APPENDIX 'A'- PART 2

GEOTECHNICAL AND ENVIRONMENTAL REPORTS

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Morrison Hershfield Ltd.

Polo Park Infrastructure Upgrades Omand's Creek Outfalls – Geotechnical Investigation Report

Prepared for:

Mr. Ron Bruce, P.Eng.
Morrison Hershfield
25 Scurfield Blvd, Unit 1
Winnipeg, MB R3Y 1G4
Attention: Ron Bruce

Project Number:
0035 013 00

Date:
April 2014
Final Report

April 11, 2014 Our File No. 0035 013 00

Mr. Ron Bruce, P.Eng.
Morrison Hershfield
25 Scurfield Blvd, Unit 1
Winnipeg, MB R3Y 1G4
Attention: Ron Bruce

RE: Final Geotechnical Report for Omand's Creek Outfalls
Polo Park Infrastructure Upgrades

TREK Geotechnical Inc. is pleased to submit our Final Report for the Omand's Creek Outfalls project.

Please contact the undersigned of our office should you have any questions. Thank you for the opportunity to serve you on this assignment.

Sincerely,

TREK Geotechnical Inc.
Per:

Michael Van Helden, Ph.D., P.Eng.
Geotechnical Engineer, Principal
Tel: 204.975.9433 ext. 102

:mvh
Encl.

cc. Nelson Ferreira, TREK Geotechnical Inc.
Kirby McRae, Tetra Tech Inc.

Revision History

Revision No.	Author	Issue Date	Description
0	MVH	April 11, 2014	Final Report

Authorization Signatures

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11/APR/14
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Michael Van Helden, Ph.D, P.Eng.
Geotechnical Engineer

APEGM
Certificate of Authorization
Trek Geotechnical Inc.
No. 4877 Date: Apr 11/14

Reviewed By:

Nelson Ferreira, M.Sc., P.Eng.
Geotechnical Engineer

Table of Contents

List of Figures

List of Appendices

1.0 Introduction

This report summarizes the results of the geotechnical investigation completed by TREK Geotechnical Inc. (TREK) for the proposed Omand's Creek Outfalls and sections of the associated land drainage system (LDS) as part of the Polo Park Infrastructure Improvements project located in Winnipeg, Manitoba. The proposed outfalls are located near the intersections of Empress Street and St. Matthews Avenue (2 outfalls) and Empress Street and Ellice Avenue (1 outfall). Portions of the new LDS system extending along Ellice Avenue and St. Matthews Avenue between St. James Street and Empress Street were also investigated. The Terms of Reference for the investigation are included in our quotation for engineering services dated February 28, 2014. The scope of work includes a subsurface investigation, laboratory testing, slope stability analysis and recommendation of any slope stabilization works (if necessary) in the vicinity of the proposed outfalls. Design parameters and recommendations for temporary shoring are also provided.

2.0 Background and Existing Information

Omand's Creek is a small waterway that flows towards the southeast direction from the northwest quadrant of Winnipeg and discharges into the Assiniboine River. The creek has been modified over the years as result of urban development and is now mostly a man-made channel that diverts water from the former Colony Creek, which once flowed into the downtown area of Winnipeg. The banks of Omand's Creek have a history of active erosion and creek bank instabilities.

The proposed outfalls will discharge storm water from the associated new LDS system as part of the Polo Park infrastructure upgrades (Figure 01). The outfalls are located near the channel road crossings at Ellice Avenue and St. Matthews Avenue as shown on Figures 02 and 03. The LDS pipes run along Ellice Avenue and St. Matthews Avenue, respectively. Minimal slope regrading is planned for the creek banks at the Ellice Avenue crossing, however widening for a turning lane from north-bound Empress Street onto eastbound St. Matthews Avenue is planned and will result in some slope steepening along the head slope of the culvert crossing (inside corner). Preliminary location plans of the proposed outfalls, LDS and profile and cross-section drawings at each outfall locations were provided by Morrison Hershfield. An existing geotechnical report prepared by Dean Gould & Associates (2009) for the St. Matthews-Omand's Creek Crossing which was recently constructed in 2011 was reviewed for pertinent information to assist in our geotechnical program. The report included logs for four test holes in the vicinity of the crossing, a slope stability analysis and recommendations for stabilization works and is included in Appendix C. Since the test hole logs provided in the 2009 geotechnical report were deemed adequate for design of the proposed works at the St. Matthew's outfall location, no additional subsurface investigations were undertaken at that location as part of this program.

3.0 Field Program

3.1 Subsurface Investigation and Laboratory Program

The subsurface investigation was undertaken on March 4th and 15th, 2014 under the supervision of TREK personnel to determine the soil stratigraphy and to evaluate the subsurface conditions for the proposed outfall at Empress Street and Ellice Avenue and portions of the associated LDS at both outfall locations. One test hole (TH14-01) was advanced to power auger refusal (PAR) at a depth of 14.2 m at Ellice Avenue near the proposed outfall, while the remaining test holes (TH14-02 to TH14-05) were each drilled to a depth of 6.1 m along the LDS alignment. The test hole locations (UTM coordinates) and geodetic elevations were surveyed by Morrison Hershfield and are shown in plan view in Figure 01.

Test holes in the vicinity of the outfalls are shown in plan and section in Figures 02 and 03 for the St. Matthews Avenue and Ellice Avenue crossings, respectively. Test holes drilled by Dean Gould (2009) at the St. Matthews Avenue crossing are shown on Figure 02 in plan and section and are included in the attached existing information (Appendix C).

The TREK test holes were drilled using an Acker MP8 truck-mounted drill rig equipped with 125 mm diameter solid stem augers. All test holes were cored through pavement along the existing roadway prior to drilling using solid stem augers. Subsurface soils observed during the drilling were visually classified in general accordance with the Unified Soil Classification System (USCS). Other pertinent information such as groundwater, caving (sloughing), and backfill conditions were also recorded.

Disturbed (auger cutting and split spoon) samples and relatively undisturbed (Shelby tube) samples were collected during drilling. Standard Penetration Tests (SPTs) were conducted in the glacial till in TH14-01 to assess its consistency. All samples retrieved during drilling were transported to TREK's testing laboratory in Winnipeg, Manitoba. Laboratory testing consisted of moisture content determination on all samples and grain size analysis (hydrometer method), Atterberg limit, and undrained shear strength testing (pocket penetrometer, Torvane and unconfined compression) on select samples.

The test hole logs are attached in Appendix A and include a description and elevation of the soil units encountered and other pertinent information such as groundwater and sloughing conditions, as well as summary of the laboratory testing results. The results of the laboratory testing are also included separately in Appendix B.

3.2 Subsurface Conditions

The soil stratigraphy in descending order below the pavement generally consists of:

- Fill materials
- Silt
- Clay
- Silt till.

A brief description of the soil units encountered at the test hole locations are provided below. All interpretations of soil stratigraphy for the purposes of design should refer to the detailed test hole logs.

Pavement

Asphalt was encountered at the ground surface in each test hole with a thickness ranging from 65 to 150 mm. Concrete was encountered beneath the asphalt in each test hole and ranges in thickness from 150 to 215 mm.

Fill

Fill materials were encountered beneath the pavement structure in all five test holes.

At the Ellice Avenue crossing (TH14-01) a 450 mm thick layer of 19 mm down crushed limestone base with a moisture content of about 4% based on one sample was encountered beneath the pavement overlying sand and gravel fill. The sand and gravel fill was encountered at a depth of 0.8 m below grade and is about 1.3 m thick with a moisture content of about 5%. It is brown, dry, poorly graded and ranges in size from fine grained sand to medium grained gravel.

Clay fill was encountered beneath the sand and gravel fill in TH14-01 near the Ellice Avenue outfall or beneath the pavement in test holes TH14-02 and TH14-03 along the Ellice Avenue LDS alignment and in TH14-04 along the St. Matthews LDS alignment. The clay fill is generally brown to dark brown, silty and contains trace sand, trace silt inclusions and trace gravel. It was frozen at the time of drilling but was stiff, dry to moist, and of intermediate to high plasticity when thawed. The clay fill in these test holes varies in thickness from about 0.1 to 1.5 m. In TH14-05 along the St. Matthews LDS alignment, a 0.5 m thick layer of clay and silt fill was encountered below the pavement structure. The clay and silt fill is brown in color, stiff, moist, of intermediate plasticity and contains trace sand.

The fill reported by Dean Gould (2009) south of the St. Matthews Avenue creek crossing consisted of gravel fill in TH-1 (southeast bank) with a moisture content of about 22% extending to a depth of 1.64 m below ground or silty clay fill logged as brown and weathered extending to 1.52 m below ground in TH-2 (southwest bank).

Silt

Silt was encountered beneath the fill layers in test holes TH14-02 to TH14-05 at depths ranging from about 0.4 m to 1.9 m top of pavement. The silt layer varies in thickness between 0.6 and 1.4 m. It is generally light brown, loose compact, and moist to wet and of no to low plasticity. The moisture content of the silt layer varies slightly between 22% and 25%.

High Plastic Clay

High plastic silty clay was observed beneath the silt and/or fill layers in all the test holes. The clay is mottled brown and grey becoming grey with depth and firm to stiff becoming softer with depth. The clay is moist and contains trace silt inclusions. The undrained shear strengths of the clay measured from unconfined compression, Torvane and pocket penetrometer tests performed on the undisturbed samples ranged from 25 to 60 kPa with an average of 41 kPa. Bulk unit weights performed on the undisturbed samples ranged from 16.7 to 17.5 kN/m^3, with an average of 17.1 kN/m^3. Moisture contents in the clay range from 35% to 59% and generally increase with depth in the upper metre of the layer and become relatively consistent below. A liquid limit of 80 and plastic limit of 20 was measured on one sample in TH14-01, resulting in plasticity index of 60%.

At the St. Matthews outfall locations, Dean Gould (2009) reported brown to grey clay that is moist and soft extending to 8.4 m depth in TH-1 (southeast bank) and to 2.74 m in TH-2. Grey highly plastic clay was reported beneath the brown/grey clay extending to a depth of 9.5 m in TH-2. The grey clay had moisture contents ranging from about 40 to 50% with a unit weight of 1,687 kg/m^3 and an unconfined compressive shear strength of 71 kPa based on one sample.

Silt Till

Silt till was observed below the high plastic clay in TH14-01 (Ellice Avenue outfall) at a depth of 9.8 m (EL. 224.1 m) below pavement. The silt till extended to the depth of exploration of 14.2 m (EL. 219.6 m) where power auger refusal was reached. The silt till is brown and contains trace sand and gravel. It is clayey, soft, wet, and of intermediate to high plasticity to a depth of about 12.2 m. A moisture content of 37% was measured in this upper 2.4 m portion of the silt till. Below 12.2 m, the silt till contains trace clay and becomes dense to very dense and dry with moisture contents ranging between 8% and 11%. A representative SPT blow count (N value) of 119 blows per 300 mm of penetration was measured at a depth of 13.7 m.

Silt till was also encountered in Dean Gould's TH-1 and TH-2 on the southeast and southwest banks, respectively, near the St. Matthews outfall locations. The till was encountered at a depth of 8.4 m (EL. 225.0 m) on the southeast bank and at 7.9 m (EL. 222.1 m) on the southwest bank. Power auger refusal was reported at an elevation of 221.6 m in TH-4. The moisture content ranged from about 13% to 21% in the two test holes.

3.3 Seepage, Sloughing, and Groundwater Observations

Seepage and sloughing conditions were observed during drilling within the soft and wet silt till layer in TH14-01. Squeezing of the test hole was also encountered in TH14-01 in the clay layer near the silt till contact at a depth of 8.5 m below pavement (EL. 225.3 m). The water level in TH14-01 was approximately 11 m below ground surface after the completion of drilling. No seepage or sloughing was observed in the remaining test holes.

Dean Gould reported "water inflow" into TH-4 at a depth of 2.1 m (EL. 227.9 m) as well as sloughing in TH-3 at a depth of 4.6 m (226.2 m).

These observations are short term and should not be considered reflective of (static) groundwater levels at the site which could only be determined though monitoring over an extended period of time. It is important to recognize that groundwater conditions may change seasonally, annually, or as a result of construction activities.

4.0 Bank Stability Assessment

4.1 Design Objective

The banks of Omand's Creek have a history of erosion and slope instability, however no signs of slope instability were observed during site reconnaissance visits at the outfall locations. In addition, the proposed outfalls enter the creek at an angle to the creek where the creek banks and the side slopes of the road crossings meet (inside corner), as shown in Figures 02 to 03. The stability of a bank slope is inherently more stable on an inside corner where two perpendicular slopes intersect (*i.e.* the creek bank and roadway crossing slopes). However, analyzing the stability of inside corner is difficult with 2-D dimensional approaches and other methods were examined but deemed to be inappropriate for this application. As such, analysis of the creek bank outside the stabilizing influence of the inside corner would represent the lower bound for the overall three-dimensional stability of the outfall. In this regard, the stability of the bank along the creek was used as the design section in the stability analysis. (Cross Sections 01 and 02)

A minimum factor of safety of 1.3 to 1.5 is commonly used for the design of infrastructure such as outfall pipes extending into a river or creek bank. Riverbanks with a minimum FS greater than 1.3 are considered to be relatively stable, however, creep movements are possible. On the basis of the three-dimensional effects described above tending to stabilize the majority of the length of the outfall pipe, it is our opinion that a minimum factor of safety of 1.3 is an adequate target for design section near the outfall, provided the lower portion of the outfall pipe is designed to accommodate some differential movements associated with creep movements of the creek banks. While it is unlikely that an instability of the creek bank could fully extend into the inside corner (e.g. into the culvert), an instability may extend up to the toe where it could impact the lower portion of the outfall pipe.

4.2 Slope Stability Analysis

Slope stability modeling was conducted to evaluate the existing stability of the creek banks and to determine any necessary stabilization works required to achieve the design FS of 1.3 for the outfall structures. Stabilization options considered included granular shear keys and ribs. Other stabilization options were considered but were either cost prohibitive or not suitable for site conditions.

Topographic data provided by Morrison Hershfield for each of the outfall locations was assumed to represent the existing conditions. It is our understanding based on preliminary geometries provided by Morrison Hershfield that the final grading at the outfalls will be consistent with existing geometries, with the exception of slope steepening associated with the widening of Empress at St. Matthews to accommodate a new turning lane near the west outfall. The slope steepening will occur on the southwest head slope of the culvert and within the inside corner and transitions to existing grades where the inside corner meets the creek bank. The steepened slope will be consistent or slightly flatter than the existing west bank slope immediately south of the culvert. As such, the existing geometry along Cross-sections 01 and 02 are considered representative of the proposed slope geometry and can be used for design. Cross sections selected for analysis are shown in plan and profile on Figures 02 and 03, respectively, for the Ellice and St. Matthews creek banks. The existing banks were assumed to be marginally stable given the history of the creek bank and observations from the site reconnaissance.

4.3 Numerical Model Description

The stability analysis was conducted using a limit-equilibrium slope stability model (Slope/W) from the GeoStudio 2007 software package (Geo-Slope International Inc.). Static piezometric lines were used to represent groundwater conditions and to calculate factors of safety. The slope stability model used the Morgenstern-Price method of slices to calculate factors of safety. Critical local and global slip surfaces were identified using a grid and radius slip surface method. The soil units used in the model include the *in-situ* high plastic clay and silt (till), as well as any materials used for stabilization works. In this regard, rockfill for a granular shear key or granular ribs was considered in the model.

Existing conditions were analysed assuming reasonable material properties and groundwater conditions that would result in a factor of safety marginally above unity for the worst case cross-section of the creek banks (Cross-section 01-west). Table 1 lists the soil properties used for the soil units in the slope stability analysis. The strength properties assumed for the high plastic clay are considered reasonable for Winnipeg clays along slopes which have experienced large strains. The silt till was assumed at Elev. 225 m at the Ellice Avenue crossing based on TREK's test holes and at Elev. 223 m at the St. Matthews Avenue crossing based on test holes reported by Dean Gould (2009).

Granular shear keys and granular ribs were examined as potential options for stabilization works. Although various configurations (e.g. depth, width) of shear keys or granular ribs were considered, only the options that satisfied the target factor of safety are reported herein.

For the case of a granular shear key, the volume of the shear key is represented in the model by soil assigned the properties of rockfill. However, the increase in strength due to granular ribs cannot be directly modeled in a two-dimensional model and must be represented as an equivalent shear key with properties between that of rockfill and native soil. The material properties for the ribs are calculated as a weighted average of rockfill and high plastic clay based on the area replacement ratio in plan view (as noted in Table 1).

Table 1 - Soil Properties used in Slope Stability Analysis

Soil Description	Unit Weight (kN/m³)	Cohesion (kPa)	Friction Angle (degrees)
High Plastic Clay	16.5	4	14
Silt (Till)	21	1	35
Rockfill (Shear Key)	21	0	45
Rockfill (Granular Ribs) (1)	19	2	30

(1) Granular ribs properties represent a weighted average of rockfill / clay based on area replacement ratio in plan view.

A worst-case groundwater level at 2 m below the top of bank elevation was assumed in the analysis, transitioning to the bottom elevation of the creek (low flow conditions). An empty creek channel was assumed for all stability analyses as it is our understanding the creek tends to be dry or contain minimal amount of water.

4.4 Stability Analysis Results

Table 2 summarizes the stability modeling cases and associated factors of safety calculated using the slope stability model. The slope model stability results for each case have been included in Appendix D (Figures D-01 to D-05) as referenced in Table 2. Key cases are discussed in detail in the following sections.

Table 9.2. Summary of Stability Analysis Results

Cross Section	Bank Location	Design Scenario	Factor of Safety	Figure No. (Appendix D)
St. Matthews Ave. Cross Section 01	West	Existing Conditions (4.6 m slope height, 3.1H:1V)	1.10	D-01
		Granular Shear Key (1m wide base at Elev. 225 m)	1.32	D-02
		Granular Ribs (2m wide base at Elev. 225 m, 1:1 replacement ratio in plan view)	1.28	D-03
	East	Existing Conditions (4.4 m slope height, 5.9H:1V)	1.47	D-04
Ellice Ave. Cross Section 02	West	Existing Conditions (4.0 m slope height, 3.6H:1V)	1.64	D-05

4.4.1 Existing Conditions

The factor of safety was calculated for the existing slope geometry along Cross-sections 01(west and east) and 02 (west only). Cross-section 01-west is approximately 4.6 m in height and sloping at an average angle of 3.1H:1V from the top of bank to the creek bottom and was critical in terms of stability with a factor of safety of 1.10 (Figure D-01). In comparison, Cross-sections 01-east and 02-west are approximately 4.4 m and 4.0 m in height with slopes at 5.9H:1V and 3.6H:1V, respectively, and had factors of safety of 1.47 to 1.64 (Figures D-04 and D-05, respectively).

The existing geometry for the Ellice Avenue outfall (Cross-section 02-west) and the east St. Matthews Avenue outfall (Cross-section 01-east) meet the design FS of 1.3. However, the southwest creek bank in the vicinity of the St. Matthews west outfall requires a minimum 20% improvement to stability to meet the design FS. Slope flattening was not possible due to geometric constraints posed by the adjacent roadway.

4.4.2 Stabilization Works Alternatives

Stabilization measures using a granular shear key and granular ribs were analyzed and optimized to achieve the design FS. The design FS can be achieved using a granular shear key with 1 m base width (Figure D-02) or granular ribs with a 1-to-1 area replacement ratio (e.g. 1.2 m wide ribs with 1.2 m clear spacing) with a 2 m base width (Figure D-03). Both options were assumed to have 1H:2V side slopes in cross-section. The rib walls oriented perpendicular to the creek alignment were assumed to be near vertical. The depth of the stabilization works was varied until the target factor of safety was achieved (Elev. 225 m).

4.4.3 Recommended Stabilization Works

Granular ribs provide a few advantages over a shear key. Since they are excavated perpendicular to the slope and backfilled one at a time, the risk of triggering slope movements is reduced, whereas there is an increased risk of slope movements with a shear key due to the removal of toe support over a larger lateral extent. In this particular project, granular ribs offer a similar level of stability improvement (change in FS) with a lower overall volume of excavation and rockfill. The quantity of rockfill required for the granular rib option presented in Table 2 is estimated to be in the order of 20% to 30% less than for the shear key option. Granular ribs can also provide improved sub-surface drainage and lowering of groundwater levels within the creek bank over the long-term. Granular ribs are therefore recommended as the preferred stabilization alternative for the southwest bank at the St. Matthews Avenue crossing, however shear keys may also be considered. No stabilization works are deemed necessary for the two other outfall locations since the design FS were met. The granular ribs are to be constructed as close to the inside corner as possible and extend 25m south along the creek, parallel to Empress Street. Installation of granular ribs would also improve creek bank stability along a portion of Empress Street.

In addition to installation of granular ribs to improve bank stability, it is recommended that the outfall be constructed using bedding and/or backfill that is free draining to promote drainage in and around the outfall pipe as means to lower groundwater levels in the slope. Any lowering of groundwater levels due to the outfall bedding and backfill has not been included in the slope stability analysis.

The following design and construction considerations should apply to the construction of granular ribs:

1. Granular ribs should have a minimum width of 1.2 m and should have a clear spacing (edge to edge) of 1.2 m. The stabilization length should be approximately 25 m, or 11 ribs.
2. Backfill for granular ribs should consist of sound, dense, durable crushed limestone. The material should be free from organics, roots, silt, sand, clay, snow, ice or any other deleterious material.
3. Backfill for granular ribs should consist of 100 mm down in accordance with Table CW 3110.1 of CW 3110 with the following modifications:
    - minimum bulk specific gravity of 2.6 (ASTM C127)
    - maximum Los Angeles abrasion loss of 35% (ASTM C131)
    - maximum soundness loss of 13% (ASTM C88)

4. The construction of granular ribs shall be a continuous operation completed one rib at a time. Commencement of excavation of a new rib shall only commence once backfilling and compaction of the previous rib is complete. Ribs should be backfilled immediately upon completion of excavation.
5. Placement of the backfill material should be in lift thicknesses (prior to compaction) of 400 mm. If a direct-insertion vibratory probe will be used for compaction, the trench may be backfilled in full prior to compaction.
6. Compaction of the backfill in the manner proposed for construction to achieve a minimum 15% increase in density over uncompacted backfill. The degree of compaction will be determined by measurement of the volume of backfill material before and after compaction.

5.0 Temporary Shoring Recommendations

It is understood the proposed outfalls and manholes will be founded at depths in the range of 3 to 4 m and that construction of the works may require braced temporary shoring. It is anticipated that the design of excavation slopes and temporary shoring will be the responsibility of the Contractor. Shoring designs or excavations greater than 3 m in height will need to be designed and sealed by a professional engineer and reviewed by TREK Geotechnical prior to construction to confirm the parameters and soil conditions used in design are consistent with the recommendations provided herein.

The earth pressure distributions provided in Figure 04 can be used for shoring design. An undrained shear strength of 30 kPa for the clay can be used for the design of shoring and the determination of an adequate factor of safety against toe instabilities (to be completed by others). The undrained shear strengths were selected based on the measured undrained shear strength profile from all test types. The effect of any surcharge loads must be added to the force on the wall in addition to the calculated earth pressures. The appropriate earth pressure condition should be used to calculate the lateral earth pressure due to surcharge loads.

Ground movements behind the shoring and associated settlement are largely unavoidable. The amount of movement cannot be predicted with a high degree of accuracy as it is as much a function of the excavation procedures and workmanship as it is of theoretical considerations. In this regard, good contact between the shoring structure and retained soil should be maintained throughout the construction process. Free draining sand fill should be used to fill in any voids behind the lagging. Additional recommendations can be provided should infrastructure sensitive to settlement exist in close proximity to the excavation.

5.1 Groundwater Considerations for Temporary Shoring

The lacustrine clay is underlain by a layer of glacial till under confined groundwater pressures. Based on the maximum depth of excavation anticipated for the outfalls and manholes, the factor of safety against base heave is considered adequate. It must be recognized however, that groundwater levels are likely to increase during spring freshet before returning to normal summer levels. TREK can provide a review of base heave should deeper excavations be considered.

6.0 Closure

The geotechnical information provided in this report is in accordance with current engineering principles and practices (Standard of Practice). The findings of this report were based on information provided (field investigation, laboratory testing, geometries). Soil conditions are natural deposits that can be highly variable across a site. If sub-surface conditions are different than the conditions previously encountered on-site or those presented here, we should be notified to adjust our findings if necessary.

All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work, or a mutually executed standard engineering services agreement. If these conditions are not attached, and you are not already in possession of such terms and conditions, contact our office and you will be promptly provided with a copy.

This report has been prepared by TREK Geotechnical Inc. (the Consultant) for the exclusive use of Morrison Hershfield (the Client) and their agents for the work product presented in the report. Any findings or recommendations provided in this report are not to be used or relied upon by any third parties, except as agreed to in writing by the Client and Consultant prior to use.

Figures

0035 013 00
Morrison Hershfield
Omand's Creek Outfalls

Tabloid (279mm x 432mm)
PLOT: 10/04/2014 1:00:53 PM
FILE NAME: 0035 013 00_R06.dwg

0 20 40 60 80m
SCALE : 1:2000 (279mm x 432mm)

LEGEND :

- TEST HOLE (TREK, 2014)
- TEST HOLE (DEAN GOULD, 2009)

NOTES :

1. AERIAL IMAGE PROVIDED BY MORRISON HERSHFIELD
2. GROUND SURFACE TOPOGRAPHY SURVEYED IN 2013 AND 2014, PROVIDED BY MORRISON HERSHFIELD

Figure 01
Overall Site Plan

TREK GEOTECHNICAL

0035 013 00
Morrison Hershfield
Omand's Creek Outfalls

Tabloid (279mm x 432mm)
PLOT: 10/04/2014 1:45:52 PM
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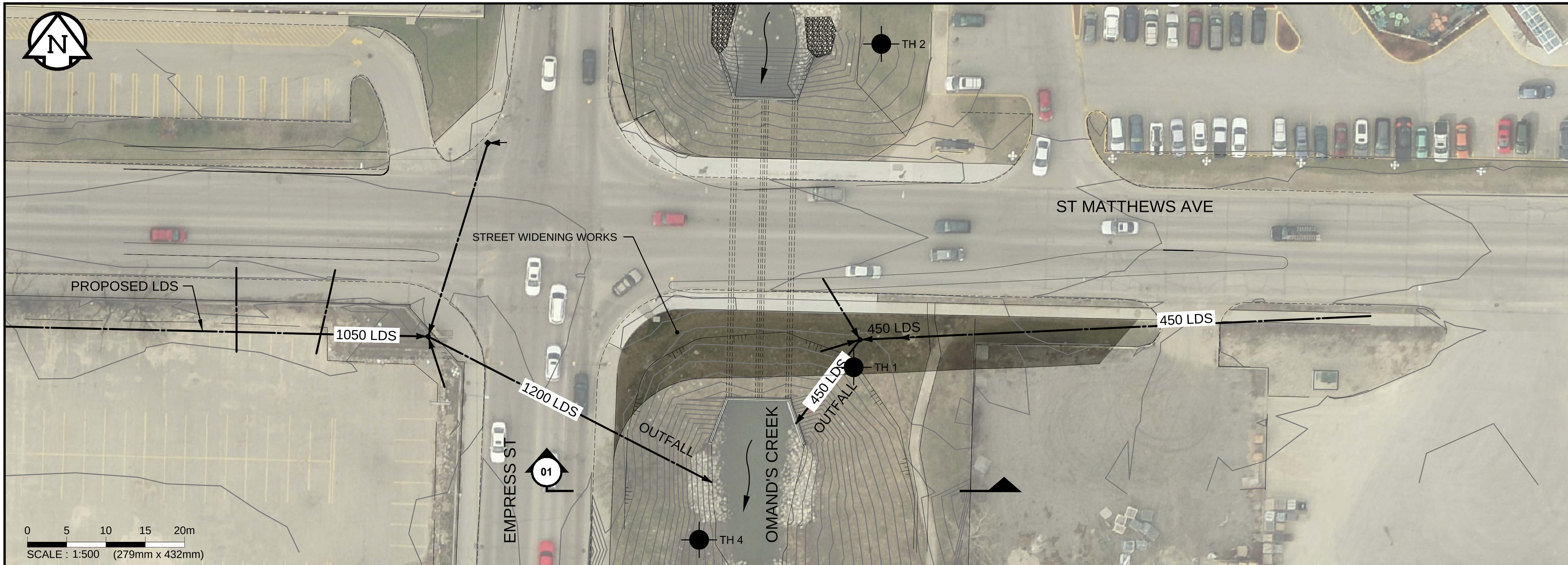

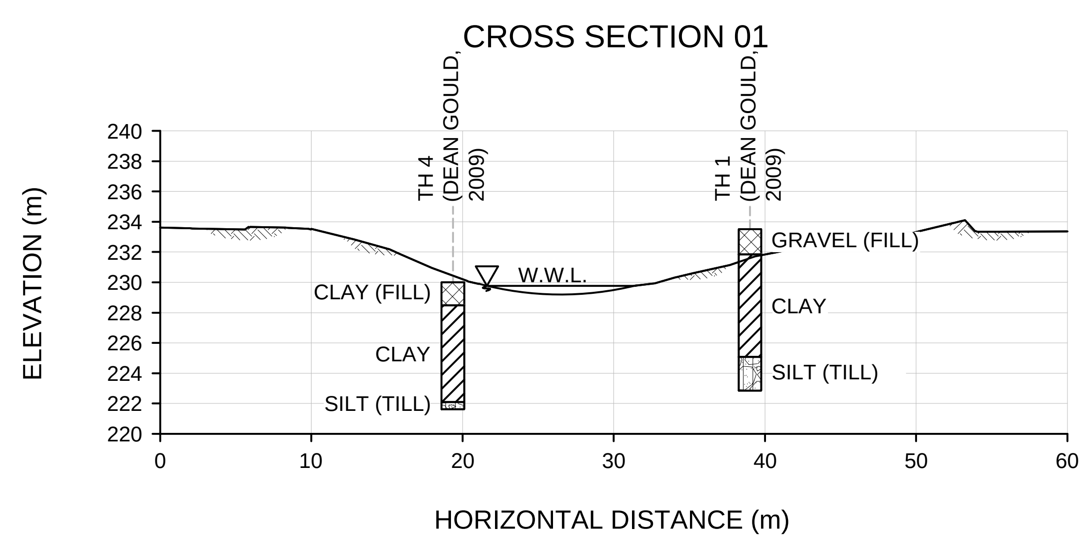

0 5 10 15 20m
SCALE : 1:500 (279mm x 432mm)

LEGEND :

- TEST HOLE (DEAN GOULD, 2009)

NOTES :

1. AERIAL IMAGE PROVIDED BY MORRISON HERSHFIELD
2. GROUND SURFACE TOPOGRAPHY SURVEYED IN 2013 AND 2014, PROVIDED BY MORRISON HERSHFIELD
3. TEST HOLE LOGS PROJECTED ONTO CROSS SECTION

Figure 02
Site Plan and Cross Section
St. Matthews Avenue Crossing

TREK GEOTECHNICAL

0035 013 00
Morrison Hershfield
Omand's Creek Outfalls

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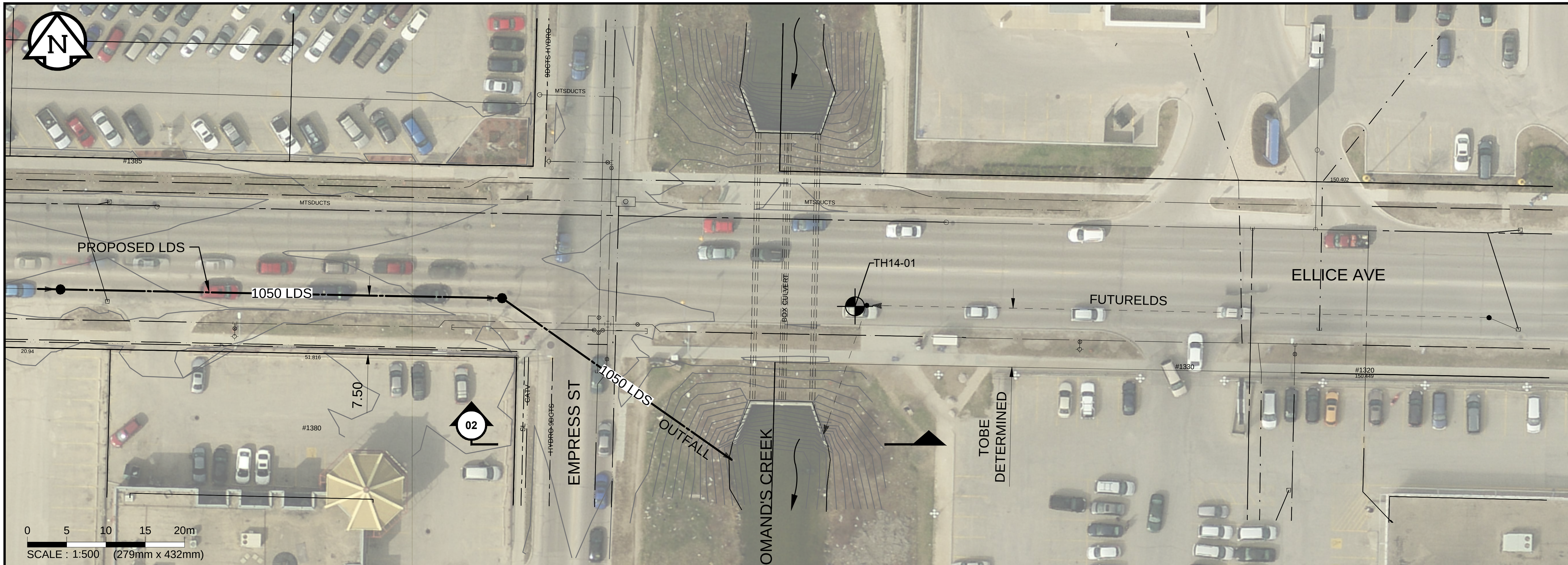
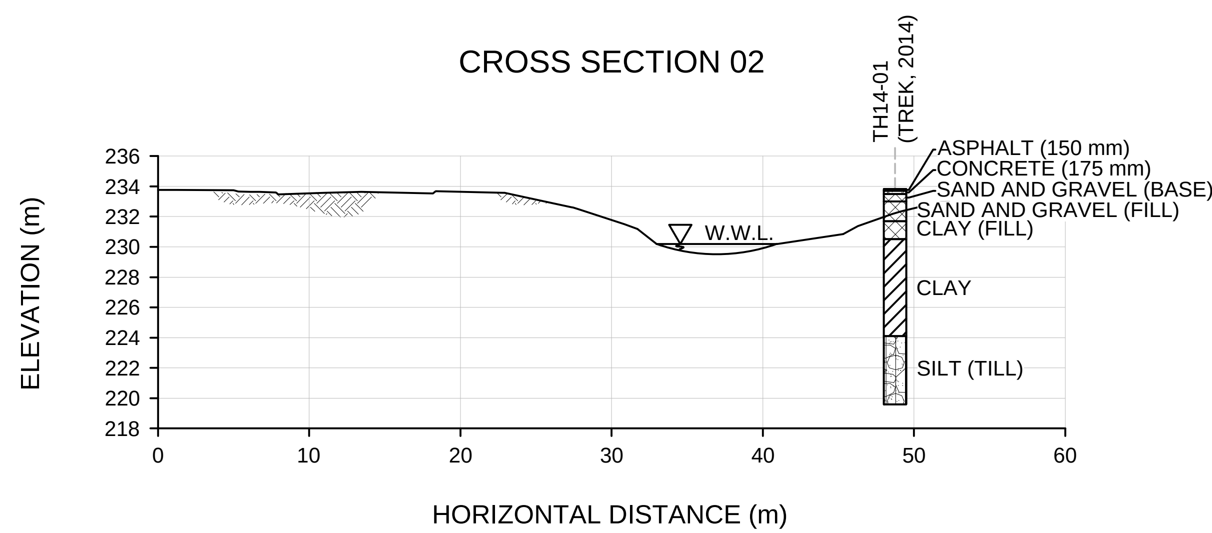




0 5 10 15 20m
SCALE : 1:500 (279mm x 432mm)

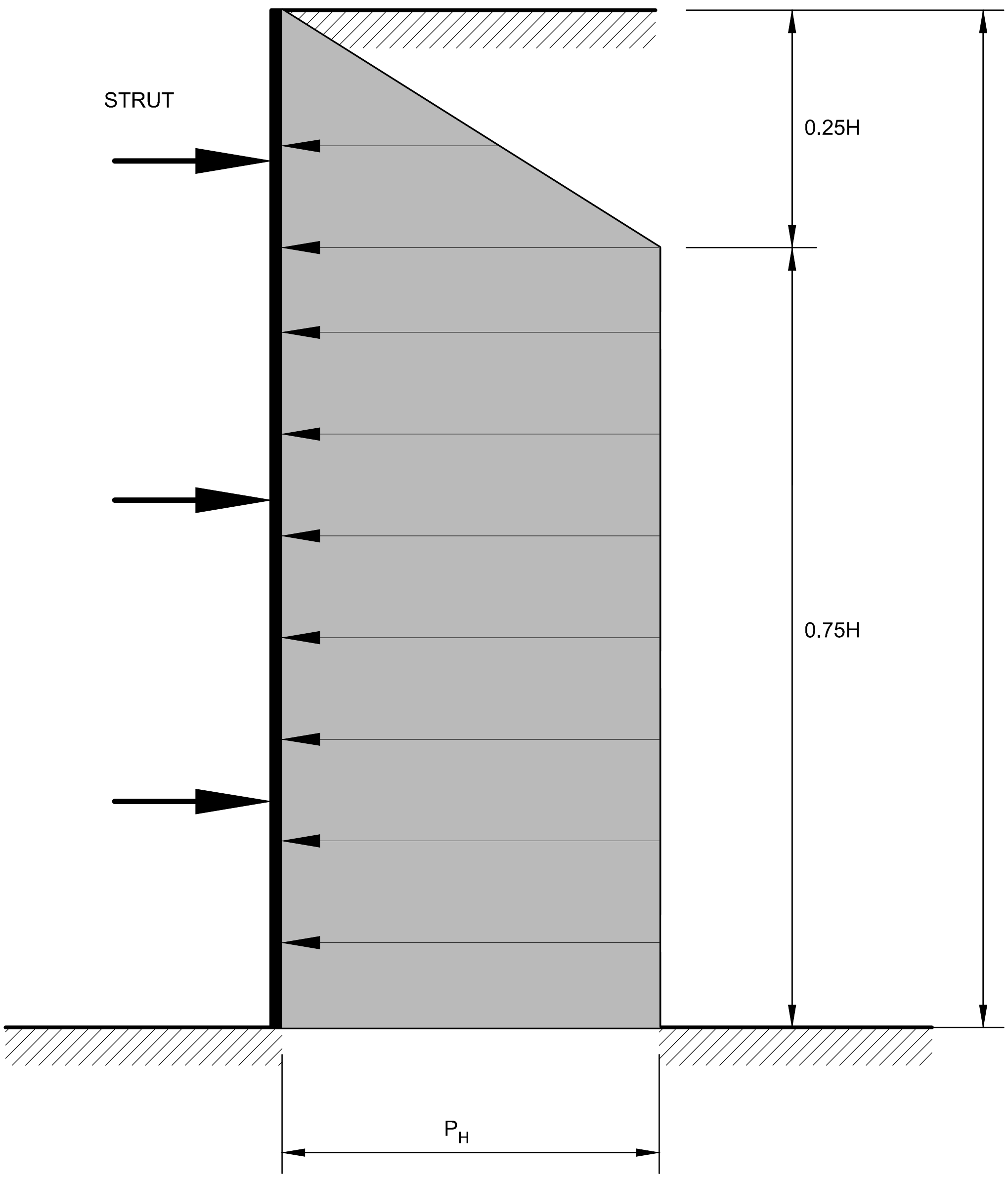
LEGEND :

TEST HOLE (TREK, 2014)

NOTES :

1. AERIAL IMAGE PROVIDED BY MORRISON HERSHFIELD
2. GROUND SURFACE TOPOGRAPHY SURVEYED IN 2013, PROVIDED BY MORRISON HERSHFIELD
3. TEST HOLE LOGS PROJECTED ONTO CROSS SECTION

Figure 03
Site Plan and Cross Section
Ellice Avenue Crossing



P_H = 0.5 γ H

WHERE :

H = DEPTH OF EXCAVATION (m)

P_H = LATERAL EARTH PRESSURE (kP_a)

γ = BULK SOIL UNIT WEIGHT (18 kN/m³)

NOTE:

- ADD SURFACE LOAD SURCHARGE IF APPLICABLE

Figure 04

Lateral Earth Pressure Distributions

Braced Excavations in Clay

Appendix A

Test Hole Logs

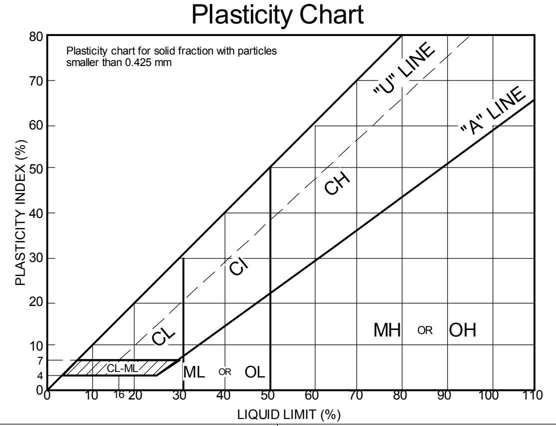
EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classification	Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW		Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent....... GW, GP, SW, SP; More than 12 percent....... GM, GC, SM, SC; 6 to 12 percent...... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP		Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM		Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC		Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW		Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP		Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM		Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC		Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML		Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart		
			CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL		Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH		Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts			
			CH		Inorganic clays of high plasticity, fat clays			
			OH		Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt		Peat and other highly organic soils	Von Post Classification Limit	Strong colour or odour, and often fibrous texture	

Plasticity Chart



Material		Particle Size mm	ASTM Sieve sizes
Sand	Coarse	2.00 to 4.75	#10 to #4
	Medium	0.425 to 2.00	#40 to #10
	Fine	0.075 to 0.425	#200 to #40
Silt or Clay		< 0.075	< #200

Material		Particle Size mm	ASTM Sieve Sizes
Boulders		> 300	> 12 in.
Cobbles		75 to 300	3 in. to 12 in.
Gravel	Coarse	19 to 75	3/4 in. to 3 in.
	Fine	4.75 to 19	#4 to 3/4 in.

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols. For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

	Asphalt		Bedrock (undifferentiated)		Cobbles
	Concrete		Limestone Bedrock		Boulders and Cobbles
	Fill		Cemented Shale		Silt Till
			Non-Cemented Shale		Clay Till

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD - Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength
VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling

▼ Water Level at End of Drilling

▼ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

The undrained shear strength (Su) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

TREK GEOTECHNICAL

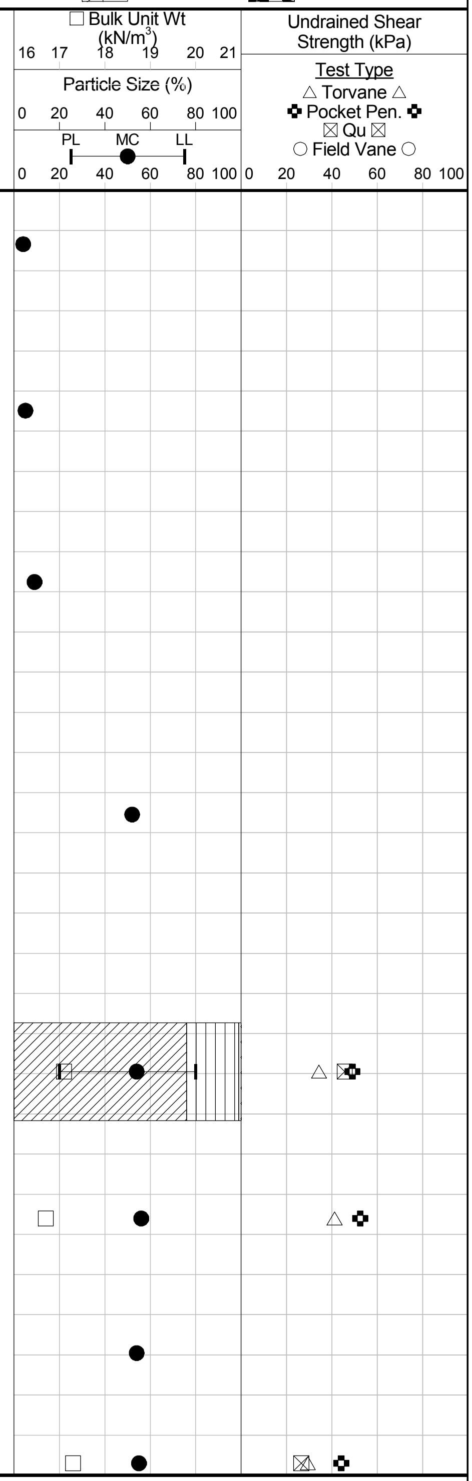
Sub-Surface Log

Client: Morrison Hershfield
Project Name: Omand's Creek Outfalls
Contractor: Paddock Drilling Ltd.
Method: 125mm Solid Stem Auger, Acker MP8 Truck Mount
Project Number: 0035 013 00
Location: UTM N-5528409.13, E-629618.972
Ground Elevation: 233.82 m
Date Drilled: March 5, 2014

Sample Type: Grab (G) | Shelby Tube (T) | Split Spoon (SS) | Split Barrel (SB) | Core (C)

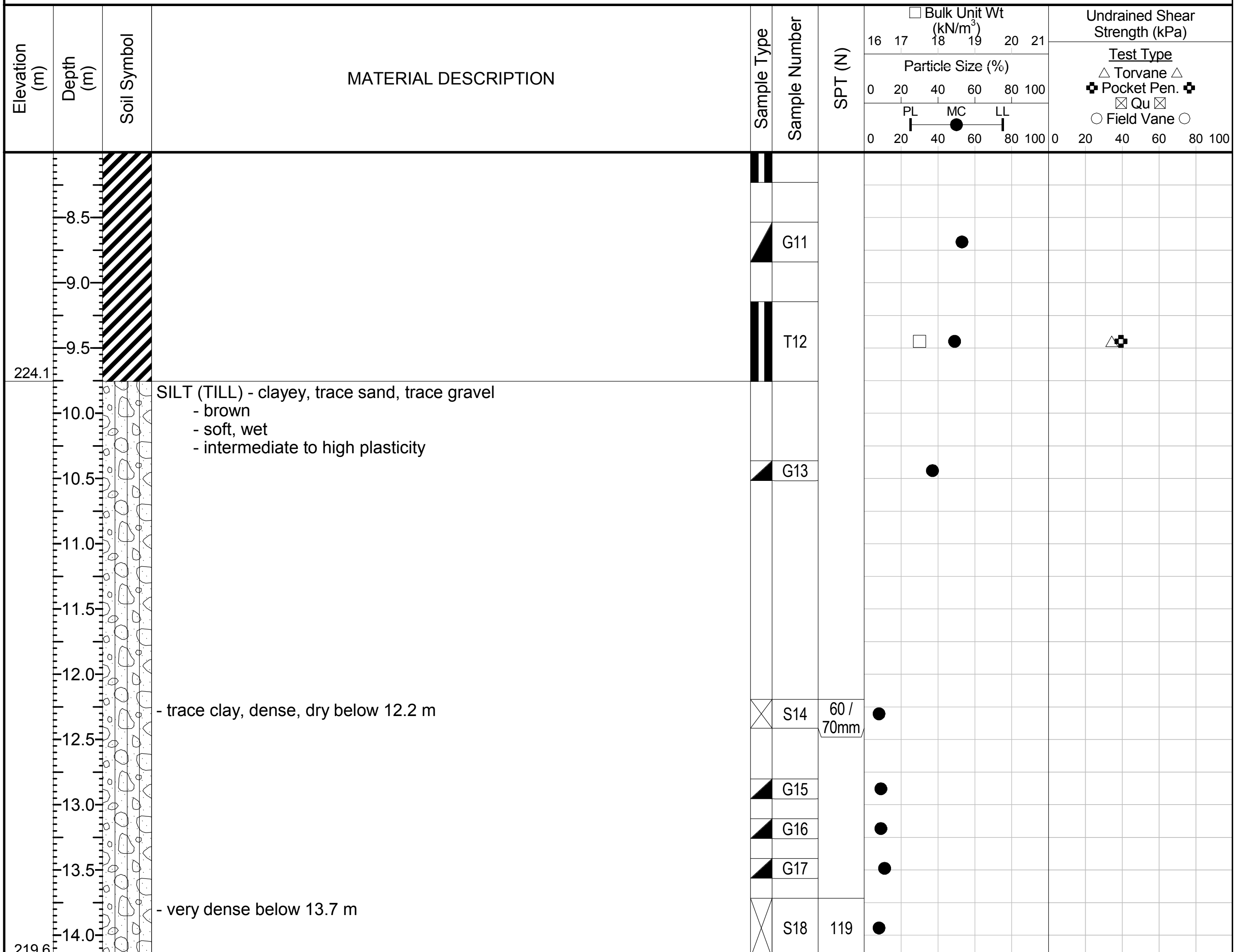
Particle Size Legend: Fines | Clay | Silt | Sand | Gravel | Cobbles | Boulders

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number	SPT (N)
233.7		ASPHALT (150 mm)			
233.5		CONCRETE (175 mm)			
233.0	0.5	SAND and GRAVEL (BASE) - 19 mm down crushed limestone	Grab	G1	
231.7	1.0 – 2.0	SAND and GRAVEL (FILL) - brown - dry - fine grained sand to medium grained gravel, poorly graded - sub-angular	Grab	G2	
230.5	2.5 – 3.0	CLAY (FILL) - silty, sandy, trace gravel - brown - frozen, stiff, dry when thawed - intermediate plasticity	Grab	G3	
	3.5 – 7.5	CLAY - silty, trace silt inclusions (< 3 mm Dia.) - mottled brown and grey - stiff, moist - high plasticity	Grab	G4	
			Grab	G6	
			Shelby Tube	T7	
			Shelby Tube	T8	
			Grab	G9	
		- firm below 7.6 m	Shelby Tube	T10	



Logged By: Paul Bevel **Reviewed By:** Nelson Ferreira **Project Engineer:** Nelson Ferreira

Sub-Surface Log



END OF TEST HOLE AT 14.2 m IN SILT (TILL)

Notes:

1) Squeezing observed below 8.5 m depth.
2) Sloughing observed below 9.8 m depth.
3) Seepage observed at 9.8 m depth.
2) Water level at 11.0 m depth upon completion of test hole.
4) Test hole backfilled with auger cuttings and sand. Test hole capped with the concrete and asphalt cores and cold patch.

Logged By: Paul Bevel **Reviewed By:** Nelson Ferreira **Project Engineer:** Nelson Ferreira

Sub-Surface Log

TREK GEOTECHNICAL

Client:	Morrison Hershfield	**Project Number:**	0035 013 00
Project Name:	Omand's Creek Outfalls	**Location:**	UTM N-5528414.917, E-629385.577
Contractor:	Paddock Drilling Ltd.	**Ground Elevation:**	233.72 m
Method:	125mm Solid Stem Auger, Acker MP8 Truck Mount	**Date Drilled:**	March 14, 2014

Sample Type: Grab (G) Shelby Tube (T) Split Spoon (SS) Split Barrel (SB) Core (C)

Particle Size Legend: Fines Clay Silt Sand Gravel Cobbles Boulders

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number
233.6		ASPHALT (75 mm)		
233.5		CONCRETE (150 mm)		
	0.5	CLAY (FILL) - silty, trace sand, trace silt inclusions (< 5 mm Dia.) - brown - frozen, stiff, dry to moist when thawed - high plasticity	Grab	G1
232.7	1.0	SILT - trace clay, trace sand - light brown - compact, moist - no to low plasticity - moist to wet below 1.5 m	Grab	G2
	2.0		Grab	G3
231.3	2.5	CLAY - silty, trace silt inclusions (< 3 mm Dia.) - mottled brown and grey - stiff, moist - high plasticity	Grab	G4
	4.5		Grab	G5
	5.0	- grey, firm below 4.6 m	Shelby Tube	T6
227.6	6.0		Grab	G7

Chart headings: SPT (N); Bulk Unit Wt (kN/m^3) 16 17 18 19 20 21; Particle Size (%) 0 20 40 60 80 100; PL MC LL 0 20 40 60 80 100; Undrained Shear Strength (kPa) — Test Type: △ Torvane △, ✤ Pocket Pen. ✤, ⊠ Qu ⊠, ○ Field Vane ○; 0 20 40 60 80 100

END OF TEST HOLE AT 6.1 m IN CLAY
Notes:
1) No seepage or sloughing observed.
2) Test hole backfilled with auger cuttings and sand. Test hole capped with the concrete and asphalt cores and cold patch.

Logged By:	Paul Bevel	**Reviewed By:**	Nelson Ferreira	**Project Engineer:**	Nelson Ferreira

TREK GEOTECHNICAL

Sub-Surface Log

Client:	Morrison Hershfield	**Project Number:**	0035 013 00
Project Name:	Omand's Creek Outfalls	**Location:**	UTM N-5528417.412, E-629266.578
Contractor:	Paddock Drilling Ltd.	**Ground Elevation:**	233.66 m
Method:	125mm Solid Stem Auger, Acker MP8 Truck Mount	**Date Drilled:**	March 14, 2014

Sample Type: Grab (G) | Shelby Tube (T) | Split Spoon (SS) | Split Barrel (SB) | Core (C)

Particle Size Legend: Fines | Clay | Silt | Sand | Gravel | Cobbles | Boulders

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number
233.6	0.0	ASPHALT (65 mm)		
233.4		CONCRETE (215 mm)		
233.3		CLAY (FILL) - silty, trace sand, trace gravel, trace silt inclusions (< 3 mm Dia.) - dark brown, frozen, stiff, dry to moist when thawed, high plasticity	G	G8
		SILT - light brown - loose, moist to wet - no to low plasticity	G	G9
232.3		CLAY - silty, trace silt inclusions - brown - frozen, stiff, dry to moist when thawed, high plasticity	G	G10
231.8		SILT - trace to some clay, brown, compact, moist, intermediate plasticity	G	G11
231.5		CLAY - silty, trace silt inclusions (< 3 mm Dia.) - mottled brown and grey - firm, moist - high plasticity	G	G12
			T	T13
			G	G14
		- grey below 4.9 m		
227.6			G	G15

Chart columns: SPT (N); Bulk Unit Wt (kN/m³) 16 17 18 19 20 21; Particle Size (%) 0 20 40 60 80 100; PL MC LL 0 20 40 60 80 100; Undrained Shear Strength (kPa), Test Type: △ Torvane △, ✪ Pocket Pen. ✪, ⊠ Qu ⊠, ○ Field Vane ○, 0 20 40 60 80 100

END OF TEST HOLE AT 6.1 m IN CLAY
Notes:
1) No seepage or sloughing observed.
2) Test hole backfilled with auger cuttings and sand. Test hole capped with the concrete and asphalt cores and cold patch.

Logged By:	Paul Bevel	**Reviewed By:**	Nelson Ferreira	**Project Engineer:**	Nelson Ferreira

TREK GEOTECHNICAL

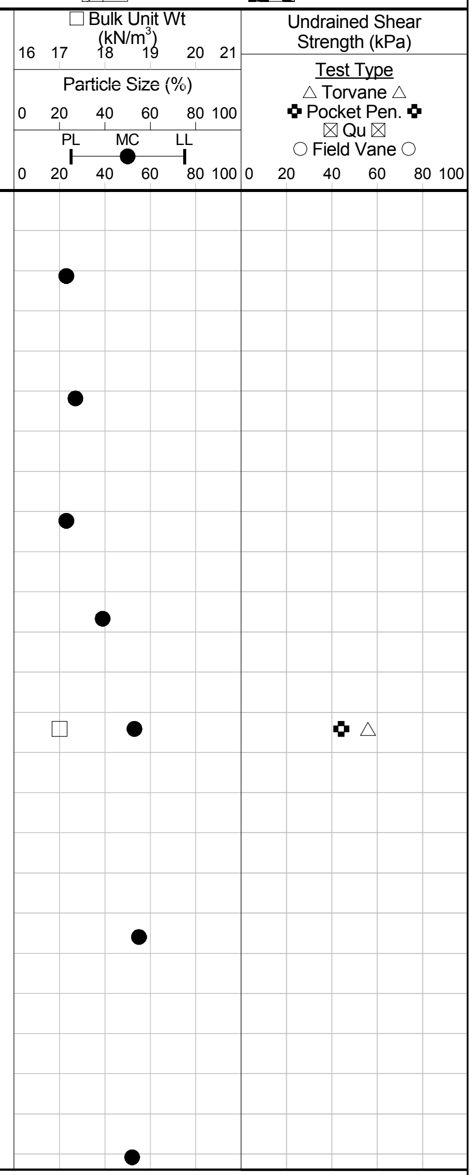
Sub-Surface Log

Client:	Morrison Hershfield	**Project Number:**	0035 013 00
Project Name:	Omand's Creek Outfalls	**Location:**	UTM N-5528057.503, E-629431.036
Contractor:	Paddock Drilling Ltd.	**Ground Elevation:**	233.72 m
Method:	125mm Solid Stem Auger, Acker MP8 Truck Mount	**Date Drilled:**	March 14, 2014

Sample Type: Grab (G) Shelby Tube (T) Split Spoon (SS) Split Barrel (SB) Core (C)

Particle Size Legend: Fines Clay Silt Sand Gravel Cobbles Boulders

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number
233.7	0.0	ASPHALT (65 mm)		
233.5	0.07	CONCRETE (165 mm)		
	0.23	CLAY (FILL) - silty, trace sand, trace silt inclusions (< 3 mm Dia.) - brown - frozen, stiff, dry to moist when thawed - high plasticity	Grab	G16, G17
231.9		SILT - light brown - loose to compact, moist to wet - no to low plasticity	Grab	G18
231.3		CLAY - silty, trace silt inclusions (< 3 mm Dia.) - mottled brown and grey - stiff, moist - high plasticity - grey below 4.6 m	Grab, Shelby Tube	G19, T20, G21, G22
227.6	6.1			



END OF TEST HOLE AT 6.1 m IN CLAY

Notes:

1) No seepage or sloughing observed.

2) Test hole backfilled with auger cuttings and sand. Test hole capped with the concrete and asphalt cores and cold patch.

Logged By: Paul Bevel **Reviewed By:** Nelson Ferreira **Project Engineer:** Nelson Ferreira

Sub-Surface Log

TREK GEOTECHNICAL

Client:	Morrison Hershfield	**Project Number:**	0035 013 00
Project Name:	Omand's Creek Outfalls	**Location:**	UTM N-5528060.416, E-629289.401
Contractor:	Paddock Drilling Ltd.	**Ground Elevation:**	233.69 m
Method:	125mm Solid Stem Auger, Acker MP8 Truck Mount	**Date Drilled:**	March 14, 2014

Sample Type: Grab (G), Shelby Tube (T), Split Spoon (SS), Split Barrel (SB), Core (C)

Particle Size Legend: Fines, Clay, Silt, Sand, Gravel, Cobbles, Boulders

Elevation (m)	Depth (m)	MATERIAL DESCRIPTION	Sample Type	Sample Number	SPT (N)	Bulk Unit Wt (kN/m^3) / Particle Size (%) / PL MC LL	Undrained Shear Strength (kPa) – Test Type: △ Torvane △, ✣ Pocket Pen. ✣, ⊠ Qu ⊠, ○ Field Vane ○
233.6		ASPHALT (65 mm)					
233.5		CONCRETE (165 mm)					
		CLAY and SILT (FILL) - trace sand - brown, frozen, stiff, moist when thawed, intermediate plasticity	Grab	G23			
232.9		SILT - trace sand - light brown - loose, moist to wet - no to low plasticity	Grab	G24			
232.2	1.5	CLAY - silty, trace silt inclusions (< 3 mm Dia.) - mottled brown and grey - stiff, moist - high plasticity	Grab	G25			
			Grab	G26			
			Grab	G27			
		- grey below 4.9 m					
			Grab	G28			
227.6	6.0		Shelby Tube	T29			

END OF TEST HOLE AT 6.1 m IN CLAY
Notes:
1) No seepage or sloughing observed.
2) Test hole backfilled with auger cuttings and sand. Test hole capped with the concrete and asphalt cores and cold patch.

Logged By: Paul Bevel **Reviewed By:** Nelson Ferreira **Project Engineer:** Nelson Ferreira

Appendix B

Lab Testing Results

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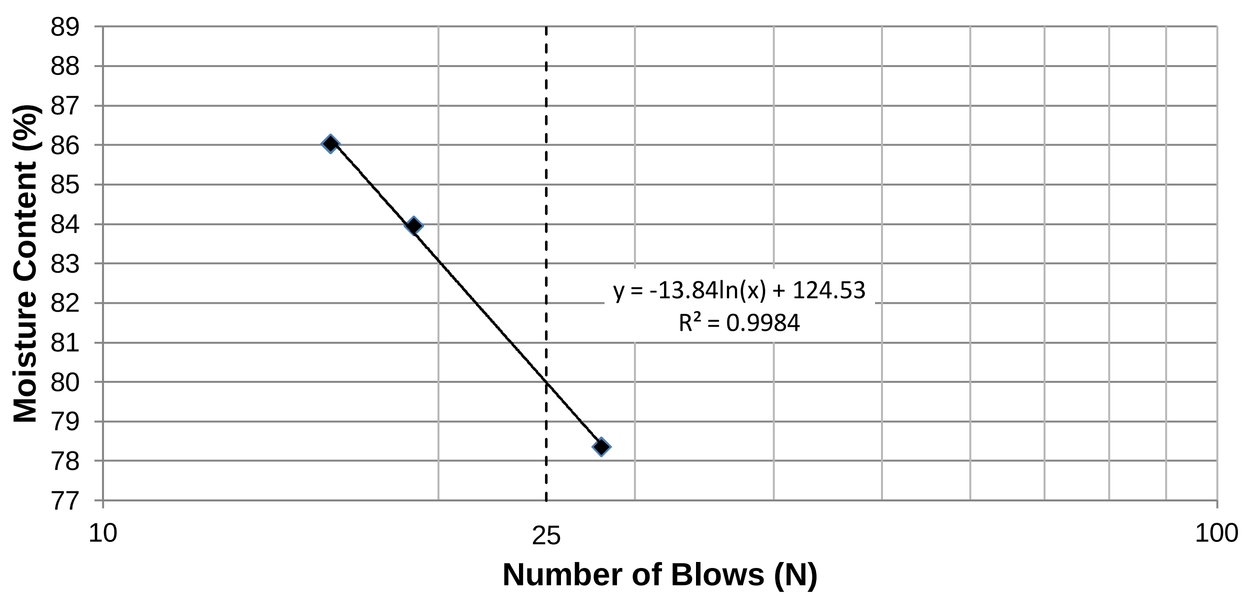
Atterberg Limits
ASTM D4318

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall
Test Hole	TH14-01
Sample #	T7
Depth (m)	5.7 - 5.8
Sample Date	05-Mar-14
Test Date	24-Mar-14
Technician	Daniel Mroz

Liquid Limit	80
Plastic Limit	20
Plasticity Index	60

Liquid Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Number of Blows (N)	28	19	16		
Mass Wet Soil + Tare (g)	23.260	22.508	22.658		
Mass Dry Soil + Tare (g)	19.218	18.655	18.683		
Mass Tare (g)	14.060	14.066	14.063		
Mass Water (g)	4.042	3.853	3.975		
Mass Dry Soil (g)	5.158	4.589	4.620		
Moisture Content (%)	78.364	83.962	86.039		



Plastic Limit

Trial #	**1**	**2**	**3**	**4**	**5**
Mass Wet Soil + Tare (g)	20.402	20.288			
Mass Dry Soil + Tare (g)	19.322	19.245			
Mass Tare (g)	14.016	14.069			
Mass Water (g)	1.080	1.043			
Mass Dry Soil (g)	5.306	5.176			
Moisture Content (%)	20.354	20.151			

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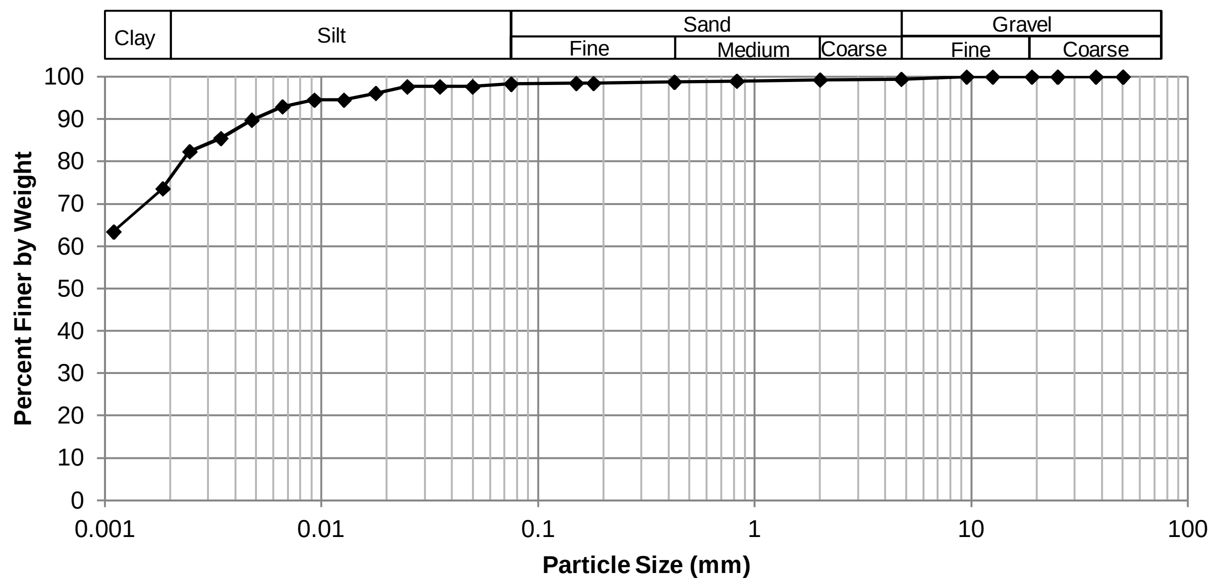
Grain Size Analysis (Hydrometer Method)
ASTM D422

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall
Test Hole	TH14-01
Sample #	T7
Depth (m)	5.7 - 5.8
Sample Date	5-Mar-14
Test Date	24-Mar-14
Technician	Daniel Mroz

Gravel	0.6%
Sand	1.2%
Silt	22.5%
Clay	75.7%

Particle Size Distribution Curve



Gravel		Sand		Silt and Clay	
Particle Size (mm)	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**	**Particle Size (mm)**	**Percent Passing**
50.0	100.00	4.75	99.44	0.0750	98.28
37.5	100.00	2.00	99.27	0.0498	97.67
25.0	100.00	0.825	98.97	0.0352	97.67
19.0	100.00	0.425	98.74	0.0249	97.67
12.5	100.00	0.180	98.46	0.0178	96.09
9.50	100.00	0.150	98.45	0.0127	94.52
4.75	99.44	0.075	98.28	0.0093	94.52
				0.0066	92.94
				0.0048	89.79
				0.0034	85.48
				0.0025	82.33
				0.0019	73.61
				0.0011	63.41

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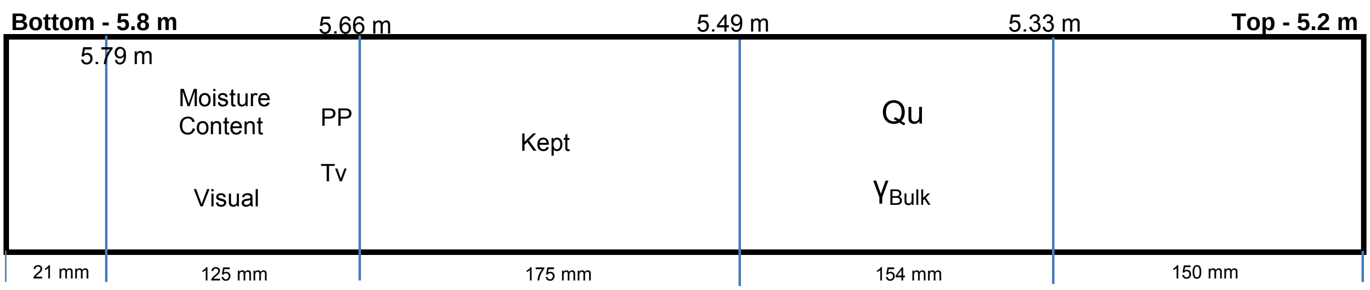
Shelby Tube Visual

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall

Test Hole	TH14-01
Sample #	T7
Depth (m)	5.2 - 5.8
Sample Date	05-Mar-14
Test Date	19-Mar-14
Technician	Daniel Mroz

Tube Extraction

Recovery (mm) 625



Visual Classification

Material	CLAY
Composition	silty
trace silt inclusions (<15 mm diam.)	
trace oxidation	
Color	grey
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	homogeneous
Gradation	-

Torvane

Reading	0.35
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	34.3

Pocket Penetrometer

Reading	1	1.00
	2	1.00
	3	1.00
	Average	1.00
Undrained Shear Strength (kPa)		49.0

Moisture Content

Tare ID	K12
Mass tare (g)	8.6
Mass wet + tare (g)	421.1
Mass dry + tare (g)	276.0
Moisture %	54.3%

Unit Weight

Bulk Weight (g)		1088.10
Length (mm)	1	154.20
	2	154.27
	3	154.22
	4	154.17
Average Length (m)		0.154
Diam. (mm)	1	71.70
	2	71.71
	3	71.95
	4	71.60
Average Diameter (m)		0.072
Volume (m^3)		6.23E-04
Bulk Unit Weight (kN/m^3)		17.1
Bulk Unit Weight (pcf)		109.0
Dry Unit Weight (kN/m^3)		11.1
Dry Unit Weight (pcf)		70.6

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Unconfined Compressive Strength
ASTM D2166

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall

Test Hole	TH14-01
Sample #	T7
Depth (m)	5.2 - 5.8
Sample Date	05-Mar-14
Test Date	19-Mar-14
Technician	Daniel Mroz

Unconfined Strength

	kPa	ksf
Max q_u	91.3	1.9
Max S_u	45.6	1.0

Specimen Data

Description CLAY - silty, trace silt inclusions (<15 mm diam.), trace oxidation, grey, moist, firm, high plasticity, homogeneous

Length	154.2	(mm)	**Moisture %**	54%	
Diameter	71.7	(mm)	**Bulk Unit Wt.**	17.1	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	11.1	(kN/m^3)
Initial Area	0.00404	(m^2)	**Liquid Limit**	80	
Load Rate	1.00	(%/min)	**Plastic Limit**	20	
			Plasticity Index	60	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.35	34.3	0.72
Vane Size		
m		

Pocket Penetrometer

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
1.00	49.1	1.02
1.00	49.1	1.02
1.00	49.1	1.02
1.00	**49.1**	**1.02**

Failure Geometry

Sketch:

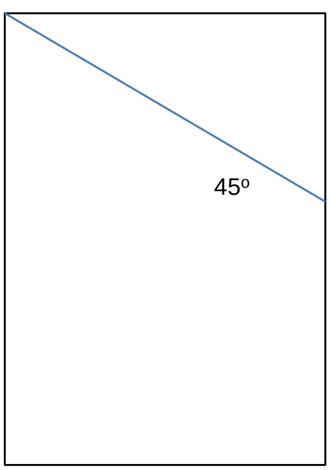
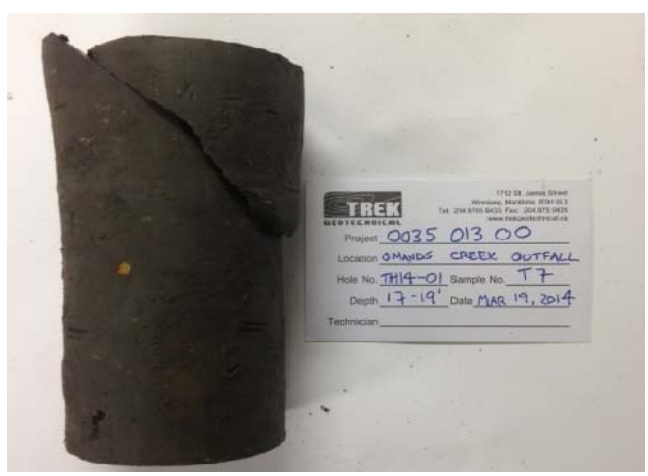


Photo:



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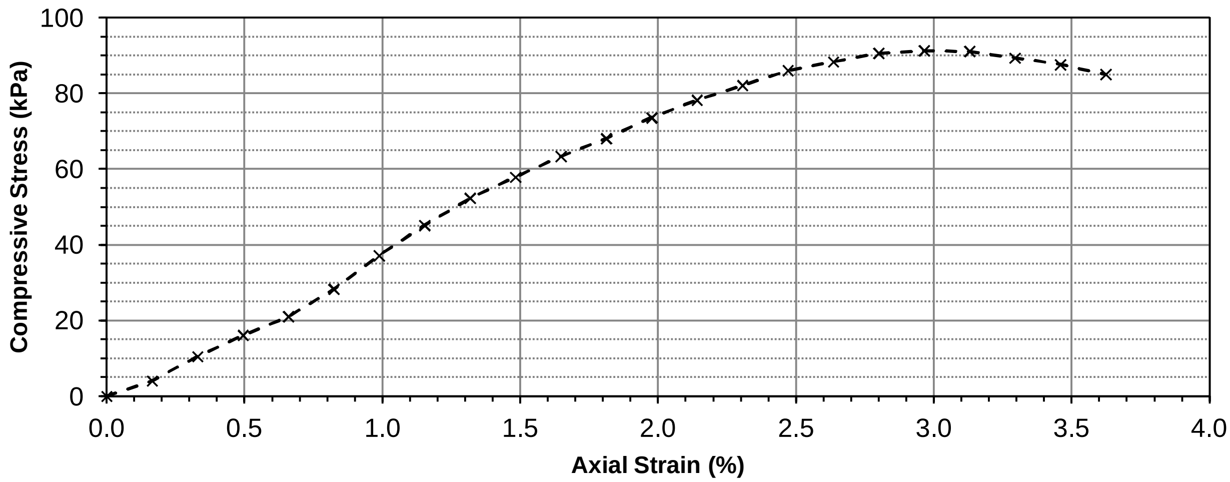
Unconfined Compressive Strength
ASTM D2166

Project No. 0035 013 00
Client Morrison Hershfield
Project Omand's Creek Outfall

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004042	0.0	0.00	0.00
10	5	0.2540	0.16	0.004049	16.3	4.04	2.02
20	13	0.5080	0.33	0.004056	42.5	10.49	5.24
30	20	0.7620	0.49	0.004062	65.5	16.12	8.06
40	26	1.0160	0.66	0.004069	85.7	21.07	10.53
50	35	1.2700	0.82	0.004076	115.4	28.31	14.16
60	46	1.5240	0.99	0.004082	151.7	37.15	18.58
70	56	1.7780	1.15	0.004089	184.6	45.15	22.58
80	65	2.0320	1.32	0.004096	214.3	52.32	26.16
90	72	2.2860	1.48	0.004103	237.4	57.86	28.93
100	79	2.5400	1.65	0.004110	260.4	63.37	31.69
110	85	2.7940	1.81	0.004117	280.2	68.07	34.04
120	92	3.0480	1.98	0.004124	303.3	73.56	36.78
130	98	3.3020	2.14	0.004131	323.1	78.23	39.11
140	103	3.5560	2.31	0.004138	339.8	82.13	41.06
150	108	3.8100	2.47	0.004145	356.7	86.05	43.03
160	111	4.0640	2.64	0.004152	366.8	88.34	44.17
170	114	4.3180	2.80	0.004159	376.9	90.62	45.31
180	115	4.5720	2.96	0.004166	380.2	91.28	45.64
190	115	4.8260	3.13	0.004173	380.2	91.12	45.56
200	113	5.0800	3.29	0.004180	373.5	89.35	44.68
210	111	5.3340	3.46	0.004187	366.8	87.59	43.80
220	108	5.5880	3.62	0.004194	356.7	85.04	42.52

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Shelby Tube Visual

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall

Test Hole	TH14-01
Sample #	T8
Depth (m)	6.1 - 6.8
Sample Date	05-Mar-14
Test Date	19-Mar-14
Technician	Daniel Mroz

Tube Extraction

Recovery (mm) 650

Bottom - 6.8 m	6.50 m	6.48 m	6.30 m	**Top - 6.1 m**
Moisture Content Visual	PP Tv	γ_{Bulk} Kept		
236 mm	25 mm	189 mm	200 mm	

Visual Classification

Material	CLAY
Composition	silty
trace silt inclusions (<15 mm diam.)	
trace oxidation	
Color	grey
Moisture	moist
Consistency	firm to stiff
Plasticity	high plasticity
Structure	homogeneous
Gradation	-

Torvane

Reading	0.42
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	41.2

Pocket Penetrometer

Reading	**1**	1.00
	2	1.20
	3	1.00
	Average	1.07
Undrained Shear Strength (kPa)		52.3

Moisture Content

Tare ID	F96
Mass tare (g)	8.6
Mass wet + tare (g)	426.8
Mass dry + tare (g)	276.1
Moisture %	56.3%

Unit Weight

Bulk Weight (g)		1297.70
Length (mm)	**1**	189.00
	2	
	3	
	4	
Average Length (m)		0.189
Diam. (mm)	**1**	72.09
	2	71.53
	3	71.80
	4	71.24
Average Diameter (m)		0.072
Volume (m^3)		7.62E-04
Bulk Unit Weight (kN/m^3)		16.7
Bulk Unit Weight (pcf)		106.3
Dry Unit Weight (kN/m^3)		10.7
Dry Unit Weight (pcf)		68.0

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Shelby Tube Visual

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall
Test Hole	TH14-01
Sample #	T10
Depth (m)	7.6 - 8.3
Sample Date	05-Mar-14
Test Date	19-Mar-14
Technician	Daniel Mroz

Tube Extraction

Recovery (mm)	700

Bottom - 8.3 m	8.15 m	7.98 m	7.82 m	**Top - 7.6 m**
	Qu γ_{Bulk}	Kept PP Tv	Moisture Content Visual	
23 mm	152 mm	175 mm	150 mm	200 mm

Visual Classification

Material	CLAY
Composition	silty
trace gravel (<10 mm diam.)	
trace silt inclusions (<15 mm diam.)	
trace oxidation	
Color	grey
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	homogeneous
Gradation	-

Torvane

Reading	0.3
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	29.4

Pocket Penetrometer

Reading	**1**	0.90
	2	0.90
	3	0.90
	Average	0.90
Undrained Shear Strength (kPa)		44.1

Moisture Content

Tare ID	N108
Mass tare (g)	8.3
Mass wet + tare (g)	397.9
Mass dry + tare (g)	259.2
Moisture %	55.3%

Unit Weight

Bulk Weight (g)		1087.30
Length (mm)	**1**	151.79
	2	151.20
	3	151.80
	4	151.63
Average Length (m)		0.152
Diam. (mm)	**1**	72.59
	2	72.30
	3	71.50
	4	71.60
Average Diameter (m)		0.072
Volume (m^3)		6.17E-04
Bulk Unit Weight (kN/m^3)		17.3
Bulk Unit Weight (pcf)		110.0
Dry Unit Weight (kN/m^3)		11.1
Dry Unit Weight (pcf)		70.8

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Unconfined Compressive Strength
ASTM D2166

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall

Test Hole	TH14-01
Sample #	T10
Depth (m)	7.6 - 8.3
Sample Date	05-Mar-14
Test Date	19-Mar-14
Technician	Daniel Mroz

Unconfined Strength

	kPa	ksf
Max q_u	53.0	1.1
Max S_u	26.5	0.6

Specimen Data

Description CLAY - silty, trace gravel (<10 mm diam.), trace silt inclusions (<15 mm diam.), trace oxidation, grey, moist, firm, high plasticity, homogeneous

Length	151.6	(mm)	**Moisture %**	55%	
Diameter	72.0	(mm)	**Bulk Unit Wt.**	17.3	(kN/m^3)
L/D Ratio	2.1		**Dry Unit Wt.**	11.1	(kN/m^3)
Initial Area	0.00407	(m^2)	**Liquid Limit**	-	
Load Rate	1.00	(%/min)	**Plastic Limit**	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.30	29.4	0.61
Vane Size		
m		

Pocket Penetrometer

Reading	**Undrained Shear Strength**	
tsf	**kPa**	**ksf**
0.90	44.1	0.92
0.90	44.1	0.92
0.90	44.1	0.92
0.90	**44.1**	**0.92**

Failure Geometry

Sketch:

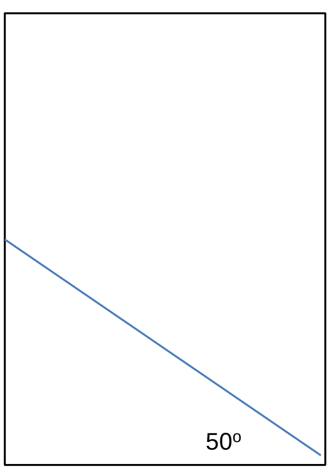

Photo:

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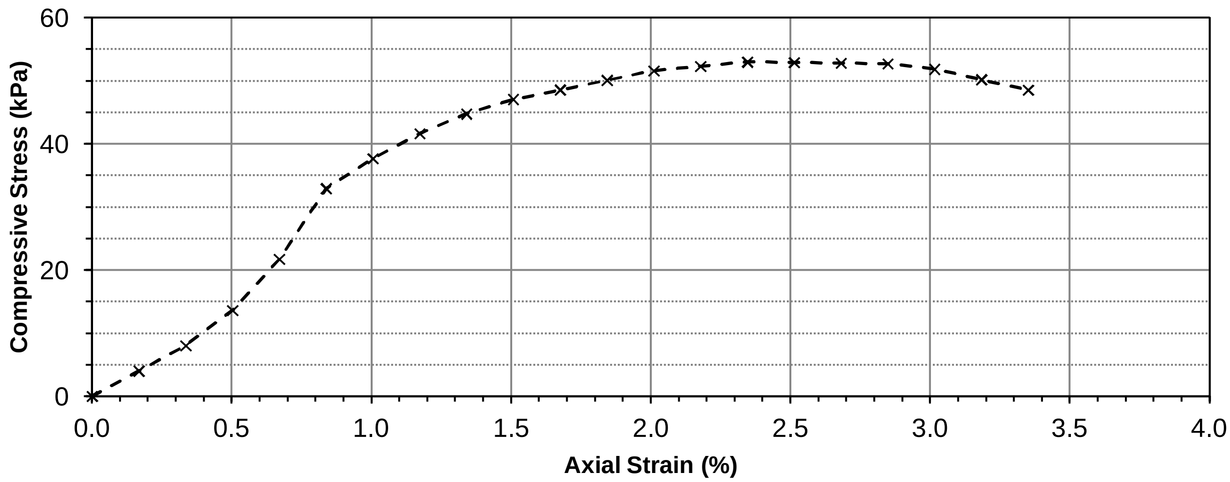
Unconfined Compressive Strength
ASTM D2166

Project No. 0035 013 00
Client Morrison Hershfield
Project Omand's Creek Outfall

Unconfined Compression Test Graph



Unconfined Compression Test Data

Deformation Dial Reading	Load Ring Dial Reading	Deflection (mm)	Axial Strain (%)	Corrected Area (m^2)	Axial Load (N)	Compressive Stress, q_u (kPa)	Shear Stress, S_u (kPa)
0	0	0.0000	0.00	0.004071	0.0	0.00	0.00
10	5	0.2540	0.17	0.004078	16.3	4.01	2.00
20	10	0.5080	0.34	0.004085	32.7	8.01	4.00
30	17	0.7620	0.50	0.004092	55.7	13.60	6.80
40	27	1.0160	0.67	0.004099	89.0	21.72	10.86
50	41	1.2700	0.84	0.004106	135.2	32.93	16.46
60	47	1.5240	1.01	0.004113	155.0	37.68	18.84
70	52	1.7780	1.17	0.004120	171.4	41.62	20.81
80	56	2.0320	1.34	0.004127	184.6	44.75	22.37
90	59	2.2860	1.51	0.004134	194.5	47.06	23.53
100	61	2.5400	1.68	0.004141	201.1	48.57	24.28
110	63	2.7940	1.84	0.004148	207.7	50.08	25.04
120	65	3.0480	2.01	0.004155	214.3	51.58	25.79
130	66	3.3020	2.18	0.004162	217.6	52.29	26.14
140	67	3.5560	2.35	0.004169	220.9	52.99	26.49
150	67	3.8100	2.51	0.004176	220.9	52.90	26.45
160	67	4.0640	2.68	0.004183	220.9	52.80	26.40
170	67	4.3180	2.85	0.004191	220.9	52.71	26.36
180	66	4.5720	3.02	0.004198	217.6	51.84	25.92
190	64	4.8260	3.18	0.004205	211.0	50.18	25.09
200	62	5.0800	3.35	0.004212	204.4	48.52	24.26

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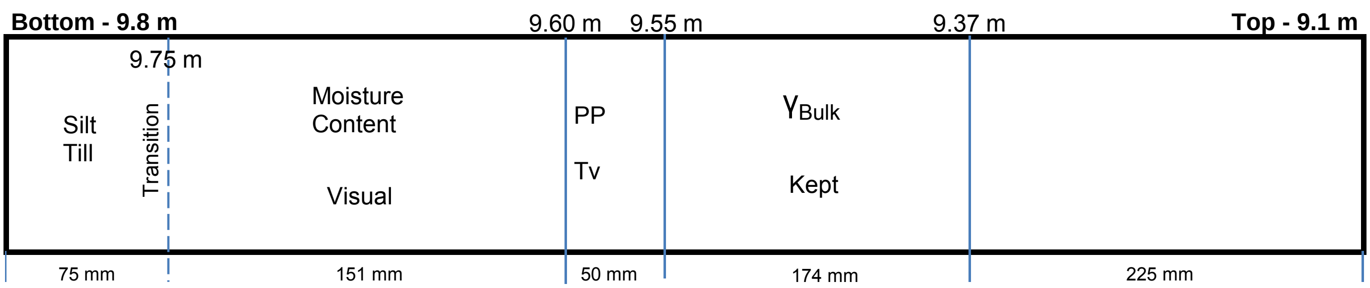
Shelby Tube Visual

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall
Test Hole	TH14-01
Sample #	T12
Depth (m)	9.1 - 9.8
Sample Date	05-Mar-14
Test Date	19-Mar-14
Technician	Daniel Mroz

Tube Extraction

Recovery (mm)	675



Visual Classification

Material	CLAY
Composition	silty
trace gravel (<10 mm diam.)	
trace coarse grained sand	
trace silt inclusions (<20 mm diam.)	
Color	grey
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	homogeneous
Gradation	-

Torvane

Reading	0.35
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	34.3

Pocket Penetrometer

Reading	**1**	0.80
	2	0.80
	3	0.80
	Average	0.80
Undrained Shear Strength (kPa)		39.2

Moisture Content

Tare ID	N107
Mass tare (g)	8.4
Mass wet + tare (g)	404.2
Mass dry + tare (g)	273.8
Moisture %	49.1%

Unit Weight

Bulk Weight (g)		1254.30
Length (mm)	**1**	173.50
	2	
	3	
	4	
Average Length (m)		0.174
Diam. (mm)	**1**	71.74
	2	71.60
	3	71.72
	4	71.80
Average Diameter (m)		0.072
Volume (m^3)		7.01E-04
Bulk Unit Weight (kN/m^3)		17.6
Bulk Unit Weight (pcf)		111.7
Dry Unit Weight (kN/m^3)		11.8
Dry Unit Weight (pcf)		74.9

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Shelby Tube Visual

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall
Test Hole	TH14-02
Sample #	T6
Depth (m)	4.6 - 5.2
Sample Date	14-Mar-14
Test Date	20-Mar-14
Technician	Daniel Mroz

Tube Extraction

Recovery (mm) 650

Bottom - 5.2 m	4.98 m	4.78 m **Top - 4.6 m**
Moisture Content Visual	γBulk Kept	PP Tv
250 mm	197 mm	203 mm

Visual Classification

Material	CLAY
Composition	silty
trace gravel (<10 mm diam.)	
trace silt inclusions (<10 mm diam.)	
trace oxidation	
Color	grey
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	homogeneous
Gradation	-

Torvane

Reading	0.26
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	25.5

Pocket Penetrometer

Reading	**1**	0.75
	2	0.70
	3	0.70
	Average	0.72
Undrained Shear Strength (kPa)		35.1

Moisture Content

Tare ID	H27
Mass tare (g)	8.4
Mass wet + tare (g)	392.3
Mass dry + tare (g)	249.6
Moisture %	59.2%

Unit Weight

Bulk Weight (g)		1368.40
Length (mm)	**1**	197.00
	2	
	3	
	4	
Average Length (m)		0.197
Diam. (mm)	**1**	71.99
	2	72.05
	3	71.56
	4	72.20
Average Diameter (m)		0.072
Volume (m^3)		8.01E-04
Bulk Unit Weight (kN/m^3)		16.8
Bulk Unit Weight (pcf)		106.7
Dry Unit Weight (kN/m^3)		10.5
Dry Unit Weight (pcf)		67.0

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Shelby Tube Visual

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall
Test Hole	TH14-03
Sample #	T13
Depth (m)	3.0 - 3.7
Sample Date	14-Mar-14
Test Date	20-Mar-14
Technician	Daniel Mroz

Tube Extraction

Recovery (mm)	600

Bottom - 3.7 m	3.56 m	3.38 m	3.17 m / **Top - 3.0 m**
γ_{Bulk}	Moisture Content Visual	Kept	PP Tv
67 mm	200 mm	200 mm	133 mm

Visual Classification

Material	CLAY
Composition	silty
trace silt inclusions (<5 mm diam.)	
trace oxidation	
Color	grey
Moisture	moist
Consistency	firm
Plasticity	high plasticity
Structure	homogeneous
Gradation	-

Torvane

Reading	0.36
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	35.3

Pocket Penetrometer

Reading	**1**	0.80
	2	0.80
	3	0.70
	Average	0.77
Undrained Shear Strength (kPa)		37.6

Moisture Content

Tare ID	H23
Mass tare (g)	8.4
Mass wet + tare (g)	413.8
Mass dry + tare (g)	268.2
Moisture %	56.0%

Unit Weight

Bulk Weight (g)		464.90
Length (mm)	**1**	66.80
	2	66.60
	3	66.69
	4	66.54
Average Length (m)		0.067
Diam. (mm)	**1**	72.06
	2	71.86
	3	71.70
	4	71.67
Average Diameter (m)		0.072
Volume (m^3)		2.70E-04
Bulk Unit Weight (kN/m^3)		16.9
Bulk Unit Weight (pcf)		107.5
Dry Unit Weight (kN/m^3)		10.8
Dry Unit Weight (pcf)		68.9

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Shelby Tube Visual

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall
Test Hole	TH14-04
Sample #	T20
Depth (m)	3.0 - 3.6
Sample Date	14-Mar-14
Test Date	20-Mar-14
Technician	Daniel Mroz

Tube Extraction

Recovery (mm) 550

Bottom - 3.6 m	3.38 m	3.17 m **Top - 3.0 m**
Moisture Content Visual	γ_{Bulk} Kept	PP Tv
225 mm	208 mm	117 mm

Visual Classification

Material	CLAY
Composition	silty
trace silt inclusions (<10 mm diam.)	
trace oxidation	
trace organics	
Color	grey
Moisture	moist
Consistency	firm to stiff
Plasticity	high plasticity
Structure	homogeneous
Gradation	-

Torvane

Reading	0.57
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	55.9

Pocket Penetrometer

Reading	**1**	1.00
	2	0.80
	3	0.90
	Average	0.90
Undrained Shear Strength (kPa)		44.1

Moisture Content

Tare ID	N83
Mass tare (g)	8.5
Mass wet + tare (g)	427.2
Mass dry + tare (g)	281.8
Moisture %	53.2%

Unit Weight

Bulk Weight (g)		1462.60
Length (mm)	**1**	207.50
	2	
	3	
	4	
Average Length (m)		0.208
Diam. (mm)	**1**	71.50
	2	71.90
	3	72.02
	4	72.04
Average Diameter (m)		0.072
Volume (m^3)		8.42E-04
Bulk Unit Weight (kN/m^3)		17.0
Bulk Unit Weight (pcf)		108.5
Dry Unit Weight (kN/m^3)		11.1
Dry Unit Weight (pcf)		70.8

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Shelby Tube Visual

Project No.	0035 013 00
Client	Morrison Hershfield
Project	Omand's Creek Outfall
Test Hole	TH14-05
Sample #	T29
Depth (m)	5.5 - 6.1
Sample Date	14-Mar-14
Test Date	20-Mar-14
Technician	Daniel Mroz

Tube Extraction

Recovery (mm) 625

Bottom - 6.1 m	5.97 m	5.77 m	5.59 m **Top - 5.5 m**
PP Tv	γ_{Bulk} Kept	Moisture Content Visual	
150 mm	207 mm	175 mm	93 mm

Visual Classification

Material	CLAY
Composition	silty
trace silt inclusions (<10 mm diam.)	
trace oxidation	
Color	grey
Moisture	moist
Consistency	stiff
Plasticity	high plasticity
Structure	homogeneous
Gradation	-

Torvane

Reading	0.51
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	50.0

Pocket Penetrometer

Reading	**1**	1.20
	2	1.30
	3	1.20
	Average	1.23
Undrained Shear Strength (kPa)		60.5

Moisture Content

Tare ID	W100
Mass tare (g)	8.4
Mass wet + tare (g)	487.8
Mass dry + tare (g)	329.5
Moisture %	49.3%

Unit Weight

Bulk Weight (g)		1495.80
Length (mm)	**1**	207.00
	2	
	3	
	4	
Average Length (m)		0.207
Diam. (mm)	**1**	71.70
	2	71.61
	3	72.37
	4	72.41
Average Diameter (m)		0.072
Volume (m^3)		8.43E-04
Bulk Unit Weight (kN/m^3)		17.4
Bulk Unit Weight (pcf)		110.7
Dry Unit Weight (kN/m^3)		11.7
Dry Unit Weight (pcf)		74.2

Appendix C

Existing Information

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GEOTECHNICAL REPORT FOR THE ST. MATHEWS–OMANDS CREEK CROSSING

PREPARED FOR DILLON CONSULTING BY A. DEAN GOULD P.ENG May 22,2009

1.0 Terms of Reference

In accordance with the proposal of March 2,2009 the writer was commissioned to undertake a subsurface investigation of the site for the proposed culvert replacement crossing of Omand's Creek adjacent Empress Street. The site is located at the intersection of St. Mathews Avenue and Empress Street and is a main road artery of the City of Winnipeg. The site is bounded by commercial building to the southeast, a beer vender to the northeast and Empress Street to the west. Omand's creek is a main waterway, which has been, relocated to its present location in early 1950 The terrain s basically level and lacks vegetation.

2.0 Subsurface Investigation

The subsurface investigation commenced on March 12,2009 and consisted of four (4) test holes, which were located through survey by Dillon Consulting in the area of the proposed crossing. The test holes were 150mm in diameter and were produced by a track-mounted auger-drilling machine owned and operated by Maple Leaf Environmental of Winnipeg. Each test hole extended from ground surface to auger refusal on dense glacial till. Test holes were logged and sampled for identifcation of the soil stratigraphy. Disturbed samples were subjected to identification in the field and a following confirmation by the writer to identify and anomalies. Insitu Dutch Cone penetration tests were performed in Test Holes 4 to obtain insitu strength tests of the glacial till for foundation design. The ground water level in all test holes was measured following completion and each hole was backfilled with local clays. Test Holes 1was dry, Test Holes 3 and 4 showed minor water inflow at depths of 1.37m and 2.13m respectively. The location of all test holes is shown on the appended plan.

3.0 Soil Profile

The soil stratigraphy at the site as determined through this investigation and described on the attached logs was found to be typical of the area, consisting of approximately 8 meters of surface lacustrine clays overlying glacial till. Overlying the clays is up to 2 meters of a granular fill. The glacial till surface at approximately Elevation 224 was found to dip slightly from east to west. Dutch cone penetration tests indicate a very dense till (N<50) at Elevation 223 +/-. Moisture content testing was performed in the writer's facility on disturbed samples and the results of that testing is shown plotted on the attached logs. Undisturbed Shelby tube samples of the clay were obtained for laboratory testing and the undrained strength was found to be 70.7 kPa, 50 Kpa less than the overburden pressure at the sample elevation of 224.38. From the stability analysis of the existing slope, through a back analysis technique soil strength parameters of phi=15 degrees and a cohesion of 2 kPa produced a computed Factor of Safety against sliding of 1.13 which appears reasonable for the current condition of slope stability. Applying these soil strength parameters in the General Bearing equation (re: Canadian Foundation Manual 3rd Edition) an ultimate bearing capacity of 140.9 kPa was determined. Using s Factor of Safety of 2.0 allowable bearing capacity in the clays was found to be 111.7 kPa slightly lower than the 120.7 kPa determined. For a typical raft footing design within the clay strata, the following allowable bearing pressure at the base (Elevation 228) that should be applied in design assuming a 2.5 surcharge due to the fill height above the obvert of the box culvert:

Depth of Fill Below Street Grade	Footing Width	ULS Capacities	Allowable Bearing Capacity
2.5 meters	1 m	140.9 kPa	111.7 kPa

The underlying glacial till was relatively soft through the upper zone (N=16-20) and became dense (N=>50) at a depth of 9.4 – 9.1 meters. The insitu strengths of the glacial till, as determined through the Dutch Cone Penetration testing are as follows;

Test Hole No.	Elevation	N Blows/300mm Average values	Ultimate Bearing Capacity of Till	Allowable Bearing Capacity of Till FS=2
1	224.7- 223.8	25 (20*)	1198.8 kPa	640.6 kPa
1	223.8-223.2	39 (27*)	1538.1 kPa	810.5 kPa
4	222.08	69 (42*)	2664.7 kPa	1273.6 kPa

* Reduction made for water table or Omand's creek levels

4.0 Foundation Considerations

For the proposed box culvert it is assumed by the writer that minimal movement could be tolerated and that the structure would be designed structurally as a monolithic unit. Movements that would occur could potentially be reflected in the surface pavements and be accommodated in the pavement joints. Some fill consolidation over the obvert of the culvert can be anticipated which can be minimized with close quality compaction control. The base support for a raft footing would distribute both structure and fill loadings on the clay soils. Concentrated loads from the walls could produce some differential loading, which can be minimized with the provision of a 300mm granular free draining layer below the slab to distribute loading. Upstream and downstream cut-offs are normally required to prevent erosion undercutting during high and low flow velocity periods. The granular layer must be provided with drains, which extend through the cut-offs to prevent uplift forces on the raft.

Foundations for a structure that is sensitive to movement and stress from traffic surface loading should utilize a pile foundation bearing upon the dense glacial till at or near Elevation 222. Piles could be of either cast in place concrete with expanded bases for heavy loads or driven concrete piles. For the cast in place piles it is not anticipated that sleeving of the holes would be required. Driven piles which are expected to reach the following set criteria at a depth of 12 meters below grade would have the following design capacities;

Pile Diameter	Final Set Blows/25mm *	Capacity
300 mm	6 blows/25 mm	450 kN
350 mm	8 blows/25 mm	600 kN
400 mm	10 blows/25 mm	800 kN

- For a pile driving hammer delivering a minimum of 30,000 ft-lbs per blow

5.0 Retaining Walls and Containment Structures

For the retaining walls, the design should be based upon the Rankin wall coefficient of 0.8 for clay soils in direct contact with the walls. Provision of drainage through a granular backfill and a weeping tile system can reduce the backfill pressure markedly allowing the coefficient of 0.35 to be applied in wall design.

Free draining backfill comprised of crushed dolomitic Limestone meeting the following grading specification is recommended for the backfill and the granular sub base below the floor slab:

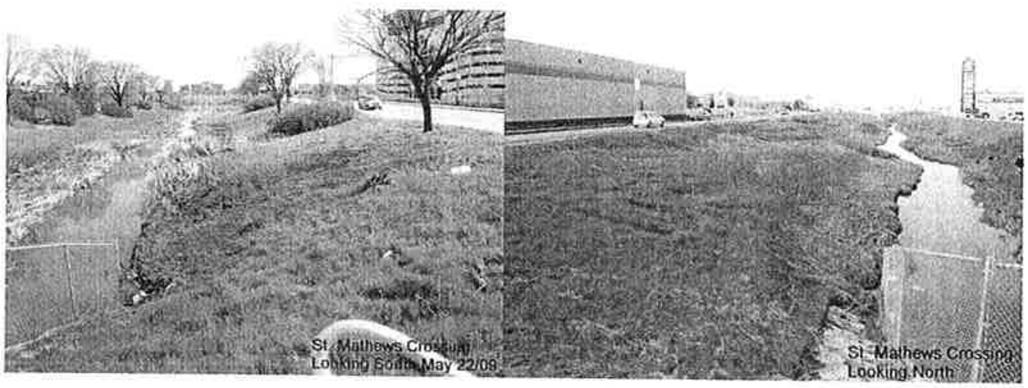
Cdn Metric Sieve Size	% of Total Weight Passing
40,000	95-100%
20,000	35-70%
10,000	10-30%
5,000	0-5%

The material should be placed in 150mm lifts and compacted to 98% of maximum dry density according to ASTM D-698

A box culvert, when designed as a raft, essentially removes weight from the base of the footing by replacing soil weight with water of lower density. The raft distributes load uniformly on a soil base that has experienced loading, consequently neither settlement nor uplift would be experienced providing the design pressures is equal to overburden pressure at the design base elevation. Should the box culvert remain empty for an extended period of time (3 months) a small amount of rebound may occur, however since the base will be underlain by between 4-5 meters of clay soil which has been preloaded with the existing culverts and street traffic, and the underlying glacial till has a low potential for rebound, the upward movement should be low.

6.0 Shoring Requirements

Due to proximity of Empress Street and the need for this major thoroughfare to be in service during the construction of the box culvert crossing, there will be a need for shoring to support the roadway during excavation for the base slab and placement of the walls. Shoring design must recognize both lateral soil loading and lateral loads produced from traffic.



The shoring should be designed on the based of a Rankin soil pressure coefficient of 0.3 considered adequate for temporary works performed during the winter or during low flow periods when Oman's creek levels are low.

7.0 Slope Stability

The Omand's Creek slopes both upstream and downstream of the structure are known to be unstable. As indicated above, a back analysis of the existing slopes shown in Section A-A and B-B attached was made to verify the mobilized effective soil parameters and to determine safe slopes.

The back analysis was performed utilizing the 2-dimensional computer program G-Slope and the Bishops Modified method of analysis. The analysis produced similar results for both sections and the following effective soil strength parameters for the brown clay (Factor of Safety against sliding 1.1 or near unity). The failure scarp locations in both sections matched the observed failure scarp positions as shown on the photographs. The lower surface of the most probable failure surface was between Elevation 227.5 and 228, approximately 1-1.5 meters below the base slab of the box culvert.

Angle of Internal Friction (phi) = 15 degrees

Cohesion = 2 kPa

Based upon this analysis remedial measures to stabilize the slopes included Rock Caisson installations and Shear Keys. The structure granular backfill will effectively become a large portion of a Shear Key.

The length of the slope stabilization is questionable as Omand's Creek from Sargent Avenue to St Mathews and south, presents evidence of instability. For this structure, a length of 20 meters upstream and downstream of the existing CMP is assumed as part of the project. A summary of the options and the computed benefits are as follows:

Stabilization Options

Option	**Factor of Safety**	**Improvement %**	**Total Length**	**Estimated Costs**
Shear Key	1.39 4m base at Elev 229.5	23.4%	38 meters west side(2000cu.m)	$ 70,000*
Rock Caissons	1.57 14-1800mm R/C @ 4m c-c	38.7%	38 meters west side	$ 91,000*

Costs estimated on basis of $40.00/cu.m of rock fill and $6,500/caisson

Seismic Considerations

The Winnipeg area is within in a low seismic zone having a peak horizontal ground velocity less than 0.4g. This complies to a Class C area of Seismic Response in accordance with the National Building Code of Canada, 2005 Table 4.1.8.4.A A calculation of the impact on structures produces minimal seismic response factors and is normally neglected in local practise.

7.0 Recommendations

Based upon the above, the following recommendations are offered:

1. That the box culvert be founded upon a structural raft footing at or about Elevation 228 (approximately 1.5 meters below the base of channel) and the allowable soil bearing pressure in design be 120 kPa

2. Below the raft a free draining granular base should be provided to distribute structure and fill loading to the base soil. Consolidation and settlement should be minimal since the base foundation has experienced loading of this magnitude under current service.

3. Upstream and downstream cut-off walls should be provided to prevent undercutting during high and low flows. The cut-off walls should be equipped with drain holes to prevent hydraulic uplift on base. The material grading specifications for the recommended granular sub base are provided in section 5.0

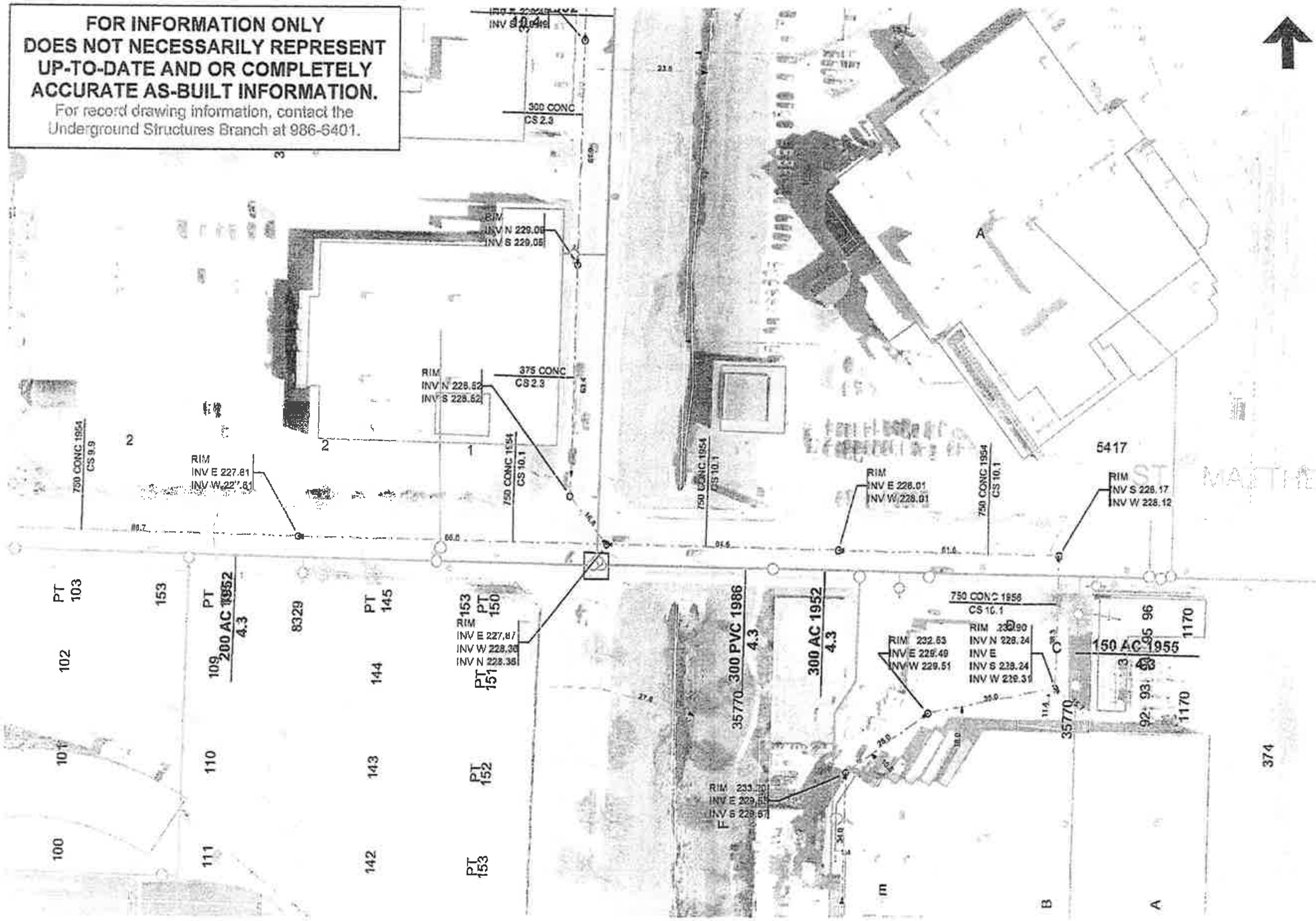
4. That embankment stabilization consisting of a shear key be installed along the west slope of Omands Creek through a distance of 20 meters upstream and downstream of the structure.

5. That type 50 sulphate resistant cement be used in all concrete in contact with the soil

Respectfully Submitted,

PROVINCE OF MANITOBA 24/05/09 A. D. GOULD REGISTERED ENGINEER

A. Dean Gould P.Eng
Geotechnical Consultant


FOR INFORMATION ONLY
DOES NOT NECESSARILY REPRESENT
UP-TO-DATE AND OR COMPLETELY
ACCURATE AS-BUILT INFORMATION.
For record drawing information, contact the
Underground Structures Branch at 986-6401.
300 CONC
CS 2.3
RIM
INV N 229.06
INV S 229.06
375 CONC
CS 2.3
RIM
INV N 228.52
INV S 228.52
750 CONC 1954
CS 9.9
RIM
INV E 227.81
750 CONC 1954
CS 10.1
RIM
INV E 228.01
INV W 228.01
RIM
INV S 228.17
INV W 228.12
5417
PT
103
102
153
PT
200 AC 1952
4.3
109
8329
PT
145
144
153
PT
150
RIM
INV E 227.87
INV W 228.38
INV N 228.38
PT
151
300 PVC 1986
4.3
35770
300 AC 1952
4.3
750 CONC 1956
CS 10.1
RIM 232.63
INV E 229.49
INV W 229.51
INV N 228.24
INV E
INV S 228.24
INV W 229.31
150 AC 1955
96
1170
92
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374
101
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143
PT
152
RIM 233.20
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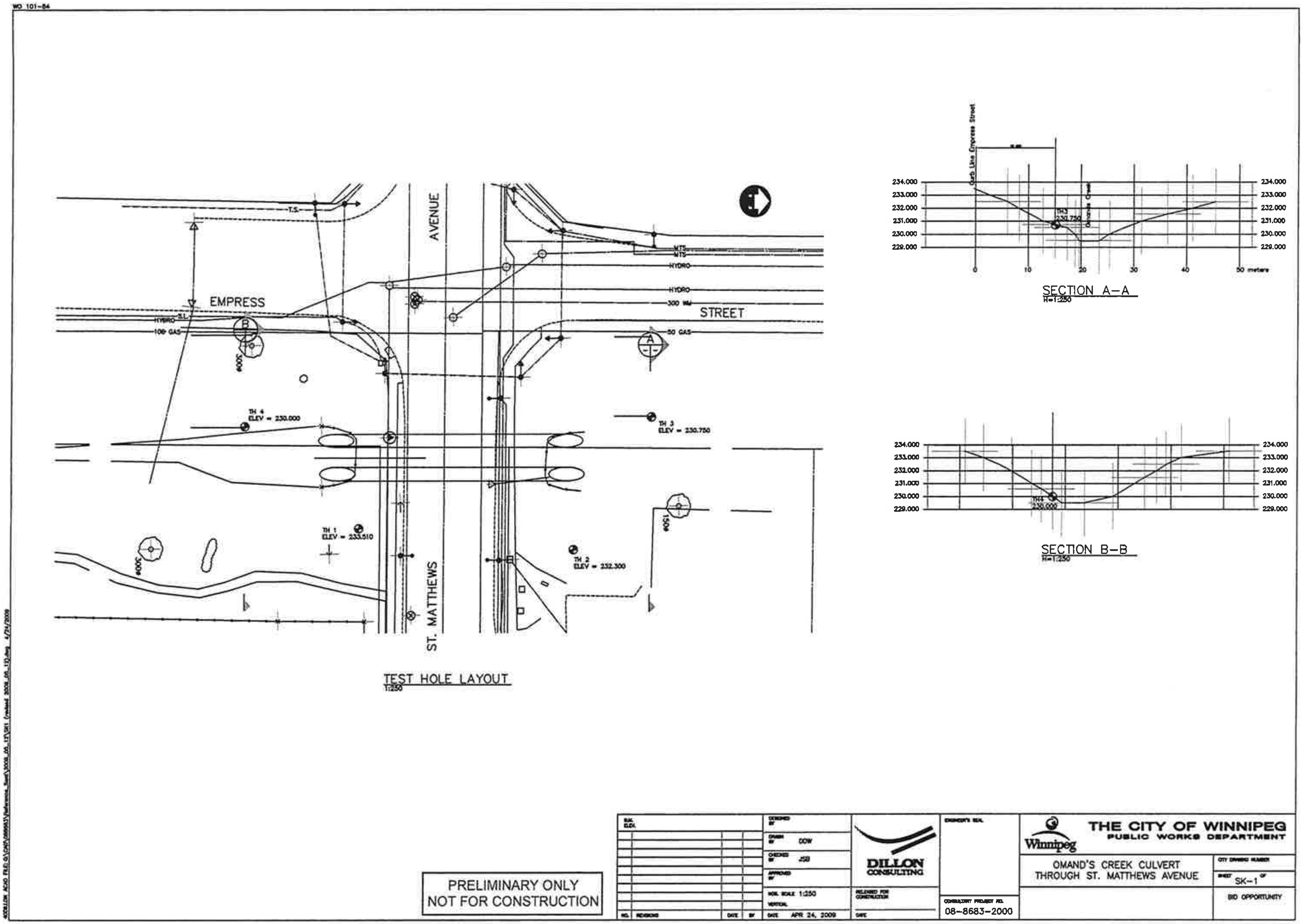
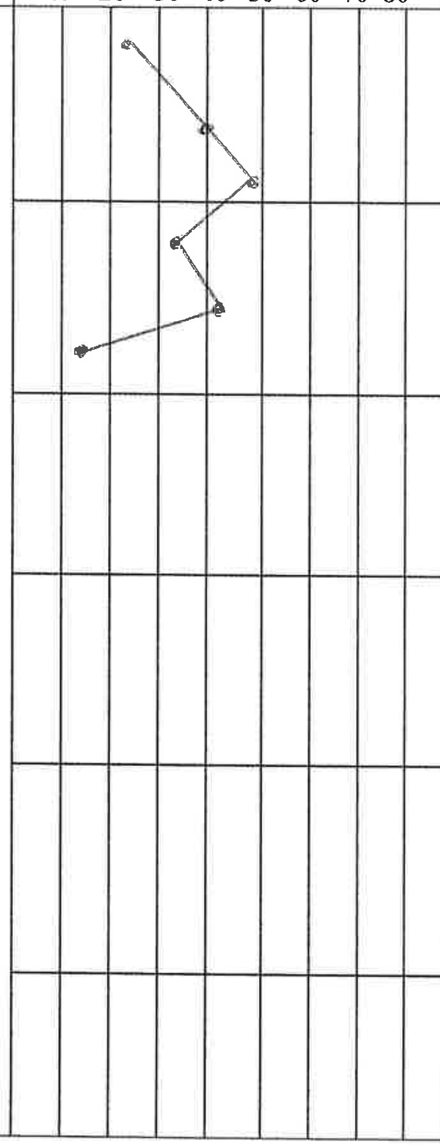
142
PT
153
A
B


WO 101-84
EMPRESS
STREET
AVENUE
ST. MATTHEWS
T.S.
HYDRO
100 GAS
S.L.
MTS
300 WM
50 GAS
300ø
150ø
TH 1
ELEV = 233.510
TH 2
ELEV = 232.300
TH 3
ELEV = 230.750
TH 4
ELEV = 230.000
TEST HOLE LAYOUT
1:250
Curb Line Empress Street
Omands Creek
TH3
230.750
TH4
230.000
234.000
233.000
232.000
231.000
230.000
229.000
0
10
20
30
40
50 meters
SECTION A-A
H=1:250
SECTION B-B
H=1:250
PRELIMINARY ONLY
NOT FOR CONSTRUCTION
DRAWN BY DOW
CHECKED BY JSB
HOR. SCALE 1:250
DATE APR 24, 2009
DILLON CONSULTING
CONSULTANT PROJECT NO.
08-8683-2000
THE CITY OF WINNIPEG
PUBLIC WORKS DEPARTMENT
OMAND'S CREEK CULVERT
THROUGH ST. MATTHEWS AVENUE
SK-1
BID OPPORTUNITY

A. Dean Gould P.Eng and Associates	**Location: St. Mathews – Omands Creek Crossing** **UTM E N**	**TEST HOLE NO. 1**	**PROJECT NO.**
Project Description: St. Mathews at Omands Creek – SE Corner **Client : Dillon Consulting**		**Drilling Date: March 12, 2009** **Driller: MAPLE LEAF ENVIRONMENTAL** **Logged By; R.J. GOULD**	

SPL No	Depth (m)	Log	SOIL DESCRIPTION Collar Elevation 233.510
			0- 1.67m Gravel Fill
			1.67 – 8.43m Brown Clay mixed with grey and becoming moist and soft at D=4.6m
	5		
			8.43 – 10.67m Tan silt Till
	10		
			End of Hole at 10.69 m No water in hole following drilling operation
			Dutch Cone Test Results
	15		
	20		
	25		

MOISTURE CONTENT
10 20 30 40 50 60 70 80



Depth	N blows/300mm
8.83-9.14	20
9.14-9.44	25
9.44-9.74	32
9.74-10.04	38
10.04-10.34	40
10.34-10.64	45
10.36-10.67	53

LEGEND

Topsoil ☐ Silt Brown clay Grey clay
Glacial till Sand and gravel ☐
Plastic Limit x.......x Liquid Limit
N=Dutch Cone penetration tests blows/300mm
Qu= Unconfined Compression Strength (kPa)

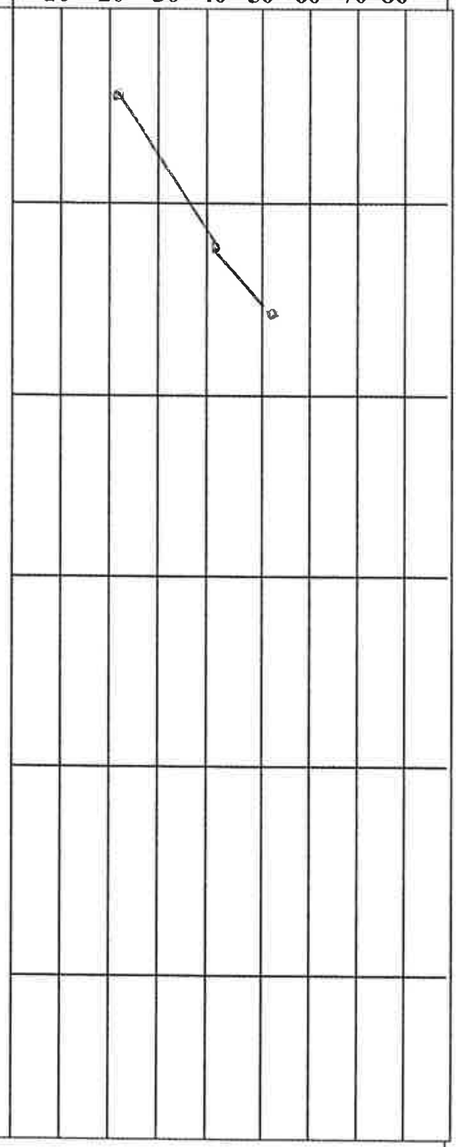
TEST HOLE 1

A. Dean Gould P.Eng and Associates	**Location: St. Mathews – Omands Creek Crossing** **UTM E N**	**TEST HOLE NO.** 2	**PROJECT NO.**

Project Description: St. Mathews at Omands Creek – NE Corner **Client : Dillon Consulting**	**Drilling Date: March 12, 2009** **Driller: MAPLE LEAF ENVIRONMENTAL** **Logged By; R.J. GOULD**

SPL No	Depth (m)	Log	SOIL DESCRIPTION Collar Elevation 232.300
			0- 2.29m Gravel Fill
			2.29 – 2.74m Brown Clay mixed with grey and becoming moist and soft at D=
	5		2.74 – 9.45m Grey Lacustrine highly plastic Clay
			qu@7.92 = 70.66 kPa Unit Wt=1687 kg/cm
			9.45m Tan silt Till
	10		End of Hole at 9.45 m No water in hole following drilling operation
	15		
	20		
	25		

MOISTURE CONTENT
10 20 30 40 50 60 70 80



LEGEND

Topsoil ☐ Silt Brown clay Grey clay

Glacial till Sand and gravel ☐

Plastic Limit x.......x Liquid Limit

N=Dutch Cone penetration tests blows/300mm

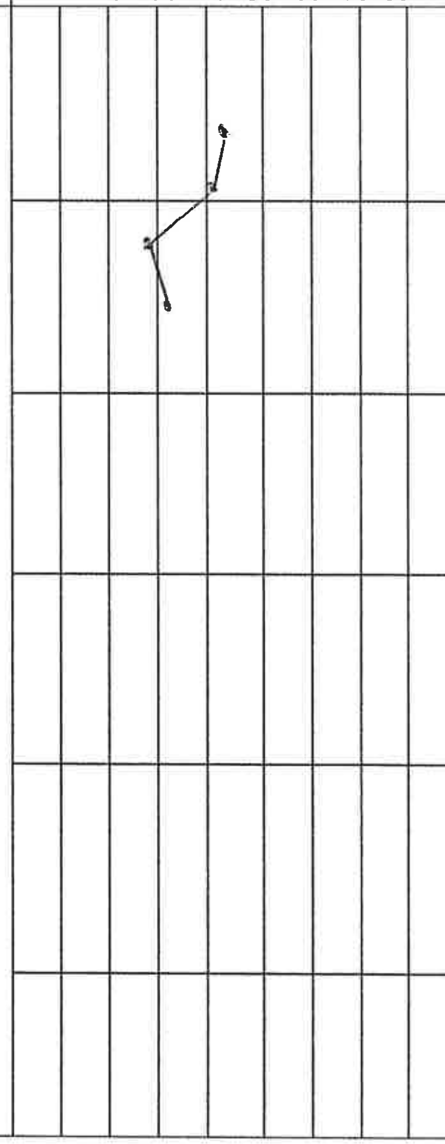
Qu= Unconfined Compression Strength (kPa)

TEST HOLE 2

A. Dean Gould P.Eng and Associates	**Location: St. Mathews – Omands Creek Crossing** **UTM E N**	**TEST HOLE NO. 3**	**PROJECT NO.**

Project Description: St. Mathews at Omands Creek – NW Corner **Client : Dillon Consulting**	**Drilling Date: March 12, 2009** **Driller: MAPLE LEAF ENVIRONMENTAL** **Logged By; R.J. GOULD**

SPL No	**Depth (m)**	**Log**	**SOIL DESCRIPTION** **Collar Elevation** 230.750	**MOISTURE CONTENT** **10 20 30 40 50 60 70 80**
			0- 1.52m Gravel Fill with some clay, natural or original soil profile commences at 1.52m same level as Omands Creek – Water inflow at 1.37m	
	5		1.52 – 7.92m Brown and Grey, highly plastic lacustrine Clay	
			4.57 m test hole sloughed-	
			7.92 – 8.38 m Tan silt Till End of Hole at 8.38 m auger refusal	
	10			
	15			
	20			
	25			



LEGEND

Topsoil ☐ Silt Brown clay Grey clay

Glacial till Sand and gravel ☐

Plastic Limit x…….x Liquid Limit

N=Dutch Cone penetration tests blows/300mm

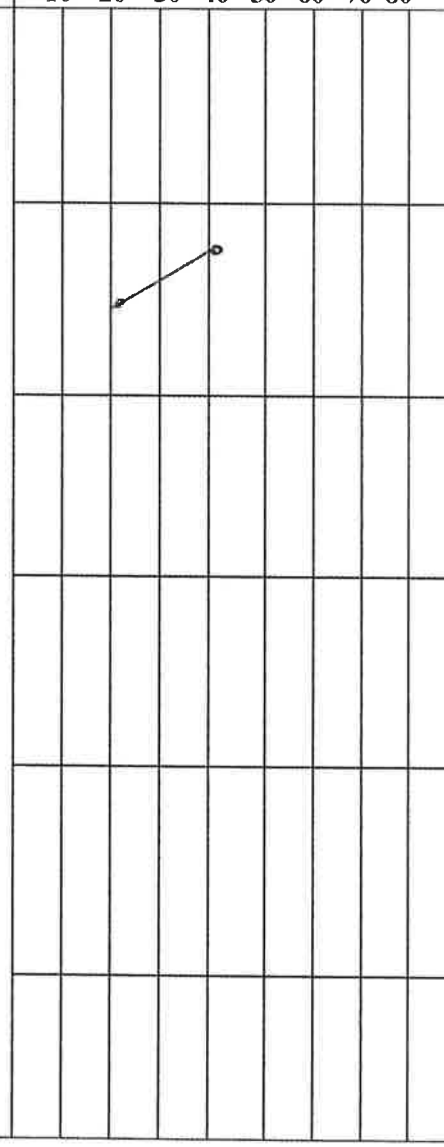
Qu= Unconfined Compression Strength (kPa)

TEST HOLE 3

A. Dean Gould P.Eng and Associates	**Location: St. Mathews – Omands Creek Crossing** **UTM E N**	**TEST HOLE NO. 4**	**PROJECT NO.**

Project Description: St. Mathews at Omands Creek – SW Corner **Client : Dillon Consulting**	**Drilling Date: March 12, 2009** **Driller: MAPLE LEAF ENVIRONMENTAL** **Logged By; R.J. GOULD**

SPL No	**Depth (m)**	**Log**	**SOIL DESCRIPTION** **Collar Elevation** 230.000	**MOISTURE CONTENT** **10 20 30 40 50 60 70 80**
			<u>0- 1.52m</u> Brown weathered silty Clay (fill)	
			<u>1.52 – 7.92m</u> Grey, higly plastic lacustrine Clay	
			water inflow at 2.13 m organic odor	
	5			
			<u>7.92 – 8.38 m</u> Tan silt Till	
	10		End of Hole at 8.38 m auger refusal No water in hole following drilling operation	
			Dutch Cone Test Results **<u>Depth N blows/300mm</u>** 7.92 – 8.38m 69	
	15			
	20			
	25			



LEGEND

Topsoil Silt Brown clay Grey clay

Glacial till Sand and gravel

Plastic Limit x…….x Liquid Limit

N=Dutch Cone penetration tests blows/300mm

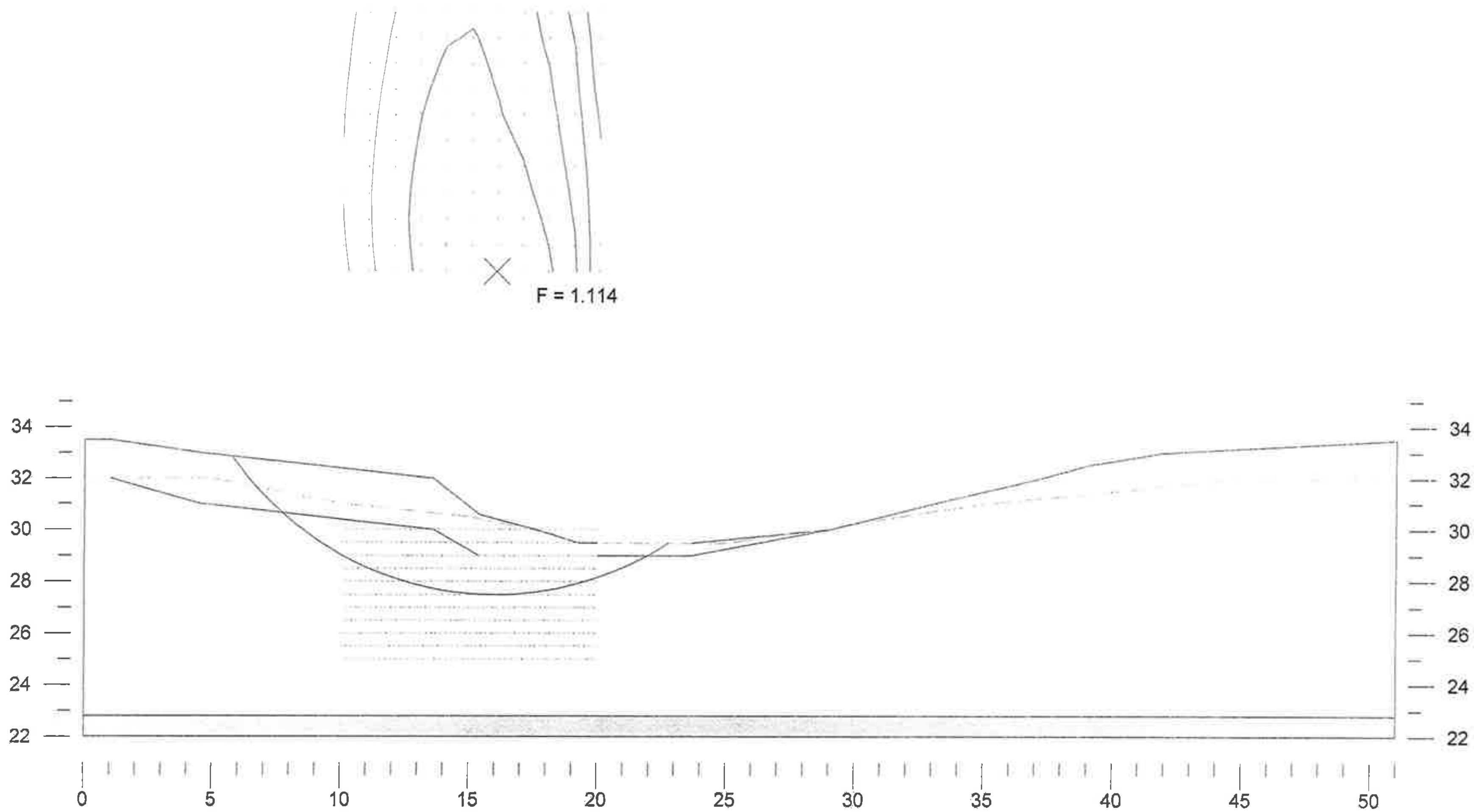
Qu= Unconfined Compression Strength (kPa)

<u>TEST HOLE 4</u>

A. Dean Gould, P.Eng - Winnipeg, MB

St. Mathews Box Culvert
May 14,2009
Cross Section B-B

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Omands Creek	9.8	0	0	1	0
Clay Fill	17	5	24	1	0
Brown Clay	17	2	15	1	0
Silt Till	20	5	30	1	0



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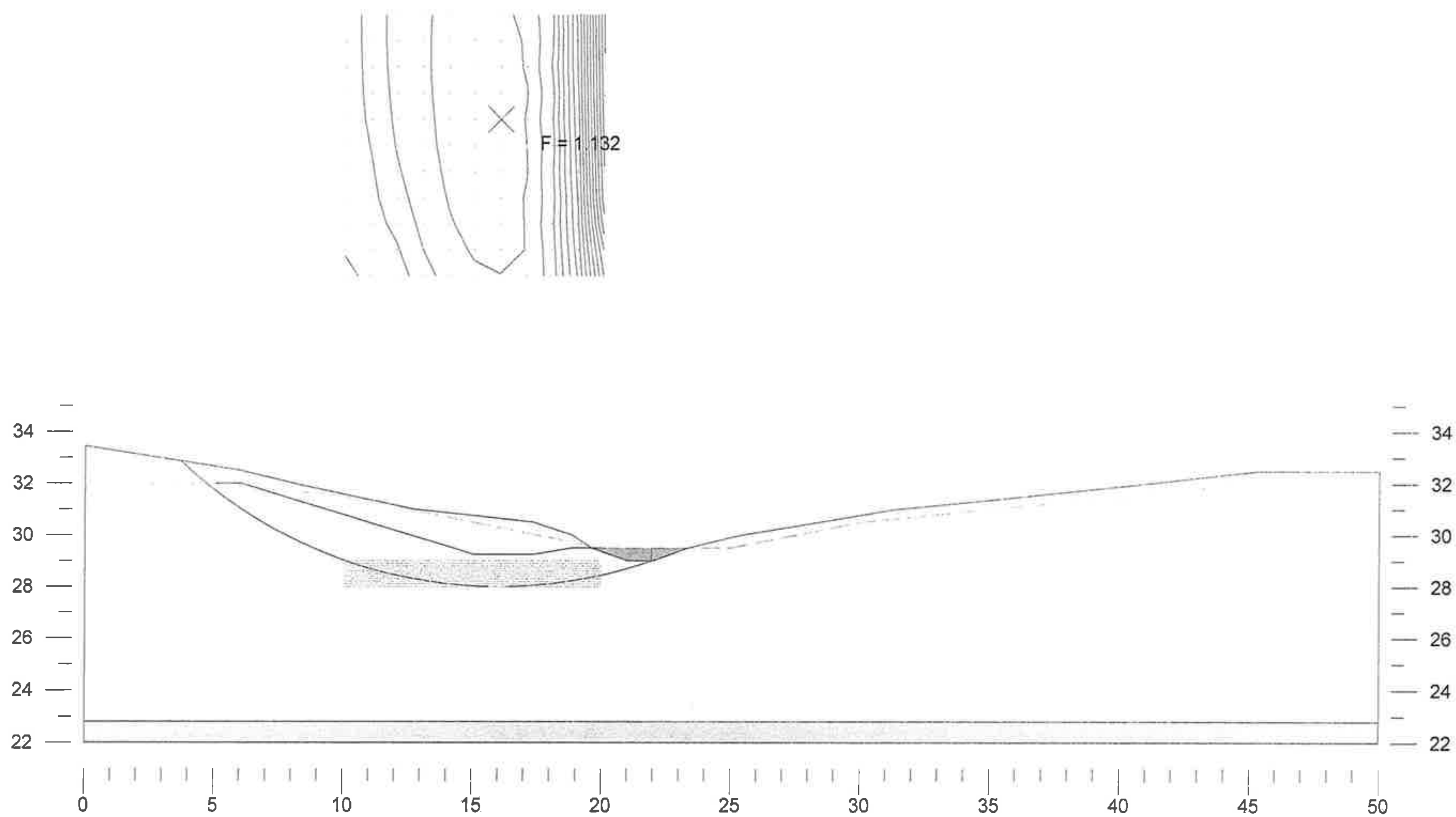
	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Omands Creek	9.8	0	0	1	0
Clay Fill	17	5	24	1	0
Brown Clay	16.5	2	15	1	0
Clay Till	20	5	30	1	0

A. Dean Gould, P.Eng - Winnipeg, MB

St. Mathews Box Culvert
May 14,2009
Cross Section A-A



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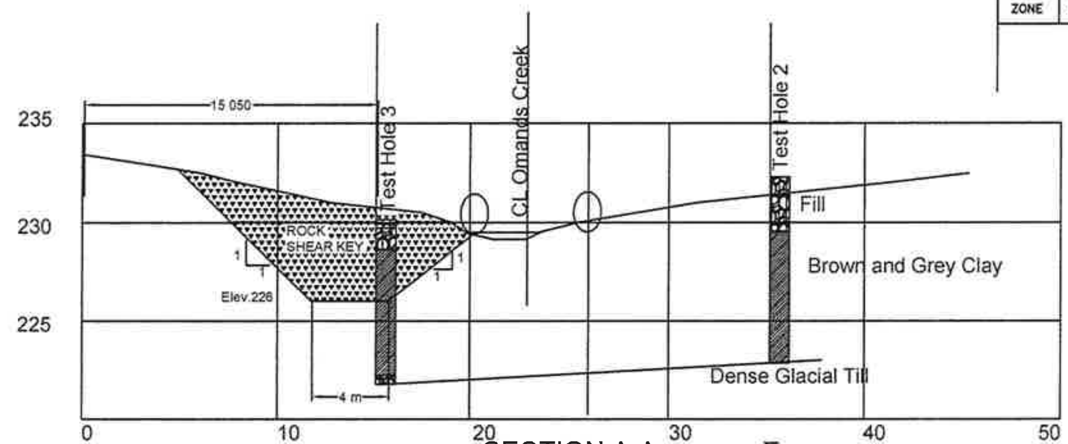
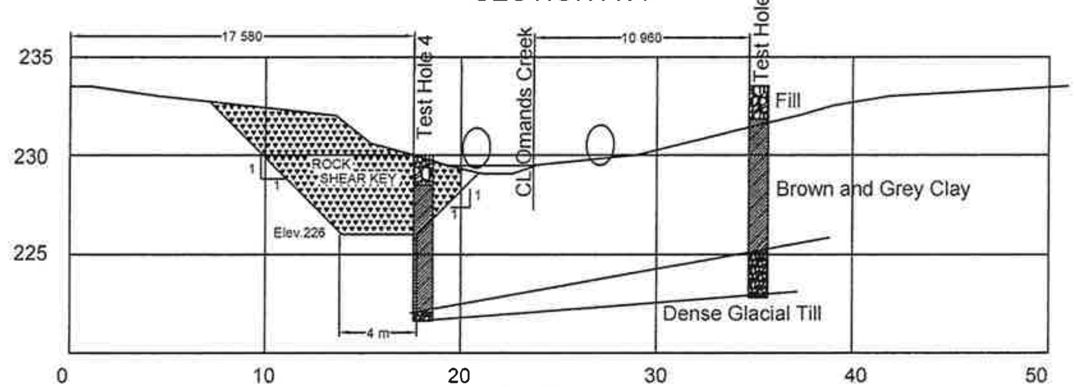
REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



SECTION A-A



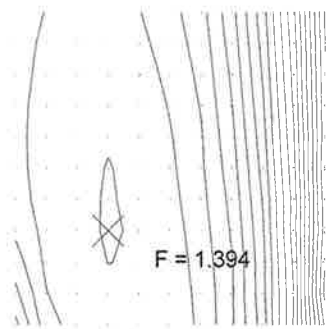
SECTION B-B

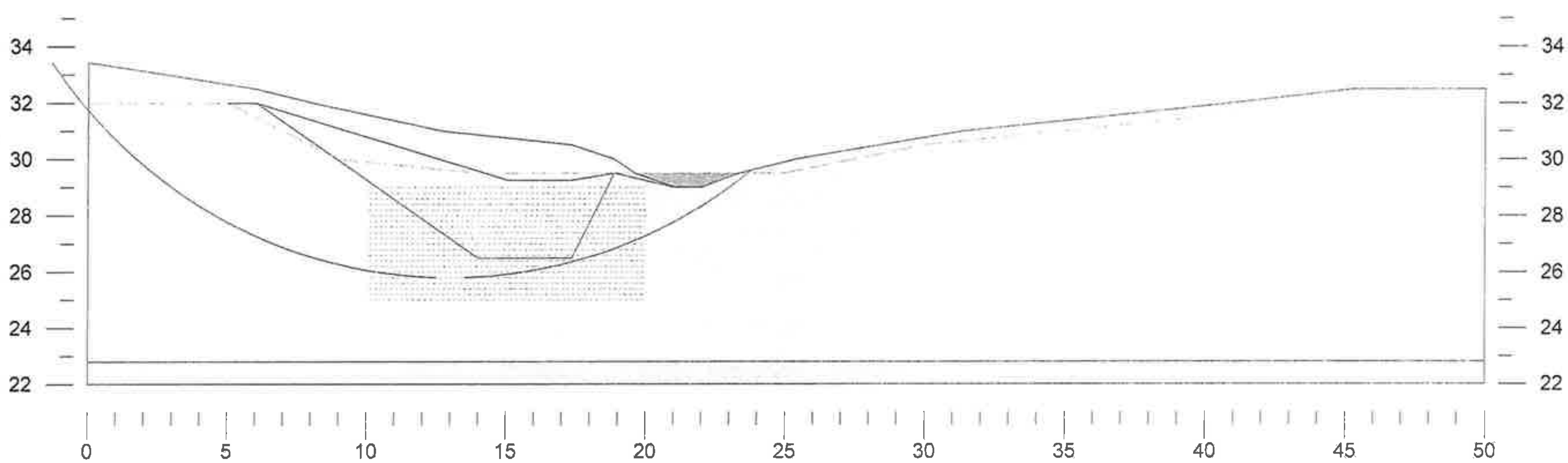
	DILLON CONSULTING - ST. MATHEWSA CULVERT			
	CROSS SECTIONS A-A AND B-B SHOWING TEST HOLE AND SOIL STRATIGRAPHY WITH SHEAR KEY STABILIZATION OPTION			
Design By: A. Dean Gould	SIZE	FSCM NO.	DWG NO. D-STMXSK	REV
Survey By: Dillon Consulting	SCALE		SHEET	

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Omands Creek	9.8	0	0	1	0
Clay Fill	17	5	24	1	0
Shear Key	19	0	40	1	0
Brown Clay	16.5	2	15	1	0
Clay Till	20	5	30	1	0

A. Dean Gould, P.Eng - Winnipeg, MB

St. Mathews Box Culvert
May 14,2009
Cross Section A-A
with Shear Key





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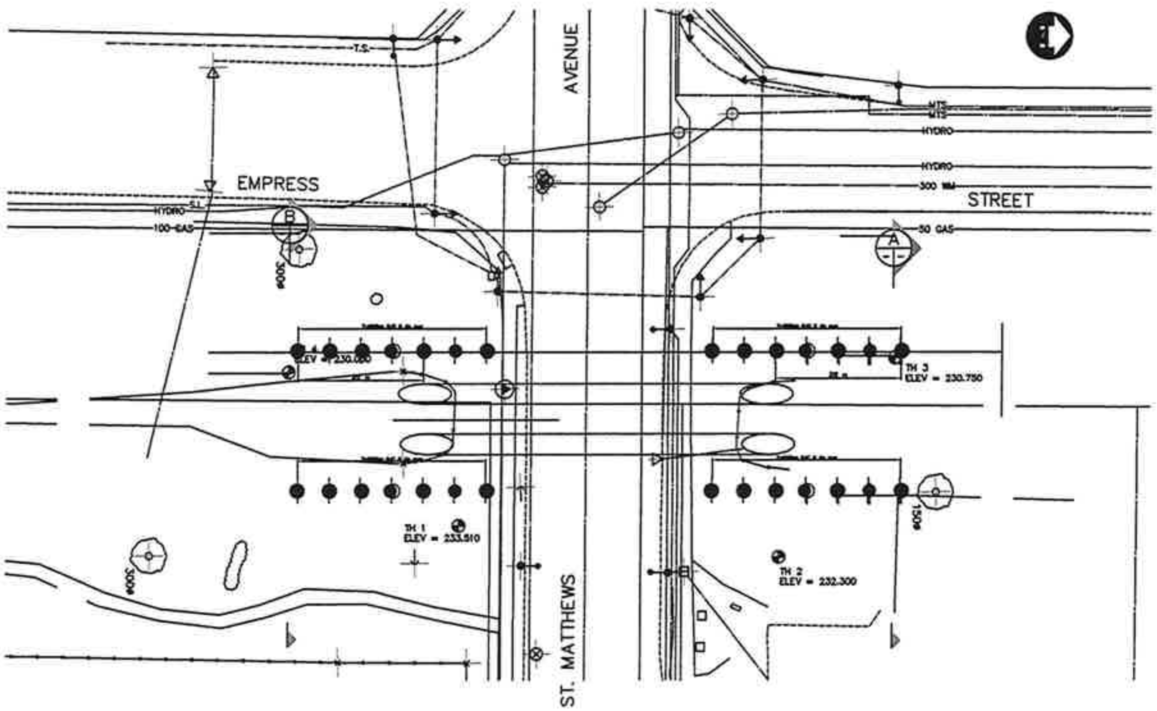
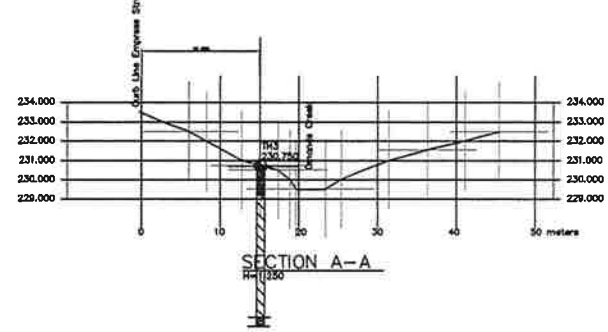
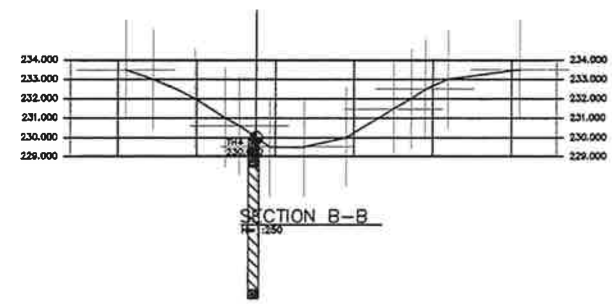
WO 101-64



TEST HOLE LAYOUT
1:250



SECTION A-A
H=1:250



SECTION B-B
H=1:250

PRELIMINARY ONLY
NOT FOR CONSTRUCTION

DESIGNED BY	
DRAWN BY	DDW
CHECKED BY	JSB
APPROVED BY	
HOR. SCALE	1:250
VERTICAL	
DATE	APR 24, 2009

DILLON CONSULTING

CONSULTANT PROJECT NO. 08-8683-2000

THE CITY OF WINNIPEG
PUBLIC WORKS DEPARTMENT

OMAND'S CREEK CULVERT
THROUGH ST. MATTHEWS AVENUE

ROCK CAISSON OPTION

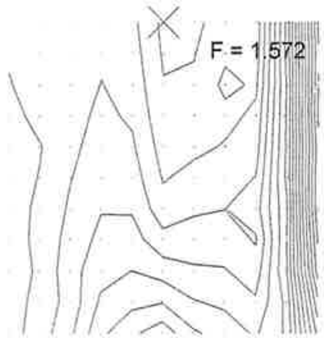
SHEET SK-1

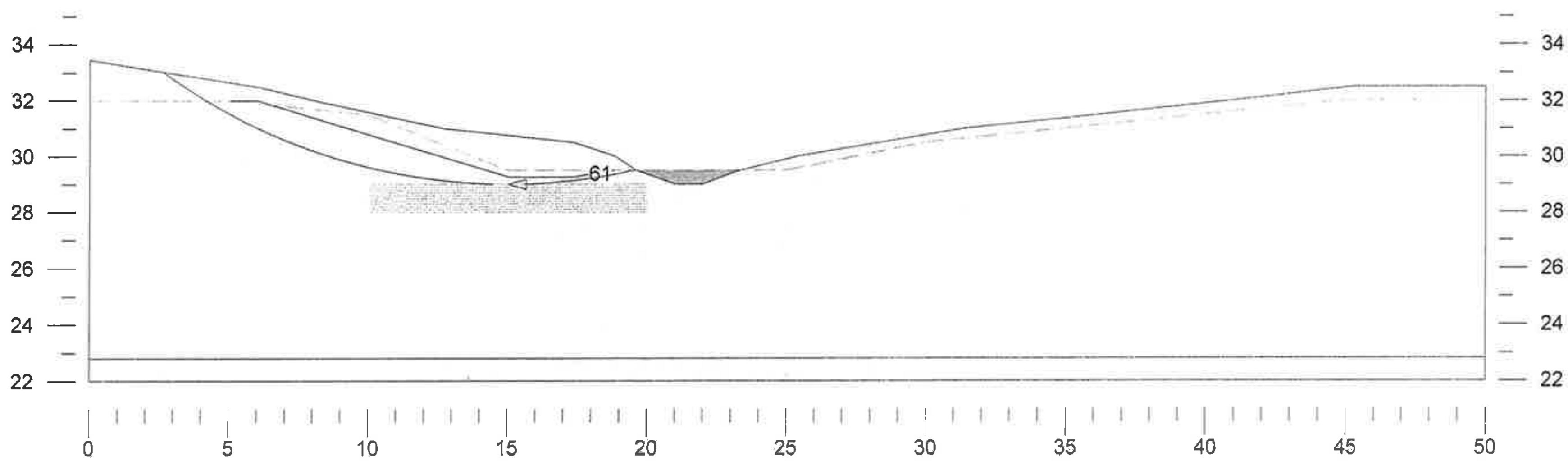
BID OPPORTUNITY

A. Dean Gould, P.Eng - Winnipeg, MB

St. Mathews Box Culvert
May 14,2009
Cross Section A-A
with 1800mm R/C at 4m o-c

	Gamma kN/m3	C kPa	Phi deg	Piezo Surf.	Ru
Omands Creek	9.8	0	0	1	0
Clay Fill	17	5	24	1	0
Brown Clay	16.5	2	15	1	0
Clay Till	20	5	30	1	0





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ROCK CAISSON CALCULATION SHEET

PROJECT;	**St Mathews Crossing**			Job No.	
Date;	May	20	2009		

Top of Caisson Elev. m		230.5		
Base of Caisson Elev. m		222		
Socket Depth mm		500	mm	
Diameter of Rock caisson mm		1828.154	mm	6 ft
Cross Sectional Area sq.m		2.624915		

Soil Strata			Unit		
Ground Water Elev.	R/C	229.5			
Ground Water Elev.		229.5	Weight	phi (deg)	c (kPa)
Brown Clay		230.5	16.5	15	2
Grey Clay		223	16.5	15	2
Till		222.5	20	30	5
Rock Caisson			22	45	0

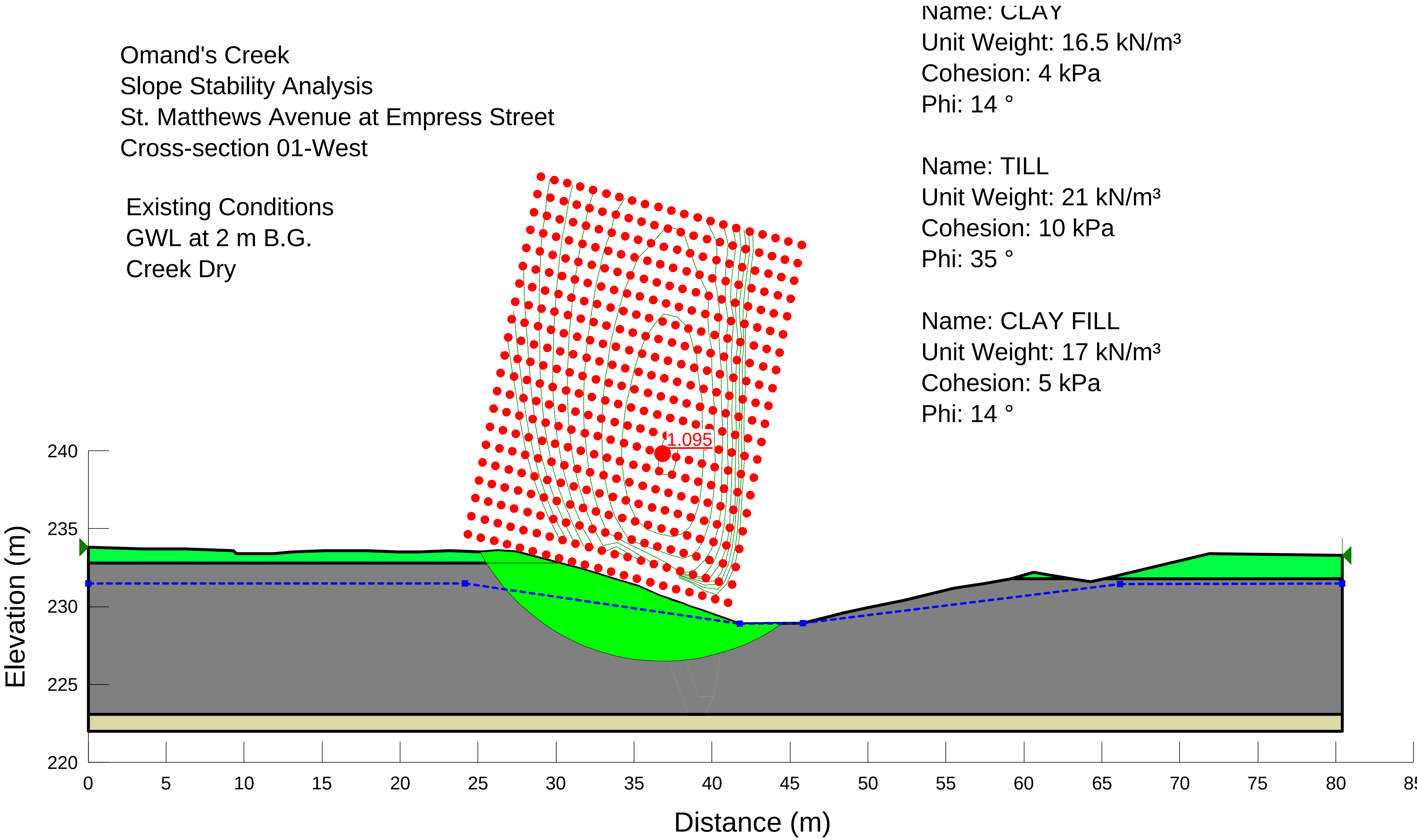
Effective Stress at Base of Caissoı

Soil Eff Press	66.75	kPa	Shear Stress Clay	19.89
Limestone Eff Press	113.5	kPa	Shear Stress R/C	113.5

Resisting Force per Caisson	**245.73**	**kN**	55242.27 lbs
Spacing c - c	4	m	
Resisting Force per Unit Length	**61.43**	**kN/m**	**External Force Value**
	4209.512	lb/lin ft	

Appendix D

Slope Stability Analysis Results



File Name: Cross-section A_010.gsz

Figure D-01

Omand's Creek
Slope Stability Analysis
St. Matthews Avenue at Empress Street
Cross-section 01-West

Granular Shear Key - 1m wide at Elev. 225 m
GWL at 2 m B.G.
Creek Dry

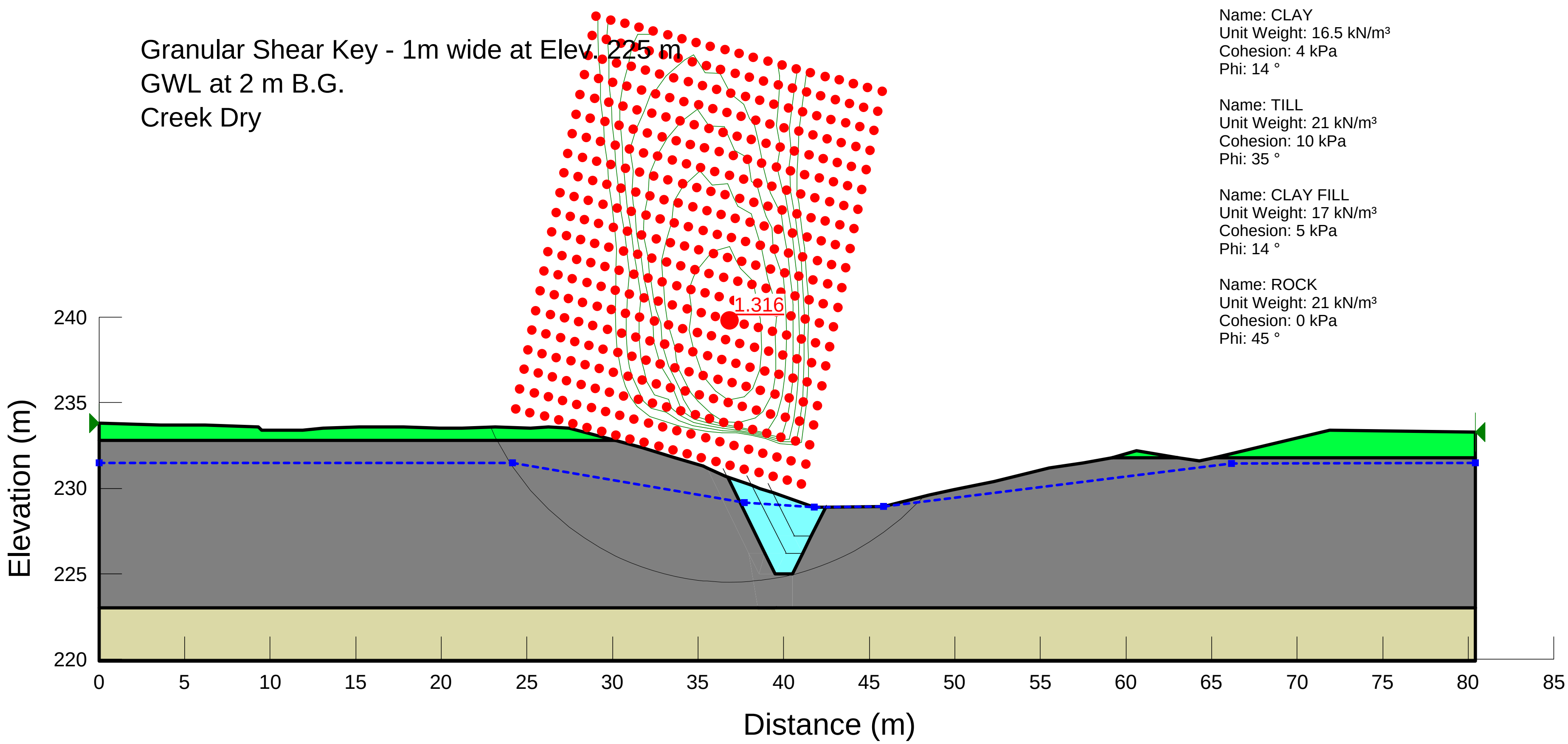


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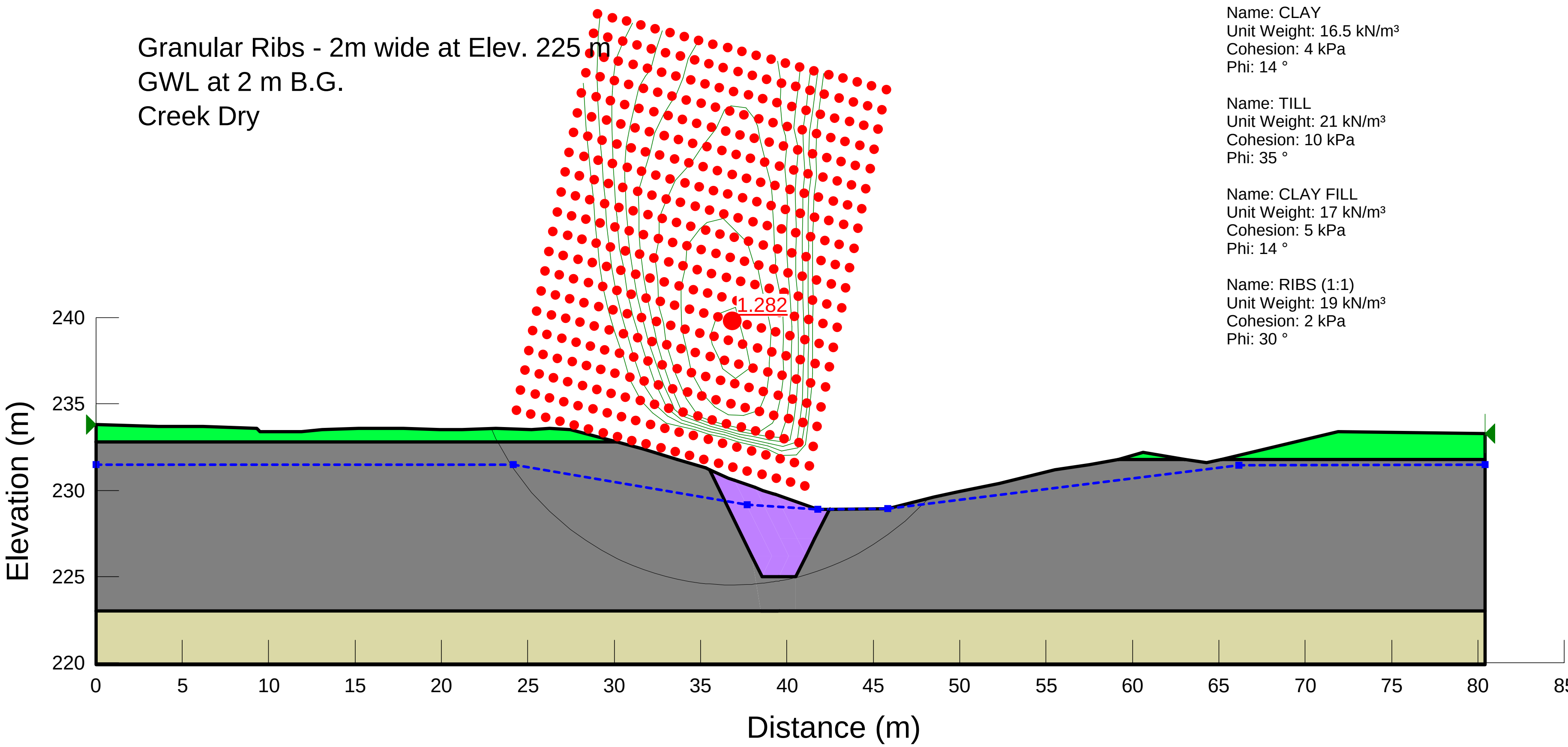
Figure D-02

Omand's Creek
Slope Stability Analysis
St. Matthews Avenue at Empress Street
Cross-section 01-West

Granular Ribs - 2m wide at Elev. 225 m
GWL at 2 m B.G.
Creek Dry

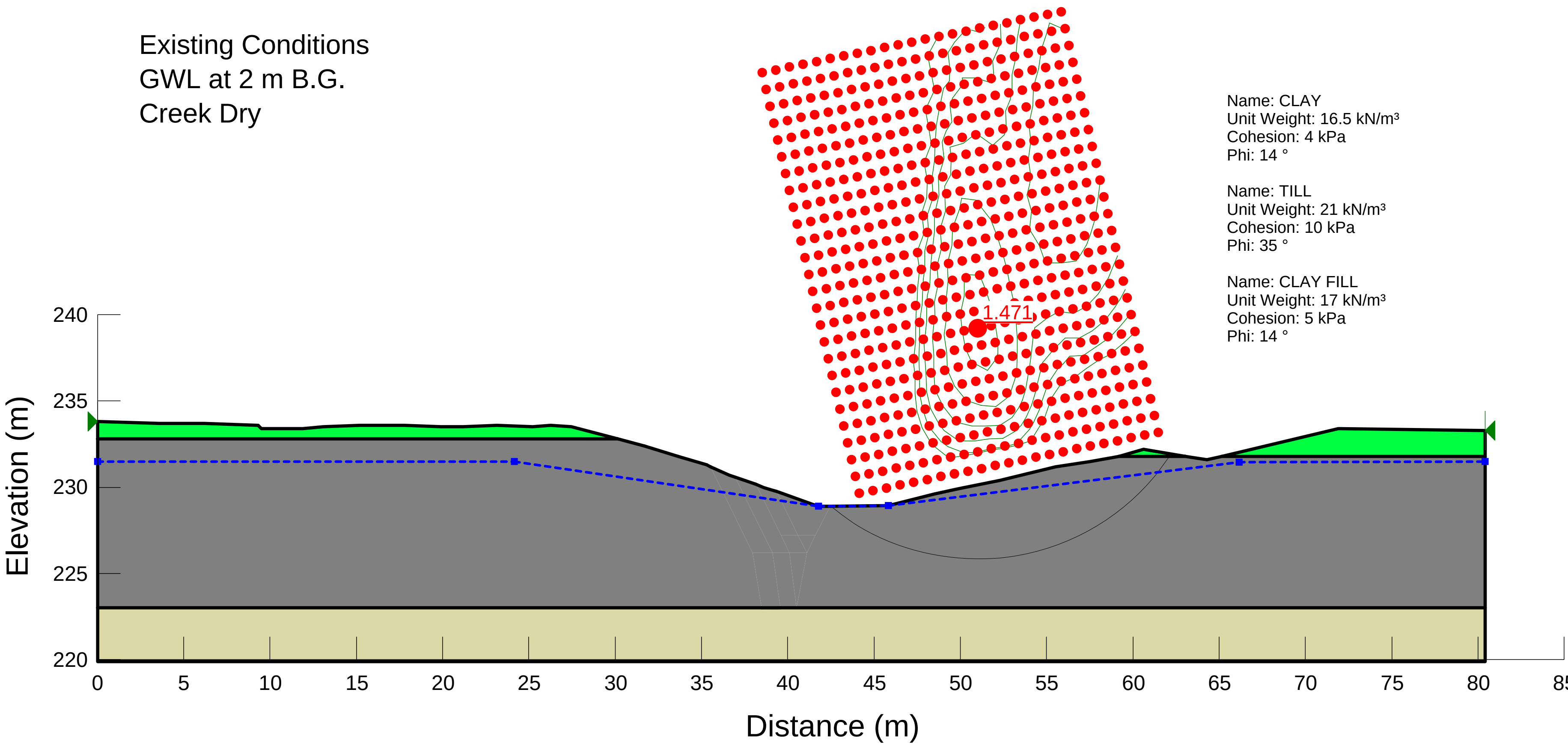


File Name: Cross-section A_027.gsz

Figure D-03

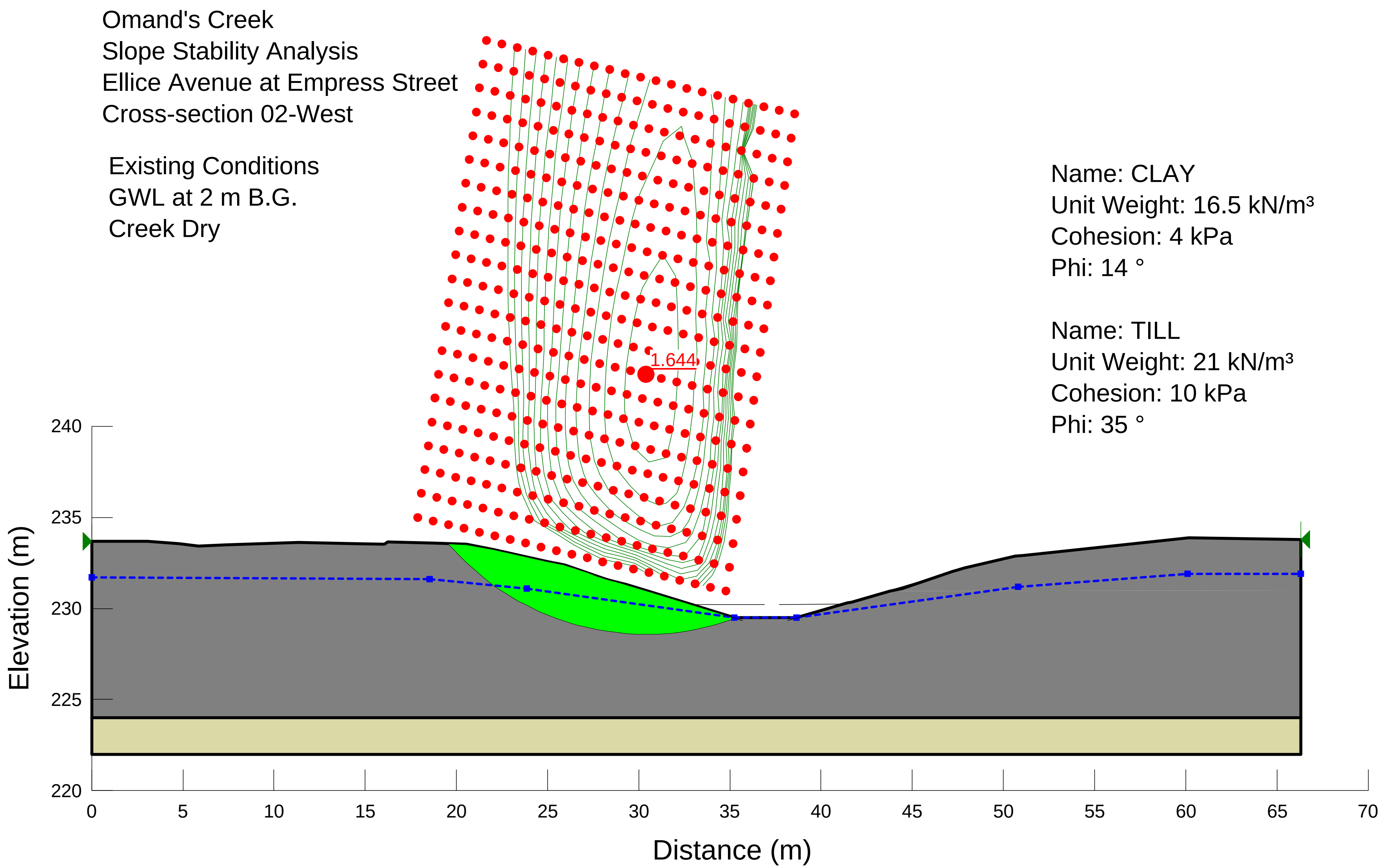
Omand's Creek
Slope Stability Analysis
St. Matthews Avenue at Empress Street
Cross-section 01-East

Existing Conditions
GWL at 2 m B.G.
Creek Dry



File Name: Cross-section A_026.gsz

Figure D-04



File Name: Cross-section D_003.gsz

Figure D-05