

**Palaeontological Impact Assessment for the proposed
mixed development, Hammanskraal X12,
Gauteng Province**

Desktop Study

For

HCAC

23 June 2019

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Expertise of Specialist

The Palaeontologist Consultant is: Prof Marion Bamford
Qualifications: PhD (Wits Univ, 1990); FRSSAf, ASSAf
Experience: 30 years research; 22 years PIA studies

Declaration of Independence

This report has been compiled by Professor Marion Bamford, of the University of the Witwatersrand, sub-contracted by Heritage Contracts and Archaeological Consulting, 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

A palaeontological Impact Assessment was requested for the proposed mixed residential and business south of Hammanskraal, called Hammanskraal X112, on a farm of the same name. To comply with 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 desktop Palaeontological Impact Assessment (PIA) was completed for the proposed project.

The proposed site lies on the southernmost exposures of sandstones and shales of the Hammanskraal Formation in the Springbok Flats Basin. It is equivalent to the Vryheid and Volksrust Formations of the Main Karoo Basin. Fossil plants of the Glossopteris flora have been recovered from a kaolinite quarry of the same age to the south of this project. Pollen has been recovered from borehole cores in the Springbok Flats Basin but no fossils have been recorded from this location. If kaolinite is present below the surface soils then there is a chance that it might preserve fossil leaf impressions. Therefore a Fossil Chance Find Protocol should be added to the EMPr. Based on this information it is recommended that no palaeontological site visit is required until fossils are recovered in the excavations.

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1. Background

A Palaeontological Impact Assessment (PIA) has been requested for the proposed development called Hammanskraal X12 situated to the south of the town of Hammanskraal, northern Gauteng Province, west of the N1 highway and east of and adjacent to the R101 road. The property is a portion of portion 76 of the Farm Hammanskraal 112 JR. The development entails the establishment of a mixed development township that includes residential, business, education institutions and public open space components and its associated facilities including services and road infrastructure.

The Scoping and Environmental Impact reporting process (S&EIR) will apply to this application. The process is done in terms of Government Notice Regulations (GNR) No. 982, 983 and 984 of the EIA Regulations of 2014 (as amended). The EIA Regulations were promulgated in terms of the National Environmental Management Act ('NEMA', Act No. 107 of 1998, as amended).

The project will involve the following activities:

Activity 9 - The development of infrastructure exceeding 1000 metres in length for the bulk transportation of water or storm water-

- (i) with an internal diameter of 0,36 metres or more; or
- (ii) (ii) with a peak throughput of 120 litres per second or more; excluding where
 - (a) such infrastructure is for bulk transportation of water or storm water or storm water drainage inside a road reserve or railway line reserve; or
 - (b) where such development will occur within an urban area.

Activity 10 - The development and related operation of infrastructure exceeding 1000 metres in length for the bulk transportation of sewage, effluent, process water, waste water, return water, industrial discharge or slimes -

- (i) with an internal diameter of 0,36 metres or more; or
- (ii) with a peak throughput of 120 litres per second or more; excluding where -
 - (a) such infrastructure is for the bulk transportation of sewage, effluent, process water, waste water, return water, industrial discharge or slimes inside a road reserve or railway line reserve; or
 - (b) where such development will occur within an urban area.

Activity 11 - The development of facilities or infrastructure for the transmission and distribution of electricity - (i) outside urban areas or industrial complexes with a capacity of more than 33 but less than 275 kilovolts; or (ii) inside urban areas or industrial complexes with a capacity of 275 kilovolts or more.

Activity 15 - The clearance of an area of 20 hectares or more of indigenous vegetation

In order to comply with 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 desktop Palaeontological Impact Assessment (PIA) was completed for the proposed development of Hammanskraal X12.

Table 1: Specialist report requirements in terms of Appendix 6 of the EIA Regulations (2017)

	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
a ii	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
c ii	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
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	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	Appendix A
ni	A reasoned opinion as to whether the proposed activity or portions thereof should be authorised	N/A
n ii	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	N/A
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 if any comments that were received during any consultation process	N/A
q	Any other information requested by the competent authority.	N/A



Figure 1: Google Earth map of the proposed development of mixed housing and business on a portion of portion 76 of Farm Hammanskraal 112 JR with the section shown by the red outline. Map supplied by HCAC.

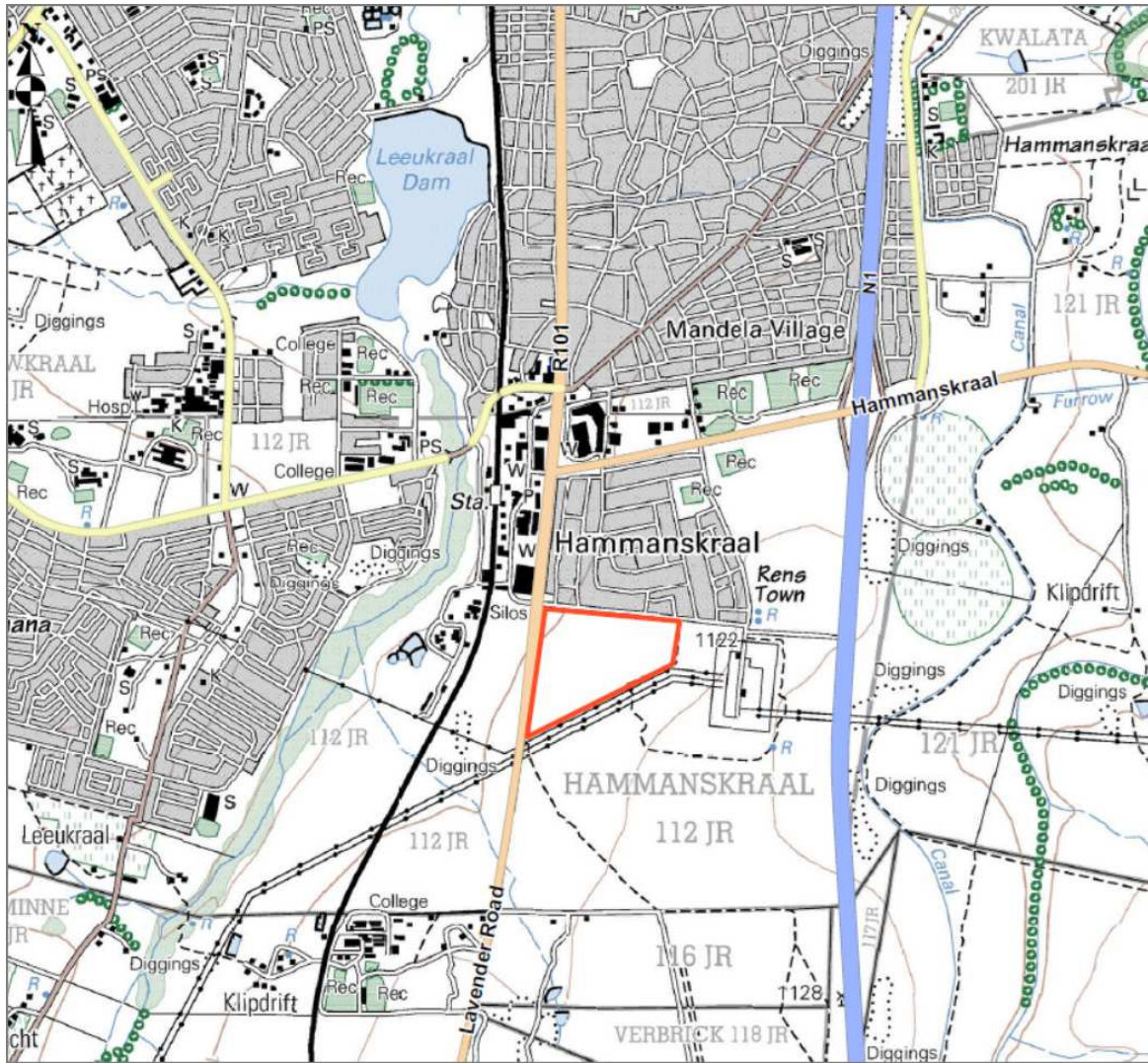


Figure 2: Site map of the project (in red outline). Map supplied by HCAC from the 1:50 000 topographic map.

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 (*not applicable to this assessment*);
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

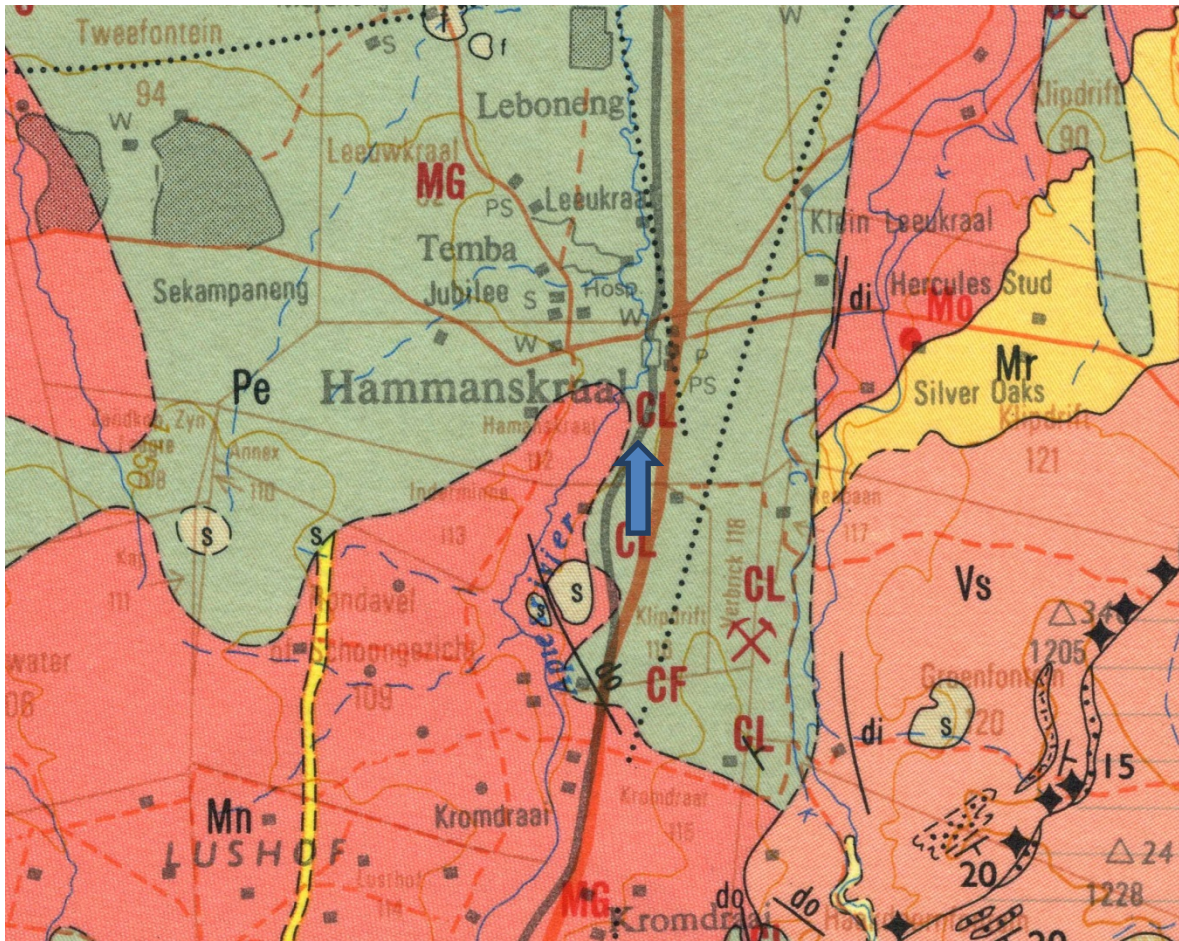


Figure 3: Geological map of the area around Hammanskraal. The location of the proposed project is indicated with the arrow. Abbreviations of the rock types are explained in Table 2. Map enlarged from the Geological Survey 1: 250 000 map 2528 Pretoria 1978.

Table 2: Explanation of symbols for the geological map and approximate ages (Barbolini et al., 2019; Buchanan, 2006; Johnson et al., 2006). SG = Supergroup; Fm = Formation. Ma = million years. Grey colour = affected lithology.

Symbol	Group/Formation	Lithology	Approximate Age
Pe	Hammanskraal Fm, Ecca Group, Karoo Supergroup	Siltstones, mudstones, sandstones and coals seams	middle Permian (Kungurian to Roadian)

Symbol	Group/Formation	Lithology	Approximate Age
Mr	Rashoop Granophyre, Bushveld Complex	Granophyre, pseudogranophyre, granite porphyry	>2050 Ma
Ma	Hybrid and metasomatised rocks, Bushveld Complex	Hybrid and metasomatised rocks	>2050 Ma
Vs	Selons River Fm, (now the Schrikkloof and Kwaggasnek Fms) Rooiberg Group, Transvaal SG.	Siliceous extrusive (volcanic) rocks	>2400 Ma

The oldest rocks in this region are those of the Rooiberg Group, namely the siliceous extrusive rocks of the Selons River Formation (now called the Schrikkloof Formation and lower Kwaggasnek Formation). They are part of the Bushveld Magmatic Province. The Rashoop Granophyre is also part of the Bushveld Complex (Buchanan, 2006). Since these rocks are more than 2050 million years and are volcanic in origin they would not contain any fossils and so will not be discussed further.

The site lies on sediments of the Karoo Supergroup and represents one of the northern smaller basins, and in particular on shales and mudstones of the Ecca Group. These are early Permian in age, or to follow more recent terminology, Cisuralian Series. As the continent of Gondwana moved northwards glacial meltwaters filled the huge Karoo Basin as well as smaller outlying basins (Johnson et al., 2006). The early Permian vegetation that colonised the swamps and deltas formed peats and eventually coals where suitable conditions occurred.

ii. Palaeontological context

Some Ecca siltstones and mudstones are richly fossiliferous and preserve impressions of plants of the *Glossopteris* flora, but not vertebrates because they predate most terrestrial animals and in general the conditions were not suitable for the preservation of bone. Plants of the *Glossopteris* flora include *Glossopteris* leaves, fructifications, cordaitaleans, lycopods, sphenophytes, ferns and some rare early conifers. Peats would have formed when the vegetation was abundant and waterlogged. Buried and altered peats eventually form coal seams under the right conditions (no oxygen but high pressures and temperatures). In more oxidising conditions peats would not form but some plant material can be preserved in clay deposits.

On the farm Haakdoornfontein 119 JR, situated on the Springbok Flats, 33 km north of Pretoria and 6.8 km south-southeast of Hammanskraal station, are the Hammanskraal refractory clay quarries. Prior to flooding and abandonment large collections of fossil plants were made (Smithies, 1978) from this site at 25° 27' 54"E, 28° 17' 47"S. The site has been described by Bennets (1965) and fossils described by Smithies (1978), Anderson and Anderson (1985), Kovacs-Endrody, 1996, 2001; Adendorff (2005), Adendorff et al., (2003)

and is a typical early to middle Permian flora dominated by glossopterid leaves, roots (*Vertebraria*) and fruits (*Arberia madagascariensis*, *Hirsutum leslii*, *Ottokaria hammanskraalensis*), ferns (*Sphenopteris*, *Asterotheca*), lycophytes (*Cyclodendron*), sphenophytes (*Annularia*, *Sphenophyllum*), and various platyspermic seeds (Smithies, 1978; Anderson and Anderson, 1985; Adendorff et al., 2003).

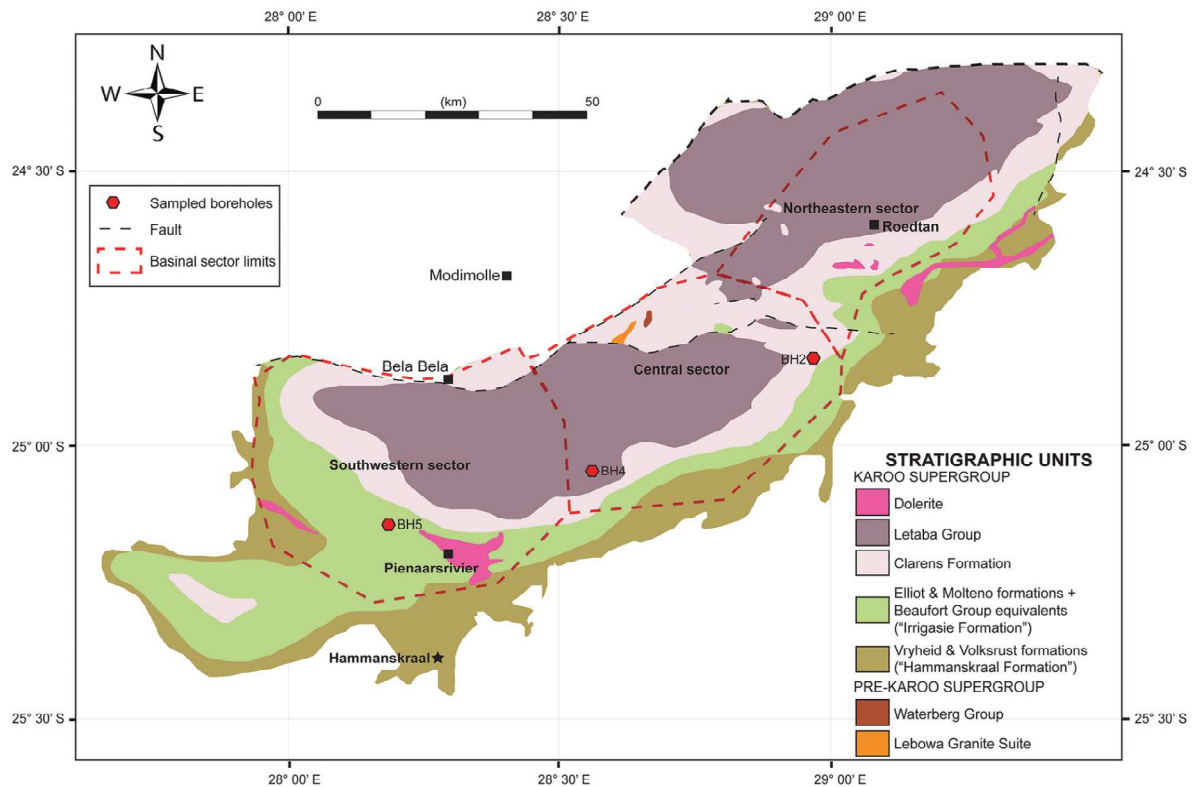


Figure 4: Stratigraphy of the Springbok Flats Basin, an outlier of the Main Karoo Basin. Note Hammanskraal is in the southernmost part and on rocks of the “Hammanskraal Formation (equivalent to the Vryheid and Volksrust Formations. (Taken from Barbolini et al., 2019, fig 2.).

It has been difficult to correlate the outlying Springbok Flats Basin with the Main Karoo Basin but recent work on the palynology for core material (study of pollen and spores produced by plants) has shown that the two coal seams in the Springbok Flats Basin from the Kungurian and Witbank No 4 Seam (lower seam) and Roadian (the upper seam). So the Hammanskraal quarry flora is middle Permian.

It should be noted that the leaf impressions from the quarry occurred only in the kaolinite and the pollens were from borehole cores into the coal producing sections. The fossils were not found in the shales, sandstones or surface soils.

From the SAHRIs palaeosensitivity map (Figure 5) the site for Hammanskraal X112 mixed residential and business development is indicated as highly sensitive (orange). This applies

to the Ecca sediments that are called Hammanskraal Formation in the Springbok Flats Basin and are equivalent to the Vryheid or Volksrust Formations of the Main Karoo Basin.

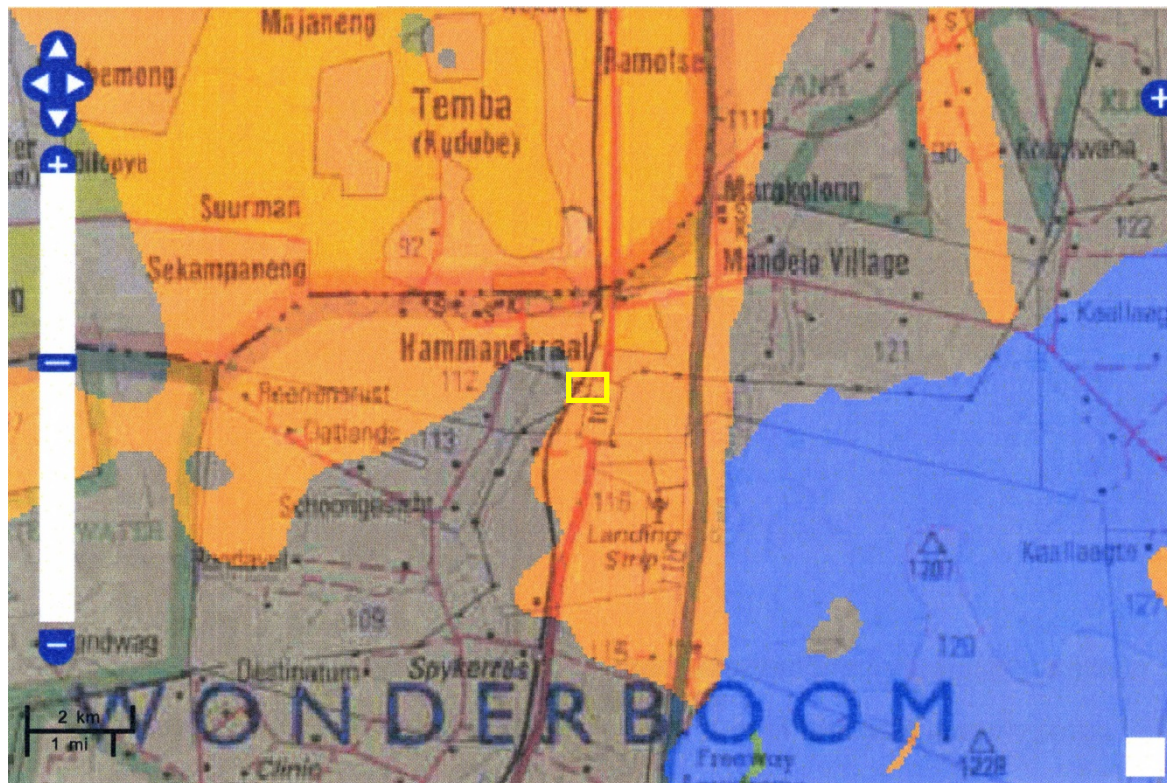


Figure 5: SAHRIS palaeosensitivity maps for the site for the proposed mixed development, south of Hammanskraal shown within the yellow rectangle. Colours indicate the following degrees of sensitivity: red = very highly sensitive; orange/yellow = high; green = moderate; blue = low; grey = insignificant/zero.

4. Impact assessment

An assessment of the potential impacts to possible palaeontological resources considers the criteria encapsulated in Table 3:

TABLE 3A: CRITERIA FOR ASSESSING IMPACTS

PART A: DEFINITION AND CRITERIA		
Criteria for ranking of the SEVERITY/NATURE of environmental impacts	H	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.

	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	L	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	L	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national
PROBABILITY (of exposure to impacts)	H	Definite/ Continuous
	M	Possible/ frequent
	L	Unlikely/ seldom

TABLE 3B: IMPACT ASSESSMENT

PART B: ASSESSMENT		
SEVERITY/NATURE	H	-
	M	The weathered and disturbed surface soils do not preserve plant fossils but there might be fossil plants below the surface if there are kaolin deposits
	L	-
	L+	-
	M+	-
	H+	-
DURATION	L	-
	M	-
	H	Where manifest, the impact will be permanent.
SPATIAL SCALE	L	Since only the possible fossils within the area would be fossil plants from the <i>Glossopteris</i> flora in the kaolinite or rarely shales, the spatial scale will be localised within the site boundary.
	M	-
	H	-
PROBABILITY	H	-
	M	-
	L	It is extremely unlikely that any fossils would be found in the loose soils but if clays are present there might be fossil plant impressions preserved. Therefore a Fossil Chance Find protocol should be added to the eventual EMPr.

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 surrounding rocks are much too old to contain fossils and are volcanic in origin. There is a chance that fossil plant impressions of the *Glossopteris* flora might occur below the surface, if kaolinite is present. According to the national maps of kaolin distribution (Bennets, 1968) there are no deposits in this location. No fossils have been recorded from this site but have been recoded from a quarry farther to the south. Since there is a small chance that fossils might occur here a Fossil Chance Find protocol has been added to this report so that once excavations for infrastructure and buildings commence any fossil finds can be monitored

and rescued. Taking account of the defined criteria, the potential impact to fossil heritage resources is 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 could possibly contain fossil plants or insects in the clays or shales below ground. No fossils would be preserved in the surface soils because they would be naturally weathered and destroyed by previous agricultural activities. None has been recorded from this location but have been reported from the Refractory Clay quarry farther south of Hammanskraal.

6. Recommendation

Based on experience and the lack of any previously recorded fossils from the location, it is extremely unlikely that any fossils would be preserved in the surface soils. There is a very small chance that fossils may occur in the shales or clays the Hammanskraal Formation, middle Permian Ecca Group, so a Chance Find Protocol should be added to the EMP: if fossils are found once excavations for foundations and infrastructure have commenced then they should be rescued and a palaeontologist called to assess and collect a representative sample.

7. References

Adendorff, R., 2005. A revision of the ovuliferous fructifications of glossopterids from the Permian of South Africa. Unpublished PhD Thesis, University of the Witwatersrand, Johannesburg. 421 pp.

Adendorff, R., Bamford, M.K., McLoughlin, S., 2003. *Liknopetalon*: a review of a rare gondwanan, Permian pteridophyte. *Review of Palaeobotany and Palynology* 126, 83–101.

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

Barbolini, N., Nxumalo, V., Wagner, N., Kramers, J., Vorster, C., Cairncross, B., Bamford, M.K., 2019. Palynostratigraphic correlation of the Springbok Flats coalfield to other coal-bearing successions in the Karoo basins of southern Africa. *South African Journal of Geology* 2019 doi:10.25131/sajg.122.0001

Bennets, K.P., 1965. The flint clay deposits of the area between Pretoria and Belfast, Transvaal. Bull. Geol. Surv. S. Afr. 45.

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.

Smithies, S.J., 1978. Studies on a Middle *Ecca* (Lower Permian) flora from Hammanskraal, Transvaal, South Africa, with emphasis on the glossopterid fructification *Ottokaria* Zeiller. Unpublished MSc dissertation, University of the Witwatersrand, Johannesburg.

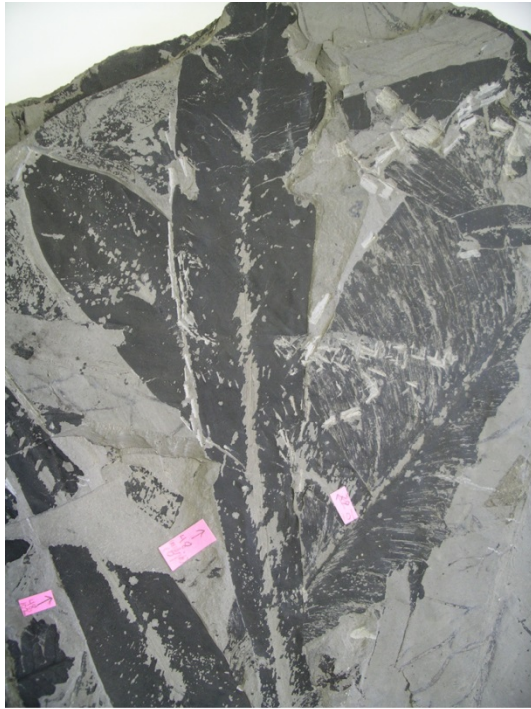
8. Chance Find Protocol

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

1. The following procedure is only required if fossils are seen on the surface and when excavations for foundations, roads, water, electricity, etc., commence.
2. When excavations begin the rocks and must be given a cursory inspection by the environmental officer or designated person. Any fossiliferous material (plants, insects, bone, coal) should be put aside in a suitably protected place. This way the construction activities will not be interrupted.
3. Photographs of similar fossil plants must be provided to the developer to assist in recognizing the fossil plants in the shales and mudstones (for example see Figure 6, 7). 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 developer/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 the site inspections by the palaeontologist will not be necessary.
8. If no fossils are found and the excavations have finished then no further monitoring is required.

Appendix A – Examples of Fossil plants



Wide and narrow *Glossopteris* leaves



Narrow *Glossopteris* leaves



Lycopodium stem with leaf abscission scars



Asterotheca (fern)

Hammanskraal fossil plants

Figure 6: Leaf impressions with black cuticle preserved from Hammanskraal kaolinite quarry.



Fern: *Asterotheca* sp.

Sphenophytes: whorls of leaves on a striated stem

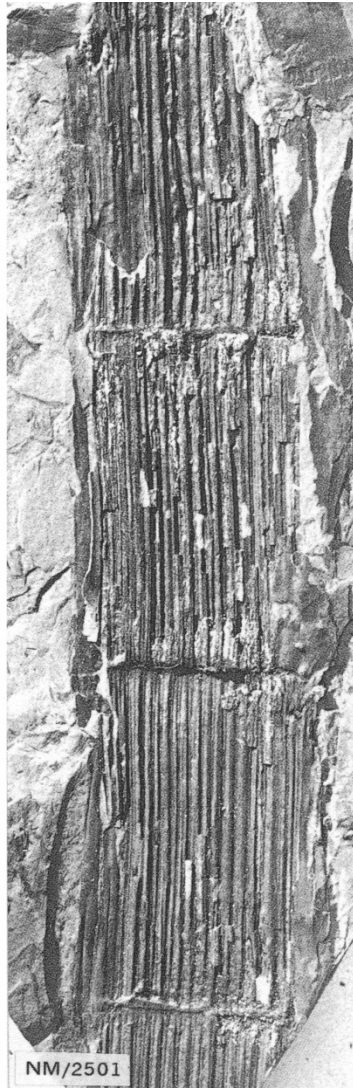


Figure 7: more typical Ecca fossil plants from the Main Karoo Basin.

Appendix B – Details of specialist

Curriculum vitae (short) - Marion Bamford PhD October 2018

i) Personal details

Surname : **Bamford**
First names : **Marion Kathleen**
Present employment : Professor; Director of the Evolutionary Studies Institute.
Member Management Committee of the NRF/DST Centre of Excellence Palaeosciences, University of the Witwatersrand, Johannesburg, South Africa-
Telephone : +27 11 717 6690
Fax : +27 11 717 6694
Cell : 082 555 6937
E-mail : marion.bamford@wits.ac.za ; marionbamford12@gmail.com

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

vii) Supervision of Higher Degrees

All at Wits University

Degree	Graduated/completed	Current
Honours	6	1
Masters	8	1
PhD	10	3
Postdoctoral fellows	9	3

viii) 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 2-8 students per year.

ix) 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 –
Cretaceous Research: 2014 -

Review of manuscripts for ISI-listed journals: 25 local and international journals

x) Palaeontological Impact Assessments

Selected – list not complete:

- Thukela Biosphere Conservancy 1996; 2002 for DWAF
- Vioolsdrift 2007 for Xibula Exploration
- Rietfontein 2009 for Zitholele Consulting
- Bloeddrift-Baken 2010 for TransHex
- New Kleinfontein Gold Mine 2012 for Prime Resources (Pty) Ltd.
- Thabazimbi Iron Cave 2012 for Professional Grave Solutions (Pty) Ltd
- Delmas 2013 for Jones and Wagener
- Klipfontein 2013 for Jones and Wagener
- Platinum mine 2013 for Lonmin
- Syferfontein 2014 for Digby Wells
- Canyon Springs 2014 for Prime Resources
- Kimberley Eskom 2014 for Landscape Dynamics

- Yzermyne 2014 for Digby Wells
- Matimba 2015 for Royal HaskoningDV
- Commissiekraal 2015 for SLR
- Harmony PV 2015 for Savannah Environmental
- Glencore-Tweefontein 2015 for Digby Wells
- Umkomazi 2015 for JLB Consulting
- Ixia coal 2016 for Digby Wells
- Lambda Eskom for Digby Wells
- Alexander Scoping for SLR
- Perseus-Kronos-Aries Eskom 2016 for NGT
- Mala Mala 2017 for Henwood
- Modimolle 2017 for Green Vision
- Klipoortjie and Finaalspan 2017 for Delta BEC
- Ledjadja borrow pits 2018 for Digby Wells
- Lungile poultry farm 2018 for CTS
- Olienhout Dam 2018 for JP Celliers
- Isondlo and Kwasobabili 2018 for GCS
- Kanakies Gypsum 2018 for Cabanga
- Nababeep Copper mine 2018
- Glencore-Mbali pipeline 2018 for Digby Wells
- SARA0 2018 for Digby Wells
- Ventersburg B 2018 for NGT
- Hanglip Service Station 2018 for HCAC

xi) Research Output

Publications by M K Bamford up to June 2018 peer-reviewed journals or scholarly books: over 130 articles published; 5 submitted/in press; 8 book chapters.
 Scopus h index = 26; Google scholar h index = 30;
 Conferences: numerous presentations at local and international conferences.

xii) NRF Rating

NRF Rating: B-2 (2016-2020)
 NRF Rating: B-3 (2010-2015)
 NRF Rating: B-3 (2005-2009)
 NRF Rating: C-2 (1999-2004)