DESKTOP PALAEONTOLOGICAL ASSESSMENT FOR THE PROPOSED GREATER BULWER-DONNYBROOK BULK WATER SUPPLY SCHEME (GBDBWSS): HARRY GWALA DISTRICT MUNICIPALITY, KWAZULU-NATAL

FOR

Kinvig and Associates

DATE: 14 December 2016

By

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EXECUTIVE SUMMARY

Gideon Groenewald was appointed by Kinvig and Associates to undertake a Desktop Survey, assessing the potential Palaeontological Impact related to the proposed Greater Bulwer-Donnybrook Bulk Water Supply Scheme (GBDBWSS): Harry Gwala District Municipality, Kwazulu-Natal.

This report forms part of the Environmental Impact Assessment and complies with the requirements of the South African National Heritage Resource Act No 25 of 1999, as well as the KwaZulu-Natal Heritage Act No 4 of 2008. In accordance with Section 38 (Heritage Resources Management), a Heritage Impact Assessment (HIA) is required to assess any potential impacts to palaeontological heritage within the development footprint of the development. Geological structures associated with groundwater are mapped as well as known and potential spring sites that are part of the National Heritage of this area.

The study area for the Desktop Survey, assessing the potential Palaeontological Impact related to the proposed Greater Bulwer-Donnybrook Bulk Water Supply Scheme (GBDBWSS): Harry Gwala District Municipality, Kwazulu-Natal is underlain by rocks of the Permian to Triassic aged Ecca and Beaufort Groups as well as Jurassic aged dolerite of the Karoo Supergroup. Quaternary aged deposits of the Masotcheni Formation and alluvium covers low lying areas.

Significant fossils are expected in outcrops on site and a Phase 1 site inspection must be done to prepare a “chance Find Protocol” for this project before deep excavation (>1.5m) are done in all areas allocated a High to Very High Palaeontological Sensitivity (orange and red colours). If fossils are recorded it will contribute significantly to our knowledge of the Palaeontological Heritage of KwaZulu-Natal.

Significant Primary and Secondary Groundwater Aquifers are associated with the alluvium and dolerite contact zones on site and design of all water distribution and treatment works for potential pollutant must ensure that no polluted water reaches these important National Heritage Sites.

It is recommended that:

- The EAP and ECO must be informed of the fact that a High to Very High Palaeontological Sensitivity is allocated to significant parts of the study area. A suitably qualified Palaeontologist must be employed to ascertain the significance of the Palaeontological Impact, do a Phase 1 Site inspection, prepare a “Chance Find Protocol” document, apply for a permit to collect fossils and arrange for a well-planned Phase 2 PIA site visit during construction in all areas where the Phase 1 study confirms the presence of or very high possibility of finding significant fossils. If fossils are recorded during any stage of the development the HIA specialist must be informed to take immediate and appropriate action to preserve them.
- These recommendations must be included in the EMPr of this project.

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INTRODUCTION

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Legal Requirements

This Palaeontological Assessment forms part of the Heritage Impact Assessment (HIA) and complies with the requirements of the South African National Heritage Resource Act No 25 of 1999 as well as the KwaZulu-Natal Heritage Act No 4 of 2008. In accordance with Section 38 of the National Resources Act No 25 of 1999 (Heritage Resources Management), a HIA is required to assess any potential impacts to palaeontological heritage within the development footprint.

Categories of heritage resources recognised as part of the National Estate in Section 3 of the Heritage Resources Act, and which therefore fall under its protection, include:

- geological sites of scientific or cultural importance;
- objects recovered from the soil or waters of South Africa, including archaeological and palaeontological objects and material, meteorites and rare geological specimens; and
- objects with the potential to yield information that will contribute to an understanding of South Africa's natural or cultural heritage.

Aims and Methodology

A Desktop investigation is often the last opportunity to record the fossil heritage within the development footprint. These records are very important to understand the past and form an important part of South Africa's National Estate.

Following the "SAHRA APM Guidelines: Minimum Standards for the Archaeological & Palaeontological Components of Impact Assessment Reports" the aims of the palaeontological impact assessment are:

- to identifying exposed and subsurface rock formations that are considered to be palaeontological significant;

- to assessing the level of palaeontological significance of these formations;
- to comment on the impact of the development on these exposed and/or potential fossil resources,
- to comment on the impact of the development on existing and potential groundwater resources
- to make recommendations as to how the developer should conserve or mitigate damage to these resources.

Prior to a field investigation a preliminary assessment (desktop study) of the topography and geology of the study area is made using appropriate 1:250 000 geological maps (2928 Drakensberg; 2930 Durban; 3028 Kokstad;3030 Port Shepstone) in conjunction with Google Earth. Potential fossiliferous rock units (groups, formations, etc) and groundwater aquifers are identified within the study area and the known fossil heritage within each rock unit is inventoried from the published scientific literature, previous palaeontological impact studies in the same region and the author's field experience on similar projects.

Priority palaeontological areas are identified within the development footprint to focus the field investigator's time and resources. The aim of the desktop survey is to document any exposed fossil material and to assess the palaeontological potential of the region in terms of the type and extent of rock outcrop in the area that might be affected by the development.

The likely impact of the proposed development on local fossil heritage is determined on the basis of the palaeontological sensitivity of the rock units concerned and the nature and scale of the development itself, most notably the minimal extent of fresh bedrock excavation envisaged. The different sensitivity classes used is explained in **Table 1** below.

Table 1: Palaeontological sensitivity analysis outcome classification

PALAEONTOLOGICAL SIGNIFICANCE/VULNERABILITY OF ROCK UNITS	
The following colour scheme is proposed for the indication of palaeontological sensitivity classes. This classification of sensitivity is adapted from that of Almond et al (2008) and Groenewald et al., (2014)	
RED	Very High Palaeontological sensitivity/vulnerability. Development will most likely have a very significant impact on the Palaeontological Heritage of the region. Very high possibility that significant fossil assemblages will be present in all outcrops of the unit. Appointment of professional palaeontologist, desktop survey, phase I Palaeontological Impact Assessment (PIA) (field survey and recording of fossils) and phase II PIA (rescue of fossils during construction) as well as application for collection and destruction permit compulsory. All groundwater resources, present and potential are included in this category for Palaeontological Sensitivity.
ORANGE	High Palaeontological sensitivity/vulnerability. High possibility that significant fossil assemblages will be present in most of the outcrop areas of the unit. Fossils most likely to occur in associated sediments or underlying units, for example in the areas underlain by Transvaal Supergroup dolomite where Cenozoic cave deposits are likely to occur. Appointment of professional palaeontologist, desktop survey and phase I Palaeontological Impact Assessment (field survey and collection of fossils) compulsory. Early application for collection permit recommended. Highly likely that a Phase II PIA will be applicable during the construction phase of projects.
GREEN	Moderate Palaeontological sensitivity/vulnerability. High possibility that fossils will be present in the outcrop areas of the unit or in associated sediments that underlie the unit. For example, areas underlain by the Gordonia Formation or undifferentiated soils and alluvium. Fossils described in the literature are visible with the naked eye and development can have a significant impact on the Palaeontological Heritage of the area. Recording of fossils will contribute significantly to the present knowledge of the development of life in the geological record of the region. Appointment of a professional palaeontologist, desktop survey and phase I PIA (ground proofing of desktop survey) recommended.

BLUE	Low Palaeontological sensitivity/vulnerability. Low possibility that fossils that are described in the literature will be visible to the naked eye or be recognized as fossils by untrained persons. Fossils of for example small domal Stromatolites as well as micro-bacteria are associated with these rock units. Fossils of micro-bacteria are extremely important for our understanding of the development of Life, but are only visible under large magnification. Recording of the fossils will contribute significantly to the present knowledge and understanding of the development of Life in the region. Where geological units are allocated a blue colour of significance, and the geological unit is surrounded by highly significant geological units (red or orange coloured units), a palaeontologist must be appointed to do a desktop survey and to make professional recommendations on the impact of development on significant palaeontological finds that might occur in the unit that is allocated a blue colour. An example of this scenario will be where the scale of mapping on the 1:250 000 scale maps excludes small outcrops of highly significant sedimentary rock units occurring in dolerite sill outcrops. Collection of a representative sample of potential fossiliferous material recommended. At least a Desktop Survey is recommended.
GREY	Very Low Palaeontological sensitivity/vulnerability. Very low possibility that significant fossils will be present in the bedrock of these geological units. The rock units are associated with intrusive igneous activities and no life would have been possible during emplacement of the rocks. It is however essential to note that the geological units mapped out on the geological maps are invariably overlain by Cenozoic aged sediments that might contain significant fossil assemblages and archaeological material. Examples of significant finds occur in areas underlain by granite, just to the west of Hoedspruit in the Limpopo Province, where significant assemblages of fossils and clay-pot fragments are associated with large termite mounds. Where geological units are allocated a grey colour of significance, and the geological unit is surrounded by very high and highly significant geological units (red or orange coloured units), a palaeontologist must be appointed to do a desktop survey and to make professional recommendations on the impact of development on significant palaeontological finds that might occur in the unit that is allocated a grey colour. An example of this scenario will be where the scale of mapping on the 1:250 000 scale maps excludes small outcrops of highly significant sedimentary rock units occurring in dolerite sill outcrops. It is important that the report should also refer to archaeological reports and possible descriptions of palaeontological finds in Cenozoic aged surface deposits. At least a Desktop Survey is recommended.

When rock units of moderate to high palaeontological sensitivity are present within the development footprint, palaeontological mitigation measures should be incorporated into the Environmental Management Plan.

Scope and Limitations of the Desktop Study

The study will include:

i) an analysis of the area's stratigraphy, age and depositional setting of fossil-bearing units;
ii) a review of all relevant palaeontological and geological literature, including geological maps, and previous palaeontological impact reports;
iii) data on the proposed development provided by the developer (e.g. location of footprint, depth and volume of bedrock excavation envisaged) and
iv) where feasible, location and examination of any fossil collections from the study area (e.g. museums);

The key assumption for this scoping study is that the existing geological maps and datasets used to assess site sensitivity are correct and reliable. However, the geological maps used were not intended for fine scale planning work and are largely based on aerial photographs alone, without ground-truthing. There is also an inadequate database for fossil heritage for much of the RSA, due to the small number of professional palaeontologists carrying out fieldwork in RSA and the Kingdom of Lesotho. In many new areas, no professional palaeontologist has surveyed the area in the past.

These factors may have a major influence on the assessment of the fossil heritage significance of a given development and without supporting field assessments may lead to either

- an underestimation of the palaeontological significance of a given study area due to ignorance of significant recorded or unrecorded fossils preserved there,
- an overestimation of the palaeontological sensitivity of a study area, for example when originally rich fossil assemblages inferred from geological maps have in fact been destroyed by weathering, or are buried beneath a thick mantle of unfossiliferous "drift" (soil, alluvium etc.).

Locality and Proposed Development

The Harry Gwala District Municipality plans to upgrade the present status of the Greater Bulwer-Donnybrook Bulk Water Supply Scheme (GBDBWSS) in KwaZulu-Natal (Figure 1).

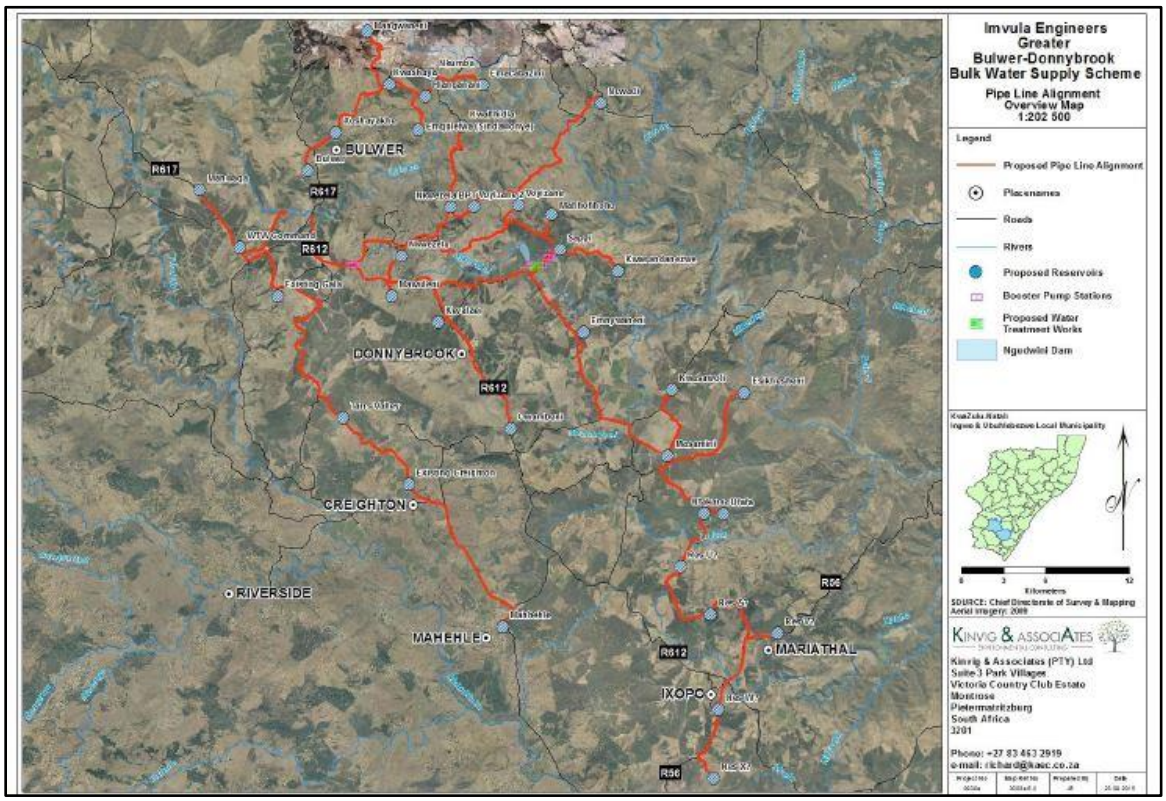

Figure 1: Layout of the GBDBWSS Project

The Harry Gwala District Municipality proposes to construct two hundred and seventy (270 km) kilometres of potable water pipe mains of diameter 110 mm to 550 mm, for the supply of water from the *Ngudwini* Dam and *Stephen Dlamini (Bulwer)* Dam to new bulk water infrastructure in the Harry Gwala District Municipality. The proposed project infrastructure is indicated in Figure 1 above:

- 270 km of potable water pipeline of size 110 mm to 550 mm;
- abstraction points from dams (*Ngudwini* Dam and *Stephen Dlamini (Bulwer)* Dam (under construction)) with existing Environmental Authorisations;
- water treatment works;
- main pump stations with 3 booster pump stations;
- 37 reservoirs with storage capacities ranging from 250 KL to 10 ML; and Associated infrastructure.

The majority of the pipeline is proposed to follows existing road servitudes (alongside the R612 from the R617 to Donnybrook; and to the east on other un-named roads) connecting existing and new reservoirs and pipelines.

GEOLOGY

The study area is underlain predominantly by Permian aged rocks of the, Ecca, and Beaufort Groups and Dolerite of the Karoo Supergroup as well as Quaternary aged sand and silt of the Masotcheni Formation and Alluvium of the local rivers (Figure 2).

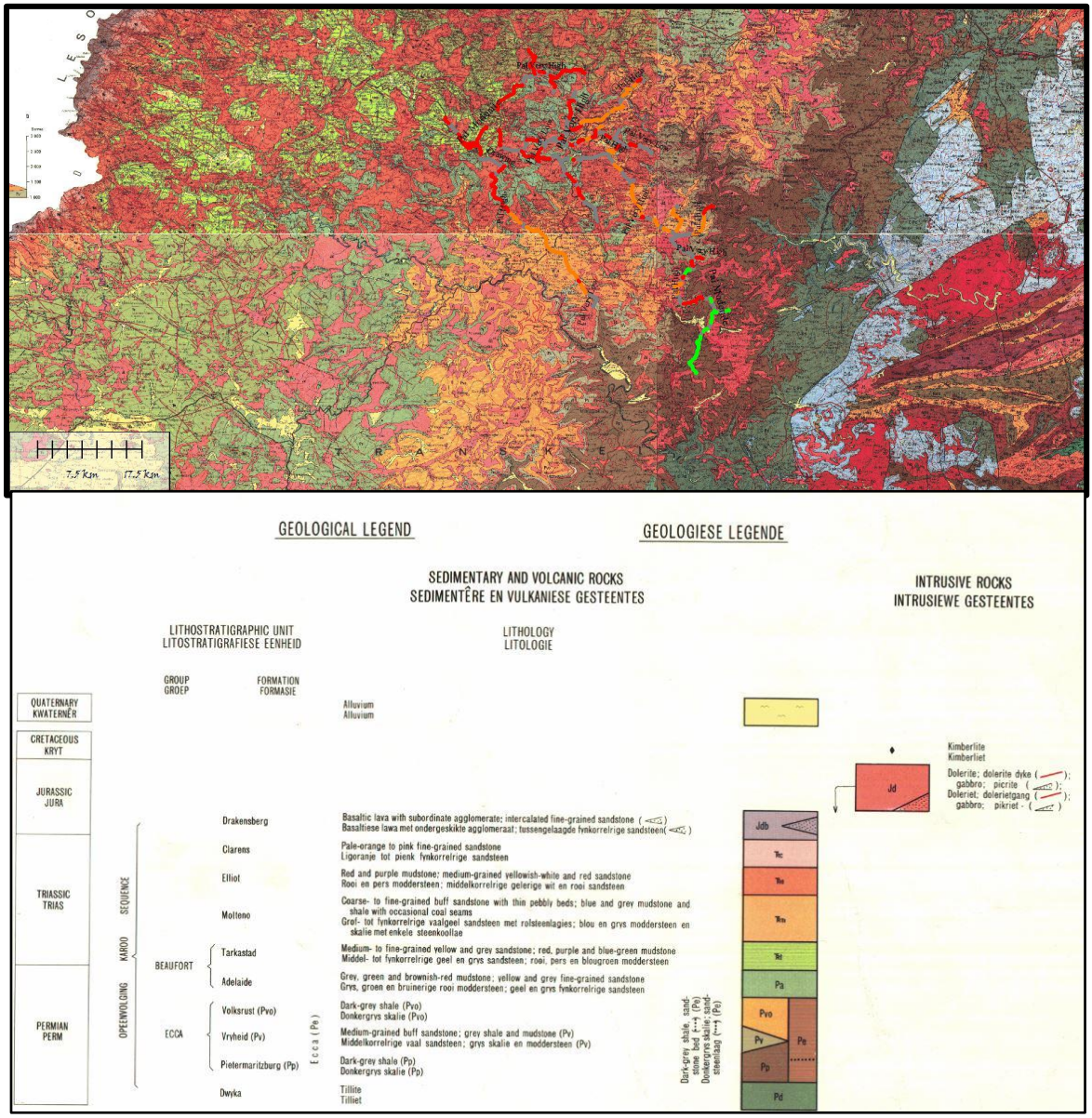

Figure 2: Geology of the study area

Karoo Supergroup

Ecca Group

Pietermaritzburg Formation (Pp)

The Permian aged Pietermaritzburg Formation is a monotonous sequence of dark grey shale and mudstone, representing a marine deposit in the north-eastern part of the Karoo Basin and no outcrops have been recorded in the study area (Johnson et al, 2009).

Vryheid Formation

The Permian aged Vryheid formation consists mainly of interbedded coarse-grained sandstone and dark grey mudstone and shale. North of the study area this formation is extensively mined for economic quantities of coal (Johnson et al, 2009). The Vryheid Formation might be a time-equivalent of the Whitehill Formation in the south of the Karoo Basin.

Volksrust Formation (Pvo)

The Permian aged Volksrust Formation is an assemblage of fine-grained sediments, consisting mainly of dark grey mudstone and shale. The deposits represent Permian aged marine deposits that were deposited in offshore shelf, but possibly also nearshore / lacustrine / lagoonal environments in this part of Gondwanaland. The upper part of the formation becomes more sandstone rich and is indicative of a westward migration of a deltaic system into the predominantly marine environments that existed during the Permian in this part of the Karoo Basin (Johnson et al, 2009). The upper part of the Volksrust Formation is more sandstone rich and there is an indication that this units might correlate with the Waterford Formation in the south of the basin (Groenewald, 2016). The new information need to be assessed by SACS.

Beaufort Group

The Permian to Triassic aged Beaufort Group consists of two distinct units, a lower Adelaide Subgroup and an upper Tarkastad Subgroup. The Permian aged Adelaide Subgroup, comprising the Normandien Formation, consists of darker coloured mudstones and sandstone and is overlain by the Triassic aged Tarkastad Subgroup with predominantly red mudstone and sandstone.

Adelaide Subgroup, Normandien Formation

The Normandien Formation is a fluvial meandering river deposit (Groenewald, 1990) and comprises of a sequence of coarse and fine-grained sandstone with minor coal beds

(Johnson et al 2009). SACS (South African Committee for Stratigraphy) still needs to publish a formal note on the lithostratigraphy of the Escarpment at Harrismith. The most recent formal academic study of the complete section was done by Groenewald (1984, 1989) and it is now an accepted fact that the entire Adelaide Subgroup is formally referred to as the Normandien Formation (Groenewald, 2016).

The Normandien Formation comprises the lower part of the Beaufort Group along the Drakensberg Escarpment and on some 1:250 000 sheets is referred to as the Adelaide Formation. In most of the outcrop areas in KwaZulu-Natal the Adelaide Subgroup consists primarily of a lower deltaic facies, historically mostly referred to as the Estcourt Formation and an upper fluvial facies referred to as the Normandien Formation (Groenewald, 1990, 1996; Johnson et al 2009).

Referring to Table 4.1, the geological history of the Drakensberg Escarpment region represents the final sedimentation into the Ecca Sea about 260 million years ago. Deltaic deposits of the Estcourt Formation contain evidence of an abundance of marine and probably estuarine invertebrates that left a wealth of trace fossils in the rock record (MacRae, 1999; McCarthy and Rubidge, 2005). The overlying fluvial deposits of the Normandien Formation (Groenewald, 1989; Johnson et al 2006) with prominent sandstone members (Rooinek and Schoondraai Members) represent a progressive basin ward migration of the depositional system.

The Tarkastad Subgroup

Katberg/Verkykerskop Formations

The Katberg Formation is defined as the lower sandstone-rich unit of the Tarkastad Subgroup and consists of fine-grained sandstone with a main provenance to the southeast. The Verkykerskop Formation is a time equivalent of the Katberg Formation, but consists predominantly of coarse-grained sandstone with a provenance to the northeast (Groenewald, 1996; Johnson et al, 2006).

Burgersdorp/Driekoppen Formations

The Katberg and Verkykerskop formations are overlain by red mudstones of the Burgersdorp and Driekoppen formations (Groenewald 1996; Johnson et al, 2006).

Dolerite (Jd)

Small sections of the development cut into Jurassic aged dolerite sill areas and although not mapped on this scale, several dolerite dyke structures are known to be present in this study area.

Masotcheni Formation (Qm)

Quaternary aged sandy and clayey colluvium and alluvial soils and palaeosoils that covers large low lying parts of the landscape, with special reference to the footslopes of the hills.

Alluvium

Quaternary aged sandy alluvium represent recent deposits of sand and sandy clay along the floodplains of the local rivers in KwaZulu-Natal.

Groundwater Related Features

The study area is underlain by shale of the Pietermaritzburg Formation, coarse-grained sandstone of the Vryheid Formation and shale of the Volksrust Formation, sandstone and shale of the Normandien Formation and fine grained sandstone of the Katberg Formation. All these secondary aquifers rocks are relatively low yielding aquifers. The dolerite sill structures and colluvium or alluvium in the valleys can be relatively good aquifers but the most vulnerable secondary aquifers are the linear dolerite dyke aquifers. These structures are mapped out as Highly Sensitive sites on the Palaeontological Sensitivity map.

The sandy soils of the colluvial and alluvial deposits are very good primary aquifer units and must be protected against groundwater pollution.

PALAEONTOLOGY

Ecca Group

Pietermaritzburg Formation (Pp)

Fossils are generally absent from the Formation although trace fossils have been recorded from the upper layers of the Pietermaritzburg Formation by Linstrom (1987).

Vryheid Formation

The Vryheid Formation is well-known for the occurrence of coal beds that resulted from the accumulation of plant material over long periods of time. Plant fossils described by Bamford (2011) from the Vryheid Formation are; *Azaniodendron fertile, Cyclodendron leslii, Sphenophyllum hammanskraalensis, Annularia sp., Raniganjia sp., Asterotheca spp., Liknopetalon enigmata, Glossopteris > 20 species, Hirsutum 4 spp., Scutum 4 spp., Ottokaria 3 spp., Estcourtia sp., Arberia 4 spp., Lidgetonnia sp., Noeggerathiopsis sp. and Podocarpidites sp.*

According to Bamford (2011) “Little data have been published on these potentially fossiliferous deposits. Around the coalmines there is most likely to be good material and yet in other areas the exposures may be too poor to be of interest. When they do occur, fossil plants are usually abundant and it would not be feasible to preserve and maintain all the sites, however, in the interests of heritage and science such sites should be well recorded, sampled and the fossils kept in a suitable institution.

Although no vertebrate fossils have been recorded from the Vryheid Formation, invertebrate trace fossils have been described in some detail by Mason and Christie (1985). It should be noted, however, that the aquatic reptile, *Mesosaurus*, which is the earliest known reptile from the Karoo Basin, as well as fish (*Palaeoniscus capensis*), have been recorded in equivalent-aged strata in the Whitehill Formation in the southern part of the basin (MacRae, 1999; Modesto, 2006). Indications are that the Whitehill Formation in the main basin might be correlated with the mid-Vryheid Formation. If this assumption proves correct, there is a possibility that Mesosaurus could be found in the Vryheid Formation (Catuneanu et al 2005).

The late Carboniferous to early Jurassic Karoo Supergroup of South Africa includes economically important coal deposits within the Vryheid Formation of Natal. The Karoo sediments are almost entirely lacking in body fossils but ichnofossils (trace fossils) are locally abundant. Modern sedimentological and ichnofaunal studies suggest that the north-eastern part of the Karoo basin was marine. In KwaZulu-Natal a shallow basin margin accommodated a prograding fluviodeltaic complex forming a broad sandy platform on which coal-bearing sediments were deposited. Ichnofossils include U-burrows (formerly *Corophioides*) which are assigned to ichnogenus *Diplocraterion* (Mason and Christie, 1985).

Volksrust Formation

Extremely well- defined and significant trace fossils as well plant fossils of the Glossopteris Assemblage have been described from the upper layers of the Formation (Johnson et al. 2009; Groenewald, 2016). Concretions containing significant coprolites of fish and some bone material are present in this formation just to the east of Ladysmith and the recording of these remains are now the first recordings of its kind in KwaZulu-Natal. It is highly likely that similar recordings will be made during the construction phase of this road. It is recommended that a Phase 1 PIA field assessment is required by AMAFA. A collection permit for fossils will be required for this project.

The bivalve *Megadesmus* is described from the Late Permian Volksrust Shale Formation in the north-eastern Karoo Basin, South Africa; this is the first reported discovery of this genus in Africa. The fossil is large, 9 cm dorsally and 8.4 cm laterally, and both valves are articulated indicating minimum transport after death. The bivalve was

encased in interbedded siltstone-shale that constitutes the distal sediments of a prograding delta at the Beaufort –Ecca Group boundary. *Megadesmus* is known from other continents (Australia, India, Siberia, South America and Tasmania) where its presence indicates exclusively marine conditions. The implication for the north eastern Karoo Basin during the Late Permian is that a marine enclave still existed in this geographic area and that terrestrial conditions did not yet prevail as in the southern basin region (Cairncross, 2005).

Beaufort Group

These 250 million year old rocks record the largest known extinction event, the end-Permian mass extinction, in which most of the known species died out.

The Beaufort Group is well-known for its richness in fossils of vertebrates and also includes several recordings of unique vertebrate burrows. (Groenewald 1991; Johnson and Verster, 1994; Rubidge, 1995; Groenewald 1996; Groenewald et al, 2001 and; Johnson et al, 2009, Groenewald, 2016).

Adelaide Subgroup (In some areas mapped as the Adelaide Formation, now formally the Normandien Formation)

The Adelaide Subgroup overlies the Volksrust Formation of the Ecca Group and the transition from deep water deposits of the Volksrust Formation to pro-delataic and deltaic deposits of the Beaufort Group present fieldworkers with problems in mapping these units (Groenewald, 1984; Muntingh, 1989; Johnson and Verster, 1994; Johnson et al, 2009). The Adelaide Subgroup comprises the *Daptocephalus* (previously *Dicynodon)* Assemblage Zone (and possibly the underlying *Cistecephalus* Assemblage Zone (Van der Walt et al, 2010; Viglietti et al, 2016; Groenewald, 2016).

Normandien Formation

The Normandien Formation comprises all the sediments of the Adelaide Subgroup and includes the Estcourt Formation (Johnson and Verster, 1989). The Karoo Basin in South Africa is well known for the fact that it represents the most complete sequence of sedimentary history in Gondwana and contains the remains of most of the therapsids (ancient ancestors of mammals) that roamed the Earth during the Permian Period (Rubidge, 1995; MacRae, 1999; McCarthy and Rubidge, 2005). The most significant geological event recorded in this sequence is the end-Permian mass extinction event (EPME) that occurred 252.4 million years ago when much of all life on Earth was terminated. This event is probably associated with the Schoondraai Member of the Normandien Formation. The 2010 excavations for the Bedford Dam of the Ingula Pumped Storage Scheme (Groenewald, 2011) provided a unique opportunity to collect vertebrate fossils, trace fossils of invertebrates (i.e. trackways, burrows) as well as plants from the rocks that were deposited during the Late Permian.

Permian Vertebrates (255 to 252 million years ago)

Permian vertebrates from the *Cistecephalus* and *Daptocephalus* assemblage zones in the main Karoo Basin include at least three genera of fish, four genera of amphibians, eight genera of parareptiles (the sister group to true reptiles), three genera of diapsid reptiles (i.e. true reptiles) and 66 genera of therapsids (ancestors of mammals) (Rubidge 1995; Smith et al, 2012). Fish, amphibians, parareptiles and diapsid reptiles from these assemblage zones are relatively rare, both in terms of number of species and number of individuals. However, therapsid fossils are known by the hundreds and form the bulk of vertebrate fossils collected from these assemblage zones.

Dicynodonts ("Two Dog Toothed animals") are well-known herbivorous (plant-eating) therapsids from the Karoo Basin. They reached up to 4 metres in length and are characterized by a horny beak and tusks. Some of the oldest examples of this group have never been recorded from the Harrismith escarpment due to deep weathering of the mudstones. One such animal is the dicynodont *Rachiocephalus,* only recorded from Warden, far towards the west (Groenewald, 1984). However, at least 35 dicynodont genera are known from the Beaufort Group in South Africa and although only a few genera have been recorded from KwaZulu Natal strata, this is most likely due to a lack of collecting activity as the most intensive collecting has taken place in the main Karoo Basin. KwaZulu Natal strata however, have the potential to contain at least 21 dicynodont genera, which are known from the Permian *Cistecephalus* and *Daptocephalus* assemblage zones in the main Karoo Basin, and these deposits are also preserved in KwaZulu Natal.

The most important indicator of the beginning of the largest and most severe mass extinction on Earth is the disappearance of almost all of the dicynodont therapsids. Only one dicynodont genus, *Lystrosaurus*, has been recorded from both sides of the Permo-Triassic boundary. After this bottle neck, however, the dicynodonts recovered and diversified during the Middle Triassic.

Although the dicynodonts were by far the most abundant vertebrates in South Africa during the Permian, other therapsids lived and often predated upon these herbivores. The gorgonopsians and therocephalians are such examples.

Gorgonopsians were one of the most fearsome predators to have roamed the Earth. These animals had unusually long canines nearly 20 cm in length (Figures 4). Gorgonopsians were the dominant predators during the Late Permian. They grew up to 5 metres in length and are often termed the 'sabred-toothed cats' of the Permian due to their exceptionally long canines. They were slightly more mammal-like compared to their

ancestors and several key features in the skull and skeleton show that they had begun to move and feed similar to mammals. During the excavation of a gorgonopsian at Bedford Dam, a small skull of a dicynodont was found associated with its ribs, possibly representing the last meal of the predator (Figure 3). These unique finds are only possible if the palaeontologist is on site at all times during an excavation.

Figure 3: Example of a fossil (Gorgonopsian skull) found at Ingula Transfer Scheme.

At least 19 gorgonopsian genera are known from the *Cistecephalus* and *Daptocephalus* assemblage zones of the main Karoo Basin, and there is thus a potential for finding several of these genera in KwaZulu Natal. Gorgonopsians were the top predators during the Late Permian as their remains are relatively rare, as they were not nearly as abundant as the herbivorous dicynodonts. Consequently, any recovery of a gorgonopsian fossil is a significant find.

Another group of therapsids, the biarmosuchians, are closely related to gorgonopsians but are more primitive. Although exceptionally rare, biarmosuchians have been recovered from the *Cistecephalus* and *Daptocephalus* assemblage zones of the main Karoo Basin. Five genera (Smith et al, 2012) are currently known from these strata and could potentially be recovered from equivalent strata in Kwazulu Natal as well.

Figure 4: Reconstruction of three therapsid genera from the Late Permian. They are *Lystrosaurus* (lower left), *Dicynodon* (upper left) and a Gorgonopsid (right).

The other main group of predatory therapsids during the Permian were the therocephalians. They looked superficially similar to mammals and are one of the few vertebrate groups to have survived the end-Permian mass extinction relatively unscathed and are thus important specimens in Permo-Triassic research pertaining to the end-Permian mass extinction. Twenty-two therocephalian genera have been recovered from the *Cistecephalus* and *Daptocephalus* assemblage zones of the main Karoo Basin (Smith et al, 2012), and have the potential to be preserved in equivalent strata in Kwazulu Natal.

Cynodonts are the most mammal-like therapsids and are the direct ancestors of living mammals. They are thus fundamental to research on the origin and evolution of mammals. At least 26 cynodont genera have been recovered from the main Karoo Basin, four of which are known from the Permian *Cistecephalus* and *Daptocephalus* assemblage zones (Botha-Brink et al, 2012; Smith et al, 2012; Smith pers. Comm. 2012), and may be potentially preserved in equivalent Kwazulu Natal deposits.

Large burrows, associated with the large dicynodonts *Daptocephalus* and *Lystrosaurus maccaigi* have also been discovered in the uppermost portion of the

Daptocephalus Assemblage Zone in the main Karoo Basin (Botha-Brink, pers. Comm., 2012) and have the potential to be preserved in equivalent strata in Kwazulu Natal.

Plant and Insect fossils from the Permian Normandien Formation

The Normandien Formation is well known for rich assemblages of plant fossils, mainly *Glossopteris, Phyllotheca* and other flora including ferns, clubmosses, liverworts and true mosses (McCarthy and Rubidge, 2005). Insect remains have been recorded from several localities (Lacey et al, 1975; Johnson and Verster, 1994 and Michael Motovski, pers comm., 2012). Of special note is a locality near Bulwer that contains numerous plant and insect fossils. Insect families include Perlaria (including one holotype), Protorthoptera, Protelytroptera, Miomoptera (including one holotype), Psocoptera/Hemiptera, Homoptera, Neuroptera (including one holotype) and Mecoptera (including two holotypes). This site comprises one of the richest fossil insect sites in the world, but is currently unprotected and under constant destruction as was the case with localities at Mooi River, Lidgetton, Mount West, Balgowan, and Far End.

Triassic Vertebrates (252 to 180 million years ago)

Numerous remains representing the survivors of the end-Permian mass extinction have been recovered from localities in the Free State and Eastern Cape Provinces in South Africa. Although no evidence of the extinction event is known from the Drakensberg Escarpment, survivors of the event are associated with the Early Triassic *Lystrosaurus* Assemblage Zone which is mostly represented by the Harrismith Member (Groenewald, 1989; Muntingh, 1989). *Lystrosaurus*, after which the assemblage zone is named, is the most abundant vertebrate found directly after the end-Permian mass extinction event. It is the only dicynodont genus found on either side of the Permo-Triassic boundary. Other Early Triassic vertebrates include large predators such as the archosauriform reptile *Proterosuchus* and the therocephalian therapsid *Moschorhinus*, as well as more relatively abundant cynodonts such as the insectivorous *Thrinaxodon* and *Galesaurus* (Rubidge et al, 1995; MacRae, 1999; Botha and Smith 2006). All vertebrates from this assemblage zone formed an important part of the recovery ecosystem following the end-Permian mass extinction and thus any finds from this zone are significant. Approximately one fish genus, 10 amphibian genera, five parareptile genera, five diapsid reptile genera, two dicynodont genera, seven therocephalian genera and four cynodont genera have been recorded from the *Lystrosaurus* Assemblage Zone, many of which have been recorded from the Harrismith Member in Kwazulu Natal.

The lower part of the *Lystrosaurus* Assemblage Zone is also well-known for preserving burrows of various sizes that may be associated with invertebrates (e.g. *Katbergia*) and vertebrates such as dicynodonts, therocephalians and cynodonts. These

important trace fossils provide important information about the behaviour of these animals (Botha and Smith, 2006; Modesto and Botha-Brink, 2010).

In the study area, there are numerous localities that contain the dicynodont *Lystrosaurus curvatus* . This animal is restricted to the uppermost strata of the Permian *Daptocephalus* Assemblage Zone and lowermost strata of the Triassic *Lystrosaurus* Assemblage Zone, and as such, acts as a biostratigraphic marker for the Permo-Triassic boundary (Botha and Smith, 2007). Thus, any locality that contains *Lystrosaurus curvatus* has the potential to contain a complete sequence marking the end-Permian mass extinction, and should thus be considered extremely sensitive.

Tarkastad Subgroup

Katberg/Verkykerskop Formations

The Katberg and Verkykerskop formations are well-defined sandstone rich units along the Drakensberg Escarpment and the lower boundary of the Tarkastad Subgroup is mapped out over the entire escarpment. The Katberg and Verkykerskop Formations are associated with the middle and upper portion of the *Lystrosaurus* Assemblage Zone.

Burgersdorp/Driekoppen Formations

The Burgersdorp/Driekoppen formations are associated with the Middle Triassic *Cynognathus* Assemblage Zone (Rubidge, 1995). Current database information shows that no fossils from this time have been found in Kwazulu Natal, but the lack of fossils may be ascribed to a lack of intensive collecting, as numerous vertebrate fossils have been recorded from this formation in other areas such as Qwaqwa and Golden Gate National Park (Groenewald et al, 2001; Rubidge 1995; Smith et al, 2012). These include seven fish genera, 16 amphibian genera, six parareptile genera, six diapsid reptile genera, four dicynodont genera, two therocephalian genera and 11 cynodont genera (Smith et al, 2012; Botha-Brink, pers. Comm. 2012). One of the most spectacular finds are casts of vertebrate burrows containing fossils of the cynodont *Trirachodon* near the town Clarens (Groenewald et al, 2001). Other burrows from the *Cynognathus* Assemblage Zone have been found associated with procolophonid parareptiles in the main Karoo Basin (Botha-Brink, pers. Comm. 2012).

Dolerite (Jd)

Dolerite is an igneous rock and will not contain fossils. It is however very important to note that dolerite contact zones with sedimentary rock units are the most important aquifer rocks in KwaZulu-Natal. These zones can follow dolerite sill boundaries but are also associated with very extensive linear dolerite dyke systems that are rarely mapped out on large scale geological maps.

Masothcheni Formation (Qm)

The Quaternary aged sediments of the Masotcheni Formation has up to 2016 been regarded as of low Palaeontological significance (Groenewald et al 2014). Very recent (August 2016) finds of significant vertebrate remains in this Formation just to the east of Ladysmith (PIA for Lombardskop Bulk Water Pipeline Development in progress, Groenewald, 2016) has now caused the upgrading of this formation to highly significant for Palaeontological Heritage impact. Although still unidentified, the vertebrate remains might indicate significant finds of animals as young as 5 million years ago in the sediments on the footslopes of landscapes in KwaZulu-Natal. That can lead to significant finds of similar fossils as those discovered at Cornelia in the Free State Province.

Alluvium

No significant fossils of Quaternary age have to date been recorded from the alluvium of the local rivers to date, but very significant fossils were recorded in similarly aged sediments elsewhere in KwaZulu-Natal, where these finds are now recorded for the first time. It is therefore recommended that the ECO must be aware of the possibility of finding vertebrate remains of Quaternary aged animals. If recorded, these remains will contribute significantly to our knowledge of the past eco-systems in this part of South Africa during the Quaternary.

GROUNDWATER AQUIFERS AND HERITAGE ITEMS

The groundwater heritage items are related to known and potential groundwater resources such as recorded natural spring sites as well as potential linear aquifers that can be affected by the proposed development.

No significant spring sites are recorded on the present 1:250 000 geological maps (2928 Drakensberg; 2930 Durban; 3028 Kokstad;3030 Port Shepstone) and no obviously important potential linear aquifers (fault zones) cut the study area. No further significant influence on this National Heritage Item is foreseen by the Paleontological Impact Specialist.

PALAEONTOLOGICAL IMPACT AND MITIGATION

The predicted palaeontological impact of the development is based on the initial mapping assessment and literature reviews as well as information gathered during the desktop investigation.

The desktop investigation confirms that the study area is underlain by fine-grained khaki-coloured to dark grey shale beds of the Pietermaritzburg Formation, coarse-grained

sandstone of the Vryheid Formation and shale of the Volksrust Formation of the Ecca Group. Only very small sections are exposed in moderately sensitive Pietermaritzburg and Very Highly Sensitive Vryheid Formation but extensive excavation will be done in the Highly Sensitive Volksrust Formation. A field survey is recommended to confirm the quality of outcrops of these sensitive formations before construction starts (Phase 1 investigation).

The outcrops of the Beaufort Group are all Very Highly Sensitive for Palaeontological Heritage and a Phase 1 site visit and report must be compiled before construction commences in these areas.

A “Chance Find Protocol” must be compiled by the Palaeontologist for these areas and must be included in the Phase 1 assessment report.

The dolerite sills of the Karoo Supergroup has a Very Low Palaeontological Sensitivity and only need a drive thorough confirmation that no pockets of highly or very highly significant sediments, that were not included on the 1:250 000 scale maps, are present.

The deep sandy and clay deposits of the Masotcheni Formation and Alluvium of the local rivers, which leads to dark or red coloured vertic soils or sand cover must be inspected during construction and the ECO needs to be vigilant and report any bone remains to the Palaeontologist.

An information session must form part of the EMPr for the Project where discussions are planned between the Palaeontologist, the Manager of the contracting team and the ECO to indicate what sediments to look out for the discovery of significant fossils.

Sections of the development cuts into Very Highly significant Vryheid and Normandien Formation sediments and several sections cut significant Very highly sensitive groundwater aquifers.

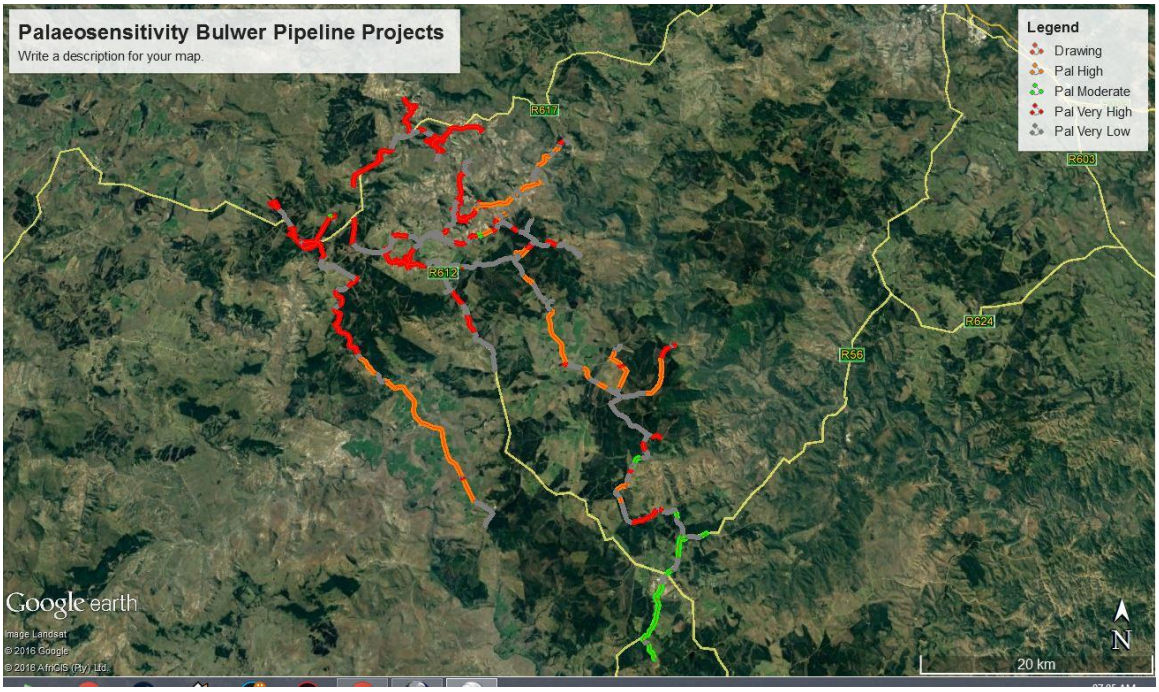

Figure 5: Palaeontological Sensitivity of the Study Area. A Very High Palaeontological sensitivity is allocated to most of the development area underlain by Normandien Formation sediments. For colour coding see Table 1

Due to weathering, no well-preserved fossils are expected before deep (>1.5m) excavations are completed in the areas underlain by Volksrust Shale and the initial field surveys will only give an indication of the potential exposure during construction. Exposure of bedrock during excavation might however result in the exposure of significant plant and trace fossils in the shale as well as possible vertebrate fossils in the Normandien Formation and alluvium. This possibility will be addressed in a “Chance Find Protocol” following the Phase 1 Site Inspection report. Recording of fossils will contribute significantly to our understanding of previous eco-systems and must be reported to the HIA specialist for appropriate action.

No significant fossil remains are expected in all areas underlain by Dolerite and excavation in all these areas can proceed with no further mitigation for Palaeontological Heritage. The Palaeontologist must however arrange with the contractor team for a “drive through” site visit to confirm that no localized pockets of very highly sensitive sediments were not mapped in the dolerite areas or were excluded during compilation of the 1:250 000 scale maps. Construction of the pipeline cut significant groundwater aquifers and the groundwater specialist must provide appropriate mitigation against pollution of these highly significant Natural National Heritage Sites.

CONCLUSION

The study area for the Desktop Survey, assessing the potential Palaeontological Impact related to the proposed Greater Bulwer-Donnybrook Bulk Water Supply Scheme (GBDBWSS): Harry Gwala District Municipality, Kwazulu-Natal is underlain by rocks of the Permian to Triassic aged Ecca and Beaufort Groups as well as Jurassic aged dolerite of the Karoo Supergroup. Quaternary aged deposits of the Masotcheni Formation and alluvium covers low lying areas.

Significant fossils are expected in outcrops on site and a Phase 1 site inspection must be done to prepare a “chance Find Protocol” for this project before deep excavation (>1.5m) are done in all areas allocated a High to Very High palaeontological Sensitivity (orange and red colours). If fossils are recorded it will contribute significantly to our knowledge of the Palaeontological Heritage of KwaZulu-Natal.

Significant Primary and Secondary Groundwater Aquifers are associated with the alluvium and dolerite contact zones on site and design of all water distribution and treatment works for potential pollutant must ensure that no polluted water reaches these important National Heritage Sites.

It is recommended that:

- The EAP and ECO must be informed of the fact that a High to Very High Palaeontological Sensitivity is allocated to significant parts of the study area. A suitably qualified Palaeontologist must be employed to ascertain the significance of the Palaeontological Impact, apply for a permit to collect fossils, do a Phase 1 Site inspection, prepare a “Chance Find Protocol” document and arrange for a well-planned Phase 2 PIA site visit during construction in all areas where the Phase 1 study confirms the presence of or very high possibility of finding significant fossils. If fossils are recorded during any stage of the development the HIA specialist must be informed to take immediate and appropriate action to preserve the fossils sites.
- These recommendations must be included in the EMPr of this project.

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QUALIFICATIONS AND EXPERIENCE OF THE AUTHOR

Dr Gideon Groenewald has a PhD in Geology from the University of Port Elizabeth (Nelson Mandela Metropolitan University) (1996) and the National Diploma in Nature Conservation from Technicon RSA (the University of South Africa) (1989). He specialises in research on South African Permian and Triassic sedimentology and macrofossils with an interest in biostratigraphy, and palaeo-ecological aspects. He has extensive experience in the locating of fossil material in the Karoo Supergroup and has more than 20 years of experience in locating, collecting and curating fossils, including exploration field trips in search of new localities in the southern, western, eastern and north-eastern parts of the country. His publication record includes multiple articles in internationally recognized journals. Dr Groenewald is accredited by the Palaeontological Society of Southern Africa (society member for 25 years) and an accredited member of the Borehole Water Association of South Africa.

DECLARATION OF INDEPENDENCE

I, Gideon Groenewald, declare that I am an independent specialist consultant and have no financial, personal or other interest in the proposed development, nor the developers or any of their subsidiaries, apart from fair remuneration for work performed in the delivery of palaeontological heritage and geohydrological impact assessment services. There are no circumstances that compromise the objectivity of my performing such work.

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