation (less than 1 µg/m³) and the proposed Project (also less than 1 µg/m³) are very low when compared with the oEMP standard of 75 µg/m³.

Baseline monitoring conducted by Golder in 2014 did not indicated much variation in the PM_{10}, NO_2 and SO_2 concentrations. Average baseline concentrations of PM_{10}, NO_2 and SO_2 were determined to be 32 µg/m³, 2 µg/m_3 and 3 µg/m³ respectively.

Based on this assessment, the construction and decommissioning impacts for the proposed gas engines were predicted to be low. Operational impacts for the gas engines were predicted to be low for PM_{10} and SO_2, but moderate for NO_2. Considering that the current air quality in the project area is not degraded as defined by the IFC, the cumulative impact of the process contributions from the gas engines through all three project phases is unlikely to lead to a significant degeneration of the ambient air quality.

Based on this assessment, the construction, operational and decommissioning impacts for the proposed gas turbines were predicted to be low. Considering that the current air quality in the project area is not degraded as defined by the IFC, the cumulative impact of the process contributions from the gas turbines through all three project phases is unlikely to lead to a significant degeneration of the ambient air quality.

8.0 ENVIRONMENTAL ACTION PLAN – GAS ENGINES

Table 23: Environmental Action Plan - Gas Engines

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
Construction Phase				
PM_{10} impacts	Low	Construction activities	■ Wet suppression (wet misting during material handling activities); ■ Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation; ■ Progressive rehabilitation and re-vegetation of areas when operationally available; ■ Reduction in unnecessary traffic volumes; ■ Routine inspections to identify areas of unpaved roads that are increasingly dusty. Maintenance work to be undertaken on these areas including watering, application of dust suppressants, compaction, dust removal and/or utilisation of soil aggregate; ■ Rigorous speed control and the institution of traffic calming measures to reduce vehicle entrainment of dust. A recommended maximum speed of 20 km/h to be set on all unpaved roads; ■ Ensuring all equipment is well maintained and in good working order to ensure that emissions are kept to a minimum; and ■ Minimising the area disturbed at any one time.	EPC environmental manager
NO_2 impacts	Low	Combustion engines	■ Maintain and service all vehicles, backup power generation and other equipment regularly to ensure that emissions are kept to a minimum; and ■ Ensuring equipment and vehicles are switched off when not in use.	EPC environmental manager
SO_2 impacts	Low	Combustion engines	■ Where possible, use low sulphur fuels to reduce SO_2 emissions.	EPC environmental manager
Operational Phase				
PM_{10} impacts	Low	OCGE stacks	Not required	EPC environmental manager

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility

NO_2 impacts	Moderate	OCGE stacks	■ Increase stack height if possible; or
			■ An investigation into various control technologies such as:
			  ▪ Low NO_X burners;
			  ▪ Homogeneous Charge Compression Ignition (HCI); and
			  ▪ Flue-Gas Recirculation (FGR).
				EPC environmental manager

SO_2 impacts	Low	OCGE stacks	Not required	EPC environmental manager
Decommissioning Phase				
PM_{10} impacts	Low	Decommissioning activities	■ Wet suppression (wet misting during material handling activities); ■ Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation; ■ Progressive rehabilitation and re-vegetation of areas when available; ■ Reduction in unnecessary traffic volumes; ■ Routine inspections to identify areas of unpaved roads that are increasingly dusty. Maintenance work to be undertaken on these areas including watering, application of dust suppressants, compaction, dust removal and/or utilisation of soil aggregate; ■ Rigorous speed control and the institution of traffic calming measures to reduce vehicle entrainment of dust. A recommended maximum speed of 20 km/h to be set on all unpaved roads; ■ Ensuring all equipment is well maintained and in good working order to ensure that emissions are kept to a minimum; and ■ Minimising the area disturbed at any one time.	EPC environmental manager
NO_2 impacts	Low	Combustion engines	■ Maintain and service all vehicles, backup power generation and other equipment regularly to ensure that emissions are kept to a minimum; and ■ Ensuring equipment and vehicles are switched off when not in use	EPC environmental manager

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
SO_2 impacts	Low	Combustion engines	■ Where possible, use low sulphur fuels to reduce SO_2 emissions.	EPC environmental manager

9.0 ENVIRONMENTAL ACTION PLAN – GAS TURBINES

Table 24: Environmental Action Plan - Gas Turbines

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
Construction Phase				
PM_{10} impacts	Low	Construction activities	■ Wet suppression (wet misting during material handling activities); ■ Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation; ■ Progressive rehabilitation and re-vegetation of areas when operationally available; ■ Reduction in unnecessary traffic volumes; ■ Routine inspections to identify areas of unpaved roads that are increasingly dusty. Maintenance work to be undertaken on these areas including watering, application of dust suppressants, compaction, dust removal and/or utilisation of soil aggregate; ■ Rigorous speed control and the institution of traffic calming measures to reduce vehicle entrainment of dust. A recommended maximum speed of 20 km/h to be set on all unpaved roads; ■ Ensuring all equipment is well maintained and in good working order to ensure that emissions are kept to a minimum; and ■ Minimising the area disturbed at any one time.	EPC environmental manager
NO_2 impacts	Low	Combustion engines	■ Maintain and service all vehicles, backup power generation and other equipment regularly to ensure that emissions are kept to a minimum; and ■ Ensuring equipment and vehicles are switched off when not in use.	EPC environmental manager
SO_2 impacts	Low	Combustion engines	■ Where possible, use low sulphur fuels to reduce SO_2 emissions.	EPC environmental manager
Operational Phase				
PM_{10} impacts	Low	Gas Turbines	Not required	EPC environmental manager

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
NO_2 impacts	Low	Gas Turbines	■ An increase in stack height if possible; and ■ And investigation into various control technologies such as: ▪ Selective catalytic reduction (SCR); ▪ Selective non-catalytic reduction (SNCR); ▪ Catalytic combustion; and ▪ Wet Low Emissions (WLE).	EPC environmental manager
SO_2 impacts	Low	Gas Turbines	Not required	EPC environmental manager
Decommissioning Phase				
PM_{10} impacts	Low	Decommissioning activities	■ Wet suppression (wet misting during material handling activities); ■ Covering or keeping stockpile heights as low as practicable to reduce their exposure to wind erosion and thus dust generation; ■ Progressive rehabilitation and re-vegetation of areas when available; ■ Reduction in unnecessary traffic volumes; ■ Routine inspections to identify areas of unpaved roads that are increasingly dusty. Maintenance work to be undertaken on these areas including watering, application of dust suppressants, compaction, dust removal and/or utilisation of soil aggregate; ■ Rigorous speed control and the institution of traffic calming measures to reduce vehicle entrainment of dust. A recommended maximum speed of 20 km/h to be set on all unpaved roads; ■ Ensuring all equipment is well maintained and in good working order to ensure that emissions are kept to a minimum; and ■ Minimising the area disturbed at any one time.	EPC environmental manager
NO_2 impacts	Low	Combustion engines	■ Maintain and service all vehicles, backup power generation and other equipment regularly to ensure that emissions are kept to a minimum; and ■ Ensuring equipment and vehicles are switched off when not in use	EPC environmental manager

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
SO_2 impacts	Low	Combustion engines	- Where possible, use low sulphur fuels to reduce SO_2 emissions.	EPC environmental manager

10.0 MONITORING PROGRAMME – GAS ENGINES

Table 25: Monitoring programme - Gas Engines

Objective	Detailed Actions	Monitoring Location	Frequency / Duration	Responsibility
Construction Phase				
PM_{10} ambient air quality guideline compliance	Ambient air quality monitoring (Passive PM_{10})	Sensitive receptors, residential area within 2.5 km of activities.	Bi-annual (1 month)	CTT Environmental Section
NO_2 ambient air quality guideline compliance	Ambient air quality monitoring (Radiello)		Biannual (1-month, 2 x 2 weeks exposure)	CTT Environmental Section
SO_2 ambient air quality guideline compliance				
Operational Phase				
PM_{10} emission limit compliance	Iso-kinetic testing.	All stacks	Bi-annual	CTT Environmental Section
NO_2 emission limit compliance	Flue gas analyser & iso-kinetic testing	All stacks	Continuous / Bi-annual	CTT Environmental Section
SO_2 emission limit compliance	Iso-kinetic testing.	All stacks	Bi-annual	CTT Environmental Section
PM_{10} ambient air quality guideline compliance	Ambient air quality monitoring (E-sampler / Passive PM_{10})	Continuation of SPI 2014 monitoring program (jointly SPI/CTT) or alternatively CTT adopts its own monitoring programme.	Bi-annual	CTT Environmental Section
NO_2 ambient air quality guideline compliance	Ambient air quality monitoring (Radiello)		Bi-annual	CTT Environmental Section

Objective	Detailed Actions	Monitoring Location	Frequency / Duration	Responsibility
SO_2 ambient air quality guideline compliance	Ambient air quality monitoring (Radiello)		Bi-annual	CTT Environmental Section
Decommissioning Phase				
PM_{10} ambient air quality guideline compliance	Ambient air quality monitoring (Passive PM_{10})	Sensitive receptors, residential area within 2.5 km of activities.	Bi-annual (1 month)	CTT Environmental Section
NO_2 ambient air quality guideline compliance	Ambient air quality monitoring (Radiello)		Biannual (1month, 2 x 2 weeks exposure)	CTT Environmental Section
SO_2 ambient air quality guideline compliance				CTT Environmental Section

11.0 MONITORING PROGRAMME – GAS TURBINES

Table 26: Monitoring programme - Gas Turbines

Objective	Detailed Actions	Monitoring Location	Frequency / Duration	Responsibility
Construction Phase				
PM_{10} ambient air quality guideline compliance	Ambient air quality monitoring (Passive PM_{10})	Sensitive receptors, residential area within 2.5 km of activities.	Bi-annual (1 month)	CTT Environmental Section
NO_2 ambient air quality guideline compliance	Ambient air quality monitoring (Radiello)		Biannual (1month, 2 x 2 weeks exposure)	CTT Environmental Section
SO_2 ambient air quality guideline compliance				
Operational Phase				
PM_{10} emission limit compliance	Iso-kinetic testing.	All stacks	Bi-annual	CTT Environmental Section
NO_2 emission limit compliance	Flue gas analyser & iso-kinetic testing	All stacks	Continuous / Bi-annual	CTT Environmental Section
SO_2 emission limit compliance	Iso-kinetic testing.	All stacks	Bi-annual	CTT Environmental Section
PM_{10} ambient air quality guideline compliance	Ambient air quality monitoring (E-sampler / Passive PM_{10})	Continuation of SPI 2014 monitoring program (jointly SPI/CTT) or alternatively CTT adopts its own monitoring programme.	Bi-annual	CTT Environmental Section
NO_2 ambient air quality guideline compliance	Ambient air quality monitoring (Radiello)		Bi-annual	CTT Environmental Section

Objective	Detailed Actions	Monitoring Location	Frequency / Duration	Responsibility
SO_2 ambient air quality guideline compliance	Ambient air quality monitoring (Radiello)		Bi-annual	CTT Environmental Section
Decommissioning Phase				
PM_{10} ambient air quality guideline compliance	Ambient air quality monitoring (Passive PM_{10})	Sensitive receptors, residential area within 2.5 km of activities.	Bi-annual (1 month)	CTT Environmental Section
NO_2 ambient air quality guideline compliance	Ambient air quality monitoring (Radiello)		Biannual (1month, 2 x 2 weeks exposure)	CTT Environmental Section
SO_2 ambient air quality guideline compliance				CTT Environmental Section

12.0 CONCLUSIONS AND RECOMMENDATIONS

12.1 Gas Engines

The following was concluded for the gas engine option based on the configurations described in Section 7.0:

- Construction and decommissioning phase impacts for the gas engine were predicted to be of low significance;
- Operational phase impacts are anticipated to be of low significance for PM_{10} and SO_2, but moderate for NO_2; and,
- Decommissioning phase impacts are anticipated to be of low significance.

12.2 Gas Turbines

The following was concluded for the gas turbine option based on the configurations described in Section 7.0:

- Construction phase impacts are anticipated to be of low significance;
- Operational phase impacts are anticipated to be of low significance; and,
- Decommissioning phase impacts are anticipated to be of low significance.

12.3 Cumulative impacts

Considering that the current air quality in the project area is not degraded[7] as defined by the IFC, the cumulative impact of the process contributions from the gas engines through all three project phases is unlikely to lead to a significant degeneration of the ambient air quality. Similarly, the cumulative impact of the process contributions from the gas turbines through all three project phases is unlikely to lead to a significant degeneration of the ambient air quality.

12.4 Specialist recommendation

The two technologies can be configured to have similar impacts. Total potential pollutant emissions from the gas engines are higher than for those for gas turbines for the same power output, therefore gas turbines are recommended.

[7] An airshed should be considered as having poor air quality if nationally legislated air quality standards or WHO Air Quality Guidelines are exceeded significantly (IFC, 2007).

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APPENDIX A

Other Atmospheric Pollutants and Health Effects

Carbon Monoxide

Carbon monoxide is one of the most common and widely distributed air pollutants (WHO, 2000). CO is an odourless, colourless and tasteless gas which has a low solubility in water. In the human body, CO reaching the lungs diffuses rapidly across the alveolar and capillary membranes and binds reversibly with the haem proteins. Approximately 80 to 90% of CO binds to haemoglobin to form carboxyhaemoglobin. This causes a reduction in the oxygen carrying capacity of the blood, which leads to hypoxia as the body is starved of oxygen.

Acute and chronic exposures

CO exposure can cause severe hypoxia, resulting in the rapid onset of nausea, headaches, vomiting, muscular weakness, loss of consciousness, shortness of breath and even death. The symptoms experienced will depend on the exposure concentration and duration. The hypoxia may cause both reversible, short-lasting neurological deficits and severe, often delayed, neurological damage. Neurobehavioral effects include impaired co-ordination, tracking, driving ability, vigilance and cognitive ability (WHO, 2000). High risk individuals to CO exposure include persons with cardiovascular disease (especially ischemic heart disease), pregnant mothers and the foetus and newborn infants.

Volatile Organic Compounds

Volatile Organic Compounds (VOCs) are organic compounds that easily vaporise at room temperature and are colourless. VOCs are released from vehicle exhaust gases either as unburned fuels or as combustion products, and are also emitted by the evaporation of solvents and motor fuels. Acute exposure to VOCs can cause eye and respiratory tract irritation and damage, headaches, dizziness, visual disorders, fatigue, loss of coordination, allergic skin reactions, nausea, and memory impairment, damage the bone marrow and even cause death. Chronic exposure to high levels of VOCs has been linked to an increase in occurrence of leukaemia, damage to the liver, kidneys and the central nervous system.

Benzene

Benzene in the atmosphere exists predominantly in the vapour phase. The atmospheric residence time, varies between a few hours and a few days, depending on the environment, climate and the concentration of other pollutants. In the lower atmosphere, benzene reacts with hydroxy radicals to produce phenols and aldehydes, which react quickly and are removed from the atmosphere by precipitation.

Benzene is a natural component of crude oil, and petrol contains approximately one to five percent by volume. Benzene is produced by the petrochemical industry in large quantities and is used in the chemical synthesis of ethyl benzene, phenol, cyclohexane and other substituted aromatic hydrocarbons. Benzene emissions are emitted from industrial sources, combustion sources such hydrocarbon fuel driven engines, wood combustion and stationary fossil fuel combustion. The major source is exhaust emissions and evaporation losses from motor vehicles, and evaporation losses during the handling, distribution and storage of petrol.

Acute and chronic exposures

Information on health effects from acute exposure to benzene is fairly limited. The most significant adverse effects from chronic exposure to benzene are haematotoxicity, genotoxicity and carcinogenicity. Chronic benzene exposure can result in bone marrow depression expressed as leucopoenia, anaemia and/or thrombocytopenia, leading to pancytopenia and aplastic anaemia. Based on this evidence, benzene is recognized to be a human and animal carcinogen. An increased mortality from leukaemia has been demonstrated in workers occupationally exposed (WHO, 2000).

Xylene

Xylene, also known as xylol, is a mixture of three molecular compounds of the hydrocarbon dimethyl benzene. Xylene is a highly flammable, clear, colourless, sweet-smelling liquid. Xylene is widely distributed and commonly found throughout the environment. It is primarily used in the production of ethyl-benzene, as a solvent in products (such as paints), and blended into petrol. Xylene is released into the atmosphere as fugitive emissions from industrial sources, vehicle exhaust pipes and through volatilisation from its use as a solvent. Xylene in air can be smelled at 0.08 to 3.7 parts of xylene per million parts of air (ppm) and can begin to be tasted in water at 0.53 to 1.8 ppm (US Department of Health and Human Services, 1995).

Acute exposures

Short term inhalation exposure to xylene will result in irritation of the nose and throat, gastro-intestinal effects such as vomiting, nausea and gastric discomfort, eye irritations and neurological effects such as mild short term memory loss, impaired reaction time and the feeling of body off-balance. In humans, short term skin exposure to xylene will result in skin irritation, dryness and the scaling of the skin.

Chronic exposure

Long term effects due to exposure to xylene include headaches, dizziness, fatigue, tremors, in-coordination, anxiety, short term memory loss and the inability to concentrate. Additional symptoms include laboured breathing, impaired pulmonary function, increased heart palpitation, severe chest pains and possible effects on the kidneys. Several human studies also indicated that there was an increased potential for spontaneous abortions among wives whose men were occupationally exposed to xylene; this has not yet been fully proven. Exposure to xylene can also result in developmental effects, such as skeletal variations (EPA, 1995).

Toluene

Toluene ($C_6H_5CH_3$) is a clear, water-insoluble liquid with an odour likened to paint thinners (EPA, 2005). It produced during the catalytic conversion of petroleum, aromatization of aliphatic hydrocarbons, and as a by-product of the coke oven industry. The primary use of toluene is as an additive to gasoline to improve octane ratings. Toluene is commonly used as a solvent, carrier or thinner in the paint, rubber, printing, cosmetic, adhesives and resin industries, as a starting material for the synthesis of other chemicals and as a constituent of fuels (WHO, 2000).

Toluene is also used in the production of polymers used to make nylon, plastic soda bottles, and polyurethanes and for pharmaceuticals, dyes, cosmetic nail products, and the synthesis of organic chemicals. Toluene is sometimes used as a substitute for benzene as it is not as toxic (Manahan, 2001).

Toluene is believed to be the most prevalent hydrocarbon in the atmosphere. Reactions with hydroxy radicals are the main mechanism by which toluene is removed from the atmosphere. The lifetime of toluene can range from a few days in summer to a few months in winter (WHO, 2000).

Acute and chronic exposures

The short-term and long-term effects of toluene on the Central Nervous System (CNS) are of most concern in acute and chronic exposures. CNS dysfunction has been observed in humans acutely exposed to low or moderate levels of toluene by inhalation. Symptoms of low to moderate exposure include fatigue, sleepiness, headaches, and nausea. CNS depression and death have occurred at higher levels of exposure (EPA, 2005).

Toluene may also cause congenital abnormalities in humans. The potential effects of toluene exposure on reproduction and hormonal imbalances in women are also of concern. Men occupationally exposed to toluene at 5 – 25 ppm have also been shown to exhibit hormonal imbalances. Limited information suggests an association between occupational toluene exposure and spontaneous abortions at an average concentration of 322 mg/m^3 (88 ppm). Toluene has minimal effects on the liver and kidney, except in cases of toluene abuse. Studies have not indicated that toluene is a carcinogenic (WHO, 2000).

Ethyl-benzene

Ethyl-benzene ($C_6H_5CH_2CH_3$) is a colourless liquid with a pungent smell. Ethyl-benzene is used primarily in the production of styrene, as a solvent, as a constituent of asphalt and fuels, production of rubber and plastic wrap. Exposure to ethyl-benzene is wide ranging; it occurs from the use of consumer products, petrol, pesticides, solvents, carpet glues, varnishes, paints, and tobacco smoke.

Acute exposure

Respiratory effects, such as throat irritation and chest constriction, irritation of the eyes, and neurological effects such as dizziness, have been noted from acute inhalation exposure to ethylbenzene in humans (EPA, 1991). In addition, symptoms of short term exposure to ethyl-benzene include: CNS toxicity, pulmonary effects and effects on the liver and kidneys (EPA, 1995)

Chronic exposure

Information on human health effects from long term exposure to ethyl-benzene is fairly limited. Some studies have produced conflicting results; some showed that ethyl-benzene impacts on the blood stream, while others indicated none. Studies conducted on animals, however, indicated that long term exposure to ethyl-benzene did affect the blood, liver and kidneys, and, in most cases, formed tumours (EPA, 1995).

Hydrogen Sulphide

Hydrogen sulphide is a toxic, flammable gas, which has an odour of rotten eggs. Hydrogen sulphide occurs in the gases emanating from volcanoes, springs, swamps, and stagnant bodies of water, as well as in crude petroleum and natural gas. Hydrogen sulphide also is associated with municipal sewers and sewage treatment plants, and pulp and paper operations. Industrial sources of hydrogen sulphide include petroleum refineries, natural gas plants, petrochemical plants, coke oven plants, food processing plants, and tanneries (US Department of Health and Human Services, 2006).

The gas odour is detectable at low concentrations. This detectable level is referred to as the odour threshold. The WHO established the odour threshold at 11.1 µg/m^3. At high concentrations, the sense of smell is paralysed (Loss of smell occurs at levels around 100 – 150 ppm (www.shoalhaven.nsw.gov.au, 07 December 2006) and one cannot detect its presence. This is important as it acts as a chemical asphyxiant which combines with haemoglobin and with cytochromes and prevents oxygen from being available for metabolic processes. It is also an irritant of the mucous membranes including the eyes and respiratory tract, which is reported to be detectable by the majority of people at concentrations of between 0.005 – 0.025 parts per million (ppm) (www.agius.com, 07 December 2006)

Acute exposure

Exposure to low concentrations of hydrogen sulphide may cause irritation to the eyes, nose, or throat. It may also cause difficulty in breathing for some asthmatics. Brief exposures to high concentrations of hydrogen sulphide (greater than 500 ppm) can cause a loss of consciousness as it acts as a chemical asphyxiant which combines with haemoglobin and with cytochromes and prevents oxygen from being available for metabolic processes. In most cases, consciousness is regained without further symptoms. However, in some individuals, there may be permanent or long-term effects such as headaches, poor attention span, poor memory, and poor motor function (WHO, 2003; US Department of Health and Human Services, 2006).

No health effects have been found in humans exposed to typical environmental concentrations of hydrogen sulphide (0.00011–0.00033 ppm). Deaths due to breathing in large amounts of hydrogen sulphide (>11.1µg/m^3) (WHO, 2000) have been reported in a variety of different occupational settings, including sewers, animal processing plants, waste dumps, sludge plants, oil and gas well drilling sites, and tanks and cesspools (US Department of Health and Human Services, 2006).

Chronic exposure

According to the WHO (2000), hydrogen sulphide does not accumulate in the body and there is no evidence that exposure causes long-term effects such as cancer or birth defects.

Ozone

Ozone (O_3) is a pale blue gas, soluble in water and inert non-polar solvents such as carbon tetrachloride or fluorocarbons. Low-level ozone not emitted directly by car engines or by industrial operations but created at ground-level though a chemical reaction between oxides of nitrogen (NOx) and volatile organic compounds (VOC), such as hydrocarbons, in the presence of sunlight (EPA, 1999 b.).

Ozone is primarily used in the preparation of pharmaceuticals, synthetic lubricants, and many other commercial organic compounds, where it is used to sever carbon-carbon bonds. It can also be used for bleaching substances and for killing microorganisms in air and water sources. Globally, many municipal drinking water systems use ozone as an alternative to chlorine for anti-bacterial purposes as ozone does not form organochlorine compounds, nor does it remain in the water after treatment (EPA, 1999 c.)

Acute exposure

Ozone toxicity increases with concentration and time. There is a great deal of evidence to show that low-level ozone can reduce lung function and irritate the respiratory system. Exposure to ozone is linked to an increase in cases of asthma, bronchitis, heart failure, and other cardiopulmonary problems. According to the EPA, susceptible people, including children, the elderly and those with pre-existing respiratory problems, can be adversely affected by ozone levels as low as 40 nmol/mol (WHO, 2000).

Chronic exposure

Ozone damage can occur without any noticeable symptoms. People who live in areas where ozone levels are frequently high may find that their initial symptoms go away over time, particularly when exposure to high ozone levels continues for several days. Ozone continues to cause lung damage even when the symptoms have disappeared (EPA, 1999 b.).

Long-term exposure to ozone has been shown to increase risk of death from respiratory illness (WHO, 2000). A study of 450,000 people living in United States cities showed a significant correlation between ozone levels and respiratory illness over the 18-year follow-up period. The study revealed that people living in cities with high ozone levels such as Houston or Los Angeles had an over 30% increased risk of dying from lung disease (EPA, 1999 b.).

Polycyclic aromatic hydrocarbons (PAH)

PAH are a class of weakly soluble, organic compounds produced by incomplete combustion or high-pressure processes (ATSDR, 2009). They are generally pale yellow, faintly aromatic, needle like crystals, and are found in: emissions from motor vehicles, gasoline and diesel engines; emission from coal, oil, and wood-burning stoves and furnaces, and cigarette smoke; in incinerators, coke ovens, and asphalt processing and use. Once emitted to the atmosphere, heavier PAH tend to adhere to particulate matter, while lighter PAH tend to remain gaseous until removed via precipitation. Food is considered to be the greatest source of human PAH exposure, due to PAH formation during cooking or from atmospheric deposition of PAH on grains, fruits and vegetables (WHO, 2000).

Acute exposure

PAH toxicity is very structurally dependent, with isomers (PAHs with the same formula and number of rings) varying from being nontoxic to being extremely toxic. The EPA has found acute PAH (such as benzo(a)pyrene) exposure of more than 0.0002 mg/L, to result in red blood cell damage and suppressed immune system.

Chronic exposure

The results of animal studies indicate that several PAH may induce a number of adverse effects, such as immunotoxicity, genotoxicity, carcinogenicity and reproductive toxicity (affecting both male and female offspring), and may possibly also influence the development of atherosclerosis (condition in which fatty material collects along the walls of arteries). In addition, the high carcinogenicity of several PAH, such as benzo(a)pyrene, is well documented (WHO, 2000; ATSDR, 2009).

Methane

Methane (CH_4) is an alkaline, colourless and odourless gas. Methane is extremely flammable, even at low concentration levels. Methane is formed through the fermentation of organic matter under anaerobic conditions and is thus a significant constituent of natural and landfill gas. Globally, methane is commonly used for electrical generation by burning it as a fuel in a gas turbine/engine or steam boiler. Compared to other hydrocarbon fuels, burning methane produces less carbon dioxide for each unit of heat released (EPA, 2010).

Acute and chronic exposure

Methane is not toxic; however, it is extremely flammable and may form explosive mixtures with air. Methane is violently reactive with oxidizers, halogens, and some halogen-containing compounds. Methane is also an asphyxiant and may displace oxygen in an enclosed space. Asphyxia may result if the oxygen concentration is reduced to below 19.5% (EPA, 2010).

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