PALAEONTOLOGICAL IMPACT ASSESSMENT

PROSPECTING RIGHT APPLICATION FOR PART OF FARM KAMAGGAS 200 PORTION 5

HBF PRODUCTS (PTY) LTD

NAMA KHOI MUNICIPALITY, NAMAKWALAND MAGISTERIAL DISTRICT, NORTHERN CAPE

By

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

Geological and Palaeontological Consultant

P. O. Box 48318, Kommetjie, 7976
Tel./Fax (021) 7833023
Cellphone 083 744 6295
jpether@iafrica.com

Prepared at the Request of

ASHA Consulting (Pty) Ltd

Dr Jayson Orton
jayson@asha-consulting.co.za
www.asha-consulting.co.za
23 Dover Road Muizenberg, 7945
021 788 1025 | 083 272 3225

2 DECEMBER 2021

EXECUTIVE SUMMARY

1. Site Name

Portion of Portion 5 of the farm Kamaggas 200 – Prospecting Right Application by HBF Products (Pty) Ltd. Also referred to as "Swartsand".

2. Location

The Project Area on Kamaggas 200/5 (~1500 ha) is situated on the left/south bank of the Buffelsrivier and is approached via the main road (R355) between Springbok and Kleinzee (Figures 1 and 2).

3. Locality Plan

The locations of the prospecting pits and drill holes are not indicated on Figure 2 as they will be determined after the Environmental Assessment reports and the Phase 1 studies have been evaluated.

4. Proposed Development

The proposed prospecting programme is limited to a few small-scale pits (~10) and some drilling (~5 holes) and does not involve large Bulk Sample trenches.

5. Affected Formations

The diamondiferous basal gravels of the older Buffelsrivier fluvial formation have been the main target of past mining. These deposits have been the correlated with the fossiliferous "Proto-Orange I Terrace", or Arrisdrift Formation, in the lower Orange River valley, of mid-Miocene age ~18-16 Ma. Younger river deposits equivalent to the Orange River Pliocene "Meso" aggradational terraces occur at lower elevation. In general the river terrace gravels are overlain by variable thicknesses of colluvial and ephemeral stream deposits, succeeded by aeolian sands, which have been affected by pedogenesis and partial cementing to form the compact material colloquially referred to as "dorbank". Overlying the compact dorbank palaeosurface are poorly-consolidated to loose aeolian red sands which can be assigned to the Koekenaap Formation.

6. Palaeontological Resources Identified

As far as the writer is aware no fossils of any description have been reliably reported from the Miocene and Pliocene fluvial terrace deposits of the Buffelsrivier, or from the overlying Quaternary colluvial and aeolian sequences. It is evident that fossils are very rare in these deposits.

Notwithstanding the apparent paucity of fossils in the Buffelsrivier fluvial deposits, the possibility that some could be discovered cannot be dismissed. In view of the lack of age constraints from fossil mammal bones, any identifiable find would be of scientific importance. In addition to rare fossil bone material the following fossils could occur:

- Lignified or petrified wood fragments.
- Plant impressions in mudstone beds.
- Moulds of dissolved aquatic bivalves and gastropods.
- Petrified teeth of mammals, reptiles and fish, varying from pebble-size to a few mm.

7. Anticipated Impact

It is evident that fossils are very rare in these deposits and consequently the impact of the limited scale prospecting is considered to be LOW (Appendix 1).

8. Recommendations

No-go areas of particular palaeontological sensitivity are not identified in the Project Area.

It is recommended that a requirement to be alert for fossil materials be included in the Environmental Management Plan (EMP) for the prospecting pitting operations. The Environmental Control Officer (ECO) for the project must inform staff of the need to watch for potential fossil occurrences in the pits and in excavated material. The Project Geologist, in closely inspecting and logging the exposures, is most likely to spot potential fossil material.

Based on the lack of fossil finds hitherto, and personal observations, a major find of several in situ associated fossil bones is not expected to be uncovered in the prospecting pits. Nevertheless, in case of a chance discovery of in situ fossil bone material, a Fossil Finds Procedure" (FFP) is provided in Appendix 2. Such material is likely to be poorly preserved and fragile and would require collection by a specialist, with careful treatment in the field using consolidants to strengthen the fossil bones before extraction.

Loose, isolated petrified bone parts and teeth may be noticed during logging of the prospecting pits. It is expected that such finds would be in the category of "allowed" rescue by prospecting staff, i.e. as for isolated bone finds in the FFP. Similarly, broken chunks of cemented deposits (conglomerate, sandstone, mudstones) may include petrified wood, shell moulds or plant impressions which must also be rescued from loss.

Lacking fossil finds hitherto, any fossil bones from the Buffelsrivier alluvial deposits and overlying "dorbank" will have a positive impact with respect to understanding the stratigraphy/ages of the Buffelsrivier alluvial terraces and for palaeontological heritage in general.

---oooOOOooo---

CONTENTS

DECLARATION OF INDEPENDENCE

THE SPECIALIST

I, **John Pether**, as the appointed specialist hereby declare/affirm the correctness of the information provided or to be provided as part of the application, and that I:

- in terms of the general requirement to be independent:
    - other than fair remuneration for work performed/to be performed in terms of this application, have no business, financial, personal or other interest in the activity or application and that there are no circumstances that may compromise my objectivity; or
    - am not independent, but another specialist that meets the general requirements set out in Regulation 13 have been appointed to review my work (Note: a declaration by the review specialist must be submitted);
- in terms of the remainder of the general requirements for a specialist, am fully aware of and meet all of the requirements and that failure to comply with any the requirements may result in disqualification;
- have disclosed/will disclose, to the applicant, the Department and interested and affected parties, all material information that have or may have the potential to influence the decision of the Department or the objectivity of any report, plan or document prepared or to be prepared as part of the application;
- have ensured/will ensure that information containing all relevant facts in respect of the application was/will be distributed or was/will be made available to interested and affected parties and the public and that participation by interested and affected parties was/will be facilitated in such a manner that all interested and affected parties were/will be provided with a reasonable opportunity to participate and to provide comments;
- have ensured/will ensure that the comments of all interested and affected parties were/will be considered, recorded and submitted to the Department in respect of the application;
- have ensured/will ensure the inclusion of inputs and recommendations from the specialist reports in respect of the application, where relevant;
- have kept/will keep a register of all interested and affected parties that participate/d in the public participation process; 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:

Name of company: Sole Proprietor

Date: 2 DECEMBER 2021

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 (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.
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.
Dwyka Group	The lowermost formations of the Karoo Supergroup. Southern Africa, then part of the Gondwana supercontinent, was in the vicinity of the South Pole about 300 Ma and covered with glaciers and ice sheets. The Dwyka sediments represent the melt-out content from the ice, when ice sheets melted back to the highlands, depositing massive tillites in the ice-scoured valleys which were then succeeded by marine muds, with melt-out dropstones from floating icebergs (the “boulder shales”).
Fluvial deposits	Sedimentary deposits consisting of material transported by, suspended in and laid down by a river or stream.
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 duricrust formed by pedogenic processes.
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

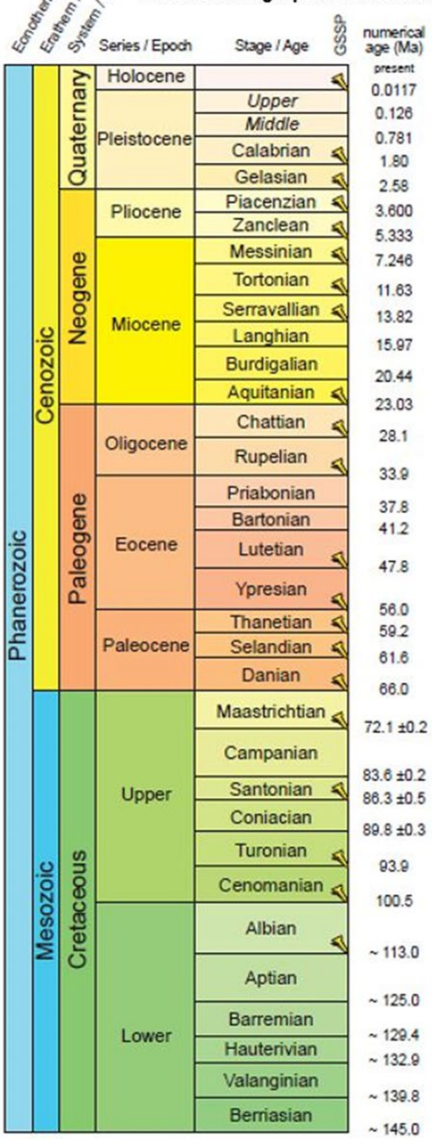
For more detail see www.stratigraphy.org.

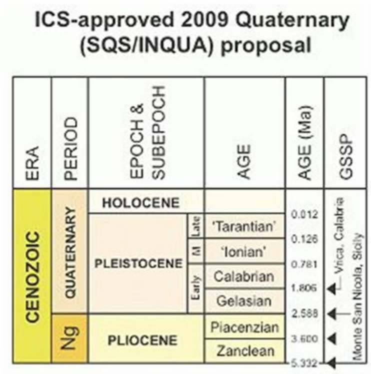
ka: Thousand years or kilo-annum (10^3 years). Implicitly means “ka ago” *i.e.* duration from the present, but “ago” is omitted. The “Present” refers to 1950 AD. Not used for durations not extending from the Present. For a duration only “kyr” is used.

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.

Mesozoic and Cenozoic Chronostratigraphy
From: International Commission on Stratigraphy.
Chronostratigraphic Chart 2016-12.pdf





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, HBF Products (Pty) Ltd., proposes to undertake prospecting on part of Portion 5 of the farm Kamaggas 200 in the Buffelsrivier valley in the Northern Cape (Figures 1 & 2) where there are alluvial terrace deposits. ASHA Consulting (Pty) Ltd. has been appointed to undertake the Heritage Impact Assessment (HIA) for the Prospecting Right Application. This report forms part of the HIA and its brief is to inform about the palaeontological sensitivity of the Project Area and the probability of palaeontological materials (fossils) being uncovered in the subsurface and being disturbed or destroyed in the process of prospecting, and to provide recommendations for palaeontological mitigation to be included in the Environmental Management Plan (EMP) for the prospecting.

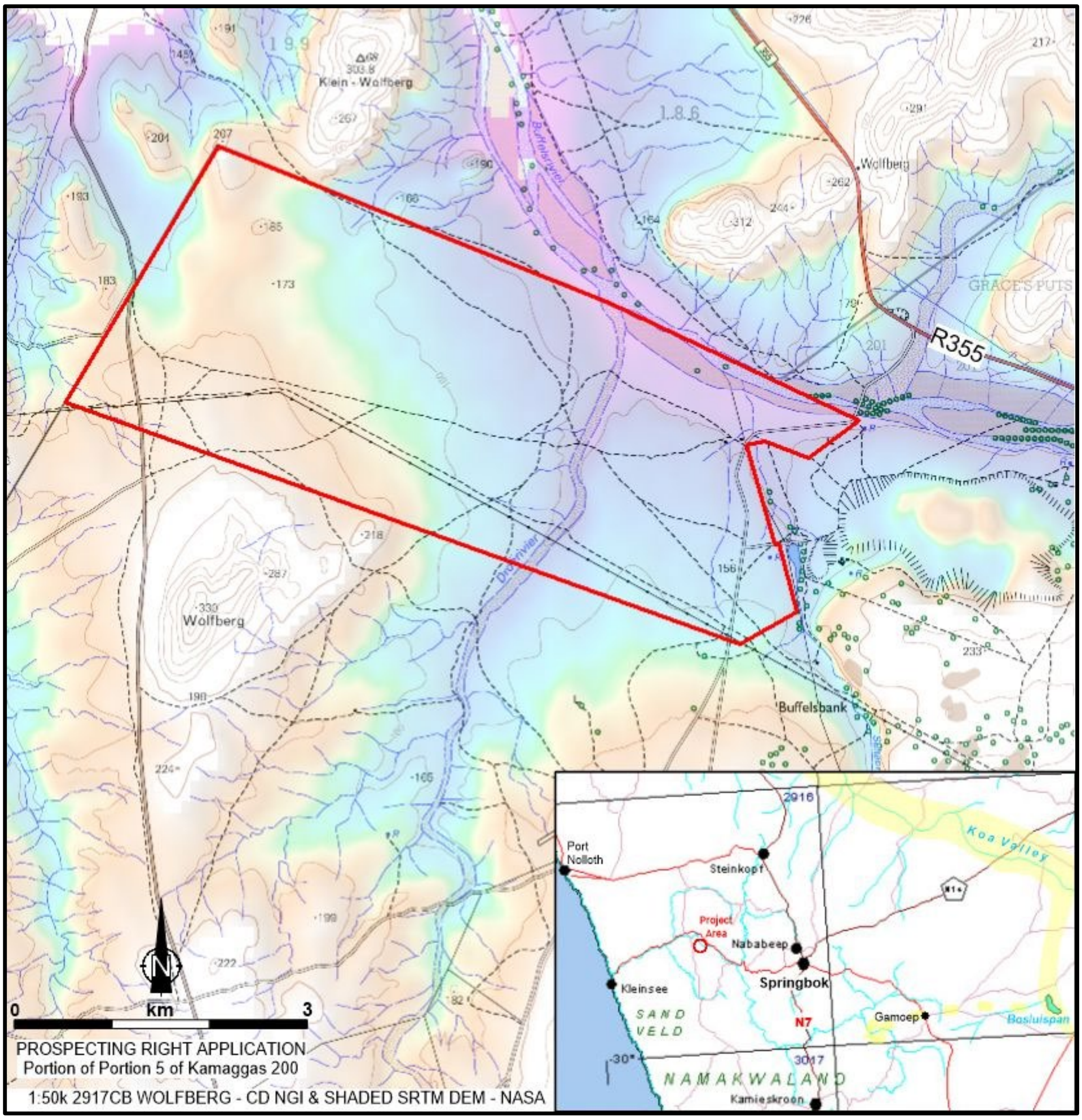


Figure 1. Location of the Kamaggas 200/5 Project Area.

2 LOCATION

The Project Area on Kamaggas 200/5 (~1500 ha), also referred to as “Swartsand”, is situated on the left/south bank of the Buffelsrivier and is approached via the main road (R355) between Springbok and Kleinzee (Figures 1 and 2). The diamondiferous alluvial gravel deposits of the lower Buffelsrivier valley have been exploited for several decades. The old Trans Hex Buffelsbank Mine is adjacent just upstream and the De Beers Nuttabooi Mine is farther downstream. On the opposite bank nearby are the historic mines of Grace’s Puts, Wolfberg and Langhoogte.

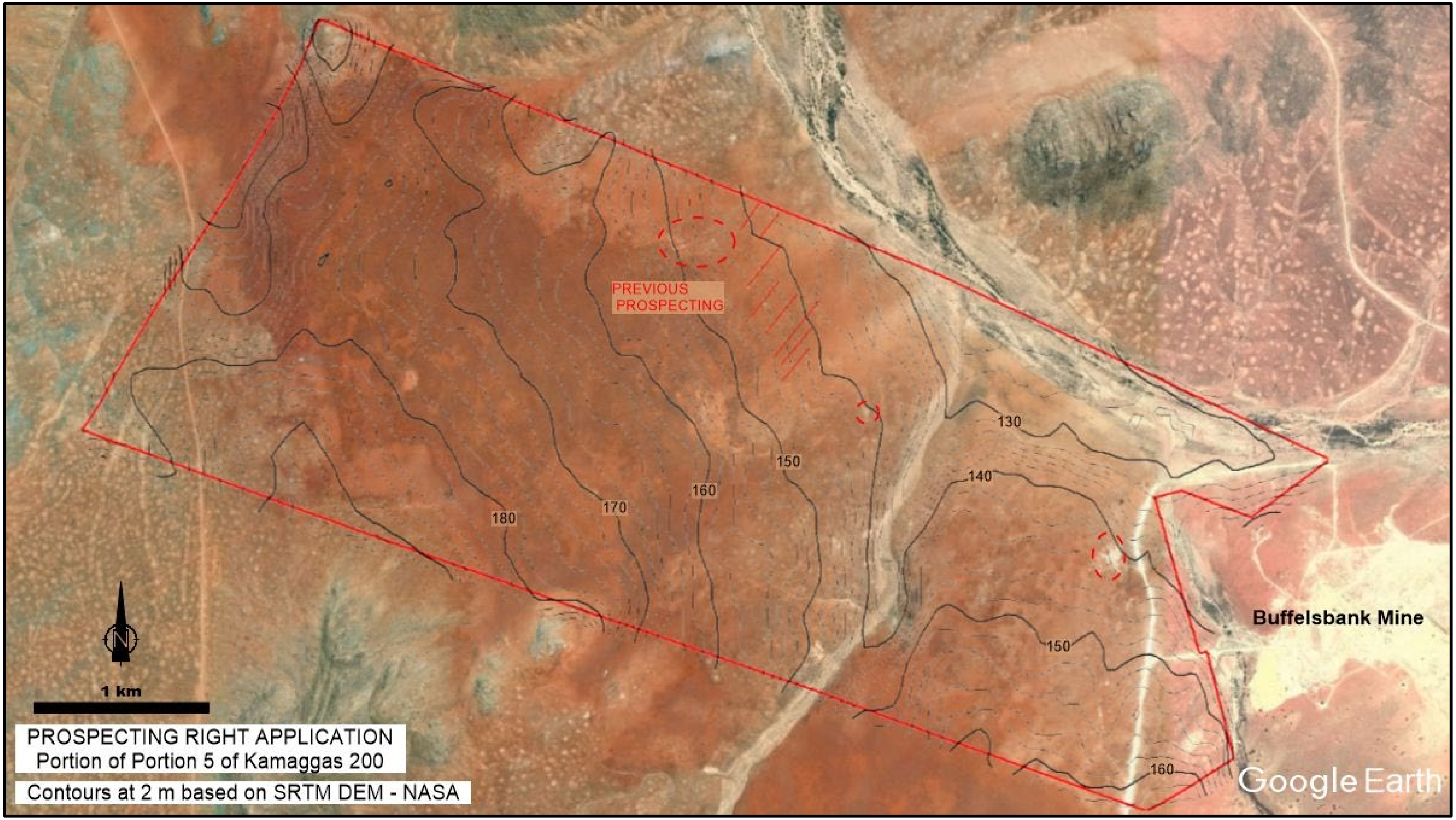


Figure 2. Aerial view of the Project Area showing main areas of previous exploration and topography (m asl.).

3 PROPOSED ACTIVITIES

The proposed prospecting programme is limited to a few small-scale pits and some drilling and does not involve large Bulk Sample trenches.

The locations of the prospecting pits and drill holes are not indicated on Figure 2 as they will be determined after the Environmental Assessment reports and the Phase 1 studies have been evaluated.

PROPOSED BASIC PROSPECTING PROGRAMME.

PHASE	ACTIVITY
Phase 1 Non-invasive.	Desktop studies: Historical data, imagery Analysis, geological mapping. Geophysical Resistivity Survey.
Phase 2 Invasive.	Prospecting by pitting where deposit thickness is <5 m. Up to 10 pits are anticipated. Drilling (reverse circulation) where deposit thickness is >5 m. About 5 drill holes to a depth of 10 m are envisaged.
Phase 3 Pre-feasibility	Analysis of results. Application for Renewal to provide for Evaluation Phase Bulk Sampling (trenching), if required.

4 APPROACH AND METHODOLOGY

The relatively few fossils from Namaqualand have been vital to our current understanding of the coastal-plain geological history, not only of Namaqualand, but also relevant to that of wider southern Africa. For instance, fossil woods and microscopic fossil pollen from ancient river (fluvial) deposits, which occur in buried river palaeochannels near the coast, attest to times before about 20 million years ago (before ~20 Ma), when Namaqualand was well-wooded with tropical forests, this ancient fossil flora providing a window through time to the ancestry of the unique Cape Flora.

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 geologic unit, which informs the Intensity/Magnitude/Severity rating in an impact assessment. The criteria for rating are in Appendix 1.

4.1 AVAILABLE INFORMATION

There is very little published information specific to the ancient fluvial deposits or terraces on the flanks of the Buffelsrivier and the available information is brief. Some aspects of the fluvial history of Namaqualand are summarised below and references are cited in the normal manner and are included in the References section. Relevant aspects of the regional geology are described.

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 ASPECTS OF THE REGIONAL GEOLOGY

5.1 THE CRETACEOUS AND PALAEOGENE COASTAL-PLAIN RIVERS

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. However, the river terrace deposits of the Buffelsrivier, and of the other coastal rivers (*e.g*. Swartlintjiesrivier, Groenrivier), do not yet have suggestions for formal or informal formation names.

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, faulted.	Oligocene
Koingnaas	Fluvial, kaolinized gravels, sands, plant fossils.	late Eocene
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.		

The geological history of the rivers of the West Coast is an intriguing topic and impinges upon several overlapping fields of study which converge on syntheses of the post- Gondwana-breakup history of the erosion of the southern African subcontinent, as informed by geomorphology, crustal cooling erosion histories and stratigraphy, both offshore and onshore. The various scenarios for the courses of palaeodrainages (ancient rivers) are the abiding interest of alluvial diamond prospectors. Some broad aspects are mentioned below.

The rifting of the Gondwana supercontinent and the opening of the Atlantic Ocean in the early Cretaceous, 130-120 Ma, was accompanied by the inception of numerous rivers draining to the new coastline. After the rifting phase with its volcanoes, faulting and terrestrial/lacustrine sedimentation, the rifted landscape was covered by sediments delivered to the expanding Cretaceous South Atlantic Ocean. Wide coastal plains and deltas formed as many large rivers deposited enormous volumes of sediments eroded from the well-watered hinterland. Marine processes spread the finer sands and muds further to form the continental shelf extending seawards. Slumping at the shelf edges carried sediments downslope into deep water. Successive continental shelves built out and upwards as the underlying crust subsided. These now fill what is called the Orange Basin offshore, which includes an accumulation of Cretaceous sediments exceeding 6 km thickness off the Namaqualand coast.

Ongoing erosion has removed nearly all traces of early Cretaceous deposits from the present-day West Coast coastal pain. A rare instance dating from the early Cretaceous rifting is preserved just north of the Buffelsrivier mouth and is evidently the surviving, deepest part of a fault-bounded lake. Discovered by drilling, the lacustrine deposits contain fossil pollen of the early Cretaceous flora (Molyneux, in Rogers *et al*., 1990), indicating deposition 145-130 Ma. Rounded cobbles of petrified, early Cretaceous *Podocarpoxylon* woods are found in the onshore marine gravels of the Quaternary raised beaches near Kleinzee and south of Port Nolloth (Bamford & Corbett, 1995), reworked successively from the now-vanished fluvial deposits of the early coastal plain.

The ongoing erosion by rivers bevelled the new continental edge, abetted by its uplift in response to the subsiding crust bending beneath the sediment load offshore, and the developing coastal plain, backed by a "Great Escarpment", approached its present configuration. A few kilometres thickness of Karoo and Nama formations had been stripped off, exposing the coastal bedrock of metasediments and gneisses. However, this bedrock had a pre-formed topography, carved out beneath the glaciers of Dwyka times ~300 Ma, which then influenced the river courses, such as the major valleys of the Orange, Olifants and Buffels rivers. During the later Cretaceous headward erosion by these larger rivers encroached into the subcontinental interior, capturing drainages there and directing their eroded sediment load to the West Coast.

In the palaeodrainage scenario proposed by Malherbe *et al*. (1986), during late Cretaceous/earliest Cenozoic times, the main subcontinental river traversed the Karoo along the course now marked by large pans and could have flowed into the coastal drainages of central Namaqualand near Gamoep (Figure 1, inset). This proposal is supported by Van der Westhuizen (2012), who points to the similarity of diamond features in common with diamonds from Bosluispan above the escarpment in the Koa River valley (Figure 1, inset) and diamonds in the Buffelsrivier deposits and in the marine deposits north of the Buffelsrivier. This "**Palaeo-Gamoep River**" connection across the escarpment divide evidently occurred before its further accentuation by ongoing uplift.

Along the outer edge of the coastal plain and extending onto the inner shelf in places are many buried, old river palaeochannels incised into the bedrock. It is possible that late Cretaceous fluvial deposits once filled the palaeochannels, but it seems that the palaeochannels were occupied by subsequent river systems and underwent cycles of infilling and flushing out with fluctuations of sea level during the early Cenozoic, until the deposits finally occupying them are mainly of late Eocene age (Koingnaas Formation). Nevertheless, due to the pervasive kaolinitic weathering of the palaeochannel deposits it is possible that remnants of the older, late Cretaceous to early Eocene deposits may be disguised in places in the bases of the channels.

The early coastal plain would have been transgressed by the sea during high sea-levels associated with peak global warming intervals during the Paleocene and Eocene (Figure 3), but no deposits of this earlier marine history are known to remain along Namaqualand. Diamondiferous Eocene marine remnants are preserved on the southern Namibian coast and must also have been present on the Namaqualand coastal plain, but were evidently later flushed off into the numerous rivers during the late Eocene and Oligocene.

The **Koingnaas Formation** (De Beer, 2010) infills the incised ancient river channels buried between the main Namaqualand rivers. These deposits have also been kaolinized, disguising their presence. Silcrete has also formed in places within the 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. Previously the presence of pollen of Oleaceae (ironwoods) and Asteraceae (daisies) indicated an age not older than Oligocene (Muller, 1981). However, new discoveries now indicate that the appearance of these floral families is earlier than Oligocene. In particular, the dispersal of early Asteraceae from their origin in South America to Africa is now considered to have occurred during the Eocene (Barreda *et al*., 2012, Mandel *et al*., 2019). Consequently the age of the Koingnaas Formation can be revised to late Eocene (Figure 3), with the aggradation of fluvial deposits in the palaeochannels likely correlating with times of rising sea levels between 44-34 Ma. This Eocene age resolves the inconsistency of the previous maximum Oligocene age constraint with the palaeoclimatic record of humid-climate deep weathering have taken place mainly during the early Cenozoic.

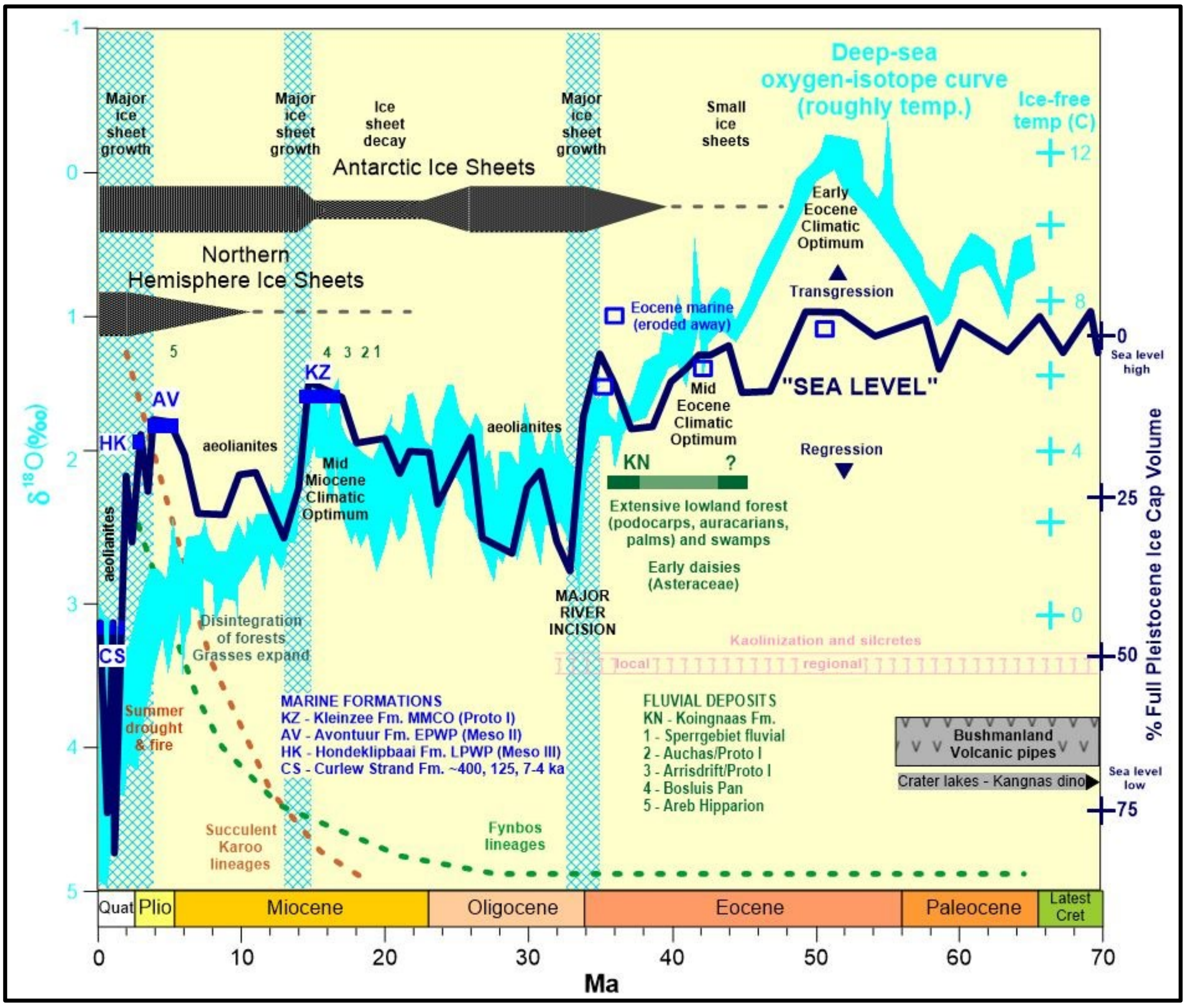


Figure 3: The Cenozoic Era (66 Ma to present) showing global palaeoclimate proxies, aspects of regional vegetation history and the context of marine formations of the West Coast Group, Alexander Bay Subgroup.

Cyan curve - history of deep-ocean temperatures, adapted from Zachos *et al*. (2008). **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). EPWP – Early Pliocene Warm Period. LPWM - Late Pliocene Warm Period.

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 wooded Namaqualand coast more nearly resembled the forests of the south coast.

Towards the end of the Eocene and during the Oligocene the global climate underwent major cooling and polar ice built up on the Antarctic continent, lowering sea level significantly (Figure 3). This “**Oligocene Regression**” is thought to have had an impact on the coastal plain by the incision and entrenchment of the river courses below the “African Surface” and further erosion back into the Escarpment. Towards the end of the Oligocene the cooler global climate began to ameliorate and with large fluctuations this warming trend continued through the early Miocene and peaked in the middle Miocene (Figure 3).

5.2 THE NEOGENE COASTAL-PLAIN RIVERS

By the time of the peak of the **Mid-Miocene Climatic Optimum ~16 Ma** (MMCO), significant melting of Antarctic ice had raised global sea level and the outer edge of the coastal plain was "transgressed" by the sea. The palaeoshoreline of this peak sea level is well-preserved north of Kleinzee, as impressive sea cliffs cut into the bedrock and into the aforementioned pre-existing river deposits at ~90 m asl. This high elevation is a combination of the meltwater added to the oceans (~40 m equivalent), as well as uplift of the continental margin (by ~50 m since ~16 Ma). When the sea receded during later Miocene global cooling the regressive, shallow-marine **Kleinzee Formation** (aka 90 m Package) was deposited.

By the mid-Miocene the Orange River was already deeply incised into the bedrock and had captured the interior subcontinental drainage and the southerly routes of the major river across the Karoo had become disconnected. The lower reaches of the Orange River were inundated by the rising sea level during the warming to the MMCO, forming a large estuary, whilst upstream the river valley was "backed up" and accumulated deposits (aggraded). Some of these Miocene deposits are now preserved as high level terraces in cut-off meander loops along the flanks of the valley and are called the "**Proto-Orange I Terrace**" deposits in De Beers geologist terminology and have also been called the **Arrisdrift Formation** due to the spectacular fossil finds at that locality which have revealed the importance of southern Africa in the evolution of the Africa fauna (Pickford & Senut, 2003). The more than 10 000 fossils from Arrisdrift include worm tubes and shark teeth indicative of the proximity of the estuary, 13 reptiles incl. the ancestor of the Nile Crocodile, 13 birds and more than 35 mammal species, while upstream at Auchas fossil finds in Proto-Orange" deposits include large tree trunks, 3 reptiles, a bird and 8 mammals. On the basis of mammal biochronology an age of ~19 Ma is indicated for the Auchas fossils and an age of ~17 Ma for the Arrisdrift assemblage (Pickford & Senut, 2003).

Above the escarpment the Koa Valley was an active river system, as shown by fossils from the bottom of Bosluis Pan which include catfish, crocodiles, tortoises, giraffids, bovids, a rhinocerotid and a small proboscidean (Elephantida) *Choerolophodon pygmaeus* which had a lifestyle similar to hippos. Most of the species also occur at Arrisdrift, but a slightly younger age of ~16 Ma has been estimated (Senut *et al*., 1996; Pickford, 2005).

The wood anatomy of the fossil tree trunks from Auchas show that they grew all year round, but with some water stress, in a warm subtropical climate (Bamford, 2003), which is consistent with the subtropical, summer rainfall palaeoclimate inferred from the Arrisdrift fossil fauna, with riverside gallery forests and woddy savannah wider afield. The MMCO was ended by global cooling and major build-up of polar ice (Figure 3) and the lowered sea level resulting in the Orange and Namaqualand rivers incising into the previous Proto-age valley fills. Major changes in the ocean and atmospheric circulations led to dryer climates in Africa, with decline of forests and the expansion of savannah grasslands, while along the West Coast the influence of cold Subantarctic waters increased, together with the onset of the early Benguela upwelling regime and the expansion of arid conditions.

A temporary return of global warming, the **Early Pliocene Warm Period** (EPWP), resulted in rising sea level and erosion of the edge of the Miocene Kleinzee Fm. as the sea approached the transgression maximum at about 50 m asl. In the Orange River valley the "**Meso-Orange II Terrace**" gravels capped the aggraded riverbed deposits. The marine **Avontuur Formation** (the 50 m Package) was deposited 5-4 Ma as sea-level receded from ~50 m asl. and the shoreline prograded seawards (Figure 3), while the Meso II deposits were incised as the regression proceeded.

The Avontuur Formation in turn was eroded by yet another episode of rising sea-level associated with the **Late Pliocene Warm Period** ~3.2 Ma (LPWP) (Figure 3). In the Orange River valley the "**Meso-Orange III Terrace**" gravels capped the re-aggraded riverbed deposits. 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. This formation, up to a few km wide, underlies the outer part of the coastal plains of the West Coast. 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.

With the onset of the Quaternary Ice Ages since about 2.6 Ma the sea level oscillated mainly between elevations of -20 to -80 m bsl., with drops to between -100 to -140 m bsl. during the numerous Ice Age glacial maxima. The Orange and the Namaqualand rivers ran in entrenched courses, with their estuarine mouths and deltas being constantly re-positioned and reworked as sea level traversed repeatedly up and down the inner shelf. Variously preserved in the lower reaches of the rivers are estuarine deposits that relate to higher sea levels of the later Quaternary, correlating with the raised beaches preserved along the open coast. The name **Curlew Strand Formation** encompasses this composite of raised beaches, equivalent to the Velddrif Formation of the SW Cape Coast. The main raised beaches occur at ~12 m asl. (dated to about 400 000 years ago - ~400 ka) and at ~6 m asl. dated to ~125 ka.

A variety of terrestrial deposits also make up the coastal plain of Namaqualand. These are extensive aeolian dune and sandsheet deposits that overlie the eroded tops of the marine sequences near the coast, and as dune plumes extending inland. A glance at the satellite images of the coast show that the dune plumes of various ages occur in specific areas and are linked to topography, sea-level oscillations, the changing 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. More locally there are colluvial (sheetwash) and ephemeral stream deposits associated with nearby hillslopes; these dominate the thinner cover of the hills of the higher, inner coastal plain. Formed within the terrestrial sequences are pedocretes and palaeosols of a variety of types, compositions and degrees of development which mark times of surface stability and relate to times of reduced aeolian activity (less windy) and/or more humid climatic intervals.

The Project Area, being located on the innermost margin of the coastal plain, lacks significant aeolian deposits attributable to a named formation and thus the coastal aeolianite formations (Table 1) are not discussed herein.

6 THE GEOLOGY OF THE PROJECT AREA

For palaeontology, the affected environment pertains to the geological formations that occur in the Project Area and their fossil content.

6.1 THE BEDROCK

The hard-rock bedrock of the wider area is comprised of granites and gneisses formed by melting of the crustal basement and metamorphosed "embedded islands" of ancient sedimentary rocks (metasediments). Beneath the Project Area the bedrock is mainly the Rietberg Granite (Figure 4). These very old bedrock formations, ranging in age from 2000 to 1000 Ma, are not of palaeontological interest.

6.2 THE BUFFELSRIVIER DEPOSITS

Published information on the exploited Buffelsrivier terraces and deposits, and other prospects on Namaqualand river terraces (*e.g.* Spoeg, Groen), is minimal. Keyser (1976) reported that the diamondiferous basal layer is best developed in channels incised into the main level of the terrace, and is a poorly-sorted, massive gravel with clasts of decomposed bedrock. These "white quartz" gravels are patchily preserved in the rivers south of the Buffelsrivier. The overlying sediments are "clean-washed to clayey (kaolinitic), reasonably sorted, and sometimes cross-bedded sands incorporating thin, disjunct, lensiform, very well-rounded ("golf-ball") and well-sorted quartz and quartzitic pebble gravels". Molyneux (in Rogers *et al.*, 1990) describes the basal deposits as consisting of a cemented gravel consisting entirely of sub-angular to sub-rounded vein-quartz clasts. This is only preserved in deeper bedrock depressions; in most instances only remnants are preserved due to reworking. The overlying sediments comprise sandstones, siltstones and clays.

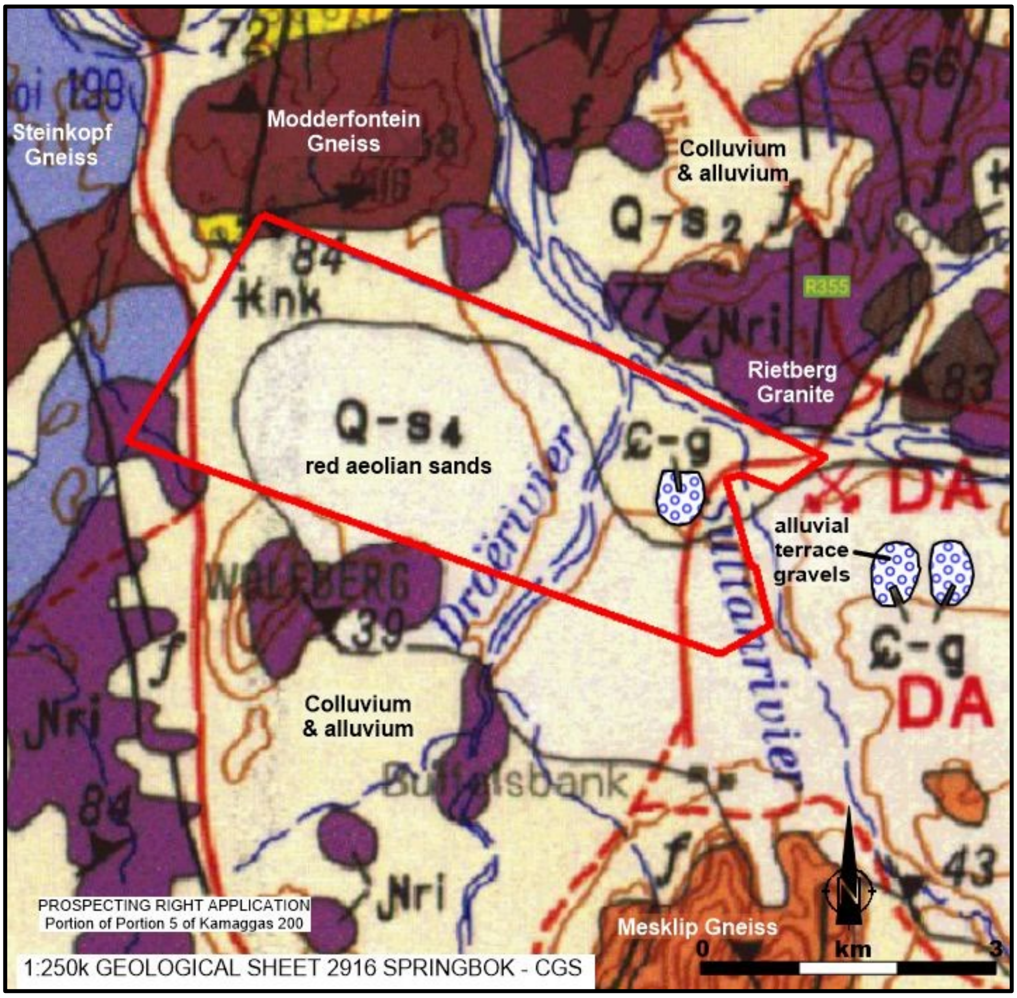


Figure 4. Basic surface geology of the Project Area.

According to Marais *et al.*, (2001) the typical basal conglomerate of the Buffelsrivier deposits is a coarse, chaotic, often poorly-structured accumulation of predominantly blocky, subangular grey quartz clasts in an unsorted matrix of clayey, kaolinitic, highly feldspathic, angular sand (Figure 5A, Figure 6B). The upper contact is marked by scour surfaces and the overlying sandstones are white and feldspathic, with interbeds of gravel, kaolinitic silts and clays. Crossbedding is common in the lower few metres of section and the "suspended" gravels are characterised by well-rounded quartz pebbles.

Notably, both Keyser (1976) and Marais *et al*. (2001) draw the distinction between the angular basal gravels and the overlying, well-rounded "suspended" gravels. At its simplest, this may reflect a transition from proximal regolith sediment sources to the more distal sediments sources upstream, within the same period of deposition. Alternatively, the angular basal gravels could be remnants of older deposits, such as the inland, coarse correlates of the late Eocene Koingnaas Formation.

Overall, the essential interpretation of Keyser (1976), who regarded the "white quartz" older terrace deposits to have been derived from the kaolinized terrain, cannot be refuted. This implies that these deposits post-date the humid climate of the early Cenozoic which promoted advanced weathering until the major step in global cooling during the Oligocene (Figure 3).

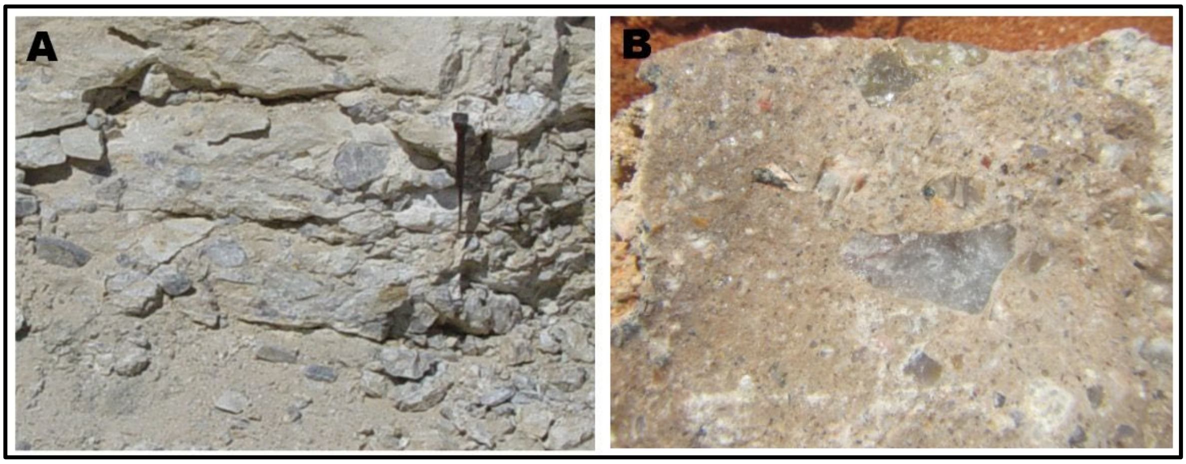


Figure 5. A – Poorly sorted basal subangular vein-quartz conglomerate (Nuttabooi). B – Similar conglomerate excavated by prospecting in the Project Area (courtesy J. Orton).

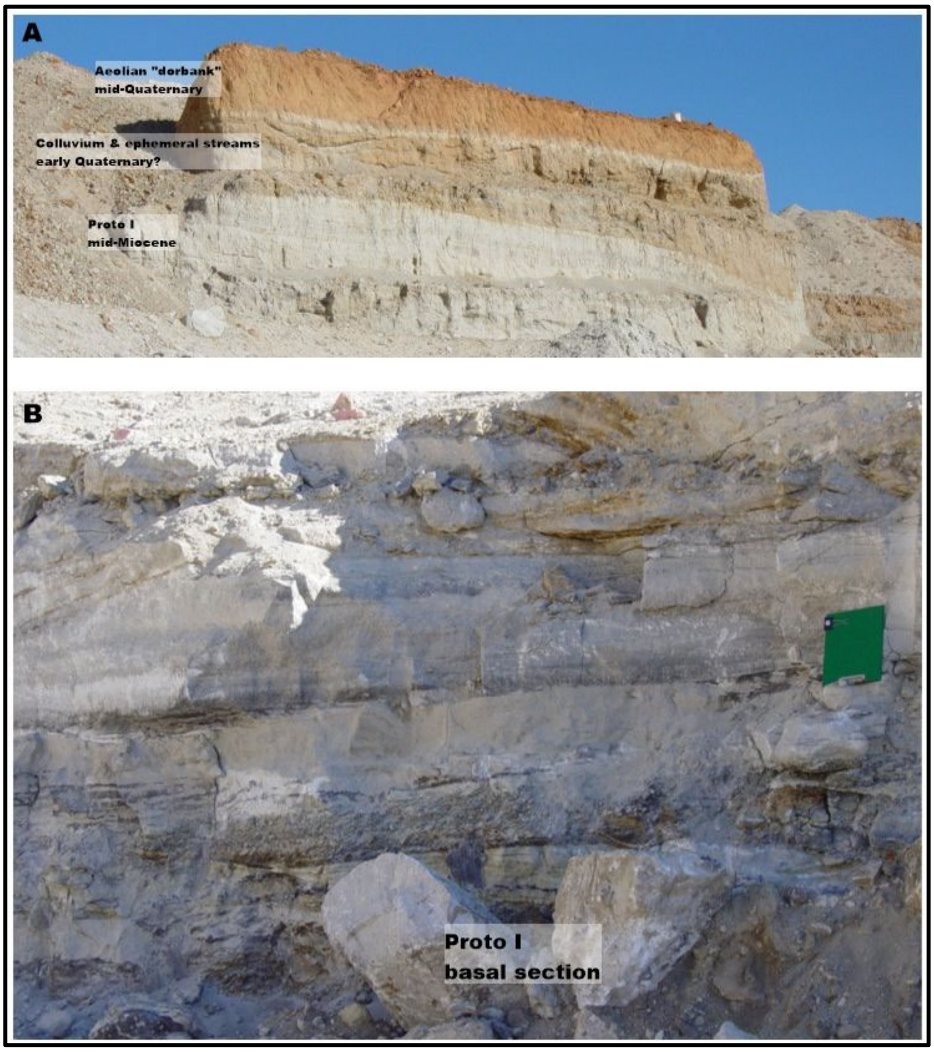


Figure 6. The exposures at Nuttabooi mine showing the basic stratigraphy (A) and the lowermost Proto I Terrace deposits (B).

The genesis of the aggraded terrace units in the Orange River, directly related to periods of high sea levels, should be duplicated in the Buffelsrivier. However, the Buffelsrivier lacked the large, exotic sediment load eroded from the subcontinental interior and the consequences of river base level control would have been overprinted by the local erosional and palaeoclimatic history of its more limited catchment area and its topography. Maps of the geometry of the Buffelsrivier “terrace” units/formations, illustrated with vertical sections, are apparently not in the public domain. However, in summaries (*e.g.* Molyneux, in Rogers *et al.*, 1990) the older Buffelsrivier fluvial formation described above is correlated with the "Proto-Orange I Terrace", or Arrisdrift Formation, of mid-Miocene age ~18-16 Ma, which relates to the Mid-Miocene Climatic Optimum (Figure 3).

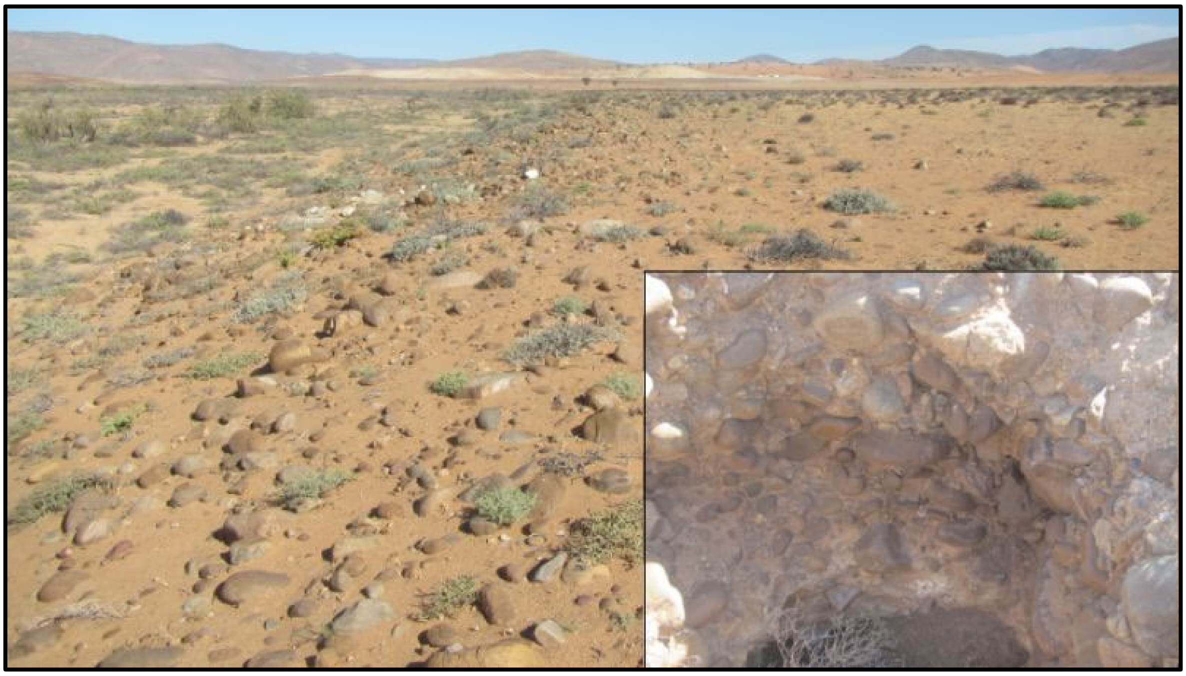


Figure 7. Edge of the Meso Terrace in the Project Area, view southeast with the Buffelsbank Mine dumps in background. Inset – Typical Meso Terrace conglomerate. Images courtesy J. Orton.

Considerable thicknesses of the pale, older "Proto" river deposits occur on the adjacent mines of Nuttabooi and Buffelsbank and, overlying the sharp upper contact, are several metres of "dorbank" comprising consolidated colluvium and aeolian sands with variously-developed pedocretes (Figure 6A) likely to have been deposited during early to mid-Quaternary time. The looser, reddish aeolian surficial coversands accumulated during the late Quaternary.

Whereas the Miocene "Proto" deposits are usually buried beneath younger cover, the eroded edge of the Pliocene "Meso" deposits forms a distinct alluvial terrace scarp with outcropping rounded quartzite cobbles (Figure 7). This "Meso Terrace" has been the main area of previous prospecting (Figure 2).

7 EXPECTED PALAEONTOLOGY

As far as the writer is aware no macrofossils of any description have been reliably reported from the Miocene and Pliocene fluvial terrace deposits of the Buffelsrivier, or from the overlying Quaternary colluvial and aeolian sequences. I dimly recall a mention of possible plant impressions being found in the fluvial deposits, but this has not been substantiated. Microfossils and fossil pollen have also not been reported.

A factor which reduces the visibility of fossils is that these deposits are well-cemented sandstones and conglomerates which require breaking up and material such as fossil bones do not poke or tumble out of the broken material, as is the case with poorly-cemented deposits, and are only visible as snapped-off sections in the rock chunks. Fossils within cemented sedimentary rocks are usually exposed by natural weathering of exposures.

Notwithstanding the apparent paucity of fossils in the Buffelsrivier fluvial deposits, the possibility that some could be discovered cannot be dismissed. In view of the lack of age constraints from fossil mammal bones, any identifiable find would be of scientific importance. Though fossil bone or tooth finds might appear to be nondescript-looking fragments, a specialist is often able to make an identification.

In addition to rare fossil bone material the following fossils could occur:

- Lignified or petrified wood fragments.
- Plant impressions in mudstone beds.
- Moulds of dissolved aquatic bivalves and gastropods.
- Petrified teeth of mammals, reptiles and fish, varying from pebble-size to a few mm.

Petrified teeth (Figure 8) are found in the heavy concentrates of the coastal diamond mines and have provided critical age constraints for our understanding of coastal-plain geohistory (Pickford & Senut, 1997). Similarly, it seems that finds in concentrates hold the most promise for a diagnostic fossil find from the Buffelsrivier deposits. The similar finding of a few small fossil teeth from the enigmatic, supposedly unfossiliferous Buffelsrivier fluvial deposits would change the low negative impact to a high positive impact of regional to international scientific extent. However, the processing of material for diamond content is intended for the later Evaluation Phase and not germane to the current prospecting programme.

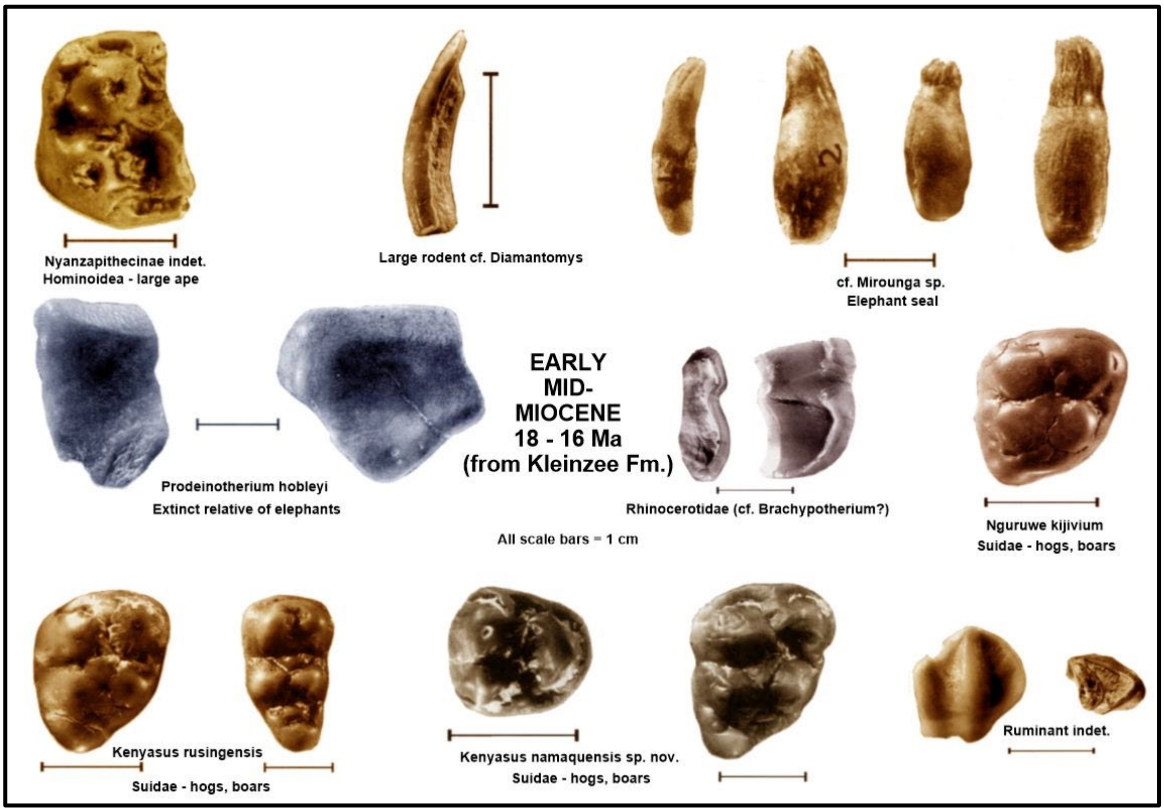


Figure 8. Fossil mammal teeth collected from rotary pan concentrate. These fossils were eroded from terrestrial deposits during the mid-Miocene sea-level transgression and incorporated into marine gravels, when the elephant seal was added.

8 ANTICIPATED IMPACT

It is evident that fossils are very rare in the Buffelsrivier deposits. Furthermore, the scale of the proposed prospecting pitting is relatively minor. The drill holes are very unlikely to produce fossil material due to the very small deposit volume affected.

Consequently, the palaeontological sensitivity of the Buffelsrivier alluvial deposits and the overlying ‘dorbank” colluvia is considered to be LOW (Appendix 1).

9 IMPACT ASSESSMENT

9.1 GENERAL IMPACT OF BULK EARTH WORKS 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 with respect to 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. This loss of the opportunity to recover them and their contexts when exposed at a particular site is irreversible. The very scarcity of fossils makes for the added importance of looking out 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.

This impact assessment, according to the rating scheme in Appendix 3, addresses the occurrence of the high-value fossil bones in the deposits. It does not differentiate between formations as the palaeontological sensitivities of the affected formations with respect to the occurrence of fossil bones are low.

9.2 EXTENTS

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

However, unlike an impact that has a defined spatial extent (*e.g.* loss of a portion of a habitat), the cultural, heritage and scientific impacts of fossil finds may be of regional to national extent, as is implicit in the National Heritage Resources Act No. 25 (1999) and, if scientifically important specimens or assemblages are uncovered, are of international interest. This is evident in the amount of foreign-funded palaeontological research that takes place in South Africa by scientists of other nationalities.

9.3 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.

9.4 INTENSITY

As mentioned above, due to the overall very sparse distribution of fossils in the affected formations the intensity/sensitivity is considered to be LOW. Conversely, when fossils are found in such poorly fossiliferous formations, they provide very significant advances in the geological understanding of the stratigraphy of a region.

9.5 PROBABILITY

Although fossils have apparently not been found in the Buffelsrivier fluvial deposits it is probable that very sparse fossils are present and it is just possible that fossils could be discovered during prospecting, but this must be considered UNLIKELY based on observations hitherto.

9.6 IMPACT ASSESSMENT TABLE

PALAEONTOLOGICAL IMPACT – Prospecting								
Potential impact description: Impacts to palaeontological resources. Destruction of or damage to fossil bones or resources by prospecting pitting and drilling.								
	Extent	**Duration**	**Intensity**	**Consequence**	**Probability**	**Significance**	**Status**	**Confidence**
Without Mitigation	Local 1	Permanent 5	Low 3	Low 9	Unlikely 2	VERY LOW 18	Negative	Medium
With Mitigation	Local 1	Permanent 5	Low 3	Low 9	Unlikely 2	VERY LOW 18	Positive	Medium
Can the impact be reversed?			NO, because palaeontological resources are unique and their loss is irreversible.					
Will impact cause irreplaceable loss or resources?			YES, valuable fossils may be lost in spite of management actions to mitigate such loss.					
Can impact be avoided, managed or mitigated?			Although they cannot be avoided, impacts can be managed and/or mitigated during the prospecting.					
Mitigation measures to reduce residual risk or enhance opportunities: • Mine personnel to be alert for rare fossil bones and follow "Fossil Finds Procedure". • On discovery of *in situ* fossil bones, cease excavation and protect fossils from further damage. • Contact SAHRA and/or appointed palaeontologist providing information and images. • Palaeontologist will assess information and establish suitable response, such as the importance of the find and recommendations for preservation, collection and record keeping.								
Cumulative Impact: For prospecting and mining excavations in coastal-plain formations the impact of both the finding and the loss of fossils is permanent. The loss of fossils would be of uncertain significance. Diligent and successful mitigation contributes to a positive cumulative impact as the rescued fossils are preserved and accumulated for scientific study. Positive impacts would continue to be felt with successful mitigation because of the scientific implications of the resulting research opportunities. Even though just a very minor portion of the bone fossils exposed in coastal-plain excavations has been seen and saved, the rescued fossils proved to be of fundamental scientific value.								
Residual impact: It will never be possible to spot and rescue all fossils which means that there will always be loss and therefore a cumulative negative impact.								

10 RECOMMENDATIONS

No-go areas of particular palaeontological sensitivity are not identified in the Project Area.

It is recommended that a requirement to be alert for fossil materials be included in the Environmental Management Plan (EMP) for the prospecting pitting operations. The Environmental Control Officer (ECO) for the project must inform staff of the need to watch for potential fossil occurrences in the pits and in excavated material. The Project Geologist, in closely inspecting and logging the exposures, is most likely to spot potential fossil material.

Based on the lack of fossil finds hitherto, and personal observations, a major find of several *in situ* associated fossil bones is not expected to be uncovered in the prospecting pits. Nevertheless, in case of a chance discovery of *in situ* fossil bone material, a Fossil Finds Procedure" (FFP) is provided in Appendix 2. Such material is likely to be poorly preserved and fragile and would require collection by a specialist, with careful treatment in the field using consolidants to strengthen the fossil bones before extraction.

Loose, isolated petrified bone parts and teeth may be noticed during logging of the prospecting pits. It is expected that such finds would be in the category of "allowed" rescue by prospecting staff, *i.e.* as for isolated bone finds in the FFP. Similarly, broken chunks of cemented deposits (conglomerate, sandstone, mudstones) may include petrified wood, shell moulds or plant impressions which must also be rescued from loss.

Open-pit prospecting and mining excavations are a scientific and fossil resource and have been the major contributor to the understanding of the deposits and palaeontology of the Namaqualand coastal plain. Prospecting and mining personnel have played a critical role in bringing fossil finds to the attention of the international scientific community. However, these have generally been the rare, visually-obvious large finds of many bones. Scattered finds and small fossils sparsely distributed in the deposits are generally missed or overlooked, as might have been the case for the Buffelsrivier fluvial deposits in the past.

Lacking fossil finds hitherto, any fossil bones from the Buffelsrivier alluvial deposits and overlying "dorbank" will have a positive impact with respect to understanding the stratigraphy/ages of the Buffelsrivier alluvial terraces and for palaeontological heritage in general.

11 REFERENCES

Bamford, M.K. 2003. Fossil Woods from Auchas and their palaeoenvironment. Memoir of the Geological Survey of Namibia 19: 23-34.

Bamford, M.K. & Corbett, I.B. 1995. More fossil wood from the Namaqualand coast, South Africa: onshore material. Palaeontologia Africana 32: 67-74.

Barreda, V. D., L. Palazzesi, L. Katinas, J. V. Crisci, M. C. Tellerıa, K. Bremer, M. G. Passala, F. Bechis & R. Corsolini. 2012. An extinct Eocene taxon of the daisy family (Asteraceae): evolutionary, ecological and biogeographical implications. Annals of Botany 109:127-134.

Chase, B.M. & Thomas, D.S.G. 2007. Multiphase late Quaternary aeolian sediment accumulation in western South Africa: timing and relationship to palaeoclimatic changes inferred from the marine record. Quaternary International 166: 29–41.

De Beer, C.H. 2010. The geology of the Garies area. Explanation: 1:250000 Sheet 3017 Garies. Council for Geoscience South Africa. 100 pp

De Villiers, S. E. & Cadman, A. 2002. An analysis of the palynomorphs obtained from Tertiary sediments at Koingnaas, Namaqualand, South Africa. Journal of African Earth Sciences 33:17–47.

Keyser, U. 1976. Namaqualand river deposits. In: Coetzee, C.B. (ed.), Mineral resources of the Republic of South Africa. Handbook of the Geological Survey of South Africa **7**: 25-27.

Lear, C.H, Elderfield, H. & Wilson, P.A. 2000. Cenozoic Deep-Sea Temperatures and Global Ice Volumes from Mg/Ca in Benthic Foraminiferal Calcite. *Science* **287**: 269-272.

Malherbe, S.J., Keyser, A.W., Botha, B.J.V., Cornelissen, A., Slabbert, M.J., Prinsloo, M.C. 1986. The Tertiary Koa River and the development of the Orange River Drainage. Annals of the Geological Survey of South Africa 20:

Mandel, J.R., Dikow, R.B. 2, Siniscalchi, C.M., Thapa, R., 1, Watson, L.E. & Funk V.A. 2019. A fully resolved backbone phylogeny reveals numerous dispersals and explosive diversifications throughout the history of Asteraceae. https://www.pnas.org/cgi/doi/10.1073/pnas.1903871116

Marais, J.A.H., Agenbacht, A.L.D., Prinsloo, M. & Basson, W.A. 2001. The Geology of the Springbok Area. Explanation: 1:250000 Geology Sheet 2916 Springbok. Council for Geoscience, Pretoria. 103 pp.

Muller, J. 1981. Fossil pollen records of extant angiosperms. *The Botanical Review* 47:1-142.

Pickford, M. 2005. *Choerolophodon pygmaeus* (Proboscidea: Mammalia) from the Middle Miocene of southern Africa. South African Journal of Science 101: 175-177.

Pickford, M. & Senut, B. 1997. Cainozoic mammals from coastal Namaqualand, South Africa. Palaeontologia Africana 34: 199-217.

Pickford, M. & Senut, B. 2003. Miocene Palaeobiology of the Orange River Valley, Namibia. Memoir of the Geological Survey of Namibia 19: 1-22.

Roberts, D.L., Botha, G.A., Maud, R.R. and Pether, J. 2006. Coastal Cenozoic Deposits (Chapter 30). In: Johnson, M. R., Anhaeusser, C. R. and Thomas, R. J. (eds.), The Geology of South Africa. Geological Society of South Africa, Johannesburg/Council for Geoscience, Pretoria: 605-628.

Rogers, J., Pether, J., Molyneux, R., Hill, R.S., Kilham, J.L.C., Cooper, G. and Corbett, I. 1990. Cenozoic geology and mineral deposits along the west coast of South Africa and the Sperrgebiet. Guidebook Geocongress '90 Geological Society of South Africa PR1: 1-111.

Senut, B., Pickford, M., de Wit, M., Ward, J., Spaggiari, R. and Morales, J. Biochronology of the Cainozoic sediments at Bosluis Pan, Northern Cape Province, South Africa. South African Journal of Science 92: 249-251.

Van der Westhuizen, A. 2012. Provenance of Alluvial Diamonds in southern Africa: A Morphological and Mineral Chemistry Study of Diamonds and Related Heavy Minerals from the Vaal-Orange System and the West Coast. Ph.D. Thesis. University of Stellenbosch.

Verboom, G. A., Archibald, J. K., Bakker, F. T., Bellstedt, D. U., Conrad, F., Dreyer, L. L., Forest, F., Galley, C., Goldblatt, P., Henning, J. F., Mummenhoff, K., Linder, H. P., Muasya, A. M., Oberlander, K. C., Savolainen, V., Snijman, D. A., van der Niet, T. & Nowell, T. L. 2009 Origin and diversification of the Greater Cape flora: Ancient species repository, hot-bed of recent radiation, or both? Molecular Phylogenetics and Evolution 51: 44–53.

Zachos, J. C., Dickens G. R., Zeebe, R. E. 2008. An early Cenozoic perspective on greenhouse warming and carbon cycle dynamics. Nature 451: 279–283.

---oooOOOooo---

12 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.

13 APPENDIX 2 - FOSSIL FIND PROCEDURES

In the context under consideration, it is improbable that fossil finds will require delineation of “no go” zones. At most a temporary pause in activity at a limited locale may be required. The strategy is to rescue the fossil 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. However, they may also serve as a guideline for other fossil material that may occur.

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

13.1 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 or tooth exposed in an excavation or spoil heap must be retrieved before it is covered by further spoil from the excavation and set aside. This also applies to potential fossils of any kind embedded in broken chunks of cemented deposit.
- **Action 2:** The Project Manager/Geologist/Environmental Control Officer (ECO) must be informed.
- **Action 3:** The responsible field person (geologist or ECO) must take custody of the fossil. The following information to be recorded:
    - Location co-ordinates (such as obtained by GPS in decimal degrees).
    - Digital images of excavation showing vertical section (mine face) and position of the find.
    - Digital images of fossil.
    - Geological context obtained from the mine geologist.
- **Action 4:** A loose 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. Cemented deposit chunks with an embedded fossil must also be labelled (*e.g*. with a paint marker) and appropriately stored for safekeeping.
- **Action 5:** Geologist/ECO contacts the standby palaeontologist and/or SAHRA to describe the occurrence and provide images asap. by email.

Response by Palaeontologist in the event of isolated bone finds

The palaeontologist or SAHRA will assess the information and liaise with the prospecting rights holder, the land owner and the ECO/geologist and a suitable response will be established.

On the discovery of conservation-worthy fossils, a collection permit must be applied for from the South African Heritages Resources Agency (SAHRA).

With the passage of time arrangements must be made to transport fossil material deemed worthy of conservation and study to an appropriate curatorial institution.

13.2 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.

On the basis of existing observations of the Buffelsrivier fluvial deposits it is unlikely that a major bone cluster find will be encountered.

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 pit foreman and the ECO.
- **Action 3:** ECO contacts the standby archaeologist and/or palaeontologist. ECO 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 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 the rights holder, the owner and the environmental consultants.

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.
- If the fossils are in an archaeological context, an archaeologist must be contacted to evaluate the site and decide if Rescue Excavation is required.
- If the fossils are in a palaeontological context, the palaeontologist must evaluate the site and decide if Rescue Excavation is required.

13.3 RESCUE EXCAVATION

Rescue Excavation refers to the removal of the material from the 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 undue delays to the mining schedule.

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 enclosed in loose material.
- Fragile material in loose/crumbly sediment would be encased in blocks using Plaster-of Paris or reinforced mortar and removed for preparation in a laboratory.
- Chunks of cemented rock with embedded fossils would be carefully trimmed of unnecessary excess rock and removed for preparation in a laboratory.

If the fossil occurrence is dense and is assessed to be a significant find then carefully controlled excavation is required.

14 APPENDIX 3 - IMPACT SIGNIFICANCE RATING METHODOLOGY

ASSESSMENT CRITERIA	
Nature	
Rating	**Criteria**
Positive	Beneficial to the receiving environment
Negative	Harmful to the receiving environment
Neutral	Neither beneficial or harmful
Severity	
Rating	**Criteria**
6 Very High	The impact is result in a complete loss of all resources. Irreparable damage to highly valued species, habitat or ecosystem
5 High	The impact will result in significant loss of resources. Very serious, long-term environmental impairment of ecosystem function that may take several years to rehabilitate.. Very serious widespread social impacts. Irreparable damage to highly valued items.
4 Medium	The impact will result in marginal loss of resources. Serious medium term environmental effects. Environmental damage can be reversed in less than a year. On-going social issues. Damage to structures/items of cultural resources of low significance, mostly repairable.
3 Low	Moderate, short- term effects but not affecting ecosystem function. Rehabilitation requires no intervention of external specialists and can be done in less than a month. On-going social issues. Some damage to insignificant cultural resiurces.
2 Very low	Minor effects on biological or physical environment. Environmental damage can be rehabilitated internally with/ without help of external consultants. Minor medium-term social impacts on local population. Low-level repairable damage to commonplace historical structures
1 None	The impact will not result in the loss of any resources. Limited damage to minimal area of low significance, (e.g. ad hoc spills within plant area). Will have no impact on the social environment. Cultural functions and processes not affected.
Spatial Scale	
Rating	**Criteria**
6 Very High	Will affect areas across international boundaries
5 High	Will affect the entire country
4 Medium	Will affect the entire province or region
3 Low	Will affect the local area or district
2 Very low	The impact will only affect the site
1 None	The impact will only affect portions of the site
Duration	
Rating	**Criteria**
6 Very High	Permanent no mitigation possible
5 High	Permanent but mitigation possible
4 Medium	Long term (6-15 years)
3 Low	Medium term (1-5 years)
2 Very low	Short term (Less than 1 year)
1 None	Immediate (Less than 1 month)

Probability	
Rating	**Criteria**
6 Very High	Certain/Definite Impact will certainly occur (100% probability of occurring)
5 High	Almost certain/ High probability Impact will occur (>75% probability of occurring)
4 Medium	Impact likely to occur (50 - 75% probability of occurring)
3 Low	Impact may occur (25-50% probability of occurring)
2 Very low	Unlikely/ Low probability. Impact unlikely to occur (0 - 25% probability of occurring)
1 None	Highly Unlikely/ None Impact unlikely to occur (0% probability of occurring)

SIGNIFICANCE Consequence x Probability Presented as a score out of 108	
Rating	**Criteria**
84-108 High	Long-term environmental change with great social importance.
50-83 Medium	Medium to long term environmental change with fair social importance.
27-49 Low	Short to medium term environmental change with little social importance.
12-26 Very low	Short-term environmental change with no social importance
3-11 None	No environmental change
Unknown	Due to lack of information

	Consequence = Severity + Spatial Scale +Duration Presented as a score out of 18																
		3	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Probability	**1**	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	2	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
	3	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
	4	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72
	5	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
	6	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108

CUMULATIVE EFFECTS	
Rating	**Criteria**
High	The impact would result in significant cumulative effects
Medium	The impact would result in moderate cumulative effects
Low	The impact would result in minor cumulative effects

REVERSIBILITY	
Rating	**Criteria**
Reversible	Impacts can be reversed though the implementation of mitigation measures
Irreversible	Impacts are permanent and can't be reversed by the implementation of mitigation measures

DEGREE TO WHICH IMPACT COULD BE AVOIDED/MANAGED/MITIGATED	
Rating	**Criteria**
High	The impact could be significantly avoided/managed/mitigated.
Medium	The impact could be fairly avoided/managed/mitigated.
Low	The impact could be avoided/managed/mitigated to a limited degree.
Very Low	The impact could not be avoided/managed/mitigated; there are no mitigation measures that would prevent the impact