DESKTOP GEOTECHNICAL APPRAISAL FOR THE PROPOSED DEVELOPMENT OF THE JUNO GROMIS 400kV TRANSMISSION LINE IN THE NORTHERN AND WESTERN CAPE PROVINCES

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I hereby declare that to the best of my knowledge North Arrow Consulting and Advisory Services nor any of its members does not have any Interest in the project or associated projects nor with the briefing client.

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1. Introduction

North Arrow Consulting and Advisory Services (hereafter North Arrow) were appointed by Nsovo Environmental Consulting (hereafter Nsovo) acting on behalf of Eskom Holdings SOC Limited (hereafter Eskom) to undertake Geological Impact Assessment as part of the preparation of a construction Environmental Management Programme (cEMPr) for the proposed development of Juno-Gromis 400kV Transmission spanning across the Northern and Western Cape Provinces. This forms part of the environmental conditions which need to be assessed with the effort to minimise possible environmental impacts on the sensitive areas along the proposed ~230km powerline route.

This report is a further review of the initial geological work undertaken by Nsovo whose results and recommendations were obtained and documented respectively.

It reviews the geological and related geotechnical conditions along the confirmed route and provides, a comparative evaluation of the geotechnical and civil engineering impacts on the costs of construction of powerline construction.

The report is therefore expected to form part of a suite of supporting documentation to ensure compliance with the current legal requirements, but also is intended to inform detailed final engineering design and construction of the powerline

2. Location

Figure 1 below shows the location of the Juno-Gromis amended powerline route and associated tower deviations which straddles the Northern and Western Cape Provinces.

3. Terms of Reference and Scope of Work

The cEMPr and hence this updated Desktop geotechnical review relates to the now confirmed route within the 3km wide servitude area (corridor) as well the route deviations (falling out outside the corridor) in the vicinity of the following sites. Appendices 4,5, 6 show the locations of the tower deviations outside the 3km servitude in the vicinity of the areas shown below:

- Tronox Mine
- Kamiesberg Mine
- Lutzville landing strip

3.1 **Objectives**

The desktop assessment was undertaken to achieve the following objectives:

- High level review relating to the nature of the geology, soils, topographic conditions and other factors relating to the entire length of the powerline including the deviations at the 3 above-mentioned sites.
- Attempt to identify geological and geotechnical conditions which may prove to be problematic for the siting of the proposed powerline towers, and which must also be considered as part of the next stages of detailed geotechnical work and engineering design prior to construction.

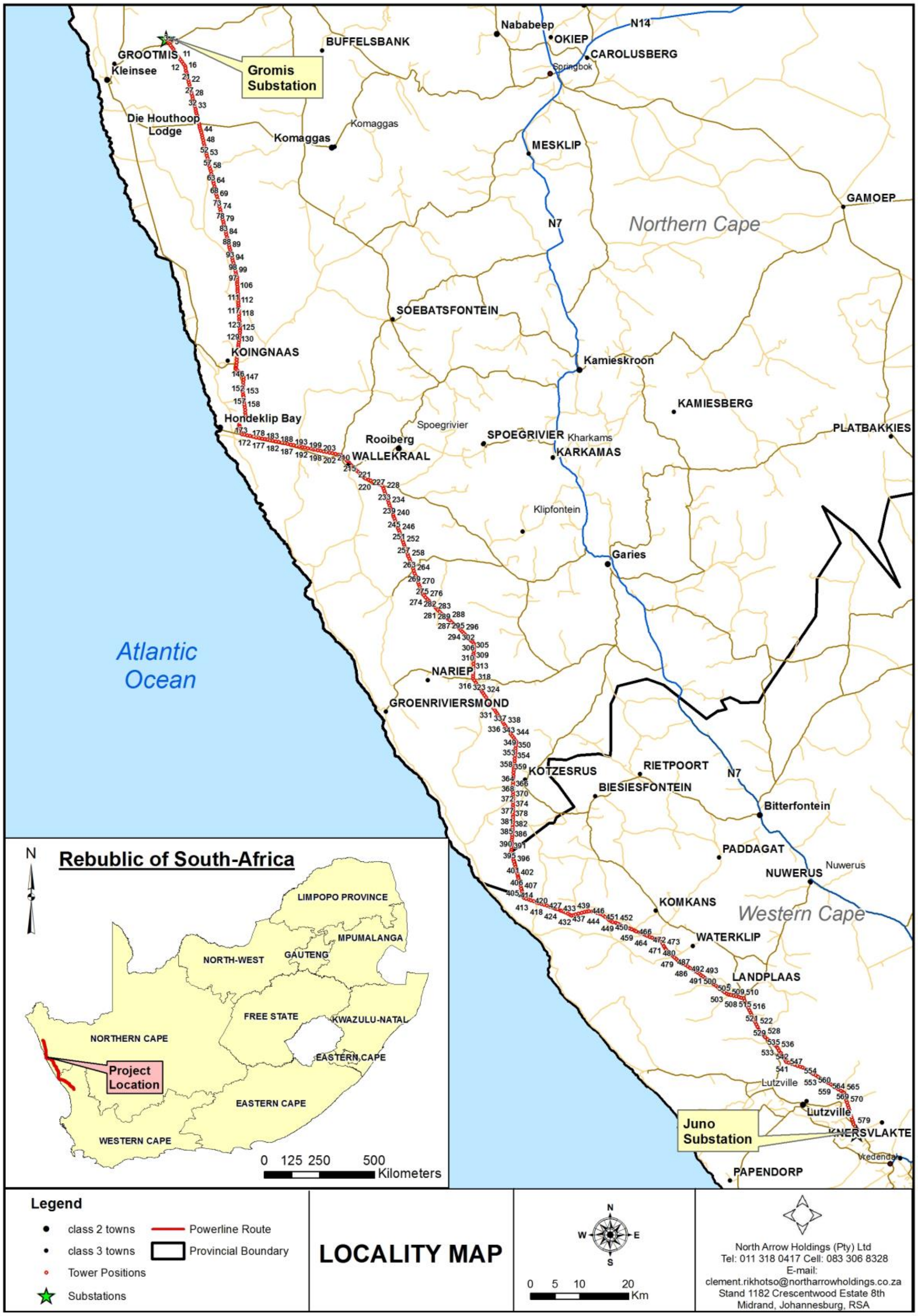


Figure 1: Location and extent of the powerline straddling the Northern and Western Cape Provinces.

3.2 **Deliverables**

- A preliminary Desktop Study geotechnical report which will integrate the results of all work done to date.
- A database for each tower site with associated geological, location, construction mitigation measures and other related attributes.

4. Previous Work

Previous work as far back as 2006 and recently in June 2016 has been done relating to desktop geological and geotechnical work along the route. The reports below detail the work undertaken and conclusions reached. This review will therefore seek to collate all the historic information with recent updates and advise accordingly.

Table 1: Summary of previous work done.

Year	Scope	Report Name	Summary of Conclusions
2006	Desktop study through drive-over and flyover of the sites only	Moore Spence Jones (Pty) Lt (November 2006). Report to Strategic Environmental Focus on a Preliminary Geotechnical Appraisal for the Proposed New Eskom Kudu Overhead Powerline: Alexander Bay to Vredendal.	A detailed geotechnical investigation be carried out along the preferred or chosen route so that construction costs can be fixed or reliably estimated.
2016	Geological assessment through drive-over and flyover of the sites only	Nsovo Environmental Consulting (June 2016). Draft geological impact assessment report for the proposed development for the Juno Gromis 400kV transmission line in the Northern and Western Cape Provinces	• Ground-truthing of surface conditions at each proposed tower location. • Towers located on sand dunes identified

5. Methodology

Below is a simplified methodology on how the review was conducted:

- Desktop Study
- Preliminary Field assessment
- Qualitative analyses of geological, geotechnical and engineering parameters

5.1 **Desktop Study**

A desktop study was undertaken which included the scrutiny of previous reports of work undertaken, relevant topocadastral plans, geological and hydrological maps, and the further investigation of geological references of the area as carried out by Nsovo.

The following information provided by Nsovo was used as input into the review:

- A hard copy of hydrological and proposed layout map of the development at a scale of 1:50km.
- A hard copy of geological and proposed layout of the development at a scale of 1:50km.
- Sectional copies of proposed layout and tower locality map of the development at a scale of 1:7km.
- A digital copy of a locality of proposed layout, powerline 3km corridor and route deviations map of the development at a scale of 1:20km.
- A digital copy of a report by Moore Spence Jones (Pty) Ltd titled, Report to Strategic Environmental Focus on a Preliminary Geotechnical Appraisal for the Proposed New Eskom Kudu Overhead Powerline: Alexander Bay to Vredendal.
- Geological and hydrological maps in the vicinity of the Tronox mine, Kamiesburg and Lutzville landing strip areas of route deviation.

- Marubini T. (June 2016). Draft geological impact assessment report for the proposed development for the Juno Gromis 400kV transmission line in the Northern and Western Cape Provinces. Nsovo Environmental Consulting.
- MS Excel spreadsheet containing co-ordinates and other field observations for each tower site and any other associated attributes.

Also, published 1:250 000 Geological Survey geology maps, covering the areas under investigation. Studies of the relevant 1:50 000 Topographic maps, covering the areas under investigation have been used. Lastly, published literature on the characteristics of the anticipated rocks and soils to be encountered, as well as the anticipated foundation solutions in such materials have also been used.

5.2 **Site Visit**

In order to assess the requirements for the licensing of the sites it is essential to gain perspective on their current status. Preliminary site visits (by drive-over on 1-16 March 2016 & by helicopter on 11-15 April 2016) were undertaken by personnel from Nsovo whose outcomes are incorporated into their geological report reviewed.

5.3 **Qualitative Analyses**

To ensure continuity of work and in keeping with previous work done in 2006 and incorporating the deviated routes, a comparative assessment (rating various aspects) of the proposed sections of the route in terms of suitability for development from topographical, geological, geotechnical and civil engineering perspectives was carried out.

6. Topography, Geology and Geotechnical Founding Conditions

Based on the topographical, geomorphological and geological mapping information described in the Section below as reviewed from historic and recent work, this assessment evaluates the impact of identified geotechnical issues associated with construction as follows:

According to the contour map of climatic N values for South Africa compiled by Weinert, the proposed routes fall into the area with an N value of >5. A climatic N-value of > 5, is associated with arid regions, where mechanical disintegration is the predominant rock weathering mode and an N-value of < 5 is associated with the humid warm areas and a higher annual rainfall, where chemical decomposition is the predominant rock weathering mode. The weathering profile in these more arid regions of the country, favour the generation of a thinner residual soil horizon. Published information on sand or soil depths suggests thickness ranges from <450mm, >450mm, 450-570mm and >750mm (see detailed Excel spreadsheet of tower station metadata) relating to various types of sand/soil profiles across the areas. These will need to be confirmed by actual trenching or drilling to confirm the profiles at each tower location.

The various geological formations that the powerline will cross contain materials that typically have certain common characteristic geotechnical parameters. Each typical soil/rock type will be discussed below, considering the potential problems which can be anticipated, as well as possible foundation solutions.

Topography also has a profound effect on the cost and the difficulty of powerline construction. The proposed line will be over an area which is dominantly flat or undulating or over steep (9 locations in sandstone) topography. Some towers (4 locations) are planned to be located on or next sand dunes. Refer to the accompanying database in MS Excel spreadsheet format for each tower metadata, in particular the towers located on or near sand dunes and on steep terrain. As highlighted in the Moore Spence Jones report, generally, where the towers are on steep areas of rugged topography the following could become necessary:

- Shortening/lengthening of span
- Deviations to avoid extremely rugged areas
- Additional stabilisation measures to support towers at steep cliff areas

- Adhoc alterations to tower design to accommodate specific conditions

These locations need to be surveyed for mean height above ground as part of the final engineering designs.

Appendix 1 shows the summarized geology map of the area across which the powerline will traverse whole Appendix 2 to 6 show the detailed geology and elevation contour maps onto which the proposed routes have been annotated, while Table 3 below, summarises the geological rock and soil types that have been identified along the routes per tower name along with their anticipated geotechnical conditions.

6.1 **Windblown (Aeolian) Sands**

These recent wind-blown sands of Aeolian age overlay marine sediments and ancient intrusive rocks. These soils have been transported under the action of wind, usually form relatively deep horizons and at surface display characteristic undulating sand dune features. Some areas have reddish brown sand dunes which are generally known to be stable. However, there are whiter, migrating dunes in some places which tend to be problematic since their migration is seasonal and could be rapid. It is to be anticipated that the route will have a surface cover of these recent transported soils.

The cover thickness can be expected to vary, according to the geological depositional processes that were active at the time. As these transported sediments are recent, they will not have undergone any significant consolidation and compaction. They can therefore be considered to be of a loose consistency, and could experience significant settlement under applied foundation loading.

Due to their method of deposition, these sandy soils are generally of low cohesion (collapsible grain structure) and consistency, and can be anticipated to be highly compressible and therefore can be expected to settle under foundation loading. Significantly high sand dune drifts can cause a significant horizontal loading on the towers for which they have not been designed for. Excavation characteristics will be Soft Excavation (SABS 1200:1988) and easily carried out by hand or light earthmoving plant.

Considering that the vast majority of the area is on stable dune sands, there will be an advantage in the adoption of standard tower design which would be cost-effective. If the horizon is thin, structures could be founded on competent underlying residual soil horizons or basement geology. Excavation characteristics will be “soft”, but care must be taken to protect construction personnel working inside the excavations from possible sidewall collapse. In areas underlain by deep sand/soil (>3m) cover the use of relatively large foundation bases, mainly to counter uplift forces will be required. In this instance, collapsible soil must be removed by excavation to a specified depth (1.5 times the width of the proposed foundation) and backfilled in thin layers (150mm thick) compacted (93 and 95% Mod AASHTO) to a specified density. In most cases the same excavated material is reused for backfilling, but provision must be made to import other or additional material to restore to the original ground level contours. Strict control over the backfill and compaction process is essential. Piled foundations may be required in certain areas which must be factored into the construction costs.

Except for the published soil profile thicknesses as per (Appendices 2-6), the actual profiles (thicknesses and extent) of Aeolian material overlying Tertiary and Quartenary marine sediments at each tower location will need to be confirmed by follow-up trench geotechnical investigations.

6.2 **Pedogenic Formations**

6.2.1 ***Calcrete***

Calcrete occurs in environments with a Weinert N-value of more than 5, therefore in the semi-arid and arid regions. Where a fluctuating perched water table has occurred in recent geological time, the near surface permeable soils can become cemented by lime rich solutions to form well cemented calcrete horizons. Where pedogenic horizons occur, their consistencies can vary from “loose” (soil contains occasional calcrete nodules) to "very soft rock" (hardpan calcrete). Due to this variability, variable foundation conditions and hence differential settlement of foundations can be expected.

In hardpan calcrete, where pedogenic development is complete, the material exhibits properties similar to very soft to hard rock, and consequently provides a good founding medium for structures. Excavations may therefore require the use of pneumatic tools to provide a level founding surface. The prevailing geotechnical conditions can therefore be expected to comprise relatively deep and loose silty sands, containing random zones of pedogenic soils (calcretes), overlying competent bedrock. It will therefore be very important that a proper geotechnical investigation is performed to determine the extent and thickness of pedogenic materials. Pedogenic materials may not be consistent in occurrence, both vertically and horizontally due to the conditions under which they developed and due to variations in the stages of development at a particular location.

6.3 **<u>Acidic Igneous Granites and Gneissic Rocks</u>**

These rocks belong to the Namaqualand Igneous and Metamorphic Complex of the Proterozoic Age. They have been derived from liquid volcanic magmas of certain mineralogical content, cooling and solidifying at various depths within the earth. Metamorphic processes from the physical and chemical alteration of granites, due to an increase in pressure and temperature on them, induced by a range of geological processes have formed gneissic rocks.

These rocks are generally competent when not weathered. Occasional rock outcrops will be encountered on which isolated towers will be positioned and this constitutes a sound foundation for lightly loaded structures. The earthworks for these towers will require Hard Excavation by blasting and/or the use of pneumatic tools in excavations. Significant cost savings can be achieved at these tower locations due to higher achievable bearing pressures, thereby necessitating smaller foundations, and the use of rock anchors.

Granites and gneisses are generally hard, coarse grained rocks, which decompose/weather to form gravelly and sandy soils. It is these constituents have been identified by Nsovo as sandstone and quartzite which are the competent remnants of the weathering effects of granites and gneissic rocks either in situ or transported by wind and water transport over time until present day location. These soils will have a collapsible grain structure; show a dispersive; sand "boils", high permeability; high erodibility; good compaction and workability.

Table 2: Summary of topography, geology and anticipated founding conditions along the powerline route.

Tower Sections	Topographic Summary	Geological Summary	Anticipated Founding Conditions	Recommendations – Remedial action
Tower 1 to 135	Undulating to flat	Aeolian material overlying Tertiary and Quaternary marine sediments	Low cohesion (collapsible grain structure	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
		Fine brownish to orange soil	Low cohesion (collapsible grain structure)	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
		Calcrete	Differential settlement, from loose soil to soft rock	Use of pneumatic tools to provide a level founding surface in hard calcrete and excavation and compaction in deep silty sands to specified density
		Sand dunes	Low cohesion (collapsible grain structure)	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
Tower 135-278	Fairly flat to undulating	Aeolian material overlying marine sediments	Low cohesion (collapsible grain structure)	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
		Aeolian material overlying Tertiary and Quaternary marine sediments	Low cohesion (collapsible grain structure)	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
		Alluvium and undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex	Low cohesion (collapsible grain structure)	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
		Undifferentiated granites and gneiss of the Namaqualand metamorphic complex	Sound foundation where unweathered	Hard excavation by blasting and/or the use of pneumatic tools to a suitable depth for foundation loading
		Aeolian material overlying undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments	Low cohesion (collapsible grain structure)	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
		Aeolian material overlying marine sediments and undifferentiated granites and gneiss of the Namaqualand metamorphic complex	Low cohesion (collapsible grain structure)	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
		Calcrete	Differential settlement, from loose soil to soft rock	Use of pneumatic tools to provide a level founding surface in hard calcrete and excavation and compaction in deep silty sands to specified density
Tower 278-394	Flat to undulating	Mostly on agricultural land dominated by:		
Tower 394-498	Flat, undulating to steep	Aeolian material overlying marine sediments as well as	Low cohesion (collapsible grain structure)	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and

		undifferentiated granites and gneiss of the Namaqualand metamorphic complex		compaction to specified density
		Undifferentiated granites and gneiss of the Namaqualand metamorphic complex with marine sediments on the lower footslopes	Sound foundation where unweathered	Hard excavation by blasting and/or the use of pneumatic tools to a suitable depth for foundation loading
		Aeolian material overlying undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments	Low cohesion (collapsible grain structure	Removal of collapsible soil by excavation to a specified depth, backfilling in thin layers and compaction to specified density
		Augengneiss of the Little Namaqualand Suite	Sound foundation where unweathered	Hard excavation by blasting and/or the use of pneumatic tools to a suitable depth for foundation loading
		Calcrete	Differential settlement, from loose soil to soft rock	Use of pneumatic tools to provide a level founding surface in hard calcrete and excavation and compaction in deep silty sands to specified density
Tower 498-587	Steep and undulating	Augengneiss of the Little Namaqualand Suite	Sound foundation where unweathered	Hard excavation by blasting and/or the use of pneumatic tools to a suitable depth for foundation loading
		Undifferentiated granites and gneiss of the Namaqualand metamorphic complex	Sound foundation where unweathered	Hard excavation by blasting and/or the use of pneumatic tools to a suitable depth for foundation loading
		Alluvium, sand and calcrete deposits of Quaternary origin	Differential settlement, from loose soil to soft rock	Use of pneumatic tools to provide a level founding surface in hard calcrete and excavation and compaction in deep silty sands to specified density
		Schist, limestone and dolomite of the Gifberg Formation	Karst weathering and carbonate leaching. Possibility of sinkholes	Further excavations and/or drilling to understand nature of geology and extent of karst/dolomitic weathering. Remedial measures will include dynamic compaction to required founding load depth
		Augengneiss of the Little Namaqualand Suite	Sound foundation where unweathered	Hard excavation by blasting and/or the use of pneumatic tools to a suitable depth for foundation loading

6.4 **Geology of the areas of route deviations**

Table 3 below shows a comparison between the geology of the area in the vicinity of the powerline 3km corridor with that of the towers falling outside the corridor in the vicinity.

Table 3: Geology of tower locations falling outside the powerline 3km corridor vs that within the corridor.

Area	Geology of area within the corridor	Tower No	Geology of tower locations outside the corridor
Tronox Mine Namaqua Sands Towers: 402-419 & 435-466	• Undifferentiated granites and gneiss of the Namaqualand metamorphic complex with marine sediments on the lower footslopes • Aeolian material overlying undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments • Aeolian material overlying marine sediments as well as undifferentiated granites and gneiss of the Namaqualand metamorphic complex • Undifferentiated granites and gneiss of the Namaqualand metamorphic complex	Towers 402-406	Aeolian material overlying marine sediments as well as undifferentiated granites and gneiss of the Namaqualand metamorphic complex
		Towers 406-418	Undifferentiated granites and gneiss of the Namaqualand metamorphic complex with marine sediments on the lower footslopes
		Towers 435-439	Aeolian material overlying undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments
		Towers 441–447	On contact between Aeolian material overlying undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments with Aeolian material overlying marine sediments as well as undifferentiated granites and gneiss of the Namaqualand metamorphic complex
		Towers 448-467	Undifferentiated granites and gneiss of the Namaqualand metamorphic complex
		Towers 468-473	Augengneiss of the Little Namaqualand Suite
Kamiesberg Mine Towers 274-324	• Aeolian material overlying undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments and Undifferentiated granites • Aeolian material overlying marine sediments as well as undifferentiated granites and gneiss of the Namaqualand metamorphic complex • Undifferentiated granites and gneiss of the Namaqualand metamorphic complex • Aeolian material overlying marine sediments as well as granites and gneisses of the Namaqualand Metamorphic Complex • Alluvium and Undifferentiated granites and gneiss of the Namaqualand metamorphic complex • Undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments	Towers 274-292	Aeolian material overlying undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments and Undifferentiated granites but straddles an apparent contact with granites and gneiss of the Namaqualand metamorphic complex
		Towers 293-303	Aeolian material overlying marine sediments as well as undifferentiated granites and gneiss of the Namaqualand metamorphic complex with towers 297-299 on granite and gneiss
		Towers 304-317	Undifferentiated granites and gneiss of the Namaqualand metamorphic complex
		Tower 318	Alluvium and Undifferentiated granites and gneiss of the Namaqualand metamorphic complex
		319-324	Aeolian material overlying marine sediments as well as granites and gneisses of the Namaqualand Metamorphic Complex
Lutzville landing strip Towers 543-571	• Augengneiss of the Little Namaqualand Suite • Alluvium, sand and calcrete deposits of Quaternary origin • Schist, limestone and dolomite of the Gifberg Formation	Towers 543-560	Alluvium, sand and calcrete deposits of Quaternary origin
		Towers 561-566	Schist, limestone and dolomite of the Gifberg Formation
		Towers 567-570	Alluvium, sand and calcrete deposits of Quaternary origin Towers 569 and 570 located on a water course
		Towers 571-572	Schist, limestone and dolomite of the Gifberg Formation

The following observations can be made from the analysis in Table 2 above:

- Tronox mine - There is no difference between the geology within the corridor and the geology falling outside the corridor on which the deviated towers are located.
- Kamiesberg Mine – Except for Undifferentiated granites and gneiss of the Namaqualand metamorphic complex as well as marine sediments which is the geology found in the corridor, the other geological units are similar within and without the corridor.
- Lutzville landing strip - There is no difference between the geology within the corridor and the geology of deviated towers falling outside the corridor. It is noted however, the presence of limestone and dolomite on some of the towers. Special investigations are required on dolomitic rock to determine the presence of karsts (or not) in which case particular engineering solutions will be required.

In summary, the route deviations have not introduced any significant new geological variable than what is already known, except to note the presence of limestone/dolomite.

7. Geotechnical factors affecting Civil Engineering design

Having outlined the anticipated tower-to-tower geotechnical foundation conditions, several considerations also need to be made as part of the construction process. Factors (some similar to previously identified in the in 2006) that could affect the costs of construction of the power line, from geotechnical and civil engineering perspectives are the following:

- The average distance between towers is 450m. Uplift forces between successive towers are a significant factor that must be accommodated in the design of foundations. Generally, the tower foundation design is facilitated by construction in areas underlain by shallow soil cover overlying bedrock. In these areas foundations will comprise simple pad footings taken into bedrock while the anchors will be simple steel dowels drilled and grouted into the weathered bedrock. However, other aspects such as foundations and the use of the lateral stabilising cables secured by ground anchors requires more competent geological conditions which are present in the form of granite or gneissic rocks should they not be found to be highly decomposed/weathered.
- Topography may also have a profound effect on the cost of line construction. Generally, where the line traverses steep areas of rugged topography the following could become necessary:
    - Shortening/lengthening of span
    - Deviations to avoid extremely rugged areas
    - Additional stabilisation measures to support towers at steep cliff areas
    - Adhoc alterations to tower design to accommodate specific conditions
    - Difficulty of construction associated with difficult and very steep terrain, relating to access to tower locations.
- Towers (569, 570) located in river courses. This requires special noting in regards foundation requirements versus thickness of overlying sand and depth to riverbed rock as well as the seasonality of river flow and quantities of water which pass through during peak floods.
- Earthworks associated with tower construction and road – there should be adequate materials for foundations (gneiss/granite borrow pits where there are outcrops) and road construction (for e.g. calcrete)
- Straightness of route i.e. degree of minimization of bends - Final design considerations would govern the number of bends and deviations in the routes. Some bends are already present as a result of the three deviations as explained above. However, there is unexplained bends between towers 140 and 170 as seen on Appendix 3.
- Access routes to the line from the district and national road network into the area and design and construction of maintenance roads along the transmission line route - The planned powerline corridor is accessible from the main gravel road network region. The construction of roads through the sand dune should also not pose a problem. However, due care in terms of environmental impact when opening up access roads should be taken. A significant problem relating to this general area is the

high erodibility of the sands and the formation of erosion gulleys or dongas either by wind or sheetwash erosion along preferential paths.

8. Seismic Hazard Zoning

The Seismic Hazard Map of South Africa, as presented in Figure 2 below, indicates that the site falls within the very low risk zone for seismic tremors, except down south in the lower tip of the towerline which approaches the yellow zone of high low risk.

The estimated peak ground acceleration is estimated to fall within the 0.2-0.24 ms range. According to this chart, there is a 10% probability that this peak ground acceleration could be exceeded within a 50-year period. Even if the risk is low, for redundancy purposes, Eskom needs to take these seismic hazard predictions into account, when designing the power line pylons, as well as their concrete foundations.

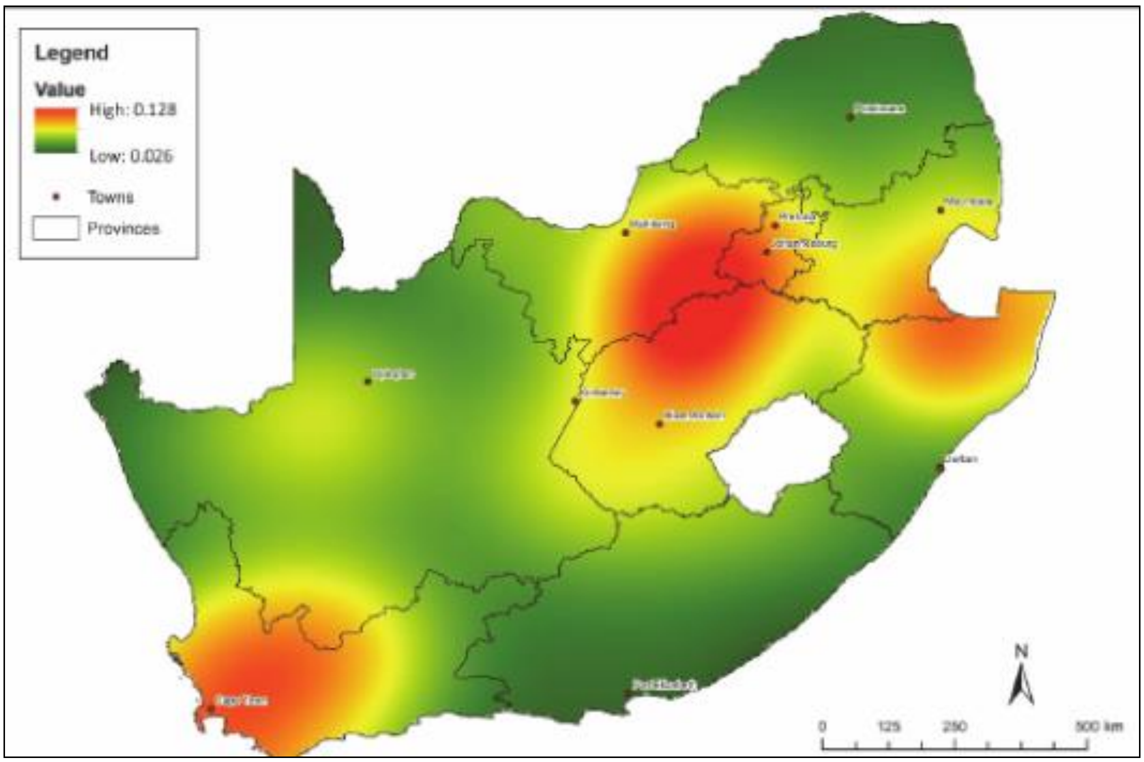


Figure 2: Seismic hazard map of South Africa representing the expected peak ground acceleration (g) being exceeded in a 50-year period (Source: Esterhuyse et al. 2014)

9. Conclusions

Based on this geotechnical review further to previous work, the geological and geotechnical conditions anticipated to be encountered are not out of the ordinary subject to detailed intrusive investigations specific to each tower site along the powerline. No fatal flaws are therefore anticipated.

The proposed line will be over an area which is dominantly flat or undulating or steep topography. The geological conditions are dominated by very fine orange, whitish and brownish sand dunes. Where there are sand dunes as these soils have been transported under the action of wind, they usually form relatively deep horizons and at surface display characteristic undulating sand dune features. which are generally known to be stable. However, there are whiter, migrating dunes in some places which tend to be problematic since their migration is seasonal and could be rapid. Due to their method of deposition, these sandy soils are generally of low cohesion (collapsible grain structure) and consistency, and can be anticipated to be highly compressible and therefore can be expected to settle under foundation loading. Some towers (11, 39, 345, 348, 359) are planned to be located on a few dunes. In areas like these, the use of relatively large foundation bases, mainly to counter uplift forces must be factored into the designs. Piled foundations may be required in selected areas requiring deep installation which will increase construction costs significantly.

Where there is outcrop of granite/gneiss, founding conditions are expected to be solid. Where there is a weathered profile of granite/gneiss over competent rock, the thickness needs to be determined for founding conditions. Where calcrete horizons occur, their consistencies can vary from “loose” (soil contains occasional calcrete nodules) to “very soft rock” (hardpan calcrete). Due to this variability, variable foundation conditions and hence differential settlement of foundations can be expected

In the areas of route deviations, there is no difference between the geology within the 3km powerline corridor/servitude and the geology of the tower locations falling outside the corridor, so this has not introduced any significant new geological variable than what is already known. It is noted however, of the presence of limestone and dolomite on some of the towers (Towers 561-566 & 571-575 & 586) near the Landing Strip deviation route and the Junos Sub-station. Special investigations are required on dolomitic rock to determine the presence of karsts (possibility of sinkhole formation) or not in which case particular engineering solutions will be required.

Finally, the geological conditions and the effect on design and construction development are therefore inferred from the information available, and could thus vary significantly from that to be found during construction. This is particularly so in view of the highly variable characteristics of the prevailing regional geological conditions as observed from field observations which focus on surface dimensions only and not sub-surface.

10. Recommendations

a) Investigate appropriateness of locations of towers on sand dunes, on steep terrain, water courses and limestone/dolomitic rocks. Conduct design and construction cost trade-off studies between relocation of towers (often in similar geology) vs. coming up with engineering solutions.
b) Investigate the powerline bends between towers 140 and 170 as seen on Appendix 3.
c) Carry out a follow-up detailed geotechnical investigation at each tower station along the length of the powerline so that the results can be included in the final engineering design which would enable construction costs to be fixed or reliably and accurately estimated. This work needs to be scoped out separately but in general would consist of the following:
    - Ground tower locations – locating with a differential GPS to ensure accuracy. Marked pegs will be placed for future reference prior to and during construction.
    - Detailed trenching investigations to map the profile (thicknesses and extent) of Aeolian material overlying Tertiary and Quaternary marine sediments. This will involve pitting/trenching, drilling, geotechnical logging, disturbed/undisturbed sampling, laboratory analyses and final reporting

11. References

- Moore Spence Jones (Pty) Ltd titled, Report to Strategic Environmental Focus on a Preliminary Geotechnical Appraisal for the Proposed New Eskom Kudu Overhead Powerline: Alexander Bay to Vredendal.
- Marubini T. (June 2016). Draft geological impact assessment report for the proposed development for the Juno Gromis 400kV transmission line in the Northern and Western Cape Provinces. Nsovo Environmental Consulting.
- Jennings, J.E. Brink, A.B.A and Williams, A.A.B. (January 1973)."Revised Guide to Soil profiling for Civil Engineering Purposes in Southern Africa" - Civil Engineer in South Africa
- National Institute for Transport and Road Research. TRH 14, (1985). "Guidelines for Road Construction Materials". Pretoria
- Depart of Public Works (2007). Guidelines for problem soils in South Africa.
- Weinert, H.H. (1980). The Natural Road Construction Materials of Southern Africa. H & R Academia Publ., Pretoria, 298 pp.

12. Appendices

Appendix 1 – Summary of the geology along the powerline

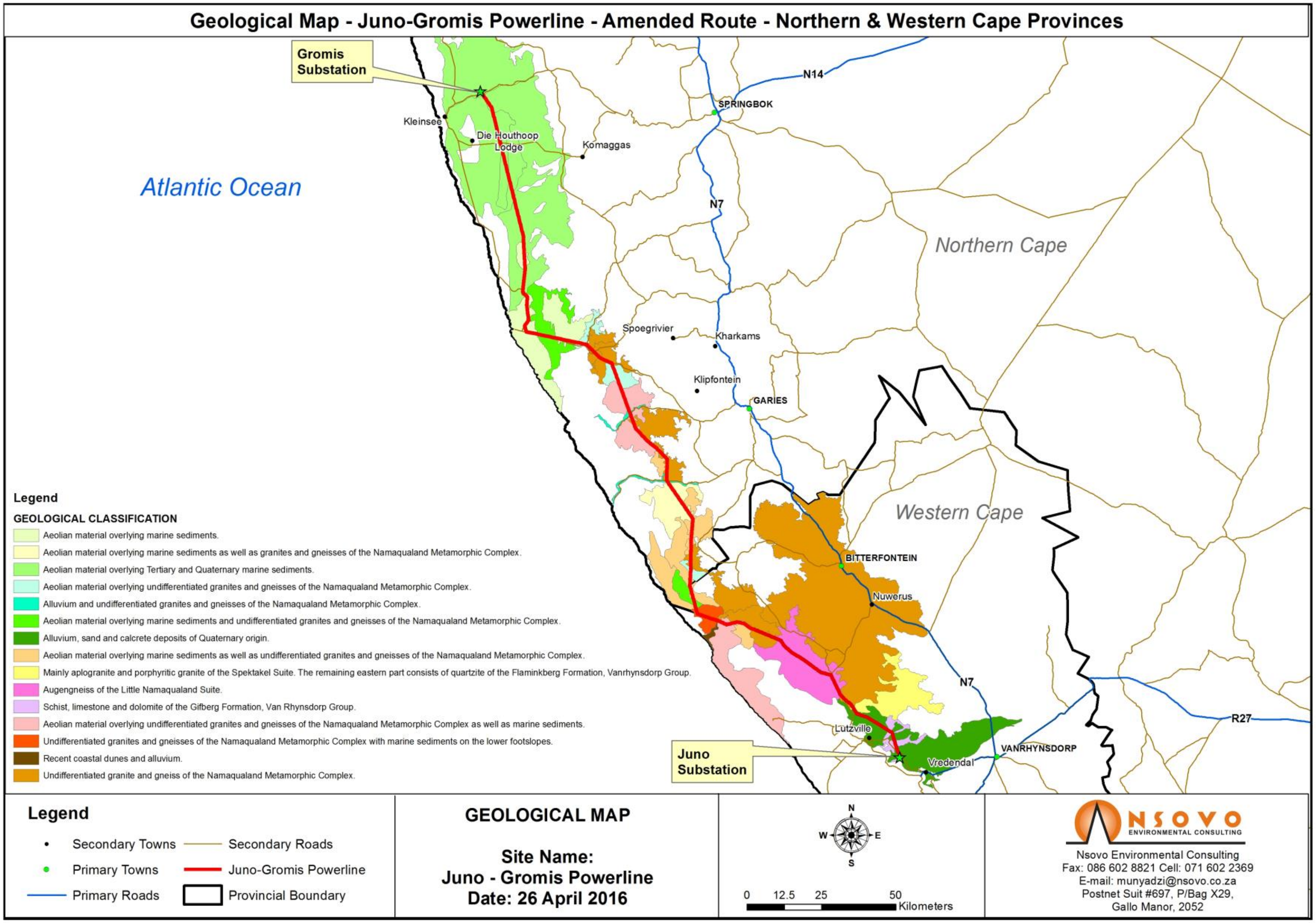
Appendix 2 – Detailed geology of tower stations 1-135

Appendix 3 – Detailed geology of tower stations 136-278

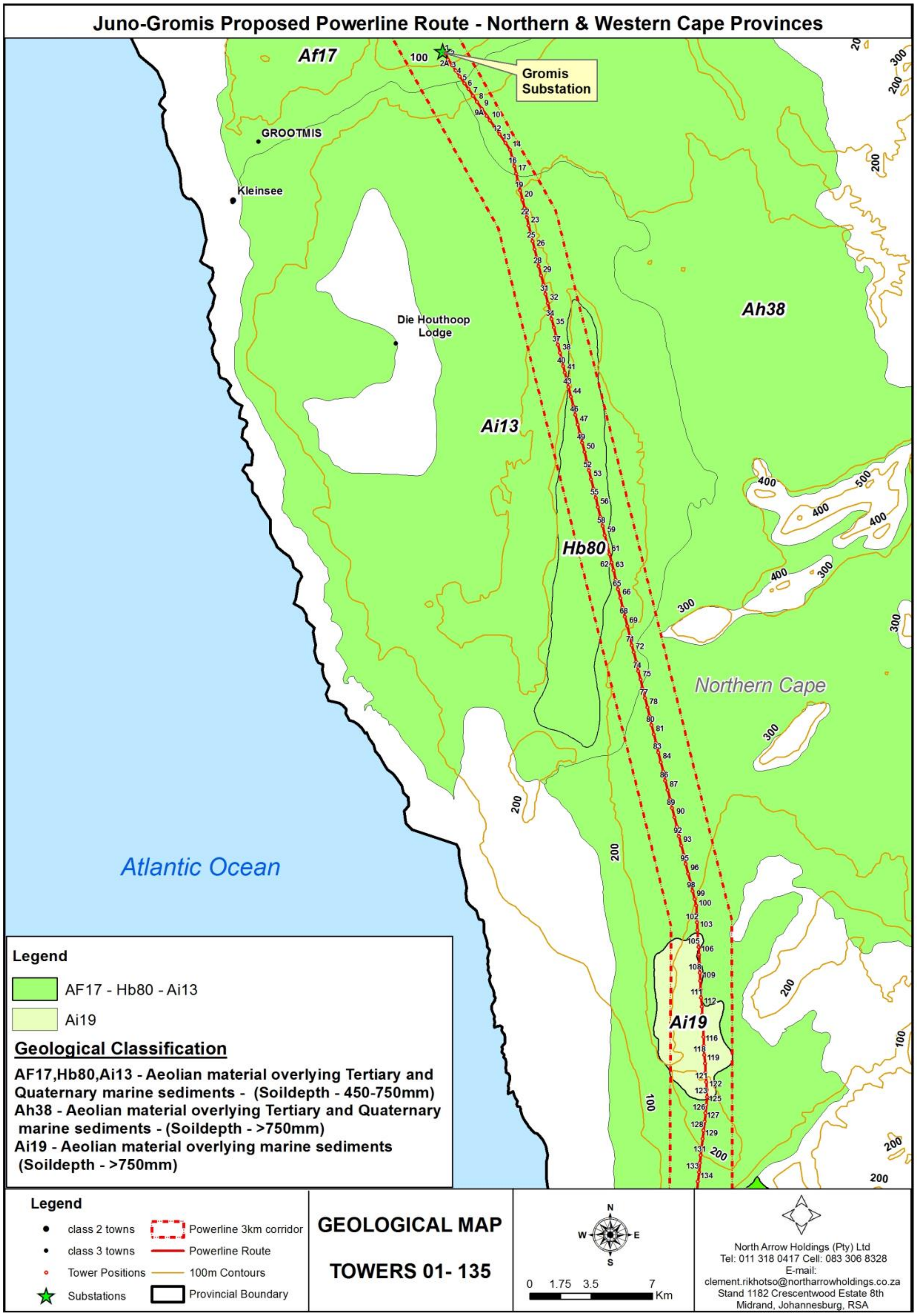
Appendix 4 – Detailed geology of tower stations 278-394

Appendix 5 – Detailed geology of tower stations 394-498

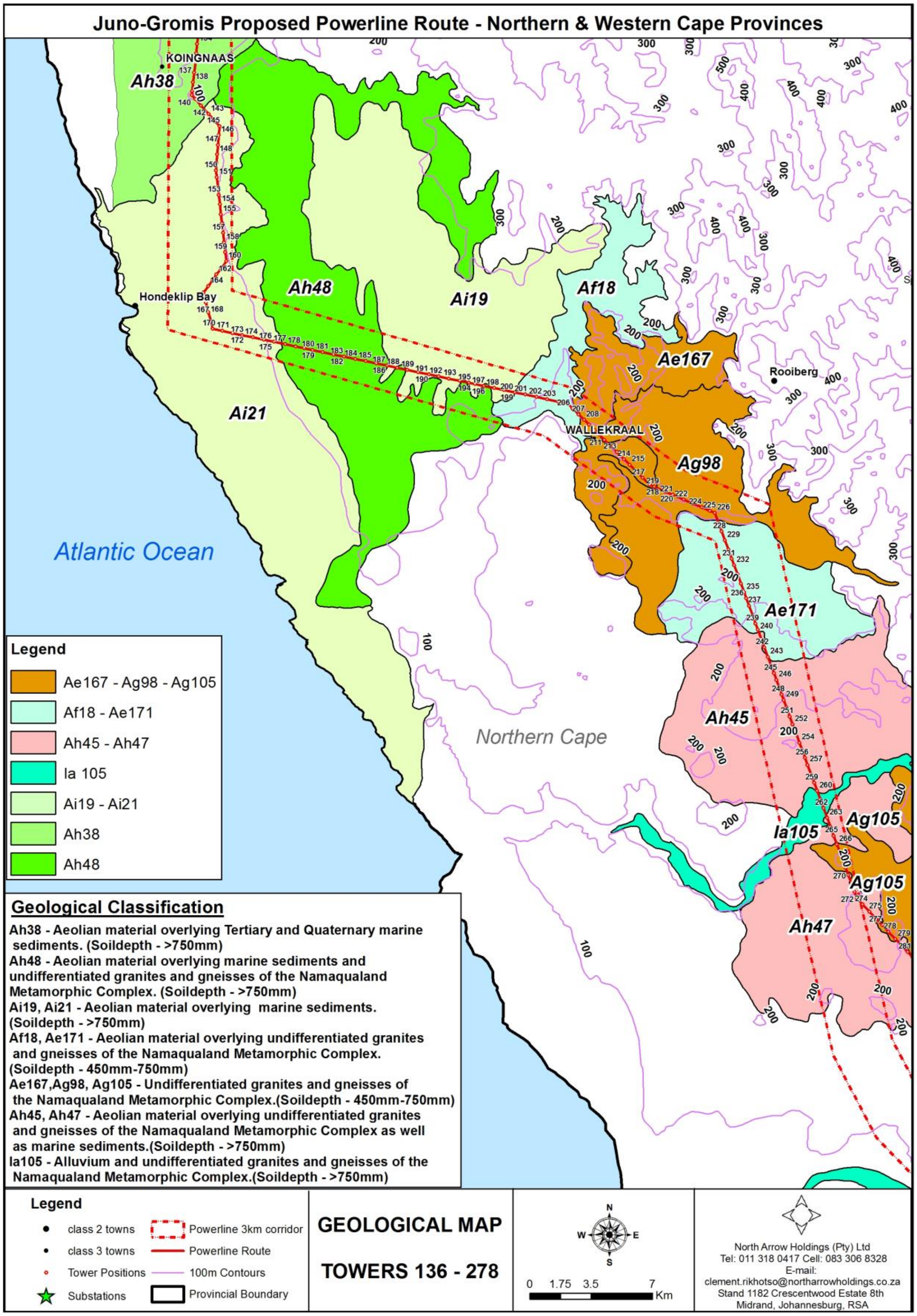
Appendix 6 – Detailed geology of tower stations 498-587



Geological Map - Juno-Gromis Powerline - Amended Route - Northern & Western Cape Provinces
Gromis Substation
Kleinsee
Die Houthoop Lodge
Komaggas
SPRINGBOK
N14
N7
Atlantic Ocean
Northern Cape
Spoegrivier
Kharkams
Klipfontein
GARIES
Western Cape
BITTERFONTEIN
Nuwerus
N7
Lutzville
Juno Substation
Vredendal
VANRHYNSDORP
R27
Legend
GEOLOGICAL CLASSIFICATION
Aeolian material overlying marine sediments.
Aeolian material overlying marine sediments as well as granites and gneisses of the Namaqualand Metamorphic Complex.
Aeolian material overlying Tertiary and Quaternary marine sediments.
Aeolian material overlying undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.
Alluvium and undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.
Aeolian material overlying marine sediments and undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.
Alluvium, sand and calcrete deposits of Quaternary origin.
Aeolian material overlying marine sediments as well as undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.
Mainly aplogranite and porphyritic granite of the Spektakel Suite. The remaining eastern part consists of quartzite of the Flaminkberg Formation, Vanrhynsdorp Group.
Augengneiss of the Little Namaqualand Suite.
Schist, limestone and dolomite of the Gifberg Formation, Van Rhynsdorp Group.
Aeolian material overlying undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex as well as marine sediments.
Undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex with marine sediments on the lower footslopes.
Recent coastal dunes and alluvium.
Undifferentiated granite and gneiss of the Namaqualand Metamorphic Complex.
Legend
Secondary Towns
Secondary Roads
Primary Towns
Juno-Gromis Powerline
Primary Roads
Provincial Boundary
GEOLOGICAL MAP
Site Name:
Juno - Gromis Powerline
Date: 26 April 2016
N
W
E
S
0 12.5 25 50
Kilometers
NSOVO
ENVIRONMENTAL CONSULTING
Nsovo Environmental Consulting
Fax: 086 602 8821 Cell: 071 602 2369
E-mail: munyadzi@nsovo.co.za
Postnet Suit #697, P/Bag X29,
Gallo Manor, 2052


Juno-Gromis Proposed Powerline Route - Northern & Western Cape Provinces
Af17
Gromis Substation
GROOTMIS
Kleinsee
Die Houthoop Lodge
Ah38
Ai13
Hb80
Northern Cape
Atlantic Ocean
Ai19
Legend
AF17 - Hb80 - Ai13
Ai19
Geological Classification
AF17,Hb80,Ai13 - Aeolian material overlying Tertiary and Quaternary marine sediments - (Soildepth - 450-750mm)
Ah38 - Aeolian material overlying Tertiary and Quaternary marine sediments - (Soildepth - >750mm)
Ai19 - Aeolian material overlying marine sediments (Soildepth - >750mm)
Legend
class 2 towns
class 3 towns
Tower Positions
Substations
Powerline 3km corridor
Powerline Route
100m Contours
Provincial Boundary
GEOLOGICAL MAP
TOWERS 01- 135
0 1.75 3.5 7 Km
North Arrow Holdings (Pty) Ltd
Tel: 011 318 0417 Cell: 083 306 8328
E-mail:
clement.rikhotso@northarrowholdings.co.za
Stand 1182 Crescentwood Estate 8th
Midrand, Johannesburg, RSA

A


Juno-Gromis Proposed Powerline Route - Northern & Western Cape Provinces
KOINGNAAS
Ah38
Ah48
Ai19
Af18
Hondeklip Bay
Ae167
Rooiberg
Ai21
WALLEKRAAL
Ag98
Atlantic Ocean
Ae171
Ah45
Northern Cape
Ag105
Ia105
Ag105
Ah47
Legend
Ae167 - Ag98 - Ag105
Af18 - Ae171
Ah45 - Ah47
Ia 105
Ai19 - Ai21
Ah38
Ah48
Geological Classification
Ah38 - Aeolian material overlying Tertiary and Quaternary marine sediments. (Soildepth - >750mm)
Ah48 - Aeolian material overlying marine sediments and undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex. (Soildepth - >750mm)
Ai19, Ai21 - Aeolian material overlying marine sediments. (Soildepth - >750mm)
Af18, Ae171 - Aeolian material overlying undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex. (Soildepth - 450mm-750mm)
Ae167,Ag98, Ag105 - Undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - 450mm-750mm)
Ah45, Ah47 - Aeolian material overlying undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex as well as marine sediments.(Soildepth - >750mm)
Ia105 - Alluvium and undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - >750mm)
Legend
class 2 towns
class 3 towns
Tower Positions
Substations
Powerline 3km corridor
Powerline Route
100m Contours
Provincial Boundary
GEOLOGICAL MAP
TOWERS 136 - 278
N
W
E
S
0 1.75 3.5 7 Km
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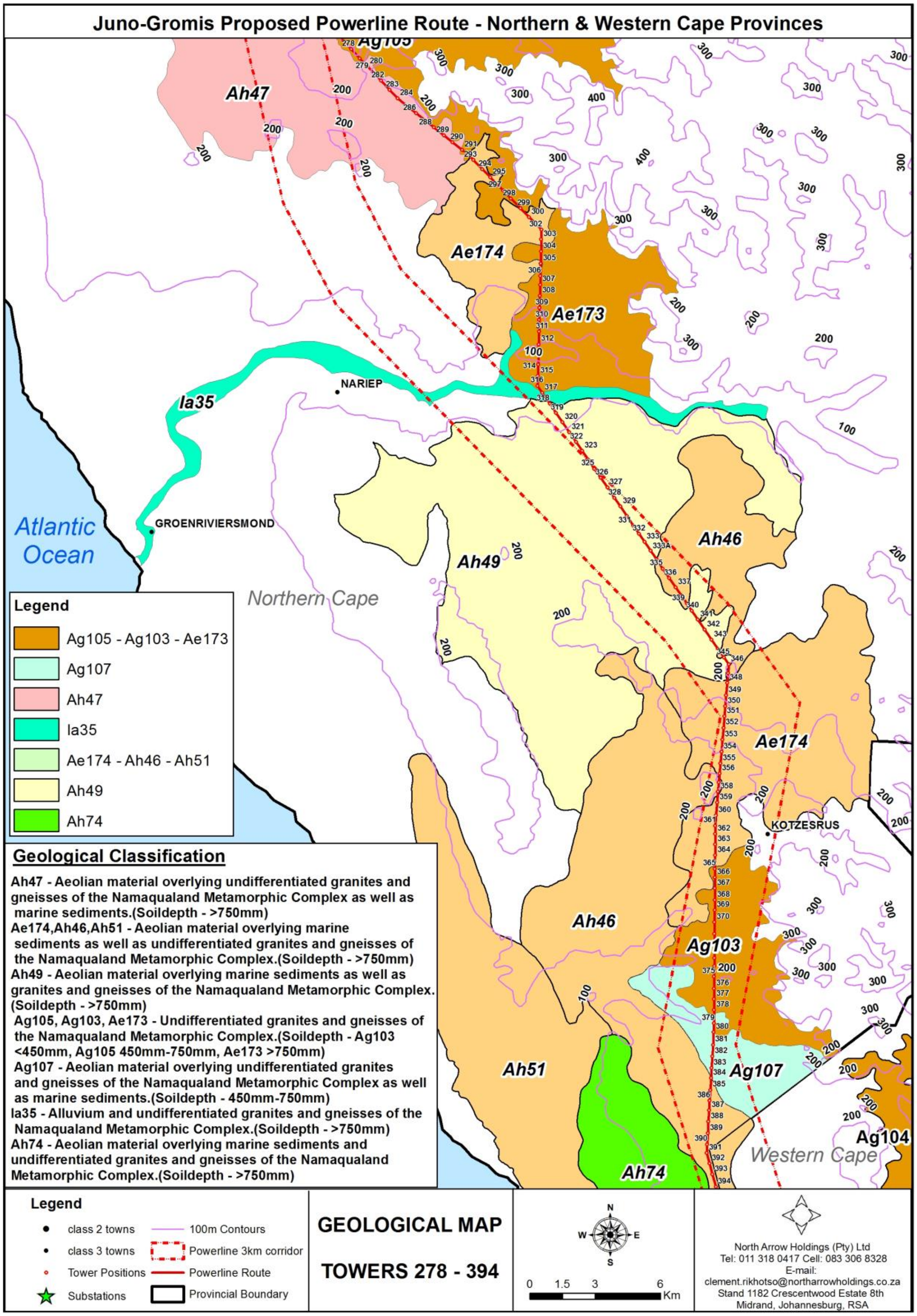
Midrand, Johannesburg, RSA



Juno-Gromis Proposed Powerline Route - Northern & Western Cape Provinces
Ag105
Ah47
Ae174
Ae173
Ia35
NARIEP
GROENRIVIERSMOND
Atlantic Ocean
Northern Cape
Ah49
Ah46
Ae174
KOTZESRUS
Ag103
Ah46
Ah51
Ag107
Ah74
Ag104
Western Cape
Legend
Ag105 - Ag103 - Ae173
Ag107
Ah47
Ia35
Ae174 - Ah46 - Ah51
Ah49
Ah74
Geological Classification
Ah47 - Aeolian material overlying undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex as well as marine sediments.(Soildepth - >750mm)
Ae174,Ah46,Ah51 - Aeolian material overlying marine sediments as well as undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - >750mm)
Ah49 - Aeolian material overlying marine sediments as well as granites and gneisses of the Namaqualand Metamorphic Complex. (Soildepth - >750mm)
Ag105, Ag103, Ae173 - Undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - Ag103 <450mm, Ag105 450mm-750mm, Ae173 >750mm)
Ag107 - Aeolian material overlying undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex as well as marine sediments.(Soildepth - 450mm-750mm)
Ia35 - Alluvium and undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - >750mm)
Ah74 - Aeolian material overlying marine sediments and undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - >750mm)
Legend
class 2 towns
class 3 towns
Tower Positions
Substations
100m Contours
Powerline 3km corridor
Powerline Route
Provincial Boundary
GEOLOGICAL MAP
TOWERS 278 - 394
N
W
E
S
0 1.5 3 6 Km
North Arrow Holdings (Pty) Ltd
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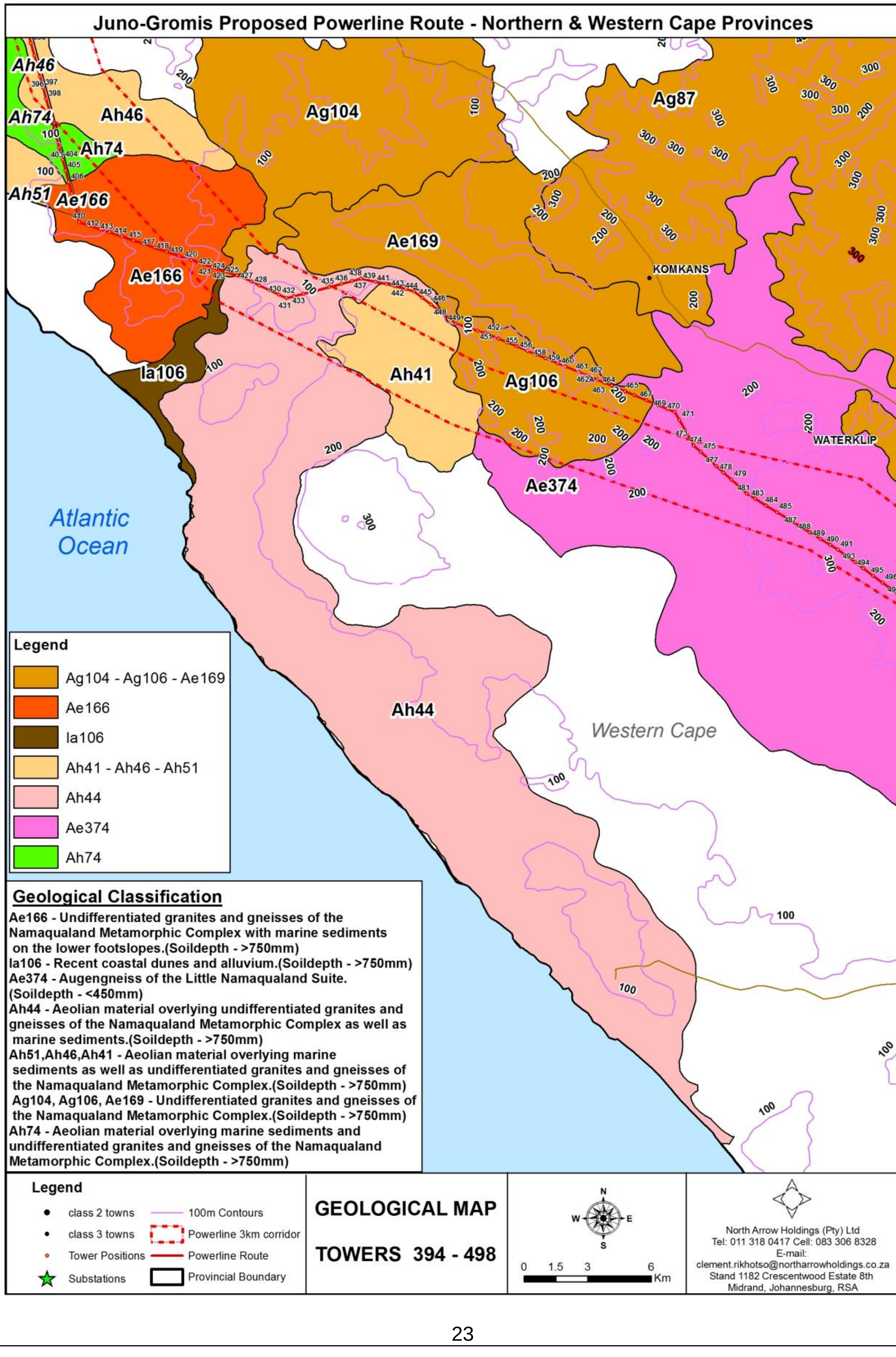
Juno-Gromis Proposed Powerline Route - Northern & Western Cape Provinces
Ah46
Ah74
Ah46
Ah74
Ah51
Ae166
Ag104
Ag87
Ae169
KOMKANS
Ae166
Ia106
Ah41
Ag106
WATERKLIP
Ae374
Atlantic Ocean
Ah44
Western Cape
Legend
Ag104 - Ag106 - Ae169
Ae166
Ia106
Ah41 - Ah46 - Ah51
Ah44
Ae374
Ah74
Geological Classification
Ae166 - Undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex with marine sediments on the lower footslopes.(Soildepth - >750mm)
Ia106 - Recent coastal dunes and alluvium.(Soildepth - >750mm)
Ae374 - Augengneiss of the Little Namaqualand Suite. (Soildepth - <450mm)
Ah44 - Aeolian material overlying undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex as well as marine sediments.(Soildepth - >750mm)
Ah51,Ah46,Ah41 - Aeolian material overlying marine sediments as well as undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - >750mm)
Ag104, Ag106, Ae169 - Undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - >750mm)
Ah74 - Aeolian material overlying marine sediments and undifferentiated granites and gneisses of the Namaqualand Metamorphic Complex.(Soildepth - >750mm)
Legend
class 2 towns
class 3 towns
Tower Positions
Substations
100m Contours
Powerline 3km corridor
Powerline Route
Provincial Boundary
GEOLOGICAL MAP
TOWERS 394 - 498
N
W
E
S
0 1.5 3 6 Km
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clement.rikhotso@northarrowholdings.co.za
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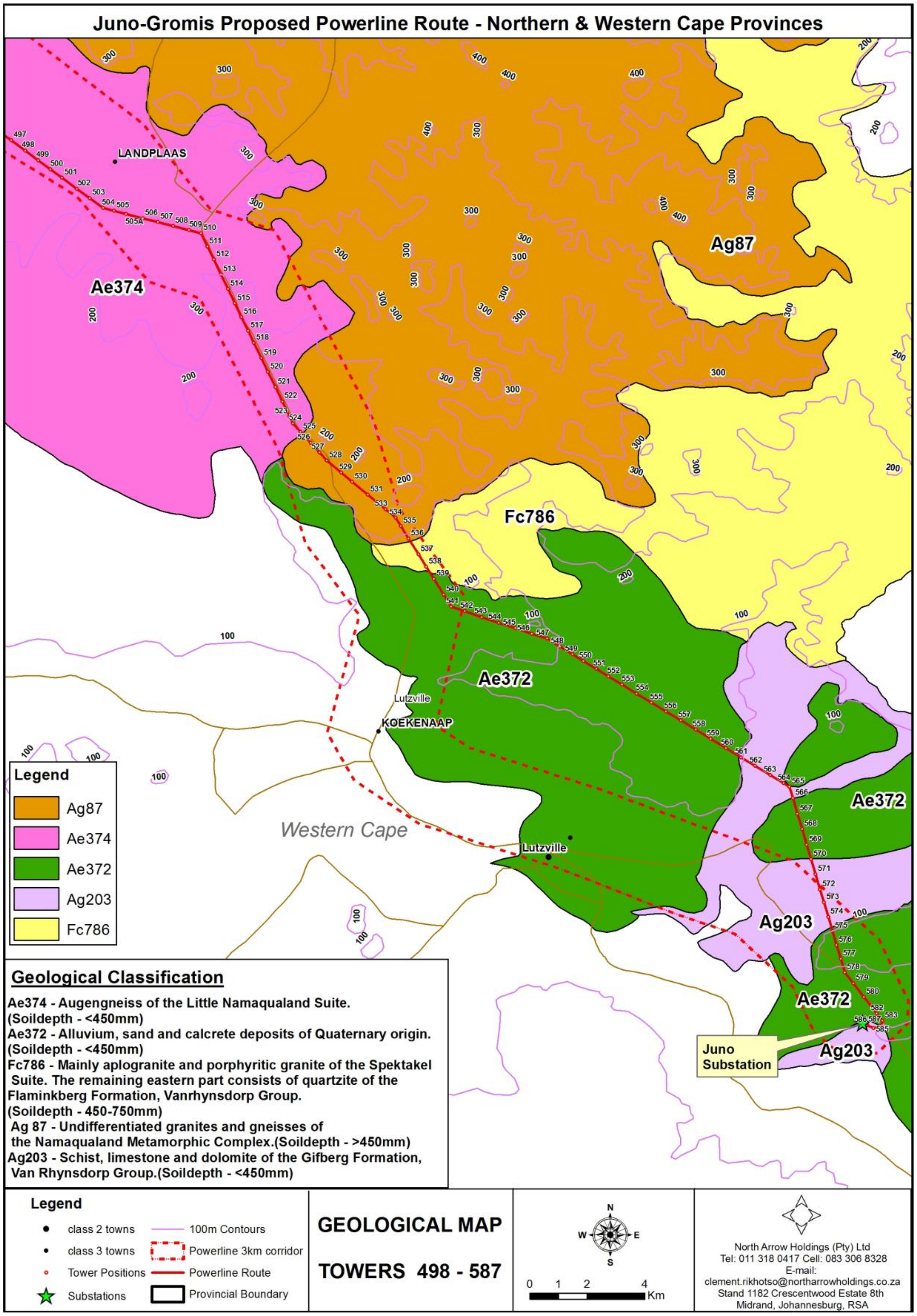
Juno-Gromis Proposed Powerline Route - Northern & Western Cape Provinces
LANDPLAAS
Ae374
Ag87
Fc786
Ae372
Ag203
Lutzville
KOEKENAAP
Western Cape
Lutzville
Juno
Substation
Legend
Ag87
Ae374
Ae372
Ag203
Fc786
Geological Classification
Ae374 - Augengneiss of the Little Namaqualand Suite.
(Soildepth - <450mm)
Ae372 - Alluvium, sand and calcrete deposits of Quaternary origin.
(Soildepth - <450mm)
Fc786 - Mainly aplogranite and porphyritic granite of the Spektakel
Suite. The remaining eastern part consists of quartzite of the
Flaminkberg Formation, Vanrhynsdorp Group.
(Soildepth - 450-750mm)
Ag 87 - Undifferentiated granites and gneisses of
the Namaqualand Metamorphic Complex.(Soildepth - >450mm)
Ag203 - Schist, limestone and dolomite of the Gifberg Formation,
Van Rhynsdorp Group.(Soildepth - <450mm)
Legend
class 2 towns
class 3 towns
Tower Positions
Substations
100m Contours
Powerline 3km corridor
Powerline Route
Provincial Boundary
GEOLOGICAL MAP
TOWERS 498 - 587
0 1 2 4 Km
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