Palaeontological specialist assessment: combined desktop and field-based study

Proposed SANParks upgrade at Elandsberg Rest Camp and staff village at Roodewerf Park Office, Tankwa Karoo National Park, Hantam Local Municipality, Northern Cape

John E. Almond PhD (Cantab.)

***Natura Viva* cc, PO Box 12410 Mill Street,**

Cape Town 8010, RSA

naturaviva@universe.co.za

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EXECUTIVE SUMMARY

The South African National Parks authority (SANParks) is proposing to construct an additional five tourism accommodation units at the exisiting Elandsberg Rest Camp as well as a new staff village with associated infrastructure close to the Roodewerf Park Office in the Tankwa Karoo National Park, Hantam Local Municipality, Northern Cape

The proposed new chalet developments at the Elandsberg Rest Camp overlie dolerite (igneous) bedrocks that are entirely unfossiliferous. No fossils were recorded from the superficial sedimentary rocks (bouldery dolerite colluvium, gravelly soils, calcrete) mantling the dolerite bedrocks in the study area.

The proposed staff village development footprint near Roodewerf overlies bouldery terrace gravels and silty alluvium of the Renosterrivier; the area has been extensively modified for agriculture (*saaidamme*). No fossils were recorded within these fluvial deposits, which are probably of Quaternary to Holocene age, but occasional reworked skeletal remains of mammals (*e.g.* rhinoceros or elephant bones, teeth) might conceivably occur here. A small relict patch of bouldery High Level terrace gravels occurs on the lower slopes of the dolerite *koppie* bordering the staff village study area on the northern side. Sparse subfossil bone fragments as well as calcretised plant root casts (*rhizoliths*) or invertebrate burrows were recorded in the overlying finer-grained gravels, but outside the anticipated development footprint.

Thermally metamorphosed or baked mudrocks of the Tierberg Formation (Ecca Group, Permian) in the vicinity of Roodewerf (*e.g.* road cuttings just south of the road bridge, quarry area south of De Zyfer) contain well-preserved, low-diversity trace fossil assemblages. These mainly comprise simple to branched horizontal burrows, some of which may belong to the ichnogenus *Chondrites*. Unless baked mudrocks of the Tierberg Formation are exploited for new building material, as in the case of existing buildings at Roodewerf, the proposed developments at the Tanqua Karoo National Park will not have a significant impact on these trace fossil assemblages, however. The trace fossils concerned are widely distributed within the extensive Tierberg Formation outcrop area (*e.g.* near Oudebaaskraal Dam and elsewhere along the Tanqua River) and are not considered to warrant special mitigation measures.

It is concluded that the proposed developments at the Tanqua Karoo National Park do not pose a significant threat to local fossil heritage resources. Pending the discovery of substantial new fossil remains during construction, no further specialist palaeontological studies, monitoring or mitigation is

recommended. The Site Engineer and / or Environmental Control Officer (ECO) responsible for monitoring environmental compliance of the development must remain aware that all sedimentary deposits have the potential to contain fossils, however, and he/she should thus monitor all deeper (> 1 m) excavations into sedimentary bedrock for fossil remains. If any significant fossil remains (*e.g.* vertebrate bones, teeth, horn cores, fossil plant-rich beds) are found during construction the South African Heritage Resources Agency (SAHRA) should be notified immediately (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense.

The palaeontologist concerned with recording, sampling and mitigation work would need a valid collection permit from the South African Heritage Resources Agency. All work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies recently published by SAHRA (2013).

1. INTRODUCTION AND BRIEF

The South African National Parks authority (SANParks) is proposing to construct (1) an additional five tourism accommodation units at the exisitng Elandsberg Rest Camp as well as (2) a new staff village with associated infrastructure close to the Roodewerf Park Office in the Tankwa Karoo National Park, Hantam Local Municipality / Karoo Hoogland Municipality, Northern Cape. In addition bulk services like water, electricity and sewage will be installed at both sites, whilst access and internal roads are to be established.

The project is currently in the planning stages of development, and SANParks is in the process of applying for Environmental Authorization from the National Department of Environmental Affairs (DEA Reference Number: 14/12/16/3/3/1/978). A Phase 1 palaeontological assessment for the proposed development has been requested by SAHRA (their ref: 9/2/017/0020, letter dated 19 August 2013).

The Tanqua Karoo National Park study area is situated to the east of the R355 Ceres to Calvinia dust road, some 60 km WNW of Sutherland (See park map in the Appendix, Fig. A1).

1.1. Scope of this palaeontological heritage study

This combined desktop and field-based palaeontological specialist report provides an assessment of the observed or inferred palaeontological heritage within the two project areas (Figs. 1 to 3), with recommendations for further specialist palaeontological studies and / or mitigation where considered necessary. The report will also inform the Environmental Management Plan for the proposed upgrade at the Tanqua Karoo National Park.

The study has been commissioned by Enviroworks Western Cape (Contact details: Mark Day. Tel 021 853 0682| Cell 084 738 1130| Fax 086 601 7507 | Email mark@enviroworks.co.za | Suite 338 | Private Bag X15 | Somerset West | 9300).

Fig. 1. Google earth© satellite image showing the location of the existing Elandsburg Rest Camp and the proposed staff village near the Roodewerf Park Office, Tanqua Karoo National Park, Northern Cape. The important trace fossil site in the Tierberg Formation at the Oudebaaskraal Dam is circled in yellow.

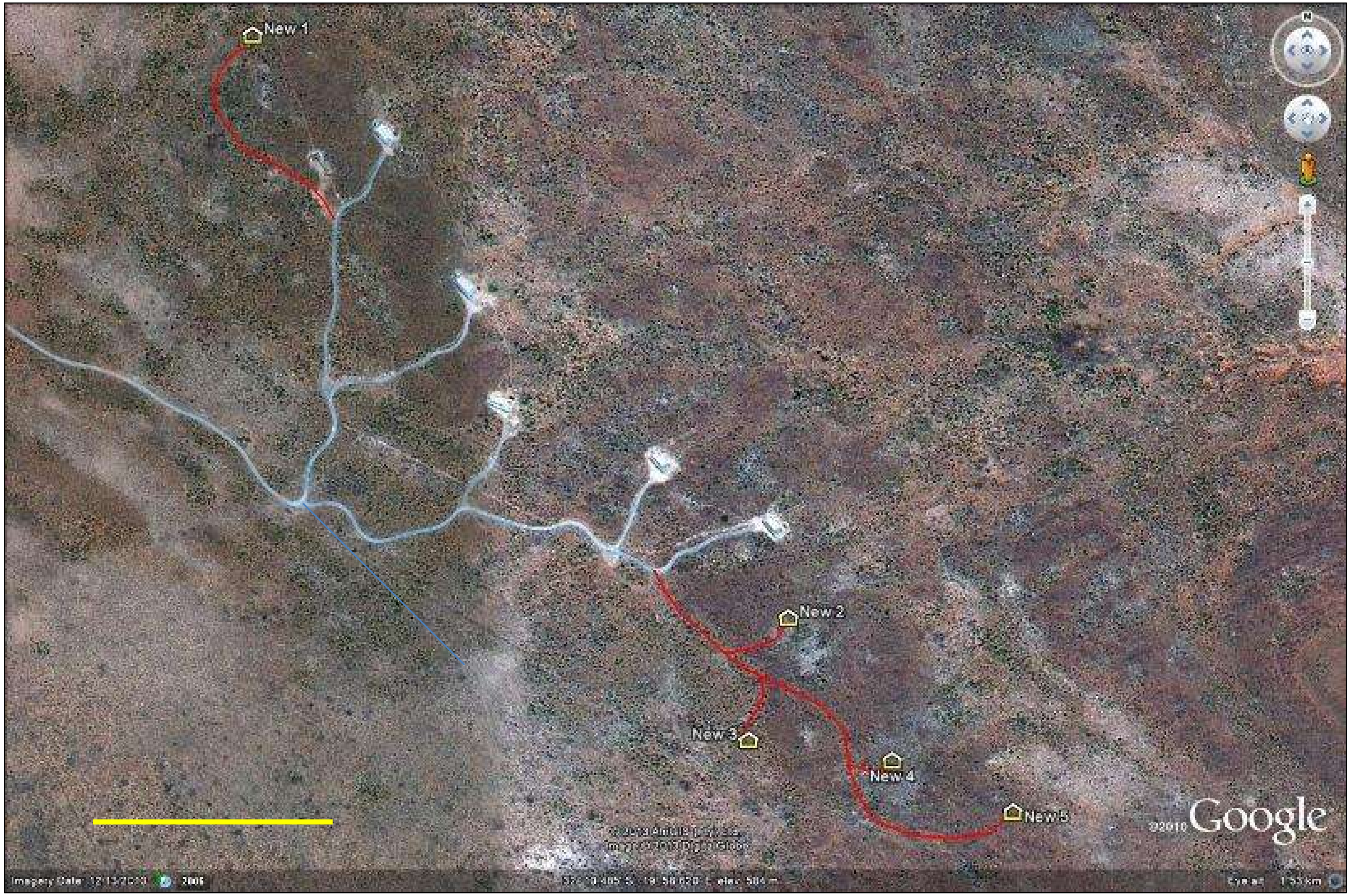

Fig. 2. Google earth© satellite image of the Elandsberg Rest Camp area showing the existing roads and buildings as well as the proposed five new accommodation units. Scale bar = *c.* 200 m. Image kindly provided by the Tanqua Karoo National Park.

Fig. 3. Provisional site plan for the proposed staff village in the valley of the Renosterrivier to the southwest of the Roodewerf Park Office. Scale bar = *c.* 200 m. A relict patch of High Level Gravels overlying dolerite to the north of the study area is indicated by the yellow dashed line. The red dashed line indicates road cuttings with trace fossil – rich baked mudrocks of the Tierberg Formation. Modified from an image kindly provided by the Tanqua Karoo National Park.

1.2. Legislative context for palaeontological assessment studies

The present combined desktop and field-based palaeontological heritage report falls under Sections 35 and 38 (Heritage Resources Management) of the South African Heritage Resources Act (Act No. 25 of 1999), and it will also inform the Environmental Management Plan for this project.

The various categories of heritage resources recognised as part of the National Estate in Section 3 of the National Heritage Resources Act include, among others:

- geological sites of scientific or cultural importance;
- palaeontological sites;
- palaeontological objects and material, meteorites and rare geological specimens.

According to Section 35 of the National Heritage Resources Act, dealing with archaeology, palaeontology and meteorites:

(1) The protection of archaeological and palaeontological sites and material and meteorites is the responsibility of a provincial heritage resources authority.

(2) All archaeological objects, palaeontological material and meteorites are the property of the State.

(3) Any person who discovers archaeological or palaeontological objects or material or a meteorite in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority, or to the nearest local authority offices or museum, which must immediately notify such heritage resources authority.

(4) No person may, without a permit issued by the responsible heritage resources authority—

(a) destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite;

(b) destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorite;

(c) trade in, sell for private gain, export or attempt to export from the Republic any category of archaeological or palaeontological material or object, or any meteorite; or

(d) bring onto or use at an archaeological or palaeontological site any excavation equipment or any equipment which assist in the detection or recovery of metals or archaeological and palaeontological material or objects, or use such equipment for the recovery of meteorites.

(5) When the responsible heritage resources authority has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management procedure in terms of section 38 has been followed, it may—

(a) serve on the owner or occupier of the site or on the person undertaking such development an order for the development to cease immediately for such period as is specified in the order;

(b) carry out an investigation for the purpose of obtaining information on whether or not an archaeological or palaeontological site exists and whether mitigation is necessary;

(c) if mitigation is deemed by the heritage resources authority to be necessary, assist the person on whom the order has been served under paragraph *(a)* to apply for a permit as required in subsection (4); and

(d) recover the costs of such investigation from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served.

Minimum standards for the palaeontological component of heritage impact assessment reports (PIAs) have recently been published by SAHRA (2013).

1.3. Approach to the palaeontological heritage study

The approach to this palaeontological heritage study is briefly as follows. Fossil bearing rock units occurring within the broader study area are determined from geological maps and satellite images. Known fossil heritage in each rock unit is inventoried from scientific literature, previous assessments of the broader study region, and the author's field experience and palaeontological database. Based on this data as well as field examination of representative exposures of all major sedimentary rock units present, the impact significance of the proposed development is assessed with recommendations for any further studies or mitigation.

In preparing a palaeontological desktop study the potentially fossiliferous rock units (groups, formations *etc*) represented within the study area are determined from geological maps and satellite images. 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 (consultation with professional colleagues as well as examination of institutional fossil collections may play a role here, or later following field assessment during the compilation of the final report). This data is then used to assess the palaeontological sensitivity of each rock unit to development. The likely impact of the proposed development on local fossil heritage is then determined on the basis of (1) the palaeontological sensitivity of the rock units concerned and (2) the nature and scale of the development itself, most significantly the extent of fresh bedrock excavation envisaged. When rock units of moderate to high palaeontological sensitivity are present within the development footprint, a Phase 1 field assessment study by a professional palaeontologist is usually warranted to identify any palaeontological hotspots and make specific recommendations for any mitigation required before or during the construction phase of the development.

On the basis of the desktop and Phase 1 field assessment studies, the likely impact of the proposed development on local fossil heritage and any need for specialist mitigation are then determined. Adverse palaeontological impacts normally occur during the construction rather than the operational or decommissioning phase. Phase 2 mitigation by a professional palaeontologist – normally involving the recording and sampling of fossil material and associated geological information (*e.g.* sedimentological data) may be required (a) in the pre-construction phase where important fossils are already exposed at or near the land surface and / or (b) during the construction phase when fresh fossiliferous bedrock has been exposed by excavations. To carry out sampling and mitigation, the palaeontologist involved will need to apply for a palaeontological collection permit from the relevant heritage management authority, The South African Heritage Resources Agency (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000,South Africa. Phone : +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za). It should be emphasized that, *providing appropriate mitigation is carried out*, the majority of developments involving bedrock excavation can make a *positive* contribution to our understanding of local palaeontological heritage.

1.4. Assumptions & limitations

The accuracy and reliability of palaeontological specialist studies as components of heritage impact assessments are generally limited by the following constraints:

1. Inadequate database for fossil heritage for much of the RSA, given the large size of the country and the small number of professional palaeontologists carrying out fieldwork here. Most development study areas have never been surveyed by a palaeontologist.

2. Variable accuracy of geological maps which underpin these desktop studies. For large areas of terrain these maps are largely based on aerial photographs alone, without ground-truthing. The maps generally depict only significant ("mappable") bedrock units as well as major areas of superficial "drift" deposits (alluvium, colluvium) but for most regions give little or no idea of the level of bedrock outcrop, depth of superficial cover (soil *etc*), degree of bedrock weathering or levels of small-scale tectonic deformation, such as cleavage. All of these factors may have a major influence on the impact significance of a given development on fossil heritage and can only be reliably assessed in the field.

3. Inadequate sheet explanations for geological maps, with little or no attention paid to palaeontological issues in many cases, including poor locality information;

4. The extensive relevant palaeontological "grey literature" - in the form of unpublished university theses, impact studies and other reports (*e.g*. of commercial mining companies) - that is not readily available for desktop studies;

5. Absence of a comprehensive computerized database of fossil collections in major RSA institutions which can be consulted for impact studies. A Karoo fossil vertebrate database is now accessible for impact study work.

In the case of palaeontological desktop studies without supporting Phase 1 field assessments these limitations may variously lead to either:

(a) *underestimation* of the palaeontological significance of a given study area due to ignorance of significant recorded or unrecorded fossils preserved there, or

(b) *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 tectonism or weathering, or are buried beneath a thick mantle of unfossiliferous "drift" (soil, alluvium *etc*).

Since most areas of the RSA have not been studied palaeontologically, a palaeontological desktop study usually entails *inferring* the presence of buried fossil heritage within the study area from relevant fossil data collected from similar or the same rock units elsewhere, sometimes at localities far away. Where substantial exposures of bedrocks or potentially fossiliferous superficial sediments are present in the study area, the reliability of a palaeontological impact assessment may be significantly enhanced through field assessment by a professional palaeontologist. In the present case, site visits to the various loop and borrow pit study areas in some cases considerably modified our understanding of the rock units (and hence potential fossil heritage) represented there.

In the case of the Tanqua Karoo National Park field study area potentially fossiliferous Karoo Supergroup bedrocks are extensively obscured by superficial deposits (alluvium, colluvium, soil *etc*) or baked by dolerite intrusions.

1.5. Information sources

The information used in this desktop study was based on the following:

1. A Basic Information Document produced by Enviroworks Western Cape, Somerset West;
2. A review of the relevant scientific literature, including published geological maps and accompanying sheet explanations;
3. The author's previous field experience with the formations concerned and their palaeontological heritage;
4. A short field assessment of each of the two study areas during 10 - 12 February 2014.

2. GEOLOGICAL OUTLINE OF THE STUDY AREA

The Tanqua Karoo National Park covers an extensive tract of arid semi-desert terrain including the northeastern part of the Tanqua Karoo itself as well as portions of the adjoining Roggeveld Escarpment (Fig. 1). The geology of the Park is shown on the adjoining 1: 250 000 geology maps 3218 Clanwilliam and 3220 Sutherland (Council for Geoscience, Pretoria) (Fig. 4). The Clanwilliam sheet has only a very brief sheet explanation, printed on the map itself, and is currently being revised. The Sutherland sheet is accompanied by a short explanation authored by Theron (1983). The Park is almost entirely underlain by Permian sediments of the **Karoo Supergroup**, including outcrop areas of the **Dwyka**, **Ecca** and **Lower Beaufort Groups**, dipping gently and younging broadly towards the northeast. Most of the lower-lying stretches of the Park are underlain by basinal mudrocks of the Tierberg Formation (Ecca Group). However, bedrock exposure of these recessive-weathering sediments away from deeply incised sections of the Tanqua River is generally very poor due to the pervasive cover by **Late Caenozoic superficial sediments** such as alluvial, colluvial and downwasted gravels, sands and silts.

The **Elandsberg Rest Camp** is situated some 13.7 km NW of the Roodewerf Park Office and at *c*. 580-600 m amsl on the Elandsberg. This is a NW-SE trending range of low hills that runs subparallel to, and slightly SW of, the Roggeveld Escarpment, intersecting the northern edge of the Park. The Elandsberg is underlain by an extensive, gentle SE-dipping dolerite sill that is dissected by several small shallow streams, some of which run NW, E and SE of the rest camp itself. The terrain is uneven and bouldery for the most part, with a dense cover of karroid bossies and low shrubs. A small patch of baked Ecca Group mudrocks (Tierberg Formation) is mapped just to the east of the study area but is not very clearly defined on satellite images.

The **Roodewerf staff village** study site is situated in the valley of the intermittent-flowing Renosterrivier, a tributary of the Tanqua River that runs NE-SW from its catchment area along the Roggeveld Escarpment (Landkloof). The proposed development lies on a broad, partially vegetated alluvial terrace at *c*. 480-490 m amsl. on the northern side of the present river course and is bordered on the north by a low (*c*. 500-510 m amsl) dolerite *koppie*. The finer, silty alluvium within the river valley has been extensively reworked for agricultural purposes in the last century, notably the construction of shallow *laane* or *saaidamme* with low embankments of silt and coarse gravels for irrigation during winter floods (Moll *et al*., 2012) (Fig. 9). The bedrock here is dolerite, a south-eastwards extension of the Elandsberg intrusion, but this is everywhere buried beneath a considerable thickness of alluvium. Thermally metamorphosed (baked) mudrocks of the **Tierberg Formation** (Ecca Group) within the thermal aureole of the large dolerite sill are present in the vicinity of the study site. Tierberg Formation exposures occur some 1 km to the NE in an embayment in the sill outcrop area to the west of the Roodewerf Office, in shallow road cuttings just south of the bridge across the Renosterrivier (*c.* 600 m NE of the study site) as well as in quarry exposures south of De Zyfer (*c*. 1.4 km east of the study site) (Fig. 20), but not within the study area itself. The flaggy, baked (and probably secondarily silicified) metasediments are much more resistant-weathering than the original, unbaked basinal mudrocks and have been extensively used as building stones, for example in the construction of stone walls at Roodewerf.

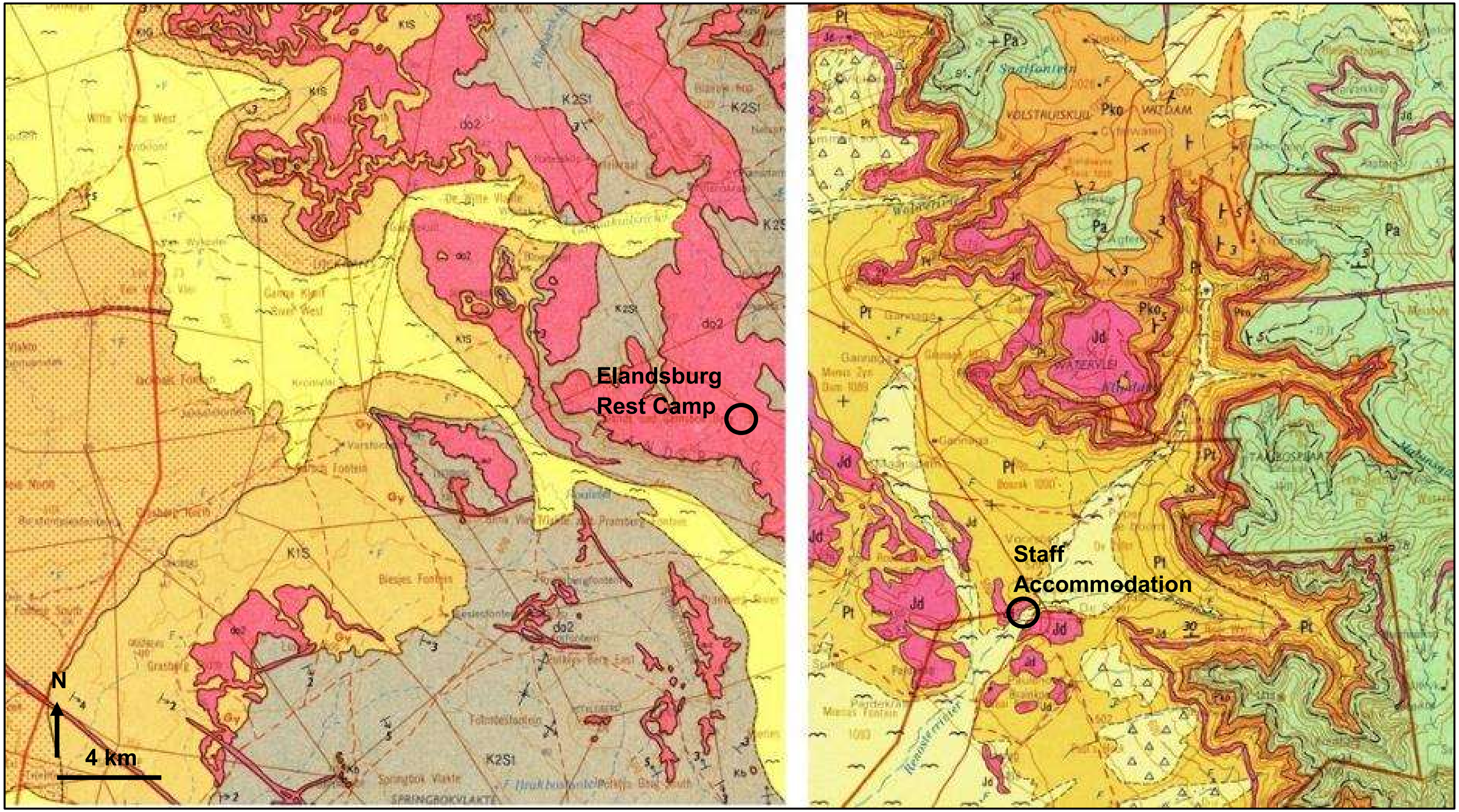

Fig. 4. Extracts from 1: 250 000 geology maps 3218 Clanwilliam (left) and 3220 Sutherland (right) (Council for Geoscience, Pretoria) showing the Tanqua Karoo National Park study area as well as the locations of the existing Elandbsurg Rest Camp overlying Karoo Dolerite (Jd, pink) and the proposed staff accommodation in the Renosterrivier Valley, underlain by alluvium (pale yellow) and flanked by Karoo Dolerite hills. Pt (dark yellow) = Tierberg Formation (Ecca Group).

3. SUMMARY OF GEOLOGICAL AND PALAEONTOLOGICAL FIELD OBSERVATIONS

A brief, illustrated account of the principal geological features observed during recent fieldwork at the two study sites within the Tanqua Karoo National Park is given in this section of the report, together with data on any fossil remains recorded. GPS co-ordinates for numbered localities mentioned in the text are given in the Appendix.

3.1. Elandsburg Rest Camp study area

The study area on the Elandsburg consists almost entirely of well-vegetated, bouldery terrain dominated by subrounded to rounded corestones weathered out from the underlying dolerite (Figs. 5 & 6). The boulders reach dimensions of over a meter and many show evidence of *in situ* splitting by freeze-thaw or thermal stress (insolation weathering / fires). The exposed surface of the corestones is typically covered with a dark brown to blackish, matt patina of "desert varnish" (ferro-manganese minerals). The corestones are embedded in, and in some places totally immersed within, an orange-brown, finely-gravelly to sandy matrix which is locally calcretised (Fig. 7). Thicker development of calcrete is seen along some shallow water courses, both within sandy alluvium as well as directly overlying the dolerite bedrock (Figs. 5 & 8). Good vertical sections through thicker sandy alluvium are exposed in several stream beds along the eastern edge of the Elandsberg where these intersect the dust road to Roodewerf. Here the alluvium overlies Tierberg Formation mudrocks and contains thin basal and internal gravel lenticles, locally calcretised and including flaked hornfels MSA / LSA artefacts that suggest a Quaternary or younger age.

No fossil remains were observed within the superficial sediments, including calcretes, in the Elandsberg study region. The dolerite bedrocks, being of intrusive igneous origin, are entirely unfossiliferous.

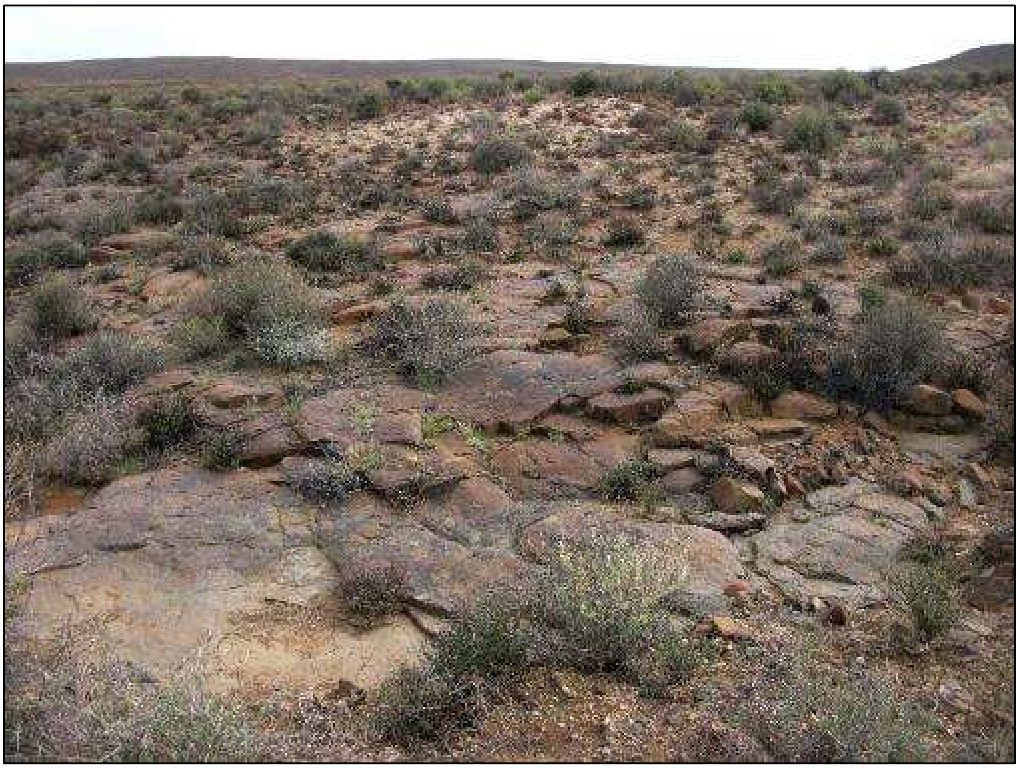

Fig. 5. Shallow stream bed exposure of jointed, semi-weathered surface of the Elandsberg dolerite sill. Note pale calcretised superficial sediments on the far bank (Loc. 062).

Fig. 6. View north-eastwards towards the Roggeveld Escarpment from the Elandsberg showing typical well-vegetated, bouldery terrain within the study area. The boulders of subrounded to well-rounded dolerite corestones with a dark, matt desert varnish patina.

Fig. 7. Recent excavation near one of the existing rest camp chalets on Elandsberg showing the orange-brown sandy to finely gravelly soil between the surface boulders (Hammer = 30 cm).

Fig. 8. Extensive development of surface calcrete within a shallow stream overlying dolerite bedrocks (Hammer = 30 cm).

3.2. Staff village study area near Roodewerf

The development footprint for the proposed staff village near Roodewerf overlies an abandoned, more-or-less flat-lying alluvial terrace at *c*. 490 m amsl on the northern side of the present course of the Renosterrivier (Fig. 9). Where buff silty alluvium predominates, this has often been reworked into low embankments of *saaidamme* (Fig. 12). The silty surface is locally overlain by sparse to concentrated, polymict sheet wash gravels of very recent age. The finer gravels contain occasional concentrations of fragmentary bone, sometimes burnt, of historical age (Fig. 13). Where coarse, pebbly to bouldery alluvial gravels predominate, for example towards the northern margin of the study area, these sometimes build subtle, low, linear ridges striking approximately east-west (Figs. 11 & 12). Ridges and intervening lower-lying swales are a characteristic feature of fluvial point bars constructed by lateral accretion in meandering river systems while linear gravel bars are also seen in braided river systems, as expected here. The coarse alluvial gravels are semi-consolidated, poorly-sorted, subrounded to rounded and comprise a range of clast lithologies such as wackes, fine-grained sandstones, hornfels, dolerite and calcrete. The gravels vary from clast- to matrix-supported, in the latter case with a matrix of gravelly silt or sand, occasionally calcretised. A few clasts contain abraded trace fossils (*e.g.* horizontal burrows). The dolerite boulders are often deeply weathered, suggesting that the gravels are of considerable age, perhaps Pleistocene.

Similar semi-consolidated, bouldery alluvial gravels and gravelly siltstones build a low cliff along the northern bank of the Renosterrivier just west of the road bridge (Loc. 049). Contrasting clast-supported and matrix-supported river conglomerates are well seen here, with occasional flaked hornfels clasts suggesting a Pleistocene or younger age for these beds (Figs. 14 & 15).

A small relict patch of fluvial High Level Gravels, several meters thick, overlies a low pediment surface cut into dolerite bedrock along the northern bank of the Renosterrivier at Locs. 045-046 (Fig. 16). The gravels here are better consolidated and more calcretised than those seen some 5-10 m below on the valley floor and they are clearly older, perhaps Late Tertiary or Pleistocene in age. The clast composition in both cases is very similar, however, and the dolerite boulders here are also highly weathered. Overlying the boulders is a horizon of finer-grained gravels and silts with local “nests” of egg-sized calcrete nodules with a fine-scale internal concentric lamination (Fig. 19). Surface gravels here contain highly abundant flaked hornfels clasts (MSA, LSA), occasional fragments of fairly dense bone (possibly partially silicified) and reworked cylindrical calcretised casts of plant roots (*rhizoliths*) or invertebrate burrows (Figs. 17 & 18). Above the gravel-mantled pediment the gentle slopes of the *koppie* are covered by colluvial rubble of dolerite.

Apart from sparse, *possibly* subfossil bone fragments and calcretised trace fossils in siltstones overlying the High Level Gravels (*outside* the proposed development footprint), as well as rare, abraded trace fossil-containing pebbles reworked from the Ecca Group bedrocks upstream, no fossil remains were recorded in the Roodewerf staff village study area during the present site visit.

It may be of interest to note that flaggy-bedded, baked mudrocks (*hornfels*) of the Tierberg Formation (Ecca Group) cropping out in the low road cutting just south of the Renosterrivier road bridge (Loc. 059) as well as in the quarry site south of De Zyfer (Loc. 064) contain locally abundant, low diversity trace fossil assemblages of Permian age (Figs. 21 & 22). The traces consist almost entirely of simple to branching horizontal burrows of 5 to 10 mm diameter with well-defined paler margins (These were probably enhanced by baking and metasomatism following dolerite intrusion and may indicate a discrete burrow wall was present). Elliptical vertical sections through the compressed burrows are well-seen in the finely-laminated, baked flagstones used to build walls at Roodewerf (Fig. 23). These burrow systems, which reach very high densities on some bedding planes, probably belong, at least in part, to the ichnogenus *Chondrites* (“fucoids”) that is typically associated with anoxic offshore mudrocks and has been attributed to chemosymbiotic invertebrates (*e.g.* Seilacher 2009, p. 142-144). Similar trace fossils, as well as a small range of other ichnogenera, are seen in well-exposed sections of the Tierberg Formation (also baked) in the vicinity of the Oudebaaskraal Dam (Almond 2008b and refs. therein). Unless baked mudrocks of the Tierberg Formation are further exploited for building material, the proposed developments at the Tanqua Karoo National Park will not have a significant impact on these trace fossil assemblages in the Roodewerf – De Zyfer area. Delicate, branching moss- or fern-like structures seen on many Tierberg bedding planes are *not* fossil plants, as commonly assumed, but pseudofossils known as *dendrites* (Fig. 24). They are formed by the abiogenic branching growth of manganese minerals (*e.g.* pyrolusite) along bedding and joint planes.

The fossil record of the Tierberg Formation, including a diversity of non-marine trace fossils together with rare micro-vertebrate remains, silicified wood and other plant remains, has been briefly summarized by Viljoen (2005) as well as Almond (2008a, 2008b).

The Late Caenozoic superficial deposits of the Karoo regions have been comparatively neglected in palaeontological terms. However, they may occasionally contain important fossil biotas, notably the bones, teeth and horn cores of mammals as well as remains of reptiles like tortoises. Good examples are the Pleistocene mammal faunas at Florisbad, Cornelia and Erfkroon in the Free State and elsewhere (Wells & Cooke 1942, Cooke 1974, Skead 1980, Klein 1984, Brink, J.S. 1987, Bousman *et al.* 1988, Bender & Brink 1992, Brink *et al*. 1995, MacRae 1999, Meadows & Watkeys 1999, Churchill *et al*. 2000, Partridge & Scott 2000, Brink & Rossouw 2000, Rossouw 2006). Other late Caenozoic fossil biotas from these superficial deposits include non-marine molluscs (bivalves, gastropods), ostrich egg shells, tortoise remains, trace fossils (*e.g.* calcretised termitaria, coprolites, invertebrate burrows), and plant material such as peats or palynomorphs (pollens) in organic-rich alluvial horizons (Scott 2000) and diatoms in pan sediments. In Quaternary deposits, fossil remains may be associated with human artefacts such as stone tools and are also of archaeological interest (*e.g.* Smith 1999 and refs. therein). Ancient solution hollows within extensive calcrete hardpans may have acted as animal traps in the past. As with coastal and interior limestones, they might occasionally contain mammalian bones and teeth (perhaps associated with hyaena dens) or invertebrate remains such as snail shells.

Fig. 9. View SSW across the Roodewerf staff village study area in the Renosterrivier Valley showing dolerite hills on either bank and disturbance of flat-lying silty floodplain areas by agriculture.

Fig. 10. Undisturbed, gravelly portion of the Renosterrivier floodplain featuring subtle linear banks or ridges of coarse, cobbly to bouldery gravels (Loc. 039). View downstream to the SW.

Fig. 11. Close up of semi-consolidated alluvial gravels of the abandoned Renosterrivier terrace showing several highly-weathered dolerite clasts (Hammer = 30 cm).

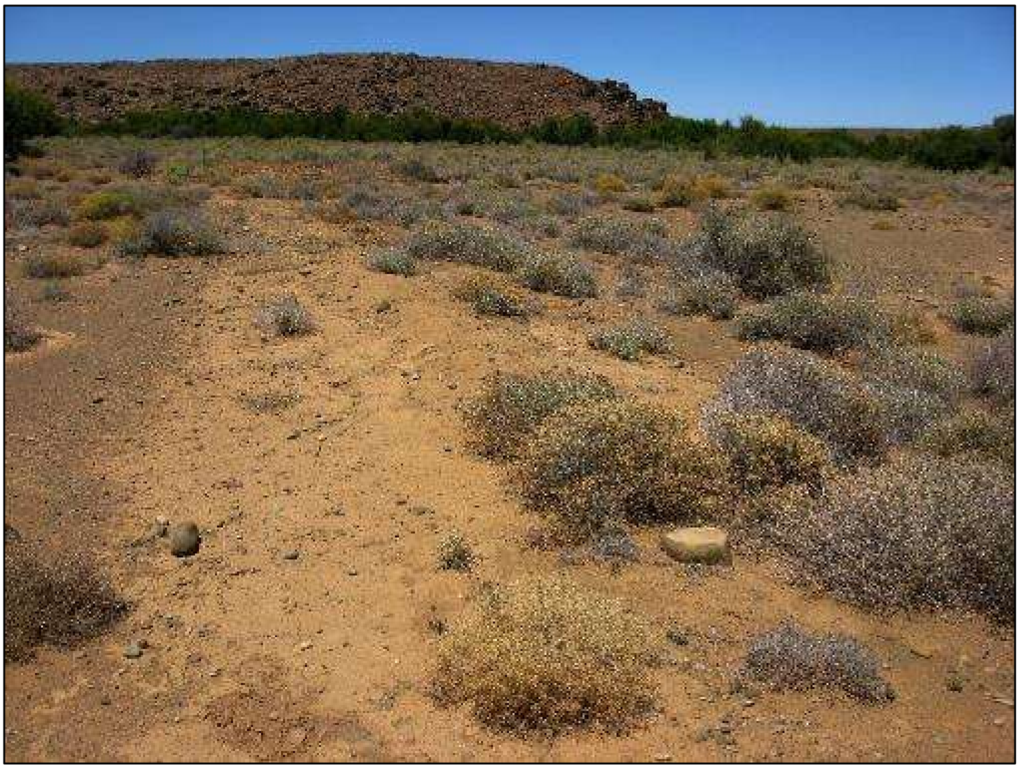

Fig. 12. Low artificial ridges of silty alluvium running NNW-SSE across the Renosterrivier floodplain in the western portion of the staff village study area (*laane / saaidamme*).

Fig. 13. Fine sheet-wash surface gravels overlying silty alluvium near Roodewerf showing fragments of weathered bone (probably burnt, Recent) (Scale in cm).

Fig. 14. Crudely-bedded, coarse bouldery alluvium along the north bank of the Renosterrivier, some 400 m upstream of the staff village study site (Loc. 049).

Fig. 15. Close-up of older fluvial conglomerates in north bank of Renosterrivier showing contrasting clast- and matrix-supported horizons (Hammer = 30 cm) (Loc. 049).

Fig. 16. Several meters of coarse, poorly-sorted High Level terrace gravels on the north bank of the Renosterrivier near the western edge of the study area (Loc. 045), view towards the east.

Fig. 17. Fragment of well-indurated bone among polymict surface gravels overlying High Level Gravels on north bank of the Renosterrivier (Loc. 067). Note local abundance of flaked clasts of black hornfels (Scale in cm).

Fig. 18. Reworked calcretised burrow infill or root cast among surface gravels (Loc. 067) (Scale in cm).

Fig. 19. Egg-sized concretionary nodules of calcrete with a concentric internal structure, gravelly silts and sands overlying High Level Terrace Gravels (Scale in cm).

Fig. 20. Contact between greyish-green dolerite sill in foreground and overlying orange-brown weathering, baked mudrocks of the Tierberg Formation, road cutting near the Renosterrivier bridge (Loc. 060).

Fig. 21. Dense assemblages of straight to curving horizontal burrows within baked mudrocks of the Tierberg Formation (Loc. 059). Burrows are *c*. 5 mm wide.

Fig. 22. Detail of clearly-branching burrow systems ("fucoids", probably *Chondrites*) from the same locality as the previous figure. The well-defined pale margins suggest that a discrete burrow wall may have been present. The burrows here are c. 7 mm wide.

Fig. 23. Vertical sections through baked Tierberg Formation mudrocks used as building stones at Roodewerf, showing elliptical sections through burrow systems that are concentrated at specific horizons (Scale in cm).

Fig. 24. Delicate branching mineral growths (*dendrites*) superficially resembling fossil ferns or mosses, Tierberg Formation (Loc. 064). Field of view is *c.* 15 cm across.

5. CONCLUSIONS AND RECOMMENDATIONS

The proposed new chalet developments at the Elandsberg Rest Camp overlie dolerite (igneous) bedrocks that are entirely unfossiliferous. No fossils were recorded from the superficial sedimentary rocks (bouldery dolerite colluvium, gravelly soils, calcrete) mantling the dolerite bedrocks in the study area.

The proposed staff village development footprint near Roodewerf overlies bouldery terrace gravels and silty alluvium of the Renosterrivier; the area has been extensively modified for agriculture (*saaidamme*). No fossils were recorded within these fluvial deposits, which are probably of Quaternary to Holocene age, but occasional reworked skeletal remains of mammals (*e.g.* rhinoceros or elephant bones, teeth) might conceivably occur here. A small relict patch of bouldery High Level terrace gravels occurs on the lower slopes of the dolerite *koppie* bordering the staff village study area on the northern side. Sparse subfossil bone fragments as well as calcretised plant root casts (*rhizoliths*) or invertebrate burrows were recorded in the overlying finer-grained gravels, but outside the anticipated development footprint.

Thermally metamorphosed or baked mudrocks of the Tierberg Formation (Ecca Group, Permian) in the vicinity of Roodewerf (*e.g.* road cuttings just south of the road bridge, quarry area south of De Zyfer) contain well-preserved, low-diversity trace fossil assemblages. These mainly comprise simple to branched horizontal burrows, some of which may belong to the ichnogenus *Chondrites*. Unless baked mudrocks of the Tierberg Formation are exploited for new building material, as in the case of existing buildings at Roodewerf, the proposed developments at the Tanqua Karoo National Park will not have a significant impact on these trace fossil assemblages, however. The trace fossils concerned are widely distributed within the extensive Tierberg Formation outcrop area (*e.g.* near Oudebaaskraal Dam and elsewhere along the Tanqua River) and are not considered to warrant special mitigation measures.

It is concluded that the proposed developments at the Tanqua Karoo National Park do not pose a significant threat to local fossil heritage resources. Pending the discovery of substantial new fossil remains during construction, no further specialist palaeontological studies, monitoring or mitigation is recommended. The Site Engineer and / or Environmental Control Officer (ECO) responsible for monitoring environmental compliance of the development must remain aware that all sedimentary deposits have the potential to contain fossils, however, and he/she should thus monitor all deeper (> 1 m) excavations into sedimentary bedrock for fossil remains. If any significant fossil remains (*e.g.* vertebrate bones, teeth, horn cores, fossil plant-rich beds) are found during construction the South African Heritage Resources Agency (SAHRA) should be notified immediately (Contact details: SAHRA, 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) so that appropriate mitigation (*i.e.* recording, sampling or collection) by a palaeontological specialist can be considered and implemented, at the developer's expense.

The palaeontologist concerned with recording, sampling and mitigation work would need a valid collection permit from the South African Heritage Resources Agency. All work would have to conform to international best practice for palaeontological fieldwork and the study (*e.g.* data recording fossil collection and curation, final report) should adhere to the minimum standards for Phase 2 palaeontological studies recently published by SAHRA (2013).

5. ACKNOWLEDGEMENTS

Mr Mark Day of Enviroworks, Western Cape, is thanked for commissioning this study and for providing the necessary background information. I am also grateful to Ms Esther Howard and Ms Elmarie van Wyk of SANParks for kindly arranging excellent accommodation and for additional assistance during our stay in the Tanqua Karoo National Park. The companionship and field assistance from Ms Madelon Tusenius (archaeologist) was, as ever, much appreciated. Drs Jurie Viljoen, Coenie de Beer and John Rogers are thanked for helpful discussions on the geology of the Tanqua Karoo National Park.

6. REFERENCES

ALMOND, J.E. 1998. Non-marine trace fossils from the western outcrop area of the Permian Ecca Group, southern Africa. Tercera Reunión Argentina de Icnologia, Mar del Plata, 1998, Abstracts p. 3.

ALMOND, J.E. 2008a. Fossil record of the Loeriesfontein sheet area (1: 250 000 geological sheet 3018). Unpublished report for the Council for Geoscience, Pretoria, 32 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2008b. Palaeozoic fossil record of the Clanwilliam sheet area (1: 250 000 geological sheet 3218). Unpublished report for the Council for Geoscience, Pretoria, 49 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2010. Eskom Gamma-Omega 765kV transmission line: Phase 2 palaeontological impact assessment. Sector 1, Tanqua Karoo to Omega Substation (Western and Northern Cape Provinces), 95 pp + appendix. Natura Viva cc, Cape Town.

ALMOND, J.E. 2010a. Proposed windfarm at Maanhaarberg near De Aar, Northern Cape Province. Palaeontological impact assessment: desktop study, 21 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2010b. Proposed photovoltaic power generation facility at De Aar, Northern Cape Province. Palaeontological impact assessment: desktop study, 17 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2011. Proposed Mainstream Solar Park at De Aar, Northern Cape Province. Palaeontological impact assessment: desktop study, 17 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2012a. Two wind energy facilities on the Eastern Plateau near De Aar, Northern Cape Province, proposed by Mulilo Renewable Energy (Pty) Ltd. Palaeontological specialist study: combined desktop and field-based assessments, 55 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2012b. Proposed Mulilo Renewable Energy PV2, PV3 and PV4 photovoltaic energy facilities on Farms Paarde Valley, Badenhorst Dam and Annex Du Plessis Dam near De Aar, Northern Cape Province. Palaeontological specialist study: combined desktop and field-based assessments, 45 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2012c. Proposed solar power generation facilities on the remaining extent of the farm Vetlaagte No. 4, De Aar, Northern Cape Province. Palaeontological specialist study: combined desktop and field-based assessments, 32 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2013a. Proposed photovoltaic (solar) energy facilities on Badenhorst Dam Farm near De Aar, Northern Cape. Palaeontological specialist study: combined desktop and field-based assessments, 55 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2013b. Proposed photovoltaic (solar) energy facilities on Du Plessis Dam Farm near De Aar, Northern Cape. Palaeontological specialist study: combined desktop and field-based assessments, 44 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. 2013c. Proposed 16 mtpa expansion of Transnet's existing manganese ore export railway line & associated infrastructure between Hotazel and the Port of Ngqura, Northern & Eastern Cape. Part 3: Kimberley to De Aar, Northern Cape. Palaeontological specialist assessment: combined field-based and desktop study, 65 pp. Natura Viva cc, Cape Town.

ALMOND, J.E. & PETHER, J. 2008. Palaeontological heritage of the Northern Cape. Interim SAHRA technical report, 124 pp. Natura Viva cc., Cape Town.

ANDERSON, A.M. 1974. Arthropod trackways and other trace fossils from the Early Permian lower Karoo Beds of South Africa. Unpublished PhD thesis, University of Witwatersrand, Johannesburg, 172 pp.

ANDERSON, A.M. 1975. Turbidites and arthropod trackways in the Dwyka glacial deposits (Early Permian) of southern Africa. Transactions of the Geological Society of South Africa 78: 265-273.

ANDERSON, A.M. 1976. Fish trails from the Early Permian of South Africa. Palaeontology 19: 397-409, pl. 54.

ANDERSON, A.M. 1981. The *Umfolozia* arthropod trackways in the Permian Dwyka and Ecca Groups of South Africa. Journal of Paleontology 55: 84-108, pls. 1-4.

ANDERSON, A.M. & MCLACHLAN, I.R. 1976. The plant record in the Dwyka and Ecca Series (Permian) of the south-western half of the Great Karoo Basin, South Africa. Palaeontologia africana 19: 31-42.

ANDERSON, J.M. & ANDERSON, H.M. 1985. Palaeoflora of southern Africa. Prodromus of South African megafloras, Devonian to Lower Cretaceous, 423 pp. Botanical Research Institute, Pretoria & Balkema, Rotterdam.

BENDER, P.A., RUBIDGE, B.S., GARDINER, B.S., LOOCK. J.C. & BREMNER, A.T. 1991. The stratigraphic range of the palaeoniscoid fish Namaichthys digitata in rocks of the Karoo sequence and its palaeoenvironmental significance. South African Journal of Science 87: 468-469.

BENDER, P.A. & BRINK, J.S. 1992. A preliminary report on new large mammal fossil finds from the Cornelia-Uitzoek site. South African Journal of Science 88: 512-515.

BOUSMAN, C.B. *et al.* 1988. Palaeoenvironmental implications of Late Pleistocene and Holocene valley fills in Blydefontein Basin, Noupoort, C.P., South Africa. Palaeoecology of Africa 19: 43-67.

BAMFORD, M. 1999. Permo-Triassic fossil woods from the South African Karoo Basin. Palaeontologia africana 35, 25-40.

BAMFORD, M.K. 2004. Diversity of woody vegetation of Gondwanan southern Africa. Gondwana Research 7, 153-164.

BRADDY, S.J. & BRIGGS, D.E.G. 2002. New Lower Permian nonmarine arthropod trace fossils from New Mexico and South Africa. Journal of Paleontology 76: 546-557.

BRINK, J.S. 1987. The archaeozoology of Florisbad, Orange Free State. Memoirs van die Nasionale Museum 24, 151 pp.

BRINK, J.S. *et al*. 1995. A new find of *Megalotragus priscus* (Alcephalini, Bovidae) from the Central Karoo, South Africa. Palaeontologia africana 32: 17-22.

BRINK, J.S. & ROSSOUW, L. 2000. New trial excavations at the Cornelia-Uitzoek type locality. Navorsinge van die Nasionale Museum Bloemfontein 16, 141-156.

BUATOIS, L. & MANGANO, M.G. 2004. Animal-substrate interactions in freshwater environments: applications of ichnology in facies and sequence stratigraphic analysis of fluvio-lacustrine successions. In: McIlroy, D. (Ed.) The application of ichnology to palaeoenvironmental and stratigraphic analysis. Geological Society, London, Special Publications 228, pp 311-333.

BUATOIS, L.A. & MÁNGANO, M.G. 2007. Invertebrate ichnology of continental freshwater environments. In: Miller, W. III (Ed.) Trace fossils: concepts, problems, prospects, pp. 285-323. Elsevier, Amsterdam.

CHURCHILL, S.E. *et al.* 2000. Erfkroon: a new Florisian fossil locality from fluvial contexts in the western Free State, South Africa. South African Journal of Science 96: 161-163.

COLE, D.I., SMITH, R.M.H. & WICKENS, H. DE V. 1990. Basin-plain to fluvio-lacustrine deposits in the Permian Ecca and Lower Beaufort Groups of the Karoo Sequence. Guidebook Geocongress '90, Geological Society of South Africa, PO2, 1-83.

COLE, D.I. & VORSTER, C.J. 1999. The metallogeny of the Sutherland area, 41 pp. Council for Geoscience, Pretoria.

COOKE, H.B.S. 1974. The fossil mammals of Cornelia, O.F.S., South Africa. In: Butzer, K.W., Clark, J.D. & Cooke, H.B.S. (Eds.) The geology, archaeology and fossil mammals of the Cornelia Beds, O.F.S. Memoirs of the National Museum, Bloemfontein 9: 63-84.

COOPER, M.R. & KENSLEY, B. 1984. Endemic South American Permian bivalve molluscs from the Ecca of South Africa. Journal of Paleontology 58: 1360-1363.

DE BEER, C.H., GRESSE, P.G., THERON, J.N. & ALMOND, J.E. 2002. The geology of the Calvinia area. Explanation to 1: 250 000 geology Sheet 3118 Calvinia. 92 pp. Council for Geoscience, Pretoria.

DUNCAN, A.R. & MARSH, J.S. 2006. The Karoo Igneous Province. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 501-520. Geological Society of South Africa, Marshalltown.

GRINE, F.E., BAILEY, R.M., HARVATI, K., NATHAN, R.P., MORRIS, A.G., HENDERSON, G.M., RIBOT, I. & PIKE, A.W.G. 2007. Late Pleistocene human skull from Hofmeyr, South Africa, and modern human origins. Science 315, 226-229.

HOLMES, P.J. & MARKER, M.E. 1995. Evidence for environmental change from Holocene valley fills from three central Karoo upland sites. South African Journal of Science 91: 617-620.

JOHNSON, M.R., VAN VUUREN, C.J., VISSER, J.N.J., COLE, D.I., De V. WICKENS, H., CHRISTIE, A.D.M., ROBERTS, D.L. & BRANDL, G. 2006. Sedimentary rocks of the Karoo Supergroup. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 461-499. Geological Society of South Africa, Marshalltown.

KEYSER, A.W. & SMITH, R.M.H. 1977-78. Vertebrate biozonation of the Beaufort Group with special reference to the Western Karoo Basin. Annals of the Geological Survey of South Africa 12: 1-36.

KITCHING, J.W. 1977. The distribution of the Karroo vertebrate fauna, with special reference to certain genera and the bearing of this distribution on the zoning of the Beaufort beds. Memoirs of the Bernard Price Institute for Palaeontological Research, University of the Witwatersrand, No. 1, 133 pp (incl. 15 pls).

KLEIN, R.G. 1984. The large mammals of southern Africa: Late Pliocene to Recent. In: Klein, R.G. (Ed.) Southern African prehistory and paleoenvironments, pp 107-146. Balkema, Rotterdam.

MACRAE, C. 1999. Life etched in stone. Fossils of South Africa, 305 pp. The Geological Society of South Africa, Johannesburg.

MEADOWS, M.E. & WATKEYS, M.K. 1999. Palaeoenvironments. In: Dean, W.R.J. & Milton, S.J. (Eds.) The karoo. Ecological patterns and processes, pp. 27-41. Cambridge University Press, Cambridge.

MOLL, M., STEYN, R., MOLL, B. & MOLL, J. 2012. Around the Tanqua Karoo National Park. A guide to some of the buildings and people who lived in them, 14 pp. South African NAtonal Parks Honorary Rangers.

NICOLAS, M.V. 2007. Tetrapod diversity through the Permo-Triassic Beaufort Group (Karoo Supergroup) of South Africa. Unpublished PhD thesis, University of Witwatersrand, Johannesburg.

NICOLAS, M. & RUBIDGE, B.S. 2010. Changes in Permo-Triassic terrestrial tetrapod ecological representation in the Beaufort Group (Karoo Supergroup) of South Africa. Lethaia 43, 45-59.

PARTRIDGE, T.C. & SCOTT, L. 2000. Lakes and pans. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.145-161. Oxford University Press, Oxford.

PARTRIDGE, T.C., BOTHA, G.A. & HADDON, I.G. 2006. Cenozoic deposits of the interior. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 585-604. Geological Society of South Africa, Marshalltown.

ROSSOUW, L. 2006. Florisian mammal fossils from erosional gullies along the Modder River at Mitasrust Farm, Central Free State, South Africa. Navorsinge van die Nasionale Museum Bloemfontein 22, 145-162.

RUBIDGE, B.S. (Ed.) 1995. Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Biostratigraphy, Biostratigraphic Series No. 1., 46 pp. Council for Geoscience, Pretoria.

RUBIDGE, B.S. 2005. Re-uniting lost continents – fossil reptiles from the ancient Karoo and their wanderlust. 27th Du Toit Memorial Lecture. South African Journal of Geology 108, 135-172.

RUBIDGE, B.S., HANCOX, P.J. & CATUNEANU, O. 2000. Sequence analysis of the Ecca-Beaufort contact in the southern Karoo of South Africa. South African Journal of Geology 103, 81-96.

RUBIDGE, B.S., ERWIN, D.H., RAMEZANI, J., BOWRING, S.A. & DE KLERK, W.J. 2010. The first radiometric dates for the Beaufort Group, Karoo Supergroup of South Africa. Proceedings of the 16th conference of the Palaeontological Society of Southern Africa, Howick, August 5-8, 2010, pp. 82-83.

RUBIDGE, B.S., ERWIN, D.H., RAMEZANI, J., BOWRING, S.A. & DE KLERK, W.J. 2013. High-precision temporal calibration of Late Permian vertebrate biostratigraphy: U-Pb zircon constraints from the Karoo Supergroup, South Africa. Geology published online 4 January 2013. doi: 10.1130/G33622.1.

RUST, I.C., SHONE, R.W. & SIEBRITS, L.B. 1991. Carnarvon Formasie: golf-oorheesde sedimentasie in ‘n vlak Karoosee. South African Journal of Science 87, 198-202.

RYAN, P.J. 1967. Stratigraphic and palaeocurrent analysis of the Ecca Series and lowermost Beaufort Beds in the Karoo Basin of South Africa. Unpublished PhD thesis, University of the Witwatersrand, Johannesburg, 210 pp.

SAHRA 2013. Minimum standards: palaeontological component of heritage impact assessment reports, 15 pp. South African Heritage Resources Agency, Cape Town.

SCOTT, L. 2000. Pollen. In: Partridge, T.C. & Maud, R.R. (Eds.) The Cenozoic of southern Africa, pp.339-35. Oxford University Press, Oxford.

SEILACHER, A. 2007. Trace fossil analysis, xiii + 226pp. Springer Verlag, Berlin.

SIEBRITS, L.B. 1987. Die sedimentology van die Formasie Carnarvon in die omgewing van Carnarvon. Unpublished MSc thesis, University of Port Elizabeth, v + 92 pp.

SIEBRITS, L.B. 1989. Die geologie van die gebied Sakrivier. Explanation of 1: 250 000 geology sheet 3020, 19 pp. Council for Geoscience, Pretoria.

SKEAD, C.J. 1980. Historical mammal incidence in the Cape Province. Volume 1: The Western and Northern Cape. 903pp. Department of Nature and Environmental Conservation, Cape Town.

SKINNER, E.M.W. & TRUSWELL, J.F. 2006. Kimberlites. In: Johnson, M.R., Anhaeusser, C.R. & Thomas, R.J. (Eds.) The geology of South Africa, pp. 651-659. Geological Society of South Africa, Marshalltown.

SMITH, A.M. & ZAWADA, P.K. 1988. The Ecca-Beaufort transition zone near Philipstown, Cape Province: a marine shelf sequence. South African Journal of Geology 91, 75-82.

SMITH, A.M. & ZAWADA, P.K. 1989. Permian storm current-produced offshore bars from an ancient shelf sequence: northwestern Karoo basin, Republic of South Africa. Journal of African Earth Sciences 9, 363-370.

SMITH, A.B. 1999. Hunters and herders in the Karoo landscape. Chapter 15 in Dean, W.R.J. & Milton, S.J. (Eds.) The Karoo; ecological patterns and processes, pp. 243-256. Cambridge University Press, Cambridge.

SMITH, R.M.H. 1980. The lithology, sedimentology and taphonomy of flood-plain deposits of the Lower Beaufort (Adelaide Subgroup) strata near Beaufort West. Transactions of the Geological Society of South Africa 83, 399-413.

SMITH, R.M.H. 1993. Sedimentology and ichnology of floodplain paleosurfaces in the Beaufort Group (Late Permian), Karoo Sequence, South Africa. Palaios 8, 339-357.

SMITH, R.M.H. & KEYSER, A.W. 1995. Biostratigraphy of the *Tapinocephalus* Assemblage Zone. Pp. 8-12 *in* Rubidge, B.S. (ed.) Biostratigraphy of the Beaufort Group (Karoo Supergroup). South African Committee for Stratigraphy, Biostratigraphic Series No. 1. Council for Geoscience, Pretoria.

SMITH, R.M.H. & ALMOND, J.E. 1998. Late Permian continental trace assemblages from the Lower Beaufort Group (Karoo Supergroup), South Africa. Abstracts, Tercera Reunión Argentina de Icnologia, Mar del Plata, 1998, p. 29.

THERON, J.N. 1983. Die geologie van die gebied Sutherland. Explanation of 1: 250 000 geological Sheet 3220, 29 pp. Council for Geoscience, Pretoria.

VAN DER WALT M., DAY M., RUBIDGE B., COOPER A.K. & NETTERBERG I. 2010. A new GIS-based biozone map of the Beaufort Group (Karoo Supergroup), South Africa. Palaeontologia Africana, 45, 5pp.

VAN DIJK, D.E., CHANNING, A. & VAN DEN HEEVER, J.A. 2002. Permian trace fossils attributed to tetrapods (Tierberg Formation, Karoo Basin, South Africa). Palaeontologia africana 38: 49-56.

VILJOEN, J.H.A. 1989. Die geologie van die gebied Williston. Explanation to geology sheet 3120 Williston, 30 pp. Council for Geoscience, Pretoria.

VILJOEN, J.H.A. 1992. Lithostratigraphy of the Collingham Formation (Ecca Group), including the Zoute Kloof, Buffels River and Wilgehout River Members and the Matjiesfontein Chert Bed. South African Committee for Stratigraphy, Lithostratigraphic Series No. 22, 10 pp.

VILJOEN, J.H.A. 1994. Sedimentology of the Collingham Formation, Karoo Supergroup. South African Journal of Geology 97: 167-183.

VILJOEN, J.H.A. 2005. Tierberg Formation. SA Committee for Stratigraphy, Catalogue of South African Lithostratigraphic Units 8: 37-40.

WELLS, L.H. & COOKE, H.B.S. 1942. The associated fauna and culture of Vlakkraal thermal springs, O.F.S.; III, the faunal remains. Transactions of the Royal Society of South Africa 29: 214-232.

WERNER, M. 2006. The stratigraphy, sedimentology and age of the Late Palaeozoic *Mesosaurus* Inland Sea, SW-Gondwana: new implications from studies on sediments and altered pyroclastic layers of the Dwyka and Ecca Group (lower Karoo Supergroup) in southern Namibia. Dr rer. nat. thesis, University of Würzburg, 428 pp, 167 figs, 1 table.

WICKENS, H. DE V. 1980. Verslag oor kartering in die Calvinia gebied. Unpublished report, Council for Geoscience, Pretoria, 19 pp.

WICKENS, H. DE V. 1984. Die stratigraphie en sedimentologie van die Group Ecca wes van Sutherland. Unpublished MSc thesis, University of Port Elizabeth, viii + 86 pp.

WICKENS, H. DE V. 1992. Submarine fans of the Permian Ecca Group in the SW Karoo Basin, their origin and reflection on the tectonic evolution of the basin and its source areas. In: De Wit, M.J. & Ransome, I.G.D. (Eds.) Inversion tectonics of the Cape Fold Belt, Karoo and Cretaceous Basins of southern Africa, pp. 117-126. Balkema, Rotterdam.

WICKENS, H. DE V. 1994. Submarine fans of the Ecca Group. Unpublished PhD thesis, University of Port Elizabeth. 350 pp.

WICKENS, H. DE V. 1996. Die stratigraphie en sedimentologie van die Ecca Groep wes van Sutherland. Council for Geosciences, Pretoria Bulletin 107, 49pp.

ZAWADA, P.K. 1992. The geology of the Koffiefontein area. Explanation of 1: 250 000 geology sheet 2924, 30 pp. Council for Geoscience, Pretoria.

7. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

Dr John Almond has an Honours Degree in Natural Sciences (Zoology) as well as a PhD in Palaeontology from the University of Cambridge, UK. He has been awarded post-doctoral research fellowships at Cambridge University and in Germany, and has carried out palaeontological research in Europe, North America, the Middle East as well as North and South Africa. For eight years he was a scientific officer (palaeontologist) for the Geological Survey / Council for Geoscience in the RSA. His current palaeontological research focuses on fossil record of the Precambrian - Cambrian boundary and the Cape Supergroup of South Africa. He has recently written palaeontological reviews for several 1: 250 000 geological maps published by the Council for Geoscience and has contributed educational material on fossils and evolution for new school textbooks in the RSA.

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape under the aegis of his Cape Town-based company *Natura Viva* cc. He is a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage Practitioners – Western Cape).

Declaration of Independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed development project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

Dr John E. Almond
Palaeontologist, *Natura Viva* cc

APPENDIX: GPS LOCALITY DATA FOR SITES LISTED IN TEXT

All GPS readings were taken in the field using a hand-held Garmin GPSmap 62sc instrument. The datum used is WGS 84. Only those localities mentioned in the text are listed here. Key fossil sites are marked on the satellite image below (Fig. 35).

Locality number	Co-ordinates	Comments
039	32 14 12.6 S 20 05 32.0 E	Subdued gravels bars on fluvial terrace, Renosterrivier
045	32 14 50.9 S 20 05 28.0 E	Relict patch of High Level Gravels on northern bank of Renosterrivier
046	32 14 50.4 S 20 05 28.9 E	Surface gravels with abundant flaked hornfels overlying High Level Gravels
049	32 14 43.2 S 20 05 49.0 E	Low cliff of alluvial conglomerates along N bank of Renosterrivier near road bridge
059	32 14 53.1 S 20 06 02.9 E	Baked Tierberg Formation mudrocks with abundant trace fossils, road cutting near Renosterrivier bridge
060	32 14 49.7 S 20 06 01.5 E	Dolerite / Ecca contact, same area as above
062	32 10 41.0 S 19 58 36.2 E	Stream exposure of Karoo dolerite near Elandsberg chalets, with calcretised superficial sediments above
064	32 14 52.0 S 20 06 28.7 E	Kraal / quarry site into baked Tierberg Formation with abundant trace fossil blocks, S of De Zyfer
065	32 14 53.2 S 20 06 26.9 E	Ditto
067	32 14 50.2 S 20 05 28.9 E	Sparse subfossil bone fragments and calcretised rhizoliths / burrows in surface gravels overlying High Level Gravels, Renosterrivier

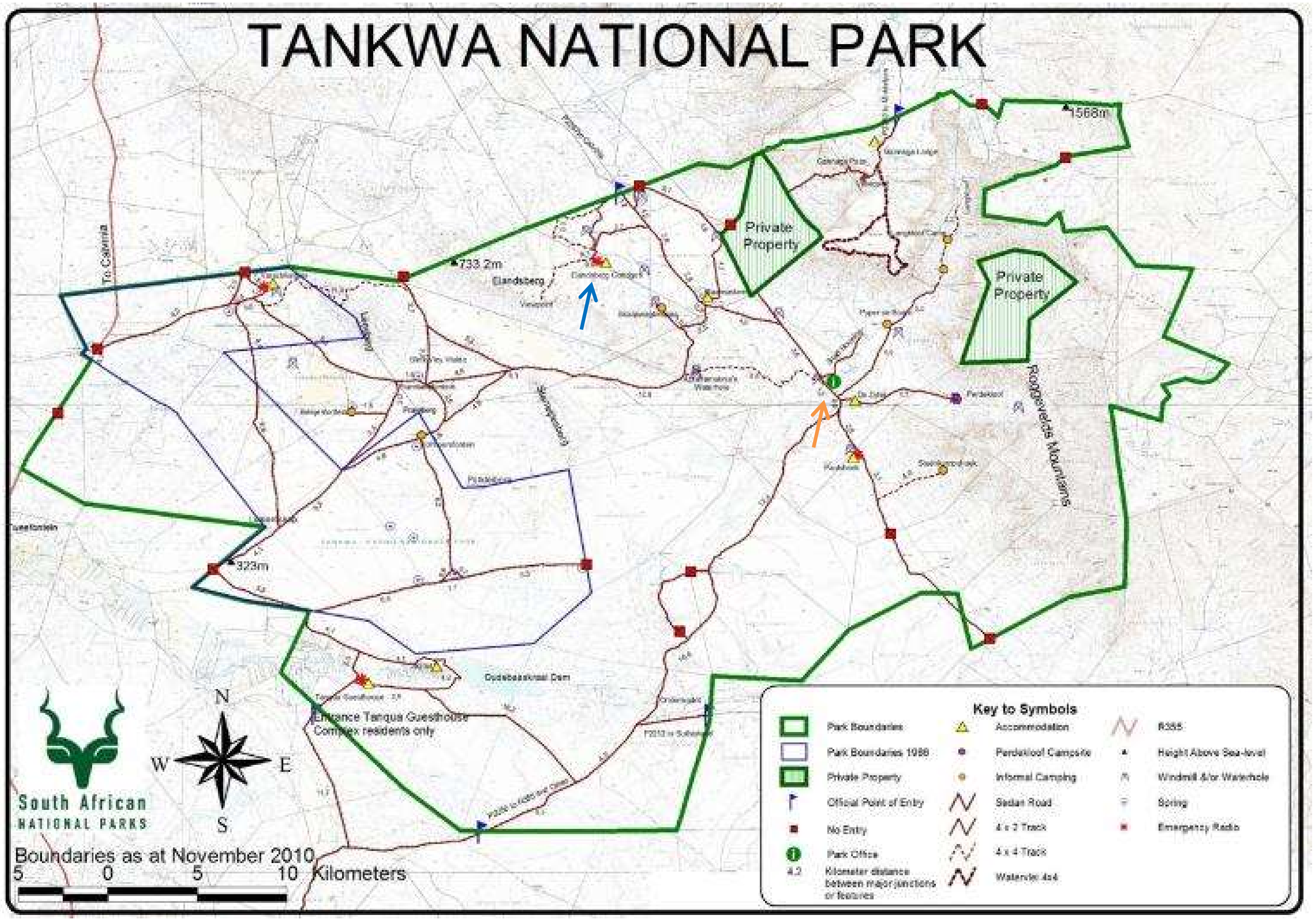

Fig. A1. SANParks map of the Tanqua Karoo National Park, Western and Northern Cape. The Elandsberg and Roodewerf study sites are indicated by blue and orange arrows respectively.