PALAEONTOLOGICAL ASSESSMENT
(Desktop Study)

PROPOSED RARE EARTHS SEPARATION PLANT
FRONTIER RARE EARTHS LIMITED
Portion 6 of Langeberg 188, Saldanha Bay Local Municipality
Vredenburg Magisterial District

By

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For

FRONTIER SEPARATION (PTY) LTD

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SUMMARY

Frontier Separation (Pty) Ltd (Frontier) is proposing to build a Rare Earth Element (REE) Separation Plant near Vredenburg, on Portion 6 of the property Langeberg 188, Saldanha Bay Local Municipality, Vredenburg Magisterial District (Figure 1). The feedstock for the plant will come from the proposed Zandkopsdrift Mine in Namaqualand, in the form of bulk mixed rare earth carbonates. The details of the REE Separation plant will be finalized following the completion of a National Environmental Management Act Environmental Impact Assessment undertaken by Africa Geo-Environmental Services (Pty) Ltd (AGES).

This report pertains only to the REE Separation Plant (Figure 1). Major unit operations for the separation plant include concentrates receiving, hydrochloric acid leaching and clarification, solvent extraction, precipitation, filtration/dewatering, drying/calcining, and product packaging. Additional infrastructure on site includes:

- Main electrical substation, control room and electrical rooms;
- Emergency back-up power generation;
- Fuel storage for genset and calciners;
- Process water and fire water storage tanks;
- Water treatment plant and boiler building;
- Storm water storage pond;
- Waste disposal settling pond.

For the evaluation of the palaeontological impact it is the extent/scale of the deeper excavations to be made that are the main concern. For the most part, the earthworks for foundations, drainage, pipes and cabling are not expected to exceed ~1.5 m in depth. A solid-waste settling pond is proposed to store the rare earth carbonates for which there is no current market. It is estimated that the pond will be 40 X 20 m, with a depth of 1.5 m.

Beneath a thin cover of sand, the project site is underlain by calcareous aeolianites (old dune sands) and calcretes ("surface limestones") of the **Langebaan Formation** (Figure 4). These strata do not appear to be very fossiliferous to the cursory eye, but the fossils that have been found are of profound scientific value, raising international interest in the region. The Langebaan Formation aeolianites have been a prime source of information on Quaternary faunas and archaeology. Notably, some fossil finds have been made in the nearby area.

Monitoring by on-site personnel and field inspections by a palaeontologist/trained fossil excavator are recommended during construction of excavations. Appendices 1 and 2 outline monitoring by construction personnel and general Fossil Find Procedures. In the event of possible fossil finds, the palaeontologist will assess the information and liaise with the developer and the ESO and a suitable response will be established. Field inspections by a specialist at appropriate stages in the making of the excavations should be carried out, in order to document the exposures and the contexts of any finds.

The author is an independent consultant/researcher and is a recognized authority in the field of coastal-plain and continental-shelf palaeoenvironments and is consulted by exploration and mining companies, by the Council for Geoscience, the Geological Survey of Namibia and by colleagues/students in academia pursuing coastal-plain/shelf projects.

Expertise

- Shallow marine sedimentology.
- Coastal plain and shelf stratigraphy (interpretation of open-pit exposures and on/offshore cores).
- Marine macrofossil taxonomy (molluscs, barnacles, brachiopods).
- Marine macrofossil taphonomy.
- Sedimentological and palaeontological field techniques in open-cast mines (including finding and excavation of vertebrate fossils (bones).

Membership of Professional Bodies

- South African Council of Natural Scientific Professions. Earth Science. Reg. No. 400094/95.
- Geological Society of South Africa.
- Palaeontological Society of Southern Africa.
- Southern African Society for Quaternary Research.
- Heritage Western Cape. Member, Permit Committee for Archaeology, Palaeontology and Meteorites.
- Accredited member, Association of Professional Heritage Practitioners, Western Cape.

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1 INTRODUCTION

Frontier Separation (Pty) Ltd (Frontier) is proposing to build a Rare Earth Element (REE) Separation Plant near Vredenburg, on Portion 6 of the property Langeberg 188, Saldanha Bay Local Municipality, Vredenburg Magisterial District (Figure 1). The details of the REE Separation plant will be finalized following the completion of a National Environmental Management Act Environmental Impact Assessment undertaken by Africa Geo-Environmental Services (Pty) Ltd (AGES).

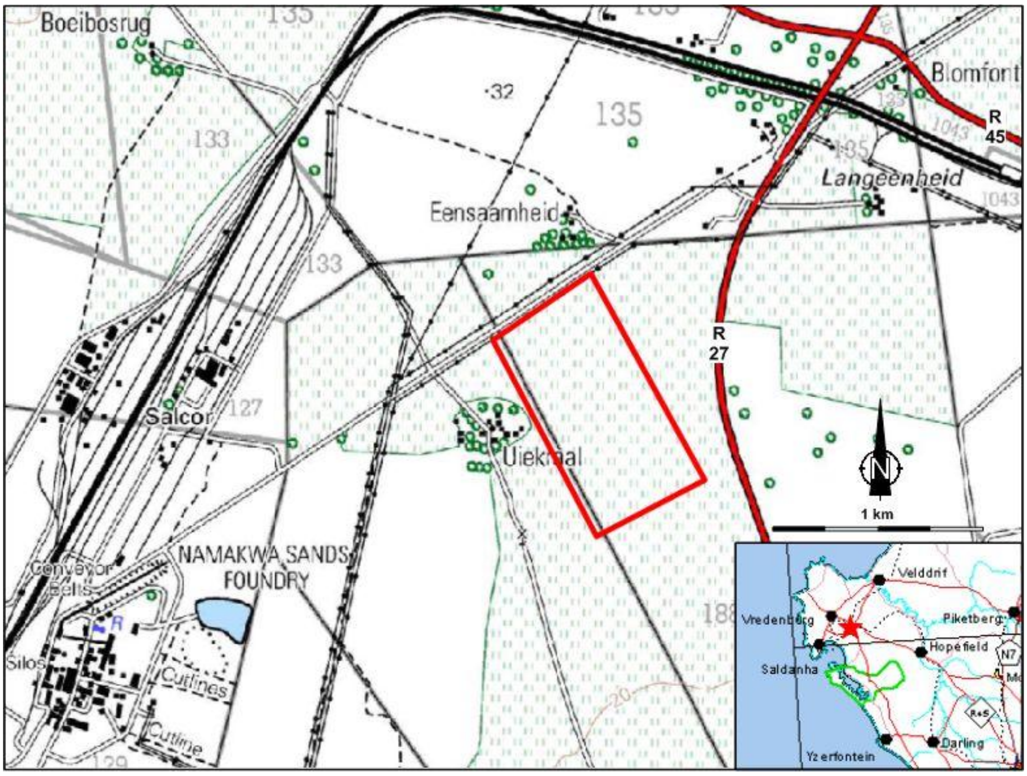

Figure 1. Location of the proposed REE Separation Plant. Extract from 3218CA_CC_2003_ED5_GEO.TIF 1:50000 topo-cadastral sheet (Chief Directorate: Surveys and Mapping).

The feedstock for the plant will come from the proposed Zandkopsdrift Mine near Kotzesrus in Namaqualand (north of Vredendal), in the form of bulk mixed rare earth carbonates. The Zandskopdrift volcanic pipe is the root zone of one of the last volcanoes to erupt in Namaqualand, about 56 Ma (million years ago) during the early Cenozoic Era. It is a carbonatitic-type of volcano and is enriched in rare earth elements (REE) which are hosted in the mineral monazite. REEs are in demand by high-technology applications and deep weathering of the pipe has resulted in secondary enrichment of the elements to payable grades.

This report is the part of the Heritage Impact Assessment in the Environmental Impact Assessment. It pertains only to the REE Separation Plant (Figures 1 & 2, Appendix 3). A proposed Hydrochloric Acid Plant in the adjacent area is the subject of a separate EIA process, as are other pipelines and electrical infrastructure.

Major unit operations for the separation plant include concentrates receiving, hydrochloric acid leaching and clarification, solvent extraction, precipitation, filtration/dewatering, drying/calcining, and product packaging. Additional infrastructure on site includes:

- Main electrical substation, control room and electrical rooms;
- Emergency back-up power generation;
- Fuel storage for genset and calciners;
- Process water and fire water storage tanks;
- Water treatment plant and boiler building;
- Storm water storage pond;
- Waste disposal settling pond.

Figure 2. Simulated oblique aerial view of the site, looking north. The EIA area is shown in red. The 25 m asl. contour is highlighted in yellow. From Google Earth with 5 m contour and translucent geological map overlays.

Palaeontological interventions mainly happen once fossil material is exposed at depth, *i.e*. once the EIA process is done and construction commences.
The main purposes of this palaeontological assessment are to:

- Outline the nature of possible palaeontological/fossil heritage resources in the subsurface of the study area.
- Suggest the mitigatory actions to be taken with respect to the occurrence of fossils during bulk earth works.

The action plans and protocols for palaeontological mitigation must therefore be *included in the Environmental Management Plan (EMP)* and embodied in the Agreed Terms of Reference for the appointed heritage assessment/mitigation practitioner. Included herein is a general fossil-finds procedure for the appropriate responses to the discovery of paleontological materials during construction of the plant.

2 APPLICABLE LEGISLATION

The National Heritage Resources Act (NHRA No. 25 of 1999) protects archaeological and palaeontological sites and materials, as well as graves/cemeteries, battlefield sites and buildings, structures and features over 60 years old. The South African Heritage Resources Agency (SAHRA) administers this legislation nationally, with Heritage Resources Agencies acting at provincial level.

According to the Act (Sect. 35), it is an offence to destroy, damage, excavate, alter or remove from its original place, or collect, any archaeological, palaeontological and historical material or object, without a permit issued by the South African Heritage Resources Agency (SAHRA) or applicable Provincial Heritage Resources Agency, *viz*. Heritage Western Cape (HWC).

Notification of SAHRA or the applicable Provincial Heritage Resources Agency is required for proposed developments exceeding certain dimensions (Section 38).

3 THRESHOLDS

The extent of subsurface disturbance and exposure exceeds 300 m in linear length and 5000 m2 (NHRA 25 (1999), Section 38 (1)). It must therefore be assessed for heritage impacts that include the assessment of the potential palaeontological heritage (a PIA).

For the evaluation of the palaeontological impact it is the extent/scale of the deeper excavations to be made that are the main concern. At time of writing all the details of bulk earthworks are not available and will be influenced by the results of geohydrological and geotechnical investigations. It is assumed that earthworks for foundations will be required. Further excavations will be made for the installation of stormwater drainage and for supporting infrastructure (trenches for power cabling, other pipelines). For the most part, these earthworks are not expected to exceed ~1.5 m in depth. A solid-waste settling pond is proposed to store the rare earth carbonates for which there is no current market. It is estimated that the pond will be 40 meters long by 20 meters wide with a depth of 1.5 meters, based on the preliminary geohydrological assessment.

As elucidated below, the affected subsurface of the site has a distinct probability of containing fossils that will be exposed during earthworks.

4 APPROACH AND METHODOLOGY

4.1 AVAILABLE INFORMATION

The point of departure is the geological map of the area *viz*. 1:125000 Sheet 255 and the accompanying explanation (Visser & Schoch (1972, 1973). The relevant part of the geological map is reproduced as Figure 4. Since then, ongoing research has added various refinements of the geology, but the map remains essentially valid. The later research contributions relevant to this assessment are cited in the normal manner as references in the text and are included in the References section.

Quarries and borrow pits in the surrounding area, such as the quarry just east of the Namakwa Sands plant, as well as pipe/cabling trenches and trail pits made in the vicinity of the site in the recent past (Namakwa Sands SALKOR, Saldanha Steel), have shown the nature of the underlying substrata and their fossil potential (Pether, 2009, 2010).

4.2 ASSUMPTIONS AND LIMITATIONS

The assumption is that the fossil potential of the formation underlying the site (Langebaan Formation) will be typical of that found in the region and more specifically, similar to that already discovered nearer to the site. Scientifically important fossil bone material is expected to be sparsely scattered in these deposits and much depends on spotting this material as it is uncovered during digging *i.e.* by monitoring excavations.

A limitation on predictive capacity exists in that it is not possible to predict the buried fossil content of an area or formation other than in such general terms. Certain processes/agents can produce significant concentrations of fossil bones, but the possibility of these specific buried palaeoenvironments being present is only hinted at by the general setting of a site.

5 GEOLOGICAL AND PALAEONTOLOGICAL SETTING

5.1 ASPECTS OF THE REGIONAL GEOLOGY

The older bedrock of the region consists of **Malmesbury Group** shales. Their origin dates from over 560 Ma, when mainly muddy sediments were deposited on the margins of an ancient ocean. The ocean basin subsequently was compressed by tectonic forces and the Malmesbury sediments were transformed to shales and were then intruded by molten magma that cooled to form the crystalline "**Cape Granites**" (Figure 3). These bedrock formations are not of palaeontological interest.

During the early history of the coastal plain it was deeply eroded by courses of the ancestral Berg River and the soft Malmesbury shales along the coast have mostly been eroded away to below sea level, while the hard granites form the hills (Figures 3 & 4). During the early Miocene about 20 Ma, rising sea level caused the rivers in these valleys to “back up”, filling the valleys with river (fluvial) sediments and peat beds with plant fossils. This fluvial valley fill is the **Elandsfontyn Formation**, the oldest formation of the **Sandveld Group** of coastal deposits. It is not exposed, being covered by marine deposits and ancient dunes.

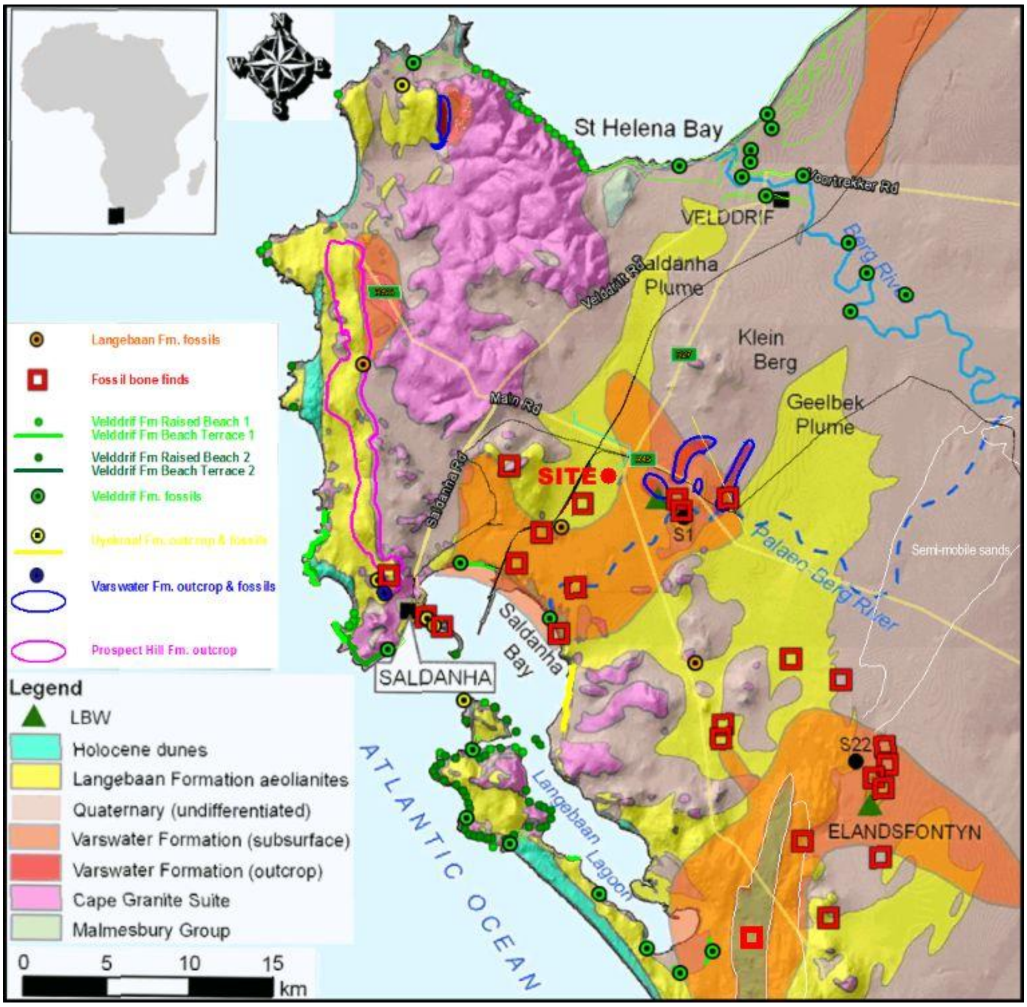

Figure 3. Simplified geology of the region. Adapted from fig. 1 of Roberts et al., 2011. The added symbols and lines denote features and formations of palaeontological interest.

The wide valleys were inundated during periods of high sea level, forming large embayments within which estuarine and marine-related deposits have been preferentially preserved. The subsurface extent of these deposits, called the **Varswater Formation**, is shown in Figure 3. The type locality of the Varswater Formation is the exposures at the West Coast Fossil Park (LBW, Figure 3). There the fossils from the upper part show that the age of the deposits is about 5 Ma and that the origin of the deposits is related to the early Pliocene sea-level highstand.

The subsurface extent of the Varswater Formation shown in Figure 3 reflects the occurrence of phosphatic marine sediments in boreholes that has been taken to be all Varswater Formation. It is clear, from observations wider afield, that the Varswater Formation so defined includes marine deposits of quite different ages. For instance, west of the West Coast Fossil Park (Figure 4), the flat plain that extends towards the coast is underlain by younger marine deposits of middle Pliocene age ~3 Ma. Rogers (1983) named these marine deposits the Uyekraal Shelly Sand Member of the "Bredasdorp Formation", the latter now superceded by the Sandveld Group. It has a capping hardpan calcrete, beneath which is green-hued shelly, gravelly sand with phosphatic casts (steinkerns) of molluscs and shark teeth (Rogers, 1982, 1983). Note that the Uyekraal Shelly Sand Member is not formally recognized and is currently subsumed in the Varswater Formation, but it is deserving of being a separate formation called the "**Uyekraal Formation**", Sandveld Group.

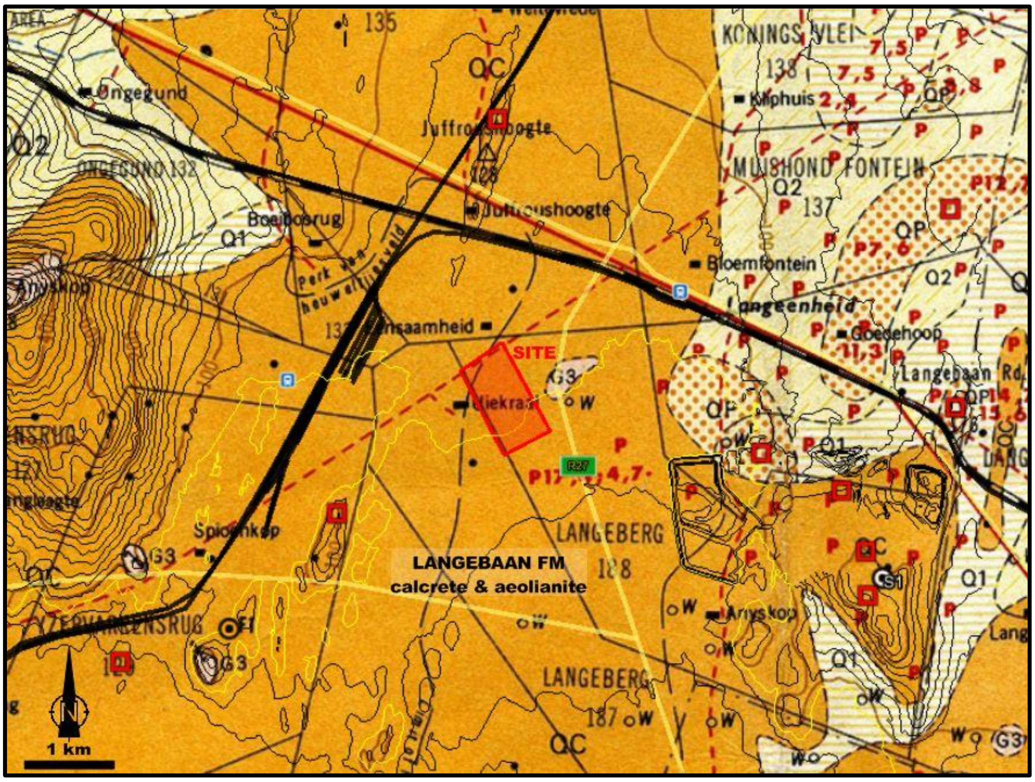

Figure 4. Geology of the surrounding area. Extract from Visser & Schoch (1972), 1:125000 Map Sheet 255: 3217D & 3218C (St Helenabaai), 3317B & 3318A (Saldanhabaai). Viewed in Google Earth with 5 m contour overlay. The 25 m asl. contour is highlighted in yellow.

Q1: A young surface unit is the recent soil-unit Q1, white to slightly-reddish sandy soil, which is mainly a stabilized sand sheet blanketing the underlying geology.
Q2: An older surface unit Q2, shallow sandy soil with heuweltjies (heuweltjiesveld), occurs inland the coast. Incipient calcretes occur in Q2. It overlies the Langebaan "Limestone" Formation. Thick quartzose sand deposits beneath Q2 are called the **Springfontyn Formation**.
QC: The **Langebaan "Limestone" Formation**, aeolianite Unit QC, is underlain mainly by marine deposits of Pliocene age (**Varswater** & **Uyekraal** fms).
QP:-Varswater Formation outcrop of phosphatic deposits.
G1, G2, G3, G4 and **G5** are outcrops of various bedrock granites of **the Cape Granite Suite**.
Ma: Bedrock outcrops of **Malmesbury Group** metasediments.

At various places around the Saldanha Bay coast are exposures of shelly marine deposits with Pliocene fossil shell assemblages and these are the eroded fringes of the Uyekraal Formation: Leentjiesklip, Hoedjiespunt peninsula, Diazville lower quarry, Duyker Eiland. On the basis of extinct fossil shells, the Uyekraal shelly beds are correlated with the Hondeklip Bay Fm. of Namaqualand, a substantial, prograded marine formation built out seawards from a sea-level maximum of 30-35 m asl. (Pether, 1994; Pether *et al*., 2000). Similarly, the Uyekraal Fm. will be extensive beneath the outer several km of the low-gradient coastal plain, but will be largely eroded from the steeper bedrock areas of the Vredenburg Peninsula. The Uyekraal Formation is the youngest marine formation (~3 Ma) that has a warm-water shell fauna in open-coast deposits and a significant number of extinct species.

"Raised beaches" of the **Velddrif Formation** occur along the coast below ~15 m asl. In Figure 3, the occurrences of these shelly deposits are shown by the green symbols, lines and polygons fringing the coast and in the current Berg River embayment. These were deposited during the Quaternary Period and the oldest "raised beach" may be as old as 1.2 Ma. The Velddrif Formation is not of concern within the scope of the project.

Aeolianites or "dune rocks/fossil dunes" overlie the marine deposits of the coastal plain. The calcareous aeolianites are evident in the coastal landscape as the ridges, low hills and mounds beneath a capping calcrete crust, or "surface limestone" in old terminology. Until recently the calcareous aeolianites of the west coast of the southern Cape have all been lumped in the **Langebaan Formation** or "Langebaan Limestones" (Figure 3, yellow plumes; Figure 4, **QC**, orange hue), thus including various aeolianites of different ages as an "amalgam" of the dune plumes that formed on the coastal plain, at differing places and times. This is reflected in the different ages indicated from fossils found at various places. For instance, the inner aeolianite ridge stretching north from Saldanha Bay up the coast to near Paternoster (Figure 3) has been found to have fossil eggshell fragments of extinct ostriches (*Diamantornis wardi*). Based on dated occurrences in East Africa and Arabia, an age of 12-9 Ma is indicated. These aeolianites, previously belonging to the Langebaan Formation, are now called the **Prospect Hill Formation** (Roberts & Brink, 2002) (Figure 3).

The considerable extent of the **Langebaan Formation** aeolianites is evident in Figure 3 and attests to the persistence of strong southerly winds and the availability of sand on beaches. Much of the aeolian sand is tiny fragments of shell. The cementing of this "calcarenite" is generally quite weak, but much denser cementing has taken place in the uppermost part of the fossil dunes in the form of a "carapace" or capping of calcrete (Figure 5). The calcrete is a type of cemented soil called a pedocrete, formed in the near-surface by evapo-transpiration after the dunes became inactive and became vegetated. The aeolianites contain further calcretes and leached *terra rosa* soils at depth, attesting to a number of periods of reduced rates of sand accumulation, surface stability and soil formation. There are more marked breaks between periods of sand accumulation, shown by erosion surfaces or very thick calcretes formed over a long time.

The dune plumes accumulated episodically, under the influence of climate (windiness, rainfall) and available sand source areas (sea-level position, sediment supply), with erosion and re-deposition of previous dunes also taking place in some areas, separated by periods of stability and soil formation. The most favourable sand supply conditions seem to have prevailed at sea levels below present, in the range of 10-40 m bsl. The oldest parts of the Langebaan Formation just postdate the ~3 Ma Uyekraal Fm., the youngest parts postdate the Velddrif Formation and are as young as ~60 ka.

The **Springfontyn Formation** is an informal category that accommodates the mainly non-calcareous, windblown sand sheets and dunes that have covered parts of the landscape during the Quaternary. Its areal extent is depicted on Figure 3 as "Quaternary undifferentiated". Visser & Schoch (1972, 1973) differentiate the coversand by its surface appearance into 2 surficial units, **Q2** (older cover) and **Q1** (younger cover) (Figure 4). The Springfontyn Fm. consists of the sequences beneath these "coversands", *i.e*. SubQ2 and SubQ1.

Unit Q2 is characterized by its surface manifestation as the distinct "heuweltjiesveld", the densely dot-patterned landscape of low hillocks that are termitaria made by *Microhodotermes viator*. Its true areal extent is not immediately appreciated as it laps onto bedrock and onto the Langebaan Fm., but for the purposes of geological mapping (Figure 4) these overlap areas are not shown. It is also apparent that Q2 underlies large areas now covered by Q1.

The dot-patterned "heuweltjiesveld" is merely the surface-soil characteristic of Unit Q2. Not much detail is known about Unit Q2 at depth (Sub-Q2). Pedogenic layers of ferruginous concretions, clayey beds and minor calcretes occur among sandy-soil beds. Clearly Q2 will differ from place to place according to the local setting. In this area, in addition to mainly windblown sands from the south, Sub-Q2 will likely comprise the local colluvial/hillwash/sheetwash deposits, small slope-stream deposits, alluvium in the lower valleys and vlei and pan deposits.

Surface **Unit Q1** is a younger "coversand" geological unit and is "white to slightly-reddish sandy soil" (Visser & Toerien, 1971; Visser & Schoch, 1973). These are patches of pale sand deposited in geologically-recent times. In places these sands are undergoing semi-active transport and locally have been remobilized into active sandsheets and dunes.

Chase & Thomas (2007) have cored Q1 coversands in a regional survey of various settings along the West Coast and applied optically stimulated luminescence (OSL) dating techniques to establish the timing of sand accumulation. Their results indicate several periods of deposition of Q1 during the last 100 ka, with activity/deposition at 63–73, 43–49, 30–33, 16–24 and 4–5 ka. Notably, underlying sands produced dates from ~150 to ~600 ka, reflecting the accumulation of Unit Q2 in the middle Quaternary.

The latest addition of dunes to the coastal plain is shown in Figure 3 as "Holocene dunes", otherwise known as the **Witzand Formation** (Rogers, 1980), for obvious reason. These are sands blown from the beach in the last few thousand years and added to the fossil dune cordon or "sand wall" parallel to the coast, or have blown further as dune plumes transgressing a few kilometres inland.

5.2 *GEOLOGY OF THE STUDY AREA*

The study area is situated between about 27-29 m asl. within the Langebaanweg palaeo-embayment and is located on top of Langebaan Formation aeolianite and calcrete (Figures 3 & 4). In Figure 4 the orange hue labelled QC shows the extent of calcreted aeolianite cover under a thin sandy soil. The contours illustrate the flat topographic setting of the study area (Figure 4) which slopes very gently to the south, with subdued aeolianite ridges in places. To the west is the aeolianite-covered, granite-cored hill of Besaansklip. To the immediate east an outcropping granite high (G3) is crossed by the R27 road (Figure 4).

During the mid-Pliocene sea-level high the ~30 m asl. palaeoshoreline lapped around the granite hill of Besaansklip. The associated marine Uyekraal Formation is expected beneath the Langebaan aeolianites. However, this formation is likely to be intersected only in deep excavations.

Unit Q2 "heuweltjiesveld" sands of the Springfontyn Formation mantle the Langebaan Formation.

5.3 *EXPECTED PALAEONTOLOGY*

5.3.1 Fossils in aeolian settings

Many fossils are associated with old, buried surfaces in the aeolianites (palaeosurfaces), usually formed during wetter or less windy periods, with reduced rates of sand accumulation and with soil formation showing the surface stability. Trace fossils such as plant roots (rhizoliths), insect burrows and mole burrows are very common. The common fossils include shells of extinct land snails, fossil tortoises, ostrich incl. egg fragments and generally sparsely scattered bones. Conversely "blowout" erosional palaeosurfaces may carry fossils concentrated by the removal of sand by the wind.

The bone concentrations most commonly found are due to hyaenas. The bones often occur in the lairs of hyaenas, such as tunnels made into the softer material beneath a calcrete "roof" (Figure 5). These most often occur on slopes where some erosion of the calcrete, producing overhangs and crevices, has facilitated the making of a burrow. Burrows made by aardvarks are also exploited by hyaenas. Hyaena lairs can be found at depth in the aeolian deposits, where they relate to buried palaeosurfaces.

Dissolution hollows formed by water locally ponding and dissolving the calcrete are another site of local fossil trapping. These can also be exploited to make burrows and lairs. These dissolution features are called "karst" and surprisingly deep "pipes" can form in this manner, usually filled with reddened sediment. Such dissolution pipes can directly trap small animals and accumulate fossils. The fossil concentrations in animal lairs and dissolution features are "superimposed" into an older, cementing aeolianite.

Hollows between dunes (interdune areas) are the sites of ponding of water seeping from the dunes, leading to the deposits of springs and small vleis. These are usually muddy, with plant fossils, but being waterholes, are usually richly fossiliferous, with concentrations of large mammal bones due to predator activity, including Stone Age hunters.

More specifically, trial pits made prior to the excavation of the second slimes dam at Namakwa Sands Smelter revealed that a particularly thick calcrete underlies the area. Such thick calcrete develops beneath long-lived surfaces on old formations, where increments of deposition have been small. The thick calcrete is polyphase in origin and disguised within it are discrete, small phases of sand deposition separated by cryptic palaeosurfaces on which fossils may occur. Fossil pans have also been incorporated into the calcrete and are indicated by the occurrence of small aquatic snails. These relate to wetter climates in the past, when ponding (a seasonal, perched water table) occurred on the impeded drainage of the calcrete. Notably, sporadic fossil bone finds are a feature of the SALKOR area, apparently in the contexts outlined above.

Figure 5. Fossil bone concentration (circled) in the infill of a cavity below the calcrete capping of the Langebaan Formation.

The Q2 Springfontyn Formation sands have lower fossil potential, but fossil bones may well occur on the buried surface of the calcrete.

Fossils in cemented aeolianites and calcretes are quite difficult to spot as they are usually coated with white limey deposit (Figures 5 & 6) and do not stand out well amongst the nodules and general bumpiness of a fresh exposure.

5.3.2 Buried archaeological material

It is possible that archaeological material may occur locally within the thin, loose sand cover covering the capping calcrete of the aeolianite. This is indicated by "out of place' marine shell (limpets, mussels), pottery pieces and quartz or silcrete stone tools. Buried archaeological material may also occur on top of the calcrete or in crevices and solution pits in it. Early and Middle Stone Age artefacts and associated fossil bones are found within and below the capping calcretes.

Figure 6. Example of fossil antelope jaw from a shallow trench into the calcrete capping of the Langebaan Formation at SALKOR. Image courtesy André Carstens.

6 NATURE OF THE IMPACT OF BULK EARTHWORKS ON FOSSILS

Fossils are rare objects, often preserved due to unusual circumstances. This is particularly applicable to vertebrate fossils (bones), which tend to be sporadically preserved and have high value w.r.t. palaeoecological and biostratigraphic (dating) information. Such fossils are non-renewable resources. Provided that no subsurface disturbance occurs, the fossils remain sequestered there.

When excavations are made they furnish the "windows" into the coastal plain depository that would not otherwise exist and thereby provide access to the hidden fossils. The impact is positive for palaeontology, provided that efforts are made to watch out for and rescue the fossils. Fossils and significant observations will be lost in the absence of management actions to mitigate such loss. The loss of the opportunity to recover them and their contexts when exposed at a particular site is irreversible.

The status of the potential impact for palaeontology is not neutral or negligible.

Although coastal dunes and coversands are not generally very fossiliferous, it is quite possible that fossiliferous material could occur. The very scarcity of fossils makes for the added importance of watching for them.

There remains a medium to high risk of valuable fossils being lost in spite of management actions to mitigate such loss. Machinery involved in excavation may damage or destroy fossils, or they may be hidden in "spoil" of excavated material.

7 SIGNIFICANCE

The fossils that have been found in the Langebaan Fm. aeolianites are of profound scientific value, raising international interest in the region. The Langebaan Fm. aeolianites have been a prime source of information on Quaternary faunas and archaeology.

At the Diazville lower quarry, Langebaan Fm. aeolianite overlying the mid-Pliocene, marine Uyekraal Formation enclosed vertebrate material indicative of a late Pliocene or younger age (Roberts & Brink, 2002) (Diazville Member). The fossil suid (bushpig) from Skurwerug dates the fossil dune-plume there to the early Pleistocene ~1.2 Ma (Hendey & Cooke, 1985).

At Elandsfontein a fossil interdunal vlei was exposed by deflation, the large number of fossil bones and ESA tools indicate an age of ~600 ka (Klein et al., 2007). Notably, prior to the wind erosion of coversands at Elandsfontein, there would have been no indication of the fossil wealth just below, which included a cranium of the pre-modern human *Homo heidelbergensis*.

At Geelbek Dunefield the deflation hollows located between the wind-blown, actively-mobile sand dunes are a source of mammalian fossils and Stone Age tools, with more being constantly exposed (Kandel *et al*., 2003). The older aeolianites surrounding Geelbek dunefield exhibit three sequential calcretes which are dated at ~250, ~150 and ~65 ka, *i.e*. stability/soil formation during glacial periods (Felix-Henningsen et al., 2003).

At Spreeuwal on the shore of Saldanha Bay, fossil vlei deposits are exposed in the intertidal zone and contain large mammal bones and some MSA artefacts (Avery & Klein, 2009). The larger mammal component includes extinct species and others not recorded historically in the Western Cape. Small mammals, birds, reptiles, amphibians, freshwater gastropods and ostracods also occur.

At Kraalbaai the aeolianite with human tracks preserved in it (Kraal Bay Member) is dated to 117-79 ka (Roberts & Berger, 1997). Dating of aeolianites near Cape Town by luminescence methods shows accumulation during MIS 7 and MIS 5 (interglacials), with calcrete formation in the intervening glacial (ice age) periods (Roberts *et al*., 2009).

Examples of hyaena bone accumulations in dens within the partly-lithified dune rocks are the Sea Harvest and Hoedjiespunt sites in Saldanha Bay. Hoedjiespunt is the find site of fossil teeth of a hominid in deposits 200-300 ka old. The Sea Harvest site produced an essentially modern human tooth that is older than 40 ka. Both sites provided considerable samples of the faunas of those times, thanks to the brown hyaenas.

The general significance of coastal-plain fossils involves:

- The history of coastal-plain evolution.
- The history of past climatic changes, past biota and environments.
- Associations of fossils with buried archaeological material and human prehistory.
- For radiometric and other dating techniques (rates of coastal change).
- Preservation of materials for the application of yet unforeseen investigative techniques.

8 IMPACT ASSESSMENT

The impact assessment is necessarily general in nature as it is not possible to predict the buried fossil content of an area other than qualitatively. The rating methodology is the modified scheme of Plomp (2004), as provided by AGES.

8.1 NATURE OF THE IMPACT

Construction activities (excavations) will result in a negative direct impact on the probable fossil content of the affected subsurface. Fossils and significant observations will be lost in the absence of management actions to mitigate such loss. This loss of the opportunity to recover them and their contexts when exposed at a particular site is irreversible.

Conversely, construction excavations furnish the "windows" into the coastal plain depository that would not otherwise exist and thereby provide access to the hidden fossils. The impact is positive for palaeontology, provided that efforts are made to watch out for and rescue the fossils.

8.1.1 Probability

The likelihood of impact is PROBABLE, *i.e*. it is likely that the impact will occur to the extent that provision must be made therefore.

8.1.2 Duration

The initial duration of the impact is shorter term (< year) and primarily related to the period over which excavations are made. This is the "time window" for mitigation.

The impact of both the finding or the loss of fossils is PERMANENT. The found fossils must be preserved "for posterity"; the lost, overlooked or destroyed fossils are lost to posterity.

8.1.3 Scale

The physical extent of impacts on potential palaeontological resources relates directly to the extents of subsurface disturbance, *i.e*. LOCAL.

8.1.4 Magnitude/ Severity

In Impact Assessment methodologies this is defined in terms of impact upon the affected environment *viz*. the degree to which environmental functions and processes are altered by the proposed development. Whereas fossils are the entombed evidence of environments of the past – palaeoenvironments that usually differ from the historical and modern environments of the region.

A more appropriate scale for informing the rating of the impact on fossil resources is the "Palaeontological Sensitivity" of the affected formations. Palaeontological Sensitivity refers to the likelihood of finding significant fossils within a geologic unit (Appendix 4). In terms of Appendix 4, the Langebaan Formation has high palaeontological sensitivity – "Assigned to geological formations known to contain palaeontological resources that include rare, well-preserved fossil materials important to on-going paleoclimatic, paleobiological and/or evolutionary studies."

Notwithstanding, it does not necessarily follow that the Magnitude/Severity of this particular project impact must be High. The depth of excavations is limited. The thick calcrete underlying the area has hitherto yielded only sporadic fossil bone finds, although its true potential is likely to be under-estimated, due to unnoticed occurrences in the past.

The Magnitude/Severity is therefore rated as MEDIUM. In the absence of effective mitigation this will be a MEDIUM-NEGATIVE impact: scientifically significant material will quite probably be destroyed or highly disturbed.

With successful mitigation the impact should be MEDIUM-POSITIVE. However, mitigation can only strive to obtain a sample or portion of the potential fossil content of the disturbed subsurface. If a significant find of fossils is made, such as a large assemblage of bones or some hominid remains, the impact may translate to HIGH-POSITIVE. A major fossil find of international significance is not usually expected nor can be predicted.

8.2 RATINGS TABLE

The prescribed Impact Rating Methodology does not cater for the nuancing of Magnitude/Severity as negative or positive. Instead, the following tables serve to illustrate the situation.

WITHOUT MITIGATION (loss of fossils typically expected to occur sporadically)

ASPECT	DESCRIPTION	WEIGHT
Probability	Probable	2
Duration	Permanent	5
Scale	Local	1
Magnitude/Severity	Medium	6
Significance	**LOW**	**24**

WITH MITIGATION (in the case of an important fossil find)

ASPECT	DESCRIPTION	WEIGHT
Probability	Probable	2
Duration	Permanent	5
Scale	Regional	3
Magnitude/Severity	High	8
Significance	**LOW**	**32**

Notably, the Significance remains low, even in the event of a fossil find of regional significance, this being due to the level of uncertainty (probable).

9 RECOMMENDATIONS

Note that the probable presence of fossils in the subsurface does not have an *a priori* influence on the decision to proceed with the development. However, mitigation measures are essential. The potential impact has a moderate influence upon the proposed project, consisting of implemented mitigation measures recommended below, to be followed during the construction phase.

Monitoring by on-site personnel and field inspections by a palaeontologist/trained fossil excavator are recommended during construction of excavations.

Appendices 1 and 2 outline monitoring by construction personnel and a general Fossil Find Procedures.

It is recommended that a palaeontologist carry out field inspections at appropriate stages in the making of the excavations. This specialist must liaise with Frontier and their contractors to carry out the inspections involving:

- Inspection of the excavations and spoil heaps for fossil content.
- Photographically record occurrences.
- Retrieve fossil bone finds. Given the nature of the deposit, these are expected to be finds of broken bone exposed in chunks of calcrete. All bone-bearing pieces should be collected.
- Compilation of the report.

In the event of a significant fossil occurrence, additional geological and palaeontological expertise must be brought to bear in order to more completely record the context.

9.1 MONITORING

Table 4. Basic measures for the Construction EMP

OBJECTIVE: To see and rescue fossil material that may be exposed in the various excavations made for installation foundations and cabling.		
Project components	Foundation excavations, trenches for cabling and pipes, spoil from excavations.	
Potential impact	Loss of fossils by their being unnoticed and/ or destroyed.	
Activity/ risk source	All bulk earthworks.	
Mitigation: target/ objective	To facilitate the likelihood of noticing fossils and ensure appropriate actions in terms of the relevant legislation.	
Mitigation: Action/ control	**Responsibility**	**Timeframe**
Inform staff of the need to watch for potential fossil occurrences.	Frontier, Environmental Site Officer (ESO), contractors.	Pre-construction.
Inform staff of the procedures to be followed in the event of fossil occurrences.	ESO/palaeontology specialist.	Pre-construction.
Monitor for presence of fossils	Contractor personnel and ESO.	Construction.
Liaise on nature of potential finds and appropriate responses.	ESO and palaeontology specialist.	Construction.
Excavate main finds, inspect pits & record selected, key/higher-risk excavations.	Palaeontology specialist.	Construction.
Obtain permit from HWC for finds.	Palaeontology specialist.	Construction
Performance Indicator	Reporting of and liaison about possible fossil finds. Fossils noticed and rescued.	
Monitoring	Due effort to meet the requirements of the monitoring procedures.	

It is probable that sparse, valuable bone fossils will go undetected, even with the most diligent mitigation practicable. On the other hand, the finding and recovery of fossils will have a positive impact ranging from local to international in extent, depending on the nature of the finds

10 APPLICATION FOR A PALAEONTOLOGICAL PERMIT

A permit from Heritage Western Cape (HWC) is required to excavate fossils. The applicant must be the qualified specialist responsible for assessment, collection and reporting (the palaeontologist). The application requires details of the registered owner of the site, their permission and a site-plan map. Neither the developer (Frontier) nor the owner of the land can be the applicant for the permit.

A permit will not be applied for prior to the making of excavations. Should fossils be found an application for a palaeontological permit will be made to HWC immediately.

All fossil finds must be recorded and the fossils and their contextual information (a report) must be deposited at a SAHRA-approved institution.

11 REPORTING

Should fossils be found a detailed report on the occurrence/s must be submitted. This report is in the public domain and copies of the report must be supplied to the IZIKO S.A. Museum and Heritage Resources Western Cape. It must fulfil the reporting standards and data requirements of these bodies.

The report will be in standard scientific format, basically:

- A summary/abstract.
- Introduction.
- Previous work/context.
- Observations (incl. graphic sections, images).
- Palaeontology.
- Interpretation.
- Concluding summary.
- References.
- Appendices

The draft report will be reviewed by the client, or externally, before submission of the Final Report.

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13 GLOSSARY

~ (tilde): Used herein as "approximately" or "about".

Aeolian: Pertaining to the wind. Refers to erosion, transport and deposition of sedimentary particles by wind. A rock formed by the solidification of aeolian sediments is an aeolianite.

AIA: Archaeological Impact Assessment.

Alluvium: Sediments deposited by a river or other running water.

Archaeology: Remains resulting from human activity which are in a state of disuse and are in or on land and which are older than 100 years, including artefacts, human and hominid remains and artificial features and structures.

asl.: above (mean) sea level.

Bedrock: Hard rock formations underlying much younger sedimentary deposits.

Calcareous: sediment, sedimentary rock, or soil type which is formed from or contains a high proportion of calcium carbonate in the form of calcite or aragonite.

Calcrete: An indurated deposit (duricrust) mainly consisting of Ca and Mg carbonates. The term includes both pedogenic types formed in the near-surface soil context and non-pedogenic or groundwater calcretes related to water tables at depth.

Clast: Fragments of pre-existing rocks, *e.g*. sand grains, pebbles, boulders, produced by weathering and erosion. Clastic – composed of clasts.

Colluvium: Hillwash deposits formed by gravity transport downhill. Includes soil creep, sheetwash, small-scale rainfall rivulets and gullying, slumping and sliding processes that move and deposit material towards the foot of the slopes.

Coversands: Aeolian blanket deposits of sandsheets and dunes.

Duricrust: A general term for a zone of chemical precipitation and hardening formed at or near the surface of sedimentary bodies through pedogenic and (or) non-pedogenic processes. It is formed by the accumulation of soluble minerals deposited by mineral-bearing waters that move upward, downward, or laterally by capillary action, commonly assisted in arid settings by evaporation. Classified into calcrete, ferricrete, silcrete.

ESA: Early Stone Age. The archaeology of the Stone Age between 2 000 000 and 250 000 years ago.

EIA: Environmental Impact Assessment.

EMP: Environmental Management Plan.

Ferricrete: Indurated deposit (duricrust) consisting predominantly of accumulations of iron sesquioxides, with various dark-brown to yellow-brown hues. It may form by deposition from solution or as a residue after removal of silica and alkalis. Like calcrete it has pedogenic and groundwater forms. Synonyms are laterite, iron pan or “koffieklip”.

Fluvial deposits: Sedimentary deposits consisting of material transported by, suspended in and laid down by a river or stream.

Fm.: Formation.

Fossil: Mineralised bones of animals, shellfish, plants and marine animals. A trace fossil is the disturbance or structure produced in sediments by organisms, such as burrows and trackways.

Heritage: That which is inherited and forms part of the National Estate (Historical places, objects, fossils as defined by the National Heritage Resources Act 25 of 1999).

HIA: Heritage Impact Assessment.

LSA: Late Stone Age. The archaeology of the last 20 000 years associated with fully modern people.

LIG: Last Interglacial. Warm period 128-118 ka BP. Relative sea-levels higher than present by 4-6 m. Also referred to as Marine Isotope Stage 5e or “the Eemian”.

Midden: A pile of debris, normally shellfish and bone that have accumulated as a result of human activity.

MIS: Marine isotope stages (MIS), marine oxygen-isotope stages, or oxygen isotope stages (OIS), are alternating warm and cool periods in the Earth's paleoclimate, deduced from oxygen isotope data reflecting changes in temperature derived from data from deep sea core samples. Working backwards from the present, MIS 1 in the scale, stages with even numbers representing cold glacial periods, while the odd-numbered stages represent warm interglacial intervals.

MSA: Middle Stone Age. The archaeology of the Stone Age between 20-300 000 years ago associated with early modern humans.

OSL: Optically stimulated luminescence. One of the radiation exposure dating methods based on the measurement of trapped electronic charges that accumulate in crystalline materials as a result of low-level natural radioactivity from U, Th and K. In OSL dating of aeolian quartz and feldspar sand grains, the trapped charges are zeroed by exposure to daylight at the time of deposition. Once buried, the charges accumulate and the total radiation exposure (total dose) received by the sample is estimated by laboratory measurements. The level of radioactivity (annual doses) to which the sample grains have been exposed is measured in the field or from the separated minerals containing radioactive elements in the sample. Ages are obtained as the ratio of total dose to annual dose, where the annual dose is assumed to have been similar in the past.

Palaeontology: The study of any fossilised remains or fossil traces of animals or plants which lived in the geological past and any site which contains such fossilised remains or traces.

Palaeosol: An ancient, buried soil whose composition may reflect a climate significantly different from the climate now prevalent in the area where the soil is found. Burial reflects the subsequent environmental change.

Palaeosurface: An ancient land surface, usually buried and marked by a palaeosol or pedocrete, but may be exhumed by erosion (*e.g*. wind erosion/deflation) or by bulk earth works.

Peat: partially decomposed mass of semi-carbonized vegetation which has grown under waterlogged, anaerobic conditions, usually in bogs or swamps.

Pedogenesis/pedogenic: The process of turning sediment into soil by chemical weathering and the activity of organisms (plants growing in it, burrowing animals such as worms, the addition of humus *etc.*).

Pedocrete: A duricrust formed by pedogenic processes.

PIA: Palaeontological Impact Assessment.

SAHRA: South African Heritage Resources Agency – the compliance authority, which protects national heritage.

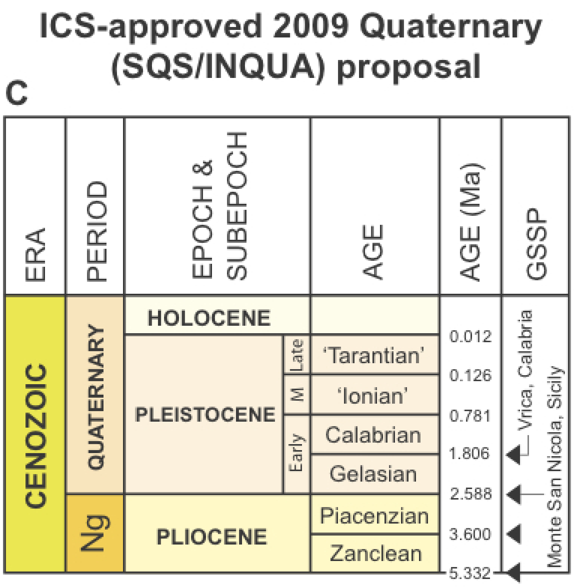
Stone Age: The earliest technological period in human culture when tools were made of stone, wood, bone or horn. Metal was unknown.

Type locality: The specific geographic locality where the stratotype of a layered stratigraphic unit is situated. The name also refers to the locality where the unit was originally described and/or named.

13.1 GEOLOGICAL TIME SCALE TERMS (YOUNGEST TO OLDEST).

ka: Thousand years or kilo-annum (10^3 years). Implicitly means "ka ago" *i.e*. duration from the present, but "ago" is omitted. The "Present" refers to 1950 AD. Generally not used for durations not extending from the Present. Sometimes "kyr" is used instead.

Ma: Millions years, mega-annum (10^6 years). Implicitly means "Ma ago" *i.e.* duration from the present, but "ago" is omitted. The "Present" refers to 1950 AD. Generally not used for durations not extending from the Present.



Holocene: The most recent geological epoch commencing 11.7 ka till the present.

Pleistocene: Epoch from 2.6 Ma to 11.7 ka. Late Pleistocene 11.7–126 ka. Middle Pleistocene 135–781 ka. Early Pleistocene 781–2588 ka (0.78-2.6.Ma).

Quaternary: The current Period, from 2.6 Ma to the present, in the Cenozoic Era. The Quaternary includes both the Pleistocene and Holocene epochs. The terms early, middle or late in reference to the Quaternary should only be used with lower case letters because these divisions are informal and have no status as divisions of the term Quaternary. The sub-divisions 'Early', 'Middle' or 'Late' apply only to the word Pleistocene. As used herein, early and middle Quaternary correspond with the Pleistocene divisions, but late Quaternary includes the Late Pleistocene and the Holocene.

Pliocene: Epoch from 5.3-2.6 Ma.

Miocene: Epoch from 23-5 Ma.

Oligocene: Epoch from 34-23 Ma.

Eocene: Epoch from 56-34 Ma.

Paleocene: Epoch from 65-56 Ma.

Cenozoic: Era from 65 Ma to the present. Includes Paleocene to Holocene epochs.

Cretaceous: Period in the Mesozoic Era, 145-65 Ma.

Jurassic: Period in the Mesozoic Era, 200-145 Ma.

Precambrian: Old crustal rocks older than 542 Ma (pre-dating the Cambrian).

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14 APPENDIX 1 – MONITORING FOR FOSSILS

A regular monitoring presence over the period during which excavations are made, by either an archaeologist or palaeontologist, is generally not practical.

The field supervisor/foreman and workers involved in digging excavations must be encouraged and informed of the need to watch for potential fossil and buried archaeological material. Workers seeing potential objects are to report to the field supervisor who, in turn, will report to the Environmental Site Officer (ESO). The ESO will inform the archaeologist and/or palaeontologist contracted to be on standby in the case of fossil finds.

To this end, responsible persons must be designated. This will include hierarchically:

- The field supervisor/foreman, who is going to be most often in the field.
- The Environmental Site Officer (ESO) for the project.
- The Project Manager.

Should the monitoring of the excavations be a stipulation in the Archaeological Report, the contracted Monitoring Archaeologist (MA) can also monitor for the presence of fossils and make a field assessment of any material brought to attention. The MA is usually sufficiently informed to identify fossil material and this avoids additional monitoring by a palaeontologist. In shallow coastal excavations, the fossils encountered are usually in an archaeological context.

The MA then becomes the responsible field person and fulfils the role of liaison with the palaeontologist and coordinates with the developer and the Environmental Site Officer (ESO). If fossils are exposed in non-archaeological contexts, the palaeontologist should be summoned to document and sample/collect them.

Other alternatives could be considered, such as the employment of a dedicated monitor for the construction period. For instance, a local person could be detached from or trained by personnel at the West Coast Fossil Park.

14.1 CONTACTS FOR REPORTING OF FOSSIL FINDS.

West Coast Fossil Park

- Pippa Haarhoff: 083 289 6902, 022 766 1606, pippah@iafrica.com

Iziko Museums of Cape Town: SA Museum, 021 481 3800.

- Dr Romala Govender: 021 481 3895, 083 441 0028.

Heritage Western Cape

- Troy Smuts: 021 483 9543
- Jenna Lavin: 021 483 9685

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15 APPENDIX 2 - FOSSIL FIND PROCEDURES

In the context under consideration, it is improbable that fossil finds will require declarations of permanent "no go" zones. At most a temporary pause in activity at a limited locale may be required. The strategy is to rescue the material as quickly as possible.

The procedures suggested below are in general terms, to be adapted as befits a context. They are couched in terms of finds of fossil bones that usually occur sparsely, such as in the aeolian deposits. However, they may also serve as a guideline for other fossil material that may occur.

In contrast, fossil shell layers are usually fairly extensive and can be easily documented and sampled (See section 15.5).

Bone finds can be classified as two types: isolated bone finds and bone cluster finds.

15.1 ISOLATED BONE FINDS

In the process of digging the excavations, isolated bones may be spotted in the hole sides or bottom, or as they appear on the spoil heap. By this is meant bones that occur singly, in different parts of the excavation. If the number of distinct bones exceeds 6 pieces, the finds must be treated as a bone cluster (below).

Response by personnel in the event of isolated bone finds

- **Action 1:** An isolated bone exposed in an excavation or spoil heap must be retrieved before it is covered by further spoil from the excavation and set aside.
- **Action 2:** The site foreman and ESO must be informed.
- **Action 3:** The responsible field person (site foreman or ESO) must take custody of the fossil. The following information to be recorded:
    - Position (excavation position).
    - Depth of find in hole.
    - Digital image of hole showing vertical section (side).
    - Digital image of fossil.
- **Action 4:** The fossil should be placed in a bag (*e.g.* a Ziplock bag), along with any detached fragments. A label must be included with the date of the find, position info., depth.
- **Action 5:** ESO contacts the standby archaeologist and/or palaeontologist. ESO to describe the occurrence and provide images asap. by email.

Response by Palaeontologist in the event of isolated bone finds

The palaeontologist will assess the information and liaise with the developer and the ESO and a suitable response will be established.

15.2 *BONE CLUSTER FINDS*

A bone cluster is a major find of bones, *i.e*. several bones in close proximity or bones resembling part of a skeleton. These bones will likely be seen in broken sections of the sides of the hole and as bones appearing in the bottom of the hole and on the spoil heap.

Response by personnel in the event of a bone cluster find

- **Action 1:** Immediately stop excavation in the vicinity of the potential material. Mark (flag) the position and also spoil that may contain fossils.
- **Action 2:** Inform the site foreman and the ESO.
- **Action 3:** ESO contacts the standby archaeologist and/or palaeontologist. ESO to describe the occurrence and provide images asap. by email.

Response by Palaeontologist in the event of a bone cluster find

The palaeontologist will assess the information and liaise with Frontier and a suitable response will be established. It is likely that a Field Assessment by the palaeontologist will be carried out asap.

It will probably be feasible to "leapfrog" the find and continue the excavation farther along, or proceed to the next excavation, so that the work schedule is minimally disrupted. The response time/scheduling of the Field Assessment is to be decided in consultation with developer/owner and the environmental consultant.

The field assessment could have the following outcomes:

- If a human burial, the appropriate authority is to be contacted. The find must be evaluated by a human burial specialist to decide if Rescue Excavation is feasible, or if it is a Major Find.
- If the fossils are in an archaeological context, an archaeologist must be contacted to evaluate the site and decide if Rescue Excavation is feasible, or if it is a Major Find.
- If the fossils are in a palaeontological context, the palaeontologist must evaluate the site and decide if Rescue Excavation is feasible, or if it is a Major Find.

15.3 *RESCUE EXCAVATION*

Rescue Excavation refers to the removal of the material from the "design" excavation. This would apply if the amount or significance of the exposed material appears to be relatively circumscribed and it is feasible to remove it without compromising contextual data. The time span for Rescue Excavation should be reasonably rapid to avoid any or undue delays, *e.g*. 1-3 days and definitely less than 1 week.

In principle, the strategy during mitigation is to "rescue" the fossil material as quickly as possible. The strategy to be adopted depends on the nature of the occurrence, particularly the density of the fossils. The methods of collection would depend on the preservation or fragility of the fossils and whether in loose or in lithified sediment. These could include:

- On-site selection and sieving in the case of robust material in sand.
- Fragile material in loose/crumbly sediment would be encased in blocks using Plaster-of Paris or reinforced mortar.

If the fossil occurrence is dense and is assessed to be a "Major Find", then carefully controlled excavation is required.

15.4 *MAJOR FINDS*

A Major Find is the occurrence of material that, by virtue of quantity, importance and time constraints, cannot be feasibly rescued without compromise of detailed material recovery and contextual observations.
A Major Find is not expected.

Management Options for Major Finds
In consultation with Frontier and the environmental consultant, the following options should be considered when deciding on how to proceed in the event of a Major Find.

Option 1: Avoidance

Avoidance of the major find through project redesign or relocation. This ensures minimal impact to the site and is the preferred option from a heritage resource management perspective. When feasible, it can also be the least expensive option from a construction perspective.

The find site will require site protection measures, such as erecting fencing or barricades. Alternatively, the exposed finds can be stabilized and the site refilled or capped. The latter is preferred if excavation of the find will be delayed substantially or indefinitely. Appropriate protection measures should be identified on a site-specific basis and in wider consultation with the heritage and scientific communities.

This option is preferred as it will allow the later excavation of the finds with due scientific care and diligence.

Option 2: Emergency Excavation

Emergency excavation refers to the "no option" situation wherein avoidance is not feasible due to design, financial and time constraints. It can delay construction and emergency excavation itself will take place under tight time constraints, with the potential for irrevocable compromise of scientific quality. It could involve the removal of a large, disturbed sample by excavator and conveying this by truck from the immediate site to a suitable place for "stockpiling". This material could then be processed later.

Consequently, emergency excavation is not a preferred option for a Major Find.

15.5 *EXPOSURE OF FOSSIL SHELL BEDS*

Response by personnel in the event of intersection of fossil shell beds

- **Action 1:** The site foreman and ESO must be informed.
- **Action 2:** The responsible field person (site foreman or ESO) must record the following information:
    - Position (excavation position).
    - Depth of find in hole.
    - Digital image of hole showing vertical section (side).
    - Digital images of the fossiliferous material.
- **Action 3:** A generous quantity of the excavated material containing the fossils should be stockpiled near the site, for later examination and sampling.
- **Action 4:** ESO contacts the standby archaeologist and/or palaeontologist. ESO to describe the occurrence and provide images asap. by email.

Response by Palaeontologist in the event of fossil shell bed finds

The palaeontologist will assess the information and liaise with Frontier and a suitable response will be established. This will most likely be a site visit to document and sample the exposure in detail, before it is covered up.

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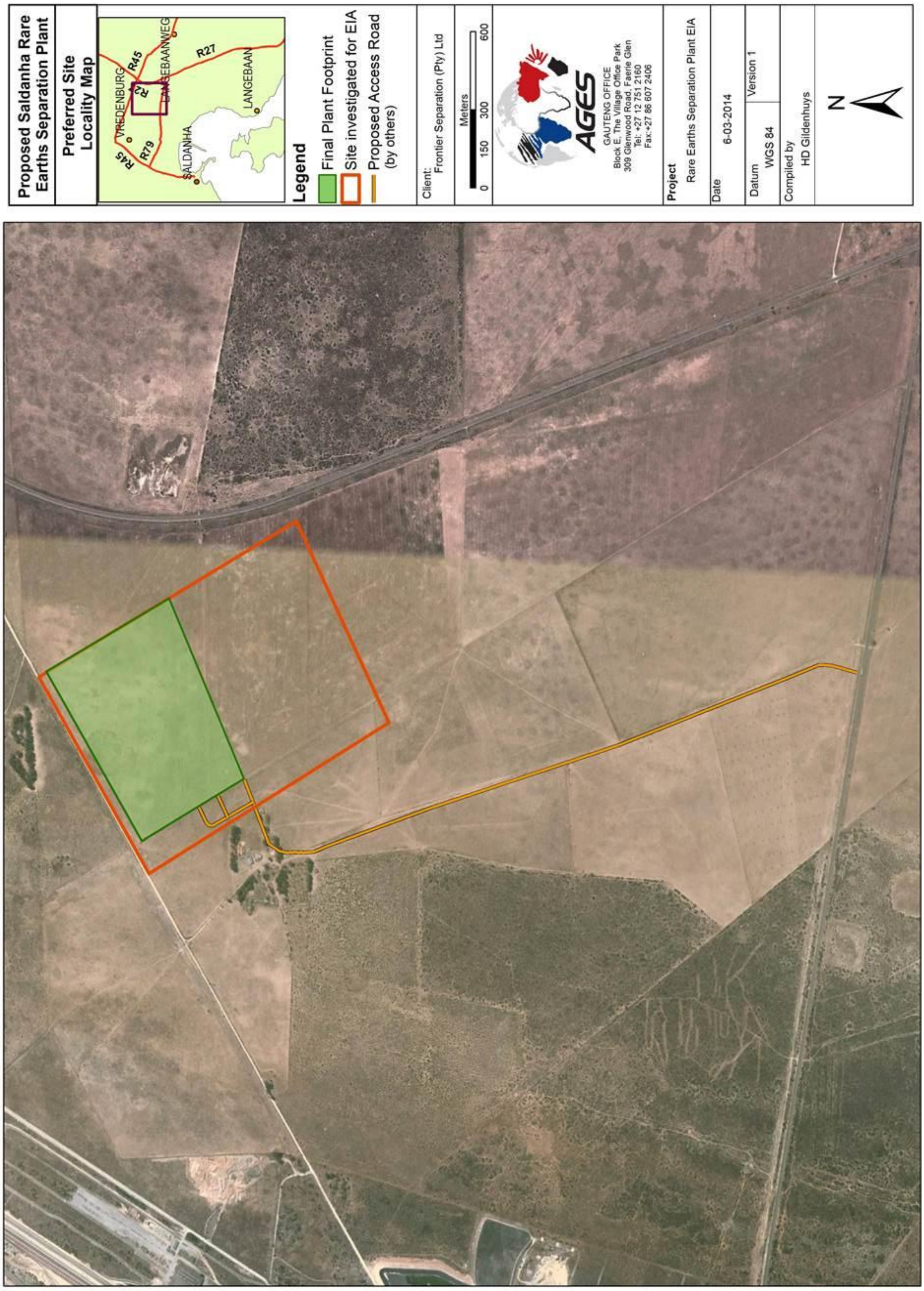
16 *APPENDIX 3 – CONSTRUCTION FOOTPRINT*



17 APPENDIX 4. PALAEONTOLOGICAL SENSITIVITY RATING

Palaeontological Sensitivity refers to the likelihood of finding significant fossils within a geologic unit.

HIGH: Assigned to geological formations known to contain palaeontological resources that include rare, well-preserved fossil materials important to on-going paleoclimatic, paleobiological and/or evolutionary studies. Fossils of land-dwelling vertebrates are typically considered significant. Such formations have the potential to produce, or have produced, vertebrate remains that are the particular research focus of paleontologists and can represent important educational resources as well.

MODERATE: Formations known to contain palaeontological localities and that have yielded fossils that are common elsewhere, and/or that are stratigraphically long-ranging, would be assigned a moderate rating. This evaluation can also be applied to strata that have an unproven, but strong potential to yield fossil remains based on its stratigraphy and/or geomorphologic setting.

LOW: Formations that are relatively recent or that represent a high-energy subaerial depositional environment where fossils are unlikely to be preserved, or are judged unlikely to produce unique fossil remains. A low abundance of invertebrate fossil remains can occur, but the palaeontological sensitivity would remain low due to their being relatively common and their lack of potential to serve as significant scientific resources. However, when fossils are found in these formations, they are often very significant additions to our geologic understanding of the area. Other examples include decalcified marine deposits that preserve casts of shells and marine trace fossils, and fossil soils with terrestrial trace fossils and plant remains (burrows and root fossils)

MARGINAL: Formations that are composed either of volcaniclastic or metasedimentary rocks, but that nevertheless have a limited probability for producing fossils from certain contexts at localized outcrops. Volcaniclastic rock can contain organisms that were fossilized by being covered by ash, dust, mud, or other debris from volcanoes. Sedimentary rocks that have been metamorphosed by the heat and pressure of deep burial are called metasedimentary. If the meta sedimentary rocks had fossils within them, they may have survived the metamorphism and still be identifiable. However, since the probability of this occurring is limited, these formations are considered marginally sensitive.

NO POTENTIAL: Assigned to geologic formations that are composed entirely of volcanic or plutonic igneous rock, such as basalt or granite, and therefore do not have any potential for producing fossil remains. These formations have no palaeontological resource potential.

Adapted from Society of Vertebrate Paleontology. 1995. Assessment and Mitigation of Adverse Impacts to Nonrenewable Paleontologic Resources - Standard Guidelines. News Bulletin, Vol. 163, p. 22-27.