GEOTECHNICAL ASSESSMENT STUDY AT GOEDEHOOP SOLAR SITE, DISTRICT HANOVER FOR AN ENVIRONMENTAL IMPACT ASSESSMENT

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1. SCOPE OF WORK

The scope of work is to conduct a study covering the geotechnical aspects of the three alternative footprint areas for construction of a 225 Mw phovoltaic solar farm. This includes the following elements:

- identify and map the different soil and rock formations
- determine the topographical and drainage variation
- identify possible sources of both road construction materials and concrete aggregate
- assess the perceived impacts foundation conditions may have on the construction and operation phases of the proposed development and recommend mitigation measures.

The study is to be conducted by way of a desktop investigation exercise supported by a brief ground truthing site visit.

2. LOCATION

(see Figure 1)

The project area is situated 26 kilometres northwest of Hanover in the Northern Cape and to the northeast of the N10 tarred road which connects the towns of Hanover and De Aar. The study area is separated into three district sites (for the purpose of this study referred to as Alternatives 1, 2 and 3) - (refer to Fig. 1).

3. METHODOLOGY ADOPTED IN PREPARING THE REPORT

A desk study was undertaken during which the geology and topography of the three alternative sites were reviewed from presently available maps and satellite imagery. These were utilized to plan localities to be visited during a site visit. The site visit was undertaken during the first week of January 2017 (wet season). During this visit a total of 62 soil profile and rock mass profile and descriptions were undertaken at localities distributed throughout the three alternative sites (refer to Appendix I) in order to asses geological and geotechnical conditions and confirm desk study results.

4. SITE SPECIFICS

4.1. EXISTING INFRASTRUCTURE

Apart from the tarred road (N10) which passes by the southwestern border of the Alternative 1, and the railway line from Noupoort to De Aar (with its service gravel road) which passes by the southwestern border of Alternative 3, two additional secondary gravel roads, (indicated as “local roads” in Fig. 1) service the project area. A number of farm tracks allow limited access to the three sites (whilst full access for the site areas is either on foot or by driving through the natural (shrub land) bush.

The northeastern border of Alternative 3 co-insides with an Eskom distribution line, whilst two Eskom lines cross the eastern lobe of Alternative 1 (and an Eskom line passes to the southwest of Alternative 2).

Barbed wire farm fences divide each site in a number of separate farm camps.

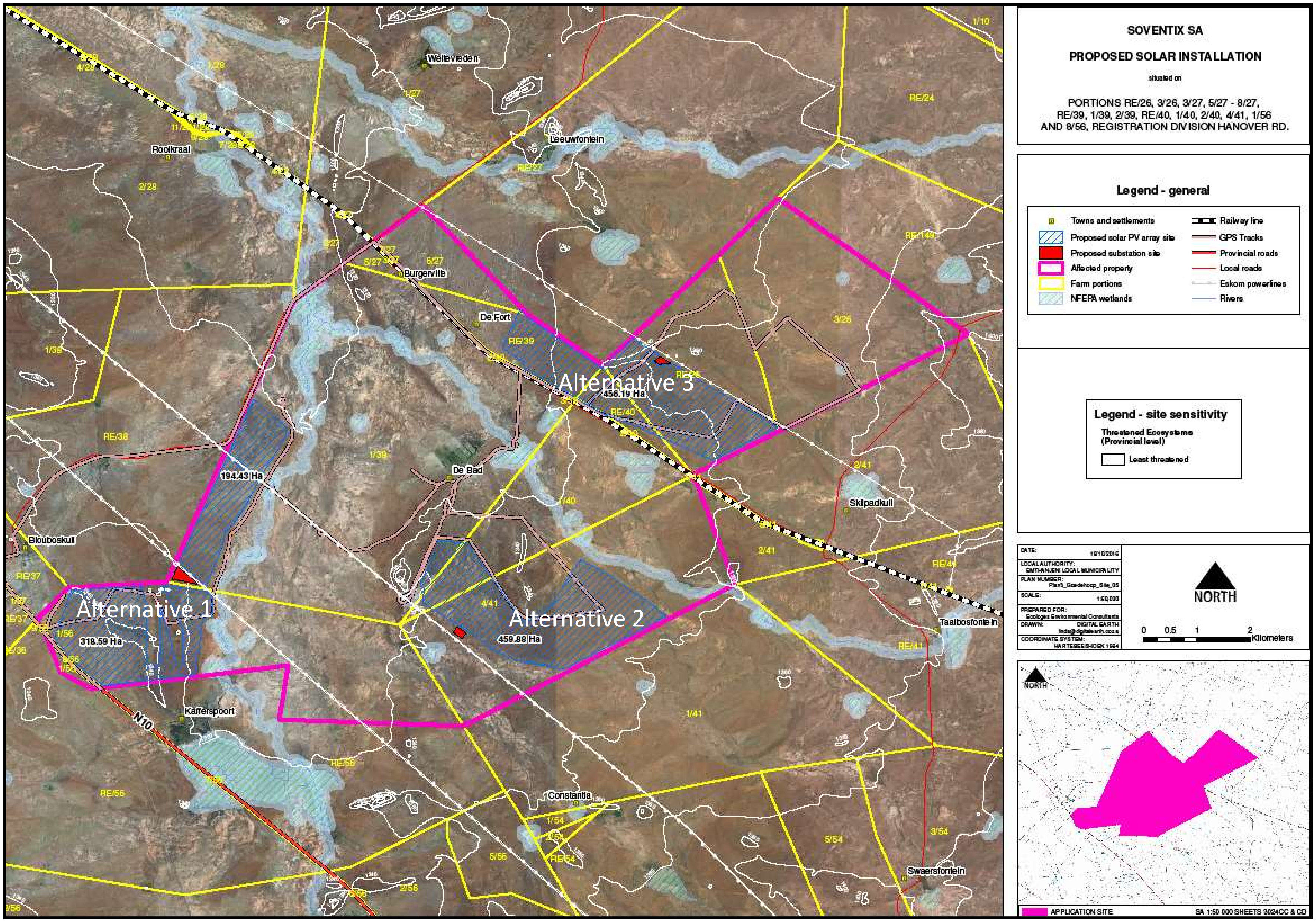

Figure 1: Location of three site alternatives – Alternative 1,2, and 3 (all indicated with blue hatching)

4.2 TOPOGRAPHY, DRAINAGE AND ON-SITE SURFACE WATER

Alternative 1

Topography on the site is more pronounced than on the two other site alternatives with a ridge of low hills (5 to 50 metres in height) cutting through the central portion thereof in a north to north western direction. The width of the ridge is generally between 100 and 400 metres. In the ridge area surface slopes are moderately steep (up to vert.: hor. = 1:10) over short distances – particularly in the vicinity of the ridge crest area. Over the remainder of the site surface slope is slight and characteristic of a plain.

Southwest of the ridge the surface slope is towards the southwest and south and north east of the ridge it is towards the east and north. The elevation varies from 1 362 masl (southern part of ridge crest) to 1 303 masl (northern most corner of site). Apart from the ridge area no concentrated drainage lines occur on the site, but the non-perennial Brak River (which drains the general area towards the north) occurs all along the eastern site border.

In the western lobe of the site one wind pump with two small concrete reservoirs occur, whilst two small (dug out) earthen reservoirs and three small concrete reservoirs occur along the eastern lobe. Another wind pump with one small concrete reservoir occurs near the southern border, whilst standing water occurs in the exiting (dormant) quarry on the western border and south of the ridge.

Alternative 2

The site occurs in an area of denuded topography with slight surface slope towards the west and south. The elevation varies from 1 340 masl (eastern border) to 1 320 masl (western border). A low ridge passes in a north-south direction through the central part of the site, with the land surface to the east of the ridge at a slightly higher elevation than that to the west thereof. Concentrated drainage channels only occur in the southwestern corner area. Furthermore a drainage channel directly south of the site border provides drainage westwards - towards the non-perennial Brak River (which drains the general area towards the north and passes by the site roughly one kilometer off the western border). A low hill (40 metres high) lies between the westernmost site border and the Brak River. Drainage on the site occurs largely as sheet flow. In the western portions of the site the appearance of the surface indicates impeded drainage – which is associated with the reduction in slope at the foot of the ridge crest occurring in the central part of and to the north of the site.

Two smallish dug out earthen dams occur – one on the northern border and one in the east, whilst two small concrete reservoirs occur on the northern border.

Alternative 3

Large portions of the site have denuded topography with slight surface slope towards the west and north. A low ridge cuts through the centre of the site in a southwest to northeast direction and tuning into a low hill with the highest elevation on the site (1 351 masl) near the northern corner. The lowest elevation on the site (1 314) masl occurs at the northwestern most corner. A number of short channels provide drainage southwestwards and westwards towards the upper reaches of the non-perennial Brak

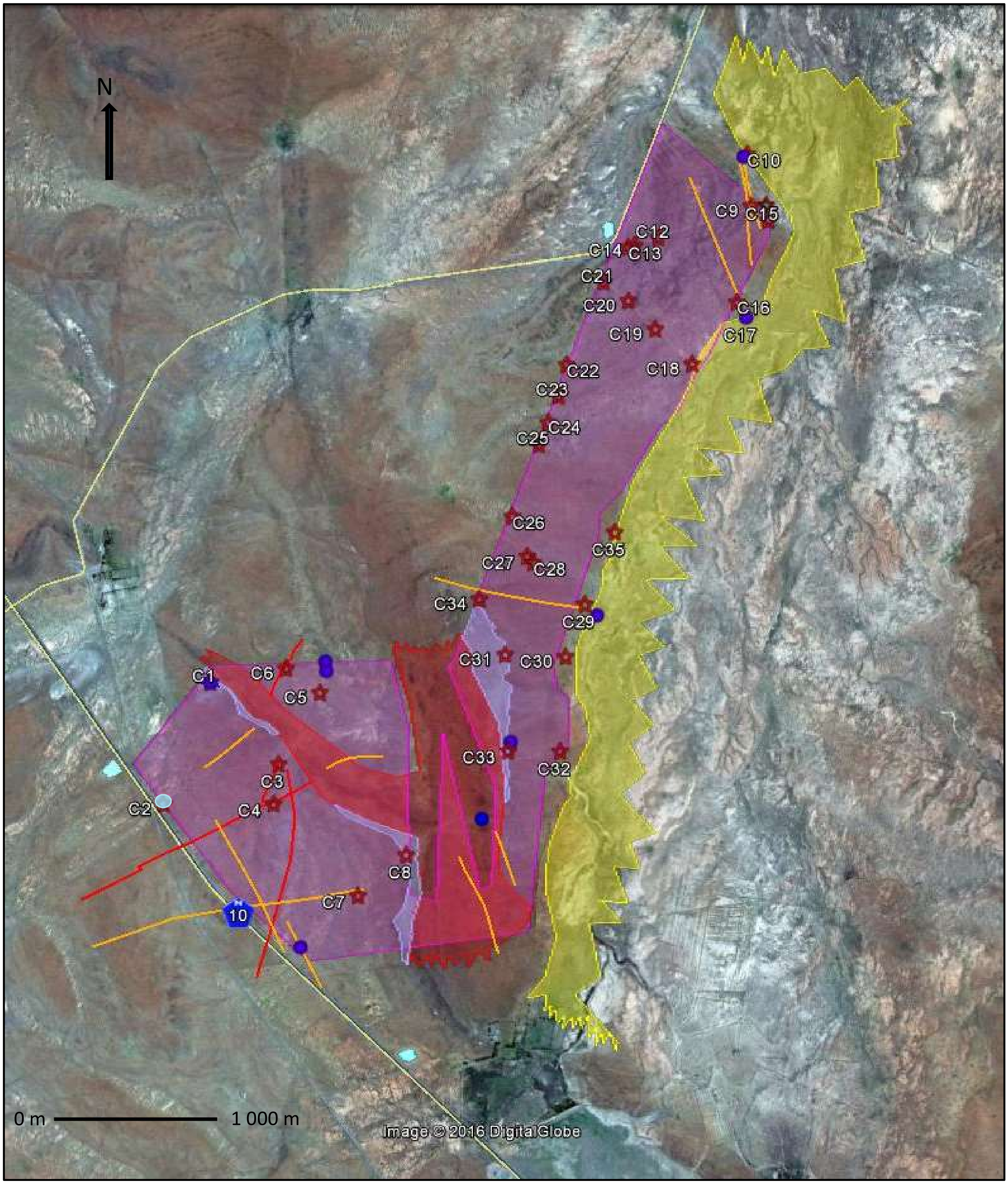

Figure 2: Position of particular observation localities (numbered red stars – refer to Appendix I) on Alternative 1. Additional polygons are as follows: Light maroon = sedimentary rock sub-outcrop on site, red coloured area = dolerite sill, red lines = dolerite dykes, orange lines = unconfirmed dolerite dykes, light purple = sedimentary rock outcrop on site, yellow = alluvial soil covering sub-outcrop, dark blue dots = reservoirs and ground fill dams, light blue = quarries/dormant quarries.

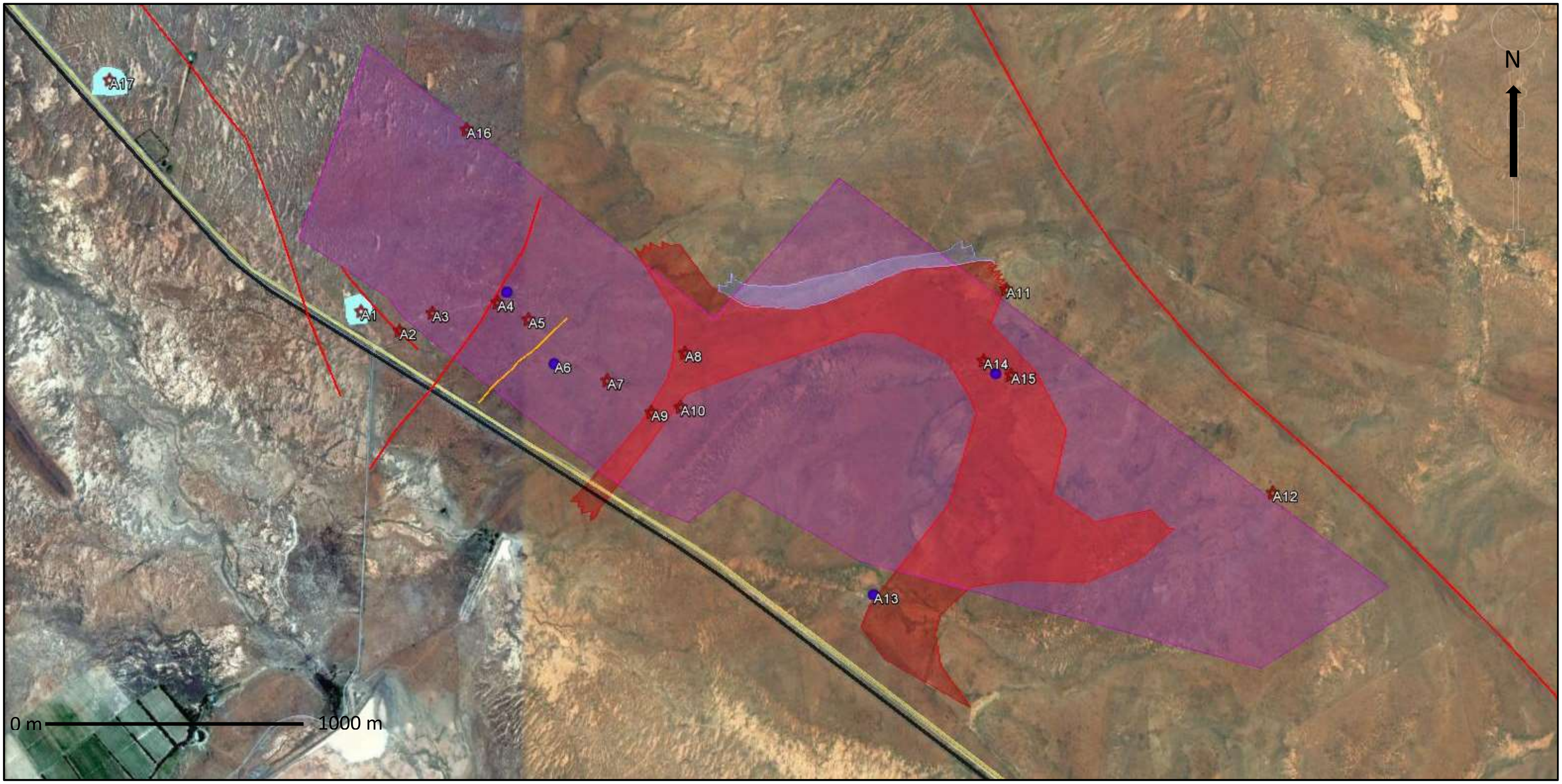

Figure 4: Position of particular observation localities (numbered red stars – refer to Appendix I) on Alternative 3. Additional polygons are as follows: Light maroon = sedimentary rock sub-outcrop on site, red coloured area = dolerite sill, red lines = dolerite dykes, orange line = unconfirmed dolerite dyke, light purple = sedimentary rock outcrop, dark blue dots = reservoirs and ground fill dams, light blue = quarries/dormant quarries.

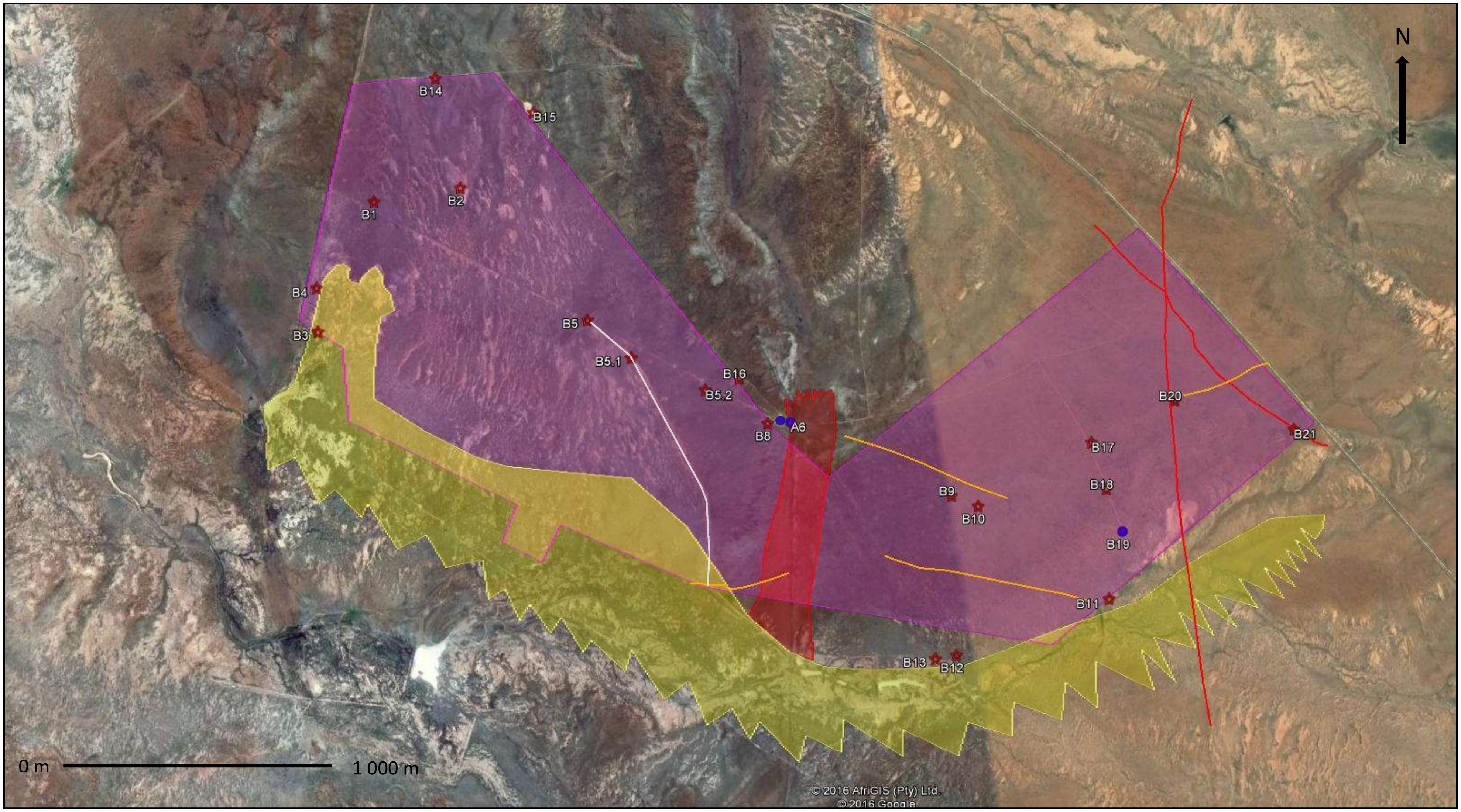

Figure 3: Position of particular observation localities (numbered red stars – refer to Appendix I) on Alternative 2. Additional polygons are as follows: Light maroon = sedimentary rock sub-outcrop on site, red coloured area = dolerite sill, red lines = dolerite dykes, orange lines = unconfirmed dolerite dykes, yellow = alluvial soil covering sub-outcrop, dark blue dots = reservoirs and ground fill dams, white line = drainage control berm.

River which drains the general area towards the north (the river itself passes roughly three kilometers west of the site).

Two watering boreholes equipped with wind pumps and small concrete reservoirs and additionally two earthen reservoirs in stream beds occur on the site.

4.3 VEGETATION COVER

The project area (including all three site alternatives) occurs in the Nama Karoo Biome and and more specifically within the Eastern Mixed Nama Karoo Vegetation type (Hoffman, T. 1996). This Vegetation type is dominated by a mix of grass and shrub vegetation types which are subject to dynamic changes in species composition depending on seasonal rainfall events. Dominant shrubs are the Bitterkaroo, Kapokbush and Thornkapok. Sweet thorn trees are common only along stream channels. Furthermore sweet thorn trees and shrubs are known to prefer soil derived from dolerite rock and small (shrub like) trees can indeed be observed on all the site alternatives to occur more abundantly in areas of dolerite sill outcrop (no such correlation was however evident along dolerite dykes).

On Alternative 1 two smallish areas of exotic vegetation (prickly pear stands) occur – one stand near the western border of the eastern lobe of the site (part of the proposed sub-station site area) and the other near the northern border.

4.4 GENERAL GEOLOGY AND SOILS

4.4.1 Bedrock

4.4.1.1 Sediments

The bedrock of the region consists of sediments (mostly fine to medium grained sandstone, but also siltstone and mudstone) of the Adelaide Subgroup, Beaufort Group, Karoo Supergroup.

4.4.1.2 Dolerite

Dolerite dykes and sills both are sheet-like rock bodies intruded into the sedimentary rock. They are distinguished by their orientation relative to the sedimentary bedding [sills are orientated parallel or sub-parallel to the sedimentary bedding (thus roughly horizontal in this area), while dykes cut across the sedimentary bedding planes (and are thus roughly orientated vertical or near-vertical in this area).

A number of dolerite dykes and sills of Karoo age have been intruded into the sediments on the sites. Due to the fact that the dykes are often very narrow (meter scale), they often do not have such a pronounced affect on topography as the sills which (due to a slow weathering rate for dolerite compared to sediments) form local topographical high points. Consequently some dolerite dykes have not been included in pre-existing 1:250 000 scale geological map for the area (Le Roux, 1985). The majority of the dykes omitted on pre-existing large scale map have been confirmed during the site visit and added to the geological map (see Figs. 2 to 4). Additionally, the location of a small number of possible dykes (not identified during the ground truthing visit but visible as linear structures on satellite images) are indicated.

4.4.2 Soils

Observations during the ground truthing exercise indicate that the overwhelming portions of all three site alternatives have very shallow soils and either bedrock sub-outcrop at less than 0,5 metres depth below ground surface or bedrock outcrop (refer to observation descriptions at particular location points in Appendix I). Outcrop is particularly prevalent in areas underlain by dolerite bedrock (refer to Figures 2 to 4). The thickest soils (0,5 to 1,2 metres thickness over minor parts) occur in areas of either gully wash material deposits (short drainage channels between localities A14 and A13 on Alternative 3) or alluvial deposits (southwestern corner and border area of Alternative 2). Furthermore, the soils are generally of a clayey sand to silty sand nature.

These results seem to generally correlate with the soils study undertaken by Van den Berg and De Wet, (2017). [They drilled 120 shallow hand augered boreholes spread over the three site alternatives and analyses thereof shows that 79% have soils with less than 0,5 metres combined soil horizon thicknesses (above bedrock), 18% have combined soil horizon thicknesses of between 0,5 and 1,0 meters and 3% have combined soil horizon thicknesses of between 1,0 and 1,2 metres. The slightly thicker of these soils are located in low-lying areas near alluvial channels.]

4.4.3 Usage of rock for construction materials

Brink (1983) cautions against the use of mudstone from the Karoo Supergroup for use as construction materials – particularly for use as concrete aggregate and to a limited extent also for road layer materials. Characteristics which have in the past been found to be of particular concern are:

- An excessive propensity to shrinkage of concretes made from sandstone aggregates
- Low moduli of elasticity of both sandstones and mudrock
- Deterioration of sandstone in the road layers after construction
- Breakdown and slaking of mudrock on exposure
- Swelling characteristics of mudrock
- Poor strength of mudrock

Preference should be given to the use of dolerite rock as construction material, however, sedimentary rock may be used with caution for the lower road layers – especially the sandstones and also mudstone/shale which have been baked by dolerite intrusions.

4.4.4 Dormant quarries

Alternative 1:Three old quarries (which appear to have been utilized for either fill or road gravel) occur along the N10 tarred road and within one kilometre of the southern site boundary (see location C2 in Appendix I for the middle one of these). An old quarry utilizing similar material for the local gravel road off the western boundary of the site occurs next to that road and near the north-western corner of the site alternative. (near locality C14 - but outside the site boundary).

An intermittently producing sandstone quarry occurs at the foot of the dolerite ridge in the western lobe of the site (see locality C1 in Appendix I). The quarry is at least ten metres deep and covers an area of several hundred square metres. The quarry appears to be utilized for road layer material.

The southwestern portion of Alternative 2 (the vicinity of the planned Eskom sub-station and directly north and northwest thereof) is considered the only part of any of the site alternatives with a thick enough soil horizon to possibly allow effective rammed pile installation to 1,0 m depth.

Alternative 2: None.

Alternative 3: Two old quarries (which appear to have been utilized either for ballast material for the railway line or for road gravel for its adjacent service road) occur along the railway line south of the site and within one kilometre of the site boundary. A dolerite dyke directly east of the southwestern site corner has been exposed in one of these quarries but appears to be of insignificant thickness (see locations A1, A2 and A17 in Appendix I).

5. PERCEIVED IMPACTS OF FOUNDATION CONDITIONS ON THE PROPOSED DEVELOPMENT AND POSSIBLE MITIGATION MEASURES

For solar panels overturning moment will be the main load on the solar panel structure support columns and excavation to 1,0 metres below natural ground level will probably be required to ensure overturning stability.

5.1 Due to hardness of, and shallow depth to dolerite bedrock, drilling/digging for placement of footing columns and digging of trenches for laying of cables will be difficult. The fact that moderately steep surface slopes occur over large parts of the areas underlain by dolerite sills, may further contribute to construction difficulties in these areas. It is thus recommended that no solar panels be erected in areas underlain by dolerite sills. (Since dolerite dykes are thin and thus do not cover pronounced surface areas, the non-construction recommendation does not include areas underlain by dolerite dykes).

5.2 Those areas of the site alternatives not underlain by dolerite bedrock are largely underlain by soft to medium hard rock sandstone/siltstone at depths of less than 0,5 metres below ground level. Considering the time-consuming nature of pad footing construction (breaking out and removal of rock and casting of reinforced concrete), and furthermore the difficulty which rock mass at depths shallower than 1,0 m will cause to placement of screwed piles, rammed piles is considered the most effective support option for solar panels. However, since driving to at least 1 metre depth, may prove difficult over large parts of the site alternatives (where rock mass depths are < 0,5 metres), as an alternative, ground beam concrete footings (which make use of concrete strip footings at very shallow depth below ground level to act as support and counterweight for solar panels) may possibly have to be utilized. This founding option is expected to be considerably more costly than using of piles.

5.3 Drainage channels of episodic rivers and very low surface slopes as well as large drainage control berms occur along (or in close proximity to) the southern border of Alternative 2 and theeastern border of Alternative 1. This indicate that submerged conditions may occur for short periods inthose areas during the rainy season. Consequently, access roads in those areas will have to be supplied with properly designed and constructed gravel surfaces with a positive elevation to allow vehicular passage during periods of submersion.

5.4 If commercially available sources of concrete aggregate prove to be too distant and expensive for utilization on site, unweathered dolerite rock which occurs in abundance on each of the sites can be considered for this purpose. The dolerite will have to be tested for quality purposes (hardness, strength, durability and mineral composition) and, if found satisfactory, a rock breaking plant will have to be established on site.

5.5 Dormant (or intermittently producing) sandstone quarries on the sites can be considered as sources of road layer material. The following qualities should be determined namely: Rock strength and degree of weathering, grading, Atterberg and compaction-moisture density values of soils/gravels.

Due to the slaking behaviour of mudstone/shale, care should be taken that these sediments, which occur interlayered as minor component within the sandstones, are are excluded from use (alternatively durability testing is required on the mudstone/shale).

5.6 The Eskom substations for site Alternatives 1 and 3 are planned for areas having rock outcrop (dolerite at Alternative 1 and sandstone/dolerite at Alternative 3), whilst the planned substation for Alternative 2 occurs in an area which may be inundated during parts of the wet season. These aspects need to be considered during the design and construction of the sub-stations.

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