Geotechnical Desktop Study Report

Vanderkloof Solar PV and BESS Cluster, Free State

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Prepared for: Vanderkloof Solar (Pty) Ltd.

10 February 2025
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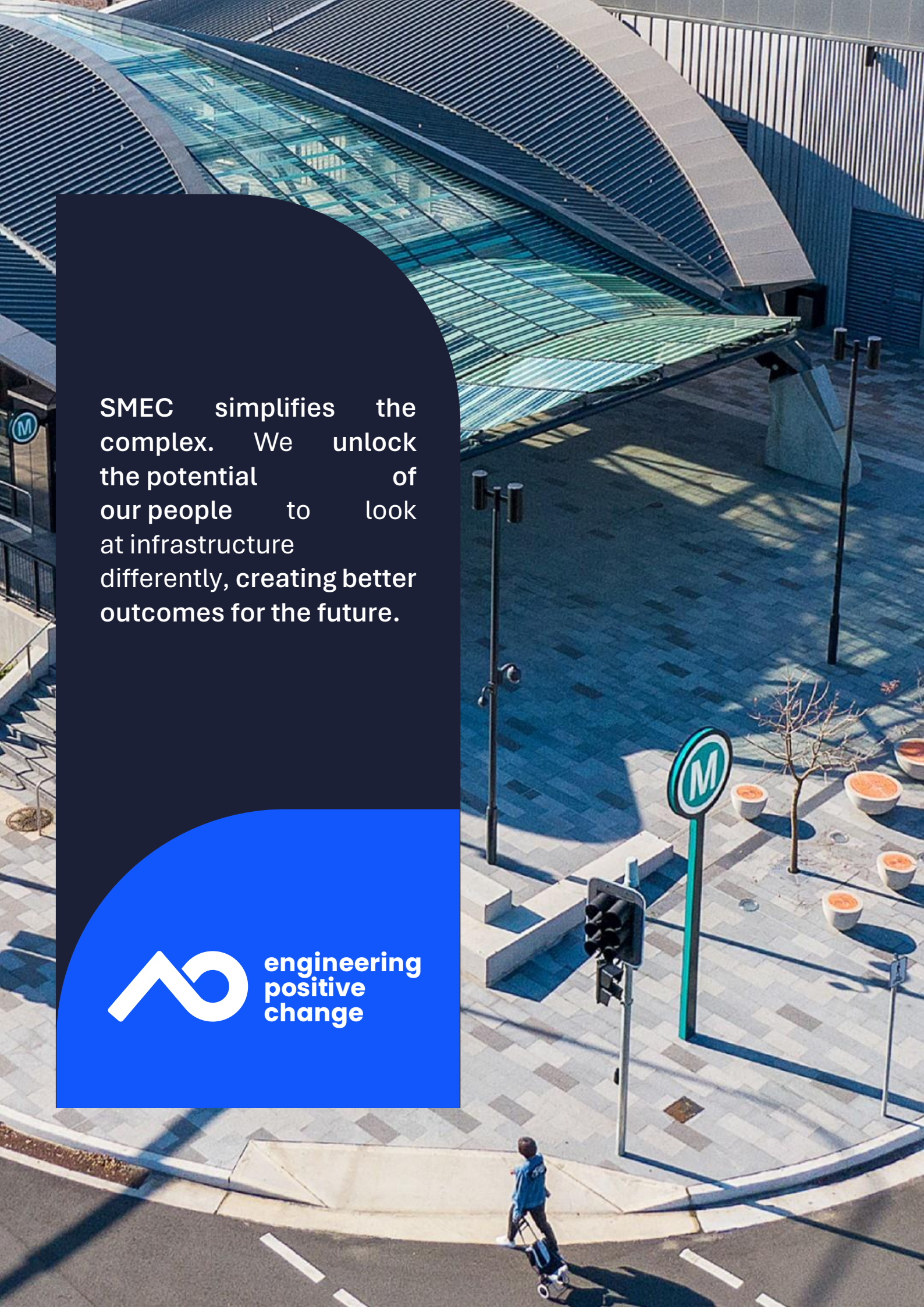

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1 Introduction

1.1 Background and Project Description

Vanderkloof Solar (Pty) Ltd is proposing the construction of a solar photovoltaic (PV) and Battery Energy Storage System (BESS) facilities (collectively known as Vanderkloof PV and BESS) located on the Portion 1 of Farm 113, Remainder of Farm 634, Remainder of Farm 39, Remainder of Farm 253, Remainder of Farm 1132, Portion 1 of Farm 1132 and Remainder of Farm 654 in the Letsemeng Local Municipality in the Xhariep District of the Free State Province.

The development is set to produce 2000 MW of energy, with the site outline covering a surface area of approximately 7478 ha.

1.2 Terms of Reference

SMEC South Africa (Pty) Ltd. ("SMEC") was appointed on 23 January 2025 by Merchant Energy (Pty) Ltd. to carry out a geotechnical desktop study for the proposed Vanderkloof PV and BESS facility in the Free State Province. The study is required to highlight any geological and geotechnical risks that may occur on site.

1.3 Objectives and Methodology

This desktop study aims to provide high-level geological and geotechnical information for the Vanderkloof PV and BESS site so that the Client can provide stakeholders with baseline geological and geotechnical information for planning purposes. The tasks required to fulfil this objective are as follows:

- Identify and review existing geological and geotechnical information relevant to the project area;
- Review site topography and climate and their influence on rock decomposition and subsequent soil formation;
- Review geohydrological information at a desktop level (viz. groundwater levels, flow direction, etc.);
- Assess seismic data to determine the seismic hazard and earthquake-prone zones in the region;
- Provide a risk assessment related to geological and geotechnical factors;
- Provide insight into the perceived geotechnical conditions of the site (viz. foreseeable soil formations, depth, and quality of underlying rock masses);
- Comment on the geotechnical feasibility of the proposed development; and
- Indicate the anticipated timeframes to conduct geotechnical investigations.

The following sources were consulted:

- 2924 Koffiefontein, 1: 250 000 Geological Series;
- 2924 Bloemfontein, 1:500 000 Hydrogeological Map Series;
- Elevation Model (DEM)-sourced elevation data;
- National Groundwater Archive (NGA); and

- SMEC's geotechnical database of projects conducted near the project area and within similar geotechnical and geological zonation/ sequences.

1.4 Codes of Practices and Standards

SMEC used the following standard codes of practice and guidelines in performing this study:

- Basis of structural design and actions for buildings and industrial buildings. Part 5: Basis for geotechnical design and actions. SANS 10160-5 (2010).
- Site Investigation Code of Practice, 1st Edition, South African Institute of Civil Engineering – Geotechnical Division, January 2010.
- Brink, A. B., and Bruin, R. M. H. (1990). Guidelines for Soil and Rock Logging in South Africa. 2nd Impression 2002. SAICE, SAIEG and AEGSA: South Africa.

1.5 Limitations of Assessment

The services performed by SMEC were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical profession practising under similar conditions for the requirements of a geotechnical desktop study (SAICE, 2010).

This geotechnical desktop study report is limited to the solar PV and BESS site and the access road. It is based on data obtained from a limited number of sources, including geological records, topographic maps, aerial imagery and geotechnical and geological literature available for the region. The nature of geotechnical engineering is such that variations in soil and rock conditions may occur even where sites seem to be consistent. Variations in what is reported here will become evident during the geotechnical investigations and construction.

On a conceptual basis, the current project phase may be considered a Category 1 geotechnical project (SANS 10160-5, 2010), requiring desktop study equivalent information to determine its feasibility.

However, once the project progresses to the next stages, it will require more detailed geotechnical input. Thus, to lower the probability of failure of the final designed structures and avoid over-design, a detailed geotechnical investigation must be considered mandatory as the project approaches detailed design status. Thus, this report will culminate with recommendations for further geotechnical investigations that will provide the engineer with the necessary parameters for further design stages.

It must be noted that any founding solutions(s) provided in this report are conceptual and that this report does not present a design for the proposed foundation support solution(s). Referral to a design solution is conceptual, and the design process, as per the latest version of SANS 10160 in general and specifically SANS 10160-5, must be undertaken under a separate appointment.

2 Site Dictates

2.1 Site Location

The site is located approximately 3.4 km south of Luckhoff Town and 19 km north of Vanderkloof Town. It can be accessed via the smaller roads joining from the R48 (Figure 1-1). The site is locally bounded by southward flowing tributaries of the Orange River.

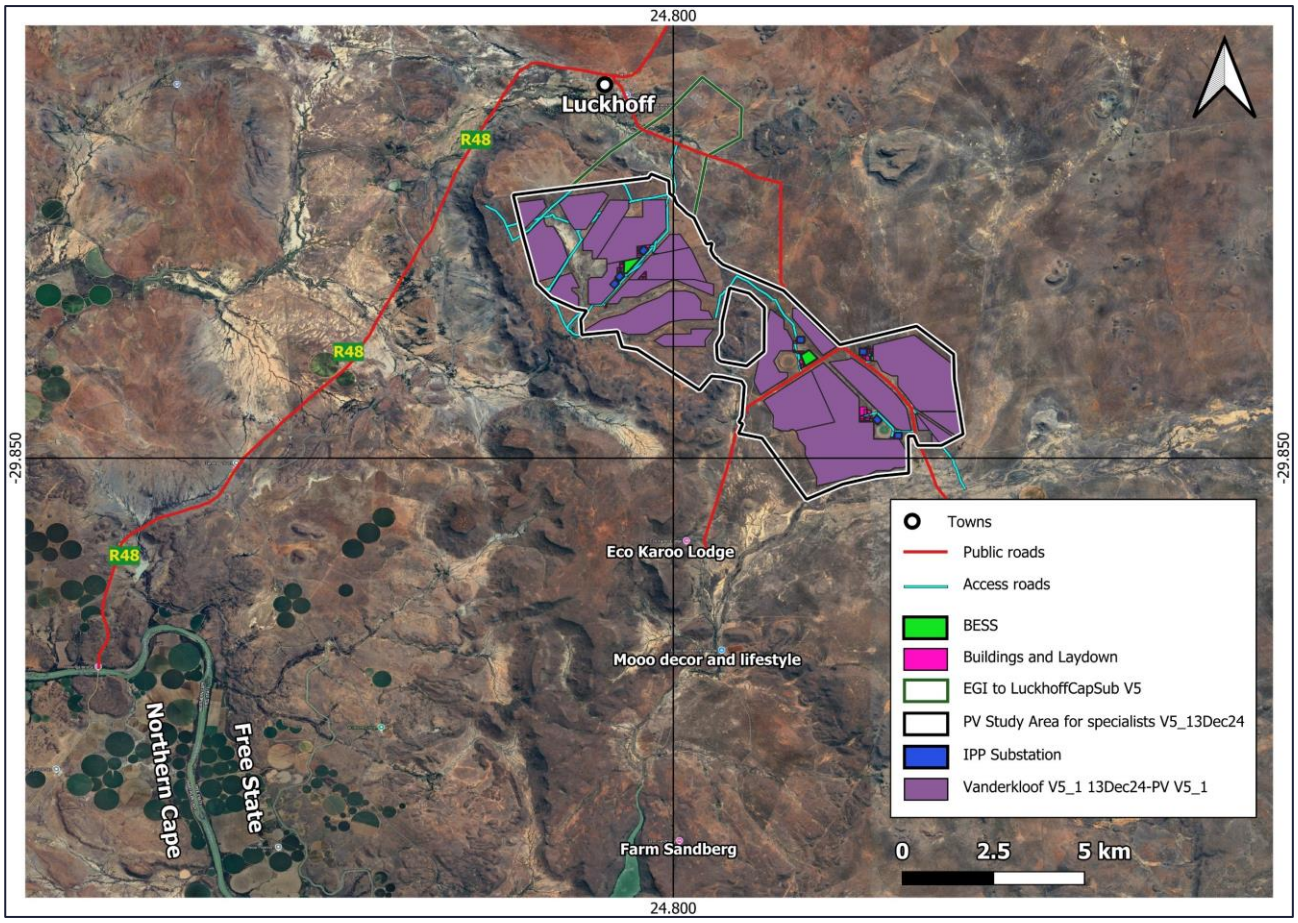

Figure 2-1: Site Location

2.2 Climate

This region experiences semi-arid climate with seasonal rainfall. Climatic data (World Weather Online, 2025) indicates that the mean annual temperature in this region is 18.1ºC. The average maximum daily temperatures vary from 31.7ºC in January to 17ºC in June-July. Corresponding minimum temperatures for these months are 17.9ºC and 3.2ºC, respectively. The mean annual precipitation is approximately 425 mm, falling mainly during summer. Precipitation is the lowest in July, with an average of 9 mm. The greatest amount of precipitation occurs in January, with an average of 67 mm. The average monthly temperature and rainfall distribution are illustrated in Figure 2-2.

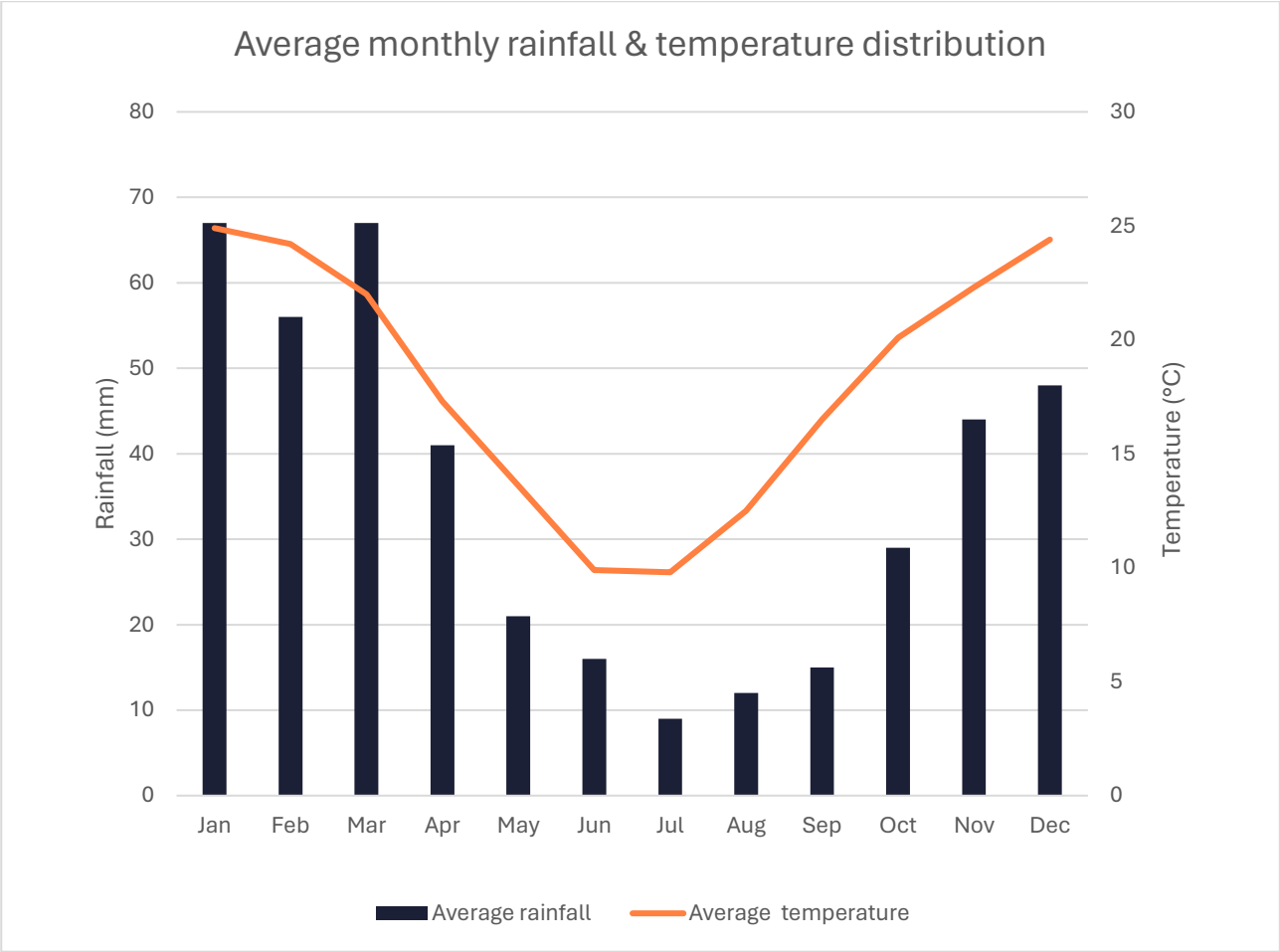

Figure 2-2: Summary of Climatic Data in the Luckhoff Region (after World Weather Online, 2025)

The climate is a pivotal factor for geotechnical considerations as it determines the mode and rate of rock mass weathering and, thus, the formation of soils. Weinert (1980) developed the N-Value to differentiate between regions of similar weathering characteristics. The N-value for this region is more than 5, indicating that although chemical decomposition occurs, disintegration is the dominant mode of weathering.

2.1 Topography, Drainage and Vegetation

The site generally gently slopes to the west, with the western part of the site on a higher elevation and the eastern part of the site on a lower elevation. The minimum and maximum elevation points above mean sea level on the western side are 1280 m and 1320 m, with 1240 m and 1280 m on the eastern cluster, respectively, with a 5 m margin of error (Figure 2-3).

The main drainage system is the Orange river bounding the site about 2 km to the west. There are also drainage lines noted in the northern port of the site.

According to 1:1 000 000 SANBI vegetation map (2018), the study area is regionally characterised by the Nama Karoo vegetation which is dominated by drought resistant shrubs, with scattered grasses and occasional succulents.

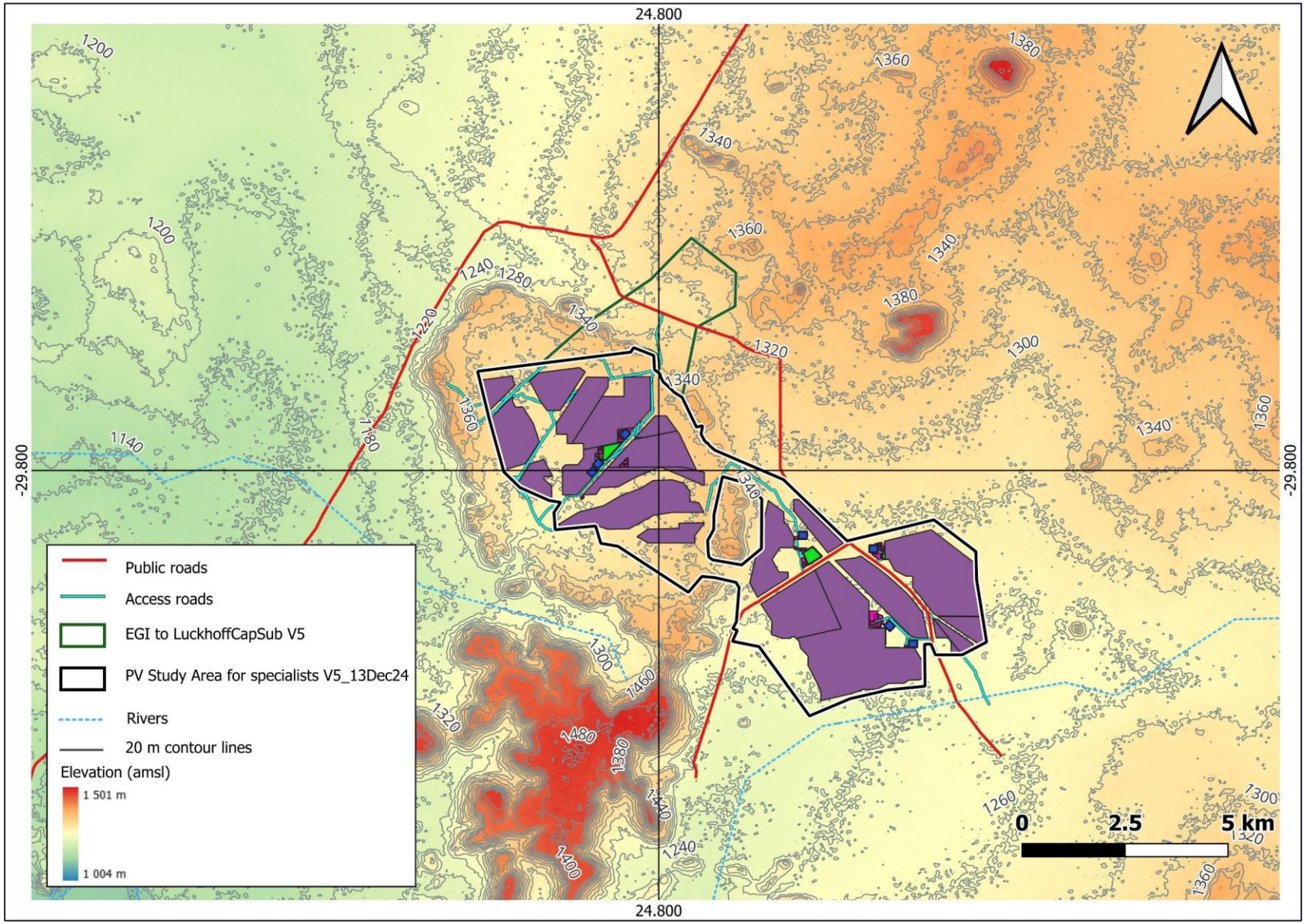

Figure 2-3: Topography and Drainage of the Study Area

2.2 Regional Geology

A review of 2924 Koffiefontein, 1:250 000 Geological Series indicates that the western portion of the PV cluster, situated on a ridge, is underlain by Post-Karoo dolerite intruding into shale, sandstone and siltstone of the Tierberg Formation, Karoo Supergroup. The eastern portion of the cluster lies on Tierberg Formation, regionally covered by the Quaternary calcrete deposits, and alluvium along the drainage lines and low-lying areas.

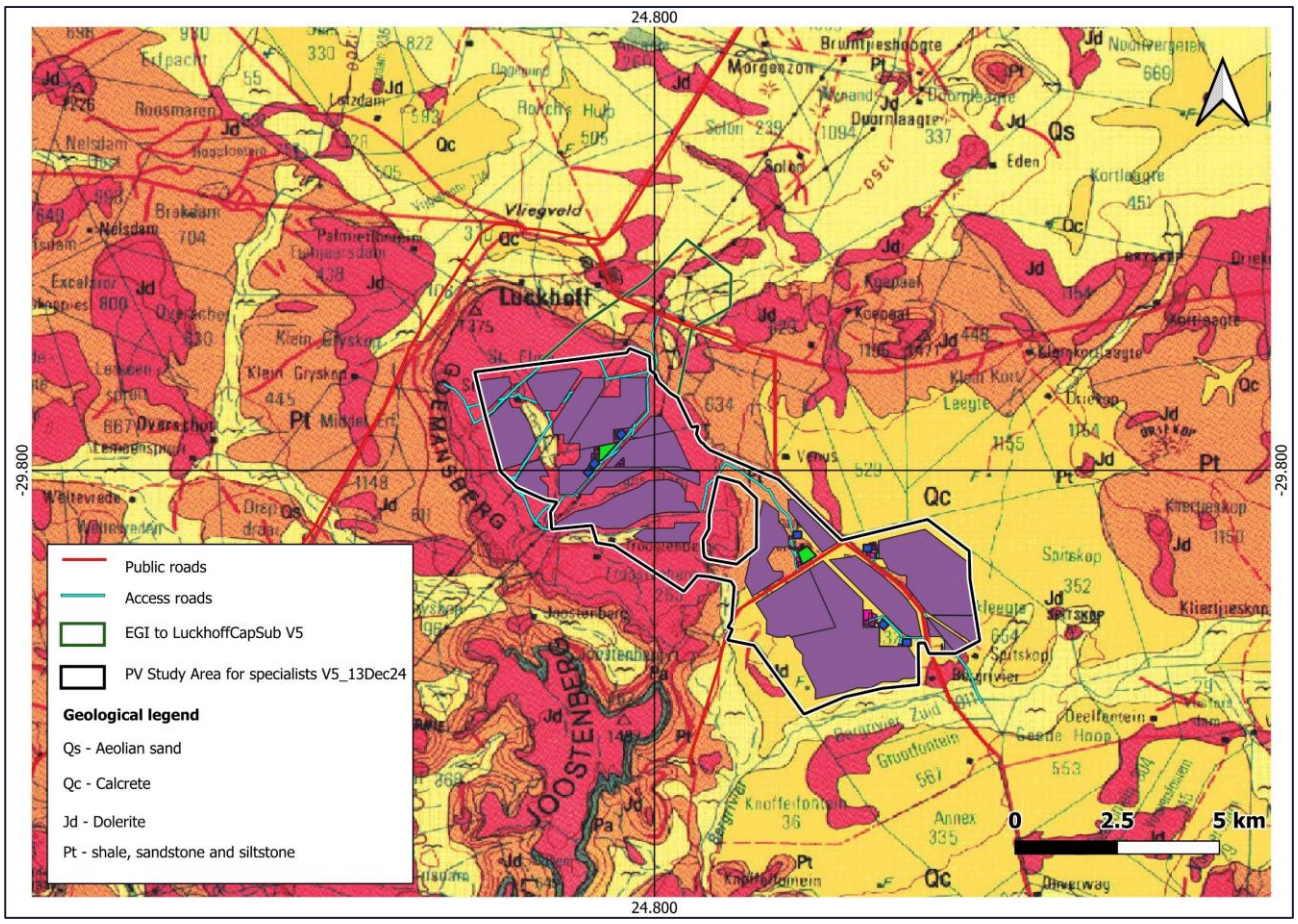

Figure 2-4: Abstract of 2924 Koffiefontein, 1:250 000 Geological Map showing lithology across and surrounding the site (Council for Geoscience, 1992).

2.3 Regional Hydrogeology

The groundwater environment characterising the site comprises fractured aquifers (b3) associated with the Karoo strata and the intruding dolerites (Figure 2-5). The borehole yielding potential within the intergranular and fractured aquifers ranges between 0.2 L/s and 0.5 L/s. Higher yields in fractured aquifers are generally limited to geological structures which act as groundwater conduits within these aquifer types.

The depth of groundwater obtained from the existing registered borehole database (National Groundwater Archive) in the vicinity of the study area range between 3.0 m and 10.0 m below ground level.

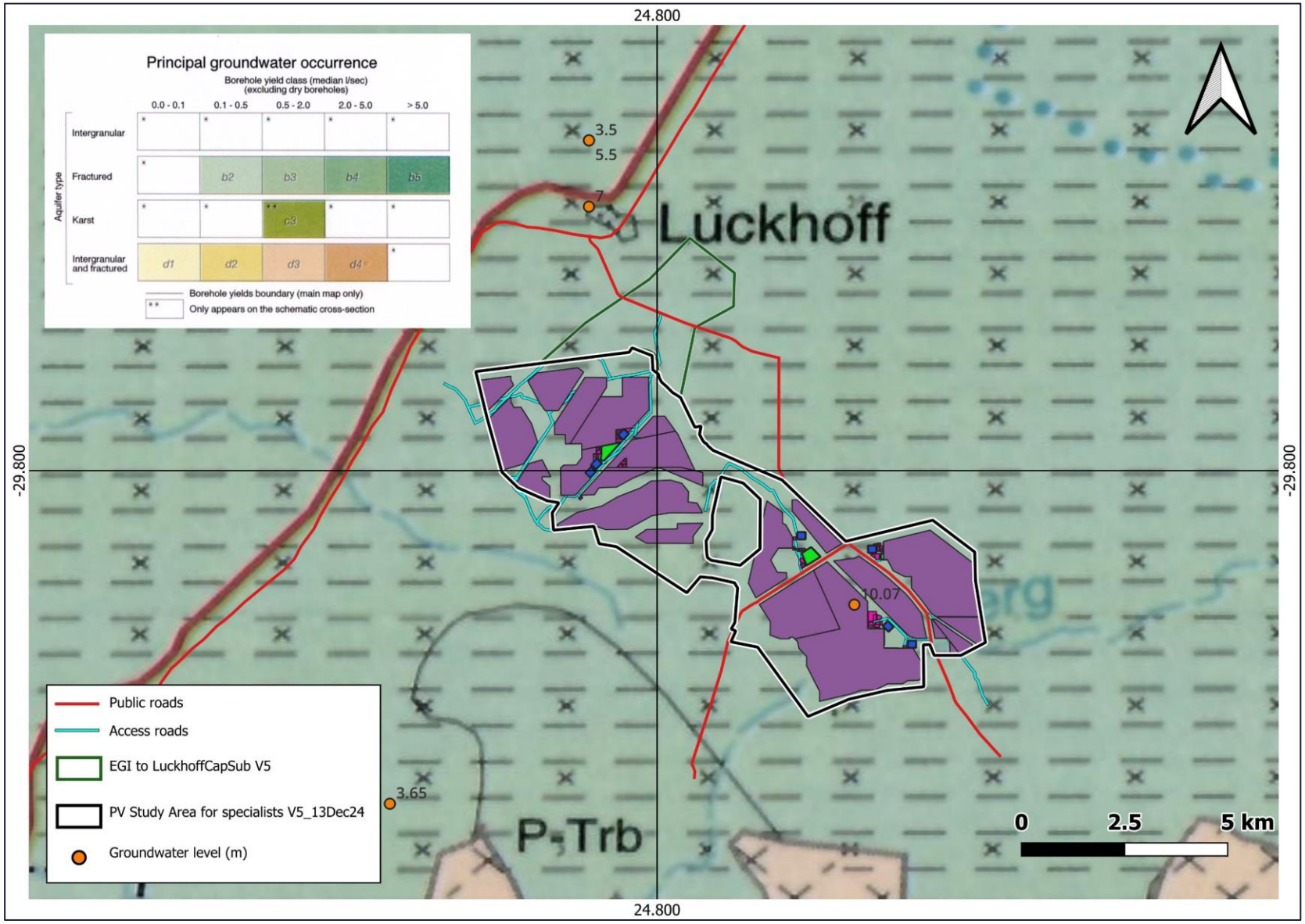

Figure 2-5: Abstract of 2924 Bloemfontein, 1:500 000 Hydrogeological Map Series Showing Groundwater Aquifers Characterising the Study Area

2.4 Seismicity

The seismic activity in and around the site was assessed based on the published seismic hazard map of South Africa (Figure 2-6). Based on this map, the Peak Ground Acceleration (PGA) at site is around 0.16 g with a 10% probability of exceedance in a 50-year period.

The South African loading code SANS 10160 (Part 4 Seismic Actions for Buildings) requires “ordinary buildings” to be designed for a seismic or mining-induced seismic activity where PGA value exceeds 0.1 g.

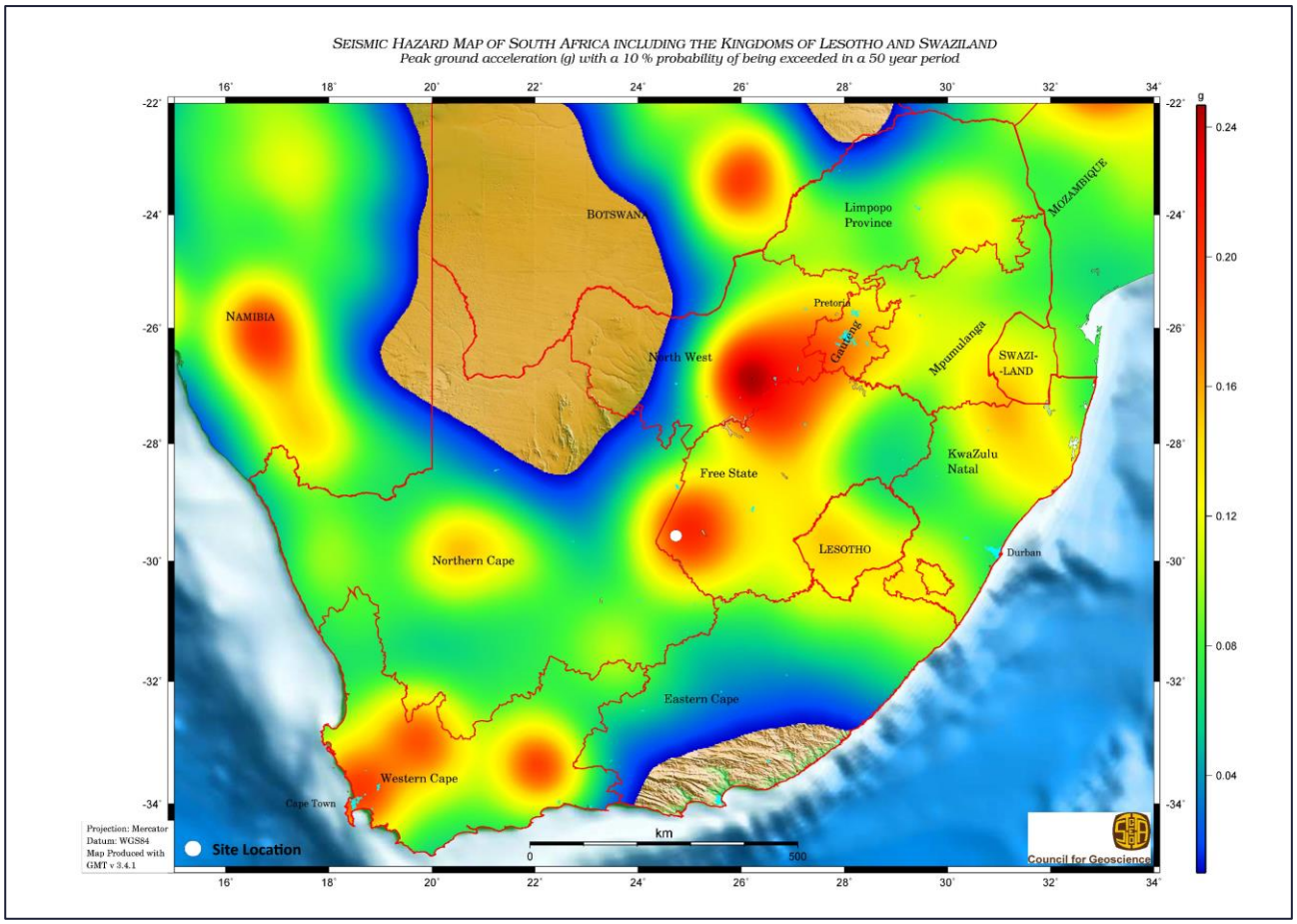

Figure 2-6: Seismic Hazards Map of South Africa (Council for Geoscience, 2003).

3 Previous Geotechnical Studies

SMEC report database was consulted to review geotechnical work that was previously undertaken near the site. A geotechnical investigation was conducted by SMEC in 2018 about 13 km west of the study area within the Tierberg Formation lithologies, intruded by dolerite sills (Report no. 17EP30/10/2018/04/2760).

The investigation was conducted for the development of a photovoltaic (PV) solar plant. It comprised the mechanical excavation of 82 no. trial pits, with Dynamic Probe Light (DPL) tests within selected pits, sampling for laboratory tests and soil Electrical Resistivity measurements at four locations.

The results indicated mainly 2 no. profiles, that is, soil underlying shallow bedrock and deeper soils. The shallow rock profile encountered refusal on medium hard and hard rock dolerite generally occurred between 0.5m and 1.0m. While the relatively deeper soil could extend to about 2 m below surface.

No groundwater was encountered within the trial pits.

In terms of material properties and usage, the sandy materials classified as SM and SC Foundation indicator test results indicated the following:

- Dolerite gravelly sand classifies as SM and SC (silty sand, sand-silt mixtures) according to USCS soil classification, with low potential for expansion. Where cohesive soils were encountered and tested, these classified as CL and to a lesser extent as ML and indicated medium potential for expansion.

Direct shear test results indicated that the transported sand has friction angles between 32° and 37° and cohesion ranging between 0 kPa and 13.1 kPa.

Point load tests on fractured shale between the depths of 1.4 m and 2.5 m indicated the equivalent UCS values between 10 MPa and 70 MPa.

4 Geotechnical Evaluation

4.1 Conceptual Geological Profile

Based on data gathered from the desktop review of regional geology and historical data, it is foreseeable that the Vanderkloof solar PV and BESS site will primarily be underlain by dolerite and Tierberg Formation lithologies, overlain by its residual profiles and transported soil layers.

The three typical ground profiles envisioned at the site are:

- Profile A: Transported soils, underlain by residual dolerite / shale.
- Profile B: Transported soils, underlain by residual dolerite / shale and dolerite/shale bedrock; and
- Profile C: Transported soils, underlain by residual dolerite / shale, hardpan calcrete and subsequent bedrock.

Variations to the above conceptual geological profile and strength index will manifest through intrusive investigations.

4.2 Geo-hazards Potential

4.2.1 Undermining

Based on the available data, there are no mines discernible near the site. Surface instability due to undermining is not foreseeable. This is however based on this high-level desktop assessment.

4.2.2 Slope Instability

The site area is located on a relatively flat topography with ~ 2% slope gradient surrounded by gentle slopes with gradient <6%. No natural slope-related instabilities are expected at the site.

4.2.3 Areas Subject to Flooding

There are drainage lines noted in the northern portion of the site however the current layout shows there will be no structures located on these features.

4.3 Problem Soils

Where thick soil profiles are encountered, risks associated with problem soils may occur viz.:

- The transported and residual soils may be expansive.
- The transported and residual soils may be compressible leading to settlement related problems.
- Site soils may be corrosive towards buried steel and concrete.

4.4 Excavatability

In terms of excavatability, per SANS 1200DA (1998), “soft excavation” conditions will be applicable through soils and very soft rock while “intermediate excavation” can be expected through soft rock to medium hard rock. However, this may only be concluded after site investigations.

4.5 Geological/ Geotechnical Risk Assessment

Conceivable geotechnical risks towards the proposed development of the Vanderkloof PV and BESS site are provided hereunder. These risks should form part of the objective of geotechnical investigations for the design of the proposed infrastructure and related environmental studies.

Table 4-1: Risk assessment from a geological/ geotechnical perspective

Risk	Causes	Impacts	Significance before mitigation	Mitigation	Significance after mitigation
Unexpected ground conditions	• Potential problem soils including heaving, compressible and corrosive ground. • Deep in situ soils.	• Settlement of foundations • Corrosion of buried structures/services • Possible change in design • Increased project costs • Project delays	High	• Conduct geotechnical site investigations and laboratory testing, • Foundations to be designed for the prevailing ground conditions. • Monitor construction works by a professional Engineering Geologist or Geotechnical Engineer	Low
Flooding	• Prolonged rain • Local watercourse e.g. tributaries and instream dams occurring within the site boundaries.	• Work stops, • Increased costs of repairs, • Project delays	Medium	• Identify areas of considerable risk (drainage lines/watercourses) and delineation of flood line through topographical and hydrological studies • Long term monitoring of groundwater levels • Install necessary temporal and permanent drainage works. • Stabilize cleared areas during construction	Low
Construction materials	• Unsuitability of on-site materials for use in construction • Lack of potential sources near the site	• Excessive costs for commercially sourced material • Project delays	High	• Laboratory testing of on-site materials for suitability for use during construction. • Identify existing material sources near the site. • Conduct material assessment for identified potential sources	Low
Undermining	• Possible historic mining activities	• Site unsuitable for development • Mining related-instabilities	Medium	• Assess documentation on historical mining activities	Low

5 Recommendations

5.1 Geotechnical Feasibility of Project

Based on information obtained for the Vanderkloof PV and BESS and interpretation thereof, there appears to be no fatal flaws for the project's development not to proceed beyond the pre-feasibility stage from a geological and geotechnical perspective.

5.2 Conceptual Founding Solutions

Based on the conceptual geological profile, the profiles are considered suitable for the development of the proposed solar PV and BESS infrastructure. Foundation solutions appropriate for the anticipated geotechnical conditions are conceptualised and provided below which will become more evident during the geotechnical investigations:

- Where thick soils are encountered, driven piles are anticipated for the solar panel foundations.
- Where shallow bedrock is encountered, predrilled piles may be employed.

For the BESS site, foundations can be placed on at least medium dense material using conventional foundation solution generally used for such infrastructure.

5.3 Further Geotechnical Investigations

For economic design and to reduce the probability of failure of the proposed development, geotechnical field investigations, substantiated by laboratory work will be required. Based on information obtained from this desktop study, the following further geotechnical investigations must be considered:

- Machine excavation of test pits across the Vanderkloof PV and BESS site to profile the ground units and facilitate recovery of bulk material samples. Test pits to be excavated using a Tractor Loader Backhoe (TLB) to a refusal depth or the machine's end of reach.
- Profiling of soil and rock horizons by a professional Engineering Geologist or Geotechnical Engineer.
- Field mapping of rock mass outcrops across the site.
- Retrieval of soil and rock samples for determination of index and engineering properties including, but not limited to:

- Foundation Indicator tests, including determination of Atterberg limits, grading and hydrometer analyses to determine clay content and activity.
- Collapse and/or consolidation tests.
- Modified AASTHO/ CBR tests to determine the utilisation of in situ material in new construction activities.
- Moisture content and chemical analysis tests on soil samples to determine aggressiveness towards buried ferrous services and foundations.

- Compile a comprehensive interpretive geotechnical report with recommendations, inter alia, on the following:

- Foundation options;

- Site development and excavatability; and
- Material utilisation.

The site investigation for the Vanderkloof PV and BESS is anticipated to take about 2 to 3 weeks, and the interpretive report including the laboratory results can be concluded in 8 weeks to 10 weeks depending on the progress of the laboratory testing.

6 Conclusion

This geotechnical desktop study report highlights the anticipated geological and subsequent ground conditions expected at the Vanderkloof solar PV and BESS site.

Based on a desktop study, a basic geological profile has been conceptualised for the project site. Briefly, the PV and BESS site may be underlain by either dolerite, sandstone, or mudstone. These are anticipated to be overlain by their residual profiles and subsequent transported soils. The residual and weathered soil profiles are expected exceed 2.0 m in some parts of the site but may also be thin where bedrock is shallower. Generally, the site is located on a gently sloping topography, and no natural instabilities anticipated during construction.

Smaller tributaries were noted to the north of site boundary based on desktop analyses. It is recommended that appropriate studies are conducted to evaluate the flooding risk at the site.

The main concerns regarding development of the project sites and which will need to be determined via on-site investigations are:

- Problem soils;
- Undefined rock mass competence laterally and with depth across the PV site and along the access road;
- Undefined depth to permanent groundwater table.

SMEC is, therefore, of the opinion that the project can proceed to the next stage which will assist in defining and quantifying the geotechnical risks to development and choosing the most appropriate founding solution.

7 Closing

This report acts merely to aid in the feasibility determination of the project, and it is imperative that geotechnical investigations of the site be undertaken should the development move forward. SMEC has undertaken several investigations for similar developments and has highlighted the minimum requirements for geotechnical investigations that will inform the respective engineering design. Undertaking geotechnical investigations will generate the necessary geomechanical design parameters of the soils and rock mass that will mitigate the risk of failure of the proposed structures and unforeseen geotechnical issues across the site.

It must be noted that the information and recommendations given in this desktop study report are conceptual. Inconsistencies from what has been reported here may likely be observed during the later investigation phases.

Furthermore, all recommendations this report makes serve merely as guidelines for the Client's consideration. Anticipated founding conditions and conceptual solutions, as described herein, must be proven before design and construction to ensure the proper economic viability of the proposed project.

8 References

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