Palaeontological Heritage Impact assessment for a proposed 88-99 MW windfarm, 30km east of Grahamstown.

Prepared for: **Coastal & Environmental Services**

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Contents:

Background

Coastal and Environmental Services have been appointed to carry out an Environmental Impact Assessment for an 88 to 99 MW (up to 4.5 MW turbines) windfarm approximately 30 km east of Grahamstown.

Rob Gess Consulting was contracted to conduct a phase one Palaeontological Impact Assessment for this proposed development.

Geology and Palaeontology

The area intended for development overlies strata of the upper portion of the Cape Supergroup and lowermost portion of the unconformably overlying Karoo Supergroup. In addition, portions of the Cape Supergroup rocks are capped by relict patches of Silcrete formed as a product of deep leaching during the Cretaceous.

Cape Supergroup rocks represent sediments deposited in the Agulhas Sea, which had opened to the south of the current southern African landmass, in response to early rifting between Africa and South America during the Ordivician.

The Witteberg Group is the uppermost of three subdivisions of the Cape supergroup and was laid down during the Late Devonian.

The stratigraphically lowest Witteberg Group strata present belong to the Late Devonian (Famennian), 359 to 372 million years old **Witpoort Formation (Witteberg Group, Cape Supergroup),** which are exposed at the centre of an anticline. This largely quatzitic unit represents mature sandy strata deposited along a linear barrier island type coast. Particularly around Grahamstown black shale lenses, interpreted as estuarine deposits preserved during brief transgressive events, have proved remarkably fossiliferous.

A series of lenses at Waterloo Farm, to the south of Grahamstown, have provided southern Africa's most important Late Devonian locality, which has yielded at least 20 taxa of fossil fish (including jawless fish (Agnatha), armoured fish (Placodermi), spiny sharks (Acanthodii), sharks (Chondrichthyes), ray finned fish (Actinopterygii) and lobe finned fishes (Sarcopterygii) including Coelacanths (Actinistia), lungfish (Dipnoi) and Osteolepiformes). In addition, it has provided evidence for Africa's earliest tetrapod (four-legged animal) remains by 80 million years, *Tutusius mlambo* and *Umzantsia amazana*. Dozens of plant and algal taxa, remains of giant eurypterids and other arthropods as well as abundant trace fossils have also been collected. As yet 21 taxa new to science have been described from Waterloo Farm, though many more await description. Those already described also include the world's oldest lamprey fossil, *Priscomyzon riniensis*, Africa's earliest coelacanth from the world's oldest known coelacanth nursery, *Serenichthys kowiensis* and the oldest known terrestrial animal from the supercontinent Gondwana, *Gondwanascorpio emzantsiensis*.The top of the Witpoort Formation coincides with the end of the Devonian and is similar in age to the end-Devonian extinction event. Witpoort Formation quartzites have yielded a range of plant stem taxa and trace fossils. Lag deposits of bone have not, as yet, been discovered, but may be expected.

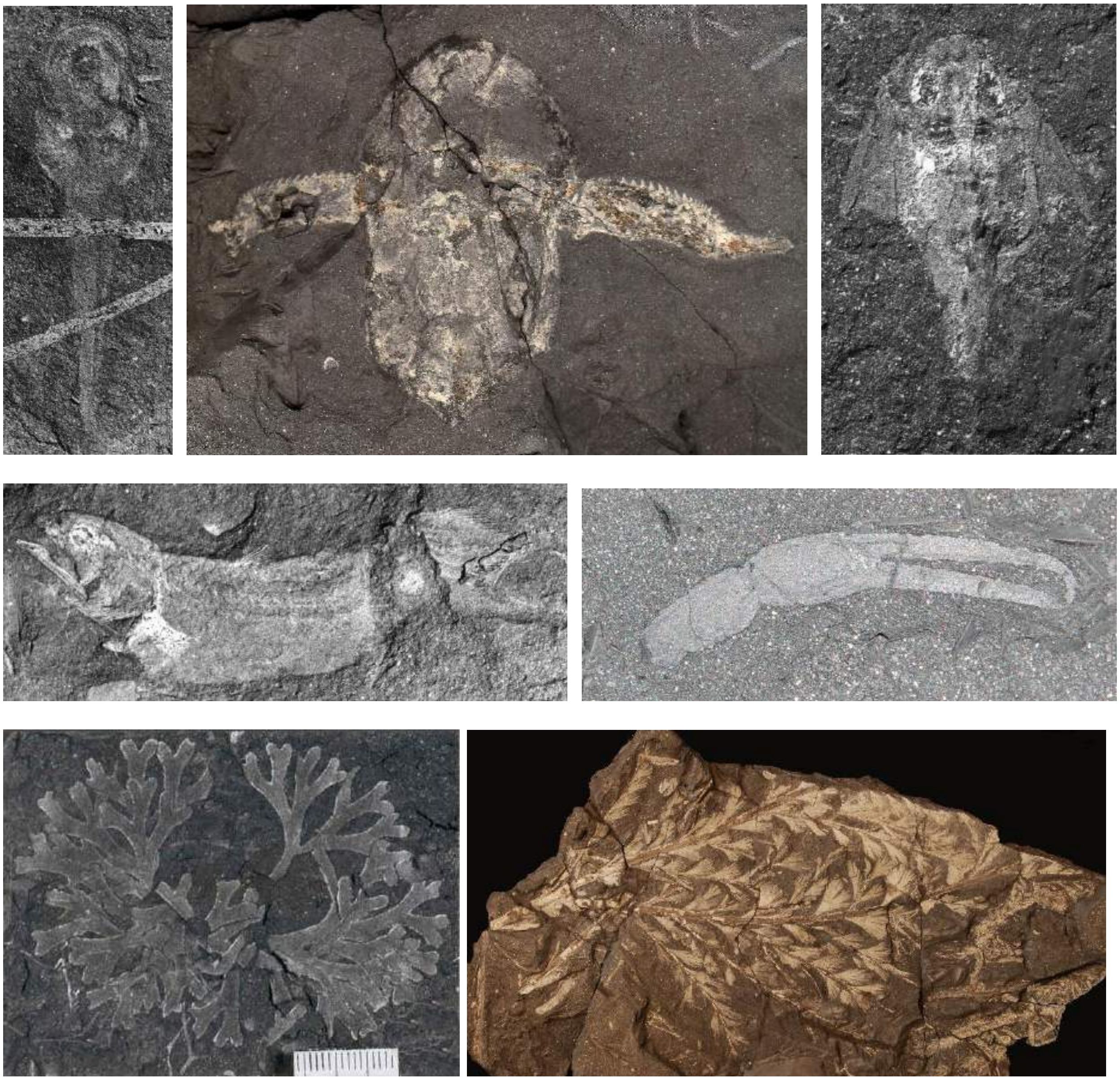

Figure 1: Selection of fossils recovered from a black shale lens at Waterloo Farm: *top left*, 4.2 cm long *Priscomyzon riniensis* (the world's oldest fossil lamprey); *top middle*, 6.5 cm long head and trunk armour of a young *Bothriolepis africana* antiarch placoderm fish; *top right*, 2.5 cm long neonatal *Groenlandaspis riniensis*, an arthrodire placoderm fish; *middle left*, 5.5 cm long type specimen of the coelacanth *Serenichthys kowiensis*; *middle right*, 3,4 cm long pincer of the scorpion, *Gondwanascorpio emzantsiensis* (the oldest known terrestrial animal from Gondwana); *bottom left*, 7 cm across tuft of the seaweed *Hungerfordia fionae*; *bottom right*, 30 cm long fronds of the progymnosperm tree *Archaeopteris notosaria* (the oldest known species of woody tree from southern Africa).

Figure 2: Fossils in quartzites at Waterloo Farm: left lycopod *Leptophloem rhombicum* stems; right, progymnosperm *Archaeopteris* trunk.

In 2015 roadworks at Coombs Hill and Rabbit Ridge, 5-10 kilometres south west of the present study area (see Fig.6) uncovered a number of palaeontologically important black shale lenses within the Witpoort Formation. Those along Rabbit Ridge represented exposure of an extensive vertically tilted black shale horizon that yielded evidence for a monotaxic assemblage of lingulid brachiopods in a back-barrier mud flats environment. This provided the first record of predominantly marine invertebrate shells within the Witpoort Formation. These sites also produced fragmentary plant remains and extensive trace fossils.

Figure 3: *left*, Lingulid brachiopods and a lycopod stem on a slab from Rabbit ridge; *right*, Chris Harris, chief excavator of Rabbit Ridge and Coombs Hill at a shale outcrop on Rabbit Ridge in 2015.

The roadworks at Coombs Hill revealed a number of black shale horizons, which contained more than one species of bivalve, in addition to a wealth of plant fossils, some of which are remarkable well preserved. Plant fossils included lycopod taxa new to science and the best preserved fronds of the progymnosperm tree, *Archaeopteris notosaria* known.

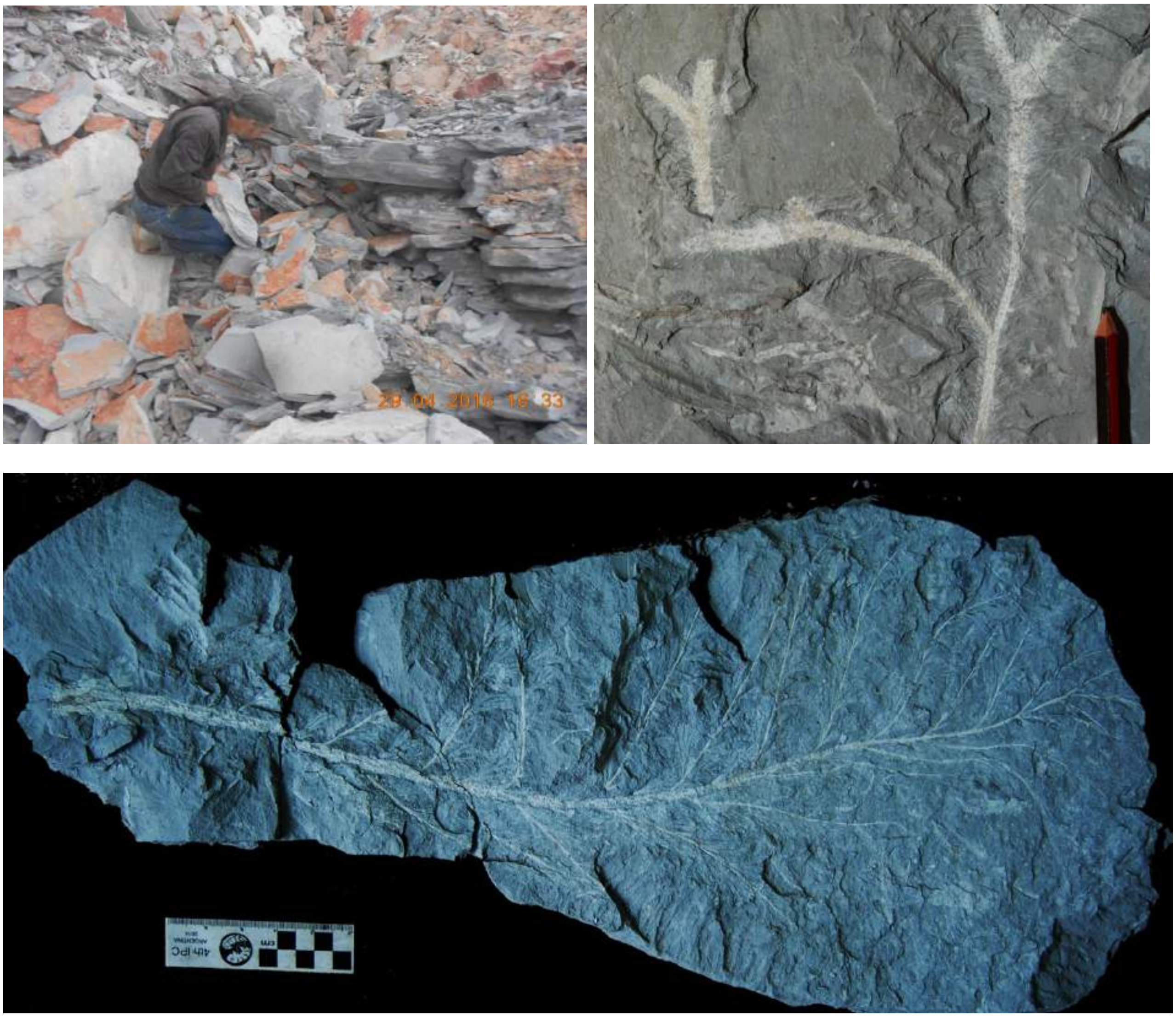

Figure 4: Black shale and fossils from Coombs Hill: *top left*, black shale disturbed during roadworks at Coombs Hill, *top right*, new species of lycopod plant; *bottom*, frond of *Archaeopteris notosaria*.

The early to mid Carboniferous is represented by overlying mudstone and sandy units of the **Lake Mentz Subgroup (Witteberg Group, Cape Supergroup**). These were deposited as sediment during the last phase of the Agulhas Sea, by which time it was much restricted and was possibly (at least partially) cut off from the open sea. The **Waaipoort Formation** (uppermost **Lake Mentz Subgroup Witteberg Group, Cape Supergroup**) provides evidence for a post-extinction Agulhas Sea fauna, dominated by a range of ray-finned-fish (Actinopterygii), but also containing a relict shark and 2 types of spiny sharks (Acanthodii).

The strata of the **Karoo Supergroup** were deposited within the Karoo sedimentary Basin, which resulted from shortening and thickening of the southern margin of Africa, with coeval folding and uplift of the Cape Supergroup strata along its southern margin. Lowermost Karoo strata of the Dwyka and lower Ecca Groups were affected by folding in the vicinity of the Cape Fold Belt.

The **Dwyka Group** (**Karoo Supergroup),** particularly here in the south of the basin, consists almost exclusively of diamictite known as the Dwyka tillite. This is a distinctive rock type which, when freshly exposed, consists of a hard fine-grained blueish-black matrix in which abundant roughly shaped clasts are embedded. These vary greatly in both lithology and size. During the formation of the Dwyka, beginning in the late Carboniferous, southern Africa drifted over the south pole, whilst simultaneously, the world was experiencing a cold episode. Glaciers flowing into the flooded Karoo basin broke up, melted and discharged a mixture of finely ground rock flour and rough chunks of rock. These formed the matrix and clasts of the Dwyka tillite. Within the study area fossils are not known from the **Dwyka Group (Karoo Supergroup)**.

During the Cretaceous and early Tertiary Periods much of Africa was weathered down to a number of level horizons collectively known as the African Surface. The area in the vicinity of Grahamstown was reduced to a flat plain close to sea level, remnants of which are referred to as the Grahamstown Peneplane. During the Tertiary, mudstones, shales and diamictites were leached to considerable depth, transforming them into soft white kaolin clay. Silica, iron and magnesium from these rocks was carried in solution by groundwater and deposited near the ground surface due to steady evaporation of mineral rich waters. This lead to the formation of a hard mineralised capping layer, often consisting of silicified soil. Resultant silcretes are referred to as the **Grahamstown Formation**. Though occasional occurrences of root and stem impressions have been recorded from the Grahamstown Formation it is generally considered unfossiliferous.

With subsequent reduction of the relative sea level, deep valleys have carved back from the retreating coastline, cutting deep valleys and catchment areas into the African Surface.

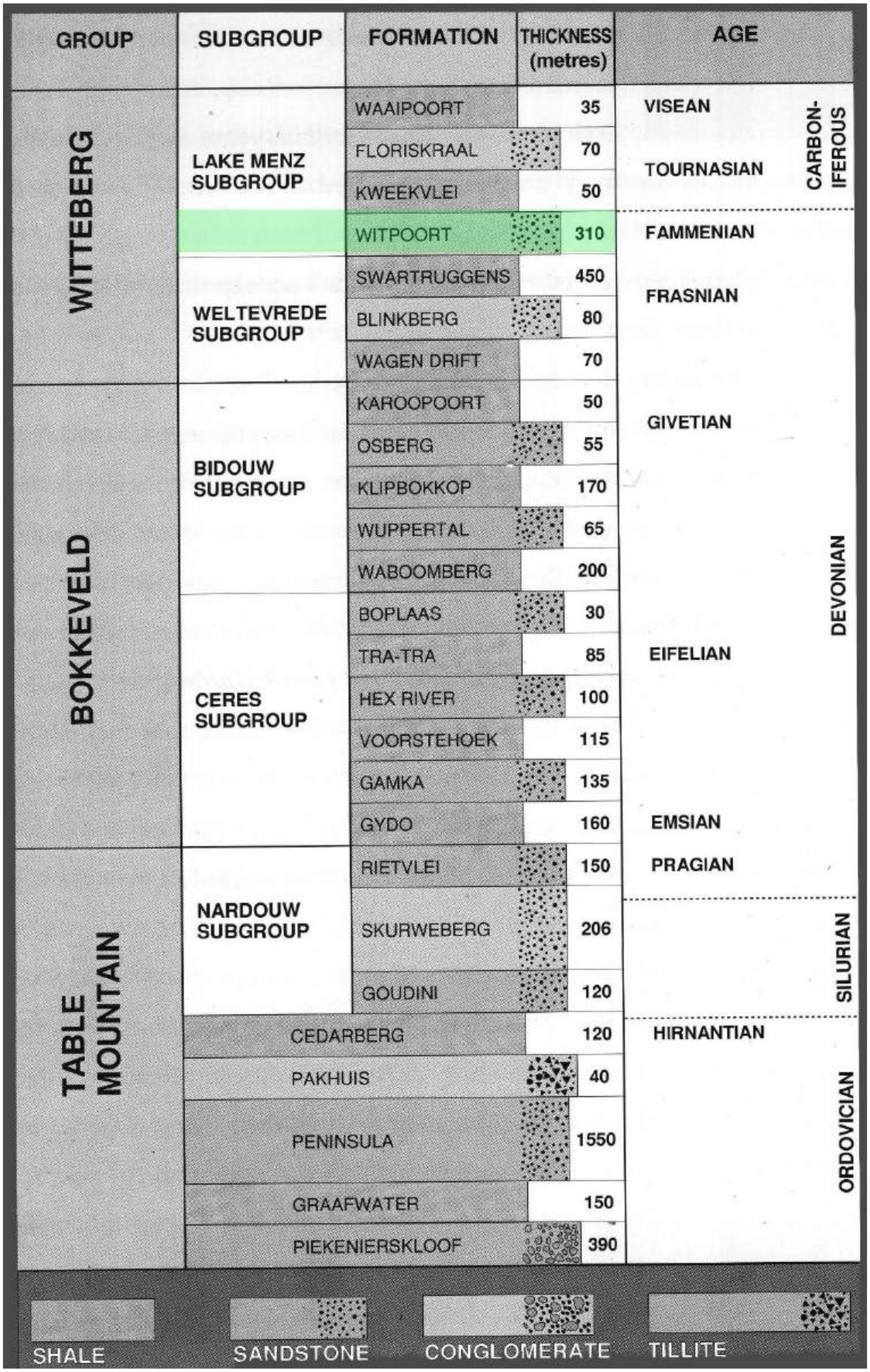

Figure 5: Stratigraphic column of the Cape Supergroup modified after Theron and Thamm (1990) following Cotter (2000). Green area indicates strata directly impacted by the development.

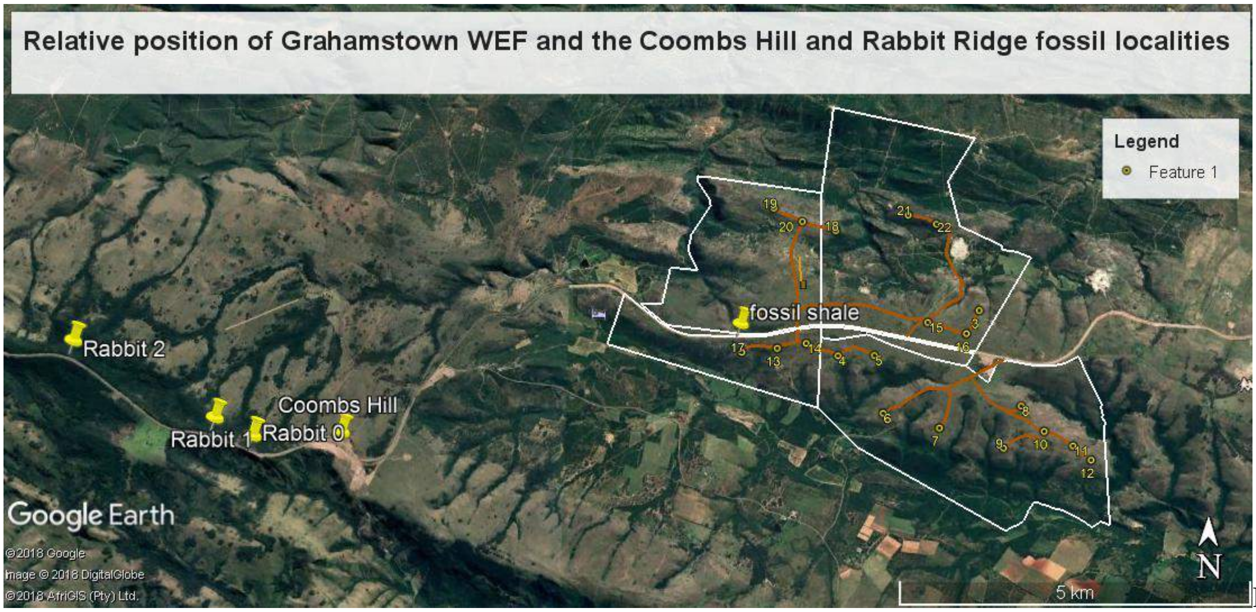

Figure 6: Relative position of proposed WEF, Coombs Hill and Rabbit Ridge fossil localities as well as fossiliferous shale located during PIA survey.

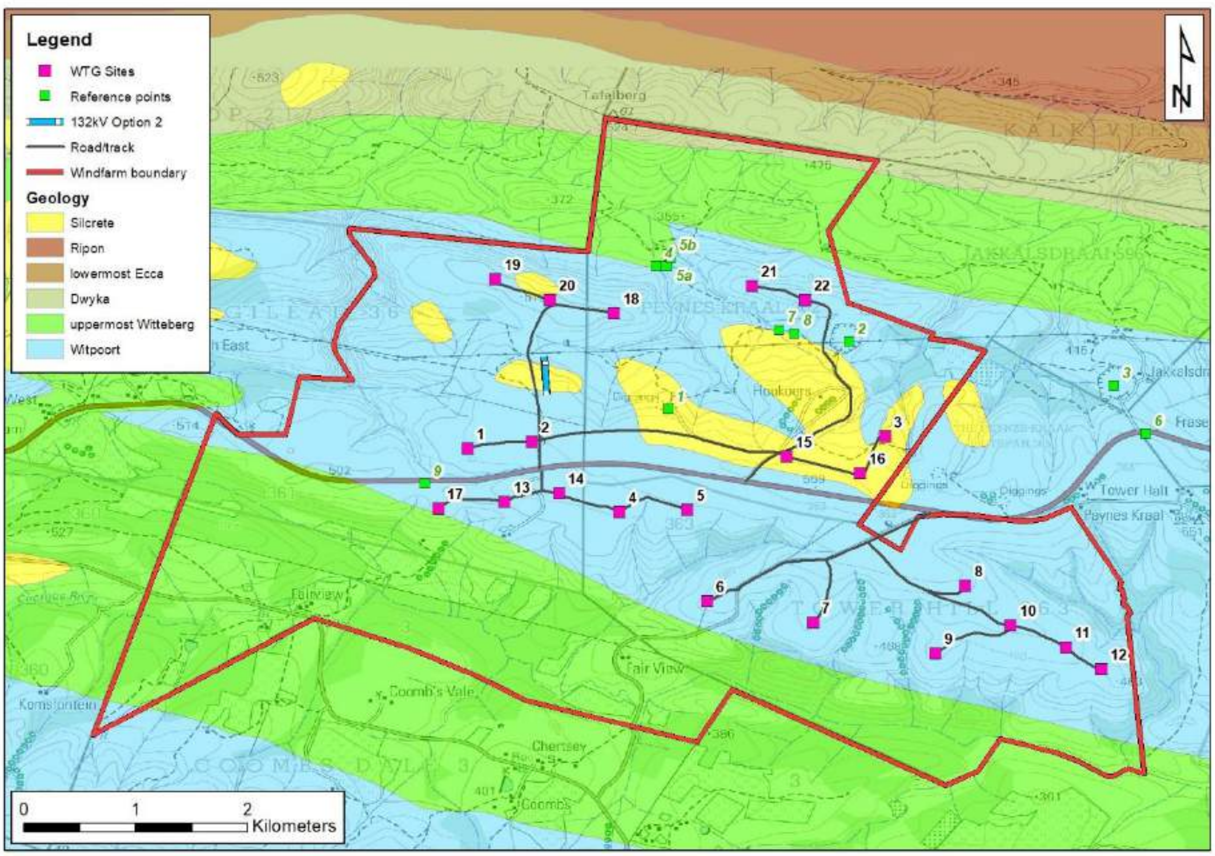

Figure 7. Geological map of the study area based on geological survey data overlain on topography, with positions of proposed wind towers marked as pink squares and points referred to in the text marked as green squares.

Site visit

The proposed development area was surveyed with a vehicle and on foot, with particular attention being paid to those areas which will be affected by the development.

The development is to be situated on a series of quartzitic hills in the centre of the study area. These result from erosion of Witpoort Formation Witteberg quartzite strata upwardly folded in a large asymmetrical east-west trending anticline. Partial loss of the uppermost quartzitic strata, that once comprised the top of the fold arch, occurred during erosion of the Cretaceous to Tertiary African Surface. This exposed, towards the northern side of the fold, a thick horizon of black carbon-rich shaly mudstone interbedded within the upper Witpoort Formation. This black mudstone may be stratigraphically equivalent to the Rabbit Ridge mudstone or possibly one of the other important black shales exposed at Waterloo Farm and Coombs Hill.

Unfortunately (from a palaeontological perspective), deep weathering of this carbonaceous shale, during the Tertiary, reduced the shale to a fine quality kaolin clay capped by silcrete of the Grahamstown Formation. Subsequent differential weathering of this soft clay led to the development of an east-west trending valley towards the north of the fold, hemmed in by quartzitic hills. Nonetheless significant deposits of clay remained along the sides of valley and where protected by remnants of silcrete. These deposits were utilised in precolonial times and a number of large quarries were exploited during the 20th century (Fig. 7. Points 1-3). One of these (Fig. 7. Points 2) appears to have begun as exploitation of a silcrete capped “sugarloaf hill” and continued downwards until weathered remains of the original black shale were encountered. Where exposed by the quarry these strata were carefully examined, during the survey, but no fossil material was located. Thin veins of fine red ochre were also seen in this quarry - identical to ochre pieces noted in a rock shelter adjacent to San rock art within the study area.

Fig. 8. View eastwards from point 2 to point 3 (fig. 7) showing valley carved into kaolin.

Fig. 9. Black Witpoort Formation clay underlying kaolin clay deposit at point 2 (fig.7).

Scale = 5 cm

Fig. 10. Close up of black Witpoort Formation shales exposed at point 2 (fig. 7)

Scale = 5cm
Figure 11. Silcrete capping material of the Tertiary Grahamstown Formation discarded at point 2 (Fig. 7)

The Witpoort Formation quartzites, which stratigraphically overlie the black shales, are well exposed in valleys and roadcuttings throughout the area but are weathered to smooth heath-covered surfaces on many of the hill crests intended for the installation of turbines. Where they are well exposed they comprise stacked packages of cross bedded mature sandstones with shallow-water ripple surfaces (Fig. 12) and ropy horizontal trace fossils (Fig. 13).

Scale = 5cm
Figure 12. Shallow water ripples in uppermost Witpoort Formation quartzites at point 5a (fig. 7).

Figure 13. Horizontal invertebrate feeding traces in uppermost Witpoort Formation quartzites exposed at point 5b (fig.7).

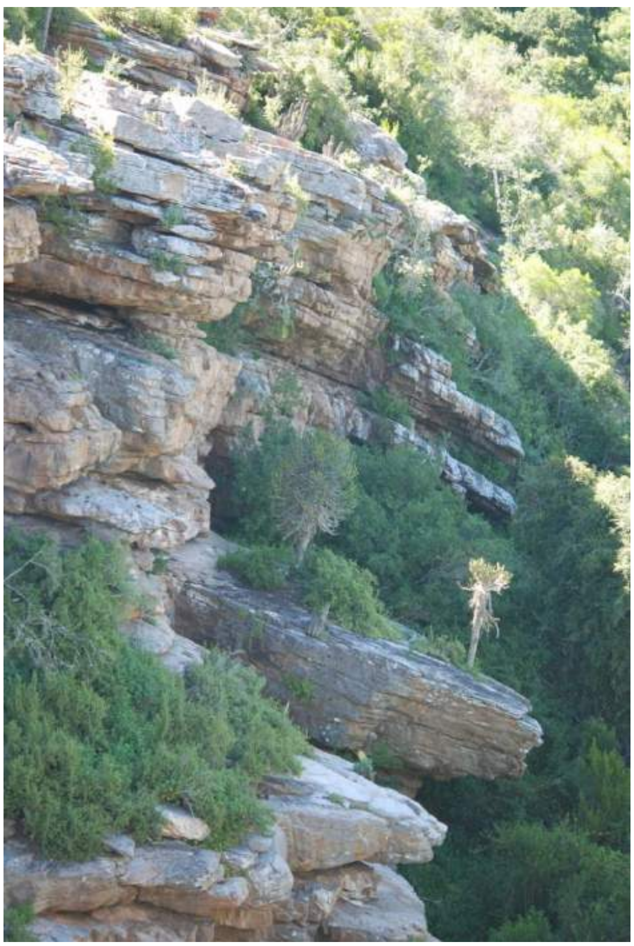

Figure 14. Stacked layers of Witpoort Formation quartzites at point 4 (fig. 7).

Figure 15. Trough cross bedding in Witpoort Formation quartzites at point 6 (fig. 7).

Scale = 5cm
Figure 16. Shallow water ripples in Witpoort Formation quartzites at point 6 (fig. 2).

Roadworks in 2018, immediately adjacent to the study site, have revealed new outcrops in a roadcutting at point 9 (Figure 7), approximately 250 metres north of wind tower position 17. These represent the uppermost part of the Witpoort formation, perhaps approximately stratigraphically equivalent to strata at Waterloo Farm. The roadcutting exposes silty and muddy finely cross bedded strata capped by a massive erosionally based transgressive quartzitic sandstone which has partially protected underlying strata from leaching. Small grey mudstone lenses were found to contain fossilised transported plant fragments reminiscent of more fragmentary material from Waterloo Farm and Coombs Hill.

Figure 17: Abundant fossilised plant fragments in dark grey uppermost Witpoort Formation mudstones exposed in new roadworks at point 9 (Figure 7).

The Witpoort Formation is stratigraphically overlain by fine grained brown shales of the Lake Mentz Subgroup. These outcrop to the north and to the south of the quartzite ridge. On the south (sea facing) slopes, the high rainfall has reduced almost all outcrop to smooth, steep, vegetated slopes. To the north of the ridge the outcrop falls within a rainshadow caused by the ridge. Here the vegetation is more arid, the soil thinner and crumbly patches of outcrop may be found. The contact is more uneven than is indicated by the survey map and upper Lake Mentz Subgroup shales are found at points 7 and 8 (Fig. 7) (Figs 17-18).

Figure. 17. Small road aggregate quarry in upper Lake Mentz Subgroup shale. Point 7 (fig. 7)

Scale = 3.5cm
Figure 18. Plant fragments in upper Lake Mentz Subgroup shale. Point 8 (fig. 7)
Although plant fragments were noted in shale at point 8, they did not constitute a significant palaeosite.

Dwyka diamictite crops out in the extreme north of the study area which will not be affected by the development. It does not contain fossils.

Conclusions and Recommendations.

It is the nature of palaeontological resources that important sites may be spacially very limited, yet they may prove to be of international significance. Discovery of such resources during development may be of great permanent benefit to the scientific community. Their destruction represents a severe permanent loss which may be of international significance.

The development area is focussed on Witpoort Formation quartzite ridges which were not, at surface, found to be significantly fossiliferous. Potentially important interbedded black shales within the quartzites are sometimes kaolinised to a deep depth; however, where they are shielded by overlying beds of quartzite they may still be usefully fossiliferous close to surface.

Quarries and roadworks within the study area and within the district have demonstrated that excavation into the Witpoort Formation not infrequently intercepts black shale layers and lenses that may be of great palaeontological value. Palaeontological investigations of these layers, in the Grahamstown district, has provided the world's only window into high latitude conditions at the end of the Devonian, a time of extreme importance in understanding the process of vertebrate terrestrialisation and the lead up to the second global Mass Extinction Event.

There is therefore a reasonable chance that excavation of holes for casting wind tower footings will intercept fossiliferous shales, which may contain important unique heritage material. Lag deposits, containing fossil stems and possibly bones might also be found preserved within the quartzites.

It is therefore recommended that:

1) **All excavated holes for wind tower footings should be examined by a palaeontologist after excavation and before casting of footings.**

2) **All new access roads should simultaneously be inspected by a palaeontologist prior to any rehabilitation**.

3) **Should any paleontologically important material be exposed this should be sampled by a professional palaeontologist and accessioned into the collection of the Albany Museum in Grahamstown**