- *Site Investigations*
- *Slope Stability*
- *Rock Mechanics*
- *Soil Mechanics*
- *Foundations*
- *Borrow Pits and Materials*
- *Roads*
- *Groundwater*
- *NHBRC*
- *Mine Stability*

The Results of a Geotechnical and Hydrogeological Investigation Carried out on Portion 104 (of 30) of the Farm Leliefontein No. 1175 at Thornville in the Msunduzi Municipality, KwaZulu Natal

Client: Mondli Consulting

Reference: 22-035

Dated: 27th March 2023

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The Results of a Geotechnical and Hydrogeological Investigation Carried out on Portion 104 (of 30) of the Farm Leliefontein No. 1175 at Thornville in the Msunduzi Municipality, KwaZulu Natal

Reference: 22-035 **Date: 27th March 2023**

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Figure 1 Site Plan showing Layout of the Site and Test Positions

Appendix A Test Pit Logs
Appendix B Laboratory Test Results

The Results of a Geotechnical and Hydrogeological Investigation Carried out on Portion 104 (of 30) of the Farm Leliefontein No. 1175 at Thornville in the Msunduzi Municipality, KwaZulu Natal

Reference: 22-035 **Date: 27th March 2023**

1. INTRODUCTION & TERMS OF REFERENCE

A filling station, food court and fast-food outlet is proposed on Portion 104 (Of 30) of the Farm Leliefontein No. 1175 at Thornville, within Msunduzi Municipality, Kwazulu – Natal The geotechnical conditions will affect the decision as to what foundations are required for the proposed structures, whether the in situ materials are suitable for subgrade use and the construction of fill embankments, and finally due to the fact that there will be underground fuel storage tanks, it is important to determine the permeability of the *in situ* materials as this will provide insights into the effectiveness of the soil and rock in retarding the migration of any contaminant plumes which may result from the operation of the filling station. As such, GeoZone GeoServices was asked by Mr B Mondli of Mondli Consulting Services, to provide a cost estimate for carrying out the work as per the details set out in Table 1 below.

Table 1: Terms of Reference

Client	Mondli Consulting
Contact	Mr B Mondli
Proposal Reference	054-22 dated 10th October 2022
Appointment Date	October 2022

The results of the investigation are presented below.

2. AVAILABLE INFORMATION

The information drawn upon for the purposes of the investigation is listed in Table 2 below:

Table 2: Information used in the Investigation

Description	Source
Satellite Imagery	Google Earth 2020
Geological Map titled ***1: 250 000 Series 2830 Durban***	Council for Geoscience
A Background Information Document (BID) for the proposed construction of Thornville development ("the Square of Thornville") proposed to include fuel service station, retail centre with anchor shop, line shops, restaurants and bed and breakfast on portion 104 (of 30) of the farm Leliefontein no. 1175 at Thornville, within Msunduzi municipality, KwaZulu – Natal	Mondli Consulting Services

3. SITE DESCRIPTION

The site is located at coordinates 29°42'57.11"S, 30°22'28.48"E, approximately 2.6 km to the north of the village of Thornville, on the R56 regional road, south of the city of Pietermaritzburg. The site has the shape of an inverted L and occupies an area of approximately 3 Ha and is bounded on the north by existing houses, to the south by a gravel road which provides access to the site, to the east, to the southwest by a borrow pit, and to the northwest by a gravel road. A double storey house is located in the northeast corner of the property, and a small dwelling stands to the west of the crook in the L. Access to the site is via an electric gate on the southern boundary of the property.

Topographically the site slopes towards the south at gradients ranging from 1:6 in the steepest portions of the site to 1:75 in the more gentle, southern portions of the property. In the northwest corner the gradients are towards the west at 1:6 vertical to horizontal.

A brick utility structure is located close to the main gate. Eskom powerlines run north-south on the eastern side of the driveway, which runs along the eastern third of the property.

Apart from the infrastructure already described, the site is essentially undeveloped and under veld grass and scattered vegetation.

Figure 1 shows the location of the site and its immediate environs.

4. FIELDWORK

The fieldwork was carried out on the 24th November 2022 and comprised eight machine dug test pits, designated TP1 to TP8. The positions of these tests are shown in Figure 1. The logs of the test pits are included in Appendix A.

5. GEOLOGY

The site is underlain by colluvial and residual soils which are underlain by shales of the Pietermaritzburg Formation and to a lesser extent dolerites of Jurassic age.

Colluvium was encountered in all of the test pits excavated across the site and extends to depths ranging from 0.2 m to 0.7 m with an averaged depth of 0.3 m. It was seen to comprise slightly moist, dark greyish brown, silty Clay with varying amounts of gravel.

Residual soils derived from the underlying shales comprise slightly moist, khaki brown/yellowish brown, firm, silty Clay with much angular shale gravel. Residual shale soils were not encountered in TP1 and TP6. Where they were encountered, they range in thickness from 0.35 m to 0.8 m. Residual soils derived from the underlying dolerite were encountered in TP2 and TP7 and comprise moist to slightly moist, deep reddish brown, firm, silty to very silty Clay. These soils extend to depths greater than 4.0 m below existing ground level.

Shale rockhead was encountered at depths ranging from 0.2 m to 0.8 m and was seen to comprise completely to highly weathered, olive brown/khaki brown/orange brown, thinly laminated, very soft rock Shale. The upper horizons are always slightly more weathered than the deeper material, and the discontinuities more prevalent and at times open.

No groundwater was encountered in any of the test pits excavated on the site. However, groundwater seepage may occur along the interface of the various soil and rock horizons during the wet summer months or after periods of heavy rainfall.

6. LABORATORY TESTING

Four bulk samples were recovered from the test pits and submitted to a soils laboratory for testing. The results of these tests are summarised in Table 3 below.
The raw data are presented in Appendix C.

Table 3: Summary of Laboratory Test Results

TP No.	Depth (m)	Description	Particle Size (% retained)			Atterberg Limits (%)			GM	MDD (kg/m^3)	OMC (%)	CBR Values					Swell (%)	Group Index & TRH14 Classification
												Compaction MDD %						
			Clay & Silt	Sand	Gravel	LL	PI	LS				90	93	95	98	100		
TP2	1.0 - 2.0	Deep reddish brown, silty to very silty Clay - Residual Dolerite																
TP3	0.4 to 0.8	Yellowish brown & orange brown, silty Clay with zones of completely to highly weathered shale.							Pending									
TP8	0.3 to 0.8	Completely to highly weathered, olive brown, very soft rock Shale.																

Key

LL	-	Liquid Limit	OMC	-	Optimum Moisture Content			
PI-		Plasticity Index	MDD	-	Maximum Dry Density	CBR	-	California Bearing Ratio
LS	-	Linear Shrinkage	G8	-	Classification in Terms of TRH14 (1985)	NP	-	Non Plastic
SP	-	Slightly Plastic	CBD	-	Cannot be Determined			

Table 4: Permeability Test Results

TP No.	Depth (m)	Sample Type	Description	Permeability k	Comment
TP2	1.0 – 2.0	Bulk recompacted to 90 percent modified AASHTO dry density.	Deep reddish brown, silty to very silty Clay - Residual Dolerite	2.21 x 10-5 cms^{-1} 2.21 x 10-7 ms^{-1}	Very Low Permeability

7. RECOMMENDATIONS

7.1 Stability of the Site

From a slope stability point of view, it is considered that the site is stable and suitable for development.

7.1 Rippability & Trenchability

Excavatability is generally consistent across the site. The test pits show refusal depths ranging from 0.4 m (TP6) to 1.1 m (TP5) in the areas underlain by shale. Refusal did not take place in the dolerite areas. As such, over the majority of the site, it is considered that soft excavation to depths ranging from 0.4 to 1.0 m may be expected using light earth moving equipment.

7.2 Site Clearance and Earthworks

Earthworks should be carried out in accordance with SABS 1200 (current version). The site will need to be modified to create the cut to fill platforms on which the proposed structures and forecourt are to be constructed.

Where fills are required, they should be constructed in layers not exceeding 200 mm loose thickness and compacted to a minimum of 93% Modified AASHTO dry density. Any boulders or material larger than two-thirds of the layer thickness must not be included in the fill material. In addition, the fill material should be worked within 2% of the optimum moisture content to reduce the danger of heave of the material during compaction, which would make it difficult to attain the specified 93% density. Where fills are to support structural foundations, they should be compacted to 95% dry density.

7.3 Drainage

One of the most important factors in the promotion of a stable site is the control and removal of both surface and groundwater from the area. The design of the stormwater management system should ensure that accumulated surface water is collected and disposed of in a responsible manner.

Both during and after construction, the site should be well graded to permit water to readily drain from the platforms, and to prevent ponding of water anywhere on the surface and to prevent the ingress of water into the newly emplaced fills and the subsurface soils.

Surface water collected on the forecourt, hardened areas, parking areas and access roads should be directed into open, lined drains and disposed of responsibly downslope of the site, taking care not to allow the water to become a nuisance to neighbouring properties. Precautions also need to be put in place to prevent hydrocarbons from contaminating surface and groundwater systems.

7.4 Foundation Recommendations

The development will comprise the construction of a filling station, shops and fast-food outlets.

Ideally foundations should be taken down to the underlying shale bedrock. Average depth to bedrock which lies at depths ranging from 0.2 m to 0.8 m in the shale areas, which is to say over the majority of the site. Where the foundations are taken down to bedrock, normal strip footings may be used, and foundation pressures of 200 kPa may be used. Where foundations are to be constructed in the residual dolerite soils, foundation pressures should not exceed 50 kPa and the footings should be lightly reinforced to stiffen them against soil heave and potential settlement. Brickforce should be included in the brickwork for structures founded on the dolerite soils, and articulation joints created within the internal and external walls.

One of the most important factors in the stable development of the site is the control and removal of stormwater. It is imperative that drainage measures be designed in such a way that stormwater and groundwater is collected and discharged in a controlled manner away from the foundations and paved areas. Septic tanks, leaking sewer lines and leaking water pipes need to be repaired without delay to prevent ingress of water into the underlying soils, particularly in the dolerite areas.

7.4.1 Additional Considerations

Under no circumstances should foundations be placed in fill unless it has been specifically engineered to support structural foundations.

In terms of ongoing site maintenance, it is important that the in-situ moisture content of the founding horizons below the structure be maintained, and in this regard the following precautions should be implemented to reduce the threat of soil heave or settlement:

- No water ponds against or within the first metre from the external perimeter of the structure.
- Gardens, located against the external perimeter of the structure, are not recommended.
- Leaks in plumbing and associated drainage are attended to without delay.
- No large shrubs and or trees are planted closer than 0.75 x the mature height of the tree.

It is imperative that GeoZone GeoServices inspect and approve all foundation excavations and earthworks before the installation of piles, the construction of retaining walls for the pouring of foundations.

7.5 Roads and Paved Areas

Table 5 below, derived from the Technical Recommendations for Highways (TRH14) summarises the material requirements for various pavement layers.

Table 5: TRH14 Material Code Requirements for Various Pavement Layers

Layer	Material Code
Subbase	G5 and G6
Selected Layer	G6, G7, G8, G9
Subgrade	G8, G9, G10

The in situ colluvial soils will in all likelihood be removed during the site clearance. Should they be exposed at subgrade level, they probably will not meet a subgrade requirement and should be undercut to a depth of 300 mm and stockpiled for use in landscaping once the construction is complete. They should be replaced with good quality G7 material, compacted to 93 percent Modified AASHTO dry density. Similarly, for the *in situ* shale soils. The dolerite soils are also expected not to meet a subgrade specification, and will need to be undercut to a depth of 300 mm and replaced by 300 mm of G7 material, compacted to the same specification given above. Where the underlying shale bedrock is encountered at subgrade level, it should be ripped to a depth of 300 mm and recompacted to 93 percent modified AASHTO dry density.

Additional testing is recommended to confirm these preliminary recommendations.

8. HYDROGEOLOGY

One of the concerns surrounding the installation of underground fuel tanks, and the operation of a filling station, is the danger posed to the environment due to the possible spread of contaminant plumes. These plumes may come directly from a rupture or leak in the underground tanks themselves, or alternatively from surface spillages which may then percolate down through the upper soil and rock horizons until they contaminate the shallow water table, and possibly the underlying deep aquifer. Hydrocarbons, being of lower density than water, will float on the surface of the aqueous phase, and will then be carried down the hydraulic gradient over time.

These hydrocarbons, known in the industry as Light Non-Aqueous Phase Liquid (LNAPL) should be prevented from entering the underlying soil horizons wherever possible. Should contamination occur, then reliance has to be placed on other ways of retarding the spread of the LNAPL plume, and it is important to understand where the water table lies and whether the soil and rock provides a suitable aquitard to the migration of any contaminant plumes.

With this in mind, part of the focus of the investigation was to determine, if present, the depth to the shallow water table and the nature and permeability of the in-situ soil and rock.

Firstly, no groundwater was encountered during the test pit investigation, nor was water recorded in the piezometers which were subsequently after completion of the fieldwork. However, it is recommended that these piezometers are dipped on a more regular basis to confirm whether a shallow groundwater table exists. It must be borne in mind that the region has also been through one of the wettest periods on record, and as such, if any groundwater seepage was to have taken place it would have been at this time. The fact that there is no shallow groundwater table present is advantageous in terms of constraining the lateral migration of LNAPLs.

The next question is whether the underlying rock will a suitable barrier or aquiclude to the downward migration of water and contaminants. The geological maps show that the region is underlain by shale of the Pietermaritzburg Formation. Clay and shale are relatively impermeable materials, with typical published values for the coefficient of permeability **k** ranging from 10^{-7} to 10^{-9} ms^{-1}. The laboratory test results show that the permeability is 10^{-7} ms^{-1} which is in agreement with published values. As such the dolerite soils have been classified as having a very low to low permeability.

In view of the above, the silty clays and the low-permeability shale horizons are expected to form a suitable aquitard to contaminants by limiting the downward migration of water and hydrocarbons into the deeper aquifer. Table 6 is an extract from the DWAF document titled *"Protocol to Manage the Potential of Groundwater Contamination from on Site Sanitation" Edition 1, 1997* which further confirms the effectiveness of shale to the migration of contaminants.

Table 6: Assessment of the Reduction of Contaminants in the Unsaturated Zone

Unsaturated Zone Conditions	**Factor affecting reduction**			
	Rates of flow in unsaturated zone	**Capacity of the media to absorb contaminants**	**Capacity to create an effective barrier to contaminants**	**Comments**
Clays (residual dolerite)	Very slow (<10 mm/d)	High	High	Very good barrier to the movement of contaminants
Bedded Shales	Slow – 10 to 100 mm per day	High	High	Good barrier to the movement of contaminants. Horizontal flow may be more relevant than vertical flow

Based on the lack of water table, and the ability of the underlying clays and rock to limit the downward migration of contaminants, it is considered that the threat of the development of a migrating contaminant plume is low.

Although conditions are good in terms of the ability of the *in-situ* materials to retard and hold contaminants, it is still important that the necessary design requirements and protocols associated with the construction of filling stations are followed to mitigate the threat of spillages and tank ruptures. The design of these systems falls outside the scope of this report. It is important that any spillages are first retained by the engineered solutions, which is a far better option than relying on the natural permeability of the geological materials to retard the migration of any contaminants that may enter the ground.

9. SUMMARY AND CONCLUSIONS

This report presents the findings of a geotechnical and hydrogeological investigation carried out for a proposed filling station, retail outlet and fast-food facility. The site is located on the R56, approximately 2.6 km north of the settlement of Thornville, KwaZulu Natal.

The site is underlain by colluvial soils, residual soils and shales of the Pietermaritzburg Formation which have been intruded by dolerite of Jurassic age. The dolerite soils have weathered down to silty Clay residuum. Founding conditions are good over the majority of the site due to the thinness of the in-situ soils and the shallow depth to bedrock. It is recommended that the foundations are taken down to the underlying shales that lie at depths ranging 0.2 to 0.8 m below existing ground level. In the dolerite areas conditions are more onerous and it is recommended that foundations are suitably reinforced and that foundation pressures do not exceed 50 kPa.

One of the most important factors in the promotion of a stable site, is the control and removal of surface water from the platforms and as such the property should be graded to prevent the accumulation and infiltration of water into the subsurface horizons, and to prevent the erosion of any cut or fill slopes which may have been constructed as part of the development. All collected water needs to be collected and dealt with to remove any contaminants, and thereafter disposed of responsibly. Leaks in services need to be repaired immediately to prevent settlement when the soils are loaded.

The colluvial and residual soils are not expected to meet subgrade requirements and these will need to be undercut and replaced with G7 material, compacted to 93 percent Modified AAHSTO dry density. The degree of undercutting required will need to be assessed once the bulk earthworks are complete. The shales are expected to meet a G9 standard, making them suitable for subgrade and general fills. However, these results should be confirmed by additional testing during the bulk earthworks stage. In some instances, where shale is exposed at surface, no undercutting will be required, with the only necessity being to rip and recompact the *in situ* shales to the required density.

The clays and shale bedrock which underlie the entire site have a very low permeability and are considered to be a good aquiclude to the vertical and horizontal migration of NAPL contaminant plumes.

With the lack of a shallow, perched groundwater table on which any NAPL may float, and an aquitard preventing the vertical migration of contaminants into the deeper aquifer, it is considered that the threat to the regional groundwater resources is low. However, it is important that the necessary protocols are followed when designing the underground tanks and associated infrastructure to mitigate the threat of leaks and spillages.

Finally, the ground conditions described in this report refer specifically to those encountered in the tests carried out on the site. It is therefore possible that conditions at variance with those described above may be encountered elsewhere on the property. In this regard it is important that GeoZone GeoServices carry out periodic inspections of the site during construction to ensure that any variation in the anticipated ground conditions can be assessed and revised recommendations made to avoid unnecessary delays and expense. Furthermore, it is important that the construction phase of the project be treated as an augmentation of the geotechnical investigation.

_______________________ 27th March 2023

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