3 GENERAL

Site A, Site B and Site C are generally characterised by shallow lying bedrock and are overlain by transported soils and ferruginous paedogenic soils.

The results of the investigation and recommendations made are given for Site A, Site B and Site C in three separate sections which follow. The recommendations are provided for preliminary design and costing purposes and are subject to review and confirmation by detailed investigations for specific structures prior to final design.

It is understood that the proposed development will comprise lightly loaded structures with loads typically in the order of 100kPa to 150kPa. The entire substation will be constructed on balanced cut to fill terrace some 148m x 118m with surrounding access roads. The final terrace position and levels are subject to the results of this investigation.

4 SITE A: DISSCUSSION

4.1 Site Stratigraphy

The proposed site is underlain by topsoil, hillwash, nodular ferricrete, residual shale and shale bedrock of the Timeball Hill Formation, occurring at varying depths below ground level. Over half the site area a horizon comprising numerous cobbles and gravels of varying origin was encountered. Due to the structural complexity of the area three separate interpretations are given for the origin of this material and will need to be confirmed by percussion drilling during the detailed investigation. Due to the proximity of Site A to the Chuniespoort Formation, this cobble bed may be an extension to the breccias often associated with the Chuniespoort, alternatively it may represent conglomerates of the Rooihoogte Formation and, for the purposes of this report, have interpreted as a “paleo” colluvium horizon.

Cross sections showing the representative soil / rock horizons are shown on Drawing J28199-A-001 appended to this report.

Soil & Rock Profile

Topsoil was encountered in all test pits excavated on site. The topsoil is underlain by a ferruginous hillwash horizon and a well developed nodular ferricrete horizon. The nodular ferricrete is noticeably absent to the north of the site i.e. TPA01, TPA08 and TPA22 and is particularly well developed, forming a layer in excess of 1m thick, in the vicinity of TPA03, TPA16, TPA17 and TPA24 (J28199-A-001).

A paleo-colluvium underlies the nodular ferricrete across approximately half the site area and in all cases resulted in TLB refusal during excavation at depths ranging from 1,6m to 2,5m below ground level.

Residual shale was encountered in the SW corner of the site and N of the site. A deeply weathered residual profile was encountered in TPA03, TPA04, TPA10 and TPA15 with residual shale occurring in excess of 2,8m below ground level.

The transition from the very stiff residual shale to very soft rock shale is gradual. Very soft rock shale was evident in TPA01, TPA06, TPA08, TPA11 and TP A16 at depths between 2,0m and 2,5m below ground level.

The very soft rock shale rock mass is characterised by a closely spaced, sub-horizontal bedding joint set inclined to the south. Residual shale joint infill material was encountered along the joint wall contacts.

Two typical soil profiles describe Site A based on the occurrence of a paleo-colluvium horizon and are described in Table 1 and Table 2.

Table 1: Site A - typical residual shale soil profile description. (Timeball Hill Formation)

Depth (m)	Description	Comment
0,0 - 0,3	**Topsoil:** dry, dark brown, soft, sandy SILT.	Collapsible grain structure. Suitable for use as general fill, refer Section 4.2. Not suitable for founding.
0,3 - 0,9	**Ferruginised Hillwash:** dry, orange-brown speckled black, soft, sandy SILT with scattered ferricrete nodules.	Absent in TPA03, TPA16, TPA17, and TPA24, where the underlying nodular ferricrete is well developed. Collapsible grain structure. Suitable for use as general fill, refer Section 4.2. Not suitable for founding.
0,9 - 1,2	**Nodular Ferricrete:** closely packed well cemented and ferruginised ferricrete nodules up to 10mm in a matrix of slightly moist, orange-brown, sandy SILT. Overall consistency is medium dense but friable.	Variable thickness from 0,0m to 1,3m. Well developed in vicinity of TPA03, TPA16, TPA17, and TPA24 being >1,0m thick. Suitable for use as selected fill, refer Section 4.2. Not suitable for founding.
1,2 – 1,7	**Reworked Residual Shale:** Slightly moist, yellow-brown mottled black, firm, sandy SILT with scattered ferricrete concretions.	Absent in some testpits. Suitable for use as general fill, refer Section 4.2.
1,7 – 2,5	**Residual Shale:** Slightly moist, yellow-brown, stiff to very stiff, relict laminated, sandy SILT.	Suitable for founding. Suitable for use as general fill, refer Section 4.2.
2,5 – +2,8	**Very Soft Rock Shale:** Yellow-brown mottled grey, highly weathered with completely weathered joint infilling, thinly laminated, very soft rock.	Suitable for founding. Suitable for use as general fill, refer Section 4.2.

Table 2: Site A - typical paleo-colluvium soil profile description. (Timeball Hill Formation)

Depth (m)	Description	Comment
0,0 - 0,3	**Topsoil:** refer Table 1	
0,3 - 0,9	**Ferruginised Hillwash:** refer Table 1	
0,9 - 1,2	**Nodular Ferricrete:** refer Table 1	
1,2 – +2,1	**Colluvium:** Relatively closely packed sub-rounded quartzite and dolomite cobbles and gravels in a matrix of slightly moist orange-brown, weakly calcretised, sandy SILT. Overall consistency is dense to very dense.	Results in TLB refusal on medium hard rock or better cobbles. Encountered over half the site area, refer J28199-A-001. Suitable for use as selected fill, refer Section 4.2. Suitable for founding. Thought to have originated from a paleo erosion platform; today of which there is no evidence as the general topography is flat lying.

A 1,0m thick alluvial soil profile comprising silty clay with isolated, hard rock quartzite boulders up to 0,5m was encountered in TPA22. The hillwash was noticeably absent within this soil profile. This area is likely to represent an area of poor drainage and consequently a relatively well developed vlei-type deposit.

Ground water seepage was not encountered within any of the test pits excavated on site.

4.2 Materials Properties

The results of the laboratory tests carried out on the materials on Site A are summarised in Table 3.

Table 3: Site A - summary of laboratory test results.

Soil Properties	Topsoil	Ferruginised Hillwash	Nodular Ferricrete	Paleo - colluvium	Residual Shale	Alluvium
Depth (m)	0.3	0.5-1.2	1.0-1.4	1.4-1.9	1.4-2.0	1.0
No. of Tests	1	1	1	2	3	1
% Gravel	0	3	40	29-48	13-47	5
% Sand	28	31	27	22-31	23-27	25
% Silt	33	32	19	19-30	20-39	32
% Clay	40	34	14	10-11	7-21	38
Grading Modulus	0.27	0.38	1.55	1.21-1.68	0.66-1.81	0.44
Liquid limit (%)	36	34	29	30-31	32-42	53
Plasticity Index (%)	19	17	14	14-15	15-23	30
Nat Moisture Content (%)	22	16.8	10.1	7.7-8.9	6.9-21.4	15.9
ModAASHTO Density (kg/m³)	NT	1765	2068	2113	2218	NT
OMC (%)	NT	16.9	10.2	8.9	7.2	NT
CBR @ 95%	NT	8	19	20	23	NT
TRH14 Classification	NT	G10	G8	G7	G7	NT
Van der Merwe Swell Index	low	low	low	low	medium-low	high
Swell Potential %	NT	NT	NT	NT	NT	<1%

*NT (not tested)
*values expressed a range

All the materials show a low potential for heave apart from the residual shale which has a low to medium swell potential and the alluvium, encountered in TPA22, which has a high swell potential.

An undisturbed sample taken of the residual shale was damaged in transit. Consolidation tests will need to be carried out on the residual shale during the detailed investigation to confirm settlement characteristics. The firm to stiff residual shale soils are likely to exhibit slight collapse potential and this should be accommodated in preliminary foundation design.

The ferruginised hillwash classifies as a G10 quality material and is suitable for use as general fill. The nodular ferricrete and paleo-colluvium classify as a G8 and G7 material respectively and are suitable for use as selected fill. Where excavated, this material should be stockpiled for reuse.

Although the laboratory results indicate that the residual shale classifies as a G7 material this result is from one sample only. Based on a visual inspection of this material it would, however, appear to be characteristic of a G9 to G10 quality material. Caution should therefore be exercised when using this material and until such time as further tests are done, this material should be limited to use as a general fill.

The construction of subbase or base course layers requires a G6 or better quality material. The materials excavated during the investigation yielded materials no better than G7 quality. Base or subbase material will therefore have to be imported from a commercial source.

4.3 Excavatability

Two distinct soil profiles are encountered in the Site A area and include a residual shale soil profile and a paleo-colluvium soil profile.

The excavatability of the rock / soil profile will be governed largely by the hardness of the rock. A gradual transition is evident from the very stiff residual shale to the very soft rock shale profile. This transition occurs between 1,7m and in excess of 3,0m below ground level in the more deeply weathered areas.

As the very soft rock shale can be excavated with relative ease, it is therefore recommended that no distinction be made between soft and intermediate excavation for the residual shale and very soft rock shale horizons.

The paleo-colluvium on site proved more difficult to excavate and resulted in TLB refusal on soft to medium hard rock cobbles. The upper 1,0m of this profile classifies as soft excavation while intermediate excavation is likely at greater depths.

The excavation classes[1] for Site A should include:

- "Soft excavation" (as defined in clause 3.1.2a and b of SABS 1200 D. This class would typically include the topsoil, upper colluvium, residual shale and very soft rock shale).
- "Intermediate excavation" (as defined in clause 3.1.2a and b of SABS 1200 D. This class would typically include the lower colluvium).

[1] SABS 1200D:1988. **Standardised specification for civil engineering construction. D: Earthworks.** S.A. Bureau of Standards, Pretoria.

4.4 Ground Water

No ground water was evident in any of the testpits excavated on site. However, the presence of 1,0m thick silty clay profile in TPA22 indicates an area of poor drainage and the possibility of water ponding during the rainy season.

5 SITE A: RECOMMENDATIONS

The following recommendations are provided for preliminary design and costing purposes. These are subject to review and confirmation by detailed investigations for specific structures prior to final design.

A recommended cut to fill terrace position (150m x 150m) is indicated on Drawing J28199-A-001 for Site A.

5.1 Foundations

Lightly loaded and sensitive tolerant structures may be founded on strip / spread footings within the stiff or better residual shale from 1,7m to 2,5m or within the dense or better colluvium typically between 1,2m and 2,1m below ground level. Very soft rock shale is typically encountered between 2,5 and in excess of 2,8m below ground level and as such would not be considered a practical founding horizon for a shallow spread footing solution.

In light of the fact that the residual shale is likely to exhibit settlement, lightly loaded and settlement sensitive structures such as brick-clad buildings should be founded on top of engineered fill mattresses or concrete raft foundations. Movement joints should also be incorporated into buildings.

An engineered fill mattress or concrete raft foundation should be designed to accommodate slight differential settlement which could possibly occur within the paleo-colluvium profile. Settlement characteristics of residual shale and paleo-colluvium profile should be confirmed during the detailed geotechnical investigation.

Footings are to be located on the stiff or better residual shale or dense or better colluvium with bearing pressures limited to 200kPa. Bearing pressures on engineered fill should be limited to 150kPa.

Where structures are to be founded on a terrace, excavations for the footings should be formed into the compacted material rather than attempting to construct the fill around the completed foundations. Backfill around the foundation plinths should be carried out to the same standard as the terrace fill. The backfill material should be placed in thinner layers (80mm to 100mm or less) where smaller compaction equipment is used.

All footings excavations should be inspected by an engineer to ensure that the founding conditions are suitable for the expected bearing pressures below the bases.

The topsoil and ferruginised hillwash exhibit collapsible grain structure and are considered unsuitable as founding stratum. The topsoil and ferruginised hillwash are unsuitable for use as engineered fill due to the high compaction moisture required which is difficult to control.

The nodular ferricrete horizon generally has a medium dense consistency and is friable. This horizon varies in thickness from 0,0m to 1,3m and is not considered as a suitable founding stratum.

The topsoil and ferruginised hillwash should be stockpiled for landscaping and rehabilitation. The hillwash and the nodular ferricrete horizon should be excavated to stockpile for use as general selected fill respectively.

5.2 Road Construction

The general subgrade conditions for both the roads are described below.

The access roads are generally underlain by topsoil and hillwash overlying a nodular ferricrete and residual / shale or paleo-colluvium. The topsoil and hillwash exhibit a collapsible grain structure and the in situ CBR is likely to be between 3 and 7%. The hillwash and topsoil are therefore not suitable for use as a subgrade material and should either be stripped or alternatively reworked and compacted. According to TRH14 the hillwash classifies as a G10 material when reworked.

Alluvium comprising silty clay was encountered in testpit TPA22. This soil profile is typically associated with seasonally wet soils and exhibits heave potential. It is recommended that in instances where alluvium is encountered that the road be undercut by a minimum of 0.8m and replaced with a pioneer layer of dumprock.

5.3 Terrace Construction

Terraces will be required in areas of the site:

- to fill to a required elevation above ground level
- to replace unsuitable materials such as the collapsible topsoil and hillwash
- to improve the load carrying capacity of the soils below surface beds and light structures.

These terraces should be constructed as follows:

- Over the entire extent of the proposed terrace, clear and grub to remove vegetation and topsoil to an average of 300mm below surface.
- Remove and stockpile all transported soils suitable for landscaping, to expose the underlying nodular ferricrete or reworked residual shale. Where structures are to be supported on the cut/fill terrace, such removal should extend about 2m beyond the structure on all sides.

- Adjust the moisture content of the exposed soils to within ±2% of the Mod AASHTO optimum moisture content (OMC) and compact the base of the excavation to 90% Mod AASHTO density over the upper 150mm to 200mm.

- Construct the terrace using G7 or better quality material placed in layers not exceeding 200mm thick and compact to 95% Mod AASHTO density at OMC ±2%.

Compaction control should be assessed by means of sand replacement tests. Nuclear density measuring devices may be used once these have been successfully calibrated against the sand replacement tests. The moisture contents should always be checked by oven drying. Regular Mod AASHTO density and CBR tests should be carried out. The construction of the terrace and compaction control should be generally in accordance with SABS 1200 DM[2] and SABS 1200 ME[3].

Fills below structures should consist of selected paleo-colluvium of G7 or better quality.

Note that the paleo-colluvium may contain some oversize material although this is not typically the case. Careful selection of material and removal of oversize material during spreading will be required to ensure that the maximum particle size does not exceed two thirds the layer thickness.

Residual shale should only be used as a general fill in non-critical areas and should be avoided in road layer works as it tends to powder when trafficked.

Given the variable nature of the soil profile encountered at Site A, material quality and quantities could be difficult to control during construction. Additional fieldwork and laboratory testing during the detailed investigation would better define the nature of the soil profile and the soil profile properties for the selected terrace footprint.

5.4 Excavations

The stability of temporary excavations is the responsibility of the contractor. But for planning purposes, the following guidance is given for the different materials encountered in the profile.

- Hillwash: excavations may be excavated at 1:1 to depths of 2m. Excavations deeper than 2m should be battered at 1:2 or flatter. This horizon is likely to be characterised by a low cohesion and is expected to be moderately to highly erodible.

- Nodular ferricrete: comprises medium dense but friable materials and slopes of 1:1

[2] SABS 1200DM:1981. **Standardised specification for civil engineering construction.** DM: Earthworks (Roads, **Subgrade**). S.A. Bureau of Standards, Pretoria.

[3] SABS 1200ME:1981. Standardised specification for civil engineering construction. ME: Roads (Subbase). S.A. Bureau of Standards, Pretoria.

could be considered for excavations.

- Paleo-colluvium: this horizon comprises dense or better material and consequently 2:1 slopes could be considered for excavations.
- Residual horizons: the residual shale horizons are generally stiff to very stiff and sub-horizontally laminated. Consequently 2:1 slopes could also be considered for temporary excavations in this material. Flatter slopes may be required where the excavation extends below the water table, if encountered.
- The very soft rock shale is closely laminated and consequently slopes of 50°should be considered.

5.5 Conclusions

It is recommended that the cut to fill terrace be positioned within the area characterised by a dense or better paleo-colluvium soil profile occurring 1,2m to 2,1m below ground level rather than within the stiff or better residual shale located slightly deeper between 1,7m and 2,5m below ground level, refer Drawing J28199-A-001.

A shallow foundation option may therefore be considered with footing foundations for light and non-settlement sensitive structures and a concrete raft or engineered fill mattress considered for light but settlement sensitive structures. Bearing pressures on the paleo colluvium and engineering fill mattress should be limited to 200kPa and 150kPa respectively.

The detailed investigation should include geological mapping to provide confirmation that the Malmani Dolomite contact is >500m north of Site A (Figure 1), in addition to percussion drilling. The Council for Geoscience recommends that if the dolomite bedrock occurs within 100m from surface, the detailed investigation allow for a dolomite stability and risk assessment for sinkhole formation.

It is recommended that an allowance be made for determining and monitoring ground water levels. A gravimetric survey would also prove useful in determining the presence of faulting in the study area.

6 SITE B: DISSCUSSION

6.1 Site Stratigraphy

The proposed site is characterised by two distinct soil profiles marking the contact between the Timeball Hill Formation shale's and underlying Rooihoogte Formation quartzite. The quartzites form the basal contact to the Chuniespoort Formation dolomites. The residual shale soil profile is similar to that encountered at Site A and comprises approximately 20% of the total site area; refer Drawing J18199-B-001.

Cross sections showing the representative soil / rock horizons are shown on Drawing J18199-B-001 appended to this report.

Soil & Rock Profile

A similar soil profile to that encountered at Site A was evident in testpits TPB11, TPB18, TPB23, TPB24 and TPB25 located within the SE corner of the site. The soil profile over this area is characterised by topsoil, hillwash and nodular ferricrete underlain by paleo-colluvium and residual shale.

Residual shale was encountered in two testpits TPB11 and TPB18 with very soft rock shale only evident in TPB11 at a depth of 1,7m below ground level. Paleo-colluvium was encountered in TPB23, TPB24 and TPB25 which were excavated to the limit of reach of the TLB i.e. 2,8m.

Over the remainder of the site a distinctly different profile is encountered and is characterised by quartzite at shallow depths. TLB refusal on hard quartzite was occurred during excavation of testpits TPB03, TPB02, TPB01, TPB08, TPB09, TPB16 and TPB17 at depths ranging between 0,5m and 1,7m below ground level. The quartzite rockhead is overlain by colluvium and nodular ferricrete with a relatively thin undeveloped residual quartzite horizon encountered in some instances.

The quartzite rock mass is characterised by a near-vertical, widely spaced joint sets. Residual quartzite joint infilling material was generally absent along joint wall contacts.

A N-S trending ridge of hardpan ferricrete is located in the centre of Site B; refer Drawing J28199-B-001. The very soft rock or better hardpan ferricrete occurs between depths 0,3m to 0,8m over this central portion of the site i.e. TPB10, TPB09, TPB13, TPB15 and TPB16.

The typical soil and rock profile encountered on Site B is summarised in Table 4, Table 5 and Table 6 below.

Table 4: Site B - typical hardpan ferricrete soil profile description.

(Rooihoogte Formation)

Occurrence	**TPB04, TPB09, TPB10, TPB13, TPB15, TPB22**	
Depth (m)	**Description**	**Comment**
0,0 - 0,3	**Colluvium:** loosely packed rounded quartzite and angular shale gravel and cobbles in a matrix of dry, red-brown, silty fine and medium SAND. Overall consistency is loose.	Not suitable for founding. Generally not suitable for use as selected fill due to oversized material, refer section 6.2.
0,3+	**Hardpan Ferricrete:** grey black mottled orange, very well cemented and ferruginised, very soft rock.	Suitable for founding. Not suitable for use as selected fill due to oversized material, refer Section 6.2.

All testpits excavated through the hardpan ferricrete resulted in TLB refusal on very soft rock hardpan ferricrete with the exception of TPB09. This testpit shows a well developed hardpan ferricrete horizon from 0,2m to 0,8m underlain by nodular ferricrete from 0,8m to 1,6m. The hardpan ferricrete is particularly well developed in the vicinity of TPB10 and TPB13, being in excess of 0,8m thick. In TPB04 and TPB22 hardpan ferricrete occurs at significantly greater depth of 2,8m and 2,5m respectively.

Table 5: Site B - typical quartzite soil profile description.

(Rooihoogte Formation)

Occurrence	**TPB01, TPB02, TPB03, TPB09, TPB16, TPB17**	
Depth (m)	**Description**	**Comment**
0,0 - 0,6	**Colluvium:** refer Table 4	
0,6 - 1,2	**Nodular Ferricrete:** closely packed well cemented and ferruginised ferricrete nodules up to 10mm in a matrix of slightly moist, orange-brown, silty SAND. Overall consistency is loose to medium dense but friable.	Variable thickness. Not encountered in TPB02, TPB03 and TPB16. Suitable for use as selected fill, refer section 6.2.
1,2 - 1,5	**Reworked residual quartzite:** dry, orange-yellow mottled black, medium dense, weakly cemented and ferruginised, fine and medium SAND.	Limited in extent and thickness. Should not be considered as a source of selected fill. Not encountered in TPB01, TPB08, TPB16 and TPB17.
+1,5	**Quartzite:** grey, moderately weathered, medium jointed, hard rock.	Results in TLB refusal. Suitable founding strata. Likely to be suitable for use as dump rock.

Table 6: Site B - typical paleo-colluvium soil profile description.

(Timeball Hill Formation)

Occurrence	**TPB23, TPB24, TPB25**	
Depth (m)	**Description**	**Comment**
0,0 - 0,5	**Topsoil:** dry, brown, loose, silty SAND with scattered fine quartzite gravels.	Not suitable for founding. Suitable for use as general fill, refer Section 6.2.
0,5 - 0,8	**Hillwash:** dry, orange-brown, soft, sandy SILT with scattered quartzite gravels.	Collapsible grain structure. Not suitable for founding. Suitable for use as general fill, refer Section 6.2.
0,8 - 1,4	**Nodular Ferricrete:** closely packed moderately well cemented and ferruginised ferricrete nodules up to 10mm in a matrix of slightly moist, orange-brown, silty SAND. Overall consistency is loose to dense but friable.	Not suitable for founding. Suitable for use as selected fill, refer section 6.2.
1,4 – +2,7	**Colluvium:** Loosely packed sub-rounded quartzite and dolomite cobbles and gravels in a matrix of slightly moist yellow-brown mottled off-white, silty fine SILT. Overall consistency is medium dense.	Thought to have originated from a paleo erosion platform today of which there is no evidence as the general topography is flat lying.

The residual shale soil profile encountered in TPB11 and TPB18 is variable and cannot be interpreted as a typical profile description.

Ground water seepage was not encountered within any of the test pits excavated on site.

6.2 Materials Properties

The results of the laboratory tests carried out on the materials on Site B are summarised in Table 7.

Table 7: Site B - summary of laboratory test results.

Underlying Geology	Rooihoogte Fm Quartzite			Timeball Hill Fm Shale			
Soil Properties	**Colluvium**	**Colluvium / Nodular Ferricrete**	**Reworked Residual Quartzite**	**Ferruginous Hillwash**	**Nodular Ferricrete**	**Reworked Residual Shale**	**Residual shale**
Depth (m)	1.3-2.5	0.2-1.3	1.4	2.5	1.3-2.5	1.4	2.5
No. of Tests	1	1	1	1	1	1	1
% Gravel	70	58	38	1	40	15	53
% Sand	12	27	44	40	28	35	18
% Silt	8	15	15	29	17	44	46
% Clay	0	1	4	31	16	6	31
Grading Modulus	2.49	2.02	1.79	0.41	1.57	0.78	5
Liquid limit (%)	21	24	27	29	32	29	30
Plasticity Index (%)	6	9	9	13	16	9	7
Nat Moisture Content (%)	7.2	14.5	22.5	15.1	13.6	16.3	17.3
ModAASHTO Density (kg/m³)	2249	1938	NT	1888	1966	NT	NT
OMC (%)	7.1	14.6	NT	15.1	13.8	NT	NT
CBR @ 95%	51	25	NT	11	23	NT	NT
TRH14 Classification	G7	G6	NT	G8	G8	NT	NT
Van der Merwe Swell Index	low	low	low	low	low	low	low
Swell Potential %	NT	NT	NT	NT	NT	NT	NT

*NT (not tested)

The colluvium and nodular ferricrete on Site B classify as G7 and G8 quality material respectively, while a mixed sample of the two, classifies as G6.

However, in most areas of Site B the colluvium comprises predominantly oversize material and will therefore not be considered practical for use as selected fill. Moreover, the colluvium forms a relatively thin layer just at surface and specifically targeting colluvium for use as selected fill will produce a large scar.

The nodular ferricrete is well developed in the areas to the north of Site B in the vicinity of TPB01, TPB08 and TPB22, ranging from 0,7m to 1,2m in thickness. It is recommended that these areas are targeted as potential borrow sources for selected fill and should be confirmed during the detailed geotechnical investigation.

The construction of subbase or base course layers requires a G6 or better quality material. Although, one sample of the nodular ferricrete and colluvium showed a G6 quality other samples of nodular ferricrete and colluvium classified as G7 and G8 respectively. Additional tests will be required during the detailed investigation to confirm the quality and suitability of these materials.

Allowance should therefore be made for importing G7 or better material from a commercial source.

The laboratory test results indicate that all materials on Site B show a low potential for heave.

6.3 Excavatability

Soft excavation is likely to be encountered in the transported and residual Timeball Hill shales in the SE corner of the site[4]. However, an abrupt change is expected in excavation characteristics at the contact of the Timeball Hill quartzite soil and rock profile encountered over the majority of Site B.

The quartzite is overlain by colluvium and nodular ferricrete which, in the central area of the site, develops to form a very well cemented and ferruginised, very soft rock, hardpan ferricrete. The colluvium and nodular ferricrete classify as soft excavation while the hardpan ferricrete is likely to classify as soft to intermediate excavation. Hard rock excavation is anticipated in areas where quartzite is encountered.

- "Soft excavation" (as defined in clause 3.1.2a and b of SABS 1200 D. This class would typically include the colluvium, hillwash, nodular ferricrete, residual soils and very soft rock shale).
- "Intermediate excavation" (as defined in clause 3.1.2a and b of SABS 1200 D. This class would typically include the hardpan ferricrete).
- "Hard rock excavation" (as defined in clause 3.1.2c of SABS 1200 D. This class would typically include hard rock quartzite).

4 SABS 1200D:1988. **Standardised specification for civil engineering construction. D: Earthworks.** S.A. Bureau of Standards, Pretoria.

6.4 Ground Water

No ground water was evident in any of the testpits excavated on site.

7 SITE B: RECOMMENDATIONS

The following recommendations are provided for preliminary design and costing purposes. These are subject to review and confirmation by detailed investigations for specific structures prior to final design.

It is recommended that the cut to fill terrace and access roads be located within the area underlain by shallow quartzite bedrock, rather than the area comprising the more deeply weathered shale. The recommendations given below have assumed that site terrace will be preferably positioned within the area of Site B underlain by quartzite bedrock, refer Drawing J28199-B-001.

7.1 Foundations

Light and settlement sensitive structures can be founded on shallow strip / spread footings within the very soft rock hardpan ferricrete or hard rock quartzite. Hardpan ferricrete occurs 0,3m below ground level along a N-S trending ridge in the centre of Site B while quartzite bedrock is encountered between 1,0m and 1,7m below ground level.

Bearing pressures within the hardpan ferricrete horizon should be limited to 300kPa as this unit shows a gradual thinning away from the central hardpan ridge e.g.: TPB09. Bearing pressures of 500kPa may be accommodated for within hard rock quartzite.

Where structures are to be founded on a terrace, excavations for the footings should be formed into the compacted material rather than attempting to construct the fill around the completed foundations. Backfill around the foundation plinths should be carried out to the same standard as the terrace fill. The backfill material should be placed in thinner layers (125mm or less) where smaller compaction equipment is used.

All footings excavations should be inspected by an engineer to ensure that the founding conditions are uniform and suitable for the expected bearing pressures below the bases.

The colluvium is not considered as a suitable founding horizon. Over sized material in the colluvium generally makes this material unsuitable for use as selected fill unless sorted. The nodular ferricrete has a variable consistency and thickness and as such should be excavated to stockpile for use as selected fill.

The topsoil should be stockpiled for landscaping and rehabilitation.

7.2 Road Construction

The design of roads and surface beds will depend on the traffic loading and the nature of the material in the road bed. As a detailed road design is not part of this scope of work, only the general subgrade conditions for both the access roads are described below.

The access roads are generally underlain by colluvium overlying a nodular ferricrete and / or hardpan ferricrete and quartzite. Despite the recommendation that no structures should be founded on the colluvium, the existing gravel roads in the area are founded on the colluvium and are performing satisfactorily. Thus it is not necessary to remove all existing colluvium below roads and surface beds but a sufficient depth to allow for the construction of layer works.

Where hard ferricrete or quartzite is present immediately below the base course, the road designers should pay particular attention to the drainage of the road prism to prevent the formation of a perched water table on the rockhead.

7.3 Terrace Construction

Terraces will be required in areas of the site:

- to fill to a required elevation above ground level
- to replace unsuitable materials such as the colluvium
- to improve the load carrying capacity of the soils below surface beds and light structures.

These terraces should be constructed as follows:

- Over the entire extent of the proposed terrace, clear and grub to remove vegetation and topsoil. This is generally 100mm over areas of shallow lying hardpan ferricrete and quartzite rock.
- Remove and stockpile all transported soils to expose the underlying hardpan ferricrete or hard rock quartzite.
- Construct the terrace using G7 or better quality material placed in layers not exceeding 150mm to 200mm thick and compact to 95% Mod AASHTO density at OMC ±2%.

Compaction control should be by means of sand replacement tests. Nuclear density measuring devices may be used once these have been successfully calibrated against the sand replacement tests. The moisture contents should always be checked by oven drying. Regular Mod AASHTO density and CBR tests should be carried out. The construction of the terrace and compaction control should be generally in accordance with SABS 1200 DM[5] and SABS 1200 ME[6].

Fills below structures should be of G7 or better quality. The colluvium and nodular ferricrete on Site B classify as G7 and G8 quality material respectively, while a mixed sample of the two, classifies as G6.

In most areas of Site B the colluvium comprises predominantly oversize material and will therefore not be considered practical for use as selected fill. Moreover, the colluvium forms a relatively thin layer just at surface and specifically targeting colluvium for use as selected fill will produce a large scar.

The nodular ferricrete is well developed in the areas to the north of Site B in the vicinity of TPB01, TPB08 and TPB22, ranging from 0,7m to 1,2m in thickness. It is recommended that these areas are targeted as potential borrow sources for selected fill and should be confirmed during the detailed geotechnical investigation.

The construction of subbase or base course layers requires a G6 or better quality material. Although, one sample of the nodular ferricrete and colluvium showed a G6 quality other samples of nodular ferricrete and colluvium classified as G7 and G8 respectively. Additional tests will be required during the detailed investigation to confirm the quality and suitability of these materials.

Allowance should therefore be made for importing G7 or better material from a commercial source.

7.4 Excavatability

The stability of temporary excavations is the responsibility of the contractor. But for planning purposes, the following guidance is given for the different materials encountered in the profile.

- Colluvium: excavations <1m in depth may be excavated at 1:1. Permanent slopes or excavations >1m should be battered at 1:2 or flatter.
- Nodular ferricrete: excavations should be battered at 1:2 or flatter due to the loose and friable nature of the nodular ferricrete.
- Hardpan ferricrete: near vertical slopes can be considered in very soft rock hardpan ferricrete.

[5] SABS 1200DM:1981. **Standardised specification for civil engineering construction.** DM: Earthworks (Roads, **Subgrade**). S.A. Bureau of Standards, Pretoria.
[6] SABS 1200ME:1981. Standardised specification for civil engineering construction. ME: Roads (Subbase). S.A. Bureau of Standards, Pretoria.

- Quartzite: the hard rock quartzite can accommodate near vertical slopes.

7.5 Conclusions

Light and settlement sensitive structures can be founded on shallow strip / spread footings within the very soft rock hardpan ferricrete or hard rock quartzite. Hardpan ferricrete occurs 0,3m below ground level along a N-S trending ridge in the centre of Site B while quartzite bedrock is encountered between 1,0m and 1,7m below ground level.

Bearing pressures within the hardpan ferricrete horizon should be limited to 300kPa as this unit shows a gradual thinning away from the central hardpan ridge e.g.: TPB09. Bearing pressures of 500kPa may be accommodated for within hard rock quartzite.

The contact between the Timeball Hill quartzite and the underlying Malmani Subgroup dolomites appears to lies >150m north of Site B according to the aerial photographic interpretation (Figure 1) and the 1:250 000 geological map (Factual Report J28199-01, Figure 2).

Because of Site B's proximity to a dolomitic area, it is likely that the dolomite contact is <100m below surface and therefore it is recommended that the detailed investigation include a dolomite stability and risk assessment for sinkhole formation. The stability assessment would also include a geohydrological study to determine ground water background levels and monitoring.

It is recommended that geological mapping, percussion drilling and a gravimetric survey be carried out as part of the detailed geotechnical investigation in order to better establish the thickness and extent quartzite underlying the site. A gravimetric survey would also establish the extent of any faulting present on site.

8 SITE C: DISSCUSSION

8.1 Site Stratigraphy

Site C is underlain by Malmani Subgroup dolomite bedrock of the Chuniespoort Formation. Cross sections showing the representative soil / rock horizons are shown on Drawing J18199-B-001 appended to this report.

Soil & Rock Profile

Medium hard rock to hard rock dolomite was encountered in 11 of the 17 testpits excavated on Site C. The undulating rockhead profile occurs between 0,3m below ground level in TPC16 and TPC18 increasing to >2,8m.

A ridge of shallow lying dolomite rock (0,0m to 0,6m) is located along a N-S trending zone in the vicinity of testpits TPC13, TPC16, TPC17 and TPC18.

The dolomite bedrock is overlain by topsoil, alluvium in the NW corner and residual chert breccia which ranges in thickness from 0,2m to in excess of 2,5m. Wad residuum is notably absent from the site and a sharp transition is seen between the overlying soils and the underlying dolomite bedrock.

Isolated zones of residual chert breccia up to 2,8m thick are evident to north and south of the site in the vicinity of TPC10, TPC11, TPC15, TPC24 and TPC25 and are shown on Drawing J28199-C-001. The residual chert gravel includes numerous sub-angular dolomite and chert gravel and cobbles.

A slickensided sandy clay alluvium profile is encountered in the NW corner to the site i.e.: TPC01, TPC02, TPC08 and TPC09. Surface depressions are seen within this area and are likely to be associated with the thick expansive clay soil profile.

A summary of the typical soil profile encountered on Site C is given in Table 7 below. Typical depths are not however, given due to the undulating dolomite rockhead profile and consequently varying transported cover thickness.

Table 8: Site C - typical dolomite soil profile description.

(Chuniespoort Formation)

Description	Comment
Topsoil: dry, brown, loose, clayey SAND to sandy CLAY.	Generally occurs to 0,3m below ground level. Not suitable for founding. Suitable for use as general fill, refer Section 8.2.
Hillwash: dry, brown, loose, porous, silty SAND to clayey SAND.	Generally occurs from 0,3m to 0,7m. Only encountered within testpits excavated to the E and SE of the study area. Exhibits collapsible grain structure. Not suitable for founding. Suitable for use as general fill, refer Section 8.2.
Residual chert breccia:. slightly moist, black-brown mottled off-white, firm, sandy CLAY with numerous sub-angular dolomite and chert cobbles and gravel.	Variable thickness. Suitable for use as general fill, refer Section 8.2.
Dolomite: light grey mottled pink grey, moderately weathered, medium hard rock to hard rock.	Undulating rockhead profile occurring from 0,3m below ground level to +2,8m. Results in TLB refusal. Suitable founding strata.

8.2 Materials Properties

The results of the laboratory tests carried out on the materials on Site C are summarised in Table 9.

Table 9: Site C - summary of laboratory test results.

Soil Properties	Topsoil	Hillwash	Alluvium	Residual chert breccia
Depth (m)	0.2	0.5	0.7	0.9-2.5
No. of Tests	2	2	1	1
% Gravel	1	1-2	8	33
% Sand	49-56	52-55	25	29
% Silt	29-33	23-25	23	24
% Clay	15-17	19-23	44	15
Grading Modulus	0.56-0.63	0.62	0.54	1.33
Liquid limit (%)	24	25-26	60	31
Plasticity Index (%)	10-11	11-12	35	15
Nat Moisture Content (%)	5.6-7.1	10.3-16.2	22.3	6.9
ModAASHTO Density (kg/m³)	NT	NT	NT	2219
OMC (%)	NT	NT	NT	6.8
CBR @ 95%	NT	NT	NT	21
TRH14 Classification	NT	NT	NT	G10
Van der Merwe Swell Index	low	low	high	low
Swell Potential %	NT	NT	<1%	NT

*NT (not tested)
*values expressed as a range

The topsoil, hillwash and residual chert breccia encountered on Site C show a low potential for heave. The alluvium encountered within the NW corner of the site shows a high potential for heave.

The transported materials on site are unsuitable for use as selected fill because of the high clay content in the soils and should be stockpiled for use as general fill only. The residual chert breccia is considered unsuitable for use as selected fill as it shows a maximum swell at 100% ModAASHTO >1,5%.

Selected fill, subbase or base materials will therefore have to be imported from a commercial source.

8.3 Excavatability

The hard rock dolomite encountered on site classifies as hard rock excavation while soft excavation is likely to be encountered in the transported soil profile overlying dolomites[7].

- "Soft excavation" (as defined in clause 3.1.2a and b of SABS 1200 D. This class would typically include the topsoil, hillwash, alluvium).
- "Hard rock excavation" (as defined in clause 3.1.2c of SABS 1200 D. This class would typically include hard rock dolomite).

8.4 Ground Water

No ground water was evident in any of the testpits excavated on site. However, the presence of a thick clay profile within the NW corner of Site C, suggests an area of poor drainage and water ponding above the dolomite rockhead during the rainy season.

7 SABS 1200D:1988. **Standardised specification for civil engineering construction. D: Earthworks.** S.A. Bureau of Standards, Pretoria.

9 SITE C: RECOMMENDATIONS

Site C is underlain by dolomitic terrain which is typically associated with sub-surface cavities which could result in surface subsidence and possible sinkhole formation. The dolomite rock head encountered at Site C is highly undulating varying from 0,3m to >2,8m below surface.

A well defined lineament has been identified in the aerial photographic interpretation and could represent a shear or fault zone (Figure 1). If faulting is present it could prove a fatal flaw for development on dolomite terrain as water ingress along fault zones is particularly problematic in terms of sinkhole development.

It is recommended that a dolomite stability assessment be incorporated as a part of the detailed investigation. The detailed investigation would include geological mapping, additional testpit excavation, percussion borehole drilling and a gravimetric survey.

The following recommendations are provided for preliminary design and costing purposes. These are subject to review and confirmation by detailed investigations for specific structures prior to final design.

9.1 Foundations

The dolomite rockhead shows an undulating profile varying from 0,3m below ground level to 2,8m below ground level.

It is recommended that the cut to fill terrace and access roads be located within the area underlain by shallow dolomite bedrock. As such, a shallow footing founding solution could be opted for founding structures or alternatively a soil raft in the cut area below structures with limited depth of founding. The recommended position for the terrace footprint is in the vicinity of TPC13, TPC16 and TPC17 shown on Drawing J28199-C-001 where depth to medium hard rock or better bedrock is shallowest varying from 0,3m to 0,9m.

However, dolomitic terrain is typically associated with sub-surface cavities which could result in surface subsidence and possible sinkhole formation. As such an alternative piling solution cannot be ruled out and would need to be confirmed during the detailed geotechnical investigation.

Bearing pressures on the dolomite bedrock are limited to 500kPa.

Where structures are to be founded on a terrace, excavations for the footings should be formed into the compacted material rather than attempting to construct the fill around the completed foundations. Backfill around the foundation plinths should be carried out to the same standard as the terrace fill, refer Section 9.3. The backfill material should be placed in thinner layers (80mm to 100mm) where smaller compaction equipment is used.

All footings excavations should be inspected by an engineer to ensure that the founding conditions are uniform and suitable for the expected bearing pressures below the bases.

Residual cert breccia appears to be absent at the preferred terrace position. However a thinly developed horizon (0,2m) was encountered in TPC22 and TPC23. These soils are not considered suitable for use as selected fill and should be stripped to spoil.

The topsoil and hillwash have a high clay content and are therefore unlikely to be suitable for use as selected fill and should be stockpiled for use in landscaping and rehabilitation.

9.2 Road Construction

The design of roads and surface beds will depend on the traffic loading and the nature of the material in the road bed. As a detailed road design is not part of this scope of work, only the general subgrade conditions for the roads are described below.

The access roads are generally underlain by a clayey sand topsoil and hillwash, underlain in places by alluvial sandy clays and clayey sand residual chert breccias of various thicknesses.

The alluvium is likely to be associated with seasonal drainage. Cognisance must therefore be taken of the very moist to wet conditions which are likely in the summer months. A free draining pioneer layer of dumprock should be considered in areas where the alluvial profile is well developed not only to facilitate construction under wet conditions but also to provide a suitable foundation layer from which to commence selected subgrade and pavement layers.

The topsoil and hillwash should be excavated to spoil and the thickness of the pioneer layer must be determined by final road level and design requirements.

Where hard dolomite is present immediately below the base course, the road designers should pay particular attention to the drainage of the road prism to prevent the formation of a perched water table on the rockhead.

9.3 Terrace Construction

Terraces will be required in areas of the site:

- to cut/fill to a required elevation above ground level
- to replace unsuitable materials such as the topsoil, hillwash and alluvium
- to improve the load carrying capacity of the soils below surface beds and light structures.

These terraces should be constructed as follows:

- Over the entire extent of the proposed terrace, clear and grub to remove vegetation and topsoil to an average of 0,6m below surface.
- Remove and stockpile all transported soils to expose the underlying hard rock dolomite.
- Adjust the moisture content of the exposed soils to within ±2% of the Mod AASHTO optimum moisture content (OMC) and compact the base of the excavation to 90% Mod AASHTO density over the upper 200mm.
- Construct the terrace using G7 or better quality material placed in layers not exceeding 150mm to 200mm thick and compact to 95% Mod AASHTO density at OMC ±2%.

Compaction control should be by means of sand replacement tests. Nuclear density measuring devices may be used once these have been successfully calibrated against the sand replacement tests. The moisture contents should always be checked by oven drying. Regular Mod AASHTO density and CBR tests should be carried out. The construction of the terrace and compaction control should be generally in accordance with SABS 1200 DM[8] and SABS 1200 ME[9].

Fills below structures should consist of material of G7 or better quality. Hillwash and gravel alluvium should only be used a general fill in non-critical areas.

9.4 Excavatability

The stability of temporary excavations is the responsibility of the contractor. But for planning purposes, the following guidance is given for the different materials encountered in the profile.

- Transported soils – temporary excavations may be excavated at 1:1. Permanent slopes or excavations should be battered at 1:2 or flatter.
- Dolomite – the medium hard rock or better dolomite can accommodate near vertical slopes.

[8] SABS 1200DM:1981. **Standardised specification for civil engineering construction.** DM: Earthworks (Roads, **Subgrade**). S.A. Bureau of Standards, Pretoria.

[9] SABS 1200ME:1981. Standardised specification for civil engineering construction. ME: Roads (Subbase). S.A. Bureau of Standards, Pretoria.

9.5 Conclusions

It is recommended that the cut to fill terrace and access roads be located within the area underlain by shallow dolomite bedrock. As such, a shallow footing founding solution could be opted for founding structures or alternatively a soil raft in areas of cut, with limited depth of founding. The recommended position for the terrace footprint is in the vicinity of TPC13, TPC16 and TPC17 shown on Drawing J28199-C-001 where depth to medium hard rock or better bedrock is shallowest varying from 0,3m to 0,9m.

However, dolomitic terrain is typically associated with sub-surface cavities which could result in surface subsidence and possible sinkhole formation. As such an alternative piling solution cannot be ruled out and would need to be confirmed during the detailed geotechnical investigation.

Bearing pressures on the dolomite bedrock are limited to 500kPa.

Materials encountered on site are generally unsuitable for use as selected fill and all structural fill below roads and surface beds will need to be imported from commercial sources or alternatively sourced from neighbouring borrow pit areas, refer Section 10.

It is recommended that a dolomite stability assessment be incorporated as a part of the detailed investigation. The detailed investigation would include additional testpit excavation, percussion borehole drilling and a gravimetric survey. Geophysical surveys are particularly useful in determining the presence faults and of cavities associated with dolomitic terrain. If faulting is present it could prove a fatal flaw for any development. A well defined lineament has been identified in the aerial photographic interpretation and could represent a shear or fault zone (Figure 1).

Ground water monitoring and a geohydrological assessment would also be required as part of the detailed investigation. A change in the background ground water levels, such as the leaking of buried services and poor storm water drainage, is one of the key contributors to surface subsidence and sinkhole formation.

10 BORROW PITS

Nodular ferricrete of G8 quality has been identified as a potential borrow source and is located within the Site A, refer Drawing J28199-A-001 and to the north of Site B, refer Drawing J28199-B-001. This material is generally suitable for use in selected subgrade layers below roads and in the construction of engineered fills below structures.

The paleo-colluvium encountered on Site A classifies as a G7 quality material and is generally suitable for use in selected subgrade layers. This soil horizon typically resulted in TLB refusal and therefore the thickness of this layer could not be determined.

Note that the paleo-colluvium may contain some oversize material although this is not typically the case. Careful selection of material and removal of oversize material during spreading will be required to ensure that the maximum particle size does not exceed two thirds the layer thickness.

Borrow material quality and quantities should be confirmed during the detailed investigation. Based on the limited test pit data available initial estimates of material quantities for Site A and Site B are given in Table 10.

Table 10: Borrow material volumes

	Site A	Site A	Site B	Site B
Material	Nodular ferricrete	Paleo colluvium	Nodular ferricrete	Nodular ferricrete
Area (m^2)	37,280m^2	42,500m^2	15,606m^2	13,000m^2
Testpits	TPA16, TPA17	TPA17, TPA18, TPA24, TPA25	TPB17,TPB18, TPB22, TPB25	TPB01, TPB08
Average thickness (m)	1,15m	<1,05m	0,85m	0,75m
Volume (m^3)	42,872m^3	44,625m^3	13,265m^3	9,750m^3

Materials suitable for use as base course or subbase (G6 quality or better) are not present in the study area and will have to be imported from a commercial source.

The Dwaalboom PPC Cement factory quarry and plant is located some 10km from the site as the crow flies. The plant produces dolomite aggregate of various size fractions including <2,4mm, <13mm and <19mm. The aggregate is likely to be a potential source for subbase and base materials and should be confirmed by carrying out tests on this material during the detailed phase of the investigation.

Laboratory results for the dolomite aggregate at Dwaalboom PPC Cement plant are given in Appendix D.

11 CONCLUSIONS

The geotechnical investigation has identified the expected profile conditions within the three alternatives study areas and the general suitability of local materials for construction purposes. Generalised foundation procedures have been given for the relevant profiles and expected structures.

The contact between the Malmani Formation dolomites and the Rooihoogte Formation quartzite has been identified from aerial photographic interpretation (Figure 1). This should be confirmed by geological mapping during the detailed phase of the investigation.

Site C is directly underlain by dolomite and is therefore considered to be at risk in terms of subsidence and sinkhole formation. As such, this site is considered as the least favoured alternative.

Site A has a variable soil profile comprising residual shale overlain by pockets of “paleo” colluvium. Additional test pitting and laboratory testing will need to be carried out on Site A in order to better define the nature and extent of the paleo colluvium for detailed design.

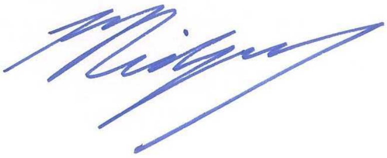
Due to the variable nature of the soil profile encountered at Site A, it is not considered as the preferred site alternative.

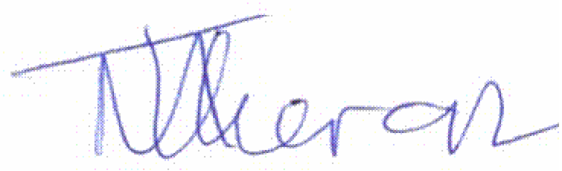
In terms of founding, Site B would be considered the preferred alternative given that it is underlain by shallow lying hardpan ferricrete and hard rock quartzite.

According to the aerial photograph interpretation the dolomite contact lies >500m north of Site A (Figure 1) and 150m to >500m to the north of the Site B. The Council of Geoscience recommends that a detailed dolomite risk and stability assessment be carried out where development over dolomite terrain is <100m below surface. It is recommended that detailed geological mapping be carried to confirm the dolomite contact surface expression and the dip and dip direction of the sedimentary strata.

The topography characterising all three site alternatives is relatively flat (1:<1). The fill is likely to be limited in depth on all three sites which will require founding of most structures on insitu materials. As such, the cut to fill terrace volumes are likely to be similar for Site A, Site B and Site C and therefore no one option appears preferable in terms of earth work volumes.

This investigation forms part of the feasibility study for the Dwaalboom Substation site selection phase. Detailed geotechnical investigations must be undertaken prior to the final design stage. The detailed investigation should cover all the various structures/development areas and potential borrow sources to assess extents and volumes as well as, a dolomite stability and risk assessment.





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