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Hydrological and Hydrogeological Assessment for the Proposed Mafeteng Solar PV Plant, Lesotho

Report

Version – 4 (Final)

08 November 2019

Royal Haskoning DHV

GCS Project Number: 18-0473

Client Reference: GCS - Lesotho Solar PV SW Study

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HYDROLOGICAL AND HYDROGEOLOGICAL ASSESSMENT

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LIST OF ACRONYMS

ALOS	Advanced Land Observing Satellite
CSIR	Council for Scientific and Industrial Research
DEM	Digital Elevation Model
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
GCS	GCS Water and Environment (Pty) Ltd
GN704	General Notice 704
IFC	International Finance Cooperation
kV	KiloVolt
LEA	Lesotho Environment Authority
LEC	Lesotho Electricity Corporation
MAE	Mean Annual Evaporation
mamsl	meters above mean level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MW	MegaWatt
NES	National Environment Secretariat
OP	Operational Procedures
PFD	Process Flow Diagram
PV	Photovoltaic
RHDHV	Royal Haskoning DHV
RM2	Rational Method Alternative 2
RM3	Rational Method Alternative 3
SANS	South African National Standards
SDF	Standard Design Flood
SWMP	Storm Water Management Plan
WR2012	Water Resources Database 2012

EXECUTIVE SUMMARY

Introduction

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Royal Haskoning DHV (RHDHV) to undertake a specialist hydrological assessment for a 20 Megawatt (MW) Photovoltaic (PV) Solar Power Plant in Mafeteng District. The project site is situated approximately 10 km from the Mafeteng Town, within the Sepechele community area. The proposed Solar PV will be established on land that is approximately 66 ha in size and situated close to the existing 132 kiloVolt (kV) substation of the Lesotho Electricity Corporation (LEC).

The African Development Bank is the project funder and one of their requirements is an Environmental Social Impact Assessment (ESIA) process, which needs to be undertaken according to the International Finance Cooperation (IFC) Standards. The ESIA comprised of the Scoping Study, ESIA and Environmental and Social Management Plan. This study report summarises the results of a scoping assessment that forms part of the specialist hydrogeological and hydrological investigations.

Receiving Environment and Baseline Conditions

The general climate of the site is described as Subtropical Highland (Köppen-Geiger classification Cwb) and natural vegetation is moist highveld grassland.

The proposed Solar PV site is located in a mountainous area on a top of quaternary catchment D23F with the plant facing in the northerly direction. The steep slopes of the hills are sparsely vegetated. Located on an altitude of about 1 750 mamsl, the area is characterised by non-perennial drainage channels which only flow during/after flashy rainfall events. Runoff flows in the northerly and north-easterly direction into the perennial Tšana-Talana River. Runoff in these mountainous regions is extremely variable and depends largely on soil type and depth, on vegetation and on rainfall. Naturalised runoff that reports to local rivers and streams near the proposed site is not likely to be significant for this project. WR2012 reports average runoff for quaternary catchment D23F at 124 mm per annum and for D15F at 54 mm per annum, on average. The quantity of runoff reporting to local streams is likely to be in this range, however, is most likely to be in the order of 70 mm per annum, which is ~10% of MAP.

It is anticipated that solar panels will tend to concentrate runoff and that runoff from the field of panels will be higher than runoff from natural veld. Post-development runoff will depend largely on the final layout of the solar plant and on soil cover conditions. Neighbouring non-perennial streams will flow very close to the Solar PV Project site.

Field Investigation

A site visit conducted (16-19 October 2018) between the provided a better understanding of local hydrological and physiological conditions of the site. The information on these conditions guided the modelling of flood lines and validation of the conceptual SWMP. Some of the hydrological and hydraulic parameters as well as other elements that could affect the modelling of flood lines on the sites were derived from this visit. Also, during the site visit, both surface and groundwater samples were collected and analysed to establish the baseline water quality information of the site. This information will be used in the monitoring programme during the construction, operational and decommissioning phases of the solar PV plant.

Flood Line Assessment

The 1:100-year flood lines were simulated from the peak flow volumes resulting from a 1:100-year return event. While the DEM data used to define the topographical setting of the areas proved to be inadequate in relatively flat areas of the site, the flood simulation results show that the proposed infrastructure is not prone to flooding.

Conceptual Stormwater Management Plan (SWMP)

The purpose of the SWMP was aimed at reducing the concentration of stormwater due to the gridded layout of the solar panels in the proposed plant area. In line with the wetland delineation study and site observations, highly erodible and dispersive soils are present at proposed plant area. A conceptual SWMP for the study site was therefore described to promote overland flow opposed to the engineered conduits, reduce the spatial extent of impervious surfaces and maintain the vegetation cover to increase interception and evapotranspiration. The proposed SWMP comprises of a network of natural drainage (grass lined) which divert stormwater towards the river course and wetland. All drainage needs to be designed based on detailed topographical survey data. Runoff between the solar panels should be directed to natural water ways in a manner that prevents soil erosion. Given the erodibility nature of the soils at the proposed site area, it was suggested that the drainage network system should therfore mimic the natural slope as far as possible. Taking into account the wetland delineation, drains should not be extended into the wetland area.

Water Balance

A water Process Flow Diagram (PFD) for the plant was drafted and it shows the linkages between different components of used. The PFD was aimed at guiding the determination and calculation of annual, monthly, and daily average water balances for the plant.

Water requirements and demands provided by the Client were estimated at 20m^3/year. Is seems that, based on the preliminary groundwater reserve determination and preliminary water demand estimations, groundwater can be used as a viable source of water supply to the facility.

Surface and Groundwater Impact Assessment

Main potential impacts on surface water that can be expected during construction, operational and decommissioning phase of the Solar PV Project are increased flooding, an increase in sedimentation and potential degrading water quality. However, impacts are expected to be of very low significance. In terms of residual impacts, very little or low residual visual impact on drainage lines is expected, due to the limited alteration of terrain of the proposed development. Based on the assumption that no contributing activities are located nearby, the cumulative impacts will thus be of very low significance.

Mitigation plans of the identified impacts during the three phases include the (1) clearing of the designated infrastructure footprint, (2) construction of the infrastructure out of the delineated flood lines, (3) proposed implementation of the recommendations of the stormwater management plan, (4) cleaning of any chemical spills, (5) and implementation of a surface water quality monitoring programme, and (6) restoration of natural vegetation to enhance soil stability. It was concluded that adhering to the recommended mitigation measures will result in relatively low negative impacts into the environment.

Recommendations

Recommendations derived from this study include the following:

- Natural drainage systems (natural grass lined) needs to be designed based on detailed topographical survey data and runoff between the solar panels should be directed to natural water ways and wetland in a manner that prevents soil erosion.
- It may be possible to further reduce runoff by promoting infiltration by using bunds and soakways. This will, however, depend on the final design of the PV modules and detailed topographical survey data.
- It is also recommended that stormwater should be routed through stone pitched drifts at road crossings.

- Outlets of the drainage channels should included energy dissipating structures at the wetland boundaries or 32m flood buffer.
- The solar PV plant authorities should ensure that the water volumes and consumption) (inflow and outflow) from different components of the plant are measured. This will help in improving future water balances should there be changes in the system;
- A detailed hydrogeological investigation would be required in order to determine sustainable yield from proposed water supply borehole as well as an update of the groundwater impact assessment;
- It recommended that all the identified impact mitigation measures be adhered to ensure that the infrastructure does not have a negative impact on the surrounding environment.

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1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Royal Haskoning DHV (RHDHV) to undertake a specialist hydrological and hydrogeological assessment for a 20 Megawatt (MW) Photovoltaic (PV) Solar Power Plant in Mafeteng District. The project site is situated approximately 10 km from the Mafeteng Town, within the Sepechele community area. The proposed Solar PV will be established on a land that is approximately 66 ha which is close to an existing 132 kiloVolt (kV) Lesotho Electricity Corporation (LEC) substation (refer to Figure 1.1).

The Government of Lesotho, under the Ministry of Energy and Meteorology (MEM), has engaged OnePower Consortium to implement the NEO I 20 MW PV Power Generation Development Project. The proposed project location entails a plot of approximately 66 ha located within the boundaries of three villages under Tšana-Talana Community Council in Mafeteng District. The three villages are: Ha Ramarothole, Ha Lempetje and Ha Raliemere. The study focused on areas adjacent to an existing LEC 132 kV powerline and substation in Mafeteng District due to the mountainous terrain of Lesotho and high irradiance in the western lowlands.

The proposed project will entail construction of a PV Power Generation Plant that will include the operation of the plant and generation of solar power that will be sold to LEC and maintenance of the plant for up to 25 years. The project will also include the following infrastructures:

- Construction of the 132 kV Powerline that is approximately 2 km from the PV Plant to the Ramathole substation;
- Operation and Maintenance Building;
- Laydown areas;
- Inverter station;
- A main site entrance road is 10 m in length and 6 m wide; and
- Total area to be fenced is approximately 66 ha.

The African Development Bank is the project funder and one of their requirements is an Environmental Social Impact Assessment (ESIA) process, which needs to be undertaken according to the International Finance Cooperation (IFC) Standards (IFC, 2012). The ESIA will comprise of the Scoping Study, ESIA and Environmental and Social Management Plan. This study report summarises the results of the specialist assessment that forms part of the hydrological and hydrogeological input.

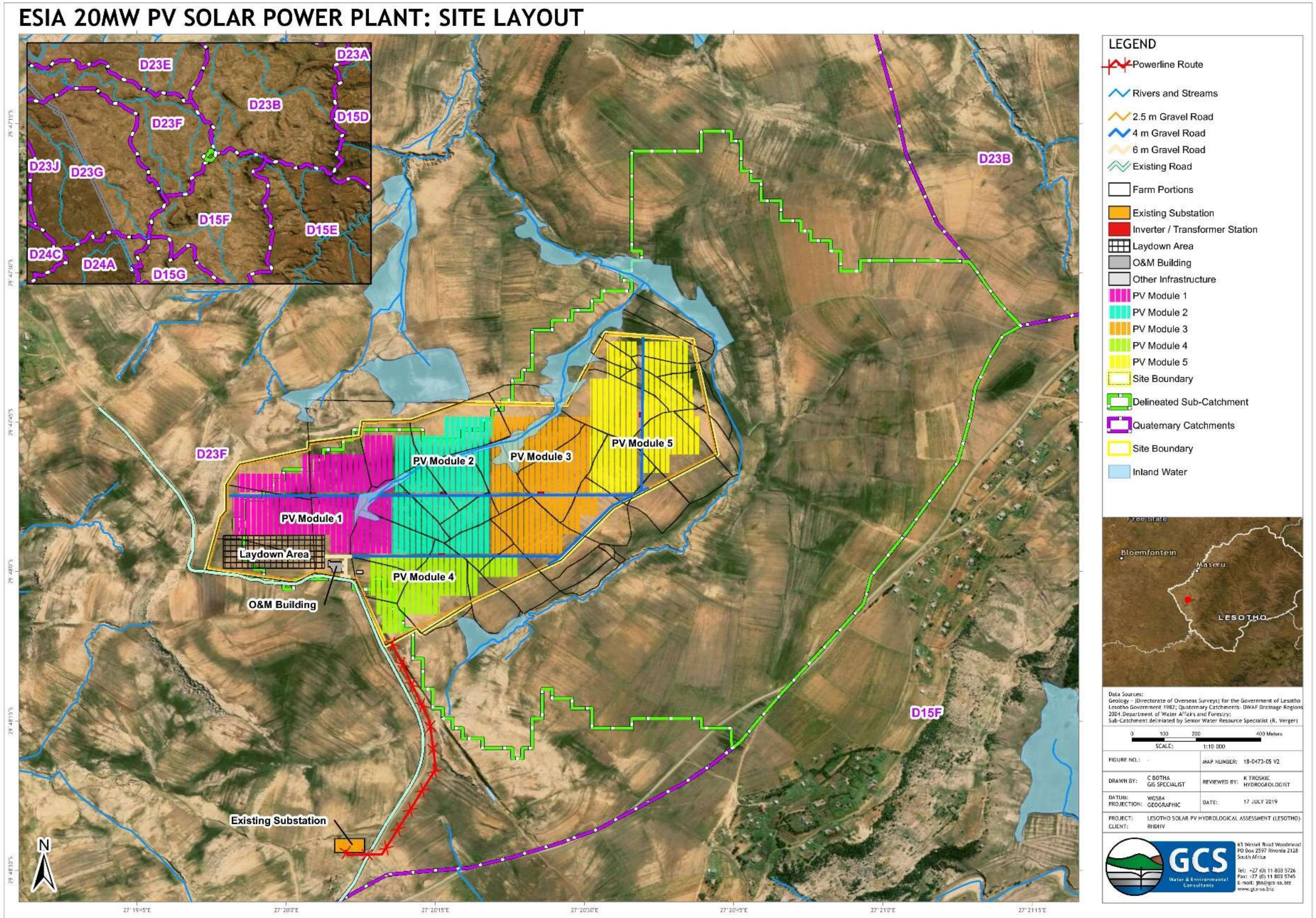


Figure 1.1: Locality Map

2 SCOPE OF WORK

2.1 Surface Water

The following scope was approved for the Lesotho Solar PV Plant:

2.1.1 Desktop Assessment

- Hydrological setting of the receiving environment.
- Identification and description of all surface water features within the study area.
- Locating, describing and providing a description of surface water features that are sensitive to the proposed development within the study area.

2.1.2 Baseline Hydrology

Determination of the study area's Mean Annual Precipitation (MAP), Mean Annual Runoff (MAR) and Mean Annual Evaporation (MAE).

2.1.3 Hydrological Assessments

- Design rainfall and peak flow calculations;
- Determination of storm volumes for the 1:20, 1:50, and 1:100-year return period event;
- Catchment geometry and hydraulic data preparation;
- Flood line modelling using HEC-RAS hydraulic modelling software (US Army Corps of Engineers, 2018);
- Analysis of the modelling results based on the 1:50 and 1:100-year flood lines.

2.1.4 Conceptual Storm Water Management Plan

- Indication and explanation of the proposed stormwater drainage infrastructure and
- Conceptual design of the drainage channel.

2.1.5 Average Water Balance

- Development of a Microsoft Visio-based water Process Flow Diagram (PDF) and
- Microsoft Office-based spreadsheet of average daily, monthly and annual water balances.

2.1.6 Surface Water Impact Assessment

Sensitivity assessment and mapping of identified sensitive features relating to surface water resources within the study area.

2.1.7 Preliminary Risk Assessment

Identification and description of potential impacts resulting from the proposed activity were determined for the following phases:

- Construction;
- Operation; and
- Decommissioning.

2.1.8 Plan of Work for the Surface Water Impact Assessment Stage

Determination of all surface water study components for the detailed EIA.

2.2 Groundwater

The following scope of work was accepted for the hydrogeological investigation and for the Scoping Study Phase of the project:

2.2.1 Project Initiation and Desktop Review, Including a Satellite image review.

A desktop study including a description of the general geology and hydrogeological conditions.

For the scoping phase of the study, a satellite image review of the study area was carried out in order to identify existing groundwater users and existing groundwater abstraction.

2.2.2 Updated baseline environment

- Description of a conceptual hydrogeological model;
- A Baseline Groundwater Reserve Determination for the sub-catchment.

2.2.3 Groundwater impact assessment (for a scoping phase only)

- Identify possible problem areas and fatal flaw areas associated with groundwater;
- Identify areas that require further investigation during the EIA phase;
- Gap analyses based on the existing data sets.

2.2.4 Reporting

- Final report incorporating findings of the study.

3 METHODOLOGY

The methodology followed in order to achieve the study objectives is described in the following sub-sections.

3.1 Information Sourcing and Literature Review

A project initiation meeting was organised at the RHDV office in Johannesburg (Rivonia) on the 4th of September 2018. Reports of relevant studies were received and included a project description presentation, a Project Brief and Description Report of the One Power Proposal for NEO I 20MW PV Generation Development Project (2016) and a draft inception report of the NEO I 20MW Photovoltaic Power Generation Development Project (2017) and relevant information related to surface water hydrology was extracted. Also, a review of applicable legislation frameworks and policy which pertain to the surface water resources in the area was undertaken

3.2 Desktop Study

Satellite imagery from Google Earth, ALOS 30 m topographical data (Takaku, et al., 2014) of the study area and other existing sources of information were used to inform the set-up of the study site. The site layout for the proposed plant was used as a reference point to primarily establish an understanding of the spatial proximity of surface water features that could be affected by the proposed developments. The information obtained from the site-visits was also used to validate the desktop assessment assumptions about the site as well as to refine the selection of the sites to be evaluated for scoping.

3.3 Baseline Hydrology and Hydrogeology

The information on hydrology and climatic setting for the surrounding study area was obtained from South African Water Resources study WR2012 (Bailey & Pitman, 2015) and South African Atlas of Agro-hydrology and Climatology (Schulze, 1997). Other variables which influence the local hydrology of the study which were analysed are topography, land-use and land cover, MAP, MAE, MAR, and temperature. While there no direct weather station located within the PV Solar Plant site, online climatic data from Mafeteng, were used to determine baseline climatic conditions.

Existing hydrogeological information was used to compile a hydrogeological conceptual model of the site. This included a description of aquifers, flow and yield. A groundwater reserve determination was undertaken as part of this process.

Recharge was estimated based on a literature review. A groundwater balance was prepared for the sub-catchment. This took into account all input and outputs. This determined the category for abstraction for the proposed site.

3.4 Hydrological Assessment

3.4.1 Peak Flow and Flow Volume

The 1:50 and 1:100-year peak flows for the modelled river section of the study area were calculated based on three widely used methods. These are the Rational Method, Rational Method Alternative 3 and the SCS-SA Method which are briefly explained in the most widely used SANRAL Drainage Manual (SANRAL, 2013). The use of the three methods was aimed at comparing the results and to select the most conservative peak flows in the modelling of the flood lines.

The hydrologic parameters used to set runoff coefficients were derived from a number of sources including soils reports, topographic data and visual assessment of Google Earth imagery time series. Runoff coefficients were guided by the recommendation provided in SANRAL (2013).

3.4.2 Floodline Modelling

Lesotho Water Act No. 15 of 2008 (Kingdom of Lesotho, 2008) stipulates that – in the efforts of preventing or minimising the risk of flooding – the Commissioner of the Water Affairs Ministry have to consult with the regional and local authorities in determining the areal extent of the floodplain which helps the regulation of the developments. This act does not specify the objective limitation into which the infrastructure development can be located in relation to the river. In the absence of the clear regulation, the South African CSIR's Guidelines for Human Settlement Planning and Design (CSIR, 2000) was used to guide the simulation of the flood lines in the proposed study area.

The 30 m Digital Elevation Model (DEM) data from Advanced Land Observing Satellite (ALOS: (Tadono, 2014) were used to derive the geometric and hydraulic parameters of the modelled river sections in the study area. RAS Mapper software was used to prepare river geometry data which were used as input into HEC-RAS for flood modelling.

The flood lines were determined for 1:50 and 1:100-year return events in HEC-RAS. The resulting flood lines were mapped in ArcGIS™, this also included a 100 m buffer from the river as means of evaluating the potential risks that the flooding events can pose on the proposed infrastructure.

3.4.3 Storm Water Management Plan

A conceptual Storm Water Management Plant (SWMP) was developed to account for the impacts on the proposed developments on the natural flow of stormwater. In the absence of site-specific legislation which regulate the development of the infrastructure in the rural areas, the SWMP conceptualised in accordance to the CSIR's Stormwater Management Guidelines for Human Settlement Planning and Design (CSIR, 2000) and the International Finance Corporation (IFC) Environmental, Health, and Safety Stormwater Guidelines (IFC, 2007). This component of the study comprised of the delineation of stormwater catchment areas which modify the natural local hydrology, locating and sizing of the required drainage system in the area. The assumptions and decisions considered in locating and sizing of the drainage system were guided by the best practice guidelines and appropriate legal legislation.

The proposed infrastructure layout and the DEM data were used to derive the drainage network in the area. For the protection of the environment from possible erosion of top soils, the drainage channels were aligned to follow the natural topography as much as possible. The 1:5-year design peak flows are recommended for the development of an industrial area, however for this study, the 1:10-year peak flows were selected for the design of the drainage channel in Catchment 2 area. Choosing the 1:10-peaks is aimed at designing the infrastructure that will reduce the cost of maintenance.

3.4.4 Average Water Balance

A schematic of the water Process Flow Diagram (PFD) was drawn using the information obtained from the client and to derive water use requirements for the proposed solar PV plant. The PDF will indicate the sources of water, storage components and discharge points within the plant area. The IFC's Utility-Scale Solar Photovoltaic guidelines (Internation Finance Corporation, 2015) stipulates that water requirements for the solar PV plants should be estimated taking into consideration the potential impact of the local users. Therefore, water use requirements were calculated as average water balance at an annual, monthly and daily time scale to define water use patterns.

3.5 Hydrogeological Assessment

3.5.1 Hydrocensus

A regional hydrocensus was undertaken (16-19 October 2018) to identify and/or update information regarding groundwater and surface water use/quality within the affected areas.

The hydrocensus was carried out within the sub-catchment delineated or within a 1km radius of the site. The hydrocensus took into account groundwater boundaries, receptors and the potential zone of influence. This information is important to identify and characterise groundwater users downstream of the proposed sites, which may be affected in the long-term.

3.6 Surface- and Groundwater Impact Assessment

Potential sensitive receptors related to surface hydrology of the study area were identified and described for the sensitivity assessment. This assessment aimed at determining how the proposed PV Solar Plant will impact surface water features within the area of the proposed site. GCS's sensitivity mapping methodology which involves identifying sensitive and non-sensitive are listed in Table 3-1 and was applied in order to inform the final site selection decision of the proposed development.

An assessment to determine the occurrence of sensitive areas on site was conducted as part of the impact assessment. Features which were considered sensitive included riparian zones. Identified features were identified at the desktop level and plotted on a map in relationship with the proposed development (Section 9).

Table 3-1: Sensitivity ratings and weighting

Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Highly significant / harmful	4
Extreme significance/ extremely harmful / within a regulated sensitive area	5

3.6.1 Preliminary Impact Assessment

The assessment of potential impacts of proposed activities was undertaken conjunctively considering the orientation of the proposed Solar PV Plant, with respect to local rivers and streams. The hydro-meteorological evaluation results were also incorporated in order to draw conclusions on potential impacts on surface water resources in the project area.

All the relevant information gathered during the desktop study and field investigations (hydrocensus) will be assessed using an appropriate risk assessment in order to determine the risk posed to groundwater due to the construction and operation of the solar power plants to be constructed. All sensitive receptors in the area including wetlands, groundwater users and surface water bodies were identified and the risk posed to these receptors were determined. The client provided the impact assessment rating methodology which involves ranking the significance of the identified impacts based on the extent, duration, intensity and probability (Table 3-2).

Table 3-2: Assessment criteria and rating

Nature	Category	
Extent (E)	Categories 1 - 4	
	1	Footprint / site
	2	Local (within a radius of 2 km's of site)
	3	Regional
	4	National
Duration (D)	Categories 1 - 4	
	1	Short (less than five years)
	2	Medium term (5-15 years)
	3	Long term (15-30 years)

	4	Permanent
Intensity (I)	Categories 1 - 4	
	1	Low
	2	Moderate
	3	High
	4	Very High
Probability (P)	Categories 1 - 4	
	1	Improbable
	2	Probable
	3	Highly Probable
	4	Definite

The significance of the identified impacts together with their relative implications to the environment is described using Table 3-3 as prescribed by the client.

Table 3-3: Environmental impacts significance

Significance = E + D + I + P	
Neg (13 - 16 points) NEGATIVE VERY HIGH	Permanent and important impacts. The design of the site may be affected. Intensive remediation is needed during construction and/or operational phases. Any activity which results in a "very high impact" is likely to be a fatal flaw.
Neg (10 - 12 points) NEGATIVE HIGH	These are impacts which individually or combined pose a significantly high negative risk to the environment. These impacts pose a high risk to the quality of the receiving environment. The design of the site may be affected. Mitigation and possible remediation are needed during the construction and/or operational phases. The effects of the impact may affect the broader environment.
Neg (7 - 9 points) NEGATIVE MODERATE	These are impacts which individually or combined pose a moderate negative risk to the quality of health of the receiving environment. These systems would not generally require immediate action but the deficiencies should be rectified to avoid future problems and associated cost to rectify once in HIGH risk. Aesthetically and/or physically non-compliance can be expected over a medium term. In this case the impact is medium term, moderate in extent, mildly intense in its effect and probable. Mitigation is possible with additional design and construction inputs.
Neg (4 - 6 points) NEGATIVE LOW	These are impacts which individually or combined pose a deleterious or adverse impact and low negative risk to the quality of the receiving environment, and may lead to potential health, safety and environmental concerns. Aesthetically and/or physical non-compliance can be expected for short periods. In this case the impact is short term, local in extent, not intense in its effect and may not be likely to occur. A low impact has no permanent impact of significance. Mitigation measures are feasible and are readily instituted as part of a standing design, construction or operating procedure.
Pos (4 - 6 points) POSITIVE LOW	These are impacts which individually or combined pose a low positive impact to the quality of the receiving environment and health, and may lead to potential health, safety and environmental benefits. In this case the impact is short term, local in extent, not intense in its effect and may not be likely to occur. A low impact has no permanent impact of significance.
Pos (7 - 9 points) POSITIVE MODERATE	These are impacts which individually or combined pose a moderate positive effect to the quality of health of the receiving environment. In this case the impact is medium term, moderate in extent, mildly intense in its effect and probable.

Pos (10 - 12 points) POSITIVE HIGH	These are impacts which individually or combined pose a significantly high positive impact on the environment. These impacts pose a high benefit to the quality of the receiving environment and health, and may lead to potential health, safety and environmental benefits. In this case the impact is longer term, greater in extent, intense in its effect and highly likely to occur. The effects of the impact may affect the broader environment.
Pos (13 - 16 points) POSITIVE VERY HIGH	These are permanent and important beneficial impacts which may arise. Individually or combined, these pose a significantly high positive impact on the environment. These impacts pose a very high benefit to the quality of the receiving environment and health, and may lead to potential health, safety and environmental benefits. In this case the impact is long term, greater in extent, intense in its effect and highly likely or definite to occur. The effects of the impact may affect the broader environment.

3.6.2 Management and Monitoring Measures

A surface water quality management plan will be drafted using the principles provided in the BPG G3: Water Monitoring Systems (DWAF, 2007). This involves the design of the initial monitoring programmes, implementation of the programme, continuous collected of data, reporting on data and information and conducting a review and update of the drafted monitoring programme.

4 LEGISLATION AND POLICY FRAMEWORK

4.1 The Constitution of Lesotho (1993)

The Constitution outlines the rights in relation to land ownership/land holding in Lesotho, as well as outlining the requirements for the country to put in place policies to protect the natural and cultural environment and to ensure that all citizens have access to a safe environment adequate for health and well-being. The Constitution further outlines the need to ensure prompt payment of full compensation for compulsory acquisition of moveable and immovable property for public purposes.

4.2 The Environmental Act of 1999 and Environmental Act of 2008

The Environmental Act of 1999 (followed by the 2008 Environmental Act) established the Lesotho Environment Authority (LEA) to provide management of the environment and natural resources in Lesotho. This Act was the first to mention the idea of an Environmental Impact Assessment (EIA). The Act specifically put a requirement for an EIA for projects, which include, among the list, projects that deal with energy and electric infrastructure including electricity generation stations. It further provides a detailed description of the requirements for the EIA process and possession of an EIA license before proceeding with the development or operation of a scheduled project. It also outlines regulations governing noise, (discharge) effluent and air quality and it highlights the need to need for obtaining permits and licenses from National Environment Secretariat (NES) for excessive noise (Noise Permit); effluent discharge to sewage system (Effluent License), emission of dust or gases (Pollution License) or to operate a land fill site or store or transport hazardous waste (Waste License).

4.3 Water Resources Act of 1978 and 2008

The legislative framework for water resources management in Lesotho is the Water Resources Act of 1978 and was updated in 2008. This Act makes provision for the management of water resources in Lesotho in an integrated and sustainable manner. It establishes the office of the Commissioner of Water and defines powers and duties of the Commissioner and the Minister responsible for water resources. The Act sets out the principles that shall be observed by authorities when carrying out duties and functions under this Act. It vests ownership of all water resources in the Basotho Nation and establishes that, in case of conflicting water uses or insufficient quantity of water, domestic water use shall be given preference over other water uses.

The Commissioner shall develop, in consultation with relevant stakeholders a Water and Sanitation Policy. The Commissioner shall also determine reserve for all water resources and classify all water resources in the country. A Water Tribunal is established to adjudicate disputes arising under this Act or any other matter relating to the management of water resources.

The Act also provides for, among other things: establishment and management of catchment areas, protected wetlands and protected springs; authorization of water use and abstraction of (ground)water; declaration of controlled activities; control of water pollution and effluent discharge permits; waterworks and dam safety; prevention of flood risk; and regulation-making powers of the Minister. The Act stipulates the requirements for obtaining a permit for any water use other than for domestic purposes and specifies that domestic water use takes priority over other uses.

4.4 International Policy Framework and Guidelines

The relevant international policy framework and guidelines relevant for this assignment include, but not limited to the following;

1) The World Bank Policies. The World Bank Operational Procedures (OP) 4.12, protects people's right to land by stipulating to its investment partners that all involuntary resettlement should adhere to a number of basic principles for addressing the adverse effects of involuntary resettlement associated with its investment projects. These principles are:

    - Involuntary resettlement should be avoided;
    - Where involuntary resettlement is unavoidable, all people affected by it should be compensated fully and fairly for lost assets;
    - Involuntary resettlement should be conceived as an opportunity for improving the livelihoods of the affected people and undertaken accordingly; and,
    - All people affected by involuntary resettlement should be consulted and involved in resettlement planning to ensure that the mitigation of adverse effects as well as the benefits of resettlement are appropriate and sustainable.

2) The International Finance Corporation (IFC) Performance Standards are designed to assist the client in designing and implementing a project in a manner where risks and impacts associated with the project are identified and mitigated to ensure the project is completed sustainably. For the hydrological investigation the IFC Performance Standard 1 (IFC, 2012), "Assessment and Management of Environmental and Social Risks and Impacts", should be applied. IFC PS1 is applicable to all projects which pose a potential risk and may have an impact on the receiving environment. IFC (2012) states that should the host country have legislative control for the management of the environment that overlaps with the guidelines of the IFC standards, the more stringent measure should be implemented for the project. For this project, the Lesotho water quality standards should be applied. The objectives of IFC (2012), where applicable to the hydrological investigation, are summarised as follows:

- The identification and quantification of environmental risks and impacts associated with the project, as well as the identification of mitigation measures to be implemented at the site to minimise or avoid said risks and impacts;
- To encourage and ensure that the client runs the project as sustainably as possible using efficient and effective environmental management plans; and
- To ensure that relevant stakeholders (e.g. local communities, government, etc.) are aware of the project and their respective communications and queries are responded to and managed effectively.

4.5 CSIR Guidelines for Human Settlement Planning and Design

No particular guidelines or regulation exists with regards to stormwater planning in Lesotho. The SWMP site was therefore done in accordance with The Council for Scientific and Industrial Research (CSIR) Storm Water Management Master Drainage Plan from Human Settlement Planning and Design guideline (CSIR, 2000).

The Storm Water Management Planning guidelines were formulated to guide the development for residential, institutions, general commercial and industrial areas and high-value central business district. Stormwater management for industrial areas should strive to protect the health, welfare of the public as well as the projection of the public from flood hazards by safely routing and discharging stormwater from developments. The guidelines also stipulate that a stormwater management plan should preserve the natural environment and provide the optimum methods of controlling surface runoff.

4.6 Water Quality

Potable water quality guidelines considered relevant to the Project include the South African Water Quality Standards for Human Consumption (SANS 241-1 2015 Drinking Water) as no drinking water standards could be obtained during this project.

Generally, no poor quality water is generated from solar PV plants. However, to effectively manage the impact of operations on the water quality a baseline, or ambient, water quality must be determined (refer to Section 9). Water quality objectives were compared and are presented in Table 4-1.

Table 4-1: Water quality guidelines used in this study

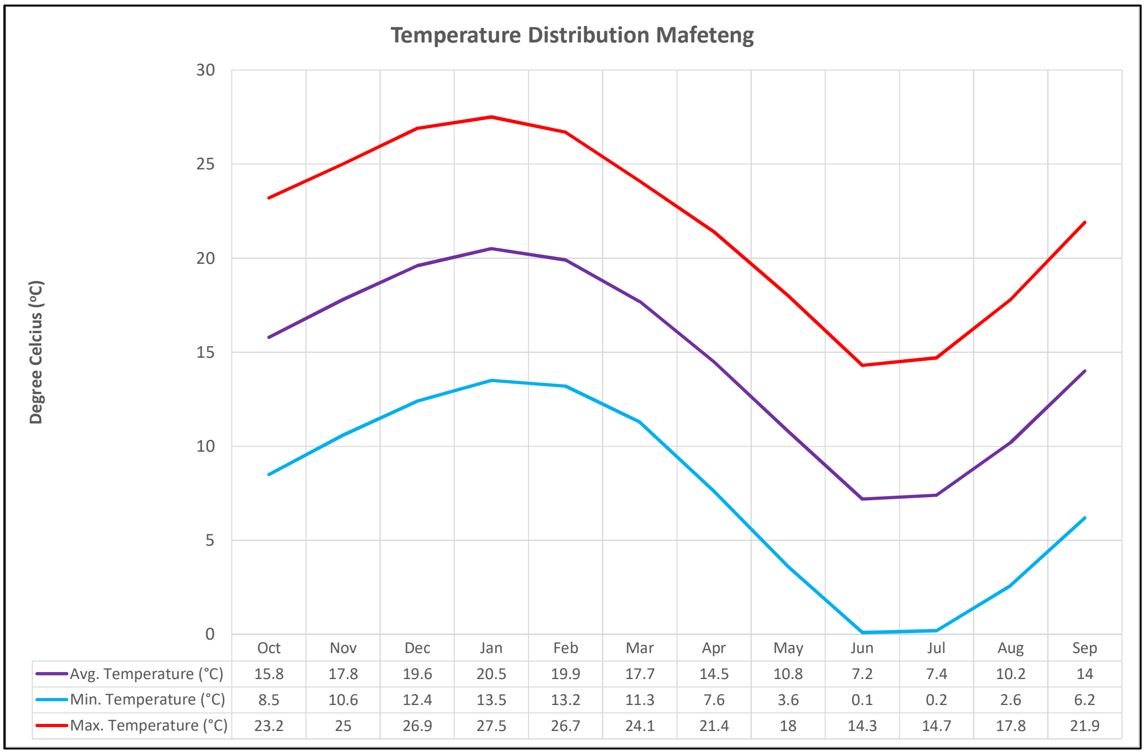
Element	Unit	SANS 241-1 2015 Drinking Water
Bicarbonate Alkalinity as HCO3	mg/L	NS
pH in water at 25°C	-	5-9.7
Total Alkalinity as CaCO3	mg/L	1200
Conductivity in mS/m @ 25°C	mS/m	170
Calcium	mg/L	NS
Iron	mg/L	2
Potassium	mg/L	NS
Magnesium	mg/L	NS
Sodium	mg/L	200
Phosphorus	mg/L	NS
Aluminium	mg/L	0.3
Arsenic	mg/L	0.01
Boron	mg/L	2.4
Barium	mg/L	0.7
Beryllium	mg/L	NS
Cadmium	mg/L	0.003
Cobalt	mg/L	NS
Chromium	mg/L	0.05
Copper	mg/L	2
Manganese	mg/L	0.4
Molybdenum	mg/L	NS
Nickel	mg/L	0.07
Lead	mg/L	0.01
Antimony	mg/L	NS
Selenium	mg/L	0.04
Tin	mg/L	NS
Vanadium	mg/L	NS
Zinc	mg/L	5
Chloride	mg/L	300
Fluoride	mg/L	1.5
Nitrite	mg/L	3.0
Nitrite as N	mg/L	0.9
Nitrate	mg/L	48.7
Nitrate as N	mg/L	11
Sulphate	mg/L	500
Mercury	mg/L	0.006
Ammonia	mg/L	1.9
Ammonia as N	mg/L	1.5

5 RECEIVING ENVIRONMENT AND BASELINE CONDITIONS

5.1 Climate

The general climate of the site is described as Subtropical Highland (Koppen Geiger classification Cwb) (Kottek, et al., 2006). This classification indicates warm summers, summer rainfall and a drier, cold winter. The main natural vegetation type is Moist Highveld Grassland as described by Kruger (2004). The site is situated on the watershed of the Caledon and Orange-Senqu River Basins, at an elevation of approximately 1 750 metres above mean sea level (mamsl).

No local temperature data is available, but temperatures from the nearby town of Mafateng is reported as shown in Figure 5.1 (Climate-Data, 2018). January is the warmest month, with an average temperature of 20.5°C. At 7.2°C on average, June is the coldest month of the year. Frost and snow may occur at any time of the year but are rare occurrences during the warmer summer months.

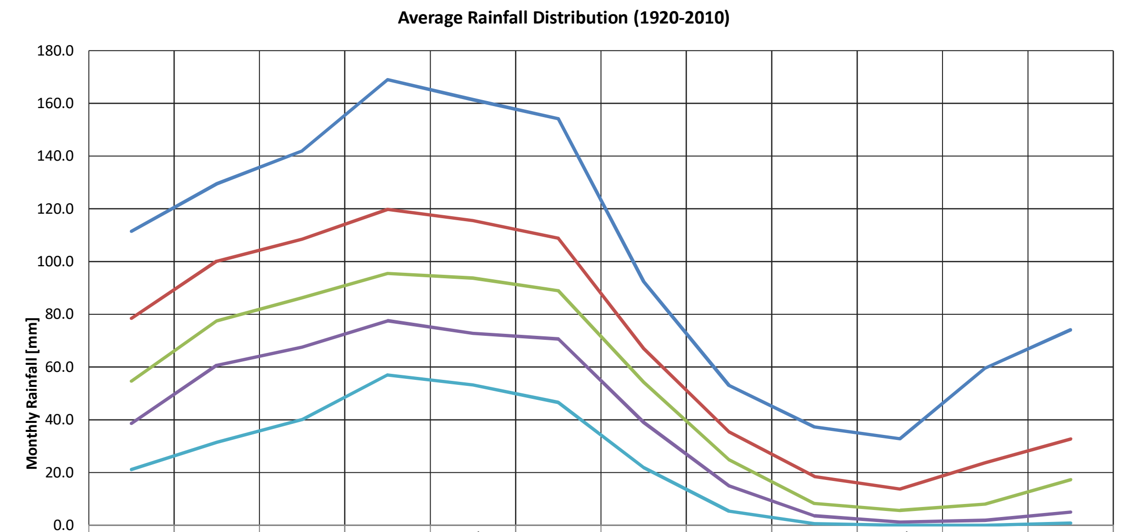


	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Avg. Temperature (°C)	15.8	17.8	19.6	20.5	19.9	17.7	14.5	10.8	7.2	7.4	10.2	14
Min. Temperature (°C)	8.5	10.6	12.4	13.5	13.2	11.3	7.6	3.6	0.1	0.2	2.6	6.2
Max. Temperature (°C)	23.2	25	26.9	27.5	26.7	24.1	21.4	18	14.3	14.7	17.8	21.9

Figure 5.1: Maximum and minimum average monthly temperature

5.2 Rainfall

Rainfall for this study report was determined from data used in WR2012 (Bailey & Pitman, 2015)) for Quaternary catchments D23F and D15F. The site falls on the boundary of these two catchments, within D23F. In the region, rainfall tends to increase with altitude, toward the upper regions of the catchment. Average Mean Annual Precipitation (MAP) for catchment D23F is estimated at 638 mm, while the D15F catchment has an average MAP of 750 mm. The best estimate of MAP at the site would be in the order of 700 mm (or slightly higher). Rainfall distribution is likely to include elements of both Rain Zone D2G (catchment D23F) and Rain Zone D1L (catchment D15F). Taking these points into consideration, an interpolated 90-year rainfall record was generated for the site that had a MAP of 700 mm and a distribution pattern as shown in Figure 5.2.



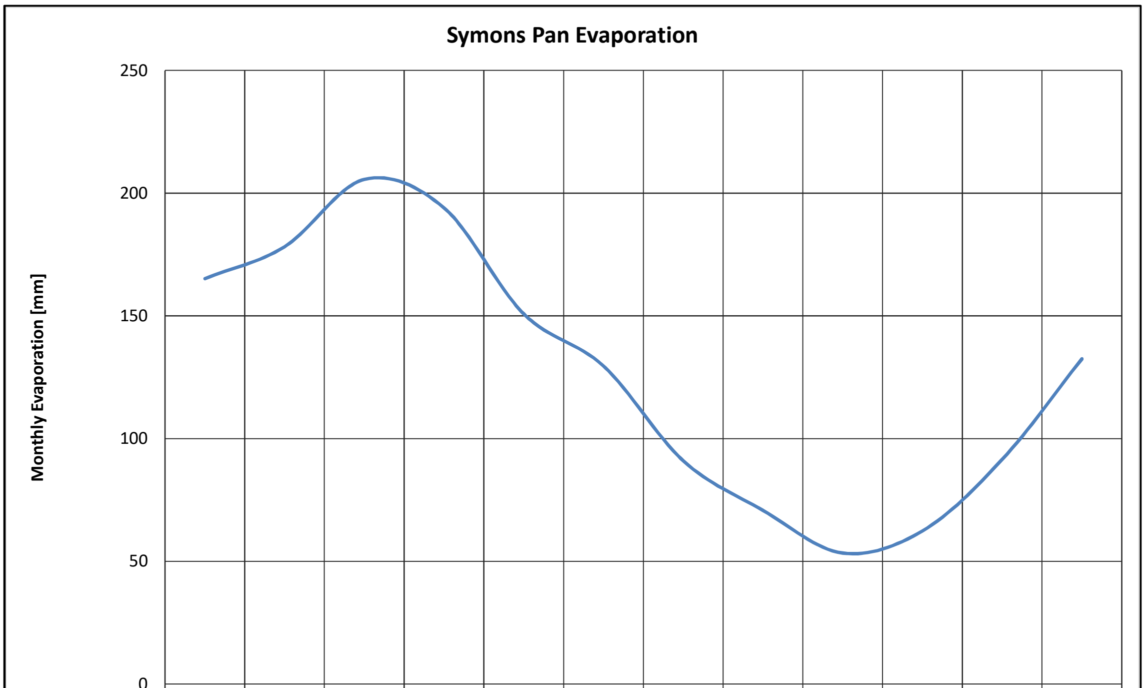
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
E10	111.5	129.5	142.0	169.0	161.4	154.2	92.4	53.1	37.3	32.8	59.6	74.1
E30	78.5	100.2	108.5	119.8	115.6	108.9	67.0	35.4	18.5	13.7	23.7	32.7
E50	54.7	77.5	86.3	95.5	93.8	89.0	54.2	24.8	8.2	5.6	8.0	17.3
E70	38.6	60.7	67.6	77.6	72.8	70.7	39.0	14.9	3.6	1.2	1.9	5.0
E90	21.1	31.5	40.1	57.0	53.2	46.6	21.9	5.3	0.6	0.0	0.0	0.8

E10 represents a value that is likely to be exceeded in 10% of years. An E50 value would be exceeded in 50 % of years, etc.

Figure 5.2: Monthly rainfall distribution pattern

5.3 Evaporation

No local evaporation data was found. WR2012 suggests that Symons Pan evaporation for the site is 1 525 mm per annum, distributed according to Evaporation Zone 20B (described in WR90). There is not sufficient data available to analyse trends of change in this data and evaporation is estimated as shown in Figure 5.3.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Symons Pan	165.2	178.2	205.6	194	150.8	129.6	91	70.8	53.4	62.4	91.5	132.5

Figure 5.3: Estimated Symons Pan evaporation

5.4 Drainage and Catchment Characteristics

The proposed Solar PV site is located in a hilly area on a top of quaternary catchment D23F with the plant facing in the northerly direction. The slopes of the hills are sparsely vegetated. Located on an altitude of about 1750 mamsl (refer to Figure 5.4). The area is characterised by non-perennial drainage channels which only flow during/after flashy rainfall events. Runoff flows in the northerly and north-easterly direction into the perennial Tšana-Talana River (Figure 5.5).

Runoff in these mountainous regions is extremely variable and depends largely on soil type and depth, on vegetation and on rainfall. Naturalised runoff that reports to local rivers and streams near the proposed site is not likely to be significant for this project. WR2012 reports average runoff for quaternary catchment D23F at 124 mm per annum and for D15F at 54 mm per annum, on average. The quantity of runoff reporting to local streams is likely to be in this range, however, is most likely to be in the order of 70 mm per annum, which is ~10% of MAP.

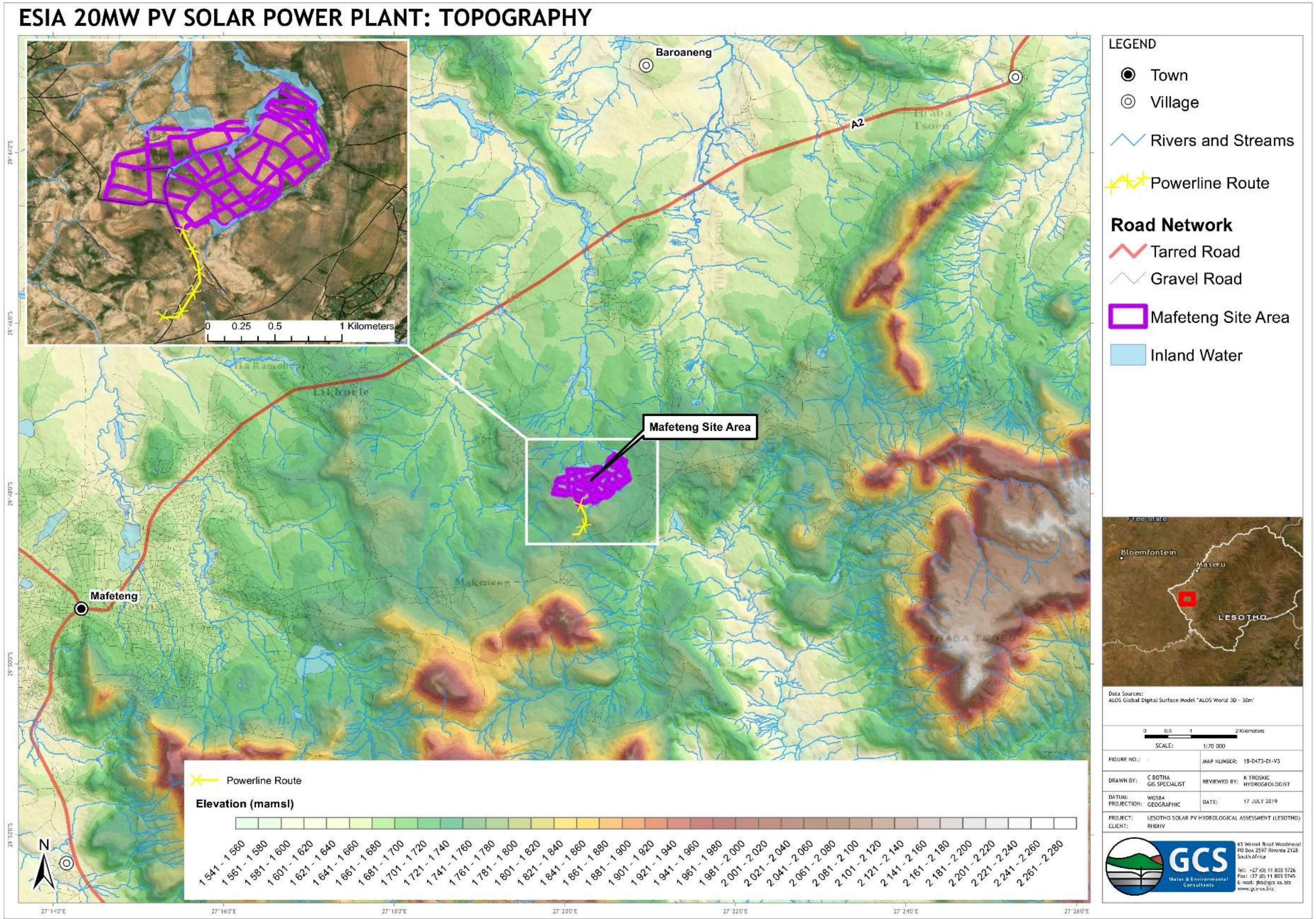


Figure 5.4: Topography Map

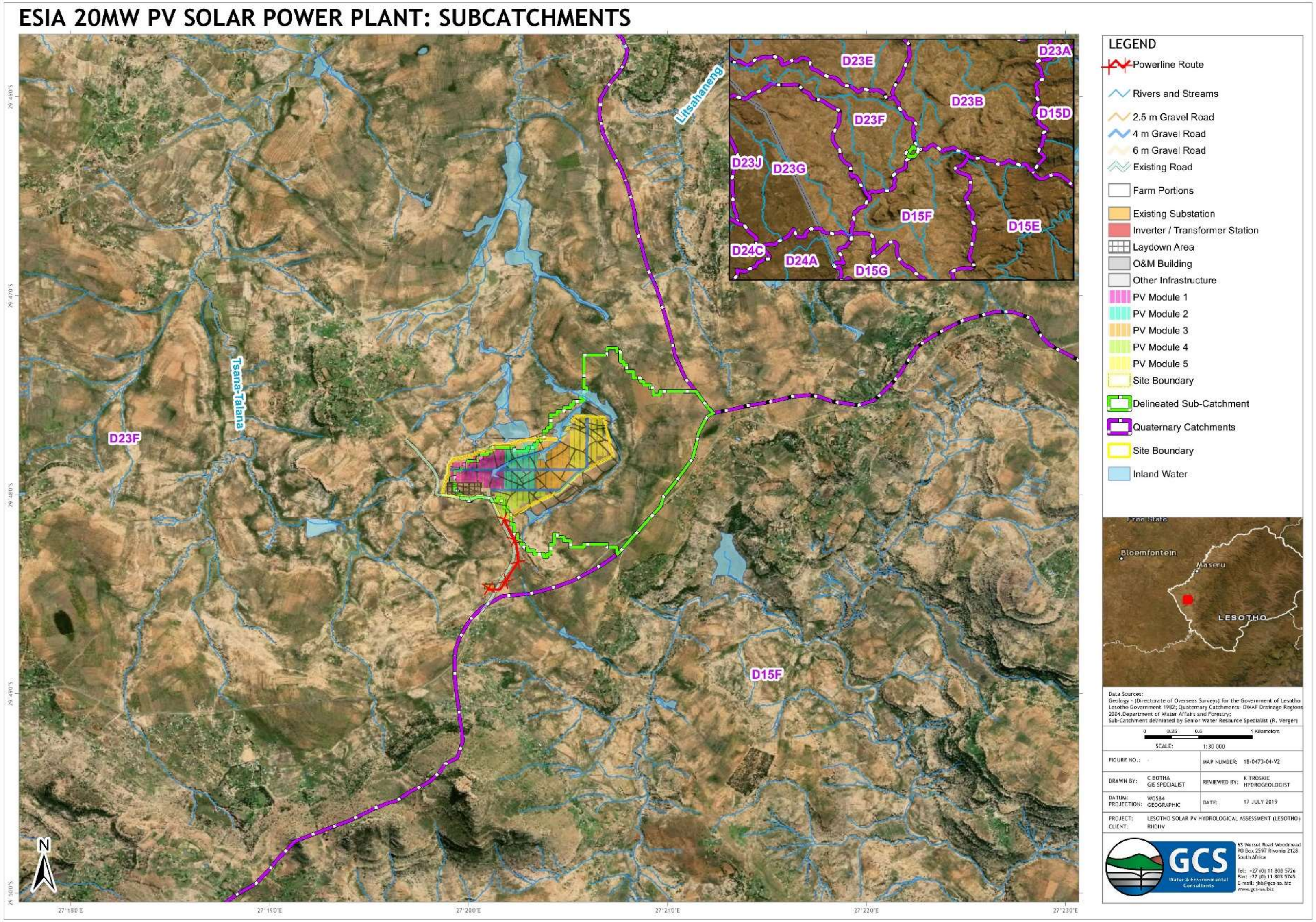


Figure 5.5: Sub-catchments and drainage lines

5.5 Peak Storm Rainfall and Floods

The Design Rainfall Estimation software (Smithers & Schulze, 2002) was used to extract the peak rainfall depths for the calculation of the design flood peaks of the PV Solar site. The software spatially-interpolates the gauged rainfall data from the stations surrounding the study of interest and tabulates peak rainfall depths for various storm durations and return periods. A total of six (6) rainfall stations located within a radius of 35 km from the Solar PV site were used to extract the design rainfall depths for the 1:2-year to 1:200-year return periods (Table 5-1). Rainfall depths were used as inputs in the calculations of the peak flow flood volumes for the study area.

The proposed site lies at the top of a catchment and only very small local catchments will contribute to floods in local streams or on the site. Point runoff can then be routed through a series of drainage paths, waterways and channels to derive flood values at any point in the system. It is anticipated that solar panels will tend to concentrate runoff and that runoff from the field of panels will be higher than runoff from natural grassland. Post-development runoff will depend largely on the final layout of the solar plant and on soil cover conditions.

Table 5-1: Design rainfall depth values for the Solar PV site

Duration	Return Period (years)						
	1:2	1:5	1:10	1:20	1:50	1:100	1:200
5min	11.6	15.7	18.7	21.8	26.1	29.6	33.4
10min	15.9	21.5	25.5	29.7	35.7	40.5	45.6
15min	19	25.8	30.7	35.7	42.8	48.6	54.7
30min	23.8	32.2	38.3	44.6	53.5	60.7	68.4
45min	27.1	36.7	43.6	50.8	61	69.2	77.9
1h	29.7	40.2	47.9	55.7	66.9	75.9	85.5
1.5h	33.9	45.8	54.5	63.5	76.2	86.4	97.4
2h	37.1	50.3	59.8	69.6	83.6	94.8	106.8
4h	44.2	59.9	71.2	82.9	99.5	112.9	127.2
6h	49	66.3	78.9	91.8	110.2	125	140.8
8h	52.7	71.3	84.8	98.7	118.5	134.4	151.4
10h	55.7	75.4	89.7	104.4	125.3	142.1	160.2
12h	58.3	78.9	93.9	109.3	131.2	148.8	167.7
16h	62.7	84.9	101	117.5	141.1	160	180.3
20h	66.3	89.8	106.8	124.3	149.2	169.2	190.7
24h	69.4	94	111.8	130.1	156.2	177.2	199.6

5.6 Geology and Hydrogeology

The Lesotho lowlands are underlain by low permeability Karoo age sedimentary rocks and basalts intruded by dolerites. The groundwater resources of the Karoo formations and alluvial sediments are widely developed for rural water supply as well as some crop irrigation.

According to the geological map (refer to Figure 5.6), the site is underlain by fine and medium grained buff and red coloured sandstone, occasional coarse beds, buff and red mudstone and siltstone f the Elliot Formation. The mudstones and sandstones are approximately 100 m thick with weathered surface clays deeply gullied.

A younger intrusive dolerite dyke is mapped towards the centre of the site striking in a southeast to northwest direction. A second dolerite dyke is mapped towards the northern section of the site striking from East to West across the site.

The Elliot Formation is regarded as a poor aquifer due to its compact nature. Groundwater mainly occurs within interbedded sandstone layers that show significant lateral variability in thickness (Davies, 2003).

Groundwater can be associated with low permeability confined sandstones as well as contact zones between the Elliot and Molteno Formations. The average borehole yield is 1.34 L/s and the depth to water table is 27 m. The average transmissivity of the Elliot Formation is 24 m^2/day (Davies, 2003).

The presence of the dolerite dykes will, however, give rise to more enhanced aquifer conditions that can be targeted as a potential water supply to the PV Plant. The more enhanced aquifer conditions will however also increase the vulnerability and susceptibility of the aquifer to potential pollutions sources.

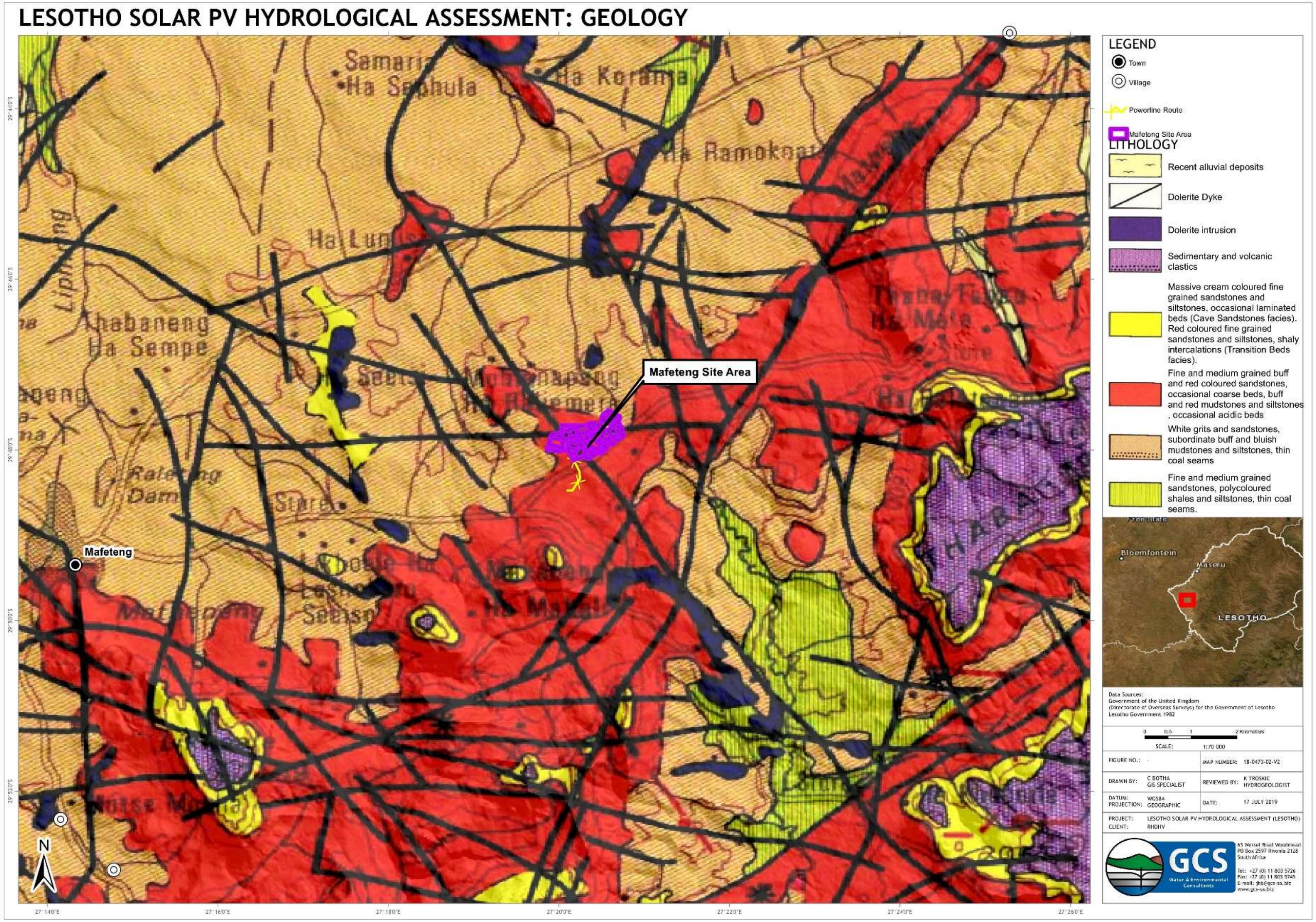


Figure 5.6: Geology Map

6 FLOOD LINE ASSESSMENT

6.1 Catchment Characteristics

The proposed solar PV plant area falls within two headwater drainage areas (named Catchment 1 and Catchment 2) which were delineated using ALOS DEM data. Catchment 1 has a well-defined water course whereas Catchment 2 has its defined river downstream towards the confluence of Catchment 1's river. The two catchments drain their waters' from the undulating hills downslope through a relatively flat terrain and their characteristics are summarised in Table 6-1.

The overall catchment area of the proposed solar PV plant is predominantly covered by grassland which – from the Google Earth historic imagery assessment – were previously cultivated. The headwater reaches of the two catchments are eroded which signifies that the soils are poorly drained. However, downstream towards the confluence of the streams from the two catchments, the topography is relatively flat with small patches of dense grass. This implies that during the wet season these areas are ponded and they contain soil moisture for a long period of time. These characteristics were all concidered to derive runoff coefficients in the peak flow determination (see Appendix A) and in populating the Manning's n values for both channels and river banks (Table 6-1).

Table 6-1: Hydraulic characteristics of the delineated catchments

Site	River	Area (km^2)	Hydraulic Length (L)	Distance to Centroid (L_c)	Slope (m/m)	Manning's n	
						Banks	Channel
Catchment 1	Seekoei River Tributary	1.64	1.91	0.96	0.020	0.035	0.030
Catchment 2		0.45	1.10	0.55	0.025	0.035	0.030

Photograph 6-1: River cross-section in the headwater of Catchment 1

Photograph 6-2: Downstream orientation of Catchment 2 river

Photograph 6-3: Eroded upstream sections of the main river

Photograph 6-4: Current land cover at the headwater reaches of Catchment 2

6.2 Peak Flow Volumes

The peak flows used for flood line determination and the design for the stormwater management plan and drainage channels were calculated using three standard methods applied in South Africa. Based on the legislation adopted for this study, peak flows resulting from a 1:5-year storm were used for the design of the channel whereas the 1:50 and 1:100-year peak flows were used in flood line modelling. A summary of the calculated peak flow results for the two catchments is presented in Table 6-2 and the results are based on the calculations and assumptions provided in Appendix A.

Peak flows calculated using the Rational Method 3 were selected for HEC-RAS hydraulic modelling as they proved to be more conservative compared to the other three. While the SCS-SA method also provided reasonable peak flows, the results from the other methods were not considered reliable especially for the small catchment.

Table 6-2: Peak flow volumes for the 1:50 and 1:100-year return period

Catchments	Rational Method Alternative 3			Rational Method Alternative 2			SCS-SA		
	1:5yr	1:50yr	1:100yr	1:5yr	1:50yr	1:100yr	1:5yr	1:50yr	1:100yr
	m^3s^{-1}								
Catchment 1	**9.65**	**19.04**	**22.74**	4.45	8.26	10.91	6.99	14.63	17.35
Catchment 2	**2.50**	**5.00**	**6.00**	1.58	3.80	4.61	1.88	6.55	7.78

6.3 Flood Line Modelling

Flood lines were simulated for the two tributaries adjacent to the proposed Solar plant using the peak flows resulting from the 1:50 and 1:100-year return periods. After evaluating the simulation results, it was noted that flood resulting from the 1:50-year event do not have any significant differences in the areal extent of the flood areas. Only the simulated flood lines resulting from peak flows of the 1:100-year return period are presented (Figure 6.1).

The modelling results show that, generally, there are relatively small quantities of flood water are drained by Catchment 2 as the 1:100-year peak flows do not reach the site boundary near the PV Module 5. While the flood lines in Catchment 1 are also not inundating portions of the solar plant, downstream (near PV Module 5) the areal extent of the flood increases, spatially. Part of the reason is that the topographic data used (ALOS) are at a relatively coarse scale (30 x 30 m cell size) and they do not adequately represent elevation differences within a small spatial area. Also given that the river is charactered by small width and deep cutting, a 30 m resolution ALOS pixel does not account for these differences. Under these conditions, the simulated 1:100-year floods do not pose any risk of flooding the proposed infrastructure.

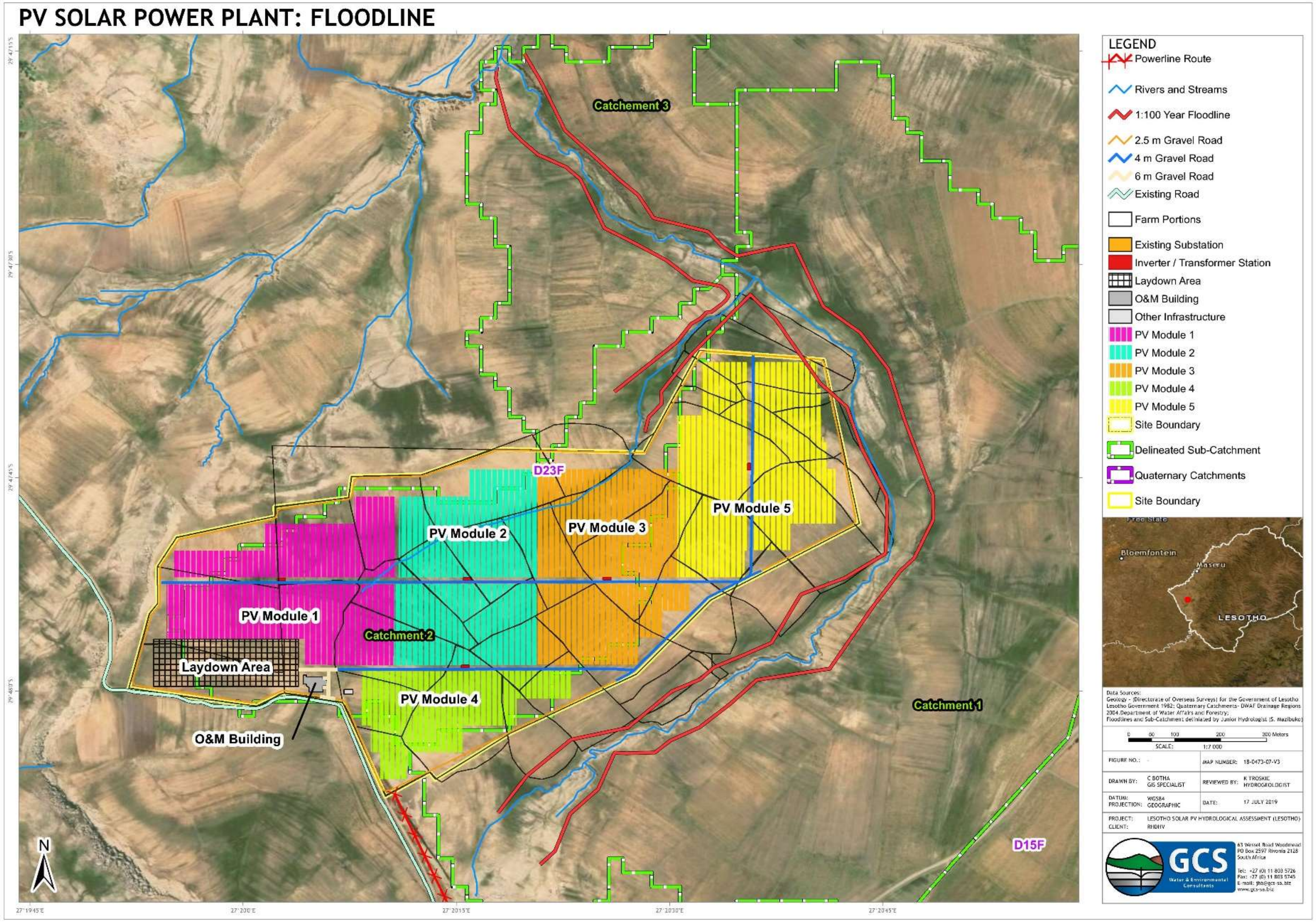


Figure 6.1: 100-year flood lines for the proposed Solar PV Plant site

7 CONCEPTUAL STORM WATER MANAGEMENT PLAN

7.1 Objective

The purpose of the SWMP was aimed at reducing the concentration of stormwater due to the gridded layout of the solar panels in the proposed plant area. Concentrated stormwater potentially enhances soil erosion and soil salinization, especially in poorly drained soils. Based on results of the wetland delineation study (RHDHV, 2019) and site observations, highly erodible and dispersive soils are present at proposed plant area..

Best international practices show that stormwater needs to be managed on solar PV Plant sites due to concentrated flow paths from solar panels and as a result potential erosion. A conceptual SWMP for the study site was described in accordance with The Council for Scientific and Industrial Research (CSIR) Storm Water Management Master Drainage Plan from Human Settlement Planning and Design guideline (CSIR, 2000). The guideline stipulates that the design of the stormwater drainage network system should promote overland flow opposed to the engineered conduits, reduce the spatial extent of impervious surfaces and maintain the vegetation cover to increase interception and evapotranspiration.

7.2 Stormwater Drainage

The proposed SWMP (Figure 7.1) comprises of a network of natural drains and energy dissipating structures which divert stormwater towards the river course and wetland (RHDHV, 2019). The ALOS DEM data were used to define natural overland flow directions from small drainage areas to define drain location and direction (see Figure 7.2).

All drainage systems needs to be designed based on detailed topographical survey data. Runoff between the solar panels should be directed to natural water ways and wetland in a manner that prevents soil erosion. Given the erodibility nature of the soils at the proposed site area, it was suggested that the drainage network system should therfore mimic the natural slope as far as possible. Taking into account the wetland delineation (RHDV, 2019), drains should not be extended into the wetland area.

Water flow direction presented in Figure 7.2 shows that stormwater will be generated from a relatively large surface area of the headwater reaches and will flow towards the river course of catchment 1. However, in the midstream to downstream areas of catchment 2, it is proposed that minimum of two (2) drains are constructed to collect and divert stormwater to the river. A minimum of four (4) drainage channels should be constructed within catchment 2 which will collect stormwater generated from the area that is predominantly covered by PV modules.

Number of drainage channels can be expanded in the same direction to reduce total flow rates and potential erosion. It may be possible to further reduce runoff by promoting infiltration by using bunds and soakways. This will, however, depend on the final design of the PV modules and detailed topographical survey data. If flow velocities are high (>1m/s), energy dissipating structures should be put in place. It is also recommended that stormwater should be routed through stone pitched drifts at road crossings. Outlets of the drainage channels should included energy dissipating structures at the wetland boundaries.

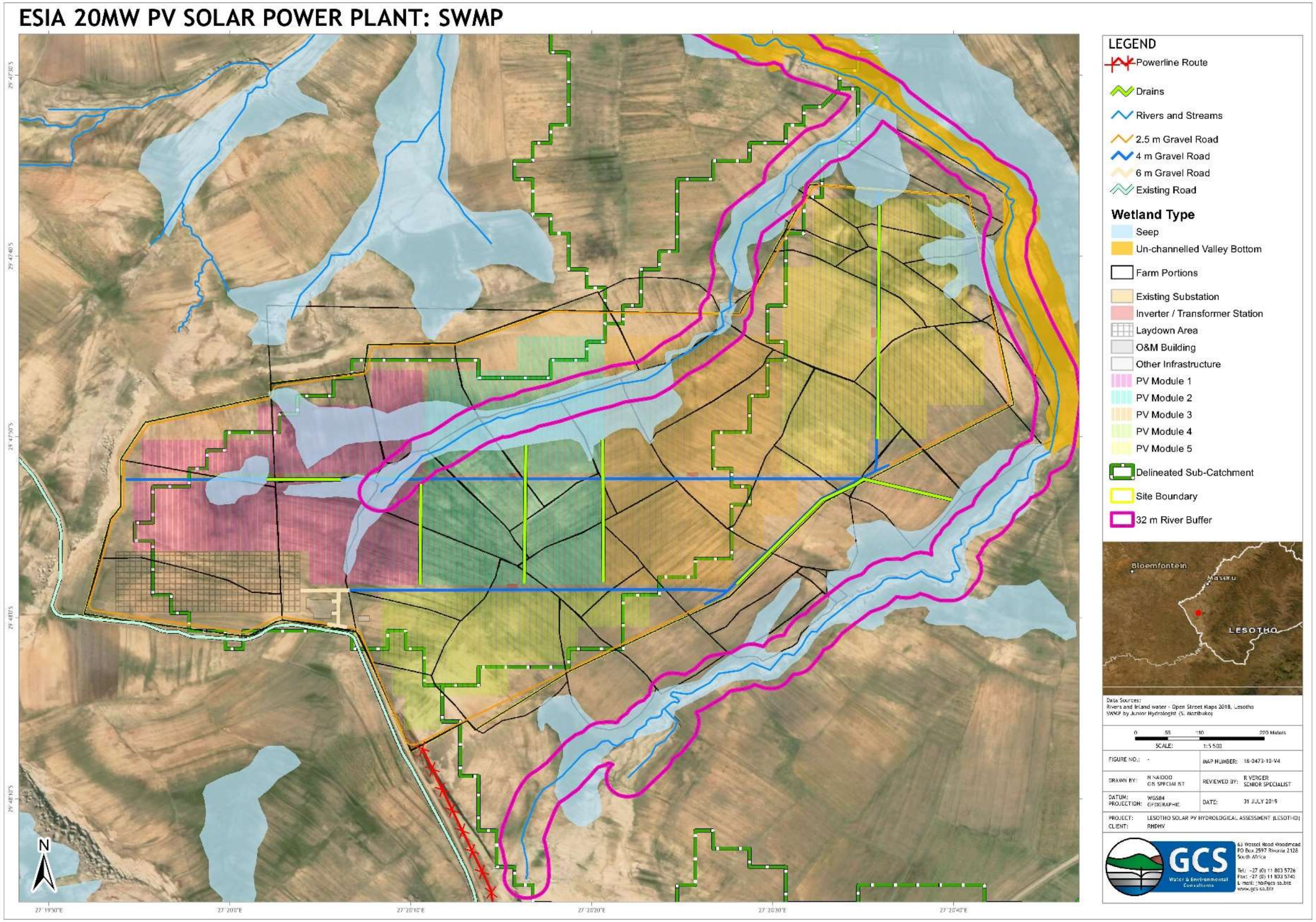


Figure 7.1: Proposed SWMP infrastructure with a 32 m buffer in the natural river channels

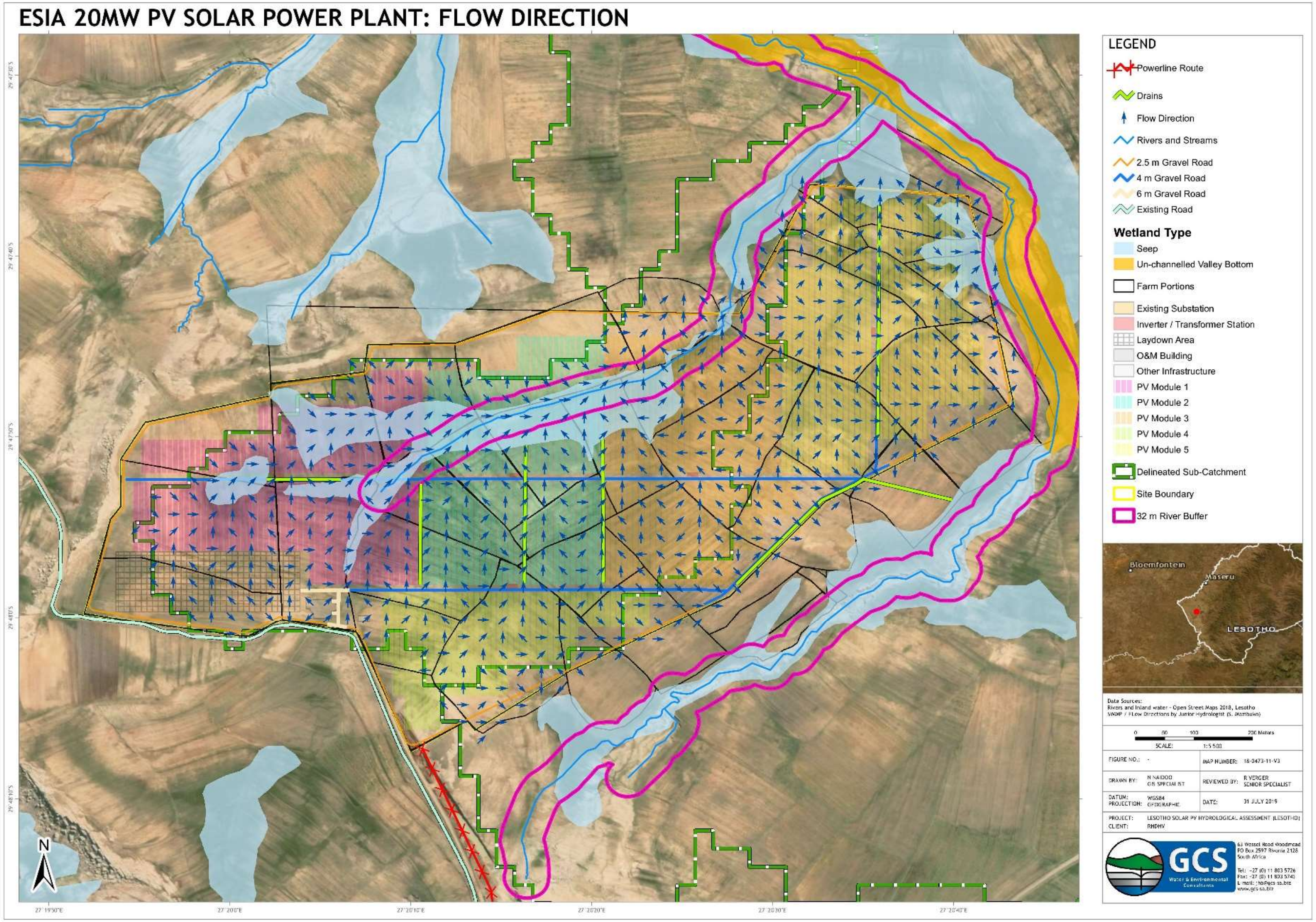


Figure 7.2: Water flow direction within the proposed solar PV Plant

7.3 Sizing of Storm Water Infrastructure

Due to highly erodible and dispersive soils, sizing of stormwater infrastructure should be based on calculations using the 1:10-year peak flows (CSIR, 2000). It is proposed that the drainage channels should be constructed with lined with natural grasses to enhance channel slope stability and reduce potential erosion. A fixed Manning's coefficient value of 0.035 for grass lining on the drain sides can be used to determine normal depths in the channels. A typical v-shaped cross-section of the drainage channel is proposed and should be designed with 1:3 slopes on both sides (Figure 7.3). If required, a berm can be added.

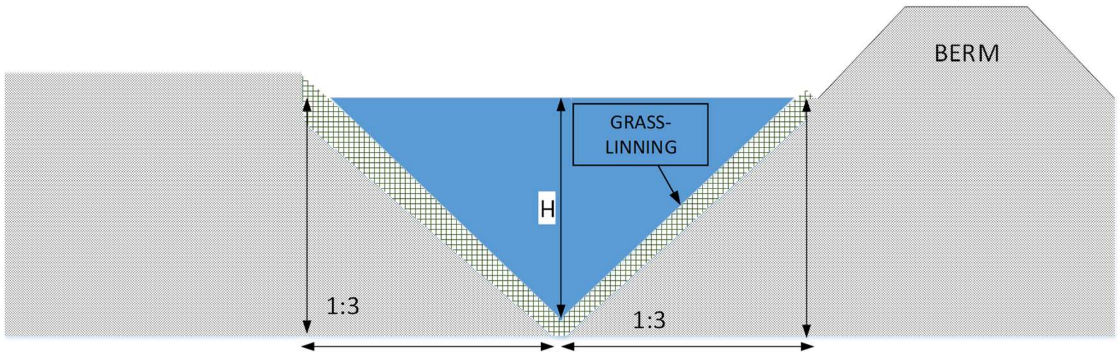


Figure 7.3: Conceptual design of the grass-lined stormwater drain

8 GROUNDWATER ASSESSMENT

8.1 Hydrocensus

As part of the scoping study, a desktop study and satellite image review of the study areas were carried out. Based on the findings, no groundwater abstraction occurs on the position of the site layout. All the surrounding villages (e.g. Ha Ramarothola, Tonki eat hope, ha Ntjoko, Ha lempetje, Ha Raliemere etc.) depend solely on groundwater in a form of both springs and boreholes. Some of these boreholes were visited during the hydrocensus conducted on the 18th to the 20th October 2018. The locations of the identified boreholes and springs are presented in Figure 8.1.

The hydrocensus point details are presented in Table 8-1. The Total Dissolved Solids (TDS), Temperature, Electrical Conductivity (EC) and pH were recorded. The TDS, EC and pH are all within the South African National Standards (SANS) 241-1:2015 drinking water quality guidelines (SABS, 2015).

Water samples were collected from BH1, BH4 and Spring 3 and laboratory analyses for these samples are discussed in Section 9.2.

Table 8-1: Hydrocensus point details and field parameters

BH ID	Coordinates		In situ chemical properties			
	Latitude	Longitude	TDS (mg/l)	Temperature (ºC)	EC (µS)	pH
BH1	-29.81133	27.33494	268	18.6	378	7.5
BH2	-29.78579	27.32037	203	20.6	292	7.91
BH3	-29.78996	27.319	288	19.8	410	7.46
BH4	-29.79551	27.35823	305	21.5	439	8.28
BH5	-29.80883	27.29594	97	21.3	137.6	7.58
BH6	-29.80124	27.29512	283	24	406	7.35
Spring_1	-29.7862	27.31861	206	16.5	298	8
Spring_2	-29.7976	27.318647	37.9	11.4	59.1	8.2
Spring_3	-29.7969	27.34634	158	22.2	228	7.87

*Water sample collected

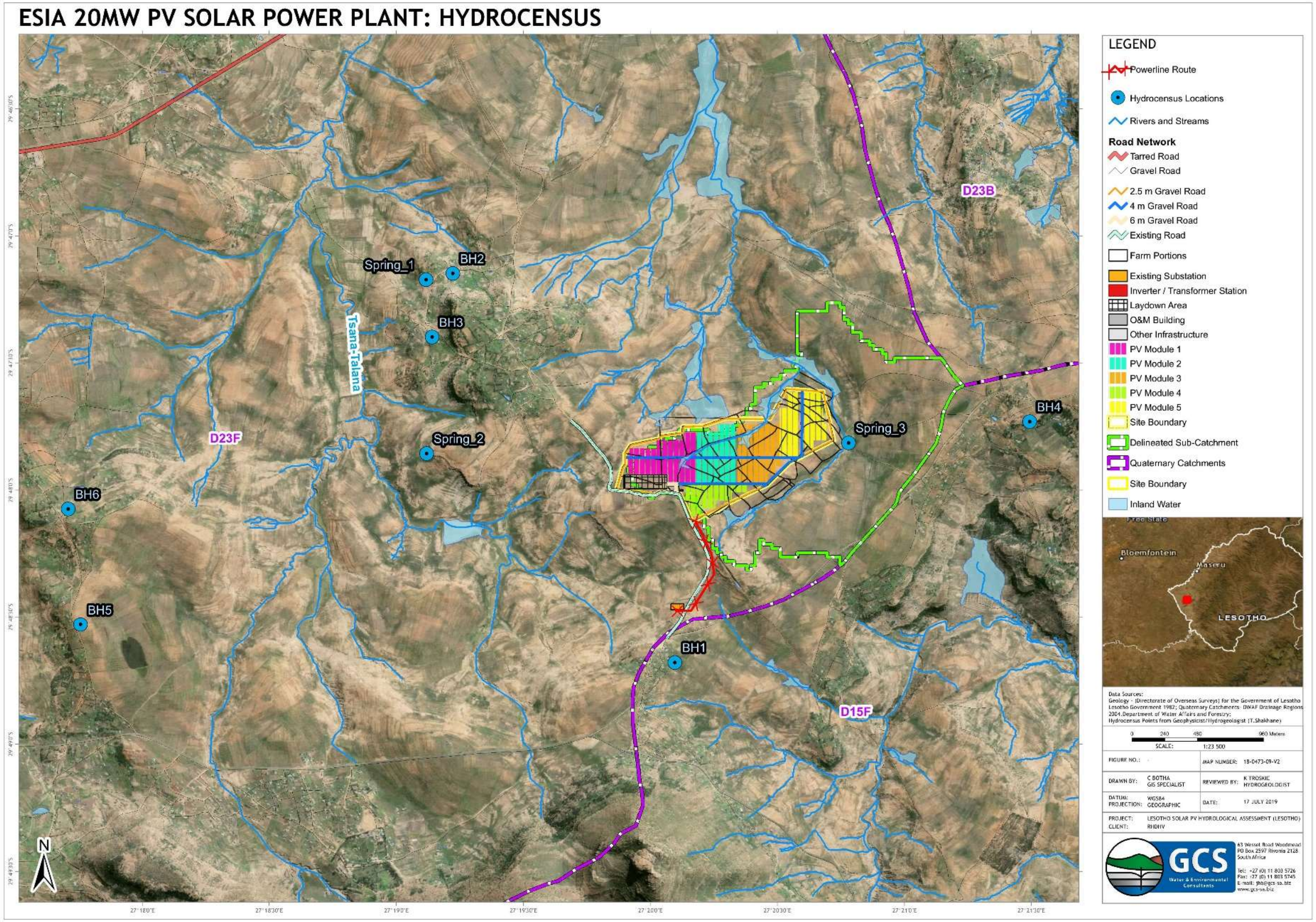


Figure 8.1: A Google Satellite map showing operational boreholes and springs in the proximity of the subject area

9 LABORATORY ANALYSIS

9.1 Baseline Surface Water Quality Analysis

Surface water samples were collected from SW1, SW2 and SW4 in streams (Figure 9.1). The laboratory results are presented in Table 9-1. The laboratory certificate is attached in Appendix B. The surface water samples were compared to the South African National Standards (SANS) 241-1:2015. With the expectation of Iron at sampling point SW1 – which is higher than the SANS standards – all other water quality parameters in all samples are within acceptable standard.

Table 9-1: Surface Water Laboratory Results

Parameter	Units	SANS 241-1:2015	SW1	SW2	SW4
General Parameters					
pH	-	>5 to <9.7	7.68	8.42	8.47
Electrical Conductivity (EC)	mS/m	170	36.2	25.9	29.9
Total Dissolved Solids (TDS)	mg/l	1 200	274	196	204
Alkalinity	mg $CaCO_3$/l	NS	141	152	160
Dissolved Oxygen (DO)	mg/l	NS	1.23	3.47	4.35
Total Hardness	mg $CaCO_3$/l	NS	73	85	120
Acidity	mg $CaCO_3$/l	NS	103	92.2	88
Bicarbonate	mg $CaCO_3$/l	NS	141	148	156
Carb alk -cal	mg $CaCO_3$/l	NS	0.638	3.63	4.35
Temperature	°C	NS	17	17	17
Anions					
Chloride, Cl	mg/l	300	13	8.35	5.52
Sulphate, SO_4	mg/l	Acute health: <500 Aesthetic: <250	26.3	11.3	15.6
Nitrate, NO_3	mg/l	11	0.229	0.313	<0.194
Nitrite, NO_2	mg/l	0.9	0.012	0.044	0.025
Ammonium, NH_4	mg/l	1.5	0.577	0.339	0.058
Ammonia, NH_3	mg/l	1.5	0.01	0.027	0.006
Cations and Metals					
Aluminium, Al	mg/l	0.3	13	2.41	<0.002
Antimony, Sb	mg/l	0.02	<0.001	<0.001	<0.001
Arsenic, As	mg/l	0.01	<0.006	<0.006	<0.006
Barium. Ba	mg/l	0.7	0.212	0.132	0.058
Beryllium, Be	mg/l	NS	<0.005	<0.005	<0.005
Boron, B	mg/l	2.4	<0.013	<0.013	<0.013
Cadmium, Cd	mg/l	0.003	<0.002	<0.002	<0.002

Parameter	Units	SANS 241-1:2015	SW1	SW2	SW4
General Parameters					
Calcium, Ca	**mg/l**	NS	17	19.9	33
Cobalt, Co	**mg/l**	0.5	<0.003	<0.003	<0.003
Copper, Cu	**mg/l**	2	0.003	<0.002	<0.002
Fluoride, F	**mg/l**	1.5	0.436	0.429	0.383
Iron, Fe	**mg/l**	Chronic health: 2 Aesthetic: 0.3	7.13	1.76	<0.004
Lead, Pb	**mg/l**	0.01	<0.004	<0.004	<0.004
Lithium, Li	**mg/l**	NS	0.008	0.006	<0.001
Magnesium, Mg	**mg/l**	NS	7.51	8.48	9.04
Manganese, Mn	**mg/l**	Chronic health: 0.4 Aesthetic: 0.1	0.607	<0.001	<0.001
Mercury, Hg	**mg/l**	0.006	<0.004	<0.004	<0.004
Nickel, Ni	**mg/l**	0.07	<0.002	<0.002	<0.002
Phosphate, PO_4	**mg/l**	NS	<0.005	<0.005	<0.005
Potassium, K	**mg/l**	NS	7.49	4.43	3.53
Rubidium, Rb	**mg/l**	NS	0.042	0.008	<0.002
Silicon, Si	**mg/l**	NS	37.8	8.15	4.43
Sodium, Na	**mg/l**	200	11.5	26.6	26.3
Uranium, U	**mg/l**	0.03	<0.015	<0.015	<0.015
Vanadium, V	**mg/l**	0.2	0.02	0.006	<0.001
Zinc, Zn	**mg/l**	5	0.015	<0.002	<0.002
Bismuth, Bi	**mg/l**	NS	<0.004	<0.004	<0.004
Gallium, Ga	**mg/l**	NS	0.027	0.005	<0.001
Lithium, Li	**mg/l**	NS	0.008	0.006	<0.001
Molybdenum, Mo	**mg/l**	NS	<0.004	<0.004	<0.004
Tellerium, Te	**mg/l**	NS	<0.001	<0.001	<0.001
Titanium, Ti	**mg/l**	NS	<0.037	<0.037	<0.037

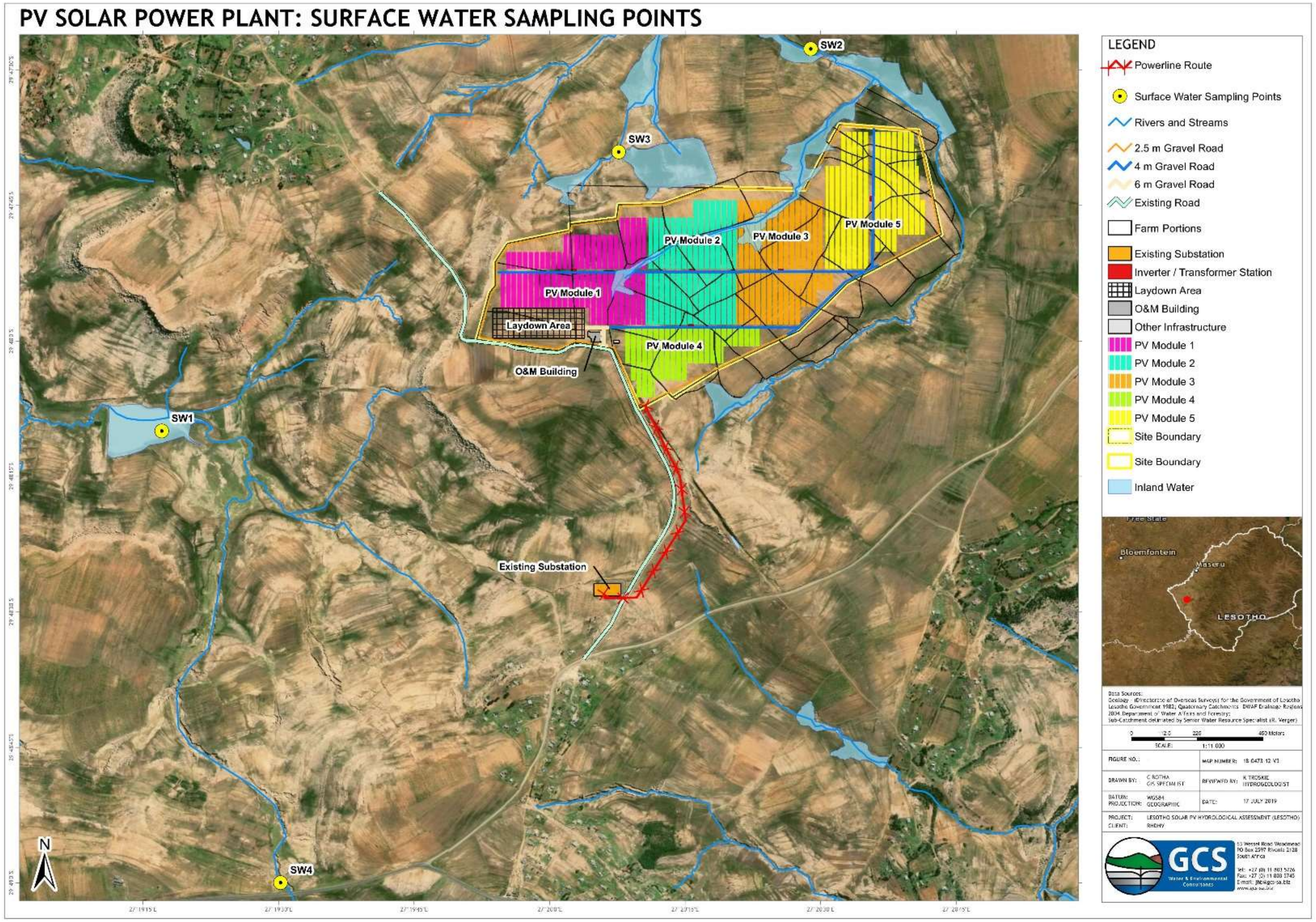


Figure 9.1: Surface water quality sampling point (SW1, SW2 and SW4)

9.1.1 Piper Diagram

A piper diagram represents the chemistry of a water sample graphically. It is a tri-linear diagram that implements major cations calcium, magnesium, sodium and potassium) and anions (chloride, sulphate and bicarbonate) to reveal the chemistry of water samples. This is then used to characterize different types of water. The piper diagram for the surface water samples is presented in Figure 9.2.

The water samples collected represent fresh water rich in calcium, magnesium and bicarbonate.

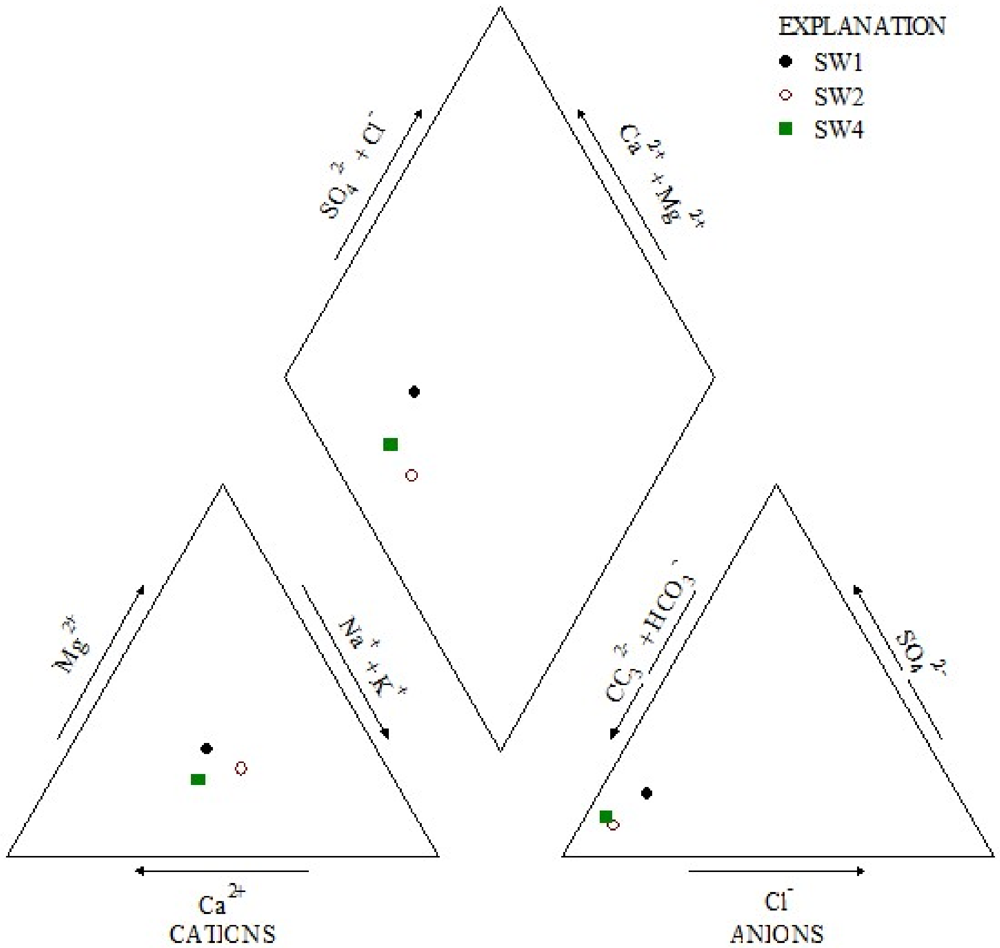


Figure 9.2: Piper Diagram – Surface Water

9.2 Groundwater Quality

Water samples were collected from BH1 and BH4. The laboratory results are presented in Table 9-2. The laboratory certificate is attached in Appendix B. The results were compared to the SANS 241-1:2015 drinking water quality guidelines.

In-situ and laboratory analysis for baseline hydrochemical facies indicate that, at the time of analysis (October 2018), none of the chemical parameters exceeded limits for drinking water standards as per the SANS 241-1:2015.

Table 9-2: Groundwater Laboratory Results

Parameter	Units	SANS 241-1:2015	BH1	BH4	Spring 3
General Parameters					
pH	**-**	>5 to <9.7	8.63	8.59	8.51
Electrical Conductivity (EC)	**mS/m**	170	29.1	34.7	21.2
Total Dissolved Solids (TDS)	**mg/l**	1200	232	251	167
Alkalinity	**mg $CaCO_3$/l**	NS	172	144	120
Dissolved Oxygen (DO)	**mg/l**	NS	4.45	4.29	4.3
Total Hardness	**mg $CaCO_3$/l**	NS	45	46	86
Acidity	**mg $CaCO_3$/l**	NS	<0.001	115	<0.001
Bicarbonate	**mg $CaCO_3$/l**	NS	165	139	116
Carb alk - cal	**mg $CaCO_3$/l**	NS	6.63	5.1	3.54
Anions					
Chloride, Cl	**mg/l**	300	8.38	25.1	1.39
Sulphate, SO_4	**mg/l**	Acute health: <500 Aesthetic: <250	13.8	14.4	5.87
Nitrate, NO_3	**mg/l**	11	0.965	3.07	1.39
Nitrite, NO_2	**mg/l**	0.9	0.024	0.025	0.022
Ammonium, NH4	**mg/l**	NS	<0.008	0.011	<0.008
Ammonia, NH_3 - cal	**mg/l**	1.5	<0.005	<0.005	<0.005
Cations and Metals					
Aluminium, Al	**mg/l**	0.3	<0.002	<0.002	<0.002
Antimony, Sb	**mg/l**	0.02	<0.001	<0.001	<0.001
Arsenic, As	**mg/l**	0.01	<0.006	<0.006	<0.006
Barium. Ba	**mg/l**	0.7	0.067	0.247	0.092
Boron, B	**mg/l**	2.4	<0.013	<0.013	<0.013
Cadmium, Cd	**mg/l**	0.003	<0.002	<0.002	<0.002
Calcium, Ca	**mg/l**	NS	14.7	16	21.1
Copper, Cu	**mg/l**	2	<0.002	<0.002	<0.002
Fluoride, F	**mg/l**	1.5	<0.263	<0.263	<0.263
Iron, Fe	**mg/l**	Chronic health: 2 Aesthetic: 0.3	<0.004	<0.004	<0.004

Parameter	Units	SANS 241-1:2015	BH1	BH4	Spring 3
Lead, Pb	**mg/l**	0.01	<0.004	<0.004	<0.004
Lithium, Li	**mg/l**	NS	0.076	0.06	0.007
Magnesium, Mg	**mg/l**	NS	2.1	1.53	8.09
Manganese, Mn	**mg/l**	Chronic health: 0.4 Aesthetic: 0.1	<0.001	<0.001	<0.001
Mercury, Hg	**mg/l**	0.006	<0.004	<0.004	<0.004
Nickel, Ni	**mg/l**	0.07	<0.002	<0.002	<0.002
Phosphate, PO4	**mg/l**	NS	<0.005	<0.005	<0.005
Potassium, K	**mg/l**	NS	2.35	1.76	2.25
Rubidium, Rb	**mg/l**	NS	0.002	0.002	<0.002
Silicon, Si	**mg/l**	NS	5.03	4.65	11.8
Sodium, Na	**mg/l**	200	68.1	77.3	17
Uranium, U	**mg/l**	0.03	<0.015	<0.015	<0.015
Vanadium, V	**mg/l**	NS	<0.001	<0.001	0.008
Zinc, Zn	**mg/l**	5	0.183	0.073	0.006

9.2.1 Piper Diagram

The piper diagram is presented in Figure 9.3. The water sample collected from Spring 3 represent recently recharged groundwater rich in calcium, magnesium and bicarbonate. The groundwater samples collected from BH1 and BH4 represent sodium bicarbonate and chloride waters in which sodium enrichment are noted. Based on the laboratory results, the groundwater samples represent unpolluted water.

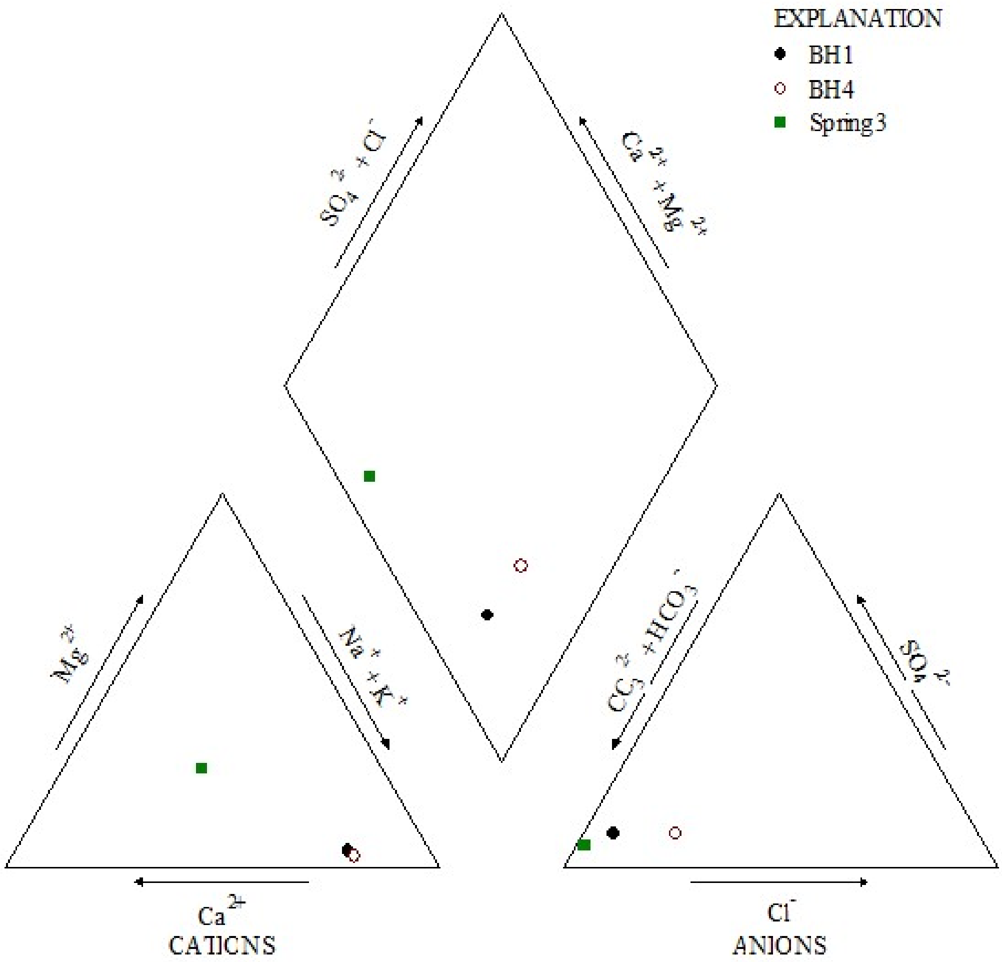


Figure 9.3: Piper Diagram - Groundwater

10 WATER BALANCE

The following section presents the linkages and water requirements for the proposed Solar PV plant.

10.1 Water Flow Diagram

A simple Process Flow Diagram (PFD) was drafted to present an insight into all linkages of water flows from source to various components of the proposed solar plant. The information obtained from the client was used to draft a final PFD (Figure 10.1). Water flow philosophy for the proposed Solar PV plant is as follows:

- Raw water is abstracted from the borehole and will be pumped into the water storage tanks;
- From the storage tanks, water is distributed to the plant office area for domestic and consumption purposes (potable water) and to the PV modules for washing purposes;
- Sewage on site will be contained in a septic tank and a soakaway system during operation. Port-a-potty style toilets will be used during construction and will be emptied by trucking on a planned regular basis; and
- The available surface water from rainfall in the office area should be captured with a Jojo tank to supplement domestic water.

Depending on the timing scheduling of cleaning of PV module, during the wet season, the plant is expected to use relatively small quantities of water as the rain falling will contribute to the cleaning of the panels.

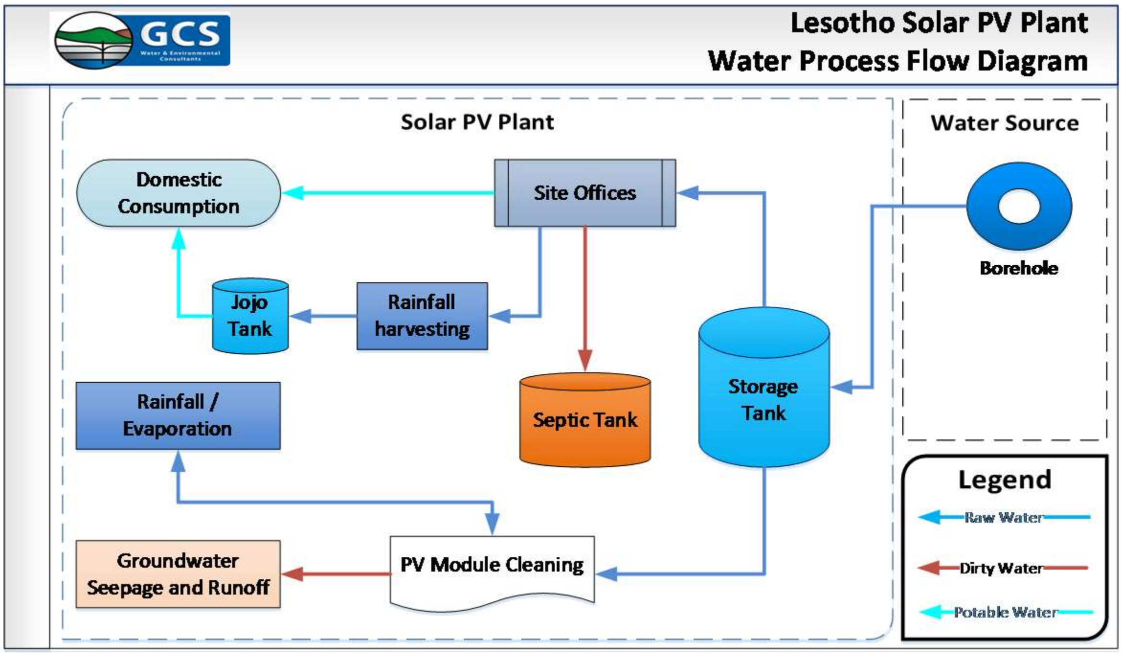


Figure 10.1: Water Process Flow Diagram for the proposed Solar PV plant

10.2 Water Balance

Water requirements and demands provided by the Client were estimated at 20m^3/year. It should be noted that the solar PV plants generally have low maintenance and servicing requirements, however, to maximise both energy yield and the plant's lifespan, proper maintenance is vital. Local site conditions and the season of the years determines the frequency of PV module cleaning. Cleaning of the PV modules can be done using two options: (i) high-pressured water spraying, (ii) the use of a dust broom or (iii) brush trolley. The latter two options are the cheapest options and do not require raw water for cleaning. Using the former option, (Internation Finance Corporation, 2015) estimates that 1.6L of water is required for cleaning a 1 m^2 PV module.

10.3 Baseline Groundwater Reserve Determination

A preliminary Groundwater Reserve Determination was compiled for sub-catchment containing the site. The Groundwater Reserve Determination takes into account the following parameters:

- Effective Recharge from rainfall and specific geological conditions;
- Basic Human needs for the site;
- Groundwater contribution to surface water (baseflow);
- Existing abstraction; and
- Surplus Reserve.

10.3.1 Quaternary Catchment

The site falls on the boundary of these two catchments, within D23F and C31F. Details are indicated in Table 10-1. Water balance studies indicate that 2.5% of annual rainfall recharges to the groundwater systems in the lowlands region. According to the GRDM the groundwater contribution to baseflow is 0.36 mm/a.

Table 10-1: Summarised Quaternary Catchment Information

Quaternary Catchment	Recharge (mm/a)	Rainfall (mm/a)	Baseflow (mm/a)
D23F	15.95	638	0.36

10.3.2 Sub-catchment Delineation

In order to delineate a sub-catchment for the site within the quaternary catchment ArcGIS is used (which provides a method to describe the physical characteristics of a surface). Using a digital elevation model as input, it is possible to delineate a drainage system and then quantify the characteristics of that system. The tools in the extension let you determine, for any location in a grid, the upslope area contributing to that point and the downslope path water would follow. This data is important during the numerical model boundary selection and impact assessment. The delineated sub-catchment is presented in Figure 5.5. The sub-catchment size is 2.1 km^2

10.3.3 Groundwater Balance

A preliminary groundwater balance was calculated for the sub-catchment to determine the surplus available for abstraction, as presented in Table 10-2.

Table 10-2: Preliminary Water Balance Calculation

Sub-catchment	Reserve Determination
Size	2.1 km^2 (2 063 821 m^2)
Groundwater Recharge	15.95 mm/a (0.001595 m/a) = 0.001595 x 2 063 821 m^2 = 32 917.94 m^3/a = 90.19 m^3/day
Basic Human Need	No groundwater users were identified within the sub-catchment
Baseflow	0.36 mm/a (0.00036 m/a) = 0.00036 x 2 063 821 m^2 = 742.98 m^3/a = 2.04 m^3/day
Total use	2.04 m^3/day
Surplus amount	88.15 m^3/day
Scale of abstraction	2.31 % of recharge

From the sub-catchment preliminary water balance calculation, the aquifer is unstressed.

11 GROUNDWATER AND SURFACE WATER IMPACT ASSESSMENT

11.1 Sensitivity Analysis

The purpose of the sensitivity analysis was to identify sensitive features relating to surface water within the proposed development area. Neighbouring non-perennial streams will flow very close to the Solar PV Project site and are demarcated as the sensitive area with respect to surface water resources (Figure 11.1).

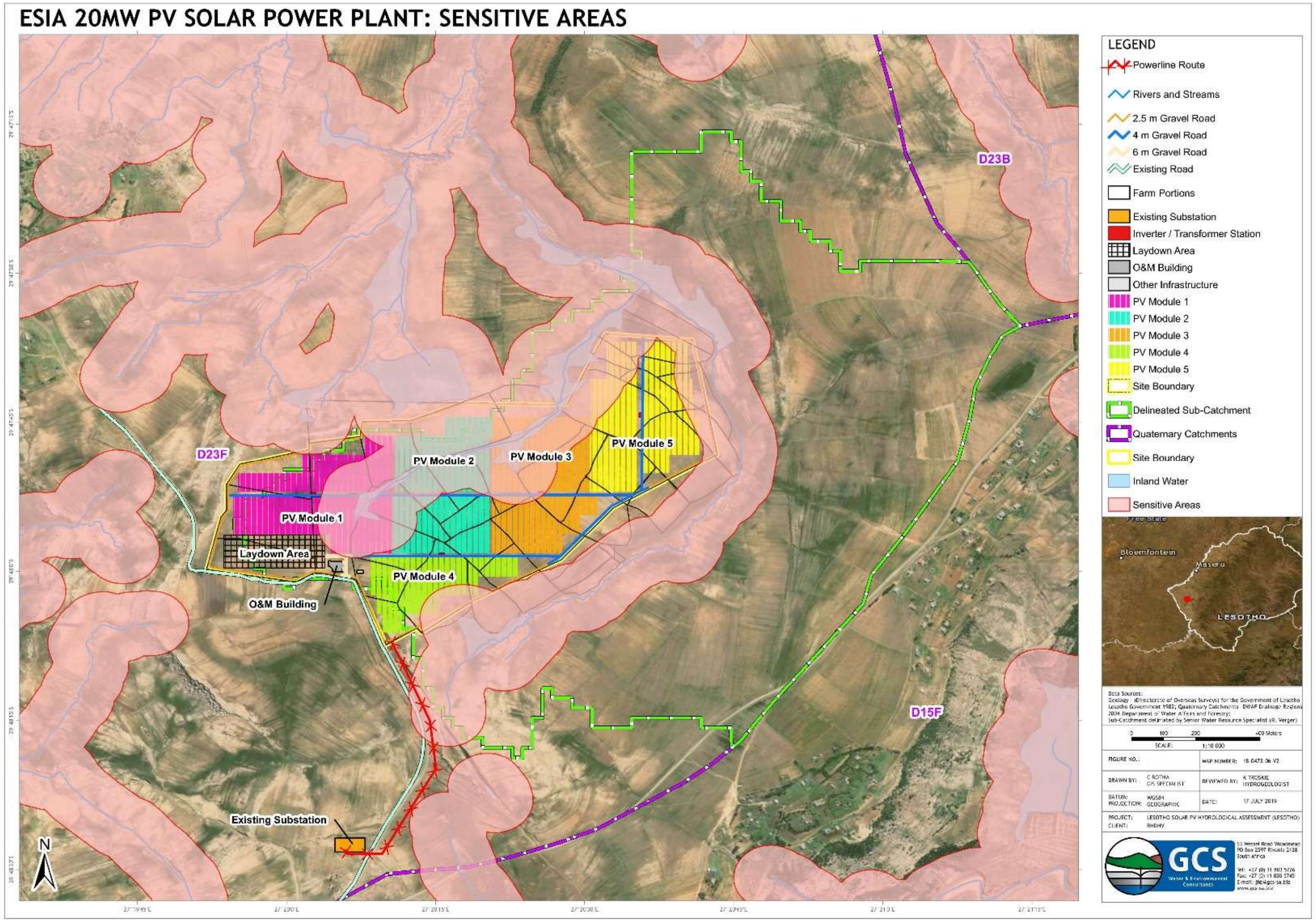


Figure 11.1: Sensitive areas presented at the at the 20MW Solar PV site

11.2 Surface and Groundwater Impact Assessment and Mitigation

The preliminary impact assessment was undertaken for the construction, operation and decommissioning phases of the proposed project. The following potential impacts or risks were identified.

11.2.1 Construction Phase

The following section describes the potential impacts associated with the construction phase of the proposed project:

Impact 1:

- Increased sedimentation.

Mitigation:

- Keep clearance only to designated footprint area.
- Correctly implement the stormwater management plan (Section 7) to prevent soil evacuation from pervious areas adjacent to established infrastructure.

Impact 2:

- Increased risk of flooding.

Mitigation:

- Stay outside the demarcated flood lines (Section 6) and 32m bufer of the neighbouring stream flows; and
- Correctly implement the stormwater management plan to prevent soil evacuation from pervious areas adjacent to established infrastructure; and

Impact 3:

- Water pollution from spills of vehicles and machinery.

Mitigation:

- The use of secondary containment where appropriate;
- Conduct quick clean-ups of any chemical spills; and
- Used oil disposal should be conducted by accredited vendors.
- Implement a water quality monitoring programme (Section 12.2.1);
- Accurate oil records must be kept (purchased, disposal, and recycled);
- Ensure clean up protocols are in place and followed

11.2.2 Operational Phase

The following section describes the potential impacts associated with the operational phase of the proposed project:

Impact 1:

- Increased sedimentation.

Mitigation:

- Keep clearance only to designated footprint area.
- Encourage vegetation growth on PV plant area;
- Correctly implement the stormwater management plan to prevent soil evacuation from pervious areas adjacent to established infrastructure (solar panels and buildings).

Impact 2:

- Water pollution from spills of vehicles and machinery as well as hazardous product stored on site.

Mitigation:

- Conduct quick clean-ups of any chemical spills; and
- Used oil disposal should be conducted by accredited vendors.
- Implement a water quality monitoring programme (Section 12.2)
- Accurate oil records must be kept (purchased, disposal, and recycled);
- Ensure clean up protocols are in place and followed.

Impact 3:

- Increased risk of flooding

Mitigation:

- Stay outside the demarcated flood lines of the neighbouring stream flows;
- Correctly implement the stormwater management plan to prevent soil evacuation from pervious areas adjacent to established infrastructure.

11.2.3 Decommissioning Phase

The following section describes the potential impacts associated with the decommissioning phase of the proposed project:

Impact 1:

- Increased sedimentation.

Mitigation:

- Re-vegetate the area where infrastructure (solar panels and buildings) is removed.

Impact 2:

- Water pollution from spills of vehicles and machinery and during decommissioning.

Mitigation:

- Conduct quick clean-ups of any chemical spills; and
- Used oil disposal should be conducted by accredited vendors;
- Accurate oil records must be kept (purchased, disposal, and recycled);
- Ensure clean up protocols are in place and followed.

11.2.4 Residual Impacts

Once the PV Solar Plant has ceased and all rehabilitation is completed, the landscape will be rehabilitated to its pre-development conditions. Very little or low residual visual impact and drainage lines are expected, due to the limited alteration of the terrain of the proposed development. The appearance of the land cover is also expected to show low differences from what it was prior to the energy generating operations. Implementation and management of post-closure rehabilitation measures will still be required.

11.2.5 Cumulative Impacts

The cumulative impact assessment considers this project within the context of other similar land uses, in the local and greater regional context. The cumulative impact is expected to be very low negative and should not reduce both the scenic value and water quality in downstream areas even after closure and rehabilitation. Based on the assumption that no contributing activities are located nearby, the cumulative impacts will thus be of very low significance.

The aforementioned impacts and the proposed mitigation measures during the construction, operational and decommissioning phases of the proposed Solar PV plant are summarised in Table 11-1 to Table 11-3, respectively. The overall environmental significance of the proposed project after its lifetime indicate that there will be relatively low negative impacts (Table 11-3). This is based on the assumption that the mitigation measures are adhered to during the construction and operation on the proposed Solar PV plant.

Table 11-1: Surface water impact assessment and mitigation plans during the construction of the proposed Solar PV plant

Construction Phase															
Potential Environmental Impact	Environmental Significance Before Mitigation						Recommended Measures	Environmental Significance After Mitigation						Action Plan
	E	D	I	P	Significance			E	D	I	P	Significance		
Increased sedimentation due to footprint clearance and vegetation removal	1	1	2	3	7	NEGATIVE MODERATE	Minimise the footprint clearance and vegetation removal as much as possible and designated foot print only.	1	1	1	3	6	NEGATIVE LOW	Adhere to the construction plan and recommended stormwater management plan measures.
Increased risk of flooding	1	3	2	2	8	NEGATIVE MODERATE	Construct the infrastructure out of the delineated flood lines (section 6). Establish infrastructure only on designated areas. Implement stormwater management plan to reduce soil erosion from pervious area.	1	2	1	1	5	NEGATIVE LOW	Construct the infrastructure out of the demarcated flood lines and correctly implement the stormwater management plan measures to reduce generated runoff from increasing the flood volume.
Water pollution from vehicles	1	1	3	2	7	NEGATIVE MODERATE	Use secondary containment, conduct quick clean-ups for any chemical spills, used oil disposal should be conducted by accredited vendors and implement a water quality monitoring programme.	1	1	2	2	6	NEGATIVE LOW	Implement a water quality monitoring programme.

Table 11-2: Surface water impact assessment and mitigation plans during the operation of the proposed Solar PV plant

Operation Phase														
Potential Environmental Impact	Environmental Significance Before Mitigation						Recommended Measures	Environmental Significance Before Mitigation						Action Plan
	E	D	I	P	Significance			E	D	I	P	Significance		
Increased Sedimentation	1	2	2	3	8	NEGATIVE MODERATE	Clear the designated footprint only, encourage vegetation growth and correctly implement the recommendation of the stormwater management plant to reduce soil erosion potential.	1	1	1	2	5	NEGATIVE LOW	Adhere to the recommended stormwater management plan measures.
Increased risk of flooding	1	3	2	1	7	NEGATIVE MODERATE	Construct the infrastructure out of the delineated flood lines (section 6). Establish infrastructure only on designated areas. Implement stormwater management plan to reduce soil erosion from pervious area.	1	2	1	1	5	NEGATIVE LOW	Construct the infrastructure out of the demarcated flood lines and correctly implement the stormwater management plan measures to reduce generated runoff from increasing the flood volume.

Operation Phase														
Potential Environmental Impact	Environmental Significance Before Mitigation						Recommended Measures	Environmental Significance Before Mitigation						Action Plan
	E	D	I	P	Significance			E	D	I	P	Significance		
Water pollution from vehicles and increased sedimentation	1	1	3	2	7	**NEGATIVE MODERATE**	Use secondary containment, conduct quick clean-ups for any chemical spills, used oil disposal should be conducted by accredited vendors and implement a water quality monitoring programme.	1	1	2	2	6	**NEGATIVE LOW**	Implement a water quality monitoring programme

Table 11-3: Surface water impact assessment and mitigation plans during the decommissioning of the proposed Solar PV plant

Decommissioning Phase														
Potential Environmental Impact	**Environmental Significance Before Mitigation**						**Recommended Measures**	**Environmental Significance Before Mitigation**						**Action Plan**
	E	**D**	**I**	**P**	**Significance**			**E**	**D**	**I**	**P**	**Significance**		
Increased Sedimentation	1	1	2	3	7	**NEGATIVE MODERATE**	Re-vegetate the area where infrastructure is removed.	1	1	1	2	5	**NEGATIVE LOW**	Plant natural vegetation to restore the state of land cover as means of improving soil stability.
Water pollution from spills of vehicle and machinery and increased sedimentation	1	1	3	3	8	**NEGATIVE MODERATE**	Conduct quick clean-ups for any chemical spills, used oil disposal should be conducted by accredited vendors.	1	1	1	2	5	**NEGATIVE LOW**	Implement safe waste management plans.

12 MANAGEMENT AND MONITORING MEASURES

12.1 Management Measures

In addition to the environmental impact measures presented and discussed in the previous sections, the following management plans should be implemented should be implemented during the construction, operation and decommissioning phases of the proposed Solar PV plant:

- *Erosion and Silt Management Plan*: prior to the commencement of site earthworks, it is essential that an erosion and silt management plan is in place and should be monitored and updated regularly as earthworks continue.
- *Infrastructure Location*: the design of the proposed infrastructure should adhere to and consider stormwater management and erosion control during the construction phase.
- *Pollution Clean-up and Storage*: any chemical substances which may accidentally spill and pollute surface water should be cleaned, removed and disposed of at a suitable facility where it must be prevented to be in contact with surface runoff. Accurate oil records must be kept (purchased, disposal, and recycled).
- *Vehicle Maintenance*: servicing of vehicles or plant equipment should be conducted within a bounded area which will enable the containment of potentially contaminated water.
- *Drainage Maintenance*: all drainage systems should be regularly monitored for possible silt build up and be cleaned to ensure the efficiency of the system.

12.2 Surface- and Groundwater Monitoring Programme

Baseline surface- and groundwater quality samples were collected (see Figure 8.1 and Figure 12.1) and will be used as the basis for comparison in the changes in water quality within close proximity to the Solar PV plant. In order to ensure compliance and enable the identification of any potential risks and impacts emanating from the proposed infrastructure and activities during the construction, operation, and decommissioning phases, the monitoring program is recommended:

Flow Volume Measurement: flow meters should be installed in the main water use components (domestic and PV cleaning) on a monthly basis. The data obtained from these instruments will be used to update an operational water balance of the proposed plant.

Pollutant Inspections: any chemical substances which may pollute surface water should be identified during weekly site inspections (construction phase) and the clean-up actions should be implemented accordingly.

- *Drainage Inspections*: all drainage systems should be inspected before the start of the wet season for a build-up of silt which may reduce the capacity of the stormwater system that may lead to structural failure which may result in excessive soil erosion.

- *Reporting*: spillage or pollutant inspection and abstraction volumes reports should be compiled on a monthly basis whereas water quality status report should be compiled on an annual basis for reporting to the relevant water authorities.

12.2.1 Surface Water Quality Monitoring

Routine (monthly during construction and bi-annual during operations) surface water quality monitoring should be undertaken to identify potential impacts on the baseline water quality receptors. The strategic points which will indicate any changes in the water quality in the project site are SW2 and SW3 (Figure 12.1). It must be ensured that any discharge into a water system is compliant with relevant water quality standards. Surface water quality sampling points should be conducted at the locations where baseline water samples were collected. Water samples must be collected and delivered directly into the accredited laboratory for the analyses of water quality variables similar to those analysed in section 9.1 and should at least include the general parameters, anions and hydrocarbons.

12.2.2 Groundwater Quality Monitoring

Groundwater monitoring is recommended at the site on an quarterly basis during construction and a annual basis during operation to ensure no detrimental impact is posed to the underlying aquifer due to the operation of the solar plant. Preliminary monitoring point coordinates are presented in Table 12-1. Samples should be analysed according to parameters listed in Table 9-2. In addition to the sample analyses in Table 9.2 , TPH (Total Petroleum Hydrocarbons) should be analysed for during construction (on a quarterly basis) and during the time period when heavy vehicles and machinery are used on site.

Table 12-1: Monitoring Point Details

BH ID	Coordinates		Frequency	Parameters to be analysed
	Latitude	Longitude		
BH1	-29.81133	27.33494	Annual	As per Table 9-2
BH4	-29.79551	27.35823		
Spring_3	-29.7969	27.34634		

12.3 Review and Update of Management Plan

It is recommended that management measures and water monitoring plan should be reviewed and updated periodically to ensure that the plant operations are not posing any risks to the environment as well as ensuring that a plant is still complying with relevant standards regularly.

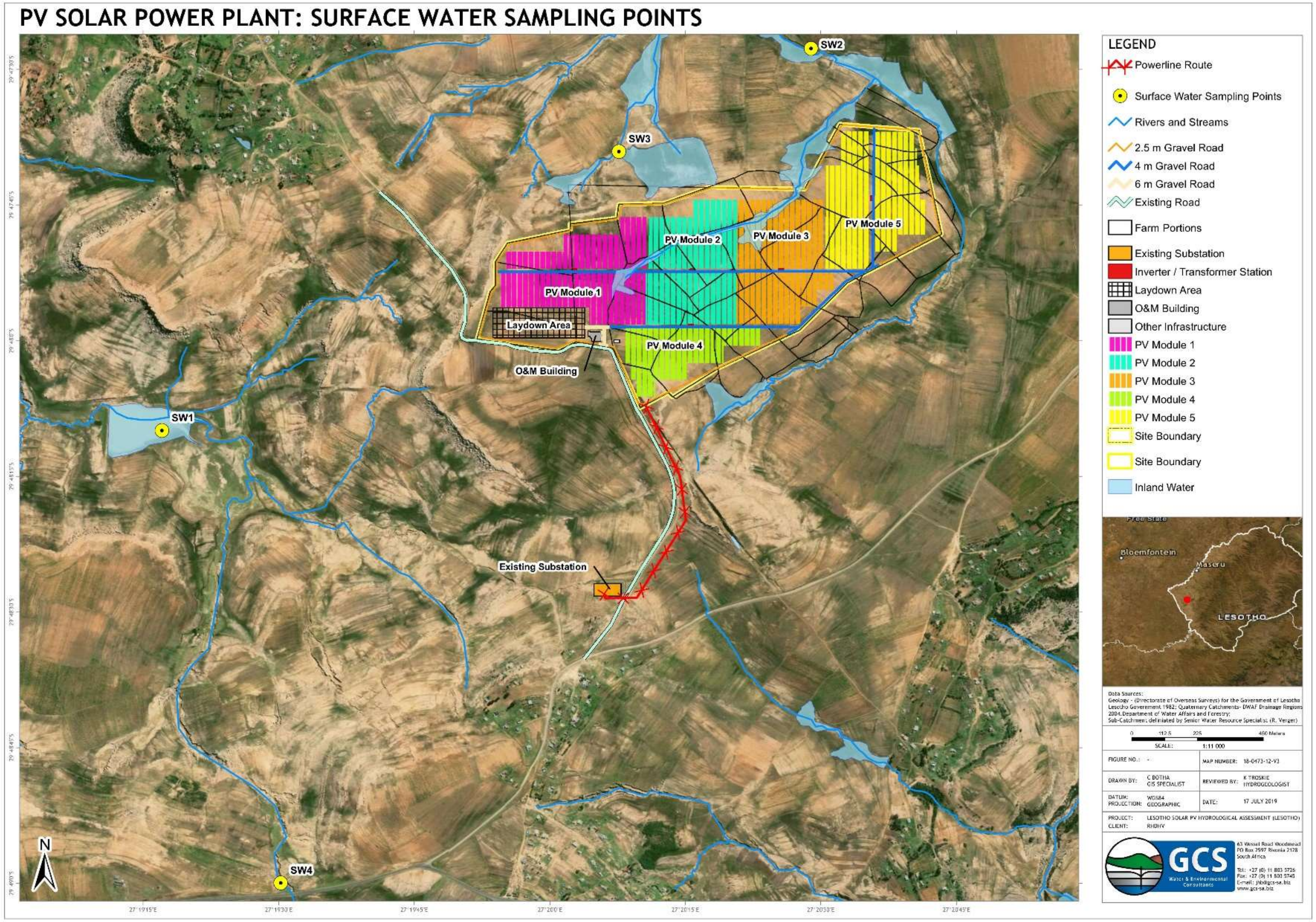


Figure 12.1: Surface water quality measurement points for the proposed PV solar plant

13 CONCLUSIONS

Conclusions derived from this study are summarised as follows:

Receiving Environment and Baseline Conditions:

- The climate of the proposed Solar PV plant is classified as Subtropical Highland which is characterised by warm wet summers and cold dry winters.
- Highest rainfall is experienced in January with the month of July being the driest. The MAP of the proposed Solar PV Plant is expected to be 700 mm and 1 525 mm accounts for MAE (Symons Pan).
- The MAR of the quaternary D23F is 70 mm which is approximately 10% of MAP. Runoff originates from the mountainous reaches at an altitude on 1 750 mamsl and flows north-easterly through a series of non-perennial drainage channels (from Catchment 1 and 2) into the perennial Tšana-Talana River.
- High intensity rainfall and poor vegetation cover in the area result in soil erosion;
- The site is underlain by fine and medium grained buff and red coloured sandstone, occasional coarse beds, buff and red mudstone and siltstone with occasional acidic beds of the Elliot Formation (Karoo Supergroup). The mudstone and sandstone succession are approximately 100 m thick with weathered surface clays deeply gullied;
- A younger intrusive dolerite dyke is mapped towards the centre of the site striking in a southeast to northwest direction. A second dolerite dyke is mapped towards the northern section of the site striking from East to West across the site. The presence of the dolerite dykes will, however, give rise to more enhanced aquifer conditions that can be targeted as a potential water supply to the PV Plant.

Flood Line Assessment:

- Peak flow values (m^3s^{-1}) used for flood determination and the conceptualisation of the stormwater management plan were derived from the Rational Method Alternative 3 and are summarised as follows:
  - Catchment 1: 9.65 (1:5-year), 19.04 (1:50-year) and 22.74 (1:100-year).
  - Catchment 2: 2.50 (1:5-year), 5 (1:50-year), and 6 (1:100-year).
- The simulated 1:100-year flood lines generally do not inundate the proposed infrastructure with the exception of a small proportion of PV Module 5 which is closer to the flood line. In general, however, the proposed infrastructure is not prone to flooding.

Stormwater Management Plan:

- The proposed SWMP comprises of natural drainage and energy dissipating structures that will divert stormwater to the river channels and wetland following the natural topography as much as possible.

- Taking into account the wetland delineation drains should not be extended into the wetland area and 32m flood buffer area.
- If flow velocities are high (>1m/s), energy dissipating structures should be put in place.

Surface- and Groundwater Quality

- The site is located within a rural area with no potential contamination sources up-gradient of the facility;
- Surface water samples were collected from SW1, SW2 and SW4;
- The surface water samples collected represent fresh water rich in calcium, magnesium and bicarbonate;
- No groundwater users were identified on the perimeter of the site;
- Groundwater samples were collected from hydrocensus boreholes, BH1 and BH4 as well as Spring 3;
- Groundwater quality results indicated compliance of all parameters with the SANS 241-1:2015 drinking water quality standards;
- The water sample collected from Spring 3 represent recently recharged groundwater rich in calcium, magnesium and bicarbonate. The groundwater samples collected from BH1 and BH4 represent sodium bicarbonate and chloride waters in which sodium enrichment are noted
- Based on the laboratory results, the groundwater samples represent unpolluted ambient water and is suitable for the intended use.

Water Balance:

- It is expected that raw water supply will be from the boreholes and will be stored in storage tanks where it will be distributed to the site office for domestic consumption and to the PV Modules for cleaning maintenance;
- Based on the groundwater reserve determination, groundwater can be used as a viable source of water supply to the site;
- Water requirements and demands provided by the Client were estimated at $20m^3$/year.

Sensitivity Analysis:

- Streams and stream banks passing next to the proposed Solar PV Plant through were demarcated as the sensitive area with respect to surface water resources as well as the wetland dineation undertaken by the Client;

- The presence of the dolerite dykes on site will give rise to enhanced aquifer conditions increase the susceptibility and vulnerability of any contaminants on site;

Impact Assessment:

- Increased sedimentation, a risk of flooding, and spillage from vehicles are the main identified potential environmental impacts during the construction, operational and decommission phases of the project.
- Mitigation plans of the identified impacts during the three phases include the (1) clearing of the designated infrastructure footprint, (2) construction of the infrastructure out of the delineated flood lines, (3) proposed implementation of the recommendations of the stormwater management plan, (4) cleaning of any chemical spills, (5) and implementation of a surface and groundwater quality monitoring programme, and (6) restoration of natural vegetation to enhance soil stability.
- If all the recommended mitigation measures are adhered to, the significance of the identified potential impacts to the environment is negative low.

Management and Monitoring Measures:

- Erosion and silt management plan should be in place before the commencement of earthwork and should regularly be updated during the construction phase to ensure that the proposed infrastructure adheres to the SWMP;
- Waste storage facility – which is isolated from surface water system is needed to contain any spillage and pollutions from the plant area. This includes all phases of the proposed infrastructure;
- There is a possibility of silt build-up on the stormwater drainage system and this will require regular monitoring and cleaning to ensure maximum efficiency and prevent system failure;
- Water inflow volumes should be recorded in all water use components of the Solar PV plant and these will inform water balance update;
- In order to ensure that potential surface- and groundwater risks are identified, routine water quality measurements are required and need to be reported on an annual basis. These measurements will be compared with the baseline measurements;
- Annual water abstractions, spillage on site should be recorded and reported to ensure that there is compliance relative to the relevant water authorities;
- The defined management and monitoring plans should regularly be reviewed and updated, periodically, to ensure compliance.

14 RECOMMENDATIONS

Recommendations derived from this study include the following:

- Natural drainage systems (natural grass lined) needs to be designed based on detailed topographical survey data and runoff between the solar panels should be directed to natural water ways and wetland in a manner that prevents soil erosion.
- It may be possible to further reduce runoff by promoting infiltration by using bunds and soakways. This will, however, depend on the final design of the PV modules and detailed topographical survey data.
- It is also recommended that stormwater should be routed through stone pitched drifts at road crossings.
- Outlets of the drainage channels should included energy dissipating structures at the wetland boundaries or 32m flood buffer.
- The solar PV plant authorities should ensure that the water volumes and consumption) (inflow and outflow) from different components of the plant are measured. This will help in improving future water balances should there be changes in the system;
- A detailed hydrogeological investigation would be required in order to determine sustainable yield from proposed water supply borehole as well as an update of the groundwater impact assessment;
- It recommended that all the identified impact mitigation measures be adhered to ensure that the infrastructure does not have a negative impact on the surrounding environment.

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APPENDIX A: CALCULATION OF PEAK FLOW FOR THE PROPOSED SOLAR PV PLANT

RATIONAL METHOD 3

Description of catchment	Catchment 1						
River detail	Seekoei River Tributary						
Calculated by	Sbongiseni Mazibuko			Date	31/10/2018		
Physical characteristics							
Size of catchment (A)	1.638	km^2		Rainfall region			
Longest watercourse (L)	1.91	km		**Area distribution factors**			
Average slope (S_{av})	0.020	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1.00	0.00	0	
Mean annual rainfall(MAR)	750	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Wetlands and pans (<3%)	10	0.03	0.30	**Lawns**			
Flat areas (3 - 10%)	80	0.08	6.40	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	10	0.16	1.60	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0	0.26	0.00	Heavy s,flat<2%	0	0.15	0
Total	100		8.30	Heavy s,steep>7%	0	0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	8	0.04	0.32	Houses	0	0.5	0
Permeable	16	0.08	1.28	Flats	0	0.7	0
Semi-permeable	68	0.16	10.88	**Industry**			
Impermeable	8	0.26	2.08	Light industry	0	0.6	0
Total	100		14.56	Heavy industry	0	0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre	0	0.8	0
Light bush & farm-lands	32	0.11	3.52	Suburban	0	0.65	0
Grasslands	64	0.21	13.44	Streets	0	0.75	0
No vegetation	4	0.28	1.12	Max flood		1	
Total	100		18.08	Total (C_2)	0		0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Grassland with a well-defined natural water course			
1.336 hours	0.497		hours				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.41	0.41	0.41	0.41	0.41	0.41	
Adjusted for dolomitic areas, C_{1D}	0.41	0.41	0.41	0.41	0.41	0.41	
Adj factor for initial saturation, F_t	0.75	0.80	0.85	0.90	0.95	1.00	
Adjusted run - off coefficient, C_{1T}	0.31	0.33	0.35	0.37	0.39	0.41	
Combined run - off coefficient, C_T	0.31	0.33	0.35	0.37	0.39	0.41	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	23.80	32.20	38.30	44.60	53.50	60.70	
Point Intensity (mm/h), P_{it}	47.86	64.76	77.02	89.69	107.59	122.07	
Area reduction factor (%),ARF_T	1.00	1.00	1.00	1.00	1.00	1.00	
Average intensity (mm/hour),I_T	47.86	64.76	77.02	89.69	107.59	122.07	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m^3/s)	6.69	9.65	12.20	15.04	19.04	22.74	

RATIONAL METHOD 3

Description of catchment	Catchment 2						
River detail	Seekoei River Tributary						
Calculated by	Sbongiseni Mazibuko				Date	31/10/2018	
Physical characteristics							
Size of catchment (A)	0.446	km^2		Rainfall region		0	
Longest watercourse (L)	1.1	km		**Area distribution factors**			
Average slope (S_{av})	0.0327	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	750	mm					
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Vleis and pans (<3%)	10	0.03	0.30	**Lawns**			
Flat areas (3 - 10%)	70	0.08	5.60	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	10	0.16	1.60	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	10	0.26	2.60	Heavy s,flat<2%	0	0.15	0
Total	100.00	0.53	10.10	Heavy s,steep>7%	0	0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	8	0.04	0.32	Houses	0	0.5	0
Permeable	16	0.08	1.28	Flats	0	0.6	0
Semi-permeable	68	0.16	10.88	Industry			
Impermeable	8	0.26	2.08	Light industry	0	0.6	0
Total	100		14.56	Heavy industry	0	0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre	0	0.8	0
Light bush & farm-lands	32	0.11	3.52	Suburban	0	0.65	0
Grasslands	64	0.21	13.44	Streets	0	0.75	0
No vegetation	4	0.28	1.12	Max flood		1	
Total	100		18.08	Total (C2)	0		0
Time of concentration (TC)							
Overland flow	Defined watercourse						
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$			Grassland with a well-defined natural water course			
0.915 hours	0.266		hours	3			
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.43	0.43	0.43	0.43	0.43	0.43	
Adjusted for dolomitic areas, C_{1D}	0.43	0.43	0.43	0.43	0.43	0.43	
Adj factor for initial saturation, F_t	0.75	0.80	0.85	0.90	0.95	1.00	
Adjusted run - off coefficient, C_{1T}	0.32	0.34	0.36	0.38	0.41	0.43	
Combined run - off coefficient, C_T	0.32	0.34	0.36	0.38	0.41	0.43	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	15.55	21.10	26.58	33.49	45.46	57.27	
Point Intensity (mm/h), P_{it}	58.38	79.24	99.83	125.78	170.72	215.09	
Area reduction factor (%),ARF_T	1.00	1.00	1.00	1.00	1.00	1.00	
Average intensity (mm/hour),I_T	58.38	79.24	99.83	125.78	170.72	215.09	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m^3/s)	2.32	3.36	4.49	5.99	8.59	11.39	

RATIONAL METHOD (Alternative 2)							
Description of catchment	Catchment 1						
River detail	Seekoei River Tributary						
Calculated by	Sbongiseni Mazibuko				Date	31/10/2018	
Physical characteristics							
Size of catchment (A)	1.64	km^2		Days of thunder per year (R)		66	days
Longest watercourse (L)	1.91	km		Weather service station		-	
Average slope (S_{av})	0.02	m/m		Weather service number		-	
Dolomite area (D%)	0.00	%		**Area distribution factors**			
Mean annual rainfall (MAP)	750.00	mm		Rural (α)	Urban (β)	Lakes (γ)	
2-year return period rainfall (M)	24	mm		1.00	0.00	0.00	
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Vleis and pans (<3%)	10	0.03	0.30	**Lawns**			
Flat areas (3 - 10%)	80	0.08	6.40	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	10	0.16	1.60	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0	0.26	0.00	Heavy s,flat<2%	0	0.15	0
Total	100		8.30	Heavy s,steep>7%	0	0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	8	0.04	0.32	Houses	0	0.5	0
Permeable	16	0.08	1.28	Flats	0	0.7	0
Semi-permeable	68	0.16	10.88	Industry			
Impermeable	8	0.26	2.08	Light industry	0	0.6	0
Total	100		14.56	Heavy industry	0	0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre	0	0.8	0
Light bush & farm-lands	32	0.11	3.52	Suburban	0	0.65	0
Grasslands	64	0.21	13.44	Streets	0	0.75	0
No vegetation	4	0.28	1.12	Max flood		1	
Total	100		18.08	Total (C2)	0		0
Time of concentration (TC)							
Overland flow	Defined watercourse			r=0.4 medium grass cover			
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87L^2}{1000S_{AV}}\right]^{0.385}$			Natural streams with two farm dams located on the river channel			
1.336	0.497		hours	0.497			
80.158	29.835		Minutes				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	0.409	0.409	0.409	0.409	0.409	0.409	
Adjusted for dolomitic areas, C_{1D}	0.409	0.409	0.409	0.409	0.409	0.409	
Adj factor for initial saturation, F_t	0.750	0.800	0.850	0.900	0.950	1.000	
Adjusted run - off coefficient, C_{1T}	0.307	0.328	0.348	0.368	0.389	0.409	
Combined run - off coefficient, C_T	0.307	0.328	0.348	0.368	0.389	0.409	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	8.98	15.15	19.82	24.49	30.66	35.33	
Point Intensity (mm/h), P_{it}	18.07	30.48	39.87	49.25	61.67	71.05	
Area reduction factor (%),ARF_T	1.00	1.00	1.00	1.00	1.00	1.00	
Average intensity (mm/hour),I_T	18.07	30.48	39.87	49.25	61.67	71.05	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m^3/s)	2.5	4.5	6.3	8.3	10.9	13.2	

RATIONAL METHOD (ALTERNATIVE 2)							
Description of catchment	Catchment 2						
River detail	Seekoei River Tributary						
Calculated by	Sbongiseni Mazibuko				Date	31/10/2018	
Physical characteristics							
Size of catchment (A)	0.45	km^2		Days of thunder per year (R)		66	days
Longest watercourse (L)	1.10	km		Weather service station		-	
Average slope (S_{av})	0.03	m/m		Weather service number		-	
Dolomite area (D%)	0.00	%		**Area distribution factors**			
Mean annual rainfall (MAP)	750.00	mm		Rural (α)	Urban (β)	Lakes (γ)	
2-year return period rainfall (M)	24.00	mm		1	0	0	
Rural				**URBAN**			
Surface slope	**%**	**Factor**	**C_s**	**Description**	**%**	**Factor**	**C2**
Vleis and pans (<3%)	10	0.03	0.30	**Lawns**			
Flat areas (3 - 10%)	80	0.08	6.40	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	10	0.16	1.60	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0	0.26	0.00	Heavy s,flat<2%	0	0.15	0
Total	100		8.30	Heavy s,steep>7%	0	0.3	0
Permeability	**%**	**Factor**	**C_p**	**Residential Areas**			
Very permeable	8	0.04	0.32	Houses	0	0.5	0
Permeable	16	0.08	1.28	Flats	0	0.6	0
Semi-permeable	68	0.16	10.88	Industry			
Impermeable	8	0.26	2.08	Light industry	0	0.6	0
Total	100		14.56	Heavy industry	0	0.7	0
Vegetation	**%**	**Factor**	**C_v**	**Business**			
Thick bush & plantation	0	0.04	0.00	City centre	0	0.8	0
Light bush & farm-lands	32	0.11	3.52	Suburban	0	0.65	0
Grasslands	64	0.21	13.44	Streets	0	0.75	0
No vegetation	4	0.28	1.12	Max flood		1	
Total	100		18.08	Total (C2)	0		0
Time of concentration (TC)							
Overland flow	Defined watercourse			r=0.4 medium grass cover			
$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$	$T_c = \left[\frac{0.87L^2}{1000S_{AV}}\right]^{0.385}$			Grassland with a well-defined natural water course			
0.915	0.266		hours	0.266			
54.884	15.977		Minutes				
Run-off coefficient							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Run-off coefficient, C_1	7.01	11.83	15.47	19.12	23.93	27.58	
Adjusted for dolomitic areas, C_{1D}	14.10	23.79	31.12	38.44	48.13	55.46	
Adj factor for initial saturation, F_t	1.00	1.00	1.00	1.00	1.00	1.00	
Adjusted run - off coefficient, C_{1T}	14.10	23.79	31.12	38.44	48.13	55.46	
Combined run - off coefficient, C_T	0.321	0.342	0.363	0.385	0.406	0.427	
Rainfall							
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Point rainfall (mm), P_T	7.01	11.83	15.47	19.12	23.93	27.58	
Point Intensity (mm/h), P_{it}	26.33	44.42	58.11	71.79	89.88	103.57	
Area reduction factor (%),ARF_T	1.00	1.00	1.00	1.00	1.00	1.00	
Average intensity (mm/hour),I_T	26.33	44.42	58.11	71.79	89.88	103.57	
Return Period (years)	**2**	**5**	**10**	**20**	**50**	**100**	**PMF**
Peak flow (m^3/s)	1.0	1.9	2.6	3.4	4.5	5.5	

SCS-SA METHOD						
Description of catchment	Catchment 1					
River detail	Seekoei River Tributary					
Calculated by	Sbongiseni Mazibuko			**Date**	31/10/2018	
Physical charateristics						
Size of catchment (A)	1.638	km^2	Time of concentration		0.497	hours
Longest watercourse (L)	1.91	km				
Average slope (S_{av})	0.019525802	m/m				
Lag estimate	2.152529622	hours				
Return period (years), T	2	5	10	20	50	100
Daily rainfall depth (one-day design rainfall, P) (mm)	69.40	94.00	111.80	130.10	156.20	177.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.993	0.991	0.989	0.987	0.985	0.983
Catchment desgin rainfall (PxARF/100) (mm)	68.923	93.126	110.564	128.428	153.793	174.105
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100	Claypan	Maseru and Saphula set	Clay	0.5	C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Veld (range) and pasture		S	Veld/pasture in fair condition		Moderate
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	79					
Final curve number	79.00					
Potenitial maximum soil water retention (S, mm)	67.52					
Initial losses (mm) (Ia=0.12*S)	6.75					
Return period (years), T	2	5	10	20	50	100
HRU	Design Stormflow Depth (Qi)					
1	30.152	49.185	63.947	79.714	102.941	122.086
2						
3						
4						
5						
Total stormflow depth (mm)	30.152	49.185	63.947	79.714	102.941	122.086
m3x10^6)	0.049	0.081	0.105	0.131	0.169	0.200
Peak discharge (qp, m³/s)	4.28	6.99	9.09	11.33	14.63	17.35

SCS-SA METHOD						
Description of catchment	Catchment 2					
River detail	Seekoei River Tributary					
Calculated by	Sbongiseni Mazibuko			**Date**	31/10/2018	
Physical charateristics						
Size of catchment (A)	0.446	km^2	Time of concentration		0.266	hours
Longest watercourse (L)	1.1	km				
Average slope (S_{av})	0.033	m/m				
Lag estimate	1.16927373	hours				
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
Daily rainfall depth (one-day design rainfall, P) (mm)	69.40	94.00	111.80	130.10	156.20	177.20
Area reduction facture (only applied for large catchments, ARF) (%)	0.997	0.997	0.996	0.995	0.994	0.994
Catchment desgin rainfall (PxARF/100) (mm)	69.224	93.678	111.344	129.483	155.312	176.057
HRU	**Area (At) (%)**	**Form**	**Series**	**Typical Texture Class**	**Depth**	**SCS-group**
1	100	Claypan	Maseru and Saphula set	Clay	0.5	C
HRU	**Land cover class**		**Cover Catefory (S/I/D)**	**Practice/ Treatment**		**Storm Flow Potenial**
1	Veld (range) and pasture		S	Veld/pasture in fair		Moderate
	HRU 1		HRU 2		HRU 3	
Initial Curve number (CN)	79					
Final curve number	79.01					
retention (S, mm)	67.52					
Initial losses (mm) (Ia=0.12*S)	8.10					
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**
HRUs	Design Stormflow Depth (Qi)					
1	29.17	48.09	62.80	78.53	101.72	120.85
2						
3						
4						
5						
Total stormflow depth (mm)	29.169	48.094	62.805	78.534	101.722	120.845
m3x10^6)	0.013	0.021	0.028	0.035	0.045	0.054
Peak discharge (qp, m^3/s)	2.08	3.43	4.48	5.60	7.26	8.62

APPENDIX B: LABORATORY CERTIFICATE

aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report

Client: Groundwater Consulting Services
Address: 63 Wessel Road, Woodmead, 2191
Report no: 59037
Project: GCS

Date of certificate: 02 November 2018
Date accepted: 25 October 2018
Date completed: 02 November 2018
Revision: 0

Lab no:				64777	64778	64779	64780	64781	64782
Date sampled:				23-Oct-2018	23-Oct-2018	23-Oct-2018	23-Oct-2018	23-Oct-2018	23-Oct-2018
Sample type:				Water	Water	Water	Water	Water	Water
Locality description:				BH1	BH4	SW1	SW2	SW4	Spring 3
	Analyses	**Unit**	**Method**						
A	pH @ 25°C	pH	ALM 20	8.63	8.59	7.68	8.42	8.47	8.51
A	Electrical conductivity (EC) @ 25°C	mS/m	ALM 20	29.1	34.7	36.2	25.9	29.9	21.2
A	Total dissolved solids (TDS)	mg/l	ALM 26	232	251	274	196	204	167
A	Total alkalinity	mg CaCO3/l	ALM 01	172	144	141	152	160	120
A	Chloride (Cl)	mg/l	ALM 02	8.38	25.1	13.0	8.35	5.52	1.39
A	Sulphate (SO_4)	mg/l	ALM 03	13.8	14.4	26.3	11.3	15.6	5.87
A	Nitrate (NO_3) as N	mg/l	ALM 06	0.965	3.07	0.229	0.313	<0.194	1.39
A	Nitrite (NO_2) as N	mg/l	ALM 07	0.024	0.025	0.012	0.044	0.025	0.022
A	Ammonium (NH_4) as N	mg/l	ALM 05	<0.008	0.011	0.577	0.339	0.058	<0.008
N	Ammonia (NH_3) as N	mg/l	ALM 26	<0.005	<0.005	0.010	0.027	0.006	<0.005
N	Total phosphorus	mg/l	ALM 12	0.333	0.167	23.0	2.73	2.93	0.167
A	Orthophosphate (PO_4) as P	mg/l	ALM 04	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
A	Fluoride (F)	mg/l	ALM 08	<0.263	<0.263	0.436	0.429	0.383	<0.263
A	Calcium (Ca)	mg/l	ALM 30	14.7	16.0	17.0	19.9	33.0	21.1
A	Magnesium (Mg)	mg/l	ALM 30	2.10	1.53	7.51	8.48	9.04	8.09
A	Sodium (Na)	mg/l	ALM 30	68.1	77.3	11.5	26.6	26.3	17.0
A	Potassium (K)	mg/l	ALM 30	2.35	1.76	7.49	4.43	3.53	2.25
A	Aluminium (Al)	mg/l	ALM 31	<0.002	<0.002	13.0	2.41	<0.002	<0.002
A	Iron (Fe)	mg/l	ALM 31	<0.004	<0.004	7.13	1.76	<0.004	<0.004
A	Manganese (Mn)	mg/l	ALM 31	<0.001	<0.001	0.607	<0.001	<0.001	<0.001
A	Copper (Cu)	mg/l	ALM 31	<0.002	<0.002	0.003	<0.002	<0.002	<0.002
A	Nickel (Ni)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Zinc (Zn)	mg/l	ALM 31	0.183	0.073	0.015	<0.002	<0.002	0.006
A	Cobalt (Co)	mg/l	ALM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Cadmium (Cd)	mg/l	ALM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Lead (Pb)	mg/l	ALM 31	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
A	Total hardness	mg CaCO3/l	ALM 26	45	46	73	85	120	86
N	Dissolved oxygen (DO)	mg/l	ALM 28	4.45	4.29	1.23	3.47	4.35	4.30
A	Arsenic (As)	mg/l	ALM 34	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report ; The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.

M. Swanepoel
Technical Signatory

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aquatico Laboratories (Pty). Ltd.

ilac-MRA sanas Testing Laboratory T0685

Test Report

Client: Groundwater Consulting Services
Address: 63 Wessel Road, Woodmead, 2191
Report no: 59037
Project: GCS

Date of certificate: 02 November 2018
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Sample type:				Water	Water	Water	Water	Water	Water
Locality description:				BH1	BH4	SW1	SW2	SW4	Spring 3
	Analyses	**Unit**	**Method**						
N	Mercury (Hg)	mg/l	ALM 35	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
A	Silicon (Si)	mg/l	ALM 33	5.03	4.65	37.8	8.15	4.43	11.8
N	Silver (Ag)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
A	Boron (B)	mg/l	ALM 33	<0.013	<0.013	<0.013	<0.013	<0.013	<0.013
A	Barium (Ba)	mg/l	ALM 33	0.067	0.247	0.212	0.132	0.058	0.092
A	Beryllium (Be)	mg/l	ALM 33	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
N	Bismuth (Bi)	mg/l	ALM 32	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
N	Gallium (Ga)	mg/l	ALM 32	<0.001	<0.001	0.027	0.005	<0.001	<0.001
N	Lithium (Li)	mg/l	ALM 32	0.076	0.060	0.008	0.006	<0.001	0.007
A	Molybdenum (Mo)	mg/l	ALM 33	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
N	Rubidium (Rb)	mg/l	ALM 32	0.002	0.002	0.042	0.008	<0.002	<0.002
N	Tellurium (Te)	mg/l	ALM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Thallium (Tl)	mg/l	ALM 32	<0.037	<0.037	<0.037	<0.037	<0.037	<0.037
A	Dissolved Uranium (U)	mg/l	ALM 37	<0.015	<0.015	<0.015	<0.015	<0.015	<0.015
A	Vanadium (V)	mg/l	ALM 33	<0.001	<0.001	0.020	0.006	<0.001	0.008
A	Bicarbonate alkalinity	mg CaCO3/l	ALM 26	165	139	141	148	156	116
A	Carbonate alkalinity	mg CaCO3/l	ALM 26	6.63	5.10	0.638	3.63	4.35	3.54
N	Antimony (Sb)	mg/l	ALM 36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Tin (Sn)	mg/l	ALM 36	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Titanium (Ti)	mg/l	ALM 36	<0.001	<0.001	0.116	0.014	<0.001	<0.001
N	Temperature	°C	ALM 20	17.0	17.0	17.0	17.0	17.0	17.0
N	Acidity	mg CaCO3/l	ALM 60	<0.001	115	103	92.2	88.0	<0.001

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