MARALLA WEST WIND ENERGY FACILITY NEAR SUTHERLAND, SUTHERLAND MAGISTERIAL DISTRICT, NORTHERN CAPE: PALAEONTOLOGICAL HERITAGE ASSESSMENT

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EXECUTIVE SUMMARY

BioTherm Energy (Pty) Ltd is proposing to develop the Maralla West Wind Energy Facility (WEF) with a total generation capacity of up to 140 MW on a site in the Klein-Roggeveld region of the Great Karoo. The site lies some 35 km to the SSE of Sutherland in the Northern Cape Province. The project area comprises the following land parcels: Portions 1 and 2 of Wolven Hoek 182, Drie Roode Heuwels 180 and Annex Drie Roode Heuwels 181.

The Maralla West WEF project area is underlain by fluvial and lacustrine sediments assigned to the lower part of the Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup) that are of Middle Permian age. The lower portion of the Abrahamskraal Formation succession in the SW Karoo is characterised by very rare tetrapod (four-legged vertebrate) remains, vertebrate burrows, vascular plants and other fossils of the *Eodicynodon* and *Tapinocephalus* Assemblage Zones. No fossil vertebrates, petrified wood or other scientifically significant fossil material have been recorded in the Abrahamskraal Formation within the present study area. The dense assemblages of reedy plant stem casts (probably horsetails) as well as small invertebrate burrows found here occur widely elsewhere within the region and are therefore not considered to be of special conservation significance. It is concluded that the Middle Permian bedrocks in the Maralla West WEF study area are generally of low palaeontological sensitivity. The same applies to a range of Late Caenozoic superficial sediments (alluvium, colluvium, calcretes, soils, surface gravels *etc*) overlying the Palaeozoic bedrocks. These may contain reworked blocks of petrified wood in the Klein-Roggeveld region, but no fossils or this or any other sort were recorded within these younger deposits during the two-day field assessment.

The overall impact significance of the construction phase of the proposed wind energy project is assessed as LOW (negative) in terms of palaeontological heritage resources. This is a consequence of (1) the paucity of irreplaceable, unique or rare fossil remains within the study area as well as (2) the extensive superficial sediment cover overlying most potentially-fossiliferous bedrocks here. This assessment applies to the proposed layout for the wind turbines, laydown area, access and internal roads, on-site IPP substation and associated WEF infrastructure within the study area. A comparable low impact significance is inferred for all project infrastructure alternatives and layout options under consideration, including different options for routing of access and internal roads, turbine layouts and siting of the on-site substation and associated Operations and Maintenance Building. Significant further impacts during the operational and de-commissioning phases of the WEF are not anticipated. There are therefore no preferences on palaeontological heritage grounds for any particular layout among the various options under consideration, including alternative sites for the on-site IPP substation. No significant further impacts on fossil heritage are anticipated during the planning, operational and de-

commissioning phases of the WEF. The no-go alternative (*i.e.* no WEF development) will have a low (neutral) impact on palaeontological heritage.

Cumulative impacts on palaeontological heritage resources that are anticipated as a result of the numerous alternative energy developments currently proposed or authorised for the Klein-Roggeveldberge region, including the Maralla West WEF, are predicted to be low (negative), *provided that* the proposed monitoring and mitigation recommendations made for these various projects are followed through. Unavoidable residual negative impacts may be partially offset by the improved understanding of Karoo palaeontology resulting from appropriate professional mitigation. This is regarded as a *positive* impact for Karoo palaeontological heritage. *Without* mitigation, cumulative impacts resulting from the large number of WEF projects in the Klein-Roggeveld region are anticipated to be of medium significance.

There are no fatal flaws in the Maralla West WEF development proposal as far as fossil heritage is concerned. *Provided that* the recommendations for palaeontological monitoring and mitigation outlined below are followed through, there are no objections on palaeontological heritage grounds to authorisation of the Maralla West WEF project. It is noted that borrow pit sites will only be identified if and when the proposed WEF wins preferred bidder status. In this case, a separate palaeontological assessment of all borrow pit sites will be necessary in the pre-construction phase.

No highly sensitive "no-go" areas within the proposed Maralla West WEF study area have been identified in this study. Pending the potential discovery of substantial new fossil remains during construction, specialist palaeontological mitigation is not recommended for this project. The following general recommendations concerning conservation and management of palaeontological heritage resources apply.

The Environmental Control Officer (ECO) responsible for the WEF development should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, turbine placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis by the ECO. Should substantial fossil remains - such as vertebrate bones and teeth, or petrified logs of fossil wood - be encountered at surface or exposed during construction, the ECO should safeguard these, preferably *in situ*. They should then alert the relevant provincial heritage management authority as soon as possible - *i.e.* SAHRA (Contact details: Dr Ragna Redelstorff, SAHRA, P.O. Box 4637, Cape Town 8000. Tel: 021 202 8651. Email: rredelstorff@sahra.org.za). This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the developer's expense.

These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Maralla West WEF alternative energy project. Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency (in this case SAHRA);
- The palaeontologist concerned with potential mitigation work will need a valid fossil collection permit from SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);
- All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies developed by Heritage Western Cape (2016) and SAHRA (2013).

1. INTRODUCTION

1.1. Scope of Work

The brief for the present report is to provide an authoritative, reasoned assessment of the palaeontological heritage resources within the Maralla West Wind Energy Facility (WEF) project area near Sutherland, Northern Cape, based on desktop studies and a short field survey. Known fossil sites are mapped in relation to the proposed WEF infrastructure layout. The palaeontological sensitivity of the area and the inferred impact significance of the proposed WEF development are then assessed. Recommendations for any necessary palaeontological mitigation or management measures during the construction phase of the WEF are made.

1.2. Objectives of the report

The Maralla West WEF study area is located in a region that is underlain by potentially fossiliferous sedimentary rocks of Late Palaeozoic and younger, Late Tertiary or Quaternary, age (These are described in more detail in Section 3 of this report). The construction phase of the proposed WEF will entail extensive surface clearance as well as excavations into the superficial sediment cover and underlying bedrock. The development may adversely affect legally-protected fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils preserved at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The planning, operational and de-commissioning phases of the WEF are unlikely to involve further adverse impacts on local palaeontological heritage.

A short desktop palaeontological heritage scoping phase report for the Maralla West and Maralla East WEFs has been submitted previously by the author (Almond 2016e). The present combined desktop and field-based palaeontological heritage assessment of the Maralla West WEF project area has been commissioned as part of the EIA Phase for this development that is being co-ordinated on behalf of Biotherm Energy (Pty) Ltd (Biotherm) by WSP | Parsons Brinckerhoff, Environment & Energy, Africa (Contact details: Ms Ashlea Strong. WSP | Parsons Brinckerhoff, Environment & Energy, Africa. WSP House, Bryanston Place, 199 Bryanston Drive, Bryanston, 2191, South Africa. Tel: +27 11 361 1392. Mob: +27 82 786 7819. Fax: +27 11 361 1381. E-mail: Ashlea.Strong@WSPGroup.co.za).

1.3. Legislative Framework

The present palaeontological heritage assessment report contributes to the consolidated heritage impact assessment for the proposed Maralla West WEF and falls under the South African Heritage Resources Act (Act No. 25 of 1999). It will also inform the Environmental Management Programme (EMPr) for this alternative energy project.

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act include, among others:

- geological sites of scientific or cultural importance;
- palaeontological sites; and
- palaeontological objects and material, meteorites and rare geological specimens.

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:

(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.
(2) All archaeological objects, palaeontological material and meteorites are the property of the State.
(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.
(4) No person may, without a permit issued by the responsible heritage resources authority—
  (a) destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;
  (b) destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;
  (c) trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or
  (d) bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.
(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—
  (a) serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;
  (b) carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;
  (c) if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and
  (d) recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

Minimum standards for the palaeontological component of heritage impact assessment reports (PIAs) have been published by Heritage Western Cape, HWC (2016) and the South African Heritage Resources Agency, SAHRA (2013).

1.4. Study approach and methodology

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc.*) represented within the study area are determined from geological maps and satellite images. The known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region, and the author's field experience (Consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development (provisional tabulations of palaeontological sensitivity of all formations in the Western, Eastern and Northern Cape have already been compiled; *e.g.* Almond & Pether 2008a, 2008b and SAHRIS website). The likely impacts of the proposed development on local fossil heritage are then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field-based assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation or monitoring required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the planning, operational or de-commissioning phases. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authorities, *i.e.* SAHRA for the Northern Cape (Contact details: Dr Ragna Redelstorff. Heritage Officer Archaeology, Palaeontology & Meteorites Unit, SAHRA. 111 Harrington Street, Cape Town, 8001. Tel: +27 (0)21 202 8651. Fax: +27 (0)21 202 4509 E-mail:rredelstorff@sahra.org.za) and Heritage Western Cape for the Western Cape (Contact details: Heritage Western Cape. Protea Assurance Building, Green Market Square, Cape Town 8000. Private Bag X9067, Cape Town 8001. Tel: 086-142 142. Fax: 021-483 9842. Email: hwc@pgwc.gov.za). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

In summary, the approach to a Phase 1 palaeontological heritage study is as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and relevant geological sheet explanations as well as satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous palaeontological assessments of the broader study region, and the author's field experience and palaeontological database. Based on this data as well as field examination of representative exposures of all major sedimentary rock units present, the impact significance of the proposed development is assessed, in this case using the methodology selected by WSP | Parsons Brinckerhoff, Environment & Energy, Africa. Recommendations for any further palaeontological studies or mitigation considered necessary are specified.

The present combined desktop and field-based PIA study was undertaken in line with the HWC (2016) and SAHRA (2013) Minimum Standards for the palaeontological component of heritage impact assessment. It was largely based on the following sources of information:

1. A brief project outline, maps and kmz files provided by WSP | Parsons Brinckerhoff, Environment & Energy, Africa;
2. Relevant geological maps and sheet explanations (*e.g.* Theron 1983, Theron *et al.* 1991, Cole & Vorster 1999) as well as Google earth© satellite imagery;
3. Several palaeontological heritage assessment reports by the present author for proposed developments in the Klein-Roggeveldberge regions between Sutherland and Matjiesfontein.

These include palaeontological impact assessments (PIAs) for the Eskom Gamma – Omega 765 kV transmission line (Almond 2010a) and those for several alternative energy facilities in the Klein-Roggeveld and Sutherland regions (*e.g.* Almond 2010a-d, 2011, 2014, 2015a-g, Almond 2016b-g, Miller 2010, Rossouw 2012).

4. A four-day palaeontological field assessment of the combined Maralla West and Maralla East WEF study area (February 2016) by the author and between one and three experienced field assistants;
5. The author's previous experience with the formations concerned and their palaeontological heritage (*cf* Almond & Pether 2008a-b and references listed above).

GPS data and brief descriptive notes for all numbered geological or palaeontological localities mentioned in the text are provided in the Appendix. Fossil localities that were recorded during fieldwork are shown in relation to relevant major components of the proposed development footprint on the satellite image provided in Figure 24. Please note that this map does *not* show all fossils that are present at surface within the study area. Additional, unrecorded fossil occurrences (the majority) are to be expected in the subsurface, where they may be impacted during the construction phase of the development. Areas on the map that do not contain known fossil sites are therefore not necessarily fossil-free or palaeontologically insensitive.

1.5. Assumptions

Since most fossils are buried beneath the surface, their nature and distribution cannot be directly assessed during field surveys of the development footprint. Palaeontological assessments therefore rely on extrapolating palaeontological sensitivities within the footprint from desktop data and field surveys of well-exposed sedimentary rocks, mostly from sites *outside,* and often well away from, the footprint itself. This approach assumes that the rock exposures seen are representative - in palaeontological terms - of the rock units (formations, members *etc*) that will be impacted by the proposed development.

1.6. Limitations of this study

The accuracy and reliability of palaeontological specialist studies as components of heritage impact assessments are generally limited by the following constraints:

1. Inadequate database for fossil heritage for much of the RSA, given the large size of the country and the small number of professional palaeontologists carrying out fieldwork here. Most development study areas have never been surveyed by a palaeontologist.

2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant ("mappable") bedrock units as well as major areas of superficial "drift" deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock outcrop, depth of superficial cover (soil *etc*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.

3. Inadequate sheet explanations for geological maps, with little or no attention paid to palaeontological issues in many cases, including poor locality information.

4. The extensive relevant palaeontological "grey literature" - in the form of unpublished university theses, impact studies and other reports (*e.g*. of commercial mining companies) - that is not readily available for desktop studies.

5. Absence of a comprehensive computerized database of fossil collections in major RSA institutions which can be consulted for impact studies. A Karoo fossil vertebrate database is now accessible for impact study work.

In the case of palaeontological desktop studies without supporting Phase 1 field assessments these limitations may variously lead to either:

a) *underestimation* of the palaeontological significance of a given study area due to ignorance of significant recorded or unrecorded fossils preserved there, or

b) *overestimation* of the palaeontological sensitivity of a study area, for example when originally rich fossil assemblages inferred from geological maps have in fact been destroyed by tectonism or weathering, or are buried beneath a thick mantle of unfossiliferous "drift" (soil, alluvium *etc*).

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist.

In the case of the Maralla West WEF study area near Sutherland in the Western Cape, preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation. However, bedrock exposure is highly constrained by extensive superficial deposits, especially in areas of low relief, as well as pervasive Karoo *bossieveld* vegetation (Central Mountain Shale Renosterveld, Koedoesberg – Moordenaars Karoo, Tanqua Wash Riviere). The study area is very extensive and much of it is hilly or mountainous with few access roads, especially in rugged upland areas (Figs. 2 to 5). However, sufficient bedrock exposures were examined during the course of the four-day field study to assess the palaeontological heritage sensitivity of the main rock units represented within the study area (See Appendix for locality data). Comparatively few academic palaeontological studies have been carried out hitherto in the region, so any reliable new palaeontological data from field-based impact studies here are of scientific interest. Palaeontological and geological data from the recent field study is usefully supplemented by those from several other field-based fossil heritage impact studies carried out in the Klein-Roggeveldberge region by the author and others in recent years (See reference list). Confidence levels for this impact assessment are consequently rated as medium, despite the unavoidable constraints of limited exposure, time and access.

1.7. Declaration of independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed development project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

John E. Almond

Dr John E. Almond (**Palaeontologist**, ***Natura Viva* cc)**

2. DESCRIPTION OF THE PROJECT

The company BioTherm Energy (Pty) Ltd (BioTherm) is proposing to develop a wind energy facility (WEF) with a total generation capacity of up to 140 MW, to be known as the Maralla West WEF, on a site located some 35 km to the SSE of Sutherland, Sutherland District, Northern Cape. The project area involves the following land parcels: Portions 1 and 2 of Wolven Hoek 182, Drie Roode Heuwels 180 and Annex Drie Roode Heuwels 181(Figs. 1 & 24).

The main infrastructural components of the proposed WEF (Fig. 24) include:

- Up to 70 wind turbine generators with a generating capacity of between 2 and 4 MW each. The turbines will have a hub height of up to 120 m and rotor diameter of up to 150 m.
- Concrete foundations to support the turbines.
- An onsite 132/400 kV substation (IPP) with transformers for voltage step-up from medium voltage to high voltage. The IPP substation will occupy an area of 150 m x 150 m. Two locations for the on-site substation are under consideration (Fig 24. The site indicated here in red is the preferred alternative). The IPP substation will occupy a common substation area together with an Eskom Substation that will connect to the national grid *via* a 400 kV powerline (to be assessed separately).
- A medium voltage collector system consisting of underground 1 to 33 kV cables (except where technical assessment suggests that overhead lines are more suitable) connecting the turbines to the onsite substation.
- A laydown area (max. 4 ha) for the temporary storage of materials during construction.
- Temporary site compound for contractors,
- Sewage disposal facility and septic tanks.
- Borrow pits.
- Access roads and internal roads.
- Car park and security fencing
- Administration, control and warehouse buildings.
- Operations and Maintenance compound including O&M buildings, car park and storage area.

Borrow pit sites will only be identified if and when the proposed WEF wins preferred bidder status. In this case, a separate palaeontological assessment of all borrow pit sites will be necessary.

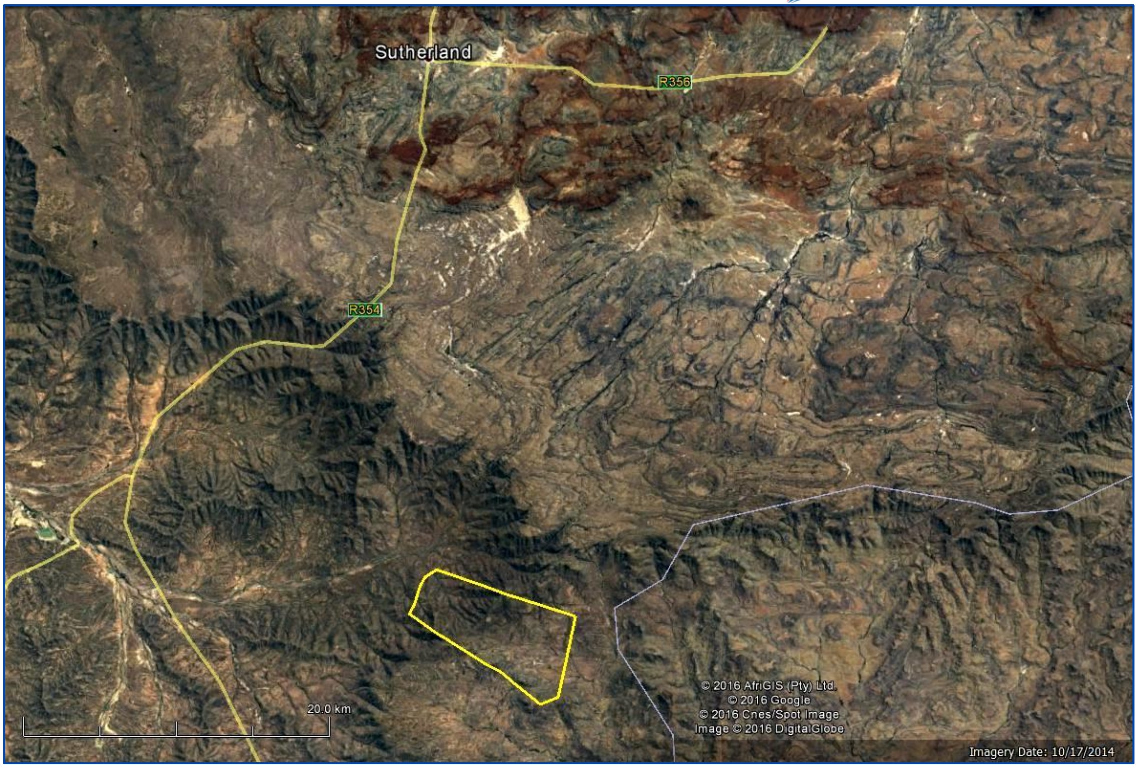

Figure 1. Google earth© satellite image of the SW Karoo showing the location of the proposed Maralla West WEF project area, situated beneath the Great Escarpment in the Klein-Roggeveldberge region, *c*. 35 km SSE of Sutherland, Northern Cape (yellow polygon).

3. DESCRIPTION OF THE AFFECTED ENVIRONMENT

3.1. Maralla West WEF study area – general description

The Maralla West WEF project area is situated in semi-arid, hilly to mountainous terrain of the Klein-Roggeveldberge region – below the main Roggeveld - Komsberg Escarpment - in the south-western part of the Great Karoo. It lies on the eastern side of the R354 Matjiesfontein to Sutherland tar road and some 35 km SSE of Sutherland, Northern Cape (Figs. 1 & 24). The unpaved road between Matjiesfontein and Sutherland *via* Haashoogte and the Komsberg Pass traverses the eastern portion of the study area. The western portion of the study area (Wolwen Hoek 182, Drie Roode Heuwels 181) spans the steep, NW-facing Klein-Roggeveldberg Escarpment (*c*. 1000-1450 m amsl) that is deeply dissected by numerous small tributaries of the Tanquarivier drainage system. The somewhat flatter, higher-lying terrain in the east (Drie Roode Heuwels 180), above the escarpment, lies at elevations of *c.* 1200-1400 m amsl and is drained towards the southeast by tributaries of the Komsbergrivier, itself a tributary of the Buffelsrivier drainage network. Levels of bedrock exposure within the study region are highly constrained by extensive superficial deposits, especially in areas of low relief but also along the escarpment itself (scree), as well as by pervasive Karoo *bossieveld* vegetation (Central Mountain Shale Renosterveld, Koedoesberg – Moordenaars Karoo, Tanqua Wash Riviere) (Figs. 2 to 5).

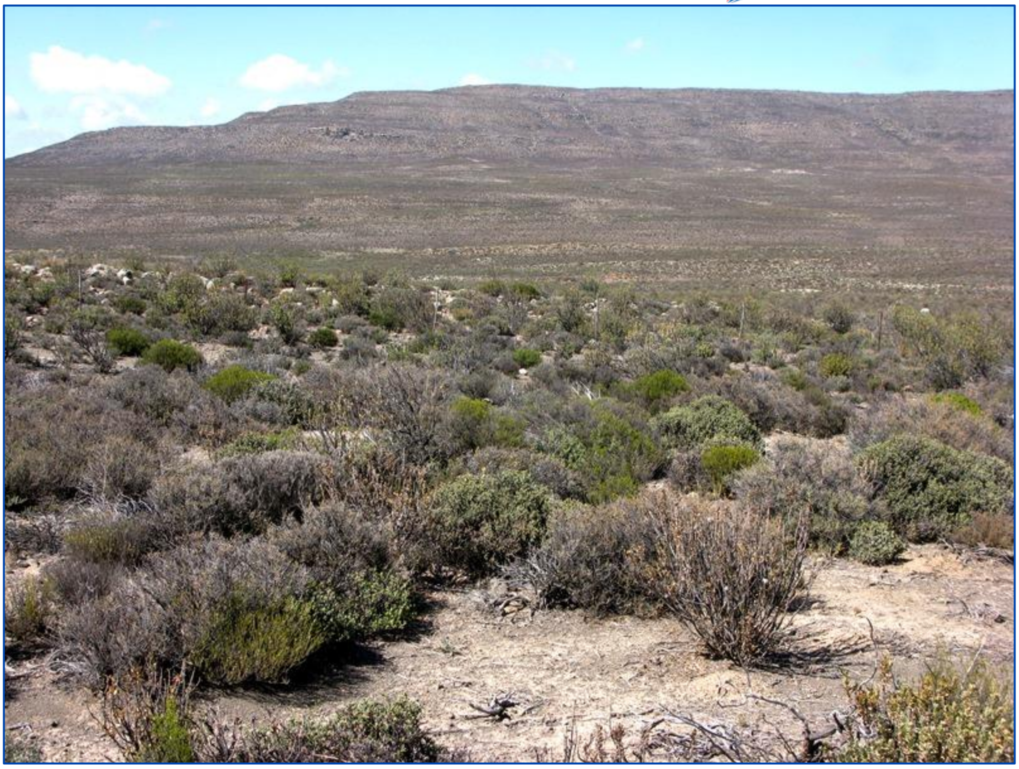

Figure 2. View southwards towards the Graskop ridge (1430 m amsl) on the southern border of the Maralla West WEF study area, Drie Roode Heuwels 180.

Figure 3. Good bedrock exposures along a stream gully incising the elevated terrain along the edge of the Klein-Roggeveld Escarpment, Drie Roode Heuwels 180.

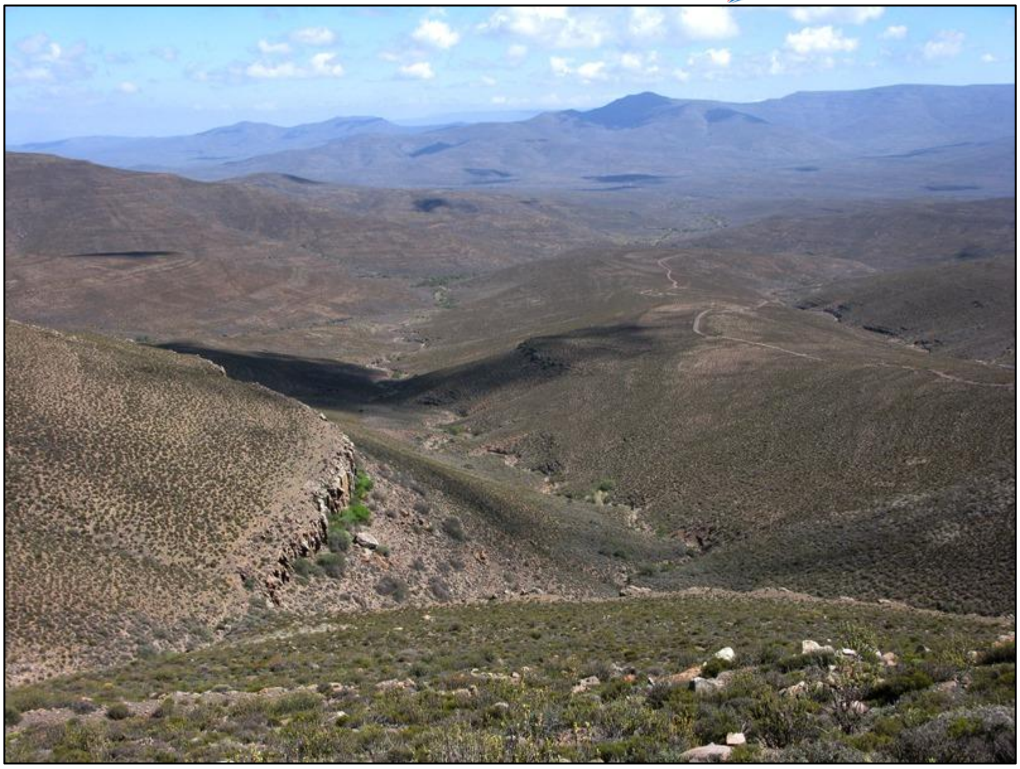

Figure 4. View westwards from the edge of the Klein Roggeveldberge Escarpment into highly dissected terrain on Wolven Hoek 182.

Figure 5. The west-facing Klein Roggeveldberge Escarpment on Wolven Hoek 182 showing prominent-weathering tabular sandstones within the Abrahamskraal Formation and rubbly sandstone scree in the foreground.

3.2. Geological context

The geology of the Maralla West WEF study area is outlined on the 1: 250 000 geology sheet 3220 Sutherland (Council for Geoscience, Pretoria; Theron 1983, Cole & Vorster 1999) (See map Fig. 8 and stratigraphic column Fig. 9). The area lies on the gently-folded northern margin of the Permo-Triassic Cape Fold Belt (CFB) and is dominated by bedrocks of the Karoo Supergroup within the Main Karoo Basin (Johnson *et al.* 2006). Gentle folding along west-east trending fold axes of Lower Beaufort Group bedrocks is apparent within the study area. In general bedding dips are not high, however (5-15 degrees on geological map), and levels of tectonic deformation are usually low, with little cleavage development. Dykes and sills associated with the Karoo Dolerite Suite of Early Jurassic age are not mapped within the study area, but are represented elsewhere within the Klein-Roggeveld region. Only one mappable sedimentary bedrock unit or formation is represented within the study area, namely:

- Fluvial and lacustrine mudrocks and sandstones of the **Abrahamskraal Formation** (**Lower Beaufort Group / Adelaide Subgroup**) of Middle Permian age. These beds crop out over the entire study area, including beneath almost all proposed wind turbine positions (Pa, pale green in Fig. 6).

Levels of bedrock exposure in the Klein-Roggeveldberge region are generally very low due to the pervasive mantle of **Late Caenozoic superficial deposits** such as alluvium, colluvium (scree, hillwash), surface gravels, pedocretes (*e.g.* calcrete) and soils, as well as karroid bossiveld vegetation. Most of these deposits are of Quaternary to Holocene age. They have not been separately mapped at 1: 250 000 scale within the Maralla West WEF project area.

Illustrated descriptions of Lower Beaufort Group bedrocks as well as various superficial sediments have been given in previous PIAs by the author for the Klein-Roggeveld region (see References). The following geological account is in part based on recent PIA reports by Almond (2015d, 2015g) which deal with WEF study areas on the southwestern and northern borders of the Maralla West WEF project (Soetwater WEF and Gunsfontein WEF respectively). A separate field-based PIA report is being submitted for the Biotherm Maralla East WEF situated immediately to the east (Almond, in prep. 2016).

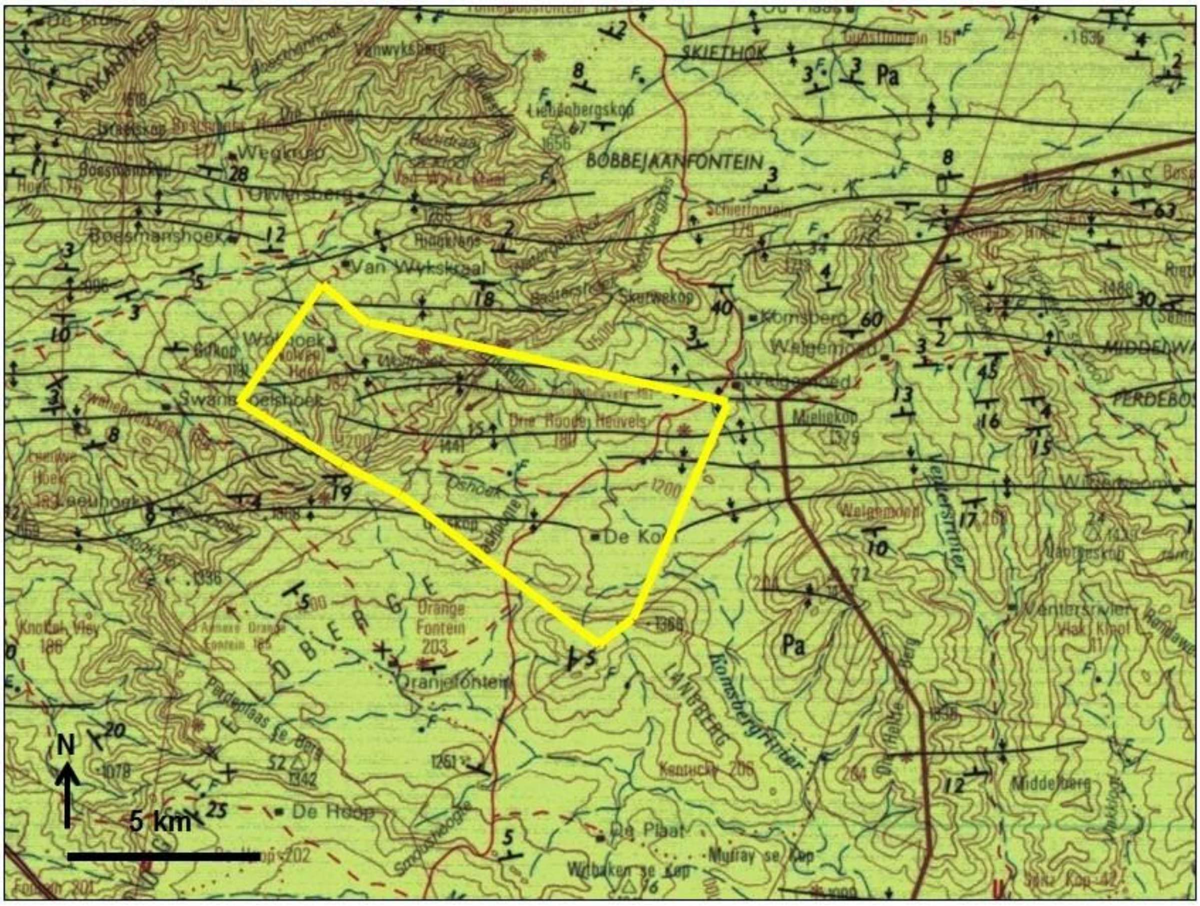

Figure 6. Extracts from 1: 250 000 scale geology sheet 3220 Sutherland showing the location of the proposed Maralla West WEF study area, *c*. 35 km SSE of Sutherland, Northern Cape Province (yellow polygon) (Abstracted from geological map published by Council for Geoscience, Pretoria). The main mappable rock unit (fm = formation) represented within the study area is the Abrahamskraal Formation (Pa, pale green) (Lower Beaufort Group, Karoo Supergroup) of Middle Permian age. There are no dykes or sills of the Karoo Dolerite Suite mapped in the area. Various Late Caenozoic superficial deposits that are not mapped at 1: 250 000 scale include alluvium, colluvium (scree deposits, hillwash), downwasted surface gravels, pedocretes (calcretes) and soils.

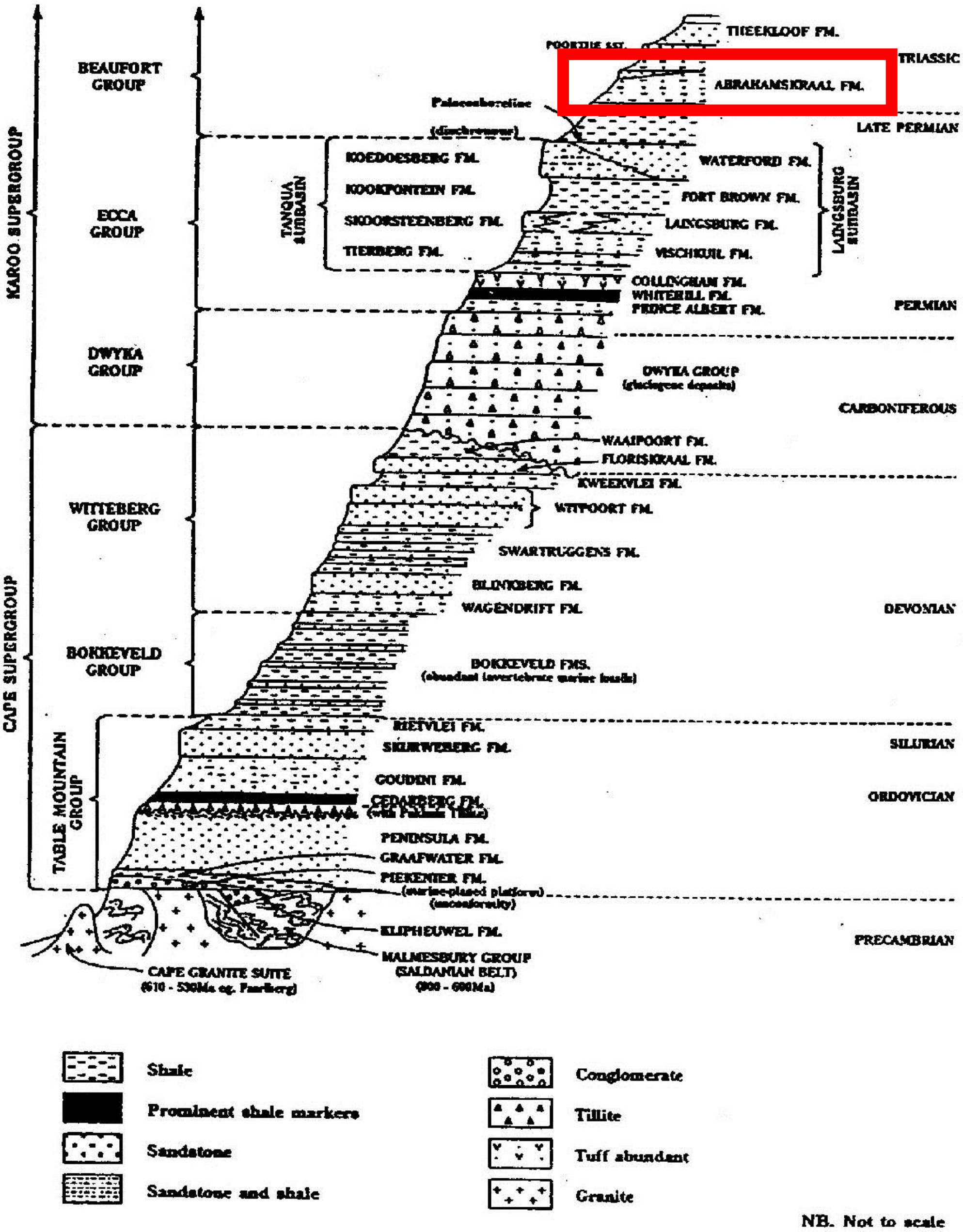

Figure 7. Schematic stratigraphic column for the Western Cape, the red box indicating the position of the Abrahamskraal Formation (Lower Beaufort Group) that crops out within the Maralla West WEF study area (Modified from original figure by H. de V. Wickens). *N.B.* The sedimentary bedrocks within the study area are all Middle Permian in age, in contrast to the time scale shown here.

3.2.1. Abrahamskraal Formation

The Abrahamskraal Formation is a very thick (*c*. 2.5km) succession of fluvial and lacustrine deposits laid down in the Main Karoo Basin by meandering rivers and in shallow lakes on an extensive, low-relief floodplain during the Mid Permian Period, some 266-260 million years ago (Rossouw & De Villiers 1952, Johnson & Keyser 1979, Turner 1981, Theron 1983, Smith 1979, 1980, 1990, 1993a, 1993b, Smith & Keyser 1995a, Loock *et al*., 1994, Cole & Vorster 1999, McCarthy & Rubidge 2005, Johnson *et al*., 2006, Day 2013a, Day & Rubidge 2014, Wilson *et al.* 2014). These sediments include (a) lenticular to sheet-like channel sandstones, often associated with thin, impersistent intraformational breccio-conglomerates (larger clasts mainly of reworked mudflakes, calcrete nodules, *plus* sparse rolled bones, teeth, petrified wood), (b) well-bedded to laminated, grey-green, blue-grey to purple-brown or maroon floodplain mudrocks with sparse to common pedocrete horizons (calcrete nodules formed in ancient soils), (c) thin, sheet-like crevasse-splay sandstones, as well as more (d) localized playa lake deposits (*e.g.* wave-rippled sandstones, laminated mudrocks, limestones, evaporites). A number of greenish to reddish weathering, silica-rich "chert" horizons are also found. Many of these appear to be secondarily silicified mudrocks or limestones but at least some contain reworked volcanic ash (tuffs, tuffites). A wide range of sedimentological and palaeontological observations point to deposition under seasonally arid climates. These include, for example, the abundance of pedogenic calcretes and evaporites (silicified gypsum pseudomorphs or "desert roses"), reddened mudrocks, sun-cracked muds, "flashy" river systems, sun-baked fossil bones, vertebrate burrowing behavior, well-developed seasonal growth rings in fossil wood, rarity of fauna, and little evidence for substantial bioturbation or vegetation cover (*e.g.* root casts / rhizoturbation) on floodplains away from the river banks.

The 1: 250 000 Sutherland geological sheet 3220 (Theron 1983) shows a large area of undifferentiated Abrahamskraal Formation beds in the Sutherland area (Fig. 6). There have since been a number of attempts, only partially successful, to subdivide the very thick Abrahamskraal Formation succession in both lithostratigraphic (rock layering) and biostratigraphic (fossil) terms (*cf* Day & Rubidge 2010, 2014, Day 2013a). The benchmark study by Loock *et al.* (1994) in the Moordenaarskaroo area north of Laingsburg led to the identification of six lithologically-defined members within the Abrahamskraal Formation (Fig. 17). Several of these members have since been mapped in the Sutherland area by Cole and Vorster (1999). Very brief descriptions of these stratigraphic members are given by Loock *et al.* (1994) but the interested reader should refer to earlier works by Le Roux (1985) and Jordaan (1990) for detailed sedimentological data that is beyond the scope of the present palaeontological heritage study.

Based on the abundance of maroon mudrocks as well as the apparent absence or rarity of fossil vertebrate remains (Section 4), it is tentatively inferred that the Maralla West WEF study area is largely underlain by the Leeuvlei and Koornplaats Members of the lower Abrahamskraal Formation (red bar in Fig. 17). According to Loock *et al.* (1995) the *c*. 860 m-thick **Leeuvlei Member** is characterized by:

- Grey overbank mudrocks with calcrete concretions and thin pyritic horizons;
- Maroon mudrocks, locally with abundant equisetalean (arthrophyte) plant debris;
- Sheet-like channel sandstone bodies composed of very fine- to fine-grained sandstone showing horizontal lamination and ripple cross-lamination. Sandstone bases are erosional and in the upper part of the member they feature lag breccio-conglomerates composed of mudflake intraclasts, reworked calcrete nodules and fossil material (rolled tetrapod bone, arthrophyte stems);
- Well-developed palaeosurfaces on sharp upper sandstone surfaces showing ripple marks, ponds, rill marks *etc*;
- Heavy mineral laminations towards the tops of sandstone packages.

- Occasional thick channel packages with a multi-storey architecture and trough cross-bedding. These packages are locally associated with accumulations of plant debris and secondary uranium mineralization (*koffieklip*).

Thicker sandstone packages that crop out along the Klein-Roggeveld Escarpment edge, and also in higher ground along the southern margin of the project area (*e.g.* Graskop), probably belong to the *c*. 260 m-thick **Koornplaats Member** of the Abrahamskraal Formation. According to Loock *et al.* (1995) this is characterized by:

- Yellow-weathering sheet-like channel sandstone packages with heavy mineral laminations (up to 2 cm thick) towards the top and basal lag breccio-conglomerates. A prominent, laterally-persistent package of five yellowish fine-grained sandstone units marks the upper part of the member in the Roggeveld – Nuweveld Escarpment area. The sandstones are associated with fossil tetrapod material and reworked plant material, including silicified wood (rarely with exotic extra-basinal pebbles) and *Vertebraria* glossopterid roots. Uranium mineralization may be associated with transported plant material.
- Grey and maroon overbank mudrocks with calcrete horizons, tetrapod fossils.

It is possible that the sandstone package building the upper part of the escarpment in the western part of the Maralla West WEF study area (Fig. 9) is equivalent to the **Grootfontein Member** of Day and Rubidge (2014; see their fig. 3 as well as Fig. 8 herein). However, more detailed geological mapping is required to confidently relate the lower Abrahamskraal Formation successions represented in the present study area to their more refined lithostratigraphic scheme.

The Abrahamskraal Formation in the Klein-Roggeveld study region is a succession of continental fluvial rocks characterized by numerous lenticular to sheet-like sandstones with intervening, more recessive-weathering mudrocks (Stear 1980, Le Roux 1985, Loock *et al.* 1994, Cole & Vorster 1999, Wilson *et al.* 2014) (Figs. 9 to 13). The channel sandstone units are up to several (5 m or more) meters thick and vary in geometry from extensive, subtabular sheets to single-storey lenticles or multi-storey channel bodies with several partially superimposed, cross-cutting lenticular subunits, often demarcated at the base by thin mudrocks and / or basal breccio-conglomerates. Obliquely side-steeping, successively higher channel bodies of laterally-migrating river systems are also seen within some intervals. The prominent, laterally-persistent sandstone ledges generate a distinctive stepped or terraced topography on hill slopes in the area (Fig. 9). The sheet sandstones are generally pale-weathering (enhanced by epilithic lichens), fine- to medium-grained, well-sorted and variously massive or structured by horizontal lamination (flaggy, with primary current lineation), or more rarely tabular to trough cross-bedding. Greyish hues of some freshly broken sandstone surfaces suggest an “impure” clay-rich mineralogy (*i.e.* wackes). Current ripple cross-lamination is common towards the tops of the sandstone beds which may also feature undulose bars and swales. The lower contacts of the channel sandstones are gradational to erosive on a small scale, and only occasionally associated with lenticular basal breccias that may infill small-scale erosive gullies. The breccias may also occur within the body of the channel sandstone unit and are almost entirely composed of reworked mudflake intraclasts. Reworked small calcrete nodules and occasional rolled (reworked) bones have been observed locally in the Klein-Roggeveldberge region. Heterolithic, thinly-interbedded sandstone and mudrock packages associated with some channel sandstones may represent delta-like levee deposits.

Within the greater part of the Abrahamskraal Formation succession building the foot and slopes of the Klein-Roggeveld Escarpment the channel sandstones – probably within the lower portion of the Leeuvlei Member - are fine-grained with tabular geometry, giving a stepped appearance to the landscape (Fig. 9). The grain-size contract between the fine-grained sandstones / wackes and the silty overbank mudrocks is often slight, so upper and lower surfaces of channel and crevasse-splay sandstones, as well as channel margins, may be ill-defined and gradational (Fig. 11). The fine- to very-fine-grained sandstones are typically well-consolidated, well-sorted, greyish to slightly pinkish-purple (sometimes colour-mottled) and well-jointed. They are usually structured by horizontal lamination or fine-scale ripple cross-lamination, or occasionally massive. Lower contacts are only moderately erosional, with no marked gullying, and are usually not associated with well-defined basal breccias.

Channel sandstones higher in the Abrahamskraal Formation succession – such as those within the Koornplaats Member - tend to be thicker-bedded (up to several meters), massive, with a distinctive large-scale, rounded corestone and crusty weathering pattern. They are variously tabular to lenticular in geometry. Grain-size is medium to coarse, with a slightly crumbly, only moderately well-consolidated texture (perhaps due to high feldspar content), and frequently speckled or clotted in appearance. Weathering hues vary from yellowish to brown (though often lichen-covered). Fabrics are variously massive, horizontally-laminated (*e.g.* flaggy, with primary current lineation), ripple cross-laminated to occasionally trough cross-bedded. Cannonball-sized spheroidal concretions of ferruginous carbonate are of diagenetic origin. The channel bases are moderately to markedly erosional and gullied. They are often associated with laterally-persistent, prominent-weathering, well-consolidated basal breccias up to 70-100 cm thick of reworked mudflakes and calcrete nodules, and occasionally also plant debris, including locally common petrified wood. Basal breccia lenses may be incorporated towards as well as at the base of the channel sandstone package and are often ferruginised. Flaggy sandstones within these successions may show well-developed, laterally-persistent, fine-scale heavy mineral banding.

Although general mudrock exposure levels within the Maralla West WEF study area are low to very low, there are in fact numerous small exposures available along stream banks and steeper hillslopes, both along the Klein-Roggeveld Escarpment as well as on the plateau (Figs. 3, 10 to 13). A high proportion of the Abrahamskraal overbank mudrocks within the study area are purple-brown to maroon, while non-reddish mudrocks may be more blue-green than greenish-grey, especially lower down in the succession. Horizons of small to large pedogenic calcrete are moderately common within the overbank mudrock packages at all stratigraphic levels. Larger-scale pedogenic calcretes are usually ferruginous, rusty brown, and often lenticular to irregular in form (Fig. 13), while smaller sphaeroidal calcrete nodules are usually pale grey. Pinkish, lenticular silica pseudomorphs after gypsum ("desert roses") are common at certain horizons within grey-green mudrocks low down within the Abrahamskraal Formation succession, indicating highly arid climatic phases on the Middle Permian floodplain. Weathered-out desert roses may locally dominate surface gravels.

Packages of several meters of thin-bedded, blue-grey siltstones with local development of wave-rippled bedding planes may be playa lake facies on the distal floodplain. Thin- to medium-bedded heterolithic intervals (interbedded fine-grained sandstone and mudrock) are usually closely-associated with channel sandstones and are probably levee to proximal floodplain facies. Lenticular channel sandstones may pass laterally into heterolithic facies, supporting this interpretation. Thin, single-storey tabular sandstones of probable crevasse splay origin may occasionally be loaded at the base, suggesting soupy substrates on the floodplain.

Several sedimentological features suggest that a significant portion of the lower Abrahamskraal Formation succession was deposited in extensive playa lakes on the Middle Permian floodplain or inner delta platform. These include the highly-tabular, laterally-continuous character of beds within both mudrock and sandstone facies, frequent horizons of large (m-scale), ferruginous carbonate diagenetic concretions (some showing septarian cracking) indicating high water tables, common bedding surfaces with small-scale symmetrical wave ripples that are often associated with invertebrate traces, amphibian trackways, possible amphibian bones, dense stands of reedy swamp vegetation and sphenophyte debris, horizons of gypsum pseudomorphs (following desiccation of saline ponds), and common upward-coarsening mudrock to fine sandstone packages with transitional, occasionally loaded sandstone bases.

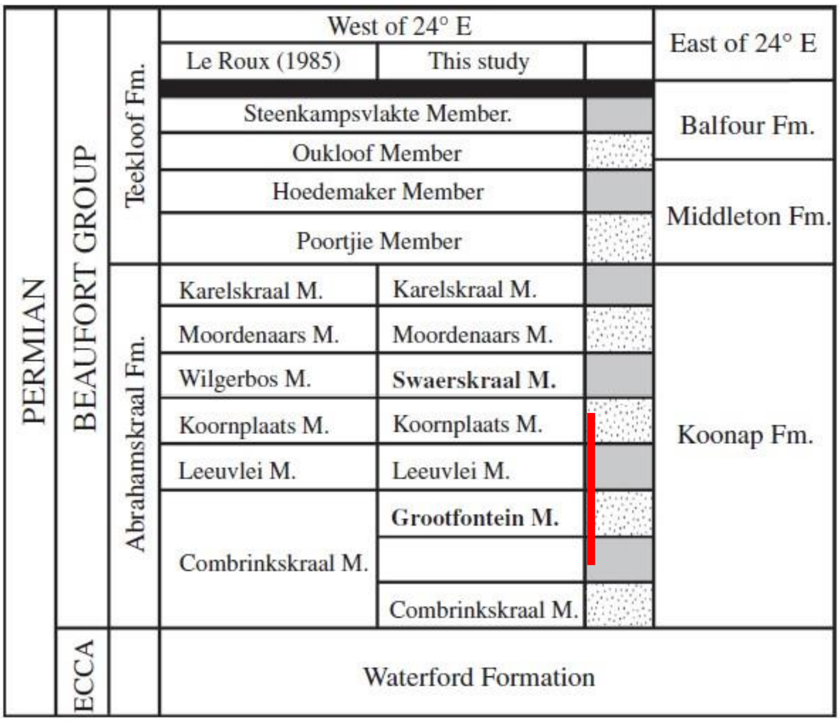

Figure 8. Revised subdivision of the Abrahamskraal Formation of Day and Rubidge (2014). The red bar indicated members that are probably represented within the Maralla West WEF study area.

Figure 9. Package of thin, closely-spaced, tabular sandstones building the upper part of the Klein-Roggeveld escarpment in the Maralla West WEF study area. This package might be equivalent to the Grootfontein Member of the lower Abrahamskraal Formation.

Figure 10. Excellent riverine exposure of the Abrahamskraal Formation along the Klein Roggeveldberge Escarpment, Wolven Hoek 182 (Loc. 301).

Figure 11. Interbedded tabular-bedded overbank mudrocks and fine-grained sandstones of the Abrahamskraal Formation, Wolven Hoek 182 (Loc. 301). Note indistinct base of several sandstone units.

Figure 12. Steep hillslope exposure of gently west-dipping Abrahamskraal Fm beds along the crest of the Klein Roggeveld Escarpment (Loc. 299).

Figure 13. Pedocrete (ancient soil) horizon marked by well-developed ferruginous calcrete concretions within hackly-weathering overbank mudrocks, Wolven Hoek 182 (Loc. 302) (Hammer = 30 cm).

3.2.2. Late Caenozoic superficial sediments

A broad spectrum of Late Caenozoic superficial deposits mantle the Karoo Supergroup bedrocks (and and hidden dolerite intrusions) in the Maralla West WEF study area. Most of these younger sediments are unconsolidated to partially consolidated and probably of Quaternary to Recent age. A wide range of well-bedded to massive, semi-consolidated, sandy to gravelly alluvial deposits are exposed in river bank sections (Fig. 15), while unconsolidated sandy to bouldery alluvium, the latter dominated by clasts of Karoo wackes, lines modern water courses. Lowland areas are largely covered by sandy and gravelly soils that are up to several meters thick and mainly of alluvial origin; they are well-exposed in the walls of erosion gullies or *dongas* (Fig. 14). Sheetwash processes have locally concentrated thin gravels at the soil surface. Upland slopes and plateau – where most of the wind turbine infrastructure will be placed - are generally covered with sandy and rubbly colluvial deposits that are principally composed of downwasted Beaufort Group sandstones and wackes (Figs. 5, 16).

Figure 14. Erosion gulley exposures of fine sandy to silty alluvium and sheetwash close to and above the Klein Roggeveldberge Escarpment, Drie Roode Heuwels 180.

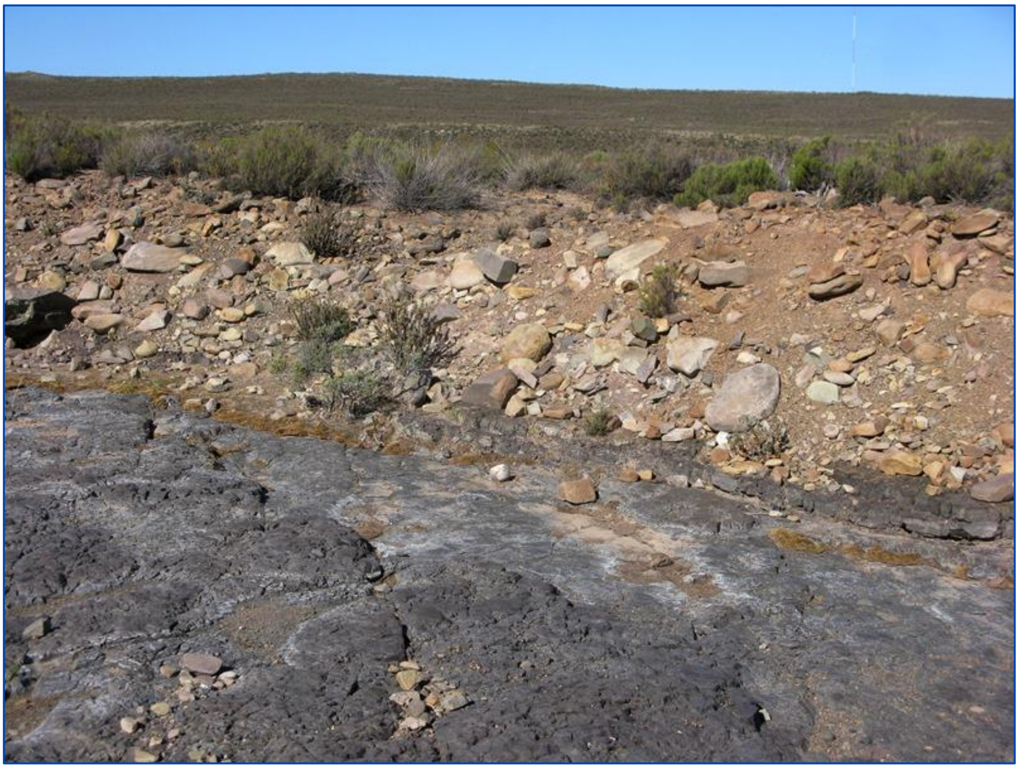

Figure 15. Coarse gravelly alluvium overlying Abrahamskraal Formation bedrocks, Drie Roode Heuwels 180 (Loc. 310).

Figure 16. Sandy soils and karroid bossieveld vegetation mantling bedrocks in flatter-lying parts of the Maralla West WEF study area above the escarpment, Drie Roode Heuwels 180 (near Loc. 310).

4. PALAEONTOLOGICAL FINDINGS

In this section of the report the principal palaeontological heritage findings within the Maralla West WEF project area are outlined and illustrated. GPS co-ordinates and associated field data for each of the numbered geological and palaeontological sites are given in the Appendix. The principal fossil sites recorded are indicated on the satellite image of the project area in Fig. 24. Please note that this is *not* a distribution map of *all* fossil occurrences within the project area – most of which are not exposed at the surface – but only a representative sample of the better-preserved fossils encountered during the field assessment. Further, unrecorded fossil occurrences are to be expected elsewhere at the ground surface or in the subsurface (the majority), where they may be impacted during the construction phase of the development. Areas on the map that do not contain known fossil sites are therefore not necessarily fossil-free or palaeontologically-insensitive. All the fossils observed during the recent field study are of widely-occurring forms and are not considered to be of exceptional scientific or conservation value; for this reason, no specialist palaeontological mitigation of the recorded sites is recommended here, although they all lie within or close to the development footprint.

The Great Karoo is world-famous for its rich record of terrestrial vertebrates and other fossils from the Permian, Triassic and Early Jurassic Periods in Gondwana (MacRae 1999, McCarthy & Rubidge 2005, Smith *et al.* 2012). The fossil record of the Klein-Roggeveld region is very poorly known by Karoo standards – as shown by the paucity of fossil vertebrate sites recorded in maps compiles by Keyser and Smith (1977-1978) and Nicolas (2007) - but our knowledge has been improved in recent years through several palaeontological impact assessments in the area (See References).

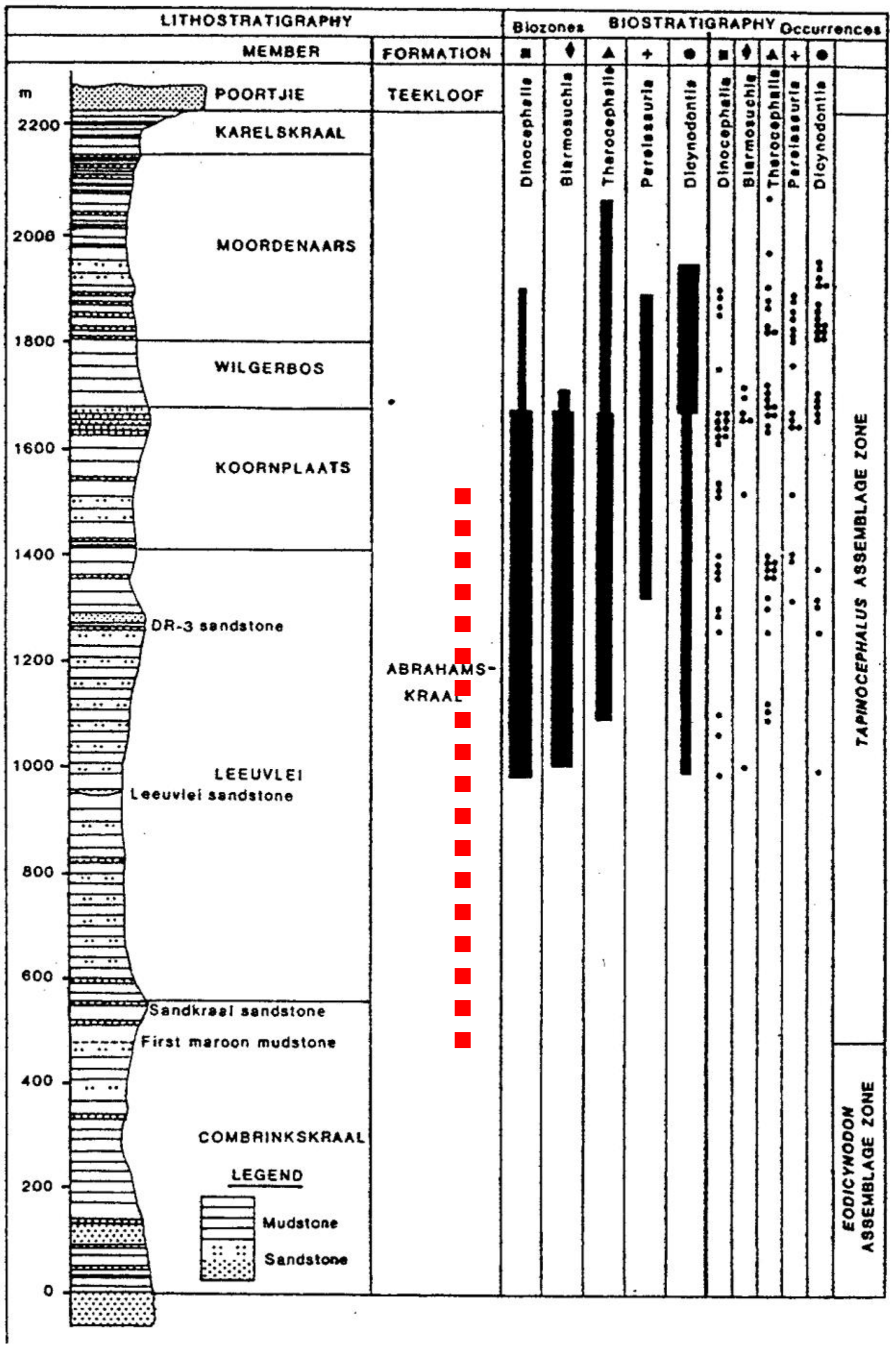

Figure 17. Chart showing the subdivision of the Abrahamskraal Formation in the western Karoo region with stratigraphic distribution of the major fossil vertebrate groups (Loock *et al*. 1994). The Maralla West WEF study area is probably underlain by sediments within the Leeuvlei and lower Koornplaats Members but upper Combrinkskraal Member beds, above the first appearance of maroon mudstones, might also be represented here (These may include the Grootfontein Member sandstone package recently recognized by Day & Rubidge 2014; see Fig. 8).

4.1. Fossils in the lower part of the Abrahamskraal Formation

A chronological series of mappable fossil biozones or assemblage zones (AZ), defined mainly on their characteristic tetrapod faunas, has been established for the Main Karoo Basin of South Africa (Rubidge 1995, 2005, Van der Walt *et al.* 2010, Smith *et al.* 2012). Maps showing the distribution of the Beaufort Group assemblage zones within the Main Karoo Basin have been provided by Keyser and Smith (1977-1978) and Rubidge (1995, 2005). A recently updated version is now available (Nicolas 2007, Van der Walt *et al.* 2010).

The earliest terrestrial vertebrate faunas of the Main Karoo Basin, recorded from the lowermost part of the Abrahamskraal Formation are assigned to the ***Eodicynodon*** **Assemblage Zone** of *c*. 268-265 million years ago (Rubidge 1995, Smith *et al.* 2012) (Fig. 17). The Combrinkskraal Member *sensu lato* (including the Combrinkskraal and Grootfontein Members of Day & Rubidge 2014) is assigned to the *Eodicynodon* AZ (*ibid*, Jinnah & Rubidge 2007). Only a few fossil tetrapod (*i.e.* four-limbed vertebrate) remains have been discovered from the lowermost Abrahamskraal Formation beds along the southern and south-western margins of the Great Karoo. They are dominated by small dicynodont therapsids (mammal-like reptiles) as well as extremely rare, large-bodied dinocephalians (Fig. 18). Sparse, disarticulated skeletal remains and sizeable burrows of small-bodied tetrapods – probably the dicynodont *Eodicynodon* itself - have recently been recorded from lower Abrahamskraal Formation beds in the Klein-Roggeveld region (Almond 2016c). Other interesting fossils from the lowermost Abrahamskraal Formation include well-preserved, reedy swamp plants (horsetail ferns) and possible lungfish burrows (*cf* Almond 2010a, Hasiotis *et al.* 1993, Odendaal & Loock 2015).

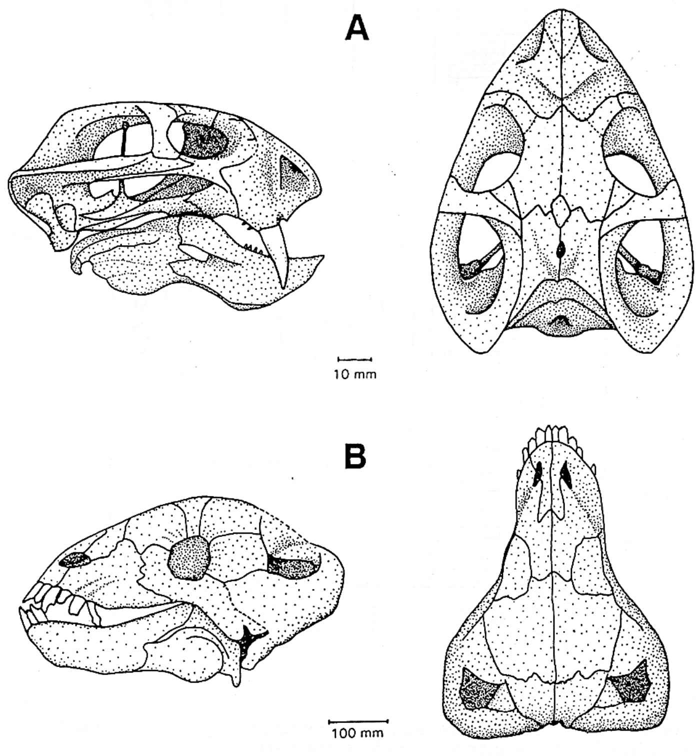

Figure 18. Skulls of two key fossil therapsids from the Middle Permian *Eodicynodon* Assemblage Zone: A – the small dicynodont *Eodicynodon*; B – the rhino-sized dinocephalian *Tapinocaninus* (From Rubidge 1995).

Rare to moderately abundant fossil vertebrates from the upper portion of the Leeuvlei Member and the overlying Koornplaats Member of the Abrahamskraal Formation are assigned to the Middle Permian ***Tapinocephalus* Assemblage Zone**. The main categories of fossils recorded within the *Tapinocephalus* fossil biozone (Keyser & Smith 1977-78, Anderson & Anderson 1985, Smith & Keyser 1995a, MacRae 1999, Rubidge 2005, Nicolas 2007, Almond 2010a, Smith *et al.* 2012, Day 2013a, Day 2013b, Day *et al.* 2015b) (Figs. 17 & 19) include:

- isolated petrified bones as well as rare articulated skeletons of tetrapods (*i.e.* air-breathing terrestrial vertebrates) such as true **reptiles** (notably large herbivorous pareiasaurs like *Bradysaurus*, small insectivorous millerettids), rare pelycosaurs, and diverse **therapsids** or "mammal-like reptiles" (*e.g.* numerous genera of large-bodied dinocephalians, herbivorous dicynodonts, flesh-eating biarmosuchians, gorgonopsians and therocephalians);

- aquatic vertebrates such as large **temnospondyl amphibians** (*Rhinesuchus*, usually disarticulated), and **palaeoniscoid bony fish** (*Atherstonia*, *Namaichthys*, often represented by scattered scales rather than intact fish);

- freshwater **bivalves** (*Palaeomutela*);

- **trace fossils** such as worm, arthropod and tetrapod burrows and trackways, coprolites (fossil droppings) and plant root casts;

- **vascular plant remains** (usually sparse and fragmentary), including leaves, twigs, roots and petrified woods ("*Dadoxylon*") of the *Glossopteris* Flora, especially glossopterid trees and arthrophytes (horsetail ferns).

In general, tetrapod fossil assemblages in the *Tapinocephalus* Assemblage Zone are dominated by a wide range of dinocephalian genera and small therocephalians *plus* pareiasaurs while relatively few dicynodonts can be expected (Day & Rubidge 2010, Jirah & Rubidge 2010 and refs. therein). Vertebrate fossils in this zone are generally much rarer than seen in younger assemblage zones of the Lower Beaufort Group (Loock *et al.* 1994).

Fossils in the *Tapinocephalus* Assemblage Zone occur in association with both mudrocks and sandstones, most notably in thin intraformational conglomerates (*beenbreksie*) at the base of channel sandstones (Rossouw & De Villiers 1952, Turner 1981, Smith & Keyser 1995a). Tetrapod bones actually occur in a wide range of taphonomic settings in the *Tapinocephalus* Assemblage Zone (Almond 2010a). For example they are recorded as:

1. Disarticulated bones within thin intraformational conglomerates at the base of shallow (unistorey) channel sandstones. The bones are often impregnated with secondary iron and manganese minerals (coffee brown and black respectively). They vary from highly-weathered and rounded fragments to intact and well-preserved specimens. Bones occur at the base of, within, or floating at the top of the conglomerates in association with calcrete nodules, mudflakes, petrified wood and gypsum pseudomorphs. Bones in these channel lags were variously eroded out of riverbanks or washed into drainage channels from upland areas, riverine areas and floodplains during floods or episodes of landscape denudation.

2. Disarticulated bones within or at the top of channel sandstones.

3. Bones coated with calcrete or embedded within calcrete nodules associated with arid climate palaeosols (ancient soils). These bones are often suncracked, showing that lay exposed on the land surface for a long time before burial.

4. Isolated bones or articulated skeletons (possible mummies) embedded within levee or floodplain mudrocks.

5. Well-articulated skeletons preserved within fossil burrows.

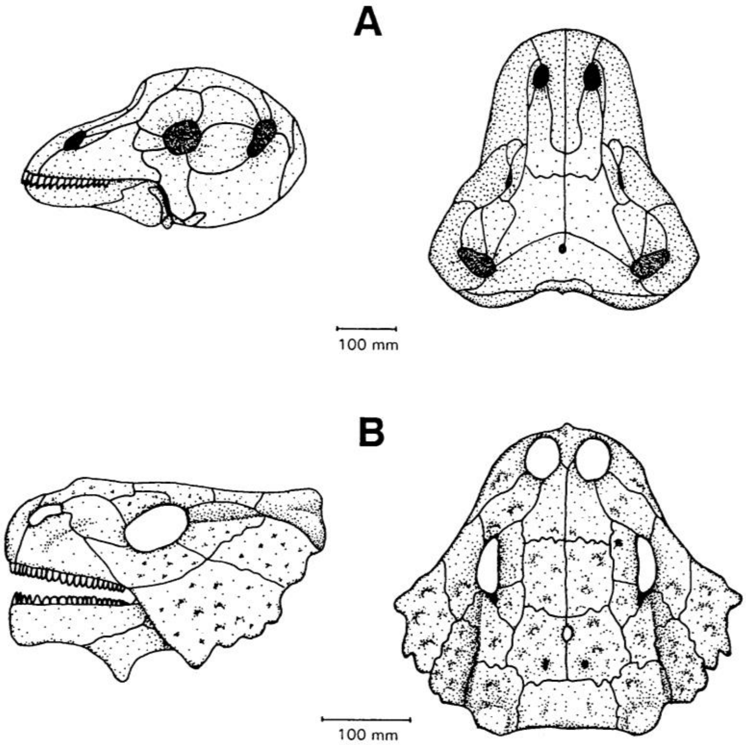

Figure 19. Skulls of two key large-bodied tetrapods of the *Tapinocephalus* Assemblage Zone: A – the dinocephalian therapsid *Tapinocephalus*; B – the pareiasaur *Bradysaurus* (From Smith & Keyser 1995b).

No tetrapod skeletal fossils or traces (*e.g.* burrows, trackways) were recorded from the Abrahamskraal Formation in the Maralla West WEF study area during the recent field study. This was despite a careful search of several good exposures showing well-developed palaeosols as well as of the infrequent calcrete-dominated breccio-conglomerates that elsewhere in the Karoo may contain reworked disarticulated bones and teeth (See Appendix for locality details). The scarcity of vertebrate fossil remains would support the contention that beds from the fossil-poor lowermost part of the Abrahamskraal Formation are represented here.

Invertebrate trace fossils recorded from the Maralla West WEF study area include several occurrences of small (*c*. 8 mm wide) meniscate back-filled burrows assigned to the ichnogenus *Scoyenia* and characteristic of damp substrates, such as the sandy margins of ponds and rivers (Figs. 21 and 22). A more unusual, broader cylindrical burrow with a segmented (back-filled) internal structure and possible short side branches was also recorded on Wolwenhoek 182 (Fig. 23).

Mudrock and sandstone bedding planes with dense assemblages of narrow, vertical, subcylindrical structures are commonly seen in the Abrahamskral Formation (Fig. 20) They are interpreted as the sand-infilled moulds of reedy plants - probably sphenophyte ferns (horsetails) - that colonised extensive swampy settings along river banks and floodplain lakes. Finely-ridged, segmented stem compressions and moulds of sphenophyte stems occur abundantly in some mudrock horizons. No petrified wood occurrences were noted in the study area.

4.2. Fossils in the Late Caenozoic superficial sediments

The wide spectrum of Late Caenozoic superficial sediments overlying the Palaeozoic and Mesozoic bedrocks in the study area are generally fossil-poor. Important occurrences of bones, teeth and horn cores may occasionally be found in better-consolidated Quaternary alluvial deposits, while finer-grained sediments and calcretes may contain fossilised burrows (*e.g.* termitaria), freshwater molluscs and plant root casts (*e.g*. Skead 1980, Klein 1984, Bousman *et al.* 1988, Brink & Rossouw 2000, Churchill *et al.* 2000, Cole *et al.* 2004, Rossouw 2006). Surface gravels on the footslopes of the Klein-Roggeveld escarpment to the southwest of the present study area as well as in nearby valleys contain locally common blocks of silicified wood that have probably been reworked from petrified logs within the Waterford Formation outcrop area (Almond 2016b, 2016c). No reworked blocks of petrified wood or other fossils were recorded from the superficial sediments in the Maralla West WEF study area, however.

Figure 20. Desiccation-cracked mudrocks with round cross-sections through sandstone casts of reedy plant stems (probably sphenophyte ferns), Wolven Hoek 182 (Loc. 299) (Scale in cm).

Figure 21. Bioturbated sandstone containing dense assemblages of sandstone-infilled invertebrate burrows (6-8 mm wide), Leeuvlei Member, Wolven Hoek 182 (Loc. 303).

Figure 22. Wave-rippled sandstone bedding plane criss-crossed by narrow straight to curving invertebrate horizontal burrows (probably *Scoyenia*), Wolven Hoek 182 (Loc. 307) (Scale in cm).

Figure 23. Segmented horizontal endichnial burrow (*c*. 1 cm wide) with intermittent lateral projections, Wolven Hoek 182 (Loc. 307).

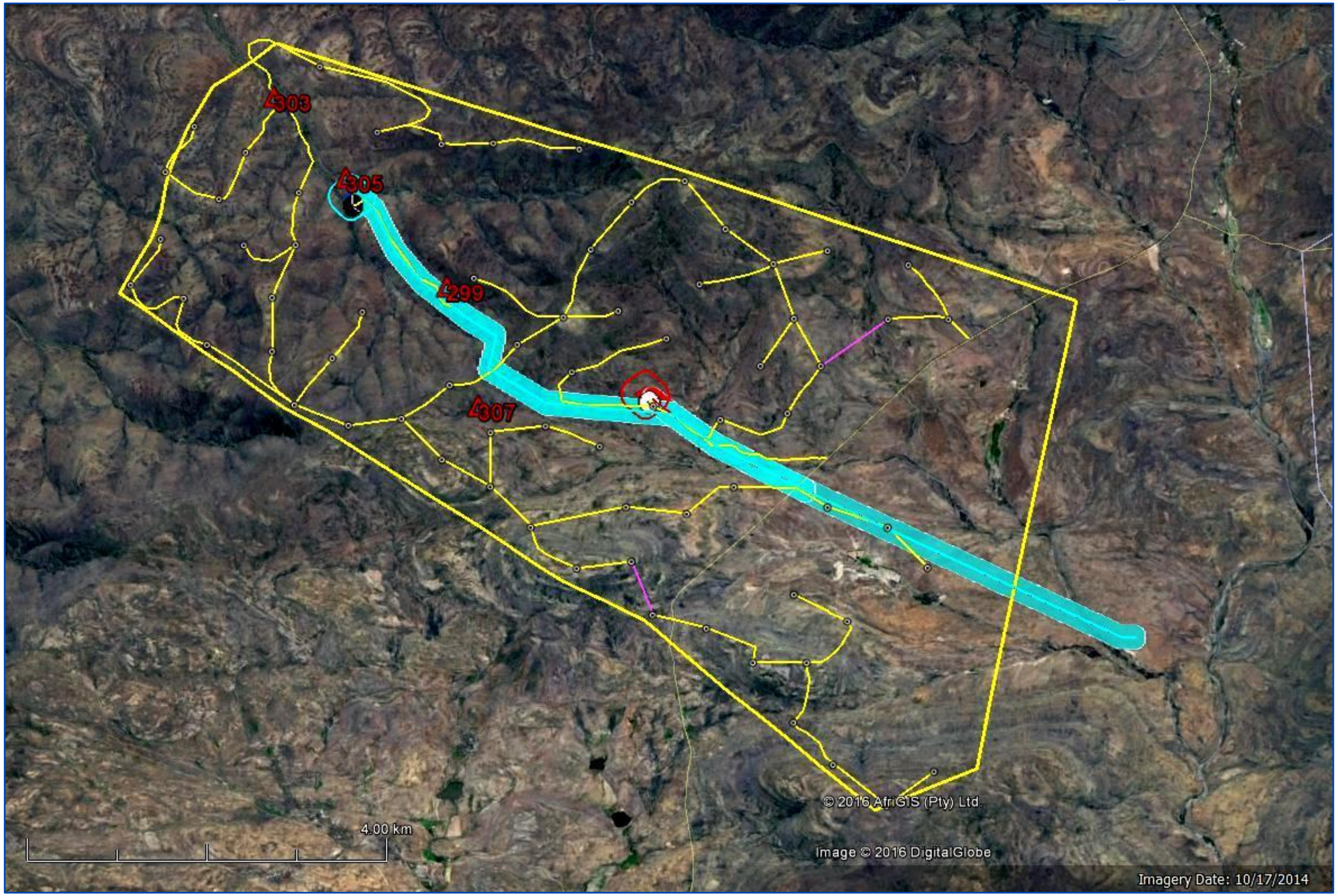

Figure 24. Google earth© satellite image of the Maralla West WEF project area (yellow polygon) showing the dissected, mountainous terrain in the Klein-Roggeveldberge region. Also shown here are the 70 proposed wind turbine sites (white dots), internal roads (yellow), alternative sites for the on-site IPP substation and associated Operations and Maintenance Building (red – preferred; blue – alternative) as well as the 132 kV powerline

corridor connecting the Maralla West and Maralla East IPP substations (pale blue). All the recorded fossil sites (numbered in red) lie within or close to the development footprint, but none of them involve conservation-worthy fossil material and therefore no specialist mitigation of these sites is recommended here.

5. ASSESSMENT OF IMPACTS

This palaeontological heritage assessment applies to the entire Maralla West WEF project area, including access roads and on-site IPP substation, but not to the 400 kV powerline connection to the national grid and Eskom on-site substation that are the subject of a separate Basic Assessment process, or any borrow pits.

In terms of the palaeontological sensitivity of the rock units represented within the Maralla West WEF project area, the outcrop area of the Lower Beaufort Group is generally considered to be high to very high sensitivity because of its rich record of Permian vertebrates and plants (MacRae 1999, McCarthy & Rubidge 2005, Almond & Pether 2008a, 2008b, Smith *et al.* 2012, SAHRIS website). The overlying Late Caenozoic superficial deposits (alluvium *etc*) are generally of low sensitivity but may also be locally high (*e.g.* fossil mammals). Fieldwork in the Klein-Roggeveld region backed-up by desktop analysis indicates that fossil material such as vascular plants, vertebrate skeletal material (bones, teeth) and trace fossils are present within the Karoo Supergroup here (See References). However, well-preserved specimens of special scientific interest and conservation significance are very rare indeed. No vertebrate bones, teeth or tetrapod trace fossils (trackways, burrows), nor any petrified wood, were found during the field study of the Maralla West WEF project area. The fossils seen here – predominantly low diversity invertebrate traces and reedy plant remains (Appendix and Figs. 20 to 23) - consist almost entirely of taxa that occur widely within the region and that are therefore not of exceptional conservation significance.

All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils may not be collected, damaged or disturbed without a permit from the relevant Provincial Heritage Resources Agency (in this case Heritage Western Cape) (See Section 1.3). The construction phase of the proposed WEF will entail extensive surface clearance as well as excavations into the superficial sediment cover and underlying bedrock. The development may adversely affect potential fossil heritage within the study area by destroying, damaging, disturbing or permanently sealing-in fossils preserved at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and de-commissioning phases of the WEF are very unlikely to involve further adverse impacts on local palaeontological heritage and are therefore not separately assessed here.

5.1. Impact assessment for the construction phase

This assessment (See Table 1) refers to impacts on fossil heritage preserved at or beneath the ground surface within the Maralla West WEF project area during the construction phase, mainly due to surface clearance and excavation activities. Such impacts on fossil heritage are *limited to the site* (development footprint) and are generally *direct*, *negative* and of *permanent* effect (non-reversible). While fossils of some sort (including microfossils, invertebrate trace fossils and plant debris) are of widespread occurrence within the project area, unique or scientifically-important fossils are very scarce indeed here, even where bedrock exposure levels are locally high. It is concluded that impacts on scientifically important palaeontological heritage resources are *improbable* and of *minor magnitude* since (1) significant fossil sites are unlikely to be affected and (2) in many cases these impacts can be mitigated. The overall impact significance of the Maralla West WEF *without mitigation* is rated as LOW in terms of palaeontological heritage resources. Should the proposed mitigation measures outlined in Section 6 below be fully implemented, the impact significance would remain low. However, residual negative impacts such as the inevitable loss of fossil heritage would be partially offset by an improved understanding of Karoo fossil heritage which is considered a *positive* impact.

There are no objections on palaeontological heritage grounds to authorisation of the proposed Maralla West WEF development. Given the overall low impact significance of the Maralla West WEF project, and the paucity of high-sensitivity fossil sites recorded here, there are no suggested modifications on palaeontological heritage grounds to the proposed layout, including wind turbine sites, access and internal roads and associated infrastructure. Likewise, there is no preference for one or other of the two sites under consideration for the on-site IPP substation and associated Operations and Maintenance

Building. Once identified, any borrow pit sites will require separate palaeontological heritage assessment before excavation commences.

Confidence levels for this assessment are rated as medium, given the necessarily superficial nature of the short field assessment counterbalanced by the number of palaeontological field studies recently carried out within the broader Klein-Roggeveld study region (See Cumulative Impacts, Section 5.2).

The impact assessment for the **No-Go Option** considers future impacts on local fossil heritage that are likely to occur in the absence of WEF development, using the present status of fossil heritage in the area as a baseline. Destruction of near-surface or surface fossil material by natural bedrock weathering and erosion will be partially offset by on-going exposure of fresh fossil material by erosion. Improvements in our understanding of palaeontology of the area (a possible positive impact) will depend on whether or not field-based academic or impact studies are carried out here, which is inherently unpredictable (There is an on-going research project on the palaeontology of the SW Karoo by Wits University).

Potential Impact		Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
	Nature of impact:	Disturbance, damage or destruction of fossils (direct, negative impacts) preserved at or beneath the ground surface within the development footprint during the construction phase, mainly due to surface clearance or excavation activities.							
	Without Mitigation	1	5	2	2	16	Low	-	Medium
	degree to which impact can be reversed:	Irreversible							
	degree of impact on irreplaceable resources:	Minor							
	Mitigation Measures	• Monitoring of all surface clearance and substantial excavations (>1 m deep) by the ECO for fossil material (e.g. bones, teeth, fossil wood) on an on-going basis during the construction phase. • Safeguarding of chance fossil finds (preferably in situ) during the construction phase by the responsible ECO, followed by reporting of finds to SAHRA. • Recording and judicious sampling of significant chance fossil finds by a qualified palaeontologist, together with pertinent contextual data (stratigraphy, sedimentology, taphonomy). • Curation of fossil material within an approved repository (museum / university fossil collection) by a qualified palaeontologist.							
	With Mitigation	1	5	2	2	16	Low	-	Medium

Table 1: Assessment of anticipated impacts on palaeontological heritage resources for the proposed Maralla West WEF (construction phase)

5.2. Assessment of cumulative impacts (construction phase)

Cumulative impacts inferred for the various alternative energy developments in the Klein-Roggeveld region between Matjiesfontein and Sutherland have been assessed here on the basis of desktop and field-based palaeontological impact assessment reports for these projects, the great majority of which were submitted by the present author (See references provided below and SAHRIS website). The projects concerned lie within a radius of some 50 km of the Maralla West WEF project area (Fig. 25). Relevant published palaeontological literature for the region has also been taken into account (*e.g.* Loock *et al.* 1994, Nicolas 2007). This assessment applies only to the construction phases of the WEF developments, since significant additional impacts on palaeontological heritage during the operational and de-commissioning phases are not anticipated.

It should be emphasized that, in the case of palaeontological heritage, it only makes sense to consider cumulative impacts on *comparable fossil assemblages* present in the same formations that are represented in the present study area as well as in the broader study region ("Comparable" here refers to assemblages of similar age, taxonomic composition, preservation and palaeoecology). For example, impacts on Permian aquatic fossil invertebrates in the Whitehill Formation (Ecca Group) that crops out in WEF project areas far to the southwest of the Maralla West WEF study area are not directly relevant to impacts on fossil assemblages of terrestrial vertebrates in the Lower Beaufort Group as represented in the latter area. The analysis in Table 2 is therefore restricted to considering cumulative impacts on fossil heritage preserved within rock units and fossil assemblages that are represented in the Maralla West WEF study area as well as in nearby project areas – specifically the Combrinkskraal – Leeuvlei and Koornplaats Members of the lowermost Abrahamskraal Formation (*i.e. Eodicynodon* and basal portion of the *Tapinocephalus* Assemblage Zones). WEF projects in the SW Karoo that potentially share fossil assemblages in the lowermost Abrahamskraal Formation include the following: Kareebosch WEF (Almond 2014), Karusa WEF (Almond 2015c), Soetwater WEF (Almond 2015d), Rietkloof WEF (Almond 2016b), Brandvalley WEF (Almond 2016c), Gunstfontein WEF (Almond 2015g), Maralla East WEF (Almond 2016e and *in prep*.) and Esizayo WEF (Almond 2016f). Further field-based PIAs (palaeontological impact assessments) of relevance include those for the Eskom Gamma-Omega 765kV transmission line (Almond 2010a) and the Komsberg Substation (Almond 2015b).

Other WEF projects in the wider region, such as the Perdekraal East WEF (Almond 2015a), Komsberg West WEF (Almond 2015f), Komsberg East WEF (Almond 2015e), Sutherland WEF (Almond 2010c), Suurplaat WEF (Almond 2010b), and the Great Karoo WEF (for which no field-based palaeontological study was done) are underlain by younger rocks within the Lower Beaufort Group, or by much older Dwyka Group and Ecca Group rocks. These successions contain significantly different fossil assemblages and so are not relevant to the present cumulative impact assessment. This also applies to further alternative energy facilities within the Cape Fold Belt near Touwsrivier and Laingsburg, such as the Konstabel WEF (Almond 2010d) and Witberg WEF (Miller 2010) that are underlain by older pre-Karoo bedrocks and to solar energy facilities above the Great Escarpment near Sutherland that overlie younger portions of the Abrahamskraal Formation.

In all the strictly *relevant* field-based palaeontological studies listed above the palaeontological sensitivity of the project area and the palaeontological heritage impact significance for the developments concerned has been rated as low. In all cases it was concluded by the author that, despite the undoubted occurrence of sporadic scientifically-important fossil remains (notably fossil vertebrates, vertebrate trackways and burrows, petrified wood), the overall impact significance of the proposed developments was low because the probability of significant impacts on *scientifically important, unique or rare fossils* was slight. While fossils do indeed occur within some of the formations present, they tend to be sparse – especially as far as fossil vertebrates are concerned - while the great majority represent common forms that occur widely within the outcrop areas of the rock units concerned. Important exceptions include (1) vertebrate burrows attributed to small therapsids, and possibly also to lungfish (Almond 2016b, Almond 2016c) and (2) well-preserved vertebrate trackways made by temnospondyl amphibians or other, unidentified tetrapods found *l*ess than 10 km east of the Maralla West WEF project area (Almond 2016e).

Cumulative impacts for the Maralla West WEF in the context of comparable alternative energy projects proposed or authorised in the Klein-Roggeveld region are assessed in Table 2. It is concluded that the cumulative impact significance of the Maralla West WEF and other regional projects is *low* (*negative*), *provided that* the proposed monitoring and mitigation recommendations made for all these various projects are followed through. Unavoidable residual negative impacts may be partially offset by the improved understanding of Karoo palaeontology resulting from appropriate professional mitigation. This is regarded as a *positive* impact for Karoo palaeontological heritage. However, *without* mitigation the magnitude of cumulative (negative, direct) impacts of such a large number of WEFs affecting the same (albeit sparsely) fossiliferous rock successions would be significantly higher and probable. The cumulative impact significance without mitigation is accordingly assessed as *medium*.

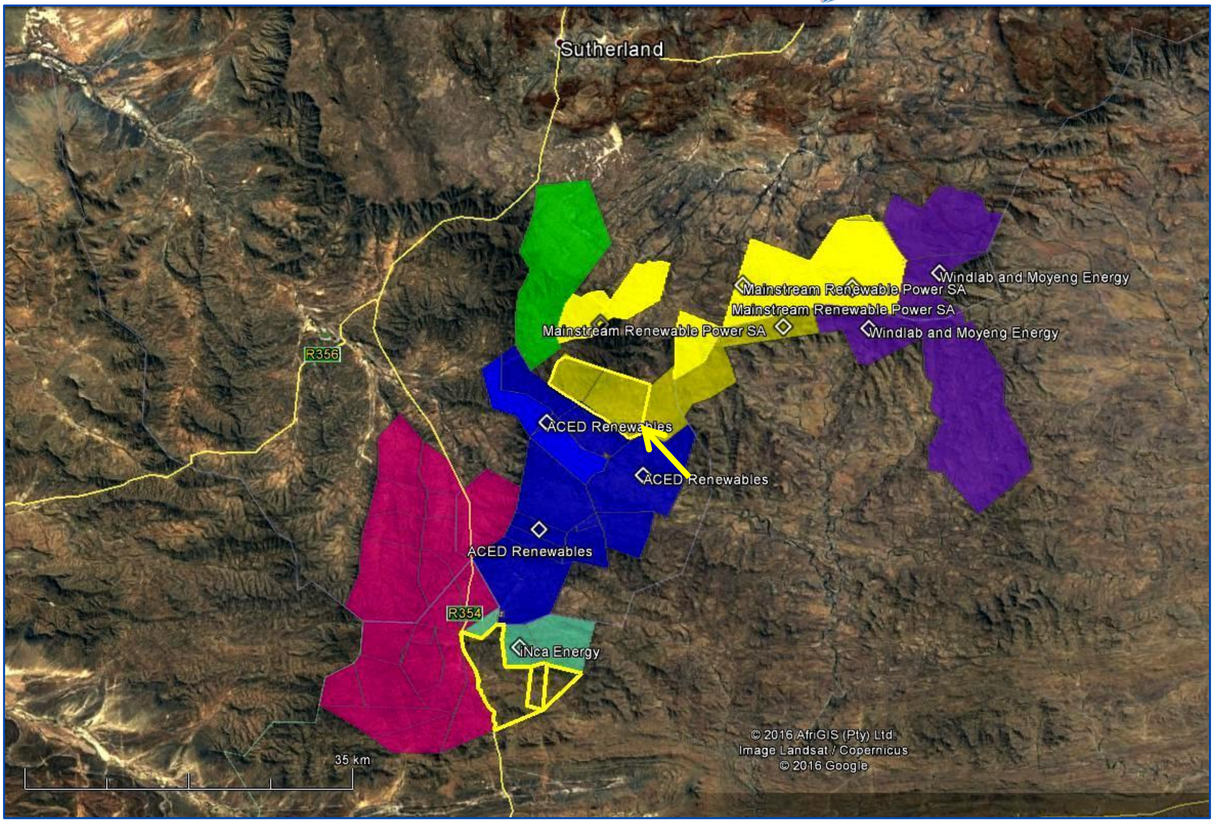

Figure 25. Google earth© satellite image of SW Karoo showing the large number of WEF projects that have been proposed or already approved in the Laingsburg – Sutherland region. The Maralla West WEF project area, outlined in yellow, is indicated by the yellow arrow. Note that impacts incurred by these various WEF projects will not always involve fossil assemblages of the same age and taxonomic composition.

Potential Impact		Extent (E)	Duration (D)	Magnitude (M)	Probability (P)	Significance (S=(E+D+M)*P)		Status (+ve or -ve)	Confidence
	Nature of impact:	Disturbance, damage or destruction of fossils (direct, negative impacts) preserved at or beneath the ground surface within the development footprint during the construction phase, mainly due to surface clearance or excavation activities.							
	Without Mitigation	3	5	4	3	36	Medium	-	Medium
	degree to which impact can be reversed:	Irreversible							
	degree of impact on irreplaceable resources:	Low							
	Mitigation Measures	• Monitoring of all surface clearance and substantial excavations (>1 m deep) by the ECO for fossil material (e.g. bones, teeth, fossil wood) on an on-going basis during the construction phase. • Safeguarding of chance fossil finds (preferably in situ) during the construction phase by the responsible ECO, followed by reporting of finds to SAHRA. • Recording and judicious sampling of significant chance fossil finds by a qualified palaeontologist, together with pertinent contextual data (stratigraphy, sedimentology, taphonomy). • Curation of fossil material within an approved repository (museum / university fossil collection) by a qualified palaeontologist.							
	With Mitigation	3	5	2	2	20	Low	-	Medium

Table 2: Assessment of anticipated cumulative impacts on palaeontological heritage resources for the proposed Maralla West WEF in the context of numerous other alternative developments in the region (construction phase).

6. MITIGATION AND MANAGEMENT MEASURES

None of the few fossil sites identified within the Maralla West WEF project area (See numbered sites in Fig. 24) are considered to be of conservation significance since they represent fossil taxa (low-diversity invertebrate traces, reedy plant material) that occur widely within the broader Klein-Roggeveld region and that are not of great scientific interest.

Given the scarcity of scientifically-important, unique fossil heritage recorded within the study area, no further specialist palaeontological studies or mitigation are recommended for this development, pending the potential discovery of significant new fossils before or during the construction phase. There are no suggested modifications on palaeontological heritage grounds to the proposed layout, including wind turbine sites, access and internal roads, IPP substation and associated infrastructure.

The following general palaeontological mitigation measures apply to the construction phase (See Table 3):

- Monitoring of all surface clearance and substantial excavations (>1 m deep) by the ECO for fossil material (*e.g.* bones, teeth, fossil wood) on an on-going basis during the construction phase.

- Safeguarding of chance fossil finds (preferably *in situ*) during the construction phase by the responsible ECO, followed by reporting of finds to SAHRA.

- Recording and judicious sampling of significant chance fossil finds by a qualified palaeontologist, together with pertinent contextual data (stratigraphy, sedimentology, taphonomy) (Phase 2 mitigation).

- Curation of fossil material within an approved repository (museum / university fossil collection) and submission of a Phase 2 palaeontological heritage report to SAHRA by a qualified palaeontologist.

Mitigation of significant chance fossil finds reported by the ECO would involve the recording, sampling and / or collection of fossil material and associated geological data by a professional palaeontologist during the construction phase of the development. The palaeontologist concerned with potential mitigation work (Phase 2) would need a valid fossil collection permit from SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection). All palaeontological fieldwork and reporting should meet the minimum standards outlined by SAHRA (2013).

Significant further impacts on palaeontological heritage resources are not anticipated during the planning, operational, decommissioning and rehabilitation phases of the WEF so no further mitigation or management measures in this respect are proposed here.

These monitoring and mitigation requirements should be incorporated into the Environmental Management Programme (EMPr) for the WEF and also included as conditions for authorisation of the development project.

Table 3 (following pages) : Recommended mitigation and management measures concerning palaeontological heritage for the Maralla West WEF

ACTIVITY	MITIGATION AND MANAGEMENT MEASURE	RESPONSIBLE PERSON	APPLICABLE DEVELOPMENT PHASE	INCLUDE AS CONDITION OF AUTHORISATION	MONITORING REQUIREMENTS
Surface clearance & substantial excavations (> 1 m deep)	Monitoring of all surface clearance and substantial excavations (>1 m deep) for fossil material (*e.g.* bones, teeth, fossil wood)	ECO	Construction	Yes	Inspect cleared ground and excavations for fossil remains. On-going, throughout construction phase
Surface clearance & substantial excavations (> 1 m deep)	Safeguarding of chance fossil finds (preferably *in situ*), followed by reporting of finds to SAHRA.	ECO	Construction	Yes	Define and secure fossil site with security tape. Report finds at earliest opportunity to SAHRA
Surface clearance & substantial excavations (> 1 m deep)	Recording and judicious sampling of significant chance fossil finds by a qualified palaeontologist, together with pertinent contextual data (stratigraphy, sedimentology, taphonomy).	Professional palaeontologist	Construction	Yes	Following consultation over chance fossil finds with SAHRA and professional palaeontologist
Surface clearance & substantial excavations (> 1 m deep)	Curation of fossil material within an approved repository (museum / university fossil collection). Submission of Phase 2 palaeontological heritage report to SAHRA.	Professional palaeontologist	Construction	Yes	Following Phase 2 palaeontological mitigation
Development of borrow pits	Separate palaeontological heritage assessment for each proposed borrow pit	Professional palaeontologist	Pre-construction	Yes	To be specified by palaeontologist and SAHRA on

Activity	Mitigation and Management Measure	Responsible Person	Applicable Development Phase	Include as Condition of Authorisation	Monitoring requirements
					submission of palaeontological assessment reports

7. STAKEHOLDER CONSULTATION

7.1. Stakeholder Consultation Process

Public participation is a requirement of the S&EIR process; it consists of a series of inclusive and culturally appropriate interactions aimed at providing stakeholders with opportunities to express their views, so that these can be considered and incorporated into the S&EIR decision-making process. Effective public participation requires the prior disclosure of relevant and adequate project information to enable stakeholders to understand the risks, impacts, and opportunities of the Proposed Project.

A comprehensive stakeholder consultation process was undertaken during the scoping phase. Stakeholders were identified through existing databases, site notices, newspaper adverts and meetings. All stakeholders identified to date have been registered on the project database. All concerns, comments, viewpoints and questions (collectively referred to as 'issues') received to date have been documented and responded to in a Comment and Response Report.

There will be ongoing communication between WSP | Parsons Brinckerhoff and stakeholders throughout the S&EIR process.

The following stakeholder comments and responses on the Draft Scoping Report for the proposed Maralla West WEF have been reviewed with respect to palaeontological heritage issues for this EIA phase report:

- Letter from the Department of Environmental Affairs (DEA Reference: 14/12/16/3/3/2/962).
- SAHRA Interim Comment, Maralla West Wind Energy Facility (Wednesday, October 26, 2016)

7.2. Stakeholder Comments and Response

Comments specifically relevant to palaeontological heritage and the corresponding specialist responses are provided in the table below.

STAKEHOLDER DETAILS	COMMENT	SPECIALIST RESPONSE
SAHRA	SAHRA Archaeology, Palaeontology and Meteorites (APM) Unit accepts and promotes the recommendations of the Archaeological and Palaeontological Scoping Reports. The pending HIA must take the following aspects (but not limited to) into consideration when assessing impacts: • The detailed Palaeontological Impact Assessment conducted by John Almond must be incorporated into the HIA;	The present palaeontological heritage assessment will be incorporated into the consolidated HIA for the Maralla West WEF project.

8. CONCLUSIONS

The Maralla West WEF project area is underlain by fluvial and lacustrine sediments assigned to the lower part of the Abrahamskraal Formation (Lower Beaufort Group, Karoo Supergroup) that are of Middle Permian age. The lower portion of the Abrahamskraal Formation succession in the SW Karoo is characterised by very rare tetrapod remains, vertebrate burrows, vascular plants and other fossils of the *Eodicynodon* and *Tapinocephalus* Assemblage Zones. No fossil vertebrates, petrified wood or other scientifically significant fossil material have been recorded in the Abrahamskraal Formation within the present study area. The dense assemblages of reedy plant stem casts (probably horsetails) as well as small invertebrate burrows found here occur widely elsewhere within the region and are therefore not considered to be of special conservation significance. It is concluded that the Middle Permian bedrocks in the Maralla West WEF study area are generally of low palaeontological sensitivity. The same applies to a range of Late Caenozoic superficial sediments (alluvium, colluvium, calcretes, soils, surface gravels *etc*) overlying the Palaeozoic bedrocks. These may contain reworked blocks of petrified wood in the Klein-Roggeveld region, but no fossils or this or any other sort were recorded within these younger deposits during the two-day field assessment.

The overall impact significance of the construction phase of the proposed wind energy project is assessed as LOW (negative) in terms of palaeontological heritage resources. This is a consequence of (1) the paucity of irreplaceable, unique or rare fossil remains within the study area as well as (2) the extensive superficial sediment cover overlying most potentially-fossiliferous bedrocks here. This assessment applies to the proposed layout for the wind turbines, laydown area, access and internal roads, on-site IPP substation and associated WEF infrastructure within the study area. A comparable low impact significance is inferred for all project infrastructure alternatives and layout options under consideration, including different options for routing of access and internal roads, turbine layouts and siting of the on-site substation and associated Operations and Maintenance Building. Significant further impacts during the operational and de-commissioning phases of the WEF are not anticipated. There are therefore no preferences on palaeontological heritage grounds for any particular layout among the various options under consideration, including alternative sites for the on-site IPP substation. No significant further impacts on fossil heritage are anticipated during the planning, operational and de-commissioning phases of the WEF. The no-go alternative (*i.e.* no WEF development) will have a low (neutral) impact on palaeontological heritage.

Cumulative impacts on palaeontological heritage resources that are anticipated as a result of the numerous alternative energy developments currently proposed or authorised for the Klein-Roggeveldberge region, including the Maralla West WEF, are predicted to be low (negative), *provided that* the proposed monitoring and mitigation recommendations made for these various projects are followed through. Unavoidable residual negative impacts may be partially offset by the improved understanding of Karoo palaeontology resulting from appropriate professional mitigation. This is regarded as a *positive* impact for Karoo palaeontological heritage. *Without* mitigation, cumulative impacts resulting from the large number of WEF projects in the Klein-Roggeveld region are anticipated to be of medium significance.

There are no fatal flaws in the Maralla West WEF development proposal as far as fossil heritage is concerned. *Provided that* the recommendations for palaeontological monitoring and mitigation outlined below are followed through, there are no objections on palaeontological heritage grounds to authorisation of the Maralla West WEF project. It is noted that borrow pit sites will only be identified if and when the proposed WEF wins preferred bidder status. In this case, a separate palaeontological assessment of all borrow pit sites will be necessary in the pre-construction phase.

No highly sensitive "no-go" areas within the proposed Maralla West WEF study area have been identified in this study. Pending the potential discovery of substantial new fossil remains during construction, specialist palaeontological mitigation is not recommended for this project. The following general recommendations concerning conservation and management of palaeontological heritage resources apply.

The Environmental Control Officer (ECO) responsible for the WEF development should be made aware of the potential occurrence of scientifically-important fossil remains within the development footprint. During the construction phase all major clearance operations (*e.g.* for new access roads, turbine placements) and deeper (> 1 m) excavations should be monitored for fossil remains on an on-going basis by the ECO. Should substantial fossil remains - such as vertebrate bones and teeth, or petrified logs of fossil wood - be encountered at surface or exposed during construction, the ECO should safeguard these, preferably *in situ*. They should then alert the relevant provincial heritage management authority as soon as possible - *i.e.* SAHRA (Contact details: Dr Ragna Redelstorff, SAHRA, P.O. Box 4637, Cape Town 8000. Tel: 021 202 8651. Email: rredelstorff@sahra.org.za). This is to ensure that appropriate action (*i.e.* recording, sampling or collection of fossils, recording of relevant geological data) can be taken by a professional palaeontologist at the developer's expense.

These mitigation recommendations should be incorporated into the Environmental Management Programme (EMPr) for the Maralla West WEF alternative energy project. Please note that:

- All South African fossil heritage is protected by law (South African Heritage Resources Act, 1999) and fossils cannot be collected, damaged or disturbed without a permit from SAHRA or the relevant Provincial Heritage Resources Agency (in this case SAHRA);
- The palaeontologist concerned with potential mitigation work will need a valid fossil collection permit from SAHRA and any material collected would have to be curated in an approved depository (*e.g.* museum or university collection);
- All palaeontological specialist work should conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere as far as possible to the minimum standards for Phase 2 palaeontological studies developed by Heritage Western Cape (2016) and SAHRA (2013).

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APPENDIX

All GPS readings were taken in the field using a hand-held Garmin GPSmap 60CSx instrument. The datum used is WGS 84. Land parcel names used in the table refer to those shown on the relevant 1: 50 000 maps 3320DA Verlatekloof, 322DC Swartland, 3220DB Komsberg and 3220DD Koornplaats (Published by the Chief Directorate: National Geo-spatial Information, Mowbray). Fossil localities that were recorded during fieldwork are shown in relation to relevant major components of the proposed development footprint on the satellite image provided in Figure 24. Please note that this map does *not* show all fossils that are present at surface within the study area, and further, unrecorded fossil occurrences (the majority) are to be expected at the surface or in the subsurface, where they may be impacted during the construction phase of the development. Areas on the map that do not contain known fossil sites are therefore not necessarily fossil-free or palaeontologically insensitive. *N.B. Fossil locality data is not for general release to the public (e.g. through publication on open access websites) for conservation reasons.*

Loc.	GPS data	Comments
298	32 43 23.5 S 20 41 33.9 E	Border between Drie Roodeheuwels 180 & Wolven Hoek 182. Edge of Klein Roggeveldberge Escarpment. View westwards down escarpment into Wolven Hoek 182. Generally poor bedrock exposure but occasional patches of hackly, purple-brown and grey-green Abrahamskraal Fm mudrocks, float blocks of ferruginous, calcrete-rich channel sandstone basal breccio-conglomerate and quartz mineral lineation. Thick *krans*-forming tabular channel sandstones along escarpment crest.
299	32 42 52.5 S 20 41 14.5 E	Wolven Hoek 182. Extensive steep hillslope exposure of gently west-dipping Abrahamskraal Fm grey-green and purple-brown overbank mudrocks, fine-grained unistorey sandstones (locally mottled) along flanks of deep tributary stream valley. Few calcrete pedocrete horizons. Assemblages of sandstone casts of reedy plant stems (probably sphenophyte ferns) associated with thin mudcrack infills.
300	32 42 49.8 S 20 41 09.2 E	Wolven Hoek 182. Good hillslope exposure of Abrahamskraal Fm mudrocks.
301	32 42 47.2 S 20 41 10.5 E	Wolven Hoek 182. Very good riverine exposure of tabular-bedded, thin (few dm) mudrock – sandstone cycles and occasional unistorey channel sandstones. Fine-grained sandstones / wackes often ill-defined with gradational bases. Well-developed, laterally continuous horizons of ferruginous carbonate concretions.
302	32 42 37.7 S 20 39 54.8 E	Wolven Hoek 182. Good river bed and hillslope exposure of Abrahamskraal Fm. Ferruginised calcrete concretions.
303	32 41 42.2 S 20 39 57.2 E	Wolven Hoek 182. Gentle hillslope exposure of Abrahamskraal Fm. Small-scale (< 1 cm diam.) horizontal and oblique invertebrate burrows within purplish-grey sandstone (possibly *Scoyenia*).
304	32 41 46.1 S 20 40 06.2 E	Wolven Hoek 182. Long riverbank exposure of Abrahamskraal Fm near Wolfhoek farmstead. Massive to thin-bedded, grey-green to purple-brown overbank mudrocks, sharp to gradational sandstone bases, no basal channel breccias.
305	32 42 12.2 S 20 40 29.3 E	Wolven Hoek 182. Long riverbank exposure of Abrahamskraal Fm near Wolfhoek farmstead. Massive to thin-bedded, grey-green to purple-brown overbank mudrocks, sharp to gradational sandstone bases, no basal channel breccias. Small-scale wave rippled associated with reedy plant stem casts.
306	32 43 32.9 S 20 41 34.6 E	Drie Roode Heuwels 180. Hillslope exposure of SE-dipping Abrahamskral Fm mudrocks along escarpment.
307	32 43 36.2 S 20 41 30.1 E	Drie Roode Heuwesl 180. Streambed exposure of SE-dipping Abrahamskral Fm mudrocks on eastern side of Klein Roggeveld Escarpment crest. Small-scale wave ripples and narrow (≤ 6 mm) horizontal burrows on sandstone bed top. Rarer wider (*c.* 1 cm) burrows with coarse segmented infill and intermittent lateral projections.
308	32 43 39.4 S 20 41 22.0 E	Drie Roode Heuwels 180. Extensive stream bank exposures of Abrahamskraal Fm. Horizons of ferruginised calcrete common.
310	32 43 19.3 S 20 43 05.5 E	Drie Roode Heuwels 180. As above.
320	32 44 00.1 S 20 43 59.0 E	Drie Roode Heuwels 180. Stream bed and bank exposures of Abrahamskraal Fm. Sharp-based channel sandstones.