**PALAEONTOLOGICAL HERITAGE REPORT: COMBINED DESKTOP & FIELD-BASED ASSESSMENT**

# PROPOSED SOVENTIX SOLAR PV PROJECT ON VARIOUS FARMS NEAR HANOVER, ENTHANJENI MUNICIPALITY, PIXLEY KA SEME DISTRICT, NORTHERN CAPE

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## EXECUTIVE SUMMARY

Soventix South Africa (Pty) Ltd is proposing to develop a 225 MW solar PV plant with infrastructure for the battery storage (BESS), gas turbines and fuel storage on various farms located between Hanover and De Aar, Enthanjeni Municipality, Pixley Ka Seme District, Northern Cape. The proposed Soventix PV plant project area is underlain by Late Permian continental sediments of the Lower Beaufort Group (Adelaide Subgroup), Karoo Supergroup. So far very few vertebrate or other fossils have been recorded in this region of the Great Karoo, in part because of the thick mantle of alluvial sediments covering most of the potentially-fossiliferous bedrocks. Two successive palaeontological field surveys of the project area confirm that bedrock exposures are very limited indeed here while the Karoo sediments have been intruded and baked by several dolerite intrusions (sills & dykes) and are often modified by near-surface weathering and calcrete veining.

No palaeontological No-Go areas or highly-sensitive fossil sites have been identified within the project area of the Soventix solar PV plant. Apart from questionable fossil invertebrate burrows, the only fossils recorded comprise (1) locally common, small blocks of well-preserved petrified wood that have been reworked from the Beaufort Group bedrocks into overlying, semi-consolidated alluvial sediments and (2) very rare tetrapod bones and teeth. The fossils found within the project area itself are all assigned a low conservation value and are not considered to require specialist mitigation. Reworked fossil wood material is likely to occur widely within a zone of older calcretised alluvium along the banks of the Brakrivier and its major tributaries. This palaeontologically more sensitive zone lies within the protected riverine buffer zone and *outside* the proposed solar PV plant footprint. A fragmentary specimen of dinocephalian therapsid (rhino-sized “mammal like reptile”), including diagnostic jaw and tooth material, is recorded just *outside* the project area on Farm Kwanselaars Hoek 40. It is of high scientific interest since it establishes - for the first time - the presence of upper *Tapinocephalus* Assemblage Zone fossils in this part of the Main Karoo Basin. Hitherto, dinocephalian fossils have not been recorded along the northern margins Beaufort Group outcrop area to the northeast of the Victoria West. This fossil site will *not* be directly impacted by the proposed development and no mitigation measures in this regard are proposed here.

It is concluded that the impact significance of the proposed Soventix 225 MW solar PV plant including battery storage (BESS), gas turbines and fuel storage infrastructure is LOW in terms of palaeontological heritage resources, both before and after mitigation. There are no

fatal flaws in the proposed alternative energy project from a palaeontological heritage viewpoint. Cumulative impacts of fossil heritage in the context of several proposed or authorised alternative energy developments in the broader region (especially around De Aar) are assessed as low, given their comparatively small footprint compared with the outcrop areas of the fossiliferous rock units concerned (notably the Beaufort Group). There are no objections to authorization of the proposed solar development, provided that the recommended mitigation measures (summarized in Table 3) are incorporated into the EMPr for this project and fully implemented.

The ECO responsible for the construction phase of the project should be aware of the potential for important new fossil finds – such as vertebrate bones and teeth, or petrified logs - and the necessity to conserve them for possible professional mitigation (See, for example, Macrae 1999 for a well-illustrated popular account of Karoo fossils). The ECO should monitor all site clearance and substantial excavations into sedimentary rocks for fossil remains on an on-going basis during the construction phase (See Chance Fossil Finds Procedure outlined in Table 3). Recommended mitigation of chance fossil finds involves safeguarding of the fossils (preferably *in situ*) by the responsible ECO and reporting of finds to SAHRA for the Northern Cape (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za). Where appropriate, judicious sampling and recording of fossil material and associated geological data by a qualified palaeontologist, appointed by the developer, may be necessary, under a Fossil Collection Permit issued by the relevant heritage Resources authority (SAHRA). Any fossil material collected should be curated within an approved repository (museum / university fossil collection) by a qualified palaeontologist.

## 1. PROJECT DESCRIPTION & BRIEF

The company Soventix South Africa (Pty) Ltd is proposing to develop a 225 MW solar PV plant on various farms located between Hanover and De Aar, Enthanjeni Municipality, Pixley Ka Seme District, Northern Cape (Fig. 1). The land portions concerned include the Remainder of Goedehoop 26C, Portion 6 of Leuwefontein 27C, the Remainder of and Portion 1 of Rietfontein 39C, the Remainder of and Portion 1 of Kwanselaars Hoek 40C, Portion 4 of Taaiboschfontein 41C and Portion 1 of Kafferspoort 56C. The land is currently used for sheep farming.

The footprint of the proposed solar plant is *c*. 520 ha. This area will include three interconnected 75 MW solar PV plants (170 ha each) with associated infrastructure including a substation that will link into the existing ESKOM overhead 400 kV powerlines that run through the project area (Fig. 2). Existing roads will be used for main access, which may need to be enlarged to facilitate access to the site during construction. Three PV plant sites have been identified as preferred in consultation with the EAP, Client and Landowner (Fig. 2). The 225 MW plant is considered the first phase and, depending on available capacity on the ESKOM powerlines, additional phase may be implemented in future; these will undergo independent authorization processes.

The SAHRA Archaeology, Palaeontology and Meteorites (APM) Unit requested that a Palaeontological Impact Assessment (PIA) including a field assessment be conducted for the proposed development as part of the EIA process (SAHRA Interim Comment of 1

September 2017. Case ID: 10210). A combined desktop and field-based palaeontological assessment report (PIA) for this renewable energy project was prepared by Almond (2017). The buildable areas have subsequently been slightly modified in the light of the original EIA process. Infrastructure for battery storage and gas turbine generation and associated fuel storage, to be sited on the periphery of the on-site substation, has now been included in a revised project design (Fig. 2). The infrastructure for the battery storage (BESS), gas turbines and fuel storage is described as follows:

> *This will require 167MWh of Lithium-Ion battery storage, equating to twenty-two (22) forty-foot (40') containers. Each shipping container is 12.2(l) x 2.43(w) x 2.59(h) in dimensions, with a collective/total footprint of approximately 667m2. Additionally, five (5) gas turbine units will be required to generate <10MW of backup electricity. Each turbine unit will take up the footprint of a 40' container. Above-ground LNG and/or LPG and/or Diesel storage will be required of less than* $80m^3$ *to provide the turbines with fuel. The additional infrastructure of the containerised batteries and gas turbines will only occupy a nominal footprint (<*$700m^2$*) in relation to the full development. The gas turbine will only run intermittently and include noise suppressants, to reduce noise emissions and potential nuisance to people and surrounding environment. The containers are likely to be installed on plinths above-ground, so as to minimise impacts on stormwater runoff as well as allow for monitoring of leaks and potential soil contamination.*

The revised solar PV plant project design is assessed in the present combined desktop and field-based palaeontological heritage study of the Soventix solar PV plant project and incorporates field data from both site visits. The report will contribute to the EIA and heritage aspects of the Environmental Management Programme (EMPr). The EIA and EMPr process for the project is being co-ordinated by Ecoleges Environmental Consultants, Machadodorp (Contact details: Mr Justin Bowers. Ecoleges Environmental Consultants, Generaal Street, Machadodorp, 1170. PO Box 516 Machadodorp, 1170. Mobile: 083 6447179. E-mail: justin@ecoleges.co.za).


**Figure 1: Google Earth© satellite image showing the location (orange polygon) of the proposed Soventix solar PV plant on several farms located approximately 30 km northwest of Hanover, Pixley Ka Seme District, Northern Cape.**

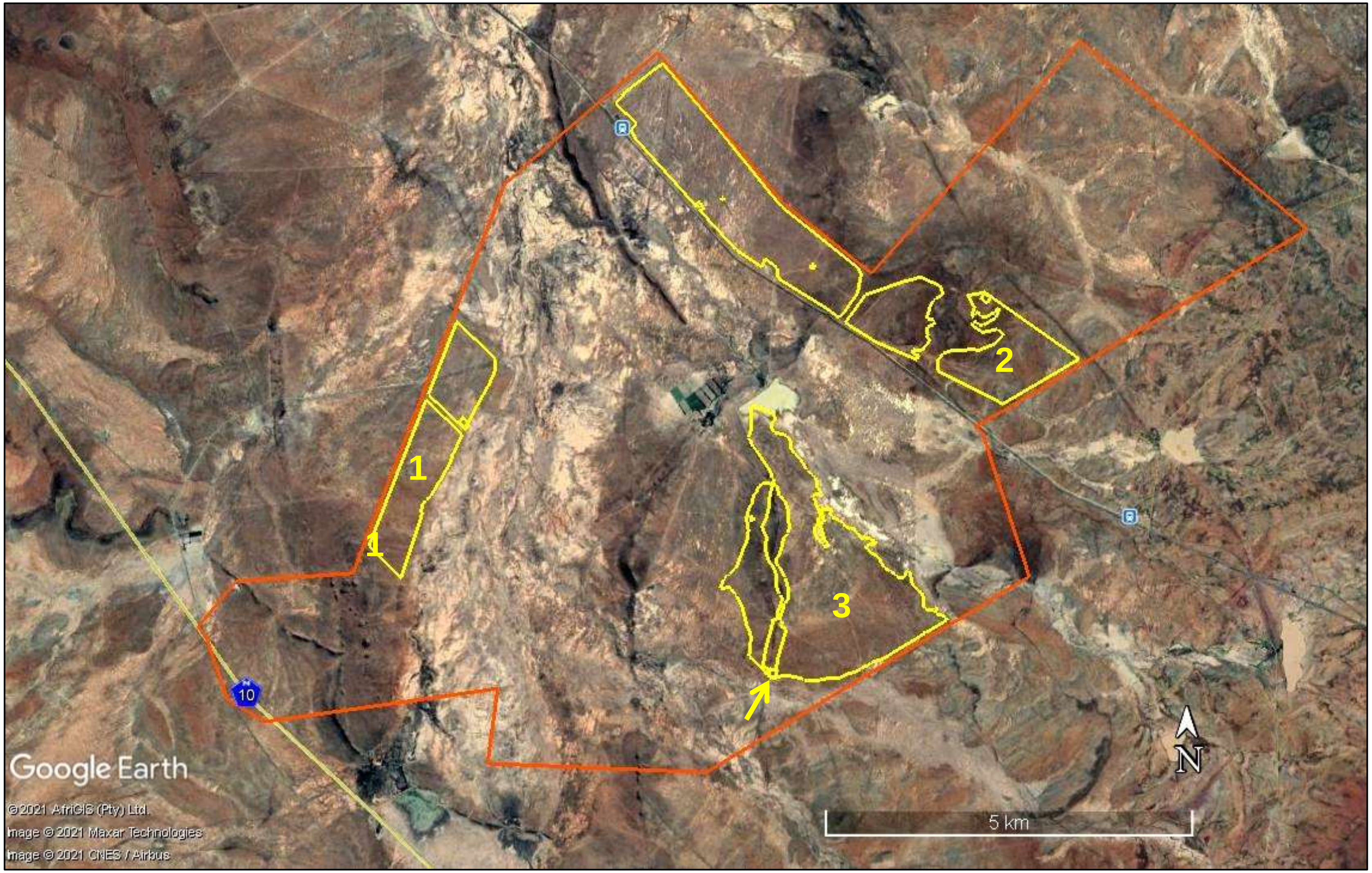


**Figure 2: Google Earth satellite image of the Soventix 225 MW solar PV plant project area near Hanover (orange polygon). The three interconnected component 75 MW solar plant sites (1, 2, 3) are shown in yellow. The location of the on-site substation, battery storage, gas turbine generation and fuel storage (small yellow square) is indicated by the arrow.**

## 2. APPROACH TO THE PALAEONTOLOGICAL HERITAGE STUDY

The approach to this palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous 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 with recommendations for any further studies or mitigation.

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 (Almond & Pether 2008). 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. The likely impact of the proposed development on local fossil heritage is 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 assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any monitoring or mitigation 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 determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. 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 palaeontological collection permits from the relevant heritage management authorities, *i.e.* SAHRA for the Northern Cape (Contact details: SAHRA, 111 Harrington Street, Cape Town. P.O. Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.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.

GPS data for some geological and all fossil localities mentioned in the text and figure legends are provided separately in the Appendix to this report.

## 2.1. Information sources

The information used in this palaeontological heritage study was based on the following:

1. A short project description, maps and kmz files provided by Ecoleges Environmental Consulting;

2. A review of the relevant satellite images, topographical maps and scientific literature, including published geological maps and accompanying sheet explanations, as well as several previous desktop and field-based palaeontological assessment studies in the broader Hanover – De Aar study region (*e.g.* Almond 2010a-b, 2011, 2012a-c, 2013a-d, 2017, Millsteed 2014, Cedar Tower Services 2015, Groenewald 2012).

3. The author's previous field experience with the formations concerned and their palaeontological heritage (Almond & Pether 2008);

4. A one-day palaeontological field assessment in October 2017 by the author and one assistant together with a one-day follow-up site visit in February 2021 to survey additional portions of the revised project area;

5. Consultation with palaeontological colleagues (Professor Bruce Rubidge, Wits University, Johannesburg and Dr Mike Day, Natural History Museum, London).

## 2.2. Assumptions & limitations

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 present study area near Hanover in the Northern Cape preservation of potentially fossiliferous bedrocks is favoured by the semi-arid climate and sparse vegetation but bedrock exposure is very limited – especially within the flatter-lying PV plant development areas – due to extensive superficial deposits, especially alluvium, sandy soils and scree. However, it is considered that sufficient bedrock and cover sediment exposures were examined during the course of this study to assess the broader palaeontological heritage sensitivity of the study area (See Appendix). Comparatively few academic palaeontological studies or field-based fossil heritage impact studies have been carried out in the region, so any new data from impact studies here are of scientific interest.

### 2.3. Legislative context for palaeontological assessment studies

The proposed alternative energy project is located in an area that is underlain by potentially fossiliferous sedimentary rocks of Palaeozoic and younger, Late Tertiary or Quaternary, age (Sections 3 and 4). The construction phase of the proposed development will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These may include, for example, surface clearance and excavations for the PV panel footings, internal access roads, underground cables, transmission line pylon footings, electrical substation, operations and services workshop area/office building and construction site camp. All these developments may adversely affect potential fossil heritage within the study area by destroying, disturbing or permanently sealing-in fossils at or beneath the surface of the ground that are then no longer available for scientific research or other public good. The operational and decommissioning phases of the wind energy facility are unlikely to involve further adverse impacts on local palaeontological heritage, however.

The present combined desktop and field-based palaeontological heritage study contributes to the Heritage Impact Assessment for the Soventix 225 MW solar PV plant project and falls under the South African Heritage Resources Act (Act No. 25 of 1999). It will also inform the Environmental Management Programme for this 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;
- 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 SAHRA (2013).

## 3. GEOLOGICAL CONTEXT

The study area for the proposed Soventix 225 MW solar PV plant is situated some 30 km NW of Hanover and 35 km SE of De Aar in the Great Karoo region of the Northern Cape (Fig. 1). The terrain is semi-arid, topographically-subdued Karoo with rocky dolerite ridges and *koppies* (especially towards the western margins of the area) and extensive alluvial *vlaktes* associated with the NW-flowing Brakrivier and its numerous tributary streams (Figs.3 to 8). Most of the landscape lies between 1300-1380 m amsl. Judging from place names on the 1: 50 000 maps (3024CC, CD) there are numerous fountains in the area, probably related to local dolerite intrusions. Due to the pervasive cover by superficial sediments (alluvium, soils, colluvium), levels of Karoo sedimentary bedrock exposure in the region are very low indeed, and mainly confined to small borrow pits, road and railway cuttings, farm dams and the more deeply-incised drainage courses. However, limited fossiliferous exposures of relevance to the present study are present on low rocky hillslopes just outside the project area.

The geology of the project area is outlined on the 1: 250 000 geology sheet 3024 Colesberg (Le Roux 1993) (Fig. 9). The area is underlain by Late Permian sedimentary rocks of the Karoo Supergroup that are intruded by Early Jurassic dolerites. According to the 1: 250 000 geological map the area is largely underlain at depth by Permian continental sediments of the **Adelaide Subgroup** (**Lower Beaufort Group**) (Pa) that in this region are extensively intruded by dolerite sills and dykes of the **Karoo Dolerite Suite** (Jd). The great majority of the Beaufort Group outcrop area is obscured by superficial sediments of probable Pleistocene to Holocene age, as well as by abundant karroid shrub and grassy vegetation (Figs. 3 to 8). These superficial sediments include silty to sandy soils and alluvium related to the broader Brakrivier drainage system, doleritic colluvium (scree, hillwash slope deposits), and downwasted surface gravels dominated by resistant clasts of hornfels, sandstone and dolerite that are modified by sheet wash processes. The dolerite intrusions weather out at surface as low rocky ridges and *koppies* that show up in rusty-brown colours in satellite images (Fig. 2). They have baked (thermally metamorphosed) the adjacent Karoo Supergroup mudrocks to hornfels, and sandstones to quartzites. Dolerite colluvial rubble extends well beyond the intrusions themselves to blanket adjacent slopes and *vlaktes*.

**Figure 3: Flat grassy *bossieveld* terrain on Goedehoop 26 showing lack of bedrock exposure here. This applies to the majority of the solar project area under consideration.**

**Figure 4: View eastwards across the northern portion of Site 3 on Kwanselaarshoek 40 showing the flat terrain mantled by alluvial soils and minimal bedrock exposure here.**

**Figure 5: One of several shallow farm dams / borrow pits excavated into weathered Lower Beaufort Group overbank mudrocks within the project area (here on Kwanselaarshoek 40) with gravelly alluvial soil cover in the foreground.**

**Figure 6: Eroded silty to sandy *vlaktes* on Kwanselaarshoek 40. The Karoo Supergroup bedrocks in such areas are often deeply buried beneath thick alluvial deposits.**

**Figure 7: Incised course of the Brakrivier on Rietfountain 39 with good sections through Late Caenozoic alluvial deposits along the steep banks. Note lack of bedrock exposure in the shallow river bed here.**

**Figure 8: Typical bouldery *koppies* of Karoo dolerite in the western portion of the study area (Farm 56).**

### 3.1. Adelaide Subgroup

The Adelaide Subgroup (Pa) (Lower Beaufort Group, Karoo Supergroup) was deposited by large-scale meandering river systems flowing northwards from the youthful Cape Fold Belt across the extensive floodplains of the ancient Karoo Basin (Smith 1980, Rubidge 1995, Johnson *et al*. 2006). The sediments mainly comprise fine-grained overbank mudrocks with subordinate lenticular channel sandstones. These last commonly have a basal conglomeratic lag of rolled mudflake pellets and calcrete nodules, the latter reflecting the prevailing semi-arid climates in Middle to Late Permian times. Small, often transient playa lakes were also present on the floodplain. In the Colesberg 1: 250 000 sheet area the poorly differentiated Lower Beaufort succession consists largely of blocky-weathering, blue-grey and subordinate reddish floodplain mudrocks, showing occasional mudcracks. There are also subordinate siltstones, fine-grained, lenticular, current cross-bedded channel sandstones, flat-laminated crevasse-splay sandstones, and occasional playa lake deposits (Le Roux 1993). Carbonate lenses and concretions, including ferruginous *koffieklip*, as well as calcrete nodules (pedogenic limestones) and silicified gypsum rosettes ("desert roses") are common.

The precise stratigraphic assignment of the Lower Beaufort Group sediments in the study area near Hanover is unresolved on the 1: 250 000 geology map (Le Roux 1993) (Fig. 9). According to the fossil biozonation map of the Beaufort Group published by Van der Walt *et al*. (2010), used in the original PIA report for this solar project by Almond (2017), the sediments here are assigned to the *Tropidostoma* Assemblage Zone that characterises the mudrock-dominated Hoedemaker Member of the Teekloof Formation west of longitude 24º East, as well as the Middleton Formation further to the east (Rubidge 1995). De Aar is situated on the (arbitrary) cut-off line between these two stratigraphic schemes. The most recent, somewhat revised, Karoo fossil biozonation mapping places the project area near Hanover within the *Endothiodon* Assemblage Zone of the Teekloof Formation (Day & Smith 2020). However, new palaeontological data recorded during the latest (February 2021) field study indicate that the project area between Hanover and De Aar in fact lies lower down within the Lower Beaufort Group stratigraphy, *viz*. within the uppermost part of the Abrahamskraal Formation and / or equivalents of the Poortjie Member at the base of the Teekloof Formation (equivalent to the uppermost Koonap and lowermost Middleton Formations in the eastern portion of the Main Karoo Basin) (*cf* Day & Rubidge 2019, Day & Rubidge 2020). The comparative thinness of the Abrahamskraal Formation in the Victoria West – De Aar area is discussed by Day & Rubidge (2014).

Only very limited exposures of the Adelaide Subgroup bedrocks are seen within and on the margins of the present study area. Prominent-weathering, pale brown channel sandstones and thin crevasse splay sandstones crop out on hillslopes on Goedehoop 26 as well as a low N-S trending ridge on Kwanselaars Hoek 40 but are largely or partially obscured by doleritic colluvium (Figs. 12 & 13). In the former occurrences small rafts or xenoliths of sandstone can be seen enclosed within the dolerite itself, while exposures of streaky, foliated sandstone reflect remobilization and baking of the Karoo Supergroup country rocks by hot dolerite magma (Figs. 23 & 24). Baking of the Beaufort Group sediments by local dolerite intrusion and related secondary ferruginisation are also apparent within channel sandstones on Kwanselaars Hoek 40. The prominent-weathering, laterally-persistent, pale brown, medium-grained channel sandstones here are thin- to medium or locally thick-bedded with large scale, low angle cross-sets and meter-scale lenses of rusty-brown ferruginous carbonate concretions. Good examples of secondarily ferruginised, well-cemented, lenticular basal channel breccias as well as shallow, irregularly lobed surface depressions generated by currently active lichen weathering processes are seen locally (Fig. 14). The intercalated, poorly-exposed overbank mudrocks are purple-brown to pale grey-green with occasional well-developed palaesols marked by sphaeroidal palaeocalcrete concretions (often septarian) as well as horizons marked by large-scale polygonal desiccation cracks (Figs. 17 to 20).

The overbank mudrocks in the vicinity of the dolerite intrusions have been thermally metamorphosed to form dark grey hornfels (often brown-patinated) which dominates surface gravels locally (Fig. 30). Small exposures of well-jointed, thin sandstone beds (probably crevasse splays as well as thin channel sandstones) and grey-green hackly-weathering mudrocks occur along more deeply-incised tributaries of the Brakrivier and in the *vlaktes* further to the east (Figs. 10, 11 & 15). Good exposures of the grey-green and purple-brown mudrock facies is also seen in several small, shallow borrow pits near the railway line (Figs. 5, 19, 21 & 25). They are crumbly, extensively calcretised and weathered near-surface and also contain well-developed, laterally-persistent horizons of pale grey to pinkish-grey calcrete nodules and lenses reflecting Permian palaeosols. Some of the calcrete nodules show internal "septarian" cracking, probably caused by diagenetic shrinkage, or are secondarily ferruginised and recrystallized due to dolerite intrusion. Occasional resistant-weathering patches or lenses of dark brown ferruginous carbonate (*koffieklip*) are encountered in the field (Fig. 16) and may be a target for plant fossil – and, incidentally, rock art - recording.

### 3.2. Karoo Dolerites

The Karoo Dolerite Suite (Jd) is an extensive network of basic igneous bodies (dykes, sills) that were intruded into sediments of the Main Karoo Basin in the Early Jurassic Period, about 183 million years ago (Duncan & Marsh 2006). These dolerites form part of the Karoo Igneous Province of Southern Africa that developed in response to crustal doming and stretching preceding the break-up of Gondwana. Hard cappings of blocky, reddish-brown to rusty-weathering dolerite are a very typical feature of the flat-topped *koppies* in the Great Karoo region. As seen from geological maps (Fig. 9), extensive dolerite intrusion of the Lower Beaufort Group rocks is observed in the Hanover region.

Blocky, well-jointed outcrops of Karoo dolerite are seen on the slopes and summits of low *koppies* and ridges or *rante* in various parts of the study area, especially towards the western margins (Figs. 8 & 22), while downwasted, well- rounded dolerite-corestones mantle the lower-lying hillslopes. Narrow dolerite dykes intruding Beaufort Group country rocks are also well on Kwanselaars Hoek 40 and in borrow pits along the railway line (Fig. 25). The country rocks adjacent to the intrusions have often been extensively baked or thermally metamorphosed. Mudrocks are altered to flinty hornfels ("lydianite" of some authors), while sandstones are metamorphosed to resistant-weathering, siliceous quartzites that may show complex deformation of the original bedding (Figs. 23 & 24). The Karoo rocks within the thermal aureole of the dolerite intrusions are also often chemically altered; they tend to be silicified, more brittle and contain numerous irregular *vugs* (cavities) lined or infilled with secondary minerals. Calcrete pedocrete concretions are secondarily ferruginised and recrystallized.

### 3.3. Kimberlite intrusions

Numerous **kimberlite pipes and dykes** of Jurassic to Cretaceous age intrude the Karoo Supergroup rocks between Hanover and De Aar, including several examples to the north and east of the present study area (black diamonds in Fig. 9). They are variously assigned to the Victoria West and Group II Provinces (Skinner & Truswell 2006) and do not contain diamonds. According to Le Roux (1993) the ultramafic kimberlite pipe rocks in the Colesberg sheet area are highly weathered with no obvious surface expression. They can usually be located only on the basis of characteristic mineral assemblages (garnet, phlogopite mica) found in ant heaps, termite mounds and prospecting holes. Kimberlite rocks are unfossiliferous, although rich Cretaceous to Paleocene fossil assemblages may be found in associated crater lake facies (not present here).

### 3.4. Late Caenozoic superficial deposits

Quaternary to Recent superficial deposits cover all but the steepest slopes of the dolerite *koppies* and *rante* as well as most of the *vlaktes* or plains at their feet, including dry river courses such as the Brakrivier in the study region (Figs. 4 to 7, 26 to 32). Various types of superficial deposits of geologically young, Late Caenozoic (Miocene / Pliocene to Recent) age (< 5 Ma) occur throughout the Great Karoo region (Prinsloo 1989, Le Roux 1993, with more extensive discussion in Holmes & Marker 1995, Cole *et al.* 2004, Partridge *et al*. 2006). They include pedocretes (*e.g.* calcretes), colluvial slope deposits (dolerite, sandstone and hornfels scree *etc*), sandy, gravelly and bouldery river alluvium, surface gravels and soils as well as spring and pan sediments. These colluvial and alluvial deposits may be extensively calcretised (*i.e.* cemented with soil limestone), especially in the neighbourhood of dolerite intrusions.

The dominant superficial sediments in the present study area comprise thick (up to several m), fine-grained, sandy to gravelly alluvial deposits of various ages associated with the Brakrivier and its tributaries (Figs. 26 to 28). These deposits are well-exposed along the more deeply-incised stream banks as well as adjoining zones of gulley erosion (*dongas*). The younger (probably Holocene) alluvium is pale brown, silty to sandy and unconsolidated (without calcrete), and contains thin lenses and horizons of gravels as well as dispersed gravel clasts. These last include locally abundant hornfels stone artefacts that tend to down-waste in eroded areas onto the underlying firmer alluvium. The distinctive older alluvial deposits are orange-brown in hue, sandy and partially consolidated with numerous creamy calcrete veins. They contain sparse to locally abundant gravels, including reworked petrified wood (Section 4) and are probably Pleistocene in age. Fine-grained sandy to sparely gravelly alluvial soils cover much of the lower-lying parts of the study area (pale areas in Fig. 2). Bare soil patches expose fine surface gravels of sheet-washed hornfels (sometimes flaked), dolerite, quartzite, sandstone and calcrete but – in contrast with previous studies near De Aar - no petrified wood was observed in this setting.

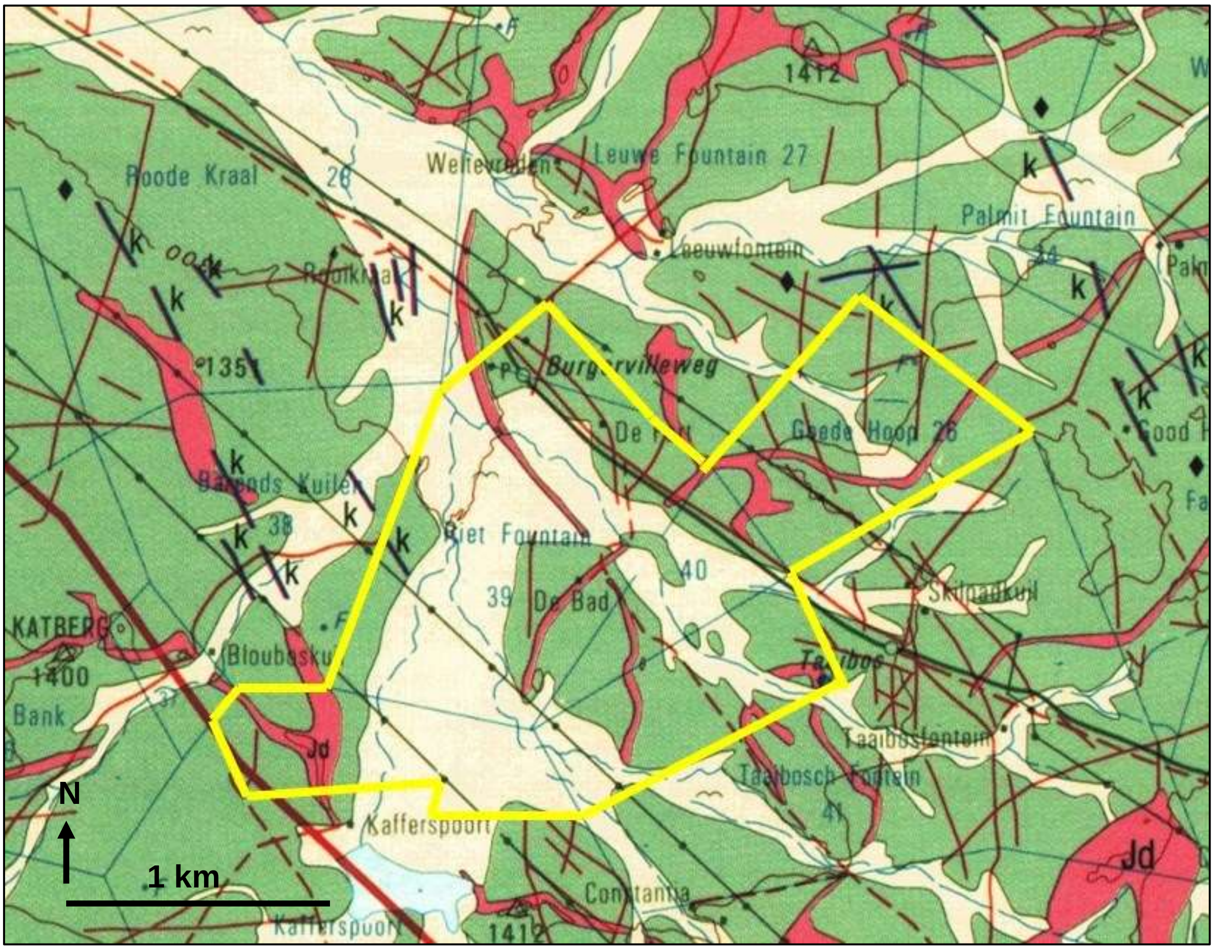


**Figure 9: Geological map of the Soventix solar PV plant project area between De Aar and Hanover, Northern Cape (yellow polygon) (Map abstracted from 1: 250 000 geology sheet 3024 Colesberg, Council for Geoscience, Pretoria). The following main rock units are mapped within the broader study region: green (Pa) = Adelaide Subgroup (Lower Beaufort Group); pink (Jd) = intrusive dykes and sills of the Karoo Dolerite Suite; white = Pleistocene to Recent superficial deposits (alluvium, colluvium *etc*); small black diamond symbols = Kimberlite pipe; blue lines – kimberlite dykes (k).**

**Figure 10: Rare exposures of Adelaide Subgroup sandstones (foreground) and mudrocks (background) in the bed and banks of the Brakrivier on Rietfountain 39 (Loc. 011).**

**Figure 11: Thin crevasse splay sandstones and grey-green overbank mudrocks exposed at the locality shown above, Rietfountain 39 (Loc. 011) (Hammer = 27 cm).**

**Figure 12: Package of pale brown, cross-bedded channel sandstones of the Adelaide Subgroup on Kwanselaarshoek 40 (Hammer = 30 cm).**

**Figure 13: Thin- to medium-bedded, tabular channel sandstones on Kwanselaarshoek 40 (Hammer = 30 cm).**

**Figure 14: Ferruginised lens of basal channel breccia showing angular clasts of reworked mudrock (Scale in cm and mm), Kwanselaarshoek 40. Such breccias may occasionally contain reworked fossil vertebrate bones and teeth.**

**Figure 15: Low ridge and scarp exposure of well-jointed channel sandstones emerging from the grassy *vlaktes* in the southern portion of project area 3 on Kwanselaarshoek 40.**

**Figure 16: Extensive lens of dark brown ferruginous carbonate (*koffieklip*) exposed in the *vlaktes* on Goodehoop 26 (Loc. 007).**

**Figure 17: Limited exposure of weathered Beaufort Group mudrocks along a shallow stream gully, Kwanselaarshoek 40. The gentle, stepped hillslopes here are largely mantled by downwasted sandstone and dolerite colluvium.**

**Figure 18: Secondarily ferruginised overbank mudrocks of the Lower Beaufort Group showing polygonal network of pale, calcretised mudcrack infills, Kwanselaarshoek 40 (Hammer = 30 cm).**

**Figure 19: Pale pinkish-grey calcrete nodules within a palaesol horizon, borrow pit exposure of Adelaide Subgroup overbank mudrocks on Goedehoop 26 (Loc. 001) (Hammer = 27 cm). Such ancient soil units are a primary focus for fossil recording.**

**Figure 20: Ovoid grey calcrete nodules showing septarian cracking among surface gravels in a bare patch on Kwanselaarshoek 40 (Loc. 010) (Scale in cm).**

**Figure 21: Shallow borrow pit near Burgervilleweg (N sector of project area 2) showing extensive secondary calcrete veining of near-surface, purple-brown mudrocks of the Lower Beaufort Group.**

**Figure 22: Well-jointed rusty-brown *koppies* reflecting surface expression of a major dyke of resistant-weathering dolerite, Kafferspoort 56.**

**Figure 23: Xenolith of Beaufort Group quartzite enclosed within a dolerite intrusion, Goodehoop 26 (Loc. 003) (Hammer = 27 cm).**

**Figure 24: Foliated and contorted quartzite in the vicinity of a dolerite intrusion, Goodehoop 26 (Loc. 005) (Hammer = 27 cm).**

**Figure 25: Narrow, subvertical, N-S trending dolerite dyke intruding Lower Beaufort Group country rocks on the margins of a shallow borrow pit near the railway line on Leuwefontein 27C (Hammer = 30 cm).**

**Figure 26: Vertical section through calcrete-veined, semi-consolidated older alluvial deposits underlying brownish unconsolidated younger alluvium exposed along the banks of the Brakrivier, Rietfountain 39 (Loc. 018) (Hammer = 27 cm).**

**Figure 27: Good gullied exposures of older (probably Pleistocene) consolidated , orange-brown alluvial deposits showing calcrete, Kafferspoort 56 (Loc. 13) (Hammer = 27 cm).**

**Figure 28: Riverbank exposure of older, more orange-brown and younger, brownish alluvium, Kafferspoort 56 (Loc 13) (Hammer = 27 cm).**

**Figure 29: Typical bare patch with sparse, fine surface gravels of hornfels, dolerite, quartzite and calcrete, Kafferspoort 56 (Loc. 015). Such patches are a search target for downwasted blocks of petrified wood.**

**Figure 30: Downwasted colluvial gravels of brownish-patinated hornfels (with several flaked stone artefacts), Goodehoop 26 (Loc. 009) (Hammer = 27 cm).**

**Figure 31: Well-developed pedocrete of cream-coloured calcrete within soils overlying dolerite, Goodehoop 26 (Loc. 008) (Hammer = 27 cm).**

**Figure 32: Downwasted and sheet-washed platy surface gravels of sandstone mantling alluvial soils on Kwanselaarshoek 40.**

## 4. PALAEONTOLOGICAL HERITAGE

### 4.1. Fossils within the Lower Beaufort Group

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). Maps showing the distribution of the Beaufort Group assemblage zones within the Main Karoo Basin have been provided by Kitching (1977), Keyser and Smith (1979), Rubidge (1995), Van der Walt *et al.* (2010) and, most recently, by Smith *et al.* (2020). According to these published sources, the study area probably lies within what used to be termed the *Tropidostoma* Assemblage Zone (AZ) that characterizes the Hoedemaker Member of the Teekloof Formation (Rubidge 1995; *cf* original PIA report by Almond 2017). This fossil biota has subsequently been incorporated into the upper part of the newly redefined *Endothiodon* Assemblage Zone (Day & Smith 2020). However, as a result of diagnostic new fossil material of dinocephalian therapsids recorded during the recent field survey (see below), it is now recognised that the project area actually lies within the upper part of the *Tapinocephalus* Assemblage Zone *(i.e.* the *Diictodon* – *Styracocephalus* Subzone), as recently redefined by Day and Rubidge (2020). This new data will require revision of the current Karoo biozonation map in the currently under-studied region along the north-western margin of the Main Karoo Basin to show the *Tapinocephalus* AZ extending further to the SE of De Aar towards Hanover (Fig.39).

The fossil record of the Abrahamskraal – Teekloof contact zone, equivalents of which may be present here, is of special scientific interest because of its record of environmental and palaeobiological events related to the major Middle Permian Mass Extinction Event of 262-260 million years ago (= Capitanian or Guadalupian Mass Extinction Event) (Day *et al.* 2015b). Since vertebrate fossils are generally rare within this interval, any new records of well-preserved, identifiable material here are of considerable scientific value (*cf* ongoing research project on this extinction event conducted by Professor Bruce Rubidge of Wits University and colleagues elsewhere).

Continental (terrestrial / lacustrine / fluvial) fossil biotas within the upper part of the Abrahamskraal Formation (Moordenaars and Karelskraal Members) as well as within the lowermost portion of the Poortjie Member of the Teekloof Formation are now assigned to the ***Diictodon* – *Styracocephalus* Subzone** of the revised ***Tapinocephalus* Assemblage Zone** (AZ) that is of Late Capitanian age (*c*. 262-260 Ma) (Day & Rubidge 2020). The highly impoverished, post-extinction vertebrate fauna represented in the uppermost part of the *Diictodon* – *Styracocephalus* Subzone (lowermost Poortjie Member) includes – or is inferred to include – only a few representatives of several tetrapod subgroups. These include amphibians, parareptiles (pareiasaurs, *Eunotosaurus*), dinocephalians (*e.g. Criocephalosaurus,* perhaps also *Styracocephalus*), dicynodonts (*e.g. Diictodon*), therocephalians (*e.g. Pristerognathus*) and gorgonopsians (Retallack *et al* 2006, Smith *et al.* 2012, Day *et al.* 2015a, 2015b, Day & Rubidge 2020, Marchetti *et al.* 2020). Fossil assemblages recorded within the present study area probably pre-date the extinction event but this remains to be established.

Due to the generally very poor exposure of Lower Beaufort Group (Adelaide Subgroup) bedrocks in the region between De Aar and Hanover, there have been very few identifiable vertebrate or other fossil finds here (See fossil site map from Nicolas 2007 in Fig. **). Fragmentary skeletal remains of small-bodied therapsids, mainly dicynodonts, as well as of the small tortoise-like reptile *Eunotosaurus* have been recorded from the Lower Beaufort Group near De Aar by Almond (2012a, 2012b, Day *et al.* 2013) but these belong to a slightly older horizon within the Lower Beaufort Group than those in the present study area. Associated fossils near De Aar include scrappy plant remains – mainly sphenophyte ferns and well-preserved silicified wood – as well as low-diversity trace fossil assemblages.

As a consequence of their proximity to numerous dolerite intrusions, the Beaufort Group sediments in the study area have been thermally metamorphosed or “baked” (*i.e*. recrystallised, impregnated with secondary minerals). Embedded fossil material of phosphatic composition, such as bones and teeth, is frequently altered by baking – bones may become blackened, for example - and can be very difficult to extract from the hard matrix by mechanical preparation. Thermal metamorphism by dolerite intrusions therefore tends to reduce the palaeontological heritage potential of Beaufort Group sediments. Near surface, the potentially fossiliferous Beaufort Group mudrocks in the project area are often highly weathered, fractured and criss-crossed with veins of secondary calcrete (Fig. 21), further reducing their palaeontological sensitivity.

Fossil vertebrate remains were only recorded from two sites within or close to the present project area during the second site visit (February 2021). Surface gravels along the margins of a farm dam on Kwanselaarshoek 40 include several fragments of robust fossil bone that may well be dinocephalian in origin but are probably unidentifiable (The bone histology is apparently well preserved) (Fig. 34). Further fragments of robust bone were recorded in a shallow stream gulley on the same form (just *outside* the project area) at surface as well as embedded within siltstone (Figs. 35 to 37). The assemblage includes several jaw fragments with embedded teeth, including a series of large incisors, greatly enlarged, deep-rooted canine tusks as well as much smaller post-canine teeth. Some of the replacement incisors show a distinctive heel-and-talon morphology typical of tapinocephalid dinocephalians, a subgroup of Middle Permian large-bodied herbivorous or omnivorous therapsids ("mammal-like reptiles"). These dental features, as well as the high degree of pachyostosis (thickening) of several bone fragments, support assignation to one or other of the dinocephalian genera *Titanosuchus* or *Jonkeria* which are mainly differentiated on the basis of the limb morphology (B. Rubidge, M. Day, S. Jirah, pers. comm., 2021). These two genera are confined to the upper portion of the *Tapinocephalus* Assemblage Zone (*i.e. Diictodon* – *Styracocephalus Subzone*) (Day & Rubidge 2020) whose presence in this particular sector of the Main Karoo Basin was not hitherto recognised (Fig. 39); fossil dinocephalians have not been recorded previously to the northeast of Victoria West (*cf* Day & Rubidge 2014, 2019).

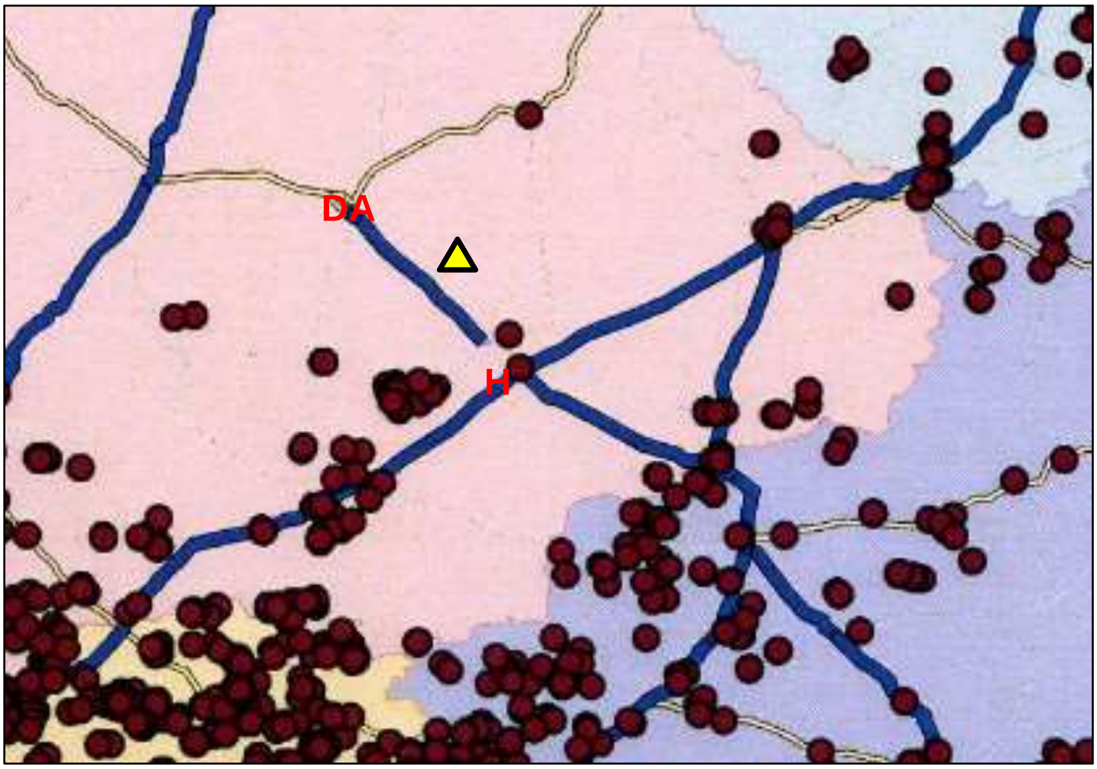


**Figure 33: Map of Beaufort Group vertebrate fossil localities showing the lack of fossil finds in the vicinity of the present study area (yellow triangle) between De Aar (DA) and Hanover (H) (Map abstracted from Nicolas 2007). Pink – N. Cape. Dark blue – Eastern Cape.**

**Figure 34: Fragments of robust, weathered and probably baked tetrapod bone exposed among surface gravels along a shallow dam on Kwanselaarshoek 40 (Loc. 566) (Scale in cm and mm). This material is unidentifiable but probably dinocephalian.**

**Figure 35: Weathered-out, fragmentary tetrapod bone material occurs within stream gravels as well as *in situ* on the NE bank of the gulley on Farm Kwanselaarshoek 40 shown in Figure 17 (Loc. 579). The lilac hue of the bone may be a consequence of thermal metamorphism. Scale in cm and mm.**

**Figure 36: Partial jaw of a dinocephalian showing sections through three small postcanine teeth (yellow circles) on upper left margin. Yellow bar indicates depth of canine tooth root (*c*. 3.5 cm) (Loc. 579).**

**Figure 37: Fragment (*c*. 9 cm across) of pachyostosed (thick-boned) upper jaw of a dinocephalian showing sections through roots of large incisor teeth towards upper margin (Loc. 579). Also sections below this through much narrower crowns of replacement incisor teeth showing a heel-and-talon tooth shape that is typical of tapinocephalid dinocephalians.**

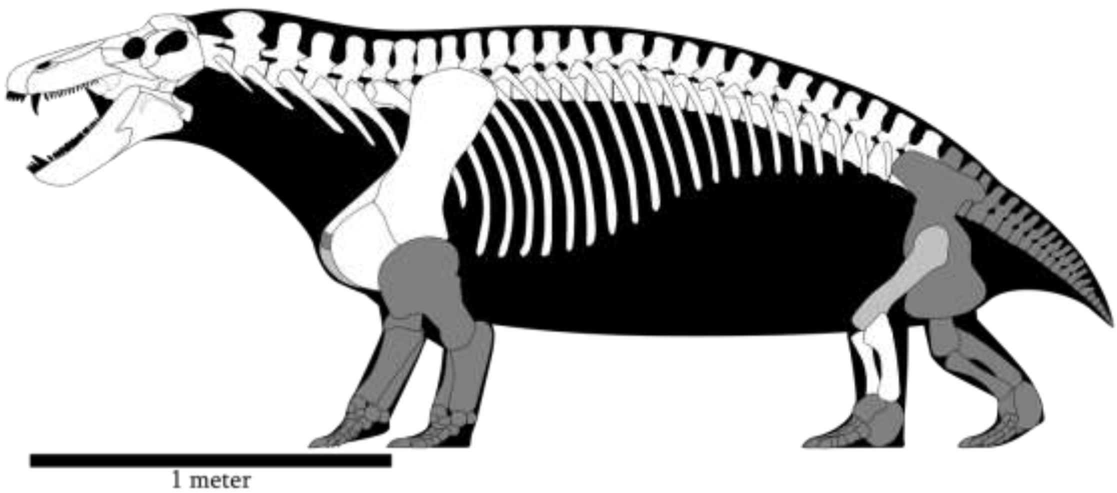


**Figure 38: Reconstruction of the large-bodied tapinocephalid dicynodont *Jonkeria*. Based on the dentition, this animal has been variously inferred to be a rhino-sized herbivore or perhaps a bear-like omnivore.**

*Possible* small-scale invertebrate burrows with a curious rugose surface texture (possibly faecal or other pellets) were seen within *koffieklip* exposures on Goedehoop 26 (Fig. 40). They are associated with mudflake intraclast breccias but their biogenic nature is equivocal.

The only other fossil remains found comprise locally common blocks of well-preserved silicified wood showing clear development of seasonal growth banding (*cf* Bamford 1999, 2004, 2016) (Figs. 41 to 43). This fossil wood was not found embedded *in situ* within the Lower Beaufort Group bedrocks however, but reworked into the overlying Late Caenozoic alluvial and colluvial deposits. Recorded fossil wood sites (See Appendix) associated with older alluvial deposits of the Brakrivier are shown on the satellite image in Fig. 44. The fossil wood specimens encountered are likely to be of widespread occurrence and not of high scientific or conservation value. They are therefore assigned a provisional field rating of IIIC Local Resource. It is likely that reworked petrified wood occurs widely within the older consolidated alluvium along the Brakrivier and its major tributaries. These older alluvial deposits are therefore considered to be palaeontologically sensitive. The best exposures lie outside the proposed solar plant development areas, close to and along the banks of the Brakrivier,and will be protected in large part within the ecological buffer zone for riverine areas.

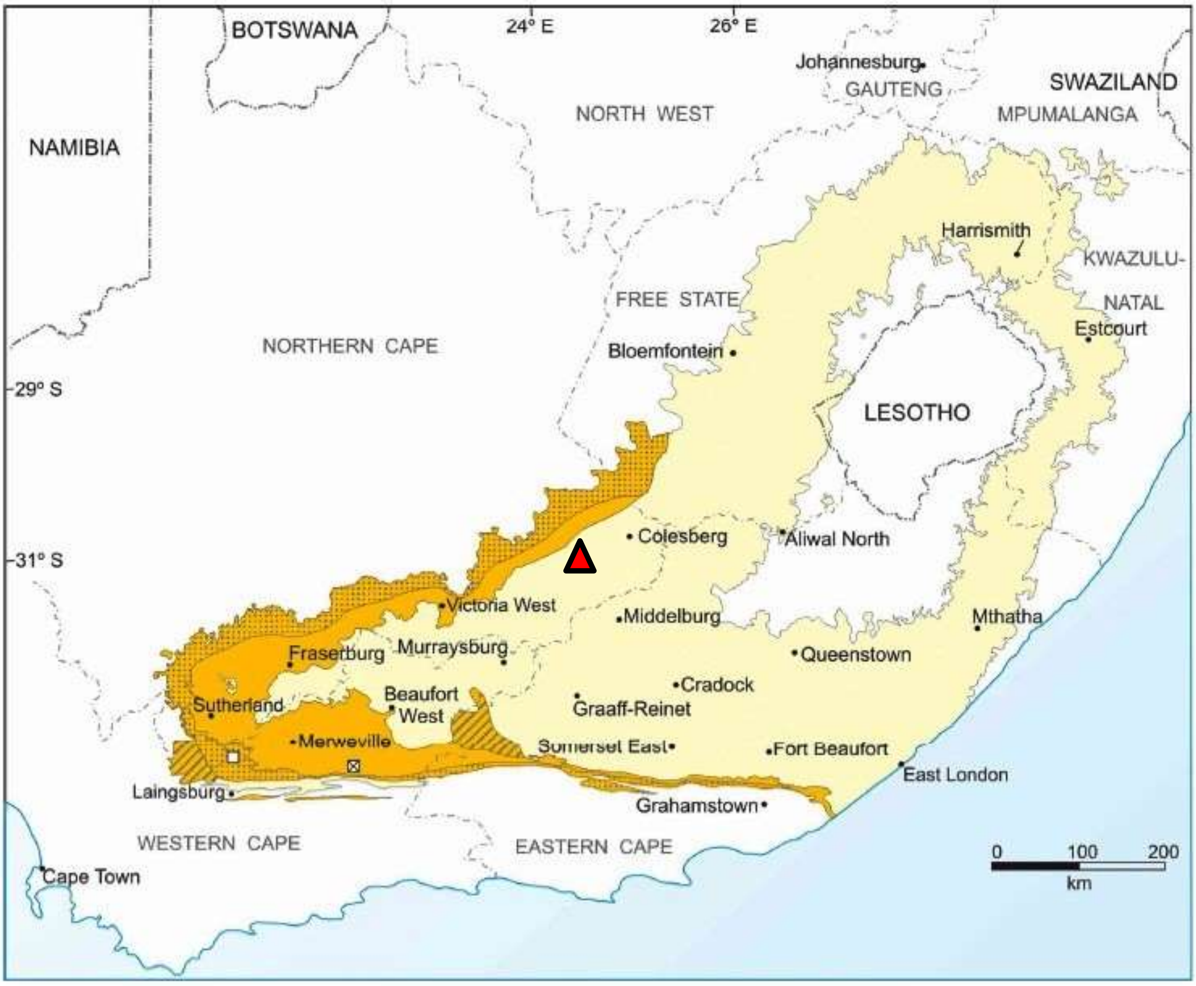


**Figure 39: Currently mapped extent of the *Tapinocephalus* Assemblage Zone fossil biota within the Main Karoo Basin, shown in dark yellow (From Day & Rubidge 2020). Diagnostic new dinocephalian fossil finds from the present study area to the NW of Hanover (red triangle) show that the upper part of the *Tapinocephalus* AZ actually extends further to the SE in the region between De Aar and Hanover (an area that is currently referred to the younger *Endothiodon* AZ).**

## 4.2. Fossils within Pleistocene to Recent alluvium

The Pleistocene to Recent superficial deposits in the Karoo have been comparatively neglected in palaeontological terms for the most part. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals (*e.g.* Skead 1980, Klein 1984, MacRae 1999, Partridge & Scott 2000). These may include ancient human remains of considerable palaeoanthropological significance (*e.g*. Grine *et al.,* 2007). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, trace fossils (*e.g.* calcretised termitaria, coprolites, rhizoliths), and plant remains such as peats or palynomorphs (pollens) in fine-grained, organic-rich alluvial horizons. Quaternary alluvial sediments may contain reworked Stone Age artifacts that are useful for constraining their maximum age. As noted in the previous section, the older, partially-consolidated alluvial deposits along the Brakrivier and its major tributaries contain locally common blocks of petrified fossil wood that have been reworked from the Permian sedimentary bedrocks. No fossil mammalian or invertebrate remains were seen during the site visit.

**Figure 40: Unidentified burrow-like structures (*c*. 1 cm across) with a rugose surface texture (perhaps faecal pellets) and possible mudrock infill, *koffieklip* lens on Goodehoop 26 (Loc. 007).**

**Figure 41: Small cherty blocks of reworked silicified wood eroded out of older alluvial deposits on Kafferspoort 56 (Loc. 014) ( Scale in cm and mm).**

**Figure 42: Small blocks of silicified wood from older alluvial deposits along the Brakrivier on Rietfountain 39 (Loc. 017) (Scale in cm and mm).**

**Figure 43: Larger angular block of silicified wood showing clear seasonal growth-banding from calcretised older alluvium on Rietfountain 39 (Loc. 020) (Scale in cm and mm).**

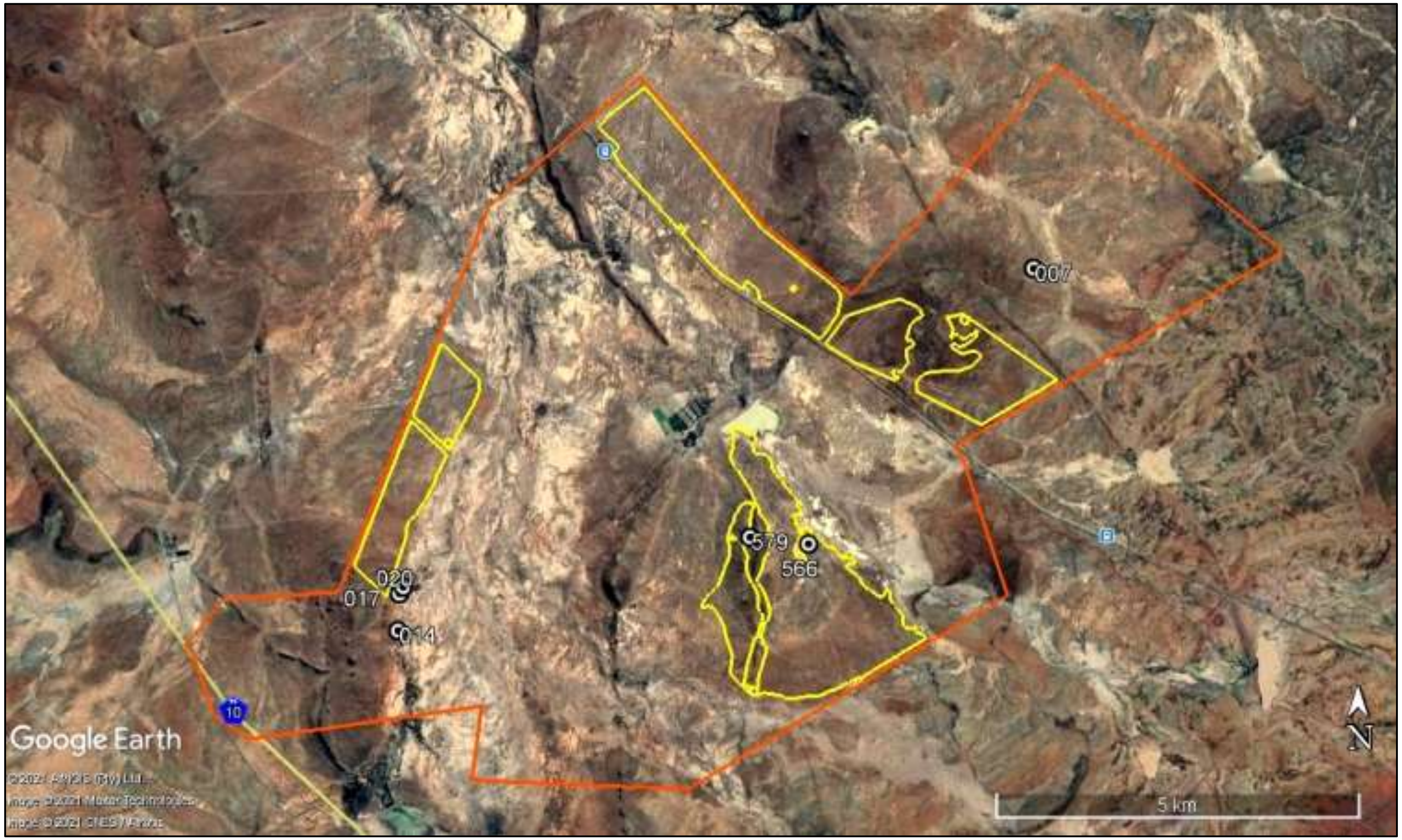


**Figure 44: Google Earth© satellite image of the Soventix solar plant project areas near Hanover (yellow polygons) showing numbered new fossil localities: 007 – questionable invertebrate burrows in *koffieklip*. 014, 017, 020 – locally common blocks of reworked Permian petrified wood eroding out of consolidated older alluvium along the Brakrivier. 586 – poorly-preserved bone fragments (possibly dinocephalian) in surface float. 579 – fragmentary remains (including partial jaws and teeth) of a tapinocephalid dinocephalian – *N.B.* this site lies just *outside* the project area. See Appendix 1 for gps locality details.**

## 5. EVALUATION OF IMPACTS ON PALAEONTOLOGICAL HERITAGE

The Soventix solar PV plant study area is located in a region of the Great Karoo that is underlain by potentially-fossiliferous sedimentary rocks of Permian and younger, Pleistocene to Holocene age (Sections 3 & 4). The construction phase of the proposed solar energy facility will entail substantial excavations into the superficial sediment cover and locally into the underlying bedrock as well. These include, for example, surface clearance and excavations for the PV panel footings, laydown areas, internal access roads, underground cables, transmission line pylon footings, electrical substation, BESS, gas turbines and fuel storage, operations and services workshop area/office building and construction camp. All these developments may adversely affect potential 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 inferred impact of the proposed PV solar plant on local fossil heritage resources – including all three of the component 75 MW solar PV plants - is briefly evaluated here in Table 1. This assessment applies only to the *construction phase* of the development since further significant impacts on fossil heritage during the planning, operational and decommissioning phases of the facilities are not anticipated. Confidence levels in this assessment are *medium*, given (1) the extensive palaeontological literature on the Karoo bedrocks concerned weighed against (2) very low levels of bedrock exposure within the study area and (3) the unpredictable distribution of well-preserved fossils in the subsurface.

As motivated in Table 1, the impact significance of the proposed development in terms of palaeontological heritage is assessed as *low (negative).* It should be noted that, should the recommended mitigation measures for the construction phase of the WEF development, as outlined in Section 6 (incl. Tables 2 & 3) of this report, be consistently followed-though, the impact significance would remain *low* (*negative*) but would entail both positive and negative impacts. Residual negative impacts from inevitable loss of some valuable fossil heritage would be partially offset by an improved palaeontological database for the study region as a direct result of appropriate mitigation. This is a *positive* outcome because any new, well-recorded and suitably-curated fossil material from this palaeontologically little-known region would constitute a useful addition to our scientific understanding of Karoo Basin fossil heritage.

There are no fatal flaws in the proposed solar PV project from a palaeontological heritage viewpoint and no objects to authorisation of the development, provided that the recommended mitigation measures are fully implemented.

**Table 1: Evaluation of anticipated impacts on fossil heritage Resources of the proposed Soventix solar PV project near Hanover (Construction Phase)**

| CRITERIA | CATEGORY | COMMENTS |
|---|---|---|
| Extent | Local | Limited to development footprint which is small. |
| Magnitude | Low | Highly significant fossil material (*e.g.* vertebrate remains) is – at most - sparsely distributed at or near surface within the study area with no significant sites recorded within the development footprint, a significant portion of which is underlain by unfossiliferous dolerite. Fossils recorded occur outside the footprint and are mostly of common types (*e.g.* petrified wood) with low conservation significance. |
| Duration | Long term | Permanent. |
| Mitigatory Potential | Moderate | Avoidance of riverine alluvial areas (already incorporated into proposed layout) + reporting of chance fossil finds to SAHRA. Residual impacts are unavoidable. |
| Acceptability | Low risk | Provided that proposed mitigation measures are implemented |
| Degree of certainty / Probability of impact occurring | Low | Fossils of some sort occur widely, so *some* level impact is unavoidable. However, most fossils are of low conservation value. The probability of loss of *well-preserved, scientifically important fossils* is rated as low. |
| Status | Negative | Loss of fossils preserved at or near surface during construction. Partially offset by new fossils reported as chance finds (positive impact). |
| Significance | Low | Specialist monitoring or mitigation measures therefore not proposed for this project *unless* significant new fossil finds made during construction phase. |

### 5.2. Cumulative impact assessment

Previous palaeontological assessments (PIAs) for several proposed or authorized alternative energy projects within a 30 km radius of the Soventix solar PV project area have been briefly reviewed (*e.g.* Almond 2010a-b, 2011, 2012a-c, 2013a-d, Millsteed 2014, Cedar Tower Services 2015, Groenewald 2012). It is noted that in several cases heritage assessments for alternative energy projects have been submitted, and even approved, without a PIA, or with only a desktop study. Several of the PIA studies referenced include field-based assessments involving Lower Beaufort Group bedrocks in the De Aar region, but in most cases these are for older bedrocks (*e.g.* Ecca Group) – and older fossil assemblages – than those represented in the Soventix study area and so are not strictly relevant for this analysis.

In the author's opinion:

- Palaeontological impact significances inferred for these projects that range from low to medium to unassessed may well reflect different assessment approaches rather than contrasting palaeontological sensitivities and impact levels;

- Meaningful cumulative impact assessments require comprehensive data on *all* major developments within a region, not just those involving alternative energy, as well as an understanding of the extent to which recommended mitigation measures are followed through;

- Trying to assess cumulative impacts on different fossil assemblages from different stratigraphic units (for example, Late Permian fossils from the Adelaide Subgroup / Lower Beaufort Group *versus* Middle Permian assemblages from the Ecca Group) has limited value.

Given the comparatively small combined footprint of the alternative energy projects under consideration compared with the very extensive outcrop areas of the Lower Beaufort Group and Late Caenozoic alluvial sediments in the Great Karoo, the cumulative impact significance of the Soventix solar PV plant proposal is assessed as LOW. There are therefore no objections on palaeontological grounds to authorization of this last project.

## 6. RECOMMENDATIONS FOR MONITORING AND MITIGATION

Proposed monitoring and mitigation measures for the Soventix solar PV plant, to be incorporated into the Environmental Management Programme for the development, are given in Table 2.

No palaeontological No-Go areas or fossil sites requiring specialist mitigation have been identified within the Soventix PV solar development footprint near Hanover; all fossil sites shown here in Fig. 30 are rated as of low sensitivity (Provisional Field Rating IIIC) (Note that the scientifically important site 579 lies just *outside* the project area and so does not require mitigation). Older consolidated fluvial deposits along the Brakrivier should be avoided during construction since they do contain fossil wood. This area lies within the ecological riverine buffer zone and outside the proposed solar PV plant footprint.

The ECO responsible for the construction phase of the project should be aware of the potential for important fossil finds and the necessity to conserve them for possible professional mitigation (See, for example, Macrae 1999 for a well-illustrated popular account of Karoo fossils). The ECO should monitor all substantial excavations into sedimentary rocks for fossil remains on an on-going basis during the construction phase. A Chance Fossil Finds Procedure for this development is outlined in Table 3.

Recommended mitigation of chance fossil finds during the construction phase of the solar PV plant and associated grid connection involves safeguarding of the fossils (preferably *in situ*) by the responsible ECO and reporting of finds to SAHRA for the Northern Cape (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za). Where appropriate, judicious sampling and recording of fossil material and associated geological data by a qualified palaeontologist, appointed by the developer, may be required by the relevant heritage regulatory authorities. Any fossil material collected should be curated within an approved repository (museum / university fossil collection) by a qualified palaeontologist. These recommendations should be included within the Environmental Management Programme for the proposed alternative energy project.

## 7. ACKNOWLEDGEMENTS

Mr Justin Bowers of Ecoleges Environmental Consultants, Machadodorp is thanked for commissioning this study and for providing the relevant background information. I am grateful to Professor Bruce Rubidge, Wits University, Johannesburg and Dr Mike Day, Natural History Museum, London, for very helpful discussions on Karoo fossil material recorded near Hanover. As always, the logistical support and effective palaeontological assistance of Ms Madelon Tusenius in the field is very much appreciated, as were helpful discussions on HIA issues in the field with Anton Pelser of Archaetnos cc, Johannesburg.

**Table 2: Proposed monitoring and mitigation measures for incorporation into the EMPr for the Soventix solar PV project**

| No. | Potential Impacts | Desired Outcomes | Targets & Indicators | Management Actions & Mitigation Measures | Responsibility | Timeframe / Frequency | Monitoring |
|---|---|---|---|---|---|---|---|
| | **FOSSIL HERITAGE RESOURCES** | | | | | | |
| | Disturbance, destruction or damage to fossils preserved at or below surface through surface clearance and excavations during construction phase . | Avoidance of palaeontologically sensitive areas (riverine alluvium).<br><br>Reporting of chance fossil finds to SAHRA. | Older (orange-brown) consolidated alluvial deposits along major water courses (*e.g.* Brakrivier) | Ongoing monitoring for chance fossil finds within development footprint during construction phase.<br><br>Substantial fossils (vertebrate bones, teeth, large blocks of petrified wood) to be safeguarded, preferably *in situ*, and reported to SAHRA for recording and sampling by professional palaeontologist. | ECO<br><br>Developer to appoint palaeontologist following significant new fossil finds | Ongoing during construction phase. | Compliance to be verified by ECO. |

<table>
<tr><td colspan="3">Table 3: CHANCE FOSSIL FINDS PROCEDURE: SOVENTIX SOLAR PV PROJECT ON VARIOUS FARMS NEAR HANOVER</td></tr>
<tr><td>Province & region:</td><td colspan="2">PIXLEY KA SEME DISTRICT, NORTHERN CAPE</td></tr>
<tr><td>Responsible Heritage Resources Agency</td><td colspan="2">SAHRA, P.O. Box 4637, Cape Town 8000.<br>Contact: Dr Ragna Redelstorff. Tel: 021 202 8651. Email: rredelstorff@sahra.org.za<br>or Ms Natasha Higgitt. Tel: 021 462 4502. Email: nhiggitt@sahra.org.za</td></tr>
<tr><td>Rock unit(s)</td><td colspan="2">Adelaide Subgroup (Lower Beaufort Group), Pleistocene alluvium</td></tr>
<tr><td>Potential fossils</td><td colspan="2">Vertebrate bones & teeth, vertebrate and other burrows, plant compressions, petrified wood</td></tr>
<tr><td rowspan="5">ECO protocol</td><td colspan="2">1. Once alerted to fossil occurrence(s): alert site foreman, stop work in area immediately (N.B. safety first!), safeguard site with security tape / fence / sand bags if necessary.</td></tr>
<tr><td colspan="2">2. Record key data while fossil remains are still in situ:<br>• Accurate geographic location – describe and mark on site map / 1: 50 000 map / satellite image / aerial photo<br>• Context – describe position of fossils within stratigraphy (rock layering), depth below surface<br>• Photograph fossil(s) in situ with scale, from different angles, including images showing context (e.g. rock layering)</td></tr>
<tr><td>3. If feasible to leave fossils in situ:<br>• Alert Heritage Resources Agency and project palaeontologist (if any) who will advise on any necessary mitigation<br>• Ensure fossil site remains safeguarded until clearance is given by the Heritage Resources Agency for work to resume</td><td>3. If not feasible to leave fossils in situ (emergency procedure only):<br>• Carefully remove fossils, as far as possible still enclosed within the original sedimentary matrix (e.g. entire block of fossiliferous rock)<br>• Photograph fossils against a plain, level background, with scale<br>• Carefully wrap fossils in several layers of newspaper / tissue paper / plastic bags<br>• Safeguard fossils together with locality and collection data (including collector and date) in a box in a safe place for examination by a palaeontologist<br>• Alert Heritage Resources Agency and project palaeontologist (if any) who will advise on any necessary mitigation</td></tr>
<tr><td colspan="2">4. If required by Heritage Resources Agency, ensure that a suitably-qualified specialist palaeontologist is appointed as soon as possible by the developer.</td></tr>
<tr><td colspan="2">5. Implement any further mitigation measures proposed by the palaeontologist and Heritage Resources Agency</td></tr>
<tr><td>Specialist palaeontologist</td><td colspan="2">Record, describe and judiciously sample fossil remains together with relevant contextual data (stratigraphy / sedimentology / taphonomy). Ensure that fossils are curated in an approved repository (e.g. museum / university / Council for Geoscience collection) together with full collection data. Submit Palaeontological Mitigation report to Heritage Resources Agency. Adhere to best international practice for palaeontological fieldwork and Heritage Resources Agency minimum standards.</td></tr>
</table>

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## 9. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

Dr John Almond has an Honours Degree in Natural Sciences (Zoology) as well as a PhD in Palaeontology from the University of Cambridge, UK. He has been awarded post-doctoral research fellowships at Cambridge University and in Germany, and has carried out palaeontological research in Europe, North America, the Middle East as well as North and South Africa. For eight years he was a scientific officer (palaeontologist) for the Geological Survey / Council for Geoscience in the RSA. His current palaeontological research focuses on fossil record of the Precambrian - Cambrian boundary and the Cape Supergroup of South Africa. He has recently written palaeontological reviews for several 1: 250 000 geological maps published by the Council for Geoscience and has contributed educational material on fossils and evolution for new school textbooks in the RSA.

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape, Mpumalanga, Free State, Limpopo, Northwest and Kwazulu-Natal under the aegis of his Cape Town-based company *Natura Viva* cc. He has been a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage Practitioners – Western Cape).

**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.

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

## APPENDIX: GPS LOCALITY DATA

All GPS readings were taken in the field using a hand-held Garmin GPSmap 60CSx

| | | |
|---|---|---|
| **001** | S30° 50' 29.1"<br>E24° 18' 47.7" | Goedehoop 26. Extensive shallow borrow pit excavated into grey-green and subordinate purple-brown mudrocks of Adelaide Subgroup. Well-indurated (possibly baked). Well-developed pedogenic calcrete horizons with rusty-brown to pinkish concretions, some showing septarian cracking. Fine-grained, grey-green sandstones / wackes, ripple cross-laminated to massive. Bedrocks near-surface with calcrete veins and overlain by orange-brown sandy soils and surface gravels (dolerite, sandstone, wacke, hornfels, occasional sparry calcite).<br>Bare soil patches in region with fine sheetwash gravels of hornfels (some flaked but patinated, rounded). |
| **002** | S30° 50' 37.1"<br>E24° 19' 22.5" | Goodehoop 26. Carpet of surface gravels on low hillslopes, dominated by patinated hornfels (occasionally flaked), locally also quartzite. Baked, well-jointed greyish quartzite in vicinity of dolerite intrusion. |
| **003** | S30° 50' 24.6"<br>E24° 20' 13.6" | Goodehoop 26. Major ridge-forming dolerite intrusion with scree of coarse dolerite rubble on flanks. Rafts (xenoliths) of baked quartzite incorporated into dolerite magma. |
| **004** | S30° 50' 23.9"<br>E24° 20' 17.0" | Goodehoop 26. Pale brown, medium-grained, medium-bedded channel sandstone with sparse, large (several dm diam.) oblate ferruginous carbonate concretions (*koffieklip*). |
| **005** | S30° 50' 21.2"<br>E24° 20' 09.6" | Goodehoop 26. Ridge of baked, convolute-laminated sandstone with a wood-like, streaky and foliated fabric, a consequence of remobilisation and metamorphism of Adelaide Subgroup country rocks during dolerite intrusion. |
| **006** | S30° 49' 36.3"<br>E24° 21' 48.0" | Goodehoop 26. Bare patch of soils and sheetwash gravels (no petrified wood seen). Occasional flaked artefacts of hornfels and quartzite. |
| **007** | S30° 50' 17.8"<br>E24° 21' 14.7" | Goodehoop 26. Extensive horizon of dark brown, sandy, ferruginous carbonate *koffieklip* with lenses of greenish mudflakes associated with problematic rounded to elongate, speckled, coarse-grained inclusions, some perhaps with a mudrock core. Possibly biogenic (*e.g.* burrows) but are currently unidentified. Provisional Field rating IIIC Local Resource. |
| **008** | S30° 51' 04.9"<br>E24° 20' 01.2" | Goodehoop 26. Area with doleritic surface rubble as well as local development of pale creamy, nodular calcrete hardpan beneath orange-brown sandy soil. |
| **009** | S30° 50' 38.6"<br>E24° 19' 25.4" | Goodehoop 26. Surface carpeted with patinated, angular hornfels surface gravels (many flaked). |
| **010** | S30° 52' 38.9"<br>E24° 19' 20.3" | Kwanselaarshoek 40. Area of low relief, with extensive exposure of pale brown silty alluvium, bare patches with sheetwash surface gravels (calcrete, dolerite, hornfels, palaeocalcrete nodules with septarian cracking). |
| **011** | S30° 53' 18.5"<br>E24° 17' 39.7" | Rietfountain 39. Stream bank exposures of Adelaide Subgroup well-jointed , thin crevasse splay sandstones and hackly-weathering, grey-green overbank mudrocks, locally intruded, baked, deformed and disrupted by dolerite dyke. |
| **012** | S30° 52' 56.9"<br>E24° 15' 48.4" | Kafferspoort 56. Extensive riverbank sections through pale brown silty modern alluvium (Holocene) with thin fine gravel lenses. Orange-brown, incipiently calcretised older alluvial deposits (probably Pleistocene) exposed away from the river banks by erosion gullies. |
| **013** | S30° 52' 59.1"<br>E24° 15' 45.5" | Kafferspoort 56. Good gullied exposures of older (probably Pleistocene) consolidated , orange-brown alluvial deposits. |
| **014** | S30° 52' 58.8"<br>E24° 15' 45.1" | Kafferspoort 56. Occasional to locally common small, angular blocks of fossil wood, showing good seasonal growth banding, eroding out of older calcretised orange-brown alluvium (occasional embedded blocks seen). Provisional Field rating IIIC Local Resource. Abundant dark grey hornfels artefacts (patinated and fresh) at surface, probably downwasted from younger alluvial deposits. |

| | | |
|---|---|---|
| **015** | S30° 52' 47.5"<br>E24° 14' 48.0" | Kafferspoort 56. Bare soil patch with surface gravels of hornfels, dolerite. |
| **016** | S30° 52' 49.1"<br>E24° 15' 04.7" | Kafferspoort 56. Good examples of blocky (ruiniform) dolerite weathering among koppies towards western edge of study area. Flatter grassy areas beween koppies with sandy orange soils. |
| **017** | S30° 52' 42.3"<br>E24° 15' 45.8" | Rietfountain 39. Occasional to locally common weathered-out small blocks of cherty fossil wood (up to 6 cm diam.) showing well-developed seasonal growth lines, overlying eroded older calcretised alluvium. Provisional Field rating IIIC Local Resource. |
| **018** | S30° 52' 40.2"<br>E24° 15' 47.5" | Rietfountain 39. Good shallow Brakrivier riverine bank exposures of calcretised, well-consolidated older alluvial deposits underlying brownish, uncalcretised younger alluvial deposits. |
| **019** | S30° 52' 39.0"<br>E24° 15' 47.7" | Rietfountain 39. Local concentration of flaked fresh, unpatinated hornfels artefacts overlying younger alluvial deposits. LSA upper grind stone at surface in this area. |
| **020** | S30° 52' 39.4"<br>E24° 15' 47.8" | Rietfountain 39. Concentration of fossil wood blocks up to *c*. 10 cm across downwasted from older alluvium. Some blocks show marked colour banding due to seasonal growth pattern. Provisional Field rating IIIC Local Resource. |
| **021** | S30° 52' 26.2"<br>E24° 16' 00.3" | Rietfountain 39. Banks of Brakrivier incised into younger alluvial deposits. |
| **022** | S30° 50' 58.0"<br>E24° 16' 35.8" | Rietfountain 39. Banks of Brakrivier incised into younger alluvial deposits. |
| **566** | S30° 52' 20.2"<br>E24° 19' 18.1" | Kwanselaarshoek 40. Several fragmentary float blocks of thick bone (probably dinocephalian) among surface gravels along edge of shallow farm dam / borrow pit. Provisional Field rating IIIC Local Resource. |
| **579** | S30° 52' 17.2"<br>E24° 18' 47.8" | Kwanselaarshoek 40. Shallow erosion gulley into weathered overbank siltstones with float blocks and additional *in situ* material of tapinocephalid dinocephalian (*Jonkeria* or *Titanosuchus*). Provisional Field rating IIIA Local Resource. Site lies outside project area so no mitigation recommended. |