

CITY OF WINNIPEG

Newton Avenue Force Main
Red River Crossing
Geotechnical Data Report

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PREPARED BY:

for **Kelly Fordyce, P.Eng.**
Geotechnical Engineer

APPROVED BY:

Dami Adedapo, Ph.D., P.Eng.
Geotechnical Department Head / Principal

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STATEMENT OF LIMITATIONS AND CONDITIONS

Limitations

This report has been prepared for City of Winnipeg in accordance with the agreement between KGS Group and City of Winnipeg (the “Agreement”). This report represents KGS Group’s professional judgment and exercising due care consistent with the preparation of similar reports. The information, data, recommendations and conclusions in this report are subject to the constraints and limitations in the Agreement and the qualifications in this report. This report must be read as a whole, and sections or parts should not be read out of context.

This report is based on information made available to KGS Group by City of Winnipeg. Unless stated otherwise, KGS Group has not verified the accuracy, completeness or validity of such information, makes no representation regarding its accuracy and hereby disclaims any liability in connection therewith. KGS Group shall not be responsible for conditions/issues it was not authorized or able to investigate or which were beyond the scope of its work. The information and conclusions provided in this report apply only as they existed at the time of KGS Group’s work.

Third Party Use of Report

Any use a third party makes of this report or any reliance on or decisions made based on it, are the responsibility of such third parties. KGS Group accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions undertaken based on this report.

Geotechnical Investigation Statement of Limitations

The geotechnical investigation findings and recommendations of this report were prepared in accordance with generally accepted professional engineering principles and practice. The findings and recommendations are based on the results of field and laboratory investigations, combined with an interpolation of soil and groundwater conditions found at and within the depth of the test holes drilled by KGS Group at the site at the time of drilling. If conditions encountered during construction appear to be different from those shown by the test holes drilled by KGS Group or if the assumptions stated herein are not in keeping with the design, KGS Group should be notified in order that the recommendations can be reviewed and modified if necessary.

1.0 INTRODUCTION

1.1 General

KGS Group was retained by the City of Winnipeg Water and Waste Department to perform geotechnical investigations to facilitate the design and construction of the proposed replacement of the 350 mm force main crossing between Fraser's Grove Park and Newton Avenue / Scotia Street in Winnipeg, Manitoba.

It is our understanding the new force main crossing will consist of 350 mm internal diameter (ID) DR9 HDPE pipe from Fraser's Grove Park and Kildonan Park; crossing beneath the Red River. It is further understood that Horizontal Directional Drilling (HDD) construction methods will be employed for the installation of the proposed conduits.

The purpose of our investigation was to identify the subsurface soil, bedrock, and groundwater conditions along the alignment of the proposed works. This factual report contains a description of the geotechnical investigations program performed by KGS Group and our findings. This GDR should be read in conjunction with the Geotechnical Baseline Report (GBR) prepared by KGS Group for the Project.

1.2 Purpose of Report

This report summarizes the geotechnical conditions observed along the alignment of the proposed force main crossing between Fraser's Grove Park and Kildonan Park and provides geotechnical considerations that would form part of the basis of design for the Work. This report includes geotechnical data collected at the project site and summary of encountered subsurface conditions along the alignment.

1.3 Report Limitations

This report has been prepared for the exclusive use of the City of Winnipeg for the specific application to the proposed Newton Avenue Force Main Red River Crossing project. It has been prepared in accordance with generally accepted geotechnical engineering practice. No other warranty, express or implied, is made.

The geotechnical data presented in this report are based on the observations and test results obtained from field investigation programs completed between 1988 and 2021. The information provided indicate soil and bedrock conditions and water levels only at specific locations and times, and only to the depths penetrated. Subsurface conditions and water levels at other locations may differ from conditions occurring at these explored locations. Also, the passage of time may result in a change in conditions at these locations. KGS Group is not responsible for any claims, damages, or liability associated with interpretation of subsurface data or for reuse of subsurface data, without KGS Group's express written authorization.

2.0 BACKGROUND INFORMATION

2.1 Other Geotechnical Investigations Near the Site

A review of available geotechnical information pertinent to the project was conducted, including the 2021 investigation program completed by KGS Group, and presented in this report. The main objective of the review was to obtain and present information similar to the subsurface and groundwater conditions with respect to the Newton Force Main Crossing from areas in close proximity to the project site. The background geotechnical information, specifically for the overburden soils, summarized in this GDR is primarily from the City of Winnipeg North Kildonan Feedermain and Northeast Interceptor Sewer replacement project sites located approximately 1.5 km downstream of the Newton Force Main Crossing site. The geotechnical drilling and laboratory material testing data from the historical investigations itemized below was relied upon to supplement the description of the overburden and bedrock for the Newton Force Main Crossing obtained from the KGS Group 2021 investigations.

- AECOM Canada Ltd., 2017. City of Winnipeg Northeast Interceptor Sewer Red River Crossing Geotechnical Report.
- Trek Geotechnical, January 2014. North Kildonan Feedermain Detailed Design – Geotechnical Report.
- KGS Group, November 2012. Forcemain Sub-Surface Investigation.
- Dyregrov and Burgess Consulting Geotechnical Engineers, February 1988. Kildonan Corridor Geotechnical Report.

These historical investigations located downstream of the proposed Newton Force Main Crossing project site have been summarized by AECOM (2017) in a Geotechnical Data Report prepared for the Northeast Interceptor Sewer replacement project. A copy of the GDR prepared by AECOM is included in Appendix A. In general, a review of the relevant reports above indicated the following (Reference #1):

- The riverbank soils consist of both lacustrine and alluvial soils overlying glacial till and limestone bedrock.
- Groundwater monitoring data indicate that the subsurface soil, till and bedrock are all hydraulically connected.
- Constructability challenges (sloughing, seepage, etc.) are anticipated, dewatering and temporary shoring will be required.
- Bedrock contains zones of large fractures and weak rock.

A site plan showing the locations of boreholes, borehole log records, and laboratory data from the previous investigations downstream are included in the AECOM (2017) GDR in Appendix A.

In general, the local geology and till to bedrock contact elevation is generally consistent between the proposed Newton Force Main Crossing site and the geotechnical data collected downstream from previous investigations. As such, the depositional structure between the sites are similar and it is appropriate that the characterization of the overburden soil units at the Newton Force Main Crossing site has been supplemented with the data obtained from the downstream project sites, as described in Section 4.0.

2.2 Regional Geologic Setting

The geology in Winnipeg generally consists of carbonate sedimentary bedrock overlaying Precambrian era granite and gneiss. The sedimentary rock consists of alternating layers of limestone, and dolomite and to a lesser extent shale. The proposed pipeline crossing is located within the limestone Selkirk member of the Red River Formation.

The surface of the bedrock is usually highly fractured and disturbed, often mixed with gravels and sands. Geological maps for Winnipeg indicate karst topography caused from dissolution of the soluble rock, and a heavily fractured upper bedrock layer. The karst topography is typically infilled with mixtures of silt, sand and gravel till soils.

During the last glacial advance and retreat, Winnipeg's glacial till was deposited by ice masses. Glaciolacustrine deposits suspended in glacial lakes confined by ice masses settled to overlie the tills. Additional information on the regional geology can be found in the Geological Engineering Report for Urban Development of Winnipeg, University of Manitoba (Reference #2).

3.0 SCOPE OF 2021 INVESTIGATION PROGRAM

3.1 General

This section provides a summary of the 2021 field investigation program, and laboratory test results; as well as the subsurface conditions encountered at the project site.

The 2021 geotechnical and geophysical investigations were completed to determine the subsurface conditions along the proposed force main conduit alignment. The results of the investigation program are presented in this Geotechnical Data Report.

3.2 Test Hole Drilling and Soil Sampling

The test hole drilling and sampling program was completed by KGS Group from August 4 to 12, 2021. A total of four (4) test holes were advanced into bedrock to investigate the subsurface stratigraphic conditions and evaluate the suitability of the bedrock for Horizontal Directional Drilling (HDD). Test hole TH21-01 was drilled on the west side of the Red River in Kildonan Park. Test hole TH21-02 was drilled within the approximate thalweg of the Red River. Test holes TH21-03 and TH21-04 were drilled on the east side of the Red River in Fraser's Grove Park. The locations of the test holes are shown on Figure 1 and a summary of the locations is presented in Table 1.

Maple Leaf Drilling of Winnipeg, Manitoba provided the drilling services using track-mounted and portable drill rig equipped with 125 mm solid stem augers, casing advancer, NQ coring, and HQ coring. The drilling was completed under the supervision and direction of KGS Group personnel. Soil samples were collected at intervals of 1.5 m (5 ft.) or at any changes in soil strata encountered during drilling. The soil samples were visually inspected for material type and classified according to the Modified Unified Soil Classification System (USCS).

Standard Penetration Tests (SPTs) were completed in the glacial till material to evaluate the in-situ density. Clay samples were tested with a field Torvane to evaluate the consistency and estimate the undrained shear strengths of cohesive soils. Upon completion of drilling, the test holes were examined for indications of sloughing and seepage and then backfilled. Test hole log records incorporating field observations, and field test results are provided in Appendix B. Photographs of the bedrock samples are included in Appendix C.

TABLE 1: SUMMARY OF 2021 TEST HOLE LOCATIONS

Test Hole ID	Location	Approx. Ground Surface Elevation (m)	Approx. Borehole Depth (m)	Approx. Bedrock Contact Elevation (m)
TH21-01	Scotia St. at Rainbow Dr. (Kildonan Park)	228.19	43.2	209.7
TH21-02	Center of Red River	217.70	33.8	209.1
TH21-03	Kildonan Drive at Larchedale Crescent (Fraser's Grove Park)	227.14	41.7	207.8
TH21-04	Kildonan Drive at Rowandale Crescent (Fraser's Grove Park)	227.14	44.7	207.9

FIGURE 1: TEST HOLE AND SEISMIC REFRACTION SURVEY LOCATION PLAN (REFERENCE 3)



3.3 Groundwater Monitoring

A total of two (2) standpipes piezometers were installed at the project site. One (1) standpipe was installed in the glacial till at TH21-01; and one (1) standpipe was installed in the bedrock at TH21-03. Table 2 summarizes the installation details and the piezometer monitoring completed to date. The installation details of the piezometers are shown on the borehole log records provided in Appendix B.

TABLE 2: GROUNDWATER MONITORING DATA

Test Hole ID		TH21-01	TH21-03
Ground Elevation (m)		228.19	227.14
Piezometer Type		Standpipe	Standpipe
Tip Elevation (m)		211.40	205.74
Monitoring Zone		Glacial Till	Bedrock
Date	River Level		
9/10/2021	223.77 ⁽¹⁾	222.20	222.58
10/28/2021	222.28 ⁽¹⁾	223.29	223.11
5/5/2022	226.37 ⁽²⁾	224.19	225.01

Notes:

(1) River Level estimated at James Avenue approximately 7.5 km upstream of the project site.

(2) River Level estimated at Kildonan Bridge approximately 1.5 km downstream of the project site.

3.4 Geophysical Seismic Refraction Survey

KGS Group retained the services of Frontier Geoscience Inc. to complete seismic refraction surveys along the two (2) preferred force main alignments. The seismic refraction surveys were completed on August 10 and 11, 2021. The objective of the geophysical survey was to obtain estimates of the depth to glacial till and bedrock along the preferred force main alignments. The locations of the seismic lines are shown on Figure 1 and the results of the seismic refraction survey are included in the Seismic Refraction Survey Report included in Appendix D. The final alignment of the proposed pipeline has shown on the construction drawings is slightly skewed from the seismic refraction lines.

3.5 Laboratory Testing

Laboratory testing was performed on select bedrock samples for use in the characterization of the subsurface. Laboratory testing on the bedrock samples was completed to determine the following mechanical properties:

- Unconfined Compressive Strength
- Youngs Modulus (E)
- Shear Modulus (G)

All testing was performed at a Canadian Council of Independent Laboratories (CCIL) certified laboratory in general accordance with ASTM International standards.

The Laboratory test results are summarized in Section 4.0 and included in Appendix E.

4.0 SUBSURFACE CONDITIONS

Summary of the local geology across the site as determined from the field investigation programs completed in 2021 and supplement by the historical geotechnical investigations completed within 1.5 km downstream of the Newton Force Main Crossing site are provided herein.

4.1.1 OVERBURDEN

The overburden deposits encountered at the project site generally consist of alluvium soils over lacustrine clay, glacial silt till deposit, and underlain by the carbonate bedrock. Variable layers of fill and silt were observed in the test holes within the upper complex zone.

UPPER COMPLEX ZONE

The Complex Zone in Winnipeg generally consists of stratified clays, and silts with variable amounts of organics, granular and fill material. This zone has high soil variability. The base of the Complex Zone is typically defined by the base of the silt layer. The silt interlayers in the Complex Zones can vary from 100 mm to up to 3 m in thickness and are typically approximately 1 m. Typically the silt is tan in colour, soft in consistency, of no to low plasticity and may have a perched groundwater table. The moisture content of the silt ranges from 20 to 35% and the unit weight is within the range of 18.8 to 20.4 kN/m³ (Reference 2).

Adjacent to the Red River in Winnipeg, alluvial soils consisting of alternating layers of clays, silts, and sands; and are known to extend below the average depth of the upper complex zone. The extent of the alluvial deposits identified in KGS Group's 2021 geotechnical investigation is outlined in Table 3 below.

TABLE 3: ALLUVIAL DEPOSITS – KGS GROUP 2021 GEOTECHNICAL INVESTIGATION

Location	Profile	Alluvial Clay	Alluvial Silt	Alluvial Sand
East Riverbank	Elevation at Base (m)	213.4 to 213.9	225.7 to 225.8	211.6 to 213.9
	Thickness (m)	11.9 to 12.3	1.3 to 1.4	1.9 to 11.9
West Riverbank	Elevation at Base (m)	223.6	--	219
	Thickness (m)	4.6	--	4.6
River Channel	Elevation at Base (m)	--	216.6	--
	Thickness (m)	--	1.1	--

Alluvial deposits were also encountered in the background geotechnical investigations completed within 1.5 km downstream of the Newton Forcemain Crossing site and are summarized in Table 4 (Reference 1).

TABLE 4: ALLUVIAL DEPOSITS – GEOTECHNICAL INVESTIGATIONS WITHIN 1.5 KM DOWNSTREAM OF NEWTON CROSSING SITE

Location	Profile	Alluvial Clay	Alluvial Silt	Alluvial Sand
East Riverbank	Elevation at Base (m)	217.7 to 226.3	214.7 to 226.0	214.4 to 222.5
	Thickness (m)	1.7 to 4.1	1.2 to 4.8	2.4 to 13.5
West Riverbank	Elevation at Base (m)	225.1 to 228.8	217.7 to 227.6	213 to 216.3
	Thickness (m)	0.3 to 2.6	0.6 to 9.1	9.2 to 12.1
River Channel	Elevation at Base (m)	217.7 to 218.7	220.6 to 220.8	216.7
	Thickness (m)	1.9 to 1.3	0.9 to 1.3	2

A summary of the laboratory material testing results on the alluvial deposits from the KGS Group 2021 geotechnical investigations and the background geotechnical investigations completed downstream of the Newton Force Main Crossing site as reported by AECOM are summarized in Table 5 (Reference 1).

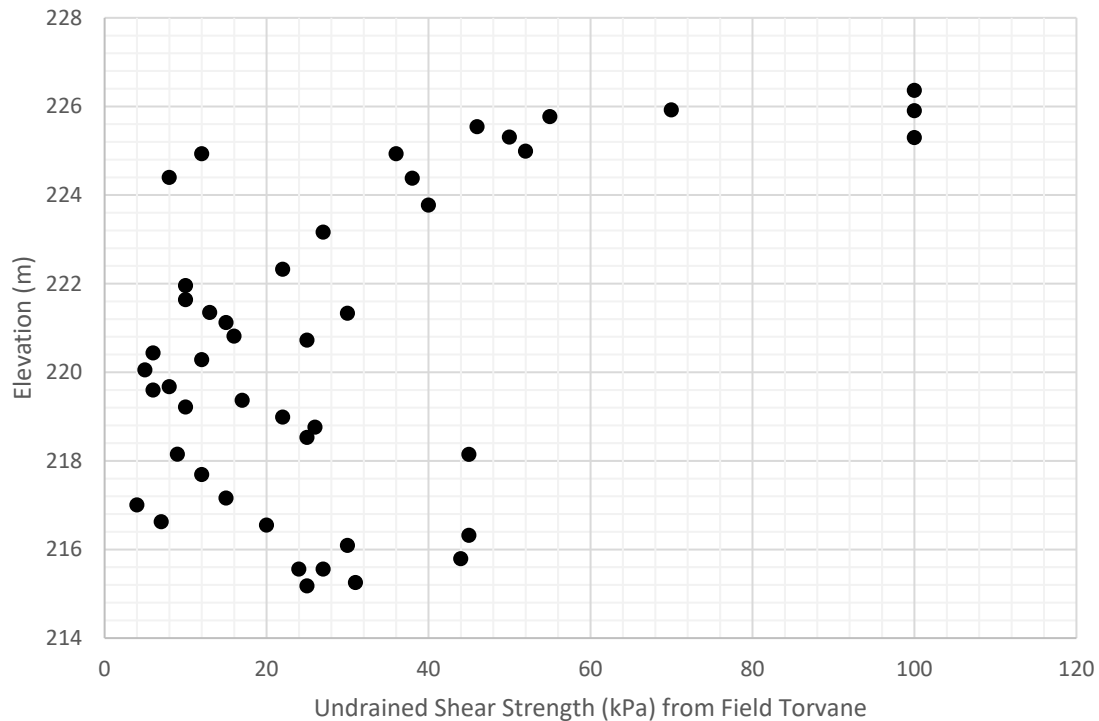
TABLE 5: SUMMARY OF LABORATORY TEST RESULTS FOR ALLUVIAL DEPOSITS

Laboratory Test	Alluvial Clay ⁽¹⁾	Alluvial Silt	Alluvial Sand
Moisture Content (%)	14 to 36	22 to 42.5	17.5 to 37
Atterberg – Plastic Limit (%)	13.0 to 17.1	NP	NP
Atterberg – Liquid Limit (%)	27.4 to 41.5	NP	NP
Plasticity Index	14.4 to 25.4	NP	NP
Grain Size – Gravel (%)	0	0	0 to 2.0
Grain Size – Sand (%)	35.7	24	31 to 74
Grain Size – Silt (%)	36.6	53 to 57	4 to 39
Grain Size - Clay (%)	27.7	19 to 23	5 to 30
Unconfined Compressive Strength (kPa)	46.4 to 106.6	45.1 to 57.3	--
Undrained Shear Strength (kPa) above El. 222 m	10 to 145	5 to 70	--
Undrained Shear Strength (kPa) below El. 222 m	10 to 80	15 to 180	--
Bulk Unit Weight (kN/m ³)	17.4 to 18.2	15.0 to 18.7	--
Dry Unit Weight (kN/m ³)	13.7	14	--

(1) One grain size test was completed on the alluvial clay during the 2016 AECOM geotechnical investigation program.

(2) NP stands for non-plastic.

Values of undrained shear strength (S_u) with elevation for the alluvial deposits as estimated from a field Torvane during the KGS Group 2021 investigation at the Newton Force Main Crossing site are summarized in Figure 2.

FIGURE 2: UNDRAINED SHEAR STRENGTH WITH ELEVATION FOR ALLUVIAL SOIL

GLACIOLACUSTRINE CLAY

Underlying the Upper Complex Zone is typically 9 to 12 m of glaciolacustrine clay deposit. In decreasing occurrence, typically the predominant mineral composition of the lacustrine clay generally consists of montmorillonite (a member of the smectite family), illite, kaolinite and some mica (Graham and Shields 1985). The clay deposit changes from brown to grey (sometimes referred to as blue clay) at depths of approximately 4.6 to 7.6 m. Within this depth range, the brown and grey clays often appear mottled, making it sometimes difficult to observe a discrete contact between the two colours. It is believed the colour change is due to the oxidation of the brown clay (Graham and Shields 1985).

The brown clay is typically stiff in consistency and of a high plasticity. The brown clay is highly fissured with the frequency of fissures decreasing with depth. White gypsum pockets and veins are typically observed within the brown clay, often filling in the fissures. The lower grey clay is firm to stiff in consistency and of intermediate to high plasticity. Fine to coarse grained gravel and boulders are found occasionally in the grey clay, near the till interface.

Typical moisture content in the clay ranges from 40 to 60%. Atterberg Limit tests within the brown and grey clay has shown the brown clay is typically more plastic than the underlying grey clay. Liquid Limits in the brown clay typically range from 80 to 110% and the Plastic Index from 60 to 80%. Liquid Limits in the grey clay typically range from 65 to 95% and the Plastic Index ranges from 40 to 65%. Unconfined compressive strengths usually range from 70 to 100 kPa within the brown clay. Measured values within the upper brown

clay are variable due to fissures. Typically the unconfined compressive strengths generally yield a lower bound to undrained shear strengths (Reference 2).

Undrained shear strengths measured from unconfined compression tests are generally higher within the upper clay zone (~ top 2 to 3 m), typically in the order of 70 to 100 kPa. Below a depth of about 4 to 5 metres, strengths typically decrease approximately uniformly with increasing depth. As the underlying till layer is approached, strengths are typically in the order of 40 kPa but may be as low as 25 kPa. The higher undrained shear strengths with the upper brown clay and lower shear strengths at depth near the till is caused by weathering near the ground surface and decreasing over consolidation ratios to approximately normally consolidated conditions near the bottom of the deposit. They may also reflect artesian ground water conditions (and therefore low vertical effective stresses).

Effective shear strength parameters of the brown and grey clay obtained from consolidated undrained compression triaxial strength testing of a large number of relatively undisturbed samples yielded intact peak strength of $c' = 19.6$ kPa and $\phi' = 20.5^\circ$ and $c' = 29.8$ kPa and $\phi' = 15.8^\circ$, respectively. While the effective large strain shear strength parameter for the brown and grey clay were $c' = 14.5$ kPa and $\phi' = 13.3^\circ$ and $c' = 7.7$ kPa and $\phi' = 15.7^\circ$, respectively (Reference 2). The effective shear strength parameters typically used by local geotechnical engineers in Winnipeg for slope stability analysis are $c' = 5$ kPa and $\phi' = 14^\circ$ for both clays.

The extent of the glaciolacustrine deposits identified in KGS Group's 2021 geotechnical investigation is outlined in Table 6 below.

TABLE 6: GLACIOLACUSTRINE DEPOSITS – KGS GROUP 2021 GEOTECHNICAL INVESTIGATION

Location	Profile	Glaciolacustrine Clay
East Riverbank	Elevation at Base (m)	213.2
	Thickness (m)	0.7
West Riverbank	Elevation at Base (m)	213.1
	Thickness (m)	5.9
River Channel	Elevation at Base (m)	213.6
	Thickness (m)	3.0

Glaciolacustrine deposits were also encountered during the previous geotechnical investigations completed within 1.5 km downstream of the Newton Force Main Crossing site with thickness ranging from 0.6 m to 15.9 m. It was noted by AECOM that the clay thickness was generally thinner on the east riverbank compared to the west riverbank which is consistent with observations at the Newton Force Main Crossing site.

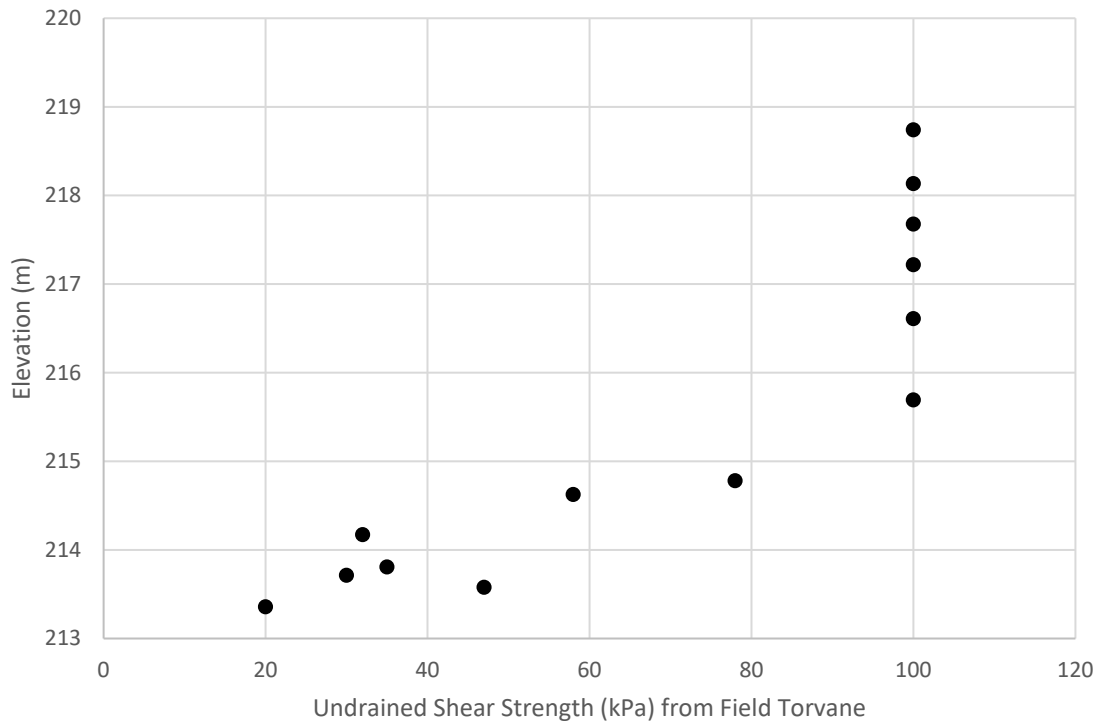
A summary of the laboratory material testing results on the glaciolacustrine clay from the KGS Group 2021 geotechnical investigations and the background geotechnical investigations completed downstream of the Newton Force Main Crossing site as reported by AECOM are summarized in Table 7 (Reference 1).

TABLE 7: SUMMARY OF LABORATORY TEST RESULTS FOR GLACIOLACUSTRINE CLAY

Laboratory Test	Glaciolacustrine Clay
Moisture Content (%)	20.8 to 52.6
Atterberg – Plastic Limit (%)	16.2 to 19.4
Atterberg – Liquid Limit (%)	49.7 to 75.0
Plasticity Index	33.5 to 50.8
Unconfined Compressive Strength (kPa)	47 to 245
Undrained Shear Strength (kPa) above El. 220 m	25 to 85
Undrained Shear Strength (kPa) below El. 220 m	20 to 85
Bulk Unit Weight (kN/m ³)	16.0 to 19.9
Dry Unit Weight (kN/m ³)	11.7 to 13.0

Values of undrained shear strength (S_u) with elevation for the glaciolacustrine clay as estimated from a field Torvane during the KGS Group 2021 investigation at the Newton Force Main Crossing site are summarized in Figure 3.

FIGURE 3: UNDRAINED SHEAR STRENGTH WITH ELEVATION FOR GLACIOLACUSTRINE CLAY



GLACIAL TILL DEPOSITS

The glaciolacustrine clays are underlain by glacial silty tills. Based on the borehole drilling, glacial silt till was encountered at elevations ranging from 211.6 to 212.9 m. The glacial till ranged in thickness from 3.1 to 5.8 m. The glacial till may include a transition zone of till lenses in clay and clay inclusions in the till. The composition of the till is variable. The till is of varying consistency with the dense to very dense portions of the deposits being a basal till (hardpan). The upper horizon of the till deposit may be frequently loose and considerably softer, and water bearing likely an ablation till (putty till). The upper ablation till typically may have water contents ranging from 10 - 15% while the denser basal till will typically have water contents in the range of 7 - 10%. The upper tills contain more clay, and have a slightly higher plasticity than the lower tills with high silt content. Unconfined compressive strengths ranging from 3.4 - 3.6 MPa have been reported for very dense tills with a moisture content of about 5% (Ref 1). Young's moduli typically range from 170 to 240 MPa (Ref 1). The tills are highly variable in terms of thickness, density and boulder content. Pockets of non-combustible gas, often under pressure are occasionally encountered in the till layer (Reference 3).

The uncorrected Standard Penetration Test blow counts ranged from 17 to greater than 50 blows/0.3 m, classifying the material as compact to very dense.

Boulders and cobbles are commonly found within till and should be anticipated within the deposits at the project site.

The extent of the glacial till deposit identified in KGS Group's 2021 geotechnical investigation is outlined in Table 8 below. Glacial till was also encountered during the geotechnical investigations completed within 1.5 km downstream of the Newton Force Main Crossing site and are also summarized in Table 8 (Reference 1).

TABLE 8: GLACIAL TILL – KGS GROUP 2021 AND BACKGROUND GEOTECHNICAL INVESTIGATIONS

Location	Profile	Glacial Till (KGS Group 2021)	Glacial Till (1.5 km downstream)
East Riverbank	Elevation at Base (m)	207.8	208.8 to 210.9
	Thickness (m)	3.8 to 5.4	0.7 to 0.6
West Riverbank	Elevation at Base (m)	209	209.8 to 210.2
	Thickness (m)	3.4	1.0 to 6.6
River Channel	Elevation at Base (m)	209.1	209.8 to 211.0
	Thickness (m)	4.5	1.7 to 6.3

A summary of the laboratory material testing results on the glacial till deposits from the KGS Group 2021 geotechnical investigations and the background geotechnical investigations completed downstream of the Newton Force Main Crossing site as reported by AECOM are summarized in Table 9 (Reference 1).

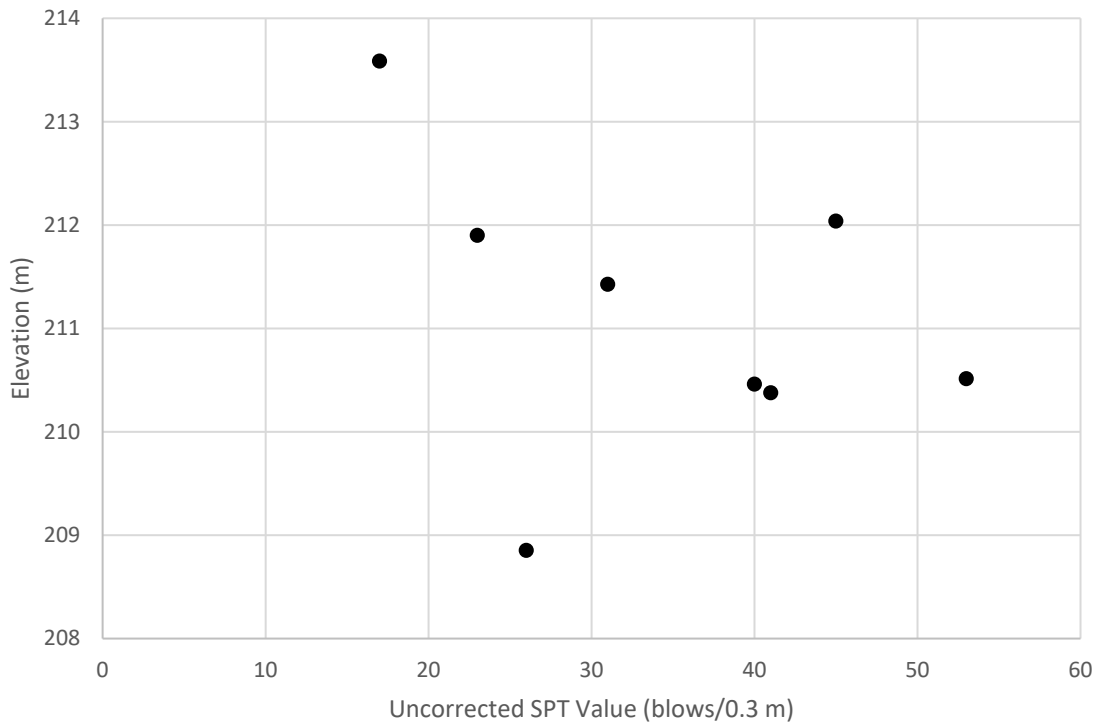
TABLE 9: SUMMARY OF LABORATORY TEST RESULTS FOR GLACIAL TILL

Laboratory Test	Glacial Till
Moisture Content (%)	8.9 to 20
Atterberg – Plastic Limit (%)	11.0 to 15.0
Atterberg – Liquid Limit (%)	29.0 to 32.0
Uncorrected Standard Penetration Test – Blow Count	8 to >50
Grain Size – Gravel (%)	0
Grain Size – Sand (%)	86.7
Grain Size – Silt (%)	7.4
Grain Size - Clay (%)	5.9

(1) One grain size test was completed on the glacial till during the 2016 AECOM geotechnical investigation program.

Uncorrected Standard Penetration Test (SPT) blow count values (blows/0.3 m) with elevation for the glacial till encountered during the KGS Group 2021 investigation at the Newton Forcemain Crossing site are summarized in Figure 4.

FIGURE 4: UNCORRECTED SPT VALUES WITH ELEVATION FOR GLACIAL TILL



4.1.2 BEDROCK

The limestone bedrock in the area of the Newton Force Main Crossing site belongs to the Selkirk member of the Red River Formation. The Selkirk member typically is medium strength with compressive strengths that vary from 30 to 40 MPa. The Young’s modulus (E) generally ranges from 15 to 25 GPa (Reference 2). The bulk modulus (k) typically ranges from 40 to 50 GPa, and the shear modulus ranges from 5 to 10 GPa.

Bedrock was cored in all four (4) test holes at the site. Based on the borehole drilling, bedrock was encountered below the silt till at elevations ranging from 207.1 to 209.7 m. The seismic refraction survey suggests that top of bedrock may be lower on the east side of the river, at an elevation of approximately El. 198 m along the proposed force main alignment. The estimated bulk compressive wave velocity (Vp) for the upper bedrock is 4100 m/s and 3200 m/s on the east side and west side, respectively. These estimated velocities suggest that the bedrock is more fractured on the west side which is consistent with the RQD values presented in Figure 5.

The bedrock consists of limestone and mottled limestone. Dolomite was observed in test hole TH21-01 from elevation 208.0 to 209.7 m. The measured RQD of the bedrock with elevation is shown Figure 5 below, and a histogram with the RQD distribution is shown on Figure 6.

FIGURE 5: BEDROCK RQD WITH ELEVATION

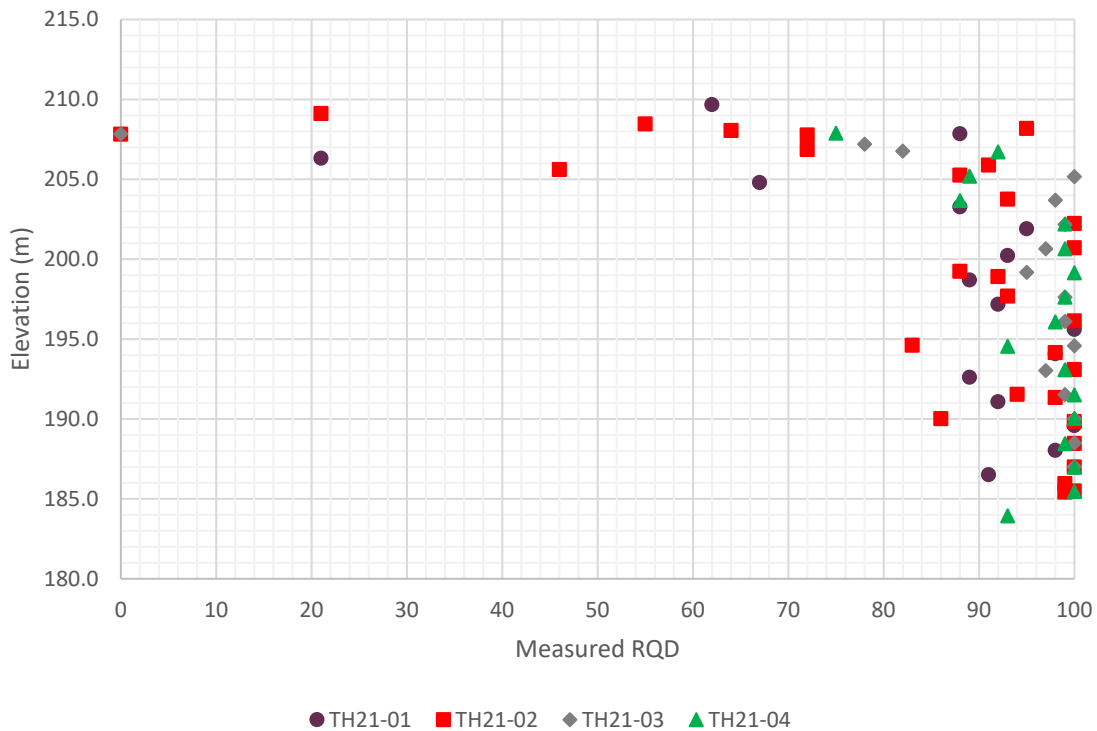
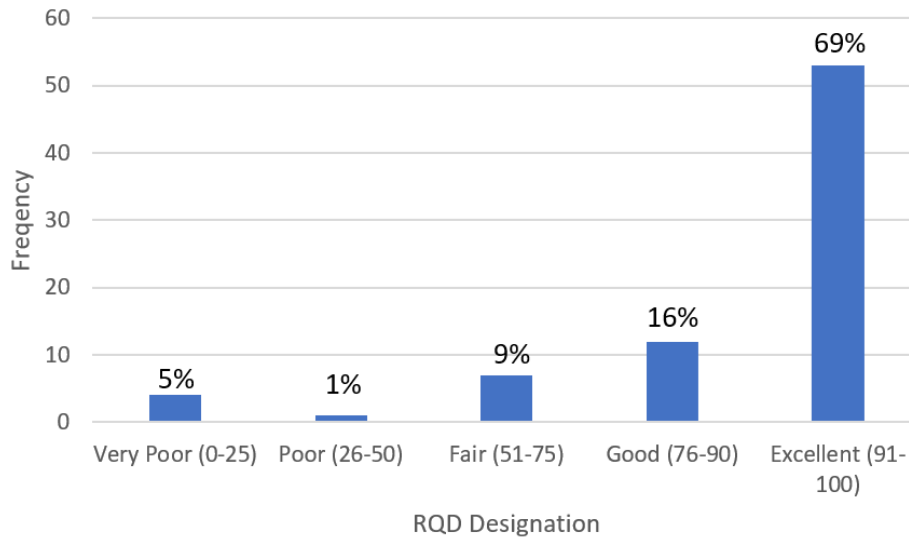
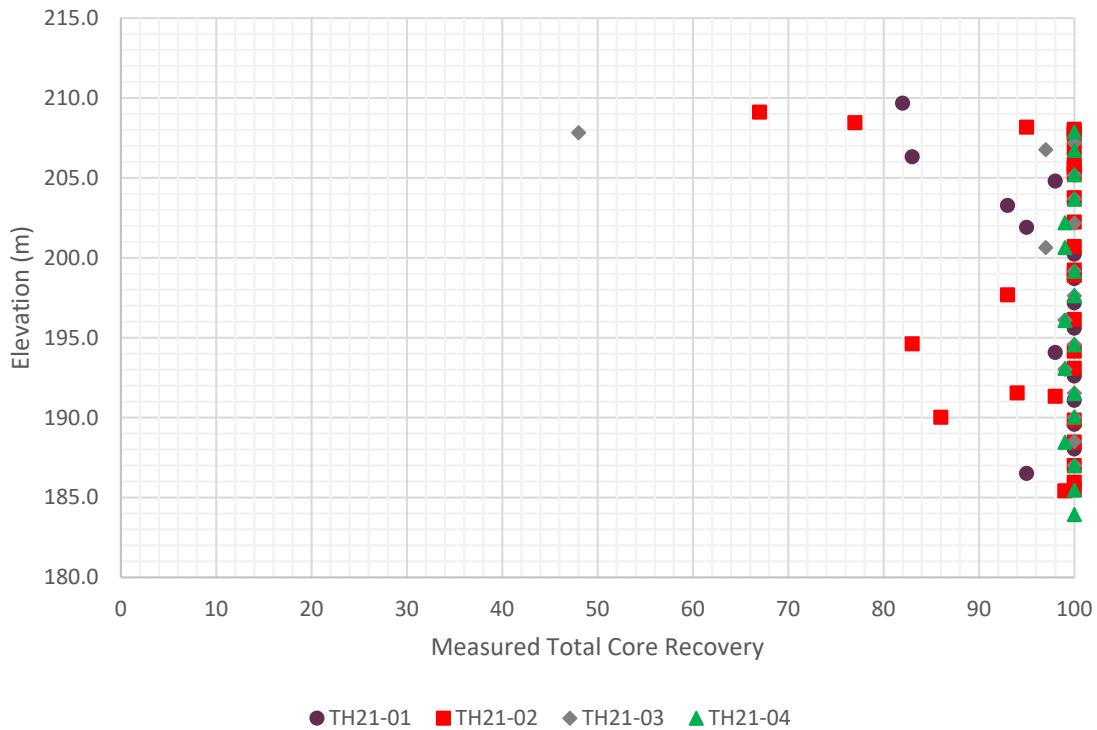


FIGURE 6: HISTOGRAM OF DISTRIBUTION OF RQD WITHIN TEST HOLES



Total Core Recovery (TCR) is the total length of the bedrock core recovered and is expressed as the percentage of actual length of the core run (typically 1.5 m). A summary of the TCR values is provided in Figure 7.

FIGURE 7: BEDROCK TOTAL CORE RECOVERY WITH ELEVATION



Laboratory testing was completed on two (2) mottled limestone bedrock samples from test hole TH21-01, at elevations 200.5 and 202.7 m. The results for compressive strength, Young's Modulus, and Shear Modulus are summarized in Table 10. The Shear Modulus was calculated using the following relationship:

$$E = 2G(1+\nu)$$

Where:

E = Young's Modulus

G = Shear Modulus

ν = Poisson's Ratio

TABLE 10: SUMMARY OF BEDROCK 2021 LABORATORY TESTING

Test Hole ID	Sample ID	Sample Depth (Elevation) [m]	Description	Compressive Strength (MPa)	Young's Modulus, E (GPa)	Shear Modulus, G (GPa) ¹	Poisson's Ratio (ν)
TH21-01	R5	25.17 (203.02)	Mottled Limestone	14.37	12.17	5.38	0.13
TH21-01	R6	27.58 (200.61)	Mottled Limestone	28.40	19.31	8.32	0.16

Notes:

1. The relationship between Young's Modulus (E) and Shear Modulus (G) is: $E = 2G(1+\nu)$

5.0 REFERENCES

1. AECOM Canada Ltd., (2018). Northeast Interceptor Sewer – Red River Crossing Geotechnical Data Report.
2. Department of Geological Engineering, the University of Manitoba, (1983). Geological Engineering Report for Urban Development of Winnipeg.
3. Frontier Geoscience Inc. (2021). Seismic Refraction Survey Report, Newton Force Main Red River Crossing, Winnipeg, MB.
4. KGS Group, Acres Engineering, UMA Engineering (2004). Appendix B, Floodway Channel Pre-Design, Floodway Expansion Project, Project Definition and Environmental Assessment, Preliminary Engineering Report.

APPENDIX A

Northeast Interceptor Sewer Replacement
Geotechnical Data Report (AECOM 2018)

City of Winnipeg

Northeast Interceptor Sewer - Red River Crossing Geotechnical Data Report

Prepared by:
AECOM Canada Ltd.
99 Commerce Drive
Winnipeg MB R3P 0Y7

Prepared for:
City of Winnipeg
110 - 1199 Pacific Avenue
Winnipeg, MB R3E 3S8

Date: March, 2018
Project #: 60509089

Distribution List

# Hard Copies	PDF Required	Association / Company Name
	Yes	City of Winnipeg

Date
March 23, 2018

Mr. Stacy Cournoyer, P.Eng
Senior Project Engineer
City of Winnipeg
110 - 1199 Pacific Avenue
Winnipeg, MB R3E 3S8

Our Reference: 60509089

Dear Mr. Cournoyer:

Regarding: Northeast Interceptor Sewer Crossing- Geotechnical Data Report

We are pleased to submit this Geotechnical Data Report for the Northeast Interceptor Sewer Crossing to be constructed in northeast Winnipeg, Manitoba. The report provides a summary of the subsurface soil, bedrock, and groundwater encountered along the final alignment of the Northeast Sewer Interceptor and the laboratory test results for the soil and bedrock.

If you have any questions concerning this report please contact the undersigned at (780) 486-7905.

Sincerely,
AECOM Canada Ltd.



Faris Alobaidy, M.Sc., P.Eng.
Senior Geotechnical Engineer

FA:rz

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The attached Report (the "Report") has been prepared by AECOM Canada Ltd. ("AECOM") for the benefit of the Client ("Client") in accordance with the agreement between AECOM and Client, including the scope of work detailed therein (the "Agreement").

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- may be based on information provided to AECOM which has not been independently verified;
- has not been updated since the date of issuance of the report and its accuracy is limited to the time period and circumstances in which it was collected, processed, made or issued;
- must be read as a whole and sections thereof should not be read out of such context;
- was prepared for the specific purposes described in the report and the Agreement; and
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time.

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This Statement of Qualifications and Limitations is attached to and forms part of the report and any use of the report is subject to the terms hereof.

General Statement – Normal Variability of Subsurface Conditions

The scope of the investigation presented herein is limited to an investigation of the subsurface conditions as to the suitability of the proposed project. This report has been prepared to aid in the evaluation of the site and to assist the engineer in the design of the facilities. The description of the project represents an understanding of the significant aspects of the project relative to the design and construction of earth work, foundations, and similar. In the event of any changes in the basic design or location of the structures as outlined in this report or plan, AECOM Canada Ltd. should be given the opportunity to review the changes and to modify or reaffirm, in writing, the conclusions and recommendations of this report.

The analyses and recommendations represented in this report are based on the data obtained from the test holes drilled at the locations indicated on the site plans and from other information discussed herein. This report is based on the assumption that the subsurface conditions everywhere on the site are not significantly different from those encountered at the test hole locations. However, variation in the soil conditions between the test holes may exist. Also, general groundwater levels and conditions may fluctuate from time to time. The nature and extent of the variations may not become evident until construction. If subsurface conditions different from those encountered in the exploratory borings are observed or encountered during construction, or appear to be present beneath or beyond excavations, AECOM Canada Ltd. should be advised at once so that the conditions can be observed and reviewed and, where necessary, the recommendations reconsidered.

Since it is possible for conditions to vary from those identified at the test hole locations and from those assumed in the analysis and preparation of recommendations, a contingency fund should be included in the construction budget to allow for the possibility of variations which may result in modification of the design and construction procedures.

In order to observe compliance with the design concepts, specifications, or recommendations and to allow design changes in the event that subsurface conditions differ from those anticipated, it is recommended that all construction operations dealing with earthwork and the foundations be observed by an experienced geotechnical engineer. In addition, it is recommended that a qualified geotechnical engineer review the plans and specifications that have been prepared to check for substantial conformance with the conclusions and recommendations contained in the report.

Quality Information

Report Prepared By:



Alexander Hill, P.Ge., FGS
Engineering Geologist

Report Reviewed By:



Faris Alobaigy, M.Sc., P.Eng.
Senior Geotechnical Engineer

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Appendix H Dilatometer Results (Dyregrov & Burgess. 1988)

1. Introduction

1.1 General

AECOM Canada Ltd. (AECOM) was retained by the City of Winnipeg Water and Waste Department (the City) to provide geotechnical engineering services to support the design and construction of the proposed Northeast Interceptor Sewer (NEIS). AECOM understands that installation of the proposed NEIS below the Red River will be completed by microtunnelling from the western siphon outlet chamber to the eastern siphon inlet chamber.

This Geotechnical Data Report (GDR) presents the results of a detailed geotechnical investigation conducted by AECOM along the proposed NEIS alignment. The detailed geotechnical investigation was conducted in general accordance with the American Society of Civil Engineers (ASCE) guidelines (Essex 2007 and ASCE/CI 36-15).

This report also provides a detailed summary of previous geotechnical investigation programs undertaken at the site and locations in close proximity to the site. The results and factual outcomes of these studies are included within Section 3 of this report.

This GDR should be read in conjunction with the Geotechnical Baseline Report (GBR). The GDR is subject to AECOM's Statement of Qualification and Limitations and General Statement regarding the Normal Variability of the Subsurface Conditions.

1.2 Aims and Objectives

The main objectives of the AECOM 2016 geotechnical investigation were to determine the subsurface soil/bedrock/groundwater conditions and engineering properties of the soil/bedrock encountered at the test hole locations drilled along the NEIS alignment. The primary focus of this report is to present and document the factual findings from the AECOM and other relevant geotechnical investigations and laboratory testing programs. The results of AECOM's laboratory testing program and test hole logs are included within this report.

The analyses and results presented in this report are based on the data obtained from the test holes drilled at discrete locations along the NEIS alignment. This report does not reflect any variations which may occur between the test hole locations. In the performance of subsurface explorations, specific information is obtained at specific locations at specific times. However, it is well known that variations in soil, bedrock, and groundwater conditions exist at most sites between test hole locations. The nature and extent of the variations may not become evident until the course of construction. If variations are then evident, it will be necessary to re-evaluate the findings and results presented in this report after performing on-site observations during the construction period and noting the characteristics of any variations.

This report is subject to the general statement regarding the normal variability of subsurface conditions provided above.

1.3 Project Details

The proposed NEIS will be constructed within the Kildonan area in the northeast region of Winnipeg. The proposed NEIS alignment crosses the Red River directly to the south of the existing Kildonan Settlers Bridge.

It is understood that the current siphon is under capacity and experiences surcharging during large wet weather events and the additional capacity is required to meet current and future wet weather flow conditions. A trenchless solution is understood to be the preferred method for installation of additional conveyance capacity. The proposed NEIS alignment across the Red River will be installed via microtunnelling through the use of a Microtunnelling Boring Machine (MTBM). With the configuration of the existing siphon, installation of a new crossing via microtunnelling will require the construction of new siphon chambers.

Construction of the NEIS will begin from the downstream siphon chamber (western siphon outlet chamber) located to the south/southeast of the Kildonan Settlers Bridge, and will be terminated at the southwest of the Kildonan Settlers Bridge (eastern siphon inlet chamber) as shown on **Figure 1** shown in **Appendix A**. The proposed siphon will be connected to the existing 1800 mm mono concrete interceptor sewer via a trenchless solution or access shaft. A summary of the NEIS lengths, sizes and installation methods are provided in Table 1-1.

Table 1-2-1: Summary of NEIS Lengths, Sizes and Proposed Installation Methods

Location	Length (m)	Size (mm)	Installation Method
Start: 1+288.61 – Western Outlet Chamber End: 1+539.70 – Eastern Inlet Chamber	251.09	900 - Carrier Pipe Casing Pipe (optional)	Microtunnelling
Eastern Inlet and Western Outlet Chambers Sewer Connection	4.1 to 6.2	1200- Carrier Pipe 2400 – Casing Pipe (optional)	Pipe Jacking

The NEIS will be installed using two (2) shafts to facilitate the trenchless forms of siphon installation. The shafts will be used to launch and/or retrieve the MTBM. The locations of the proposed shafts are shown on **Figure 1** shown in **Appendix A**. Based on current geotechnical information and groundwater depths, it is understood that sealed methods of shaft construction are permitted, while dewatering or lowering of the groundwater table is not permitted.

The overburden depth (fill and surficial soils, not including bedrock thickness) above the pipe crown varies from 5.0 to 21.7 m along the NEIS alignment. Typically, a minimum soil cover of approximately two (2) times the tunnel diameter is required above the pipe crown. The river crossing will be constructed via microtunnelling methods, either installed as a two pass system (i.e. large diameter casing pipe with a 900 mm carrier pipe) or as a single pass installation comprising of a single 900 mm pipe. The surficial geology of the site and NEIS alignment is shown on **Figure 2** in **Appendix A**.

1.4 Scope of Work

The scope of work for the detailed geotechnical investigation along the NEIS alignment is summarized below:

1. Review of geological survey maps and relevant background information.
2. Obtain and review geotechnical reports provided to AECOM with respect to the subject site. AECOM will also review geotechnical reports available in AECOM's library to collect information on the soil and bedrock within and near to the subject site.
3. Prepare a GDR that documents the findings from AECOM's 2016 investigation and from previous geotechnical investigations and laboratory testing.

2. Background Information

2.1 Review of Background Reports

A review of available geotechnical information pertinent to the project was conducted including the geotechnical report prepared by AECOM Canada Ltd (2017). The main objective of the review was to obtain and present information specific to the subsurface and groundwater conditions with respect to the NEIS alignment and areas adjacent to the site. The available memorandums and reports were also reviewed to prepare a GDR that presents the factual information collected from the site investigation and laboratory testing. The following information was provided to the project team by the City and Associated Engineering:

1. Friesen Drillers Ltd (February 2018). Hydrogeological Assessment/Aquifer Characterization, Northeast Interceptor Sewer River Crossing Project- River Lot 25 Parish of Kildonan, Kildonan Settlers Bridge- Chief Peguis Trail, Winnipeg, Manitoba.
2. AECOM Canada Ltd (2017). City of Winnipeg Northeast Interceptor Sewer Red River Crossing Geotechnical Report.
3. TREK Geotechnical (December 2015). Northeast Interceptor Crossing Options Study – Geotechnical Assessment.
4. TREK Geotechnical (January 2014). North Kildonan Feedermain Detailed Design- Geotechnical Report.
5. KGS Group (November 2012). Forcemain Sub-Surface Investigation.
6. Dyregrov and Burgess Consulting Geotechnical Engineers (February 1988). Kildonan Corridor Geotechnical Report.
7. Settlers Bridge Design and Construction (Various Reports 1988 to 1990): Relevant information includes test logs, record drawings of the construction works which included riprap and riverbank stabilization on the west bank (rock columns), and performance monitoring results related to ground movements and groundwater levels.

The location of pertinent exploratory holes from past and existing geotechnical investigations relevant to the site are shown on **Figure 3 in Appendix A**.

Additional information was requested from the City by the project team with regard to riverbank stability issues encountered during construction of the west abutment of the Kildonan Settlers Bridge. The City provided the following documents for the project team review:

- Kildonan Bridge at the Red River – Geotechnical Report (Dyregrov & Burgess, February 1988).
- Various Riverbank Stability Monitoring Results Reports (Dyregrov & Burgess, June 1989 to April 1991).
- Kildonan Bridge West Embankment Monitoring Program – Letter Reports (A. Dean Gould, June 1990, July 1990, November 1990 and December 1990).
- Opinion on Request for Amendment to River and Streams Permit no. 78-89 Kildonan Bridge over the Red River, West Bank (A. Baracos, May 1990).

The above information was reviewed to improve the project team's understanding of specific site conditions and behaviour of the riverbank during the construction of the Kildonan Bridge approximately 20 to 30 m north of the proposed interceptor pipe location.

In summary, a review of the identified reports indicated the following:

- The riverbank soils consist of both lacustrine and alluvial soils overlying glacial till and limestone bedrock.
- Groundwater monitoring data indicate that the subsurface soils, till and bedrock are all hydraulically connected.
- The west riverbank will likely require stabilization measures if disturbed during construction.
- Constructability challenges (sloughing, seepage etc.) are anticipated, dewatering and temporary shoring will be required.
- Bedrock contains zones of large fractures and weak rock.
- Ground stabilization (1989/90) was completed on the west bank adjacent to the existing bridge location.

A detailed summation of the Associated Engineering Ltd. (February 2016) Crossing Options Assessment Study is not included as part of this report given the absence of any relevant subsurface ground and/or groundwater information derived from geotechnical investigation.

2.1.1 TREK Geotechnical (December 2015) – Northeast Interceptor Crossing Options Study, Geotechnical Assessment

A geotechnical assessment was provided to review potential crossing options (subsequently incorporated as part of the Associated Engineering Ltd. 2016 report) with respect to the potential geotechnical impacts along the proposed interceptor alignment. The TREK Geotechnical (TREK) report included the following scope of work:

- Review of existing information.
- Review of subsurface conditions.
- Slope stability assessment.
- Geotechnical recommendations for crossing options.

No additional geotechnical investigation was undertaken as part of this assessment, and as such utilized information and data obtained from the KGS (2012) and Dyregrov and Burgess (1987) investigations. Subsurface information was also derived from the TREK (2013) geotechnical investigation and extrapolated along the NEIS alignment.

2.1.2 Record Drawings

The following as-built record drawing has been obtained as part of this study and is provided in **Appendix B**:

1. North-East Interceptor River Crossing (1970). Drawing No. 494.

2.2 Background Information from Previous Geotechnical Investigations

AECOM has reviewed the previous geotechnical investigations relevant to the NEIS alignment and adjacent structures offset from the NEIS alignment. The primary objective of the review was to collect information on the subsurface soil/bedrock conditions in the project area.

Table 2-1 summarizes the geotechnical investigations that have been completed at and in near proximity to the site.

Table 2-1: Summary of Site Specific Geotechnical Investigations

Organization	Type and Number of Investigation	Drilling Date	Associated Structure	Distance (m) and Relevancy to NEIS Alignment	Comments
Friesen Drillers Ltd.	MR (4 no.)	October 12 to 17, 2017	Existing NEIS alignment	Distance: 0 to 30 Drilled at or near to eastern inlet and western outlet chambers	TH-01, 02, 03 and 04
					Groundwater monitoring and sampling wells on eastern and western riverbanks.
AECOM	SSA/RC (4 no.)	August 19 to September 9, 2016	Existing NEIS alignment	Distance: 0 to 25 Directly along proposed NEIS alignment.	TH16-01, 02, 03 and 04
KGS Group*	SSA/RC (3 no.) SSA (2 no.)	November 7 to 14, 2012	Existing NEIS alignment	Distance: 0 to 25 North and south of existing siphon alignment	TH12-01, 02, 02B, 03, 03B

Notes: MR- Mud Rotary; SSA- Solid Stem Auger; RC- Rock Core; *- Report not available for review at the time of preparation.

Geotechnical investigations which have previously been undertaken within the areas adjacent to the site but not specific to the NEIS alignment are also summarised in Table 2-2 below.

Table 2-2: Summary of Geotechnical Investigations Offset from NEIS Alignment

Organization	Type and Number of Investigation	Drilling Date	Associated Structure	Distance (m) and Relevancy to NEIS Alignment	Comments
TREK Geotechnical	SSA/RC (3. No)	November 7 to 18, 2013	North Kildonan Feedermain	Distance: 150 to 200 North of existing and proposed NEIS alignment	TH13-01, 04 and 05
Dyregrov and Burgess	SSA (10 no.) HSA (3 no.) RC (14 no.) DMT (5 no.)	June 6, 1987 to October 15, 1987	Kildonan Settlers Bridge	Distance: 75 to 100 North of proposed and existing NEIS alignment	Boring 1 to 23 DMT 3 to 7

Notes: SSA- Solid Stem Auger; HAS- Hollow Stem Auger; RC- Rock Core; DMT- Dilatometer Test.

The locations of the exploratory holes outlined in Table 2-1 are shown on **Figure 3 in Appendix A**. Test hole logs related to previous geotechnical investigations are included as **Appendix C** in this report. Test hole records for the AECOM 2016 geotechnical investigation are included in **Appendix D**. The laboratory testing results for all geotechnical investigation phases (including AECOM 2016) is provided in **Appendix**

E of this report with the exception of the KGS 2012 investigation. The results of the KGS (2012) laboratory testing program were not made available at this time of this report.

2.2.1 TREK Geotechnical (January 2014) - Detailed Design Geotechnical Report

In support of the Kildonan Feedermain replacement/rehabilitation project, TREK was engaged to provide geotechnical engineering services to facilitate the detailed design of the feedermain. As part of the scope of work, TREK completed the following in relation to the detailed design phase of the project:

- Background information and literature review.
- Sub-surface geotechnical investigation.
- Soil and groundwater assessment.
- Riverbank stability analysis and assessment.
- Geotechnical design recommendations.

Based on the preliminary design completed by Associated Engineering (July 2013), installation of the proposed feedermain was to be completed using Horizontal Directional Drilling (HDD) methods. In order to identify potential geotechnical concerns along the feedermain alignment, and to provide geotechnical design parameters, a geotechnical investigation was undertaken by TREK in 2013.

The TREK geotechnical investigation consisted of three (3) test holes drilled into the carbonate bedrock within the eastern and western riverbanks. Groundwater monitoring wells were installed at each of the test hole locations (see Section 3.3 of this report). The geotechnical testing program consisted of index classification testing and strength testing of soils and rocks. The results of the geotechnical laboratory tests are included within the TREK report (2014). Further information concerning the encountered subsurface soil and groundwater conditions are provided in Section 3.0 of this report. A summary of the drilling and testing components are shown in Table 2-3, below. The test hole records for the 2013 investigation are provided in **Appendix C** along with representative subsurface soil profiles. The geotechnical material testing results are also provided within **Appendix E** of this report.

Table 2-3: Summary of North Kildonan Feedermain Geotechnical Investigation- TREK Geotechnical (January 2014)

Test Hole	Test Hole Elevation (m)	Location	Drilling Method	Completion Depth (m)	Thickness of Overburden Soils (m)	Elevation of Bedrock Contact (m)
TH13-01	227.36	Eastern Riverbank	Solid Stem Auger and Diamond Drill Core	36.9	18.2	209.2
TH13-04	227.19	Western Riverbank	Solid Stem Auger and Diamond Drill Core	21.6	17.1	210.1
TH13-05	226.63	Western Riverbank	Solid Stem Auger and Diamond Drill Core	35.1	16.3	210.0

The TREK 2014 report indicates that the subsurface ground profile along the feedermain generally consists of alluvial soils overlying glacio-lacustrine clay and glacial till. Carbonate bedrock was encountered underlying the glacial till in all test holes. The TREK (2013) test holes are presented in **Appendix C** of this report.

A slope stability analysis was performed on five cross-sections along or near to the feedermain alignment. The five cross-sections selected for analysis were chosen based upon topographical and bathymetric survey profiles of existing conditions (along the eastern and western riverbanks) to determine the potential impact of existing slope instability on the future crossing. Cross section A was constructed directly along the feedermain alignment, and is shown as **Figure 2-1**, below.

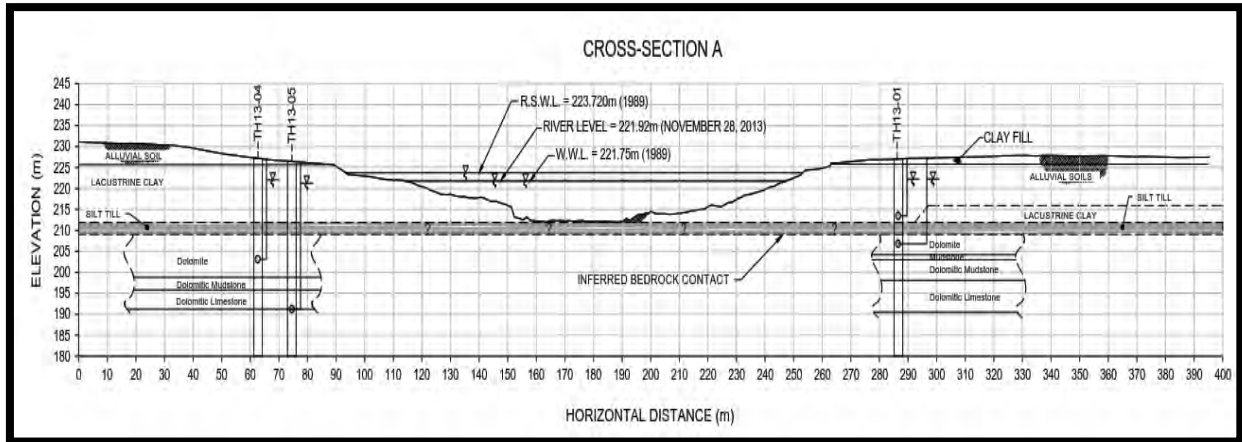


Figure 2-1: Cross Section “A” taken from TREK Geotechnical 2014 North Kildonan Feedermain Geotechnical Report

The slope stability analysis incorporated soil parameters based on the findings of the geotechnical investigation and material testing program. Typical slope heights analyzed as part of the assessment ranged between 13.5 m and 18.0 m with varying slope profiles as illustrated in **Figure 2-1**. The adopted soil strength parameters used within the slope stability analysis are summarised below.

Table 2-4: Soil Properties Used in Stability Modelling- TREK Geotechnical (January 2014)

Soil Description	Unit Weight (kN/m ³)	Cohesion (kPa)	Friction Angle (°)	Hydraulic Conductivity (m/s)
Glacio-Lacustrine Clay	17	5	14	1 x 10 ⁻¹⁰
Alluvial Soils	18	2	23	1 x 10 ⁻⁰⁹
Glacial Till	19	10	30	1 x 10 ⁻⁰⁷
Engineered Fill (Clay)	18	2	23	1 x 10 ⁻⁰⁹

Notes: Groundwater Information for the TREK (2013) Geotechnical Information is provided in Section 3.3.1 of this Report.

TREK concluded that the existing eastern and western riverbank slopes have a Factor of Safety (FS) between 1.3 and 1.5. The report also recommended that erosion protection in the form of stone rip-rap be placed along the lower riverbanks.

2.2.2 Dyregrov and Burgess (February 1988)- Kildonan Corridor Geotechnical Report

The report was commissioned to provide geotechnical engineering recommendations for the detailed design of the Settlers Bridge crossing of the Red River within the Kildonan Corridor. The report summarizes the findings of the geotechnical investigation and geotechnical laboratory testing results. The test hole records related to the investigation are included in **Appendix C** of this report. The corresponding laboratory test results are included in **Appendix E** of this report. The report also presents the findings and outcomes of slope stability analyses performed to determine the impacts of the bridge crossing on the existing slopes and adjacent structures.

The geotechnical investigation consisted of an extensive drilling and testing program focused at locations along the eastern and western riverbanks and in-channel crossing points. A summary of the drilling and testing components are shown in Table 2-5, below.

Table 2-5: Summary of Kildonan Corridor Geotechnical Investigation (Dyregrov and Burgess)

Test Hole	Test Hole Elevation (m)	Location	Drilling Method	Completion Depth (m)	Thickness of Overburden Soils (m)	Elevation of Bedrock Contact (m)	Groundwater Elevation at Completion of Drilling (m)
Boring 1	230.63	Western Riverbank	Solid Stem Auger	7.6	NP	NP	228.2 (Seepage)
Boring 2	230.91	Western Riverbank	Solid Stem Auger	10.7	NP	NP	228.3 (Seepage)
Boring 3	230.58	Western Riverbank	Solid Stem Auger	13.7	NP	NP	-
Boring 4	230.64	Western Riverbank	Solid Stem Auger	20.4	20.4	210.2*	221.2 (Inflow)

Test Hole	Test Hole Elevation (m)	Location	Drilling Method	Completion Depth (m)	Thickness of Overburden Soils (m)	Elevation of Bedrock Contact (m)	Groundwater Elevation at Completion of Drilling (m)
Boring 5	228.72	Western Riverbank	Solid Stem Auger	18.7	18.7	210.0*	-
Boring 6	227.47	Eastern Riverbank	Hollow Stem Auger	12.5	NP	NP	-
Boring 7	227.13	Eastern Riverbank	Solid Stem Auger	16.2	16.2	210.9*	Seepage (no elevation)
Boring 8	227.17	Eastern Riverbank	Solid Stem Auger	17.7	17.7	209.4*	220.0
Boring 9	230.08	Eastern Riverbank	Solid Stem Auger	6.4	NP	NP	-
Boring 10	230.02	Eastern Riverbank	Solid Stem Auger	6.1	NP	NP	-
Boring 11	229.48	Eastern Riverbank	Solid Stem Auger	6.1	NP	NP	-
Boring 12	226.74	Western Riverbank	Hollow Stem Auger	12.8	NP	NP	-
Boring 13	227.60	Western Riverbank	Hollow Stem Auger	18.6	18.6	NP	-
Boring 14	223.64	In-Channel	Rock Coring	19.1	5.7	210.3	-
Boring 15	223.67	In-Channel	Rock Coring	21.7	3.4	210.6	-
Boring 16	223.61	In-Channel	Rock Coring	20.1	3.8	210.6	-
Boring 16A	NR	In-Channel	Rock Coring	23.6	5.3	209.7	-
Boring 16B	NR	In-Channel	Rock Coring	20.0	4.7	209.7	-
Boring 16C	NR	In-Channel	Rock Coring	22.3	4.9	209.9	-
Boring 16D	NR	In-Channel	Rock Coring	22.5	3.9	210.2	-
Boring 17	223.65	In-Channel	Rock Coring	22.6	5.6	209.7	-
Boring 18	223.68	In-Channel	Rock Coring	22.3	1.6	211.1	-
Boring 19	223.62	In-Channel	Rock Coring	20.7	4.9	209.8	-
Boring 20	223.61	In-Channel	Rock Coring	22.6	6.0	210.1	-
Boring 21	223.63	In-Channel	Rock Coring	22.4	11.9	210.2	-

Test Hole	Test Hole Elevation (m)	Location	Drilling Method	Completion Depth (m)	Thickness of Overburden Soils (m)	Elevation of Bedrock Contact (m)	Groundwater Elevation at Completion of Drilling (m)
Boring 22	223.68	In-Channel	Rock Coring	19.0	11.5	210.7	-
Boring 23	223.70	In-Channel	Rock Coring	20.9	11.8	210.7	-
DMT 3	223.70	In-Channel	Dilatometer Testing	7.9	NP	NP	-
DMT 4	223.61	In-Channel	Dilatometer Testing	7.5	NP	NP	-
DMT 5	223.61	In-Channel	Dilatometer Testing	8.5	NP	NP	-
DMT 6	223.60	In-Channel	Dilatometer Testing	10.6	NP	NP	-
DMT 7	223.60	In-Channel	Dilatometer Testing	13.1	2.6	NP	-

Notes: NP- Not Proven; *- Inferred ; NR- Not Reported

Groundwater information collected from the Dyregrov and Burgess (1987) geotechnical investigation is summarized in Section 3.3.1 of this report.

2.3 Regional Geology

2.3.1 Bedrock Geology

The shallow bedrock geology of the Winnipeg area generally comprises of carbonate rock of the Selkirk and Fort Garry Members belonging to the Red River Formation. The Red River Formation consists of alternating layers of limestone and dolomite (with basal shale layers). The NEIS alignment is located on either side of the geological contact between the Selkirk Member and the lower part of the Fort Garry Member of the Red River Formation (TREK - January 2014).

The upper surface of the bedrock is generally characterised with poor rock mass characteristics and is highly fractured. Karstic features are also common within the upper zone of the carbonate bedrock. The Karst topography is typically infilled with mixtures of silt, sand and gravel till material. The Winnipeg Formation underlies the Red River Formation, and typically consists of sandstone and shale units. The basement bedrock geology is comprised of the Pre-Cambrian Basal Granites at depth. The actual bedrock conditions encountered at the site are described in Section 3.0 of this report below.

2.3.2 Surficial Geology

The overlying surficial soils generally comprise of alluvial deposits, glacio-lacustrine silty clays and glacial till soils of varying thicknesses and compositions. The glacial till soils were laid down by the advancing and retreating glacial ice masses. This in-turn resulted in disturbance of the upper zone within the

shallow carbonate bedrock. The glacio-lacustrine soils are a product of fine materials deposited through suspension within the glacial lakes.

The glacio-lacustrine soils are typically 9 to 12 m thick, but vary significantly spatially within the Red River Valley of southern central Manitoba. The glacio-lacustrine soils are further sub-divided into two distinct sub-units; the Upper and Lower (brown and grey clay, respectively) clay. The transition zone between the two sub-units is typically located between an approximate depth of 4.6 and 7.6 m (Graham and Shields 1985).

Glacial till soils underlie the glacio-lacustrine soils, and the soil boundary interface is usually marked by a transition zone consisting of clay and silt lenses surrounded by a sand/gravel matrix.

2.3.3 Hydrogeology

There are three significant bedrock aquifers beneath the City of Winnipeg. The largest is known as the Upper Carbonate Aquifer which is generally found within the upper 7 m of the carbonate bedrock profile. This aquifer is contained in an extensive network of fractures and Karstic solution cavities formed by the dissolution of the Upper carbonate rocks. Other aquifers include the Lower and Middle Carbonate Aquifers at the base of the carbonate bedrock profile and the underlying Winnipeg Formation sandstones. A Middle Carbonate Aquifer has also been encountered locally. In general, these Lower and Middle aquifers are not utilized due either to the presence of saline water or the higher productivity of the Upper Carbonate Aquifer.

Groundwater flow within the Upper Carbonate Aquifer is towards the Red River (the major discharge point for this aquifer), and in particular towards the St. Boniface Industrial Park on the east side of the river where consumptive groundwater use occurs. West of the Red River, the water quality varies from brackish to saline, except beneath the northwest part of the city. Therefore, groundwater in this aquifer is mostly used for commercial and industrial heating and cooling. The majority of these systems recycle the water back into the subsurface and there is very little consumptive use.

Prior to the start of development of this aquifer in the late 1800's, the potentiometric surface was estimated to be approximately 3 to 6 m below ground surface in the central Winnipeg area. Extensive consumptive use of this groundwater resulted in a decline in the potentiometric surface to depths of 21 to 24 m. Consumptive use has declined since the early 1970's and since that time the potentiometric surface has been rising. Currently in the downtown area, the potentiometric surface is approximately 7 m below grade. This rise in water level has resulted in groundwater related problems with some deeper foundations in the city and must be considered in components design for this project. At the subject site, overburden up to 18 m including silt till was encountered during the investigation. Carbonate bedrock up to depths of 9.8 m (200.4 m Elv.), 16.7 m (193.3 m Elv.) and 9.9 m (200.5 m Elv.), was proofed at the west riverbank, river channel and east riverbank, respectively.

2.3.3.1 Friesen Drillers Ltd. (February 2018)- Hydrological Assessment/Aquifer Characterization

Friesen Drillers conducted a hydrogeological investigation to determine the potential for aquifer depressurization which would allow for deep excavations at the project (as well as at locations within the tunnel). The hydrogeological investigation included; test well drilling, aquifer pump testing and technical analysis. In summary, the scope of investigation comprised the installation of four (4) 5-inch (127 mm) diameter PVC cased test wells into the carbonate bedrock to a maximum depth of 61 m. The groundwater wells were installed within both the eastern and western riverbanks (two wells at each

riverbank), and details of each groundwater well are summarized in Table 2-6. The groundwater well construction report for each location is shown as **Appendix C** of this report.

Table 2-6: Well Construction Details- Friesen Drillers (February 2018)

Test Hole	Test Hole Coordinates	Casing Depth (m)	Response Zone (m)	Total Drilling Depth (m)
TH-01 (Eastern Riverbank)	5534768 N 636562 E	18.0	18.0 to 36.0	36.0
TH-02 (Eastern Riverbank)	5534792 N 636568 E	23.0	23.0 to 60.0	60.0
TH-03 (Western Riverbank)	5534844 N 636365 E	19.0	19.0 to 60.0	60.0
TH-04 (Western Riverbank)	5534879 N 636380 E	18.0	18.0 to 60.0	60.0

Notes: Ground Elevations not surveyed

The results of the detailed hydrogeological investigation are presented in a separate report entitled included as **Appendix F**.

2.4 AECOM Site Specific Investigation

The AECOM 2016 geotechnical investigation field program (including laboratory test results) is summarised as below. The 2016 AECOM geotechnical investigation was completed to determine the subsurface conditions at the proposed NEIS alignment.

2.5 Test Hole Drilling and Soil Sampling

From August 19 to September 9, 2016, four (4) test holes (TH16-01 to TH16-04) were drilled at the approximate locations shown on **Figure 3** in **Appendix A**. Test holes TH16-01 and TH16-02 were drilled along the northwest riverbank in the vicinity of the western outlet chamber location, while test hole TH16-03 was drilled within the Red River channel, and test hole TH16-04 was drilled in the vicinity of the eastern inlet chamber location.

Drilling was completed by Maple Leaf Drilling using the following equipment: track-mounted Acker Renegade drill rig equipped with 125 mm solid stem augers and HQ sized (96 mm OD) core barrel for test holes TH16-01 and TH16-02, Cricket B20 equipped with BQ sized (60 mm OD) core barrel mounted on a floating barge for test hole TH16-03, and track mounted Mobile B54X drill rig equipped with 125 mm solid stem augers and NQ sized (75.7 mm OD) core barrel for test hole TH16-04. Subsurface conditions observed during drilling were visually classified and documented by AECOM geotechnical personnel. Other pertinent information such as groundwater and drilling conditions were also recorded during the field investigation.

Disturbed soil samples collected from auger cuttings and split-spoon samplers, as well as relatively undisturbed Shelby Tube samples were obtained at regular intervals. Standard penetration tests (SPTs) were completed at selected intervals in the test holes and blow counts for 300 mm penetration (SPT "N"

blow counts) were recorded. NQ and HQ rock core samples were logged in the field and collected for further analysis. Recovered soil and rock core samples were transported to AECOM's materials testing laboratory in Winnipeg for further visual examination and testing.

Detailed test hole logs have been prepared for each test hole, and are attached as **Appendix D**. The test hole logs include description and depth of the soil units encountered, sample type, sample location, results of field and laboratory testing, and other pertinent information such as seepage and sloughing.

2.5.1 Laboratory Testing

The laboratory testing program included the determination of moisture contents, grain size distribution (hydrometer method), and Atterberg Limits. Laboratory test results are included in **Appendix E**, and the type and number of laboratory tests are summarized in Table 2-7.

The bedrock core samples were also tested to estimate Unconfined Compressive Strength (UCS) as per ASTM D7012 Methods C and D and were outsourced to other laboratories.

Table 2-7: Summary of Type and Number of Geotechnical Laboratory Tests (AECOM 2016)

Laboratory Test	Number of Tests Completed	Data Location
Moisture Content Determination	54	Test Hole Logs & Appendix D
Atterberg Limits (3 Points)	12	Test Hole Logs & Appendix D
Grain Size Distribution (Hydrometer Method)	8	Test Hole Logs & Appendix D
Unconfined Compressive Strength of Rock	6	Test Hole Logs & Appendix D

The geotechnical testing program undertaken as part of the historic geotechnical investigation programs (see Section 2.2) has been summarized in Table 2-8, below.

Table 2-8: Summary of Type and Number of Laboratory Tests- Historic Geotechnical Programs

Laboratory Test	TREK Geotechnical (2014) Number of Tests Completed	Dyregrov and Burgess (1987) Number of Tests Completed
Moisture Content Determination	50	76
Atterberg Limits (3 Points)	3	2
Grain Size Distribution (Hydrometer Method)	2	6
Unconfined Compressive Strength of Soil	4	25
Pocket Penetrometer	4	35
Torvane	4	30
Bulk Density	4	33
Unconfined Compressive Strength of Rock	7	Not Tested

The results of the KGS (2012) laboratory testing program were not available during preparation of this report.

3. Subsurface Conditions

3.1 General

The following sections describe the subsurface conditions encountered during the AECOM 2016 geotechnical investigation and information referenced from review of geotechnical investigations previously carried out at the site. The results of the AECOM 2016 investigation are in general agreement with investigations carried out in the past by other firms for City owned projects in the site area. It is however prudent to note that subsurface conditions can vary significantly between test holes within the same site. A schematic of the soil stratigraphy based on the findings of the AECOM 2016 investigation and relevant historic soils data (derived from past geotechnical reports) along the NEIS pipe profile is presented as **Figure 4** shown in **Appendix A**. A subsurface soil profile obtained from the TREK 2014 detailed design report is presented in **Appendix C**.

Detailed descriptions of the subsurface conditions encountered at the test hole locations as part of the AECOM 2016 investigation are provided on the test hole logs presented in **Appendix D**. A description of the terms and symbols used on the test hole logs are also included in **Appendix D**. A brief description of the subsurface soil/bedrock units encountered along the NEIS and adjacent locations are provided in the following sections.

3.2 Subsurface Profile

Soils encountered during the investigation consisted of the following:

- Clay Fill
- Alluvial Deposits
 - Clay Interlayer
 - Silt Interlayer
 - Sand Interlayer
 - Organics
- Glacio-Lacustrine Clay
- Glacial Till
- Carbonate Bedrock

Each of these units is described below.

3.2.1 Clay Fill

Clay fill was not encountered in any of the test hole locations undertaken by AECOM in 2016, however was noted in several other test holes carried out by other engineering firms, including; TREK (2013), KGS (2012) and Dyregrov & Burgess (1987).

Silty clay fill was encountered as part of the KGS 2012 geotechnical investigation on both the eastern and western riverbank locations directly along the proposed NEIS alignment. The silty clay fill was noted in four KGS test holes (TH12-02, 02B, 03 and 03B), with a corresponding thickness of between 0.40 m and 0.60 m.

The TREK 2013 geotechnical investigation encountered clay fill in one test hole (TH13-01) drilled near to the eastern bridge abutment north of the proposed NEIS alignment with a thickness of 1.5 m. The clay fill was described as silty clay with trace to some sand and gravel and trace organics, brown, moist, stiff and was of high plasticity. The laboratory testing results state that the moisture content ranged from 23 percent to 26 percent, with an average value of 25 percent. In seven test holes, the 1987 Dyregrov and Burgess investigation further encountered silty clay fill to depths of between 0.2 m and 1.2 m below ground surface.

3.2.2 Alluvial Deposits

Alluvial deposits were encountered at ground surface in all of the AECOM 2016 test holes (TH16-01, TH16-02, TH16-03 and TH16-4) drilled along the NEIS alignment. The alluvial deposit comprised of alternating layers of clays, silts, sands and/or organics with varying properties and classifications.

The extent of the alluvial deposits identified as part of the AECOM 2016 geotechnical investigation is outlined in Table 3-1, below. The findings of the 2012 KGS investigation are also included within Table 3-1 as these test holes are located along the proposed NEIS alignment.

Table 3-1: Alluvial Deposits- Soil Profile along NEIS Alignment (AECOM 2016 and KGS 2012)

Location	Profile	Alluvial Clay	Alluvial Silt	Alluvial Sand
Eastern Riverbank	Elevation at Base (m)	217.7 to 226.3	NR	214.4 to 219.7
	Thickness (m)	1.7 to 3.8		7.5 to 13.5
	Average Thickness (m)	3.2		10.3
Western Riverbank	Elevation at Base (m)	225.1 to 228.8	225.4 to 227.5	213.0 to 216.3
	Thickness (m)	0.3 to 2.1	0.6 to 1.4	9.2 to 12.1
	Average Thickness (m)	1.3	1.0	10.7
River Channel	Elevation at Base (m)	NR	NR	NR
	Thickness			
	Average Thickness (m)			

Notes: NR- Not Recorded

Alluvial deposits were also encountered as part of the TREK (2013) and Dyregrov and Burgess (1987) geotechnical investigations and the extent of the alluvial deposits are illustrated in Table 3-2, below.

Table 3-2: Alluvial Deposits-Soil Profile offset from NEIS Alignment (TREK 2013, Dyregrov and Burgess 1987)

Location	Profile	Alluvial Clay	Alluvial Silt	Alluvial Sand
Eastern Riverbank	Elevation at Base (m)	223.4 to 224.6	214.7 to 226.0	215.2 to 222.5
	Thickness (m)	2.8 to 4.1	1.2 to 4.8	2.4 to 7.3
	Average Thickness (m)	3.4	3.7	4.2
Western Riverbank	Elevation at Base (m)	225.6 to 228.6	217.7 to 227.6	NR
	Thickness (m)	1.5 to 2.6	0.8 to 9.1	
	Average Thickness (m)	2.1	2.7	
River Channel	Elevation at Base (m)	217.7 to 218.7	220.6 to 220.8	216.7
	Thickness	1.9 to 3.1	0.9 to 1.3	2.0
	Average Thickness (m)	2.5	1.1	2.0

A summary of the laboratory testing results for the alluvial deposits conducted as part of the AECOM 2016 geotechnical investigation is presented in Table 3-3.

Table 3-3: Summary of Laboratory Test Results for Alluvial Deposits- AECOM 2016 Investigation

Laboratory Test	Alluvial Clay	Alluvial Silt	Alluvial Sand	Organics
Moisture Content (%)	14 to 36 (26)	22 to 28	18 to 37 (30.6)	44
SPT 'N' Blow Counts (uncorrected)	-	-	1 to 19	-
Atterberg - Plastic Limit (%)	15.0 to 17.1 (16.0)	-	NP to 16.0 (14.4)	NP
Atterberg - Liquid Limit (%)	38.2 to 40.2 (39.2)	-	NP to 41.5-(32.3)	NP
Grain Size - Gravel (%)	0.0	-	0.0 to 2.0 (0.4)	-
Grain Size - Sand (%)	35.7	-	39.1 to 68.8 (60.0)	-
Grain Size - Silt (%)	36.6	-	3.9 to 33.0 (20.7)	-
Grain Size - Clay (%)	27.7	-	4.6 to 28.0 (19.0)	-

Notes: NP- Non-Plastic; (26) - Average Value

The reported laboratory results from the previous geotechnical investigations have also been summarized in Table 3-4 below. The geotechnical laboratory results for the KGS 2012 investigation have not been made available to AECOM and therefore none are reported.

Table 3-4: Summary of Laboratory Test Results for Alluvial Deposits- Previous Geotechnical Investigations

Laboratory Test	Alluvial Clay	Alluvial Silt	Alluvial Sand
Moisture Content (%)	18.2 to 35 (29)	23.5 to 42.5 (31.2)	17.5 to 31.3 (26.7)
Atterberg - Plastic Limit (%)	24.0	15.0 (15.0)	NT
Atterberg - Liquid Limit (%)	70.0	45.0 (45.0)	NT
Grain Size - Gravel (%)	NT	0 (0)	0 (0)
Grain Size - Sand (%)	NT	24.(24)	31 to 74 (55)
Grain Size - Silt (%)	NT	53 to 57 (55)	18 to 39 (28)
Grain Size - Clay (%)	NT	19 to 23 (21)	8 to 30 (17)
Unconfined Compressive Strength (kPa)	46.4 to 106.6 (76.5)	45.1 to 57.3 (51.2)	NT
Undrained Shear Strength (kPa)	23.2 to 53.30 (38.3)	22.6 to 28.7 (25.6)	NT
Dilatometer Testing - Undrained Shear Strength (kPa)	8.7 to 144.6 (56.7)	14.2 to 45 (21.3)	NT
Pocket Penetrometer - Undrained Shear Strength (kPa)	55.6 to 114.9 (81.8)	52.7 to 183.8 (96.0)	NT
Torvane - Undrained Shear Strength (kPa)	27.8	15.8 to 68.7 (46.3)	NT
Bulk Unit Weight (kN/m ³)	17.4 to 18.2 (17.9)	15.0 to 18.7 (17.3)	NT
Dry Unit Weight (kN/m ³)	13.7 (13.7)	14.0 (14.0)	NT

Notes: (29) - Average Value; NT- Not Tested

In addition to the soil classification and strength testing as outlined in Table 3-4, consolidation testing was performed as part of the Dyregrov and Burgess (1987) investigation on one sample. The results of the consolidation testing is summarized in Table 3-5, and is also presented in **Appendix G** of this report.

Table 3-5: Summary of Consolidation Test Results for Alluvial Clay- Previous Geotechnical Investigations

Test Hole	Sample Depth (m)	In-Situ Moisture Content (%)	Preconsolidation Pressure (kPa)	Compression Index (Cc)	Recompression Index (Cr)
Boring 6	3.0	31	122	0.31*	0.09*

Notes: Based on AECOM Interpretation; Initial Void Ratio (e₀) not reported as part of test. Atterberg Limits not undertaken.

The results of the dilatometer testing conducted by Dyregrov and Burgess (1987) are provided in further detail in Table 3-6, and are also provided in **Appendix H** of this report.

Table 3-6: Summary of Dilatometer Test Results for Alluvial Deposits- Dyregrov and Burgess (1987)

Test Hole	Location	Alluvial Soil Unit	
		Alluvial Clay-Test Results (kPa)	Alluvial Silt- Test Results (kPa)
DMT 1	Western Riverbank	8.7 to 63.5 (42.2)	1.8 to 27.2 (13.7)
DMT 2	Eastern Riverbank	58.2 to 144.6 (86.1)	28.6
DMT 3	In-Channel	10.3 to 38.6 (20.2)	NT
DMT 4	In-Channel	51.0 to 59.0 (56.0)	27 to 45 (33.7)
DMT 5	In-Channel	24.0 to 34.0 (29)	NT
DMT 8	In-Channel	10.3 to 37.0 (23.4)	14.2 to 30.5 (22.4)

Notes: Testing performed for the purposes of detailed design for the North Settlers Bridge; (13.7) - Average Value; NT- Not Tested

Values of undrained shear (S_u) with elevation for the alluvial soil deposits are illustrated in **Figure 3-1** below.

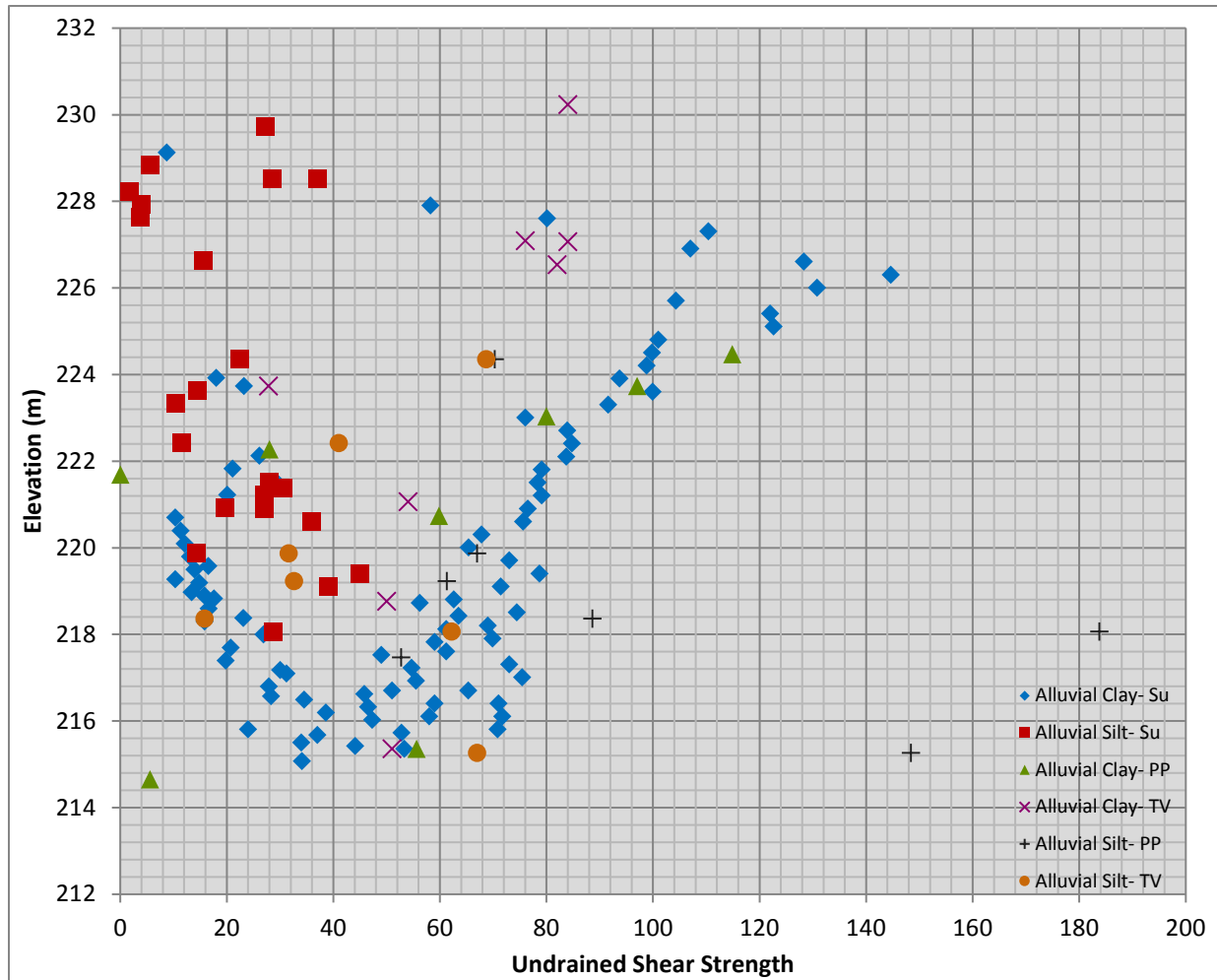


Figure 3-1: Undrained Shear Strength with Elevation for Alluvial Soil Deposits- AECOM (2017), TREK (2014) and Dyregrov and Burgess (1988)

3.2.2.1 Alluvial Clay

The alluvial clay contained trace silt to silty, trace sand to sandy, trace gravel and trace organics. The alluvial clay was brown to dark grey, very soft to firm, dry to wet, and was of an intermediate plasticity.

3.2.2.2 Alluvial Silt

The alluvial silt contained trace clay to clayey, trace to some sand, and was dark brown to light brown, soft to stiff, dry to moist, and of low to intermediate plasticity.

3.2.2.3 Alluvial Sand

The alluvial sand contained trace clay to clayey, trace silt to silty, trace to some gravel, and was brown to grey, very loose to compact, moist to wet, and fine to medium grained.

3.2.2.4 Organics

An organic layer measuring 0.6 m in thickness was encountered in the AECOM 2016 test hole TH16-04 within the alluvial deposit at an elevation of approximately 217 m. The organic layer was sandy, contained trace to some silt and trace clay. The organic was described as dark brown to black, very loose, and wet.

Topsoil was also encountered in four test holes completed as part of the Dyregrov and Burgess (1987) investigation with a recorded thickness of between 0.2 and 0.3 m.

3.2.3 Glacio-Lacustrine Clay

A layer of Glacio-Lacustrine clay was encountered in all test holes drilled along the NEIS alignment with a corresponding thickness of between 0.6 m and 15.9 m. It was generally noted that the clay was thinnest beneath the river channel, and generally increased in thickness with distance away from the river channel. The Glacio-Lacustrine clay was however thinner in the east when compared to the test hole findings located along the western riverbanks. Glacio-lacustrine clay was encountered in AECOM's test hole TH16-04 below the alluvial sand deposit. Elsewhere the findings of previously undertaken geotechnical investigations by TREK (2013) and Dyregrov and Burgess (1987) generally agreed with the findings of the test holes drilled along the NEIS alignment by AECOM (2016) and KGS (2012).

3.2.3.1 Reported Geotechnical Properties

Published literature and technical reports were reviewed to obtain data with respect to the subsurface soils and bedrock within the Winnipeg area, specifically along the proposed NEIS alignment. Each soil and bedrock unit is outlined below.

Geotechnical parameters of the glacio-lacustrine clay (Upper and Lower Clays) have been referenced from the Floodway Channel Pre-design Floodway Expansion Project (KGS Group, Acres Engineering and UMA Engineering, 2004) report and are presented within Table 2-7. The Floodway Channel project is located approximately 10 to 20 km east and southeast of the NEIS alignment and comprised of extensive study of the glacio-lacustrine soils.

The Upper clay is typically stiff in consistency, highly plastic, fissured and containing gypsum pockets. The Lower clay is typically soft to firm in consistency and has an intermediate to high plasticity. Fine to coarse grained gravel and boulders are found occasionally in the Lower clay near the glacial till interface (Graham and Shields, 1985). Clay minerals account for between 67 and 81 percent of the total composition of the Lake Agassiz clay (glacio-lacustrine clay) in Winnipeg. The clay size fractions typically consist of up to 75 percent montmorillonite, 10 percent illite and 10 percent kaolinite and approximately 5 percent quartz mineral. Over-consolidation ratio of the clay is generally less than 2.

The typical soil index classification and unconfined compressive strength parameters are summarized in Table 3-7.

Table 3-7: Published Geotechnical Soil Parameters- Glacio-Lacustrine Clay

Soil Property	Typical Range of Values
Moisture Content (%)	40 to 60- Upper and Lower Clay
Liquid Limit (%)	80 to 110- Upper Clay 65 to 95- Lower Clay
Plasticity Index (%)	60 to 80- Upper Clay 40 to 65- Lower Clay
Undrained Shear Strength (kPa)	70 to 100- Upper Clay 25 to 40- Lower Clay

Notes: Based on Graham & Shields (1985)

Effective shear strength parameters of the Upper and Lower clay obtained from consolidated undrained compression triaxial strength testing of a large number of relatively undisturbed samples yielded intact peak strengths of:

- Upper Clay- $c' = 19.6$ kPa and $\phi' = 20.5^\circ$ and;
- Lower Clay- $c' = 29.8$ kPa and $\phi' = 15.8^\circ$.

While the effective large strain shear strength (fully softened) parameters for the Upper and Lower clay were reported as follows:

- Upper Clay- $c' = 14.5$ kPa and $\phi' = 13.3^\circ$ and;
- Lower Clay- $c' = 7.7$ kPa and $\phi' = 15.7^\circ$.

Typical industry accepted effective shear strength parameters used in the Winnipeg area for the glacio-lacustrine clay for slope stability analysis are summarised in Table 3-8.

Table 3-8: Effective Shear Strength Parameters of Glacio-Lacustrine Clay

Parameter	Value
Effective Cohesion (c'), kPa	5.0
Effective Friction Angle (ϕ'), degrees	14.0

3.2.3.2 Geotechnical Investigation Findings- Glacio-Lacustrine Clay

The glacio-lacustrine clay generally contained trace to some silt, trace sand to sandy, trace to some gravel, trace organics, and was brown to grey, very soft to stiff, moist to wet, and of an intermediate to high plasticity. A summary of the laboratory testing results for the glacio-lacustrine clay layer conducted as part of the AECOM 2016 investigation is presented in Table 3-9. Undrained shear strength values obtained from torvane testing has been referenced from the KGS 2012 test hole logs and included within Table 3-10.

Table 3-9: AECOM 2016 Investigation- Summary of Laboratory Test Results – Glacio-Lacustrine Clay

Laboratory Test	Minimum Value	Average Value	Maximum Value
Moisture Content (%)	20.8	46.6.0	52.6
Atterberg - Plastic Limit (%)	16.2	17.8	19.4
Atterberg - Liquid Limit (%)	49.7	60.0	70.2
Uncorrected Standard Penetration Test- Blow Counts	2	5	4
Pocket Penetrometer- Undrained Shear Strength (kPa)	28.0	45.3	75.8
Torvane- Undrained Shear Strength (kPa)*	28.0	45.1	100.0

The reported laboratory results from the previous geotechnical investigations have also been summarized in Table 3-10.

Table 3-10: Summary of Laboratory Test Results for Glacio-Lacustrine Clay - Previous Geotechnical Investigations

Laboratory Test	Minimum Value	Average Value	Maximum Value
Moisture Content (%)	10.2	49.5	63.0
Atterberg - Plastic Limit (%)		18.0	
Atterberg - Liquid Limit (%)		75.0	
Unconfined Compressive Strength (kPa)	47.2	103.0	245.1
Undrained Shear Strength (kPa)	24.0	53.0	123.0
Pocket Penetrometer- Undrained Shear Strength (kPa)	31.1	105.5	148.4
Torvane- Undrained Shear Strength (kPa)	24.5	60.5	84.7
Bulk Unit Weight (kN/m ³)	16.0	17.1	19.9
Dry Unit Weight (kN/m ³)	11.7	14.2	13.0

Notes: (Average Value); NT- Not Tested

In addition to the soil classification and strength testing as outlined in Table 3-10, consolidation testing was performed as part of the Dyregrov and Burgess (1987) investigation on two samples. The results of the consolidation testing are summarized in Table 3-11 and are presented in **Appendix G** of this report.

Table 3-11: Summary of Consolidation Test Results for Glacio-Lacustrine Clay- Previous Geotechnical Investigations

Test Hole	Sample Depth (m)	In-Situ Moisture Content (%)	Preconsolidation Pressure (kPa)	Compression Index (Cc)	Recompression Index (Cr)
Boring 4	4.6	59	390	0.47*	0.20*
Boring 5	13.7	NR	250	0.79	0.12*

Notes: NR- Not Recorded; *- Based on AECOM Interpretation; Initial Void Ratio (e_0) not reported as part of test. Atterberg Limits not undertaken

Plots of moisture content with elevation and undrained shear strength (S_u) with elevation are shown below as Figure 3-2 and Figure 3-3, respectively.

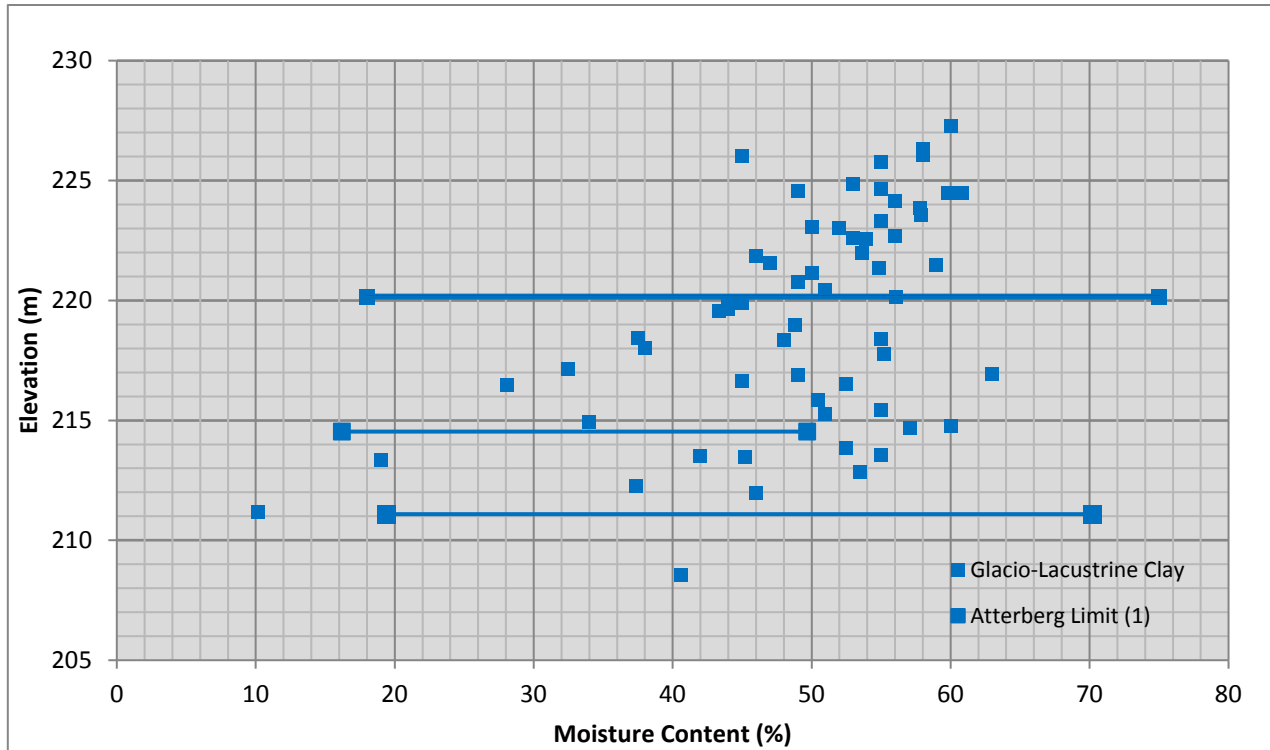


Figure 3-2: Moisture Content with Elevation for Glacio-Lacustrine Clay- AECOM (2017), TREK (2014) and Dyregrov and Burgess (1988)

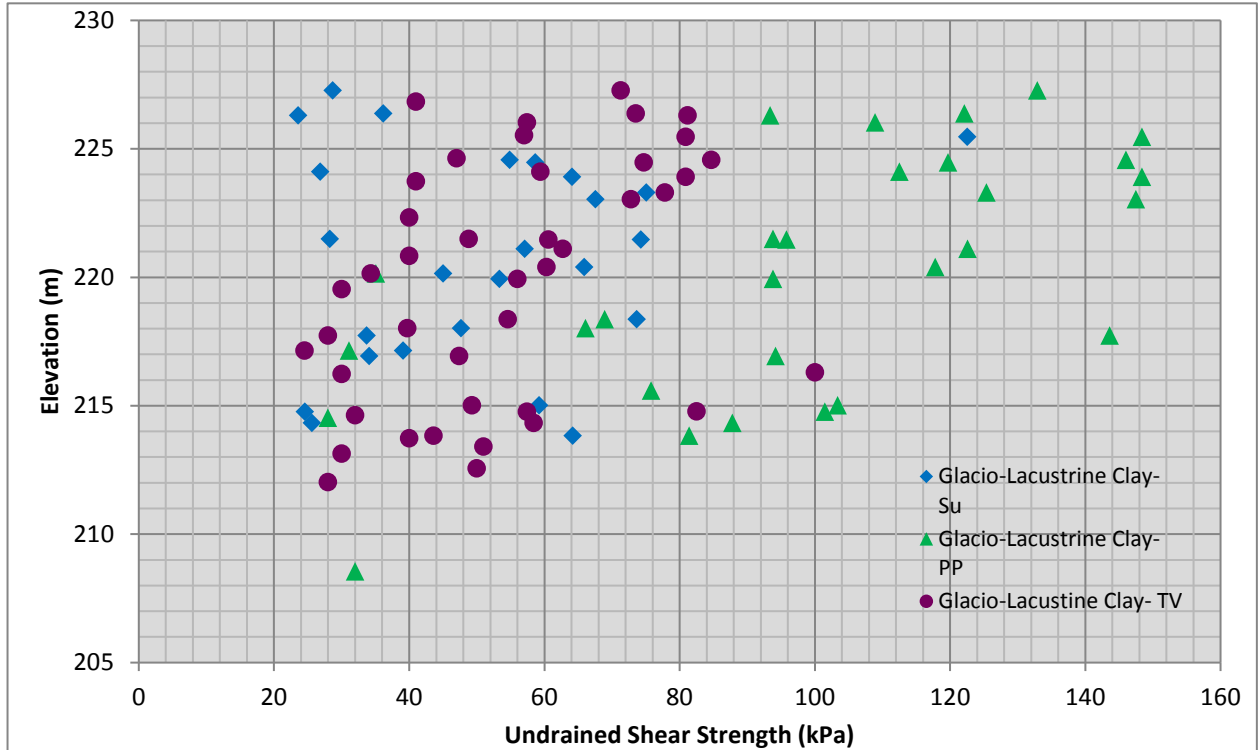


Figure 3-3: Undrained Shear Strength with Elevation for Glacio-Lacustrine Clay- AECOM (2016), TREK (2013) and Dyregrov and Burgess (1987)

The results of a single direct shear strength test for the Glacio-Lacustrine clay performed by Dyregrov & Burgess (1988) is provided in Table 3-12.

Table 3-12: Direct Shear Test Results- Dyregrov and Burgess (1988)

Test Results Condition	Strength Parameters	
	Effective Cohesion (kPa)	Effective Angle of Shearing Resistance (°)
Peak	18	16.0
Post Peak	4.1	13.0
Residual	1.4	10.5

Notes: Performed on remoulded samples

The reported laboratory test results are generally consistent with the published findings for the glacio-lacustrine clay within the Winnipeg area. The undrained shear strength profile (as shown in **Figure 3-3**) for the glacio-lacustrine clay trends gradually towards lower undrained shear strength values closer to the clay/glacial till boundary.

3.2.4 Glacial Till

A glacial till layer was encountered in all test holes below the Glacio-Lacustrine clay with of varying thicknesses. The glacial till layer was noted to overlie the carbonate bedrock. The profile of the encountered glacial till layer is outlined in Table 3-13.

Table 3-13: General Profile for Glacial Till

Location	Profile	Glacial Till
Eastern Riverbank	Elevation at Base (m)	208.8 to 210.9
	Thickness (m)	0.7 to 6.0
	Average Thickness (m)	2.5
Western Riverbank	Elevation at Base (m)	209.8 to 210.2
	Thickness (m)	1.0 to 6.6
	Average Thickness (m)	2.3
River Channel	Elevation at Base (m)	209.8 to 211.0
	Thickness	1.7 to 6.3
	Average Thickness (m)	3.9

Notes: Based on information from the AECOM 2016 and previous geotechnical investigations.

3.2.4.1 Reported Geotechnical Properties - Glacial Till

Within the Winnipeg area, the composition of the glacial till deposit is highly variable and its density varies both with depth and with distance. Near the glacio-lacustrine/glacial till interface, the upper zone of the till is typically characterized by a softer sub-unit (locally termed “putty till”), and has a typical moisture content ranging from 10 and 15 percent. The lower sub-unit has typical in-situ moisture content values of between 7 and 10 percent.

Reported unconfined compressive strength values of the very dense tills (with in-situ moisture contents of 5 percent) range between 3.4 and 3.6 MPa (Baracos, A.G. Shields, D.H., and Kjartenson, B. 1983). The elastic modulus of the glacial till soils has also been reported at a range of between 170 and 240 MPa (Baracos, A.G. Shields, D.H., and Kjartenson, B. 1983). These parameters are based upon the results of

material testing performed on representative samples of glacial till deposits from within the Winnipeg area.

3.2.4.2 Geotechnical Investigation Findings- Glacial Till

The glacial till was generally described as a sand containing some silt to silty, trace to some clay and gravel, and was light brown in colour, very loose to very dense, and moist to wet. The glacial till generally transitioned from a low plasticity soil to a non-plastic soil with depth.

Whilst not encountered during the advancement of the AECOM 2016 test holes, the glacial till is known to contain cobble and boulder size obstructions. A summary of boulder and cobble size obstructions noted within the glacial till layer as part of other geotechnical investigations adjacent to the NEIS alignment is outlined in Table 3-14.

Table 3-14: Obstructions Encountered within the Glacial Till

Test Hole	Approximate Elevation of Obstruction (m)	Comment
TREK Geotechnical (2013)- TH13-01	210.70	Boulder
Dyregrov and Burgess (1987)- Boring 13	209.00 - 210.60	Boulder Zone

A summary of the lab testing results for the glacial till layer is presented in Table 3-15.

Table 3-15: Summary of Laboratory Test Results- Glacial Till

Laboratory Test	Minimum Value	Average Value	Maximum Value	Comments
Moisture Content (%)	8.9	17.0	35.0	
Atterberg - Plastic Limit (%)	11.0	13.0	15.0	
Atterberg - Liquid Limit (%)	29.0	30.5	32.0	Low to Intermediate Plasticity
Uncorrected Standard Penetration Test - Blow Count	8	26	>50	Loose to Very Dense (Average- Compact)
Grain Size - Gravel (%)	0.0			One Sample
Grain Size - Sand (%)	86.7			
Grain Size - Silt (%)	7.4			
Grain Size - Clay (%)	5.9			

A plot of moisture content with elevation is shown as **Figure 3-4**, below.

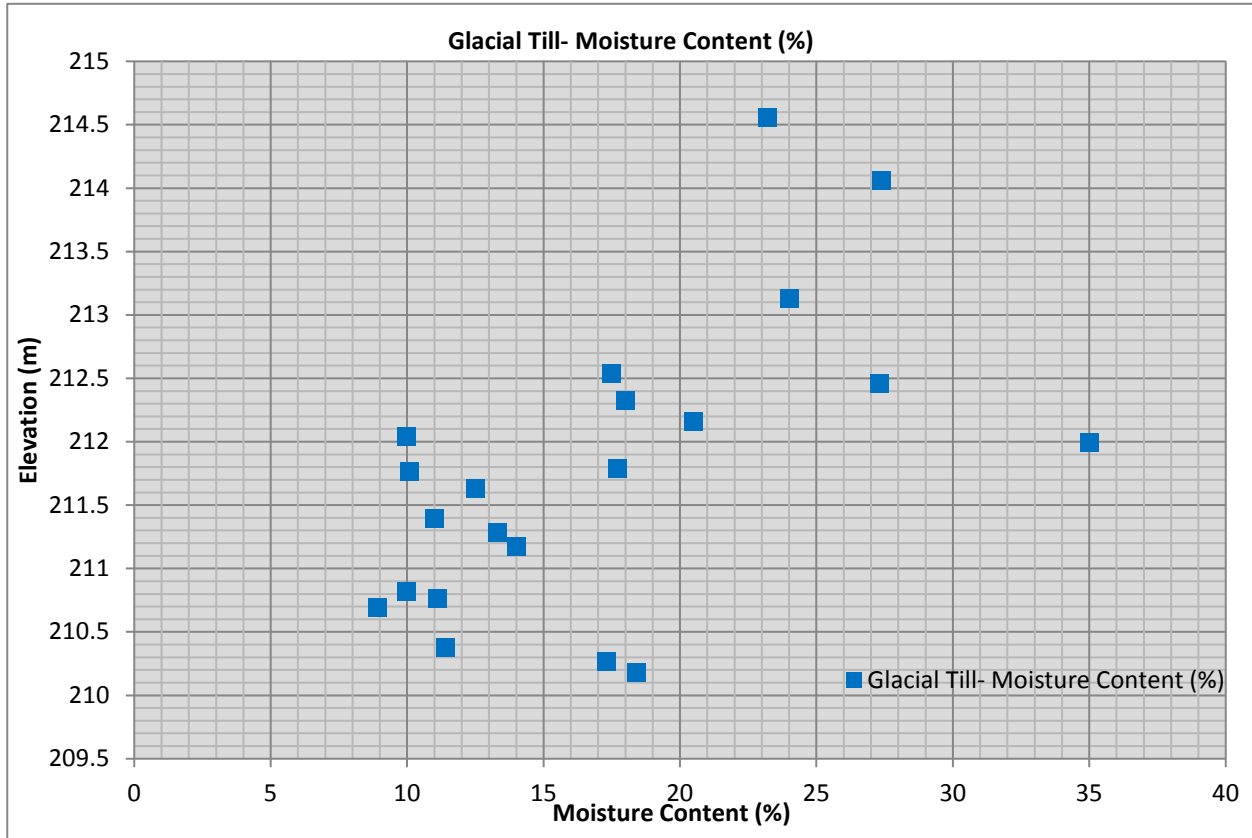


Figure 3-3: Moisture Content with Elevation for Glacial Till- AECOM (2016), TREK (2013) and Dyregrov and Burgess (1987)

3.2.5 Carbonate Bedrock

Carbonate bedrock was encountered below the glacial till in all AECOM 2016 test holes drilled along the NEIS alignment. Bedrock was also proven in a large number of test holes carried out as part of the previous geotechnical investigations. The carbonate bedrock was largely composed of limestone, dolomitic limestone and dolomitic mudstone/mudstone. The lithology of the bedrock geology varies slightly along the length of the NEIS alignment, with bedrock beneath the western bank largely dolomite and limestone, whereas dolomitic limestone and mudstone have been identified below the eastern bank. These findings are generally consistent with the pre-established bedrock mapping of the area and published literature. The bedrock lithology and elevations are summarized in Table 3-16. Where different bedrock units were encountered, the elevations of these units have also been provided.

Table 3-16: Summary of Carbonate Bedrock Unit Types and Contact Elevations

Test Hole	Location	Bedrock Surface Elevation (m)	Type of Bedrock Unit
AECOM (2016) TH16-01	Western Riverbank	209.9	Dolomitic Limestone
AECOM (2016) TH16-02	Western Riverbank	210.2	Limestone
TREK (2014) TH13-04	Western Riverbank	210.1	Dolomite
TREK (2014) TH13-05	Western Riverbank	210.0	Dolomite
		198.8	Dolomitic Mudstone
		195.8	Dolomitic Limestone
KGS (2012) TH12-03	Western Riverbank	209.8	Limestone
KGS (2012) TH12-03B	Western Riverbank	209.9	Inferred Limestone
Dyregrov & Burgess (1987) Boring 4	Western Riverbank	210.2	Inferred Limestone
Dyregrov & Burgess (1987) Boring 13	Western Riverbank	209.0	Inferred Limestone
AECOM (2016) TH16-03	River Channel	210.0	Limestone
Dyregrov & Burgess (1987) Boring 14	River Channel	210.3	Limestone
Dyregrov & Burgess (1987) Boring 15	River Channel	210.6	Limestone
Dyregrov & Burgess (1987) Boring 16	River Channel	210.6	Limestone
Dyregrov & Burgess (1987) Boring 16A	River Channel	209.7	Limestone
Dyregrov & Burgess (1987) Boring 16B	River Channel	209.8	Limestone
Dyregrov & Burgess (1987) Boring 16C	River Channel	210.0	Limestone
Dyregrov & Burgess (1987) Boring 16D	River Channel	210.2	Limestone
Dyregrov & Burgess (1987) Boring 17	River Channel	209.7	Limestone
Dyregrov & Burgess (1987) Boring 18	River Channel	211.0	Limestone
Dyregrov & Burgess (1987) Boring 19	River Channel	209.8	Limestone
Dyregrov & Burgess (1987) Boring 20	River Channel	209.8	Limestone
Dyregrov & Burgess (1987) Boring 21	River Channel	210.2	Limestone
Dyregrov & Burgess (1987) Boring 22	River Channel	210.7	Limestone
Dyregrov & Burgess (1987) Boring 23	River Channel	210.7	Limestone
AECOM (2016) TH16-04	Eastern Riverbank	210.2	Dolomitic Limestone
		204.2	Limestone

Test Hole	Location	Bedrock Surface Elevation (m)	Type of Bedrock Unit
TREK (2014) TH13-01	Eastern Riverbank	209.2	Dolomite
		204.2	Mudstone
		203.0	Dolomitic Mudstone
		198.1	Dolomitic Limestone
KGS (2012) TH12-01	Eastern Riverbank	209.6	Limestone
KGS (2012) TH12-02	Eastern Riverbank	210.0	Limestone
KGS (2012) TH12-02B	Eastern Riverbank	209.7	Inferred Limestone

Notes: Based on the findings of NEIS alignment and subject area geotechnical investigations

In terms of the NEIS alignment, the following test holes are most applicable:

- AECOM (2016)- TH16-01
- AECOM (2016)- TH16-02
- AECOM (2016)- TH16-03
- AECOM (2016)- TH16-04
- KGS (2012)- TH12-02
- KGS (2012)- TH12-02B
- KGS (2012)- TH12-03
- KGS (2012)- TH12-03B

3.2.5.1 Total Core Recovery (TCR)

Total Core Recovery (TCR) is the total length of the bedrock core recovered and is expressed as the percentage of actual length of core run (typically 1.5 m). A summary of the TCR values is provided in Table 3-17 (core-run depths in meters displayed in brackets). Where the TCR has not been recorded, the drill core data has been omitted from Table 3-17.

Table 3-17: Total Core Recovery- Carbonate Bedrock

Test Hole	Total Core Recovery (%) per Core Run (meters)										
	R1/C1	R2/C2	R3/C3	R4/C4	R5/C5	R6/C6	R7/C7	R8/C8	R9/C9	R10/C10	R11/C11
AECOM-TH16-01	100 (17.1 to 18.4)	98 (18.4 to 19.7)	95 (19.7 to 21.2)	100 (21.2 to 22.7)	99 (22.7 to 24.2)	98 (24.2 to 25.8)	-	-	-	-	-
AECOM-TH16-02	100 (16.2 to 16.8)	96 (16.8 to 18.3)	91 (18.3 to 20.0)	99 (20.0 to 21.4)	100 (21.4 to 22.9)	100 (22.9 to 24.4)	99 (24.4 to 26.0)	-	-	-	-

Test Hole	Total Core Recovery (%) per Core Run (meters)										
	R1/C1	R2/C2	R3/C3	R4/C4	R5/C5	R6/C6	R7/C7	R8/C8	R9/C9	R10/C10	R11/C11
AECOM-TH16-03	94 (13.8 to 15.3)	100 (15.3 to 16.7)	100 (16.7 to 18.1)	36 (18.1 to 19.8)	89 (19.8 to 21.4)	98 (21.4 to 22.9)	97 (22.9 to 24.5)	96 (24.5 to 25.9)	99 (25.9 to 27.5)	100 (27.5 to 29.0)	99 (29.0 to 30.5)
AECOM-TH16-04	100 (17.8 to 18.6)	97 (18.6 to 20.0)	97 (20.0 to 21.7)	85 (21.7 to 23.2)	100 (23.2 to 24.7)	100 (24.7 to 26.2)	100 (26.2 to 27.7)	-	-	-	-
KGS- TH12-01	85 (16.8 to 17.3)	98 (17.3 to 18.6)	100 (18.6 to 20.1)	100 (20.1 to 21.6)	100 (21.6 to 23.2)	100 (23.2 to 24.7)	100 (24.7 to 25.9)	-	-	-	-
KGS- TH12-02	98 (18.3 to 19.9)	98 (19.9 to 21.5)	98 (21.5 to 23.0)	100 (23.0 to 24.5)	100 (24.5 to 26.1)	-	-	-	-	-	-
KGS- TH12-03	88 (21.0 to 21.5)	100 (21.5 to 23.0)	97 (23.0 to 24.5)	100 (24.5 to 26.0)	97 (26.0 to 27.6)	100 (27.6 to 29.1)	100 (29.1 to 30.2)	-	-	-	-
Dyregrov & Burgess-Boring 14	100 (13.8 to 14.6)	91 (14.6 to 16.1)	94 (16.1 to 17.6)	100 (17.6 to 19.1)	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 15	99 (13.1 to 14.9)	99 (14.9 to 15.8)	99 (15.8 to 17.1)	100 (17.1 to 18.7)	84 (18.7 to 20.2)	100 (20.2 to 21.7)	-	-	-	-	-
Dyregrov & Burgess-Boring 16	75 (13.0 to 14.6)	95 (14.6 to 16.2)	98 (16.2 to 17.1)	93 (17.1 to 18.9)	0- (18.9 to 20.1)	-	-	-	-	-	-
Dyregrov & Burgess-Boring 16A	100 (13.9 to 14.5)	0 (14.5 to 19.7)	0 (19.7 to 22.1)	30 (22.1 to 23.6)	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 16B	100 (13.9 to 14.8)	98 (14.8 to 16.3)	96 (16.3 to 17.9)	96 (17.9 to 19.5)	94 (19.5 to 20.0)	-	-	-	-	-	-

Test Hole	Total Core Recovery (%) per Core Run (meters)										
	R1/C1	R2/C2	R3/C3	R4/C4	R5/C5	R6/C6	R7/C7	R8/C8	R9/C9	R10/C10	R11/C11
Dyregrov & Burgess-Boring 16C	100 (13.7 to 14.6)	92 (14.6 to 16.2)	98 (16.2 to 17.7)	100 (17.7 to 18.6)	0 (18.6 to 19.8)	0 (19.8 to 20.7)	93 (20.7 to 22.3)	-	-	-	-
Dyregrov & Burgess-Boring 16D	69 (13.4 to 14.9)	0 (14.9 to 15.8)	88 (15.8 to 16.4)	100 (16.4 to 17.9)	0 (17.9 to 19.4)	30 (19.4 to 21.0)	80 (21.0 to 22.5)	-	-	-	-
Dyregrov & Burgess-Boring 17	0 (14.0 to 15.5)	99 (15.5 to 16.5)	97 (16.5 to 18.1)	97 (18.1 to 19.6)	100 (19.6 to 19.9)	0 (19.9 to 20.2)	100 (20.2 to 21.1)	93 (21.1 to 22.6)	-	-	-
Dyregrov & Burgess-Boring 18	0 (13.1 to 13.9)	87 (13.9 to 14.6)	95 (14.6 to 16.2)	95 (16.2 to 17.7)	95 (17.7 to 19.2)	95 (19.2 to 20.7)	93 (20.7 to 22.3)	-	-	-	-
Dyregrov & Burgess-Boring 19	30 (13.8 to 14.6)	100 (14.6 to 16.2)	96 (16.2 to 17.7)	96 (17.7 to 19.2)	97 (19.2 to 20.7)	-	-	-	-	-	-
Dyregrov & Burgess-Boring 20	64 (13.5 to 14.9)	97 (14.9 to 16.5)	95 (16.5 to 18.0)	92 (18.0 to 19.5)	97 (19.5 to 21.0)	92 (21.0 to 22.6)	-	-	-	-	-
Dyregrov & Burgess-Boring 21	0 13.4 to 14.8)	99 (14.8 to 16.3)	97 (16.3 to 17.8)	95 (17.8 to 19.4)	98 (19.4 to 20.9)	100 (20.9 to 22.4)	-	-	-	-	-
Dyregrov & Burgess-Boring 22	0 (13.0 to 13.8)	99 (13.8 to 14.4)	99 (14.4 to 16.0)	96 (16.0 to 17.6)	93 (17.6 to 19.0)	-	-	-	-	-	-
Dyregrov & Burgess-Boring 23	87 (13.0 to 14.8)	97 (14.8 to 16.3)	100 (16.3 to 17.8)	95 (17.8 to 19.4)	97 (19.4 to 20.9)	-	-	-	-	-	-

Notes: R1/C1- Core Run Designation; (13.8 to 14.6)- Depth of Core Run in meters; D&B- Dyregrov & Burgess (1987) Investigation.

3.2.5.2 Rock Quality Designation (RQD)

The Rock Quality Designation (RQD) values were obtained by measuring the total length of the recovered bedrock core pieces longer than 100 mm expressed as a percentage of the length of the core run.

The RQD values are a general indicator of the rock mass quality. The relationship between the rock mass quality and RQD values as suggested by Deere (1969) is presented in Table 3-18

Table 3-17: Designation of Rock Quality

RQD (%)	Designation of Rock Quality
0-25	Very Poor
25-50	Poor
50-75	Fair
75-90	Good
90-100	Excellent

A summary of the RQD values is provided in Table 3-19.

Table 3-18: Rock Quality Designation- Carbonate Bedrock

Test Hole	Rock Quality Designation (%) per Core Run (meters)													
	R1/C1	R2/C2	R3/C3	R4/C4	R5/C5	R6/C6	R7/C7	R8/C8	R9/C9	R10 /C10	R11 /C11	R12 /C12	R13 /C13	R14 /C14
AECOM-TH16-01	82 (17.1 to 18.4)	96 (18.4 to 19.7)	87 (19.7 to 21.2)	100 (21.2 to 22.7)	79 (22.7 to 24.2)	98 (24.2 to 25.8)	-	-	-	-	-	-	-	-
AECOM-TH16-02	71 (16.2 to 16.8)	87 (16.8 to 18.3)	91 (18.3 to 20.0)	96 (20.0 to 21.4)	93 (21.4 to 22.9)	96 (22.9 to 24.4)	99 (24.4 to 26.0)	-	-	-	-	-	-	-
AECOM-TH16-03	83 (13.8 to 15.3)	89 (15.3 to 16.6)	94 (16.6 to 18.1)	27 (18.1 to 19.8)	62 (19.8 to 21.4)	39 (21.4 to 22.9)	33 (22.9 to 24.5)	80 (24.5 to 25.9)	68 (25.9 to 27.5)	73 (27.5 to 29.0)	87 (29.0 to 30.5)	-	-	-
AECOM-TH16-04	92 (17.8 to 18.6)	96 (18.6 to 20.0)	86 (20.0 to 21.7)	75 (21.7 to 23.2)	81 (23.2 to 24.7)	98 (24.7 to 26.2)	95 (26.2 to 27.7)	-	-	-	-	-	-	-
TREK-TH13-01	0 (16.8 to 18.6)	75 (18.6 to 20.1)	30 (20.1 to 21.6)	0 (21.6 to 23.1)	17 (23.1 to 24.6)	91 (24.6 to 26.1)	96 (26.1 to 27.7)	62 (27.7 to 29.3)	73 (29.3 to 30.8)	35 (30.8 to 32.3)	31 (32.3 to 33.8)	74 (33.8 to 35.3)	94 (35.3 to 36.9)	-
TREK-TH13-04	86 (17.1 to 18.6)	100 (18.6 to 20.1)	100 (20.1 to 21.6)	-	-	-	-	-	-	-	-	-	-	-

Test Hole	Rock Quality Designation (%) per Core Run (meters)													
	R1/C1	R2/C2	R3/C3	R4/C4	R5/C5	R6/C6	R7/C7	R8/C8	R9/C9	R10 /C10	R11 /C11	R12 /C12	R13 /C13	R14 /C14
TREK-TH13-05	0 (16.3 to 16.8)	38 (16.8 to 18.3)	73 (18.3 to 19.8)	95 (19.8 to 21.3)	83 (21.3 to 22.9)	98 (22.9 to 24.3)	92 (24.3 to 25.8)	75 (25.8 to 27.3)	69 (27.3 to 28.7)	92 (28.7 to 30.2)	100 (30.2 to 31.2)	100 (31.2 to 32.3)	99 (32.3 to 33.5)	85 (33.5 to 35.1)
Dyregrov & Burgess-Boring 14	- (13.8 to 14.6)	80 (14.6 to 16.1)	75 (16.1 to 17.6)	95 (17.6 to 19.1)	-	-	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 15	60 (13.1 to 14.9)	60 (14.9 to 15.8)	79 (15.8 to 17.1)	70 (17.1 to 18.7)	17 (18.7 to 20.2)	45 (20.2 to 21.7)	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 16	- (13.0 to 14.6)	68 (14.6 to 16.2)	- (16.2 to 17.1)	- (17.1 to 18.9)	- (18.9 to 20.1)	-	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 16A	67 (13.9 to 14.5)	0 (14.5 to 19.7)	0 (19.7 to 22.1)	0 (22.1 to 23.6)	-	-	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 16B	56 (13.9 to 14.8)	83 (14.8 to 16.3)	90 (16.3 to 17.9)	73 (17.9 to 19.5)	- (19.5 to 20.0)	-	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 16C	85 (13.7 to 14.6)	91 (14.6 to 16.2)	96 (16.2 to 17.7)	100 (17.7 to 18.6)	0 (18.6 to 19.8)	0 (19.8 to 20.7)	0 (20.7 to 22.3)	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 16D	67 (13.4 to 14.9)	0 (14.9 to 15.8)	0 (15.8 to 16.4)	93 (16.4 to 17.9)	0 (17.9 to 19.4)	10 (19.4 to 21.0)	63 (21.0 to 22.5)	-	-	-	-	-	-	-

Test Hole	Rock Quality Designation (%) per Core Run (meters)													
	R1/C1	R2/C2	R3/C3	R4/C4	R5/C5	R6/C6	R7/C7	R8/C8	R9/C9	R10 /C10	R11 /C11	R12 /C12	R13 /C13	R14 /C14
Dyregrov & Burgess-Boring 17	0 (14.0 to 15.5)	99 (15.5 to 16.5)	75 (16.5 to 18.1)	79 (18.1 to 19.6)	0 (19.6 to 19.9)	0 (19.9 to 20.2)	70 (20.2 to 21.1)	30 (21.1 to 22.6)	-	-	-		-	-
Dyregrov & Burgess-Boring 18	0 (13.1 to 13.9)	82 (13.9 to 14.6)	87 (14.6 to 16.2)	65 (16.2 to 17.7)	87 (17.7 to 19.2)	0 (19.2 to 20.7)	0 (20.7 to 22.3)	-	-	-	-			
Dyregrov & Burgess-Boring 19	0 (13.8 to 14.6)	0 (14.6 to 16.2)	94 (16.2 to 17.7)	74 (17.7 to 19.2)	0 (19.2 to 20.7)	-	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 20	53 (13.5 to 14.9)	81 (14.9 to 16.5)	93 (16.5 to 18.0)	69 (18.0 to 19.5)	73 (19.5 to 21.0)	79 (21.0 to 22.6)	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 21	0 (13.4 to 14.8)	44 (14.8 to 16.3)	81 (16.3 to 17.8)	45 (17.8 to 19.4)	67 (19.4 to 20.9)	36 (20.9 to 22.4)	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 22	0 (13.0 to 13.8)	45 (13.8 to 14.4)	83 (14.4 to 16.0)	73 (16.0 to 17.6)	66 (17.6 to 19.0)	-	-	-	-	-	-	-	-	-
Dyregrov & Burgess-Boring 23	83 (13.0 to 14.8)	70 (14.8 to 16.3)	88 (16.3 to 17.8)	47 (17.8 to 19.4)	61 (19.4 to 20.9)	-	-	-	-	-	-	-	-	-

A summary of the RQD values is provided below:

- Minimum: 0%; Maximum: 100%; Average: 62.4%.
- Median: 73.5%; Quartile 1 (i.e., 25% of RQD data lies below): 38.5%, Quartile 3 (i.e., 75% of RQD data lies below): 89.5%

Based on the RQD values, the bedrock quality along the NEIS ranges from very poor to excellent.

3.2.5.3 Uniaxial Compressive Strength (UCS)

Uniaxial Compressive Strength (UCS) was estimated from laboratory tests performed on non-weathered and intact bedrock cores. A summary of the UCS results are presented in Table 3-20.

Table 3-19: Summary of Unconfined Compression Test Results

Test Hole No.	Bedrock Type	Location	Sample Elevation (m)	Core Run	Sample No.	UC Strength (MPa)	Strength Rating
AECOM-TH16-01	Limestone	West River Bank	203.83	C5	C5	93.5	R4 – Strong Rock
AECOM-TH16-02	Limestone	West River Bank	205.03	C4	C4	149.6	R5 – Very Strong Rock
AECOM-TH16-03	Limestone	East Riverbank	203.60	C5	C5	58.9	R4 – Strong Rock
AECOM-TH16-03	Limestone	East Riverbank	199.90	C7	C7	39.7	R3 – Medium Strong Rock
AECOM-TH16-04	Dolomitic Limestone	East Riverbank	204.75	C5	C5	77.8	R4 – Strong Rock
AECOM-TH16-04	Limestone	East Riverbank	202.15	C6	C6	96.6	R4 – Strong Rock
TREK-TH13-01	Dolomite	East Riverbank	207.46	C2	CB57	49.1	R3 – Medium Strong Rock
TREK-TH13-01	Dolomitic Limestone	East Riverbank	196.96	C9	CB64	31.2	R3 – Medium Strong Rock
TREK-TH13-01	Dolomitic Limestone	East Riverbank	196.46	C10	CB65	21.8	R2- Weak
TREK-TH13-01	Dolomitic Limestone	East Riverbank	192.62	C12	CB67	33.1	R3 – Medium Strong Rock
TREK-TH13-05	Dolomite	West Riverbank	207.06	C3	CB72	39.5	R3 – Medium Strong Rock
TREK-TH13-05	Dolomite	West Riverbank	204.46	C5	CB74	39.5	R3 – Medium Strong Rock
TREK-TH13-05	Dolomitic Mudstone	West Riverbank	196.50	C10	CB79	11.9	R2- Weak

The measured UCS values are generally consistent with the strength testing data from the Manitoba Department of Energy and Mines for the Selkirk Member and Lower Fort Garry Member (Bannatyne, 1988).

3.3 Groundwater Conditions

Groundwater depths were measured within the monitoring wells installed as part of the AECOM 2016 geotechnical investigation and are summarized in the following section. Groundwater monitoring records from previous geotechnical investigations are also included in Section 3.3.1.

3.3.1 AECOM 2016 Geotechnical Investigation

To assess groundwater levels at the site, a vibrating wire piezometer (VWP) was installed in TH16-01 within the Glacio-lacustrine clay layer at a depth of 15.4 m and two standpipe piezometers (SPP) were installed in test holes TH16-02 and TH16-04 within the underlying carbonate aquifer (i.e., carbonate bedrock and glacial till) at depths of 25.8 m and 18.3 m, respectively.

Short monitoring results of the groundwater level (GWL) from the instruments at the site are provided in Table 3-21 along with previously reported readings completed by KGS and TREK. Monitoring results for the vibrating wire piezometers over the reported period indicated the presence of negative piezometric head (i.e., piezometric elevation is below tip elevation). The negative piezometric head is considered not credible and likely related to instruments malfunction or the pore water pressure at the piezometer tip has become stabilized. The monitoring will be continued to record additional readings.

Hydraulic pressure head due to varying groundwater elevation at the inlet and outlet of the proposed alignment will vary, pending the final invert elevation. The pressure head can vary from approximately 25.5 m (elevation 205.5 m, approximately) at the inlet (east bank of Red River) to 23.5 m (elevation 202.5 m, approximately) at the outlet (west bank of Red River). It should be noted that groundwater levels and subsequently sloughing may change seasonally, annually or as a result of construction activities.

Table 3-20: Summary of GWL Monitoring Results

Soil Unit	Test Hole ID	Instrument Type	Installed by	Ground Elevation (m)	Tip Elevation (m)	Monitoring Date	GWL Elevation (m)
Alluvial	TH13-01	Standpipe	TREK	227.36	215.17	Nov-07-2013	222.99
						Nov-28-2013	222.41
						Mar-20-2014	222.16
	TH12-02B	Standpipe	KGS	228.46	216.86	May-15-2013	223.26
Lacustrine	TH12-03B	Pneumatic	KGS	230.86	219.00	May-15-2013	226.04
	TH16-01	Vibrating wire	AECOM	227.03	211.64	-	-
Till	TH12-02B	Standpipe	KGS	228.46	210.76	May-15-2013	225.20
	TH12-03B	Standpipe	KGS	230.86	209.86	May-15-2013	225.20
	TH16-04	Standpipe	AECOM	228.05	209.76	Aug-23-2016	223.76
						Sep-23-2016	223.48
						Nov-18-2016	223.60
						March-09-2017	224.66

Soil Unit	Test Hole ID	Instrument Type	Installed by	Ground Elevation (m)	Tip Elevation (m)	Monitoring Date	GWL Elevation (m)
Bedrock	TH12-02	Standpipe	KGS	228.37	202.31	May-15-2013	225.05
	TH12-03	Standpipe	KGS	230.84	200.82	May-15-2013	225.11
	TH13-01	Standpipe	TREK	227.36	207.24	Nov-07-2013	223.18
						Nov-28-2013	223.18
						Mar-20-2014	223.43
	TH13-04	Standpipe	TREK	227.16	205.55	Nov-14-2013	223.16
						Nov-28-2013	223.24
						Mar-20-2014	223.50
	TH13-05	Standpipe	TREK	226.26	191.21	Nov-14-2013	223.30
						Nov-28-2013	223.30
						Mar-20-2014	223.56
	TH16-02	Standpipe	AECOM	226.33	200.52	Aug-24-2016	223.85
						Sep-23-2016	223.49
Nov-18-2016						223.77	
Mar-09-2017						224.70	

The groundwater monitoring results from the Dyregrov and Burgess (1987) geotechnical investigation have also been summarized in Table 3-22.

Table 3-21: Summary of GWL Monitoring Results- Dyregrov and Burgess (1987)

Soil Unit	Test Hole ID	Instrument Type	Ground Elevation (m)	Tip Elevation (m)	Monitoring Date		
					Sept. 28 1987	Oct. 6 1987	Nov. 24 1987
Alluvial Sand	Boring 6	Standpipe	227.50	221.37	NR	223.13	222.80
Alluvial Clay	Boring 12	Pneumatic	226.74	218.94	226.41	NR	226.56
	Boring 6	Standpipe	227.47	215.27	NR	223.14	222.80
Lacustrine	Boring 13	Pneumatic	227.60	218.55	226.02	NR	224.95
	Boring 13	Pneumatic	227.60	212.69	225.80	NR	226.41

Notes: NR- Not Recorded

3.3.2 Flood Elevations

River flood levels at the site for different flood events have been provided in Table 3-23.

Table 3-22: Summary of River Flood Event Elevations

Return Period	River Flood Elevation (m)
1:2 Year	224.55
1:5 Year	226.35
1:10 Year	226.64
1:50 Year	227.27
1:100 Year	227.49

4. References

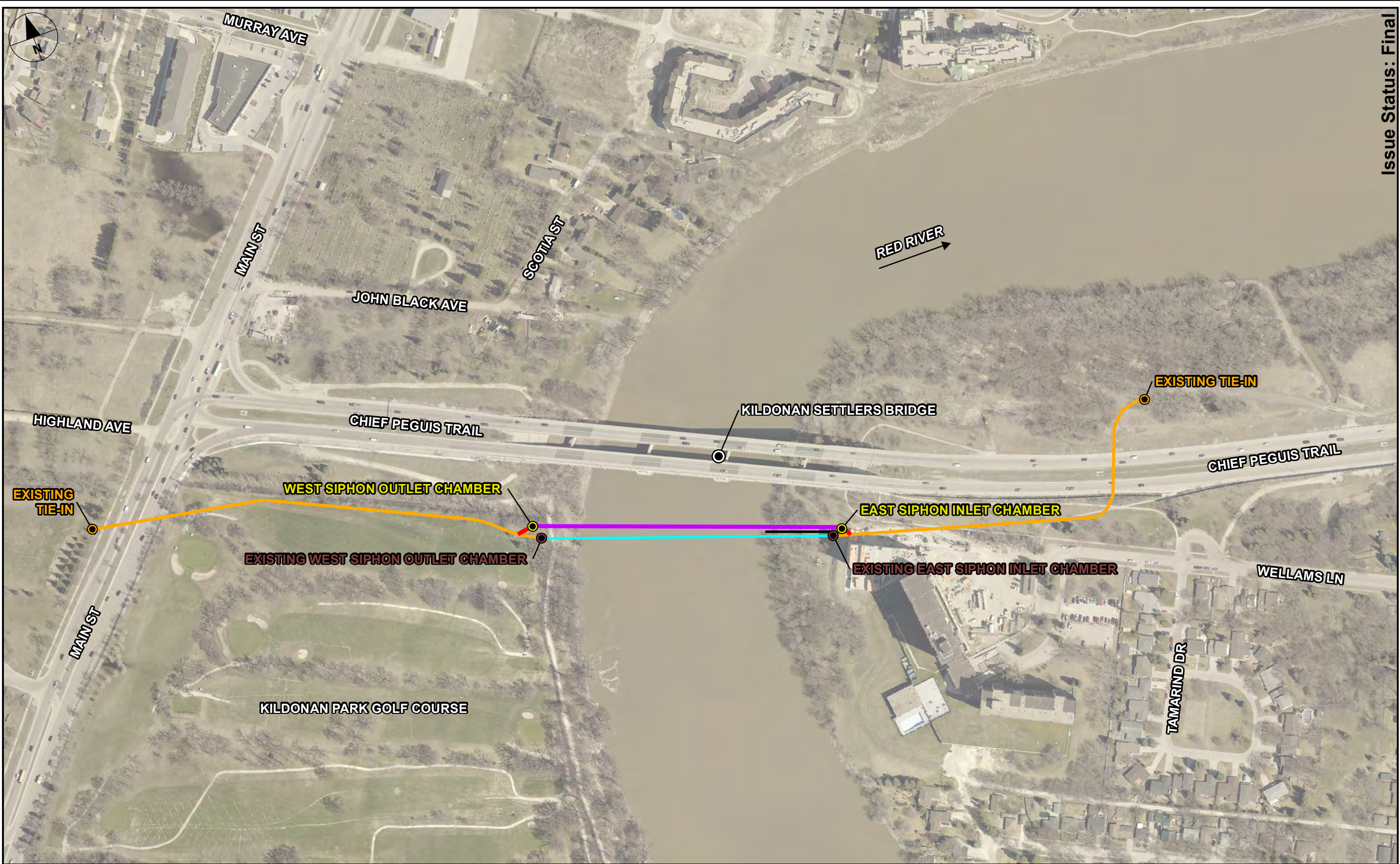
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- 2- ASCE/CI 36-15 (2015). Standard Design and Construction Guidelines for Microtunneling. Published by American Society of Civil Engineers.
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- 7- ASTM D5607-08. Standard Test Method for Performing Laboratory Direct Shear Strength Tests of Rock Specimens Under Constant Normal Force.
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Appendix **A**

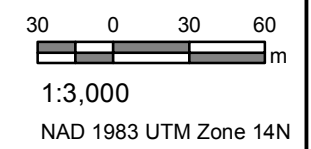
Figures

- Figure 1: Site Location Plan and NEIS Alignment
- Figure 2: Surficial Geology Plan
- Figure 3: Test Hole Location Plan
- Figure 4: Stratigraphic Section



LEGEND

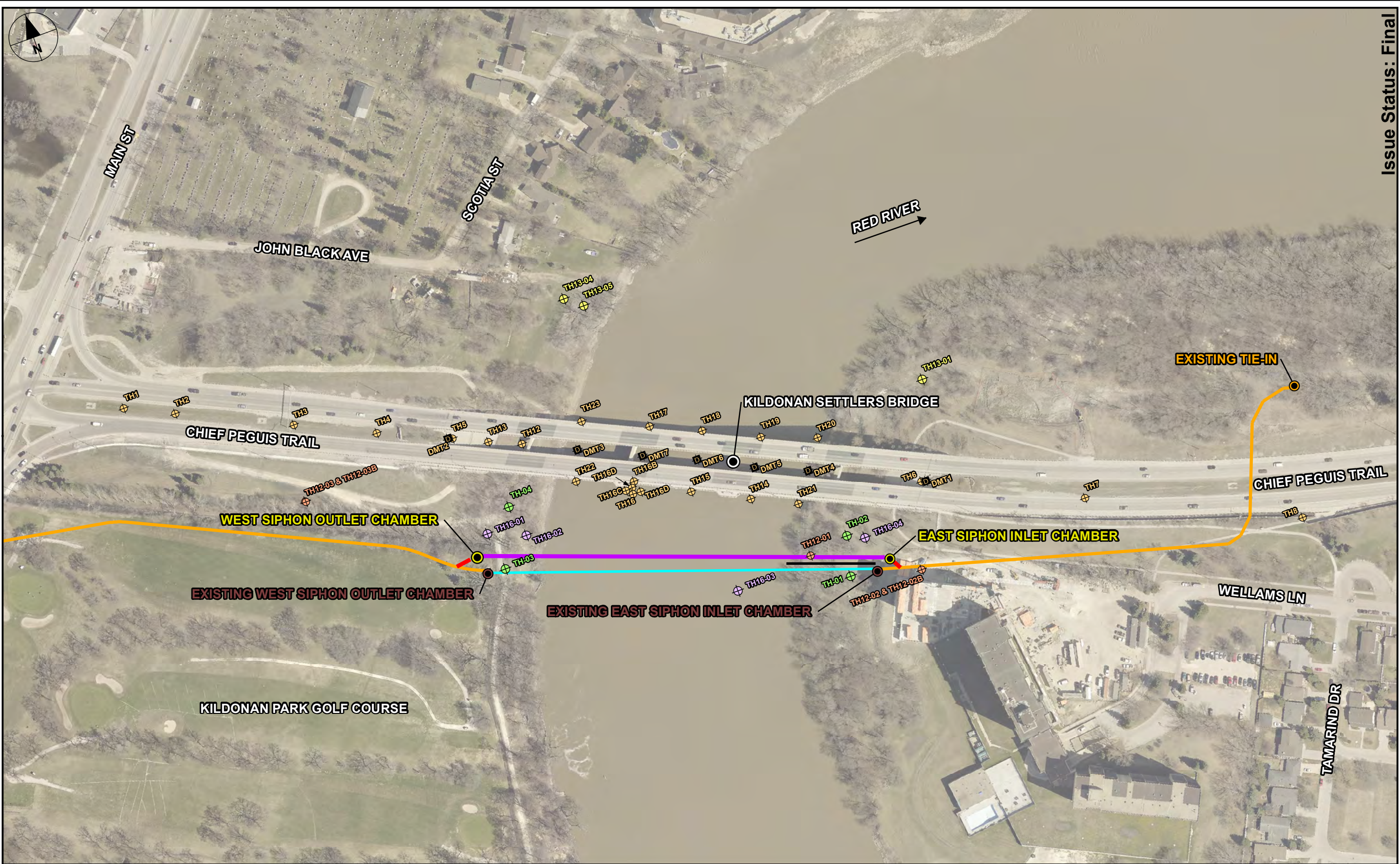
	NEIS ALIGNMENT (MICROTUNNELING)		EXISTING 1200 CSP CS OUTFALL
	CONNECTION TO EXISTING 1800 MONO CONC INTERCEPTOR		EXISTING 500 & 800 STEEL SIPHON
	EXISTING 1800 MONO CONC INTERCEPTOR		



Issue Status: Final

SITE LOCATION PLAN AND NEIS ALIGNMENT

NORTHEAST INTERCEPTOR
 GEOTECHNICAL DATA REPORT
 CITY OF WINNIPEG, WATER AND WASTE DEPARTMENT



Issue Status: Final

LEGEND

NEIS ALIGNMENT (MICROTUNNELING)	EXISTING 1200 CSP CS OUTFALL	TEST HOLE (DYREGROV, 1988)	TEST HOLE (TREK, 2013)
CONNECTION TO EXISTING 1800 MONO CONC INTERCEPTOR	EXISTING 500 & 800 STEEL SIPHON	DILATOMETER TESTING (DYREGROV, 1998)	TEST HOLE (AECOM, 2016)
EXISTING 1800 MONO CONC INTERCEPTOR		TEST HOLE (KGS, 2012)	TEST HOLE (FRIESEN DRILLERS LTD., 2017)

NOTE: LOCATION OF DYREGROV TEST HOLES AND DILATOMETER ARE APPROX.

Scale: 1:2,250
NAD 1983 UTM Zone 14N

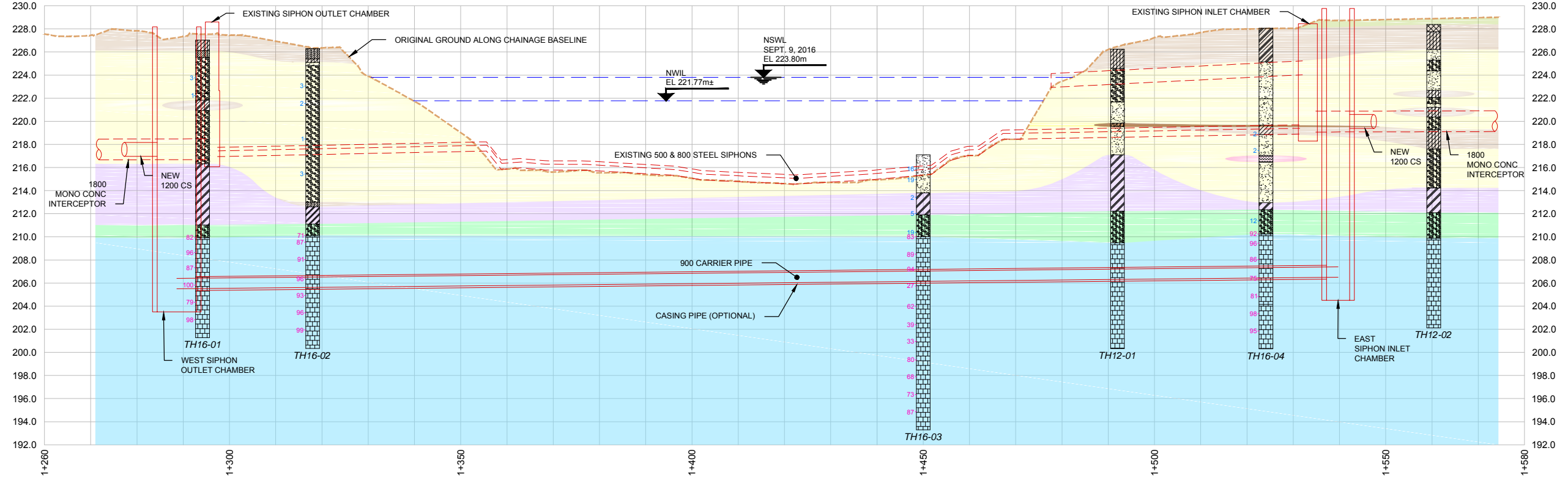
LEGEND

- COHESIVE FILL
- SAND
- SAND & GRAVEL
- SILTY SAND
- LIMESTONE BEDROCK
- ORGANIC SOIL
- SILTY CLAY/ CLAYEY SILT
- INORGANIC SILT
- INORGANIC HIGH PLASTIC CLAY
- CLAYEY SAND
- INORGANIC MEDIUM PLASTIC CLAY
- COHESIVE FILL (CLAY FILL)
- GRANULAR ALLUVIAL SOILS (SILTY SANDS/ SANDS/ GRAVELS)
- COHESIVE ALLUVIAL SOILS (SILT/ CLAY)
- GLACIO-LASCUSTRINE CLAY
- CARBONATE BEDROCK (LIMESTONE/ DOLOMITE)
- GRANULAR GLACIAL TILL
- ORGANICS
- 66 SPT (N) VALUES
- 100 RQD VALUES

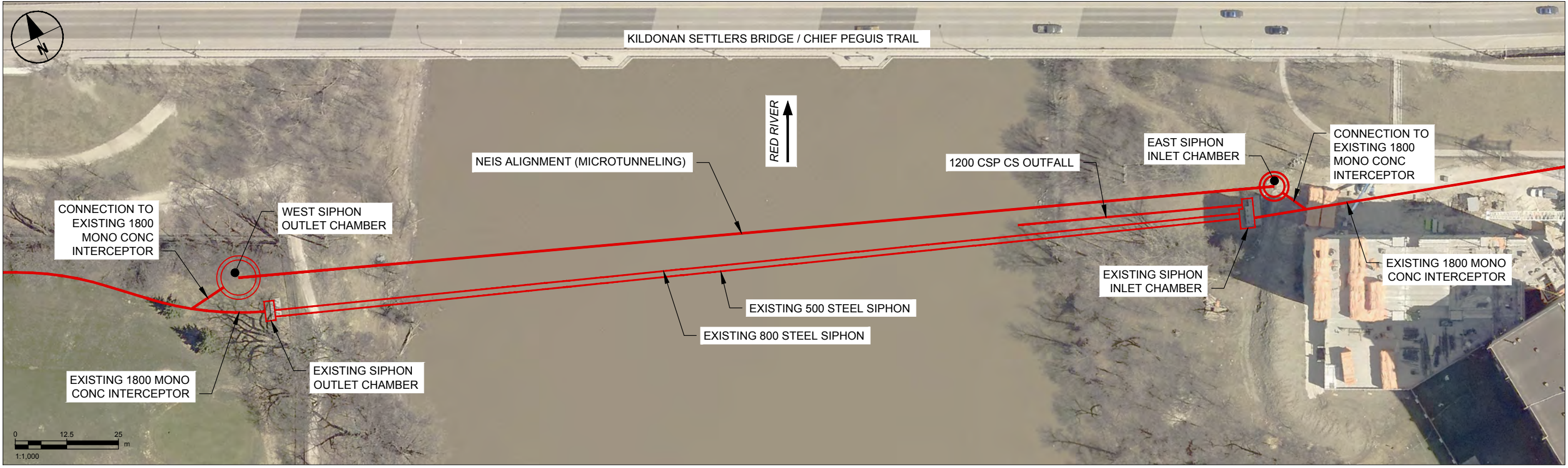
NOTE 1: THIS FIGURE SHOULD BE USED FOR BASELINE PURPOSES ONLY AND SHOULD BE READ IN CONJUNCTION WITH THE GEOTECHNICAL BASELINE (GBR) AND DATA REPORT (GDR). THIS FIGURE PROVIDES BASELINE STRATIGRAPHIC CROSS SECTION ALONG THE TUNNEL SECTIONS ONLY. FOR BASELINE STRATIGRAPHIC CONDITIONS AT THE SHAFT LOCATIONS, REFER TO GBR.

NOTE 2: SUBSURFACE CONDITIONS ARE KNOWN ONLY AT THE TEST HOLE LOCATIONS. GROUND CONDITIONS BETWEEN TEST HOLES ARE INFERRED AND SIMPLIFIED. THE ACTUAL GROUND CONDITIONS BETWEEN THE TEST HOLES MAY VARY FROM THE INFERRED CONDITIONS.

NOTE 3: DETAILED DESCRIPTIONS OF MATERIALS, CHARACTERISTICS AND VARIABILITY ANTICIPATED WITHIN EACH SOIL UNIT AND BEDROCK FORMATION ARE PRESENTED IN THE GDR AND GBR. FOR DETAILS OF THE TEST HOLE LOGS AND GROUNDWATER MEASUREMENTS REFER TO GDR.



Issue Status: Final



STRATIGRAPHIC SECTION OF NEIS ALIGNMENT

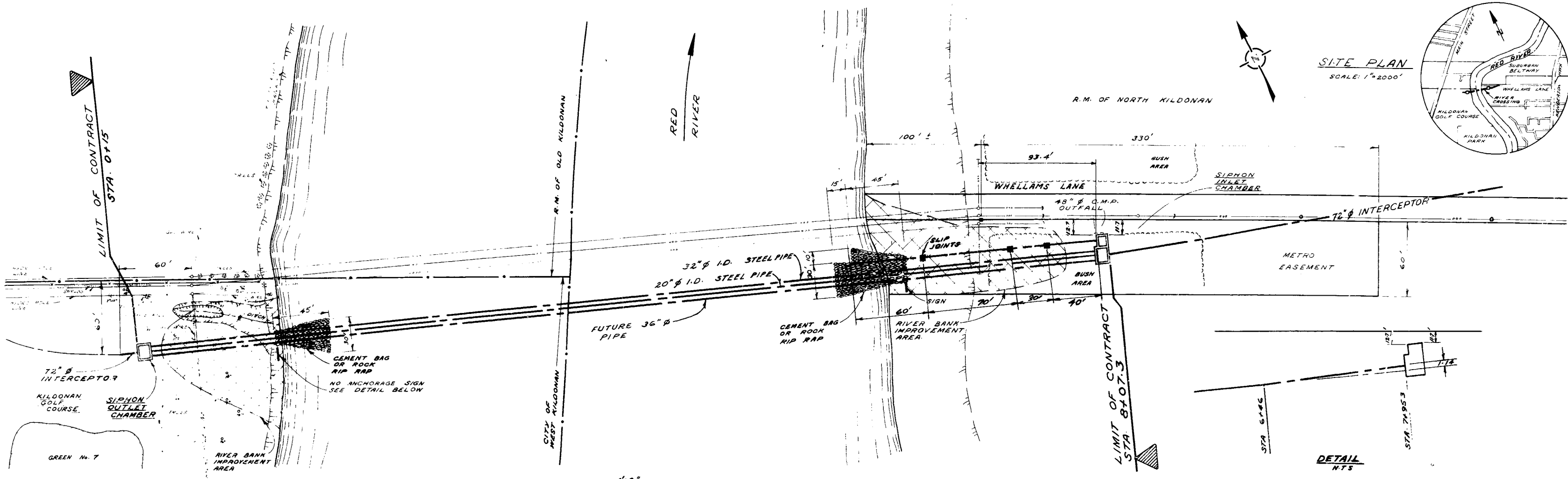
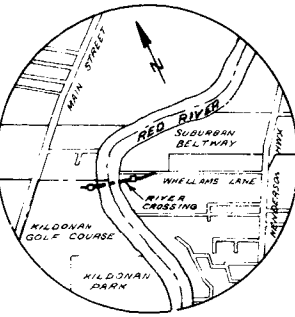
NORTHEAST INTERCEPTOR
GEOTECHNICAL DATA REPORT
CITY OF WINNIPEG, WATER AND WASTE DEPARTMENT

Appendix **B**

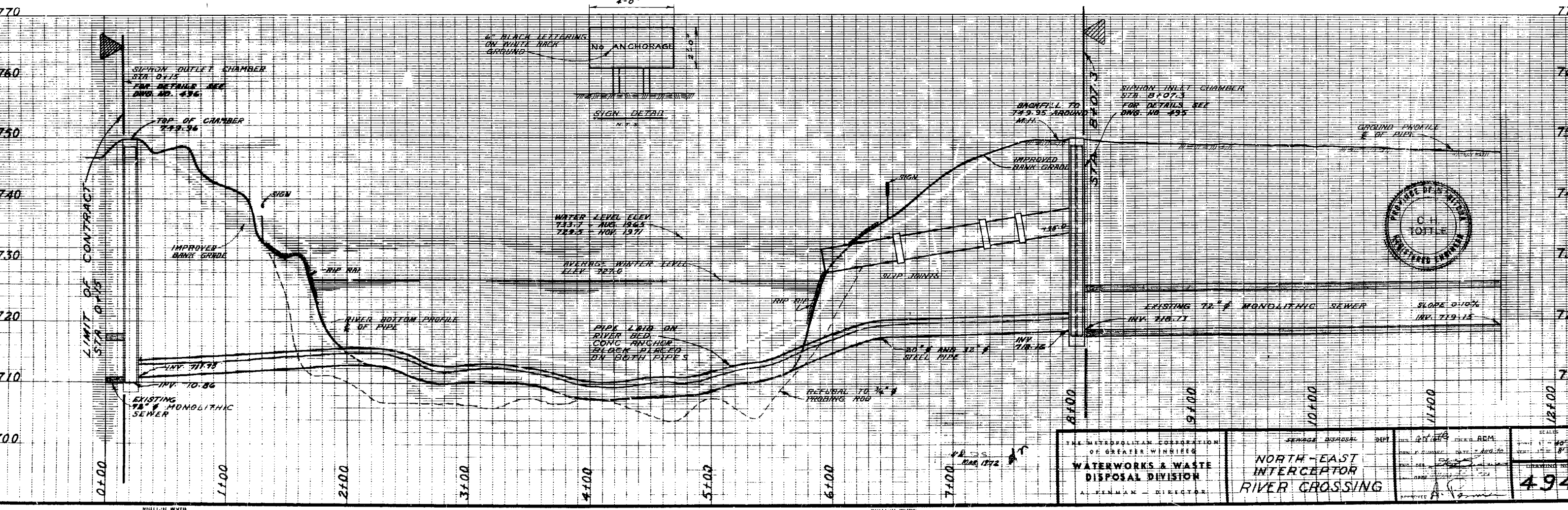
Record Drawings

- Drawing 494: Northeast Interceptor River Crossing As-Built Record Drawing

SITE PLAN
SCALE: 1"=2000'



DETAIL
N.T.S.



THE METROPOLITAN CORPORATION OF GREATER WINNIPEG WATERWORKS & WASTE DISPOSAL DIVISION A. SENMAN - DIRECTOR		SEWERAGE DISPOSAL DEPT. PROJECT NO. 494 DATE: AUG. 76 DRAWING NO.	SCALE: 1"=40' SHEET 11 OF 11 DRAWING NO.
NORTH-EAST INTERCEPTOR RIVER CROSSING		494	

Appendix **C**

Previous Geotechnical Investigations Test Hole Logs

- C-1: TREK Geotechnical (2013) Test Hole Logs
- C-1A: TREK Geotechnical (2014) Ground Profile
- C-2: KGS (2012) Test Hole Logs
- C-3: Dyregrov & Burgess (1987) Test Hole Logs



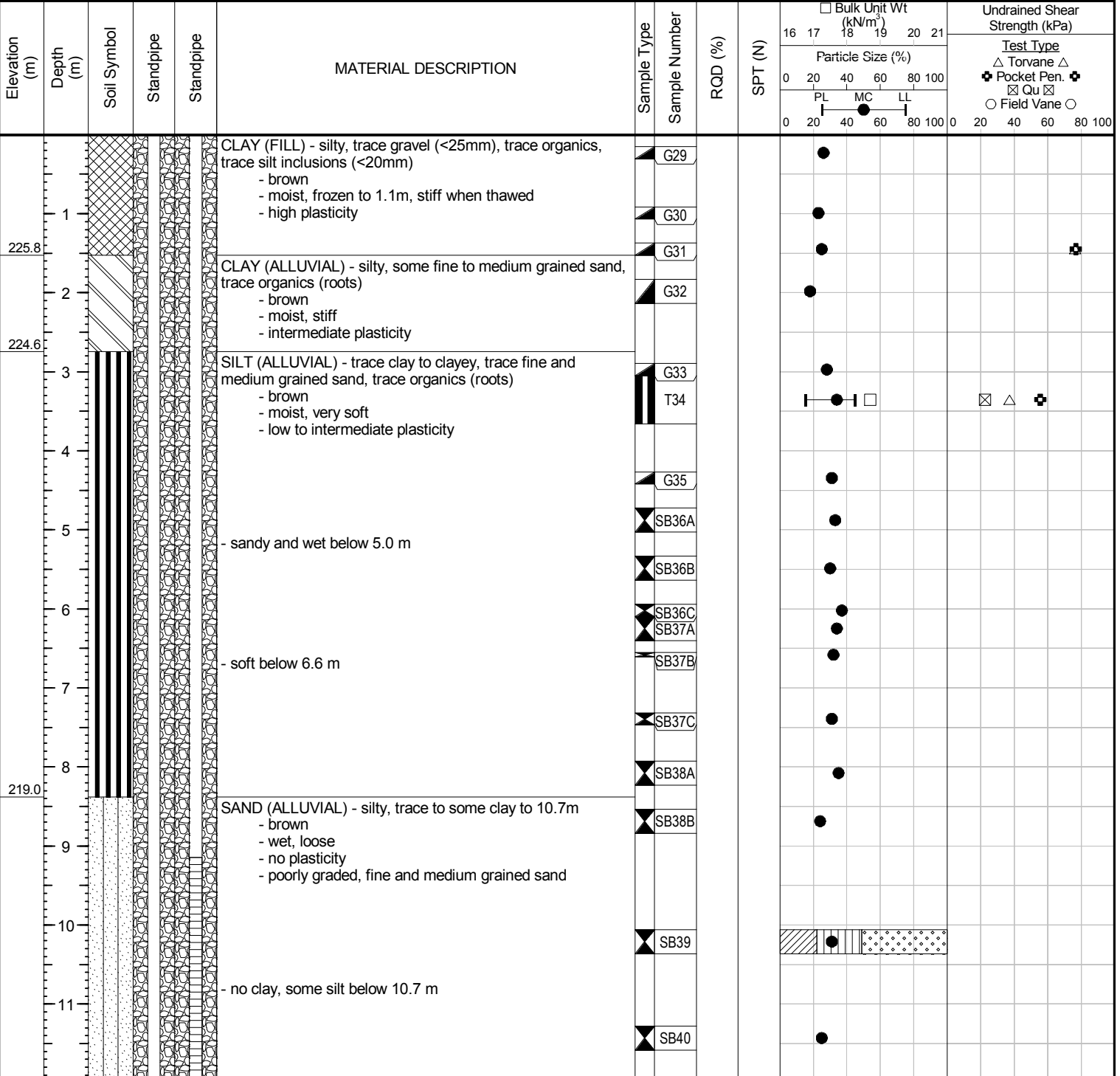
Sub-Surface Log

Test Hole TH13-01

1 of 3

Client: Associated Engineering **Project Number:** 0115 004 00
Project Name: Detailed Design North Kildonan Feedermain **Location:** UTM N-5534866.43, E-636644.43
Contractor: Paddock Drilling Ltd. **Ground Elevation:** 227.36 m
Method: Acker SS3 Track Mount (see notes for drilling method) **Date Drilled:** 7 November 2013

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
Backfill Legend: Bentonite Cement Drill Cuttings Filter Pack Sand Grout Slough



SUB-SURFACE LOG 01:15:004 00 DETAILED DESIGN NORTH KILDONAN FEEDERMAIN - LOGS.GPJ TREK GEOTECHNICAL.GDT 15/11/14

Logged By: Stephen Renner **Reviewed By:** Nelson Ferreira **Project Engineer:** Nelson Ferreira



Sub-Surface Log

Test Hole TH13-01

2 of 3

Elevation (m)	Depth (m)	Soil Symbol	Standpipe	Standpipe	MATERIAL DESCRIPTION	Sample Type	Sample Number	ROD (%)	SPT (N)	Bulk Unit Wt (kN/m ³)		Undrained Shear Strength (kPa)	
										18	19	0	20
215.2					CLAY (ALLUVIAL) - silty, some fine to medium grained sand, trace organics (roots) - brown - moist, stiff - intermediate plasticity		T41			18	19	0	20
214.6	13				SAND (TILL) - trace silt, trace clay - brown - wet, loose - no to low plasticity - poorly graded, fine and medium grained sand		SB42A			16	17	0	20
	14				- dense below 14.6 m		SB42B			18	19	0	20
	15						SB43			20	21	0	20
	16				- trace till inclusions (<20mm) below 15.7 m		SS44		29			0	20
	17				- boulder at 16.7 m		SS45B					0	20
	18						SS45A		50			0	20
209.2	18				DOLOMITE (BEDROCK) - beige, vertical and horizontal, rough undulating fractures, slightly altered, clay infilling		CB56						
	19						CB57	75					
	20				- 0.1 m clay (rock flour) seams between 20.7 m and 20.8 m		CB58	30					49100
	21				- 0.2 m clay (rock flour) seams between 21.6 and 21.8 m - yellowish fractured limestone between 21.8 to 24.3 m		CB59	0					
204.2	23				MUDSTONE (BEDROCK) - beige to brown, layered to varved, highly fractured with clay infill.		CB60	17					
203.0	24				DOLOMITIC MUDSTONE (BEDROCK) - mottled light brown to grey, minor rough undulating sub vertical fractures.		CB61	91					

SUB-SURFACE LOG 01:15:004.00 DETAILED DESIGN NORTH KILDONAN FEEDERMAIN - LOGS.GPJ TREK GEOTECHNICAL.GDT 15/11/14

Logged By: Stephen Renner

Reviewed By: Nelson Ferreira

Project Engineer: Nelson Ferreira



Sub-Surface Log

Test Hole TH13-01

3 of 3

Elevation (m)	Depth (m)	Soil Symbol	Standpipe	Standpipe	MATERIAL DESCRIPTION	Sample Type	Sample Number	ROD (%)	SPT (N)	Bulk Unit Wt (kN/m ³)		Undrained Shear Strength (kPa)							
										16	17	18	19	20	21	0	20	40	60
	27				- chalk nodules at 26.8 m		CB62	96											
	28						CB63	62											
198.1	29				DOLOMITIC LIMESTONE (BEDROCK) - beige to grey mottled, some chert nodules (grey) in a dolomitic limestone matrix (beige), vuggy.		CB64	73											31200 ☒
	30																		
	31						CB65	35											21800 ☒
	32																		
	33						CB66	31											
	34				- 0.3 m thick highly fractured layer at 33.5 m														
	35				- fractures decreasing below 34.7 m		CB67	74											33100 ☒
	36						CB68	94											

END OF TEST HOLE At 36.9 m in DOLOMITIC LIMESTONE (BEDROCK)

Notes:

- 1) Power auger refusal at 16.9 m depth.
- 2) Seepage observed below 5.3 m
- 3) Water level at 1.5 m depth immediately after dilling prior to coring.
- 4) Test hole drilled using solid stem auger up to 4.6 m then switched to hollow stem auger. At power auger refusal, switched to HQ coring.

SUB-SURFACE LOG 01:15:004 00 DETAILED DESIGN NORTH KILDONAN FEEDERMAIN - LOGS.GPJ TREK GEOTECHNICAL.GDT 15/11/14

Logged By: Stephen Renner

Reviewed By: Nelson Ferreira

Project Engineer: Nelson Ferreira



Sub-Surface Log

Test Hole TH13-04

1 of 2

Client: Associated Engineering **Project Number:** 0115 004 00
Project Name: Detailed Design North Kildonan Feedermain **Location:** UTM N-5534987.21, E-636455.82
Contractor: Paddock Drilling Ltd. **Ground Elevation:** 227.19 m
Method: Acker SS3 Track Mount (see notes for drilling method) **Date Drilled:** 6 November 2013

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
Backfill Legend: Bentonite Cement Drill Cuttings Filter Pack Sand Grout Slough

Elevation (m)	Depth (m)	Soil Symbol	Standpipe	MATERIAL DESCRIPTION	Sample Type	Sample Number	RQD (%)	SPT (N)	Bulk Unit Wt (kN/m ³)		Undrained Shear Strength (kPa)	
									16	17	18	19
								Particle Size (%)				
								0 20 40 60 80 100 PL MC LL 0 20 40 60 80 100				
								0 20 40 60 80 100 0 20 40 60 80 100 <input type="checkbox"/> Torvane <input type="checkbox"/> Pocket Pen. <input type="checkbox"/> Qu <input type="checkbox"/> Field Vane <input type="checkbox"/>				
227.7	1			CLAY (ALLUVIAL) - silty, some gravel, trace fine sand, trace to some organics (roots and rootlets) - dark brown - moist, very stiff - high plasticity		G46						
						G47						>>
	2			CLAY (LACUSTRINE) - silty to 2.4m, some gravel, trace fine sand, trace organics (roots and rootlets), trace oxidation - dark brown, moist, soft to firm, high plasticity		G48						
				- grey below 2.4 m		SB01						
				- trace silt inclusions (<15mm) and soft below 2.7 m		SB02						
	3					G49						
				- firm to stiff, trace to some oxidation below 3.7 m		T03						
	4					SB04						
						SB05						
	5					SB06						
				- trace coarse sand below 5.8 m		SB07						
	6					T08						
				- trace gravel (<25mm) below 7.3 m		SB09						
	7					SB10						
				- trace to some silt inclusions (<15mm) below 7.9 m		SB11						
	8					SB12						
						T13						
	9					SB14						
				- trace till inclusions (<75mm) below 10.4 m		SB15						
	10					SB16						
						SB17						

Logged By: Stephen Renner **Reviewed By:** Nelson Ferreira **Project Engineer:** Nelson Ferreira

SUB-SURFACE LOG 01:15:004 00 DETAILED DESIGN NORTH KILDONAN FEEDERMAIN - LOGS.GPJ TREK GEOTECHNICAL_GDT_15/11/14



Sub-Surface Log

Test Hole TH13-05

1 of 3

Client: Associated Engineering **Project Number:** 0115 004 00
Project Name: Detailed Design North Kildonan Feedermain **Location:** UTM N-5534979.78, E-636465.14
Contractor: Paddock Drilling Ltd. **Ground Elevation:** 226.26 m
Method: CME-850 Track Mount (see notes for drilling method) **Date Drilled:** 15 November 2013

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

Backfill Legend: Bentonite Cement Drill Cuttings Filter Pack Sand Grout Slough

Elevation (m)	Depth (m)	Soil Symbol	Standpipe	MATERIAL DESCRIPTION	Sample Type	Sample Number	RQD (%)	SPT (N)	Bulk Unit Wt (kN/m ³)		Undrained Shear Strength (kPa)									
									16	17		18	19	20	21					
									Particle Size (%)		Test Type									
									0	20	40	60	80	100	<input type="checkbox"/> Torvane <input type="checkbox"/> <input checked="" type="checkbox"/> Pocket Pen. <input checked="" type="checkbox"/> <input checked="" type="checkbox"/> Qu <input checked="" type="checkbox"/> <input type="checkbox"/> Field Vane <input type="checkbox"/>					
									0	20	40	60	80	100	0	20	40	60	80	100
				- overburden soils not logged - drilling advanced to power auger refusal then drilling method switched to HQ coring																
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				

Logged By: Martial Lemoine **Reviewed By:** Nelson Ferreira **Project Engineer:** Nelson Ferreira

SUB-SURFACE LOG 0115 004 00 DETAILED DESIGN NORTH KILDONAN FEEDERMAIN - LOGS.GPJ TREK GEOTECHNICAL_GDT_15/11/14



Sub-Surface Log

Test Hole TH13-05

2 of 3

Elevation (m)	Depth (m)	Soil Symbol	Standpipe	MATERIAL DESCRIPTION	Sample Type	Sample Number	ROD (%)	SPT (N)	Bulk Unit Wt (kN/m ³)		Undrained Shear Strength (kPa)						
									16	17	18	19	20	21	0	20	40
									Particle Size (%)				Test Type				
									0 20 40 60 80 100				△ Torvane △ ⊕ Pocket Pen. ⊕ ⊠ Qu ⊠ ○ Field Vane ○				
									PL MC LL				0 20 40 60 80 100				
210.1	16.0			SILT (TILL) - trace clay, trace sand, trace gravel - light grey, moist, loose, no to low plasticity	SS69	CB70	0										
210.0	16.0			DOLOMITE (BEDROCK) - beige, vertical and horizontal, rough undulating fractures, slightly altered, clay infilling		CB71	38										
208.7	18.0			DOLOMITE (BEDROCK) - beige to light grey layering, massive, minor vugs, minor vertical and horizontal tight fractures		CB72	73										39500 ⊠
	20.0					CB73	95										
	22.0					CB74	83										39500 ⊠
	23.0			- visible hairline fractures between 22.9 m to 24.4 m		CB75	98										
201.9	24.0			DOLOMITE (BEDROCK) - beige layers with light brown mottled and cream coloured layers, massive, minor vertical and horizontal tight fractures		CB76	92										
	26.0					CB77	75										

SUB-SURFACE LOG 01:15:004.00 DETAILED DESIGN NORTH KILDONAN FEEDERMAIN - LOGS.GPJ TREK GEOTECHNICAL.GDT 15/11/14



Sub-Surface Log

Test Hole TH13-05

3 of 3

Elevation (m)	Depth (m)	Soil Symbol	Standpipe	MATERIAL DESCRIPTION	Sample Type	Sample Number	ROD (%)	SPT (N)	Bulk Unit Wt (kN/m ³)		Undrained Shear Strength (kPa)		
									16	17	18	19	20
198.8	27			DOLOMITIC MUDSTONE (BEDROCK) - mottled light brown to grey, light brown mottles are soft calcareous mudstone, grey mottles are hard dolomite, trace chert nodules, vuggy, rough undulating sub vertical fractures 0.1 m thick clay (rock flour) seam at 28.7 m		CB78	69						
	28												
	29					CB79	92					11900	
195.8	30			DOLOMITIC LIMESTONE (BEDROCK) - beige to grey mottled, some chert nodules (grey) in a dolomitic limestone matrix (beige), vuggy, minor, very rough, angular, subhorizontal fracturing.		CB80	100						
	31						CB81	100					
	32						CB82	99					
	33						CB83	85					
	34												
191.2	35												

END OF TEST HOLE At 35.1 m in DOLOMITIC LIMESTONE (BEDROCK)

Notes:

- 1) Power auger refusal at 16.2 m.
- 2) No seepage or sloughing observed.
- 3) Water level at 3.7 m depth immediately after dilling prior to coring.
- 4) Test hole drilled using solid stem augers to 16.2 m then drilling method switched to HQ coring.

SUB-SURFACE LOG 01:15:004 00 DETAILED DESIGN NORTH KILDONAN FEEDERMAIN - LOGS.GPJ TREK GEOTECHNICAL.GDT 15/11/14

Logged By: Martial Lemoine

Reviewed By: Nelson Ferreira

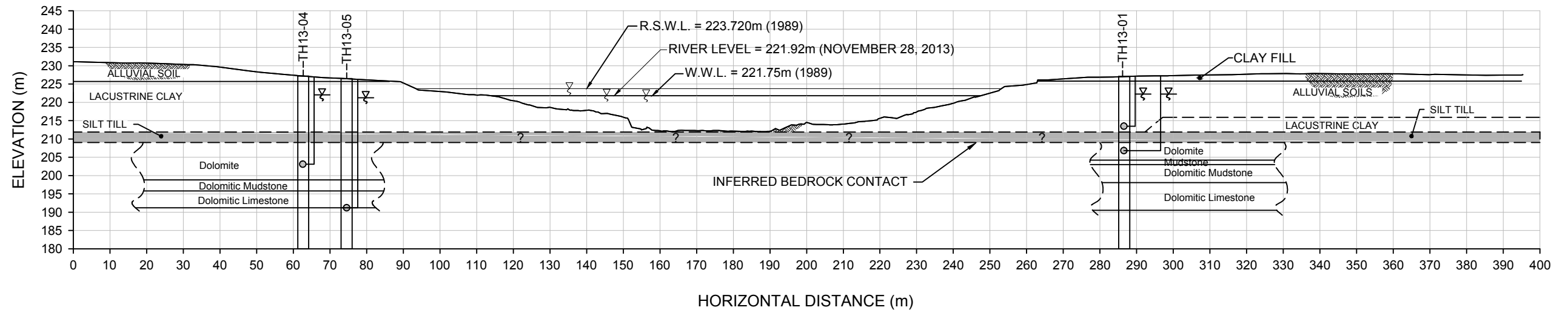
Project Engineer: Nelson Ferreira

Tabloid (279mm x 432mm)

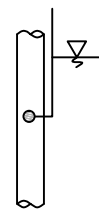
PLOT: 15/01/2014 12:11:52 PM

FILE NAME: 0115 004 00_RS.dwg

CROSS-SECTION A

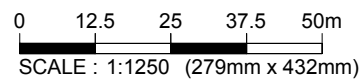


NOTE:



GROUND WATER LEVEL IN STANDPIPE
PIEZOMETER NOVEMBER 28, 2013

W.W.L. = WINTER WATER LEVEL
R.S.W.L. = REGULATED SUMMER WATER LEVEL





SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH12-01

SHEET 1 of 3

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT
PROJECT Chief Peguis Bridge Sewer Replacement
SITE East of Red River and South of Chief Peguis Trail
LOCATION North of Existing Sewermain on the Lower Bank
DRILLING METHOD Acker Track Drill Rig, 125 mm ø Solid Stem and HQ Core Barrel

JOB NO. 12-0107-018
GROUND ELEV. 226.37
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 11/7/2012
UTM (m) N 5,534,788
 E 636,543

ELEVATION (m)	DEPTH (m)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE	NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲		DYNAMIC CONE (N) blows/ft Δ			Cu POCKET PEN (kPa) ★		Cu TORVANE (kPa) ◆		
							20	40	60	PL	MC	LL	20	40	60	80
1	5		SILTY CLAY - Brown, damp, firm, intermediate plasticity, trace rootlets, trace fine grained sand, trace fine grained gravel.		S1											
2	10		SAND & GRAVEL - Light grey, moist, dense, medium to coarse grained sand, fine to coarse grained gravel, some clay. - Hole squeezing at 1.83 m.		S2											
3	15		SAND - Brown, moist to wet, loose, fine to medium grained, trace oxidation. - Water noticed on sample below 4.57 m. - Grey, no oxidation below 5.33 m.		S3											
4	20		SILTY CLAY - Grey, moist, firm, high plasticity.		S4											
5	25		SAND - Grey, moist, loose, medium grained, trace coarse grained sand.		S5											
6	30		SAND - Grey, moist, loose, medium grained, trace coarse grained sand. - Some with silt, reduced sand below 7.92 m		S6											
7	30		SILTY CLAY - Grey, moist, firm, high plasticity, trace silt nodules, trace medium grained sand, trace fine grained gravel.		S7											

GEO-TECHNICAL SOIL LOG P:\PROJECTS\2012\12-0107-018\DESIGN\GEOLOG\SCHIEF PEGUIS TRAIL SEWERMAIN.GPJ

SAMPLE TYPE Auger Grab Core Barrel
CONTRACTOR Paddock Drilling Ltd. **INSPECTOR** C. FRIESEN **APPROVED** DRAFT **DATE** 11/26/12

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE	NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲	DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★			Cu TORVANE (kPa) ◆		
									20	40	60	80	20	40
			• Stiff below 10.06 m.		S7									
	35		• Reduced fine grained gravel below 10.67 m.											
	40		• Grain Size Distribution: Gravel (1.2%), Sand (11.7%), Silt (30.5%), Clay (56.6%) at 11.58 m.		S8									
			• Reduced silt nodules below 12.50 m.											
	45		• Firm below 12.95 m.											
			• Grain Size Distribution: Gravel (0.8%), Sand (10.2%), Silt (23.7%), Clay (65.3%) at 13.11 m.		S9									
	50		SILTY TILL - Tan, moist, compact, with medium to coarse grained sand, some fine grained gravel, trace coarse grained gravel.											
			• Loose, reduced coarse grained sand, reduced fine to coarse grained gravel below 14.63 m.		S10									
	55		• Auger refusal at 18.76 m on bedrock. Switched over to core below 16.76 m.											
			LIMESTONE BEDROCK - White, fractured with vertical and horizontal fractures.		R1	85								
	60				R2	98								
	65		• Clay seam at 19.69 m.											
			• Clay between 20.12 and 20.19 m.											
	70		• Yellow fractured limestone between 21.41 and 22.25 m.		R4	100								

GEOTECHNICAL-SOIL LOG P:\PROJECTS\2012\12-01\DESIGN\GEOLOGS\CHIEF PEGJUS TRAIL SEWERMAIN.GPJ

SAMPLE TYPE  Auger Grab  Core Barrel

CONTRACTOR
Paddock Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
DRAFT

DATE
11/26/12



SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH12-02

SHEET 1 of 3

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT
PROJECT Chief Peguis Bridge Sewer Replacement
SITE East of Red River and South of Chief Peguis Trall
LOCATION South of Existing Sewermain on the Upper Bank
DRILLING METHOD Acker Track Drill Rig, 125 mm ϕ Solid Stem and HQ Core Barrel

JOB NO. 12-0107-018
GROUND ELEV. **228.37**
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 11/8/2012
UTM (m)
 N 5,534,757
 E 636,604

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE NUMBER	RECOVERY %	SPT (N) blows/0.15 m \blacktriangle	DYNAMIC CONE (N) blows/ft \triangle	C _u POCKET PEN (kPa) \star			C _u TORVANE (kPa) \blacklozenge		
										PL	MC	LL	PL	MC	LL
			SILTY CLAY FILL - Brown, moist, stiff, intermediate to high plasticity some medium to coarse grained sand, some fine grained gravel, trace coarse grained gravel, trace rootlets.			S1									
	1		SILTY CLAY - Brown, moist, stiff, high plasticity, trace fine to medium grained sand.												
	5		- Increased sand content below 1.83 m.												
	2		SAND - Brown, moist, compact, fine to medium grained, trace coarse grained sand, trace silt, trace clay.			S2									
	3		SILTY SAND - Brown, moist, loose, fine to medium grained, with silt, trace clay.			S3									
	4		SAND - Brown, moist, compact, fine to medium grained, trace silt.												
	5														
	6		- Water noticed on sample at ~ 5.49 m.			S4									
	20		SANDY SILT - Brown, moist, firm, intermediate to high plasticity, trace oxidation.												
	7		SILTY SAND - Brown, moist, soft, fine to medium grained, trace oxidation.			S5									
	25		- Grey, no oxidation below 6.71 m.												
	8		SAND - Grey, moist, compact, medium grained, some fine and coarse grained sand.												
	8		SILTY CLAY - Grey, moist, firm, high plasticity.												
	8		- Medium grained sand layer between 7.39 and 7.47 m.												
	8		SILTY SAND - Grey, moist, soft, fine to medium grained sand, with silt.			S6									
	8		- Organic layer between 8.53 and 8.64 m.												
	9		SILTY CLAY - Grey, moist, firm, high plasticity, trace fine grained sand.												
	30		- Increased sand between 9.75 and 9.96 m.			S7									

GEOTECHNICAL SOIL LOG P:\PROJECTS\2012\12-0107-018\DESIGN\GEOLOGS\CHIEF PEGUIS TRAIL SEWERMAIN.GPJ

SAMPLE TYPE Auger Grab Split Spoon Core Barrel

CONTRACTOR
Paddock Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
DRAFT

DATE
11/26/12

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★ Cu TORVANE (kPa) ◆			
									PL	MC	LL	
								20 40 60	20 40 60 80			
	35		- Increased sand between 10.36 and 10.52 m.									
11			SILTY SAND - Grey, moist, compact, medium grained, trace fine grained sand, trace clay. - Test hole squeezing at 10.67 m.			S8						
12	40		- 25 mm thick organic layer at 12.60 m.									
13			- Decreased sand between 12.95 and 13.26 m.			S9						
14	45		SILTY CLAY - Grey, moist, firm, high plasticity, trace coarse grained sand, trace fine grained gravel, trace silt nodules. - Grain Size Distribution: Gravel (1.0%), Sand (8.8%), Silt (21.9%), Clay (57.0%) at 14.63 m.			S10						
15	50											
16	55		SILT TILL - Tan, moist, compact, with medium to coarse grained sand, some fine grained gravel, trace coarse grained gravel. - Loose, decreased gravel below 16.46 m.			S11						
17						S12	100					
18	60		- Auger refusal at 18.34 m on bedrock. Switched over to core below 18.34 m.			S13						
19			LIMESTONE BEDROCK - White, competent, vertical and horizontal fractures.			R1	98					
20	65					R2	98					
21	70											

GEO/TECHNICAL/ SOIL LOG P-PROJECT/SR12/12-01/07-218/DESIGN/GEV/DGS/SCHIEF PEGUIS TRAIL SEWERMAIN GPJ



SAMPLE TYPE Auger Grab Split Spoon Core Barrel

CONTRACTOR
Paddock Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
DRAFT

DATE
11/26/12

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★ Cu TORVANE (kPa) ◆		
									20	40	60
22			<p>Increased fractures below 22.54 m. Vertical fracture between 23.01 and 23.67 m.</p>		22.2	R3	98				
23	75										
24	80										
25	85										
26	85										
			END OF TEST HOLE AT 26.06 m		25.8						
			Notes: 1. Installed casagrande standpipe at a depth of 26.06 m with a stick-up of 0.64 m 2. Backfilled test hole with silica sand between 26.06 and 22.17 m and bentonite chips from 22.17 m to grade.		26.1						
27	90										
28											
29	95										
30	100										
31											
32	105										
33											
	110										

GEO/TECHNICAL SOIL LOG P:\PROJECTS\2012\12-01\DESIGN\GEOLOGS\SCHIEF PEGJUS TRAIL SEVERMAN.GPJ

SAMPLE TYPE	<input checked="" type="checkbox"/> Auger Grab	<input checked="" type="checkbox"/> Split Spoon	<input type="checkbox"/> Core Barrel
CONTRACTOR	INSPECTOR		APPROVED
Paddock Drilling Ltd.	C. FRIESEN		DRAFT
			DATE
			11/26/12



SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH12-02B

SHEET 1 of 2

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT
PROJECT Chief Peguis Bridge Sewer Replacement
SITE East of Red River and South of Chief Peguis Trail
LOCATION -3 m West of TH12-02
DRILLING METHOD Acker Track Drill Rlg, 125 mm ø Solid Stem

JOB NO. 12-0107-018
GROUND ELEV.
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 11/9/2012
UTM (m) N
 E

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲	DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★		Cu TORVANE (kPa) ◆	
										20	40	60	80
		[Cross-hatched]	SILTY CLAY FILL - Brown, moist, stiff, intermediate to high plasticity, some medium to coarse grained sand, some fine grained gravel, trace coarse grained gravel, trace rootlets.										
	1	[Diagonal lines]	SILTY CLAY - Brown, moist, stiff, high plasticity, trace fine to medium grained sand.										
	5		· Increased sand content below 1.83 m.										
	2		SAND - Brown, moist, compact, fine to medium grained, trace coarse grained sand, trace silt, trace clay.										
	3		SILTY SAND - Brown, moist, loose, fine to medium grained, with silt, trace clay.										
	4		SAND - Brown, moist, compact, fine to medium grained, trace silt.										
	5												
	6	[Diagonal lines]	· Water noticed on sample at ~ 5.49 m. SANDY SILT - Brown, moist, firm, intermediate to high plasticity, trace oxidation.										
	7		SILTY SAND - Brown, moist, soft, fine to medium grained, trace oxidation. · Grey, no oxidation below 6.71 m.										
	8		SAND - Grey, moist, compact, medium grained, some fine and coarse grained sand. SILTY CLAY - Grey, moist, firm, high plasticity. · Medium grained sand layer between 7.39 and 7.47 m.										
	9		SILTY SAND - Grey, moist, soft, fine to medium grained sand, with silt. · Organic layer between 8.53 and 8.64 m.										
	9		SILTY CLAY - Grey, moist, firm, high plasticity, trace fine grained sand. · Increased sand between 9.75 and 9.96 m.										

SAMPLE TYPE

CONTRACTOR
Paddock Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
DRAFT

DATE
11/26/12

GEO-TECHNICAL SOIL LOGS P:\PROJECTS\2012\12-0107-01\DESIGN\GEOLOG\CHIEF PEGUIS TRAIL SEWERMAIN.GPJ

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★ Cu TORVANE (kPa) ◆			
									20	40	60	80
35			· Increased sand between 10.36 and 10.52 m.									
			SILTY SAND - Grey, moist, compact, medium grained, trace fine grained sand, trace clay. · Test hole squeezing at 10.67 m.		11.4 11.6							
			· 25 mm thick organic layer at 12.50 m.									
			· Decreased sand between 12.95 and 13.26 m.									
			SILTY CLAY - Grey, moist, firm, high plasticity, trace coarse grained sand, trace fine grained gravel, trace silt nodules.									
			SILT TILL - Tan, moist, compact, with medium to coarse grained sand, some fine grained gravel, trace coarse grained gravel. · Loose, decreased gravel below 16.46 m.		16.8 17.4 17.7							
			AUGER REFUSAL AT 18.34 m		18.3							
			Notes: 1. Stratigraphy assumed from TH12-02 drilled ~3 m away. 2. Installed casagrande standpipe at a depth of 17.88 m with a slick-up of 0.91 m. 3. Installed PN 034983 at a depth of 11.58 m. below grade. 4. Backfilled test hole with silica sand between 17.68 and 16.76 m and bentonite chips from 16.76 m to grade.									

GEOTECHNICAL SOIL LOG P:\PROJECTS\2012\12-01\07-31\DESIGN\GEOL\LOGS\SCHIEF PEGJUIS TRAIL SEWERMAIN.GPJ

SAMPLE TYPE		CONTRACTOR		INSPECTOR		APPROVED		DATE	
		Paddock Drilling Ltd.		C. FRIESEN		DRAFT		11/26/12	

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT
PROJECT Chief Peguis Bridge Sewer Replacement
SITE West of Red River and South of Chief Peguis Trail
LOCATION North of Existing Sewermain on the Upper Bank
DRILLING METHOD CME Track Drill Rig, 125 mm Ø Solid Stem and HQ Core Barrel

JOB NO. 12-0107-018
GROUND ELEV. 230.84
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 11/13/2012
UTM (m) N 5,534,926
 E 636,265

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲	DYNAMIC CONE (N) blows/ft Δ	Cu POCKET PEN (kPa) ★			Cu TORVANE (kPa) ◆
										20	40	60	80
			<p>SILTY CLAY FILL - Black, moist, stiff, high plasticity, trace rootlets. - Trace medium to coarse grained sand, trace fine to coarse grained gravel below 0.23 m.</p> <p>SILTY CLAY - Brown, moist, stiff, high plasticity, trace coarse grained sand. - No sand below 1.22 m.</p>										
			<p>SILTY SAND TO SANDY SILT - Light brown, moist, soft/loose, fine grained sand.</p>			S1							
			<p>SILTY CLAY - Brown, moist, stiff, high plasticity, trace silt nodules (~1-3 mm diameter). - 10 mm diameter gravel piece at 3.73 m.</p>			S2							
			<p>Grey below 5.49 m. Firm below 6.10 m.</p>			S3							
			<p>Slightly increased silt nodules (up to 5 mm diameter) below 9.14 m.</p>			S4							
						S5							
						S6							

G:\TECHNICAL\SOIL LOG P\PROJECTS\2012\12-0107-018\DESIGN\GEOLOG\SS\CHIEF PEGUIS TRAIL SEWERMAIN.GPJ

SAMPLE TYPE	<input checked="" type="checkbox"/> Auger Grab	<input checked="" type="checkbox"/> Split Spoon	<input type="checkbox"/> Core Barrel
CONTRACTOR	INSPECTOR		APPROVED
Paddock Drilling Ltd.	C. FRIESEN		DRAFT
			DATE 11/26/12

GEO/TECHNICAL - SOIL LOG P:\PROJECTS\2012\12-03\10\DESIGN\GEOLOG\LOGS\CHIEF PEGUIS TRAIL SEWERMAIN.GPJ

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★ Cu TORVANE (kPa) ◆	
									PL	MC
11.0	35									
12.0	40		Trace silt pockets below 12.19 m. Trace fine grained gravel below 12.50 m.							
13.0										
14.0	45									
15.0	50		Reduced silt, trace coarse grained sand, no fine grained gravel below 15.24 m.							
16.0										
17.0	55		Occasional silt pockets/nodules below 16.92 m.							
18.0	60		Grain Size Distribution: Gravel (0.7%), Sand (7.5%), Silt (19.4%), Clay (72.4%) at 17.68 m. Trace fine grained gravel below 16.29 m.							
19.0										
20.0	65		SILT TILL - Tan with grey, moist, compact, fine to coarse grained sand, fine grained gravel, trace clay.							
21.0	70		Auger refusal at 21.03 m on bedrock. Switched over to core below 21.03 m. LIMESTONE BEDROCK - White, competent, horizontal fractures.		21.0					

SAMPLE TYPE	<input type="checkbox"/> Auger Grab	<input checked="" type="checkbox"/> Split Spoon	<input type="checkbox"/> Core Barrel
CONTRACTOR	INSPECTOR		APPROVED
Paddock Drilling Ltd.	C. FRIESEN		DRAFT
			DATE
			11/26/12

CLIENT CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT
PROJECT Chief Peguis Bridge Sewer Replacement
SITE West of Red River and South of Chief Peguis Trail
LOCATION ~2 m West of TH12-03
DRILLING METHOD CME Track Drill Rig, 125 mm ϕ Solid Stem

JOB NO. 12-0107-018
GROUND ELEV.
TOP OF PVC ELEV.
WATER ELEV.
DATE DRILLED 11/14/2012
UTM (m) N
 E

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	SPT (N) blows/0.15 m \blacktriangle	DYNAMIC CONE (N) blows/ft \triangle	Cu POCKET PEN (kPa) *		Cu TORVANE (kPa) \blacklozenge	
										20	40	60	80
			<p>SILTY CLAY FILL - Black, moist, stiff, high plasticity, trace rootlets.</p> <ul style="list-style-type: none"> Trace medium to coarse grained sand, trace fine to coarse grained gravel below 0.23 m. 										
			<p>SILTY CLAY - Brown, moist, stiff, high plasticity, trace coarse grained sand.</p> <ul style="list-style-type: none"> No sand below 1.22 m. 										
			<p>SILTY SAND TO SANDY SILT - Light brown, moist, soil/loose, fine grained sand.</p>										
			<p>SILTY CLAY - Brown, moist, stiff, high plasticity, trace silt nodules (~1-3 mm diameter).</p> <ul style="list-style-type: none"> 10 mm diameter gravel piece at 3.73 m. 										
			<ul style="list-style-type: none"> Grey below 5.49 m. Firm below 6.10 m. 										
			<ul style="list-style-type: none"> Slightly increased silt nodules (up to 5 mm diameter) below 9.14 m 										

GEO/TECHNICAL SOIL LOG P:\PROJECTS\2012\12-0107-018\DESIGN\GEOLOGICAL\CHIEF PEGUIS TRAIL SEWERMAN GPJ

SAMPLE TYPE
CONTRACTOR Paddock Drilling Ltd. **INSPECTOR** C. FRIESEN **APPROVED** DRAFT **DATE** 11/26/12

GEOTECHNICAL SOIL LOGS \PROJECTS\2012\12-0107-1\10\DESIGN\GEOLOG\GCS\CHIEF PEGJUS TRAIL SEWERMAIN.GPJ

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲ DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★ Cu TORVANE (kPa) ◆			
									20	40	60	
35												
11					11.6							
40			<ul style="list-style-type: none"> Trace silt pockets below 12.19 m. Trace fine grained gravel below 12.50 m. 		11.8							
12												
13												
45												
14												
15			<ul style="list-style-type: none"> Reduced silt, trace coarse grained sand, no fine grained gravel below 15.24 m. 									
50												
16												
17			<ul style="list-style-type: none"> Occasional silt pockets/nodules below 16.92 m. 									
55												
18												
60			<ul style="list-style-type: none"> Trace fine grained gravel below 18.29 m. 									
19												
65			SILT TILL - Tan with grey, moist, compact, fine to coarse grained sand, fine grained gravel, trace clay.									
20					20.1							
21					20.7							
70			AUGER REFUSAL AT 20.98 m		21.0							
			Notes: 1. Stratigraphy assumed from TH12-03 drilled ~2 m away.									

SAMPLE TYPE

CONTRACTOR
Paddock Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
DRAFT

DATE
11/26/12



SUMMARY LOG

REFERENCE NO.

HOLE NO.
TH12-03B

SHEET 3 of 3

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	PIEZ. LOG	DEPTH (m)	SAMPLE TYPE	NUMBER	RECOVERY %	SPT (N) blows/0.15 m ▲	DYNAMIC CONE (N) blows/ft △	Cu POCKET PEN (kPa) ★	Cu TORVANE (kPa) ◆
									20 40 60	20 40 60	20 40 60 80	20 40 60 80
22			2. Installed casagrande standpipe at a depth of 20.96 m with a stick-up of 0.66 m.									
	75		3. Installed PN 034985 at a depth of 11.64 m. below grade.									
			4. Backfilled test hole with silica sand between 20.96 and 20.12 m and bentonite chips from 20.12 m to grade.									
			5. Test hole squeezing at 8.53 m shortly after drilling.									
23												
	80											
24												
	85											
25												
	90											
26												
	95											
27												
	100											
28												
	105											
29												
	110											

GEO-TECHNICAL SOIL LOG P:\PROJECTS\2012\12-0107-019\DESIGN\GEO\LOGS\SCHIEF PEGUS TRAIL SEWERMAN GP.J

SAMPLE TYPE		CONTRACTOR		INSPECTOR		APPROVED		DATE	
		Paddock Drilling Ltd.		C. FRIESEN		DRAFT		11/26/12	

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG

CKD.

NCB

DATE OF INVEST. 6/08/87

JOB NO. 87422

HOLE NO. 1

WATER CONTENT

w_p - □ w - ○ w_L - △
 PERCENT %
 10 20 30 40 50 60

DEPTH
(M)

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

450 & 500 mm
Augers

DATUM Geodetic

SURFACE ELEVATION 230.63 m

CONDITION

TYPE

PENETRATION
RESISTANCE

OTHER TESTS

Fill

Clay -black

Clay -silty
-brown
-stiff
-alluvial

Silt -tan
-wet to saturated
-firm

Clay -mottled brown
-highly plastic
-stiff
-lacustrine

U

$q_u = 109.7 \text{ kpa}$
 $\gamma_w = 16.48 \text{ kn/m}^3$
 $pp = 146.0 \text{ kpa}$
 $T_v = 84.7 \text{ kpa}$

End hole at 7.6 m.
Seepage and caving from 2.4 to 2.7 m.

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BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 6/08/87 JOB NO. 87422 HOLE NO. 2

WATER CONTENT			DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %									
10	20	30	40	50	60				
			0	▨	Fill -clay, silt, some gravel				
			1	▨	Clay -black				
			2	▨	Clay -silty -brown -stiff				
			3	▨	Silt -tan -saturated				
			4	▨	Clay -mottled brown -highly plastic -firm to stiff -lacustine				
			5	▨		U	qu=47.2kpa γ _w =16.51kn/m ³ pp=93.4kpa Tv=81.2kpa		
			6	▨					
			7	▨					
			8	▨	grey	U	qu=150.1kpa γ _w =16.85kn/m ³ pp=125.4kpa Tv=77.8kpa		
			9	▨					
			10	▨					
			11	▨	End hole at 10.7 m. Seepage and caving from silt layer	U	qu=131.8kpa γ _w =17.60kn/m ³ pp=117.8kpa Tv=60.3kpa		

DYREGROV & BURGESS

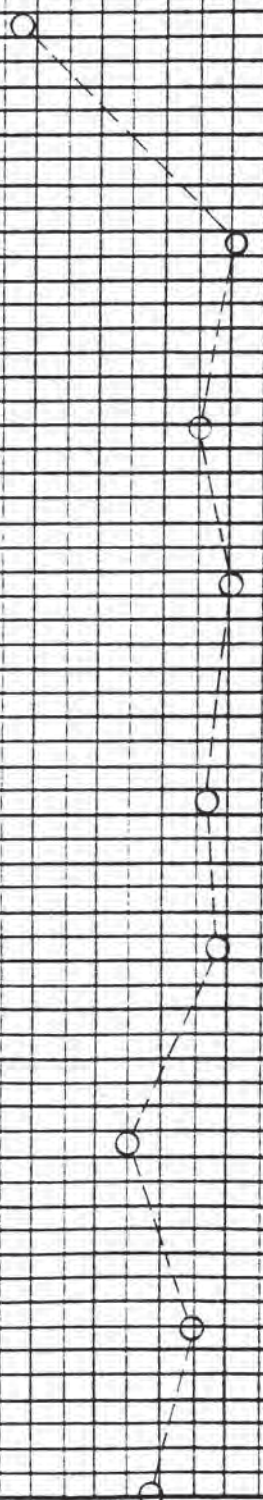
BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 6/08/87 JOB NO. 87422 HOLE NO. 3

WATER CONTENT					DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION		SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	PERCENT %				DATUM	SURFACE ELEVATION	CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS
10	20	30	40	50	60		230.58 m				500 mm Auger	
						SS	Topsoil					
							Clay -silty -brown -stiff					
							Silt -tan -wet to saturated					
							Clay -mottled brown -highly plastic -stiff to firm -lacustrine	U			qu=57.4kpa γ _w =16.40kn/m ³ pp=132.9kpa Tv=71.3kpa	
							--- grey					
								U			qu=117.3kpa γ _w =16.27kn/m ³ pp=119.7kpa Tv=74.7kpa	
								U			qu=148.5kpa γ _w =16.81kn/m ³ pp=95.8kpa Tv=60.6kpa	
								U			qu=147.3kpa γ _w =16.58kn/m ³ pp=68.9kpa Tv=54.6kpa	
							End of hole at 13.7 m in clay.	U			Plate A-4	



DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG

CKD.

NCB

DATE OF INVEST. 6/08/87

JOB NO. 87422

HOLE NO. 4

WATER CONTENT

w_p - □ w - ○ w_L - △
 PERCENT %
 10 20 30 40 50 60

DEPTH
(M)

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

DATUM Geodetic

CONDITION

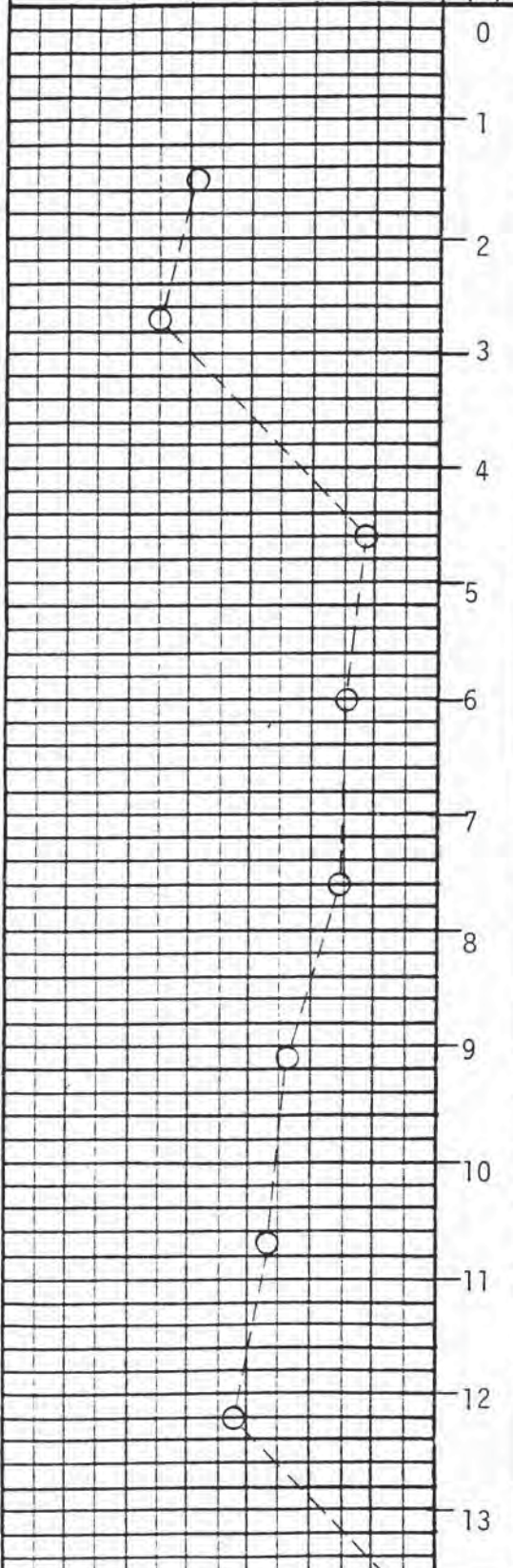
TYPE

PENETRATION RESISTANCE

450 & 500 mm Augers

SURFACE ELEVATION 230.64 m

OTHER TESTS



Depth (m)	Soil Description	Condition	Type	Penetration Resistance
0 - 1	Fill -clay -concrete rubble			
1 - 2	Clay -silty -brown			
2 - 3	Silt -tan -wet to saturated			
3 - 5	Clay -mottled brown -highly plastic -stiff to firm -lacustrine	U	U	
5 - 7	---grey			
7 - 8		U	U	
8 - 11		U	U	
11 - 13		U	U	

$\gamma_w = 16.30 \text{ kn/m}^3$
 $pp = 108.9 \text{ kpa}$
 $Tv = 57.4 \text{ kpa}$

$qu = 135.1 \text{ kpa}$
 $\gamma_w = 17.00 \text{ kn/m}^3$
 $pp = 147.5 \text{ kpa}$
 $Tv = 72.8 \text{ kpa}$

$qu = 106.7 \text{ kpa}$
 $\gamma_w = 16.72 \text{ kn/m}^3$
 $pp = 93.8 \text{ kpa}$
 $Tv = 56.0 \text{ kpa}$

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BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 6/08/87 JOB NO. 87422 HOLE NO. 4

WATER CONTENT						DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION		SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	PERCENT %					DATUM	SURFACE ELEVATION	CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS
10	20	30	40	50	60			Geodetic	230.64 m				450 & 500 mm Augers
						14		Clay -grey -highly plastic -lacustrine		U			qu=68.2kpa γ _w =16.04kn/m ³ pp=94.2kpa Tv=47.4kpa
						15							
						16							
						17							qu=128.4kpa γ _w =16.51kn/m ³ pp=81.4kpa Tv=43.6kpa
						18							
						19		Silt (Glacial Till) -sandy, gravelly -wet -loose to 19.5 m -medium dense below 19.5 m					
						20							
						21		End of hole at 20.4 m. -Smooth auger refusal -Possible bedrock at 20.4 m -Water inflow from 20.4 m -Water level stabilized at 9.4 m in about 15 minutes					

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 6/08/87 JOB NO. 87422 HOLE NO. 5

WATER CONTENT			DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE 450 & 500 mm Augers
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %									
10	20	30	40	50	60				
			0	⊗	Fill -silty -clay				
			1	⊗	Clay -black				
			1.76	△	Clay -silty -brown -alluvial			See Dilatometer Test Results (DMT 2)	
			2	⊗					
			3	⊗	Clay -mottled brown -highly plastic -stiff to firm -lacustrine				
			4	⊗					
			5	⊗		U		qu=53.7kpa γ _w =16.18kn/m ³ pp=112.5kpa Tv=59.4kpa	
			6	□	---grey				
			6.87	△					
			7	⊗					
			8	⊗		U		qu=114.2kpa γ _w =17.38kn/m ³ pp=122.6kpa Tv=62.7kpa	
			9	⊗					
			10	⊗					
			11	⊗		U		qu=95.3kpa γ _w =17.78kn/m ³ pp=66.1kpa Tv=39.7kpa	
			12	□					
			12.89	△					
			13	⊗					

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 6/08/87 JOB NO. 87422 HOLE NO. 5

WATER CONTENT			DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE 450 & 500 mm Augers
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %									
10	20	30	40	50	60				
			14		Clay (cont'd)	U		qu=118.4kpa γ _w =16.51kn/m ³ pp=103.4kpa Tv=49.3kpa	
			15						
			16		Silt (Glacial Till)				
			17		-sandy -gravelly -clayey -loose				
			18						
			19		End of hole at 18.7 m -Possible bedrock -No seepage				

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BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 7/08/87 JOB NO. 87422 HOLE NO. 7

WATER CONTENT			DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE 450 & 600 mm Augers
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %									
10	20	30	40	50	60				
			0	SS	Topsoil				
			1		Silt -sandy -some clay -brown -alluvial				
			2						
			3		Sand -some silt -trace clay -saturated			MA	
			4						
			5		Silt -some sand and clay -grey -wet -firm				
			6						
			7						
			8		Sand -fine grained -grey, saturated	U		MA $\gamma_w = 17.95 \text{ kg/m}^3$ pp=61.3kpa Tv=32.6kpa	
			9		Silt -some sand and clay				
			10		Clay -grey -highly plastic -firm				
			11		100 mm gravel layer, shells	U		qu=67.7kpa $\gamma_w = 18.34 \text{ kg/m}^3$ pp=151.2kpa Tv=69.9kpa	
			12						
			13						

DYREGROV & BURGESS

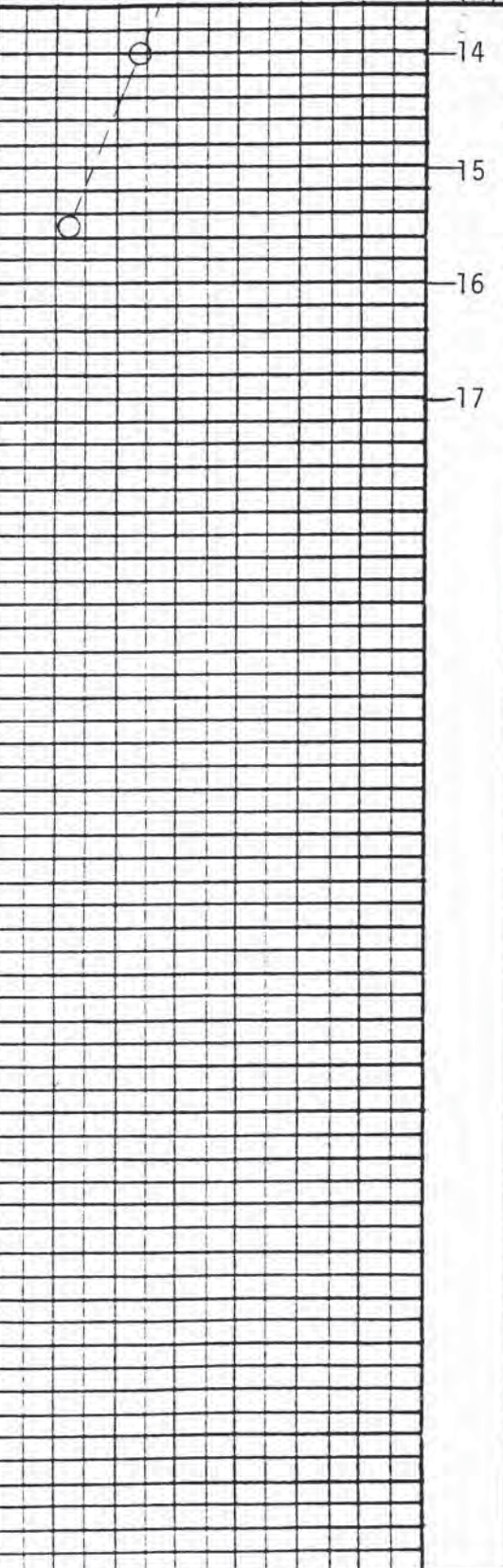
BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 7/08/87 JOB NO. 87422 HOLE NO. 7

WATER CONTENT						DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	PERCENT %						CONDITION	TYPE	PENETRATION RESISTANCE	
10	20	30	40	50	60			DATUM Geodetic				550 & 600 mm Augers
								SURFACE ELEVATION 227.13 m				



14	---	Clay & Glacial Till				
15						
16		Silt (Glacial Till) -wet, loose, clayey				
17		End of hole at 16.2 m. -Smooth auger refusal -Water seepage 20 minutes after completion of drilling -600 mm casing to 10 m depth -Possible bedrock at 16.2 m				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 7/08/87 JOB NO. 87422 HOLE NO. 8

WATER CONTENT			DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS
PERCENT %									
10	20	30	40	50	60				
			0	⊗	Fill -clay, concrete rubble				550 & 600 mm Augers
			1		Silt -clayey, brown, stiff -alluvial				
			2		Sand -fine grained -some silt -brown				$\gamma_w = 18.01 \text{ kg/m}^3$ $p_p = 56.2 \text{ kpa}$ $T_v = 39.7 \text{ kpa}$
			3		--- saturated	U			
			4						
			5						
			6		--- grey				
			7						
			8						
			9		Silt -some sand and clay -wet -stiff to firm	U		$q_u = 57.3 \text{ kpa}$ $\gamma_w = 16.97 \text{ kg/m}^3$ $p_p = 183.8 \text{ kpa}$ $T_v = 62.2 \text{ kpa}$	
			10						
			11		--- 50 mm gravel layer				
			12					$q_u = 49.1 \text{ kpa}$ $\gamma_w = 15.97 \text{ kg/m}^3$	
			13		Clay -grey -highly plastic -stiff to firm	U		$p_p = 101.5 \text{ kpa}$ $T_v = 57.4 \text{ kpa}$	

DYREGROV & BURGESS

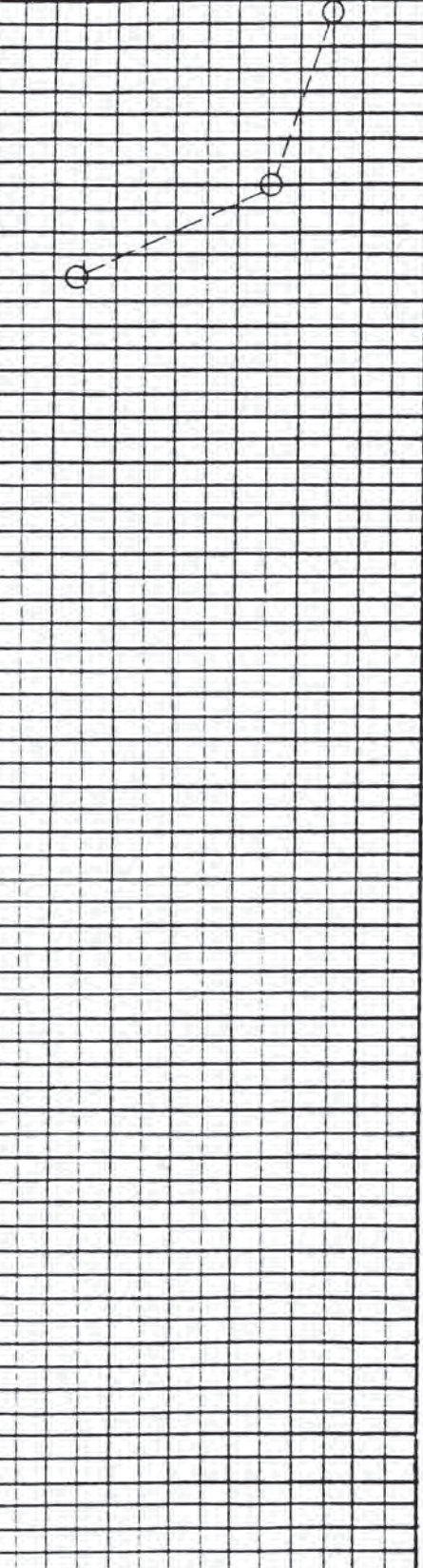
BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 7/08/87 JOB NO. 87422 HOLE NO. 8

WATER CONTENT					DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION		SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	PERCENT %				DATUM	SURFACE ELEVATION	CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS
10	20	30	40	50	60		Geodetic	227.17 m				550 & 600 mm Augers



14		Clay (cont'd)			
15		---gravelly			
16	0.1	Silt (Glacial Till)			
17	0.2	-sandy, gravelly			
	0.3	-some clay			
	0.4	-tan			
	0.5	-seepage from 16.5 m			
18		End of hole at 17.7 m			
		-Rough auger refusal at 17.7 m			
		-Water level at 7.2 m on completion of drilling			
		-600 mm casing to 4.6 below grade			

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG

CKD.

NCB

DATE OF INVEST. 27/08/87

JOB NO. 87422

HOLE NO. 13

WATER CONTENT

$W_p - \square$ $W - \circ$ $W_L - \triangle$
 PERCENT %
 10 20 30 40 50 60

DEPTH

(M)

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

DATUM Geodetic

CONDITION

TYPE

PENETRATION RESISTANCE

Hollow Stem

SURFACE ELEVATION 227.60 m

OTHER TESTS

Fill -clay
 -some gravel

Clay -silty
 -brown
 -alluvial

Clay -mottled brown
 -highly plastic
 -stiff to firm
 -lacustrine

Station - 3+90.9

$q_u = 56.5 \text{ kpa}$
 $\gamma_w = 16.77 \text{ kn/m}^3$
 $pp = 93.8 \text{ kpa}$
 $T_v = 48.8 \text{ kpa}$

U

U

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 27/08/87 JOB NO. 87422 HOLE NO. 13

WATER CONTENT						DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION		SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △		PERCENT %				DATUM	SURFACE ELEVATION	CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS
10	20	30	40	50	60			Geodetic	227.60 m				Hollow Stem
						14		Clay (cont'd)					
						15							
						16							
						17							
						18	Di	Silt (Glacial Till) -sandy and gravelly -bouldery					
						19		End of hole at 18.6 in glacial till.					
						20		Backfill with sand to 14.9. Place pneumatic piezometer @ 14.9 (P2) Sand to 14.2 m Bentonite to 13.1 m					
								Set pneumatic piezometer (P3) with tip @ 9.1 m. Sand to 8.5 m. Bentonite to 7.5 m.					

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. SDG CKD. NCB DATE OF INVEST. 18/09/87 JOB NO. 87422 HOLE NO. 14

WATER CONTENT						DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE B-24 75 mm Bit
W _p - □	W - ○	W _L - △	PERCENT %						DATUM	CONDITION	TYPE	
10	20	30	40	50	60			Geodetic				
								SURFACE ELEVATION 223.64				
						0		Water				
						1						
						2						
						3						
						4						
						5						
						6						
						7						
						8		Overburden Soils				For DMT results see DMT 5
						9	A	Glacial Till				
						10	A					
						11	A					
						12	A					
						13	A					
								Limestone Bedrock				Plate A-21

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

Kildonan Corridor

LOGGED/DWN. NCB CKD. NCB DATE OF INVEST. 18/09/87 JOB NO. 87422 HOLE NO. 14

WATER CONTENT						DEPTH (M)	SOIL SYMBOL	SOIL DESCRIPTION			SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △		DATUM Geodetic				CONDITION	TYPE	PENETRATION	RESISTANCE	OTHER TESTS		
PERCENT %													SURFACE ELEVATION 223.64 m	
10	20	30	40	50	60									

						14		Sound Rock						Rec. - 100%
						15		Sound Rock 25 mm clay seam at 15.2 m						Rec. - 91% RQD - 80%
						16		Sound Rock 25 mm clay seam at 16.7 m						REC. - 94% RQD - 75%
						17								
						18		Sound Rock No clay seams						Rec. - 100% RQD - 95%
						19								

						20		End hole at 19.1 m. Rock surface estimated at Elev. - 210.38 m. Top 150 mm unsound.						
--	--	--	--	--	--	----	--	---	--	--	--	--	--	--

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 24/09/87

JOB NO. 87422

HOLE NO. 15

WATER CONTENT

$w_p - \square$ $w - \circ$ $w_L - \triangle$
 PERCENT %
 10 20 30 40 50 60

DEPTH

m

SOIL SYMBOL

SOIL DESCRIPTION

DATUM

SURFACE ELEVATION 223.67 m

SOIL SAMPLE

CONDITION

TYPE

PENETRATION
RESISTANCE

DRILL TYPE

OTHER TESTS

WATER

1

2

3

4

5

6

7

8

9

10

ALLUVIAL SOILS

11

GLACIAL TILL
(depth to till extrapolated
from DMT 6)

12

13

LIMESTONE BEDROCK

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 24/09/87

JOB NO. 87422

HOLE NO. 15

WATER CONTENT

$w_p - \square$ $w - \circ$ $w_L - \triangle$
 PERCENT %
 10 20 30 40 50 60

DEPTH

m

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

DATUM

SURFACE ELEVATION

CONDITION

TYPE

PENETRATION
RESISTANCE

OTHER TESTS

14

BROKEN ROCK

SOUND ROCK

REC - 99%
RQD - 60%

15

NO RECOVERY

SOUND ROCK

REC - 99%
RQD - 60%

16

NO RECOVERY

SOUND ROCK

REC - 99%
RQD - 79%

17

SOUND ROCK

REC - 100%
RQD - 70%

18

NO RECOVERY

19

BROKEN ROCK

SOUND ROCK

REC - 84%
RQD - 17%

20

SOUND ROCK

REC - 100%
RQD - 45%

22

End hole at 21.7 m.
Rock surface estimated at elev.
210.53
Top 0.9 m unsound rock.

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 25/09/87

JOB NO. 87422

HOLE NO. 16

WATER CONTENT

$W_p - \square$ $W - \circ$ $W_L - \triangle$
 PERCENT %
 10 20 30 40 50 60

DEPTH
m

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

DATUM

SURFACE ELEVATION 223.61 m

CONDITION

TYPE

PENETRATION
RESISTANCE

OTHER TESTS

WATER

1

2

3

4

5

6

7

8

9

10

ALLUVIAL SOILS

11

GLACIAL TILL
 -SOFT/LOOSE
 -PUSHED DRILL RODS TO
 BEDROCK SURFACE

12

13

LIMESTONE BEDROCK

FOR TESTS IN
ALLUVIUM SEE
DMT 7

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 25/09/87

JOB NO. 87422

HOLE NO. 16

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION		SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △		DATUM				CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS		
PERCENT %												SURFACE ELEVATION	
10	20	30	40	50	60								
						14	[Hand-drawn soil symbol: irregular blocks]	BROKEN ROCK TO 13.7 m					
								3 - 6mm clay seams at 14.0 m					REC - 75%
						15		SOUND ROCK					REC - 95%
						16							RQD - 68%
						17		225 mm seam or soft rock					REC - 98%
						18	SOUND ROCK					REC - 93%	
						19							
						20	NO RECOVERY						
							Abandon hole at 20.1 m Drill rods jamming						

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 06/10/87

JOB NO. 87422

HOLE NO. 16A

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE	
W _p - □	W - ○	W _L - △	PERCENT %						DATUM	CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS
10	20	30	40	50	60				SURFACE ELEVATION				
						1		WATER					
						2							
						3							
						4							
						5							
						6							
						7							
						8							
						9							
						10		ALLUVIAL SOILS					
						11		GLACIAL TILL (depth extrapolated from DMT)					
						12							
						13							

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 06/10/87

JOB NO. 87422

HOLE NO. 16A

WATER CONTENT

$w_p - \square$ $w - \circ$ $w_L - \triangle$
 PERCENT %
 10 20 30 40 50 60

DEPTH

m

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

DATUM

CONDITION

TYPE

PENETRATION

RESISTANCE

SURFACE ELEVATION

OTHER TESTS

14

GLACIAL TILL
LIMESTONE BEDROCK

GLACIAL TILL

LIMESTONE BEDROCK

REC - 100%
ROD - 67%

15

UNSOUND ROCK

16

NO CORE RECOVERY

17

18

19

20

UNSOUND ROCK

21

NO CORE RECOVERY

22

23

UNSOUND ROCK

REC - 30%

24

End hole at 23.6 m.

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 07/10/87

JOB NO. 87422

HOLE NO. 16B

WATER CONTENT			DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %					DATUM				
10	20	30	40	50	60	SURFACE ELEVATION 223.69 m			
			1		WATER				
			2						
			3						
			4						
			5						
			6						
			7						
			8						
			9						
			10		ALLUVIUM				
			11		GLACIAL TILL (depth to till extrapolated from DMT 7)				
			12						
			13						

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.		CKD.	DATE OF INVEST.	JOB NO.	HOLE NO.				
WATER CONTENT			SOIL DESCRIPTION		SOIL SAMPLE	DRILL TYPE			
W _p - □	W - ○	W _L - △	DATUM		CONDITION	TYPE	PENETRATION RESISTANCE		
PERCENT %			SURFACE ELEVATION					OTHER TESTS	
10	20	30	40	50	60	DEPTH	SOIL SYMBOL		
						m			
						14	[Rock Pattern]	LIMESTONE BEDROCK SOUND ROCK	REC - 100% ROD - 56%
						15		SOUND ROCK	REC - 98% ROD - 83%
						16			
						17		SOUND ROCK	REC - 96% ROD - 90%
						18		SOUND ROCK	REC - 94% ROD - 73%
						19			
						20		NO RECOVERY	
								End hole at 20.0 m Drill rods jamming in broken rock and clay.	

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 14/10/87

JOB NO. 87422

HOLE NO. 16C

WATER CONTENT

$W_p - \square$ $W - \circ$ $W_L - \triangle$
 PERCENT %
 10 20 30 40 50 60

DEPTH
m

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

DATUM

SURFACE ELEVATION

CONDITION

TYPE

PENETRATION
RESISTANCE

OTHER TESTS

WATER

ALLUVIUM

GLACIAL TILL
 (depth to till extrapolated
 from DMT 7)

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 14/10/87

JOB NO. 87422

HOLE NO. 16C

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	CONDITION	TYPE	PENETRATION RESISTANCE				OTHER TESTS			
PERCENT %												
10	20	30	40	50	60							
						14		LIMESTONE BEDROCK SOUND ROCK				REC - 100% RQD - 85%
						15		SOUND ROCK				REC - 92% RQD - 91%
						16						
						17		SOUND ROCK				REC - 98% RQD - 96%
						18		SOUND ROCK				REC - 100% RQD - 100%
						19		NO RECOVERY				
						20		BROKEN ROCK, NO RECOVERY NO RECOVERY				
						21		SOUND ROCK				REC - 93% RQD - 73%
						22						
						23		End hole at 22.3 m.				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 15/10/87

JOB NO. 87422

HOLE NO. 16D

WATER CONTENT			DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE	
W _p - □	W - ○	W _L - △				DATUM	CONDITION	TYPE		PENETRATION RESISTANCE
PERCENT %										
10	20	30	40	50	60					
						WATER				
			1							
			2							
			3							
			4							
			5							
			6							
			7							
			8							
			9							
			10			ALLUVIUM				
			11	▲		GLACIAL TILL (depth to glacial till extrapolated from DMT 7)				
			12	▲						
			13	▲						
						LIMESTONE BEDROCK				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 15/10/87

JOB NO. 87422

HOLE NO. 16D

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE	
W _p - □	W - ○	W _L - △	PERCENT %						DATUM	CONDITION	TYPE		PENETRATION RESISTANCE
10	20	30	40	50	60				SURFACE ELEVATION				
						14		150 mm clay or soft rock				REC - 69%	
								---- 150 mm clay or soft rock				RQD - 67%	
						15		NO RECOVERY					
						16		SOUND ROCK				REC - 88%	
						17		SOUND ROCK				REC - 100%	
												RQD - 93%	
						18		SOUND ROCK					
								NO RECOVERY					
						19		SOUND ROCK					
						20		UNSOUND ROCK				REC - 30%	
												RQD - 10%	
						21		SOUND ROCK				REC - 80%	
						22		BROKEN ROCK				RQD - 63%	
								End hole at 22.5 m.					

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 06/10/87

JOB NO. 87422

HOLE NO. 17

WATER CONTENT			DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE	
W _p - □	W - ○	W _L - △				DATUM	CONDITION	TYPE		PENETRATION RESISTANCE
PERCENT %					SURFACE ELEVATION				OTHER TESTS	
10	20	30	40	50	60	223.65 m				
			1		WATER					
			2							
			3							
			4							
			5							
			6							
			7							
			8							
			9		ALLUVIAL SOILS					For tests in alluvium see DMT 7
			10							
			11	▲	GLACIAL TILL					
			12	▲	VERY DENSE, HARD BELOW 11.2 m					
			13	▲						

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 21/09/87

JOB NO. 87422

HOLE NO. 18

WATER CONTENT			DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %					DATUM				
10	20	30	40	50	60	SURFACE ELEVATION 223.68			
			1		WATER				
			2						
			3						
			4						
			5						
			6						
			7						
			8						
			9						
			10						
			11		GLACIAL TILL				
			12						
			13		LIMESTONE BEDROCK, BROKEN TO 13.1m				
					SOUND ROCK, 13.1 - 13.8 m				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 21/09/87

JOB NO. 87422

HOLE NO. 18

WATER CONTENT

W_p - □ W - ○ W_L - △
 PERCENT %
 10 20 30 40 50 60

DEPTH

m

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

DATUM

CONDITION

TYPE

PENETRATION

RESISTANCE

OTHER TESTS

SURFACE ELEVATION 223.68 m

14

NO RECOVERY 13.8 - 13.9 m
 SOUND ROCK
 25 mm clay seam at 14.6 m

REC - 87%
 RQD - 82%

15

SOUND ROCK

REC - 95%
 RQD - 87%

16

SOUND ROCK

REC - 95%
 RQD - 65%

17

SOUND ROCK

REC - 95%
 RQD - 87%

18

SOUND ROCK

REC - 95%

21

SOUND ROCK

REC - 93%

22

23

End hole at 22.3 m.

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 19/09/87

JOB NO. 87422

HOLE NO. 19

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION		SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △		DATUM				CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS		
PERCENT %													SURFACE ELEVATION 223.62
10	20	30	40	50	60								
						1		WATER					
						2							
						3							
						4							
						5							
						6							
						7							
						8							
						9							
						10	▲	GLACIAL TILL (depth to glacial till extrapolated from DMT 5)					
						11	▲						
						12	▲						
						13	▲						

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 19/09/87

JOB NO. 87422

HOLE NO. 19

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	CONDITION	TYPE	PENETRATION RESISTANCE				OTHER TESTS			
PERCENT %												
10	20	30	40	50	60		DATUM					
							SURFACE ELEVATION					
						14		GLACIAL TILL LIMESTONE BEDROCK BROKEN ROCK TO 14.6 m				REC - 30%
						15		SOUND ROCK				REC - 100%
						16						
						17		SOUND ROCK				REC - 96% RQD - 94%
						18		SOUND ROCK				REC - 96% RQD - 74%
						19						
						20		SOUND ROCK				REC - 97%
						21		End hole at 20.7 m.				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 03/10/87

JOB NO. 87422

HOLE NO. 20

WATER CONTENT

W_p - □ W - ○ W_L - △
 PERCENT %
 10 20 30 40 50 60

DEPTH
m

SOIL SYMBOL

SOIL DESCRIPTION

SOIL SAMPLE

DRILL TYPE

DATUM

CONDITION

TYPE

PENETRATION
RESISTANCE

SURFACE ELEVATION 223.61 m

OTHER TESTS

WATER

ALLUVIAL SOILS
(for test results see DMT 4)

GLACIAL TILL
(depth to till extrapolated
from DMT 4)

1.5, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

LIMESTONE BEDROCK

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 03/10/87

JOB NO. 87422

HOLE NO. 20

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	CONDITION	TYPE	PENETRATION RESISTANCE				OTHER TESTS			
PERCENT %												
10	20	30	40	50	60			DATUM SURFACE ELEVATION 223.61 m				
						14		BROKEN ROCK 13.4 - 14.0 m SOUND ROCK BELOW 14.0 m				REC - 64% RQD - 53%
						15		SOUND ROCK				REC - 97% RQD - 81%
						16						
						17		SOUND ROCK				REC - 95% RQD - 93%
						18		SOUND ROCK				REC - 92% RQD - 69%
						19		100 mm clay seam				
						20		SOUND ROCK				REC - 97% RQD - 73%
						21		SOUND ROCK				REC - 92% RQD - 79%
						22						
						23		End hole at 22.6 m.				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 28/09/87

JOB NO. 87422

HOLE NO. 21

WATER CONTENT			DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %					DATUM				
10	20	30	40	50	60	SURFACE ELEVATION 223.63 m			
			1		WATER				
			2		ALLUVIAL SOILS (for test results see DMT 4)				
			3						
			4						
			5						
			6						
			7						
			8		GLACIAL TILL (depth to till extrapolated from DMT 4)				
			9						
			10						
			11						
			12						
			13		LIMESTONE BEDROCK				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 28/09/87

JOB NO. 87422

HOLE NO. 21

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE	
W _p - □	W - ○	W _L - △	CONDITION	TYPE	PENETRATION RESISTANCE				OTHER TESTS				
PERCENT %													
10	20	30	40	50	60		DATUM						
							SURFACE ELEVATION						
							14		NO RECOVERY TO 14.2 m				
							15		SOUND ROCK, 14.2 - 14.8 m				
							16	---	25 mm clay seam				REC - 99%
							16		SOUND ROCK				RQD - 44%
							17		SOUND ROCK				REC - 97%
							17						RQD - 81%
							18	---	6 mm clay seams (2)				REC - 95%
							18	---	12 mm clay seam				RQD - 45%
							19		SOUND ROCK				
							20		SOUND ROCK				REC - 98%
							20						RQD - 67%
							21		SOUND ROCK				REC - 100%
							22						RQD - 36%
							23		End hole at 22.4 m.				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 23/09/87

JOB NO. 87422

HOLE NO. 22

WATER CONTENT			DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %					DATUM				
10	20	30	40	50	60	SURFACE ELEVATION 223.68 m			
			1		WATER				
			2		ALLUVIAL SOILS (for testing see DMT 3)				
			3						
			4						
			5						
			6						
			7						
			8		GLACIAL TILL (depth to glacial till extrapolated from DMT 3)				
			9						
			10						
			11						
			12						
			13		LIMESTONE BEDROCK				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 23/09/87

JOB NO. 87422

HOLE NO. 22

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	CONDITION	TYPE	PENETRATION RESISTANCE				OTHER TESTS			
PERCENT %												
10	20	30	40	50	60			DATUM SURFACE ELEVATION 223.68 m				
						14	⊘	BROKEN ROCK, 13.0-13.8 m SOUND ROCK				no REC REC - 99% RQD - 45%
						15	⊘	SOUND ROCK				REC - 99% RQD - 83%
						16	⊘					
						17	⊘	SOUND ROCK				REC - 96% RQD - 73%
						18	⊘	SOUND ROCK				REC - 93% RQD - 66%
						19	⊘	End hole at 19.0 m.				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 22/09/87

JOB NO. 87422

HOLE NO. 23

WATER CONTENT						DEPTH M	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	PERCENT %						DATUM	CONDITION	TYPE	
10	20	30	40	50	60			SURFACE ELEVATION 223.70 m				
						1		WATER				
						2		ALLUVIAL SOILS (For testing see DMT 3)				
						3						
						4						
						5						
						6						
						7						
						8						
						9		GLACIAL TILL (Depth to till extrapolated from DMT 3)				
						10						
						11						
						12						
						13		LIMESTONE BEDROCK				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 22/09/87

JOB NO. 87422

HOLE NO. 23

WATER CONTENT			DEPTH	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %					DATUM				
10	20	30	40	50	60	SURFACE ELEVATION 223.70 m			
			14		SOUND ROCK				REC. - 87% RQD. - 83%
			15		SOUND ROCK				REC. - 97% RQD - 10%
			16						
			17		SOUND ROCK				REC. - 100% RQD - 88%
			18		SOUND ROCK				REC. - 95% RQD - 47%
			19						
			20		SOUND ROCK				REC. - 97% RQD - 61%
			21		End hole at 20.9 m.				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST.

22/09/87

JOB NO. 8/422

HOLE NO. DMT 3

WATER CONTENT			DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	
PERCENT %					DATUM				
10	20	30	40	50	60	SURFACE ELEVATION	223.70 m		
			1			WATER			
			2	▨		SILT - clayey			UNDRAINED SHEAR STRENGTH (kPa) — 10.3 — 11.3 — 12.1 — 13.1 — 13.9 — 14.8 — 15.8 — 16.6 — 15.8 — 26.9 — 20.7 — 19.8 — 31.2 — 27.9 — 34.5 — 38.6
			3	▨		CLAY - silty			
			4	▨					
			5	▨					
			6	▨					
			7	▨		STRATIFIED SILTY CLAY AND CLAYEY SILT			
			8			End Dilatometer testing at 7.9 m. Refusal on glacial till or boulder at 7.9 m.			

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 30/09/87

JOB NO. 87422

HOLE NO. DMT 4

WATER CONTENT			DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △				CONDITION	TYPE	PENETRATION RESISTANCE	OTHER TESTS
PERCENT %					DATUM				
10	20	30	40	50	60	SURFACE ELEVATION 223.61			
			1		WATER				UNDRAINED SHEAR STRENGTH (kPa)
			2	▨	CLAYEY SILT				28
			3	▨	STRATIFIED SILT, SAND, AND CLAY				27
			4	▨					27
			5	▨	SILTY SAND				36
			6	▨					45
			7	▨	SILTY CLAY				39
			8		End dilatometer test at 7.5 m. Refusal on boulder or glacial till.				∅=34 ⁰
									∅=36 ⁰
									51
									59
									58

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 30/09/87

JOB NO. 87422

HOLE NO. DMT 5

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	PERCENT %						DATUM	CONDITION	TYPE	
10	20	30	40	50	60			SURFACE ELEVATION	OTHER TESTS			
						1		WATER				
						2						
						3						
						4						
						5						
						6						
						7						
						8		CLAYEY SILT, SILTY CLAY AND SAND				UNDRAINED SHEAR STRENGTH (kPa) 24 34 φ = 39°
						9		End dilatometer testing at 8.5 m Refusal on glacial till				

DYREGROV & BURGESS

BOREHOLE LOG

PROJECT

KILDONAN CORRIDOR

LOGGED/DWN.

CKD.

DATE OF INVEST. 30/09/87

JOB NO. 87422

HOLE NO. DMT 6

WATER CONTENT						DEPTH m	SOIL SYMBOL	SOIL DESCRIPTION	SOIL SAMPLE			DRILL TYPE
W _p - □	W - ○	W _L - △	PERCENT %						DATUM	CONDITION	TYPE	
10	20	30	40	50	60			SURFACE ELEVATION 223.61				
						1		WATER				
						2						
						3						
						4						
						5						
						6						
						7						
						8						
						9						
						10		ALLUVIAL SOILS				
						11		Drill rod pushed from 10.0 to 10.6 m. Refusal on glacial till or boulder at 10.6 m.				
						12						

Appendix **D**

AECOM 2016 Geotechnical Investigations Test Hole Logs

- AECOM 2016 Geotechnical Investigation Test Hole Logs

AECOM Canada Ltd.

GENERAL STATEMENT

NORMAL VARIABILITY OF SUBSURFACE CONDITIONS























The scope of the investigation presented herein is limited to an investigation of the subsurface conditions as to suitability for the proposed project. This report has been prepared to aid in the evaluation of the site and to assist the engineer in the design of the facilities. Our description of the project represents our understanding of the significant aspects of the project relevant to the design and construction of earth work, foundations and similar. In the event of any changes in the basic design or location of the structures as outlined in this report or plan, we should be given the opportunity to review the changes and to modify or reaffirm in writing the conclusions and recommendations of this report.

The analysis and recommendations presented in this report are based on the data obtained from the borings and test pit excavations made at the locations indicated on the site plans and from other information discussed herein. This report is based on the assumption that the subsurface conditions everywhere are not significantly different from those disclosed by the borings and excavations. However, variations in soil conditions may exist between the excavations and, also, general groundwater levels and conditions may fluctuate from time to time. The nature and extent of the variations may not become evident until construction. If subsurface conditions differ from those encountered in the exploratory borings and excavations, are observed or encountered during construction, or appear to be present beneath or beyond excavations, we should be advised at once so that we can observe and review these conditions and reconsider our recommendations where necessary.

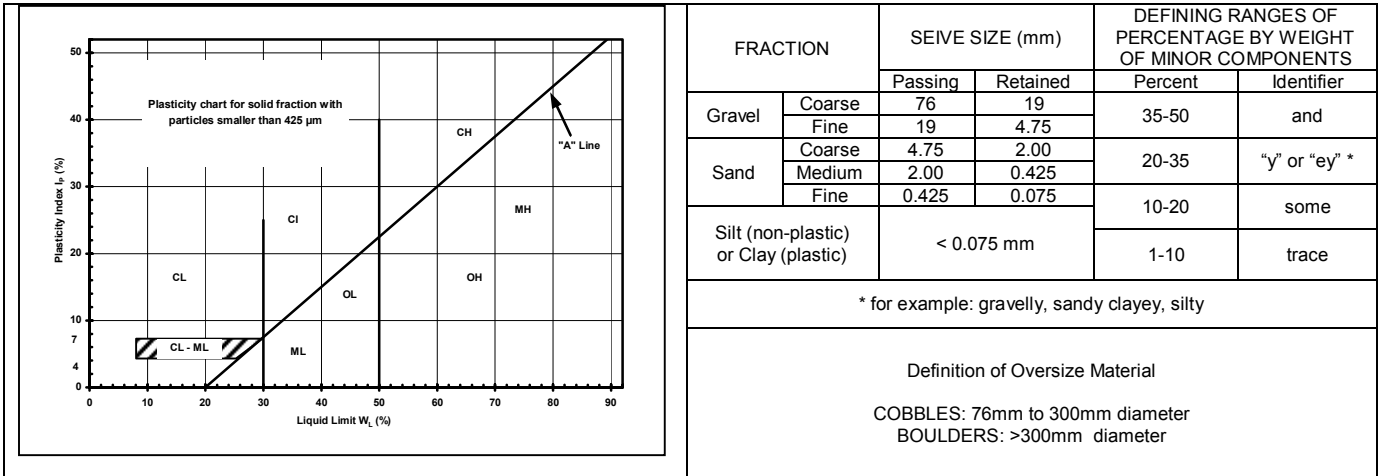
Since it is possible for conditions to vary from those assumed in the analysis and upon which our conclusions and recommendations are based, a contingency fund should be included in the construction budget to allow for the possibility of variations which may result in modification of the design and construction procedures.

In order to observe compliance with the design concepts, specifications or recommendations and to allow design changes in the event that subsurface conditions differ from those anticipated, we recommend that all construction operations dealing with earth work and the foundations be observed by an experienced soils engineer. We can be retained to provide these services for you during construction. In addition, we can be retained to review the plans and specifications that have been prepared to check for substantial conformance with the conclusions and recommendations contained in our report.

EXPLANATION OF FIELD & LABORATORY TEST DATA

Description			AECOM Log Symbols	USCS Classification	Laboratory Classification Criteria				
					Fines (%)	Grading	Plasticity	Notes	
COARSE GRAINED SOILS	GRAVELS (More than 50% of coarse fraction of gravel size)	CLEAN GRAVELS (Little or no fines)	Well graded gravels, sandy gravels, with little or no fines		GW	0-5	$C_u > 4$ $1 < C_c < 3$	Dual symbols if 5-12% fines. Dual symbols if above "A" line and $4 < W_p < 7$ $C_u = \frac{D_{60}}{D_{10}}$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$	
			Poorly graded gravels, sandy gravels, with little or no fines		GP	0-5	Not satisfying GW requirements		
		DIRTY GRAVELS (With some fines)	Silty gravels, silty sandy gravels		GM	> 12			Atterberg limits below "A" line or $W_p < 4$
			Clayey gravels, clayey sandy gravels		GC	> 12			Atterberg limits above "A" line or $W_p < 7$
	SANDS (More than 50% of coarse fraction of sand size)	CLEAN SANDS (Little or no fines)	Well graded sands, gravelly sands, with little or no fines		SW	0-5	$C_u > 6$ $1 < C_c < 3$		
			Poorly graded sands, gravelly sands, with little or no fines		SP	0-5	Not satisfying SW requirements		
		DIRTY SANDS (With some fines)	Silty sands, sand-silt mixtures		SM	> 12			Atterberg limits below "A" line or $W_p < 4$
			Clayey sands, sand-clay mixtures		SC	> 12			Atterberg limits above "A" line or $W_p < 7$
FINE GRAINED SOILS	SILTS (Below 'A' line negligible organic content)	$W_L < 50$	Inorganic silts, silty or clayey fine sands, with slight plasticity		ML		Classification is Based upon Plasticity Chart		
		$W_L > 50$	Inorganic silts of high plasticity		MH				
	CLAYS (Above 'A' line negligible organic content)	$W_L < 30$	Inorganic clays, silty clays, sandy clays of low plasticity, lean clays		CL				
		$30 < W_L < 50$	Inorganic clays and silty clays of medium plasticity		CI				
		$W_L > 50$	Inorganic clays of high plasticity, fat clays		CH				
	ORGANIC SILTS & CLAYS (Below 'A' line)	$W_L < 50$	Organic silts and organic silty clays of low plasticity		OL				
		$W_L > 50$	Organic clays of high plasticity		OH				
	HIGHLY ORGANIC SOILS		Peat and other highly organic soils		Pt	Von Post Classification Limit		Strong colour or odour, and often fibrous texture	
	Asphalt		Till			AECOM			
	Concrete		Bedrock (Undifferentiated)						
	Fill		Bedrock (Limestone)						

When the above classification terms are used in this report or test hole logs, the designated fractions may be visually estimated and not measured.



LEGEND OF SYMBOLS

Laboratory and field tests are identified as follows:

- q_u - undrained shear strength (kPa) derived from unconfined compression testing.
- T_v - undrained shear strength (kPa) measured using a torvane
- pp - undrained shear strength (kPa) measured using a pocket penetrometer.
- L_v - undrained shear strength (kPa) measured using a lab vane.
- F_v - undrained shear strength (kPa) measured using a field vane.
- γ - bulk unit weight (kN/m^3).
- SPT - Standard Penetration Test. Recorded as number of blows (N) from a 63.5 kg hammer dropped 0.76 m (free fall) which is required to drive a 51 mm O.D. Raymond type sampler 0.30 m into the soil.
- DPPT - Drive Point Pentrometer Test. Recorded as number of blows from a 63.5 kg hammer dropped 0.76 m (free fall) which is required to drive a 50 mm drive point 0.30 m into the soil.
- w - moisture content (W_L, W_P)

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

S_u (kPa)	CONSISTENCY
<12	very soft
12 – 25	soft
25 – 50	medium or firm
50 – 100	stiff
100 – 200	very stiff
200	hard

The resistance (N) of a non-cohesive soil can be related to compactness condition as follows

N – BLOWS/0.30 m	COMPACTNESS
0 - 4	very loose
4 - 10	loose
10 - 30	compact
30 - 50	dense
50	very dense

PROJECT: Northeast Interceptor Sewer River Crossing CLIENT: City of Winnipeg TESTHOLE NO: TH16-01
 LOCATION: 14 U - 5534868 m N, 636362 m E PROJECT NO.: 60509089
 CONTRACTOR: Maple Leaf Drilling Ltd. METHOD: Acker Renegade, 125 mm SSA/HQ Barrel ELEVATION (m): 227.03

SAMPLE TYPE GRAB SHELBY TUBE SPLIT SPOON BULK NO RECOVERY CORE

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS		UNDRAINED SHEAR STRENGTH	COMMENTS	ELEVATION
						Becker	Dynamic Cone			
0		CLAY - silty, trace sand - dark brown, firm, dry to moist - intermediate plasticity		G40						
1		SILT - some clay to clayey, trace to some sand - dark brown, soft to firm, moist - low to intermediate plasticity		G41						226
2		SAND - clayey, silty - brown, loose to compact, moist to wet - fine to medium grained		G42						225
3		- very loose below 3.0 m		G43A						224
3				S43	3				SPT Blows: [1/1/2], Spoon Recovery: 0%	
4				G44						223
5		- dark grey mottling below 4.4 m SAND - some clay, some silt - dark grey, very loose, moist to wet - fine to medium grained		S45	1				SPT Blows: [0/0/1], Spoon Recovery: 100%	222
6		CLAY - silty, some sand - dark grey, very soft to soft, moist - intermediate plasticity - moist to wet below 5.8 m		G46						221
6				G47						221
7		SAND - clayey, silty - dark grey, loose, moist to wet - fine to medium grained		G48						220
7				G49						219
8										218
9		(T50): Gravel 0.0%, Sand 39.1%, Silt 33.0%, Clay 28.0%		T50					Tube Recovery: 83%	
10		- clayey, silty below 9.8 m								

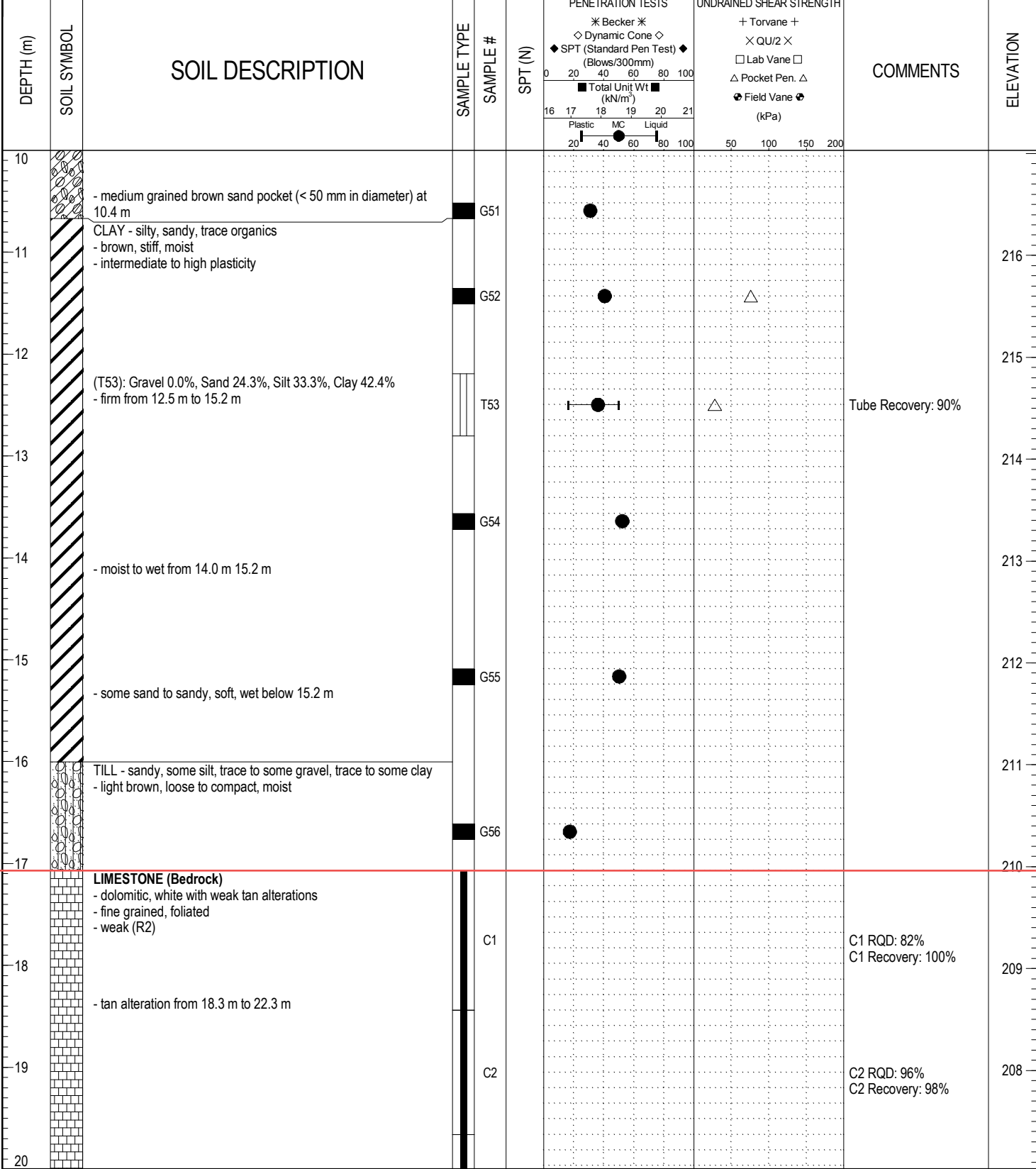
LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UMA WINN.GDT 11/18/16



LOGGED BY: Ryan Harras COMPLETION DEPTH: 25.76 m
 REVIEWED BY: Omer Eissa COMPLETION DATE: 8/24/16
 PROJECT ENGINEER: Adam Braun Page 1 of 3

PROJECT: Northeast Interceptor Sewer River Crossing CLIENT: City of Winnipeg TESTHOLE NO: **TH16-01**
 LOCATION: 14 U - 5534868 m N, 636362 m E PROJECT NO.: 60509089
 CONTRACTOR: Maple Leaf Drilling Ltd. METHOD: Acker Renegade, 125 mm SSA/HQ Barrel ELEVATION (m): 227.03

SAMPLE TYPE GRAB SHELBY TUBE SPLIT SPOON BULK NO RECOVERY CORE



LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UWA WINN.GDT 11/18/16



LOGGED BY: Ryan Harras COMPLETION DEPTH: 25.76 m
 REVIEWED BY: Omer Eissa COMPLETION DATE: 8/24/16
 PROJECT ENGINEER: Adam Braun Page 2 of 3

PROJECT: Northeast Interceptor Sewer River Crossing CLIENT: City of Winnipeg TESTHOLE NO: TH16-01
 LOCATION: 14 U - 5534868 m N, 636362 m E PROJECT NO.: 60509089
 CONTRACTOR: Maple Leaf Drilling Ltd. METHOD: Acker Renegade, 125 mm SSA/HQ Barrel ELEVATION (m): 227.03

SAMPLE TYPE GRAB SHELBY TUBE SPLIT SPOON BULK NO RECOVERY CORE

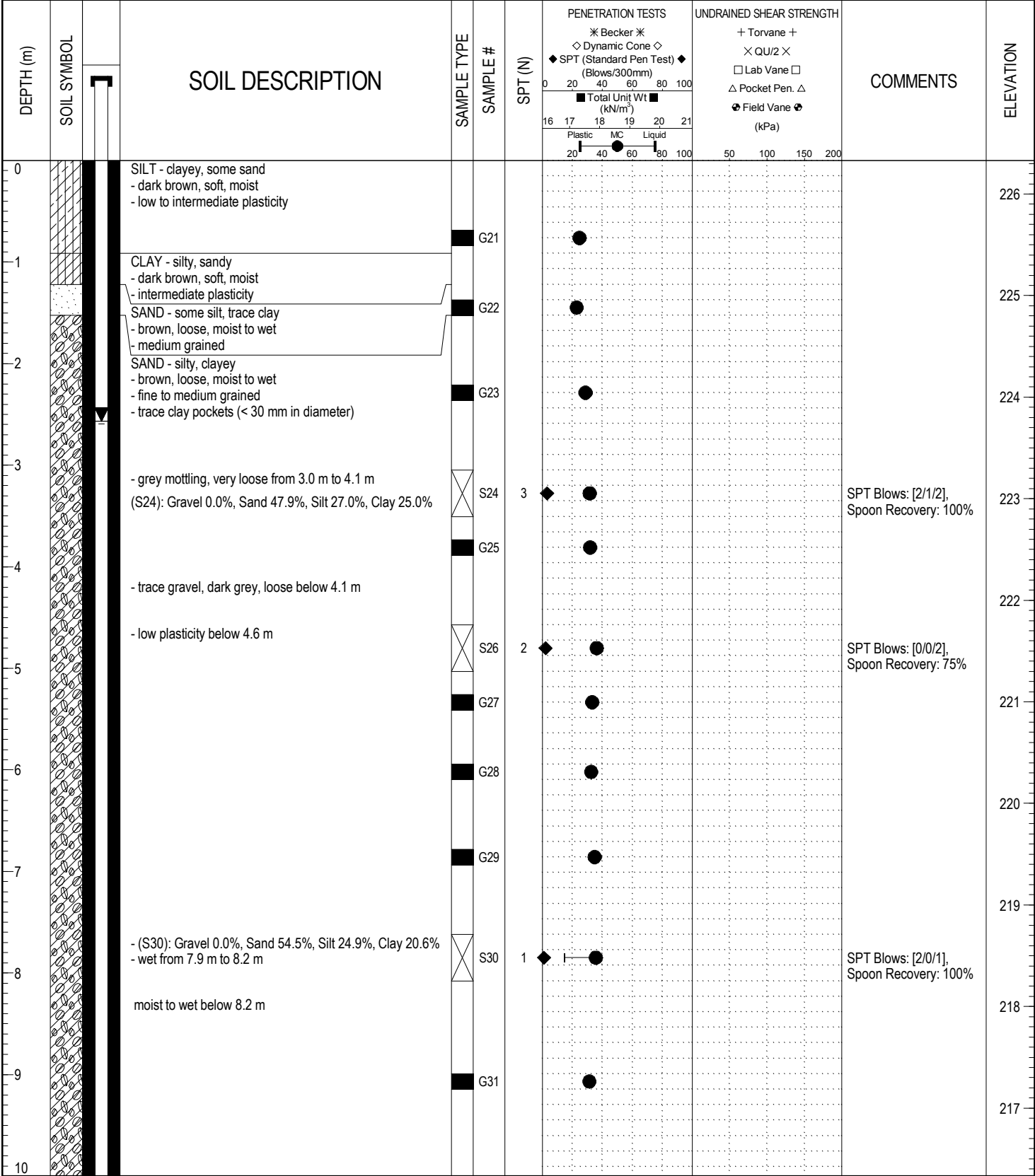
DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS		UNDRAINED SHEAR STRENGTH		COMMENTS	ELEVATION
						* Becker * ◇ Dynamic Cone ◇ ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) ■ Total Unit Wt ■ (kN/m ³)	+ Torvane + × QU/2 × □ Lab Vane □ △ Pocket Pen. △ ⊕ Field Vane ⊕ (kPa)				
20				C3						C3 RQD: 87% C3 Recovery: 95%	206
21											
22				C4						C4 RQD: 100% C4 Recovery: 100%	205
23											
24				C5						C5 RQD: 79% C5 Recovery: 99%	204
25				C6						C6 RQD: 98% C6 Recovery: 98%	202
26		END OF TEST HOLE AT 25.76 m IN BEDROCK NOTES: 1. Seepage not observed. 2. Sloughing observed below 15.2 m. 3. Auger refusal met at 17.1 m on bedrock. 4. HQ coring below 17.1 m. 5. Test hole backfilled with bentonite-grout mix upon completion.									201
27											200
28											199
29											198
30											

LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UJMA WINN.GDT 11/18/16



LOGGED BY: Ryan Harras COMPLETION DEPTH: 25.76 m
 REVIEWED BY: Omer Eissa COMPLETION DATE: 8/24/16
 PROJECT ENGINEER: Adam Braun Page 3 of 3

PROJECT: Northeast Interceptor Sewer River Crossing		CLIENT: City of Winnipeg		TESTHOLE NO: TH16-02			
LOCATION: 14 U - 5534859 m N, 636384 m E				PROJECT NO.: 60509089			
CONTRACTOR: Maple Leaf Drilling Ltd.			METHOD: Acker Renegade, 125 mm SSA/HQ Barrel		ELEVATION (m): 226.33		
SAMPLE TYPE		GRAB	SHELBY TUBE	SPLIT SPOON	BULK	NO RECOVERY	CORE
BACKFILL TYPE		BENTONITE	GRAVEL	SLOUGH	GROUT	CUTTINGS	SAND

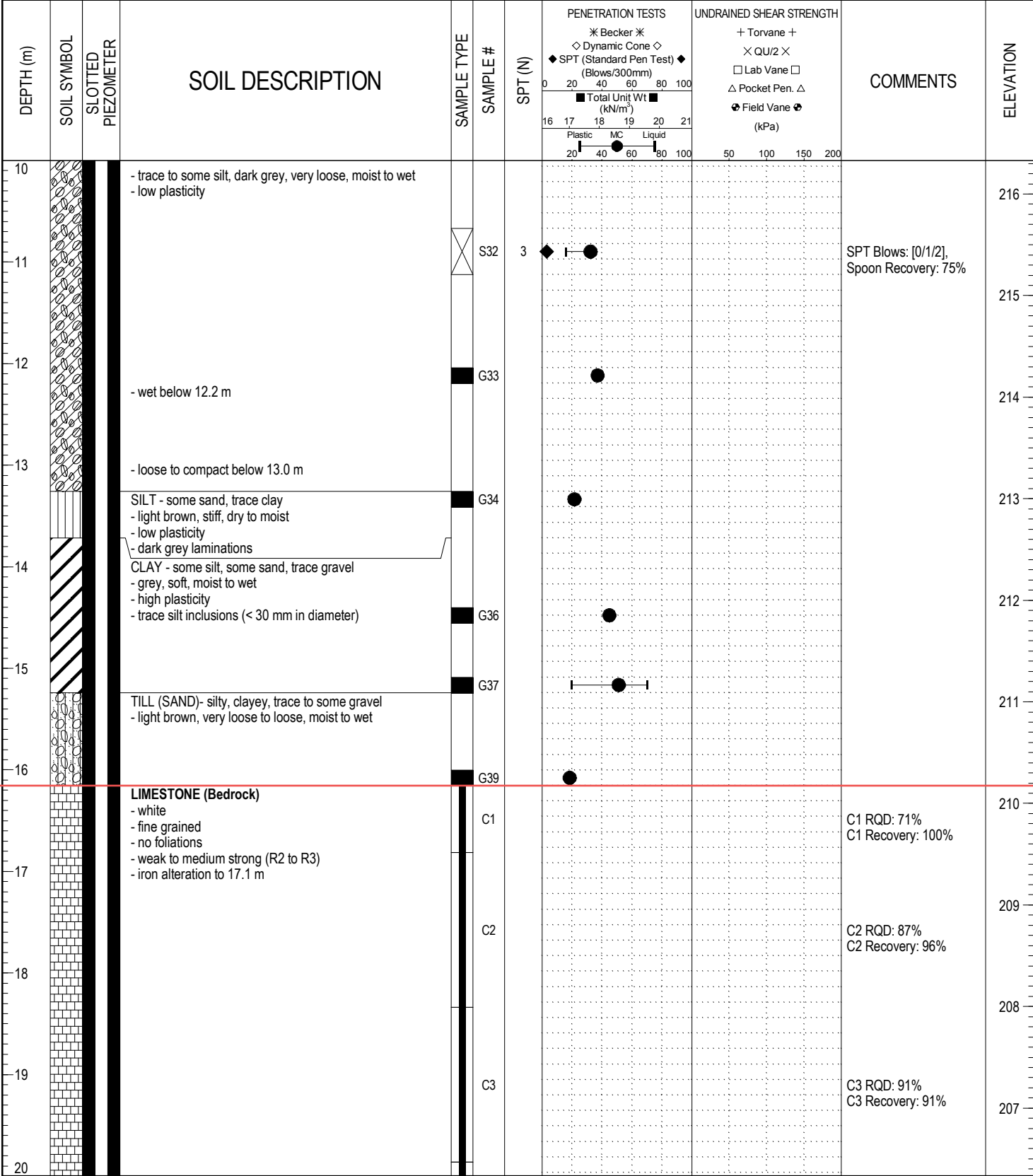


LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UJMA WINN.GDT 11/18/16



LOGGED BY: Ryan Harras	COMPLETION DEPTH: 25.96 m
REVIEWED BY: Omer Eissa	COMPLETION DATE: 8/23/16
PROJECT ENGINEER: Adam Braun	Page 1 of 3

PROJECT: Northeast Interceptor Sewer River Crossing CLIENT: City of Winnipeg TESTHOLE NO: TH16-02
 LOCATION: 14 U - 5534859 m N, 636384 m E PROJECT NO.: 60509089
 CONTRACTOR: Maple Leaf Drilling Ltd. METHOD: Acker Renegade, 125 mm SSA/HQ Barrel ELEVATION (m): 226.33
 SAMPLE TYPE GRAB SHELBY TUBE SPLIT SPOON BULK NO RECOVERY CORE
 BACKFILL TYPE BENTONITE GRAVEL SLOUGH GROUT CUTTINGS SAND



LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UMA WINN.GDT 11/18/16



LOGGED BY: Ryan Harras COMPLETION DEPTH: 25.96 m
 REVIEWED BY: Omer Eissa COMPLETION DATE: 8/23/16
 PROJECT ENGINEER: Adam Braun Page 2 of 3

PROJECT: Northeast Interceptor Sewer River Crossing	CLIENT: City of Winnipeg	TESTHOLE NO: TH16-02
LOCATION: 14 U - 5534859 m N, 636384 m E	PROJECT NO.: 60509089	
CONTRACTOR: Maple Leaf Drilling Ltd.	METHOD: Acker Renegade, 125 mm SSA/HQ Barrel	ELEVATION (m): 226.33
SAMPLE TYPE <input checked="" type="checkbox"/> GRAB <input type="checkbox"/> SHELBY TUBE <input type="checkbox"/> SPLIT SPOON <input type="checkbox"/> BULK <input type="checkbox"/> NO RECOVERY <input type="checkbox"/> CORE		
BACKFILL TYPE <input checked="" type="checkbox"/> BENTONITE <input type="checkbox"/> GRAVEL <input type="checkbox"/> SLOUGH <input type="checkbox"/> GROUT <input type="checkbox"/> CUTTINGS <input type="checkbox"/> SAND		

DEPTH (m)	SOIL SYMBOL	SLOTTED PIEZOMETER	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS	UNDRAINED SHEAR STRENGTH	COMMENTS	ELEVATION
20							* Becker * ◇ Dynamic Cone ◇ ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) 0 20 40 60 80 100 ■ Total Unit Wt ■ (kN/m ³) 16 17 18 19 20 21 Plastic MC Liquid 20 40 60 80 100	+ Torvane + × QU/2 × □ Lab Vane □ △ Pocket Pen. △ ⊕ Field Vane ⊕ (kPa) 50 100 150 200		206
21					C4				C4 RQD: 96% C4 Recovery: 99%	205
22					C5				C5 RQD: 93% C5 Recovery: 100%	204
23					C6				C6 RQD: 96% C6 Recovery: 100%	203
24					C7				C7 RQD: 99% C7 Recovery: 99%	202
25										201
26			END OF TEST HOLE AT 25.96 m IN BEDROCK							200
27			NOTES: 1. Seepage observed at 4.6 m. 2. Water at 4.0 m upon removal of auger. 3. Sloughing observed below 10.7 m. 4. Auger refusal met at 16.2 m on bedrock. 5. HQ coring below 16.2 m. 6. Standpipe piezometer installed at depth of 25.8 m. 7. Groundwater monitoring: - August 24, 2016 at 2.49 m below ground surface - September 23, 2016 at 2.84 m below ground surface - November 18, 2016 at 2.57 m below ground surface							199
28										198
29										197
30										196

LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UMA WINN.GDT 11/18/16



LOGGED BY: Ryan Harras	COMPLETION DEPTH: 25.96 m
REVIEWED BY: Omer Eissa	COMPLETION DATE: 8/23/16
PROJECT ENGINEER: Adam Braun	Page 3 of 3

PROJECT: Northeast Interceptor Sewer River Crossing CLIENT: City of Winnipeg TESTHOLE NO: **TH16-03**
 LOCATION: 14 U - 5534783 m N, 636494 m E PROJECT NO.: 60509089
 CONTRACTOR: Maple Leaf Drilling Ltd. METHOD: Floating Barge, Cricket B20, BQ Barrel ELEVATION (m): 223.80

SAMPLE TYPE GRAB SHELBY TUBE SPLIT SPOON BULK NO RECOVERY CORE

DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS		UNDRAINED SHEAR STRENGTH	COMMENTS	ELEVATION
						* Becker * ◇ Dynamic Cone ◇ ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) ■ Total Unit Wt (kN/m ³)	+ Torvane + × QU/2 × □ Lab Vane □ △ Pocket Pen. △ ⊕ Field Vane ⊕ (kPa)			
0		WATER								223
1										222
2										221
3										220
4										219
5										218
6										217
7		SAND (Alluvial) - some gravel - brown, compact, wet								216
8			×	S1	16	◆			SPT Blows [4/6/10], Spoon Recovery 10%	215
9			×	S2	19	◆			SPT Blows [18/12/7], Spoon Recovery 0%	214
10										213
11		CLAY - trace silt - grey, very soft, moist to wet - high plasticity	×	S3	2	◆			SPT Blows [2/1/1], Spoon Recovery 10%	212
12		TILL (SAND) - silty, some clay, trace gravel - light brown, loose, wet - low plasticity	×	S4-A S4-B	5	◆ ● ●			SPT Blows [1/2/3], Spoon Recovery 100%	211
13		- sandy, compact, no plasticity below 13.2 m	×	S5	19	◆			SPT Blows [8/10/9], Spoon Recovery 0%	210
14		LIMESTONE (Bedrock) - white/brown - fine grained - weak to medium strong (R2 to R3) - no foliations								209
15				C1					C1 RQD: 83% C1 Recovery: 94%	208
16				C2					C2 RQD: 89% C2 Recovery: 100%	207
17				C3					C3 RQD: 94% C3 Recovery: 100%	206

LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UWA WINN.GDT 11/18/16



LOGGED BY: Mustafa Alkiki COMPLETION DEPTH: 30.51 m
 REVIEWED BY: Omer Eissa COMPLETION DATE: 9/9/16
 PROJECT ENGINEER: Adam Braun Page 1 of 2

PROJECT: Northeast Interceptor Sewer River Crossing CLIENT: City of Winnipeg TESTHOLE NO: **TH16-03**
 LOCATION: 14 U - 5534783 m N, 636494 m E PROJECT NO.: 60509089
 CONTRACTOR: Maple Leaf Drilling Ltd. METHOD: Floating Barge, Cricket B20, BQ Barrel ELEVATION (m): 223.80

SAMPLE TYPE GRAB SHELBY TUBE SPLIT SPOON BULK NO RECOVERY CORE

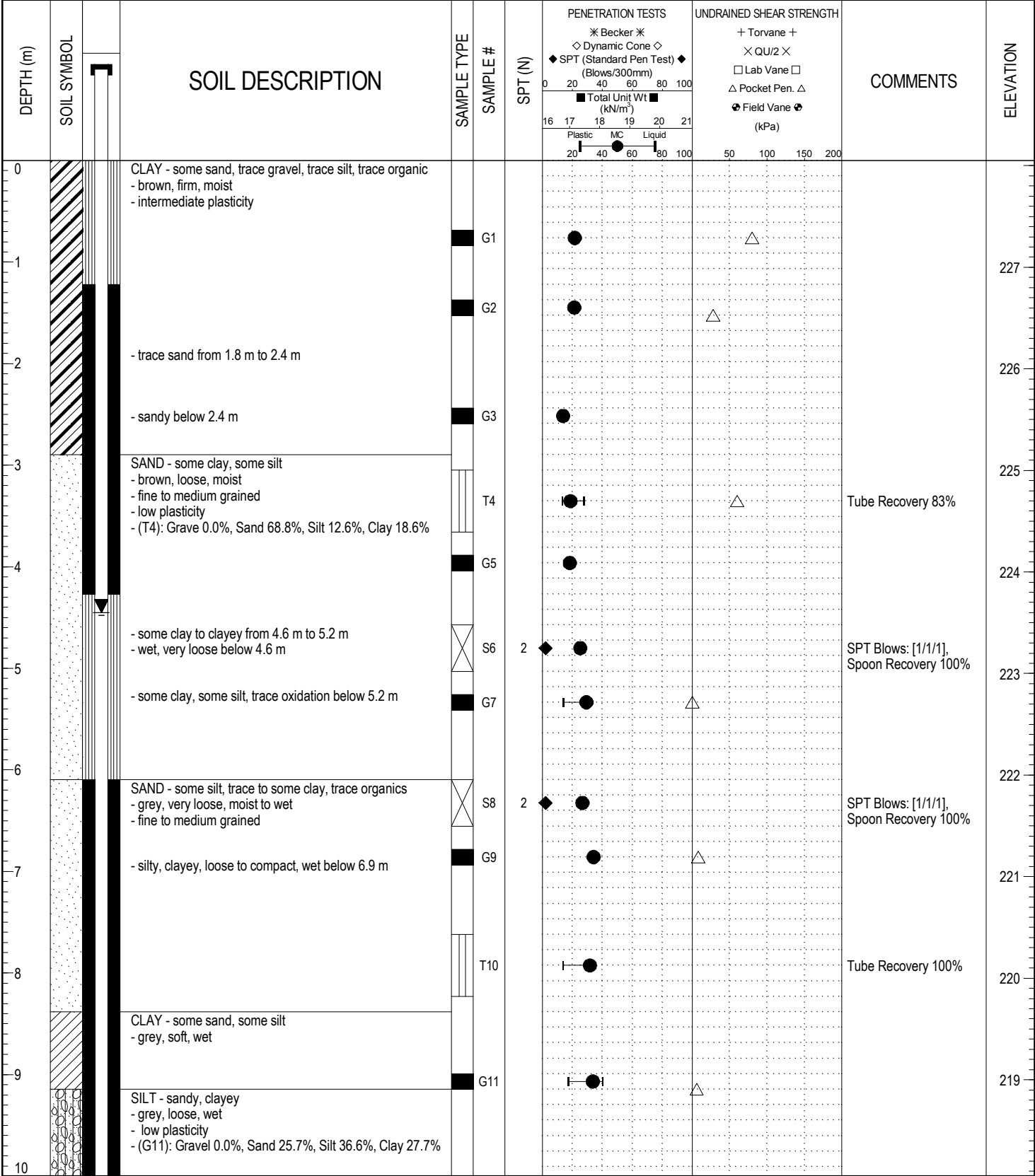
DEPTH (m)	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS		UNDRAINED SHEAR STRENGTH		COMMENTS	ELEVATION
						* Becker * ◇ Dynamic Cone ◇ ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) ■ Total Unit Wt (kN/m ³)	+ Torvane + × QU/2 × □ Lab Vane □ △ Pocket Pen. △ ⊕ Field Vane ⊕ (kPa)				
18		- tan to yellow, solution pitting, altered from 18.2 m to 20.9 m									205
19				C4						C4 RQD: 27% C4 Recovery: 36%	204
20				C5						C5 RQD: 62% C5 Recovery: 89%	203
21				C6						C6 RQD: 39% C6 Recovery: 98%	202
22		LIMESTONE (Bedrock) - tan/white - fine grained, - medium strong (R3) - increased foliation		C7						C7 RQD: 33% C7 Recovery: 97%	201
23				C8						C8 RQD: 80% C8 Recovery: 96%	200
24				C9						C9 RQD: 68% C9 Recovery: 99%	199
25				C10						C10 RQD: 73% C10 Recovery: 100%	198
26				C11						C11 RQD: 87% C11 Recovery: 99%	197
27											196
28											195
29											194
30											193
31		END OF TEST HOLE AT 30.51 m IN LIMESTONE (BEDROCK)									192
32		NOTES: 1. Test hole drilled in-water by floating barge using NQ casing to 13.8 m below water surface then switched to BQ core barrel. 2. Test hole backfilled with coated enviroplug to river bed. 3. Water elevation is based on COW data recorded on September 8, 2016.									191
33											190
34											189
35											188
36											188

LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UMA WINN.GDT 11/18/16



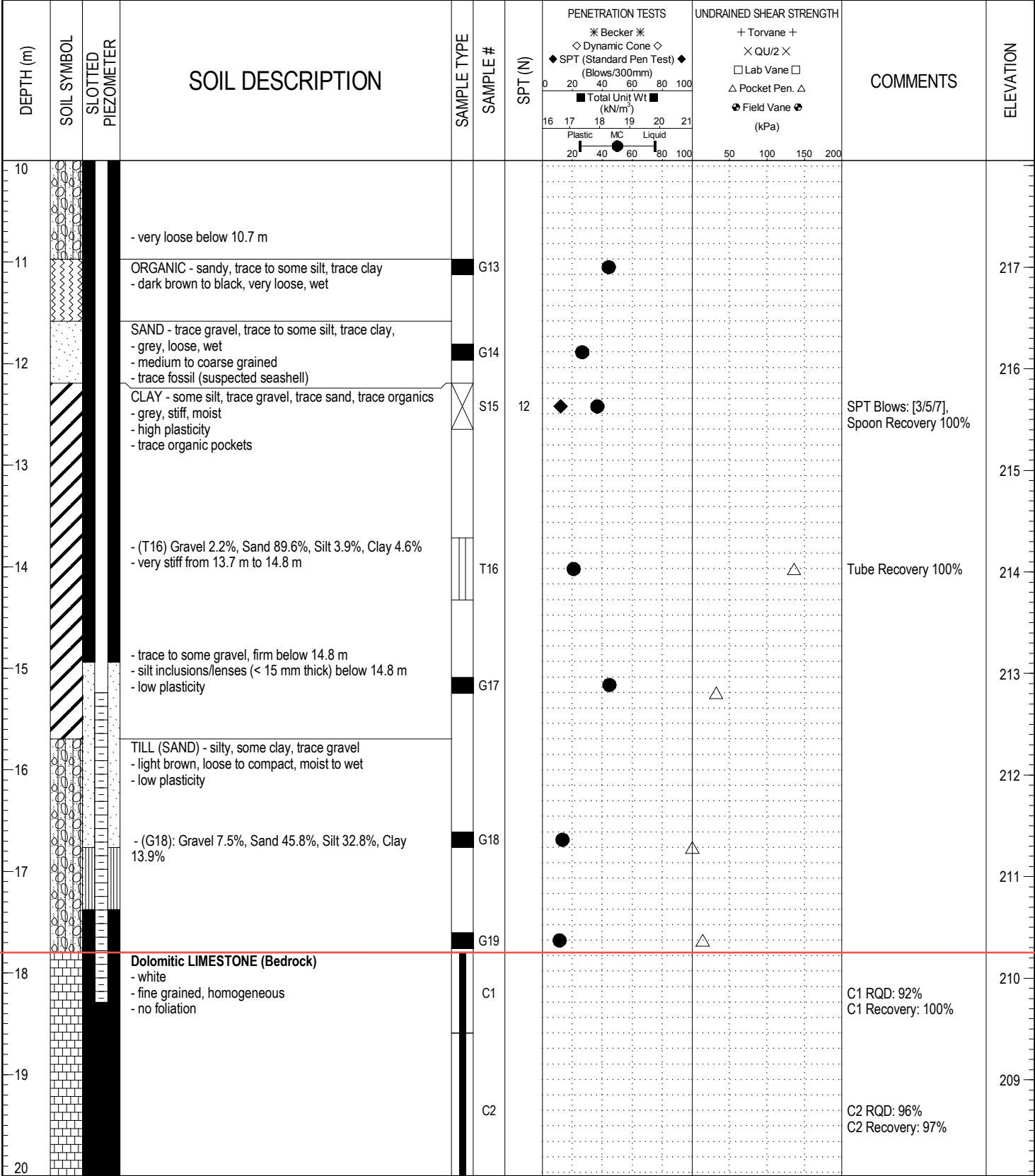
LOGGED BY: Mustafa Alkiki COMPLETION DEPTH: 30.51 m
 REVIEWED BY: Omer Eissa COMPLETION DATE: 9/9/16
 PROJECT ENGINEER: Adam Braun Page 2 of 2

PROJECT: Northeast Interceptor Sewer River Crossing		CLIENT: City of Winnipeg		TESTHOLE NO: TH16-04		
LOCATION: 14 U - 5534787 m N, 636578 m E				PROJECT NO.: 60509089		
CONTRACTOR: Maple Leaf Drilling Ltd.			METHOD: B54X, 125 mm SSA/NQ Barrel		ELEVATION (m): 228.05	
SAMPLE TYPE	GRAB	SHELBY TUBE	SPLIT SPOON	BULK	NO RECOVERY	CORE
BACKFILL TYPE	BENTONITE	GRAVEL	SLOUGH	GROUT	CUTTINGS	SAND



LOGGED BY: Sam Oshati	COMPLETION DEPTH: 27.74 m
REVIEWED BY: Omer Eissa	COMPLETION DATE: 8/19/16
PROJECT ENGINEER: Adam Braun	Page 1 of 3

PROJECT: Northeast Interceptor Sewer River Crossing		CLIENT: City of Winnipeg		TESTHOLE NO: TH16-04		
LOCATION: 14 U - 5534787 m N, 636578 m E				PROJECT NO.: 60509089		
CONTRACTOR: Maple Leaf Drilling Ltd.			METHOD: B54X, 125 mm SSA/NQ Barrel		ELEVATION (m): 228.05	
SAMPLE TYPE	GRAB	SHELBY TUBE	SPLIT SPOON	BULK	NO RECOVERY	CORE
BACKFILL TYPE	BENTONITE	GRAVEL	SLOUGH	GROUT	CUTTINGS	SAND



LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UMA WINN.GDT 11/18/16



LOGGED BY: Sam Oshati	COMPLETION DEPTH: 27.74 m
REVIEWED BY: Omer Eissa	COMPLETION DATE: 8/19/16
PROJECT ENGINEER: Adam Braun	Page 2 of 3

PROJECT: Northeast Interceptor Sewer River Crossing		CLIENT: City of Winnipeg		TESTHOLE NO: TH16-04		
LOCATION: 14 U - 5534787 m N, 636578 m E				PROJECT NO.: 60509089		
CONTRACTOR: Maple Leaf Drilling Ltd.			METHOD: B54X, 125 mm SSA/NQ Barrel		ELEVATION (m): 228.05	
SAMPLE TYPE	<input checked="" type="checkbox"/> GRAB	<input type="checkbox"/> SHELBY TUBE	<input checked="" type="checkbox"/> SPLIT SPOON	<input type="checkbox"/> BULK	<input type="checkbox"/> NO RECOVERY	<input type="checkbox"/> CORE
BACKFILL TYPE	<input checked="" type="checkbox"/> BENTONITE	<input type="checkbox"/> GRAVEL	<input type="checkbox"/> SLOUGH	<input type="checkbox"/> GROUT	<input type="checkbox"/> CUTTINGS	<input type="checkbox"/> SAND

DEPTH (m)	SOIL SYMBOL	SLOTTED PIEZOMETER	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	SPT (N)	PENETRATION TESTS		UNDRAINED SHEAR STRENGTH		COMMENTS	ELEVATION
							* Becker * ◇ Dynamic Cone ◇ ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) 0 20 40 60 80 100 ■ Total Unit Wt ■ (kN/m ³) 16 17 18 19 20 21 Plastic MC Liquid 20 40 60 80 100	+ Torvane + × QU/2 × <input type="checkbox"/> Lab Vane <input type="checkbox"/> △ Pocket Pen. △ ⊕ Field Vane ⊕ (kPa) 50 100 150 200				
20												
21					C3						C3 RQD: 86% C3 Recovery: 97%	207
22			- clay filled seam from 22.2 m to 22.8 m		C4						C4 RQD: 75% C4 Recovery: 85%	206
23												205
24			LIMESTONE (Bedrock) - mottled tan-grey/white - fine grained, R2 to R3 - weak to medium strong - foliated		C5						C5 RQD: 81% C5 Recovery: 100%	204
25												203
26					C6						C6 RQD: 98% C6 Recovery: 100%	202
27					C7						C7 RQD: 95% C7 Recovery: 100%	201
28			END OF TEST HOLE AT 27.74 m IN BEDROCK NOTES: 1. Seepage not observed. 2. Auger refusal met at 17.8 m on bedrock. 3. HQ coring below 17.8 m. 4. Standpipe piezometer installed at 18.3 m. 5. Groundwater monitoring: - August 23, 2016 at 4.29 m below ground surface - September 23, 2016 at 4.58 m below ground surface - November 18, 2016 at 4.45 m below ground surface									200
29												199
30												

LOG OF TEST HOLE 60509089 - TEST HOLE LOGS.GPJ UMA WINN.GDT 11/18/16



LOGGED BY: Sam Oshati	COMPLETION DEPTH: 27.74 m
REVIEWED BY: Omer Eissa	COMPLETION DATE: 8/19/16
PROJECT ENGINEER: Adam Braun	Page 3 of 3

Appendix **E**

Geotechnical Laboratory Reports

- E-1: AECOM 2017 Geotechnical Testing Results
- E-2a: TREK Geotechnical 2014 Geotechnical Soil Testing Results
- E-2b: TREK Geotechnical 2014 Geotechnical Rock Testing Results
- E-3: Dyregrov and Burgess 1988 Geotechnical Testing Results

Memorandum

To Omer Eissa Page 1

CC

Subject City of Winnipeg – North East Interceptor – Materials Testing Results

From Zeyad Shukri

Date September 22, 2016 Project Number 60509089.100

Please find attached the following material test result(s) on sample(s) submitted to the Winnipeg Geotechnical Laboratory:

- Fifty-four (54) Moisture Content tests.
- Twelve (12) Atterberg Limits (3 points) tests.
- Eight (8) Grain Size Distribution (hydrometer) tests.

If you have any questions, please contact the undersigned.

Sincerely,



Zeyad Shukri Al-Hayazai, M.Sc., P.Eng.
Senior Geotechnical Engineer

Att.



AECOM Canada Ltd.
 Winnipeg Geotechnical Laboratory
 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381

Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-01
 Sample Depth: 6.10 - 6.25 m
 Sample Number: G47

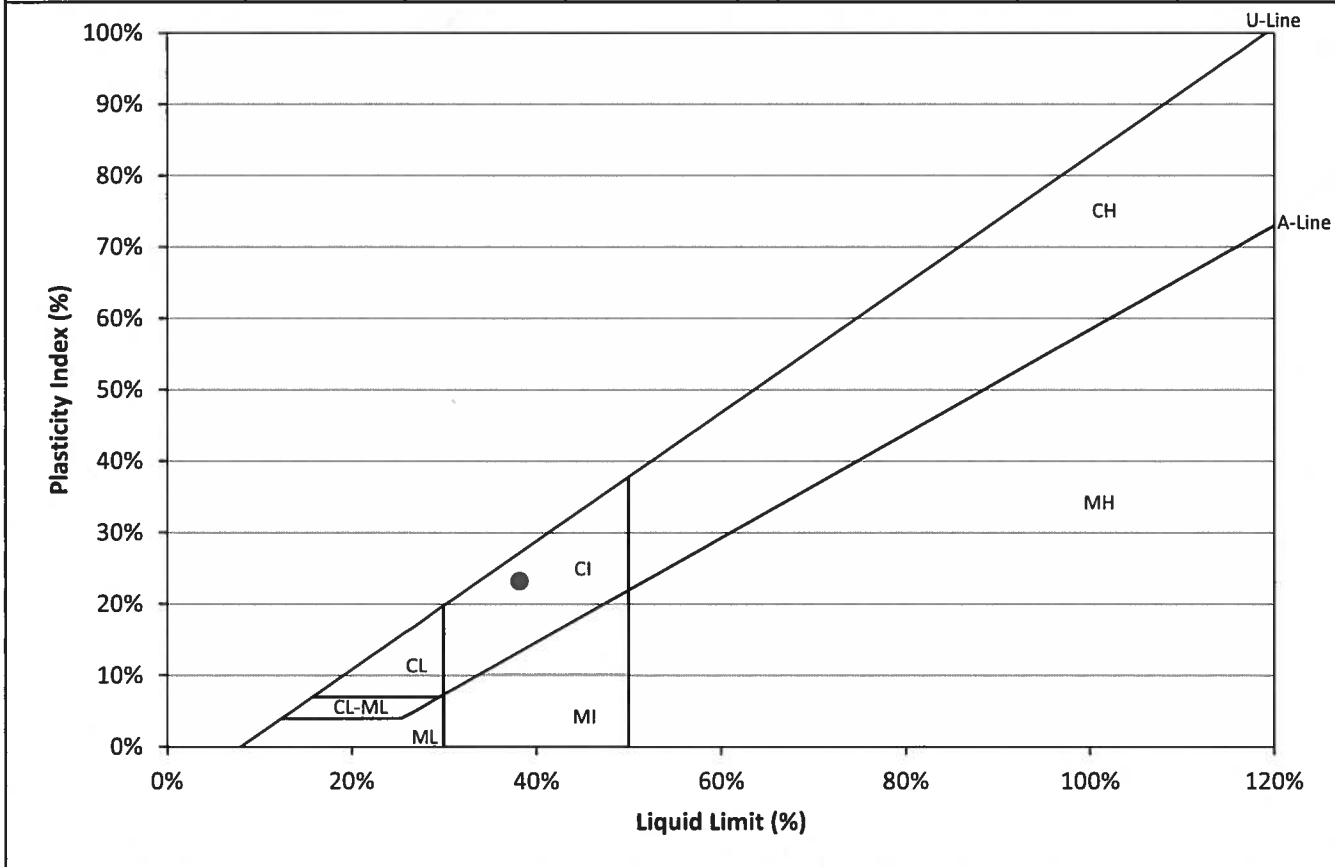
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 20, 2016

Atterberg Limits (ASTM D4318)

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	31	22	18
Wet Sample (g)	7.4	7.1	6.8
Dry Sample (g)	5.4	5.2	4.9
Water Content (%)	37.1%	38.7%	39.6%

Plastic Limit		
Trial	1	2
Wet Sample (g)	6.7	8.1
Dry Sample (g)	5.8	7.0
Water Content (%)	14.9%	15.1%



Liquid Limit (%): 38.2% Plastic Limit (%): 15.0% Plasticity Index (%): 23.2%



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 Winnipeg Geotechnical Laboratory
 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381

Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-01
 Sample Depth: 9.14 - 9.75 m
 Sample Number: T50

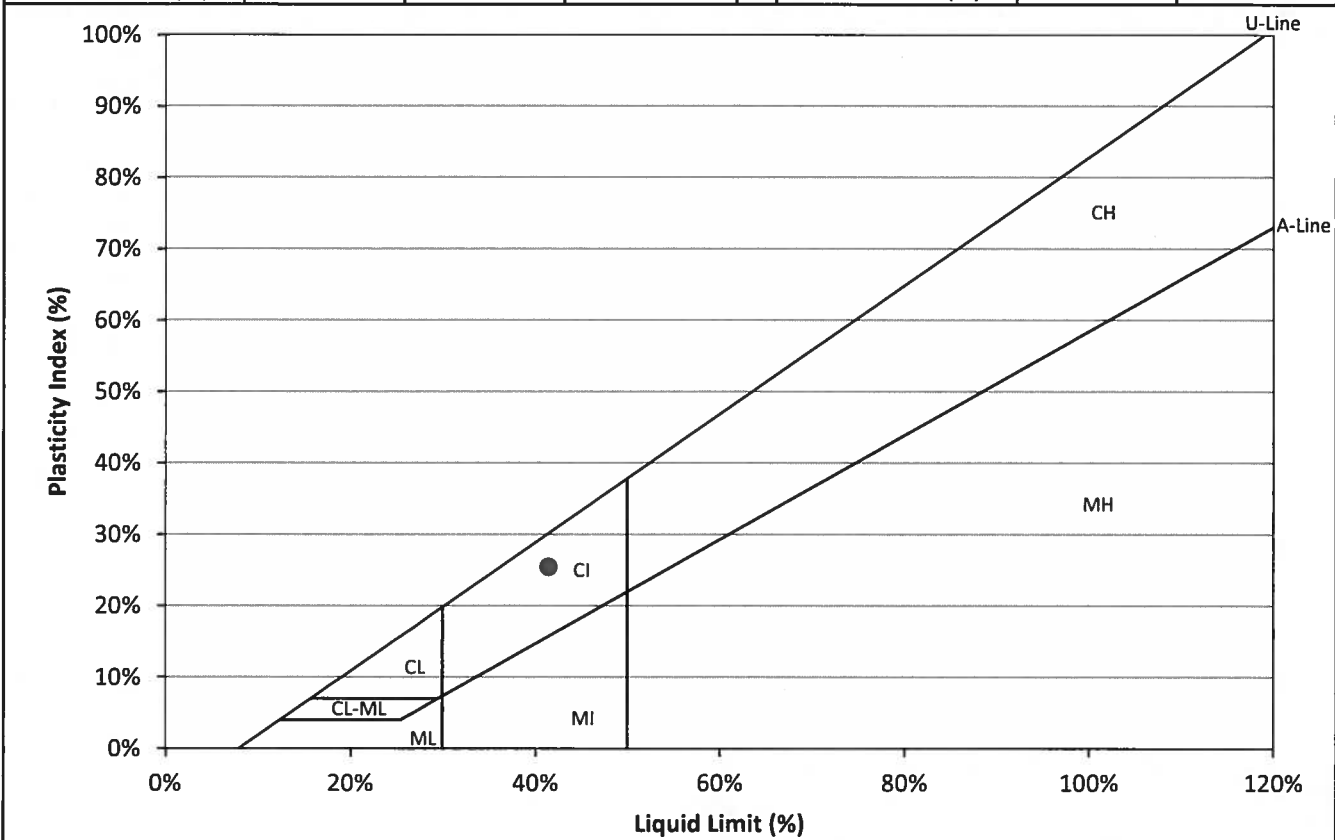
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 20, 2016

Atterberg Limits (ASTM D4318)

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	33	24	19
Wet Sample (g)	6.4	8.3	8.5
Dry Sample (g)	4.5	5.9	6.0
Water Content (%)	40.6%	41.7%	42.4%

Plastic Limit		
Trial	1	2
Wet Sample (g)	7.7	7.1
Dry Sample (g)	6.7	6.1
Water Content (%)	15.9%	16.2%



Liquid Limit (%): 41.5%	Plastic Limit (%): 16.0%	Plasticity Index (%): 25.4%
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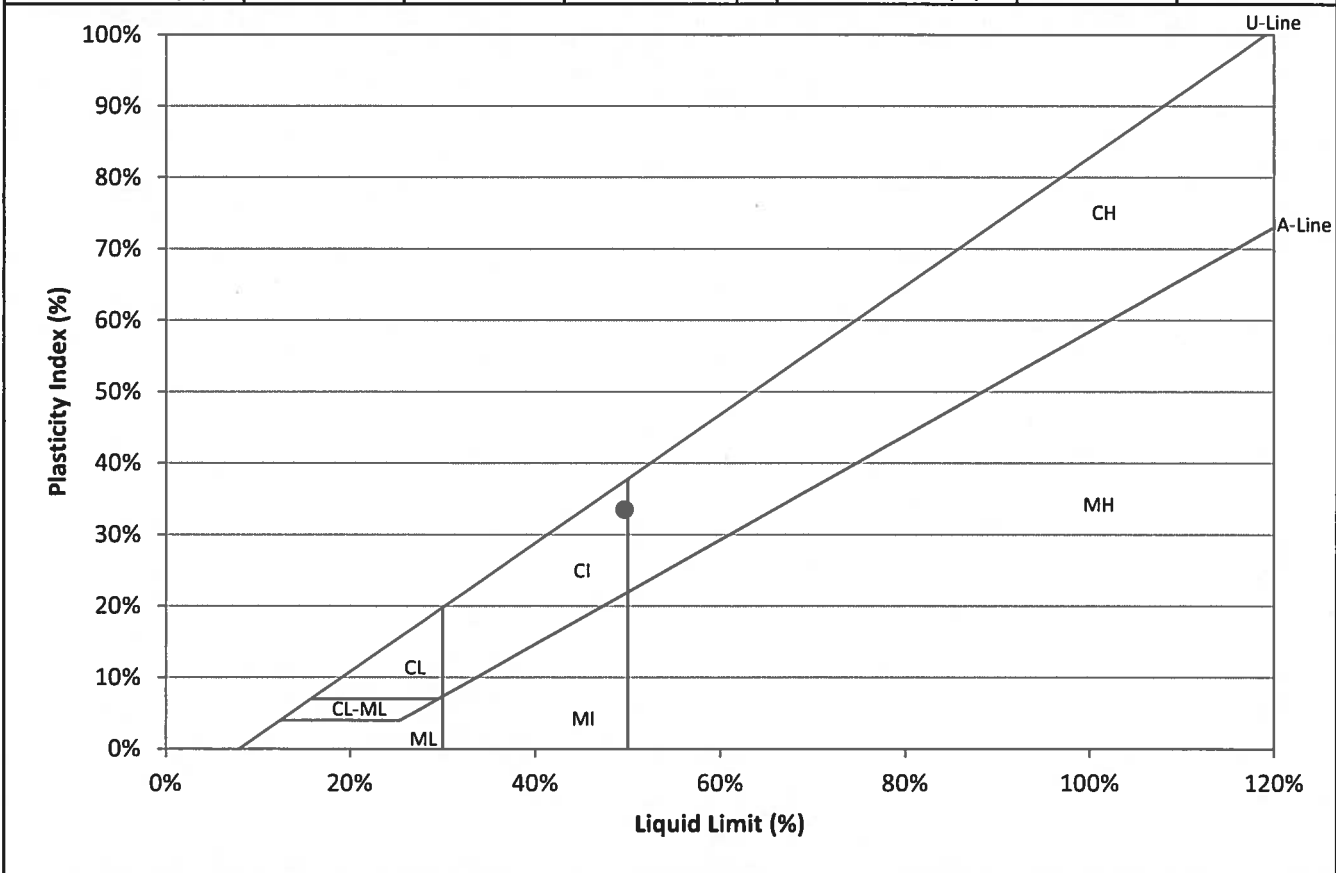
AECOM Canada Ltd.
 Winnipeg Geotechnical Laboratory
 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381 Fax: 204 284 2040

Project Name:	North East Interceptor	Supplier:	AECOM
Project Number:	60509089	Specification:	N/A
Client:	City of Winnipeg	Field Technician:	RHarras
Sample Location:	TH16-01	Sample Date:	Varies
Sample Depth:	12.19 - 12.80 m	Lab Technician:	EManimbao
Sample Number:	T53	Date Tested:	September 20, 2016

Atterberg Limits (ASTM D4318)

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit				Plastic Limit		
Blows	33	29	21	Trial	1	2
Wet Sample (g)	7.5	7.7	8.1	Wet Sample (g)	8.3	8.6
Dry Sample (g)	5.1	5.2	5.4	Dry Sample (g)	7.2	7.4
Water Content (%)	48.1%	48.8%	50.7%	Water Content (%)	16.0%	16.3%



Liquid Limit (%): 49.7%	Plastic Limit (%): 16.2%	Plasticity Index (%): 33.5%
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 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381

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Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-02
 Sample Depth: 15.24 - 15.39 m
 Sample Number: G37

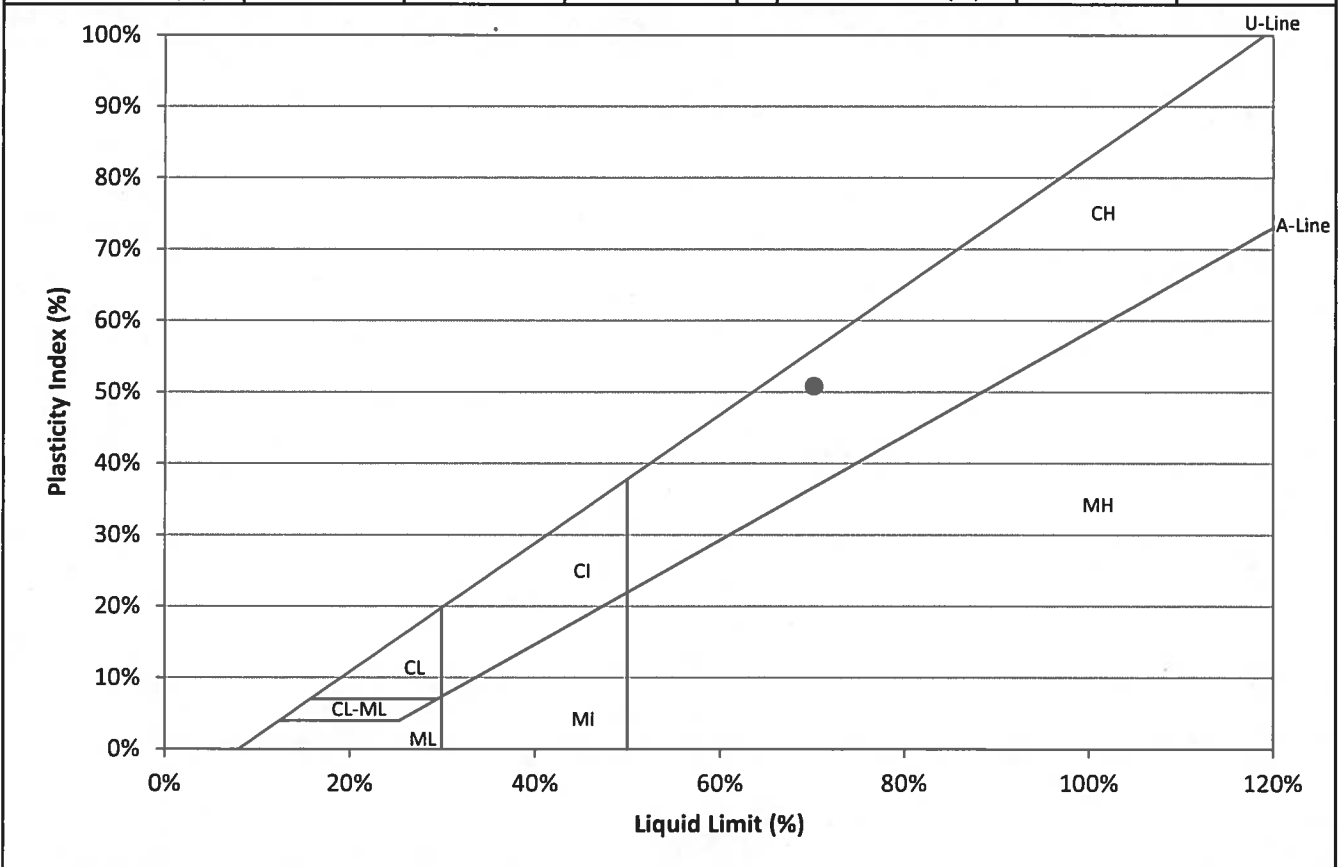
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 20, 2016

Atterberg Limits (ASTM D4318)

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

	Liquid Limit		
Blows	30	22	18
Wet Sample (g)	6.5	7.7	6.8
Dry Sample (g)	3.9	4.5	4.0
Water Content (%)	69.2%	70.9%	72.1%

	Plastic Limit	
Trial	1	2
Wet Sample (g)	6.6	8.5
Dry Sample (g)	5.5	7.1
Water Content (%)	19.1%	19.6%



Liquid Limit (%): 70.2%	Plastic Limit (%): 19.4%	Plasticity Index (%): 50.8%
-------------------------	--------------------------	-----------------------------



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 99 Commerce Drive
 Winnipeg, Manitoba
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Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-02
 Sample Depth: 7.62 - 8.08 m
 Sample Number: S30

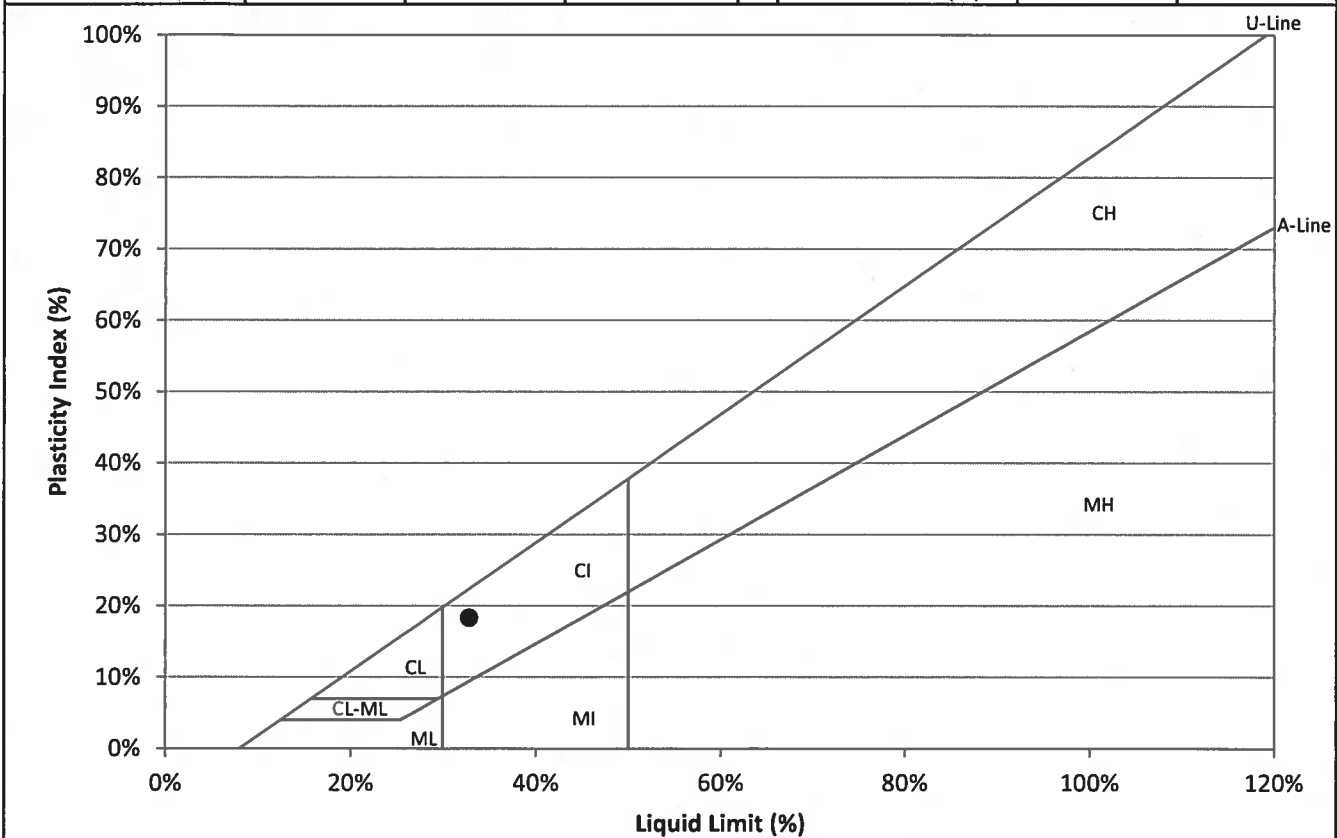
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 20, 2016

Atterberg Limits (ASTM D4318)

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	28	25	19
Wet Sample (g)	9.0	7.1	6.9
Dry Sample (g)	6.8	5.4	5.2
Water Content (%)	32.2%	32.7%	34.2%

Plastic Limit		
Trial	1	2
Wet Sample (g)	7.3	7.4
Dry Sample (g)	6.4	6.4
Water Content (%)	14.4%	14.7%



Liquid Limit (%): 32.8% Plastic Limit (%): 14.5% Plasticity Index (%): 18.3%



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 Winnipeg Geotechnical Laboratory
 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381

Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-02
 Sample Depth: 10.67 - 11.28 m
 Sample Number: S32

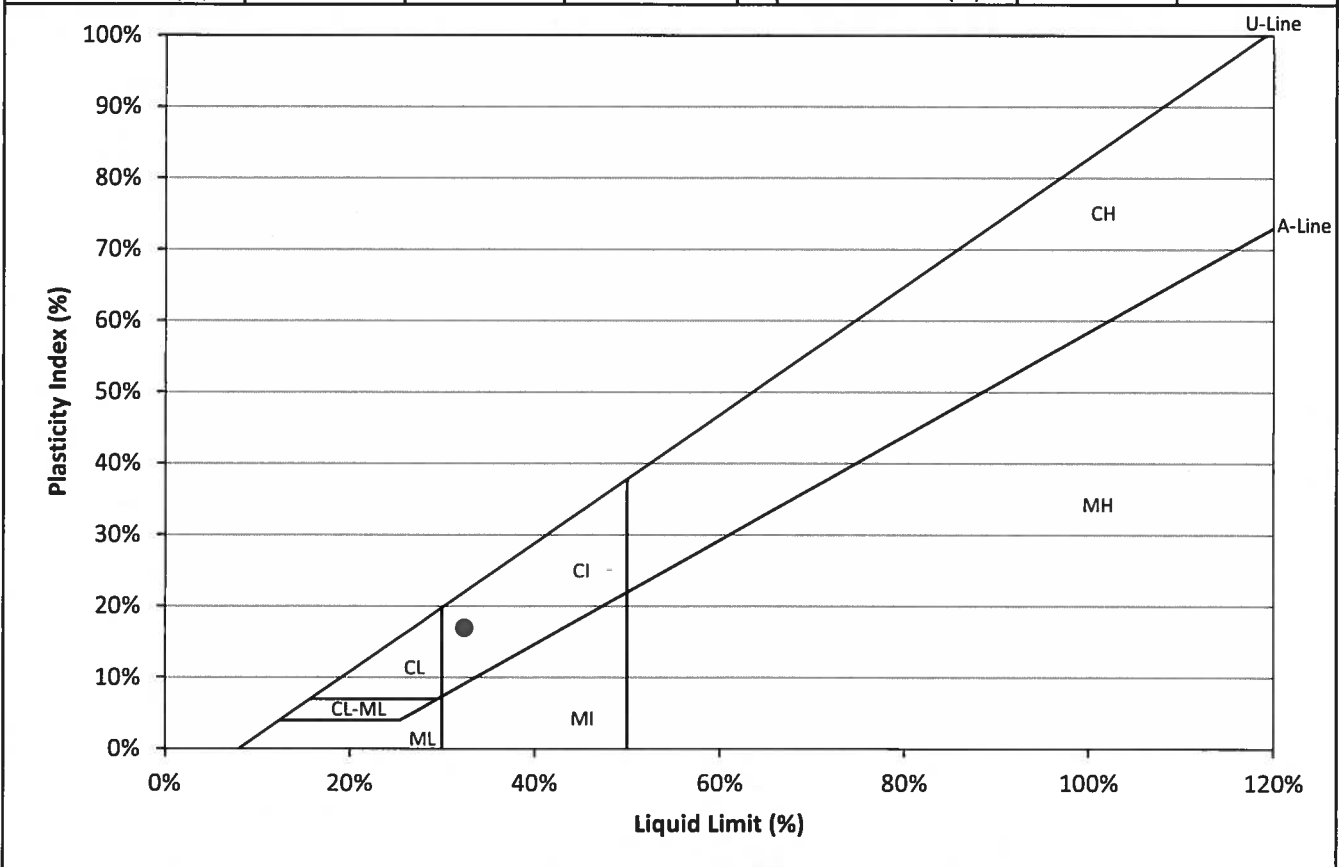
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 20, 2016

Atterberg Limits (ASTM D4318)

Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	28	25	16
Wet Sample (g)	8.6	8.0	8.4
Dry Sample (g)	6.5	6.1	6.3
Water Content (%)	32.2%	32.6%	34.2%

Plastic Limit		
Trial	1	2
Wet Sample (g)	6.3	6.8
Dry Sample (g)	5.5	5.9
Water Content (%)	15.5%	15.6%



Liquid Limit (%): 32.4%	Plastic Limit (%): 15.5%	Plasticity Index (%): 16.9%
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 Winnipeg Geotechnical Laboratory
 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381

Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-04
 Sample Depth: 5.33 - 5.49m
 Sample Number: G7

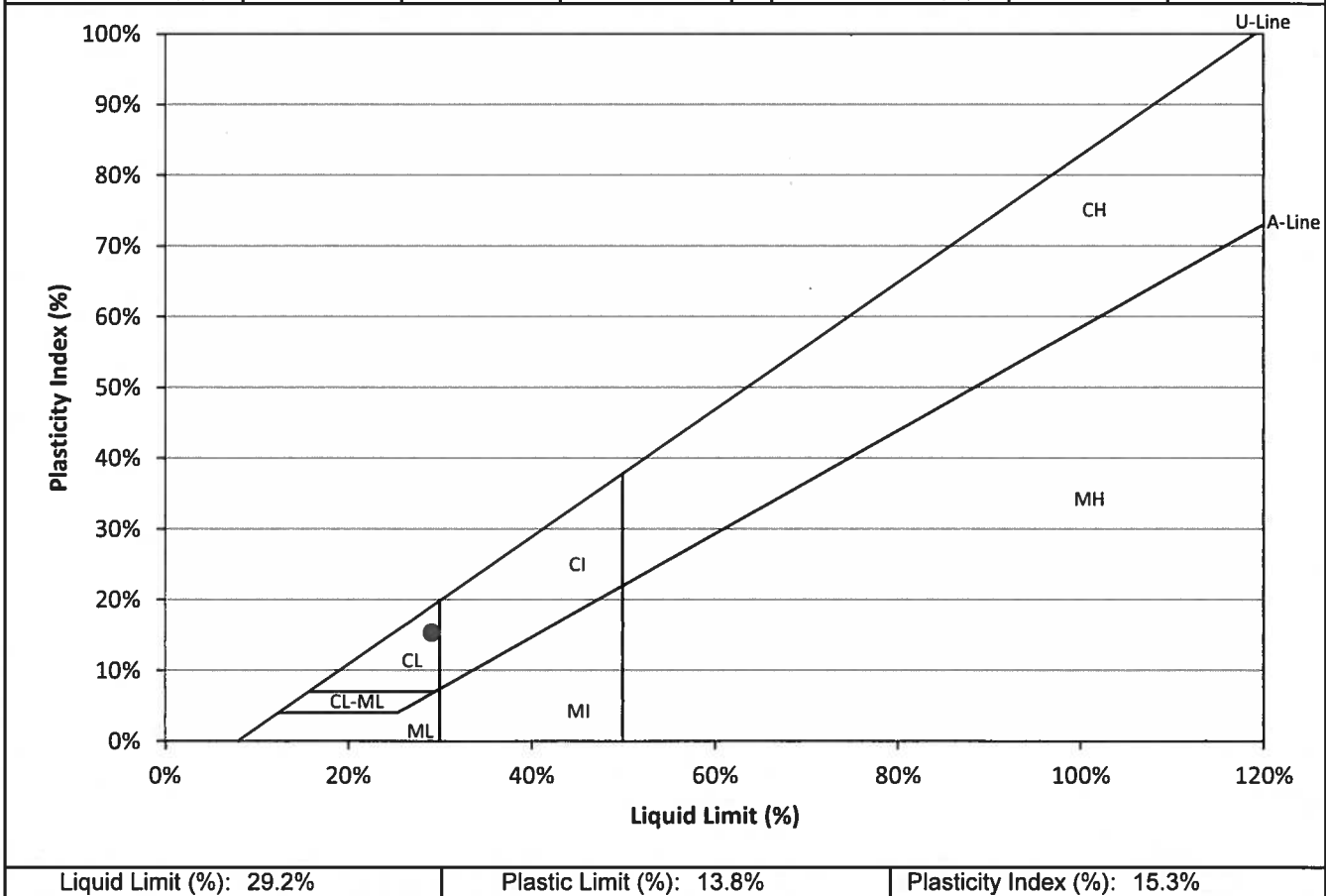
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 21, 2016

Atterberg Limits

ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	33	26	22
Wet Sample (g)	9.2	7.2	7.9
Dry Sample (g)	7.2	5.6	6.1
Water Content (%)	27.4%	28.8%	30.1%

Plastic Limit		
Trial	1	2
Wet Sample (g)	8.9	9.2
Dry Sample (g)	7.8	8.1
Water Content (%)	14.0%	13.7%





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 Winnipeg Geotechnical Laboratory
 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381 Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-04
 Sample Depth: 9.14 - 9.30m
 Sample Number: G11

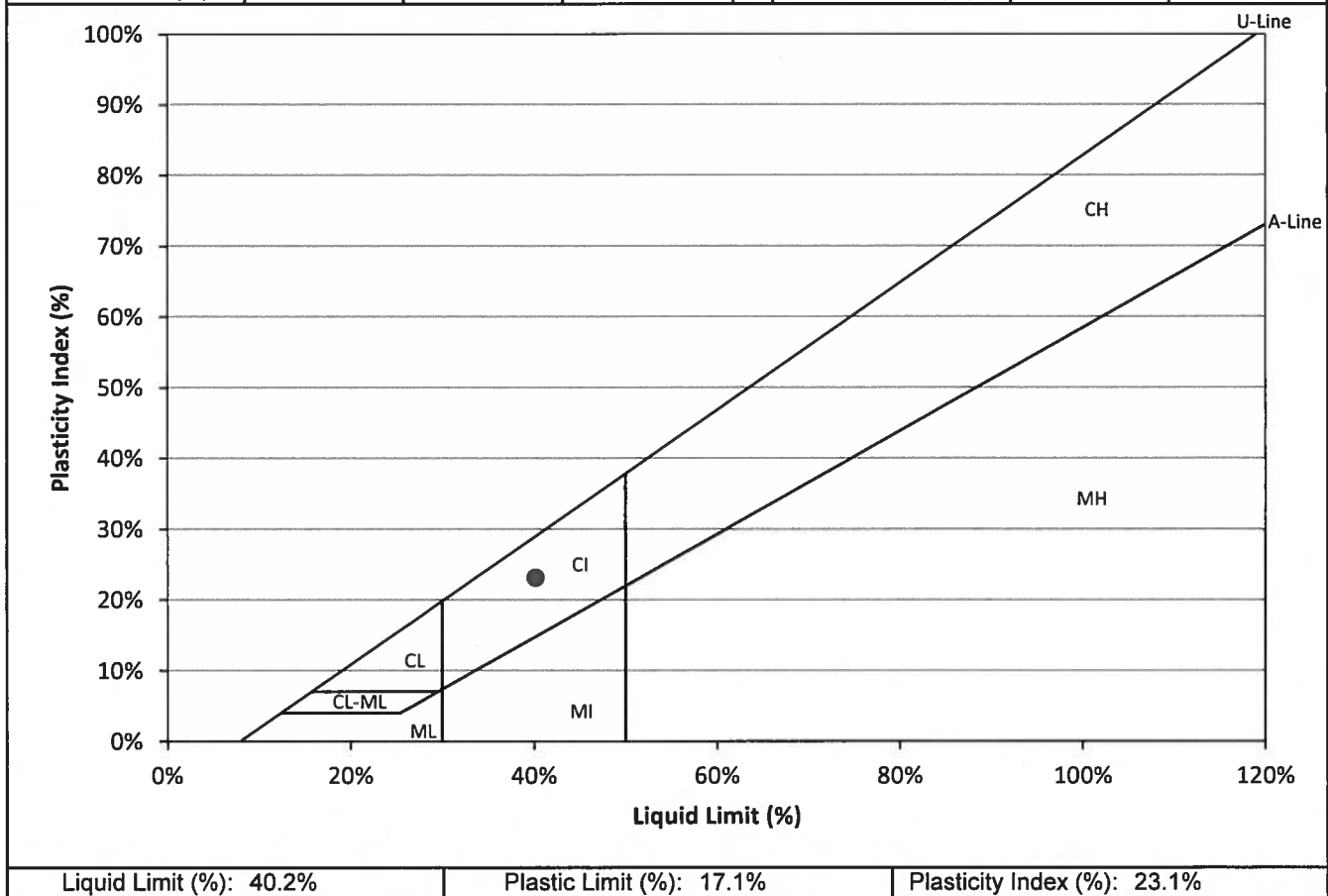
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 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 21, 2016

Atterberg Limits

ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	31	23	19
Wet Sample (g)	8.6	8.6	8.5
Dry Sample (g)	6.2	6.1	6.0
Water Content (%)	38.9%	40.6%	41.4%

Plastic Limit		
Trial	1	2
Wet Sample (g)	7.6	8.7
Dry Sample (g)	6.5	7.4
Water Content (%)	17.1%	17.2%





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 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381 Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-04
 Sample Depth: 10.97 - 11.13m
 Sample Number: G13

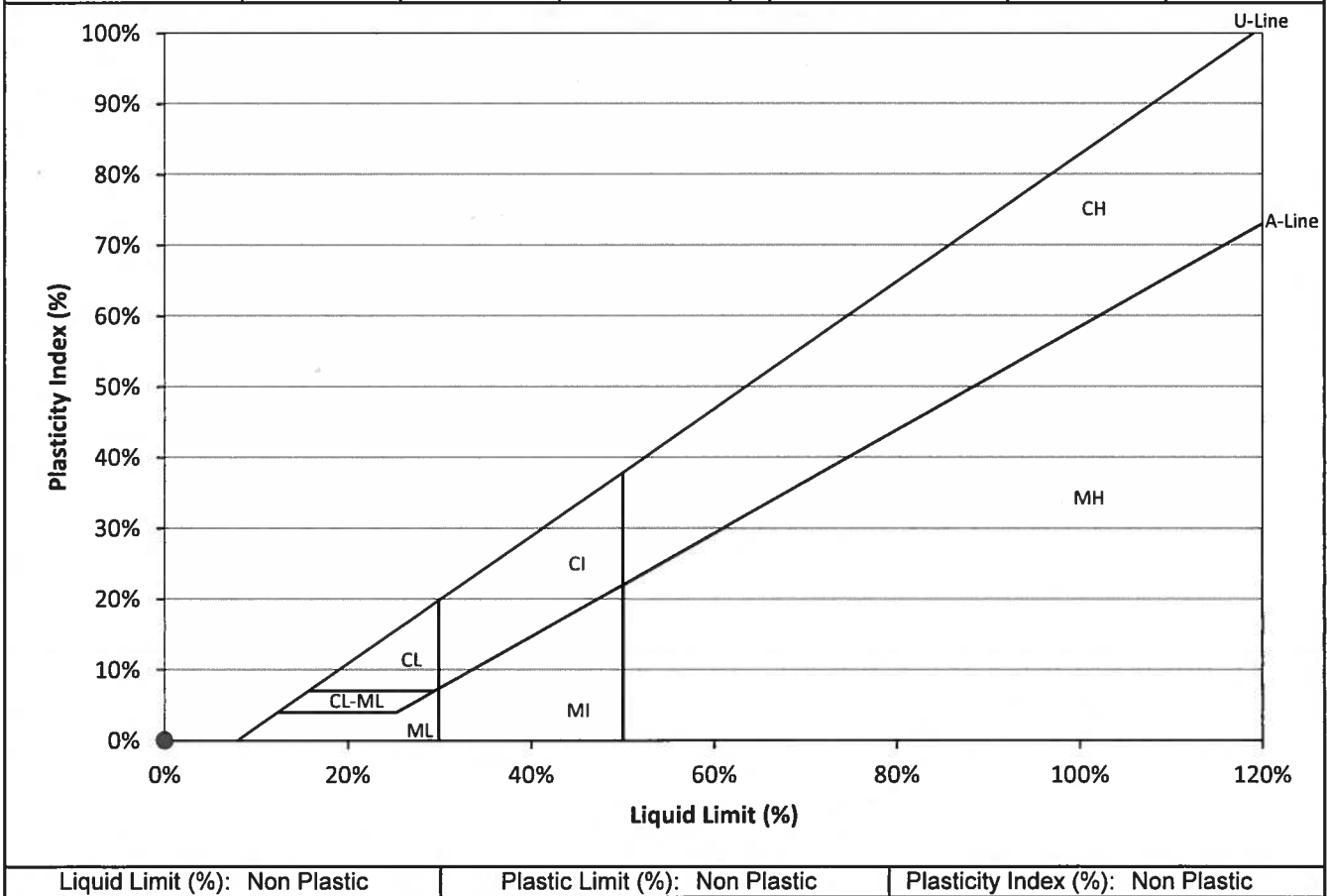
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 20, 2016

Atterberg Limits

ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	0	0	0
Wet Sample (g)	0.0	0.0	0.0
Dry Sample (g)	0.0	0.0	0.0
Water Content (%)	N/A	N/A	N/A

Plastic Limit		
Trial	1	2
Wet Sample (g)	0.0	0.0
Dry Sample (g)	0.0	0.0
Water Content (%)	N/A	N/A





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 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381 Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-04
 Sample Depth: 3.05 - 3.66m
 Sample Number: T4

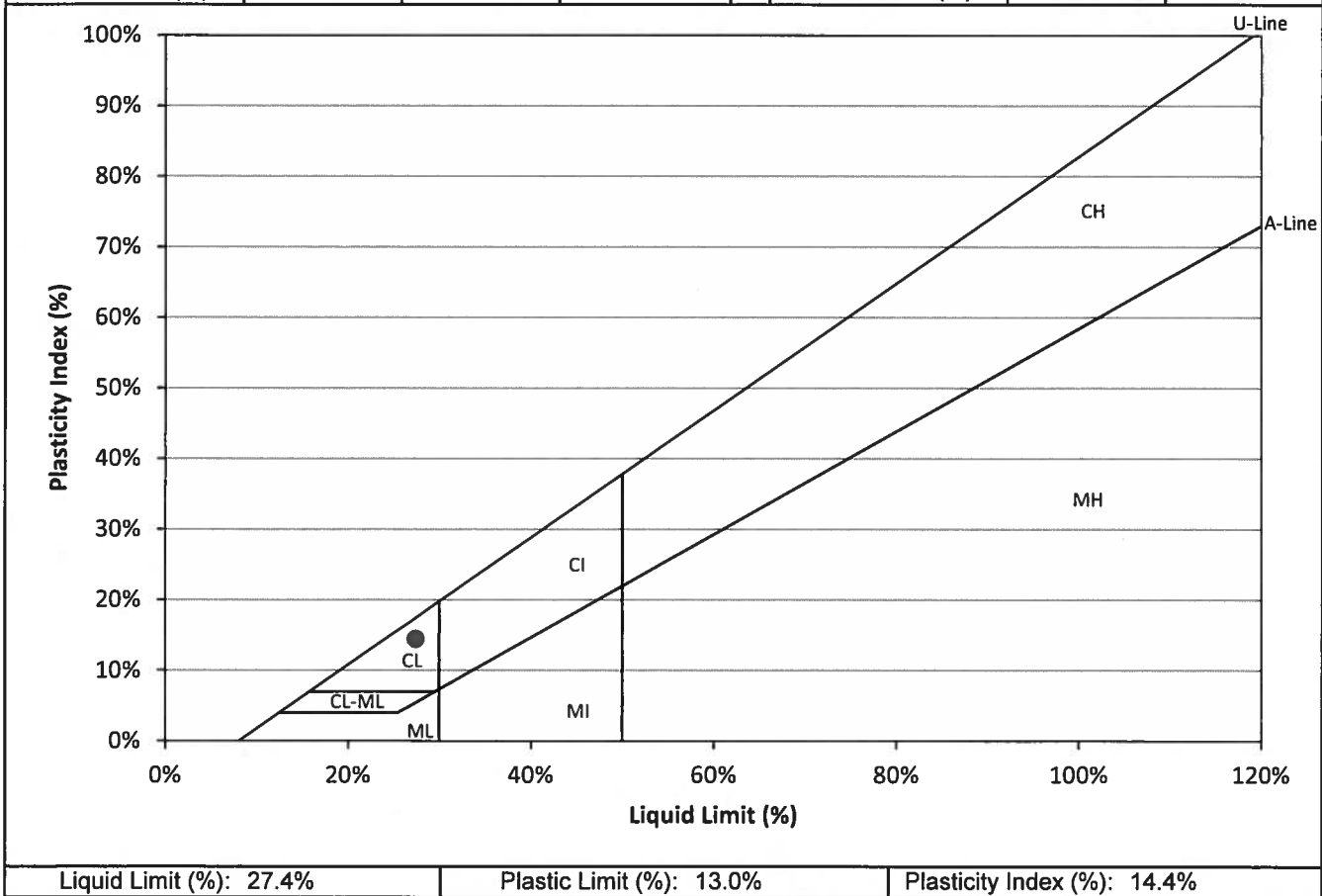
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 20, 2016

Atterberg Limits

ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	30	21	16
Wet Sample (g)	10.1	9.7	8.5
Dry Sample (g)	8.0	7.6	6.6
Water Content (%)	26.7%	27.9%	28.8%

Plastic Limit		
Trial	1	2
Wet Sample (g)	7.3	7.4
Dry Sample (g)	6.5	6.6
Water Content (%)	13.0%	13.0%





AECOM Canada Ltd.
 Winnipeg Geotechnical Laboratory
 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381

Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-04
 Sample Depth: 7.62 - 8.23m
 Sample Number: T10

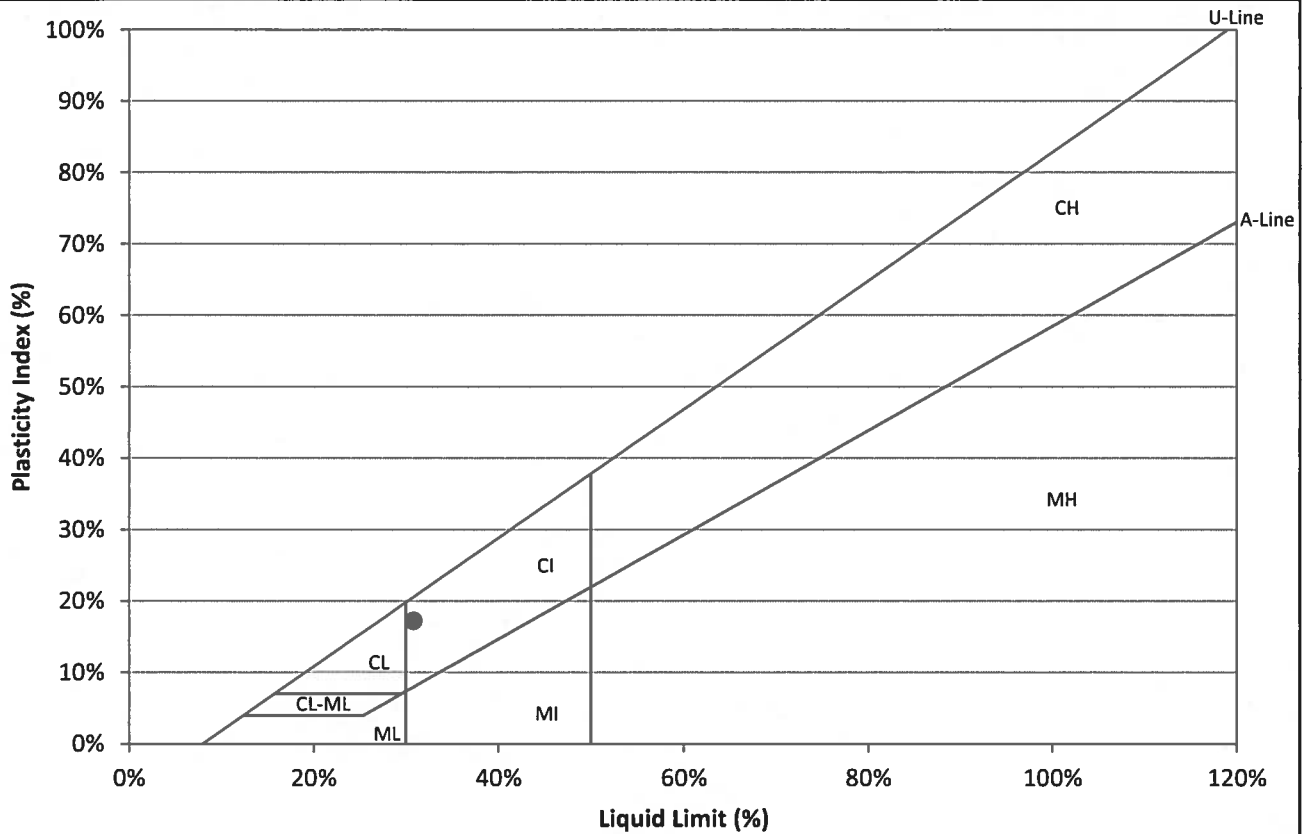
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 21, 2016

Atterberg Limits

ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	28	21	17
Wet Sample (g)	8.3	6.7	8.0
Dry Sample (g)	6.4	5.1	6.0
Water Content (%)	30.2%	31.6%	32.3%

Plastic Limit		
Trial	1	2
Wet Sample (g)	6.8	7.1
Dry Sample (g)	6.0	6.3
Water Content (%)	13.6%	13.7%



Liquid Limit (%): 30.8%

Plastic Limit (%): 13.6%

Plasticity Index (%): 17.2%



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 Winnipeg Geotechnical Laboratory
 99 Commerce Drive
 Winnipeg, Manitoba
 R3P 0Y7
 Phone: 204 477 5381

Fax: 204 284 2040

Project Name: North East Interceptor
 Project Number: 60509089
 Client: City of Winnipeg
 Sample Location: TH16-04
 Sample Depth: 13.72 - 14.33m
 Sample Number: T16

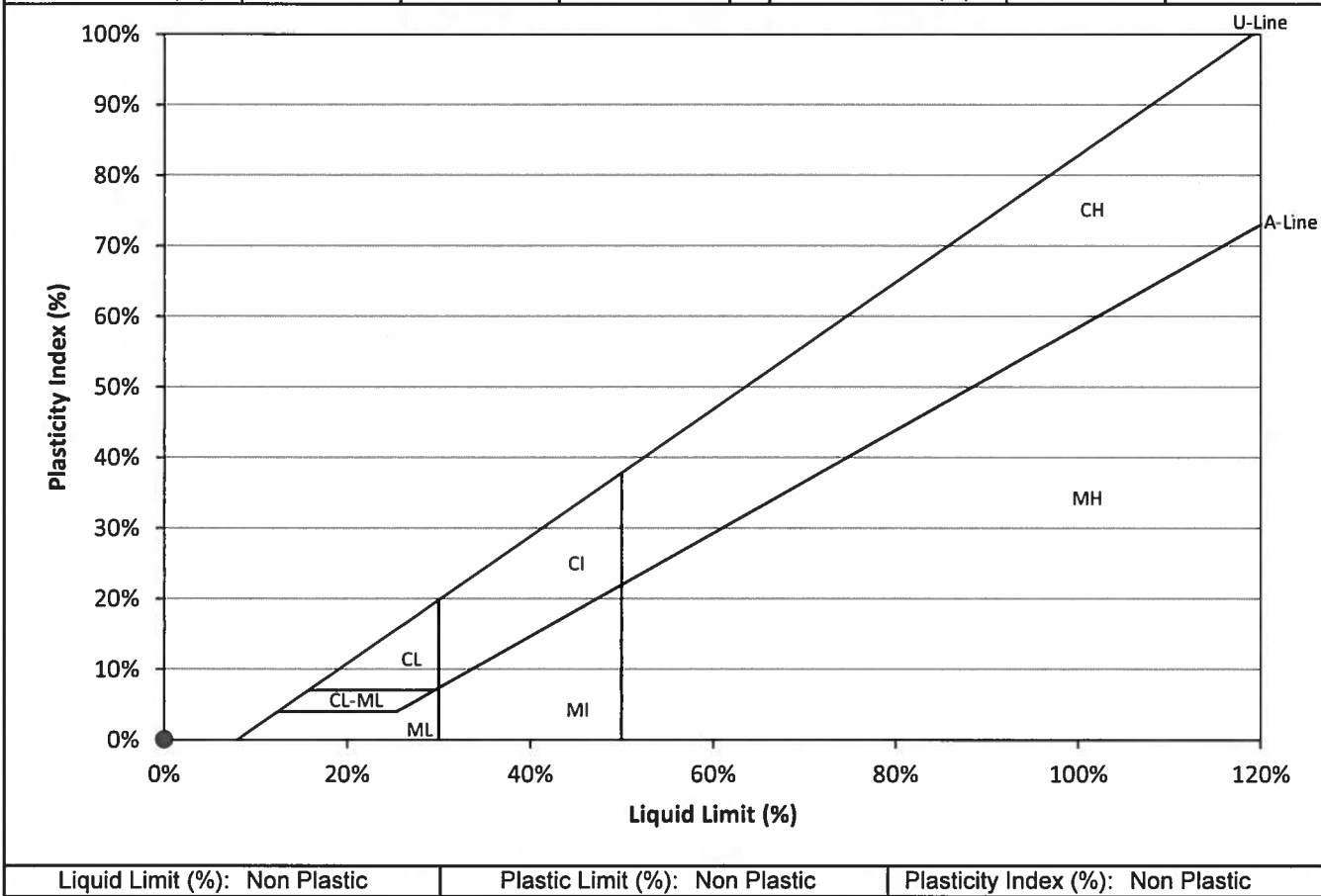
Supplier: AECOM
 Specification: N/A
 Field Technician: RHarras
 Sample Date: Varies
 Lab Technician: EManimbao
 Date Tested: September 20, 2016

Atterberg Limits

ASTM D4318: Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

Liquid Limit			
Blows	0	0	0
Wet Sample (g)	0.0	0.0	0.0
Dry Sample (g)	0.0	0.0	0.0
Water Content (%)	N/A	N/A	N/A

Plastic Limit		
Trial	1	2
Wet Sample (g)	0.0	0.0
Dry Sample (g)	0.0	0.0
Water Content (%)	N/A	N/A



GRAIN SIZE DISTRIBUTION

(ASTM D422-63)



MATERIALS LABORATORY

AECOM

99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada

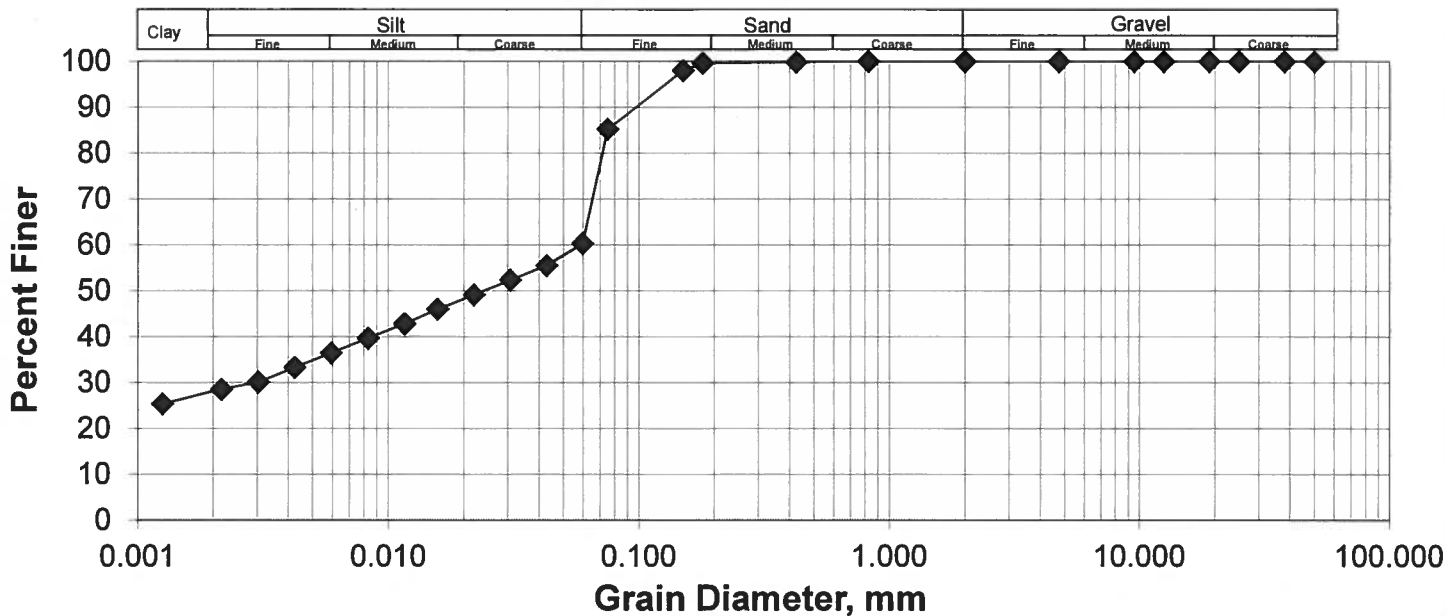
tel (204) 477-5381 fax (204) 284-2040

Job No.: 60509089
 Client: City of Winnipeg
 Project: North East Interceptor
 Date Tested: 19-Sep-16
 Tested By: EManimbao

Hole No.: TH 16-01
 Sample No.: T50
 Depth: 9.14 - 9.75m
 Date Sampled: Varies
 Sampled By: AECOM

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	100.0	0.0750	85.2
38.0	100.0	0.83	100.0	0.0596	60.3
25.0	100.0	0.43	99.8	0.0429	55.5
19.0	100.0	0.18	99.6	0.0307	52.3
12.5	100.0	0.15	98.0	0.0220	49.2
9.5	100.0	0.075	85.2	0.0157	46.0
4.75	100.0			0.0116	42.8
2.00	100.0			0.0083	39.6
				0.0059	36.5
				0.0042	33.3
				0.0030	30.1
				0.0022	28.5
				0.0013	25.3

GRAIN SIZE DISTRIBUTION CURVE



Gravel	0.0%	Silt	33.0%
Sand	39.1%	Clay	28.0%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).

GRAIN SIZE DISTRIBUTION

(ASTM D422-63)



MATERIALS LABORATORY

AECOM

99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada

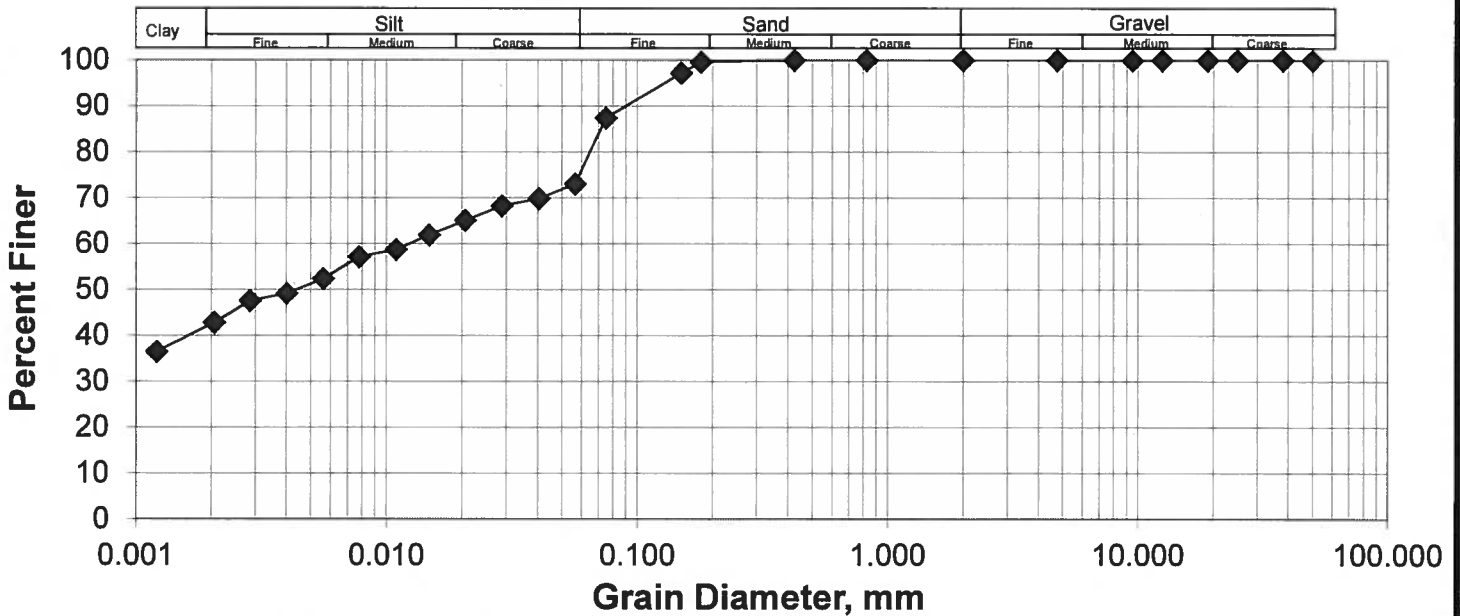
tel (204) 477-5381 fax (204) 284-2040

Job No.: 60509089
 Client: City of Winnipeg
 Project: North East Interceptor
 Date Tested: 19-Sep-16
 Tested By: EManimbao

Hole No.: TH 16-01
 Sample No.: T53
 Depth: 12.19 - 12.80m
 Date Sampled: Varies
 Sampled By: AECOM

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	100.0	0.0750	87.4
38.0	100.0	0.83	100.0	0.0565	73.0
25.0	100.0	0.43	100.0	0.0405	69.8
19.0	100.0	0.18	99.6	0.0288	68.2
12.5	100.0	0.15	97.2	0.0207	65.1
9.5	100.0	0.075	87.4	0.0148	61.9
4.75	100.0			0.0110	58.7
2.00	100.0			0.0078	57.1
				0.0056	52.3
				0.0040	49.2
				0.0029	47.6
				0.0021	42.8
				0.0012	36.5

GRAIN SIZE DISTRIBUTION CURVE



Gravel	0.0%	Silt	33.3%
Sand	24.3%	Clay	42.4%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).

GRAIN SIZE DISTRIBUTION
(ASTM D422-63)



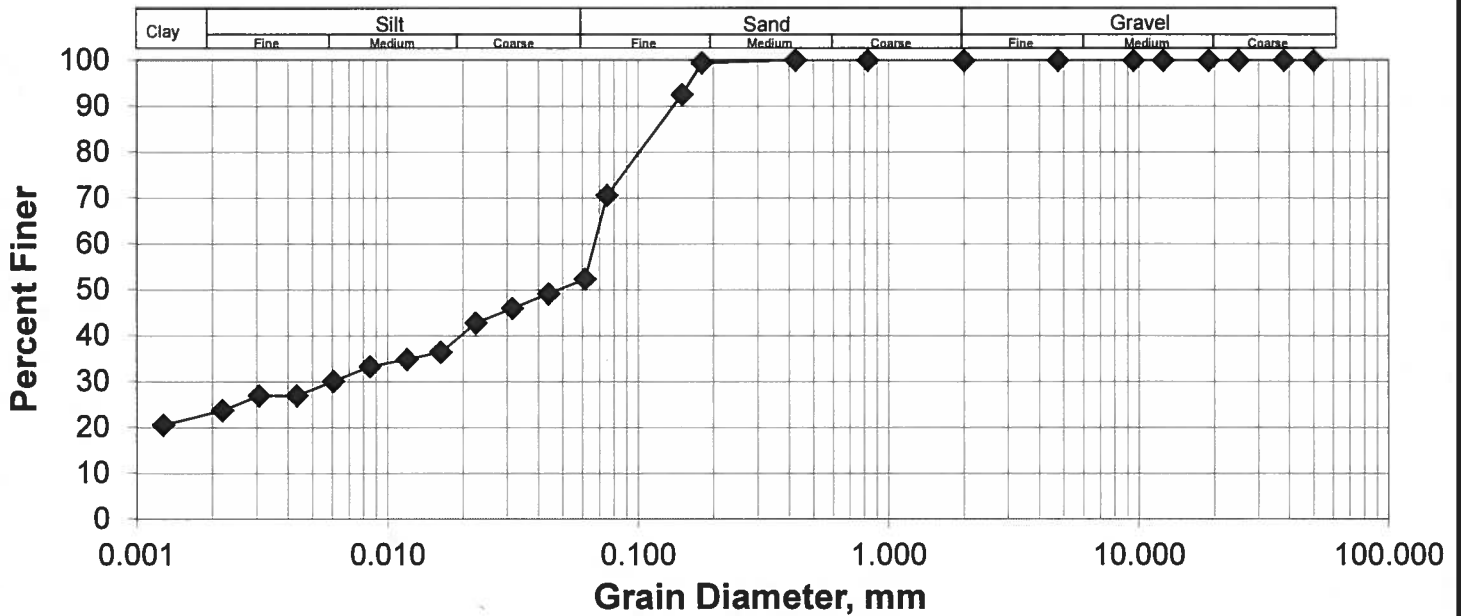
MATERIALS LABORATORY
AECOM
99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada
tel (204) 477-5381 fax (204) 284-2040

Job No.: 60509089
Client: City of Winnipeg
Project: North East Interceptor
Date Tested: 19-Sep-16
Tested By: EManimbao

Hole No.: TH 16-02
Sample No.: S24
Depth: 3.05 - 3.51m
Date Sampled: Varies
Sampled By: AECOM

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	100.0	0.0750	70.6
38.0	100.0	0.83	100.0	0.0615	52.3
25.0	100.0	0.43	100.0	0.0440	49.2
19.0	100.0	0.18	99.4	0.0315	46.0
12.5	100.0	0.15	92.6	0.0225	42.8
9.5	100.0	0.075	70.6	0.0163	36.5
4.75	100.0			0.0119	34.9
2.00	100.0			0.0085	33.3
				0.0061	30.1
				0.0043	26.9
				0.0031	26.9
				0.0022	23.8
				0.0013	20.6

GRAIN SIZE DISTRIBUTION CURVE



Gravel	0.0%	Silt	29.0%
Sand	47.9%	Clay	23.1%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).

GRAIN SIZE DISTRIBUTION

(ASTM D422-63)



MATERIALS LABORATORY

AECOM

99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada

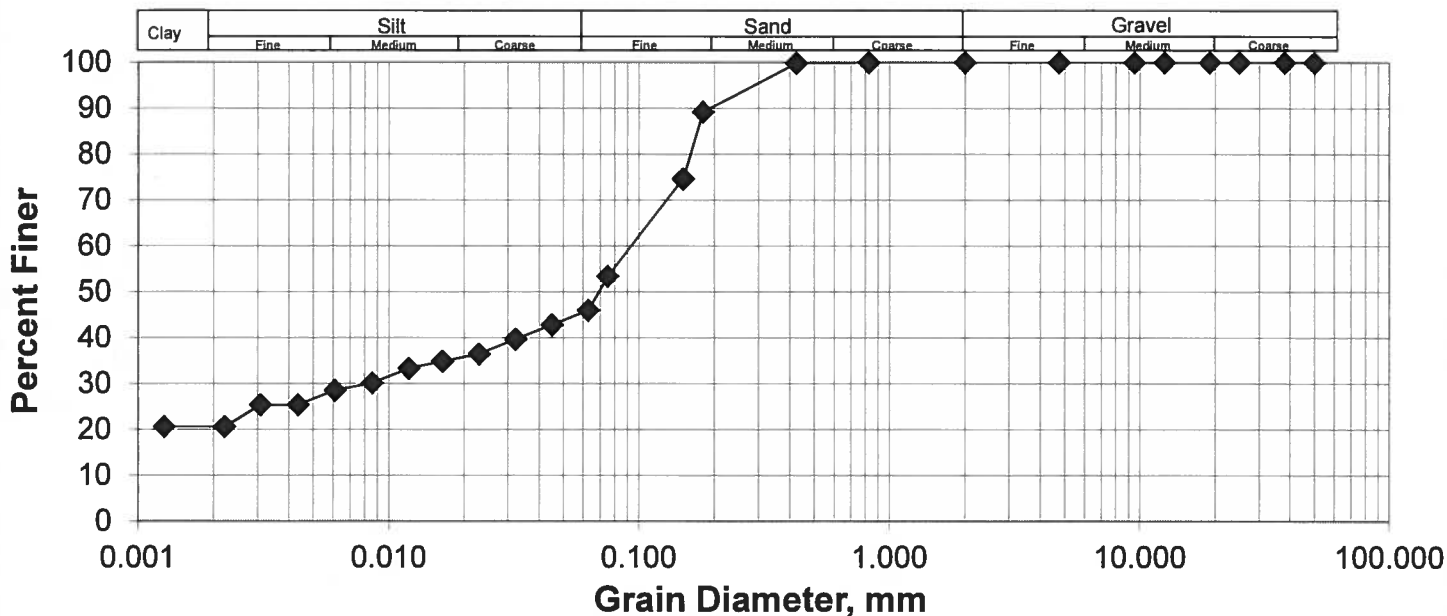
tel (204) 477-5381 fax (204) 284-2040

Job No.: 60509089
 Client: City of Winnipeg
 Project: North East Interceptor
 Date Tested: 19-Sep-16
 Tested By: EManimbao

Hole No.: TH 16-02
 Sample No.: S30
 Depth: 7.62 - 8.23m
 Date Sampled: Varies
 Sampled By: AECOM

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	100.0	0.0750	53.4
38.0	100.0	0.83	100.0	0.0629	46.0
25.0	100.0	0.43	99.8	0.0450	42.8
19.0	100.0	0.18	89.2	0.0322	39.6
12.5	100.0	0.15	74.6	0.0230	36.5
9.5	100.0	0.075	53.4	0.0164	34.9
4.75	100.0			0.0120	33.3
2.00	100.0			0.0086	30.1
				0.0061	28.5
				0.0044	25.3
				0.0031	25.3
				0.0022	20.6
				0.0013	20.6

GRAIN SIZE DISTRIBUTION CURVE



Gravel	0.0%	Silt	24.9%
Sand	54.5%	Clay	20.6%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).

GRAIN SIZE DISTRIBUTION

(ASTM D422-63)



MATERIALS LABORATORY

AECOM

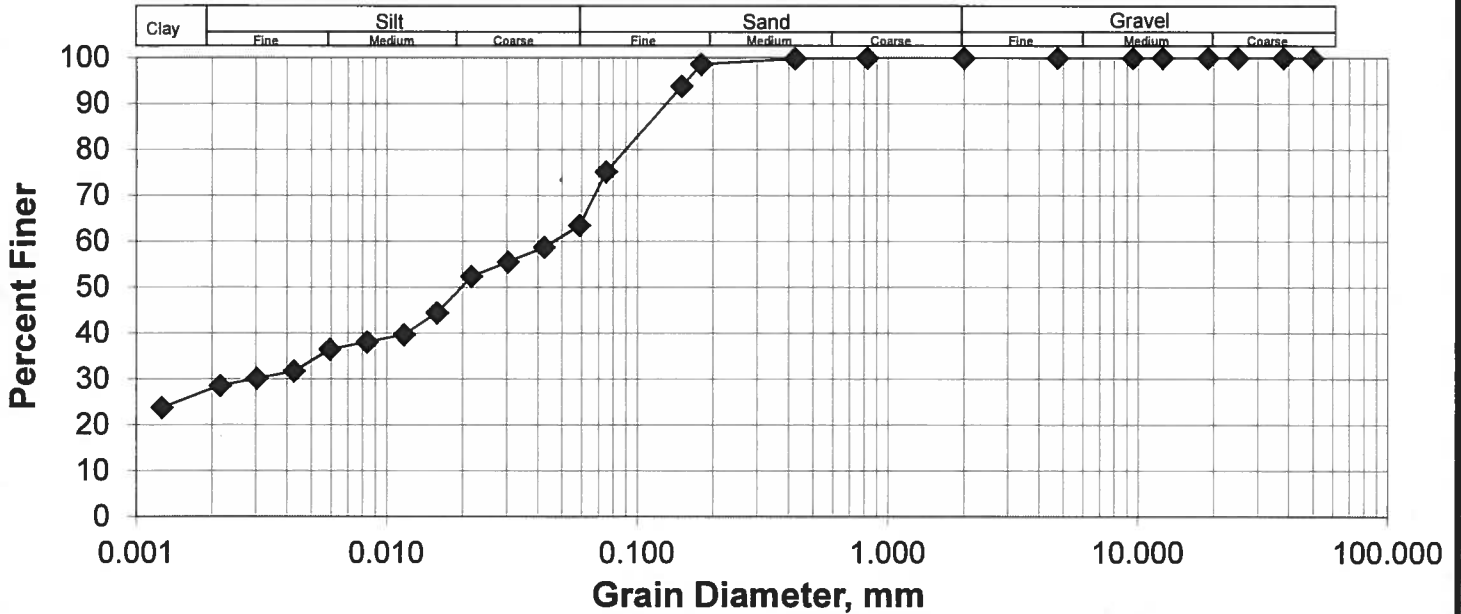
99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada
tel (204) 477-5381 fax (204) 284-2040

Job No.: 60509089
 Client: City of Winnipeg
 Project: North East Interceptor
 Date Tested: 19-Sep-16
 Tested By: EManimbao

Hole No.: TH 16-04
 Sample No.: G11
 Depth: 9.14 - 9.30m
 Date Sampled: Varies
 Sampled By: AECOM

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	100.0	0.0750	75.2
38.0	100.0	0.83	100.0	0.0588	63.5
25.0	100.0	0.43	99.8	0.0424	58.7
19.0	100.0	0.18	98.6	0.0304	55.5
12.5	100.0	0.15	93.8	0.0217	52.3
9.5	100.0	0.075	75.2	0.0158	44.4
4.75	100.0			0.0118	39.6
2.00	100.0			0.0084	38.1
				0.0059	36.5
				0.0043	31.7
				0.0030	30.1
				0.0022	28.5
				0.0013	23.8

GRAIN SIZE DISTRIBUTION CURVE



Gravel	0.0%	Silt	36.6%
Sand	35.7%	Clay	27.7%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).

GRAIN SIZE DISTRIBUTION

(ASTM D422-63)



MATERIALS LABORATORY

AECOM

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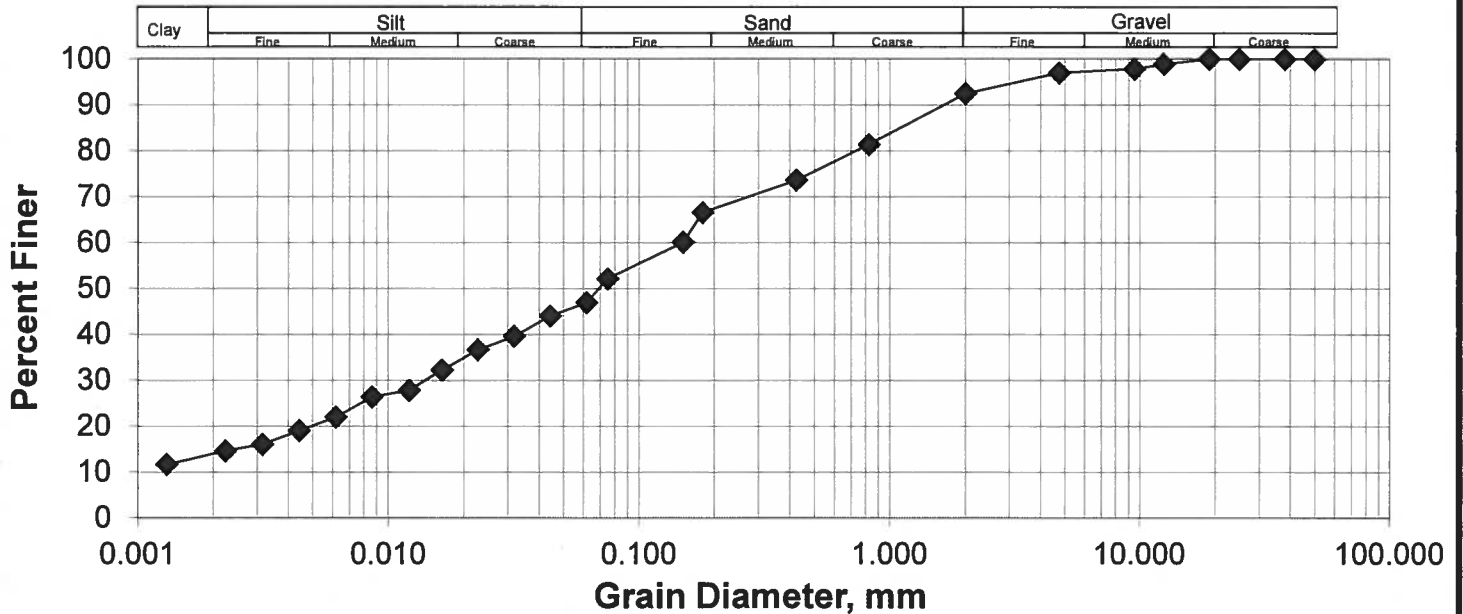
tel (204) 477-5381 fax (204) 284-2040

Job No.: 60509089
 Client: City of Winnipeg
 Project: North East Interceptor
 Date Tested: 19-Sep-16
 Tested By: EManimbao

Hole No.: TH 16-04
 Sample No.: G18
 Depth: 16.76 - 16.92m
 Date Sampled: Varies
 Sampled By: AECOM

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	92.5	0.0750	52.2
38.0	100.0	0.83	81.4	0.0619	46.9
25.0	100.0	0.43	73.6	0.0443	44.0
19.0	100.0	0.18	66.6	0.0318	39.6
12.5	98.9	0.15	60.1	0.0228	36.7
9.5	97.8	0.075	52.2	0.0164	32.3
4.75	97.0			0.0121	27.8
2.00	92.5			0.0086	26.4
				0.0062	22.0
				0.0044	19.0
				0.0032	16.1
				0.0022	14.6
				0.0013	11.7

GRAIN SIZE DISTRIBUTION CURVE



Gravel	7.5%	Silt	32.8%
Sand	45.8%	Clay	13.9%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).

GRAIN SIZE DISTRIBUTION

(ASTM D422-63)



MATERIALS LABORATORY

AECOM

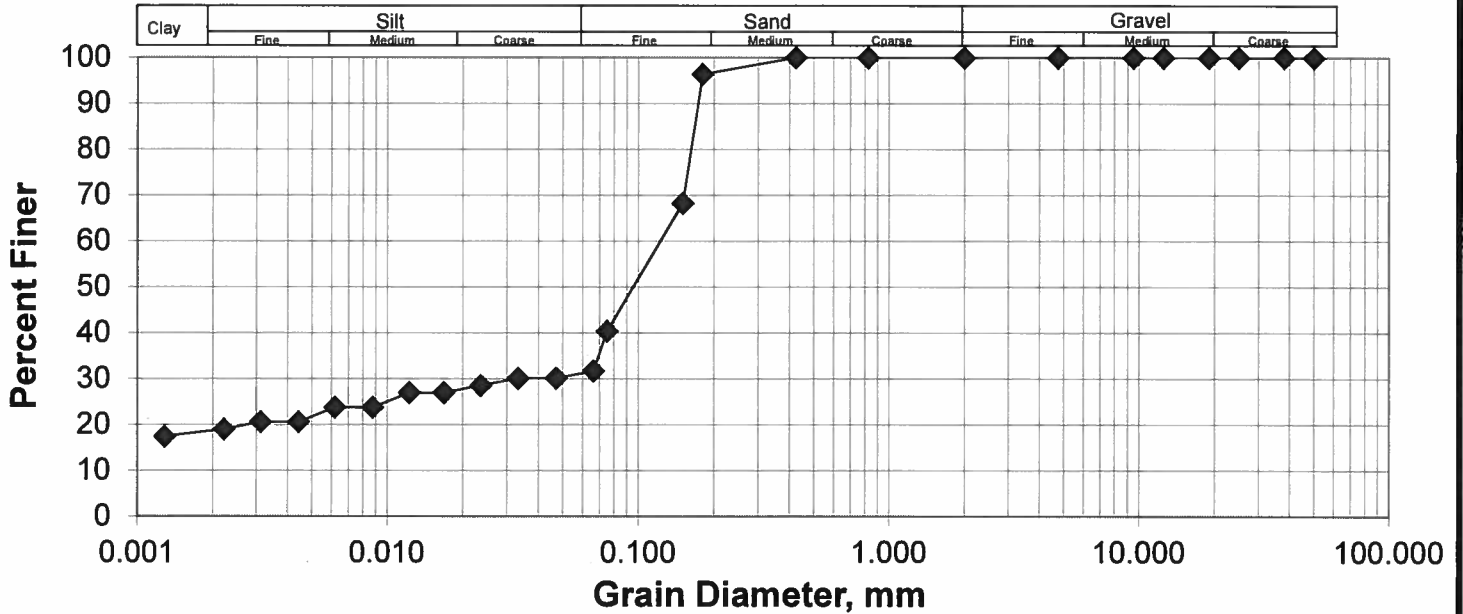
99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada
tel (204) 477-5381 fax (204) 284-2040

Job No.: 60509089
 Client: City of Winnipeg
 Project: North East Interceptor
 Date Tested: 19-Sep-16
 Tested By: EManimbao

Hole No.: TH 16-04
 Sample No.: T4
 Depth: 3.05 - 3.66m
 Date Sampled: Varies
 Sampled By: AECOM

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	100.0	0.0750	40.4
38.0	100.0	0.83	100.0	0.0661	31.7
25.0	100.0	0.43	100.0	0.0470	30.1
19.0	100.0	0.18	96.4	0.0332	30.1
12.5	100.0	0.15	68.2	0.0236	28.5
9.5	100.0	0.075	40.4	0.0168	26.9
4.75	100.0			0.0123	26.9
2.00	100.0			0.0088	23.8
				0.0062	23.8
				0.0044	20.6
				0.0031	20.6
				0.0022	19.0
				0.0013	17.4

GRAIN SIZE DISTRIBUTION CURVE



Gravel	0.0%	Silt	12.6%
Sand	68.8%	Clay	18.6%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).

GRAIN SIZE DISTRIBUTION

(ASTM D422-63)



MATERIALS LABORATORY

AECOM

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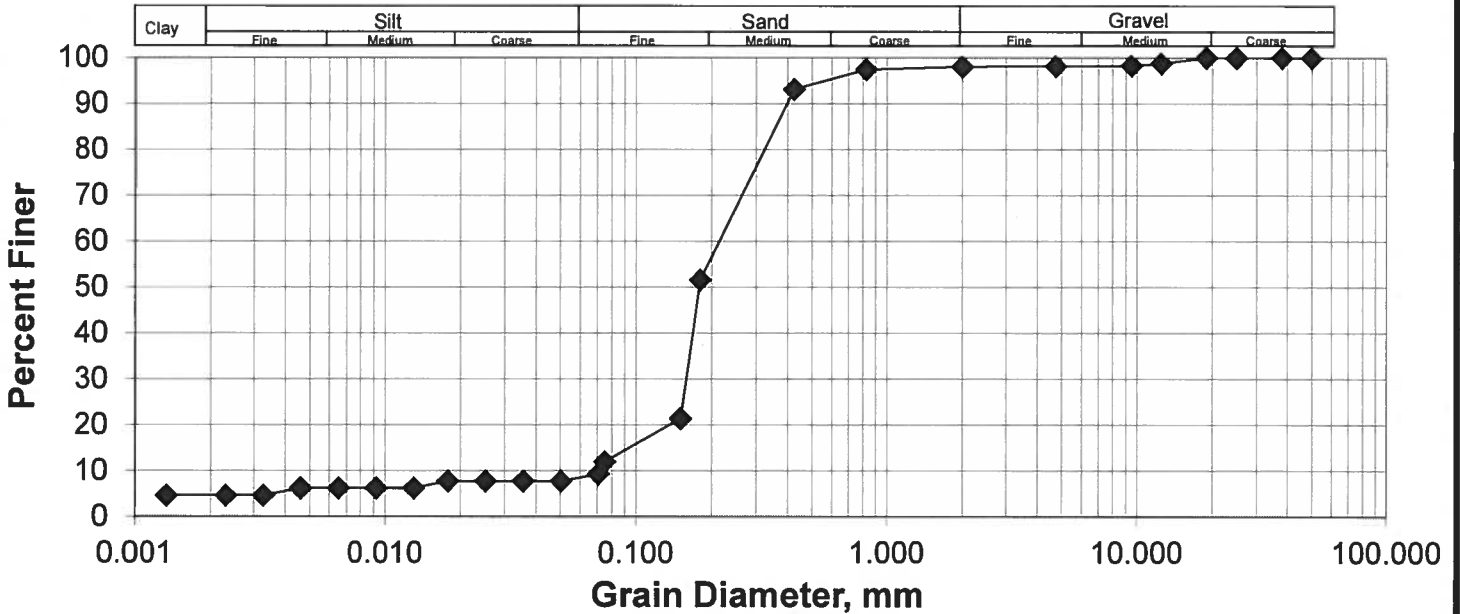
tel (204) 477-5381 fax (204) 284-2040

Job No.: 60509089
 Client: City of Winnipeg
 Project: North East Interceptor
 Date Tested: 19-Sep-16
 Tested By: EManimbao

Hole No.: TH 16-04
 Sample No.: T16
 Depth: 13.72 - 14.33m
 Date Sampled: Varies
 Sampled By: AECOM

GRAVEL SIZES		SAND SIZES		FINES	
Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing	Grain Size (mm.)	Total Percent Passing
50.0	100.0	2.00	98.0	0.0750	12.0
38.0	100.0	0.83	97.4	0.0708	9.3
25.0	100.0	0.43	93.1	0.0503	7.7
19.0	100.0	0.18	51.6	0.0355	7.7
12.5	98.8	0.15	21.4	0.0251	7.7
9.5	98.3	0.075	12.0	0.0178	7.7
4.75	98.2			0.0130	6.2
2.00	98.0			0.0092	6.2
				0.0065	6.2
				0.0046	6.2
				0.0033	4.6
				0.0023	4.6
				0.0013	4.6

GRAIN SIZE DISTRIBUTION CURVE



Gravel	2.0%	Silt	3.9%
Sand	89.6%	Clay	4.6%

** Note: Soil Classification based on Grain Size from Canadian Foundation Engineering Manual, 3rd edition (1992).



6 - 854 Marion Street
Winnipeg, Manitoba
R2J 0K4
eng_tech@mts.net
www.eng-tech.ca

ROCK CORE

AECOM Canada Ltd.
99 Commerce Drive
Winnipeg, Manitoba
R3P 0Y7

File No.: 16-027-01

Ref. No.: 16-27-1-20

Attention: Omer Eissa

Project: CITY OF WINNIPEG NE INTERCEPTOR; AECOM PROJECT 60509089

Contractor: Maple Leaf Drilling Ltd.
Date Cored: August / September : 2016
Cored By: Maple Leaf Drilling Ltd.

Page: 1 of 1
Date Received: Nov 7/16
Received By: ENG-TECH

Core No.	Location	Length		Average Diameter (mm)	Compressive Strength (MPa)	Date Tested (m/d/y)
		Cored (mm)	Tested (mm)			
1	TH 16 – 01 West Riverbank; C5.	239.9	125.4	63.3	93.5	Nov 22/16
2	TH 16 – 02 West Riverbank; C4.	164.5	125.5	63.3	149.6	Nov 22/16
3	TH 16 – 03 East side of Red River; C5.	253.2	77.5	36.2	58.9	Nov 22/16
4	TH 16 – 03 East side of Red River; C7.	117.7	74.1	36.2	39.7	Nov 22/16
5	TH 16 – 04 East Riverbank; C5.	323.8	100.0	50.5	77.8	Nov 22/16
6	TH 16 – 04 East Riverbank; C6.	298.4	102.4	50.5	96.6	Nov 22/16

Comments: The unconfined strength was determined in accordance with ASTM D2938-95 procedure with the cores in the as received moisture content.

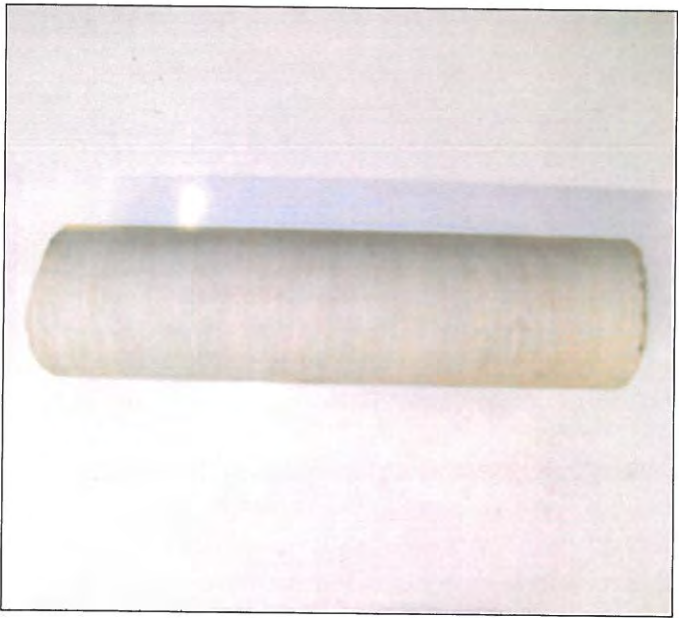
Cc: Email: omer.eissa@aecom.com
Enclosure: Photographs of Cores (6 pages)

ENG-TECH Consulting Limited

Per

Danny Holfeld, Principal
Ph: (204) 233-1694 Fx: (204) 235-1579

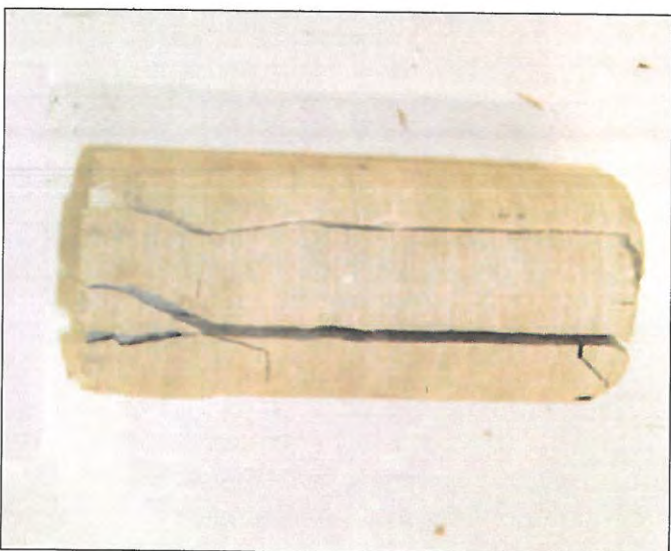
CORE NUMBER 1
TH 16-01
WEST RIVER BANK C5



BEFORE TRIMMING



AFTER TRIMMING

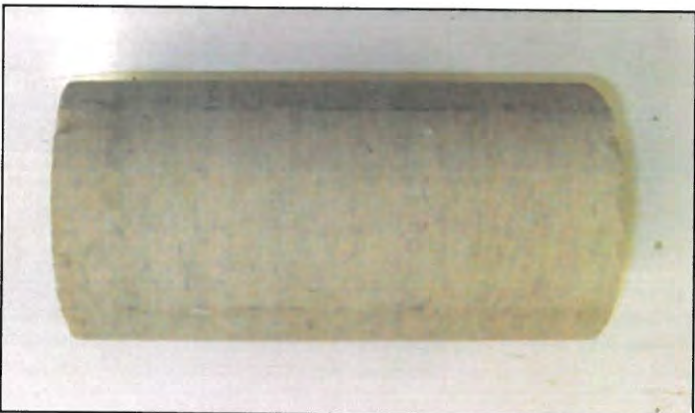


AFTER TEST

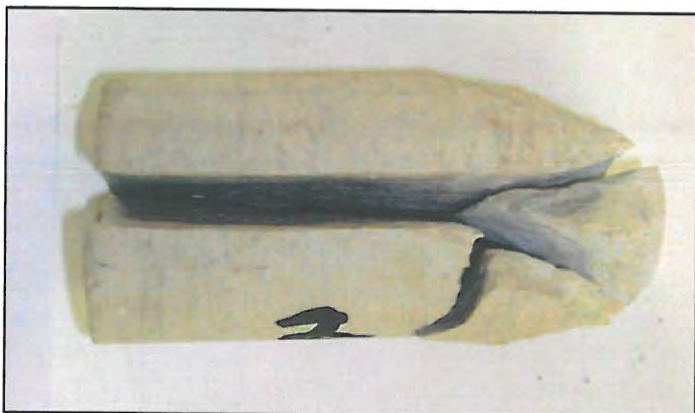
CORE NUMBER 2
TH 16-02
WEST RIVER BANK C4



BEFORE TRIMMING

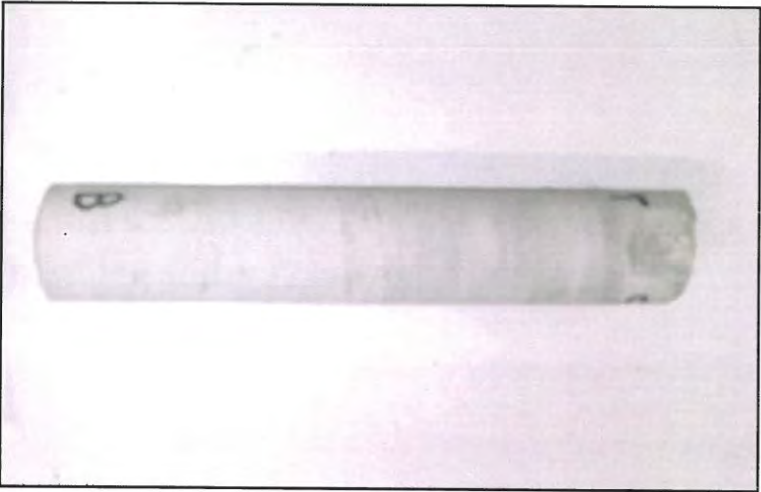


AFTER TRIMMING



AFTER TESTING

CORE NUMBER 3
TH 16-03
EASTSIDE OF RED RIVER C5



BEFORE TRIMMING

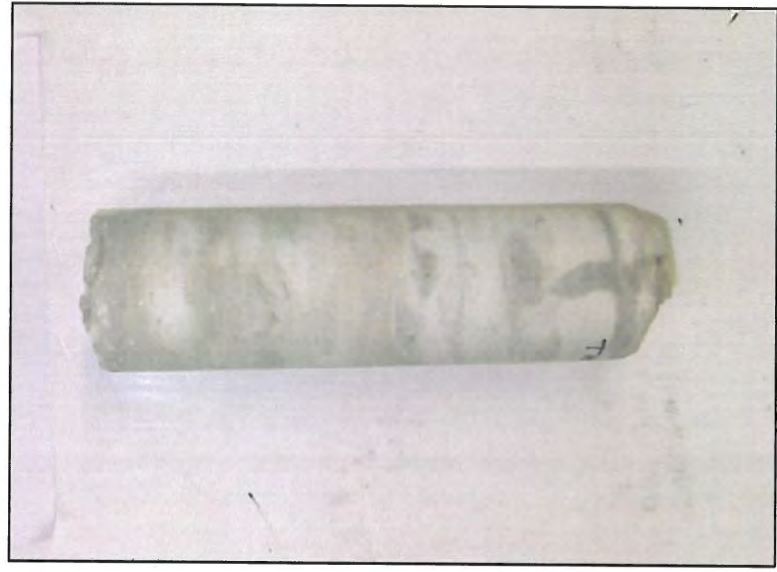


AFTER TRIMMING



AFTER TESTING

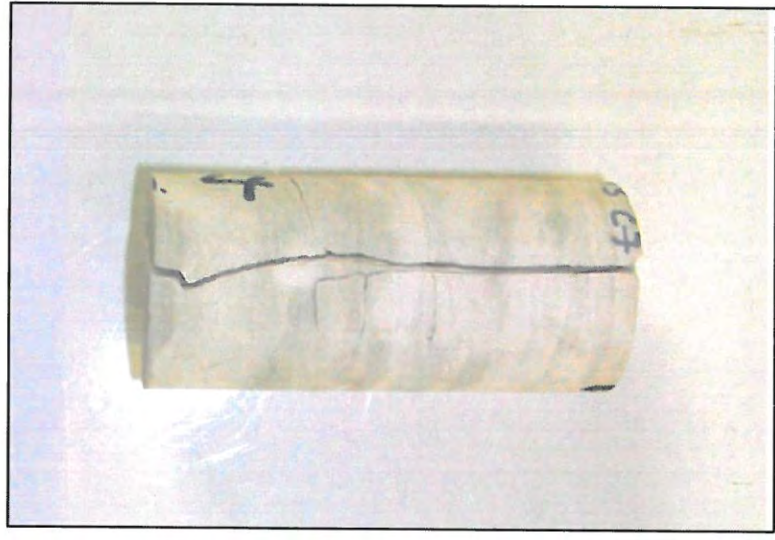
CORE NUMBER 4
TH 16-03
EASTSIDE OF RED RIVER C7



BEFORE TRIMMING



AFTER TRIMMING

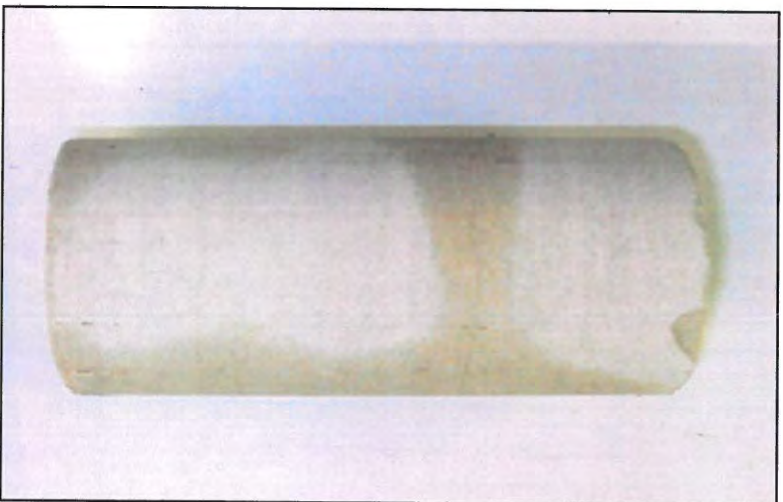


AFTER TESTING

CORE NUMBER 5
TH 16-04
EAST RIVER BANK C5



BEFORE TRIMMING



AFTER TRIMMING

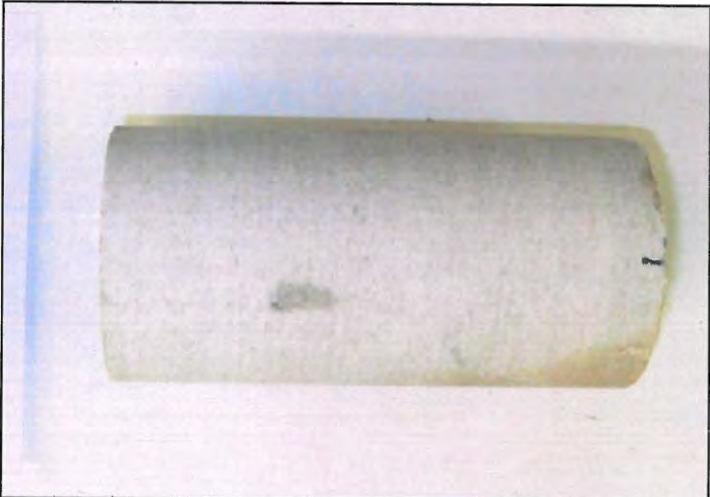


AFTER TESTING

CORE NUMBER 6
TH 16-04
EAST RIVER BANK C6



BEFORE TRIMMING



AFTER TRIMMING



AFTER TESTING



www.trekgeotechnical.ca
 1712 St. James Street
 Winnipeg, MB R3H 0L3
 Tel: 204.975.9433 Fax: 204.975.9435

**Moisture Content Report
 ASTM D2216-98**

Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Sample Date 22-Oct-13
Test Date 24-Oct-13
Technician Chiran Peiris

Test Hole	TH13-01	TH13-01	TH13-01	TH13-01	TH13-01	TH13-01
Depth (m)	0.2 - 0.3	0.9 - 1.1	1.4 - 1.5	1.8 - 2.1	2.9 - 4.6	5.9 - 6.1
Sample #	G29	G30	G31	G32	G33	G35
Tare ID	P30	K3	F32	F124	D8	N99
Mass of tare	8.3	8.4	8.2	8.3	8.4	8.4
Mass wet + tare	339.3	399.8	439.9	224.7	390.2	403.8
Mass dry + tare	270.3	327.4	352.9	191.4	306.6	309.4
Mass water	69.0	72.4	87.0	33.3	83.6	94.4
Mass dry soil	262.0	319.0	344.7	183.1	298.2	301.0
Moisture %	26.3%	22.7%	25.2%	18.2%	28.0%	31.4%

Test Hole	TH13-01	TH13-01	TH13-01	TH13-01	TH13-01	TH13-01
Depth (m)	4.3 - 4.4	4.7 - 4.9	5.3 - 5.6	6.1 - 6.4	6.6 - 6.6	7.3 - 7.5
Sample #	SB 36A	SB 36B	SB 36C	SB 37A	SB 37B	SB 37C
Tare ID	F104	E10	Z30	Z75	F102	F66
Mass of tare	8.5	8.8	8.3	8.4	8.5	8.4
Mass wet + tare	588	468.8	653.3	446.3	387.3	649.9
Mass dry + tare	444.3	363.1	479.5	334.3	296.3	498.5
Mass water	143.7	105.7	173.8	112.0	91.0	151.4
Mass dry soil	435.8	354.3	471.2	325.9	287.8	490.1
Moisture %	33.0%	29.8%	36.9%	34.4%	31.6%	30.9%

Test Hole	TH13-01	TH13-01	TH13-01	TH13-01	TH13-01	TH13-01
Depth (m)	7.9 - 8.2	8.5 - 8.8	10.1 - 10.4	11.3 - 11.6	12.8 - 13.3	13.3 - 13.7
Sample #	SB 38A	SB 38B	SB 39	SB 40	SB 42A	SB 42B
Tare ID	H79	E96	N90	Z64	Z101	F33
Mass of tare	8.4	8.6	8.5	8.2	8.3	8.4
Mass wet + tare	398.0	599.7	656.3	470.9	474.1	457.6
Mass dry + tare	296.2	486.4	501.9	379.0	386.3	361.1
Mass water	101.8	113.3	154.4	91.9	87.8	96.5
Mass dry soil	287.8	477.8	493.4	370.8	378.0	352.7
Moisture %	35.4%	23.7%	31.3%	24.8%	23.2%	27.4%



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Winnipeg, MB R3H 0L3
Tel: 204.975.9433 Fax: 204.975.9435

Moisture Content Report ASTM D2216-98

Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Sample Date 22-Oct-13
Test Date 24-Oct-13
Technician Chiran Peiris

Test Hole	TH13-01	TH13-01	TH13-01	TH13-04	TH13-04	TH13-04
Depth (m)	14.9 - 15.2	15.2 - 15.7	16.8 - 17.2	1.8 - 2.4	2.4 - 3.0	3.7 - 4.3
Sample #	SB 43	SB 44	SB 45B	SB 1	SB 2	SB 4
Tare ID	W39	F29	N54	F56	D29	Z50
Mass of tare	8.2	8.3	8.3	8.2	8.1	8.2
Mass wet + tare	403.8	379.1	294.2	359.7	403.0	626.7
Mass dry + tare	318.9	315.9	268.0	228.2	258.3	410.1
Mass water	84.9	63.2	26.2	131.5	144.7	216.6
Mass dry soil	310.7	307.6	259.7	220.0	250.2	401.9
Moisture %	27.3%	20.5%	10.1%	59.8%	57.8%	53.9%

Test Hole	TH13-04	TH13-04	TH13-04	TH13-04	TH13-04	TH13-04
Depth (m)	4.3 - 4.9	4.9 - 5.5	5.5 - 6.1	6.7 - 7.3	7.3 - 7.9	7.9 - 8.5
Sample #	SB 5	SB 6	SB 7	SB 9	SB 10	SB 11
Tare ID	N71	N37	H41	N68	P21	W16
Mass of tare	8.4	8.6	8.4	8.3	8.5	8.3
Mass wet + tare	466.7	502.5	369.4	402.5	481.1	505.9
Mass dry + tare	306.8	327.4	250.7	283.3	326.2	344.5
Mass water	159.9	175.1	118.7	119.2	154.9	161.4
Mass dry soil	298.4	318.8	242.3	275.0	317.7	336.2
Moisture %	53.6%	54.9%	49.0%	43.3%	48.8%	48.0%

Test Hole	TH13-04	TH13-04	TH13-04	TH13-04	TH13-04	TH13-04
Depth (m)	8.5 - 9.1	9.8 - 10.4	10.4 - 11.0	11.0 - 11.6	11.6 - 12.2	12.8 - 13.4
Sample #	SB 12	SB 14	SB 15	SB 16	SB 17	SB 19
Tare ID	F89	F53	F55	Z130	W27	A103
Mass of tare	8.3	8.5	8.4	8.3	8.2	8.4
Mass wet + tare	649.4	602.3	542.2	781.3	552.8	551.4
Mass dry + tare	421.3	472.1	363.0	520.3	354.8	382.3
Mass water	228.1	130.2	179.2	261.0	198.0	169.1
Mass dry soil	413.0	463.6	354.6	512.0	346.6	373.9
Moisture %	55.2%	28.1%	50.5%	51.0%	57.1%	45.2%



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**Moisture Content Report
 ASTM D2216-98**

Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Sample Date 22-Oct-13
Test Date 24-Oct-13
Technician Chiran Peiris

Test Hole	TH13-04	TH13-04	TH13-04	TH13-04	TH13-04	TH13-04
Depth (m)	13.4 - 14.0	14.0 - 14.6	15.1 - 15.2	15.2 - 15.7	15.8 - 16.5	16.5 - 16.6
Sample #	SB 20	SB 21	SB 22	SB 23	SB 24	SB 25
Tare ID	A26	E38	W65	W15	P08	F14
Mass of tare	8.2	8.3	8.3	8.3	8.5	8.5
Mass wet + tare	402.6	568.1	582.7	350.7	486.7	337.1
Mass dry + tare	265.1	415.6	529.6	261.9	439.4	310.3
Mass water	137.5	152.5	53.1	88.8	47.3	26.8
Mass dry soil	256.9	407.3	521.3	253.6	430.9	301.8
Moisture %	53.5%	37.4%	10.2%	35.0%	11.0%	8.9%

Test Hole	TH13-04	TH13-04	TH13-04	TH13-04		
Depth (m)	0.5 - 0.8	1.2 - 1.5	1.8 - 2.1	2.7 - 3.0		
Sample #	G46	G47	G48	G49		
Tare ID	D15	K1	N65	N72		
Mass of tare	8.4	8.3	8.4	8.4		
Mass wet + tare	366.8	373.1	414.0	380.5		
Mass dry + tare	296.0	294.2	260.6	244.0		
Mass water	70.8	78.9	153.4	136.5		
Mass dry soil	287.6	285.9	252.2	235.6		
Moisture %	24.6%	27.6%	60.8%	57.9%		

Test Hole						
Depth (m)						
Sample #						
Tare ID						
Mass of tare						
Mass wet + tare						
Mass dry + tare						
Mass water						
Mass dry soil						
Moisture %						



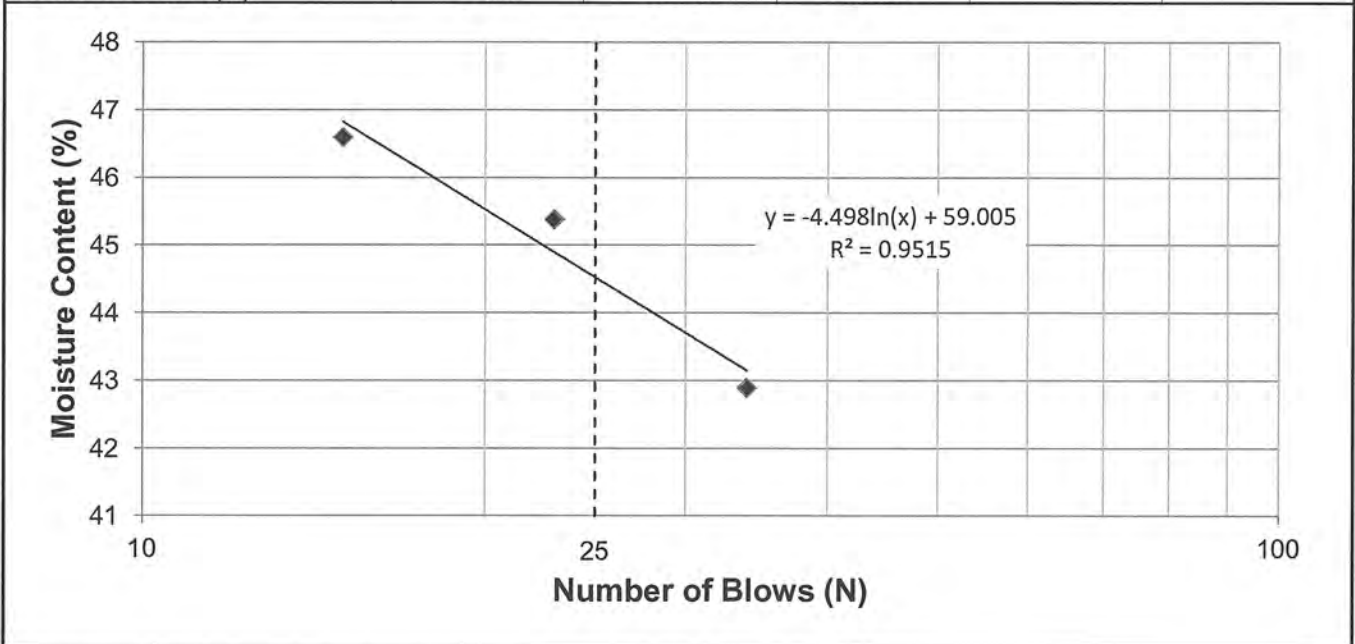
Project No. 0115 004 00
Client Associated Engineering
Project Detailed design of North Kildonan Feedermain

Test Hole TH13-01
Sample # T 34
Depth (m) 3-3.5
Sample Date 12-Nov-13
Test Date 25-Nov-13
Technician Chiran Peiris

Liquid Limit	45
Plastic Limit	15
Plasticity Index	29

Liquid Limit

Trial #	1	2	3	4	5
Number of Blows (N)	34	15	23		
Mass Wet Soil + Tare (g)	18.021	19.111	19.345		
Mass Dry Soil + Tare (g)	16.832	17.544	17.640		
Mass Tare (g)	14.060	14.181	13.883		
Mass Water (g)	1.189	1.567	1.705		
Mass Dry Soil (g)	2.772	3.363	3.757		
Moisture Content (%)	42.893	46.595	45.382		



Plastic Limit

Trial #	1	2	3	4	5
Mass Wet Soil + Tare (g)	20.660	20.395			
Mass Dry Soil + Tare (g)	19.799	19.534			
Mass Tare (g)	14.222	13.986			
Mass Water (g)	0.861	0.861			
Mass Dry Soil (g)	5.577	5.548			
Moisture Content (%)	15.438	15.519			



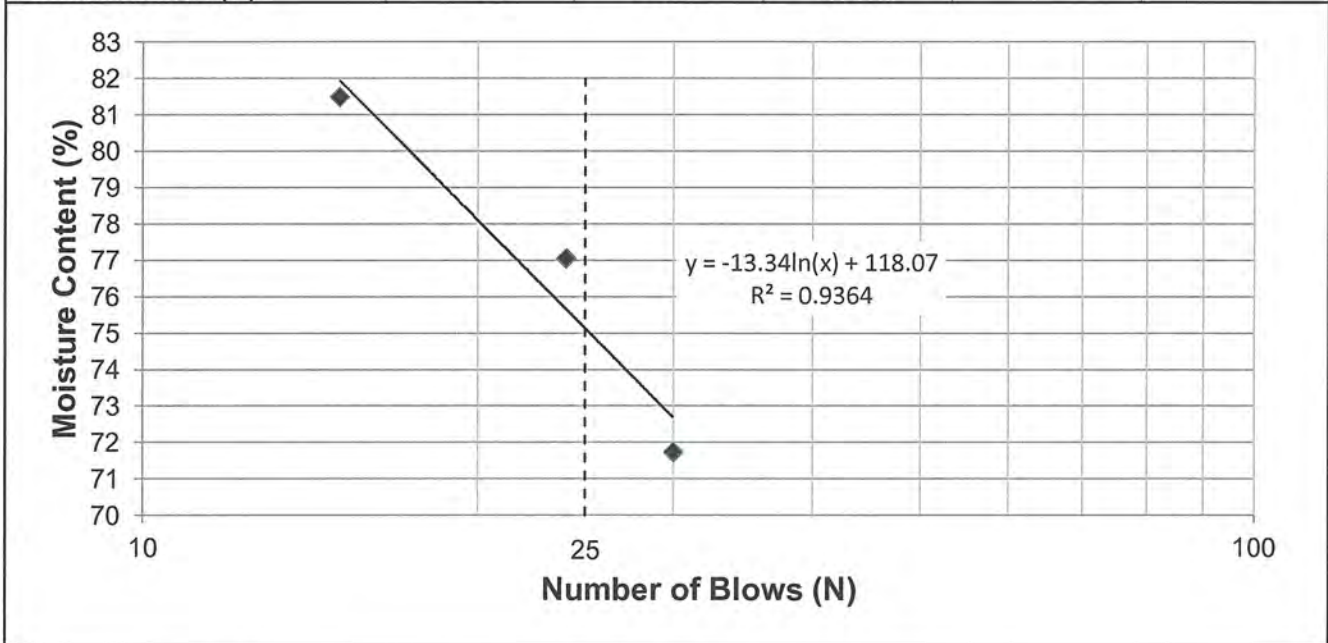
Project No. 0115 004 00
Client Associated Engineering
Project Detailed design of North Kildonan Feedermain

Test Hole TH13-01
Sample # T 08
Depth (m) 6-6.7
Sample Date 15-Nov-13
Test Date 25-Nov-13
Technician Chiran Peiris

Liquid Limit	75
Plastic Limit	18
Plasticity Index	57

Liquid Limit

Trial #	1	2	3	4	5
Number of Blows (N)	30	24	15		
Mass Wet Soil + Tare (g)	19.850	20.389	18.145		
Mass Dry Soil + Tare (g)	17.367	17.635	16.305		
Mass Tare (g)	13.906	14.061	14.047		
Mass Water (g)	2.483	2.754	1.840		
Mass Dry Soil (g)	3.461	3.574	2.258		
Moisture Content (%)	71.742	77.057	81.488		



Plastic Limit

Trial #	1	2	3	4	5
Mass Wet Soil + Tare (g)	20.611	20.638			
Mass Dry Soil + Tare (g)	19.619	19.630			
Mass Tare (g)	14.222	13.967			
Mass Water (g)	0.992	1.008			
Mass Dry Soil (g)	5.397	5.663			
Moisture Content (%)	18.381	17.800			



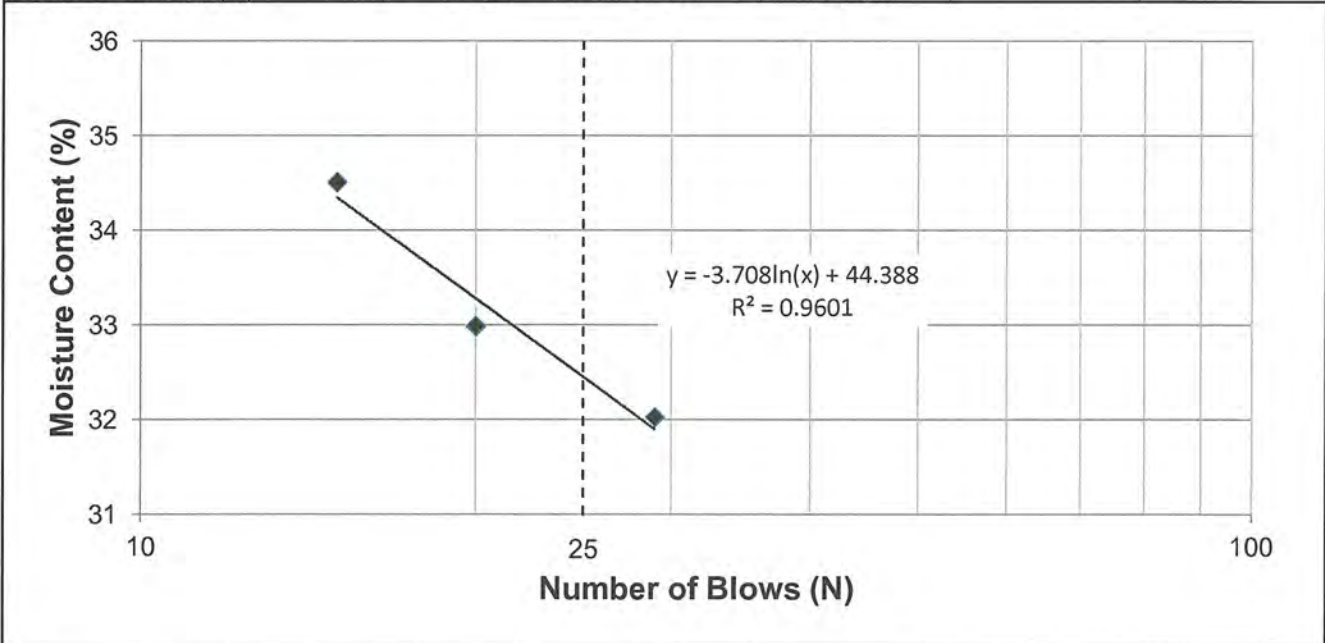
Project No. 0115 004 00
Client Associated Engineering
Project Detailed design of North Kildonan Feedermain

Test Hole TH13-01
Sample # SB 42B
Depth (m) 13-13.7
Sample Date 15-Nov-13
Test Date 25-Nov-13
Technician Chiran Peiris

Liquid Limit	32
Plastic Limit	15
Plasticity Index	17

Liquid Limit

Trial #	1	2	3	4	5
Number of Blows (N)	15	20	29		
Mass Wet Soil + Tare (g)	19.717	20.793	21.239		
Mass Dry Soil + Tare (g)	18.267	19.125	19.516		
Mass Tare (g)	14.065	14.069	14.136		
Mass Water (g)	1.450	1.668	1.723		
Mass Dry Soil (g)	4.202	5.056	5.380		
Moisture Content (%)	34.507	32.991	32.026		



Plastic Limit

Trial #	1	2	3	4	5
Mass Wet Soil + Tare (g)	20.928	20.248			
Mass Dry Soil + Tare (g)	20.033	19.440			
Mass Tare (g)	14.121	14.019			
Mass Water (g)	0.895	0.808			
Mass Dry Soil (g)	5.912	5.421			
Moisture Content (%)	15.139	14.905			

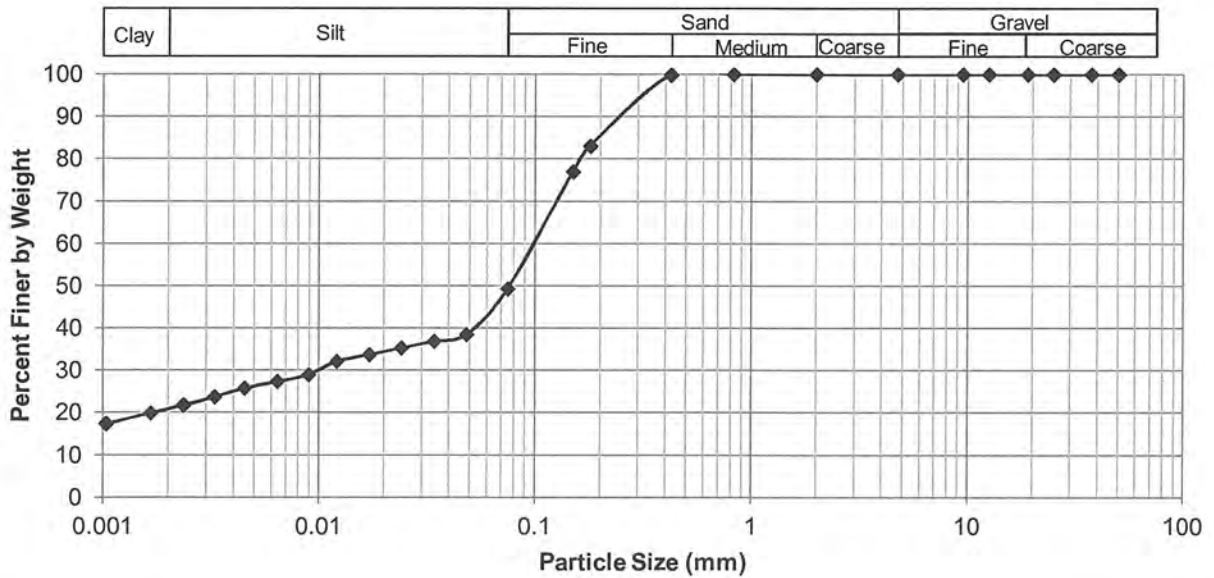


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Test Hole TH13-01
 Sample # SB 39
 Depth (m) 4.6 - 5.0
 Sample Date 15-Nov-13
 Test Date 22-Nov-13
 Technician Chiran Peiris

Gravel	0.0%
Sand	50.7%
Silt	27.3%
Clay	22.0%

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	100.00	0.0750	49.26
37.5	100.00	2.00	100.00	0.0484	38.46
25.0	100.00	0.825	100.00	0.0343	36.87
19.0	100.00	0.425	99.84	0.0242	35.28
12.5	100.00	0.180	83.00	0.0171	33.69
9.50	100.00	0.150	76.96	0.0121	32.11
4.75	100.00	0.075	49.26	0.0089	28.93
				0.0064	27.34
				0.0045	25.75
				0.0033	23.74
				0.0024	21.74
				0.0017	19.86
				0.0010	17.39



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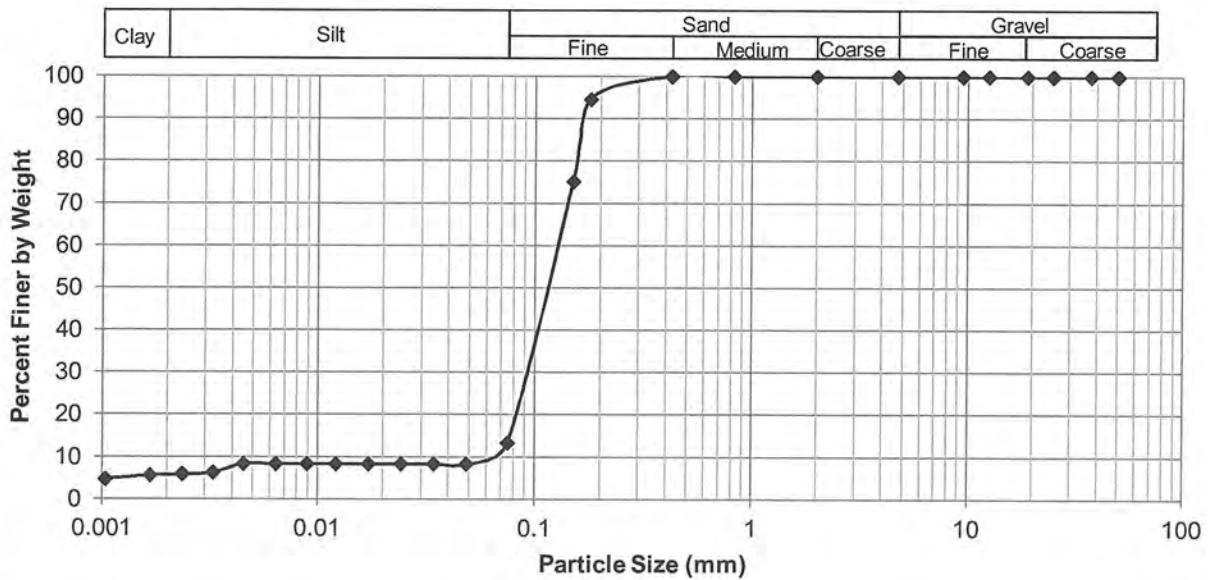
Grain Size Analysis (Hydrometer Method)
ASTM D422

Project No. 0115 004 00
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Project Detailed Design North Kildonan Feedermain

Test Hole TH13-01
Sample # SB 43
Depth (m) 4.6 - 5.0
Sample Date 15-Nov-13
Test Date 22-Nov-13
Technician Chiran Peiris

Gravel	0.0%
Sand	50.7%
Silt	27.3%
Clay	22.0%

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	100.00	0.0750	13.29
37.5	100.00	2.00	100.00	0.0484	8.28
25.0	100.00	0.825	99.98	0.0343	8.28
19.0	100.00	0.425	99.96	0.0242	8.28
12.5	100.00	0.180	94.55	0.0171	8.28
9.50	100.00	0.150	75.09	0.0121	8.28
4.75	100.00	0.075	13.29	0.0089	8.28
				0.0064	8.28
				0.0045	8.28
				0.0033	6.27
				0.0024	5.86
				0.0017	5.57
				0.0010	4.68



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Project Detailed Design North Kildonan Feedermain

Test Hole TH13-01
Sample # T34
Depth (m) 3.0 - 3.7
Sample Date 15-Nov-13
Test Date 20-Nov-13
Technician Hachem Ahmed

Tube Extraction

Recovery (mm) 550

Bottom - 3.7 m

3.0 m - Top

PP Tv Visual Moisture	Some clay	Qu Y _{Bulk} With clay
180 mm	210 mm	160 mm

Visual Classification

Material	Silt (Alluvial)
Composition	Some clay to with clay
Trace sand	
Trace oxidation	
Trace organics (roots)	

Color	dark grey
Moisture	moist
Consistency	stiff
Plasticity	high plasticity
Structure	-
Gradation	-

Torvane

Reading	0.70
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	68.7

Pocket Penetrometer

Reading	1	1.30
	2	1.60
	3	1.40
	Average	1.43
Undrained Shear Strength (kPa)		70.3

Moisture Content

Tare ID	N03
Mass tare (g)	8.4
Mass wet + tare (g)	493.8
Mass dry + tare (g)	370.3
Moisture %	34.1%

Unit Weight

Bulk Weight (g)	1097.00
Length (mm)	1 140.95
	2 140.82
	3 140.93
	4 140.14
Average Length (m)	0.141
Diam. (mm)	1 71.94
	2 71.66
	3 72.51
	4 72.37
Average Diameter (m)	0.072

Volume (m³)	5.75E-04
Bulk Unit Weight (kN/m³)	18.7
Bulk Unit Weight (pcf)	119.1
Dry Unit Weight (kN/m³)	14.0
Dry Unit Weight (pcf)	88.8

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Project Detailed Design North Kildonan Feedermain

Test Hole TH13-01
Sample # T34
Depth (m) 3.0 - 3.7
Sample Date 15-Nov-13
Test Date 20-Nov-13
Technician Hachem Ahmed

Unconfined Strength

	kPa	ksf
Max q_u	45.1	0.9
Max S_u	22.5	0.5

Specimen Data

Description Silt (Alluvial) - Some clay to with clay, Trace sand, Trace oxidation, Trace organics (roots), dark grey, moist, stiff, high plasticity

Length	140.7	(mm)	Moisture %	34%	
Diameter	72.1	(mm)	Bulk Unit Wt.	18.7	(kN/m ³)
L/D Ratio	2.0		Dry Unit Wt.	14.0	(kN/m ³)
Initial Area	0.00409	(m ²)	Liquid Limit	-	
Load Rate	1.00	(%/min)	Plastic Limit	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	Undrained Shear Strength	
	kPa	ksf
tsf		
0.70	68.7	1.43
Vane Size		
m		

Pocket Penetrometer

Reading	Undrained Shear Strength	
	kPa	ksf
tsf		
1.30	63.8	1.33
1.60	78.5	1.64
1.40	68.7	1.43
1.43	70.3	1.47

Failure Geometry

Sketch:

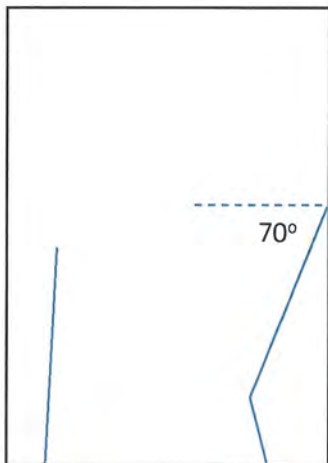
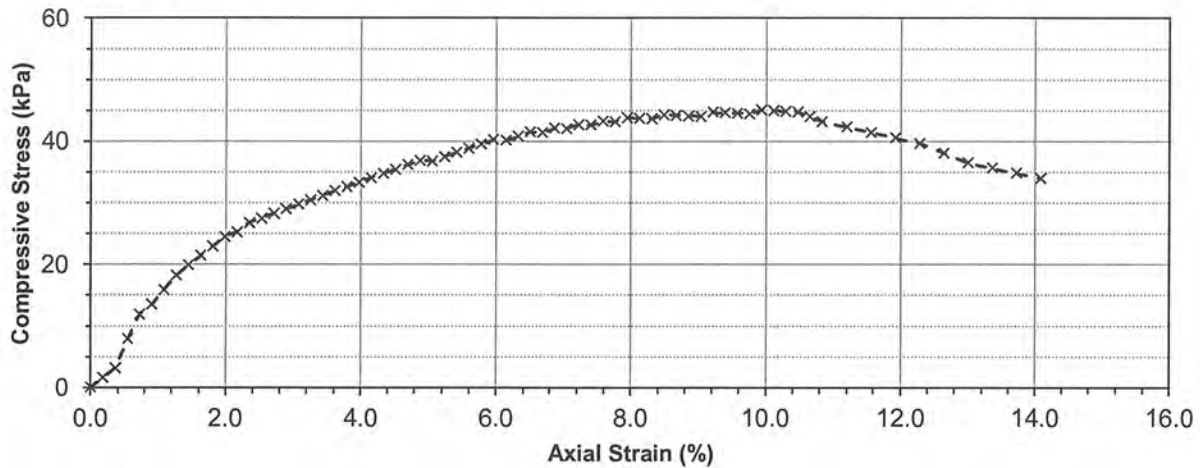


Photo:



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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	0.004085	0.0	0.00	0.00
10	2	0.2540	0.18	0.004092	6.5	1.60	0.80
20	4	0.5080	0.36	0.004100	13.1	3.19	1.59
30	10	0.7620	0.54	0.004107	32.7	7.96	3.98
40	15	1.0160	0.72	0.004115	49.1	11.93	5.97
50	17	1.2700	0.90	0.004122	55.7	13.50	6.75
60	20	1.5240	1.08	0.004130	65.5	15.86	7.93
70	23	1.7780	1.26	0.004137	75.3	18.21	9.11
80	25	2.0320	1.44	0.004145	82.4	19.89	9.94
90	27	2.2860	1.62	0.004153	89.0	21.43	10.72
100	29	2.5400	1.81	0.004160	95.6	22.98	11.49
110	31	2.7940	1.99	0.004168	102.2	24.53	12.26
120	32	3.0480	2.17	0.004176	105.5	25.27	12.63
130	34	3.3020	2.35	0.004183	112.1	26.80	13.40
140	35	3.5560	2.53	0.004191	115.4	27.53	13.77
150	36	3.8100	2.71	0.004199	118.7	28.27	14.13
160	37	4.0640	2.89	0.004207	122.0	29.00	14.50
170	38	4.3180	3.07	0.004214	125.3	29.73	14.87
180	39	4.5720	3.25	0.004222	128.6	30.46	15.23
190	40	4.8260	3.43	0.004230	131.9	31.18	15.59
200	41	5.0800	3.61	0.004238	135.2	31.90	15.95
210	42	5.3340	3.79	0.004246	138.5	32.61	16.31
220	43	5.5880	3.97	0.004254	141.8	33.32	16.66
230	44	5.8420	4.15	0.004262	145.1	34.03	17.02



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Unconfined Compressive Strength
ASTM D2166

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Project Detailed Design North Kildonan Feedermain

Unconfined Compression Test Data (cont'd)

Elapsed Time (s)	Axial Disp. (mm)	Deflection (mm)	Axial Strain (%)	Corrected Area (m ²)	Axial Load (N)	Compressive Stress, q _u (kPa)	Shear Stress, S _u (kPa)
240	45	6.0960	4.3323	0.004270	148.3	34.74	17.37
250	46	6.3500	4.51	0.004278	151.7	35.46	17.73
260	47	6.6040	4.69	0.004286	155.0	36.16	18.08
270	48	6.8580	4.87	0.004294	158.3	36.85	18.43
280	48	7.1120	5.05	0.004303	158.3	36.78	18.39
290	49	7.3660	5.23	0.004311	161.6	37.48	18.74
300	50	7.6200	5.42	0.004319	164.9	38.17	19.08
310	51	7.8740	5.60	0.004327	168.1	38.86	19.43
320	52	8.1280	5.78	0.004336	171.4	39.54	19.77
330	53	8.3820	5.96	0.004344	174.7	40.22	20.11
340	53	8.6360	6.14	0.004352	174.7	40.15	20.07
350	54	8.8900	6.32	0.004361	178.0	40.82	20.41
360	55	9.1440	6.50	0.004369	181.4	41.51	20.75
370	55	9.3980	6.68	0.004377	181.4	41.43	20.71
380	56	9.6520	6.86	0.004386	184.6	42.10	21.05
390	56	9.9060	7.04	0.004394	184.6	42.02	21.01
400	57	10.1600	7.22	0.004403	187.9	42.68	21.34
410	57	10.4140	7.40	0.004412	187.9	42.60	21.30
420	58	10.6680	7.58	0.004420	191.2	43.26	21.63
430	58	10.9220	7.76	0.004429	191.2	43.18	21.59
440	59	11.1760	7.94	0.004438	194.5	43.84	21.92
450	59	11.4300	8.12	0.004446	194.5	43.75	21.87
460	59	11.6840	8.30	0.004455	194.5	43.66	21.83
470	60	11.9380	8.48	0.004464	197.8	44.31	22.16
480	60	12.1920	8.66	0.004473	197.8	44.23	22.11
490	60	12.4460	8.85	0.004481	197.8	44.14	22.07
500	60	12.7000	9.03	0.004490	197.8	44.05	22.03
510	61	12.9540	9.21	0.004499	201.1	44.70	22.35
520	61	13.2080	9.39	0.004508	201.1	44.61	22.30
530	61	13.4620	9.57	0.004517	201.1	44.52	22.26
540	61	13.7160	9.75	0.004526	201.1	44.43	22.22
550	62	13.9700	9.93	0.004535	204.4	45.07	22.53
560	62	14.2240	10.11	0.004544	204.4	44.98	22.49
570	62	14.4780	10.29	0.004554	204.4	44.89	22.44
580	62	14.7320	10.47	0.004563	204.4	44.80	22.40
590	61	14.9860	10.65	0.004572	201.1	43.99	21.99
600	60	15.2400	10.83	0.004581	197.8	43.18	21.59
620	59	15.7480	11.19	0.004600	194.5	42.29	21.14
640	58	16.2560	11.55	0.004619	191.2	41.40	20.70
660	57	16.7640	11.91	0.004638	187.9374	40.52	20.26
680	56	17.2720	12.27	0.004657	184.6457	39.65	19.83
700	54	17.7800	12.64	0.004676	178.0178	38.07	19.04
720	52	18.2880	13.00	0.004695	171.4345	36.51	18.26
740	51	18.7960	13.36	0.004715	168.1428	35.66	17.83



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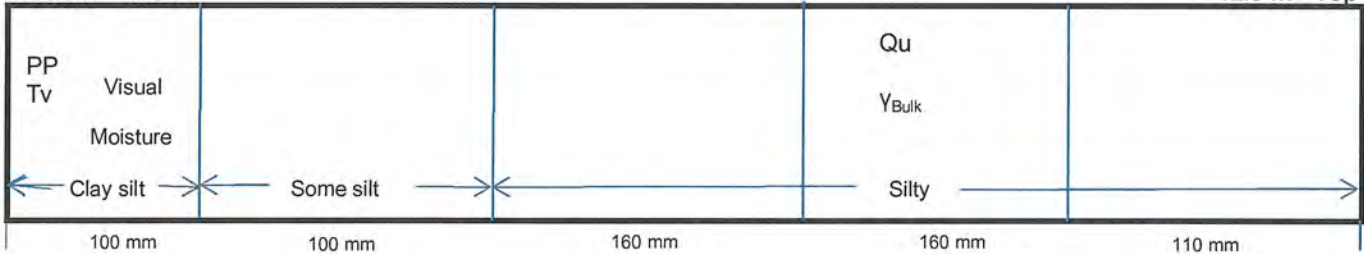
Test Hole TH13-01
 Sample # T41
 Depth (m) 12 - 12.8
 Sample Date 15-Nov-13
 Test Date 21-Nov-13
 Technician Hachem Ahmed

Tube Extraction

Recovery (mm) 630

Bottom - 12.8 m

12.0 m - Top



Visual Classification

Material	Caly and silt (Alluvial)
Composition	Some silt to silty
Trace organics	
Trace oxidation	
Color	Dark grey
Moisture	Moist
Consistency	Stiff
Plasticity	Intermediate
Structure	-
Gradation	-

Torvane

Reading	0.52
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	51.0

Pocket Penetrometer

Reading	1	1.10
	2	1.20
	3	1.10
	Average	1.13
Undrained Shear Strength (kPa)		55.6

Moisture Content

Tare ID	f151
Mass tare (g)	8.4
Mass wet + tare (g)	409.4
Mass dry + tare (g)	309.3
Moisture %	33.3%

Unit Weight

Bulk Weight (g)	1161.70
Length (mm)	1 151.52
	2 151.64
	3 151.82
	4 151.37
Average Length (m)	0.152
Diam. (mm)	1 72.38
	2 72.58
	3 72.38
	4 72.55
Average Diameter (m)	0.072

Volume (m ³)	6.25E-04
Bulk Unit Weight (kN/m ³)	18.2
Bulk Unit Weight (pcf)	116.0
Dry Unit Weight (kN/m ³)	13.7
Dry Unit Weight (pcf)	87.0

Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Test Hole TH13-01
Sample # T41
Depth (m) 12 - 12.8
Sample Date 15-Nov-13
Test Date 21-Nov-13
Technician Hachem Ahmed

Unconfined Strength

	kPa	ksf
Max q_u	106.6	2.2
Max S_u	53.3	1.1

Specimen Data

Description Caly and silt (Alluvial) - Some silty to silt, Trace organics, Trace oxidation, Dark grey, Moist, Stiff, Intermediate

Length	151.6	(mm)	Moisture %	33%	
Diameter	72.5	(mm)	Bulk Unit Wt.	18.2	(kN/m ³)
L/D Ratio	2.1		Dry Unit Wt.	13.7	(kN/m ³)
Initial Area	0.00413	(m ²)	Liquid Limit	-	
Load Rate	1.00	(%/min)	Plastic Limit	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	Undrained Shear Strength	
	kPa	ksf
tsf		
0.52	51.0	1.07
Vane Size		
m		

Pocket Penetrometer

Reading	Undrained Shear Strength	
	kPa	ksf
tsf		
1.10	54.0	1.13
1.20	58.9	1.23
1.10	54.0	1.13
1.13	55.6	1.16

Failure Geometry

Sketch:

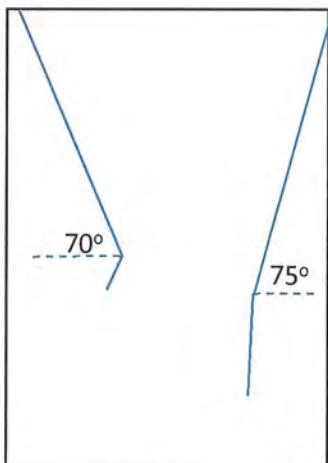
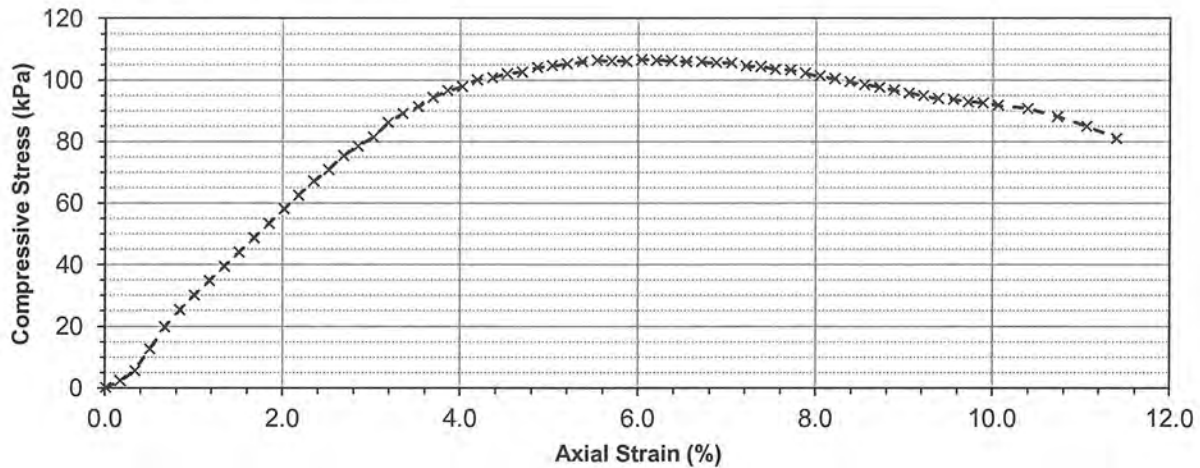


Photo:



Project No. 0115 004 00
 Client Associated Engineering
 Project Detailed Design North Kildonan Feedermain

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	0.004125	0.0	0.00	0.00
10	3	0.2540	0.17	0.004132	9.8	2.37	1.19
20	7	0.5080	0.34	0.004139	22.9	5.53	2.76
30	16	0.7620	0.50	0.004146	52.4	12.63	6.32
40	25	1.0160	0.67	0.004153	82.4	19.85	9.92
50	32	1.2700	0.84	0.004160	105.5	25.36	12.68
60	38	1.5240	1.01	0.004167	125.3	30.07	15.04
70	44	1.7780	1.17	0.004174	145.1	34.75	17.38
80	50	2.0320	1.34	0.004181	164.9	39.43	19.71
90	56	2.2860	1.51	0.004188	184.6	44.09	22.04
100	62	2.5400	1.68	0.004195	204.4	48.72	24.36
110	68	2.7940	1.84	0.004203	224.2	53.35	26.67
120	74	3.0480	2.01	0.004210	244.0	57.96	28.98
130	80	3.3020	2.18	0.004217	263.8	62.55	31.28
140	86	3.5560	2.35	0.004224	283.5	67.12	33.56
150	91	3.8100	2.51	0.004231	300.0	70.91	35.45
160	97	4.0640	2.68	0.004239	319.8	75.45	37.73
170	101	4.3180	2.85	0.004246	333.1	78.45	39.22
180	105	4.5720	3.02	0.004253	346.6	81.48	40.74
190	111	4.8260	3.18	0.004261	366.8	86.08	43.04
200	115	5.0800	3.35	0.004268	380.2	89.09	44.54
210	118	5.3340	3.52	0.004276	390.3	91.29	45.65
220	122	5.5880	3.69	0.004283	403.8	94.28	47.14
230	125	5.8420	3.85	0.004290	413.9	96.47	48.24



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Unconfined Compressive Strength
ASTM D2166

Project No. 0115 004 00
Client Associated Engineering
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Unconfined Compression Test Data (cont'd)

Elapsed Time (s)	Axial Disp. (mm)	Deflection (mm)	Axial Strain (%)	Corrected Area (m ²)	Axial Load (N)	Compressive Stress, q _u (kPa)	Shear Stress, S _u (kPa)
240	127	6.0960	4.0214	0.004298	420.6	97.87	48.93
250	130	6.3500	4.19	0.004305	430.7	100.04	50.02
260	131	6.6040	4.36	0.004313	434.1	100.65	50.32
270	133	6.8580	4.52	0.004321	440.8	102.03	51.01
280	134	7.1120	4.69	0.004328	444.2	102.63	51.31
290	136	7.3660	4.86	0.004336	451.0	104.01	52.00
300	137	7.6200	5.03	0.004343	454.3	104.59	52.30
310	138	7.8740	5.19	0.004351	457.7	105.19	52.59
320	139	8.1280	5.36	0.004359	461.1	105.78	52.89
330	140	8.3820	5.53	0.004367	464.4	106.35	53.18
340	140	8.6360	5.70	0.004374	464.4	106.16	53.08
350	140	8.8900	5.86	0.004382	464.4	105.98	52.99
360	141	9.1440	6.03	0.004390	467.8	106.56	53.28
370	141	9.3980	6.20	0.004398	467.8	106.37	53.18
380	141	9.6520	6.37	0.004406	467.8	106.18	53.09
390	141	9.9060	6.53	0.004414	467.8	105.99	52.99
400	141	10.1600	6.70	0.004421	467.8	105.80	52.90
410	141	10.4140	6.87	0.004429	467.8	105.61	52.80
420	141	10.6680	7.04	0.004437	467.8	105.42	52.71
430	140	10.9220	7.21	0.004445	464.4	104.47	52.23
440	140	11.1760	7.37	0.004453	464.4	104.28	52.14
450	139	11.4300	7.54	0.004462	461.1	103.34	51.67
460	139	11.6840	7.71	0.004470	461.1	103.15	51.58
470	138	11.9380	7.88	0.004478	457.7	102.21	51.11
480	137	12.1920	8.04	0.004486	454.3	101.27	50.64
490	136	12.4460	8.21	0.004494	451.0	100.34	50.17
500	135	12.7000	8.38	0.004502	447.6	99.41	49.71
510	134	12.9540	8.55	0.004511	444.2	98.48	49.24
520	133	13.2080	8.71	0.004519	440.8	97.55	48.78
530	132	13.4620	8.88	0.004527	437.5	96.64	48.32
540	131	13.7160	9.05	0.004536	434.1	95.71	47.86
550	130	13.9700	9.22	0.004544	430.7	94.79	47.40
560	129	14.2240	9.38	0.004552	427.4	93.88	46.94
570	129	14.4780	9.55	0.004561	427.4	93.71	46.86
580	128	14.7320	9.72	0.004569	424.0	92.80	46.40
590	128	14.9860	9.89	0.004578	424.0	92.62	46.31
600	127	15.2400	10.05	0.004586	420.6	91.72	45.86
620	126	15.7480	10.39	0.004603	417.2	90.64	45.32
640	123	16.2560	10.72	0.004621	407.1	88.11	44.06
660	119	16.7640	11.06	0.004638	393.6676	84.88	42.44
680	114	17.2720	11.39	0.004656	376.8533	80.95	40.47
700	105	17.7800	11.73	0.004673	346.5609	74.16	37.08



Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Test Hole TH13-04
Sample # T08
Depth (m) 6.1 - 6.7
Sample Date 15-Nov-13
Test Date 21-Nov-13
Technician HA

Tube Extraction

Recovery (mm) 450

Bottom - 6.7

6.1 m - Top

PP Tv Visual Moisture	Qu Y _{Bulk}	
120 mm	170 mm	160 mm

Visual Classification

Material	Clay
Composition	Silty
Trace silt inclusions (< 10mm dia.)	
Trace gravel	

Color	Dark grey
Moisture	Moist
Consistency	Firm
Plasticity	High plasticity
Structure	-
Gradation	-

Torvane

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

Pocket Penetrometer

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

Moisture Content

Tare ID	P10
Mass tare (g)	8.3
Mass wet + tare (g)	470.6
Mass dry + tare (g)	304.4
Moisture %	56.1%

Unit Weight

Bulk Weight (g)	1152.10
------------------------	---------

Length (mm)	1	150.91
	2	150.83
	3	150.90
	4	150.88
Average Length (m)		0.151

Diam. (mm)	1	72.38
	2	71.83
	3	72.08
	4	72.63
Average Diameter (m)		0.072

Volume (m³)	6.18E-04
Bulk Unit Weight (kN/m³)	18.3
Bulk Unit Weight (pcf)	116.3
Dry Unit Weight (kN/m³)	11.7
Dry Unit Weight (pcf)	74.5

Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Test Hole TH13-04
Sample # T08
Depth (m) 6.1 - 6.7
Sample Date 15-Nov-13
Test Date 21-Nov-13
Technician HA

Unconfined Strength

	kPa	ksf
Max q_u	90.0	1.9
Max S_u	45.0	0.9

Specimen Data

Description Clay - Silty, Trace silt inclusions (< 10mm dia.), Trace gravel, Dark grey, Moist, Firm, High plasticity

Length	150.9	(mm)	Moisture %	56%	
Diameter	72.2	(mm)	Bulk Unit Wt.	18.3	(kN/m ³)
L/D Ratio	2.1		Dry Unit Wt.	11.7	(kN/m ³)
Initial Area	0.00410	(m ²)	Liquid Limit	-	
Load Rate	1.00	(%/min)	Plastic Limit	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

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

Pocket Penetrometer

Reading	Undrained Shear Strength	
	kPa	ksf
tsf		
0.70	34.3	0.72
0.75	36.8	0.77
0.70	34.3	0.72
0.72	35.2	0.73

Failure Geometry

Sketch:

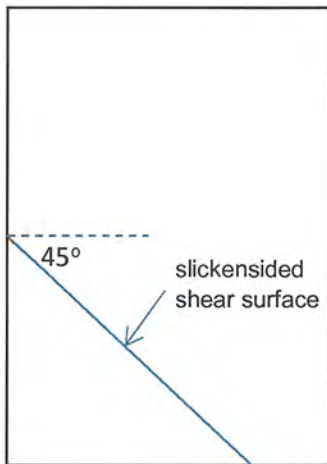
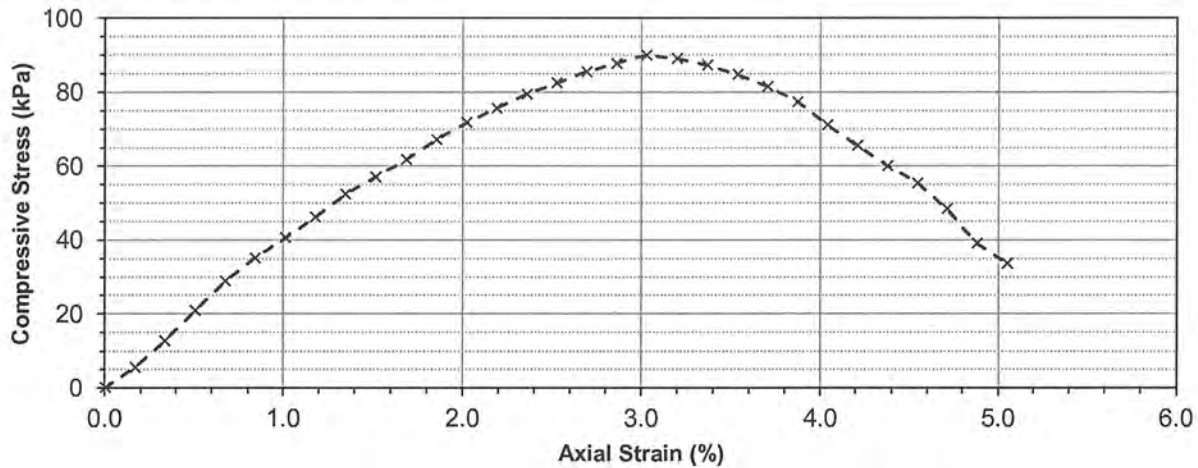


Photo:



Project No. 0115 004 00
 Client Associated Engineering
 Project Detailed Design North Kildonan Feedermain

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	0.004098	0.0	0.00	0.00
10	7	0.2540	0.17	0.004104	22.9	5.58	2.79
20	16	0.5080	0.34	0.004111	52.4	12.74	6.37
30	26	0.7620	0.51	0.004118	85.7	20.81	10.41
40	36	1.0160	0.67	0.004125	118.7	28.77	14.38
50	44	1.2700	0.84	0.004132	145.1	35.10	17.55
60	51	1.5240	1.01	0.004139	168.1	40.62	20.31
70	58	1.7780	1.18	0.004146	191.2	46.12	23.06
80	66	2.0320	1.35	0.004153	217.6	52.39	26.20
90	72	2.2860	1.52	0.004161	237.4	57.06	28.53
100	78	2.5400	1.68	0.004168	257.2	61.70	30.85
110	85	2.7940	1.85	0.004175	280.2	67.12	33.56
120	91	3.0480	2.02	0.004182	300.0	71.74	35.87
130	96	3.3020	2.19	0.004189	316.5	75.56	37.78
140	101	3.5560	2.36	0.004196	333.1	79.37	39.69
150	105	3.8100	2.53	0.004204	346.6	82.44	41.22
160	109	4.0640	2.69	0.004211	360.0	85.49	42.74
170	112	4.3180	2.86	0.004218	370.1	87.75	43.87
180	115	4.5720	3.03	0.004226	380.2	89.98	44.99
190	114	4.8260	3.20	0.004233	376.9	89.03	44.51
200	112	5.0800	3.37	0.004240	370.1	87.29	43.64
210	109	5.3340	3.54	0.004248	360.0	84.75	42.37
220	105	5.5880	3.70	0.004255	346.6	81.45	40.72
230	100	5.8420	3.87	0.004263	329.7	77.35	38.67



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Unconfined Compressive Strength
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Unconfined Compression Test Data (cont'd)

Elapsed Time (s)	Axial Disp. (mm)	Deflection (mm)	Axial Strain (%)	Corrected Area (m ²)	Axial Load (N)	Compressive Stress, q _u (kPa)	Shear Stress, S _u (kPa)
240	92	6.0960	4.0403	0.004270	303.3	71.03	35.52
250	85	6.3500	4.21	0.004278	280.2	65.51	32.76
260	78	6.6040	4.38	0.004285	257.2	60.01	30.01
270	72	6.8580	4.55	0.004293	237.4	55.30	27.65
280	63	7.1120	4.71	0.004300	207.7	48.31	24.15
290	51	7.3660	4.88	0.004308	168.1	39.03	19.52
300	44	7.6200	5.05	0.004316	145.1	33.61	16.81



Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Test Hole TH13-04
Sample # T13
Depth (m) 9.1 - 9.8
Sample Date 15-Nov-13
Test Date 21-Nov-13
Technician Hachem Ahmed

Tube Extraction

Recovery (mm) 450

Bottom - 9.8 m

9.1 m - Top

PP Tv Visual Moisture	Qu Y _{Bulk}	
110 mm	170 mm	190 mm

Visual Classification

Material	Clay
Composition	Silty
Trace silt inclusions	
Trace gravel	

Color	Dark grey
Moisture	Moist
Consistency	Firm
Plasticity	High plasticity
Structure	-
Gradation	-

Torvane	
Reading	0.25
Vane Size (s,m,l)	m
Undrained Shear Strength (kPa)	24.5

Pocket Penetrometer	
Reading	1 0.60
	2 0.50
	3 0.80
	Average 0.63
Undrained Shear Strength (kPa)	31.1

Moisture Content

Tare ID	K22
Mass tare (g)	8.5
Mass wet + tare (g)	462.8
Mass dry + tare (g)	351.3
Moisture %	32.5%

Unit Weight

Bulk Weight (g)	1196.70
Length (mm)	1 152.25
	2 152.31
	3 152.35
	4 152.39
Average Length (m)	0.152

Diam. (mm)	1 71.81
	2 72.71
	3 72.43
	4 72.32
Average Diameter (m)	0.072

Volume (m³)	6.26E-04
Bulk Unit Weight (kN/m³)	18.8
Bulk Unit Weight (pcf)	119.4
Dry Unit Weight (kN/m³)	14.2
Dry Unit Weight (pcf)	90.1

Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Test Hole TH13-04
Sample # T13
Depth (m) 9.1 - 9.8
Sample Date 15-Nov-13
Test Date 21-Nov-13
Technician Hachem Ahmed

Unconfined Strength

	kPa	ksf
Max q_u	78.3	1.6
Max S_u	39.1	0.8

Specimen Data

Description Silty clay - trace silt inclusions, trace gravel, dark grey, moist, firm, high plasticity

Length	152.3	(mm)	Moisture %	33%	
Diameter	72.3	(mm)	Bulk Unit Wt.	18.8	(kN/m ³)
L/D Ratio	2.1		Dry Unit Wt.	14.2	(kN/m ³)
Initial Area	0.00411	(m ²)	Liquid Limit	-	
Load Rate	1.00	(%/min)	Plastic Limit	-	
			Plasticity Index	-	

Undrained Shear Strength Tests

Torvane

Reading	Undrained Shear Strength	
	kPa	ksf
tsf		
0.25	24.5	0.51
Vane Size		
m		

Pocket Penetrometer

Reading	Undrained Shear Strength	
	kPa	ksf
tsf		
0.60	29.4	0.61
0.50	24.5	0.51
0.80	39.2	0.82
0.63	31.1	0.65

Failure Geometry

Sketch:

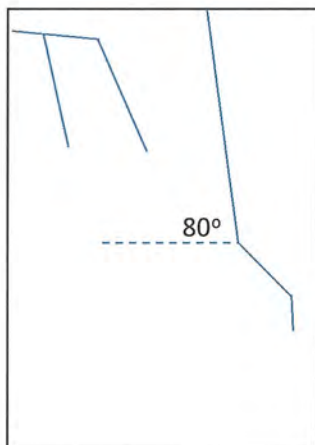
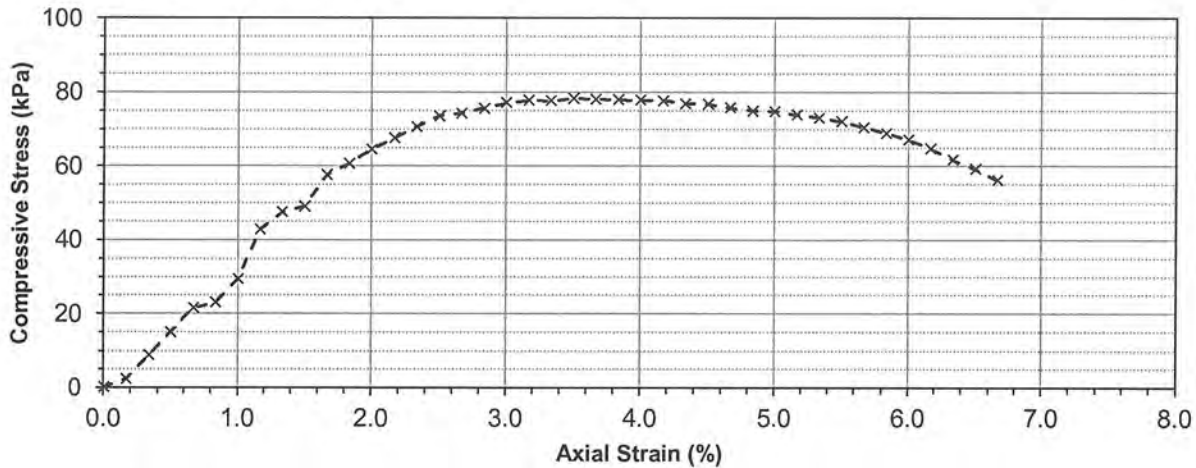


Photo:



Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

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	0.004107	0.0	0.00	0.00
10	3	0.2540	0.17	0.004114	9.8	2.38	1.19
20	11	0.5080	0.33	0.004121	36.0	8.73	4.37
30	19	0.7620	0.50	0.004128	62.2	15.07	7.54
40	27	1.0160	0.67	0.004135	89.0	21.53	10.76
50	29	1.2700	0.83	0.004142	95.6	23.08	11.54
60	37	1.5240	1.00	0.004149	122.0	29.40	14.70
70	54	1.7780	1.17	0.004156	178.0	42.83	21.42
80	60	2.0320	1.33	0.004163	197.8	47.52	23.76
90	62	2.2860	1.50	0.004170	204.4	49.01	24.51
100	73	2.5400	1.67	0.004177	240.7	57.62	28.81
110	77	2.7940	1.83	0.004184	253.9	60.67	30.34
120	82	3.0480	2.00	0.004191	270.4	64.50	32.25
130	86	3.3020	2.17	0.004199	283.5	67.53	33.77
140	90	3.5560	2.33	0.004206	296.7	70.56	35.28
150	94	3.8100	2.50	0.004213	309.9	73.56	36.78
160	95	4.0640	2.67	0.004220	313.2	74.22	37.11
170	97	4.3180	2.83	0.004227	319.8	75.66	37.83
180	99	4.5720	3.00	0.004235	326.4	77.08	38.54
190	100	4.8260	3.17	0.004242	329.7	77.73	38.86
200	100	5.0800	3.33	0.004249	329.7	77.59	38.80
210	101	5.3340	3.50	0.004257	333.1	78.25	39.13
220	101	5.5880	3.67	0.004264	333.1	78.12	39.06
230	101	5.8420	3.84	0.004271	333.1	77.98	38.99



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Unconfined Compressive Strength
ASTM D2166

Project No. 0115 004 00
Client Associated Engineering
Project Detailed Design North Kildonan Feedermain

Unconfined Compression Test Data (cont'd)

Elapsed Time (s)	Axial Disp. (mm)	Deflection (mm)	Axial Strain (%)	Corrected Area (m ²)	Axial Load (N)	Compressive Stress, q _u (kPa)	Shear Stress, S _u (kPa)
240	101	6.0960	4.0020	0.004279	333.1	77.85	38.92
250	101	6.3500	4.17	0.004286	333.1	77.71	38.86
260	100	6.6040	4.34	0.004294	329.7	76.79	38.39
270	100	6.8580	4.50	0.004301	329.7	76.65	38.33
280	99	7.1120	4.67	0.004309	326.4	75.76	37.88
290	98	7.3660	4.84	0.004316	323.1	74.86	37.43
300	98	7.6200	5.00	0.004324	323.1	74.73	37.37
310	97	7.8740	5.17	0.004331	319.8	73.84	36.92
320	96	8.1280	5.34	0.004339	316.5	72.95	36.48
330	95	8.3820	5.50	0.004347	313.2	72.05	36.03
340	93	8.6360	5.67	0.004354	306.6	70.42	35.21
350	91	8.8900	5.84	0.004362	300.0	68.78	34.39
360	89	9.1440	6.00	0.004370	293.4	67.15	33.58
370	86	9.3980	6.17	0.004378	283.5	64.77	32.38
380	82	9.6520	6.34	0.004385	270.4	61.65	30.83
390	79	9.9060	6.50	0.004393	260.4	59.28	29.64
400	75	10.1600	6.67	0.004401	247.3	56.19	28.09



TREK GEOTECHNICAL INC.
19-6104-3

LABORATORY TESTING RESULTS
DECEMBER 2013

DRILL HOLE NUMBER	SAMPLE #	DEPTH		COMPRESSIVE STRENGTH		MATERIAL
		FROM	TO	C _u	Strain	
		(FT)	(FT)	(MPa)	(%)	
TH13-01	CB57	65' 4"	66'	49.1	0.056	Limestone
	CB64	99' 9"	100' 5"	31.2	0.042	Limestone
	CB65	101' 4"	102' 2"	21.8	0.045	Limestone
	CB67	114'	114' 11"	33.1	0.066	Limestone
TH13-05	CB72	62' 9"	63' 6"	39.5	0.048	Limestone
	CB74	71' 5"	72' 4"	39.5	0.081	Limestone
	CB79	97' 4"	98' 3"	11.9	0.037	Limestone



THURBER ENGINEERING LTD.

UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

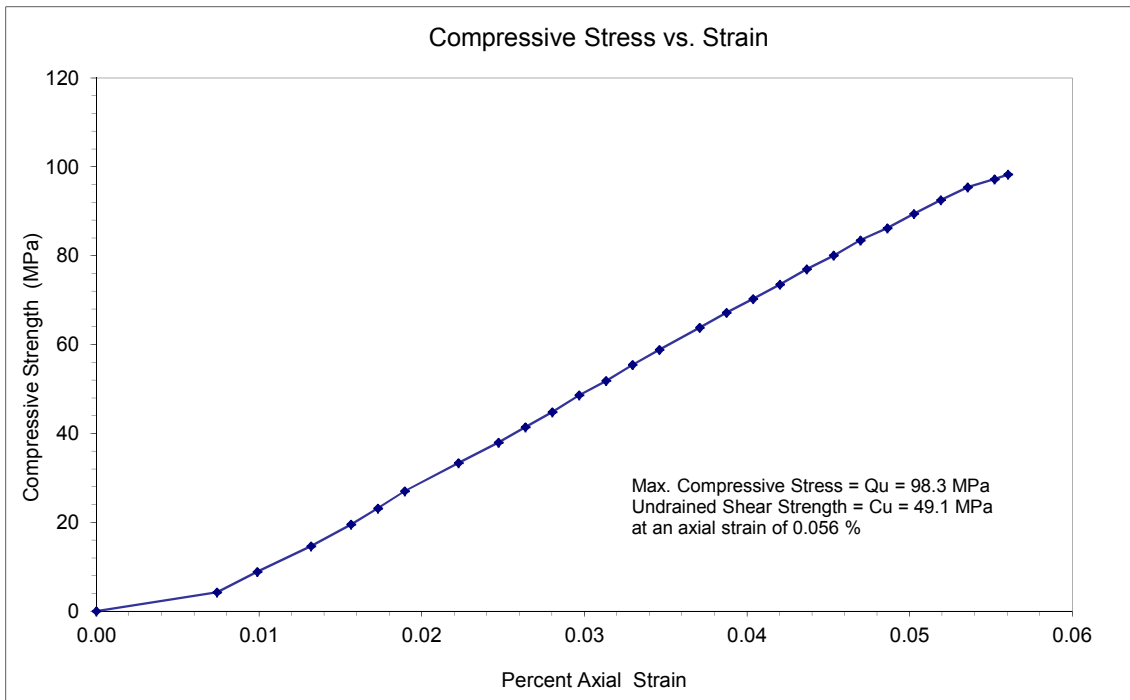
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-1c

Unconfined Compressive Strengths

TEST DATE: Dec 4/13
SAMPLE: TH13-01, CB57, @ 65'-4" to 66'
DESCRIPTION: Limestone, massive.

SPECIMEN DETAILS:

Wet Density (kg/m³): 2487
Dry Density (kg/m³): 2478
Moisture Content (%): 0.4





THURBER ENGINEERING LTD.

UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

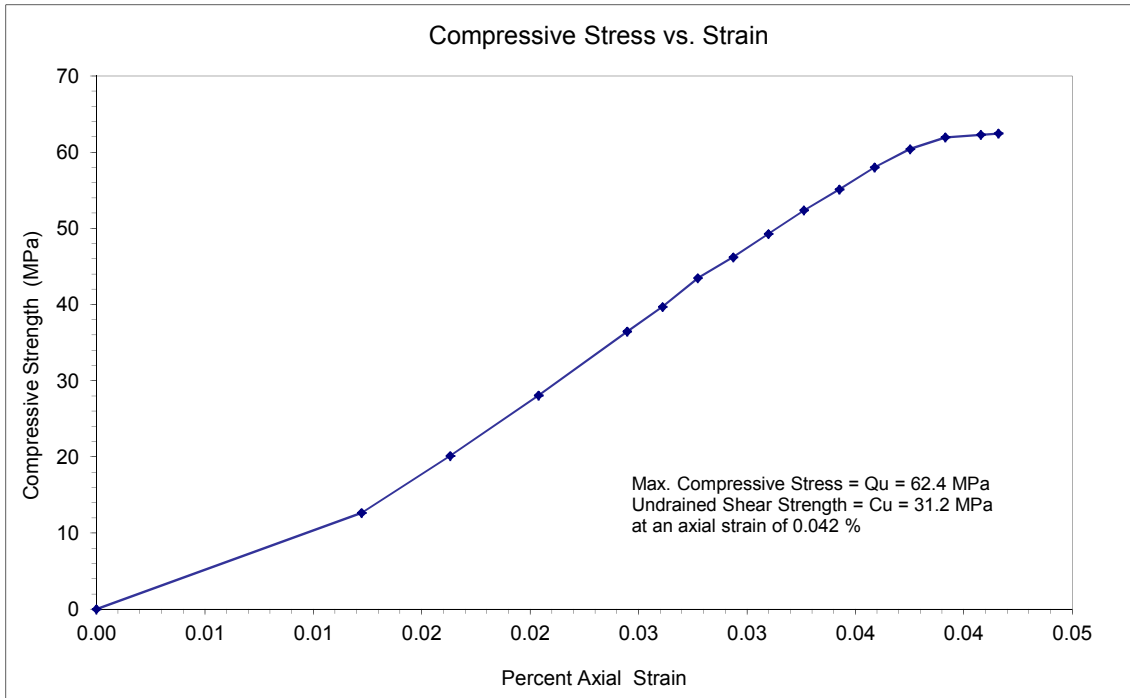
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-4c

Unconfined Compressive Strengths

TEST DATE: Dec 4/13
SAMPLE: TH13-01, CB64, @ 99'-9" to 100'-5"
DESCRIPTION: Limestone, nodular.

SPECIMEN DETAILS:

Wet Density (kg/m³): 2561
Dry Density (kg/m³): 2535
Moisture Content (%): 1.0





THURBER ENGINEERING LTD.

UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

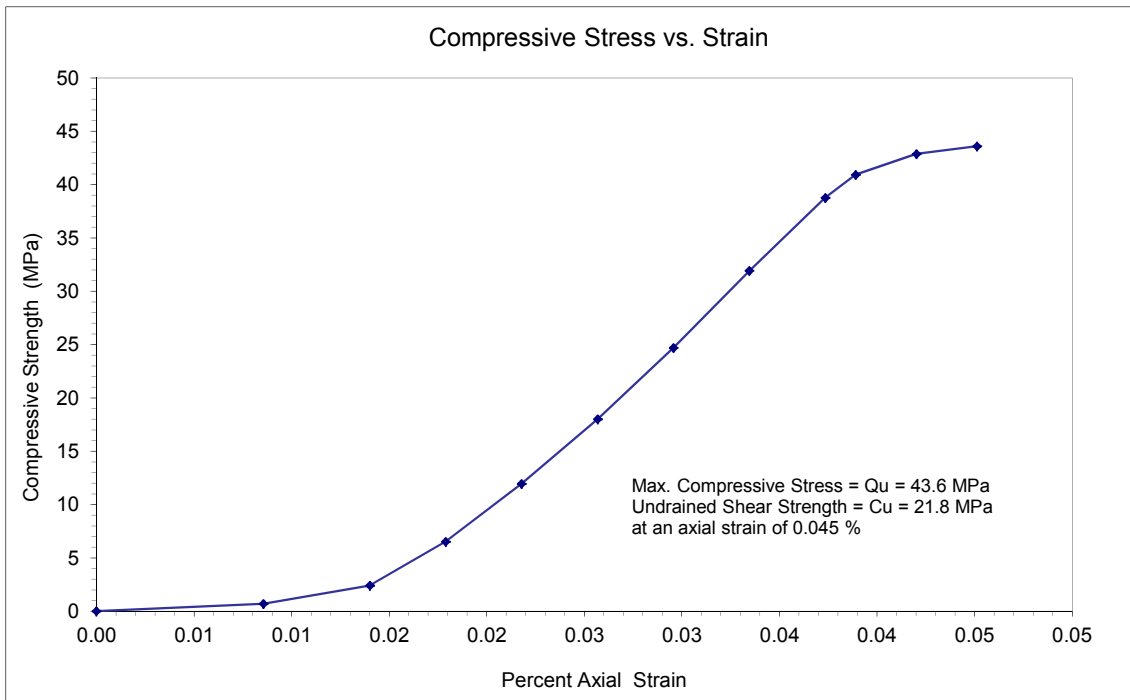
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-2c

Unconfined Compressive Strengths

TEST DATE: Dec 4/13
SAMPLE: TH13-01, CB65, @ 101'-4" to 102'-2"
DESCRIPTION: Limestone, nodular.

SPECIMEN DETAILS:

Wet Density (kg/m³): 2305
Dry Density (kg/m³): 2206
Moisture Content (%): 4.5





THURBER ENGINEERING LTD.

UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

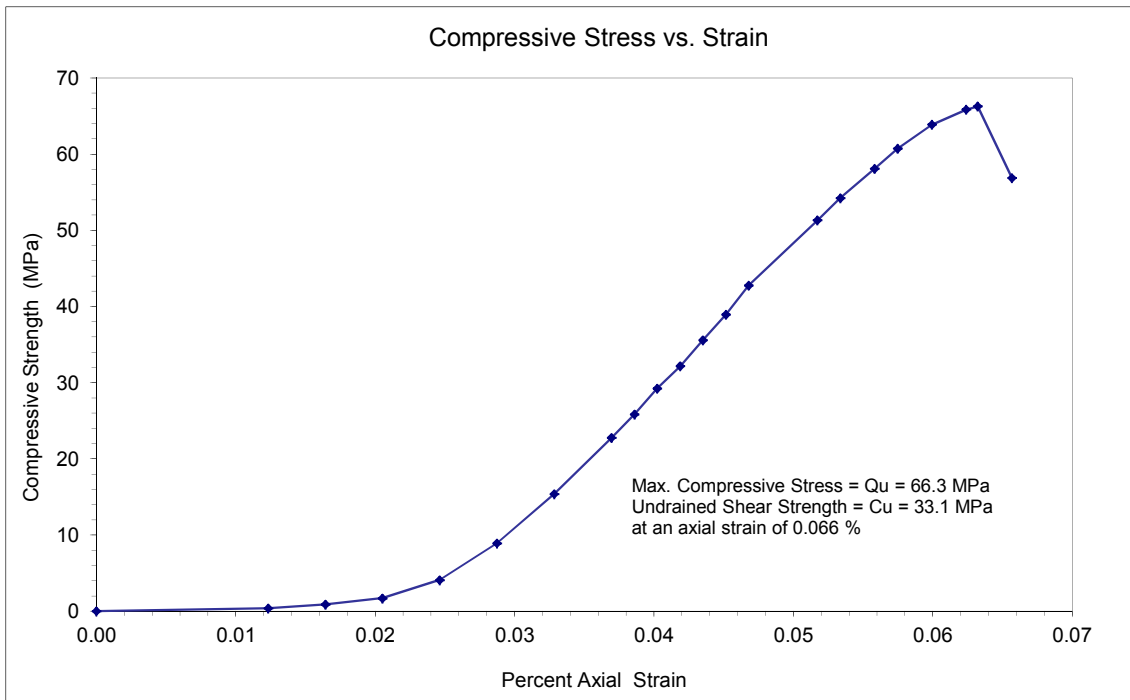
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-3c

Unconfined Compressive Strengths

TEST DATE: Dec 4/13
SAMPLE: TH13-01, CB67, @ 114' to 114'-11"
DESCRIPTION: Limestone, nodular.

SPECIMEN DETAILS:

Wet Density (kg/m³): 2547
Dry Density (kg/m³): 2502
Moisture Content (%): 1.8





THURBER ENGINEERING LTD.

UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

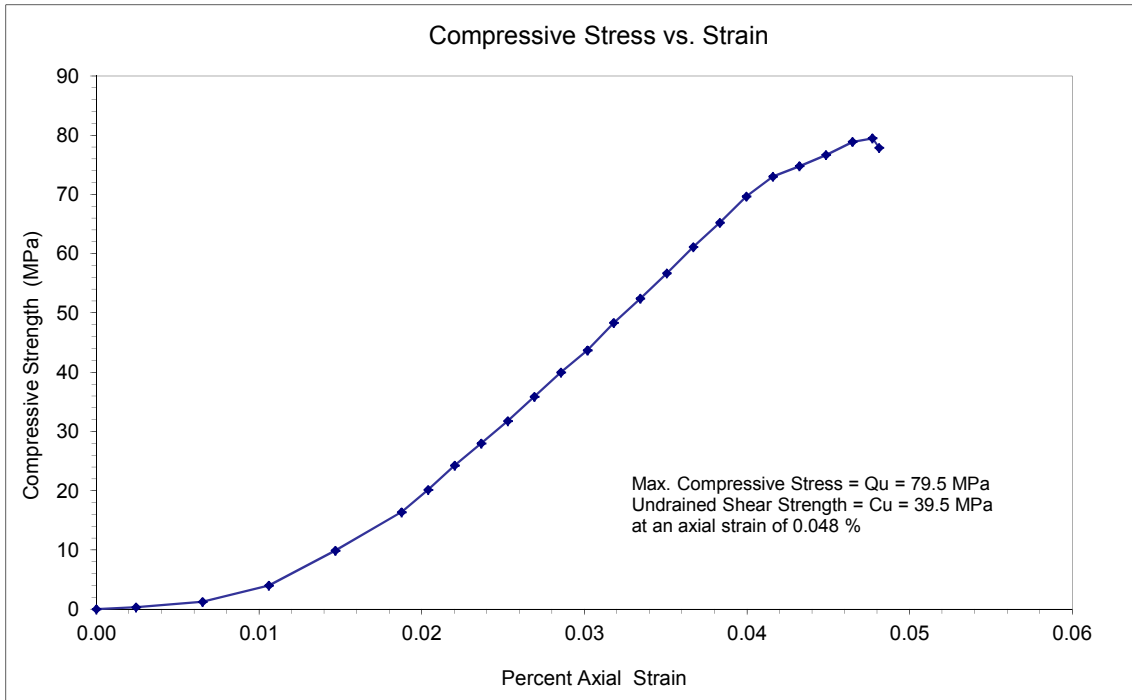
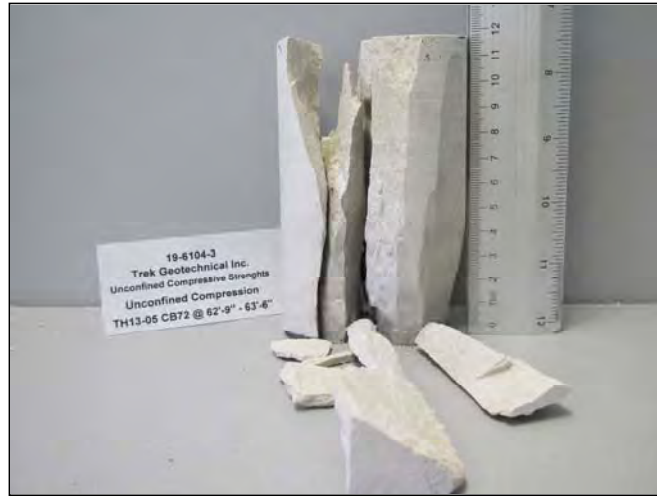
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-5c

Unconfined Compressive Strengths

TEST DATE: Dec 4/13
SAMPLE: TH13-05, CB72, @ 62'-9" to 63'-6"
DESCRIPTION: Limestone, massive.

SPECIMEN DETAILS:

Wet Density (kg/m³): 2647
Dry Density (kg/m³): 2633
Moisture Content (%): 0.6





THURBER ENGINEERING LTD.

UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

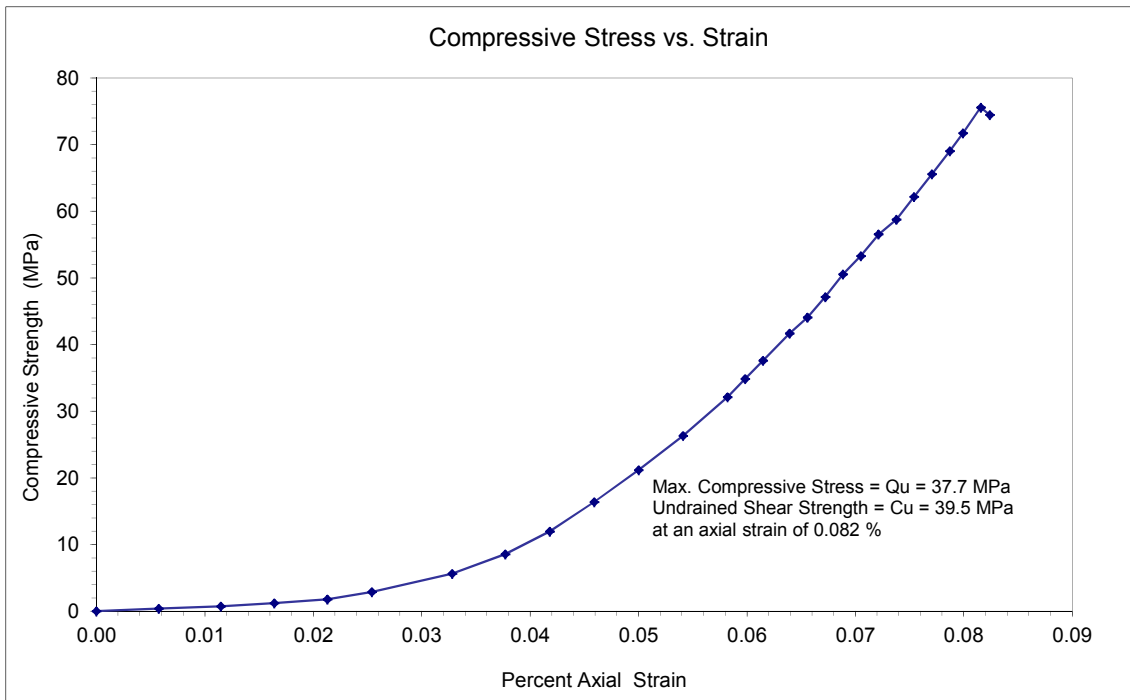
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-6c

Unconfined Compressive Strengths

TEST DATE: Dec 4/13
SAMPLE: TH13-05, CB74, @ 71'-5" to 72'-4"
DESCRIPTION: Limestone, massive.

SPECIMEN DETAILS:

Wet Density (kg/m^3): 2534
Dry Density (kg/m^3): 2496
Moisture Content (%): 1.5





THURBER ENGINEERING LTD.

UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

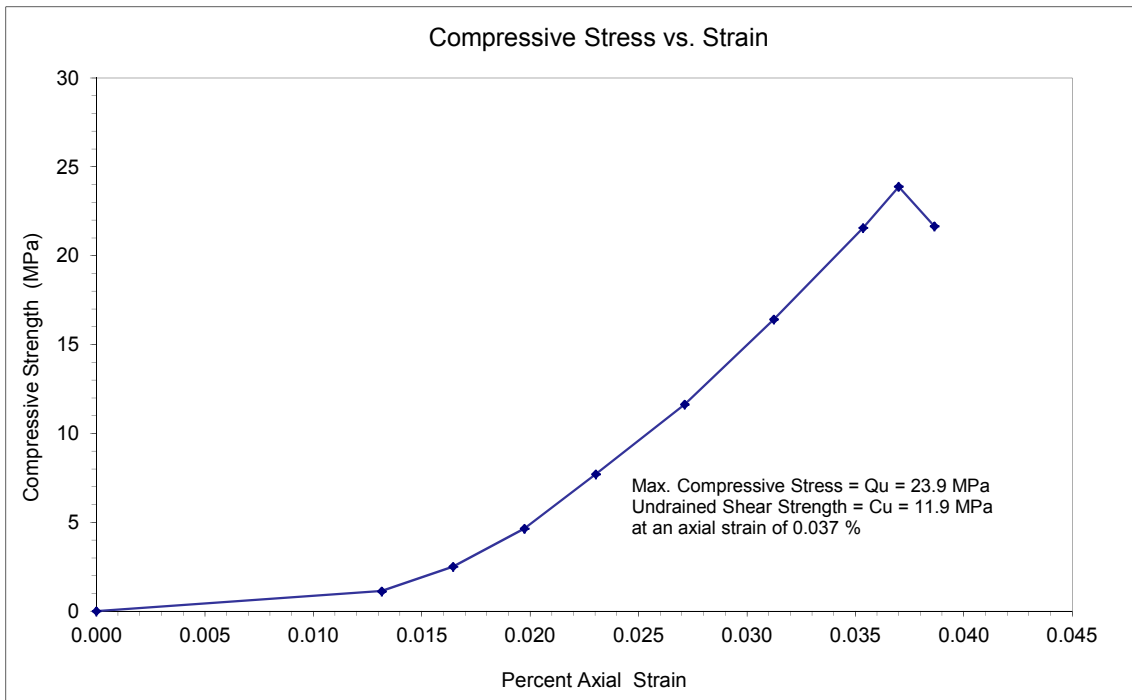
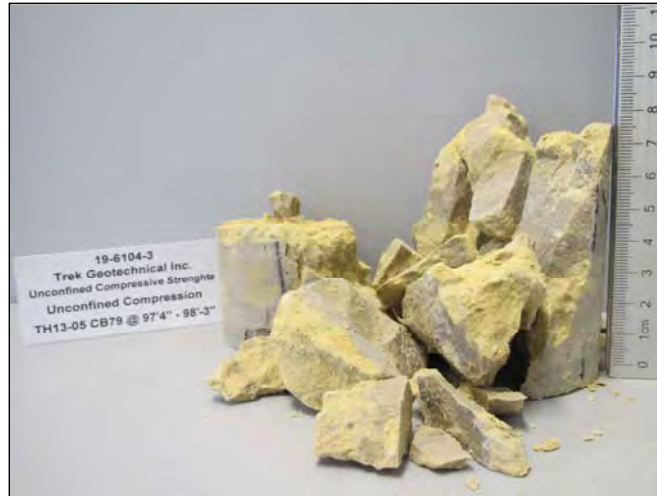
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-7c

Unconfined Compressive Strengths

TEST DATE: Dec 4/13
SAMPLE: TH13-05, CB79, @ 97'-4" to 98'-3"
DESCRIPTION: Limestone, nodular.

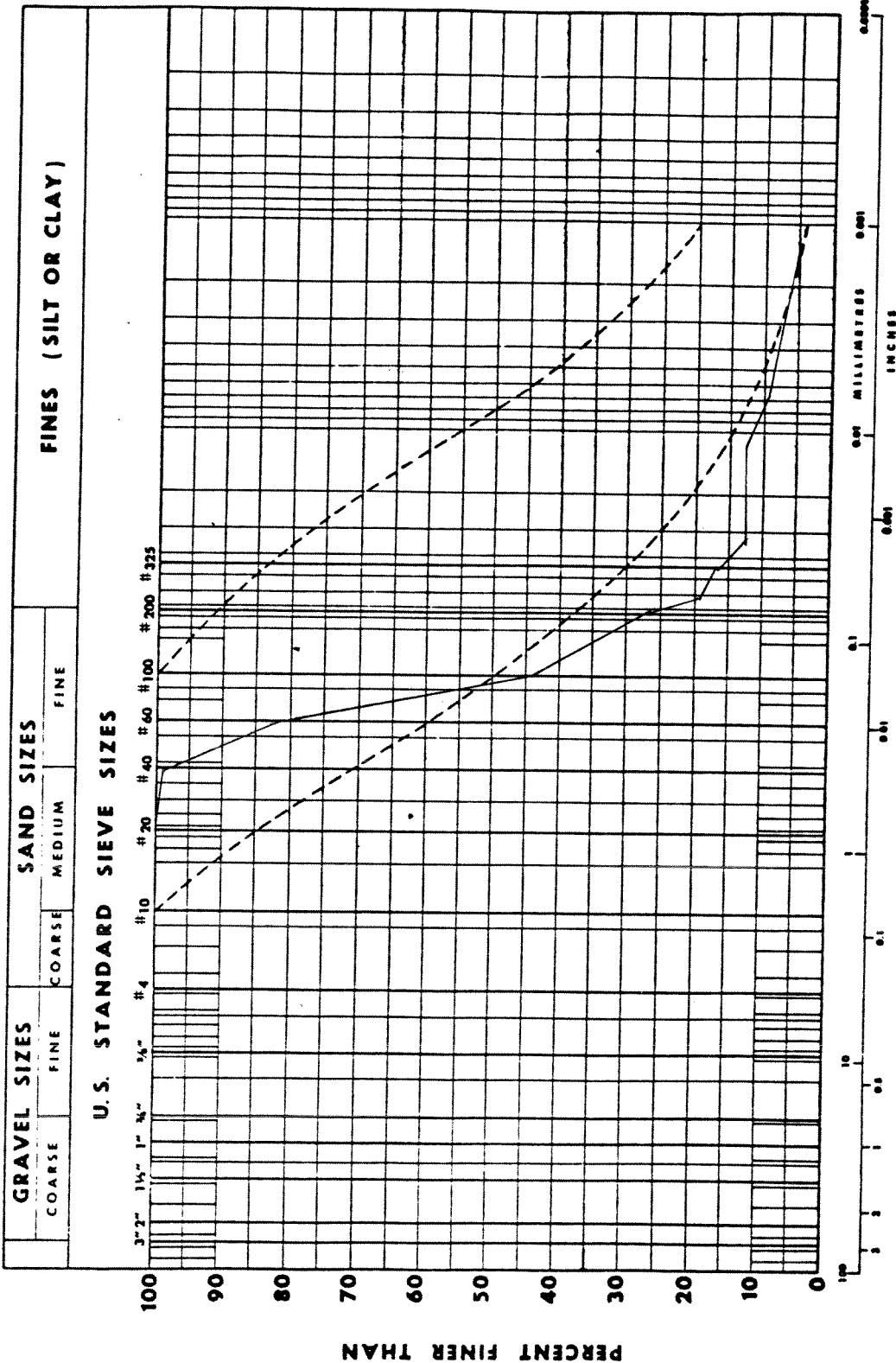
SPECIMEN DETAILS:

Wet Density (kg/m³): 2388
Dry Density (kg/m³): 2256
Moisture Content (%): 5.8



GRAIN SIZE CURVE

LAB ORDER NO. 87422
 CLIENT _____
 SAMPLE _____
 SOURCE KILDONAN CORRIDOR
 HOLE 6 DEPTH 4.6 m DATE REC'D. _____
 TECHNICIAN SDG DATE TESTED 14/10/87



D₁₀ = _____ mm
 D₃₀ = _____ mm
 D₆₀ = _____ mm
 C_u = _____
 C_c = _____

GRAIN SIZE

REMARKS: --- Particle size limits within which soils are likely to be frost susceptible.

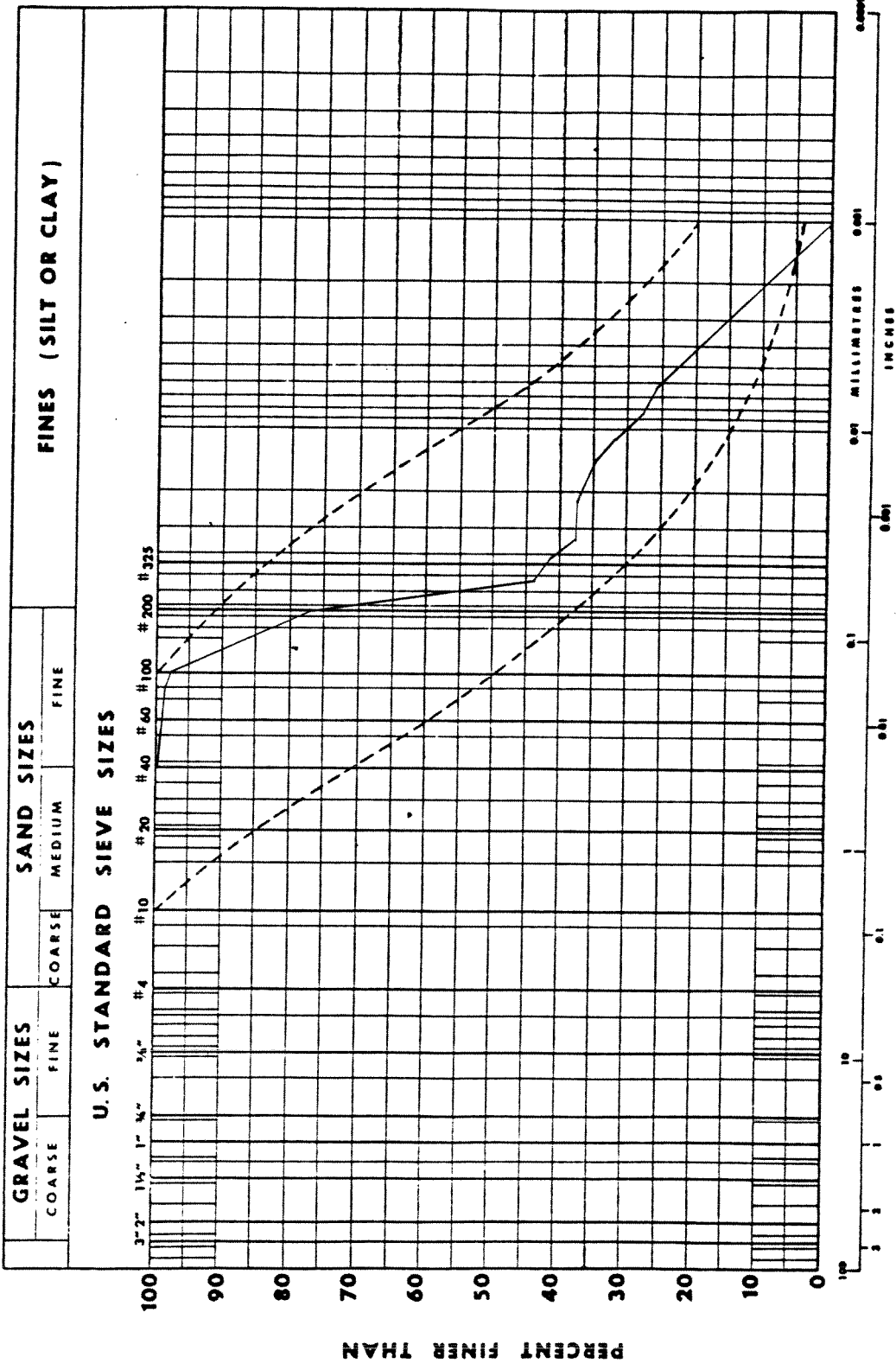
GRADATION OF TESTED SAMPLE

GRAVEL	_____ %	SAND	74 %	SILT	18 %	CLAY	8 %
--------	---------	------	------	------	------	------	-----

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

LAB ORDER NO.	87422		
CLIENT			
SAMPLE			
SOURCE	KILDONAN CORRIDOR		
HOLE	6	DEPTH	7.6 m
DATE REC'D.	14/10/87		
TECHNICIAN	SDG	DATE TESTED	14/10/87

GRAIN SIZE CURVE



D ₁₀	_____	MM
D ₃₀	_____	MM
D ₆₀	_____	MM
C _u	_____	
C _c	_____	

REMARKS: --- Particle size limits within which soils are likely to be frost susceptible.
 _____ GRADATION OF TESTED SAMPLE

GRAVEL	_____ %	SAND	24 %	SILT	53 %	CLAY	23 %
--------	---------	------	------	------	------	------	------

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

DYREGROV & BURGESS
 Consulting Geotechnical Engineers

GRAIN SIZE CURVE

LAB ORDER NO. 87422

CLIENT

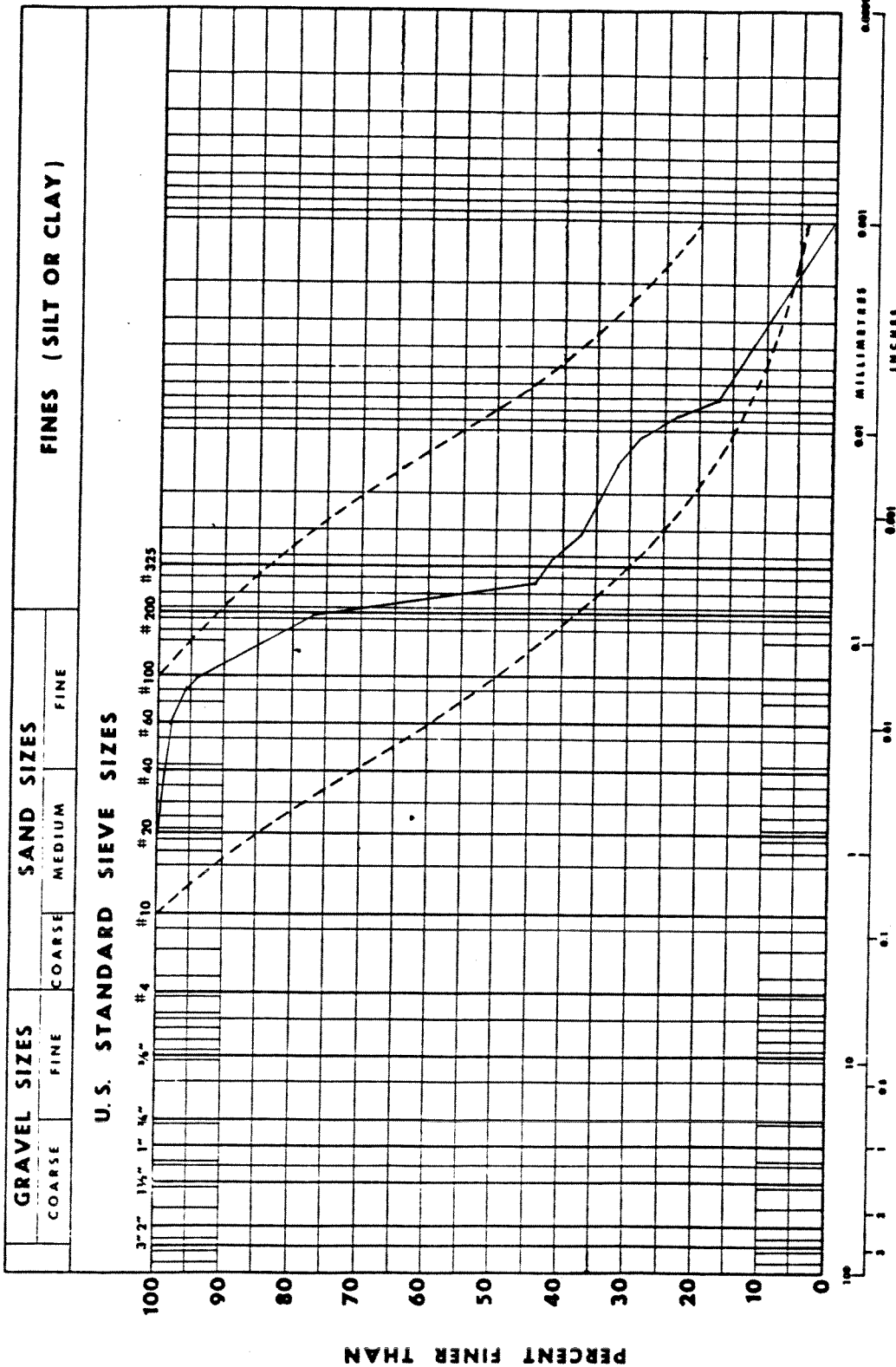
SAMPLE

SOURCE KILDONAN CORRIDOR

HOLE 6 DEPTH 10.4m DATE REC'D.

TECHNICIAN SDG

DATE TESTED 14/10/87



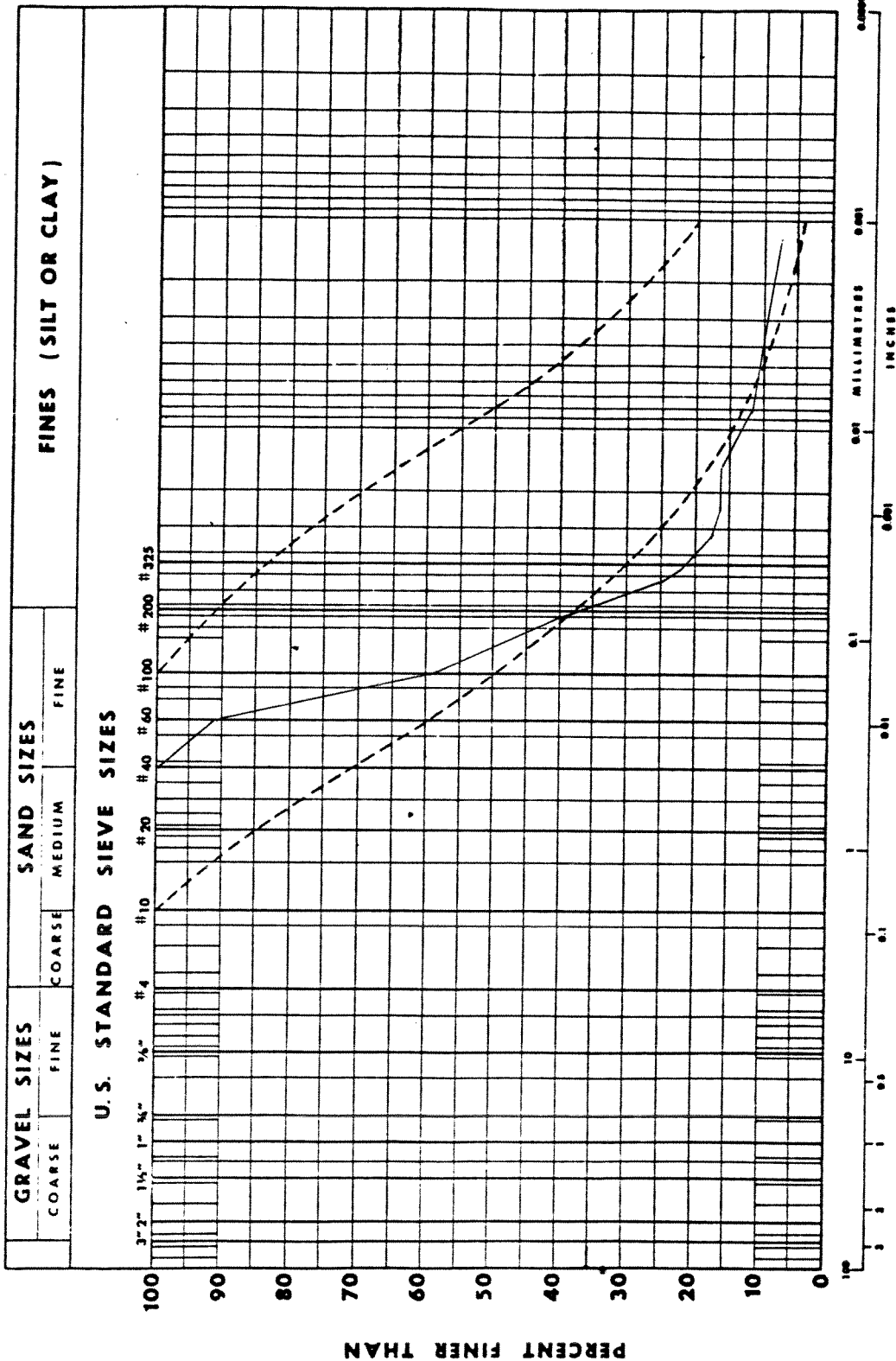
D ₁₀	mm
D ₃₀	mm
D ₆₀	mm
C _u	
C _c	

GRAVEL	%	SAND	24	%	SILT	57	%	CLAY	19	%
--------	---	------	----	---	------	----	---	------	----	---

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

GRAIN SIZE CURVE

LAB ORDER NO. 87422
 CLIENT _____
 SAMPLE _____
 SOURCE KILDONAN CORRIDOR
 HOLE 7 DEPTH 3.0 m DATE REC'D. _____
 TECHNICIAN SDG DATE TESTED 14/10/87



D₁₀ = _____ MM
 D₃₀ = _____ MM
 D₆₀ = _____ MM
 C_u = _____
 C_c = _____

REMARKS: - - - - - Particle size limits within which soils are likely to be frost susceptible.

GRADATION OF TESTED SAMPLE

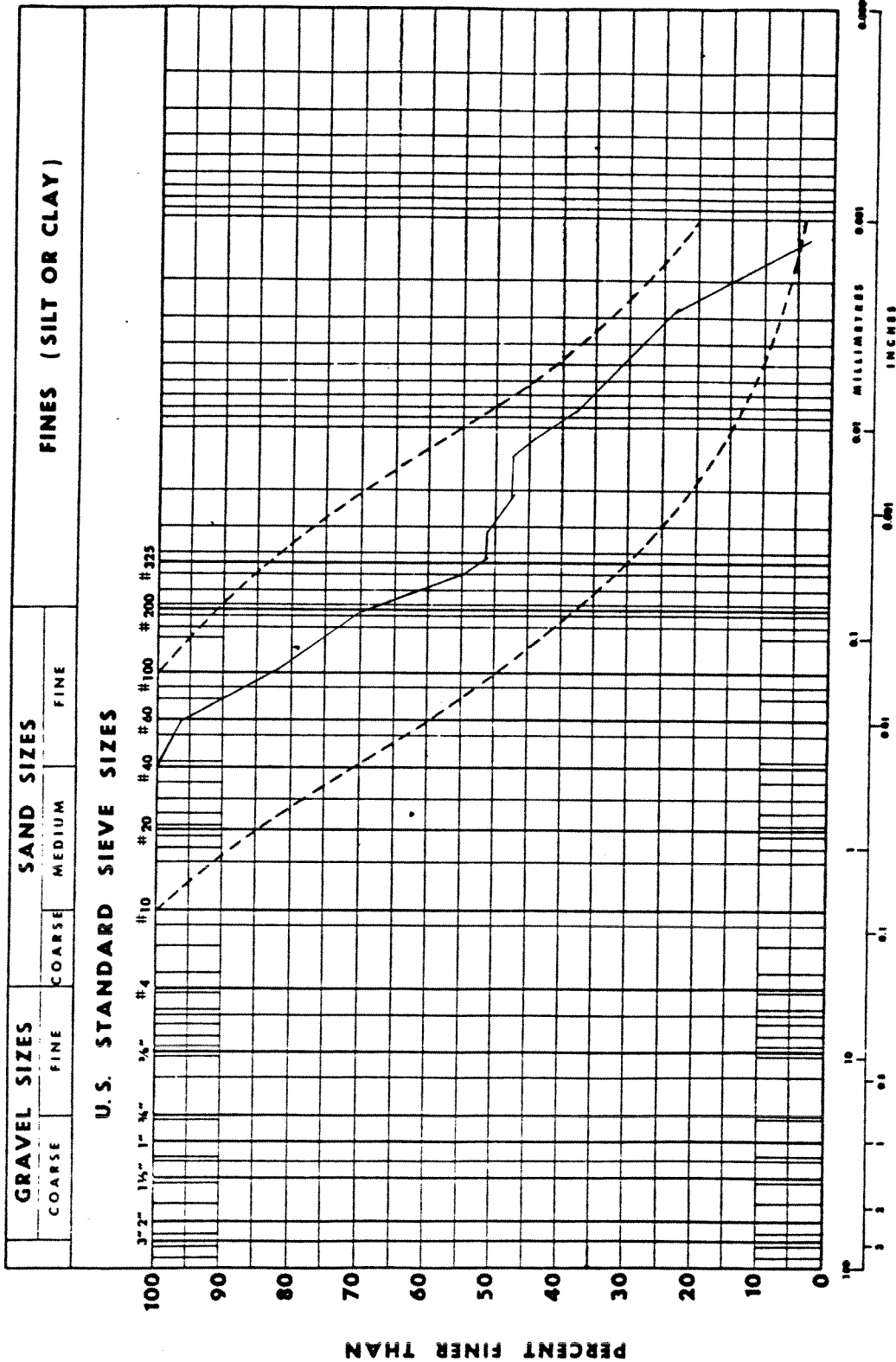
GRAVEL _____ %	SAND 64 %	SILT 26 %	CLAY 10 %
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NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

DYREGROV & BURGESS
Consulting Geotechnical Engineers

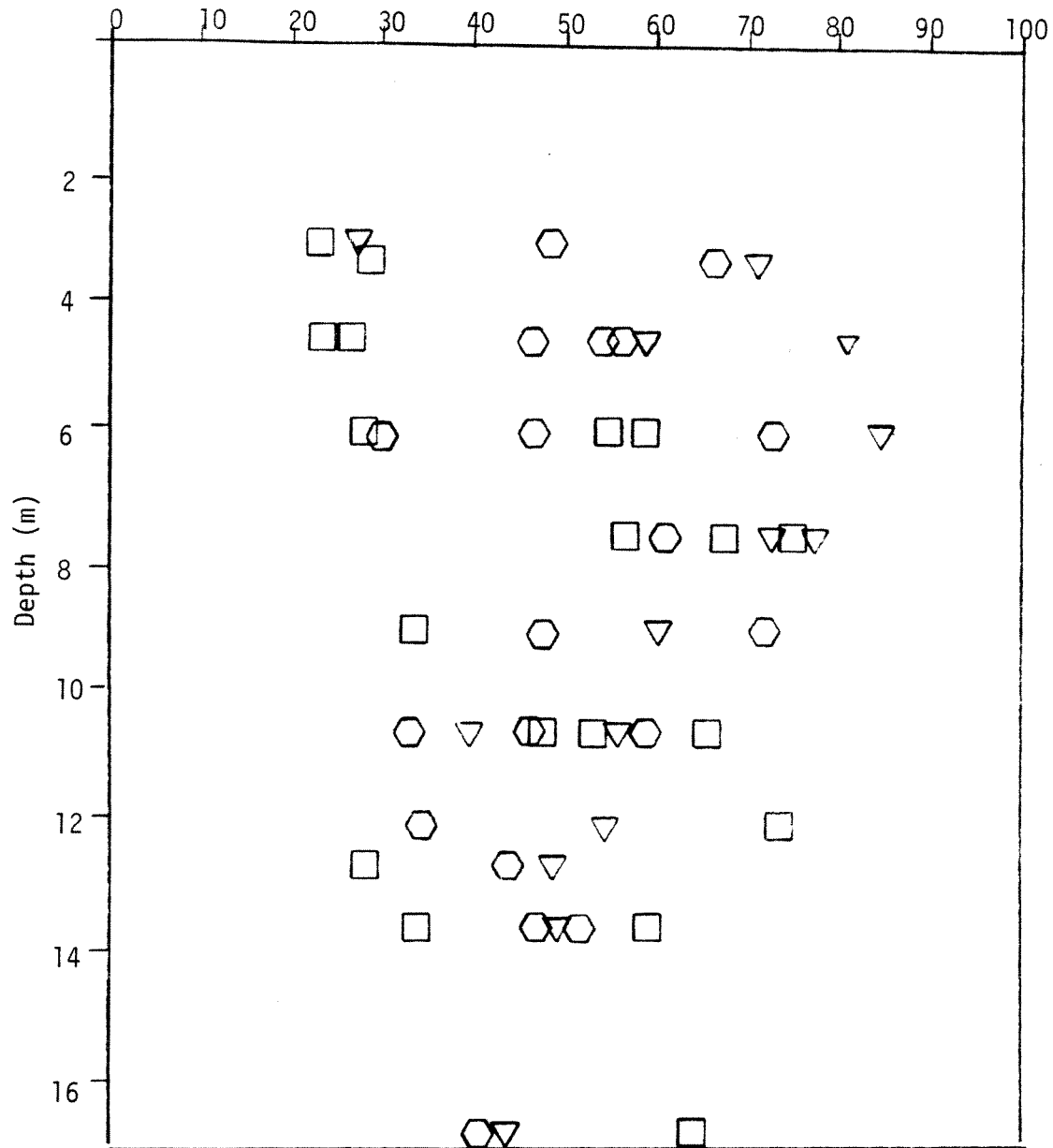
GRAIN SIZE CURVE

LAB ORDER NO. 87422
 CLIENT _____
 SAMPLE _____
 SOURCE KILDONAN CORRIDOR
 HOLE 7 DEPTH 7.9 m DATE REC'D. _____
 TECHNICIAN SDG DATE TESTED 14/10/87



Test Holes 1-5, 12&13

Undrained Shear Strength (kPa)



- Unconfined compression
- ▽ Torvane
- ⬡ Pocket Penetrometer

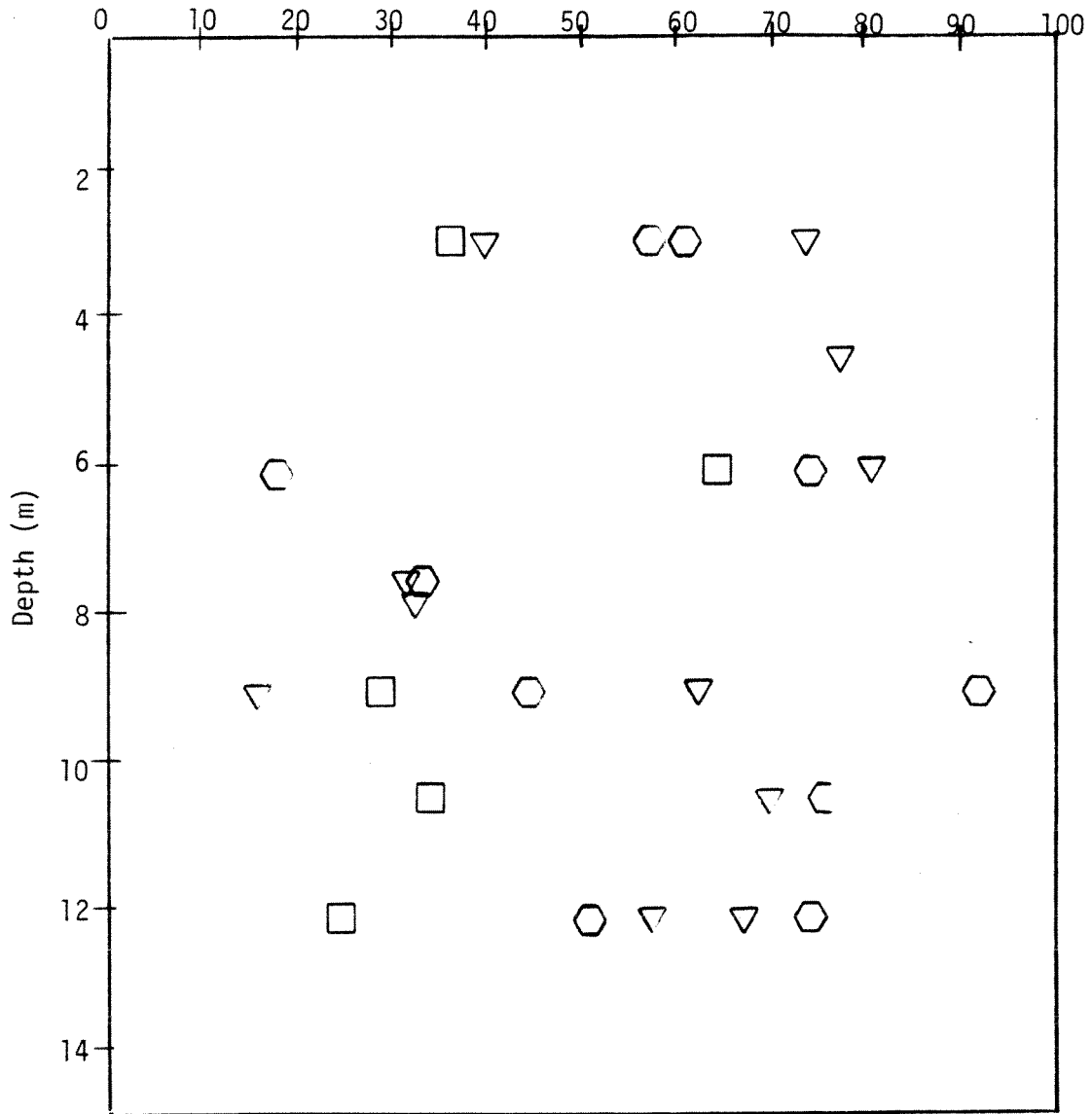
DYREGROV & BURGESS
CONSULTING GEOTECHNICAL ENGINEERS

STRENGTH DATA
WEST APPROACH

SCALE	DATE	MADE	CHKD	JOB	FIGURE 01
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Test Holes 6-11

Undrained Shear Strength (kPa)



- Unconfined compression
- ▽ Torvane
- ⬡ Pocket Penetrometer

DYREGROV & BURGESS			STRENGTH DATA		
CONSULTING GEOTECHNICAL ENGINEERS			EAST APPROACH		
SCALE	DATE	MADE	CHKD	JOB	FIGURE C2

Appendix **F**

Friesen Drillers Ltd. Hydrogeological Assessment Report

- F-1: Friesen Drillers Ltd. (February 2018) Hydrogeological Assessment Report



February 28, 2018

Mr. Adam Braun, P.Eng.
Municipal Engineer, Conveyance, Water
AECOM
99 Commerce Dr. Winnipeg, Manitoba R3P 0Y7

Dear Mr. Braun,

Subject **Hydrogeological Assessment / Aquifer Characterization**
Northeast Interceptor Sewer River Crossing Project – River Lot 25 Parish of Kildonan
Kildonan Settlers Bridge - Chief Peguis Trail, Winnipeg, Manitoba

Friesen Drillers Ltd. is pleased to present this report detailing the results of our hydrogeological investigation at the above noted site. Friesen Drillers was retained by AECOM to undertake hydrogeological test drilling and aquifer testing to determine the potential for aquifer depressurization which would allow for deep excavations as part of the above noted project. It is our understanding that the project is to include deep chambers sunk into the bedrock at sites on the east and west banks of the river, and a tunnel excavated under the river connecting the two sites where a pipe would be installed. The investigation involved test well drilling, aquifer pump testing and technical analysis.

Project Background

The City of Winnipeg sanitary waste system makes a number of crossings of the rivers in Winnipeg. The Northeast Interceptor is an 1800 mm Interceptor sewer servicing the northeast quadrant of the City, conveying flows to the North End Water Pollution Control Center. The siphon crossing at the Kildonan Settlers Bridge was installed in approximately 1971 and consists of two steel pipelines installed by sinking the pipelines across the river and open cut methods on each bank. In an effort to increase capacity of the siphon crossing, the city has proposed micro-tunneling to install a pipe protected in the carbonate bedrock underlying the river channel sediments. The location of the Northeast Interceptor site and a cross section showing the existing and proposed interceptor infrastructure are shown below and on the following page in Figures 1 and 2.



Figure 1 – Well Locations – Interceptor Site – Winnipeg, MB. (Source – Google Earth, 2016)

Friesen Drillers was retained by AECOM to undertake a groundwater investigation of the site. The objective of the investigation was to assess the hydrogeological conditions and to determine the potential for a dewatering system at the site.

water...the lifeblood of the land

Project Background (Cont'd)

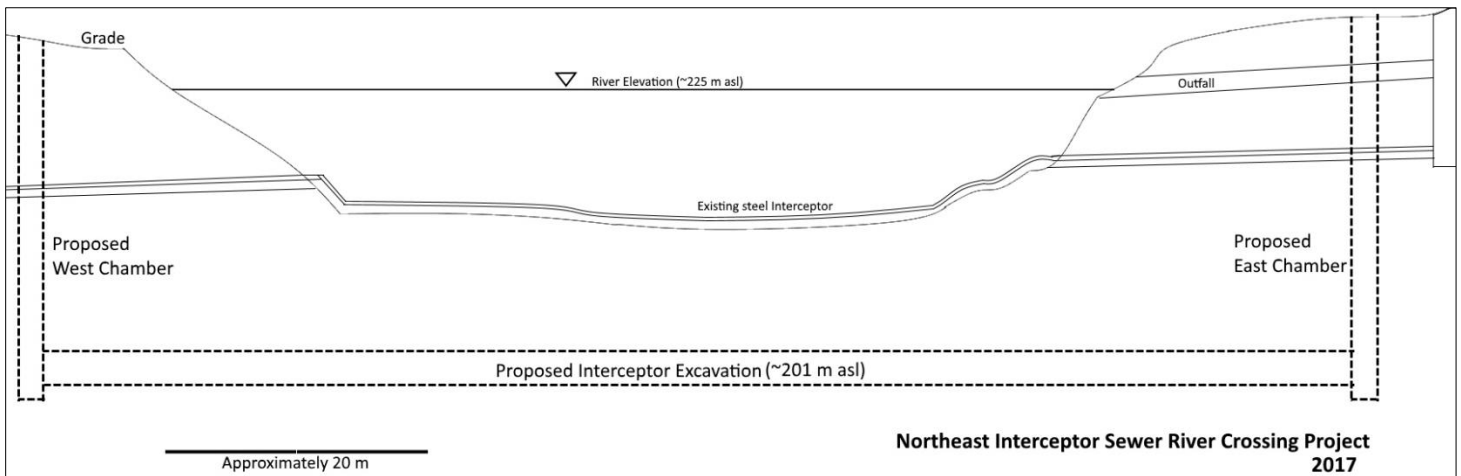


Figure 2 - Cross section of Red River Channel showing existing interceptor infrastructure and the proposed new chambers and tunnel excavation; scale is approximate, elevation given as meters above sea level (asl). (Modified source – AECOM, 2017)

Scope of Services

The following is the scope of work for the Interceptor project:

- Obtain a Groundwater Exploration Permit (GEP) from Manitoba Sustainable Development (MSD). This is required by the Water Rights Act prior to commencing the work. A copy of the GEP is attached.
- Install four 5 inch (12.7 cm) diameter PVC cased test wells into the carbonate aquifer to a maximum depth of 200 feet (60.96 m) below grade. The wells will be located at two sites on opposing river banks, with two wells installed at each site. It should be noted that the upper fractured zone of the carbonate aquifer will be the target well completion.
- Complete a short term pumping test on each site, including monitoring for recovery.
- Provide engineering services, which include test supervision, aquifer parameter analysis, local well inventory preparation and analytical sampling and monitoring. Provide dewatering estimates for proposed deep structures on the site.
- Prepare a report which details the results, discussions of groundwater conditions, and options for dewatering, proposed well design, and monitoring.
- The test wells will be maintained and kept functional once this hydrogeological investigation stage is completed.
- Friesen Drillers applied for a Groundwater Exploration Permit (GEP) for the site on October 27, 2016. The Province awarded a GEP on November 15, 2016 which detailed the scope of work. A copy of the GEP is attached. The permit expires in one year.

Site Setting

The NE Interceptor site is located along the Kildonan Settlers Bridge over the Red River, which is part of Chief Peguis Trail in north Winnipeg. The site is in a region of the city with both old and new residential neighborhoods and minor commercial and industrial development. The following property uses surround the site:

- North - Residential and commercial development.
- East – Multi dwelling and single home residential.
- South – Red River and Kildonan Park.



Site Setting (Cont'd)

- West - Kildonan Golf Course.

The topography of the area is of relatively low relief and surface drainage is towards the Red River. Water supplies for residents in the area are provided by the City of Winnipeg municipal water supply system, although many private wells still exist in the area. In addition, some industrial wells are also present nearby which are used for industrial cooling.

The site is located at the center of the Red River basin, along the Red River. The Red River is well known for interactions with the Carbonate Aquifer in the north part of Winnipeg (Render, 1970).

Geological and Hydrogeological Setting

The surficial geology underlying the Interceptor site consists of a succession of till and silty grey clay, approximately 45 to 55 feet (13.7-16.8 m) thick, overlying up to 26 feet (7.9 m) of calcareous grey till. The lower till unit was shown to compose a greater total thickness at the east chamber site and was less than 10 feet (3.0 m) thick or absent at the west chamber site. The carbonate bedrock was intersected at a depth of approximately 57 feet (17.4 m) below grade in most of the boreholes, although at the east bank site, bedrock was intersected at a depth of 78 (23.8 m) feet below grade. In some locations, the upper surface of the bedrock is highly fractured and karstic features have also been noted in the area. The thickness of the fractured rubble zone is known to be variable across the area. The rubble zone grades into more competent, fractured carbonate rock of the Fort Garry Member of the Red River Formation. The Red River Formation typically consists of alternating layers of limestone and dolostone with basal shale layers. The Red River Formation is in turn underlain by the Winnipeg Formation clastic (sandstone and shale) unit, and Precambrian basal granites (Render, 1970). A geological cross section is shown below as Figure 3.

The general hydrogeological conditions of the area were determined from a review of the applicable hydrogeological reports and information available through MSD. Groundwater aquifers in the Winnipeg area can be found in the overburden till (in specific places), the Red River Formation carbonate, and the deeper Winnipeg Formation (Betcher et. al, 1995). The inter-till sand and gravel aquifers are generally of limited extent in areas of more granular till deposits and are typically hydraulically connected to the underlying carbonate bedrock. Consequently, to adequately drain the till and inter till material, the underlying and generally higher yielding carbonate bedrock must be hydraulically depressurized.

Groundwater flow in the carbonate bedrock of the Red River Formation occurs preferentially in the fracture and joint sets of the rock. The size, extent, and interconnectivity of the fracture systems govern horizontal and vertical groundwater movement through the bedrock. Due to this geologic condition, aquifer transmissivity and storativity can vary significantly over relatively short distances, resulting in substantial variations in well yield (Render, 1970). This variability was reflected in the test drilling results conducted at the Interceptor site.

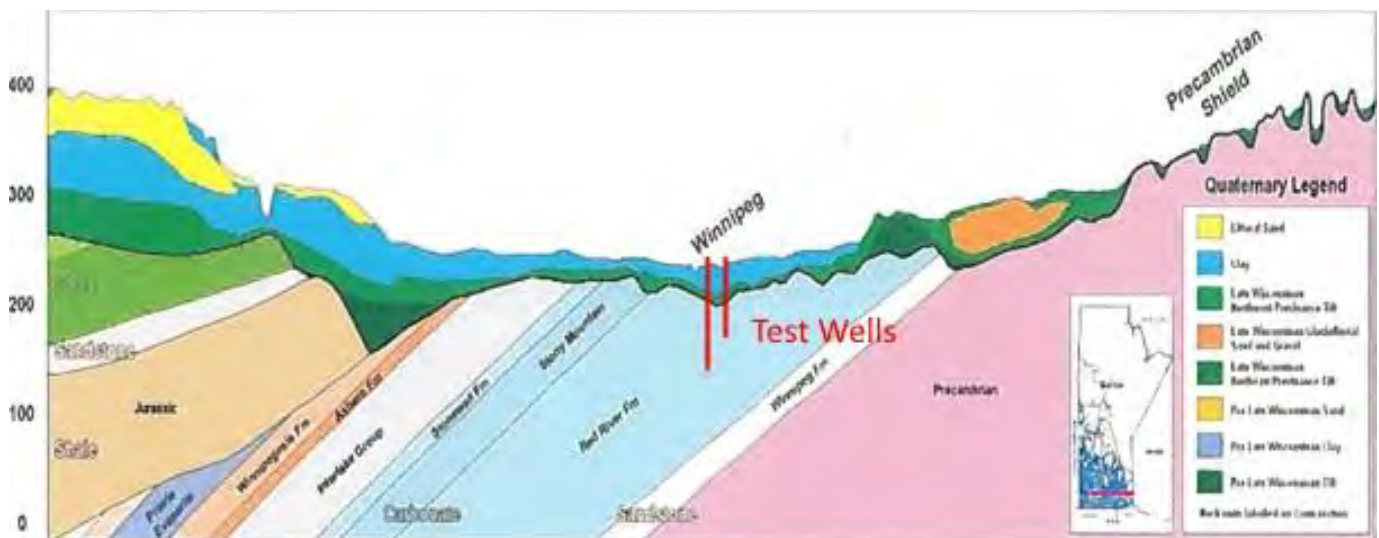


Figure 3 - Geological cross section through Southern Manitoba; the approximate location of the test wells are plotted in red. (source Manitoba Geological Survey, 2013)



Geological and Hydrogeological Setting (Cont'd)

Render (1980) separated the carbonate aquifer into two distinct zones: an upper zone, which is typically higher producing on a local scale, and a lower zone. The thickness of the upper zone is highly variable and changes significantly over short distances. As noted above, the only permeability in the bedrock is through the fractures and joints sets of the bedrock. Fracture zones in the upper bedrock have been noted to exceed 100 feet.

Baracos et. al. (1983) conducted mapping of the transmissive conditions in the upper carbonate aquifer in the Winnipeg region. A portion of this map is shown below as Figure 4. From these maps, the transmissivity of the carbonate aquifer in the area around the Interceptor site is anticipated to be between 10,000 and 100,000 U.S.G.P.D./ft. (1.44×10^{-3} to 1.44×10^{-2} m²/s). It should be noted in the mapping that Baracos et al. (1983) did not differentiate between the upper and lower aquifer in the immediate area. Recent testing of nearby wells has indicated transmissivity conditions even higher than 100,000 U.S.G.P.D./ft. (1.44×10^{-2} m²/s). The high variability of the transmissive conditions highlights the importance of aquifer testing, even across relatively small areas. The design and discharge requirements of a dewatering system will change drastically for transmissivity values across this range. Given the scope and size of the proposed dewatering project, it is prudent to consider the potential for highly transmissive conditions to be encountered at the site, as these conditions can occur within the Winnipeg area.



Figure 4 – Transmissivity of the upper carbonate aquifer in northern Winnipeg; Provincial monitoring wells plotted as green dots. (modified source - Baracos et. al.,1983)

The nearest MSD hydrograph station is G05OJ159, about 0.75 miles (~1,200 m) west from the Interceptor site. The hydrograph record is plotted with the Red River elevation in Figure 5, shown on the following page.

The hydrograph record from G05OJ159 indicates seasonal and yearly fluctuations in groundwater levels. The typical static water level is between 224.0 to 227.0 meters geodetic. Although G05OJ159 was only installed in the early 2000s, other hydrograph stations in the area indicate that the water levels have been rising over the past 25 years. For example, station G05OJ025, shown on the following page as Figure 6, contains a hydrograph record dating back to the late 1960s. The dynamic history of groundwater levels within the City are apparent from Figure 6. Since the year 2000, water levels have been on a progressive rise, although there was a change into a slightly declining trend after 2011. During the testing conducted in October, 2017, static water levels in the test wells at the West chamber site were 15.3 feet (4.7 m) below grade, or approximately 222.8 m geodetic (based on a grade elevation of 227.5 m geodetic). It should be noted that the annual low points on the hydrograph typically occur in the mid to late summer months, when groundwater demand for commercial and industrial purposes is at the highest point.



Geological and Hydrogeological Setting (Cont'd)

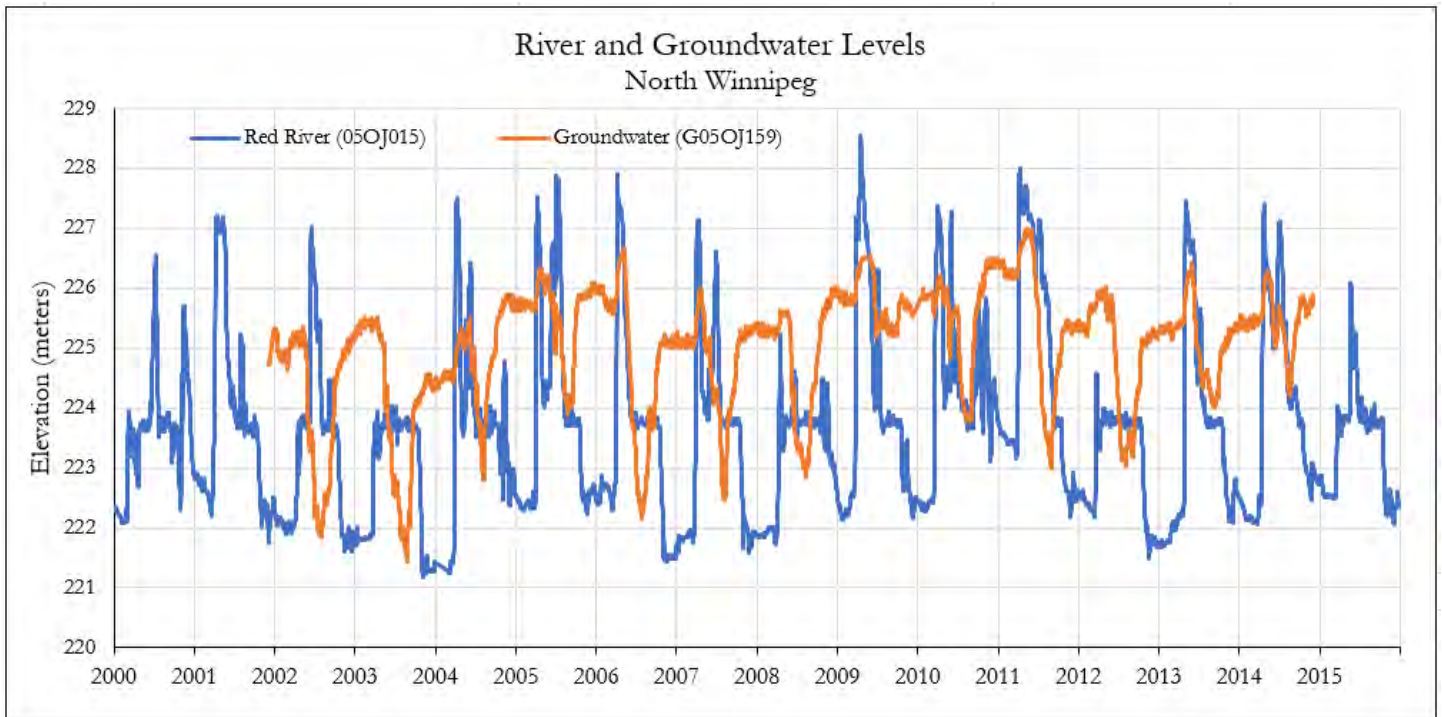


Figure 5 – Groundwater observation station (G05OJ159) plotted in blue with the Red River elevation at the James Ave pumping station (05OJ015) plotted in orange. (source MSD, 2016; Environment Canada, 2017)

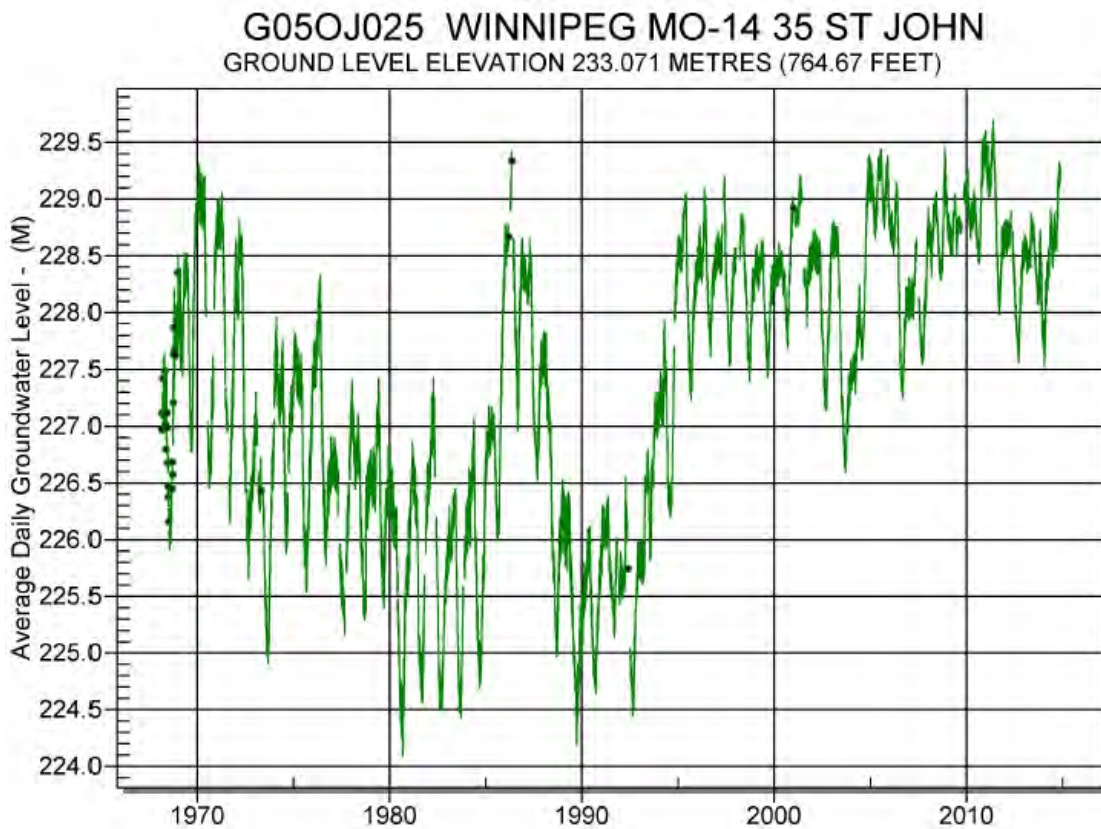


Figure 6 – Long term provincial hydrograph station G05OJ025, located in north west Winnipeg. (MSD, 2015)

The interconnection between the Red River and the Carbonate Aquifer is shown to be highly dynamic (Figure 5). Throughout most of the *water...the lifeblood of the land*



Geological and Hydrogeological Setting (Cont'd)

year, the potentiometric surface of the aquifer is above the river level. However, during the mid/late summer months, groundwater levels in the aquifer are drawn down significantly to below the elevation of the river. In the fall, the aquifer levels begin to recover as the river drops down to its lowest annual level. The fluctuating gradient between the aquifer and the river has been shown to have significant implications for stability of the Red River banks in the Winnipeg area (Baracos, 1978; Tutkaluk et al., 1998). Due to the proximity of the Interceptor site to a major bridge and multi story apartment complexes, the potential impacts on slope stability that may arise from dewatering are an important consideration for the project. These considerations will not be addressed in this report.

Groundwater Use and Aquifer Levels in Winnipeg

The necessity for dewatering during construction projects in Winnipeg has an interesting history which is pertinent to the Interceptor project. Winnipeg's development of the carbonate aquifer has been dynamic, as illustrated below in Figure 7. From 1880 to 1919, the city utilized groundwater from wells along Pipeline Road. It was noted that before any groundwater pumping began, the potentiometric surface in the downtown area of Winnipeg was near and in some places above the ground surface (Render, 1965). At the peak of groundwater production for municipal purposes, the potentiometric surface was said to have declined to more than 12 meters below the surface.

In 1919, the city began using the Shoal Lake Aqueduct, which marked the beginning of a transition in the use of groundwater from the carbonate aquifer from municipal to industrial purposes. In 1920, two large meat packing plants began using about 7,500 m³/day for mechanical refrigeration. Annual groundwater use grew steadily in the years following as multiple expansion projects were undertaken. Much of this development was concentrated to a relatively small area in the east of Winnipeg along the main rail line.

In 1960, the Red River Floodway project began which involved the excavation of a major channel surrounding the city to relieve the Red River during flooding events. The channel construction encountered significant groundwater challenges and resulted in drawdown occurring in the eastern areas of the city.

In 1970, the meat packing plants were operating at maximum capacity, along with the Manitoba Cold Storage Company (Render, 2011). In addition to the development of the carbonate aquifer, a deep sandstone well was known to be located in the building. In fact, a number of deep industrial water wells in the downtown area were completed into the Winnipeg Formation sandstone.

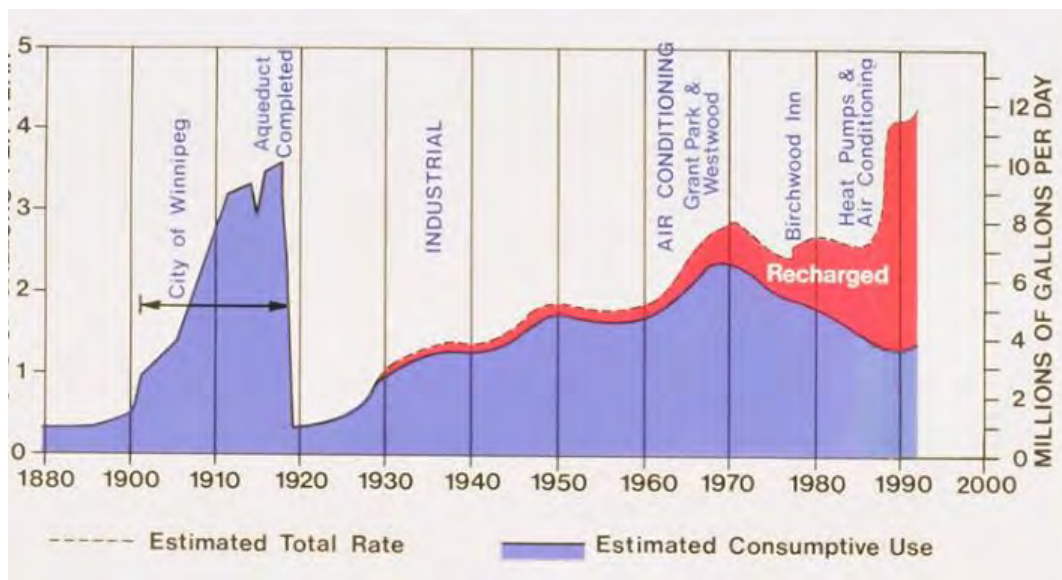


Figure 7 - Estimated groundwater use within the City of Winnipeg from 1880 to 1990. (source – Render, 2011)

The meat packing plants were completely shut down by 1991. It was the first time in Winnipeg's history since 1880 that the aquifer was not being significantly used for consumptive municipal or industrial purposes. As a result, static water levels in the carbonate aquifer began to recover.



Groundwater Use and Aquifer Levels in Winnipeg (Cont'd)

The recovery of water levels in the carbonate bedrock have been more pronounced in the eastern parts of the city. The change in the potentiometric surface elevation is illustrated below in Figures 8 and 9. Based on Figure 8, the area around the Interceptor site has experienced a rise of at least 6.6 to 9.8 feet (2.0 to 3.0 m) in groundwater levels from 1970 to 2009.

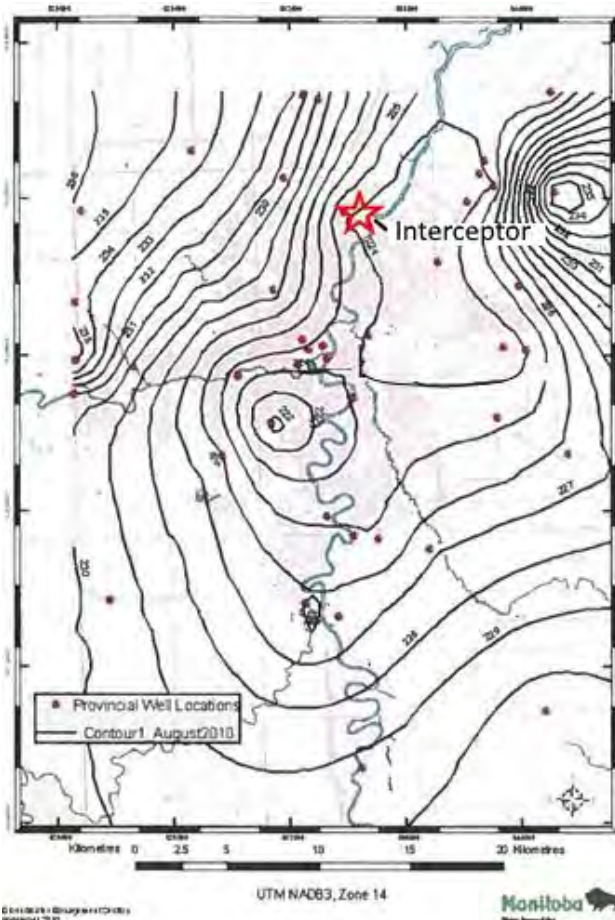


Figure 8 - Potentiometric surface, Interceptor site indicated by red star. (source – MSD, 2010)

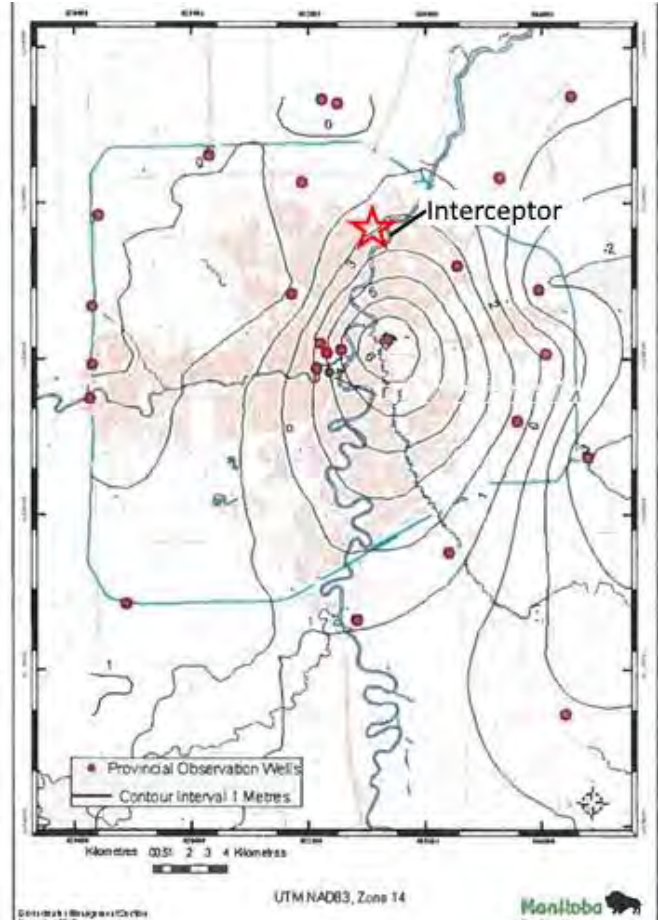


Figure 9 - Potentiometric difference (1970-2009) – Interceptor site indicated by red star. (source – MSD, 2010)

The dynamic history of groundwater use within the city of Winnipeg has resulted in very different geotechnical conditions encountered during construction projects over the decades. In some cases, revisiting outfall chambers and other deep structures within the city, which originally were constructed without concern for groundwater, are now encountering significant challenges as a result of rising water levels (Bell and Neufeld, 2017).

Regional Groundwater Geochemistry

A major groundwater quality boundary in the carbonate aquifer runs through the city of Winnipeg, with relatively fresh water towards the east and increasingly saline water towards the west. In the area of the Interceptor site, the groundwater quality is expected to be relatively fresh, with typical Total Dissolved Solids (TDS) values ranging from 800 to 1,200 mg/L.

The groundwater in the underlying Winnipeg Formation is generally of poor quality (brackish to saline) in the area around the City of Winnipeg, so it has not been extensively developed. The groundwater quality in the Winnipeg Formation at the Interceptor site is saline.

The proximity of the Interceptor site to the Red River creates additional concerns with respect to groundwater quality and groundwater/surface water interactions. An hydraulic connection between the river and aquifer is likely to exist at the Interceptor site. These types of interactions can present significant challenges to pumping wells located adjacent to a surface water body. For example, one production well in the City of Selkirk’s old water supply system was installed within a short distance from the banks of the Red River. After only a short period of groundwater pumping, the well began producing highly evaporitic water as a result of influx from the river.



Regional Groundwater Geochemistry (Cont'd)

In that case, the quality of the water was a serious complication for the treatment process. As a result, the well was taken off line (Render, 1986; Bell, 2016)

For the Interceptor project, the concerns regarding groundwater/surface water interactions include both groundwater quality and quantity. Large scale pumping adjacent to the river will likely induce flow from the river into the aquifer and impact groundwater quality. It should be noted that it is a violation of the “The Ground Water and Water Well Act” in the Province of Manitoba to permanently and intentionally damage water quality in the aquifer. This issue would require a significant monitoring effort, as the extent of the potential impacts to groundwater quality from large scale pumping are not understood at this time.

An hydraulic connection to the river is also likely to influence the quantity of water available for pumping at the Interceptor site. A drawdown cone generated at the site would be expected to encounter boundary conditions as a result of the river connection. These boundary conditions would likely result in higher required pumping rates due to the influx of river water. These challenges are discussed in detail in the Data Analysis section.

To aid in the assessment of groundwater/surface water interactions at the site, stable environmental isotopes of ¹⁸oxygen and deuterium were used. The results of these analyses are discussed in subsequent sections.

Investigations

Test Well Drilling

To complete an assessment of the aquifer parameters at the Interceptor site, a total of four test wells were installed at two sites. The locations of the test wells were selected based on discussions between staff from AECOM and Friesen Drillers. Underground services were cleared and marked prior to drilling. A summary of well construction details is given in Table 1, shown below.

Table 1 Well Construction Details Interceptor Site, Winnipeg, Manitoba								
Well Name	Casing	Depth of Casing	Zone of Completion	Total Depth	Grout	Grout Placement	UTM X	UTM Y
TH-01 (east site)	5 inch PVC	60 ft. (18 m)	60-120 ft. (18-36 m)	120 ft. (36 m)	Bentonite	0-60 ft. (0-25 m)	636562.89	5534768.31
TH-02 (east site)	5 inch PVC	76 ft. (23 m)	76-197 ft. (23-60 m)	197 ft. (60 m)	Bentonite	0-76 ft. (0-23 m)	636568.72	5534792.94
TH-03 (west site)	5 inch PVC	62 ft. (19 m)	62-197 ft. (19-60 m)	197 ft. (60 m)	Bentonite	0-62 ft. (0-19 m)	636365.7	5534844.5
TH-04 (west site)	5 inch PVC	58 ft. (18 m)	58-197 ft. (18-60 m)	197 ft. (60 m)	Bentonite	0-58 ft. (0-18 m)	636380.6	5534879.3

Table 1 - Construction details of the four test wells – Interceptor site, Winnipeg.

All of the wells were constructed using five inch diameter PVC casing installed from grade down to the upper surface of the competent carbonate bedrock. The casing was set into a three tier, step down socket and was grouted in place with bentonite. The casing extended through the overburden and the lower portion of the borehole was drilled open hole in the carbonate bedrock to final depth. Upon completion, the well locations were marked with a hand held, portable GPS unit that is accurate to +/- 5 m. Copies of the driller’s logs are attached.

To effectively dewater the surficial deposits at the site, the underlying upper carbonate aquifer would need to be depressurized. The test wells were completed into the upper carbonate bedrock aquifer to allow for an assessment of the hydraulic conditions within the upper carbonate bedrock aquifer. Based on the deeper casing and lower capacity, it is likely that TH-02 is installed in a karstic feature.



Pumping/Recovery Testing

To assess the local aquifer conditions and to determine how the wells respond to pumping, a short term pumping test was completed for each site. The pumping tests were conducted using a 5 HP submersible pump, with groundwater levels recorded at regular intervals automatically with pressure transducers in nearby monitoring wells and also manually with a depth sounder in the pumping well. The discharge rate was measured through the use of an orifice weir. Power was provided for the pumping test by means of a portable gasoline powered generator. Table 2, shown below, provides the specific parameters recorded during the pumping tests. The pumping test drawdown data from the east and west chamber sites is also attached.

Table 2 Water Level Drawdowns Observed During Testing – NE Interceptor Site, Winnipeg, Manitoba					
Pumping Well	Static Water Level	Pumping Water Level	Pumping Rate (avg.)	Monitoring Well	Distance to Monitoring Well
TH-01 (East chamber)	15.29 ft. (4.66 m)	31.51 ft. (9.60 m)	110 U.S.G.P.M. (6.94 x 10 ⁻³ m ³ /s)	TH-02	100 ft. (30.5 m)
TH-03 (West chamber)	14.45 ft. (4.40 m)	17.78 ft. (5.42 m)	65 U.S.G.P.M. (4.10 x 10 ⁻³ m ³ /s)	TH-04	125 ft. (38.1 m)

Table 2 - Pumping test parameters for each test site; Northeast Interceptor River Crossing.

Well Inventory

To fulfill the conditions set out in the GEP, an inventory of all private and commercial wells within a one mile radius of the Interceptor site was conducted. The inventory was conducted using the MSD GWDRILL database (2016). The results of the inventory are shown in Table 3, attached. In total, 70 private and commercial wells were identified within a one mile radius. It should be noted that the current status of the identified wells is not known and the locations of the wells were not verified. In addition, some well coordinates were documented as the location of multiple wells.

It should be noted that existing industrial cooling wells are located immediately to the east of the proposed site along Henderson Highway. This system is a major licensed user and would certainly be impacted by drawdown resulting from dewatering operations.

The wells range in depth from about 70 ft. (21.3 m) to 400 ft. (122 m), with an average depth of approximately 130 feet (39.6 m) below grade. The database contains records of wells dating back to the 1960s, with numerous logs containing incomplete information. As a result, many of these wells may no longer be in use and may have been abandoned.

It is important to note that it is standard practice to install the pump within the well casing, above the bedrock. As the proposed drawdown is below the top of the bedrock, it would very likely interrupt the service of many of the wells identified in the inventory. In addition, it is a requirement for impacted third parties to be accommodated during disruption. This would either lowering pumps or providing alternative water supplies.

Due to the conditions of the Water Rights Act, liability for negatively impacting nearby groundwater users rests with the well owner (City of Winnipeg) and cannot be transferred through contract agreements. Consequently, to mitigate the risks and liability to the City, it is recommended that a field inventory of nearby wells be undertaken prior to operation of an aquifer depressurization system. The field inventory should include an inspection of licensed users by a qualified hydrogeologist or engineer registered with Engineers Geoscientists Manitoba (EGM).

Data Analysis

Aquifer Testing Analysis

The Theis method (1935) is the most common method for analyzing the results from aquifer pumping tests. Some crucial assumptions of the method were noted during the development. They are detailed as follows:



Aquifer Testing Analysis (Cont'd)

- Darcy's law is valid
- The aquifer is horizontal and constant thickness
- The aquifer is infinite in areal extent
- The aquifer is bounded by impermeable strata above and below
- Uniform hydraulic conductivity
- Isotropic hydraulic conductivity
- Head always remains above the top of the pumped aquifer
- There are no water level changes that are not due to the pumping.
- Infinitesimal diameter of well
- Fully penetrating the aquifer formation
- Perfectly efficient well
- Single pumping well
- Constant pumping rate
- Constant storage properties through time
- The head is known everywhere prior to pumping.

Through a review of the assumptions, it can be seen that some of the conditions for the analysis of the pumping tests conducted at the on the Interceptor site are invalid for the Theis (1935) approach. The Theis (1935) approach is highly idealized to the assessment of the aquifer, and represents the state of the art for the determination of aquifer parameters. The conditions are also not being violated severely, so this approach will be used for the analysis.

The pumping test results were entered into Waterloo Hydrogeologic's Aquifer Test Professional v2016.1 for analysis of the aquifer parameters. The data was analyzed using the Cooper-Jacob (1946) and Theis (1935) methods. The hydraulic parameters determined from the pump tests are shown below in Table 4 and 5. During the pumping tests, the T_{critical} was considered to be 15 minutes for casing storage; consequently, only measurements taken after 15 minutes were used for the analysis of aquifer parameters.

Table 4 Confined Aquifer Parameters - East Chamber Site North East Interceptor Project – Winnipeg, MB		
West chamber Site	Pump Well TH-01	Monitoring Well TH-02
Static Water Level	15.29 feet (4.66 m)	15.72 feet (4.79 m)
Pumping Water Level	31.51 feet (9.60 m)	20.10 feet (6.13 m)
Drawdown	16.22 ft. @ 110 U.S.GPM – 195 minutes (6.94 m @ 3.16 x 10 ⁻³ m ³ /s)	4.38 feet (1.34 m)
Method	Transmissivity	Storativity
Theis Method ¹	10,000 U.S.G./day/ft. (1.44 x 10 ⁻³ m ² /s)	1.00 x 10 ⁻³
Cooper – Jacob Method ²	10,000 U.S.G./day/ft. (1.44 x 10 ⁻³ m ² /s)	1.00 x 10 ⁻³
Notes	¹ Theis (1935) method using Waterloo Hydrogeologic Limited – AquiferTest Pro v2016.1 ² Cooper-Jacob (1946) method using Waterloo Hydrogeologic Limited – AquiferTest Pro v2016.	

Table 4 - Aquifer parameters from the pumping test of TH-01, at the east chamber site.

Table 5 Confined Aquifer Parameters – West Chamber Site North East Interceptor Project – Winnipeg, MB		
	Pump Well TH-03	Monitoring Well TH-04
Static Water Level	14.50 feet (4.40 m)	11.50 feet (3.50 m)
Pumping Water Level	17.78 feet (5.42 m)	14.13 feet (4.31 m)
Drawdown	3.28 ft. @ 65 U.S.GPM – 300 minutes (1.00 m @ 4.10 x 10 ⁻³ m ³ /s)	2.63 feet (0.80 m)
Method	Transmissivity	Storativity
Theis Method ¹	20,000 U.S.G./day/ft. (2.87 x 10 ⁻³ m ² /s)	1.00 x 10 ⁻⁵
Cooper – Jacob Method ²	20,000 U.S.G./day/ft. (2.87 x 10 ⁻³ m ² /s)	1.00 x 10 ⁻⁵
Notes	¹ Theis (1935) method using Waterloo Hydrogeologic Limited – AquiferTest Pro v2016.1 ² Cooper-Jacob (1946) method using Waterloo Hydrogeologic Limited – AquiferTest Pro v2016.1	

Table 5 - Aquifer parameters from the pumping test of Well TH-03; west chamber site.

In reviewing the pumping test results, the Cooper-Jacob (1946) method was used primarily, since emphasis is not placed on early time measurements. By this method, transmissivity values at the east chamber site were inferred from the data to be approximately 10,000 U.S.G.PD./ft. (1.44 x 10⁻³ m²/s) and the value for storativity was estimated to be approximately 10⁻³. The transmissivity values at the west



Aquifer Testing Analysis (Cont'd)

bank site were inferred from the data to be approximately 20,000 U.S.G.P.D./ft. ($2.87 \times 10^{-3} \text{ m}^2/\text{s}$), with a value for storativity of approximately 10^{-5} . These results are within the range of values expected for fractured, karstic limestone/dolomite formations and are congruent with previous studies of the carbonate aquifer in the Winnipeg region (Baracos et al., 1983). Figures 10, 11, 12 and 13, shown on subsequent pages, show the drawdown vs time and Theis analysis plots from both pumping tests.

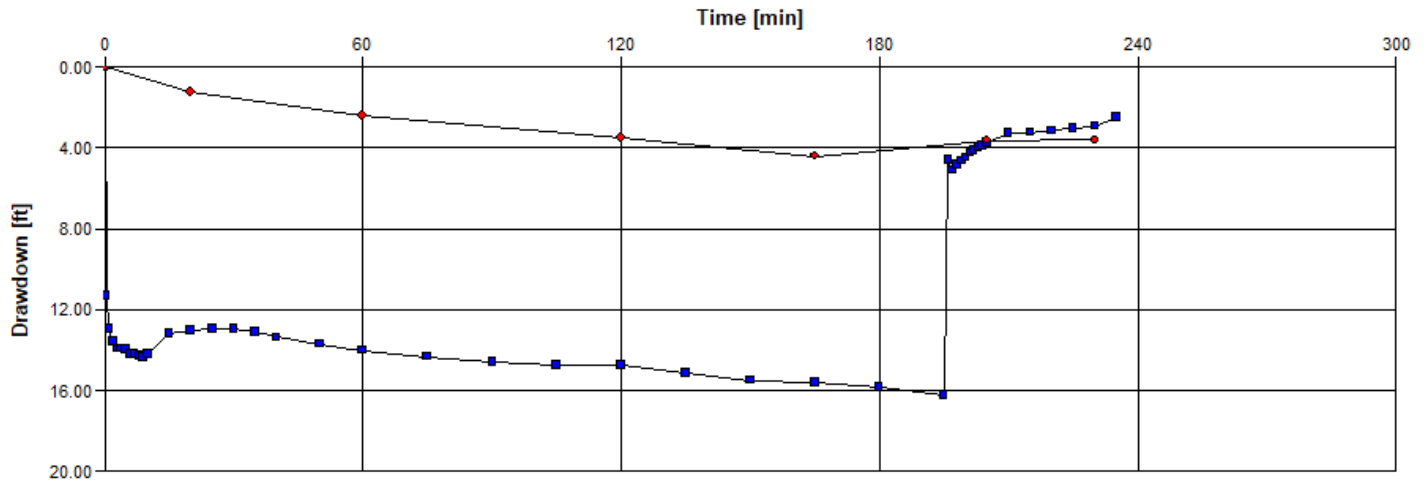


Figure 10 - Drawdown vs. time from the pump test of well TH-01; East chamber site; Pumping rate 110 U.S.GPM. ($3.16 \times 10^{-3} \text{ m}^3/\text{s}$).

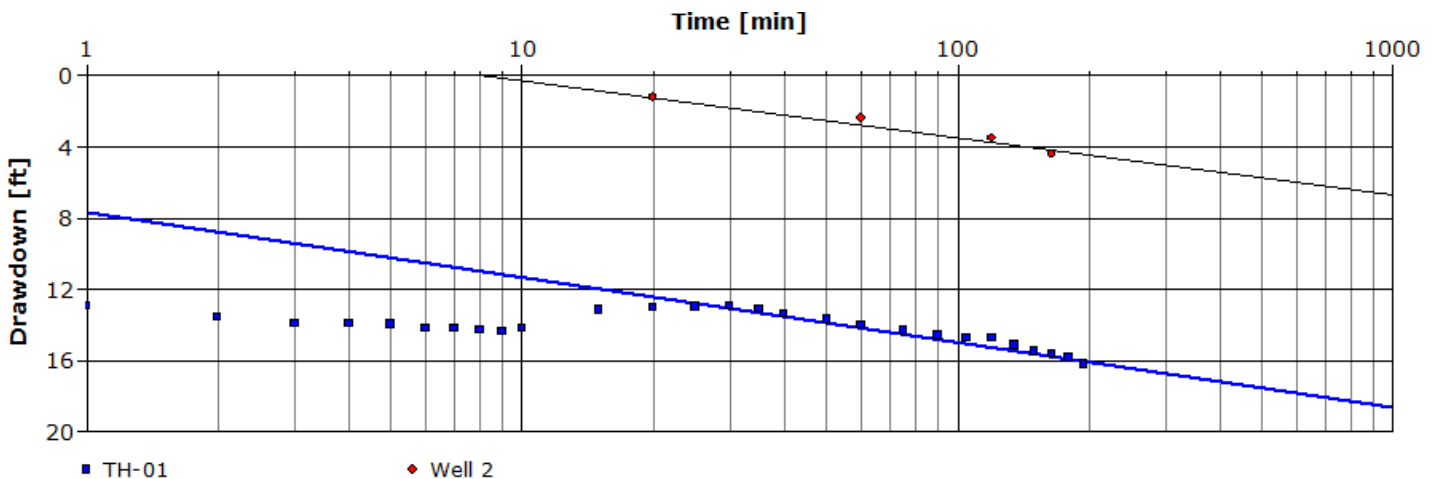


Figure 11 - Cooper Jacob method (1946) analysis of pump test data from well TH-01; East chamber site; Pumping rate is 110 U.S.GPM. ($3.16 \times 10^{-3} \text{ m}^3/\text{s}$).

The results of the pumping test analysis indicate variable conditions across the east and west chamber sites. This variability reflects the high heterogeneity and anisotropic conditions in the upper carbonate aquifer. Effectively, the analysis indicates values for transmissivity from up to and greater than 20,000 U.S.G.P.D./ft. ($2.87 \times 10^{-3} \text{ m}^2/\text{s}$) to less than 10,000 U.S.G.P.D./ft. ($1.44 \times 10^{-3} \text{ m}^2/\text{s}$). This variability is also reflected in Render (1970) and Baracos et al. (1983). It is important to note that the upper range of values for transmissivity inferred from the testing are still significantly lower than those that have been mapped for the area and encountered at nearby sites. According to Baracos et al. (1983), transmissive conditions could be in the range of 100,000 U.S.G.P.D./ft. or more (Figure 3). The large diameter and depth of the proposed chambers, and the anticipated duration of dewatering requirements increase the likelihood that the higher range of transmissive conditions will be encountered. Consequently, drawdown predictions have been undertaken for a range of conditions. These values should provide a reasonable estimation of the upper ranges of discharge rates that would be required to depressurize the aquifer to the necessary elevation.

The late time data from the pumping test of TH-01 (Figure 11) appear to form a slight downward trend. This departure from a straight line suggests a potential negative boundary condition. Conversely, the late time data from the pumping test of TH-01 (Figure 13) appears to curve slightly upwards, which suggests a potential positive boundary condition. It should be noted that longer duration pumping tests would be required to confirm these conditions. Pumping for a longer duration is likely to result in an hydraulic connection with the Red River. This could cause the pumping water levels to flat line or even increase when pumping. A river connection would likely result in higher discharge rates required to achieve the necessary drawdown.



Aquifer Testing Analysis (Cont'd)

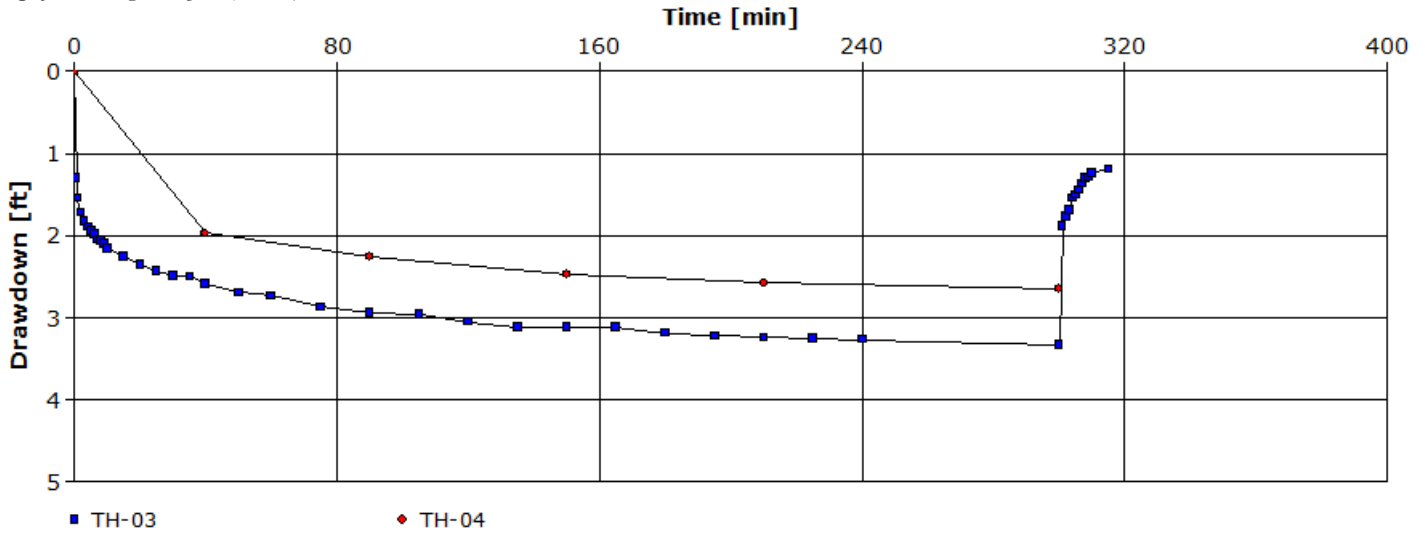


Figure 12 - Drawdown vs. time from the pump test of TH-03; West chamber site; Pumping rate is 65 U.S.GPM. ($4.10 \times 10^{-3} \text{ m}^3/\text{s}$).

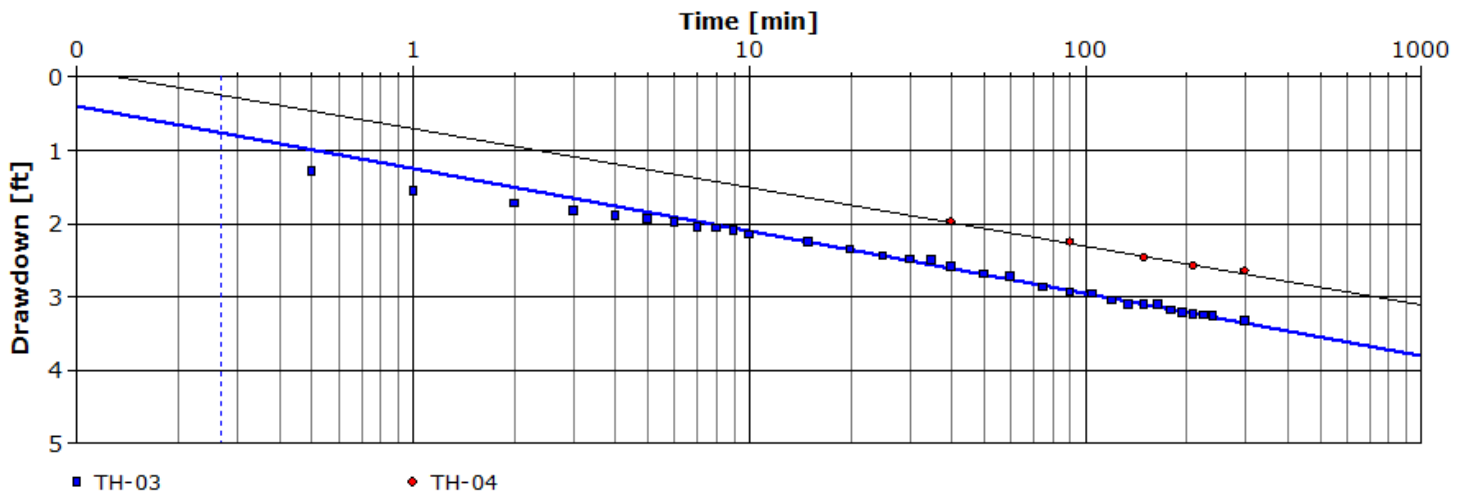


Figure 13 – Cooper Jacob method (1946) analysis of pump test data from well TH-03; West chamber site; Pumping rate is 65 U.S.GPM. ($4.10 \times 10^{-3} \text{ m}^3/\text{s}$).

Figure 14, shown below, illustrates the changes to water levels that can result from aquifer boundary conditions. The implications of the different boundaries can yield both positive and negative results for a pumping well, depending on the intended use. For the purposes of dewatering, a negative boundary condition is desirable, as a lower pumping rate would be required to generate the same amount of drawdown. At the Interceptor site, the Red River is likely to impose a positive boundary during longer term pumping. The decreased drawdown results from river water influx to the aquifer. Under positive boundary conditions, higher pumping rates would be required to generate the same amount of drawdown as would be generated with unbounded conditions.



Aquifer Testing Analysis (Cont'd)

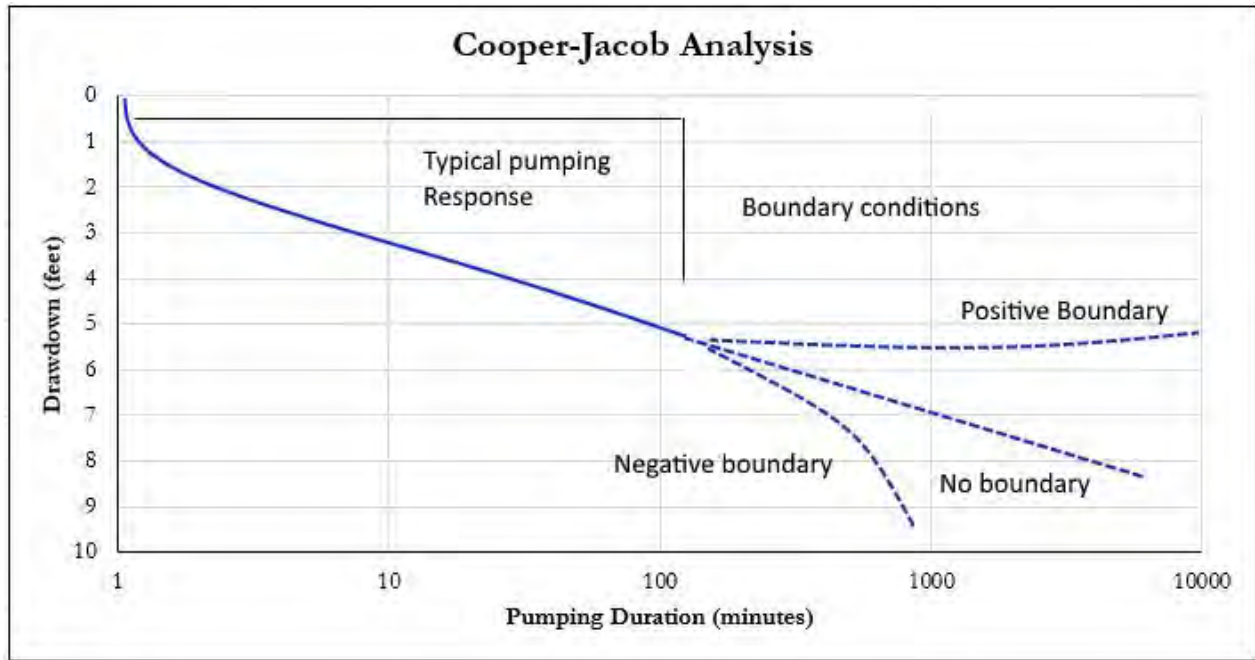


Figure 14 – Theoretical water level response to positive, neutral and negative aquifer boundary conditions on a Cooper-Jacob plot.

Groundwater Geochemistry Sampling

The analytical results for the groundwater samples collected during the study were provided by ALS Laboratories of Winnipeg for analysis of routine parameters.

In general, the results were consistent between the chamber sites and with other sampling that has been conducted in the area. The groundwater is considered to be of moderate quality and would likely be eligible for discharge into local drainage networks (pending approval). Baracos et. al. (1983) indicated that TDS for the area should be between 600-1,000 mg/L. Samples from the Interceptor site suggest that TDS values are about 1,000 mg/L. There was no significant change to groundwater quality observed during the testing, although longer pumping durations may result in changes to groundwater quality, particularly if surface water is captured by the wells.

Table 6, shown below, provides some highlights of the results from the analytical sampling of the pump wells during the aquifer testing at the east and west chamber sites. The complete results from ALS laboratories are attached (L2015597).

A piper plot of the well against a nearby provincial monitoring station (G05OJ159) is shown on the following page as Figure 15.

Table 6 Groundwater Analytical Results Northeast Interceptor Site – Kildonan Settlers Bridge City of Winnipeg, Manitoba	
Parameter	Result
Total Dissolved Solids	964-1,060 mg/L
Chloride Ion (Soluble)	211-250 mg/L
Conductivity	1,450-1,590 umhos/cm
Hardness (as CaCO ₃)	540-617 mg/L
pH	7.6
Calcium	95-109 mg/L
Sodium	173-201 mg/L

Table 6 –Groundwater analytical chemistry – Northeast Interceptor Site. (source – ALS L2015597)

The results compare well with the regional water quality in the area. The groundwater samples plot towards the center of the diagram with no significant distinction between the major ions.

water...the lifeblood of the land



Groundwater Quality (Cont'd)

In addition to the routine geochemistry, samples were also collected for the stable environmental isotope analysis. The purpose of this analysis is to determine the origin and provenance of groundwater at the site, and to assess the potential for influx from the river.

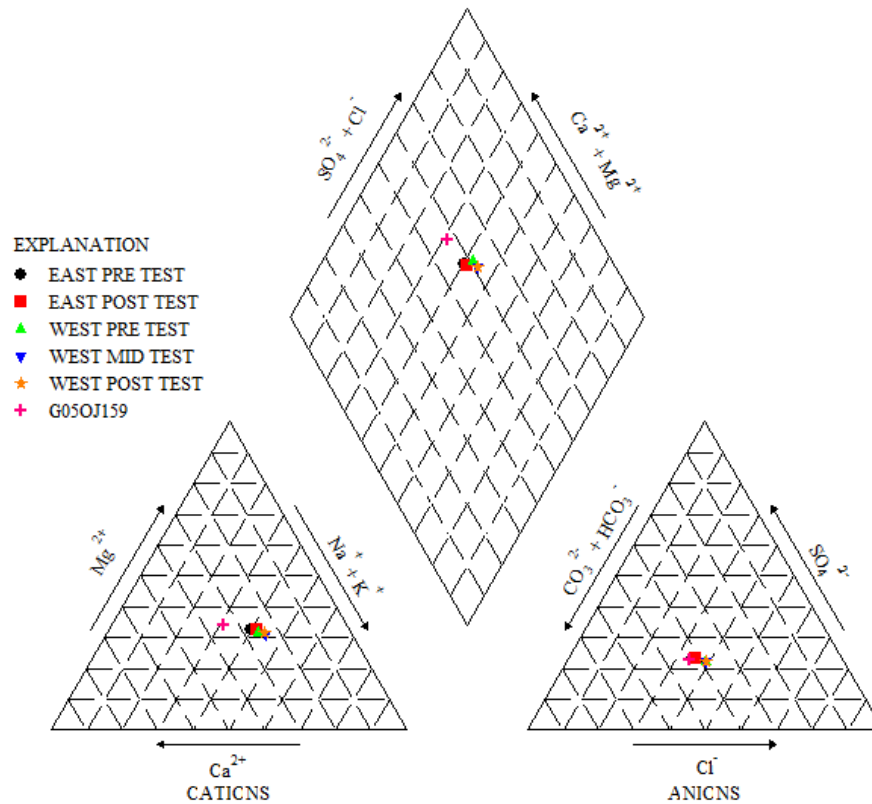


Figure 15 – Piper Plot; Interceptor Site (data source: ALS L2015597; MSD, 2016)

The ratios of the main isotopes that compose the water molecule ($^{18}\text{O}/^{16}\text{O}$) and $^2\text{H}/^1\text{H}$ are important for hydrogeological investigations (Freeze and Cherry, 1979). The units are presented in delta (δ) units as parts per thousand or ‰ (Freeze and Cherry, 1979) relative to standard mean oceanic water (SMOW). The two isotopes of water have different freezing and vapour points, which leads to different concentrations as a result of freezing, condensation, melting, and evaporation (Freeze and Cherry, 1979). As water is evaporated from the ocean, there is a decline in the ^{18}O concentration by a specific amount. As the vapor condenses, the precipitation has a higher ^{18}O concentration. This process continues as the vapor moves inland, and undergoes many cycles of condensation and evaporation. This fact makes deuterium and $^{18}\text{oxygen}$ very useful for hydrogeological investigations, as the origin and mixing of different waters can be determined. In order to determine the changes from local precipitation, deuterium and $^{18}\text{oxygen}$ results are plotted to determine the local meteoric water line, which would be expected to be the typical concentrations in recent precipitation events in the area.

Within Manitoba, glacial water (~10,000 years ago), typically shows $^{18}\text{oxygen}$ concentrations of -23 to -19 ‰. Groundwater that contains a mixture of more recent groundwater with older glacial waters typically has an isotopic composition between -19 and -17 ‰, and recent meteoric groundwater has a composition between -17 to -14 ‰ (Freeze and Cherry, 1979).

A plot of the results against the local meteoric water line (IAEA, 2012) is shown on the following page as Figure 16. At the Interceptor location, a distinction is apparent between the isotope results from the east and west chamber sites. The samples from both sites plot generally along the GMWL as recent meteoric groundwater. However, the samples collected from the west chamber site are depleted by nearly 2‰ relative to samples from the east chamber site. The relatively depleted composition indicates older meteoric groundwater and potential mixing with glacial waters. The difference in isotopic composition suggests different origins for groundwater at the two sites. This result is consistent with the interpretation of the Red River as the convergence of easterly and westerly regional flow systems. The results from the west chamber site indicate a mixture of glaciogenic and recent meteoric groundwater. It is further apparent from Figure 12 that the isotopic composition of the groundwater at the west chamber site changed with pumping. The groundwater sample collected at the end of the test appears to be more recent than the groundwater from the pre and midtest samples and plots slightly below the GMWL.



Groundwater Quality (cont'd)

The change in isotopic composition of the groundwater during the pumping test is characteristic of the bedrock aquifer conditions in the Winnipeg area. Drawdown induced in the carbonate bedrock allows for localized vertical drainage of the overlying clay and till deposits (Day, 1977). Groundwater in the overburden is expected to be enriched in ¹⁸oxygen relative to the older bedrock groundwater. The shift to more recent groundwater with pumping suggests an interconnection between the bedrock aquifer and the overlying till and clay material (Day, 1977). In addition, the shift to slightly below the GMWL suggests a potential evaporitic component to the water, which likely represents some influence from the river. It should be noted that the geochemical changes noted in this investigation occurred over a relatively short pumping duration. Longer term pumping to depressurize the aquifer would likely cause more significant shifts in the groundwater geochemistry. This result highlights the importance for regular monitoring of groundwater quality for the duration of the project, should dewatering be required.

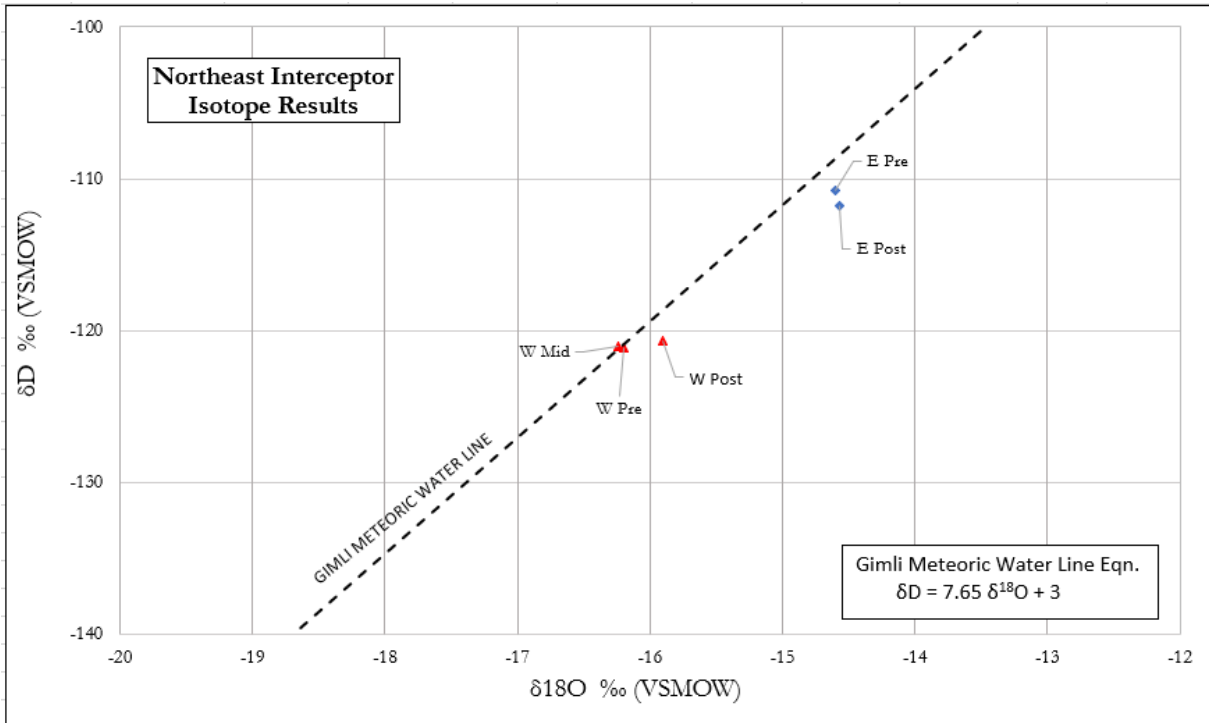


Figure 16 – Groundwater samples collected at the start, middle and end of the pumping tests conducted at the east and west chamber sites; plotted against the Gimli Meteoric Water Line. (source - ALS L2015597, 2017; IAEA, 2012)

Estimation of Discharge Requirements

Based on the Geotechnical Report prepared for the Interceptor site by AECOM (2017), uncertainty remains regarding the final installation method to be used. The options presented indicate chamber structures will require excavation to 202-204 m geodetic for micro-tunnelling installation, or to 216-218 m geodetic for Horizontal Directional Drilling (HDD) installation (AECOM, 2017). As both of these options would result in excavations below the local static water level (conservatively assumed to be 225 m geodetic, based on station G05OJ159), groundwater management will be required regardless of the installation method. Where dewatering is considered, less required drawdown is generally preferable. However, to establish an upper threshold to the potential dewatering efforts that may be required, for the purposes of this assessment a required drawdown to an elevation of 201 m will be conservatively assumed. This equates to a total drawdown of approximately 79 feet (24 m) at each chamber location.

It is important to note that the pumping test durations were relatively short and the pumping rates were relatively low. Although a slight shift in isotopic composition was observed during the testing, assessment of the river influence and the potential interconnection of the drawdown cones between the two chamber sites required assumptions to be made regarding long term pumping requirements. If long term pumping causes drawdown interference effects between the west and east chamber sites, a lower overall pumping rate would be required.

If a significant hydraulic connection to the river is encountered, a higher overall pumping rate would be required. These considerations will be discussed further in the following sections.



Estimation of Discharge Requirements (Cont'd)

Due to the large amounts of drawdown required in the aquifer, the drawdown in the wells would be into bedrock. Consequently, the pumps would need to be set very deep in the well. This may cause some challenges for well operation. Due to the depths involved, backup pumps and wells will be required.

It should be noted that the calculations in the following sections do not take into account natural gradients and other unknown pumping wells that might be present. In addition, the calculations assume static conditions in both the river stage and the groundwater levels. It is known from the provincial monitoring stations that water levels fluctuate regularly, both in the aquifer and the river hydrographs. Consequently, the amount of drawdown and corresponding discharge requirements may be different at the time of construction. In addition, the construction project is assumed to take up to six months to complete, and the hydrogeological conditions are expected to fluctuate during the construction duration. Continuous monitoring would be very important to maintain the required drawdown.

Based on the aquifer conditions inferred from the pumping tests, the total combined pumping rate was calculated to be 1,200 U.S.G.P.M. ($7.57 \times 10^{-2} \text{ m}^3/\text{s}$) to lower the groundwater level to 201 m geodetic at both the east and west chamber sites. It should be noted that the required discharge rates at the time of pumping may be greater or less than the estimate, based on the conditions at the time of pumping. The calculation was based on the Theis equation with the following assumed parameters:

- Static water level of 225 m geodetic (~8.2 ft. (2.5 m) below grade).
- Pumping water level 201 m geodetic (~86.9 ft. (26.5 m) below grade).
- Transmissivity value of 20,000 U.S.G.P.D./ft. ($2.87 \times 10^{-3} \text{ m}^2/\text{s}$).
- Storativity value of 1.0×10^{-4} .
- Pumping duration of 180 days.

Following the above assumptions, the required drawdown could be generated by simultaneously pumping four wells at each chamber location at an approximate rate of 300 U.S.G.P.M. ($1.89 \times 10^{-2} \text{ m}^3/\text{s}$) each. The predicted drawdown cone resulting from dewatering at the above rates is illustrated in Figure 17, shown below.

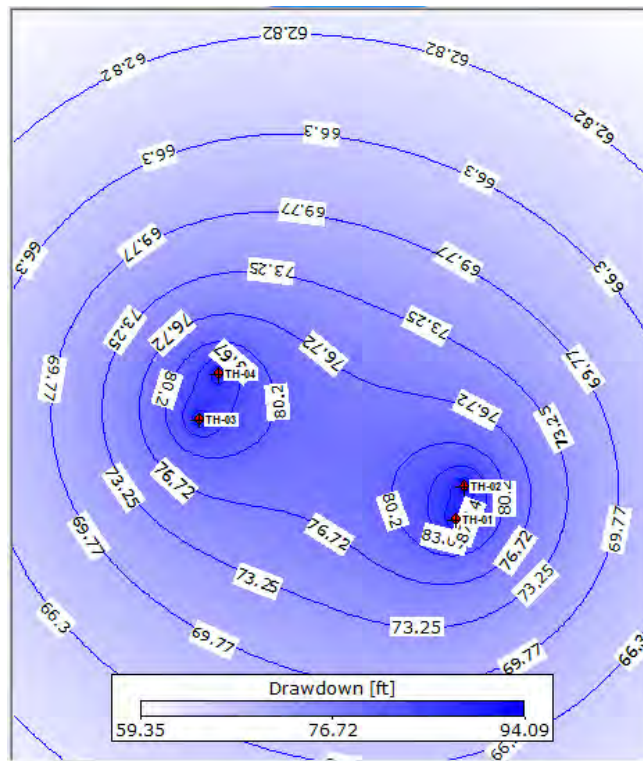


Figure 17 – Predicted Drawdown cone generated from pumping four wells at 300 U.S.G.P.M. each for 180 days; assumed transmissivity of 20,000 U.S.G.P.D./ft. and storativity of 1.0×10^{-4} ; modeled using AquiferTest v2016.1.



Expansion of the Drawdown Cone

Due to the relatively long pumping duration and high discharge rates that would be required to dewater the Interceptor site, the drawdown cone generated during the project would be extensive and would extend beyond the project site. Tables 7 and 8, shown below, contain the estimated drawdown that would be observed in a well during dewatering at increasing radial distance from the project site under different aquifer transmissivity conditions. Table 7 was calculated assuming the transmissive conditions inferred from the pumping test, while Table 8 was calculated using the higher transmissivity values mapped within the area.

The calculated drawdown at a radial distance of 2.0 miles was 19.8 feet (6.0 m) under lower transmissive conditions and 42.5 feet (13.0 m) under the higher transmissive conditions. The amount of drawdown generated could cause disruptions of service for nearby groundwater users. A detailed well inventory should be completed by a qualified engineer or hydrogeologist prior to major pumping operations. Due to the extensive drawdown, it is recommended that the radius of a field inventory be expanded to at least 2 miles.

Table 7 Drawdown Estimation at Distance - 180 days of Pumping Transmissivity of 20,000 U.S.G.P.D./ft. ($2.87 \times 10^{-3} \text{ m}^2/\text{s}$), Storage Coefficient of 1.0×10^{-4} Discharge Rate of 600 U.S.G.P.M. ($3.79 \times 10^{-2} \text{ m}^3/\text{s}$) from Each Site (1,200 U.S.G.P.M Total)									
Distance from site	Pump well	75 feet	500 feet	1,000 feet	2,000 feet	5280 feet (1 mile)	10560 feet (2 miles)	21120 feet (4 miles)	42240 feet (8 miles)
Drawdown (ft.)	131.7	79.3	56.5	48.2	39.8	28.1	19.8	11.4	3.1

Table 7 – Estimated Drawdown after 180 days of continuous pumping at a combined rate of 1,200 U.S.G.P.M. ($2.87 \times 10^{-2} \text{ m}^3/\text{s}$) from the east and west chamber sites (600 U.S.G.P.M per site) – Northeast Interceptor Project.

Table 8 Drawdown Estimation at Distance - 180 days of Pumping Transmissivity of 100,000 U.S.G.P.D./ft. ($1.44 \times 10^{-2} \text{ m}^2/\text{s}$), Storage Coefficient of 1.0×10^{-4} Discharge Rate of 2,200 U.S.G.P.M. ($1.39 \times 10^{-1} \text{ m}^3/\text{s}$) from Each Site (4,400 U.S.G.P.M Total)									
Distance from site	Pump well	75 feet	500 feet	1,000 feet	2,000 feet	5280 feet (1 mile)	10560 feet (2 miles)	21120 feet (4 miles)	42240 feet (8 miles)
Drawdown (ft.)	103.2	80.9	69.2	63.9	58.1	49.2	42.5	35.6	28.7

Table 8 – Estimated Drawdown after 180 days of continuous pumping at a combined rate of 4,400 U.S.G.P.M. ($2.78 \times 10^{-1} \text{ m}^3/\text{s}$) from the east and west chamber sites (2,200 U.S.G.P.M per site) – Northeast Interceptor Project.

Influence of the Red River

Previous work in the region has established that the Red River and the Carbonate Aquifer are hydraulically connected, especially over its course from the north of the City of Winnipeg to Lake Winnipeg (Render, 1970). Flow between a hydraulically connected stream/aquifer system is shown to be a function of the head difference between the river stage and the aquifer potentiometric surface (Sophocleous, 2002). A common approach to estimate flow in these systems is to consider flow between the river and the aquifer to be controlled by leakage through a permeable layer in one dimension (Rushton and Tomlinson, 1979). The specific discharge between the river and the aquifer, based on Darcy’s law where flow is a direct function of the hydraulic conductivity and head difference, can be expressed by the following equation:

- $q = k \Delta b$

Where q is flow between the river and the aquifer (positive for baseflow – for gaining streams; and negative for river recharge – for losing streams); $\Delta b = h_a - h_r$, (h_a is aquifer head, and h_r is river head); and k is a constant representing the streambed leakage coefficient (hydraulic conductivity of the semi-impervious streambed layer divided by its thickness).

Based on the log of geotechnical test hole TH16-03, a clay and till layer with a total thickness of 17.4 ft. (5.3 m) separates the river bottom and the top of the carbonate aquifer (AECOM, 2017). A hydraulic conductivity of $1.0 \times 10^{-6} \text{ m/s}$ will be assumed for the clay and till, although typical ranges for these materials are between 10^{-12} and 10^{-4} m/s (Freeze and Cherry, 1979).

The volume of river water contributed to the aquifer is estimated by applying the value of specific discharge across the flow area. It is important to note that these values are estimated from limited data. It is very likely that the material at the base of the river is complex and variable. Consequently, estimates of the streambed leakage coefficient and leakage volumes are only approximate and used in this assessment for comparison purposes between the conditions present in the natural state and during dewatering. For the Interceptor site, the area of flow is estimated based on a channel width of 510 ft. (155 m), to include an area of approximately $2.6 \times 10^5 \text{ ft.}^2$ ($2.4 \times 10^4 \text{ m}^2$).



Influence of the Red River (Cont'd)

An estimate of groundwater flow under natural conditions was undertaken assuming a groundwater elevation of 225 m geodetic (G05OJ159) and a river stage of 223.8 m geodetic (reported by AECOM for Sep 09, 2016). The resulting flow under these conditions was calculated to be positive $3.1 \times 10^{-2} \text{ m}^3/\text{s}$ (~450 U.S.G.P.M.), indicating an upward vertical gradient from the aquifer into the river. This result is consistent with the interpretation of the Red River as a point of groundwater discharge. If the level in the aquifer would be lowered to 201 m geodetic, the resulting flow is calculated to be $-5.5 \times 10^{-2} \text{ m}^3/\text{s}$ (~850 U.S.G.P.M.). The negative result indicates a reversal of the hydraulic gradient by an order of magnitude from the river into the aquifer. The dewatering wells would create a gradient reversal to downward vertical gradient.

Interpretation of the gradient reversal calculation requires some important considerations. The above calculations imply that the mechanisms for flow into the river are the same as for flow out of the river into the aquifer. It has been shown in multiple studies that this may not be representative of real conditions (Sophocleous, 2002). In addition, extensive monitoring would be required to determine how the drawdown cone will develop under the river. The pumping test did not reveal a positive boundary condition which would indicate a strong connection to the river. However, pumping at higher discharge rates and for a longer duration would likely reveal a hydraulic connection between the two units. Overall, the hydraulic gradient between the aquifer and the river will likely be variable and is difficult to estimate.

To illustrate the water flux under natural state and dewatering conditions, a model was constructed using the SEEP/W module of GeoStudio 2018. A geologic model was constructed from data available from the geotechnical investigation (AECOM, 2017). The results of the modeling are shown below and on the following page in Figures 18, 19, and 20. The modeled results of pre and post pumping conditions are consistent with the above flow calculations. An interesting aspect illustrated by the model is the potential for increased flux across the west bank of the river channel. At this location, the confining material appears to be thinned out and allows for increased groundwater flow. This result is consistent with the higher transmissive conditions inferred for the west chamber site from the pumping tests.

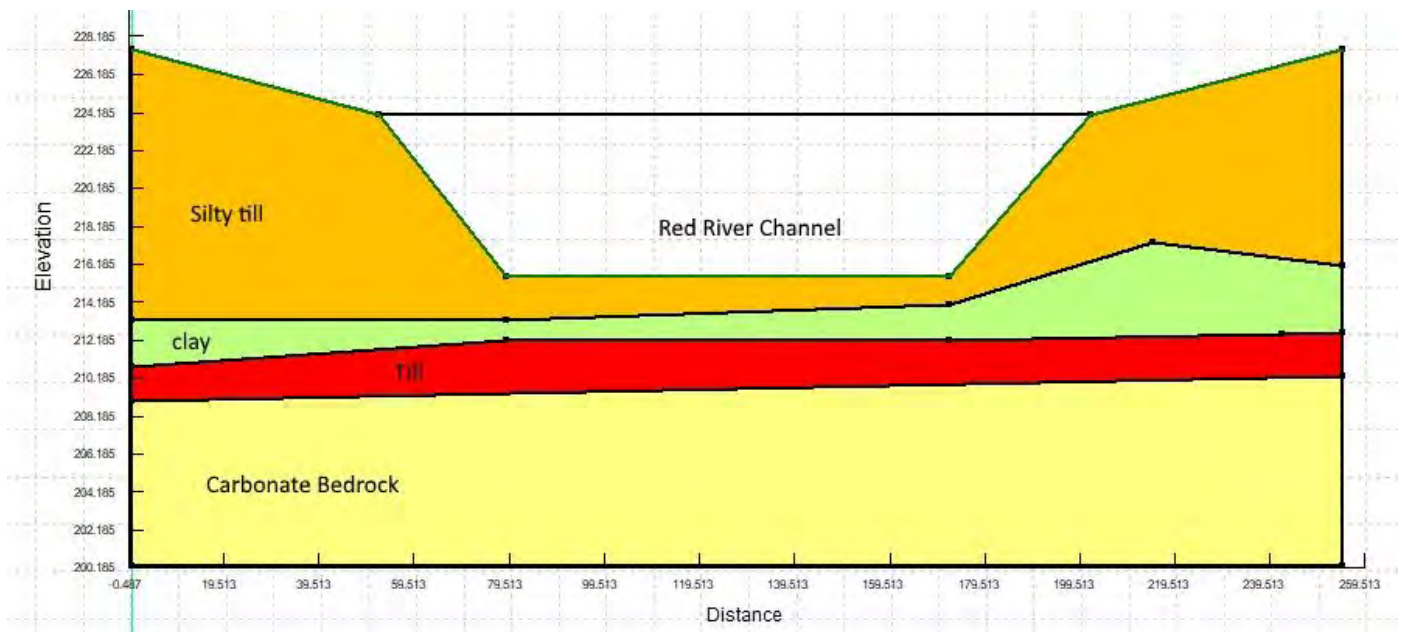


Figure 18 - Geological model of the Interceptor site for SEEP/W modeling. (AECOM, 2017)

The results from the seepage analysis suggest that the river will likely contribute water to the aquifer during dewatering operations. Preliminary calculations suggest the river contribution could increase the required discharge by as much as 70%. The pumping rate of the dewatering wells would likely need to be increased to accommodate the river water influx. It should be noted that the estimate of seepage is very sensitive to the hydraulic conductivity at the site and, to a lesser extent, to the area of flow. It is expected that leakage would be highly variable across the river channel.

The conditions at the Interceptor site encountered during the testing indicate the potential for river water discharge into the aquifer at potentially high rates. This could become a matter of worker safety and should be addressed carefully. An assessment of the geological/hydrogeological conditions across the entire river bank would be necessary to better quantify these risks. Back up wells and pumps should be included in the dewatering system to mitigate against these risks.



Influence of the Red River (Cont'd)

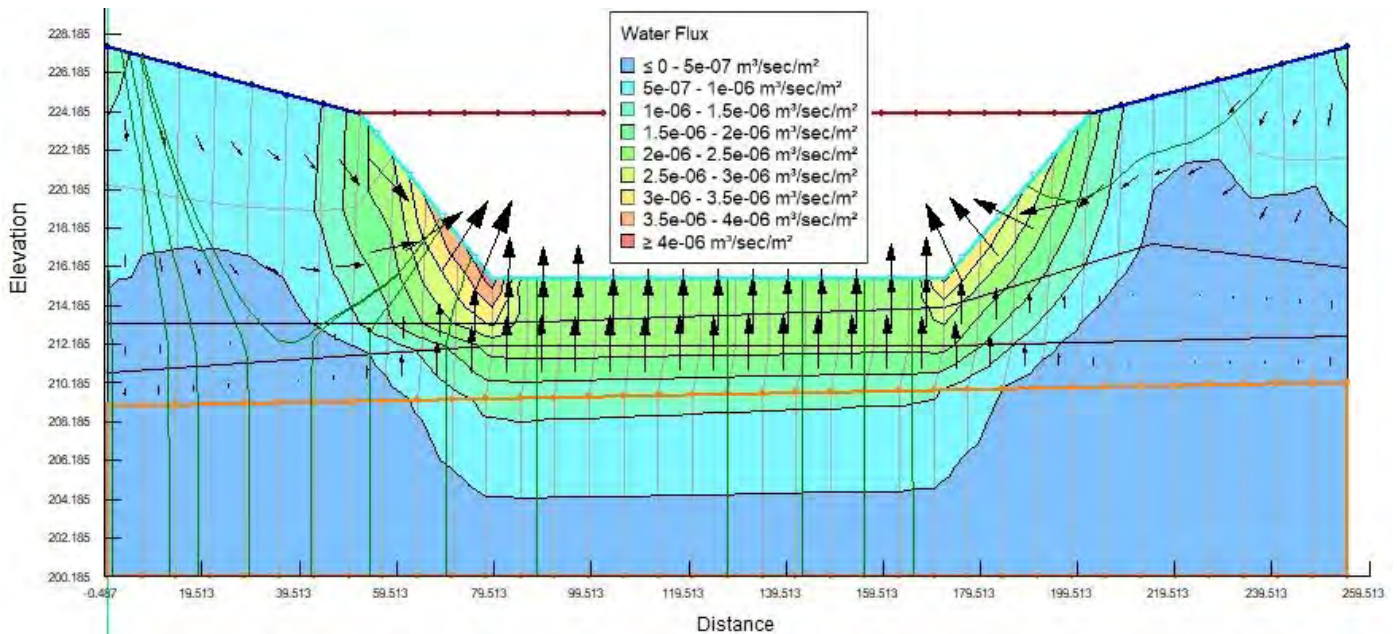


Figure 19 - Natural state conditions groundwater flux, Interceptor Site. (SEEP/W GeoStudio 2018).

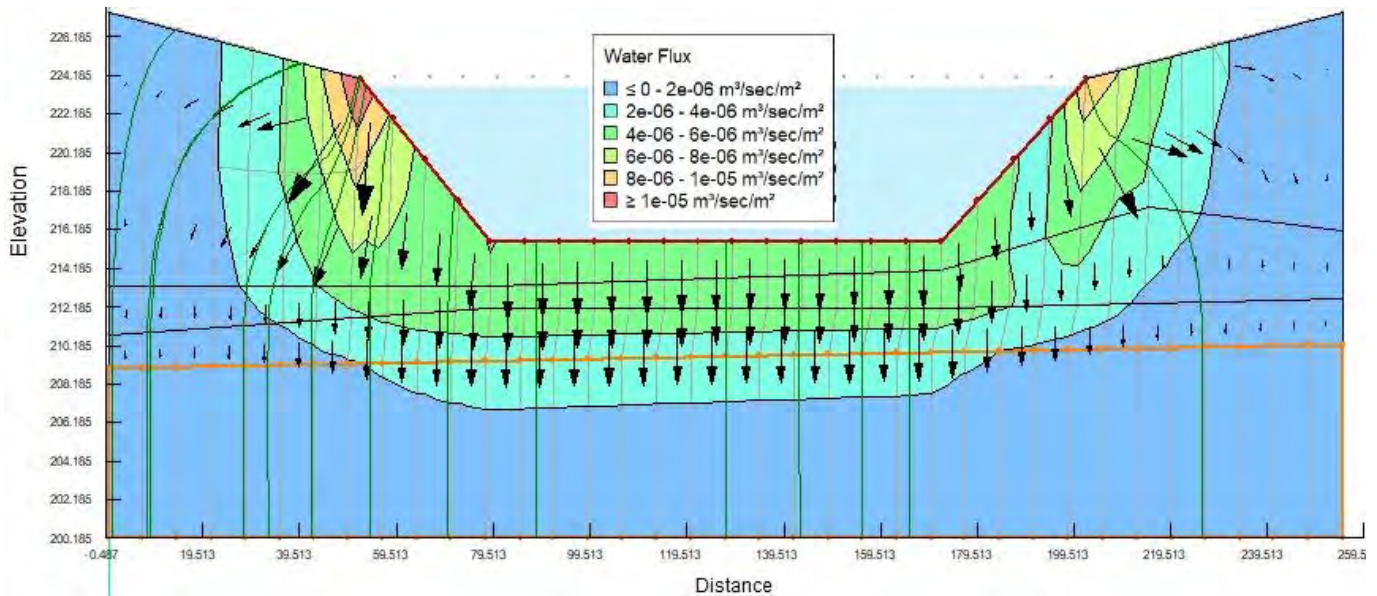


Figure 20 - Dewatering conditions groundwater flux, Interceptor Site. (SEEP/W GeoStudio 2018).

Discussion and Recommendations

The Interceptor site represents the typical transmissive variability of the carbonate aquifer in the Winnipeg area which has always made numerical simulations of groundwater difficult to assess. Lowering the potentiometric surface by up to 80 feet (~24 m) is a major undertaking and should be done with great care. Seepage control mechanisms that do not involve pumping should be investigated. Both a geotechnical engineer and a hydrogeological engineer should be involved in the design. The location of the site at a major river adds considerable challenges to the project. In addition, the generated drawdown cone will be significant and will extend a great distance from the site. This drawdown may disrupt nearby private and licensed groundwater users. It is important to note that liability for negatively impacting nearby groundwater users rests with the well owner, in this case the City of Winnipeg, and cannot be transferred through contract agreements. The potential for third party impacts is significant for this project due to the large amounts of drawdown that would likely be generated.



Discussion and Recommendations (Cont'd)

The proposed dewatering project also raises some significant geotechnical concerns which should be addressed in more detail by a geotechnical engineer. For example, reversal of the hydraulic gradient between the river and the aquifer is shown to impact slope stability of the river banks. In addition, drawdown in the aquifer would be expected to drain the overlying soils. The removal of a large volume of water from the aquifer and overburden for the duration of the project increases the potential for building and land settlement issues that could affect residents and businesses within the radius of influence of the pump wells. Water accounts for 15 to 25% volume of clays and till and creating significant drawdown could cause settlement issues as the porewater drains from the overlying clays and tills. This could potentially cause cracks and shifting foundations/settlement. As the site is located adjacent to a bridge structure and numerous large commercial and residential buildings, these considerations should be addressed by a geotechnical engineer.

Should geotechnical engineering dictate that dewatering is required, the following activities are recommended:

- The site will require a GEP from MSD. In addition, the volume of groundwater withdrawal would likely exceed 200 dam³, which would also subject the project to Class 2 Environment Act Licensing. Finally, issues related to groundwater discharge may also require additional permitting.
- From the hydrogeological testing, the aquifer at the Interceptor site is shown to be moderately transmissive, with an estimated bulk transmissivity of 20,000 U.S.G.P.D./ft. and a storativity of 1.0×10^{-4} . Transmissivity maps of the region indicate values for transmissivity as high as 100,000 U.S.G.P.D./ft or more.
- To generate the necessary drawdown under the observed conditions, a dewatering system will likely need to sustain a total combined discharge rate of at least 1,200 U.S.G.P.M. ($2.87 \times 10^{-2} \text{ m}^3/\text{s}$). This estimate is based on conditions presented in the geotechnical report (AECOM, 2017) and on regional monitoring data (MSD, 2016). As a result, the conditions at the time of construction may be different which could require the pumping rate to be higher or lower.
- Influx from the Red River will likely result in higher required discharge rates at each chamber site. In addition, the upper ranges of transmissivity values mapped in the area indicate potential required discharge rates as high as 4,400 U.S.G.P.M. ($2.78 \times 10^{-1} \text{ m}^3/\text{s}$)
- The timing of the project should be carefully considered. Although the aquifer levels are typically lower during the summer months, the drawdown is generated by a greater number of wells brought online for cooling purposes. Completion of the project during the late fall/winter months would likely reduce the potential for third party impacts, as fewer users typically pump at that time. In addition, river levels would be at their seasonal low points in the late fall/winter months, which may reduce the potential seepage rates.
- An inventory of domestic private water wells and licensed systems should be undertaken. This would be needed to address any potential issues with respect to pumping. Sampling should be done to confirm this program. Pumps may need to be lowered and wells put out of service would need to be provided with an alternate water supply.
- The desktop well inventory conducted in this investigation identified 70 private and commercial wells within a one mile radius of the site. The inventory included a review of the general location and construction details of nearby groundwater users. It should be noted that this work did not involve a field assessment of the condition of the wells/hook up. In addition, the database may not contain a record of every well present in the area. Consequently, to mitigate the risks and liability to the City, it is recommended that a field inventory of nearby wells be undertaken prior to operation of an aquifer depressurization system. The field inventory should include an inspection of licensed users by a qualified hydrogeologist.
- The four, 5 inch diameter PVC test wells installed during the investigation have been maintained for future use. A typical 5 inch well is capable of sustaining flow rates up to a maximum of approximately 120 U.S.G.P.M. Consequently, the existing wells on the site are unlikely to generate sufficient drawdown when pumped at the maximum capacity.
- Based on the results of the investigation, it is suggested that a dewatering system should include at least two 12-inch diameter pumping wells at each chamber site in order to sustain the required flow rates. The wells should be designed by a Professional Engineer registered in the Province of Manitoba.
- In the event of a power supply failure, the chambers and tunnel could become flooded in a relatively short period of time as a result of the physical setting and transmissive conditions. It is recommended that a back up well should be installed and back up power supplies and an automatic transfer should be included.



Discussion and Recommendations (Cont'd)

- Groundwater quality will require extensive monitoring. The test results indicated little change to groundwater quality with pumping at the site. However, the isotopic results suggest a potential interconnection between the carbonate aquifer and the Red River is likely. The city would need to be sure the dewatering will not cause permanent water quality changes to the aquifer.
- In the event that large scale dewatering is needed, additional observation wells may be required
- The system should be designed, tested and monitored by a Professional Engineer or Geoscientist registered with EGM.

If the project is to proceed without dewatering, the importance of considerations related to groundwater remains, as construction activity will be below the water table and within the carbonate aquifer system. The potential for third party impacts will be present even if dewatering is not undertaken. Tunneling within the bedrock has the potential to change groundwater quality, which may include increased turbidity and the introduction of organic or other compounds to the aquifer. In addition to geochemical considerations, the potential to influence local groundwater levels still exists, as the conditions in the local bedrock and the connection between the aquifer and river may be altered. To mitigate against potential negative impacts which may arise from the Interceptor project, the following recommendations are provided for installations without dewatering.

- The GEP initiated for this investigation should be cancelled.
- A desktop well inventory should be undertaken which focusses on licensed groundwater users located within one mile from the site. Site visits and water sampling should be undertaken for the sites closest to the chamber locations.
- The test wells at each chamber site should be instrumented to monitor groundwater level fluctuations during the construction phases.
- The test wells should be sampled before, during and after project completion to establish baseline conditions and identify potential changes resulting from the project.

At the completion of the project, all production and test wells installed during this investigation should be sealed according to provincial guidelines by a licensed well driller.

We thank for the opportunity to work on this interesting project and to be of service to AECOM. Should you require anything further, please call us at 204-326-2485.

Sincerely

Friesen Drillers Limited

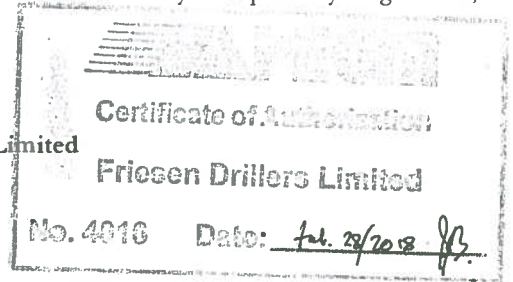
J.E.(Justin) Neufeld, B.Sc.(G.Sc.), GIT
Groundwater Geologist



Reviewed by

Friesen Drillers Limited

J.J.(Jeff) Bell, B.Sc.(G.E.), P.Eng.
Hydrogeological Engineer



Attachments

- Groundwater Exploration Permit – City of Winnipeg
- Drillers Logs – TH-01/02/03/04 - Friesen Drillers Limited
- Pumping Test Data – East and West Chamber Sites - Friesen Drillers Limited
- Table 3 – Water Well Inventory.



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Limitations

The scope of this report is limited to the matters expressly covered and is intended solely for the client to whom it is addressed. Friesen Drillers Limited makes no warranties, expressed or implied, including without limitation, as to the marketability of the site, or fitness to a particular use. The assessment was conducted using standard engineering and scientific judgment, principles, and practices, within a practical scope and budget. It is based partially on the observations of the assessor during the site visit in conjunction with archival information obtained from a number of sources, which is assumed to be correct. Except as provided, Friesen Drillers Limited has made no independent investigations to verify the accuracy or completeness of the information obtained from secondary sources or personal interviews. Generally, the findings, conclusions, and recommendations are based on a limited amount of data (e.g. number of boreholes drilled or water quality samples submitted for laboratory analysis) interpolated between sampling points and the actual conditions on the site may vary from that described above. Any findings regarding the site conditions different from those described above upon which this report was based will consequently change Friesen Drillers Limited's conclusions and recommendations.

Disclaimer

This Friesen Drillers Limited report has been prepared in response to the specific requests for services from the client to whom it is addressed. The content of this document is not intended to be relied upon by any person, firm, or corporation, other than the client of Friesen Drillers Limited, to whom it is addressed. Friesen Drillers Limited denies any liability whatsoever to other parties who may obtain access to this document by them, without express prior written authority of Friesen Drillers Limited and the client who has commissioned this document.





Water Use Licensing Section
Box 16, 200 Sauiteaux Crescent
Winnipeg, Manitoba, Canada R3J 3W3
T 204-945-6118 F 204-948-2357
Rob.Matthews@gov.mb.ca

November 15, 2016

File: Winnipeg, City of -41 (Northeast Interceptor Sewer River Crossing)

Stacy Cournoyer, P.Eng.
Sr. Project Engineer
City of Winnipeg
110-1199 Pacific Avenue
Winnipeg, MB R3E 3S8

Dear Ms. Cournoyer:

Attached herewith is a **Groundwater Exploration Permit** issued in response to an application submitted by Friesen Drillers Ltd. on behalf of the City of Winnipeg and AECOM Canada Limited, registered on October 28, 2016, for a licence to construct well(s) and divert groundwater for dewatering purposes in connection with the installation of a deep sewage shaft on **River Lot 54, Parish of Kildonan, for Northeast Interceptor Sewer River Crossing Project.**

The Groundwater Exploration Permit authorizes the City of Winnipeg to undertake test well drilling, testing and aquifer assessment on the above mentioned site for dewatering purposes in connection with the installation of a deep sewage shaft. The purpose of the pump testing is to determine the aquifer conditions at the proposed site and to determine water level impacts on existing local wells and/or registered projects with earlier precedence dates than the proposed project. Please note that during testing, pumping must cease if any local water supplies are negatively impacted as a result of testing. The City of Winnipeg would further be responsible to correct any water supply problems or provide temporary water supply to anyone whose water supplies are negatively impacted as a result of testing. Please familiarize yourself with the terms and conditions of the Groundwater Exploration Permit.

A licensing decision on this project will be held pending submission of the required information. Please note that diversion of water without a Water Rights Licence or written authorization would constitute a violation of *The Water Rights Act* and may be subject to enforcement.

Please contact Ronaldo Miranda, directly at 204-945-6475 should you have any questions regarding the requirements outlined in this letter and the attached permit or the water rights licensing aspects of this project.

Yours truly,

A handwritten signature in black ink, appearing to read "Rob Matthews". The signature is stylized and written in a cursive-like font.

Rob Matthews
Manager
Water Use Licensing Section

cc: J. Paulynn Estrella – Legal, E.I.T., Friesen Drillers Ltd.
Graham Phipps, SD
Ronaldo Miranda, SD

Groundwater Exploration Permit

Pursuant to The Water Rights Act

FILE – Winnipeg, The City of -41 (Northeast Interceptor Sewer River Crossing)

is hereby permitted to explore for and construct a groundwater well or wells on the following described lands, **RL 54, Parish of Kildonan**, for **hydrogeologic site assessment and dewatering** purposes, subject, however, to the following conditions:

1. The permittee must have legal access to the site where the exploration work and project wells are to be located.
2. This Authorization is not transferable or assignable to any other party.
3. Prior to undertaking any work or construction of any works authorized by this permit the permittee is required to retain the services of a **hydrogeologist** registered with Association of Professional Engineers and Geoscientists of Manitoba (APEGM), who would be required to:
 - Plan and supervise the drilling of boreholes, test wells, production wells, observation wells and well pump testing as authorized by this permit.
 - Conduct a constant rate pumping test on proposed dewatering well(s) in accordance with Form H (http://www.gov.mb.ca/conservation/waterstewardship/licensing/wlb/pdf/form_h_july_2013.pdf).
 - Carry out an inventory of private and commercial wells within a 1 mile radius of the project well site. The inventory may need to be expanded based on the assessment of the expected area of water level drawdown impact resulting from future pumping.
 - Prepare and submit to the Water Use Licensing Section a technical report on drilling of boreholes and wells, pump testing of well, well inventory and water quality sampling. The report would contain, but not limited to, such things as: well driller's reports for test wells, dewatering wells and observation wells; a plan showing the location of these wells on the property and/or GPS locations of the wells; an analysis of aquifer pumping tests; calculations of transmissivity; and a description of the amount of water level interference that would be expected to occur at existing local wells that are located within a 1 mile radius of the project well site. The report would also indicate if any local wells are expected to be adversely affected by the proposed use of water and where these wells are located. Two copies of the report shall be submitted, one hardcopy and one digital copy.
4. During any pumping tests that may be conducted, pumping must cease immediately if any local water supplies are negatively impacted as a result of the tests. The permittee is also responsible to correct any water supply problems or provide temporary water supply to anyone whose water supplies are negatively impacted as a result of the tests.
5. This permit expires within twelve (12) months of the date of issuance.
6. Please note that diversion of water without a Water Rights Licence or written authorization would constitute a violation of *The Water Rights Act* and may be subject to enforcement.

Issued at the City of Winnipeg in the Province of Manitoba, this 15th day of November A.D. 2016


for The Honourable Minister of Sustainable Development

Well Construction Report



Sheet 1 of 1

For PDF submission: Report must be printed on legal size paper (8.5 x 14 inches) and be signed in ink.

Form No. WELLCON-V01-PDF

Owner Name: City Of Winnipeg
 First _____ Last _____
 Mailing Address 4th Floor, 510 Main Street
 Town/City Winnipeg, MB
 Postal Code R3B 1B9 Phone _____
 Email _____

Well Location: (see note 3; attach sketch if necessary)
 Civic Address _____
 (if different than mailing address)
 Quarter _____ Section _____ Township _____ Range _____ E W
 Parish _____ Type & Lot No. _____

Well Name: (if applicable) TH-04
 Well Identification Tag Number 692
 Location of Tag Attached to casing stick-up
 Other (specify) _____

GPS: (see note 4), Accuracy +/- 28 feet metres
 Latitude (decimal degrees) 59.95068
 Longitude (decimal degrees) 97.09891

Rockwood Sensitive Area: Yes - Permit No. _____ No

Test Hole (see note 5) - Sealed Yes No or
Well Use: test well - Sealed Yes No
 production/source recharge/return
 monitoring dewatering geotechnical
 other (specify) _____

Method of Construction:
 auger bored backhoe/dug
 rotary (mud) rotary (air)
 dual rotary driven jetted
 other (specify) _____

Water Use: (Check all that apply)
 domestic public/semi-public irrigation
 commercial/industrial livestock/poultry
 earth energy (heating/cooling)
 other (specify) _____

Lithologic Description: (see notes 6 and 7) - Measure From/To depths from ground surface. Attach another sheet if needed.

From (ft)	To (ft)	Colour	Material Description (use recommended names on guide)	Observations
0	15	Brown	Till	
15	31	Grey	Silt	
31	52	Grey	Clay	
52	56	Brown	Till	
56	197	Brown	Limestone	
197			Bottom of Hole	
0				
0				
0				
0				

Well Construction: (see note 8) - Measure From/To depths from ground surface. Attach another sheet if needed.

From (ft)	To (ft)	Borehole	Casing	Liner	Open Hole	Well Screen	Surface Seal	Annular Fill	Filter Pack	ID (inches)	OD (inches)	Type of Material	Method of Placement	
												(ex: casing and screen material, screen type and slot size, use of shale traps, packers, screen blanks or tail pipes, and type and size of surface seal/annular fill/filter pack material)		
0	58	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		7 7/8			
0	58	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		5	5 1/2	Insert Glued PVC	
58	197	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			4 3/4		
0	58	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				Envirogrout	Poured

Well Completion: Day 17 Month October Year 2017
 Top of casing 18 inches ags bgs; Well vented: Yes No
 Well disinfected: Yes No; Well cover installed: Yes No
 Pitless adapter/unit installed at _____ feet bgs; Not installed

Source of Drilling Water: Groundwater Surface water
 Water contains a minimum of 10 mg/L free chlorine: Yes No
 Name/Location of water source Friesen Drillers Ltd.

Drilling Additives Used: Yes (list type & quantity) 6 Bags Wyo-Ben Extra High Yield Bentonite No

Well Yield Test (see note 9),
 Date of Test: Day 17 Month October Year 2017
 Same as date of well completion
Static Water Level Before Test 14.2 feet bgs ags
 Method of Test: pumping air lift bailing recovery
 other (specify) _____
 Water level at end of test 18.5 feet bgs ags
 Length of test 1 hours _____ minutes
 Estimated rate of discharge 52 IGPM USGPM

Well Development: air lifting surging pumping jetting
 bailing hydrofracturing other (specify) _____
Water Quality Characteristics: fresh salty clear cloudy
 sediment odour (specify) _____
Flowing Artesian Well No Yes - If yes, estimated rate of artesian flow _____ IGPM USGPM Annular space cemented: Yes No
 Flow control device installed: Yes No
 Does water leak from around the outside of the casing: Yes No

Recommended Pumping Rate: _____ IGPM USGPM with pump intake at _____ feet bgs;
 Will your company be installing a pump?: Yes No

Remarks (see note 10) _____

Well Drilling Contractor: Company Name Friesen Drillers Ltd Licence No. 607-17
 Well Driller: Print Name Chris Loepky Signature _____

Declaration: I certify that to the best of my knowledge the information provided herein is accurate and true and complies with The Groundwater and Water Well Act.

Well Construction Report



Sheet 1 of 1

For PDF submission: Report must be printed on legal size paper (8.5 x 14 inches) and be signed in ink.

Form No. WELLCON-V01-PDF

Owner Name: City Of Winnipeg
 First _____ Last _____
 Mailing Address 4th Floor, 510 Main Street
 Town/City Winnipeg, MB
 Postal Code R3B 1B9 Phone _____
 Email _____

Well Location: (see note 3; attach sketch if necessary)
 Civic Address _____
 (if different than mailing address)
 Quarter _____ Section _____ Township _____ Range _____ E W
 Parish _____ Type & Lot No. _____

Well Name: (if applicable) TH-01
 Well Identification Tag Number 689
 Location of Tag Attached to casing stick-up
 Other (specify) _____

GPS: (see note 4), Accuracy +/- 28 feet metres
 Latitude (decimal degrees) 49.94964
 Longitude (decimal degrees) 97.09641
Rockwood Sensitive Area: Yes - Permit No. _____ No

Test Hole (see note 5) - Sealed Yes No or
Well Use: test well - Sealed Yes No
 production/source recharge/return
 monitoring dewatering geotechnical
 other (specify) _____

Method of Construction:
 auger bored backhoe/dug
 rotary (mud) rotary (air)
 dual rotary driven jetted
 other (specify) _____

Water Use: (Check all that apply)
 domestic public/semi-public irrigation
 commercial/industrial livestock/poultry
 earth energy (heating/cooling)
 other (specify) _____

Lithologic Description: (see notes 6 and 7) - Measure From/To depths from ground surface. Attach another sheet if needed.

From (ft)	To (ft)	Colour	Material Description (use recommended names on guide)	Observations
0	12	Brown	Till	
12	31	Grey	Silt	
31	45	Grey	Clay	
45	58	Brown	Till	
58	120	Brown	Limestone	
120			Bottom of Hole	
0				
0				
0				
0				

Well Construction: (see note 8) - Measure From/To depths from ground surface. Attach another sheet if needed.

From (ft)	To (ft)	Borehole	Casing	Liner	Open Hole	Well Screen	Surface Seal	Annular Fill	Filter Pack	ID (inches)	OD (inches)	Type of Material (ex: casing and screen material, screen type and slot size, use of shale traps, packers, screen blanks or tail pipes, and type and size of surface seal/annular fill/filter pack material)	Method of Placement (ex: poured, tremie)
0	60	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>								7 7/8		
0	60		<input checked="" type="checkbox"/>							5	5 1/2	Insert Glued PVC	
60	120			<input checked="" type="checkbox"/>							4 3/4		
0	60					<input checked="" type="checkbox"/>						Envirogrout	Poured

Well Completion: Day 12 Month October Year 2017
 Top of casing 18 inches ags bgs; Well vented: Yes No
 Well disinfected: Yes No; Well cover installed: Yes No
 Pitless adapter/unit installed at _____ feet bgs; Not installed

Source of Drilling Water: Groundwater Surface water
 Water contains a minimum of 10 mg/L free chlorine: Yes No
 Name/Location of water source Friesen Drillers Ltd.

Drilling Additives Used: Yes (list type & quantity) 6 Bags Wyo-Ben Extra High Yield Bentonite No

Well Yield Test (see note 9),
 Date of Test: Day 12 Month October Year 2017
 Same as date of well completion
Static Water Level Before Test 16.7 feet bgs ags
 Method of Test: pumping air lift bailing recovery
 other (specify) _____
 Water level at end of test 28 feet bgs ags
 Length of test _____ hours 30 minutes
 Estimated rate of discharge 52 IGPM USGPM

Well Development: air lifting surging pumping jetting
 bailing hydrofracturing other (specify) _____
Water Quality Characteristics: fresh salty clear cloudy
 sediment odour (specify) _____
Flowing Artesian Well No Yes - If yes, estimated rate of artesian flow _____ IGPM USGPM Annular space cemented: Yes No
 Flow control device installed: Yes No
 Does water leak from around the outside of the casing: Yes No

Recommended Pumping Rate: _____ IGPM USGPM with pump intake at _____ feet bgs;
 Will your company be installing a pump?: Yes No

Remarks (see note 10) _____

Well Drilling Contractor: Company Name Friesen Drillers Ltd Licence No. 607-17
 Well Driller: Print Name Chris Loepky Signature _____
Declaration: I certify that to the best of my knowledge the information provided herein is accurate and true and complies with The Groundwater and Water Well Act.

Well Construction Report



Sheet 1 of 1

For PDF submission: Report must be printed on legal size paper (8.5 x 14 inches) and be signed in ink.

Form No. WELLCON-V01-PDF

Owner Name: City Of Winnipeg
 First _____ Last _____
 Mailing Address 4th Floor, 510 Main Street
 Town/City Winnipeg, MB
 Postal Code R3B 1B9 Phone _____
 Email _____

Well Location: (see note 3; attach sketch if necessary)
 Civic Address _____
 (if different than mailing address)
 Quarter _____ Section _____ Township _____ Range _____ E W
 Parish _____ Type & Lot No. _____

Well Name: (if applicable) TH-03
 Well Identification Tag Number 691
 Location of Tag Attached to casing stick-up
 Other (specify) _____

GPS: (see note 4), Accuracy +/- 28 feet metres
 Latitude (decimal degrees) 59.95037
 Longitude (decimal degrees) 97.09913
Rockwood Sensitive Area: Yes - Permit No. _____ No

Test Hole (see note 5) - Sealed Yes No **or**
Well Use: test well - Sealed Yes No
 production/source recharge/return
 monitoring dewatering geotechnical
 other (specify) _____

Method of Construction:
 auger bored backhoe/dug
 rotary (mud) rotary (air)
 dual rotary driven jetted
 other (specify) _____

Water Use: (Check all that apply)
 domestic public/semi-public irrigation
 commercial/industrial livestock/poultry
 earth energy (heating/cooling)
 other (specify) _____

Lithologic Description: (see notes 6 and 7) - Measure From/To depths from ground surface. Attach another sheet if needed.

From (ft)	To (ft)	Colour	Material Description (use recommended names on guide)	Observations
0	12	Brown	Till	
12	28	Grey	Silt	
28	57	Grey	Clay	
57	60	Brown	Chunky Limestone	
60	197	Brown	Limestone	
197			Bottom of Hole	
0				
0				
0				
0				

Well Construction: (see note 8) - Measure From/To depths from ground surface. Attach another sheet if needed.

From (ft)	To (ft)	Borehole	Casing	Liner	Open Hole	Well Screen	Surface Seal	Annular Fill	Filter Pack	ID (inches)	OD (inches)	Type of Material (ex: casing and screen material, screen type and slot size, use of shale traps, packers, screen blanks or tail pipes, and type and size of surface seal/annular fill/filter pack material)		Method of Placement (ex: poured, tremie)
0	62	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		7 7/8			
0	62	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		5	5 1/2	Insert Glued PVC	
62	197	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			4 3/4		
0	62	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				Envirogrout	Poured

Well Completion: Day 16 Month October Year 2017
 Top of casing 18 inches ags bgs; Well vented: Yes No
 Well disinfected: Yes No; Well cover installed: Yes No
 Pitless adapter/unit installed at _____ feet bgs; Not installed

Source of Drilling Water: Groundwater Surface water
 Water contains a minimum of 10 mg/L free chlorine: Yes No
 Name/Location of water source Friesen Drillers Ltd.

Drilling Additives Used: Yes (list type & quantity) 6 Bags Wyo-Ben Extra High Yield Bentonite No

Well Yield Test (see note 9),
 Date of Test: Day 16 Month October Year 2017
 Same as date of well completion
Static Water Level Before Test 16.1 feet bgs ags
 Method of Test: pumping air lift bailing recovery
 other (specify) _____
 Water level at end of test 17.9 feet bgs ags
 Length of test 1 hours _____ minutes
 Estimated rate of discharge 52 IGPM USGPM

Well Development: air lifting surging pumping jetting
 bailing hydrofracturing other (specify) _____
Water Quality Characteristics: fresh salty clear cloudy
 sediment odour (specify) _____
Flowing Artesian Well No Yes - If yes, estimated rate of artesian flow _____ IGPM USGPM Annular space cemented: Yes No
 Flow control device installed: Yes No
 Does water leak from around the outside of the casing: Yes No

Recommended Pumping Rate: _____ IGPM USGPM with pump intake at _____ feet bgs;
 Will your company be installing a pump?: Yes No

Remarks (see note 10) _____

Well Drilling Contractor: Company Name Friesen Drillers Ltd Licence No. 607-17
 Well Driller: Print Name Chris Loepky Signature _____

Declaration: I certify that to the best of my knowledge the information provided herein is accurate and true and complies with The Groundwater and Water Well Act.

Well Construction Report



Sheet 1 of 1

For PDF submission: Report must be printed on legal size paper (8.5 x 14 inches) and be signed in ink.

Form No. WELLCON-V01-PDF

Owner Name: City Of Winnipeg
 First _____ Last _____
 Mailing Address 4th Floor, 510 Main Street
 Town/City Winnipeg, MB
 Postal Code R3B 1B9 Phone _____
 Email _____

Well Location: (see note 3; attach sketch if necessary)
 Civic Address _____
 (if different than mailing address)
 Quarter _____ Section _____ Township _____ Range _____ E W
 Parish _____ Type & Lot No. _____

Well Name: (if applicable) TH-02
 Well Identification Tag Number 690
 Location of Tag Attached to casing stick-up
 Other (specify) _____

GPS: (see note 4), Accuracy +/- 28 feet metres
 Latitude (decimal degrees) 49.94986
 Longitude (decimal degrees) 97.09632

Rockwood Sensitive Area: Yes - Permit No. _____ No

Test Hole (see note 5) - Sealed Yes No or
Well Use: test well - Sealed Yes No
 production/source recharge/return
 monitoring dewatering geotechnical
 other (specify) _____

Method of Construction:
 auger bored backhoe/dug
 rotary (mud) rotary (air)
 dual rotary driven jetted
 other (specify) _____

Water Use: (Check all that apply)
 domestic public/semi-public irrigation
 commercial/industrial livestock/poultry
 earth energy (heating/cooling)
 other (specify) _____

Lithologic Description: (see notes 6 and 7) - Measure From/To depths from ground surface. Attach another sheet if needed.

From (ft)	To (ft)	Colour	Material Description (use recommended names on guide)	Observations
0	14	Brown	Till	
14	34	Grey	Silt	
34	52	Grey	Clay	
52	73	Brown	Till	
73	78	Brown	Till	
78	197	Brown	Limestone	
197			Bottom of Hole	
0				
0				
0				

Well Construction: (see note 8) - Measure From/To depths from ground surface. Attach another sheet if needed.

From (ft)	To (ft)	Borehole	Casing	Liner	Open Hole	Well Screen	Surface Seal	Annular Fill	Filter Pack	ID (inches)	OD (inches)	Type of Material	Method of Placement	
												(ex: casing and screen material, screen type and slot size, use of shale traps, packers, screen blanks or tail pipes, and type and size of surface seal/annular fill/filter pack material)		
0	76	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		8 3/4			
0	76	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>		5	5 1/2	Insert Glued PVC	
76	197	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			4 3/4		
0	76	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>				Envirogrout	Poured

Well Completion: Day 13 Month October Year 2017
 Top of casing 18 inches ags bgs; Well vented: Yes No
 Well disinfected: Yes No; Well cover installed: Yes No
 Pitless adapter/unit installed at _____ feet bgs; Not installed

Source of Drilling Water: Groundwater Surface water
 Water contains a minimum of 10 mg/L free chlorine: Yes No
 Name/Location of water source Friesen Drillers Ltd.

Drilling Additives Used: Yes (list type & quantity) 6 Bags Wyo-Ben Extra High Yield Bentonite No

Well Yield Test (see note 9),
 Date of Test: Day 13 Month October Year 2017
 Same as date of well completion
Static Water Level Before Test 16 feet bgs ags
 Method of Test: pumping air lift bailing recovery
 other (specify) _____
 Water level at end of test 77 feet bgs ags
 Length of test 1 hours _____ minutes
 Estimated rate of discharge 5 IGPM USGPM

Well Development: air lifting surging pumping jetting
 bailing hydrofracturing other (specify) _____
Water Quality Characteristics: fresh salty clear cloudy
 sediment odour (specify) _____

Flowing Artesian Well No Yes - If yes, estimated rate of artesian flow _____ IGPM USGPM
 Annular space cemented: Yes No
 Flow control device installed: Yes No
 Does water leak from around the outside of the casing: Yes No

Recommended Pumping Rate: _____ IGPM USGPM with pump intake at _____ feet bgs;
 Will your company be installing a pump?: Yes No

Remarks (see note 10) _____

Well Drilling Contractor: Company Name Friesen Drillers Ltd Licence No. 607-17
 Well Driller: Print Name Chris Loepky Signature _____

Declaration: I certify that to the best of my knowledge the information provided herein is accurate and true and complies with The Groundwater and Water Well Act.



Contact Info
Address
Company Name
City, State/Province

Pumping Test - Water Level Data

Project: Northeast Interceptor River Crossing West

Number: AECOM2017-NEINT

Client: AECOM - Adam Braun

Location: Kildonan Settlers Bridge - Winnipeg Pumping Test: West Bank Pumping Well: TH-03

Test Conducted by: FDL Test Date: 2017-10-20 Discharge: variable, average rate 65 [U.S. gal/min]

Observation Well: TH-03 Static Water Level [ft]: 14.45 Radial Distance to PW [m]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0	14.45	0.00
2	0.5	15.75	1.30
3	1	16.00	1.55
4	2	16.17	1.72
5	3	16.28	1.83
6	4	16.35	1.90
7	5	16.39	1.94
8	6	16.43	1.98
9	7	16.50	2.05
10	8	16.52	2.07
11	9	16.55	2.10
12	10	16.61	2.16
13	15	16.71	2.26
14	20	16.80	2.35
15	25	16.89	2.44
16	30	16.94	2.49
17	35	16.95	2.50
18	40	17.04	2.59
19	50	17.14	2.69
20	60	17.18	2.73
21	75	17.32	2.87
22	90	17.39	2.94
23	105	17.41	2.96
24	120	17.50	3.05
25	135	17.56	3.11
26	150	17.56	3.11
27	165	17.56	3.11
28	180	17.64	3.19
29	195	17.67	3.22
30	210	17.69	3.24
31	225	17.70	3.25
32	240	17.72	3.27
33	300	17.78	3.33
34	301	16.34	1.89
35	302	16.22	1.77
36	303	16.14	1.69
37	304	16.00	1.55
38	305	15.95	1.50
39	306	15.90	1.45
40	307	15.82	1.37
41	308	15.75	1.30
42	309	15.74	1.29
43	310	15.70	1.25
44	315	15.64	1.19



Contact Info
Address
Company Name
City, State/Province

Pumping Test - Water Level Data

Project: Northeast Interceptor River Crossing West

Number: AECOM2017-NEINT

Client: AECOM - Adam Braun

Location: Kildonan Settlers Bridge - Winnipeg Pumping Test: West Bank Pumping Well: TH-03

Test Conducted by: FDL Test Date: 2017-10-20 Discharge: variable, average rate 65 [U.S. gal/min]

Observation Well: TH-04 Static Water Level [ft]: 11.48 Radial Distance to PW [m]: 209.46

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0	11.48	0.00
2	40	13.45	1.97
3	90	13.74	2.26
4	150	13.95	2.47
5	210	14.06	2.58
6	300	14.13	2.65



Contact Info
Address
Company Name
City, State/Province

Pumping Test - Water Level Data

Project: Northeast Interceptor River Crossing East

Number: AECOM2017-NEINT

Client: AECOM - Adam Braun

Location: Kildonan Settlers Bridge - Winnipeg Pumping Test: EastBank Pumping Well: TH-01

Test Conducted by: FDL Test Date: 2017-10-17 Discharge: variable, average rate 110 [U.S. gal/min]

Observation Well: TH-01 Static Water Level [ft]: 15.29 Radial Distance to PW [m]: -

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0	15.29	0.00
2	0.5	26.60	11.31
3	1	28.21	12.92
4	2	28.85	13.56
5	3	29.19	13.90
6	4	29.19	13.90
7	5	29.24	13.95
8	6	29.49	14.20
9	7	29.49	14.20
10	8	29.55	14.26
11	9	29.64	14.35
12	10	29.49	14.20
13	15	28.45	13.16
14	20	28.30	13.01
15	25	28.23	12.94
16	30	28.20	12.91
17	35	28.36	13.07
18	40	28.65	13.36
19	50	28.99	13.70
20	60	29.30	14.01
21	75	29.60	14.31
22	90	29.87	14.58
23	105	30.02	14.73
24	120	30.00	14.71
25	135	30.41	15.12
26	150	30.77	15.48
27	165	30.89	15.60
28	180	31.12	15.83
29	195	31.51	16.22
30	196	19.85	4.56
31	197	20.35	5.06
32	198	20.12	4.83
33	199	19.89	4.60
34	200	19.73	4.44
35	201	19.54	4.25
36	202	19.39	4.10
37	203	19.24	3.95
38	204	19.16	3.87
39	205	19.04	3.75
40	210	18.54	3.25
41	215	18.49	3.20
42	220	18.42	3.13
43	225	18.33	3.04
44	230	18.19	2.90
45	235	17.76	2.47



Contact Info
Address
Company Name
City, State/Province

Pumping Test - Water Level Data

Project: Northeast Interceptor River Crossing East

Number: AECOM2017-NEINT

Client: AECOM - Adam Braun

Location: Kildonan Settlers Bridge - Winnipeg Pumping Test: EastBank Pumping Well: TH-01

Test Conducted by: FDL Test Date: 2017-10-17 Discharge: variable, average rate 110 [U.S. gal/min]

Observation Well: Well 2 Static Water Level [ft]: 15.72 Radial Distance to PW [m]: 25.31

	Time [min]	Water Level [ft]	Drawdown [ft]
1	0	15.72	0.00
2	20	16.95	1.23
3	60	18.13	2.41
4	120	19.22	3.50
5	165	20.10	4.38
6	205	19.34	3.62
7	230	19.32	3.60

Table 3
Well Inventory – 1,600 meter radius (1 mile)
Northeast Interceptor
Kildonan Settlers Bridge - Winnipeg, Manitoba

No.	Location	Owner	Driller	Well Use	Date	Depth (ft.)	S.W.L. (ft.)	P.W.L. (ft.)	Rate igpm
1	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
2	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
3	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
4	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
5	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
6	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
7	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
8	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
9	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
10	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
11	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
12	RL 31	VALLEY STEEL BUILDERS	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
13	RL 25	CITY OF WINNIPEG	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
14	RL 18	KGS GROUP/ JOHN BURNS	Friesen Drillers Ltd.	P	2014	140	16.9	23.3	90
15	RL 64	DERKSEN CONSTRUCTION	Paul Slusarchuk Well Drilling LTd.	P	1973	133.9	35	48	7.493
16	RL 23	WRB	Friesen Drillers Ltd.	O	2001	N/A	27	N/A	100
17	RL 30	SIKH SOCIETY	Stonewall Drilling	P	1990	70	16	25	29.987
18	RL 30	VALLEY BUILDERS	Maple Leaf Enterprises LTd.	P	2002	85	26	27	16.003
19	RL 30	R MEHNEL	Paul Slusarchuk Well Drilling LTd.	P	1966	85.9	28	29	19.987
20	RL 30	J SHOOMSKI	Paul Slusarchuk Well Drilling LTd.	P	1967	122.9	31	32	11.992
21	RL 30	G KOSTYNIUK	AQUARIUS WELL DRILLING	P	1972	96.9	26	36	3.997
22	RL 30	ST LUKE'S CHURCH	Paul Slusarchuk Well Drilling LTd.	P	1978	144.9	26	N/A	29.987
23	RL 30	J HNATUIK	Paul Slusarchuk Well Drilling LTd.	P	1963	80.9	25	26	25.989
24	RL 30	G SINCLAIR	Paul Slusarchuk Well Drilling LTd.	P	1968	101.9	26	28	29.987
25	RL 30	P BOYKO	Ford Drilling Ltd.	P	1968	119.9	28	N/A	39.987
26	RL 30	G KAPELUS	Paul Slusarchuk Well Drilling LTd.	P	1966	328.8	27	60	5
27	RL 30	SIKH SOCIETY	Friesen Drillers Ltd.	P	1983	84.9	15	N/A	15
28	RL 30	HINES	Paul Slusarchuk Well Drilling LTd.	P	1968	103.9	29	30	24.987
29	RL 31	CONNALLY	AQUARIUS WELL DRILLING	P	1972	106.9	25	35	3.997
30	RL 31	D MOSS	Stonewall Drilling	P	1998	73	32	N/A	50
31	RL 31	TONY NGUYEN	Paul Slusarchuk Well Drilling LTd.	P	1990	164.9	14	N/A	24.987
32	RL 31	V NOCITA	ROTARY DRILLING CO.	P	1964	79.9	15	26	6.003
33	RL 31	VENTURA CUSTOM HOMES LTD	Stonewall Drilling	P	2005	108	6	10	60
34	RL 31	D MALTHOUSE	Echo Drilling Ltd.	P	1995	89.9	30	60	49.974

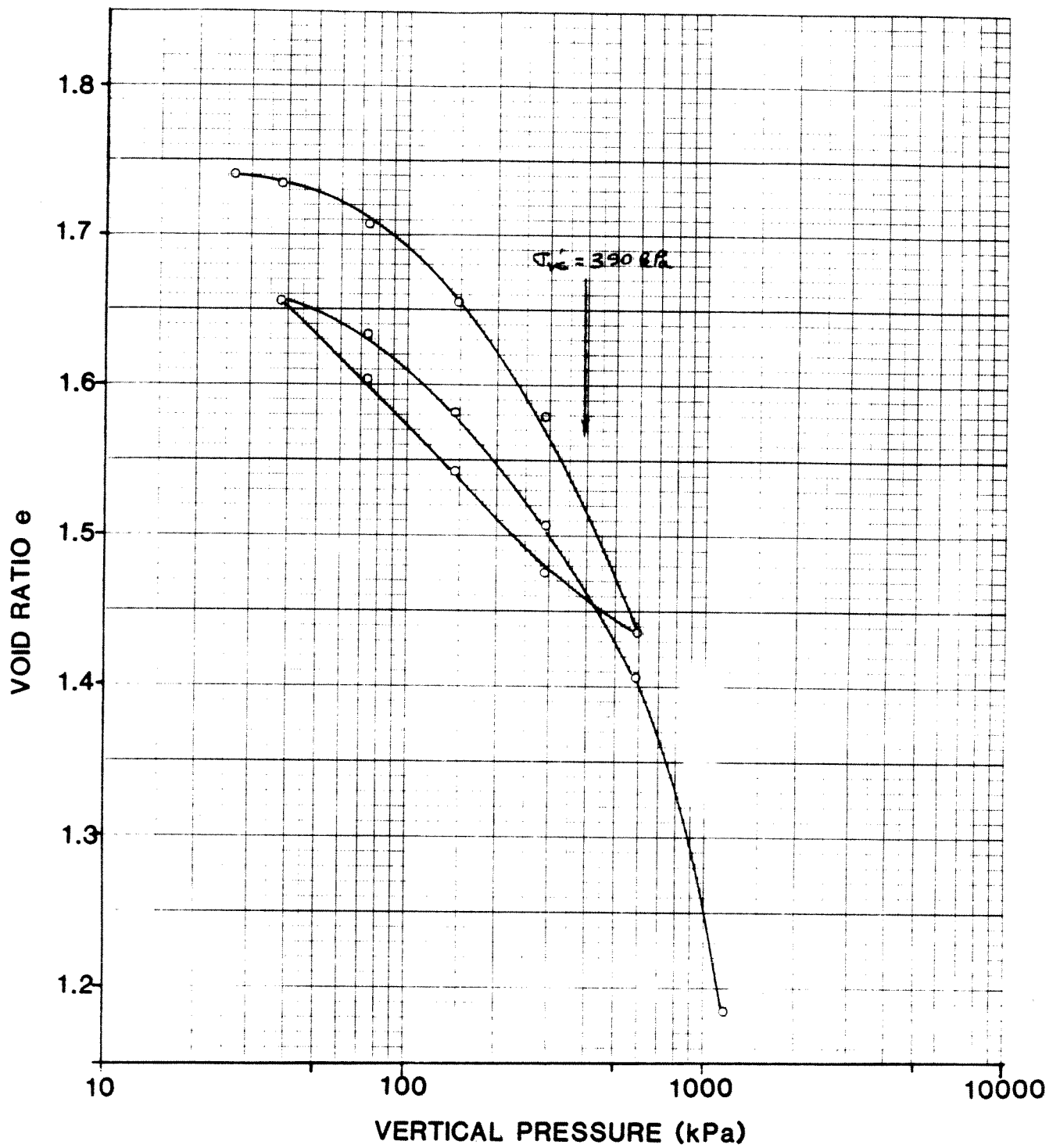
35	RL 31	M GOODMAN	Paul Slusarchuk Well Drilling LTd.	P	1968	99.9	15	30	10
36	RL 31	PARKCITY ELECTRIC	Perimeter Drilling Ltd.	P	1995	299.8	3	N/A	6.992
37	RL 31	W OSTASH	PRUDEN DRILLING CO. LTD.	P	1966	117.9	22	22	10
38	RL 31	E PRYSTANSKI	Paul Slusarchuk Well Drilling LTd.	P	1967	86.9	9	19	29.987
39	RL 31	A WOLFRAN	AQUARIUS WELL DRILLING	P	1973	105.9	20	N/A	11.992
40	RL 31	A WORMIAK	Friesen Drillers Ltd.	P	1973	104.9	10	25	3.496
41	RL 31	S GLOWA	Ford Drilling Ltd.	P	1973	116.9	30	N/A	6.003
42	RL 31	R ANDJILIE	Friesen Drillers Ltd.	P	1974	114.9	26	35	7.995
43	RL 31	A WOLFRAM	Paul Slusarchuk Well Drilling LTd.	P	1981	226.9	28	N/A	7.995
44	RL 31	D BERNHARDT	Paul Slusarchuk Well Drilling LTd.	P	1986	144.9	12	N/A	15
45	RL 31	A GUFFEI	Paul Slusarchuk Well Drilling LTd.	P	1988	93.9	13	38	19.987
46	RL 31	A GUFFEI	Paul Slusarchuk Well Drilling LTd.	P	1988	108.9	18	N/A	19.987
47	RL 31	J SANTOS	Stonewall Drilling	P	1988	174.9	21	N/A	6.992
48	RL 31	J SOARS	Paul Slusarchuk Well Drilling LTd.	P	1989	89.9	12	N/A	29.987
49	RL 31	G BAKER	ROTARY DRILLING CO.	P	1963	87.9	24	N/A	6.491
50	RL 31	G BAKER	ROTARY DRILLING CO.	P	1963	82.9	24	40	6.003
51	RL 31	C L ARNEL	ROTARY DRILLING CO.	P	1964	75	17	39	3.997
52	RL 31	ELAINE ST.GEORGE	Paul Slusarchuk Well Drilling LTd.	P	1968	109.9	15	45	7.493
53	RL 31	BALBON	Paul Slusarchuk Well Drilling LTd.	P	1968	111.9	32	34	10
54	RL 31	W LISOWSKI	SONIC DRILLING CO. LTD	P	1966	134.9	N/A	N/A	N/A
55	RL 31	RAGAN	Paul Slusarchuk Well Drilling LTd.	P	1967	71	9	12	34.987
56	RL 31	P MGOLAS	SCIENTIFIC DRILLING CO.	P	1966	80.9	25	30	6.491
57	RL 31	F GREENING	Paul Slusarchuk Well Drilling LTd.	P	1966	110.9	29	30	8.997
58	RL 31	P MEDEIROS	Paul Slusarchuk Well Drilling LTd.	P	1988	134.9	15	N/A	29.987
59	RL 32	J WHITEWAY	HYGAARD'S WELL DRILLING	P	1988	99.9	31	N/A	15
60	RL 32	G SHUPENIA	Paul Slusarchuk Well Drilling LTd.	P	1990	183.9	30	70	7.995
61	RL 32	W SMTH	Paul Slusarchuk Well Drilling LTd.	P	1972	82.9	26	30	10
62	RL 32	G S KAUFMAN	Paul Slusarchuk Well Drilling LTd.	P	1968	274.8	28	N/A	49.974
63	RL 29	P DUMES	ROHNE, FRANK	P	1963	76	28	28	19.987
64	RL 29	R SHYMANSKI	Paul Slusarchuk Well Drilling LTd.	P	1972	103.9	22	28	10
65	RL 29	BUBBLE BATH CAR WASH	Stonewall Drilling	P	1992	129.9	30	N/A	99.96
66	RL 33	JOHN MARINIC	Perimeter Drilling Ltd.	P	1997	400	14	N/A	40
67	RL 33	MIKE MATRICIAN	Selkirk Drillers	P	1998	105	34	N/A	15

68	RL 33	WILLART HOLDINGS LTD	Paul Slusarchuk Well Drilling LTD.	P	1970	103.9	34	45	7.995
69	RL 33	HELEN MATRICIAN	UNKNOWN	P	1900	N/A	N/A	N/A	N/A
70	RL 28	T SKULASON	PRUDEN DRILLING CO. LTD.	P	1970	95.9	26	26	10
Notes	<p>All information sourced from Manitoba Sustainable Development – GWDRILL, (2014 edition) Friesen Drillers Limited has not verified or field confirmed any data present in this table. All yields and static water levels are as reported and have not been verified by Friesen Drillers Limited. Current well use or operations are unknown for all wells listed.</p> <p>RL – River Lot in the Parish of Kildonan; S.W.L. – Static water level; P.W.L. – Pumping water level; N.A. – Not provided or not available; P – Production;</p>								

Appendix **G**

Consolidation Test Results (Dyregrov and Burgess 1988)

- G-1: Consolidation Test Results (Dyregrov and Burgess 1988)



DYREGROV & BURGESS
CONSULTING GEOTECHNICAL ENGINEERS

CONSOLIDATION TEST RESULTS
TEST HOLE 4 - 4.6 m DEPTH

SCALE

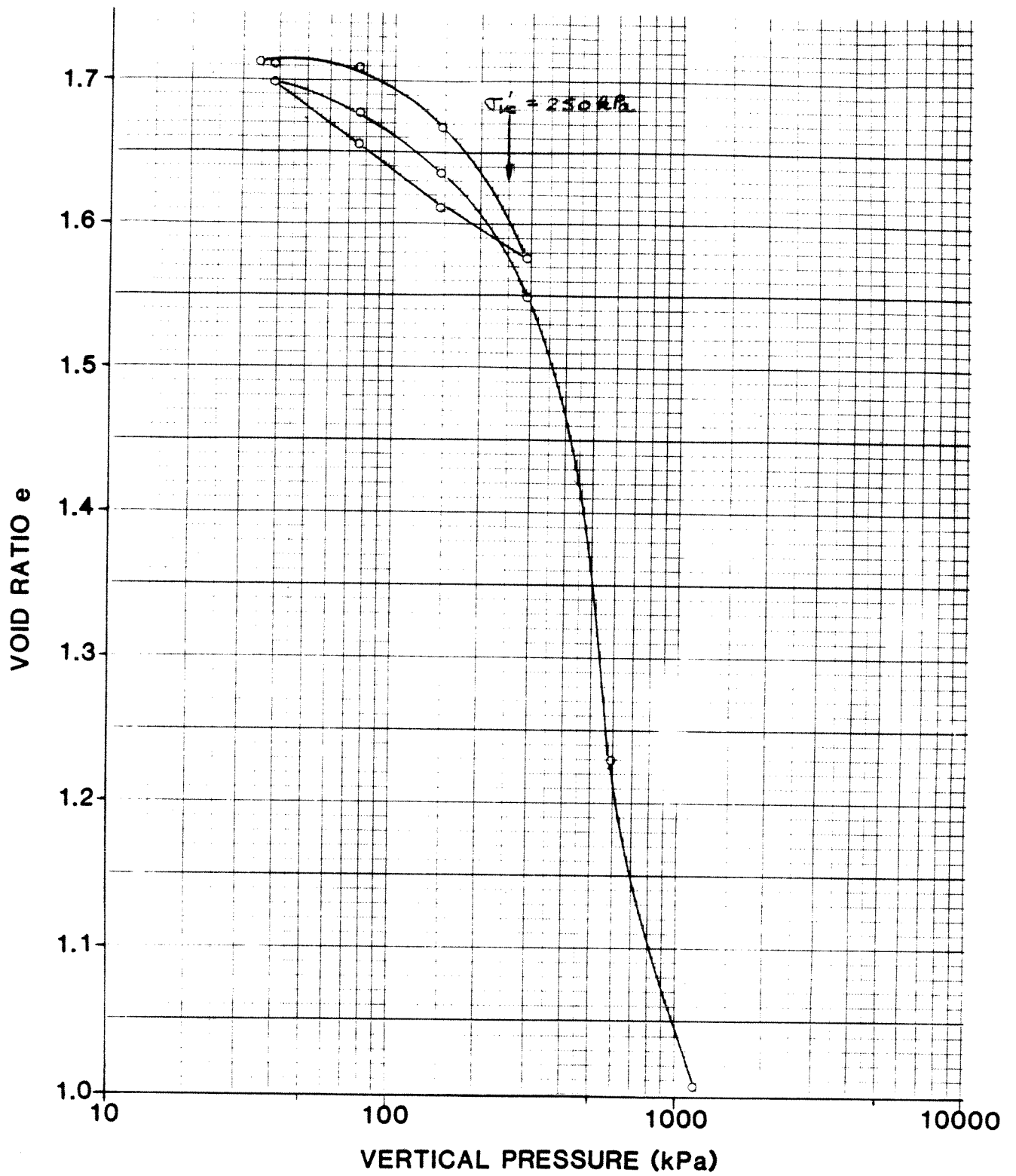
DATE

MADE

CHKD

JOB

FIGURE B7



DYREGROV & BURGESS
CONSULTING GEOTECHNICAL ENGINEERS

CONSOLIDATION TEST RESULTS
TEST HOLE 5 - 13.7 m DEPTH

SCALE

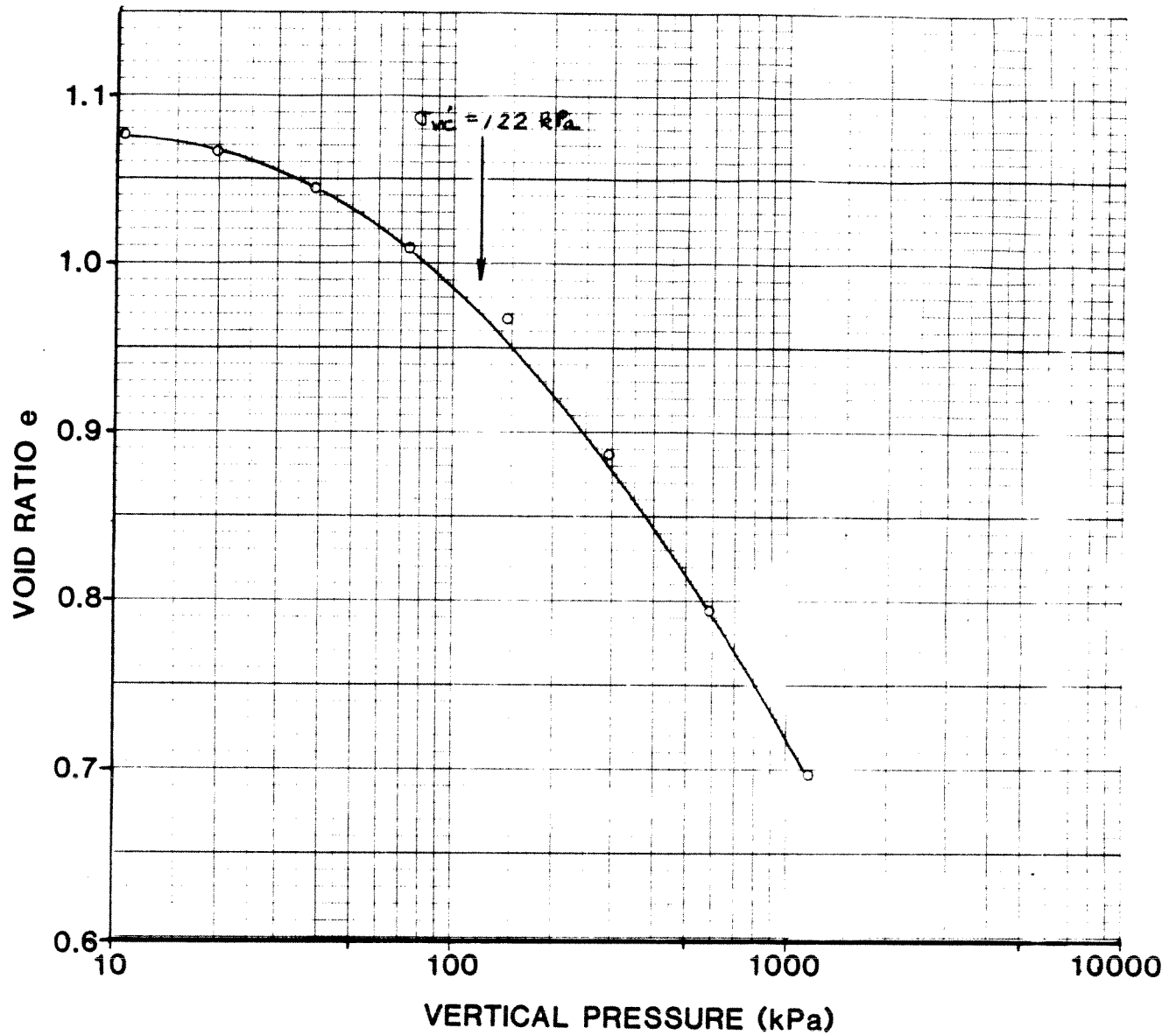
DATE

MADE

CHKD

JOB

FIGURE B8



DYREGROV & BURGESS
CONSULTING GEOTECHNICAL ENGINEERS

CONSOLIDATION TEST RESULTS
TEST HOLE 6 - 3 m DEPTH

SCALE

DATE

MADE

CHKD

JOB

FIGURE

B9

Appendix **H**

Dilatometer Test Results (Dyregrov and Burgess 1988)

- H-1: Dilatometer Test Results (Dyregrov and Burgess 1988)

DILATOMETER TEST RESULTS

Explanation of Abbreviations

Z - Test Depth, Metres

A,B - Pressure Readings, Bar

ED - Young's Modulus, Bar

ID - Material Index

KD - Horizontal Stress Index

UO - Groundwater Porepressure, Bar

PC - Preconsolidation Pressure, Bar

OCR - Overconsolidation Ratio

KO - Ratio of Horizontal to Vertical Earth Pressures

CU - Undrained Shear Strength, Cohesive Soils, Bar

PHI - Angle of Shearing Resistance, Cohesionless Soils, Degrees

M - Constrained Modulus, Bar

Note: Bar X 100 = kPa

kPa X 20.9 = Pounds per square foot

RECORD OF DILATOMETER TEST NO. DMT 1
 USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE, J-GED, MARCH 80)
 K0 IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
 MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE, J-GED, JUNE 82)

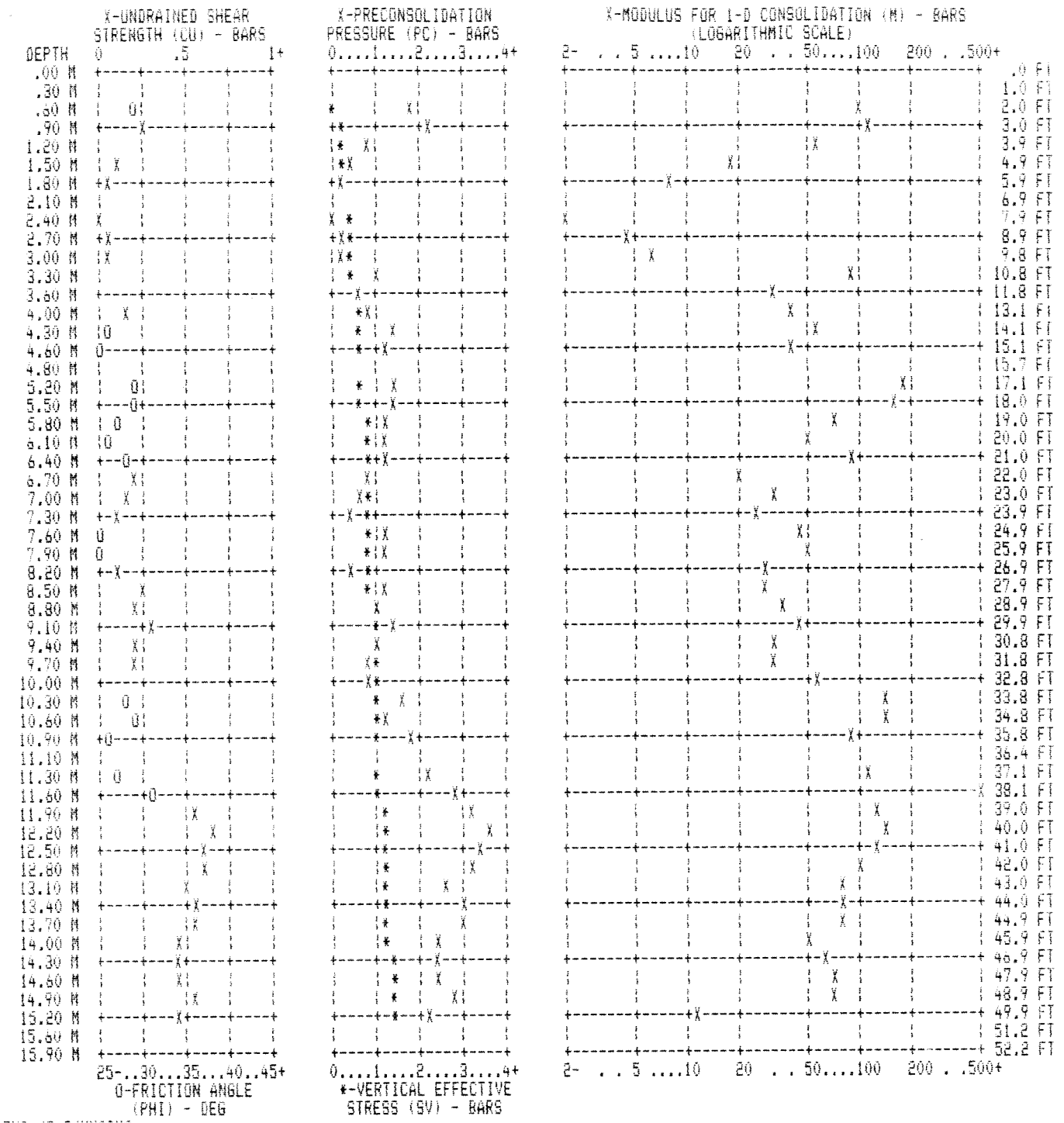
LOCATION: TEST HOLE 6
 PERFORMED - DATE: AUGUST 28, 1987
 BY: BURGESS & GILCHRIST Paddock DRILLING LTD.

CALIBRATION INFORMATION:
 DELTA A = .12 BARS DELTA B = .73 BARS GAGE 0 = .70 BARS GWT DEPTH = 4.00 M

1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H2O UNIT WEIGHT = 1.000 T/M3

Z (M)	THRUST (KG)	A (BAR)	B (BAR)	ED (BAR)	ID *****	KD *****	UO (BAR)	GAMMA (T/M3)	SV (BAR)	PC (BAR)	OCR *****	K0 *****	CU (BAR)	PHI (DEG)	M (BAR)	SOIL TYPE *****
.60		1.50	3.40	38.	1.27	11.27	.000	1.600	.077	1.79	23.18	1.75		29.4	100.0	SANDY SILT
.90		2.20	4.20	42.	.77	12.59	.000	1.600	.124	2.19	17.64	2.12	.272		113.9	CLAYEY SILT
1.20		1.50	3.20	31.	1.02	5.13	.000	1.600	.171	.74	4.34	1.18			56.8	SILT
1.50		1.30	2.50	13.	.52	3.22	.000	1.600	.218	.46	2.10	.83	.087		17.1	SILTY CLAY
1.80		1.10	2.20	9.	.52	1.92	.000	1.500	.264	.25	.94	.52	.055		7.7	MUD
2.10		1.10	1.80	-5.	-.29		.000	P01 =	.53	P0 =	.52	P1 =	.37			QUESTIONABLE
2.40		.80	1.70	2.	.24	.62	.000	1.500	.352	.06	.16	.06	.018		1.5	MUD
2.70		1.00	2.00	5.	.38	1.04	.000	1.500	.396	.14	.36	.24	.039		4.6	MUD
3.00		1.00	2.05	7.	.51	.93	.000	1.500	.441	.13	.30	.20	.037		6.2	MUD
3.30		2.20	4.80	64.	1.20	3.14	.000	1.700	.488	.99	2.02	.82			86.6	SILT
3.60		1.70	3.50	35.	.93	2.00	.000	1.600	.536	.54	1.00	.54			30.6	SILT
4.00		2.00	3.90	38.	.81	2.28	.000	1.600	.599	.74	1.23	.62	.155		38.5	CLAYEY SILT
4.30		2.00	4.40	56.	1.24	2.13	.029	1.600	.617	1.34	2.17	.74		25.7	55.3	SANDY SILT
4.60		1.80	4.00	49.	1.30	1.72	.059	1.600	.634	1.16	1.82	.71		25.1	41.8	SANDY SILT
5.20		2.40	7.40	151.	2.92	2.21	.118	1.800	.676	1.31	1.94	.66		29.5	178.6	SILTY SAND
5.50		2.40	7.20	144.	2.81	2.11	.147	1.800	.699	1.31	1.88	.66		29.2	162.5	SILTY SAND
5.80		2.00	5.20	86.	2.19	1.56	.177	1.700	.721	1.11	1.54	.63		27.4	72.6	SILTY SAND
6.10		2.00	4.50	60.	1.53	1.53	.206	1.600	.740	1.19	1.60	.66		25.9	51.1	SANDY SILT
6.40		2.20	6.00	107.	2.50	1.63	.236	1.800	.761	1.18	1.55	.63		28.0	92.8	SILTY SAND
6.70		2.50	4.00	29.	.42	2.08	.265	1.600	.782	.83	1.06	.56	.180		21.0	SILTY CLAY
7.00		2.30	4.20	38.	.80	1.72	.294	1.600	.799	.63	.79	.47	.145		32.5	CLAYEY SILT
7.30		2.00	3.70	31.	.85	1.29	.324	1.600	.817	.41	.50	.33	.104		26.3	CLAYEY SILT
7.60		2.10	4.40	53.	1.39	1.31	.353	1.600	.835	1.23	1.48	.66		25.0	44.9	SANDY SILT
7.90		2.20	4.70	60.	1.50	1.35	.383	1.600	.852	1.27	1.49	.65		25.5	51.1	SANDY SILT
8.20		2.20	4.00	35.	.86	1.33	.412	1.600	.870	.46	.53	.35	.115		29.4	CLAYEY SILT
8.50		3.30	4.90	27.	.35	2.52	.442	1.600	.888	1.28	1.44	.68	.261		29.8	SILTY CLAY
8.80		3.00	4.90	38.	.58	2.09	.471	1.600	.905	.97	1.08	.57	.211		34.4	SILTY CLAY
9.10		3.60	5.50	38.	.45	2.67	.500	1.700	.924	1.45	1.57	.71	.292		43.8	SILTY CLAY
9.40		3.00	4.90	38.	.60	1.95	.530	1.600	.944	.91	.96	.53	.201		32.5	SILTY CLAY
9.70		3.00	4.90	38.	.61	1.88	.559	1.600	.961	.87	.91	.51	.196		32.5	CLAYEY SILT
10.00		3.10	5.70	64.	1.00	1.88	.589	1.700	.980	.89	.91	.51			54.2	SILT
10.30		3.20	8.20	151.	2.43	1.79	.618	1.800	1.002	1.69	1.68	.64		28.1	142.4	SILTY SAND
10.60		2.80	8.30	169.	3.64	1.31	.648	1.800	1.026	1.27	1.24	.56		29.3	144.0	SAND
10.90		3.20	6.80	100.	1.60	1.72	.677	1.700	1.048	1.82	1.74	.68		26.4	85.2	SANDY SILT
11.30		3.70	7.80	118.	1.52	2.08	.716	1.700	1.076	2.21	2.06	.72		26.6	116.8	SANDY SILT
11.60		5.00	15.50	352.	3.17	2.90	.746	1.900	1.099	2.72	2.48	.71		30.7	501.4	SILTY SAND
11.90		5.80	8.80	78.	.52	3.86	.775	1.800	1.124	3.13	2.79	.96	.562		119.4	SILTY CLAY
12.20		6.30	9.50	86.	.51	4.18	.805	1.800	1.148	3.63	3.16	1.02	.635		137.5	SILTY CLAY
12.50		6.20	9.20	78.	.48	3.99	.834	1.800	1.171	3.45	2.94	.98	.612		122.2	SILTY CLAY
12.80		6.10	8.80	67.	.43	3.82	.864	1.800	1.195	3.28	2.74	.95	.590		102.0	SILTY CLAY
13.10		5.50	7.90	56.	.41	3.25	.893	1.700	1.217	2.59	2.13	.84	.490		76.1	SILTY CLAY
13.40		5.90	8.20	53.	.35	3.50	.922	1.700	1.237	2.96	2.39	.89	.547		75.2	SILTY CLAY
13.70		6.00	8.40	56.	.37	3.49	.952	1.800	1.260	3.00	2.38	.89	.555		80.2	SILTY CLAY
14.00		5.90	7.40	42.	.32	2.95	.981	1.700	1.282	2.35	1.83	.77	.458		52.3	CLAY
14.30		5.50	7.80	53.	.40	2.95	1.011	1.700	1.302	2.38	1.83	.77	.465		65.9	SILTY CLAY

Z	THRUST	A	B	ED	ID	KD	UO	GAMMA	SV	PC	OCR	KO	CU	PHI	M	SOIL TYPE
(M)	(KG)	(BAR)	(BAR)	(BAR)			(BAR)	(T/M3)	(BAR)	(BAR)			(BAR)	(DEG)	(BAR)	
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
14.60		5.60	8.00	56.	.42	2.95	1.040	1.700	1.323	2.43	1.83	.77	.473		70.5	SILTY CLAY
14.90		6.00	8.40	56.	.38	3.18	1.070	1.700	1.343	2.77	2.06	.82	.528		74.9	SILTY CLAY
15.20		5.40	6.50	9.	.07	2.72	1.099	1.500	1.361	2.20	1.62	.72	.441		10.6	MUD
END OF SOUNDING																



END OF SOUNDING

FIG. D3

RECORD OF DILATOMETER TEST NO. DMT 2
 USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE, J-GED, MARCH 80)
 K0 IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
 MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE, J-GED, JUNE 82)

LOCATION: NEAR TEST HOLE 5
 PERFORMED - DATE: AUGUST 28, 1987
 BY: BURGESS & GILCHRIST PADDOCK DRILLING LTD.

CALIBRATION INFORMATION:
 DELTA A = .12 BARS DELTA B = .73 BARS GAGE 0 = .70 BARS GWT DEPTH= 4.00 M

1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H2O UNIT WEIGHT = 1.000 T/M3

Z (M)	THRUST (KG)	A (BAR)	B (BAR)	ED (BAR)	ID	KD	UO (BAR)	GAMMA (T/M3)	SV (BAR)	PC (BAR)	OCR	K0	CU (BAR)	PHI (DEG)	FI (BAR)	SOIL TYPE
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
.50		2.20	4.40	49.	.91	20.16	.000	1.600	.077	2.83	36.77	2.79			155.6	SILT
.90		2.50	5.40	75.	1.18	14.47	.000	1.700	.126	2.75	21.92	2.30			212.9	SILT
1.20		4.20	8.20	115.	.96	19.55	.000	1.800	.177	6.21	35.05	2.74			359.8	SILT
1.50		2.40	4.90	60.	1.00	7.60	.000	1.700	.229	1.83	8.03	1.54			133.8	SILT
1.80		2.10	6.80	140.	3.05	4.74	.000	1.800	.280	1.26	4.51	.89		32.2	259.7	SILTY SAND
2.10		2.80	5.50	67.	.91	6.41	.000	1.700	.332	2.04	6.16	1.38			138.4	SILT
2.40		2.70	5.20	60.	.85	5.34	.000	1.700	.382	1.77	4.62	1.22	.286		112.2	CLAYEY SILT
2.70		3.60	7.00	93.	.93	6.70	.000	1.700	.432	2.85	6.59	1.42			194.9	SILT
3.00		4.40	6.40	42.	.32	7.81	.000	1.700	.482	4.03	8.37	1.57	.582		94.1	CLAY
3.30		5.60	7.70	46.	.26	9.30	.000	1.800	.533	5.86	10.99	1.76	.801		110.4	CLAY
3.60		7.20	9.80	64.	.28	11.14	.000	1.800	.586	8.55	14.58	1.97	1.104		165.9	CLAY
4.00		7.20	10.10	75.	.33	9.92	.000	1.800	.657	7.99	12.16	1.83	1.070		186.1	CLAY
4.30		8.30	11.20	75.	.28	11.15	.029	1.800	.681	9.93	14.59	1.97	1.283		194.4	CLAY
4.60		9.20	13.00	107.	.37	11.92	.059	1.900	.706	11.43	16.21	2.05	1.446		286.6	SILTY CLAY
4.90		8.60	11.70	82.	.30	10.70	.088	1.800	.731	10.00	13.69	1.92	1.308		210.2	CLAY
5.20		7.40	11.00	100.	.44	8.70	.118	1.800	.754	7.48	9.92	1.69	1.043		236.2	SILTY CLAY
5.50		8.30	10.90	64.	.25	9.63	.147	1.800	.778	9.02	11.60	1.80	1.220		156.9	CLAY
5.80		8.40	10.90	60.	.23	9.44	.177	1.800	.801	9.01	11.25	1.77	1.226		146.7	CLAY
6.10		7.40	10.30	75.	.33	7.89	.206	1.800	.825	7.02	8.52	1.58	1.010		168.6	CLAY
6.40		7.40	10.20	71.	.32	7.65	.236	1.800	.848	6.87	8.10	1.55	.998		158.1	CLAY
6.70		7.40	9.90	60.	.27	7.42	.265	1.800	.872	6.75	7.74	1.52	.988		131.9	CLAY
7.00		7.20	9.80	64.	.29	6.97	.294	1.800	.895	6.27	7.01	1.46	.937		135.8	CLAY
7.30		7.60	10.40	71.	.31	7.18	.324	1.800	.919	6.75	7.34	1.49	.999		153.5	CLAY
7.60		7.20	9.70	60.	.28	6.56	.353	1.800	.943	6.01	6.38	1.40	.916		124.3	CLAY
7.90		6.40	8.90	60.	.32	5.54	.383	1.800	.966	4.74	4.90	1.25	.760		113.9	CLAY
8.20		6.90	9.40	60.	.30	5.89	.412	1.800	.990	5.33	5.39	1.30	.839		117.6	CLAY
8.50		7.00	9.40	56.	.28	5.82	.442	1.800	1.013	5.37	5.30	1.29	.848		109.9	CLAY
8.80		7.00	9.50	60.	.30	5.66	.471	1.800	1.037	5.25	5.07	1.27	.837		115.2	CLAY
9.10		6.80	9.40	64.	.33	5.31	.500	1.800	1.060	4.87	4.59	1.21	.791		118.1	CLAY
9.40		6.80	9.20	56.	.29	5.18	.530	1.800	1.084	4.78	4.41	1.19	.783		103.1	CLAY
9.70		6.90	9.30	56.	.29	5.13	.559	1.800	1.107	4.82	4.35	1.18	.791		102.6	CLAY
10.00		6.80	9.20	56.	.29	4.91	.589	1.800	1.131	4.59	4.06	1.15	.765		100.0	CLAY
10.30		6.80	9.20	56.	.29	4.79	.618	1.800	1.155	4.50	3.90	1.12	.756		98.5	CLAY
10.60		6.40	9.00	64.	.36	4.32	.646	1.800	1.178	3.91	3.32	1.04	.678		104.5	SILTY CLAY
10.90		6.30	8.80	60.	.35	4.13	.677	1.800	1.202	3.72	3.10	1.01	.654		95.8	CLAY
11.20		6.80	9.20	56.	.30	4.44	.707	1.800	1.225	4.25	3.47	1.06	.730		94.1	CLAY
11.50		7.20	9.80	64.	.32	4.64	.736	1.800	1.249	4.64	3.72	1.10	.787		109.2	CLAY
11.80		6.80	9.10	53.	.28	4.23	.765	1.800	1.272	4.09	3.22	1.03	.714		85.5	CLAY
12.10		6.30	8.40	46.	.27	3.76	.795	1.700	1.294	3.46	2.67	.94	.626		68.2	CLAY
12.40		7.10	9.90	71.	.37	4.25	.824	1.800	1.316	4.27	3.24	1.03	.744		115.4	SILTY CLAY
12.70		6.80	9.20	56.	.31	3.95	.854	1.800	1.340	3.87	2.89	.98	.690		87.4	CLAY
13.00		6.90	9.20	53.	.28	3.93	.883	1.800	1.364	3.92	2.87	.97	.699		81.6	CLAY
13.30		6.40	8.60	49.	.29	3.49	.913	1.800	1.387	3.30	2.38	.89	.612		69.9	CLAY
13.60		7.20	9.80	64.	.33	3.76	.942	1.800	1.411	4.10	2.91	.98	.730		98.9	CLAY
13.90		7.40	10.00	64.	.32	4.02	.972	1.800	1.434	4.26	2.97	.99	.754		99.8	CLAY
14.20		6.80	9.00	49.	.28	3.53	1.001	1.800	1.458	3.54	2.43	.90	.653		70.5	CLAY
14.50		7.20	9.40	49.	.26	3.73	1.030	1.800	1.481	3.91	2.64	.93	.710		79.2	CLAY

Z (M)	THRUST (KG)	A (BAR)	B (BAR)	ED (BAR)	ID	KD	UO (BAR)	GAMMA (T/M3)	SV (BAR)	PC (BAR)	OCR	KO	CU (BAR)	PHI (DEG)	N (BAR)	SOIL TYPE
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
14.80		7.30	9.70	56.	.29	3.71	1.060	1.800	1.505	3.95	2.62	.93	.717		83.8	CLAY
15.10		7.30	9.90	60.	.31	3.63	1.089	1.800	1.528	3.87	2.53	.91	.708		87.9	CLAY
END OF SOUNDING																

DEPTH M	X-UNDRAINED SHEAR STRENGTH (OU) - BARS 0.....1.....2+				X-PRECONSOLIDATION PRESSURE (PC) - BARS 0.....5.....10+				X-MODULUS FOR 1-D CONSOLIDATION (M) - BARS (LOGARITHMIC SCALE) 2- . . 510 20 . . 50....100 200 . .500+				FT				
	0	1	2	+	0	5	10	+	2	5	10	20		50	100	200	500
1.00																	1.0
1.30																	1.3
1.60					*	X								X			1.6
1.90					*	X									X		1.9
1.20					*		X									X	1.2
1.50					*	X								X			1.5
1.80		0			**	X									X		1.8
2.10					*	X								X			2.1
2.40	X				*	X							X				2.4
2.70					**	X									X		2.7
3.00		X			*		X						X				3.0
3.30		X	X		*		X						X				3.3
3.60			X		**		X							X			3.6
4.00			X		*			X						X			4.0
4.30			X		*				X						X		4.3
4.60			X	X	**										X		4.6
4.90			X		*									X			4.9
5.20			X		*			X						X			5.2
5.50			X		**									X			5.5
5.80			X	X	*									X	X		5.8
6.10			X		*			X						X	X		6.1
6.40			X		**			X						X			6.4
6.70			X		*			X						X			6.7
7.00		X			*			X						X			7.0
7.30			X		**			X						X			7.3
7.60			X		*			X						X			7.6
7.90		X			*		X							X			7.9
8.20		X			**		X							X			8.2
8.50		X			*		X							X			8.5
8.80		X			*		X							X			8.8
9.10		X			**		X							X			9.1
9.40		X			*		X							X			9.4
9.70		X			*		X							X			9.7
10.00		X			**		X							X			10.0
10.30		X			*		X							X			10.3
10.60		X			*		X							X			10.6
10.90		X			**		X							X			10.9
11.20		X			*		X						X				11.2
11.50		X			*		X						X				11.5
11.80		X			**		X							X			11.8
12.10	X				*	X						X					12.1
12.40	X				*	X						X					12.4
12.70	X				**	X						X					12.7
13.00	X				*	X						X					13.0
13.30	X				*	X						X					13.3
13.60	X				**	X						X					13.6
13.90	X				*	X						X					13.9
14.20	X				*	X						X					14.2
14.50	X				**	X						X					14.5
14.80	X				*	X						X					14.8
15.10	X				*	X						X					15.1
15.30																	15.3
15.60																	15.6
15.90																	15.9

25-.30...35...40...45+
 0-FRICTION ANGLE (PHI) - DEG
 0.....5.....10+
 *-VERTICAL EFFECTIVE STRESS (SV) - BARS

END OF SOUNDING

FIG. D6

CITY OF WINNIPEG
 FILE NAME: KILDONAN CORRIDOR
 FILE NUMBER: 87422

TEST NO. 3

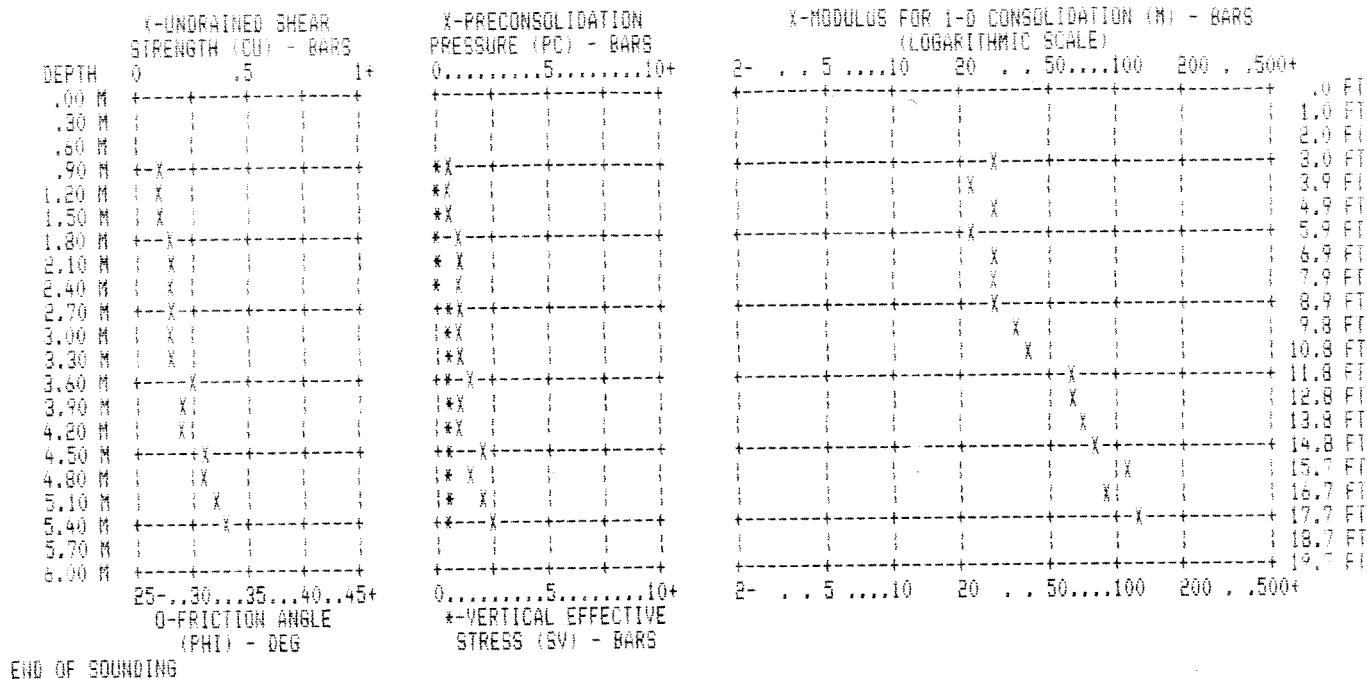
RECORD OF DILATOMETER TEST NO. 3
 USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE, J-GED, MARCH 80)
 K0 IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
 MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE, J-GED, JUNE 82)

LOCATION: BETWEEN HOLES 22 & 23
 PERFORMED - DATE: 22 SEPTEMBER 1987
 BY: BURGESS

CALIBRATION INFORMATION:
 DELTA A = .55 BARS DELTA B = .10 BARS GAGE 0 = .60 BARS GWT DEPTH=-2.00 M

1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H2O UNIT WEIGHT = 1.000 T/M3

Z (M)	THRUST (KG)	A (BAR)	B (BAR)	ED (BAR)	ID	KD	UO (BAR)	GAMMA (T/M3)	SV (BAR)	PC (BAR)	OCR	K0	CU (BAR)	PHI (DEG)	M (BAR)	SOIL TYPE
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
.90		1.10	2.20	16.	.64	4.95	.285	1.600	.150	.62	4.11	1.15	.103		29.2	CLAYEY SILT
1.20		1.20	2.20	13.	.45	4.88	.314	1.600	.168	.67	4.02	1.14	.113		22.5	SILTY CLAY
1.50		1.30	2.40	16.	.53	4.77	.343	1.600	.185	.72	3.88	1.12	.121		28.6	SILTY CLAY
1.80		1.40	2.40	13.	.38	4.73	.373	1.600	.203	.78	3.83	1.12	.131		22.1	SILTY CLAY
2.10		1.50	2.60	16.	.46	4.65	.402	1.600	.221	.82	3.72	1.10	.139		28.1	SILTY CLAY
2.40		1.60	2.70	16.	.43	4.60	.432	1.600	.238	.87	3.66	1.09	.148		27.9	SILTY CLAY
2.70		1.70	2.80	16.	.41	4.56	.461	1.600	.256	.92	3.61	1.09	.158		27.8	SILTY CLAY
3.00		1.80	3.00	20.	.47	4.50	.491	1.600	.274	.97	3.55	1.08	.166		33.7	SILTY CLAY
3.30		1.90	3.10	24.	.57	4.11	.520	1.600	.291	.90	3.08	1.01	.158		37.6	SILTY CLAY
3.60		2.50	4.00	31.	.48	6.01	.550	1.600	.309	1.72	5.57	1.32	.269		61.3	SILTY CLAY
3.90		2.20	3.80	35.	.65	4.66	.579	1.600	.327	1.22	3.75	1.10	.207		59.6	CLAYEY SILT
4.20		2.20	4.00	42.	.81	4.31	.608	1.600	.344	1.14	3.31	1.04	.198		69.1	CLAYEY SILT
4.50		2.90	4.60	38.	.51	5.94	.638	1.700	.363	1.99	5.47	1.31	.312		75.2	SILTY CLAY
4.80		2.80	5.10	60.	.87	5.21	.667	1.700	.384	1.71	4.45	1.20	.279		110.8	CLAYEY SILT
5.10		3.20	5.10	46.	.55	5.91	.697	1.700	.405	2.19	5.42	1.30	.345		89.3	SILTY CLAY
5.40		3.50	5.80	60.	.66	6.21	.726	1.700	.425	2.49	5.86	1.35	.386		121.1	CLAYEY SILT
END OF SOUNDING																



END OF SOUNDING

DYREGROV AND BURGESS
 FILE NAME: KILDONAN CORRIDOR
 FILE NUMBER: 87422

TEST NO. 4

RECORD OF DILATOMETER TEST NO. 4
 USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE, J-GED, MARCH 80)
 K₀ IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
 MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE, J-GED, JUNE 82)

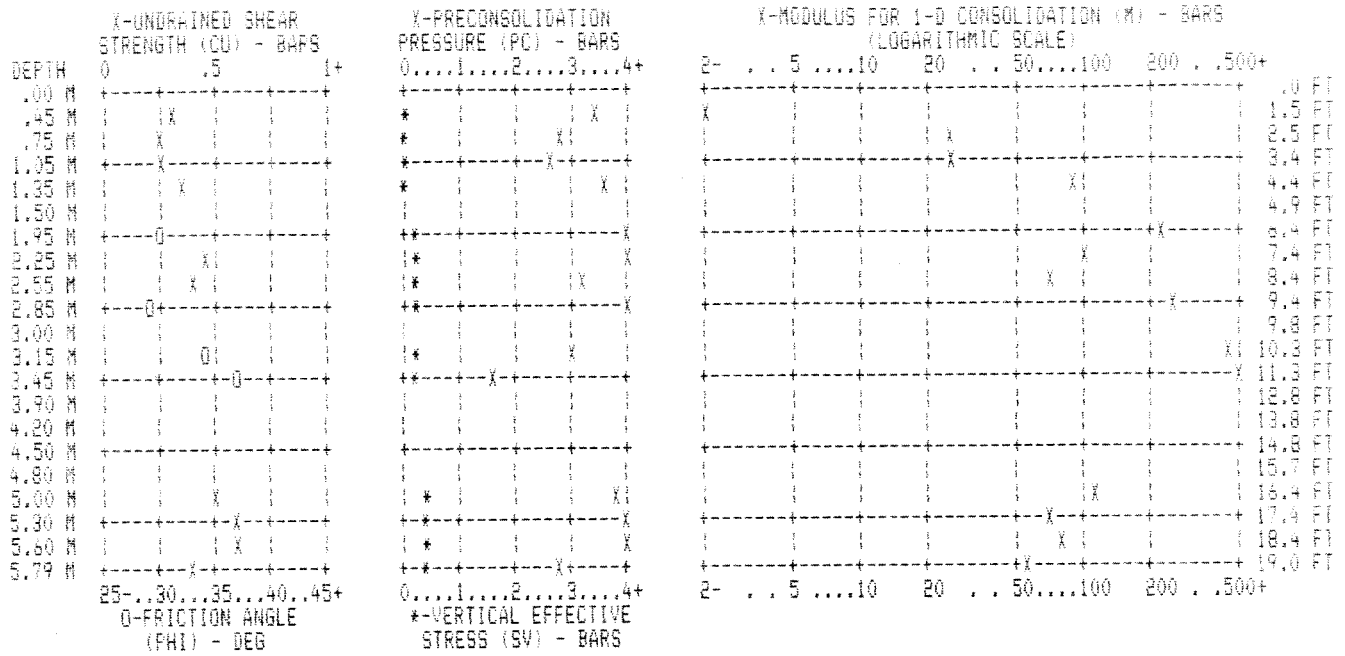
LOCATION: BETWEEN HOLES 20 AND 21
 PERFORMED - DATE: 30 SEPTEMBER 1987
 BY: N.C. BURGESS

CALIBRATION INFORMATION:
 DELTA A = 1.00 BARS DELTA B = .10 BARS GAGE 0 = .70 BARS GWT DEPTH = -1.67 M

1 BAR = 1.019 KG/CM² = 1.044 TSF = 14.51 PSI ANALYSIS USES H₂O UNIT WEIGHT = 1.000 T/M³

Z (M)	THRUST (KG)	A (BAR)	B (BAR)	ED (BAR)	ID	KD	UO (BAR)	GAMMA (T/M ³)	SV (BAR)	PC (BAR)	OCR	K ₀	CU (BAR)	PHI (DEG)	M (BAR)	SOIL TYPE
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
.45		1.10	2.20	0.	.00	44.15	.298	1.500	.027	3.37	*****	4.30	.284		.0	MUD
.75		1.20	2.50	7.	.17	30.02	.237	1.500	.042	2.85	68.42	3.49	.271		25.8	MUD
1.05		1.30	2.60	7.	.16	23.44	.267	1.500	.056	2.63	46.51	3.04	.269		24.1	MUD
1.35		1.80	3.60	28.	.42	24.35	.296	1.600	.073	3.58	49.36	3.11	.363		85.3	SILTY CLAY
1.95		1.90	5.10	77.	1.27	15.69	.355	1.700	.111	4.78	43.07	2.26		30.2	223.9	SANDY SILT
2.25		2.50	4.50	33.	.40	18.02	.385	1.700	.132	4.06	30.87	2.62	.452		100.3	SILTY CLAY
2.55		2.30	4.10	26.	.34	14.28	.414	1.600	.151	3.23	21.46	2.28	.387		72.4	CLAY
2.85		2.40	6.00	91.	1.23	12.55	.444	1.700	.170	4.85	28.56	1.90		29.5	247.3	SANDY SILT
3.15		2.40	8.50	182.	2.66	10.30	.473	1.800	.192	2.99	15.57	1.51		33.8	460.6	SILTY SAND
3.45		2.10	9.50	230.	4.18	7.35	.502	1.800	.215	1.58	7.32	1.04		38.6	512.4	SAND
5.00		3.60	6.00	47.	.43	9.65	.655	1.700	.330	3.84	11.65	1.80	.519		116.7	SILTY CLAY
5.30		4.00	5.90	29.	.23	10.21	.684	1.700	.350	4.46	12.73	1.86	.591		73.5	CLAY
5.60		4.00	6.00	33.	.27	9.55	.713	1.700	.371	4.25	11.47	1.79	.576		80.4	CLAY
5.79		3.20	5.00	26.	.27	7.12	.732	1.700	.384	2.78	7.25	1.48	.418		54.9	CLAY

END OF SOUNDING



END OF SOUNDING

D'AREGGIO AND BURGESS
 FILE NAME: KILDONAN CORRIDOR
 FILE NUMBER: 37422

TEST NO. 0075

RECORD OF DILATOMETER TEST NO. DMT5
 USING DATA REDUCTION PROCEDURES (N. MARCHETTI (ASCE, J-GEO, MARCH 80)
 Q₀ IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
 MODIFIED BURNZ AND KULRANY FORMULA USED FOR OCR IN SANDS (ASCE, J-GEO, JUNE 83)

LOCATION: BETWEEN HOLES 14 & 19
 PERFORMED - DATE: 30 SEPTEMBER 1987
 BY: BURGESS

CALIBRATION INFORMATION:
 DELTA A = 1.00 BARS DELTA B = .10 BARS GAGE D = .70 BARS GUT DEPTH = 7.60 ft

1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H2O UNIT WEIGHT = 1.000 T/M3

Z (ft)	THrust (kg)	A (BAR)	B (BAR)	EQ (BAR)	TD (BAR)	KD (BAR)	Q0 (BAR)	GAMMA (T/M3)	SV (BAR)	PC (BAR)	OCR (BAR)	F0	CU (BAR)	PHI (DEG)	N (BAR)	SOIL TYPE
*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****	*****
.20		1.50	3.20	22.	.63	49.74	.775	1.600	.020	3.01	*****	4.58	.244		37.9	CLAYEY SILT
.40		2.00	3.80	26.	.80	38.77	.805	1.600	.038	3.84	*****	4.01	.337		35.5	SILT, CLAY
.60		2.80	4.70	197.	4.06	23.95	.834	1.800	.058	3.36	57.70	2.97		39.6	654.6	SAND
END OF SOUNDING																

X-UNDRAINED SHEAR
 STRENGTH (CU) - BARS
 DEPTH 0 .1 .2 .3 .4+
 1.00 M +-----+
 1.30 M | | | | |
 1.60 M | | | | |
 1.90 M +-----+
 25+ .30 .35 .40 .45+
 0-FRICTION ANGLE
 (PHI) - DEG

X-PRECONSOLIDATION
 PRESSURE (PC) - BARS
 0.....1.....2+
 * | | | | X
 * | | | | X
 +-----+
 0.....1.....2+
 +-VERTICAL EFFECTIVE
 STRESS (SV) - BARS

X-MODULUS FOR 1-D CONSOLIDATION (K) - BARS
 LOGARITHMIC SCALE
 2- . . 5 . . . 10 20 . . 50 . . . 100 200 . . 500+
 +-----+
 | | | | | X | | |
 | | | | | X | | |
 +-----+
 2- . . 5 . . . 10 20 . . 50 . . . 100 200 . . 500+
 . . FT
 1.0 FT
 2.0 FT
 3.0 FT

END OF SOLIDING

DYREGROV AND BURGESS
 FILE NAME: WILSONIAN CORRIDOR
 FILE NUMBER: 87422

TEST NO. DMT8

RECORD OF DILATOMETER TEST NO. DMT8
 USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE, J-GED, MARCH 80)
 K0 IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
 MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE, J-GED, JUNE 82)

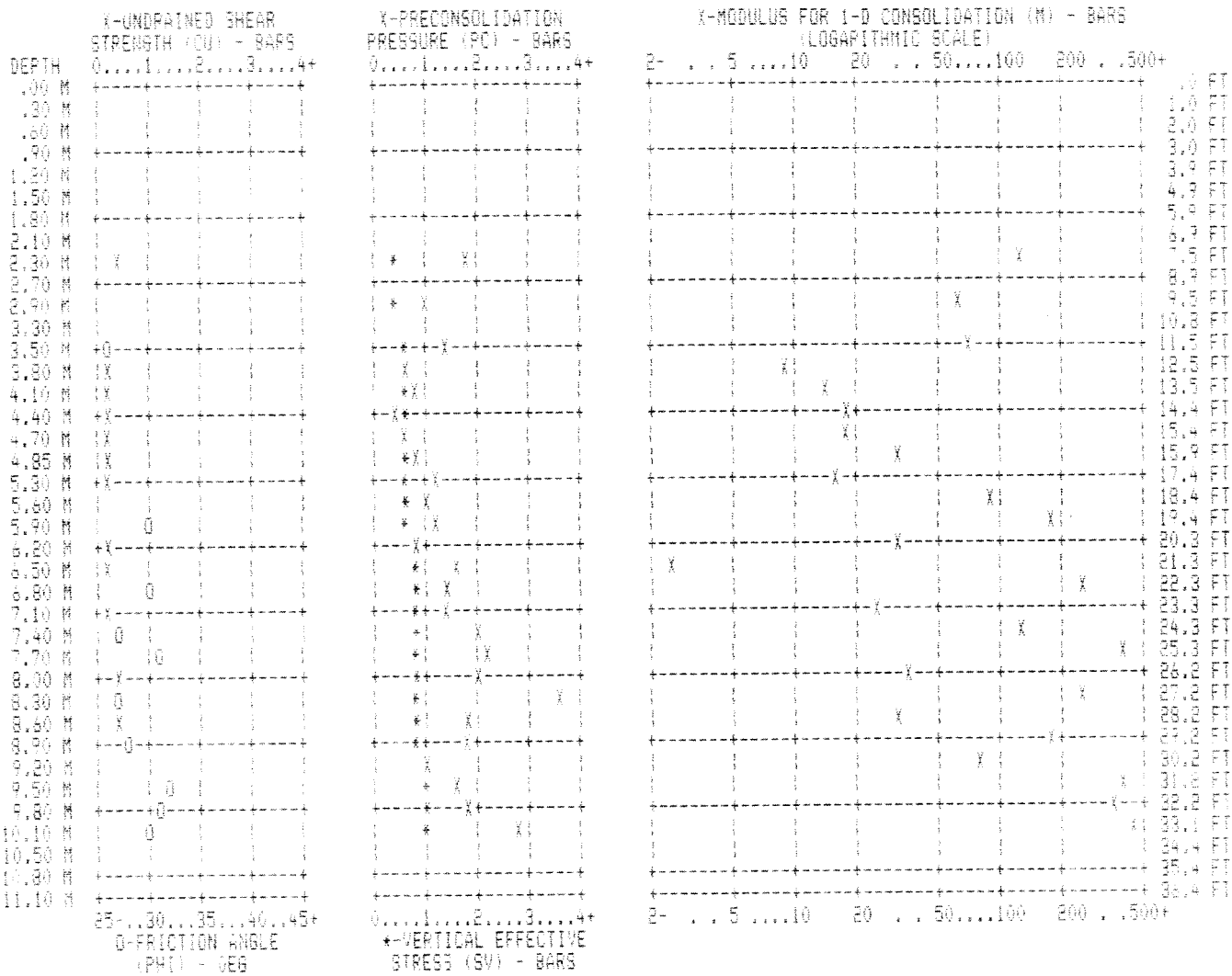
LOCATION: TEST HOLE 7
 PERFORMED - DATE:
 BY: N. BURGESS

CALIBRATION INFORMATION:
 DELTA A = .25 BARS DELTA B = 1.00 BARS GAGE 0 = .50 BARS GWT DEPTH = 3.00 M

1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H2O UNIT WEIGHT = 1.000 T/M3

Z (M)	THRUST (KG)	A (BAR)	B (BAR)	ED (BAR)	LD *****	KD *****	UO (BAR)	GAMMA (T/M3)	SV (BAR)	PC (BAR)	OCR *****	K0 *****	CU (BAR)	PHI (DEG)	M (BAR)	SOIL TYPE *****
2.30		2.50	5.50	64.	.85	5.38	.000	1.700	.402	1.88	4.68	1.22	.305		119.5	CLAYEY SILT
2.90		1.80	4.40	49.	.96	2.97	.000	1.500	.499	.92	1.85	.78			83.2	SILT
3.50		1.80	4.80	64.	1.30	2.58	.049	1.700	.547	1.42	2.60	.78		28.4	74.9	SANDY SILT
3.80		1.50	3.10	9.	.21	2.23	.079	1.500	.565	.67	1.18	.60	.142		8.8	MUD
4.10		1.80	3.40	13.	.26	2.45	.108	1.500	.581	.80	1.37	.66	.165		13.5	CLAY
4.40		1.40	3.20	20.	.59	1.65	.137	1.500	.599	.44	1.74	.44	.103		17.0	SILT/CLAY
4.70		1.70	3.50	20.	.46	2.04	.167	1.500	.616	.63	1.03	.55	.139		10.4	SILTY CLAY
4.85		2.00	4.10	31.	.53	2.44	.182	1.500	.625	.85	1.36	.66	.176		32.7	SILTY CLAY
5.30		2.40	4.00	13.	.19	2.93	.226	1.500	.652	1.18	1.81	.77	.281		15.8	CLAY
5.60		2.40	5.60	71.	1.14	2.68	.255	1.700	.671	1.08	1.58	.71			85.0	SILT
5.90		2.20	7.80	158.	3.15	2.09	.285	1.800	.693	1.25	1.81	.64		29.7	180.7	SILTY SAND
6.20		2.20	4.40	35.	.63	2.23	.314	1.500	.714	.84	1.18	.60	.179		33.3	CLAYEY SILT
6.50		3.00	4.30	2.	.02	3.29	.343	1.500	.730	1.59	2.18	.85	.300		2.5	MUD
6.80		2.60	9.40	202.	3.43	2.27	.373	1.800	.749	1.43	1.90	.64		30.5	245.0	SAND
7.10		3.00	4.80	20.	.25	3.02	.402	1.500	.770	1.46	1.90	.79	.283		25.5	CLAY
7.40		2.90	6.90	100.	1.39	2.64	.432	1.700	.789	2.07	2.63	.78		26.7	120.5	SANDY SILT
7.70		3.60	12.50	279.	3.20	3.09	.461	1.900	.812	2.14	2.64	.72		31.0	412.2	SILTY SAND
8.00		3.70	5.60	24.	.23	3.50	.491	1.700	.836	2.00	2.40	.89	.370		33.7	CLAY
8.30		4.40	10.00	158.	1.84	3.98	.520	1.800	.858	3.70	4.31	.93		27.3	253.5	SANDY SILT
8.60		3.60	6.50	24.	.25	3.15	.550	1.500	.878	1.79	2.03	.82	.341		31.2	CLAY
8.90		3.00	8.60	158.	2.34	2.17	.579	1.500	.899	1.80	2.00	.68		28.4	178.6	SILTY SAND
9.20		3.00	6.40	78.	1.11	2.21	.608	1.700	.921	1.08	1.17	.60			78.5	SILT
9.50		3.50	13.60	322.	4.28	2.30	.638	1.900	.945	1.68	1.78	.60		32.0	394.1	SAND
9.80		3.50	12.80	293.	3.88	2.24	.667	1.700	.971	1.76	1.81	.62		31.2	352.7	SAND
10.10		4.50	14.20	308.	2.83	2.14	.697	1.900	.998	2.78	2.78	.75		30.3	455.9	SILTY SAND

END OF SOUNDING



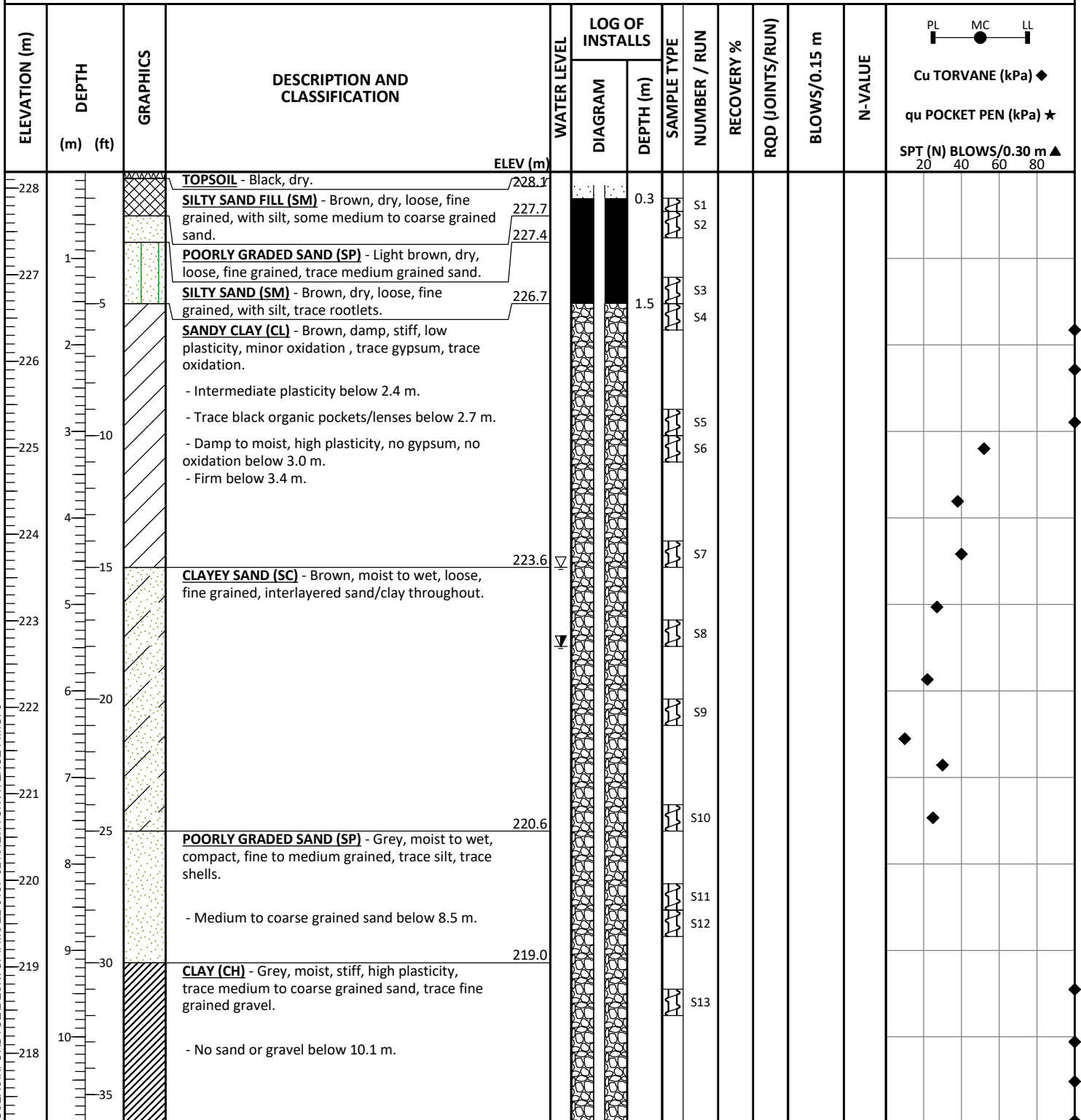
END OF SOUNDING

FIG. D14

APPENDIX B

2021 Geotechnical Investigation Test Hole Logs

CLIENT PROJECT LOCATION DESCRIPTION DRILL RIG / HAMMER METHOD(S)	CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT Newton Force Main Red River Crossing Replacement Winnipeg, MB Scotia Street at Rainbow Drive (Kildonan Park) Acker Renegade Track Mounted Drill Rig with Auto-Hammer 0.0 m to 16.6 m: 100 mm ϕ SSA - switched due to encountering dense till 16.6 m to 43.2 m: Triple Tube, HQ Core	PROJECT NO. SURFACE ELEV. TOC STICK-UP / ELEV. START DATE UTM (m)	21-3913-001 228.19 m -0.10 m / 228.09 m (Standpipe) 8-9-2021 N 5,533,809 E 636,141 Zone 14
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WATER LEVELS	▽ During Drilling/Digging 4.57 m on 8-9-2021 During Drilling ▽ Remeasured/Static 5.49 m on 8-13-2021 CS Standpipe During Drilling	CONTRACTOR Maple Leaf Drilling Ltd. APPROVED J. MACLENNAN	INSPECTOR C. FRIESEN DATE 10-25-2021
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KGS_LOG_C:\USERS\KFORDYCE\DESKTOP\FMS\22-0107-021\NEWTON AVENUE_FM.GPJ

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	LOG OF INSTALLS		SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	SPT (N) BLOWS/0.30 m ▲					
				DIAGRAM	DEPTH (m)							PL	MC	LL			
217							S14										
216	12		- Trace black streaking, trace medium to coarse grained sand below 12.2 m.				S15										
215	13						S16										
214	14		- Trace silt pockets, trace fine to medium grained sand, no coarse grained gravel, no black streaking below 13.6 m. - Firm below 13.7 m.				S17										
213	15		- Trace medium to coarse grained sand, trace fine grained gravel, soft below 14.8 m.				S18										
212	16		SILT TILL (TILL) - Light brown, damp to moist, compact, some medium to coarse grained sand, trace to some fine to coarse grained gravel. - Moist, some fine to coarse grained sand, trace fine grained gravel, no coarse grained gravel below 15.8 m.				S19										
211	17		- Dense below 16.8 m.				S20	31		11 14 17	31						
210	18						S21										
209	19		DOLOMITE - brown, fine-grained. - Weak fractured rock from 18.5 m to 18.8 m.				S22	44		1 6 34	40						
208	20		- Broken core zone along vertical fracture from 19.5 m to 19.7 m. - Trace of red brown shale from 20.0 m to 20.1 m.				R1	82	62 (10)								
207	21		LIMESTONE - strong, white to tan, medium-grained. - 50 mm soft clay seam at 21.1 m.				R2	106	88 (9)								
206	22		- Broken core zone, multiple breaks / close spacing bedding joints. from 22.0 m to 22.4 m.				R3	83	21 (25)								
205	23		- Multiple close spaced breaks along bedding planes.														

WATER LEVELS	▽ During Drilling/Digging	4.57 m on 8-9-2021 During Drilling
	▽ Remeasured/Static	5.49 m on 8-13-2021 CS Standpipe

CONTRACTOR Maple Leaf Drilling Ltd.	INSPECTOR C. FRIESEN
APPROVED J. MACLENNAN	DATE 10-25-2021

KGS_LOG_C:\USERS\KFORDCY\DESKTOP\FMS\22-0107-02\NEWTON AVENUE_FM.GPJ

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	LOG OF INSTALLS		SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	SPT (N) BLOWS/0.30 m ▲				
					DIAGRAM	DEPTH (m)							20	40	60	80	
204	80							R4	98	67 (18)							
			<p>MOTTLED LIMESTONE - strong, mottled brown, white and grey, medium-grained.</p> <ul style="list-style-type: none"> - trace nodules from 24.5 m to 25.2 m. - 25 mm open joint at 24.8 m. - Compressive strength is 14.4 MPa, Young's Modulus is 12.0 GPa and Poisson's ratio is 0.13 at 25.2 m. 					R5	93	88 (8)							
			<ul style="list-style-type: none"> - Compressive strength is 28.4 MPa, Young's Modulus is 19.3 GPa and Poisson's ratio is 0.13 at 27.6 m. 					R6	95	95 (11)							
			<ul style="list-style-type: none"> - 50 mm soft clay seam at 29.5 m. 					R7	100	93 (10)							
			<ul style="list-style-type: none"> - 7 mm clay seam at 31.1 m. - Moderate to wide space joints, trace vugs below 31.2 m. 					R8	100	89 (6)							
								R9	100	92 (7)							
								R10	100	100 (6)							
								R11	98	98 (2)							
								R12	100	89 (11)							

KGS_LOG_C:\USERS\KFORDCY\DESIGN\KTOP\FMS\22-0107-02\NEWTON AVENUE_FM.GPJ

WATER LEVELS	▽ During Drilling/Digging	4.57 m on 8-9-2021 During Drilling
	▽ Remeasured/Static	5.49 m on 8-13-2021 CS Standpipe
	During Drilling	

CONTRACTOR Maple Leaf Drilling Ltd.	INSPECTOR C. FRIESEN
APPROVED J. MACLENNAN	DATE 10-25-2021

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	LOG OF INSTALLS		SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPa) ◆ qu POCKET PEN (kPa) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80					
					DIAGRAM	DEPTH (m)												
191																		
38	125							R13	100	92 (7)								
39	130							R14	100	100 (1)								
41	135							R15	100	98 (5)								
42	140							R16	95	91 (2)								
43	145			185.0														
44	150		Notes: 1. End of test hole at 43.2 m. 2. Refusal encountered in till at a depth of 16.6 m. 3. Test hole caved to 13.7 m upon completion of drilling/digging. 4. Flush mount installed at surface.															
45	155																	
46	160																	
47	165																	
48	170																	
49	175																	
50	180																	

WATER LEVELS	▽ During Drilling/Digging	4.57 m on 8-9-2021 During Drilling
	▽ Remeasured/Static	5.49 m on 8-13-2021 CS Standpipe

CONTRACTOR Maple Leaf Drilling Ltd.	INSPECTOR C. FRIESEN
APPROVED J. MACLENNAN	DATE 10-25-2021

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CLIENT	CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT	PROJECT NO.	21-3913-001
PROJECT	Newton Force Main Red River Crossing Replacement	SURFACE ELEV.	217.70 m
LOCATION	Winnipeg, MB	START DATE	8-4-2021
DESCRIPTION	Center of Red River	UTM (m)	N 5,533,672
DRILL RIG / HAMMER	B20 Portable Drill Rig with Winch Drop Hammer		E 636,201 Zone 14
METHOD(S)	0.0 m to 8.6 m: Water Rotary - switched due to encountering bedrock 8.6 m to 33.8 m: Triple Tube, NQ Core		

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL			
										Cu TORVANE (kPa) ◆			
										qu POCKET PEN (kPa) ★			
										SPT (N) BLOWS/0.30 m ▲			
										20	40	60	80
217	1		SILT (ML) - Dark grey, wet, very loose, non-plastic, with fine grained gravel, trace organic odour. ELEV (m) 216.6	S1	33			200	0				
216	5		CLAY (CI) - Grey, wet, very soft, intermediate plasticity, trace silt, trace shells. ELEV (m) 213.6	S2	22			100	0				
215	10				0			101	1				
214	4		SILT TILL (TILL) - Light brown, wet, compact, trace fine to coarse grained sand, trace fine to coarse grained gravel. ELEV (m) 213.6	S3	44			10611	17				
213	15		- Harder drilling below 5.5 m. - Dense below 5.7 m.	S4	6			222619	45				
212	20		- Fine to coarse grained gravel in SPT sampler at 7.2 m. - Very dense below 7.2 m.	S5	11			262627	53				
211	25												
210	30		LIMESTONE - strong, white to grey, massive. - Weak altered zone from 8.6 m to 9.4 m. - Close spaced fractures from 9.4 m to 10.3 m. - Close to moderate spaced joints, three open joints observed from 10.3 m to 12.5 m.	S6	100			60/90mm	+100			>>>	
209	30			R1	67		21(2)						
208	30			R2	77		55(1)						
208	30			R3	95		95						
208	30			R4	100		64(1)						
208	30			R5	100		64(2)						
207	35			R6	100		0(1)72(10)						

WATER LEVELS	CONTRACTOR Maple Leaf Drilling Ltd.	INSPECTOR G. BAKER/C. FRIESEN
	APPROVED J. MACLENNAN	DATE 10-25-2021

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ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPa) ◆ qu POCKET PEN (kPa) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80
206	12		- Weak fracture at 12.2 m.		R7	100	72 (8)			
	40					R8	100	91 (2)		
						R9	100	46 (6)		
205	13			MOTTLED LIMESTONE - strong, mottled white to grey, moderate to wide spaced joints, trace vugs.		R10	100	88 (8)		
	45			- Occasional nodules from 12.5 m to 14.5 m.		R11	100	93 (6)		
204	14					R12	100	100 (4)		
	50					R13	100	100 (2)		
203	15					R14	100	88 (2)		
	55					R15	100	92 (7)		
202	16					R16	93	93 (5)		
	60					R17	100	100 (3)		
201	17					R18	83	83 (1)		
	65									
200	18									
	70									
199	19									
	75									
198	20									
	80									
197	21									
	85									
196	22									
	90									
195	23									
	95									
194	24									

WATER LEVELS CONTRACTOR Maple Leaf Drilling Ltd. APPROVED J. MACLENNAN	INSPECTOR G. BAKER/C. FRIESEN DATE 10-25-2021
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ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEV (m)	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPa) ◆ qu POCKET PEN (kPa) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80
193	25					R19	100	98 (4)			
192	26					R20	100	100 (3)			
191	27					R21	94	94 (1)			
190	28					R22	98	98 (3)			
189	29					R23	86	86 (1)			
188	30					R24	100	100 (2)			
187	31					R25	100	100 (1)			
186	32					R26	100	100 (1)			
185	33					R27	100	99 (1)			
184	34				183.9	R28	100	100 (0)			
183	35		Notes: 1. End of test hole at 33.8 m. 2. Test hole backfilled with grout. 3. Grout mix consisted of 1 part cement, 0.75 part bentonite, 5.7 part water. 4. Depth of Red River is 6.1m.			R29	99	99 (1)			

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WATER LEVELS	CONTRACTOR Maple Leaf Drilling Ltd.	INSPECTOR G. BAKER/C. FRIESEN
	APPROVED J. MACLENNAN	DATE 10-25-2021

CLIENT PROJECT LOCATION DESCRIPTION DRILL RIG / HAMMER METHOD(S)	CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT Newton Force Main Red River Crossing Replacement Winnipeg, MB Kildonan Drive at Larchdale Crescent (Fraser's Grove Park) Acker Renegade Track Mounted Drill Rig with Auto-Hammer 0.0 m to 18.3 m: 125 mm ø SSA - switched due to sloughing 18.3 m to 41.7 m: Triple Tube, HQ Core	PROJECT NO. SURFACE ELEV. TOC STICK-UP / ELEV. START DATE UTM (m)	21-3913-001 227.14 m -0.10 m / 227.04 m (Standpipe) 8-12-2021 N 5,533,496 E 636,194 Zone 14
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ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	LOG OF INSTALLS		SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPa) ◆ qu POCKET PEN (kPa) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80
					DIAGRAM	DEPTH (m)							
227			TOPSOIL - Black, dry. /227.1					S1					
	1		SILTY SAND (SM) - Brown, dry, loose, fine grained, some silt, trace medium grained sand. - Trace silt below 0.7 m.		0.6			S2					
226	5		SANDY CLAY (CI) - Brown, damp, stiff, intermediate to high plasticity, some silt. - Firm below 1.5 m.					S3					
	2							S4					
225	10		CLAYEY SAND (SC) - Brown, moist, loose, fine grained, some clay. - Moist to wet below 2.7 m.					S5					
	3							S6					
224	15		SAND (SP) - Brown, moist to wet, compact, fine to medium grained, trace clay. - Grey, trace clay below 5.1 m. - Trace wood at 5.2 m.					S7					
	4							S8					
223	20		CLAYEY SAND (SC) - Grey, moist to wet, loose, fine grained, some to with clay. - Interlayered sand and clay below 5.9 m.					S9					
	5							S10					
222	25		CLAY (CL) - Grey, moist, soft, low plasticity. - Intermediate plasticity, trace fine grained sand from 8.5 m to 8.8 m.					S11					
	6							S12					
221	30		CLAYEY SAND (SC) - Grey, moist, loose, fine grained, trace to some clay. - Trace clay below 9.4 m.					S13					
	7							S14					
220	35		SANDY CLAY (CI) - Grey, moist, soft, low plasticity, some to with fine grained sand. - Low to intermediate plasticity, some fine grained sand below 10.4 m.										

WATER LEVELS	▽ During Drilling/Digging 3.96 m on 8-12-2021 During Drilling During Drilling	CONTRACTOR Maple Leaf Drilling Ltd.	INSPECTOR C. FRIESEN
		APPROVED J. MACLENNAN	DATE 10-25-2021

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ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	LOG OF INSTALLS		SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	SPT (N) BLOWS/0.30 m ▲					
					DIAGRAM	DEPTH (m)							20	40	60	80		
216			- Intermediate to high plasticity, firm below 11.0 m. - Trace to some fine grained sand below 11.3 m.															
215	12		CLAYEY SAND (SC) - Grey, moist, loose, fine to medium grained, some clay.				S15											
214	13		CLAY (CH) - Greyish brown, moist, firm, high plasticity, trace silt nodules, some fine to medium grained sand.				S16											
213	14		- Trace coarse grained sand, trace fine grained gravel below 13.9 m.				S17											
212	15		SILT TILL (TILL) - Light brown, moist, compact, some fine to coarse grained sand, trace fine to coarse grained gravel.				S18											
211	16		- With coarse grained sand below 14.6 m.				S19											
210	17		- Broken gravel in SPT sampler at 16.8 m. - Some fine to coarse grained gravel below 16.8 m.				S20	72			8 10 13	23						
209	18						S21											
208	19						S22	42			44 29 12	41						
207	20		MOTTLED LIMESTONE - grey to light yellow brown, Moderate to wide spaced joints. - Highly fractured limestone from 19.3 m to 19.9 m.				S23											
206	21						S24	42			14 13 13 13	26						
205	22						R1	48	0									
204	23		- Vugs from 22.9 m to 23.8 m. - Softer to 23.4 m. - Softer at 23.8 m.				R2	100	78 (3)									
203	24						R3	97	82 (11)									
202	25						R4	100	100 (4)									

WATER LEVELS ▽ During Drilling/Digging 3.96 m on 8-12-2021 During Drilling
During Drilling

CONTRACTOR
Maple Leaf Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
J. MACLENNAN

DATE
10-25-2021

CLIENT	CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT	PROJECT NO.	21-3913-001
PROJECT	Newton Force Main Red River Crossing Replacement	SURFACE ELEV.	227.14 m
LOCATION	Winnipeg, MB	START DATE	8-11-2021
DESCRIPTION	Kildonan Drive at Rowandale Crescent (Fraser's Grove Park)	UTM (m)	N 5,533,587
DRILL RIG / HAMMER	Acker Renegade Track Mounted Drill Rig with Auto-Hammer		E 636,371 Zone 14
METHOD(S)	0.0 m to 18.3 m: 125 mm ϕ SSA - switched due to sloughing 18.3 m to 44.7 m: Triple Tube, HQ Core		

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPa) ◆ qu POCKET PEN (kPa) ★ SPT (N) BLOWS/0.30 m ▲
227			TOPSOIL - Black, dry.								
			SILTY SAND (SM) - Brown, dry, loose, fine grained.			S1					
	1		SANDY SILT (MH) - Brown, damp, stiff, low plasticity, some fine grained sand lenses.			S2					
226	5		SANDY CLAY (CI) - Brown, moist, firm, intermediate plasticity, with fine grained sand.			S3					
	2		- Increased fine grained sand content below 2.0 m. - Moist to wet, soft below 2.1 m.			S4					
225	10		- Some fine grained sand below 3.0 m.			S5					
224	15		CLAYEY SAND (SC) - Brown, moist to wet, loose, fine to medium grained, trace to some clay.			S6					
	4		- Trace wood from 3.6 m to 3.9 m. - Grey, some clay below 4.0 m.			S7					
223	20		SANDY CLAY (CI) - Grey, moist, soft, intermediate to high plasticity, some fine grained sand.			S8					
222	25					S9					
221	30		CLAYEY SAND (SC) - Grey, moist to wet, loose, fine grained, trace to some clay.			S10					
220	35		SANDY CLAY (CI) - Grey, moist, soft, low to intermediate plasticity.			S11					
219						S12					
218						S13					
217			CLAY (CI) - Grey, moist, firm, intermediate plasticity, trace fine			S14					

WATER LEVELS	During Drilling/Digging	2.67 m on 8-11-2021 During Drilling	CONTRACTOR	INSPECTOR
	During Drilling		Maple Leaf Drilling Ltd.	C. FRIESEN
			APPROVED	DATE
			J. MACLENNAN	10-25-2021

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ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	SAMPLE TYPE NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPa) ◆ qu POCKET PEN (kPa) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80
216			grained sand. - Trace wood from 11.3 m to 11.4 m. - Soft, some to with fine grained sand from 11.4 m to 11.6 m.		S15 S16					
215	12		CLAYEY SAND (SC) - Grey, moist, compact, medium grained, trace shells. - Some clay, trace fine to coarse grained gravel below 12.5 m.		S17					
214	13		- Medium to coarse grained sand, some fine grained sand, trace clay below 13.1 m. - Trace coarse grained sand from 13.3 m to 13.4 m.		S18					
213	14		POORLY GRADED SAND WITH GRAVEL (SP) - Grey, moist to wet, dense, medium to coarse grained, some fine grained sand, some fine to coarse grained gravel, trace shells.		S19					
212	15		- Trace cobbles at 15.2 m. - With clay, trace silt pockets below 15.2 m.		S20					
211	16		SILT TILL (TILL) - Light brown, moist, compact, some medium to coarse grained sand, some fine to coarse grained gravel.		S21					
210	17				S22					
209	18		- Dense below 18.6 m.		S23	25		25 17 14	31	
208	19		MOTTLED LIMESTONE - strong, mottled white to grey, very few joints. - Trace of rusty oxidation from 19.3 m to 19.4 m.		R1	100	75 (7)			
207	20				R2	100	92 (7)			
206	21				R3	100	89 (10)			
205	22		- Some vugs from 22.6 m to 23.5 m.							
204	23		- Broken core zone, likely from drilling from 23.5 m to 23.6 m.							

WATER LEVELS ▽ During Drilling/Digging 2.67 m on 8-11-2021 During Drilling
During Drilling

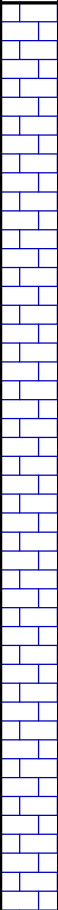
CONTRACTOR **Maple Leaf Drilling Ltd.** INSPECTOR **C. FRIESEN**
APPROVED **J. MACLENNAN** DATE **10-25-2021**

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ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPa) ◆ qu POCKET PEN (kPa) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80
203	80					R4	100	88 (3)			
202	25					R5	99	99 (5)			
201	26					R6	99	99 (4)			
200	27					R7	100	100 (4)			
199	28					R8	100	99 (5)			
198	29		- Finer grained section from 29.6 m to 31.7 m.			R9	99	98 (6)			
197	30					R10	100	93 (7)			
196	31					R11	99	99 (2)			
195	32		- Mottled brown, medium grained, trace of vugs with no alterations associated in the vuggy areas from 31.7 m to 44.7 m.			R12	100	100 (1)			
194	33										
193	34										
192	35										
191	36										
190	37										

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WATER LEVELS ▽ During Drilling/Digging During Drilling	2.67 m on 8-11-2021 During Drilling	CONTRACTOR Maple Leaf Drilling Ltd.	INSPECTOR C. FRIESEN
		APPROVED J. MACLENNAN	DATE 10-25-2021

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL	MC	LL
											Cu TORVANE (kPa) ◆		
ELEV (m)													
190													
189	38 125					R13	100	100 (2)					
188	39 130		- Large piece of coral at 39.1 m.			R14	99	99 (2)					
187	40												
186	41 135					R15	100	100 (2)					
185	42												
184	43 140					R16	100	100 (1)					
183	44 145					R17	100	93 (4)					
182	45												
181	46 150		Notes: 1. End of test hole at 44.7 m. 2. Test hole backfilled with grout. 3. Grout mix consisted of 1 part cement, 0.4 part bentonite, 3.3 part water. 4. Backfilled testhole with bentonite grout mixture to 1.8m. 5. Grout level dropped to 2.9m overnight. Topped up hole with bentonite chips to grade.										
180	47 155												
179	48												
178	49 160												
177	50												

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WATER LEVELS	▽ During Drilling/Digging	2.67 m on 8-11-2021 During Drilling	CONTRACTOR	INSPECTOR
	During Drilling		Maple Leaf Drilling Ltd.	C. FRIESEN
			APPROVED	DATE
			J. MACLENNAN	10-25-2021

APPENDIX C

2021 Bedrock Core Photos



Photo 1: TH21-01, Depth: 60'9" to 71'4.5"



Photo 2: TH21-01, Depth: 71'4.5" to 81'9"



Photo 3: TH21-01, Depth: 81'9" to 91'9"



Photo 4: TH21-01, Depth: 91'9" to 101'9"



Photo 5: TH21-01, Depth: 101'9" to 116'9"



Photo 6: TH21-01, Depth: 111'6.5" to 126'8"



Photo 7: TH21-01, Depth: 120'2.5" to 136'9"



Photo 8: TH21-01, Depth: 129'1" to 141'9" (End of Hole)



Photo 1: TH21-02, Depth: 28'2" to 40'10"



Photo 2: TH21-02, Depth: 40'10" to 55'9"



Photo 3: TH21-02, Depth: 55'9" to 70'9"



Photo 4: TH21-02, Depth: 70'9" to 82'2"



Photo 5: TH21-02, Depth: 82'2" to 95'11"

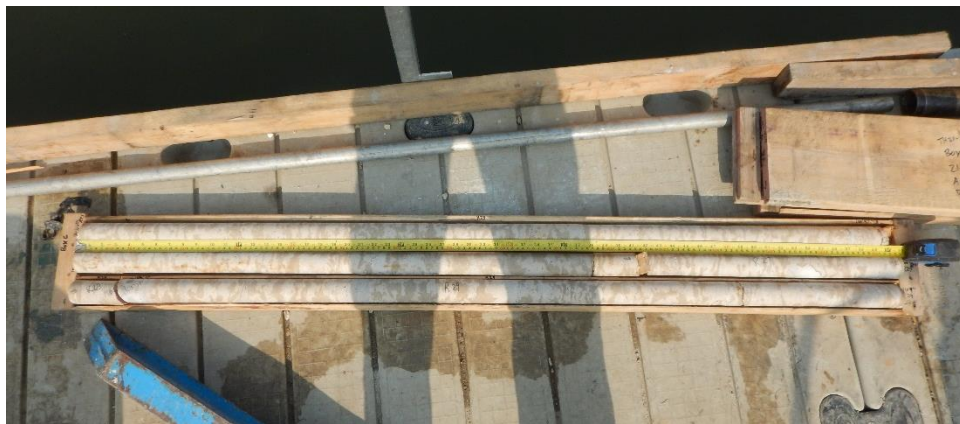


Photo 6: TH21-02, Depth: 95'11" to 110'9" (End of Hole)



Photo 1: TH21-03, Depth: 63'4" to 81'11"



Photo 2: TH21-03, Depth: 73'10.75" to 96'10"



Photo 3: TH21-03, Depth: 92'10.5" to 111'11"



Photo 4: TH21-03, Depth: 111'11" to 121'10"



Photo 5: TH21-03, Depth: 121'10" to 131'8"



Photo 6: TH21-03, Depth: 131'8" to 136'10" (End of Hole)



Photo 3: TH21-04, Depth: 91'10" to 106'11"



Photo 4: TH21-04, Depth: 101'6.25" to 116'11"



Photo 5: TH21-04, Depth: 110'11" to 126'11"



Photo 6: TH21-04, Depth: 120'9.5" to 136'9"



Photo 7: TH21-04, Depth: 130'0.5" to 146'9" (End of Hole)

APPENDIX D

Geophysical Seismic Refraction Survey Report
(Frontier Geoscience 2021)

FRONTIER GEOSCIENCES INC.

SEISMIC REFRACTION

SURVEY REPORT

NEWTON FORCE MAIN RED RIVER CROSSING

WINNIPEG, MB

Submitted to:

KGS Group

October 26, 2021

Authors:

Sean Henry, B.Sc.

Caitlin Gugins, P.Geo.

Project: FGI-1743

CHANGE LOG

<u>Version</u>	<u>Date of Issue</u>	<u>Changes</u>
Draft	Sept. 6, 2021	Draft Report for Review
Final	Oct. 26, 2021	Final Report - updated Figures 3 and 4, discussion updated

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2. Seismic Refraction Survey	2
2.1 Terrestrial Refraction Survey	2
2.1.1 Survey Equipment	2
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2.2 Overwater Refraction Survey	3
2.2.1 Survey Equipment	3
2.2.2 Survey Procedure	3
2.3 Seismic Refraction Interpretive Method	3
3. Geophysical Results	4
3.1 General	4
3.2 Discussion	5
4. Limitations	6

Illustrations

	Location
Figure 1 Survey Location Plan	Appendix
Figure 2 Site Plan	Appendix
Figure 3 Interpreted Seismic Refraction Depth Section SL21-01	Appendix
Figure 4 Interpreted Seismic Refraction Depth Section SL21-02	Appendix

1. Introduction

During the period of August 10 and 11, 2021, Frontier Geosciences Inc. carried out a seismic refraction investigation for KGS Group, in Winnipeg, MB. The survey area is located across the Red River, near Newton Ave. A Survey Location Plan of the area is shown at a scale of 1:50,000 in Figure 1 in the Appendix.

The purpose of the geophysical survey was to obtain overburden and bedrock compressional wave velocity information, in support of the Newton Force Main Red River Crossing Replacement project. A total of 705 metres of seismic refraction data was collected along two separate seismic lines. A Site Plan showing the locations of the lines is presented at a 1:2,000 scale in Figure 2, in the Appendix.



Example of Survey Setup at the River's Edge

2. Seismic Refraction Survey

2.1 Terrestrial Refraction Survey

2.1.1 Survey Equipment

The seismic refraction investigation was carried out using a Geometric Geode, 24 channel, signal enhancement seismograph and Oyo Geospace 10 Hz geophones. Geophone intervals along the multicored seismic cable were maintained at 5 metres, in order to ensure high resolution data of subsurface layering. Seismic energy was provided from a Buffalo gun, shotgun source firing 8 gauge, blank, shotgun shells into hand-excavated shotholes. Shot initiation or zero time was established by metal to metal contact of a striking hammer contacting the firing pin of the shotgun.

2.1.2 Survey Procedure

For each spread, the seismic cable was stretched out in a straight line and the geophones implanted in the soil. Up to seven separate 'shots' were then initiated: one at either end of the geophone array, up to three at intermediate locations along the seismic cable, and two off each end of the line, to ensure adequate coverage of the subsurface. The shots were triggered individually and arrival times for each geophone were recorded digitally in the seismograph. For quality assurance, field inspection of raw data after each shot was carried out, with additional shots recorded if first arrivals were unclear.

Throughout the survey, notes were recorded regarding seismic line positions in relation to topographic and geological features. Relative elevations along the seismic lines were recorded by chain and inclinometer and referenced to handheld GPS measurements.

2.2 Overwater Refraction Survey

2.2.1 Survey Equipment

The overwater seismic refraction surveying was carried out with two, land-based, Geode seismographs and up to twenty-four geophones, together with a waterborne airgun energy source. A small Bolt airgun was used which released 10 cubic inches of compressed air into the river. A Gisco seismic radio trigger in the survey boat was used to initiate recordings at the two, shore-based seismographs.

2.2.2 Survey Procedure

In operation, the 'shooting' boat was manoeuvred in-line with the recording stations and the seismic source was lowered to just above the river bottom then initiated. The recording stations were automatically triggered by a radio link between the shooting vessel and recording seismographs. Accurate positioning of the shooting vessel was determined with a handheld GPS receiver. With numerous shot locations spanning the breadth of the lake, detailed travel time data was established similar to land-based operations. Water depths were recorded at each 'shooting' station.

2.3 Seismic Refraction Interpretive Method

The final interpretation of the seismic data was arrived at using the method of differences technique. This method utilizes the time taken to travel to a geophone from shotpoints located to either side of the geophone. Velocities are calculated as the slope of first break pick times and geophone distances. When there is a significant change in slope a new velocity is calculated and assigned to the new layer. Basal velocities are calculated by the arrivals of off-end shots, where picked arrivals are refracted from the basal layer. Each geophone is assigned a velocity and time for each layer. Using the total time, a small vertical time is computed which represents the time taken to travel from the refractor up to the ground surface. This time is then multiplied by the velocity of each overburden layer to obtain the thickness of each layer at that point. The thicknesses are splined along the seismic line to create a continuous boundary between layers.

3. Geophysical Results

3.1 General

The interpreted results of the seismic refraction lines are illustrated in profile in Figures 3 and 4, at a scale of 1:500, in the Appendix. The seismic velocity layer interfaces are marked on the seismic profiles in blue, purple and red. The interface line colours are not a specific velocity contour, but rather the interpreted discrete boundary above which velocities are defined within a certain range and below which velocities are within a significantly increased velocity range.



Seismic Shotgun Operation on Terrestrial Lines

3.2 Discussion

The results of the seismic refraction survey indicate the area is underlain by up to four distinct velocity layers. The two seismic profiles display a surficial layer with a range of compressional wave velocities between 360 m/s and 450 m/s. This velocity range is indicative of unconsolidated materials such as loose, dry to damp sands, silts and clays. This layer averages approximately 3.8 metres in thickness and reaches a maximum of approximately 6.2 metres along line SL21-02 near station 338N. This surficial layer is absent across the river.

Underlying the surficial layer is an upper intermediate layer with an interpreted compressional wave velocity range between 1000 m/s and 1400 m/s, consistent with drillhole intersections of moist to wet, sands and clays. Layer thicknesses vary significantly across the survey lines, from a minimum of around 2.7 metres surrounding station 188N on line SL21-02, while reaching a maximum of over 15 metres near station 90NW on line SL21-01.

Underlying the upper intermediate layer is a lower intermediate velocity layer with a narrow compressional wave velocity range of 1600 m/s to 1750 m/s. These velocities are consistent with a more compact material, such as the silt till layer encountered in the drillholes. The greatest calculated thicknesses for this layer is approximately 11 m occurring at the beginning of line SL21-02, and thinning to 1.5 metres near station 264N on line SL21-02. While identifiable over the terrestrial portions this layer was not as apparent over the coarser cross river portions of the lines, likely due to it's thickness relative to depth. As a result, the depth for this layer was interpolated along the river bottom, and therefore it's thickness has a higher level of uncertainty underneath the river.

The basal layer with compressional wave velocities of 3250 m/s to 4100 m/s is the interpreted competent bedrock surface. These high velocities are consistent with nearby borehole logs encountering limestone, with higher velocities in this range indicative of a lesser degree of weathering and/or fracturing. Depths to the interpreted bedrock surface range from around 5.5 metres underlying the river near station 240N on line SL21-02 to a maximum of 26 metres at station 100NW on line SL21-01.

4. Limitations

The depths to subsurface boundaries derived from seismic refraction surveys are generally accepted as accurate to within ten percent of the true depths to the boundaries, below 10 metres. Above 10 metres, the accuracy of seismic refraction data is approximately +/- 1.5 metres due mainly to the greater statistical error in determining the upper velocity layers from fewer data points. In some cases, unusual geological conditions may produce false or misleading data points with the result that computed depths to subsurface boundaries may be less accurate. In seismic refraction surveying difficulties with a 'hidden layer' or a velocity inversion may produce erroneous depths. The first condition is caused by the inability to detect the existence of a layer because of insufficient velocity contrasts or layer thicknesses. A velocity inversion exists when an underlying layer has a lower velocity than the layer directly above it. The interpreted depths shown on drawings are to the closest interface location, which may not be vertically below the measurement point if the refractor dip direction departs significantly from the survey line location. Structural discontinuities occurring on a scale less than the geophone spacing or isolated boulders would go undetected in the interpretation of the data. The seismic refraction method may not detect a narrow canyon-like feature incised into bedrock, if the canyon width is narrow relative to the depth of burial of the feature.

Due to the method constraints of the overwater seismic refraction surveying, there is limited data on the velocities and depths of the overburden materials on the overwater profile. As a result, overburden velocities and bedrock depth errors may be greater than fifteen percent on the overwater segments of refraction lines.

FRONTIER GEOSCIENCES INC.

The information in this report is based upon geophysical measurements and field procedures and our interpretation of the data. The results are interpretive in nature and are considered to be a reasonably accurate representation of existing subsurface conditions within the limitations of the seismic refraction method.

For: Frontier Geosciences Inc.



Sean Henry, B.Sc.

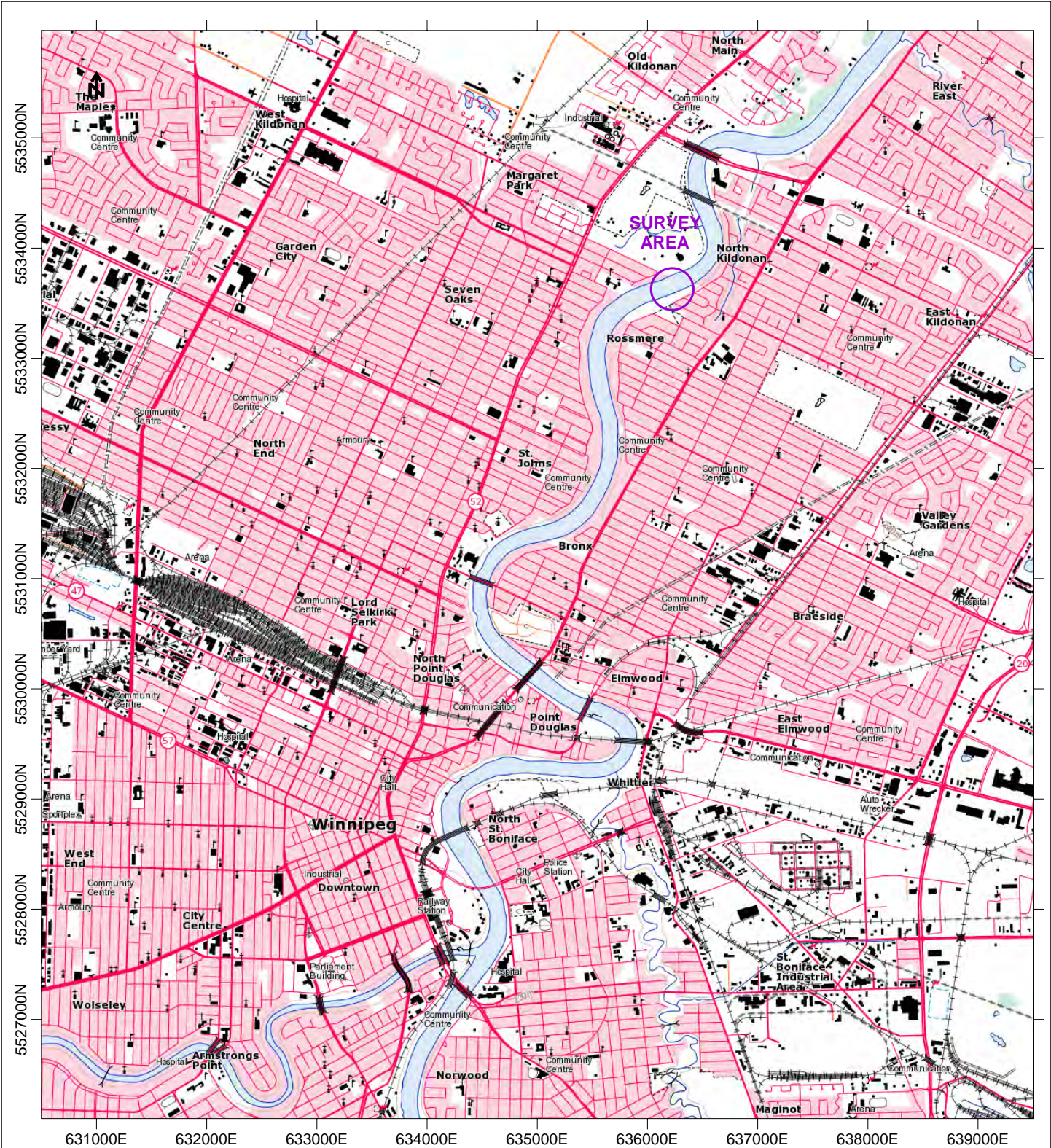


Caitlin Gugins, P.Geo.



Oct 26, 2021

APPENDIX



5535000N
5534000N
5533000N
5532000N
5531000N
5530000N
5529000N
5528000N
5527000N

631000E 632000E 633000E 634000E 635000E 636000E 637000E 638000E 639000E



KILOMETRES

KGS GROUP
 NEWTON FORCE MAIN
 RED RIVER CROSSING REPLACEMENT
 SEISMIC REFRACTION SURVEY

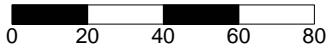
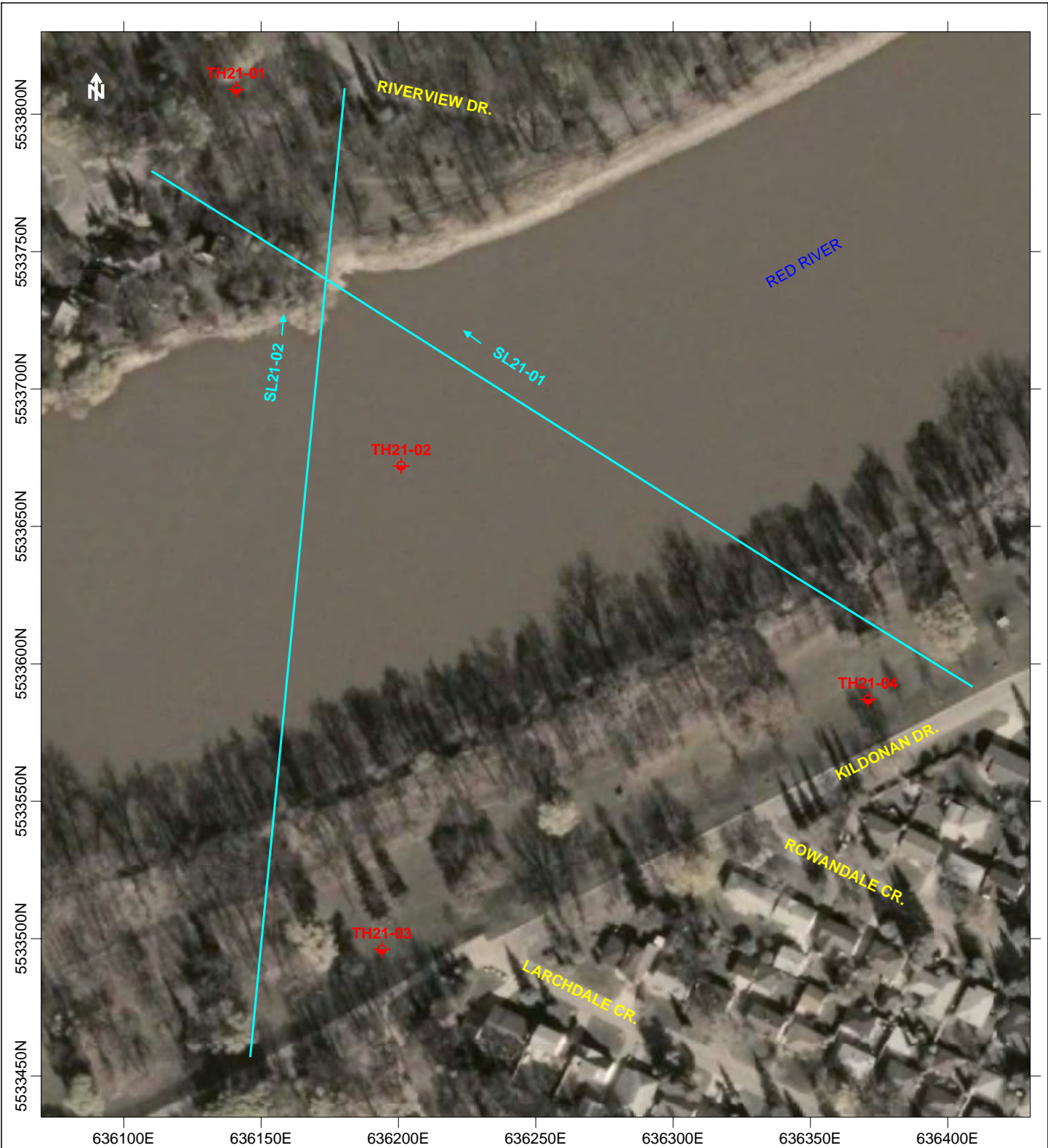
SURVEY LOCATION PLAN

FRONTIER GEOSCIENCES INC.

DATE: AUG. 2021

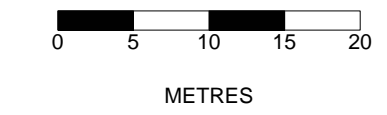
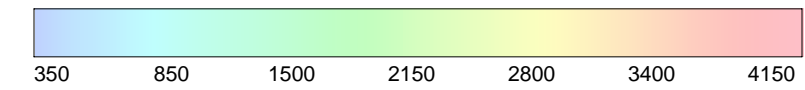
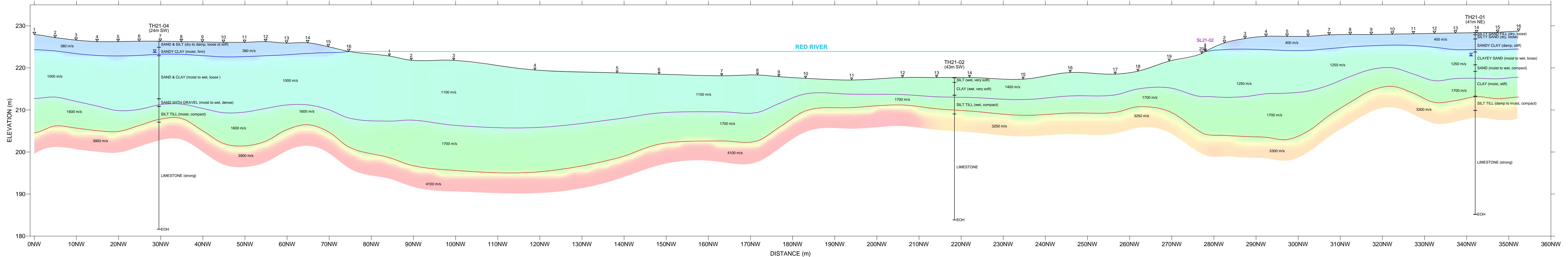
SCALE 1:50,000

FIG. 1

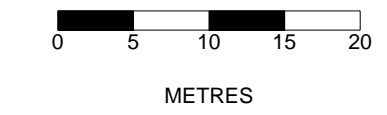
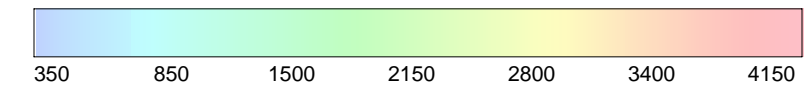
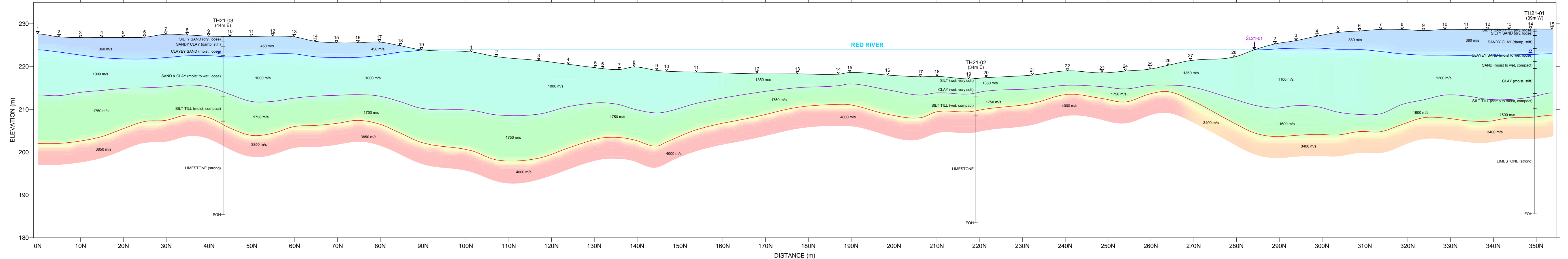


METRES

KGS GROUP NEWTON FORCE MAIN RED RIVER CROSSING REPLACEMENT SEISMIC REFRACTION SURVEY		
SITE PLAN		
FRONTIER GEOSCIENCES INC.		
DATE: AUG. 2021	SCALE 1:2,000	FIG. 2



KGS GROUP		
NEWTON FORCE MAIN RED RIVER CROSSING REPLACEMENT		
SEISMIC REFRACTION SURVEY		
INTERPRETED SEISMIC REFRACTION DEPTH SECTION SL21-01		
FRONTIER GEOSCIENCES INC.		
DATE: AUG. 2021	SCALE: 1:500	FIG. 3



KGS GROUP		
NEWTON FORCE MAIN		
RED RIVER CROSSING REPLACEMENT		
SEISMIC REFRACTION SURVEY		
INTERPRETED SEISMIC REFRACTION		
DEPTH SECTION		
SL21-02		
FRONTIER GEOSCIENCES INC.		
DATE: AUG. 2021	SCALE 1:500	FIG. 4

APPENDIX E

2021 Geotechnical Investigation Laboratory Data

Geo-Lab Report

Revision # 0

Report Date: *October 24, 2021*
Client: *KGS Group*
Address: *865 Waverley St., Winnipeg, MB R3T 5P4*
Attn: *Dami Adedapo*
Project No: *21-3913-001*
Project Name: *Newton FM Crossing*
Solum Job No.: *13501211014(206)*

Sample Received Date: *October 14, 2021*

Sample Quantity: *4 cores*

Test	Quantity	ASTM Destination
YOUNG'S MODULUS, Poisson's Ratio W/ UCS	2	D7012



President: Saad Farag

Elastic Moduli for Rock (ASTM D7012)

Project Info: 21-3913-001 / Newton FM Crossing

Reviewed by: S. F.

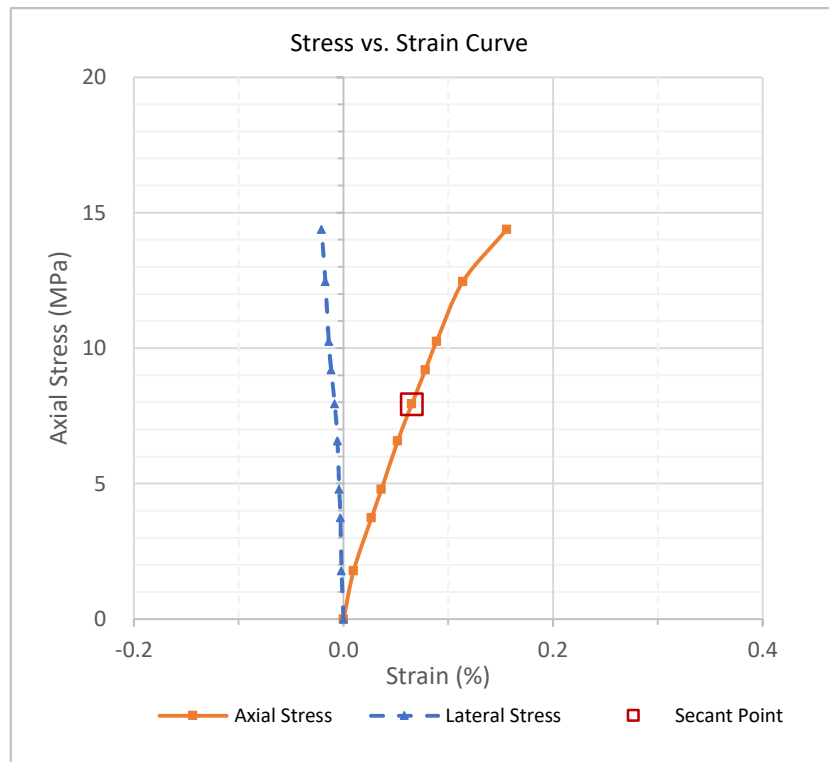
Client: KGS Group

Solum Job No.: 13501211014(206)

Sample Info: TH21-01 R5 82'7"

Diameter (cm)	6.03	Height (cm)	12.46	H/D Ratio	2.06	Mass (g)	872.8	MC(%)	0.7
Shear Rate (%/min)	0.04	Wet BD (kg/m ³)	2452						

Axial Strain (%)	Axial Stress (MPa)	Lateral Strain (%)
0.00	0.00	0.000
0.01	1.78	-0.002
0.03	3.74	-0.003
0.04	4.79	-0.004
0.05	6.58	-0.006
0.07	7.94	-0.008
0.08	9.20	-0.012
0.09	10.25	-0.014
0.11	12.46	-0.017
0.16	14.38	-0.021



Test Result

Compressive Strength (MPa) 14.37

Axial Modulus of Elasticity (GPa) 12.17 *(secant, ~ 50% of Ultimate Strength)

Radial Modulus of Elasticity (GPa) 95.57

Poisson's Ratio 0.13

Elastic Moduli for Rock (ASTM D7012)

Project Info: 21-3913-001 / Newton FM Crossing

Reviewed by: S. F.

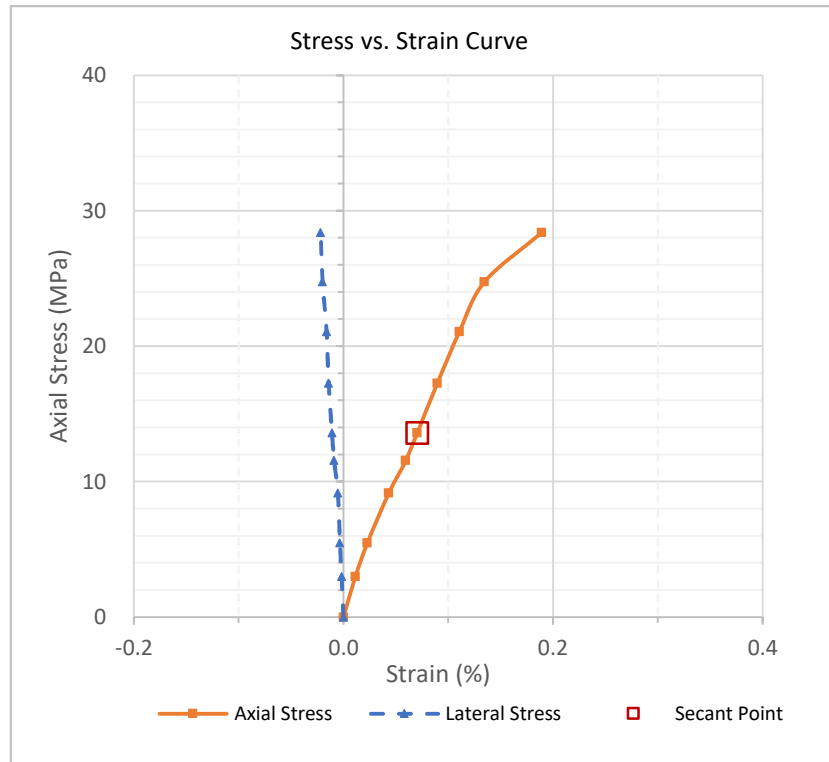
Client: KGS Group

Solum Job No.: 13501211014(206)

Sample Info: TH21-01 R6 90'6"

Diameter (cm)	6.06	Height (cm)	13.05	H/D Ratio	2.16	Mass (g)	910.6	MC(%)	0.9
Shear Rate (%/min)	0.04	Wet BD (kg/m ³)	2422						

Axial Strain (%)	Axial Stress (MPa)	Lateral Strain (%)
0.00	0.00	0.000
0.01	2.99	-0.002
0.02	5.49	-0.003
0.04	9.17	-0.005
0.06	11.56	-0.009
0.07	13.61	-0.011
0.09	17.25	-0.014
0.11	21.07	-0.016
0.13	24.75	-0.020
0.19	28.40	-0.022



Test Result

Compressive Strength (MPa) 28.40

Axial Modulus of Elasticity (GPa) 19.31 *(secant, ~ 50% of Ultimate Strength)

Radial Modulus of Elasticity (GPa) 124.16

Poisson's Ratio 0.16



GEOTECHNICAL & MATERIAL
TESTING LABORATORY

STANDARD LABORATORY TERMS AND CONDITIONS

1.0 Description of Services to be Performed by Solum Consultants Ltd. (Solum)

Solum shall provide geotechnical and material laboratory testing services on samples in accordance with these terms and conditions and executed Laboratory Testing Request Forms. Solum shall perform its work in accordance with accepted laboratory standards and accepted standard operating procedures. Solum reserves the right to modify methods as necessary based upon experience and/or current scientific literature. If the Client requests a manner of analysis that varies from standard operating or recommended procedures, the Client shall not hold Solum responsible for the results. Such variations of analysis will be noted on the reports. Solum reserves the right to subcontract laboratory testing if a particular test cannot be performed by Solum.

2.0 Reports, Confidentiality and Third Parties

Laboratory reports provided by Solum will be composed of a cover page, tables and figures if applicable. Reports will be e-mailed in PDF format to the individual(s) specified on the Laboratory Testing Request Forms. Laboratory reports may also be faxed or mailed to the Client upon request. Except as required by law, Solum shall not disclose testing results or reports to any party other than the Client, unless the Client, in writing, requests information to be provided to a third party. Solum shall abide by any additional confidentiality requirements requested by the Client provided that such requirements are provided to Solum at or before execution of the testing.

Information provided by Solum is intended for Client use only. Any use by a third party, of reports or documents authored by Solum, or any reliance on or decisions made by a third party based on the findings described in said documents, are the sole responsibility of such third parties, and Solum accepts no responsibility of damages suffered by any third party as a result of decisions made or actions conducted.

3.0 Laboratory Testing Request Form (Chain of Custody)

The laboratory testing request form must be completed by the Client and be accompanied with the samples. Other form of COC may be accepted; however, the condition of Solum COC is still applied. Testing will not commence until the laboratory testing request form has been completed. If requested by the Client, Solum shall provide a copy of the laboratory testing request form with the report.

No persons other than the designated representatives for each Laboratory Testing Request Form are authorized to act regarding changes to the testing request form. Any changes or amendments of the laboratory testing request form must be in writing and be completed by the originator.

4.0 Acceptance, Contamination and Disposal of Samples

Loss or damages to samples remains the responsibility of the Client until Solum representatives acceptance of samples by notation on the laboratory testing request form.

As to any samples that are suspected of containing hazardous substances, the Client will specify the suspected or known substance and level of contamination. This information is to be stated on the laboratory testing request form and be accompanied with the samples before testing can commence. Solum may refuse acceptance of samples if it determines they present a risk to health and safety.

Samples accepted by Solum shall remain the property and liability of the Client while in the custody of Solum. Solum will discard all non-contaminated samples after two weeks of submitting lab report or a month from the date of receiving the samples without additional retention period at a fixed disposal charge, or if requested by the Client, samples may be returned to the Client at no cost to Solum. If requested by client, Solum will store samples provided the client agrees to pay for the storage charge. Contaminated material may be returned/shipped to the Client at the Client's expense or Solum will discard samples with disposal rates varying for samples containing higher levels of contamination, refer to price list.

Soil samples requested to be stored will be stored inside the lab up to the expiration of storage period. Soil samples will be discarded upon the expiration date of the storage period unless client requests either extending storage period or return samples back to client at no cost to Solum.

5.0 Indemnification/Hold Harmless

Solum shall protect, indemnify and save harmless Client, and its directors, officers, employees, agents, representatives, invitees and subcontractors, and at Client's request, investigate and defend such entities from and against all claims, demands and causes of action, of every kind and character, without limitation, arising in favour of or made by third parties, on account of bodily injury, death or damage to or loss of their property resulting from any negligent act or willful misconduct of Solum.

The Client shall protect, indemnify and save harmless Solum, and its directors, officers, employees, agents, representatives, invitees and subcontractors, and at Solum's request, investigate and defend such entities from and against all claims, demands and causes of action, of every kind and character, without limitation, arising in favour of or made by third parties, on account of bodily injury, death or damage to or loss of their property resulting from any negligent act or willful misconduct of Client.

6.0 Limitation of Liability

The total liability of Solum or its staff whether based in contract or tort, will be limited to the lesser of the fees paid or actual damages incurred by the Client. Solum will not be responsible for any consequential or indirect damages even if caused by negligence of Solum. Solum will only be liable for damages resulting from negligence of Solum. All claims by the Client shall be deemed relinquished if not made within one year after the testing date. No warranty is either expressed or implied, or intended by any agreement or by furnishing oral or written reports or findings.

7.0 Termination of Testing Work Order

The Client may order work suspended or terminated upon seven days advance written notice. If work is suspended, Solum shall receive, upon resumption, an adjustment in the cost of services to compensate for additional costs incurred due to the interruption of services. Upon suspension or termination, Solum shall preserve samples provided that the Client agrees to pay the sample storage charge.

8.0 Pricing, Payments and Invoicing

Invoices will be based on most current Solum laboratory testing rates; rates may change without notice. Solum invoices shall be paid within thirty (30) days of receipt of the invoice. Amounts not paid when due shall bear interest at the rate of 18% per annum from the date due until the date of payment.

KGS
GROUP

Experience in Action