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A COMPREHENSIVE AND QUANTITATIVE GEOTECHNICAL AND PAVEMENT INVESTIGATION FOR GREENFIELD URBAN ROAD DEVELOPMENT IN PERTH, WESTERN AUSTRALIA

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Abstract: ***Pre and post Geotechnical investigation is an essential key requirement for infrastructure development anywhere in the world. It is a regulatory need for both local and state government infrastructure planning, design, and construction in Australia. Due to the current Pandemic, Australian Federal Government offered various stimulus packages to keep running the building industry, leading to more infrastructure development where there are aggravated risks without a comprehensive investigation, consideration and practices. Responsive, quality decision-making and context-sensitive geotechnical investigation are critical to lowering the probability of structural, financial, and life-threatening risks. It has enormous potential to build a resilient and cost-effective structure for asset owners. The study brought a practical case is called "Verde Drive West extension, and Prinsep Road construction" for best practice example from the City Cockburn, Western Australian growing local government. In this growing council, more than half a billion-dollar value projects are planning and implementing. The project illustrates how cost-effective site-specific investigation assesses their potential impact on the proposed development, develops geotechnical and engineering geologic design parameters, and achieves design and field information for efficient decision-making in the infrastructure building. This study showed that a detail investigation with a better reference could make less ambiguity for clients, consultants, and contractors. It includes a brief site description and condition, detail field exploration, results, laboratory testing, conclusion, and recommendations. The study concludes that the findings will help understand academic and practitioner in better project-specific scoping for subsoil investigation through context-sensitive approaching predominantly in Perth, Western Australia.***

Keywords- Infrastructure development, geotechnical investigation, decision making, context-sensitive approach, Subsurface Information

I. INTRODUCTION

The investigation is the most critical phase of any construction or development program that is unusually complex and variable with a low degree of predictability. The limitations of investigational methodology should incorporate conservative measures into design and construction to avoid unsatisfactory results. An inadequate investigation may result in construction delays and extra costs, or even structural collapse or other failure forms (Hunt, 2005). The field and laboratory investigations required to obtain this essential information constitute the ***soil exploration.*** Before the **1930s,** soil exploration was consistently inadequate because rational soil investigation methods had yet to develop.

On the other hand, at present, the amount of soil exploration and testing and the refinements in the techniques for performing the investigations are often quite out of proportion to the results' practical value (Terzaghi et al., 1996). Investigations can be divided into several phases based on their purpose, with various investigation stages in each phase. In general, phases range from feasibility to preliminary, design, final design, construction, and post-construction. The investigation scope will depend upon the size of the proposed construction area, i.e., a building footprint, or several to hundreds of acres, or square miles, and the investigator's experience in the area (Hunt, 2005). Therefore, s*tarting* a *risk register at the outset is the key to best practice to minimise and mitigate the risks (*Simons et al., 2002*)*. The fundamental objective of a geotechnical investigation is the characterisation of the geologic environment in the determination of the following (Hunt, 2005):

- Lateral distribution and thickness of the soil and rock strata within the zone of influence of the proposed construction or development,

- Groundwater conditions, considering the seasonal changes and the effects of extraction due to construction or development,
- Physical and engineering properties of the soil and rock formations, and groundwater quality,
- Hazardous conditions, including unstable slopes, active or potentially active faults, regional seismicity, floodplains, ground subsidence, collapse, and heave potential,
- Ground response to changing natural conditions and construction or development brought about by surface loadings from structures, unloading by surface or subsurface excavations, or unloading from mineral resources extraction.
- Suitability of the geologic materials for aggregate and for the construction of pavements and embankments,

Simons et al. (2002) also highlighted that the object of investigation;

- to enable an adequate and economical design to be prepared, including the arrangement of temporary works, ground improvement techniques and groundwater control schemes
- to plan the best method of construction, and to foresee difficulties and delays which may arise for whatever reason
- the design of remedial works if any failures have occurred
- to explore sources of indigenous materials for use in construction
- to select sites for the disposal of waste or surplus materials

Therefore, an investigation is essential that will identify such problems at an early stage. Unfortunately, on many occasions, insufficient attention is paid to this critical aspect of site investigation (Simons et al., 2002). This study brought this case that will assist the practitioner and academic in getting in-depth in a combination of theory and practical industry practices on urban road infrastructure development.

The proposed Verde Drive extension consists of a 2-lane undivided urban cross-section west of Solomon Road and was recently upgraded east of Solomon to a 2-lane divided urban cross-section.

The Verde Drive west extended from the Solomon Road roundabout upgraded and extended west as a 2-lane divided urban carriageway to tie-in to the existing Public Transport Authority's Cockburn Central Station carpark allowing future tie-in and interface to MRWA's future Armadale Road to North Lake Road Bridge works. Prinsep Road consists of a 2-lane undivided rural/industrial cross-section. Prinsep Road is to be extended south to tie-in to the proposed Verde Drive extension. Due to MRWA's works' sequencing, the Verde Drive extension will temporarily tie-in to PTA's existing Cockburn Central Station carpark until such time that MRWA's Armadale Road to North Lake Road Bridge works are constructed and interfaced. Verde Drive and Prinsep Road's existing road reserves are approximately 32m and 20m wide respectively. Localised widening proposed on existing planning boundaries provided by the City to align the Verde Drive and Prinsep Road extension and accommodate the proposed roundabout for Verde Drive and Prinsep Road. The land acquisition was part of the project scope to facilitate the alignment of the proposed extensions. Following ***figures 1*** has detailed the project location in Cockburn Central East (CCE) as well as exiting Verdi drive, Solomon road, Cockburn Central Station. The CCE area is bound by Kwinana Freeway

Figure 1: Location Map of Project Road

to the west and Armadale road to the south, interlinking to existing Cockburn Central station parks, where the State governments has planed and commenced the major infrastructure upgrade to alleviate congestion and to accommodate current and future traffic growth in D2031 as well as Metronet connection (Thornlie-Cockburn) rail links including prescient station upgrades as shown in ***figure 3*** and ***figure 4.*** The City of Cockburn also conducted a Traffic Impact Assessment (TIA) for a structured plan following the Western Australian Planning Commission Structure Plan Framework (WAPC, 2015) and the Transport Impact Assessment Guidelines (WAPC, 2016) to support the movement network plan for the Cockburn Central East Structure Plan (CCE SP) as detailed in ***figure 2.*** From the TIA, it was revealed that Verde Drive is predicted to carry approximately 18,000vpd, Armadale Road is predicted to carry approximately 60,000vpd east of the study area, The projected traffic volumes on Jandakot Road is approximately 19,500vpd east of Solomon Road, and about 27,700vpd to the west and approximately 67,500vpd to the west, and the Prinsep Road extension reduces the daily traffic flows along the parallel Solomon Road (11,000vpd – 14,200vpd) as detail from MRWA option 3 that was recently established from State network modelling where, The PTA recently detailed Station Access Strategy (SAS) to determine suitable access to a consolidated car park to the east, amongst other improved modes of access; bus, walk and cycle. The SAS recognises Cockburn Central as a secondary activity center within Perth (as identified by the WAPC) and that it is a Transit-Oriented Development (TOD) node (GTA, 2017).

The study broadly explains the in-depth field and laboratory investigation in infrastructure planning, design, and construction for ***figure 5***. The closing discussion will provide recommendations regarding geotechnical and pavement on project planning and design of various infrastructure components. The study has detailed the terminology as part of this unique project as follows:

Terminology	
AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway Transport Officials
ADT	Average Daily Traffic
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ASS	Acid Sulfate Soils
BH	Bore Hole
BM	Benchmark
CBR	California Bearing Ratio
CPT	Electric Friction Cone Penetrometer Test
DBYD	Dial Before You Dig
DCP	Dynamic Cone Penetrometer
HFL	Highest Flood Level
KPH	Kilometre Per Hour
MDD	Maximum Dry Density
MRWA	Main Roads Western Australia
MSL	Mean Sea Level
PCU	Passenger Car Unit
PD	Pavement Dipping test
PTA	Public Transport Authority
RCC	Reinforced Cement Concrete
SAS	Station Access Strategy
TIA	Traffic Impact Assessment
TOD	Transit Oriented Development

Figure 1a: Location Map of Project Road with proposed alignments

Figure 2: Cockburn Central East Structure Plan (CCE SP)

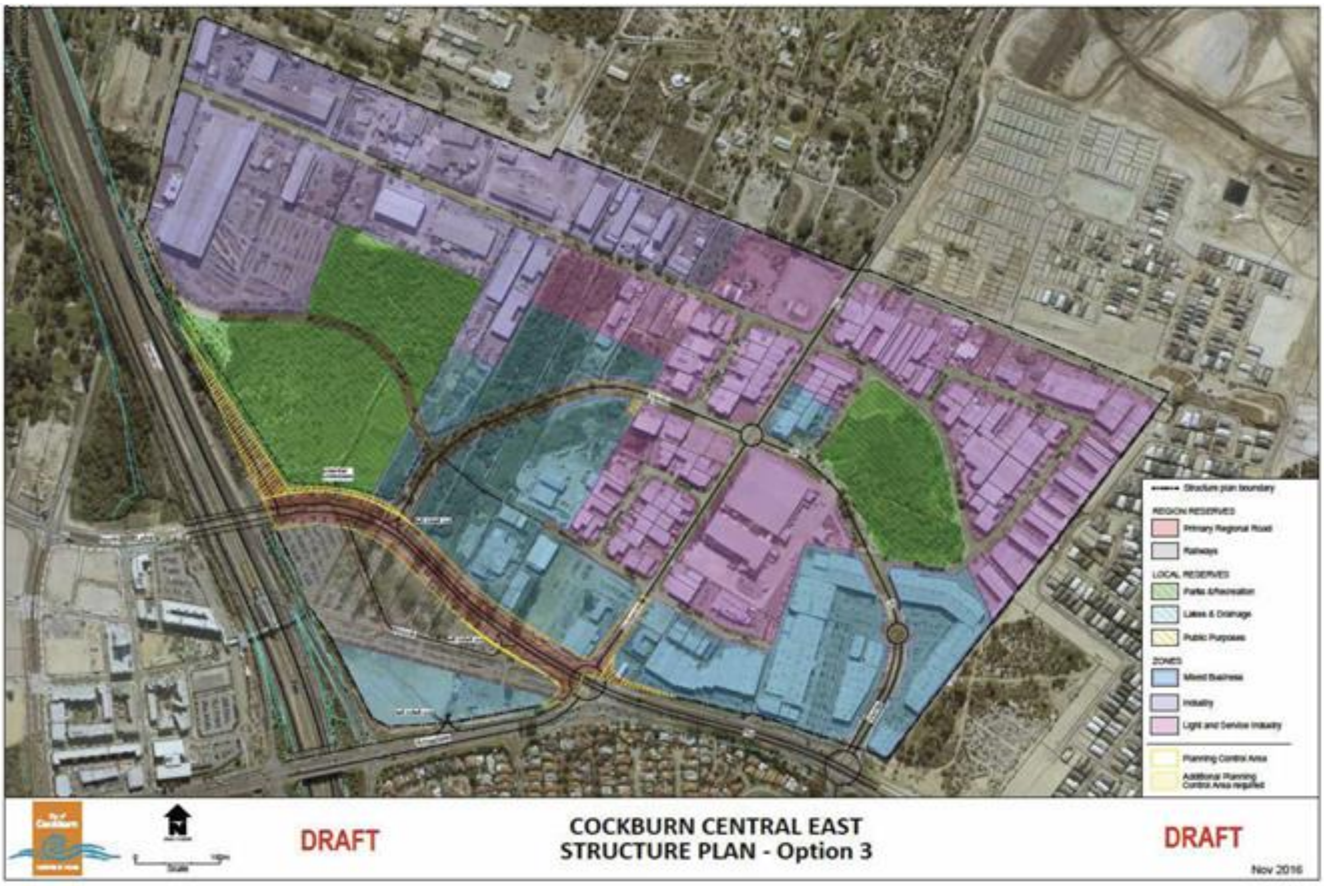


Figure 3: Location Map of Cockburn Central East Structure Plan – Option 3

Figure 4: Location Map of Armadale Road, North Lake Road Bridge project – Option 3

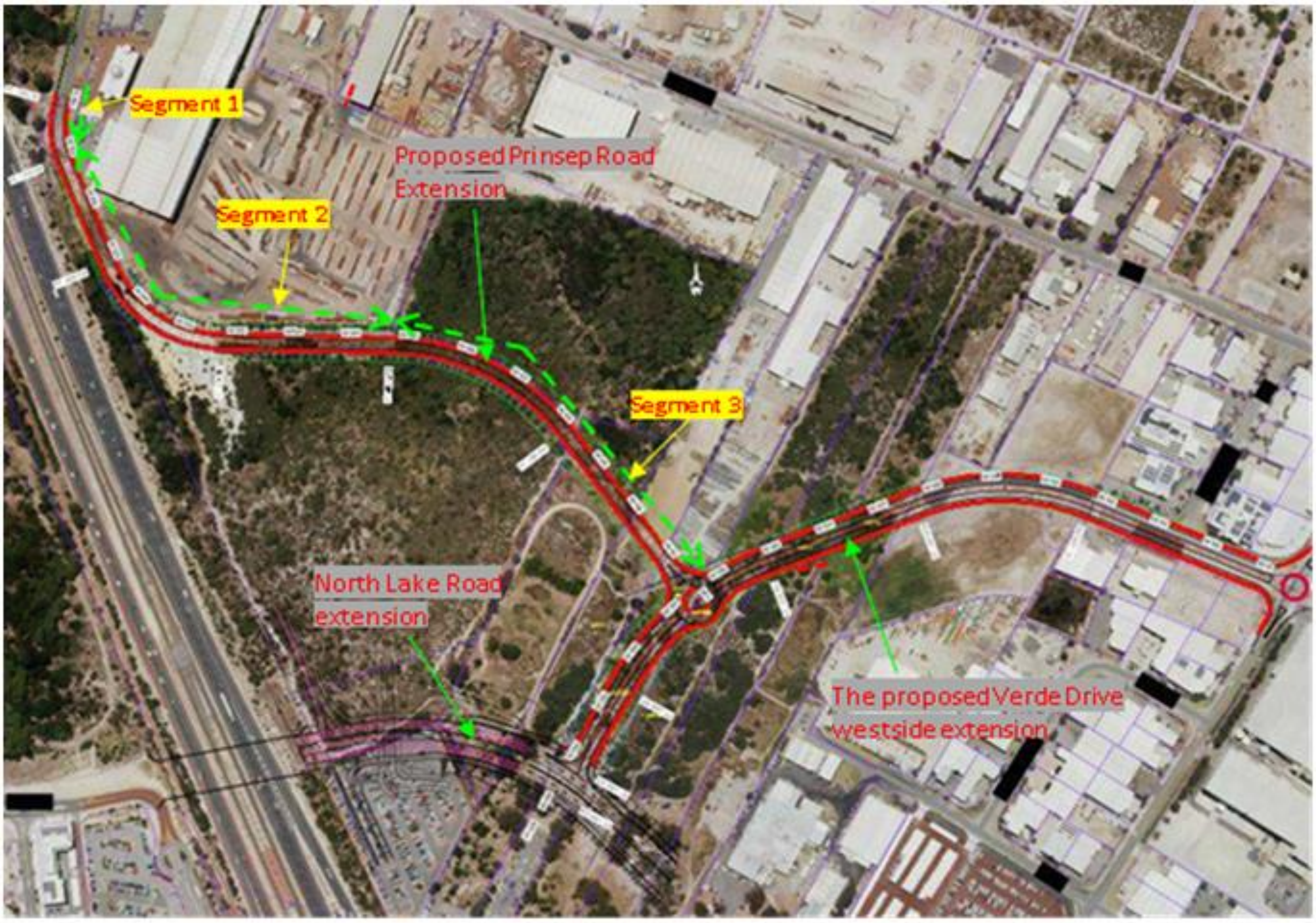


Figure 5: Verde Drive West and Prinsep Road layout

II. METHODOLOGY

This study's methodology includes a literature review, desktop study and field investigation, field data analysis, laboratory testing. The study has detailed these investigations and analysis in regard to an urban road development context through a recently constructed project called "Verde Drive West extension and Prinsep Road construction" throughout the project life cycle and stages. The field investigations were itemised and performed based on on-site constraints and challenges. The major tests were tested pit/borehole, pavement dipping, DCP, ASS and field permeability, DCP test data and CBR correlation, CPT data and interpretation, Soil Permeability at specific locations to generalise the project parameter including water table information and finally, laboratory test and results to establish the physical data for various engineering consideration, design and decision making. Due to limited texts for this study, the study has detailed Prinsep Road detail investigation and with limited details of Verde Drive investigation only.

III. ANALYSIS AND RESULT

1 DESKTOP STUDY

1.1 Existing Surface Conditions and Groundwater Information

A desktop study was conducted before undertaking the field investigation to understand the site condition and better understand the site geology, surface elevations, and groundwater levels. The findings of the desktop study are described in the following sub-sections. A review of "Perth Groundwater Atlas" of the Department of Water was conducted as a desktop study. "Perth Groundwater Atlas" revealed that the site's natural ground surface elevation varies from 26.0 m to 27.0 m AHD. Perth Groundwater Atlas also revealed that the annual average groundwater table level (May 2003 data) at the site is 23.0 m to 24.0 m AHD. The historic maximum groundwater table level is 25.0 m to 26.0 m AHD. These levels indicate that the groundwater table's average depth varies approximately between 2.0 m and 3.0 m below the present ground level. It was noted that the accuracy of the data might vary. The groundwater table usually varies seasonally by up to several meters due to rainfall, changes in catchment characteristics, local groundwater extraction activities, climate change and other factors.

1.2 Subsurface Information

A review of the 1:50,000 Environmental Geology series map of Western Australia (Fremantle Part Sheets 2033 I and 2033 IV) was conducted before commencing the site investigation. The Environmental Geology map (Fremantle) revealed that the site was comprised of sand, as S8, as relatively veneer over strong, blocky, brown silts and clays, thin Bassendean Sand over Guildford formation. Additionally, *the site comprises sandy silt- dark brownish-grey silt, with disseminated fine-grained quartz sand, firm, variable clay content, lacustrine origin, and Swamp deposits. Fremantle's Environmental Geological map also revealed that the site soil has high permeability, low corrosion potential, medium slope stability, and medium to high bearing capacity. The upper sand's physical properties are modified by the underlying material, generally high watertable, prone to flooding in part.*

1.3 Acid Sulfate Soils (ASS) Information

The Acid Sulfate Soil (ASS) risk map (Perth Groundwater Atlas, Department of Water, WA) were verified where it was suggested that the site lies within an area of High to Moderate (H-M) and Moderate to Low (M-L) potential ASS, occurring within 3.0 m of the natural ground surface that could be disturbed by most development activities. An extract of the Acid Sulfate Soils (ASS) map is presented in Figure 6.

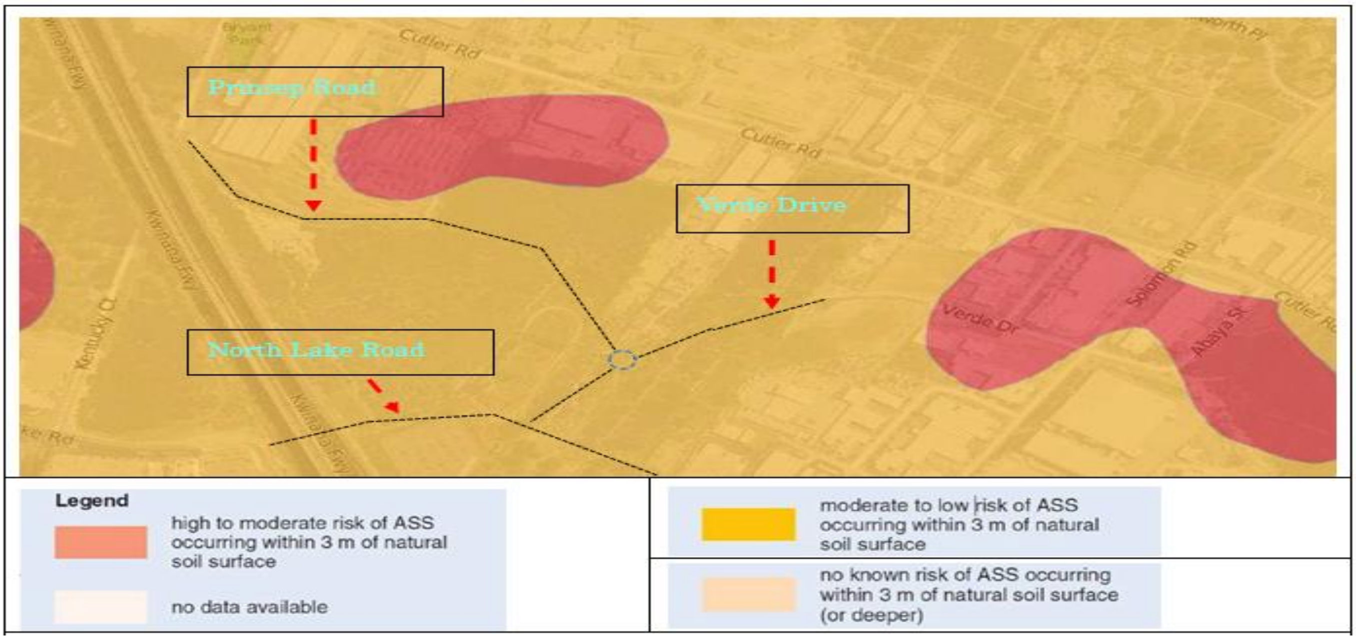


Figure 6. Acid Sulfate Soils (ASS) Map Extract
(Courtesy from Perth Groundwater Atlas map, Department of Water, WA acid sulfate soils)

2. FIELD INVESTIGATION

2.1 General

The site investigation was carried out in two days: 6 and 24 November 2018. The test pits, pavement dipping and DCP tests were conducted on 6 November. Boreholes for ASS sampling and field permeability tests were conducted on 24 November 2018. The fieldwork was carried out under the supervision of authors on behalf of Perth Geotechnics (PG). *The weather was sunny, cloudy and hot during the investigation period. A site plan showing the test pit/ borehole locations, pavement dipping, DCP test, ASS and field permeability tests are provided in figure 7 and figure 8.* The field investigation comprises the following:

- Deployment of two competent engineers to do the field works;
- Organise subcontractor and clear underground services for test pits excavation and pavement dipping works;
- Managing the traffic during the pavement dipping works;
- Undertaking 11 test pits (TP) subsurface probing by using an excavator to either a depth of 3.0 m or refusal. The test pits were distributed as follows:
    - 5 x TPs along segment 2 (Figure 5),
    - 6 x TPs along segment 3 (Figure 5).
- Logging the soil strata and identifying the soil layers and profiles as per AS1726;
- Recording the ground watertable during the sub-surface probing works;
- Soil sampling during the test pit/borehole excavation works for subsequent laboratory testing;
- Acid Sulfate Soils (ASS) sampling from 3 Bore Holes (BH1- 3) along segment 3;
- Undertaking 25 x Field pH (pHF) and field peroxide (pHFOX) tests, 9 x Suspension Peroxide Oxidation – Combined Acidity and Sulfate (SPOCAS) suite for ASS risk assessment;
- Conduct Cone Penetration Tests (CPTu1 and CPT2) along segment 3, up to either 7.0 m depth or refusal;
- Conduct Dynamic Cone Penetration (DCP1-12) tests up to 1.0 m depth adjacent to the test pits along segment 2 and 3, and at the sub-grade level of the road pavement dipping (PD1) along segment 1;
- Conducting 4 field permeability tests (FPT1-4) along segment 2 and 3;
- Deployment of an excavator with an operator to do the pavement dipping works by a mechanical auger;
- Conducting 1 Pavement Dipping test (PD1) along segment 1, to a depth of 1.0 m up to the subgrade layer of the existing road pavement.

2.2 Survey

Field investigation locations were determined on-site using a Garmin 12 channel handheld GPS with a claimed accuracy of ±5m. The approximate Coordinates (GDA94/MGA 94) and reduced levels (m AHD) of all tests are shown in the location summary table in the following relevant sections.

2.3 Underground Services

Prior to the commencement of the fieldwork, underground services within the proposed development area were identified. Underground utility plans were obtained from 'Dial Before You Dig (DBYD)' on 5 November and 'Services Scan' by 'Award Scanning' on 6 November 2018. All fieldworks were carried out by or under the direction of PG in general accordance with AS1726 (1993). Care was taken to avoid any damage to existing underground services. The scope of the fieldwork completed, as mentioned above. The author engaged Cable Locates (contractor) to investigate and prepare detail probe drill information on 9 November 2018 to ensure that the DBYD and factual information have consistency. And to assist the design of various subsurface design items such as Stormwater drainage utility relocation, underground power and many more.

2.4 Test Pits and Bore Holes

A total of 11 Test Pits (TP1-TP11) were drilled using a 3-tonne excavator, and additional 3 Bore Holes (BH1- BH3) were drilled using a hand auger to either a depth of 3.0 m or refusal along with the proposed Prinsep Road extension. The excavated soil was stockpiled adjacent to each hole for logging and sampling purpose. Bulk samples (disturbed) of soil materials were obtained for laboratory testing, including geotechnical and environmental tests. The subsurface conditions exposed by the test hole were logged in accordance with AS1726-1993, the holes were photographed to provide a visual record of the subsurface conditions encountered. The test holes were reinstated to best match the initial conditions with the excavated spoil. The investigation revealed that the site has the following generalised subsurface units along segment 2 and segment 3, mentioned in ***figure 5.*** The photographic detail of the test pit (TP1- TP11) has captured in ***figure 9 to figure 29.*** The boreholes details also appended in ***figure 31 to figure 35.***

- **Unit 1: Topsoil, SAND (SP)/ Silty SAND (SM)/Clayey SAND (SC) -** very loose to loose, fine to coarse-grained, dark grey, black, grey, brown, yellowish-brown, dry, with silt, rootlets, organics. The thickness of this unit varies between 0.0 m and 0.3 m.
- **Unit 2: SAND (SP)/ Silty SAND (SM) –** fine to coarse-grained, dark grey, black, grey, light grey, brown, dry to wet, very loose to dense, sub-angular to sub-rounded, quartz with few rootlets, trace of silt. This unit was found to extend to the maximum investigated depth of 3.0 m.

The groundwater table was observed at all test pit/borehole locations except TP1. The water depth varies from 0.33 to 2.0 m from the existing surface level. Details of the Test Pits and Bore Holes are summarised in Table 1, and the logs are attached in the figures. The detail bore logs for TP1 to TP11 have detailed in ***figure 64*** to ***figure 74.*** The detail bore logs for BH1 to BH3 have also detailed in ***figure 57 to figure 59.*** Besides, ***figure 60 to figure 63*** details the bore logs for Verde Dr.

Table 1. Summary of Test Pits (TPs) and Bore Holes (BHs) locations

Test Pit (TP) No.	Layer (m)		Coordinates (GDA94)		Water table (m)	Termination Depth (m)
	Unit 1 Topsoil	Unit 2 Sand layer	Easting	Northing		
01	0 - 0.3	0.3 – 3.0	50 392 092	6 445 793	N/A	3.0
02	0 - 0.2	0.2 – 2.5	50 392 117	6 445 736	1.8	2.5
03	0 - 0.2	0.2 – 2.0	50 392 167	6 445 671	1.2	2.0
04	0 - 0.2	0.2 – 2.7	50 392 210	6 445 656	2.0	2.7
05	0 - 0.2	0.2 - 2.0	50 392 281	6 445 655	0.9	2.0
06	0 - 0.2	0.2 – 2.3	50 392 346	6 445 655	1.2	2.3
07	0 - 0.2	0.2 – 2.0	50 392 394	6 445 648	0.9	2.0
08	0 - 0.3	0.3 – 2.0	50 392 498	6 445 606	0.8	2.0
09	0 - 0.2	0.2 - 2.0	50 392 530	6 445 572	0.65	2.0
10	0 - 0.3	0.3 - 2.0	50 392 558	6 445 536	0.7	2.0
11	0 - 0.2	0.2 - 2.0	50 392 600	6 445 456	0.9	2.0
Bore Holes (BH)						
01	0 - 0.2	0.2 – 1.5	50 392 445	6 445 643	0.33	1.5
02	0 - 0.2	0.2 – 2.0	50 392 537	6 445 553	0.8	2.0
03	0 - 0.2	0.2 – 2.0	50 392 595	6 445 448	1.0	2.0

N/A= Not Available

Pavement Dipping

One (1) Pavement Dipping (PD) was drilled and excavated at the existing pavement of Prinsep Road along Segment 1. The pavement dipped profile revealed that the pavement layers generally consists of an asphalt layer, a base course layer, a sub-base layer followed by the subgrade. A summary of the layer thicknesses exposed by *the PD is presented in Table 2 and the pavement dipping log is presented in **figure 36, 37 and 40,*** and log detail in ***figure 118.*** Besides, ***figure 123 to figure 124*** details for Verde Dr.

Table 2. Summary of Existing Pavement Profile based on Pavement Dipping

Pavement Dipping (PD)	Layer thickness (mm)			Termination depth (mm)	Coordinates (GDA94)	
	Asphalt	Base course	Sub base		Easting	Northing
Segment 1						
01	35	90	225	1000	50 392 086	6 445 863

2.6 Dynamic Cone Penetrometer (DCP) Test

The Dynamic Cone Penetrometer (DCP1-12) tests were conducted next to the test pits and at the subgrade level of the existing pavement dipping location during the dipping works. The DCP test certificates are presented in ***figure 103*** and ***figure 104***. Besides, ***figure 139 to figure 140*** details for Verde Dr. The DCP test data was used to estimate the field density and California Bearing Ratio (CBR) of the sub-grade materials following the Australian Standard HB 160-2006. The DCP also conducted at TP1 to TP11 and at PD1 location, detailed in ***figure 41 to figure 49.***

The DCP tests data and its correlations with CBR are summarised in Table (3-5)

Table 3. Summary of the DCP test next to Test Pit (TP1-5) locations

Correlation Type	Correlation of Sand Density Table 6.4.6.1(B) HB 160-2006					Correlation between DCP & CBR *Table 6.4.6.1(C) HB 160-2006*				
DCP No.	**DCP1 (TP1)**	**DCP2 (TP2)**	**DCP3 (TP3)**	**DCP4 (TP4)**	**DCP5 (TP5)**	**DCP1 (TP1)**	**DCP2 (TP2)**	**DCP3 (TP3)**	**DCP4 (TP4)**	**DCP5 (TP5)**
Depth (mm)	No. of Blows/100 mm					CBR (%)				
0-100	4	3	<1	<1	<1	8	6	<2	<2	<2
100-200	7	6	2	<1	1	14	12	4	<2	2
200-300	7	4	2	2	2	14	8	4	4	4
300-400	8	4	2	4	4	18	8	4	4	8
400-500	8	5	2	6	3	18	10	4	12	6
500-600	4	4	3	6	2	8	8	6	12	4
600-700	4	4	2	9	3	8	8	4	20	6
700-800	5	5	2	13	3	10	10	4	30	6
800-900	4	4	3	12	2	8	8	6	27	4
900-1000	5	4	2	11	3	10	8	4	25	6
Note: Density Classification is obtained based on the number of blows required for 100 mm penetration of the DCP Very Loose (VL) < 1; Loose (L) 1 – 2; Medium Dense (MD) 2 – 3; Dense (D) 4 – 8; Very Dense (VD) > 8										

It was observed from the DCP and CBR correlations that the CBR values vary between <2% and 30% along segment 2, between DCP1 and DCP5.

Table 4. Summary of DCP test adjacent to Test Pit (TP6-10) locations

Correlation Type	Correlation of Sand Density Table 6.4.6.1(B) HB 160-2006					Correlation between DCP & CBR *Table 6.4.6.1(C) HB 160-2006*				
DCP No.	**DCP6 (TP6)**	**DCP7 (TP7)**	**DCP8 (TP8)**	**DCP9 (TP9)**	**DCP10 (TP10)**	**DCP6 (TP6)**	**DCP7 (TP7)**	**DCP8 (TP8)**	**DCP9 (TP9)**	**DCP10 (TP10)**
Depth (mm)	No. of Blows/100 mm					CBR (%)				
0-100	<1	<1	<1	4	<1	<2	<2	<2	8	<2
100-200	2	<1	<1	3	<1	4	<2	<2	6	<2
200-300	3	<1	2	2	<1	6	<2	4	4	<2
300-400	3	<1	2	2	2	6	<2	4	4	4
400-500	2	<1	1	2	1	4	<2	2	4	2
500-600	3	1	2	3	2	6	2	4	6	4
600-700	3	<1	2	2	3	6	<2	4	4	6
700-800	4	<1	3	3	2	8	<2	6	6	4
800-900	4	<1	2	2	3	8	<2	4	4	6
900-1000	5	<1	2	3	3	10	<2	4	6	6
Note: Density Classification is obtained based on Number of blows required for 100 mm penetration of DCP Very Loose (VL) < 1; Loose (L) 1 – 2; Medium Dense (MD) 2 – 3; Dense (D) 4 – 8; Very Dense (VD) > 8										

It was observed from the DCP and CBR correlations that the CBR values vary between <2% and 10% along segment 2 and 3, between DCP6 and DCP10.

Table 5. Summary of DCP test adjacent to TP11 and subgrade of existing pavement (PD1)

Correlation Type	Correlation of Sand Density Table 6.4.6.1(B) HB 160-2006				Correlation between DCP & CBR *Table 6.4.6.1(C) HB 160-2006*			
DCP No.	**DCP11 (TP11)**	**DCP12 (PD1)**	**-**	**-**	**DCP11 (PD1)**	**DCP12 (PD2)**	**-**	**-**
Depth (mm)	No. of Blows/ 100 mm				CBR (%)			
0-100	2	8	-	-	4	18	-	-
100-200	2	11	-	-	4	25	-	-
200-300	3	12	-	-	6	27	-	-
300-400	2	25>R	-	-	4	>60	-	-
400-500	3	-	-	-	6	-	-	-
500-600	4	-	-	-	8	-	-	-
600-700	4	-	-	-	8	-	-	-
700-800	3	-	-	-	6	-	-	-
800-900	4	-	-	-	8	-	-	-
900-1000	4	-	-	-	8	-	-	-
Note: Density Classification is obtained based on Number of blows required for 100 mm penetration of DCP Very Loose (VL) < 1; Loose (L) 1 – 2; Medium Dense (MD) 2 – 3; Dense (D) 4 – 8; Very Dense (VD) > 8								

It was observed from DCP and CBR correlations that the CBR values vary between 4% and >60% along segment 3 and 1, between DCP11 and DCP12. Overall, the DCP test results revealed that the soil tested is in a very loose to very dense condition. (Refer to Section 5.10 for field recommendations concerning preparation of the site in terms of densification requirements).

2.7 Electric Friction Cone Penetrometer Test (CPT)

The cone penetrometer tests (CPTs) were undertaken by Probdrill by using a 7-tonne track CPT drill rig. The investigation was carried out in accordance with AS 1289.6.5.1-1999. CPTu1 and CPT2 were conducted along segment 3, up to either 7.0 m depth or refusal. CPTu1 and CPT2 were close to BH1 and BH3 locations respectively. ***Figure 50 and figure 51*** have shown the field scenarios where tests were conducted. The details about data presentation and interpretation are captured in ***figure 75 to figure 88*** for CPTu1 and ***figure 89 to figure 102*** for CPT2.

The CPT traces are presented in Appendix D as plots of cone tip resistance (q_c), sleeve friction (f_s) and friction ratio (F_R = f_s/q_c x 100%) versus depth. A summary of the Cone Penetration Tests along Segment 3 is presented in Table 6.

Table 6. A summary of the Cone Penetration Tests (CPTs) along Segment 3

Cone Penetration Test (CPT) No.	**Soil**	**Coordinates (GDA94)**		**Tip Resistance (MPa)**	**Friction Ratio (%)**	**Water table Depth (m)**	**Termination Depth (m)**
		Easting	**Northing**				
CPTu1 (0 -7.5 m)	SAND	50 392 438	6 445 651	1.0 – 17.0	0.1 – 2.0	0.6	7.5
CPT2 (0 -7.1 m)	SAND	50 392 588	6 445 485	2.0 – 30.0	0.3 – 0.7	0.7	7.1

After each probing, the cone hole was dipped by a weighted measuring tape with the intention to directly measuring the depth to the groundwater table. CPTu1 and CPT2 probe holes showed groundwater table at a depth of 0.6 m and 0.7 m, respectively. The CPTs were probed up to the target depth of 7.5 m and 7.1 m respectively. The following figure has detailed the location and type of tests were performed on Prinsep road alignment showing on road's geometry design.

2.8 Field Permeability Test

The field permeability tests (FPT1 to FPT4) were conducted on 24 November 2019 using the Guelph Permeameter, as per ASTM D 5126 – 90 at 4 locations along Segment 2 and 3. The tests were conducted 500 mm below the existing ground surface. The Guelph Permeameter is a constant head device that operates on the Mariotte siphon principle. It provides a straightforward values of the field saturated hydraulic conductivity, matrix flux potential and the soil sorptivity in the field. Permeability test results are summarised in Table 7 and the test field location has detailed in ***figure 52*** certificates are presented in ***figure 105*** to ***figure 108*** respectively. Besides, ***figure 121 to figure 122*** details for Verde Dr.

Table 7. Summary of the Field Permeability Test Results

Permeability Test ID	Coordinates (GDA94)		Permeability Rate		Soil Description	Test Depth (m)
	Easting	Northing	cm/sec	m/day		
FPT1	50 392 106	6 445 751	6.3×10^{-3}	5.4	Sand	0.5
FPT2	50 392 369	6 445 654	6.8×10^{-4}	0.59	Sand with silt	0.5
FPT3	50 392 479	6 445 626	7.1×10^{-4}	0.61	Sand	0.5
FPT4	50 392 565	6 445 545	8.6×10^{-4}	0.74	Sand	0.5

Field Permeability Tests FPT2, FPT3 and FPT4 were conducted in wet conditions, whereas FPT1 was conducted in dry conditions. It is found from the permeability tests that the permeability rate varies from 0.59 m/day to 0.74 m/day in wet condition and 5.4 m/day in dry condition.

3 LABORATORY TEST

3.1 General

Laboratory testing on collected soil samples was undertaken by a NATA accredited laboratory. The testing standard applying to each test is recorded on the laboratory testing certificates/reports. The geotechnical and environmental laboratory test results are summarised in Table 8, 10 and Table 11, respectively. The laboratory test certificates are included in ***figure 109*** to ***figure 120*** and ***figure 147*** to ***figure 158***, respectively for Prinsep Road. Besides, ***figure 141 to figure 146*** details for Verde Dr.

3.2 Geotechnical Test Results

Three (3) soil samples were collected from test pit locations TP2, TP7 and TP11 for laboratory testing. The laboratory tests were conducted at Liquid Labs WA, a NATA accredited soil testing laboratory located at Welshpool WA. Schedule of the laboratory tests included:

- Particle Size Distribution (PSD) in accordance with WA 115.1;
- Modified Maximum Dry Density (MMDD) in accordance with WA 133.1;
- 4-Days Soaked, California Bearing Ratio (CBR) in accordance with WA 105.1, 110.1, 133.1, 141.1.

The laboratory tests results are summarised in Table 8. The test certificates are attached in ***figure 109*** to ***figure 120*** to this report.

Table 8. Summary of Laboratory Test Results

Sample Location	TP2 (0.3 – 0.8) m	TP7 (0.2 – 0.8) m	TP11 (0.3 – 0.8) m
Particle Size Distribution (PSD)			
Gravel (%)	0	0	0
Sand (%)	98	97	99
Percent Fines < 75µm (%)	2	3	1
Modified Maximum Dry Density (MMDD)			
MMDD, t/m^3	1.788	1.722	1.726
Optimum Moisture Content, OMC (%)	12.8	13.7	13.5
California Bearing Ratio (CBR) Test – 4 Soaked			
CBR at 2.5 mm Penetration (%)	4	-	-
CBR at 5.0 mm Penetration (%)	-	9	9

It was observed from the laboratory test results that the percent fines for the sand layer are 0% to 3%. PSD data revealed that the site comprises of uniformly graded sand.

Modified Proctor test revealed that maximum dry density of the sand (sub-grade) is 1.722 t/m^3 to 1.7882 t/m^3 at an optimum moisture content of 12.8 to 13.7%; The values of the California Bearing Ratio (CBR) range from 4% to 9%. Generally, the fine-grained soils CBR values are lower, and ranging from 5% to 15%.

4 ACID SULFATE SOIL

4.1 General of Acid sulfate soils (ASS) Assessment

A preliminary assessment of Acid Sulfate Soils (ASS) was performed at the proposed Prinsep Road extension area. The aim of the assessment of results was to undertake sufficient sampling and testing to identify the potential for ASS within the 3.0 m depth and subsequently the requirement for further detailed investigation and testing. The detailed investigation work may include compliance with the current Department of Environment Regulations (DER) guidelines which require sampling every 250 mm throughout the vertical soil profile at test locations no more than 50 m apart, to at least 1.0 m below the proposed excavation/disturbance level.

The ASS sampling was carried out on 24 November 2018 during the drilling of the borehole. The weather on the day of the fieldwork was sunny, cloudy and hot. A hand auger was used to collect discrete samples from the boreholes. Soil samples were collected from three (3) boreholes (BH1, BH2 and BH3) along Segment 3, at 0.25 m intervals down the profile starting from the ground surface down to a depth of 3.0 m, with a minimum of one sample per soil layer encountered. Sampling from most of the boreholes were not possible down to 3.0 m depth due to the shallow groundwater encountered. During the construction time, if ASS encountered anywhere then further investigation and environment management plan will be required. Selection of the borehole for ASS sampling was made based on locations believed to have the most likelihood of ASS potential.

The collected soil samples were immediately placed in polyethylene (non-reactive) snap-lock bags (with air removed prior to sealing). Each sample bag was marked with a unique identification number, location, date and sample interval. Each borehole was progressively backfilled in reverse order of the materials to minimise the risk of generating acid sulfate soils condition. The samples were kept out of direct sunlight and stored on ice in an esky, and delivered to ALS laboratories in Perth. Methods employed in this investigation followed the "Identification and investigation of acid sulfate soils and acidic landscapes "Acid Sulfate Soils Guideline Series, DER 2013.

4.2 ASS Site Assessment Criteria

Assessment of ASS in Western Australia is based on the Department of Environment and Conservation (DEC, 2013) *Acid Sulfate Soils Guideline Series*. The guidelines include acidity based action criteria for field pH_F and pH_{FOX} testing and laboratory SCR analysis.

For the field tests, the following general criteria (DEC 2013) were referenced to define Actual ASS (AASS) and potential ASS (PASS):

- AASS: both pH_F and $pH_{FOX} < 4.0$
- PASS: $pH_F > 4.0$ and $pH_{FOX} < 4.0$
- Non-Acid Sulfate soils (NASS): both pH_F and $pH_{FOX} > 4.0$
- Effervescence ≥ extreme
- Change in pH (ΔpH) > 1.0, where $\Delta pH = pH_F - pH_{FOX}$
- $pH_{FOX} < 5.5$.
- To a much lesser extent a 'strong' or 'extreme' reaction rate.

The net acidity action criteria used in this ASS Investigation are outlined in Table 9. The DEC action criteria are based on concentrations of the oxidisable sulfur measured for a broad category of soil types. Works undertaken in soils that exceed these action criteria require the preparation and implementation of a management plan approved by the DEC. Laboratory analysis is required to assess if a soil exceeds the net acidity action based criteria.

Table 9. Texture-based Acid Sulfate Soils' Action Criteria' (DEC 2013)

Type of Material		Net Acidity Action Criteria			
Texture Range	Approx. Clay Content (%)	<1000 Tonnes of Material is Disturbed		>1000 Tonnes of Material is Disturbed	
		Equivalent Sulfur (%S) (oven-dry basis)	Equivalent Acidity (mol H+/t) (oven-dry basis)	Equivalent Sulfur(%S) (oven-dry basis)	Equivalent Acidity (mol H+/t) (oven-dry basis)
Coarse Texture: Sands to Loamy Sands	<5	0.03	18.7	0.3	18.7
Medium Texture: Sandy Loams to Light Clays	5 – 40	0.06	37.4	0.03	18.7
Fine Texture: Medium to Heavy Clays and Silty Clays	> 40	0.10	64.8	0.03	18.7

The adopted assessment criteria for this investigation is 0.03 equivalent sulfur (%S) based on the sand identified during the field investigation and that less than 1000 tonnes of material is likely to be disturbed.

4.3 ASS Laboratory Test Results and analysis

As mentioned earlier, Acid Sulfate Soils (ASS) samples were collected from 3 borehole locations (BH1, BH2 and BH3) along Segment 3, at 250 mm intervals down to 3.0 m depth as suggested by the Department of Environment Regulation (DER).

- All collected samples (25 nos.) were tested for field pH and "peroxide tested" for reactivity in order to identify the level of acidity.
- 9 nos. samples were tested for Chromium Reducible Sulphur or SPOCAS suite for presence of sulphur content.

The preliminary ASS laboratory test results are summarised in Table (10 - 12). The test certificates are attached in ***figure 147*** to ***figure 158***.

Table 10. Summary of Preliminary ASS Laboratory Test Results of (BH1-BH2)

Sample Depth (m)	pHF	pHFOX	Reaction rate	SPOC-AS %S	Remarks if NAAS/AASS/PASS	pHF	pHFOX	Reaction rate	SPOC-AS %S	Remarks if NAAS/AASS/PASS
	BH1					BH2				
0	4.1	3.1	M		PASS	4.9	3.7	S		PASS
0.25	3.8	3.2	S		AASS	4.3	3.4	S		PASS
0.5	4.1	3.3	S	0.02	PASS	4.5	3.5	S	0.02	PASS
0.75	4.0	3.5	S		PASS	3.8	3.3	S		AASS
1.0	5.1	4.4	S	<0.02	NASS	3.7	3.2	S	<0.02	AASS
1.25	4.8	4.0	S		NASS	4.1	3.4	S		PASS
1.5	5.1	4.2	S	<0.02	NASS	3.8	3.3	S	<0.02	AASS
1.75	-	-	-		-	3.8	3.3	S		AASS
2.0	-	-	-		-	3.7	3.5	S		AASS
2.25	-	-	-		-	-	-	-		-
2.5	-	-	-	-	-	-	-	-	-	-

Note: M = Moderate, X = Extreme, S= Slight, NASS = Non-Acid Sulfate soils, AASS = Actual Acid Sulfate soils, PASS = Potential Acid Sulfate soils. S = Net Acidity excluding ANC (sulfur units)

Table 11. Summary of Preliminary ASS Laboratory Test Result of (BH3)

Sample Depth (m)	pHF	pHFOX	Reaction rate	SPOC-AS %S	Remarks if NAAS/AASS/PASS	pHF	pHFOX	Reaction rate	SPOC-AS %S	Remarks if NAAS/AASS PASS
	BH3					BH4				
0	5.3	4.2	S		NASS					
0.25	5.8	4.8	S		NASS					
0.5	4.7	4.5	S	<0.02	NASS					
0.75	4.5	4.4	S		NASS					
1.0	4.6	4.6	S	<0.02	NASS					
1.25	5.2	4.5	S		NASS					
1.5	5.2	4.5	S	<0.02	NASS					
1.75	5.2	4.5	S		NASS					
2.0	5.1	4.3	S		NASS					
2.25	-	-	-	-	-					
2.5		-	-	-	-					

Note: M = Moderate, X = Extreme, S= Slight, NASS = Non-Acid Sulfate soils, AASS = Actual Acid Sulfate soils, PASS = Potential Acid Sulfate soils. S = Net Acidity excluding ANC (sulfur units).

Analysis of the results presented above shows the following:

- pHF values range between 3.7 and 5.8.
- pHFOX values range between 3.1 and 4.8.
- 12 samples were assessed to have both pHF and pHFOX > 4.0, which suggests non-ASS (NASS).
- 7 samples have pHF > 4.0 and pHFOX < 4.0, which may indicate PASS.
- 6 samples were assessed to have both pHF and pHFOX < 4.0, which suggests that samples tested are Actual-ASS (AASS).
- None of the tested samples showed a strong and extreme reaction rate.
- Interpretation of the results are presented below:
  - ▪ The tested samples comprised sand, trace of silt, brown, dark grey, black, grey, light grey, moist to wet, and were collected from three (3) borehole locations. Groundwater was encountered between 0.33 to 1.0 m below the ground surface level.
  - ▪ The pHFOX value (ranges between 3.1 and 4.8) is around one to two unit below the field pHF value ranges between 3.7 and 5.8.
  - ▪ Sulphides may be present; however organic matter and fines particle may also be responsible for the decrease in pH.
  - ▪ The Samples did not show any strong and extreme reaction rate.
  - ▪ Based on the ASS indicators discussed above, the inferred PASS risk of 7 samples and Actual-ASS (AASS) of 6 samples are low to moderate risk. Low to moderate risk samples are located below the groundwater table.

Further laboratory analyses (Suspension Peroxide Oxidation – Combined Acidity and Sulfate, SPOCAS suite) were undertaken on 9 nos. sample from the three (3) bore hole locations (BH1 to BH3) to confirm any oxidisable sulphides and the presence of self-neutralising ability. The Net acidity excluding Excess Acid Neutralisation Capacity was estimated in between <0.02%S and 0.02%S at 9 nos. sample.

Results of %S greater than 0.03 indicate the presence of PASS, but all test results are below the 0.03%S level, indicating that sulphur was not present.

The SPOCAS result is qualitative. Field (pHF and pHFOX) tests are not qualitative and serve principally as a basis for laboratory sample selection and extrapolation of laboratory results. Qualitative testing in conjunction with indicators criteria as per "Identification and investigation of acid sulfate soils and acidic landscapes "Acid Sulfate Guideline Series, DER 2013 (Table 9: Indicators of ASS, Table 10 and 11: Results – field pH test and field pHFOX test) were used to assess the likelihood of acid sulfate soils in the collected samples.

The volume of samples tested for ASS as part of the testing program is only a very small fraction of a percent of the anticipated volume of soil disturbance. Sometimes testing a large volume of sample is not practical or economical. Therefore, it should be noted that further ASS disturbance risk may exist as some ASS materials may not have been tested as part of the current program. Hence, it would be prudent to have mitigation management plans in place in the event that ASS soils are encountered during construction works. Our office will need to be contacted if there are any changes occur or findings are different during the construction phase.

ENGINEERING CONSIDERATIONS AND RECOMMENDATIONS

5.a Inferred subsurface conditions along Segment 1 to 2

The generalised subsurface conditions along Segment 2 to Segment 3 were inferred based on the profiles of test pit/boreholes, DCP tests, CPT data and laboratory test results and are described as follows:

- **Unit 1: Topsoil, SAND (SP)/ Silty SAND (SM)/Clayey SAND (SC) -** very loose to loose, fine to coarse-grained, dark grey, black, grey, brown, yellowish-brown, dry, with silt, rootlets, organics. The thickness of this unit varies between 0.0 m and 0.3 m.

- **Unit 2: SAND (SP)/ Silty SAND (SM) –** fine to coarse-grained, dark grey, black, grey, light grey, brown, dry to wet, very loose to dense, sub-angular to sub-rounded, quartz with few rootlets, trace of silt. This unit was found to extend to the maximum investigated depth of 3.0 m.

The groundwater table was observed at all test pit/borehole locations except TP1. The water depth varies from 0.33 to 2.0 m from the existing surface level.

The thickness of the topsoil varies along with the site. Therefore, care should be taken during earthworks involving the removal of the topsoil. An experienced engineer should supervise the earthworks in order to decide the depth of the topsoil. We recommend removing all uncontrolled materials and topsoil (or uncontrolled fill materials) from the site during earthworks. The topsoil includes organic materials, uncontrolled fill of building rubbles, bricks, concrete, wood, different types of waste, etc.

5.b Subgrade Assessment

The subgrade of the existing roads is underlain by sand. A subgrade compacted to a target density is considered to have adequate strength, stiffness and load-bearing capacity for the proposed road extension.

In general, a density index of at least 75% or a dry density ratio of 98% of the modified compaction values at -1% to +2% optimum moisture content is considered appropriate for the road subgrade.

5.1 California Bearing Ratio for Subgrade

Based on the DCP test results, field observations and laboratory test results, it is recommended that the unbound pavement be designed of a subgrade CBR value of not exceeding 13%.

5.2 Geotechnical Design Parameters for the Subgrade

The geotechnical design parameters for the subgrade are presented in Table 9. The parameters are inferred primarily from the site soil profiles identified from the test pits, DCP tests, and CPTs data. Note that the classification of the site based on the full CPT profile is presented in ***figure 75*** to ***figure 88***, and ***figure 89*** to ***figure 102*** respectively

The design parameters are presented in this appendix may be used with caution if they were to be used for other purposes.

Table 12. Geotechnical Design Parameters for the Subgrade

Soil layer	Bulk unit weight, γ (kN/m^3)	Effective friction angle, φ' (degrees)	Resilient Modulus, E' (MPa)*
Medium Dense SAND	18	34	50
Dense SAND	19	36	75

* Note the following:

- The resilient modulus represents the dynamic modulus of elasticity, which is higher than the conventional static counterpart,
- The values listed above assume a conservative correlation between E' and CBR in the form E' ≈ 5 CBR (MPa), assuming the soil is compacted to its modified maximum dry density and optimum moisture content. For other CBR values measure in the field, the correlation above between CBR and E' may be used.

5.3 Existing Pavement Conditions along Segment

Dynamic Cone Penetrometer (DCP) test data were interpreted in accordance with the relevant Australian Standard. DCP test results revealed that the existing subgrade is in a dense state. Subsurface conditions along Segment 1 (Prinsep Road) was inferred based on the profiles of pavement dip and DCP test, and these are described below:

- **Base-course –** Sandy GRAVEL – fine to coarse-grained, greenish grey, sub-angular to angular, dry, dense to very dense, sub-angular to sub-rounded quartz sand, trace of fine material, with gravel up to 25 mm.
- **Sub-base –** Crushed LIMESTONE – fine to coarse-grained, yellowish-brown, dry, dense to very dense, fine to coarse-grained, with sub-angular to sub-rounded sand, trace fine material, with limestone pieces up to 30 mm.
- **Sub-grade –** SAND (SP) – fine to medium-grained, sub-angular to sub-rounded, brown, grey, dry, dense to very dense with few crushed limestone up to 30 mm. Groundwater table was not observed at pavement dipping location PD1.

5.4 Groundwater Level

During the field investigation, groundwater table was observed at all of the test pit, bore hole and CPT locations. The depth varies from 0.33 to 2.0 m from the existing surface level. The groundwater records were made on 6 and 24 November 2018.

5.5 Permeability Tests

Field Permeability Tests FPT2, FPT3 and FPT4 were conducted in wet conditions, and FPT1 was conducted in dry conditions. It is found from the permeability tests that the permeability rate varies from 0.59 m/day to 0.74 m/day in wet condition and 5.4 m/day in dry condition.

5.6 Dewatering Requirements

As mentioned earlier, the groundwater was observed at all of the test pit/borehole locations. The depth varies from 0.33 to 2.0 m from the existing surface level.

Dewatering may be avoidable if considering the following points:

- Backfilling during or at the end of the summer/dry season. During this time of the year, the groundwater should be at its lowest level.
- During backfilling, compaction must not be attempted if the exposed ground (after removing topsoil) is saturated or groundwater is at the excavation level. In this scenario, the compacted lift thickness can be increased to above a suitable high level.

5.7 Geotechnical Design Parameters for Retaining Structures

Design parameters of earth pressure for retaining structures are presented in Table 13. These parameters should be considered as preliminary.

Table 13. Geotechnical Design Parameters for Retaining Structures

Material type	γ (kN/m^3)	φ' (degrees),	K_0	Wall friction, δ = 0°	
				Ka	Kp
In situ Loose to Medium Dense SAND	17	31	0.48	0.32	3.12
Dense SAND or Compacted Sand Fill	18	34	0.44	0.28	3.54

Notes: γ = Bulk unit weight, φ' = Effective friction angle, K_0 = Coefficient of earth pressure at rest, Ka = Coefficient of drained active earth pressure, Kp = Coefficient of drained passive earth pressure.

5.8 General Earthworks Recommendation at the Sub-grade level

It is recommended that a geotechnical engineer supervises the site activities to ensure that all organic, roots, demolition debris, very soft to soft clayey material has been adequately removed from the area and that the fill material is adequately compacted.

- Remove and grub all trees from the site, including root masses and tree stumps.
- Strip off the topsoil and all uncontrolled materials (or uncontrolled fill materials) from the site during earthworks. Topsoil includes organic soils, uncontrolled fill of building rubbles, bricks, concrete, wood, different types of waste etc. We recommend replacing approximately **500 mm** topsoil along the proposed alignment and roundabout with clean sand or engineered fill. However, the depth of topsoil varies along with the site. Therefore, care should be taken during earthworks in removing topsoil. An experienced engineer should supervise the earthworks in order to decide the topsoil depth at the site.
- Site soil can be used after screening unsuitable materials.
- Cut and level the site, as required for receiving a uniform thickness of fill.
- Proof roll the exposed surface at the excavation level with a minimum of six passes of a heavy vibratory roller prior to placement of any fill. Proof compaction must not be attempted if the exposed ground is saturated.
- Remove to spoil all unsuitable materials exposed by proof rolling and replace with structural fill.
- Place and compact structural fill in lifts not exceeding 300 mm loose thickness with a vibratory plant (>10 tonnes) up to the finished subgrade level to 95% of its modified maximum dry density (MMDD) in accordance with AS1289.5.2.1. The material at compaction should be moisture conditioned within -1% to +2% of its optimum moisture content.
- DCP blow count against density at few locations were found very loose to loose condition, this is because of shallow groundwater level and water loosen the sand. It is recommended that the construction works need to be carried out on summer reason, that period of time the groundwater level is going lower and can easily compact the subgrade level.
- From the laboratory test results soaked CBR value were found lower, if the subgrade compaction will be carried out on summer then required CBR can be achieved and not required any ground improvement works.Excavations across the site are prone to instability due to sandy soil observed at the site. Care will need to be taken when compacting in the vicinity of existing structures to avoid damage from excessive vibrations.

- The sandy nature of the site soils means that these materials will dry quickly where exposed which will lead to significant rutting under construction vehicle loads. It is common practice to maintain correct percentage of moisture content during embankment preparation.

5.8.1 Excavatability

The loose to dense state of the in-situ soils suggests that these materials should be excavatable with standard earthmoving equipment.

5.8.2 Cut/Fill Batters Relevant to Road Construction

Cut and fill batters in sand are considered to be stable at 2H:1V. Flatter batters may be required to control erosion and for landscaping purposes and for safety requirements.

For Detention embankment design, all major fill embankments for detention basins should be designed as dams and will, therefore require the same degree of geotechnical and hydraulic assessment. The minimum recommended embankment crest widths are provided in Table 7.3 (Guide to Road Design – Part 5A: Drainage – Road Surface, Networks, Basins and Subsurface):

Internal batter gradients in detention basins need to be consistent with the requirements of personal safety and generally within the following upper limits:

- where the permanent water depth is less than 150 mm when surcharging, 1:2 to 1:4 on earth structures, and vertical on rock gibber or gabion basket structures
- where the permanent water depth is between 150 mm and 1500 mm when unfenced and surcharging, a maximum slope of 1:5
- All batters that are accessible to the public should have a maximum slope of 1:8. According to Guide to Road Design Part 3: Geometric Design, Fill batters with the following slopes can be considered to be:
- recoverable for cars with 4:1 or flatter batter slopes
- non-recoverable for cars with batter slopes from 3:1 to 4:1, but they are considered to be traversable. Cars are likely to continue to the bottom of the slope
- non-recoverable (and non-traversable) for cars with batter slopes steeper than 3:1
- recoverable for trucks with batter slopes of 10:1

5.8.3 Table Drains

The side slopes of table drains should be flat enough to minimise the possibility of errant vehicles overturning. Side slopes not steeper than 4:1 with a desirable slope of 6:1 are preferred.

5.8.4 Median Drains

Where depressed medians are adopted, the median will be required to perform functions similar to those of a table drain. Median drains are desirably constructed with side slopes of 10:1 to reduce the chance of vehicles overturning. Steeper slopes (up to 6:1 maximum without road safety barrier protection) can be considered where the median is narrow, to be able to form a V drain. This will assist in developing a drain with enough depth to minimise moisture ingress into the pavement and increase the spacing between outlets.

5.8.5 Safety Barrier

Safety barrier protection may be warranted where side slopes exceed 4:1 or 1.0 m in height.

5.8.6 General Recommendations

Clayey materials should not be used as sub-base or base course, which will cause extra swelling due to high ground watertable. It may cause excessive rutting or problems to the asphalt layer as
well. If a clay material is encountered during exposure of the subgrade sandy soil by excavation, it should be replaced with well graded, non-reactive engineered with proper compaction.

The Full depth of asphalt pavements must not be constructed below the water table or within the zone affected by the capillary rise, even when sub-soil drainage has been installed. Concrete pavements may be an alternative at these locations but asphalt pavement can be constructed considering a drainage blanket layer.

A drainage blanket may be required in certain site conditions to intercept water from above or below and to divert it out of the pavement. Drainage blankets can protect the pavement from upward groundwater flows, surface infiltration and rise of water by capillary action. It is common practice to provide either a granular filter or a non-woven geotextile filter fabric around drainage blankets to avoid movement of fines into the drainage layer.

5.8.7 Concluding Remarks on ASS Assessment

- Based on the ASS indicators discussed in this report, the inferred PASS risk was found to be low to moderate risk in 7 samples. Actual ASS (AASS) was found to be low to moderate risk in
6 samples. Low to moderate risk samples are located below the groundwater table. The Samples did not show any strong and extreme reaction rate.
- Net acidity excluding Excess Acid Neutralisation Capacity (ANC) was estimated in between
<0.02%S and 0.02%S at 9 samples. The net acidity found in the tested samples are lower than the adopted 0.03%S limit.
- Testing samples from Prinsep Road extension area was performed in this investigation; no odour, clayey materials or organic matter were observed. Reaction rate reported from field screening tests were slight/low and the net acidity found in the tested samples are lower than the adopted 0.03%S limit. Presence of Actual Acid Sulfate Soils (AASS) in the tested locations is unlikely.
- The samples were collected up to 2.0 to 2.5 m depth at all test locations, if ASS encountered anywhere during the construction time, then further investigation and environment management plan will be required.

The following figures have detailed where the field and laboratory tests were conducted, showing Verde Drive and Prinsep Road's locations detailing aerial imageries. It is revealed that the project implemented combining greenfield, infill and brownfield development context. It is a good integration and a pragmatic lesson for the entry-level engineer. It has a critical thought for academic or research further to explore many aspects for their interest or curiosities.

Figure 7: Geotechnical and Pavement Investigation for Prinsep Road extension
Site Plan: Test Pit (TP), Cone Penetration Test (CPT), Bore Hole (BH) for ASS and Field Infiltration Test (FPT) Locations

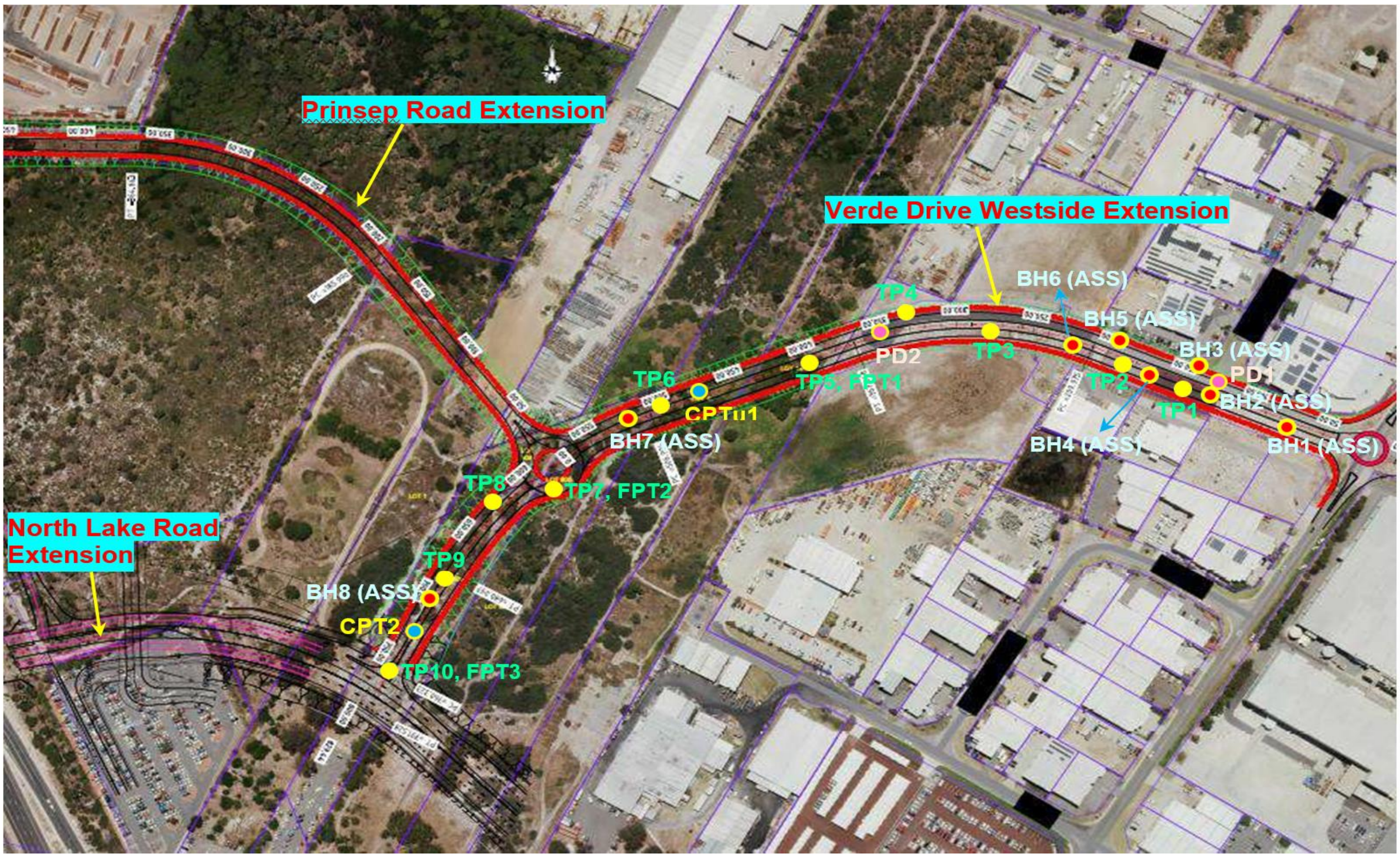


Figure 8: Geotechnical and Pavement Investigation for Verde Drive Westside Extension
Site Plan: Test Pit (TP), Cone Penetration Test (CPT), Bore Hole (BH) for ASS and Field Infiltration Test (FPT) Locations

Figure 9: Soil Profile of Test Pit location (TP1)

Figure 11: Soil Profile, Test Pit location (TP2) and ground watertable encountered at a depth of 1.8 m

Figure 10: Soil from Test Pit location (TP1)

Figure 12: Soil from Test Pit location (TP2)

Figure 13: Soil Profile, Test Pit location (TP3) and ground watertable encountered at a depth of 1.2 m

Figure 14: Soil from Test Pit location (TP3)

Figure 15: Soil Profile, Test Pit location (TP4) and ground watertable encountered at a depth of 2.0 m

Figure 16: Soil from Test Pit location (TP4)

Figure 17: Soil Profile, Test Pit location (TP5) and ground watertable encountered at a depth of 0.9 m

Figure 18: Soil from Test Pit location (TP5)

Figure 19: Soil Profile, Test Pit location (TP6) and ground watertable encountered at a depth of 1.2 m

Figure 20: Soil from Test Pit location (TP6)

Figure 21: Soil Profile, Test Pit location (TP7) and ground watertable encountered at a depth of 0.9 m

Figure 22: Soil from Test Pit location (TP7)

Figure 23: Soil Profile, Test Pit location (TP8) and ground watertable encountered at a depth of 0.8 m

Figure 24: Soil from Test Pit location (TP8)

Figure 25: Soil Profile, Test Pit location (TP9) and ground watertable encountered at a depth of 0.65 m

Figure 26: Soil Profile, Test Pit location (TP10) and ground watertable encountered at a depth of 0.7 m

Figure 27: Soil from Test Pit location (TP10)

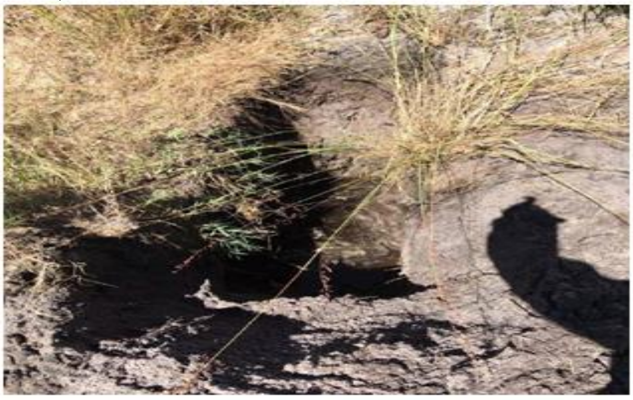


Figure 28: Soil Profile, Test Pit location (TP11) and ground watertable encountered at a depth of 0.9 m

Figure 29: Soil from Test Pit location (TP11)

Figure 30: Subsurface Probing by Hand Auger at Bore Hole Location (BH1)

Figure 31: Soil from Bore Hole Location (BH1) and ground watertable encountered at 0.33 m depth

Figure 32: Subsurface Probing by Hand Auger at Bore Hole Location (BH2)

Figure 33: Soil from Bore Hole Location (BH2) and ground watertable was encountered at 0.8 m depth

Figure 34: Subsurface Probing by Hand Auger at Bore Hole Location (BH3)

Figure 35: Soil from Bore Hole Location (BH3) and ground watertable encountered at 1.0 m depth

Figure 36: Pavement Profile of Dipping Location PD1

Figure 37: Spoil from Pavement Dipping 1 (PD1)

Figure 38: Photo 01: Prinsep Road is looking from southern to northern direction

Figure 39: Photo 02: Site is looking (close to TP11 location) from south-eastern to North-western direction

Figure 40: Photo 03: Pavement Dipping/drilling at the location (PD1)

Figure 41: Photo 04: Subsurface probing by excavator at Test Pit location (TP1)

Figure 42: Photo 05: Soil collapsing into Test Pit location (TP3) and ground watertable encountered at 1.2 m depth

Figure 43: Photo 06. Waterlogged close to Test Pit location (TP6)

Figure 44: Photo 07: Wet track between Test Pit location TP6 and TP7

Figure 45: Photo 08. Soil collapsing into Test Pit location (TP7) and ground watertable encountered at 0.9 m depth

Figure 46: Photo 09: Soil collapsing into Test Pit location (TP9) & ground watertable encountered at 0.65 m depth

Figure 47: Photo 10: Soil collapsing into Test Pit location (TP11) & ground watertable encountered at 0.9 m depth

Figure 48: Photo 11: Conducted Dynamic Cone Penetrometer (DCP) Test at Location DCP6

Figure 49: Photo 12: Conducted a Dynamic Cone Penetrometer (DCP) Test at Location DCP10

Figure 50: Photo 13: Conducting Cone Penetration Test at the location (CPTu1)

Figure 51: Photo 14. Conducting Cone Penetration Test at the location (CPT2)

Figure 52: Photo 15: Conducting Field Infiltration Test at Location FPT4

Figure 53: Photo 16. Subsurface probing and Acid Sulphate Soil (ASS) sampling at Bore Hole location (BH1)

Figure 54: Soil Profile, Test Pit location (TP7) and ground watertable encountered at a depth of 1.2 m

5.8.8 Side slope of Road Cross Section

The study conducted a detail pavement structural design based on a geotechnical investigation. The objectives of this pavement design were as follows:

- Review and summarise the existing geotechnical and design information,
- Detail the granular pavement thickness design,
- Detail the thin asphalt surfacing for the granular pavement thickness design,
- Detail the Full Depth Asphalt (FDA) pavement thickness design, and
- Provide site-specific construction advice for the above items.

The design conducted both CIRCLY analysis from Axle load using various layer modulus and MRWA Engineering Road Note 9. The asphalt characteristics also analyse using *"Shell Predictive procedure*". The Equivalent Standard Axle (ESA's) for the design lane determined through two forms of design traffic loading procedures:

1. ERN9 incorporating the heavy vehicles by class.
2. Guide to Pavement Technology Part 2: Pavement Structural Design factoring presumptive traffic load distributions

Considering the soil characteristics of the existing embankment, which was likely to be used to construct the earth embankments, the side slope ratio of 2.0 (horizontal) to 1.0 (vertical) had been applied. A typical section has been presented in ***Figure 55***.

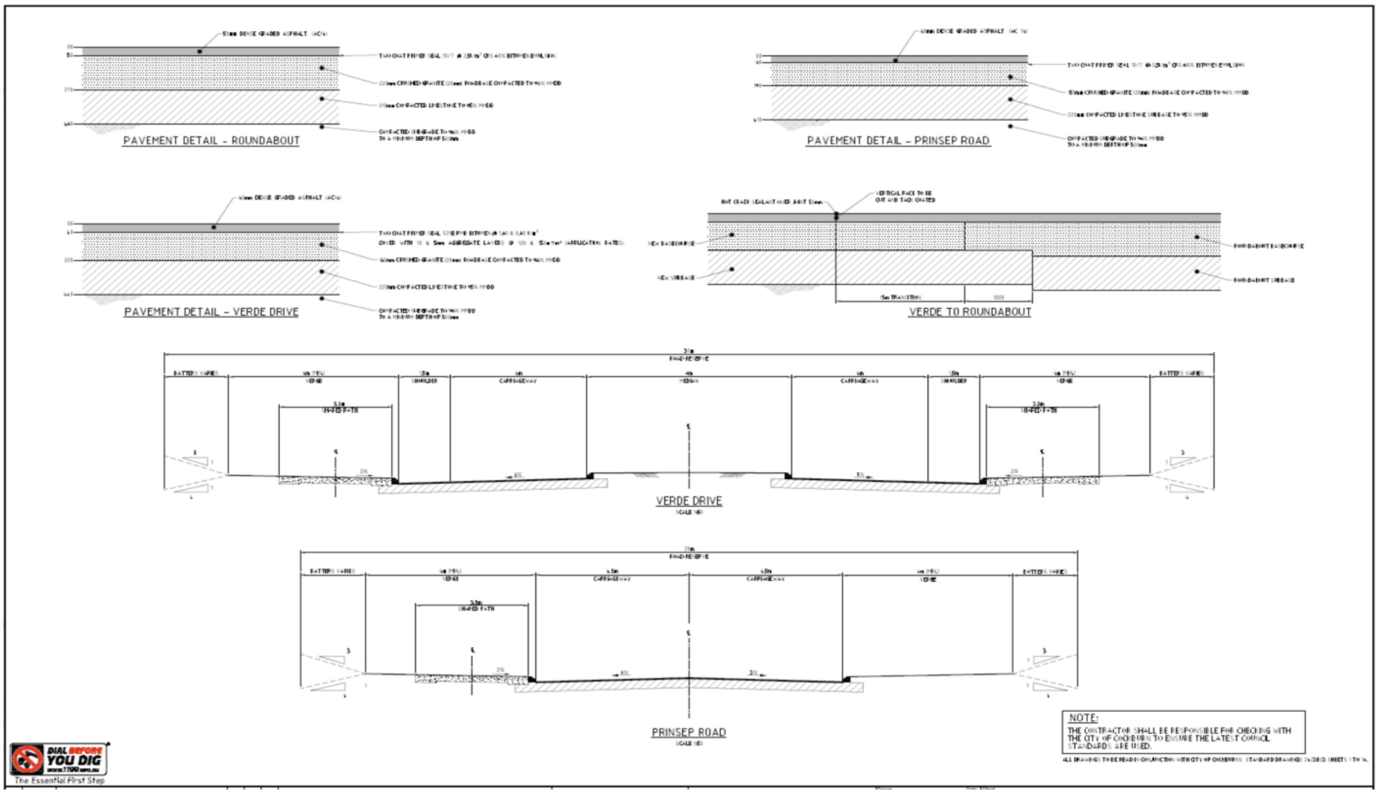


Figure-55: Typical Cross-Section, Source: Project document; the detail design of Road Template

Figure-56: Typical Cross-Section,

5.8.9. Preparation of Detailed Engineering Drawings

Detailed Engineering Drawings consisted of general drawings; alignment plan, profile and cross-section had been prepared on A3 size papers in the scales appropriate to each. Drawings had been prepared in MXroad and then transmitted to AutoCAD for labelling, text editing and printing. A set of detail design drawings had been presented as part of deliverables. The drawings were prepared for the project roads based on a detailed topographic survey: plan, profile and cross-section drawings. These drawings had been prepared on A3 size papers, and the scales used are Plan and profile-H1:1500, V1:500, and Cross-section- H1:400, V1:200.

6 LIMITATION OF THIS STUDY

The research acknowledges several research constraints, in Perth, there are subsurface conditions are created by natural processes and human activities. For example, water levels can vary with time and action; the fill may be placed on a site and pollutants may migrate with time. Because a report is based on conditions that existed at the subsurface exploration time, decisions should not be based on a report whose adequacy may have been affected by time. However, this detail has a comprehensive outcome form a practical case.

Site assessment identifies actual subsurface conditions only those points where samples are taken and when they are taken. Data derived from literature and external data source review, sampling and subsequent laboratory testing are interpreted by engineer's to provide an opinion about overall site conditions, their likely impact on the proposed development and recommendation actions.

Actual conditions may differ from those inferred to exist. The actual interface between materials may be far more gradual or abrupt than assumed based on the facts obtained. The report assumes that the site conditions revealed through selective point sampling indicate actual conditions throughout the area.

Due to text and time constraints, short detail and result have described pointing the outcome. Further study may represent a range of different settings based on requirement and ongoing state and local development activities and proposed structure plan as detailed in ***figure 56*** and ***figure 2***, densities and geological forms to enable comparisons to be made on a qualitative and quantitative basis.

IV. DISCUSSION

The study detailed the investigation of greenfield urban road planning, design, execution and mapped the aerial history, demographic changing footprint in the essence of time to compare the project road. The study detailed only the Prinsep road due to limited text for this article. However, significant tasks had been executed during the project initiation to closing for both Verde Drive, Prinsep road as well as linking to Armadale Road and North lake Road bridge new alignment. It is revealed that the existing soils below the topsoil in land zoned could be divided into granular and clay for a residential building, but the road runs through a long stretch; therefore, diverse soil and geology can be comprised. In many cases, the foundation soil is mix in a combination of both types of soils for residential building—however, the individual soil class or all identified soil classes are investigated, and its consequences are considered for road infrastructure development. It is revealed that clay soils' problem occurs due to swelling/shrink problems (CSIRO, 2003).

During data analysis and design, the locations of unsuitable materials or areas may cause construction difficulties, or require special treatments such as geotextile separation layers or de-watering systems, or require removal and replacement of the soft regions and unsuitable materials with the satisfactory material were clearly recommended and required CBR strength for each pavement layer were detailed. The required stable batter slope according to geology and soil type was tabulated to minimise the erosion. The risk assessment was conducted, and the risks register detailed where chances were supposed to be associated with the extent of field and laboratory testing. Further investigation was recommended during the construction stage, where risks appeared to unacceptably high. Where rock, limestone, the capstone was detected, the appropriate methodology was noted to deal with the excavation of rock that cannot be excavated by ripping and breaking down and disposing of large mass rock boulders to assist contractor pricing. Due to high groundwater, special subsurface drainage such as deep formation drains, filter blankets and automated pump system was designed with assistance from experts consultants. Instruction, the recommendation also listed where additional geotechnical designs are considered necessary, the pavement may be adversely affected by the ingress of water, the expansive soils require removal or provision of a capping layer.

This study highlights that the investigation identifies actual subsurface conditions only those points where samples are taken and when they are taken. Authors interpret the data derived from literature and external data source review, sampling and subsequent laboratory testing to provide an opinion about overall site conditions, context and likely impact on the proposed development and recommendation actions. However, the actual conditions may differ from those inferred to exist. This study acknowledges that infrastructure development is a time-consuming matter in urban or mix-used development, achieving various approval from various agencies, including utility relocation and upgrade in conjunction with Environmental impact mitigation and restrictions as well as complex constructional challenges and many more. ***Figure 1, Ia, 3, and 5*** showed that the project road location was constructed in low land, soft soil, where embankment was a maximum 5m high from exiting natural surface as showed in ***figure 8***. Besides, where Armadale road cross over freeway as detailed in North Lake road Bridge, the embankment height was more 10m ***Figure 3 & 4.*** Moreover, it showed the current scenario from google earth has completely changed from its original with the new road and surrounding infrastructure with Metronet, carparks, Cockburn central west (CCW) development with the densely populated urban environment as showed in ***figure 56***, the image taken from work in progress condition. Therefore, this study acknowledges that the Quality decision-making (QDM) can severely impact the infrastructure development; where a project takes place that will have consequences in Life Cycle Cost (LCC) of Infrastructure and leads design scope changes reinstatement cost results increase project costs (Malik, 2015). So, a Comprehensive and Quantitative Geotechnical and Pavement Investigation is essential for sustainable and efficient infrastructure outcome

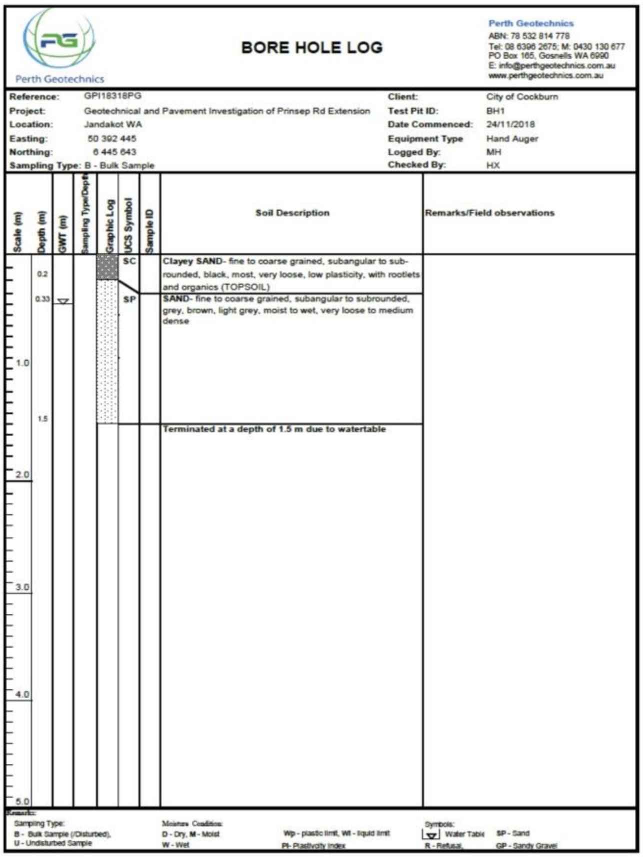


Figure 57: Borehole Log at Location BH1

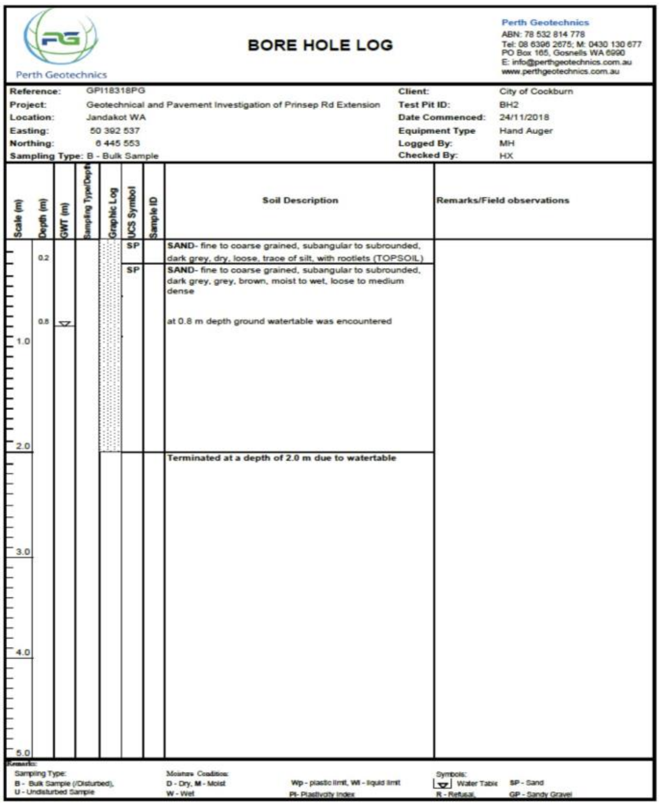
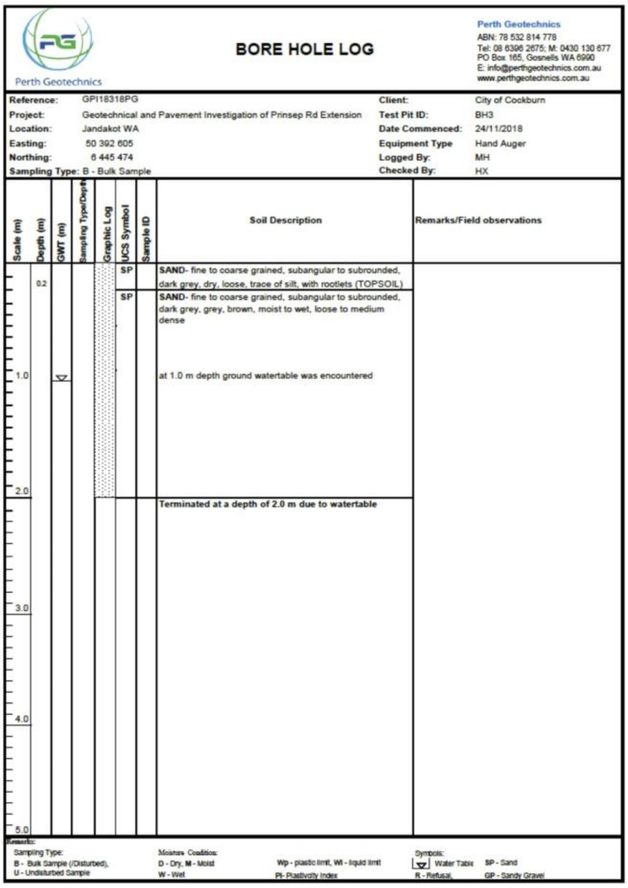


Figure 58: Borehole Log at Location BH2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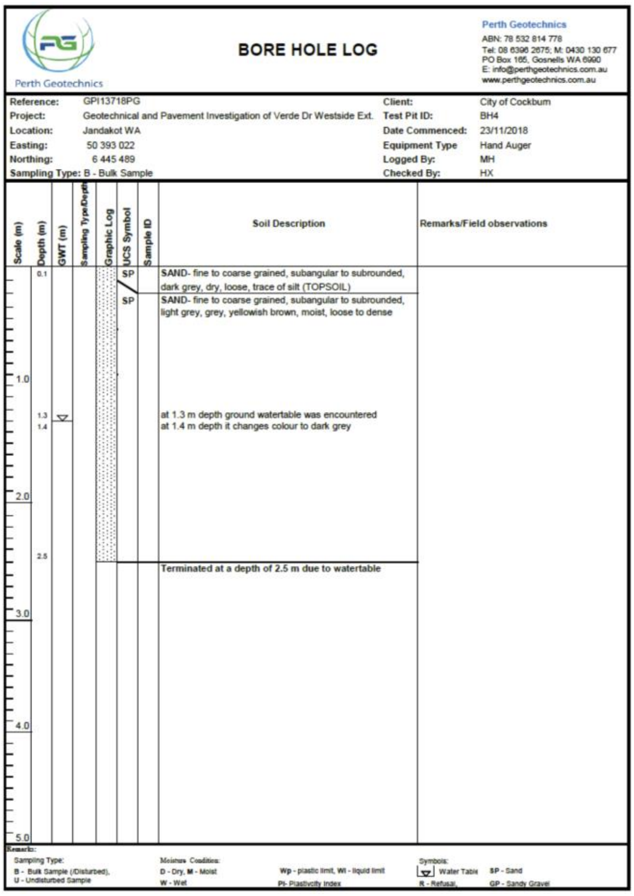
Reference: GPI18318PG | Client: City of Cockburn
Project: Geotechnical and Pavement Investigation of Prinsep Rd Extension | Test Pit ID: BH3
Location: Jandakot WA | Date Commenced: 24/11/2018
Easting: 50 392 605 | Equipment Type: Hand Auger
Northing: 6 445 474 | Logged By: MH
Sampling Type: B - Bulk Sample | Checked By: HX

Depth (m)	GWT (m)	UCS Symbol	Soil Description
0.2		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, dry, loose, trace of silt, with rootlets (TOPSOIL)
		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, brown, moist to wet, loose to medium dense
	1.0		at 1.0 m depth ground watertable was encountered
2.0			Terminated at a depth of 2.0 m due to watertable

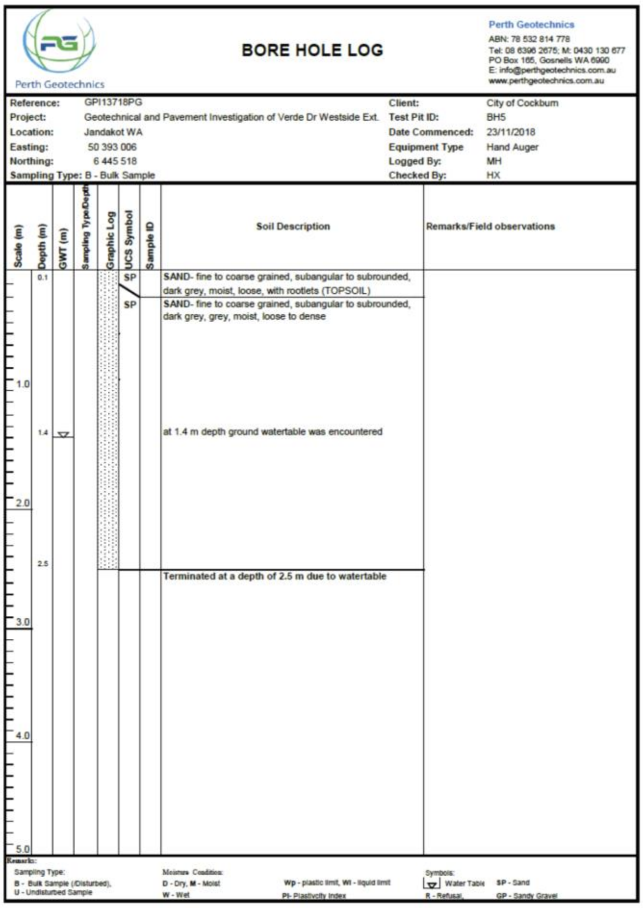
Remarks: Sampling Type: B - Bulk Sample (/Disturbed), U - Undisturbed Sample; Moisture Condition: D - Dry, M - Moist, W - Wet; Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index; Symbols: Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 59: Borehole Log at Location BH3


Perth Geotechnics
BORE HOLE LOG
Reference: GPI13718PG | Client: City of Cockburn
Project: Geotechnical and Pavement Investigation of Verde Dr Westside Ext. | Test Pit ID: BH4
Location: Jandakot WA | Date Commenced: 23/11/2018
Easting: 50 393 022 | Equipment Type: Hand Auger
Northing: 6 445 489 | Logged By: MH
Sampling Type: B - Bulk Sample | Checked By: HX

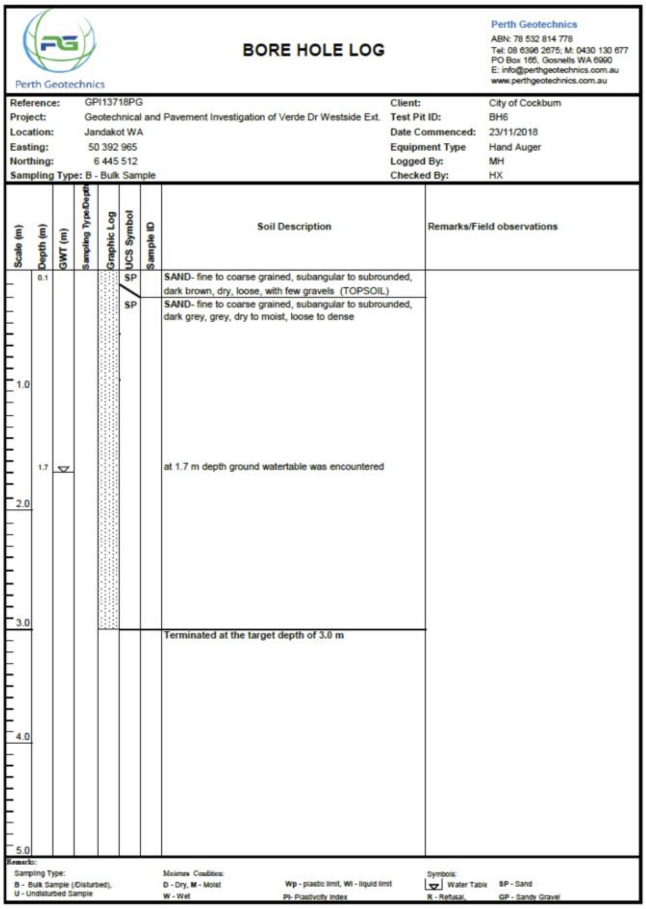
Depth (m)	GWT (m)	UCS Symbol	Soil Description
0.1		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, dry, loose, trace of silt (TOPSOIL)
		SP	SAND- fine to coarse grained, subangular to subrounded, light grey, grey, yellowish brown, moist, loose to dense
1.3 / 1.4	1.3		at 1.3 m depth ground watertable was encountered; at 1.4 m depth it changes colour to dark grey
2.5			Terminated at a depth of 2.5 m due to watertable

Figure 60: Borehole Log (Verde Dr.) at Location BH4


Perth Geotechnics
BORE HOLE LOG
Reference: GPI13718PG | Client: City of Cockburn
Project: Geotechnical and Pavement Investigation of Verde Dr Westside Ext. | Test Pit ID: BH5
Location: Jandakot WA | Date Commenced: 23/11/2018
Easting: 50 393 006 | Equipment Type: Hand Auger
Northing: 6 445 518 | Logged By: MH
Sampling Type: B - Bulk Sample | Checked By: HX

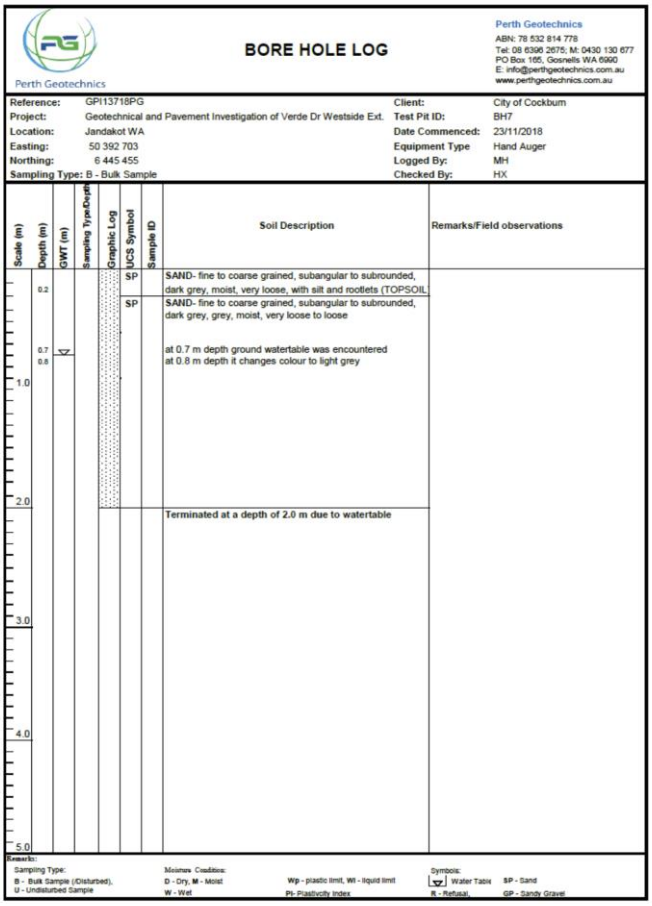
Depth (m)	GWT (m)	UCS Symbol	Soil Description
0.1		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, moist, loose, with rootlets (TOPSOIL)
		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, moist, loose to dense
1.4	1.4		at 1.4 m depth ground watertable was encountered
2.5			Terminated at a depth of 2.5 m due to watertable

Figure 61: Borehole Log (Verde Dr.) at Location BH5


Perth Geotechnics
BORE HOLE LOG
Reference: GPI13718PG | Client: City of Cockburn
Project: Geotechnical and Pavement Investigation of Verde Dr Westside Ext. | Test Pit ID: BH6
Location: Jandakot WA | Date Commenced: 23/11/2018
Easting: 50 392 965 | Equipment Type: Hand Auger
Northing: 6 445 512 | Logged By: MH
Sampling Type: B - Bulk Sample | Checked By: HX

Depth (m)	GWT (m)	UCS Symbol	Soil Description
0.1		SP	SAND- fine to coarse grained, subangular to subrounded, dark brown, dry, loose, with few gravels (TOPSOIL)
		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry to moist, loose to dense
1.7	1.7		at 1.7 m depth ground watertable was encountered
3.0			Terminated at the target depth of 3.0 m

Figure 62: Borehole Log (Verde Dr.) at Location BH6



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BORE HOLE LOG

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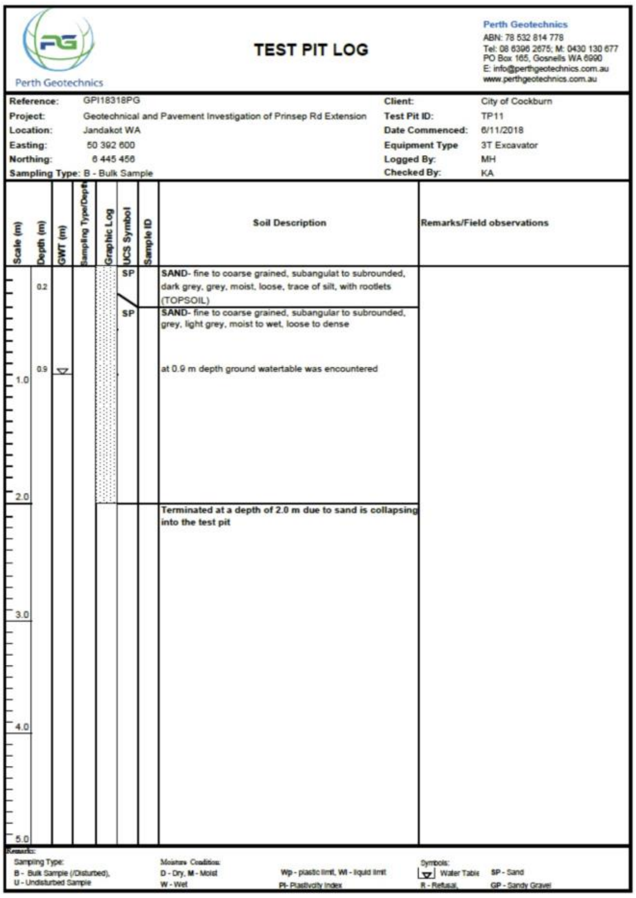
Reference: GPI13718PG
Project: Geotechnical and Pavement Investigation of Verde Dr Westside Ext.
Location: Jandakot WA
Easting: 50 392 703
Northing: 6 445 455
Sampling Type: B - Bulk Sample
Client: City of Cockburn
Test Pit ID: BH7
Date Commenced: 23/11/2018
Equipment Type: Hand Auger
Logged By: MH
Checked By: HX

Scale (m)	Depth (m)	GWT (m)	Sampling Type/Depth	Graphic Log	UCS Symbol	Sample ID	Soil Description	Remarks/Field observations
	0.2				SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, moist, very loose, with silt and rootlets (TOPSOIL)	
1.0	0.7 0.8	▽			SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, moist, very loose to loose at 0.7 m depth ground watertable was encountered at 0.8 m depth it changes colour to light grey	
2.0							Terminated at a depth of 2.0 m due to watertable	
3.0								
4.0								
5.0								

Remarks:
Sampling Type: B - Bulk Sample (Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: ▽ Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 63: Borehole Log (Verde Dr.) at Location BH7



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TEST PIT LOG

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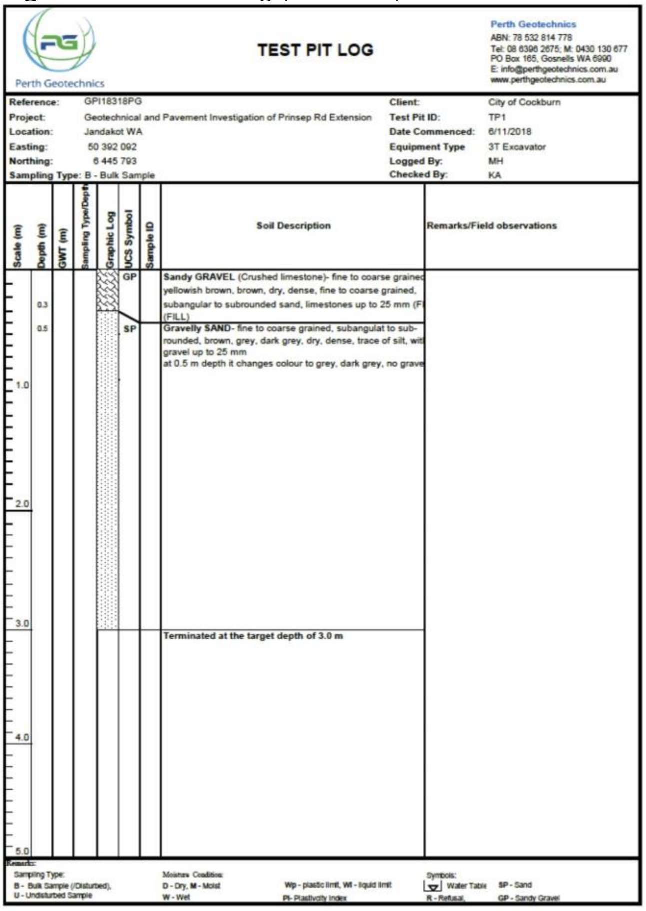
Reference: GPI18318PG
Project: Geotechnical and Pavement Investigation of Prinsep Rd Extension
Location: Jandakot WA
Easting: 50 392 600
Northing: 6 445 456
Sampling Type: B - Bulk Sample
Client: City of Cockburn
Test Pit ID: TP11
Date Commenced: 6/11/2018
Equipment Type: 3T Excavator
Logged By: MH
Checked By: KA

Scale (m)	Depth (m)	GWT (m)	Sampling Type/Depth	Graphic Log	UCS Symbol	Sample ID	Soil Description	Remarks/Field observations
	0.2				SP		SAND- fine to coarse grained, subangulat to subrounded, dark grey, grey, moist, loose, trace of silt, with rootlets (TOPSOIL)	
1.0	0.9	▽			SP		SAND- fine to coarse grained, subangular to subrounded, grey, light grey, moist to wet, loose to dense at 0.9 m depth ground watertable was encountered	
2.0							Terminated at a depth of 2.0 m due to sand is collapsing into the test pit	
3.0								
4.0								
5.0								

Remarks:
Sampling Type: B - Bulk Sample (Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: ▽ Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 64: Test Pit Log at Location TP11



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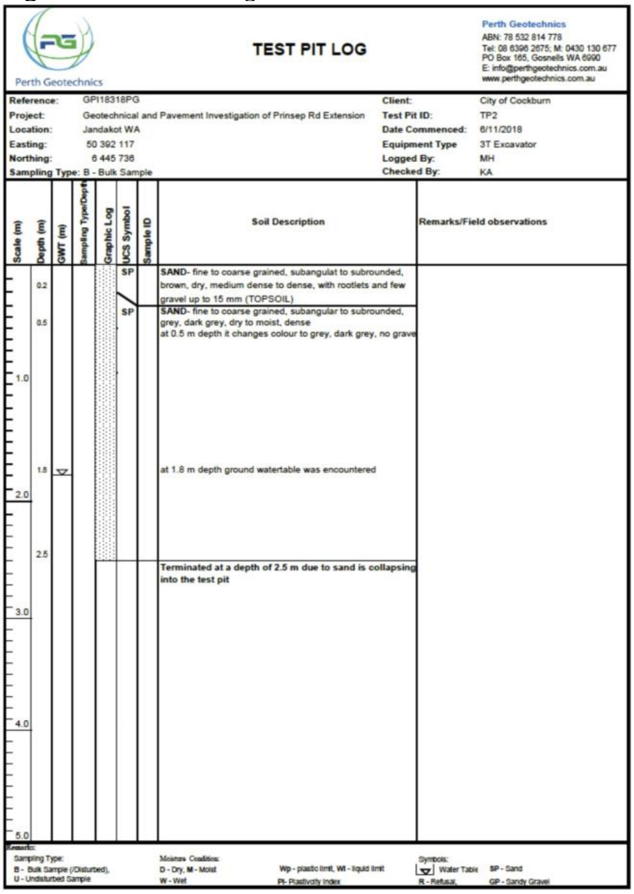
Reference: GPI18318PG
Project: Geotechnical and Pavement Investigation of Prinsep Rd Extension
Location: Jandakot WA
Easting: 50 392 092
Northing: 6 445 793
Sampling Type: B - Bulk Sample
Client: City of Cockburn
Test Pit ID: TP1
Date Commenced: 6/11/2018
Equipment Type: 3T Excavator
Logged By: MH
Checked By: KA

Scale (m)	Depth (m)	GWT (m)	Sampling Type/Depth	Graphic Log	UCS Symbol	Sample ID	Soil Description	Remarks/Field observations
	0.3				GP		Sandy GRAVEL (Crushed limestone)- fine to coarse grained, yellowish brown, brown, dry, dense, fine to coarse grained, subangular to subrounded sand, limestones up to 25 mm (FILL)	
1.0	0.5				SP		Gravelly SAND- fine to coarse grained, subangulat to sub-rounded, brown, grey, dark grey, dry, dense, trace of silt, with gravel up to 25 mm at 0.5 m depth it changes colour to grey, dark grey, no gravel	
2.0								
3.0							Terminated at the target depth of 3.0 m	
4.0								
5.0								

Remarks:
Sampling Type: B - Bulk Sample (Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: ▽ Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 65: Test Pit Log at Location TP1



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Reference: GPI18318PG
Project: Geotechnical and Pavement Investigation of Prinsep Rd Extension
Location: Jandakot WA
Easting: 50 392 117
Northing: 6 445 736
Sampling Type: B - Bulk Sample
Client: City of Cockburn
Test Pit ID: TP2
Date Commenced: 6/11/2018
Equipment Type: 3T Excavator
Logged By: MH
Checked By: KA

Scale (m)	Depth (m)	GWT (m)	Sampling Type/Depth	Graphic Log	UCS Symbol	Sample ID	Soil Description	Remarks/Field observations
	0.2				SP		SAND- fine to coarse grained, subangulat to subrounded, brown, dry, medium dense to dense, with rootlets and few gravel up to 15 mm (TOPSOIL)	
1.0	0.5				SP		SAND- fine to coarse grained, subangular to subrounded, grey, dark grey, dry to moist, dense at 0.5 m depth it changes colour to grey, dark grey, no gravel	
2.0	1.8	▽					at 1.8 m depth ground watertable was encountered	
3.0	2.5						Terminated at a depth of 2.5 m due to sand is collapsing into the test pit	
4.0								
5.0								

Remarks:
Sampling Type: B - Bulk Sample (Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: ▽ Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 66: Test Pit Log at Location TP2

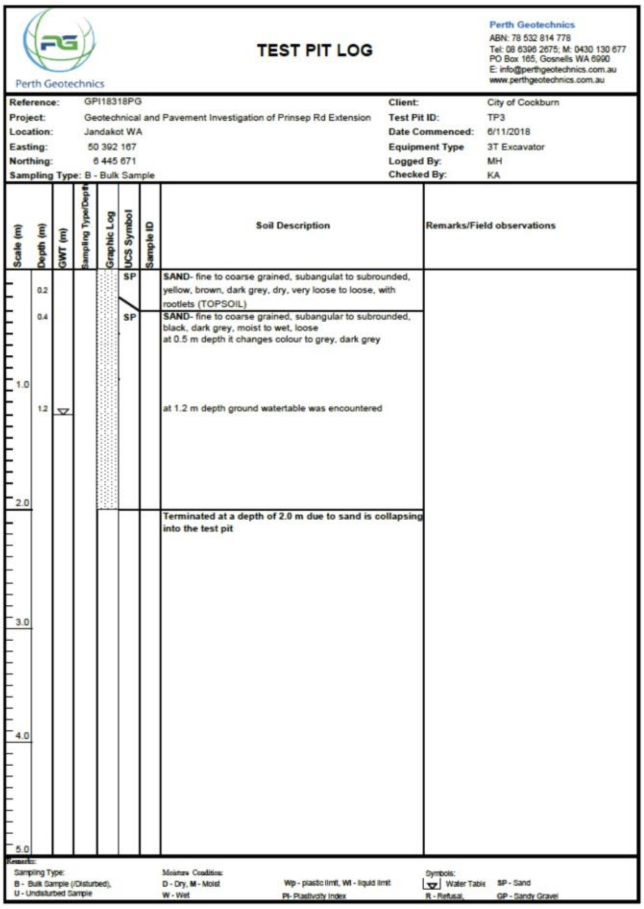


Figure 67: Test Pit Log at Location TP3

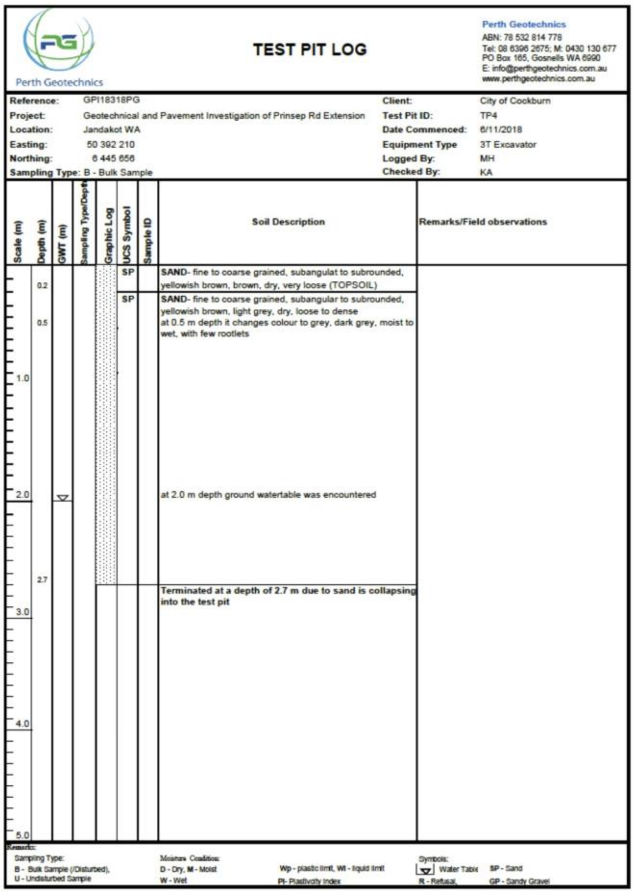


Figure 68: Test Pit Log at Location TP4

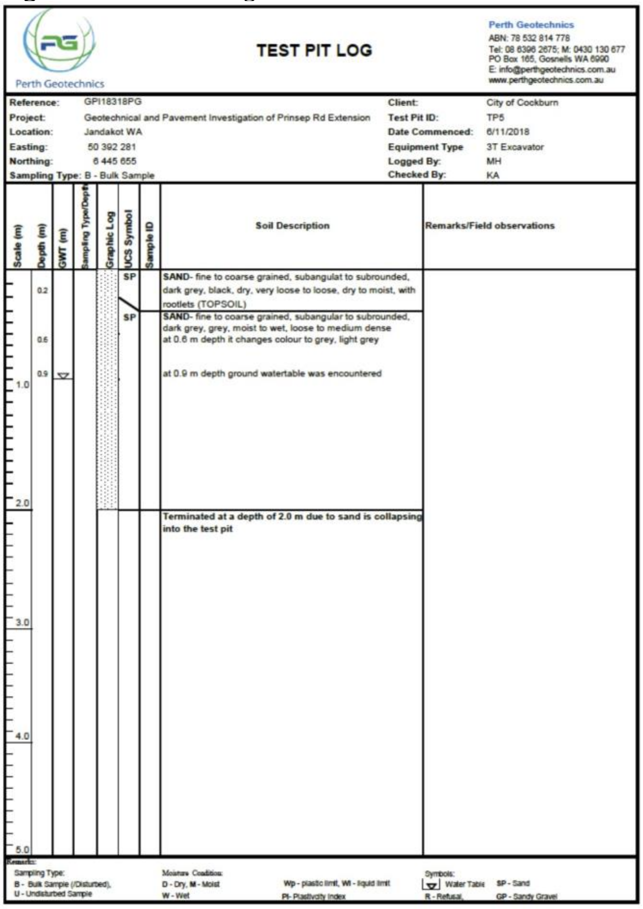


Figure 69: Test Pit Log at Location TP5

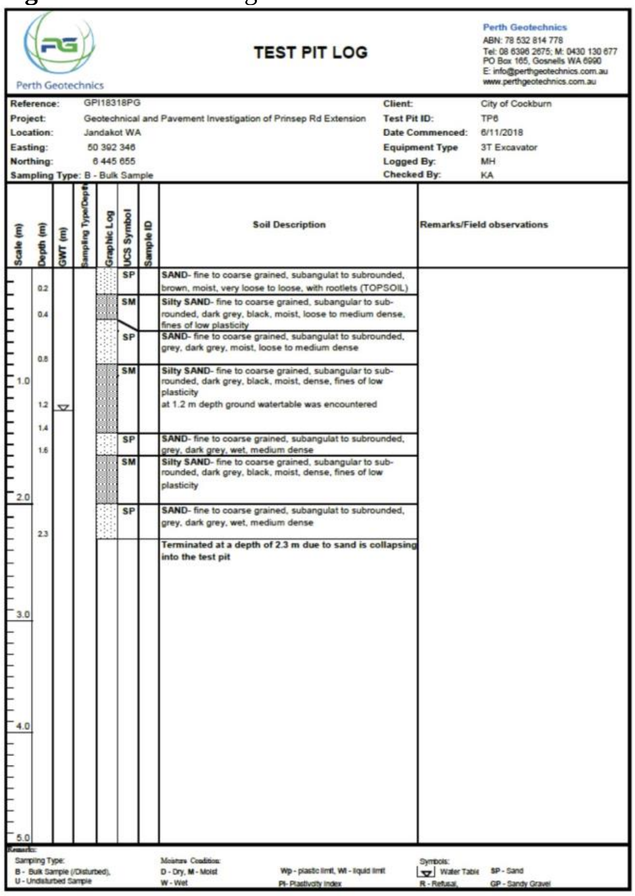


Figure 70: Test Pit Log at Location TP6

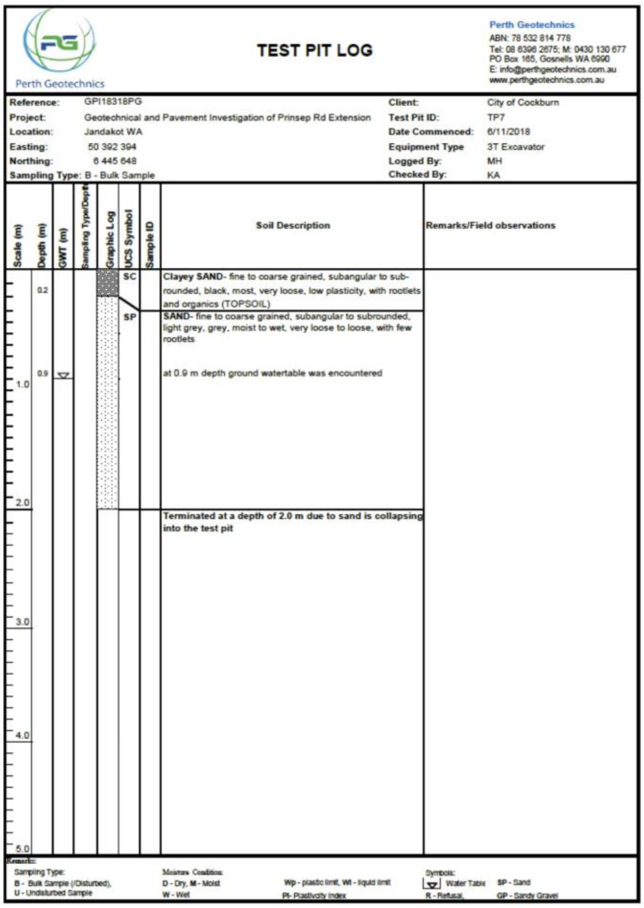


Figure 71: Test Pit Log at Location TP7

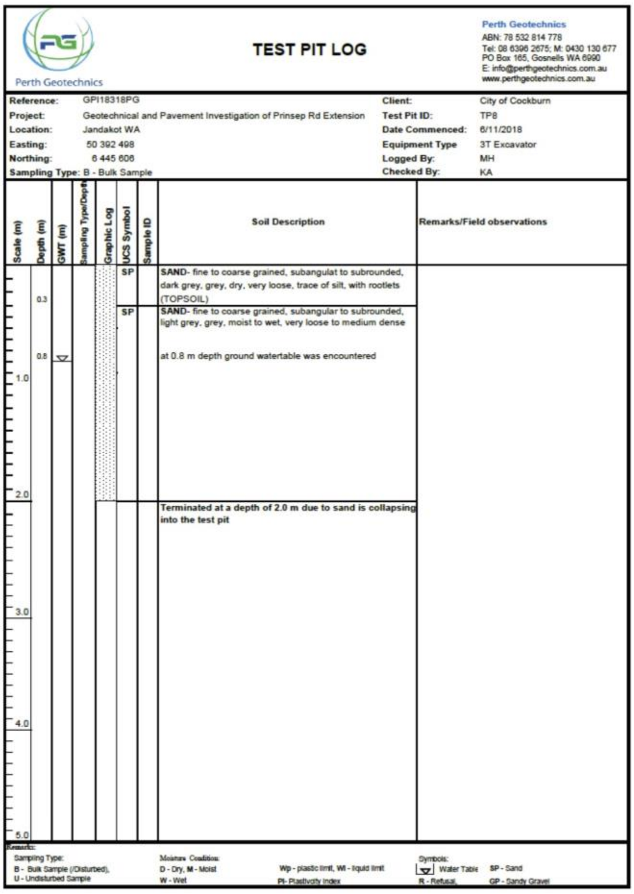


Figure 72: Test Pit Log at Location TP8

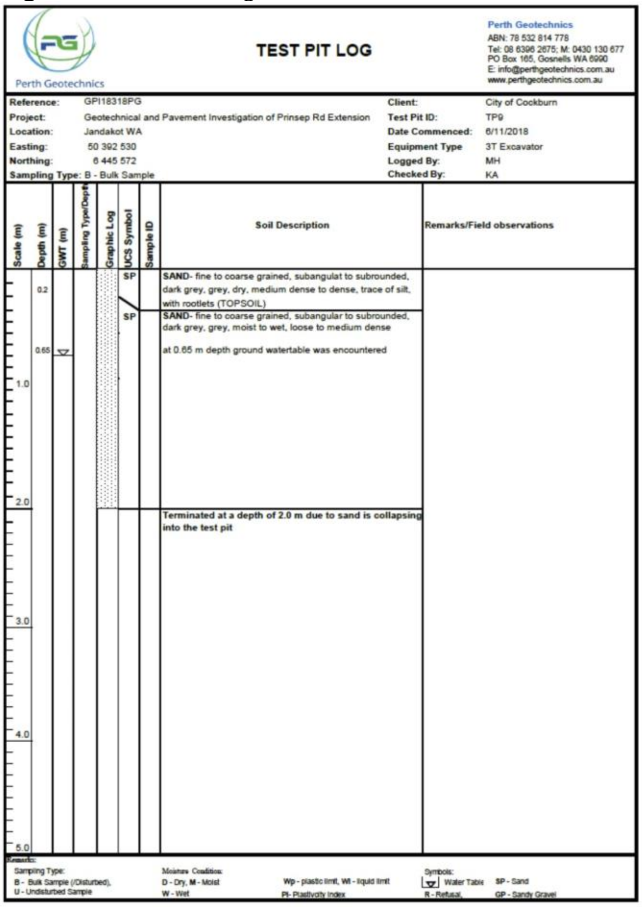


Figure 73: Test Pit Log at Location TP9

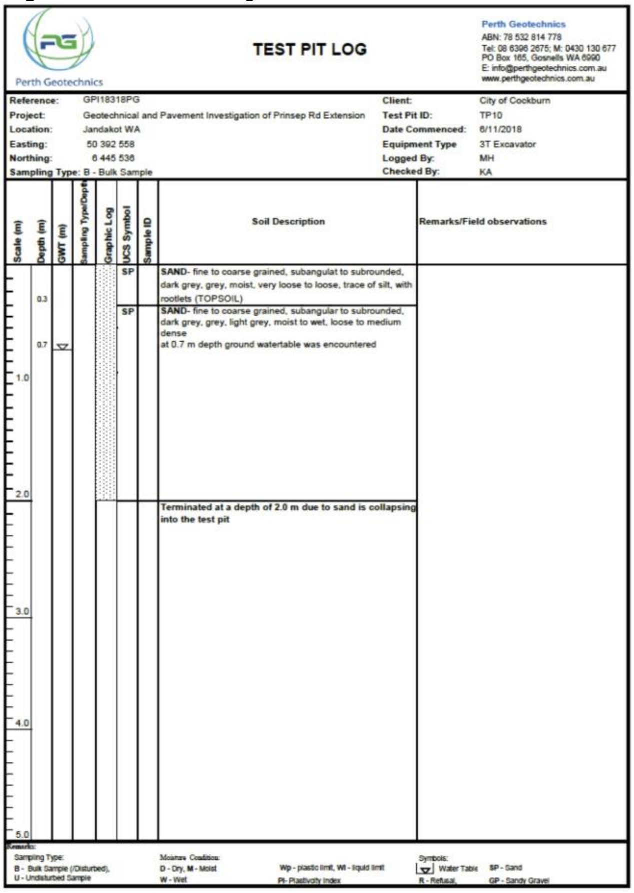


Figure 74: Test Pit Log at Location TP10

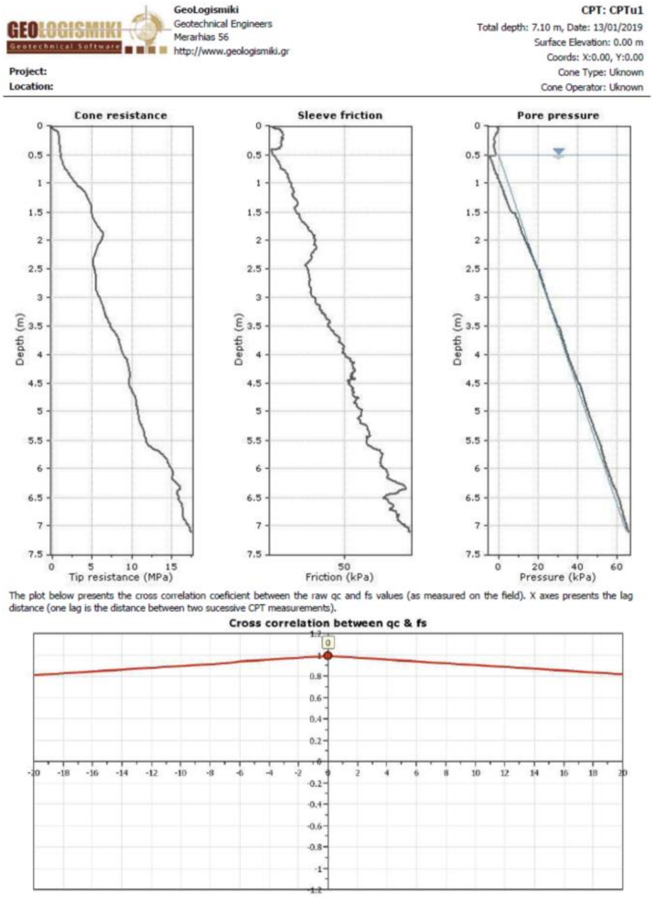


Figure 75: CPT data presentation and interpretation for CPTu1 (1 of 14)

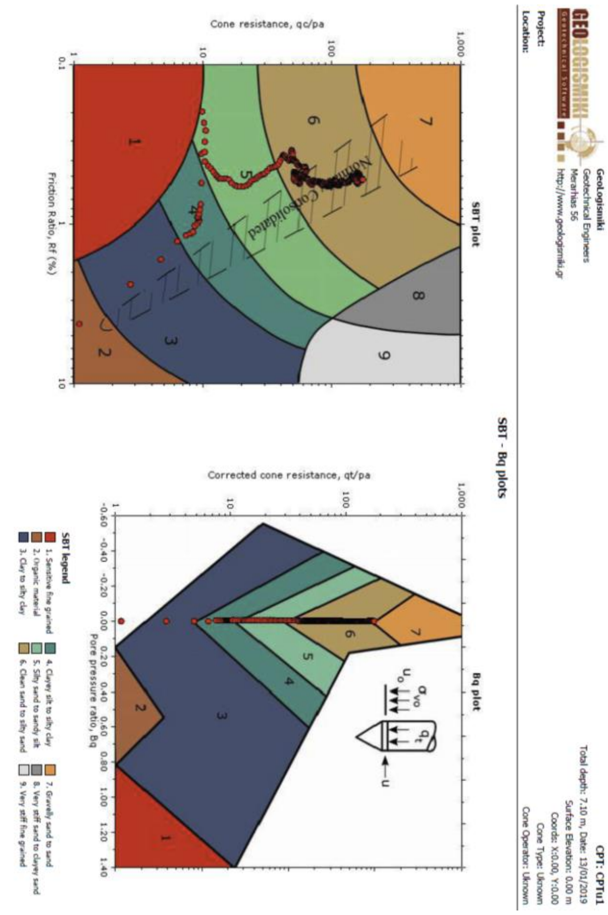


Figure 76: CPT data presentation and interpretation for CPTu1 (2 of 14)

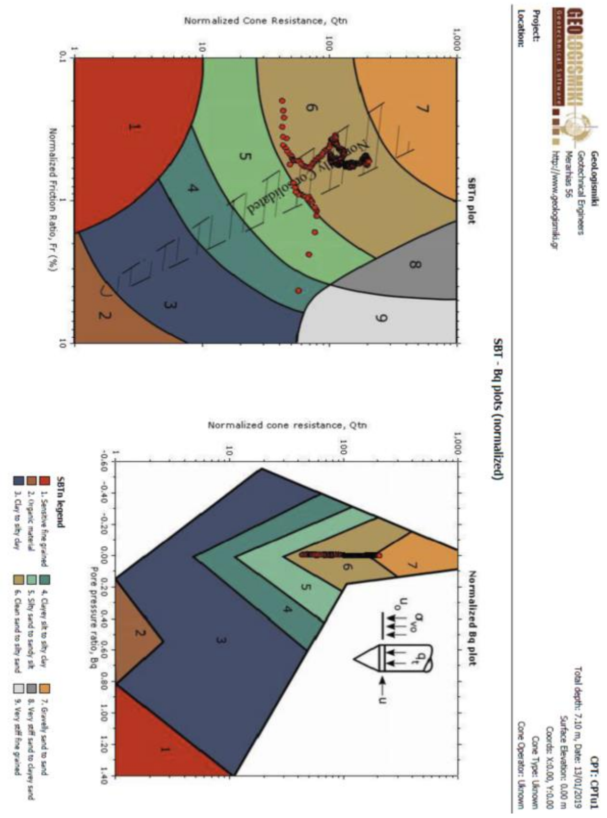


Figure 77: CPT data presentation and interpretation for CPTu1 (3 of 14)

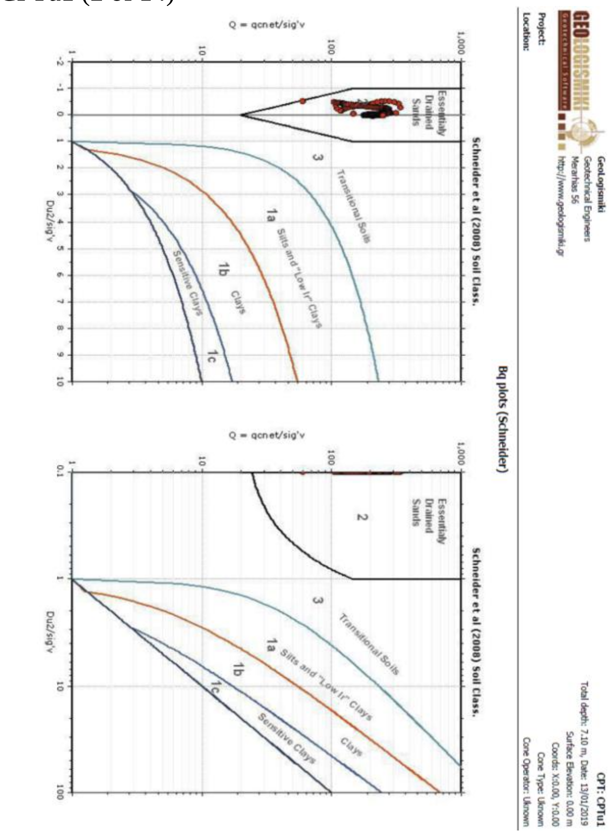


Figure 78: CPT data presentation and interpretation for CPTu1 (4 of 14)

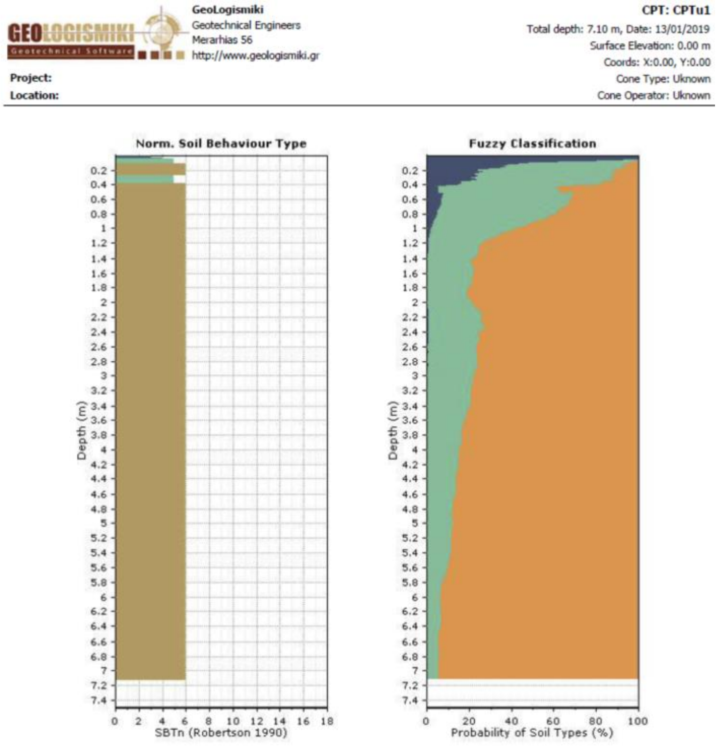


Figure 79: CPT data presentation and interpretation for CPTu1 (5 of 14)

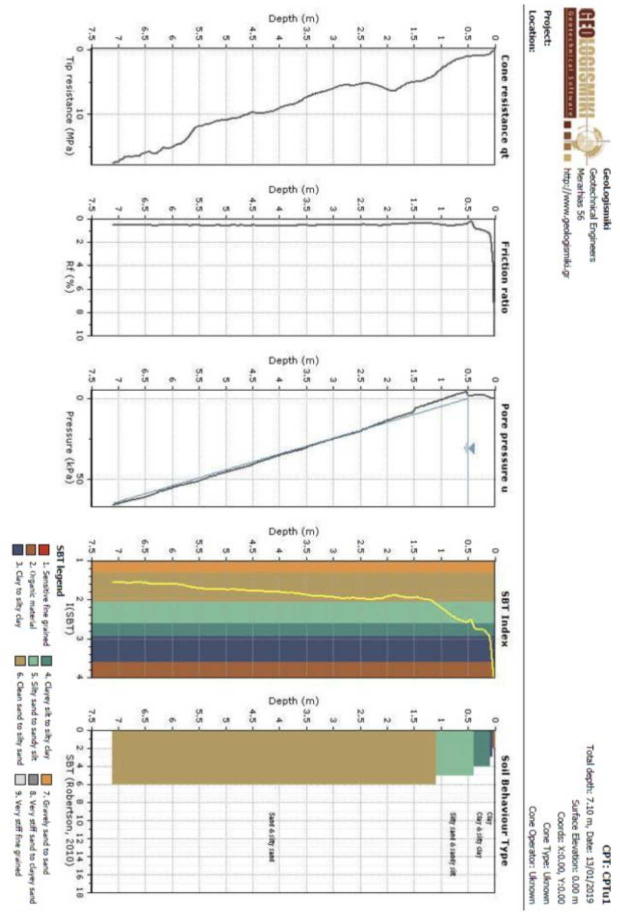


Figure 80: CPT data presentation and interpretation for CPTu1 (6 of 14)

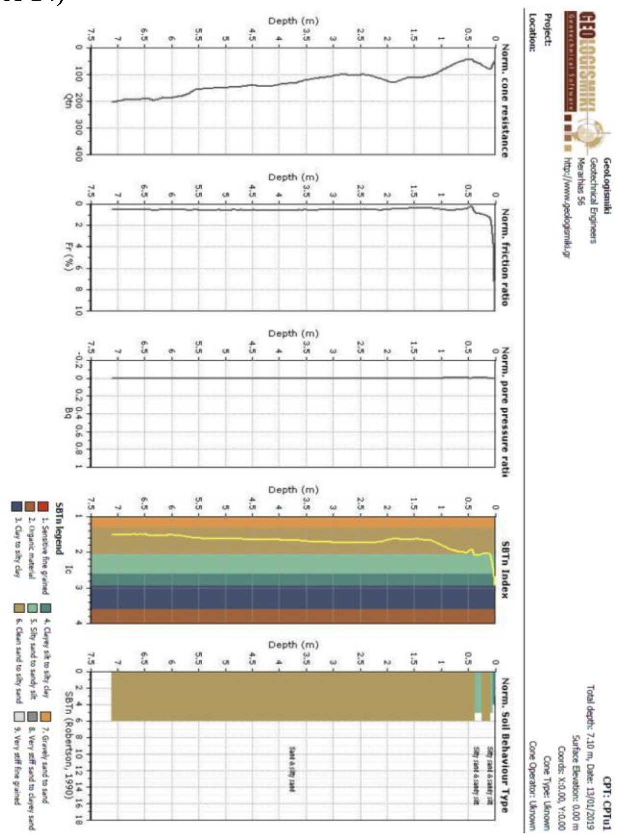


Figure 81: CPT data presentation and interpretation for CPTu1 (7 of 14)

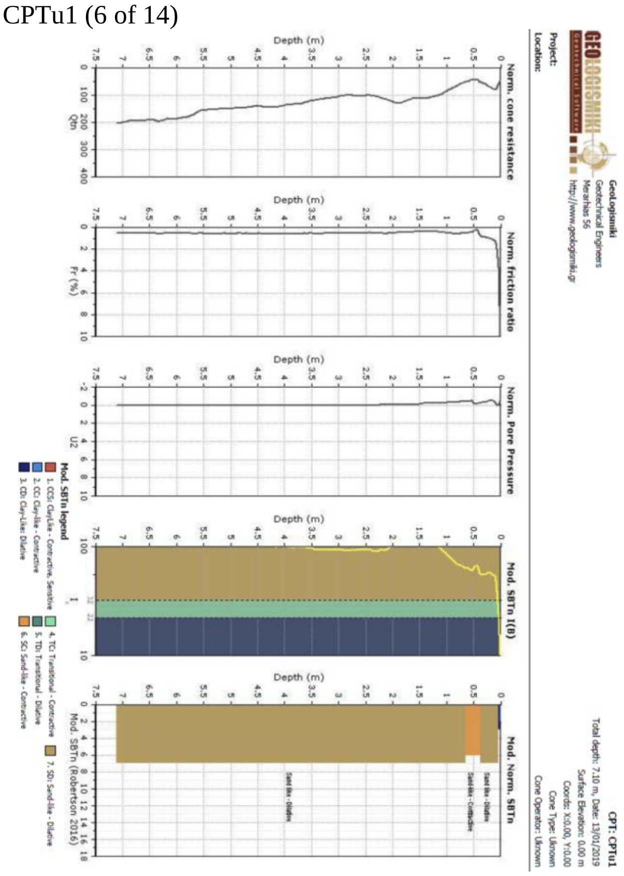


Figure 82: CPT data presentation and interpretation for CPTu1 (8 of 14)

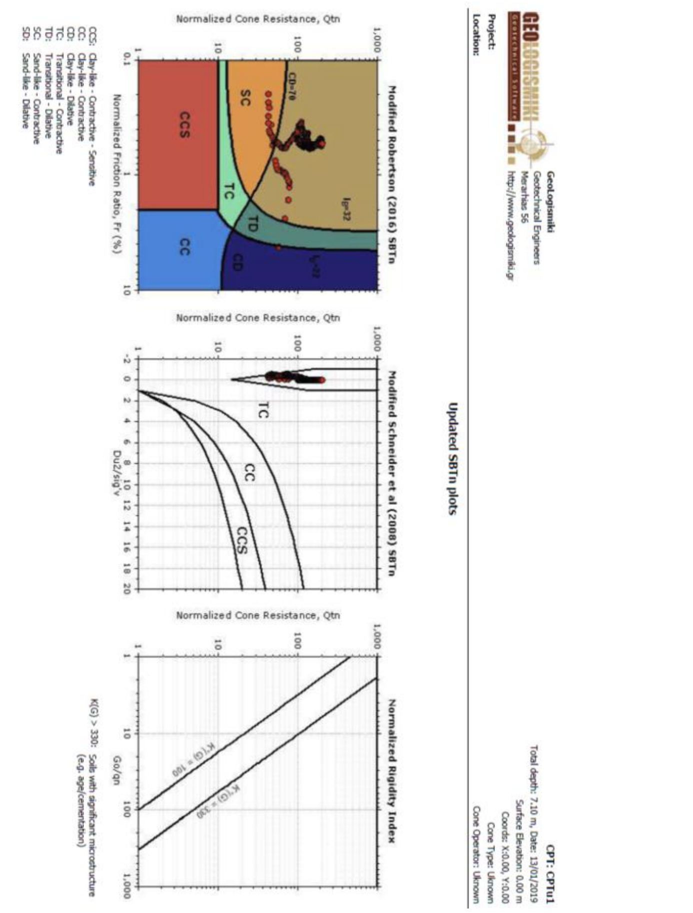


Figure 83: CPT data presentation and interpretation for CPTu1 (9 of 14)

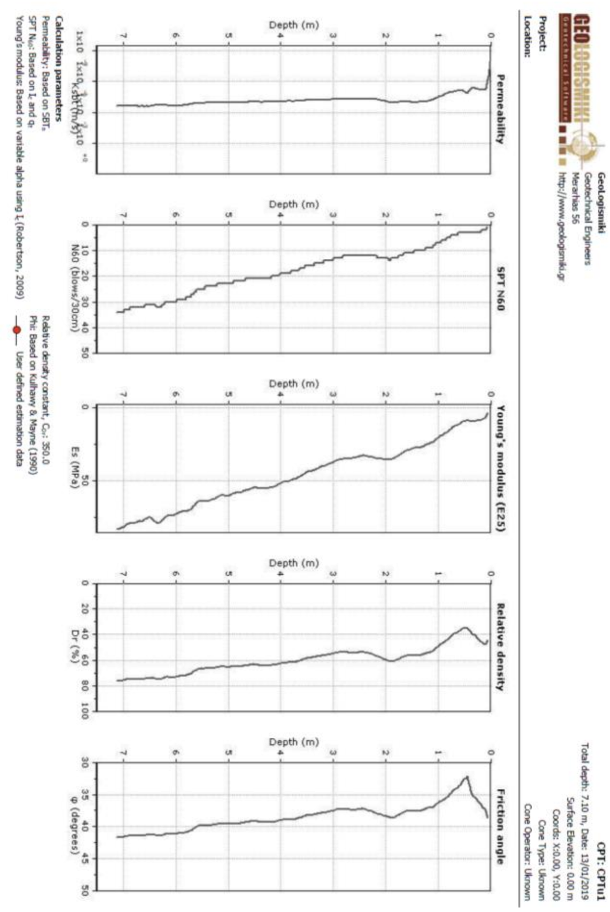


Figure 84: CPT data presentation and interpretation for CPTu1 (10 of 14)

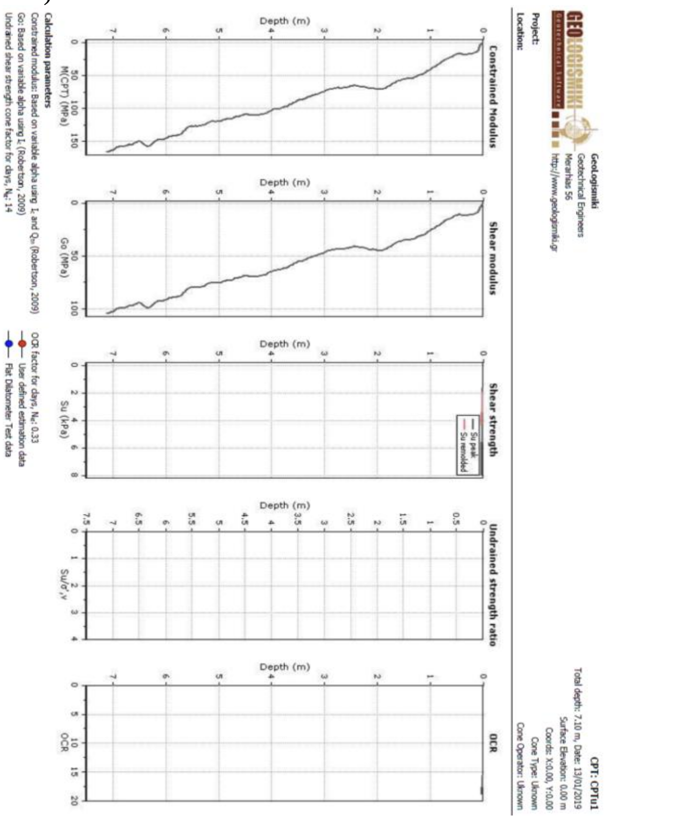


Figure 85: CPT data presentation and interpretation for CPTu1 (11 of 14)

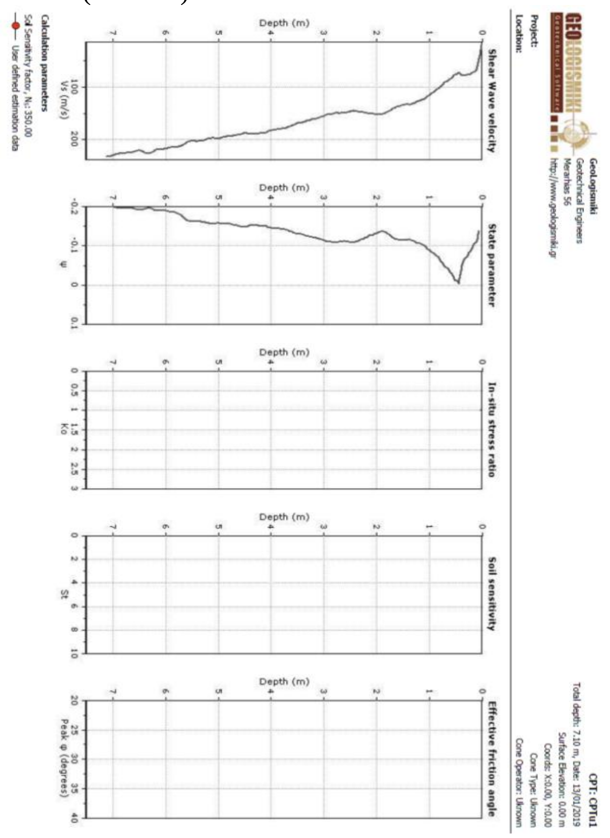
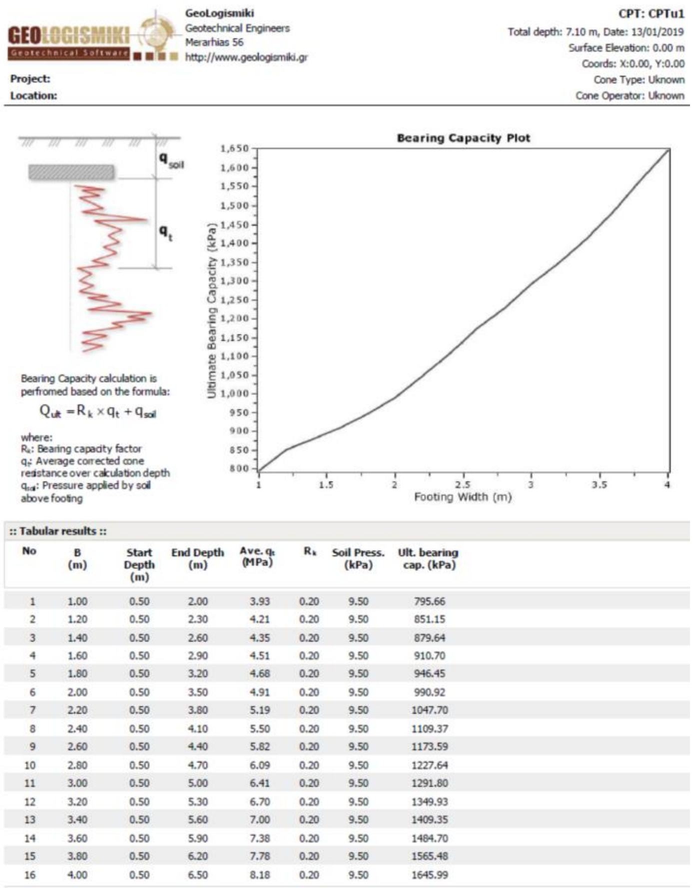
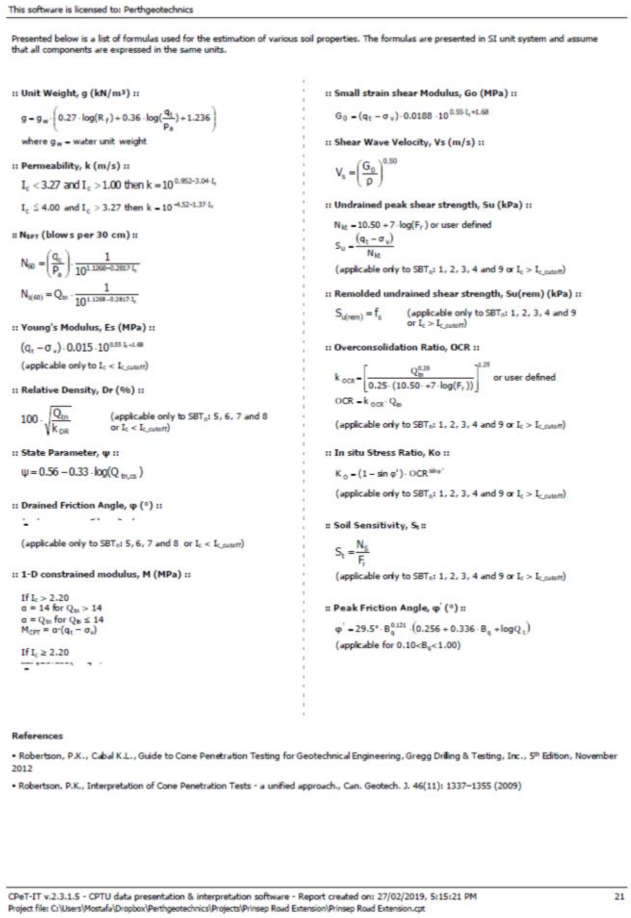


Figure 86: CPT data presentation and interpretation for CPTu1 (12 of 14)



No	B (m)	Start Depth (m)	End Depth (m)	Ave. q_t (MPa)	R_k	Soil Press. (kPa)	Ult. bearing cap. (kPa)
1	1.00	0.50	2.00	3.93	0.20	9.50	795.66
2	1.20	0.50	2.30	4.21	0.20	9.50	851.15
3	1.40	0.50	2.60	4.35	0.20	9.50	879.64
4	1.60	0.50	2.90	4.51	0.20	9.50	910.70
5	1.80	0.50	3.20	4.68	0.20	9.50	946.45
6	2.00	0.50	3.50	4.91	0.20	9.50	990.92
7	2.20	0.50	3.80	5.19	0.20	9.50	1047.70
8	2.40	0.50	4.10	5.50	0.20	9.50	1109.37
9	2.60	0.50	4.40	5.82	0.20	9.50	1173.59
10	2.80	0.50	4.70	6.09	0.20	9.50	1227.64
11	3.00	0.50	5.00	6.41	0.20	9.50	1291.80
12	3.20	0.50	5.30	6.70	0.20	9.50	1349.93
13	3.40	0.50	5.60	7.00	0.20	9.50	1409.35
14	3.60	0.50	5.90	7.38	0.20	9.50	1484.70
15	3.80	0.50	6.20	7.78	0.20	9.50	1565.48
16	4.00	0.50	6.50	8.18	0.20	9.50	1645.99

Figure 87: CPT data presentation and interpretation for CPTu1 (13 of 14)



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Presented below is a list of formulas used for the estimation of various soil properties. The formulas are presented in SI unit system and assume that all components are expressed in the same units.

:: Unit Weight, g (kN/m³) ::

$$g = g_w \cdot \left(0.27 \cdot \log(R_f) + 0.36 \cdot \log(\frac{q_t}{P_a}) + 1.236\right)$$

where g_w = water unit weight

:: Permeability, k (m/s) ::

$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952-3.04 \cdot I_c}$

$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52-1.37 \cdot I_c}$

:: N_{SPT} (blows per 30 cm) ::

$$N_{60} = \left(\frac{q_c}{P_a}\right) \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

$$N_{1(60)} = Q_{tn} \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

:: Young's Modulus, Es (MPa) ::

$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{0.55 \cdot I_c + 1.68}$

(applicable only to $I_c < I_{c\_cutoff}$)

:: Relative Density, Dr (%) ::

$100 \cdot \sqrt{\frac{Q_{tn}}{k_{DR}}}$ (applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: State Parameter, ψ ::

$\psi = 0.56 - 0.33 \cdot \log(Q_{tn,cs})$

:: Drained Friction Angle, φ (°) ::

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: 1-D constrained modulus, M (MPa) ::

If $I_c > 2.20$
$\alpha = 14$ for $Q_{tn} > 14$
$\alpha = Q_{tn}$ for $Q_{tn} \leq 14$
$M_{CPT} = \alpha \cdot (q_t - \sigma_v)$

If $I_c \geq 2.20$

:: Small strain shear Modulus, Go (MPa) ::

$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 \cdot I_c + 1.68}$

:: Shear Wave Velocity, Vs (m/s) ::

$$V_s = \left(\frac{G_0}{\rho}\right)^{0.50}$$

:: Undrained peak shear strength, Su (kPa) ::

$N_{kt} = 10.50 + 7 \cdot \log(F_r)$ or user defined

$$S_u = \frac{(q_t - \sigma_v)}{N_{kt}}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Remolded undrained shear strength, Su(rem) (kPa) ::

$S_{u(rem)} = f_s$ (applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Overconsolidation Ratio, OCR ::

$$k_{OCR} = \left[\frac{Q_{tn}^{0.20}}{0.25 \cdot (10.50 + 7 \cdot \log(F_r))}\right]^{1.25}$$ or user defined

$OCR = k_{OCR} \cdot Q_{tn}$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: In situ Stress Ratio, Ko ::

$K_O = (1 - \sin \varphi') \cdot OCR^{\sin \varphi'}$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Soil Sensitivity, S_t ::

$$S_t = \frac{N_S}{F_r}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Peak Friction Angle, φ' (°) ::

$\varphi' = 29.5° \cdot B_q^{0.121} \cdot (0.256 + 0.336 \cdot B_q + \log Q_t)$

(applicable for $0.10 < B_q < 1.00$)

References

- Robertson, P.K., Cabal K.L., Guide to Cone Penetration Testing for Geotechnical Engineering, Gregg Drilling & Testing, Inc., 5th Edition, November 2012
- Robertson, P.K., Interpretation of Cone Penetration Tests - a unified approach., Can. Geotech. J. 46(11): 1337–1355 (2009)

CPeT-IT v.2.3.1.5 - CPTU data presentation & interpretation software - Report created on: 27/02/2019, 5:15:21 PM 21

Project file: C:\Users\Mostafa\Dropbox\Perthgeotechnics\Projects\Prinsep Road Extension\Prinsep Road Extension.cpt

Figure 88: CPT data presentation and interpretation for CPTu1 (14 of 14)

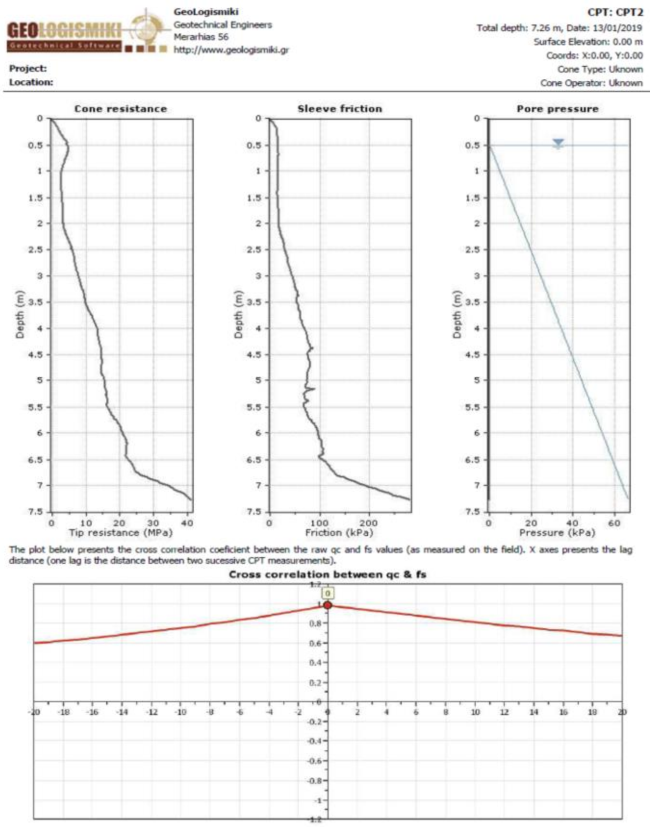


Figure 89: CPT data presentation and interpretation for CPT2 (1 of 14)

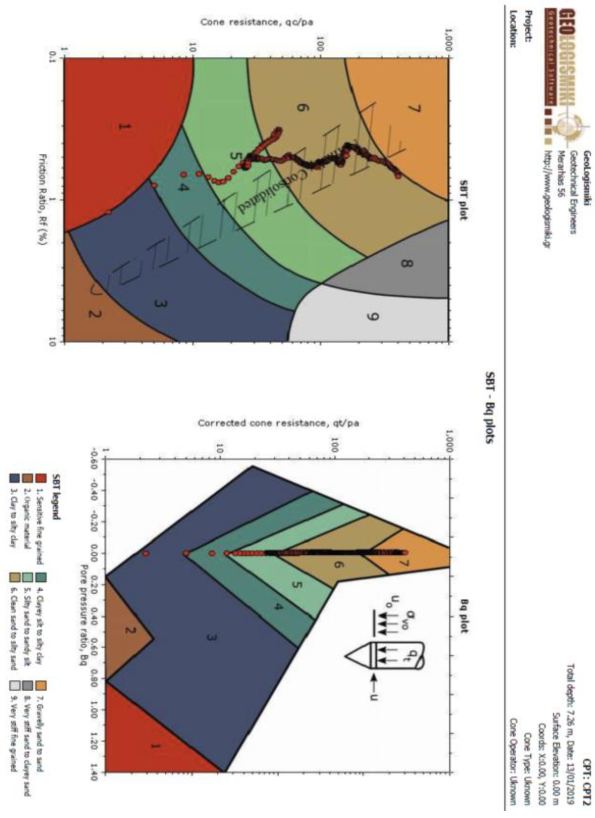


Figure 90: CPT data presentation and interpretation for CPT2 (2 of 14)

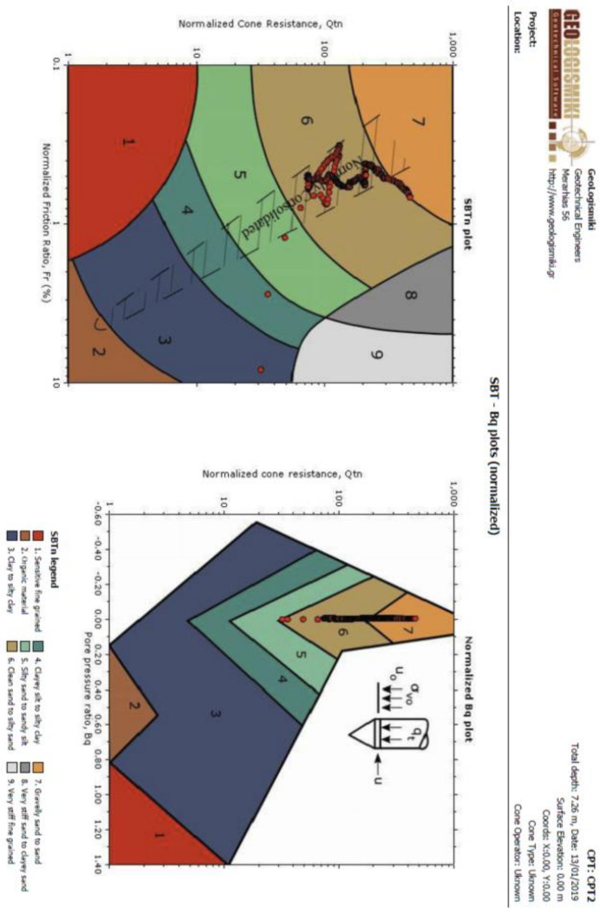


Figure 91: CPT data presentation and interpretation for CPT2 (3 of 14)

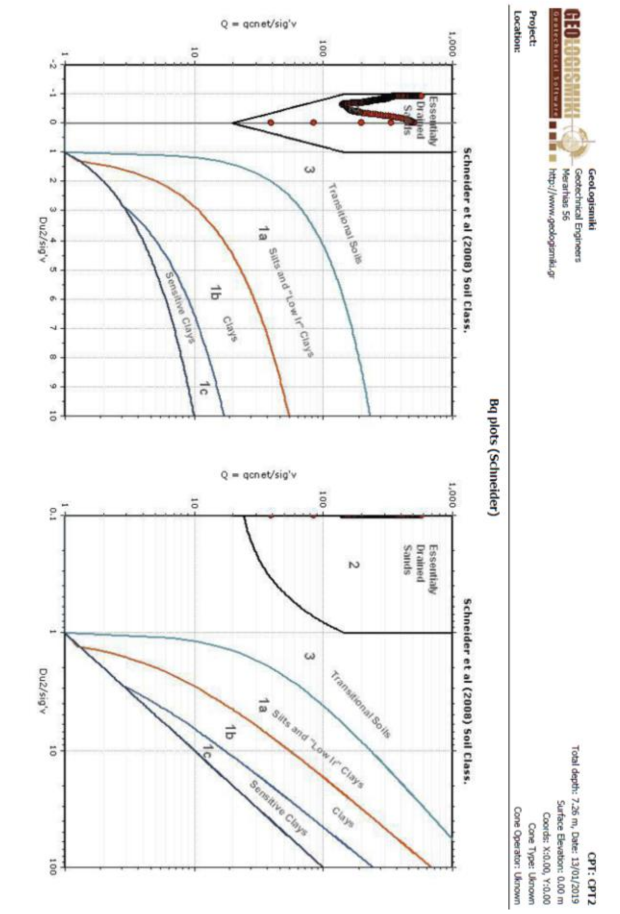


Figure 92: CPT data presentation and interpretation for CPT2 (4 of 14)

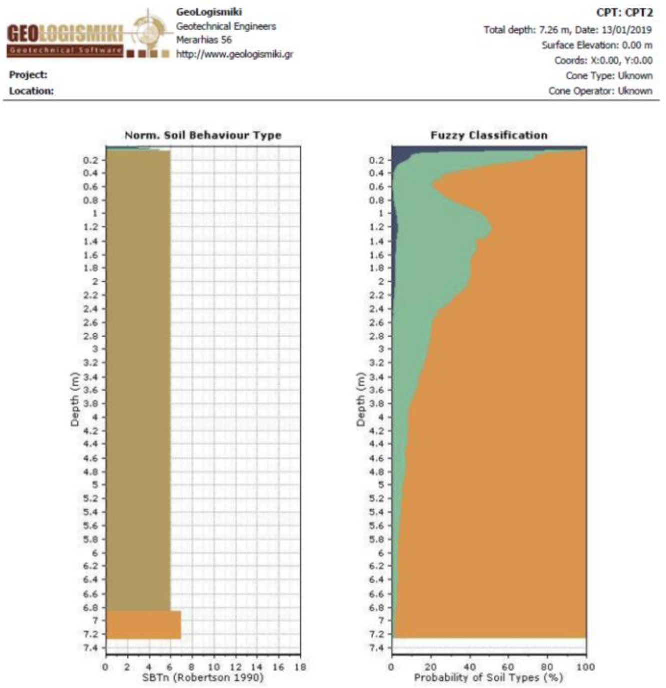


Figure 93: CPT data presentation and interpretation for CPT2 (5 of 14)

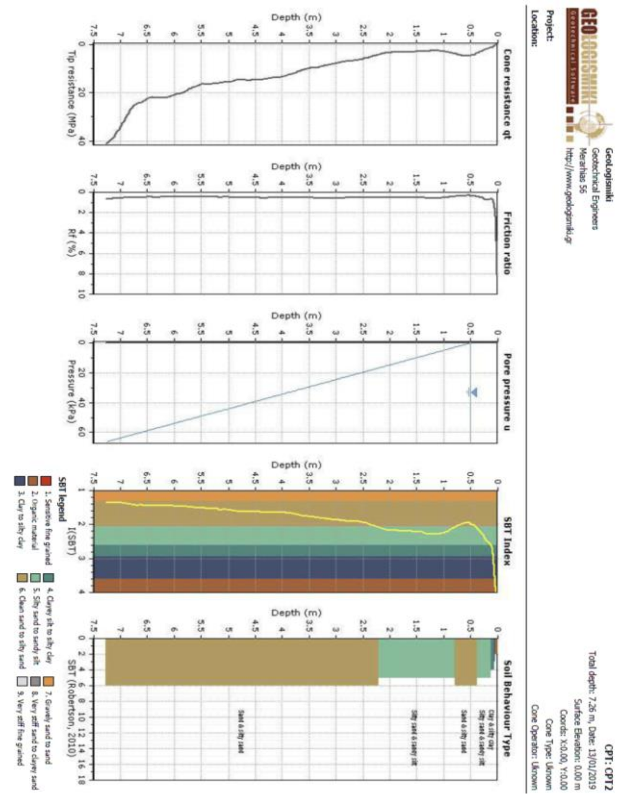


Figure 94: CPT data presentation and interpretation for CPT2 (6 of 14)

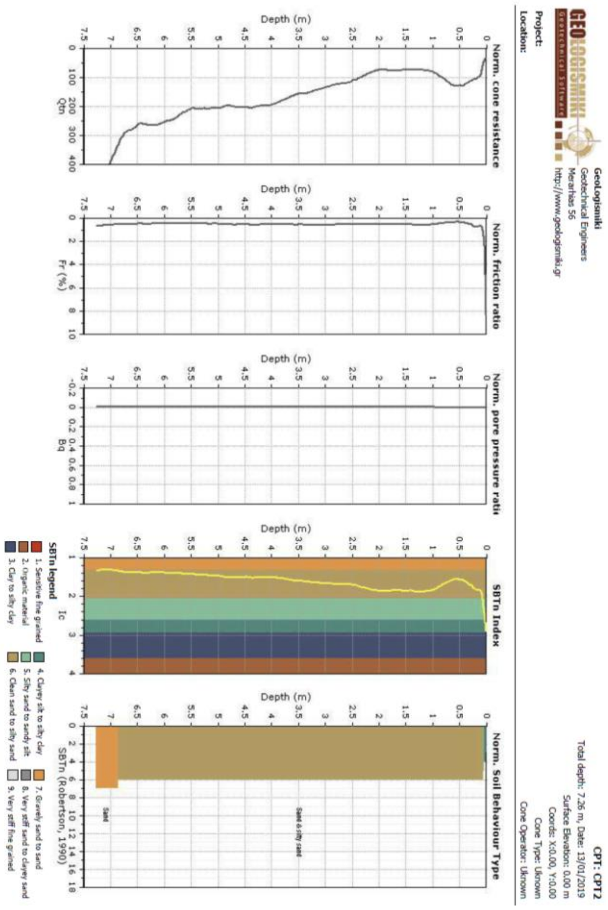


Figure 95: CPT data presentation and interpretation for CPT2 (7 of 14)

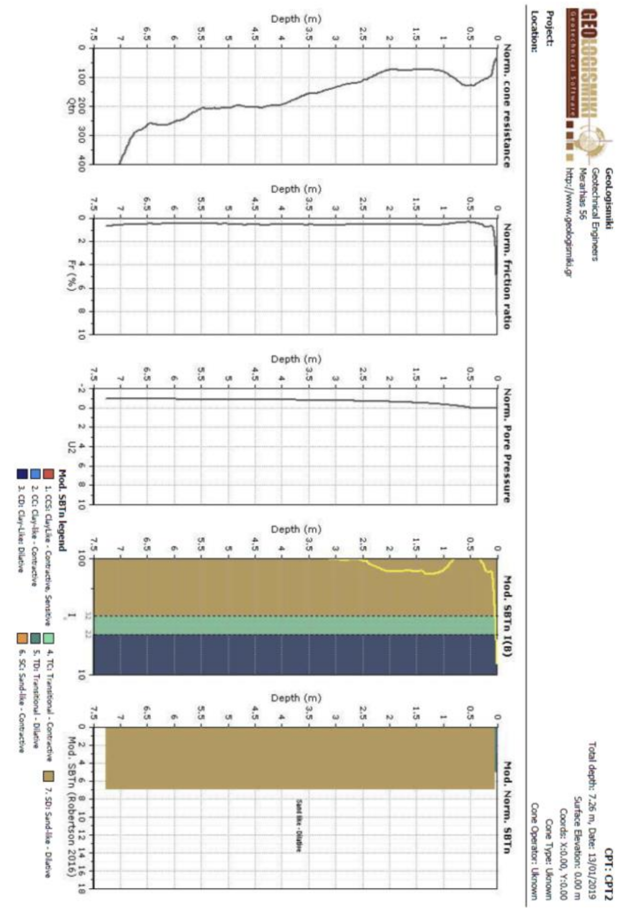


Figure 96: CPT data presentation and interpretation for CPT2 (8 of 14)

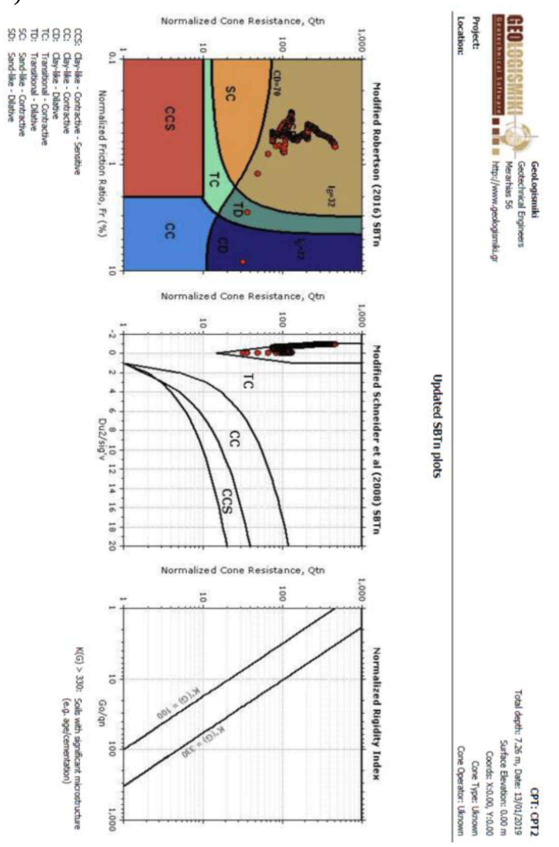


Figure 97: CPT data presentation and interpretation for CPT2 (9 of 18)

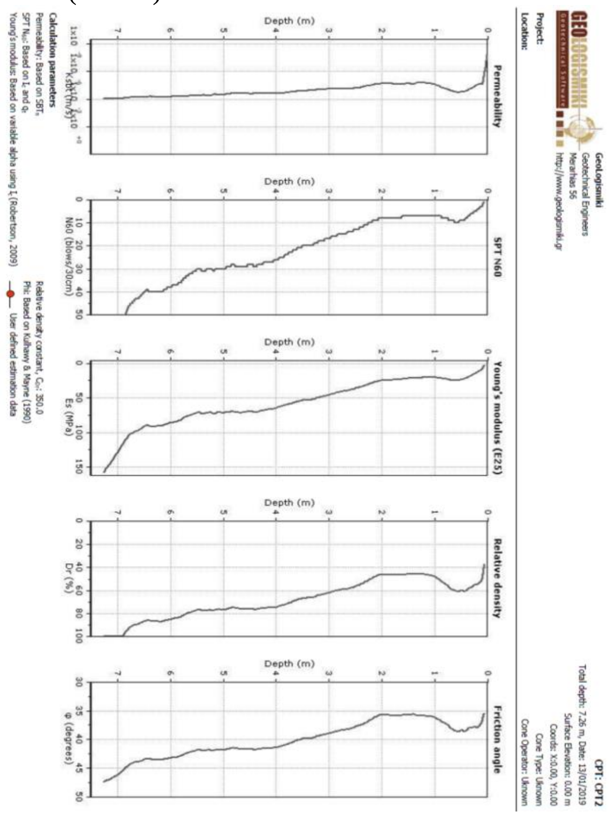


Figure 98: CPT data presentation and interpretation for CPT2 (10 of 14)

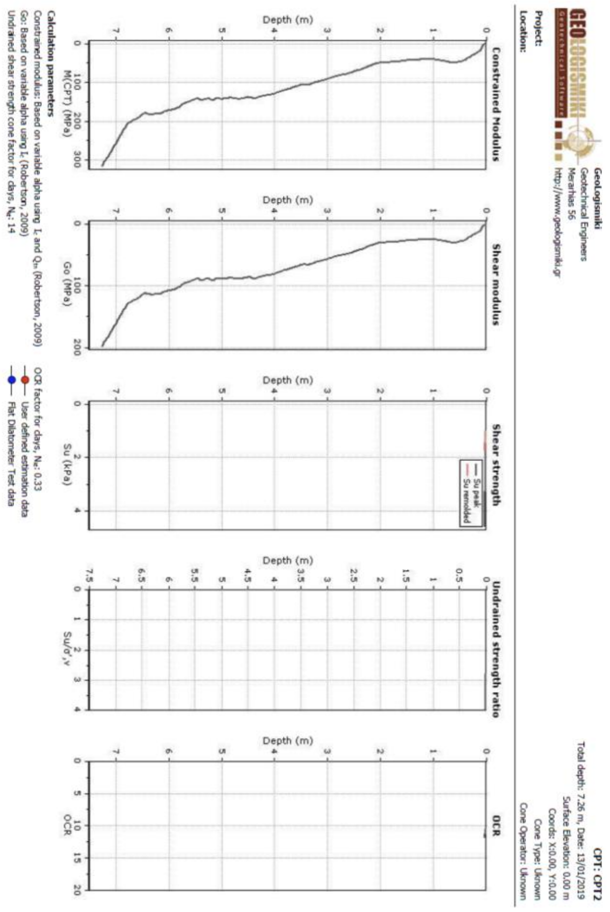


Figure 99: CPT data presentation and interpretation for CPT2 (11 of 14)

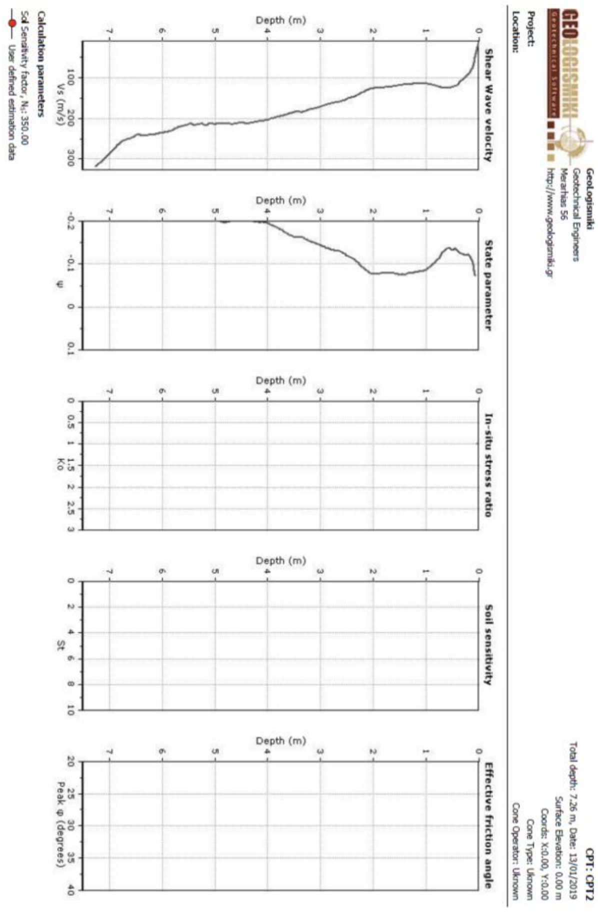
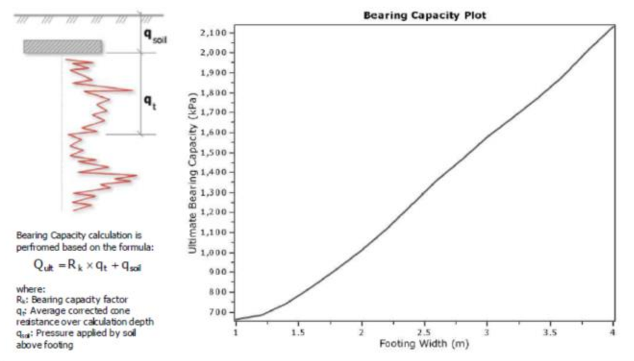


Figure 100: CPT data presentation and interpretation for CPT2 (12 of 14)

GeoLogismiki
Geotechnical Engineers
Merarhias 56
http://www.geologismiki.gr

CPT: CPT2
Total depth: 7.26 m, Date: 13/01/2019
Surface Elevation: 0.00 m
Coords: X:0.00, Y:0.00
Cone Type: Uknown
Cone Operator: Uknown

Project:
Location:



:: Tabular results ::

No	B (m)	Start Depth (m)	End Depth (m)	Ave. q_t (MPa)	R_k	Soil Press. (kPa)	Ult. bearing cap. (kPa)
1	1.00	0.50	2.00	3.27	0.20	9.50	663.26
2	1.20	0.50	2.30	3.38	0.20	9.50	684.60
3	1.40	0.50	2.60	3.67	0.20	9.50	743.81
4	1.60	0.50	2.90	4.09	0.20	9.50	827.11
5	1.80	0.50	3.20	4.52	0.20	9.50	914.19
6	2.00	0.50	3.50	5.01	0.20	9.50	1011.75
7	2.20	0.50	3.80	5.54	0.20	9.50	1118.04
8	2.40	0.50	4.10	6.16	0.20	9.50	1241.98
9	2.60	0.50	4.40	6.76	0.20	9.50	1362.49
10	2.80	0.50	4.70	7.29	0.20	9.50	1467.86
11	3.00	0.50	5.00	7.83	0.20	9.50	1575.22
12	3.20	0.50	5.30	8.33	0.20	9.50	1675.27
13	3.40	0.50	5.60	8.81	0.20	9.50	1771.28
14	3.60	0.50	5.90	9.37	0.20	9.50	1883.70
15	3.80	0.50	6.20	10.00	0.20	9.50	2009.15
16	4.00	0.50	6.50	10.60	0.20	9.50	2129.23

Figure 101: CPT data presentation and interpretation for CPT2 (13 of 14)

Presented below is a list of formulas used for the estimation of various soil properties. The formulas are presented in SI unit system and assume that all components are expressed in the same units.

:: Unit Weight, g (kN/m³) ::

$$g = g_w \cdot \left(0.27 \cdot \log(R_f) + 0.36 \cdot \log\left(\frac{q_t}{p_a}\right) + 1.236\right)$$

where g_w = water unit weight

:: Permeability, k (m/s) ::

$I_c < 3.27$ and $I_c > 1.00$ then $k = 10^{0.952-3.04 \cdot I_c}$

$I_c \leq 4.00$ and $I_c > 3.27$ then $k = 10^{-4.52-1.37 \cdot I_c}$

:: N_{SPT} (blows per 30 cm) ::

$$N_{60} = \left(\frac{q_c}{P_a}\right) \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

$$N_{1(60)} = Q_{tn} \cdot \frac{1}{10^{1.1268-0.2817 \cdot I_c}}$$

:: Young's Modulus, Es (MPa) ::

$(q_t - \sigma_v) \cdot 0.015 \cdot 10^{0.55 \cdot I_c + 1.68}$

(applicable only to $I_c < I_{c\_cutoff}$)

:: Relative Density, Dr (%) ::

$100 \cdot \sqrt{\frac{Q_{tn}}{k_{DR}}}$ (applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: State Parameter, ψ ::

$\psi = 0.56 - 0.33 \cdot \log(Q_{tn,cs})$

:: Drained Friction Angle, φ (°) ::

[illegible]

(applicable only to SBT_n: 5, 6, 7 and 8 or $I_c < I_{c\_cutoff}$)

:: 1-D constrained modulus, M (MPa) ::

If $I_c > 2.20$
$\alpha = 14$ for $Q_{tn} > 14$
$\alpha = Q_{tn}$ for $Q_{tn} \leq 14$
$M_{CPT} = \alpha \cdot (q_t - \sigma_v)$

If $I_c \geq 2.20$

[illegible]

:: Small strain shear Modulus, Go (MPa) ::

$G_0 = (q_t - \sigma_v) \cdot 0.0188 \cdot 10^{0.55 \cdot I_c + 1.68}$

:: Shear Wave Velocity, Vs (m/s) ::

$$V_s = \left(\frac{G_0}{\rho}\right)^{0.50}$$

:: Undrained peak shear strength, Su (kPa) ::

$N_{kt} = 10.50 + 7 \cdot \log(F_r)$ or user defined

$$S_u = \frac{(q_t - \sigma_v)}{N_{kt}}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Remolded undrained shear strength, Su(rem) (kPa) ::

$S_{u(rem)} = f_s$ (applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Overconsolidation Ratio, OCR ::

$$k_{OCR} = \left[\frac{Q_{tn}^{0.20}}{0.25 \cdot (10.50 \cdot +7 \cdot \log(F_r))}\right]^{1.25}$$ or user defined

$OCR = k_{OCR} \cdot Q_{tn}$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: In situ Stress Ratio, Ko ::

$K_0 = (1 - \sin\varphi') \cdot OCR^{\sin\varphi'}$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Soil Sensitivity, S_t ::

$$S_t = \frac{N_S}{F_r}$$

(applicable only to SBT_n: 1, 2, 3, 4 and 9 or $I_c > I_{c\_cutoff}$)

:: Peak Friction Angle, φ' (°) ::

$\varphi' = 29.5° \cdot B_q^{0.121} \cdot (0.256 + 0.336 \cdot B_q + \log Q_t)$

(applicable for $0.10 < B_q < 1.00$)

References

• Robertson, P.K., Cabal K.L., Guide to Cone Penetration Testing for Geotechnical Engineering, Gregg Drilling & Testing, Inc., 5th Edition, November 2012

• Robertson, P.K., Interpretation of Cone Penetration Tests - a unified approach., Can. Geotech. J. 46(11): 1337–1355 (2009)

Figure 102: CPT data presentation and interpretation for CPT2 (14 of 14)

Perth Geotechnics

DYNAMIC CONE PENETROMETER (DCP)
TEST CERTIFICATE

(AS 1289.6.3.2)
Correlation of Sand Density - Table 6.4.6.1 (A) & (B) HB 160-2006

Client	City of Cockburn	Project	Prinsep Road Extension
Reference	GPI18318PG	Location	Jandakot
Date Tested	06/11/2018	Tested By	MH/KA

References:	DCP1 (TP1)	DCP2 (TP2)	DCP3 (TP3)	DCP4 (TP4)	DCP5 (TP5)	DCP6 (TP6)
Depth below ground level test commenced	Penetration Resistance - Blows/100mm					
0-100	4	3	<1	<1	<1	<1
100-200	7	6	2	<1	1	2
200-300	7	4	2	2	2	3
300-400	8	4	2	4	4	3
400-500	8	5	2	6	3	2
500-600	4	4	3	6	2	3
600-700	4	4	2	9	3	3
700-800	5	5	2	13	3	4
800-900	4	4	3	12	2	4
900-1000	5	4	2	11	3	5
Depth below ground level test commenced	Density Classification					
0-100	D	MD	VL	VL	VL	VL
100-200	D	D	L	VL	L	L
200-300	D	D	L	L	L	MD
300-400	D	D	L	D	D	MD
400-500	D	D	L	D	MD	L
500-600	D	D	MD	D	L	MD
600-700	D	D	L	VD	MD	MD
700-800	D	D	L	VD	MD	D
800-900	D	D	MD	VD	L	D
900-1000	D	D	L	VD	MD	D

Remarks: R= Refusal

Table A: H = Hard >10, VSt = Very Stiff, 5 – 10, St = Stiff, 3 – 4, F = Firm, 1 – 2, VS = Very Soft < 1
Table B: VD = Very Dense > 8, D = Dense, 4 – 8, MD = Medium Dense, 2 – 3, L = Loose, 1 – 2, VL = Very Loose < 1

Figure 103: DCP data for test pits (TP1 to TP6)

Perth Geotechnics

DYNAMIC CONE PENETROMETER (DCP)
TEST CERTIFICATE

(AS 1289.6.3.2)
Correlation of Sand Density - Table 6.4.6.1 (A) & (B) HB 160-2006

Client	City of Cockburn	Project	Prinsep Road Extension
Reference	GPI18318PG	Location	Jandakot
Date Tested	06/11/2018	Tested By	MH/KA

References:	DCP7 (TP7)	DCP8 (TP8)	DCP9 (TP9)	DCP10 (TP10)	DCP11 (TP11)	DCP12 (PD1)
Depth below ground level test commenced	Penetration Resistance - Blows/100mm					
0-100	<1	<1	4	<1	2	8
100-200	<1	<1	3	<1	2	11
200-300	<1	2	2	<1	3	12
300-400	<1	2	2	2	2	25>R
400-500	<1	1	2	1	3	-
500-600	1	2	3	2	4	-
600-700	<1	2	2	3	4	-
700-800	<1	3	3	2	3	-
800-900	<1	2	2	3	4	-
900-1000	<1	2	3	3	4	-
Depth below ground level test commenced	Density Classification					
0-100	VL	VL	VL	VL	VL	VL
100-200	VL	VL	VL	L	L	L
200-300	L	L	L	MD	MD	MD
300-400	L	MD	MD	MD	D	D
400-500	MD	MD	D	MD	D	-
500-600	MD	D	D	MD	D	-
600-700	D	D	D	MD	D	-
700-800	D	VD	D	D	D	-
800-900	D	D	D	D	D	-
900-1000	D	D	D	D	D	-

Remarks: R= Refusal

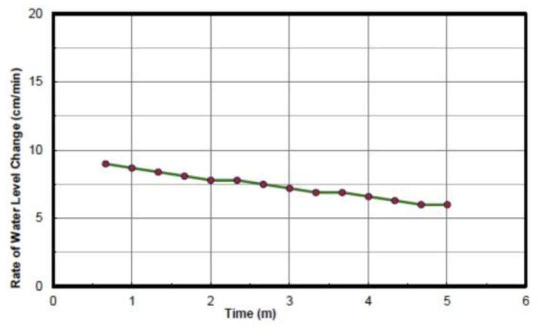
Table A: H = Hard >10, VSt = Very Stiff, 5 – 10, St = Stiff, 3 – 4, F = Firm, 1 – 2, VS = Very Soft < 1
Table B: VD = Very Dense > 8, D = Dense, 4 – 8, MD = Medium Dense, 2 – 3, L = Loose, 1 – 2, VL = Very Loose < 1

Figure 104: DCP data for test pits (TP7 to TP10, and PD1)

PERTH GEOTECHNICS

Test ID	FPT1	Reference	GPI18318PG
Project	Geotechnical and Pavement Investigation	Client	City of Cockburn
Location	Prinsep Road Extension, Jandakot WA	Soil Type	Sand
Co-ordinates	Easting: 50 392 106 Northing: 6 445 751	Test Depth	500 mm from surface
Instrument Name	Guelph Permeameter	Date Tested	24/11/2018

PERMEABILITY TEST CERTIFICATES
(ASTM D 5126-90)



Water Hydraulic conductivity K_{fs}: 6.3E-03 cm/sec
5.4E+00 m/day

Tested By: Mohammad Amzad Hossain

Date: 27/11/2018

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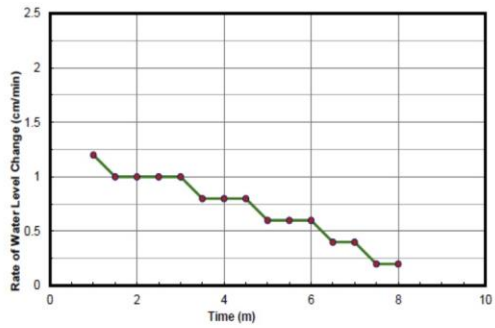
Figure 105: Field Permeability test at TP2

PERTH GEOTECHNICS

Test ID	FPT2	Reference	GPI18318PG
Project	Geotechnical and Pavement Investigation	Client	City of Cockburn
Location	Prinsep Road Extension, Jandakot WA	Soil Type	Sand with silt
Co-ordinates	Easting: 50 392 369 Northing: 6 445 654	Test Depth	500 mm from surface
Instrument Name	Guelph Permeameter	Date Tested	24/11/2018

PERMEABILITY TEST CERTIFICATES
(ASTM D 5126-90)



Water Hydraulic conductivity K_{fs}: 6.8E-04 cm/sec
5.9E-01 m/day

Tested By: Mohammad Amzad Hossain

Date: 27/11/2018

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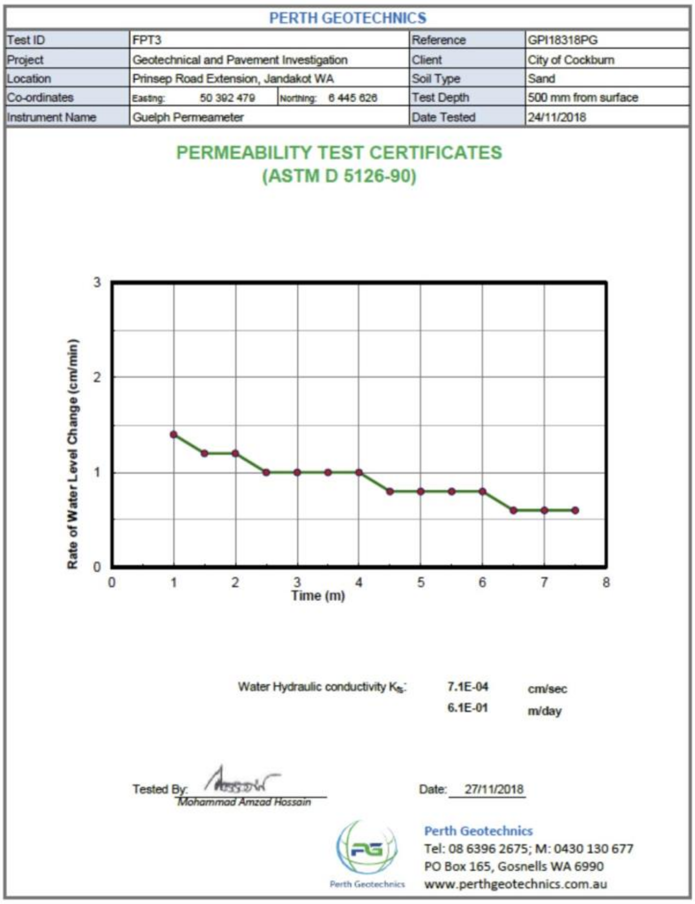
Figure 106: Field Permeability test at TH6



PERTH GEOTECHNICS

Test ID	FPT3	Reference	GPI18318PG
Project	Geotechnical and Pavement Investigation	Client	City of Cockburn
Location	Prinsep Road Extension, Jandakot WA	Soil Type	Sand
Co-ordinates	Easting: 50 392 479 Northing: 6 445 626	Test Depth	500 mm from surface
Instrument Name	Guelph Permeameter	Date Tested	24/11/2018

PERMEABILITY TEST CERTIFICATES
(ASTM D 5126-90)

Water Hydraulic conductivity K_{fs}: 7.1E-04 cm/sec
6.1E-01 m/day

Tested By: Mohammad Amzad Hossain
Date: 27/11/2018

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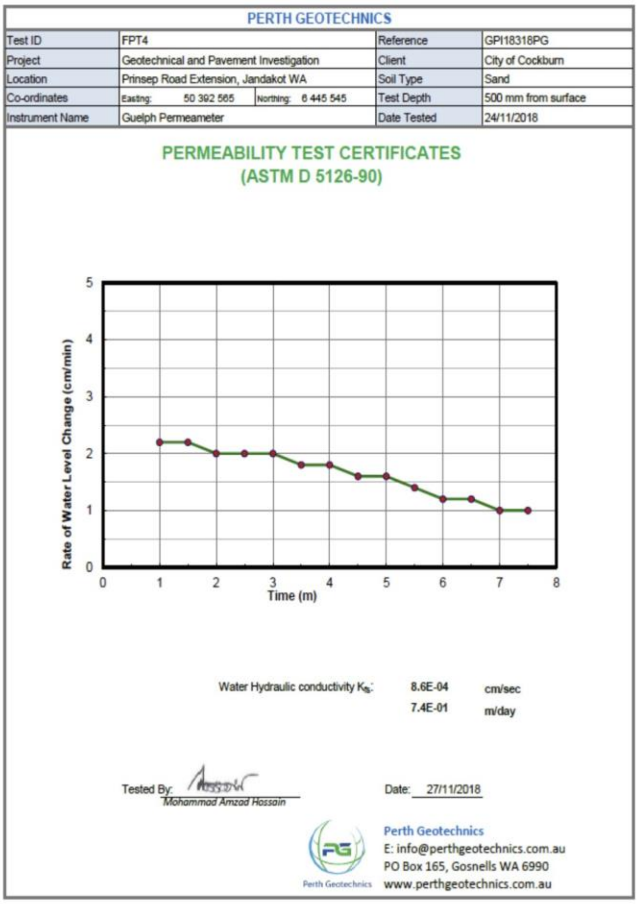
Figure 107: Field Permeability test at TP8



PERTH GEOTECHNICS

Test ID	FPT4	Reference	GPI18318PG
Project	Geotechnical and Pavement Investigation	Client	City of Cockburn
Location	Prinsep Road Extension, Jandakot WA	Soil Type	Sand
Co-ordinates	Easting: 50 392 565 Northing: 6 445 545	Test Depth	500 mm from surface
Instrument Name	Guelph Permeameter	Date Tested	24/11/2018

PERMEABILITY TEST CERTIFICATES
(ASTM D 5126-90)

Water Hydraulic conductivity K_{fs}: 8.6E-04 cm/sec
7.4E-01 m/day

Tested By: Mohammad Amzad Hossain
Date: 27/11/2018

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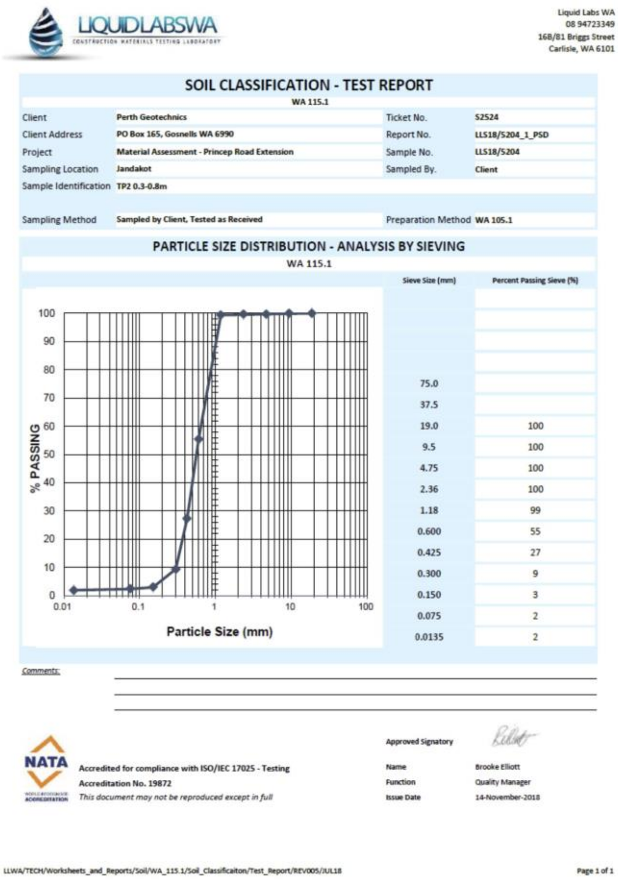
Figure 108: Field Permeability test at TP10



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SOIL CLASSIFICATION - TEST REPORT
WA 115.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5204_1_PSD
Project	Material Assessment - Princep Road Extension	Sample No.	LLS18/5204
Sampling Location	Jandakot	Sampled By.	Client
Sample Identification	TP2 0.3-0.8m		
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

PARTICLE SIZE DISTRIBUTION - ANALYSIS BY SIEVING
WA 115.1

Sieve Size (mm)	Percent Passing Sieve (%)
75.0	
37.5	
19.0	100
9.5	100
4.75	100
2.36	100
1.18	99
0.600	55
0.425	27
0.300	9
0.150	3
0.075	2
0.0135	2

Comments:

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Figure 109: Particle Size analysis at TP2

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DRY DENSITY & MOISTURE CONTENT RELATION OF SOIL TEST REPORT
WA 133.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5204_1_MMDD
Project	Marterial Assessment - Princep Road Extension	Sample No.	LLS18/5204
Sampling Location	Jandakot	Date Received	7/11/2018
Sample Identification	TP2 0.3-0.8m	Date Tested	8/11/2018
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

Oversize Material

Retained 19.0mm (%)	0

WA 133.1, 110.1	Laboratory Moisture & Density Results				
Moisture Content (%)	7.0	10.6	12.7	14.9	
Dry Density (t/m³)	1.728	1.753	1.788	1.756	

Plot: Dry Density vs. Moisture Content

Modified Maximum Dry Density (t/m³)	1.788
Modified Optimum Moisture Content (%)	12.8

Comments:

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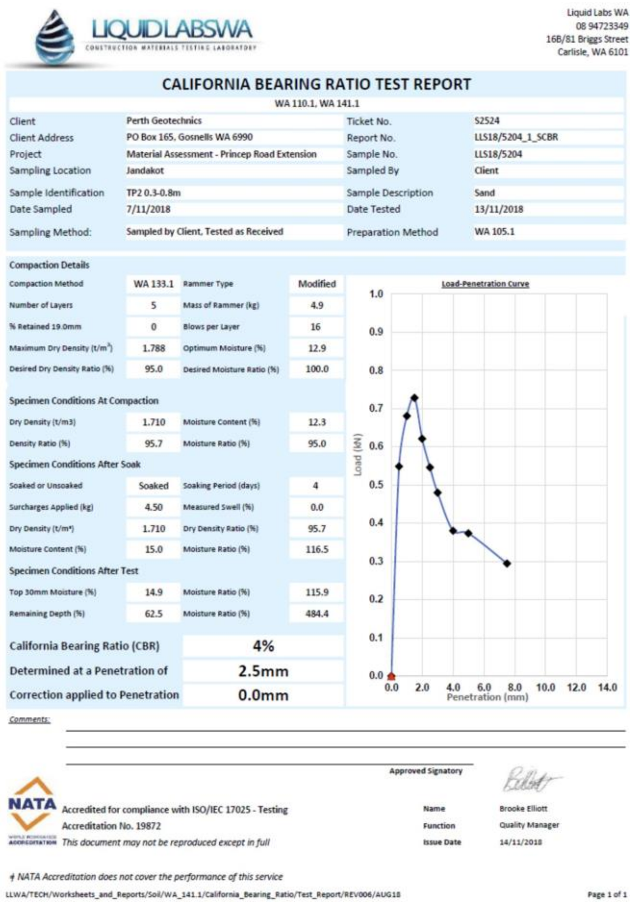
Figure 110: Max dry density and moisture content at TP2



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CALIFORNIA BEARING RATIO TEST REPORT

WA 110.1, WA 141.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5204_1_SCBR
Project	Material Assessment - Princep Road Extension	Sample No.	LLS18/5204
Sampling Location	Jandakot	Sampled By	Client
Sample Identification	TP2 0.3-0.8m	Sample Description	Sand
Date Sampled	7/11/2018	Date Tested	13/11/2018
Sampling Method:	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

Compaction Details

Compaction Method	WA 133.1	Rammer Type	Modified
Number of Layers	5	Mass of Rammer (kg)	4.9
% Retained 19.0mm	0	Blows per Layer	16
Maximum Dry Density (t/m³)	1.788	Optimum Moisture (%)	12.9
Desired Dry Density Ratio (%)	95.0	Desired Moisture Ratio (%)	100.0
Specimen Conditions At Compaction			
Dry Density (t/m3)	1.710	Moisture Content (%)	12.3
Density Ratio (%)	95.7	Moisture Ratio (%)	95.0
Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.710	Dry Density Ratio (%)	95.7
Moisture Content (%)	15.0	Moisture Ratio (%)	116.5
Specimen Conditions After Test			
Top 30mm Moisture (%)	14.9	Moisture Ratio (%)	115.9
Remaining Depth (%)	62.5	Moisture Ratio (%)	484.4

California Bearing Ratio (CBR)	4%
Determined at a Penetration of	2.5mm
Correction applied to Penetration	0.0mm

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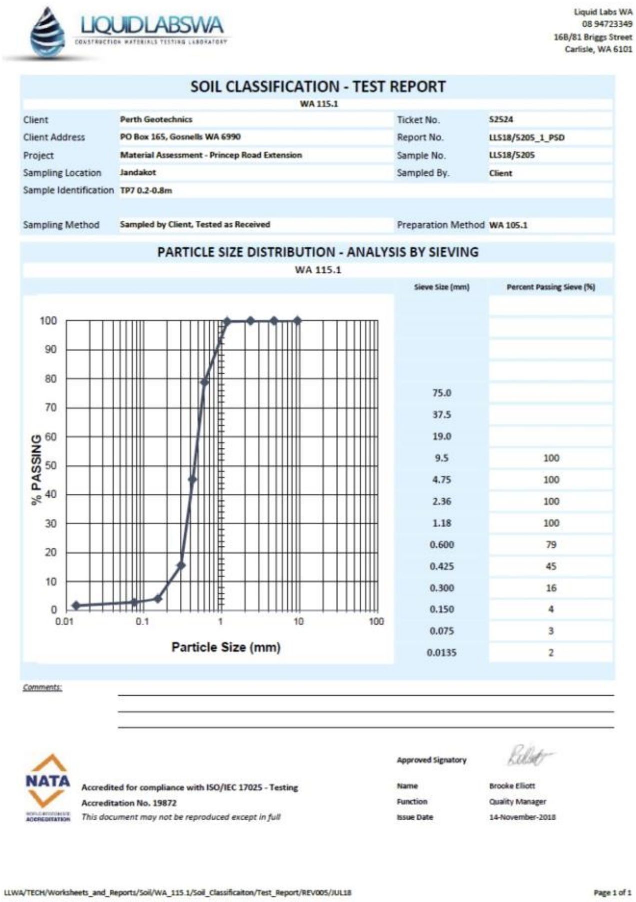
Figure 111: CBR analysis at TP2



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SOIL CLASSIFICATION - TEST REPORT

WA 115.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5205_1_PSD
Project	Material Assessment - Princep Road Extension	Sample No.	LLS18/5205
Sampling Location	Jandakot	Sampled By.	Client
Sample Identification	TP7 0.2-0.8m		
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

PARTICLE SIZE DISTRIBUTION - ANALYSIS BY SIEVING

WA 115.1

Sieve Size (mm)	Percent Passing Sieve (%)
75.0	
37.5	
19.0	
9.5	100
4.75	100
2.36	100
1.18	100
0.600	79
0.425	45
0.300	16
0.150	4
0.075	3
0.0135	2

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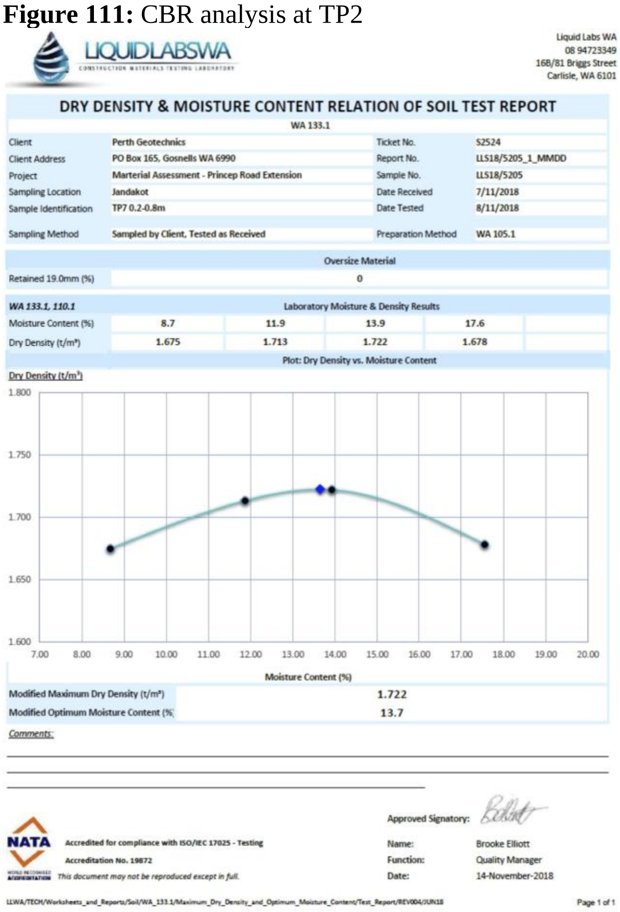
Figure 112: Particle Size analysis at TP7



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DRY DENSITY & MOISTURE CONTENT RELATION OF SOIL TEST REPORT

WA 133.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5205_1_MMDD
Project	Material Assessment - Princep Road Extension	Sample No.	LLS18/5205
Sampling Location	Jandakot	Date Received	7/11/2018
Sample Identification	TP7 0.2-0.8m	Date Tested	8/11/2018
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

Oversize Material

Retained 19.0mm (%)	0

Laboratory Moisture & Density Results

WA 133.1, 110.1				
Moisture Content (%)	8.7	11.9	13.9	17.6
Dry Density (t/m³)	1.675	1.713	1.722	1.678

Plot: Dry Density vs. Moisture Content

Modified Maximum Dry Density (t/m³)	1.722
Modified Optimum Moisture Content (%)	13.7

Comments:

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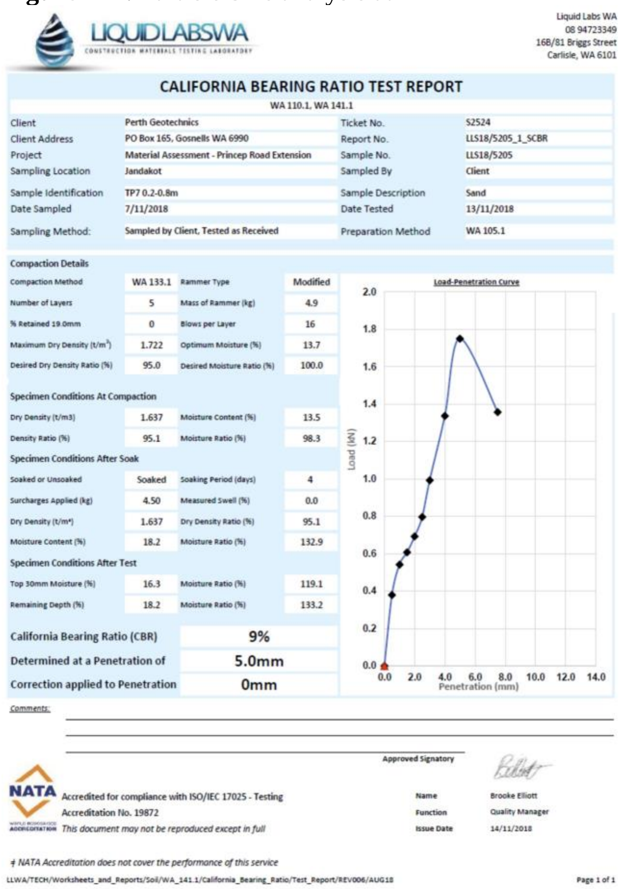
Figure 113: Max dry density and moisture content at TP7



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CALIFORNIA BEARING RATIO TEST REPORT

WA 110.1, WA 141.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5205_1_SCBR
Project	Material Assessment - Princep Road Extension	Sample No.	LLS18/5205
Sampling Location	Jandakot	Sampled By	Client
Sample Identification	TP7 0.2-0.8m	Sample Description	Sand
Date Sampled	7/11/2018	Date Tested	13/11/2018
Sampling Method:	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

Compaction Details

Compaction Method	WA 133.1	Rammer Type	Modified
Number of Layers	5	Mass of Rammer (kg)	4.9
% Retained 19.0mm	0	Blows per Layer	16
Maximum Dry Density (t/m³)	1.722	Optimum Moisture (%)	13.7
Desired Dry Density Ratio (%)	95.0	Desired Moisture Ratio (%)	100.0
Specimen Conditions At Compaction			
Dry Density (t/m3)	1.637	Moisture Content (%)	13.5
Density Ratio (%)	95.1	Moisture Ratio (%)	98.3
Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.637	Dry Density Ratio (%)	95.1
Moisture Content (%)	18.2	Moisture Ratio (%)	132.9
Specimen Conditions After Test			
Top 30mm Moisture (%)	16.3	Moisture Ratio (%)	119.1
Remaining Depth (%)	18.2	Moisture Ratio (%)	133.2

California Bearing Ratio (CBR)	9%
Determined at a Penetration of	5.0mm
Correction applied to Penetration	0mm

Comments:

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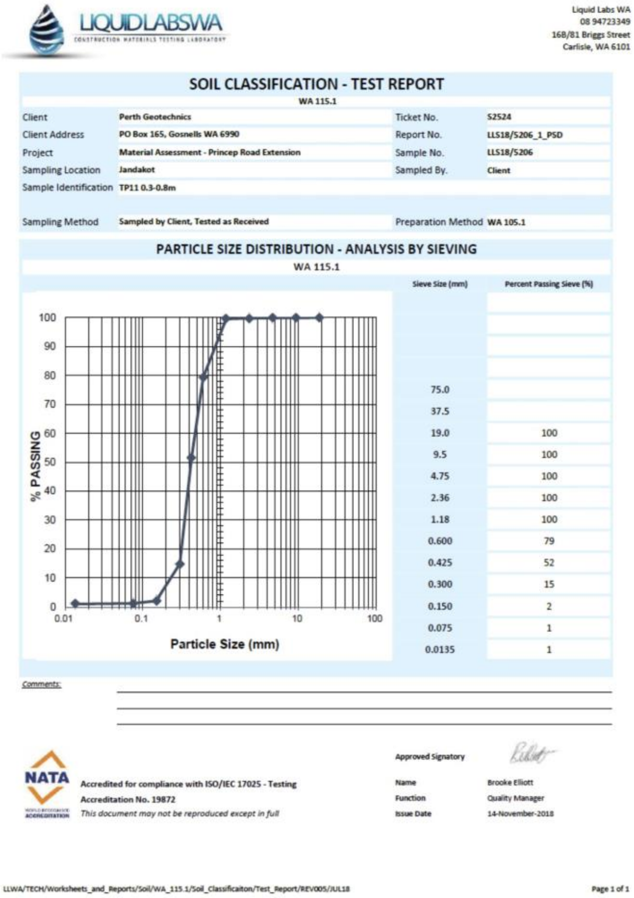
Figure 114: CBR analysis at TP7



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SOIL CLASSIFICATION - TEST REPORT

WA 115.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5206_1_PSD
Project	Material Assessment - Princep Road Extension	Sample No.	LLS18/5206
Sampling Location	Jandakot	Sampled By.	Client
Sample Identification	TP11 0.3-0.8m		
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

PARTICLE SIZE DISTRIBUTION - ANALYSIS BY SIEVING

WA 115.1

Sieve Size (mm)	Percent Passing Sieve (%)
75.0	
37.5	
19.0	100
9.5	100
4.75	100
2.36	100
1.18	100
0.600	79
0.425	52
0.300	15
0.150	2
0.075	1
0.0135	1

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Figure 115: Particle Size analysis at TP11

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DRY DENSITY & MOISTURE CONTENT RELATION OF SOIL TEST REPORT

WA 133.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5205_1_MMDD
Project	Marterial Assessment - Princep Road Extension	Sample No.	LLS18/5205
Sampling Location	Jandakot	Date Received	7/11/2018
Sample Identification	TP11 0.3-0.8m	Date Tested	8/11/2018
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

Oversize Material

Retained 19.0mm (%): 0

WA 133.1, 110.1	Laboratory Moisture & Density Results			
Moisture Content (%)	8.2	10.8	14.4	15.7
Dry Density (t/m³)	1.701	1.711	1.722	1.703

Plot: Dry Density vs. Moisture Content

Modified Maximum Dry Density (t/m³)	1.726
Modified Optimum Moisture Content (%	13.5

Comments:

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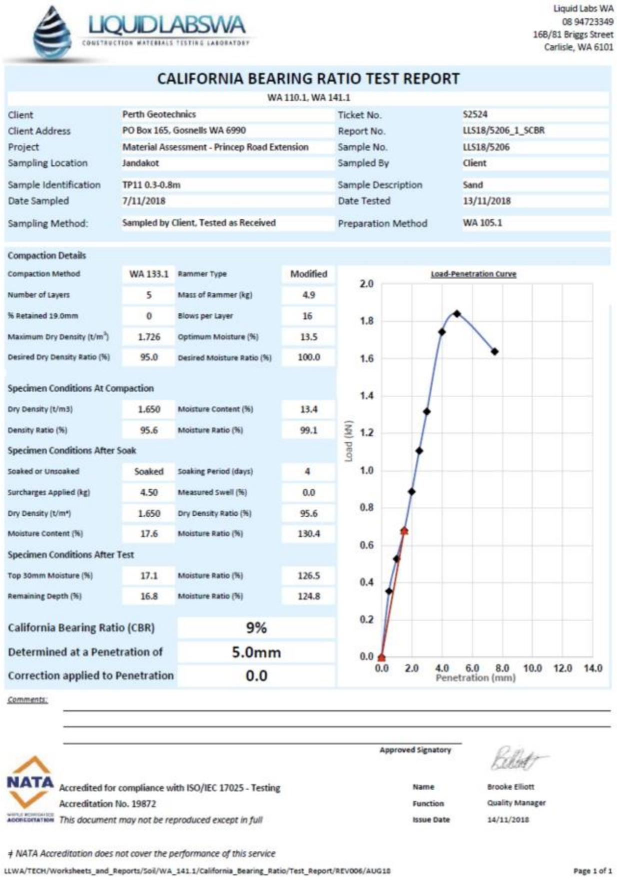
Figure 116: Max dry density and moisture content at TP11



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CALIFORNIA BEARING RATIO TEST REPORT

WA 110.1, WA 141.1

Client	Perth Geotechnics	Ticket No.	S2524
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5206_1_SCBR
Project	Material Assessment - Princep Road Extension	Sample No.	LLS18/5206
Sampling Location	Jandakot	Sampled By	Client
Sample Identification	TP11 0.3-0.8m	Sample Description	Sand
Date Sampled	7/11/2018	Date Tested	13/11/2018
Sampling Method:	Sampled by Client, Tested as Received	Preparation Method	WA 105.1

Compaction Details			
Compaction Method	WA 133.1	Rammer Type	Modified
Number of Layers	5	Mass of Rammer (kg)	4.9
% Retained 19.0mm	0	Blows per Layer	16
Maximum Dry Density (t/m³)	1.726	Optimum Moisture (%)	13.5
Desired Dry Density Ratio (%)	95.0	Desired Moisture Ratio (%)	100.0
Specimen Conditions At Compaction			
Dry Density (t/m3)	1.650	Moisture Content (%)	13.4
Density Ratio (%)	95.6	Moisture Ratio (%)	99.1
Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.650	Dry Density Ratio (%)	95.6
Moisture Content (%)	17.6	Moisture Ratio (%)	130.4
Specimen Conditions After Test			
Top 30mm Moisture (%)	17.1	Moisture Ratio (%)	126.5
Remaining Depth (%)	16.8	Moisture Ratio (%)	124.8

California Bearing Ratio (CBR)	9%
Determined at a Penetration of	5.0mm
Correction applied to Penetration	0.0

Comments:

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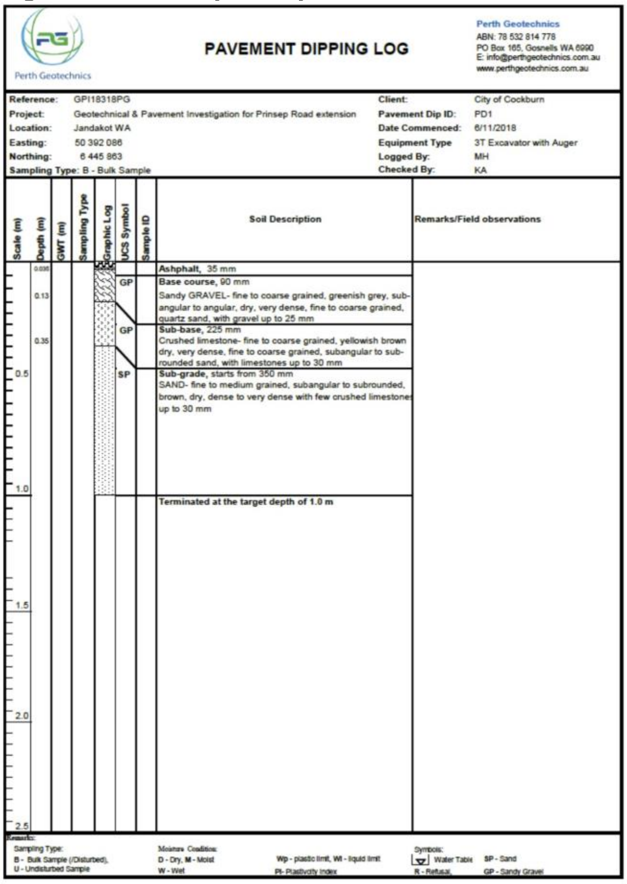
Figure 117: CBR analysis at TP11



Perth Geotechnics

PAVEMENT DIPPING LOG

Perth Geotechnics
ABN: 78 532 814 778
PO Box 165, Gosnells WA 6990
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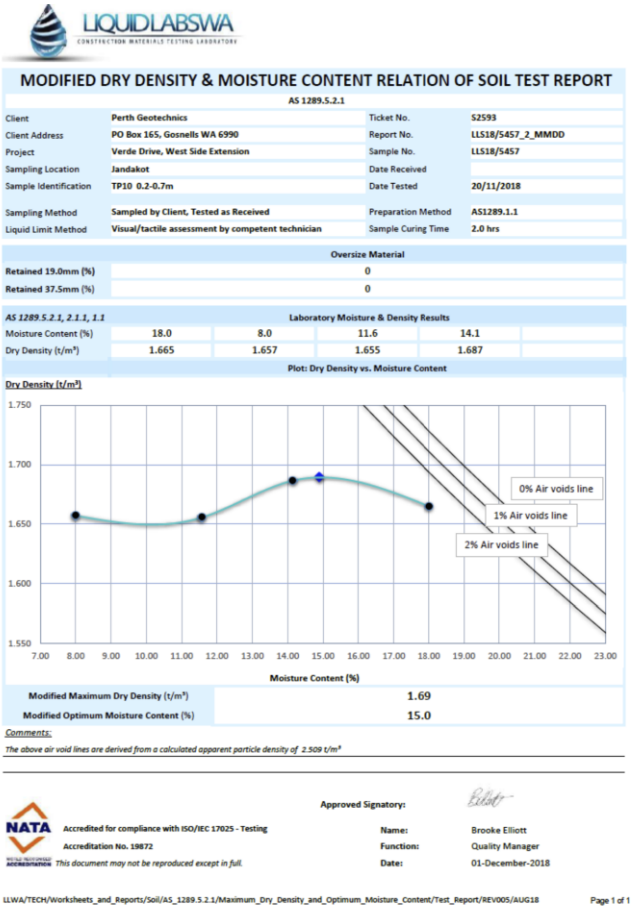
www.perthgeotechnics.com.au

Reference:	GPI18318PG	**Client:**	City of Cockburn
Project:	Geotechnical & Pavement Investigation for Prinsep Road extension	**Pavement Dip ID:**	PD1
Location:	Jandakot WA	**Date Commenced:**	6/11/2018
Easting:	50 392 086	**Equipment Type**	3T Excavator with Auger
Northing:	6 445 863	**Logged By:**	MH
Sampling Type:	B - Bulk Sample	**Checked By:**	KA

Depth (m)	UCS Symbol	Soil Description	Remarks/Field observations
0.035		**Ashphalt**, 35 mm	
0.13	GP	**Base course**, 90 mm Sandy GRAVEL- fine to coarse grained, greenish grey, sub-angular to angular, dry, very dense, fine to coarse grained, quartz sand, with gravel up to 25 mm	
0.35	GP	**Sub-base**, 225 mm Crushed limestone- fine to coarse grained, yellowish brown dry, very dense, fine to coarse grained, subangular to sub-rounded sand, with limestones up to 30 mm	
	SP	**Sub-grade**, starts from 350 mm SAND- fine to medium grained, subangular to subrounded, brown, dry, dense to very dense with few crushed limestone up to 30 mm	
		Terminated at the target depth of 1.0 m	

Remarks:
Sampling Type: B - Bulk Sample (/Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 118: Pavement dipping at PD1



LIQUIDLABSWA
CONSTRUCTION MATERIALS TESTING LABORATORY

MODIFIED DRY DENSITY & MOISTURE CONTENT RELATION OF SOIL TEST REPORT

AS 1289.5.2.1

Client	Perth Geotechnics	Ticket No.	S2593
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5457_2_MMDD
Project	Verde Drive, West Side Extension	Sample No.	LLS18/5457
Sampling Location	Jandakot	Date Received	
Sample Identification	TP10 0.2-0.7m	Date Tested	20/11/2018
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	AS1289.1.1
Liquid Limit Method	Visual/tactile assessment by competent technician	Sample Curing Time	2.0 hrs

Oversize Material	
Retained 19.0mm (%)	0
Retained 37.5mm (%)	0

AS 1289.5.2.1, 2.1.1, 1.1	Laboratory Moisture & Density Results				
Moisture Content (%)	18.0	8.0	11.6	14.1	
Dry Density (t/m³)	1.665	1.657	1.655	1.687	

Plot: Dry Density vs. Moisture Content

Modified Maximum Dry Density (t/m³)	1.69
Modified Optimum Moisture Content (%)	15.0

Comments:

The above air void lines are derived from a calculated apparent particle density of 2.509 t/m³

Approved Signatory:

NATA Accredited for compliance with ISO/IEC 17025 - Testing
Accreditation No. 19872
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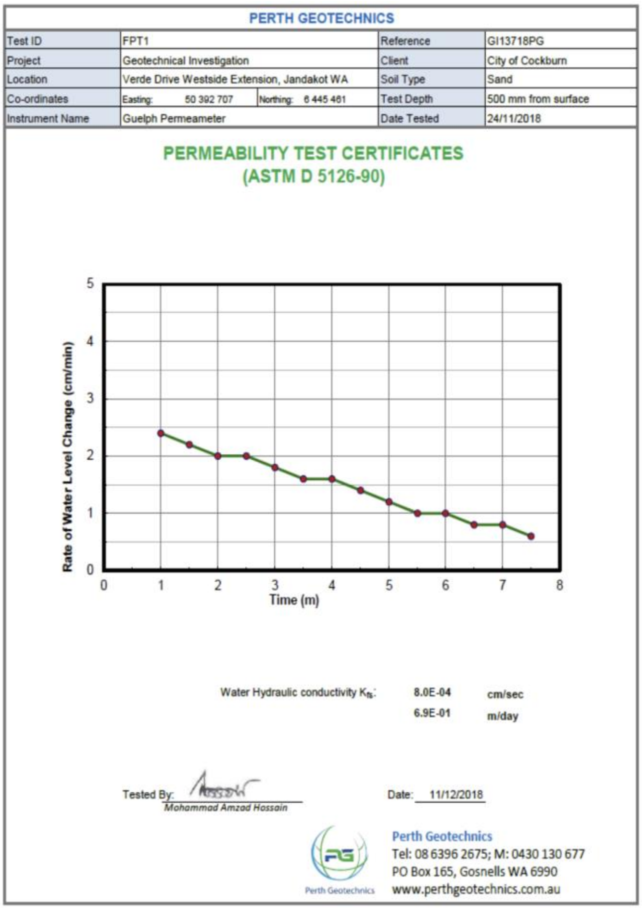
Name: Brooke Elliott
Function: Quality Manager
Date: 01-December-2018

LLWA/TECH/Worksheets_and_Reports/Soil/AS_1289.5.2.1/Maximum_Dry_Density_and_Optimum_Moisture_Content/Test_Report/REV005/AUG18 Page 1 of 1

Figure 119: Max dry density and moisture content at TP10



PERTH GEOTECHNICS

Test ID	FPT1	Reference	GI13718PG
Project	Geotechnical Investigation	Client	City of Cockburn
Location	Verde Drive Westside Extension, Jandakot WA	Soil Type	Sand
Co-ordinates	Easting: 50 392 707 Northing: 6 445 461	Test Depth	500 mm from surface
Instrument Name	Guelph Permeameter	Date Tested	24/11/2018

PERMEABILITY TEST CERTIFICATES
(ASTM D 5126-90)

Water Hydraulic conductivity K_{fs}: 8.0E-04 cm/sec
6.9E-01 m/day

Tested By: Mohammad Amzad Hossain
Date: 11/12/2018

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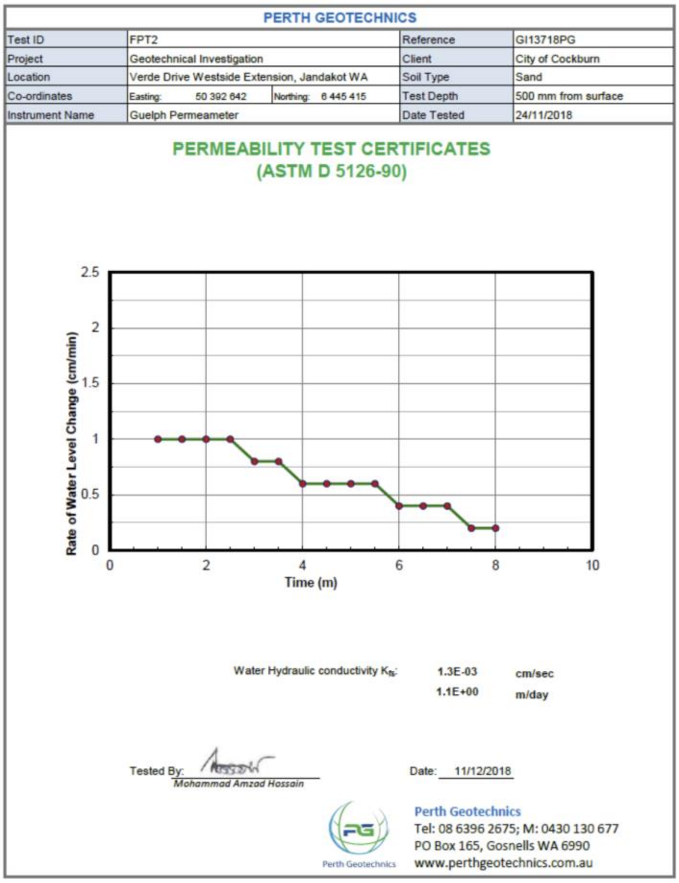
Figure 120: Field Permeability test (Verde Dr.) at TP5



PERTH GEOTECHNICS

Test ID	FPT2	Reference	GI13718PG
Project	Geotechnical Investigation	Client	City of Cockburn
Location	Verde Drive Westside Extension, Jandakot WA	Soil Type	Sand
Co-ordinates	Easting: 50 392 642 Northing: 6 445 415	Test Depth	500 mm from surface
Instrument Name	Guelph Permeameter	Date Tested	24/11/2018

PERMEABILITY TEST CERTIFICATES
(ASTM D 5126-90)

Water Hydraulic conductivity K_{fs}: 1.3E-03 cm/sec
1.1E+00 m/day

Tested By: Mohammad Amzad Hossain
Date: 11/12/2018

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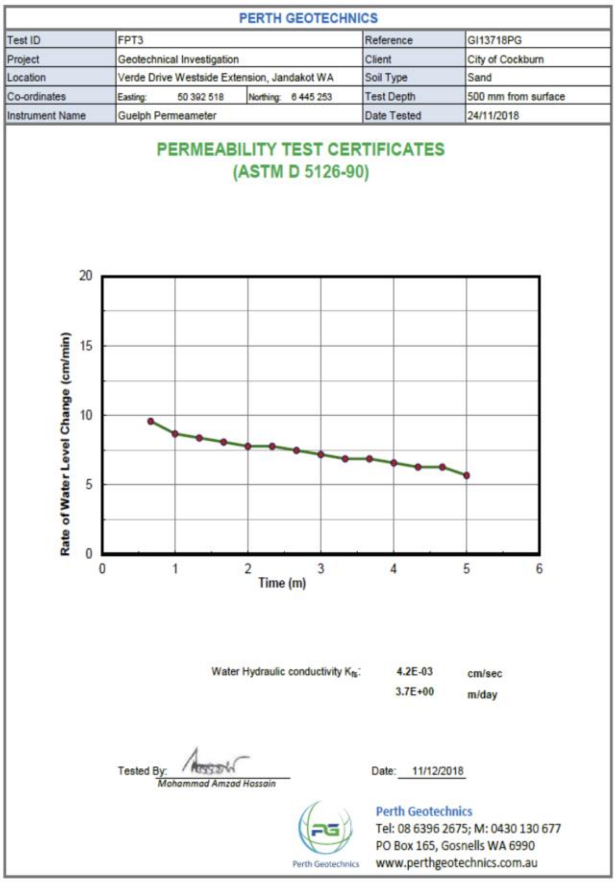
Figure 121: Field Permeability test (Verde Dr.) at TP7



PERTH GEOTECHNICS

Test ID	FPT3	Reference	GI13718PG
Project	Geotechnical Investigation	Client	City of Cockburn
Location	Verde Drive Westside Extension, Jandakot WA	Soil Type	Sand
Co-ordinates	Easting: 50 392 518 Northing: 6 445 253	Test Depth	500 mm from surface
Instrument Name	Guelph Permeameter	Date Tested	24/11/2018

PERMEABILITY TEST CERTIFICATES
(ASTM D 5126-90)

Water Hydraulic conductivity K_{fs}: 4.2E-03 cm/sec
3.7E+00 m/day

Tested By: Mohammad Amzad Hossain
Date: 11/12/2018

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Figure 122: Field Permeability test (Verde Dr.) at TP10

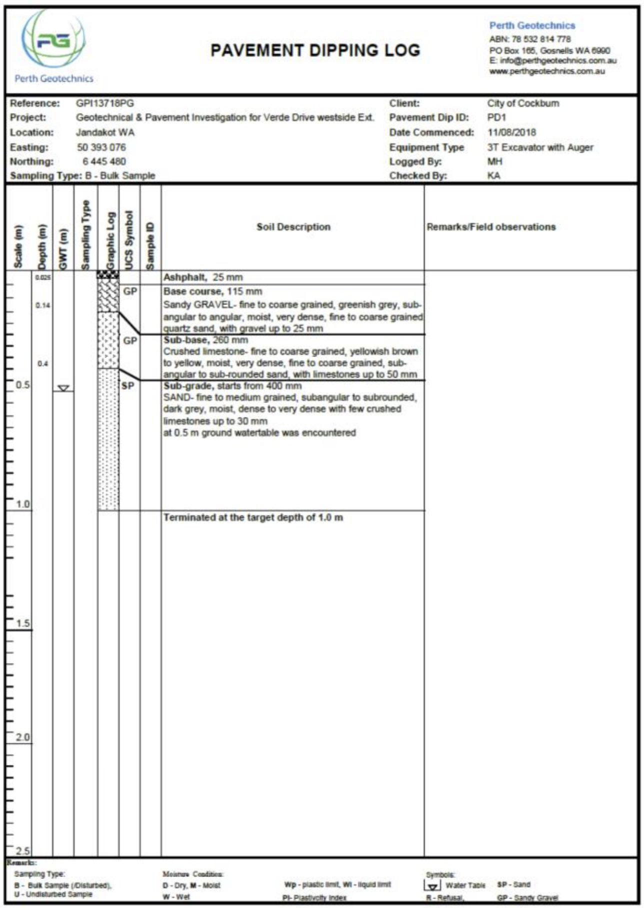


Figure 123: Pavement dipping (Verde Dr.) at PD1

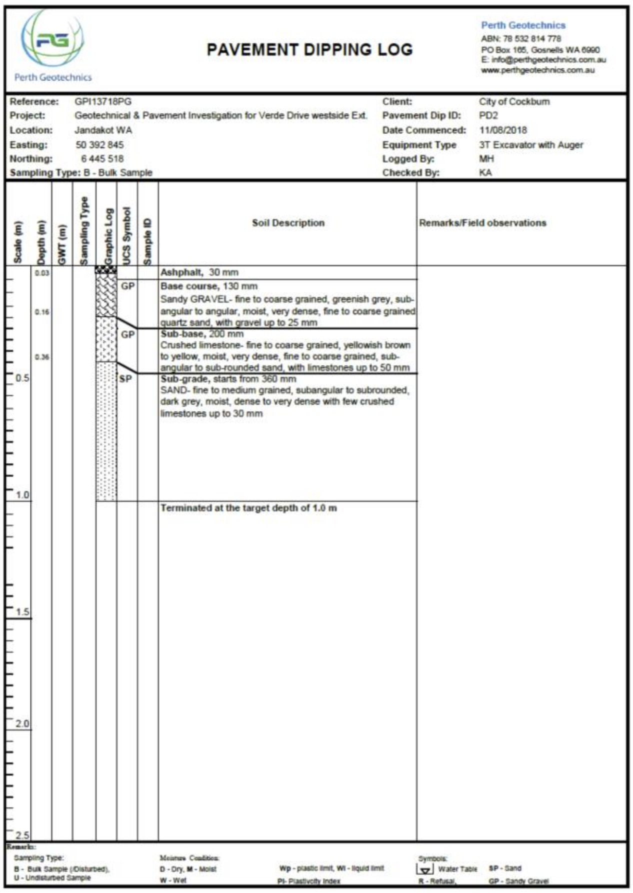


Figure 124: Pavement dipping (Verde Dr.) at PD2

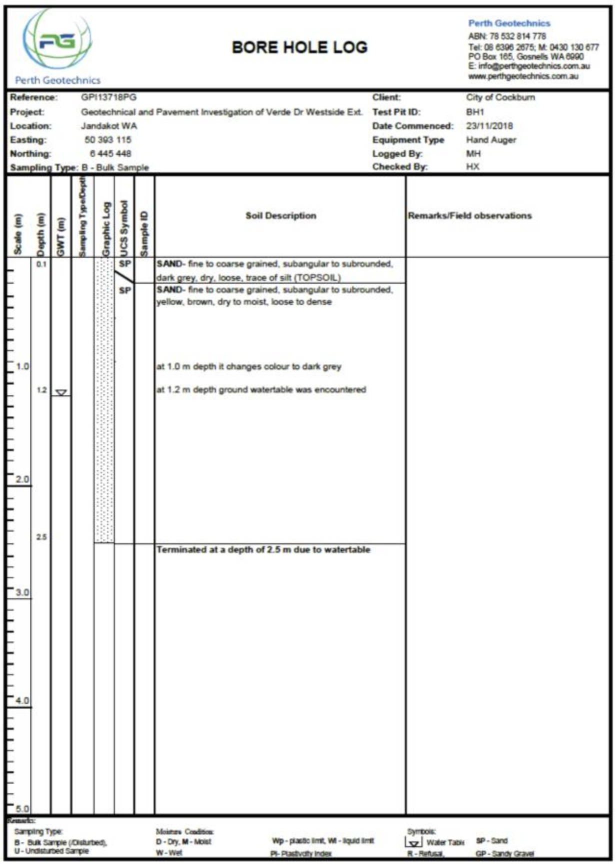


Figure 125: Borehole Log (Verde Dr.) at Location BH1

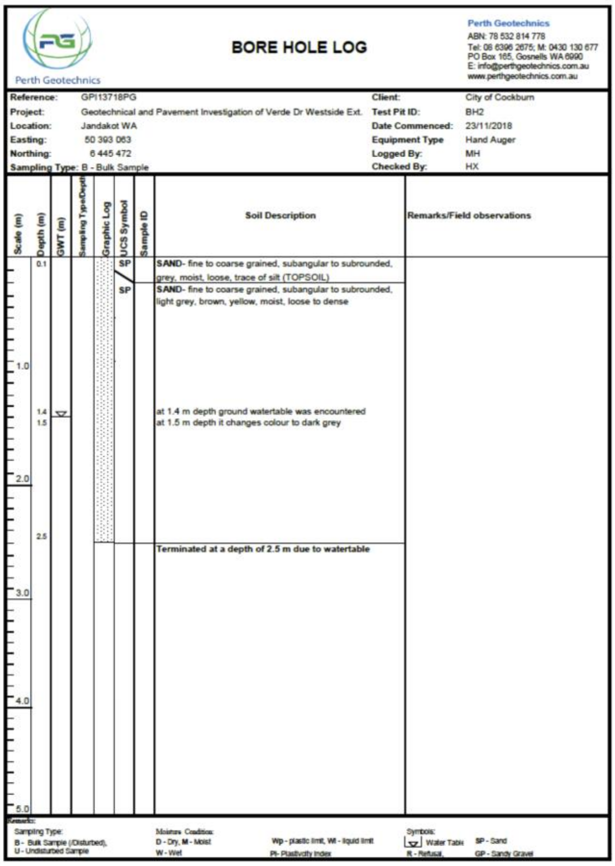


Figure 126: Borehole Log (Verde Dr.) at Location BH2

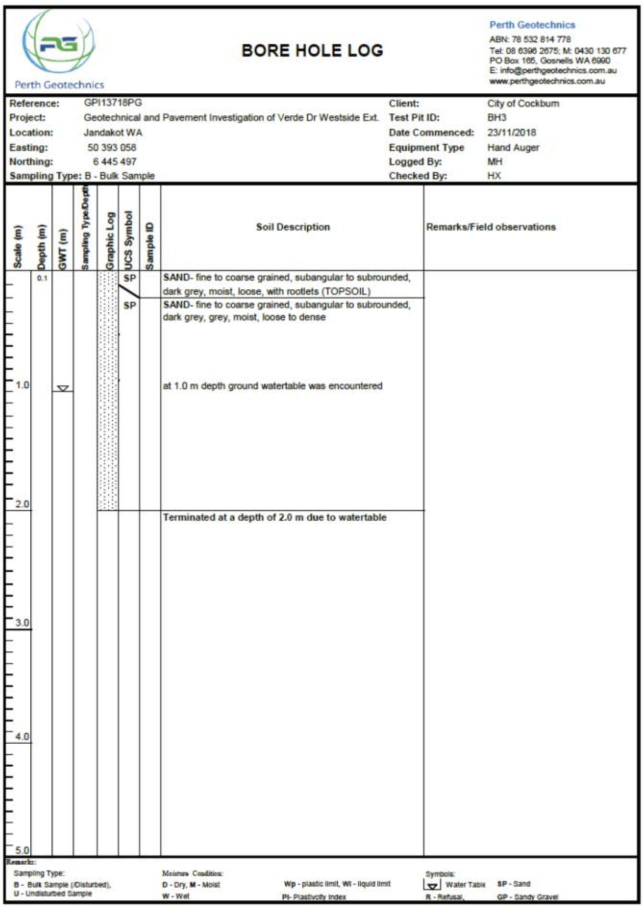


Figure 127: Borehole Log (Verde Dr.) at Location BH3

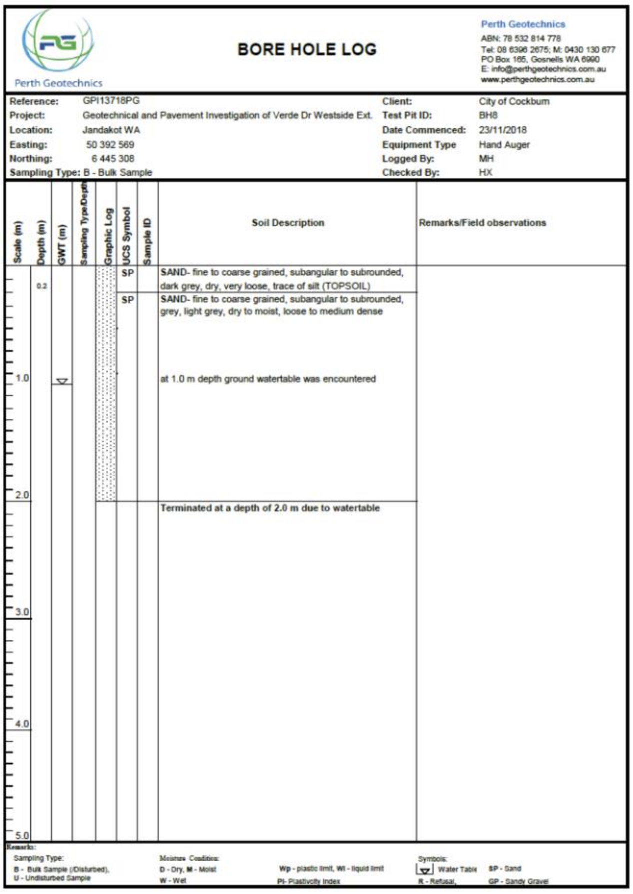


Figure 128: Borehole Log (Verde Dr.) at Location BH8

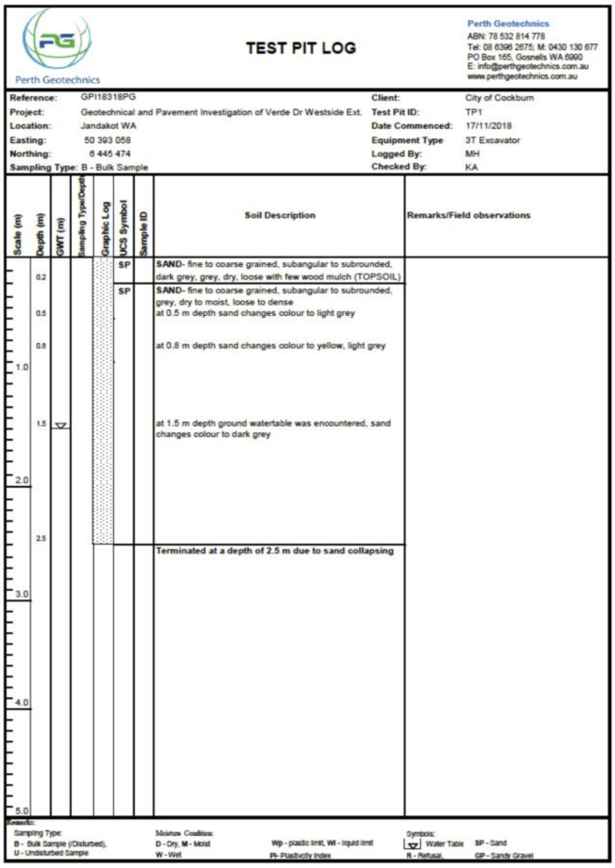


Figure 129: Test Pit Log (Verde Dr.) at Location TP1

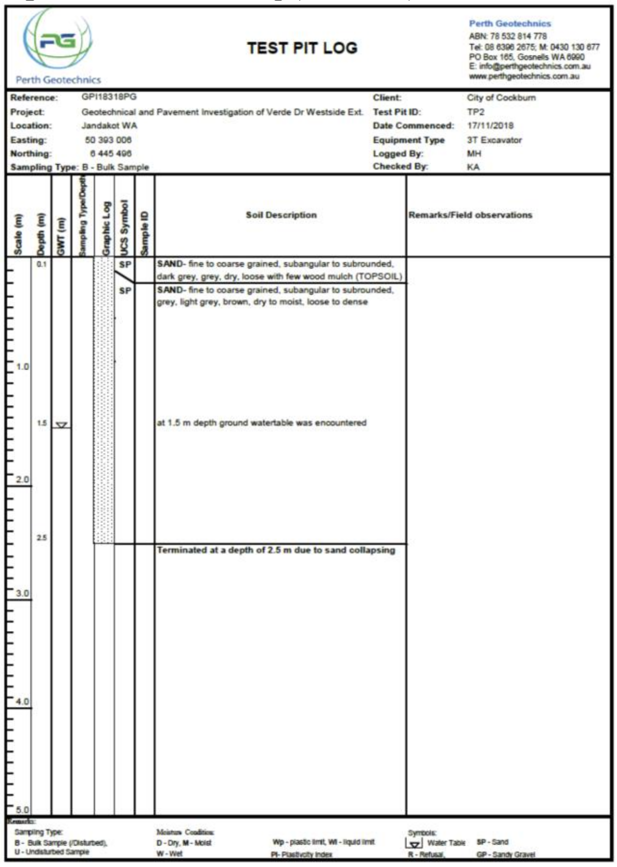
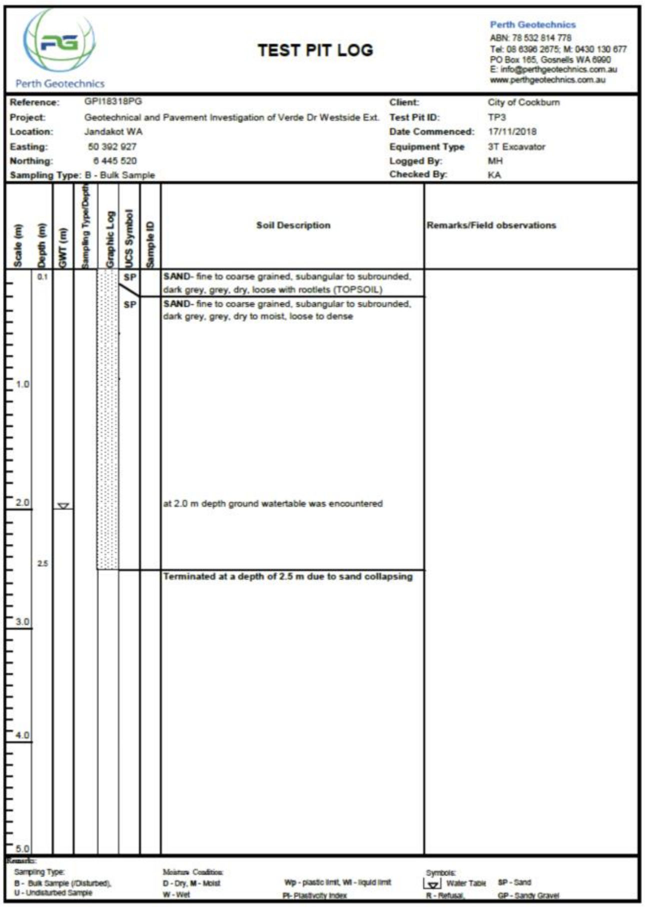


Figure 130: Test Pit Log (Verde Dr.) at Location TP2



TEST PIT LOG

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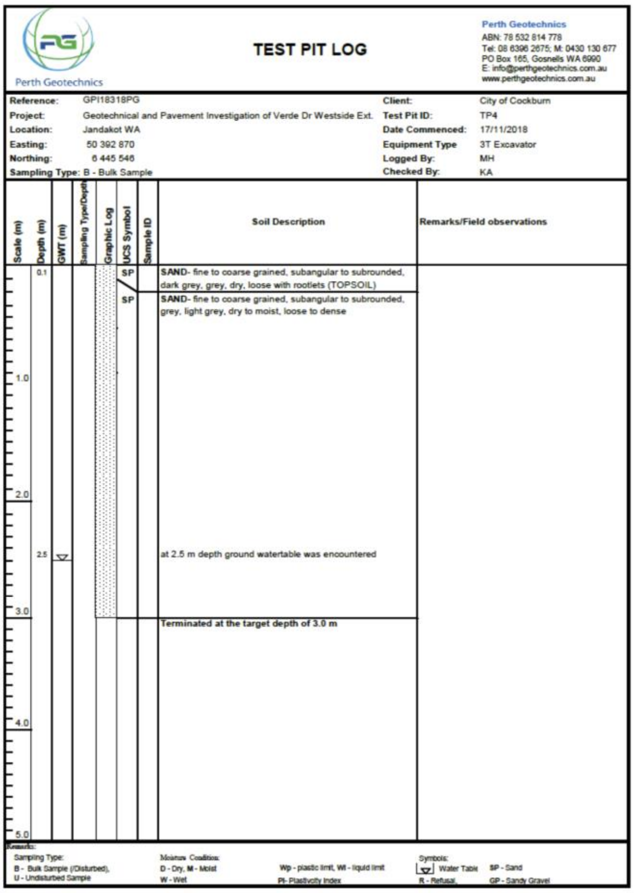
Reference:	GPI18318PG	Client:	City of Cockburn
Project:	Geotechnical and Pavement Investigation of Verde Dr Westside Ext.	Test Pit ID:	TP3
Location:	Jandakot WA	Date Commenced:	17/11/2018
Easting:	50 392 927	Equipment Type	3T Excavator
Northing:	6 445 520	Logged By:	MH
Sampling Type: B - Bulk Sample		Checked By:	KA

Scale (m)	Depth (m)	GWT (m)	Sampling Type/Depth	Graphic Log	UCS Symbol	Sample ID	Soil Description	Remarks/Field observations
	0.1				SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry, loose with rootlets (TOPSOIL)	
					SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry to moist, loose to dense	
1.0								
2.0		▽					at 2.0 m depth ground watertable was encountered	
	2.5						Terminated at a depth of 2.5 m due to sand collapsing	
3.0								
4.0								
5.0								

Remarks:
Sampling Type: B - Bulk Sample (/Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 131: Test Pit Log (Verde Dr.) at Location TP3



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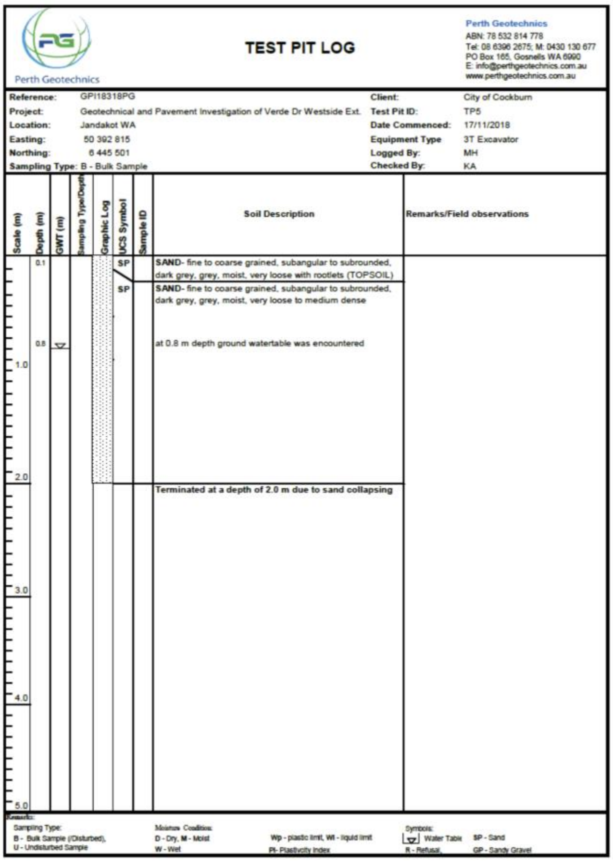
Reference:	GPI18318PG	Client:	City of Cockburn
Project:	Geotechnical and Pavement Investigation of Verde Dr Westside Ext.	Test Pit ID:	TP4
Location:	Jandakot WA	Date Commenced:	17/11/2018
Easting:	50 392 870	Equipment Type	3T Excavator
Northing:	6 445 546	Logged By:	MH
Sampling Type: B - Bulk Sample		Checked By:	KA

Scale (m)	Depth (m)	GWT (m)	Sampling Type/Depth	Graphic Log	UCS Symbol	Sample ID	Soil Description	Remarks/Field observations
	0.1				SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry, loose with rootlets (TOPSOIL)	
					SP		SAND- fine to coarse grained, subangular to subrounded, grey, light grey, dry to moist, loose to dense	
1.0								
2.0								
	2.5	▽					at 2.5 m depth ground watertable was encountered	
3.0							Terminated at the target depth of 3.0 m	
4.0								
5.0								

Remarks:
Sampling Type: B - Bulk Sample (/Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 132: Test Pit Log (Verde Dr.) at Location TP4



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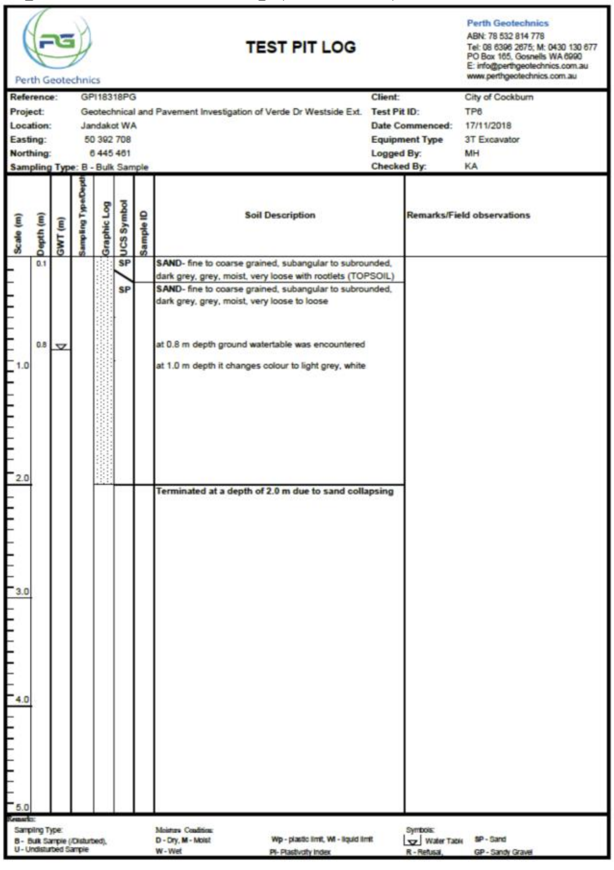
Reference:	GPI18318PG	Client:	City of Cockburn
Project:	Geotechnical and Pavement Investigation of Verde Dr Westside Ext.	Test Pit ID:	TP5
Location:	Jandakot WA	Date Commenced:	17/11/2018
Easting:	50 392 815	Equipment Type	3T Excavator
Northing:	6 445 501	Logged By:	MH
Sampling Type: B - Bulk Sample		Checked By:	KA

Scale (m)	Depth (m)	GWT (m)	Sampling Type/Depth	Graphic Log	UCS Symbol	Sample ID	Soil Description	Remarks/Field observations
	0.1				SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, moist, very loose with rootlets (TOPSOIL)	
					SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, moist, very loose to medium dense	
	0.8	▽					at 0.8 m depth ground watertable was encountered	
1.0								
2.0							Terminated at a depth of 2.0 m due to sand collapsing	
3.0								
4.0								
5.0								

Remarks:
Sampling Type: B - Bulk Sample (/Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 133: Test Pit Log (Verde Dr.) at Location TP5



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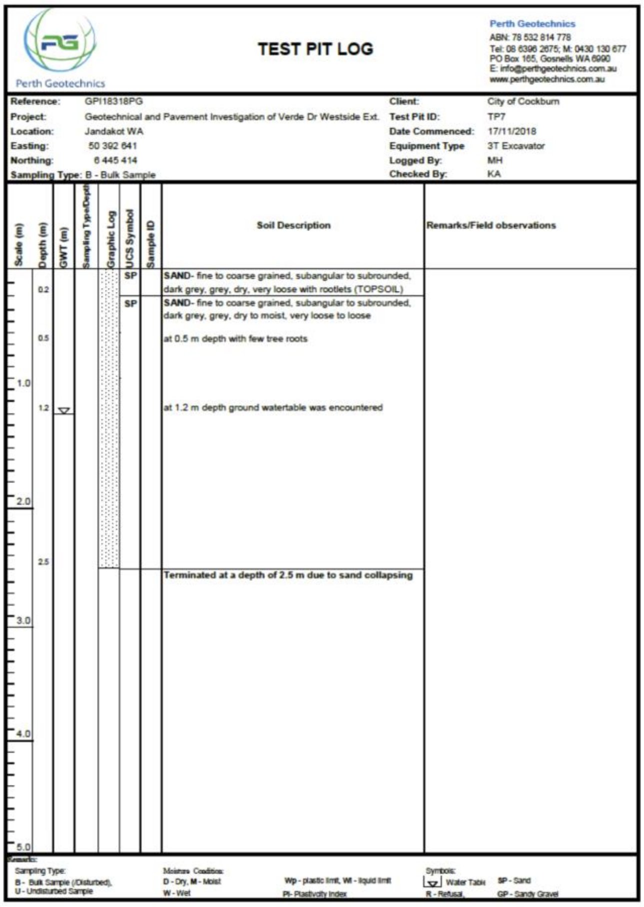
Reference:	GPI18318PG	Client:	City of Cockburn
Project:	Geotechnical and Pavement Investigation of Verde Dr Westside Ext.	Test Pit ID:	TP6
Location:	Jandakot WA	Date Commenced:	17/11/2018
Easting:	50 392 708	Equipment Type	3T Excavator
Northing:	6 445 461	Logged By:	MH
Sampling Type: B - Bulk Sample		Checked By:	KA

Scale (m)	Depth (m)	GWT (m)	Sampling Type/Depth	Graphic Log	UCS Symbol	Sample ID	Soil Description	Remarks/Field observations
	0.1				SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, moist, very loose with rootlets (TOPSOIL)	
					SP		SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, moist, very loose to loose	
	0.8	▽					at 0.8 m depth ground watertable was encountered	
1.0							at 1.0 m depth it changes colour to light grey, white	
2.0							Terminated at a depth of 2.0 m due to sand collapsing	
3.0								
4.0								
5.0								

Remarks:
Sampling Type: B - Bulk Sample (/Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI- Plasticity Index
Symbols: Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 134: Test Pit Log (Verde Dr.) at Location TP6



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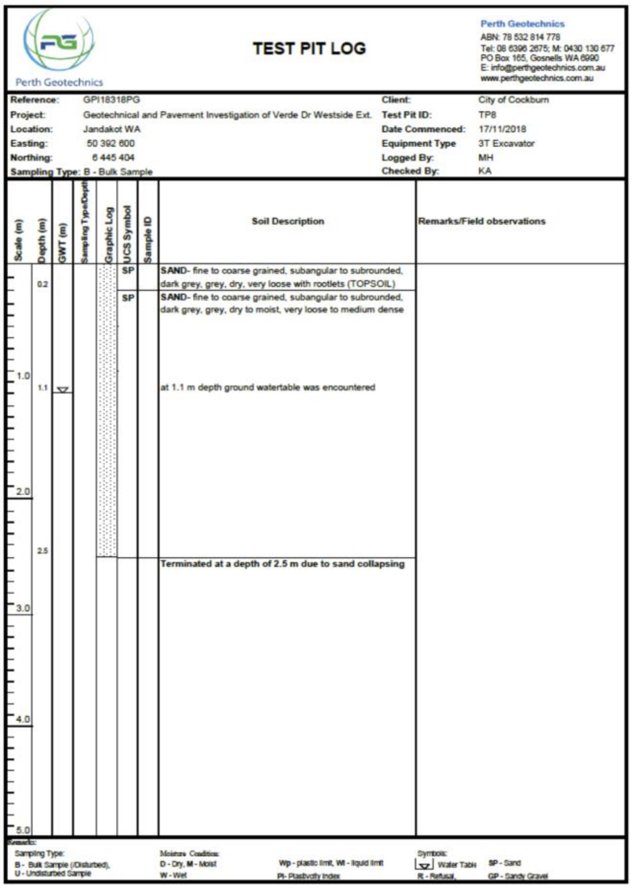
www.perthgeotechnics.com.au

Reference: GPI18318PG | Client: City of Cockburn
Project: Geotechnical and Pavement Investigation of Verde Dr Westside Ext. | Test Pit ID: TP7
Location: Jandakot WA | Date Commenced: 17/11/2018
Easting: 50 392 641 | Equipment Type: 3T Excavator
Northing: 6 445 414 | Logged By: MH
Sampling Type: B - Bulk Sample | Checked By: KA

Depth (m)	GWT (m)	UCS Symbol	Soil Description
0.2		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry, very loose with rootlets (TOPSOIL)
		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry to moist, very loose to loose
0.5			at 0.5 m depth with few tree roots
1.2	▽		at 1.2 m depth ground watertable was encountered
2.5			Terminated at a depth of 2.5 m due to sand collapsing

Remarks:
Sampling Type: B - Bulk Sample (Disturbed), U - Undisturbed Sample
Moisture Condition: D - Dry, M - Moist, W - Wet
Wp - plastic limit, Wl - liquid limit, PI - Plasticity Index
Symbols: ▽ Water Table, R - Refusal, SP - Sand, GP - Sandy Gravel

Figure 135: Test Pit Log (Verde Dr.) at Location TP7



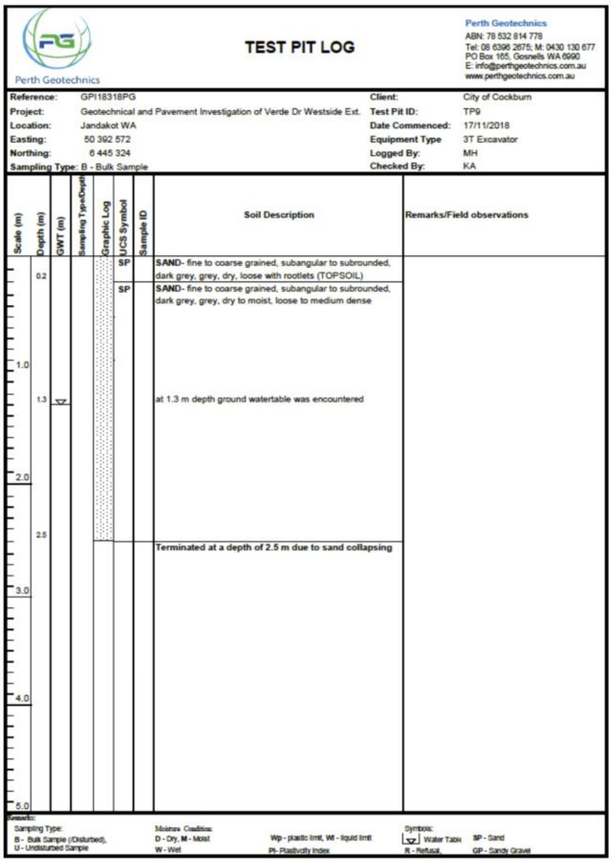
Perth Geotechnics

TEST PIT LOG

Reference: GPI18318PG | Client: City of Cockburn
Project: Geotechnical and Pavement Investigation of Verde Dr Westside Ext. | Test Pit ID: TP8
Location: Jandakot WA | Date Commenced: 17/11/2018
Easting: 50 392 600 | Equipment Type: 3T Excavator
Northing: 6 445 404 | Logged By: MH
Sampling Type: B - Bulk Sample | Checked By: KA

Depth (m)	GWT (m)	UCS Symbol	Soil Description
0.2		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry, very loose with rootlets (TOPSOIL)
		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry to moist, very loose to medium dense
1.1	▽		at 1.1 m depth ground watertable was encountered
2.5			Terminated at a depth of 2.5 m due to sand collapsing

Figure 136: Test Pit Log (Verde Dr.) at Location TP8



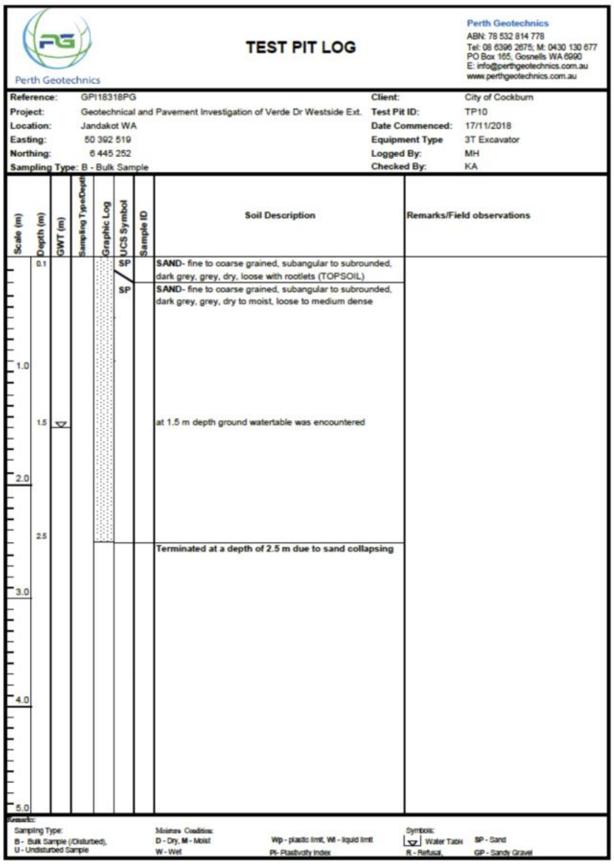
Perth Geotechnics

TEST PIT LOG

Reference: GPI18318PG | Client: City of Cockburn
Project: Geotechnical and Pavement Investigation of Verde Dr Westside Ext. | Test Pit ID: TP9
Location: Jandakot WA | Date Commenced: 17/11/2018
Easting: 50 392 572 | Equipment Type: 3T Excavator
Northing: 6 445 324 | Logged By: MH
Sampling Type: B - Bulk Sample | Checked By: KA

Depth (m)	GWT (m)	UCS Symbol	Soil Description
0.2		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry, loose with rootlets (TOPSOIL)
		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry to moist, loose to medium dense
1.3	▽		at 1.3 m depth ground watertable was encountered
2.5			Terminated at a depth of 2.5 m due to sand collapsing

Figure 137: Test Pit Log (Verde Dr.) at Location TP9



Perth Geotechnics

TEST PIT LOG

Reference: GPI18318PG | Client: City of Cockburn
Project: Geotechnical and Pavement Investigation of Verde Dr Westside Ext. | Test Pit ID: TP10
Location: Jandakot WA | Date Commenced: 17/11/2018
Easting: 50 392 519 | Equipment Type: 3T Excavator
Northing: 6 445 252 | Logged By: MH
Sampling Type: B - Bulk Sample | Checked By: KA

Depth (m)	GWT (m)	UCS Symbol	Soil Description
0.1		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry, loose with rootlets (TOPSOIL)
		SP	SAND- fine to coarse grained, subangular to subrounded, dark grey, grey, dry to moist, loose to medium dense
1.5	▽		at 1.5 m depth ground watertable was encountered
2.5			Terminated at a depth of 2.5 m due to sand collapsing

Figure 138: Test Pit Log (Verde Dr.) at Location TP10

Perth Geotechnics

DYNAMIC CONE PENETROMETER (DCP)
TEST CERTIFICATE

(AS 1289.6.3.2)
Correlation of Sand Density - Table 6.4.6.1 (A) & (B) HB 160-2006

Client	City of Cockburn	Project	Verde Drive Westside Extension
Reference	GPI13718PG	Location	Jandakot
Date Tested	17/11/2018	Tested By	MH/HX

References:	DCP1 (TP1)	DCP2 (TP2)	DCP3 (TP3)	DCP4 (TP4)	DCP5 (TP5)	DCP6 (TP6)
Depth below ground level test commenced	**Penetration Resistance - Blows/100mm**					
0-100	<1	<1	<1	1	<1	<1
100-200	2	2	1	1	<1	<1
200-300	3	2	2	2	1	<1
300-400	4	3	3	2	2	1
400-500	4	4	4	3	2	<1
500-600	4	4	6	4	3	<1
600-700	5	6	8	4	2	1
700-800	6	7	8	4	3	<1
800-900	7	8	7	4	2	<1
900-1000	8	8	8	5	3	1
Depth below ground level test commenced	**Density Classification**					
0-100	VL	VL	VL	L	VL	VL
100-200	L	L	L	L	VL	VL
200-300	MD	L	L	L	L	VL
300-400	D	MD	MD	L	L	L
400-500	D	D	D	MD	L	VL
500-600	D	D	D	D	MD	VL
600-700	D	D	D	D	L	L
700-800	D	D	D	D	MD	VL
800-900	D	D	D	D	L	VL
900-1000	D	D	D	D	MD	L

Remarks: R= Refusal

Table A: H = Hard >10, VSt = Very Stiff, 5 – 10, St = Stiff, 3 – 4, F = Firm, 1 – 2, VS = Very Soft < 1
Table B: VD = Very Dense > 8, D = Dense, 4 – 8, MD = Medium Dense, 2 – 3, L = Loose, 1 – 2, VL = Very Loose < 1

Figure 139: DCP data for Verde Dr. test pits (TP1 to TP6)

Perth Geotechnics

DYNAMIC CONE PENETROMETER (DCP)
TEST CERTIFICATE

(AS 1289.6.3.2)
Correlation of Sand Density - Table 6.4.6.1 (A) & (B) HB 160-2006

Client	City of Cockburn	Project	Verde Drive Westside Extension
Reference	GPI13718PG	Location	Jandakot
Date Tested	17/11/2018	Tested By	MH/HX

References:	DCP7 (TP7)	DCP8 (TP8)	DCP9 (TP9)	DCP10 (TP10)	DCP11 (PD1)	DCP12 (PD2)
Depth below ground level test commenced	**Penetration Resistance - Blows/100mm**					
0-100	<1	<1	1	1	10	9
100-200	<1	<1	2	2	12	11
200-300	1	2	3	2	15	14
300-400	1	2	2	3	25>R	25>R
400-500	2	1	2	2	-	-
500-600	2	2	3	3	-	-
600-700	1	2	2	2	-	-
700-800	2	3	3	3	-	-
800-900	2	2	3	3	-	-
900-1000	2	2	3	3	-	-
Depth below ground level test commenced	**Density Classification**					
0-100	VL	VL	L	L	VD	VD
100-200	VL	VL	L	L	VD	VD
200-300	L	L	MD	L	VD	VD
300-400	L	L	L	MD	VD	VD
400-500	L	L	L	L	-	-
500-600	L	L	MD	MD	-	-
600-700	L	L	L	L	-	-
700-800	L	MD	MD	MD	-	-
800-900	L	D	MD	MD	-	-
900-1000	L	D	MD	MD	-	-

Remarks: R= Refusal

Table A: H = Hard >10, VSt = Very Stiff, 5 – 10, St = Stiff, 3 – 4, F = Firm, 1 – 2, VS = Very Soft < 1
Table B: VD = Very Dense > 8, D = Dense, 4 – 8, MD = Medium Dense, 2 – 3, L = Loose, 1 – 2, VL = Very Loose < 1

Figure 140: DCP data for Verde Dr. test pits (TP7 to TP10, PD1, PD2)

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CONSTRUCTION MATERIALS TESTING LABORATORY

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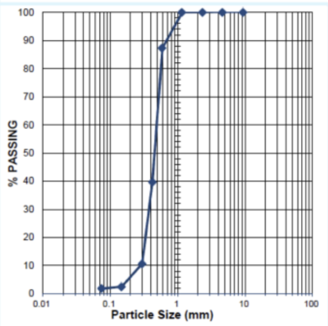
Carlisle, WA 6101

SOIL CLASSIFICATION TEST REPORT

Client	Perth Geotechnics	Ticket No.	52593
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5528_2_PSD
Project	Verde Drive, West Side Extension	Sample No.	LLS18/5528
Sampling Location	Jandakot	Sampled By	Client
Sample Identification	TP4 0.3-0.8m		
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	AS1289.1.1
Sample History	Air Dried	Wet or Dry Sieved	Dry Sieved

PARTICLE SIZE DISTRIBUTION - ANALYSIS BY SIEVING
AS 1289.3.6.1



Sieve Size (mm)	Percent Passing Sieve (%)
75.00	
53.00	
37.50	
19.00	
9.50	100
4.75	100
2.36	100
1.180	100
0.600	87
0.425	40
0.300	11
0.150	2
0.075	2

Comments:

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Approved Signatory	
Name	Brooke Elliott
Function	Quality Manager
Issue Date	01-December-2018

LLWA/TECH/Worksheets_and_Reports/Soil/AS_1289.3.6.1/Soil_Classification/Test_Report/REV004/JUN18 Page 1 of 1

Figure 141: Particle Size analysis at TP4 (Verde Dr.)

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CONSTRUCTION MATERIALS TESTING LABORATORY

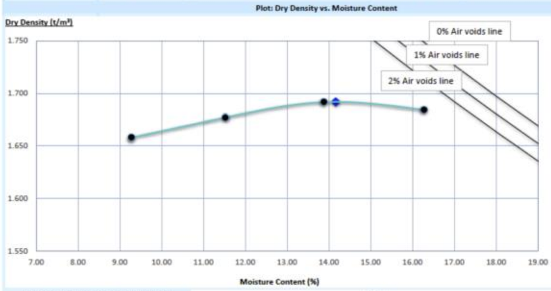
MODIFIED DRY DENSITY & MOISTURE CONTENT RELATION OF SOIL TEST REPORT
AS 1289.5.2.1

Client	Perth Geotechnics	Ticket No.	52593
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5528_2_MMDD
Project	Verde Drive, West Side Extension	Sample No.	LLS18/5528
Sampling Location	Jandakot	Date Received	-
Sample Identification	TP4 0.3-0.8m	Date Tested	23/11/2018
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	AS1289.1.1
Liquid Limit Method	Visual/tactile assessment by competent technician	Sample Curing Time	2.0 hrs

Oversize Material	
Retained 19.0mm (%)	0
Retained 37.5mm (%)	0

AS 1289.5.2.1, 2.1.1, 1.1	Laboratory Moisture & Density Results			
Moisture Content (%)	16.3	9.3	11.5	13.9
Dry Density (t/m³)	1.684	1.658	1.677	1.692

Plot: Dry Density vs. Moisture Content



Modified Maximum Dry Density (t/m³)	1.69
Modified Optimum Moisture Content (%)	14.0

Comments:
The above air void lines are derived from a calculated apparent particle density of 2.444 t/m³

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Name:	Matt van Herk
Function:	Laboratory Manager
Date:	01-December-2018

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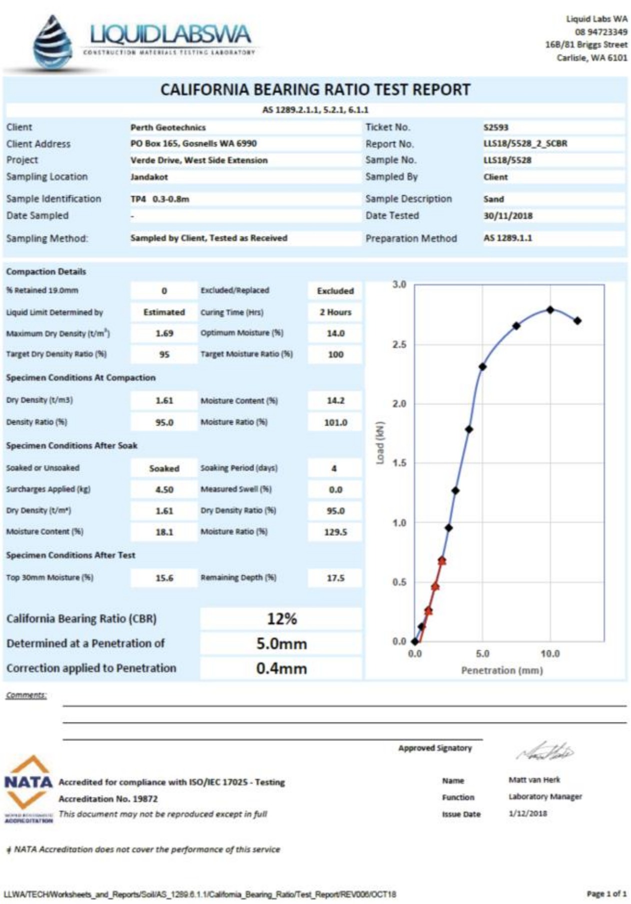
Figure 142: Max dry density and moisture content at TP4 (Verde Dr.)



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CALIFORNIA BEARING RATIO TEST REPORT
AS 1289.2.1.1, 5.2.1, 6.1.1

Client	Perth Geotechnics	Ticket No.	S2593
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5528_2_SCBR
Project	Verde Drive, West Side Extension	Sample No.	LLS18/5528
Sampling Location	Jandakot	Sampled By	Client
Sample Identification	TP4 0.3-0.8m	Sample Description	Sand
Date Sampled	-	Date Tested	30/11/2018
Sampling Method:	Sampled by Client, Tested as Received	Preparation Method	AS 1289.1.1

Compaction Details			
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Liquid Limit Determined by	Estimated	Curing Time (Hrs)	2 Hours
Maximum Dry Density (t/m³)	1.69	Optimum Moisture (%)	14.0
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100
Specimen Conditions At Compaction			
Dry Density (t/m3)	1.61	Moisture Content (%)	14.2
Density Ratio (%)	95.0	Moisture Ratio (%)	101.0
Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.61	Dry Density Ratio (%)	95.0
Moisture Content (%)	18.1	Moisture Ratio (%)	129.5
Specimen Conditions After Test			
Top 30mm Moisture (%)	15.6	Remaining Depth (%)	17.5
California Bearing Ratio (CBR)	12%		
Determined at a Penetration of	5.0mm		
Correction applied to Penetration	0.4mm		

Comments:

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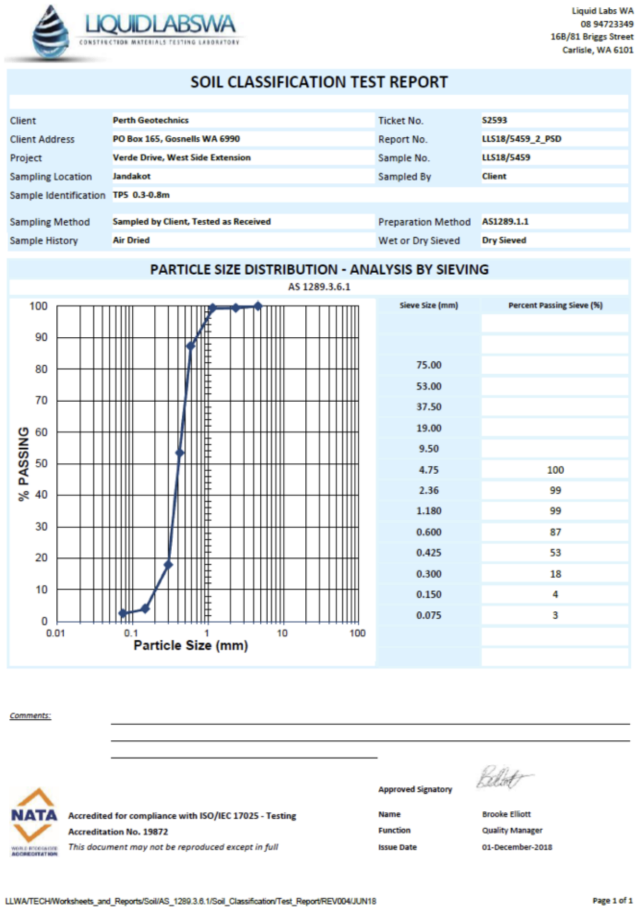
Page 1 of 1

Figure 143: CBR analysis at TP4 (Verde Dr.)



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Carlisle, WA 6101

SOIL CLASSIFICATION TEST REPORT

Client	Perth Geotechnics	Ticket No.	S2593
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5459_2_PSD
Project	Verde Drive, West Side Extension	Sample No.	LLS18/5459
Sampling Location	Jandakot	Sampled By	Client
Sample Identification	TP5 0.3-0.8m		
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	AS1289.1.1
Sample History	Air Dried	Wet or Dry Sieved	Dry Sieved

PARTICLE SIZE DISTRIBUTION - ANALYSIS BY SIEVING
AS 1289.3.6.1

Sieve Size (mm)	Percent Passing Sieve (%)
75.00	
53.00	
37.50	
19.00	
9.50	
4.75	100
2.36	99
1.180	99
0.600	87
0.425	53
0.300	18
0.150	4
0.075	3

Comments:

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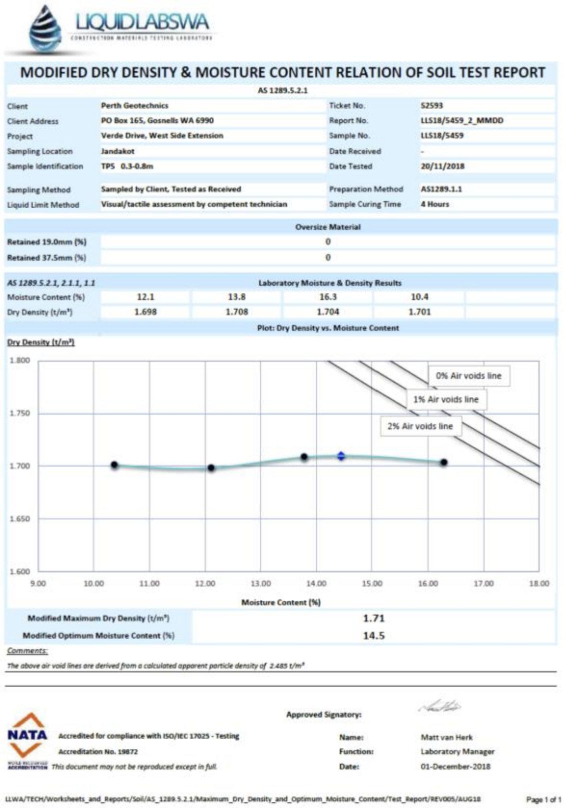
Function: Quality Manager
Issue Date: 01-December-2018
LLWA/TECH/Worksheets_and_Reports/Soil/AS_1289.3.6.1/Soil_Classification/Test_Report/REV004/JUN18
Page 1 of 1

Figure 144: Particle Size analysis at TP5 (Verde Dr.)



MODIFIED DRY DENSITY & MOISTURE CONTENT RELATION OF SOIL TEST REPORT
AS 1289.5.2.1

Client	Perth Geotechnics	Ticket No.	S2593
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5459_2_MMDD
Project	Verde Drive, West Side Extension	Sample No.	LLS18/5459
Sampling Location	Jandakot	Date Received	-
Sample Identification	TP5 0.3-0.8m	Date Tested	20/11/2018
Sampling Method	Sampled by Client, Tested as Received	Preparation Method	AS1289.1.1
Liquid Limit Method	Visual/tactile assessment by competent technician	Sample Curing Time	4 Hours

Oversize Material

Retained 19.0mm (%)	0
Retained 37.5mm (%)	0

AS 1289.5.2.1, 2.1.1, 1.1	Laboratory Moisture & Density Results			
Moisture Content (%)	12.1	13.8	16.3	10.4
Dry Density (t/m³)	1.698	1.708	1.704	1.701

Plot: Dry Density vs. Moisture Content

Modified Maximum Dry Density (t/m³)	1.71
Modified Optimum Moisture Content (%)	14.5

Comments:
The above air void lines are derived from a calculated apparent particle density of 2.485 t/m³

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Page 1 of 1

Figure 145: Max dry density and moisture content at TP5 (Verde Dr.) (Verde Dr.)

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CALIFORNIA BEARING RATIO TEST REPORT
AS 1289.2.1.1, 5.2.1, 6.1.1

Client	Perth Geotechnics	Ticket No.	S2593
Client Address	PO Box 165, Gosnells WA 6990	Report No.	LLS18/5459_2_SCBR
Project	Verde Drive, West Side Extension	Sample No.	LLS18/5459
Sampling Location	Jandakot	Sampled By	Client
Sample Identification	TP5 0.3-0.8m	Sample Description	Sand
Date Sampled	-	Date Tested	27/11/2018
Sampling Method:	Sampled by Client, Tested as Received	Preparation Method	AS 1289.1.1

Compaction Details			
% Retained 19.0mm	0	Excluded/Replaced	Excluded
Liquid Limit Determined by	Estimated	Curing Time (Hrs)	2 Hours
Maximum Dry Density (t/m³)	1.71	Optimum Moisture (%)	14.5
Target Dry Density Ratio (%)	95	Target Moisture Ratio (%)	100
Specimen Conditions At Compaction			
Dry Density (t/m3)	1.62	Moisture Content (%)	14.7
Density Ratio (%)	95.0	Moisture Ratio (%)	101.5
Specimen Conditions After Soak			
Soaked or Unsoaked	Soaked	Soaking Period (days)	4
Surcharges Applied (kg)	4.50	Measured Swell (%)	0.0
Dry Density (t/m³)	1.62	Dry Density Ratio (%)	95.0
Moisture Content (%)	18.5	Moisture Ratio (%)	128.0
Specimen Conditions After Test			
Top 30mm Moisture (%)	16.2	Remaining Depth (%)	18.3
California Bearing Ratio (CBR)	13%		
Determined at a Penetration of	5.0mm		
Correction applied to Penetration	3.7mm		

Comments:

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Page 1 of 1

Figure 146: CBR analysis at TP5 (Verde Dr.)

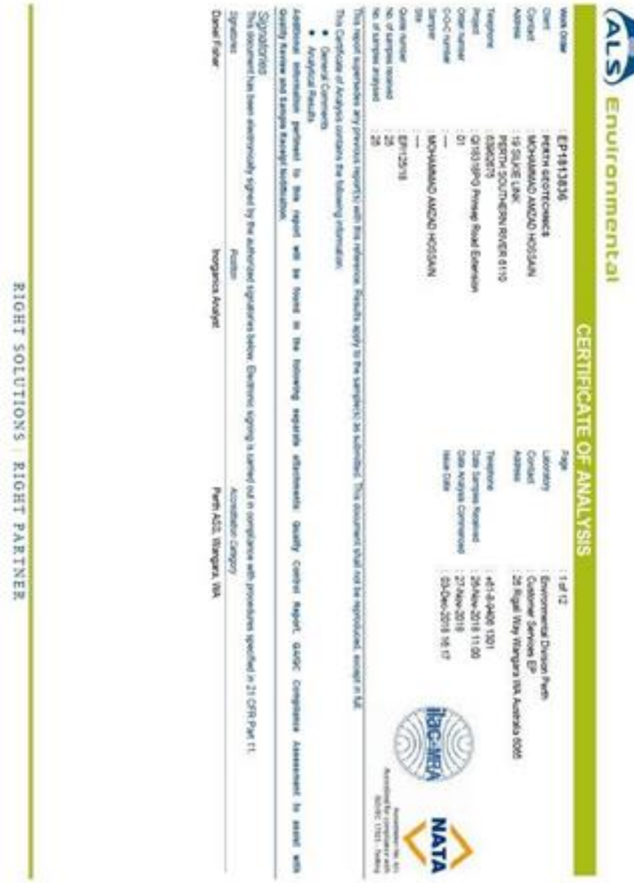


Figure 147: Acid Sulfate Soil (ASS) Certificate (1 of 12)

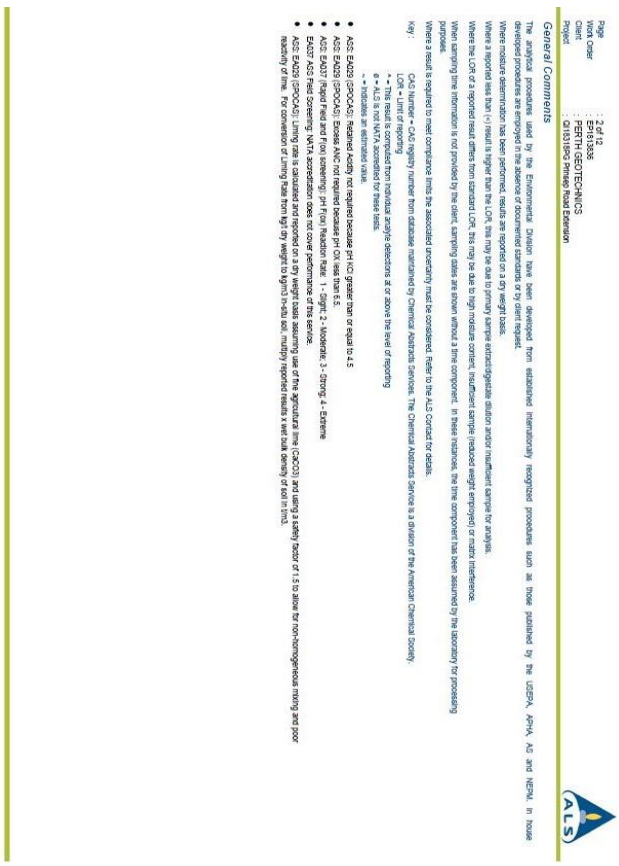


Figure 148: Acid Sulfate Soil (ASS) Certificate (2 of 12)

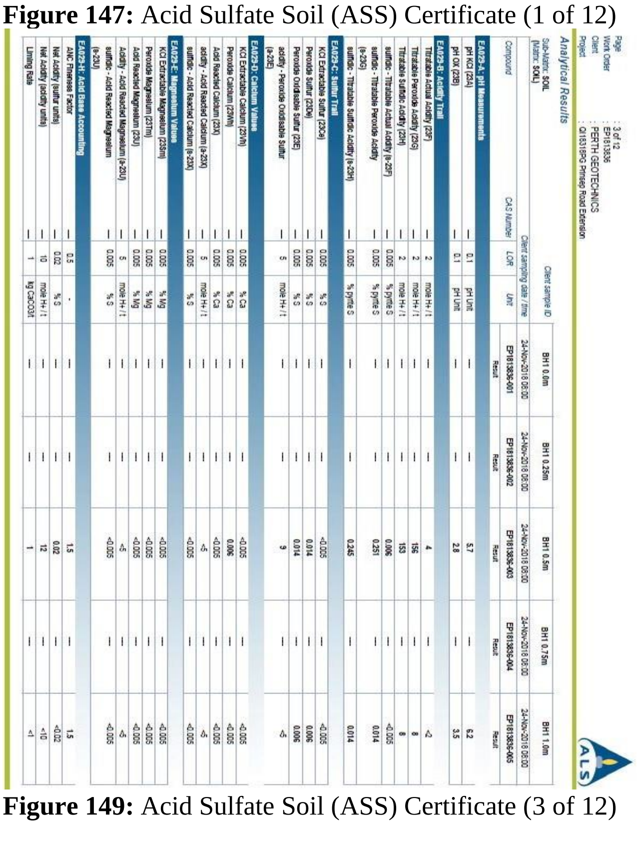


Figure 149: Acid Sulfate Soil (ASS) Certificate (3 of 12)

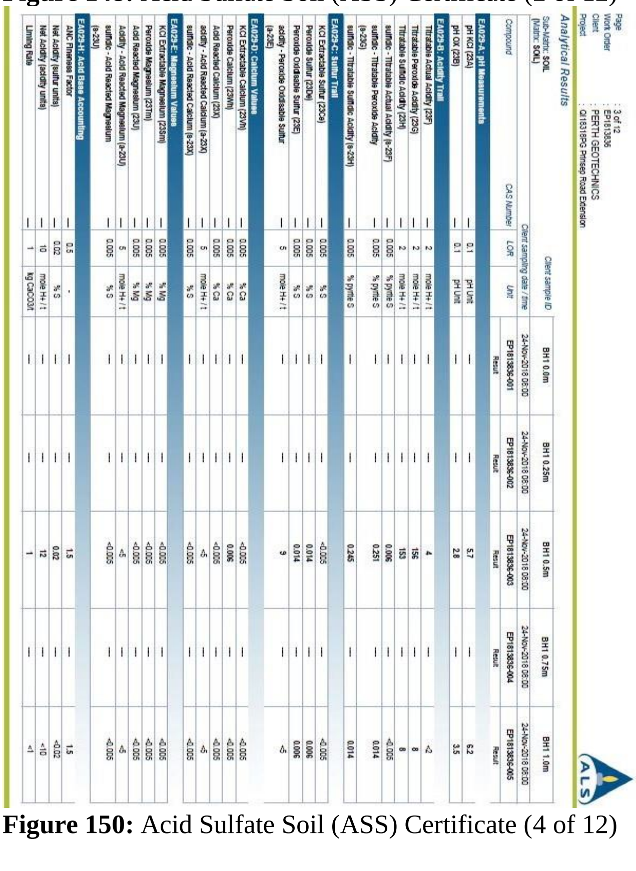
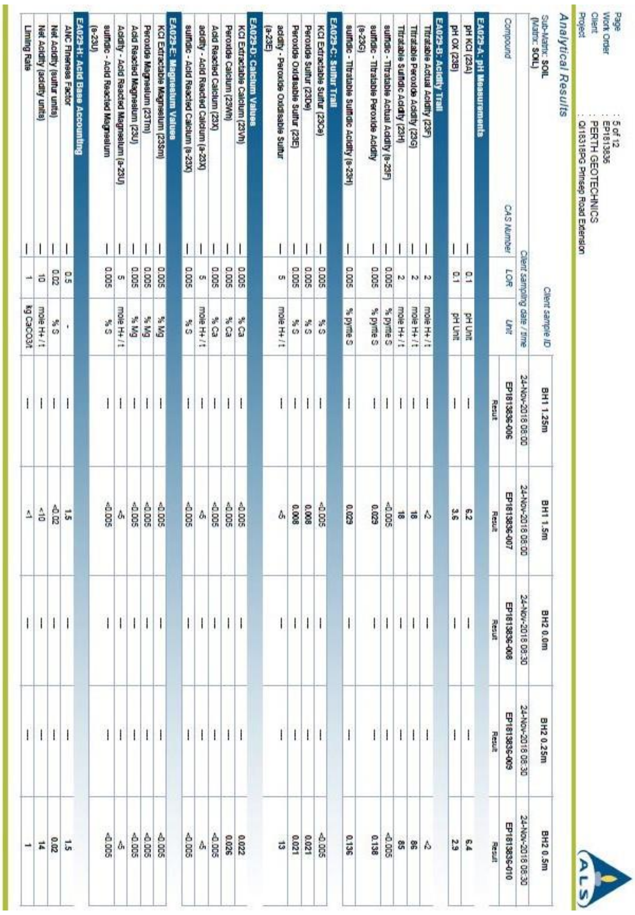


Figure 150: Acid Sulfate Soil (ASS) Certificate (4 of 12)

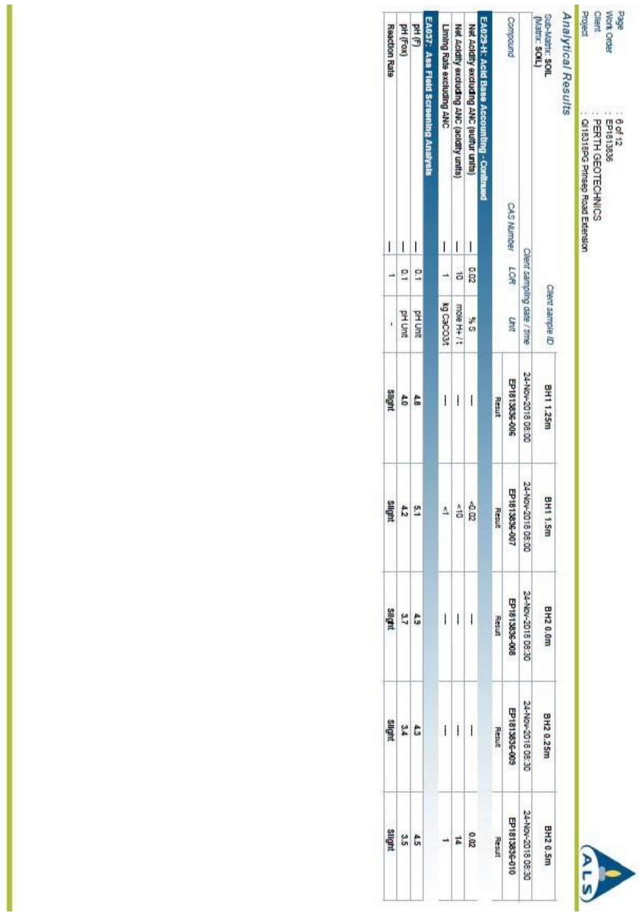


Page : 5 of 12
Work Order : EP1813836
Client : PERTH GEOTECHNICS
Project : QI18318PG Prinsep Road Extension

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	BH1 1.25m	BH1 1.5m	BH2 0.0m	BH2 0.25m	BH2 0.5m
			Client sampling date / time	24-Nov-2018 08:00	24-Nov-2018 08:00	24-Nov-2018 08:30	24-Nov-2018 08:30	24-Nov-2018 08:30
Compound	CAS Number	LOR	Unit	EP1813836-006	EP1813836-007	EP1813836-008	EP1813836-009	EP1813836-010
				Result	Result	Result	Result	Result
EA029-A: pH Measurements								
pH KCl (23A)	—	0.1	pH Unit	—	6.2	—	—	6.4
pH OX (23B)	—	0.1	pH Unit	—	3.6	—	—	2.9
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)	—	2	mole H+ / t	—	<2	—	—	<2
Titratable Peroxide Acidity (23G)	—	2	mole H+ / t	—	18	—	—	86
Titratable Sulfidic Acidity (23H)	—	2	mole H+ / t	—	18	—	—	85
sulfidic - Titratable Actual Acidity (s-23F)	—	0.005	% pyrite S	—	<0.005	—	—	<0.005
sulfidic - Titratable Peroxide Acidity (s-23G)	—	0.005	% pyrite S	—	0.029	—	—	0.138
sulfidic - Titratable Sulfidic Acidity (s-23H)	—	0.005	% pyrite S	—	0.029	—	—	0.136
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)	—	0.005	% S	—	<0.005	—	—	<0.005
Peroxide Sulfur (23De)	—	0.005	% S	—	0.008	—	—	0.021
Peroxide Oxidisable Sulfur (23E)	—	0.005	% S	—	0.008	—	—	0.021
acidity - Peroxide Oxidisable Sulfur (a-23E)	—	5	mole H+ / t	—	<5	—	—	13
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)	—	0.005	% Ca	—	<0.005	—	—	0.022
Peroxide Calcium (23Wh)	—	0.005	% Ca	—	<0.005	—	—	0.026
Acid Reacted Calcium (23X)	—	0.005	% Ca	—	<0.005	—	—	<0.005
acidity - Acid Reacted Calcium (a-23X)	—	5	mole H+ / t	—	<5	—	—	<5
sulfidic - Acid Reacted Calcium (s-23X)	—	0.005	% S	—	<0.005	—	—	<0.005
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)	—	0.005	% Mg	—	<0.005	—	—	<0.005
Peroxide Magnesium (23Tm)	—	0.005	% Mg	—	<0.005	—	—	<0.005
Acid Reacted Magnesium (23U)	—	0.005	% Mg	—	<0.005	—	—	<0.005
Acidity - Acid Reacted Magnesium (a-23U)	—	5	mole H+ / t	—	<5	—	—	<5
sulfidic - Acid Reacted Magnesium (s-23U)	—	0.005	% S	—	<0.005	—	—	<0.005
EA029-H: Acid Base Accounting								
ANC Fineness Factor	—	0.5	-	—	1.5	—	—	1.5
Net Acidity (sulfur units)	—	0.02	% S	—	<0.02	—	—	0.02
Net Acidity (acidity units)	—	10	mole H+ / t	—	<10	—	—	14
Liming Rate	—	1	kg CaCO3/t	—	<1	—	—	1

Figure 151: Acid Sulfate Soil (ASS) Certificate (5 of 12)

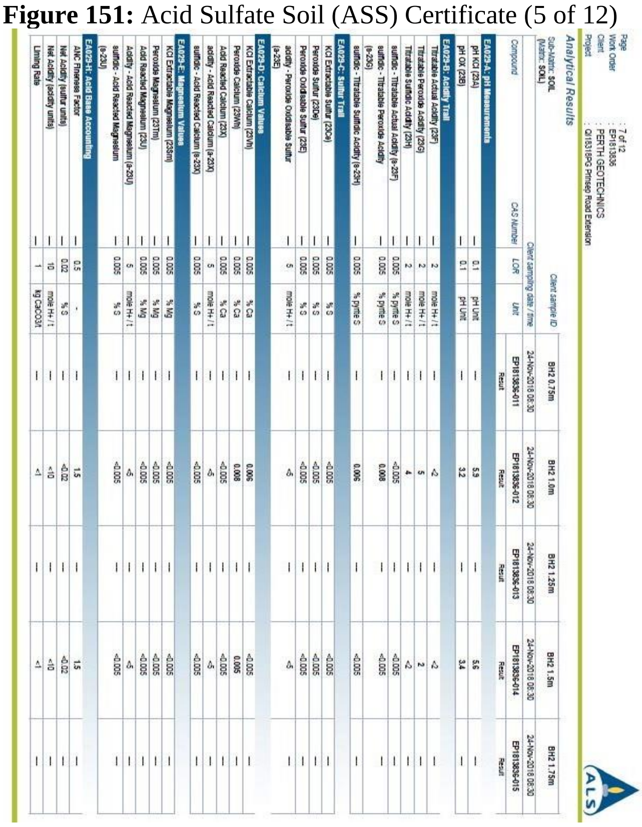


Page : 6 of 12
Work Order : EP1813836
Client : PERTH GEOTECHNICS
Project : QI18318PG Prinsep Road Extension

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	BH1 1.25m	BH1 1.5m	BH2 0.0m	BH2 0.25m	BH2 0.5m
			Client sampling date / time	24-Nov-2018 08:00	24-Nov-2018 08:00	24-Nov-2018 08:30	24-Nov-2018 08:30	24-Nov-2018 08:30
Compound	CAS Number	LOR	Unit	EP1813836-006	EP1813836-007	EP1813836-008	EP1813836-009	EP1813836-010
				Result	Result	Result	Result	Result
EA029-H: Acid Base Accounting - Continued								
Net Acidity excluding ANC (sulfur units)	—	0.02	% S	—	<0.02	—	—	0.02
Net Acidity excluding ANC (acidity units)	—	10	mole H+ / t	—	<10	—	—	14
Liming Rate excluding ANC	—	1	kg CaCO3/t	—	<1	—	—	1
EA037: Ass Field Screening Analysis								
pH (F)	—	0.1	pH Unit	4.8	5.1	4.9	4.3	4.5
pH (Fox)	—	0.1	pH Unit	4.0	4.2	3.7	3.4	3.5
Reaction Rate	—	1	-	Slight	Slight	Slight	Slight	Slight

Figure 152: Acid Sulfate Soil (ASS) Certificate (6 of 12)

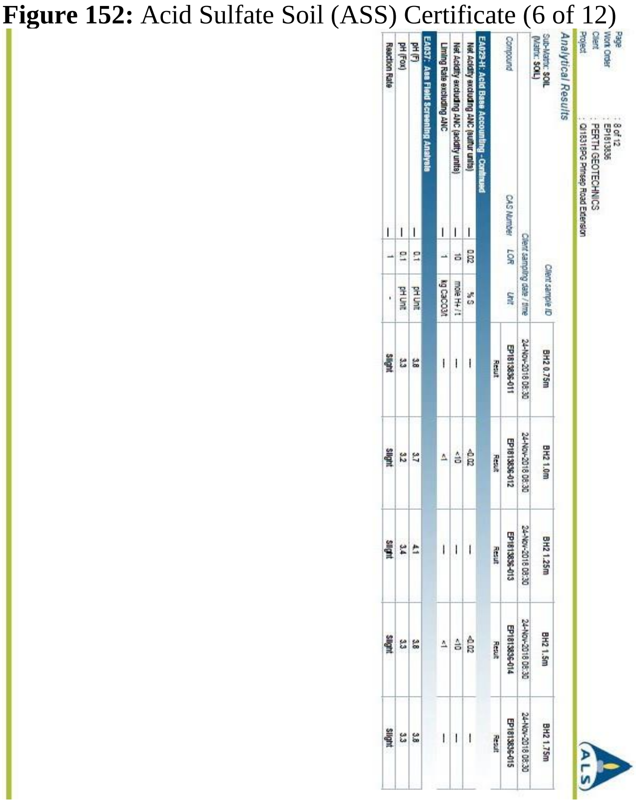


Page : 7 of 12
Work Order : EP1813836
Client : PERTH GEOTECHNICS
Project : QI18318PG Prinsep Road Extension

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	BH2 0.75m	BH2 1.0m	BH2 1.25m	BH2 1.5m	BH2 1.75m
			Client sampling date / time	24-Nov-2018 08:30	24-Nov-2018 08:30	24-Nov-2018 08:30	24-Nov-2018 08:30	24-Nov-2018 08:30
Compound	CAS Number	LOR	Unit	EP1813836-011	EP1813836-012	EP1813836-013	EP1813836-014	EP1813836-015
				Result	Result	Result	Result	Result
EA029-A: pH Measurements								
pH KCl (23A)	—	0.1	pH Unit	—	5.9	—	5.6	—
pH OX (23B)	—	0.1	pH Unit	—	3.2	—	3.4	—
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)	—	2	mole H+ / t	—	<2	—	<2	—
Titratable Peroxide Acidity (23G)	—	2	mole H+ / t	—	5	—	2	—
Titratable Sulfidic Acidity (23H)	—	2	mole H+ / t	—	4	—	<2	—
sulfidic - Titratable Actual Acidity (s-23F)	—	0.005	% pyrite S	—	<0.005	—	<0.005	—
sulfidic - Titratable Peroxide Acidity (s-23G)	—	0.005	% pyrite S	—	0.008	—	<0.005	—
sulfidic - Titratable Sulfidic Acidity (s-23H)	—	0.005	% pyrite S	—	0.006	—	<0.005	—
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)	—	0.005	% S	—	<0.005	—	<0.005	—
Peroxide Sulfur (23De)	—	0.005	% S	—	<0.005	—	<0.005	—
Peroxide Oxidisable Sulfur (23E)	—	0.005	% S	—	<0.005	—	<0.005	—
acidity - Peroxide Oxidisable Sulfur (a-23E)	—	5	mole H+ / t	—	<5	—	<5	—
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)	—	0.005	% Ca	—	0.006	—	<0.005	—
Peroxide Calcium (23Wh)	—	0.005	% Ca	—	0.008	—	0.005	—
Acid Reacted Calcium (23X)	—	0.005	% Ca	—	<0.005	—	<0.005	—
acidity - Acid Reacted Calcium (a-23X)	—	5	mole H+ / t	—	<5	—	<5	—
sulfidic - Acid Reacted Calcium (s-23X)	—	0.005	% S	—	<0.005	—	<0.005	—
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)	—	0.005	% Mg	—	<0.005	—	<0.005	—
Peroxide Magnesium (23Tm)	—	0.005	% Mg	—	<0.005	—	<0.005	—
Acid Reacted Magnesium (23U)	—	0.005	% Mg	—	<0.005	—	<0.005	—
Acidity - Acid Reacted Magnesium (a-23U)	—	5	mole H+ / t	—	<5	—	<5	—
sulfidic - Acid Reacted Magnesium (s-23U)	—	0.005	% S	—	<0.005	—	<0.005	—
EA029-H: Acid Base Accounting								
ANC Fineness Factor	—	0.5	-	—	1.5	—	1.5	—
Net Acidity (sulfur units)	—	0.02	% S	—	<0.02	—	<0.02	—
Net Acidity (acidity units)	—	10	mole H+ / t	—	<10	—	<10	—
Liming Rate	—	1	kg CaCO3/t	—	<1	—	<1	—

Figure 153: Acid Sulfate Soil (ASS) Certificate (7 of 12)



Page : 8 of 12
Work Order : EP1813836
Client : PERTH GEOTECHNICS
Project : QI18318PG Prinsep Road Extension

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)			Client sample ID	BH2 0.75m	BH2 1.0m	BH2 1.25m	BH2 1.5m	BH2 1.75m
			Client sampling date / time	24-Nov-2018 08:30	24-Nov-2018 08:30	24-Nov-2018 08:30	24-Nov-2018 08:30	24-Nov-2018 08:30
Compound	CAS Number	LOR	Unit	EP1813836-011	EP1813836-012	EP1813836-013	EP1813836-014	EP1813836-015
				Result	Result	Result	Result	Result
EA029-H: Acid Base Accounting - Continued								
Net Acidity excluding ANC (sulfur units)	—	0.02	% S	—	<0.02	—	<0.02	—
Net Acidity excluding ANC (acidity units)	—	10	mole H+ / t	—	<10	—	<10	—
Liming Rate excluding ANC	—	1	kg CaCO3/t	—	<1	—	<1	—
EA037: Ass Field Screening Analysis								
pH (F)	—	0.1	pH Unit	3.8	3.7	4.1	3.8	3.8
pH (Fox)	—	0.1	pH Unit	3.3	3.2	3.4	3.3	3.3
Reaction Rate	—	1	-	Slight	Slight	Slight	Slight	Slight

Figure 154: Acid Sulfate Soil (ASS) Certificate (8 of 12)

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Project : QI18318PG Prinsep Road Extension

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	BH2 2.0m	BH3 0.0m	BH3 0.25m	BH3 0.5m	BH3 0.75m
Client sampling date / time				24-Nov-2018 08:30	24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 09:00
				EP1813836-016	EP1813836-017	EP1813836-018	EP1813836-019	EP1813836-020
				Result	Result	Result	Result	Result
EA029-A: pH Measurements								
pH KCl (23A)	—	0.1	pH Unit	—	—	—	6.1	—
pH OX (23B)	—	0.1	pH Unit	—	—	—	3.3	—
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)	—	2	mole H+ / t	—	—	—	<2	—
Titratable Peroxide Acidity (23G)	—	2	mole H+ / t	—	—	—	25	—
Titratable Sulfidic Acidity (23H)	—	2	mole H+ / t	—	—	—	24	—
sulfidic - Titratable Actual Acidity (s-23F)	—	0.005	% pyrite S	—	—	—	<0.005	—
sulfidic - Titratable Peroxide Acidity (s-23G)	—	0.005	% pyrite S	—	—	—	0.041	—
sulfidic - Titratable Sulfidic Acidity (s-23H)	—	0.005	% pyrite S	—	—	—	0.039	—
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)	—	0.005	% S	—	—	—	<0.005	—
Peroxide Sulfur (23De)	—	0.005	% S	—	—	—	<0.005	—
Peroxide Oxidisable Sulfur (23E)	—	0.005	% S	—	—	—	<0.005	—
acidity - Peroxide Oxidisable Sulfur (a-23E)	—	5	mole H+ / t	—	—	—	<5	—
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)	—	0.005	% Ca	—	—	—	0.011	—
Peroxide Calcium (23Wh)	—	0.005	% Ca	—	—	—	0.014	—
Acid Reacted Calcium (23X)	—	0.005	% Ca	—	—	—	<0.005	—
acidity - Acid Reacted Calcium (a-23X)	—	5	mole H+ / t	—	—	—	<5	—
sulfidic - Acid Reacted Calcium (s-23X)	—	0.005	% S	—	—	—	<0.005	—
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)	—	0.005	% Mg	—	—	—	<0.005	—
Peroxide Magnesium (23Tm)	—	0.005	% Mg	—	—	—	<0.005	—
Acid Reacted Magnesium (23U)	—	0.005	% Mg	—	—	—	<0.005	—
Acidity - Acid Reacted Magnesium (a-23U)	—	5	mole H+ / t	—	—	—	<5	—
sulfidic - Acid Reacted Magnesium (s-23U)	—	0.005	% S	—	—	—	<0.005	—
EA029-H: Acid Base Accounting								
ANC Fineness Factor	—	0.5	-	—	—	—	1.5	—
Net Acidity (sulfur units)	—	0.02	% S	—	—	—	<0.02	—
Net Acidity (acidity units)	—	10	mole H+ / t	—	—	—	<10	—
Liming Rate	—	1	kg CaCO3/t	—	—	—	<1	—

Figure 155: Acid Sulfate Soil (ASS) Certificate (9 of 12)

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Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	BH2 2.0m	BH3 0.0m	BH3 0.25m	BH3 0.5m	BH3 0.75m
Client sampling date / time				24-Nov-2018 08:30	24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 09:00
				EP1813836-016	EP1813836-017	EP1813836-018	EP1813836-019	EP1813836-020
				Result	Result	Result	Result	Result
EA029-H: Acid Base Accounting - Continued								
Net Acidity excluding ANC (sulfur units)	—	0.02	% S	—	—	—	<0.02	—
Net Acidity excluding ANC (acidity units)	—	10	mole H+ / t	—	—	—	<10	—
Liming Rate excluding ANC	—	1	kg CaCO3/t	—	—	—	<1	—
EA037: Ass Field Screening Analysis								
pH (F)	—	0.1	pH Unit	3.7	5.3	5.8	4.7	4.5
pH (Fox)	—	0.1	pH Unit	3.5	4.2	4.8	4.5	4.4
Reaction Rate	—	1	-	Slight	Slight	Slight	Slight	Slight

Figure 156: Acid Sulfate Soil (ASS) Certificate (10 of 12)

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Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	BH3 1.0m	BH3 1.25m	BH3 1.5m	BH3 1.75m	BH3 2.0m
Client sampling date / time				24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 00:00
				EP1813836-021	EP1813836-022	EP1813836-023	EP1813836-024	EP1813836-025
				Result	Result	Result	Result	Result
EA029-A: pH Measurements								
pH KCl (23A)	—	0.1	pH Unit	6.5	—	6.2	—	—
pH OX (23B)	—	0.1	pH Unit	3.3	—	3.4	—	—
EA029-B: Acidity Trail								
Titratable Actual Acidity (23F)	—	2	mole H+ / t	<2	—	<2	—	—
Titratable Peroxide Acidity (23G)	—	2	mole H+ / t	26	—	8	—	—
Titratable Sulfidic Acidity (23H)	—	2	mole H+ / t	26	—	8	—	—
sulfidic - Titratable Actual Acidity (s-23F)	—	0.005	% pyrite S	<0.005	—	<0.005	—	—
sulfidic - Titratable Peroxide Acidity (s-23G)	—	0.005	% pyrite S	0.043	—	0.014	—	—
sulfidic - Titratable Sulfidic Acidity (s-23H)	—	0.005	% pyrite S	0.043	—	0.014	—	—
EA029-C: Sulfur Trail								
KCl Extractable Sulfur (23Ce)	—	0.005	% S	<0.005	—	<0.005	—	—
Peroxide Sulfur (23De)	—	0.005	% S	<0.005	—	<0.005	—	—
Peroxide Oxidisable Sulfur (23E)	—	0.005	% S	<0.005	—	<0.005	—	—
acidity - Peroxide Oxidisable Sulfur (a-23E)	—	5	mole H+ / t	<5	—	<5	—	—
EA029-D: Calcium Values								
KCl Extractable Calcium (23Vh)	—	0.005	% Ca	0.016	—	0.011	—	—
Peroxide Calcium (23Wh)	—	0.005	% Ca	0.016	—	0.013	—	—
Acid Reacted Calcium (23X)	—	0.005	% Ca	<0.005	—	<0.005	—	—
acidity - Acid Reacted Calcium (a-23X)	—	5	mole H+ / t	<5	—	<5	—	—
sulfidic - Acid Reacted Calcium (s-23X)	—	0.005	% S	<0.005	—	<0.005	—	—
EA029-E: Magnesium Values								
KCl Extractable Magnesium (23Sm)	—	0.005	% Mg	<0.005	—	<0.005	—	—
Peroxide Magnesium (23Tm)	—	0.005	% Mg	<0.005	—	<0.005	—	—
Acid Reacted Magnesium (23U)	—	0.005	% Mg	<0.005	—	<0.005	—	—
Acidity - Acid Reacted Magnesium (a-23U)	—	5	mole H+ / t	<5	—	<5	—	—
sulfidic - Acid Reacted Magnesium (s-23U)	—	0.005	% S	<0.005	—	<0.005	—	—
EA029-H: Acid Base Accounting								
ANC Fineness Factor	—	0.5	-	1.5	—	1.5	—	—
Net Acidity (sulfur units)	—	0.02	% S	<0.02	—	<0.02	—	—
Net Acidity (acidity units)	—	10	mole H+ / t	<10	—	<10	—	—
Liming Rate	—	1	kg CaCO3/t	<1	—	<1	—	—

Figure 157: Acid Sulfate Soil (ASS) Certificate (11 of 12)

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Client : PERTH GEOTECHNICS
Project : QI18318PG Prinsep Road Extension

Analytical Results

Sub-Matrix: SOIL (Matrix: SOIL)

Compound	CAS Number	LOR	Unit	BH3 1.0m	BH3 1.25m	BH3 1.5m	BH3 1.75m	BH3 2.0m
Client sampling date / time				24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 09:00	24-Nov-2018 00:00
				EP1813836-021	EP1813836-022	EP1813836-023	EP1813836-024	EP1813836-025
				Result	Result	Result	Result	Result
EA029-H: Acid Base Accounting - Continued								
Net Acidity excluding ANC (sulfur units)	—	0.02	% S	<0.02	—	<0.02	—	—
Net Acidity excluding ANC (acidity units)	—	10	mole H+ / t	<10	—	<10	—	—
Liming Rate excluding ANC	—	1	kg CaCO3/t	<1	—	<1	—	—
EA037: Ass Field Screening Analysis								
pH (F)	—	0.1	pH Unit	4.6	5.2	5.2	5.2	5.1
pH (Fox)	—	0.1	pH Unit	4.6	4.5	4.5	4.5	4.3
Reaction Rate	—	1	-	Slight	Slight	Slight	Slight	Slight

Figure 158: Acid Sulfate Soil (ASS) Certificate (12 of 12)

The projects implemented through five process group such as *initiation, planning, execution, monitoring and controlling and closing,* the project also considered the various essential aspects as part of integrated transport planning aims to achieve a positive outcome ensuring sustainable mobility, including public transport, walking, cycling, private vehicles and the street network, especially for community and neighbourhood. Therefore, the data was used for various component improvement and selection with specific requirements with context-specific presentations and interpretation.

V. CONCLUSION AND RECOMMENDATION

The study acknowledges that many projects are continuously planning and implementing statewide, where the projects have different challenges and constraints due to diverse geology and unknown subsurface risks. Adopting a comprehensive and quantitative geotechnical and pavement Investigation could have significant influences and could establish cost and economic benefit concerning the difficulty in excavating local materials (rock or soil), foundation conditions, the supply of suitable road-making materials, management of groundwater, and stability of road cuttings and embankments. It could expose the community impact in the context of site conditions, ground vibration, noise, construction traffic, changes to groundwater levels, water quality, local habitat, sustainability, the visual appearance of batter slopes and dust generated during construction. It will also assess the environmental impacts of identifying and treating groundwater, drainage, acid sulphate soils, erosion-prone soils such as silt, buried landfill and waste dumps, and the appropriate preventative or remedial treatments in mitigation. This study aims to reframe how comprehensively a context-sensitive and site-specific planning and investigation can be performed today, where sophisticated equipment machinery, automation is the guiding force, digital reporting capabilities. This study collates the following recommendation to achieve an efficient, cost-effective inventory toward building a civilisation in the global transformation of the modern world;

- Ensure about the investigation and scoping based on terrain characteristics
- Ensure the Geotechnical Investigation and its output information gathered from field and laboratory fits and tailors the overall design process,
- To predict how the ground is likely to behave under the changes proposed in a road design and associated construction activities and to recommend how risks related to and such risks can be mitigated,
- Assess and evaluate in situ and imported materials that will be part of the project roadworks or building materials,
- Assess and evaluate various aspects that observed and recorded during site reconnaissance, such as
    - rock cuttings, blasting or draping or rockfall area,
    - groundwater and spring, water stream, water channel activity that may dry or not traceable in summer but have a significant impact in winter or rainy season,
    - quarries in current use or obsolete,
    - evidence of landslips or unstable soil conditions,
    - changes in vegetation growth,
    - soil subsidence such as sinkholes and any cracking or damage to existing structures,
    - contaminated water either from chemical waste,
    - low land, marshy land, swampy areas that may contain silt or peat or other unusable material
    - various soil types or geology presence,
    - surface cracking indicating expansive soils or some other physical movement,
    - dissolved salts or exposed acid sulphate soils,
    - Accessibility and mobility to the site for a detailed geotechnical investigation for drilling, excavation or field testing,
- According to AS 2008, there should consider the following consideration in Laboratory testing;
    - description of sampling procedures used for laboratory tests undertaken on soil and rock samples,
    - reference to standard test methods followed,
    - inclusion of endorsed laboratory test reports for all tests undertaken from an accredited organisation such as; NATA
    - tabulation of a summary of all test results following the standards such as ASTM, AASHTO, AS/ANZ,
- AS 2008 also suggest that the Results of field investigation and laboratory tests consider the followings;
    - compilation and presentation of field and laboratory test results in a logical sequence using diagrams and tables where possible,
    - description of the types and variability of materials encountered in each proposed cutting, foundations area, and the variability of materials, in situ Californian Bearing Ratio (CBR) of materials at or near subgrade level, location of any soft, wet or unstable areas,
    - factual characteristics and properties of the various materials encountered by coring and bulldozer trenches,

The detail on pavement structural investigation is a critical aspect of geotechnical investigation for transport agencies worldwide. The geotechnical engineer should require a better understanding of pavement surfacing types, performance characteristics that may influence the choice of pavement surfacing type, level of service of pavement surfacing, the selection of the most appropriate surfacing for new pavements, identifying and correcting deficiencies in existing road surfacing and the choice of surfacing for rehabilitation. The following key points also recommended for key personnel for their decision making;

- The pavement designer should consult with the geotechnical engineer for advice on how best to address such difficulties to suit the project's specific circumstances and the local environment to achieve a cost-effective, resilient pavement structural design,
- The design team should conduct a visual inspection to identify the existing asphalt condition, cracking, depression following the Client's survey form. It is recommended to perform a video and photo register to specify the designer's matter during design and correct existing pavement data,
- Various pavement reinforcement techniques are available locally based on context and site-specific condition; the benefits potentially differ between areas with existing cracking and areas with no existing cracking, but there are no methods available to quantify the benefits,
- The reinforcement of full-depth asphalt pavements is intuitively beneficial, but there are no methods available to undertake the design. The reinforcement claims to reduce rutting and extends the time before reflection cracking occurs. If rutting and premature cracking prove to be issued in the performance of full-depth asphalt pavements, then asphalt reinforcement may be worth a closer look. However, the benefits cannot be quantified, so experience personnel should check and recommend in this context,
- Pavement widening, overlay, resurfacing, and others, pavement thickness varies, or different thickness may be assigned within intersections and roundabouts. It is recommended to adopt the most conservative pavement thickness to minimise the number of thickness changes to manage in construction,
- Due to heavy vehicle turning in and out in Verde drive and Prinsep road, the speed and geometric consideration should be ensured in pavement design,
- Value Engineering and Value Management should be considered that could bring many following opportunities:
- Pavement life cycle cost and cost optimisation;
  - ❖ Low noise pavements rankings; DGA, SMA7 to OGA as noisiest to quietest, it was required to note that noise level differences reduce with age. At lower speeds, engine noise becomes more dominant, rather than tyre noise.
  - ❖ Further research or hard evidence to support any significant reduction in noise levels
  - ❖ Pavement reinforcement or crack repairing; there may have several products or method currently used by Clients such as (HaTelit by HUESKER), geogrid, geotextile and others. The designer should provide context-sensitive site-specific way and consideration,
  - ❖ The designer should conduct a benefit-cost ratio (BCR), pros and cons in asphalt product selection because the market has now diversity such as Reclaimed Asphalt Pavements (RAP), polymer-modified bitumen (PMB), hot-mix asphalt (HMA), Recycled Tire Rubber (RTR), crumb rubber asphalt (CRA), Low Carbon Asphalt (LCA), High Recycling Technology (HRT). The designer should provide context-sensitive site-specific way and consideration,
- The design and deliverables should be staged submissions (15%, 85% and 100%) to provide the context of the design and expedite the design review closeout process,
- The re-use of pavement materials in embankments should be avoided for heavy vehicle roads. It could consider relaxing specification requirements for lower-traffic roads to facilitate re-use in pavements and sustainability objectives,
- The designer needs to ensure client specification about various types of contracts such as Design and Construction, lump sum, or other to meet the spread rate or strength parameter,
- In general, to apply the 5-year asphalt fatigue requirement to pavements to provide sufficient cover to reduce the risk of block cracks reflection through to the surfacing. The application may vary based on different pavement consideration and composition. The designer should liaise with Clients to ensure the application,
- Adopt technological shift in the economic scale, change direction in strategies and leads *to various social and economic benefits such as employment, better access to health and education services, trade and cultural activities, ITS, automation*, and
- Plan and implement a City-wide approach to supporting sustainable development decision-making.

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