REPORT

Central Térmica de Temane Project - Hydrogeological Specialist 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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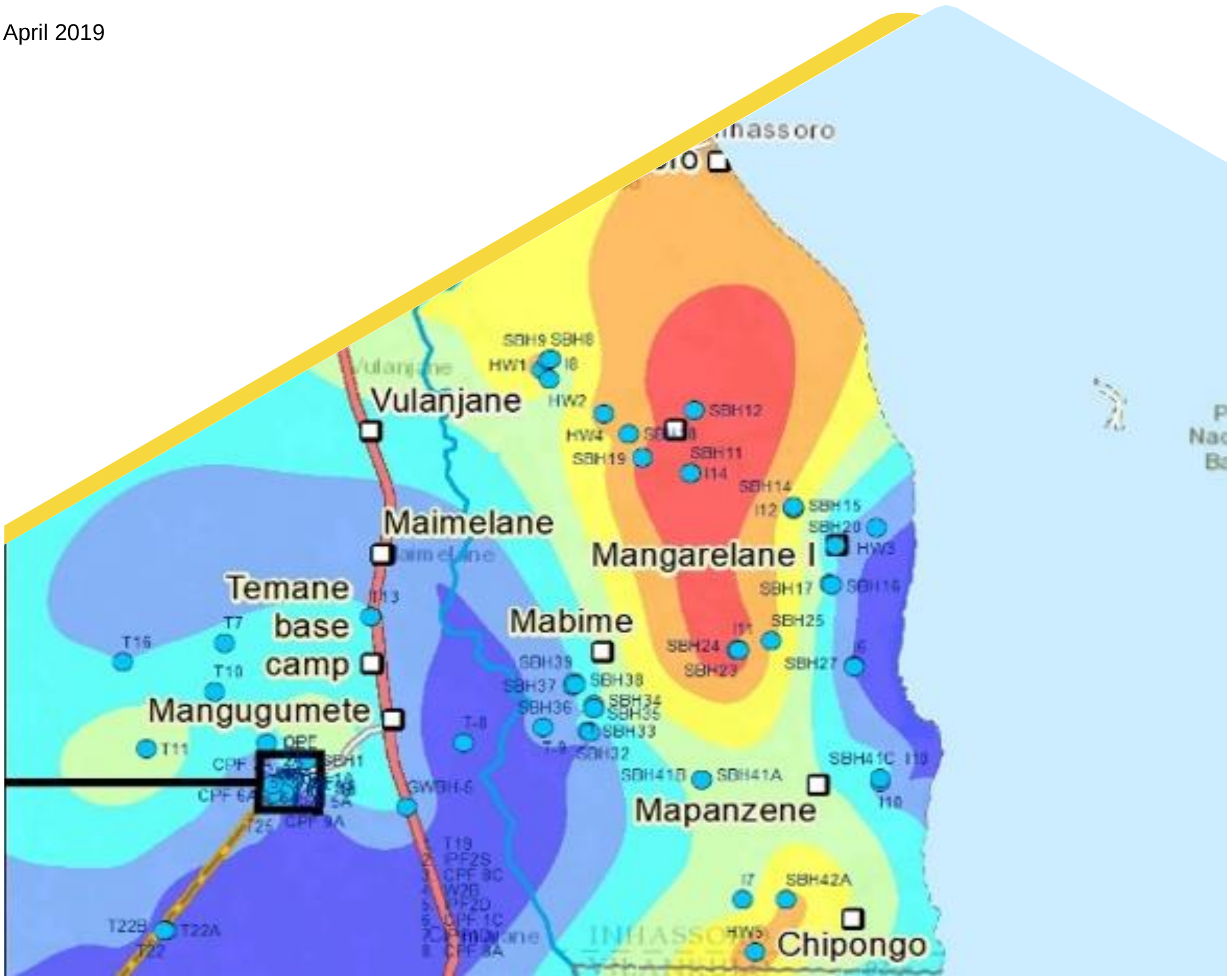

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Executive Summary

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. This report constitutes the outcomes of the hydrogeological investigations with the following aims:

- Characterise prevailing groundwater conditions in the study area;
- Define the water bearing strata in the area;
- Determine current groundwater level distribution, flow directions, and baseline groundwater quality;
- Define all potential impacts from the project activities on the groundwater regime in the affected area; and
- Propose management and mitigation measures.

Groundwater is directly determined and controlled by lithology and structural geology. Four main hydrogeological units have been identified in the CTT Project study area based on their physical properties and relative geological age, namely:

- The unconfined shallow weathered Jofane perched (weathered) aquifer,
- The deep confined Jofane limestone aquifer,
- The unconfined alluvial aquifer along the Govuro River (quaternary deposits), and
- The unconfined unconsolidated coastal aquifer (quaternary deposits).

Most of the available information reviewed is concentrated around the existing CPF as this is where extensive drilling and aquifer testing has been done since the inception of the CPF, therefore this information provides a good insight of the hydrogeological regime underlying the adjacent CTT site. The baseline was established through review of existing groundwater information that included results from 2014 field investigations that included an extensive hydrocensus and on-site drilling and testing. The groundwater system has been characterised based on aquifer properties and water quality. The Table below provides a summary of the aquifer types and properties associated with the groundwater occurrence in the study area.

Depth (mbs)	Average water level (mbgl)	Aquifer parameters (T)	Water quality	Importance
Unconfined shallow (perched) weathered Jofane aquifer				
14 - 20	3 - 4	15 m^2/day	120 mS/m	No water supply significance but early warning for potential contamination
Confined Jofane karst aquifer				
20 - 60	12 - 17	90 to 700 m^2/day	85 to 280 mS/m	Main source of water for communities in the Temane area

Depth (mbs)	Average water level (mbgl)	Aquifer parameters (T)	Water quality	Importance
Unconfined alluvial aquifer along the Govuro River				
<30	<15	1000 m^2/day	25 to 50 mS/m	highly vulnerable to contamination due to the high permeability of the unconsolidated formations and unconfined character of the aquifer
Unconfined unconsolidated coastal aquifer				
10 - 50	20 - 35	100 to 200 m^2/day	10 to 40 mS/m	Contains fresh groundwater, due to rainfall recharge; not equally developed across area

Extensive groundwater quality testing shows that groundwater quality in the study area is virtually unaffected by human activity. Except for a few localised cases, the regional water quality is by and large unchanged. Whereas the groundwater quality is saline, especially in inland areas, due to the Jofane aquifer being situated on limestone, groundwater is generally potable.

Measured water levels range between 0.2 to 38.7 metres below ground level (mbgl) for the study area. The average water level measured is 16.5 mbgl. The shallow water levels up to 2 mbgl are all at hand dug wells near or within alluvial deposits. Deeper water levels (>20 mbgl) are often encountered towards the coast under the coastal dune system or where deeper wells were installed alongside gas/oil well installations. The current water level monitoring does not indicate any significant water level impacts from existing activities near the CTT.

Simplified numerical modelling was performed to assess the potential for water level decline based on the required water abstraction for each of the two technology options considered. The following was concluded:

- Due to the high transmissivity values, the abstraction over the life of operations does not make much difference to the overall simulated head distribution of the aquifer.

For purposes of this study the technology options are defined as follows:

- **Option 1**: Combined Cycle Gas Turbine (CCGT); and
- **Option 2**: Open Cycle Gas Engines (OCGE).

Simulation shows the water level within the pumping boreholes after 20 years of operational use, to be as follows:

- Option 1 (CCGT) @ W5A borehole: Water level is 28 m below the steady state water level;
- Option 1 (CCGT) @ T9 borehole: Water level is 0.16 m below the steady state water level;
- Option 2 (OCGE) @ W5A borehole: Water level is 0.115 m below the steady state water level; and
- Option 2 (OCGE) @ T9 borehole: Water level is 0.055 m below the steady state water level.

The difference between option 1 and option 2 is clearly visible in the simulations. Option 2 has a reduced effect on the water level compared to Option 1 over a simulated 20 year period. Although the model shows that the boreholes can supply the required volume of water for Option 1, it is likely in reality that the boreholes may fail over time depending on rainfall/recharge and other abstraction interferences at the required rate of abstraction.

The following conclusions can be drawn from the outcome of the impact assessment of the CTT Project on the groundwater systems, for both the OCGT and OCGE options:

- Some groundwater quality deterioration is expected during the construction and operational phases of the project. Various activities can potentially result in water quality deterioration. However, if acceptable materials handling, waste and water management, and other mitigation measures are in place the impacts can be reduced to negligible or low.
- Impacts related to potential pollution and effluent management, i.e. sewage and treated oily water are of importance in terms of the receiving surface water environment and are both rated as moderate significance pre-mitigation. Effluent quality should comply with the Mozambican and IFC effluent quality discharge standard. Irrigation of the effluents is linked to effluent management and must comply with the discharge standards. Achievement of compliance reduces the impacts to a low significance.
- The most significant impact on the groundwater systems are the potential water level decline caused by abstraction of groundwater from local supply boreholes. Past investigations have proven that the water supply boreholes are installed in high yielding aquifer systems that can supply long-term water supply to required infrastructure. However, for the CCGT option the water requirements are significantly higher than for the OCGE option. Although the aquifers likely have the potential to supply the required volume of water for operations, the development of additional abstraction boreholes will be required. The expected water level decline in abstraction boreholes may impact the long-term sustainability of the supply boreholes which may impact on other activities (i.e. associated infrastructure such as the CPF) in the area.

With the implementation of the water and waste management plan, monitoring programme and recommendations to comply with the EMP proposed in Section 7 of this study, the impacts to the groundwater systems are low to negligible.

Based on the evaluation and assessment undertaken of the two proposed technologies, the OCGE would be recommended option from a groundwater perspective. The only differentiating factor between the two technologies from a water management point of view, is that the OCGE option has a lower water requirement (3.39 m^3/h compared to 25.9 m^3/h) and thus generates smaller volumes of effluent. The OCGE option does not require demineralised water and as it does not use heat steam recovery generators, no blowdown is generated. The OCGE is a more water-efficient process with a smaller ‘effluent footprint’.

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ACRONYMS / ABBREVIATIONS

Acronym or Abbreviation	Full Term
CCGT	Combined Cycle Gas Turbine
CPF	Central Processing Facility
CTRG	Central Térmica de Ressano Garcia
CTT	Central Térmica de Temane
DNAIA	National Directorate of Environmental Impact Assessment
EC	Electrical conductivity
EDM	Electricidade de Mozambique
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
ESIA	Environmental and Social Impact Assessment
IFC	International Finance Corporation
mamsl	Metres above mean sea level
MICOA	Ministry for Coordination of Environmental Affairs - Mozambique
MITADER	Ministério da Terra, Ambiente e Desenvolvimento Rural
MPI	Moz Power Invest, S.A.
OCGE	Open Cycle Gas Engines
PPZ	partial protection zone
SEIAs	Simplified Environmental Impact Assessments
SEPI	Sasol Exploration Production International
SNE	Sasol New Energy Holdings (Pty) Ltd
TEC	Temane Energy Consortium (Pty) Ltd

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 either 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) or from an alternative gas source. 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)];

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 or from an alternative gas source;

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 (Figure 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 (Figure 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.

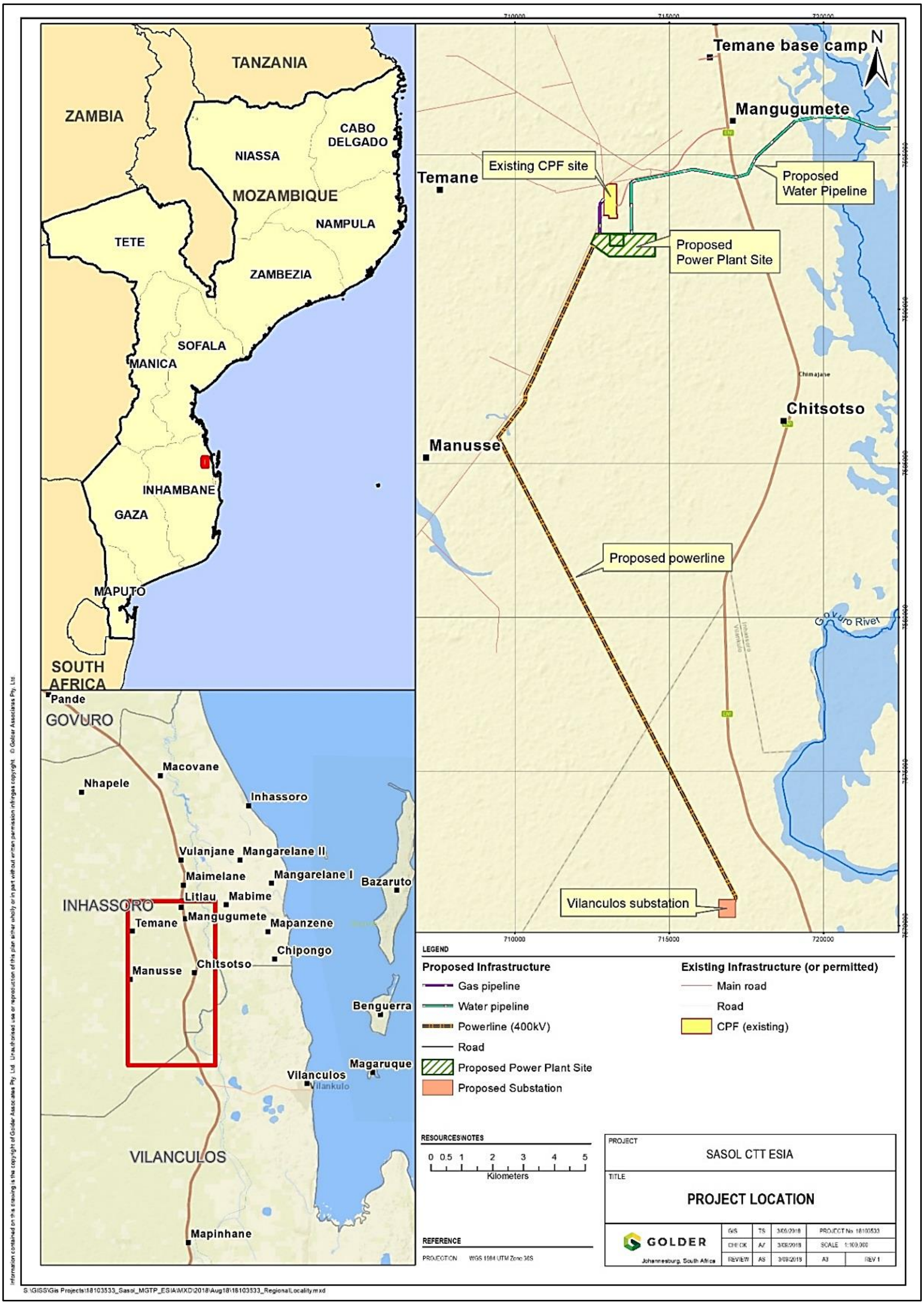

Figure 1: Project Location

2.0 DESCRIPTION OF THE KEY PROJECT COMPONENTS

The CTT project will produce electricity from natural gas in a power plant located 500m 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 450MW;
- Gas pipeline (±2 km) that will feed the Power Plant with natural gas from the CPF or from an alternative gas source;
- 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 100m width. The transmission line servitude will fall inside the PPZ;
- Water supply pipeline to a borehole located either on site or at borehole 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.

Figure 2: Examples of gas to power plant sites (source: www.industcards.com and www.wartsila.com)

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:

- Steam turbines for 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 3.

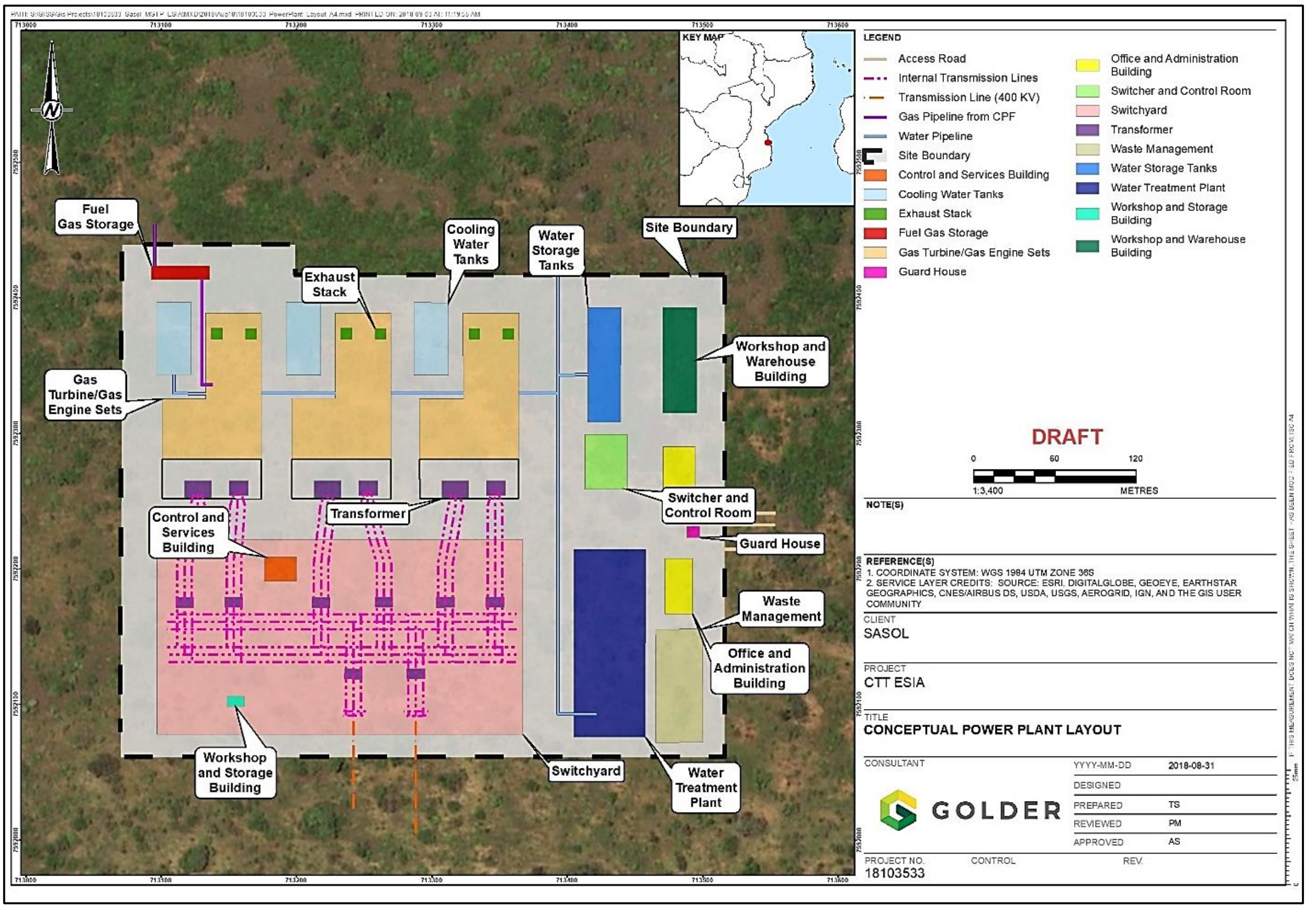

Figure 3: Conceptual layout of CTT plant site

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 4, Figure 5 and Figure 6 show examples of the activities involved with a temporary beach landing site, offloading and transporting of large heavy equipment by road to site.

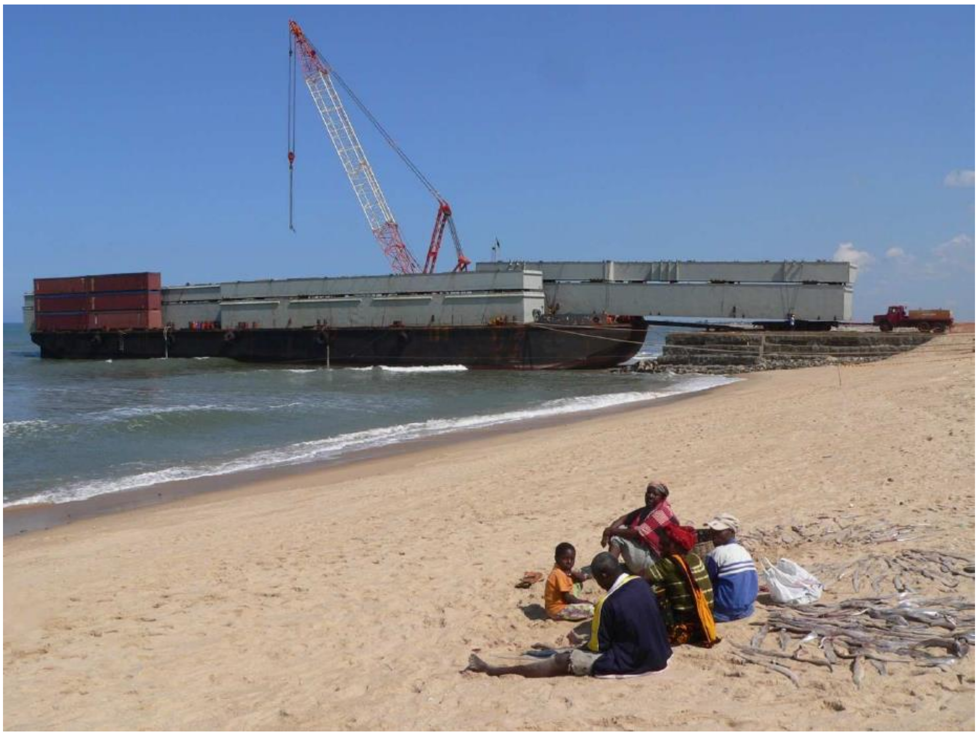

Figure 4: Typical beach landing site with barge offloading heavy equipment (source: Comarco)

Figure 5: Example of large equipment being offloaded from a barge. Note the levels of the ramp, the barge and the jetty (source: SUBTECH)

Figure 6: 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 7 and Figure 8 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 Grovuro 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.

Figure 7: The three beach landing site options and route options at Inhassoro

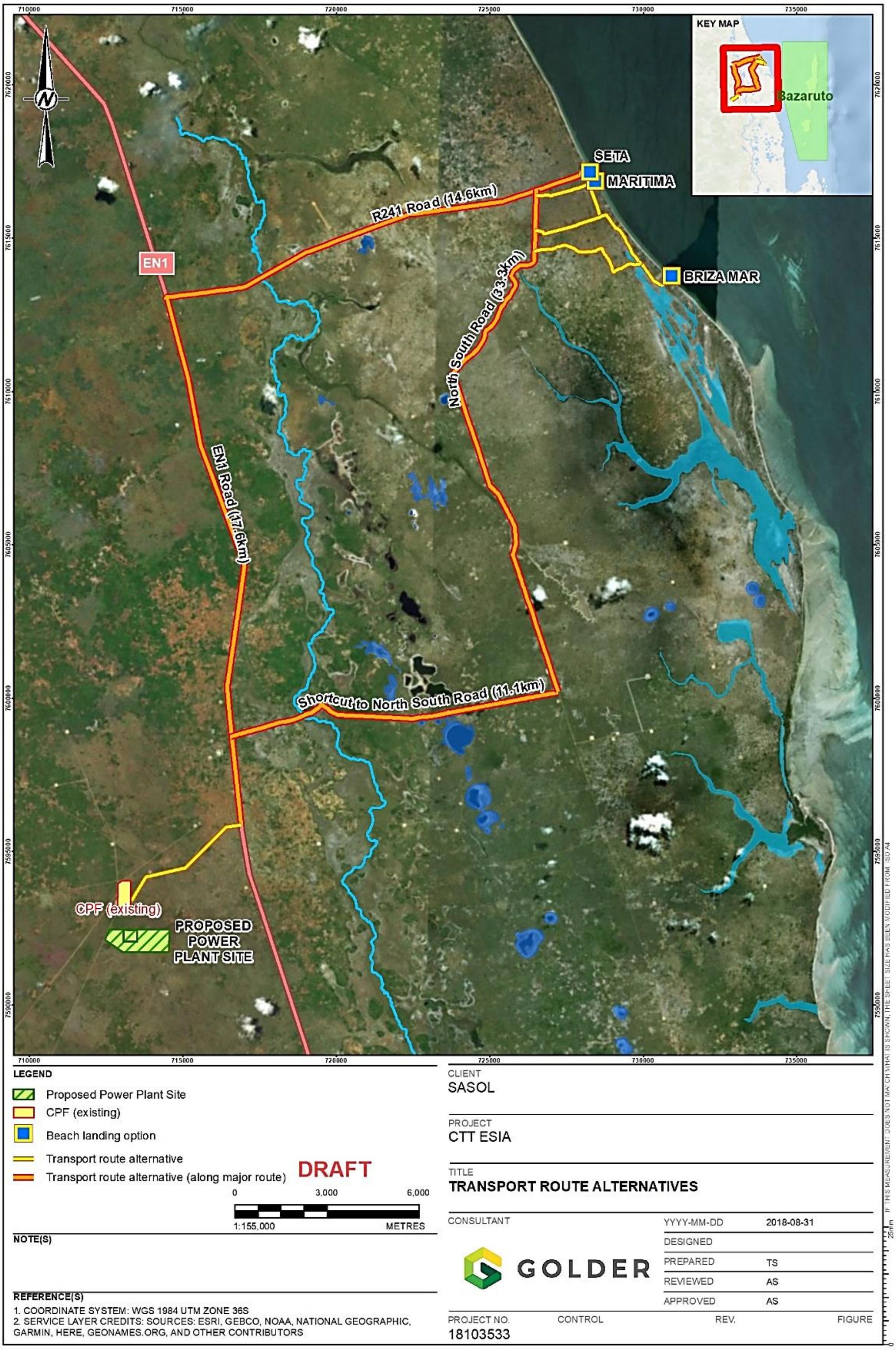

Figure 8: The two main transportation route alternatives from the beach landing sites to the CTT site

2.4 Water Source

Raw water for the Project will be supplied from aquifers in the area and treated as required. Two boreholes of differing water quality and abstraction rates are currently being considered as the source of raw water to the CTT site, T9 and W5A (Figure 10). Alternatively, a new borehole may be installed at the Power Plant site.

Borehole T9 in an alluvial aquifer, delivers good quality water similar to the quality of the Govuro River, but is located about 12 km from the site on the east bank of the Govuro River (total dissolved salts of 140 mg/l). Borehole W5A in the same vicinity of the CPF, approximately 2 km from the proposed CTT site, delivers water from the karst aquifer. However, the water is very hard and water quality has elevated concentrations of the macro ions with high total dissolved salts and electrical conductivity (880 mg/l and 156 mS/m respectively) (Coffey, 2014). Borehole W5A has a sustainable abstraction rate of 4.1 l/s and borehole T9 a sustainable abstraction rate of 5.5 l/s.

Raw water sourced from borehole W5A is of poorer quality and would result in increased volumes of brine but is close to the CTT plant requiring less piping and pumping costs. Raw water from borehole T9 is of much better quality resulting in less brine, but increased costs to pump and pipe to the plant site.

The selected borehole (water source) will be used to supply either of the two technology options. Raw water is pumped directly to the combined Raw Water / Fire Water reservoir tank. Due to the low suspended solids content (<10 mg/l) the raw water does not require filtration.

The CCGT option requires a water supply of 25.9m^3/h and the OCGE option has a requirement of 3.39 m^3/h. Clean storm water harvested will be used to offset borehole water supply.

3.0 LEGISLATION

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 making a decision.

This document represents the Hydrogeological Impact Assessment undertaken to support the ESIA. This study is undertaken in terms of EIA Process Regulations (Decree 45/2004), as amended by Decree 42/2008. These regulations establish the EIA requirements for projects and the Prevention, control, mitigation and rehabilitation procedures to be followed. This is achieved through Environmental Impact Assessments (EIAs), Simplified Environmental Impact Assessments (SEIAs) and/or the adoption of good environmental management norms according to the classification of a new project’s activities.

A category A project (full EIA) applies for all new energy power plants that may cause negative impacts to the environment (Appendix I of the Decree 45/2004 of 29 September, as amended by Decree 42/2008 of 4 November. The Ministerial Decree 129/2006 and Decree 130/2006 which sets out principles for the compilation of EIA study and Public Participation Phases during the ESIA process will also be considered.

Other relevant legislation include:

- Water Law (Law 16/1991)
- National Environment Policy (Resolution 5/1995).

- Environmental Law (Decree 20/1997).
- Environmental Regulations for Petroleum Operations (Decree 56/2010)
- Regulations on Environmental Quality and Effluent Emission Standards (Decree 18/2004), with additions and amendments in supplement (Decree 67/2010)
- Regulations on Water Quality for Human Consumption (Ministerial Diploma 180/2004).
- Residue (Waste) Management Regulation (Decree 13/2006)
- Regulations on Environmental Quality and Effluent Emission Standards (Decree 18/2004), with additions and amendments in supplement (Decree 67/2010)
- Regulations on Water Quality for Human Consumption (Ministerial Diploma 180/2004).
- Residue (Waste) Management Regulation (Decree 13/2006)

The following World Bank Group standards (Equator Principles and the environmental and social policies of the International Finance Corporation (IFC) 2012), also apply to the study. Through the Equator Principles, the IFC's Performance Standards are now recognised as international best practice in project finance. The relevant Performance Standards are summarised as follows:

- Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts;
- Performance Standard 3: Resource Efficiency and Pollution Prevention;
- Performance Standard 4: Community Health, Safety, and Security; and
- Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources;

In addition to the legislation and guidelines listed above, the corporate policies of Sasol and EDM will also apply to the CTT Project.

4.0 HYDROGEOLOGICAL ASSESSMENT

4.1 Scope of study

The aim of this investigation is to:

- Characterise prevailing groundwater conditions in the study area;
- Define the water bearing strata in the area;
- Determine current groundwater level distribution, flow directions, and baseline groundwater quality; and
- Define all potential impacts from the project activities on the groundwater regime in the affected area.
- Propose management and mitigation measures

4.2 Study methodology

The approach and method applied for the hydrogeological study was to rely on the existing data that has been collected up to date from the listed inputs:

- Review of relevant background information;
- Existing Operational EMPs;
- Annual reports concerning Sasol's existing impact on groundwater at the CPF; and

4.2.1 Desktop review of available information

Relevant documentation was reviewed in order to build up the hydrogeological understanding and knowledge specific to the project area, to gain an understanding of the scope and context of the proposed project and to ensure that groundwater specific regulatory requirements are address during the study. We provide below a list of documents used during the desktop review:

- Strategic Environmental and Social Overview: The Anchor Tourism Investment Programme. Inhassoro Anchor Tourism Project 2010.
- Natural Gas Project: Annual Integrated Disclosure Report March 2014.
- Mozambique Government (2004) “Regulations on Water Quality for Human Consumption (Ministerial Diploma 180/2004 of 15 September).
- Mozambique PSA Surface Facilities - Basis of Design 2013.
- Palmer, J., (2003): Sasol Temane CPF Hydrogeological Report 2003.
- Aquifer Sustainability Investigation, Sasol Temane, Mozambique.
- Groundwater Quality Monitoring Report: Sasol Temane, November 2013 to April 2014.
- Sasol Petroleum Ltd PSA Development and LPG Project - Hydrogeology Baseline & Impact Assessment, March 2014.
- Sasol exploration and Production International - Future Exploration, Appraisal and Development Activities in the Sasol License Areas, Inhambane Province, Mozambique. Vol 1: Final environmental Impact assessment report.
- Coffey (2014) Mozambique Gas to Power Water Supply Feasibility Study.

4.2.2 Field study method

The baseline information was established through review of existing groundwater information that included results from 2014 field investigations that included an extensive hydrocensus and on-site drilling and testing.

During the previous investigations in two hydro censuses were completed (Figure 9). A total of 92 groundwater points were recorded during the first phase hydrocensus. Of these, 67 groundwater points belong to Sasol and the remaining 25 are either privately owned or they belong to a rural community. Five of the 25 private/community hydrocensus points are not actual boreholes but rather hand dug wells that do not penetrate deeper than 1 mbgl. Only 10 of the remaining 20 boreholes were in use. During the second phase hydrocensus 59, groundwater points were recorded at 39 different sites. Of the boreholes recorded 19 are privately owned and the remaining 30 were all located at Sasol’s well pads.

It can thus be concluded that the data reviewed from the hydrocensus covered a large geographical area and can be used to establish the groundwater baseline and impact assessment of the area potentially impacted on by the CTT Project area.

4.2.3 Impact Assessment

An impact is essentially any change (positive or negative) to a resource or receptor brought about by the presence of the project component or by the execution of a project related activity.

The purpose of impact assessment is to identify and evaluate the likely significance of the potential impacts on identified receptors and natural resources according to defined assessment criteria, to develop and describe measures that will be taken to avoid, minimise, reduce or compensate for any potential adverse environmental effects and to report the significance of the residual impacts that remain following mitigation.

The evaluation of baseline data gathered during desktop and field studies provides information for the process of evaluating and describing how the project could affect the groundwater environment. Assessment of impacts is undertaken using an Impact Assessment Matrix in terms of the requirements, which provides a quantitative indication of the severity of an impact prior to and following mitigation. The approach adopted for assessing the significance and rating of impacts identified for the proposed CTT project is detailed in Section 6.1.

4.2.4 Mitigation and Monitoring

Based on consideration of the findings of the impact assessment with regards to the potential of future groundwater impacts, mitigation actions and monitoring are proposed.

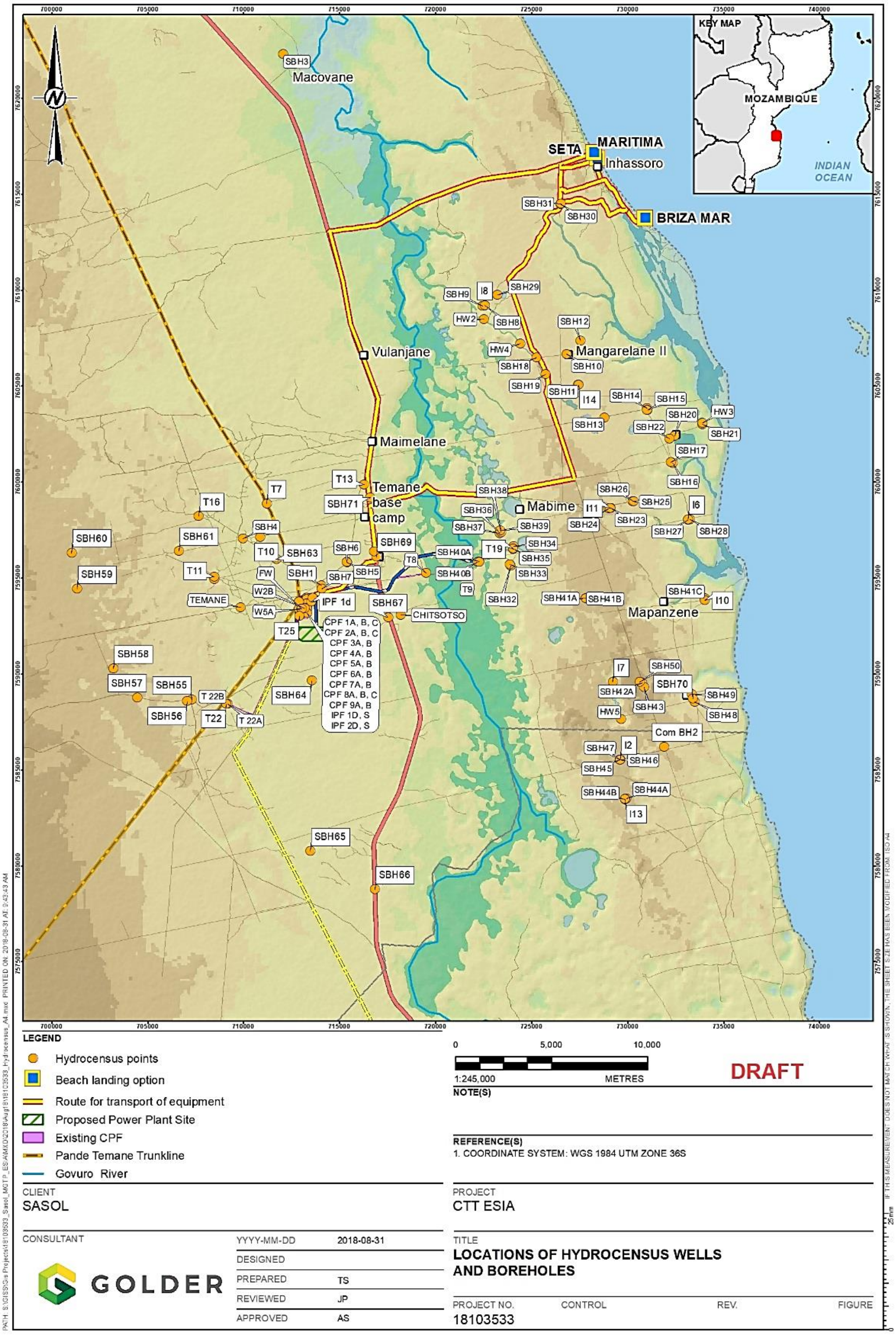

Figure 9: Location of 2014 hydrocensus boreholes relative to the CTT Project footprint

5.0 BASELINE CONDITIONS

This section describes the current (pre-project) hydrogeological conditions in the study area, also referred to as the "baseline". It is important to describe and understand the baseline before making an evaluation of the potential impacts of the proposed project on the surface water environment.

The groundwater baseline and Site Conceptual Model (SCM) for the Central Termica de Temane (CTT) Project were established based on existing information collected from the sources discussed above. The data was used to establish the groundwater users, lithological sequence, aquifer parameters, water quality, groundwater levels and flow directions, and define the aquifer systems for the project site.

Most of the available information reviewed is concentrated around the existing CPF as this is where extensive drilling and aquifer testing has been done since the inception of the CPF, therefore this information provides a good insight of the hydrogeological regime underlying the adjacent CTT Project site.

5.1 Aquifer types

Groundwater is directly determined and controlled by lithology and structural geology within the study area. Four main hydrogeological units have been identified in the CTT Project study area based on their physical properties and relative geological age, namely:

- The unconfined shallow (perched) weathered Jofane aquifer,
- The deep confined Jofane karst aquifer,
- The unconfined alluvial aquifer along the Govuro River (quaternary deposits), and
- The unconfined unconsolidated coastal aquifer (quaternary deposits).

For the CTT power plant site the underlying geohydrological regime can be described in short as follows:

Drilling of monitoring boreholes (at the CPF) has revealed that an unconfined perched aquifer exists below the site to a depth of 14 – 20 metres below ground level (mbgl). This aquifer is considered to be minor and exists within highly weathered and leached Jofane Limestone. The base of the aquifer is defined by a uniform impermeable clay layer that varies in thickness, attaining a maximum thickness of 6 m. This system cannot be considered to be a source of useable groundwater and will only be of significance at the CTT plant site for water quality monitoring. Any contamination detected in the system will be a first order warning against pollution of the viable Jofane Limestone aquifer.

The confined karst aquifer within the Jofane Limestone Formation exists below the clay layer described above. Drilling has shown that this aquifer consists of weathered and leached limestone but becomes more competent with depth. The more competent parts are often associated with cavernous/honeycomb formation. Water levels range between 12 to 17 mbgl but can vary considerably as they are controlled by rainfall events.

The Jofane limestone aquifer is the main source of water for communities in the Temane area. Water quality of the system is prone to be of high salinity in areas and does exceed drinking water quality standards occasionally. However, there is evidence of areas within the aquifer that are characterised by fresher water, most likely linked to higher recharge zones. These areas are most likely not overlain by the clay layer found at the CTT site, which confines the system in places. The system is considered to be vulnerable to potential pollution especially in areas where the clay layer is absent.

Table 1 below provides a summary of the aquifer types and properties associated with the groundwater occurrence in the study area:

Table 1: Aquifer types and properties

Depth (mbs)	Average water level (mbgl)	Aquifer parameters (T)	Water quality	Importance
Unconfined shallow (perched) weathered Jofane aquifer				
14 - 20	3 - 4	15 m^2/day	120 mS/m	No water supply significance but early warning for potential contamination
Confined Jofane karst aquifer				
20 - 60	12 - 17	90 to 700 m^2/day	85 to 280 mS/m	Main source of water for communities in the Temane area
Unconfined alluvial aquifer along the Govuro River				
<30	<15	1000 m^2/day	25 to 50 mS/m	highly vulnerable to contamination due to the high permeability of the unconsolidated formations and unconfined character of the aquifer
Unconfined unconsolidated coastal aquifer				
10 - 50	20 - 35	100 to 200 m^2/day	10 to 40 mS/m	Contains fresh groundwater, due to rainfall recharge; not equally developed across area

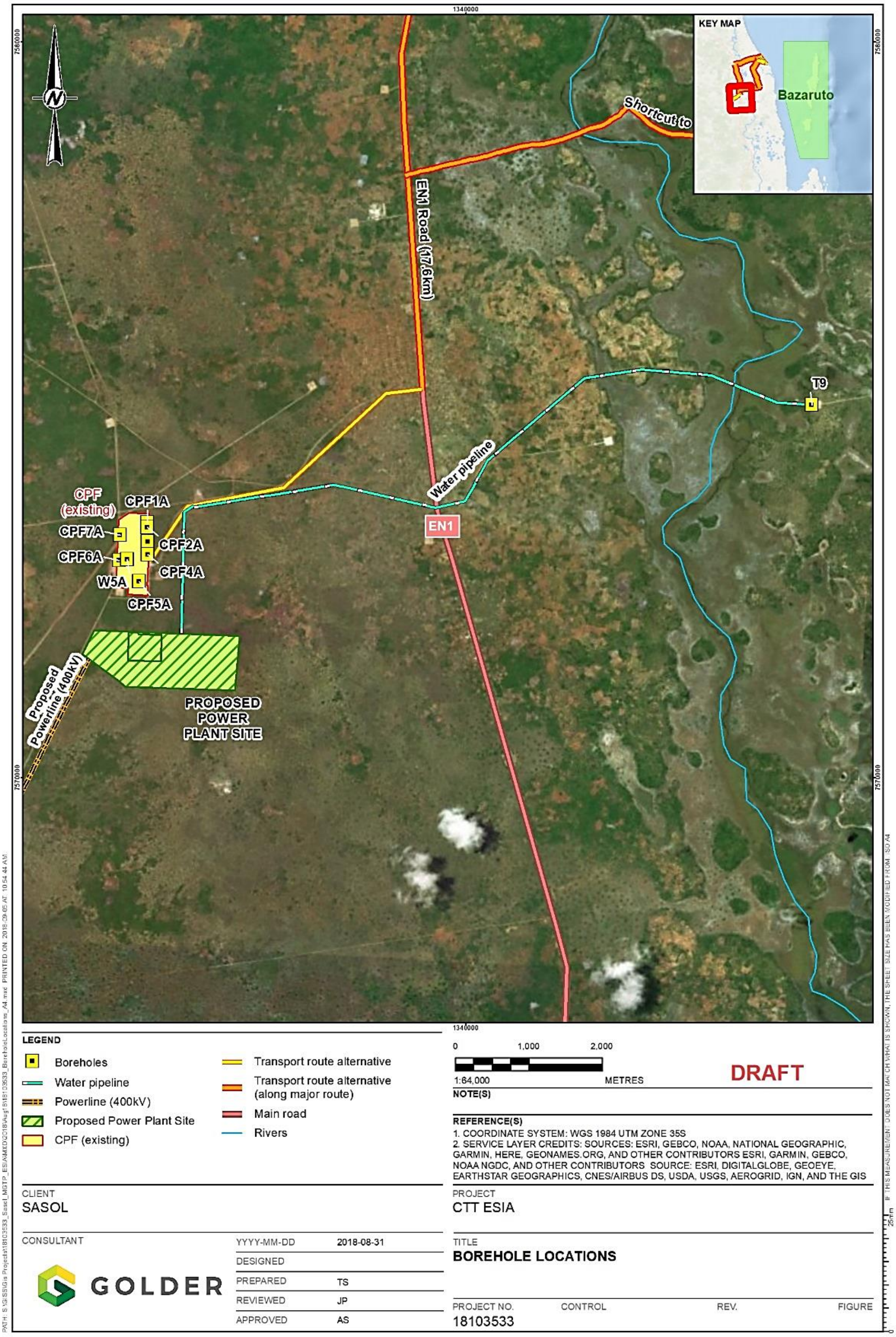

Figure 10: Location of CPF monitoring and water supply boreholes

5.2 Hydrochemistry

Rison Groundwater Consulting CC has been assisting Sasol Temane with their groundwater quality monitoring program since 2006. Groundwater samples are collected bi-annually according to the prescribed Sasol sampling protocol. The 95% percentile data from the times series are summarised for the boreholes is provided in Table 2 and the borehole locations shown on Figure 10. Each of the CPF monitoring points consist of a shallow and deep borehole pair, the deep boreholes are denoted with “A” and the shallow boreholes are denoted with “B”. The shallow boreholes are not listed below because they are not fully penetrating and as a result are always dry.

Results are compared against the Mozambique Domestic Water supply guideline’s (2004) and to the baseline water quality range, specifically for the area.

Generally the groundwater quality is within acceptable ranges with some exceptions. For pH all sites fall within the acceptable ranges and for salinity (measured as Electrical Conductivity), sites T9, PC-8201C, PC-8201B, PC-8201A, T25, and Temane exceed the provided background range of 170 mS/m but not the domestic supply guideline of 200 mS/m. The EC time series is plotted on Figure 11 , and fluctuations in quality is especially observed for the water supply boreholes, with the CPF boreholes showing seasonal variations. Elevated salinity is coupled to NaCl content in the Temane and Chitsotso boreholes.

The only parameter that is problematic is the nitrate level (Figure 12 and Figure 13), with CPF5A, CPF7A, and CPF6A showing consistent elevated levels.

Table 2: 95% percentile water quality data summary for monitoring boreholes

	pH	EC	Alk	Ca	Mg	Na	Cl	F	NO3	B
Units		mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L
Background range	7	80 to 170	394 to 556	111 to 181	5.5 to 73	22 to 139	17 to 220	0.04 to 0.43	0.1 to 6.6	-
Mozambique Limits (2004)	6.5 - 8.5	200	-	50	50	200	250	1.5	50	-
T9	7.56	181	451	108	61	164	286.2	0.4	2.98	332
PC-8201C	7.37	163	476	125	44	133	197.7	0.4	8.25	345
PC-8201B	7.34	199	509	132	67	174	310.2	0.4	1.76	340
PC-8201A	6.7	174	500	155	59	130	229	0.38	6.6	333
T25	7.65	196	500	136	67	175	315.6	0.4	1.78	346
IPF2D	7.62	111	447	160	11	56	83.2	<0.3	2.91	102
IPF2S	7.24	129	446	153	17	87	161.4	<0.3	0.97	333
IPF1D	7.5	96	370	139	19	51	85.2	<0.3	0.29	200
IPF1S	7.24	129	446	153	17	87	161.4	<0.3	0.97	333
T22B	7.3	91	446	107	36	33	23.4	0.4	0.81	171
T22A	7.26	108	487	115	42	52	52.1	0.4	2.46	175

	pH	EC	Alk	Ca	Mg	Na	Cl	F	NO3	B
Units		mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L
Background range	7	80 to 170	394 to 556	111 to 181	5.5 to 73	22 to 139	17 to 220	0.04 to 0.43	0.1 to 6.6	-
Mozambique Limits (2004)	6.5 - 8.5	200	-	50	50	200	250	1.5	50	-
Temane	7.67	196	506	139	59	178	301.6	0.4	2.46	417
Chitsotso	7.24	157	414	115	48	155	237.5	0.6	4.63	378
CPF9A	7.58	58	265	78	11	27	11.1	0.3	1.45	172
CPF8A	7.72	67	284	105	7	26	28	0.3	3.7	191
CPF7A	7.43	148	506	145	62	71	72.3	0.5	44.75	225
CPF6A	7.3	106	410	147	17	42	18.3	<0.3	29.03	138
CPF5A	7.83	125	388	145	21	90	106	0.4	17.39	190
CPF4A	7.2	114	388	153	21	49	115.9	0.3	5.76	112
CPF3A	7.31	94	437	133	22	35	38.4	<0.3	1.67	177
CPF2A	7.31	102	439	147	22	34	52.5	0.4	5.01	147
CPF1A	6.98	89	434	130	20	34	22.1	<0.3	5.62	188

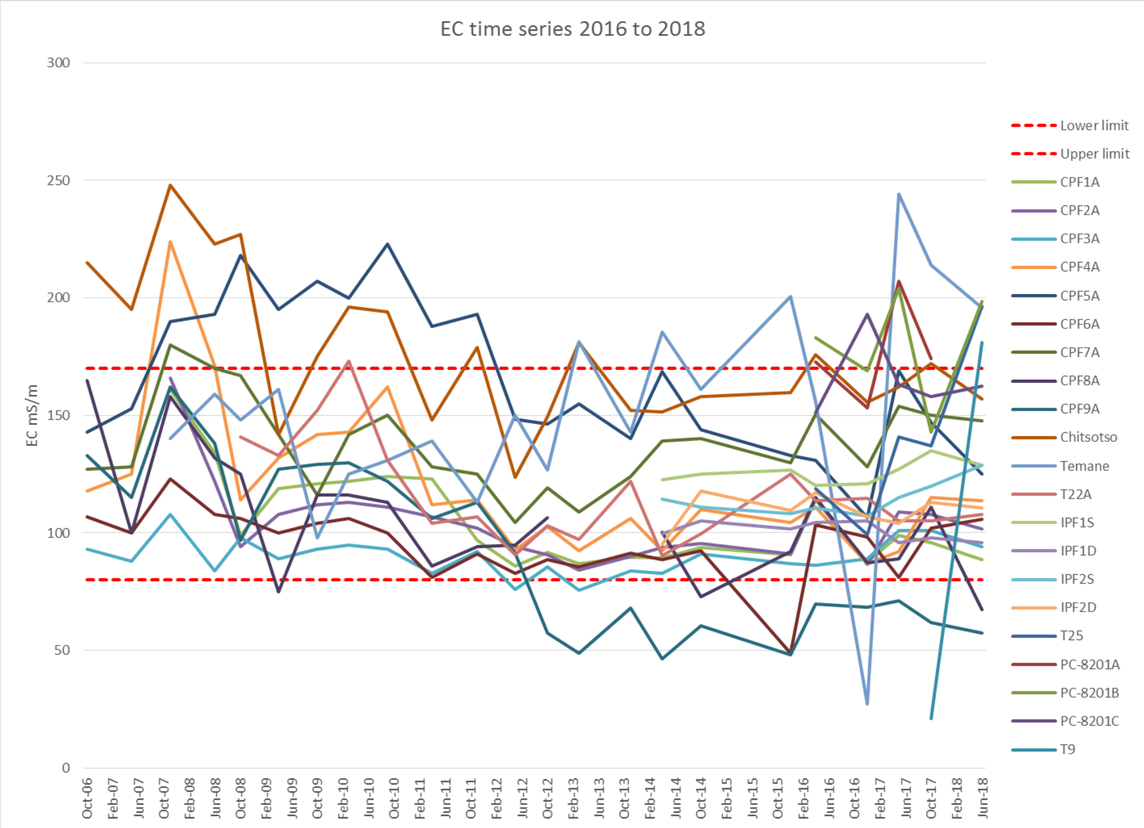

Figure 11: Electrical Conductivity time series (2006 to 2018)

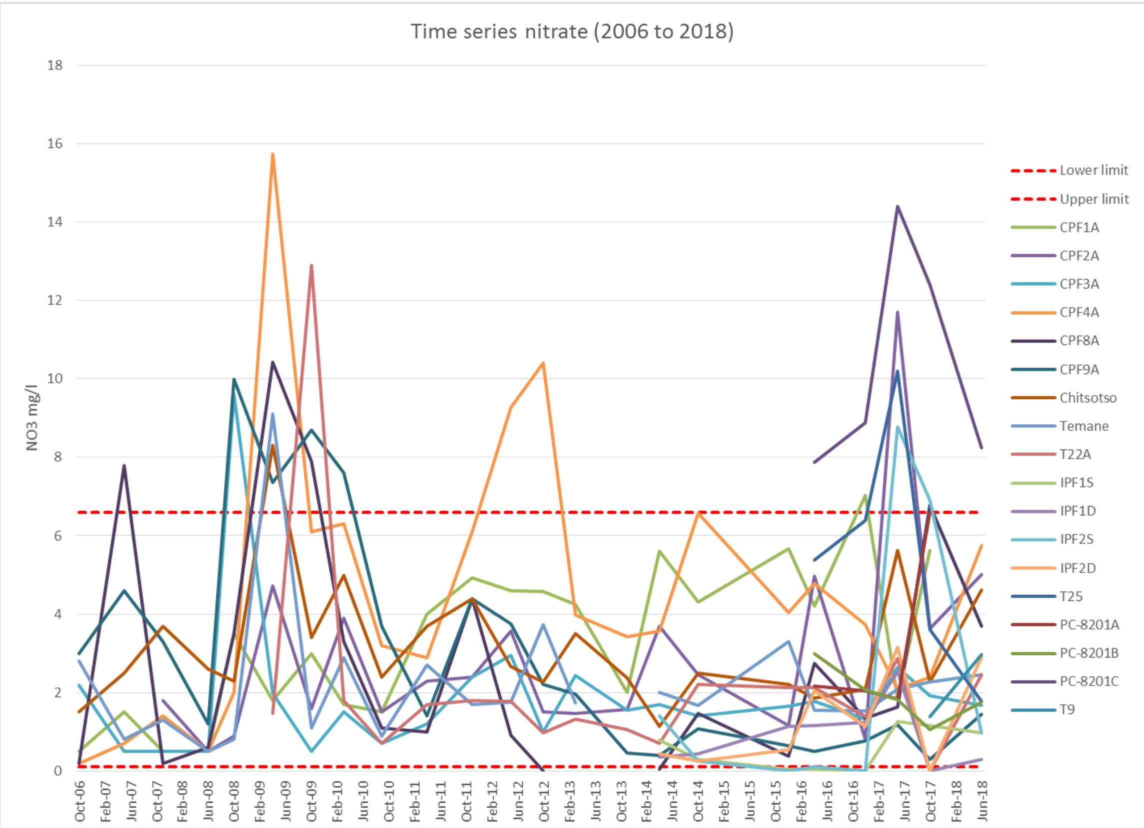

Figure 12: Nitrate time series (lower range 2006 to 2018)

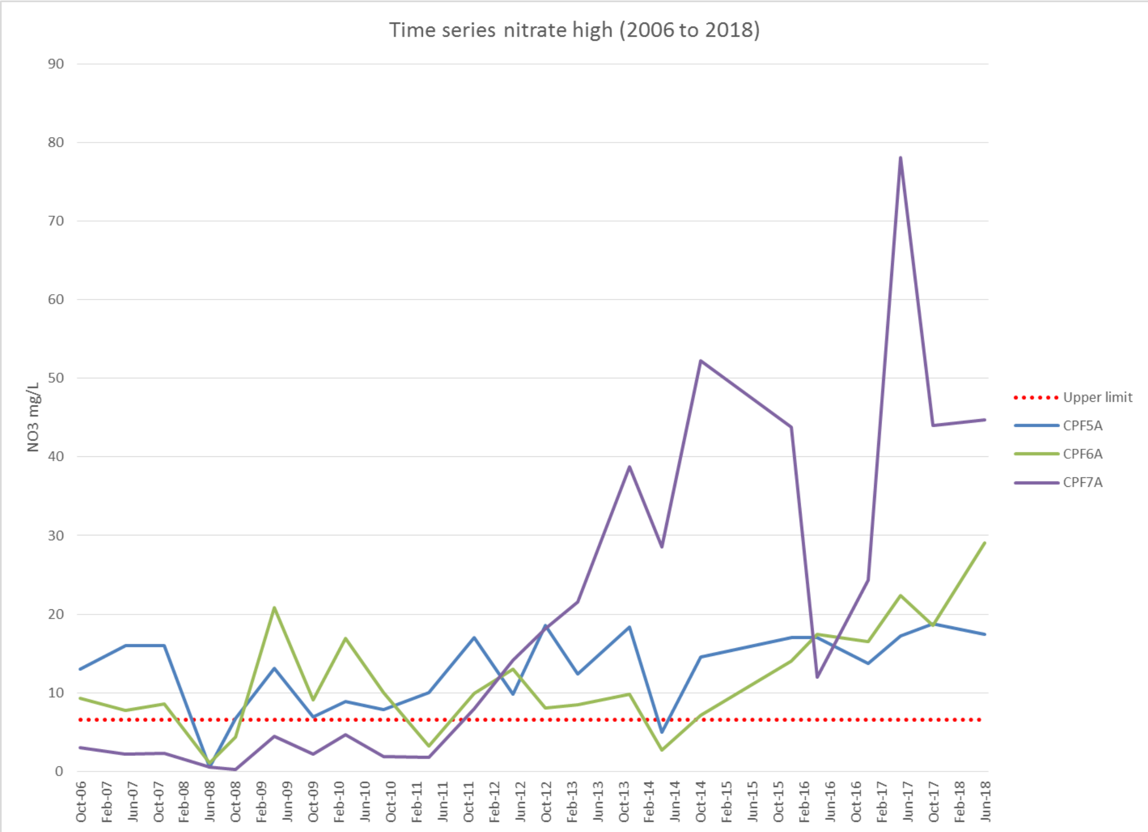

Figure 13: Nitrate time series - (high range 2006 to 2018)

The chemical character of the various groundwater samples was determined and compared with the aid of a Piper diagram. The Piper diagram is one of the most commonly used techniques to interpret groundwater chemistry data. This method proposes the plotting of cations and anions on adjacent tri-linear fields with these points then being extrapolated to a central diamond field. Here the chemical character of water, in relation to its environment, could be observed and changes in the quality interpreted. The cation and anion plotting points are derived by computing the percentage equivalents per million for the main diagnostic cations of Ca, Mg and Na, and anions Cl, SO_4 and HCO_3.

The Piper Diagram indicates the hydrochemical character for samples analysed in April 2014 (Figure 14). The Piper Diagram shows that the hydrochemical character of most samples is dominated by calcium and bicarbonate, and comparison to time series data show that there is no shift in hydrochemical character observed over time. Boreholes CPF5A, Temane and Chitsotso boreholes showed some enrichment in NaCl.

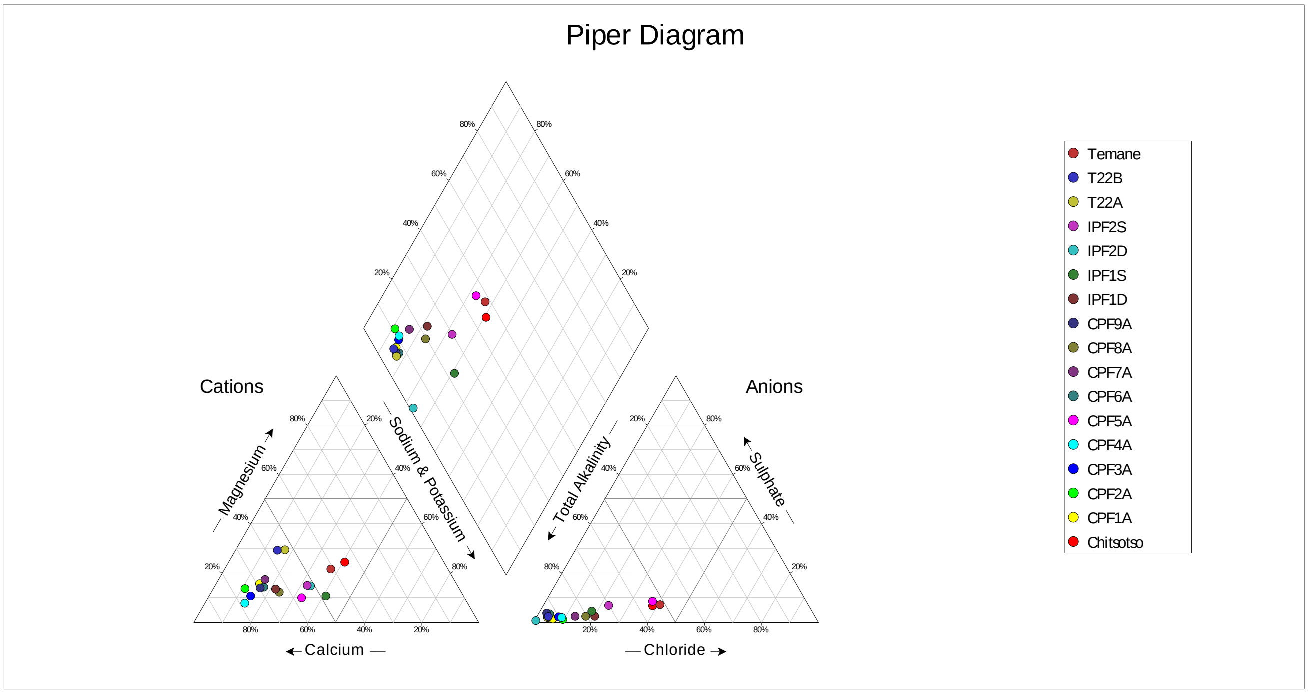

Figure 14: Piper diagram of monitoring boreholes at the CPF

Extensive groundwater quality testing shows that groundwater quality in the study area is virtually unaffected by human activity. Except for a few localised cases, the regional water quality is by and large unchanged. Whereas the groundwater quality is saline, especially in inland areas, due to the Jofane aquifer being situated on limestone, groundwater is generally potable.

5.3 Water Levels

Water levels have been measured bi-annually at all Sasol monitoring boreholes around the CPF over 10 years, showing a generally decreasing trend in borehole water levels since 2003. The floods in 2000 recharged groundwater (Rison 2014a &b) after which the levels gradually decreased, dropping during dry seasons and rising during and after rainy seasons. This is shown in Figure 15, and Figure 16 shows water levels for the study area as a whole.

Measured water levels range between 0.2 to 38.7 metres below ground level (mbgl). The average water level measured is 16.5 mbgl. The shallow water levels up to 2 mbgl are all at hand dug wells near or within alluvial deposits. Deeper water levels (>20 mbgl) are often encountered towards the coast under the coastal dune system or where deeper wells were installed alongside gas/oil well installations.

A borehole 6 km from the CPF (T22B) shows the same trends as the other boreholes, illustrating that the small amounts of abstraction done at the CPF does not materially influence the groundwater levels.

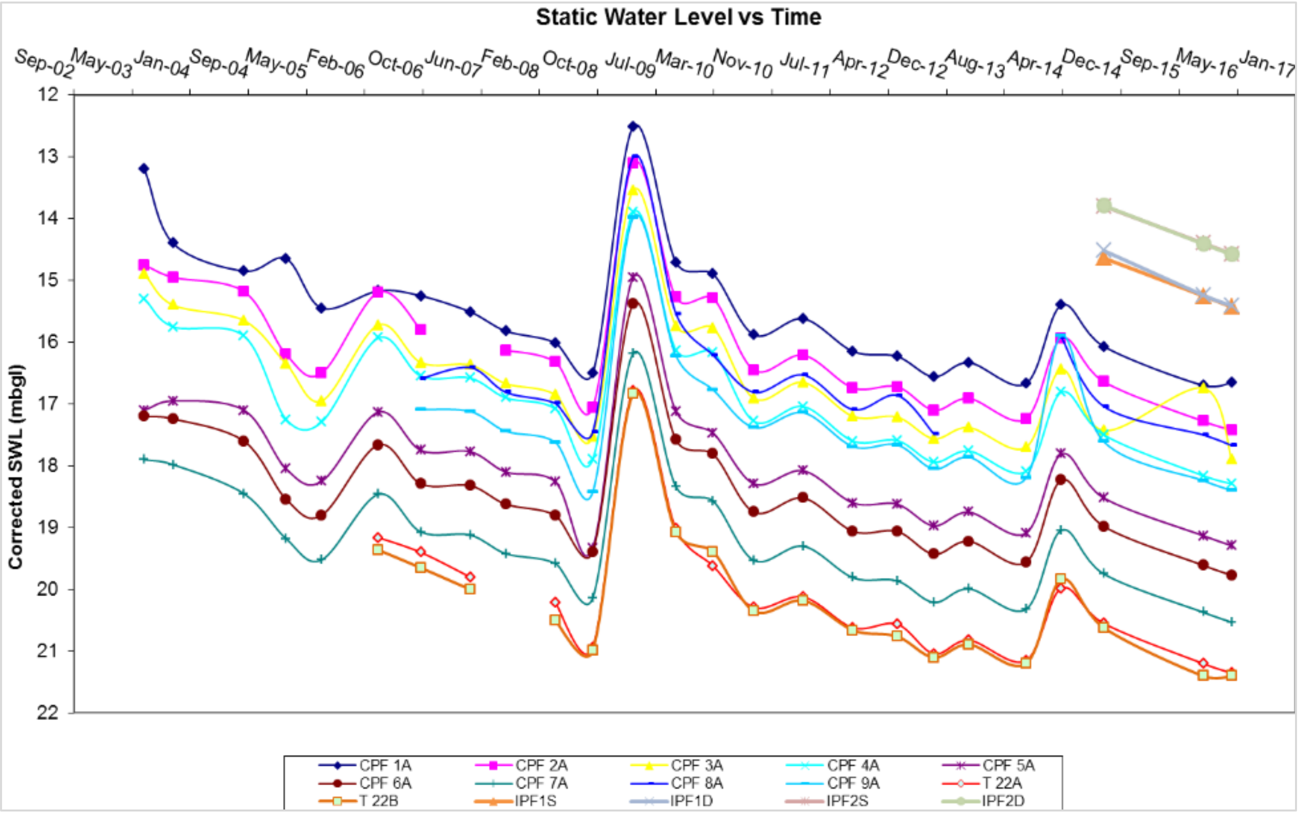

Figure 15: Time series of changes in groundwater levels in boreholes around the CPF (2003 – 2016)

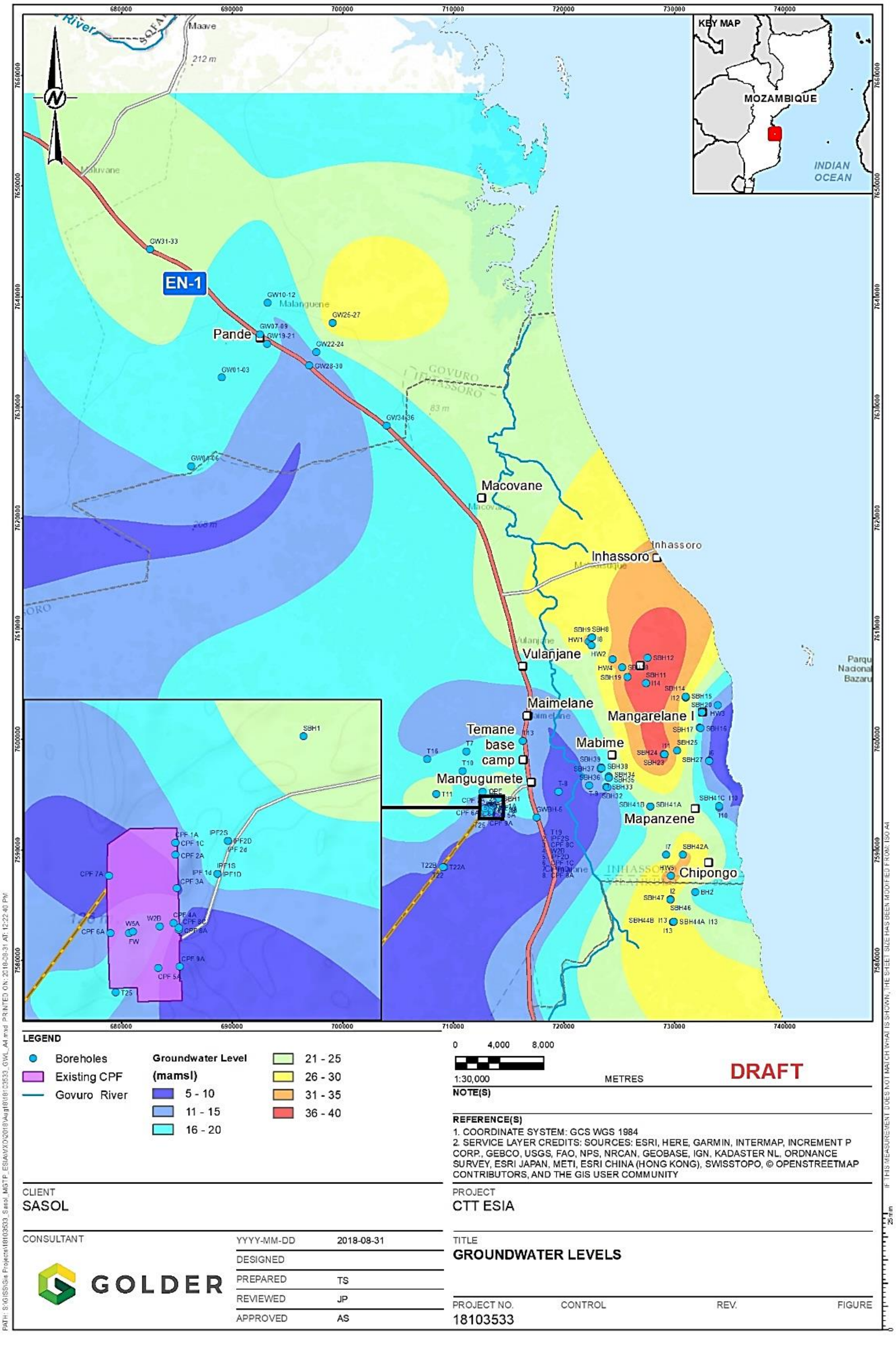

Figure 16: Average groundwater levels (mbgl) for the study area

5.4 Groundwater Flow

In order to assess groundwater flow in any area, one needs to first determine the relationship between groundwater and topographic elevations. Very often groundwater flow is controlled by the topographic surface, which causes flow from topographic highs towards topographic lows. Groundwater levels recorded during the hydrocensus were used to establish whether or not such a relationship exists. Shallow boreholes/wells were excluded from this correlation because they represent a minor perched aquifer's flow that is almost certainly controlled by the topography. A total of 47 water levels were used in the correlation between topographic and groundwater elevation. The result was a 75% correlation which suggests that the topographic surface controls groundwater flow direction to an extent (Figure 17).

Water levels measured at all the sites recorded were corrected for elevation and the Bayesian interpolation was then undertaken to generate a piezometric contour map for the general project area (Figure 18).

The Bayes interpolation technique assumes a relationship between the topography and the depth to the water table. It is realistic to assume that the water table depth will decrease with proximity to the Govuro River. It can be concluded that during the rainy season the river will add water to the groundwater system with the opposite being true during low flow conditions in winter, thus implying a surface groundwater interaction in the system.

It can be seen that the Temane area has a general water level elevation of 16 to 25 mamsl, with flow towards the Govuro River to the east. The well fields to the northeast towards Inhassoro is characterised by deeper water level elevations (>31mamasl), creating a localised water divide between the coastal dunes and the Govuro river. A similar situation occurs towards the south eastern coastal area (Chipongo area).

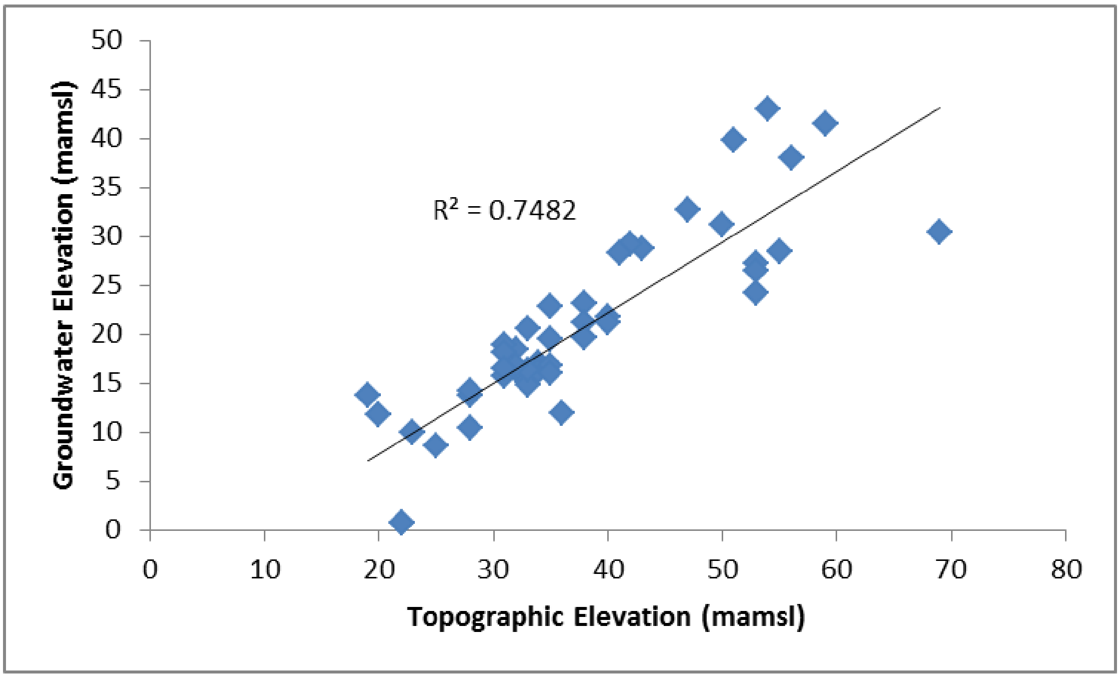

Figure 17: A 75% correlation between topographic and groundwater elevation

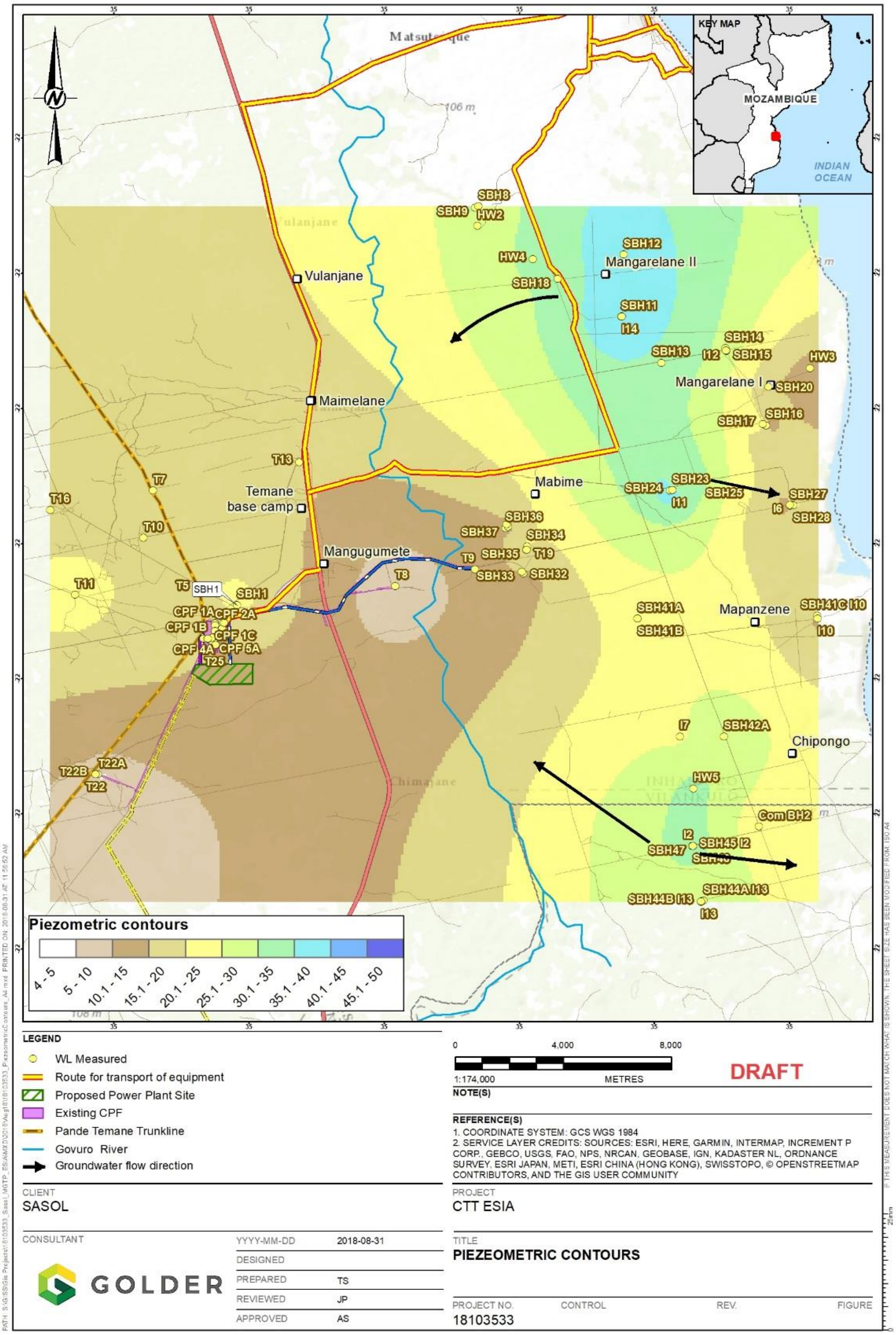

Figure 18: Piezometric contours (mamsl) for the general project area

5.5 Aquifer Recharge

The groundwater budget depends on the vertical recharge rate and subsequent evaporation and lateral seepage. The recharge is also closely related to the evaporation rate above the saturated zone. The evaporation occurs through several processes that depend on the duration and intensity of rainfall, the soil and soil moisture conditions, vegetation features and the prevailing weather (atmospheric demand). Most of these variables are not measured so evaporation and its impact on the groundwater recharge are estimated from empirical models or reference evaporation such as pan measurements (Coastal & Environmental Services & SAL CDS, 2010).

A report prepared by Hartley (2005) states a conservative estimate of rainfall recharge to karst groundwater systems was calculated at 5 % of the MAP (Mean Annual Precipitation). The average annual rainfall figures calculated at Temane for the period 2002 to 2005 was 831 mm which is equivalent 0.04m recharge per annum.

5.6 Expected radius of influence during pumping

5.6.1 Approach

As noted in Section 2.4, raw water for the Project will be supplied from aquifers in the area and treated. Two boreholes of differing water quality and abstraction rates are currently being considered as the source of raw water to the CTT site, T9 and W5A (Figure 10). The two technology options differ significantly in the expected water supply demand, and the impact on the water resource must be quantified and understood. Therefore, a simplified numerical model was constructed based on existing information to determine which option is likely to have the least impact on the aquifers in the Project area.

Water requirements for the two options can be defined as follows:

- During construction the CCGT option requires a water supply of 5.31m^3/h and the OCGE option has a requirement of 4.31 m^3/h to support the potable requirements at the construction camp.
- During operation the CCGT option requires a water supply of 25.9m^3/h and the OCGE option has a requirement of 3.39 m^3/h for the power plant with an estimated 0.44 m^3/h additional for potable supply for both options.

Currently an estimated 8.3 m^3/h is abstracted from the two boreholes to supply the CPF water supply requirements.

The objective of the numerical model was to thus to determine the depth of drawdown and the extent of the cone of depression for the following scenarios:

1) Current situation (baseline) pumping 8.3 m^3/hour
2) Construction phase (option 1) pumping an additional 5.31 m^3/hour (13.61 m^3/hour in total)
3) Construction phase (option 2) pumping an additional 4.31 m^3/hour (12.61 m^3/hour in total)
4) Operational phase (option 1) pumping an additional 26.34 m^3/hour (34.64 m^3/hour in total)
5) Operational phase (option 2) pumping an additional 3.43 m^3/hour (11.43 m^3/hour in total)

5.6.2 Conceptual model

The conceptual model used for the construction of the numerical model was based on work completed during previous investigations, including the Coffey study (2014), Figure 19. Measured transmissivity values are high and therefore it is expected that the water levels will not be severely impacted by abstraction as was previously simulated.

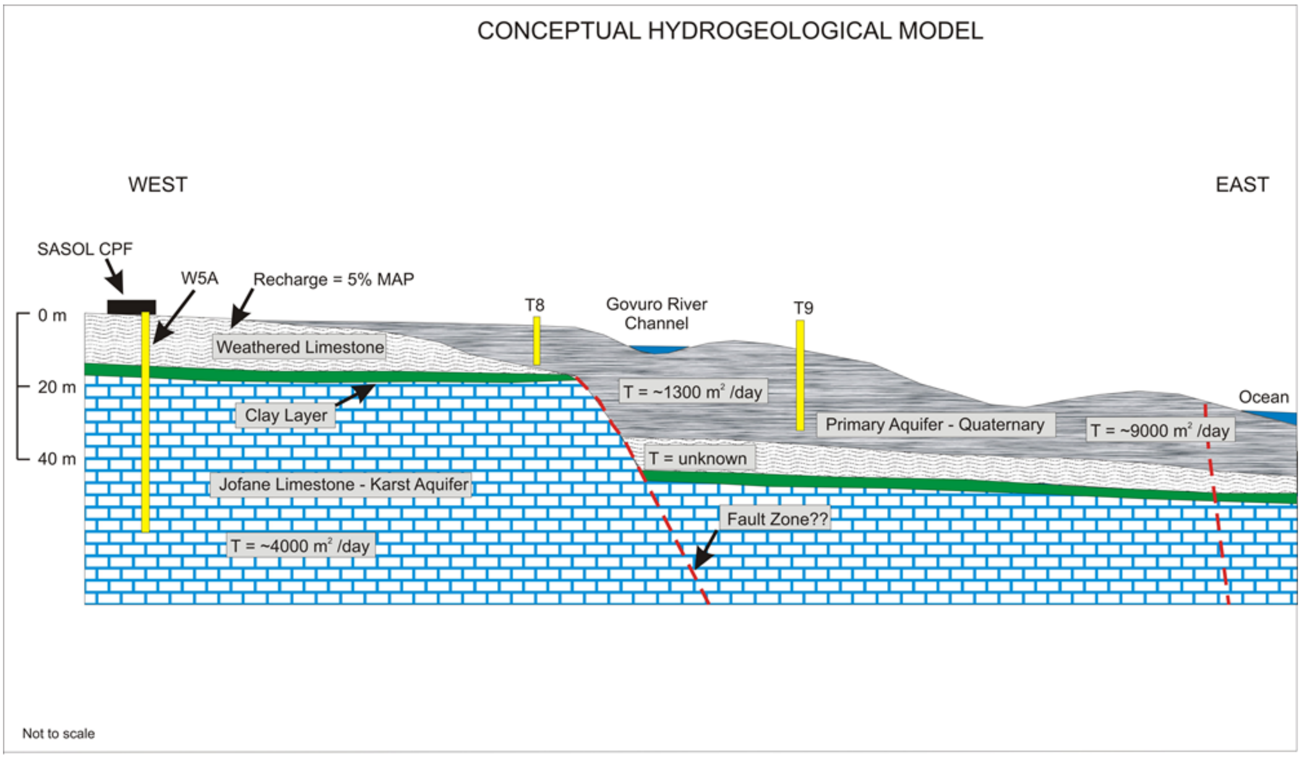

Figure 19: Conceptual model (after Van Bart, 2014)

It was assumed that the CPF activities have been operational for 10 years and pumping at 8.3 m³/hour for the entire period. Thereafter a two-year construction period and a twenty year operational period were simulated.

5.6.3 Model setup

The groundwater flow and contaminant transport software package Feflow (Finite-element simulation system for subsurface flow and transport processes) developed by DHI-WASY GmbH was selected for development of the groundwater flow model. The model was constructed with 5 layers to represent the conceptual model as shown in Figure 20. The layers were chosen to be at a specific depth from surface in order to calculate the K value easily.

Weathered limestone 20m T=1300m2/d K = 65 m/d	Primary aquifer 41m T=1300m2/d K=97m/d	L1
Clay, 1m, K = 0.01m/d		L2
Jofane limestone 71 m T= 4000m2/d K = 56 m/d		L3
	Clay, 1m, K = 0.01m/d	L4
	Jofane limestone 50m T= 4000m2/d K = 80 m/d	L5

Figure 20: Diagram to depict the model setup

The model mesh was generated using the Triangle method. The mesh consisted of 15853 elements per layer and 8149 nodes per layer. Figure 21 shows the mesh, the surface elevation and boundary conditions. Dirichlet boundary conditions were used as seepage faces to represent the coastline and the Govuro River.

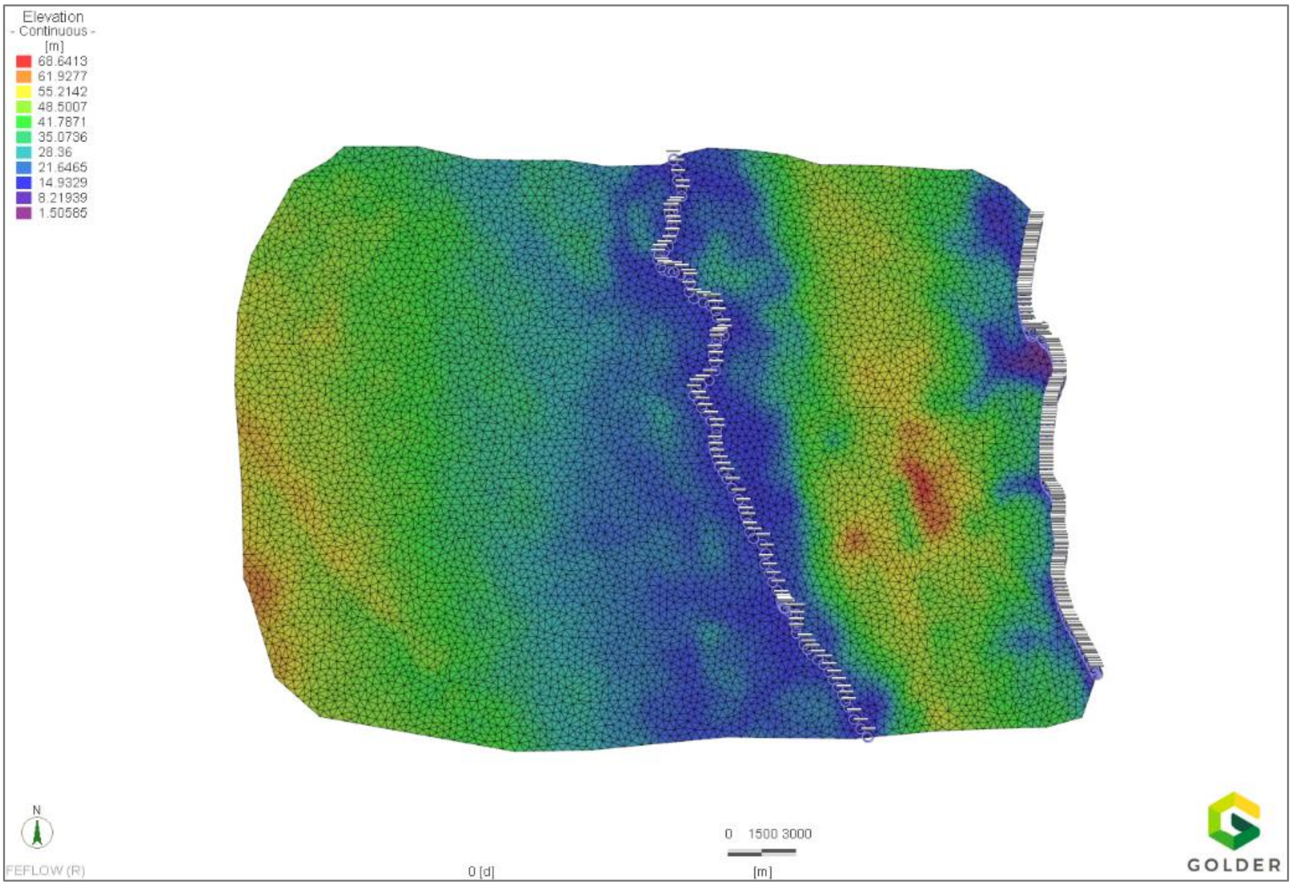

Figure 21: Model mesh showing surface elevation and boundary conditions

Well boundary conditions were applied for T9 and W5A and the abstraction was divided between these two boreholes so that T9 accounted for 55% of the abstraction and W5A accounted for 45% of the abstraction based on the sustainable yield that is higher in T9 than in W5A. Table 3 and Figure 22 shows the abstraction values used in the model for the various scenarios and options.

Table 3: Abstraction values used for the various scenarios and options

ABSTRACTION	m^3/hour	m^3/day	T9 (m^3/day)	W5A (m^3/day)
Current (10-year period)	8.3	199.2	109.6	89.6
Construction option 1 (2 years)	13.6	326.6	179.7	147.0
Construction option 2 (2 years)	12.6	302.6	166.5	136.2
Operational option 1 (20 years)	34.6	831.4	457.2	374.1
Operational option2 (20 years)	12.1	291.1	160.1	131.0

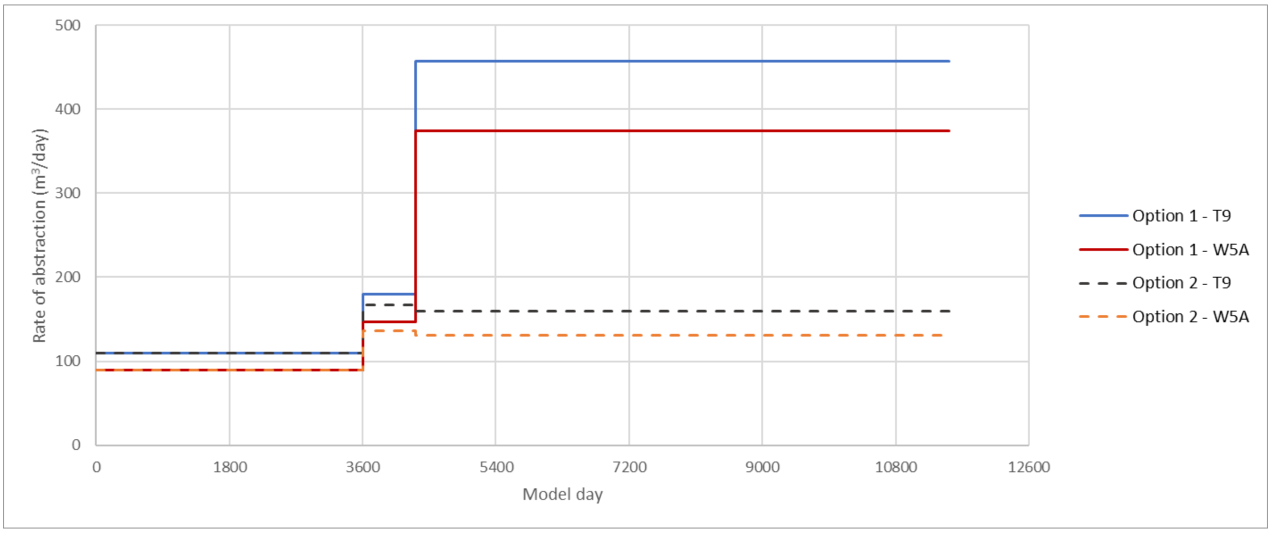

Figure 22: Abstraction values over time

5.6.4 Model results

The model was run as a steady state model without any abstraction. The simulated steady state water levels (Figure 23) are flat and do not follow topography which can be expected as the transmissivity values are very high. Figure 24 shows the simulated steady state water levels in plan view.

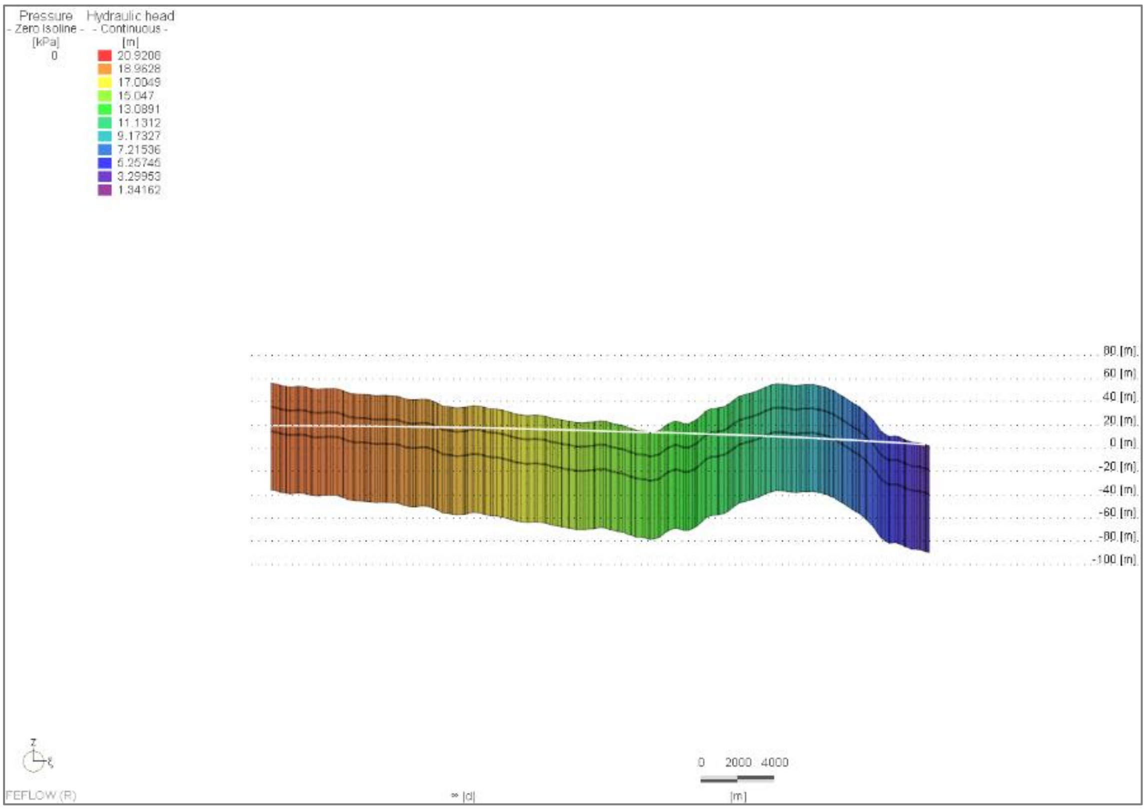

Figure 23: Simulated steady state water level (white line) - cross section view

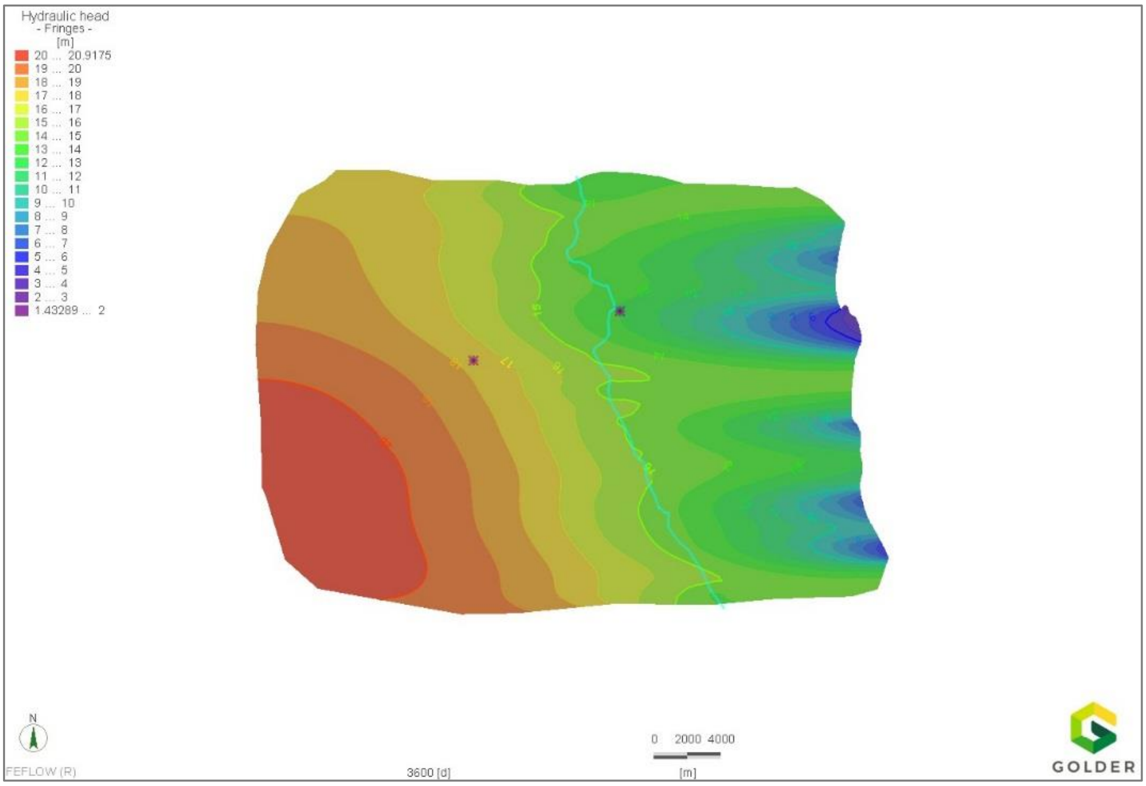

Figure 24: Simulated steady state head (before abstraction)

Due to the high transmissivity values, the abstraction through the expected project does not make much difference the overall simulated head distribution of the aquifer.

Simulation show the water level within the pumping boreholes after 20 years operational as follows:

- Option 1 @ W5A: Water level is 28 m below the steady state water level
- Option 1 @ T9: Water level is 0.16 m below the steady state water level
- Option 2 @ W5A: Water level is 0.115 m below the steady state water level
- Option 2 @ T9: Water level is 0.055 m below the steady state water level

The difference between option 1 and option 2 is clearly visible in **Figure 25**. Simulations thus show that Option 2 has a reduced effect on the water level compared to Option 1 over a simulated 20year period. Although the model shows that the boreholes can supply the required volume of water for Option 1, it is likely in reality that the boreholes may fail over time depending on rainfall/recharge and other abstraction interferences at the required rate of abstraction.

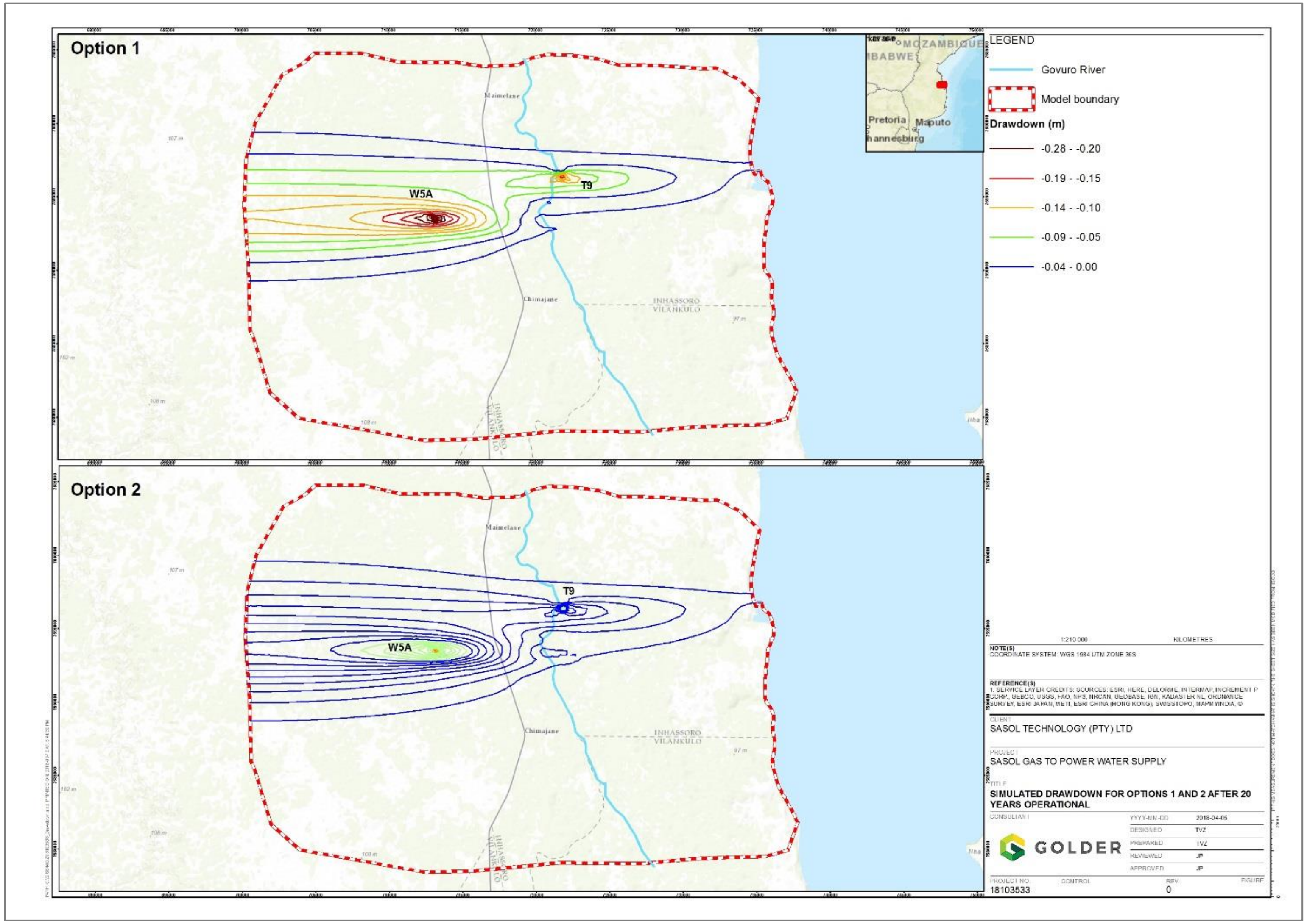

Figure 25: Simulated drawdown for the two options after 20 years of operation

5.7 Hydrogeological Site Conceptual Model

Site-specific hydrogeological information gathered from the baseline studies completed for the project area was used to develop a conceptual model for the general project area. A simplified diagrammatic representation of the conceptual model is presented in Figure 26.

The hydrogeological regime is directly determined and controlled by the lithological distribution as well as structural geology. Four main hydrogeological units have been identified based on their physical properties and relative geological age, namely:

- The unconfined shallow weathered Jofane perched (weathered) aquifer,
- The deep confined Jofane limestone aquifer,
- The unconfined alluvial aquifer along the Govuro River (quaternary deposits), and
- The unconfined unconsolidated coastal aquifer (quaternary deposits).

Most of the information available is concentrated around the existing CPF as this is where extensive drilling and aquifer testing has been done since the inception of the CPF. Drilling of monitoring boreholes at the CPF has revealed that an unconfined perched aquifer exists below the site to a depth of 14 – 20 mbs. This aquifer is considered to be minor and exists within highly weathered and leached Jofane Limestone. The base of the aquifer is defined by a uniform impermeable clay layer that varies in thickness, attaining a maximum thickness of 6 m. Transmissivity of this zone is low and an average value of 15 m^2/day was calculated from FHTs. This system cannot be considered to be a source of useable groundwater and only has significance at the CPF (and proposed power plant) for water quality monitoring. Any contamination detected in the system will be a first order warning against pollution of the viable Jofane Lime stone aquifer.

The confined karst aquifer within the Jofane Limestone Formation exists below the clay layer described above. Drilling has shown that this aquifer consists of weathered and leached limestone but becomes more competent with depth. The more competent parts are often associated with cavernous/honeycomb formation. Water levels range between 12 to 17 mbs but can vary considerably as they are controlled by rainfall events. Transmissivity values recorded are variable between 90 to 700 m^2/day, with an average recorded of approximately 400 m^2/day.

The Jofane limestone aquifer is the main source of water for communities in the Temane area. Water quality of the system are prone to be of high salinity in areas and do exceed drinking water quality standards occasionally. However, there is evidence of areas within the aquifer that are characterised by fresher water, most likely linked to higher recharge zones. These areas are most likely not overlain by the clay layer found at the CPF site, which confines the system in places. The system is considered to be vulnerable to potential pollution especially in areas where the clay layer is absent. The aquifer is clearly heterogeneous which explains why there is only a 75% correlation between topography and groundwater level elevation. It has been estimated that this aquifer is recharged at a conservative rate of 5% of the MAP.

The groundwater quality in the Jofane limestone aquifer is relatively poor and has a higher salinity than other waters in the project area. The reason for high salinity is probably related to longer residence in the karst aquifer where limestone interacts with the water and results in minerals going into solution.

As one moves eastwards, the surface geology changes from weathered limestone to unconsolidated quaternary deposits of the Govuro River channel and the coastal sand dunes.

Although no testing was done during this investigation of the alluvial sediments along the Govuro River, previous studies indicated variable results for this system, with occasional high contamination and a high degree of groundwater/surface water interaction is expected. High yields and transmissivity (of up to 1000 m^2/day) were recorded for the aquifer. The system can be considered a viable source of groundwater, of limited extent. The system is highly vulnerable to contamination due to the high permeability of the unconsolidated formations and unconfined character of the aquifer.

Towards the coast (Inhassoro area), a primary aquifer exists within the old and young dunes that overlay the Jofane Limestones. The Dune Aquifer contains fresh groundwater, due to rainfall recharge, although in the Vilanculos area the thickness of this aquifer does not appear to be well developed. The Dune Aquifer is principally recharged by rainfall. Recharge estimates from studies in sandy soils in other parts of the country range from 17-33 % (GCS, 2001) of the annual rainfall. In more clayey areas, the recharge is less. This aquifer is best defined as a primary unconfined aquifer that is continuously recharged by the river and rainfall.

Aquifer testing showed variable transmissivity values from 9 to 210 m^2/day. However, it is expected that the true transmissivity will be between 100 to 200m^2/day. The variance of T values in the tested boreholes can be attributed to:

- Solid casing installation across the complete aquifer zone in exploration boreholes at the well pads.
- Silting of screens/slots in casing due to iron bacteria which is very common in the area in production boreholes.
- Occurrence of low permeable clay lenses within the dune system.

The coastal dune system forms a localised water divide between the Govuro River and the coastline, drainage is thus not just towards the coastline but a portion of groundwater thus feeds towards the Govuro River. Water level below ground level for the aquifer is on average approximately 15m. There are however instances recorded during the past hydrocensus, where communities were abstracting water from the sands at shallow hand dug wells of less than 2m in depth near the coastline.

Some mixing is expected along the coast between the sand and limestone aquifers. In close proximity to the coast care should be taken not to abstract groundwater in large quantities which could result in saltwater intrusion into the freshwater aquifer. Current water quality of the aquifer is generally excellent and most chemical parameters are well within acceptable drinking water guidelines. There is no evidence of any negative impacts on community wells and boreholes from the current well field developments.

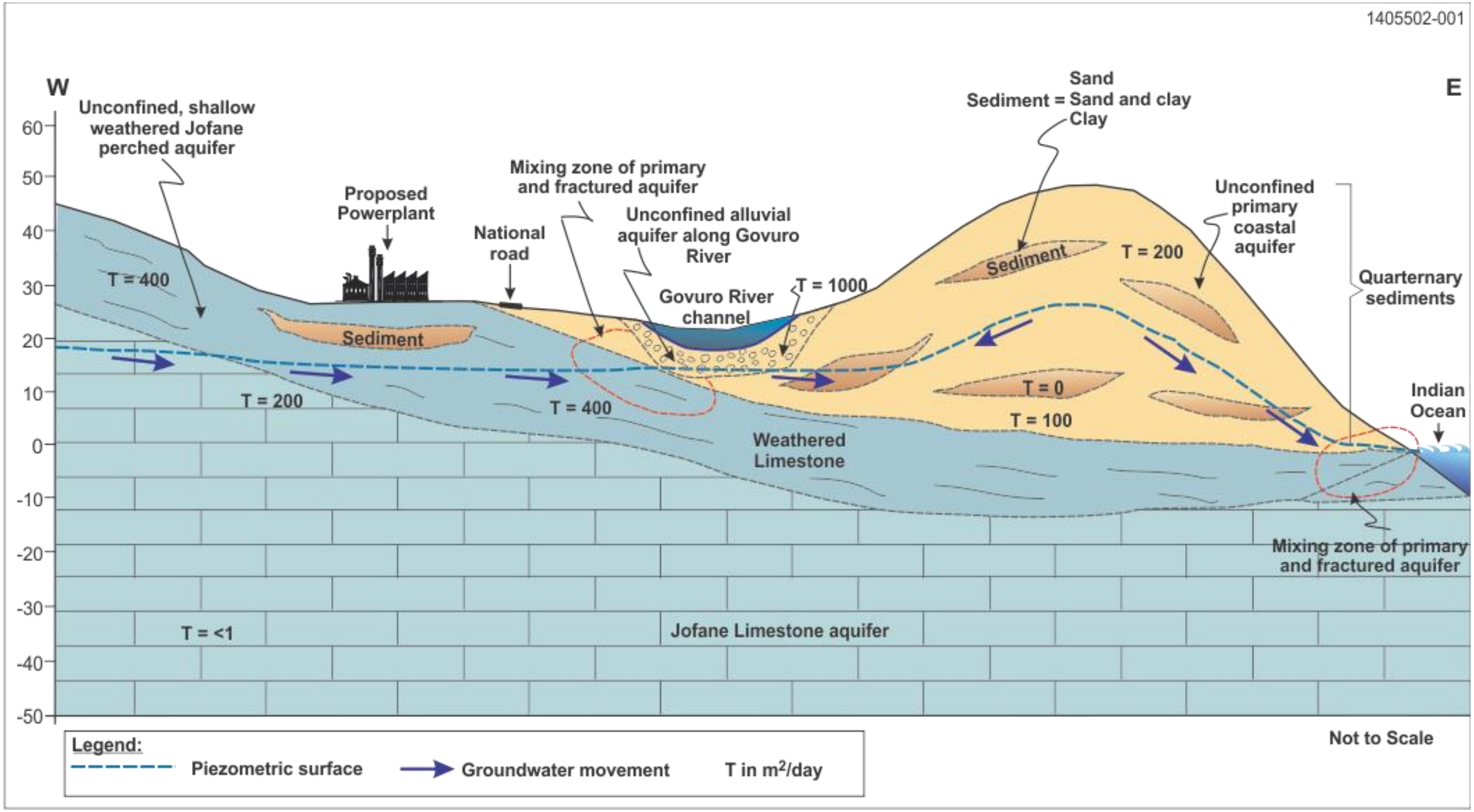

Figure 26: Hydrogeological Site Conceptual Model

6.0 IMPACT ASSESSMENT

6.1 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).

Impact significance will be rated using the scoring system shown in Table 4 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 4.

Table 4: Scoring system for evaluating impacts

Impact Magnitude			Impact Probability
Severity	Duration	Extent	
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 5.

Table 5: 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

Value	Significance	Comment
		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 6 below. In order 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 which are as a result of activities outside of the ADI.

Table 6: 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 are encouraged to 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.

6.2 Impact Assessment and Mitigation Measures - Combined Cycle Gas Turbine (Option 1)

From a hydrogeological perspective, the following sections summarise the potential impacts during the various phases of the Project for Option 1 and provide a significance rating for each impact before and after mitigation.

6.2.1 Construction phase impacts

The potential groundwater impacts of the project during the construction phase are listed and ranked in Table 7 and described in the sub-sections below. The rating presented is based on pre-mitigation and post mitigation interventions.

Table 7: Construction phase impact table - CCGT

Indicator of potential impact	Pre-mitigation					Post-mitigation				
	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Ground water deterioration - Poor sanitation	2	1	1	2	**Negligible 8**	1	1	1	2	**Negligible 6**
Ground water deterioration - Accidental spillages and Hazardous materials	4	1	1	2	**Negligible 12**	2	1	1	2	**Negligible 8**
Ground water deterioration – Waste water disposal	6	1	2	3	**Low 27**	4	1	1	2	**Negligible 12**
Groundwater level decline-additional water abstraction	2	2	2	4	**Low 24**	2	2	1	4	**Low 20**

6.2.1.1 Groundwater Quality Deterioration

The construction phase activities that could potentially impact on the **quality of the groundwater resource** include the materials handling, and waste generation associated with the construction of the gas pipeline, the electrical transmission line, access and maintenance roads, and the power plant. This potential for groundwater contamination can result from irresponsible practices during construction such as:

- Poor sanitation practices at construction sites (temporary facilities need to be provided at all construction sites)
- French drains (and sceptic tanks combo system) for human waste/washing water etc. at construction camp
- Accidental spillages and storage of hazardous chemicals at the construction sites and camp
- Hazardous waste materials will be generated during the construction phase ranging from used solvents, used oil and grease, etc.
- Indiscriminate disposal of waste materials and chemicals (i.e. oils, greases, etc.)
- Servicing of construction equipment and vehicles in non- designated areas

All of the above impacts are rated negligible due to the fact that the duration and Extent will be of very short term and the impacts are not expected to extend beyond the sites themselves. Waste water management measures need to be in place to ensure that impacts are minimised.

Domestic waste water will be generated at the construction camp kitchen, bathrooms, residential block, and administration areas will be discharged in subsurface drains, until the permanent waste water treatment plant is completed. There is no current detail information on the expected volumes of domestic waste water that will be generated and the design of the systems.

Mitigation measures

The protocols that should be applied during the construction phase should be developed and documented in the EMP. The protocols should address the following:

- Storage of new and used oils in bunded areas;
- No co-handling of reactive liquids or solids;
- Creation and monitoring of an inventory of chemicals held on site;
- Storage of hazardous or toxic substances securely and controlled use thereof;
- Availability and accessibility of HAZOP sheets of all chemicals;

If the recommended construction protocols are followed, then impact during construction will be reduced to low significance.

Wastewater treated and discharged on site must comply with the sanitary effluent standards (Decree 18/2004 of 2 June – Appendix IV – Standards of Emission of Domestic Liquid Effluents and the IFC General Environmental, Health and Safety Guidelines for Sanitary Effluent (30 April 2007), and may be used on site as service water or irrigated.

6.2.1.2 Decline in groundwater levels

Abstraction of groundwater for potable use for construction crews, could add to the pressure on the local groundwater resources, and **decline in groundwater levels**. Raw water for the Project will be supplied from aquifers in the area and treated accordingly. Two boreholes of differing water quality and abstraction rates are currently being considered as the source of raw water to the CTT site, T9 and W5A. Alternatively a new borehole may be installed at the Power Plant site.

Not only will there be supply to crews working at various sites, but a construction camp (including accommodation for construction workers) will be set up for the duration of the construction phase. Daily water allowance of 150l/person/day is made during construction. This implies that for the CCGT Option there will be an expected 850 person on site which will require a water supply of 5.31 m^3/hour. This will add additional pressure on the supply boreholes from which the Sasol already abstracts 8.3m^3/h for the CPF water requirements.

The scenarios of various abstraction rates and water requirements were simulated in a simplified numerical model (See Section 5.6) and it can be seen from the results that the additional water requirements during the construction period has a very low impact at local scale only. However, with mitigation and management of abstraction boreholes, the impact of water level decline can be reduced further to being limited to close proximity of the abstractions wells only.

Mitigation measures

Mitigation and management of abstraction boreholes need to include continuous level and abstraction volume monitoring. All abstraction boreholes should be set up and managed so that the sustainable yield is not exceeded during a 24-hour period, and to always allow for boreholes to recover sufficiently between abstraction cycles.

6.2.2 Operational phase impacts

The potential groundwater impacts of the project during the construction phase are listed and ranked in Table 8 and described in the sub-sections below. The rating presented in are based on pre-mitigation and post mitigation interventions.

Table 8: Operational phase impact table - CCGT

Indicator of potential impact	Pre-mitigation					Post-mitigation				
	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Groundwater deterioration - Irrigation of Effluents	10	4	2	4	**Moderate 64**	6	4	2	2	**Low 28**
Groundwater deterioration - Spills from the evaporation pond	10	4	2	5	**High 80**	8	4	2	4	**Moderate 56**
Groundwater deterioration - Accidental spillages and Hazardous materials	4	3	2	2	**Low 18**	2	2	2	2	**Negligible 12**
Groundwater deterioration – Waste management	4	3	2	2	**Low 18**	2	2	2	2	**Negligible 12**
Groundwater level decline- additional water abstraction	8	3	3	5	**Moderate 70**	6	3	2	3	**Low 33**

6.2.2.1 Groundwater Quality Deterioration

The operational phase activities that could potentially impact on the **quality of the groundwater resource** include the irrigation of effluents, accidental spillages and overflows from surface water impoundments, materials handling and waste/waste water generation associated with the power plant operation.

The sanitary effluent and treated oily water effluent streams are to be irrigated to the surrounding environment. There is a potential to pollute the local aquifer systems should non-compliant effluent be irrigated. As there is expected to be minimal surface flow of the irrigated water, with almost all of the water draining to underground, the perimeter boreholes should be regularly monitored to assess any potential contamination. The impact is considered to be of moderate significance but can be reduced to low with mitigation.

The evaporation pond will serve as the local pollution control dam at the CTT plant site. The pond will handle onsite wastewater streams including the ultrafiltration reject, brine, cooling water blow down, as well as non-compliant sewage and treated oily water effluents streams from the CTT plant. The water qualities of these streams will include very high salts, total suspended solids, oils as well as other contaminants. Liner failure and leakages and inadequate capacity of the evaporation pond to handle higher than anticipated waste stream volumes could potentially result in spillages to the surrounding environment. Spills from the evaporation could cause local ground water pollution. The impact is considered to be of high significance but may be reduced to moderate with mitigation.

This potential for groundwater contamination can also result from poor housekeeping that may result in accidental spillages and storage of hazardous chemicals; poor waste management and other waste disposal practices. All of these impacts are rated low and can be reduced to negligible after mitigation. Waste management measures need to be in place to ensure that impacts are minimised.

Mitigation measures

The oily water effluent and sewage effluent streams must comply with required discharge water quality standards for treated effluent as stipulated in terms of the Mozambican and IFC standards. Continuous monitoring of the effluent streams is required prior to irrigation to determine compliance to discharge standards. Non-compliant effluent should be discharged to the evaporation pond.

Measures for containment of spills and warning systems for leaks must be included in the design of the evaporation pond. The protocols that should be applied in the event of a spill in the operational phase should be developed and documented in the EMP. A clean-up plan should be prepared and carried out in this event.

The protocols that should be applied during the operational phase should be developed and documented in the EMP. The protocols should address the following:

- Storage of new and used oils in bunded areas;
- No co-handling of reactive liquids or solids;
- Creation and monitoring of an inventory of chemicals held on site;
- Storage of hazardous or toxic substances securely and controlled use thereof;
- Availability and accessibility of HAZOP sheets of all chemicals; and
- Waste disposal according to protocols and in designated containers/areas only.

A groundwater monitoring network need to be established on site that are targeted at specific potential sources of groundwater contamination.

6.2.2.2 Decline in groundwater levels

Raw water for the Project will be supplied from aquifers in the area and treated accordingly. Two boreholes of differing water quality and abstraction rates are currently being considered as the source of raw water to the CTT site, T9 and W5A. Alternatively a new borehole may be installed at the Power Plant site. The selected borehole (water source) will be used to supply either of the two technology options. The CCGT option requires a water supply of 25.9m^3/h. Clean stormwater harvested will also be used to offset borehole water supply. In addition to the Power Plant water supply it is estimated that an additional 0.44 m^3/h will be required for potable use on site. This will add additional pressure on the supply boreholes from which the Sasol already abstracts 8.3m^3/h for the CPF water requirements.

The scenarios of various abstraction rates and water requirements were simulated in a simplified numerical model (See Section 5.6) and the water level decline at each borehole was simulated as:

- Option 1 @ W5A: Water level is 28 m below the steady state water level
- Option 1 @ T9: Water level is 0.16 m below the steady state water level

It can thus be seen that the rate of water abstraction that is required significantly impacts borehole W5A, which is likely to result in a water level decline in other potential supply boreholes in close proximity of the CPF.

Based on the simulations the impact is considered to be a high moderate rating before mitigation. However, with mitigation and management of abstraction boreholes, the impact of water level decline can be reduced further to being limited to close proximity of the abstractions wells only.

Mitigation measures

Mitigation and management of abstraction boreholes need to include continuous level and abstraction volume monitoring. It is recommended that additional boreholes be used to augment the water supply from W5A and T9, as the required abstraction is likely to not be sustainable in the long-term from only the two boreholes. With the addition of other water supply boreholes, the impact can be reduced to low.

All abstraction boreholes should be set up and managed so that the sustainable yield is not exceeded during a 24-hour period, and to always allow for boreholes to recover sufficiently between abstraction cycles.

6.2.3 Decommissioning phase impacts

The potential groundwater impacts during the decommisioning phase identified are presented in Table 9 and described in the sub-sections below. The rating presented in are based on pre-mitigation and post mitigation interventions.

Table 9: Decommissioning phase impact table - CCGT

Indicator of potential impact	Pre-mitigation					Post-mitigation				
	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance

Groundwater deterioration – soil contamination	8	2	2	4	**Moderate 48**	8	2	2	2	**Low 24**
Groundwater deterioration – Accidental spillages and Hazardous materials	8	2	2	4	**Moderate 48**	6	2	2	2	Low 20
Groundwater level decline – reduction in water abstraction	6	5	2	4	**Positive +52**	6	5	2		**Positive +52**

6.2.3.1 Groundwater Quality Deterioration

During decommission of the site several activities are likely to result in the deterioration of groundwater quality.

The decommissioning of plant infrastructure, specifically the oil storage tanks, evaporation pond, sewage treatment plant and oily water treatment system could result in storm water run-off and soil contamination in the vicinity of these facilities. Contaminated soil has the potential to cause pollution of groundwater. This impact has been rated as a moderate significance.

Spillage of oils, fuel and chemicals during decommissioning can result in the pollution of water resources if due care is not taken. The impact is also rated with a moderate significance.

Mitigation measures

The protocols that limit potential pollution from the effluent facilities should be applied during the decommissioning phase should be developed and documented in the EMP. The mitigation measures will reduce the impacts to a low significance.

6.2.3.2 Decline in groundwater levels

Water supply requirements will be reduced during the decommissioning phase, since no more water supply will be required for the Power Plant site. Initially there may still be water supply needs during the demolishing of infrastructure, but afterwards all water abstraction will cease resulting in the likely recovering of water levels to pre-operation levels.

Mitigation measures

Not applicable.

6.3 Impact Assessment and Mitigation Measures - Open Cycle Gas Engines (Option 2)

From a hydrogeological perspective, the following sections summarises the potential impacts during the various phases of the Project for Option 2 and provides a significance rating for each impact before and after mitigation.

6.3.1 Construction phase impacts

The potential groundwater impacts of the project during the construction phase are listed and ranked in Table 7 and described in the sub-sections below. The ratings presented are based on pre-mitigation and post mitigation interventions.

Table 10: Construction phase impact table - OCGE

Indicator of potential impact	Pre-mitigation					Post-mitigation				
	Magnitude	Duration	Geographic Extent	Probability	Significance	Magnitude	Duration	Geographic Extent	Probability	Significance
Ground water deterioration - Poor sanitation	2	1	1	2	Negligible 8	1	1	1	2	Negligible 6
Ground water deterioration - Accidental spillages and Hazardous materials	4	1	1	2	Negligible 12	2	1	1	2	Negligible 8
Ground water deterioration – Waste water disposal	6	1	2	3	Low 27	4	1	1	2	Negligible 12
Groundwater level decline-additional water abstraction	2	2	2	4	Low 24	2	2	1	4	Low 20

6.3.1.1 Groundwater deterioration

The construction phase activities that could potentially impact on the **quality of the groundwater resource** include the materials handling, and waste generation associated with the construction of the gas pipeline, the electrical transmission line, access and maintenance roads, and the power plant. This potential for groundwater contamination can result from irresponsible practices during construction such as:

- Poor sanitation practices at construction sites (temporary facilities need to be provided at all construction sites)
- French drains (and sceptic tanks combo system) for human waste/washing water etc. at construction camp
- Accidental spillages and storage of hazardous chemicals at the construction sites and camp
- Hazardous waste materials will be generated during the construction phase ranging from used solvents, used oil and grease, etc.
- Indiscriminate disposal of waste materials and chemicals (i.e. oils, greases, etc.)
- Servicing of construction equipment and vehicles in non- designated areas

All of the above impacts are rated negligible due to the fact that the duration and Extent will be of very short term and the impacts are not expected to extend beyond the sites themselves. Waste water management measures need to be in place to ensure that impacts are minimised.

Domestic waste water will be generated at the construction camp kitchen, bathrooms, residential block, and administration areas will be discharged in subsurface drains, until the permanent waste water treatment plant is completed. There is no current detail information on the expected volumes of domestic waste water that will be generated and the design of the systems.

Mitigation measures

The protocols that should be applied during the construction phase should be developed and documented in the EMP. The protocols should address the following:

- Storage of new and used oils in bunded areas;
- No co-handling of reactive liquids or solids;
- Creation and monitoring of an inventory of chemicals held on site;
- Storage of hazardous or toxic substances securely and controlled use thereof;
- Availability and accessibility of HAZOP sheets of all chemicals;

If the recommended construction protocols are followed, then impact during construction will be reduced to low significance.

Wastewater treated and discharged on site must comply with the sanitary effluent standards (Decree 18/2004 of 2 June – Appendix IV – Standards of Emission of Domestic Liquid Effluents and the IFC General Environmental, Health and Safety Guidelines for Sanitary Effluent (30 April 2007), and ma ybe used on site as service water or irrigated.

6.3.1.2 Decline in groundwater levels

Abstraction of groundwater for potable use for construction crews, could add to the pressure on the local groundwater resources, and **decline in groundwater levels**. Raw water for the Project will be supplied from aquifers in the area and treated accordingly. Two boreholes of differing water quality and abstraction rates are currently being considered as the source of raw water to the CTT site, T9 and W5A. Alternatively a new borehole may be installed at the Power Plant site.

Not only will there be supply to crews working at various sites, but a construction camp (including housing/accommodation for construction and operations) will be set up for the duration of the construction phase. Daily water allowance of 150l/person/day is made during construction. This implies that for the OCGE Option there will be an expected 690 persons on site which will require a water supply of 4.3 m^3/hour. This will add additional pressure on the supply boreholes from which the Sasol already abstracts 8.3m^3/h for the CPF water requirements.

The scenarios of various abstraction rates and water requirements were simulated in a simplified numerical model (See Section 5.6) and it can be seen from the results that the additional water requirements during the construction period has a very low impact at local scale only. However, with mitigation and management of abstraction boreholes, the impact of water level decline can be reduced further to being limited to close proximity of the abstractions wells only.

Mitigation measures

Mitigation and management of abstraction boreholes need to include continuous level and abstraction volume monitoring. All abstraction boreholes should be set up and managed so that the sustainable yield is not exceeded during a 24 hour period, and to always allow for boreholes to recover sufficiently between abstraction cycles.

6.3.2 Operational phase impacts

The potential groundwater impacts of the project during the construction phase are listed and ranked in Table 8 and described in the sub-sections below. The rating presented in are based on pre-mitigation and post mitigation interventions.

Table 11: Operational phase impact table - OCGE

Indicator of potential impact	**Pre-mitigation**					**Post-mitigation**				
	Magnitude	**Duration**	**Geographic Extent**	**Probability**	**Significance**	**Magnitude**	**Duration**	**Geographic Extent**	**Probability**	**Significance**
Ground water deterioration - Irrigation of Effluents	10	4	2	4	**Moderate 64**	6	4	2	2	**Low 28**
Ground water deterioration - Spills from the evaporation pond	10	4	2	5	**High 80**	8	4	2	4	**Moderate 56**
Accidental spillages and Hazardous materials	4	3	2	2	**Low 18**	2	2	2	2	**Negligible 12**
Ground water deterioration – Waste management	4	3	2	2	**Low 18**	2	2	2	2	**Negligible 12**
Groundwater level decline-additional water abstraction	6	4	2	3	**Low 36**	4	4	2	2	**Low 20**

6.3.2.1 Groundwater Deterioration

The operational phase activities that could potentially impact on the **quality of the groundwater resource** include the irrigation of effluents, accidental spillages and overflows from surface water impoundments, materials handling and waste/waste water generation associated with the power plant operation.

The sanitary effluent and treated oily water effluent streams are to be irrigated to the surrounding environment. There is a potential to pollute the local aquifer systems should non-compliant effluent be irrigated. As there is expected to be minimal surface flow of the irrigated water, with almost all of the water draining to underground, the perimeter boreholes should be regularly monitored to assess any potential contamination. The impact is considered to be of moderate significance but can be reduced to low with mitigation.

The evaporation pond will serve as the local pollution control dam at the CTT plant site. The pond will handle onsite wastewater streams including the ultrafiltration reject, brine, cooling water blow down, as well as non-compliant sewage and treated oily water effluents streams from the CTT plant. The water qualities of these streams will include very high salts, total suspended solids, oils as well as other contaminants. Liner failure and leakages and inadequate capacity of the evaporation pond to handle higher than anticipated waste stream volumes could potentially result in spillages to the surrounding environment. Spills from the evaporation could cause local ground water pollution. The impact is considered to be of high significance but may be reduced to moderate with mitigation.

This potential for groundwater contamination can also result from poor housekeeping that may result in accidental spillages and storage of hazardous chemicals; poor waste management and other waste disposal practices. All of these impacts are rated low and can be reduced to negligible after mitigation. Waste water management measures need to be in place to ensure that impacts are minimised.

Mitigation measures

The oily water effluent and sewage effluent streams must comply with required discharge water quality standards for treated effluent as stipulated in terms of the Mozambican and IFC standards. Continuous monitoring of the effluent streams is required prior to irrigation to determine compliance to discharge standards. Non-compliant effluent should be discharged to the evaporation pond.

Measures for containment of spills and warning systems for leaks must be included in the design of the evaporation pond. The protocols that should be applied in the event of a spill in the operational phase should be developed and documented in the EMP. A clean-up plan should be prepared and carried out in this event.

The protocols that should be applied during the operational phase should be developed and documented in the EMP. The protocols should address the following:

- Storage of new and used oils in bunded areas;
- No co-handling of reactive liquids or solids;
- Creation and monitoring of an inventory of chemicals held on site;
- Storage of hazardous or toxic substances securely and controlled use thereof;
- Availability and accessibility of HAZOP sheets of all chemicals; and
- Waste disposal according to protocols and in designated containers/areas only.

A groundwater monitoring network need to be established on site that are targeted at specific potential sources of groundwater contamination.

6.3.2.2 Decline in groundwater levels

Raw water for the Project will be supplied from aquifers in the area and treated. Two boreholes of differing water quality and abstraction rates are currently being considered as the source of raw water to the CTT site, T9 and W5A. Alternatively a new borehole may be installed at the Power Plant site. The selected borehole (water source) will be used to supply either of the two technology options. The CCGT option requires a water supply of 25.9m^3/h. Clean stormwater harvested will also be used to offset borehole water supply. In addition to the Power Plant water supply it is estimated that an additional 0.44 m^3/h will be required for potable use on site. This will add additional pressure on the supply boreholes from which the Sasol already abstracts 8.3m^3/h for the CPF water requirements.

The scenarios of various abstraction rates and water requirements were simulated in a simplified numerical model (See Section 5.6) and the water level decline at each borehole was simulated as:

- Option 2 @ W5A: Water level is 0.115 m below the steady state water level
- Option 2 @ T9: Water level is 0.055 m below the steady state water level

It can thus be seen that the rate of water abstraction that is required does not significantly impact the abstraction boreholes boreholes W5A and T5, and that the aquifer yield can sustain the required abstraction.

Based on the simulations the impact is considered to be of low rating before mitigation. However, with mitigation and management of abstraction boreholes, the impact of water level decline can further be reduced.

Mitigation measures

Mitigation and management of abstraction boreholes need to include continuous level and abstraction volume monitoring. All abstraction boreholes should be set up and managed so that the sustainable yield is not exceeded during a 24 hour period, and to always allow for boreholes to recover sufficiently between abstraction cycles.

6.3.3 Decommissioning phase impacts

The potential groundwater impacts during the decommissioning phase are described in the sub-sections below. The rating presented in Table 12 are based on pre-mitigation and post mitigation intervention.

Table 12: Decommissioning phase impact table - OCGE

Indicator of potential impact	**Pre-mitigation**					**Post-mitigation**				
	Magnitude	**Duration**	**Geographic Extent**	**Probability**	**Significance**	**Magnitude**	**Duration**	**Geographic Extent**	**Probability**	**Significance**
Groundwater deterioration – soil contamination	8	2	2	4	**Moderate 48**	8	2	2	2	**Low 24**
Groundwater deterioration – Accidental spillages and Hazardous materials	8	2	2	4	**Moderate 48**	6	2	2	2	Low 20
Groundwater level decline – reduction in water abstraction	6	5	2	4	**Positive +52**	6	5	2		**Positive +52**

6.3.3.1 Groundwater Quality Deterioration

During decommission of the site several activities are likely to result in the deterioration of groundwater quality.

The decommissioning of plant infrastructure, specifically the oil storage tanks, evaporation pond, sewage treatment plant and oily water treatment system could result in soil contamination in the vicinity of these facilities. Contaminated soil has the potential to cause pollution of groundwater. This impact has been rated as a moderate significance.

Spillage of oils, fuel and chemicals during decommissioning can result in the pollution of water resources if due care is not taken. The impact is also rated with a moderate significance.

Mitigation measures

The protocols that limit potential pollution from the effluent facilities should be applied during the decommissioning phase should be developed and documented in the EMP. The mitigation measures will reduce the impacts to a low significance.

6.3.3.2 Decline in groundwater levels

Water supply requirements will be reduced during the decommissioning phase, since no more water supply will be required for the Power Plant site. Initially there may still be water supply needs during the demolishing of infrastructure, but afterwards all water abstraction will cease resulting in the likely recovering of water levels to pre-operation levels.

Mitigation measures

Not applicable.

7.0 ENVIRONMENTAL ACTION PLAN

Mitigation measures proposed for the CTT project are presented in Table 13 , and are applicable to either the CCGT or OCGE option.

Table 13: Environmental Action Plan

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
Construction Phase				
Sewage effluent management	Pollution of surface and groundwater resources	Workers camp – sewage plant Temporary toilet facilities at construction sites	Any discharge from sewage works should meet the IFC Environmental and the Mozambican standards for treated sanitary effluent. Temporary facilities to be maintained regular and waste to disposed only at approved waste facilities.	CTT contractor

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
Stormwater management	Chemical pollution of surface and groundwater resources	Spillages of chemicals and oils	Potentially contaminated stormwater shall be kept separate from other drainage at construction sites. Potentially contaminated stormwater shall, if necessary, be tested and treated to remove contaminants before being released into the environment.	CTT contractor
Hazardous chemicals and materials handling	Chemical pollution of surface and groundwater resources	Spillages of chemicals and oils, poor housekeeping; Vehicle and equipment maintenance	Storage of new and used oils in bunded areas. No co-handling of reactive liquids or solids. Creation and monitoring of an inventory of chemicals held on site. Storage of hazardous or toxic substances securely and controlled use thereof. Vehicle and equipment maintenance limited to designated areas only.	CTT contractor
Waste management	Pollution of surface and groundwater resources	Improper waste disposal	All waste materials should be handled and disposed in compliance with the Waste Management Plan.	CTT contractor
Abstraction of groundwater	Decline in groundwater levels	Abstraction for potable use at construction camp/ construction sites	Use recycled water or rainwater for vehicle washing, dust settlement, and toilet flushing on construction sites. Recycling of washing and cleaning water where possible. Water storage and delivery facilities should be safe and leakage free to reduce water wastage. Raising awareness and	CTT contractor

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
			promotion of behavioural change within the construction camp about water use.	
Operational Phase				
Hazardous chemicals and materials handling	Chemical pollution of surface and groundwater resources	Spillages of chemicals and oils, poor housekeeping; Vehicle and equipment maintenance	Storage of new and used oils in bunded areas. No co-handling of reactive liquids or solids. Creation and monitoring of an inventory of chemicals held on site. Storage of hazardous or toxic substances securely and controlled use thereof. Vehicle and equipment maintenance limited to designated areas only.	CTT
Waste management	Pollution of surface and groundwater resources	Improper waste disposal	All waste materials should be handled and disposed in compliance with the Waste Management Plan.	CTT
Prevention of pollution by effluent management	Pollution of surface and groundwater resources	Sewage treatment plant, treated oily effluent plant	Effluent streams must comply with the Mozambican and IFC discharge water quality standards for treated effluents. Continuous analysis of quality of the effluent streams prior to irrigation to determine compliance to discharge standards. Non-compliant effluent should be discharged to the evaporation pond. Water quality analysis of groundwater in the receiving environment.	CTT
Stormwater management	Pollution of surface and	Spillages from First flush sump and	Potentially contaminated stormwater shall be kept	CTT

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
	groundwater resources	Clean stormwater sump	separate from other drainage at the plant area. Potentially contaminated stormwater shall, if necessary, be tested and treated to remove contaminants before being released into the environment.	
			Appropriate use of soak-ways, seepage fields and vegetation filters will be put in place to prevent contamination of water resources. Water quality analysis on water bodies in the receiving environment.	
Pollution control facility management (evaporation pond)	Pollution of surface and groundwater resources	Spillages and leakages from evaporation pond	Leakage management system in place. Water quality analysis of perimeter boreholes around evaporation pond. Regular desludging of pond is to be undertaken (dependant in evaporation rates). Sludge to be handled by waste contractor. Clean up protocol in place.	CTT
Abstraction of groundwater	Decline in groundwater levels	Abstraction for potable use. Abstraction for Power plant operations	Use recycled water or rainwater for vehicle washing, dust settlement, and toilet flushing. Recycling of washing and cleaning water where possible. Water storage and delivery facilities should be safe and leakage free to reduce water wastage. Raising awareness and	CTT

Aspect	Potential Impact	Impact Source	Detailed Actions	Responsibility
			promotion of behavioural change within the plant area about water use. Monitoring of abstraction boreholes.	
Decommissioning Phase				
Stormwater management	Chemical pollution of surface and groundwater resources	Effluent treatment systems and evaporation pond. Spillages of chemicals and oils during decommissioning.	Potentially contaminated stormwater shall be kept separate from other drainage at demolishing sites. Potentially contaminated stormwater shall, if necessary, be tested and treated to remove contaminants before being released into the environment. Adhere to protocols and measures in place to manage clean up and rehabilitate area.	All contractors
Hazardous chemicals and materials handling	Chemical pollution of surface and groundwater resources	Spillages of chemicals and oils, poor housekeeping; Vehicle and equipment maintenance	Storage of new and used oils in bunded areas. No co-handling of reactive liquids or solids. Creation and monitoring of an inventory of chemicals held on site. Storage of hazardous or toxic substances securely and controlled use thereof. Vehicle and equipment maintenance limited to designated areas only.	All contractors
Waste management	Pollution of surface and groundwater resources	Improper waste disposal	All waste materials should be handled and disposed in compliance with the Waste Management Plan.	All contractors

8.0 MONITORING PROGRAMME

A monitoring programme proposed for the CTT project is presented in Table 14 and is applicable to either the CCGT option or the OCGE option.

Table 14: Monitoring programme

Objective	Detailed Actions	Monitoring Location	Frequency	Responsibility
Construction Phase				
To assess compliance of discharge quality of sewage effluent	Monitoring of any discharge from sewage works should meet the IFC Environmental and the Mozambican standards for treated sanitary effluent. Non-compliant effluent should be discharged to a pollution control dam.	Construction worker's camp – sewage plant	Monthly	CTT
To assess compliance of potentially contaminated or contaminated stormwater to discharge standards	Monitor the stormwater runoff from site activities. If necessary, the stormwater should be tested and treated to remove contaminants before being released into the environment. IFC Environmental and the Mozambican standards for treated effluent must be complied with.	At stormwater discharge points around the plant area.	At all times	CTT

Objective	Detailed Actions	Monitoring Location	Frequency	Responsibility
To assess water quality of aquifers	Monitoring of groundwater quality	Install dedicated monitoring boreholes at the upstream and downstream perimeter of the CTT plant construction area.	Monthly	CTT
To assess groundwater levels at abstraction boreholes	Installation of continuous flow and water level equipment at abstraction boreholes	Continuous monitoring of groundwater levels and abstraction rates at boreholes W5A and T9	Continuous	CTT
Operational Phase				
To assess compliance of the treated effluent to discharge standards	Monitoring of treated effluent to determine compliance to the effluent standards as stipulated in terms of the Mozambican and IFC standards for discharge and irrigation. Non-compliant effluent should be discharged to an evaporation pond.	Sewage treatment plant discharge point, oily water management system	Continuously	CTT
To assess water quality of aquifers	Monitoring of groundwater quality	Continue monitoring of boreholes at CTT plant.	Quarterly until no	CTT
To assess groundwater levels at	Installation of continuous flow and water level	Continuous monitoring of groundwater levels	Continuous	CTT

Objective	Detailed Actions	Monitoring Location	Frequency	Responsibility
abstraction boreholes	equipment at abstraction boreholes	and abstraction rates at boreholes W5A and T9		
To assess compliance of the stormwater discharge quality	Monitor the stormwater runoff from site activities. Stormwater should be tested and treated to remove contaminants before being released into the environment. IFC Environmental and the Mozambican standards for treated effluent must be complied with.	At stormwater discharge points around the plant area.	At all times	CTT
To assess the impact of water supply, if any, on the local groundwater	Monitor groundwater levels at monitoring points near abstraction boreholes and other sensitive receptors i.e. affected community wells/boreholes.	Continuous monitoring of groundwater levels and abstraction rates at boreholes W5A and T9. Install/include dedicated monitoring boreholes near abstraction points.	Continuous for W5A and T9. Monthly for monitoring boreholes.	CTT
To assess water quality of aquifers	Monitoring of groundwater quality	Install dedicated monitoring boreholes at the CTT plant – location of boreholes will depend on infrastructure layout i.e. evaporation	Monthly	CTT

Objective	Detailed Actions	Monitoring Location	Frequency	Responsibility
		pond, chemical storage areas, waste disposal areas, etc.		
Decommissioning Phase				
To assess compliance of the stormwater discharge quality	Monitor the stormwater runoff from site activities. Stormwater should be tested and treated to remove contaminants before being released into the environment. IFC Environmental and the Mozambican standards for treated effluent must be complied with.	At stormwater discharge points around the plant area.	At all times	CTT and contractors
To assess the impact of water supply, if any, on the local groundwater	Monitor groundwater levels at monitoring points near abstraction boreholes and other sensitive receptors i.e. affected community wells/boreholes.	Continuous monitoring of groundwater levels and abstraction rates at boreholes W5A and T9. Install/include dedicated monitoring boreholes near abstraction points.	Continuous for W5A and T9 until residual impacts have been stopped and water levels recovered to pre-operation levels.	CTT
To assess water quality of aquifers	Monitoring of groundwater quality	Monitor dedicated monitoring boreholes at the CTT plant – location of boreholes will	Quarterly until residual impacts have been stopped and/or permission is granted by authorities.	CTT

Objective	Detailed Actions	Monitoring Location	Frequency	Responsibility
		depend on infrastructure layout i.e. evaporation pond, chemical storage areas, etc.		

9.0 CONCLUSIONS

The following conclusions can be drawn from the outcome of the impact assessment of the CTT Project on the groundwater systems, for both the OCGT and OCGE options, *viz*.

- Some groundwater quality deterioration is expected during the construction and operational phases of the project. Various activities can potentially result in water quality deterioration. However, if acceptable materials handling, waste and water management, and other mitigation measures are in place the impacts can be reduced to negligible or low. The exception is spills from the evaporation pond that will be reduced to moderate.
- Impacts related to potential pollution and effluent management, *i.e.* sewage and treated oily water are of importance in terms of the receiving surface water environment and are both rated as moderate significance pre-mitigation. Effluent quality should comply with the Mozambican and IFC effluent quality discharge standard. Irrigation of the effluents is linked to effluent management and must comply with the discharge standards. Achievement of compliance reduces the impacts to a low significance.
- The most significant impact on the groundwater systems (with exception of spills from the evaporation dam) is the potential water level decline caused by abstraction of groundwater from local supply boreholes. Past investigations have proven that the water supply boreholes are installed in high yielding aquifer systems that can supply long-term water supply to required infrastructure. However, for the CCGT option the water requirements are significantly higher than for the OCGE option. Although the aquifers are more than likely have the potential to supply the required volume of water for operations, the development of additional abstraction boreholes will be required. The expected water level decline in abstraction boreholes are likely to impact the long-term sustainability of the supply boreholes which may impact on other activities (i.e. CPF) in the area.

With the implementation on the water and waste management plan, monitoring programme and recommendations to comply with the EMP, the impacts to the groundwater systems are low to negligible.

SPECIALIST RECOMMENDATION

Based on the evaluation and assessment undertaken of the two proposed technologies, the OCGE would be the recommended option from a groundwater perspective. The only differentiating factor between the two technologies from a water management point of view is that the OCGE option has a lower water requirement (3.39 m^3/h compared to 25.9 m^3/h) and thus generates smaller volumes of effluent. The OCGE option does not require demineralised water and as it does not use heat steam recovery generators no blowdown is generated. The OCGE is a more water efficient process with a smaller ‘effluent footprint’.

Signature Page

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