Palaeontological Impact Assessment for the proposed Hendrina Green Hydrogen and Ammonia facility, Mpumalanga Province

Site Visit Report (Phase 2)

For

Beyond Heritage

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Expertise of Specialist

The Palaeontologist Consultant: Prof Marion Bamford
Qualifications: PhD (Wits Univ, 1990); FRSSAf, ASSAf, PSSA
Experience: 34 years research; 26 years PIA studies
Over 350 projects completed.

Declaration of Independence

This report has been compiled by Professor Marion Bamford, of the University of the Witwatersrand, sub-contracted by Beyond Heritage, Modimolle, South Africa. The views expressed in this report are entirely those of the author and no other interest was displayed during the decision making process for the Project.

Specialist: Prof Marion Bamford

Signature: 

Executive Summary

ENERTRAG SA (Pty) Ltd, proposes to develop the Hendrina Green Hydrogen and Ammonia Facility located near Hendrina in the Mpumalanga Province, located within the Steve Tshwete Local Municipality. WSP Group Africa (Pty) Ltd has been appointed by Enertrag SA to conduct an Environmental Authorisation (EA) Application for the project. Three alternative sites are under consideration, each of about 25ha in area and with their own links to the grid. A site visit by a palaeontologist was requested by SAHRA (Case Id: 20205).

To comply with the regulations of the South African Heritage Resources Agency (SAHRA) in terms of Section 38(8) of the National Heritage Resources Act, 1999 (Act No. 25 of 1999) (NHRA), a site visit (Phase 2) Palaeontological Impact Assessment (PIA) was completed for the proposed development.

The three alternative sites lie on the potentially very highly sensitive Vryheid Formation (Ecca Group, Karoo Supergroup) that could preserve impressions of fossil plants of the *Glossopteris* flora. The site visit and walk through by the palaeontologist in April 2023 (late summer of a la Niña year with high rainfall) confirmed that there were NO FOSSILS of any kind present on the land surface. Most of the area is on secondary grasslands or agricultural fields so there were no rocky outcrops and no fossils visible on the surface. It is not known what lies below the ground surface. Nonetheless, a Fossil Chance Find Protocol should be added to the EMPr. Based on this information it is recommended that no further palaeontological impact assessment is required unless fossils are found by the contractor, developer, environmental officer or other designated responsible person once excavations for foundations, storage tanks, infrastructure and access roads or the new substation have commenced. All sites are on the Vryheid Formation so there is no preferred option as far as the palaeontology is concerned.

The significance of the palaeontological impact is only relevant to the construction phase. It is low negative pre-mitigation and very low positive post-mitigation. There is no cumulative impact because each fossil site is independent of the others.

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1. Background

ENERTRAG SA was established in 2017, with the intention to investigate and develop renewable energy projects in South Africa. The transition from coal-based energy supply to renewables in the Country is inevitable, as coal resources are depleted, coal-based power stations reach the end of their economic life and considering international obligations and commitments to reduced emissions. The Project development area is blanketed with numerous coal prospecting and mining rights. Coal mining and energy derived from coal mining is the likely alternative to the Project. ENERTRAG SA are developing renewable energy projects to contribute to the Just Transition that promises to decarbonise South Africa's energy sector and aims to:

- replace coal-based electricity with renewable electricity
- decarbonise different sectors of the economy through the replacement of fossil-based hydrogen and ammonia with green hydrogen and ammonia.

ENERTRAG SA proposes to develop the Hendrina Renewable Energy Complex, the complex comprises of five separate projects. The projects are:

- Hendrina North Wind Energy Facility (up to 200MW) over 3600ha;
- Hendrina South Wind Energy Facility (up to 200MW) over 2900ha;
- Hendrina North Grid Infrastructure (up to 275kV) – 15km;
- Hendrina South Grid Infrastructure (up to 275kV) – 16km;
- **Green Hydrogen and Ammonia Facility (up to 25ha).**

Each of these projects are being assessed, as part of the Complex development, and involve the undertaking of Listed Activities identified in the Environmental Impact Assessment (EIA) Regulations, 2014 (as amended) and as such require an Environmental Authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) before being undertaken.

This report pertains specifically to the Green Hydrogen and Ammonia Facility ("the Project").

The Hendrina Green Hydrogen and Ammonia Facility will cover an area of about 25 ha and will comprise the following components on based on the assumption that an up to 150MW electrolyser is installed (maximum):

- Water treatment.
- Water reservoir(s).
- Electrolyser.
- Air separator.
- Ammonia processing unit.
- Liquid air energy system (LAES) for nitrogen storage.
- Feedstock and product storage.
- Utilities.
- Gantry and loading bay.

Associated infrastructure further include:

- Electrical infrastructure required for power supply to the facility.
- Temporary and permanent laydown areas required for temporary storage and assembly of components and materials.
- Access road/s to the site and internal roads between project components, with a width of up to up to 6m wide respectively.
- Fencing and lighting.
- Lightning protection.
- Telecommunication infrastructure.
- Stormwater channels.
- Water pipelines
- Offices.
- Operational control centre.
- Operation and Maintenance Area / Warehouse / workshop.
- Ablution facilities.
- A gate house.
- Control centre, offices, warehouses.
- Security building.

Project Location

The Project is located 17km west of Hendrina, in the Steve Tshwete Local Municipality, of the Nkangala District Municipality, Mpumalanga Province. Three alternative Project locations are being investigated for the development of the proposed Project:

Site Alternative 1 is located on Portion 3 of the Farm Dunbar 189IS, at the site of an old abandoned farmyard and has three powerline options from the associated Hendrina North and South Wind Energy Facilities ("WEF") as follows:

- Powerline option 1 is up to 2km in length, to the Hendrina North WEF substation Option 1 on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 7km in length, to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;
- Powerline option 3 is up to 1.5km in length, to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS.

water supply to the Site:

- constructing a new pipeline (up to 16km) from the Komati Power Station

Site Alternative 2 is located on Portion 3 of the Farm Dunbar 189IS and Portion 18 of the Farm Weltevreden 193IS, adjacent to the proposed Hendrina South WEF substation and has three powerline options from the associated wind farms as follows:

- Powerline option 1 is up to 3km in length to the Hendrina North WEF Option 1 substation on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 8km in length to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;

- Powerline option 3 is up to 0.5km in length to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS;

water supply to the Site:

- constructing a new pipeline (up to 16km) from the Komati Power Station

Site Alternative 3 is located on Portions 14 and 15 of the Farm Weltevreden 193IS and has three powerline options from the associated wind farms as follows:

- Powerline option 1 is up to 5km in length to the Hendrina North WEF Option 1 substation on Portion 1 of the Farm Dunbar 189IS;
- Powerline option 2 is up to 5km in length to the Hendrina North WEF substation Option 2 on Portion 3 of the Farm Hartebeestkuil 185IS;
- Powerline option 3 is up to 7km in length to the Hendrina South WEF substation on Portion 3 of the Farm Dunbar 189IS.

water supply to the Site:

- constructing a new pipeline (up to 16km) from the Komati Power Station

The Project, and associated water pipeline and powerlines, is proposed over the following farm portions.

Table 1: Farm Portions affected by the Project Alternatives

Parent Farm	**Farm No**	**Portion No**
Facility Alternative Site 1		
Dunbar	189IS	3
Facility Alternative Site 2		
Dunbar	189IS	3
Weltevreden	193IS	18
Facility Alternative Site 3		
Weltevreden	193IS	14
Weltevreden	193IS	15
Associated pipelines and powerlines may affect portions of the following land parcels:		
Bultfontein	187IS	1
Bultfontein	187IS	2
Bultfontein	187IS	3
Bultfontein	187IS	4
Bultfontein	187IS	6
Bultfontein	187IS	10
Bultfontein	187IS	14
Dunbar	189IS	0
Dunbar	189IS	1
Dunbar	189IS	2
Dunbar	189IS	4
Dunbar	189IS	5
Dunbar	189IS	6
Dunbar	189IS	7
Geluk	26IS	6
Geluk	26IS	7

Hartebeestkuil	185IS	3
Komati Power Station	56IS	0
Wilmansrust	47IS	1
Wilmansrust	47IS	3
Wilmansrust	47IS	9

A Palaeontological Impact Assessment was requested for the Hendrina Green Hydrogen and Ammonia facility (SAHRA case Id: 20205). To comply with the regulations of the South African Heritage Resources Agency (SAHRA) in terms of Section 38(8) of the National Heritage Resources Act, 1999 (Act No. 25 of 1999) (NHRA), a site visit and walkthrough (Phase 2) Palaeontological Impact Assessment (PIA) was completed for the proposed development and is reported herein.

Table 1: National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and Environmental Impact Assessment (EIA) Regulations, 2014 (as amended) - Requirements for Specialist Reports (Appendix 6).

	A specialist report prepared in terms of the Environmental Impact Regulations of 2017 must contain:	**Relevant section in report**
ai	Details of the specialist who prepared the report,	Appendix B
aii	The expertise of that person to compile a specialist report including a curriculum vitae	Appendix B
b	A declaration that the person is independent in a form as may be specified by the competent authority	Page 1
c	An indication of the scope of, and the purpose for which, the report was prepared	Section 1
ci	An indication of the quality and age of the base data used for the specialist report: SAHRIS palaeosensitivity map accessed – date of this report	Yes
cii	A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 5
d	The date and season of the site investigation and the relevance of the season to the outcome of the assessment	N/A
e	A description of the methodology adopted in preparing the report or carrying out the specialised process	Section 2
f	The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Section 4
g	An identification of any areas to be avoided, including buffers	N/A
h	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	N/A
i	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 5

	A specialist report prepared in terms of the Environmental Impact Regulations of 2017 must contain:	**Relevant section in report**
j	A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Section 4
k	Any mitigation measures for inclusion in the EMPr	Section 8, Appendix A
l	Any conditions for inclusion in the environmental authorisation	N/A
m	Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 8, Appendix A
ni	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised	Section 6
nii	If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Sections 6, 8
o	A description of any consultation process that was undertaken during the course of carrying out the study	N/A
p	A summary and copies of any comments that were received during any consultation process	N/A
q	Any other information requested by the competent authority.	N/A
2	Where a government notice gazetted by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	N/A

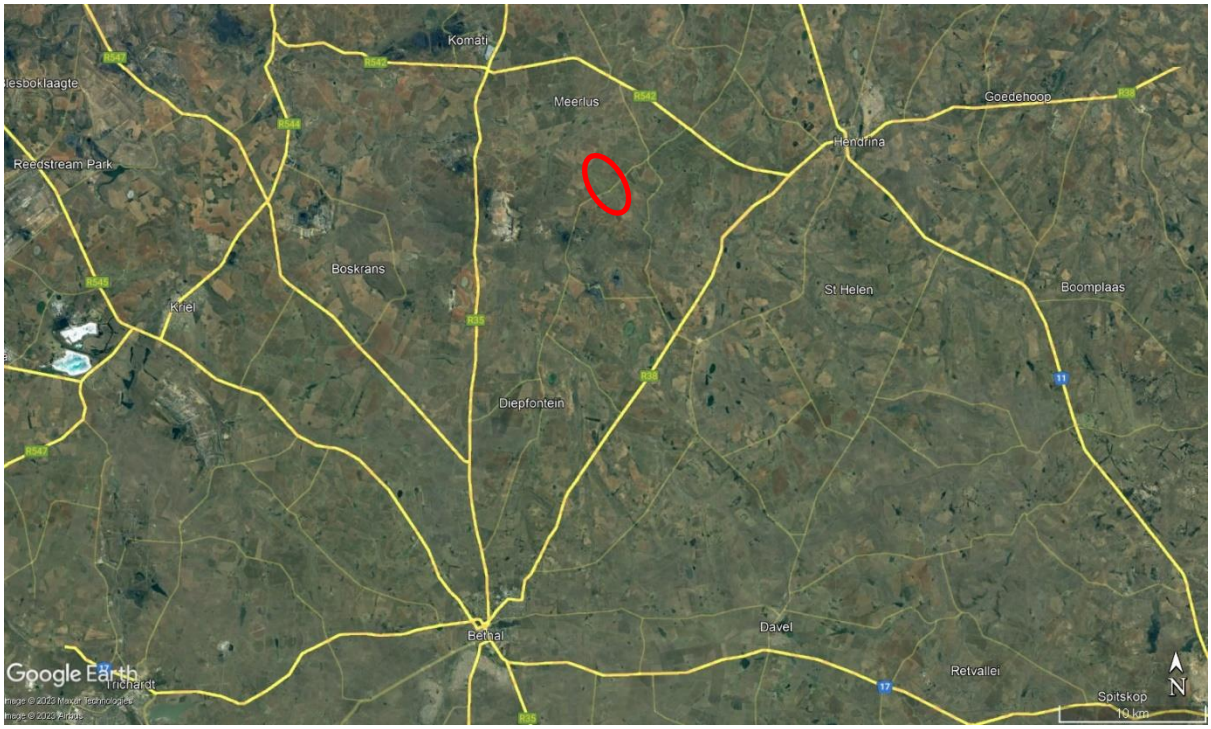

Figure 1: Google Earth map of the proposed Hendrina Green Hydrogen and Ammonia facility (in the red oval) showing the relevant landmarks, roads and towns.

Figure 2: Google Earth map for the three alternatives sites for the proposed Hendrina Green Hydrogen and Ammonia Facility, with Option A (white line) being the preferred one.

2. Methods and Terms of Reference

The Terms of Reference (ToR) for this study were to undertake a PIA and provide feasible management measures to comply with the requirements of SAHRA.
The methods employed to address the ToR included:

1. Consultation of geological maps, literature, palaeontological databases, published and unpublished records to determine the likelihood of fossils occurring in the affected areas. Sources included records housed at the Evolutionary Studies Institute at the University of the Witwatersrand and SAHRA databases;
2. Where necessary, site visits by a qualified palaeontologist to locate any fossils and assess their importance, as is the case here;
3. Where appropriate, collection of unique or rare fossils with the necessary permits for storage and curation at an appropriate facility (*not applicable to this assessment*); and
4. Determination of fossils' representivity or scientific importance to decide if the fossils can be destroyed or a representative sample collected (*not applicable to this assessment*).

3. Geology and Palaeontology

i. Project location and geological context

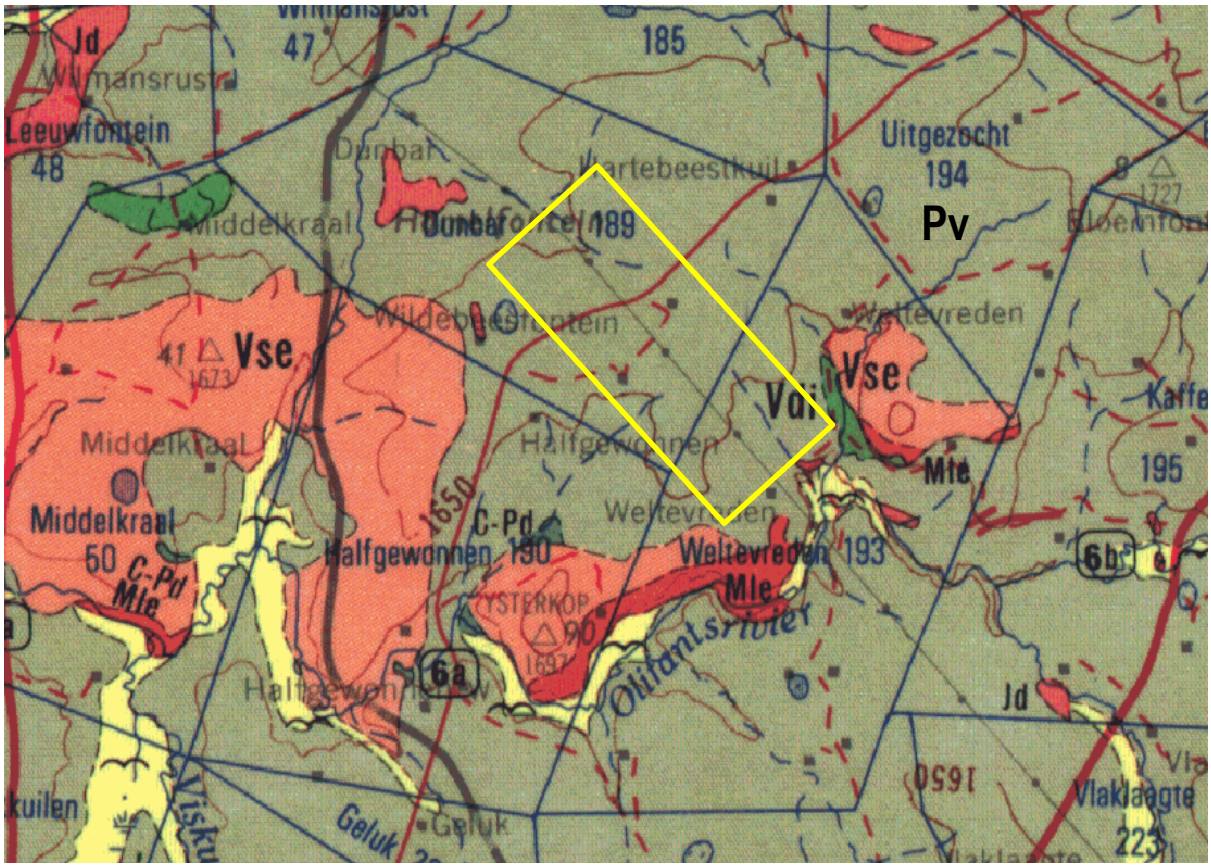

Figure 3: Geological map of the area of the proposed Hendrina Green Hydrogen and Ammonia facility within the yellow rectangle. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 250 000 map 2628 East Rand.

Table 2: Explanation of symbols for the geological map and approximate ages (Johnson et al., 2006; Partridge et al., 2006). SG = Supergroup; Fm = Formation; Ma = million years; grey shading = formations impacted by the project.

Symbol	Group/Formation	Lithology	Approximate Age
Qc	Quaternary	Alluvium, sand, calcrete	Quaternary Ca 1.0 Ma to present
Jd	Jurassic dykes	Dolerite dykes, intrusive	Jurassic, Ca 183 Ma
Pv	Vryheid Fm, Ecca Group, Karoo SG	Shales, mudstone, sandstone, coal seams	Early Permian Ca 290-270 Ma
Mle	Lebowa Granite Suite, Bushveld Igneous Complex	Medium-grained porphyritic grantite, red coarse-grained biotite granite	Palaeoproterozoic
Vse	Selons River Fm (now Schrikkloof Fm) Rooiberg Group	Flow-banded rhyolite, quartzitic lenses; felsic lava	Palaeoproterozoic 2056 Ma

The site lies in the northeastern part of the Karoo basin where the lower Karoo Supergroup strata are exposed (Figure 3). It is unconformably underlain by the volcanic rocks of the Rooiberg Group. Along the rivers and streams much younger reworked sands and alluvium overly the older strata.

According to more recent publications the Rooiberg Group is divided into four formations based on the proportions of various volcanic rocks that are present (Buchanan, 2006) with the upper Selons River Formation now called the Kwaggasnek and Sckhrikkloof Formations. Dated at 2056 Ma (Zeh et al., 2020) these volcanic rocks do not preserve any fossils. The Lebowa Granite Suite does not preserve any fossils either.

The Karoo Supergroup rocks cover a very large proportion of South Africa and extend from the northeast (east of Pretoria) to the southwest and across to almost the KwaZulu Natal south coast. It is bounded along the southern margin by the Cape Fold Belt and along the northern margin by the much older Transvaal Supergroup rocks. Representing some 120 million years (300 – 183Ma), the Karoo Supergroup rocks have preserved a diversity of fossil plants, insects, vertebrates and invertebrates.

During the Carboniferous Period South Africa was part of the huge continental landmass known as Gondwanaland and it was positioned over the South Pole. As a result, there were several ice sheets that formed and melted, and covered most of South Africa (Visser, 1986, 1989; Isbell et al., 2012). These are the oldest rocks in the system and are are known as the Dwyka Group. (Johnson et al., 2006).

Overlying the Dwyka Group rocks are rocks of the Ecca Group that are Early Permian in age. There are eleven formations recognised in this group but they do not all extend throughout the Karoo Basin. In the central and east part are the following formations, from base upwards are the Pietermaritzburg Formation, **Vryheid Formation** and the Volksrust Formation. All of these sediments have varying proportions of sandstones,

mudstones, shales and siltstones and represent shallow to deep water settings, deltas, rivers, streams and overbank depositional environments.

Overlying the Ecca Group are the rocks of the Beaufort Group and the Stormberg Group that complete the Karoo sequence. They are not present in this part of the basin. Large exposures of Jurassic dolerite dykes occur throughout the area but more to the south. These intruded through the Karoo sediments around 183 million years ago at about the same time as the Drakensberg basaltic eruption (Johnson et al., 2006).

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ii. Palaeontological context

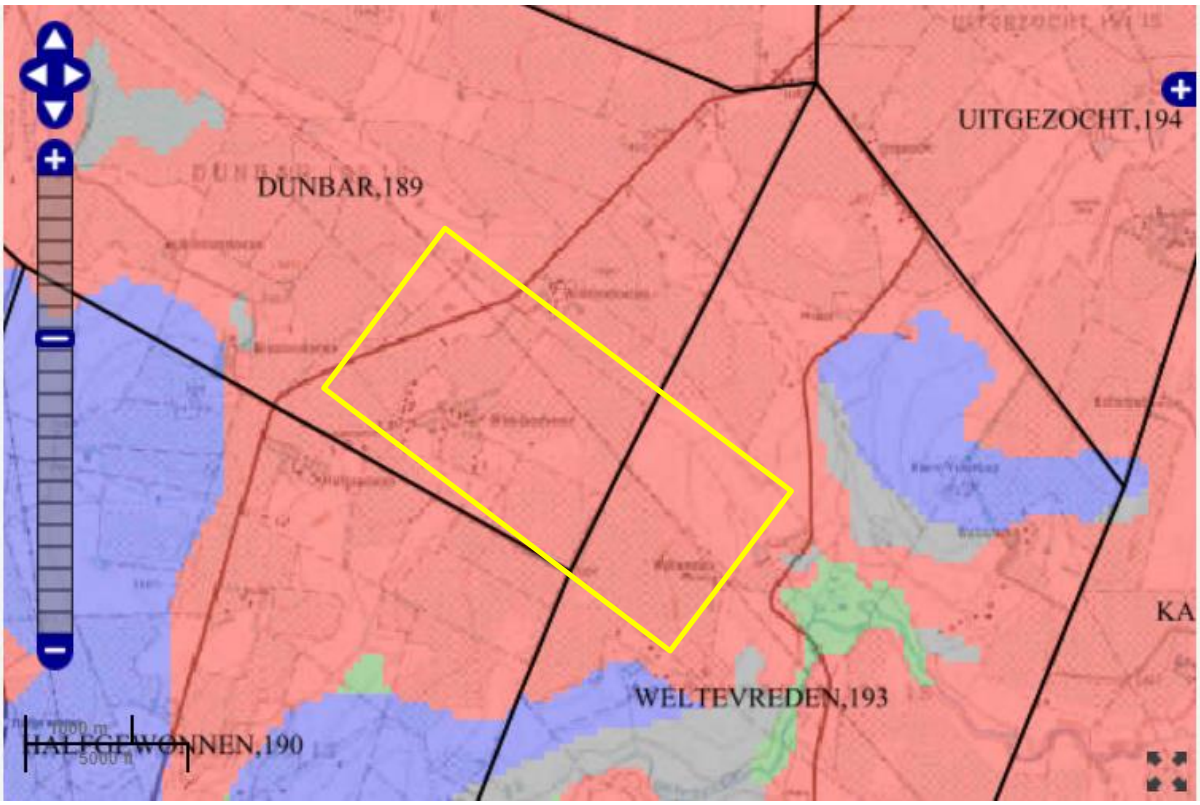

Figure 4: SAHRIS palaeosensitivity map for the three alternative sites for the proposed Hendrina Green Hydrogen and Ammonia facility shown within the yellow rectangle. Background colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero.

The palaeontological sensitivity of the area under consideration is presented in Figure 4. The site for development is in the Vryheid Formation (red) of the Ecca Group, Karoo Supergroup.

From the SAHRIS map above the area is indicated as very highly sensitive (red) for the Vryheid Formation so a site visit is required and has been completed. Volcanic rocks do not preserve fossils, only sedimentary rocks might preserve fossils if there were organisms present at the time of their deposition. At the time of deposition of the Vryheid Formation there were extensive deltas and floodplains with vegetation growing on the banks and in the flooded areas, or swamps. Overtime these became peats and were buried in the sediments that gradually filled the Karoo inland sea. With increased pressure from the overburden and increased geothermal temperatures, the peats were altered over time to form coal seams. These coal seams of varying thickness, depth and extent are exploited today for coal.

The coal itself does not preserve any recognisable plant material because the organic matter has been compressed, devolatilised and altered, however, in the carbonaceous shales or siltstones between coal seams it is possible to find impressions or compressions of the plants that originally formed the peats (Plumstead, 1969). The extinct seed fern glossopteris was the dominant plant in all Gondwana floras. It was a deciduous shrub to large tree with long tongue-shaped leaves. Other woody plants growing in the swamps were the cordaitaleans, a group of extinct early gymnosperms (Plumstead, 1969; Gastaldo et al., 2020). Many other plants made up this rich flora including lycopods, sphenophytes, ferns, mosses and early gymnosperms, as well as a variety of plants known only from their spores.

No vertebrates are known to occur with the *Glossopteris* flora because different conditions are required for the preservation of plants and animals. In general, plants require a reducing environment such as burial in an anoxic mud, while bones can survive exposure and an oxidising environment (Cowan, 1995). Moreover, in the Early Permian there were very few vertebrates but fish and invertebrates were present. In some depositional environments it is possible to find fish bones and traces of the invertebrates in the form of burrows and trackways (Cowan, 1995).

Although when present, the plants of the *Glossopteris* flora are abundant, but their distribution is difficult to predict (Kovacs-Endrody, 1976, 1991). This has resulted in known sites being well studied while the greater distribution remains unknown (Bamford and Gastaldo, 2023).

iii. Site visit observations

The proposed sites for the facility are on disturbed lands that have been cultivated, are lying fallow or are traversed by underground pipelines and overhead powerlines. The topography is flat to slightly undulating and the land surface has been cleared of any rocks for the agricultural activities (ploughed fields for crops, fallow fields and cattle grazing) as well as evidence of coal mining in the form of mine dumps, haul roads and access roads.

The three sites were walked down but some sections were inaccessible because of flooding from recent rains. Most fallow areas are overgrown with thick grasslands and weeds. The land cover comprises deep sandy, reddish soil, and crops or grasslands.

There were no outcrops of shales or mudstones that might preserve fossil plant impressions and so NO FOSSILS of plants or vertebrates were seen on the surface. According to the borehole core logs for the area southwest of Hendrina soils and sandstones overlie the uppermost coal seam, Seam A, to a depth of about 20m, and the shales and mudstones are below that (Snyman, 1998; fig 17). Soils and coarse sandstones do not preserve fossils so it would be unlikely to find them except where erosion has occurred.

No fossils were found anywhere in the three alternative sites for the Hendrina Green Hydrogen and Ammonia facility (Figures 5-7).

Figure 5: Site visit photographs for the Hendrina Green Energy and Ammonia facility. A - Access road along the northern section of the project area around the small settling ponds on the edge of the R35 east of the Komati power station. B - General view of the landscape around the northern end of the project area. C - Deep existing trenches that possibly were for a pipeline. D - General view of the landscape showing the overgrown ground vegetation across the project area. No rocky outcrops and no fossils.

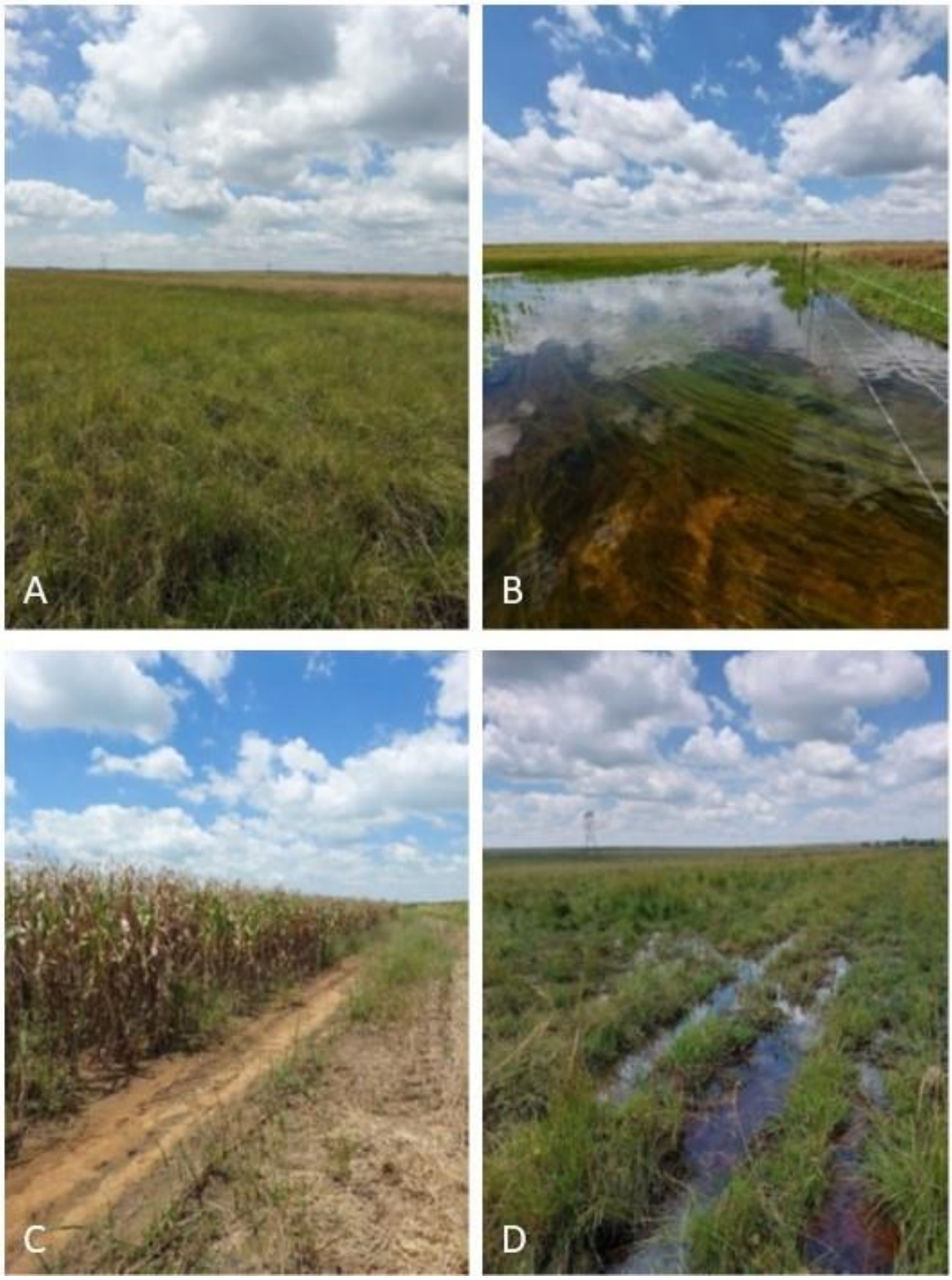

Figure 6: Site visit photographs for the Hendrina Green Energy and Ammonia facility. A - General view of the landscape showing the overgrown ground vegetation. B - General view of the waterlogged conditions in the central project area. C - Existing crops that are scattered across the entire project area. D - Waterlogged conditions along the southern portions of the project area. No rocky outcrops and no fossils were seen.

Figure 7: Site visit photographs for the Hendrina Green Energy and Ammonia facility. A - General view of the extremely overgrown ground vegetation. B - General view of the landscape around the south eastern end of the project area. C – One of the proposed lines will run through a small community situated along the eastern section of the project area. No rocky outcrops and no fossils were seen.

4. Impact assessment

Assessment of Impacts and Mitigation (WSP format)

The assessment of impacts and mitigation evaluates the likely extent and significance of the potential impacts on identified receptors and resources against defined assessment criteria, to develop and describe measures that will be taken to avoid, minimise or compensate for any adverse environmental impacts, to enhance positive impacts, and to report the significance of residual impacts that occur following mitigation.

Following the mitigation sequence/hierarchy of five levels:

a) Avoid/prevent significant impact
b) Minimise
c) Rehabilitate/restore
d) Off-set
e) No-go,

mitigation in the form of removing any important fossils (steps a and b) will reduce realty the impact of this project on the palaeontological heritage.

The key objectives of the risk assessment are to identify any additional potential environmental issues and associated impacts likely to arise from the proposed project, and to propose a significance ranking. Ranked criteria listed in Table 3a and the scores for the palaeontological impact are given in Table 3b.

Table 3a: Palaenontological Impact Assessment and Scoring according to WSP protocols.

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Impact Magnitude (M) The degree of alteration of the affected environmental receptor	Very low: No impact on processes	Low: Slight impact on processes	Medium: Processes continue but in a modified way	High: Processes temporarily cease	Very High: Permanent cessation of processes
Impact Extent (E) The geographical extent of the impact on a given environmental receptor	Site: Site only	Local: Inside activity area	Regional: Outside activity area	National: National scope or level	International: Across borders or boundaries
Impact Reversibility (R) The ability of the environmental receptor to rehabilitate or restore after the activity has caused environmental change	Reversible: Recovery without rehabilitation		Recoverable: Recovery with rehabilitation		Irreversible: Not possible despite action

CRITERIA	SCORE 1	SCORE 2	SCORE 3	SCORE 4	SCORE 5
Impact Duration (D) The length of permanence of the impact on the environmental receptor	Immediate: On impact	Short term: 0-5 years	Medium term: 5-15 years	Long term: Project life	Permanent: Indefinite
Probability of Occurrence (P) The likelihood of an impact occurring in the absence of pertinent environmental management measures or mitigation	Improbable	Low Probability	Probable	Highly Probability	Definite
Significance (S) is determined by combining the above criteria in the following formula:	$[S = (E + D + R + M) \times P]$ $Significance = (Extent + Duration + Reversibility + Magnitude) \times Probability$				
IMPACT SIGNIFICANCE RATING					
Total Score	**4 to 15**	**16 to 30**	**31 to 60**	**61 to 80**	**81 to 100**
Environmental Significance Rating (Negative (-))	**Very low**	**Low**	**Moderate**	**High**	**Very High**
Environmental Significance Rating (Positive (+))	**Very low**	**Low**	**Moderate**	**High**	**Very High**

Table 3b: Impact Assessment score and significance for Palaeontology for the Hendrina Green Hydrogen and Ammonia Facility (3 alternates). Mit = mitigation.

Project: Hendrina GH & A – CONSTRUCTION PHASE						
Criteria (from table above)	Alt 1		Alt 2		Alt 3	
	Pre-mit	Post-mit	Pre-mit	Post-mit	Pre-mit	Post-mit
Impact Magnitude (M)	2	1	2	1	2	1
Impact Extent (E)	1	1	1	1	1	1
Impact Reversibility (R)	5	3	5	3	5	3
Impact Duration (D)	5	1	5	1	5	1
Probability of Occurrence (P)	2	1	2	1	2	1
Significance (M+E+R+D) x P	26	6	26	6	26	6
Significance Rating	Low	Very low	Low	Very low	Low	Very low
Negative / Positive	Neg	Pos	Neg	Pos	Neg	Pos

Phase
There would potentially be an impact only during the Construction Phase when the ground will be broken for foundations and amenities. Fossils are inert and inactive so do not move. There would be no impact during the operational and decommissioning phases.

Mitigation
The impact on the palaeontological heritage can be reduced greatly by a palaeontologist conducting a pre-construction site visit to look for fossils and removing any scientifically important fossils with the relevant SAHRA permit. This has been done. (See Section 8 and Appendix A).

Positive/Negative Impact
The discovery and removal of fossils as a direct result of this project has a positive impact because prior to this project the particular fossils or fossil deposit were unknown to science.

Additional Environmental Impacts
As far as the palaeontology is concerned, there are no additional impacts because the fossils are inert and inactive.

Cumulative Impacts
As far as the palaeontology is concerned, there are no cumulative impacts because each site is unique and may or may not have fossils. Fossil bones may be scattered over the landscape but their distribution is erratic and unpredictable. If a bone-bed or plant outcrop occurs this would be in an aerially small concentration of fossils and very unlikely to extend beyond tens of metres. Therefore, projects on adjacent land parcels are unlikely to add any impact on this project.

No-Go areas
There are no-go areas because the fossils, if present, can be removed and curated in a recognised institution such as a museum or university that has the facilities to store and research the fossil material.

Alternative sites
As far as the palaeontology is concerned, all three sites have the same significance so there is no preference.

Based on the nature of the project, surface activities may impact upon the fossil heritage if preserved in the development footprint. The geological structures suggest that the rocks are the correct age and type to preserve fossils. The site visit and walk through confirmed that there were NO FOSSILS in the proposed project areas. Furthermore, the material to be excavated for foundations is soil and this does not preserve fossils. Since there is an extremely small chance that fossils from the Vryheid Formation may occur below ground and may be disturbed, a Fossil Chance Find Protocol has been added to this report. Taking account of the defined criteria, the potential impact to fossil heritage resources is low to very low.

5. Assumptions and uncertainties

Based on the geology of the area and the palaeontological record as we know it, it can be assumed that the formation and layout of the dolomites, sandstones, shales and sands are typical for the country and some do contain fossil plant, insect, invertebrate and vertebrate material. The site visit and walk through in April 2023 (late summer) by the palaeontologist confirmed that there are no fossils on the surface along the areas assessed. Some sites were under water but the emergent vegetation was the same as in accessible areas so it can be assumed that the substrate was the same. The sands of the Quaternary period would not preserve fossils. It is not known if there are shales bearing fossil plants below the ground surface.

6. Recommendation

Based on the fossil record but confirmed by the site visit and walk through there are NO FOSSILS of the *Glossopteris* flora even though fossils have been recorded from rocks of a similar age and type in South Africa. It is extremely unlikely that any fossils would be preserved in the overlying soils and sands of the Quaternary. There is a very small chance that fossils may occur in below the ground surface in the shales of the Vryheid Formation but more than 20m down, so a Fossil Chance Find Protocol should be added to the EMPr. If fossils are found by the environmental officer or other responsible person once excavations and drilling have commenced, then they should be rescued and a palaeontologist called to assess and collect a representative sample.

7. References

Anderson, J.M., Anderson, H.M., 1985. Palaeoflora of Southern Africa: Prodromus of South African megafloras, Devonian to Lower Cretaceous. A.A. Balkema, Rotterdam. 423 pp.

Buchanan, B.C., 2006. The Rooiberg Group. 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. Pp 283 – 289.

Cowan, R., 1995. History of Life. 2nd Edition. Blackwell Scientific Publications, Boston. 462pp.

Gastaldo, R.A., Bamford, M.K., 2023. The influence of taphonomy and time on the paleobotanical record of the Permian–Triassic transition of the Karoo Basin (and elsewhere). Journal of African Earth Sciences JOAES-S-22-01322

Gastaldo, R.A., Bamford, M., Calder, J., DiMichele, W.A., Ianuzzi, R., Jasper, A., Kerp, H., McLoughlin, S., Opluštil, S., Pfefferkorn, H.W., Roessler, R., and Wang, J., 2020, The non-analog vegetation of the Late Paleozoic icehouse–hothouse and their coal-forming forested environments: in Martinetto, E. Tschopp, E., and Gastaldo, R.A., (eds), Nature Through Time: Springer Nature Switzerland, Cham, Switzerland, p. 291-316. ISBN 978-3-030-35057-4.
https://doi.org/10.1007/978-3-030-35058-1

Isbell, J.L., Henry, L.C., Gulbranson, E.L., Limarino, C.O., Fraiser, F.L., Koch, Z.J., Ciccioli, P.l., Dineen, A.A., 2012. Glacial paradoxes during the late Paleozoic ice age: Evaluating the equilibrium line altitude as a control on glaciation. Gondwana Research 22, 1-19.

Johnson, M.R., van Vuuren, C.J., Visser, J.N.J., Cole, D.I., Wickens, H.deV., Christie, A.D.M., Roberts, D.L., Brandl, G., 2006. Sedimentary rocks of the Karoo Supergroup. 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. Pp 461 – 499.

Kovacs-Endrody, E., 1976. Notes on some *Glossopteris* species from Hammanskraal (Transvaal). Palaeontologia africana 19, 67-95.

Kovacs-Endrody, E. 1991. On the Late Permian age of Ecca Glossopteris floras in the Transvaal Province with a key to and descriptions of twenty five Glossopteris species. Memoir of the Geological Survey of South Africa, 77, 111pp.

Plumstead, E.P., 1969. Three thousand million years of plant life in Africa. Geological Society of southern Africa, Annexure to Volume LXXII. 72pp + 25 plates.

Visser, J.N.J., 1986. Lateral lithofacies relationships in the glacigene Dwyka Formation in the western and central parts of the Karoo Basin. Transactions of the Geological Society of South Africa 89, 373-383.

Visser, J.N.J., 1989. The Permo-Carboniferous Dwyka Formation of southern Africa: deposition by a predominantly subpolar marine icesheet. Palaeogeography, Palaeoclimatology, Palaeoecology 70, 377-391.

8. Chance Find Protocol

Monitoring Programme for Palaeontology – to commence once the excavations / drilling activities begin.

1. The following procedure is only required if fossils are seen on the surface and when excavations commence.
2. When excavations begin the rocks and discard must be given a cursory inspection by the environmental officer or designated person. Any fossiliferous material (trace fossils, fossils of plants, insects, bone or coalified plant material) should be put aside in a suitably protected place. This way the project activities will not be interrupted.
3. Photographs of similar fossils must be provided to the developer to assist in recognizing the fossil plants, vertebrates, invertebrates or trace fossils in the shales and mudstones (for example see Figure 8). This information will be built into the EMP's training and awareness plan and procedures.
4. Photographs of the putative fossils can be sent to the palaeontologist for a preliminary assessment.

5. If there is any possible fossil material found by the contractor or environmental officer then the qualified palaeontologist sub-contracted for this project, should visit the site to inspect the selected material and check the dumps where feasible.
6. Fossil plants or vertebrates that are considered to be of good quality or scientific interest by the palaeontologist must be removed, catalogued and housed in a suitable institution where they can be made available for further study. Before the fossils are removed from the site a SAHRA permit must be obtained. Annual reports must be submitted to SAHRA as required by the relevant permits.
7. If no good fossil material is recovered then no site inspections by the palaeontologist will be necessary. A final report by the palaeontologist must be sent to SAHRA once the project has been completed and only if there are fossils.
8. If no fossils are found and the excavations have finished then no further monitoring is required.

9. Appendix A – Examples of fossils from the Vryheid Formation

Figure 8:Photographs of fossil plants from the *Glossopteris* flora that could occur in the shales of the Vryheid Formation.

10. Appendix B – Details of specialists

Curriculum vitae (short) - Marion Bamford PhD
January 2023

Present employment: Professor; Director of the Evolutionary Studies Institute. Member Management Committee of the NRF/DSI Centre of Excellence Palaeosciences, University of the Witwatersrand, Johannesburg, South Africa
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ii) **Academic qualifications**
Tertiary Education: All at the University of the Witwatersrand:
1980-1982: BSc, majors in Botany and Microbiology. Graduated April 1983.
1983: BSc Honours, Botany and Palaeobotany. Graduated April 1984.
1984-1986: MSc in Palaeobotany. Graduated with Distinction, November 1986.
1986-1989: PhD in Palaeobotany. Graduated in June 1990.

iii) **Professional qualifications**
Wood Anatomy Training (overseas as nothing was available in South Africa):
1994 - Service d'Anatomie des Bois, Musée Royal de l'Afrique Centrale, Tervuren, Belgium, by Roger Dechamps
1997 - Université Pierre et Marie Curie, Paris, France, by Dr Jean-Claude Koeniguer
1997 - Université Claude Bernard, Lyon, France by Prof Georges Barale, Dr Jean-Pierre Gros, and Dr Marc Philippe

iv) **Membership of professional bodies/associations**
Palaeontological Society of Southern Africa
Royal Society of Southern Africa - Fellow: 2006 onwards
Academy of Sciences of South Africa - Member: Oct 2014 onwards
International Association of Wood Anatomists - First enrolled: January 1991
International Organization of Palaeobotany – 1993+
Botanical Society of South Africa
South African Committee on Stratigraphy – Biostratigraphy - 1997 - 2016
SASQUA (South African Society for Quaternary Research) – 1997+
PAGES - 2008 –onwards: South African representative
ROCEEH / WAVE – 2008+
INQUA – PALCOMM – 2011+onwards

v) **Supervision of Higher Degrees**

All at Wits University

Degree	Graduated/completed	Current

Honours	13	0
Masters	13	3
PhD	13	7
Postdoctoral fellows	14	4

vi) **Undergraduate teaching**
Geology II – Palaeobotany GEOL2008 – average 65 students per year
Biology III – Palaeobotany APES3029 – average 25 students per year
Honours – Evolution of Terrestrial Ecosystems; African Plio-Pleistocene Palaeoecology; Micropalaeontology – average 12 - 20 students per year.

vii) **Editing and reviewing**
Editor: Palaeontologia africana: 2003 to 2013; 2014 – Assistant editor
Guest Editor: Quaternary International: 2005 volume
Member of Board of Review: Review of Palaeobotany and Palynology: 2010 –
Associate Editor: Cretaceous Research: 2018-2020
Associate Editor: Royal Society Open: 2021 -
Review of manuscripts for ISI-listed journals: 30 local and international journals

viii) **Palaeontological Impact Assessments**
25 years' experience in PIA site and desktop projects

- Selected from recent projects only – list not complete:
- Skeerpoort Farm Mast 2020 for HCAC
- Vulindlela Eco village 2020 for 1World
- KwaZamakhule Township 2020 for Kudzala
- Sunset Copper 2020 for Digby Wells
- McCarthy-Salene 2020 for Prescali
- VLNR Lodge 2020 for HCAC
- Madadeni mixed use 2020 for Enviropro
- Frankfort-Windfield Eskom Powerline 2020 for 1World
- Beaufort West PV Facility 2021 for ACO Associates
- Copper Sunset MR 2021 for Digby Wells
- Sannaspos PV facility 2021 for CTS Heritage
- Smithfield-Rouxville-Zastron PL 2021 for TheroServe
- Glosam Mine 2022 for AHSA
- Wolf-Skilpad-Grassridge OHPL 2022 for Zutari
- Iziduli and Msenge WEFs 2022 for CTS Heritage
- Hendrina North and South WEFs & SEFs 2022 for Cabanga
- Dealesville-Springhaas SEFs 2022 for GIBB Environmental
- Vhuvhili and Mukondeleli SEFs 2022 for CSIR
- Chemwes & Stilfontein SEFs 2022 for CTS Heritage
- Equestria Exts housing 2022 for Beyond Heritage
- Zeerust Salene boreholes 2022 for Prescali
- Tsakane Sewer upgrade 2022 for Tsimba
- Transnet MPP inland and coastal 2022 for ENVASS
- Ruighoek PRA 2022 for SLR Consulting (Africa)
- Namli MRA Steinkopf 2022 for Beyond Heritage

ix) **Research Output**
Publications by M K Bamford up to January 2022 peer-reviewed journals or scholarly books: over 170 articles published; 5 submitted/in press; 14 book chapters.
Scopus h-index = 31; Google Scholar h-index = 39; -i10-index = 116 based on 6568 citations.
Conferences: numerous presentations at local and international conferences.