water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

# Geotechnical Report: Lower Coerney Dam Site

Support of the Water Reconciliation Strategy for the Algoa Water Supply System

**7 March 2019**
**Revision:** 1
**Reference:** 112546

# Document control record

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**Document control**

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|---|---|---|---|---|---|---|
| **Report title** | | Geotechnical Report:  Lower Coerney Dam Site | | | | |
| **Document ID** | | 12065 | **Project number** | | 112546 | |
| **File path** | | \\Aurecon.info\shares\ZACPT\Projects\Projects\112546   Algoa Recon Support\03 Prj Delivery\11 Options Analysis\10 Geotechnical\Report Lower Coerney\2019 03 07 - Lower Coerney Geotechnical Report - Final.docx | | | | |
| **Client** | | Department of Water & Sanitation | | | | |
| **Client contact** | | Mr Tony Moore | **Client reference** | | | |
| **Rev** | **Date** | **Revision details/status** | **Author** | **Reviewer** | **Verifier** (if required) | **Approver** |
| 0 | 13 December 2018 | First draft | GN Davis | S Naidoo | | E v d Berg |
| 0 | 31 January 2019 | Final draft | GN Davis | S Naidoo | | E v d Berg |
| 1 | 7 March 2019 | Final | GN Davis | S Naidoo | | E v d Berg |
| | | | | | | |
| **Current revision** | | **1** | | | | |

| | |
|---|---|
| **Coordinates** | -33° 26' 53.5" 25° 37' 32.9" |
| **Keywords** | Engineering geology; ground investigations, geotechnical; founding conditions; dam; spillway |

**Approval**

| | | | |
|---|---|---|---|
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**DEPARTMENT OF WATER AND SANITATION**

Directorates: National Water Resource Planning and Options Analysis

## Support of the Water Reconciliation Strategy for the Algoa Water Supply System

# Geotechnical Report: Lower Coerney Dam Site

**March 2019**

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This report is to be referred to in bibliographies as:

Department of Water and Sanitation, South Africa 2019, Geotechnical Report: Lower Coerney Dam Site. Report Number P WMA 07/N40/00/2619/2. Prepared by Aurecon South Africa (Pty) Ltd as part of the Support of the Water Reconciliation Strategy for the Algoa Water Supply System.

**Department of Water and Sanitation**
**Directorates: National Water Resource Planning and Options Analysis**

# SUPPORT OF THE WATER RECONCILIATION STRATEGY FOR THE ALGOA WATER SUPPLY SYSTEM

## APPROVAL

**Title** : Geotechnical Report: Lower Coerney Dam Site
**Consultant** : Aurecon South Africa (Pty) Ltd
**Report status** : Final
**Date** : March 2019

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**Bold** type indicates this Report.

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# Executive Summary

Aurecon South Africa (Pty) Ltd were appointed by the Department of Water & Sanitation (DWS) to investigate various options for augmenting water supply to Port Elizabeth. As part of the wider study geotechnical investigations have been conducted at the two most favourable dam sites, namely a site immediately upstream of the existing Scheepersvlakte Dam, called Upper Scheepersvlakte, and a site located in the adjacent catchment, designated the Lower Coerney site. This report presents the findings of the Lower Coerney investigations; the findings for the Upper Scheepersvlakte option are presented in a separate report.

These geotechnical investigations included the following elements;

- Geophysical (resistivity) surveys,
- Test pitting,
- Rotary core drilling,
- Field testing including SPT's and packer (Lugeon) testing,
- Laboratory testing, followed by
- Interpretation, analysis and reporting.

The underlying geology comprises thin grey sandstones, siltstones and mudrocks of the Sundays River Formation of the Uitenhage Group, part of a collection of sedimentary strata within the structurally controlled Algoa Basin.

The seismic hazard of the area is considered to be very low and the Peak Ground Acceleration (PGA) values are less than 0.02g, with a 10% probability of being exceeded in a 50-year period.

The dam site is characterised by gentle, almost flat slopes; as is the greater basin. For the most part, the site is covered by very dense bush.

The geological profile is characterised by soil strata with thickness up to 7 m to 8 m on the left flank, but 3 m to 4 m on the right flank and river section. Various horizons are recognised, including topsoil, colluvium as well as colluvium with evidence of pedocrete development, and a horizon of gravel-sands, considered to represent reworked terrace gravels, that blankets the bedrock across the entire dam footprint, as well as the basin. Bedrock comprises an alternating succession of sandstones and mudrocks, including silty sandstones. The lateral continuity of these strata is uncertain. The bedrock is characterised by extensive, pervasive weathering, and these rocks are generally considered weak rocks.

The transported soils essentially comprise mixtures of sand and silt; either sandy silt or silty sand. Clay is typically absent or negligible. A coarser fraction is present within the 'reworked terrace gravels' but is not uniformly distributed. In places a concentrated coarse fraction occurs and in others the coarse fraction is a minor component. The permeability of the respective soil strata varies between 1.84 x $10^{-5}$ cm/s and 2.62 x $10^{-7}$ cm/s. The suite of dispersivity tests indicate the soils are at least of intermediate dispersivity.

The geological profile, as well as other factors such as the topography, indicates that only an embankment dam is possible at this site. There are no suitable sources of rock in the immediate vicinity, and an earthfill embankment is the only viable option. A cut-off (under the embankment) would generally have to extend to the base of the gravel soils in order to ensure the potential seepage is effectively cut off. The side channel spillway on the left flank would be underlain by soils and weak bedrock; full concrete lining of the chute will be required and provision for energy dissipation must be included at the downstream end.

Packer tests within the bedrock yielded variable results, and included some significant losses ascribed to wash-out of weathered, soft rock interbeds.

In addition to the delineation of local borrow areas, follow-up investigations required for detailed design purposes would also address aspects such as confirmation of the geological continuity (laterally and with depth) across the dam and spillway footprint, as well as the geohydrological characterisation of the buried stratum of gravel-sands. Any other design optimisations would also require that appropriate geological and geotechnical investigations are carried out.

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| 112546-GEO-DRG-CC-005 | Borehole key |

# Abbreviations

| | |
|---|---|
| DWS | Department of Water and Sanitation |
| FSL | Full Supply Level |
| GPS | Global Positioning System |
| GWS | Government Water Scheme |
| mamsl | Metres above mean sea level |
| NOCL | Non-overspill Crest Level |
| ORP | Orange River Project |
| PGA | Peak Ground Acceleration |
| SPT | Standard Penetration Test |

# 1 Introduction

Aurecon South Africa (Pty) Ltd was appointed by the Department of Water & Sanitation (DWS) to investigate various options for improving the assurance of supply that is provided by the Scheepersvlakte Dam to the Nooitgedagt WTW. Of the various options identified, two possible alternate new dam sites were recognised as the most favourable, namely a site immediately upstream of the existing Scheepersvlakte Dam, called Upper Scheepersvlakte, and a site located in the adjacent catchment, designated the Lower Coerney site. The locations of these sites are illustrated below in **Figure 1.1.**

In order to support selection of a preferred site, geotechnical investigations were initiated at both these options. This report presents the findings of these geotechnical investigations of the Lower Coerney dam site. The findings of the Upper Scheepersvlakte site are presented in a separate report (Reference 112546-G1-00). For ease of comparison, however, the comparative findings of both sites are summarised in each report.

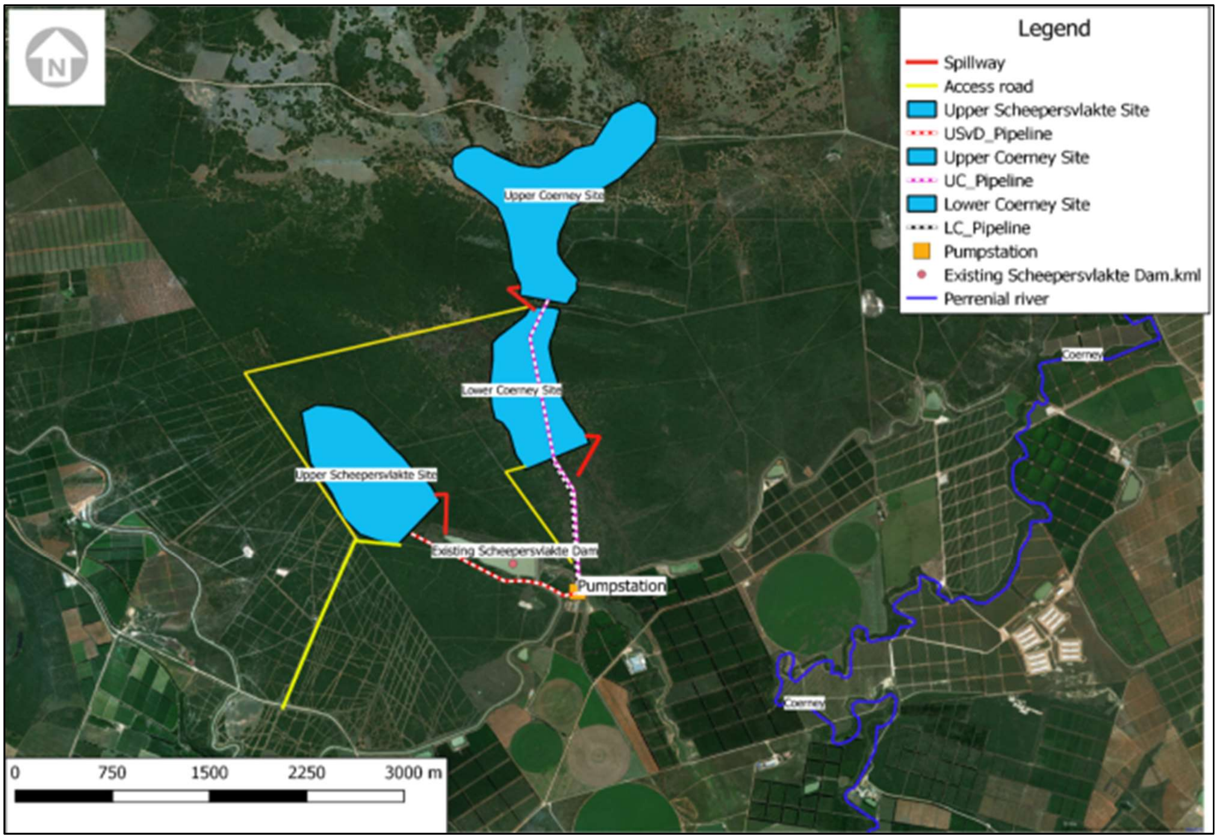

Figure 1.1: General locality plan of the respective alternate dam sites

The preliminary dam details are summarised below in **Table 1.1.**

**Table 1.1: Dam design details, Upper Scheepersvlakte and Lower Coerney sites**

| Dam feature | Upper Scheepersvlakte Dam | Lower Coerney Dam |
|---|---|---|
| Type of dam | Zoned Earthfill Embankment | Zoned Earthfill Embankment |
| NOC (amsl) | 130.3 | 103.8 |
| FSL (amsl) | 128.1 | 98.8 |
| Freeboard (m) | 2.2 | 5.0 |
| Crest width (m) | 5.0 | 5.0 |
| DS slope (1V:H) | 2.0 | 2.0 |
| US slope (1V:H) | 3.0 | 3.0 |
| Embankment fill volume ($m^3$) | 373,740 | 355,993 |
| Core trench volume ($m^3$) | 36,488 | 46,798 |
| Crest length (m) | 524 | 623 |
| Total gross dam capacity ($m^3$) | 4,600,000 | 4,600,000 |
| Surface area at FSL (ha) | 589,301 | 597,317 |
| Maximum wall height (m) | 25.3 | 19.0 |
| Catchment area (km²) | 3.5 | 34 |
| Unrouted SEF Inflow ($m^3/s$) | 220 | 890 |
| Spillway configuration description | Concrete-lined, 10m wide, side channel spillway located on the left abutment. (Note: spillway position dependant on geotechnical conditions) | Concrete-lined, 36 m wide, side channel spillway located on the left abutment. (Note: spillway position dependant on geotechnical conditions) with downstream concrete outlet chamber, 4x4x3m, with 2 valves for the two pipes. |
| Outlet works description | Dry well tower (25 m high) with inside dimensions of 4x4m. Three offtake levels controlled by valves. | Dry well tower (19 m high) with inside dimensions of 4x4m. Three offtake levels controlled by valves. |
| Access road length (km) | 2.0 | 1.0 |

# 2 Available information

A number of investigations have been conducted over the years, specifically for the original Scheepersvlakte Dam. No prior investigations have been conducted for the proposed Upper Scheepersvlakte dam, however.

The proximity of these investigations (less than 1 km as the crow flies) implies some relevance to general conditions that would be encountered at the Lower Coerney site, but these earlier investigations are not unpacked in this report. One useful reference report was the Completion Report for Scheepersvlakte Dam (DWAF, 1992).

In the reporting on the Scheepersvlakte investigations[1] it is mentioned, however, that earlier investigations were conducted in 1978/79 at what is presumably the current Lower Coerney option, before investigations shifted to the Scheepersvlakte "side-valley" option that proceeded to be constructed. At the time these investigations were also called "Scheepersvlakte" but actually might be referred to as "Coerney". These original investigations at the Coerney option considered three centre-lines. It is mentioned that 20 boreholes (total length 340,97 m) were drilled; concentrated mostly at an "upper" site. There is also mention of trenching only having been carried out at a "middle" site, while a "lower" site was also investigated.

The Scheepersvlakte "side valley" report (Geological Survey, 1987) mentioned that a separate report would be prepared for these "Coerney" investigations, but it remains doubtful whether this was actually done.

A geotechnical investigation of the Coerney site was carried out in 2016 by Outeniqua Lab EC who were appointed by Inconsult Engineers[2]. The work primarily comprised excavation and profiling of test pits (17 No), accompanied by laboratory testing.

Other available information that was consulted is listed below. Publications and other reference articles, books etc. are listed in Chapter 9 References.

- Geological map Sheet 3324 Port Elizabeth. Council for Geoscience.

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[1] Scheepersvlakte Dam – Side Valley Site; 1st Engineering Geological Feasibility / Design Report – Founding Conditions. February 1987. Geological Survey Report.

[2] Outeniqua Lab EC cc. 2016. Geotechnical Report. *Geotechnical Site Investigation for the Proposed Scheepersvlakte Irrigation Scheme Dam near Port Elizabeth in the Eastern Cape*. Report to Inconsult Engineers, dated 22 July 2016.

# 3 Investigation methodology

## 3.1 Geophysical surveys

Resistivity surveys were conducted by specialist geophysicists, Engineering & Exploration Geophysical Surveys cc (EEGS).

The purpose of commencing these geotechnical investigations with the geophysical surveys was primarily to identify sub-surface anomalies that might potentially impact on the envisaged layout, and thus provide potential targets for the boreholes, which would aim to validate these anomalies.

It might be noted that vegetation proved too dense to allow working access, and environmental constraints placed strict limits on the extent of permissible bush clearing. It was therefore necessary to appoint a service provider, B K Bush Clearing, to manually clear cut-lines along these geophysical traverses. It is worth noting that these "cut-lines" had a width intended for pedestrian traffic, not vehicular access, even though in places it was possible to use these cut-lines for access by the TLB. The larger trees were however not cut and access was still limited.

Three traverses were set out; one longitudinal traverse along the centre-line, one traverse essentially perpendicular to the centre-line, roughly aligned along the intake – outlet conduit, and the third traverse aligned along the spillway. The positions of these traverses are shown in Drawing 112546-GEO-DRG-CC-001.

Detailed description of the methodologies, and the equipment used, as well as the results, are presented in the Appendices. The findings are incorporated into the discussion on the geological profiles encountered.

## 3.2 Test pitting

Test pits were excavated both on the dam footprint, including the spillway, as well as within the potential reservoir. A test pit summary is presented below in **Table 3.1**. A total of eleven test pits were excavated on the dam footprint, and three within the reservoir. Test pit positions are indicated on the site plan (Dwg 112546-GEO-DRG-CC-001-A). Clearing of traverse lines for the geophysics greatly enhanced the ability to access the dam footprint area for test pitting. Access within the general basin area was however severely restricted; only a few existing tracks enabled limited access. The greater part of the basin was inaccessible and has not yet been investigated.

**Table 3.1: Test pit summary**

| Test Pit No | Coordinates |  | Termination depth (m) | Remarks |
|---|---|---|---|---|
|  | Y | X |  |  |
| LC02 | Y-058111 | X3702708 | 2.75 | No refusal, no water |
| LC03 | Y-058187 | X3702632 | 2.4 | No refusal, no seepage |
| LC04 | Y-058140 | X3702665 | 1.35 | Near-refusal, no seepage |
| LC05 | Y-058115 | X3702619 | 2.25 | No refusal, no seepage |
| LC06 | Y-058320 | X3702486 | 1.65 | No refusal but slow excavation, no seepage |
| LC07 | Y-058175 | X3702718 | 2.25 | Near-refusal, no seepage |
| LC08 | Y-058402 | X3702424 | 1.5 | No refusal but slow at 1.5 m, no seepage |
| LC09 | Y-058262 | X3702543 | 2.4 | No refusal, no seepage |
| LC10 | Y-058447 | X3702411 | 1.6 | No refusal but slow at 1.6 m, no seepage |
| LC11 | Y-058381 | X3702592 | 1.95 | No refusal but slow at 1.95 m, no seepage |
| LC12 | Y-058355 | X3702759 | 2.35 | Refusal on boulders, no seepage |
| LC20 | Y-058164 | X3702165 | 1.95 | No refusal but slow at 1.95 m, no seepage |
| LC22 | Y-057865 | X3702228 | 2.4 | Refusal on hardpan calcrete, no seepage |
| LC23 | Y-057735 | X3702243 | 2.25 | No refusal, no seepage |

The test pits were excavated using a light JCB 3DX tractor-loader backhoe (TLB), sub-contracted from Rennasance Construction by Tosca Lab (Pty) Ltd.

Test pits were profiled by a graduate civil engineer and an engineering geologist in accordance with accepted southern African standards (as per Jennings, Brink, and Williams, 1973).

The two-person team carrying out the test pitting ensured compliance with accepted safety requirements as reflected in the South African Code of Practice (SAICE: 2007). Further observance of good safety practice is exhibited by the following;

- Compilation of a Health & Safety File in compliance with the South African OHS Act, including the necessary legal appointments.
- Maintaining good management of the TLB and the excavation process, including placement of spoil away from the pit edges, maintaining a safe distance from the machine, conducting a full briefing / induction of the operator, excavation of a sloping ramp at one end for easier entry / egress etc.
- Conducting a risk assessment by the competent person prior to entering the test pit.
- Test pits were closed after profiling, and sampling. No pits were left open overnight.

Test pit positions were recorded with a Garmin hand-held GPS. Coordinates in South African grid, WGS84 datum, are reflected in **Table 3.1**.

## 3.3 Rotary core drilling

A total of six rotary cored boreholes were drilled on the dam footprint / spillway and positions are shown on Drawing 112546-GEO-DRG-CC-001-A. No boreholes were drilled within the general reservoir area. Borehole details are summarised below in **Table 3.2.** All boreholes were drilled vertically.

**Table 3.2: Borehole summary**

| BH No | Coordinates | | Elevation | BH length (m) | Remarks |
|---|---|---|---|---|---|
| | Y | X | | | |
| LC BH01 | -58099.59 | 3702689.25 | 83.36 | 15.01 | Mid-right flank |
| LC BH02 | -58215.90 | 3702532.15 | 89.15 | 20.45 | Intake, lower left flank |
| LC BH03 | -58252.35 | 3702625.65 | 84.30 | 20.43 | Outlet, lower left flank |
| LC BH04 | -58170.99 | 3702620.43 | 81.82 | 15.04 | Mid -embankment / lowest point |
| LC BH05 | -58427.33 | 3702391.34 | 102.01 | 10.03 | Extreme left flank / spillway crest |
| LC BH06 | -58387.47 | 3702608.97 | 89.98 | 10.1 | Spillway |

Specialist geotechnical drilling contractor, RWBE Geotechnical Drilling, was appointed for the drilling. Where possible, Standard Penetration Testing (SPT's) was carried out. In practice, the presence of gravels and cobbles within the soil profile severely limited the number of tests that were possible. Water acceptance (also referred to as packer or Lugeon) tests were carried out in selected boreholes, after the methodology described by Houlsby (1976).

Boreholes were located to investigate key elements of the dam – with due cognisance of the geophysics survey results. Borehole cores were logged in accordance with accepted standards. Logs are included in the Appendices, as are photographs of the borehole cores.

Boreholes were set out initially using a hand-held GPS, but the completed boreholes were accurately surveyed by DWS Survey Services.

## 3.4 Laboratory testing

Representative samples were submitted to Tosca Lab in Port Elizabeth for testing. A list of tests conducted is presented below (**Table 3.3**). Samples comprised both disturbed bulk samples as well as undisturbed samples.

Table 3.3: Summary of laboratory tests conducted

| Test | Quantities |
|---|---|
| Foundation Indicators | 19 |
| Moisture content | 7 |
| Relative density | 4 |
| Standard AASTHO (Proctor) compaction | 8 |
| Permeability | 7 |
| Shear box | 10 |
| Suite of dispersivity tests, comprising i) Pinhole test, ii) crumb test, iii) double hydrometer test, and iv) exchangeable sodium percentage (ESP) test. | 4 |

Detailed test results are included in the Appendices, and the findings are discussed below (Section 5.3).

# 4 Regional geology

## 4.1 Stratigraphy and lithology

Geologically, the area of interest falls within the Algoa Basin which is one of the complex graben and half-graben structures along the present eastern and southern coast associated accumulations of Jurassic and Cretaceous deposits. These basins formed along the margins of the newly-formed African continent at the time of the break-up of Gondwana (Shone, 2006).

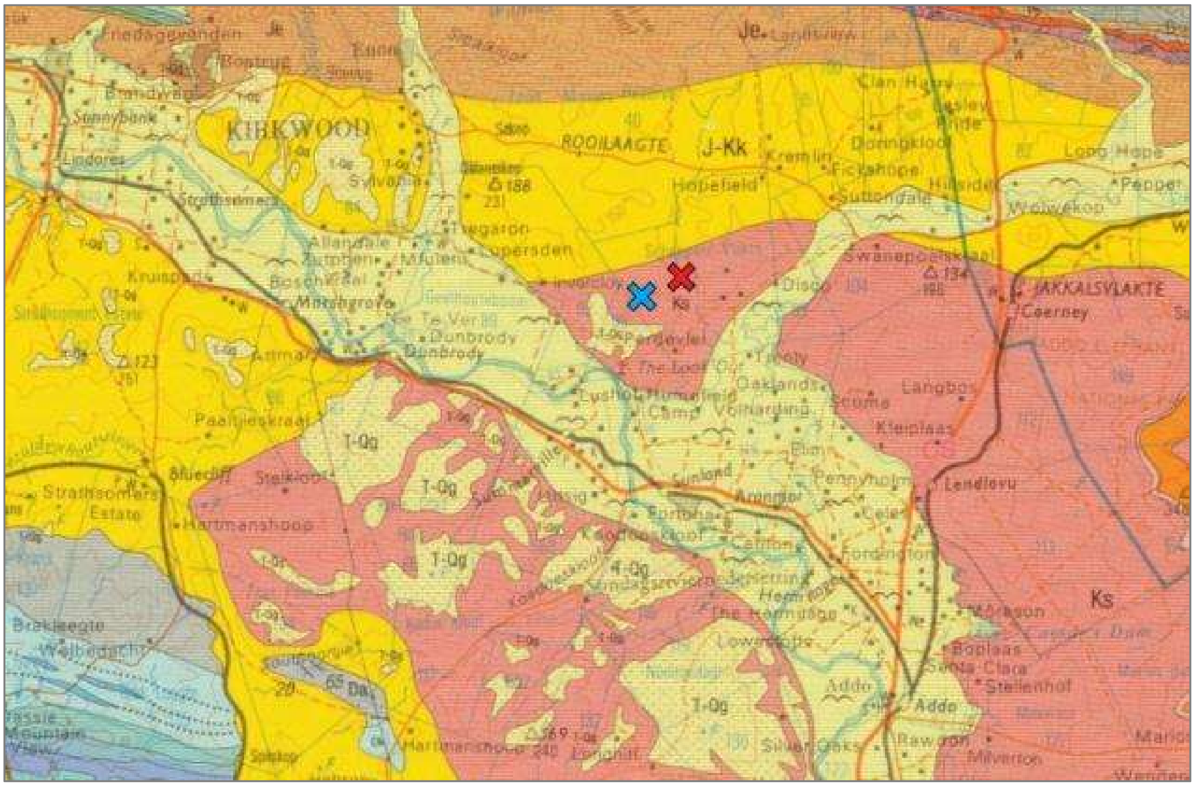
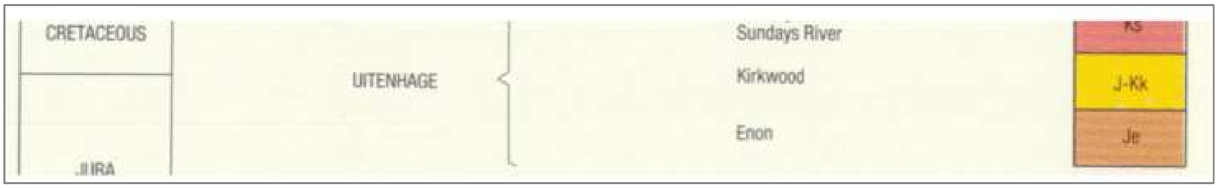


**Figure 4.1: Excerpt of geological map (Sheet 3324)**
***The two site options are marked with crosses (blue = Upper Scheepersvlakte, red = Lower Coerney)***



| | | | |
|---|---|---|---|
| CRETACEOUS | UITENHAGE | Sundays River | Ks |
| | | Kirkwood | J-Kk |
| JURA | | Enon | Je |

**Figure 4.2: Geological explanation, excerpt from geological map**

According to the 1:250 000 geological map (Port Elizabeth Sheet 3324, Council for Geoscience), the dam sites are both underlain by the strata of the Sunday River Formation, although in both instances the upper reaches of the respective basins are underlain by strata of the Kirkwood Formation. All are part of Uitenhage Group (Figure 4.1, Figure 4.2).

The older Kirkwood Formation consists of porous and permeable, coarse- to medium-grained, buff- and olive coloured lithic sandstone. Sandstone beds may be up to several metres thick and of variable lateral extent, interbedded with thick (often more than 30 m thick), red and greyish green siltstones and mudrocks.

The younger Sundays River Formation overlies and appears to grade laterally into the Kirkwood Formation. This Sundays River Formation consists of thin grey sandstones, siltstones and mudrocks. The sandstones are less porous and permeable than the older Kirkwood strata.

The oldest Enon Formation sediments of the Uitenhage Group are located to the north of the area of interest and do not impact directly on the discussion on the prevailing geological and geotechnical conditions of the respective sites. There is however an indirect impact, and this is dealt with at a later point.

## 4.2 Structural geology and seismic hazard

It is mentioned above that the Algoa basin is a half-graben structure. Such a basin is defined by faulting, in this case on the northern boundary, and the relative subsidence of the 'fault-defined' block (horst) in effect created the basin in which the sediments accumulated. The Algoa basin is known to be more complex than most, with diagonal faults cutting the horst block.

Several other prominent faults are recognised in the general area, including the Coega Fault which extends from west of the Groendal Dam to beyond the mouth of the Coega River. This fault has a vertical displacement in excess of 2000 m. these prominent NW to SE trending faults are as close as 35 -  40 km from the proposed balancing dam sites.

While the sediments within the Algoa Basin are not significantly deformed, and only display a nominal shallow dip towards the present coast, these basins are located within the Cape Fold Belt and the older Table Mountain Group strata are intensely folded. These shallow dips of approximately 10 degrees are seemingly confirmed by detailed mapping of the Scheepersvlakte Dam foundations.

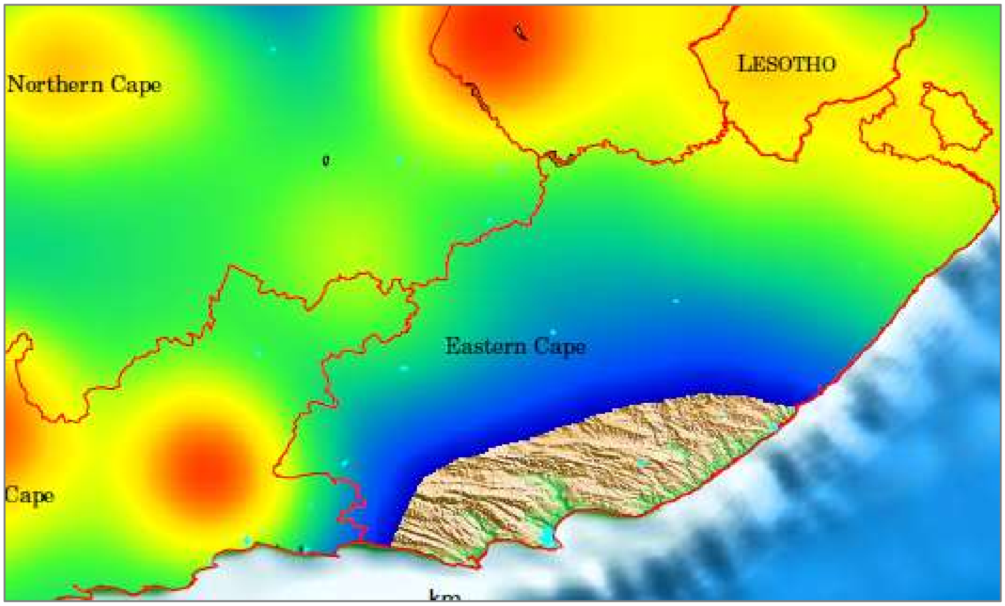


**Figure 4.3: Excerpt of the seismic hazard map of South Africa (after Kijko et al, 2003)**

Even though the very existence of the Algoa Basin is directly linked to faulting, and other regional-scale faults are also recognised, the seismic hazard of the area is considered to be very low. Figure 4.3 is an excerpt of the seismic hazard map (after Kijko, et al, 2003) which shows the Peak Ground Acceleration (PGA) values of less than 0.02g, where these are with a 10% probability of being exceeded in a 50-year period.

## 4.3 Economic geology

There are no known reserves of economically important minerals within the respective dam basins. Within the general area economic activities relating to the geology would revolve around construction materials, including suitable rocks for processing of aggregates, as well as clays for brick-making. There are no such active commercial quarry sites in either of the two dam basins.

## 4.4 Weathering and geomorphology

The area of interest lies to the east of Weinert's N = 5 line and it is estimated that the appropriate value is likely in the order of 3 to 3.5 (Port Elizabeth is at 2.6), as per Weinert, 1980. This indicates that chemical decomposition is the dominant mode of weathering. Typically, this would suggest deep residual soil profiles, but this is not a feature of the profiles encountered.

The higher-lying areas in the general area are also characterised by the formation of pedocretes associated with the African erosion surface; in this instance calcrete. On the respective dam sites, the calcrete formation was recognised, but was not developed to any significant degree. A harder capping of calcrete hardpan or ‘duricrust’ is noted on the higher-lying areas beyond the dam basin.

There is no evidence of erosion and depositions being currently-active geological processes.

The evolution of the sedimentary basin, as well as periods of fluctuating sea levels have however complicated the geological sequence observed. The area extending between the current coast and the Zuurberge mountain range to the north of the dam sites representing a relatively level wave cut platform linked to a period of elevated sea level. Such wave erosion in the period roughly between 20 and 2 million years ago would have resulted in erosion of the older Enon Formation conglomerates at the foothills of the Zuurberge – and redistribution of these gravels in a ‘veneer’ across the coastal plain, while also concentrating these gravels in alluvial channels.

# 5 Investigation findings

## 5.1 Site description

The dam site is characterised by gentle, almost flat slopes; as is the greater basin. For the most part, the site is covered by very dense bush. As mentioned, this required cutting of traverse lines for the geophysical survey to proceed. Limited jeep tracks along farm boundaries also facilitated vehicle access (**Plate 5.1**), specifically downstream of the dam site, and traversing the left flank, and another traversing the basin area. With the exception of these tracks the bush is generally impenetrable, although open areas were occasionally present.

The description that follows includes the subdivision of ‘river section’. It is noted however that there is no clearly defined water course as such.

**Plate 5.1 General panorama of Lower Coerney site, from the access track a short distance downstream of the centre-line (which is to the left)**

## 5.2 Geological profile

### 5.2.1 Left flank, including spillway

Subsurface conditions on the left flank, inclusive of the spillway (**Plate 5.2**), have been investigated by geophysical traverses, test pits as well as boreholes, as shown on Drawing 112546-GEO-DRG-CC-001-A. The summarised findings are presented below in **Table 5.1** in the case of the test pits and **Table 5.2** for the boreholes. A longitudinal geological section has been compiled (drawings 112546-GEO-DRG-CC-002A-A and 112546-GEO-DRG-CC-002B-A).

It has been mentioned that the dense bush restricted access, and that this was then chiefly via the narrow cleared intersect lines, and the track which traverses the left flank. The positions of the test pits, as well as the boreholes were partly governed by this access. A broad spread of test pits was achieved across the left flank; extending from lower flank, to mid- and upper flank areas. A test pit was also excavated midway along the spillway alignment.

**Table 5.1: Lower Coerney left flank test pits; summarised geological profile (depths in m)**

| TP no | Topsoil; silty to clayey sand, loose to medium dense, or dense | Colluvium; silty sand with gravels, medium dense to dense, or very dense | Colluvium, partly pedogenic; silty sand with calcrete / ferricrete nodules / near-hardpan, dense to very dense | Mixed origin; clayey silt, very stiff |
|---|---|---|---|---|
| LC09 | 0 – 0.4 | 0.4 – 0.85 | 0.85 – 1.2 | 1.2 – 2.4+ |
| LC11 | 0 – 0.3 | 0.3 – 0.5 | 0.5 – 1.95+ | |
| LC06 | 0 – 0.2 | 0.2 – 0.5 | 0.5 – 1.65+ | |
| LC08 | 0 – 0.3 | | 0.3 – 1.5+ | |
| LC10 | 0 – 0.3 | 0.3 – 0.7 | 0.7 – 1.6+ | |

**Table 5.2: Lower Coerney left flank boreholes, summarised geological profile (depths in m)**

| BH no | Colluvium; slightly clayey, silty sand | Alluvium / mixed origin; gravels in sand matrix | Mudstone; highly to completely weathered, soft to very soft rock | Mudstone; unweath'd, hard rock | Interbedded mudstone / sandstone; highly to moderately weathered, generally medium hard rock | Sandstone; highly (to completely) weathered, hard (soft / to sand) rock | Sandstone; moderately weathered, hard rock |
|---|---|---|---|---|---|---|---|
| LC BH02 | 0 – 2.65 | 2.65 – 7.7 | 7.7 – 9.75 | | 9.75 – 14.15 | 15.15 – 19.33 | 19.33 – 20.45 |
| LC BH03 | 0 – 1.28 | 1.28 – 4.05 | | 15.16 – 20.43 | 4.05 - 12 | | 12 – 15.16 |
| LC BH05 | 0 - 4 | 4 – 7.2 | 7.2 – 10.03 | | | | |
| LC BH06 | 0 – 5.45 | 5.45 – 6.7 | | | | 6.7 – 10.1 | |

Plate 5.2: General view of left flank conditions, looking here along the spillway alignment in a downstream direction

Boreholes were drilled at specific elements of the proposed dam layout; specifically, the lower flank areas to cover the intake / conduit outlet (boreholes LC BH02 and LC BH03, respectively), as well as the upper flank / crest coinciding with the spillway crest (borehole LC BH05). A further borehole was drilled roughly midway along the spillway chute (LC BH05)

The geophysics profiles confirm the flank is essentially a 'conductor', which would generally be consistent with weathered rock. The left flank in particular is characterised by a 'conductor'; a slight increase in resistivity is apparent with depth, but this is in a disjointed, irregular manner and the impression of horizontal layering is not readily apparent. The profile indicates a number of the lateral interruptions, which might indicate faulting. This resistivity profile is consistent for the traverse along the centre-line and also the traverse along the spillway alignment.

The various strata identified within the geological profile on the left flank are described in more detail below. For detailed description of the shallow soil strata, reliance is placed on the test pits, while for the deeper soil horizons and the underlying bedrock, the information is derived from the boreholes. The geological profile comprises;

- Topsoil,
- Colluvium,
- Colluvium that has been altered by pedogenic action,
- Alluvium or reworked terrace gravels,
- Bedrock, comprising variable combinations of mudstone, siltstone and sandstone.

The upmost **topsoil** horizon is described as dry, brown, medium dense occasionally loose or even dense, blocky or micro-blocky structure or even shattered occasionally, with occasional burrows or pinholes, otherwise intact silty sand. Roots are typically found. The thickness varies between 0.2 m and 0.4 m.

The general **colluvial material** is described as dry, reddish to orange brown, medium dense to dense, occasionally very dense, intact, slightly clayey, silty sand. In places this horizon might contain minor fine calcrete nodules as well as roots. Minor pinholes are recorded on occasion. In places a minor fraction of fine or medium, angular to sub-rounded gravels is recognised. Only if the presence of the pedogenic nodules is particularly minor is this material considered as 'colluvium'; should the pedocrete development be significant then these soils would be considered as part of the underlying horizon. Thickness varies between 0.2 m and 0.45 m.

A colluvial soil stratum with significant **pedocrete** development is identified. These materials comprise slightly moist, dark to reddish brown or orange brown / orange, mottled whitish, intact, slightly clayey silty sand (i.e. as per the above colluvium), with scattered calcrete accretions that vary between powder calcrete to honeycomb calcrete, and calcrete nodules. In limited instances, the stratum contained both calcrete as well as ferricrete nodules. In test pit LC11 the ferruginised sand horizon approaches hardpan ferricrete and comprises very dense silty to sandy (gravel-sized) nodules. The overall consistency varies between dense and very dense. In places distinction can be made between an upper horizon of medium dense to dense consistency, with minor or macro pinholes, and a lower horizon described as dense to very dense. In one instance this stratum was noted to contain sub-rounded, medium gravels of hard rock quartzite. Horizon thickness varies between 0.9 m and 1.45 m.

Test pit LC10 on the extreme upper left flank terminated in calcrete-cemented, clayey, silty sand with loosely-packed, medium and coarse, sub-rounded quartzite gravels. This is the only test pit that seemingly intersected the **gravel horizon**. The boreholes, however, confirm this horizon to extend to all parts of the left flank. Although described as alluvium it is considered more likely to see this deposit as representing reworked terrace gravels.  This gravel stratum is encountered at depths between 1.28 m and 5.45 m. The stratum thickness varies between 1.25 m and 5.05 m. Broadly this gravel layer is most well developed on the lower flank areas, but is intersected at depth across the entire flank. This transported gravel horizon is directly underlain by bedrock.

A single occurrence (test pit LC09) was recorded where a lower soil horizon of **uncertain origin** (i.e. mixed origin) was noted at a depth between 1.2 m and 2.4 m, i.e. a minimum thickness of 1.2 m. This material comprises slightly moist, reddish brown, very stiff, intact clayey silt.

The rockhead is encountered at a depth varying between 4 m and 7.7 m.

Bedrock comprises a succession of sandstones and mudstones in varying proportions. Horizons of mudstone, or sandstone are recognised, as well as strata where the mudstones / sandstones are interbedded. The boundaries of these lithological changes have not been confirmed with absolute certainty; partly because the boreholes do not intersect all changes, but also due to the often-gradational nature of these variations. It is further expected that significant lateral variation will characterise the strata, and that the horizons are not necessarily laterally continuous. From the limited borehole intersections of traceable contacts, it would appear that the strata dip into the flank at shallow angles of 4° to 5°.

The bedrock is characterised by pervasive weathering, and as a rule the rock mass is weathered throughout.

Two boreholes (only one on the left flank) did however reveal unweathered rock at the base of the borehole. Borehole LC03 intersected unweathered mudstone at a depth of 15.16 m (approximate elevation 69 masl). The uppermost bedrock horizon either comprises mudstone or sandstone; characterised by a ‘highly to completely’ degree of weathering, to the extent that the rock is soft to very soft and in places is weathered to clay, or sand, depending on whether the rock is mudstone or sandstone. Generally, the profile is characterised by improving weathering with increasing depth; with a progressive change from highly / completely weathered rock at surface to moderately or even slightly weathered rock at the borehole termination depths. At these depths the rock is described as ‘hard rock’.

It is worth noting that while the unweathered mudstones classify as hard rock, these rocks are known to be susceptible to slaking, and will therefore rapidly deteriorate upon exposure to the atmosphere. Such propensity to slake will also be experienced within predominantly sandstone horizons, but where interbedded mudstone strata are present.

The generally expected shallow dip of the strata is further borne out by the discontinuities, which reflect the common occurrence of shallow joints dipping at 0° to 10°. This discontinuity set is considered to represent the bedding. Other prominent joints include very steeply dipping / sub-vertical joints (80° to 90°) , and less commonly, joints dipping at angles between 40° and 60°. At shallower depths within the bedrock, the rock mass is typically characterised by the interbeds, which have weathered to clay, or sand. Commonly, the drilling within these weak rocks is characterised by notable material losses; which are assumed linked to these weathered interbeds of clay / sand. Even if not lost (‘washed’), the weathered interbeds are characteristically weaker than the surrounding material.

### 5.2.2 River section

The summarised geological profile within the river section, as revealed by test pits and boreholes, is presented in **Table 5.3** and **Table 5.4**, respectively. A measure of overlap is considered in these summary tables, hence the seeming repetition.

Table 5.3: River section, summarised test pit profiles (depths in metres)

| TP no | Topsoil; loose to medium dense or dense, silty to medium sand | Colluvium; medium dense or dense, silty sand | Colluvium / partly pedogenic; loose to medium dense / dense | Gravels / cobbles in sand matrix, overall loose to medium dense / very dense; Mixed origin | Alluvium; very dense, silty clayey sand |
|---|---|---|---|---|---|
| LC02 | 0 – 0.3 | 0.3 – 1 | 1 – 1.95 | 1.95 – 2.75+ | |
| LC03 | 0 – 0.3 | 0.3 – 1.15 | 2.05 – 2.4+ | 1.15 – 2.05 | |
| LC04 | 0 – 0.3 | | | 0.3 – 0.9 | 0.9 – 1.35+ |
| LC05 | 0 – 0.3 | | | 0.3 – 2.25+ | |
| LC12 | 0 – 0.2 | | | 0.2 – 2.35+ | |

The resistivity profile within the central section is characterised by a prominent resistant layer at surface, extending to an estimated depth of 5 m – 10 m. This horizon was considered to represent a measure of cementation within the upper soil horizon. Beneath this surface ‘resistor’ the profile is characterised by ‘conductors’. Further layering in this regard is not readily apparent, and these conductor values are consistent with weathered rock.

**Table 5.4: River section, summarised borehole profiles (depths in metres)**

| BH no | Colluvium; slightly clayey, silty sand | Alluvium / mixed origin; gravels in sand matrix | Mudstone; highly to completely weathered, soft to very soft rock | Mudstone’ slightly to moderately weathered, soft to medium hard rock | Mudstone; unweath’d, hard rock | Interbedded mudstone / sandstone; highly to moderately weathered, generally medium hard rock | Sandstone; highly (to completely) weathered, hard (soft / to sand) rock | Sandstone; moderately weathered, hard rock |
|---|---|---|---|---|---|---|---|---|
| LC BH02 | 0 – 2.65 | 2.65 – 7.7 | 7.7 – 9.75 | | | 9.75 – 14.15 | 15.15 – 19.33 | 19.33 – 20.45 |
| LC BH03 | 0 – 1.28 | 1.28 – 4.05 | | | 15.16 – 20.43 | 4.05 - 12 | | 12 – 15.16 |
| LC BH04 | 0 - 2 | 2 – 3.25 | | 10.95 – 13.3 | 13.3 – 15.04+ | | 3.25 – 7.5 | 7.5 – 10.95 |
| LC BH01 | 0 – 0.8 | 0.8 – 2.7 | 4.55 – 10.94 | 13.1 – 15.01+ | | | 2.7 – 4.55<br>10.94 – 13.1 | |

The geological profile within the central portion is characterised by the following strata;

- Topsoil,
- Colluvium,
- Colluvium that is altered by pedogenesis,
- Gravel soils, considered to be of mixed origin (reworked terrace gravels),
- Occasional / rare alluvial stratum, and
- Bedrock

Plate 5.3: River section view, looking towards right flank (test pit LC03 in foreground)

The upper **topsoil** horizon covers the entire central section. This horizon is typically a fairly consistent 0.3 m thick. The topsoil comprises silty sand and at the time of the test pitting was typically described as dry, with consistency varying between very loose and medium dense. Occasionally the material is dense. Roots are generally present.

The underlying horizon of **colluvium** was intersected in test pits LC02 and LC03. The colluvial material comprises silty sand, or slightly clayey silty sand. The moisture content at the time was described as slightly moist, and the consistency as medium dense or dense. Pinholes were recognised in the structure. Roots are present. This colluvium is not present across the entire footprint in the river section and is likely patchy. Where present, the thickness varies between 0.7 m and 0.85 m.

Distinction is made between the colluvial material described above, and colluvium which is exhibits evidence of some **pedogenic** alteration. This material is also only evident in test pits LC02 and LC03 and is therefore not developed across the entire footprint. The material is described as slightly moist, reddish brown to light brown, loose to medium dense or dense, silty sand with ferricrete nodules or honeycomb calcrete with calcrete nodules. The thickness of this patchy horizon varies up to 0.9 m.

The stratum of **reworked terrace gravels** is recognised across the entire footprint. These materials comprise a coarse fraction of gravels or cobbles of very hard rock quartzite with a matrix of silty to fine sand. The gravels are generally medium to coarse in size, and typically rounded or sub-rounded. The relative abundance of the coarse and fine fractions varies; in places the coarse fraction is tightly packed, i.e. clast-supported but in other strata the matrix dominates, i.e. matrix-supported, and characterised by occasional cobbles / gravels. The overall consistency varies between loose and medium dense or dense or very dense. Occasionally pinholes are recognised within the stratum. Horizon thickness typically varies between 0.6 m and 0.9 m but may be thicker; in the case of test pit LC12 the total thickness of this stratum is greater than 2 m. The boreholes confirm total thickness of this gravel stratum to vary between 1.25 m and 5 m. In the case of test pit LC12, two horizons are recognised; an upper horizon that is predominantly sand with occasional coarser fraction, and a lower horizon where the coarser fraction is dominant.

Sandy **alluvium** was recognised in only one places. Test pit LC04 intersected alluvial silty, clayey sand between depths between 0.9 m and 1.35 m. This sandy stratum was described as very dense.

The deeper **bedrock** profile within the river section is mainly confirmed by borehole LC BH04, but other boreholes which confirm the lateral continuity of these horizons include LC BH01. Rockhead is intersected at depths between 2.7 m and 3.25 m (elevations of 78.57 and 80.66 masl, for boreholes LC BH04 and LC BH01, respectively). Bedrock comprises interbedded sandstone and mudstone horizons. In borehole LC BH01, drilled on the lower right flank, bedrock predominantly comprises mudstone strata with subordinate interbedded sandstone horizons. In LC BH04 the uppermost horizons, extending from the rockhead at a depth of 3.25 m to a depth of 10,95 m, i.e. with a thickness of 7.7 m, the bedrock predominantly comprises sandstone with minor mudstone interbeds, while below 10.95 m depth the rock is predominantly mudstone but with minor sandstone interbeds.

The rock mass is characteristically highly weathered, improving with increasing depth, and unweathered mudstone is intersected at a depth of 13.3 m (LC BH04). Borehole LC BH01, in contrast, shows no improvement in weathering and the rock mass is highly weathered throughout – to a depth of at least 15 m. These weathered rocks generally comprise soft to medium hard rock. The uppermost strata may be very soft rock in places. In addition, certain strata tend to hard rock; typically, the sandstone horizons at depth where highly weathered. Where unweathered mudstone is intersected this also tends to hard rock in places.

It must be noted that the mudstones in particular are susceptible to slaking, i.e. will rapidly disintegrate upon exposure to the elements. This phenomenon will also affect the sandstone beds where interbedded mudstone lenses of laminations occur. Even rock that appears as hard rock will therefore disintegrate on exposure. This characteristic holds implications for foundation excavations and treatment and is discussed in more detail in Section 6.1.3.

Up to four discontinuity sets are recognised within the rock strata, although some horizons only see one or two sets. Shallow dipping (10°) discontinuities are ubiquitous and represent the bedding planes. Other common joint orientations include moderately steep joints (dipping 50° to 60°) and sub-vertical joints (80° to 90°). Joint surfaces are commonly smooth. Joint infill material is rarely recorded, and generally only staining of the surfaces might be noted. In terms of joint infill, however, it is pertinent to note the occurrence of horizons that are occasionally weathered to clay, particularly within the mudstone horizons. Also relevant are the material losses, particularly within the upper horizons, where these are ascribed to wash-out of very soft rock interbeds.

### 5.2.3 Right flank

Only limited investigation points were carried out on the right flank. A single borehole (LC BH01) is complimented by one test pit (LC02). The limiting factor in this regard was the accessibility due to the thick bush. The geological profiles are summarised below in **Table 5.5** and **Table 5.6**. Nearby borehole and test pit profile summaries are included in these tables for greater clarity. The geological longitudinal section is presented in Drawing 112546-GEO-DRG-CC-002A.

Results from this borehole (LC BH01) have been incorporated into the above section on the geological profile in the river section (Section 5.2.2) but is incorporated here in the context of the right flank.

**Table 5.5: Right flank, summarised test pit profiles (depths in metres)**

| TP no | Topsoil; loose to medium dense or dense, silty to medium sand | Colluvium; medium dense or dense, silty sand | Colluvium / partly pedogenic; loose to medium dense / dense | Gravels / cobbles in sand matrix, overall loose to medium dense / very dense. Mixed origin | Alluvium; very dense, silty clayey sand |
|---|---|---|---|---|---|
| LC02 | 0 – 0.3 | 0.3 - 1 | 1 – 1.95 | 1.95 – 2.75+ | |
| LC04 | 0 – 0.3 | | | 0.3 – 0.9 | 0.9 - 1.35+ |
| LC05 | 0 – 0.3 | | | 0.3 – 2.25+ | |

**Table 5.6: Right flank, summarised borehole profiles (depths in m)**

| BH no | Colluvium; slightly clayey, silty sand | Alluvium / mixed origin; gravels in sand matrix | Mudstone; highly to completely weathered, soft to very soft rock | Mudstone’ slightly to moderately weathered, soft to medium hard rock | Mudstone; unweath’d, hard rock | Interbedded mudstone / sandstone; highly to moderately weathered, generally medium hard rock | Sandstone; highly (to completely) weathered, hard (soft / to sand) rock | Sandstone; moderately weathered, hard rock |
|---|---|---|---|---|---|---|---|---|
| LC BH04 | 0 - 2 | 2 – 3.25 | | 10.95 – 13.3 | 13.3 – 15.04+ | | 3.25 – 7.5 | 7.5 – 10.95 |
| LC BH01 | 0 – 0.8 | 0.8 – 2.7 | 4.55 – 10.94 | 13.1 – 15.01+ | | | 2.7 – 4.55<br>10.94 – 13.1 | |

The geological profile is characterised by the following horizons;

- Topsoil
- Colluvium
- Colluvium partly altered by pedogenesis
- Reworked terrace gravels, overlying
- Bedrock.

The upper **topsoil** horizon is expected to cover the entire flank. On the lower flank area this horizon is 0.3 m thick. The topsoil comprises dry, loose to medium dense silty sand. Roots are generally present.

The underlying horizon of **colluvial material** comprises silty sand. The moisture content at the time was described as slightly moist, and the consistency as medium dense. Pinholes were recognised in the structure. Roots are present. Thickness is 0.7 m.

An underlying **horizon of colluvium displaying some pedogenic** alteration occurs at depths between 1 m and 1.95 m. The material comprises slightly moist, reddish brown to light brown, loose to medium, silty sand with ferricrete nodules.

The stratum of **reworked terrace gravels** was intersected at depths between 1.95 m and the base of the test pit at 2.75 m (minimum thickness 0.8 m). The test pit was terminated due to the ravelling and undercutting, and the true thickness might be greater. It is not confirmed whether this horizon extends across the entire right flank, or whether it thins out on the upper slope areas. In test pit LC02 these gravels and cobbles are tightly packed. The borehole (LC BH01) indicates a thickness of 1.9 m.

**Bedrock** is intersected by borehole LC BH01 at a depth of 2.7 m (elevations 80.66 masl). Bedrock comprises interbedded sandstone and mudstone horizons; predominantly mudstone strata with subordinate interbedded sandstone horizons.

The rock mass is characteristically highly weathered, and shows no improvement in weathering– to a depth of at least 15 m. These weathered rocks generally comprise soft to medium hard rock. The uppermost strata may be very soft rock in places. In addition, certain strata tend to hard rock; typically, the sandstone horizons at depth where highly weathered.

It re-iterated that the mudstones in particular are susceptible to slaking, i.e. will rapidly disintegrate upon exposure to the elements. This phenomenon will also affect the sandstone beds where interbedded mudstone lenses of laminations occur. Even rock that appears as hard rock will therefore disintegrate on exposure. This characteristic holds implications for foundation excavations and treatment and is discussed in more detail in Section 6.1.3.

Generally, two or three discontinuity sets are recognised within the respective rock strata. Shallow dipping (0° - 10°) discontinuities are ubiquitous and represent the bedding planes. Other common joint orientations include moderately steep joints (dipping at 70°) and sub-vertical joints (80° to 90°). Joint surfaces are commonly smooth. Joint infill material is rarely recorded, and generally only staining of the surfaces might be noted. Horizons are recognised where the rock is weathered to clayey sand, or very soft rock in the case of the uppermost sandstone horizon.

### 5.2.4 Reservoir basin

Test pits were excavated within the reservoir area, primarily to confirm potential for sourcing suitable materials for embankment construction. Access was severely restricted and only three test pits were excavated (numbered LC20, LC22 and LC23), along a track that traverses the basin. Test pit positions relative to the dam footprint are shown on Drawing 112546-GEO-DRG-CC-001.

Geological profiles within these test pits are summarised below (**Table 5.7**). The test pits excavated on the dam footprint are also relevant to the description of the soils to be encountered within the general reservoir, but reference is made to the descriptions in the sections above (Sections 5.2.1 to 5.2.3).

**Table 5.7: Reservoir area, summarised geological test pit profiles (depths in m)**

| TP no | Topsoil; medium dense to dense, silty sand | Colluvium; dense, silty sand | Colluvium / partly pedogenic; dense / very dense silty sand, ferruginised, plus ferricrete and calcrete nodules | Gravels / cobbles in sand matrix, Overall very dense to medium dense. Reworked terrace gravels |
|---|---|---|---|---|
| LC20 | 0 – 0.3 | | 0.3 – 1.95 | 1.95+ |
| LC22 | 0 – 0.25 | 0.25 – 0.55 | | 0.55 – 2.4+ |
| LC23 | 0 – 0.25 | | | 0.25 – 2.25+ |

The typical soil profile within the reservoir area comprises;

- Topsoil,
- Colluvium,
- Colluvium that is partly pedogenic, and
- Reworked terrace gravels / gravelly soils of mixed origin.

The upper **topsoil** stratum varies in thickness between 0.25 m and 0.3 m. These soils are described as dry, brow, medium dense sometimes tending to dense, intact to blocky, silty sand. Roots, i.e. organic material, are typically present. Occasionally these soils are pinholed.

**Colluvium** is not uniformly encountered within the reservoir footprint. Where present, the material comprises dry, pale orange, dense, silty sand. In test pit LC22 this horizon is 0.3 m thick.

Material of **mixed colluvial and pedogenic origin** is recognised in test pit LC20, although the reworked terrace gravels intersected in LC22 also show calcrete accretion. The profile exposed in test pit LC20 displays quite variable parent material as well as variable pedocrete development. Within an upper stratum (0.3 – 0.9 m depth) the material comprises dense, ferruginised sand with minor fine ferricrete nodules, this is underlain (depths 0.9 to 1.95 m) by very dense ferruginised sand that contains both ferricrete nodules as well as irregular calcrete accretions. The test pit was terminated in material that comprised this ferruginised sand, but which also included quartzite gravels and further tended to hardpan ferricrete in places.

The horizon considered to represent **reworked terrace gravels** is variably developed. Thickness varied between and at least 2 m. These deposits are not uniform and in places some stratification is noted. Essentially, this material comprises slightly clayey, silty sand (matrix) with a coarser fraction comprising sub-rounded to sub-angular gravels and occasional boulders. The overall consistency is medium dense in horizons where the sandy matrix predominates.

None of the test pits within the reservoir footprint intersected **bedrock**.

## 5.3 Material properties

### 5.3.1 Foundation Indicator results

Foundation Indicator results, i.e. combined grading analyses including sieve and hydrometer analyses, as well as Atterberg constants, are summarised below in **Table 5.8**.

Table 5.8: Summarised Foundation Indicator results

| Test pit no | Depth (m) | Material type | Soil composition | | | | GM | Atterberg limits | | | LS ( % ) | Activity | Unified Class. | AASHTO class. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Clay (%) | Silt (%) | Sand (%) | Gravel (%) | | LL (%) | PI (%) | WPI (%) | | | | |
| **Colluvium** | | | | | | | | | | | | | | |
| LC03 | 0.3 – 1.15 | Colluvium | 1 | 35 | 62 | 2 | 0.61 | 15 | 4 | 4 | 2.0 | 4.0 | SC-SM | A – 4 |
| LC03 | 0.3 – 2.05 | Colluvium | 0 | 41 | 58 | 1 | 0.56 | 15 | 3 | 3 | 1.5 | - | SM | A – 4 |
| **Colluvium, partly pedogenic** | | | | | | | | | | | | | | |
| LC02 | 1.0 – 1.95 | Colluvium with fine FeO nodules | 0 | 63 | 36 | 1 | 0.3 | 21 | 7 | 7 | 3.5 | - | CL | A – 4 |
| LC06 | 0.5 – 1.65 | Colluvium + part pedogenic | 0 | 53 | 45 | 2 | 0.31 | 32 | 18 | 17 | 9.0 | - | CL | A – 6 |

| Test pit no | Depth (m) | Material type | Soil composition |  |  |  | GM | Atterberg limits |  |  | LS ( % ) | Activity | Unified Class. | AASHTO class. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | Clay (%) | Silt (%) | Sand (%) | Gravel (%) |  | LL (%) | PI (%) | WPI (%) |  |  |  |  |
| LC08 | 0.5 – 1.5 | Colluvium + part pedogenic | 0 | 58 | 39 | 3 | 0.76 | 26 | 12 | 12 | 6.0 | - | CL | A – 6 |
| LC09 | 0.4 – 0.85 | Colluvium with fine FeO nodules | 0 | 57 | 43 | 0 | 0.21 | 37 | 19 | 19 | 9.5 | - | CL | A – 6 |
| LC09 | 0.85 – 1.2 | Colluvium + part pedogenic | 0 | 18 | 34 | 48 | 1.78 | 30 | 18 | 8 | 9.0 | - | SC | A – 2 – 6 |
| LC10 | 1.0 – 1.6 | Colluvium + part pedogenic | 0 | 62 | 36 | 2 | 0.31 | 29 | 15 | 14 | 7.5 | - | CL | A – 6 |
| LC11 | 0.5 – 1.5 | Pedogenic | 1 | 22 | 37 | 40 | 1.68 | 31 | 10 | 4 | 5.0 | 10.0 | SC | A – 2 – 4 |
| LC20 | 0.9 – 1.95 | Pedogenic | 0 | 64 | 32 | 4 | 0.33 | 39 | 20 | 18 | 10.0 | - | CL | A – 6 |
| **Mixed origin (reworked terrace gravels)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| LC04 | 0.3 – 1.35 | Terrace gravels | 1 | 32 | 57 | 10 | 0.77 | 17 | 7 | 6 | 3.5 | 7.0 | SC-SM | A – 2 – 4 |
| LC05 | 0.3 – 1.3 | Terrace gravels | 0 | 30 | 67 | 3 | 0.77 | 15 | 5 | 4 | 2.5 | - | SC-SM | A – 2 – 4 |
| LC05 | 1.3 – 2.75 | Terrace gravels | 0 | 8 | 39 | 53 | 2.11 | 49 | 20 | 6 | 10.0 | - | GM | A – 2 – 7 |
| LC07 | 0.9 – 2.0 | Terrace gravels | 0 | 51 | 49 | 0 | 0.38 | 25 | 11 | 11 | 5.5 | - | CL | A – 6 |
| LC09 | 1.2 – 2.4 | Mixed Origin | 4 | 62 | 28 | 6 | 0.38 | 39 | 18 | 16 | 9.0 | 4.5 | CL | A – 6 |
| LC23 | 0.5 – 2.0 | Terrace gravels | 1 | 34 | 61 | 4 | 0.59 | 19 | 7 | 4 | 3.5 | 7.0 | SC-SM | A – 2 – 4 |

<u>Legend</u> GM = Grading modulus
LL = Liquid Limit
PI = Plasticity Index
WPI = Weighted Plasticity Index
LS = Linear Shrinkage
Activity = Activity of the soil according to Van der Merwe's 1964 method

No samples of the **topsoil** were tested, as it was considered that the topsoil would be stripped from the footprint due to the organic content (i.e. presence of roots) and would not be a key element in construction.

The **colluvial** soils primarily comprise silty sand; with the sand fraction of approximately 60% and the silt fraction between 35% and 40%. Clay and gravel fractions are negligible; up to 1% and 2%, respectively. Due to the negligible clay fraction the Liquid Limits (LL) as well as the Plasticity Index (PI) values are very low (15%, and 3% to 4%, respectively). The very low PI values further result in identical Weighted PI[3] values on account of the high fraction passing 0.425 mm. These colluvial materials might therefore be considered to exhibit very low plasticity (almost non-plastic).

Where the **colluvial soils also are associated with evidence of pedogenic action**, these soils predominantly comprise sandy silt, where the dominant silt fraction is typically approximately 60% and the lesser sand fraction varies between 35% to 45%. The clay fraction is typically zero, and the gravel fraction is also negligible (only up to 3%). While generally consistent, these materials also exhibit some wide variability which is likely ascribed to variable pedocrete development. Some of these soils are gravelly (40% to 50%), with sand and silt fractions at 35 – 40%, and approximately 20%, respectively. The clay fraction is constant at zero. The Plasticity Indices (PI's) vary between 10% and 20%, i.e. maybe considered to be moderate. Occasional lower values are recorded. Because of the variable gradings, the Weighted PI values show a wider spread; between 4% and 20%. The Liquid Limit values generally vary between 20% and 40% (indicating soils with low to intermediate plasticity), while the Linear shrinkage values vary between 3.5% an 10%, i.e. low to moderate values.

The gravel soils are considered under the umbrella of '**reworked terrace gravels'** but these materials are not entirely uniform and significant variability is evident. Importantly only the finer fraction was submitted for testing, i.e. the coarse fraction comprising cobbles and boulders, as well as the gravels were not included in the test samples. The finer fraction of these soils generally comprises silty sand, where the sand fraction is between 50% and 70%, and the silt fraction is typically approximately 30 but occasionally up to 50%. The clay fraction is commonly zero but might be up to 4%. In the context of the selective sampling the gravel fraction is not representative of the bulk sample but was recorded up to 40 – 50%. It has been stated previously that this stratum is, in any event, not uniform. Considering the Atterberg constants, the Liquid Limit varies between 15% and 50% illustrating low to intermediate plasticity, the Plasticity Index ranges between 5% and 20%, i.e. low to moderate values, and the Linear Shrinkage varies between 2.5% and 10%, also considered low to moderate.

### 5.3.2 Physical properties

Relative densities for selected samples are summarised below in **Table 5.9**. Moisture contents are summarised in **Table 5.10**.

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[3] *A short note regarding PI versus Weighted PI; The Weighted Plasticity Index (WPI) is defined as the value of the plasticity index (PI) times the % passing the 425 micron sieve (0.425 mm sieve), i.e. the Weighted PI is representative of the PI for the whole sample.*

Table 5.9: Summarised relative density values

| Test pit | Material type | Depth (m) | Origin | Relative density |
|---|---|---|---|---|
| LC03 | Silty sand | 0.3 – 2.05 | Colluvium | 2.600 |
| LC09 | Sandy silt | 0.4 – 0.85 | Colluvium, part pedogenic | 2.580 |
| LC06 | Sandy silt | 0.5 – 1.65 | Colluvium, part pedogenic | 2.560 |
| LC04 | Silty sand with gravel | 0.3 – 1.35 | Terrace gravel | 2.570 |

Table 5.10: Summarised moisture content results

| Test pit no | Material type | Depth (m) | Origin | Moisture Content |
|---|---|---|---|---|
| LC04 | Silty sand with gravel | 0.3 – 1.35 | Terrace gravel | 6.1 |
| LC23 | Silty sand | 0.5 – 2.0 | Terrace gravel | 5.1 |
| LC06 | Sandy silt | 0.5 – 1.65 | Colluvium, part pedogenic | 12.4 |
| LC08 | Sandy silt | 0.5 – 1.5 | Colluvium, part pedogenic | 8.3 |
| LC09 | Sandy silt | 1.2 – 2.4 | Mixed Origin | 17.3 |
| LC20 | Sandy silt | 0.9 – 1.95 | Pedogenic | 10.9 |

### 5.3.3 Compaction

Summarised Proctor compaction results are presented in **Table 5.11**.

Table 5.11: Summarised Proctor compaction results

| Test pit no | Material | Depth (m) | Origin | Proctor density (kg/m$^3$) | o m c (%) |
|---|---|---|---|---|---|
| LC03 | Silty sand | 0.3 – 2.05 | Colluvium | 1857 | 11.1 |
| LC06 | Sandy silt | 0.5 – 1.65 | Colluvium, part pedogenic | 1676 | 18.9 |
| LC08 | Sandy silt | 0.5 – 1.5 | Colluvium, part pedogenic | 1759 | 17.8 |
| LC11 | Silty sandy gravel | 0.5 – 1.5 | Pedogenic | 1522 | 21.7 |
| LC20 | Sandy silt | 0.9 – 1.95 | Pedogenic | 1739 | 22.6 |
| LC09 | Sandy silt | 1.2 – 2.4 | Mixed Origin | 1617 | 23.8 |
| LC23 | Silty sand | 0.5 – 2.0 | Terrace gravels | 1826 | 11.7 |
| LC04 | Silty sand with gravel | 0.3 – 1.35 | Terrace gravels | 1868 | 12.7 |

The **colluvium** horizon is characterised by a maximum dry density (Proctor compaction) of 1857 kg/m$^3$ with an optimum moisture content (omc) of 11%

Typically, the sandy silt of **colluvial / part pedogenic** origin exhibits maximum dry density (Proctor compaction) values in the range of 1617 to 1759 kg/m$^3$, with optimum moisture contents (omc) between 18% and 24%. Where the pedogenic material is more variable and comprises silty, sandy gravel, the maximum dry density (Proctor compaction) is 1522 kg/m$^3$ and an optimum moisture content (omc) of 22%.

The fine fraction of the **terrace gravels** possesses maximum dry density (Proctor compaction) values in the range of 1825 to 1868 kg/m$^3$, with optimum moisture contents (omc) between 11% and 13%.

### 5.3.4 Shear strengths

Remoulded samples were subjected to shear box testing. The results are summarised below in **Table 5.12**.

**Table 5.12: Summarised drained slow shearbox test results**

| Test pit no | Material type | Depth (m) | Origin | Maximum effective shear stress kPa | Apparent Friction Angle (°) | Moulded density (kg/m$^3$) |
|---|---|---|---|---|---|---|
| LC3 | Silty sand | 03 – 2.05 | Colluvium | 36.5 | 18.3 | 1676 |
| LC3 | Silty sand | 0.3 – 1.15 | Colluvium | 38.1 | 19.2 | 1693 |
| LC3 | Silty sand | 0.3 – 2.05 | Colluvium | 35.4 | 20.2 | 1704 |
| LC4 | Silty sand with gravels | 0.3 – 1.35 | Terrace gravels | 43.2 | 26.4 | 1722 |
| LC6 | Sandy silt | 0.5 – 1.65 | Colluvium, part pedogenic | 41.6 | 21.4 | 1570 |
| LC8 | Sandy silt | 0.5 – 1.5 | Colluvium, part pedogenic | 40.9 | 24.7 | 1634 |
| LC9 | Sandy silt | 1.2 – 2.4 | Mixed origin | 32.8 | 23.3 | 1509 |
| LC11 | Silty sandy gravel | 0.5 – 1.5 | Colluvium, part pedogenic | 33.9 | 20.2 | 14343 |
| LC20 | Sandy silt | 0.9 – 1.95 | Colluvium, part pedogenic | 35.7 | 24.8 | 1596 |
| LC23 | Silty sand | 0.5 – 2.0 | Terrace gravel | 33.4 | 19.2 | 1682 |

### 5.3.5 Permeability

The results of permeability tests on the soil samples are summarised below (**Table 5.13**). Results of water acceptance (Lugeon) tests are presented elsewhere (Section 6.3).

Table 5.13: Lower Coerney, summarised permeability test results

| Hole no | Material | Depth (m) | Material origin | Permeability (cm/s) |
|---|---|---|---|---|
| LC04 | Clayey, silty sand | 0.4 – 1.35 | Alluvium | $3.16 \times 10^{-6}$ |
| LC03 | Silty sand | 0.3 – 2.05 | Colluvium | $1.84 \times 10^{-5}$ |
| LC03 | Silty sand | 0.3 – 1.15 | Colluvium | $2.31 \times 10^{-5}$ |
| LC06 | Sandy silt | 0.5 – 1.65 | Colluvium, part pedogenic | $4.11 \times 10^{-7}$ |
| LC08 | Sandy silt | 0.5 – 1.5 | Colluvium, part pedogenic | $3.72 \times 10^{-6}$ |
| LC11 | Silty, sandy gravel | 0.5 – 1.5 | Pedogenic | $1.88 \times 10^{-6}$ |
| LC20 | Sandy silt | 0.9 – 1.95 | Pedogenic | $2.62 \times 10^{-7}$ |

The clayey, silty sand of **alluvial origin** exhibits a permeability of $3.16 \times 10^{-6}$ cm/s.

The silty sand **colluvium** yielded permeabilities between $1.84 \times 10^{-5}$ and $2.3 \times 10^{-5}$ cm/s.

The **colluvium / part pedogenic** material is fairly variable, and this is reflected in the permeability results. The sandy silt material of **pedogenic origin** understandably proved to be the least pervious, with values ranging between $2.62 \times 10^{-7}$ and $4.11 \times 10^{-7}$ cm/s. Where the material is more sandy, or even coarser, the permeability was measured at $1.88 \times 10^{-6}$ cm/s.

### 5.3.6 Dispersivity

Selected samples were subjected to a suite of tests to assess the dispersivity, including the Double Hydrometer, as well as the Pinhole Test and the Crumb Test. No single test is deemed entirely reliable in confirming the dispersivity of a soil, and for this reason a suite of tests is usually conducted. Results are summarised below in **Table 5.14**.

Table 5.14: Lower Coerney, summarised dispersivity test results

| Hole no | Material type | Depth (m) | Material origin | Double hydro-meter (%) | Pinhole test | Crumb test | Sodium Adsorp-tion Ratio (SAR) | Extract-able Sodium Percentage (ESP) |
|---|---|---|---|---|---|---|---|---|
| LC03 | Silty sand | 0.3 – 2.05 | Colluvium | 40.13 | ND3 | Grade 2 | 7.22 | 9.63 |
| LC03 | Silty sand | 0.3 – 1.15 | Colluvium | 35.97 | ND3 | Grade 2 | 6.71 | 9.01 |
| LC06 | Sandy silt | 0.5 – 1.65 | Colluvium, part pedogenic | 43.26 | ND2 | Grade 3 | 6.92 | 9.26 |
| LC04 | Silty sand | 0.3 – 1.35 | Terrace gravels | 48.3 | ND2 | Grade 2 | 5.92 | 8.03 |

For the double hydrometer, the percentage dispersion results for all materials vary between 35% and 50% which is considered to represent an intermediate degree of dispersion (ASTM D4221, 2006).

The Pinhole Test results vary between ND2 and ND3, i.e. between non-dispersive and intermediate dispersivity (after Sherard, 1976).

The Crumb Test results alternated between grade 2 and Grade 3, i.e. between slight and moderate reactions (after Emerson, 1964).

In terms of the chemical tests, both the SAR (Sodium Adsorption Ration) as well as the ESP (Exchangeable Sodium Percentage) values indicate an ‘intermediate’ degree of dispersion, after Harmse (1980).

### 5.3.7 Rock material strengths

Opportunities for obtaining rock samples suitable for Uniaxial Compressive Strength (UCS) testing were extremely limited. Apart from the sample length requirements, which were at odds with the generally broken nature of the cores, the low strengths of these weak rocks were considered a major hurdle in sample preparation and the chances of the cores surviving the machining process were unlikely. As an alternative, selected core pieces were subjected to Point Load Strength (PLS) Testing. Furthermore, as a way around the limited number of samples, tests from both Lower Coerney as well as Upper Scheepersvlakte boreholes are considered jointly here. These results are presented below (**Table 5.15**).

The difficulties of obtaining accurate rock material strengths for very weak material are acknowledged, but from the above it is evident that the rocks are very weak. Assuming a typical conversion factor of 24 implies that these rocks have the equivalent uniaxial compressive strength values up to 1 MPa, and commonly less than 1 MPa.

### Table 5.15: Summarised Point Load strengths

| BH No | Depth (m) | Material description | Test type | $I_{s(50)}$ MPa |
|---|---|---|---|---|
| LC1 | 5.90 | Sandstone, highly weathered, fine-grained | axial | 0.01 |
| LC2 | 10.04 | Sandstone, highly weathered, coarse-grained | axial | 0.05 |
| LC4 | 6.38 | Sandstone, highly weathered, coarse-grained | axial | 0.01 |
| US1 | 10.85 | Sandstone, highly weathered, medium to fine-grained | diametral | 0.06 |
| US1 | 10.85 | Sandstone, highly weathered, medium to fine grained | diametral | 0.09 |
| US5 | 2.83 | Sandstone, highly weathered | axial | 0.03 |
| US4 | 8.74 | Siltstone, highly weathered | diametral | 0.03 |
| US4 | 8.74 | Siltstone, highly weathered | axial | 0.07 |
| LC2 | 12.92 | Mudstone, unweathered | diametral | 0.1 |
| LC3 | 19.80 | Mudstone, unweathered, carbonaceous | diametral | 0.03 |
| LC3 | 15.36 | Mudstone, unweathered | diametral | 0.03 |
| LC3 | 19.80 | Mudstone, unweathered, carbonaceous | axial | 0.11 |
| LC4 | 14.85 | Mudstone, unweathered, carbonaceous | axial | 0.09 |

# 6 Geotechnical considerations

The nearby Scheepersvlakte Dam, completed in 1990, provides a view of the typical structure layout being considered for the Lower Coerney site (and also for that matter the Upper Scheepersvlakte alternative). In addition, the conditions experienced and recorded in some detail, permit some parallels to be drawn between the current options.

## 6.1 Site suitability and founding conditions

The site is characterised by gently sloping flanks and a relatively wide river section. Ignoring for a moment the founding conditions, this topography places certain limitations on the favoured structure. The biggest influence on the favoured structure type would however be the founding geology.

The key characteristics of the geological conditions that impact on the selection of the favoured dam type may be summarised as follows;

- Variable soil cover,
- In particular, the presence of a mixed gravels in sandy matrix horizon at depth, across the entire footprint, as well as the reservoir area, and
- Weak bedrock comprising sandstones and mudstones, characterised by pervasive weathering.

The availability of suitable construction materials is a further important consideration; this is discussed in more detail below (Section 6.5 Construction materials), but is briefly referred to in this section. These topics are individually addressed below.

### 6.1.1 Topography

In terms of the topography, the ratio of crest length to the maximum height of the dam is a common consideration in dam type selection. For this Lower Coerney site the ratio is roughly 30, which already points to an embankment dam.

### 6.1.2 Soil horizons

Cumulative thickness of the various soil strata varies between just less than 3 m to almost 8 m. Soil cover appears shallowest on the right flank, extending into the river section, while on the left flank soil thicknesses are generally between 7 m and 8 m. The soil thickness solely is therefore not reason alone to translate into selection of a specific structure. Of significance in terms of the soil strata, however, is the presence of a gravel horizon at depth. This horizon blankets the entire site, including dam and spillway footprint as well as the basin area, and has implications for the dam type and also founding depths. Depths and thicknesses of this horizon are summarised below (**Table 6.1**). A view of in situ conditions as exposed with a test pit is shown below in **Plate 6.1**.

**Table 6.1: Gravel horizon, summarised depths and thickness (all metres)**

| BH no | Depth; upper boundary | Elevation (masl) | Depth; lower boundary | Elevation (masl) | Horizon thickness (m) | Comment |
|---|---|---|---|---|---|---|
| LC BH01 | 0.8 | 82.56 | 2.7 | 80.66 | 1.9 | Right flank<br>Coarser fraction comprises 20-40%; finer matrix not recovered |
| LC BH02 | 2.65 | 86.50 | 7.7 | 81.45 | 5.05 | Lower left flank.<br>Matrix typically lost, material recovery 40-90% therefore coarse fraction abundant |
| LC BH03 | 1.28 | 83.02 | 4.05 | 80.25 | 2.77 | Lower left flank<br>Matrix mostly lost, recoveries 20 – 100%; conclude variable coarse fraction |
| LC BH04 | 2 | 79.82 | 3.25 | 78.57 | 1.25 | River section<br>Matrix lost, recovery 30 – 50% |
| LC BH05 | 4 | 98.01 | 7.2 | 94.81 | 3.2 | Upper left flank / spillway crest<br>Coarse fraction a relatively minor component |
| LC BH06 | 5.45 | 84.53 | 6.7 | 83.28 | 1.25 | Left flank, mid spillway chute<br>Coarse fraction generally minor component but concentrated at base of horizon. |

When initially encountered in some test pits this gravel horizon was considered to represent an alluvial palaeo-channel, i.e. representative of an earlier river course, subsequently buried by younger sediments. On later reflection, with due consideration of the geological history and landscape evolution, and following completion of all the boreholes, this gravel horizon is considered more likely to represent reworked terrace gravels, rather than purely a palaeo-channel. The horizon is however not uniform. In general, the gravels and occasional cobble fraction are relatively minor, typically loosely packed components, and the silty sand matrix is dominant. In some instances, however, this gravel horizon is more ‘concentrated’, particularly on some parts of the lower flanks and within the current river section, and the coarser fraction, predominantly comprising gravels but also occasional cobbles and even rare boulders, is tightly packed, i.e. clast-supported. It is possible that within these lower elevations this concentration of the coarser fraction might be representative of palaeo-alluvial activity, i.e. at least partly represent palaeo-channels. On the upper flank area in particular, the coarse fraction is a minor component, and the fine fraction comprising silty sand dominates.

The significance of this stratum for the dam design is that these materials are potentially highly pervious, and in such cases would represent potential preferred seepage paths. This aspect, including the implications for excavation depths, as well as foundation treatment is discussed in more detail below.

**Plate 6.1: The gravelly layer as exposed within a test pit (this view test pit LC22); the boundary indicated by the dotted line**

Plate 6.2: Spoil from the same test pit, better illustrating the nature of the gravelly material.

### 6.1.3 Bedrock

As alluded to above, the soil horizons viewed in isolation do not represent the most decisive factor in determining the dam type. Considering the soil depths jointly with the bedrock conditions is however key in assessing the optimal dam type.

The gravelly horizon described above overlies the bedrock. As described above, the bedrock comprises a sequence of interbedded sandstones and mudstones, including fine grained silty sandstones. The degree of interbedding is variable throughout the sequence; certain strata would be either entirely sandstone or mudstone, but other horizons are recognised that they are either predominantly sandstone, with relatively minor mudstone interbeds, or vice versa. Aside from the lithological differences, the degree of weathering, together with the nature of the jointing are key influences on the overall bedrock conditions and therefore suitability as founding horizon.

Generally, the bedrock is characterised by pervasive weathering. For the most part the strata are highly weathered, i.e. the effects of the weathering are evident throughout the rock mass.

Typically, where the uppermost rock strata mainly comprise mudstones these are classified as highly to completely weathered, and where the uppermost bedrock horizon comprises sandstone these strata are generally highly weathered, although a thin layer of highly to completely weathered material is also recognised. The significance of the ‘completely weathered’ horizons is that these are approaching a soil in terms of appearance and behaviour. As a result, these upper sandstone strata comprise medium hard to very soft rock where completely weathered; even to sand in some instances. The upper mudrock horizons would generally comprise soft rock to very soft rock. More importantly, in places, the weathering has produced clay layers that vary in thickness from as little as 40 mm to as much as 300 mm[4]. Where an improvement in degree of weathering was noted at depth it is possible to define the thickness of the highly weathered strata; varying between 4.25 m and 11.6 m. With the shallow boreholes on the left flank the base of the highly weathered horizon was not intersected, and even in borehole LC BH01 on the right flank the base was not recorded with the minimum thickness therefore 13.3 m. With only two exceptions where boreholes intersected unweathered rock at the base (boreholes LC BH03 and LC BH04, respectively), any observed improvement in the degree of weathering was only gradational – generally to ‘moderate’ weathering, or occasionally moderately to slightly weathered. In both the above cases, this unweathered rock comprised mudstone / carbonaceous mudstone, albeit with minor interbedded sandstone strata in LC BH04.

### 6.1.4 Suitable dam types

The impact of the above discussion on most suitable dam type may be summarised as follows;

- The flat topography favours an embankment dam.
- The soil cover on its own is not a limiting factor, but the underlying bedrock comprises weak rocks. No suitable founding for a mass concrete gravity structure would be defined within shallow depths. It follows that an embankment structure would be optimal in terms of the prevailing founding conditions.
- Although not discussed above (but elaborated on in Section 6.5), the availability of potential construction materials in proximity to the site would dictate that an earthfill embankment is favoured, rather than a rockfill structure.

## 6.2 Excavation depths

The various elements of the envisaged embankment structure have different founding requirements, and these are discussed below. The key elements are listed as follows;

- The embankment, with the impervious core and the outer shell zones considered separately,
- The conduit, including intake and outlet,
- The spillway.

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[4] *Note these thicknesses are as recorded on the cores. These weak materials are however susceptible to being washed, i.e. lost, in the drilling process and the horizons thicknesses are not necessarily an accurate representation of actual in situ conditions.*

Typical foundation requirements for an earthfill embankment may be summarised as follows;

- For embankment outer shell zones,
  - A minimum required foundation Deformation Modulus of 0.2 GPa
- For the cut-off trench,
  - A minimum required foundation Deformation Modulus of 2 GPa
  - In addition, the cut-off would be founded on material that would be deemed groutable.

### 6.2.1 Embankment shell zones

For the embankment shell zones, it is reasonable to assume that foundation excavations will comprise removal of a nominal 300 mm to 500 mm, primarily to ensure the upper, potentially organic-rich, potentially compressible topsoil stratum is removed.

### 6.2.2 Embankment cut-off

For the cut-off trench, focusing entirely on the geotechnical profile and not considering the hydraulic requirements, the interpreted minimum excavation depths for the respective boreholes are summarised below (**Table 6.2**). The presence of the gravel-sand horizon within the soil profile is worth mentioning in terms of the decisions regarding depth of cut-off trench excavations. It is recognised that this horizon represents a potential pervious layer, albeit likely variably and that some areas might not be as pervious as others. This gravel-sand layer at its deepest is almost 8 m below surface, but in places only extends to depths of 3 m or 4 m. Such depths are not considered excessive, and special treatment is not considered necessary. Considering the potential seepage, and that the depths are not limiting, it is recommended that the cut-off extend, as a minimum, to the base of this gravel-sand layer.

Table 6.2: Summarised excavation depths for impervious cut-off trench

| BH No | Excavation depth (m) | Elevation (masl) | Rockhead depth | Comments |
|---|---|---|---|---|
| **Left flank** | | | | |
| LC BH05 | 7.2 | 94.81 | 7.2 | The principle of founding beneath the gravel layer implies an excavation depth of 7.2 m. However, this borehole is located on extreme upper flank area and cut-off depths of 7+ m are perhaps excessive. A shallower cut-off (say 3.5 – 4 m) may be considered, but this would terminate the cut-off within this potentially pervious gravel stratum. |
| LC BH06 | 6.7 | 83.28 | 6.7 | Borehole was drilled on spillway chute alignment but is considered here to be indicative of mid-left flank conditions. Founding beneath gravelly stratum would imply depths of almost 7 m. |
| LC BH02 | 7.8 | 81.35 | 7.7 | Found at 7.8 m i.e. below gravel -sand stratum of reworked terrace gravels. |
| LC BH03 | 4.6 | 79.70 | 4.05 | Found below gravel horizon. Remove uppermost bedrock horizon (thickness 0.55 m) to get beneath very soft rock horizon.<br>Might consider founding immediately beneath gravel soils, but rather remove uppermost horizon of very soft / soft rock / occasionally weathered to sand. |
| **River section** | | | | |
| LC BH04 | 5.5 | 76.32 | 3.25 | Possible to found at a minimum depth of 3.5 m but sandstone comprises very soft / soft rock and minor core losses recorded. Preferably found at a depth of 5.5 m. |
| **Right flank** | | | | |
| LC BH01 | 3.5 | 83.32 | 2,7 | Found within the upper, highly weathered sandstone stratum, but notably beneath the uppermost highly to completely weathered, very soft rock. |

*Note that the geological conditions are evaluated in all boreholes on the assumption that the respective boreholes are representative of conditions for the embankment – even though the individual borehole might have been drilled for a different purpose or is offset from the centre-line.*

### 6.2.3 Intake and outlet works

In general, the outlet works would comprise an intake structure, outlet pipes within a concrete encasement, and an outlet structure. Boreholes LC BH02 and LC BH03 were drilled at the intake and outlet positions respectively, while the conditions in the central portion of the conduit may be extrapolated from borehole LC BH04. The geological profiles are described above (Sections 5.2.2 and 5.2.1). Implications for the founding of these structures are summarised below (**Table 6.3**).

Table 6.3: Summarised excavation depths for outlet works

| BH No | Excavation depth (m) | Elevation (masl) | Thickness of gravel sand stratum (m) | Rockhead depth | Comments |
|---|---|---|---|---|---|
| LC BH02 (intake) | 2.7 | 86.45 | 5.0 | 7.7 | Founding on gravel -sand stratum of reworked terrace gravels.<br>SPT N-value = 43 at depth 2.64 m |
| LC BH03 (outlet) | 1.3 | 83.00 | 2.7 | 4.05 | Found on gravel-sand horizon.<br>No SPT test. |
| LC BH04 | 2.0 | 79.82 | 1.25 | 3.25 | Found at 2 m depth on gravel sand stratum.<br>SPT N-value 66 at depth 1.95 m. |

A Standard Penetration Test (SPT) was conducted in borehole LC BH02, at a depth of 2.64 m, i.e. within the horizon of reworked terrace gravels. On the face of it the (single) result of N = 43 suggest dense soils, with an associated allowable bearing capacity of approximately 200 kPa. Another SPT test in borehole LC BH04 yielded an N-value of 66 at a depth of 1.95 m, similarly suggesting allowable bearing capacities in excess of 350 kPa. Some caution must be attached to blindly accepting these values, due to the presence of medium to coarse gravels within the tested horizon and the uncertainty whether the test results are truly representative or might reflect skewed data from interception of these boulders / gravels.

A key element of founding of the outlet works (intake structure, conduit as well as outlet structure) would be the occurrence of highly variable conditions that might have implications in terms of foundation characteristics, notably the possibility of differential settlement. The reworked gravel-sand stratum is present over the entire footprint and in that sense the founding conditions might be considered relatively uniform, which would mitigate against the possibility of differential settlement. Note that the excavation depths (and founding levels) reflected above in Table 6.3 do not consider inlet and outlet design levels or conduit design gradient. Such optimisation will be carried out in the design phase and will have implications for final excavation depths within this gravel-sand stratum.

### 6.2.4 Spillway

Only two boreholes (LC BH05 and LC BH06) provide confirmation of the geological profile along the spillway alignment. Borehole LC BH05 is located at a position corresponding roughly with the spillway ogee, while borehole LC BH06 is located roughly midway along the chute. No borehole is located at the end of the spillway, but test pit LC12 exposed the upper soil profile.

It is assumed that the spillway ogee section will comprise a mass concrete, gravity structure. The spillway chute will have to be concrete-lined, as discussed below (Section 6.4).

The mass concrete gravity ogee spillway structure cannot be founded at depths shallower that 7.2 m, i.e. the structure cannot be founded on the soil horizons, but must be founded on the underlying bedrock as a minimum. Bedrock was intersected at a depth of 7.2 m, and comprises very soft to soft rock, predominantly mudstone with subordinate sandstone. The borehole was terminated at 10 m, and the extent to which the bedrock condition improves with depth is uncertain. The uppermost bedrock horizon should also be removed prior to concrete placement, in order to remove the weakest material. It should be noted that the mudstone will be susceptible to slaking; Excavation and foundation preparation cycles will have to allow for near-immediate protection of the exposed rock surfaces, typically by casting of a blinding layer immediately following cleaning of the rock surface.

For the remainder of the chute, the same principle will be followed for determination of the founding depths; i.e. that the soil strata must be removed and that the concrete-lining be founded on the underlying bedrock. In places this bedrock will comprise mudstone, and in other areas the rock will be sandstone.

At this stage there is no confirmation of actual bedrock conditions at the end of the spillway. It is however a reasonable assumption that underlying bedrock will comprise weak strata that would be susceptible to erosion. It goes without saying that appropriate energy dissipation must be incorporated at the end of the spillway lining, and that measures must be incorporated to prevent undercutting of the concrete.

## 6.3 Foundation permeability and foundation treatment

The chief concern regarding foundation permeability is linked to the presence of the gravel–sand horizon, which is known to be present across the entire dam footprint. If left ‘untreated’ there would be a risk of this stratum functioning as a ‘buried channel’ or preferential seepage path beneath the embankment. The consequences could then potentially be manifested in the form of uncontrolled seepage and the inability of the reservoir to fill and, in the worst case, internal erosion and failure.

Consideration of likely scenarios relating to seepage within the horizon of reworked terrace gravels has been addressed at a high level by GWA Consulting Hydrogeologists cc (see Appendices). This evaluation was also in the context of the potential for sub-surface seepage occurring in a northerly direction, that might be cut-off by the dam, and create future problems in terms of shallow water tables downstream of the dam. The key points of this evaluation can be summarised as follows;

- Groundwater hydraulic gradients are steep, with low permeability.
- The hydraulic gradients show sub-surface seepage in a southerly direction (downstream).
- With the filling of the reservoir it is expected that these gravels will become saturated over time. Actual flow rates are unconfirmed, but with the knowledge that these reworked terrace gravels are variable, it can be assumed that general seepage rates will be low, but zones of higher seepage flows cannot be excluded.
- With the dam cut-off extending through this gravel layer into the underlying bedrock, it can be assumed that the reservoir will not impact on the geo-hydrological regime downstream of the dam.

The indicated excavation depths for the cut-off (Table 6.2) have been defined on the basis of ensuring that this potential seepage path, represented by the gravel–sand stratum, is cut off.

Limited water pressure (packer) tests were carried out within the underlying bedrock to assess the rock permeability. These results are presented on the detailed borehole logs (Appendix B) and are summarised below (**Table 6.4**).

The results of the water acceptances tests in some boreholes indicate some significant losses. These instances are presumed to be associated with weathered zones within the rock mass that are typically associated with material losses. The occurrence of such losses is indicative of very weak material that is ground by the drilling action, and subsequently lost to the circulating drilling fluid. This assumed mechanism is supported by interpretation of the water acceptance test data; specifically, the relationship between the applied pressures and the measured water losses (after Houlsby, 1976). The significance of these losses lies in the possibility that they reflect the potential for erosion damage to the founding rock mass under conditions of seepage and high hydraulic gradients.

If the jointed founding rock mass was characterised by open joints with hard wall rock, for example, the foundation would be considered ‘groutable’, and foundation treatment comprising foundation grouting (compaction and/or curtain grouting) could be readily specified. In the case of these weathered, weak rocks, which evidently are susceptible to wash out, and are further characterised by interbedded mudstones, which in places are weathered to clays, the ‘groutability’ of the rock mass is more questionable.

**Table 6.4: Summarised Water Acceptance (Packer) Test results**

| BH No | Test section (depths in m) | Lugeon (UL) value | Comment |
|---|---|---|---|
| LC BH02 | 7.5 – 10.97 | 64 | Wash out. Weathered zones in mudrock likely origin |
| | 11 – 13.97 | 12 | Wash out. Ascribed to weathered zones which are associated with material losses |
| | 14 – 16.97 | 0 | Tight |
| | 17 – 20.45 | 35 | Turbulent flow. Prominent weathered zone in the sandstone that is associated with prominent staining, and therefore assumed to represent a seepage path. |
| LC BH03 | 4.5 – 7.65 | 0 | Tight |
| | 7.5 – 10.58 | 15 | Wash out. No obvious link identified in the core logging. |
| | 10.5 – 12.59 | 1 | Dilation / tight |
| | 12.5 – 13.36 | 0 | Tight |
| | 15.5 – 18.59 | 0 | Tight |
| | 18.5 – 20.43 | 0 | Tight |
| LC BH04 | 4 – 7.78 | 0 | Tight |
| | 7.5 – 10.94 | 13 | Wash out. Ascribed to local highly weathered zones, associated with significant material losses. |
| | 11 – 13.94 | 0 | Tight |
| | 13.5 – 15.04 | 0 | Tight |

It is understood that no foundation grouting was carried out for Scheepersvlakte Dam.

## 6.4 Erodibility

The question of erodibility of these weak rocks has specific bearing on the spillway chute. Two shallow boreholes were drilled to investigate the ground profile in this area on the left flank, namely boreholes LC BH05 and LC BH06. No borehole was drilled at the end of the chute.

While steps for a detailed appraisal of the erodibility can be followed, some points of logic are pertinent;

- The soil horizons would offer no resistance to erosion and would clearly be washed away in the case of an earth channel. The silty to clayey sands extend to respective depths of 6.7 m and 7.2 m in the two boreholes. The basal soil stratum comprises the gravel-sand reworked terrace deposits and even this material is considered to be erodible.
- Within these boreholes the rockhead was intersected at these respective depths of 6.7 m and 7.2 m.
- The upper bedrock horizon either comprises completely weathered, becoming highly weathered sandstone or interbedded sandstone / mudstone, or highly and occasionally weathered mudstone with subordinate sandstone. Irrespective of the lithology, the bedrock comprises weak rock. The mudstones in particular are considered susceptible to slaking.

- A rock mass exposed to the elements would therefore deteriorate over time as the mudstones, or mudstone interbeds, disintegrate (slake). Repetitive cycles of exposed rock disintegrating, and the resulting fine fraction being eroded means that any resistance to erosion is only temporary. The process would even affect a strong rock mass, and in the case of these already weak rocks, the slaking process would simply impact further on rock which is considered to be erodible.

From the above points, it is evident that an unlined spillway chute is not practical or feasible. A concrete lining of the entire length of the spillway chute is necessary in order to prevent erosion; as constructed for the Scheepersvlakte Dam.

There is at this stage, no confirmation of the geological profile at the end of the spillway. All information suggests conditions will be characterised by soil deposits – possibly of quite substantial thickness - overlying weak, erodible rocks. Consideration will have to be given to sufficient energy-damping at the end of the concrete chute, at the point where the water will be released into the river channel.

## 6.5 Construction materials

It has been stated above (Section 6.1) that the availability of suitable construction materials in proximity to the dam site is a major factor in considering the most suitable structure. Considering that the prevailing conditions favour an embankment dam, the following materials would be required;

- Embankment fill materials, including general fill and impervious core materials,
- Rip-rap for upstream slope protection,
- Concrete aggregates, including coarse aggregate, as well as sand (fine aggregate), for the concrete elements, including the concrete spillway chute, spillway ogee, intake, conduit as well as outlet works.
- Sand for use in filters.
- Other materials that would be required would include materials for roads construction. This aspect is not addressed.

### 6.5.1 Embankment fill materials

The existing Scheepersvlakte Dam comprises a homogeneous earthfill structure, with various filters, as recorded in the Completion Report (DWA, 1988). The structure includes a cut-off trench, but there is apparently no impervious core. The initial design envisaged a conventional zoned embankment with an impervious core, and shell zones of semi-pervious material. The shortage of semi-pervious material within the basin, however, led to a change in design to a homogeneous embankment.

The following earthfill specifications (**Table 6.5**) were stated in the design report for Scheepersvlakte Dam (DWA, 1988).

**Table 6.5: Scheepersvlakte Dam, homogeneous earthfill specifications (DWA, 1988)**

| **Grading analyses** | | | |
|---|---|---|---|
| Sieve size | % passing | | |
| | **Maximum** | **Minimum** | **Mean** |
| 4.75 | 100 | 45.7 | 89.8 |
| 2.00 | 100 | 37.0 | 86.7 |
| 0.425 | 99.2 | 29.2 | 80.9 |
| 0.150 | 93.9 | 220 | 71.0 |
| 0.050 | 70.0 | 10.8 | 46.3 |
| 0.005 | 48.6 | 00 | 19.3 |
| 0.002 | 40.7 | 0.0 | 16.9 |
| **Atterberg limits** | | | |
| | **Maximum** | **Minimum** | **Mean** |
| Liquid limit (%) | 43.0 | 20.0 | 34.2 |
| Plastic limit (%) | 29.1 | 11.9 | 18.4 |
| Plasticity Index | 25.0 | 4.0 | 15.8 |
| Linear shrinkage (%) | 10.7 | 1.3 | 7.6 |
| **Compaction (Std Proctor)** | | | |
| | **Maximum** | **Minimum** | **Mean** |
| Maximum dry density (kg/$m^3$) | 1884 | 1542 | 1736 |
| Optimum moisture content (%) | 24.2 | 10.8 | 16.3 |
| **Direct shear** | | | |
| | **Maximum** | **Minimum** | **Mean** |
| Angle of internal friction (°) | 45.0 | 19.4 | 35.4 |
| Cohesion (kPa) | 153.3 | 9.29 | 18.8 |
| **Triaxial shear** | | | |
| | **Maximum** | **Minimum** | **Mean** |
| Angle of internal friction (°) | 44.8 | 23.6 | 31.7 |
| Cohesion (kPa) | 40.0 | 0.0 | 15.5 |
| **Coefficient of permeability (cm/sec)** | | | |
| | **Maximum** | **Minimum** | **Mean** |
| | 4.1 x $10^{-5}$ | 1.6 x $10^{-8}$ | 1.1 x $10^{-6}$ |
| **Relative density** | | | |
| | **Maximum** | **Minimum** | **Mean** |
| | 2.75 | 2.50 | 2.65 |

The proximity of the Scheepersvlakte Dam to this proposed Lower Coerney site means that certain lessons learnt would be of value to construction of the Lower Coerney dam.

The material properties confirmed in these investigations are tabulated below and compared to typical requirements for the main elements of a zoned earthfill structure, i.e. the impervious core (**Table 6.6**) and the outer shell zones (**Table 6.7**), respectively.

**Table 6.6: Summarised material properties and comparison against typical requirements (impervious core), after Badenhorst, 1988**

| Parameter | Criteria | Material types | | | | |
|---|---|---|---|---|---|---|
| | | Alluvium | Colluvium | Colluvium / partly pedogenic | Pedogenic | Other |
| Grading | >60% passing 0.425 mm sieve | 29 to 97% (3) | 94 – 95% (3) | 45 – 98% (5) | 40 – 91% (2) | 85 – 89% (2) |
| Clay % | 10<%<30 | 0 to 1% (3) | 0 to 1% (3) | 0% (5) | 0 to 1% (2) | 0 to 4% (2) |
| Liquid Limit % | 30<LL<60 | 17 to 49% (3) | 15 to 19% (3) | 21 to 37 % (5) | 31 to 39% (2) | 15 to 39% (2) |
| Plasticity Index % | 12<PI<35 | 7 to 20% (3) | 3 to 7% (3) | 7 to 19% (5) | 10 to 20% (2) | 5 to 18% (2) |
| Linear Shrinkage % | 4<LS<10 | 3.5 to 10.0% (3) | 1.5 to 3.5% (3) | 3.5 to 9.5% (5) | 5 to 10% (2) | 2.5 to 9% (2) |
| Maximum Dry Density $kg/m^3$ | 1450<MDD<1880 | 1868 (1) | 1826 – 1857 (2) | 1676 – 1759 (2) | 1522 – 1739 (2) | 1617 (1) |
| Optimum moisture content omc % | 14<omc<25 | 12.7 (1) | 11.1 – 11.7 (2) | 17.8 – 18.9 (2) | 21.7 – 22.6 (2) | 23.8 (1) |
| Shear Strength kPa | 12<kPa<24 | | 33.4 to 38.1 (4) | 40.9 to 41.6 (2) | 33.9 to 35.7 (2) | 32.8 (1) |
| Friction angle | $18<\Phi°<30$ | | 18.3 to 20.2 (4) | 21.4 to 24.7 (2) | 20.2 to 24.8 (2) | 23.3 (1) |
| Permeability *k* cm/s | $<1 \times 10^{-4}$ | $3.16 \times 10^{-6}$ (1) | $1.84 \times 10^{-7}$ to $2.31 \times 10^{-7}$ (2) | $4.11 \times 10^{-9}$ to $3.72 \times 10^{-8}$ (2) | $2.62 \times 10^{-9}$ to $1.88 \times 10^{-8}$ (2) | |

*Where numbers of samples are shown in brackets. Note also the stated maximum PI by Badenhorst (1988) is considered too high.*

To facilitate easy comparison where material properties fall outside the broadly-stated objectives, the relevant cells in the above table (Table 6.6) have been highlighted.

The following comments summarise broad observations in respect of the suitability of the local materials for use in the impervious core;

- In terms of the material grading, the clay contents are very low. This applies across the spectrum of materials on the footprint and the basin area. The percentages passing the

0.425 mm sieves typically show significant scatter, and although ‘flagged’ in the above table as non-compliant, for the most part, the gradings are compliant and only occasional anomalous values are recorded.

- Considering the Atterberg limits, the results again show some scatter, commonly reflecting results falling outside the requirement on the low side specifically, but at the same time the results show scatter extending into the ‘acceptable’ range.
- The standard Proctor compaction results show general compliance, but occasional values for the optimum moisture contents are too low.
- The shear strength data shows the respective materials all exhibit greater shear strengths than required, while the friction angles comply with the requirements.
- In spite of the almost non-existent clay fraction in all soil types, the measured permeabilities all show relatively impervious materials, well within the range required.

It would be pertinent to note lessons from construction of Scheepersvlakte Dam, notably in terms of the required moisture content (DWAF, 1992). As a result of the relatively high moisture requirements (for the homogeneous fill), coupled with the high clay content, construction difficulties were experienced. The high required optimum moisture contents also resulted in compaction problems.

**Table 6.7: Summarised material properties and comparison against typical requirements for outer shell zones (after Badenhorst, 1988)**

| Parameter | Criteria | Material types | | | | |
|---|---|---|---|---|---|---|
| | | Alluvium | Colluvium | Colluvium / partly pedogenic | Pedogenic | Other |
| Grading | >40% passing 0.425 mm sieve | 29 to 97% (3) | 94 – 95% (3) | 45 – 98% (5) | 40 – 91% (2) | 85 – 89% (2) |
| Clay % | <10% | 0 to 1% (3) | 0 to 1% (3) | 0% (5) | 0 to 1% (2) | 0 to 4% (2) |
| Liquid Limit % | LL <30 | 17 to 49% (3) | 15 to 19% (3) | 21 to 37 % (5) | 31 to 39% (2) | 15 to 39% (2) |
| Plasticity Index % | 4< PI<12.5 | 7 to 20% (3) | 3 to 7% (3) | 7 to 19% (5) | 10 to 20% (2) | 5 to 18% (2) |
| Linear Shrinkage % | 0<LS<7 | 3.5 to 10.0% (3) | 1.5 to 3.5% (3) | 3.5 to 9.5% (5) | 5 to 10% (2) | 2.5 to 9% (2) |
| Maximum Dry Density kg/m$^3$ | 1750<MDD<2100 | 1868 (1) | 1826 – 1857 (2) | 1676 – 1759 (2) | 1522 – 1739 (2) | 1617 (1) |
| Optimum moisture content omc % | 6<omc<16 | 12.7 (1) | 11.1 – 11.7 (2) | 17.8 – 18.9 (2) | 21.7 – 22.6 (2) | 23.8 (1) |
| Shear Strength kPa | kPa<12 | | 33.4 to 38.1 (4) | 40.9 to 41.6 (2) | 33.9 to 35.7 (2) | 32.8 (1) |

| Parameter | Criteria | Material types | | | | |
|---|---|---|---|---|---|---|
| | | Alluvium | Colluvium | Colluvium / partly pedogenic | Pedogenic | Other |
| Friction angle | $28<\Phi°<38$ | | 18.3 to 20.2 (4) | 21.4 to 24.7 (2) | 20.2 to 24.8 (2) | 23.3 (1) |
| Permeability *k* cm/s | $>1 \times 10^{-4}$ | $3.16 \times 10^{-6}$ (1) | $1.84 \times 10^{-7}$ to $2.31 \times 10^{-7}$ (2) | $4.11 \times 10^{-9}$ to $3.72 \times 10^{-8}$ (2) | $2.62 \times 10^{-9}$ to $1.88 \times 10^{-8}$ (2) | |

*Where numbers of samples are shown in brackets.*

As per the above table, the shading of the cells has been applied to highlight where the material properties are not fully compliant with the requirements for a typical outer shell zone.

A broad summary of the general material suitability for use in the outer shell zones can be presented as follows;

- The grading is generally satisfactory in that the fraction passing the 0.425 mm sieve is greater than 40%. Where the typically absent clay fraction is a difficulty for an impervious core, the negligible clay content favours use in these outer shell zones (but the important permeabilities must be noted).
- The Atterberg limits show some scatter, but some properties fall within specification. Some Liquid Limit values are too high, as are Plasticity Index values and some Linear Shrinkages.
- In terms of the compaction characteristics, the alluvial and colluvial materials are typically compliant, but where there is some pedogenic material present the dry densities may be too low, and the optimum moisture contents too high.
- As before the shear strengths are very high, i.e. even greater than required. Friction angles are typically too low.
- Very low permeabilities were recorded, and this is seemingly at odds with the grading analyses, in particular, the negligible clay contents.

By way of a general conclusion regarding the suitability of the local soils for use in embankment construction, specifically for the impervious core and outer shell zones, it is evident that further investigation of the various material sources would be required to accurately define specific borrow areas. The various soil types that might be considered show some scatter in material properties and better definition of the usable areas would be required, coupled with stringent field control and compliance testing. Current investigations were limited in extent and were further restricted to the dam footprint and limited points within the reservoir area. Greater coverage is necessary for follow-up investigations, and it might also be necessary to extend these beyond the confines of the reservoir.

### 6.5.2 Filter sands

Sands suitable for use in the various filter zones are not readily available in the general area of the proposed Lower Coerney site. This is also borne out by experiences during construction of the Scheepersvlakte embankment. No sources of natural sand for use in the filters could be identified. Initially, the manufactured crusher sand was used, but there were limitations due to the crusher being required to produce coarse aggregate. Subsequently, a number of options were explored whereby various sources of sands were mixed with crusher run from a number of commercial crushers. Such products were hauled from as far afield as Patterson, or the Uitenhage district, some 40 km away.

### 6.5.3 Coarse aggregate for concrete

Current investigations did not actively target the proving of potential hard rock sources that might be crushed to produce coarse aggregate. Certainly, there are no expectations for such potential sources within the Lower Coerney basin. Even in the general area of the Lower Coerney site and the Lower Sundays River valley in general, the chances of identifying a suitable source of coarse aggregate are considered to be remote. The general geology comprises weak sandstones and mudstones or siltstones which are not associated with crushed aggregates. The volumes of concrete required would be quite limited, however, and it is most likely that coarse aggregate requirements would be met from commercial sources.

## 6.6 Stability of cut slopes

Construction activities will result in temporary cut slopes, for instance for the cut-off trench, but also for the intake, conduit and the outlet works, as well as for the spillway ogee and chute excavations. These excavated faces within the soil horizons might be as deep as 8 m.

The gravel–sand stratum of reworked terrace gravels is of particular concern in terms of the stability of cut slopes. Where the cut slopes intersect this horizon, there is a likelihood that ravelling and spalling will occur within these gravel soils. This can result in undercutting of the overlying strata, and an associated risk of slope failure. The stability of these horizons will be further compromised when wet. Excavation within these gravels also carries the risk that removal of the coarser fraction can result in further disturbance of the stratum, and due care is called for in these instances.

All slopes must be cut to safe angles, and/or shored as appropriate; particular attention must be paid to the gravel–sand horizons as described above. It is essential that these safe slope angles for these cut faces be verified by a suitably qualified and experienced geotechnical practitioner.

## 6.7 Reservoir basin slope stability

The slopes defining the reservoir basin are characteristically very gently sloping. There are consequently no concerns regarding the possibility of catastrophic failure of the reservoir slopes to the extent of being a risk to the structure.

# 7 Conclusions and Recommendations

## 7.1 Site comparatives

This report presents the findings of the ground investigations conducted at the Lower Coerney dam site. It is noted however that this site is one of two alternative potential sites. While the findings of the alternative Upper Scheepersvlakte site are presented in a separate report, the key elements of both sites are summarised below (**Table 7.1**) in order to facilitate geotechnical comparison between these respective sites.

It is acknowledged that selection of the favoured option is dependent on a multitude of factors; Table 7.1 below however only summarises the geological / geotechnical factors. Consideration of the other factors is beyond the scope of this geotechnical report.

**Table 7.1: Summarised geotechnical factor comparisons**

| Geological factors | Upper Scheepersvlakte | Lower Coerney |
|---|---|---|
| **General geology** | Underlain by strata of the Sundays River Formation, Uitenhage Group, comprising consists of thin grey sandstones, siltstones and mudrocks. | Underlain by strata of the Sundays River Formation, Uitenhage Group, comprising consists of thin grey sandstones, siltstones and mudrocks. |
| **Geological profile; dam footprint** | ***Left flank;*** soils to 0.8m; very soft rock sandstone / dense residual soils to 5 m; very soft to soft rock sandstone / interbedded mudstone from 5 m; from 11.2 m medium hard rock sandstone.<br>***Central section*** (conduit – intake and outlet)<br>*Intake* = topsoil to 0.35m; sandy soils with some gravels to 11.1m; soft rock sandstone from 11.1m; medium hard rock sandstone from 11.5m<br>*Outlet* = Soils to 7.7m (with some gravels in places); soft to very soft rock (to clay) alternating sandstone / mudstone from 7.7m, becoming soft rock / medium hard rock from 10.1<br>***Right flank;*** soils to 3.5m; gravel horizon to 5 m; bedrock from 5 m, very soft rock mudstone to stiff clay to 5.65m; very soft to soft rock interbedded mudstone from 5.65m. | ***Left flank;*** (upper), soils to 7.2m (including horizon of gravelly soils 4 – 7,2m); very soft rock mudstone, subordinate sandstone from 7.2m.<br>***Central section*** (conduit – intake and outlet)<br>*Intake*; sandy soil to 2.65m; gravelly soils to 7.7m; soft to very soft rock (occasionally to clay) mudstone from 7.7m; medium hard to hard rock interbedded mudstone / sandstone from 9.8m.<br>*Outlet*; sandy soil to 1.3m; gravel-sand horizon to 4m; very soft to soft rock sandstone from 4m; soft to medium hard rock sandstone interbedded mudstone from 4.6m; hard rock sandstone from 12m.<br>*Central section*; sandy soils to 2m; gravelly horizon to 3.25m; soft to very soft rock sandstone from 3.25m; medium hard rock sandstone from 5.5m; hard rock sandstone from 7.5m; mudstones more prominent from 11m.<br>***Right flank***; topsoil to 0.8m; gravelly horizon to 2.7m; highly weathered, medium hard to soft rock from 2.7 m. Interbedded sandstones, mudstones. |
| **Founding considerations** | In terms of cut-off, a horizon is recognised at depth, across the footprint except on upper left flank, comprising rounded gravels in a sandy matrix, interpreted as reworked terrace gravels. This horizon is conservatively considered a potential seepage path, and the cut-off depths are to intersect this.<br>In places the upper bedrock horizons prove to be pervious, but groutability will be questionable. | A gravelly horizon (1.2 to 5 m thick) is recognised which occurs across the footprint; considered to represent reworked terrace gravels. Note however the horizon is variable. Mostly the matrix was not recovered, but this stratum represents a potential preferred seepage path (a buried channel). Cut-off design is to consider this feature. |
| **Excavation depths** | For **cut -off**, while depths of a nominal 1.5m on the upper left flank (takes to weathered bedrock) might be considered, a depth of 5 m would be more consistent with an estimated 5 m on mid left flank (ensuring the cut-off extends beneath the | For the **cut-off**, on extreme / uppermost left flank, the principle of excavating to base of alluvial gravels implies a depth up to 7.2m, maybe some relaxation allowed on extreme upper flank.; in central section assume minimum depth of 5.5m but note |

| Geological factors | Upper Scheepersvlakte | Lower Coerney |
|---|---|---|
| | gravel-sand stratum), in central portion the cut off will be deeper, at least to 8 m but in places maybe up to 11 m; to depths of to 35m on mid-to upper right flank. | some variability; on mid right flank consider minimum depth of 3.5m (below gravel layer). |
| **Foundation treatment** | Items to consider would be durability of exposed mudrocks (would need to cover almost immediately on exposure).<br>Permeability of rock mass and therefore need for treatment uncertain (or whether grouting of these weathered rocks would even be successful). | Mudrocks are susceptible to slaking; provision must be made for immediate protection after exposure.<br>As above re presence of potential 'buried channel'; must ensure cut-off intersects this stratum.<br>Permeability of rock mass is generally very low / tight, but instances of wash-out of softer strata are recorded. The 'groutability' of these weathered rocks is however uncertain.<br>At face value the outlet conduit could likely be founded on the gravel-sand stratum, but this does not consider required founding levels. |
| **Spillway; geological profile** | Upper spillway (near ogee / sill); topsoil to 0.35m; very soft rock / medium hard rock at 1.2 m. Sandstones and interbedded mudstones.<br>Lower spillway; Soils to 3.35 m; very soft rock from 3.35 m. Sandstone with interbedded mudstone. | Upper spillway (near ogee / sill); soils to 4 m; gravelly soil horizon to 7.2 m; very soft / soft rock (mainly mudstone, subordinate sandstone) from 7.2 m.<br>Lower spillway (actually midway); soils to 5.45 m; gravelly soils to 6.7 m; very soft rock sandstone (sand in places) from 6.7 m; interbedded sandstone / mudstone from 8 m. |
| **Spillway considerations** | Weak bedrock, with mudstone interbeds. Assume erodible and that full concrete lining will be required. For ogee, assume founding of the mass concrete gravity structure at 5 m. | Soils underlain by weak bedrock that would be susceptible to erosion. Assume full concrete lining is required. No deep information at end of spillway, but appropriate energy dissipation is necessary. |
| **Reservoir slopes** | Natural slopes are essentially flat / gently sloping; no slope stability issues foreseen. | Natural slopes are essentially flat / gently sloping; no slope stability issues foreseen. |
| **Construction materials** | Limited testing of materials in basin indicates general compliance of local materials for use in impervious core; albeit with some scatter (particular with gradings). These materials are typically non-compliant with typical requirements for outer shell zones (or show wide scatter).<br>Other materials like coarse aggregate and filter sands / fine aggregate will have to be imported. | Materials for the impervious core and the outer shell zones will generally be available in broad proximity to the dam and reservoir basin. The local soils show general compliance with typical material requirements but with some scatter – particularly for outer shell zones, and more work is required to define borrow areas. Other materials like coarse aggregate and filter sands / fine aggregate will have to be imported. |

## 7.2 Follow-up investigations

Ground investigations conducted to date have been conducted at feasibility-level to provide inputs into preliminary design. As such the geotechnical information would not be sufficient for detail design, particularly if there are some design changes, and further geotechnical investigations will be necessary at the favoured site.

Current investigations were severely constrained by the limited access due to the dense bush, and importantly understandable environmental restrictions on permissible bush-clearing. With a decision regarding selection of the favoured site, together with the necessary approvals, it is expected that it will be possible to gain more access to the footprint as well as the greater reservoir area.

Particular geotechnical aspects that would need to be addressed in follow-up design-level investigations include, but not be limited to, the following;

- Additional confirmation of the general founding conditions, particularly the continuity (both laterally and vertically) of the conditions as understood from the currently limited boreholes. Deep trenches might be considered for final verification of the actual founding conditions.
- Founding conditions at the end of the spillway. Current assumptions are that weak, weathered rock will be intersected, and appropriate design of the stilling basin would require verification of the actual conditions and overburden thicknesses.
- Actual borrow areas preferably located within the reservoir basin need to be defined. Current investigations have indicated many of the soils would be suitable for use either as impervious core, or outer shell zones, but there is still some scatter. Further investigations will be necessary to provide greater assurance of actual borrow areas that define materials satisfying the specifications. Such investigations would comprise an extensive fieldwork programme, backed up by laboratory testing. Other materials including filter sands and coarse aggregate will have to be sourced commercially.
- The geohydrological characteristics of the identified gravel-sand horizon need to be better understood; in particular the potential negative effects of seepage via this stratum.

It is premature at this stage to address construction stage geotechnical activities in any detail, but the following might be borne in mind;

- Involvement of a geotechnical specialist during construction is essential. Activities would include regular inspection of all excavated faces and cut slopes from a stability point of view, oversight of any further geotechnical exploration and quality assurance testing, engineering geological mapping of the cut-off trench and recording of the as-built details, etc.
- One of the first actions on establishing a contractor would be the controlled backfilling of all investigations points (boreholes and test pits that are located on the dam footprint.

# 8 Report limitations

1. Aurecon Ground Engineering (Tshwane) has prepared this report for the use of our Client, Department of Water and Sanitation (DWS). The report has not been prepared for use by parties other than the Client, and the Client's respective consulting advisors.
2. This report has been written with the express intent of providing sufficient information for Preliminary Design purposes. The geotechnical investigation has been conducted in accordance with accepted practice, and the opinions and conclusions expressed are made in good faith, based on the information available to the Ground Engineering team of Aurecon (Tshwane) at the time of preparing this report.
3. There are always some variations in subsurface conditions across a site due to geological conditions that cannot be defined fully even by exhaustive investigation. Hence, it is possible that the measurements and values obtained during the investigation may not represent the extremes of conditions which exist within the site. The precision with which subsurface conditions are identified depends on the method of drilling, the frequency and recovery of samples, the method of sampling, and the uniformity of the subsurface conditions. Subsurface conditions may therefore vary from the conditions encountered in the test pit / borehole locations.
4. The borehole logs and test pit profiles represent the subsurface conditions at the specific test location only. Boundaries between zones on the logs are often not distinct, but rather are transitional and have been interpreted. The soil descriptions in this report are based on accepted methods of classification and identification employed in geotechnical practice, as stated in this report. Classification and identification of soil involves judgement, and the Aurecon Ground Engineering infers accuracy in the classification and identification methods to the extent that is common in current geotechnical practice, and within the limitations of the ground investigation that was performed.
5. Furthermore, subsurface conditions, including groundwater levels can change over time. The groundwater conditions described in this report refer only to those observed at the place and time of observation noted in the report. These conditions may vary seasonally or as a consequence of construction activities in the area. This should be borne in mind, particularly if the report is used after a protracted delay or a period of protracted climatic conditions.
6. Should conditions exposed at the site during subsequent investigation or construction works vary significantly from those provided in this report, we request that Aurecon (Tshwane) Ground Engineering be informed and have the opportunity to review any of the

findings or conclusions of this report. It is highly recommended that during construction the site conditions be inspected by a representative of Aurecon Ground Engineering to confirm the geotechnical conditions and interpretations as well as recommendations in this report.

Note: the above list of limitations should be considered a live document, subject to amendment over time. This serves to highlight specific limitations and risks to the Client. These listed limitations are not protection against substandard work.

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# Appendix A:
# Summary of soil and rock description terminology

# STANDARD DESCRIPTIONS USED IN SOIL PROFILING

## 1. MOISTURE CONDITION

| Term | Description |
|---|---|
| Dry | |
| Slightly moist | Requires addition of water to reach optimum moisture content for compaction |
| Moist | Near optimum content |
| Very Moist | Requires drying to attain optimum content |
| Wet | Fully saturated and generally below water table |

## 2. COLOUR

The Predominant colours or colour combinations are described including secondary coloration described as banded, streaked, blotched, mottled, speckled or stained.

## 3. CONSISTENCY

### 3.1 Non-Cohesive Soils

| Term | Description |
|---|---|
| Very Loose | Crumbles very easily when scraped with geological pick |
| Loose | Small resistance to penetration by sharp end of geological pick |
| Medium Dense | Considerable resistance to penetration by sharp end of geological pick |
| Dense | Very high resistance to penetration to sharp end of geological pick. Requires many blows of hand pick for excavation. |
| Very Dense | High resistance to repeated blows of geological pick. Requires power tools for excavation |

### 3.2 Cohesive Soils

| Term | Description |
|---|---|
| Very soft | Easily penetrated by thumb. Sharp end of pick can be pushed in 30 - 40mm. Easily moulded by fingers. |
| Soft | Pick head can easily be pushed into the shaft of handle. Moulded by fingers with some pressure. |
| Firm | Indented by thumb with effort. Sharp end of pick can be pushed in up to 10mm. Can just be penetrated with an ordinary spade. |
| Stiff | Penetrated by thumbnail. Slight indentation produced by pushing pick point into soil. Cannot be moulded by fingers. Requires hand pick for excavation. |
| Very Stiff | Indented by thumbnail. Slight indentation produced by blow of pick point. Requires power tools for excavation. |

## 4. STRUCTURE

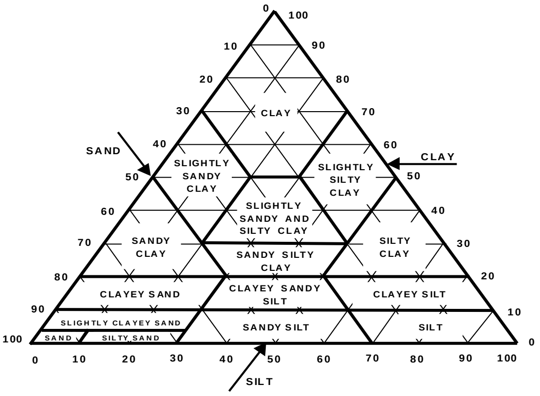
| Term | Description |
|---|---|
| Intact | Absence of fissures or joints |
| Fissured | Presence of closed joints |
| Shattered | Presence of closely spaced air filled joints giving cubical fragments |
| Micro-shattered | Small scale shattering with shattered fragments the size of sand grains |
| Slickensided | Polished planar surfaces representing shear movement in soil |
| Bedded Folitated | Many residual soils show structures of parent rock. |

## 5. SOIL TYPE

### 5.1 Particle Size

| Term | Size ( mm ) |
|---|---|
| Boulder | >200 |
| Pebbles | 60 – 200 |
| Gravel | 60 – 2 |
| Sand | 2 – 0,06 |
| Silt | 0,06 – 0,002 |
| Clay | <0,002 |

### 5.2 Soil Classification



## 6. ORIGIN

### 6.1 Transported Soils

| Term | Agency of Transportation |
|---|---|
| Colluvium | Gravity deposits |
| Talus | Scree or coarse colluvium |
| Hillwash | Fine colluvium |
| Alluvial | River deposits |
| Aeolian | Wind deposits |
| Litoral | Beach deposits |
| Estuarine | Tidal – river deposits |
| Lacustine | Lake deposits |

### 6.2 Residual soils

These are products of in-situ weathering of rocks and are described as e.g. Residual Shale

### 6.3 Pedocretes

Formed in transported and residual soils etc.
calcrete, silcrete, manganocrete and ferricrete.

# SUMMARY OF DESCRIPTIONS USED IN ROCK CORE LOGGING

## 1. WEATHERING

| Term | Symbol | Diagnostic Features |
|---|---|---|
| Residual Soil | W5 | Rock is discoloured and completely changed to a soil in which original rock fabric is completely destroyed. There is a large change in volume. |
| Completely Weathered | W5 | Rock is discoloured and changed to a soil but original fabric is mainly preserved. There may be occasional small corestones. |
| Highly Weathered | W4 | Rock is discoloured, discontinuities may be open and have discoloured surfaces, and the original fabric of the rock near the discontinuities may be altered; alternation penetrates deeply inwards, but corestones are still present. |
| Moderately Weathered | W3 | Rock is discoloured, discontinuities may be open and will have discoloured surfaces with alteration starting to penetrate inwards, intact rock is noticeably weaker than the fresh rock. |
| Slightly Weathered | W2 | Rock may be slightly discoloured, particularly adjacent to discontinuities, which may be open and will have slightly discoloured surfaces, the intact rock is not noticeably weaker than the fresh rock. |
| Unweathered | W1 | Parent rock showing no discolouration, loss of strength or any other weathering effects. |

## 2. HARDNESS

| Classification | Field Test | Compressive Strength Range MPa |
|---|---|---|
| Very Soft Rock | Can be peeled with a knife. Material crumbles under firm blows with the sharp end of a geological pick. | 1 to 3 |
| Soft Rock | Can be scraped with a knife, indentation of 2 to 4 mm with firm blows of the pick point. | 3 to 10 |
| Medium Hard Rock | Cannot be scraped or peeled with a knife. Hand held specimen breaks with firm blows of the pick. | 10 to 25 |
| Hard Rock | Point load tests must be carried out in order to distinguish between these classifications | 25 - 70 |
| Very Hard Rock | These results may be verified by uniaxial compressive strength tests on selected samples. | 70 - 200 |
| Extremely Hard Rock | | >200 |

## 3. COLOUR

The predominant colours or colour combination are described including secondary colouration described as banded, streaked, blotched, mottled, speckled or stained.

## 4. FABRIC

| 4.1 Grain Size | | 4.2 Discontinuity Spacing | | |
|---|---|---|---|---|
| Term | Size (mm) | Description for: Bedding, foliation, laminations | Spacing (mm) | Descriptions for joints, faults, etc. |
| Very Coarse | >2,0 | Very Thickly Bedded | > 2000 | Very Widely |
| Coarse | 0,6 – 2,0 | Thickly Bedded | 600 – 2000 | Widely |
| Medium | 0,2 – 0,6 | Medium Bedded | 200 – 600 | Medium |
| Fine | 0,06 – 0,2 | Thinly Bedded | 20 – 200 | Closely |
| Very Fine | < 0,06 | Laminated | 6 – 20 | Very closely |
| | | Thinly Laminated | <6 | |

## 5. ROCK NAME

Classified in terms of origin:

| | |
|---|---|
| IGNEOUS | Granite, Diorite, Gabbro, Syenite, Diabase, Dolerite, Trachyte, Andesite, Basalt. |
| METAMORPHIC | Slate, Quartzite, Gneiss, Schist, |
| SEDIMENTARY | Shale, Mudstone, Siltstone, Sandstone, Dolomite, Conglomerate, Tillite, Quartzite, Limestone. |

## 6. STRATIGRAPHIC HORIZON

Identification of rock type in terms of stratigraphic horizons.

# Appendix B:
# Borehole logs

*ABREVIATIONS*
*N/A not applicable*
*N/M not measureable*
*IT invalid test*
*NT no test*

*JOINT INFILL*
*Cl Clay*
*Slt Silt*
*Snd Sand*
*St Stained*
*Cn Clean*

*JOINT SPACING*
*VCJ very close spacing*
*CJ close spacing*
*MJ medium spacing*
*WJ wide spacing*
*VWJ very wide spacing*

*JOINT ROUGHNESS*
*S smooth*
*SR slightly rough*
*R rough*

*WEATHERING SHADING*
*BROWN soil*
*100% completely weathered*
*75% highly weathered*
*50% moderately weathered*
*25% slightly weathered*
*0% unweathered*

**Lower Coerney**

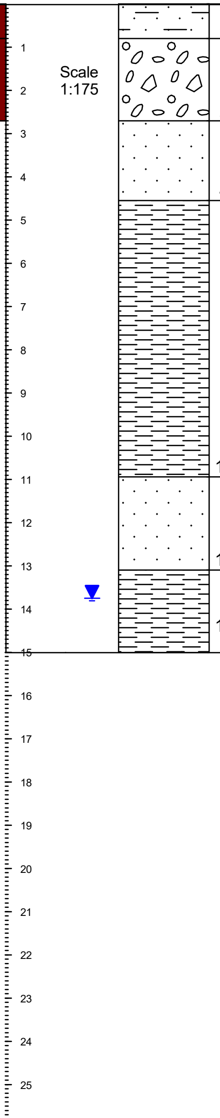
*HOLE No: LC1*

*Sheet 1 of 1*

| Reduced Level | Material Recovery % | Core Recovery % | RQD (%) |
|---|---|---|---|
| 83.36 | 80 | 0 | 0 |
| 82.56 | 102 | 0 | 0 |
| | 21 | 0 | 0 |
| | 33 | 0 | 0 |
| | 38 | 11 | 0 |
| | 117 | 0 | 0 |
| 80.66 | 33 | 0 | 0 |
| | 79 | 0 | 0 |
| | 73 | 16 | 0 |
| | 133 | 83 | 0 |
| | 99 | 90 | 40 |
| 78.81 | 97 | 97 | 43 |
| | 105 | 96 | 17 |
| | 115 | 27 | 0 |
| | 94 | 94 | 50 |
| | 107 | 107 | 66 |
| 72.42 | 95 | 91 | 43 |
| | 97 | 95 | 25 |
| 70.26 | 93 | 88 | 17 |
| 68.35 | 96 | 76 | 21 |

| Frac Freq No / m |
|---|
| 14 |
| 17 |
| 20 |
| 20 |
| 11 |
| 10 |
| 16 |
| 11 |
| 20 |
| 20 |
| 14 |
| 15 |

| | Joint Inclin. (deg) | Joint Spacing | Joint Rough-ness | Joint Infill | Weathering | |
|---|---|---|---|---|---|---|
| 0.00<br>0.80 | N/A | N/A | N/A | N/A | 🟥 | Brown to red-brown, slightly clayey silty sand. Colluvium. |
| 2.70 | N/A | N/A | N/A | N/A | 🟥 | Round / sub-round, medium to coarse gravel (10-50mm) of very hard rock quartzite. Alluvium.<br>NOTE:<br>1. Matrix lost |
| 4.55 | 10-20<br>70 | CJ<br>- | R/S<br>R/S | weathered film<br>weathered film | 🟩 | Light brown, highly weathered, closely jointed (60-200mm), medium hard rock sandstone.<br>NOTE:<br>1. 2.7-3.35m has highly to completely weathered, very soft rock. |
| 10.94 | 10-20<br>70 | VCJ<br>- | S<br>S | -<br>- | 🟩 | Light yellow-brown / grey / brown / purple-brown, highly weathered, very closely to closely jointed (<60-180mm), soft rock to medium hard rock, mainly mudstone also interbedded with fine silty sandstone (5-6.5m, 7.5-8m).<br>NOTE:<br>1. In places completely weathered to clayey sand<br>2. Completely broken zone at 6.4-6.9m<br>3. Mudstone susceptible to slaking |
| 13.10 | 0<br>30<br>90 | VCJ<br>MJ<br>- | S<br>S<br>R/S | -<br>-<br>St | 🟩 | Light brown, highly weathered, very closely jointed (50-60mm), medium hard rock to hard rock sandstone.<br>NOTE:<br>1. Hard rock = wall rock |
| 15.01 | 0-10<br>30 | VCJ<br>- | S<br>S | -<br>- | 🟩 | Yellow to grey-brown, highly weathered, closely jointed (60-150mm), soft rock to medium hard rock / hard rock, mainly mudstone with subordinate interbedded sandstone 13.27-13.44m<br>NOTE:<br>1. Also fine silty sandstone<br>2. Mudstone 14.5+m very broken |



Scale 1:175

NOTES:

Water level at 13.75m, as measured on 03 October 2018

| | | |
|---|---|---|
| **Contractor: RWBE** | **Logged by: Gary Davis** | **Elevation: 83.36** |
| **Machine: D90 YWE** | **Logged date: 4/10/2018** | **North: -58099.59** |
| **Drilled by: Mothu** | **Drilled date: -** | **East: 3702689.25** |

*ABREVIATIONS*
*N/A not applicable*
*N/M not measureable*
*IT invalid test*
*NT no test*

*JOINT INFILL*
*Cl Clay*
*Slt Silt*
*Snd Sand*
*St Stained*
*Cn Clean*

*JOINT SPACING*
*VCJ very close spacing*
*CJ close spacing*
*MJ medium spacing*
*WJ wide spacing*
*VWJ very wide spacing*

*JOINT ROUGHNESS*
*S smooth*
*SR slightly rough*
*R rough*

*WEATHERING SHADING*
*BROWN soil*
*100% completely weathered*
*75% highly weathered*
*50% moderately weathered*
*25% slightly weathered*
*0% unweathered*

aurecon

**Lower Coerney**

*HOLE No: LC2*
*Sheet 1 of 1*

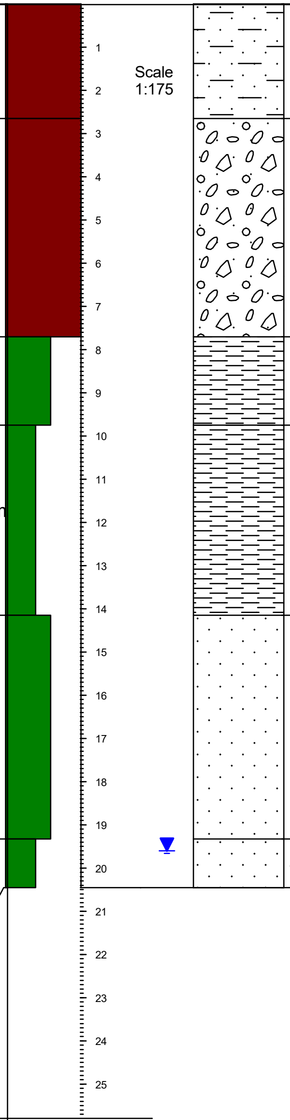
| Reduced Level | Material Recovery % | Core Recovery % | RQD (%) |
|---|---|---|---|
| 89.15 | 87 | 0 | 0 |
| | 82 | 0 | 0 |
| | 98 | 0 | 0 |
| | 71 | 0 | 0 |
| | 89 | 0 | 0 |
| | 108 | 0 | 0 |
| 86.50 | 96 | 0 | 0 |
| | 43 | 14 | 0 |
| | 70 | 0 | 0 |
| | 95 | 0 | 0 |
| | 83 | 0 | 0 |
| | 39 | 0 | 0 |
| | 43 | 0 | 0 |
| | 65 | 18 | 0 |
| | 76 | 47 | 22 |
| 81.45 | 71 | 41 | 31 |
| | 98 | 92 | 25 |
| 79.40 | 103 | 43 | 0 |
| | 95 | 93 | 49 |
| | 102 | 98 | 77 |
| | 72 | 59 | 0 |
| 75.00 | 86 | 84 | 64 |
| | 97 | 97 | 80 |
| | 91 | 87 | 68 |
| 69.82 | 96 | 96 | 75 |
| 68.70 | 108 | 108 | 79 |

| Frac Freq No / m |
|---|
| 12 |
| 13 |
| 12 |
| 11 |
| 11 |
| 15 |
| 7 |
| 7 |
| 2 |
| 11 |
| 11 |
| 6 |

| SPT Test |
|---|
| 43 |

| Packer Test |
|---|
| NT |
| 64 |
| 12 |
| 0 |
| 35 |

| Joint Inclin. (deg) | Joint Spacing | Joint Rough-ness | Joint Infill |
|---|---|---|---|
| N/A | N/A | N/A | N/A |
| N/A | N/A | N/A | N/A |
| 10<br>40 | VCJ<br>VCJ | R/S<br>S | Cl<br>- |
| 10<br>50 | VC-MJ<br>VC-MJ | R/S<br>S | St with film of Cl<br>- |
| 0-20<br>90 | VCJ<br>WJ | R<br>R/S | St<br>- |
| 0-10<br>60 | VCJ<br>MJ | R/S<br>R/S | -<br>- |



0.00

Pale reddish brown, slightly clayey silty sand. Colluvium.

2.65

Round to sub-round matrix supported, medium to coarse gravel (10-60mm) of very hard rock quartzite in matrix of silty to clayey sand. Alluvium.

NOTE:
1. Matrix typically lost
2. 6.5-7.7m alluvial gravel cemented by hardpan calcrete

7.70

Yellow-brown (khaki) to grey-brown, highly to completely weathered, closely jointed (60-200mm), generally soft rock to very soft rock (but in places weathered to clay) mudstone.

NOTE:
1. Weathered zones (to clay) 8.1-8.2m, 8.42-8.46m, 9.17-9.47m

9.75

Brown to dark grey, highly to moderately weathered, generally close to medium jointed (60-250mm) occasionally very closely jointed, generally medium hard rock to hard rock, but soft rock / very soft rock in places, interbedded mudstone / sandstone.

NOTE:
1. Significant material loss, assumed 13.5m+ ascribed to completely weathered (clay) horizon
2. Mudstone beds at 11.0-11.28m, 11.45-11.68m, 12.5-14.0m

14.15

Brown, highly weathered, close to widely jointed (100-1000mm), hard rock, medium to coarse sandstone.

NOTE:
1. Minor interbedded mudstone at 14.45-14.55m
2. Prominent weathered zone at 15.75-15.95m, joints prominently stained, possible seepage path

19.33

Grey to brown, moderately weathered, close to medium jointed (100-550mm), hard rock, fine to medium sandstone, laminated in places.

NOTE:
1. With pieces of charcoal
2. Laminations = planes of weakness - also susceptible to slaking

20.45

NOTES:

Water level at 19.60m, as measured on 03 October 2018

**Contractor: RWBE**
**Machine: D90 YWE**
**Drilled by: Mothu**

**Logged by: Gary Davis**
**Logged date: 4/10/2018**
**Drilled date: -**

**Elevation: 89.15**
**North: -58215.9**
**East: 3702532.15**

*ABBREVIATIONS*
*N/A not applicable*
*N/M not measureable*
*IT invalid test*
*NT no test*

*JOINT INFILL*
*Cl Clay*
*Slt Silt*
*Snd Sand*
*St Stained*
*Cn Clean*

*JOINT SPACING*
*VCJ very close spacing*
*CJ close spacing*
*MJ medium spacing*
*WJ wide spacing*
*VWJ very wide spacing*

*JOINT ROUGHNESS*
*S smooth*
*SR slightly rough*
*R rough*

*WEATHERING SHADING*
*BROWN soil*
*100% completely weathered*
*75% highly weathered*
*50% moderately weathered*
*25% slightly weathered*
*0% unweathered*

**Lower Coerney**

*HOLE No: LC3*

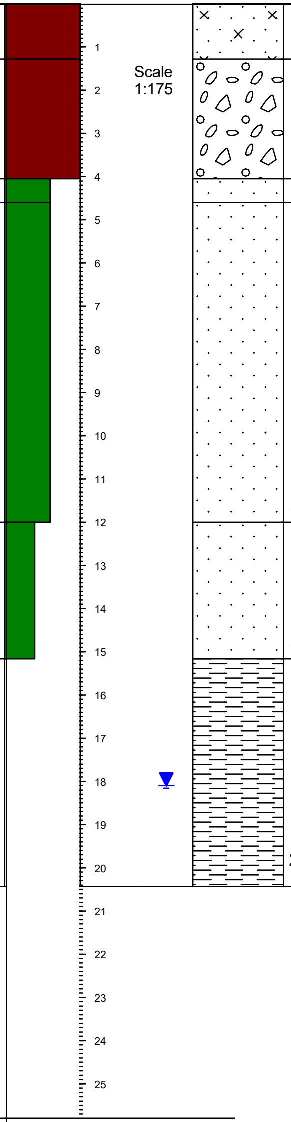
*Sheet 1 of 1*

| Reduced Level | Material Recovery % | Core Recovery % | RQD (%) |
|---|---|---|---|
| 84.30 | 100 | 0 | 0 |
| | 100 | 0 | 0 |
| 83.02 | 85 | 0 | 0 |
| | 66 | 0 | 0 |
| | 33 | 0 | 0 |
| | 155 | 0 | 0 |
| | 67 | 0 | 0 |
| | 100 | 0 | 0 |
| | 18 | 0 | 0 |
| 80.25 | 45 | 0 | 0 |
| 79.70 | 100 | 12 | 0 |
| | 100 | 86 | 0 |
| | 99 | 94 | 30 |
| | 100 | 100 | 33 |
| | 76 | 76 | 41 |
| | 91 | 88 | 7 |
| | 15 | 15 | 0 |
| | 108 | 95 | 0 |
| 72.30 | 75 | 75 | 65 |
| | 125 | 125 | 123 |
| 69.14 | 85 | 82 | 41 |
| | 93 | 81 | 54 |
| | 97 | 66 | 34 |
| | 93 | 93 | 88 |
| 63.87 | 63 | 57 | 38 |
| | 259 | 259 | 212 |

| Frac Freq No / m |
|---|
| 15 |
| 15 |
| 20 |
| 14 |
| 7 |
| 20 |
| 11 |
| 13 |
| 3 |
| 8 |
| 11 |
| 6 |
| 12 |
| 8 |
| 3 |
| 4 |

| Packer Test |
|---|
| NT |
| 0 |
| 15 |
| 1 |
| 0 |

| Joint Inclin. (deg) | Joint Spacing | Joint Rough-ness | Joint Infill | Depth | Description |
|---|---|---|---|---|---|
| N/A | N/A | N/A | N/A | 0.00 | Orange-brown, silty sand. Colluvium. |
| N/A | N/A | N/A | N/A | 1.28 | Orange-brown, silty to slightly clayey sand (matrix) with medium to coarse (1-6cm) gravel, round to sub-round, very hard rock quartzite. Alluvium.<br>NOTE:<br>1. Matrix mostly lost |
| 10 | VCJ | S | W | 4.05 | Yellow to grey-brown, highly to completely weathered, very closely jointed (up to 60mm), very soft rock to soft rock sandstone with subordinate mudstone. Occasionally weathered to sand. |
| 0-10<br>80 | VC-CJ<br>- | S<br>R/S | W, St<br>St | 4.60 | Brown to grey-brown, highly weathered (moderately weathered zone at 6.9-7.7m), very closely to closely jointed (<60-200mm), soft rock to medium hard rock (to 6m) then medium hard rock (hard rock where moderately weathered and medium hard rock to soft rock in mudstone), mainly sandstone with interbedded mudstone.<br>NOTE:<br>1. Mudstone to muddy siltstone at 4.6-4.8m, 4.9-5.1m, 9.1-10.0m |
| 0-10 | VC-WJ | S | - | 12.00 | Mainly grey to brown, moderately weathered to unweathered, closely to medium jointed (150-500mm), hard rock, mainly sandstone.<br>NOTE:<br>1. From 14m, laminations of mudstone becoming more common, weakness - susceptible to slaking, some poor zones. |
| 0-10 | MJ | S | - | 15.16 | Dark grey, unweathered, medium to widely jointed (but note susceptible to slaking/disintegration), hard rock mudstone / carbonaceous mudstone.<br>NOTE:<br>1. Varying susceptibility to slaking (particularly susceptible at 15.9-17.8m; 18.95-19.05m). Some zones of complete disintegration. |
| | | | | 20.43 | |



NOTES:

Water level at 18.10m, as measured on 03 October 2018

**Contractor: RWBE**
**Machine: D90 YWE**
**Drilled by: Mothu**

**Logged by: Gary Davis**
**Logged date: 4/10/2018**
**Drilled date: -**

**Elevation: 84.3**
**North: -58252.35**
**East: 3702625.65**

*ABREVIATIONS*
*N/A not applicable*
*N/M not measureable*
*IT invalid test*
*NT no test*

*JOINT INFILL*
*Cl Clay*
*Slt Silt*
*Snd Sand*
*St Stained*
*Cn Clean*

*JOINT SPACING*
*VCJ very close spacing*
*CJ close spacing*
*MJ medium spacing*
*WJ wide spacing*
*VWJ very wide spacing*

*JOINT ROUGHNESS*
*S smooth*
*SR slightly rough*
*R rough*

*WEATHERING SHADING*
*BROWN soil*
*100% completely weathered*
*75% highly weathered*
*50% moderately weathered*
*25% slightly weathered*
*0% unweathered*

aurecon

**Lower Coerney**

*HOLE No: LC4*

*Sheet 1 of 1*

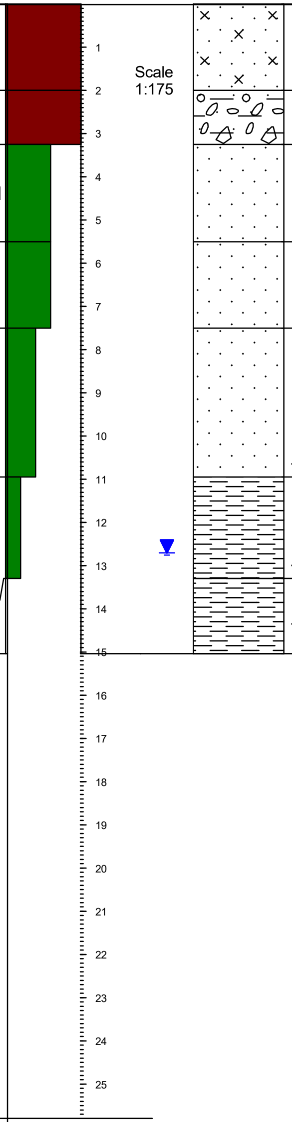
| Reduced Level | Material Recovery % | Core Recovery % | RQD (%) |
|---|---|---|---|
| 81.82 | 100 | 0 | 0 |
| | 72 | 0 | 0 |
| | 100 | 0 | 0 |
| | 43 | 0 | 0 |
| 79.82 | 87 | 0 | 0 |
| | 34 | 0 | 0 |
| 78.57 | 600 | 100 | 0 |
| | 53 | 0 | 0 |
| | 85 | 77 | 11 |
| 76.32 | 93 | 93 | 61 |
| | 102 | 102 | 70 |
| 74.32 | 81 | 81 | 63 |
| | 91 | 77 | 64 |
| | 98 | 98 | 80 |
| | 94 | 94 | 50 |
| 70.87 | 103 | 103 | 83 |
| | 67 | 67 | 11 |
| 68.52 | 138 | 123 | 13 |
| | 59 | 55 | 0 |
| 66.78 | 101 | 101 | 61 |

| Frac Freq No / m |
|---|
| 12 |
| 14 |
| 10 |
| 9 |
| 6 |
| 5 |
| 10 |
| 8 |
| 9 |
| 20 |
| 20 |
| 11 |

| SPT Test |
|---|
| 66 |

| Packer Test |
|---|
| NT |
| 0 |
| 13 |
| 0 |

| Joint Inclin. (deg) | Joint Spacing | Joint Rough-ness | Joint Infill |
|---|---|---|---|
| N/A | N/A | N/A | N/A |
| N/A | N/A | N/A | N/A |
| 10<br>50-60 | CJ<br>? | S<br>R/S | Snd/W/Cl<br>W/Snd |
| 10-30 | C-MJ | R/S | W film |
| 10<br>60<br>30<br>90 | VCJ<br>MJ<br>C-WJ<br>? | S/R<br>S<br>S<br>S | -<br>-<br>-<br>- |
| 10<br>30<br>60<br>90 | VC-CJ<br>MJ<br>?<br>? | S<br>S<br>S<br>S | St<br>St<br>St<br>St |
| 10<br>80-90 | VC-MJ<br>? | S<br>S | -<br>- |



| | |
|---|---|
| 0.00 | Slightly reddish brown, slightly clayey silty sand. Colluvium. |
| 2.00 | Rounded to sub-rounded, coarse gravel (20-60mm) of very hard rock quartzite with matrix of clayey sand. Alluvial.<br>NOTE:<br>1. Matrix lost |
| 3.25 | Light brown, occasionally grey-brown, highly weathered, very close to closely jointed (generally 60-150mm), generally coarse, soft to very soft rock sandstone with interbedded mudstone lenses.<br>NOTE:<br>1. Assume material loss in upper 50mm due to very soft rock / soil<br>2. Also other minor losses |
| 5.50 | Light brown, highly weathered, close to medium jointed (generally 60-200mm, up to 450mm), medium hard rock, generally medium to coarse sandstone with minor mudstone interbeds. |
| 7.50 | Light brown to grey brown, moderately weathered, locally highly weathered, close to medium jointed (100-600mm), generally hard rock with medium to fine sandstone, occasionally coarse grained with occasional muddy sandstone interbeds. |
| 10.95 | Generally grey-brown to dark grey, slightly to moderately weathered, very close to closely jointed (<60-100mm), soft rock to medium hard rock mudstone with minor interbeds of fine sandstone.<br>NOTE:<br>1. Material loss at 11.5-12m estimated. Assume completely weathered clay interbed.<br>2. From 12.6m, horizon very closely jointed (completely fractured), weak horizons to very soft rock / clay.<br>3. Mudstone assumed susceptible to slaking |
| 13.30 | Dark grey, unweathered, very closely to medium jointed (<60-550mm), medium hard rock to hard rock in places, to soft rock, carbonaceous mudstone with occasional interbedded sandstone / susceptible to slaking (particularly to depth of 14m) |
| 15.04 | |

<u>NOTES</u>:

Water level at 12.70m, as measured on 03 October 2018

**Contractor: RWBE**
**Machine: D90 YWE**
**Drilled by: Mothu**

**Logged by: Gary Davis**
**Logged date: 4/10/2018**
**Drilled date: -**

**Elevation: 81.82**
**North: -58170.99**
**East: 3702620.43**

*ABREVIATIONS*
*N/A not applicable*
*N/M not measureable*
*IT invalid test*
*NT no test*

*JOINT INFILL*
*Cl Clay*
*Slt Silt*
*Snd Sand*
*St Stained*
*Cn Clean*

*JOINT SPACING*
*VCJ very close spacing*
*CJ close spacing*
*MJ medium spacing*
*WJ wide spacing*
*VWJ very wide spacing*

*JOINT ROUGHNESS*
*S smooth*
*SR slightly rough*
*R rough*

*WEATHERING SHADING*
*BROWN soil*
*100% completely weathered*
*75% highly weathered*
*50% moderately weathered*
*25% slightly weathered*
*0% unweathered*

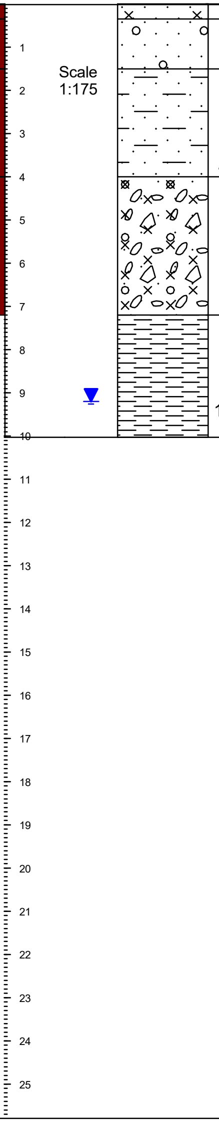
**aurecon**

**Lower Coerney**

*HOLE No: LC5*

*Sheet 1 of 1*

| Reduced Level | Material Recovery % | Core Recovery % | RQD (%) | Frac Freq No / m | Joint Inclin. (deg) | Joint Spacing | Joint Rough-ness | Joint Infill | Weathering |
|---|---|---|---|---|---|---|---|---|---|
| 102.01<br>101.66 | 90 | 0 | 0 | | N/A | N/A | N/A | N/A | 🟥 |
| | 57 | 0 | 0 | | N/A | N/A | N/A | N/A | 🟥 |
| | 125 | 0 | 0 | | | | | | 🟥 |
| 100.51 | 124 | 0 | 0 | | | | | | 🟥 |
| | 100 | 0 | 0 | | N/A | N/A | N/A | N/A | 🟥 |
| 98.01 | 95 | 0 | 0 | | | | | | 🟥 |
| | 98 | 0 | 0 | | N/A | N/A | N/A | N/A | 🟥 |
| | 96 | 0 | 0 | | | | | | 🟥 |
| 94.81 | 99 | 0 | 0 | | | | | | 🟥 |
| | 97 | 90 | 50 | 5 | 0-10 | MJ | S | W | 🟩 |
| 91.98 | 100 | 100 | 68 | 6 | | | | | 🟩 |



| | |
|---|---|
| 0.00 | Orange to red-brown, silty sand. Colluvium / topsoil. |
| 0.35 | Red-brown, silty sand with scattered pockets / nodules calrete. Colluvium with some Pedogenic. |
| 1.50 | Yellow-brown to red-brown, clayey sand. Colluvium. |
| 4.00 | Red-brown, becoming olive-brown near base, slightly clayey silty sand (matrix) with scattered medium to coarse gravel (1-6 and up to 10cm), occasionally cobbles of very hard rock quartzite. Alluvium, reworked terrace gravel?<br>NOTE:<br>1. Scattered calcrete development. |
| 7.20 | Grey-brown to yellow-brown, highly weathered (to completely weathered in places), medium to widely jointed, very soft rock to soft rock, predominantly mudstone with subordinate sandstone.<br>NOTE:<br>1. Susceptible to slaking. |
| 10.03 | |

<u>NOTES</u>:

Water level at 9.20m, as measured on 03 October 2018

| | | |
|---|---|---|
| **Contractor: RWBE** | **Logged by: Gary Davis** | **Elevation: 102.01** |
| **Machine: D90 YWE** | **Logged date: 4/10/2018** | **North: -58427.33** |
| **Drilled by: Mothu** | **Drilled date: -** | **East: 3702391.34** |

*ABREVIATIONS*
*N/A not applicable*
*N/M not measureable*
*IT invalid test*
*NT no test*

*JOINT INFILL*
*Cl Clay*
*Slt Silt*
*Snd Sand*
*St Stained*
*Cn Clean*

*JOINT SPACING*
*VCJ very close spacing*
*CJ close spacing*
*MJ medium spacing*
*WJ wide spacing*
*VWJ very wide spacing*

*JOINT ROUGHNESS*
*S smooth*
*SR slightly rough*
*R rough*

*WEATHERING SHADING*
*BROWN soil*
*100% completely weathered*
*75% highly weathered*
*50% moderately weathered*
*25% slightly weathered*
*0% unweathered*

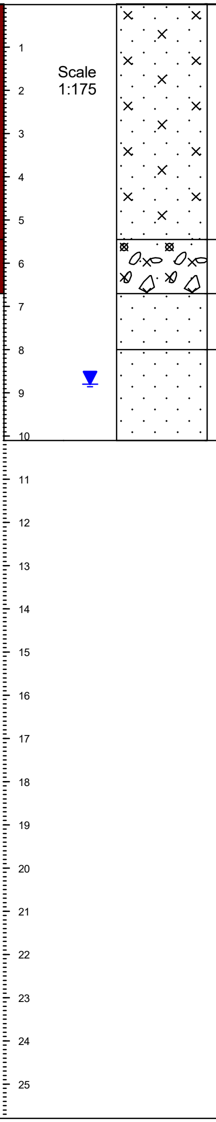
aurecon

**Lower Coerney**

*HOLE No: LC6*

*Sheet 1 of 1*

| Reduced Level | Material Recovery % | Core Recovery % | RQD (%) | Frac Freq No / m | Joint Inclin. (deg) | Joint Spacing | Joint Rough-ness | Joint Infill | Weathering | Depth |
|---|---|---|---|---|---|---|---|---|---|---|
| 89.98 | 95 | 0 | 0 | | N/A | N/A | N/A | N/A | 🟥 | 0.00 |
| | 100 | 0 | 0 | | | | | | | |
| | 99 | 0 | 0 | | | | | | | |
| | 92 | 0 | 0 | | | | | | | |
| | 99 | 0 | 0 | | | | | | | |
| | 100 | 0 | 0 | | | | | | | |
| 84.53 | 105 | 0 | 0 | | | | | | | 5.45 |
| | 99 | 0 | 0 | | N/A | N/A | N/A | N/A | 🟥 | |
| 83.28 | 94 | 0 | 0 | | | | | | | 6.70 |
| 81.98 | 100 | 94 | 90 | 2 | 60 | MJ | R/S | W | 🟩 | 8.00 |
| | 100 | 93 | 34 | 10 | 0-10 | VC-CJ | S | W film | 🟩 | |
| | | | | 15 | | | | | | |
| 79.88 | 108 | 92 | 28 | | | | | | | 10.1 |



Red to orange-brown, silty to clayey sand. Colluvium.

Orange-brown to brown, silty sand (matrix) with scattered, sub-rounded to sub-angular, medium to coarse (10-40mm) gravel of very hard rock quartzite / loosely packed, matrix supported but concentrated from 6m+. Alluvium (or reworked terrace gravel).

Yellow to grey-brown to whitish, highly to completely weathered, medium jointed (400-600mm), very soft rock to sand, sandstone (saprolite mainly) but includes bands of hard rock quartzite.

NOTE:
1. From 7.9m weathered to clay

Light yellow-brown, highly weathered, closely jointed (60-200mm), generally soft rock to medium hard rock, but some very soft rock interbedded, fine sandstone and mudstone from 9.55m, completley brown to 9.7m, also very soft rock mudstone interbeds.

NOTES:

Water level at 8.80m, as measured on 03 October 2018

Weathering Scale 1:175

**Contractor: RWBE**
**Machine: D90 YWE**
**Drilled by: Mothu**

**Logged by: Gary Davis**
**Logged date: 4/10/2018**
**Drilled date: -**

**Elevation: 89.98**
**North: -58387.47**
**East: 3702608.97**

# Appendix C:
# Core photographs

Aurecon
Lower Coerney Dam

**Location:** Kirkwood

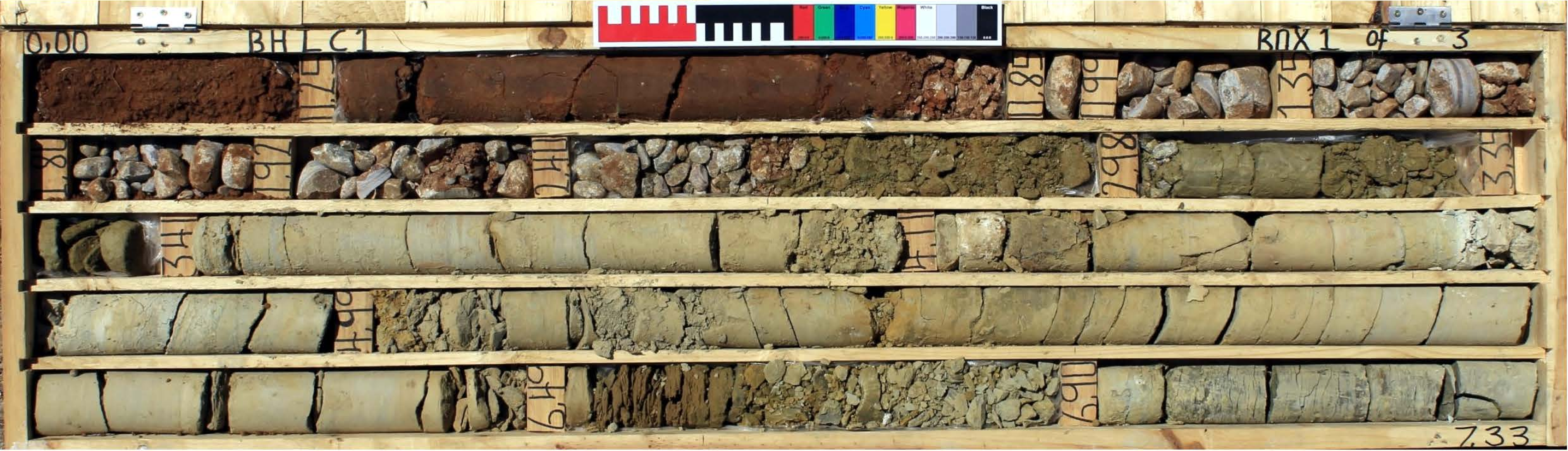
**Bore Hole No.:** BH LC 1

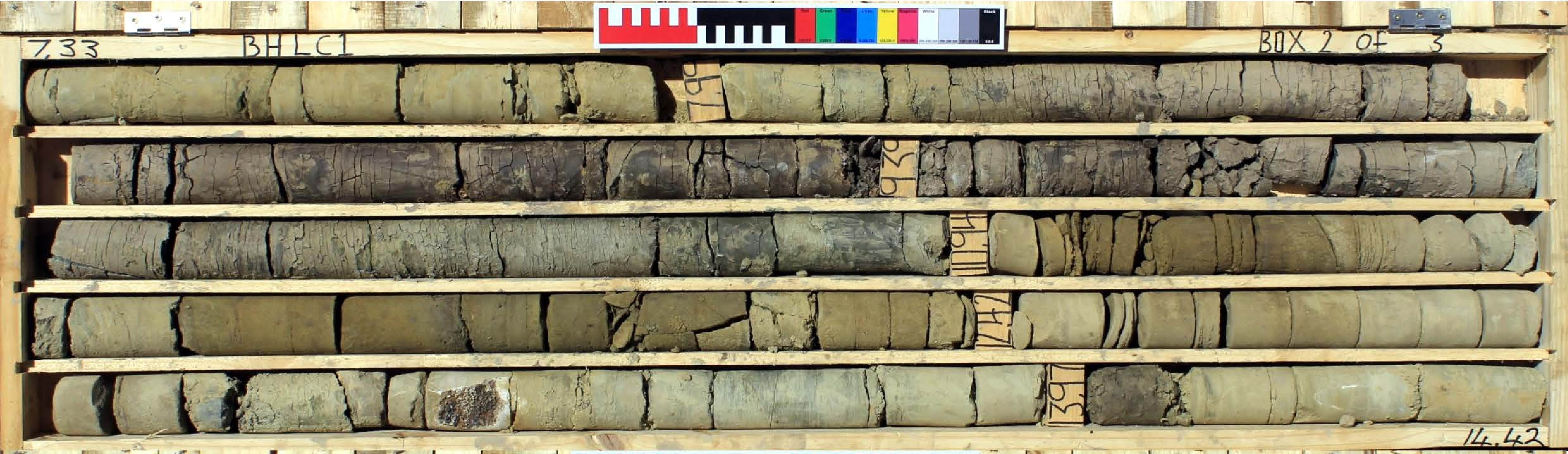
**Box No.:** 1 to 3

**Depth Range:** 0.00 to 15.01

**Date of Works:** Sep - Oct

# RWBE Geotechnical Drilling





Aurecon
Lower Coerney Dam

**Location:** Kirkwood

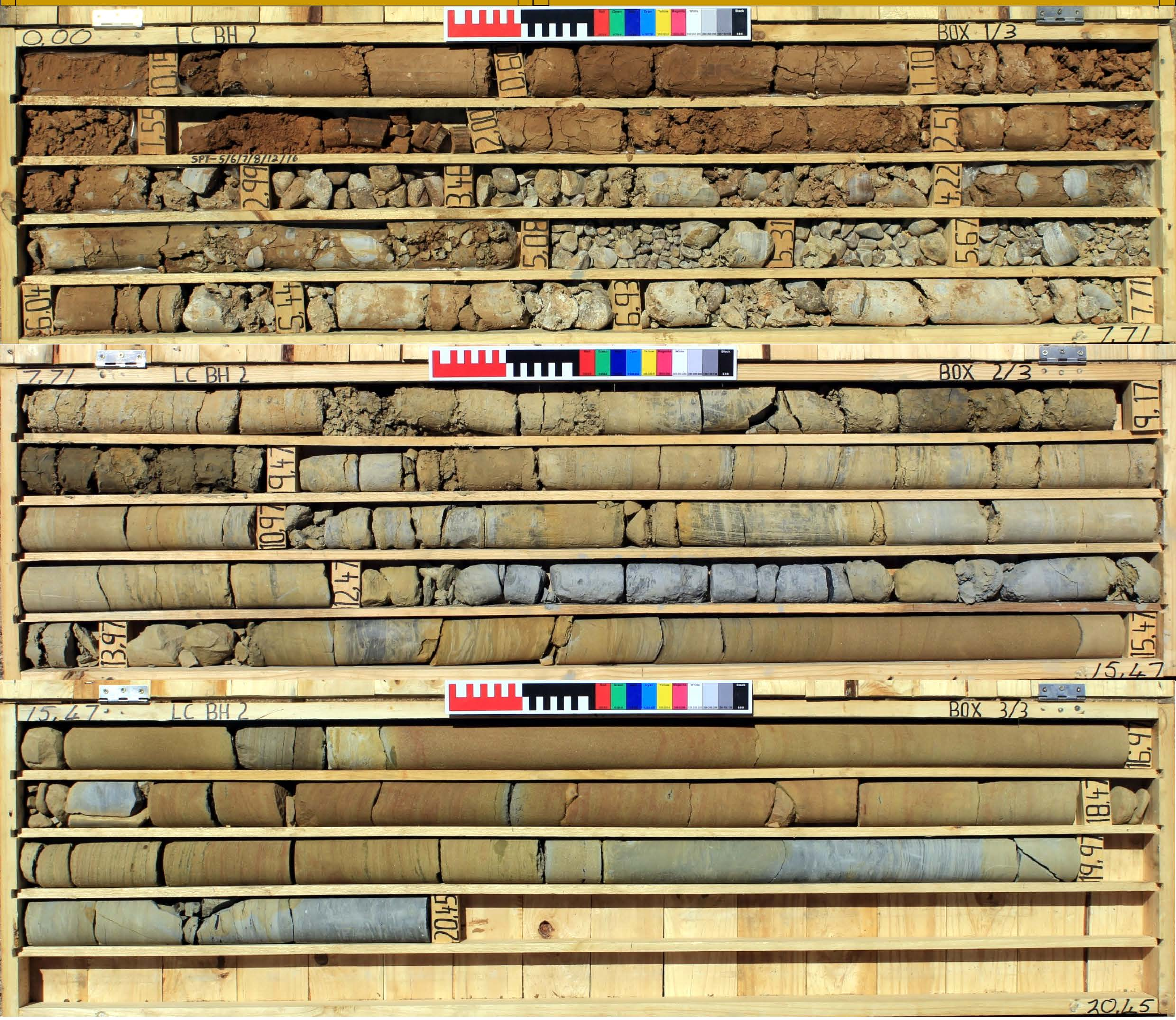
**Bore Hole No.:** BH LC 2

**Box No.:** 1 to 3

**Depth Range:** 0.00 to 20.45

**Date of Works:** Sep - Oct

# RWBE Geotechnical Drilling



Aurecon
Lower Coerney Dam

**Location:** Kirkwood

**Bore Hole No.:** BH LC 3

**Box No.:** 1 to 3

**Depth Range:** 0.00 to 20.43

**Date of Works:** Sep - Oct

# RWBE Geotechnical Drilling

Aurecon
Lower Coerney Dam

**Location:** Kirkwood

**Bore Hole No.:** BH LC 4

**Box No.:** 1 to 2

**Depth Range:** 0.00 to 15.04

**Date of Works:** Sep - Oct

# RWBE Geotechnical Drilling

Aurecon
Lower Coerney Dam

**Location:** Kirkwood

**Bore Hole No.:** BH LC5

**Box No.:** 1 to 2

**Depth Range:** 0.00 to 10.03

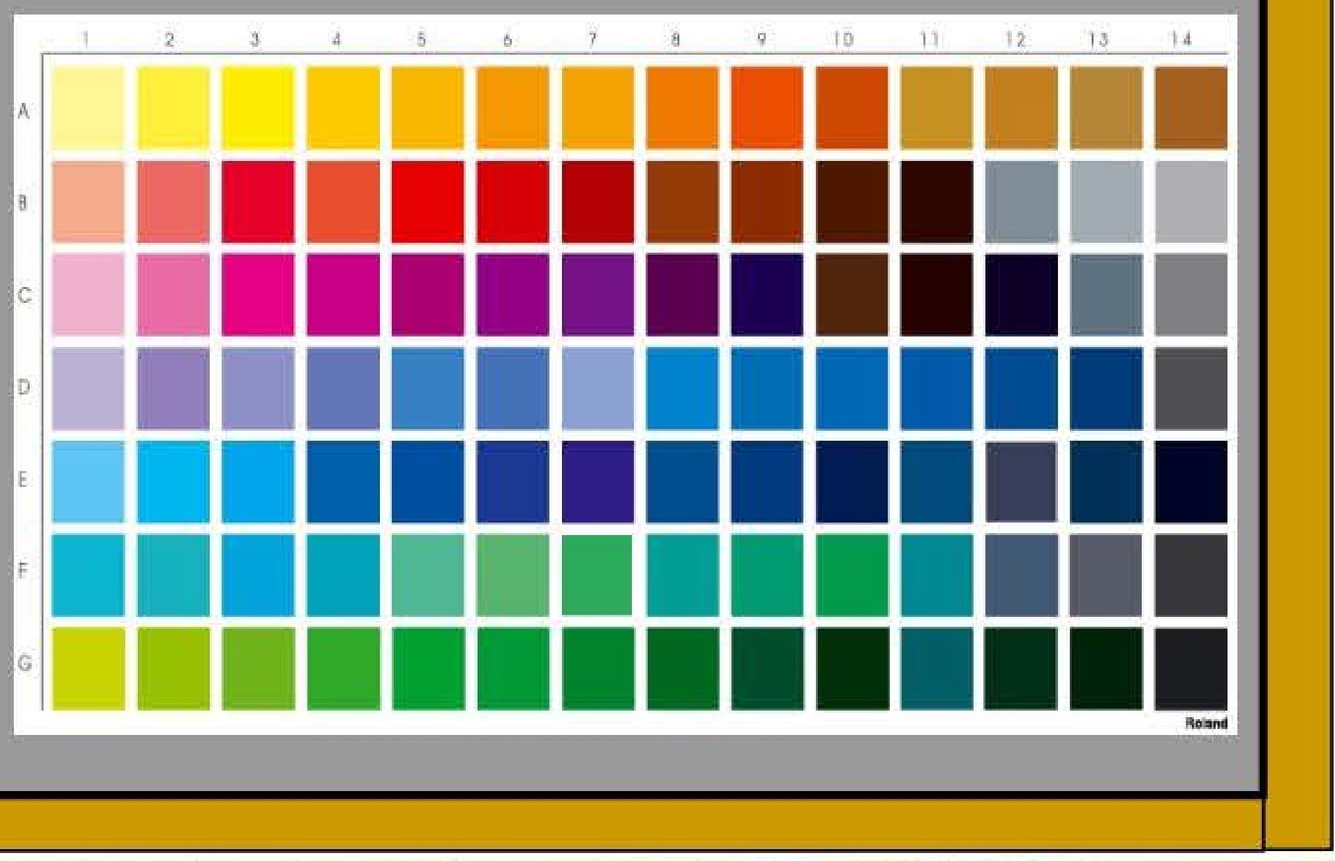
**Date of Works:** Sep - Oct

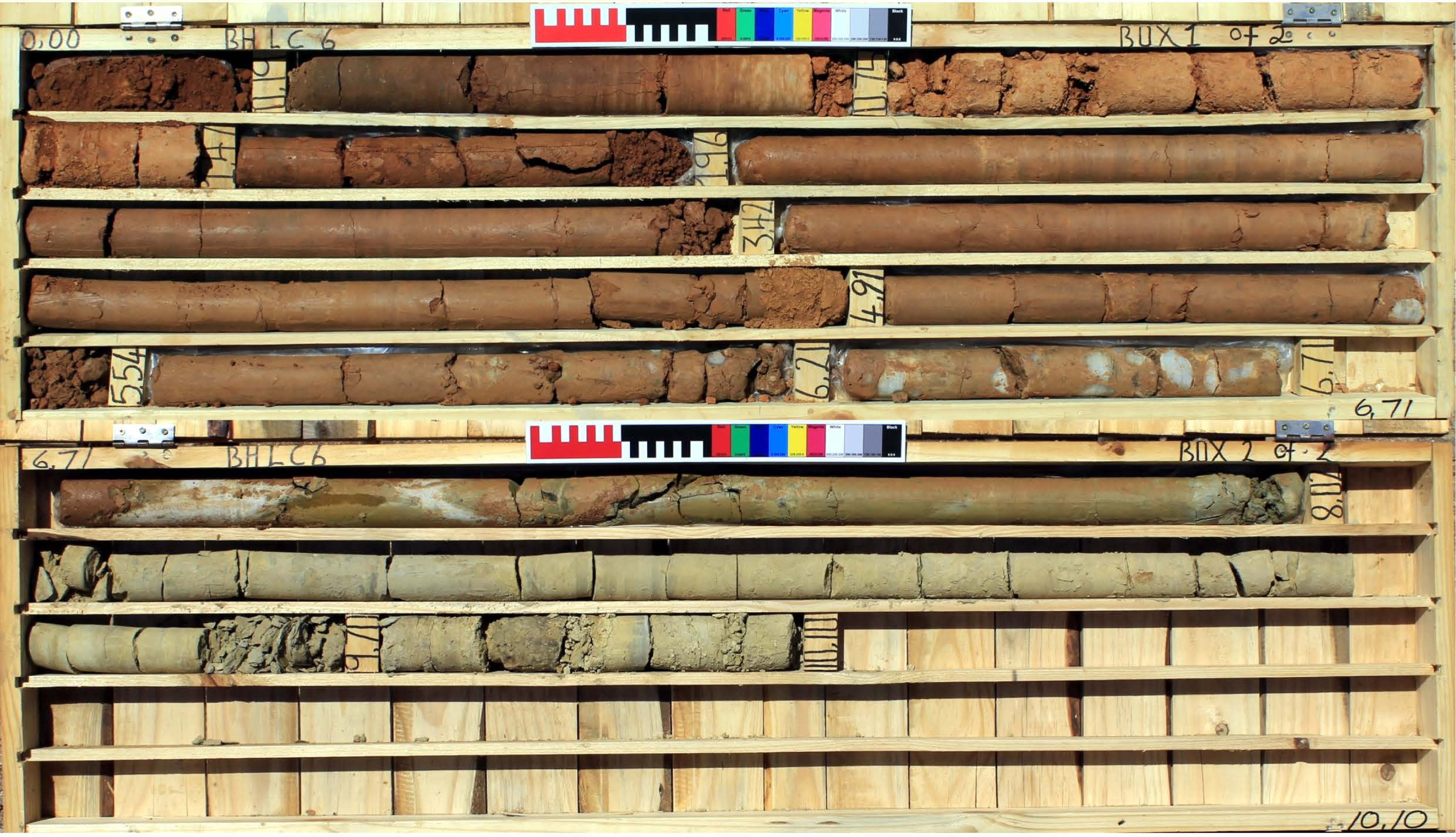
# RWBE Geotechnical Drilling

Aurecon
Lower Coerney Dam

| | |
|---|---|
| **Location:** | Kirkwood |
| **Bore Hole No.:** | BH LC 6 |
| **Box No.:** | 1 to 2 |
| **Depth Range:** | 0.00 to 10.10 |
| **Date of Works:** | Sep - Oct |

# RWBE Geotechnical Drilling





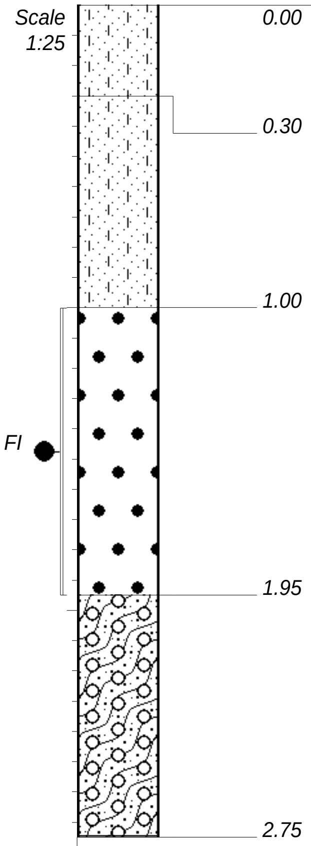
# Appendix D:
# Soil profiles

**DEPARTMENT OF WATER
AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC02**
*Sheet 1 of 1*

*JOB NUMBER:* 112546



Dry, brown, LOOSE to MEDIUM DENSE, intact to shattered, silty sand with roots.
Topsoil.

Slightly moist, reddish light brown, MEDIUM DENSE, intact with micro pinholes, silty sand with roots.
Colluvium.

Slightly moist, reddish brown, LOOSE to MEDIUM DENSE, intact with fine ferricrete nodules.
Colluvium with pedogenic action.

Tightly packed, rounded quartzite gravels and cobbles of VERY HARD ROCK with matrix of slightly moist, light brown, sand with overall consistency of loose to medium dense.
Colluvium.

END OF HOLE.

NOTES

1) Loose materials on sidewalls.

2) Profiled from surface and spoil, considering risk of failure.

3) Raveling and undercutting in gravel horizon, assume overall consistency loose to medium dense

4) No refusal.

5) No water seepage encountered.

6) FI sample taken between 1.00--1.95m

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 17/05/2018

*ELEVATION :* 86m
*X-COORD :* 25°37’30.00"E
*Y-COORD :* 33°26’56.00"S

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

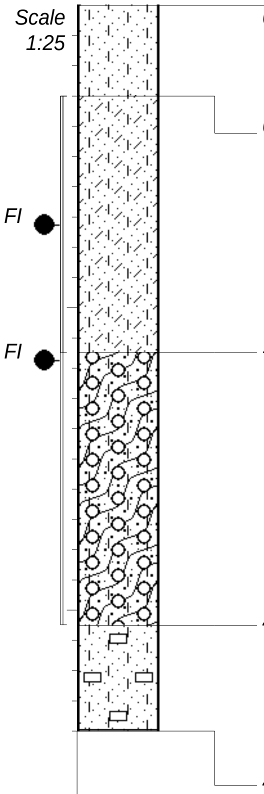
*HOLE No:* **LC02**
*Right Flank*

**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC03**
*Sheet 1 of 1*

*JOB NUMBER:* 112546



| | |
|---|---|
| 0.00 | Dry, brown, VERY LOOSE to MEDIUM DENSE, intact to shattered, silty fine to medium sand with roots.<br>Topsoil. |
| 0.30 | Slightly moist, brown, DENSE, intact, clayey silty sand with roots.<br>Colluvium. |
| 1.15 | Slightly moist, light brown, MEDIUM DENSE to DENSE, intact with micro pinholes, silty fine sand with fine to coarse mostly sub-rounded and occasionally angular quartzite gravel and roots.<br>Colluvium. |
| 2.05 | Slightly moist, light brown, DENSE, intact with micro pinholes, silty fine sand and calcrete ( honeycomb powder patches with medium calcrete nodules).<br>Colluvium, part pedogenic. |
| 2.40 | END OF HOLE. |

NOTES

1) No water seepage encountered.
2) FI, Shear box, and Relative density sample taken between 0.30--1.15m.
3) FI and MOD/AASHTO sample taken between 0.30--2.05m.
4) Stable sidewalls.
5) No refusal.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*TYPE SET BY :* DM
*SETUP FILE :* AURETP.SET

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 17/05/2018

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

*ELEVATION :* 86m
*X-COORD :* 25°37’32.90"E
*Y-COORD :* 33°26’53.50"S

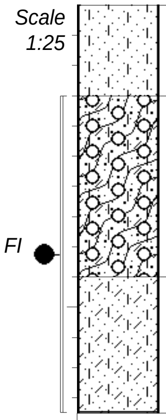
*HOLE No:* **LC03**
*River Section*

**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC04**
*Sheet 1 of 1*

*JOB NUMBER:* 112546



| | |
|---|---|
| 0.00 | Dry, dark brown, DENSE, shattered, silty sand. Topsoil with roots. |
| 0.30 | Dry, brown, VERY DENSE, intact, clayey silty sand with medium to coarse angular to sub-rounded quartzite gravels and occasionally rounded quartzite cobbles and roots.<br>Alluvium. |
| 0.90 | Slightly moist, greyish brown, VERY DENSE, intact, silty clayey sand.<br>Alluvium. |
| 1.35 | END OF HOLE. |

NOTES

1) No water seepage encountered.

2) Stable sidewalls.

3) FI and MOD/AASHTO sample taken between 0.30--1.35m

4) Near refusal at 1.35m

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

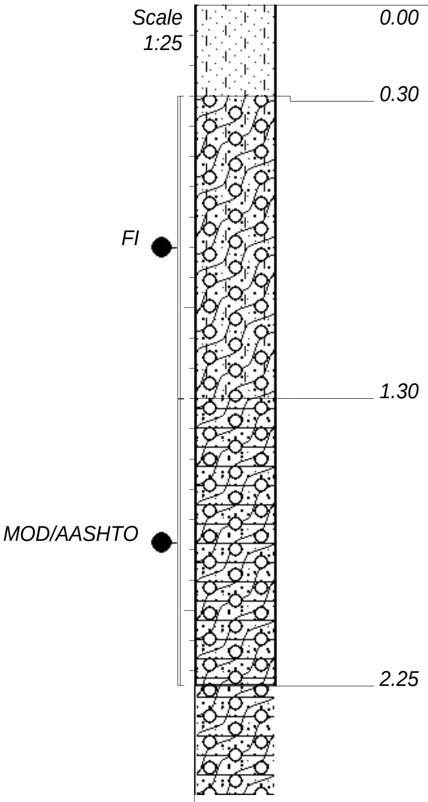
*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 17/05/2018

*ELEVATION :* 84m
*X-COORD :* 25°37’31.10"E
*Y-COORD :* 33°26’54.60"S

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

*HOLE No:* **LC04**
*River Section*



Dry, brown, MEDIUM DENSE, shattered, silty sand with roots.
Topsoil.

Slightly moist to dry, light brown, MEDIUM DENSE to DENSE, intact with macro pinholes, silty fine sand with medium angular to sub-rounded quartzite gravel and occasional rounded quartzite cobbles and roots.
Mixed origin.

Slightly moist to dry, light brown, LOOSE to DENSE, intact, sand with coarse quartzite gravel and quartzite cobbles and occasional sandstone.
Potentially alluvium

END OF HOLE.

Note: Alternating horizons and stringers with lenses of LOOSE, medium to coarse sand, tight packed (clast supported), round to sub-round medium to coarse quartzite gravel, occasional cobbles (mainly) of VERY HARD ROCK and rare fragments of sandstone.
Alluvium.
Overall consistency is DENSE.

NOTES

1) Stable sidewalls.

2) No refusal.

3) No water seepage encountered.

4) FI sample taken between 0.30--1.30m.

5) MOD/AASHTO sample taken between 1.30--2.25m.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 17/05/2018

*ELEVATION :* 86m
*X-COORD :* 25°37’30.13"E
*Y-COORD :* 33°26’53.10"S

*HOLE No:* **LC05**
*River Section*

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

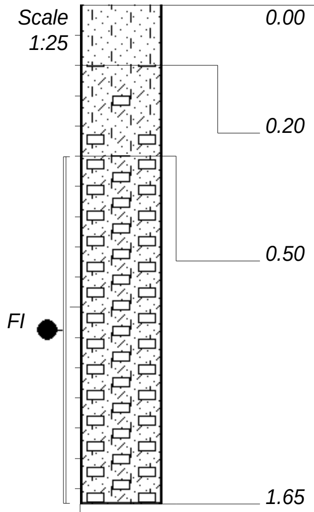
**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC06**
*Sheet 1 of 1*

*JOB NUMBER:* 112546

*Scale*
*1:25*



Dry, brown, MEDIUM DENSE, blocky to micro blocky with occasional animal burrows or pinholes, silty sand with roots.
Topsoil.

Dry, reddish brown, DENSE, intact, slightly clayey silty sand with minor fine calcrete nodules and roots.
Colluvium.

Slightly moist, dark brown to reddish brown mottled whitish, DENSE to VERY DENSE, intact, slightly clayey silty sand with scattered calcrete accretion (generally powder to honeycomb, occasionally associated with nodules).
Colluvium, part pedogenic.

END OF HOLE.

NOTES

1) Stable sidewalls.
2) No water seepage encountered.
3) No refusal, very slow excavation at 1.65m.
4) FI and MOD/AASHTO sample taken between 0.50--1.65m.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 18/05/2018

*ELEVATION :* 96m
*X-COORD :* 25°37’38.02"E
*Y-COORD :* 33°26’48.75"S

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

*HOLE No:* **LC06**
***Left Flank***

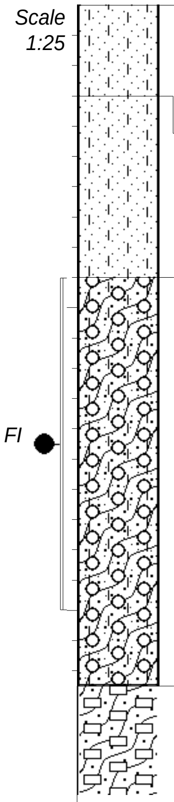
**DEPARTMENT OF WATER**
**AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC07**
*Sheet 1 of 1*

*JOB NUMBER:* 112546

*Scale*
*1:25*



| | |
|---|---|
| 0.00 | Dry, brown, MEDIUM DENSE, shattered with macro pinholes, silty sand with roots.<br>Topsoil. |
| 0.30 | Slightly moist, light brown, MEDIUM DENSE to DENSE, intact, silty sand with roots.<br>Alluvium. |
| 0.90 | Slightly moist, yellow brown, LOOSE to MEDIUM DENSE, intact with macro pinholes, silty fine sand with medium to coarse sub-angular to sub-rounded quartzite gravel.<br>Alluvium. |
| 2.25 | END OF HOLE:<br>Note: near to refusal at concreted macro pinhole honeycomb calcrete and loose sub-angular to sub-rounded quartzite gravel.<br>Overall consistency is DENSE to VERY DENSE, intact but pinholed, calcretised sand ( calcrete honeycomb across calcrete aggregated into becoming harden in places). |

NOTES

1) No water seepage encountered.
2) Stable sidewalls.
3) FI sample taken between 0.90--2.00m.
4) Near refusal.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 17/05/2018

*ELEVATION :* 84
*X-COORD :* 25°37’32.49"E
*Y-COORD :* 33°26’56.31"S

*HOLE No:* **LC07**
*River Section*

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

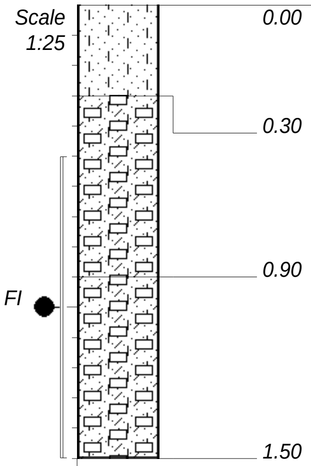
*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC08**
*Sheet 1 of 1*

*JOB NUMBER:* 112546



Dry, brown, MEDIUM DENSE, occasionally loose, intact with fine pinholes, silty sand with roots.
Topsoil.

Slightly moist, pale orange brown, MEDIUM DENSE to DENSE, intact with minor pinholes, slightly clayey silty sand with calcrete accretion.
Colluvium, part pedogenic.

Slightly moist, red brown, DENSE to VERY DENSE, intact, slightly clayey silty sand with minor calcrete accretions. Colluvium, part pedogenic.

END OF HOLE.

NOTES

1) Stables sidewalls.
2) No water seepage encountered.
3) FI and MOD/AASHTO sample taken between 0.50--1.50m.
4) No refusal, very slow excavation at 1.50m.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 18/05/2018

*ELEVATION :* 103m
*X-COORD :* 25°37’41.20"E
*Y-COORD :* 33°26’46.70"S

*HOLE No:* **LC08**
***Left Flank***

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

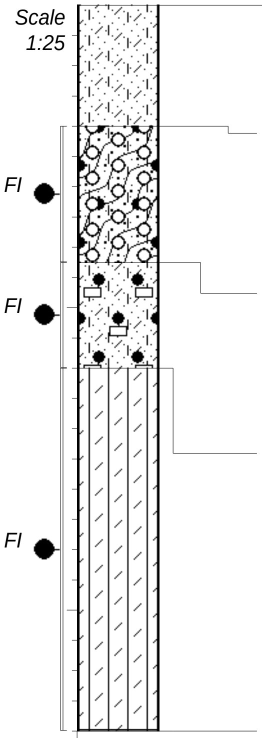
*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC09**
*Sheet 1 of 1*

*JOB NUMBER:* 112546



| | |
|---|---|
| 0.00 | Dry, brown, LOOSE to MEDIUM DENSE, intact to shattered, silty clayey sand with roots.<br>Topsoil. |
| 0.40 | Slightly moist, orange brown, MEDIUM DENSE to DENSE, intact, silty sand with minor fine angular and occasional sub-rounded medium quartzite gravel with occasional fine ferricrete nodules and roots.<br>Colluvium, part pedogenic. |
| 0.85 | Slightly moist, orange, DENSE to VERY DENSE, intact with macro pinholes, clayey silty sand with ferruginised ferricrete and calcrete nodules.<br>Colluvium, part pedogenic. |
| 1.20 | Slightly moist, reddish brown, VERY STIFF, intact, clayey silt.<br>Mixed origin |
| 2.40 | END OF HOLE. |

NOTES

1) No water seepage encountered.
2) Stable sidewalls.
3) FI and MOD/AASHTOO sample taken between 1.20--2.40m.
4) FI sample taken between 0.85--1.20m.
5) FI sample taken between 0.40--0.85m.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 17/05/2018

*ELEVATION :* 94m
*X-COORD :* 25°37’35.80"E
*Y-COORD :* 33°26’50.60"S

*HOLE No:* **LC09**
*River Section*

*TYPE SET BY :* DM
*SETUP FILE :* AURETP.SET

*DATE :* 14/12/2018 12:21
*TEXT :* ..ns\Logs\112546LogsDM.doc

aurecon

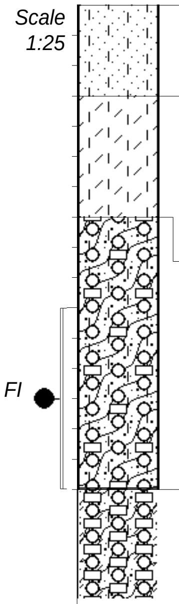
**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC10**
*Sheet 1 of 1*

*JOB NUMBER:* 112546

*Scale 1:25*



*0.00*

Dry, brown, LOOSE to MEDIUM DENSE, intact with macro pinholes, silty sand with roots.
Topsoil.

*0.30*

Slightly moist, reddish brown, VERY DENSE to DENSE, intact with minor pinholes, clayey silty with roots.
Colluvium.

*0.70*

Slightly moist, dark reddish brown, DENSE TO VERY DENSE, intact, silty sand with calcrete nodules and occasional honeycomb calcrete (lessening towards base) and medium sub-rounded quartzite gravel of VERY HARD ROCK.
Colluvium, part pedogenic.

*1.60*

END OF HOLE:

Note: Very difficult or slow excavation, cemented calcrete, VERY DENSE, clayey silty sand with loosely packed medium to coarse sub-rounded quartzite gravels of VERY HARD ROCK.
Colluvium.

NOTES

1) Stable sidewalls.
2) No water seepage encountered.
3) FI sample taken between 1.00--1.60m.
4) No refusal, slow excavation at 1.60m.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 18/05/2018

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

*ELEVATION :* 107m
*X-COORD :* 25°37’42.95"E
*Y-COORD :* 33°26’46.30"S

*HOLE No:* **LC10**
***Left Flank***

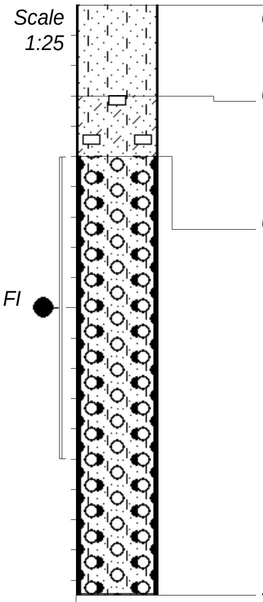
**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC11**
*Sheet 1 of 1*

*JOB NUMBER:* 112546

*Scale 1:25*



| | |
|---|---|
| *0.00* | Dry, light brown, DENSE, intact with pinholes, silty sand with roots.<br>Topsoil. |
| *0.30* | Dry, orange brown, DENSE, intact, slightly clayey silty sand with scattered calcrete nodules and diffuse calcretisation and fine roots.<br>Colluvium. |
| *0.50* | Ferruginised sand, near hardpan ferricrete. Dry, red-brown mottled black, intact, VERY DENSE, silty to sandy gravel (nodules).<br>Pedogenic. |
| *1.95* | END OF HOLE. |

NOTES

1) Stable sidewalls.
2) No water seepage encountered.
3) FI and MOD/AASHTO compaction sample taken between 0.50--1.50m.
4) No refusal, slow excavation at 1.95m.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 18/05/2018

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

*ELEVATION :* 92m
*X-COORD :* 25°37’40.42"E
*Y-COORD :* 33°26’52.18"S

*HOLE No:* **LC11**
***Left Flank***

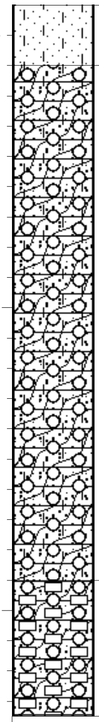
**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC12**
*Sheet 1 of 1*

*JOB NUMBER:* 112546

*Scale 1:25*



| | |
|---|---|
| *0.00* | Dry, light brown, MEDIUM DENSE occasional DENSE, intact to shattered with pinholes, silty sand with roots.<br>Topsoil. |
| *0.20* | Dry, orange brown, DENSE, intact, silty sand with occasional scattered generally medium to coarse quartzite cobbles/ gravels of VERY HARD ROCK and minor sandstone.<br>Colluvium. |
| *1.90* | Tightly packed generally comprising fine to coarse sub-rounded quartzite gravel and occasional cobbles of VERY HARD ROCK, occasional MEDIUM HARD ROCK sandstone with matrix of fine to coarse sand and traces of calcrete.<br>Alluvium. |
| *2.35* | END OF HOLE. |

NOTES

1) Sidewalls stable.
2) No water seepage encountered.
3) No sample taken.
4) Refusal on boulders at 2.35m.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 18/05/2018

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

*ELEVATION :* 84m
*X-COORD :* 25°37’39.45"E
*Y-COORD :* 33°26’57.59"S

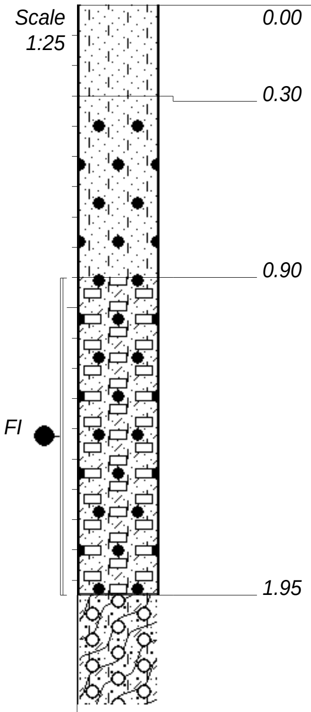
*HOLE No:* **LC12**
*River Section*

**DEPARTMENT OF WATER AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC20**
*Sheet 1 of 1*

*JOB NUMBER:* 112546



Dry, brown, MEDIUM DENSE, intact to blocky, silty sand with roots.
Topsoil.

Dry, red brown, DENSE, intact, ferruginised silty sand with minor fine ferricrete nodules.
Colluvium, partly pedogenic.

Slightly moist, dark red-brown, VERY DENSE, intact, ferruginised slightly clayey silty sand with fine ferricrete nodules, also scattered calcrete accretions with medium irregular nodules.
Pedogenic.

END OF HOLE.

Note: Ferruginised clayey silty sand with medium to coarse quartzite sub-rounded gravels of VERY HARD ROCK in places tending to hardpan (aggregated nodules).

NOTES

1) No refusal, very slow excavation at 1.95m.

2) No water seepage encountered.

3) Stable sidewalls.

4) FI and MOD/AASHTO compaction sample taken between 0.90--1.95m.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 18/05/2018

*ELEVATION :* 97m
*X-COORD :* 33°26’38.34"S
*Y-COORD :* 25°37’31.93"E

*HOLE No:* **LC20**
**Basin Area**

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

aurecon

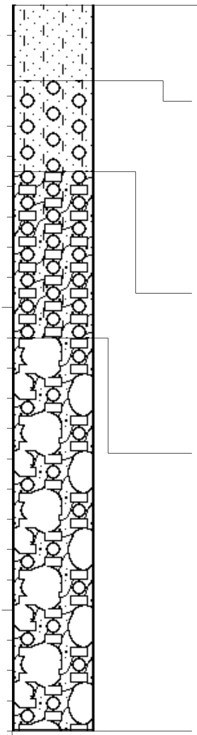
**DEPARTMENT OF WATER**
**AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC22**
*Sheet 1 of 1*

*JOB NUMBER:* 112546

*Scale*
*1:25*



*0.00*

Dry, brown, MEDIUM DENSE, intact with pinholes, silty sand and roots.
Topsoil.

*0.25*

Dry, pale orange, DENSE, intact, silty sand.
Colluvium.

Note: At 0.55m poorly developed, LOOSELY packed, medium to coarse, sub-angular to sub-rounded quartzite gravels (not pebble marker).

*0.55*

Dry, pale orange, DENSE, intact, silty sand with occasional medium to coarse sub-round quartzite gravels of VERY HARD ROCK with calcrete accretions more abundant near base.
Terrace gravel, partly pedogenic.

*1.10*

Tightly packed, medium to coarse rounded to sub-rounded quartzite gravels and occasional cobbles and boulders of VERY HARD ROCK with occasional calcrete within horizon, matrix of VERY DENSE, sand.
Terrace gravel, partly pedogenic.

*2.40*

END OF HOLE.

NOTES

1) No water seepage encountered.

2) No sample taken.

3) Stable sidewalls with caving.

4) Assessed refusal, on spoil, pieces of hardpan calcrete to cemented gravels and cobbles.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 18/05/2018

*ELEVATION :* 89m
*X-COORD :* 25°37’20.34"E
*Y-COORD :* 33°26’40.45"S

*HOLE No:* **LC22**
*Basin Area*

*TYPE SET BY : DM*
*SETUP FILE : AURETP.SET*

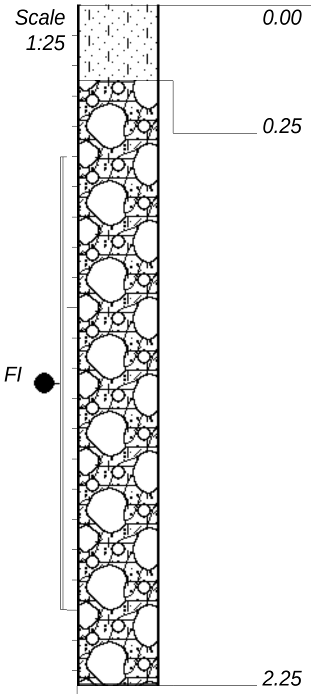
*DATE : 14/12/2018 12:21*
*TEXT : ..ns\Logs\112546LogsDM.doc*

**DEPARTMENT OF WATER**
**AND SANITATION**

**LOWER COERNEY DAM**

*HOLE No:* **LC23**
*Sheet 1 of 1*

*JOB NUMBER:* 112546



Dry, brown, MEDIUM DENSE to DENSE, intact with micro pinholes, slightly silty sand and roots.
Topsoil.

Dry, light brown, MEDIUM DENSE, intact, slightly clayey silty sand with loosely packed angular to sub-rounded fine to coarse quartzite gravel and occasional medium sandstone gravel up to 1.10m depth and occasional sub-rounded boulders (200 - 300mm diameter) and medium to coarse sandstone gravel beyond 1.10m.
Terrace gravel.

END OF HOLE.

NOTES

1) No water seepage encountered.

2) FI, Proctor compaction and shear box sample taken between 0.50--2.00m.

3) No refusal.

4) Stable sidewalls.

*CONTRACTOR :* Rennasance Construction
*MACHINE :* JCB 3DX
*DRILLED BY :* LAWRENCE
*PROFILED BY :* DM & GD

*INCLINATION :*
*DIAM :*
*DATE :*
*DATE :* 18/05/2018

*ELEVATION :* 94m
*X-COORD :* 25°37’15.33"E
*Y-COORD :* 33°26’40.96"S

*HOLE No:* **LC23**
*Basin Area*

*TYPE SET BY :* DM
*SETUP FILE :* AURETP.SET

*DATE :* 14/12/2018 12:21
*TEXT :* ..ns\Logs\112546LogsDM.doc

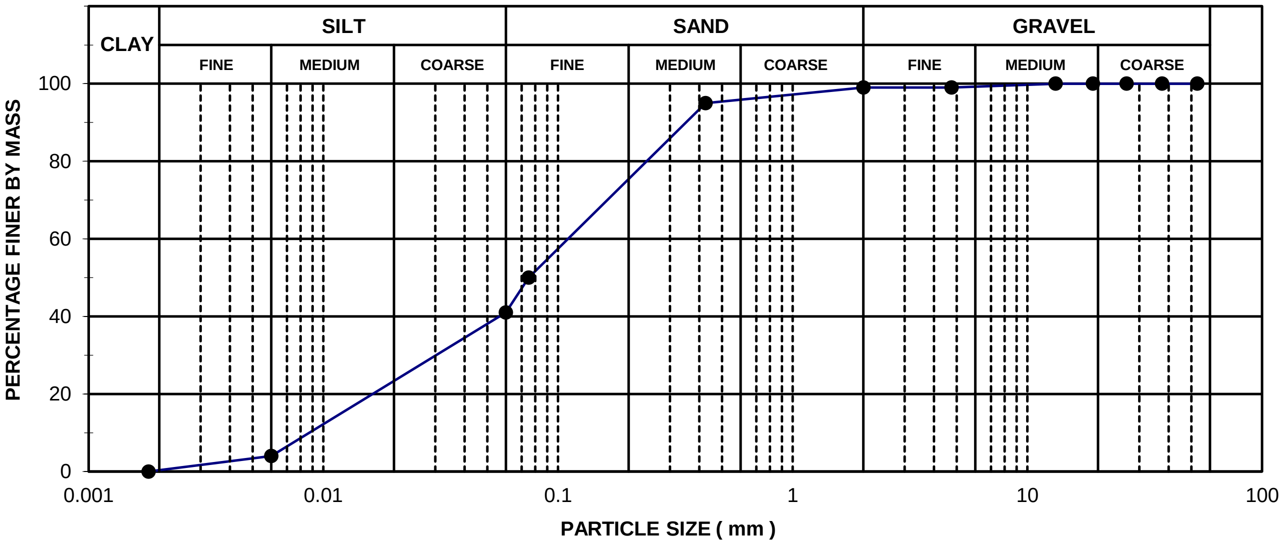
# Appendix E:
# Laboratory test data

# FOUNDATION INDICATOR TEST RESULTS

| | | | |
|---|---|---|---|
| TEST LOCATION | LC03 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98988 | PROJECT NUMBER | 112546 |
| DEPTH | 0.3-2.05 m | SITE | Lower Coerney |

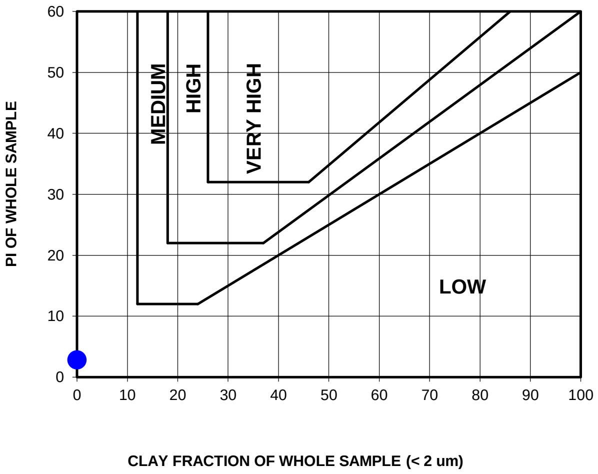
| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **50** | Liquid limit | (%) | **15** | % Gravel | **1** |
| 37.500 | **100** | 0.060 | **41** | Plastic limit | (%) | **12** | % Sand | **58** |
| 26.500 | **100** | 0.006 | **4** | Plasticity Index | (%) | **3** | % Silt | **41** |
| 19.000 | **100** | 0.0018 | **0** | Weighted PI | (%) | **3** | % Clay | **0** |
| 13.200 | **100** | | | Linear Shrinkage | (%) | **1.5** | Activity | **#DIV/0!** |
| 4.750 | **99** | | | Grading Modulus | | **0.56** | Unified Classification | **SM** |
| 2.000 | **99** | | | Uniformity coefficient | | **10** | TRB Classification | **A - 4** |
| 0.425 | **95** | | | Coefficient of curvature | | **0.9** | | |

## PARTICLE SIZE DISTRIBUTION

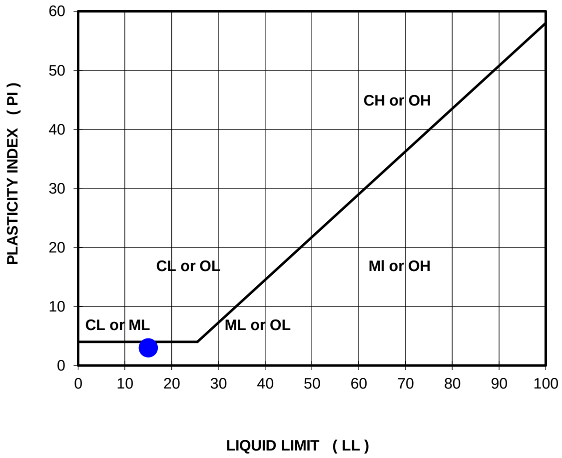


## POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



## CASAGRANDE 'A' LINE



**TOSCALAB (Pty) Ltd.**
CIVIL ENGINEERING MATERIALS LABORATORY
Reg.No. 2014/263692/07

56 Uitenhage Road, Sydenham, PE, 6001
PO Box 27067, Greenacres, PE, 6057
Tel: +27 (0)41 487-3130 • Fax: +27 (0)41 487-3160
E-mail: info@toscalab.co.za
**ISO/IEC 17025 ACCREDITED**

sanas
Testing Laboratory
T 0481

**CLIENT:** Aurecon SA
4 Daventry Street
Lynwood Ridge

**PROJECT :** Kirkwood 112546
**JOB/ROAD :** C19226
**REPORT DATE :** 27.06.2018

**ATT:** Mr. G Davies

**SAMPLING PROCEDURE:** Delivered to the Laboratory

## TEST RESULT SUMMARY

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SAMPLE NUMBER | | S98987 | S98988 | S98988 | S98989 | S98990 | S98991 | S98992 |
| POSITION | | LC2 | LC3 | LC3 | LC3 | LC4 | LC5 | LC5 |
| DEPTH (M) | | 1.0-1.95 | 0.3-2.05 | 0.3-1.15 | 0.3-2.05 | 0.3-1.35 | 0.3-1.3 | 1.3-2.75 |
| DESCRIPTION | | Colluvium with fine FeO Nodules | Colluvium (Small) | Colluvium (Un-Disturbed) | Colluvium (Large) | Alluvium | Mixed Origin | Potentially Alluvium |
| UNIFIED SOIL CLASSIFICATION | | CL | SM | SM | SM | SC | SM/SC | SC |
| HRB CLASSIFICATION | | | | | | | | |
| *SIEVE ANALYSIS - TMH 1 Test Method A1, A2, A3, A5 & A6* | | | | | | | | |
| PASSING | 75.0 mm | | | | | | | |
| | 63.0 mm | | | | | | | |
| | 53.0 mm | | | | | | | 100 |
| | 37.5 mm | | | | | 100 | | 97 |
| | 26.5 mm | | | | | 98 | | 95 |
| | 19.0 mm | | | | | 95 | | 90 |
| | 13.2 mm | | 100 | 100 | 100 | 94 | 100 | 80 |
| | 4.75 mm | 100 | 99 | 99 | 99 | 91 | 98 | 56 |
| | 2.00 mm | 99 | 99 | 98 | 99 | 90 | 97 | 47 |
| | 0.425 mm | 95 | 95 | 94 | 94 | 84 | 85 | 29 |
| | 0.075 mm | 76 | 50 | 47 | 45 | 49 | 41 | 13 |
| | 0.060 mm | 63 | 41 | 36 | 34 | 33 | 30 | 8 |
| | 0.006 mm | 4 | 4 | 5 | 3 | 5 | 3 | 1 |
| | 0.0018 mm | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| *SOIL MORTAR ANALYSIS - TMH 1 Test Method A5* | | | | | | | | |
| Soil Mortar Analysis % < 2.00mm | 2.000 - 0.425 | 4 | 4 | 5 | 5 | 7 | 12 | 39 |
| | 0.425 - 0.250 | 4 | 12 | 13 | 15 | 9 | 15 | 16 |
| | 0.250 - 0.150 | 7 | 17 | 18 | 19 | 17 | 18 | 12 |
| | 0.150 - 0.075 | 8 | 16 | 17 | 16 | 13 | 12 | 6 |
| | < 0.075 | 78 | 50 | 48 | 45 | 55 | 43 | 29 |
| GRADING MODULUS | | 0,30 | 0,57 | 0,61 | 0,62 | 0,77 | 0,78 | 2,11 |
| *ATTERBERG LIMITS : TMH 1 Test Method A2 - A4* | | | | | | | | |
| LIQUID LIMIT | | 21 | 15 | 15 | - | 17 | 15 | 49 |
| PLASTICITY INDEX | | 7 | 3 | 4 | SP | 7 | 5 | 20 |
| LINEAR SHRINKAGE | | 3,5 | 1,5 | 2,0 | 1,0 | 3,5 | 2,5 | 10,0 |
| *PROCTOR : MOISTURE DENSITY RELATIONSHIP : BS 1377 PART 4* | | | | | | | | |
| Maximum Proctor Density (Kg/m$^3$) | | - | - | - | 1857 | 1868 | - | - |
| O.M.C. (%) | | - | - | - | 11,1 | 12,7 | - | - |
| *RELATIVE DENSITY OF SOIL: TMH1 1986 A12T* | | | | | | | | |
| RELATIVE DENSITY | | - | 2,600 | - | - | 2,570 | - | - |
| *MOISTURE CONTENT: SANS 3001:GR20:2010* | | | | | | | | |
| MOISTURE CONTENT | | - | 9,8 | - | - | 6,1 | - | - |
| *PERMEABILITY AND DISPERSIVE TESTS* | | | | | | | | |
| PERMEABILITY ( m/s ) | | | | 2.31 x 10$^{-7}$ | 1.84 x 10$^{-7}$ | 3.16 x 10$^{-8}$ | | |
| DOUBLE HYDROMETER : ASTM D422 (%) | | | | 35,97 | 40,13 | 48,3 | | |
| PINHOLE TEST : ASTM D4647 | | | | ND 3 | ND 3 | ND 2 | | |
| CRUMB TEST : BS1377 (1990) PART 5: 6.3 | | | | Grade 2 | Grade 2 | Grade 2 | | |
| *DRAINED SLOW SHEARBOX TEST : BS 1377 (1990) PART 7 :4 / 5* | | | | | | | | |
| MAXIMUM EFFECTIVE SHEAR STRESS... σ'd (kPa) | | | 36,5 | 38,1 | 35,4 | 43,2 | | |
| APPARENT FRICTION ANGLE ( degrees) | | | 18,3 | 19,2 | 20,2 | 26,4 | | |
| Moulded Density (kg/m$^3$) | | | 1676 | 1693 | 1704 | 1722 | | |

The above test results are pertinent only to the samples received and tested at the laboratory. This report shall not be reproduced, except in full,without the prior consent of Tosca Lab (Pty)Ltd.

Name : Frederik Elbers
Position : Technical Signatory

**CLIENT:** Aurecon SA
4 Daventry Street
Lynwood Ridge

**ATT:** Mr. G Davies

**PROJECT :** Kirkwood 112546
**JOB/ROAD :** C19226
**REPORT DATE :** 27.06.2018

**SAMPLING PROCEDURE:** Delivered to the Laboratory

## *TEST RESULT SUMMARY*

| | | | | | | |
|---|---|---|---|---|---|---|
| SAMPLE NUMBER | S98993 | S98994 | S98995 | S98996 | S98997 | S98998 |
| POSITION | LC6 | LC7 | LC8 | LC9 | LC9 | LC9 |
| DEPTH (M) | 0.5-1.65 | 0.9-2 | 0.5-1.5 | 0.4-0.85 | 0.85-1.2 | 1.2-2.4 |
| DESCRIPTION | Colluvium Part Pedogenic | Alluvium | Colluvium Part Pedogenic | Colluvium with Fine FeO Nodules | Colluvium part Pedogenic | Mixed Origin |
| UNIFIED SOIL CLASSIFICATION | CL | CL | CL | CL | GC | CL |
| HRB CLASSIFICATION | | | | | | |
| *SIEVE ANALYSIS - TMH 1 Test Method A1, A2, A3, A5 & A6* | | | | | | |
| PASSING 75.0 mm | | | | | | |
| 63.0 mm | | | | | | |
| 53.0 mm | | | | | | |
| 37.5 mm | | | | | 100 | |
| 26.5 mm | | | | | 96 | |
| 19.0 mm | | | | | 90 | 100 |
| 13.2 mm | 100 | | 100 | | 83 | 99 |
| 4.75 mm | 99 | | 98 | | 61 | 96 |
| 2.00 mm | 98 | 100 | 97 | 100 | 52 | 94 |
| 0.425 mm | 96 | 97 | 96 | 98 | 45 | 89 |
| 0.075 mm | 75 | 65 | 70 | 81 | 25 | 79 |
| 0.060 mm | 53 | 51 | 58 | 57 | 18 | 66 |
| 0.006 mm | 5 | 3 | 1 | 3 | 2 | 11 |
| 0.0018 mm | 0 | 0 | 0 | 0 | 0 | 4 |
| *SOIL MORTAR ANALYSIS - TMH 1 Test Method A5* | | | | | | |
| Soil Mortar Analysis % < 2.00mm 2.000 - 0.425 | 2 | 3 | 2 | 2 | 14 | 5 |
| 0.425 - 0.250 | 3 | 7 | 3 | 2 | 13 | 2 |
| 0.250 - 0.150 | 8 | 12 | 10 | 6 | 13 | 3 |
| 0.150 - 0.075 | 11 | 14 | 14 | 9 | 13 | 6 |
| < 0.075 | 76 | 65 | 72 | 81 | 48 | 84 |
| GRADING MODULUS | 0,31 | 0,38 | 0,38 | 0,22 | 1,79 | 0,38 |
| *ATTERBERG LIMITS : TMH 1 Test Method A2 - A4* | | | | | | |
| LIQUID LIMIT | 32 | 25 | 26 | 37 | 30 | 39 |
| PLASTICITY INDEX | 18 | 11 | 12 | 19 | 18 | 18 |
| LINEAR SHRINKAGE | 9,0 | 5,5 | 6,0 | 9,5 | 9,0 | 9,0 |
| *PROCTOR : MOISTURE DENSITY RELATIONSHIP : BS 1377 PART 4* | | | | | | |
| Maximum Proctor Density (Kg/m$^3$) | 1676 | - | 1759 | - | - | 1617 |
| O.M.C. (%) | 18,9 | - | 17,8 | - | - | 23,8 |
| *RELATIVE DENSITY OF SOIL: TMH1 1986 A12T* | | | | | | |
| RELATIVE DENSITY | 2,560 | - | - | 2,580 | - | - |
| *MOISTURE CONTENT: SANS 3001:GR20:2010* | | | | | | |
| MOISTURE CONTENT | 12,4 | - | 8,3 | - | - | 17,3 |
| *PERMEABILITY AND DISPERSIVE TESTS* | | | | | | |
| PERMEABILITY ( m/s ) | $4.11 \times 10^{-9}$ | | $3.72 \times 10^{-8}$ | | | |
| DOUBLE HYDROMETER : ASTM D422 (%) | 43,26 | | | | | |
| PINHOLE TEST : ASTM D4647 | ND 2 | | | | | |
| CRUMB TEST : BS1377 (1990) PART 5: 6.3 | Grade 3 | | | | | |
| *DRAINED SLOW SHEARBOX TEST : BS 1377 (1990) PART 7 :4 / 5* | | | | | | |
| MAXIMUM EFFECTIVE SHEAR STRESS... σ'd (kPa) | 41,6 | | 40,9 | | | 32,8 |
| APPARENT FRICTION ANGLE ( degrees) | 21,4 | | 24,7 | | | 23,3 |
| Moulded Density (kg/m$^3$) | 1570 | | 1634 | | | 1509 |

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Name : Frederik Elbers
Position : Technical Signatory

**CLIENT:** Aurecon SA
4 Daventry Street
Lynwood Ridge

**ATT:** Mr. G Davies

**PROJECT :** Kirkwood 112546
**JOB/ROAD :** C19226
**REPORT DATE :** 27.06.2018

**SAMPLING PROCEDURE:** Delivered to the Laboratory

## *TEST RESULT SUMMARY*

| | | | | | | |
|---|---|---|---|---|---|---|
| SAMPLE NUMBER | S98999 | S99000 | S99001 | S99002 | S99003 | S99004 |
| POSITION | LC10 | LC11 | LC20 | LC23 | US1 | US2 |
| DEPTH (M) | 1.0-1.6 | 0.5-1.5 | 0.9-1.95 | 0.5-2.0 | 1.1-1.4 | 0.1-1.5 |
| DESCRIPTION | Colluvium Part Pedogenic | Pedogenic | Pedogenic | Colluvium | Pedogenic | Colluvium part Pedogenic |
| UNIFIED SOIL CLASSIFICATION | CL | SC | CL | CL | CL | CL |
| HRB CLASSIFICATION | | | | | | |

*SIEVE ANALYSIS - TMH 1 Test Method A1, A2, A3, A5 & A6*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PASSING | 75.0 mm | | | | | | |
| | 63.0 mm | | | | | | |
| | 53.0 mm | | | | | | |
| | 37.5 mm | | 100 | | | | |
| | 26.5 mm | | 94 | | | 100 | |
| | 19.0 mm | | 89 | | 100 | 99 | 100 |
| | 13.2 mm | 100 | 86 | 100 | 99 | 98 | 99 |
| | 4.75 mm | 99 | 73 | 97 | 97 | 91 | 97 |
| | 2.00 mm | 98 | 60 | 96 | 96 | 87 | 94 |
| | 0.425 mm | 95 | 40 | 91 | 95 | 83 | 88 |
| | 0.075 mm | 76 | 32 | 80 | 50 | 60 | 77 |
| | 0.060 mm | 62 | 23 | 64 | 35 | 50 | 77 |
| | 0.006 mm | 1 | 2 | 3 | 5 | 1 | 9 |
| | 0.0018 mm | 0 | 1 | 0 | 1 | 0 | 3 |

*SOIL MORTAR ANALYSIS - TMH 1 Test Method A5*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Soil Mortar Analysis % < 2.00mm | 2.000 - 0.425 | 3 | 34 | 5 | 2 | 4 | 6 |
| | 0.425 - 0.250 | 3 | 2 | 1 | 5 | 3 | 2 |
| | 0.250 - 0.150 | 7 | 5 | 4 | 23 | 8 | 4 |
| | 0.150 - 0.075 | 10 | 6 | 6 | 19 | 15 | 6 |
| | < 0.075 | 78 | 54 | 84 | 52 | 70 | 82 |
| GRADING MODULUS | | 0,32 | 1,68 | 0,33 | 0,59 | 0,70 | 0,40 |

*ATTERBERG LIMITS : TMH 1 Test Method A2 - A4*

| | | | | | | |
|---|---|---|---|---|---|---|
| LIQUID LIMIT | 29 | 31 | 39 | 19 | 27 | 20 |
| PLASTICITY INDEX | 15 | 10 | 20 | 7 | 12 | 7 |
| LINEAR SHRINKAGE | 7,5 | 5,0 | 10,0 | 3,5 | 6,0 | 3,5 |

*PROCTOR : MOISTURE DENSITY RELATIONSHIP : BS 1377 PART 4*

| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum Proctor Density (Kg/m$^3$) | - | 1522 | 1739 | 1826 | - | - |
| O.M.C. (%) | - | 21,7 | 22,6 | 11,7 | - | - |

*RELATIVE DENSITY OF SOIL: TMH1 1986 A12T*

| | | | | | | |
|---|---|---|---|---|---|---|
| RELATIVE DENSITY | - | - | - | - | - | - |

*MOISTURE CONTENT: SANS 3001:GR20:2010*

| | | | | | | |
|---|---|---|---|---|---|---|
| MOISTURE CONTENT | - | - | 10,9 | 5,1 | - | - |

*PERMEABILITY AND DISPERSIVE TESTS*

| | | | | | | |
|---|---|---|---|---|---|---|
| PERMEABILITY ( m/s ) | | 1.88 x 10 -8 | 2.62 x 10 -9 | | | |
| DOUBLE HYDROMETER : ASTM D422 (%) | | | | | | |
| PINHOLE TEST : ASTM D4647 | | | | | | |
| CRUMB TEST : BS1377 (1990) PART 5: 6.3 | | | | | | |

*DRAINED SLOW SHEARBOX TEST : BS 1377 (1990) PART 7 :4 / 5*

| | | | | | | |
|---|---|---|---|---|---|---|
| MAXIMUM EFFECTIVE SHEAR STRESS... σ'd (kPa) | | 33,9 | 35,7 | 33,4 | | |
| APPARENT FRICTION ANGLE ( degrees) | | 20,2 | 24,8 | 19,2 | | |
| Moulded Density (kg/m$^3$) | | 1434 | 1596 | 1682 | | |

The above test results are pertinent only to the samples received and tested at the laboratory. This report shall not be reproduced, except in full,without the prior consent of Tosca Lab (Pty)Ltd.

Name : Frederik Eilbers
Position : Technical Signatory

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Testing Laboratory
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**CLIENT:** Aurecon SA
4 Daventry Street
Lynwood Ridge

**ATT:** Mr. G Davies

**PROJECT :** Kirkwood 112546
**JOB/ROAD :** C19226
**REPORT DATE :** 27.06.2018

**SAMPLING PROCEDURE:** Delivered to the Laboratory

## TEST RESULT SUMMARY

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| SAMPLE NUMBER | S99005 | S99006 | S99007 | S99007 | S99008 | S99009 | S99010 |
| POSITION | US3 | US4 | US5 | US5 | US5 | US6 | US7 |
| DEPTH (M) | 0.6-1.5 | 0.2-0.7 | 0.2-1.1 | 0.2-1.1 | 0.7-2.8 | 0.5-2.0 | 0.2-1.0 |
| DESCRIPTION | Colluvium, Part Pedogenic | Colluvium | Colluvium (Undisturbed) | Colluvium | Colluvium | Colluvium Part Pedogenic | Pedogenic |
| UNIFIED SOIL CLASSIFICATION | CL | CL | CL | CL | CL | CL-ML | SC |
| HRB CLASSIFICATION | | | | | | | |

*SIEVE ANALYSIS - TMH 1 Test Method A1, A2, A3, A5 & A6*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PASSING 75.0 mm | | | | | | | |
| 63.0 mm | | | | | | | |
| 53.0 mm | | | | | | | |
| 37.5 mm | 100 | | | | | | 100 |
| 26.5 mm | 97 | 100 | 100 | 100 | 100 | | 97 |
| 19.0 mm | 96 | 99 | 96 | 95 | 98 | | 89 |
| 13.2 mm | 95 | 97 | 92 | 92 | 97 | | 83 |
| 4.75 mm | 88 | 93 | 85 | 83 | 95 | | 62 |
| 2.00 mm | 78 | 91 | 80 | 78 | 94 | 100 | 51 |
| 0.425 mm | 69 | 89 | 76 | 74 | 93 | 96 | 40 |
| 0.075 mm | 53 | 59 | 61 | 50 | 73 | 51 | 23 |
| 0.060 mm | 36 | 50 | 55 | 39 | 61 | 41 | 17 |
| 0.006 mm | 4 | 1 | 3 | 2 | 3 | 3 | 1 |
| 0.0018 mm | 0 | 0 | 0 | 0 | 0 | 1 | 0 |

*SOIL MORTAR ANALYSIS - TMH 1 Test Method A5*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Soil Mortar Analysis % < 2.00mm | 2.000 - 0.425 | 12 | 2 | 5 | 6 | 2 | 4 | 22 |
| | 0.425 - 0.250 | 3 | 3 | 3 | 4 | 3 | 11 | 8 |
| | 0.250 - 0.150 | 7 | 12 | 7 | 10 | 8 | 18 | 13 |
| | 0.150 - 0.075 | 10 | 18 | 9 | 16 | 11 | 16 | 11 |
| | < 0.075 | 69 | 65 | 76 | 64 | 77 | 52 | 45 |
| GRADING MODULUS | | 1,00 | 0,61 | 0,84 | 0,98 | 0,41 | 0,53 | 1,87 |

*ATTERBERG LIMITS : TMH 1 Test Method A2 - A4*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| LIQUID LIMIT | 29 | 23 | 30 | 32 | 26 | 16 | 34 |
| PLASTICITY INDEX | 16 | 10 | 14 | 16 | 12 | 4 | 11 |
| LINEAR SHRINKAGE | 8,0 | 5,0 | 7,0 | 8,0 | 6,0 | 2,0 | 5,5 |

*PROCTOR : MOISTURE DENSITY RELATIONSHIP : BS 1377 PART 4*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Maximum Proctor Density (Kg/m$^3$) | 1682 | - | - | - | 1684 | 1743 | - |
| O.M.C. (%) | 18,3 | - | - | - | 18,9 | 16,5 | - |

*RELATIVE DENSITY OF SOIL: TMH1 1986 A12T*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| RELATIVE DENSITY | 2,570 | - | 2,600 | - | - | 2,580 | - |

*MOISTURE CONTENT: SANS 3001:GR20:2010*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MOISTURE CONTENT | 14,3 | - | 11,2 | - | 10,2 | 12,8 | - |

*PERMEABILITY AND DISPERSIVE TESTS*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PERMEABILITY ( m/s ) | 6.13 x 10-9 | | 4.51 x 10-8 | | | 1.63 x 10-7 | |
| DOUBLE HYDROMETER : ASTM D422 (%) | | | | | 43,11 | 31,27 | |
| PINHOLE TEST : ASTM D4647 | | | | | ND 3 | ND 3 | |
| CRUMB TEST : BS1377 (1990) PART 5: 6.3 | | | | | Grade 3 | Grade 2 | |

*DRAINED SLOW SHEARBOX TEST : BS 1377 (1990) PART 7 :4 / 5*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MAXIMUM EFFECTIVE SHEAR STRESS... σ'd (kPa) | 39,6 | | 33,5 | | 31,6 | 38,1 | |
| APPARENT FRICTION ANGLE ( degrees) | 21,3 | | 22,4 | | 23,8 | 19,4 | |
| Moulded Density (kg/m$^3$) | 1579 | | 1611 | | 1563 | 1600 | |

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Position : Technical Signatory

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**CLIENT:** Aurecon SA
4 Daventry Street
Lynwood Ridge

**ATT:** Mr. G Davies

**PROJECT :** Kirkwood 112546
**JOB/ROAD :** C19226
**REPORT DATE :** 27.06.2018

**SAMPLING PROCEDURE:** Delivered to the Laboratory

## *TEST RESULT SUMMARY*

| SAMPLE NUMBER | S99011 | S99012 | S99013 | S99014 | S99015 | S99016 |
|---|---|---|---|---|---|---|
| POSITION | US10 | US21 | US22 | US23 | US24 | US25 |
| DEPTH (M) | 0.45-1.25 | 0.0-1.45 | 0.5-2.0 | 0.5-1.7 | 0.5-1.5 | 0.5-1.3 |
| DESCRIPTION | Residual Sand | Colluvium | Colluvium Part Pedogenic | Colluvium part Pedogenic | Colluvium Part Pedogenic | Pedogenic |
| UNIFIED SOIL CLASSIFICATION | SC / SM | CL | CL | CL | CL | CL |
| HRB CLASSIFICATION | | | | | | |

*SIEVE ANALYSIS - TMH 1 Test Method A1, A2, A3, A5 & A6*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PASSING | 75.0 mm | | | | | | |
| | 63.0 mm | | | | | | |
| | 53.0 mm | 100 | | | | | |
| | 37.5 mm | 94 | | | | | |
| | 26.5 mm | 92 | | 100 | | | 100 |
| | 19.0 mm | 88 | | 98 | 100 | | 97 |
| | 13.2 mm | 82 | | 98 | 99 | | 95 |
| | 4.75 mm | 69 | 100 | 89 | 96 | | 88 |
| | 2.00 mm | 64 | 99 | 81 | 93 | 100 | 82 |
| | 0.425 mm | 59 | 98 | 70 | 88 | 99 | 76 |
| | 0.075 mm | 28 | 64 | 60 | 74 | 74 | 63 |
| | 0.060 mm | 23 | 46 | 46 | 48 | 60 | 57 |
| | 0.006 mm | 2 | 1 | 1 | 5 | 8 | 2 |
| | 0.0018 mm | 0 | 0 | 0 | 0 | 2 | 0 |

*SOIL MORTAR ANALYSIS - TMH 1 Test Method A5*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Soil Mortar Analysis % < 2.00mm | 2.000 - 0.425 | 7 | 1 | 14 | 5 | 1 | 7 |
| | 0.425 - 0.250 | 10 | 4 | 2 | 2 | 2 | 3 |
| | 0.250 - 0.150 | 21 | 11 | 5 | 5 | 9 | 6 |
| | 0.150 - 0.075 | 18 | 20 | 6 | 9 | 14 | 8 |
| | < 0.075 | 44 | 64 | 73 | 80 | 75 | 77 |
| GRADING MODULUS | | 1,49 | 0,39 | 0,89 | 0,45 | 0,28 | 0,79 |

*ATTERBERG LIMITS : TMH 1 Test Method A2 - A4*

| | | | | | | |
|---|---|---|---|---|---|---|
| LIQUID LIMIT | 19 | 27 | 41 | 26 | 27 | 39 |
| PLASTICITY INDEX | 6 | 12 | 21 | 12 | 14 | 20 |
| LINEAR SHRINKAGE | 3,0 | 6,0 | 10,5 | 6,0 | 7,0 | 10,0 |

*PROCTOR : MOISTURE DENSITY RELATIONSHIP : BS 1377 PART 4*

| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum Proctor Density (Kg/m$^3$) | - | 1779 | 1635 | - | 1730 | - |
| O.M.C. (%) | - | 17,3 | 19,8 | - | 16,6 | - |

*RELATIVE DENSITY OF SOIL: TMH1 1986 A12T*

| | | | | | | |
|---|---|---|---|---|---|---|
| RELATIVE DENSITY | - | 2,610 | - | - | - | 2,600 |

*MOISTURE CONTENT: SANS 3001:GR20:2010*

| | | | | | | |
|---|---|---|---|---|---|---|
| MOISTURE CONTENT | - | 9,7 | 10,7 | - | 10,1 | - |

*PERMEABILITY AND DISPERSIVE TESTS*

| | | | | | | |
|---|---|---|---|---|---|---|
| PERMEABILITY ( m/s ) | | 5.02 x 10-9 | | | | |
| DOUBLE HYDROMETER : ASTM D422 (%) | | | | | 38,72 | |
| PINHOLE TEST : ASTM D4647 | | | | | ND 3 | |
| CRUMB TEST : BS1377 (1990) PART 5: 6.3 | | | | | Grade 2 | |

*DRAINED SLOW SHEARBOX TEST : BS 1377 (1990) PART 7 :4 / 5*

| | | | | | | |
|---|---|---|---|---|---|---|
| MAXIMUM EFFECTIVE SHEAR STRESS... σ'd (kPa) | | 37,3 | | | 34,3 | |
| APPARENT FRICTION ANGLE ( degrees) | | 21,9 | | | 20,2 | |
| Moulded Density (kg/m$^3$) | | 1635 | | | 1595 | |

The above test results are pertinent only to the samples received and tested at the laboratory. This report shall not be reproduced, except in full,without the prior consent of Tosca Lab (Pty)Ltd.

Name : Frederik Eilbers
Position : Technical Signatory

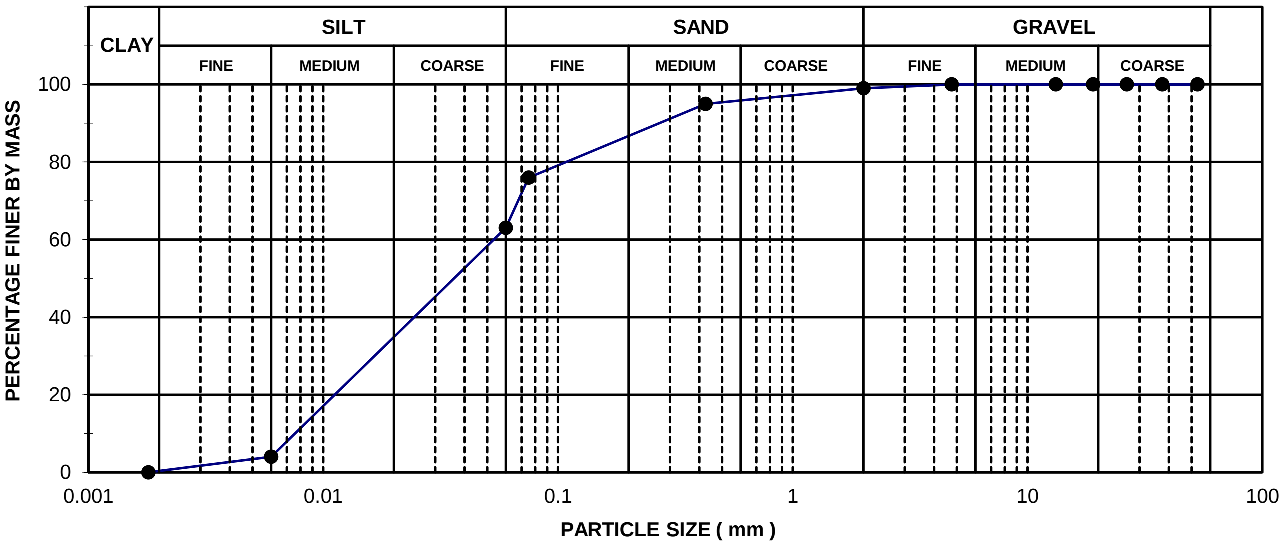
aurecon

# FOUNDATION INDICATOR TEST RESULTS

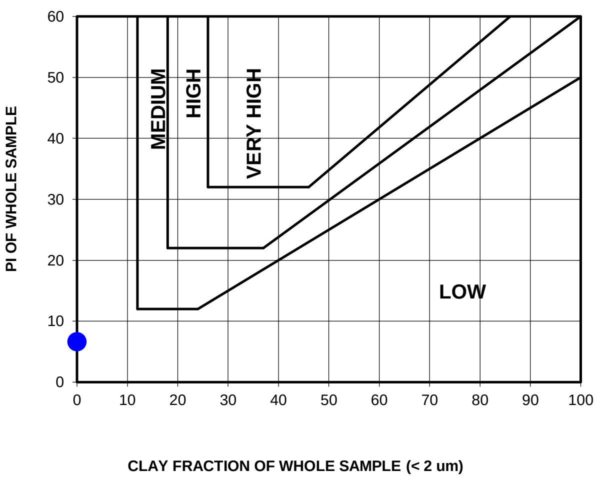
| | | | |
|---|---|---|---|
| TEST LOCATION | LC02 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98987 | PROJECT NUMBER | 112546 |
| DEPTH | 1.0-1.95 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **76** | Liquid limit | (%) | **21** | % Gravel | **1** |
| 37.500 | **100** | 0.060 | **63** | Plastic limit | (%) | **14** | % Sand | **36** |
| 26.500 | **100** | 0.006 | **4** | Plasticity Index | (%) | **7** | % Silt | **63** |
| 19.000 | **100** | 0.0018 | **0** | Weighted PI | (%) | **7** | % Clay | **0** |
| 13.200 | **100** | | | Linear Shrinkage | (%) | **3.5** | Activity | **#DIV/0!** |
| 4.750 | **100** | | | Grading Modulus | | **0.30** | Unified Classification | **CL** |
| 2.000 | **99** | | | Uniformity coefficient | | **5** | TRB Classification | **A - 4** |
| 0.425 | **95** | | | Coefficient of curvature | | **1.3** | | |

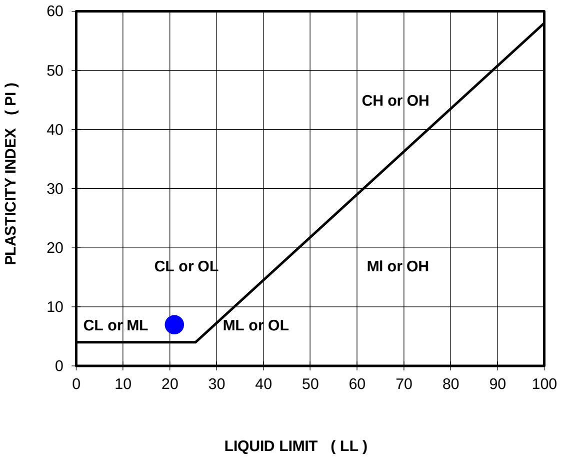
## PARTICLE SIZE DISTRIBUTION



POTENTIAL EXPANSIVENESS
Van der Merwe's Activity Chart



CASAGRANDE 'A' LINE

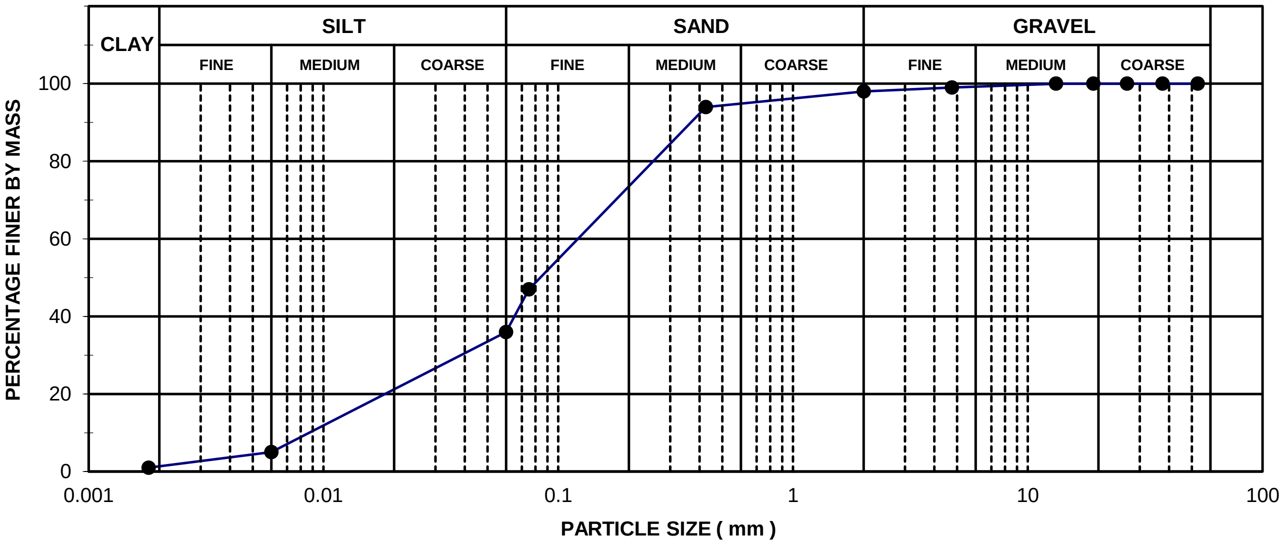


# FOUNDATION INDICATOR TEST RESULTS

| | | | |
|---|---|---|---|
| TEST LOCATION | LC03 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98988 | PROJECT NUMBER | 112546 |
| DEPTH | 0.3-1.15 m | SITE | Lower Coerney |

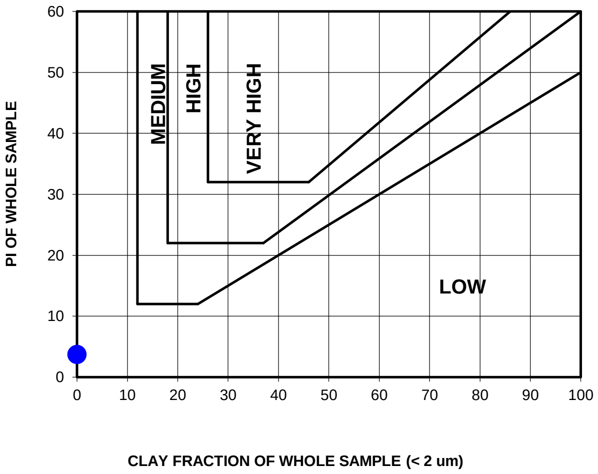
| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **47** | Liquid limit | (%) | **15** | % Gravel | **2** |
| 37.500 | **100** | 0.060 | **36** | Plastic limit | (%) | **11** | % Sand | **62** |
| 26.500 | **100** | 0.006 | **5** | Plasticity Index | (%) | **4** | % Silt | **35** |
| 19.000 | **100** | 0.0018 | **1** | Weighted PI | (%) | **4** | % Clay | **1** |
| 13.200 | **100** | | | Linear Shrinkage | (%) | **2.0** | Activity | **4.0** |
| 4.750 | **99** | | | Grading Modulus | | **0.61** | Unified Classification | **SC-SM** |
| 2.000 | **98** | | | Uniformity coefficient | | **12** | TRB Classification | **A - 4** |
| 0.425 | **94** | | | Coefficient of curvature | | **1.0** | | |

## PARTICLE SIZE DISTRIBUTION

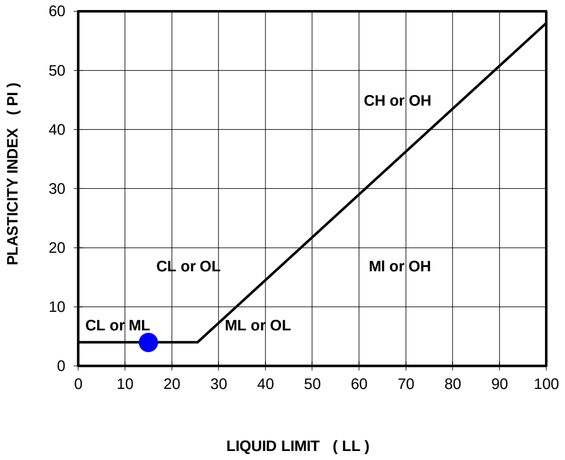


**POTENTIAL EXPANSIVENESS**

**Van der Merwe's Activity Chart**



**CASAGRANDE 'A' LINE**

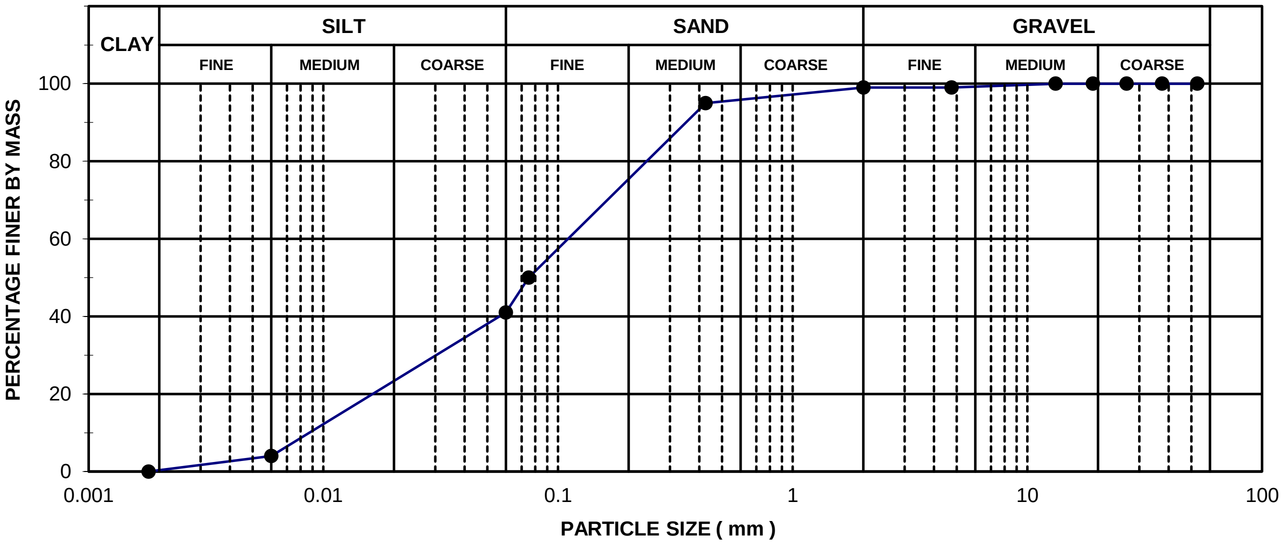


## FOUNDATION INDICATOR TEST RESULTS

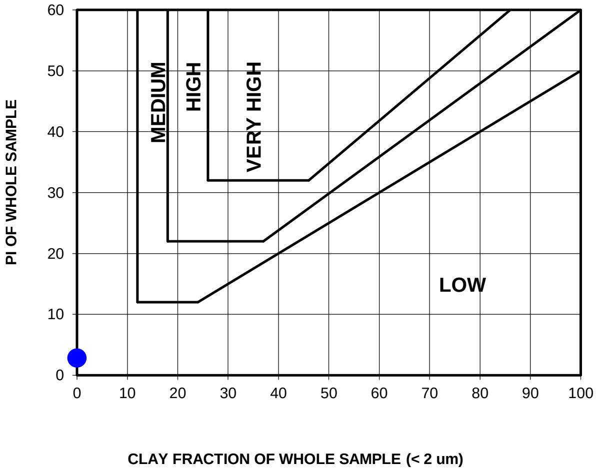
| | | | |
|---|---|---|---|
| TEST LOCATION | LC03 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98988 | PROJECT NUMBER | 112546 |
| DEPTH | 0.3-2.05 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **50** | Liquid limit | (%) | **15** | % Gravel | **1** |
| 37.500 | **100** | 0.060 | **41** | Plastic limit | (%) | **12** | % Sand | **58** |
| 26.500 | **100** | 0.006 | **4** | Plasticity Index | (%) | **3** | % Silt | **41** |
| 19.000 | **100** | 0.0018 | **0** | Weighted PI | (%) | **3** | % Clay | **0** |
| 13.200 | **100** | | | Linear Shrinkage | (%) | **1.5** | Activity | **#DIV/0!** |
| 4.750 | **99** | | | Grading Modulus | | **0.56** | Unified Classification | **SM** |
| 2.000 | **99** | | | Uniformity coefficient | | **10** | TRB Classification | **A - 4** |
| 0.425 | **95** | | | Coefficient of curvature | | **0.9** | | |

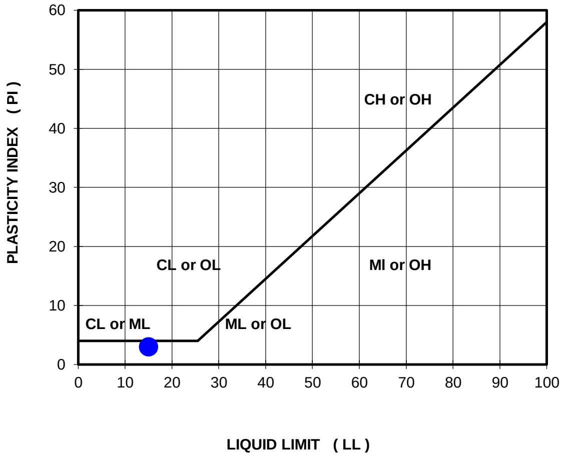
### PARTICLE SIZE DISTRIBUTION



**POTENTIAL EXPANSIVENESS**
Van der Merwe's Activity Chart



**CASAGRANDE 'A' LINE**

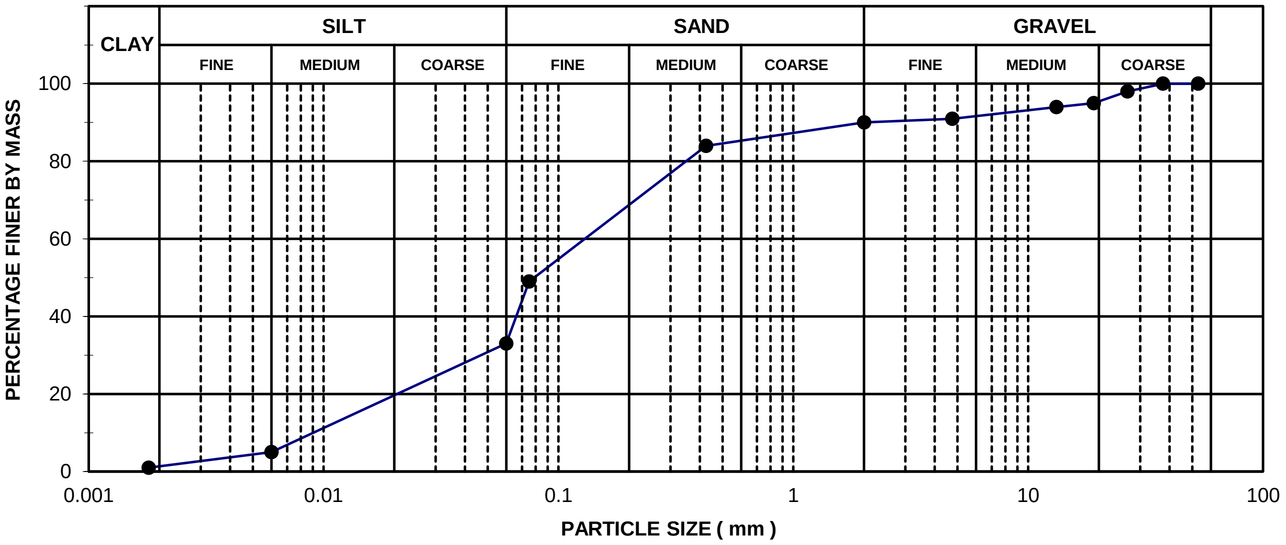


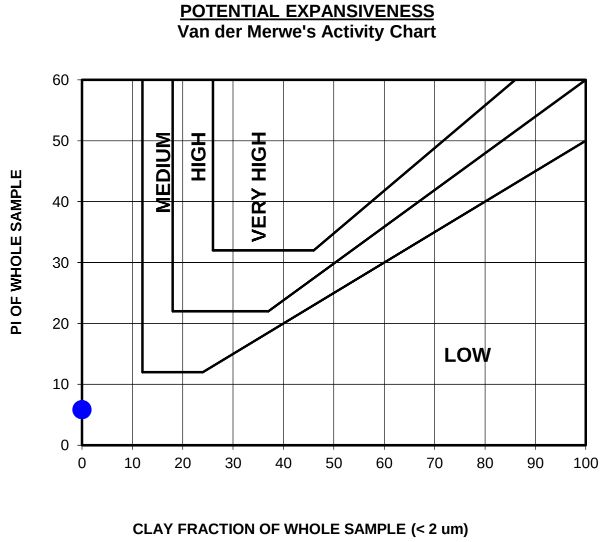
# FOUNDATION INDICATOR TEST RESULTS

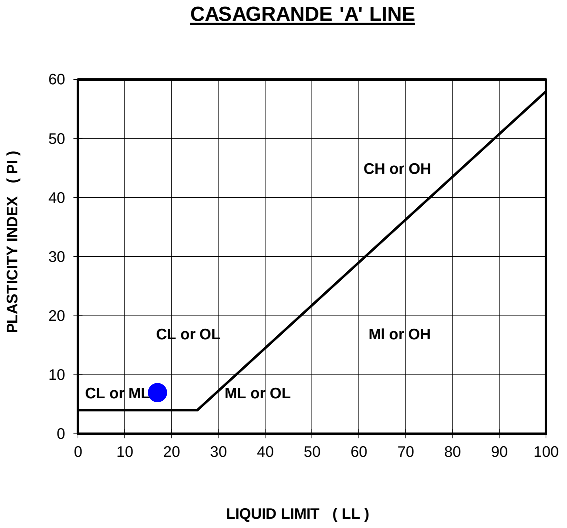
| | | | |
|---|---|---|---|
| TEST LOCATION | LC04 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98990 | PROJECT NUMBER | 112546 |
| DEPTH | 0.3-1.15 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **49** | Liquid limit | (%) | **17** | % Gravel | **10** |
| 37.500 | **100** | 0.060 | **33** | Plastic limit | (%) | **10** | % Sand | **57** |
| 26.500 | **98** | 0.006 | **5** | Plasticity Index | (%) | **7** | % Silt | **32** |
| 19.000 | **95** | 0.0018 | **1** | Weighted PI | (%) | **6** | % Clay | **1** |
| 13.200 | **94** | | | Linear Shrinkage | (%) | **3.5** | Activity | **7.0** |
| 4.750 | **91** | | | Grading Modulus | | **0.77** | Unified Classification | **SC-SM** |
| 2.000 | **90** | | | Uniformity coefficient | | **12** | TRB Classification | **A - 2 - 4** |
| 0.425 | **84** | | | Coefficient of curvature | | **1.0** | | |

## PARTICLE SIZE DISTRIBUTION





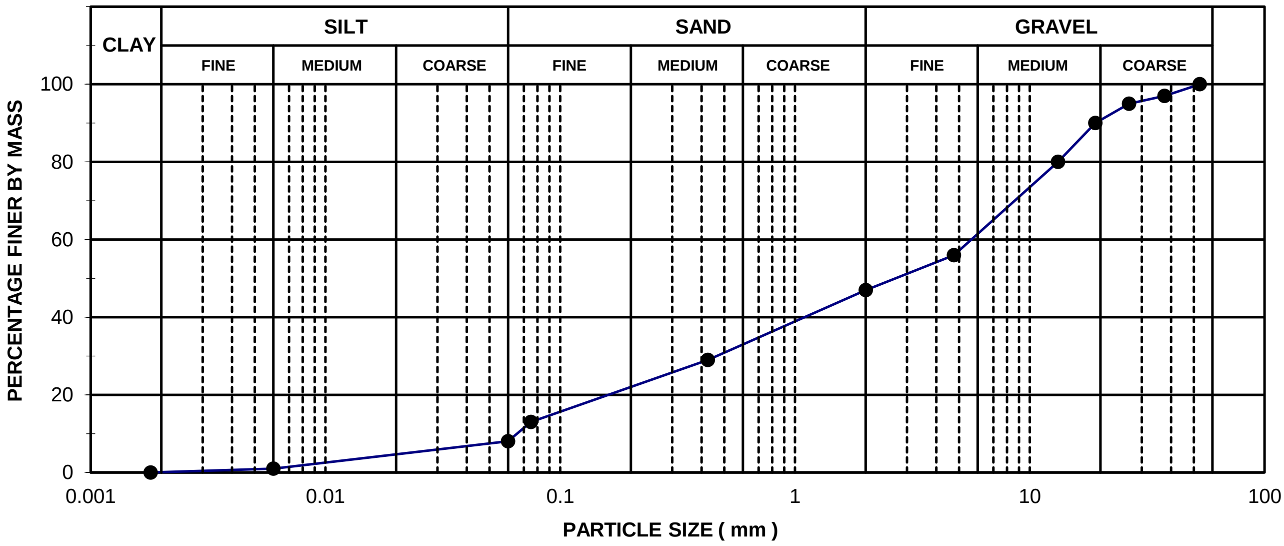


# FOUNDATION INDICATOR TEST RESULTS

| | | | |
|---|---|---|---|
| TEST LOCATION | LC05 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98992 | PROJECT NUMBER | 112546 |
| DEPTH | 1.3-2.75 m | SITE | Lower Coerney |

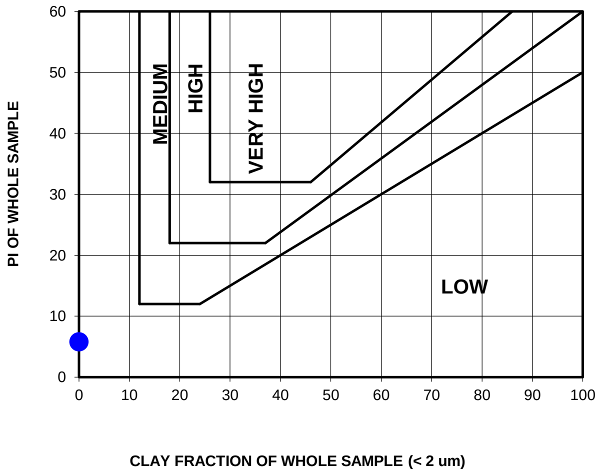
| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **13** | Liquid limit | (%) | **49** | % Gravel | **53** |
| 37.500 | **97** | 0.060 | **8** | Plastic limit | (%) | **29** | % Sand | **39** |
| 26.500 | **95** | 0.006 | **1** | Plasticity Index | (%) | **20** | % Silt | **8** |
| 19.000 | **90** | 0.0018 | **0** | Weighted PI | (%) | **6** | % Clay | **0** |
| 13.200 | **80** | | | Linear Shrinkage | (%) | **10.0** | Activity | **#DIV/0!** |
| 4.750 | **56** | | | Grading Modulus | | **2.11** | Unified Classification | **GM** |
| 2.000 | **47** | | | Uniformity coefficient | | **93** | TRB Classification | **A - 2 - 7** |
| 0.425 | **29** | | | Coefficient of curvature | | **0.6** | | |

## PARTICLE SIZE DISTRIBUTION

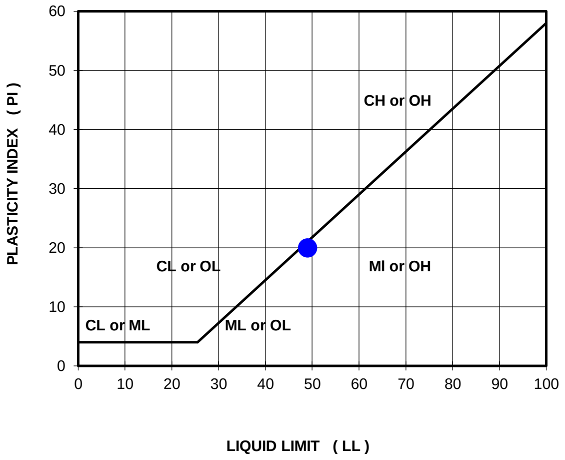


## POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



## CASAGRANDE 'A' LINE

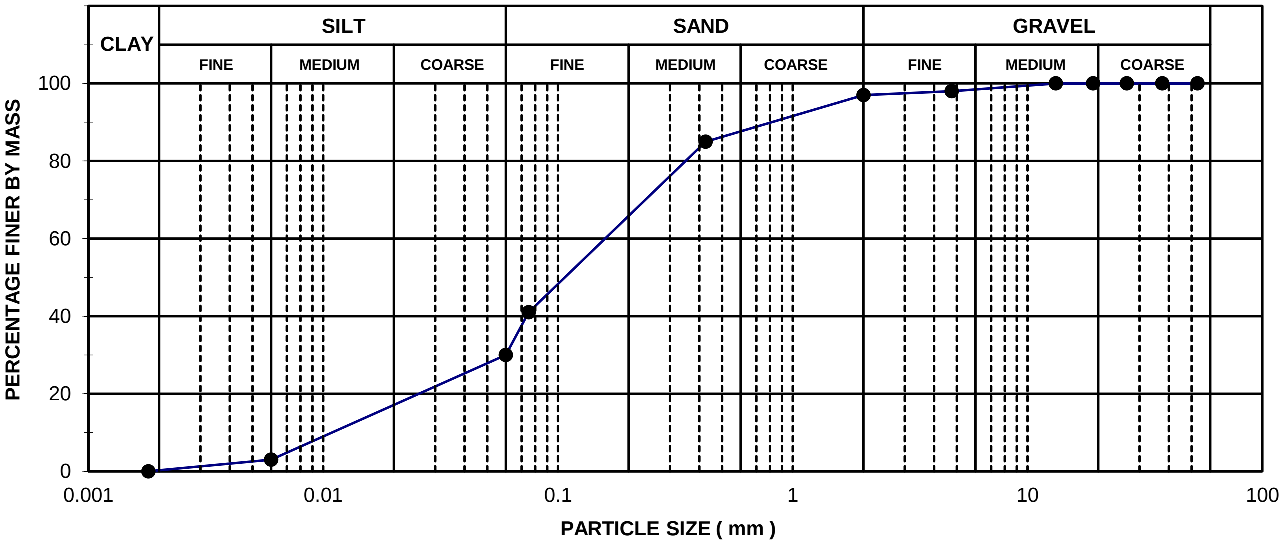


# FOUNDATION INDICATOR TEST RESULTS

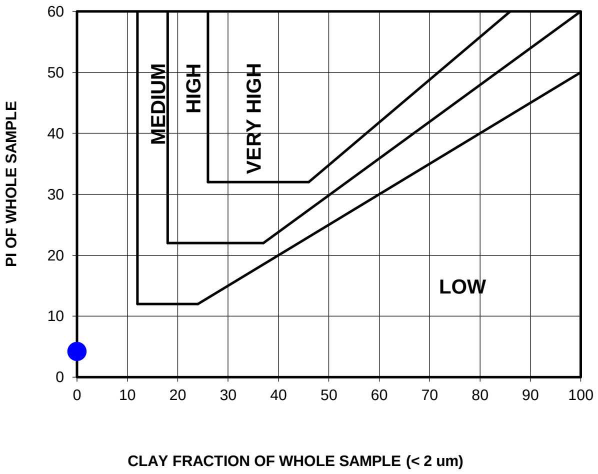
| | | | |
|---|---|---|---|
| TEST LOCATION | LC05 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98991 | PROJECT NUMBER | 112546 |
| DEPTH | 0.3-1.3 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **41** | Liquid limit | (%) | **15** | % Gravel | **3** |
| 37.500 | **100** | 0.060 | **30** | Plastic limit | (%) | **10** | % Sand | **67** |
| 26.500 | **100** | 0.006 | **3** | Plasticity Index | (%) | **5** | % Silt | **30** |
| 19.000 | **100** | 0.0018 | **0** | Weighted PI | (%) | **4** | % Clay | **0** |
| 13.200 | **100** | | | Linear Shrinkage | (%) | **2.5** | Activity | **#DIV/0!** |
| 4.750 | **98** | | | Grading Modulus | | **0.77** | Unified Classification | **SC-SM** |
| 2.000 | **97** | | | Uniformity coefficient | | **11** | TRB Classification | **A - 2 - 4** |
| 0.425 | **85** | | | Coefficient of curvature | | **0.8** | | |

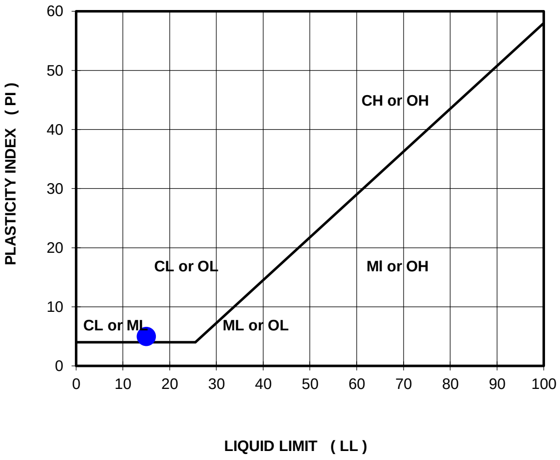
## PARTICLE SIZE DISTRIBUTION



POTENTIAL EXPANSIVENESS
Van der Merwe's Activity Chart



CASAGRANDE 'A' LINE



## FOUNDATION INDICATOR TEST RESULTS

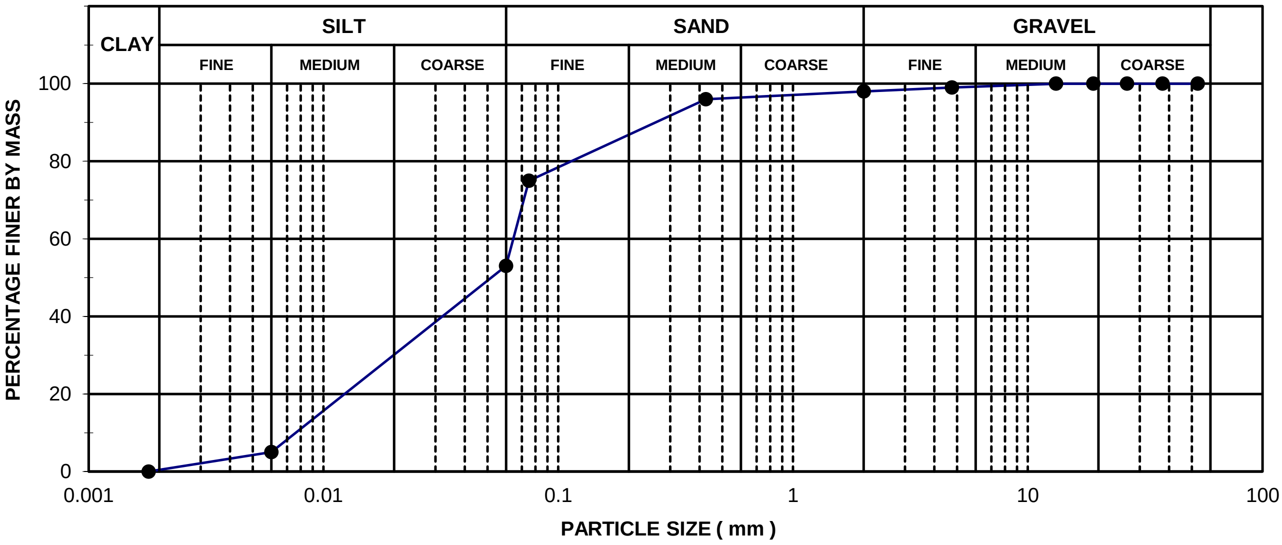
| | | | |
|---|---|---|---|
| TEST LOCATION | LC06 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98993 | PROJECT NUMBER | 112546 |
| DEPTH | 0.5-1.65 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | |
|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing |
| 53.000 | **100** | 0.075 | **75** |
| 37.500 | **100** | 0.060 | **53** |
| 26.500 | **100** | 0.006 | **5** |
| 19.000 | **100** | 0.0018 | **0** |
| 13.200 | **100** | | |
| 4.750 | **99** | | |
| 2.000 | **98** | | |
| 0.425 | **96** | | |

| ATTERBERG LIMITS | | |
|---|---|---|
| Liquid limit | (%) | **32** |
| Plastic limit | (%) | **14** |
| Plasticity Index | (%) | **18** |
| Weighted PI | (%) | **17** |
| Linear Shrinkage | (%) | **9.0** |
| Grading Modulus | | **0.31** |
| Uniformity coefficient | | **6** |
| Coefficient of curvature | | **1.5** |

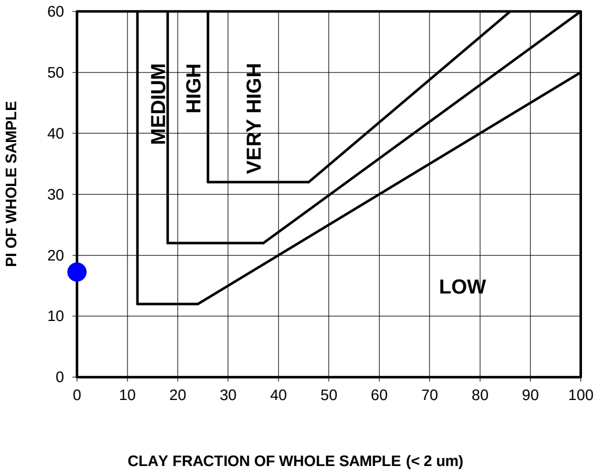
| SOIL CLASSIFICATION | |
|---|---|
| % Gravel | **2** |
| % Sand | **45** |
| % Silt | **53** |
| % Clay | **0** |
| Activity | **#DIV/0!** |
| Unified Classification | **CL** |
| TRB Classification | **A - 6** |

### PARTICLE SIZE DISTRIBUTION

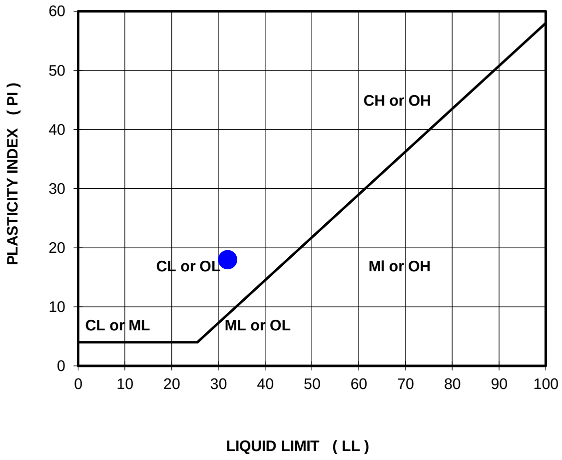


### POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



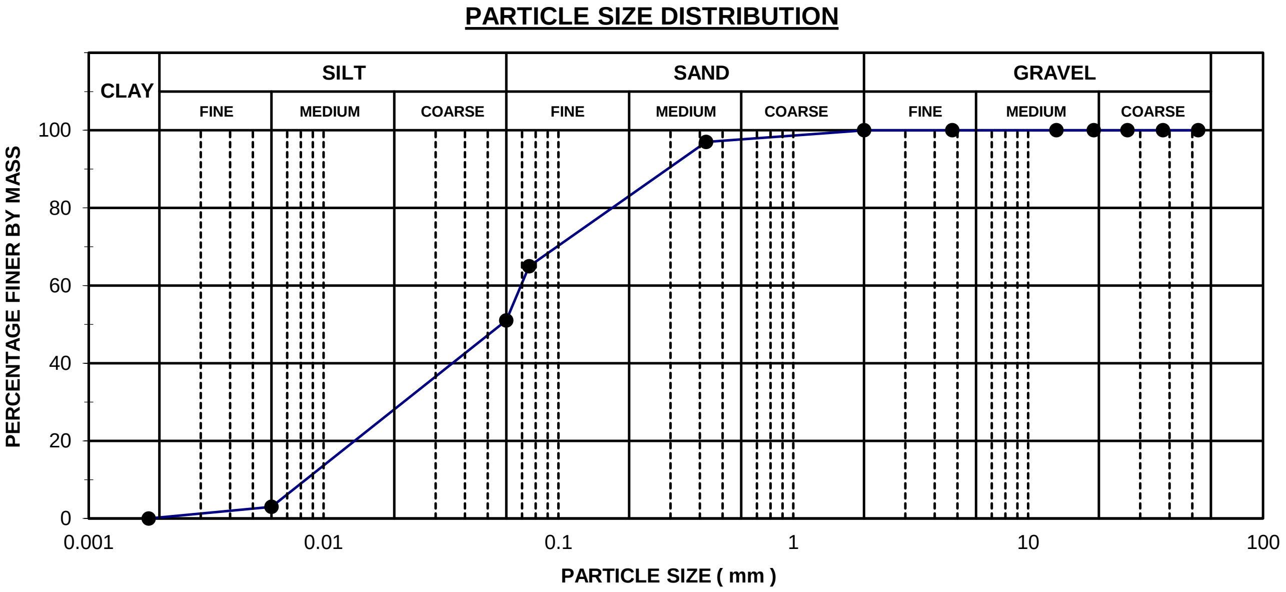
### CASAGRANDE 'A' LINE

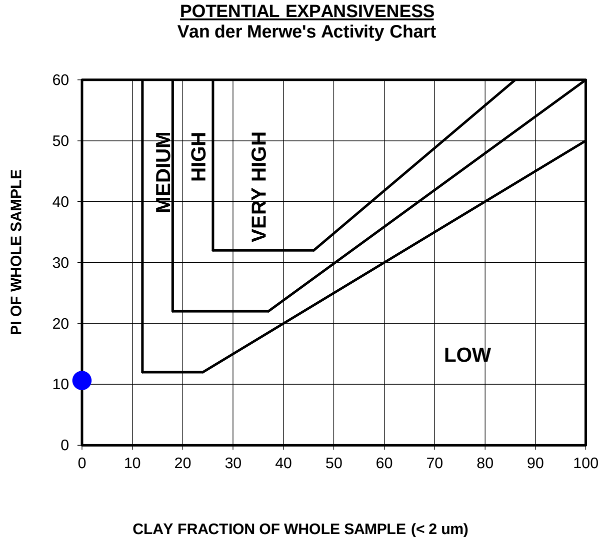


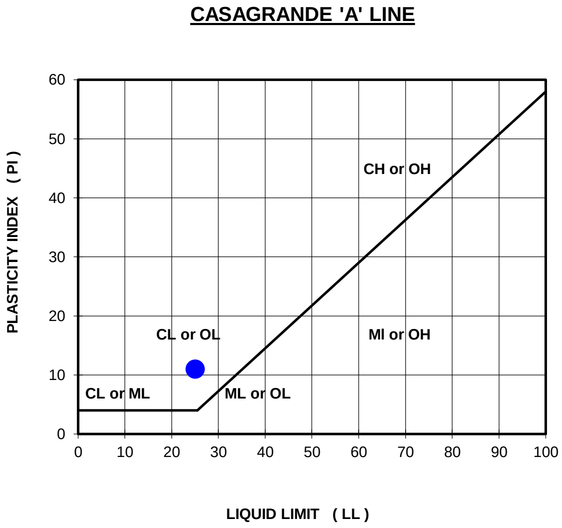
## FOUNDATION INDICATOR TEST RESULTS

| | | | |
|---|---|---|---|
| TEST LOCATION | LC07 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98994 | PROJECT NUMBER | 112546 |
| DEPTH | 0.9-2.0 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **65** | Liquid limit | (%) | **25** | % Gravel | **0** |
| 37.500 | **100** | 0.060 | **51** | Plastic limit | (%) | **14** | % Sand | **49** |
| 26.500 | **100** | 0.006 | **3** | Plasticity Index | (%) | **11** | % Silt | **51** |
| 19.000 | **100** | 0.0018 | **0** | Weighted PI | (%) | **11** | % Clay | **0** |
| 13.200 | **100** | | | Linear Shrinkage | (%) | **5.5** | Activity | **#DIV/0!** |
| 4.750 | **100** | | | Grading Modulus | | **0.38** | Unified Classification | **CL** |
| 2.000 | **100** | | | Uniformity coefficient | | **5** | TRB Classification | **A - 6** |
| 0.425 | **97** | | | Coefficient of curvature | | **1.4** | | |







# FOUNDATION INDICATOR TEST RESULTS

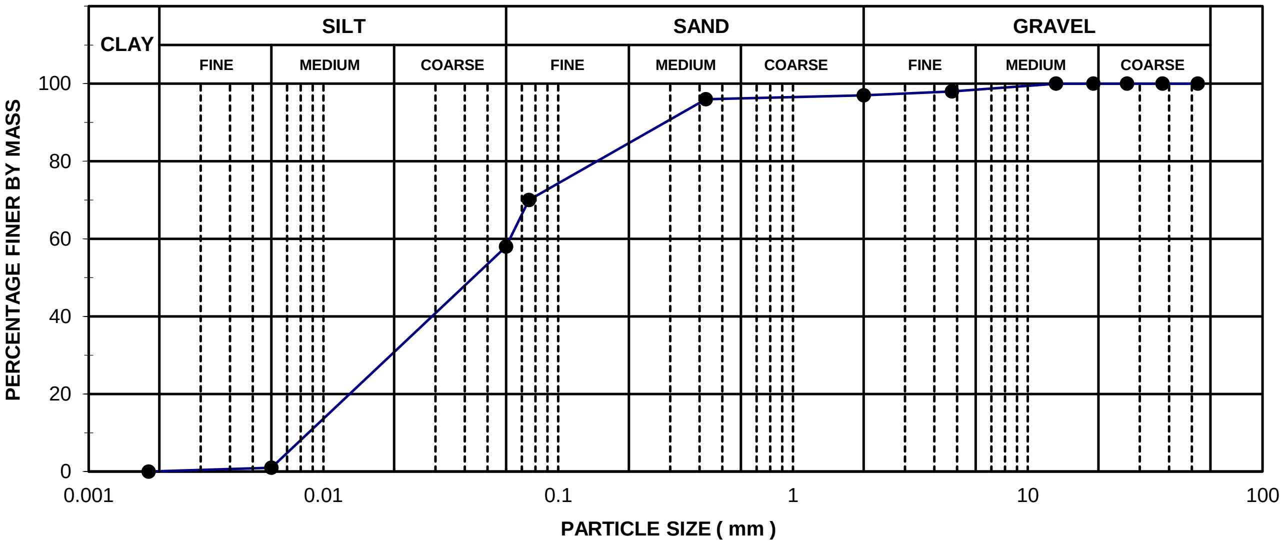
| | | | |
|---|---|---|---|
| TEST LOCATION | LC08 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98995 | PROJECT NUMBER | 112546 |
| DEPTH | 0.5-1.5 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | |
|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing |
| 53.000 | **100** | 0.075 | **70** |
| 37.500 | **100** | 0.060 | **58** |
| 26.500 | **100** | 0.006 | **1** |
| 19.000 | **100** | 0.0018 | **0** |
| 13.200 | **100** | | |
| 4.750 | **98** | | |
| 2.000 | **97** | | |
| 0.425 | **96** | | |

| ATTERBERG LIMITS | | |
|---|---|---|
| Liquid limit | (%) | **26** |
| Plastic limit | (%) | **14** |
| Plasticity Index | (%) | **12** |
| Weighted PI | (%) | **12** |
| Linear Shrinkage | (%) | **6.0** |
| Grading Modulus | | **0.76** |
| Uniformity coefficient | | **4** |
| Coefficient of curvature | | **1.2** |

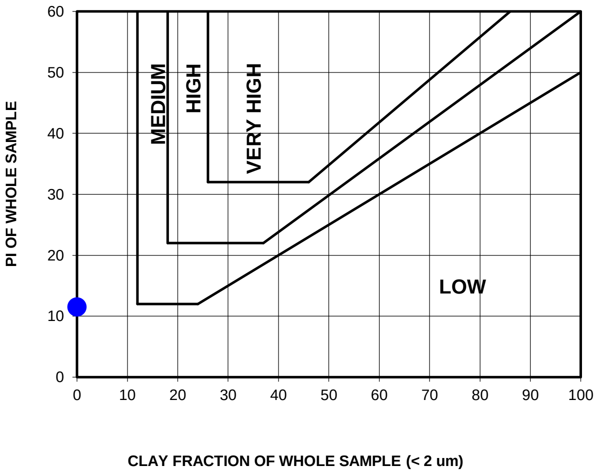
| SOIL CLASSIFICATION | |
|---|---|
| % Gravel | **3** |
| % Sand | **39** |
| % Silt | **58** |
| % Clay | **0** |
| Activity | **#DIV/0!** |
| Unified Classification | **CL** |
| TRB Classification | **A - 6** |

## PARTICLE SIZE DISTRIBUTION

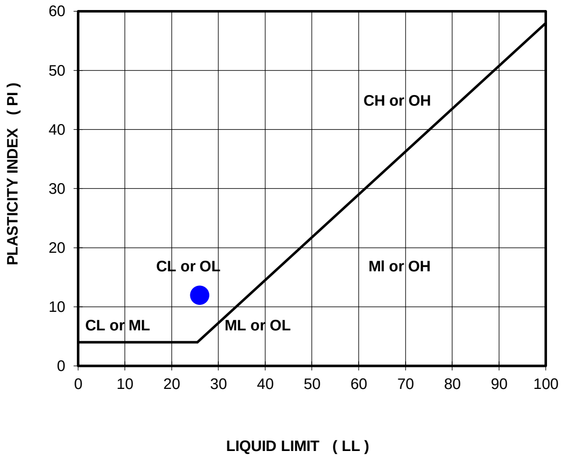


### POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



### CASAGRANDE 'A' LINE



# FOUNDATION INDICATOR TEST RESULTS

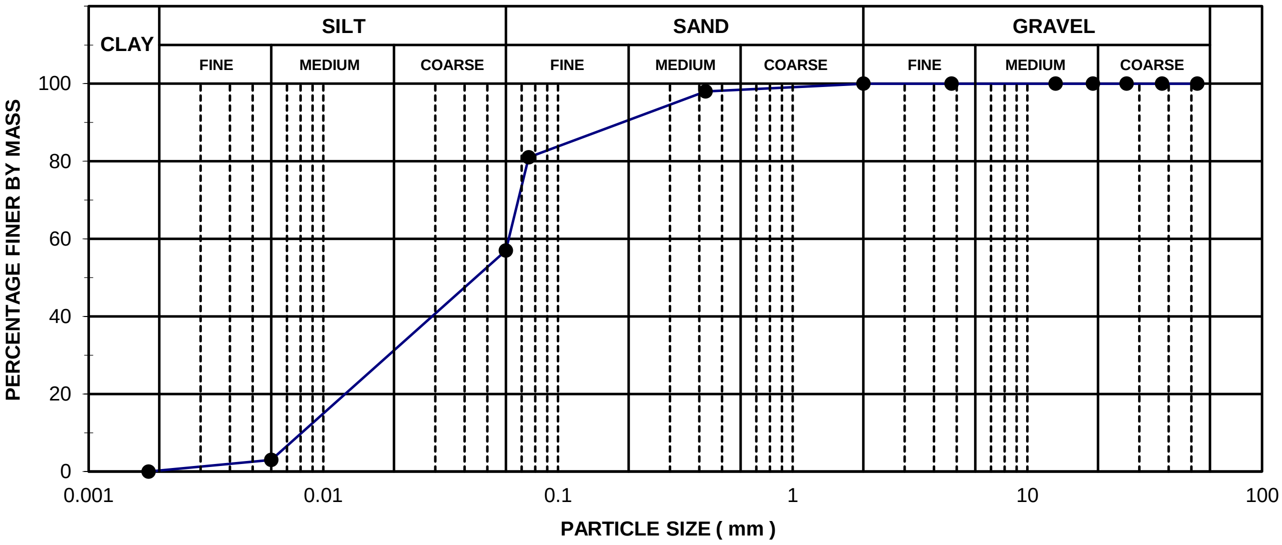
| | | | |
|---|---|---|---|
| TEST LOCATION | LC09 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98996 | PROJECT NUMBER | 112546 |
| DEPTH | 0.4-0.85 m | SITE | Lower Coerney |

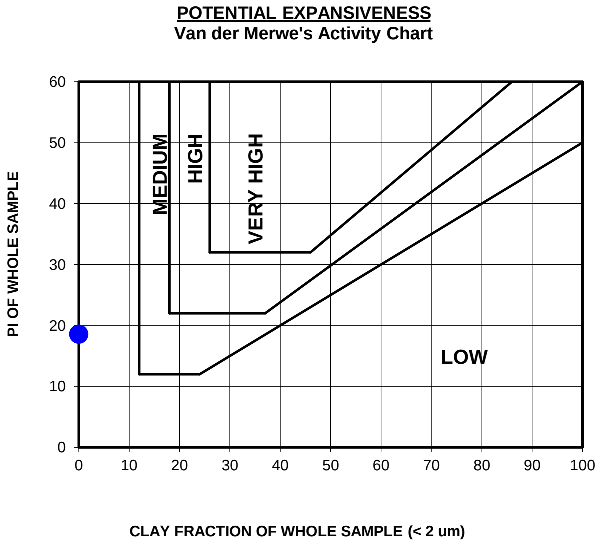
| SIEVE ANALYSIS | | | |
|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing |
| 53.000 | **100** | 0.075 | **81** |
| 37.500 | **100** | 0.060 | **57** |
| 26.500 | **100** | 0.006 | **3** |
| 19.000 | **100** | 0.0018 | **0** |
| 13.200 | **100** | | |
| 4.750 | **100** | | |
| 2.000 | **100** | | |
| 0.425 | **98** | | |

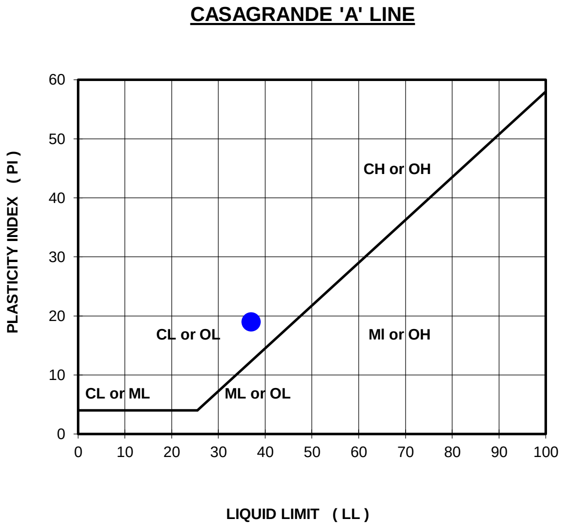
| ATTERBERG LIMITS | | |
|---|---|---|
| Liquid limit | (%) | **37** |
| Plastic limit | (%) | **18** |
| Plasticity Index | (%) | **19** |
| Weighted PI | (%) | **19** |
| Linear Shrinkage | (%) | **9.5** |
| Grading Modulus | | **0.21** |
| Uniformity coefficient | | **5** |
| Coefficient of curvature | | **1.4** |

| SOIL CLASSIFICATION | |
|---|---|
| % Gravel | **0** |
| % Sand | **43** |
| % Silt | **57** |
| % Clay | **0** |
| Activity | **#DIV/0!** |
| Unified Classification | **CL** |
| TRB Classification | **A - 6** |
| | |

## PARTICLE SIZE DISTRIBUTION







# FOUNDATION INDICATOR TEST RESULTS

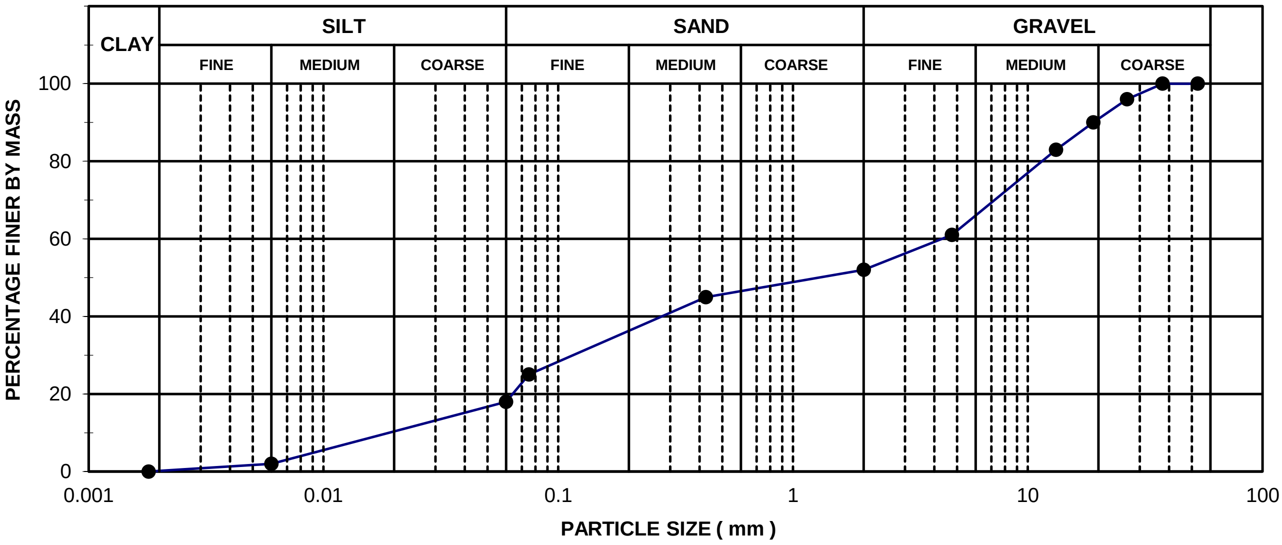
| | | | |
|---|---|---|---|
| TEST LOCATION | LC09 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98997 | PROJECT NUMBER | 112546 |
| DEPTH | 0.85-1.2 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | |
|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing |
| 53.000 | **100** | 0.075 | **25** |
| 37.500 | **100** | 0.060 | **18** |
| 26.500 | **96** | 0.006 | **2** |
| 19.000 | **90** | 0.0018 | **0** |
| 13.200 | **83** | | |
| 4.750 | **61** | | |
| 2.000 | **52** | | |
| 0.425 | **45** | | |

| ATTERBERG LIMITS | | |
|---|---|---|
| Liquid limit | (%) | **30** |
| Plastic limit | (%) | **12** |
| Plasticity Index | (%) | **18** |
| Weighted PI | (%) | **8** |
| Linear Shrinkage | (%) | **9.0** |
| Grading Modulus | | **1.78** |
| Uniformity coefficient | | **135** |
| Coefficient of curvature | | **0.2** |

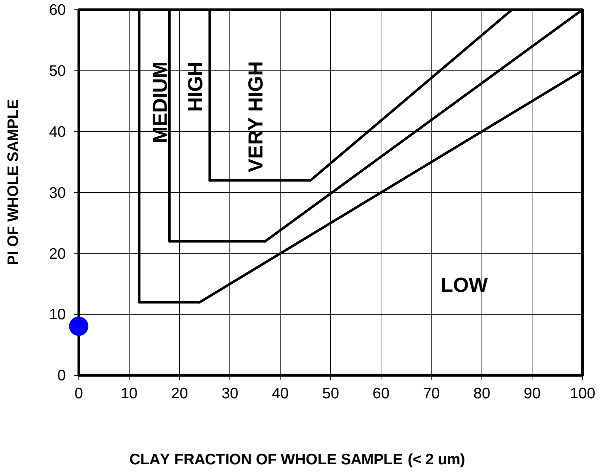
| SOIL CLASSIFICATION | |
|---|---|
| % Gravel | **48** |
| % Sand | **34** |
| % Silt | **18** |
| % Clay | **0** |
| Activity | **#DIV/0!** |
| Unified Classification | **SC** |
| TRB Classification | **A - 2 - 6** |
| | |

## PARTICLE SIZE DISTRIBUTION

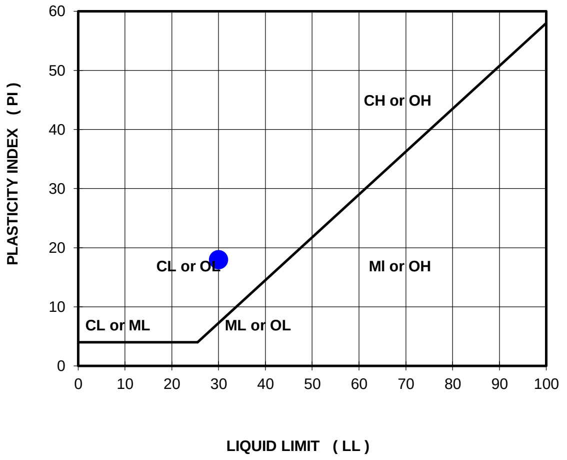


### POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



### CASAGRANDE 'A' LINE



aurecon

# FOUNDATION INDICATOR TEST RESULTS

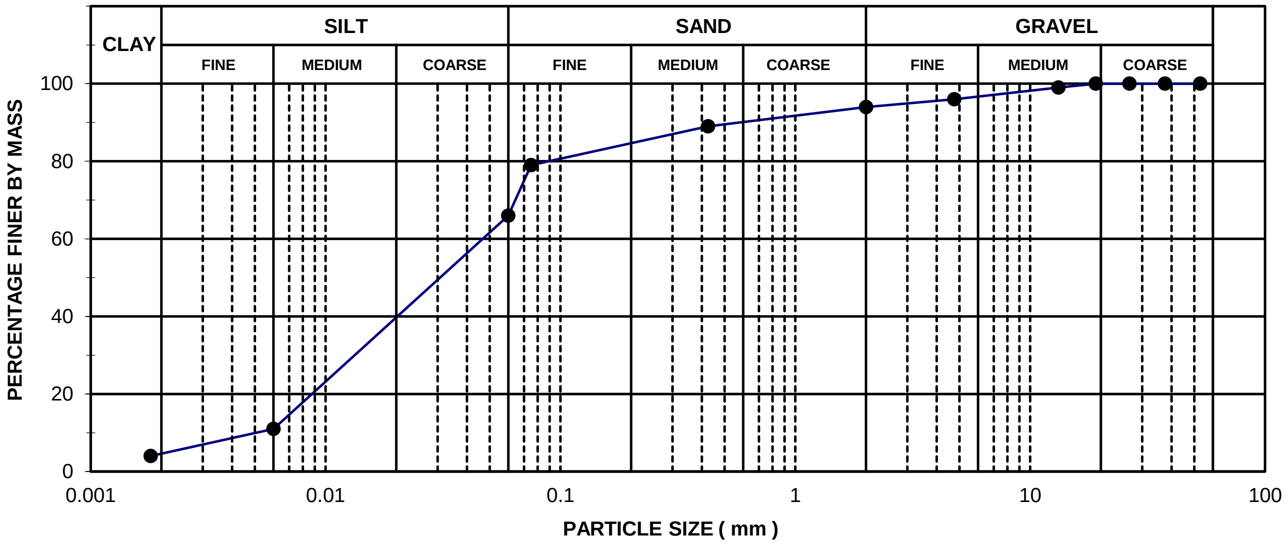
| | | | |
|---|---|---|---|
| TEST LOCATION | LC09 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98998 | PROJECT NUMBER | 112546 |
| DEPTH | 1.2-2.4 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | |
|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing |
| 53.000 | **100** | 0.075 | **79** |
| 37.500 | **100** | 0.060 | **66** |
| 26.500 | **100** | 0.006 | **11** |
| 19.000 | **100** | 0.0018 | **4** |
| 13.200 | **99** | | |
| 4.750 | **96** | | |
| 2.000 | **94** | | |
| 0.425 | **89** | | |

| ATTERBERG LIMITS | | |
|---|---|---|
| Liquid limit | (%) | **39** |
| Plastic limit | (%) | **21** |
| Plasticity Index | (%) | **18** |
| Weighted PI | (%) | **16** |
| Linear Shrinkage | (%) | **9.0** |
| Grading Modulus | | **0.38** |
| Uniformity coefficient | | **10** |
| Coefficient of curvature | | **2.1** |

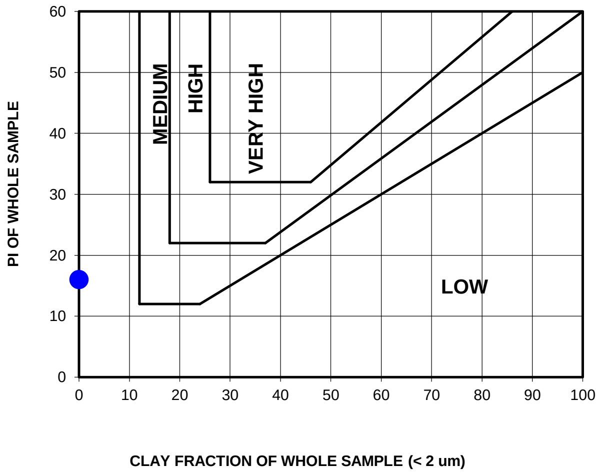
| SOIL CLASSIFICATION | |
|---|---|
| % Gravel | **6** |
| % Sand | **28** |
| % Silt | **62** |
| % Clay | **4** |
| Activity | **4.5** |
| Unified Classification | **CL** |
| TRB Classification | **A - 6** |

## PARTICLE SIZE DISTRIBUTION

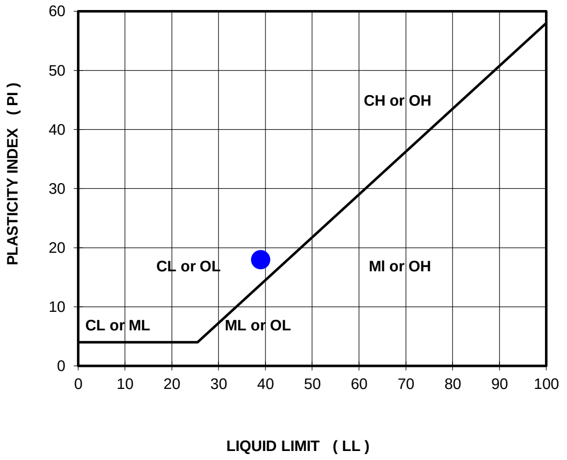


## POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



## CASAGRANDE 'A' LINE

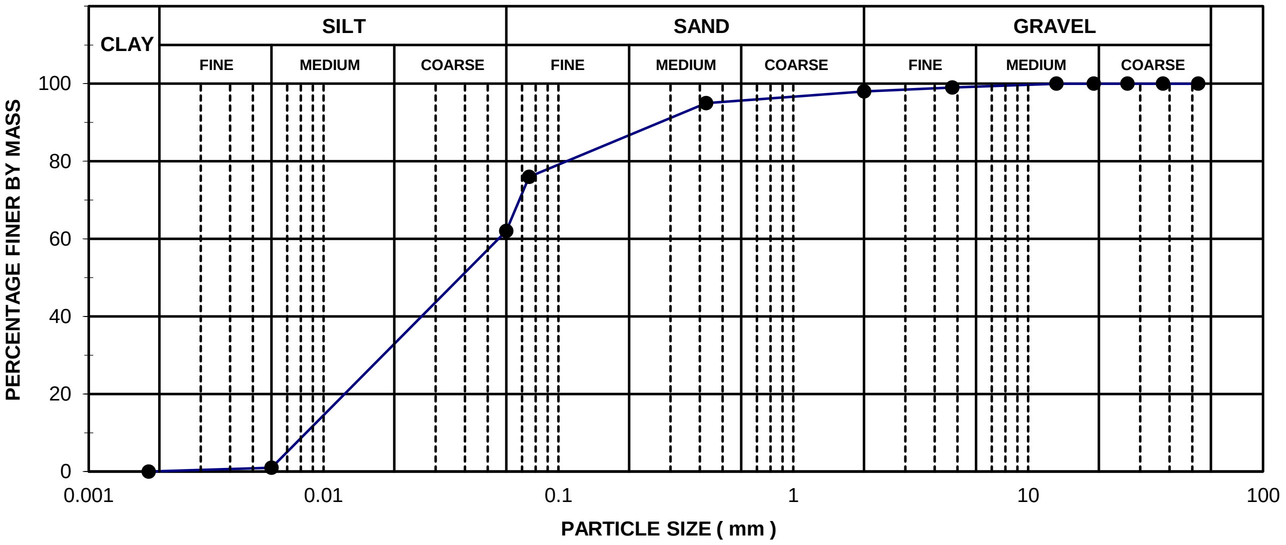


# FOUNDATION INDICATOR TEST RESULTS

| | | | |
|---|---|---|---|
| TEST LOCATION | LC10 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S98999 | PROJECT NUMBER | 112546 |
| DEPTH | 1.0-1.6 m | SITE | Lower Coerney |

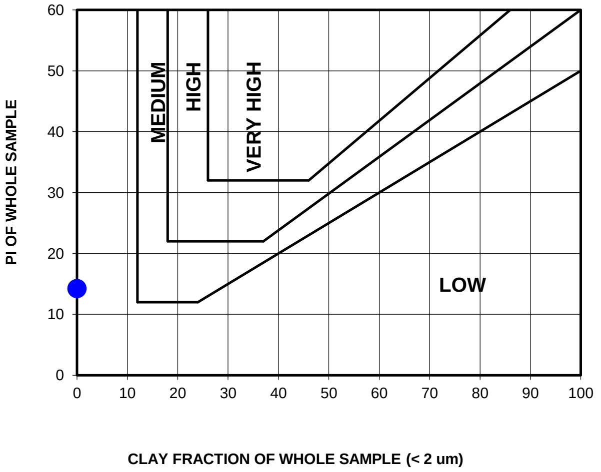
| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **76** | Liquid limit | (%) | **29** | % Gravel | **2** |
| 37.500 | **100** | 0.060 | **62** | Plastic limit | (%) | **14** | % Sand | **36** |
| 26.500 | **100** | 0.006 | **1** | Plasticity Index | (%) | **15** | % Silt | **62** |
| 19.000 | **100** | 0.0018 | **0** | Weighted PI | (%) | **14** | % Clay | **0** |
| 13.200 | **100** | | | Linear Shrinkage | (%) | **7.5** | Activity | **#DIV/0!** |
| 4.750 | **99** | | | Grading Modulus | | **0.31** | Unified Classification | **CL** |
| 2.000 | **98** | | | Uniformity coefficient | | **4** | TRB Classification | **A - 6** |
| 0.425 | **95** | | | Coefficient of curvature | | **1.2** | | |

## PARTICLE SIZE DISTRIBUTION

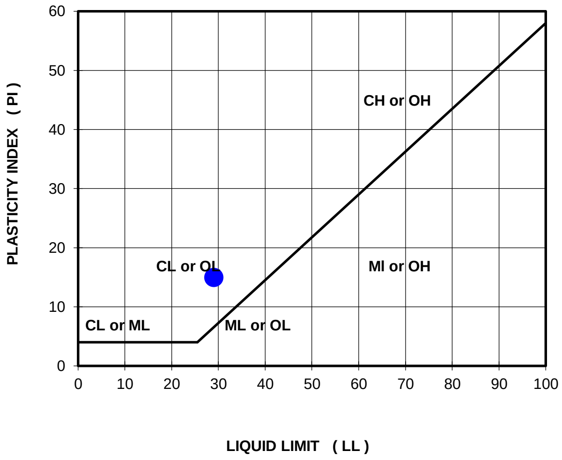


## POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



## CASAGRANDE 'A' LINE



# FOUNDATION INDICATOR TEST RESULTS

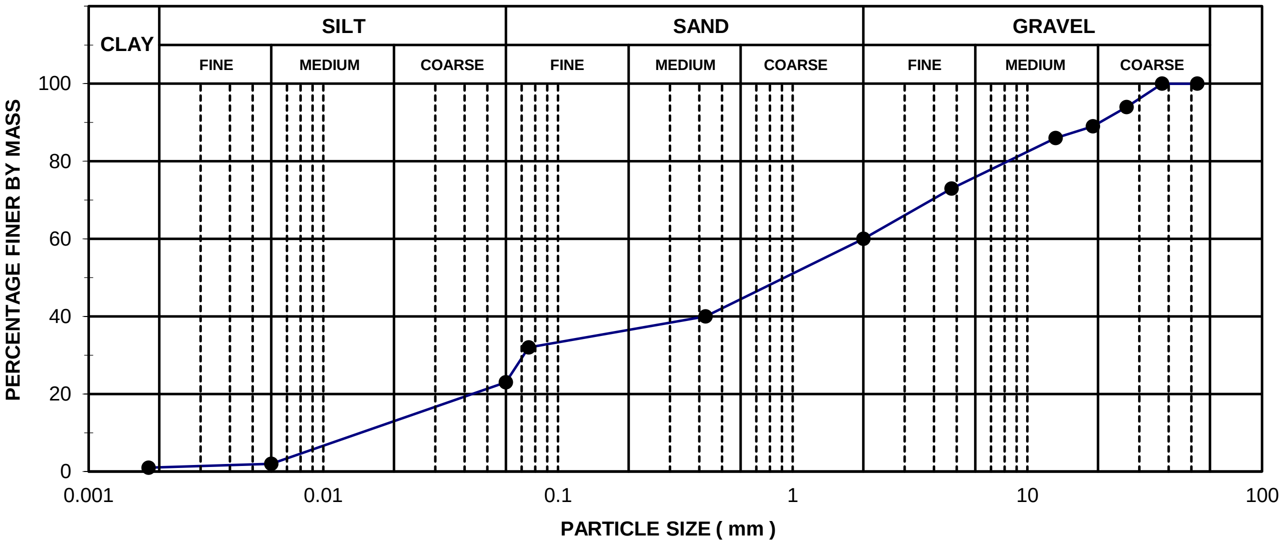
| | | | |
|---|---|---|---|
| TEST LOCATION | LC11 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S99000 | PROJECT NUMBER | 112546 |
| DEPTH | 0.5-1.5 m | SITE | Lower Coerney |

| SIEVE ANALYSIS | | | |
|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing |
| 53.000 | **100** | 0.075 | **32** |
| 37.500 | **100** | 0.060 | **23** |
| 26.500 | **94** | 0.006 | **2** |
| 19.000 | **89** | 0.0018 | **1** |
| 13.200 | **86** | | |
| 4.750 | **73** | | |
| 2.000 | **60** | | |
| 0.425 | **40** | | |

| ATTERBERG LIMITS | | |
|---|---|---|
| Liquid limit | (%) | **31** |
| Plastic limit | (%) | **21** |
| Plasticity Index | (%) | **10** |
| Weighted PI | (%) | **4** |
| Linear Shrinkage | (%) | **5.0** |
| Grading Modulus | | **1.68** |
| Uniformity coefficient | | **75** |
| Coefficient of curvature | | **0.1** |

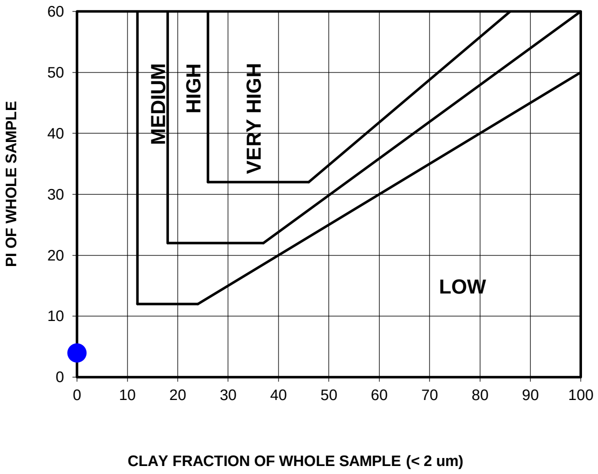
| SOIL CLASSIFICATION | |
|---|---|
| % Gravel | **40** |
| % Sand | **37** |
| % Silt | **22** |
| % Clay | **1** |
| Activity | **10.0** |
| Unified Classification | **SC** |
| TRB Classification | **A - 2 - 4** |

## PARTICLE SIZE DISTRIBUTION

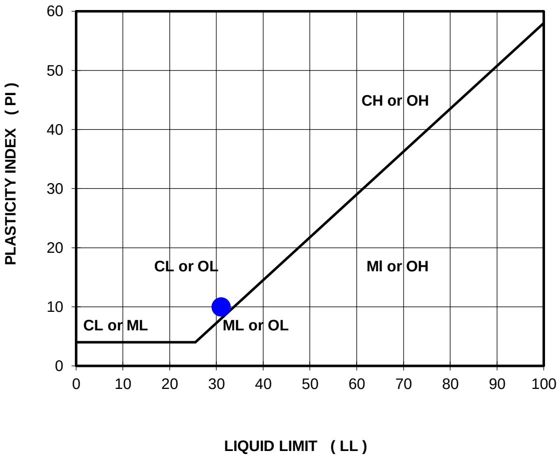


### POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



### CASAGRANDE 'A' LINE

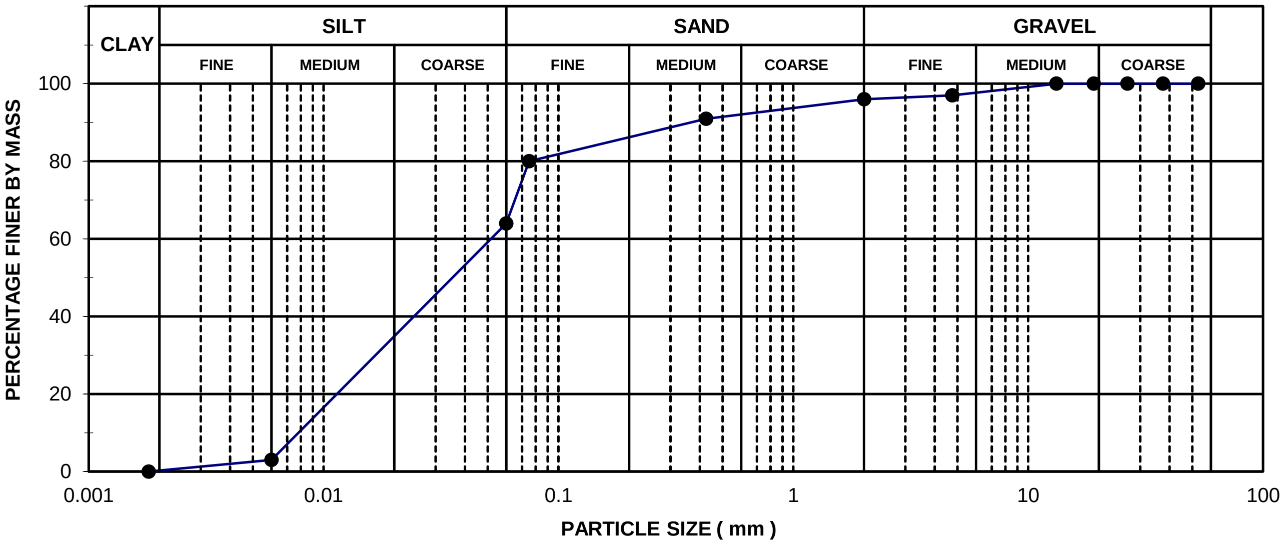


# FOUNDATION INDICATOR TEST RESULTS

| | | | |
|---|---|---|---|
| TEST LOCATION | LC20 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S99001 | PROJECT NUMBER | 112546 |
| DEPTH | 0.9-1.95 m | SITE | Lower Coerney |

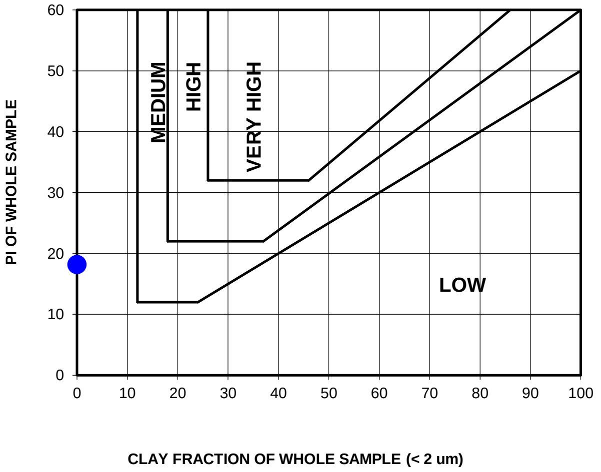
| SIEVE ANALYSIS | | | | ATTERBERG LIMITS | | | SOIL CLASSIFICATION | |
|---|---|---|---|---|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing | | | | | |
| 53.000 | **100** | 0.075 | **80** | Liquid limit | (%) | **39** | % Gravel | **4** |
| 37.500 | **100** | 0.060 | **64** | Plastic limit | (%) | **19** | % Sand | **32** |
| 26.500 | **100** | 0.006 | **3** | Plasticity Index | (%) | **20** | % Silt | **64** |
| 19.000 | **100** | 0.0018 | **0** | Weighted PI | (%) | **18** | % Clay | **0** |
| 13.200 | **100** | | | Linear Shrinkage | (%) | **10.0** | Activity | **#DIV/0!** |
| 4.750 | **97** | | | Grading Modulus | | **0.33** | Unified Classification | **CL** |
| 2.000 | **96** | | | Uniformity coefficient | | **5** | TRB Classification | **A - 6** |
| 0.425 | **91** | | | Coefficient of curvature | | **1.3** | | |

## PARTICLE SIZE DISTRIBUTION

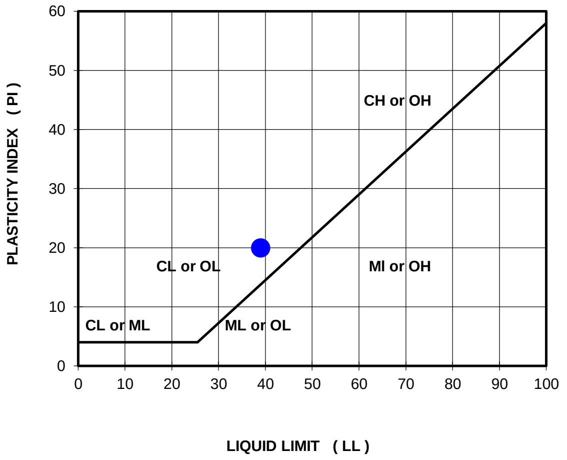


### POTENTIAL EXPANSIVENESS

Van der Merwe's Activity Chart



### CASAGRANDE 'A' LINE



aurecon

# FOUNDATION INDICATOR TEST RESULTS

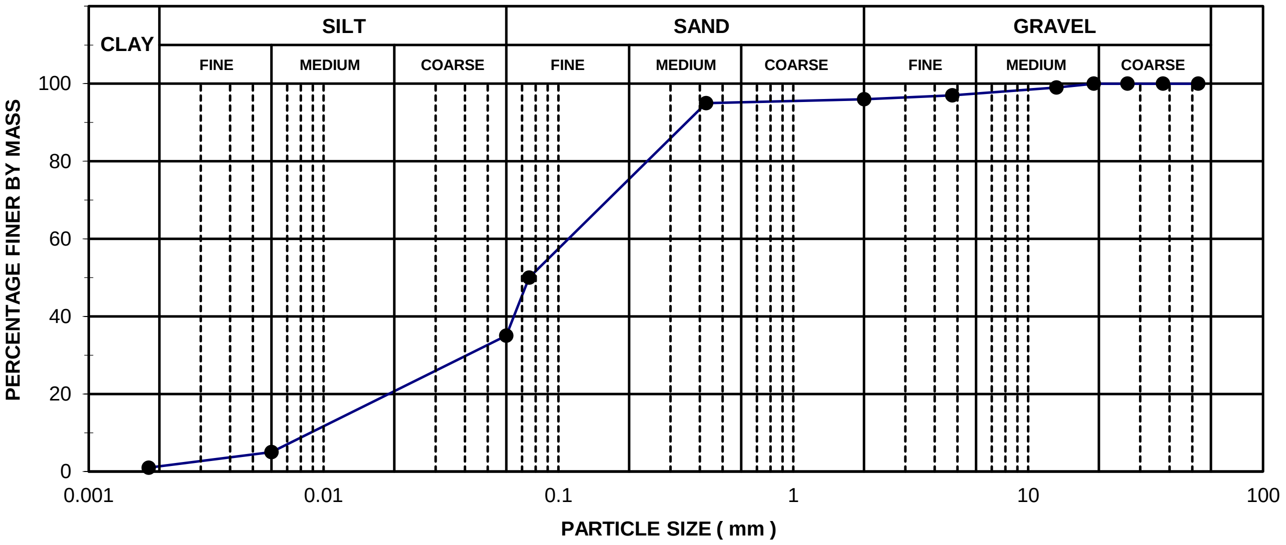
| | | | |
|---|---|---|---|
| TEST LOCATION | LC23 | PROJECT | Algoa Water Supply System |
| SAMPLE NO. | S99002 | PROJECT NUMBER | 112546 |
| DEPTH | 0.5-2.0 m | SITE | Lower Coerney |

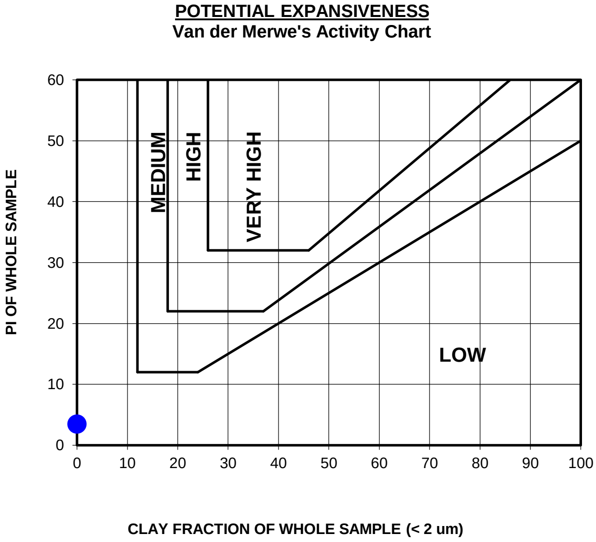
| SIEVE ANALYSIS | | | |
|---|---|---|---|
| Sieve (mm) | % Passing | Sieve (mm) | % Passing |
| 53.000 | **100** | 0.075 | **50** |
| 37.500 | **100** | 0.060 | **35** |
| 26.500 | **100** | 0.006 | **5** |
| 19.000 | **100** | 0.0018 | **1** |
| 13.200 | **99** | | |
| 4.750 | **97** | | |
| 2.000 | **96** | | |
| 0.425 | **95** | | |

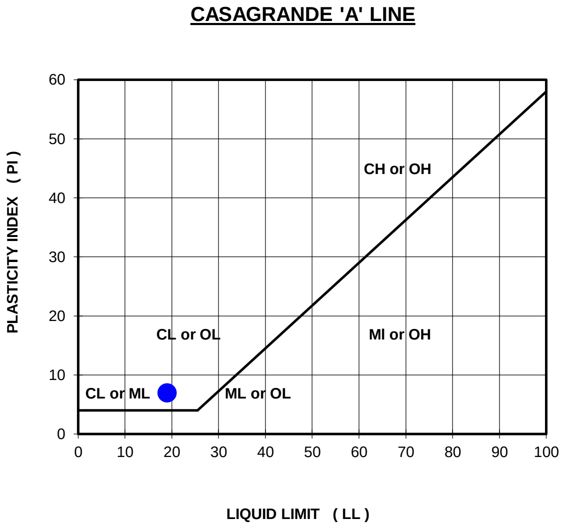
| ATTERBERG LIMITS | | |
|---|---|---|
| Liquid limit | (%) | **19** |
| Plastic limit | (%) | **12** |
| Plasticity Index | (%) | **7** |
| Weighted PI | (%) | **4** |
| Linear Shrinkage | (%) | **3.5** |
| Grading Modulus | | **0.59** |
| Uniformity coefficient | | **10** |
| Coefficient of curvature | | **1.1** |

| SOIL CLASSIFICATION | |
|---|---|
| % Gravel | **4** |
| % Sand | **61** |
| % Silt | **34** |
| % Clay | **1** |
| Activity | **7.0** |
| Unified Classification | **SC-SM** |
| TRB Classification | **A - 2 - 4** |

## PARTICLE SIZE DISTRIBUTION







# Appendix F:
# Packer (Lugeon) test data

RWBE GEOTECHNICAL
DRILLING

P.O.Box 395
Graaff Reinet
6280

Fax No: 086 645 9149
Cell No: 082 851 5989
Email: rwbe@absamail.co.za

# REPORT ON WATER PRESURE TESTING

| | | | |
|---|---|---|---|
| **SCHEME:** | Lower Coerney Dam | **BOREHOLE NO:** | **LC 4** |
| **DRILLER:** | Mothau | | |

| DATE | DEPTH STAGES | PRESSURE | TESTING TIMES | WATER GAUGE READING | | |
|---|---|---|---|---|---|---|
| | Meters | Kpa | Minutes | From | To | Total Liters |
| Pump | Bean | | | | | |
| | | | | | | |
| Calibration: | | | | | | |
| | | | | | | |
| | | | | | | |
| 28-Sep | From 7.50 to 10.97 m | 65 | 10 | 402 | 494 | 92 |
| | | 120 | 10 | 500 | 678 | 178 |
| | | 170 | 10 | 685 | 933 | 248 |
| | | 120 | 10 | 940 | 1158 | 218 |
| | Water Level 6.70 m | 65 | 10 | 1158 | 1302 | 144 |
| 28-Sep | From 11.00 to 13.97 m | 100 | 10 | 350 | 361.8 | 11.8 |
| | | 170 | 10 | 364 | 395 | 31 |
| | | 250 | 10 | 397 | 459 | 62 |
| | | 170 | 10 | 460 | 512 | 52 |
| | Water Level 8.10 m | 100 | 10 | 515 | 551 | 36 |
| 29-Sep | From 14.00 to 16.97 m | 125 | 10 | 555.3 | 555.3 | 0 |
| | | 220 | 10 | 556 | 556 | 0 |
| | | 320 | 10 | 559 | 559 | 0 |
| | | 220 | 10 | 565.9 | 565.9 | 0 |
| | Water Level 9.70 m | 125 | 10 | 566 | 566 | 0 |
| 29-Sep | From 17.00 to 20.45 m | 155 | 10 | 570 | 925 | 355 |
| | | 270 | 10 | 950 | 1375 | 425 |
| | Max Kpa 340 | 385 | 10 | 390 | 855 | 465 |
| | | 270 | 10 | 866 | 1276 | 410 |
| | Water Level 13.00 m | 155 | 10 | 290 | 590 | 300 |
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Notes

RWBE GEOTECHNICAL DRILLING

P.O.Box 395
Graaff Reinet
6280

Fax No: 086 645 9149
Cell No: 082 851 5989
Email: rwbe@absamail.co.za

# REPORT ON WATER PRESURE TESTING

| | | | |
|---|---|---|---|
| **SCHEME:** | Lower Coerney Dam | **BOREHOLE NO:** | **LC 3** |
| **DRILLER:** | Mothau | | |

| DATE | DEPTH STAGES | PRESSURE | TESTING TIMES | WATER GAUGE READING | | |
|---|---|---|---|---|---|---|
| | Meters | Kpa | Minutes | From | To | Total Liters |
| Pump | Bean | | | | | |
| | | **10** | **2** | **169** | **197** | **28** |
| Calibration: | | **15** | **2** | **208** | **240** | **32** |
| | | **20** | **2** | **249** | **292** | **43** |
| | | | | | | |
| 26-Sep | From 4.50 to 7.65 m | 40 | 10 | 568.1 | 568.1 | 0 |
| | | 70 | 10 | 580 | 580 | 0 |
| | | 100 | 10 | 596.2 | 596.2 | 0 |
| | | 70 | 10 | 599.5 | 599.5 | 0 |
| | Water Level 4.30 m | 40 | 10 | 603.4 | 603.4 | 0 |
| 26-Sep | From 7.50 to 10.58 m | 65 | 10 | 784.1 | 790.7 | 6.6 |
| | | 120 | 10 | 792 | 826.4 | 34.4 |
| | | 170 | 10 | 830 | 880.8 | 50.8 |
| | | 120 | 10 | 883 | 925.2 | 42.2 |
| | Water Level 5.90 m | 65 | 10 | 927.8 | 958 | 30.2 |
| 27-Sep | From 10.50 to 12.59 m | 95 | 10 | 960 | 960 | 0 |
| | | 165 | 10 | 961 | 962.6 | 1.6 |
| | | 235 | 10 | 964 | 972.8 | 8.8 |
| | | 165 | 10 | 973 | 977.8 | 4.8 |
| | Water Level 4.00 m | 95 | 10 | 978 | 979 | 1 |
| 27-Sep | From 12.50 to 13.36 m | 115 | 10 | 13.5 | 13.5 | 0 |
| | | 200 | 10 | 16.4 | 16.4 | 0 |
| | | 280 | 10 | 21.2 | 21.2 | 0 |
| | | 200 | 10 | 25.7 | 25.7 | 0 |
| | Water Level 4.50 m | 115 | 10 | 28.7 | 28.7 | 0 |
| 27-Sep | From 15.50 to 18.59 m | 140 | 10 | 90.6 | 90.6 | 0 |
| | | 245 | 10 | 92.8 | 92.8 | 0 |
| | | 350 | 10 | 96.4 | 98 | 1.6 |
| | | 245 | 10 | 99.9 | 99.9 | 0 |
| | Water Level 4.70 m | 140 | 10 | 101.5 | 101.5 | 0 |
| 28-Sep | From 18.50 to 20.43 m | 165 | 10 | 123 | 123 | 0 |
| | | 395 | 10 | 125.1 | 125.1 | 0 |
| | | 420 | 10 | 135.9 | 135.9 | 0 |
| | | 295 | 10 | 139.2 | 139.2 | 0 |
| | Water Level 6.00 m | 165 | 10 | 141.4 | 141.4 | 0 |
| | | | | | | |
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Notes

RWBE GEOTECHNICAL DRILLING

P.O.Box 395
Graaff Reinet
6280

Fax No: 086 645 9149
Cell No: 082 851 5989
Email: rwbe@absamail.co.za

# REPORT ON WATER PRESURE TESTING

| | | | |
|---|---|---|---|
| **SCHEME:** | Lower Coerney Dam | **BOREHOLE NO:** | **LC 4** |
| **DRILLER:** | Rasta | | |

| DATE | DEPTH STAGES | PRESSURE | TESTING TIMES | WATER GAUGE READING | | |
|---|---|---|---|---|---|---|
| | Meters | Kpa | Minutes | From | To | Total Liters |
| Pump | Bean | | | | | |
| | | | | | | |
| Calibration: | | | | | | |
| | | | | | | |
| | | | | | | |
| 25-Sep | From 4.00 to 7.78 m | 35 | 10 | 516.2 | 516.2 | 0 |
| | | 65 | 10 | 516.9 | 516.9 | 0 |
| | | 90 | 10 | 519.3 | 519.3 | 0 |
| | | 65 | 10 | 521.9 | 521.9 | 0 |
| | Water Level 6.60 m | 35 | 10 | 522.7 | 522.7 | 0 |
| 25-Sep | From 7.50 to 10.94 m | 65 | 10 | 544.2 | 544.2 | 0 |
| | | 120 | 10 | 546.5 | 549.1 | 2.6 |
| | | 170 | 10 | 555 | 625.4 | 70.4 |
| | | 120 | 10 | 630 | 670 | 40 |
| | Water Level 3.50 m | 65 | 10 | 672 | 700.2 | 28.2 |
| 25-Sep | From 11.00 to 13.94 m | 100 | 10 | 705 | 705 | 0 |
| | | 170 | 10 | 710 | 710 | 0 |
| | | 250 | 10 | 713 | 713 | 0 |
| | | 170 | 10 | 714 | 714 | 0 |
| | Water Level 4.00 m | 100 | 10 | 714 | 714 | 0 |
| 26-Sep | From 13.50 to 15.04 m | 120 | 10 | 715.1 | 715.1 | 0 |
| | | 215 | 10 | 715.9 | 715.9 | 0 |
| | | 305 | 10 | 719.2 | 719.2 | 0 |
| | | 215 | 10 | 722 | 722 | 0 |
| | Water Level 10.00 m | 120 | 10 | 724.8 | 724.8 | 0 |
| | | | | | | |
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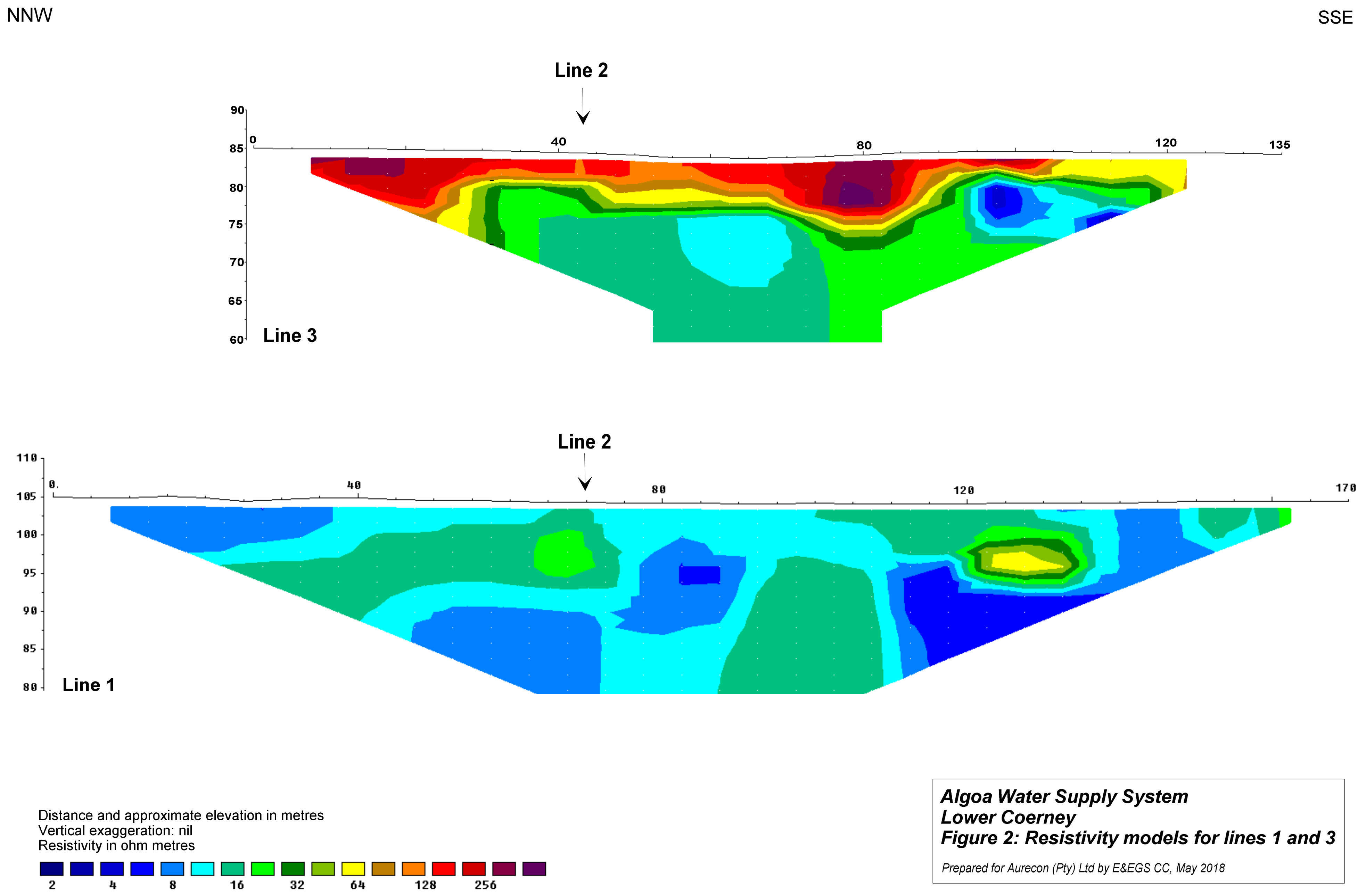
Notes

# Appendix G:
# Geophysical survey results

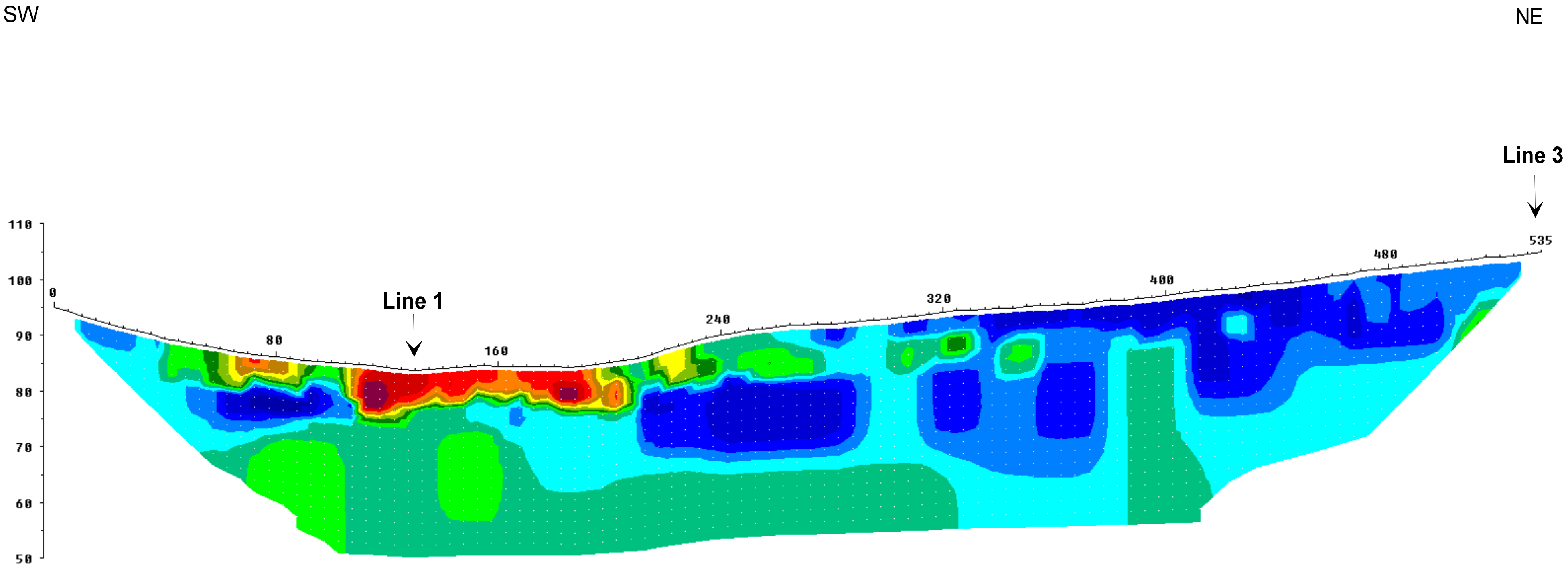
***Algoa Water Supply System***
***Lower Coerney***
***Figure 1: Resistivity traverse arrangement***

*Prepared for Aurecon (Pty) Ltd by E&EGS CC, May 2018*



***Algoa Water Supply System***
***Lower Coerney***
***Figure 2: Resistivity models for lines 1 and 3***

*Prepared for Aurecon (Pty) Ltd by E&EGS CC, May 2018*



Distance and approximate elevation in metres
Vertical exaggeration 2:1
Resistivity in ohm metres

2 4 8 16 32 64 128 256

***Algoa Water Supply System***
***Lower Coerney***
***Figure 3: Resistivity models for line 2***

*Prepared for Aurecon (Pty) Ltd by E&EGS CC, May 2018*

**ENGINEERING & EXPLORATION GEOPHYSICAL SERVICES CC**
CK94/10526/23 Geophysical Contractors
[redacted]

170, Jakaranda Street,
Doringkloof,
Gauteng, 0157
012 - 6673369 (tel) 6675186(fax)
10th May, 2018

Aurecon South Africa (Pty) Ltd,
P O Box 905,
Pretoria,
0001.

Attn: Gary Davis

Dear Sir,

## RESISTIVITY SURVEY ON LOWER COERNEY, KIRKWOOD

A resistivity survey has been carried out on Lower Coerney, near Kirkwood, at the planned site of a dam. The investigation for the dam is in support of the Algoa Water Supply Project.

The area is underlain by sedimentary rock of Cretaceous age. Two boreholes were drilled about 600 metres to the south of the site by Water Affairs in 1986 and 1987; they intersected siltstone along with mudstone and sandstone beneath a layer of hillwash and completely weathered siltstone that is two and a half metres thick.

The survey consists of three traverses, one along the centre line of the dam, one on the north-eastern side of the site and one in the valley itself. The required traverse positions were indicated on a kmz file supplied by Aurecon and followed cut lines prepared by a third party.

Fieldwork was undertaken from the 7th to 9th May. An ABEM LS2 was employed for the task using a Wenner-Schlumberger protocol and a five-metre electrode separation. The positions of the traverses were recorded with a Garmin GPS (appendix). Changes in elevation along the traverses were recorded with a dumpy level; these were assigned a realistic base level using elevations taken from Goggle Earth.

The data were modelled using Res2Dinv, a program that fits internally-generated model data to the field data over several iterations. The results of the operation are cross-sections showing lateral and vertical changes in resistivity.

The traverse arrangement is shown on figure 1 and the resistivity models in figures 2 and 3. Warm colours (yellow-red) in the models reflect resistors and cooler colours (green-blue), relative conductors.

The resistivity of a rock unit is controlled mostly by the content and quality of the water it holds and its clay content, hence a resistivity interpretation is based on inferences drawn from contrasts in these quantities. This site is characterised by conductors but there is a resistive layer about five metres thick within the valley (figures 2 and 3). Exposed at surface in the valley floor, this layer albeit with a reduction in resistivity can be traced for a little distance beneath the north-east bank. Its surface expression is taken to reflect hardpan and its extension also a layer of increased cementation. Apart from this layer, resistivity increases generally with depth, although often in an irregular fashion and with breaks in continuity, to give an impression of horizontal layering, especially on the model for line 2 (figure 3). The most conductive zone is up to twenty metres thick. This vertical change is expected to reflect a variation in the weathering with the most conductive area corresponding to weathered rock. The lateral changes that interrupt it may arise from a local variation in lithology, however, it is possible that they may indicate faults. If the latter, the most likely position for a fault zone is beneath the valley floor and between 320 and 400 metres on line 2.

In summary, the area has a hardpan layer exposed in the valley floor that may extend beneath below the valley side and a horizon of weathered rock up to twenty metres thick. There are no clearly defined anomalies indicative of a fault, but their absence cannot be entirely discounted.

Yours sincerely,

R W Day Pr.Sci.Nat.

# Appendix

## Resistivity traverse coordinates (Lo25 WGS84)
## Lower Coerney

| Line | Station | LoY | LoX |
|---|---|---|---|
| 1 | 0 | 58102 | -3702609 |
| 1 | 20 | 58113 | -3702626 |
| 1 | 40 | 58125 | -3702642 |
| 1 | 60 | 58136 | -3702657 |
| 1 | 80 | 58149 | -3702674 |
| 1 | 100 | 58159 | -3702691 |
| 1 | 120 | 58168 | -3702708 |
| 1 | 135 | 58176 | -3702722 |
| 2 | 0 | 58025 | -3702729 |
| 2 | 20 | 58045 | -3702719 |
| 2 | 40 | 58061 | -3702710 |
| 2 | 60 | 58080 | -3702701 |
| 2 | 80 | 58098 | -3702692 |
| 2 | 100 | 58115 | -3702681 |
| 2 | 120 | 58132 | -3702671 |
| 2 | 140 | 58148 | -3702658 |
| 2 | 160 | 58163 | -3702646 |
| 2 | 180 | 58178 | -3702631 |
| 2 | 200 | 58193 | -3702618 |
| 2 | 220 | 58203 | -3702604 |
| 2 | 240 | 58218 | -3702592 |
| 2 | 260 | 58232 | -3702577 |
| 2 | 280 | 58246 | -3702564 |
| 2 | 300 | 58261 | -3702550 |
| 2 | 320 | 58277 | -3702535 |
| 2 | 340 | 58290 | -3702523 |
| 2 | 360 | 58304 | -3702508 |
| 2 | 380 | 58317 | -3702494 |
| 2 | 400 | 58333 | -3702481 |
| 2 | 420 | 58346 | -3702467 |
| 2 | 440 | 58360 | -3702453 |
| 2 | 460 | 58374 | -3702439 |
| 2 | 480 | 58389 | -3702426 |
| 2 | 500 | 58402 | -3702412 |
| 2 | 520 | 58418 | -3702395 |
| 2 | 535 | 58429 | -3702387 |
| 3 | 0 | 58406 | -3702351 |
| 3 | 20 | 58416 | -3702368 |
| 3 | 40 | 58425 | -3702385 |
| 3 | 60 | 58437 | -3702403 |
| 3 | 80 | 58447 | -3702420 |
| 3 | 100 | 58458 | -3702434 |
| 3 | 120 | 58470 | -3702453 |
| 3 | 140 | 58480 | -3702469 |
| 3 | 160 | 58493 | -3702486 |
| 3 | 170 | 58500 | -3702494 |

# Appendix H:
# Groundwater evaluation

GROUNDWATERAFRICA
GWA CONSULTING HYDROGEOLOGISTS cc T\A
Reg. No.: CK 2004-059516-23

38 Disa Avenue
Kommetjie
7975

Erik van der Berg
Erik.VanDerBerg@aurecongroup.com

19 November 2018

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## Groundwater concerns in the Lower Coerney Dam site area

---

This brief assessment of the groundwater situation in the Lower Coerney Dam site area follows from concerns about the shallow alluvial gravels that were encountered during core drilling at the proposed dam site. The issues raised are:

- Groundwater flow direction
- Groundwater flow rate
- Potential groundwater effect on the planned dam.

The discussion below attempts to present what can be deduced from the data supplied. This consists of the locations of the core boreholes (Figure 1), the geological logs of the core holes and groundwater levels (Table 1).

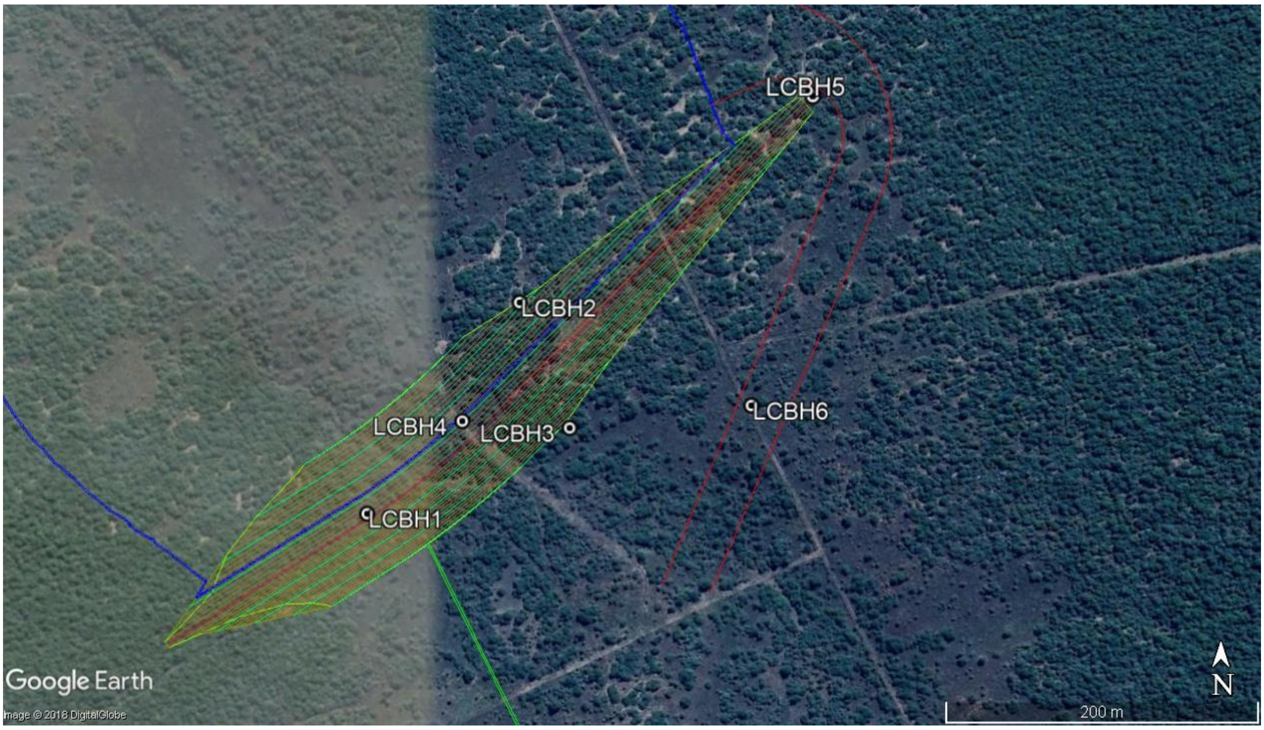


Figure 1. Borehole locations

## Natural groundwater levels, flow direction & flow rate

Natural groundwater levels appear to mirror topography to produce a groundwater flow direction downstream in a roughly southerly direction (Figure 2). The hydraulic gradient is steep, around 0.03 – 0.05 (Table 1) which shows that the permeability of the saturated rocks are very low, as one would expect from the Kirkwood Formation mudstones, siltstones and sandstones. Even with the steep hydraulic gradients, the flow rates will be very low.

Table 1. Rest water levels and approximate hydraulic gradients

| BH no | Collar elevation (mamsl) | RWL (mbgl) | RWL (mamsl) | | Approximate Distance (m) | Difference in RWL (m) | Hydraulic gradient |
|---|---|---|---|---|---|---|---|
| LC1 | 83.36 | 13.75 | 69.61 | | | | |
| LC2 | 89.15 | 19.6 | 69.55 | | | | |
| LC3 | 84.30 | 18.1 | 66.20 | LC2 - LC3 | 100 | 3.35 | 0.034 |
| LC4 | 81.82 | 12.7 | 69.12 | | | | |
| LC5 | 102.01 | 9.2 | 92.81 | | | | |
| LC6 | 89.98 | 8.8 | 81.18 | LC5 - LC6 | 220 | 11.63 | 0.053 |

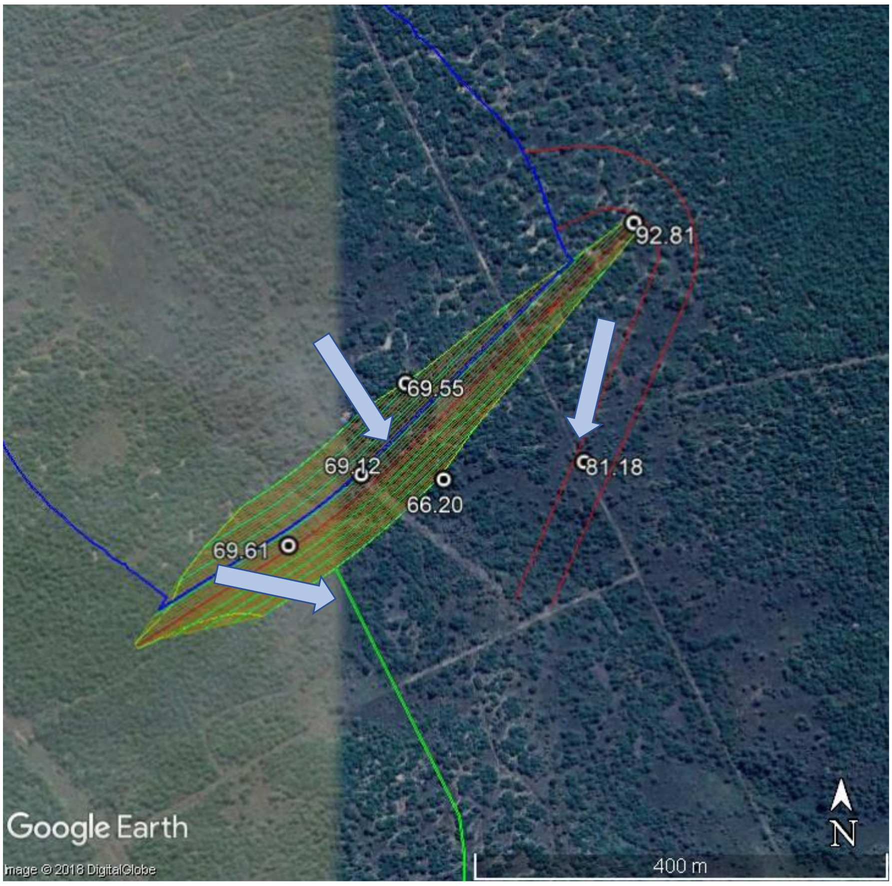


Figure 2. Rough groundwater flow direction

:

## Perched groundwater flow rate after dam construction

The groundwater table lies below the alluvial gravels. However, after constructing the dam, water can be expected to leak through the upper, near-surface layers and saturate the gravel layer. The leakage may be slow due to the presence of clayey material in places, and with time it may reduce as additional clayey and silty material accumulates on the bottom of the dam. The hydraulic gradient, however, will be high and if the gravels are highly permeable, water will be able to flow relatively rapidly in this layer. The flow rate through the gravels, however, may not be a function of the permeability of the gravels but rather the leakage rate through the base of the dam, as this latter flow rate may be less than that of the gravels themselves. This is obviously unknown.

The maximum flow rate, ie the potential flow through the gravels can be estimated once the hydraulic conductivity or transmissivity of the gravels are known. This can be obtained by conducting injection tests on the core boreholes if they are still sufficiently open (they were not back-filled but may be blocked with debris); or alternatively new boreholes can be drilled for testing purposes. The results of the permeability tests done on the bedrock are obviously not suitable to be used to estimate the gavels' permeability.

It is likely that leakage via the base of the dam and through the gravels will not daylight as new springs downstream of the dam wall as it appears as if the vegetation is sufficiently dense to opportunistically utilize this shallow water – water that would naturally be in this zone during heavy rainfall periods. A botanist should be consulted to comment on this.

## Potential effect on natural groundwater flow

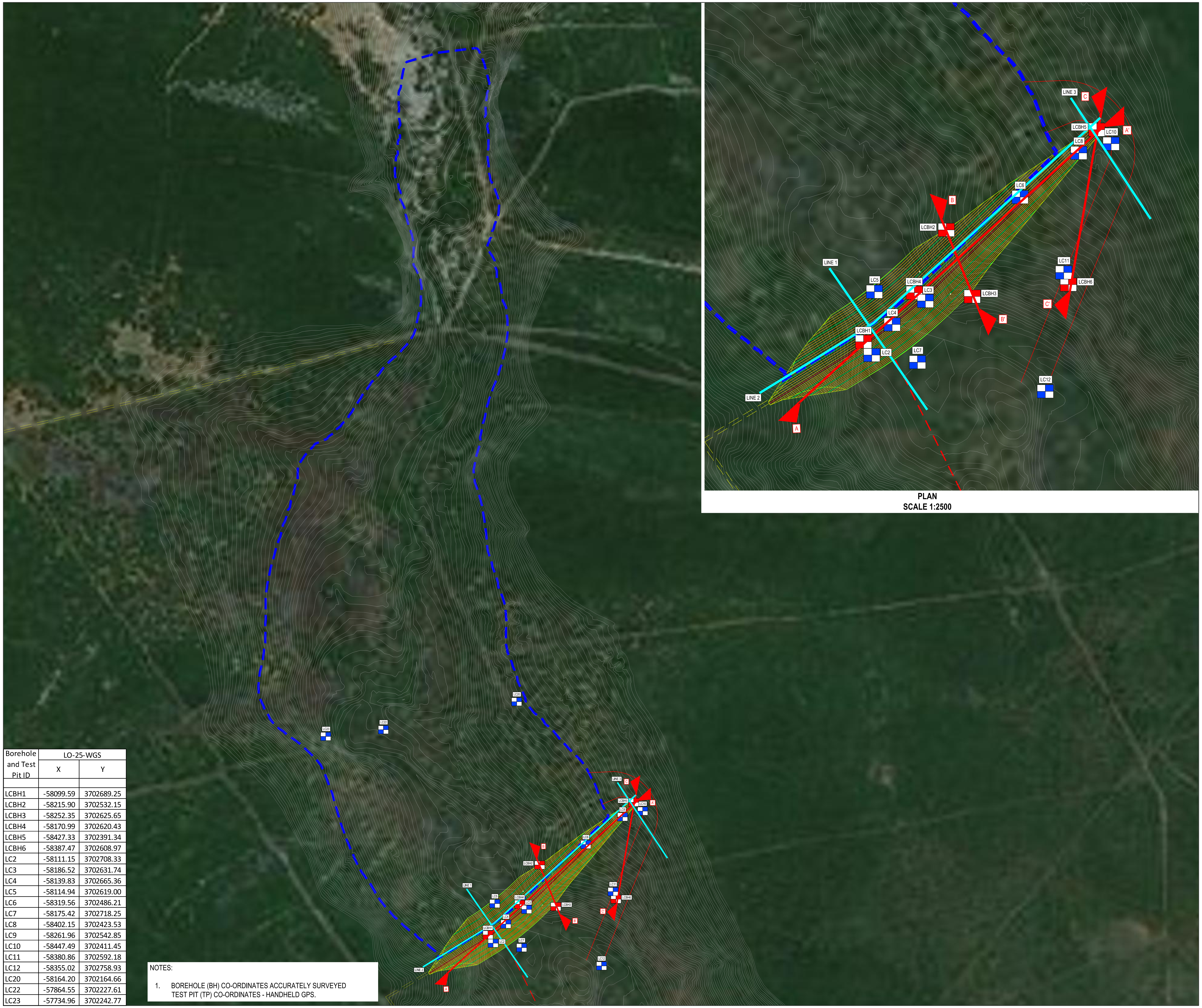
The leakage to the gravels and the underlying hard-rock geology would only produce a very limited impact on the hydrogeology of the area. The underlying hard-rock's permeability is probably too low to receive much water, and therefore the effect of the dam will likely be localized and small. The gravels have been discussed above; but the net effect on these will likely also be small because they are unlikely to be continuous for a great distance, and even if the are it is unlikely that they will be highly permeable throughout their length. This, however is not known, but 2D resistivity surveys can assist in mapping the gravel layer.

## Potential groundwater effect on the planned dam

As stated above, the gravels will likely become permanently saturated below the dam and below the dam wall. I do not have the expertise to comment on whether this could have an effect on the stability of the dam wall.

Ricky Murray
19 November 2018

# Appendix I:
# Drawings



**PLAN**
**SCALE 1:2500**

| Borehole and Test Pit ID | LO-25-WGS | |
|---|---|---|
| | X | Y |
| | | |
| LCBH1 | -58099.59 | 3702689.25 |
| LCBH2 | -58215.90 | 3702532.15 |
| LCBH3 | -58252.35 | 3702625.65 |
| LCBH4 | -58170.99 | 3702620.43 |
| LCBH5 | -58427.33 | 3702391.34 |
| LCBH6 | -58387.47 | 3702608.97 |
| LC2 | -58111.15 | 3702708.33 |
| LC3 | -58186.52 | 3702631.74 |
| LC4 | -58139.83 | 3702665.36 |
| LC5 | -58114.94 | 3702619.00 |
| LC6 | -58319.56 | 3702486.21 |
| LC7 | -58175.42 | 3702718.25 |
| LC8 | -58402.15 | 3702423.53 |
| LC9 | -58261.96 | 3702542.85 |
| LC10 | -58447.49 | 3702411.45 |
| LC11 | -58380.86 | 3702592.18 |
| LC12 | -58355.02 | 3702758.93 |
| LC20 | -58164.20 | 3702164.66 |
| LC22 | -57864.55 | 3702227.61 |
| LC23 | -57734.96 | 3702242.77 |

NOTES:

1. BOREHOLE (BH) CO-ORDINATES ACCURATELY SURVEYED
TEST PIT (TP) CO-ORDINATES - HANDHELD GPS.

LEGEND

| | |
|---|---|
| 🟥 | BOREHOLE POSITION |
| 🟦 | TEST PIT POSITION |
| - - - | FULL SUPPLY LEVEL (FSL) |
| - - - | CANAL |
| — | SPILLWAY |
| A ▲—▲ A' | GEOLOGICAL LONGITUDINAL SECTIONS |
| — | RESISTIVITY SURVEYS |

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| | | | |

| SCALE | SIZE |
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| 1:750 | A1 |

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S NYATHI

REVIEWED
G DAVIS

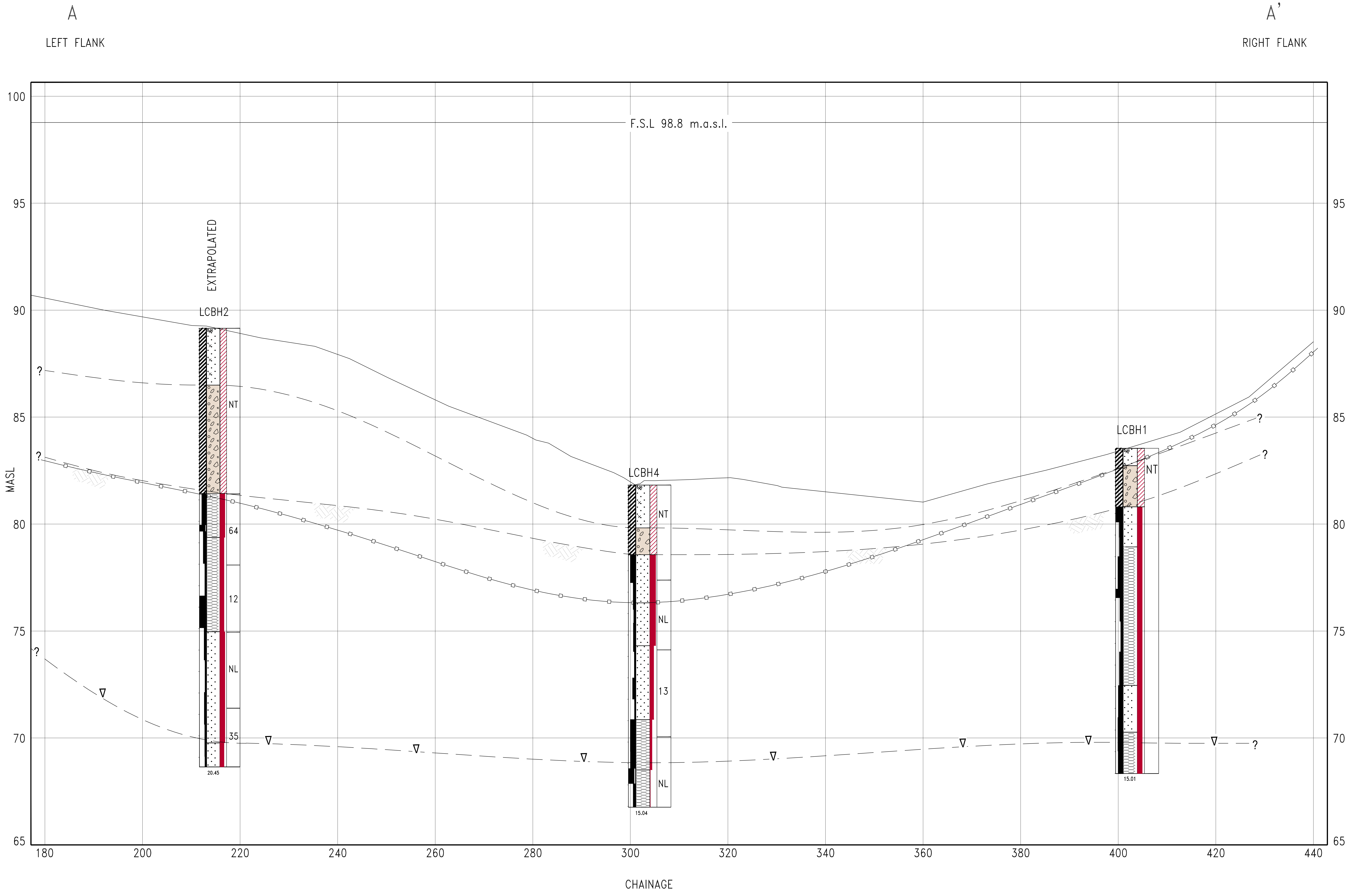
APPROVED
G DAVIS
DATE

PROJECT
SUPPORT OF WATER RECONCILATION
STRATEGY FOR THE ALGOA
WATER SUPPLY SYSTEM

TITLE
LOWER COERNEY DAM SITE
INVESTIGATION LAYOUT

DRAWING NUMBER

| PROJECT No. | WBS | TYPE | DISC | NUMBER | REV |
|---|---|---|---|---|---|
| 112546 - | GEO - | DRG - | CC - | 001 - | A |



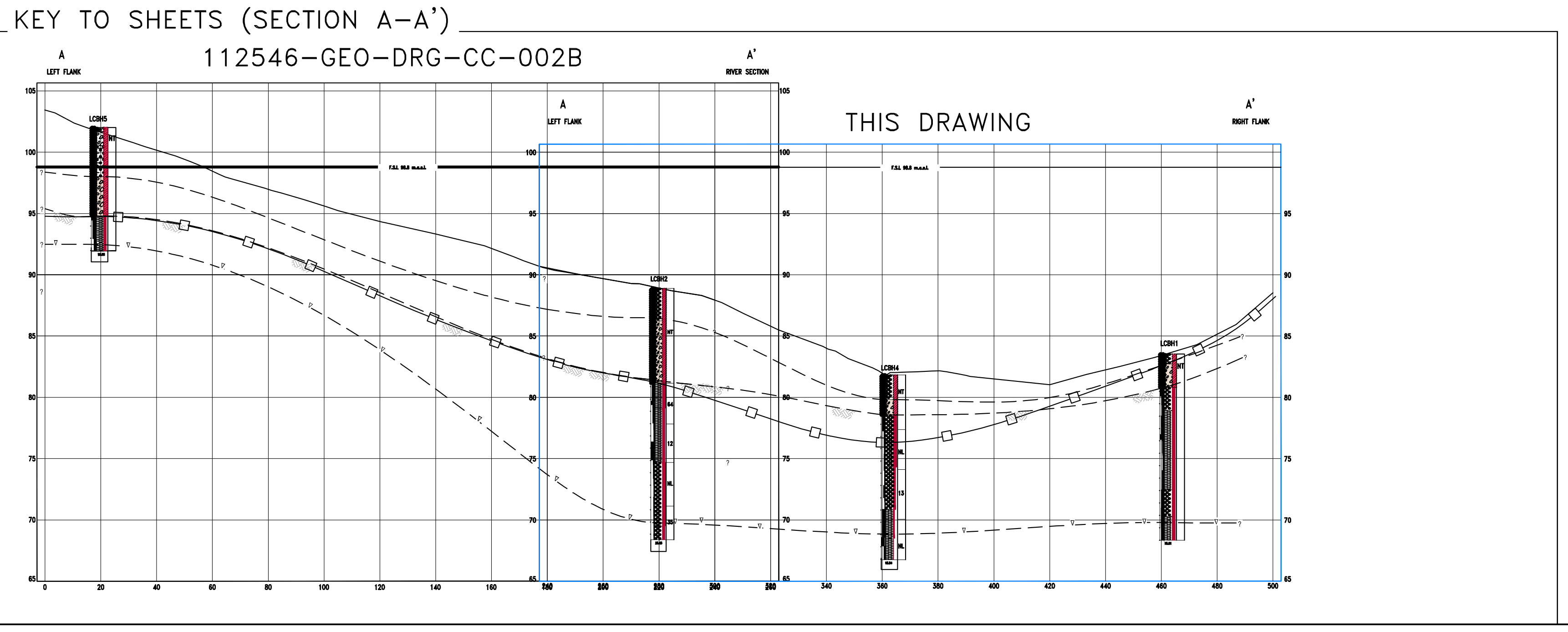
## LEGEND

- NATURAL GROUND LEVEL
- GEOLOGICAL BOUNDARY
- UPPER BOUNDARY OF BEDROCK
- WATER REST LEVEL
- RECOMMENDED EXCAVATION DEPTH

LITHOLOGY:

- COLLUVIUM
- REWORKED TERRACE GRAVELS
- MUDSTONE } BEDROCK
- SANDSTONE } BEDROCK

KEY TO SHEETS (SECTION A–A')



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STRATEGY FOR THE ALGOA
WATER SUPPLY SYSTEM

**TITLE**
GEOTECHNICAL INVESTIGATION OF
LOWER COERNEY DAM SITE
RIVER SECTION & RIGHT FLANK : SECTION A-A'

**DRAWING NUMBER**

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|---|---|---|---|---|---|
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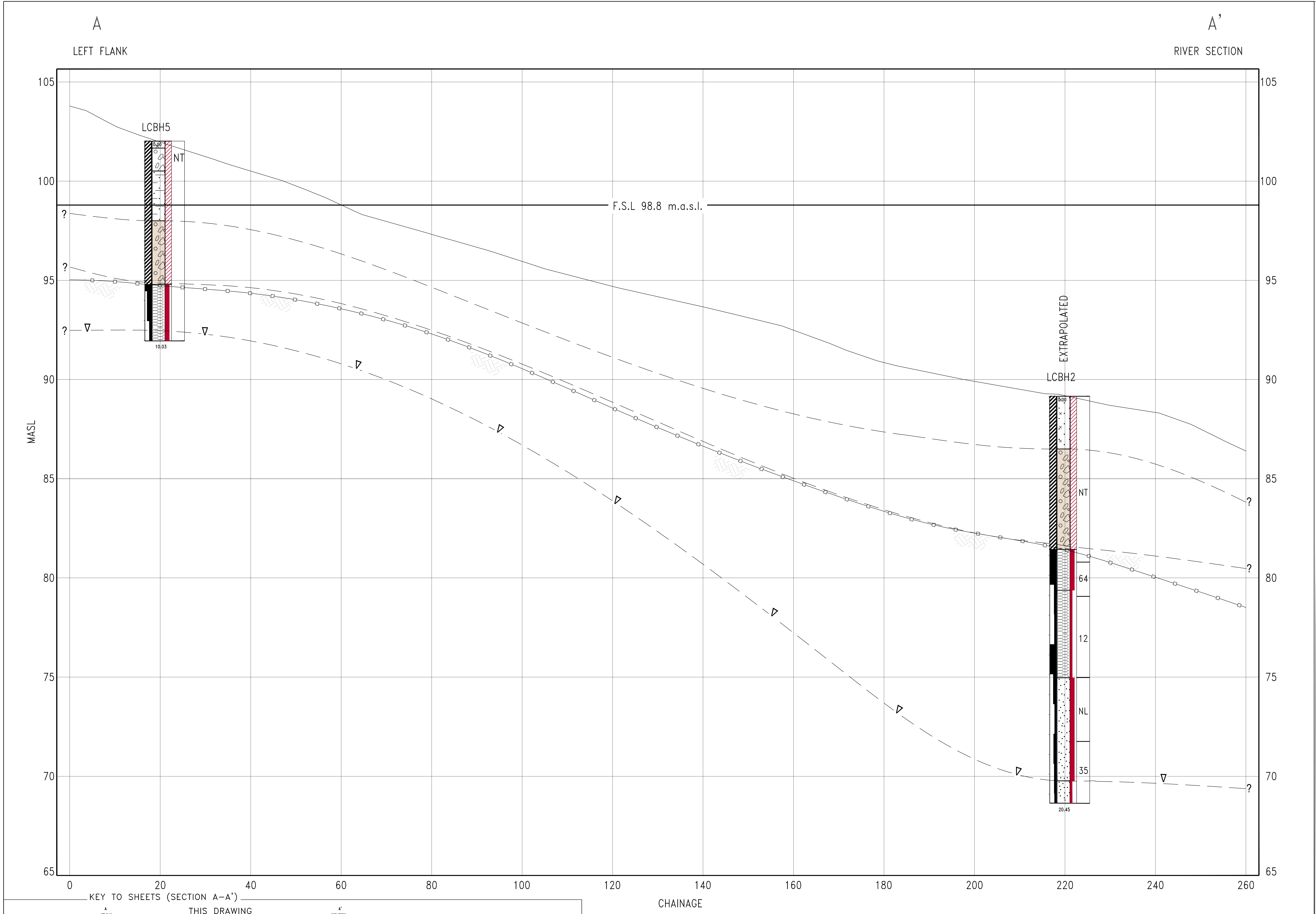
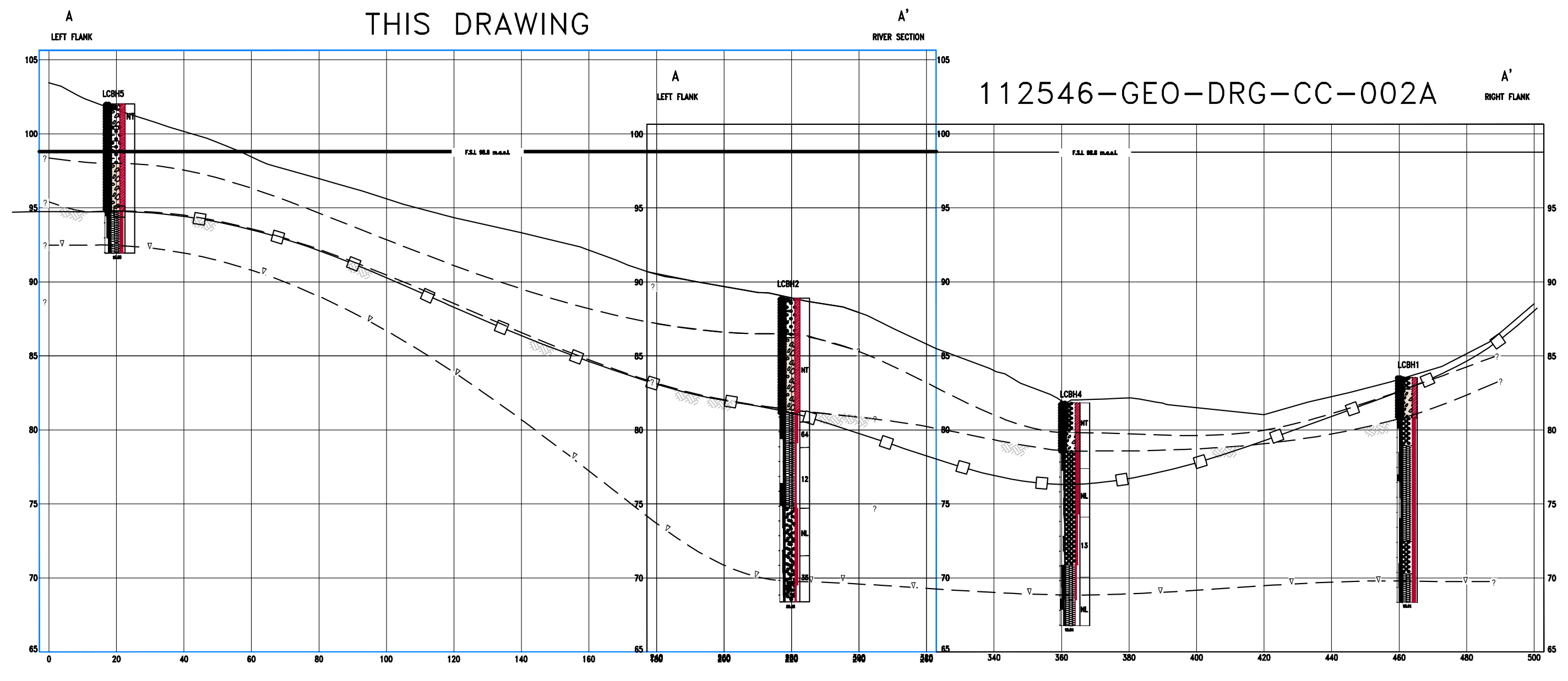


KEY TO SHEETS (SECTION A–A')



LITHOLOGY:

- TOPSOIL
- COLLUVIUM
- REWORKED TERRACE GRAVELS
- MUDSTONE
- SANDSTONE

MUDSTONE, SANDSTONE } BEDROCK

FOR BOREHOLE KEY, REFER TO
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## LEGEND

- NATURAL GROUND LEVEL
- GEOLOGICAL BOUNDARY
- UPPER BOUNDARY OF BEDROCK
- WATER REST LEVEL
- RECOMMENDED EXCAVATION DEPTH

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LEFT FLANK : SECTION A-A'

DRAWING NUMBER

| PROJECT No. | WBS | TYPE | DISC | NUMBER | REV |
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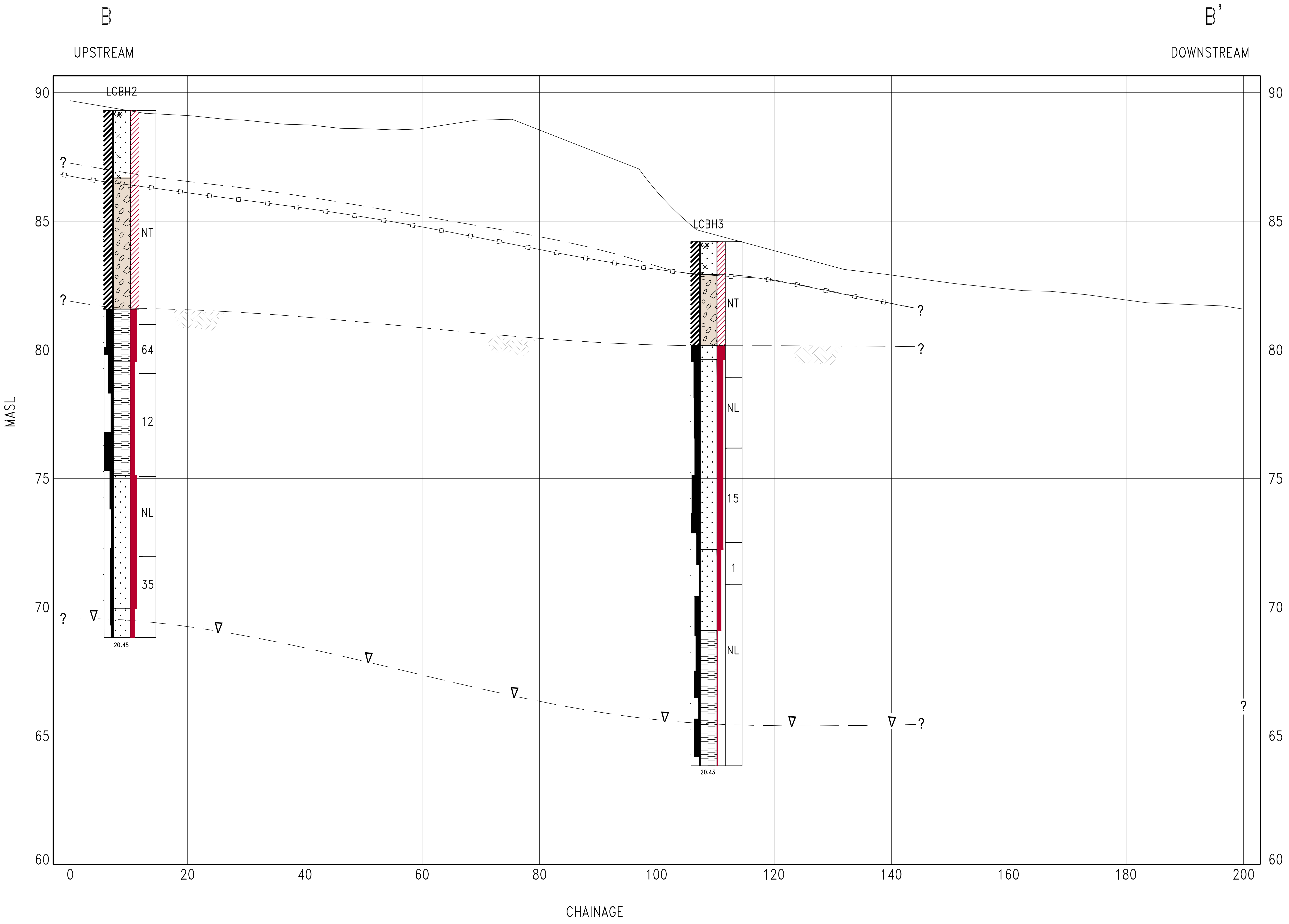

LITHOLOGY:

▨ COLLUVIUM

▨ REWORKED TERRACE GRAVELS

▨ MUDSTONE
▨ SANDSTONE } BEDROCK

FOR BOREHOLE KEY, REFER TO
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## LEGEND

| | |
|---|---|
| ── | NATURAL GROUND LEVEL |
| — — — | GEOLOGICAL BOUNDARY |
| — — — | UPPER BOUNDARY OF BEDROCK |
| — ∇ — ∇ — | WATER REST LEVEL |
| —□—□— | RECOMMENDED EXCAVATION DEPTH |

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|---|---|
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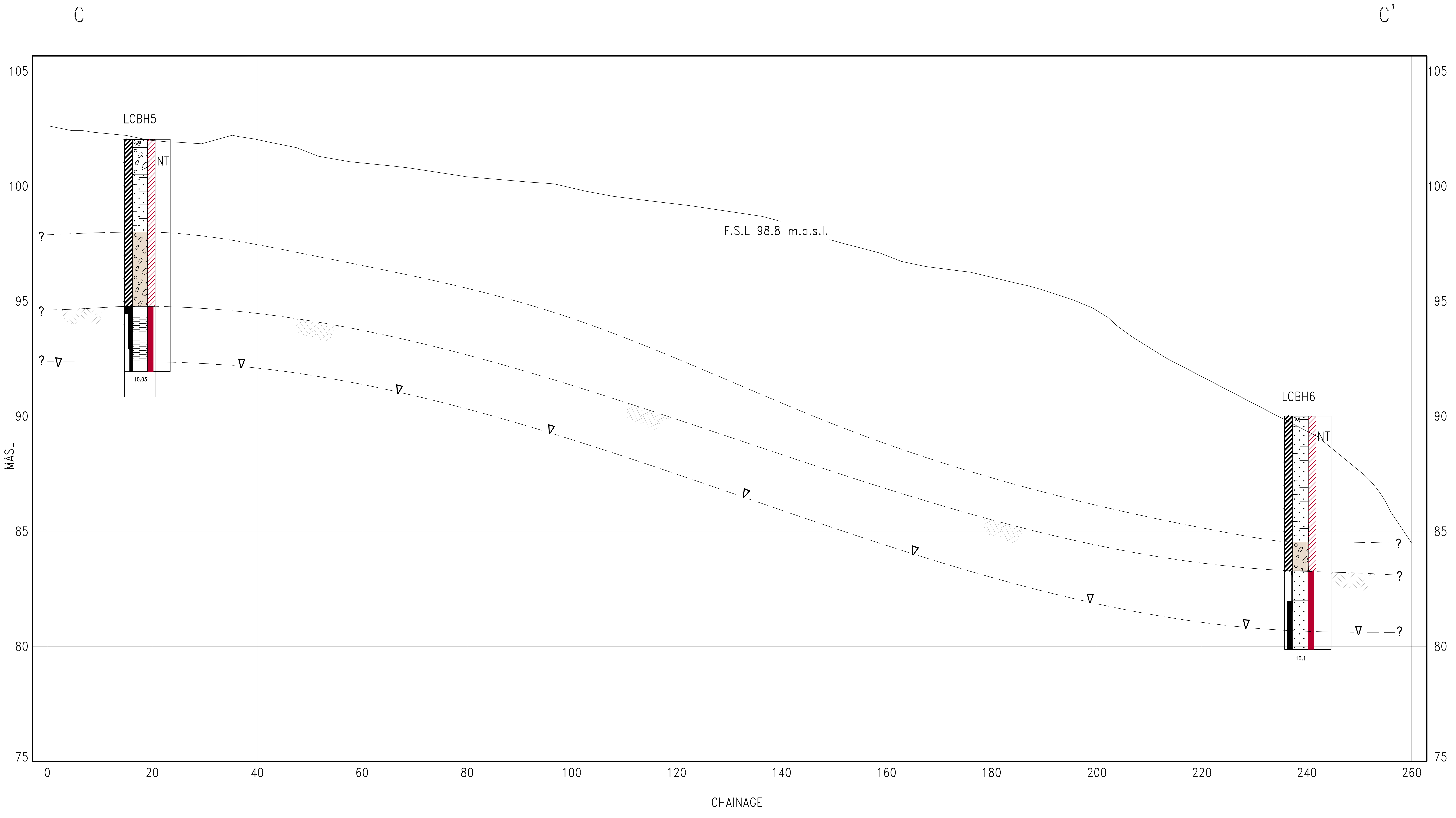
LOWER COERNEY DAM
SECTION B-B'

DRAWING NUMBER

| PROJECT No. | WBS | TYPE | DISC | NUMBER | REV |
|---|---|---|---|---|---|
| 112546 - | GEO - | DRG - | CC - | 003 - | A |



LITHOLOGY:

- ⁙ COLLUVIUM
- ▨ REWORKED TERRACE GRAVELS
- ▤ MUDSTONE } BEDROCK
- ⁙ SANDSTONE } BEDROCK

FOR BOREHOLE KEY, REFER TO
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## LEGEND

- ——— NATURAL GROUND LEVEL
- — — — GEOLOGICAL BOUNDARY
- — — — UPPER BOUNDARY OF BEDROCK
- — ∇ — ∇ — WATER REST LEVEL

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DRAWING NUMBER

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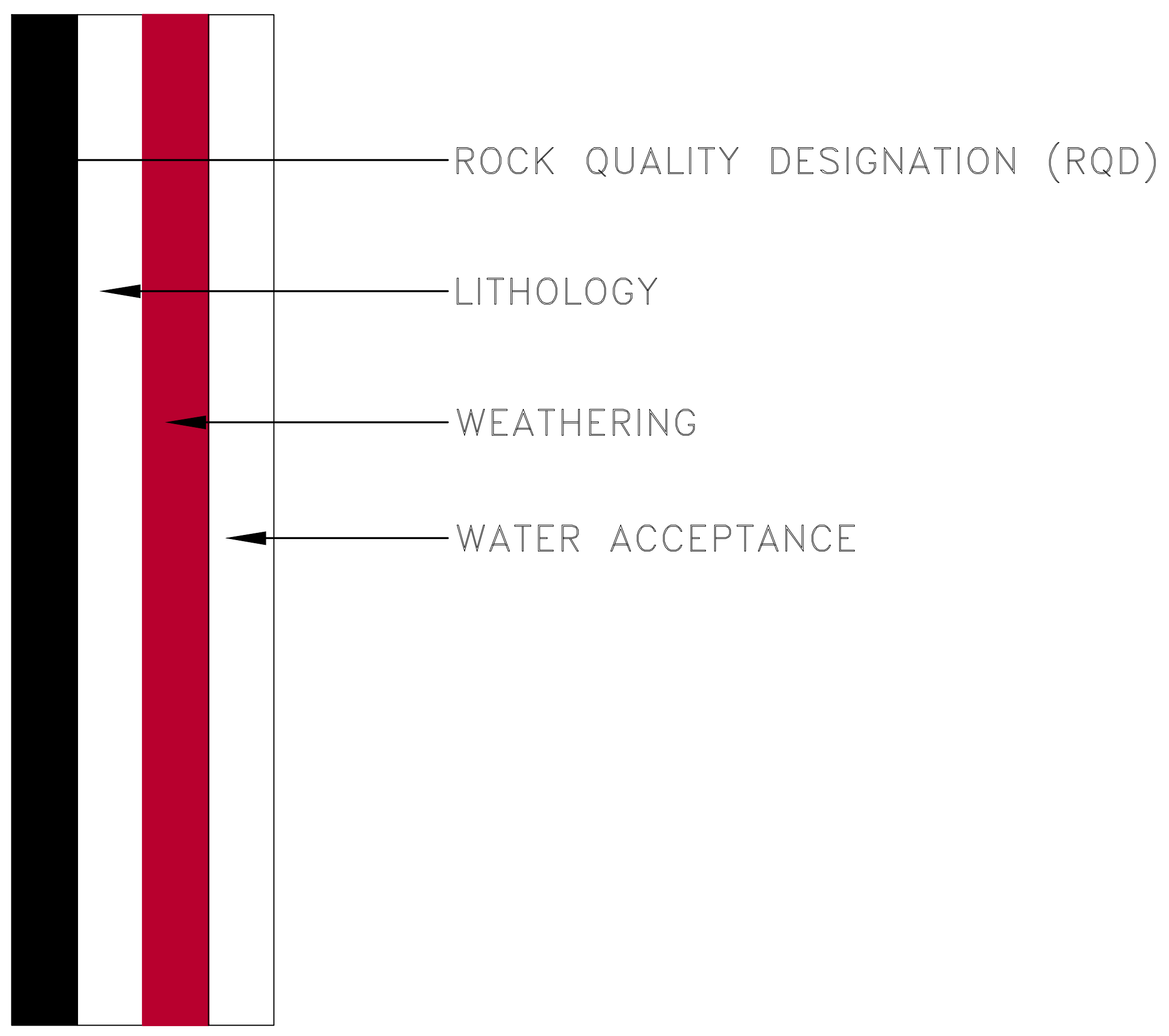
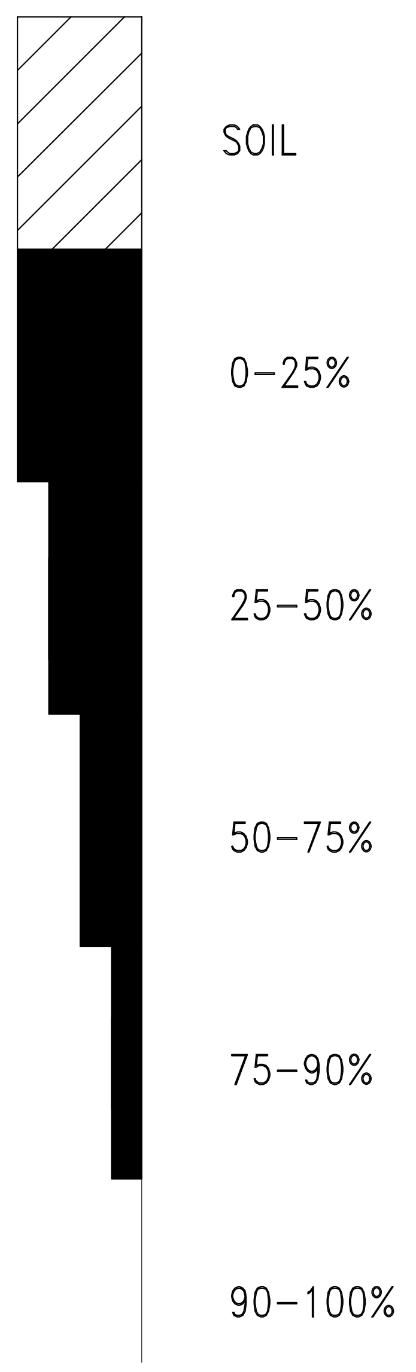
# BOREHOLE KEY

KEY:



NOTE:
NOT DRAWN INTO SCALE

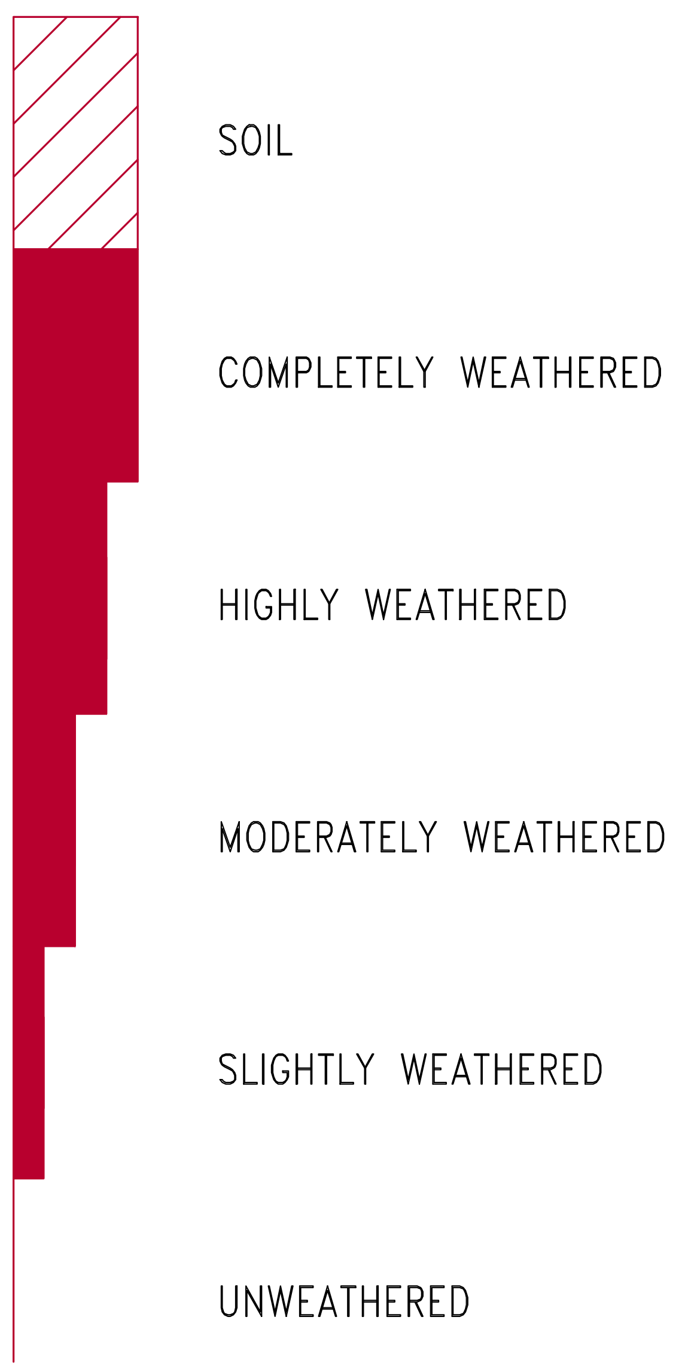
ROCK QUALITY DESIGNATION (RQD)



LITHOLOGY

| | | |
|---|---|---|
| ▨ | TOPSOIL | |
| ▨ | COLLUVIUM | |
| ▨ | REWORKED TERRACE GRAVELS | |
| ▨ | MUDSTONE<br>SANDSTONE | BEDROCK |

WEATHERING



WATER ACCEPTANCE

| | |
|---|---|
| NT | NO TEST |
| 3 | WATER ACCEPTANCE (IN LUGEONS) |
| NL | NO LOSS |
| NS | PACKER NOT SEALED |

NOTE:

LITHOLOGY IS INDICATED ON RESPECTIVE DRAWINGS
112546–GEO–DRG–CC–002A–A
112546–GEO–DRG–CC–002B–A
112546–GEO–DRG–CC–003–A &
112546–GEO–DRG–CC–004–A:

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