PALAEONTOLOGICAL IMPACT ASSESSMENT

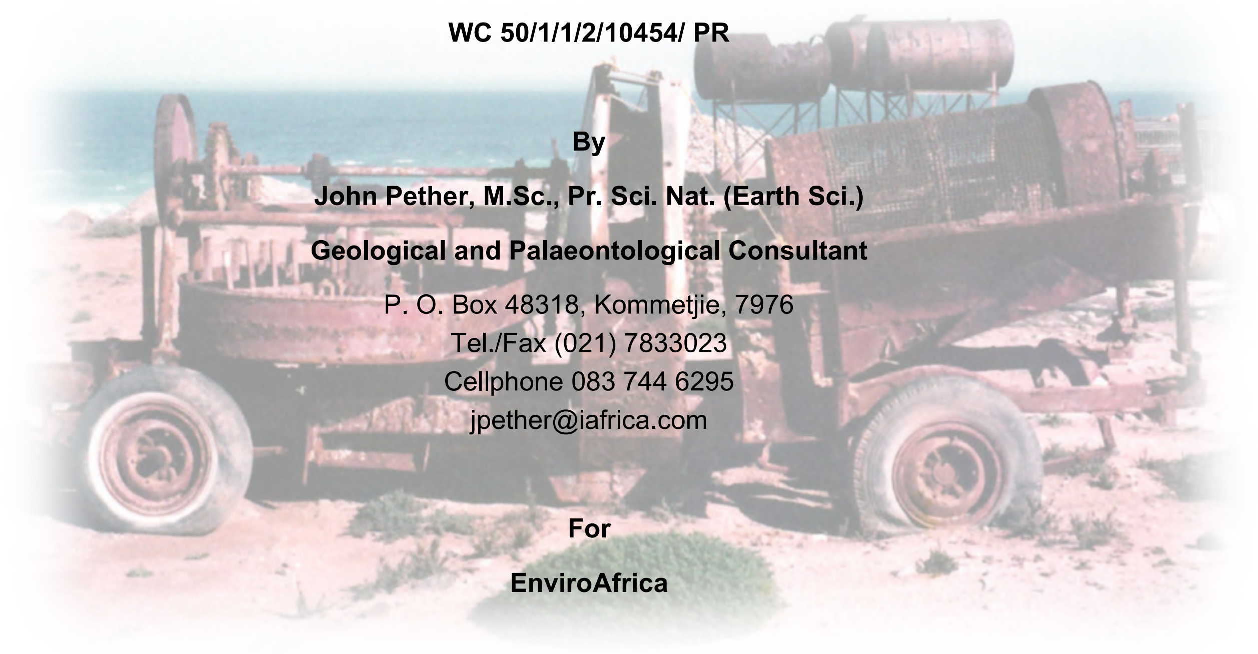
(Desktop Study)

PROPOSED FISH BY THE SEA (PTY) LTD DIAMOND PROSPECTING WITH BULK SAMPLING ON RIETFONTEIN EXT 4/151 & GRAAUW DUINEN 4/152, BETWEEN LOW AND HIGHWATER MARKS

NAMAQUALAND, MATZIKAMA LOCAL MUNICIPALITY, WEST COAST DISTRICT

VREDENDAL MAGISTERIAL DISTRICT, WESTERN CAPE

WC 50/1/1/2/10454/ PR



By

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For

EnviroAfrica

Client

Fish by the Sea (PTY) LTD.

Updated Version - 10 JUNE 2024

EXECUTIVE SUMMARY

1. Site Name

Prospecting Right Application WC 50/1/1/2/10454/ PR for diamond prospecting between low and highwater marks on farm portions Rietfontein Extension 4/151 and Graauw Duinen 4/152, by Fish by the Sea (Pty) Ltd. (Figure 1).

2. Location

The Application Area is situated along the coast just south of the Soutrivier salt pans and is partly adjacent to the Namakwa Sands heavy mineral sands mine (Figure 1). It is approached via Vredendal, Lutzville and past Koekenaap on the road to the Namakwa Sands mine. At Namakwa Sands mine a gravel road continues north to Salt Pan, *i.e.* the mouth of the Soutrivier, from where tracks link to the coast. The site can also be reached via farm roads from Nuwerus or Bitterfontein.

3. Locality Plan

The locations of the prospecting and bulk sampling trenches on the beach between low and highwater are not yet specified.

4. Proposed Activities

- **Phase 1: Gathering of existing data & Geophysical Survey** *e.g.* published and proprietary data from previous geological exploration. Ground resistivity measurements may be used to identify potential target areas.
- **Phase 2: Prospecting Pits**. Up to 20 small prospecting pits.
- **Phase 3: Bulk Sampling Trenches:** The purpose of bulk sampling or trial mining of the intertidal strip is to establish the feasibility of proceeding with a Mining Right Application and involves processing material from a large trench until about 1000 carats have been obtained to establish the diamond size distribution and value. The nominal footprint of a bulk sample trench is 100 X 300 m and to depths of 2-5 m.

5. Affected Formations

The initial prospecting along the seashore and will affect the **modern beach deposits** and the raised beach deposits of the **Curlew Strand Fm.**, such as the Holocene High raised beach deposits and most likely also the Last Interglacial raised beach. The overlying dune sands of the **Witzand Fm**. may be disturbed.

6. Anticipated Impacts

The intensity/magnitude of a palaeontological impact is determined by the palaeontological sensitivity of the affected geological formation, together with the extent or volume of excavations made into the formation. The subfossil, extant shells expected in the beach excavations do not constitute an impact on palaeontological heritage. Any fossil bones are the main focus of concern, due to their potential scientific importance, but are also likely to be subfossil extant species. The intensity of impact of the beach prospecting is LOW and the significance of possible subfossil bone finds may range to MEDIUM.

8. Recommendations

It is recommended that a requirement to be alert for fossil bones and archaeological shipwreck material which may be uncovered during the prospecting be included in the Environmental Management Programme (EMP) for the proposed prospecting operations. Under supervision of the Environmental Control Officer (ECO) and as part of Environmental and Health & Safety awareness training, personnel involved in the prospecting must be instructed to be alert for the occurrence of fossil bones. In the event of such discoveries the **Fossil Finds Procedure** provided below, for incorporation into the Environmental Management Programme for the proposed prospecting, must be followed.

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DECLARATION OF INDEPENDENCE

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VREDENDAL MAGISTERIAL DISTRICT, WESTERN CAPE

WC 50/1/1/2/10454/ PR

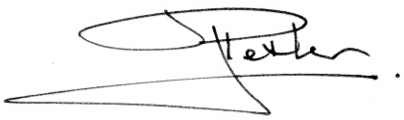
Terms of Reference

This assessment forms part of the Heritage Assessment and it assesses the overall palaeontological (fossil) sensitivities of formations underlying the Project Area in terms of the proposed development.

Declaration

I …**John Pether**……, as the appointed independent specialist hereby declare that I:

- act/ed as the independent specialist in the compilation of the above report;
- regard the information contained in this report as it relates to my specialist input/study to be true and correct, and
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the NEMA, the Environmental Impact Assessment Regulations, 2014 and any specific environmental management Act;
- have and will not have any vested interest in the proposed activity proceeding;
- have disclosed to the EAP any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the NEMA, the Environmental Impact Assessment Regulations, 2014 and any specific environmental management act;
- have provided the EAP with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not; and
- am aware that a false declaration is an offence in terms of regulation 48 of the 2014 NEMA EIA Regulations.



Signature of the specialist

Date: 10 June 2024

CURRICULUM VITAE

John Pether, M.Sc., Pr. Sci. Nat. (Earth Sci.)

Independent Consultant/Researcher recognized as an authority with 37 years' experience in the field of coastal-plain and continental-shelf palaeoenvironments, fossils and stratigraphy, mainly involving the West Coast/Shelf of southern Africa. Has been previously employed in academia (South African Museum) and industry (Trans Hex, De Beers Marine). At present an important involvement is in Palaeontological Impact Assessments (PIAs) and mitigation projects in terms of the National Heritage Resources Act 25 (1999) (~350 PIA reports to date) and is an accredited member of the Association of Professional Heritage Practitioners (APHP). Continues to be involved as consultant to offshore and onshore marine diamond exploration ventures. Expertise includes:

- Coastal plain and shelf stratigraphy (interpretation of open-pit exposures, on/offshore cores and exploration drilling).
- Sedimentology and palaeoenvironmental interpretation of shallow marine, aeolian and other terrestrial surficial deposits.
- Marine macrofossil taxonomy (molluscs, barnacles, brachiopods) and biostratigraphy.
- 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.
- Association of Professional Heritage Practitioners (APHP), Western Cape. Accredited Member No. 48.

Past Clients Palaeontological Assessments

AECOM SA (Pty) Ltd.	Guillaume Nel Environmental Management Consultants.
Agency for Cultural Resource Management (ACRM).	Klomp Group.
AMATHEMBA Environmental.	Megan Anderson, Landscape Architect.
Anél Blignaut Environmental Consultants.	Ninham Shand (Pty) Ltd.
Arcus Gibb (Pty) Ltd.	PD Naidoo & Associates (Pty) Ltd.
ASHA Consulting (Pty) Ltd.	Perception Environmental Planning.
Aurecon SA (Pty) Ltd.	PHS Consulting.
BKS (Pty) Ltd. Engineering and Management.	Resource Management Services.
Bridgette O'Donoghue Heritage Consultant.	Robin Ellis, Heritage Impact Assessor.
Cape Archaeology, Dr Mary Patrick.	Savannah Environmental (Pty) Ltd.
Cape EAPrac (Cape Environmental Assessment Practitioners).	Sharples Environmental Services cc
CCA Environmental (Pty) Ltd.	Site Plan Consulting (Pty) Ltd.
Centre for Heritage & Archaeological Resource Management (CHARM).	SRK Consulting (South Africa) (Pty) Ltd.
Chand Environmental Consultants.	Strategic Environmental Focus (Pty) Ltd.
CK Rumboll & Partners.	UCT Archaeology Contracts Office (ACO).
CNdV Africa	UCT Environmental Evaluation Unit
CSIR - Environmental Management Services.	Urban Dynamics.
Digby Wells & Associates (Pty) Ltd.	Van Zyl Environmental Consultants
Enviro Logic	Western Cape Environmental Consultants (Pty) Ltd, t/a ENVIRO DINAMIK.
Environmental Resources Management SA (ERM).	Wethu Investment Group Ltd.
Greenmined Environmental	Withers Environmental Consultants.

Stratigraphic consulting including palaeontology

Afri-Can Marine Minerals Corp	Council for Geoscience
De Beers Marine (SA) Pty Ltd.	De Beers Namaqualand Mines.
Geological Survey Namibia	IZIKO South African Museum.
Namakwa Sands (Pty) Ltd	NAMDEB

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.
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.
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 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.
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 small dunes.
Fluvial deposits	Sedimentary deposits consisting of material transported by, suspended in and laid down by a river or stream.
MIS - Marine Isotope Stages	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-day interglacial which is MIS 1, stages with odd numbers represent warm interglacial intervals and stages with even numbers represent cold glacial periods.
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.
Palaeosol	An ancient, buried soil formed on a palaeosurface. The soil 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.
Pedocrete	A cemented soil formed by pedogenic processes, such as calcrete, silcrete and laterite.
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.*).
Rhizolith	Fossil root. Most commonly formed by pedogenic carbonate deposition around the root and developed in palaeosols.

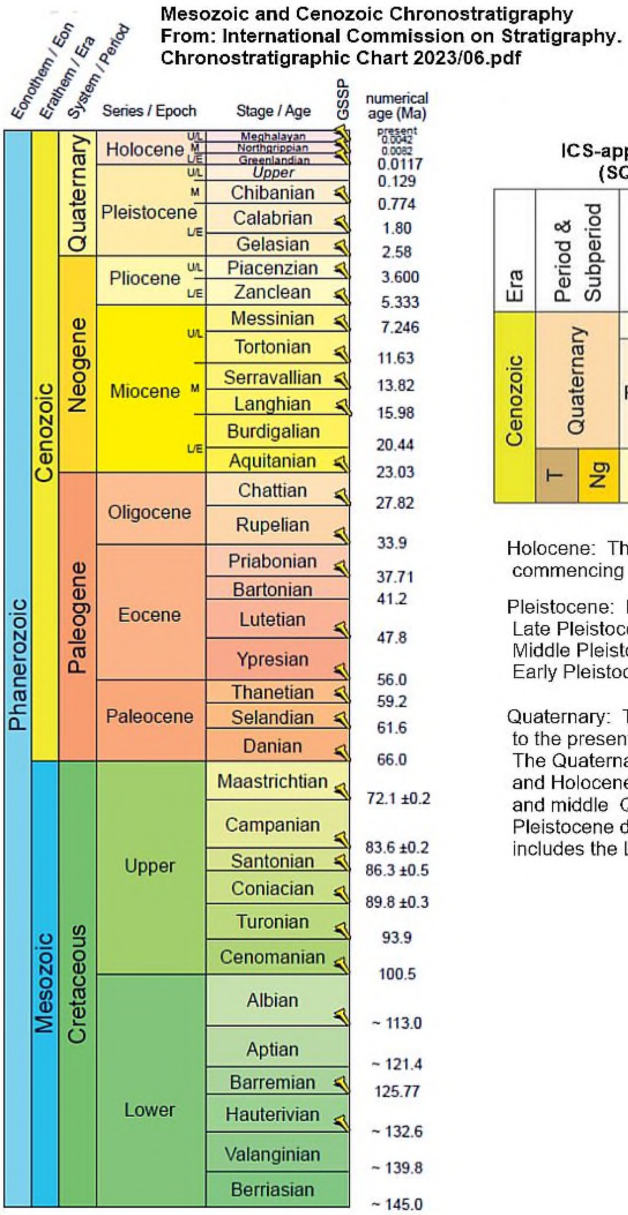
GEOLOGICAL TIME SCALE TERMS

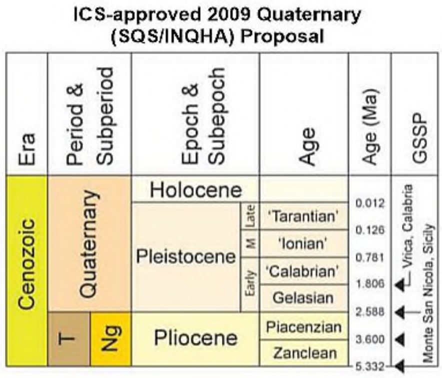
For more detail see www.stratigraphy.org.

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. Not used for durations not extending from the Present. For a duration only "kyr" is used.

Ma: Million 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. Not used for durations not extending from the Present. For a duration only "Myr" is used.

Late Pliocene Warm Period: An interval of warm climate and high sea level around ~3 Ma. This interval was previously referred to as the Mid Pliocene Warm Period (MPWP) when the boundary between the Pliocene and Quaternary was set at ~1.8 Ma at the beginning of the Calabrian (see figure below). Now that the Pliocene/Quaternary boundary is set further back in time by international agreement to the beginning of the Gelasian at ~2.6 Ma, the MPWP at ~3 Ma is no longer "mid", but is in the late Pliocene. However, for continuity it is still often referred to as the MPWP.





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.

Quaternary: The current Period, from 2.6 Ma to the present, in the Cenozoic Era.
The Quaternary includes both the Pleistocene and Holocene epochs. As used herein, early and middle Quaternary correspond with the Pleistocene divisions, but late Quaternary includes the Late Pleistocene and the Holocene.

1 INTRODUCTION

The applicant, Fish by the Sea (Pty) Ltd., proposes to prospect for diamonds between low and highwater marks on farm portions Rietfontein Extension 4/151 and Graauw Duinen 4/152 in southern Namaqualand in the northwestern Western Cape Province (Figure 1). EnviroAfrica is the EAP consultant undertaking the Environmental Impact Assessment (EIA) process and this Palaeontological Impact Assessment (PIA) report forms part of the EIA and its brief is to inform about the palaeontological sensitivity of the application area and the probability of palaeontological materials (fossils) being disturbed or destroyed in the process of the proposed prospecting.

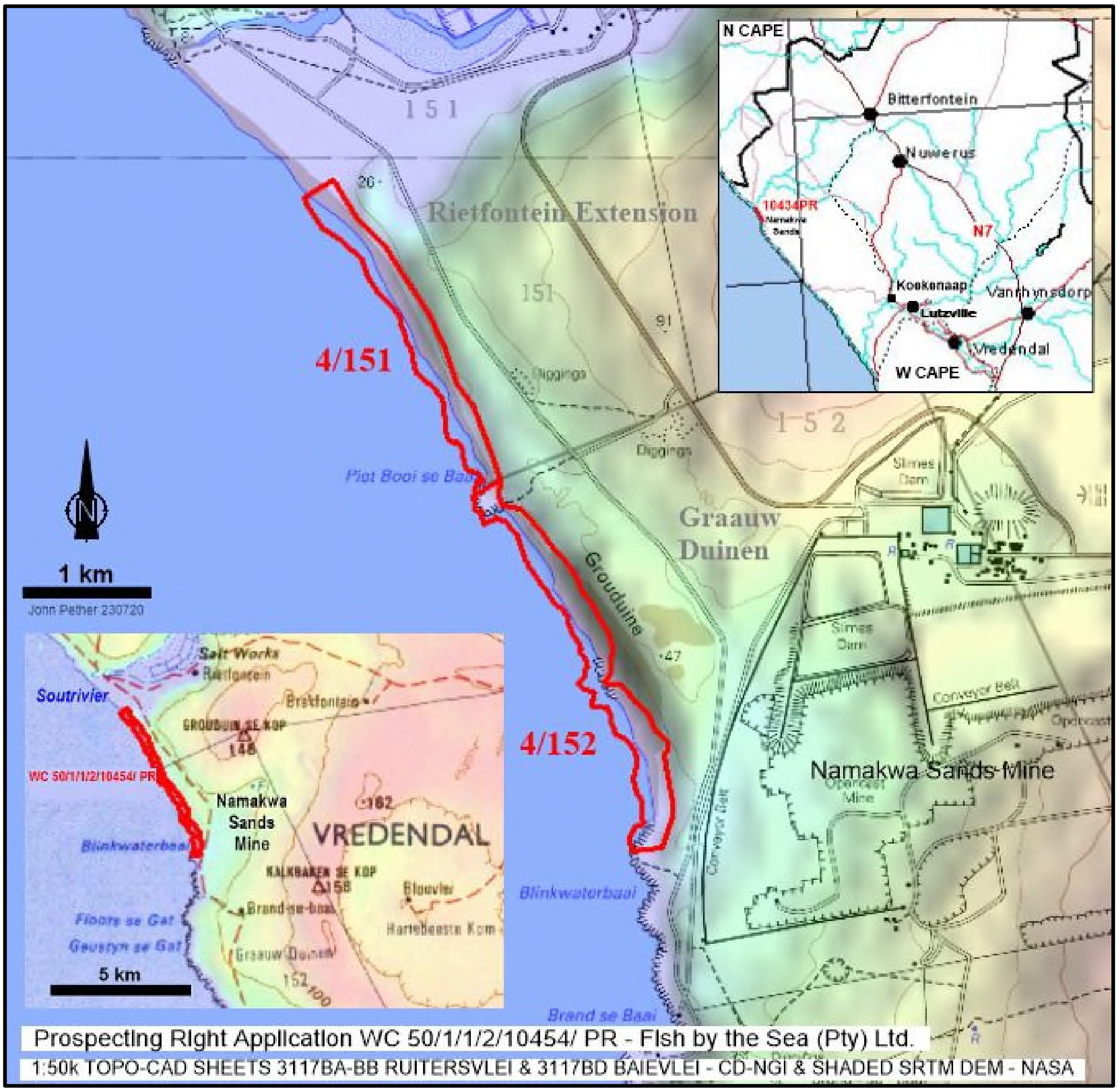


Figure 1. Location of the proposed Prospecting Application Area.

2 LOCATION

The Application Area is situated along the coast just south of the Soutrivier salt pans and is partly adjacent to the Namakwa Sands heavy mineral sands mine (Figure 1). It is approached via Vredendal, Lutzville and past Koekenaap on the road to Nuwerus, along which the tar road continues to Brand se Baai and the Namakwa Sands mine. At Namakwa Sands mine a gravel road continues north to Salt Pan, *i.e.* the mouth of the Soutrivier, from where tracks link to the coast. The site can also be reached via farm roads from Nuwerus or Bitterfontein.

3 PROPOSED ACTIVITIES

PHASE 1 – Literature Study, Imagery Analysis, Geological Mapping, Geophysical Survey

This will comprise a desktop review of all information and data gathered by previous exploration in the surrounding area, as well as review of aerial photography and satellite imagery to aid with structural and geological mapping of the prospecting area and surrounds. Ground resistivity measurements may be used to identify potential target areas.

PHASE 2 – Preliminary Evaluation – Prospecting Pits

This phase will determine a ballpark estimate of grade and size and thus the potential *in-situ* value of the deposit by sampling.

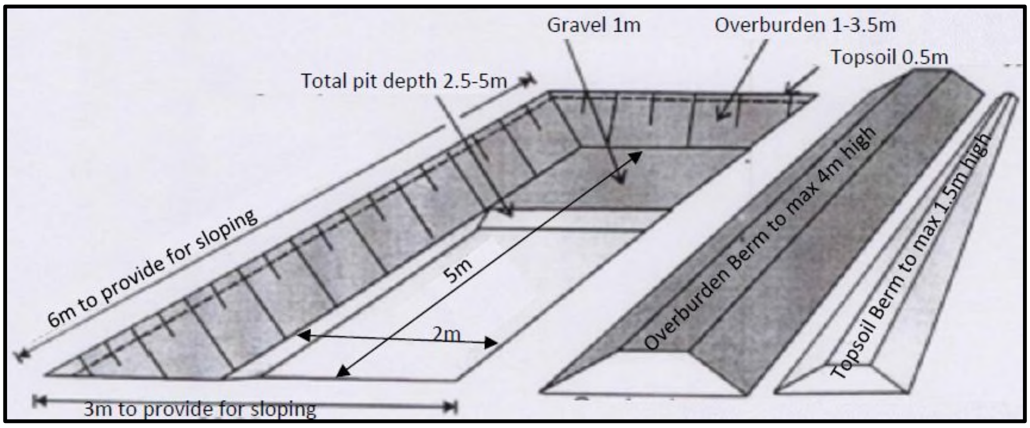


Figure 2. Typical prospecting pit (from Prospecting Work Programme.

The footprint of a prospecting pit is about 6 by 3 m and up to 5 m deep (Figure 2). It is anticipated that up to 20 pits will be excavated between low and highwater marks on the beach.

PHASE 3 – Bulk Sampling Trenches

The purpose of bulk sampling or trial mining of the intertidal strip is to establish the feasibility of proceeding with a Mining Right Application and involves processing material from a large trench until about 1000 carats have been obtained to establish the diamond size distribution and value. The nominal footprint of a bulk sample trench is 100 X 300 m and to depths of 2-5 m.

Sand overburden will be used to build a seawall (berm) at low tide level. The excavated underlying gravels will conveyed to a nearby rotary size-classifier (trommelsif) where sand and large pebbles will be sieved out and the plant feed size fraction (+2 mm, <21 mm) will be bagged. The bags of plant feed will be transported to a Bourevestnik containerised, modular plant which is an X-ray-based sorter which separates the diamonds based on their glow under X-rays, producing an “X-ray concentrate” consisting of diamonds and some adjacent pebbles which is subsequent sorted to capture the diamonds. The advantage of the popular Bourevestnik system is that density separation of the heavy pebble fraction of the plant feed to produce a heavy concentrate, such as by rotary pans or a Dense Media Separation (DMS) plant, is not required.

4 APPROACH AND METHODOLOGY

Deposits or formations are rated in terms of their potential to include fossils of scientific importance, *viz*. their palaeontological sensitivity. Palaeontological Sensitivity refers to the likelihood of finding significant fossils within a geological formation, which informs the Intensity/Magnitude/Severity rating in a Palaeontological Impact Assessment. The criteria for rating are in Appendix 1. The palaeontological sensitivity, together with the extent or volume of excavations into the geological formation, determines the palaeontological impact.

Note that different types of fossils occur in a single formation which differ in their scientific/palaeontological importance. The fossil bones and teeth of vertebrate animals are always of high palaeontological sensitivity and scientific importance and generally occur quite sparsely in deposits. For example, in aeolian formations the scarce fossil bones are rated HIGH, while fossil shells of land snails and the trace fossils made by termites are commonly present and are of LOW sensitivity.

4.1 AVAILABLE INFORMATION

This assessment is based on the published scientific literature on the origin and palaeontology of the Namaqualand coastal-plain deposits and the author's comprehensive field experience of the formations involved and their fossil content. Relevant aspects of the regional geology are described. References are cited in the normal manner and are included in the References section. The relevant 1:250 000 Council for Geoscience (CGS) geological map is Sheet 3017 GARIES and Explanation (De Beer, 2010). The annotated pertinent part of the map is presented in Figure 3.

4.2 ASSUMPTIONS AND LIMITATIONS

The assumption is that the fossil potential of a formation will be typical of its genesis/depositional environment and more specifically, similar to that observed in equivalent deposits nearby the Project Area. Scientifically important fossil material is expected to be very 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.

5 THE REGIONAL GEOLOGY

Figure 3. Surface geology of the Project Area and surrounds. The approximate subsurface extents of the underlying marine formations are also indicated.

5.1 The Bedrock

Outcrops of metasediments of the **Gariep Supergroup**, **Gifberg Group**, occur along the shore of the Application Area, namely the marbles and limestones of the **Widouw Formation** (Nwi/pale blue) (Figure 3). Conglomerates and quartzites of the **Karoetjies Kop Formation** (Nkr/green) (being the type/example area) occur to the north and south. These metasediments are of Late Proterozoic age (Cryogenian – Ediacaran) and were deposited between ~800 to ~600 Ma. The first basic multicellular animals were evolving around this time, but such fossils are unlikely to have been preserved, due to the metamorphism subsequently undergone by these old sediments.

Between the rocky coast and the bedrock hills of the "Hardeveld" inland is the sand-covered "Sandveld" made up of much younger buried and surface deposits known collectively as the **West Coast Group** (Table 1).

5.2 The West Coast Group

The **West Coast Group** is the name proposed to accommodate the various named formations comprising the Cenozoic coastal deposits between the Orange River and Elandsbaai (Roberts *et al*., 2006), of both marine and terrestrial origin (Table 1). The stratigraphic terminology proposed by Pether *et al*. (2000), Roberts *et al*. (2006) and De Beer (2010) is mainly used, but is elaborated and modified according to the author's own observations.

Table 1. Namaqualand Coastal Stratigraphy – The West Coast Group.

Formation Name	Deposit type	Age
Witzand	Aeolian pale dunes & sandsheets.	Holocene, <~12 ka.
Curlew Strand, Holocene High	**Marine, 2-3 m Package.**	**Holocene, 7-4 ka.**
Swartlintjies & Swartduine	Aeolian dune plumes.	Latest Quat., <20 ka.
Hardevlei	Aeolian, semi-active surficial dunes, >100 m asl.	Latest Quat., <25 ka.
Koekenaap	Aeolian, surficial red aeolian sands.	later late Quat., 80-30 ka.
Unnamed coastal fms.	Aeolianites, limited pedogenesis, weak pedocrete	earlier late Quat., 125-80 ka.
Curlew Strand, MIS 5e, LIG.	**Marine, 4-6 m Package.**	**earliest late Quat., ~125 ka.**
Fossil Heuweltjiesveld palaeosurface on Olifantsrivier & Dorbank fms.		
Unnamed "Dorbank" fms.	Aeolian, reddened, semi-lithified.	later mid-Quat., ~400-140 ka.
Curlew Strand, MIS 11.	**Marine, 8-12 m Package.**	**mid Quat., ~400 ka.**
Olifantsrivier	Aeolianite, colluvia, pedocrete.	early-mid Quat., ~2-0.4 Ma.
Graauw Duinen Member 2	Aeolianite, colluvia, pedocrete.	latest Plio-early Quat.
Hondeklipbaai	**Marine, 30 m Package, LPWP.**	**late Pliocene, ~3 Ma.**
Graauw Duinen Member 1	Aeolianite, colluvia, pedocrete.	mid Pliocene.
Avontuur	**Marine, 50 m Package, EPWP.**	**early Pliocene, ~5 Ma.**
Unnamed	Aeolianites, weathered.	later Miocene (14-5 Ma)
Kleinzee	**Marine, 90 m Package, MMCO.**	**mid Miocene, ~16 Ma.**
Unnamed	Aeolianites, leached. Faulting.	Oligocene
Koingnaas	Fluvial, kaolinized gravels, sands, plant fossils.	late Eocene, ~44-34 Ma
De Toren	Silcreted colluvial palaeosurfaces 200-400 m asl.	Paleocene - Eocene
MMCO – Mid Miocene Climatic Optimum. EPWP – Early Pliocene Warm Period. LPWP – Late Pliocene Warm Period. MIS – Marine Isotope Stage.		

5.2.1 The Early Coastal Plain

Silcreted angular gravels and sands that overlie deeply-weathered bedrock and which occur as mesa-like features on high ground 100-400 m asl. are mapped as the **De Toren Formation** on the Garies geological sheet (De Beer, 2010). These silcretes mark an older palaeosurface of the coastal plain and represent talus and colluvial deposits.

Many more rivers once traversed the ancient coastal plain and their buried channels (palaeo-channels) and deposits have been discovered during diamond exploration. The **Koingnaas Formation** (De Beer, 2010), infills the ancient river channels buried between the main, now ephemeral Namaqualand rivers. These deposits have been kaolinized, disguising their presence. Silcrete has also formed in places within the waterlogged channels. The "white-clay" channel sediments consist of subangular quartz conglomerates, locally rich in diamonds, overlain by beds of clayey sand, clay and carbonaceous material containing plant fossils (Molyneux, in Rogers *et al.*, 1990). The fossil pollen has provided evidence of the vegetation type present and the age of the Koingnaas Formation. Yellowwood forest with auracaria conifers, ironwoods and palms dominated the West Coast. Fossil wood identified as tropical African mahogany has been found. Importantly, the fossil pollen includes pollen of the earliest Asteraceae (daisies).

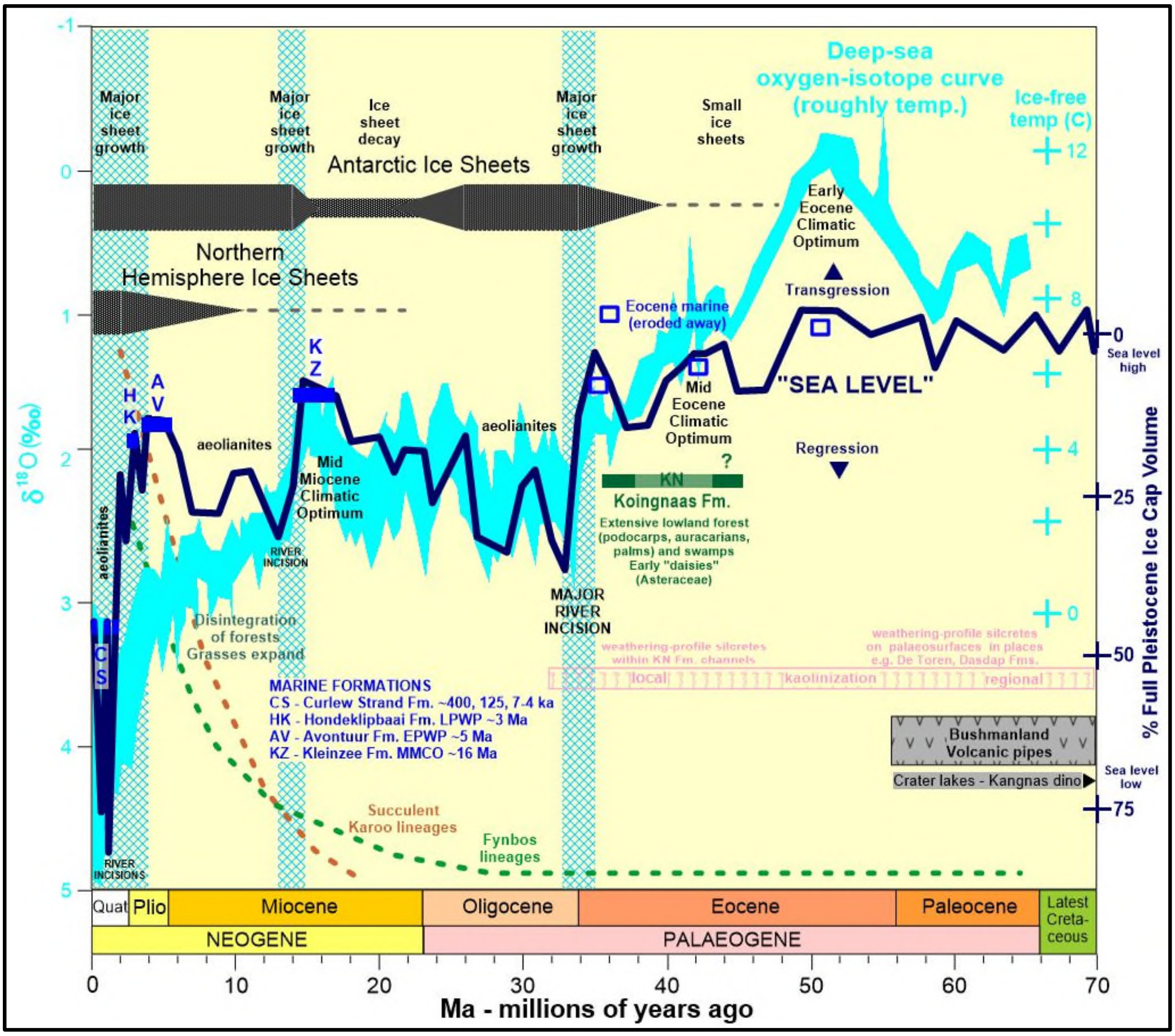


Figure 4. The Cenozoic Era (66 Ma to present) showing the context of formations of the West Coast Group with respect to global sea-level history, palaeoclimate proxies and aspects of regional vegetation history.

Cyan curve - history of deep-ocean temperatures, adapted from Zachos *et al.* (2008). **Dark blue curve** is an estimate of global ice volumes, adapted from Lear *et al.* (2000). Global ice volumes roughly indicate sea-level history caused by the subtraction from the sea of water as land-ice. The expansion of Fynbos and Karoo floras is adapted from Verboom *et al.* (2009).

The age of the Koingnaas Formation is most likely late Eocene, between 44-34 Ma (Figure 4). Notably, the Koingnaas pollen assemblage, with many extinct types of uncertain affinity and no analogues elsewhere, indicates that the uniqueness of the Cape Floristic Region is rooted in "deep time" (De Villiers & Cadman, 2002). The Koingnaas Formation deposits are remainders of a fossil landscape when the tropical wooded Namaqualand coast more nearly resembled the forests of the south coast.

5.2.2 The Fossiliferous Marine Deposits

At times during the Cretaceous and Palaeogene Periods (66-34 Ma) the higher part of the coastal plain was occupied by the sea, but marine deposits from these times have been eroded away, or remain as undiscovered residual patches beneath the thick cover.

During the Neogene Period the outer part of the coastal plain below ~100 m asl. was inundated by the sea during periods of global warmth when melting of the Antarctic ice cap raised sea level. The oldest marine formation is the **Kleinzee Formation** which occupies the inner, high part of the coastal bevel and extends seawards from ~90 m asl. (also called the 90 m Package). It was deposited during the decline from the high sea level of the warm **Mid-Miocene Climatic Optimum** ~16 Ma (Figure 4). The previous Miocene marine beds were eroded during rising sea-level of the **Early Pliocene Warm Period** and the **Avontuur Formation** (the 50 m Package) was deposited 5-4 Ma as sea-level receded from the transgression maximum of about 50 m asl. and the shoreline prograded seawards (Figure 5). The Avontuur Formation in turn was eroded by yet another rising sea-level associated with the **Late Pliocene Warm Period** 3.3-3.0 Ma (Figure 5). The **Hondeklipbaai Formation** or 30 m Package was deposited as sea level declined from a high of about 30-33 m asl. and a substantial, prograded marine formation built out seawards. Fossil shells are found in places in these Miocene and Pliocene marine formations and each contains warm-water species and also important extinct fossil shell species which are characteristic of that formation and which facilitate correlation of formations over wide regions.

Close to the seaside, the Hondeklipbaai Formation is eroded and overlain by the younger, Quaternary "raised beaches" that extend from about 12-15 m asl. (Figures 5 & 6). The name **Curlew Strand Formation** has been proposed for this composite of raised beaches, equivalent to the Velddrif Formation of the SW Cape Coast. Three successive raised beaches are recognized at 8-12, 4-6 and 2-3 m asl., with ages of ~400 ka (ka = thousand years ago), ~125 ka and 7-4 ka, respectively. The fossil shells in these raised beaches are predominantly the cold-water fauna of modern times.

5.2.3 The Aeolian Formations

A variety of terrestrial deposits also make up the coastal plain of Namaqualand. For the most part these are extensive aeolian dune and sandsheet deposits that overlie the eroded tops of the marine sequences. More locally there are colluvial (sheetwash) and ephemeral stream deposits associated with nearby hillslopes. Formed within the upper parts of the marine and terrestrial sequences are pedocretes and palaeosols of a variety of types, compositions and degrees of development. A glance at the satellite images of the coast show that the pale swathes of modern and Holocene aeolian activity occur in specific areas, linked to antecedent topography, sea-level oscillations, locations of sandy beaches and fluvial sediment inputs. Similarly, the deeper-time aeolian record is expected to comprise buried dune fields, dune plumes and sand sheets that accumulated at different times in various areas of the coastal plain.

Later Miocene Aeolianites

The mid-Miocene, marine Kleinzee Formation has been extensively eroded and has been largely reworked into aeolian sands. The later-Miocene aeolianites occupy the higher part of the coastal notch where they overlie residuals of the Kleinzee Formation and extend into the hinterland. These old aeolian deposits are quite altered by pedogenic and groundwater processes. The occurrence of reworked petrified teeth of the bear-dog *Agnotherium* sp. (13-12 Ma) and the gomphothere *Tetralophodon* (12-9 Ma) in the basal gravels of the early Pliocene Avontuur Formation at

Hondeklipbaai indicates the pre-existence of terrestrial deposits of this later Miocene age range (Figure 4).

The Graauw Duinen Formation

This name has been proposed to accommodate the aeolianites as exemplified in the Namakwa Sands excavations on Graauw Duinen 152 (Roberts *et al.*, 2006; De Beer, 2010) where the aeolianites are excellently exposed in coast-normal mining faces. Based on personal observations of the aeolianites exposed at Graauw Duinen 152 (Namakwa Sands) there are actually three distinct aeolian formations in the subsurface there. The first main aeolianite formation (**Member 1**) overlies/postdates the marine early Pliocene Avontuur Fm. and is overlain in the west by the marine late Pliocene Hondeklipbaai Fm., *i.e.* it is broadly of mid-Pliocene age (Figure 5). The second aeolian formation (**Member 2**) overlies/postdates the Hondeklipbaai Fm. in the west and overlies the pedocreted palaeosurface of the first aeolian formation inland, *i.e.* it is of latest Pliocene to earliest Quaternary age. The third aeolian formation overlies the pedocreted palaeosurface of Member 2. Notably, this formation contains rare Early Stone Age (ESA) material and is referred to the Olifantsrivier Formation (Figure 5).

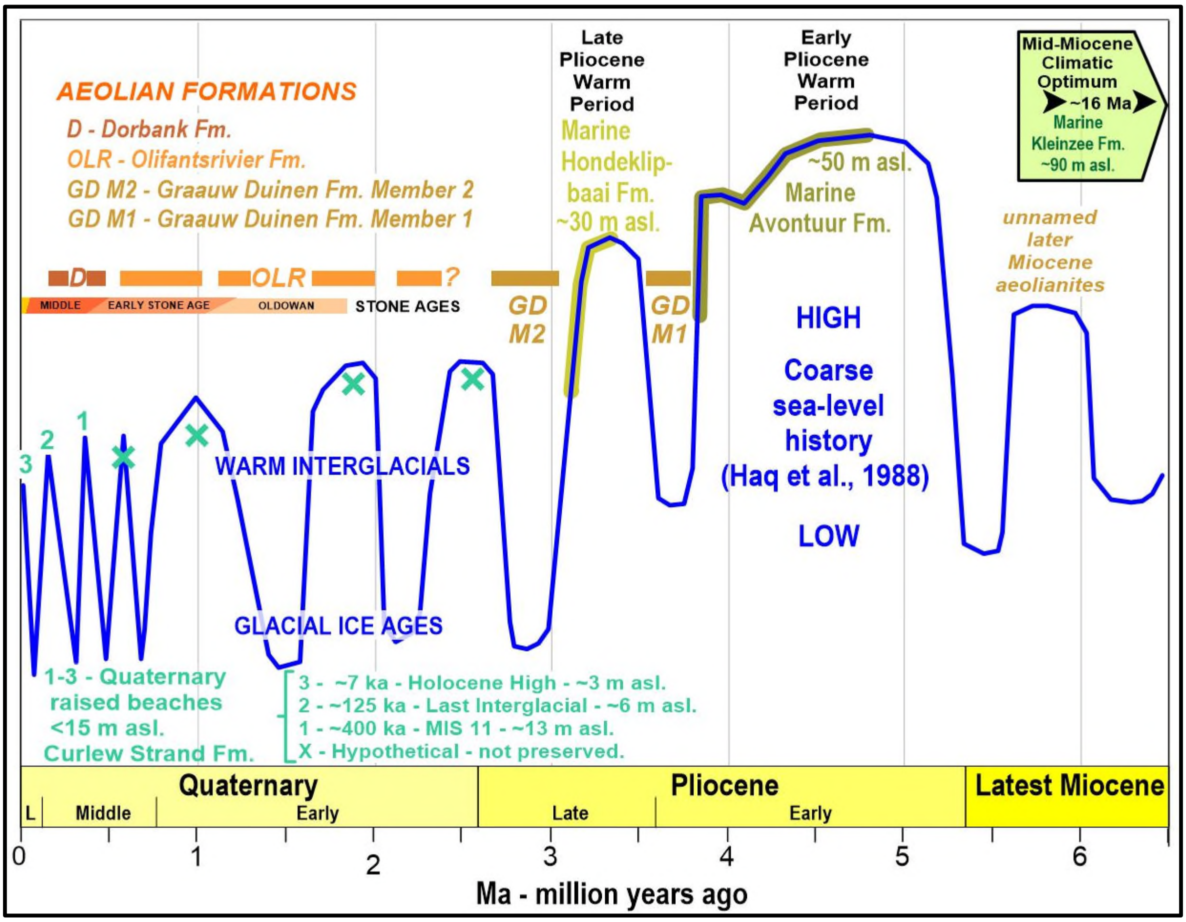


Figure 5. Context of latest Miocene, Pliocene and Quaternary marine and aeolian formations correlated with coarse-scale sea-level history based on major margin unconformities.

The Olifantsrivier Formation

This formation is a typical, variously reddened aeolianite with interbedded palaeosols, pedocretes, abundant root casts and termite burrows (pers. obs.), as exemplified in cliff exposures up to 30 m thick north of the Olifants River mouth and in the Namakwa Sands mine pit. Isolated cobble manuports and ESA/Acheulean handaxes and cleavers are found within the formation. Middle Stone Age (MSA) artefacts are also reported, but these occur on the eroded surfaces and slopes of the formation. The ESA artefacts indicate an age range from ~1.4 Ma to ~350 ka (Figure 5). Fossils eroding out of a channel fill within the aeolianite succession on Geelwal Karoo 262 include *Numidocapra crassicornis*, a bovid hitherto found only in North Africa and Ethiopia where the age range for this fossil species is 2.5-1.7 Ma. Also found were teeth of *Dinofelis barlowi*, an extinct sabre-toothed felid, indicating an age range of 2.5-1.9 Ma. (Stynder & Reed, 2015). These finds suggest that the lower part of the Olifantsrivier Formation is older than ~1.7 Ma and extends from the earliest Quaternary (Figure 5), while the upper part which includes ESA material is latest early Quaternary/earliest middle Quaternary (Figure 5). This broad age range constraint is reflected by the several included member units separated by pedocretes.

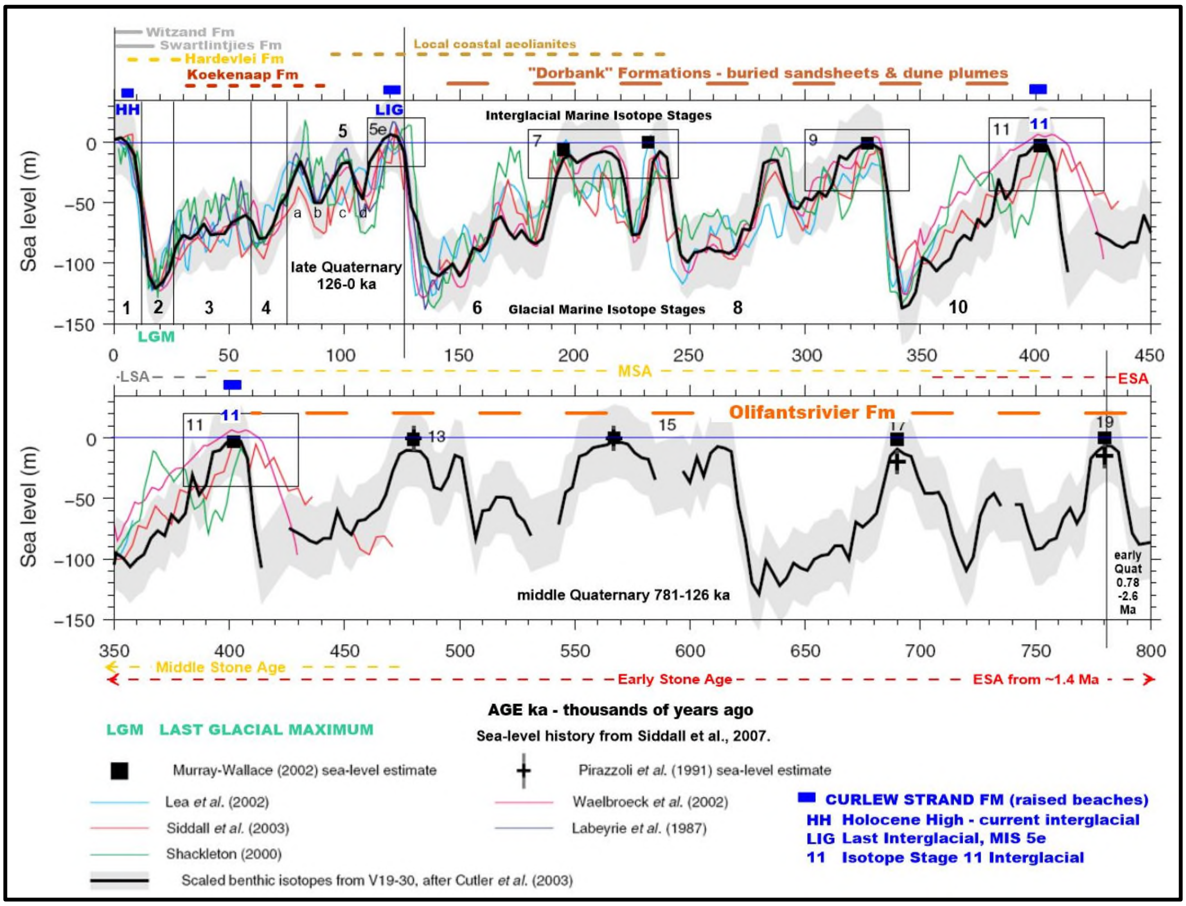


Figure 6. Sea-level history (from Siddall *et al.*, 2007) and the age ranges of middle and late Quaternary formations of Namaqualand.

The "Panvlei Formation" Surfaces

Proposed by De Beer (2010), the Panvlei Formation "represents sands, fluvial deposits and soils derived from bedrock erosion and reworking of Cenozoic sediments of all ages". Semi-silicified dorbank and calcretized and pedocreted deposits are included. The formation is overlain by "unconsolidated sands of Pleistocene to Holocene age". Its purpose is to depict those surface areas that are closely underlain by the capping pedocrete of the underlying formation or by the compact surface of the "dorbank" aeolian sands with pedogenic clay. These "Panvlei" areas could be referred to instead as "Panvlei Surfaces" as they closely underlain by older aeolianite units.

The Dorbank Formation

There are unnamed units that post-date the capping pedocrete of the Olifantsrivier Fm. and precede the uppermost, unconsolidated formations described below. For example, thick "dorbank" comprised of up to several metres of reddened and semi-lithified, decalcified, medium and coarse sands are typically exposed in excavations somewhat inland of the coast, overlying the eroded surfaces on

Miocene and Pliocene marine deposits or older pedocreted aeolianites. This Dorbank Formation is typically a stack of successive sand sheets forming beds, 0.5 to ~1 m thick, with slightly differing hues of the neoformed pedogenic clays. The dorbank is quite hard and incipiently to variously cemented, but notably, this formation lacks the development of distinct, laterally continuous, pale pedocrete horizons, other marked, post-depositional features and generally also lacks an evolved pedocrete capping. The Dorbank Formation is widespread along the Namaqualand coast where it occupies a spatio-temporal context as the youngest consolidated aeolianite beneath weakly-compacted to loose surface sands. Notably, MSA artefacts occur within its upper portion and on its top surface, these suggesting that the age is in the later part of the middle Quaternary, younger than about 400 ka (Figure 6). Dating of the overlying Koekenaap Fm. surficial sands, together with some few dates from the top of the Dorbank Fm. farther south, indicates that the Dorbank Fm. is older than ~130 ka, pre-dating the Last Interglacial (Figure 6).

Local Coastal Aeolianites

At the coast the aeolianites overlying the Quaternary raised beaches include smaller units that reflect local permutations of aeolian deposition during highstands of MISs 11 and 5e and at other times when sea levels were close to, but did not exceed, the present level *viz*. MISs 9, 7, 5c and 5a (Figure 6). During some of these stages shoreline aeolianite units were deposited at places along the coast, herein called **Local Coastal Aeolianites**. They occur beneath the surficial, loose Witzand Fm. dune sands and differ from place to place, *i.e*. pink sands, or yellow sands, or grey sands, and are more locally confined to the coast and are apparently of different ages. The smaller patches of Witzand Fm. dunes at the coast are the modern analogue.

The Koekenaap Formation

Overlying the hard surface of the dorbank are compact, but unconsolidated, red sands, the "Red Aeolian Sand" or RAS that is exploited at Namakwa Sands mine, proposed as the Koekenaap Fm. (Roberts *et al*., 2006; De Beer, 2010). The red sands of the Koekenaap Fm. occupy much of the surface of the Namaqualand coastal plain (Figure 7) and underlie the following formations described below. Preliminary results of Optically-Stimulated-Luminescence (OSL) dating of reddened coversands (Chase, 2006; Chase & Thomas, 2006, 2007) indicate late Quaternary ages between ~80 ka and ~30 ka and are presumed to reflect depositional ages of the red aeolian sands (Figure 6). The typical vegetation type is Namaqualand Heuweltjie Strandveld.

The Hardevlei Formation

Comprised of unconsolidated, pale-red to pale-yellow coversand deposits (sand sheets and small dunes) that are younger that the RAS of the Koekenaap Formation (De Beer, 2010). This formation encompasses wide swathes of pale sand blown northwards from both river and shoreline sources, as well as patches inland that reflect the reworking of older sands of the Koekenaap Fm. The Hardevlei Fm. is also mined at Namakwa Sands. Aerial images show the complex morphology of these low, relict dunes which in places exhibit a reticulate pattern of linear dunes linked by transverse, barchanoid elements. The complex pattern reflects a polyphase history and a varying wind regime. The OSL dates from the yellowish, inland reticulate dunes (Chase & Thomas, 2006, 2007) are generally less than ~20 ka and are probably representative of the aeolian activity/deposition of the Hardevlei Formation (Figure 6). The associated veld types are Namaqualand Sand Fynbos and Inland Duneveld.

The Swartlintjies Formation

The Swartlintjies Formation is proposed for the large, pale plumes of semi-stabilized parabolic dunes that extend from the beaches north of the main rivers (Roberts *et al*., 2006; De Beer, 2010). It has been suggested that these dune plumes originated during lower ice-age sea levels (Figure 6, ~20 ka) and were blown from the lower reaches of the rivers that then extended across the inner shelf

(Tankard & Rogers, 1978). The dune plumes are clearly comprised of superimposed generations of smaller plumes and sand mobility in the plumes is currently ongoing in places. The typical vegetation is Namaqualand Coastal Duneveld.

The Witzand Formation

This formation accommodates sand and shell fragments blown from sandy beaches mainly during the Holocene, in the form of partly-vegetated dune cordons backing the beach and the attached small dune plumes transgressing inland. As the major dune plumes are separated as the Swartlintjies Fm., the Witzand Fm. entails only the smaller dune cordons and plumes adjacent to the coast. These include active dunes and the more-vegetated, pale-grey dunes that are the origin of the name “Graauw Duinen” for some of the properties along the coast where these dunes occur. . The typical vegetation is Namaqualand Seashore Vegetation

6 AFFECTED FORMATIONS

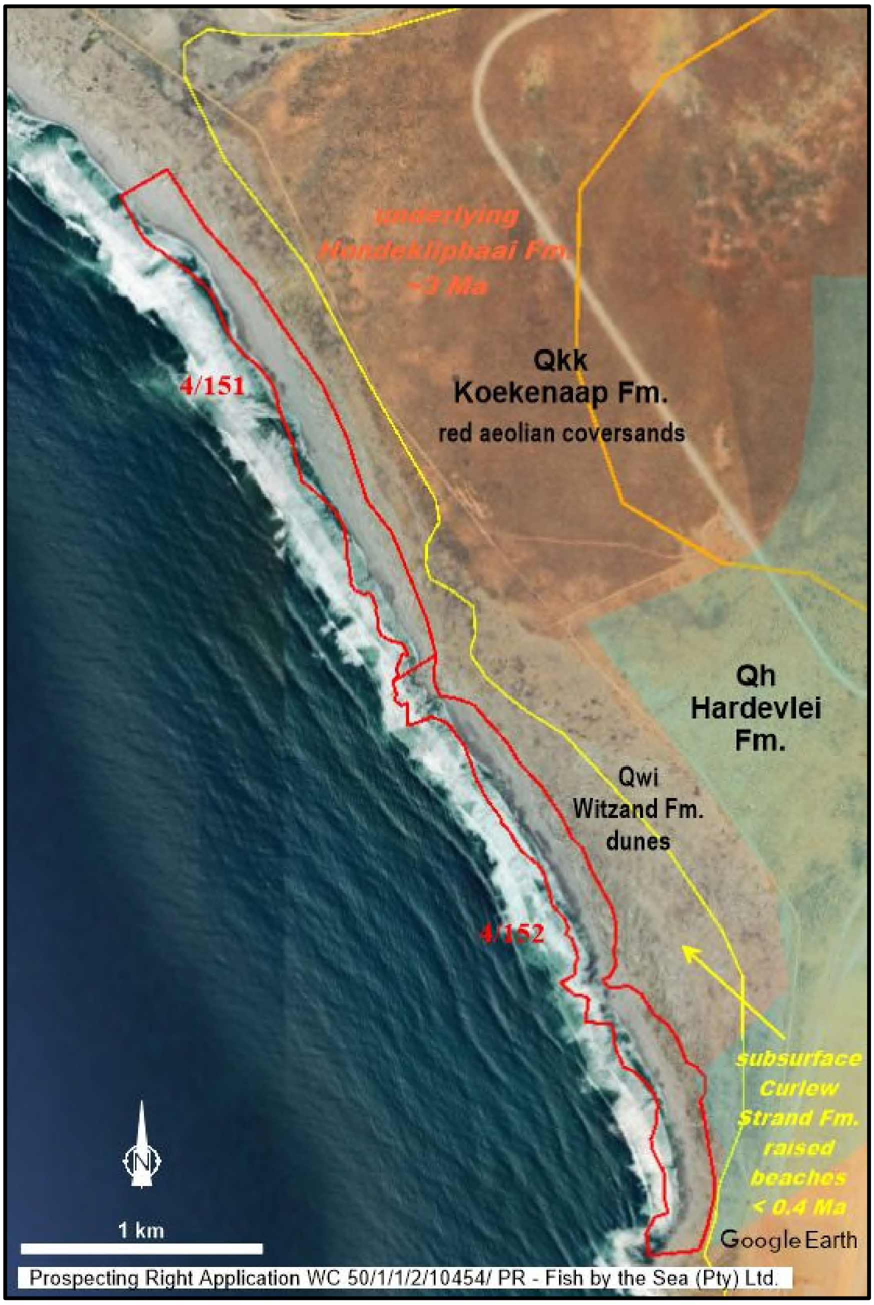


Figure 7. Aerial aspect of the surficial sand cover and the approximate maximum palaeo-shoreline of the Curlew Strand Formation.

The prospecting trenching along the seashore and will affect the modern beach deposits. The dune sands of the Witzand Fm. may be disturbed in places (Figure 7). The trenches may intersect beach deposits of the Curlew Strand Fm. underlying the beach, such as the Holocene High beach deposits and most likely also the Last Interglacial raised beach.

The schematic near-coastal stratigraphy illustrated in Figure 8 is but one permutation of the formations which may occur and represents most of the formations. However, usually there are "missing" formations at any particular site. For instance, the MIS 11 raised beach is preferentially preserved where the bedrock gradient is low and the deposits extend far inland. On steeper bedrock it may be eroded away and absent, with the LIG raised beach directly abutting the cliffed Hondeklipbaai and Dorbank fms. The Local Coastal Aeolianites are only present in places.

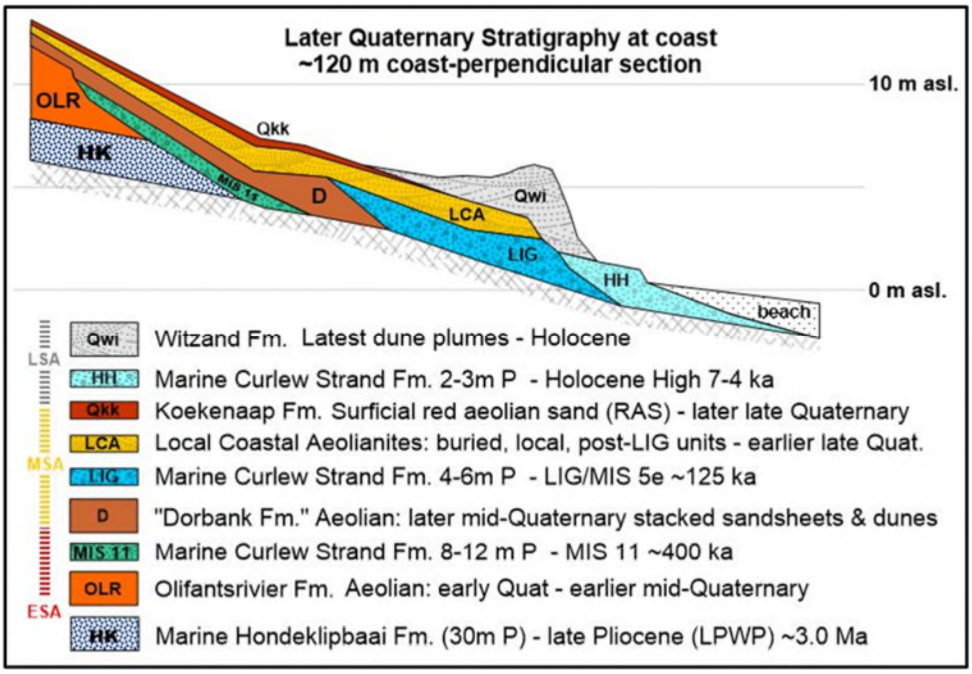


Figure 8. Schematic geological section of one permutation of the stratigraphy at the coast.

Sandy beaches situated above exhumed palaeochannels with no bedrock outcrop may be underlain by the seawards extentions of the Curlew Strand Fm. and/or consolidated aeolianites, often with calcrete cappings. In places the local drainages have delivered alluvial deposits to the shoreline, which occur interbedded between the marine and aeolian deposits. Seaward extentions of the Hondeklipbaai Fm. also occur. In some instances the Koingnaas Fm. kaolinitic quartz gravels in a major palaeochannel have not been eroded away and occur at depth beneath the beaches.

7 ANTICPATED PALAEONTOLOGICAL IMPACT OF THE PROSPECTING

In open-coast settings the fossil shells in the **Curlew Strand Formation** Quaternary raised beaches are the mainly of the cold-water fauna of modern times and of LOW palaeontological sensitivity. The very sparse fossil bones in the Curlew Strand Formation are mainly seals, cetaceans (whales and dolphins) and seabirds and are likely to be closely related or identical to modern marine species, but may include species that we would not expect nowadays and finds may be of scientific importance.

The Witzand Formation has a Moderate sensitivity rating (Figure 9). Fossil bones in the subsurface of the Witzand Formation are expected to be in an archaeological context and their loss will be rated as highly negative from that perspective. Palaeontologically, the formation is recent and is judged unlikely to produce unique fossil remains. The "subfossil" bones are likely to be extant species. However, unexpected species could occur. Nevertheless, here the archaeological concerns take precedence.

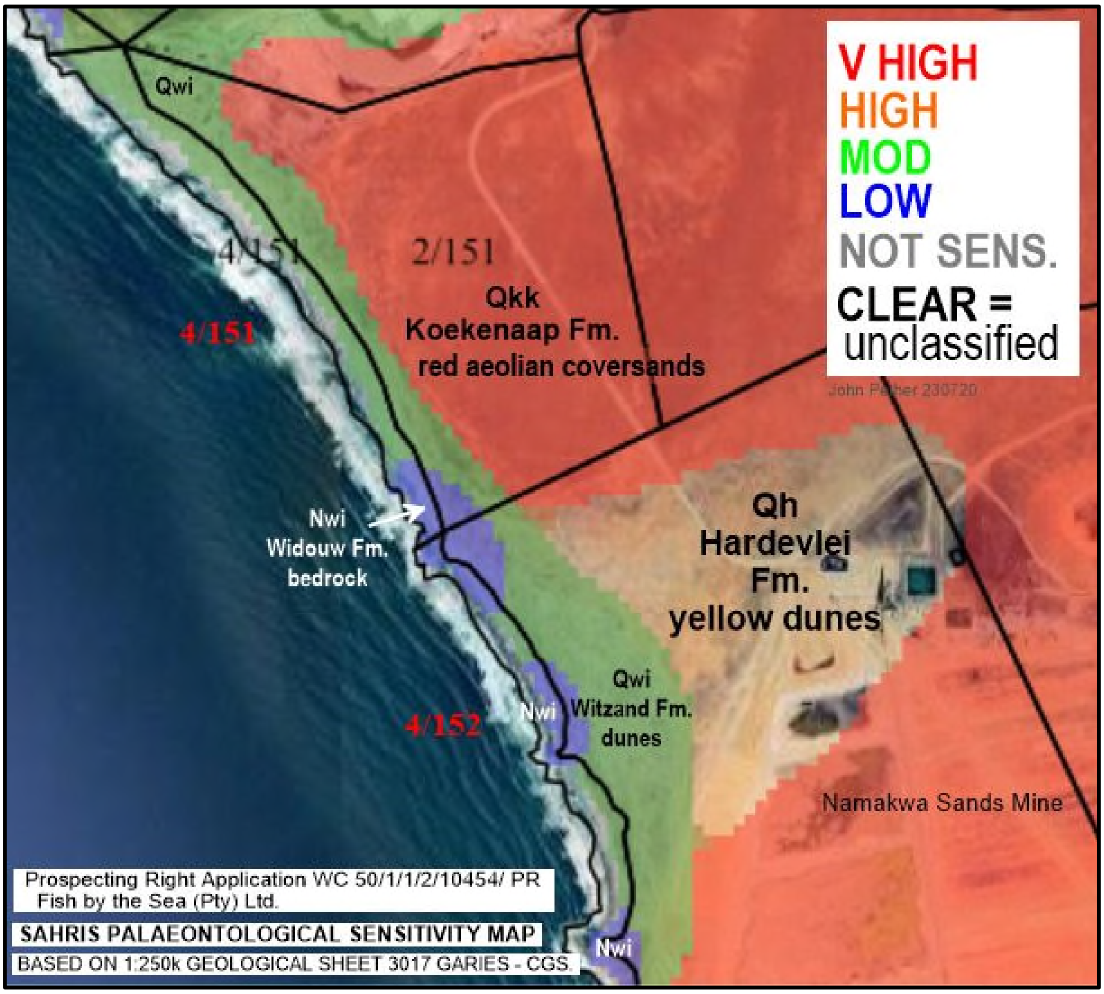


Figure 9. Palaeontological Sensitivity of the Project Area. Refer to Figure 7.

8 IMPACT ASSESSMENT RATING

8.1 Extents

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

8.2 Duration

The impact of both the finding and the loss of fossils is permanent. The found fossils must be preserved "for posterity"; the lost, overlooked or destroyed fossils are lost to posterity. The duration of impact is therefore PERMANENT with or without mitigation.

8.3 Intensity

The intensity/magnitude of a palaeontological impact is determined by the palaeontological sensitivity of the affected geological formation, together with the extent or volume of excavations made into the formation.

The subfossil, extant shells expected in the beach excavations do not constitute an impact on palaeontological heritage. Any fossil bones are the main focus of concern, due to their potential scientific importance, but are also likely to be subfossil extant species. The intensity of impact of the beach pit and bulk sampling prospecting and is LOW.

8.4 PROBABILITY

The volume of subsurface disturbance of the proposed prospecting pits and particularly the larger bulk sampling trenches renders the discovery subfossil bones in the abovementioned formations PROBABLE, *i.e*. distinctly possible.

8.5 IMPACT ASSESSMENT TABLE

For simplicity, the assessment table below refers in general only to the discovery of subfossil bones in the beach pit and bulk sample trenches.

E = Extent, D = Duration, I = Intensity, P = Probability of occurrence. Where Significance = (E + D + I) x P.							
	E	**D**	**I**	**P**	**Significance**	**Status**	Prospecting personnel to be alert for unearthing of fossil bones in the beach trenches and follow the Fossil Finds Procedure.
Without Mitigation	1	5	4	3	30 – low MEDIUM	Negative	
With Mitigation	1	5	4	3	30 –low MEDIUM	Positive	
Rating scheme according to Appendix 2.							

9 RECOMMENDATIONS

There are no known outcrops of sensitive fossiliferous strata in the Application Area that require protection as NO-GO sites.

9.1 MITIGATION

It is recommended that a requirement to be alert for fossil bones and archaeological shipwreck material which may be uncovered during the prospecting be included in the Environmental Management Programme (EMP) for the proposed prospecting operations.

Under supervision of the Environmental Control Officer (ECO) and as part of Environmental and Health & Safety awareness training, personnel involved in the prospecting must be instructed to be alert for the occurrence of fossil bones. In the event of such discoveries the **Fossil Finds Procedure** provided below, for incorporation into the Environmental Management Programme for the proposed prospecting, must be followed.

Fossil bones may be spotted during excavation of overburden or embedded in the gravel. These are likely to be larger bones such as those of whales and can easily be obtained. The next opportunity to observe material is at the gravel rotary classifier and grizzly rock screen on the beach where the separated oversize gravel tailings and the plantfeed gravel accumulate. It is assumed that the composition of the oversize is not regularly examined and logged. However, the operation of the classifier is monitored to some degree as the plantfeed is regularly bagged, *i.e*. there is a regular presence of personnel. All personnel must be coached to keep a check on the accumulating oversize piles for possible fossil bones. Petrified bones and teeth reworked from older formations may also occur in the basal gravels – these are of dark colour varying from brown to black. Regular checks of the oversize pile at the rotary classifier would seem to be the most feasible attempt at mitigation.

9.2 FOSSIL FINDS PROCEDURE

Should fossil bones be encountered in trenches or at the rotary classifier the unearthed bones must be retrieved for safekeeping and the works foreman and the ECO for the project must be informed immediately. If a concentration of bones is unearthed work must cease at the site, the works foreman and the ECO must be informed immediately, and the find site must be protected from further disturbance. It should be feasible to relocate the prospecting site to an adjacent spot and thus avoid machine downtime.

Heritage Western Cape (HWC) and/or an appropriate specialist archaeologist or palaeontologist must be informed and supplied with contextual information by email:

- A description of the nature of the find.
- Detailed images of the finds (with scale included).
- Position, pit/hole number of the find and depth.
- Digital images of the context. *i.e*. the excavation (with scales).

HWC and the palaeontologist will assess the information provided for fossil finds and liaise with the ECO, the environmental consultants and the developer and a suitable response will be established.

On the discovery of conservation-worthy fossils, a collection permit must be applied for from HWC. The applicant should be the qualified specialist responsible for assessment, collection and reporting. Should fossils be found that require rapid collecting, application for a palaeontological permit must be made to HWC immediately. Arrangements must be made to transport rescued fossil material deemed worthy of conservation and study to an appropriate curatorial institution.

In addition to the information and images of the find, the application requires details of the registered owners of the sites, their permission and a site-plan map. All fossils must be deposited at a HWC-approved institution. The rescue and reporting of discovered archaeological or palaeontological remains by a contracted specialist shall be at the Developer's expense.

The Project Geologist is welcome to contact the writer by email with images for preliminary opinions about potential finds and stratigraphy at no initial cost.

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11 APPENDIX 1 - PALAEONTOLOGICAL SENSITIVITY RATING

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

VERY HIGH: Formations/sites known or likely to include vertebrate fossils pertinent to human ancestry and palaeoenvironments and which are of international significance.

HIGH: Assigned to geological formations known to contain palaeontological resources that include rare, well-preserved fossil materials important to on-going palaeoclimatic, palaeobiological 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 palaeontologists 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.

12 APPENDIX 2. METHODOLOGY FOR ASSESSING THE SIGNIFICANCE OF IMPACTS

EFFECT	**Extents/Spatial Scale**		**E**
	Localized	At localized scale and a few hectares in extent.	1
	Study area	The proposed site and its immediate environs.	2
	Regional	District and Provincial level.	3
	National	Country.	4
	International	Internationally.	5
	Duration/Temporal Scale		**D**
	Very short	Less than 1 year.	1
	Short term	Between 2 to 5 years.	2
	Medium term	Between 5 and 15 years.	3
	Long term	Exceeding 15 years and from a human perspective almost permanent.	4
	Permanent	Resulting in a permanent and lasting change.	5
	Magnitude/Intensity (Palaeontological Sensitivity)		**M**
	No potential	Formations entirely lacking fossils such as igneous rocks.	0
	Marginal	Limited probability for producing fossils from certain contexts at localized outcrops.	2
	Low	Depositional environment where fossils are unlikely to be preserved, or are judged unlikely to produce unique fossil remains.	4
	Medium	Strong potential to yield fossil remains based on stratigraphy and/or geomorphologic setting.	6
	High	Formations known to contain palaeontological resources that include rare, well-preserved fossil materials.	8
	Very high	Formations/sites known or likely to include vertebrate fossils pertinent to human ancestry and palaeoenvironments and which are of international significance.	10
	Probability/Likelihood		**P**
	Very improbable	Probably will not happen.	1
	Improbable	Some possibility, but low likelihood.	2
	Probable	Distinct possibility of these impacts occurring.	3
	Highly probable	The impact is most likely to occur.	4
	Definite	The impact will definitely occur regardless of prevention measures.	5

SIGNIFICANCE = (E+D+M)P		
< 30	LOW	The impact would not have a direct influence on the decision to develop in the area
30-60	MEDIUM	The impact could influence the decision to develop in the area unless it is effectively mitigated
>60	HIGH	The impact must have an influence on the decision process to develop in the area

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