Geotechnical Reconnaissance Study for Proposed Soyuz 2 Solar PV Park Solar Energy Facility near Britstown, Northern Cape.

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GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

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EXECUTIVE SUMMARY

Soyuz 2 Solar PV Park (Pty) Ltd has appointed Terramanzi Group (Pty) Ltd to undertake the necessary Environmental Authorisation for the proposed development of six Solar PV facilities (Soyuz Solar PV Park) and associated infrastructure near Britstown in the Northern Cape. This study forms part of the Basic Assessment (BA) for the proposed development of the Soyuz Solar PV Park. Roschel Maharaj of Terramanzi (Pty) Ltd. requested that GEOSS South Africa (Pty) Ltd undertake a geotechnical reconnaissance assessment for all six of the Soyuz Solar PV Park facilities. The following study pertains specifically to the Soyuz 2 Solar PV Park.

The primary objective of the reconnaissance assessment is to identify and confirm the geology and soil conditions of the area, with specific reference to the likely distribution of potential geotechnical challenges related to the underlying geology. The impacts of the proposed development have been assessed according to the methodology provided by Terramanzi Group (Pty) Ltd. The information that has been provided is for planning purposes only and forms part of the environmental Basic Assessment process.

The following soil profile is expected within the area that has been proposed for development:

Depth (mbgl)	Generalised Soil Profile
0.0 to 0.5/1.0	Dry, red to reddish brown, loose to medium dense, fine to medium grained silty **SAND** containing rounded calcrete pebbles**.** Note: Horizon potentially represents the topsoil and transported alluvium
0.5/1.0 to 1.2/1.5	Laterally discontinuous, hard yet brittle, white **CALCRETE**, variably interbedded with 0.1 to 0.2 m thick layers of fine to medium grained red **SAND**
1.2/1.5 to 2.0	Dry, dark grey, highly fractured and friable, unweathered, fine-grained **SHALES** of the Tierberg Formation. Note: Fractures are infilled by calcium carbonate to form a characteristic calcrete-shale honeycomb structure. ***OR*** Dry, dark grey, fractured, weathered, **DOLERITE** of the Karoo Dolerite sequence. Note: Fractures are infilled by calcium carbonate
2.0 to 3.0 (end of profile)	Dry, dark grey, highly fractured and friable, unweathered, fine-grained **SHALES** of the Tierberg Formation. ***OR*** Dry, dark grey, fractured, unweathered, **DOLERITE** of the Karoo Dolerite sequence.

A summary of the pertinent findings are as follows:

1. Increased soil erosion may transpire as an impact of development, this may persist for the life of the project. However, the impact of this is expected to be low and is anticipated to have little effect on the site from a geotechnical point of view.

2. Variable soil and rock conditions will exist across the site, broadly these have been divided based on geological conditions, as follows:
    a. Zone A – Karoo sandstone, siltstone and mudrock.
    b. Zone B – Karoo dolerite.
    c. Zone C – Quaternary sediments
3. The footprint of each proposed structure would have to be investigated prior to the compilation of final design(s).
4. Owing to the variable geological and soil conditions across the proposed development area, the subgrade conditions will vary across the site. Dolerite has been proven to perform well as an aggregate for wearing courses. Dolerite has also been incorporated as an aggregate in concrete mixes. Calcrete has also been shown to be effective as a wearing course; however, requires full material characterisation before use. Karoo mudrock and sandstone should be avoided when selecting aggregates for concrete mixes.
5. The excavatability of the stratum on site is anticipated to be variable, based on material composition and texture, the degree of weathering, and the nature of discontinuities within the rock and/or soil mass.
6. The seismicity in the region is considered to have a nominal peak horizontal ground acceleration that is less than 0.1 g once every 475 years. Therefore, the design phase would typically not make allowances for seismicity.
7. Intrusive investigations will be required to confirm the anticipated conditions at the PV Facility and all other associated structures.
8. Any road cuttings should be designed by an appropriately qualified professional, where required.
9. GEOSS has endeavoured to highlight and characterise all potential geotechnical risks that are presented by the site that has been proposed for development. However, due to the anisotropic (variable) nature of earth materials, each point on the site will present results that differ. For this reason, it is considered of the utmost importance that the foundation excavations be inspected prior to casting to ensure that soil with an adequate bearing capacity is obtained beneath each footing. These works should be carried out by an appropriately qualified individual.

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ABBREVIATIONS & SYMBOLS

BH	Borehole
CGS	Council for Geoscience
EC	electrical conductivity
EOH	End of Hole
g	Gravity
L/s	litres per second

LL	Liquid Limit
LS	Linear Shrinkage
m	metres
mm	millimetre
mS/m	milli-Siemens per metre
PV	Solar Photovoltaic
BESS	Battery Energy Storage System
SEF	Solar Energy Facility
O&M	Operation & Management
EGI	Electrical Grid Infrastructure
OHPL	Overhead Power Line

GLOSSARY OF TERMS

Aquifer: a geological formation, which has structures or textures that hold water or permit appreciable water movement through them [from National Water Act (Act No. 36 of 1998)].

Electrical Conductivity: the ability of groundwater to conduct electrical current, due to the presence of charged ionic species in solution (Freeze and Cherry, 1979).

Fractured aquifer: Fissured and fractured bedrock resulting from decompression and/or tectonic action. Groundwater occurs predominantly within fissures and fractures.

Groundwater: Water found in the subsurface in the saturated zone below the water table or piezometric surface i.e., the water table marks the upper surface of groundwater systems.

Pedocrete: Superficial deposits, not of sedimentary origin, which have formed through either weathering residues, or cementation or replacement of existing soils (by precipitates derived from soil-water and or groundwater), or a combination of such processes. Several chemical agents replace or cement, e.g., calcium carbonates (calcrete) and/or iron oxides (ferricrete).

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Cover photo:

Photo captured during field visit.

GEOSS project number:

2022_09-4918 (Phase A1)

Review:

Dale Barrow (20 February 2023)

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April 2018 to March 2020	Iziko Museums of South Africa, South Africa

SPECIALIST DECLARATION

I, Louis Jonk, as the appointed independent specialist hereby declare that we:

- act/ed as the independent specialist in this application;
- regard the information contained in this report as it relates to my specialist input/study to be true and correct, and
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and any specific environmental management Act;
- have and will not have no vested interest in the proposed activity proceeding;
- have disclosed, to the applicant, EAP and competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and any specific environmental management Act;
- are fully aware of and meet the responsibilities in terms of NEMA, the Environmental Impact Assessment Regulations, 2010 (specifically in terms of regulation 17 of GN No. R. 543) and any specific environmental management Act, and that failure to comply with these requirements may constitute and result in disqualification;
- have provided the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not; and
- am aware that a false declaration is an offence in terms of regulation 71 of GN No. R. 543.

Louis Jonk
GEOSS South Africa (Pty) Ltd.
Pr. Sci. Nat. – *121278/21*
20 February 2023

1. INTRODUCTION

1.1 Terms of Reference

Soyuz 2 Solar PV Park (Pty) Ltd has appointed Terramanzi Group (Pty) Ltd to undertake the necessary Environmental Authorisation for the proposed development of six Solar PV facilities (Soyuz Solar PV Park) and associated infrastructure near Britstown in the Northern Cape (**MAP 1**). This study forms part of the Basic Assessment (BA) for the proposed development of the Soyuz Solar PV Park. Roschel Maharaj of Terramanzi (Pty) Ltd. requested that GEOSS South Africa (PTY) Ltd undertake geotechnical reconnaissance assessments for all six of the Soyuz Solar PV Park facilities. The following study pertains specifically to the Soyuz 2 Solar PV Park.

The proposed Soyuz 2 Solar PV Park facility includes the development a 300 MW PV facility. Furthermore, the PV Facility will include associated infrastructure such as a Battery Energy Storage System (BESS), associated Overhead Powerline (OHPL) infrastructure, and ancillary support structures and access roads. Solar PV technology will be used in the proposed project to generate electricity from energy derived from the sun.

1.2 Objectives

The project scope includes an appraisal of the geotechnical conditions.

The primary objective of the reconnaissance assessment is to summarise and confirm the geology of the area, including the likely distribution of potential geotechnical challenges related to the underlying geology. The following high-level information is presented in this report:

- Whether problem soils are likely to be encountered on-site.
- An assessment of expected excavatability within the respective geological areas.
- Whether any geohazards are immediately apparent within the site area.
- A general discussion of possible and likely engineering characteristics of the respective geological materials.
- Possible development constraints that may be present across the site.
- An evaluation of the seismic potential of the area based on available published literature.
- Suggested further works prior to construction.
- Broad recommendations that may be used to guide the geotechnical design of the proposed infrastructure and installation of associated services.

The information that has been provided is for planning purposes only and forms part of the environmental Basic Assessment process.

1.3 Proposed Development

Soyuz 2 Solar PV Park (Pty) Ltd (hereinafter referred to as "the Project Applicant") has appointed Terramanzi Group (Pty) Ltd to undertake the necessary Environmental Authorisation for the proposed development of six Solar PV facilities (Soyuz Solar PV Park) and associated infrastructure near Britstown in the Northern Cape. The PV Facility will be developed across the following affected farm portions:

- Soyuz 1 Solar PV Park (240 MW) - Farm 145 (3/145).
- Soyuz 2 Solar PV Park (300 MW) - Pettspot (2/97).
- Soyuz 3 Solar PV Park (240 MW) - Pettspot (2/97).
- Soyuz 4 Solar PV Park (300 MW) - Twyfelhoek (5/127).
- Soyuz 5 Solar PV Park (150 MW) - Twyfelhoek (1/127).
- Soyuz 6 Solar PV Park (240 MW) - Farm 91 (1/126).

The total developable area (i.e., the total developable areas of the Soyuz Solar PV Park) covers 3144.41 ha, of which the developable area for the Soyuz Solar PV1 site is 650.83 ha. At the time of compilation of this report, all information regarding the associated infrastructure such as substations, collector station, EGI or BESS was provided by Terramanzi Group (Pty) Ltd and all geotechnical considerations are based thereon.

No details regarding the OHPL were provided as of the time of report compilation save that it will have a capacity of 132 kV. As such, the following specifications were assumed from previous work done on a similar project and, therefore, do not represent the final design specifications for the OHPL for this project. It is assumed that OHPL for connection of the PV facility to the existing national grid will be supported by monopole twin circuit pylons (or similar) with a maximum height of 20m with a concrete and cable foundation. Additionally, it is assumed that power lines will have a 30m wide corridor for specialist assessment.

The Soyuz 2 Solar PV Park facility will make use of numerous bifacial PV modules installed on single axis tracker mounting structures at a height of up to 6m above ground level. Further to this, the site will include inverters, transformers, and underground and overhead cabling up to 33kV between project components.

In addition to this, the PV facility will include an O&M building (0.15 ha), a 1 200 MWh BESS (6.00 ha), a 300 MW back-to-back substation which includes a facility substation and Eskom collector/switching station with feeder bays (1.50 ha), 0.30 ha of paved areas, access and internal roads, and fencing around development areas.

During the construction period it is assumed that the facility will have one temporary construction camp taking up an area of 1.00 ha. The site will also include several temporary laydown areas with a combined footprint of 4.00 ha.

As of the report compilation, no detail regarding road design was received. As such, the following parameters were assumed from previous work done on similar projects and, therefore, does not represent design specification for the final road network of this project. It is assumed that main access roads will have a width of 5 m, while internal access roads are to be constructed between different development portions, with a width of 4 m. Finally, it is assumed that available aggregate material will be used to upgrade existing access roads to 5 m in width.

1.4 Scope and Limitations of Assessment

The primary aims of this investigation were to confirm the general geotechnical conditions of the site and to determine potential geotechnical impacts on the environment based on existing, available desktop information i.e., information extracted from published literature, and consultancy reports. Findings determined from the desktop studies were then directly verified in the field through a physical site reconnaissance visit.

This study was conducted in a manner consistent with the level of care and skill ordinarily exercised by members of the geotechnical profession practicing under similar conditions.

Geological environments are seldom uniform and the subsurface geological and geotechnical conditions at each of the PV facilities at the Soyuz Solar PV Park will need to be thoroughly established in the field prior to the commencement of construction through intrusive site investigation and laboratory testing. The engineering recommendations provided in this report are therefore preliminary.

1.5 Information Available

Data were acquired from the following topo-cadastral, geological, pedological, and hydrogeological sources:

- The 1: 50 000 topo-cadastral map – Sheets 3023CB, 3023DA, 3023DB, 3023CD, 3023DC, and 3023DD
- The 1: 250 000 geological series map – Sheet 3022, Britstown.
- The 1: 500 000 hydrogeological map – Sheet 3122, Beaufort West.
- Aerial imagery (Google Earth imagery).
- Engineering Geology of South Africa (relevant) Volumes 1, 3 and 4 (Brink, 1979; 1983; 1985).
- Soils of South Africa (Fey, 2010)
- The Geology of South Africa (Johnson et al., 2006)

Data hosted GEOSS' internal database generated during previous geotechnical and hydrogeological investigations undertaken in the area, as well as published geological, geotechnical and hydrogeological literature available for the region were also consulted.

Details pertaining to the project development were collected/compiled from email and telephonic correspondences between GEOSS South Africa (Pty) Ltd. and Terramanzi Group (PTY) Ltd.

1.6 Assessment Methodology

This reconnaissance assessment involved gathering, reviewing, and interpreting all relevant data to the project from all known sources, which was followed by a non-intrusive site visit across the entire development area in the summer from the 26th to the 28th of January 2023. The drainage capacity of the topsoil is considered a typical geotechnical parameter and needs to be assessed. As the reconnaissance trip was conducted during the rainy summertime where rains had occurred on-site 4 days prior, this allowed for a high-level assessment of the drainage properties. Furthermore, evidence of erosive conditions such as gullies and ditches are more likely to be present during the rainy summer months, as ditched and gullies that formed during a specific rain season are commonly repaired after the rainy season ends.

1.7 Assumptions and Limitations

The assessment that has been made is based on desktop studies, a review of literature, an analysis of the information, and a physical reconnaissance site visit. Although a site reconnaissance visit was conducted to confirm much of the high-level findings, the report is not based on detailed intrusive works, i.e., trial pit excavation, soil profiling, geotechnical drilling, and/or testing.

The assessments in this report are high level and follow up work will need to be undertaken prior to final design and construction, to confirm actual subsurface conditions and material characterisation of the soil.

The duration of the construction phase per project was not specified. From previous work for similar projects, a duration of ±12 to 18 months is assumed, keeping in mind that projects may be constructed in parallel. Please note that the impact rating will change should the construction duration increase. A description of the weighting system and a description of the terms used is attached in **Appendix A**.

It is important to stress that the impact assessment component of this report highlights the risks/impacts of construction, operation, and decommissioning of such a proposed facility on the geotechnical conditions that are expected on/across the site.

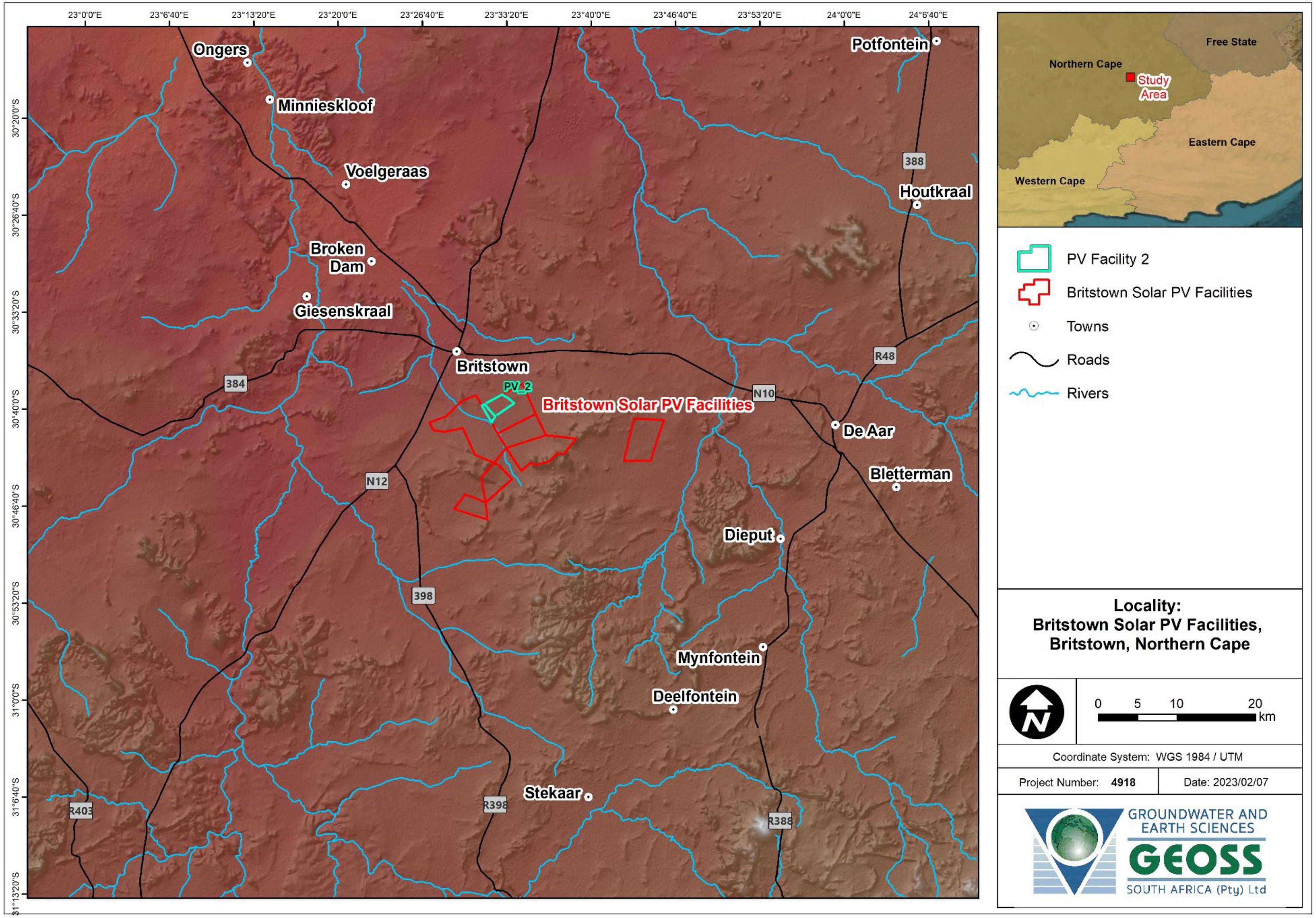
2. SETTING

2.1 Site Location and Description

The complete extent of the Soyuz Solar PV Park is more than 3 144.40 ha and is approximately located 7.10 km southeast of Britstown, Northern Cape. The 300 MW Soyuz 2 Solar PV Park is the northern most facility of the Solar Park and constitutes a developable area of 501.81 ha.

2.2 Topography and Site Features

The Soyuz Solar PV Park development lies within are characterised mostly by topographically-subdued, flat to very gently hilly terrain with localised topographic highs in the form of butts or ridges formed from negative weathering of more competent Karoo dolerites. All of the proposed sites for the Soyuz Solar PV Park development are situated on topographical lows in the area, with Soyuz 2 Solar PV Park located at an elevation of 1185 to 1214 m above mean sea level. Although agriculture is the dominant industry within the area, the landscape in the area has remained relatively unchanged as the regional farming practices are dominated by livestock development. During the summer months, the vegetation is dominated by medium-length grasses and small brushes of the Upper Karoo Bioregion with numerous scattered domical termitaria as seen in **Figure 12.B** & **Figure 15.B** of **Appendix C** (Mucina & Rutherford, 2012). The study area displays very little bedrock outcrop, except for the margins of local topographic highs, the outward dipping edge of localised ridges, and occasional small borrow pits exploiting Quaternary-age deposits.



Map 1: Locality map showing the location of the proposed Soyuz 2 Solar PV Facility and surrounds.

2.3 Climate

The Soyuz Solar PV Plant is located close to Britstown. This area forms part of the Nama Karoo Biome (Mucina & Rutherford, 2012) which receives an average of 258.0 mm/year of rain per annum. Generally, the study area experiences cold and dry winters with hot and wet summers. It receives the bulk of its annual rainfall during summer and early autumn (i.e., between December and March). **Figure 1** shows the monthly average air temperature and **Figure 2** shows the monthly median rainfall and evaporation distribution for the study area (Schulze, 2009). Potential evaporation exceeds the rainfall year-round across the study area.

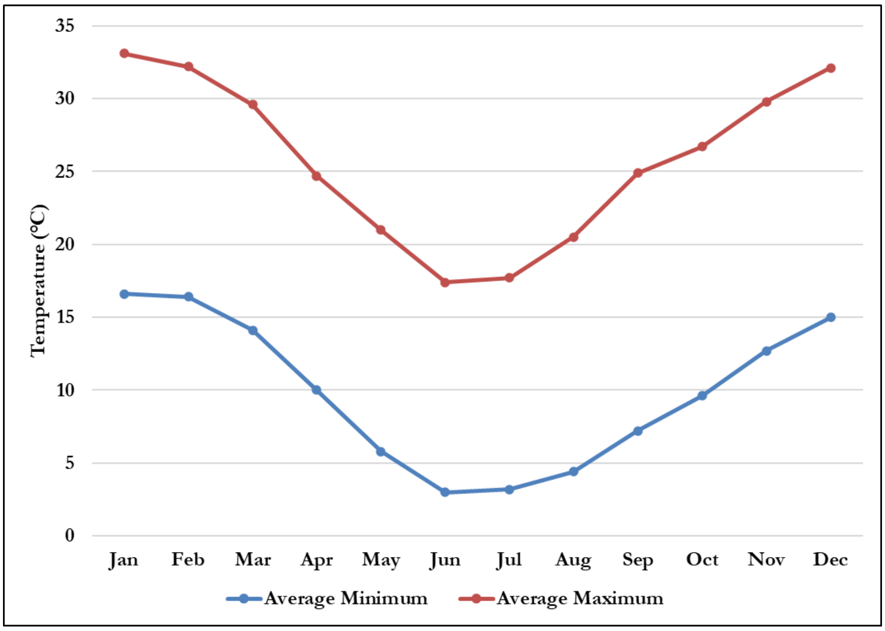


Figure 1: Monthly average air temperature for the study area (Schulze, 2009).

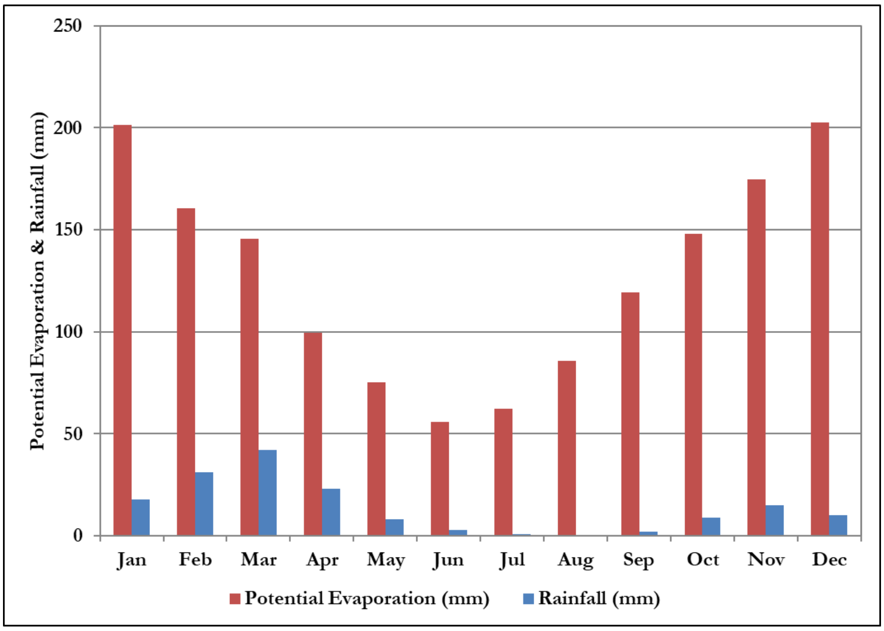


Figure 2: Monthly average air temperature for the study area (Schulze, 2009).

2.4 Weinert 'N' Value

Climate has a significant effect on the formation of residual soils and rock weathering. It is an indicator of the typical soil conditions that may be encountered on a specific site (Weinert, 1975). In **Figure 3** a general modal developed by Weinert (1975) is presented, which categorises the climate of southern Africa based on what he termed the N-value. The Weinert 'N'-value for the project area is shown to be greater than 5 (Brink, 1979).

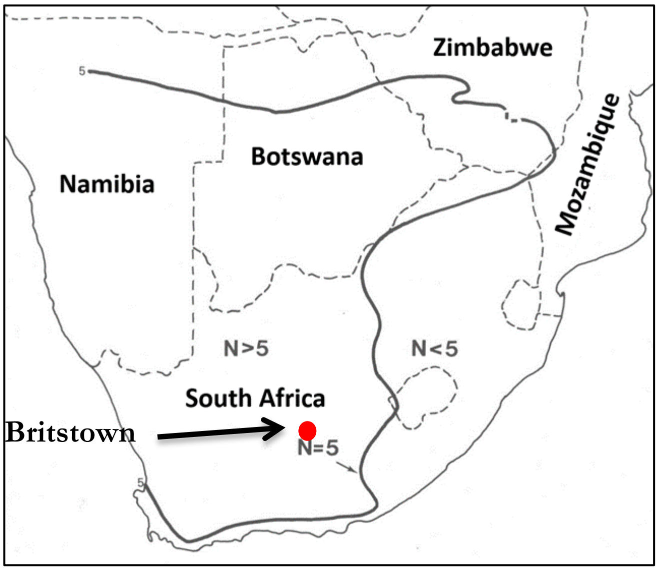


Figure 3: Climatic 'N' value = 5 plotted for southern Africa (after Weinert, 1967).

Weinert (1975) showed that where 'N'-values are greater than 5, residual soils are typically shallow, transported soils of variable thickness with calcrete and/or other pedocretes (Brink, 1979).

2.5 Geology

The Council for Geoscience (CGS) mapped the region at a 1:250 000 scale (2824 Kimberly, GCS 1993). The geological setting is shown in **Map** 4 and the main geology of the area is listed in **Table 1**. The site is mostly underlain by shale, siltstone and sandstone of the Karoo-aged Tierberg Formation of the Ecca Group, which have been intruded by Jurassic-aged dolerites, and overlain by quaternary-aged surficial cover (**Map** 4).

Table 1: Geological formations within the study area (CGS, 1991).

Code	Formation	Group	Lithology
⌒⌒	*Quaternary-aged sediments*		Alluvium
Jd	*Jurassic aged intrusives*		Dolerite
Pa	Abrahamskraal	Adelaide	Red and greenish-grey mudstone, subordinate siltstone and sandstone
Pwa	Waterford	Ecca	Sandstones, rhythmites, shales, and mudstones. Structures include wave ripples and slumping
Pt	Tierberg	Ecca	Grey shale with interbedded siltstones in the upper part

2.5.1 Soil Type Distribution

Soils refer to the uppermost layer of sediments found within a specific area. Although all soils consist of essentially the same five elements i.e., organic matter, minerals, gasses, liquids, and organisms, varying pedogenic (soil forming) processes can lead to a wide diversity of soil types with large variation in both chemical and engineering properties.
Following the soil distribution maps of Fey (2010) The Soyuz Solar PV Park is located within the following five main soil type distributions (**Figure 4**).

- Calcic soils – Soft or hardpan, marked carbonate or gypsum enrichment.
- Cumulic soils – Incipient soil formation in colluvial, alluvial or aeolian sediment.
- Lithic soils - Incipient soil formation on weathered rock or saprolite.
- Duplex soils – Marked textural contrast through clay enrichment.
- Oxidic soils – Residual iron enrichment through weathering, typically uniform in colour.

A reconnaissance visit to the site at the end of January confirmed that the major soil types present at the Soyuz 2 PV Solar Park were Cumulic soils and Calcic soils with a strongly developed calcium carbonate horizon within the first-meter depth of the subsoil.

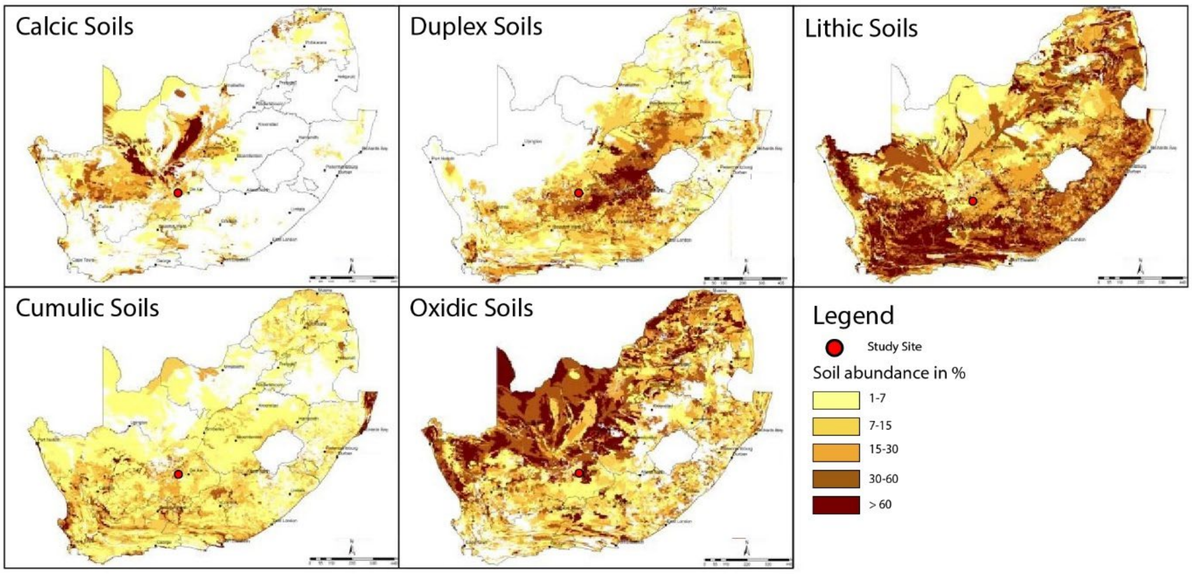


Figure 4: Soil type distributions across South Africa with respect to Soyuz Solar PV Park (after Fey, 2010)

2.5.2 Pedocrete Development

Pedocretes describe materials that have formed in situ due to the cementation or replacement of soils by authigenic minerals such as iron or calcium carbonate from direct precipitation out of soil or from groundwater. Pedocretes are fairly common throughout southern Africa and are classified as either indurated (hardpans, honeycombs, nodules) or non-indurated (soft or powdery forms). Brink (1985) compiled a general map of pedocretes distribution across southern Africa, which shows that the Soyuz Solar PV Park is located well within the common distribution of calcrete soils (**Figure 5**).

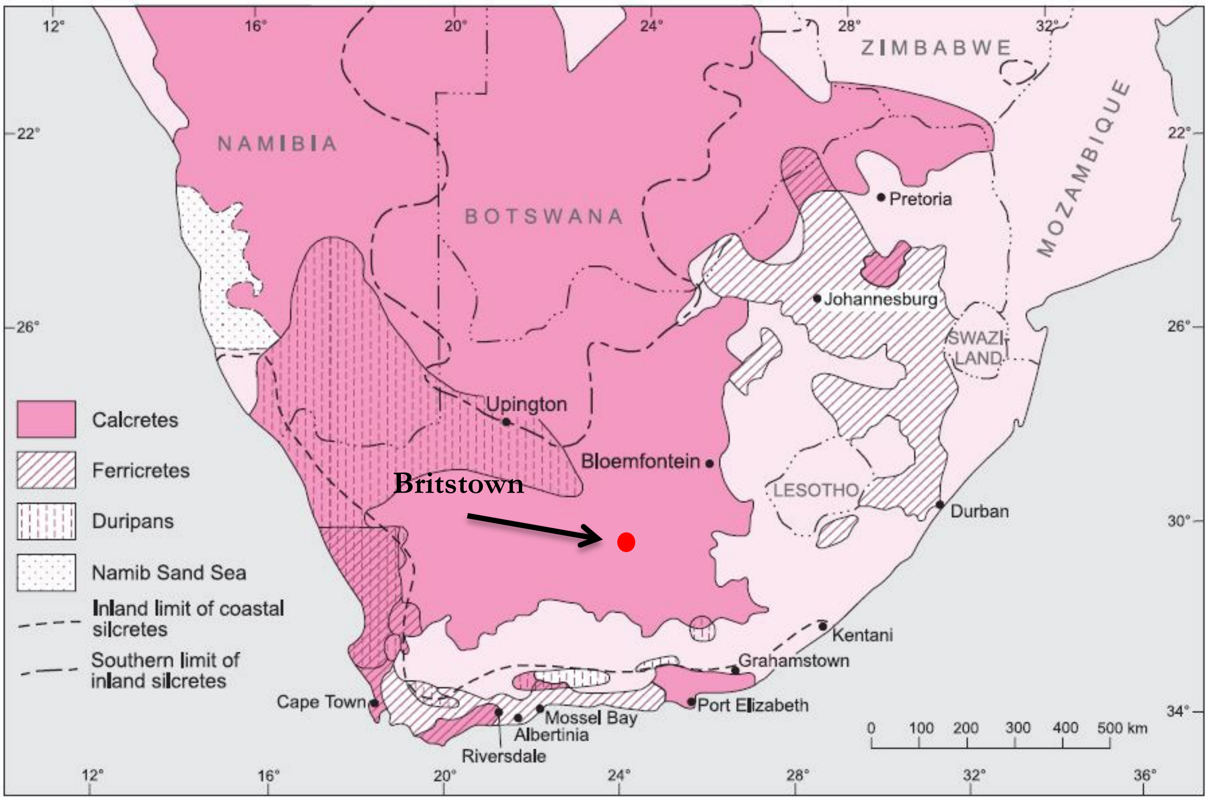


Figure 5: Distribution of pedocretes across southern Africa (after Partridge et al. (2006)

This was corroborated by findings during the project reconnaissance visit in January 2023, where the presence of several well-developed calcrete layers was documented both above and below the natural ground level (**Figure 15** & **Figure 16** of **Appendix C**).

2.6 Geotechnical Properties and Engineering Geology

2.6.1 Geological Zones

Based on the combinations of geological and pedological conditions, the site has been broadly classified into three zones of similar geological and geotechnical characteristics (Zones A, B and C). The zones are presented in **Map 5** and are expanded upon in subsequent sections.

2.6.2 Sandstones, siltstones and mudstones (Zone A)

Geotechnical properties collected from available literature sources on sedimentary rocks of the Karoo Supergroup are presented in **Appendix B: 10.1.** A photographic image mosaic representing this zone is presented in **Figure 13** of **Appendix C**

The rocks of the Tierberg, Waterkloof, and Abrahamskraal formations of the Karoo Supergroup are characterised by laterally extensive, interbedded shales/mudrocks and sandstones which deposited into a network of deltas and meandering rivers during the Permian period. Problems with slope stability may be experienced where these sandstones and shales/mudrocks are closely intercalated, as weathering of the fine-grained rocks may result in undercutting which can lead to rockfalls (Brink, 1983). Porewater pressure may develop at the interface between sand- and mud-/siltstones (Brink, 1983). Rocks of the Karoo Supergroup can develop into clays with swelling characteristics during extensive weathering, making them unsuitable for use as construction materials.

Where sandstones are thickly bedded and highly jointed, joint-controlled block and wedge failures can potentially occur (Brink, 1983). According to Brink (1983), two main types of slope instabilities associated with Karoo sedimentary successions include debris flow from weathered material as well as unweathered block movement on delaminated bedding plains. The main mechanisms associated with this type of slope failure include excessive weathering of the shale material and rapid changes in slope morphology. Although rare in the Great Karoo area, this type of slope failure can occur in localised points of regular water ponding, excessive erosion, or earthworks on or around slopes.

2.6.3 Dolerite (Zone B)

Geotechnical properties collected from available literature sources on Jurassic ages dolerite rocks are presented in **Appendix B: 10.2.** A photographic image mosaic representing this zone is presented in **Figure 14** of **Appendix C**

The end of Karoo sedimentation was marked by the intrusion of dolerite dykes and sills into the Karoo sedimentary rocks. These intrusive dolerite bodies had a limited thermal metamorphic effect on the surrounding Karoo sediments, with the extent of metamorphism of the host lithology generally equivalent to the thickness of the dyke that it is in contact with (Brink, 1983).

Several tests were undertaken to determine the strength properties of dolerite rock during the late 1960s and early 1970s. From these tests the general description of dolerite was derived as follows, bluish-grey, very hard to extremely hard rock, variably fine- and medium-grained, variably jointed and fractured, with calcite, chlorite and zeolite minerals present on the joint and fracture surfaces in varying amounts (Brink, 1983). Of relevance to this assessment, dolerite rocks are considered to be erosion resistant. Accordingly, dolerite units have good but locally variable founding conditions and are typically suitable for shallow foundations; however, represent hard excavation conditions for earthworks. The material is also typically suitable as subgrade for access roads/tracks with basic preparation.

2.6.4 Quaternary Sediments (Zone C)

Geotechnical properties collected from available literature sources pertaining to quaternary sediments are presented in **Appendix B: 10.3.** A photographic image mosaic representing this zone is presented in Figure 15 of **Appendix C**

Quaternary-aged sediments in the region include alluvium, terrace gravels, sheet wash deposits, and localised aeolian deposits (CGS, 1991). The geotechnical characteristics of such materials are variable, with geotechnical constraints including potentially collapsible grain structures associated with coarser sandy sediments, and challenging excavation conditions associated with terrace gravels

(Brink, 1985). Furthermore, fine grained clay rich alluvial deposits can potentially present an expansive character. Coarse grained clastic material from this zone can serve as a base aggregate for road construction with adequate material characterisation, but not as fine aggregate in concrete (Brink, 1985).

Much of the sediments in Zone C have undergone pedogenesis to develop laterally discontinuous Calcic and Cumulic soils packages of varying thicknesses (Fey, 2010). This was especially evident through the extensive development of both surface and subsurface calcrete horizons (pedocretes). Pedocretes have been shown to have a generally positive influence on slope stability and erosion (Gidagasu, 1976); however, they pose some concerns as a foundation layer. Unlike typical soil profiles, pedocrete strength deteriorates with depth (Brink, 1985). Founding on pedocretes (such as calcretes) is only advisable if the horizon is of an adequate thickness and/or if the soil underneath the pedocrete horizon does not have a strong collapsible or expansive character (Brink, 1985). Additionally, small-scale karst-like features can occur in weathered calcretes and lead to small sinkholes; however, this is most prevalent in coastal areas (Netterberg, 1980).

Pedocretes, and especially calcretes, are widely used in road construction and commonly utilised as wearing courses for unpaved roads (**Figure 12.D**) and have been used in all layers of the road prism (Brink, 1985). Note that the material properties of pedocrete vary greatly and their performance as a construction material can fluctuate from poor to excellent. Intrusive investigation into the soil profile along with comprehensive laboratory testing is, therefore, essential to adequately determine the material properties and geotechnical conditions at the site.

2.7 Generalised soil profile

Even though no intrusive assessments were performed during this investigation, the following generalised soil profile was developed through the description of profiles available at borrow pits and erosional gullies near the proposed development as summarised in **Table 2** See **Figure 16** in **Appendix C** and **Appendix D** for full representative soil profile and example outcrop.

Table 2: Generalised soil profile

Depth (mbgl)	**Generalised Soil Profile**
0.0 to 0.5/1.0	Dry, red to reddish brown, loose to medium dense, fine to medium grained silty **SAND** containing rounded calcrete pebbles. Note: Horizon potentially represents the topsoil and transported alluvium
0.5/1.0 to 1.2/1.5	Laterally discontinuous, hard yet brittle, white calcrete, variably interbedded with 0.1 to 0.2 m thick layers of fine to medium grained red **SAND**
1.2/1.5 to 2.0	

	Dry, dark grey, highly fractured and friable, unweathered, fine-grained **SHALES** of the Tierberg Formation. Note: Fractures are infilled by calcium carbonate to form a characteristic calcrete-shale honeycomb structure. ***OR*** Dry, dark grey, fractured, weathered, **DOLERITE** of the Karoo Dolerite sequence. Note: Fractures are infilled by calcium carbonate
2.0 to 3.0 (end of profile)	Dry, dark grey, highly fractured and friable, unweathered, fine-grained **SHALES** of the Tierberg Formation. ***OR*** Dry, dark grey, fractured, unweathered, **DOLERITE** of the Karoo Dolerite sequence.

2.8 Slope Classification

The topography in the region has been classified in terms of development based on classes suggested by Stiff et al. (1996), see **Map 3**. The majority of the region is classified as "intermediate" followed by "favourable" due to the flat nature of the site.

2.9 Hydrogeology

In the region earmarked for development, two aquifer types occur namely intergranular and fractured, and fractured aquifers, with fractured aquifers dominating the area. Both the intergranular and fractured aquifer as well as the fractured aquifer are shown to have an indicative yield potential of 0.5 to 2.0 L/s (DWAF, 2002).

The regional groundwater quality is classified following DWAF (1998) as "marginal" directly underlying the study area with an associated electrical conductivity (EC) of 70 – 300 mS/m (DWAF, 2002).

It should be noted that the above classifications are based on regional datasets, and therefore only provide an indication of conditions to be expected. In field testing will be required to confirm the local water quality and yield potential.

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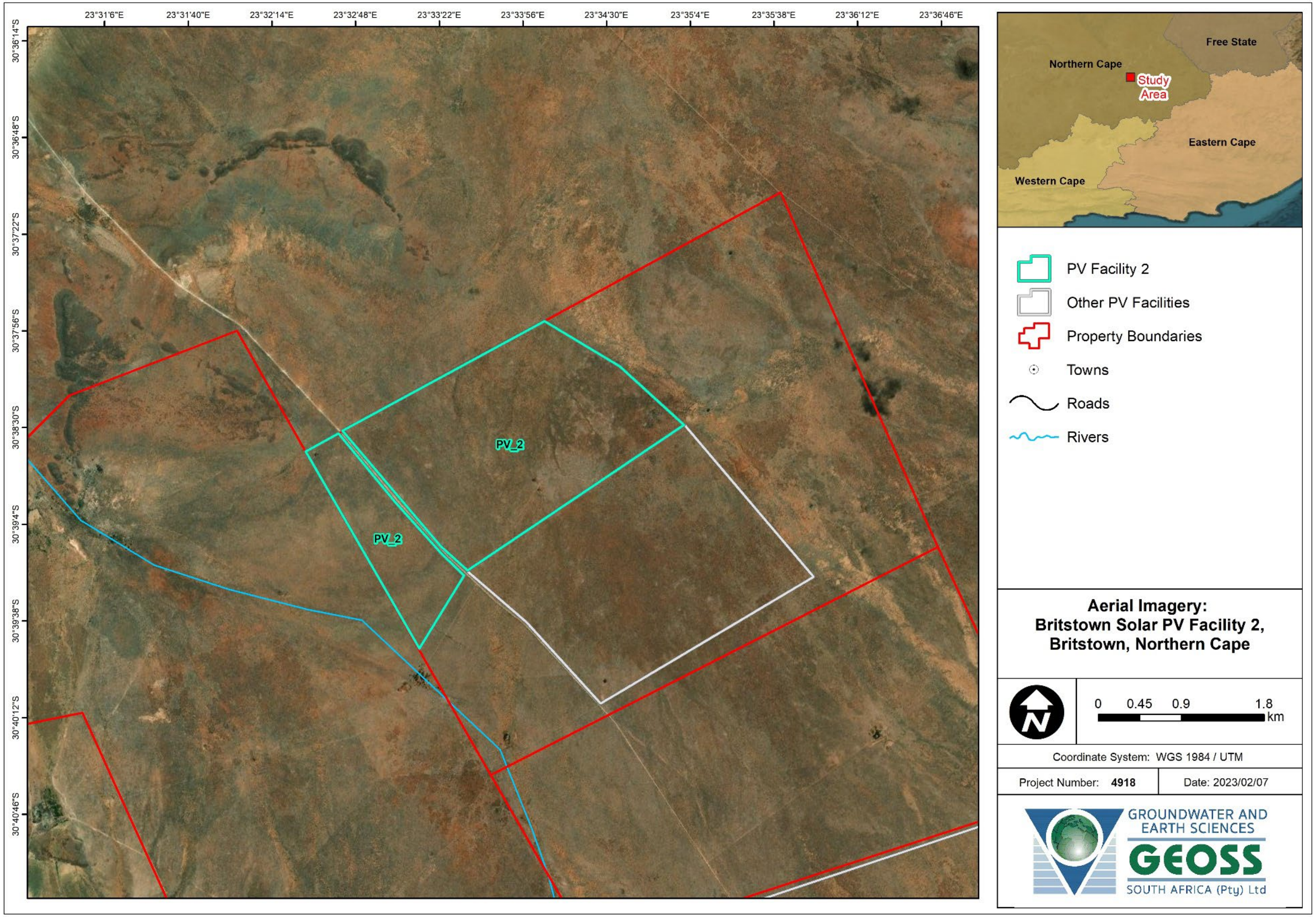
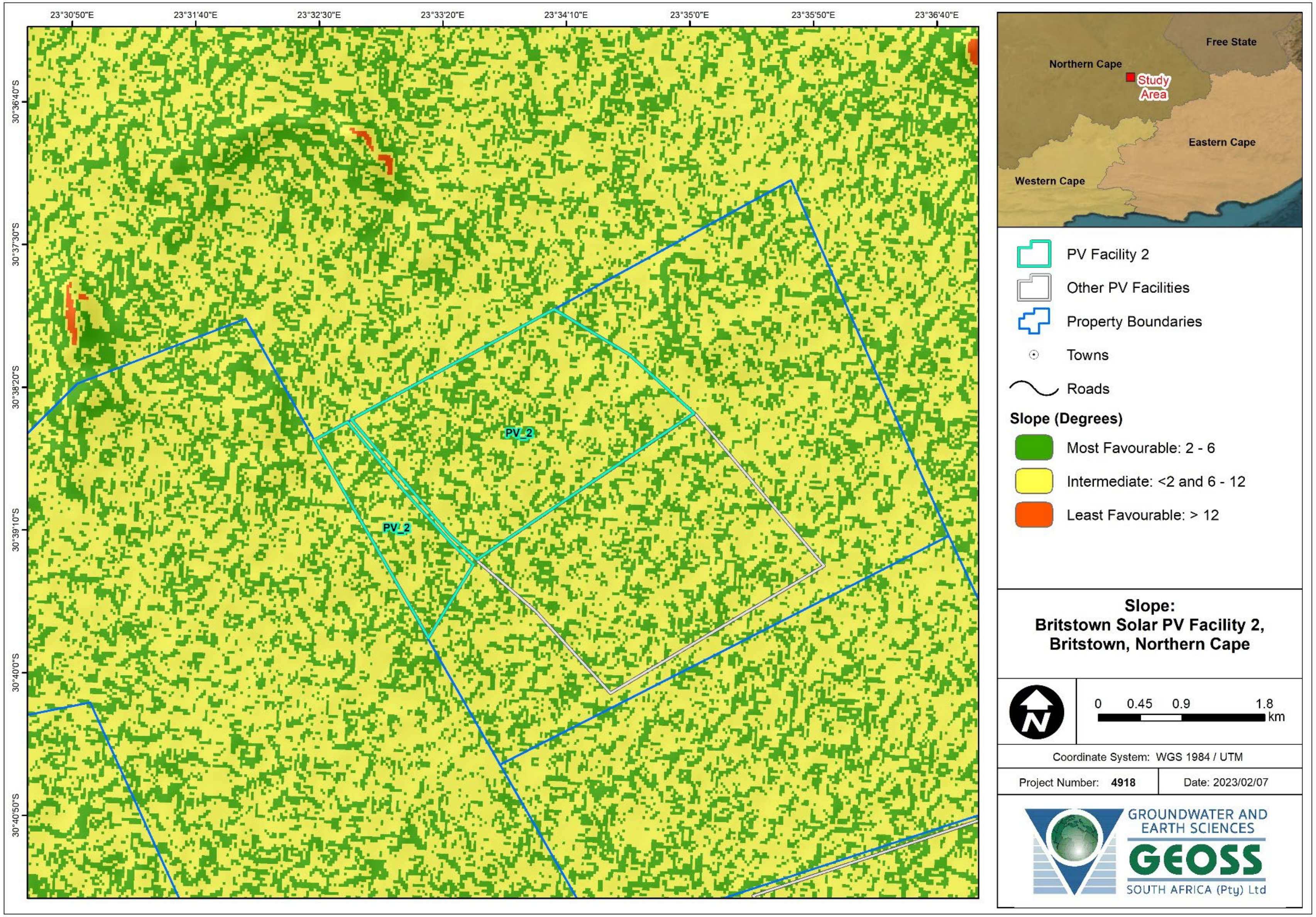
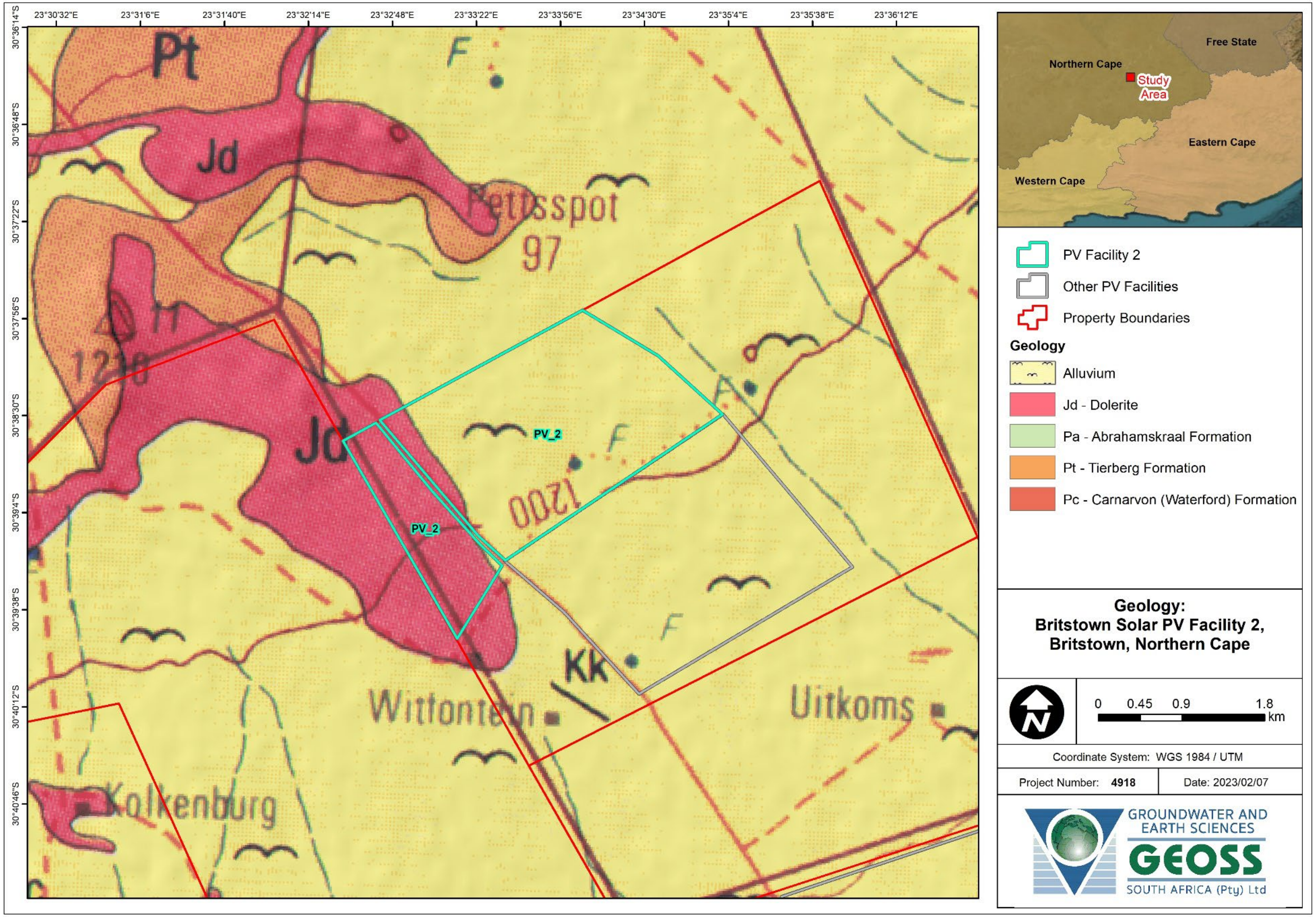


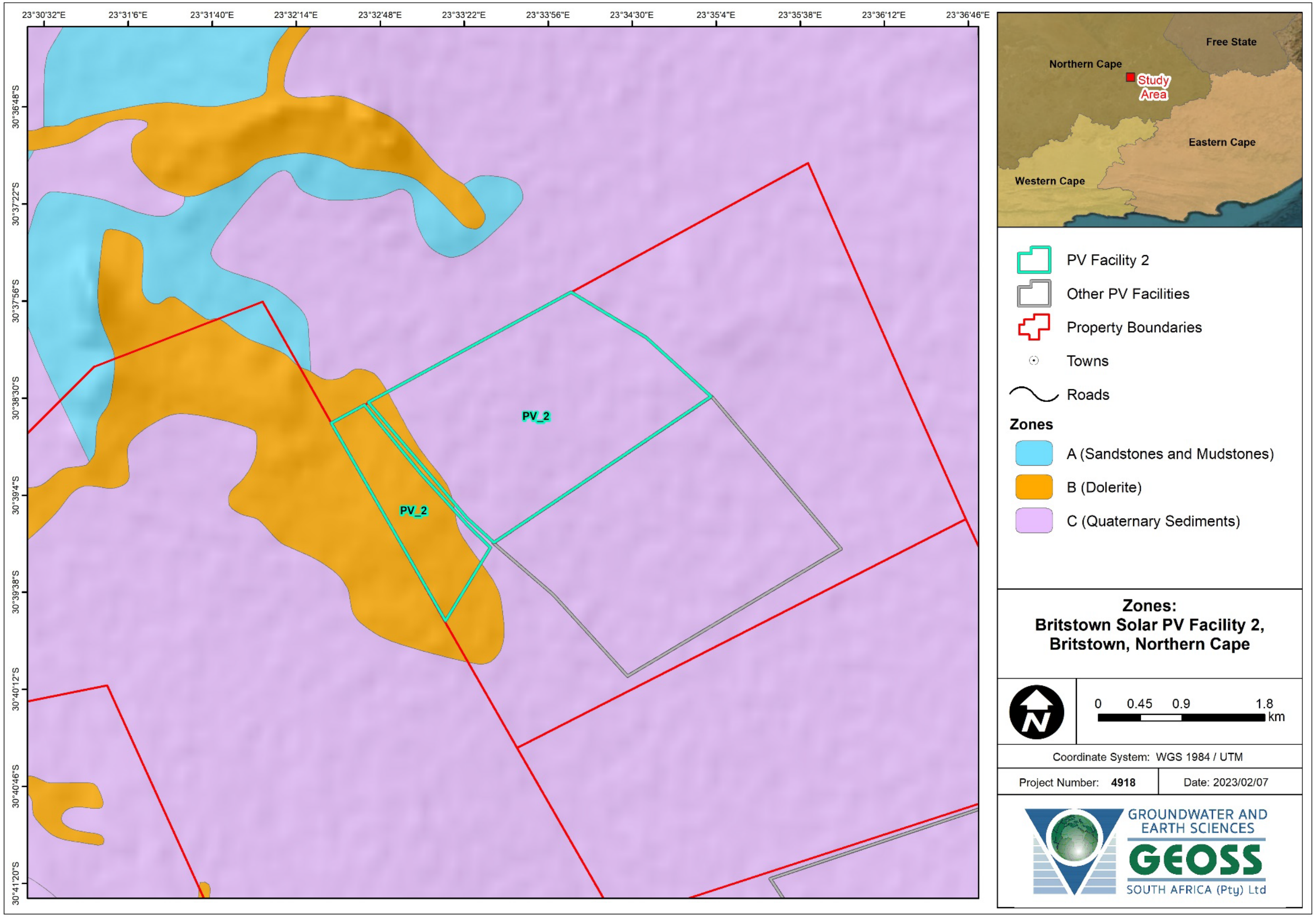
Map 2: Aerial map showing the approximate boundaries of the development.



Map 3: Aerial imagery overlain by slope classification (based on Stiff et al. 1996).



Map 4: Geological setting of the area (3022 - Britstown, GCS 1989).



Map 5: Geological zones superimposed on aerial imagery.

2.10 Seismicity

It is common practise to design structures for seismic loads when the nominal peak horizontal ground acceleration (NPGA) exceeds a 0.1 g once every 475 years (Retief and Dunaiski, 2009). Retief and Dunaiski, (2009) delineated such regions in southern Africa, the approximate position of Britstown is shown in red on Figure 6 relative to these regions. The region surrounding Britstown is shown to have a nominal peak ground acceleration of less than 0.1 g.

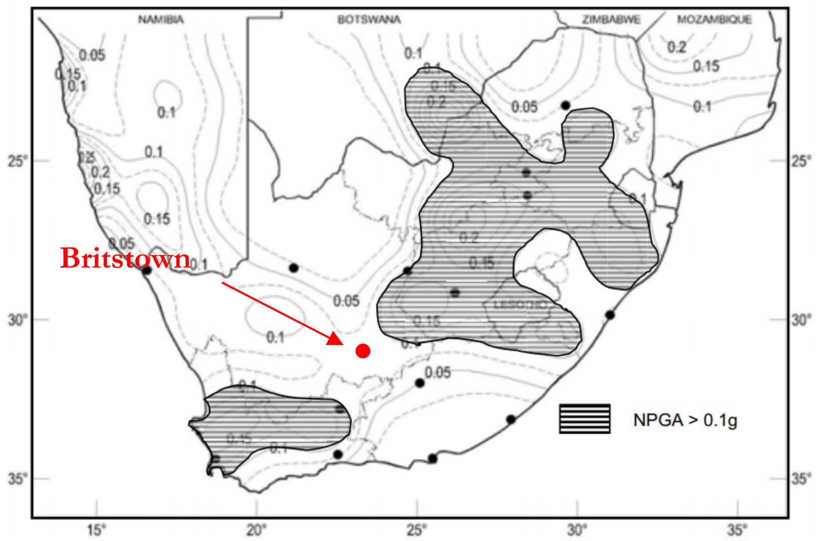


Figure 6: Zones in South Africa with nominal peak ground acceleration of more than 0.1 g for 10% in 50 years probability (after Retief and Dunaiski, 2009).

3. GEOTECHNICAL EVALUATION & RECOMMENDATIONS

3.1 General

It is anticipated that in regions planned for solar panel construction no out of the ordinary geotechnical risks will be encountered and conventional foundation solutions for the PV tables/monopoles could be adopted.

Large pylons which may later form part of the project OHPL and EGI are subjected to high wind shear and thus dense soil with moderate to high shear strength and bearing capacity is required for founding. Therefore, foundation conditions are a key constraint on engineering costs and effect project feasibility.

3.2 Drainage

The proposed Soyuz 2 Solar PV Park is located in a region that has a generally flat topography and is characterised by large depositional lows interspersed with locally developed topographical highs (**Figure 12.A** of **Appendix C**). The upper, relatively shallow soils from the region have good drainage potential (Fey, 2010); however, this is not true for locally developed underlying calcrete horizons. As such, ponding is highly likely to occur in areas where calcrete horizons develop near surface soils and within areas of less than 2 degrees slope. Locally developed mudcracks on the soil surface record evidence of episodic ponding, possibly after downpours (**Figure 12.B** of **Appendix C**). Direct evidence of ponding was also recorded during the reconnaissance visit, with localised ponding persisting 4 days after the previous rain event.

Large scale erosion scars are not especially prevalent throughout the area, potentially due to the generally flat topography in the region. Furthermore, susceptibility studies for erosion (Le Roux, 2011) have shown that the study site falls in areas of low to moderate soil loss from erosion (**Figure 7**).

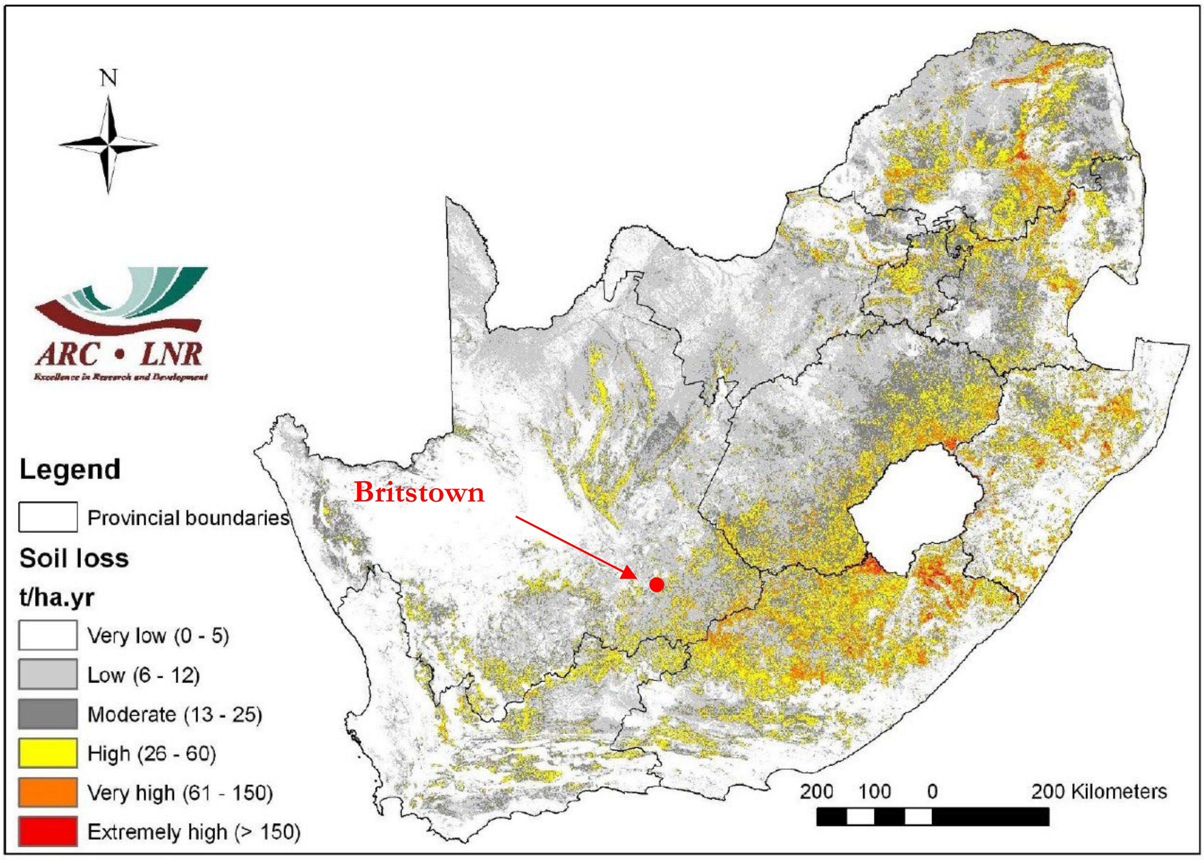


Figure 7: Soil loss across South Africa, after Le Roux, 2011

This indicates low risk for large scale erosion; however, smaller-scale gullies and ditches are quite prevalent along regions where roads coincide with higher slope indices. Consequently, culvert design would need to appropriately cater for runoff, particularly where proposed roads cross such areas of higher slope angles. This would have to be evaluated during future more intrusive geotechnical investigations.

3.3 Foundations

It is anticipated that conventional foundations can be adopted for all constructions in all areas of the site, however, in areas of inadequate bearing capacity or generally poor founding conditions piling may be required. As the sites lies outside of regions that experience a PGA exceeding 0.1 g regional seismicity seismic loads are typically not considered when designing structures here.

The foundation conditions at the position of each structure (PV panel, BESS, O&M, substation) that is to be developed within the study area would have to be investigated in more detail following intrusive investigative methods before construction to accurately constrain the engineering properties of the founding material.

3.4 Excavation

Excavation classes across the area will vary greatly. Thicker soil cover present in and along the banks of drainage channels should allow for easy excavation (SANS 1200). The flat-lying reworked alluvium which covers the majority of the site should present with relatively soft excavation in the upper 0.5 to 1.0 m; however, excavation classes may vary below this depth due to variable degrees of calcrete development here (SABS 1200 DM). Where Dolerite is present, the excavation class will depend on the degree of weathering of the dolerite rock. Similarly, the excavation class of the mudrocks and sandstones of the Beaufort Group will vary depending on the degree of weathering.

In areas of unweathered medium hard rock dolerite and/or shale pneumatic rock breakers and/or blasting may be required for the installation of foundations, and where roads are to traverse challenging terrain.

3.5 Problem Soils

Generally speaking, problem soils are not expected in the study area. Soils derived from the Waterford Formation may be potentially expansive, whilst soils derived from quaternary alluvium may have a potentially collapsible grain structure and expansive character. Furthermore, well developed calcrete horizons at founding depth can yield misleading bearing capacities as compaction for calcretes decreases with depth. The presence of these characteristics in the soil is not expected to hamper development; however, detailed material characterisation would need to be performed during the detailed design phase.

4. PRELIMINARY GEOLOGICAL AND GEOTECHNICAL IMPACT ASSESSMENT

4.1 Impact of the Project on the Geological Environment during the Construction period

The impact of the project alternatives on the geological environment will predominantly relate to the impact that the development will have on the soils/rock units beneath the site. The impact of the development and construction, and operation of the proposed Soyuz 2 Solar PV Park activity on the geological environment is limited to topsoil stripping, excavations for pad foundations (if required), trenching, the construction of access roads, and associated light infrastructure. Bulk earthworks, where required for the construction of platforms and access roads, may generate a significant impact on the soils and rocks where construction takes place.

The primary concern associated with geotechnical works is increased soil erosion on site, due to the stripping of vegetation during the construction phase of the project. Removal of vegetation reduces infiltration, thereby increasing runoff yielding increased erosion. Further, compaction during earthworks reduces rainwater infiltration and increases surface runoff and increasing erosion. The construction of paved and/or hard-surfaced areas increases runoff and often localises discharge of stormwater, which may lead to increased erosion and consequently loss of topsoil. Disturbance of the soil may extend beyond the footprint of the structures should such conditions persist for long periods, e.g., more than 10 years.

4.2 Proposed Soyuz 2 Solar PV Park

For ease of reference, separate impact rating tables have been presented in the subsequent sections for the construction phase, the operational phase, and the decommissioning phase:

- Expected impacts on soil, during the construction phase, within the development area of Soyuz 2 Solar PV Park are presented in **Table 3**.
- Expected impacts on soil, during the operational phase, within the development area of Soyuz 2 Solar PV Park are presented in **Table 4**.
- Expected impacts on soil, during the decommissioning phase, within the development of Soyuz 2 Solar PV Park are presented in **Table 5**.

Table 3: Impact table of soil erosion, contamination and destabilisation due to the Construction Phase.

IMPACT NATURE	**Impact – Nature of Impact** **Geological Impact – soil erosion**		**STATUS**	**NEGATIVE**
Impact Description	Soil erosion, contamination and destabilisation			
Impact Source(s)	Stripping of vegetation during construction Machinery and earth-moving plant causing spills contaminating soils			
Receptor(s)	Soil, biota, and vegetation			
PARAMETER	**WITHOUT MITIGATION**	**SCORE**	**WITH MITIGATION**	**SCORE**
EXTENT (A)	Preferred Alternative:	1	Preferred Alternative:	1
	No-Go Alternative:		No-Go Alternative:	
DURATION (B)	Preferred Alternative:	1	Preferred Alternative:	1
	No-Go Alternative:		No-Go Alternative:	
PROBABILITY (C)	Preferred Alternative:	2	Preferred Alternative:	1
	No-Go Alternative:		No-Go Alternative:	
INTENSITY OR MAGNITUDE (D)	Preferred Alternative:	-1	Preferred Alternative:	1
	No-Go Alternative:		No-Go Alternative:	
SIGNIFICANCE RATING (F) = (A*B*D)*C	Preferred Alternative:	**-2**	Preferred Alternative:	**1**
	No-Go Alternative:		No-Go Alternative:	
CUMULATIVE IMPACTS	Low			
CONFIDENCE	Medium			
MITIGATION MEASURES	• Do not prolong the construction period; and rehabilitate any disturbed areas following completion of the construction period, whether complete or on hold. • Only designated laydown areas and access roads, within appropriate locations, should be used. • Where required, during construction, temporary drainage channels should divert surface runoff to appropriate areas. • Appropriately design drainage for infrastructure and roads. • Implement erosion control measures, where appropriate, e.g. erosion control mats. • Vehicles should be well maintained, parked over drip trays/hard-surfaced areas, and parked within designated areas.			

Table 4: Impact table of soil erosion, contamination and destabilisation due to the Operational Phase.

<table>
<tr><td>IMPACT NATURE</td><td colspan="2">Impact – Nature of Impact
Geological Impact – soil erosion</td><td>STATUS</td><td>NEGATIVE</td></tr>
<tr><td>Impact Description</td><td colspan="4">Soil erosion, contamination and destabilisation</td></tr>
<tr><td>Impact Source(s)</td><td colspan="4">The concentration of runoff due to hard surfaces, i.e. paved areas, PV tables, and support structures.
Creating access roads in areas of open veld resulting in the increased runoff.
The concentration of natural drainage (and increasing runoff) due to paved areas.
Increased siltation within natural water courses due to increased runoff and soil erosion.</td></tr>
<tr><td>Receptor(s)</td><td colspan="4">Soil, biota, and vegetation</td></tr>
<tr><td>PARAMETER</td><td>WITHOUT MITIGATION</td><td>SCORE</td><td>WITH MITIGATION</td><td>SCORE</td></tr>
<tr><td rowspan="2">EXTENT (A)</td><td>Preferred Alternative:</td><td>1</td><td>Preferred Alternative:</td><td>1</td></tr>
<tr><td>No-Go Alternative:</td><td></td><td>No-Go Alternative:</td><td></td></tr>
<tr><td rowspan="2">DURATION (B)</td><td>Preferred Alternative:</td><td>2</td><td>Preferred Alternative:</td><td>1</td></tr>
<tr><td>No-Go Alternative:</td><td></td><td>No-Go Alternative:</td><td></td></tr>
<tr><td rowspan="2">PROBABILITY (C)</td><td>Preferred Alternative:</td><td>2</td><td>Preferred Alternative:</td><td>1</td></tr>
<tr><td>No-Go Alternative:</td><td></td><td>No-Go Alternative:</td><td></td></tr>
<tr><td rowspan="2">INTENSITY OR MAGNITUDE (D)</td><td>Preferred Alternative:</td><td>-2</td><td>Preferred Alternative:</td><td>1</td></tr>
<tr><td>No-Go Alternative:</td><td></td><td>No-Go Alternative:</td><td></td></tr>
<tr><td rowspan="2">SIGNIFICANCE RATING (F) = (A*B*D)*C</td><td>Preferred Alternative:</td><td>-8</td><td>Preferred Alternative:</td><td>1</td></tr>
<tr><td>No-Go Alternative:</td><td></td><td>No-Go Alternative:</td><td></td></tr>
<tr><td>CUMULATIVE IMPACTS</td><td colspan="4">Low</td></tr>
<tr><td>CONFIDENCE</td><td colspan="4">Medium</td></tr>
<tr><td>MITIGATION MEASURES</td><td colspan="4">• Design appropriate drainage around photovoltaic tables, access roads and support structures.
• Only designated access roads should be used during operation, driving in vegetated areas will flatten and remove vegetation over time inducing increased runoff resulting in soil erosion.
• Implement erosion control measures, where appropriate, e.g. erosion control mats.
• Natural drainage in the region should be designed and managed appropriately.
• Vehicles should be well maintained, parked over drip trays/hard-surfaced areas, and parked within designated areas.</td></tr>
</table>

Table 5: Impact table of soil erosion, contamination and destabilisation due to the Decommissioning Phase.

IMPACT NATURE	**Impact – Nature of Impact** **Geological Impact – soil erosion**		**STATUS**	**NEGATIVE**
Impact Description	Soil erosion, contamination and destabilisation			
Impact Source(s)	Soil destabilisation and erosion due to infrastructure removal. Spillages from vehicles. Increased siltation within natural water courses due to increased runoff and soil erosion.			
Receptor(s)	Soil, biota, and vegetation			
PARAMETER	**WITHOUT MITIGATION**	**SCORE**	**WITH MITIGATION**	**SCORE**
EXTENT (A)	Preferred Alternative:	1	Preferred Alternative:	1
	No-Go Alternative:		No-Go Alternative:	
DURATION (B)	Preferred Alternative:	2	Preferred Alternative:	1
	No-Go Alternative:		No-Go Alternative:	
PROBABILITY (C)	Preferred Alternative:	2	Preferred Alternative:	1
	No-Go Alternative:		No-Go Alternative:	
INTENSITY OR MAGNITUDE (D)	Preferred Alternative:	-2	Preferred Alternative:	1
	No-Go Alternative:		No-Go Alternative:	
SIGNIFICANCE RATING (F) = (A*B*D)*C	Preferred Alternative:	**-8**	Preferred Alternative:	**1**
	No-Go Alternative:		No-Go Alternative:	
CUMULATIVE IMPACTS	Low			
CONFIDENCE	Medium			
MITIGATION MEASURES	• Vehicles should be well maintained, parked over drip trays/hard-surfaced areas, and parked within designated areas. • Land rehabilitation to near natural state, i.e. removal of foundations and filling of any resultant voids within the soil, as well as removal of hard surfaced areas. Replacement soil should be sourced locally to ensure homogeneity.			

4.3 Summary of Impacts on Geological and Geotechnical Conditions

The impacts to be considered from a geotechnical standpoint for the proposed Soyuz 2 Solar PV Park are contained in **Table 6**. It is important to point out that regardless of the specific location(s) at which the various components of the proposed development are constructed within the property boundaries shown in **Map 2**, the outcome of the impact assessment remains valid.

Table 6: Summary table of impacts on geological and geotechnical conditions

DESCRIPTION OF IMPACT	Overall Significance	
	No-Go Alternative	Preferred Alternative
Increased soil erosion	Low	Low
Soil contamination	Low	Low
Soil destabilisation	Low	Low

5. LEGISLATIVE AND PERMIT REQUIREMENTS

This section has been divided as follows, based on the impacts that may transpire during the construction, operation and decommissioning phases of the proposed development:

- Loss of geological materials.
- Removal of geologic materials.
- Contamination of geologic materials as a consequence of typical maintenance activities.

From a permitting perspective, mining and quarrying on the proposed site is likely seen as a listed activity in terms of the National Environmental Management Act, 1998 (Act No 107 of 1998), as amended. It is advised that the environmental assessment practitioner assess the project with regards to this activity. Furthermore, where there may be existing services on the proposed development an excavation/wayleave permit may be required.

The norms and references given below are not exhaustive.

5.1 Loss of geological material (soil erosion)

Relevant legislation and guidelines pertaining to soil conservation, particularly soil erosion includes:

- Conservation of Agricultural Resources Act, 1983 (Act No 43 of 1983)
- Environmental Conservation Act, 1998 (Act No 73 of 1989)
- National Forestry Act, 1998 (Act No 84 of 1998, as amended
- National Environmental Management Act, 1998 (Act No 107 of 1998), as amended
- The Department of Water Affairs and Forestry, February 2005. Environmental Best Practice Specifications: Construction Integrated Environmental Management Sub-Series No. IEMS 1.6. Third Edition. Pretoria.

5.2 Contamination of geologic materials

Relevant literature pertaining to contamination of soil, includes:

- National Environmental Management: Waste Act, 2008 (Act No 59 of 2008)
- National Water Act, 1998 ((Act No 36 of 1998) (NWA) Section 19.

6. PLAN OF STUDY FOR IMPACT ASSESSMENT PHASE

6.1 Aims of geotechnical investigation for environmental impact assessment phase

The geotechnical impact assessment phase of the project will aim to define the potential geotechnical impacts of the development with a specific focus on the proposed position of planned structures. These structures will potentially include O&M structures, BESS structures, EGI-related structures, substations, individual PV panels, access roads, etc.

The information required for this phase will primarily include a more focussed geotechnical assessment and review of proposed site plan in relation to the structural properties of the individual buildings and the immediate environment. Specific impact focal points include

Soil Erosion
Soil Contamination
Soil Destabilisation

6.2 Proposed plan of study of geotechnical investigation for environmental impact assessment phase

The proposed plan of study would consist of a desktop-based review of all available information on the site, with the inclusion of more detailed structural properties of the proposed structures. A special focus will also be given to the following areas which are especially prone to geotechnical impacts:

Locations of temporary construction areas
Locations of temporary laydown areas
Locations of access roads

The specific position of structures will also be assessed in relation to:

Currently known erosion paths
Areas of non-ideal slope angles
Areas with especially prevalent calcic soils

6.3 Limitations of the proposed plan of study

It should be noted that this study plan for the impact assessment phase does not include any physical investigative methods or laboratory testing. It is, however, essential that a detailed and intrusive geotechnical investigation be performed before the final structural design and construction phase of the project.

7. CONCLUSIONS

This report summarises the results from a reconnaissance specialist study that aimed to project a high-level overview of envisaged risks from a geotechnical standpoint and provide broad recommendations for high-level designs. Based on the findings of this study, development should proceed provided the mitigation measures are implemented. The following conclusions can be drawn from the investigation:

1. The impact of the proposed development is expected to be low and is anticipated to have little effect on the site from a geotechnical point of view.
2. Increased soil erosion may transpire as an impact of development, this may persist for the life of the project. However, the impact of this is expected to be very low and is anticipated to have little effect on the site from a geotechnical point of view.
3. Variable soil and rock conditions exist across the site, broadly these have been divided as follows:
    a. Zone A – Karoo sandstones, siltstones, and mudstones
    b. Zone B – Karoo dolerite
    c. Zone C – Quaternary sediments
4. Each proposed structure's footprint would have to be investigated before the compilation of final design. This is due to the potentially expansive and collapsible characteristics inherent within the soil. Furthermore, intrusive investigations characterising the sub-soil beneath calcrete horizons are required to define the stability of the soil profile at each site.
5. Owing to the variable geologic and soil conditions across the proposed development area, the subgrade conditions will vary across the site. Dolerite has been proven to perform well as an aggregate for wearing courses and has been incorporated as an aggregate in concrete mixes. Calcrete has also been used extensively as wearing course for unpaved roads; however, the material must be sufficiently characterised before incorporation due to variable performance. Karoo mudrock and sandstone should be avoided when selecting aggregates for concrete mixes.
6. The excavatability of the stratum on site is anticipated to be moderately variable, based on material composition and texture, the degree of weathering, and the nature of discontinuities within the rock and/or soil mass.
7. The seismicity in the region is considered to have an NPGA that is below 0.1 g once every 475 years. The design phase for such regions typically does not consider allowances for potential regional seismicity.
8. From a geotechnical perspective, no areas that should be avoided or classified as "no-go areas" were identified for the proposed development; however, this is subject to confirmation by intrusive investigations and detailed material characterisation.
9. Intrusive investigations will be required to confirm the anticipated conditions at each of the PV cluster positions and all other associated structures.
10. Any road cuttings should be designed by an appropriately qualified professional.
11. GEOSS has endeavoured to highlight and characterise all potential geotechnical risks that are presented by the site that has been proposed for development. However, due to the anisotropic (variable) nature of earth materials, each point on the site will present results that differ. For this reason, it is considered of the utmost importance that the foundation

excavations be inspected before casting to ensure that soil with an adequate bearing capacity is obtained beneath each footing. These works should be carried out by an appropriately qualified individual.

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9. APPENDIX A: IMPACT ASSESSMENT METHODOLOGY

Impact Table Methodology

1. Definitions of terminology

The following points, tables and descriptions presented below were presented by Terramanzi Group (Pty) Ltd to be used as a guideline when assessing potential risks and impacts for the proposed development.

1. Definitions of terminology

ITEM	DEFINITION
EXTENT	
Local	Extending only as far as the boundaries of the activity, limited to the site and its immediate surroundings
Regional	Impact on the broader region
National	Will have an impact on a national scale or across international borders
DURATION	
Short-term	0-5 years
Medium-Term	5-15 years
Long-Term	>15 years, where the impact will cease after the operational life of the activity
Permanent	Where mitigation, either by natural process or human intervention, will not occur in such a way or in such a time span that the impact can be considered transient.
MAGNITUDE OR INTENSITY	
Low	Where the receiving natural, cultural or social function/environment is negligibly affected or where the impact is so low that remedial action is not required.
Medium	Where the affected environment is altered, but not severely and the impact can be mitigated successfully and natural, cultural or social functions and processes can continue, albeit in a modified way.
High	Where natural, cultural or social functions or processes are substantially altered to a very large degree. If a negative impact then this could lead to unacceptable consequences for the cultural and/or social functions and/or irreplaceable loss of biodiversity to the extent that natural, cultural or social functions could temporarily or permanently cease.
PROBABILITY	
Improbable	Where the possibility of the impact materialising is very low, either because of design or historic experience
Probable	Where there is a distinct possibility that the impact will occur
Highly Probable	Where it is most likely that the impact will occur
Definite	Where the impact will undoubtedly occur, regardless of any prevention measures
SIGNIFICANCE	
Low	Where a potential impact will have a negligible effect on natural, cultural or social environments and the effect on the decision is negligible. This will not require special design considerations for the project
Medium	Where it would have, or there would be a moderate risk to natural, cultural or social environments and should influence the decision. The project will require modification or mitigation measures to be included in the design
High	Where it would have, or there would be a high risk of, a large effect on natural, cultural or social environments. These impacts should have a major influence on decision making.
Very High	Where it would have, or there would be a high risk of, an irreversible negative impact on biodiversity and irreplaceable loss of natural capital that could result in the project being environmentally unacceptable, even with mitigation. Alternatively, it could lead to a major positive effect. Impacts of this nature must be a central factor in decision making.
STATUS OF IMPACT	
Whether the impact is positive (a benefit), negative (a cost) or neutral (status quo maintained)	
DEGREE OF CONFIDENCE IN PREDICTIONS	
The degree of confidence in the predictions is based on the availability of information and specialist knowledge (e.g. low, medium or high)	
MITIGATION	

Mechanisms used to control, minimise and or eliminate negative impacts on the environment and to enhance project benefits Mitigation measures should be considered in terms of the following hierarchy: (1) avoidance, (2) minimisation, (3) restoration and (4) off-sets.

2. Scoring System for Impact Assessment Ratings

To comparatively rank the impacts, each impact has been assigned a score using the scoring system outlined in the Table below. This scoring system allows for a comparative, accountable assessment of the indicative cumulative positive or negative impacts of each aspect assessed.

IMPACT PARAMETER	**SCORE**	
Extent (A)	**Rating**	
Local	1	
Regional	2	
National	3	
Duration (B)	**Rating**	
Short term	1	
Medium Term	2	
Long Term	3	
Permanent	4	
Probability (C)	**Rating**	
Improbable	1	
Probable	2	
Highly Probable	3	
Definite	4	
IMPACT PARAMETER	**NEGATIVE IMPACT SCORE**	**POSITIVE IMPACT SCORE**
Magnitude/Intensity (D)	**Rating**	**Rating**
Low	-1	1
Medium	-2	2
High	-3	3
SIGNIFICANCE RATING (F) = (A*B*D)*C	**Rating**	**Rating**
Low	0 to - 40	0 to 40
Medium	- 41 to - 80	41 to 80
High	- 81 to - 120	81 to 120
Very High	> - 120	> 120

Please complete the following Tables for <u>EACH IDENTIFIED IMPACT</u>.

IMPACT NATURE	**Impact – Nature of Impact** Eg. Botanical Impact – Loss of natural vegetation		**STATUS**	**POSITIVE/NEGATIVE**
Impact Description				
Impact Source(s)				
Receptor(s)				
PARAMETER	**WITHOUT MITIGATION**	**SCORE**	**WITH MITIGATION**	**SCORE**
EXTENT (A)	Preferred Alternative:		Preferred Alternative:	
	No-Go Alternative:		No-Go Alternative:	
DURATION (B)	Preferred Alternative:		Preferred Alternative:	
	No-Go Alternative:		No-Go Alternative:	
PROBABILITY (C)	Preferred Alternative:		Preferred Alternative:	
	No-Go Alternative:		No-Go Alternative:	
INTENSITY OR MAGNITUDE (D)	Preferred Alternative:		Preferred Alternative:	
	No-Go Alternative:		No-Go Alternative:	
SIGNIFICANCE RATING (F) = (A*B*D)*C	Preferred Alternative:		Preferred Alternative:	
	No-Go Alternative:		No-Go Alternative:	
CUMULATIVE IMPACTS				
CONFIDENCE				
MITIGATION MEASURES				

10. APPENDIX B: GEOTECHNICAL INFORMATION

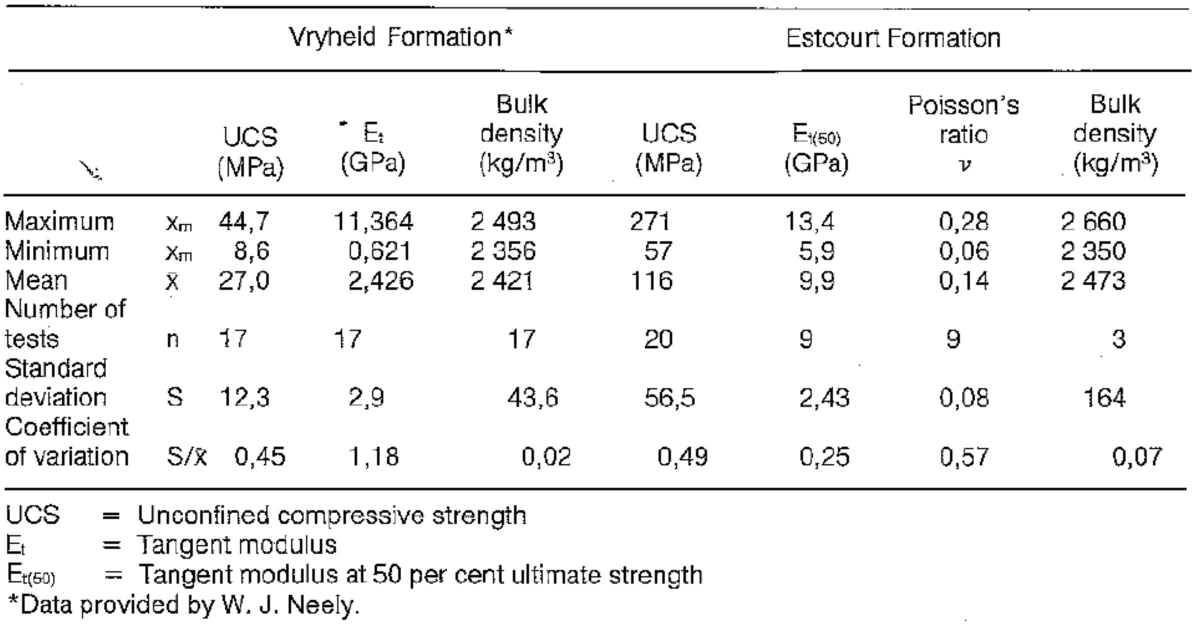
10.1 Karoo Supergroup (Zone A)

Karoo sandstone is often not desirable in construction, e.g. as an aggregate, as it may cause concrete to deteriorate over time (Brink, 1977). In this regard, the following has been observed when making use of Karoo sandstones in construction (after Brink, 1983):

1. Deflection and shrinkage of reinforced members.
2. Corrosion of reinforcing steel.
3. Coincident cracking of concrete and reinforcement.
4. Surface crazing or pattern cracking.
5. Premature distress of roads constructed using aggregates derived from Karoo sandstones.

Control of material properties is required when making use of Karoo sandstones in construction.

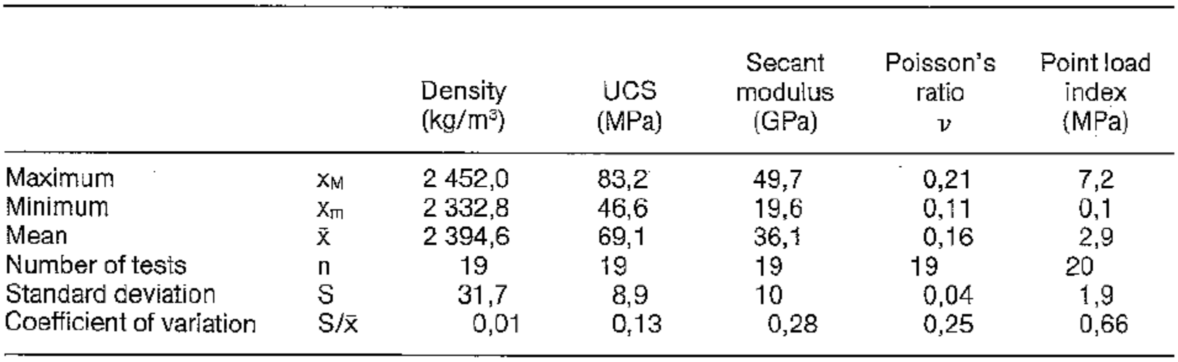
Table 7: Strength and deformation characteristics of some Karoo Sandstones (Brink, 1983).



		Vryheid Formation*			Estcourt Formation			
		UCS (MPa)	* E_t (GPa)	Bulk density (kg/m^3)	UCS (MPa)	$E_{t(50)}$ (GPa)	Poisson's ratio ν	Bulk density (kg/m^3)
Maximum	x_m	44,7	11,364	2 493	271	13,4	0,28	2 660
Minimum	x_m	8,6	0,621	2 356	57	5,9	0,06	2 350
Mean	$\bar{x}$	27,0	2,426	2 421	116	9,9	0,14	2 473
Number of tests	n	17	17	17	20	9	9	3
Standard deviation	S	12,3	2,9	43,6	56,5	2,43	0,08	164
Coefficient of variation	S/$\bar{x}$	0,45	1,18	0,02	0,49	0,25	0,57	0,07

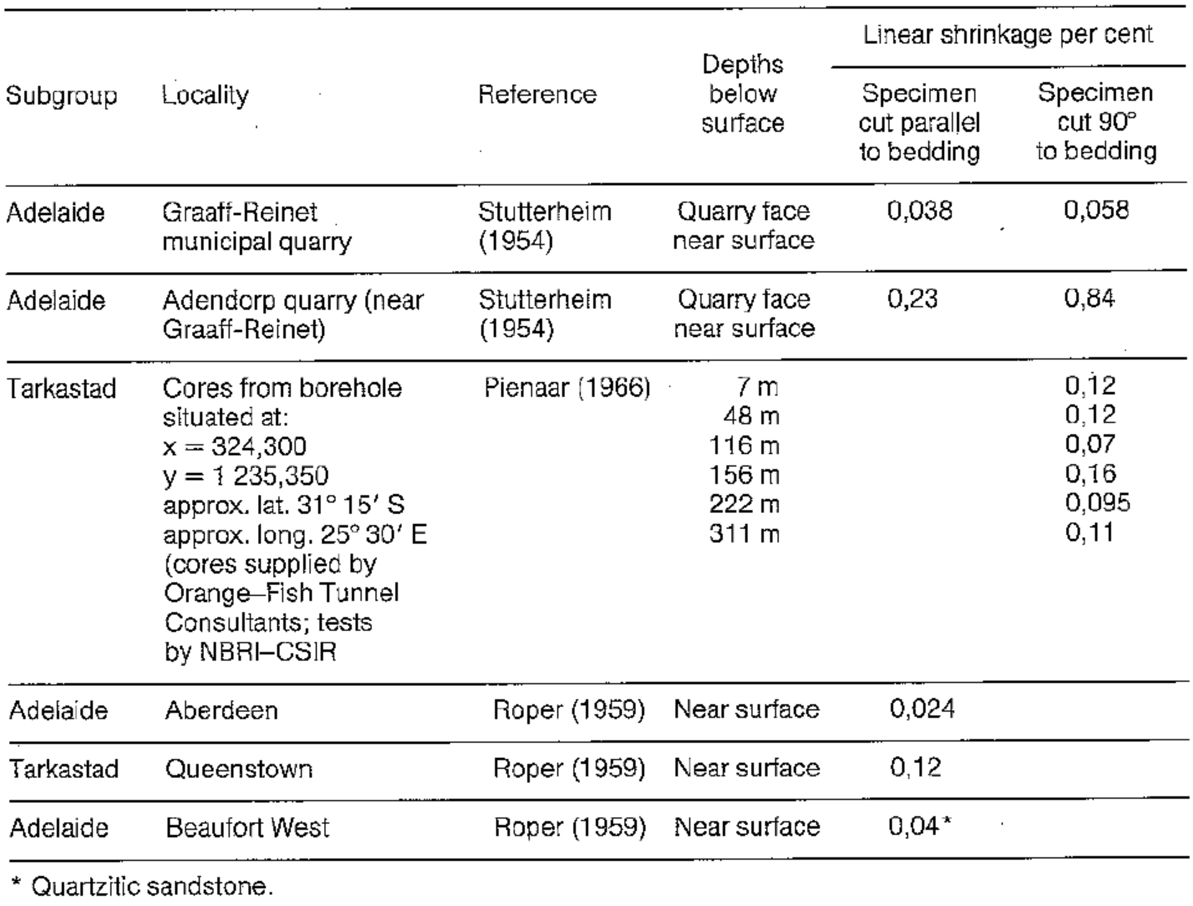
UCS = Unconfined compressive strength
E_t = Tangent modulus
$E_{t(50)}$ = Tangent modulus at 50 per cent ultimate strength
*Data provided by W. J. Neely.

Table 8: Geotechnical properties of Ecca Group sandstone at Matimba Power Station (Brink, 1983).



		Density (kg/m^3)	UCS (MPa)	Secant modulus (GPa)	Poisson's ratio ν	Point load index (MPa)
Maximum	x_M	2 452,0	83,2	49,7	0,21	7,2
Minimum	x_m	2 332,8	46,6	19,6	0,11	0,1
Mean	$\bar{x}$	2 394,6	69,1	36,1	0,16	2,9
Number of tests	n	19	19	19	19	20
Standard deviation	S	31,7	8,9	10	0,04	1,9
Coefficient of variation	S/$\bar{x}$	0,01	0,13	0,28	0,25	0,66

Table 9: Drying and shrinkage determinations on some sandstones of the Beaufort Group (Brink, 1983).



Subgroup	Locality	Reference	Depths below surface	Linear shrinkage per cent	
				Specimen cut parallel to bedding	Specimen cut 90° to bedding
Adelaide	Graaff-Reinet municipal quarry	Stutterheim (1954)	Quarry face near surface	0,038	0,058
Adelaide	Adendorp quarry (near Graaff-Reinet)	Stutterheim (1954)	Quarry face near surface	0,23	0,84
Tarkastad	Cores from borehole situated at: x = 324,300 y = 1 235,350 approx. lat. 31° 15′ S approx. long. 25° 30′ E (cores supplied by Orange–Fish Tunnel Consultants; tests by NBRI–CSIR	Pienaar (1966)	7 m 48 m 116 m 156 m 222 m 311 m		0,12 0,12 0,07 0,16 0,095 0,11
Adelaide	Aberdeen	Roper (1959)	Near surface	0,024	
Tarkastad	Queenstown	Roper (1959)	Near surface	0,12	
Adelaide	Beaufort West	Roper (1959)	Near surface	0,04*	

* Quartzitic sandstone.

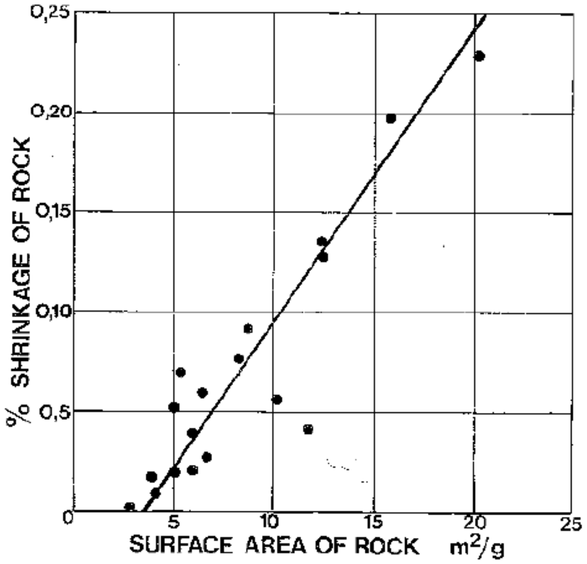
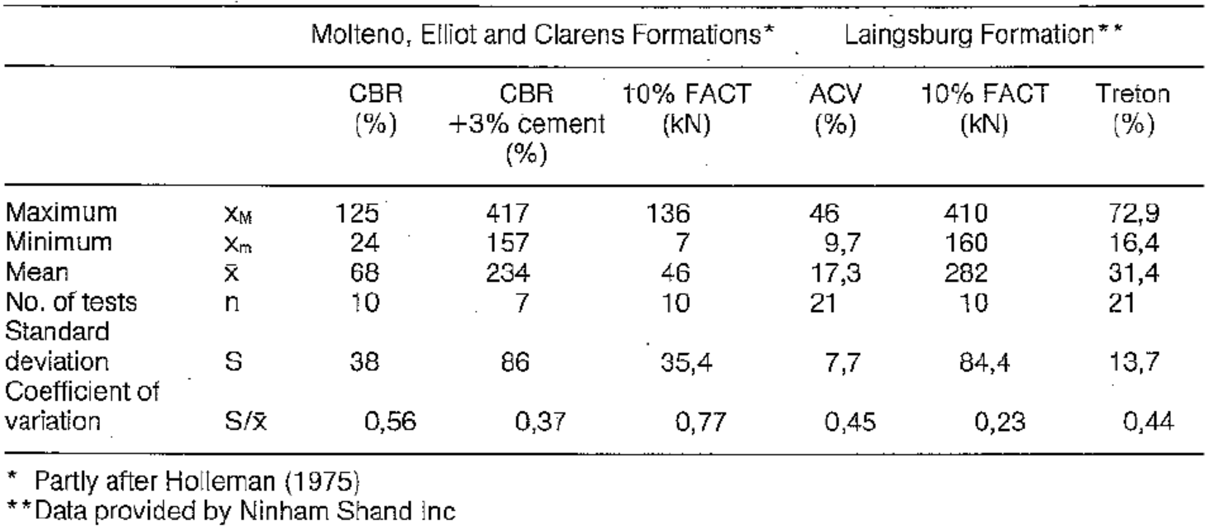


Figure 8: Relation between shrinkage and surface area for a variety of rocks including Karoo sandstone (Brink, 1983).

Table 10: Road construction characteristics of some Karoo sandstones (Brink, 1983).

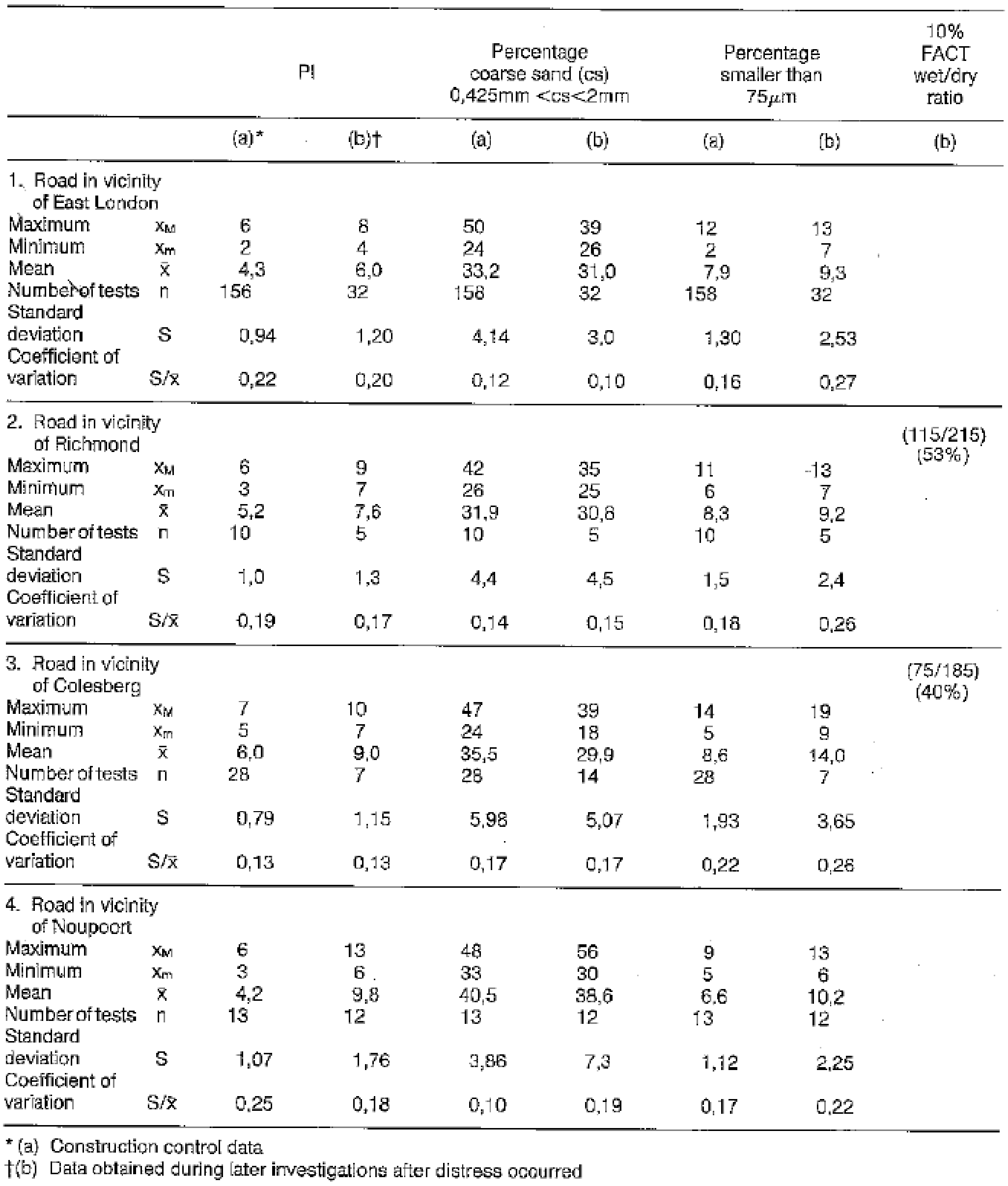


		Molteno, Elliot and Clarens Formations*			Laingsburg Formation**		
		CBR (%)	CBR +3% cement (%)	10% FACT (kN)	ACV (%)	10% FACT (kN)	Treton (%)
Maximum	x_M	125	417	136	46	410	72,9
Minimum	x_m	24	157	7	9,7	160	16,4
Mean	$\bar{x}$	68	234	46	17,3	282	31,4
No. of tests	n	10	7	10	21	10	21
Standard deviation	S	38	86	35,4	7,7	84,4	13,7
Coefficient of variation	$S/\bar{x}$	0,56	0,37	0,77	0,45	0,23	0,44

* Partly after Holleman (1975)

**Data provided by Ninham Shand Inc

Table 11: Changes in engineering properties of Adelaide Subgroup sandstone aggregates under traffic (Brink, 1983).



		PI		Percentage coarse sand (cs) 0,425mm <cs<2mm		Percentage smaller than 75μm		10% FACT wet/dry ratio
		(a)*	(b)†	(a)	(b)	(a)	(b)	(b)
1. Road in vicinity of East London								
Maximum	x_M	6	8	50	39	12	13	
Minimum	x_m	2	4	24	26	2	7	
Mean	$\bar{x}$	4,3	6,0	33,2	31,0	7,9	9,3	
Number of tests	n	156	32	158	32	158	32	
Standard deviation	S	0,94	1,20	4,14	3,0	1,30	2,53	
Coefficient of variation	S/x	0,22	0,20	0,12	0,10	0,16	0,27	
2. Road in vicinity of Richmond								(115/215) (53%)
Maximum	x_M	6	9	42	35	11	13	
Minimum	x_m	3	7	26	25	6	7	
Mean	$\bar{x}$	5,2	7,6	31,9	30,8	8,3	9,2	
Number of tests	n	10	5	10	5	10	5	
Standard deviation	S	1,0	1,3	4,4	4,5	1,5	2,4	
Coefficient of variation	$S/\bar{x}$	0,19	0,17	0,14	0,15	0,18	0,26	
3. Road in vicinity of Colesberg								(75/185) (40%)
Maximum	x_M	7	10	47	39	14	19	
Minimum	x_m	5	7	24	18	5	9	
Mean	$\bar{x}$	6,0	9,0	35,5	29,9	8,6	14,0	
Number of tests	n	28	7	28	14	28	7	
Standard deviation	S	0,79	1,15	5,98	5,07	1,93	3,65	
Coefficient of variation	$S/\bar{x}$	0,13	0,13	0,17	0,17	0,22	0,26	
4. Road in vicinity of Noupoort								
Maximum	x_M	6	13	48	56	9	13	
Minimum	x_m	3	6	33	30	5	6	
Mean	$\bar{x}$	4,2	9,8	40,5	38,6	6.6	10,2	
Number of tests	n	13	12	13	12	13	12	
Standard deviation	S	1,07	1,76	3,86	7,3	1,12	2,25	
Coefficient of variation	$S/\bar{x}$	0,25	0,18	0,10	0,19	0,17	0,22	

* (a) Construction control data

†(b) Data obtained during later investigations after distress occurred

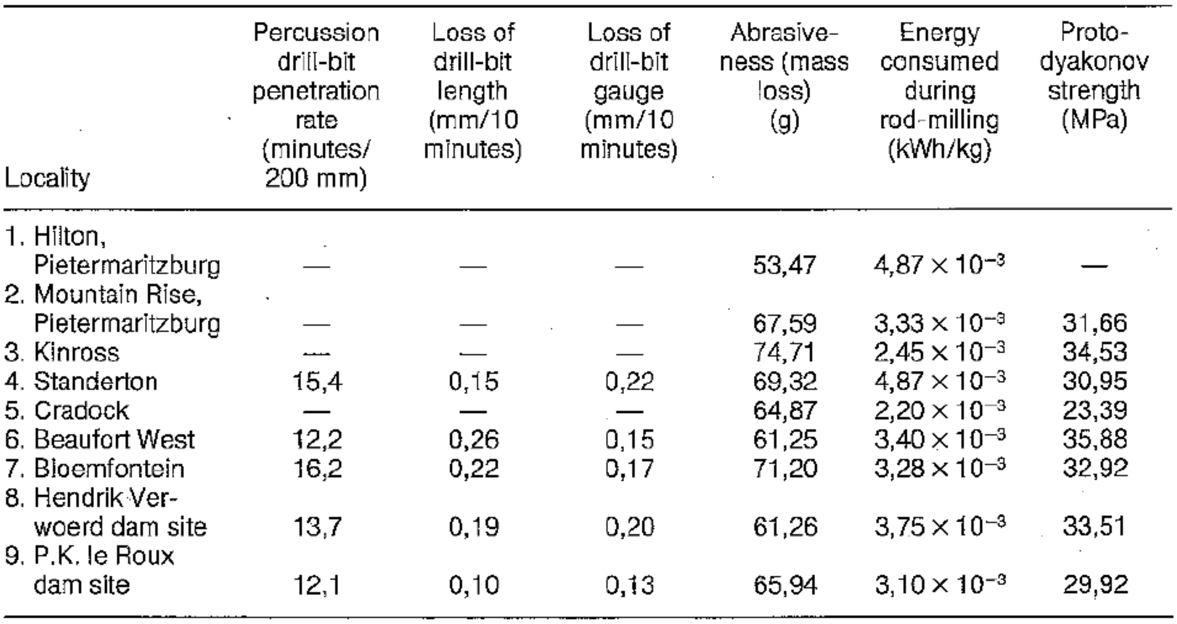
10.2 Dolerite (Zone B)

Dolerite has been extensively used as a concrete aggregate because of its sound properties and widespread occurrence in the Karoo (Brink, 1983). Some caution is required when it is considered to use certain marginal basalt-like phases of dolerite sills and dykes as sources of aggregate as these rocks may contain volcanic glass, or its alteration product palagonite which may react deleteriously with certain cements causing shrinkage cracks in concrete (Brink, 1983).

Dolerite is also a very useful source as a road construction aggregate. In bituminous surfacing, the adhesive properties of crushed fresh dolerite are usually satisfactory however, rock from chill zones could be insufficiently adhesive. With regards to subbase and base layers, freshly crushed dolerite is also an ideal aggregate. However, environmental conditions (Weinert N-value) and the stage of weathering must receive careful attention where dolerite is selected as natural gravel as this can have potential catastrophic consequences on pavement layers (Brink, 1983).

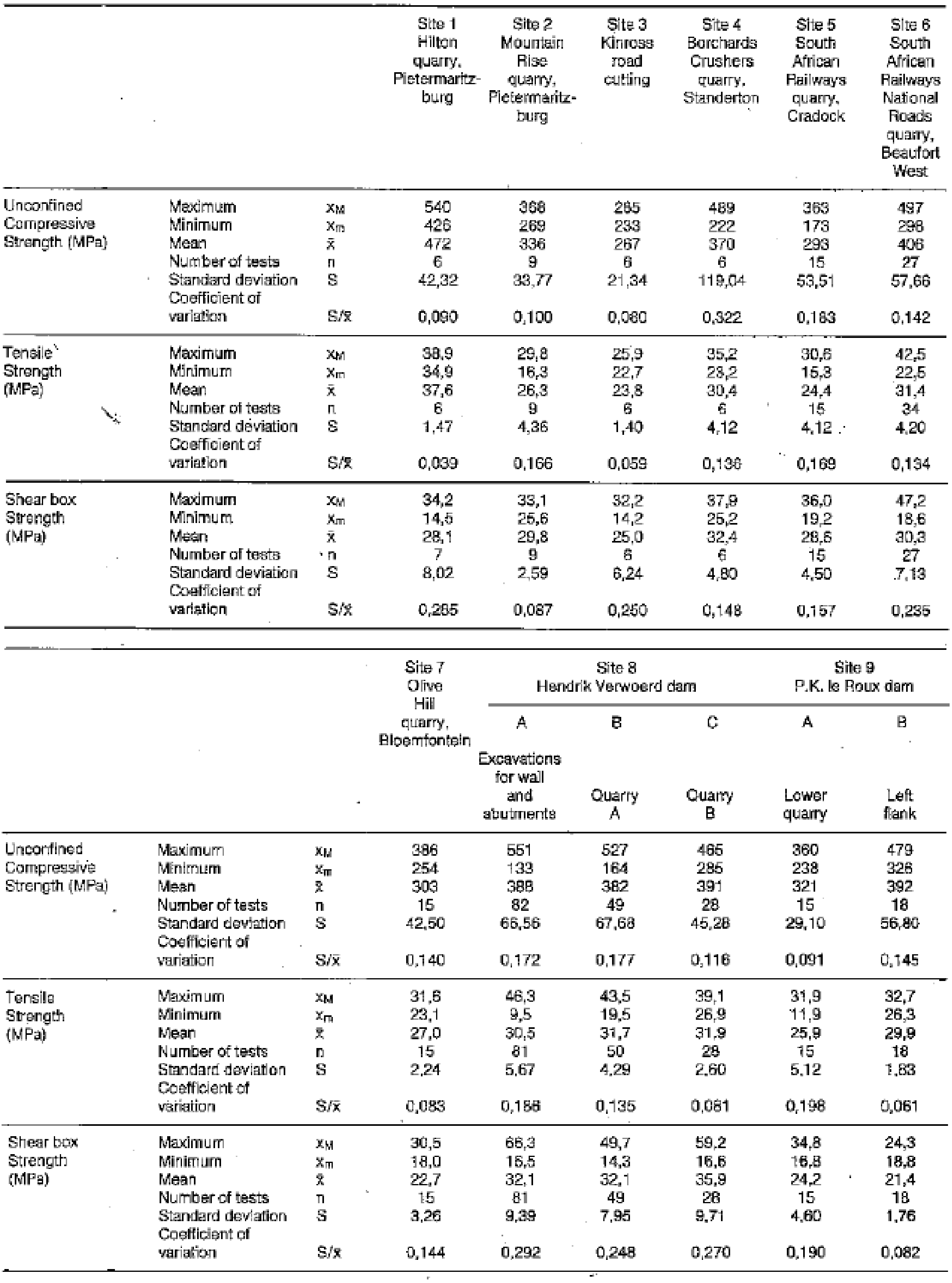
In areas where the where the Weinert N-value is more than 5 it is unlikely to encounter foundation problems on weathered dolerite, except where the soil profile contains transported soils with poor founding characteristics (Brink, 1983).

Table 12: Engineering properties of very hard rock dolerite from various locations (Brink, 1983).



Locality	Percussion drill-bit penetration rate (minutes/ 200 mm)	Loss of drill-bit length (mm/10 minutes)	Loss of drill-bit gauge (mm/10 minutes)	Abrasive-ness (mass loss) (g)	Energy consumed during rod-milling (kWh/kg)	Proto-dyakonov strength (MPa)
1. Hilton, Pietermaritzburg	—	—	—	53,47	$4,87 \times 10^{-3}$	—
2. Mountain Rise, Pietermaritzburg	—	—	—	67,59	$3,33 \times 10^{-3}$	31,66
3. Kinross	—	—	—	74,71	$2,45 \times 10^{-3}$	34,53
4. Standerton	15,4	0,15	0,22	69,32	$4,87 \times 10^{-3}$	30,95
5. Cradock	—	—	—	64,87	$2,20 \times 10^{-3}$	23,39
6. Beaufort West	12,2	0,26	0,15	61,25	$3,40 \times 10^{-3}$	35,88
7. Bloemfontein	16,2	0,22	0,17	71,20	$3,28 \times 10^{-3}$	32,92
8. Hendrik Verwoerd dam site	13,7	0,19	0,20	61,26	$3,75 \times 10^{-3}$	33,51
9. P.K. le Roux dam site	12,1	0,10	0,13	65,94	$3,10 \times 10^{-3}$	29,92

Table 13: Strength properties of fresh dolerite from various locations (Brink, 1983).



			Site 1 Hilton quarry, Pietermaritzburg	Site 2 Mountain Rise quarry, Pietermaritzburg	Site 3 Kinross road cutting	Site 4 Borchards Crushers quarry, Standerton	Site 5 South African Railways quarry, Cradock	Site 6 South African Railways National Roads quarry, Beaufort West
Unconfined Compressive Strength (MPa)	Maximum	x_M	540	368	285	489	363	497
	Minimum	x_m	426	269	233	222	173	298
	Mean	$\bar{x}$	472	336	267	370	293	406
	Number of tests	n	6	9	6	6	15	27
	Standard deviation	S	42,32	33,77	21,34	119,04	53,51	57,66
	Coefficient of variation	$S/\bar{x}$	0,090	0,100	0,080	0,322	0,183	0,142
Tensile Strength (MPa)	Maximum	x_M	38,9	29,8	25,9	35,2	30,6	42,5
	Minimum	x_m	34,9	16,3	22,7	28,2	15,3	22,5
	Mean	$\bar{x}$	37,6	26,3	23,8	30,4	24,4	31,4
	Number of tests	n	6	9	6	6	15	34
	Standard deviation	S	1,47	4,36	1,40	4,12	4,12	4,20
	Coefficient of variation	$S/\bar{x}$	0,039	0,166	0,059	0,136	0,169	0,134
Shear box Strength (MPa)	Maximum	x_M	34,2	33,1	32,2	37,9	36,0	47,2
	Minimum	x_m	14,5	25,6	14,2	25,2	19,2	18,6
	Mean	$\bar{x}$	28,1	29,8	25,0	32,4	28,6	30,3
	Number of tests	n	7	9	6	6	15	27
	Standard deviation	S	8,02	2,59	6,24	4,80	4,50	7,13
	Coefficient of variation	$S/\bar{x}$	0,285	0,087	0,250	0,148	0,157	0,235

			Site 7 Olive Hill quarry, Bloemfontein	Site 8 Hendrik Verwoerd dam			Site 9 P.K. le Roux dam	
				A	B	C	A	B
				Excavations for wall and abutments	Quarry A	Quarry B	Lower quarry	Left flank
Unconfined Compressive Strength (MPa)	Maximum	x_M	386	551	527	465	360	479
	Minimum	x_m	254	133	164	285	238	326
	Mean	$\bar{x}$	303	388	382	391	321	392
	Number of tests	n	15	82	49	28	15	18
	Standard deviation	S	42,50	66,56	67,68	45,28	29,10	56,80
	Coefficient of variation	$S/\bar{x}$	0,140	0,172	0,177	0,116	0,091	0,145
Tensile Strength (MPa)	Maximum	x_M	31,6	46,3	43,5	39,1	31,9	32,7
	Minimum	x_m	23,1	9,5	19,5	26,9	11,9	26,3
	Mean	$\bar{x}$	27,0	30,5	31,7	31,9	25,9	29,9
	Number of tests	n	15	81	50	28	15	18
	Standard deviation	S	2,24	5,67	4,29	2,60	5,12	1,83
	Coefficient of variation	$S/\bar{x}$	0,083	0,186	0,135	0,081	0,198	0,061
Shear box Strength (MPa)	Maximum	x_M	30,5	66,3	49,7	59,2	34,8	24,3
	Minimum	x_m	18,0	16,5	14,3	16,6	16,8	18,8
	Mean	$\bar{x}$	22,7	32,1	32,1	35,9	24,2	21,4
	Number of tests	n	15	81	49	28	15	18
	Standard deviation	S	3,26	9,39	7,95	9,71	4,60	1,76
	Coefficient of variation	$S/\bar{x}$	0,144	0,292	0,248	0,270	0,190	0,082

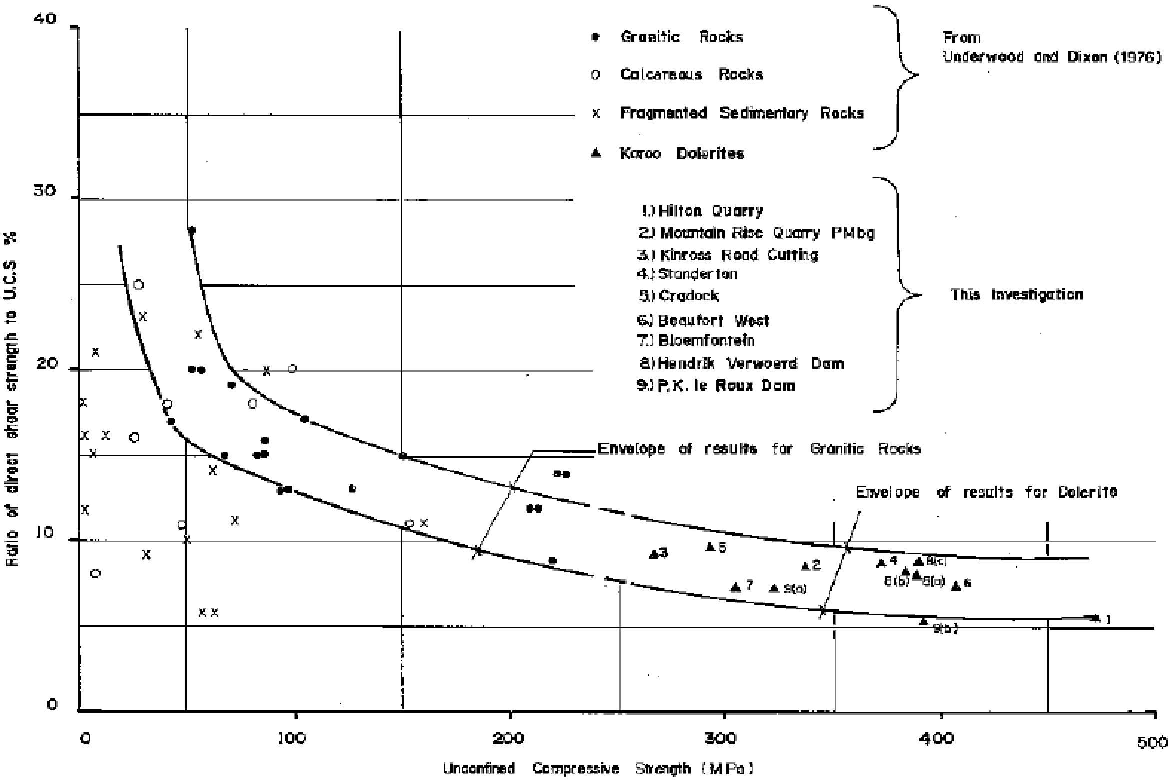


Figure 9: Variations of the shear strength to unconfined compressive strength ratio with the UCS for dolerite compared with other rock types (Brink, 1983).

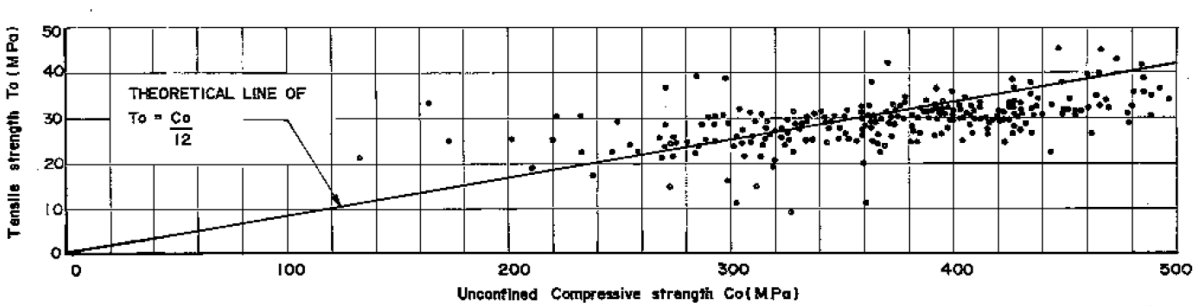
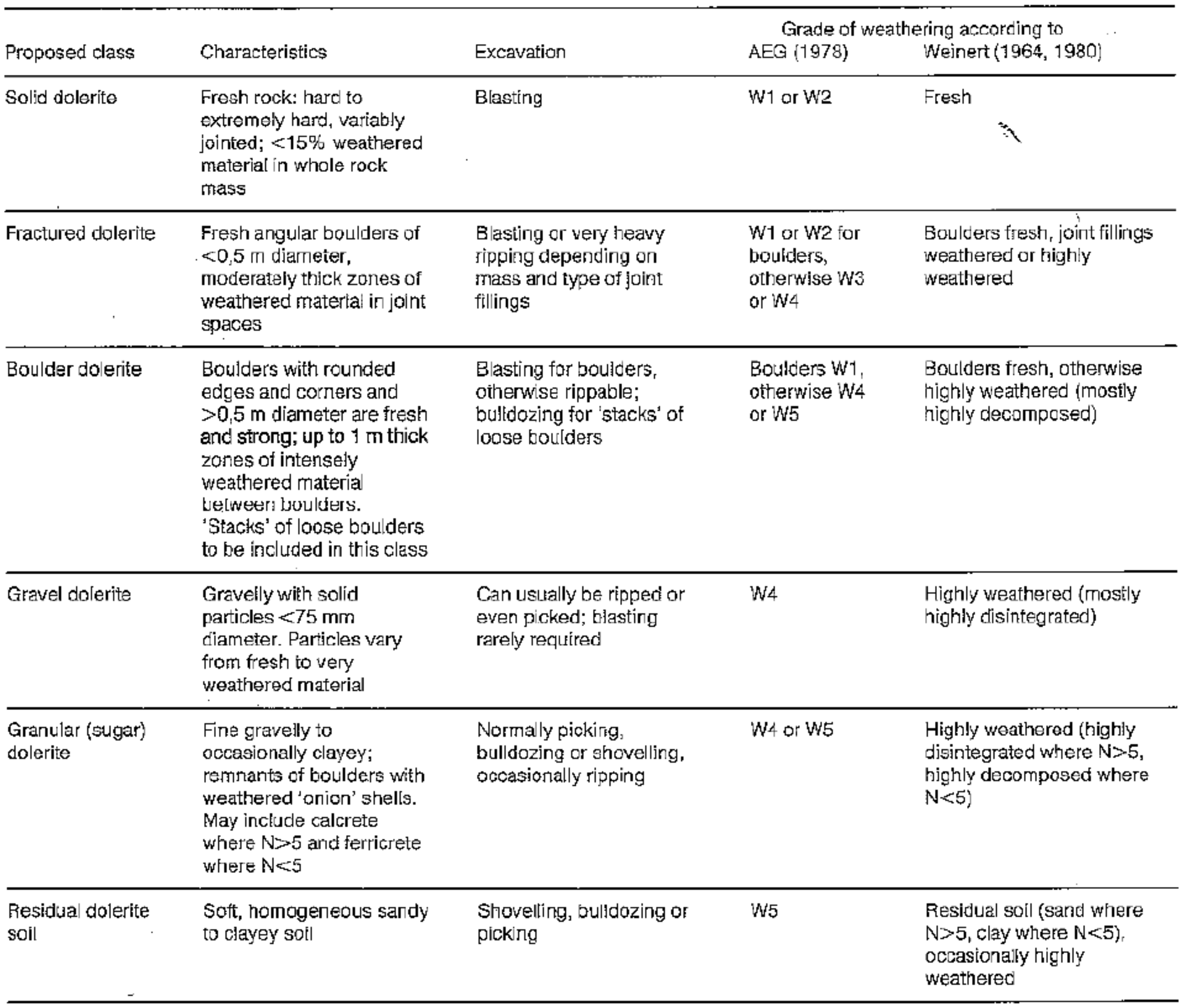


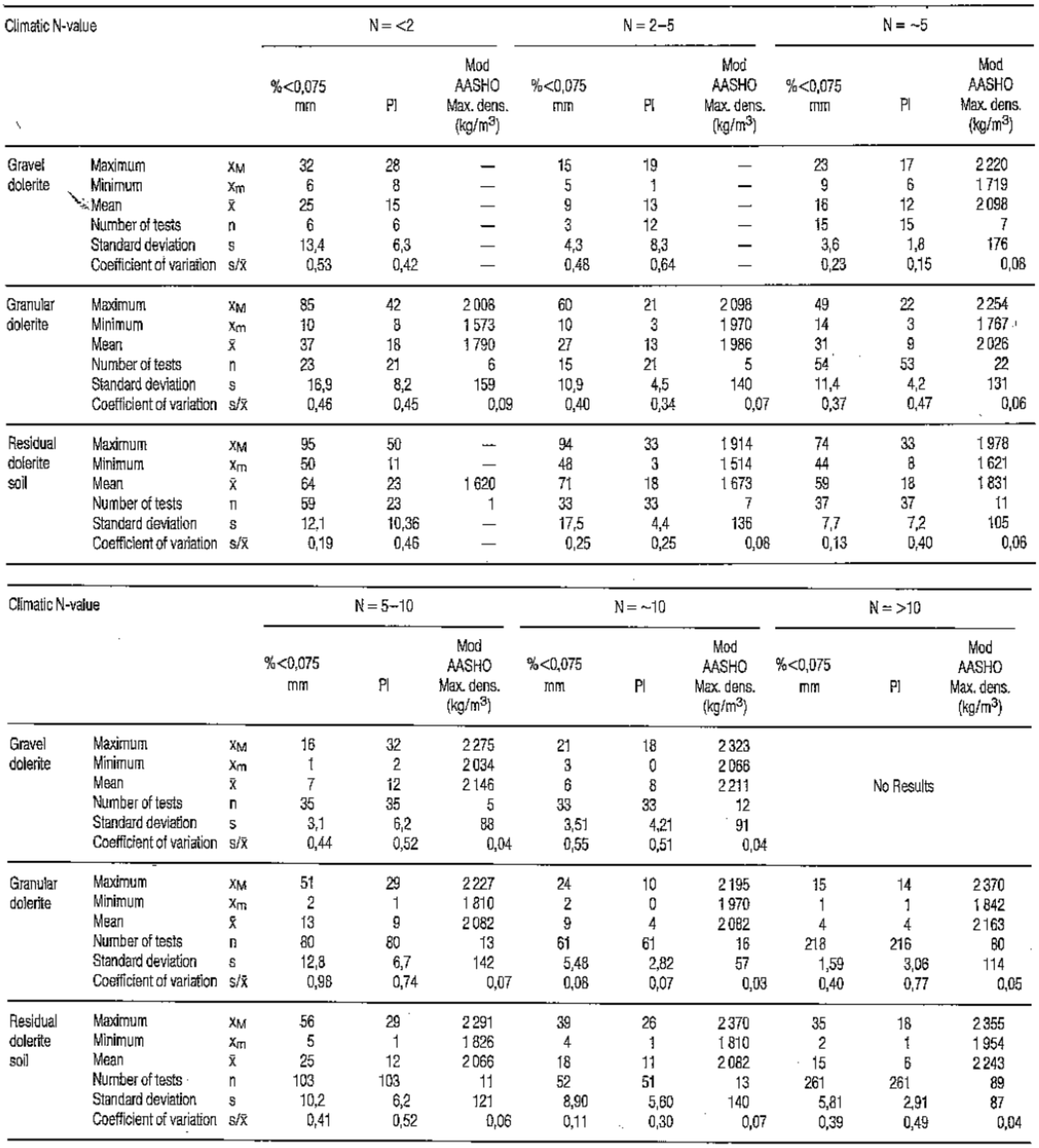
Figure 10: Relation between tensile strength and UCS of fresh dolerite specimen from South Africa (Brink, 1983).

Table 14: Weathering classes and characteristics of dolerite in South Africa (Brink, 1983).



			Grade of weathering according to	
Proposed class	Characteristics	Excavation	AEG (1978)	Weinert (1964, 1980)
Solid dolerite	Fresh rock: hard to extremely hard, variably jointed; <15% weathered material in whole rock mass	Blasting	W1 or W2	Fresh
Fractured dolerite	Fresh angular boulders of <0,5 m diameter, moderately thick zones of weathered material in joint spaces	Blasting or very heavy ripping depending on mass and type of joint fillings	W1 or W2 for boulders, otherwise W3 or W4	Boulders fresh, joint fillings weathered or highly weathered
Boulder dolerite	Boulders with rounded edges and corners and >0,5 m diameter are fresh and strong; up to 1 m thick zones of intensely weathered material between boulders. 'Stacks' of loose boulders to be included in this class	Blasting for boulders, otherwise rippable; bulldozing for 'stacks' of loose boulders	Boulders W1, otherwise W4 or W5	Boulders fresh, otherwise highly weathered (mostly highly decomposed)
Gravel dolerite	Gravelly with solid particles <75 mm diameter. Particles vary from fresh to very weathered material	Can usually be ripped or even picked; blasting rarely required	W4	Highly weathered (mostly highly disintegrated)
Granular (sugar) dolerite	Fine gravelly to occasionally clayey; remnants of boulders with weathered 'onion' shells. May include calcrete where N>5 and ferricrete where N<5	Normally picking, bulldozing or shovelling, occasionally ripping	W4 or W5	Highly weathered (highly disintegrated where N>5, highly decomposed where N<5)
Residual dolerite soil	Soft, homogeneous sandy to clayey soil	Shovelling, bulldozing or picking	W5	Residual soil (sand where N>5, clay where N<5), occasionally highly weathered

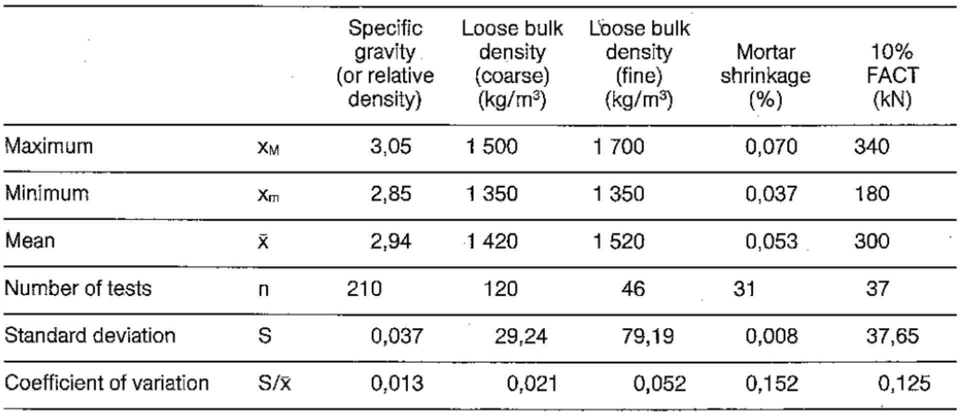
Table 15: Influence of climate on selected physical properties of weathering classes of dolerites (Brink, 1983).



Climatic N-value			N = <2			N = 2–5			N = ~5		
			%<0,075 mm	PI	Mod AASHO Max. dens. (kg/m³)	%<0,075 mm	PI	Mod AASHO Max. dens. (kg/m³)	%<0,075 mm	PI	Mod AASHO Max. dens. (kg/m³)
Gravel dolerite	Maximum	x_M	32	28	—	15	19	—	23	17	2 220
	Minimum	x_m	6	8	—	5	1	—	9	6	1 719
	Mean	$\bar{x}$	25	15	—	9	13	—	16	12	2 098
	Number of tests	n	6	6	—	3	12	—	15	15	7
	Standard deviation	s	13,4	6,3	—	4,3	8,3	—	3,6	1,8	176
	Coefficient of variation	$s/\bar{x}$	0,53	0,42	—	0,48	0,64	—	0,23	0,15	0,08
Granular dolerite	Maximum	x_M	85	42	2 008	60	21	2 098	49	22	2 254
	Minimum	x_m	10	8	1 573	10	3	1 970	14	3	1 767
	Mean	$\bar{x}$	37	18	1 790	27	13	1 986	31	9	2 026
	Number of tests	n	23	21	6	15	21	5	54	53	22
	Standard deviation	s	16,9	8,2	159	10,9	4,5	140	11,4	4,2	131
	Coefficient of variation	$s/\bar{x}$	0,46	0,45	0,09	0,40	0,34	0,07	0,37	0,47	0,06
Residual dolerite soil	Maximum	x_M	95	50	—	94	33	1 914	74	33	1 978
	Minimum	x_m	50	11	—	48	3	1 514	44	8	1 621
	Mean	$\bar{x}$	64	23	1 620	71	18	1 673	59	18	1 831
	Number of tests	n	59	23	1	33	33	7	37	37	11
	Standard deviation	s	12,1	10,36	—	17,5	4,4	136	7,7	7,2	105
	Coefficient of variation	$s/\bar{x}$	0,19	0,46	—	0,25	0,25	0,08	0,13	0,40	0,06

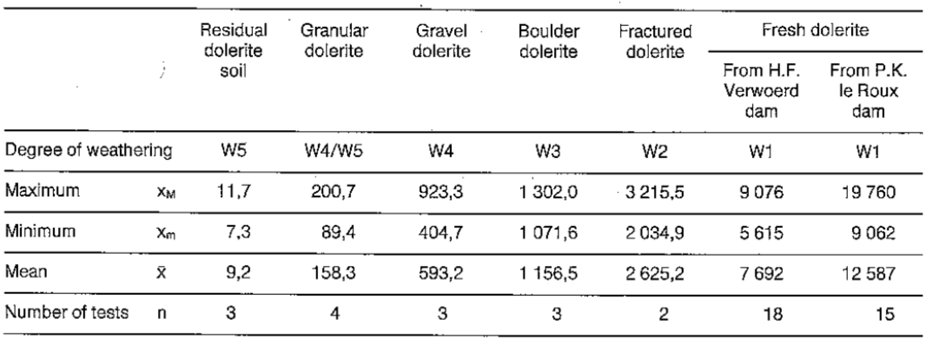
Climatic N-value			N = 5–10			N = ~10			N = >10		
			%<0,075 mm	PI	Mod AASHO Max. dens. (kg/m³)	%<0,075 mm	PI	Mod AASHO Max. dens. (kg/m³)	%<0,075 mm	PI	Mod AASHO Max. dens. (kg/m³)
Gravel dolerite	Maximum	x_M	16	32	2 275	21	18	2 323			
	Minimum	x_m	1	2	2 034	3	0	2 066			
	Mean	$\bar{x}$	7	12	2 146	6	8	2 211		No Results	
	Number of tests	n	35	35	5	33	33	12			
	Standard deviation	s	3,1	6,2	88	3,51	4,21	91			
	Coefficient of variation	$s/\bar{x}$	0,44	0,52	0,04	0,55	0,51	0,04			
Granular dolerite	Maximum	x_M	51	29	2 227	24	10	2 195	15	14	2 370
	Minimum	x_m	2	1	1 810	2	0	1 970	1	1	1 842
	Mean	$\bar{x}$	13	9	2 082	9	4	2 082	4	4	2 163
	Number of tests	n	80	80	13	61	61	16	218	216	80
	Standard deviation	s	12,8	6,7	142	5,48	2,82	57	1,59	3,06	114
	Coefficient of variation	$s/\bar{x}$	0,98	0,74	0,07	0,08	0,07	0,03	0,40	0,77	0,05
Residual dolerite soil	Maximum	x_M	56	29	2 291	39	26	2 370	35	18	2 355
	Minimum	x_m	5	1	1 826	4	1	1 810	2	1	1 954
	Mean	$\bar{x}$	25	12	2 066	18	11	2 082	15	6	2 243
	Number of tests	n	103	103	11	52	51	13	261	261	89
	Standard deviation	s	10,2	6,2	121	8,90	5,60	140	5,81	2,91	87
	Coefficient of variation	$s/\bar{x}$	0,41	0,52	0,06	0,11	0,30	0,07	0,39	0,49	0,04

Table 16: Concrete making properties of dolerite (Brink, 1983).



		Specific gravity (or relative density)	Loose bulk density (coarse) (kg/m³)	Loose bulk density (fine) (kg/m³)	Mortar shrinkage (%)	10% FACT (kN)
Maximum	x_M	3,05	1 500	1 700	0,070	340
Minimum	x_m	2,85	1 350	1 350	0,037	180
Mean	$\bar{x}$	2,94	1 420	1 520	0,053	300
Number of tests	n	210	120	46	31	37
Standard deviation	S	0,037	29,24	79,19	0,008	37,65
Coefficient of variation	$S/\bar{x}$	0,013	0,021	0,052	0,152	0,125

Table 17: Deformation characteristics (expressed in MPa) for different weathering classes of dolerite from South Africa as determined by a GB Menard pressure meter and jacking tests (Brink, 1983).



		Residual dolerite soil	Granular dolerite	Gravel dolerite	Boulder dolerite	Fractured dolerite	Fresh dolerite	
							From H.F. Verwoerd dam	From P.K. le Roux dam
Degree of weathering		W5	W4/W5	W4	W3	W2	W1	W1
Maximum	x_M	11,7	200,7	923,3	1 302,0	3 215,5	9 076	19 760
Minimum	x_m	7,3	89,4	404,7	1 071,6	2 034,9	5 615	9 062
Mean	$\bar{x}$	9,2	158,3	593,2	1 156,5	2 625,2	7 692	12 587
Number of tests	n	3	4	3	3	2	18	15

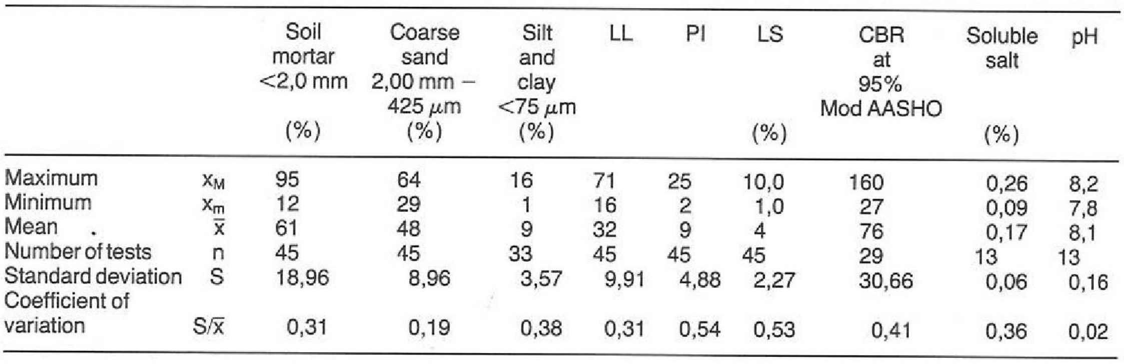
10.3 Quaternary Sediments (Zone C)

Quaternary sediments overlying the Karoo Supergroup are variable in nature based on various case studies presented by Brink (1985). Potential geotechnical problems arising from such sediments include expansive characteristics in fine grained soils and collapsible characteristics in coarse grained soils. Alluvial deposits act as valuable sources for construction material, with coarse grained material from gravel lenses or layers suitable for use as concrete aggregate, road base, or subbase (Brink 1985). This excludes alluvium traversing rocks of the Karoo Supergroup for use as fine aggregate in concrete, as these sediments may contain shale fragments or montmorillonite-illite clay which can greatly increase the drying shrinkage (Brink 1977)

Based on investigations previously undertaken in the region, some 10 km west of the Genesis Eco-Energy cluster, such soils may be encountered. Soil cover is generally described as thick with soft excavation conditions for earthworks. Due to the collapsible nature of the soils conventional shallow foundations are not recommended in thickly developed alluvium (Bradshaw, 2022).

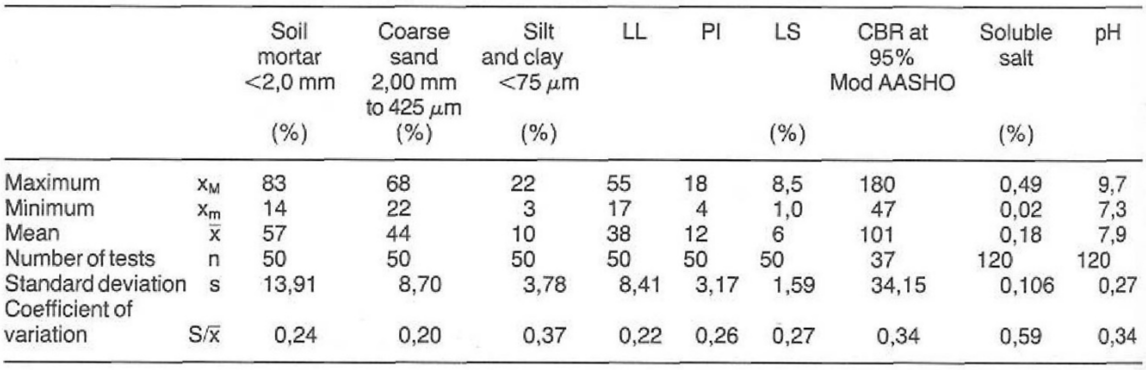
Calcrete has been shown to be a useful, if variable material for wearing courses in road works.
The material does, however, show some variability. The following tables surmise some of engineering properties of this material.

Table 18: Typical properties of duripans (dorbanks) used up to subbase level on the Springbok-Pofadder road (Brink, 1985)



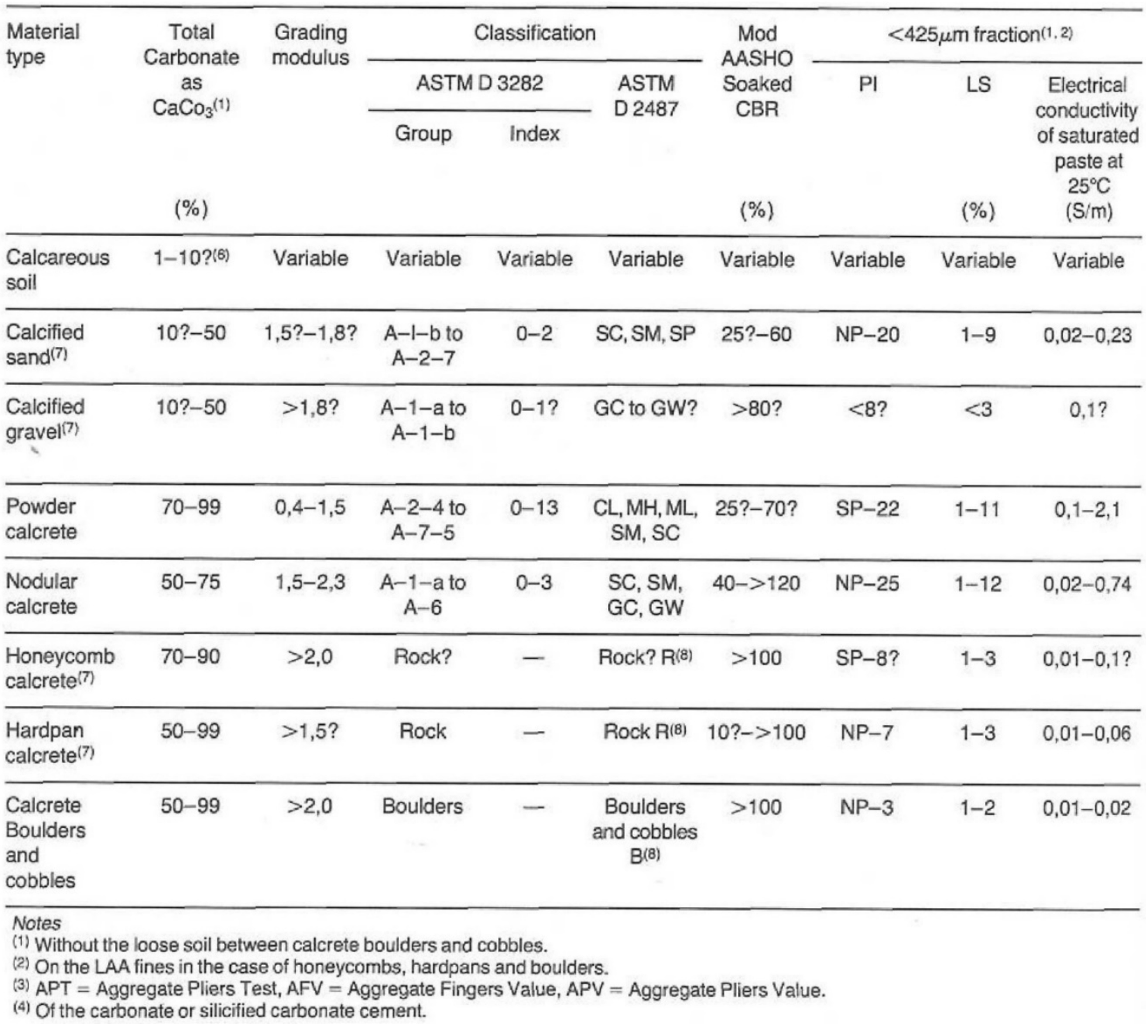
		Soil mortar <2,0 mm (%)	Coarse sand 2,00 mm – 425 µm (%)	Silt and clay <75 µm (%)	LL	PI	LS (%)	CBR at 95% Mod AASHO	Soluble salt (%)	pH
Maximum	x_M	95	64	16	71	25	10,0	160	0,26	8,2
Minimum	x_m	12	29	1	16	2	1,0	27	0,09	7,8
Mean	$\bar{x}$	61	48	9	32	9	4	76	0,17	8,1
Number of tests	n	45	45	33	45	45	45	29	13	13
Standard deviation	S	18,96	8,96	3,57	9,91	4,88	2,27	30,66	0,06	0,16
Coefficient of variation	$S/\bar{x}$	0,31	0,19	0,38	0,31	0,54	0,53	0,41	0,36	0,02

Table 19: Typical properties of calcretes used up to subbase level on the Springbok-Pofadder road. The calcretes were mainly hardpans requiring blasting and ripping (Brink,1985



		Soil mortar <2,0 mm (%)	Coarse sand 2,00 mm to 425 μm (%)	Silt and clay <75 μm (%)	LL	PI	LS (%)	CBR at 95% Mod AASHO	Soluble salt (%)	pH
Maximum	x_M	83	68	22	55	18	8,5	180	0,49	9,7
Minimum	x_m	14	22	3	17	4	1,0	47	0,02	7,3
Mean	$\bar{x}$	57	44	10	38	12	6	101	0,18	7,9
Number of tests	n	50	50	50	50	50	50	37	120	120
Standard deviation	s	13,91	8,70	3,78	8,41	3,17	1,59	34,15	0,106	0,27
Coefficient of variation	$S/\bar{x}$	0,24	0,20	0,37	0,22	0,26	0,27	0,34	0,59	0,34

Table 20: Summary of some properties of calcretes in comparison with calcareous and calcified soils (After Netterberg, 1982)



Material type	Total Carbonate as CaCo$_3$(1) (%)	Grading modulus	Classification			Mod AASHO Soaked CBR (%)	<425μm fraction(1, 2)		
			ASTM D 3282 Group	ASTM D 3282 Index	ASTM D 2487		PI	LS (%)	Electrical conductivity of saturated paste at 25°C (S/m)
Calcareous soil	1–10?(6)	Variable	Variable	Variable	Variable	Variable	Variable	Variable	Variable
Calcified sand(7)	10?–50	1,5?–1,8?	A–I–b to A–2–7	0–2	SC, SM, SP	25?–60	NP–20	1–9	0,02–0,23
Calcified gravel(7)	10?–50	>1,8?	A–1–a to A–1–b	0–1?	GC to GW?	>80?	<8?	<3	0,1?
Powder calcrete	70–99	0,4–1,5	A–2–4 to A–7–5	0–13	CL, MH, ML, SM, SC	25?–70?	SP–22	1–11	0,1–2,1
Nodular calcrete	50–75	1,5–2,3	A–1–a to A–6	0–3	SC, SM, GC, GW	40–>120	NP–25	1–12	0,02–0,74
Honeycomb calcrete(7)	70–90	>2,0	Rock?	—	Rock? R(8)	>100	SP–8?	1–3	0,01–0,1?
Hardpan calcrete(7)	50–99	>1,5?	Rock	—	Rock R(8)	10?–>100	NP–7	1–3	0,01–0,06
Calcrete Boulders and cobbles	50–99	>2,0	Boulders	—	Boulders and cobbles B(8)	>100	NP–3	1–2	0,01–0,02

Notes

(1) Without the loose soil between calcrete boulders and cobbles.

(2) On the LAA fines in the case of honeycombs, hardpans and boulders.

(3) APT = Aggregate Pliers Test, AFV = Aggregate Fingers Value, APV = Aggregate Pliers Value.

(4) Of the carbonate or silicified carbonate cement.

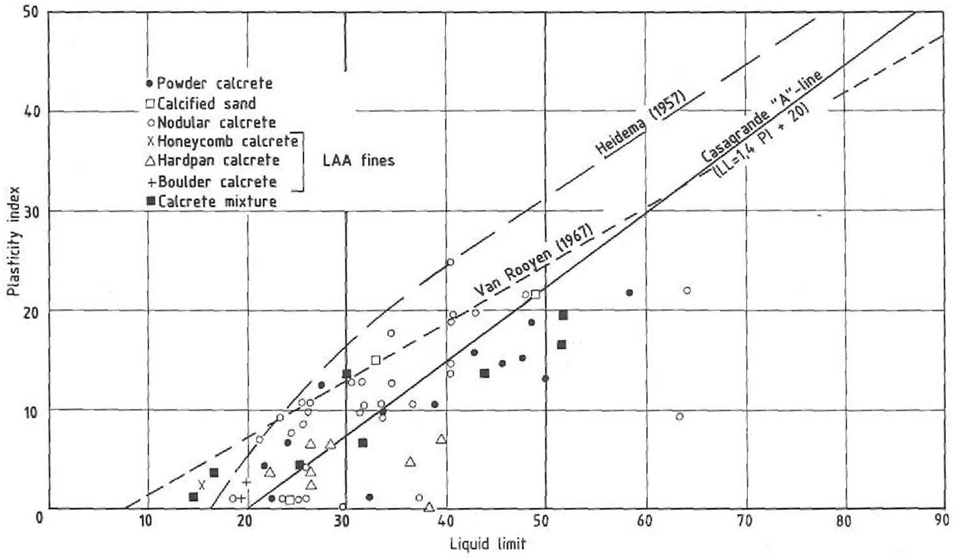


Figure 11: Position of calcretes on the Casagrande plasticity chart. (After Netterberg 1982)

11. APPENDIX C: SITE RECONNAISSANCE PHOTOGRAPHS

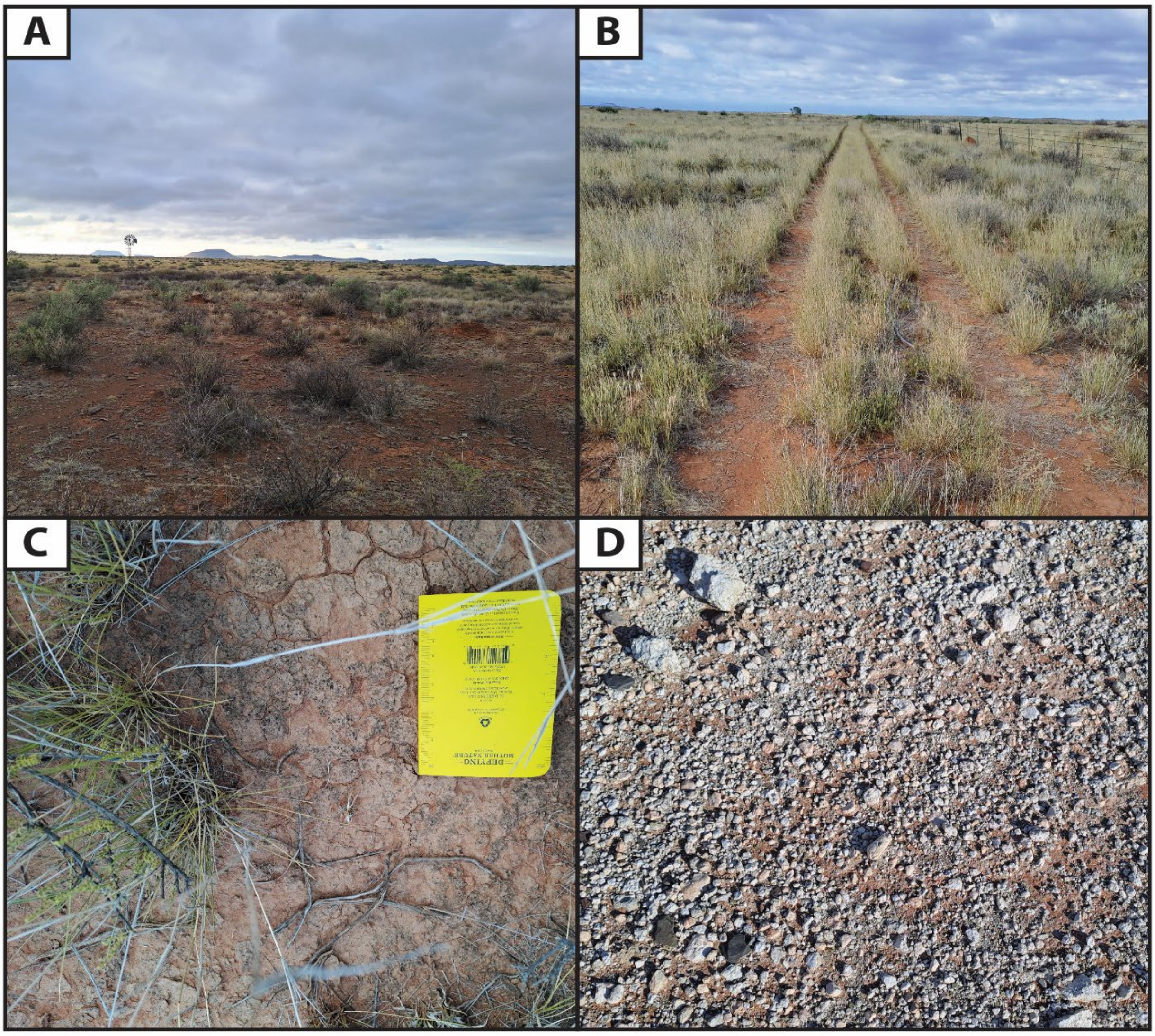


Figure 12: Notable features within the general area of the site. (A) shows the flat topography of the site looking south. (B) shows medium tall grasses along with flat farm road currently on the site. (C) mudcracks formed on the site indicated periodic water ponding. (D) example of calcrete nodules being used as surface course for unpaved roads.

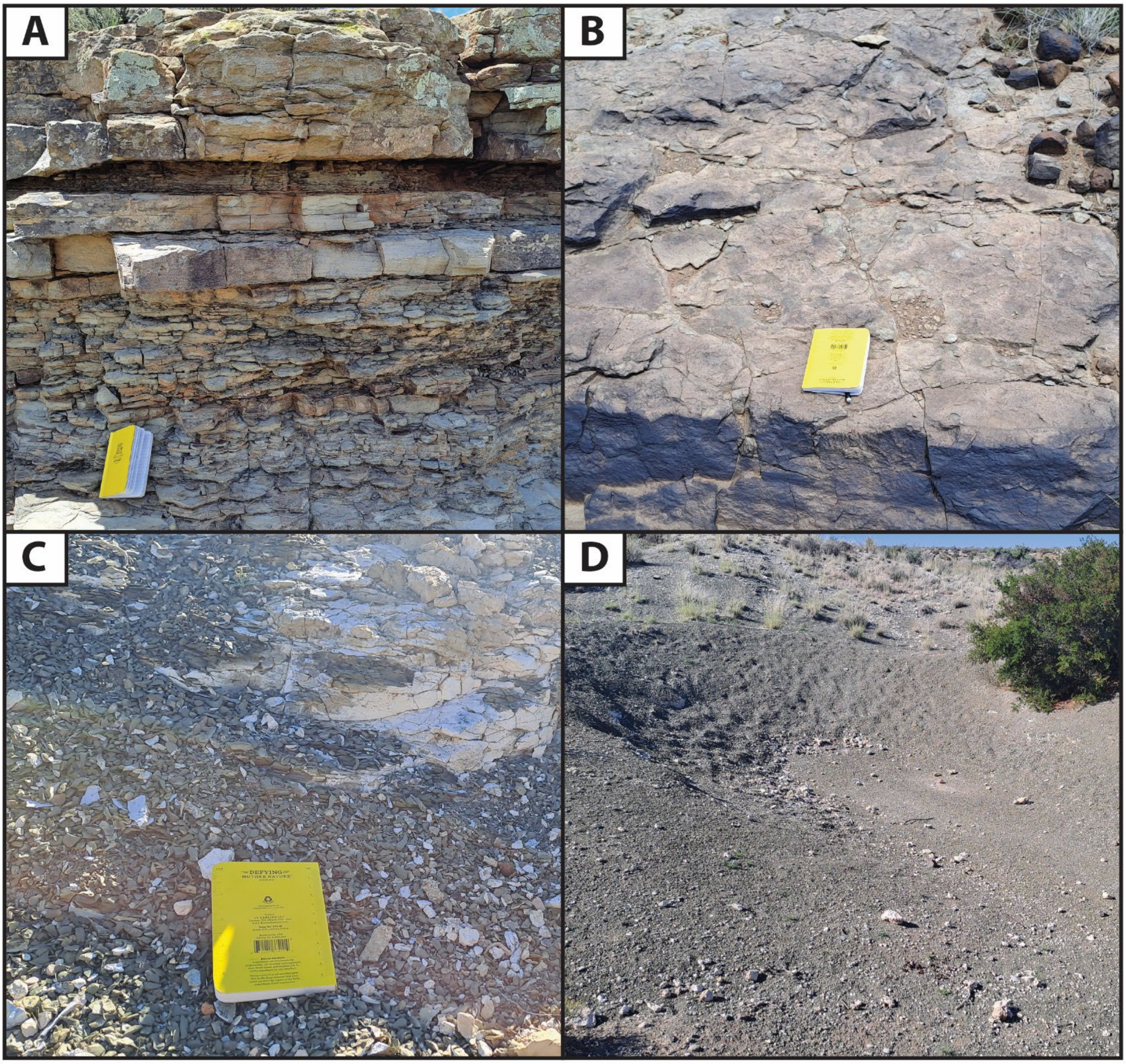


Figure 13: Mosaic highlighting main features of Geotechnical Zone A. (A) shows outcrop of interbedded units of shale and sandstone typical of the Tierberg Formation. Note that trace fossils were found within this specific outcrop. (B) shows outcrop of sandstones from the Tierberg Formation at natural ground level. (C) Shows closeup of highly fragments shales of the Tierberg Formation with some calcrete present in larger fractures. (D) example of Tierberg Formation shales outcropping at natural ground level being excavated for use as road course.

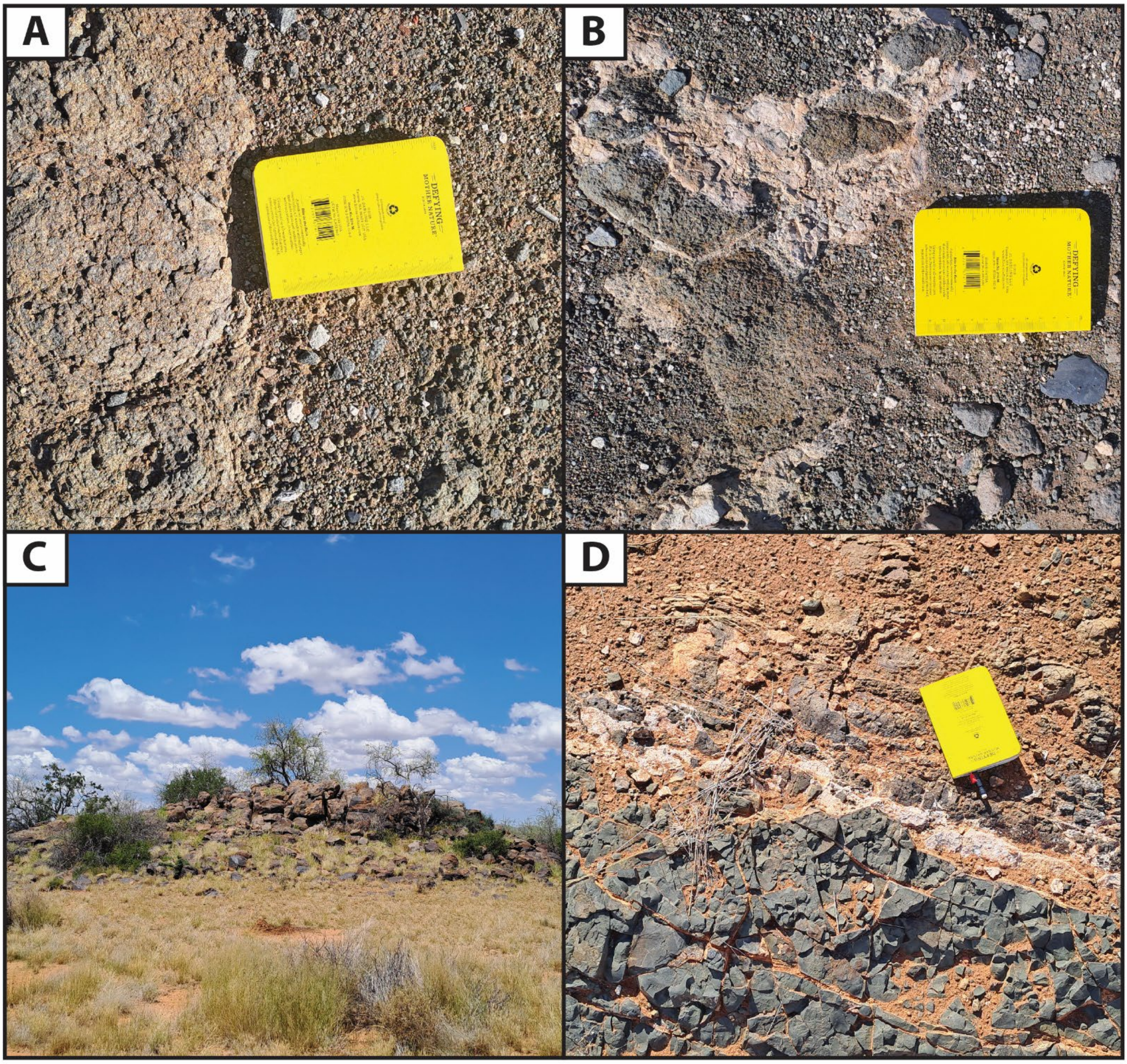


Figure 14: Mosaic highlighting main features of Geotechnical Zone B. (A) shows outcrop of weathered dolerites at natural ground level. (B) shows outcrop of weathered dolerites with calcrete precipitating in fractures at natural ground level. (C) shows typical topographic high formed from a moderately weathered dolerite stock. (D) image showing contact between Tierberg Formation Shales and weathered dolerite. Note the slight baked texture in the shales in direct contact with the dolerites.

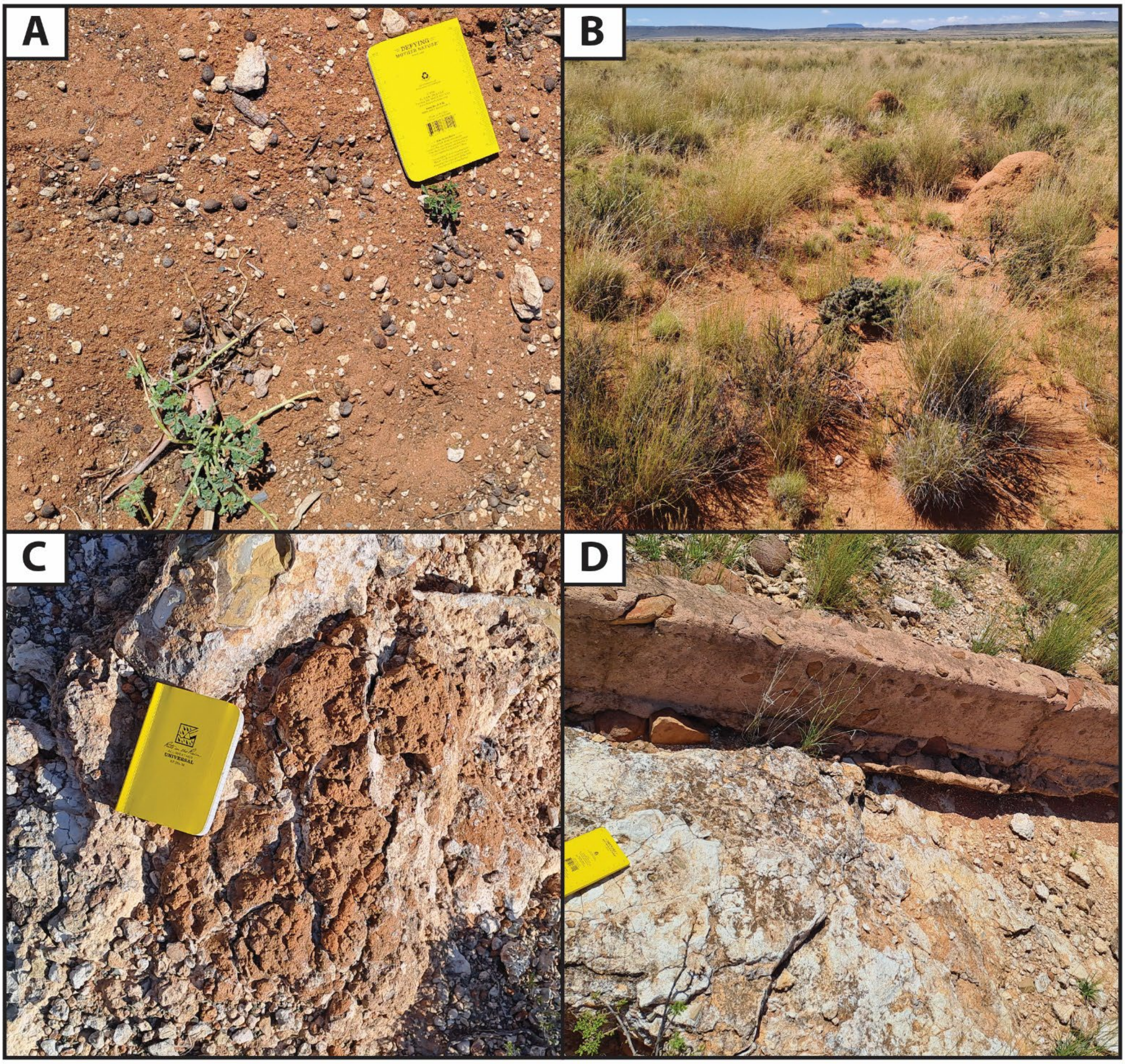


Figure 15: Mosaic highlighting main features of Geotechnical Zone C. (A) shows typical red weathering, loose sandy soils with carbonate nodules characteristic of Geotechnical Zone C. (B) shows grasses and termite mounds which typically form in the soils of Geotechnical Zone C. (C) shows outcrop of sandy Oxidic soil completely encased in calcrete at natural ground level. (D) image shows outcrop of a laterally extensive calcrete layer at natural ground level. Note that the outcrop was encountered within a slight depression.

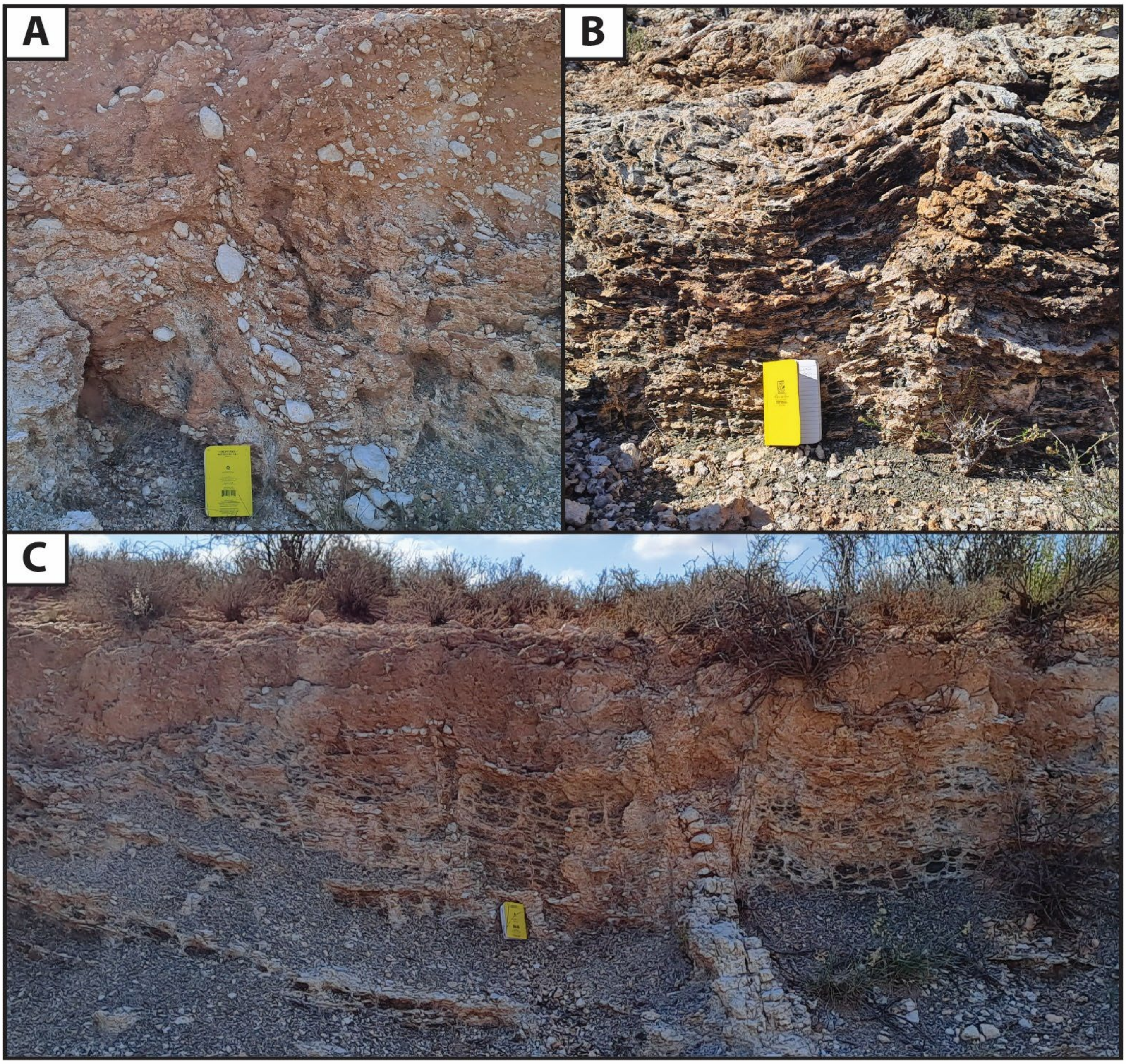


Figure 16: Mosaic illustrating the general soil profile encountered at the study area from multiple locations. (A) shows typical red weathering Oxidic soil with nodular calcrete underlain by a more continuous and competent calcrete layer. (B) shows a well-developed calcrete layer present almost at surface. Note the well-developed layering as well as presence of shales from the Tierberg Formation. (C) shows the most complete soil profile, highlighting development of Oxidic soil at the top of the profile, with calcrete horizons developing at approximately 0.5 to 1.0 m depth. These calcrete horizons are then underlain by unweathered yet fractures layers of the Tierberg Formation shales.

12. APPENDIX D: GENERALISED SOIL PROFILE

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GEOSS
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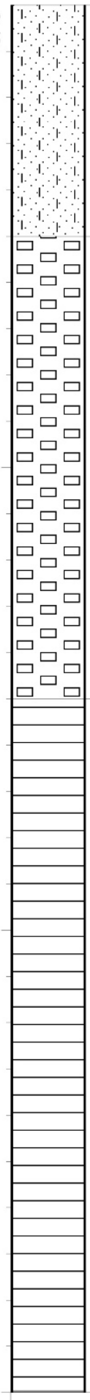
Soyuz Solar PV Park

HOLE No: SP01
Sheet 1 of 1

JOB NUMBER: 4918_A1

Scale 1:15



0.00

Dry, light red to brownish red, silty medium **SAND**.

Note: (i) Light red to brownish red SAND likely represents layer of Quaternary aridisol.

0.50

Dry, hard **CALCRETE** layer .

Note: (i) CALCRETE (thickness +/- 0.1 m) interbedded with thin layers of dry, light red to brownish red, slity SAND (thickness +/- 0.2 m).

1.50

Dry,dark grey **SHALE**.

Note: (i) Dark Grey SHALE; likely represents the unweatehred basement rock of the Tierberg Formation.(ii) SHALES (Thickness +/- 0.25 m) interbedded with thin layers of CALCRETE (thickness +/- 0.1 m).

3.00

CONTRACTOR : N/A
MACHINE : N/A
DRILLED BY : N/A
PROFILED BY : L. Jonk

TYPE SET BY : L. Jonk
SETUP FILE : STANDARD.SET

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DIAM : Open Profile
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DATE : 25 January 2023

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Y-COORD : S-30.62694797´

HOLE No: SP01

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GROUNDWATER AND EARTH SCIENCES
GEOSS
SOUTH AFRICA (Pty) Ltd

Red Rocket (Pty) Ltd
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LEGEND
Sheet 1 of 1

JOB NUMBER: 4918_A1

░	SAND	{SA04}
┆	SILTY	{SA07}
☰	SHALE	{SA12}
▭	CALCRETE	{SA26}

CONTRACTOR :
MACHINE :
DRILLED BY :
PROFILED BY :

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INCLINATION :
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DATE : 07/02/2023 12:28
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ELEVATION :
X-COORD :
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LEGEND
SUMMARY OF SYMBOLS

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(Last page)