MULILO RENEWABLE ENERGY

DE AAR 2 (SOUTH)

WIND ENERGY FACILITY

PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT

AUGUST 2012
J674

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1.0 INTRODUCTION

In March 2012, Mr Constantin Hatzilambros of Mulilo Renewable Energy (MRE) invited Geotechnics Africa Western Cape (GAWC) to prepare proposals and related cost structure for a geotechnical appraisal study to be undertaken for the proposed De Aar 2 Wind Energy Facility (WEF). The project area occupies the plateau of a prominent mountain located to the east and north-east of De Aar and south of the R48, *en route* to Philipstown.

The project area has been divided into two sections, referred to as De Aar 2 North and De Aar 2 South, as shown on the locality plan in Figure 1 and Google Earth image in Figure 2.

This report, which contains the information and findings pertaining to De Aar 2 South, has been based on a desk study and subsequent site reconnaissance visits undertaken to inspect and record the general surface conditions at each turbine position. It comments on the terrain traversed by the proposed access routes and includes general remarks on the topography, drainage, outcrop features, surficial soils and potentially problematic subgrade conditions, based on surface exposures and the results of a limited number of laboratory tests.

The anticipated founding conditions, excavatability of the bedrock and other potential geotechnical constraints that would need to be taken into consideration for the detailed investigation and planning phase, are also discussed.

In order to assess the availability of groundwater, information was obtained from the farmers regarding the distribution of springs and productive boreholes from which groundwater is being abstracted for the watering of livestock and game on their farms.

A phased approach for further investigation is recommended, commencing with a more detailed borrow pit identification and investigation programme, followed by the refinement of the proposed access routes and, where considered necessary, detailed site-specific foundation investigations at the proposed turbine positions, with the emphasis on ease of construction and environmental considerations.

2.0 INFORMATION SUPPLIED

MRE provided the following information to assist with the planning of the fieldwork and compilation of this document.

(i) List of farms, farm portions and reference numbers, owners and their contact details.
(ii) List of co-ordinates of the turbine positions.
(iii) Google Earth images showing the farm boundaries, turbine positions and proposed access routes linking them.
(iv) 1:50 000 topocadastral map, “Wind Power Generation Facility, De Aar 2: Plateau East 2 South, WEF; Drawing No. PES 100-01/A, showing Wind Turbine Generators Preferred Layout 105 WTG Total, dated September 2011.
(v) Unnumbered topocadastral map, at a scale of 1:70 000, showing the revised turbine layout and proposed access routes linking turbine positions for De Aar 2 South.
(vi) Turbine information and drawing showing erection/assemblage procedure and foundation dimensions.
(vii) Google Earth image showing the location of heritage sites and distribution of environmentally sensitive areas with specific reference to bat populations and their habitats, and nesting sites of breeding raptors.

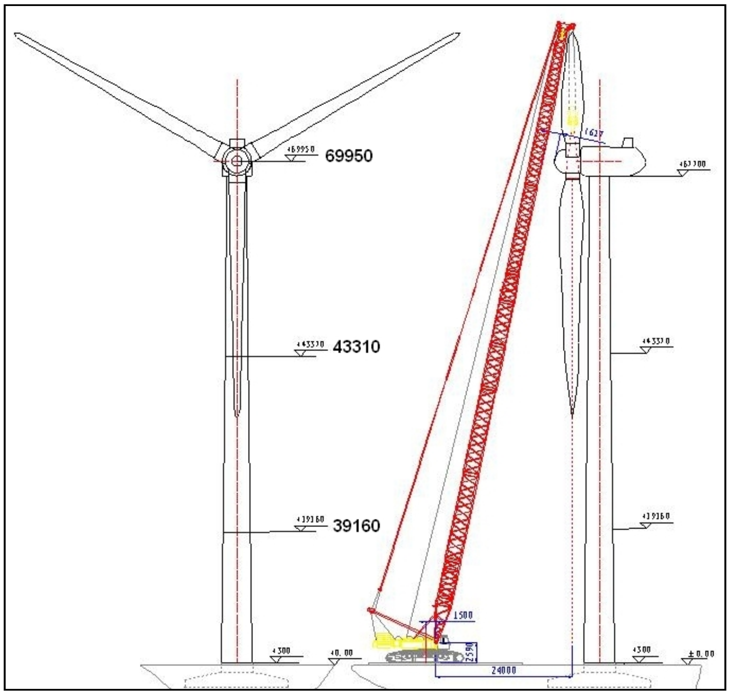
In addition, GAWC obtained the following:-

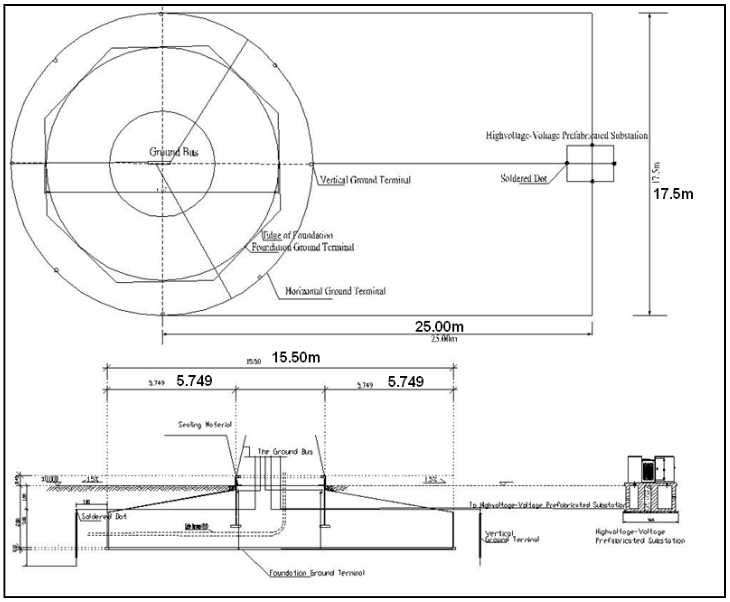
(i) 1:250 000 geological series, Sheet 3024, Colesberg, and accompanying explanation booklet.
(ii) Borehole information from the respective farmers.

(iii) Climate of De Aar region recorded from 1993 to date. Data reported by Weather Station No. 685380 (FADY); Latitude – 30.65, Longitude 24.01 and Altitude 1287m.

3.0 PROPOSED WEF

The dimensions of the proposed turbines and their towers in relation to the erection and assemblage plant are illustrated below:-





The proposed WEF and turbines will consist of the following:-

(i) 105 three-bladed dynamo-electric constant frequency wind turbine generators; the approximately 70m high towers will be supported on 17,5m diameter and 3,0m thick foundation bases, which, apparently will impose contact stresses of less than 450kPa.

(ii) Three 400m x 200m construction camps and lay-down areas for both De Aar 2 North and South, will be established on the following farms:-

- Slingers Hoek 2 Portion 2
- Vendussie Kuil Re/165
- Slingers Hoek Re/2

(iii) Eskom's north-east to south-west running powerlines into which the proposed northern facility will feed electricity into the national grid. The details of these powerlines are as follows:-

(i) Farm portions crossed by the western 400kV line:		
De Aar 2 North	**De Aar 2 South**	**400 kV Substation connection**
• 4/148 • 6/136 • 1/136	• 5/1	• 1/136
(ii) Farm portions crossed by the central 400kV and 132 kV lines:		
De Aar 2 North	**De Aar 2 South**	**400 kV Substation connection**
• Re/148 • 2/148 • 6/136 • 1/136	• 5/1	• 6/136
(iii) Farm portion crossed by the eastern 220 kV line:		
De Aar 2 North	**De Aar 2 South**	**400 kV Substation connection**
• 1/165	• 5/1 • 2/165 • Re/2	• 1/165

(iv) Existing MET-Mast, Met 1 on farm Slingershoek 2, Portion 2, see Figure 9b.

(v) Proposed access routes linking the turbine positions shown on the Google Earth images and topocadastral maps in Figures 7, 8 and 9.

(vi) Main access roads and proposed routes to the De Aar 2 South farms; these will enter the project area from the east, i.e. via the Meyersfontein farm road off road R389 linking Philipstown and Hopetown, see Figure 7.

4.0 THE SITE

4.1 Site Location

The proposed WEF will be established on the relatively flat-topped mountain plateau that commences approximately 23km to the north-east of De Aar and 4km to 5km south of the R48 to Philipstown, see Figures 1, 2, 7 and 9. The project area extends eastwards to, and slightly beyond the R389 road linking Philipstown and Hopetown. The farm portions, upon which the turbines will be erected, cover a total area of approximately 9 047ha. The area to be occupied by the turbines stretches for a distance of 12,5km from west to east and 13,6km from north to south. The coordinates encompassing the WEF range from latitude -30.555444º west to -30.601375º east and longitude 24.292166º north to 24.319214º south.

4.2 Farm Portions

The details of the farms and farm portions, encompassing the proposed turbine positions and lay-down areas, are listed below:-

Farm Portion	Portion Reference	Title Reference	Area (ha)	Land Use for WEF
Hanover Rd, N10, Slingershoek	Re 2	T60004/1994	4219.1954	9 WTG
Philipstown Rd, R389, Vendussie Kuil	11/165	T35342/1975	782.8702	8 WTG

Farm Portion	Portion Reference	Title Reference	Area (ha)	Land Use for WEF
Philipstown Rd,R389, Vendussie Kuil	Re 165	T12807/1959	552.96	10 WTG
Philipstown Rd, R389, Vendussie Kuil	2/165	T110355/2004	434.3345	5 WTG & Substation, Control Building
Maatjesfountain 5, 1 Hanover Rd, N10	5/1	T13665/1964	504.72	14 WTG
Slingershoek 2, Hanover Rd ,N10	2/2	T57794/1999	1,412.38	29 WTG
Knapdaar	8/1	T64553/1996	1140.4	30 WTG
		TOTAL	9046.86	105 WTG

4.3 Land-Use Practices

Livestock farming is the primary land-use in this Great Karoo region. Sheep comprise the largest animal numbers; however, goats, cattle and some re-introduced game (zebra, kudu, springbok, eland, blue wildebeest and ostrich) are stocked on a few farming enterprises. Naturally occurring fauna include smaller antelope, caracal (rooikat), baboon, mongoose, rabbit, tortoise, suricate, porcupine, antbear, civet, genet, small scavengers such as jackal and foxes, and gregarious rock dassies, springhare and ground squirrels.

Stock grazing appears to be well controlled and there was no evidence of overstocking. Cattle farming appears to be limited to the grass-dominated plains, refer Appendix E.

4.4 Vegetation

De Aar lies in the central part of the arid Karoo where the vegetation is dominated by drought-resistant low karoid scrub with intermittent grass-covered plains. A variety of succulents occur mostly on and around the outcrop features where the scrub becomes stunted and the tufted grasses sparse, mainly as a consequence of the thinner soil cover.

The occurrence of taller shrubs around the more prominent boulder outcrops is ascribed to run-off concentrating around the outcrop features and on the colluvial slopes due to the thicker soil cover. The succulents normally produce good floral displays in exceptional rainfall years. Photographs of some of these plants and other flowering species noted during our field inspection and reconnaissance visits are contained in Appendix C.

Evidence of past burning was noted in some areas; however, the vegetation has since recovered fully. It is uncertain whether these fires were accidental or controlled. Fires caused by lightening are known to occur from time to time, especially in summer when the vegetation is extremely dry and flammable.

4.5 Topography

The outstretched Karoo floor ranges in elevation from approximately 1300m to 1550m above mean sea level (msl). The mountain plateau, upon which the WEF will be established, rises rapidly from this base level by up to 300m, i.e. to the summit of 'Tafelkop', which is 1630m above msl, see Figure 6 and Plate 1.

The earlier smooth plantation surface of the mountain plateau evidently sloped towards the south-east and was subsequently carved by the ensuing drainage courses, which, through valley-head dissection and retreat, denuded the once smooth table-top topography to its current relatively rugged form over geological time.

Conspicuous flat-topped mesas, attaining similar elevations above the Karoo floor, stand away from the southern, western and northern escarpments. Very widely separated far more extensive smooth table-top relics, bevelled by the down-cutting streams and spreading valley floors through planation and pedimentation can be seen in the distance in all directions from the plateau.

4.6 Drainage

The mountain plateau has been divided into approximately seven drainage catchments, as delineated on the topocadastral plan in Figure 3. The directions in which they drain and the rivers into which these ephemeral (non-perennial or short-lived) systems discharge, are summarised in the table below:-

Catchment	General Drainage Direction	Rivers Draining these Catchments
A	West to south-west	Brak River
B	South	Brak River
C	East to north-east	Hondeblaf River
D	West to south-west	Brak River
E	South	Brak River
F	East	Barberspan
G	North to north-east	Hondeblaf River
H	Discontinuous	Furrow

These water courses are relatively steep-sided and narrow where they cut into, or across the ridges and escarpments. The more mature features separating the ridges, particularly in the lower courses, on the other hand, form broad valleys with smooth flat and very gently sloping valley floors; the flanks of these more subdued depressions rise slowly onto the sweeping pediments of the rocky hillslopes and outcrop-dominated ‘koppies’, see Plates 1, 2, 5 and 7.

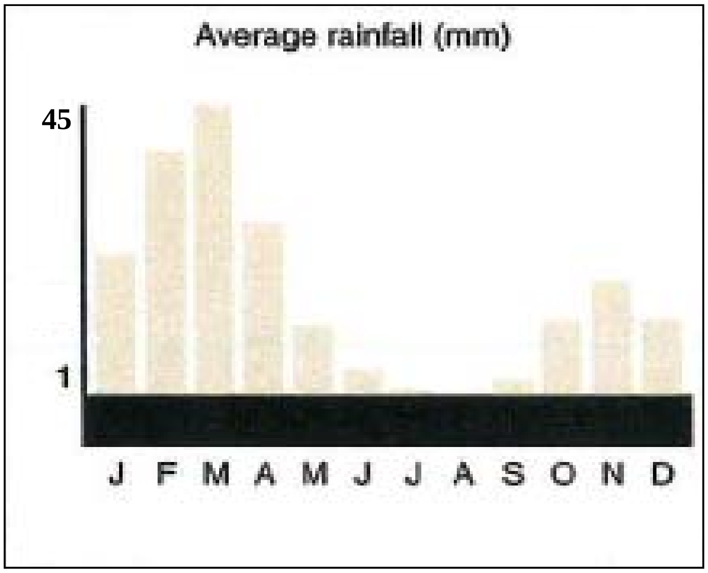
Aggradation of sediments eroded from the hills and ridges has given rise to the accumulation of relatively thick gulleywash deposits within the more prominent drainage depressions, see Plate 6.

The bedrock is almost invariably shallow and the surface sediments clayey (see Plate 8); consequently, precipitation during intermittent heavy rainstorms often exceeds the capacity of the thin soil cover to absorb the active and erosive run-off. As a result, near vertically-sided gulleys have been cut back into these sediments, see Plate 6, whereas, in the case of the broad valley floors, comprising mainly sheetwash flows, which are more widely spread and unrestricted, are less eroded.

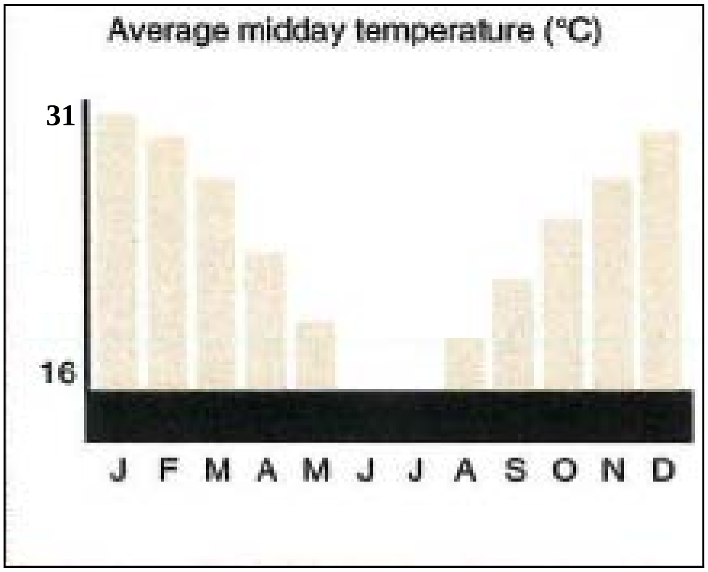
The gorge on the farm Slingers Hoek 2, Portion 2, (see Plate 1), and similar but less extensive steep-sided deeply incised valleys encroach into the perimeters of the plateau through scarp retreat. These features provide clear evidence of a once much more vigorously flowing and erosive drainage system. The current catchment network drains into secondary streams before concentrating into formal ‘rivers’ that cross the Karoo floor.

4.7 Climate

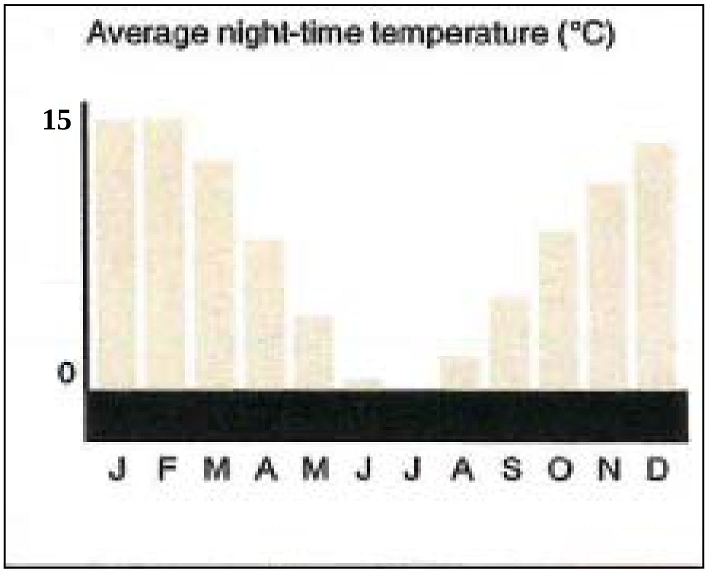
De Aar is reported to receive approximately 196mm of rain per year, and although most of this rain falls during autumn, it includes a few summer thunderstorms. The chart below shows that the average monthly rainfall figures vary between 1mm in August and 45mm in March.



The chart below presents the monthly distribution of the average daily maximum temperatures; it shows the average midday temperatures for De Aar to range from 16ºC in June to 30.3ºC in January.



The region is the coldest during July when the mercury drops to 0.3ºC on average during the night. The chart below shows the monthly variation of the average minimum night-time temperatures.



Snowfall occurs from time to time in winter. Since 1995 three snow days were recorded in 1999, two in 2001 and one in 2010.

5.0 NATURE OF INVESTIGATION

An initial desk study, based on the available Google Earth landsat imagery and digital data showing the relevant farm boundaries, access routes (existing and proposed), turbine positions, lay-down sites and proposed routes linking them, as compiled by MRE, was conducted to plan the reconnaissance visit. The fieldwork visit, which was undertaken from 3 May to 4 June 2012, entailed the following:-

(i) Site drive-over to confirm the broad geology, and to assess the general surface conditions and farm roads crossing the terrain, including the accessibility of Eskom's service roads.

(ii) Visits to each of the proposed turbine positions to evaluate and record the surface conditions, general topography, vegetation, soil cover, outcrop features, drainage and general conditions along the proposed access routes. These aspects are briefly described and supported by photographs on the field record sheets in Appendix E.

(iii) Sampling and testing of the dominant surface soils to obtain an indication of their composition and engineering properties, see Plates 7 and 8.

(iv) Inspection of natural exposures where the materials appeared to be suitable for the establishment of borrow pits; indicator samples and, where possible, bulk samples were taken and submitted to Geoscience Laboratories to conduct indicator and compaction tests, see examples of sampled materials and potential borrow pit areas on Plates 13, 26 and 27.

(v) Inspection of existing borrow pits along the main access roads in which the materials that resembled those noted during the field inspections *en route* to the various turbine positions, were sampled for indicator and compaction testing, see Plates 23 to 25.

(vi) Meetings held with the respective farmers to discuss the access conditions on their farms and to obtain information on the boreholes on which windmills have been erected to draw groundwater for their livestock to drinl. The data requested included the following:-

- Depth of borehole.
- Depth to water table.

- Yield.
- Water quality.

(vii) Recording and photographing of relevant topographical and surface features, weathering characteristics of the bedrock and typical outcrops; these are included in Appendix A (Plates 1 to 22)

The detailed laboratory test results of the samples submitted to Geoscience Laboratories for indicator, pH, conductivity and compaction testing, are included in Appendix D.

6.0 GEOLOGY

6.1 General

The surface geology within the project area, as shown on the extract taken from the 1:250 000 geological series, Sheet 3024, Colesberg, is dominated by dolerite that intruded the Permo-Triassic sedimentary rocks of the Karoo Sequence during the Jurassic period.

The sediments were deposited under fresh water conditions during a regime of quiet sedimentation that persisted uninterruptedly between 190 and 260 million years ago. The dolerite intrusions are widely scattered over the whole region and range from a vast network of dykes, sheets and sills. These intrusions have modified the landscape because of their resistant nature to weathering.

The sheets and sills, which have intruded along the bedding of the horizontally deposed sedimentary rocks have resulted in flat-topped mountains and hills, which are referred to as mesas. The mountains that owe their presence to the much harder dolerite cap-rock, are at various stages of formation; once their dolerite tops are eventually eroded away, the resultant hillocks soon disappear.

Their colluvial slopes are invariably concave, rising gradually from the extensive ever-widening Karoo floor before steepening more rapidly towards the rocky escarpments fringing the mountain plateau, see Plates 1, 2, 9 and 14. The top talus slopes commence below the free-face outcrops forming the escarpment. This material is reduced in size downslope by weathering. A change in material composition occurs where the upper mainly coarse colluvium, transported predominantly through gravitative processes, transforms to finer colluvium transported by unconcentrated surface wash. The latter is responsible for the gently concave profile of the pediment that reaches down to the local base level. Pediment slopes seldom exceed 5º, Ref 5.

Similar perfectly flat-topped mountains and mesas break the skyline in the distance. The Karoo floor that separates these features comprises mainly horizontal layers of Ecca Group shale and siltstone.

6.2 Intrusive Dolerite

The more than 20km diameter mountain plateau and surrounding weathering relics, upon which the WEF will be established, are dominated by the intrusive dolerite sheet, see Figures 4, 5 and 8. The dolerite is easily recognised as very hard rock, grey when fresh to orange-brown on the weathered surfaces. The low-relief outcrops and soil-supported weathered boulder-relics are often black due to a thin surface veneer of manganese oxide, referred to as ‘desert varnish’, see Plate 12.

6.3 Sedimentary Rocks

6.3.1 Katberg Formation

Rocks of the Katberg Formation of the Tarkastad Subgroup are shown to be the youngest on the published Colesberg geological map; however, they have been completely eroded away and are no longer represented within the project area. The nearest occurrence of these sedimentary rocks is shown on the geological map to lie approximately 100km east of Philipstown.

6.3.2 Adelaide Sub-Group

The older sedimentary rocks of the Adelaide Subgroup, into which the dolerite sheet forming the mountain has intruded, consist of grey mudstone with subordinate lenses of sandstone.

The published geological map shows relics of the mudstone to occupy the crestal zones of some of the dolerite ridges on the plateau. The central south-draining catchment-basin that flows into the Brak River has also cut through the dolerite sheet into the same Beauford mudstone, see Figures 4, 5 and 8.

The mudstone at the dolerite contact has been altered (baked) by the molten intrusion to dark grey indurated very hard rock hornfels, see Plate 12. The sandstone layers, on the other hand have been altered to quartzitic sandstone and quartzite where it is in direct contact with the dolerite, see Plate 10. The mudstone and hornfels seen at the crests of some of the ridges coincide with the distribution of these rocks shown on the geological map. Exposures of this mudstone and hornfels were also noted where the colluvium has been eroded on the mountain slopes below the dolerite cap-rock. The following turbine positions lie within the areas shown to be underlain by Adelaide Subgroup sedimentary rocks but close to the contact with the dolerite sheet, or visa versa.

Turbine No	Description of Surface Conditions
S13	No outcrops; characteristics of area underlain by mudstone/sandstone but shown to be located on dolerite.
S87	Northern tip of north-south trending mudstone relic capping dolerite ridge.
S86A	Located on edge of dolerite near mudstone contact.
S64	On localised quartzitic sandstone exposure but shown to be on dolerite.

The areas underlain by mudstone/hornfels are characterised by relatively smooth and gentle grass-covered plains and hillcrests. Outcrops are rare and inconspicuous, and only project through the gravel-strewn surface in isolated areas, see Plate 11.

6.3.3 Tierberg Formation

The oldest rocks of the Karoo sedimentary rocks in this region belong to the Tierberg Formation of the Ecca Group. These practically horizontal layers of shale and siltstone dominate the almost featureless scrub-covered Karoo Floor to the north and west of the mountain encompassing the project area. The R48 linking De Aar and Philipstown, traverses this predominantly bluish shale and pale subordinate sandstone; however, it crosses localised remnants of the Adelaide Subgroup on the farms Jakkalsfontein and Rustfontein. Both De Aar and Philipstown are underlain by Tierberg Formation shale.

7.0 GROUNDWATER

7.1 Springs

The published topocadastral map shows three springs, F1, F2 and F6, on farms Knapdaar 1/8, Slingershoek 2/2 and the neighbouring farm to the south-west of Knapdaar 1/8, respectively.

Salt deposits occur where seep zones develop during the wet season; however, these tend to dry up completely in the dry summer season and/or during periods of drought, see Plate 19.

7.2 Boreholes

The windmills shown on the topocadastral map are currently being used to pump drinking water for livestock and game from groundwater sources. The abstracted water is normally stored in reservoirs located near the crests of ‘koppies’ and ridges. This water then feeds into drinking troughs at these locations, or is often piped over considerable distances to the sheep and cattle camps (kraals) located in the valleys below. The farmers were requested to provide any records received from the drillers when these boreholes were sunk. This data is listed in the table below:-

Farm Name & Number (North)	Portion	Borehole/ Wind-pump No	Borehole Depth (m)	Depth to Water (m)	Yield (ℓ/hr)
Pienaarskloof 136	1	W33	40m	10m	**
		W34	45m	13m	**
		W35	*	*	**
Pienaarskloof 136	6	W18	20m	10m	**
		W19	20m	10m	**
		W50	50m	25m	**
		W51	65m	22m	**
Brack Fountain 148	2	W12	30m	20m	**
		W13	25m	15m	**
		W14	40m	30m	**
		W15	20m	10m	**
Brack Fountain 148	Re	W25	*	*	**
Brack Fountain 148	4	W20	30m	20m	**
		W23	35m	25m	**
Washbank 149	1	W38	*	*	*
		W39	*	*	*
Enkeldebult 150	Re	W46	*	*	*
		W47	*	*	*
		W48	*	*	*
		W49	*	*	*
Enkeldebult 150	4	W44	*	*	*
		W45	*	*	*
Zwagers Hoek 151	1	W41	*	*	*
		W43	*	*	*
Zwagers Hoek 151	2	W40	*	*	*
		W42	*	*	*
Vendussie Kuil 165	1	W16	20m	10m	**
Vendussie Kuil 165	Outside side boundary	W8	45m	Dry	**
Vendussie Kuil 165	7	W36	*	*	**
		W37	*	*	**
Brack Fountain (Diepfont)	Unknown	W21	30m	20m	**
		W22	25m	15m	**
Farm Name & Number (South)	**Portion**	**Borehole/ Wind-pump No**	**Borehole Depth (m)**	**Depth to Water (m)**	**Yield (ℓ/hr)**
Meyersfontein		W1	29m	Dry (?)	-
		W2	15m	6,9m	4158
		W7	19m	6,3m	37 800
		W10	31,7m	9,5m	15 129
Slinger Hoek 2	2	W3	24m	Dry (?)	-
		W6	24m	Dry (?)	-
		W9	25,4m	18m	1513
Vendussie Kuil 165	11	W24	27m	**	**
		W26	21m	**	**
		W27	21m	**	**
		W28	12m	**	**
		W30	9m	**	**
		W31	6m	**	**
Vendussie Kuil 165	Re	W29	9m	**	**
		W32	21m	**	**
Vendussie Kuil 165	2	W17	20m	10m	-

Note: ** No information * Awaiting information

7.3 Water Samples

The results of chemical analyses previously conducted on two water samples taken from boreholes drilled on the farm Rooiwal, were obtained from the owner; these are as follows:-

Sample No.	pH	Conductivity (mS/m)
1	7,4	146
3	8,6	132

8.0 LABORATORY TESTING

8.1 General

Representative disturbed samples were taken from the sheetwash horizons covering the plains and gulleywash contained in the drainage depressions on the plateau. Bulk samples of some of these soils were also taken to confirm the anticipated poor compaction characteristics of these materials.

Indicator and bulk samples were taken of the materials exposed in the existing borrow pits on the Meyersfontein road and where similar materials were encountered *en route* to the proposed turbine sites.

These samples were submitted to Geoscience Laboratories to determine the following:-

- Particle size distribution.
- Atterberg limits.
- Moisture density relationship.
- California Bearing Ratio (CBR).
- pH and Conductivity.

The indicator properties, soil classification and compaction results are summarised in Table 2; these together with the pH and conductivity results are discussed under separate headings below.

8.2 Sheetwash and Gulleywash

8.2.1 Index Tests and Classification

The reddish-brown transported soils covering the pediments of the hills and ridges, the brown and dark brown sheetwash soils covering the plains and the gulleywash deposits contained in the drainage depression, all exhibit fine to prominent desiccation cracks, see Plate 8. They are shown to be predominantly fine grained with 10% to 28% clay, 32% to 61% silt, 19% to 41% sand and 0% to 13% gravel; the resultant grading moduli (GM), range from 0,28 to 0,85.

The plastic fines of these samples produce liquid limits (LL), plasticity indices (PI), and linear shrinkages (LS), ranging from 24 to 56, 9 to 27 and 4 to 14, respectively, which, in terms of the Van der Merwe activity chart (Figure 10A), places them in the low to potentially medium and highly expansive categories, Ref 12. Their moisture contents, after the rains that fell prior to, and during the fieldwork, range from 14,1% to 16,3%.

These materials classify in the Unified Classification System as inorganic clayey soils of low plasticity, CL, inorganic silty and clayey soils of high plasticity, MH and CH, and clayey sands, SC.

8.2.2 pH and Conductivity

The pH-values of the three transported soils tested vary between 5,9 and 6,7, and the electric conductivities between 11,2 and 29,8mS/m. The correlation between electric conductivity and corrosivity used by Waterlab (Pty) Ltd places the transported soils in the “mildly corrosive” category. Mc Vicar’s pH classes (Ref. 10) places pH-values of 6,5 to 7,0 in the “slightly acidic” category and those from 5,5 to 6,4 in the “moderately acidic” category. The samples tested are therefore considered to be slightly to moderately acidic.

8.2.3 Compaction Tests

California Bearing Ratio (CBR) and moisture density relationship tests, undertaken on the red-brown gravelly sandy and clayey SILT (Sample SL4), shows this material to have a maximum dry density of 1920kg/m^3 at an optimum moisture content (OMC) of 10,5%. The sample swelled by 0,4% after soaking it for four days in the CBR mould.

The CBR-values at the modified AASHTO compactive effort are 3, 6, 9 and 17 at 90%, 93%, 95% and 98% compaction, respectively, which, together with its plastic properties and particle size distribution, place it in a G10 category in terms of the TRH14 classification, Ref 2. The more clayey sheetwash and gulleywash materials that exhibit distinct desiccation cracks at the surface would therefore fall into the “worse than G10” category.

8.3 **Calcretised Transported Soil**

8.3.1 Index Tests and Classification

The thick orange- to red-brown calcareous transported soil exposed in the borrow pit, BP1, on the Meyersfontein road, see Plate 24, comprises slightly plastic silty SAND with 9% silt, 88% sand and 3% gravel. It has a grading modulus of 1.5. In the Unified Classification System, it possesses characteristics of both poorly graded sand with little or no fines, SP, and silty sand, SM, which gives it a boundary classification, SPM. In the USPRA Classification System it falls into the A-1-b group.

8.3.2 Compaction Tests

The material has a maximum dry density of 1684kg/m^3 at an omc of 15,4% and swelled by 0,1% after soaking it for four days in the CBR-mould. The

CBR-values at 90%, 93%, 95% and 98% of the modified AASHTO compactive effort are 12, 18, 23 and 33, which, together with its plastic properties and particle size distribution, satisfies all the requirements of a G7 material.

8.4 **Mudstone**

8.4.1 Index Tests and Classification

The sample, BP1, taken from the stockpile in the existing mudstone borrow pit on the Meyersfontein service road, see Plate 23 and Figure 7, is composed of 2% clay and silt, 29% sand and 69% gravel, which gives a grading modulus (GM) of 2,8. It has a LL of 25, PI of 10 and LS of 5 and classifies in the Unified Classification System as a poorly graded gravel-sand mixture with little or no fines, GP; it falls into the A-1-a group of the USPRA Classification System.

The mudstone sample designated, PBP11, is slightly indurated and is composed of 1% clay, 5% silt, 36% sand and 57% gravel; it has a GM of 2,6, LL of 34, PI of 6 and LS of 3, and, in the Unified System possesses characteristics of both SP and SM groups, i.e. poorly graded gravelly sand with a little or no fines, (SP), and poorly graded sand-silt mixtures. (SM), hence its boundary classification, SPM.

8.4.2 Compaction Test

The modified AASHTO maximum dry density of sample, BP1, is 2030km/m³ at an omc of 6,9%, and the respective CBR-values at 90%, 93%, 95% and 98% compaction are 15, 20, 25 and 33. Therefore, it satisfies all the requirements of a G7 material in terms of the TRH14 classification.

8.5 **Dolerite**

8.5.1 Index Tests and Classification

Highly to completely weathered sugary dolerite was sampled at the following locations, SL7, PBP1 to PBP3 and PBP6. These olive-brown and yellow- to red-brown highly weathered to completely weathered slightly calcretised sugary dolerite materials are shown to be either slightly plastic or non-plastic, and composed of 0-6% clay, 3-19% silt, 65-97% sand and 0-16% gravel, with grading moduli ranging from 1,3 to 2,5.

In the Unified Classification System, they all possess characteristics of either well graded sands with little or no fines, SW, silty sands, SM, clayey sands, SC, or well graded gravel-sand mixtures with little or no fines, GW, and poorly graded gravel-sand-silt mixtures, GM, hence their boundary classifications, SWM, SMC and GWM.

In the USPRA Classification System they fall into the A-1-a, A-1-b and A-2-4 groups.

8.5.2 pH and Conductivity Tests

The sugary dolerite sample, PBP6, has a pH of 6,0 which, in terms of Mac Vicar's pH classification, falls into the "moderately acidic" category. It's conductivity of 11,24 mS/m indicates that it could be "mildly aggressive".

8.5.3 Compaction Tests

The compaction test performed on the sugary dolerite shows it to have a maximum dry density of 1956kg/m^3 at an omc of 13,2%; it swelled by only 0,1% after soaking the compacted material for four days in the CBR-mould.

The CBR-values at 90%, 93%, 95% and 98% of the mod AASHTO compactive effort are 15, 21, 28 and 46, respectively, which, together with its index properties, places this material in the G7 category of the THR14 classification.

9.0 EVALUATION AND RECOMMENDATIONS

9.1 General Considerations

Based on the information supplied to date, this preliminary geotechnical study has shown that the general terrain will be suitable for the establishment of the proposed WEF, provided that:

- Full cognisance is taken of the potential geotechnical constraints outlined in this document.
- The necessary precautionary measures are taken in the design and detailed planning of the project.
- The environmental constraints listed below, are catered for.

(i) Archaeological and historical sites are protected and preserved.
(ii) Current agricultural value of the land is maintained.
(iii) Wild life habitats are conserved.
(iv) Rare or endangered fauna and flora species remain unaffected during and after construction.
(v) Interference with natural groundwater and surface-water regimes is kept to a minimum; natural drainage paths must not be altered and excessive abstraction of groundwater must be prevented as this could have an adverse effect on nearby springs.
(vi) Visual impact on the scenery and natural features is avoided or kept to a minimum.

The above criteria must be borne in mind during the refinement of the access routes linking the turbine sites, particularly where they traverse steep slopes and cross natural drainage paths. The overall impact must be assessed during the detailed planning phase, and the new or re-aligned access routes must follow a least-impact corridor, which would need to be established on site during the refinement of the proposed routes indicated on the plans prepared to date.

9.2 **Clearing Operations**

9.2.1 Vegetation

Every effort must be made to disturb the natural vegetation as little as possible. It is assumed that rare and endemic plant species have been identified and those that will be affected will be rescued and relocated to similar habitats elsewhere on the farms where no development will take place. Since the mountain plateau and Karoo landscape lacks trees and is dominated by low scrub, succulents, natural grasses and small shrubs, which occur mainly around outcrop features and on the steeper colluvial slopes below the escarpments, little effort would be required to clear the vegetation.

The topsoil in which most of the roots are concentrated is generally thin and would therefore only require the top approximately 50mm to be stripped. However, thicker humified soils were noted in some of the erosion gulleys cut into the broad valley floors, see Plate 6. This material should be stockpiled to re-establish the vegetation when disturbed areas are re-instated and borrow pits, for example, are rehabilitated.

9.2.2 Outcrop Features

The anticipated surface and bedrock conditions recorded at the proposed turbine positions and along the proposed access routes are discussed and supported by photographs on the field record sheets in Appendix E. The anticipated sub-surface conditions at these locations are also illustrated on the idealised sections in Figures 11/A1 to 11/E2.

The outcrops and soil cover noted at the proposed turbine positions have been evaluated on a visual basis and on past experience gained in similar geological and topographical conditions. Where there were no outcrops or only a few could be found, the anticipated bedrock topography, weathering and discontinuities were described from outcrop features located within 50m of the co-ordinated positions, as requested by MRE. However, in some instances outcrops had to be sought beyond this limitation. The outcrops located away from the set positions are denoted with an ‘A’ for ‘alternative’, and where more than one position was described, the turbine number is followed by a ‘B’.

The anticipated outcrop conditions, illustrated on the sketch sections in Figures 11/A1 to 11/E2, which should be referred to when the clearing operations are planned and executed, are briefly discussed below:-

(i) Bedrock and/or Outcrop Types D and E2:-
Practically flat and featureless grass-covered surfaces with very little or no outcrops or occasional boulders projecting through the soil cover, see Figures 11/D and 11/E2.

The open grass-covered and gravel-strewn plains and plateaus are characteristics of bedrock conditions depicted as Type E2. The bedrock and cover materials beneath the broad sheetwash-covered valley floors separating the ridges and hills are normally represented by conditions depicted as Type D. These areas can be readily cleared using light earthmoving plant.

(ii) Outcrop Types A5a to A5d:-
Gently sloping predominantly soil-covered pediments surrounding the hills and ridges, which may also include the sloping plains on the plateaus.

These areas are characterised by soil-dominated surfaces with scattered to isolated random small to medium and occasional large boulders that are detached from the bedrock and project slightly above the surrounding ground surface, see Figures 11/A5a to 11/A5d.

As in the case described for (i) above, clearing operations would be relatively easy except for some deeply embedded boulders and isolated boulder-outcrops that would need to be grubbed out by a powerful excavator.

(iii) Outcrop Types A4 and C1:-

More densely concentrated boulders projecting above the surrounding ground surface and scattered low-relief boulder-outcrops where the boulders are normally set closely together, see Figures 11/A4 and 11/C1.

Clearing of these features is expected to be more difficult and require heavy ripping by a powerful track-mounted excavator or bulldozer aided by pneumatic rock-splitting plant to detach the joint-bounded blocks from the intact bedrock. Large boulders and boulder-clusters that are separated from the intact rock-mass through more advanced weathering along horizontal joints could be grubbed out more easily by an excavator.

(iv) Outcrop Type A3:-

Low-relief closely to medium jointed dolerite outcrops in which soil-filled slots formed along the joint sets, narrow rapidly with depth and become closed to closed tight from a shallow depth below ground surface, see Figure 11/A3.

Once all the loose soil-supported boulders that project through the surface soils have been removed, the remaining joint-bounded blocks would most likely have to be separated from the intact rock-mass by a pneumatic breaker. Areas of more intact rock would most likely require light blasting to remove prominent closely-set joint-bounded blocks projecting above the surrounding ground surface. Pneumatic breakers and/or jackhammers would be required to remove any remaining jaggered pieces of rock.

(v) Outcrop Types A1, A2, B1 and B2:-

Low-relief medium to widely jointed dolerite outcrops and widely and very widely jointed to massive medium hard rock through hard rock to very hard rock dolerite pavement and domed outcrops, see Figures 11/A1, 11/A2, 11/B1 and 11/B2.

Where these features, project above the surface and need to be cleared, blasting would undoubtedly be required.

(vi) Outcrop Type C2:-

Boulder-stacks with joint-bounded blocks, rounded at the edges and corners through weathering, see Figure 11/C2.

These often attractive features are normally inhabited by small creatures and should be avoided. Any disturbance of the boulders, particularly blasting, will be unsightly and impossible to reinstate.

(vii) Outcrop Type E1:-

Isolated mudstone or sandstone outcrops, normally with no or very little surface expression:-

These areas would only require the gravel-strewn surfaces to be cleared. Since the bedrock is normally closely and very closely jointed, clearing of any isolated outcrops would be possible using heavy track-mounted excavators and/or pneumatic breakers and jackhammers.

9.3 Excavation of Services Trenches and Road Cuttings

9.3.1 General

Shallow bedrock conditions should be anticipated throughout the project area, in particular when excavations for cable trenches, road cuttings and tower base excavations are planned and costed. The only areas in which rock is expected to be deeper than 0,5m is in the lower reaches of the broad drainage depressions (see Plate 6), on the colluvial slopes beneath the escarpments and possibly around prominent steep-sided dolerite ridges and hills.

Contrary to visual perception, closely set boulders exposed at the surface on the colluvial slopes that resemble boulder outcrops, may have been transported by gravitative forces. Inspection of existing road cuttings on these slopes revealed that they are in fact predominantly of colluvial origin and embedded in the covering soil horizon. This transported horizon is often underlain by residual soil or highly to completely weathered dolerite bedrock.

Excavation of services trenches on the more gentle slopes will, in most cases, encounter shallow refusal on deeply 'rooted' low-relief medium to large joint-bounded boulder relics and clustered dolerite boulder outcrops. Although heavy ripping, aided by blasting, will be necessary to dig services trenches in most of these areas, a powerful excavator equipped with a rock bucket should first be used to remove as many of the loose boulders and joint-bounded blocks as possible.

A pneumatic rock-breaker should be capable of removing the more tightly set boulders and blocks by opening up the joints to 'free' them from the intact bedrock. This approach should be followed before resorting to blasting. It must be noted that the resultant trenches are likely to be much wider than planned due to over-break along the dominant joint sets.

Blasting of the less frequently jointed and 'fresher' rock would also result in substantial over-break, which must be allowed for in the costing of services trenches, road cuttings and bulk excavations. More detailed investigations and on-site refining of the routes linking the turbines would enable a more accurate prediction of the excavatability of the rock to be made.

9.3.2 Classification of Evaluation in Rock

In terms of the SANS 1200 D Earthworks Specification, trenching in the thin transported horizon (hillwash, sheetwash and gulleywash), and in the residual dolerite on the colluvial slopes, would classify as “soft” excavation, while in the highly weathered very soft rock through soft rock to medium hard rock dolerite and mudstone, including the boulder horizons on the colluvial slopes, would most likely classify as “intermediate” excavation.

Excavation in the highly weathered and calcretised dolerite exposed at the potential borrow pit sites, PBP1 to PBP3 and PBP6, and the highly weathered closely jointed soft rock to medium hard rock mudstone at PBP11, would most likely fall into the “soft” to “intermediate” excavation categories, In unrestricted excavations, cutting into these materials would most likely be feasible using powerful earthmoving plant, e.g. a 30 ton track-mounted excavator equipped with a rock-bucket.

Separated joint planes containing soil in-fill could result in rock excavation classified as “intermediate”, to be reduced to “soft”. The same principal may apply in the case of “hard” excavation being down-graded to “intermediate” or even “soft” excavation where the rock is intensely fractured and weathered along the joint and bedding planes.

Trenching in medium hard rock through hard rock to very hard rock dolerite, sandstone or indurated mudstone, in which joints and bedding planes are closed to closed tight, would classify as “hard” excavation.

9.4 **Groundwater**

9.4.1 General

Despite the arid climate and the low average annual rainfall of 196mm that this region receives mainly during autumn, run-off disperses rapidly across the plateau and into defined catchments from where it organises into the major drainage valleys before flowing onto the surrounding Karoo Floor. Much of this water soaks into the soil covering the plains and drainage depressions, and into the joints in the outcrops, which then permeates the bedrock. These discontinuities serve as reservoirs from which groundwater is abstracted mainly by windmills for stock watering purposes.

9.4.2 Borehole/Windmills

The information obtained from the farm owners shows that the water table is relatively shallow, occurring mostly at depths ranging from 6m to 10m below natural ground level on the southern farms and 15m to 30m on the northern farms. Based on this information, good to reasonably good quality fresh water is rare. The groundwater typically found in displacement zones or within zones where the bedrock is highly fractured, is normally brackish as testified by the farm name “Brack Fountain”.

Yields in some of the boreholes are reported to range from 4158ℓ/hour, which is considered to be the norm, to 37800ℓ/hour, which is exceptional. It is understood that some of the lower yielding boreholes tend to become very weak or dry up during spells of persistent drought.

Where these boreholes and windmills are located far away from the intended concrete batching plants, closer abstraction boreholes would need to be sunk. It is recommended that geophysical methods, (electric resistivity, and/or magnetic surveys) be employed to site new borehole positions.

The fact that most of the tapped water is fit for animal consumption makes it suitable for mixing concrete and cementitious mortars; nevertheless, chemical analyses, to establish whether any deleterious salts are present or leachates derived from the soil will be aggressive towards cement or corrosive towards ferrous-based metals, should be undertaken.

9.4.3 Springs

Rainwater that infiltrates the soil and bedrock often emerges at the surface in the form of springs where geological and topographical conditions are favourable. The fact that this water is normally linked to precipitation in the high-lying areas above the springs, their connection to rainfall is often reflected by seasonal variations.

Since dolerite, mudstone and sandstone are themselves impervious, the passage of water through the rock mass occurs along fractures. Once the thin soil-cover is penetrated, rain-water maintains its downward path under the force of gravity and travels through the rock mass along these joint planes and other discontinuities. This moving or vadose water ultimately reaches a zone where all the fractures are saturated with water known as the phreatic zone, the uppermost part of which is referred to as the water table.

The water that travels along joints forms a discontinuous surface, which is still referred to as the water table. Therefore, the depth to the water table may vary significantly, depending on the geology and continuity of the fractures. Normally it is where shear zones of highly fractured rock, faults or geological contacts daylight, mainly in valleys or drainage depressions that the water table emerges in the form of a spring.

Some of the springs reported by the farmers and indicated on the published maps, are not all persistent and tend to dry up during droughts or are reduced to a mere trickle, which, apparently is still sufficient to sustain game and other smaller creatures.

It is important therefore that new boreholes that may be sighted near these springs or seep zones are not over-exploited, as this could lower the water table and cause them to dry up completely.

9.4.4 Surface Water

9.4.4.1 Drainage affecting Slope Stability

Most landslides are triggered by water; both surface water and groundwater influences the stability of a slope if sound stormwater principles are not followed. In spite of the fact that areas of low susceptibility tend to be in the drier regions of the country, drainage measures, nevertheless, should be taken in road cuttings.

Surface water normally affects a slope in two ways:-

- It may seep into the cut embankment at the top of the cut.
- It may flow down the face of the embankment.

Therefore, ponding should be permitted neither at the toe nor at the crest of the embankment. This can be prevented by installing interceptor or cut-off drains that should preferably be lined with concrete or gunite to combat erosion. Run-off must also be controlled by reshaping the surfaces.

Inspection of existing cuttings, where farm roads and Eskom's service roads provide access onto the mountain plateau, revealed relatively deep bedrock conditions; however, no apparent signs of instability, or scars from earlier landslides could be detected in the field or on the Google Earth images. Nevertheless, drainage along some of these roads was seen to be poor and would need to be upgraded if they are to be incorporated in the access road network.

If appropriate drainage measures are not incorporated in the design and during construction of new road cuttings and their embankments, instability problems and unnecessary surface erosion could render these routes inaccessible, unless on-going maintenance is performed.

9.4.4.2 Crossing of Drainage Features

Infiltration is expected to be slow due to the shallow bedrock conditions and the fine clayey nature of most of the transported soils. It is important therefore that satisfactory drainage measures be incorporated in the design of the access roads, particularly where they traverse the valley floors or less conspicuous drainage lines. A detailed topographic survey of the proposed routes would facilitate easier identification of these water courses and preferential flow paths of unrestricted run-off.

The flooding potential of the major drainage depressions should be determined in order to cater for the volume of water that is likely to flow down the valleys during peak rainfall events. The various catchments delineated on the topographical plan in Figure 3, may be used for preliminary quantitative evaluation purposes.

White salts precipitated on the outcrop surfaces and along joints in the bedrock (see Plate 18), are indicative of seasonal seep zones that must be catered for in the design of the roads. Effective drainage, at least to the material depth must be provided to prevent the subgrade and subbase layers from becoming saturated in these areas.

Carefully designed culverts, placed at the crossings of drainage lines, should be founded on bedrock. Scour protection must be provided where the bedrock is relatively deep, particularly where gulleys or rills have eroded back into the old sheetwash and gulleywash sediments, see Plate 6. These erosion scars should be lined with geofabric and then filled in with boulders to arrest further erosion.

The alternative to culverts would be to construct concrete ‘drifts’, particularly in light of the fact that the drainage features only flood during occasional peak rainstorm events.

9.5 Rock Falls

Some form of rock-fall protection must be provided where slopes are steep and the bedrock is closely to medium jointed, particularly where loose joint-bounded blocks and boulders are precariously balanced along the escarpment cliffs and steep colluvial slopes above the road cuttings, see Plate 14.

It is imperative that blasting be controlled or avoided as large blocks could topple from these rock-faces by the induced tremors. Proper barring down of these rock faces would reduce the incidence of rock falls substantially, particularly along the northern and western plateau and valley escarpments.

A potentially hazardous area, in which precautionary measures would need to be taken, is where the proposed access route onto the 'Tafelkop' plateau skirts its northern escarpment, see Plates 1 and 2.

9.6 Foundations

9.6.1 General

The founding conditions at each turbine position have been described on a visual basis to document the following:-

- Topography, vegetation and land-use.
- Nature and extent of soil cover.
- Geology.
- Outcrops and their projection above surrounding ground level.
- Discontinuities; i.e. spacing, separation, infilling and orientation of joints and, in the case of the mudstone and sandstone outcrops, nature of the bedding exposures.

These criteria are described and supported by photographs on the individual data record sheets contained in Appendix E; the supporting photographs provide a visual record of the conditions encountered.

9.6.2 Founding Considerations

Shallow foundations are considered feasible at all the proposed turbine sites. Where no or insufficient outcrops were encountered, the nearest features were sought and described, i.e. within the specified 50m radius from the co-ordinated location. In most cases it would still be necessary to adjust these positions in terms of the following:-

- Ease of preparing the surface for the construction of the tower bases.
- Necessity of casting a blinding layer on irregular and/or sloping outcrop surfaces.
- Depth and ease of excavation in areas where outcrops are absent or sparse.
- Measures that need to be taken to attain a stable founding stratum.
- Results of detailed site-specific investigations that need to be undertaken in areas where conditions are uncertain.
- Avoidance of prominent outcrop features that would result in unsightly damage and disturbances to the environment.
- Proximity to drainage features or concentrated run-off from the hillslopes.

It is recommended that these decisions be made on site by the project team, i.e. the appointed civil engineer, environmentalist, engineering geologist/geotechnical engineer and earthworks contractor,

9.6.3 Founding Options

9.6.3.1 Turbine Positions Located on Dolerite

Since most of the turbine positions are located on solid dolerite outcrop features or boulder outcrops, blasting would be necessary if the bases are to be buried in the ground. Therefore once all loose boulders or detachable joint-bounded blocks have been removed, consideration should rather be given to founding the bases on the outcrop surfaces for the following reasons:-

- Blasting particularly if the blasted rubble is not removed, will be unslightly
- Preparation of the resultant excavations could be costly.
- Blasting could destabilise and topple large boulders from nearby boulder-stacks, or from the cliff faces around the crests of nearby 'koppies', ridges or escarpments.
- Excavations are likely to be uneven and over-break is expected to be substantial, which would require trimming and unnecessary backfilling.
- Separation along horizontal stress-release joints beneath the tower bases could have an adverse effect on the founding stratum and stability of the structures.

It is recommended that rock anchors be installed and grouted into the bedrock to withstand tension forces and counter over-turning moments. Preloading or tensioning of the anchor cables should not be necessary and may therefore be cast in the concrete bases. However, the necessity of anchors and depth of installation at each turbine position must be carefully assessed by a suitably qualified and experienced geotechnical engineer, and installed by a specialist contractor.

9.6.3.2 Turbine Positions Located on Mudstone or Sandstone

In most areas where mudstone and sandstone is expected to be present beneath the soil cover, it would be necessary to dig test pits and/or to drill small diameter rotary cored boreholes to confirm the geology and assess the following:-

- Excavatabilty of the mudstone/sandstone
- Variations in rock strength with depth.
- Spacing of joints and separation along the joint planes.
- Thickness of bedding and separation along bedding planes.

In spite of the closely fractured nature of the mudstone and sandstone bedrock, they possess more than adequate bearing capacity to support the tower bases, apparently, which will impose contact stresses of less than 450kPa. Nevertheless, as in the case of the bases founded on the dolerite outcrop surfaces, it is recommended that rock anchors be installed and grouted into the bedrock.

9.6.4 Anticipated Founding Conditions and Recommendations

The descriptions of the type and nature of the outcrop features at each turbine position presented on the data record sheets in Appendix E, should be read in conjunction with the idealised sections illustrated in Figures 11A1 to 11E2 (see Plates 8 – 23). The anticipated founding conditions and preparation procedures for the expected bedrock conditions are summarised in the table below:-

Outcrop-Type	Generalised Description	Proposed Founding Procedure
A1 & A2	Flat smooth hard rock to very hard rock DOLERITE pavement outcrop.	• Remove loose surface boulders. • Clear vegetation and clean out soil-filled slots and joints. • Drill and install rock anchors, if considered necessary. • Cast tower base on top of bedrock surface incorporating anchors. • Stone-dress façade of tower base using locally available boulders.
A3 & A4	Low-relief flat-topped boulders separated by wide soil-filled slots that close up rapidly with depth and/or joint-bounded boulder outcrops projecting slightly above surrounding ground surface.	• Remove vegetation and soil from open joints. • Remove loose boulders and detachable joint-bounded blocks. • Cast blinding layer. • Drill and install rock anchors, if considered necessary. • Cast foundation base and stone-dress façade using locally available boulders.

Outcrop-Type	Generalised Description	Proposed Founding Procedure
A5a-d	Round-topped to speroidal very widely separated highly to medium weathered medium hard rock to hard rock DOLERITE boulders separated by deep soil-filled slots and depressions.	• Remove vegetation and deeply embedded soil-supported boulders. • Remove detachable boulders using a pneumatic breaker to expose more ‘solid’ bedrock. Light blasting may be required. • Cast blinding layer. • Drill and install rock anchors. • Cast tower base, incorporating rock anchors. • Stone-dress base façade using locally available boulders.
B1	Domed outcrop comprising medium to slightly weathered very widely jointed to massive hard rock to very hard rock DOLERITE with scattered to locally concentrated loose surface boulders.	• Remove loose surface boulders. • Remove surrounding soil cover to expose bedrock over entire tower base footprint. • Cast blinding layer to level founding surface. • Drill and install rock anchors. • Cast concrete base and stone-dress façade using locally available boulders.
B2	Sloping domed outcrop comprising medium to slightly weathered very widely jointed to massive hard rock to very hard rock DOLERITE with loose locally concentrated surface boulders.	• Remove loose surface boulders and clean out soil-filled slots and depressions. • Cast mass concrete or, if necessary, perform controlled blasting to create level platform, which will require a blinding layer to provide a smooth and level founding surface. • Drill and install rock anchors. • Cast base incorporating anchors • Stone-dress façade using locally available boulders.

Outcrop-Type	Generalised Description	Proposed Founding Procedure
C1	Stepped outcrop comprising highly to medium weathered medium to widely and very widely jointed medium hard rock to hard rock DOLERITE; joint-bounded blocks separated by wide and very wide open soil-filled joints below ground level.	• Remove detachable boulders and soil-filled slots, including vegetation. • Remove joint-bounded blocks using pneumatic breaker to open up narrow to closed joints (light blasting where necessary. • Cast blinding layer to provide smooth and level founding surface. • Drill and install rock anchors. • Cast concrete base incorporating rock anchors. • Stone-dress façade using locally available boulders.
C2	Talus-covered stepped outcrop comprising medium to slightly weathered medium to widely and very widely jointed hard rock and very hard rock DOLERITE; normally covered by loose toppled joint-bounded blocks and boulders.	• Remove loose toppled boulders and joint-bounded blocks. • Secure rock-face above turbine position. • Remove detachable joint-bounded blocks overlying 'solid' bedrock. • Perform light and controlled blasting where necessary. • Cast blinding layer to provide smooth and level founding surface. • Drill and install rock anchors. • Stone-dress base façade using locally available boulders.

Outcrop-Type	Generalised Description	Proposed Founding Procedure
D	No apparent outcrops and unknown thickness of transported soil covering completely weathered very dense residual sugary dolerite (possibly with some core-stones) grading into highly weathered very soft rock and soft rock DOLERITE gradually becoming medium hard rock with depth.	• Strip surface vegetation and topsoil. • Excavate transported and residual soil to intact rock. • Remove remnant spheroidally weathered boulders and core stones. • Clean exposed bedrock surface and remove remaining soil from open joints and slots. • Drill and install rock anchors. • Cast blinding layer, if required. • Cast concrete base incorporating rock anchors. • Stone-dress base façade using locally available boulders.
E1	Grey or pale brown medium weathered closely jointed intensely fractured highly to medium weathered medium hard rock to hard rock indurated MUDSTONE/quartzitic SANDSTONE or dark grey very hard rock HORNFELS; invariably associated with indurated mudstone-strewn gravel surface.	• Remove surface vegetation and loose gravel. • Excavate into shallow rock to level surface using powerful track-mounted excavator and/or pneumatic breaker; controlled light blasting may be necessary. • Cast blinding layer once all disturbed material has been removed. • Drill and install rock anchors. • Cast concrete base incorporating rock anchors. • Stone-dress base façade using locally available boulders.
E2	No apparent outcrops but indurated mudstone gravel-strewn surface; thickness of transported soil horizon uncertain, which needs to be confirmed. Bedrock expected to be similar to Type E1.	• Strip vegetation and excavate soil cover. • Clean exposed bedrock surface. • Continue by following procedure described for Type-E1 above.

The contact between the dolerite and mudstone/sandstone was encountered in several places, see Plate 10. At none of the locations was the contact material found to be highly weathered; in fact, the mudstone and sandstone were generally hardened through metamorphism by the intruded dolerite. Nonetheless, where the turbines are located near these contacts, it is recommended that the founding conditions be closely evaluated at the detailed investigation stage.

9.7 **Materials**

9.7.1 General

The most favourable areas in which potential borrow pits may be located are as follows:-

- At the foot of the colluvial slopes around prominent hills and ridges.
- On the flanks of steep-sided drainage valleys.
- Where secondary drainage depressions extend into the hills and ridges.
- On the colluvial slopes below the mountain scarps or at the crests of these slopes as was seen in the Eskom service road cuttings.
- On outstretched gently sloping pediments where sugary dolerite was exposed on the eroded surfaces of farm tracks traversing the pediments of the escarpment slopes.

Expansion of the existing borrow pits along the main access and arterial roads should also be considered. However, it would be necessary to determine whether these have been registered and permission to expand them would be granted by the respective land owners. In terms of the minerals and Petroleum Resources Development Act (No28 of 2002), the sourcing of material for road construction purposes, i.e. the use of borrow pits, is regarded as mining and accordingly is subject to the requirements of the Act.

9.7.2 Mudstone

The observations made in the field and the results of the indicator and compaction tests undertaken to assess the suitability of the mudstone material exposed in isolated areas and in the existing borrow pit, BP1, revealed the following (see Plate 23 and Figure 7):-

(i) The mudstone slakes upon exposure to seasonal wet and dry cycles, which reduces the coarse gravel fraction to fine predominantly sand-size particles.

(ii) The slightly metamorphosed or bakes mudstone is more resistant to weathering and slaking, and would produce a better quality road building material.

(iii) As reported by local farmers, the mudstone material from borrow pit, BP1, that was used to surface a section of the Meyersfontein road, produces a good quality wearing course that provides a smooth durable riding surface for light vehicle traffic.

(iv) Expansion of borrow pit, BP1, and the establishment of new borrow pits in areas underlain by mudstone would need to be investigated in detail to prove satisfactory reserves. A test pit investigation at each site, supported by laboratory testing, which should include slake-durability tests, is recommended.

9.7.3 Sugary Dolerite

The indicator tests undertaken on the highly to completely weathered sugary dolerite exposed through localised erosion of the farm tracks traversing the northern mountain pediment on Zwagershoek and Washbank, see results of PBP1 and PBP2 in Table 2, and Plate 26, showed that the composition of this material is similar to those sampled at potential borrow pit locations, PBP3 and PBP6, see Plate 27. The results of the compaction tests show that this material satisfies the requirements of a G7 material in terms of the TRH14 classification. The deeper less weathered dolerite is expected to produce a more gravelly material that would most probably classify as G5.

It is recommended that a detailed borrow pit investigation be conducted in the areas identified during the reconnaissance visit. Other sources would need to be located once the material requirements, limitations to haulage distances, accessibility and preferred locations from an environmental point of view, have been determined. Detailed investigation and proving of borrow pits would require a powerful excavator equipped with a ripper bucket, to achieve the maximum depth of excavation for the extraction in the less weathered gravelly highly weathered dolerite beneath the more sugary material lower down in the profile. The surface areas of these borrow pits could be extensive due to relatively shallow hard bedrock conditions as observed at PBP12.

9.7.4 Transported Soils

The laboratory tests have confirmed that the red-brown calcretised transported soil sampled in the existing borrow pit, BP2, will provide a suitable source of G7 material, see Plate 24.

However, the red-brown uncalcified transported material that surrounds the outcrop features on the mountain plateau is too fine and high in plastic properties to be used as a road building material in its natural state. Its poor compaction characteristics and engineering properties that places it in a G10 category or 'worse than G10' in the case of the shattered clayey soils, make it unsuitable to be used in any of the road pavement layers. Recently repaired patches along the Meyersfontein road, where the red-brown uncalcified fine transported material (G10) was used, had already reverted to potholes and caused soft 'muddy' and slippery conditions when it rained.

The fact that this poor quality transported material (Plates 6 – 8), occurs at the surface throughout the project area, the subgrade of the proposed access roads that cross the plains and valleys on the plateau would require special treatment. The procedure and extent of road-bed treatment, in areas underlain by this G10 and "worse than G10" material, would depend on the following:-

- Traffic and axil loads.
- Thickness of horizon.
- Availability and proximity of a replacement material.
- Its response to chemical stabilisation.

Further testing should therefore include chemical stabilisation to establish the lime demand required to reduce the plasticity and increase the bearing strength of this material.

9.7.5 Pedogenic Material

No suitable deposits of calcrete were encountered during the field reconnaissance inspections; however, partially calcretised highly to completely weathered dolerite, as shown on Plate 31, would be suitable as a selected subgrade and wearing course materials depending on the uniformity of the material at the source.

9.7.6 Sandstone

A brief inspection of the sandstone and mudstone borrow pit on road R389 linking De Aar and Philipstown (see Plate 25), revealed that it could possibly be extended laterally; however, if it is to be used as a subbase or wearing coarse material, the sandstone would have to be crushed down to an aggregate-size gravel. In any event, all the necessary laboratory tests would have to be undertaken to determine whether this material will be suitable for the purposes intended.

9.7.7 Concrete Aggregate

Blasted rubble derived from ‘fresh’ dolerite can be crushed and used as a source of concrete aggregate, i.e. if a crusher will be established on site. Alternatively, the crushed material, in particular the more weathered dolerite, and indurated mudstone, hornfels or quartzitic sandstone can be mixed with the transported soils to improve their bearing strength as a road building material or to construct hardstands to support the turbine erection and assemblage plant. Favourable conditions for the establishment of a quarry to produce a concrete aggregate on the site occur where massive domes of very hard rock dolerite dominate the hills and ridges, as described on the Field Record Sheets in Appendix E.

Natural boulders should be stockpiled as these could be used to dress the façades of the tower bases where they will be cast on top of the outcrop surfaces.

The smaller boulders could be used in gabion walls to support embankments of road cuttings on the steep colluvial slopes, or for erosion protection where the access roads cross the drainage features.

9.8 **Access Roads**

The next phase of investigation should be based on the compilation of a detailed soil engineering map, limited to a predetermined access road corridor for design and construction purposes. The map or maps would need to be drawn to a much larger scale and in sufficient detail to facilitate setting out of the final access routes to the fixed turbine positions. This would enable a more realistic construction programme and costing of the subgrade preparation and related 'earthworks' for the construction of the roads, to be made; this would entail the following:-

9.8.1 Upgrading of Main and Secondary Access Roads:-

(i) The requirements for the upgrading of the existing access roads off the R389 must be clearly understood and information regarding volumes and quality of road construction materials, including haulage limitations, would first need to be established.

(ii) The possibility of expanding existing borrow pits needs to be determined and the suitability and uniformity of the materials confirmed, once the following has been established:-

- Ownership.
- Permission for further exploitation.
- Registration of these borrow pits.
- The borrow pits are located within an economical haulage distance.

(iii) If the layer-works of the existing roads need to be determined and designed for heavy vehicle axil loads, a centre line investigation, supported by laboratory testing would need to be undertaken. The investigation must be aimed at establishing variations in subgrade conditions and thickness of layers that can be salvaged.

9.8.2 Upgrading of Farm Tracks

Firstly the availability of construction materials within an economical haulage distance must be determined and borrow pits established. These roads have not always been well planned and would have to be re-alignment or re-routed in certain areas where problems due to poor subgrade conditions or construction difficulties are likely to be experienced.

Deep rutting was evident where these roads cross clayey gulleywash deposits that become soft in the wet; similar conditions were also noted where these roads cross poorly drained plains that are invariably covered by clayey soils. The poor and very poor subgrade materials would either have to be replaced with a suitable imported material or stabilised with an appropriate chemical stabiliser. The drainage would also have to be upgraded in areas where surface water tends to pond.

9.8.3 Proposed New Access Routes

New access roads along the proposed routes linking the turbine positions shown on the available plans must be investigated in much more detail. It is recommended that a centreline survey be conducted once a corridor of least impact to the environment and lowest occurrence of visible obstructions has been identified. It would then be necessary to determine the depth to bedrock and quality and thickness of the transported horizon.

It is important to note the following:-

(i) The transported soils are generally poor to very poor subgrade materials; they range from red-brown clayey silty and gravelly sands around the higher-lying outcrop features to brown and dark brown clayey soils covering the practically flat plains to pale-coloured potentially medium to highly expansive clayey alluvium contained in the drainage depressions.

(ii) The fact that the transported soil horizons are often thin, they can be excavated and replaced with a suitable imported granular material.

(iii) Where these horizons are too thick to be replaced or a suitable nearby source of granular replacement material can not be found, chemical stabilisation or mixing the transported materials with fine crushed aggregate to improve their compaction characteristics, should be considered.

(iv) Boulder-dominated subgrades would also require an imported material to be sourced to replace the boulders.

(v) Soil disturbed by the removal of surface boulders would have to be reinstated. Large voids would have to be filled and require more extensive compaction.

(vi) Large domed outcrops that cannot be removed or circumvented would have to be covered with a suitable granular material upon which the road pavement layers can be placed. Drainage in these areas is imperative to prevent run-off from the domes from concentrating next to the road and infiltrating the pavement layers.

(vii) Where sugary dolerite is exposed during the road-bed preparation, this material will provide a suitable in-situ subgrade.

9.9 Electric Conductivity of Intrusive Dolerite

Electric resistivity surveys, previously undertaken on dolerite intrusions in the Karoo revealed resistivity values in the range 100 to 500 Ohm.m. Since electric conductivity is the inverse of electric resistivity, and 1 Ohm.m = 1000mS/m, the electric conductivity values range from 2 to 10mS/m.

Clay content enhances conductivity of a formation, therefore dolerite becomes more resistive in its less weathered state and significantly more conductive when it is completely weathered, hence the fact that the conductivity of the transported soils that derive from the weathered dolerite range from 11,2 to 29,8mS/m.

9.10 Aggressiveness

Conductivity values which are generally accepted as an indication of corrosivity of soil towards buried ferrous-based metal objects are as follows:-

Soil Conductivity (mS/m)	**Corrosivity**
>50	Very corrosive
20 - 50	Corrosive
10 - 20	Mildly corrosive
<10	Not generally corrosive

Leachates derived from the transported soils are therefore likely to be mildly corrosive to corrosive.

The analyses of the two water samples taken from boreholes previously drilled on the farm Rooiwal show that, with conductivities of 132 and 146mS/m, the water is likely to be highly corrosive.

It is recommended that field resistivity values be obtained for the various conditions encountered within the project area; a survey applying geophysical methods should be conducted during the detailed investigation phase.

9.13 Groundwater

The quality of the water must be tested to confirm whether it is suitable for mixing concrete; however, indications are that it may be highly corrosive to water pipes in which case cathodic protection would be required.

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