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GEOTECHNICAL INVESTIIGATION FOR THE COVES: A PROPOSED DEVELOPMENT ON A PORTION OF THE FARM DE RUST 478 JQ

1 INTRODUCTION AND TERMS OF REFERENCE

At the request of Mr. H. Pietersen of Pietersen & Associates, Golder Associates Africa (Pty) Ltd conducted a geotechnical investigation for township establishment purposes for the proposed residential development on the Farm De Rust 478 JQ, a portion of the remainder of portion 126 and a portion of portion 127. The development will be known as Heron Cove.

This report with the relevant Geotechnical Map, **Figure 1** in **Appendix A**, summarises the results of the investigation. The Map shows the suitability of the site for the development of residential structures, taking into account inter alia the following:-

- Collapsible soils;
- Shallow groundwater or seepage;
- Active soils;
- Highly compressible soils;
- Erodability of soils;
- Difficulty of excavation to 1,50 m depth;
- Steep slopes;
- Areas subject to flooding.

The test pit positions are indicated on the attached maps, **Figures 1 & 2** in **Appendix A.** The classification used on the map is based on that proposed by Brink, Partridge & Williams, entitled “Appropriate Methods of Engineering Geological Evaluation for Rapid Urbanisation in Developing Countries”.

The site has been investigated by Golder Associates Africa and the data has been supplemented by previous work conducted by A strauss, D G Walker and J van der Merwe.

One of the specific requirements for this project is to evaluate the suitability of the site to be developed within the current 1:50 year flood line. The intended method of achieving this is to construct an earth terrace.

Therefore, an assessment of the potential borrow material was made and the enhancement or otherwise that the terrace will have on the proposed development.

Samples of the soils were taken to assess the engineering properties of the materials. This testing included grading, Atterberg limits and moisture density relationships as well as strength (MOD-CBR).

2 SITE DESCRIPTION

The site for the proposed development is situated on a portion of the farm Grootplaas some 7km upstream of the Hartebeestpoort Dam wall. The proposed development is situated on the southern shores of the floodplain of the Hartebeestpoort Dam and is bounded on the east by a small stream, which enters the dam at this point. The site is bounded on the south by irrigated land.

A portion of the development falls within the cultivated lands, where access was denied. The site had been landscaped in the past by raising the area surrounding the floodplain by some 1,5m to 2,0m in places with material obtained from the floodplain.

3 SITE GEOLOGY

The site is situated on fill and Recent alluvial deposits overlying weathered diabase rock and residual soil belonging to a Post-Transvaal intrusive sill as well as rock and soil of the Transvaal Supergroup.

4 FINDINGS & RECOMMENDATIONS

4.1 Summary of Findings

Based on the results of the investigation the site was zoned in terms of development suitability as indicated on **Figure 1, Appendix A.** With reference to **Table 1** (an index table for **Figure 1, Appendix A**, with a summary of possible solutions), it should be noted that the subscript symbol (parameter) indicates the type of problem envisaged, while the class indicates the severity of the problem. Where more than one class of problem occurs in a particular area the most severe is stated first with less severe categories being suffixed to the end. Thus an area designated as $\mathbf{2_A1_B}$ has a surficial horizon (>750mm) of collapsible material, in addition to which a permanent or seasonal water table within 1,50m of the surface is also present.

Based on the investigations conducted, the following conclusions have been drawn:

- A generalised soil profile for the site consists of fill, overlying alluvium and in some instances pebble marker gravels and/or residual diabase.
- Shallow groundwater seepage, representing a perched water table, has developed within the clayey alluvium at an average depth of 1,90m of surface. It is therefore

recommended that adequate damp proofing measures are incorporated into the design of all structures. This should also be borne in mind for potential basements.

- The zone(s) designated with **3_L (NHBRC class H III)** (**Figure 1, Appendix A**), falls within the 1:50 year flood line;
- The zone(s) designated with **2_C (NHBRC class H II)** (**Figure 1, Appendix A**) are potentially expansive with fluctuations in moisture content. This covers the soils underlying the development area.
- The zone(s) designated with **1_C (NHBRC class H I)** (**Figure 1, Appendix A**) are potentially expansive with fluctuations in moisture content. This covers the soils underlying the development area.
- The gravely hillwash, encountered in the proposed borrow area classifies as G6 in terms of TRH 14, making it suitable for use as sub-grade and engineered fill.

Tables 2-5 summarise material properties encountered, with a brief description of the soils tested, as well as indicator and engineering properties.

The subscript **C** on **Figure 1, Appendix A** indicating the presence of potentially active soil, applies to both the in situ fill, derived from the material on the floodplain, and the clayey alluvial soil. The results indicated that the fill and alluvium are "medium to high" potentially expansive with fluctuations in moisture content. The combined thickness of these two layers, as encountered, is in excess of 3,0m.

Assuming that the upper 2,0m of the profile are subject to moisture fluctuations, the heave has been calculated as follows:

- The van der Merwe-Savage method of swell analysis predicts 29-58mm heave assuming a 2,0m thick layer of soil that will heave as a result of moisture fluctuation. This method is conservative and does not take into account the imposed load or in-situ moisture content;
- The Weston method of calculating heave, which takes into account the current in situ soil moisture and imposed load. This method predicts between 0,1 and 0,3 per cent swell assuming an imposed stress of 50kPa. This equates to a heave of between 3 and 12mm at current moisture. However, this is probably not conservative enough, as the in situ moisture content is high with the irrigation that is taking place. Allowing for more natural moisture conditions and an in situ moisture content closer to that of TP13, then a heave in the order of 20-25mm should be allowed for.

4.2 Foundations

The precautionary measures recommended for lightly loaded (<100kPa) structures within zones with **3_L** entail the following raising the entire area by means of an engineered terrace, using suitable materials. Structures can then be founded on the terrace using more conventional reinforced strip or spread footings, or raft type foundations. The earth terrace is discussed in more detail later.

The areas designated with Zone **2_C** on **Figure 1, Appendix A** are underlain by potentially expansive soil. The options available for lightly loaded (<100kPa) structures entail the following:

- Reinforced concrete raft designed to accommodate the expected heave.
- Raising the entire area by means of an engineered terrace, using suitable inert materials. Structures can be founded on the terrace using a lighter, reinforced raft type foundations, designed to cope with residual movement (heave).
- Piled foundations taken down to competent material below the potentially expansive soil. Piles should be restricted in both directions by ground beams. The upper reaches of the piles need to be isolated from the active soil to minimise drag effects by the clays with moisture fluctuations. The depth of the required isolation will depend on the specific profile at each location, but will be in the order of at least 3m.
- Suspended ground floors should be considered Alternatively, active soil below all ground floor slabs could be removed to a depth of 0,6m and replaced with suitable inert G7 or better class material in layers not exceeding 100mm in thickness compacted to 95% Mod AASHTO density. Floor slabs should be reinforced. Strict quality control is essential during the compaction procedure to ensure that the desired compaction is achieved and to minimise the risk of settlement under the floors. However, with the latter option, there remains a significant risk of cracking in the floor. The latter could be considered if used in conjunction with earth terrace
- The design of first floor slabs should take the expected amount of movement into account.
- Landscaping around all structures is recommended to ensure that ponding of surface water does not occur within 3m of structures. All water borne services should be provided with flexible couplings, especially where entering or leaving structures to prevent leakage. A 1,5m wide concrete apron should be cast around all structures to help minimise moisture fluctuations.

4.3 Excavation Characteristics

The excavation characteristics of the different soil horizons have been evaluated according to the South African Bureau of Standards standardised excavation classification for earthworks (SABS 1200D) and earthworks (small works – SABS 1200DA). In terms of this classification and the in-situ soil/rock consistencies as profiled, the relationships given below are generally applicable.

1. "soft excavation" - very loose/very soft through to dense or stiff."

2. "intermediate excavation" - very dense/very stiff through to very soft rock.

3. “hard rock excavation – soft rock or better.”

The site in general is classified as “soft” excavation in terms of SABS 1200. The site soils were all easily excavatable to an average depth of 3,15m with the TLB (CAT 428). For specific excavation characteristics refer to the soil profiles in **Appendix B.**

4.4 Materials Usage

4.4.1 General

The fill and alluvium (clayey) material is not suitable for use in earthworks and should be spoiled. The fill encountered in TP4 (gravel and cobbles) compacts with a maximum dry density of 1 823kg/m^3 at an optimum moisture content of 12,4%. The material is moderately plastic with the plasticity index of the whole sample being 3,8%. The percentage swell after 4 days varies between 0,19 and 0,44%. The CBR is 26 at 95% Mod AASHTO density. This material classifies as G6 in terms of TRH 14, making it suitable for use as selected sub-grade as well as for engineered fill.

The residual diabase (sandy silt) encountered below the hillwash in TP7, is not suitable for use in layerworks, but could be used for general fill purposes. The gavel in a silty matrix, as encountered in TP8 is potentially suitable for use as sub-grade and even sub-base, but this needs to be confirmed with tests.

The hillwash (gravel in a clayey silt matrix) as encountered in the potential borrow area compacts with a maximum dry density of 1 873kg/m^3 at an optimum moisture content of 12,1%. The material is moderately plastic with the plasticity index of the whole sample ranging from 3,1 to 6,3%. The percentage swell after 4 days varies between 0,57 and 1,82%. The CBR varies between 19 and 22 at 95% Mod AASHTO density. This material classifies as G6 in terms of TRH 14, making it suitable for use as selected sub-grade as well as for engineered fill. The hillwash is however on average only 0,75m thick.

The pebble marker gravel is considered to be potentially suitable for use as sub-grade and poor sub-base, but the PI might be to high. This material was however encountered either deep in the profile or as a thin layer in pockets across the site.

4.4.2 Road works

The results of the laboratory tests, the field observations and interpretations have been used to evaluate the suitability of the various on site materials for construction purposes. The test results are summarised in **Table 3** and the results are attached in **Appendix B**. The material usage is summerised in **Table 5**.

TABLE 5: MATERIAL USAGE

Material	Potential Use
Silty gravelly hilwash/tallus overlying weathered diabase (Zone 1)	Subgrade and selected layers, material has small, but variable plasticity, strength (CBR) also low though higher than the weathered shale, and has a G7 classification
Clayey soils (Zone 2)	Spoil, material too plastic for use in pavement structure

<u>Potential borrow area at damsite:</u>

This material forms part of a nearby dam basin. It is found along the dam perimeter. The material comprises mostly gravels consisting of 65% gravel, 17% sand, 12% silt and 5% clay.

This material will act as good quality sub-base and base material since its high grading modulus and CBR values. In terms of TRH14, it is classified as a G6 material.

The mod. AASHTO maximum dry density is 1983kg/m^3 with an optimum moisture content of 12.4%. The in situ moisture content is approximately 4.6% below optimum moisture content. It is expected that this material is suitable for use in road layers up to selected if lime stabilised (± 2%) and marginally suitable as a subbase if cement stabilised.

4.5 Groundwater

Shallow water seepage associated with the presence of a perched water table was encountered at an average depth of 1,90m across the site. This water table is probably sustained due to intensive irrigation of the area.

It is therefore recommended that adequate damp proofing measures be incorporated into the design of all structures. The shallow water table should also be borne in mind for potential basements.

4.6 Access Road

The proposed alignment for the access road is underlain by clayey alluvial soil. The results indicates that this material is only “low” potentially expansive with fluctuations in moisture content. However, analysing the results with Weston’s method of estimating swell, 0,8% swell should be taken into account in the design allowing for seasonal fluctuations in soil moisture. This relates to heave of 16mm for a 2,0m thick layer of active soil.

This, as well as the axle loads and anticipated traffic should be taken into account in the design of the road.

The founding conditions for the road pavement are generally poor. The transported and upper residual soil profile exhibits, almost without exception, a low to medium expansiveness. All the laboratory tests results are tabled in Table 1. Estimates of swell and heave are presented in Tables 2 and 3.

In all the considerations presented below, a Class E1 (UTG 2) segmental block road design is assumed for the internal roads, i.e. the Promenade and Boulevard. A lightly trafficked black top road design for the access road is assumed.

In Zone 1, Transported soils (hillwash/talus) are overlying weathered shale. The transported soil comprises intact, slightly clayey silt and sand with variable quantities of gravel to cobble sized clasts and roots. The residual soil is a completely weathered shale comprising stiff slightly clayey silt with gravel and larger clasts of harder weathered shale. PI ranges between 11 and 24. The grading modulus is variable, ranging from 0.3 to 1.16. The maximum dry density was found to be 1 773 kg/m3, but the CBR is relatively low, i.e. 9 at 93 per cent MOD AASHTO. The latter is the reason for the TRH 14 classification of G7, despite how good the material looks visually. It appears that the material breaks down under compaction to form a fine soil (silt) with low strength characteristics. However, the soil is good for subgrade or selected layers. Apart from stripping the biotic topsoil, no problem is anticipated with the pavement foundation. The average lime consumption percentage is 1,9%.

In Zone 2, the clayey soils extend to a depth in excess of 1.5m. They exhibit a plasticity index greater than 12, and even the plasticity of the whole sample exceeds 12, indicating a fine, medium to high expansive soil condition. The observed moisture condition is high and seems to be at or just below optimum moisture content. The observed shattered soil structure is indicative of soil activity confirmed by the laboratory testing.

The material encountered is unsuitable for inclusion in the road pavement. The high plasticity of the soil suggests that the subgrade layer should be treated with lime as minimum to reduce the soil activity in subgrade layers. The other alternative is to import material of lower plasticity. In either case, at least 3x150mm layers should be considered. The balance of the road pavement should be imported. The average lime consumption percentage is 2,3%.

Adequate drainage needs to provided to ensure that ponding of water in the vicinity of the road is prevented. Trees should be removed from close to the road surface as they will desiccate the soil.

5 USE OF AN ENGINEERED FILL TERRACE

A more detailed consideration of the use of an engineered fill terrace is presented here. This has been undertaken as it is the developers preferred option for developing the site. This makes sense from a number of perspectives:

- The development area can be raised above the 1:50 year flood level, hence minimising the risk of flooding;
- A more reasonably graded slope for development is achieved;
- Assuming suitably inert material is employed and it is engineered to a suitable specification, then there is a reduction in the effects of the active clays underlying the site;
- There is also scope for relaxing the requirements/specification of the foundations that would otherwise be required to counter the poor soil conditions.

The discussion below relates to the latter two bullets, assuming that the former two are requisite for development.

The effects of placing a soil mattress over the active clay soils will reduce the effects of the clays. The degree to which this will be effective is a function of the activity of the soil. The test pits and tests do indicate that the activity of the soil does vary, but it is between medium and high expansiveness. The chart below illustrates the envelope of total heave that could be expected for a soil mattress of varying thickness. The assumptions for the calculations are:

- The upper 2m of the clays are subject to moisture fluctuations and it is only this which is considered to be active portion of the soil profile;
- The soil mattress varies from 0 to 3m thick;
- The soil activity is between medium and highly expansive;
- The soils within the top 2m can vary from dry to saturated, thus full heave of the soil is possible;

No cognisance is taken of the additional surcharge imposed by the foundation. This will reduce the total expected heave.

The graph illustrates that, should a soil mattress of variable thickness be used, then high differential movements can be expected (up to 100% total heave). Conversely, for a uniformly thick mattress the differential movement can be assumed to half the total and that a 3m thick mattress appears to be viable enough to allow a relatively light raft foundation and not to have to be overly concerned about variations in soil properties under the mattress.

The implication of this option is that there would be a considerable volume of clay soil that would have to be spoiled to effect a uniformly thick soil mattress and that the majority of the spoil would be cut from the upper portion of the terrace. The spoil could potentially be used for landscaping.

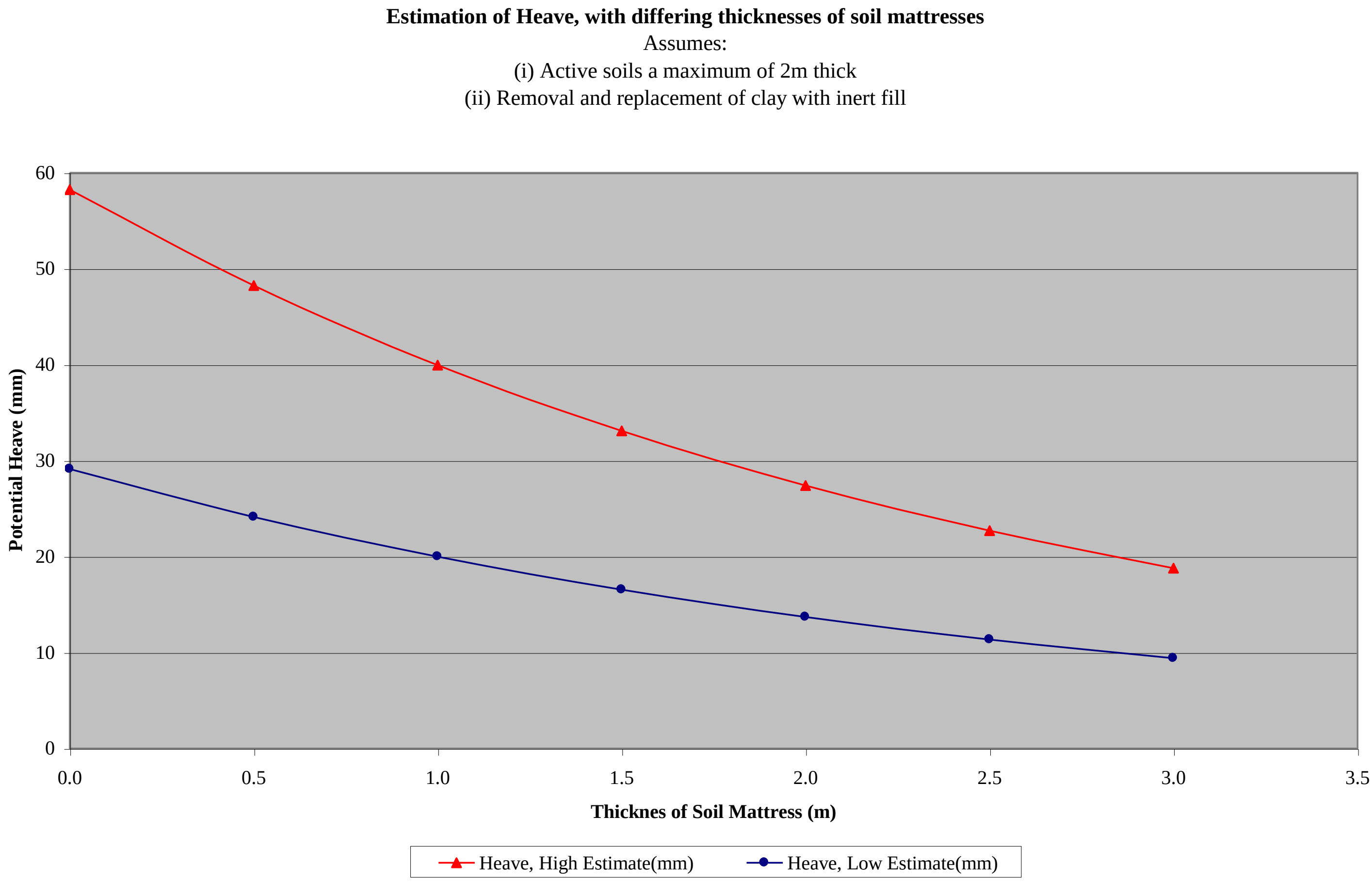

Figure 2: Estimation of Heave with differing thicknesses of soil mattresses

6 DETAILED GEOTECHNICAL DESCRIPTION

A description of the various soil horizons encountered during the investigation is given below. **Tables 2 & 3** provide a summary of laboratory test results.

6.1 Fill

The bulk of the site is blanketed with a layer of silty or sandy clay, interpreted as fill. The fill comprises of moist to very moist light reddish or orange brown speckled yellow soft to stiff shattered sandy clay or slickensided silty clay. This layer often contains occasional (<10% of layer) or minor (10 to 30% of layer) amounts of fine gravel. This layer as encountered is 1,20m thick on average.

This material is highly plastic, of low shear strength and above optimum moisture content. In addition, this material is medium to highly potentially expansive with fluctuations in moisture content.

The fill encountered in TP4 consists of rounded fine to coarse gravel and cobbles closely packed in a shattered silty clay matrix. The consistency of this layer is medium dense and is 1,80m thick.

6.2 Alluvium

A layer of alluvium comprising moist orange or reddish brown mottled light yellow firm to stiff shattered and/or slickensided clayey silt to silty clay underlies the fill. This layer extends to the maximum excavated depth in test pits TP1, TP4, TP5 and TP6.

This material is moderately to highly plastic of low shear strength and above optimum moisture content. In addition, this material is medium to highly potentially expansive with fluctuations in moisture content.

6.3 Hillwash

The site investigated as potential borrow area, is blanketed with a layer of hillwash. The hillwash comprises either angular fine to coarse hornfels gravel closely packed in a shattered sandy clay matrix or subrounded fine to coarse quartz gravel closely packed in a shattered clayey matrix. The consistency of both variations is medium dense. This layer is 0,75m thick on average.

This material is considered to be moderately plastic of low shear strength and at optimum moisture content.

6.4 Pebble Marker

A distinct pebble marker horizon was encountered in TP2, TP3 and TP11 below the transported soil and separates the transported soil from the residual soil horizon. The pebble marker consists of rounded coarse gravel and cobbles closely packed in a clayey matrix. The consistency is generally medium dense and this horizon as encountered is 0,35m thick on average.

This material is considered to be moderately plastic of low shear strength and at optimum moisture content.

6.5 Residual Diabase

Residual diabase was encountered below the above soil horizons in TP3 and TP12.

In TP3 this layer comprises of moist orange brown becoming yellow khaki speckled white firm intact clayey silt. This material is moderately plastic of low to moderate shear strength and above optimum moisture content. In addition, this material is medium potentially expansive with fluctuations in moisture content.

The residual horizon encountered in TP12 consists of slightly moist orange brown mottled red becoming khaki speckled white firm jointed sandy silt. This material is considered to be slightly to moderately plastic of moderate shear strength and at or below optimum moisture content.

In TP3 this layer comprises of moist orange brown becoming yellow khaki speckled white firm intact clayey silt. This material is moderately plastic of low to moderate shear strength and above optimum moisture content. In addition, this material is medium potentially expansive with fluctuations in moisture content.

The residual horizon encountered in TP12 consists of slightly moist orange brown mottled red becoming khaki speckled white firm jointed sandy silt. This material is considered to be slightly to moderately plastic of moderate shear strength and at or below optimum moisture content.

7 SITE INVESTIGATION

7.1 Fieldwork

In total fourteen test pits were excavated with a CAT 428 TLB supplied by MCC Plant Hire form Midrand. Eight pits in the area of the proposed residential development, four in the potential borrow area and two along the access road. The positions of the test pits are indicated on **Figure 1, Appendix A** in **Appendix A.** The test pits were inspected by an Engineering Geologist and soil profiles were recorded using standard procedures. The soil profiles are included in **Appendix B.**

7.2 Laboratory Testing

Bulk as well as small disturbed soil samples were retrieved from the test pits and submitted to a commercial soils laboratory for testing. The following tests were performed in order to determine the engineering properties of the various soil horizons:

- Indicator Tests

These tests were conducted to determine the particle distribution and plasticity of the soils. The material was all fine grained and therefore the grading was done to 0,002 mm.

- Mod AASHTO & CBR Tests

The material was tested for earthwork purposes and the modified AASHTO moisture density relationship and CBR tests were conducted to determine compaction and strength characteristics.

- ICL (Initial consumption of Lime)

The material was tested to determine how much lime is necessary to break down the plasticity. The ICL is therefore a minimum percentage of lime needed and 0.5 to 1% should be added to this figure for stabilisation purposes.

The depth of the samples are indicated on the relevant profile sheets in **Appendix B.** The test results are included in **Appendix C.**

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TABLE 1:GEOTECHNICAL CLASSIFICATION FOR TOWNSHIP DEVELOPMENT AND SUMMARY OF RECOMMENDATIONS

Parameter		Class	Soil Problem	Recommendation
C	Active Soil	2	20-25mm heave expected	The options for lightly loaded (<100kPa) structures include: Reinforced concrete raft designed to accommodate the expected heave. Raising the entire area by means of an engineered terrace, using suitable materials. Structures can be founded on the terrace using a lighter raft foundation. Piled foundations, taken down to competent material below the potentially expansive soil. Piles restricted in both directions by ground beams. The upper reaches of the piles isolated from the active soil to minimise drag effects by the clays. The depth of the required isolation will depend on the specific profile at each location, but will be in the order of at least 3m. Suspended ground floor slabs. Alternatively, active soil below all ground floor slabs could be removed to a depth of 0,6m and replaced with suitable inert G7 or better class material in layers compacted to 95% Mod AASHTO density. Slabs reinforced. Strict quality control is essential for earthworks to ensure that the desired compaction is achieved and to minimise the risk of movement. Latter could be considered if used in conjunction with earth terrace. The design of first floor slabs to take the expected amount of movement into account. Landscaping around all structures is recommended to ensure that ponding of surface water does not occur within 3m of structures. All water borne services should be provided with flexible couplings, especially where entering or leaving structures to prevent leakage. A 1,5m wide concrete apron should be cast around all structures to help minimise moisture fluctuations.
L	Areas subject to flooding	3	Areas below 1:50 year flood line	Areas of the site are located below the 1:50 year flood line and susceptible to periodic flooding. It is understood that the entire area will be raised by means of an engineered terrace and therefore to above the flood line. If there remain areas below the flood line, these should be excluded from development and be reserved as public open space.

TABLE 2:SUMMARY OF BASIC SOIL PROPERTIES

Test Pit	Depth (m)	Material Description	LL	PI	LS	PRA Class	Unified Class	PI Whole	Soil Activity	% Gravel	% Sand	% Silt	% Clay	Moisture (%)	mm Swell (Weston 30k Pa)
TP2	0.90	Firm shattered silty CLAY, Fill	41.8	21.8	10.0	A-7-6[12]	CL	16.1	Medium	19.3	19.9	27.4	33.4	23.0	4
TP3	1.50	Firm intact sandy & clayey SILT, Residual Diabase	44.7	17.5	8.7	A-7-6[12]	ML/OL	16.8	Medium	0.2	27.1	53.5	19.2	33.7	6
TP4	0.3-1.8	GRAVEL & COBBLES in a silty clay matrix, Fill	47.0	21.2	10.0	A-2-6[0]	GC	3.8	Low	75.6	9.6	10.8	4.0	/	
TP5	1.0	Firm shattered & slickensided CLAY, Fill	48.1	23.9	13.3	A-7-6[15]	CL	22.7	Medium	1.2	19.3	67.3	12.2	28.3	12
TP5	1.4-2.4	Firm shattered & slickensided clayey SILT Alluvium	52.4	31.4	14.7	A-7-6[18]	CH	29.7	High	1.4	22.1	57.2	19.3		
TP6	1.0	Firm shattered sandy & clayey SILT, Alluvium	35.4	13.4	6.0	A-6[9]	CL	12.8	Medium	0.2	30.4	47.6	21.7	25.1	4.5
TP7	1.0-2.0	Dense intact sandy SILT, Residual Diabase	34.4	11.6	6.0	A-6[6]	CL	10.3	Low	1.4	49.3	37.5	11.8	/	

Test Pit	Depth (m)	Material Description	LL	PI	LS	PRA Class	Unified Class	PI Whole	Soil Activity	% Gravel	% Sand	**% Silt**	**% Clay**	**Moisture (%)**	**mm Swell (Weston 30k Pa)**
TP8	0.1-1.0	GRAVEL in a silty clay matrix, hillwash	46.7	18.9	8.0	A-2-6[1]	GM	6.3	Low	62.4	12.3	20.4	4.9	/	
TP10	0.1-0.6	GRAVEL in a silty matrix, Hillwash	50.0	17.9	8.0	A-2-6[0]	GM	3.1	Low	80.5	5.3	10.4	3.8	/	
TP13	0.4	Firm mocro shattered silty CLAY, Alluvium	41.8	21.0	10.0	A-7-6[13]	CL	18.5	Low	5.5	15.9	35.7	42.9	13.9	25

Test Pit No.	Zone	Description	Depth (m)	PI (%)	GM	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Unified Class.	% Lime Consumption	CBR@ 93% & 95% of Mod AASATO	Maximum Mod AASHTO dry density (kg/m^3)	In Situ Moisture Content (%)	Optimum Moisture Content (%)
TP A5	1	Silty gravelly hillwash/Talus overlying weathered diabase	0.50-1.30m	20.2/7.8	1.86	45.4	34.2	7.7	12.7	SM				12.9	
TP A8	1		0.50-1.10m	18.8/12.8	0.93	21.1	22.7	43.0	13.2	ML/OL				16.4	
TP A10	1		0.40-1.50m	17.3/10.1	1.16	23.2	36.8	29.7	10.3	SM	1.60			15.2	
TP A11	1		0.50-1.50m	24.9/19	0.69	12.4	24.8	39.6	23.2	MH/OH		9,9	1 773	18.3	19.1
TP A13	1		0.0- 0.80m	16.1/14.1	0.43	2.1	38.7	43.2	16.0	CL	1.40			18.3	
TP A14	1		0.50-1.70m	14.4/10.1	0.89	15.5	36.0	37.4	11.0	ML/OL				19.6	
TP A16	1		0.0 -1.2m	11.1/9.9	0.37	5.5	19.5	63.4	11.7	ML/OL	2.80			20.8	
Averages :				17.5	0.9	17.9	30.4	37.7	14.0	-	1.9	9.0	1773	17.4	19.1
TP A3	2	Clayey Alluvial Soils	0.40-1.30m	23.1/18.3	0.61	11.5	22.0	38.8	27.6	MH/OH		6,8	1 701	22.1	21.3
TP A4	2		0.40-0.70m	23.8/21.7	0.30	3.1	23.5	38.6	34.8	CH	2.80			24.1	
TP A6	2		0.20-0.60m	37.2/30.5	0.60	15.7	17.3	35.2	31.8	CH	2.80	4,4	1 776	10.4	18.0
Averages :				21.7	0.7	14.8	26.6	37.6	21.0		2.3	6.7	1753	18.0	19.4
Dam Site			-	11.9/3.7	2.16	65.7	17.3	12.5	4.5	GM		22,25	1 983	7.8	12.4

MC = Moisture Content, PI = Plasticity Index, GM =Silty Gravels, OL = Organic Silts and Organic Silty clays of low plasticity, OH = Organic Clays of high plasticity, SM = Silty Sands, CL = Inorganic clays, silty clays, sandy clays of low plasticity, GC = Clayey gravels, clayey sandy gravels, ML = Inorganic silts, silty or clayey fine sands, with slight plasticity

Key to Table 2

LL	Liquid Limit
PI	Plasticity Index
LS	Linear Shrinkage
GM	Grading Modulus
N/A	Not Active

TABLE 3:SUMMARY OF MATERIAL DENSITY TESTING

Test Pit	Depth (m)	Material Description	MDD (kg/m^3)	OMC (%)	GM	CBR @ 90 % MOD	CBR @ 93 % MOD	CBR @ 95 % MOD	TRH 14 Classification
TP A4	0.3-1.8	GRAVEL & COBBLES in a silty clay matrix, Fill	1823	12.4	2.42	19	23	26	G6
TP A5	1.4-2.4	Firm shattered & slickensided clayey SILT Alluvium	1609	16.6	0.19	1	1	2	Spoil
TP A7	1.0-2.0	Dense intact sandy SILT, Residual Diabase	1866	14.5	0.49	2	3	3	Spoil
TP A8	0.1-1.0	GRAVEL in a silty clay matrix, Hillwash	1917	11.2	2.02	14	17	19	G6
TP A10	0.1-0.6	GRAVEL in a silty matrix, Hillwash	1829	13.0	2.48	19	21	22	G6

Key to Table 3

MDD Maximum Dry Density (kg/m^3)

OMC Optimum Moisture Content (%)

CBR Californian Bearing Ratio

TABLE 4: HEAVE CALCULATIONS: WESTON METHOD

Test Position	Depth	Description	Liquid Limit [%]	$P_{0.425}$	WLL	Vert. Pres. [kPa]	NMC [%]	Swell [%]	Swell [mm]
TP 5	0.50-1.30m	Clayey sandy silt in a 80% matrix of fine to coarse diabase gravel	47.4	38	18	7.4	12.9	0.08	0.42
TP 8	0.50-1.10m	Ferruginised fine gravel nodules in a matrix of sandy, clayey fine silt	47.2	68	32	7.4	16.4	0.54	2.7
TP 10	0.40-1.50m	Fine to medium rounded gravel in a matrix of ferruginised sandy clayey silt.	50.2	59	30	5.9	15.2	0.50	2.0
TP 11	0.50-1.50m	Slickensided sandy clayey silt	56.2	76	43	7.4	18.3	1.37	6.9
TP 13	0.0-0.80m	Sandy clayey silt	35.9	88	32	2	18.3	0.64	3.2
TP 14	0.50-1.70m	Sandy clayey silt	41.8	70	29	7.4	19.6	0.24	1.2
TP 16	0.0 -1.2m	Sandy clayey silt	40.7	89	36	2	20.8	0.85	4.2
								Average	3
TP 3	0.40-1.30m	Shattered clayey sandy silt	52.3	79	41	5.9	22.1	0.84	3
TP 4	0.40-0.70m	Shattered clayey sandy silt	50.2	91	46	5.9	24.1	1.04	4
TP 6	0.20-0.60m	Clayey sandy silt in a matrix of fine to medium diabase gravel	64.3	82	53	3	10.4	17.54	35
								Average	8

Swell % = 0.000411 * (WLL)^+4.17 * (p)^-0.386 * (NMC)^-2.33

WLL = Weighted Liquid Limit = liquid limit * P0.425

p = vertical pressure in kPa under which swell takes place

NMC = initial or natural moisture content

TABLE 5: HEAVE CALCULATIONS: VAN DER MERWE-SAVAGE METHOD

Test Position	Depth	Description	Pot. Expansiveness	F	T	D	Heave [mm]
TP 5	***0.50-1.30m***	Clayey sandy silt in a 80% matrix of fine to coarse diabase gravel	Low	0	0.5	0	0
TP 8	***0.50-1.10m***	Ferruginised fine gravel nodules in a matrix of sandy, clayey fine silt	High	0.11	0.5	0	91
TP 10	***0.40-1.50m***	Fine to medium rounded gravel in a matrix of ferruginised sandy clayey silt.	Low	0	0.4	0	0
TP 11	***0.50-1.50m***	Slickensided sandy clayey silt	Medium	0.055	0.5	0	46
TP 13	***0.0- 0.80m***	Sandy clayey silt	Medium	0.055	0.5	0	46
TP 14	***0.50-1.70m***	Sandy clayey silt	Low	0	0.5	0	0
TP 16	***0.0 -1.2m***	Sandy clayey silt	Low	0	0.5	0	0
						Average	26
TP 3	***0.40-1.30m***	Shattered clayey sandy silt	Medium	0.005	0.4	0	4
TP 4	***0.40-0.70m***	Shattered clayey sandy silt	Medium	0.005	0.4	0	4
TP 6	***0.20-0.60m***	Clayey sandy silt in a matrix of fine to medium diabase gravel	High	0.11	0.2	0	102
						Average	31

Heave (m) = F * (e^-0.377D) * (1-(e^-0.377T))

D = Thickness of non swelling layer

T = Thickness of swelling layer

F = 0 for low expansiveness

F = 0.055 for medium expansiveness

F = 0.11 for high expansiveness

F = 0.221 for very high expansiveness

APPENDIX A
SITE LAYOUT, TESTPIT POSITIONS AND GEOLOGY PLAN

APPENDIX B
SOIL PROFILES

APPENDIX C
LABORATORY TEST RESULTS