AECOM

City of Winnipeg

# Northeast Interceptor Sewer - Red River Crossing Geotechnical Data Report


Prepared by:

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Prepared for:

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Date: March, 2018

Project #: 60509089

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**Date**
March 23, 2018

Mr. Stacy Cournoyer, P.Eng
Senior Project Engineer
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**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.**

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REGISTERED PROFESSIONAL
March 23, 2018

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

FA:rz

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# 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:**

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**Report Reviewed By:**

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# 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<br>End: 1+539.70 – Eastern Inlet Chamber | 251.09 | 900 - Carrier Pipe<br>Casing Pipe (optional) | Microtunnelling |
| Eastern Inlet and Western Outlet Chambers Sewer Connection | 4.1 to 6.2 | 1200- Carrier Pipe<br>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 to17, 2017 | Existing NEIS alignment | Distance: 0 to 30<br>Drilled at or near to eastern inlet and western outlet chambers | TH-01, 02, 03 and 04<br>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<br>Directly along proposed NEIS alignment. | TH16-01, 02, 03 and 04 |
| **KGS Group*** | SSA/RC (3 no.)<br>SSA (2 no.) | November 7 to14, 2012 | Existing NEIS alignment | Distance: 0 to 25<br>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<br>North of existing and proposed NEIS alignment | TH13-01, 04 and 05 |
| **Dyregrov and Burgess** | SSA (10 no.)<br>HSA (3 no.)<br>RC (14 no.)<br>DMT (5 no.) | June 6, 1987 to October 15, 1987 | Kildonan Settlers Bridge | Distance: 75 to 100<br>North of proposed and existing NEIS alignment | Boring 1 to 23<br>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-lacustine 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.

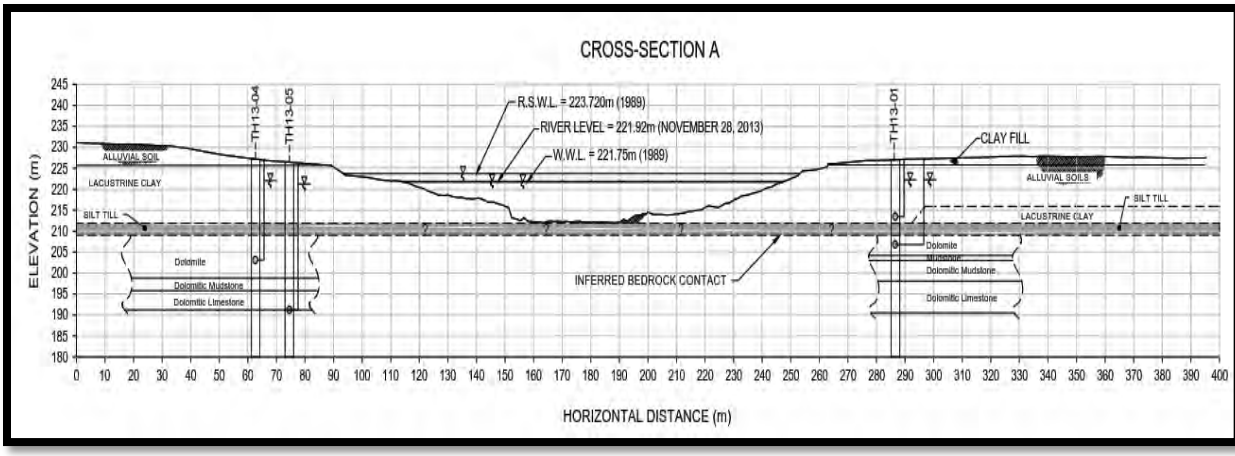


**Figure 2-1: Cross Section "A" taken from TREK Geotechnical 2014 North Kildonan Feedermain Geotechnical Report**

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 | $1 \times 10^{-10}$ |
| Alluvial Soils | 18 | 2 | 23 | $1 \times 10^{-09}$ |
| Glacial Till | 19 | 10 | 30 | $1 \times 10^{-07}$ |
| Engineered Fill (Clay) | 18 | 2 | 23 | $1 \times 10^{-09}$ |

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<br>(Eastern Riverbank) | 5534768 N<br>636562 E | 18.0 | 18.0 to 36.0 | 36.0 |
| TH-02<br>(Eastern Riverbank) | 5534792 N<br>636568 E | 23.0 | 23.0 to 60.0 | 60.0 |
| TH-03<br>(Western Riverbank) | 5534844 N<br>636365 E | 19.0 | 19.0 to 60.0 | 60.0 |
| TH-04<br>(Western Riverbank) | 5534879 N<br>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)<br>Number of Tests Completed | Dyregrov and Burgess (1987)<br>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 | | 214.4 to 219.7 |
| | Thickness (m) | 1.7 to 3.8 | NR | 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) | | | |
| | Thickness | NR | NR | NR |
| | 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 | |
| | Thickness (m) | 1.5 to 2.6 | 0.8 to 9.1 | NR |
| | 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 to114.9 (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 ($e_o$) 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.

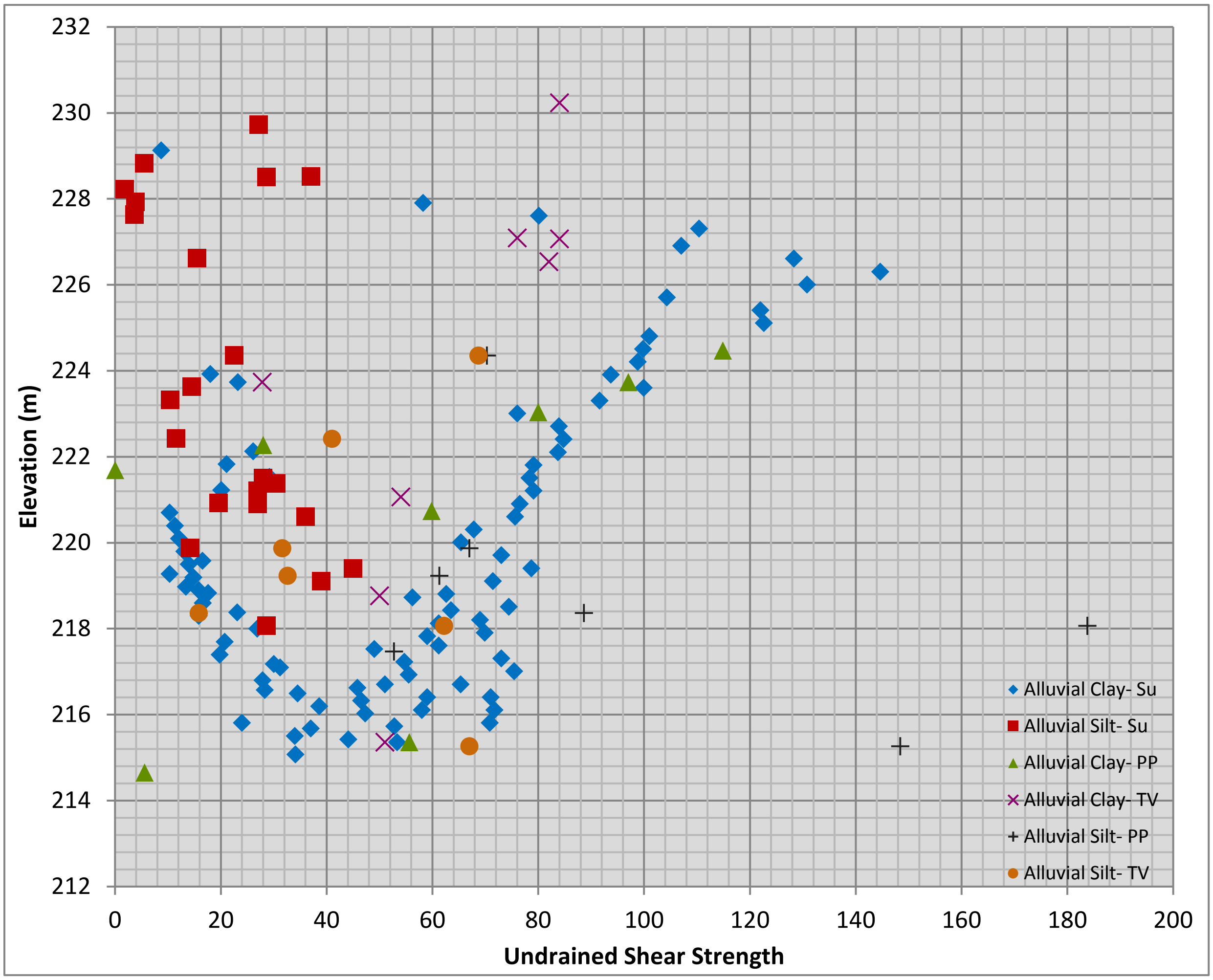


**Figure 3-1: Undrained Shear Strength with Elevation for Alluvial Soil Deposits- AECOM (2017), TREK (2014) and Dyregrov and Burgess (1988)**

### 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-lacustine 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<br>65 to 95- Lower Clay |
| **Plasticity Index (%)** | 60 to 80- Upper Clay<br>40 to 65- Lower Clay |
| **Undrained Shear Strength (kPa)** | 70 to 100- Upper Clay<br>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 ϕ'= 20.5° and;
- Lower Clay- c' = 29.8 kPa and ϕ'= 15.8°.

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 ϕ'= 13.3° and;
- Lower Clay- c' = 7.7 kPa and ϕ'= 15.7°.

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 ($e_o$) not reported as part of test. Atterberg Limits not undertaken

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

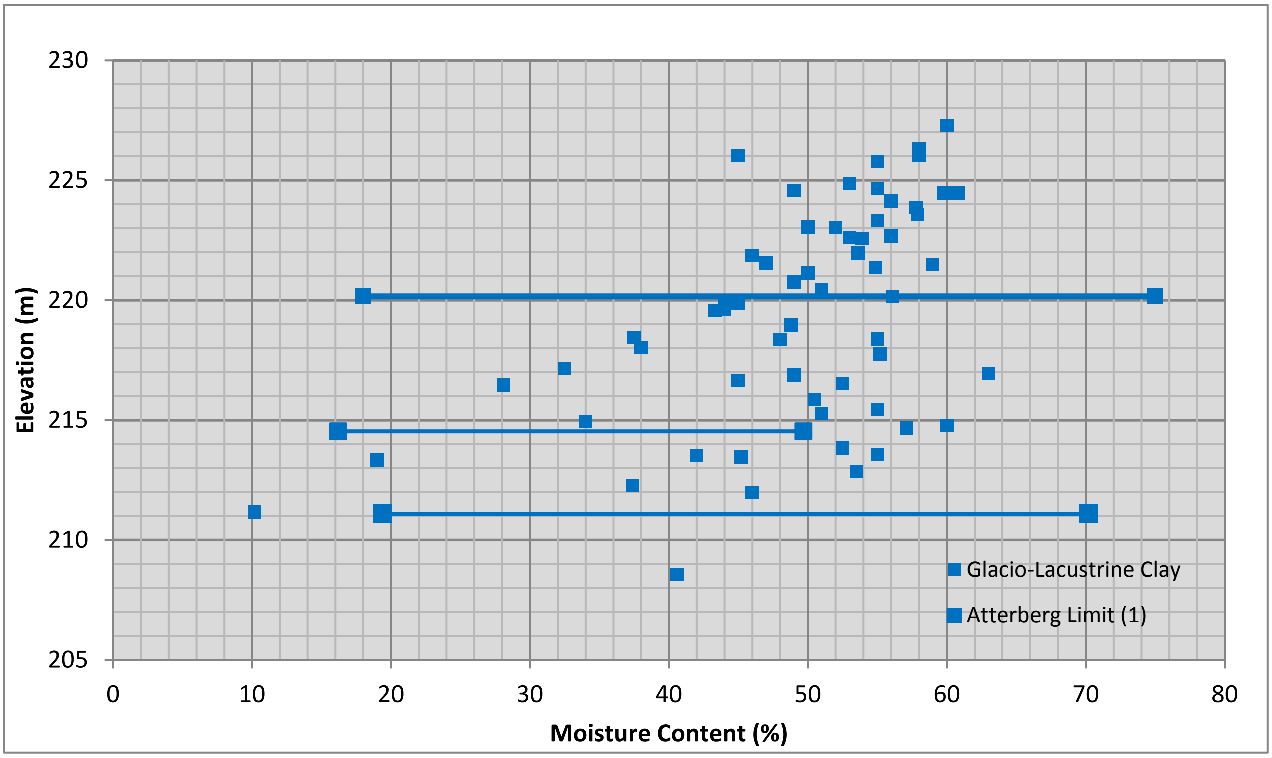


**Figure 3-2: Moisture Content with Elevation for Glacio-Lacustrine Clay- AECOM (2017), TREK (2014) and Dyregrov and Burgess (1988)**

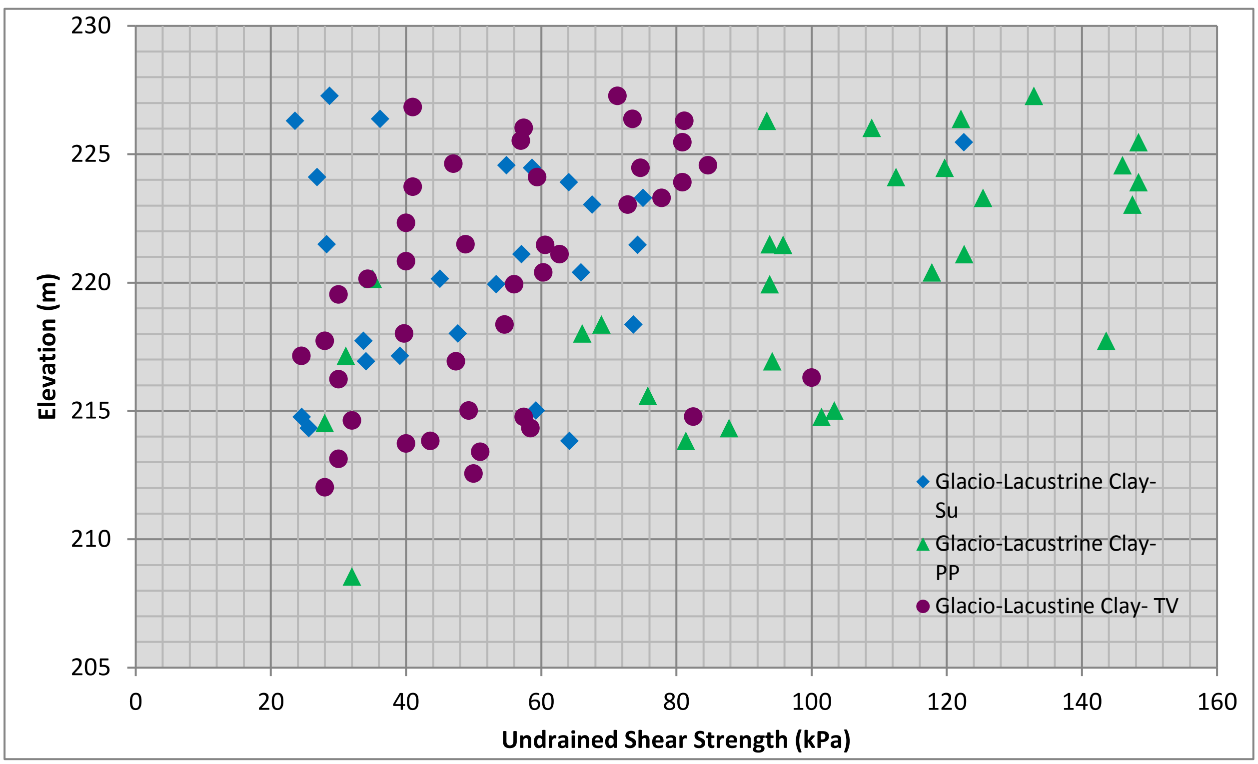


**Figure 3-3: Undrained Shear Strength with Elevation for Glacio-Lacustrine Clay- AECOM (2016), TREK (2013) and Dyregrov and Burgess (1987)**

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.

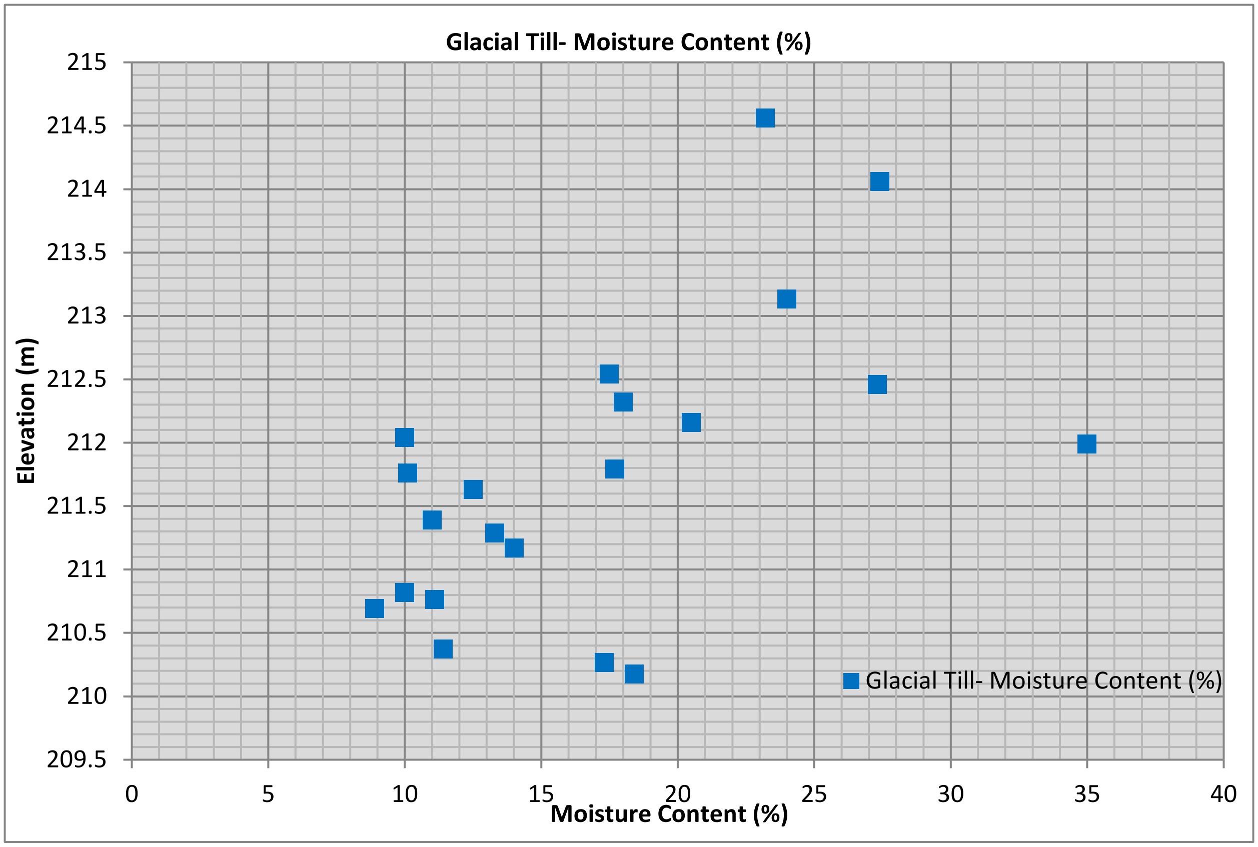


**Figure 3-3: Moisture Content with Elevation for Glacial Till- AECOM (2016), TREK (2013) and Dyregrov and Burgess (1987)**

### 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 t0 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 becoming 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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6- ASTM D4644-04. Standard Test Method for Slake Durability of Shales and Similar Weak Rocks.

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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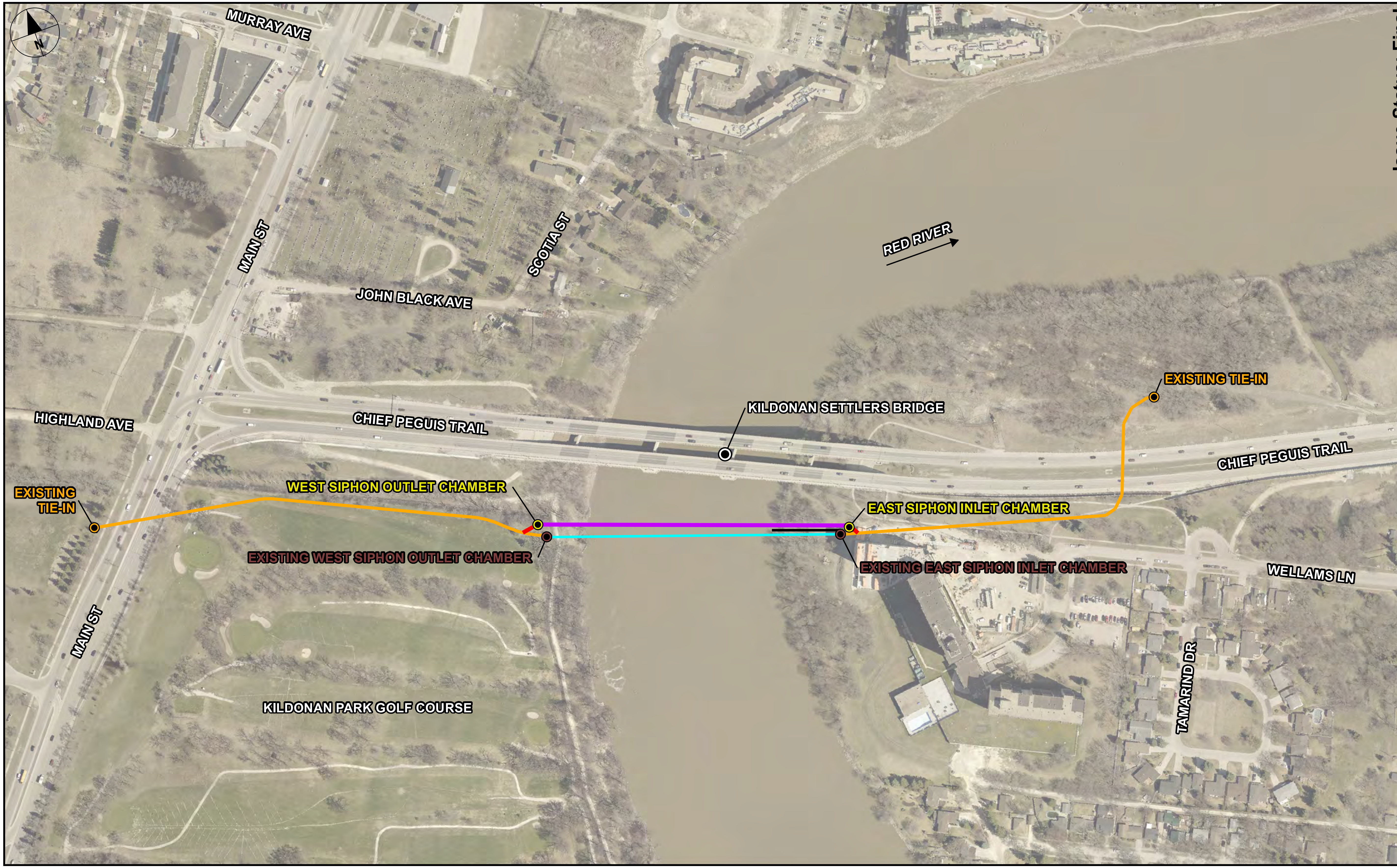
20- TREK Geotechnical (January 2014). North Kildonan Feedermain Detailed Design – Geotechnical Report.

# 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)
- CONNECTION TO EXISTING 1800 MONO CONC INTERCEPTOR
- EXISTING 1800 MONO CONC INTERCEPTOR
- EXISTING 1200 CSP CS OUTFALL
- EXISTING 500 & 800 STEEL SIPHON

30 0 30 60 m

1:3,000

NAD 1983 UTM Zone 14N

AECOM

FIGURE: 1

SITE LOCATION PLAN AND NEIS ALIGNMENT

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


ANSI B 279.4mm x 431.8mm
Approved:
Checked:
Designer:
Project Management Initials:
Last saved by: MAHEC (2018-03-22) Last Plotted: never
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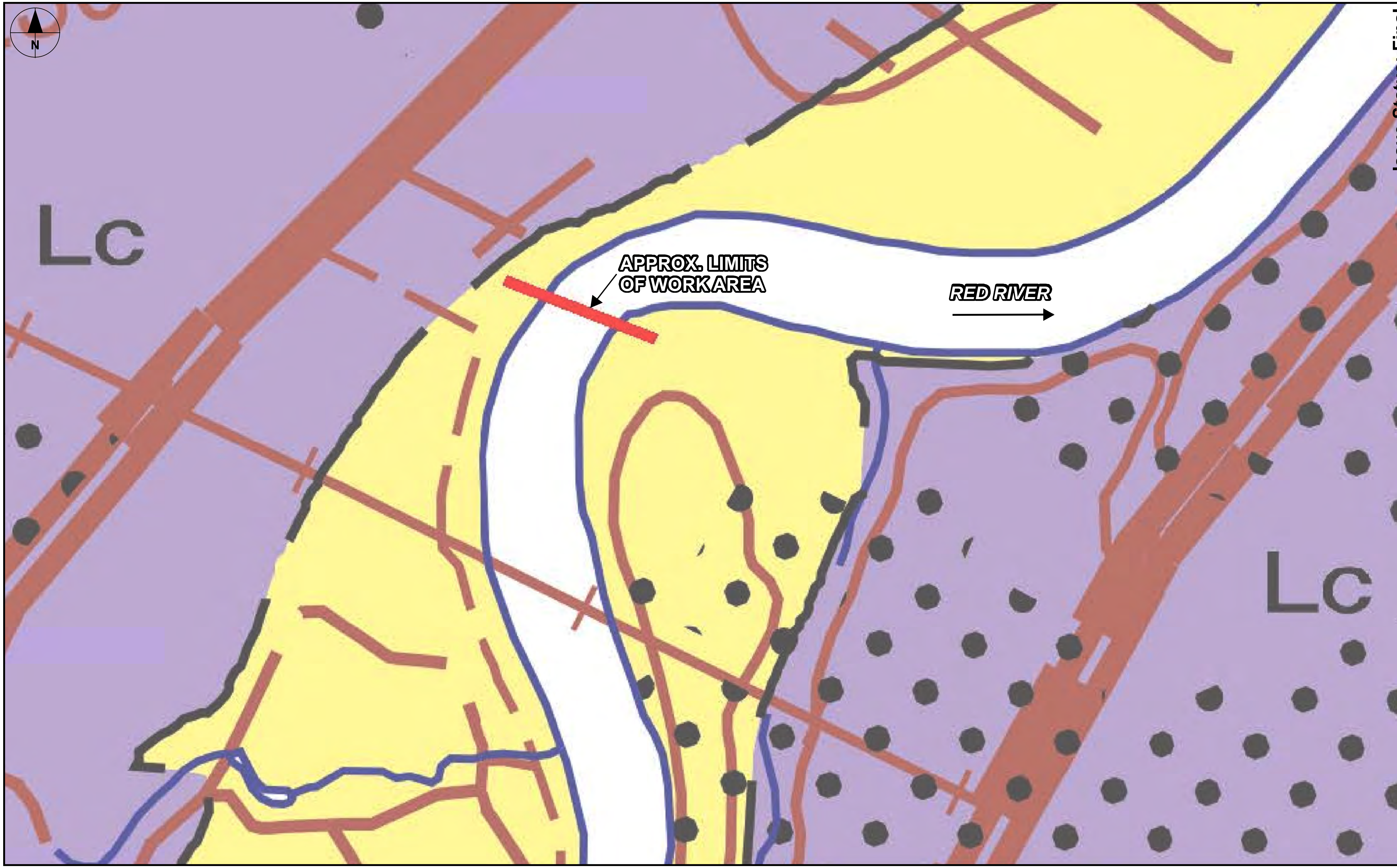


**SURFICIAL GEOLOGY LEGEND**

| LITHOLOGY (MATERIAL) | | LITHOGENSIS (ORIGINS OF MATERIAL) |
|---|---|---|
| Ac | CHANNEL DEPOSITS | ALLUVIAL SEDIMENTS: SAND AND GRAVEL, SAND, SILT, CLAY, ORGANIC DETRITUS; 1-20 m THICK; CHANNEL AND OVERBANK SEDIMENTS; DEPOSITED BY POSTGLACIAL RIVERS. |
| Lc | CLAY TO SILTY CLAY | OFFSHORE GLACIOLACUSTRINE SEDIMENTS: CLAY, SILT, MINOR SAND; 1-20 m THICK; VERY LOW RELIEF MASSIVE AND LAMINATED DEPOSITS; DEPOSITED FROM SUSPENSION IN OFFSHORE, DEEP WATER OF GLACIAL LAKE AGASSIZ, COMMONLY SCOURED AND HOMOGENIZED BY ICEBERGS. |

**SCALE: NTS**

AECOM

**FIGURE: 2**

**SURFICAL GEOLOGY**

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

ANSI B 279.4mm x 431.8mm

Approved: Checked: Designer: Project Management Initials:

Last saved by: MAHEC (2018-03-22) Last Plotted: never
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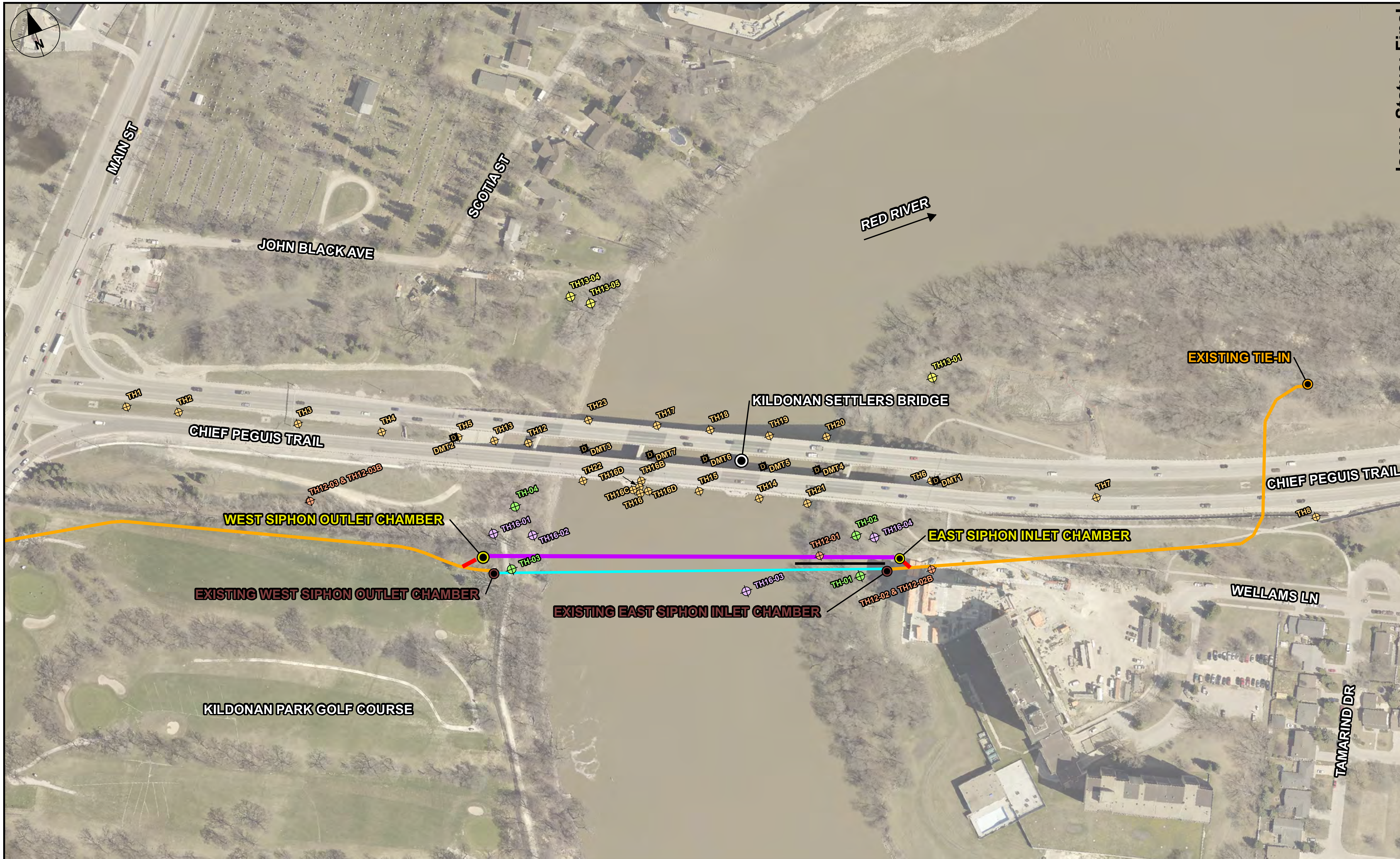



**LEGEND**

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

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

20 0 20 40 m

1:2,250

NAD 1983 UTM Zone 14N

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

TEST HOLE LOCATION PLAN

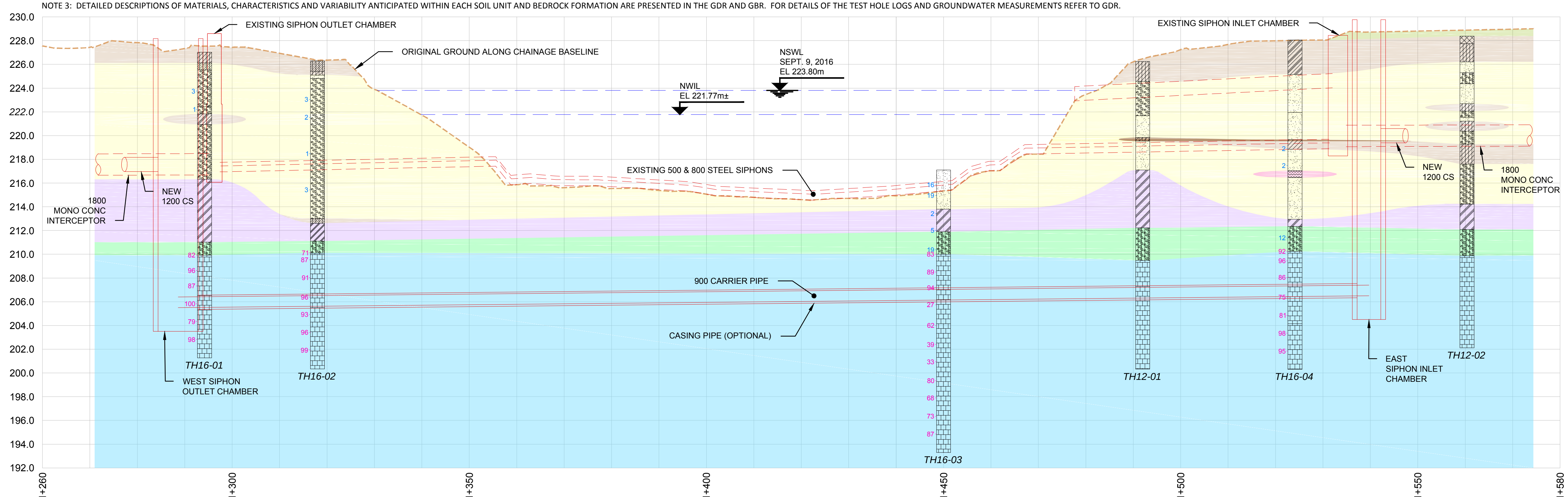
AECOM

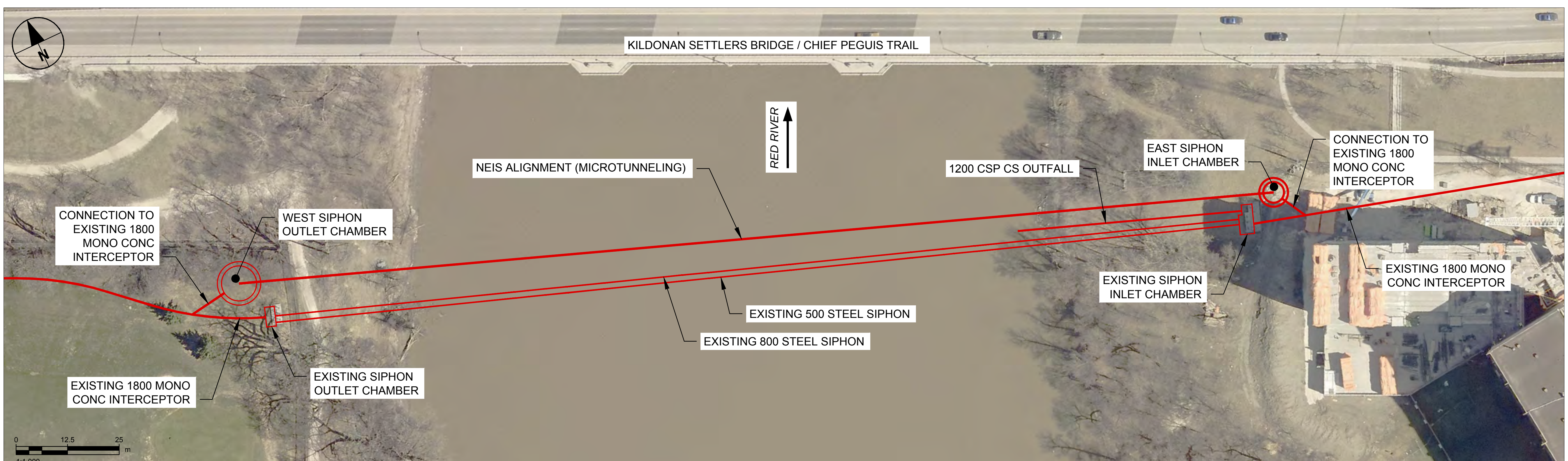
FIGURE: 3

## 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

FIGURE: 4

STRATIGRAPHIC SECTION OF NEIS ALIGNMENT

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

ANSI B 279.4mm x 431.8mm
Approved:
Checked:
Designer:
Project Management Initials:

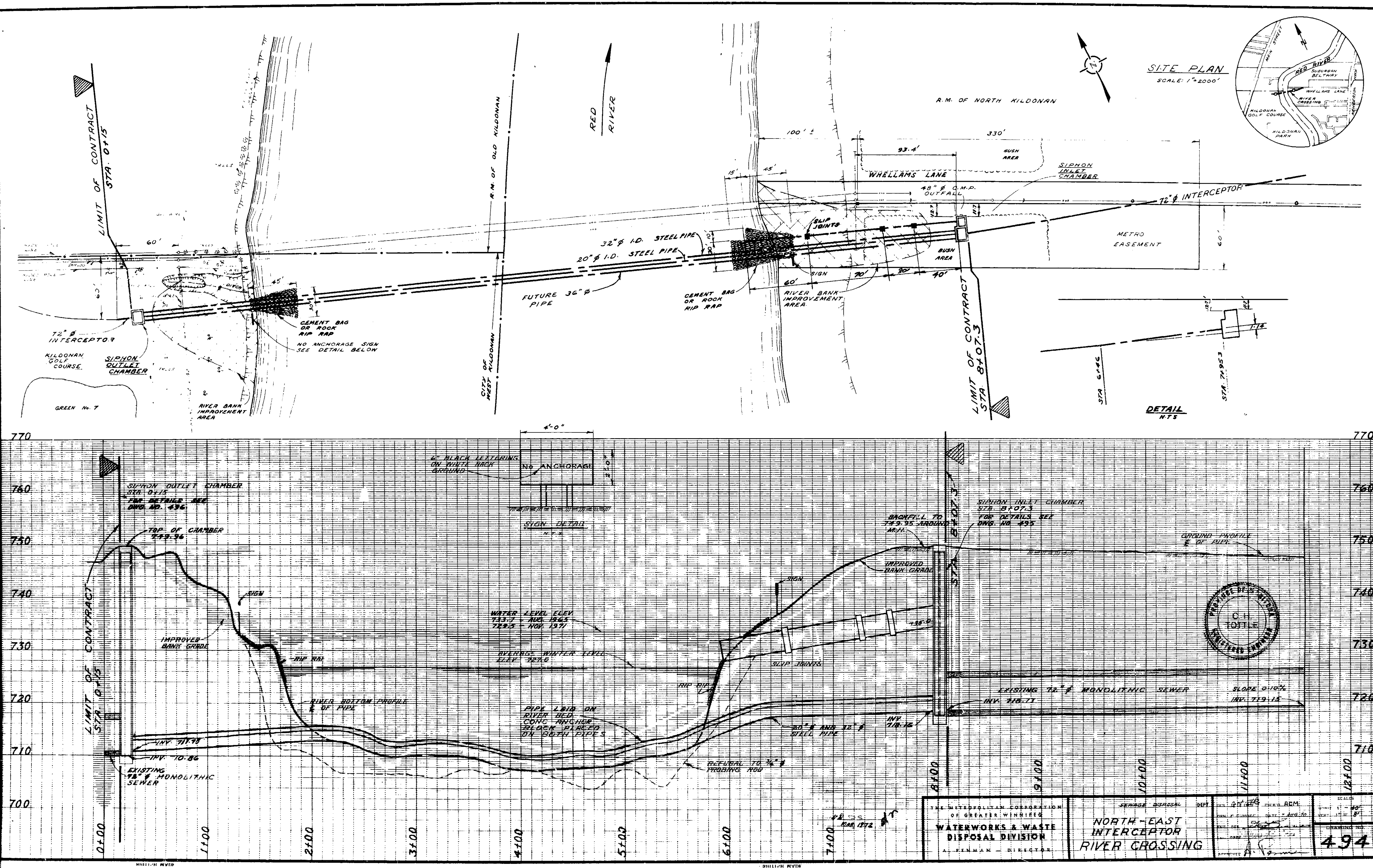
Last saved by: MAHEC(2018-03-22) Last Plotted: 2018-03-22
Filename: P:\60509089\900-WORK\910-CAD\25-SKETCHES\B\GEOTECHNICAL DATA REPORT\60509089-FIG-30-0000-B-1004.DWG

AECOM

# Appendix B

## Record Drawings

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


SITE PLAN
SCALE: 1" = 2000'
MAIN STREET
RED RIVER
SUBURBAN BELTWAY
WHELLAMS LANE
RIVER CROSSING
KILDONAN GOLF COURSE
KILDONAN PARK
R.M. OF NORTH KILDONAN
R.M. OF OLD KILDONAN
CITY OF WEST KILDONAN
RED RIVER
LIMIT OF CONTRACT STA. 0+15
LIMIT OF CONTRACT STA. 8+07.3
WHELLAMS LANE
48" ø C.M.P. OUTFALL
SIPHON INLET CHAMBER
72" ø INTERCEPTOR
METRO EASEMENT
BUSH AREA
SLIP JOINTS
32" ø I.D. STEEL PIPE
20" ø I.D. STEEL PIPE
FUTURE 36" ø PIPE
CEMENT BAG OR ROCK RIP RAP
NO ANCHORAGE SIGN SEE DETAIL BELOW
RIVER BANK IMPROVEMENT AREA
SIGN
72" ø INTERCEPTOR
KILDONAN GOLF COURSE
SIPHON OUTLET CHAMBER
GREEN No. 7
DITCH
DETAIL
N.T.S.
STA. 6+46
STA. 7+95.3
6" BLACK LETTERING ON WHITE BACK GROUND
NO ANCHORAGE
4'-0"
SIGN DETAIL
N.T.S.
SIPHON OUTLET CHAMBER STA. 0+15 FOR DETAILS SEE DWG. NO. 436
TOP OF CHAMBER 749.36
IMPROVED BANK GRADE
RIP RAP
RIVER BOTTOM PROFILE ℄ OF PIPE
WATER LEVEL ELEV. 733.7 – AUG. 1965 729.3 – NOV. 1971
AVERAGE WINTER LEVEL ELEV. 727.6
PIPE LAID ON RIVER BED CONC. ANCHOR BLOCK PLACED ON BOTH PIPES
REFUSAL TO 3/4" ø PROBING ROD
SLIP JOINTS
20" ø AND 32" ø STEEL PIPE
INV. 711.73
INV. 710.86
EXISTING 72" ø MONOLITHIC SEWER
BACKFILL TO 749.95 AROUND M.H.
SIPHON INLET CHAMBER STA. 8+07.3 FOR DETAILS SEE DWG. NO. 495
GROUND PROFILE ℄ OF PIPE
IMPROVED BANK GRADE
EXISTING 72" ø MONOLITHIC SEWER
SLOPE 0.10%
INV. 718.73
INV. 719.15
INV. 718.16
STA. 8+07.3
770
760
750
740
730
720
710
700
0+00
1+00
2+00
3+00
4+00
5+00
6+00
7+00
8+00
9+00
10+00
11+00
12+00
PROVINCE OF MANITOBA C.H. TOTTLE REGISTERED ENGINEER
THE METROPOLITAN CORPORATION OF GREATER WINNIPEG
WATERWORKS & WASTE DISPOSAL DIVISION
A. PENMAN – DIRECTOR
SEWAGE DISPOSAL DEPT.
NORTH-EAST INTERCEPTOR
RIVER CROSSING
DRAWING NO.
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

TREK GEOTECHNICAL

# Sub-Surface Log

| | | | |
|---|---|---|---|
| **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

Columns: Elevation (m) | Depth (m) | Soil Symbol | Standpipe | Standpipe | MATERIAL DESCRIPTION | Sample Type | Sample Number | RQD (%) | SPT (N) | Bulk Unit Wt (kN/m³) 16 17 18 19 20 21; Particle Size (%) 0 20 40 60 80 100; PL MC LL 0 20 40 60 80 100 | Undrained Shear Strength (kPa): Test Type △ Torvane △, ✿ Pocket Pen. ✿, ⊠ Qu ⊠, ○ Field Vane ○; 0 20 40 60 80 100

| Elevation (m) | Material Description |
|---|---|
| 227.36 (surface) | CLAY (FILL) - silty, trace gravel (<25mm), trace organics, trace silt inclusions (<20mm)<br>- brown<br>- moist, frozen to 1.1m, stiff when thawed<br>- high plasticity |
| 225.8 | CLAY (ALLUVIAL) - silty, some fine to medium grained sand, trace organics (roots)<br>- brown<br>- moist, stiff<br>- intermediate plasticity |
| 224.6 | SILT (ALLUVIAL) - trace clay to clayey, trace fine and medium grained sand, trace organics (roots)<br>- brown<br>- moist, very soft<br>- low to intermediate plasticity<br>- sandy and wet below 5.0 m<br>- soft below 6.6 m |
| 219.0 | SAND (ALLUVIAL) - silty, trace to some clay to 10.7m<br>- brown<br>- wet, loose<br>- no plasticity<br>- poorly graded, fine and medium grained sand<br>- no clay, some silt below 10.7 m |

Samples: G29, G30, G31, G32, G33, T34, G35, SB36A, SB36B, SB36C, SB37A, SB37B, SB37C, SB38A, SB38B, SB39, SB40

Depth scale (m): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

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

SUB-SURFACE LOG 0115 004 00 DETAILED DESIGN NORTH KILDONAN FEEDERMAIN - LOGS.GPJ TREK GEOTECHNICAL.GDT 15/1/14

TREK GEOTECHNICAL

# Sub-Surface Log

| Elevation (m) | Depth (m) | MATERIAL DESCRIPTION |
|---|---|---|
| 215.2 | | |
| | | CLAY (ALLUVIAL) - silty, some fine to medium grained sand, trace organics (roots)<br>- brown<br>- moist, stiff<br>- intermediate plasticity |
| 214.6 | | SAND (TILL) - trace silt, trace clay<br>- brown<br>- wet, loose<br>- no to low plasticity<br>- poorly graded, fine and medium grained sand<br><br>- dense below 14.6 m<br><br>- trace till inclusions (<20mm) below 15.7 m<br><br>- boulder at 16.7 m |
| 209.2 | 18 | DOLOMITE (BEDROCK)<br>- beige, vertical and horizontal, rough undulating fractures, slightly altered, clay infilling<br><br>- 0.1 m clay (rock flour) seams between 20.7 m and 20.8 m<br><br>- 0.2 m clay (rock flour) seams between 21.6 and 21.8 m<br>- yellowish fractured limestone between 21.8 to 24.3 m |
| 204.2 | 23 | MUDSTONE (BEDROCK)<br>- beige to brown, layered to varved, highly fractured with clay infill. |
| 203.0 | | DOLOMITIC MUDSTONE (BEDROCK)<br>- mottled light brown to grey, minor rough undulating sub vertical fractures. |

| Sample Number | RQD (%) | SPT (N) |
|---|---|---|
| T41 | | |
| SB42A | | |
| SB42B | | |
| SB43 | | |
| SS44 | | 29 |
| SS45B | | |
| SS45A | | 50 |
| CB56 | | |
| CB57 | 75 | |
| CB58 | 30 | |
| CB59 | 0 | |
| CB60 | 17 | |
| CB61 | 91 | |

Bulk Unit Wt (kN/m³): 16 17 18 19 20 21
Particle Size (%): 0 20 40 60 80 100
PL MC LL: 0 20 40 60 80 100

Undrained Shear Strength (kPa)
Test Type
△ Torvane △
✚ Pocket Pen. ✚
⊠ Qu ⊠
○ Field Vane ○
0 20 40 60 80 100

49100 ⊠

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

# Sub-Surface Log

TREK GEOTECHNICAL

| Elevation (m) | Depth (m) | MATERIAL DESCRIPTION | Sample Number | RQD (%) | Undrained Shear Strength (kPa) |
|---|---|---|---|---|---|
| | 26.8 | - chalk nodules at 26.8 m | CB62 | 96 | |
| | | | CB63 | 62 | |
| 198.1 | | DOLOMITIC LIMESTONE (BEDROCK) - beige to grey mottled, some chert nodules (grey) in a dolomitic limestone matrix (beige), vuggy. | CB64 | 73 | 31200 ⊠ |
| | | | CB65 | 35 | 21800 ⊠ |
| | | | CB66 | 31 | |
| | 33.5 | - 0.3 m thick highly fractured layer at 33.5 m | | | |
| | 34.7 | - fractures decreasing below 34.7 m | CB67 | 74 | 33100 ⊠ |
| 190.5 | | | CB68 | 94 | |

Column headings also include: Soil Symbol, Standpipe, Standpipe, Sample Type, SPT (N), Bulk Unit Wt (kN/m³) 16 17 18 19 20 21, Particle Size (%) 0 20 40 60 80 100, PL MC LL 0 20 40 60 80 100; Test Type: △ Torvane △, ✚ Pocket Pen. ✚, ⊠ Qu ⊠, ○ Field Vane ○ (0 20 40 60 80 100).

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.

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

# Sub-Surface Log

TREK GEOTECHNICAL

| | | | |
|---|---|---|---|
| **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

Columns: Elevation (m) | Depth (m) | Soil Symbol | Standpipe | MATERIAL DESCRIPTION | Sample Type | Sample Number | RQD (%) | SPT (N) | Bulk Unit Wt (kN/m³) 16 17 18 19 20 21; Particle Size (%) 0 20 40 60 80 100; PL MC LL 0 20 40 60 80 100 | Undrained Shear Strength (kPa) — Test Type: △ Torvane △, ✤ Pocket Pen. ✤, ⊠ Qu ⊠, ○ Field Vane ○; 0 20 40 60 80 100

| Elevation (m) | Depth (m) | Material Description | Sample Number |
|---|---|---|---|
| | 0 | CLAY (ALLUVIAL) - silty, some gravel, trace fine sand, trace to some organics (roots and rootlets)<br>- dark brown<br>- moist, very stiff<br>- high plasticity | G46, G47 |
| 225.7 | 1.5 | CLAY (LACUSTRINE) - silty to 2.4m, some gravel, trace fine sand, trace organics (roots and rootlets), trace oxidation<br>- dark brown, moist, soft to firm, high plasticity<br>- grey below 2.4 m<br>- trace silt inclusions (<15mm) and soft below 2.7 m<br>- firm to stiff, trace to some oxidation below 3.7 m<br>- trace coarse sand below 5.8 m<br>- trace gravel (<25mm) below 7.3 m<br>- trace to some silt inclusions (<15mm) below 7.9 m<br>- trace till inclusions (<75mm) below 10.4 m | G48, SB01, SB02, G49, T03, SB04, SB05, SB06, SB07, T08, SB09, SB10, SB11, SB12, T13, SB14, SB15, SB16, SB17 |



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

# Sub-Surface Log

TREK GEOTECHNICAL

| Elevation (m) | Depth (m) | MATERIAL DESCRIPTION | Sample Type | Sample Number | RQD (%) | SPT (N) |
|---|---|---|---|---|---|---|
| | | | | SB18 | | |
| | 13 | | | SB19 | | |
| | | | | SB20 | | |
| | 14 | - trace to some till inclusions below 14.0 m | | SB21 | | |
| 212.2 | 15 | | | SB22 | | |
| 211.8 | | SILT (TILL) - trace clay, trace gravel (<25mm), trace sand - light brown, moist, loose, low plasticity | | SS23 | | |
| 211.3 | | CLAY - silty, trace gravel - grey, moist, soft to firm, high plasticity | | | | |
| | 16 | SILT (TILL) - trace clay, trace gravel (<25mm), trace sand (poorly graded) - light brown, moist, loose, low plasticity - dense below 16.4 m | | SB24 | | |
| | | | | SB25 | | |
| 210.1 | 17 | DOLOMITE (BEDROCK) - beige, vertical and horizontal, rough undulating fractures, slightly altered, clay infilling | | CB26 | 86 | |
| | 18 | | | | | |
| | 19 | | | CB27 | 100 | |
| | 20 | | | | | |
| | 21 | | | CB28 | 100 | |
| 205.5 | | | | | | |

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

END OF TEST HOLE at 21.6 m in DOLOMITE (BEDROCK)
Notes:
1) Power auger refusal at 16.7 m.
2) No seepage or sloughing observed.
3) Water level at 4.2 m depth immediately after drilling prior to coring.
4) Test hole drilled using solid stem augers to 16.7 m then drill method switched to HQ coring.

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

# Sub-Surface Log

TREK GEOTECHNICAL

| | | | |
|---|---|---|---|
| **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$^3$) 16 17 18 19 20 21 / Particle Size (%) 0 20 40 60 80 100 / PL MC LL 0 20 40 60 80 100 | Undrained Shear Strength (kPa) Test Type: △ Torvane △, Pocket Pen., ⊠ Qu ⊠, ○ Field Vane ○ 0 20 40 60 80 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0–12 | | | - overburden soils not logged<br>- drilling advanced to power auger refusal then drilling method switched to HQ coring | | | | | | |

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

# Sub-Surface Log

| Elevation (m) | Depth (m) | MATERIAL DESCRIPTION | Sample Number | RQD (%) | Undrained Shear Strength (kPa) Qu |
|---|---|---|---|---|---|
| 210.1 | 16 | | | | |
| 210.0 | | SILT (TILL) - trace clay, trace sand, trace gravel - light grey, moist, loose, no to low plasticity | SS69 | | |
| | | DOLOMITE (BEDROCK) - beige, vertical and horizontal, rough undulating fractures, slightly altered, clay infilling | CB70 | 0 | |
| | | | CB71 | 38 | |
| 208.7 | | DOLOMITE (BEDROCK) - beige to light grey layering, massive, minor vugs, minor vertical and horizontal tight fractures | | | |
| | 19 | | CB72 | 73 | 39500 |
| | | | CB73 | 95 | |
| | | | CB74 | 83 | 39500 |
| | 23 | - visible hairline fractures between 22.9 m to 24.4 m | | | |
| | | | CB75 | 98 | |
| 201.9 | | DOLOMITE (BEDROCK) - beige layers with light brown mottled and cream coloured layers, massive, minor vertical and horizontal tight fractures | | | |
| | | | CB76 | 92 | |
| | | | CB77 | 75 | |

Column headers: Elevation (m); Depth (m); Soil Symbol; Standpipe; MATERIAL DESCRIPTION; Sample Type; Sample Number; RQD (%); SPT (N); Bulk Unit Wt (kN/m³) 16 17 18 19 20 21; Particle Size (%) 0 20 40 60 80 100; PL MC LL 0 20 40 60 80 100; Undrained Shear Strength (kPa) — Test Type: △ Torvane △, ✪ Pocket Pen. ✪, ⊠ Qu ⊠, ○ Field Vane ○; 0 20 40 60 80 100

Depth scale: 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26

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

TREK GEOTECHNICAL

# Sub-Surface Log

| Elevation (m) | Depth (m) | Soil Symbol | Standpipe | MATERIAL DESCRIPTION | Sample Type | Sample Number | RQD (%) | SPT (N) | Bulk Unit Wt (kN/m³) 16 17 18 19 20 21 / Particle Size (%) 0 20 40 60 80 100 / PL MC LL 0 20 40 60 80 100 | Undrained Shear Strength (kPa) Test Type: △ Torvane △, ✪ Pocket Pen. ✪, ⊠ Qu ⊠, ○ Field Vane ○ 0 20 40 60 80 100 |
|---|---|---|---|---|---|---|---|---|---|---|
| 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 | | | |
| | 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, subhorizonal fracturing. | | CB80 | 100 | | | |
| | 31 | | | | | CB81 | 100 | | | |
| | 32–33 | | | | | CB82 | 99 | | | |
| 191.2 | 34–35 | | | | | CB83 | 85 | | | |

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.

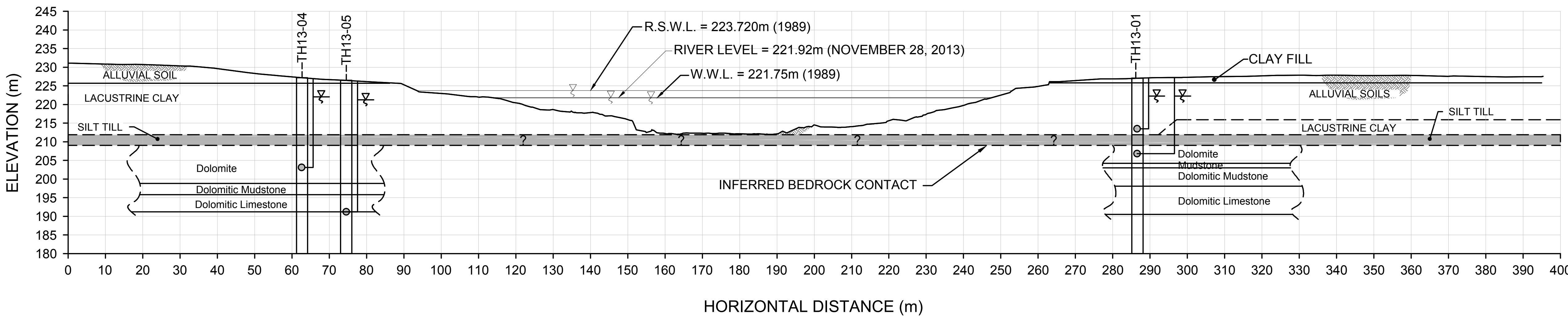
**Logged By:** Martial Lemoine **Reviewed By:** Nelson Ferreira **Project Engineer:** Nelson Ferreira

Tabloid (279mm x 432mm)

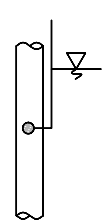
PLOT: 15/01/2014 12:11:52 PM

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

0 12.5 25 37.5 50m
SCALE : 1:1250 (279mm x 432mm)

Drawing 02
Inferred Soil and Bedrock Stratigraphy

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-01**

SHEET 1 of 3

| | | | |
|---|---|---|---|
| CLIENT | CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT | JOB NO. | 12-0107-018 |
| PROJECT | Chief Peguis Bridge Sewer Replacement | GROUND ELEV. | 226.37 |
| | | TOP OF PVC ELEV. | |
| SITE | East of Red River and South of Chief Peguis Trail | WATER ELEV. | |
| LOCATION | North of Existing Sewermain on the Lower Bank | DATE DRILLED | 11/7/2012 |
| DRILLING METHOD | Acker Track Drill Rig, 125 mm ø Solid Stem and HQ Core Barrel | UTM (m) | N 5,534,788<br>E 636,543 |

| ELEVATION (m) | DEPTH (m) (ft) | GRAPHICS | DESCRIPTION AND CLASSIFICATION | SAMPLE TYPE | NUMBER | RECOVERY % | SPT (N) blows/0.15 m ▲ / DYNAMIC CONE (N) blows/ft △ (20 40 60) | Cu POCKET PEN (kPa) ★ / Cu TORVANE (kPa) ◆ (20 40 60 80) / PL MC LL % (20 40 60 80) |
|---|---|---|---|---|---|---|---|---|
| | 0 | | SILTY CLAY - Brown, damp, firm, intermediate plasticity, trace rootlets, trace fine grained sand, trace fine grained gravel. | | | | | |
| | | | | Auger Grab | S1 | | | ● |
| | 1.68 | | SAND & GRAVEL - Light grey, moist, dense, medium to coarse grained sand, fine to coarse grained gravel, some clay.<br>- Hole squeezing at 1.83 m. | Auger Grab | S2 | | | ● |
| | | | | Auger Grab | S3 | | | ● |
| | 4.57 | | SAND - Brown, moist to wet, loose, fine to medium grained, trace oxidation.<br>- Water noticed on sample below 4.57 m<br>- Grey, no oxidation below 5.33 m. | Auger Grab | S4 | | | ● |
| | 6.40 | | SILTY CLAY - Grey, moist, firm, high plasticity. | Auger Grab | S5 | | | ● ◆ |
| | 6.71 | | SAND - Grey, moist, loose, medium grained, trace coarse grained sand.<br>- Some to with silt, reduced sand below 7.92 m | Auger Grab | S6 | | | ● |
| | 9.14 | | SILTY CLAY - Grey, moist, firm, high plasticity, trace silt nodules, trace medium grained sand, trace fine grained gravel. | | | | | ◆ |

SAMPLE TYPE: Auger Grab; Core Barrel

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-01**



| ELEVATION (m) | DEPTH (m) | DEPTH (ft) | DESCRIPTION AND CLASSIFICATION | SAMPLE TYPE | NUMBER | RECOVERY % |
|---|---|---|---|---|---|---|
| | | | - Stiff below 10.06 m. | Auger Grab | S7 | |
| | 11 | 35 | - Reduced fine grained gravel below 10.67 m. | | | |
| | | | - Grain Size Distribution: Gravel (1.2%), Sand (11.7%), Silt (30.5%), Clay (56.6%) at 11.58 m. | Auger Grab | S8 | |
| | 12 | 40 | - Reduced silt nodules below 12.50 m. | | | |
| | 13 | | - Firm below 12.95 m.<br>- Grain Size Distribution: Gravel (0.8%), Sand (10.2%), Silt (23.7%), Clay (65.3%) at 13.11 m. | Auger Grab | S9 | |
| | 14 | 45 | **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. | Auger Grab | S10 | |
| | 15, 16 | 50 | | Auger Grab | S11 | |
| | 17 | 55 | - Auger refusal at 18.76 m on bedrock. Switched over to core below 16.76 m.<br>**LIMESTONE BEDROCK** - White, fractured with vertical and horizontal fractures. | Core Barrel | R1 | 85 |
| | 18 | 60 | | Core Barrel | R2 | 98 |
| | 19 | | | Core Barrel | R3 | 100 |
| | 20 | 65 | - Clay seam at 19.69 m.<br>- Clay between 20.12 and 20.19 m. | | | |
| | 21 | 70 | - Yellow fractured limestone between 21.41 and 22.25 m. | Core Barrel | R4 | 100 |

SPT (N) blows/0.15 m ▲ — DYNAMIC CONE (N) blows/ft △ (20 40 60)

Cu POCKET PEN (kPa) ★ — Cu TORVANE (kPa) ◆ (20 40 60 80)

PL — MC — LL % (20 40 60 80)

SAMPLE TYPE: Auger Grab; Core Barrel

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-01**



| ELEVATION (m) | DEPTH (m) | DEPTH (ft) | GRAPHICS | DESCRIPTION AND CLASSIFICATION | SAMPLE TYPE | NUMBER | RECOVERY % | SPT (N) blows/0.15 m ▲ / DYNAMIC CONE (N) blows/ft △ (20 40 60) | Cu POCKET PEN (kPa) ★ / Cu TORVANE (kPa) ◆ (20 40 60 80) / PL MC LL % (20 40 60 80) |
|---|---|---|---|---|---|---|---|---|---|
| | 22 | | | - Reduced fractures below 22.25 m. | Core Barrel | R5 | 100 | | |
| | 23 | 75 | | | | | | | |
| | 24 | 80 | | | | R6 | 100 | | |
| | 25 | | | - Increased fractures below 24.69 m. | | R7 | 100 | | |
| | 26 | 85 | | **END OF TEST HOLE AT 25.91 m** | | | | | |
| | 27 | 90 | | Notes: 1. Water level measured at 15.70 m below grade after drilling. 2. Backfilled test hole with a thick bentonite grout mixture and bentonite chips. | | | | | |
| | 28 | | | | | | | | |
| | 29 | 95 | | | | | | | |
| | 30 | 100 | | | | | | | |
| | 31 | | | | | | | | |
| | 32 | 105 | | | | | | | |
| | 33 | 110 | | | | | | | |

SAMPLE TYPE: Auger Grab; Core Barrel

CONTRACTOR: Paddock Drilling Ltd.

INSPECTOR: C. FRIESEN

APPROVED: DRAFT

DATE: 11/26/12

**KGS GROUP**

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-02**



| | | | |
|---|---|---|---|
| CLIENT | CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT | JOB NO. | 12-0107-018 |
| PROJECT | Chief Peguis Bridge Sewer Replacement | GROUND ELEV. | 228.37 |
| | | TOP OF PVC ELEV. | |
| SITE | East of Red River and South of Chief Peguis Trail | WATER ELEV. | |
| LOCATION | South of Existing Sewermain on the Upper Bank | DATE DRILLED | 11/8/2012 |
| DRILLING METHOD | Acker Track Drill Rig, 125 mm ø Solid Stem and HQ Core Barrel | UTM (m) | N 5,534,757<br>E 636,604 |

Column headings: 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 △ (20 40 60) | Cu POCKET PEN (kPa) ★; Cu TORVANE (kPa) ◆ (20 40 60 80); PL MC LL % (20 40 60 80)

| Depth (m) | Description and Classification | Sample |
|---|---|---|
| 0.00 | **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 |
| | **SILTY CLAY** - Brown, moist, stiff, high plasticity, trace fine to medium grained sand. | |
| | - Increased sand content below 1.83 m. | |
| | **SAND** - Brown, moist, compact, fine to medium grained, trace coarse grained sand, trace silt, trace clay. | S2 |
| | **SILTY SAND** - Brown, moist, loose, fine to medium grained, with silt, trace clay. | S3 |
| | **SAND** - Brown, moist, compact, fine to medium grained, trace silt. | S4 |
| | - Water noticed on sample at ~ 5.49 m. | |
| | **SANDY SILT** - Brown, moist, firm, intermediate to high plasticity, trace oxidation | |
| | **SILTY SAND** - Brown, moist, soft, fine to medium grained, trace oxidation. | S5 |
| | - Grey, no oxidation below 6.71 m. | |
| | **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. | |
| | **SILTY SAND** - Grey, moist, soft, fine to medium grained sand, with silt | S6 |
| | - Organic layer between 8.53 and 8.64 m. | |
| | **SILTY CLAY** - Grey, moist, firm, high plasticity, trace fine grained sand | |
| | - Increased sand between 9.75 and 9.96 m. | S7 |

SAMPLE TYPE: Auger Grab | Split Spoon | Core Barrel

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. TH12-02



| 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 △ 20 40 60 | Cu POCKET PEN (kPa) ★ Cu TORVANE (kPa) ◆ 20 40 60 80; PL MC LL % 20 40 60 80 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | - 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. | | | Auger Grab | S8 | | | |
| | | | - 25 mm thick organic layer at 12.50 m. | | | | | | | |
| | | | - Decreased sand between 12.95 and 13.26 m. | | | Auger Grab | S9 | | | |
| | | | **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. | | | Auger Grab | S10 | | | |
| | | | **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. | | | Auger Grab | S11 | | | |
| | | | | | | Split Spoon | S12 | 100 | 2, 4, 4 | |
| | | | | | | Auger Grab | S13 | | | |
| | | | - Auger refusal at 18.34 m on bedrock. Switched over to core below 18.34 m. | | | | | | | |
| | | | **LIMESTONE BEDROCK** - White, competent, vertical and horizontal fractures. | | | Core Barrel | R1 | 98 | | |
| | | | | | | Core Barrel | R2 | 98 | | |

Elevation (m): 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21. Depth (ft): 35, 40, 45, 50, 55, 60, 65, 70.

SAMPLE TYPE: Auger Grab; Split Spoon; Core Barrel

CONTRACTOR: Paddock Drilling Ltd. | INSPECTOR: C. FRIESEN | APPROVED: DRAFT | DATE: 11/26/12

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-02**



| ELEVATION (m) | DEPTH (m) | DEPTH (ft) | DESCRIPTION AND CLASSIFICATION | DEPTH (m) | SAMPLE TYPE | NUMBER | RECOVERY % |
|---|---|---|---|---|---|---|---|
| | 22 | | | 22.2 | Core Barrel | R3 | 98 |
| | 23 | 75 | - Increased fractures below 22.54 m.<br>- Vertical fracture between 23.01 and 23.67 m. | | | | |
| | 24 | 80 | | | Core Barrel | R4 | 100 |
| | 25 | | | | Core Barrel | R5 | 100 |
| | | | | 25.8 | | | |
| | 26 | 85 | END OF TEST HOLE AT 26.06 m | 26.1 | | | |
| | 27 | 90 | Notes:<br>1. Installed casagrande standpipe at a depth of 26.06 m with a stick-up of 0.64 m<br>2. Backfilled test hole with silica sand between 26.06 and 22.17 m and bentonite chips from 22.17 m to grade. | | | | |
| | 28 | | | | | | |
| | 29 | 95 | | | | | |
| | 30 | 100 | | | | | |
| | 31 | | | | | | |
| | 32 | 105 | | | | | |
| | 33 | 110 | | | | | |

Column headings also include: GRAPHICS; PIEZ. LOG; SPT (N) blows/0.15 m ▲; DYNAMIC CONE (N) blows/ft △ (20 40 60); Cu POCKET PEN (kPa) ★; Cu TORVANE (kPa) ◆ (20 40 60 80); PL MC LL % (20 40 60 80)

SAMPLE TYPE: Auger Grab; Split Spoon; Core Barrel

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

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-02B**

SHEET 1 of 2

| | | | |
|---|---|---|---|
| CLIENT | CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT | JOB NO. | 12-0107-018 |
| PROJECT | Chief Peguis Bridge Sewer Replacement | GROUND ELEV. | |
| | | TOP OF PVC ELEV. | |
| SITE | East of Red River and South of Chief Peguis Trail | WATER ELEV. | |
| LOCATION | ~3 m West of TH12-02 | DATE DRILLED | 11/9/2012 |
| | | UTM (m) | N |
| DRILLING METHOD | Acker Track Drill Rig, 125 mm ø Solid Stem | | E |

Column headings: 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 △ (20 40 60) | Cu POCKET PEN (kPa) ★; Cu TORVANE (kPa) ◆ (20 40 60 80); PL MC LL % (20 40 60 80)

| Depth (m) | Description and Classification |
|---|---|
| 0 – ~0.6 | **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. |
| ~0.6 – ~2.1 | **SILTY CLAY** - Brown, moist, stiff, high plasticity, trace fine to medium grained sand.<br>- Increased sand content below 1.83 m. |
| ~2.1 – ~3.0 | **SAND** - Brown, moist, compact, fine to medium grained, trace coarse grained sand, trace silt, trace clay. |
| ~3.0 – ~4.0 | **SILTY SAND** - Brown, moist, loose, fine to medium grained, with silt, trace clay. |
| ~4.0 – ~5.6 | **SAND** - Brown, moist, compact, fine to medium grained, trace silt.<br>- Water noticed on sample at ~ 5.49 m. |
| ~5.6 – ~6.2 | **SANDY SILT** - Brown, moist, firm, intermediate to high plasticity, trace oxidation. |
| ~6.2 – ~6.7 | **SILTY SAND** - Brown, moist, soft, fine to medium grained, trace oxidation.<br>- Grey, no oxidation below 6.71 m. |
| ~6.7 – ~7.0 | **SAND** - Grey, moist, compact, medium grained, some fine and coarse grained sand. |
| ~7.0 – ~7.9 | **SILTY CLAY** - Grey, moist, firm, high plasticity.<br>- Medium grained sand layer between 7.39 and 7.47 m. |
| ~7.9 – ~9.0 | **SILTY SAND** - Grey, moist, soft, fine to medium grained sand, with silt.<br>- Organic layer between 8.53 and 8.64 m. |
| ~9.0 – | **SILTY CLAY** - Grey, moist, firm, high plasticity, trace fine grained sand.<br>- Increased sand between 9.75 and 9.96 m. |

SAMPLE TYPE

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-02B**



| ELEVATION (m) | DEPTH (m) (ft) | DESCRIPTION AND CLASSIFICATION | PIEZ. LOG DEPTH (m) |
|---|---|---|---|
| | | · Increased sand between 10.36 and 10.52 m. | |
| | 35 | SILTY SAND - Grey, moist, compact, medium grained, trace fine grained sand, trace clay. · Test hole squeezing at 10.67 m. | 11.4 / 11.6 |
| | 40 | · 25 mm thick organic layer at 12.50 m. · Decreased sand between 12.95 and 13.26 m. | |
| | 45 | SILTY CLAY - Grey, moist, firm, high plasticity, trace coarse grained sand, trace fine grained gravel, trace silt nodules. | |
| | 50–55 | 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. | 16.8 / 17.4 / 17.7 / 18.3 |
| | 60 | AUGER REFUSAL AT 18.34 m | |

Depth scale (m): 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21; (ft): 35, 40, 45, 50, 55, 60, 65, 70

Column headings: SAMPLE TYPE, NUMBER, RECOVERY %, SPT (N) blows/0.15 m ▲, DYNAMIC CONE (N) blows/ft △ (20 40 60), Cu POCKET PEN (kPa) ★, Cu TORVANE (kPa) ◆ (20 40 60 80), PL MC LL % (20 40 60 80)

Notes:
1. Stratigraphy assumed from TH12-02 drilled ~3 m away.
2. Installed casagrande standpipe at a depth of 17.68 m with a stick-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.

SAMPLE TYPE

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-03**

SHEET 1 of 3

| | | | |
|---|---|---|---|
| CLIENT | CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT | JOB NO. | 12-0107-018 |
| PROJECT | Chief Peguis Bridge Sewer Replacement | GROUND ELEV. | 230.84 |
| | | TOP OF PVC ELEV. | |
| SITE | West of Red River and South of Chief Peguis Trail | WATER ELEV. | |
| LOCATION | North of Existing Sewermain on the Upper Bank | DATE DRILLED | 11/13/2012 |
| DRILLING METHOD | CME Track Drill Rig, 125 mm ø Solid Stem and HQ Core Barrel | UTM (m) | N 5,534,926<br>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 △ (20 40 60) | Cu POCKET PEN (kPa) ★ / Cu TORVANE (kPa) ◆ (20 40 60 80) / PL MC LL % (20 40 60 80) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | | **SILTY CLAY FILL** - Black, moist, stiff, high plasticity, trace rootlets.<br>- Trace medium to coarse grained sand, trace fine to coarse grained gravel below 0.23 m. | | | | | | | |
| | | | **SILTY CLAY** - Brown, moist, stiff, high plasticity, trace coarse grained sand.<br>- No sand below 1.22 m. | | | Auger Grab | S1 | | | |
| | 2 | | **SILTY SAND TO SANDY SILT** - Light brown, moist, soft/loose, fine grained sand. | | | Auger Grab | S2 | | | |
| | 3.4 | | **SILTY CLAY** - Brown, moist, stiff, high plasticity, trace silt nodules (~1-3 mm diameter).<br>- 10 mm diameter gravel piece at 3.73 m. | | | Auger Grab | S3 | | | |
| | | | - Grey below 5.49 m. | | | Auger Grab | S4 | | | |
| | | | - Firm below 6.10 m. | | | Auger Grab | S5 | | | |
| | | | | | | Auger Grab | S6 | | | |
| | | | - Slightly increased silt nodules (up to 5 mm diameter) below 9.14 m. | | | | | | | |

SAMPLE TYPE: Auger Grab, Split Spoon, Core Barrel

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. TH12-03



| ELEVATION (m) | DEPTH (m) | DEPTH (ft) | DESCRIPTION AND CLASSIFICATION | DEPTH (m) | SAMPLE TYPE / NUMBER | RECOVERY % |
|---|---|---|---|---|---|---|
| | | | | | S7 | |
| | 11 | 35 | | | | |
| | | | | | S8 | |
| | 12 | 40 | - Trace silt pockets below 12.19 m.<br>- Trace fine grained gravel below 12.50 m. | | | |
| | 13 | | | | S9 | |
| | 14 | 45 | | | | |
| | | | | | S10 | |
| | 15 | 50 | - Reduced silt, trace coarse grained sand, no fine grained gravel below 15.24 m. | | | |
| | 16 | | | | S11 | |
| | 17 | 55 | - Occasional silt pockets/nodules below 16.92 m. | | | |
| | 18 | | - Grain Size Distribution: Gravel (0.7%), Sand (7.5%), Silt (19.4%), Clay (72.4%) at 17.68 m. | | S12 | |
| | | 60 | - Trace fine grained gravel below 18.29 m. | | | |
| | 19 | | **SILT TILL** - Tan with grey, moist, compact, fine to coarse grained sand, fine grained gravel, trace clay. | | S13 | |
| | 20 | 65 | | | S14 | 61 |
| | 21 | | - Auger refusal at 21.03 m on bedrock. Switched over to core below 21.03 m. | 21.0 | S15 | |
| | | 70 | **LIMESTONE BEDROCK** - White, competent, horizontal fractures. | | R1 | 88 |

SPT (N) blows/0.15 m ▲ — DYNAMIC CONE (N) blows/ft △ (20, 40, 60): S14: 11, 11, 3

Cu POCKET PEN (kPa) ★ — Cu TORVANE (kPa) ◆ (20, 40, 60, 80); PL — MC — LL (%) (20, 40, 60, 80)

PIEZ. LOG

SAMPLE TYPE: Auger Grab; Split Spoon; Core Barrel

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-03**



| 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 △ (20 40 60) | Cu POCKET PEN (kPa) ★ / Cu TORVANE (kPa) ◆ (20 40 60 80) / PL MC LL % (20 40 60 80) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 22 | | - Thin clay seam at 21.77 m.<br>- Vertical fracture between 21.84 and 22.05 m. | | | | R2 | 100 | | |
| | 23 (75) | | | | | | R3 | 97 | | |
| | 24 | | | | 23.0 | | | | | |
| | 25 (80) | | | | | | R4 | 100 | | |
| | 26 (85) | | | | | | | | | |
| | 27 | | | | | | R5 | 97 | | |
| | 28 (90) | | | | 27.6 | | R6 | 100 | | |
| | 29 (95) | | - Rubble zone between 28.46 and 28.52 m.<br>- Vertical fracture between 28.52 and 28.70 m. | | | | | | | |
| | 30 | | | | 29.7 | | R7 | 100 | | |
| | | | **END OF TEST HOLE AT 30.02 m** | | 30.0 | | | | | |
| | 31 (100) | | Notes:<br>1. Installed casagrande standpipe at a depth of 30.02 m with a stick-up of 0.91 m.<br>2. Backfilled test hole with silica sand between 30.02 and 27.58 m, bentonite chips from 27.58 to 23.93 m, slough from 23.93 to 21.03 m and bentonite chips from 21.03 m to grade. | | | | | | | |
| | 32 (105) | | | | | | | | | |
| | 33 (110) | | | | | | | | | |

SAMPLE TYPE: Auger Grab; Split Spoon; Core Barrel

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-03B**

SHEET 1 of 3

| | | | |
|---|---|---|---|
| CLIENT | CITY OF WINNIPEG - WATER AND WASTE DEPARTMENT | JOB NO. | 12-0107-018 |
| PROJECT | Chief Peguis Bridge Sewer Replacement | GROUND ELEV. | |
| | | TOP OF PVC ELEV. | |
| SITE | West of Red River and South of Chief Peguis Trail | WATER ELEV. | |
| LOCATION | ~2 m West of TH12-03 | DATE DRILLED | 11/14/2012 |
| DRILLING METHOD | CME Track Drill Rig, 125 mm ø Solid Stem | UTM (m) | N<br>E |

Column headings: 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 △ (20 40 60) | Cu POCKET PEN (kPa) ★ / Cu TORVANE (kPa) ◆ (20 40 60 80) / PL MC LL % (20 40 60 80)

Depth scale (m): 1, 2, 3, 4, 5, 6, 7, 8, 9; (ft): 5, 10, 15, 20, 25, 30

**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.

**SILTY CLAY** - Brown, moist, stiff, high plasticity, trace coarse grained sand.
- No sand below 1.22 m.

**SILTY SAND TO SANDY SILT** - Light brown, moist, soft/loose, fine grained sand.

**SILTY CLAY** - Brown, moist, stiff, high plasticity, trace silt nodules (~1-3 mm diameter).
- 10 mm diameter gravel piece at 3.73 m.
- Grey below 5.49 m.
- Firm below 6.10 m.
- Slightly increased silt nodules (up to 5 mm diameter) below 9.14 m

SAMPLE TYPE

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

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

**KGS GROUP**

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-03B**



| ELEVATION (m) | DEPTH (m) | DEPTH (ft) | DESCRIPTION AND CLASSIFICATION | PIEZ. LOG DEPTH (m) |
|---|---|---|---|---|
| | | 35 | | |
| | 11 | | | 11.6 |
| | | | | 11.8 |
| | 12 | 40 | - Trace silt pockets below 12.19 m. | |
| | | | - Trace fine grained gravel below 12.50 m. | |
| | 13 | | | |
| | | 45 | | |
| | 14 | | | |
| | 15 | 50 | - Reduced silt, trace coarse grained sand, no fine grained gravel below 15.24 m. | |
| | 16 | | | |
| | | 55 | | |
| | 17 | | - Ocassional silt pockets/nodules below 16.92 m. | |
| | 18 | 60 | - Trace fine grained gravel below 18.29 m. | |
| | 19 | | SILT TILL - Tan with grey, moist, compact, fine to coarse grained sand, fine grained gravel, trace clay. | |
| | | 65 | | |
| | 20 | | | 20.1 |
| | | | | 20.7 |
| | 21 | | AUGER REFUSAL AT 20.98 m | 21.0 |
| | | 70 | Notes:<br>1. Stratigraphy assumed from TH12-03 drilled ~2 m away. | |

Other columns: SAMPLE TYPE, NUMBER, RECOVERY %; SPT (N) blows/0.15 m ▲; DYNAMIC CONE (N) blows/ft △ (20 40 60); Cu POCKET PEN (kPa) ★; Cu TORVANE (kPa) ◆ (20 40 60 80); PL MC LL % (20 40 60 80)

SAMPLE TYPE

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

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

KGS GROUP

# SUMMARY LOG

REFERENCE NO.

HOLE NO. **TH12-03B**



| ELEVATION (m) | DEPTH (m) | DEPTH (ft) | GRAPHICS | DESCRIPTION AND CLASSIFICATION | PIEZ LOG | DEPTH (m) | SAMPLE TYPE | NUMBER | RECOVERY % | SPT (N) blows/0.15 m ▲ / DYNAMIC CONE (N) blows/ft △ (20 40 60) | Cu POCKET PEN (kPa) ★ / Cu TORVANE (kPa) ◆ (20 40 60 80); PL MC LL % (20 40 60 80) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 22 – 33 | 75 – 110 | | 2. Installed casagrande standpipe at a depth of 20.98 m with a stick-up of 0.66 m.<br>3. Installed PN 034985 at a depth of 11.64 m. below grade.<br>4. Backfilled test hole with silica sand between 20.98 and 20.12 m and bentonite chips from 20.12 m to grade.<br>5. Test hole squeezing at 8.53 m shortly after drilling. | | | | | | | |

SAMPLE TYPE

| CONTRACTOR | INSPECTOR | APPROVED | DATE |
|---|---|---|---|
| Paddock Drilling Ltd. | C. FRIESEN | DRAFT | 11/26/12 |

GEOTECHNICAL SOIL LOG P:\PROJECTS\2012\12-0107-013\DESIGN\GEOLOGS\CHIEF PEGUIS TRAIL SEWERMAIN.GPJ

**DYREGROV & BURGESS**

# BOREHOLE LOG

**PROJECT** Kildonan Corridor

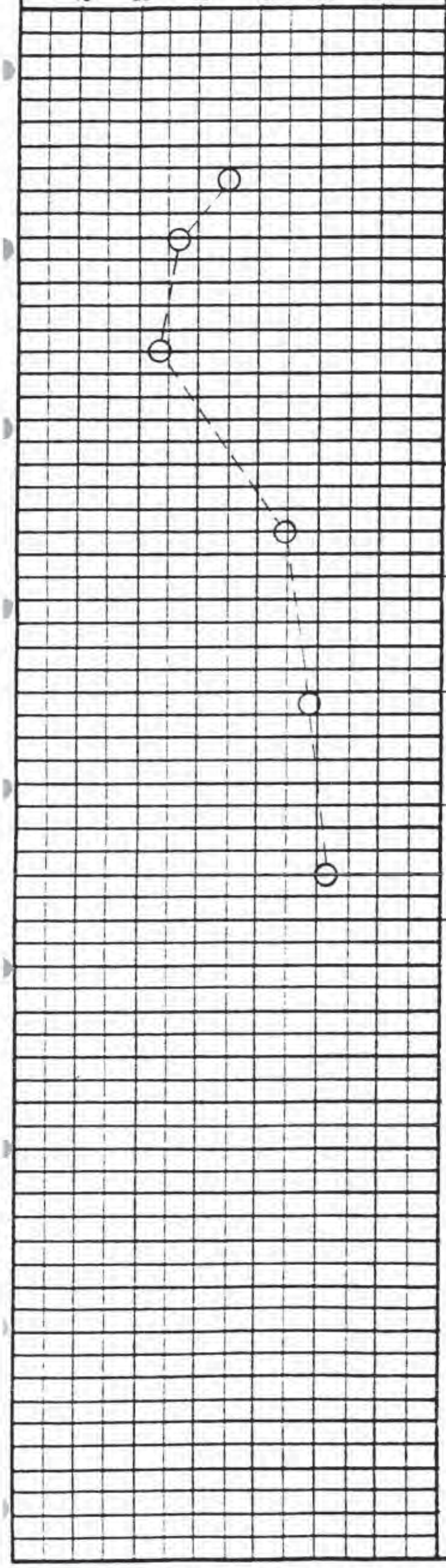
| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 6/08/87 | 87422 | 1 |

**DATUM** Geodetic

**SURFACE ELEVATION** 230.63 m

**DRILL TYPE** 450 & 500 mm Augers

**WATER CONTENT** — Wp - □  W - ○  WL - △ — PERCENT % (10, 20, 30, 40, 50, 60)



| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 0 | Fill | | | | |
| | Clay -black | | | | |
| 1 | Clay -silty<br>-brown<br>-stiff<br>-alluvial | | | | |
| 2 | Silt -tan<br>-wet to saturated<br>-firm | | | | |
| 3–4 | Clay -mottled brown<br>-highly plastic<br>-stiff<br>-lacustrine | | | | |
| 6–7 | | | U | | qu=109.7kpa<br>$\gamma_w$=16.48kn/m$^3$<br>pp=146.0kpa<br>Tv=84.7kpa |
| 8 | End hole at 7.6 m.<br>Seepage and caving from 2.4 to 2.7 m. | | | | |

Plate A-2

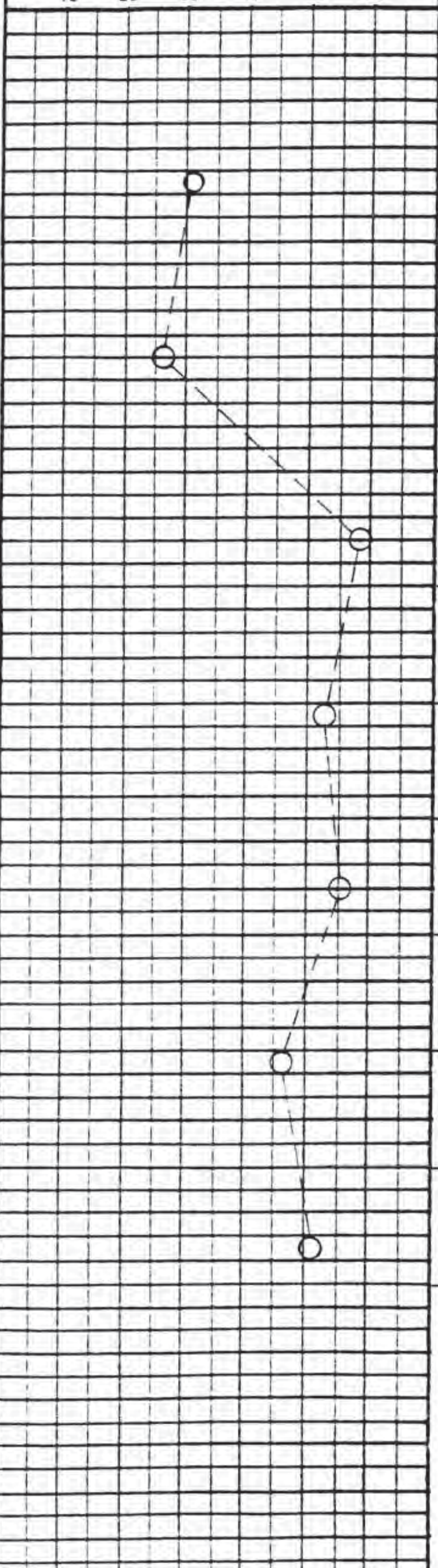
# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: Kildonan Corridor

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

WATER CONTENT — $W_P$ - □ W - ○ $W_L$ - △ PERCENT % (10 20 30 40 50 60)



DATUM: Geodetic

SURFACE ELEVATION: 230.91 m

DRILL TYPE: 450 &500 mm Augers

| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE TYPE | OTHER TESTS |
|---|---|---|---|
| 0 | Fill -clay, silt, some gravel | | |
| 1 | Clay -black | | |
| | Clay -silty -brown -stiff | | |
| 3 | Silt -tan -saturated | | |
| 4 | Clay -mottled brown -highly plastic -firm to stiff -lacustine | | |
| 5 | | U | qu=47.2kpa<br>$\gamma_w$=16.51kn/m$^3$<br>pp=93.4kpa<br>Tv=81.2kpa |
| 8 | --- grey | U | qu=150.1kpa<br>$\gamma_w$=16.85kn/m$^3$<br>pp=125.4kpa<br>Tv=77.8kpa |
| 11 | End hole at 10.7 m.<br>Seepage and caving from silt layer. | U | qu=131.8kpa<br>$\gamma_w$=17.60kn/m$^3$<br>pp=117.8kpa<br>Tv=60.3kpa |

Plate A-3

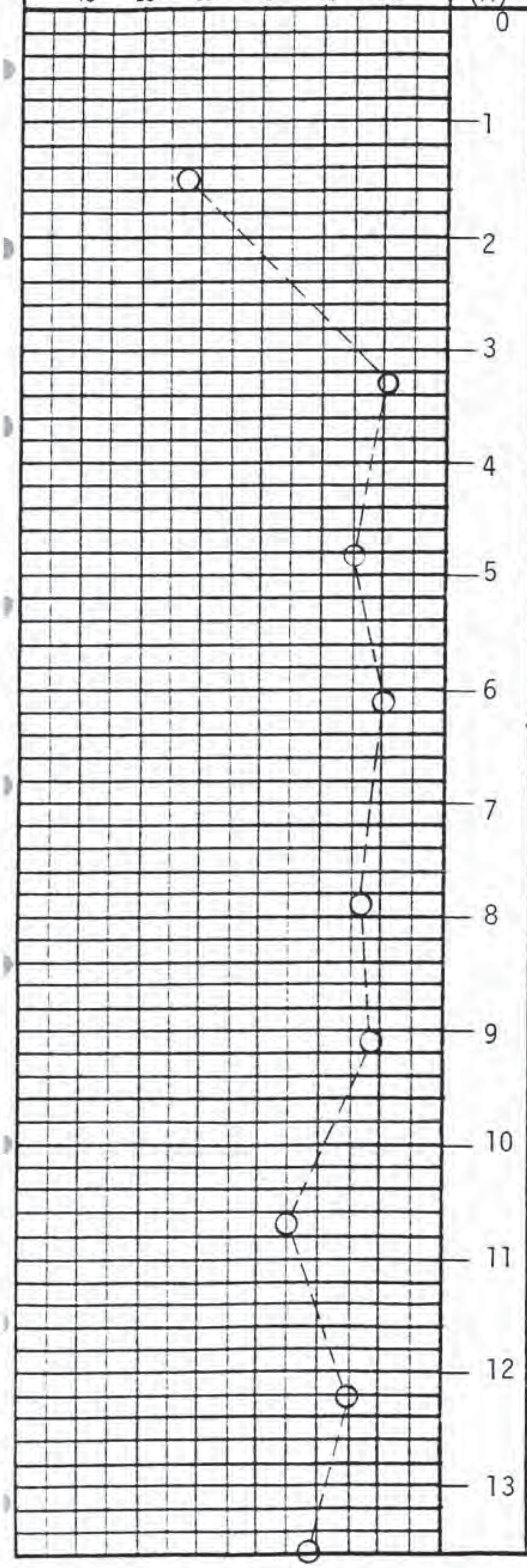
**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: Kildonan Corridor

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

WATER CONTENT — Wp - □ W - ○ WL - Δ. PERCENT % (10, 20, 30, 40, 50, 60)



DATUM: Geodetic

SURFACE ELEVATION: 230.58 m

DRILL TYPE: 500 mm Auger

| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE TYPE | OTHER TESTS |
|---|---|---|---|
| 0 | Topsoil | | |
| 0–2.2 | Clay -silty -brown -stiff | | |
| 2.2–3.0 | Silt -tan -wet to saturated | | |
| 3.0 | Clay -mottled brown -highly plastic -stiff to firm -lacustrine | U | qu=57.4kpa<br>$\gamma_w$=16.40kn/m$^3$<br>pp=132.9kpa<br>Tv=71.3kpa |
| 5.5 | — — —grey | | |
| 6 | | U | qu=117.3kpa<br>$\gamma_w$=16.27kn/m$^3$<br>pp=119.7kpa<br>Tv=74.7kpa |
| 9 | | U | qu=148.5kpa<br>$\gamma_w$=16.81kn/m$^3$<br>pp=95.8kpa<br>Tv=60.6kpa |
| 12 | | | qu=147.3kpa<br>$\gamma_w$=16.58kn/m$^3$<br>pp=68.9kpa<br>Tv=54.6kpa |
| 13.7 | End of hole at 13.7 m in clay. | U | |

Plate A-4

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: Kildonan Corridor

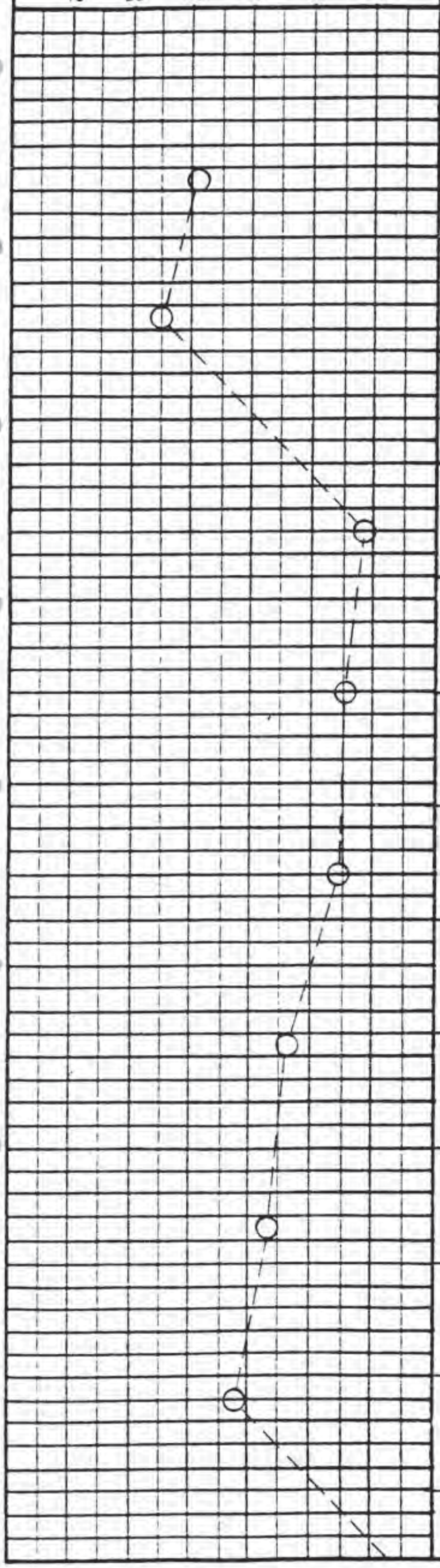
| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 6/08/87 | 87422 | 4 |

WATER CONTENT: Wp - □  W - ○  WL - △. PERCENT % (10, 20, 30, 40, 50, 60)

DATUM: Geodetic

SURFACE ELEVATION: 230.64 m

DRILL TYPE: 450 & 500 mm Augers



| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE TYPE | OTHER TESTS |
|---|---|---|---|
| 0 – 1.2 | Fill -clay -concrete rubble | | |
| 1.2 – 2.0 | Clay -silty -brown | | |
| 2.0 – 3.0 | Silt -tan -wet to saturated | | |
| 3.0 – 13.5 | Clay -mottled brown -highly plastic -stiff to firm -lacustrine | | |
| ~4.8 | | U | $\gamma_w$=16.30kn/m$^3$ pp=108.9kpa Tv=57.4kpa |
| ~6.7 | - - -grey | | |
| ~7.8 | | U | qu=135.1kpa $\gamma_w$=17.00kn/m$^3$ pp=147.5kpa Tv=72.8kpa |
| ~10.9 | | U | qu=106.7kpa $\gamma_w$=16.72kn/m$^3$ pp=93.8kpa Tv=56.0kpa |

Plate A-5

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: Kildonan Corridor

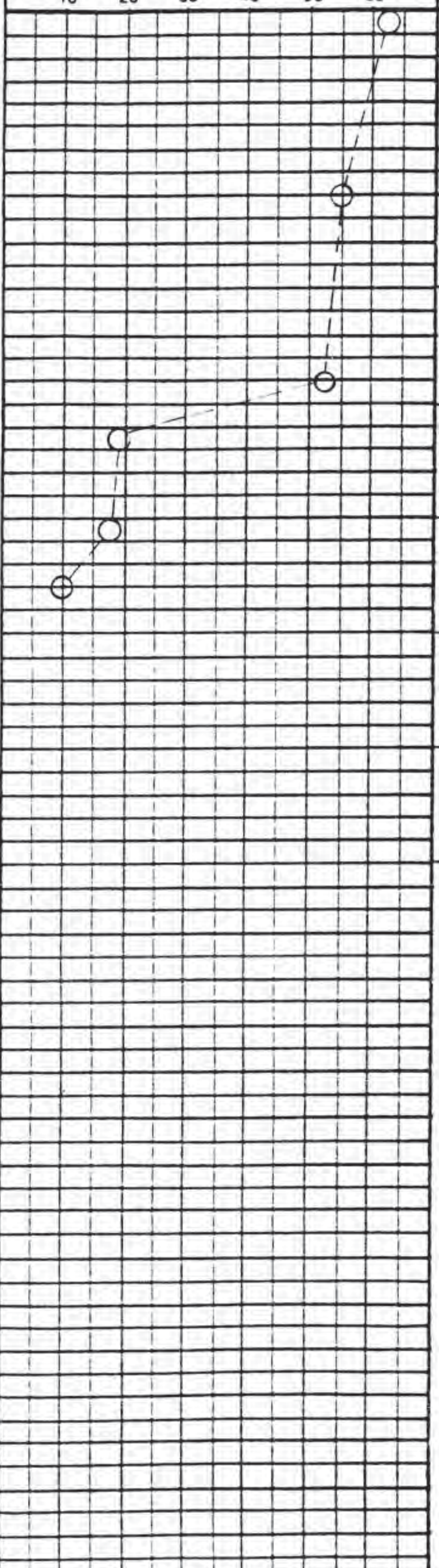
| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 6/08/87 | 87422 | 4 |

DRILL TYPE: 450 & 500 mm Augers

DATUM: Geodetic

SURFACE ELEVATION: 230.64 m

WATER CONTENT: Wp - □  W - ○  WL - Δ  PERCENT %  (10, 20, 30, 40, 50, 60)



| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE TYPE | OTHER TESTS |
|---|---|---|---|
| 14–18 | Clay -grey<br>-highly plastic<br>-lacustrine | U | qu=68.2kpa<br>$\gamma_w$=16.04kn/m$^3$<br>pp=94.2kpa<br>Tv=47.4kpa |
| | | | qu=128.4kpa<br>$\gamma_w$=16.51kn/m$^3$<br>pp=81.4kpa<br>Tv=43.6kpa |
| 18–20.4 | Silt (Glacial Till)<br>-sandy, gravelly<br>-wet<br>-loose to 19.5 m<br>-medium dense below 19.5 m | | |
| 20.4 | End of hole at 20.4 m.<br>-Smooth auger refusal<br>-Possible bedrock at 20.4 m<br>-Water inflow from 20.4 m<br>-Water level stabilized at 9.4 m in about 15 minutes | | |

Plate A-6

# BOREHOLE LOG

**DYREGROV & BURGESS**

**PROJECT** Kildonan Corridor

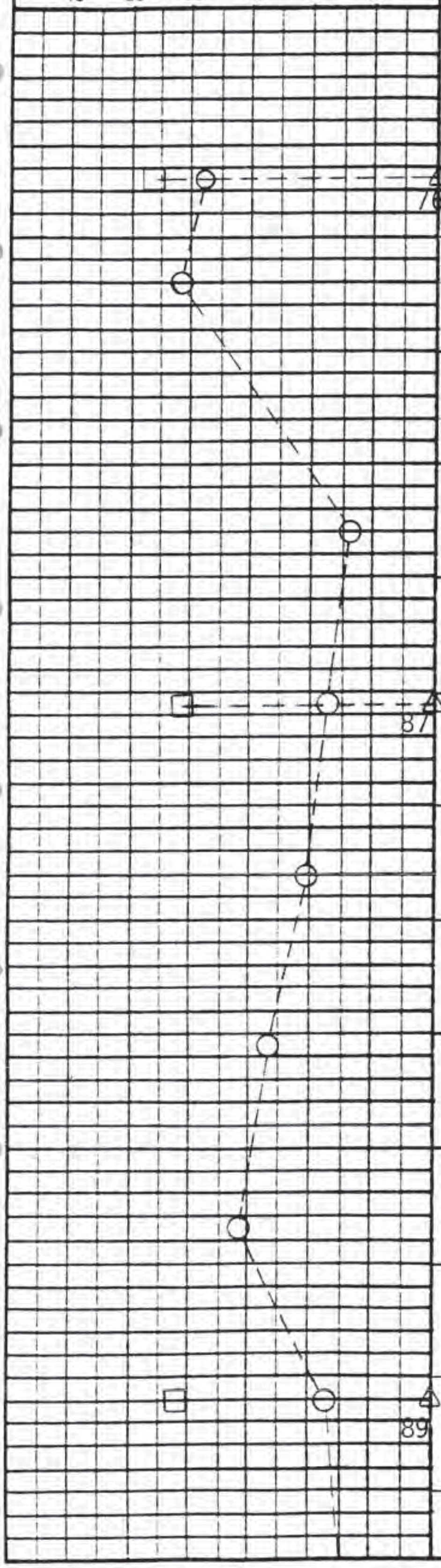
| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 6/08/87 | 87422 | 5 |

**DRILL TYPE:** 450 & 500 mm Augers

**DATUM:** Geodetic

**SURFACE ELEVATION:** 228.72 m

**WATER CONTENT** — Wp - □  W - ○  WL - △  PERCENT %




| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION / TYPE / PENETRATION RESISTANCE) | OTHER TESTS |
|---|---|---|---|
| 0 – 1 | Fill -silty -clay | | |
| 1 | Clay -black | | |
| 1 – 2.3 | Clay -silty -brown -alluvial | | See Dilatometer Test Results (DMT 2) |
| 2.3 – 13 | Clay -mottled brown -highly plastic -stiff to firm -lacustrine | | |
| ~4.8 | | U | qu=53.7kpa<br>$\gamma_w$=16.18kn/m$^3$<br>pp=112.5kpa<br>Tv=59.4kpa |
| ~6.4 | ---grey | | |
| ~7.9 | | U | qu=114.2kpa<br>$\gamma_w$=17.38kn/m$^3$<br>pp=122.6kpa<br>Tv=62.7kpa |
| ~10.9 | | U | qu=95.3kpa<br>$\gamma_w$=17.78kn/m$^3$<br>pp=66.1kpa<br>Tv=39.7kpa |

Plate A-7

**DYREGROV & BURGESS**

# BOREHOLE LOG

**PROJECT** Kildonan Corridor

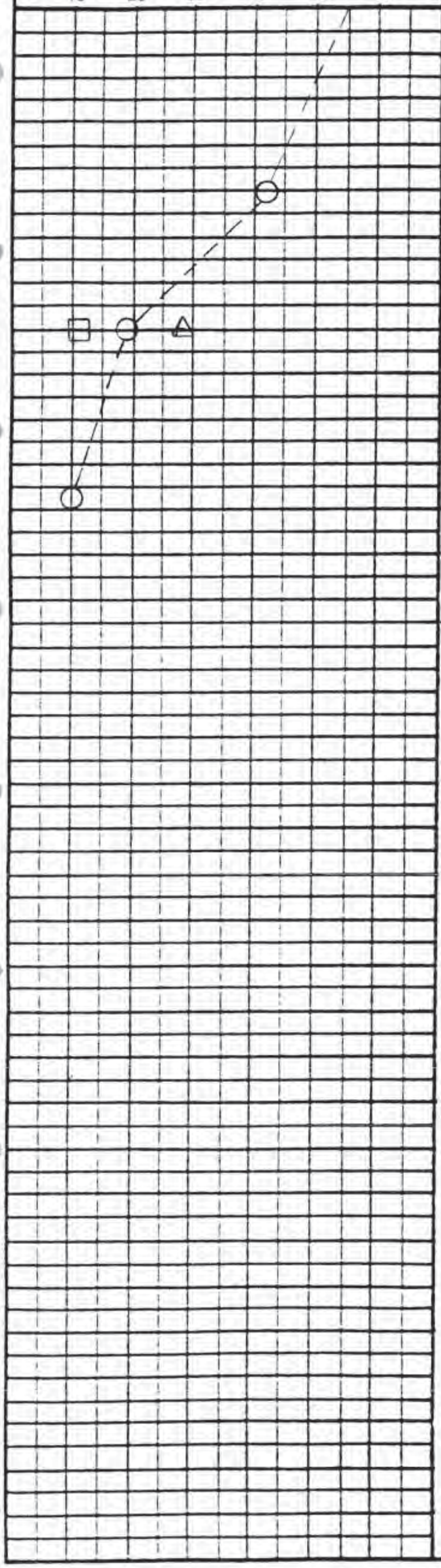
| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 6/08/87 | 87422 | 5 |

**DRILL TYPE** 450 & 500 mm Augers

**DATUM** Geodetic

**SURFACE ELEVATION** 228.72 m

**WATER CONTENT** — $W_P$ - □ W - ○ $W_L$ - △ PERCENT % (10 20 30 40 50 60)



| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 14–16 | Clay (cont'd) | ⧄ | U | | qu=118.4kpa<br>$\gamma_W$=16.51kn/$m^3$<br>pp=103.4kpa<br>Tv=49.3kpa |
| 16–18.7 | Silt (Glacial Till)<br>-sandy<br>gravelly<br>-clayey<br>-loose | | | | |
| 18.7 | End of hole at 18.7 m<br>-Possible bedrock<br>-No seepage | | | | |

Plate A-8

**DYREGROV & BURGESS**

# BOREHOLE LOG

**PROJECT** Kildonan Corridor

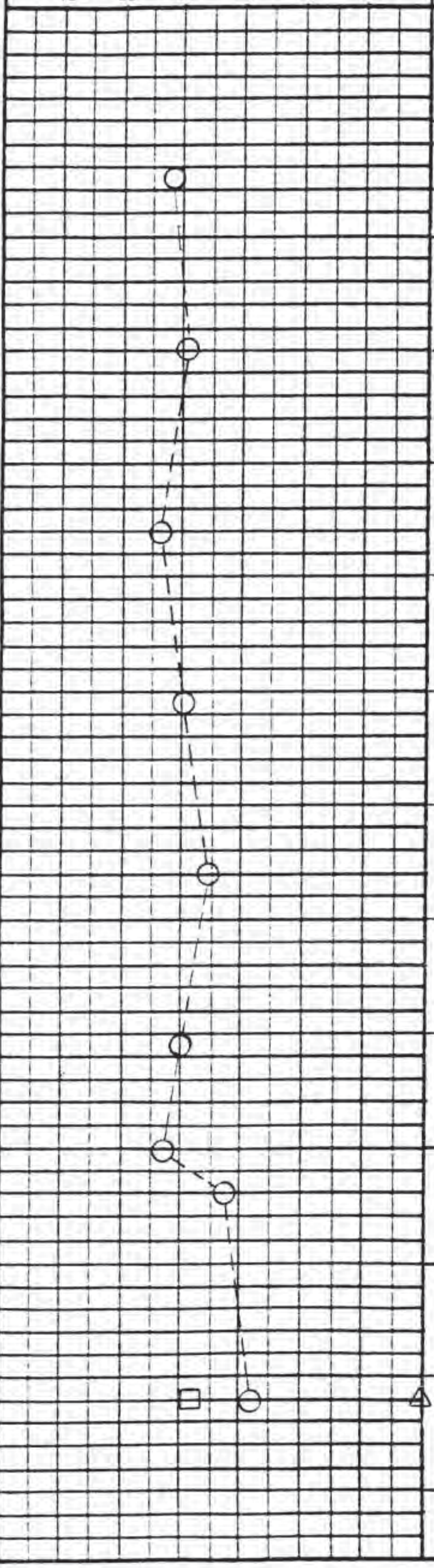
| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 10/08/87 | 87422 | 6 |

**DRILL TYPE:** Hollowstem 550 & 600 mm Augers

**DATUM:** Geodetic

**SURFACE ELEVATION:** 227.47 m

**WATER CONTENT** — Wp - □  W - ○  $W_L$ - △ — PERCENT %




| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE TYPE | OTHER TESTS |
|---|---|---|---|
| 0 – 4 | <u>Clay</u> -silty<br>-some sand<br>-alluvial<br>-stiff to 1.2 m<br>-soft from 1.2 to 3.3 m | U (at ~3.2 m) | See dilatometer test results to 15.2 m depth (DMT 1)<br>$\gamma_w$=17.90kg/m$^3$<br>pp=114.9kpa |
| 4 – 7.3 | <u>Sand</u> -little to some silt<br>-trace to some clay<br>-fine to medium grained<br>--- very dense, 5.2 - 6.4 m<br>--- medium grained, grey, saturated | U (at ~6.3 m) | -MA<br>-MA<br>pp=35.9kpa |
| 7.3 – 12 | <u>Silt</u> -some sand<br>-some to little clay<br>-firm to stiff | U (at ~7.9 m)<br>U (at ~9.2 m)<br>U (at ~10.1 m) | -MA<br>$\gamma_w$=18.00 kg/m$^3$<br>pp=67.0kpa<br>Tv=31.6kpa<br>$_w$=17.71kg/m$^3$<br>pp=88.6kpa<br>Tv=15.8kpa<br>-MA<br>$\gamma_w$ = 14.97kg/m$^3$<br>pp=52.7kpa |
| 12 – 12.5 | <u>Clay</u> -silty, very stiff, alluvial | U | pp=148.4kpa<br>Tv=67.0kpa |

End of hole at 12.5 m
Standpipe piezometers SP 1 and SP 2 installed

Plate A-9

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT Kildonan Corridor

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 10/08/87 | 87422 | 6 |

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DEPTH | SOIL SYMBOL

SOIL DESCRIPTION

DATUM Geodetic

SURFACE ELEVATION 227.47 m

SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE

DRILL TYPE: Hollowstem 550 & 600 mm Augers

OTHER TESTS

SP 1
Tip at 12.2 m
Sand to 11.6 m
Bentonite to 10.4 m
230 mm Ø augers

SP 2
Tip at 6.1 m
Sand at 5.6 m
Bentonite to 4.6 m
230 mm Ø augers
Pipe ID - 19 mm

Plate A-10

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: Kildonan Corridor

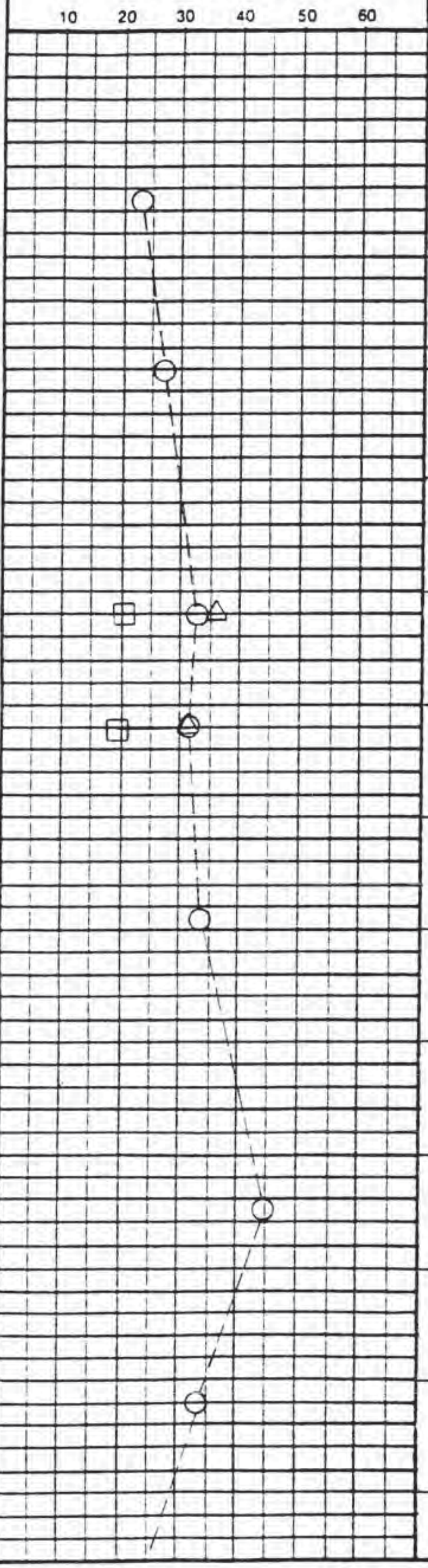
| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 7/08/87 | 87422 | 7 |

DRILL TYPE: 450 & 600 mm Augers

DATUM: Geodetic

SURFACE ELEVATION: 227.13 m

WATER CONTENT — Wp - □  W - ○  WL - △  PERCENT %




| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 0 | Topsoil | | | | |
| 0–2.1 | Silt -sandy -some clay -brown -alluvial | | | | |
| 2.1–4.6 | Sand -some silt -trace clay; --- saturated (at 3) | | | | MA (at 3) |
| 4.6–8.1 | Silt -some sand and clay -grey -wet -firm | | | | |
| 8 | | ⊘ | U | | MA; $\gamma_w$=17.95kg/m$^3$; pp=61.3kpa; Tv=32.6kpa |
| 8.1–8.7 | Sand -fine grained -grey, saturated | | | | |
| 8.7–9.3 | Silt -some sand and clay | | | | |
| 9.3–13.6 | Clay -grey -highly plastic -firm; --- 100 mm gravel layer, shells (at 10.4) | | | | qu=67.7kpa |
| 11 | | ⊘ | U | | $\gamma_w$=18.34kg/m$^3$; pp=151.2kpa; Tv=69.9kpa |

Plate A-11

# DYREGROV & BURGESS

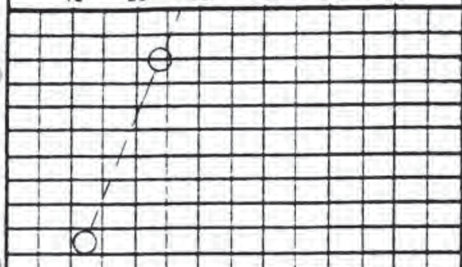
## BOREHOLE LOG

PROJECT: Kildonan Corridor

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

DATUM: Geodetic
SURFACE ELEVATION: 227.13 m
DRILL TYPE: 550 &600 mm Augers

WATER CONTENT (Wp - □, W - ○, WL - △, PERCENT %: 10 20 30 40 50 60)



| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 14 | ---Clay & Glacial Till | | | | |
| 15 | | | | | |
| 16 | Silt (Glacial Till) -wet, loose, clayey | | | | |
| 17 | End of hole at 16.2 m.<br>-Smooth auger refusal<br>-Water seepage 20 minutes after completion of drilling<br>-600 mm casing to 10 m depth<br>-Possible bedrock at 16.2 m | | | | |

Plate A-12

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: Kildonan Corridor

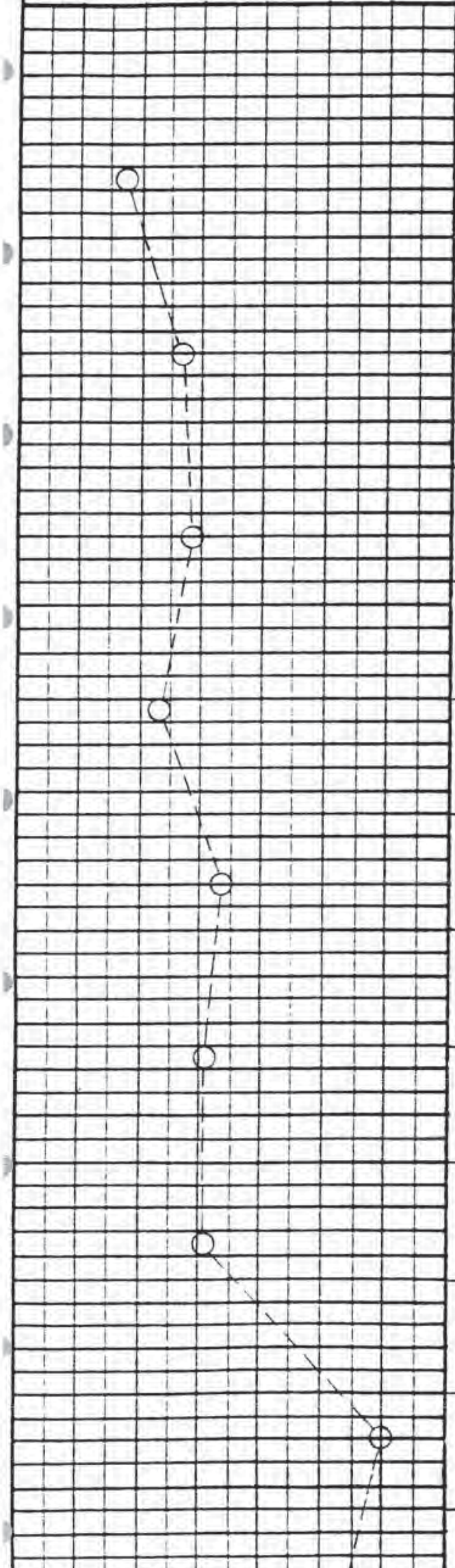
| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 7/08/87 | 87422 | 8 |

DRILL TYPE: 550 & 600 mm Augers

DATUM: Geodetic

SURFACE ELEVATION: 227.17 m

WATER CONTENT — Wp - □ W - ○ $W_L$ - △. PERCENT % (10, 20, 30, 40, 50, 60)



| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE TYPE | OTHER TESTS |
|---|---|---|---|
| 0 | Fill -clay, concrete rubble | | |
| | Silt -clayey, brown, stiff -alluvial | | |
| 1–2 | Sand -fine grained -some silt -brown | | |
| 3 | ---saturated | U | $\gamma_w$=18.01kg/$m^3$ pp=56.2kpa Tv=39.7kpa |
| 5–6 | ---grey | | |
| 8–9 | Silt -some sand and clay -wet -stiff to firm | U | qu=57.3kpa $\gamma_w$=16.97kg/m pp=183.8kpa Tv=62.2kpa |
| 11 | ---50 mm gravel layer | | |
| 12 | | U | qu=49.1kpa $\gamma_w$=15.97kg/$m^3$ pp=101.5kpa Tv=57.4kpa |
| 12.5–13 | Clay -grey -highly plastic -stiff to firm | | |

Column headings: CONDITION, TYPE, PENETRATION RESISTANCE, SOIL SYMBOL

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: Kildonan Corridor

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

DATUM: Geodetic

SURFACE ELEVATION: 227.17 m

DRILL TYPE: 550 & 600 mm Augers

WATER CONTENT: Wp - □ W - ○ WL - Δ. PERCENT % (10 20 30 40 50 60)

SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE

OTHER TESTS

| DEPTH (M) | SOIL DESCRIPTION |
|---|---|
| 14 | Clay (cont'd) |
| 15 | ---gravelly |
| 16 | Silt (Glacial Till)<br>-sandy, gravelly<br>-some clay<br>-tan |
| 17 | -seepage from 16.5 m |
| 18 | End of hole at 17.7 m<br>-Rough auger refusal at 17.7 m<br>-Water level at 7.2 m on completion of drilling<br>-600 mm casing to 4.6 below grade |

Plate A-14

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: Kildonan Corridor

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| SDG | NCB | 27/08/87 | 87422 | 12 |

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10, 20, 30, 40, 50, 60)

DATUM: Geodetic

SURFACE ELEVATION: 226.74 m

DRILL TYPE: Hollow Stem

| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE TYPE | OTHER TESTS |
|---|---|---|---|
| 0 | Fill -clay -some gravel | | P1 Pneumatic piezometer tip @ 7.8m sand to 7.1 m bent. to6.1m |
| 0.6 | Clay -silty -brown -stiff -alluvial -medium to highly plastic | | |
| 3 | | U | qu=46.4kpa $\gamma_w$=18.00kn/$m^3$ pp=97.0kpa Tv=27.8kpa |
| 5 | -grey | | |
| 6 | | U | $\gamma_w$=17.37kn/$m^3$ pp=59.8kpa |
| 9 | Clay -mottled brown to grey -highly plastic -lacustrine | U | qu=67.4kpa $\gamma_w$=19.95kn/$m^3$ pp=143.6pa |
| 12 | | U | qu=51.2kpa $\gamma_w$=17.60kn/$m^3$ pp=87.8kpa Tv=58.4kpa |
| 12.8 | End of hole at 12.8 m. Install pneumatic piezometer | | |

Plate A-18

# BOREHOLE LOG

**DYREGROV & BURGESS**

**PROJECT** Kildonan Corridor

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

**WATER CONTENT**: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

**DEPTH** (M)

**SOIL SYMBOL**

**SOIL DESCRIPTION**

**DATUM** Geodetic

**SURFACE ELEVATION** 227.60 m

**SOIL SAMPLE**: CONDITION, TYPE, PENETRATION RESISTANCE

**DRILL TYPE** Hollow Stem

**OTHER TESTS**

| Depth (M) | Soil Description | Sample Type | Other Tests |
|---|---|---|---|
| 0 | Fill -clay -some gravel | | Station - 3+90.9 |
| 0.6 | Clay -silty -brown -alluvial | | |
| 2 | Clay -mottled brown -highly plastic -stiff to firm -lacustrine | | |
| 6.3 | | U | qu=56.5kpa<br>$\gamma_w$=16.77kn/m$^3$<br>pp=93.8kpa<br>Tv=48.8kpa |
| 12.6 | | U | |

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

Plate A-19

# BOREHOLE LOG

**DYREGROV & BURGESS**

PROJECT: Kildonan Corridor

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

WATER CONTENT: Wp - □ W - ○ $W_L$ - Δ. PERCENT % (10 20 30 40 50 60)

DEPTH (M) | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE: Hollow Stem | OTHER TESTS

DATUM: Geodetic

SURFACE ELEVATION: 227.60 m

| DEPTH (M) | SOIL DESCRIPTION |
|---|---|
| 14–17 | Clay (cont'd) |
| 17–18.6 | Silt (Glacial Till)<br>-sandy and gravelly<br>-bouldery |

End of hole at 18.6 in glacial till.

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.

Depth scale: 14, 15, 16, 17, 18, 19, 20

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: Kildonan Corridor

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

DRILL TYPE: B-24, 75 mm Bit

DATUM: Geodetic

SURFACE ELEVATION: 223.64

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

SOIL SAMPLE: CONDITION, TYPE, PENETRATION RESISTANCE

| DEPTH (M) | SOIL DESCRIPTION | OTHER TESTS |
|---|---|---|
| 0 | Water | |
| ~7.6 | Overburden Soils | For DMT results see DMT 5 |
| ~8.5 | Glacial Till | |
| ~13.6 | Limestone Bedrock | |

Depth scale: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

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

DRILL TYPE: B-24, 75 mm Bit

DATUM: Geodetic

SURFACE ELEVATION: 223.64 m

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

| DEPTH (M) | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 14 | Sound Rock | | | | Rec. - 100% |
| 15 | Sound Rock<br>25 mm clay seam at 15.2 m | | | | Rec. - 91%<br>RQD -80% |
| 16–17 | Sound Rock<br>25 mm clay seam at 16.7 m | | | | REC. -94%<br>RQD -75% |
| 18 | Sound Rock<br>No clay seams | | | | Rec. -100%<br>RQD - 95% |
| 19–20 | End hole at 19.1 m.<br>Rock surface estimated at Elev. - 210.38 m.<br>Top 150 mm unsound. | | | | |

Plate A-22

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 24/09/87 | JOB NO. 87422 | HOLE NO. 15 |
|---|---|---|---|---|

WATER CONTENT: Wp - □   W - ○   $W_L$ - △. PERCENT % (10, 20, 30, 40, 50, 60)

DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE | OTHER TESTS

DATUM

SURFACE ELEVATION 223.67 m

| DEPTH (m) | SOIL DESCRIPTION |
|---|---|
| 0 – ~9.8 | WATER |
| ~9.8 – ~10.7 | ALLUVIAL SOILS |
| ~10.7 – ~13.1 | GLACIAL TILL (depth to till extrapolated from DMT 6) |
| ~13.1 – | LIMESTONE BEDROCK |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

PLATE A-23

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

LOGGED/DWN. | CKD. | DATE OF INVEST. 24/09/87 | JOB NO. 87422 | HOLE NO. 15

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DATUM

SURFACE ELEVATION

DRILL TYPE

| DEPTH (m) | SOIL DESCRIPTION | OTHER TESTS |
|---|---|---|
| 14 | BROKEN ROCK | |
| | SOUND ROCK | REC - 99% RQD - 60% |
| | NO RECOVERY | |
| 15 | SOUND ROCK | REC - 99% RQD - 60% |
| | NO RECOVERY | |
| 16 | SOUND ROCK | REC - 99% RQD - 79% |
| 17 | SOUND ROCK | REC - 100% RQD - 70% |
| 18 | NO RECOVERY | |
| | BROKEN ROCK | |
| 19–20 | SOUND ROCK | REC - 84% RQD - 17% |
| 21 | 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.

PLATE A-24

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 25/09/87 | JOB NO. 87422 | HOLE NO. 16 |
|---|---|---|---|---|

WATER CONTENT: Wp - □  W - ○  WL - △  PERCENT % (10 20 30 40 50 60)

DEPTH: m

DATUM

SURFACE ELEVATION 223.61 m

SOIL SAMPLE: CONDITION, TYPE, PENETRATION RESISTANCE

DRILL TYPE

| DEPTH (m) | SOIL DESCRIPTION | OTHER TESTS |
|---|---|---|
| 0 – ~9.3 | WATER | |
| ~9.3 – ~10.3 | ALLUVIAL SOILS | FOR TESTS IN ALLUVIUM SEE DMT 7 |
| ~10.3 – ~13 | GLACIAL TILL<br>-SOFT/LOOSE<br>-PUSHED DRILL RODS TO BEDROCK SURFACE | |
| ~13 – | LIMESTONE BEDROCK | |

PLATE A-25

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 25/09/87 | JOB NO. 87422 | HOLE NO. 16 |
|---|---|---|---|---|

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION: DATUM, SURFACE ELEVATION | SOIL SAMPLE: CONDITION, TYPE, PENETRATION RESISTANCE | DRILL TYPE | OTHER TESTS

| DEPTH (m) | SOIL DESCRIPTION | OTHER TESTS |
|---|---|---|
| 14 | BROKEN ROCK TO 13.7 m | |
| | 3 - 6mm clay seams at 14.0 m | REC - 75% |
| 15 | SOUND ROCK | REC - 95%<br>RQD - 68% |
| 16 | | |
| | 225 mm seam or soft rock | REC - 98% |
| 17 | | |
| 18 | SOUND ROCK | REC - 93% |
| 19 | | |
| | NO RECOVERY | |
| 20 | | |
| | Abandon hole at 20.1 m<br>Drill rods jamming | |

PLATE A-26

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 06/10/87 | JOB NO. 87422 | HOLE NO. 16A |
|---|---|---|---|---|

WATER CONTENT — Wp - □ W - ○ WL - △. PERCENT % — 10 20 30 40 50 60

DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION — DATUM, SURFACE ELEVATION | SOIL SAMPLE — CONDITION, TYPE, PENETRATION RESISTANCE | DRILL TYPE | OTHER TESTS

| DEPTH (m) | SOIL DESCRIPTION |
|---|---|
| 0 – ~9.2 | WATER |
| ~9.2 – ~10.4 | ALLUVIAL SOILS |
| ~10.4 – 13.6 | GLACIAL TILL (depth extrapolated from DMT 7) |

Depth scale: 1 2 3 4 5 6 7 8 9 10 11 12 13

PLATE A-27

# BOREHOLE LOG

**DYREGROV & BURGESS**

**PROJECT** KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 06/10/87 | JOB NO. 87422 | HOLE NO. 16A |
|---|---|---|---|---|

WATER CONTENT: Wp - □ W - ○ $W_L$ - Δ. PERCENT % (10 20 30 40 50 60)

SOIL SAMPLE: CONDITION, TYPE, PENETRATION RESISTANCE

DRILL TYPE

DATUM

SURFACE ELEVATION

| DEPTH m | SOIL DESCRIPTION | OTHER TESTS |
|---|---|---|
| 14 | GLACIAL TILL | |
| | LIMESTONE BEDROCK | REC - 100%<br>RQD - 67% |
| 15 | UNSOUND ROCK | |
| 16 | NO CORE RECOVERY | |
| 17 | | |
| 18 | | |
| 19 | | |
| 20 | UNSOUND ROCK | |
| 21 | NO CORE RECOVERY | |
| 22 | UNSOUND ROCK | REC - 30% |
| 23 | | |
| 24 | End hole at 23.6 m. | |

# BOREHOLE LOG

**DYREGROV & BURGESS**

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 07/10/87 | JOB NO. 87422 | HOLE NO. 16B |
|---|---|---|---|---|

WATER CONTENT — $W_P$ - □ W - ○ $W_L$ - △ PERCENT % (10, 20, 30, 40, 50, 60)

DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE | OTHER TESTS

DATUM

SURFACE ELEVATION 223.69 m

| DEPTH (m) | SOIL DESCRIPTION |
|---|---|
| 0 – ~9.2 | WATER |
| ~9.2 – ~10.4 | ALLUVIUM |
| ~10.4 – 13+ | GLACIAL TILL (depth to till extrapolated from DMT 7) |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

PLATE A-29

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 07/10/87 | 87422 | 16B |

WATER CONTENT: Wp - □ W - ○ WL - Δ. PERCENT % (10 20 30 40 50 60)

DATUM

SURFACE ELEVATION 223.69 m

DRILL TYPE

| DEPTH m | SOIL DESCRIPTION | CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 14 | LIMESTONE BEDROCK<br>SOUND ROCK | | | | REC - 100%<br>RQD - 56% |
| 15 | SOUND ROCK | | | | REC - 98%<br>RQD - 83% |
| 16–17 | SOUND ROCK | | | | REC - 96%<br>RQD - 90% |
| 18–19 | SOUND ROCK | | | | REC - 94%<br>RQD - 73% |
| 20 | NO RECOVERY | | | | |

End hole at 20.0 m
Drill rods jamming in broken rock and clay.

PLATE A-30

## DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 14/10/87 | 87422 | 16C |

| WATER CONTENT ($W_P$ - □, W - ○, $W_L$ - △; PERCENT %; 10 20 30 40 50 60) | DEPTH (m) | SOIL SYMBOL | SOIL DESCRIPTION (DATUM; SURFACE ELEVATION) | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | DRILL TYPE / OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | 0–9 | | WATER | | | | |
| | 9–10.5 | | ALLUVIUM | | | | |
| | 10.5–13.5 | | GLACIAL TILL (depth to till extrapolated from DMT 7) | | | | |

PLATE A-31

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 14/10/87 | JOB NO. 87422 | HOLE NO. 16C |
|---|---|---|---|---|

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10, 20, 30, 40, 50, 60)

DATUM / SURFACE ELEVATION

SOIL SAMPLE: CONDITION, TYPE, PENETRATION RESISTANCE

DRILL TYPE

| DEPTH m | SOIL DESCRIPTION | OTHER TESTS |
|---|---|---|
| 14 | LIMESTONE BEDROCK<br>SOUND ROCK | REC - 100%<br>RQD - 85% |
| 15 | SOUND ROCK | REC - 92%<br>RQD - 91% |
| 16–17 | SOUND ROCK | REC - 98%<br>RQD - 96% |
| 18 | SOUND ROCK | REC - 100%<br>RQD - 100% |
| 19 | NO RECOVERY | |
| 20 | BROKEN ROCK, NO RECOVERY | |
| | NO RECOVERY | |
| 21–22 | SOUND ROCK | REC - 93%<br>RQD - 73% |
| | End hole at 22.3 m. | |

23

PLATE A-32

## DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 15/10/87 | JOB NO. 87422 | HOLE NO. 16D |
|---|---|---|---|---|

| WATER CONTENT (Wp - □ W - ○ WL - △. PERCENT %; 10 20 30 40 50 60) | DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION (DATUM; SURFACE ELEVATION) | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | DRILL TYPE / OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | 0–9.5 | | WATER | | | | |
| | 9.5–10.5 | | ALLUVIUM | | | | |
| | 10.5–13.3 | | GLACIAL TILL (depth to glacial till extrapolated from DMT 7) | | | | |
| | 13.3– | | LIMESTONE BEDROCK | | | | |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

PLATE A-33

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 15/10/87 | 87422 | 16D |

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DATUM

SURFACE ELEVATION

DRILL TYPE

| DEPTH (m) | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 14 | 150 mm clay or soft rock<br>150 mm clay or soft rock | | | | REC - 69%<br>RQD - 67% |
| 15 | NO RECOVERY | | | | |
| 16 | SOUND ROCK | | | | REC - 88% |
| 17 | SOUND ROCK | | | | REC - 100%<br>RQD - 93% |
| 18 | SOUND ROCK | | | | |
| | NO RECOVERY | | | | |
| 19 | SOUND ROCK | | | | |
| 20 | UNSOUND ROCK | | | | REC - 30%<br>RQD - 10% |
| 21–22 | SOUND ROCK | | | | REC - 80%<br>RQD - 63% |
| | BROKEN ROCK | | | | |
| | End hole at 22.5 m. | | | | |

PLATE A-34

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 06/10/87 | JOB NO. 87422 | HOLE NO. 17 |
|---|---|---|---|---|

| WATER CONTENT (Wp - □ W - ○ WL - △ PERCENT % 10 20 30 40 50 60) | DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION (DATUM; SURFACE ELEVATION 223.65 m) | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | DRILL TYPE / OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | 0–8.5 (1, 2, 3, 4, 5, 6, 7, 8) | | WATER | | | | |
| | 8.5–10.3 (9, 10) | | ALLUVIAL SOILS | | | | For tests in alluvium see DMT 7 |
| | 10.3–13.7 (11, 12, 13) | △ | GLACIAL TILL<br>VERY DENSE?HARD BELOW 11.2 m | | | | |

PLATE A-35

**DYREGROV & BURGESS**

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 06/10/87 | JOB NO. 87422 | HOLE NO. 17 |
|---|---|---|---|---|

WATER CONTENT: Wp - □ W - ○ WL - △ PERCENT % (10 20 30 40 50 60)

DRILL TYPE

| DEPTH m | SOIL DESCRIPTION (DATUM / SURFACE ELEVATION) | CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 14 | GLACIAL TILL | | | | |
| | LIMESTONE BEDROCK | | | | |
| 15 | NO RECOVERY 14.3 to 15.5 m | | | | |
| 16 | SOUND ROCK | | | | REC - 99%<br>RQD - 99% |
| 17 | SOUND ROCK | | | | REC - 97%<br>RQD - 75% |
| 18–19 | SOUND ROCK | | | | REC - 97%<br>RQD - 79% |
| 20 | SOUND ROCK | | | | REC 100% |
| | BROKEN ROCK | | | | REC 0% |
| 21 | SOUND ROCK | | | | REC - 100%<br>RQD - 70% |
| 22 | SOUND ROCK | | | | REC - 93%<br>RQD - 30% |
| 23 | End hole at 22.6 m. | | | | |

PLATE A-36

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 21/09/87 | JOB NO. 87422 | HOLE NO. 18 |
|---|---|---|---|---|

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10, 20, 30, 40, 50, 60)

DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE | OTHER TESTS

DATUM

SURFACE ELEVATION 223.68

| Depth (m) | Soil Description |
|---|---|
| 0 – ~11 | WATER |
| ~11 – ~12.7 | GLACIAL TILL |
| ~12.7 – 13.8 | LIMESTONE BEDROCK, BROKEN TO 13.1m<br>SOUND ROCK, 13.1 - 13.8 m |

PLATE A-37

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 21/09/87 | 87422 | 18 |

DRILL TYPE:

DATUM:

SURFACE ELEVATION: 223.68 m

WATER CONTENT: Wp - □ W - ○ $W_L$ - △ PERCENT % (10 20 30 40 50 60)

| DEPTH (m) | SOIL DESCRIPTION | CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 14 | NO RECOVERY 13.8 - 13.9 m | | | | |
| | SOUND ROCK<br>25 mm clay seam at 14.6 m | | | | REC - 87%<br>RQD - 82% |
| 15 | SOUND ROCK | | | | REC - 95%<br>RQD - 87% |
| 16–17 | SOUND ROCK | | | | REC - 95%<br>RQD - 65% |
| 18 | SOUND ROCK | | | | REC - 95%<br>RQD - 87% |
| 19–20 | SOUND ROCK | | | | REC - 95% |
| 21–22 | SOUND ROCK | | | | REC - 93% |
| 23 | End hole at 22.3 m. | | | | |

PLATE A-38

## DYREGROV & BURGESS

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 19/09/87 | JOB NO. 87422 | HOLE NO. 19 |
|---|---|---|---|---|

| WATER CONTENT (Wp - □ W - ○ WL - △; PERCENT %; 10 20 30 40 50 60) | DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION (DATUM; SURFACE ELEVATION 223.62) | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | DRILL TYPE / OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | 0–9 | | WATER | | | | |
| | 9–13+ | | GLACIAL TILL (depth to glacial till extrapolated from DMT 5) | | | | |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

PLATE A-39

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 19/09/87 | JOB NO. 87422 | HOLE NO. 19 |
|---|---|---|---|---|

| WATER CONTENT (Wp - □, W - ○, WL - △; PERCENT %; 10 20 30 40 50 60) | DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION (DATUM; SURFACE ELEVATION) | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | DRILL TYPE / OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | | | GLACIAL TILL | | | | |
| | 14 | | LIMESTONE BEDROCK<br>BROKEN ROCK TO 14.6 m | | | | REC - 30% |
| | 15–16 | | SOUND ROCK | | | | REC - 100% |
| | 17 | | SOUND ROCK | | | | REC - 96%<br>RQD - 94% |
| | 18–19 | | SOUND ROCK | | | | REC - 96%<br>RQD - 74% |
| | 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: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE | OTHER TESTS

DATUM

SURFACE ELEVATION 223.61 m

| DEPTH (m) | SOIL DESCRIPTION |
|---|---|
| 0 – 1.4 | WATER |
| 1.4 – 7.5 | ALLUVIAL SOILS (for test results see DMT 4) |
| 7.5 – 13.5 | GLACIAL TILL (depth to till extrapolated from DMT 4) |
| 13.5 | LIMESTONE BEDROCK |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

PLATE A-41

## DYREGROV & BURGESS

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 03/10/87 | 87422 | 20 |

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT %: 10 20 30 40 50 60

SOIL DESCRIPTION — DATUM — SURFACE ELEVATION 223.61 m

SOIL SAMPLE: CONDITION / TYPE / PENETRATION RESISTANCE

DRILL TYPE

| DEPTH m | SOIL DESCRIPTION | OTHER TESTS |
|---|---|---|
| 14 | BROKEN ROCK 13.4 - 14.0 m<br>SOUND ROCK BELOW 14.0 m | REC - 64%<br>RQD - 53% |
| 15–16 | SOUND ROCK | REC - 97%<br>RQD - 81% |
| 17 | SOUND ROCK | REC - 95%<br>RQD - 93% |
| 18–19 | SOUND ROCK<br>100 mm clay seam | REC - 92%<br>RQD - 69% |
| 20 | SOUND ROCK | REC - 97%<br>RQD - 73% |
| 21–22 | SOUND ROCK | REC - 92%<br>RQD - 79% |
| 23 | End hole at 22.6 m. | |

PLATE A-42

# BOREHOLE LOG

**DYREGROV & BURGESS**

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 28/09/87 | 87422 | 21 |

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DRILL TYPE

DATUM

SURFACE ELEVATION 223.63 m

| DEPTH (m) | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| 0 – 1.4 | WATER | | | | |
| 1.4 – 7.5 | ALLUVAIL SOILS (for test results see DMT 4) | | | | |
| 7.5 – 13.3 | GLACIAL TILL (depth to till extrapolated from DMT 4) | | | | |
| 13.3 | LIMESTONE BEDROCK | | | | |

PLATE A-43

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 28/09/87 | 87422 | 21 |

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DEPTH (m) | SOIL SYMBOL | SOIL DESCRIPTION (DATUM, SURFACE ELEVATION) | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE | OTHER TESTS

| DEPTH (m) | SOIL DESCRIPTION | OTHER TESTS |
|---|---|---|
| 14 | NO RECOVERY TO 14.2 m | |
| | SOUND ROCK, 14.2 - 14.8 m | |
| 15–16 | 25 mm clay seam<br>SOUND ROCK | REC - 99%<br>RQD - 44% |
| 16–17.8 | SOUND ROCK | REC - 97%<br>RQD - 81% |
| 18–19 | 6 mm clay seams (2)<br>12 mm clay seam<br>SOUND ROCK | REC - 95%<br>RQD - 45% |
| 19.4–20.9 | SOUND ROCK | REC - 98%<br>RQD - 67% |
| 21–22.4 | SOUND ROCK | REC - 100%<br>RQD - 36% |
| 23 | End hole at 22.4 m. | |

PLATE A-44

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 23/09/87 | 87422 | 22 |

WATER CONTENT: Wp - □  W - ○  $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE | OTHER TESTS

DATUM

SURFACE ELEVATION 223.68 m

| Depth (m) | Soil Description |
|---|---|
| 0 – ~1.5 | WATER |
| ~1.5 – ~7.9 | ALLUVIAL SOILS (for testing see DMT 3) |
| ~7.9 – ~13 | GLACIAL TILL (depth to glacial till extrapolated from DMT 3) |
| ~13 | LIMESTONE BEDROCK |

Depth scale: 1 2 3 4 5 6 7 8 9 10 11 12 13

PLATE A-45

## DYREGROV & BURGESS

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 23/09/87 | JOB NO. 87422 | HOLE NO. 22 |
|---|---|---|---|---|

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DRILL TYPE

DATUM

SURFACE ELEVATION 223.68 m

| DEPTH m | SOIL DESCRIPTION | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|
| | BROKEN ROCK, 13.0-13.8 m | | | | no REC |
| 14 | SOUND ROCK | | | | REC - 99%<br>RQD - 45% |
| 15 | SOUND ROCK | | | | REC - 99%<br>RQD - 83% |
| 16–17 | SOUND ROCK | | | | REC - 96%<br>RQD - 73% |
| 18 | SOUND ROCK | | | | REC - 93%<br>RQD - 66% |
| 19 | End hole at 19.0 m. | | | | |

PLATE A-46

## DYREGROV & BURGESS

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 22/09/87 | JOB NO. 87422 | HOLE NO. 23 |
|---|---|---|---|---|

WATER CONTENT: Wp - □  w - ○  $W_L$ - △. PERCENT % (10, 20, 30, 40, 50, 60)

DEPTH M | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE | OTHER TESTS

DATUM

SURFACE ELEVATION 223.70 m

| Depth (M) | Soil Description |
|---|---|
| 0 – 1 | WATER |
| 1 – 8 | ALLUVIAL SOILS<br>(For testing see DMT 3) |
| 8 – 13 | GLACIAL TILL<br>(Depth to till extrapolated from DMT 3) |
| 13 – | LIMESTONE BEDROCK |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

PLATE A-47

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. 22/09/87 | JOB NO. 87422 | HOLE NO. 23 |
|---|---|---|---|---|

DATUM

SURFACE ELEVATION 223.70 m

| WATER CONTENT (Wp - □ W - ○ $W_L$ - △; PERCENT %: 10 20 30 40 50 60) | DEPTH | SOIL SYMBOL | SOIL DESCRIPTION | CONDITION | TYPE | PENETRATION RESISTANCE | DRILL TYPE / OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | 14 | | SOUND ROCK | | | | REC.- 87%<br>RQD. - 83% |
| | 15–16 | | SOUND ROCK | | | | REC. - 97%<br>RQD - 70% |
| | 17 | | SOUND ROCK | | | | REC. - 100%<br>RQD - 88% |
| | 18–19 | | SOUND ROCK | | | | REC. - 95%<br>RQD - 47% |
| | 20 | | SOUND ROCK | | | | REC. - 97%<br>RQD - 61% |
| | 21 | | End hole at 20.9 m. | | | | |

PLATE A-48

**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 — Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DEPTH (m) | SOIL SYMBOL | SOIL DESCRIPTION | SOIL SAMPLE (CONDITION, TYPE, PENETRATION RESISTANCE) | DRILL TYPE | OTHER TESTS

DATUM

SURFACE ELEVATION 223.70 m

| DEPTH (m) | SOIL DESCRIPTION |
|---|---|
| 0 – 2 | WATER |
| 2 – 2.8 | SILT - clayey |
| 2.8 – 6 | CLAY - silty |
| 6 – 7.9 | STRATIFIED SILTY CLAY AND CLAYEY SILT |

End Dilatometer testing at 7.9 m. Refusal on glacial till or boulder at 7.9 m.

OTHER TESTS: 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

PLATE A-49

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 30/09/87 | 87422 | DMT 4 |

WATER CONTENT: Wp - □ W - ○ $W_L$ - △ PERCENT % (10 20 30 40 50 60)

DRILL TYPE:

DATUM:

SURFACE ELEVATION: 223.61

| DEPTH (m) | SOIL DESCRIPTION | OTHER TESTS: UNDRAINED SHEAR STRENGTH (kPa) |
|---|---|---|
| 0–1.7 | WATER | |
| 1.7–2.8 | CLAYEY SILT | 28, 27, 27 |
| 2.8–4.9 | STRATIFIED SILT, SAND, AND CLAY | 36, 45, 39 |
| 4.9–6.8 | SILTY SAND | $\phi=34^o$, $\phi=36^o$ |
| 6.8–7.5 | SILTY CLAY | 51, 59, 58 |

End dilatometer test at 7.5 m. Refusal on boulder or glacial till.

SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE

**DYREGROV & BURGESS**

# BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 30/09/87 | 87422 | DMT 5 |

WATER CONTENT: Wp - □ W - ○ $W_L$ - △. PERCENT % (10 20 30 40 50 60)

DRILL TYPE

DATUM

SURFACE ELEVATION 223.61

| DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION | CONDITION | TYPE | PENETRATION RESISTANCE | OTHER TESTS |
|---|---|---|---|---|---|---|
| 0–7.7 | | WATER | | | | |
| 7.7–8.5 | | CLAYEY SILT, SILTY CLAY AND SAND | | | | UNDRAINED SHEAR STRENGTH (kPa) 24, 34, $\phi$ = 39° |
| 8.5 | | End dilatometer testing at 8.5 m<br>Refusal on glacial till | | | | |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9

PLATE A-51

**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 (Wp - □, W - ○, $W_L$ - △; PERCENT %: 10 20 30 40 50 60) | DEPTH m | SOIL SYMBOL | SOIL DESCRIPTION (DATUM; SURFACE ELEVATION 223.61) | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | DRILL TYPE / OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | 0–10 | | WATER | | | | |
| | 10–10.6 | | ALLUVIAL SOILS | | | | |
| | | | Drill rod pushed from 10.0 to 10.6 m. Refusal on glacial till or boulder at 10.6 m. | | | | |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

PLATE A-52

# DYREGROV & BURGESS

## BOREHOLE LOG

PROJECT: KILDONAN CORRIDOR

| LOGGED/DWN. | CKD. | DATE OF INVEST. | JOB NO. | HOLE NO. |
|---|---|---|---|---|
| | | 30/09/87 | 87422 | DMT 7 |

| WATER CONTENT (Wp - □, W - ○, $W_L$ - △; PERCENT %: 10 20 30 40 50 60) | DEPTH (m) | SOIL SYMBOL | SOIL DESCRIPTION (DATUM; SURFACE ELEVATION) | SOIL SAMPLE: CONDITION | TYPE | PENETRATION RESISTANCE | DRILL TYPE / OTHER TESTS |
|---|---|---|---|---|---|---|---|
| | 0–10.4 | | WATER | | | | |
| | 10.4–13.1 | | GLACIAL TILL - soft/loose<br>- Drill rods pushed with no rotation from 10.4 to 13.1 m. Refusal on probable bedrock at 13.1 m. | | | | |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13

PLATE A-53

AECOM

# 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.

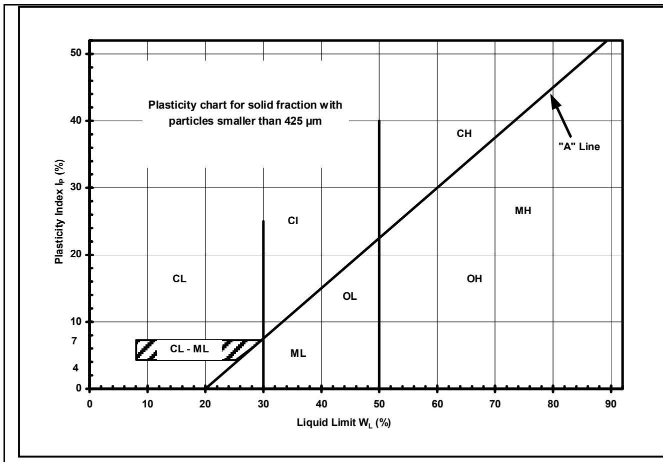
In order to observe compliance with the design concepts, specifications or recommendations and to allow design changes in the event that subsurface conditions differ from those anticipated, we recommend that all construction operations dealing with earth work and the foundations be observed by an experienced 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 | $C_U > 4$<br>$1 < C_C < 3$ | | Dual symbols if 5-12% fines. Dual symbols if above "A" line and $4<W_P<7$<br>$C_U = \frac{D_{60}}{D_{10}}$<br>$C_C = \frac{(D_{30})^2}{D_{10} x D_{60}}$ |
| | | | 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 | $C_U > 6$<br>$1 < C_C < 3$ | | |
| | | | 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 ORGAINIC SOILS | | | Peat and other highly organic soils | | Pt | Von Post Classification Limit | | Strong colour or odour, and often fibrous texture | |

| | | | | | |
|---|---|---|---|---|---|
| | Asphalt | | Till | | |
| | 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.




| FRACTION | | SEIVE SIZE (mm) | | DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS | |
|---|---|---|---|---|---|
| | | Passing | Retained | Percent | Identifier |
| Gravel | Coarse | 76 | 19 | 35-50 | and |
| | Fine | 19 | 4.75 | | |
| Sand | Coarse | 4.75 | 2.00 | 20-35 | "y" or "ey" * |
| | Medium | 2.00 | 0.425 | | |
| | Fine | 0.425 | 0.075 | 10-20 | some |
| Silt (non-plastic) or Clay (plastic) | | < 0.075 mm | | 1-10 | trace |

* for example: gravelly, sandy clayey, silty

Definition of Oversize Material

COBBLES: 76mm to 300mm diameter
BOULDERS: >300mm diameter

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.

$\gamma$ - 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 (Su) of a cohesive soil can be related to its consistency as follows:

| Su (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

Column headings: DEPTH (m) | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | SPT (N) | PENETRATION TESTS (✳ 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) | UNDRAINED SHEAR STRENGTH (+ Torvane +; × QU/2 ×; □ Lab Vane □; △ Pocket Pen. △; Field Vane (kPa) 50 100 150 200) | COMMENTS | ELEVATION

| Depth (m) | Soil Description | Sample # | SPT (N) | Comments | Elevation |
|---|---|---|---|---|---|
| 0 | CLAY - silty, trace sand<br>- dark brown, firm, dry to moist<br>- intermediate plasticity | G40 | | | |
| 1 | SILT - some clay to clayey, trace to some sand<br>- dark brown, soft to firm, moist<br>- low to intermediate plasticity | G41 | | | 226 |
| | SAND - clayey, silty<br>- brown, loose to compact, moist to wet<br>- fine to medium grained | | | | |
| 2 | | G42 | | | 225 |
| 3 | - very loose below 3.0 m | G43A | | | 224 |
| | | S43 | 3 | SPT Blows: [1/1/2],<br>Spoon Recovery: 0% | |
| | | G44 | | | |
| 4 | | | | | 223 |
| | - dark grey mottling below 4.4 m | | | | |
| | SAND - some clay, some silt<br>- dark grey, very loose, moist to wet<br>- fine to medium grained | S45 | 1 | SPT Blows: [0/0/1],<br>Spoon Recovery: 100% | |
| 5 | CLAY - silty, some sand<br>- dark grey, very soft to soft, moist<br>- intermediate plasticity<br><br>- moist to wet below 5.8 m | G46 | | | 222 |
| 6 | | G47 | | | 221 |
| | SAND - clayey, silty<br>- dark grey, loose, moist to wet<br>- fine to medium grained | | | | |
| 7 | | G48 | | | 220 |
| | | G49 | | | |
| 8 | | | | | 219 |
| 9 | | | | | 218 |
| | (T50): Gravel 0.0%, Sand 39.1%, Silt 33.0%, Clay 28.0% | T50 | | Tube Recovery: 83% | |
| 10 | - clayey, silty below 9.8 m | | | | |

| | | |
|---|---|---|
| AECOM | 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

PENETRATION TESTS: 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

UNDRAINED SHEAR STRENGTH: Torvane; QU/2; Lab Vane; Pocket Pen.; Field Vane (kPa) 50 100 150 200

| DEPTH (m) | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | SPT (N) | COMMENTS | ELEVATION |
|---|---|---|---|---|---|---|
| 10 | - medium grained brown sand pocket (< 50 mm in diameter) at 10.4 m | Grab | G51 | | | |
| 11 | CLAY - silty, sandy, trace organics<br>- brown, stiff, moist<br>- intermediate to high plasticity | Grab | G52 | | | 216 |
| 12 | (T53): Gravel 0.0%, Sand 24.3%, Silt 33.3%, Clay 42.4%<br>- firm from 12.5 m to 15.2 m | Shelby Tube | T53 | | Tube Recovery: 90% | 215 |
| 13 | | Grab | G54 | | | 214 |
| 14 | - moist to wet from 14.0 m 15.2 m | | | | | 213 |
| 15 | - some sand to sandy, soft, wet below 15.2 m | Grab | G55 | | | 212 |
| 16 | TILL - sandy, some silt, trace to some gravel, trace to some clay<br>- light brown, loose to compact, moist | Grab | G56 | | | 211 |
| 17 | **LIMESTONE (Bedrock)**<br>- dolomitic, white with weak tan alterations<br>- fine grained, foliated<br>- weak (R2) | Core | C1 | | C1 RQD: 82%<br>C1 Recovery: 100% | 210 |
| 18 | - tan alteration from 18.3 m to 22.3 m | | | | | 209 |
| 19 | | Core | C2 | | C2 RQD: 96%<br>C2 Recovery: 98% | 208 |
| 20 | | | | | | |

AECOM

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

| 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 (Becker; Dynamic Cone; SPT (Standard Pen Test) (Blows/300mm) 0 20 40 60 80 100; Total Unit Wt (kN/m³) 16 17 18 19 20 21; Plastic MC Liquid 20 40 60 80 100) | UNDRAINED SHEAR STRENGTH (Torvane; QU/2; Lab Vane; Pocket Pen.; Field Vane) (kPa) 50 100 150 200 | COMMENTS | ELEVATION |
|---|---|---|---|---|---|---|---|---|---|
| 20–25.76 | Bedrock | | CORE | C3 | | | | C3 RQD: 87%<br>C3 Recovery: 95% | |
| 21 | | | CORE | | | | | | 206 |
| 22 | | | CORE | C4 | | | | C4 RQD: 100%<br>C4 Recovery: 100% | 205 |
| 23 | | | CORE | | | | | | 204 |
| | | | CORE | C5 | | | | C5 RQD: 79%<br>C5 Recovery: 99% | |
| 24 | | | CORE | | | | | | 203 |
| 25 | | | CORE | C6 | | | | C6 RQD: 98%<br>C6 Recovery: 98% | 202 |
| 25.76 | | END OF TEST HOLE AT 25.76 m IN BEDROCK<br>NOTES:<br>1. Seepage not observed.<br>2. Sloughing observed below 15.2 m.<br>3. Auger refusal met at 17.1 m on bedrock.<br>4. HQ coring below 17.1 m.<br>5. Test hole backfilled with bentonite-grout mix upon completion. | | | | | | | |
| 26 | | | | | | | | | 201 |
| 27 | | | | | | | | | 200 |
| 28 | | | | | | | | | 199 |
| 29 | | | | | | | | | 198 |
| 30 | | | | | | | | | |

AECOM

| 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

PENETRATION TESTS: Becker; Dynamic Cone; SPT (Standard Pen Test) (Blows/300mm) 0 20 40 60 80 100; Total Unit Wt (kN/m³) 16 17 18 19 20 21; Plastic MC Liquid 20 40 60 80 100

UNDRAINED SHEAR STRENGTH: Torvane; QU/2; Lab Vane; Pocket Pen.; Field Vane (kPa) 50 100 150 200

| DEPTH (m) | SOIL DESCRIPTION | SAMPLE # | SPT (N) | COMMENTS |
|---|---|---|---|---|
| 0 | SILT - clayey, some sand<br>- dark brown, soft, moist<br>- low to intermediate plasticity | G21 | | |
| 1 | CLAY - silty, sandy<br>- dark brown, soft, moist<br>- intermediate plasticity | | | |
| | SAND - some silt, trace clay<br>- brown, loose, moist to wet<br>- medium grained | G22 | | |
| 2 | SAND - silty, clayey<br>- brown, loose, moist to wet<br>- fine to medium grained<br>- trace clay pockets (< 30 mm in diameter) | G23 | | |
| 3 | - grey mottling, very loose from 3.0 m to 4.1 m<br>(S24): Gravel 0.0%, Sand 47.9%, Silt 27.0%, Clay 25.0% | S24 | 3 | SPT Blows: [2/1/2],<br>Spoon Recovery: 100% |
| | | G25 | | |
| 4 | - trace gravel, dark grey, loose below 4.1 m | | | |
| | - low plasticity below 4.6 m | S26 | 2 | SPT Blows: [0/0/2],<br>Spoon Recovery: 75% |
| 5 | | G27 | | |
| 6 | | G28 | | |
| 7 | | G29 | | |
| | - (S30): Gravel 0.0%, Sand 54.5%, Silt 24.9%, Clay 20.6%<br>- wet from 7.9 m to 8.2 m | S30 | 1 | SPT Blows: [2/0/1],<br>Spoon Recovery: 100% |
| 8 | moist to wet below 8.2 m | | | |
| 9 | | G31 | | |
| 10 | | | | |

ELEVATION: 226, 225, 224, 223, 222, 221, 220, 219, 218, 217

AECOM

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

PENETRATION TESTS: Becker; Dynamic Cone; SPT (Standard Pen Test) (Blows/300mm) 0 20 40 60 80 100; Total Unit Wt (kN/m³) 16 17 18 19 20 21; Plastic MC Liquid 20 40 60 80 100

UNDRAINED SHEAR STRENGTH: Torvane; QU/2; Lab Vane; Pocket Pen.; Field Vane (kPa) 50 100 150 200

| DEPTH (m) | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | SPT (N) | COMMENTS | ELEVATION |
|---|---|---|---|---|---|---|
| 10 | - trace to some silt, dark grey, very loose, moist to wet<br>- low plasticity | | | | | 216 |
| 11 | | SPLIT SPOON | S32 | 3 | SPT Blows: [0/1/2],<br>Spoon Recovery: 75% | 215 |
| 12 | - wet below 12.2 m | GRAB | G33 | | | 214 |
| 13 | - loose to compact below 13.0 m | | | | | 213 |
| | SILT - some sand, trace clay<br>- light brown, stiff, dry to moist<br>- low plasticity<br>- dark grey laminations | GRAB | G34 | | | |
| 14 | CLAY - some silt, some sand, trace gravel<br>- grey, soft, moist to wet<br>- high plasticity<br>- trace silt inclusions (< 30 mm in diameter) | GRAB | G36 | | | 212 |
| 15 | | GRAB | G37 | | | 211 |
| | TILL (SAND)- silty, clayey, trace to some gravel<br>- light brown, very loose to loose, moist to wet | | | | | |
| 16 | | GRAB | G39 | | | 210 |
| | **LIMESTONE (Bedrock)**<br>- white<br>- fine grained<br>- no foliations<br>- weak to medium strong (R2 to R3)<br>- iron alteration to 17.1 m | CORE | C1 | | C1 RQD: 71%<br>C1 Recovery: 100% | |
| 17 | | CORE | C2 | | C2 RQD: 87%<br>C2 Recovery: 96% | 209 |
| 18 | | | | | | 208 |
| 19 | | CORE | C3 | | C3 RQD: 91%<br>C3 Recovery: 91% | 207 |
| 20 | | | | | | |

AECOM

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

| 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

| DEPTH (m) | SOIL SYMBOL | SLOTTED PIEZOMETER | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | SPT (N) | PENETRATION TESTS: 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 | UNDRAINED SHEAR STRENGTH: Torvane; QU/2; Lab Vane; Pocket Pen.; Field Vane (kPa) 50 100 150 200 | COMMENTS | ELEVATION |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | | | | | | | | | | |
| | | | | | | | | | | 206 |
| | | | | | C4 | | | | C4 RQD: 96%<br>C4 Recovery: 99% | |
| 21 | | | | | | | | | | |
| | | | | | | | | | | 205 |
| 22 | | | | | | | | | | |
| | | | | | C5 | | | | C5 RQD: 93%<br>C5 Recovery: 100% | 204 |
| 23 | | | | | | | | | | |
| | | | | | | | | | | 203 |
| | | | | | C6 | | | | C6 RQD: 96%<br>C6 Recovery: 100% | |
| 24 | | | | | | | | | | |
| | | | | | | | | | | 202 |
| 25 | | | | | | | | | | |
| | | | | | C7 | | | | C7 RQD: 99%<br>C7 Recovery: 99% | 201 |
| 26 | | | END OF TEST HOLE AT 25.96 m IN BEDROCK | | | | | | | |
| | | | | | | | | | | 200 |
| 27 | | | | | | | | | | |
| | | | | | | | | | | 199 |
| 28 | | | | | | | | | | |
| | | | | | | | | | | 198 |
| 29 | | | | | | | | | | |
| | | | | | | | | | | 197 |
| 30 | | | | | | | | | | |

END OF TEST HOLE AT 25.96 m IN BEDROCK

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

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

PENETRATION TESTS: ✳ 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

UNDRAINED SHEAR STRENGTH: + Torvane +; × QU/2 ×; □ Lab Vane □; △ Pocket Pen. △; Field Vane (kPa) 50 100 150 200

| DEPTH (m) | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | SPT (N) | COMMENTS | ELEVATION |
|---|---|---|---|---|---|---|---|
| 0 | Water | WATER | | | | | 223 – 217 |
| 6.7 | Sand | SAND (Alluvial) - some gravel<br>- brown, compact, wet | | | | | 217 |
| 8 | | | Split spoon | S1 | 16 | SPT Blows [4/6/10], Spoon Recovery 10% | 216 |
| 9 | | | Split spoon | S2 | 19 | SPT Blows [18/12/7], Spoon Recovery 0% | 215 |
| 10 | Clay | CLAY - trace silt<br>- grey, very soft, moist to wet<br>- high plasticity | Split spoon | S3 | 2 | SPT Blows [2/1/1], Spoon Recovery 10% | 214 – 213 |
| 12 | Till | TILL (SAND) - silty, some clay, trace gravel<br>- light brown, loose, wet<br>- low plasticity | Split spoon | S4-A<br>S4-B | 5 | SPT Blows [1/2/3], Spoon Recovery 100% | 212 |
| 13.2 | | - sandy, compact, no plasticity below 13.2 m | Split spoon | S5 | 19 | SPT Blows [8/10/9], Spoon Recovery 0% | 211 – 210 |
| 14 | Limestone | **LIMESTONE (Bedrock)**<br>- white/brown<br>- fine grained<br>- weak to medium strong (R2 to R3)<br>- no foliations | Core | C1 | | C1 RQD: 83%<br>C1 Recovery: 94% | 209 |
| 16 | | | Core | C2 | | C2 RQD: 89%<br>C2 Recovery: 100% | 208 – 207 |
| 17.5 – 18 | | | Core | C3 | | C3 RQD: 94%<br>C3 Recovery: 100% | 206 |

| | | |
|---|---|---|
| AECOM | 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

Column headings: DEPTH (m) | SOIL SYMBOL | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | SPT (N) | PENETRATION TESTS: ✳ Becker ✳, ◇ Dynamic Cone ◇, ◆ SPT (Standard Pen Test) ◆ (Blows/300mm) 0 20 40 60 80 100; ■ Total Unit Wt ■ (kN/m³) 16 17 18 19 20 21; Plastic MC Liquid 20 40 60 80 100 | UNDRAINED SHEAR STRENGTH: + Torvane +, × QU/2 ×, □ Lab Vane □, △ Pocket Pen. △, Field Vane (kPa) 50 100 150 200 | COMMENTS | ELEVATION

| DEPTH (m) | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | COMMENTS | ELEVATION |
|---|---|---|---|---|---|
| 18 | - tan to yellow, solution pitting, altered from 18.2 m to 20.9 m | CORE | | | |
| 19 | | CORE | C4 | C4 RQD: 27%<br>C4 Recovery: 36% | 205 |
| 20 | | CORE | | | 204 |
| 21 | | CORE | C5 | C5 RQD: 62%<br>C5 Recovery: 89% | 203 |
| 22 | **LIMESTONE (Bedrock)**<br>- tan/white<br>- fine grained,<br>- medium strong (R3)<br>- increased foliation | CORE | C6 | C6 RQD: 39%<br>C6 Recovery: 98% | 202 |
| 23 | | CORE | | | 201 |
| 24 | | CORE | C7 | C7 RQD: 33%<br>C7 Recovery: 97% | 200 |
| 25 | | CORE | C8 | C8 RQD: 80%<br>C8 Recovery: 96% | 199 |
| 26 | | CORE | | | 198 |
| 27 | | CORE | C9 | C9 RQD: 68%<br>C9 Recovery: 99% | 197 |
| 28 | | CORE | C10 | C10 RQD: 73%<br>C10 Recovery: 100% | 196 |
| 29 | | CORE | | | 195 |
| 30 | | CORE | C11 | C11 RQD: 87%<br>C11 Recovery: 99% | 194 |
| 31 | **END OF TEST HOLE AT 30.51 m IN LIMESTONE (BEDROCK)** | | | | 193 |
| 32 | | | | | 192 |
| 33 | | | | | 191 |
| 34 | | | | | 190 |
| 35 | | | | | 189 |
| 36 | | | | | 188 |

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.

| AECOM | 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

PENETRATION TESTS: 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

UNDRAINED SHEAR STRENGTH: Torvane; QU/2; Lab Vane; Pocket Pen.; Field Vane (kPa) 50 100 150 200

| DEPTH (m) | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | SPT (N) | COMMENTS | ELEVATION |
|---|---|---|---|---|---|---|
| 0 | CLAY - some sand, trace gravel, trace silt, trace organic<br>- brown, firm, moist<br>- intermediate plasticity | | | | | |
| | | GRAB | G1 | | | |
| 1 | | | | | | 227 |
| | | GRAB | G2 | | | |
| 2 | - trace sand from 1.8 m to 2.4 m | | | | | 226 |
| | - sandy below 2.4 m | GRAB | G3 | | | |
| 3 | SAND - some clay, some silt<br>- brown, loose, moist<br>- fine to medium grained<br>- low plasticity<br>- (T4): Grave 0.0%, Sand 68.8%, Silt 12.6%, Clay 18.6% | SHELBY TUBE | T4 | | Tube Recovery 83% | 225 |
| 4 | | GRAB | G5 | | | 224 |
| | - some clay to clayey from 4.6 m to 5.2 m<br>- wet, very loose below 4.6 m | SPLIT SPOON | S6 | 2 | SPT Blows: [1/1/1], Spoon Recovery 100% | |
| 5 | - some clay, some silt, trace oxidation below 5.2 m | GRAB | G7 | | | 223 |
| 6 | SAND - some silt, trace to some clay, trace organics<br>- grey, very loose, moist to wet<br>- fine to medium grained | SPLIT SPOON | S8 | 2 | SPT Blows: [1/1/1], Spoon Recovery 100% | 222 |
| 7 | - silty, clayey, loose to compact, wet below 6.9 m | GRAB | G9 | | | 221 |
| 8 | | SHELBY TUBE | T10 | | Tube Recovery 100% | 220 |
| | CLAY - some sand, some silt<br>- grey, soft, wet | | | | | |
| 9 | | GRAB | G11 | | | 219 |
| | SILT - sandy, clayey<br>- grey, loose, wet<br>- low plasticity<br>- (G11): Gravel 0.0%, Sand 25.7%, Silt 36.6%, Clay 27.7% | | | | | |
| 10 | | | | | | |

AECOM

| 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

PENETRATION TESTS: 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

UNDRAINED SHEAR STRENGTH: Torvane; QU/2; Lab Vane; Pocket Pen.; Field Vane (kPa) 50 100 150 200

| DEPTH (m) | SOIL DESCRIPTION | SAMPLE TYPE | SAMPLE # | SPT (N) | COMMENTS | ELEVATION |
|---|---|---|---|---|---|---|
| 10 | - very loose below 10.7 m | | | | | |
| 11 | ORGANIC - sandy, trace to some silt, trace clay<br>- dark brown to black, very loose, wet | GRAB | G13 | | | 217 |
| 12 | SAND - trace gravel, trace to some silt, trace clay,<br>- grey, loose, wet<br>- medium to coarse grained<br>- trace fossil (suspected seashell) | GRAB | G14 | | | 216 |
| | CLAY - some silt, trace gravel, trace sand, trace organics<br>- grey, stiff, moist<br>- high plasticity<br>- trace organic pockets | SPLIT SPOON | S15 | 12 | SPT Blows: [3/5/7],<br>Spoon Recovery 100% | |
| 13 | | | | | | 215 |
| 14 | - (T16) Gravel 2.2%, Sand 89.6%, Silt 3.9%, Clay 4.6%<br>- very stiff from 13.7 m to 14.8 m | SHELBY TUBE | T16 | | Tube Recovery 100% | 214 |
| 15 | - trace to some gravel, firm below 14.8 m<br>- silt inclusions/lenses (< 15 mm thick) below 14.8 m<br>- low plasticity | GRAB | G17 | | | 213 |
| 16 | TILL (SAND) - silty, some clay, trace gravel<br>- light brown, loose to compact, moist to wet<br>- low plasticity | | | | | 212 |
| | - (G18): Gravel 7.5%, Sand 45.8%, Silt 32.8%, Clay 13.9% | GRAB | G18 | | | |
| 17 | | | | | | 211 |
| | | GRAB | G19 | | | |
| 18 | **Dolomitic LIMESTONE (Bedrock)**<br>- white<br>- fine grained, homogeneous<br>- no foliation | CORE | C1 | | C1 RQD: 92%<br>C1 Recovery: 100% | 210 |
| 19 | | CORE | C2 | | C2 RQD: 96%<br>C2 Recovery: 97% | 209 |
| 20 | | | | | | |

| | | |
|---|---|---|
| AECOM | 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: GRAB, SHELBY TUBE, SPLIT SPOON, BULK, NO RECOVERY, CORE

BACKFILL TYPE: BENTONITE, GRAVEL, SLOUGH, GROUT, CUTTINGS, SAND

PENETRATION TESTS: 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

UNDRAINED SHEAR STRENGTH: Torvane; QU/2; Lab Vane; Pocket Pen.; Field Vane (kPa) 50 100 150 200

| DEPTH (m) | SOIL DESCRIPTION | SAMPLE # | COMMENTS | ELEVATION |
|---|---|---|---|---|
| 20 | | | | |
| 21 | | C3 | C3 RQD: 86%<br>C3 Recovery: 97% | 207 |
| 22 | - clay filled seam from 22.2 m to 22.8 m | C4 | C4 RQD: 75%<br>C4 Recovery: 85% | 206 |
| 23 | | | | 205 |
| 24 | **LIMESTONE (Bedrock)**<br>- mottled tan-grey/white<br>- fine grained, R2 to R3 - weak to medium strong<br>- foliated | C5 | C5 RQD: 81%<br>C5 Recovery: 100% | 204 |
| 25 | | C6 | C6 RQD: 98%<br>C6 Recovery: 100% | 203 |
| 26 | | | | 202 |
| 27 | | C7 | C7 RQD: 95%<br>C7 Recovery: 100% | 201 |
| 28 | END OF TEST HOLE AT 27.74 m IN BEDROCK<br>NOTES:<br>1. Seepage not observed.<br>2. Auger refusal met at 17.8 m on bedrock.<br>3. HQ coring below 17.8 m.<br>4. Standpipe piezometer installed at 18.3 m.<br>5. Groundwater monitoring:<br>- August 23, 2016 at 4.29 m below ground surface<br>- September 23, 2016 at 4.58 m below ground surface<br>- November 18, 2016 at 4.45 m below ground surface | | | 200 |
| 29 | | | | 199 |
| 30 | | | | |

AECOM

| 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

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204 284 2040 fax

# 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

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/MAlkiki |
| Sample Location: | Varies | Sample Date: | Varies |
| Sample Depth: | Varies | Lab Technician: | EManimbao |
| Sample Number: | Varies | Date Tested: | September 13, 2016 |

# Moisture Content (ASTM D2216-10)

Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

| Location | Sample | Depth (m) | Moisture Content (%) |
|---|---|---|---|
| TH16-01 | G40 | 0.76 - 0.91 m | **21.4%** |
| | G41 | 1.52 - 1.68 m | **27.7%** |
| | G42 | 2.29 - 2.44 m | **32.1%** |
| | G43A | 3.05 - 3.20 m | **32.6%** |
| | G43 | 3.05 - 3.20 m | **N/A** |
| | G44 | 3.81 - 3.96 m | **32.3%** |
| | S45 | 4.57 - 5.03 m | **33.3%** |
| | G46 | 5.33 - 5.49 m | **35.4%** |
| | G46 | 6.10 - 6.25 m | **35.6%** |
| | G48 | 6.86 - 7.01 m | **34.5%** |
| | G49 | 7.62 - 7.77 m | **34.7%** |
| | T50 | 9.14 - 9.75 m | **32.7%** |
| | G51 | 10.67 - 10.82 m | **31.0%** |
| | G52 | 11.43 - 11.58 m | **40.6%** |
| | T53 | 12.19 - 12.80 m | **36.1%** |
| | G54 | 13.72 - 13.87 m | **52.3%** |
| | G55 | 15.24 - 15.39 m | **50.2%** |
| | G56 | 16.76 - 16.92 m | **17.3%** |
| TH16-02 | G21 | 0.76 - 0.91 m | **24.7%** |
| | G22 | 1.52 - 1.68 m | **22.8%** |
| | G23 | 2.29 - 2.44 m | **28.7%** |
| | S24 | 3.05 - 3.51 m | **31.5%** |
| | G25 | 3.81 - 3.96 m | **31.8%** |
| | S26 | 4.57 - 5.03 m | **36.2%** |
| | G27 | 5.33 - 5.49 m | **33.2%** |
| | G28 | 6.10 - 6.25 m | **32.5%** |
| | G29 | 6.86 - 7.01 m | **34.8%** |
| | S30 | 7.62 - 8.08 m | **35.6%** |
| | G31 | 9.14 - 9.30 m | **31.3%** |
| | S32 | 10.67 - 11.13 m | **32.3%** |
| | G33 | 12.19 - 12.34 m | **37.0%** |
| | G34 | 13.26 - 13.41 m | **21.5%** |
| | G36 | 14.48 - 14.63 m | **44.9%** |
| | G37 | 15.24 - 15.39 m | **51.1%** |
| | G39 | 16.15 - 16.31 m | **18.4%** |
| TH16-03 | S4A | 11.67 - 12.13 m | **52.6%** |
| | S4B | 11.89 - 12.34 m | **17.7%** |
| TH16-04 | G1 | 0.76 - 0.91 m | **21.5%** |

| Location | Sample | Depth (m) | Moisture Content (%) |
|---|---|---|---|
| | G2 | 1.52 - 1.68 m | **21.2%** |
| | G3 | 2.44 - 2.59 m | **13.7%** |
| | T4 | 3.05 - 3.66 m | **18.7%** |
| | G5 | 3.96 - 4.11 m | **18.2%** |
| | S6 | 4.57 - 5.03 m | **25.2%** |
| | G7 | 5.33 - 5.49 m | **29.3%** |
| | S8 | 6.10 - 6.55 m | **26.6%** |
| | G9 | 6.86 - 7.01 m | **34.1%** |
| | T10 | 7.62 - 8.23 m | **31.7%** |
| | G11 | 9.14 - 9.30 m | **33.6%** |
| | G13 | 10.97 - 11.13 m | **44.2%** |
| | G14 | 11.89 - 12.04 m | **26.5%** |
| | S15 | 12.19 - 12.65 m | **36.6%** |
| | T16 | 13.72 - 14.33 m | **20.8%** |
| | G17 | 15.24 - 15.39 m | **44.7%** |
| | G18 | 16.76 - 16.92 m | **13.3%** |
| | G19 | 17.68 - 17.83 m | **11.4%** |

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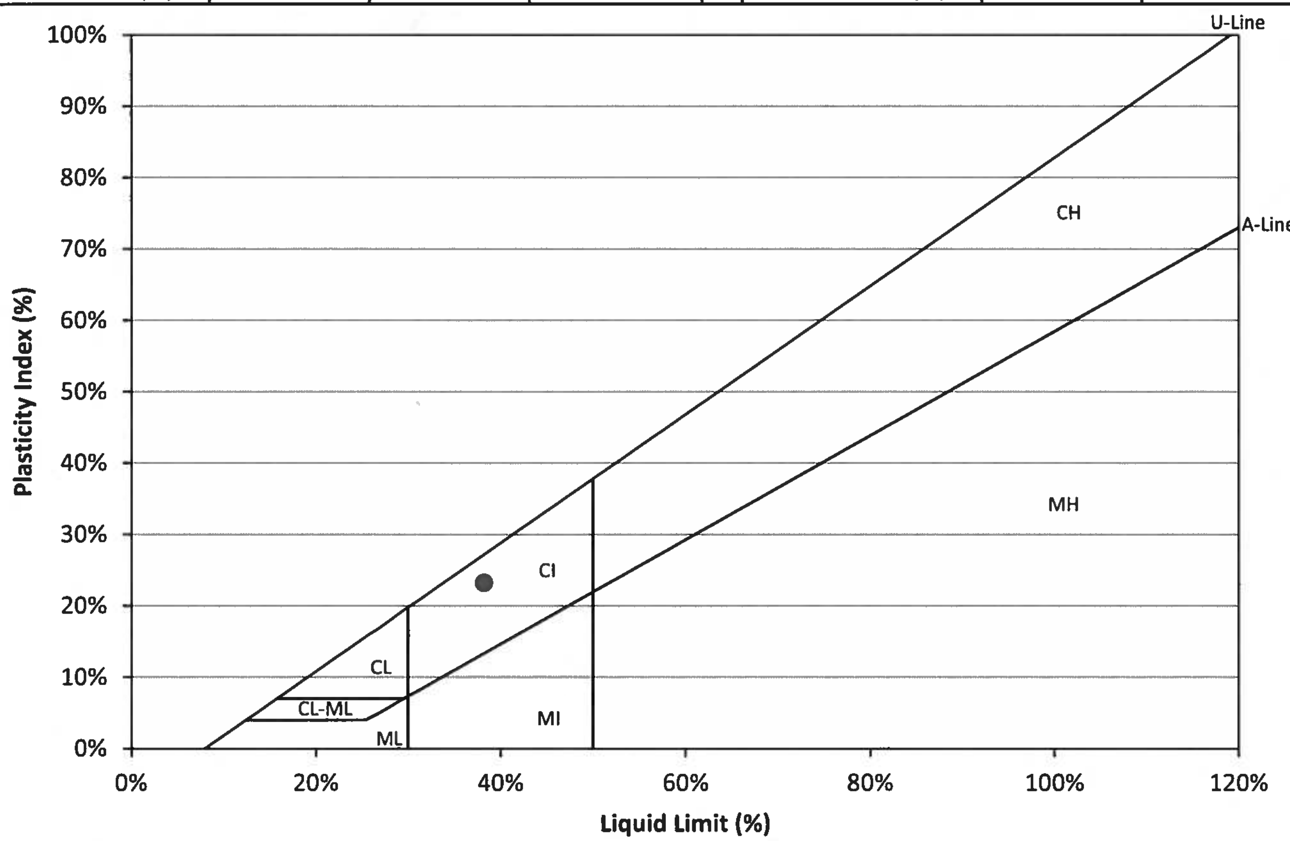
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-01 | Sample Date: | Varies |
| Sample Depth: | 6.10 - 6.25 m | Lab Technician: | EManimbao |
| Sample Number: | G47 | 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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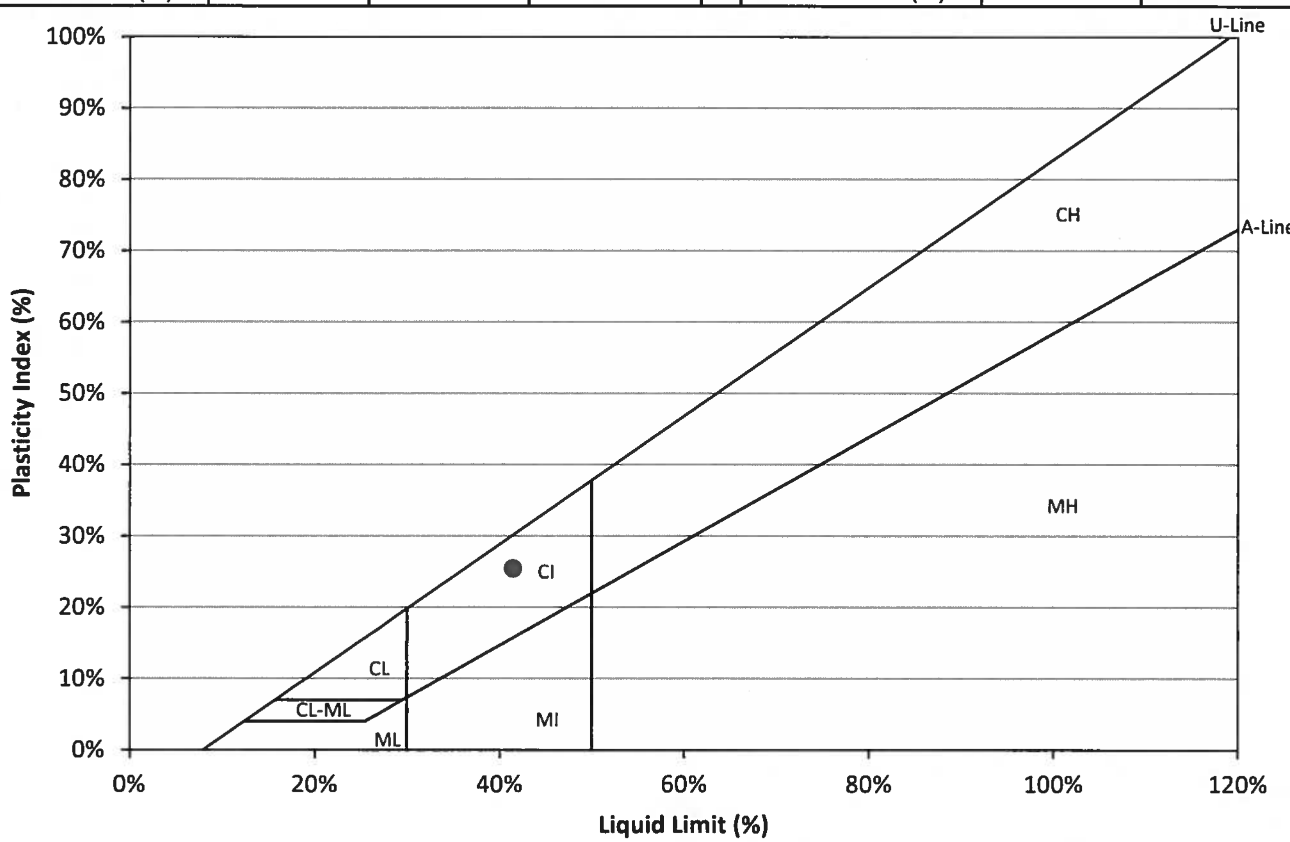
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-01 | Sample Date: | Varies |
| Sample Depth: | 9.14 - 9.75 m | Lab Technician: | EManimbao |
| Sample Number: | T50 | 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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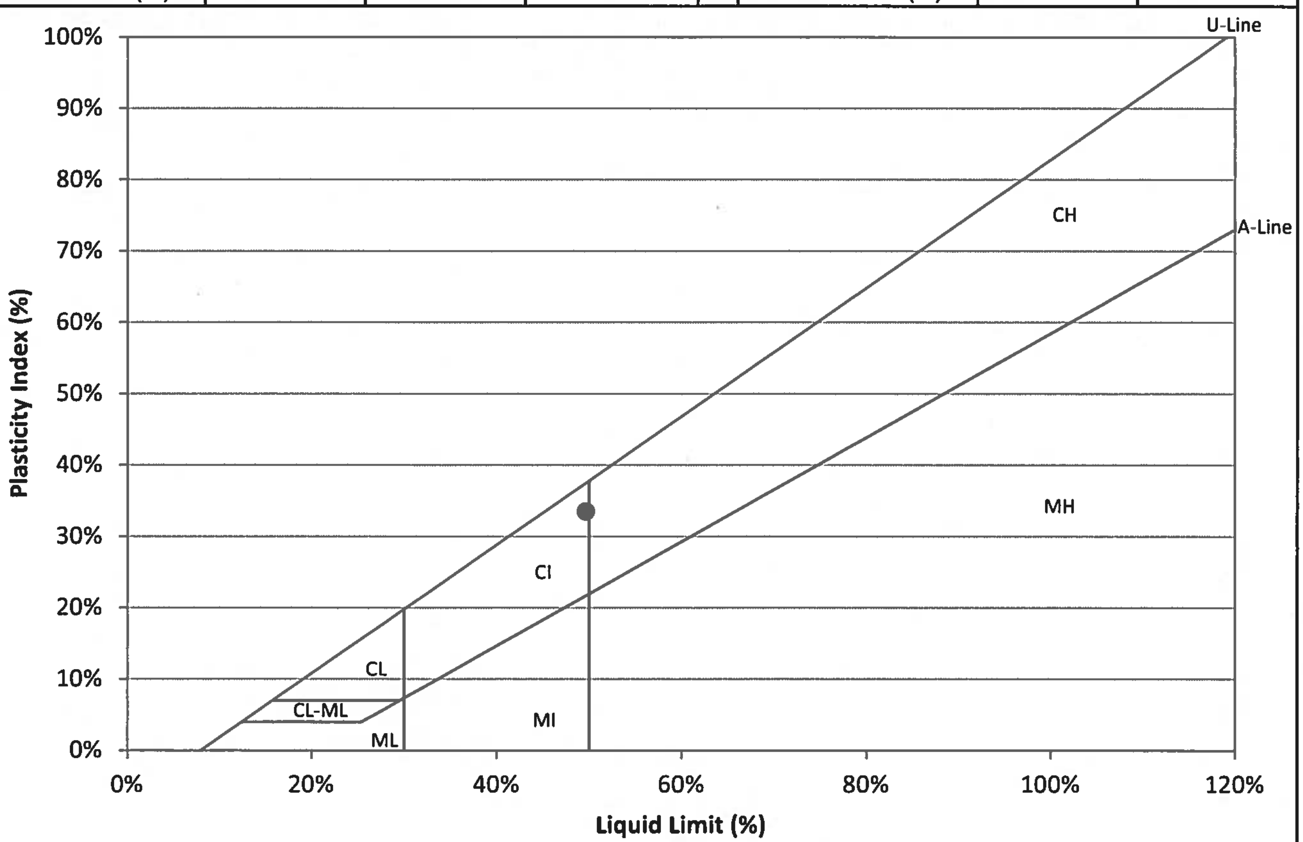
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-01 | Sample Date: | Varies |
| Sample Depth: | 12.19 - 12.80 m | Lab 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 | | | |
|---|---|---|---|
| Blows | 33 | 29 | 21 |
| Wet Sample (g) | 7.5 | 7.7 | 8.1 |
| Dry Sample (g) | 5.1 | 5.2 | 5.4 |
| Water Content (%) | 48.1% | 48.8% | 50.7% |

| Plastic Limit | | |
|---|---|---|
| Trial | 1 | 2 |
| Wet Sample (g) | 8.3 | 8.6 |
| Dry Sample (g) | 7.2 | 7.4 |
| Water Content (%) | 16.0% | 16.3% |




| | | |
|---|---|---|
| Liquid Limit (%): 49.7% | Plastic Limit (%): 16.2% | Plasticity Index (%): 33.5% |

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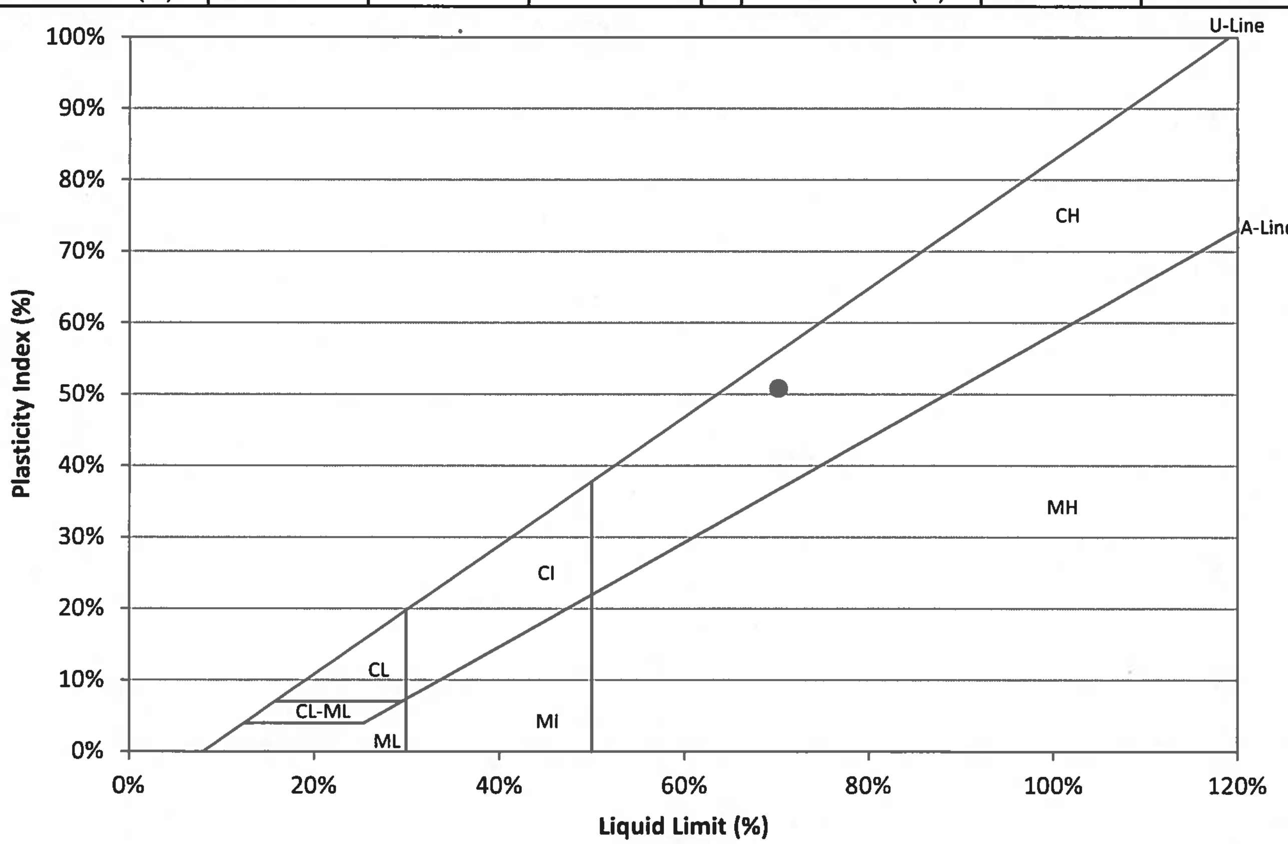
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-02 | Sample Date: | Varies |
| Sample Depth: | 15.24 - 15.39 m | Lab Technician: | EManimbao |
| Sample Number: | G37 | 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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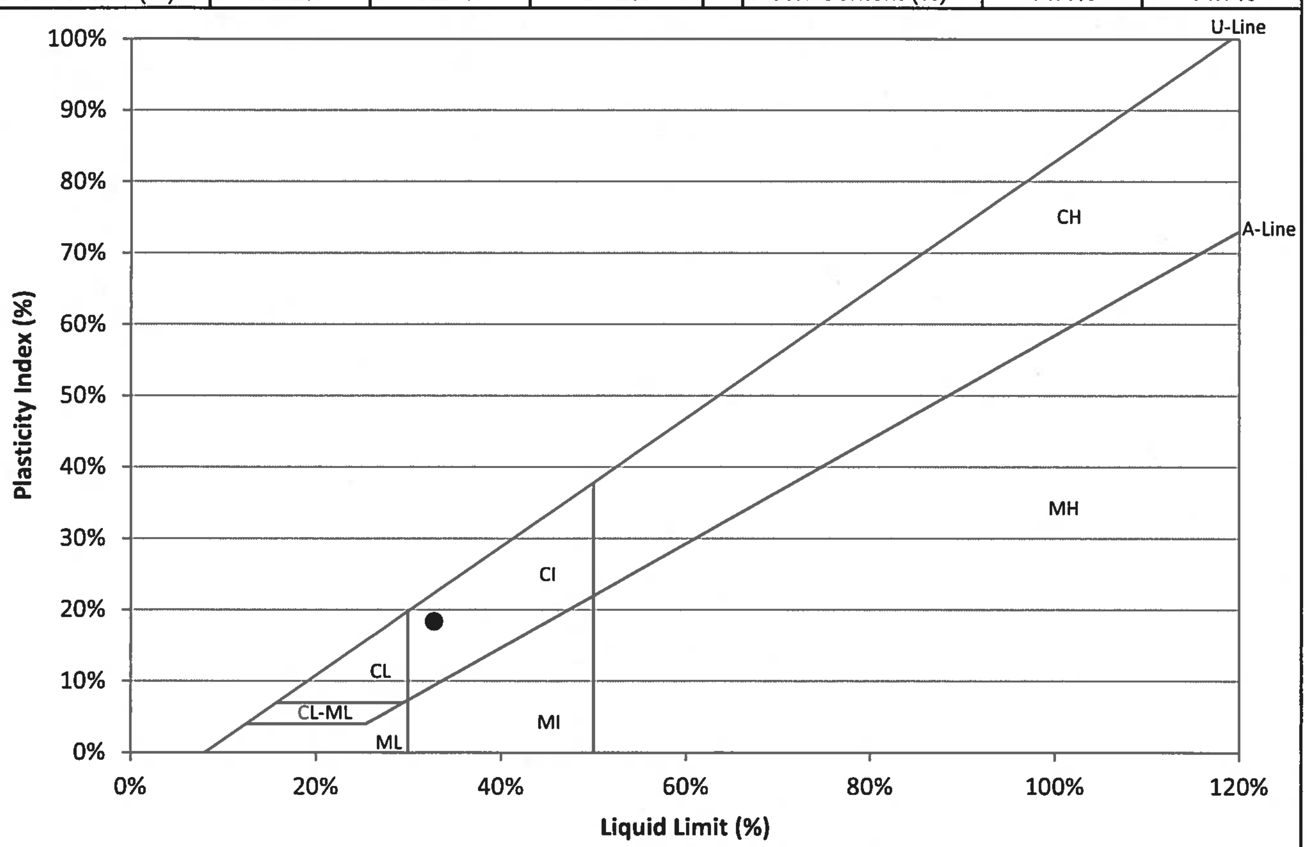
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-02 | Sample Date: | Varies |
| Sample Depth: | 7.62 - 8.08 m | Lab Technician: | EManimbao |
| Sample Number: | S30 | 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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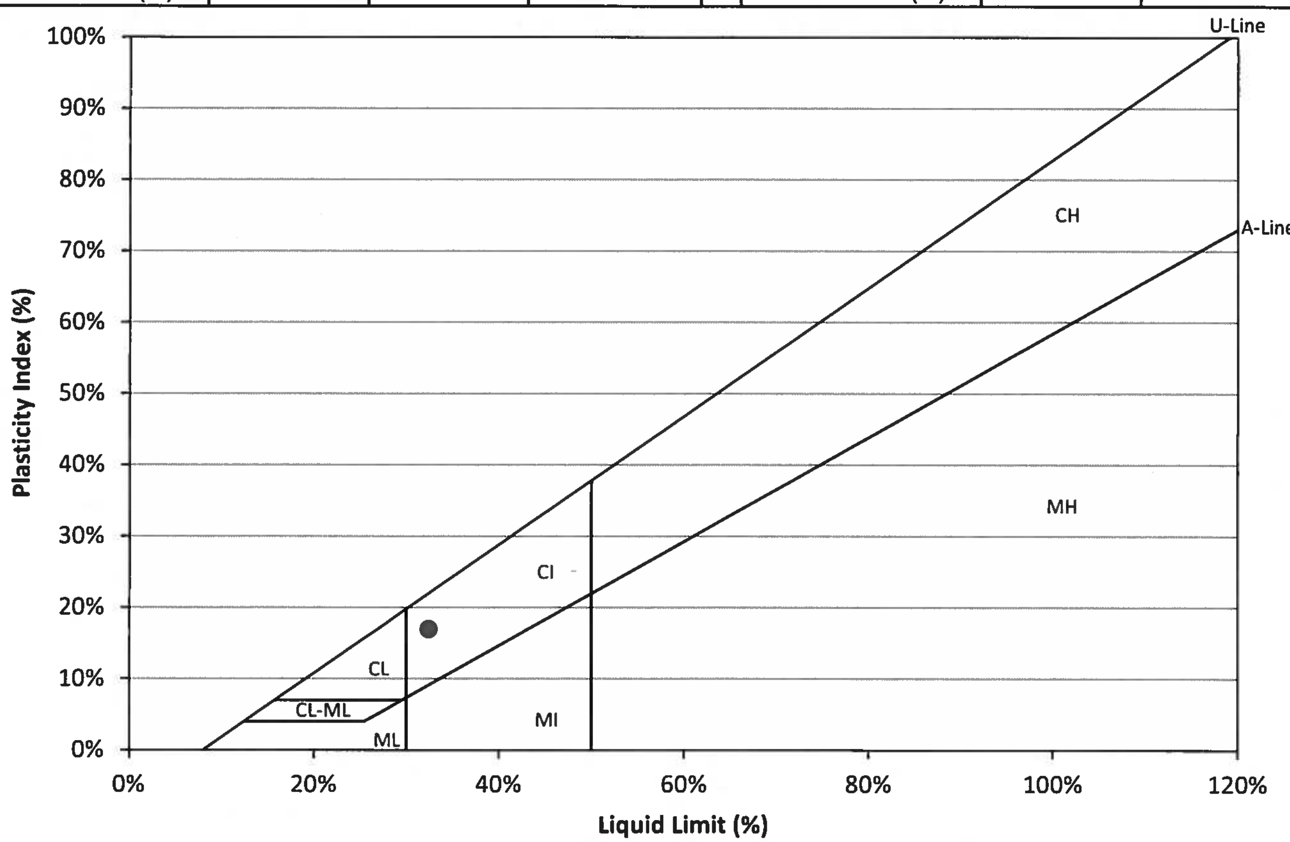
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-02 | Sample Date: | Varies |
| Sample Depth: | 10.67 - 11.28 m | Lab Technician: | EManimbao |
| Sample Number: | S32 | 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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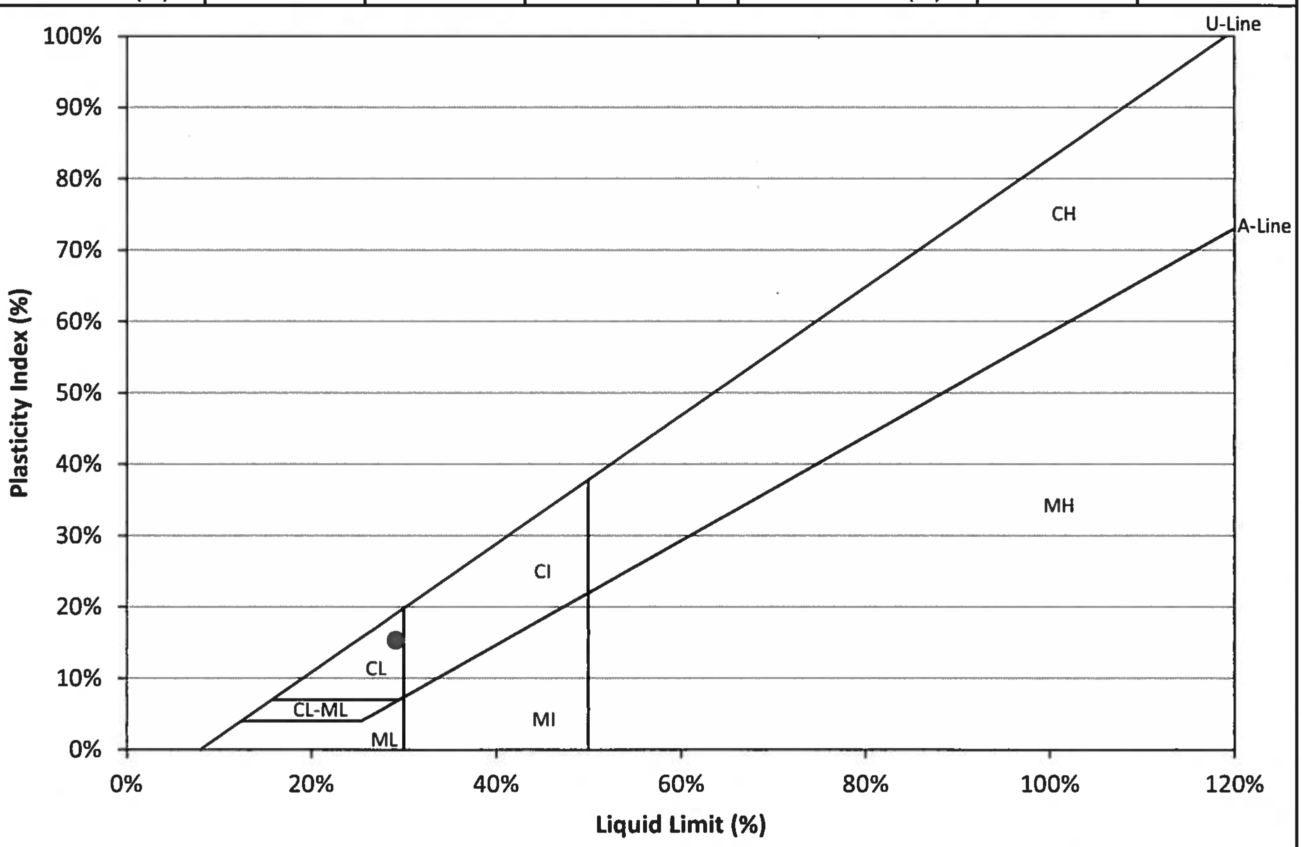
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-04 | Sample Date: | Varies |
| Sample Depth: | 5.33 - 5.49m | Lab Technician: | EManimbao |
| Sample Number: | G7 | 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% |




| Liquid Limit (%): 29.2% | Plastic Limit (%): 13.8% | Plasticity Index (%): 15.3% |
|---|---|---|

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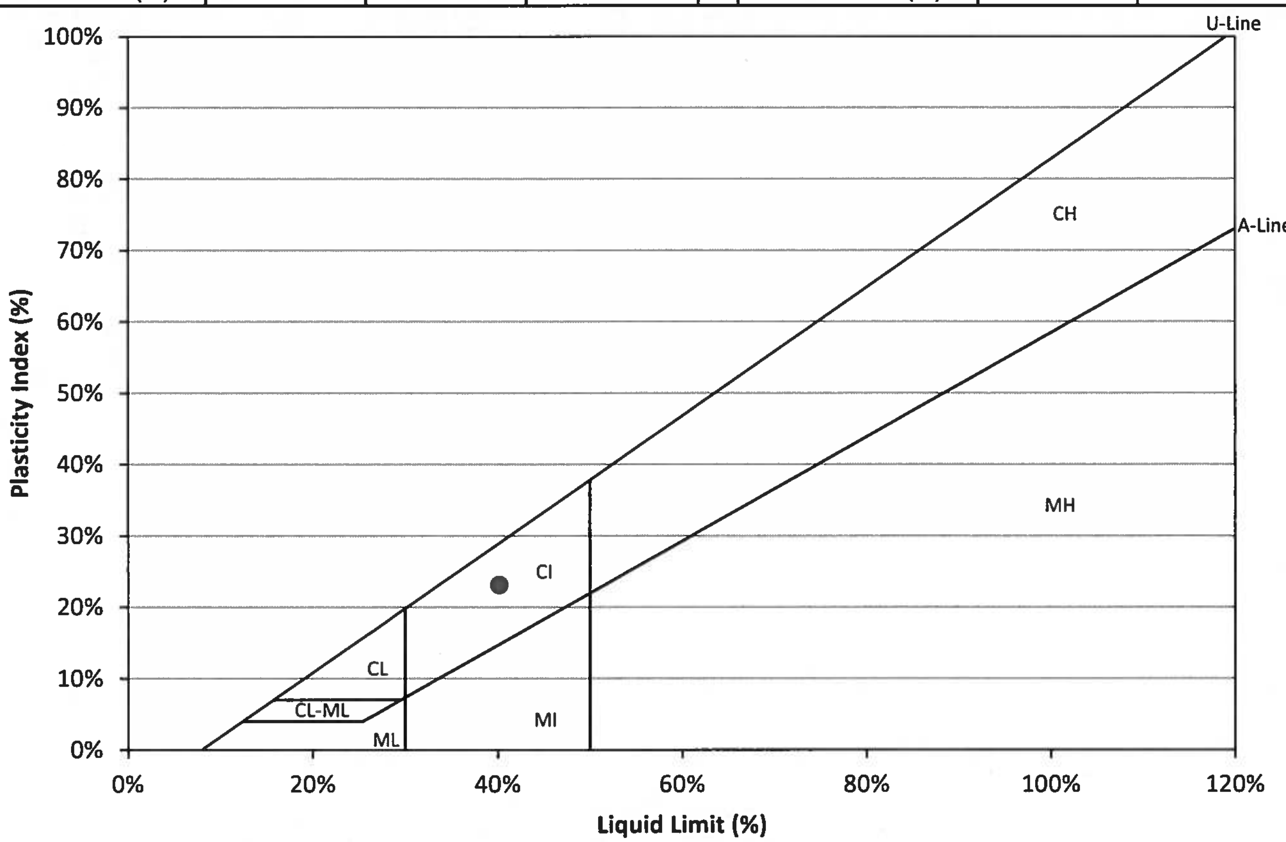
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-04 | Sample Date: | Varies |
| Sample Depth: | 9.14 - 9.30m | Lab Technician: | EManimbao |
| Sample Number: | G11 | 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% |




| | | |
|---|---|---|
| Liquid Limit (%): 40.2% | Plastic Limit (%): 17.1% | Plasticity Index (%): 23.1% |

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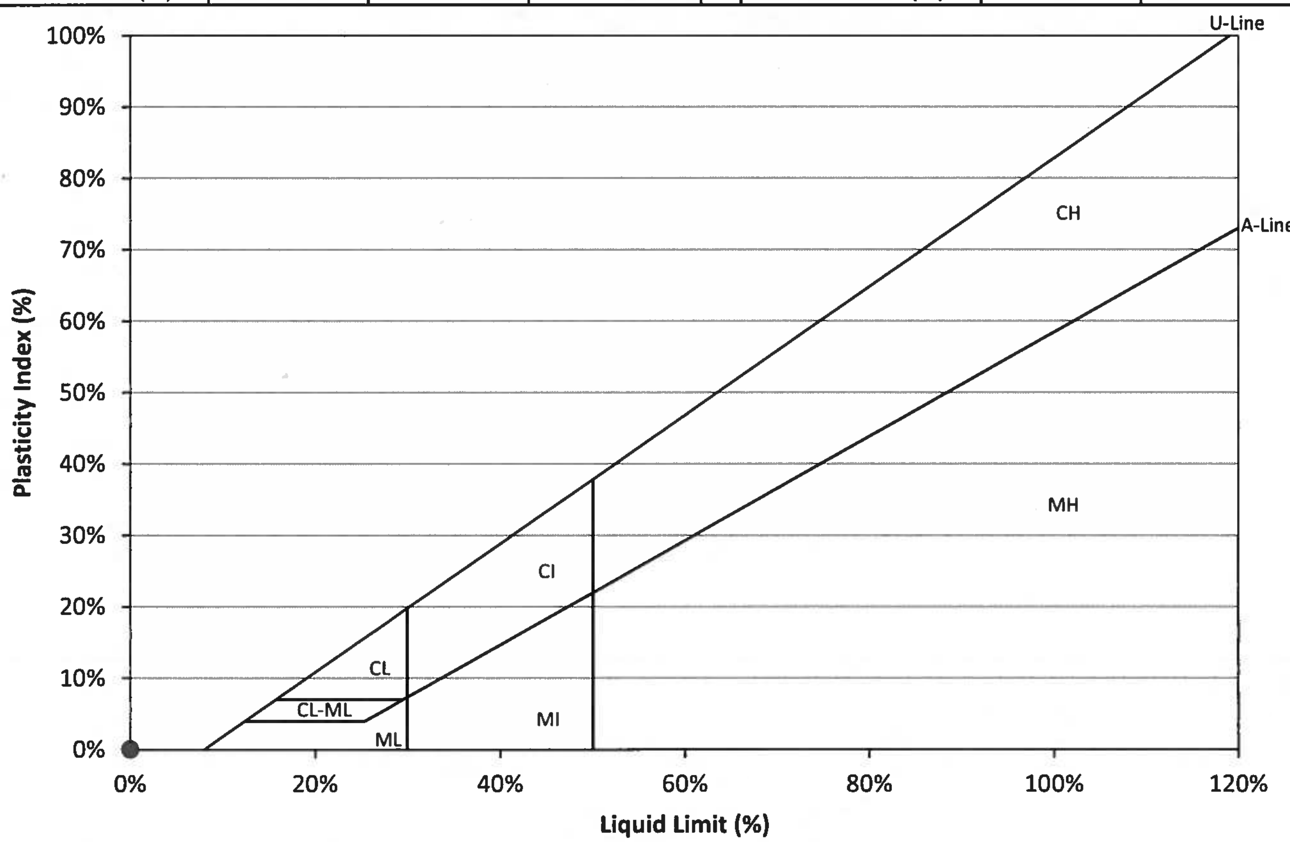
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-04 | Sample Date: | Varies |
| Sample Depth: | 10.97 - 11.13m | Lab Technician: | EManimbao |
| Sample Number: | G13 | 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 |




| | | |
|---|---|---|
| Liquid Limit (%): Non Plastic | Plastic Limit (%): Non Plastic | Plasticity Index (%): Non Plastic |

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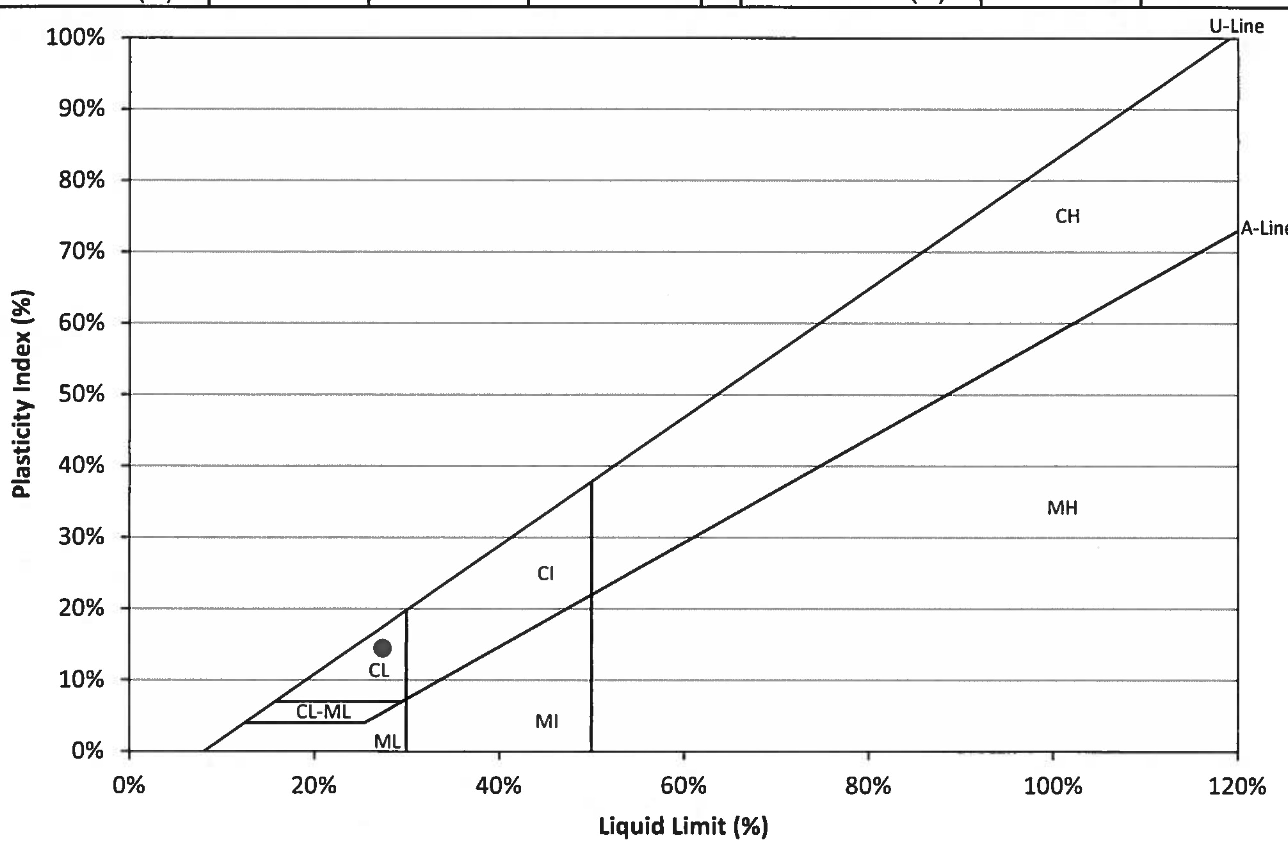
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-04 | Sample Date: | Varies |
| Sample Depth: | 3.05 - 3.66m | Lab Technician: | EManimbao |
| Sample Number: | T4 | 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% |




| | | |
|---|---|---|
| Liquid Limit (%): 27.4% | Plastic Limit (%): 13.0% | Plasticity Index (%): 14.4% |

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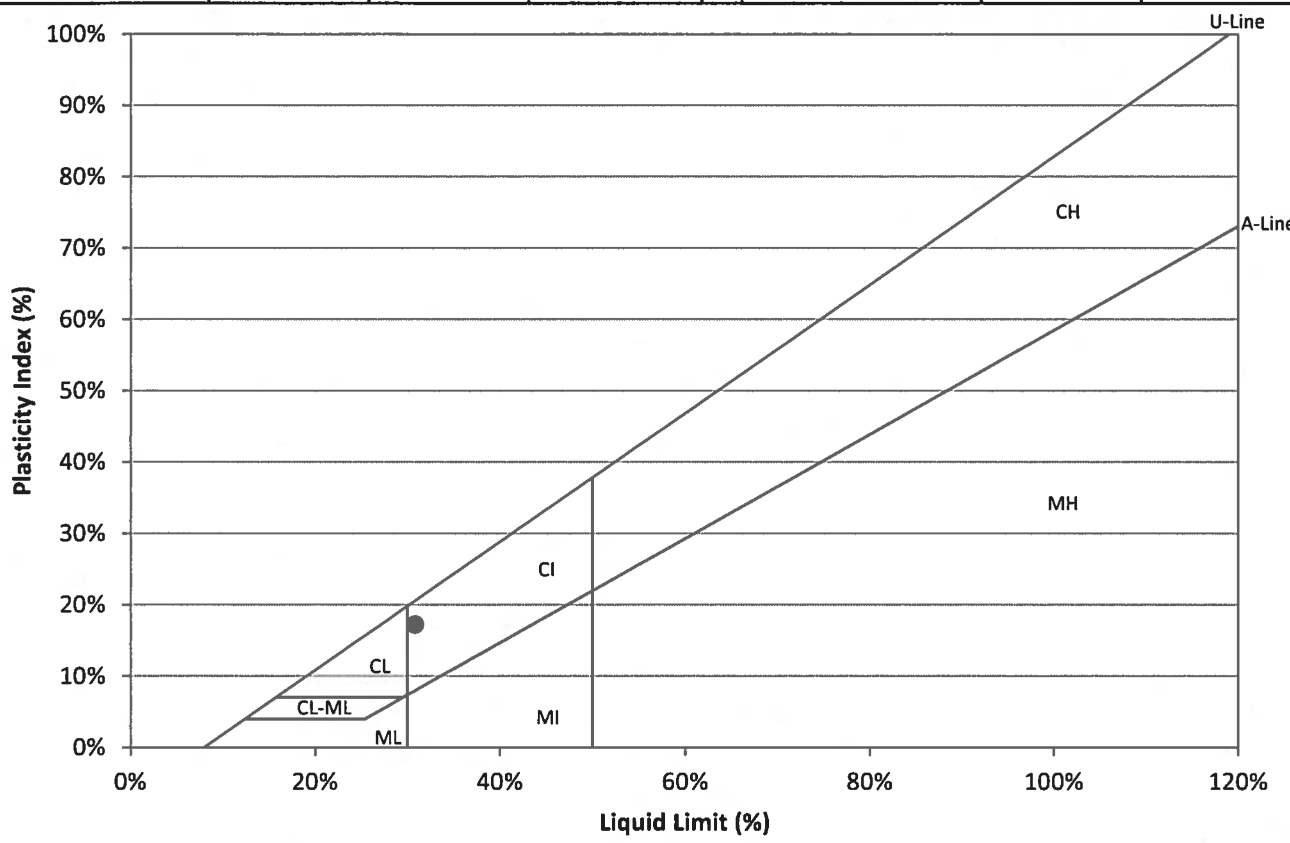
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-04 | Sample Date: | Varies |
| Sample Depth: | 7.62 - 8.23m | Lab Technician: | EManimbao |
| Sample Number: | T10 | 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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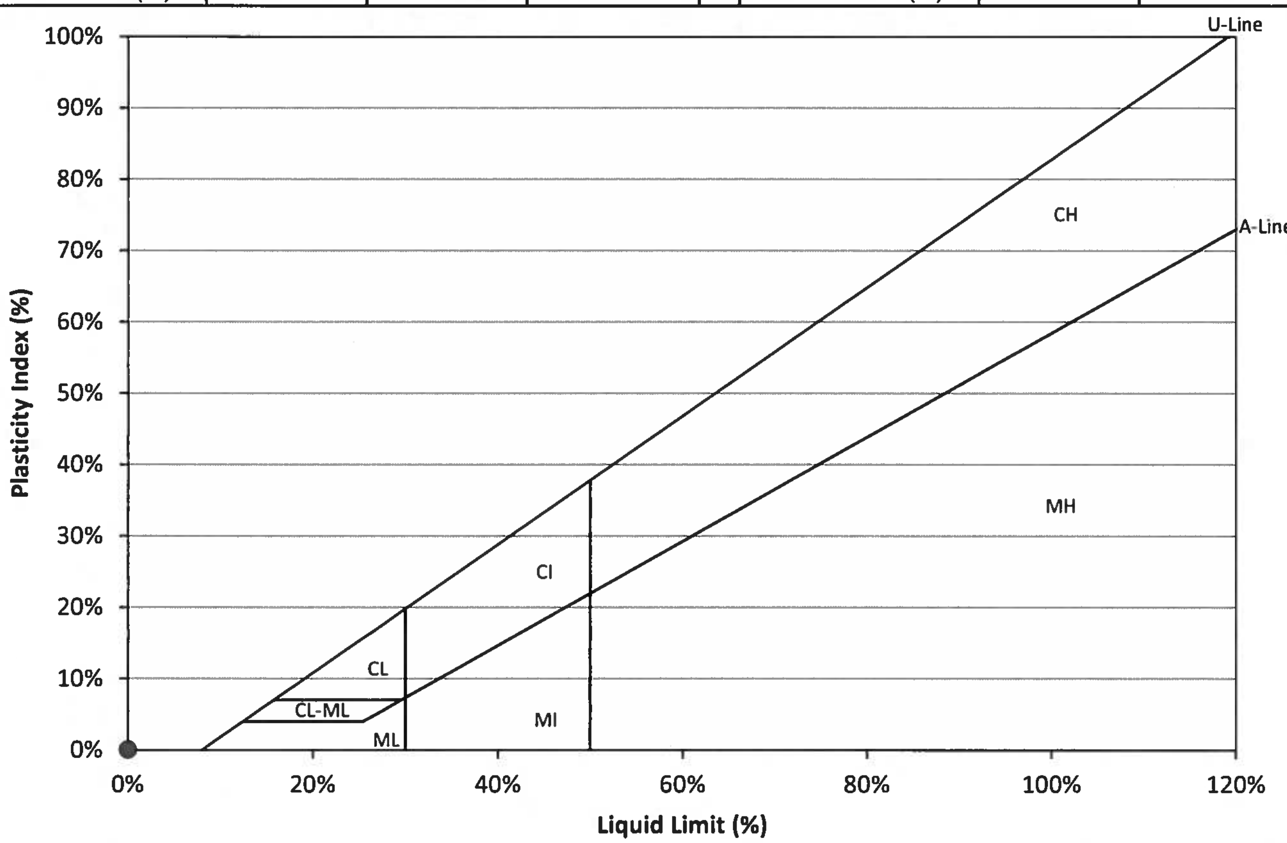
| | | | |
|---|---|---|---|
| Project Name: | North East Interceptor | Supplier: | AECOM |
| Project Number: | 60509089 | Specification: | N/A |
| Client: | City of Winnipeg | Field Technician: | RHarras |
| Sample Location: | TH16-04 | Sample Date: | Varies |
| Sample Depth: | 13.72 - 14.33m | Lab Technician: | EManimbao |
| Sample Number: | T16 | 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 |




| | | |
|---|---|---|
| Liquid Limit (%): Non Plastic | Plastic Limit (%): Non Plastic | Plasticity Index (%): Non Plastic |

## GRAIN SIZE DISTRIBUTION
**(ASTM D422-63)**

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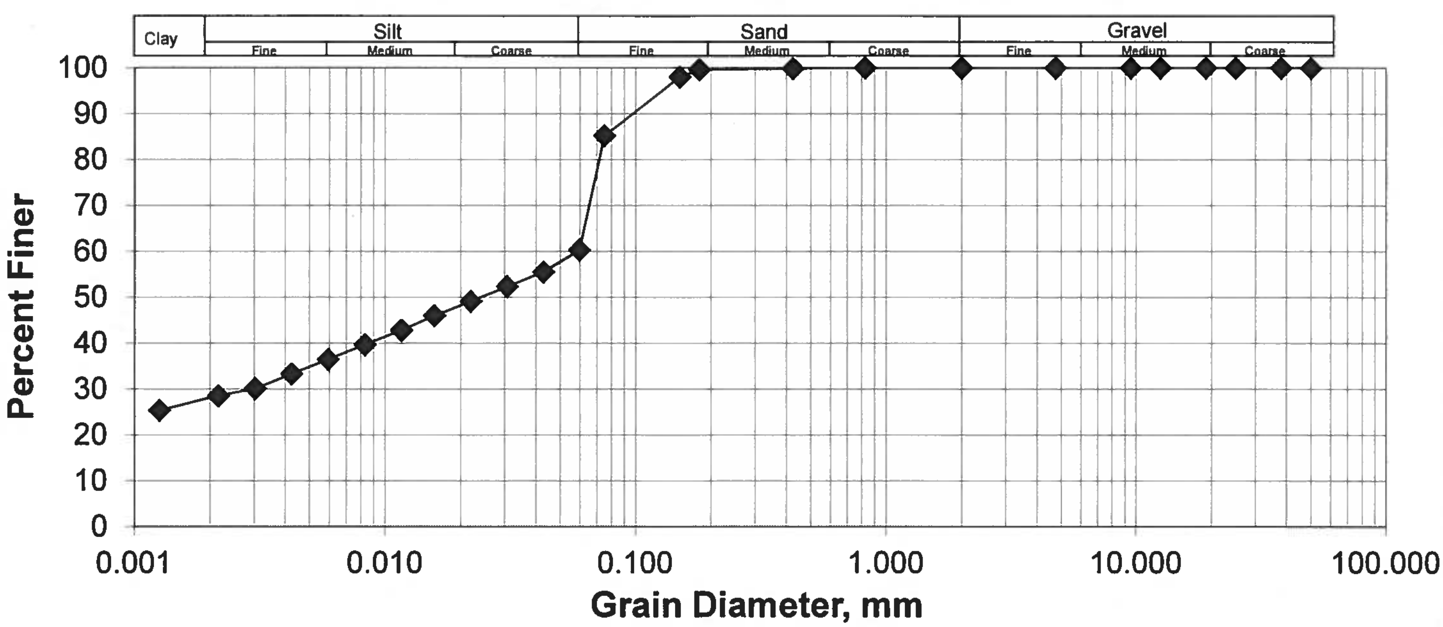
MATERIALS LABORATORY
AECOM
99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada
tel (204) 477-5381 fax (204) 284-2040

| | | | |
|---|---|---|---|
| Job No.: | 60509089 | Hole No.: | TH 16-01 |
| Client: | City of Winnipeg | Sample No.: | T50 |
| Project : | North East Interceptor | Depth: | 9.14 - 9.75m |
| Date Tested: | 19-Sep-16 | Date Sampled: | Varies |
| Tested By: | EManimbao | 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)**

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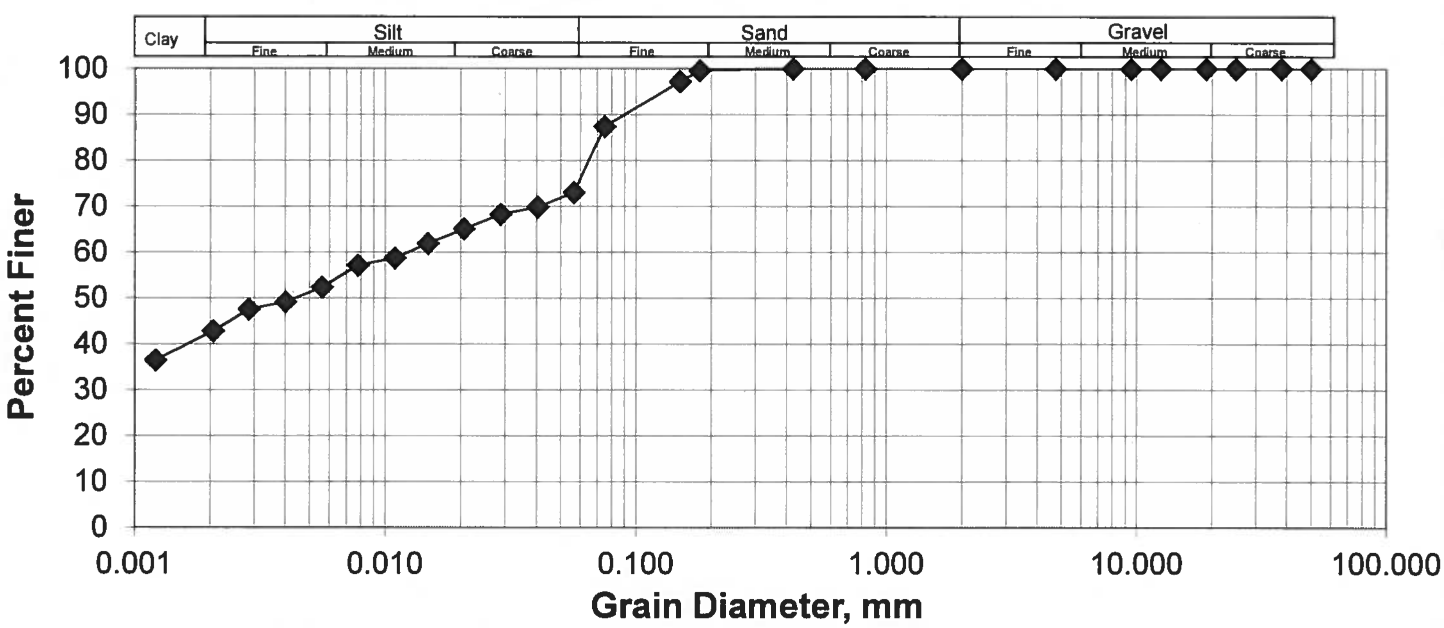
tel (204) 477-5381 fax (204) 284-2040

| | | | |
|---|---|---|---|
| Job No.: | 60509089 | Hole No.: | TH 16-01 |
| Client: | City of Winnipeg | Sample No.: | T53 |
| Project : | North East Interceptor | Depth: | 12.19 - 12.80m |
| Date Tested: | 19-Sep-16 | Date Sampled: | Varies |
| Tested By: | EManimbao | 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).

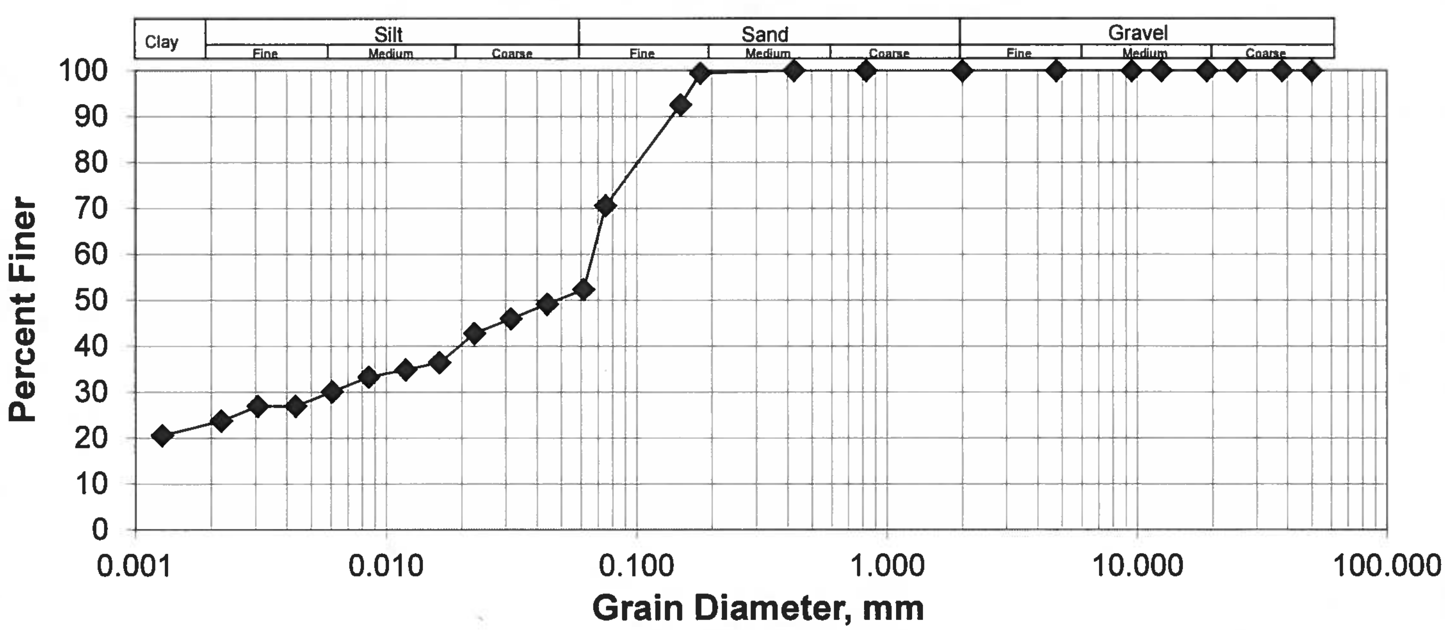
## GRAIN SIZE DISTRIBUTION
**(ASTM D422-63)**

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

| | | | |
|---|---|---|---|
| Job No.: | 60509089 | Hole No.: | TH 16-02 |
| Client: | City of Winnipeg | Sample No.: | S24 |
| Project : | North East Interceptor | Depth: | 3.05 - 3.51m |
| Date Tested: | 19-Sep-16 | Date Sampled: | Varies |
| Tested By: | EManimbao | 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)**

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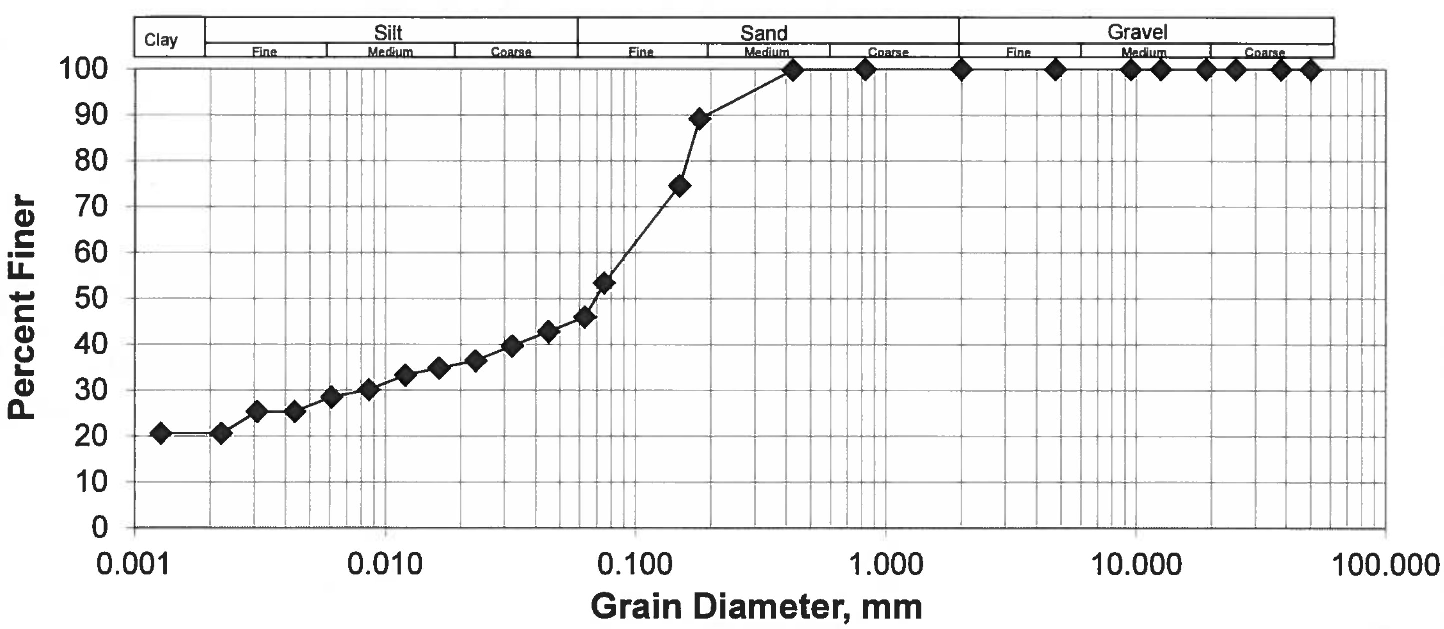
AECOM
99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada
tel (204) 477-5381 fax (204) 284-2040

| | | | |
|---|---|---|---|
| Job No.: | 60509089 | Hole No.: | TH 16-02 |
| Client: | City of Winnipeg | Sample No.: | S30 |
| Project : | North East Interceptor | Depth: | 7.62 - 8.23m |
| Date Tested: | 19-Sep-16 | Date Sampled: | Varies |
| Tested By: | EManimbao | 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)**

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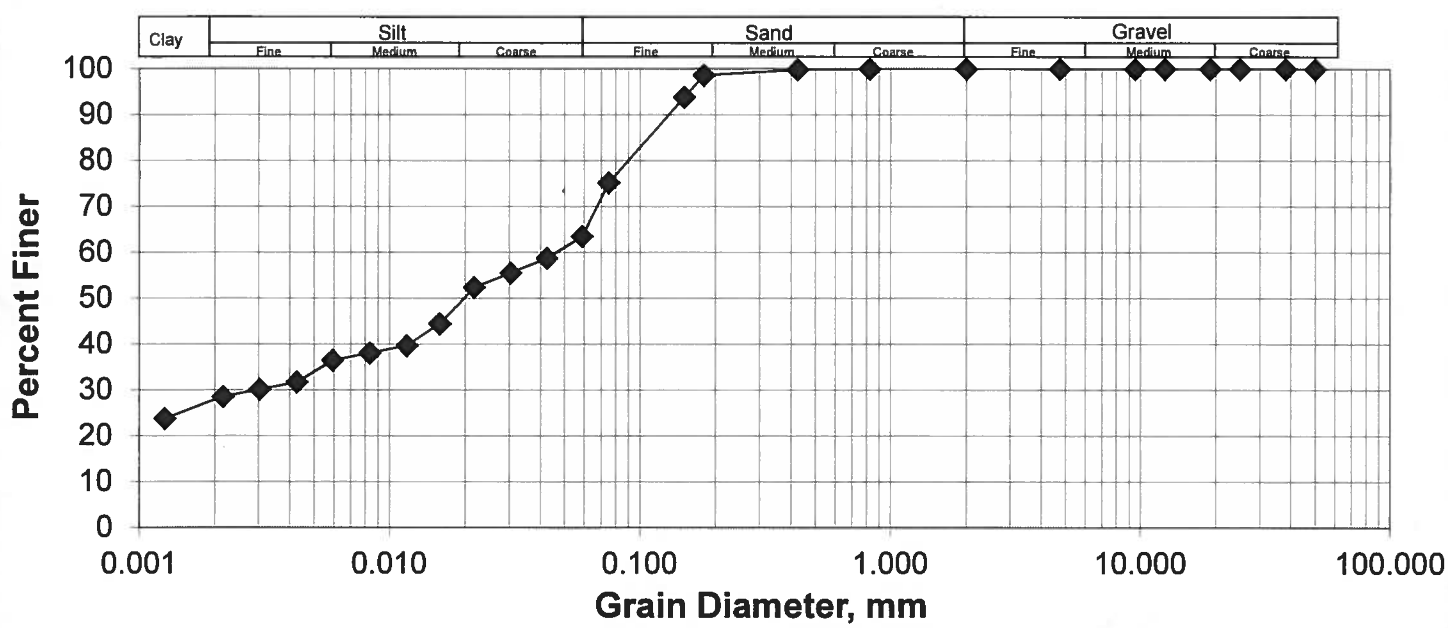
tel (204) 477-5381 fax (204) 284-2040

| | | | |
|---|---|---|---|
| Job No.: | 60509089 | Hole No.: | TH 16-04 |
| Client: | City of Winnipeg | Sample No.: | G11 |
| Project : | North East Interceptor | Depth: | 9.14 - 9.30m |
| Date Tested: | 19-Sep-16 | Date Sampled: | Varies |
| Tested By: | EManimbao | 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)**

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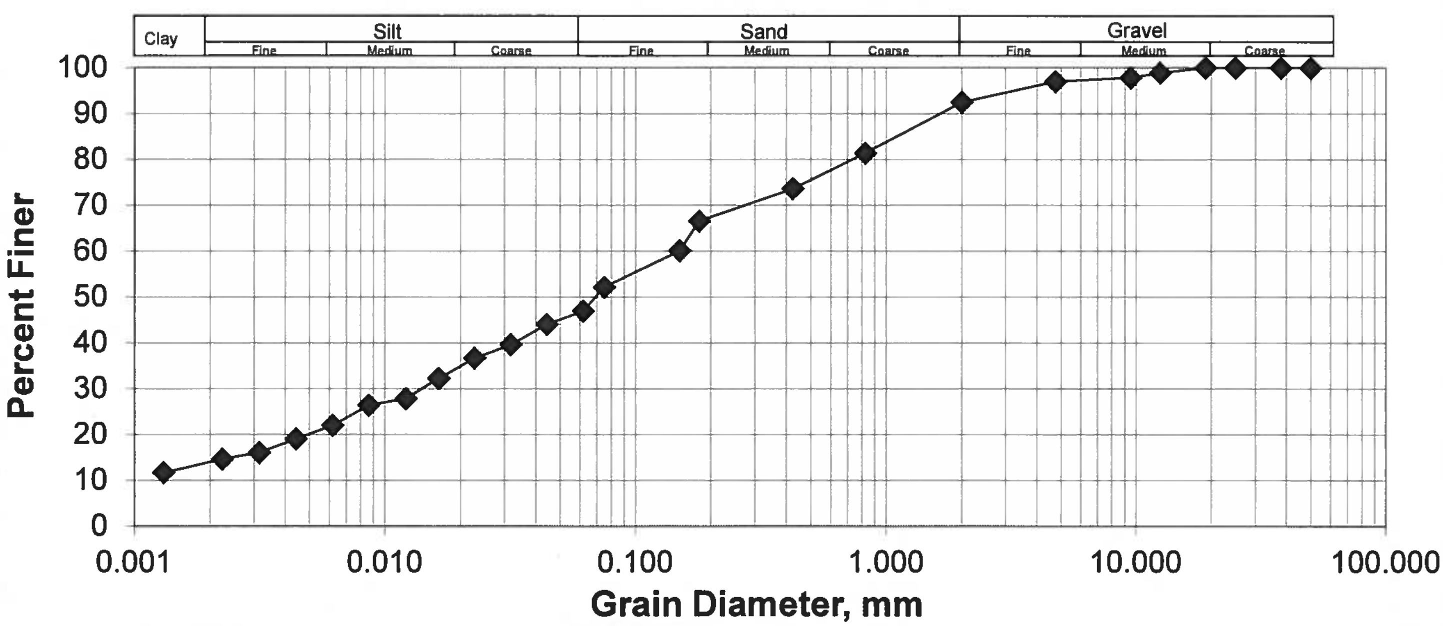
tel (204) 477-5381 fax (204) 284-2040

| | | | |
|---|---|---|---|
| Job No.: | 60509089 | Hole No.: | TH 16-04 |
| Client: | City of Winnipeg | Sample No.: | G18 |
| Project : | North East Interceptor | Depth: | 16.76 - 16.92m |
| Date Tested: | 19-Sep-16 | Date Sampled: | Varies |
| Tested By: | EManimbao | 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).

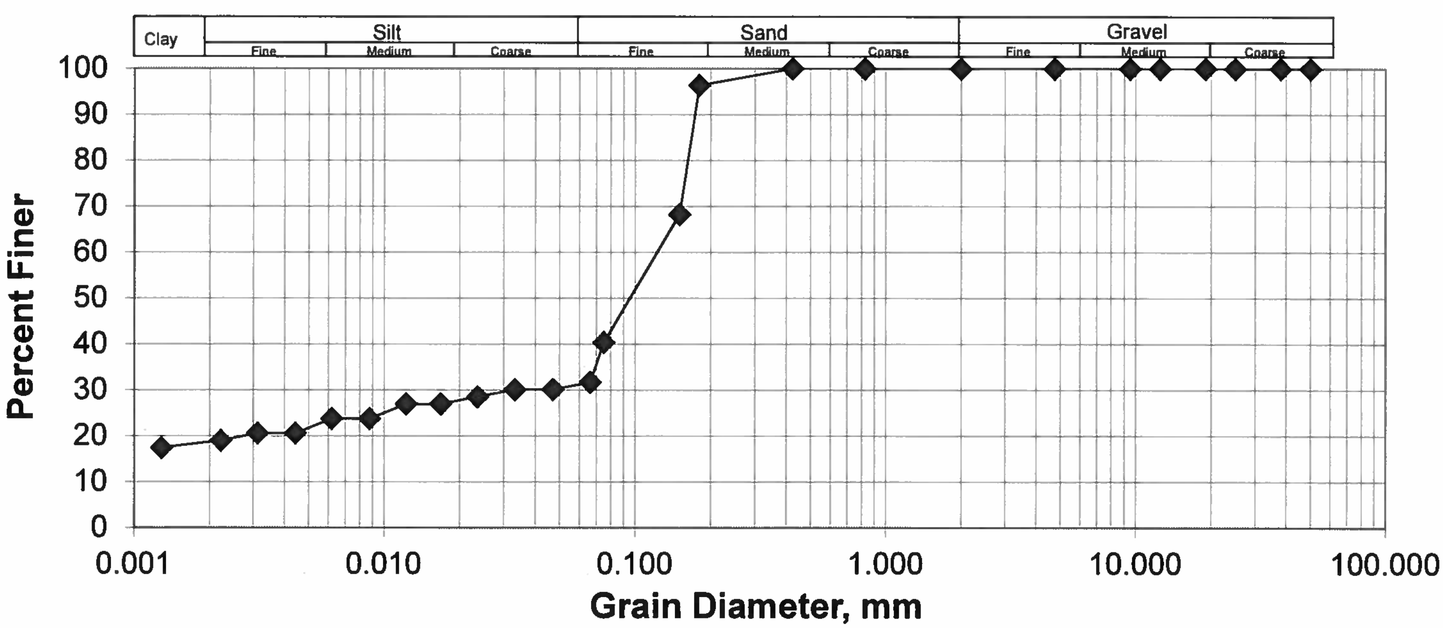
## GRAIN SIZE DISTRIBUTION
**(ASTM D422-63)**

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

| | | | |
|---|---|---|---|
| Job No.: | 60509089 | Hole No.: | TH 16-04 |
| Client: | City of Winnipeg | Sample No.: | T4 |
| Project : | North East Interceptor | Depth: | 3.05 - 3.66m |
| Date Tested: | 19-Sep-16 | Date Sampled: | Varies |
| Tested By: | EManimbao | 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
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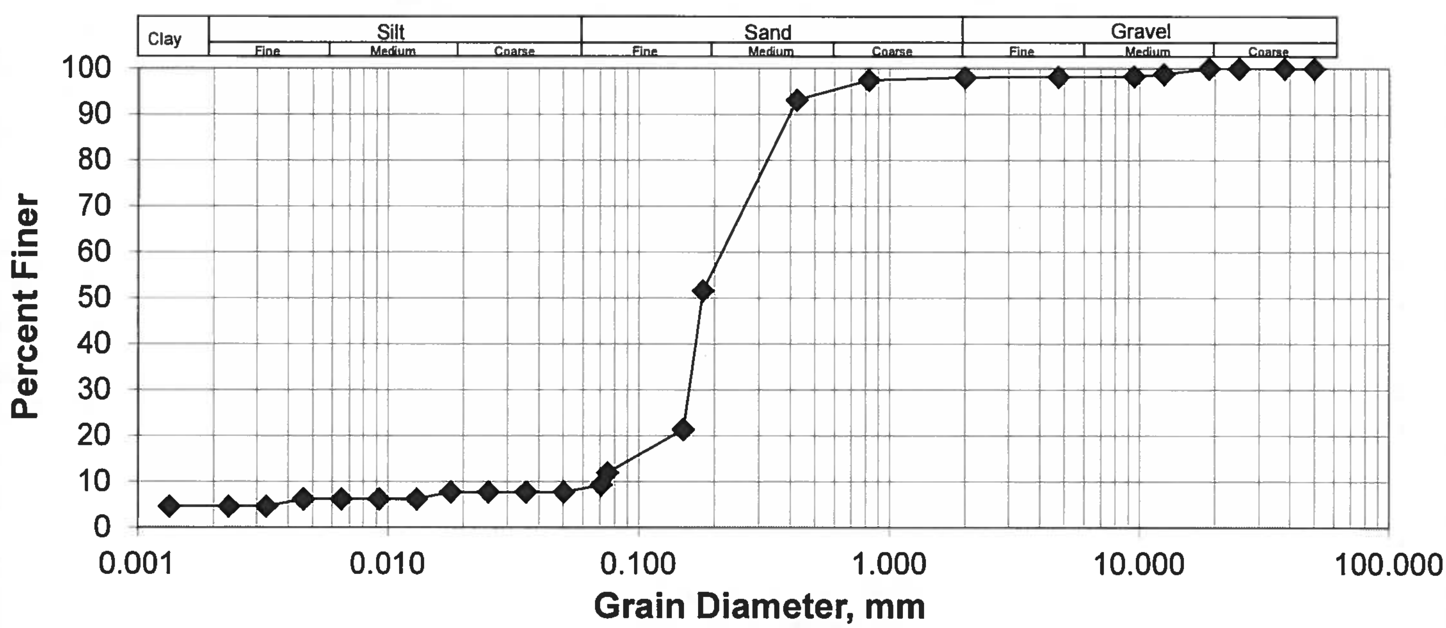
99 Commerce Dr., Winnipeg, MB R3P 0Y7 Canada
**tel** (204) 477-5381 **fax** (204) 284-2040

| | | | |
|---|---|---|---|
| Job No.: | 60509089 | Hole No.: | TH 16-04 |
| Client: | City of Winnipeg | Sample No.: | T16 |
| Project : | North East Interceptor | Depth: | 13.72 - 14.33m |
| Date Tested: | 19-Sep-16 | Date Sampled: | Varies |
| Tested By: | EManimbao | 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. | Page: | 1 of 1 |
| Date Cored: | August / September : 2016 | Date Received: | Nov 7/16 |
| Cored By: | Maple Leaf Drilling Ltd. | 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 |

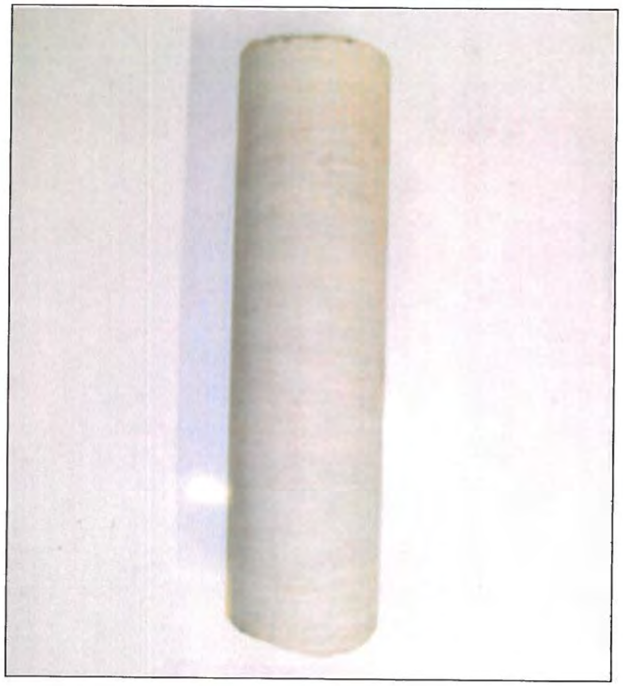
Comments: The unconfined strength was determined in accordance with ASTM D2938-95 procedure with the cores in the as received moisture content.

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

**ENG-TECH Consulting Limited**

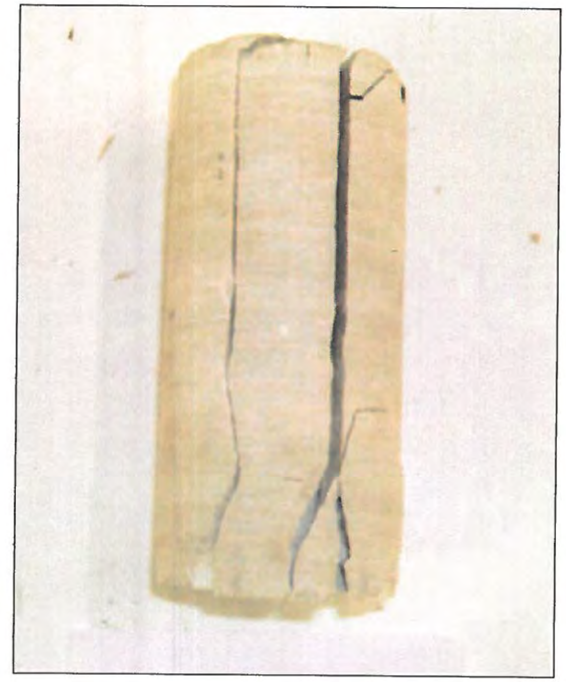
Per
Danny Holfeld, Principal
Ph: (204) 233-1694 Fx: (204) 235-1579

**CORE NUMBER 1**
**TH 16-01**
**WEST RIVER BANK C5**



**BEFORE TRIMMING**

**AFTER TRIMMING**

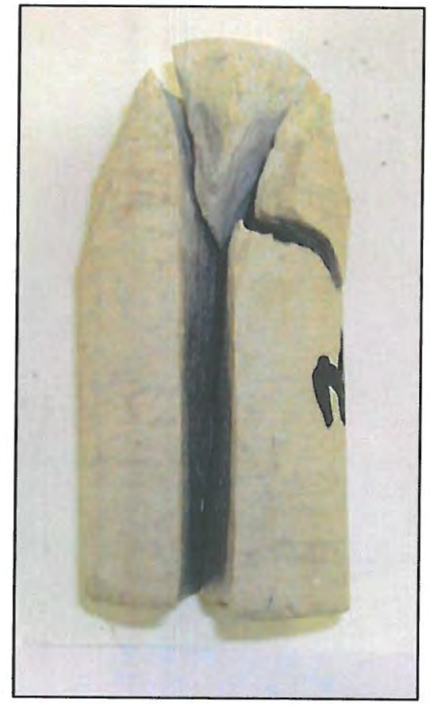


**AFTER TEST**

**CORE NUMBER 2**
**TH 16-02**
**WEST RIVER BANK C4**

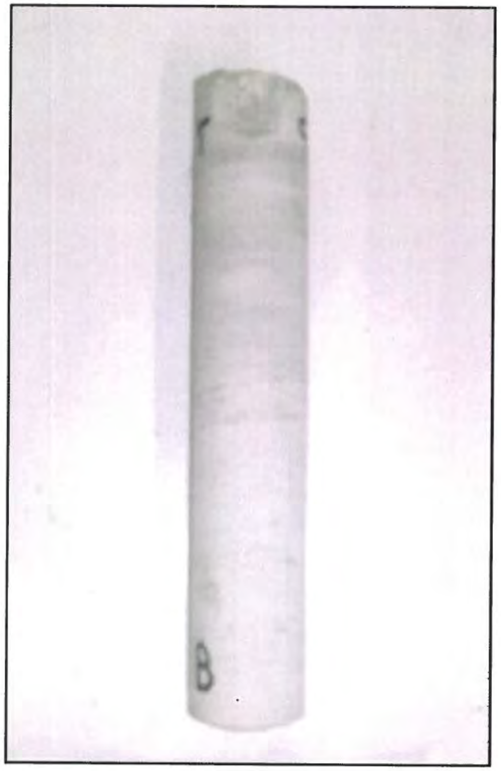
**BEFORE TRIMMING**

**AFTER TRIMMING**



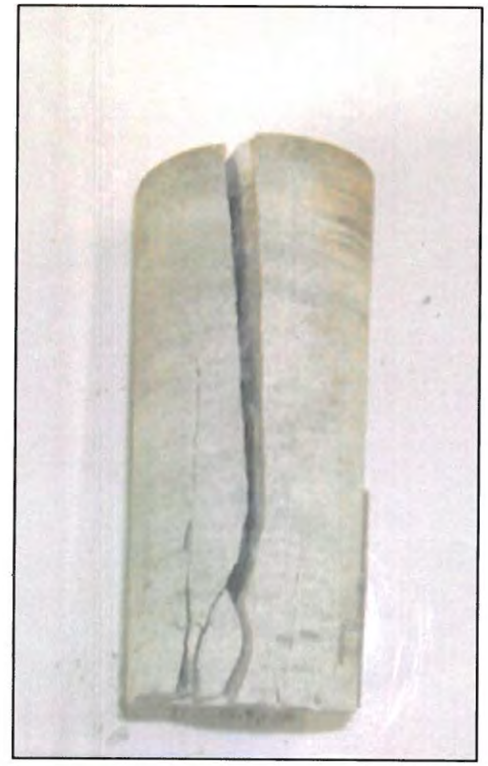
**AFTER TESTING**

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



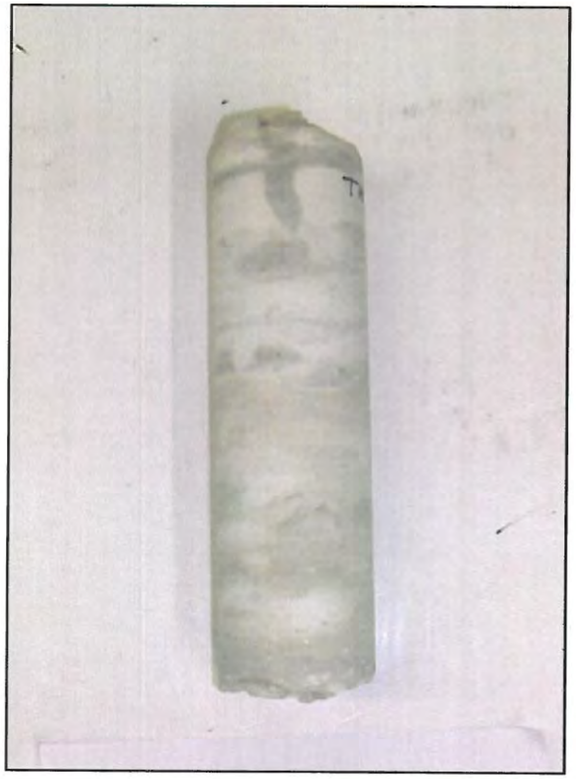

**BEFORE TRIMMING**

**AFTER TRIMMING**



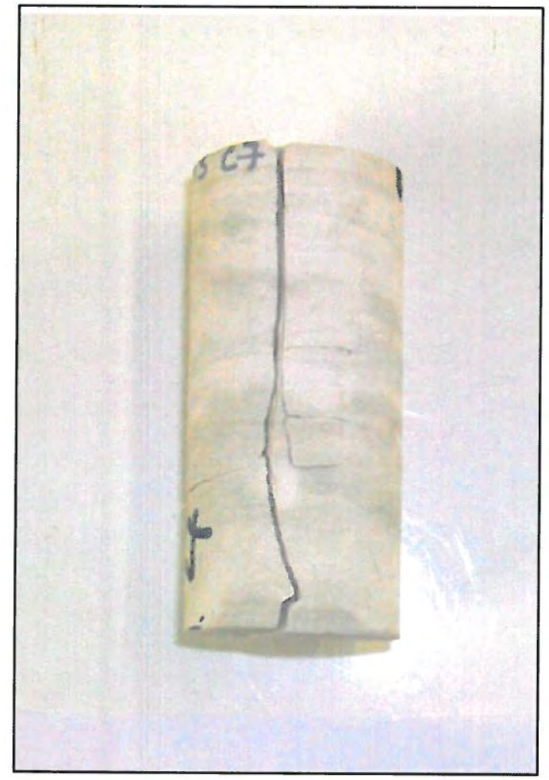
**AFTER TESTING**

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



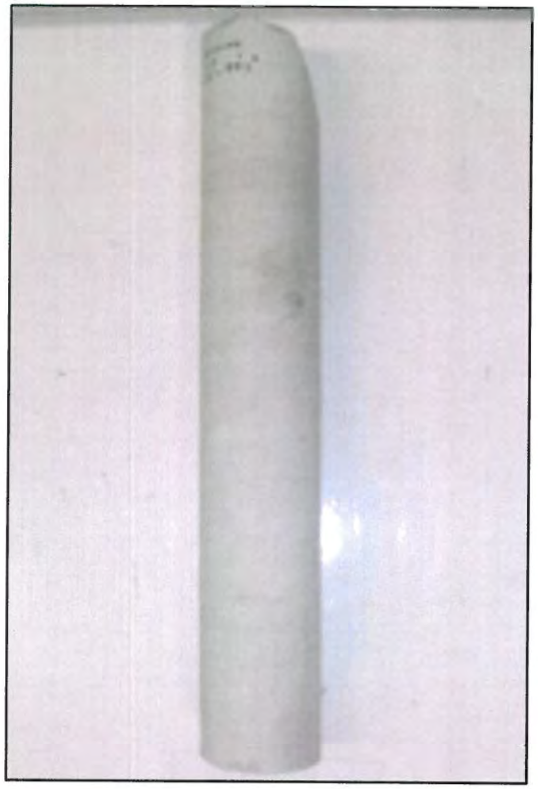
**BEFORE TRIMMING**

**AFTER TRIMMING**

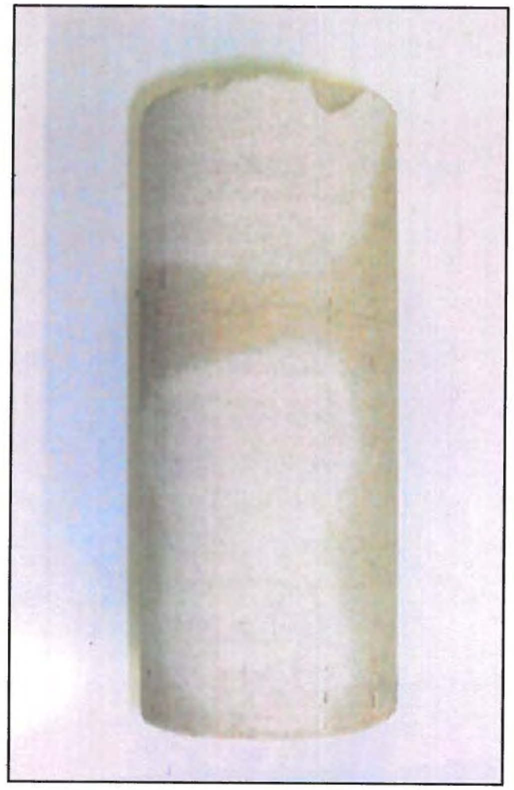


**AFTER TESTING**

**CORE NUMBER 5**
**TH 16-04**
**EAST RIVER BANK C5**



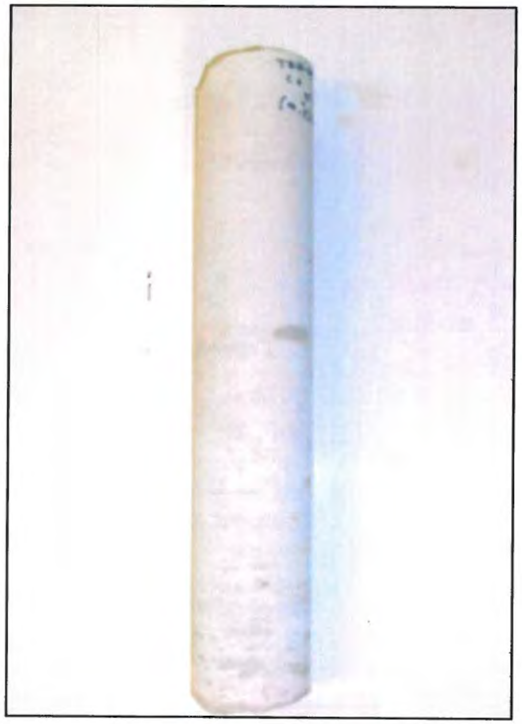
**BEFORE TRIMMING**



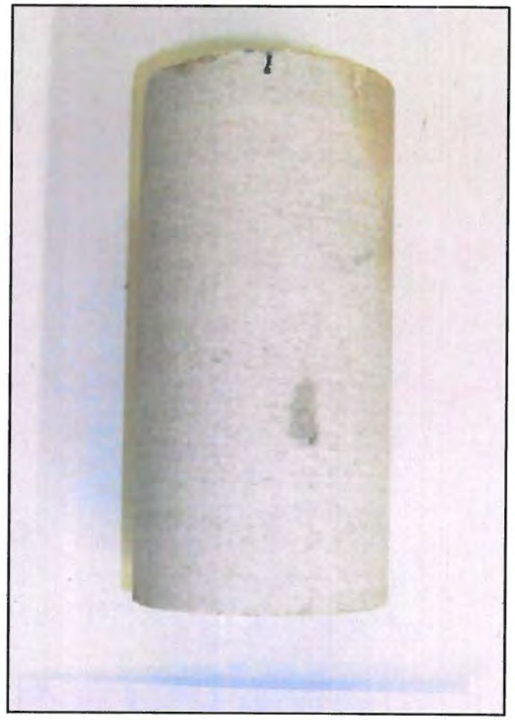
**AFTER TRIMMING**

**AFTER TESTING**

**CORE NUMBER 6**
**TH 16-04**
**EAST RIVER BANK C6**



**BEFORE TRIMMING**



**AFTER TRIMMING**

**AFTER TESTING**

TREK GEOTECHNICAL
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
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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** | TH13-01 | 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 % | | | | | | |

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# Atterberg Limits
## ASTM D4318

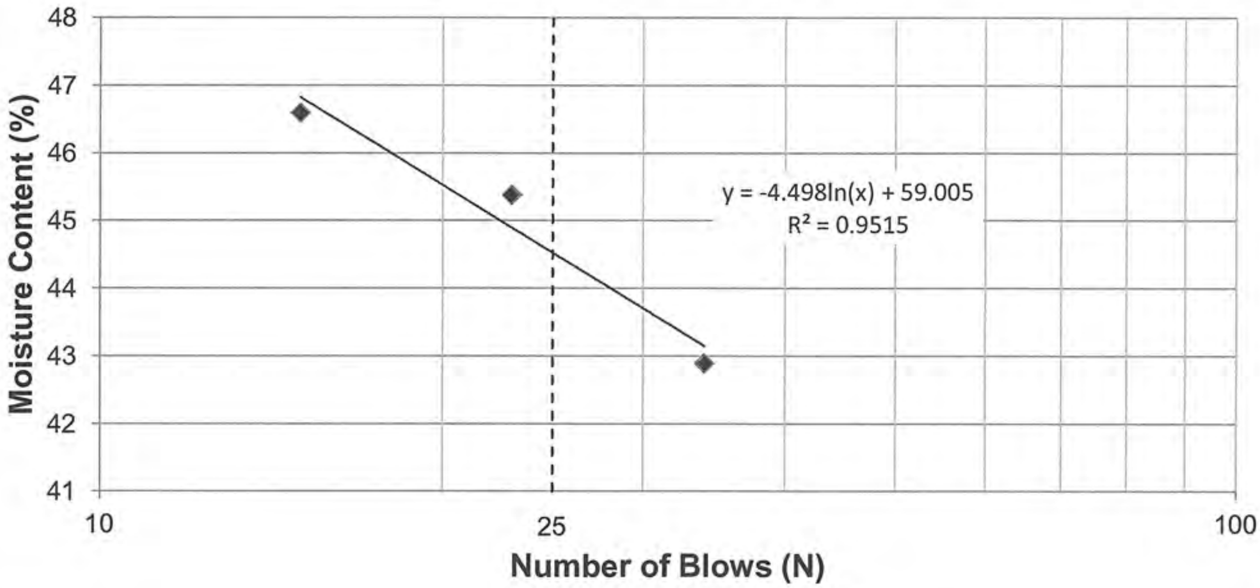
**Project No.** 0115 004 00
**Client** Associated Engineering
**Project** Detailed design of North Kildonan Feedermain

**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 | | | |

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# Atterberg Limits
## ASTM D4318

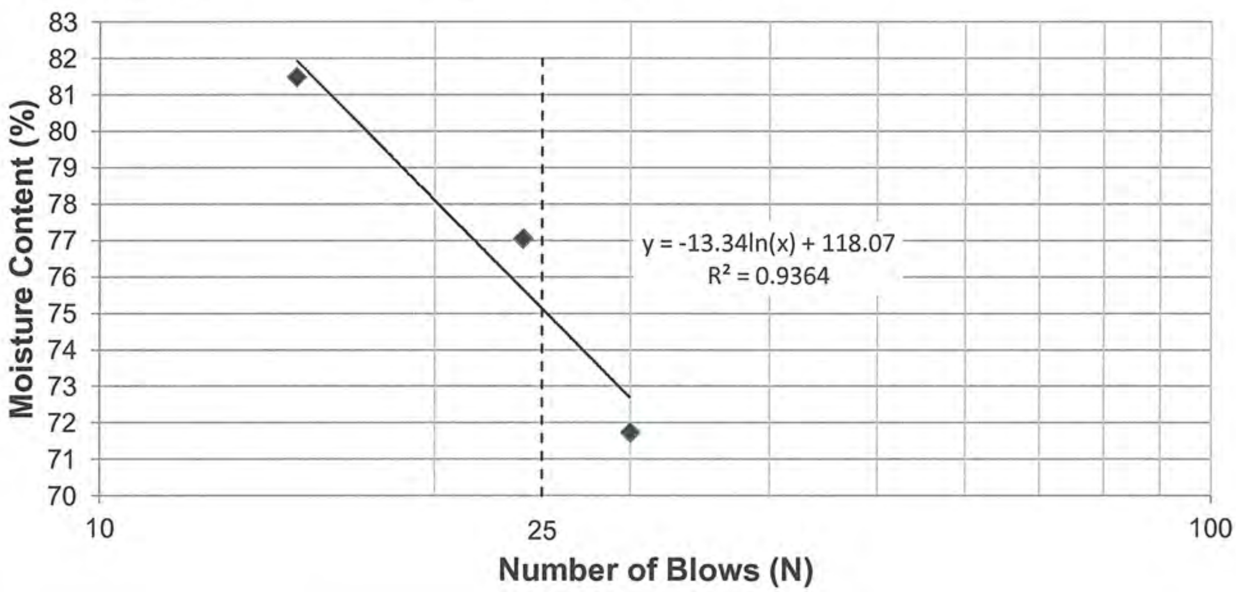
| | |
|---|---|
| **Project No.** | 0115 004 00 |
| **Client** | Associated Engineering |
| **Project** | Detailed design of North Kildonan Feedermain |

| | |
|---|---|
| **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 | | | |

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# Atterberg Limits
## ASTM D4318

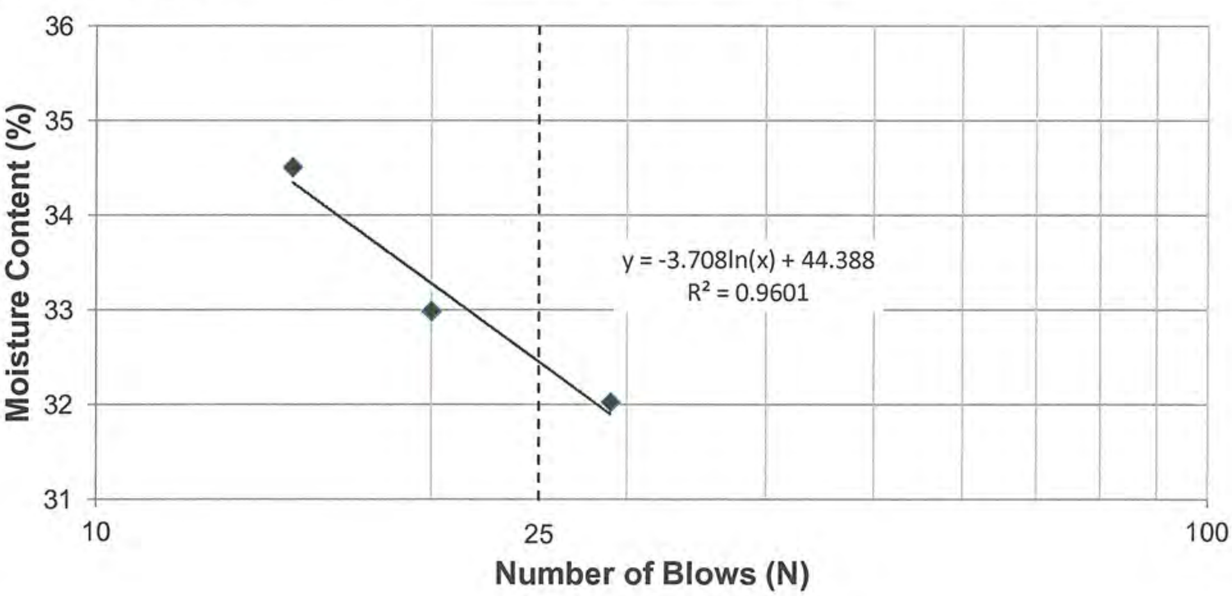
| | |
|---|---|
| **Project No.** | 0115 004 00 |
| **Client** | Associated Engineering |
| **Project** | Detailed design of North Kildonan Feedermain |

| | |
|---|---|
| **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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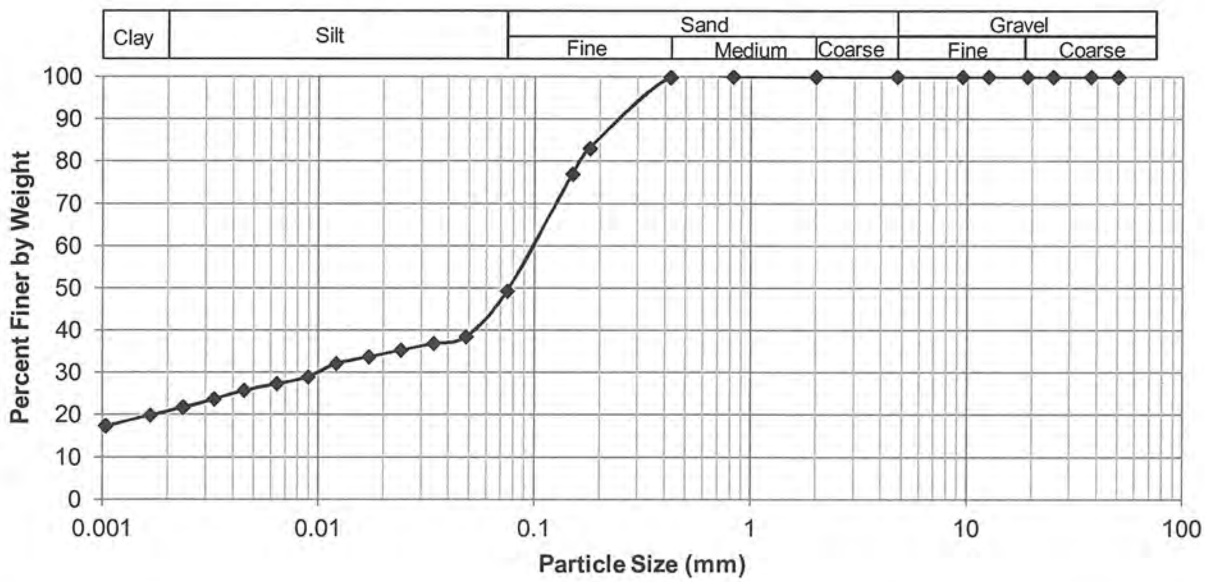
# Grain Size Analysis (Hydrometer Method)
## ASTM D422

| | |
|---|---|
| **Project No.** | 0115 004 00 |
| **Client** | Associated Engineering |
| **Project** | Detailed Design North Kildonan Feedermain |
| **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% |




| 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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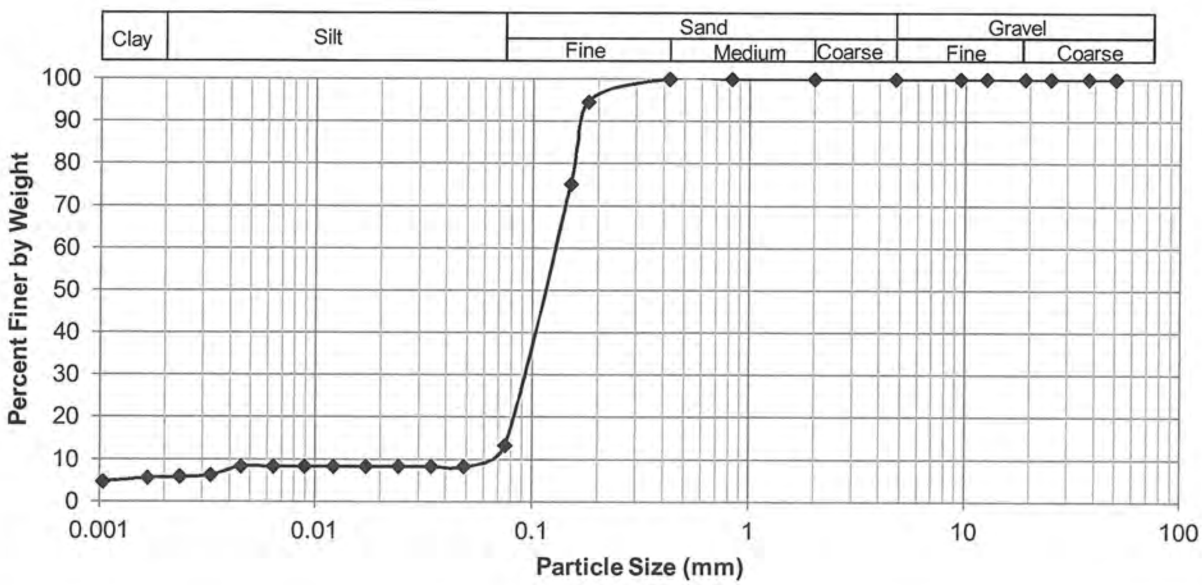
# Grain Size Analysis (Hydrometer Method)
## ASTM D422

| | |
|---|---|
| **Project No.** | 0115 004 00 |
| **Client** | Associated Engineering |
| **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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# Shelby Tube Visual

| | |
|---|---|
| **Project No.** | 0115 004 00 |
| **Client** | Associated Engineering |
| **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 | | Qu / $\gamma_{Bulk}$ |
|---|---|---|
| | Some clay | 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 ($m^3$)** | | 5.75E-04 |
| **Bulk Unit Weight ($kN/m^3$)** | | 18.7 |
| **Bulk Unit Weight (pcf)** | | 119.1 |
| **Dry Unit Weight ($kN/m^3$)** | | 14.0 |
| **Dry Unit Weight (pcf)** | | 88.8 |

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# Unconfined Compressive Strength
**ASTM D2166**

| | |
|---|---|
| **Project No.** | 0115 004 00 |
| **Client** | Associated Engineering |
| **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 | |
|---|---|---|
| tsf | kPa | ksf |
| 0.70 | 68.7 | 1.43 |
| **Vane Size** | | |
| m | | |

### Pocket Penetrometer

| Reading | Undrained Shear Strength | |
|---|---|---|
| tsf | kPa | ksf |
| 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:

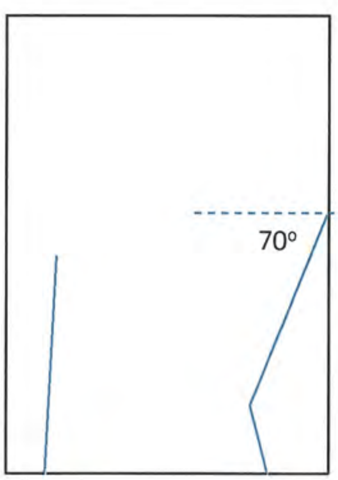


Photo:

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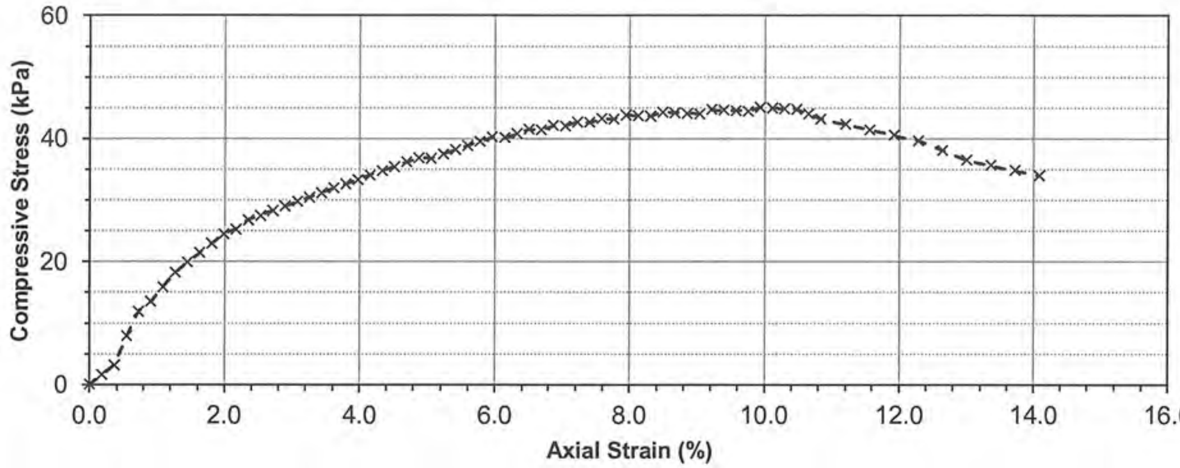
# Unconfined Compressive Strength
**ASTM D2166**

**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 | 0.004085 | 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**

**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 | 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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# Shelby Tube Visual

| | |
|---|---|
| **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 |

## Tube Extraction

**Recovery (mm)** 630

**Bottom - 12.8 m** — **12.0 m - Top**

| PP / Tv / Visual / Moisture | | | Qu / $\gamma_{Bulk}$ | |
|---|---|---|---|---|
| ← Clay silt → | ← Some silt → | ← Silty | | → |
| 100 mm | 100 mm | 160 mm | 160 mm | 110 mm |

## 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 |

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# Unconfined Compressive Strength

**ASTM D2166**

| | |
|---|---|
| **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) |
| **Diameter** | 72.5 | (mm) |
| **L/D Ratio** | 2.1 | |
| **Initial Area** | 0.00413 | ($m^2$) |
| **Load Rate** | 1.00 | (%/min) |

| | | |
|---|---|---|
| **Moisture %** | 33% | |
| **Bulk Unit Wt.** | 18.2 | ($kN/m^3$) |
| **Dry Unit Wt.** | 13.7 | ($kN/m^3$) |
| **Liquid Limit** | - | |
| **Plastic Limit** | - | |
| **Plasticity Index** | - | |

## Undrained Shear Strength Tests

### Torvane

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

### Pocket Penetrometer

| Reading | Undrained Shear Strength | |
|---|---|---|
| **tsf** | **kPa** | **ksf** |
| 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:

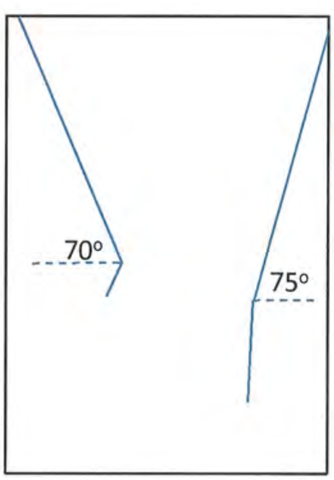


Photo:

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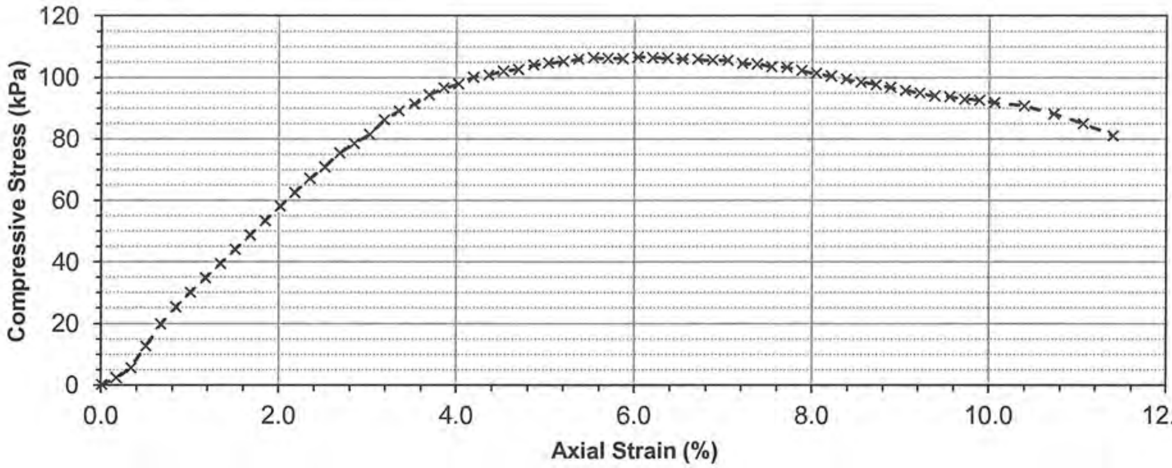
# Unconfined Compressive Strength
**ASTM D2166**

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

## Unconfined Compression Test 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
**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 | 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 |

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# Shelby Tube Visual

| | |
|---|---|
| **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, $\gamma_{Bulk}$ | |
|---|---|---|
| 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 ($m^3$)** | | 6.18E-04 |
| **Bulk Unit Weight ($kN/m^3$)** | | 18.3 |
| **Bulk Unit Weight (pcf)** | | 116.3 |
| **Dry Unit Weight ($kN/m^3$)** | | 11.7 |
| **Dry Unit Weight (pcf)** | | 74.5 |

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# Unconfined Compressive Strength
**ASTM D2166**

| | |
|---|---|
| **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) |
| **Diameter** | 72.2 | (mm) |
| **L/D Ratio** | 2.1 | |
| **Initial Area** | 0.00410 | ($m^2$) |
| **Load Rate** | 1.00 | (%/min) |

| | | |
|---|---|---|
| **Moisture %** | 56% | |
| **Bulk Unit Wt.** | 18.3 | ($kN/m^3$) |
| **Dry Unit Wt.** | 11.7 | ($kN/m^3$) |
| **Liquid Limit** | - | |
| **Plastic Limit** | - | |
| **Plasticity Index** | - | |

## Undrained Shear Strength Tests

### Torvane

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

### Pocket Penetrometer

| Reading | Undrained Shear Strength | |
|---|---|---|
| tsf | kPa | ksf |
| 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:

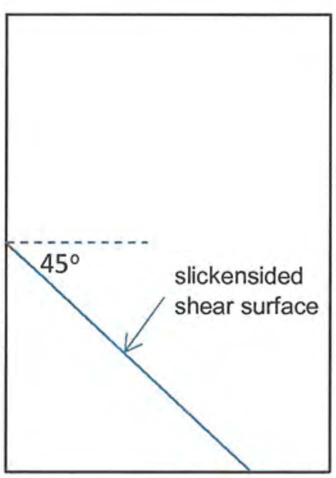


Photo:

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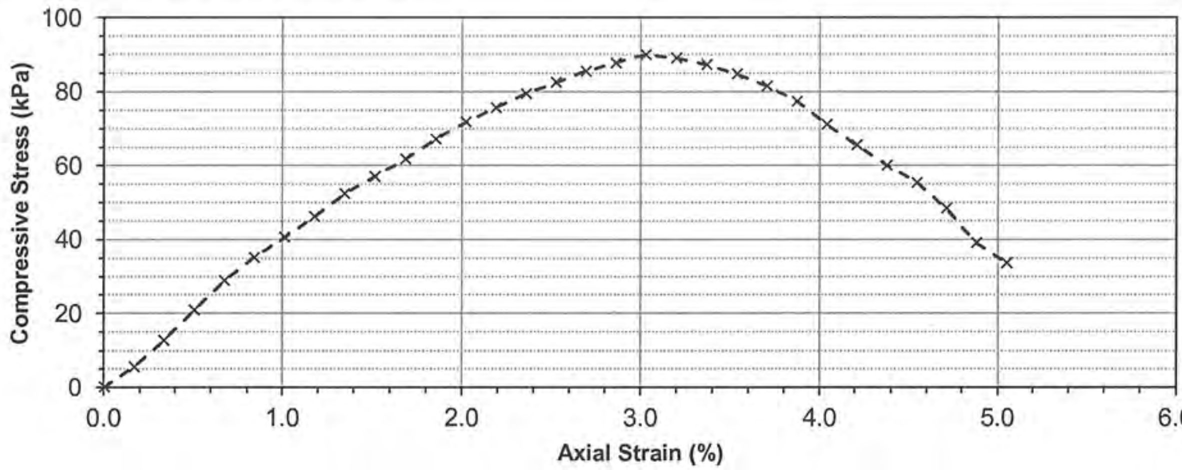
# Unconfined Compressive Strength
**ASTM D2166**

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

## Unconfined Compression Test 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
**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 | 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 |

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# Shelby Tube Visual

| | |
|---|---|
| **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, $\gamma_{Bulk}$ | |
|---|---|---|
| 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 ($m^3$)** | | 6.26E-04 |
| **Bulk Unit Weight ($kN/m^3$)** | | 18.8 |
| **Bulk Unit Weight (pcf)** | | 119.4 |
| **Dry Unit Weight ($kN/m^3$)** | | 14.2 |
| **Dry Unit Weight (pcf)** | | 90.1 |

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# Unconfined Compressive Strength
**ASTM D2166**

| | |
|---|---|
| **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 | |
|---|---|---|
| tsf | kPa | ksf |
| 0.25 | 24.5 | 0.51 |
| **Vane Size** | | |
| m | | |

### Pocket Penetrometer

| Reading | Undrained Shear Strength | |
|---|---|---|
| tsf | kPa | ksf |
| 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:

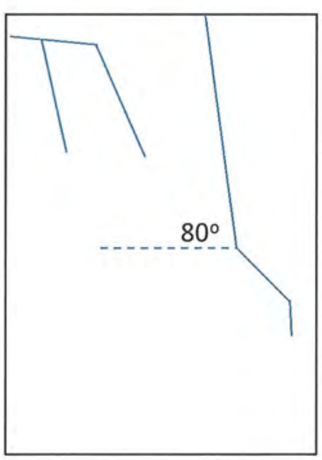


Photo:

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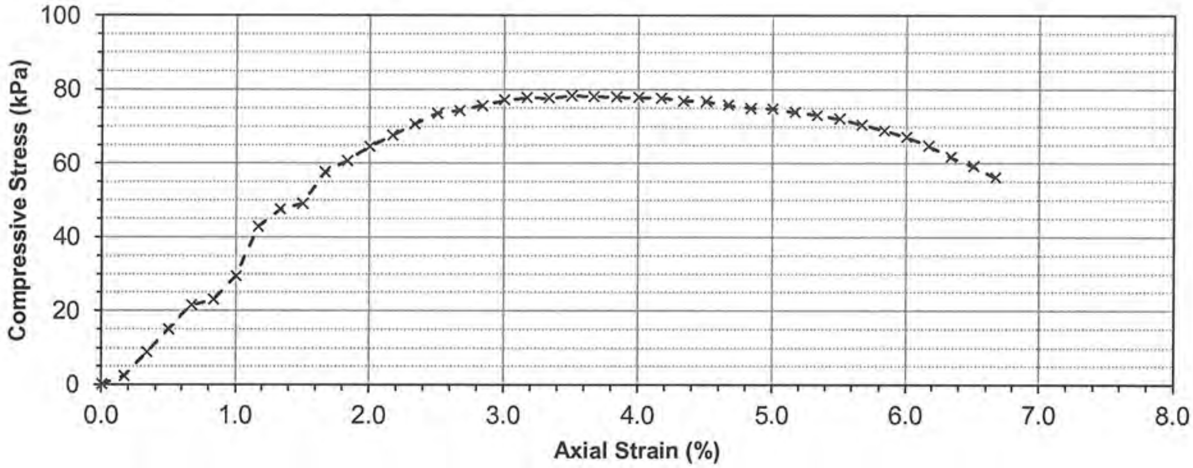
# Unconfined Compressive Strength
**ASTM D2166**

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

## Unconfined Compression Test 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 (FT) | TO (FT) | $C_u$ (MPa) | Strain (%) | |
| 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 |

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## THURBER ENGINEERING LTD.

## UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

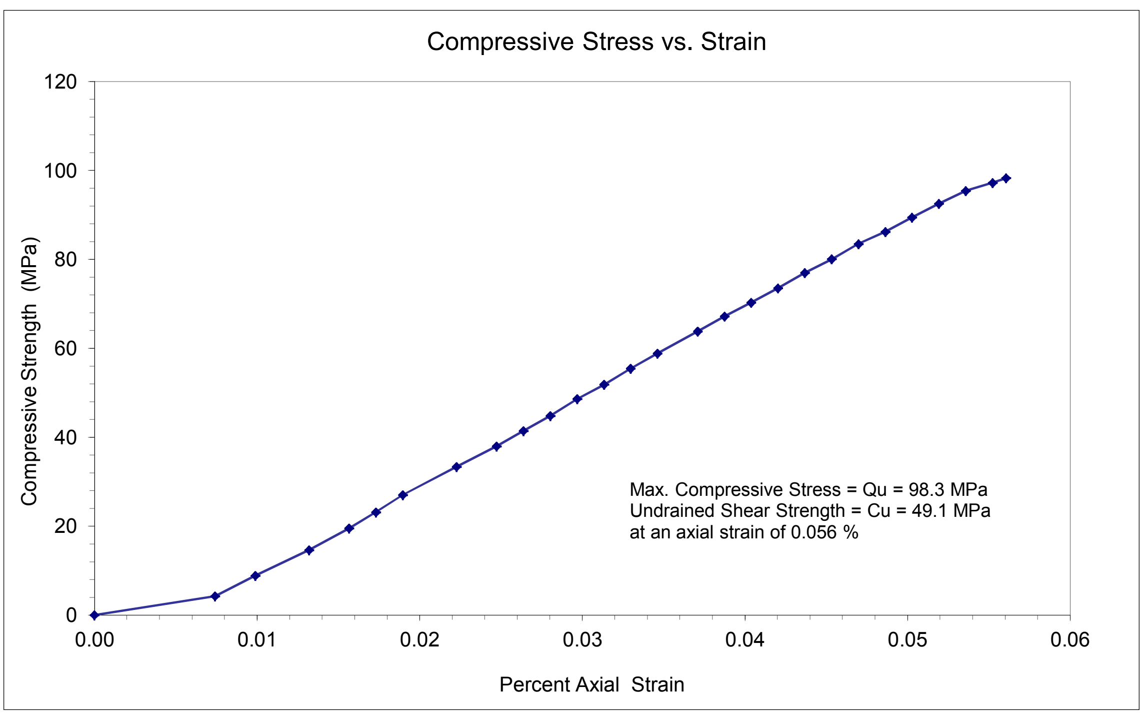
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-1c

### Unconfined Compressive Strengths

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

SPECIMEN DETAILS:

| | |
|---|---|
| Wet Density (kg/m$^3$): | 2487 |
| Dry Density (kg/m$^3$): | 2478 |
| Moisture Content (%): | 0.4 |

# THURBER ENGINEERING LTD.

## UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

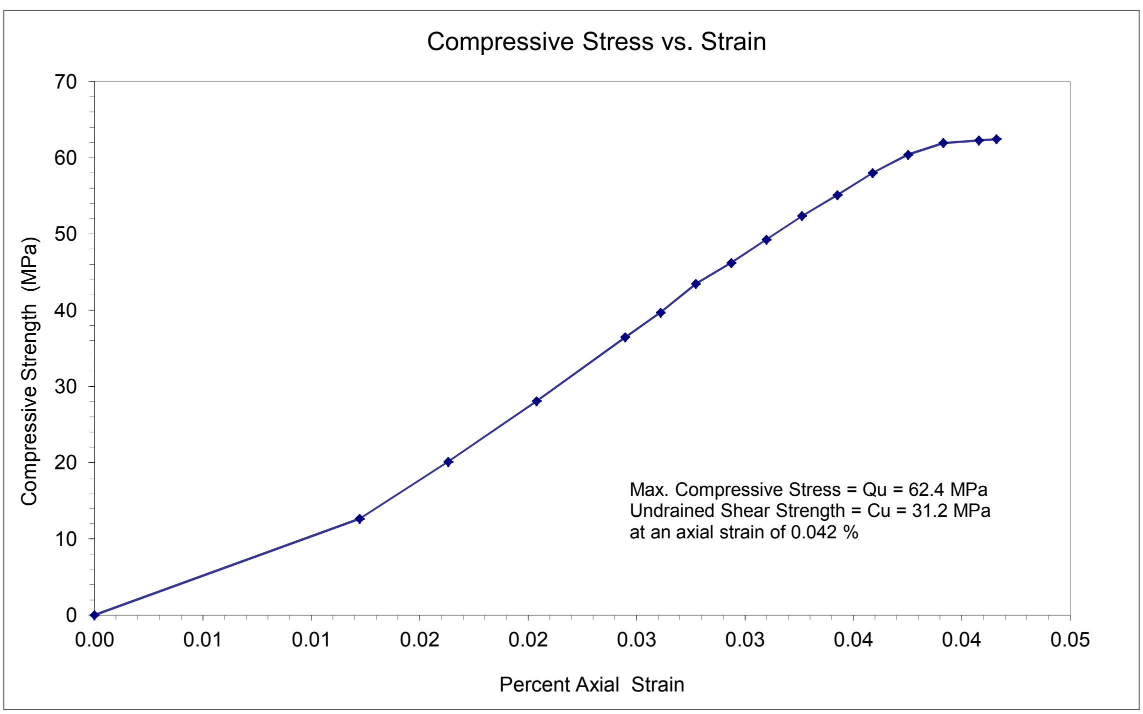
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-4c

### 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/m$^3$): | 2561 |
| Dry Density (kg/m$^3$): | 2535 |
| Moisture Content (%): | 1.0 |

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**UNCONFINED COMPRESSION TEST REPORT**

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

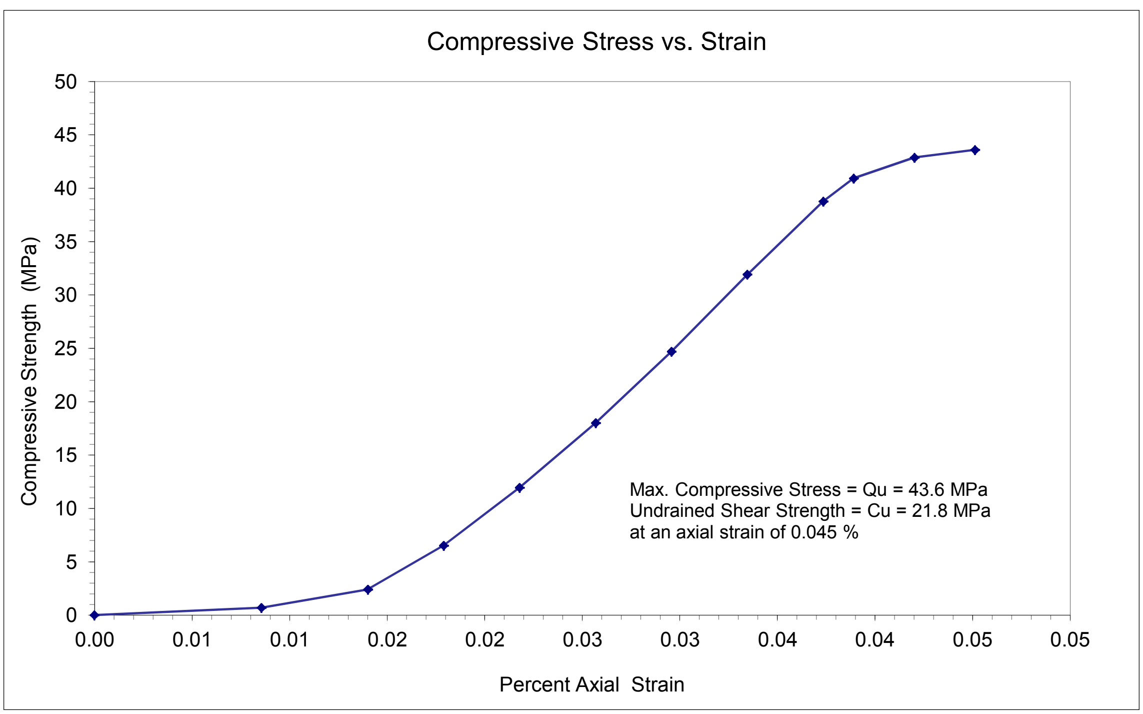
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-2c

## 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/m$^3$): 2305
Dry Density (kg/m$^3$): 2206
Moisture Content (%): 4.5

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## UNCONFINED COMPRESSION TEST REPORT

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

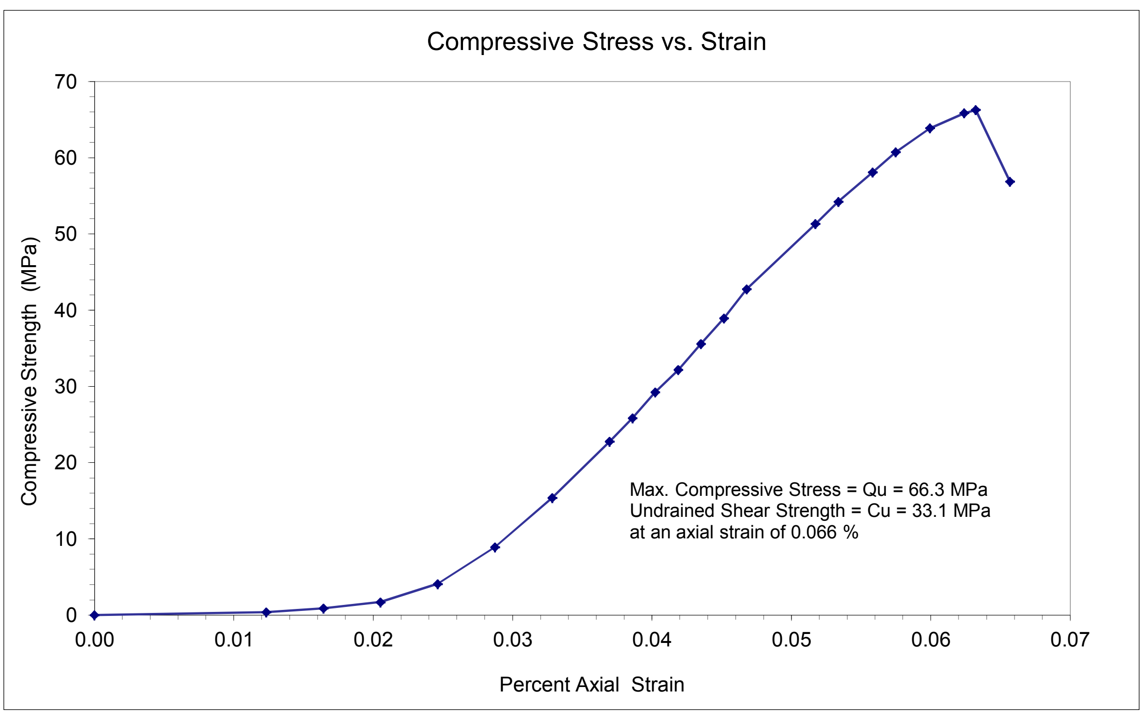
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-3c

### Unconfined Compressive Strengths

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

SPECIMEN DETAILS:

| | |
|---|---|
| Wet Density (kg/m$^3$): | 2547 |
| Dry Density (kg/m$^3$): | 2502 |
| Moisture Content (%): | 1.8 |

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**UNCONFINED COMPRESSION TEST REPORT**

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

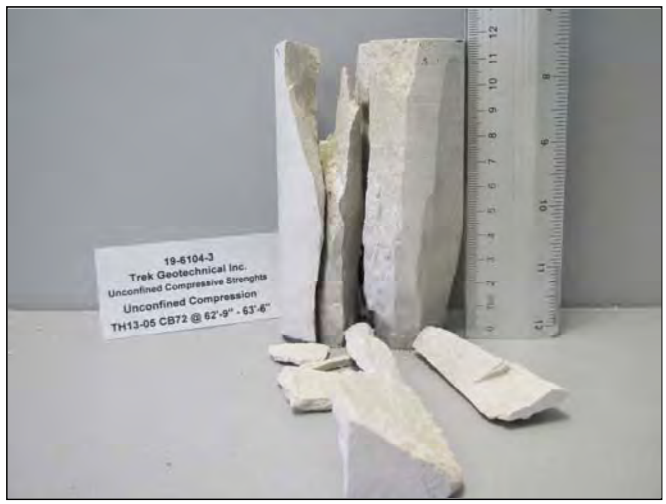
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-5c

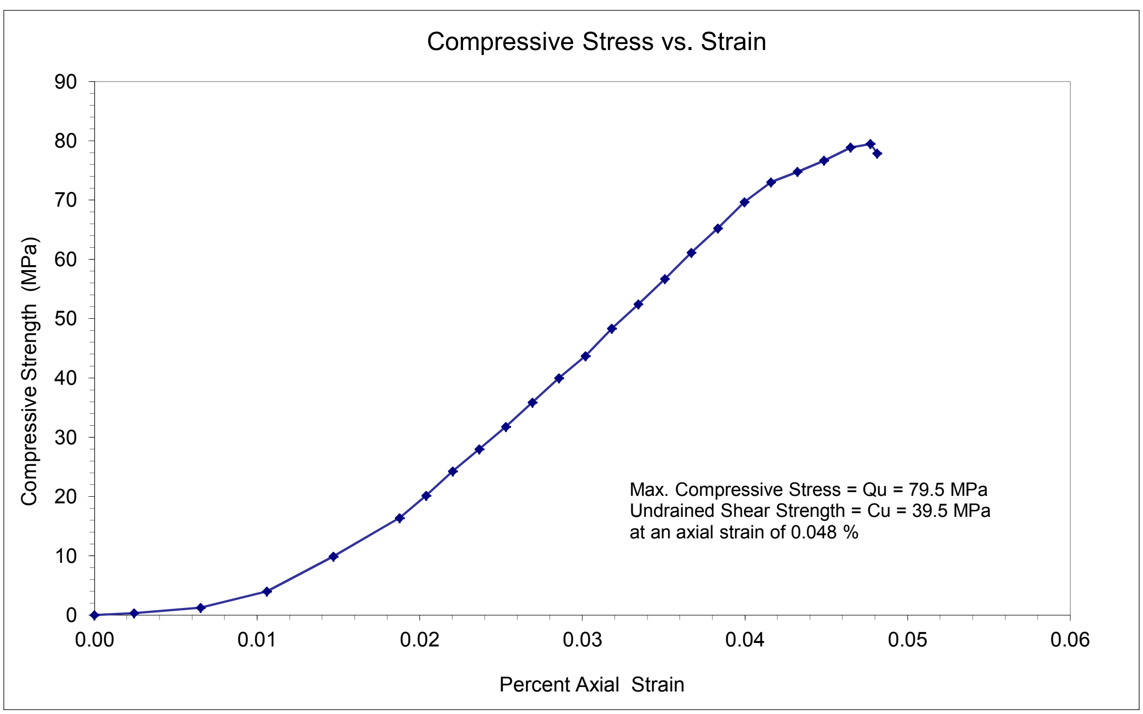
## Unconfined Compressive Strengths

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

SPECIMEN DETAILS:

| | |
|---|---|
| Wet Density (kg/m$^3$): | 2647 |
| Dry Density (kg/m$^3$): | 2633 |
| Moisture Content (%): | 0.6 |



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**UNCONFINED COMPRESSION TEST REPORT**

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

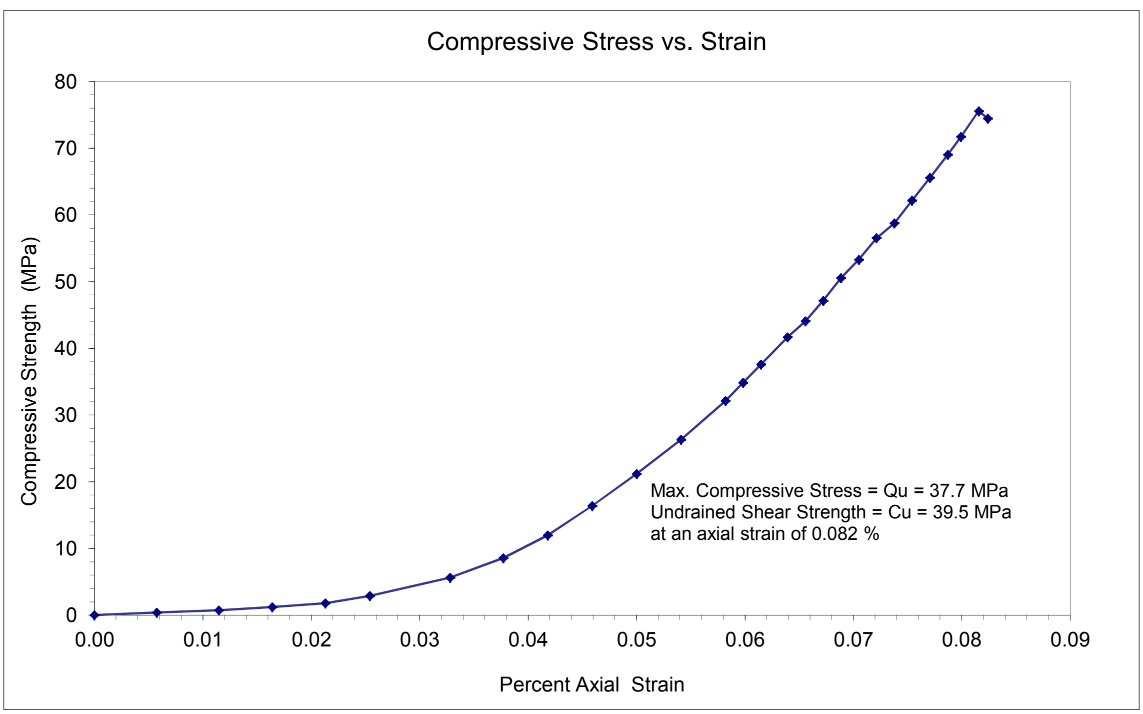
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-6c

## 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 |

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**UNCONFINED COMPRESSION TEST REPORT**

TREK GEOTECHNICAL INC
FILE NUMBER : 19-6104-3

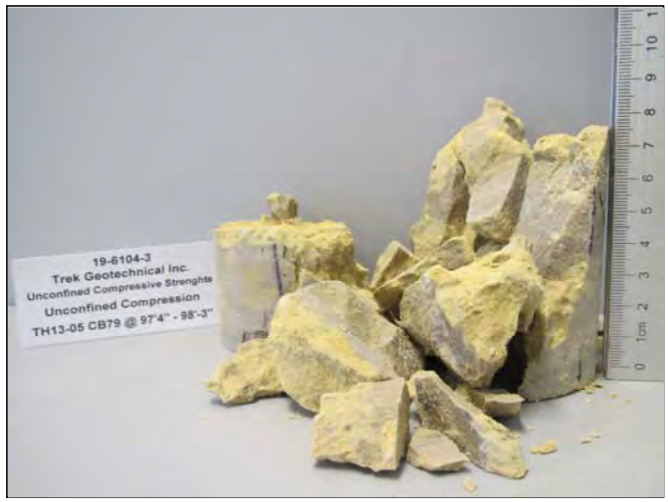
REPORT DATE: Dec 4/13
REPORT NUMBER: UC13-7c

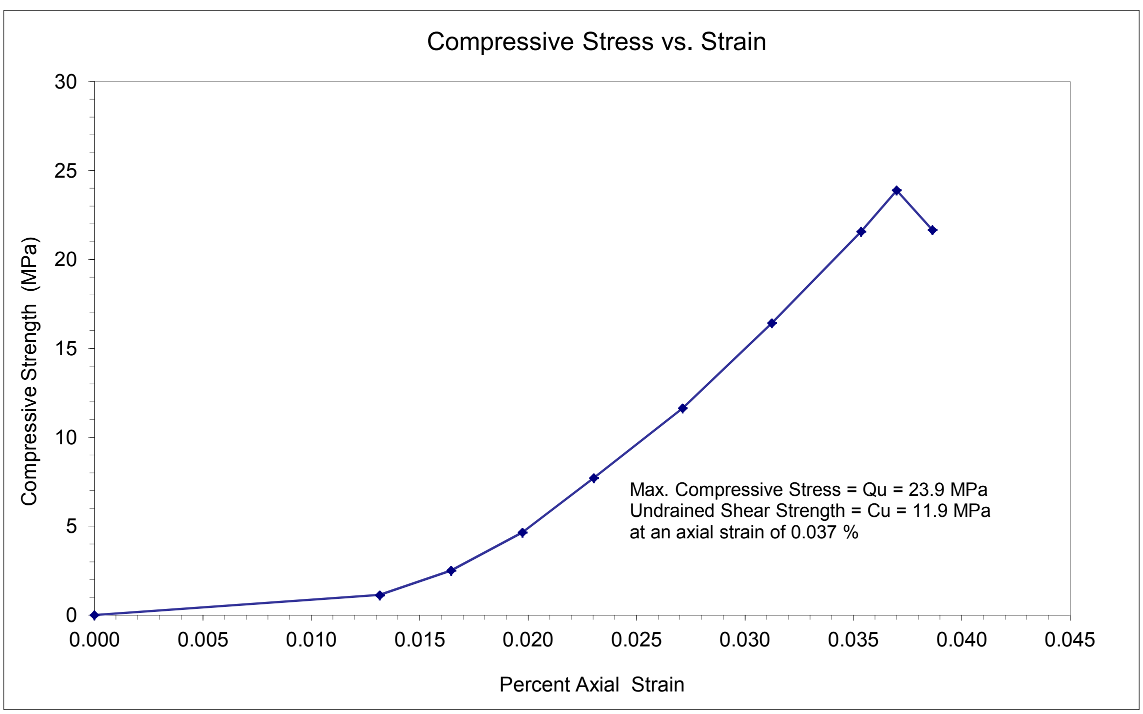
## Unconfined Compressive Strengths

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

SPECIMEN DETAILS:

| | |
|---|---|
| Wet Density ($kg/m^3$): | 2388 |
| Dry Density ($kg/m^3$): | 2256 |
| Moisture Content (%): | 5.8 |

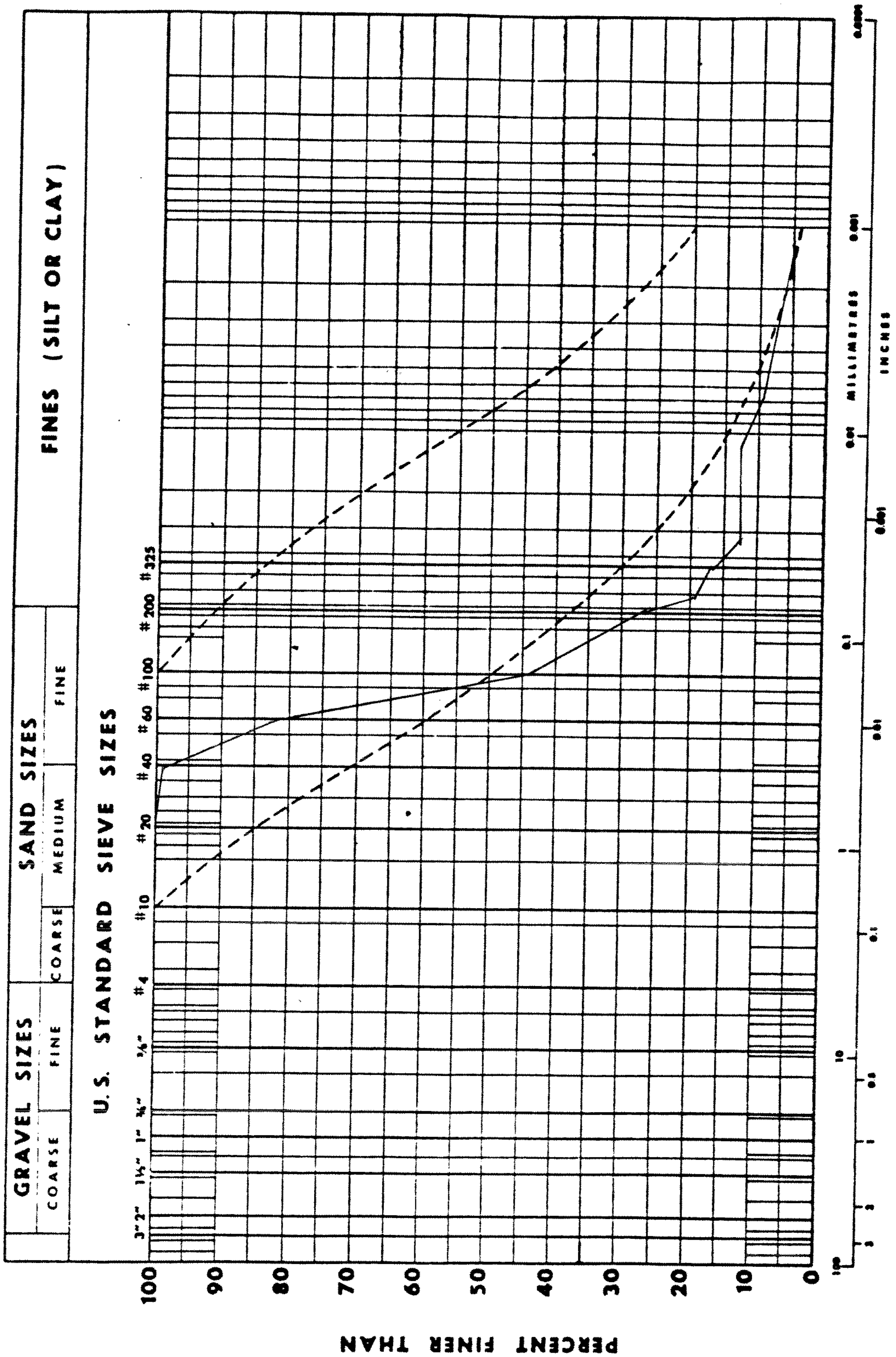


**DYREGROV & BURGESS**
Consulting Geotechnical Engineers

# 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 |




$D_{10}$ = ____ 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 | SILT | CLAY |
|---|---|---|---|
| __ % | 74 % | 18 % | 8 % |

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

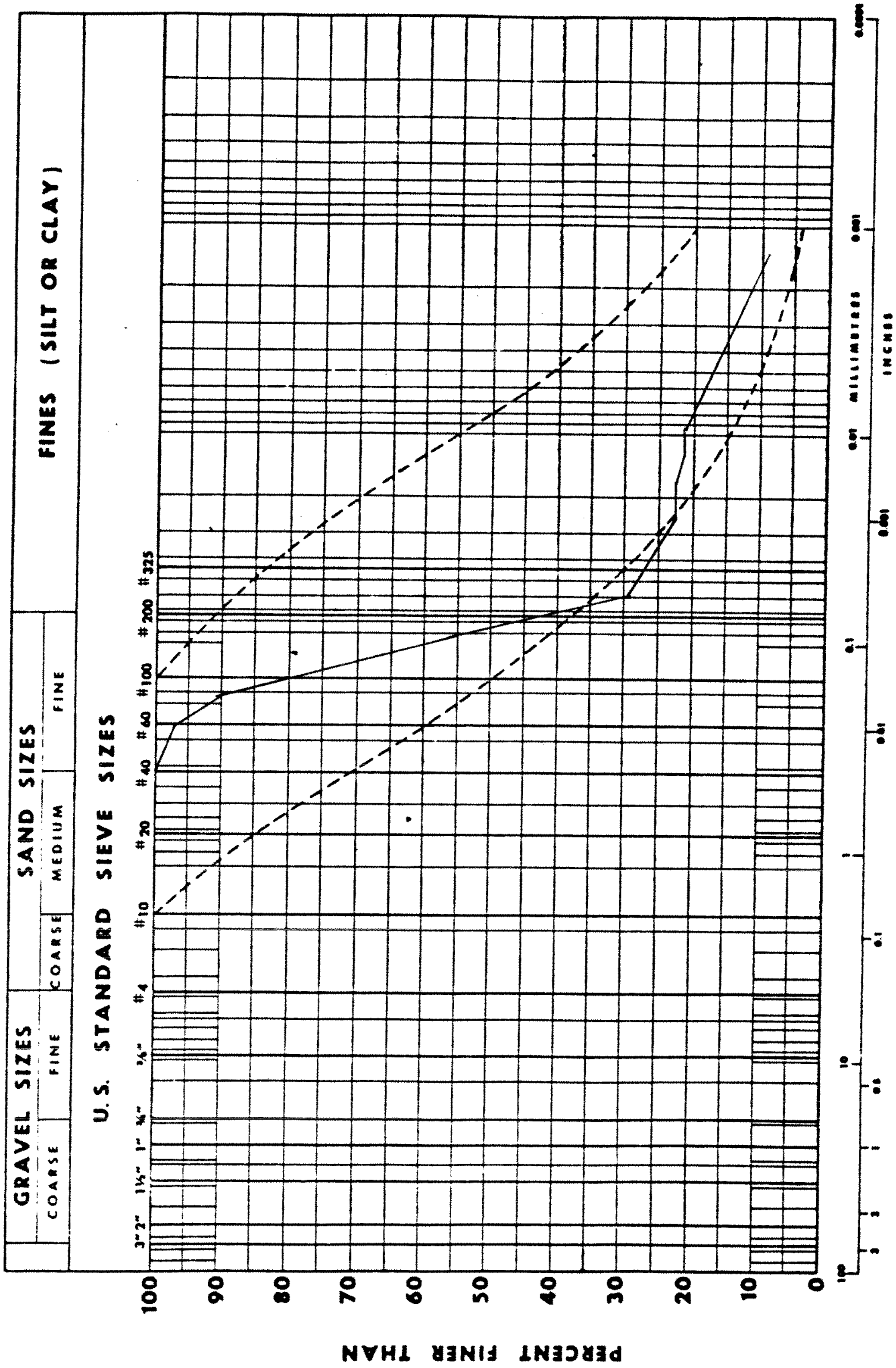
PLATE B1

TA 461 12/77

**DYREGROV & BURGESS**
Consulting Geotechnical Engineers

# GRAIN SIZE CURVE

| | |
|---|---|
| LAB ORDER NO. | 87422 |
| CLIENT | |
| SAMPLE | |
| SOURCE | KILDONAN CORRIDOR |
| HOLE 6 | DEPTH 6.1 m DATE REC'D. |
| TECHNICIAN SDG | DATE TESTED 14/10/87 |




D10 = ______ MM.
D30 = ______ MM.
D60 = ______ MM.
Cu ______
Cc ______

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

| GRAVEL | SAND | SILT | CLAY |
|---|---|---|---|
| ____ % | 55 % | 28 % | 17 % |

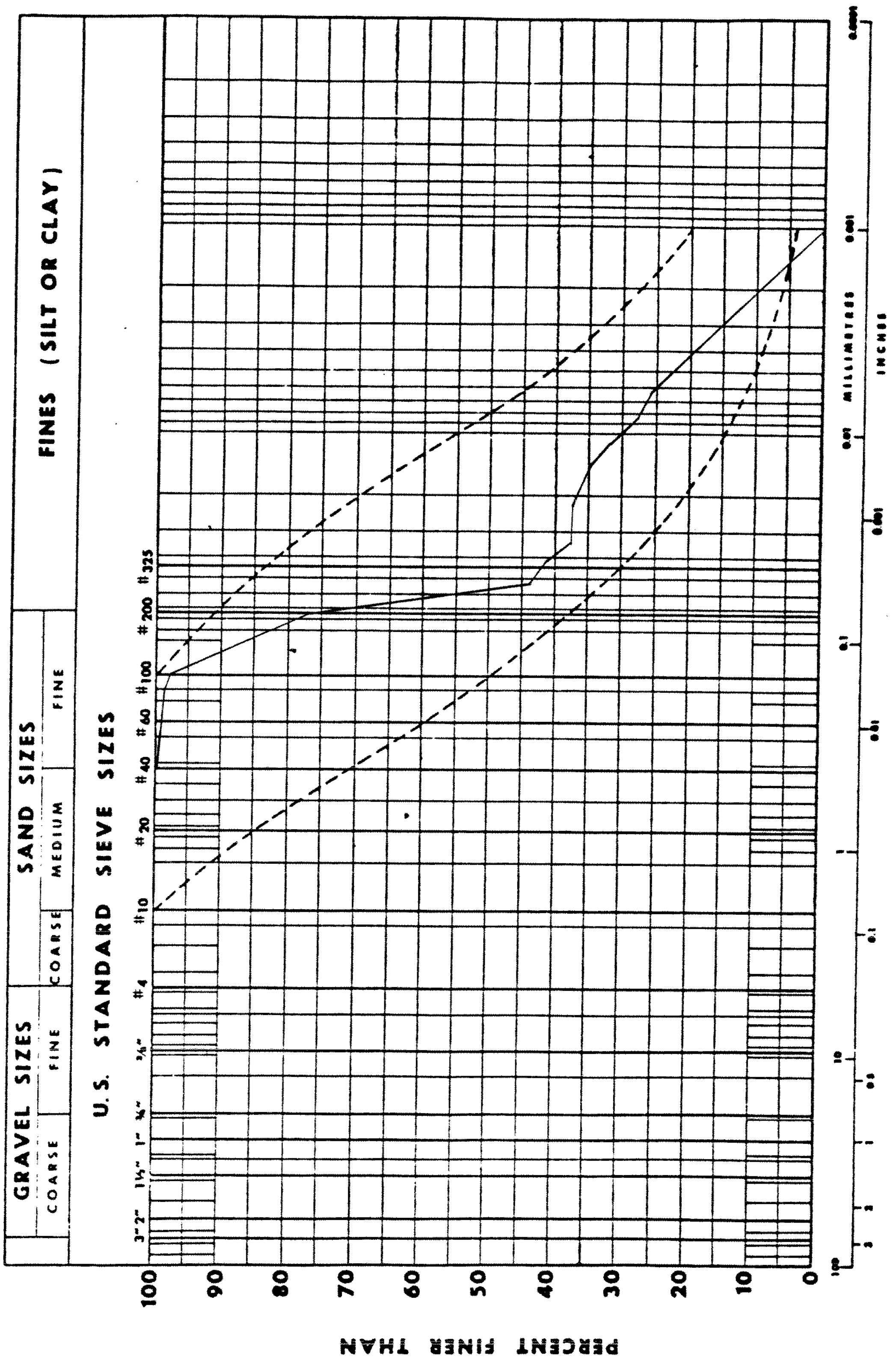
NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

PLATE B2

**DYREGROV & BURGESS**
Consulting Geotechnical Engineers

# GRAIN SIZE CURVE

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




$D_{10}$ = ____ 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 | SILT | CLAY |
|---|---|---|---|
| ____ % | 24 % | 53 % | 23 % |

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

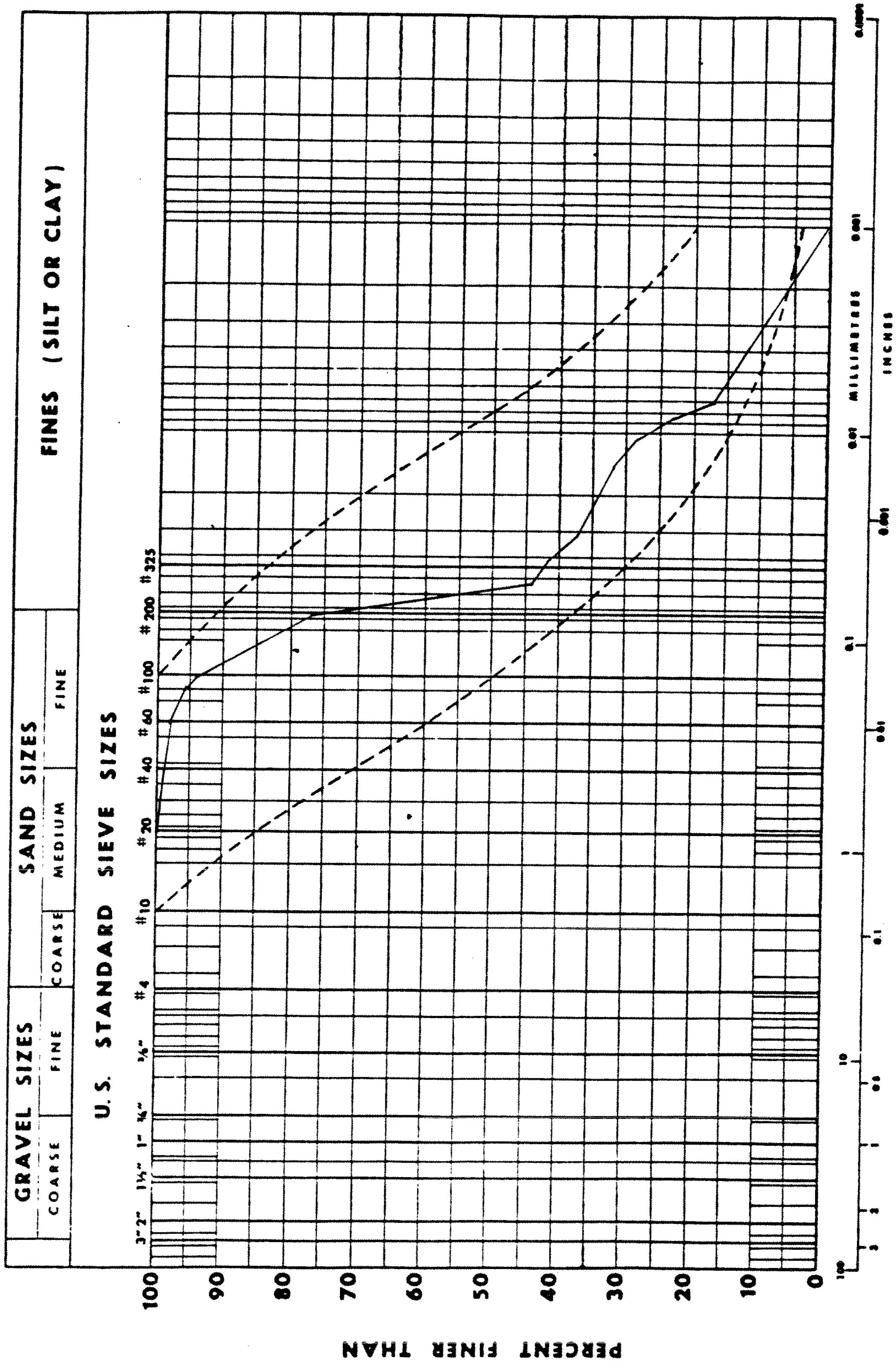
PLATE B3

TA 461 12/77

**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.
$C_U$ ______
$C_C$ ______

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

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

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

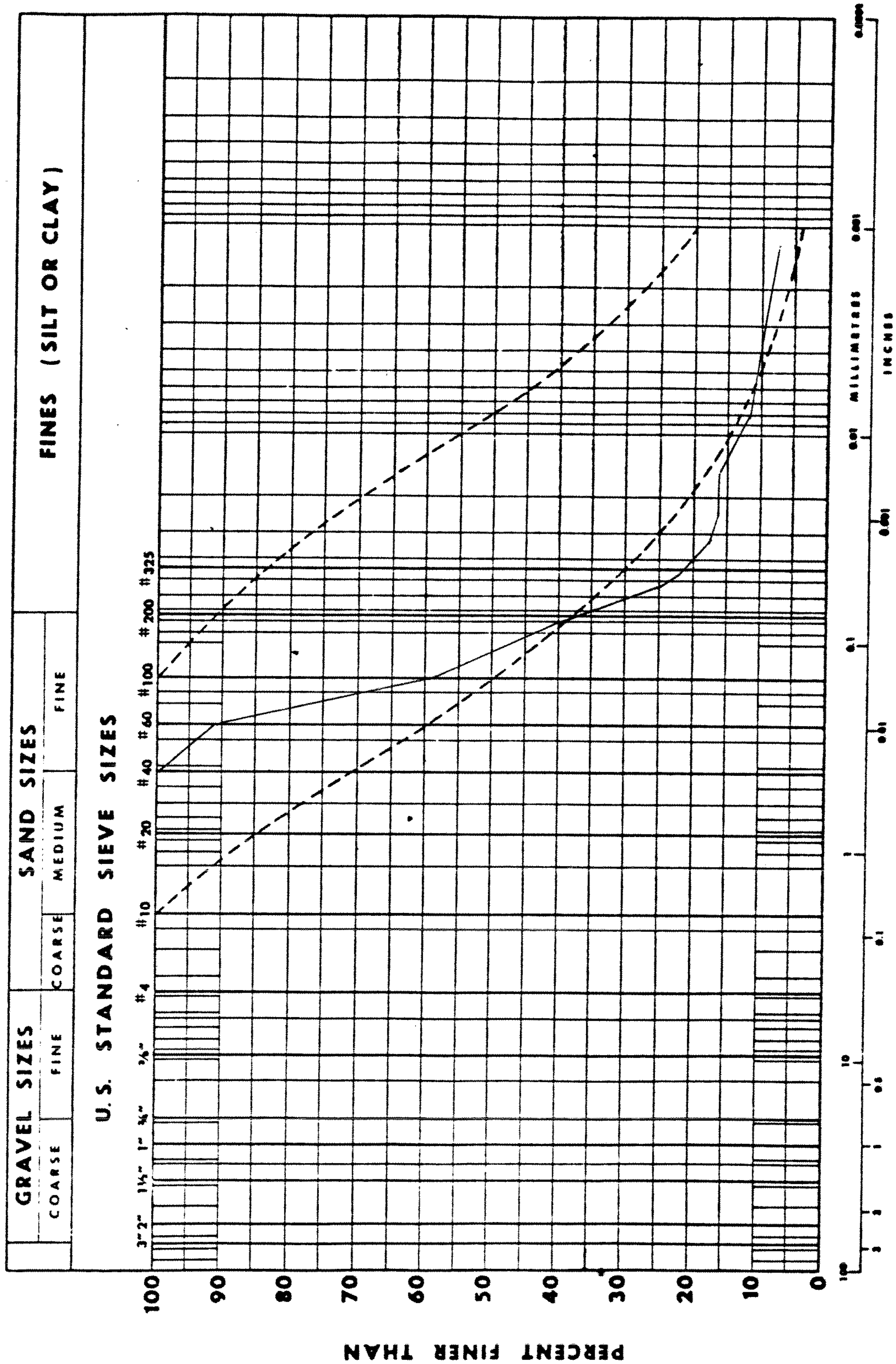
PLATE B4

TA 461 12/77

**DYREGROV & BURGESS**
Consulting Geotechnical Engineers

# 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 |




$D_{10}$ = ____ 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 | SILT | CLAY |
|---|---|---|---|
| ____ % | 64 % | 26 % | 10 % |

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

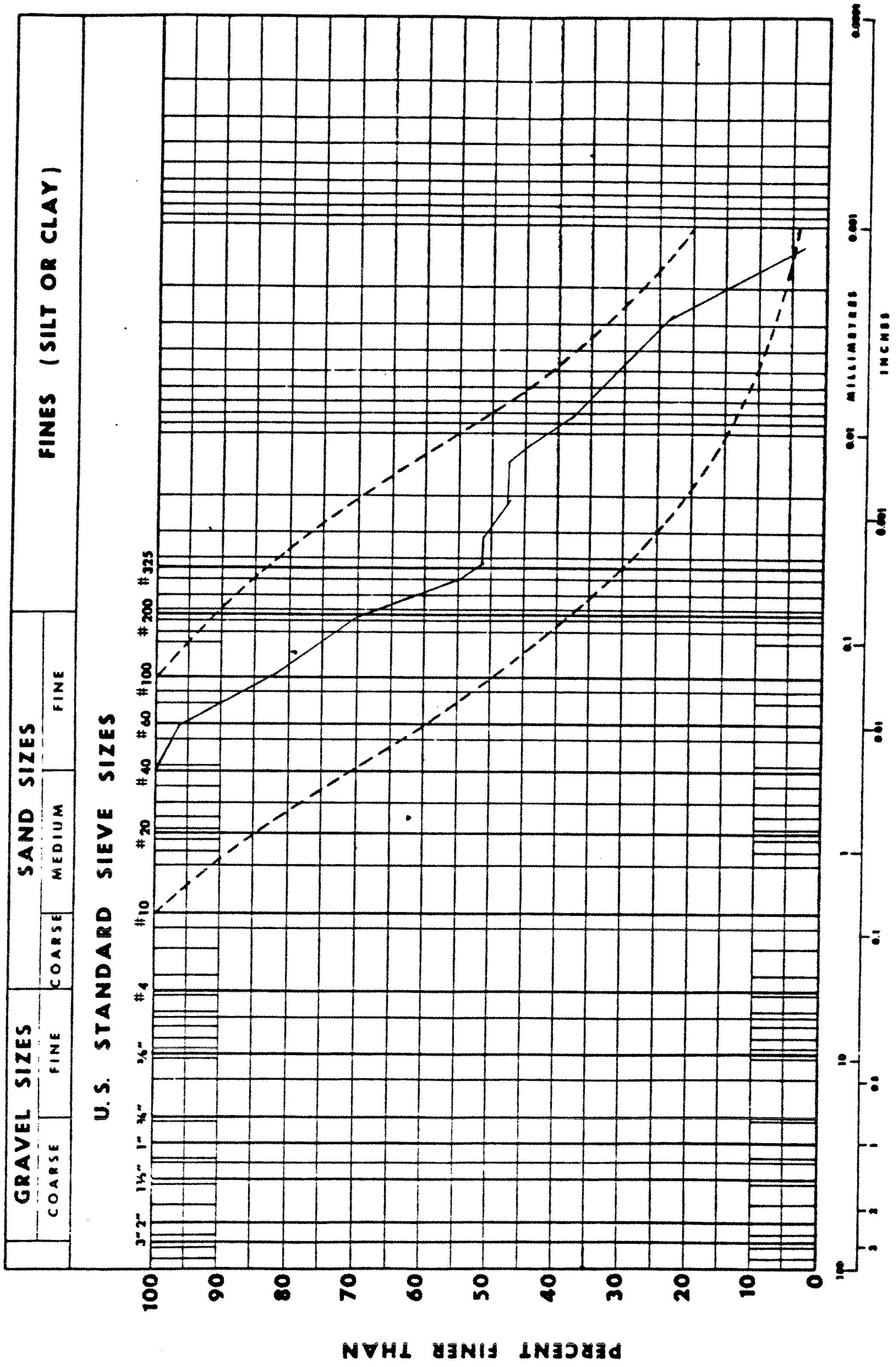
**PLATE** B5

TA 461 12/77

**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 |




$D_{10}$ = ______ MM.
$D_{30}$ = ______ MM.
$D_{60}$ = ______ MM.
$C_u$ ______
$C_c$ ______

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

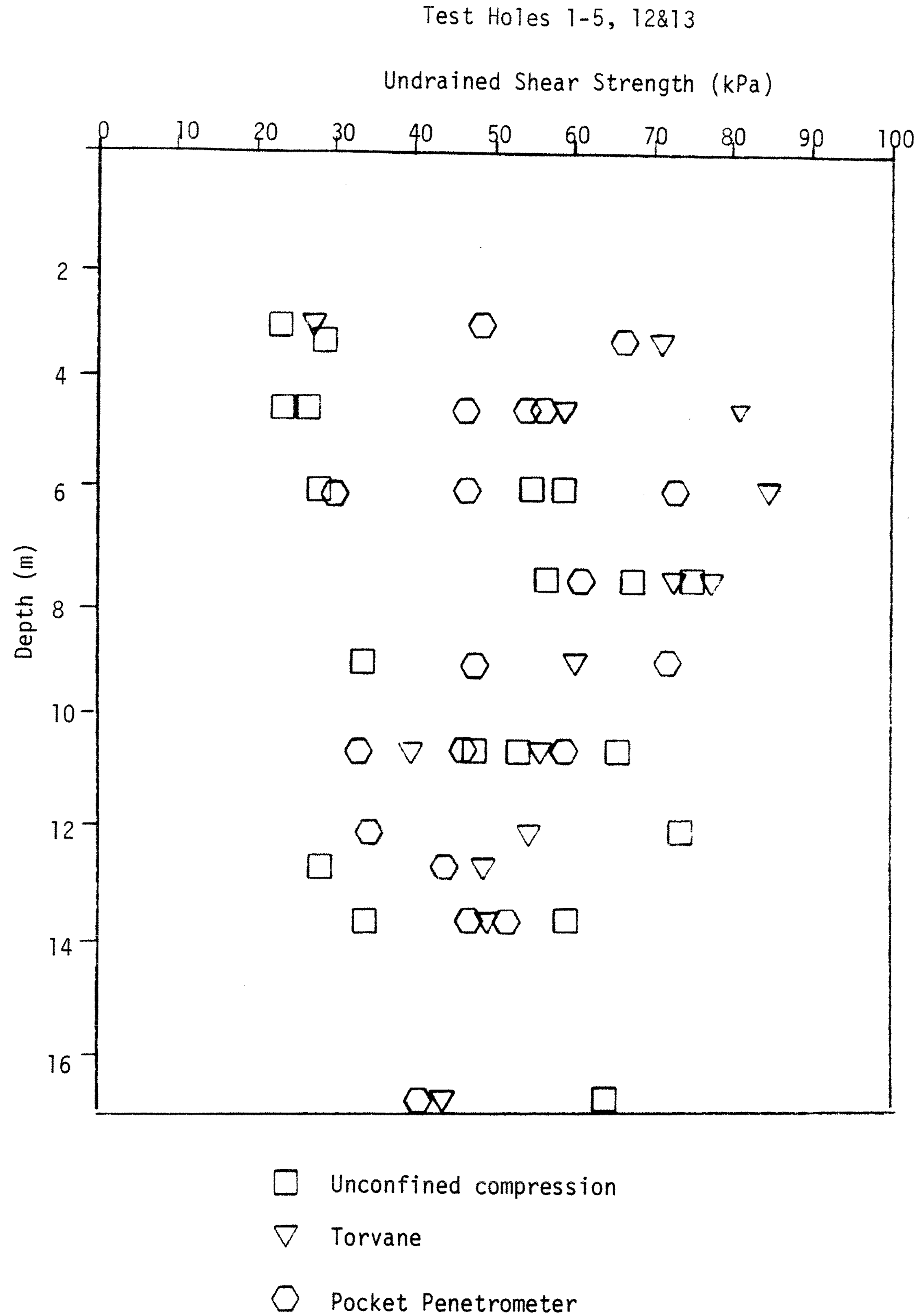
——— GRADATION OF TESTED SAMPLE

| GRAVEL | SAND | SILT | CLAY |
|---|---|---|---|
| ___ % | 31 % | 39 % | 30 % |

NOTE: UNIFIED SOIL CLASSIFICATION SYSTEM

PLATE B6

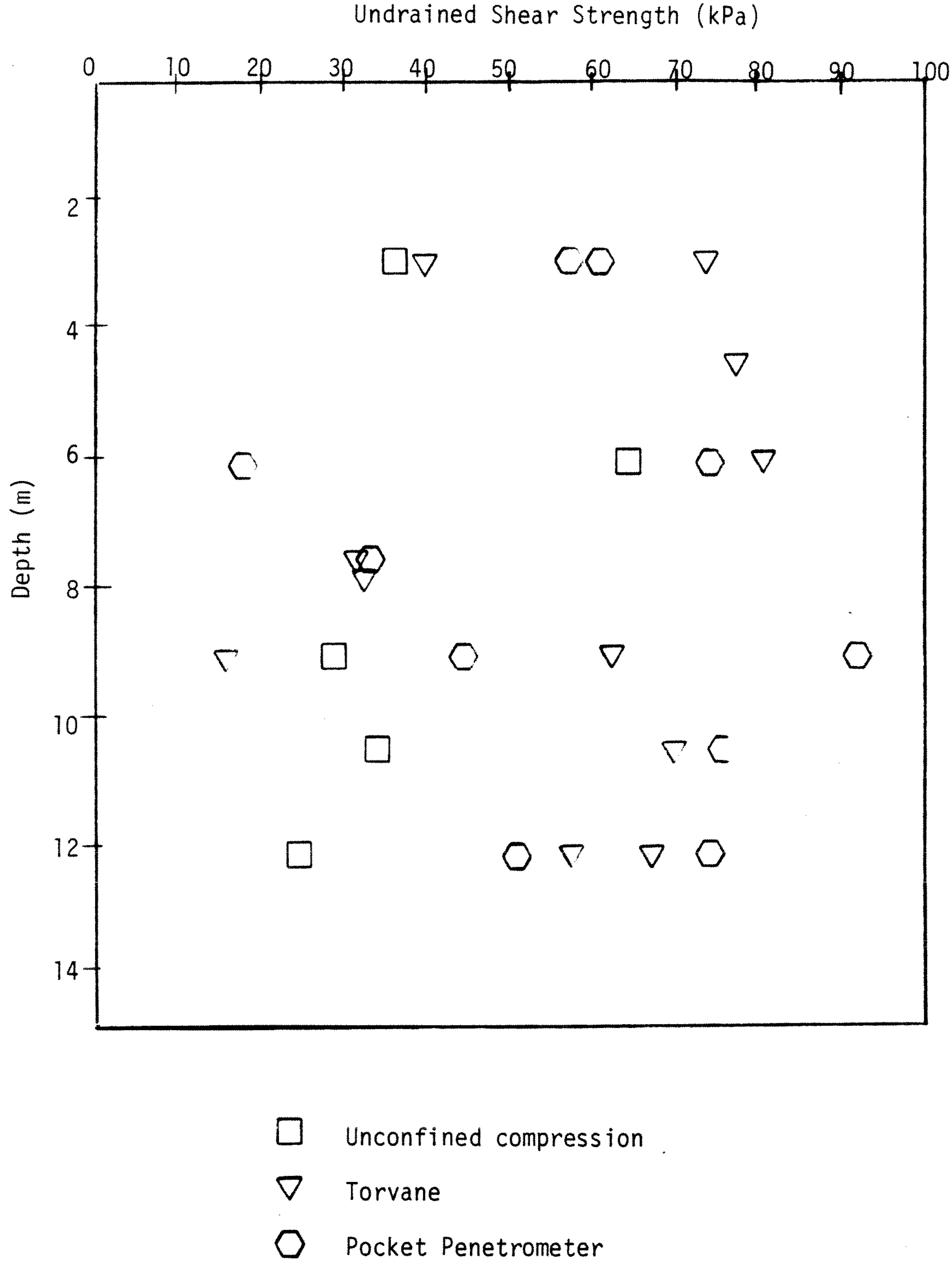
TA 461 12/77




| DYREGROV & BURGESS<br>CONSULTING GEOTECHNICAL ENGINEERS | STRENGTH DATA<br>WEST APPROACH |
|---|---|

| SCALE | DATE | MADE | CHKD | JOB | FIGURE C1 |
|---|---|---|---|---|---|

Test Holes 6-11




**DYREGROV & BURGESS**
CONSULTING GEOTECHNICAL ENGINEERS

STRENGTH DATA
EAST APPROACH

| SCALE | DATE | MADE | CHKD | JOB | FIGURE C2 |
|---|---|---|---|---|---|

AECOM

# 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.

**Project Background (Cont'd)**

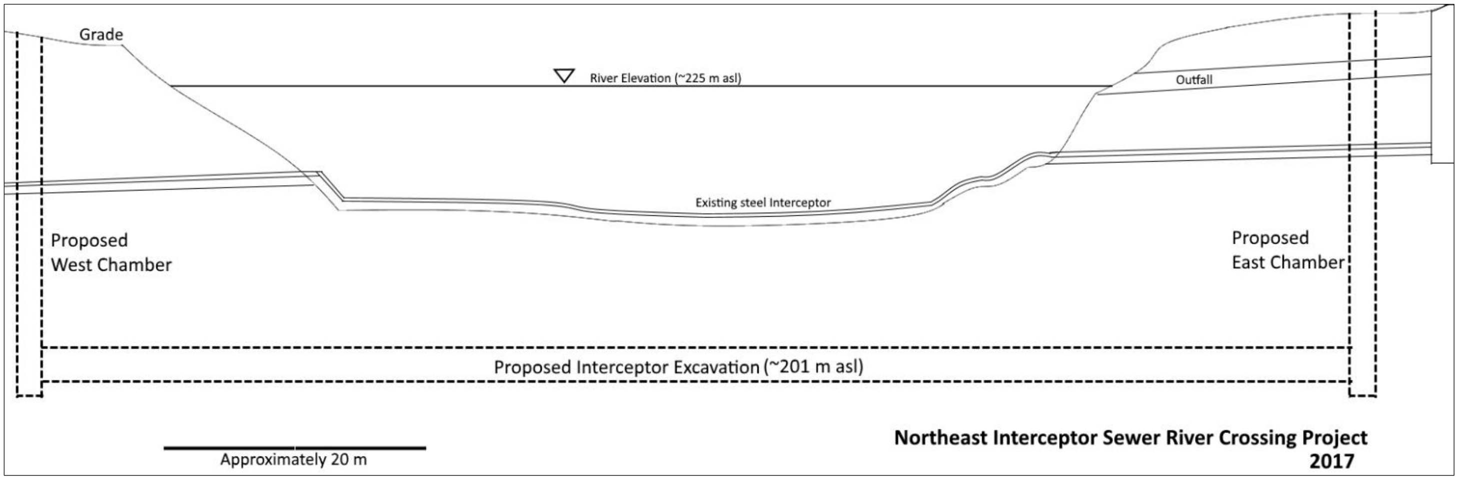



Figure 2 - Cross section of Red River Channel showing existing interceptor infrastructure and the proposed new chambers and tunnel excavation; scale is approximate, elevation given as meters above sea level (asl). (Modified source – AECOM, 2017)

**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.

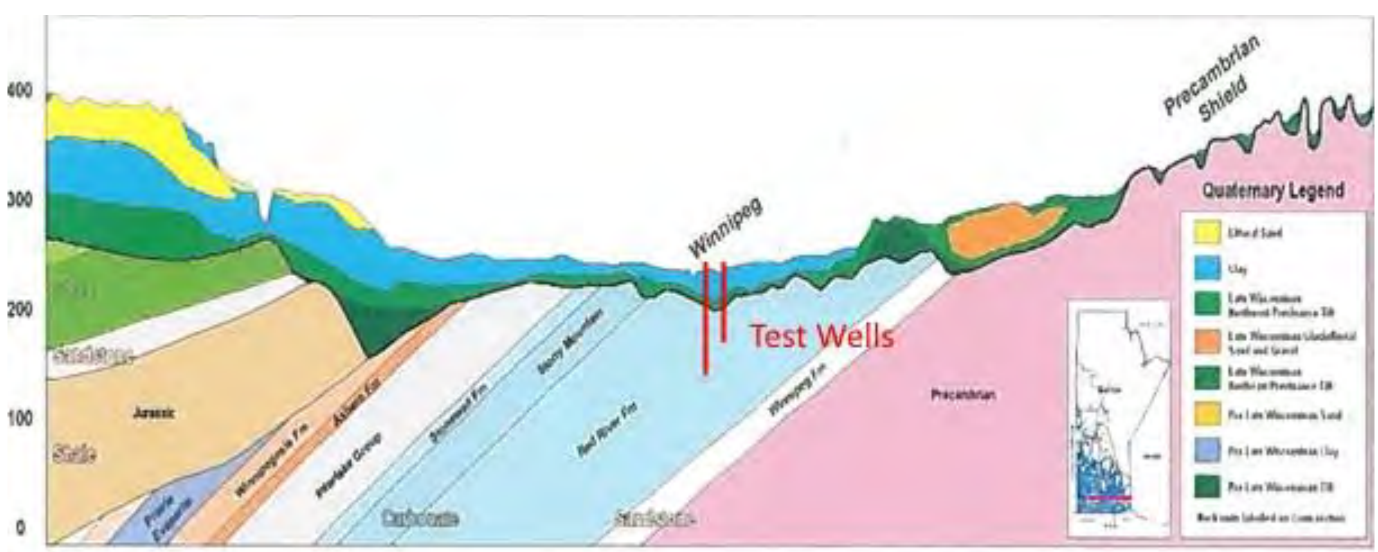



Figure 3 - Geological cross section through Southern Manitoba; the approximate location of the test wells are plotted in red. (source Manitoba Geological Survey, 2013)

**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. ($1.44 \times 10^{-3}$ to $1.44 \times 10^{-2}$ $m^2/s$). It should be noted in the mapping that Baracos it 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. ($1.44 \times 10^{-2}$ $m^2/s$). 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.

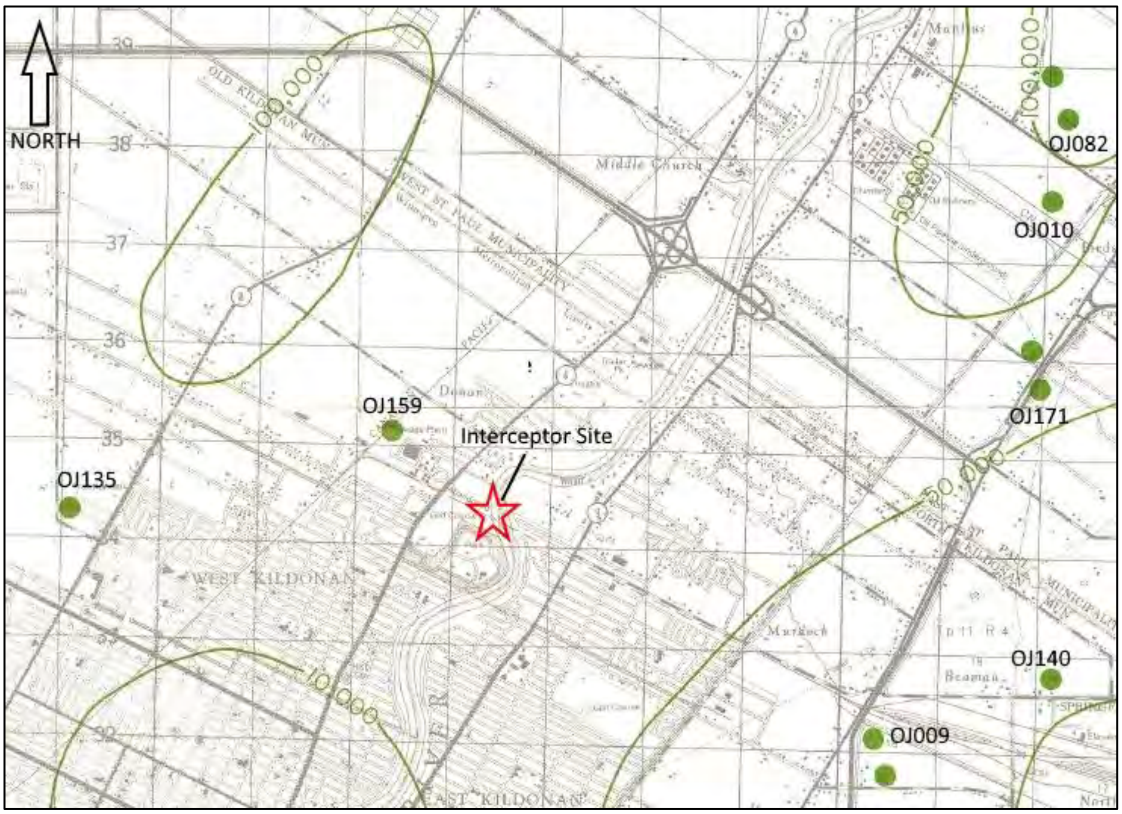



Figure 4 – Transmissivity of the upper carbonate aquifer in northern Winnipeg; Provincial monitoring wells plotted as green dots. (modified source - Baracos et. al.,1983)

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 annul 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)**

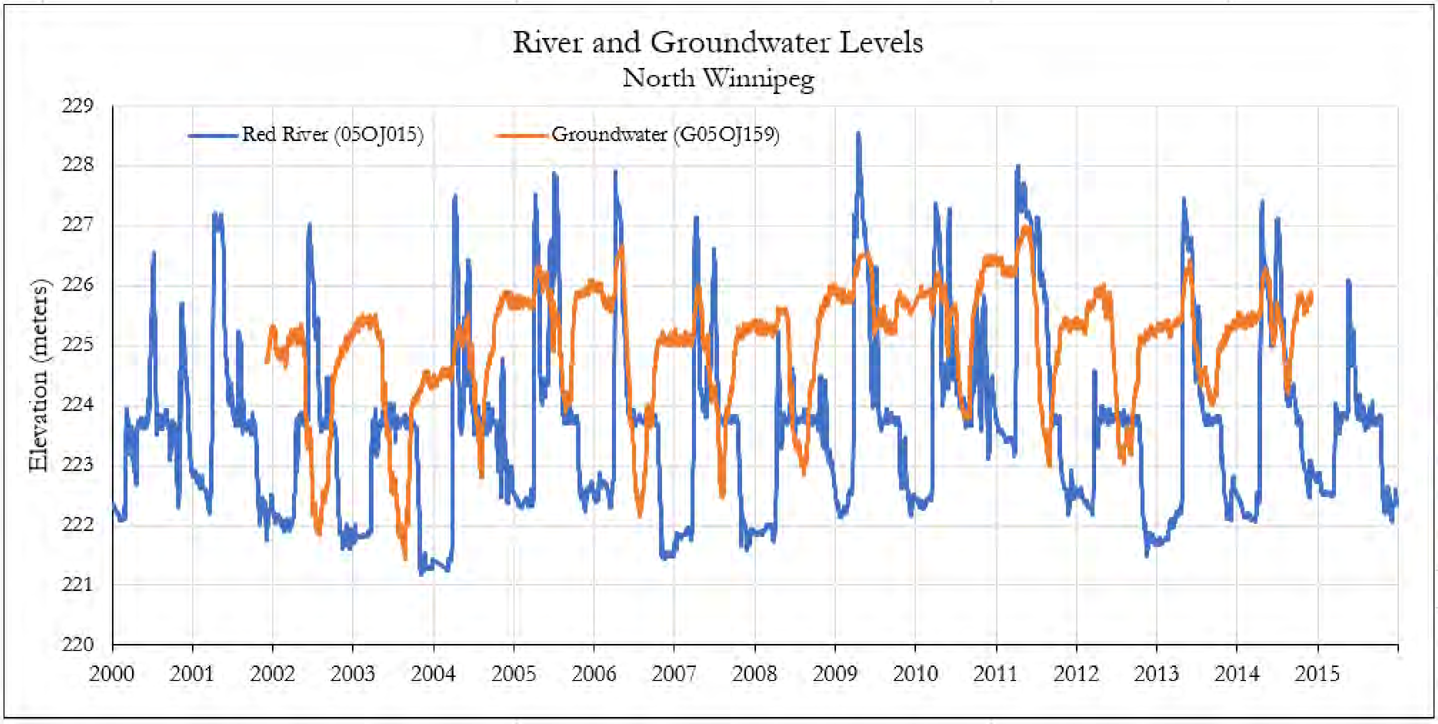



Figure 5 – Groundwater observation station (G05OJ159) plotted in blue with the Red River elevation at the James Ave pumping station (05OJ015) potted in orange. (source MSD, 2016; Environment Canada, 2017)

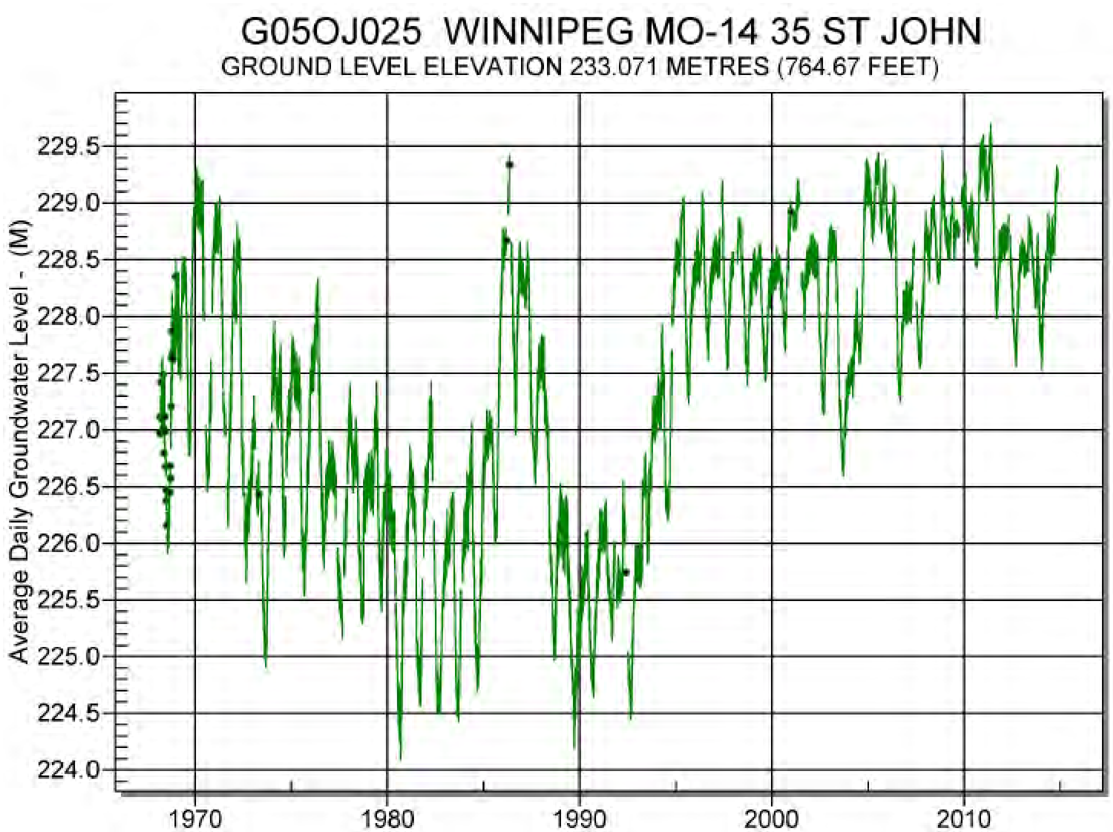



Figure 6 – Long term provincial hydrograph station G05OJ025, located in north west Winnipeg. (MSD, 2015)

The interconnection between the Red River and the Carbonate Aquifer is shown to be highly dynamic (Figure 5). Throughout most of the

**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.

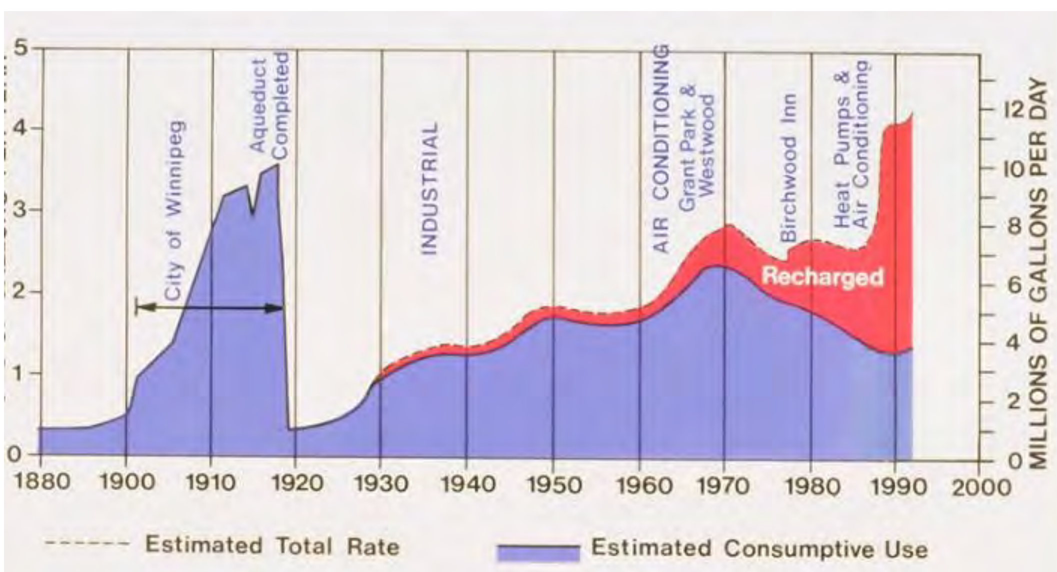



Figure 7 - Estimated groundwater use within the City of Winnipeg from 1880 to 1990. (source – Render, 2011)

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.

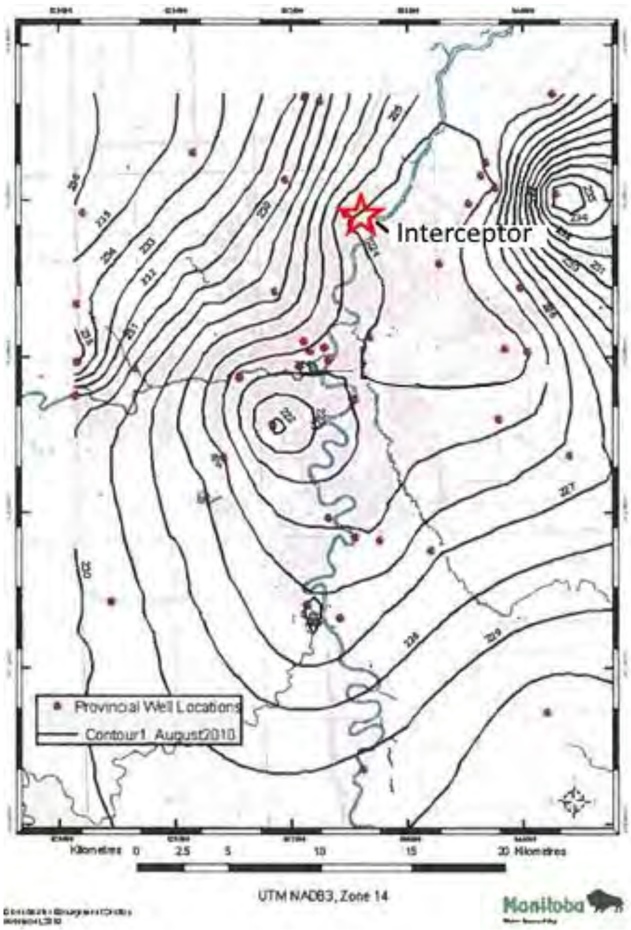



Figure 8 - Potentiometric surface, Interceptor site indicated by red star. (source – MSD, 2010)

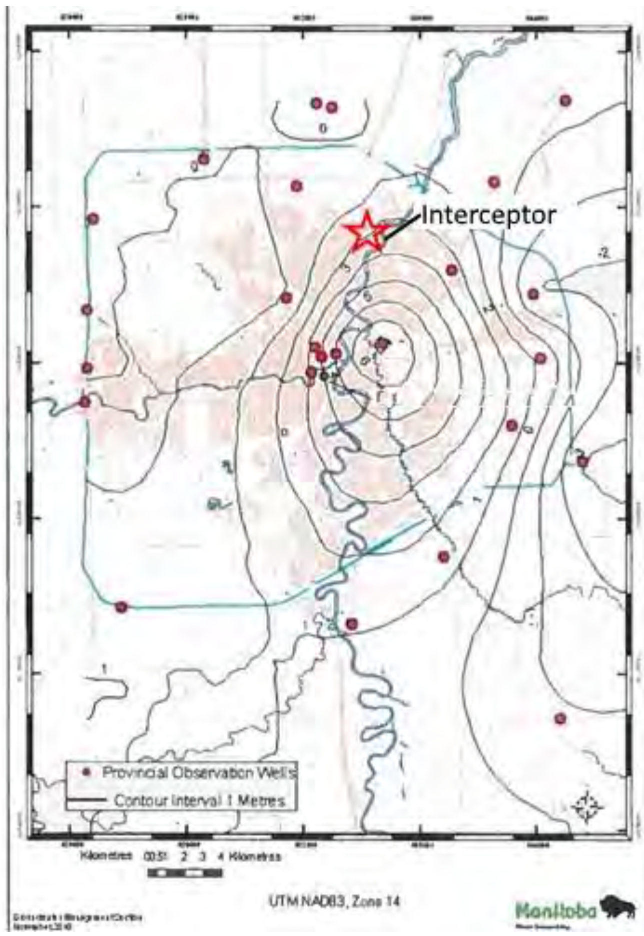



Figure 9 - Potentiometric difference (1970-2009) – Interceptor site indicated by red star. (source – MSD, 2010)

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 $^{18}$oxygen 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, at 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<br>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. ($6.94 \times 10^{-3}$ $m^3/s$) | 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. ($4.10 \times 10^{-3}$ $m^3/s$) | 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<br>Confined Aquifer Parameters - East Chamber Site<br>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<br>(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<br>[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<br>Confined Aquifer Parameters – West Chamber Site<br>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<br>(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<br>[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.P.D./ft. (1.44 x $10^{-3}$ $m^2/s$) 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 x $10^{-3}$ $m^2/s$), 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.

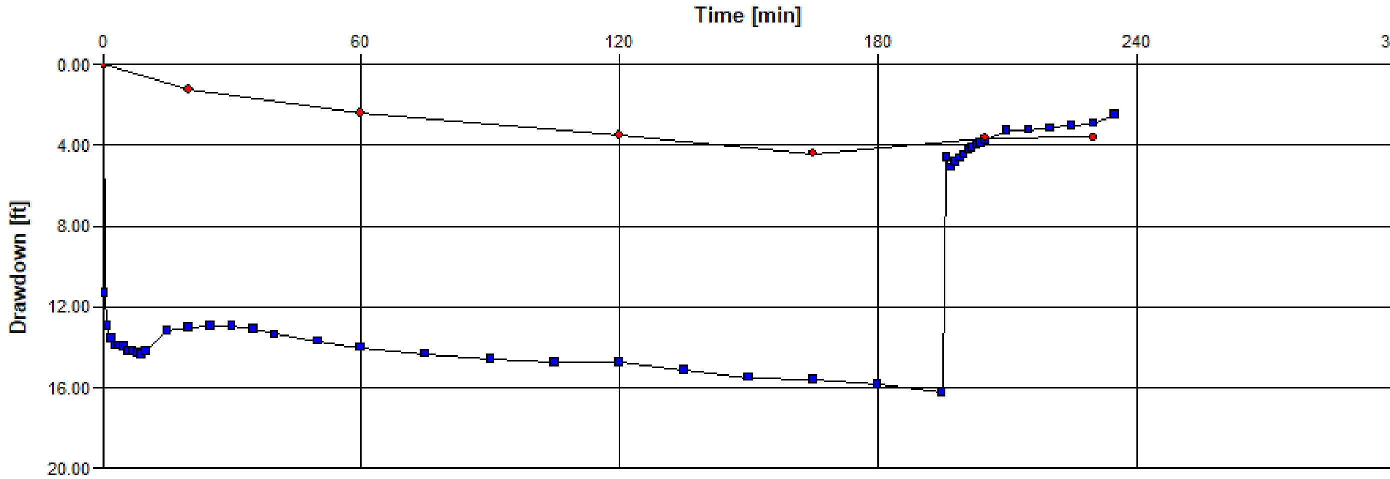



Figure 10 - Drawdown vs. time from the pump test of well TH-01; East chamber site; Pumping rate 110 U.S.GPM. (3.16 x $10^{-3}$ $m^3/s$).

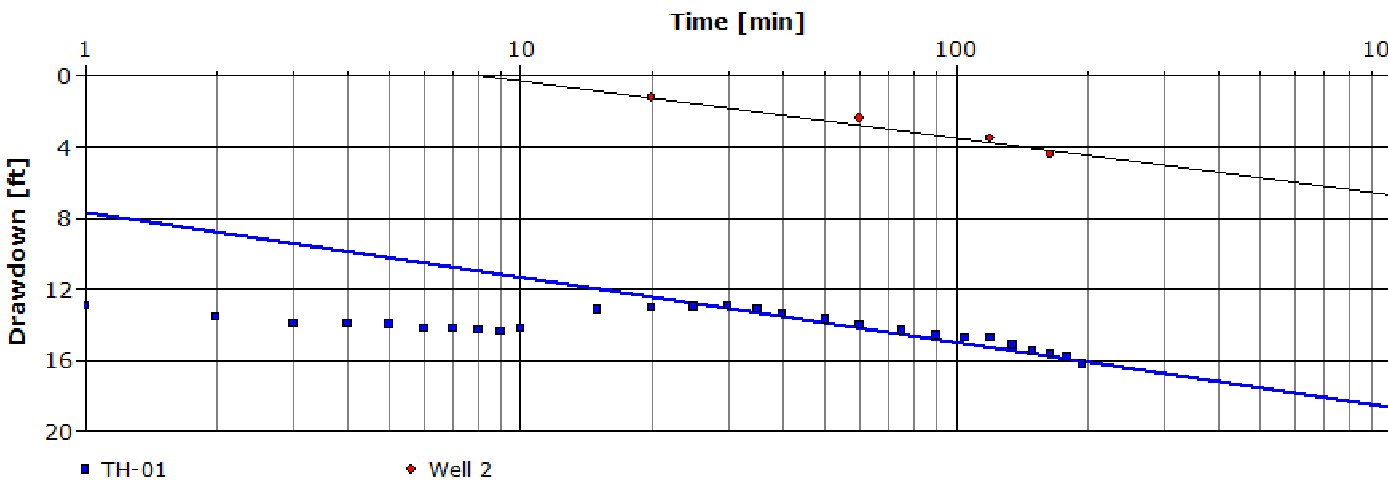



Figure 11 – Cooper Jacob method (1946) analysis of pump test data from well TH-01; East chamber site; Pumping rate is 110 U.S.GPM. (3.16 x $10^{-3}$ $m^3/s$).

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 x $10^{-3}$ $m^2/s$) to less than 10,000 U.S.G.P.D./ft. (1.44 x $10^{-3}$ $m^2/s$). 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 beem 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 likelyhood 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)*

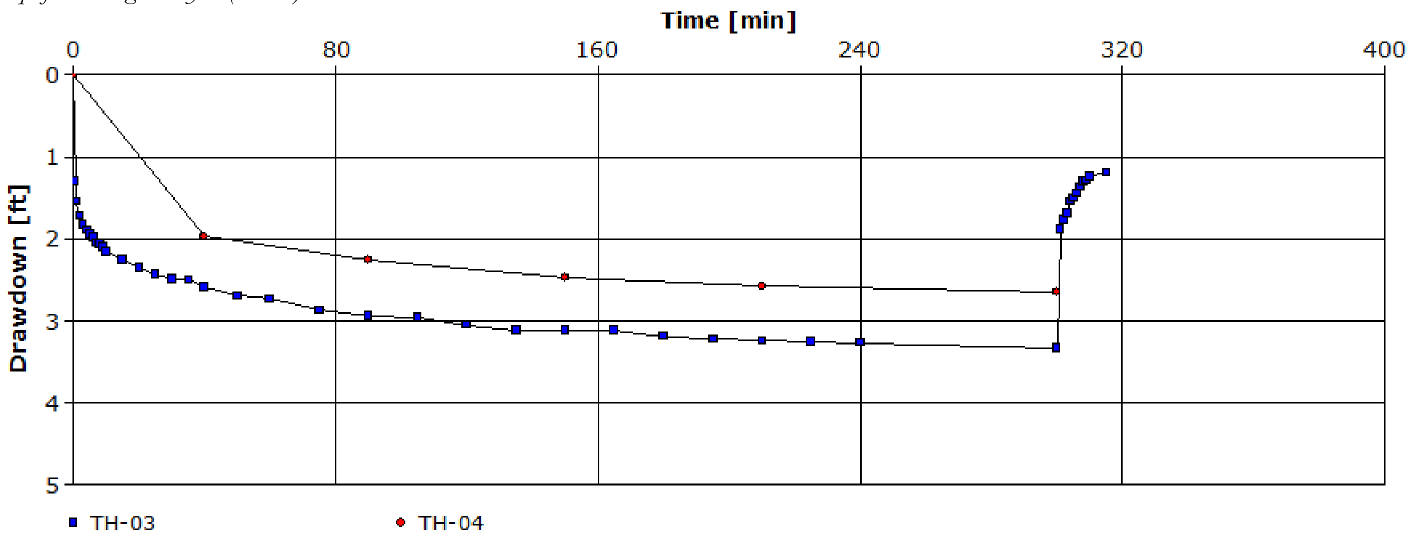



Figure 12 - Drawdown vs. time from the pump test of TH-03; West chamber site; Pumping rate is 65 U.S.GPM. ($4.10 \times 10^{-3}$ $m^3/s$).

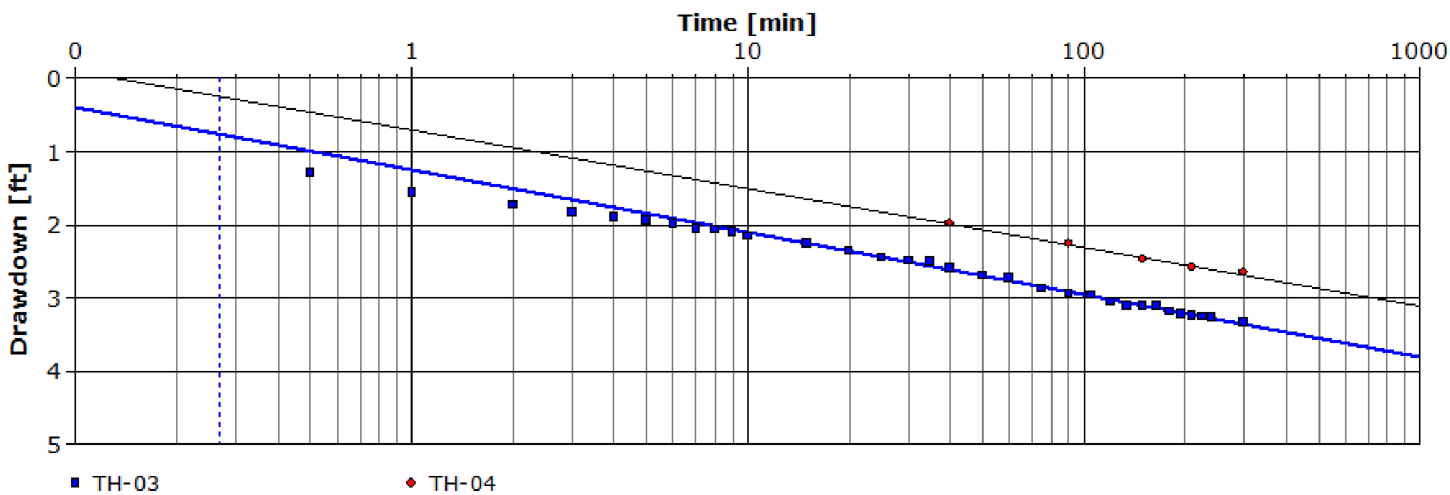



Figure 13 – Cooper Jacob method (1946) analysis of pump test data from well TH-03; West chamber site; Pumping rate is 65 U.S.GPM. ($4.10 \times 10^{-3}$ $m^3/s$).

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)*

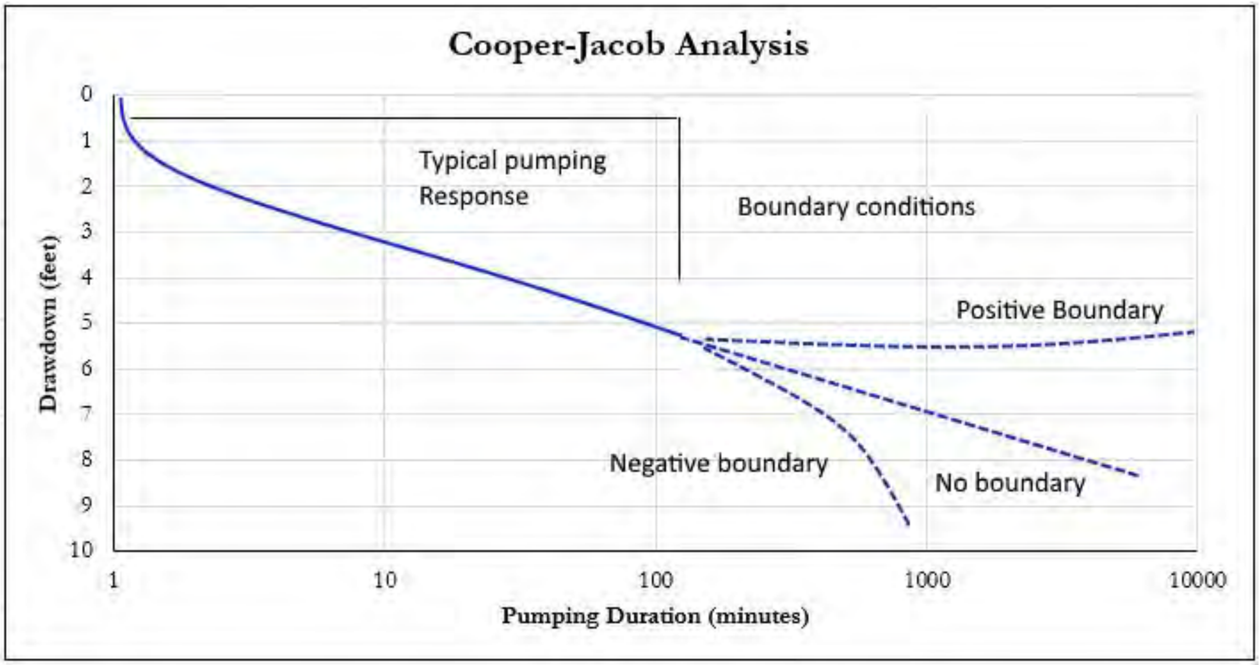



Figure 14 – Theoretical water level response to positive, neutral and negative aquifer boundary conditions on a Cooper-Jacob plot.

*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.

*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.

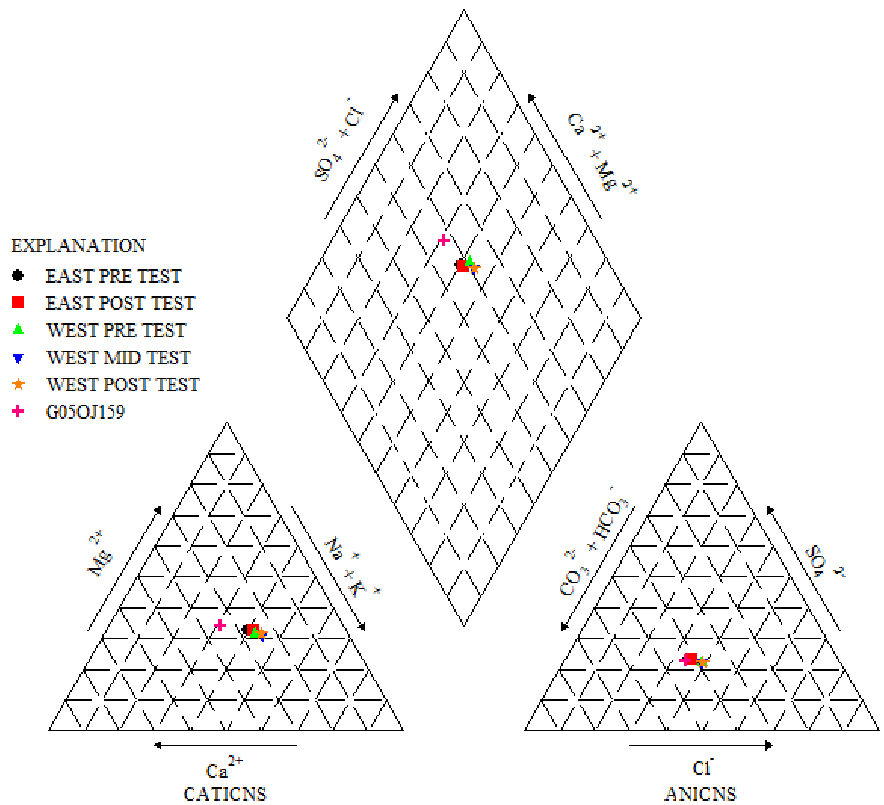



Figure 15 – Piper Plot; Interceptor Site (data source: ALS L2015597; MSD, 2016)

The ratios of the main isotopes that compose the water molecule ($^{18}O/^{16}O$) and $^{2}H/^{1}H$ 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 $^{18}$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 $^{18}$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 $^{18}$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 $^{18}$oxygen 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.

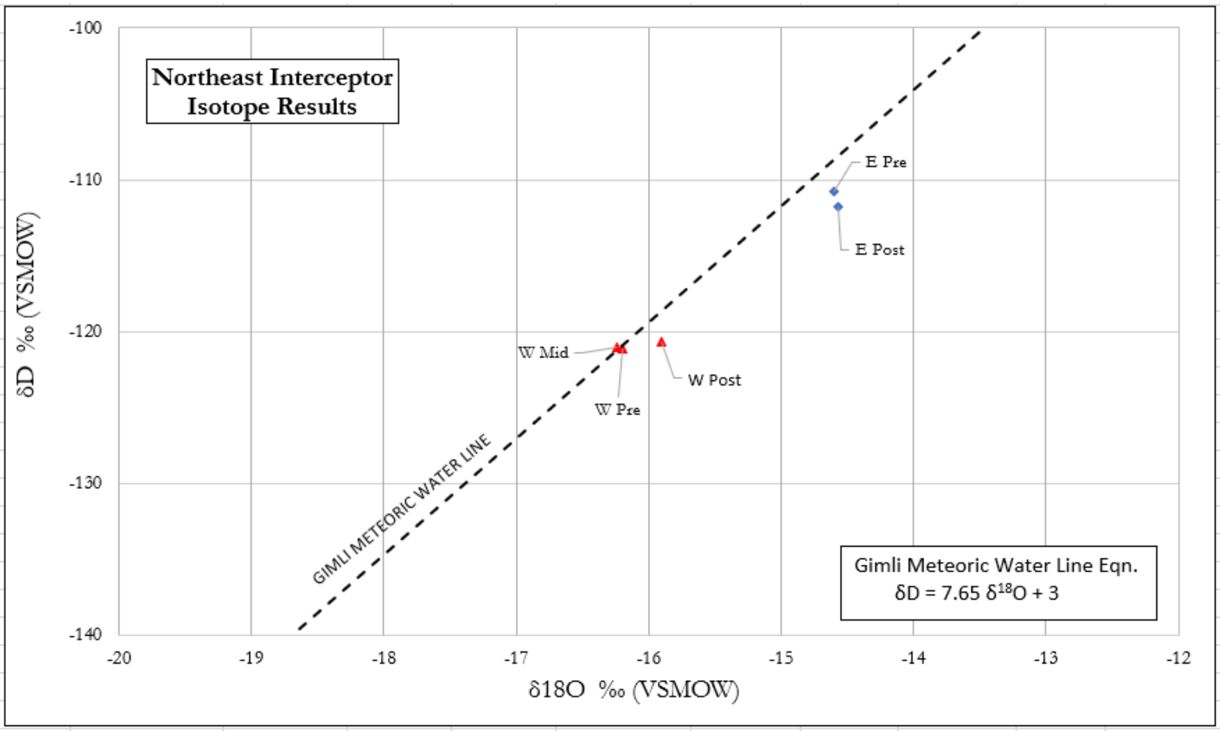



Figure 16 – Groundwater samples collected at the start, middle and end of the pumping tests conducted at the east and west chamber sites; plotted against the Gimli Meteoric Water Line. (source - ALS L2015597, 2017; IAEA, 2012)

**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 wo 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. ($7.57 \times 10^{-2}$ $m^3/s$) 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. ($2.87 \times 10^{-3}$ $m^2/s$).
- Storativity value of $1.0 \times 10^{-4}$.
- Pumping duration of 180 days.

Following the above assumptions, the required drawdown could be generated by simultaneously pumping two wells at each chamber location at an approximate rate of 300 U.S.G.P.M. ($1.89 \times 10^{-2}$ $m^3/s$) each. The predicted drawdown cone resulting from dewatering at the above rates is illustrated in Figure 17, shown below.

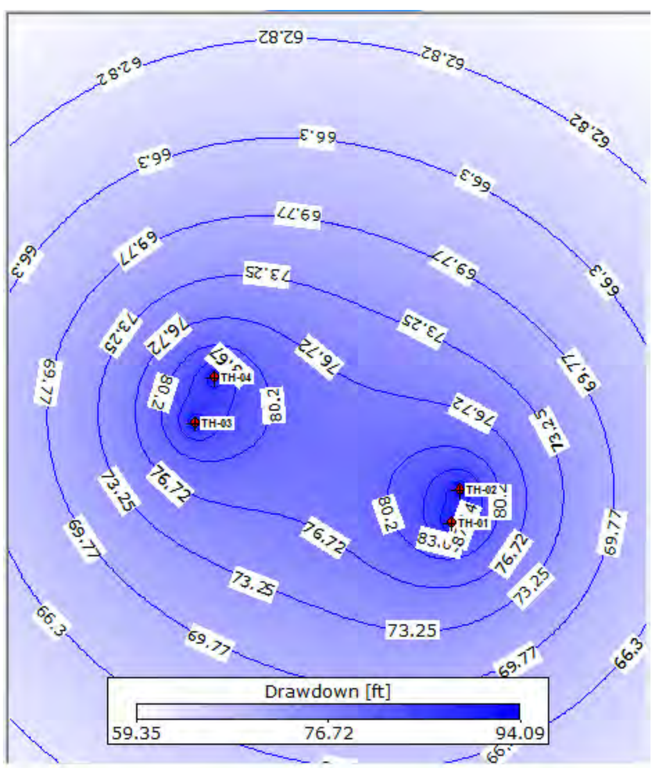



Figure 17 – Predicted Drawdown cone generated from pumping four wells at 300 U.S.G.P.M. each for 180 days; assumed transmissivity of 20,000 U.S.G.P.D./ft. and storativity of $1.0 \times 10^{-4}$; modeled using AquiferTest v2016.1.

*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 US.G.P.D./ft. (2.87 x $10^{-3}$ $m^2$/s), Storage Coefficient of 1.0 x $10^{-4}$**
**Discharge Rate of 600 U.S.G.P.M. (3.79 x $10^{-2}$ $m^3$/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 x $10^{-2}$ $m^3$/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 US.G.P.D./ft. (1.44 x $10^{-2}$ $m^2$/s), Storage Coefficient of 1.0 x $10^{-4}$**
**Discharge Rate of 2,200 U.S.G.P.M. (1.39 x $10^{-1}$ $m^3$/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 x $10^{-1}$ $m^3$/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:

- $q = k\,\Delta h$

Where $q$ is flow between the river and the aquifer (positive for baseflow – for gaining streams; and negative for river recharge – for losing streams); $\Delta h = ha - hr$, ($ha$ is aquifer head, and $hr$ 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 x $10^{6}$ 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 x $10^5$ $ft.^2$ (2.4 x $10^4$ $m^2$).

*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 x $10^{-2}$ $m^3/s$ (~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 x $10^{-2}$ $m^3/s$ (~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.

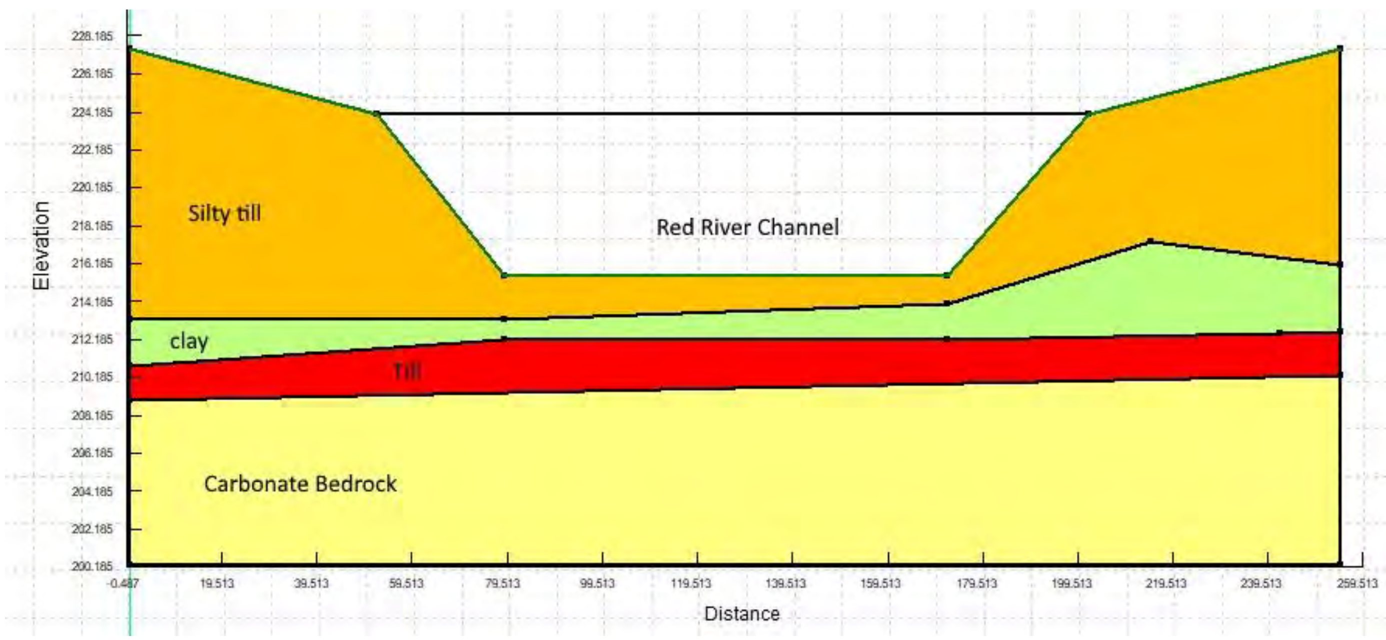



Figure 18 - Geological model of the Interceptor site for SEEP/W modeling. (AECOM, 2017)

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)*

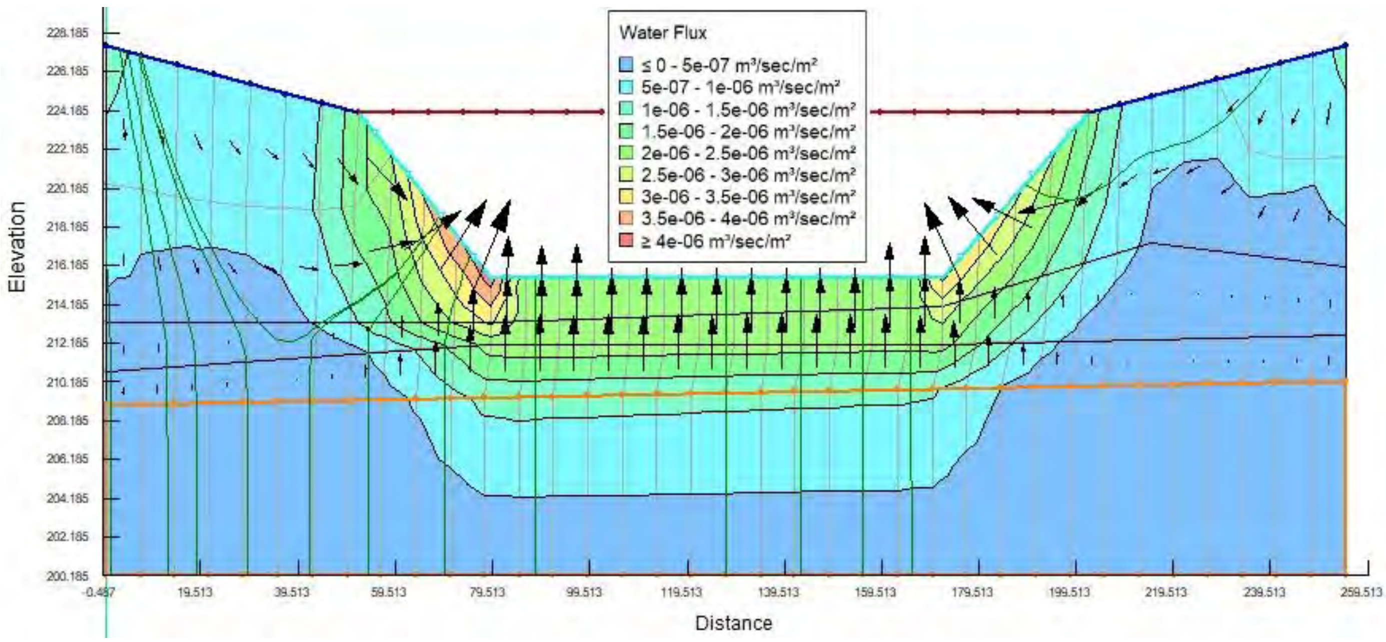



Figure 19 - Natural state conditions groundwater flux, Interceptor Site. (SEEP/W GeoStudio 2018).

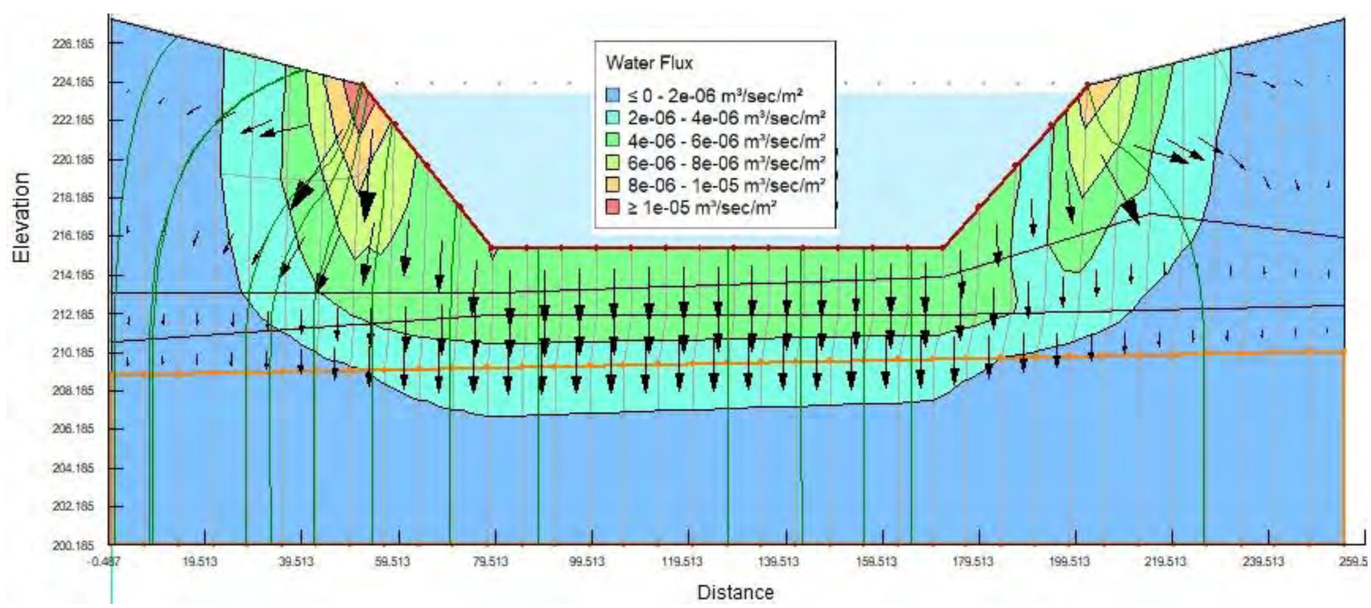



Figure 20 – Dewatering conditions groundwater flux, Interceptor Site. (SEEP/W GeoStudio 2018).

**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 dam$^3$, 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 x $10^{-4}$. 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 x $10^{-2}$ m$^3$/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 x $10^{-1}$ m$^3$/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

PROVINCE OF MANITOBA
J. J. BELL
Member
22621
REGISTERED PROFESSIONAL ENGINEER
Feb. 28/2018

Reviewed by

**Friesen Drillers Limited**

J.J.(Jeff) Bell, B.Sc.(G.E.), P.Eng.
Hydrogeological Engineer

Certificate of Authorization
Friesen Drillers Limited
No. 4016 Date: Feb. 28/2018

**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.

**References**

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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 who 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.

Manitoba
**Sustainable Development**

Water Use Licensing Section
Box 16, 200 Saulteaux 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,

Rob Matthews
Manager
Water Use Licensing Section

cc: J. Paulynn Estrella – Legal, E.I.T., Friesen Drillers Ltd.
Graham Phipps, SD
Ronaldo Miranda, SD

Manitoba
Sustainable Development
Water Use Licensing Section

FORM F

200 Saulteaux Crescent
Winnipeg, Manitoba
R3J 3W3

# 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

[signature]

for The Honourable Minister of Sustainable Development

# Well Construction Report

Manitoba

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 (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 | 58 | X | | | | | | | | | 7 7/8 | | |
| 0 | 58 | | X | | | | | | | 5 | 5½ | Insert Glued PVC | |
| 58 | 197 | | | | X | | | | | | 4¾ | | |
| 0 | 58 | | | | | | X | | | | | Envirogrout | Poured |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

**Well Completion:** Day 17 Month October Year 20 17
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 20 17
☒ 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 Loeppky 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

Manitoba

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 Name:** (if applicable) TH-01
Well Identification Tag Number 689
Location of Tag ☒ Attached to casing stick-up
☐ Other (specify)____

**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.____

**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 | X | | | | | | | | | 7 7/8 | | |
| 0 | 60 | | X | | | | | | | 5 | 5½ | Insert Glued PVC | |
| 60 | 120 | | | | X | | | | | | 4¾ | | |
| 0 | 60 | | | | | | X | | | | | Envirogrout | Poured |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

**Well Completion:** Day 12 Month October Year 20 17
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 20 17
☒ 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 Loeppky 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

Manitoba

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. ___

**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

**Well Name:** (if applicable) TH-03
Well Identification Tag Number 691
Location of Tag ☒ Attached to casing stick-up
☐ Other (specify)

**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 | X | | | | | | | | | 7 7/8 | | |
| 0 | 62 | | X | | | | | | | 5 | 5½ | Insert Glued PVC | |
| 62 | 197 | | | | X | | | | | | 4¾ | | |
| 0 | 62 | | | | | | X | | | | | Envirogrout | Poured |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

**Well Completion:** Day 16 Month October Year 20 17
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 20 17
☒ 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 Loeppky 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

Manitoba

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.____

**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

**Well Name:** (if applicable) TH-02
Well Identification Tag Number 690
Location of Tag ☒ Attached to casing stick-up
☐ Other (specify)____

**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 (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 | 76 | X | | | | | | | | | 8¾ | | |
| 0 | 76 | | X | | | | | | | 5 | 5½ | Insert Glued PVC | |
| 76 | 197 | | | | X | | | | | | 4¾ | | |
| 0 | 76 | | | | | | X | | | | | Envirogrout | Poured |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |

**Well Completion:** Day 13 Month October Year 20 17
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 20 17
☒ 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 Loeppky 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<br>Address<br>Company Name<br>City, State/Province | Pumping Test - Water Level Data | Page 1 of 1 |
|---|---|---|---|
| | | 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**<br>**Address**<br>**Company Name**<br>**City, State/Province** | **Pumping Test - Water Level Data** Page 1 of 1 |
|---|---|---|
| | | 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<br>Address<br>Company Name<br>City, State/Province | **Pumping Test - Water Level Data** <br>Project: Northeast Interceptor River Crossing East<br>Number: AECOM2017-NEINT<br>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<br>Well Inventory – 1,600 meter radius (1 mile)<br>Northeast Interceptor<br>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 SMITH | 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 |

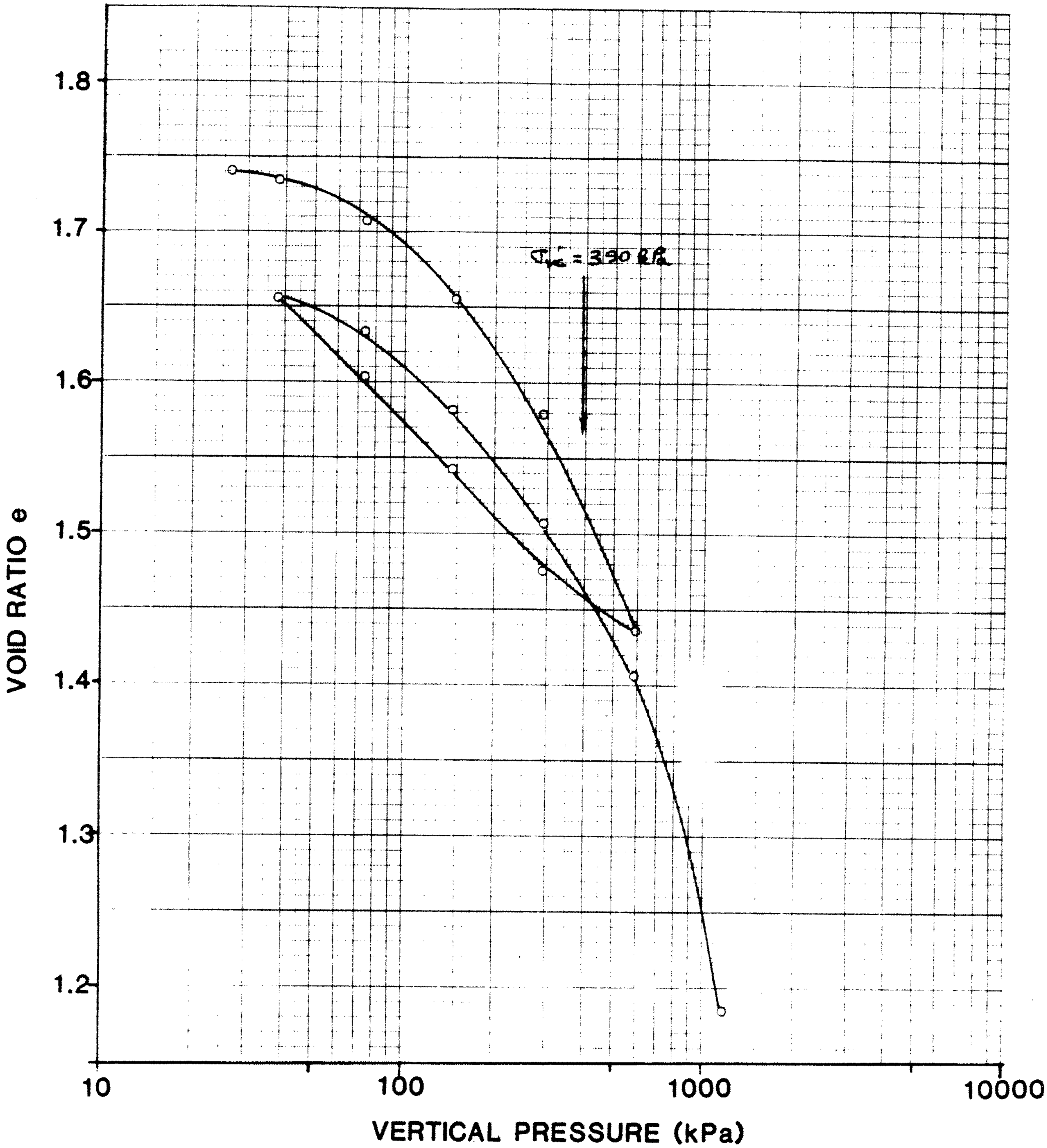
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 68 | RL 33 | WILLART HOLDINGS LTD | Paul Slusarchuk Well Drilling LTd. | P | 1970 | 103.9 | 34 | 45 | 7.995 |
| 69 | RL 33 | HELEN MATRICIAN | UNKNOWN | P | 1900 | N/A | N/A | N/A | N/A |
| 70 | RL 28 | T SKULASON | PRUDEN DRILLING CO. LTD. | P | 1970 | 95.9 | 26 | 26 | 10 |

| | |
|---|---|
| **Notes** | All information sourced from Manitoba Sustainable Development – GWDRILL, (2014 edition)<br>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.<br><br>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; |

# Appendix G

## Consolidation Test Results (Dyregrov and Burgess 1988)

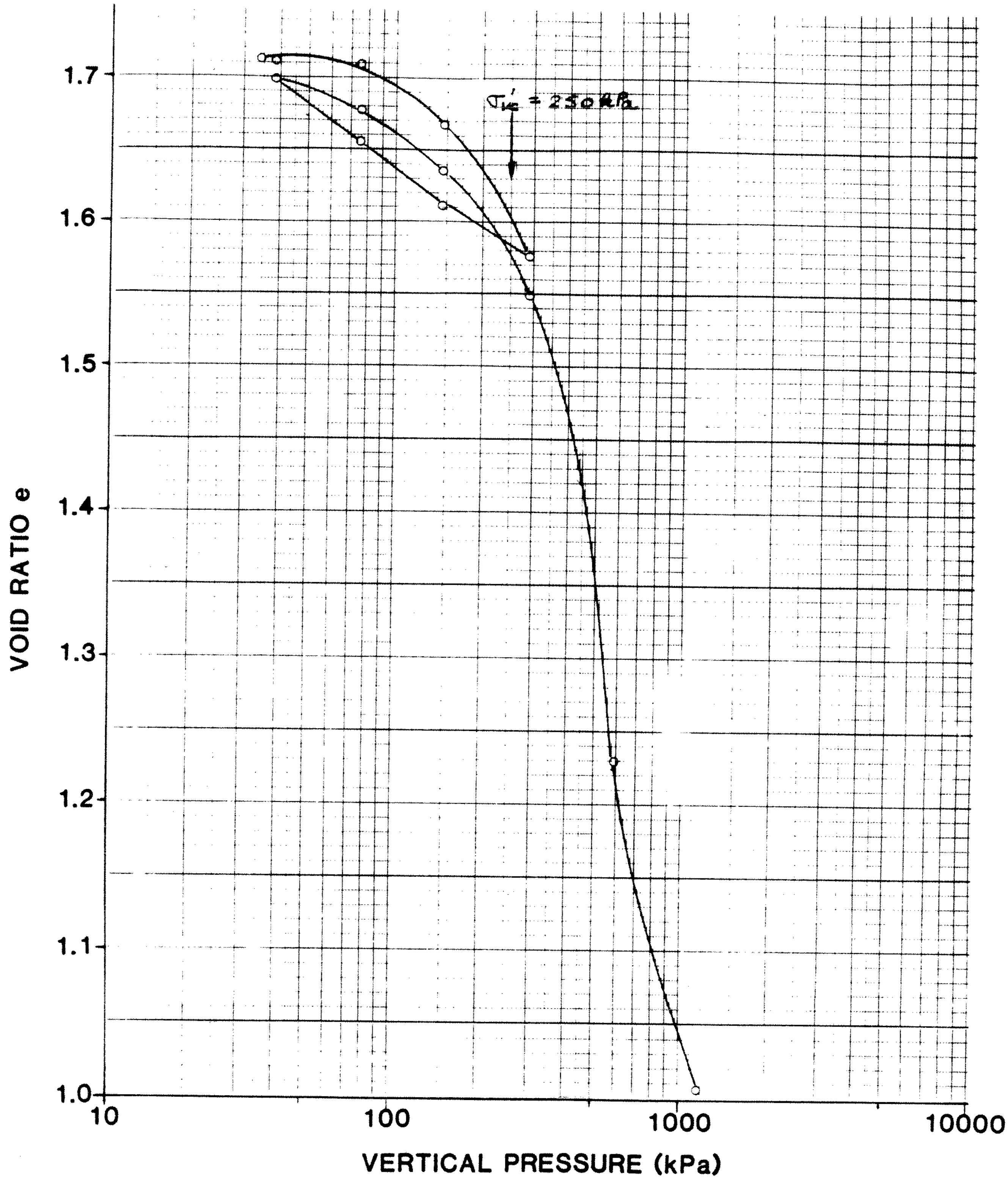
- G-1: Consolidation Test Results (Dyregrov and Burgess 1988)




**DYREGROV & BURGESS**
CONSULTING GEOTECHNICAL ENGINEERS

CONSOLIDATION TEST RESULTS
TEST HOLE 4 - 4.6 m DEPTH

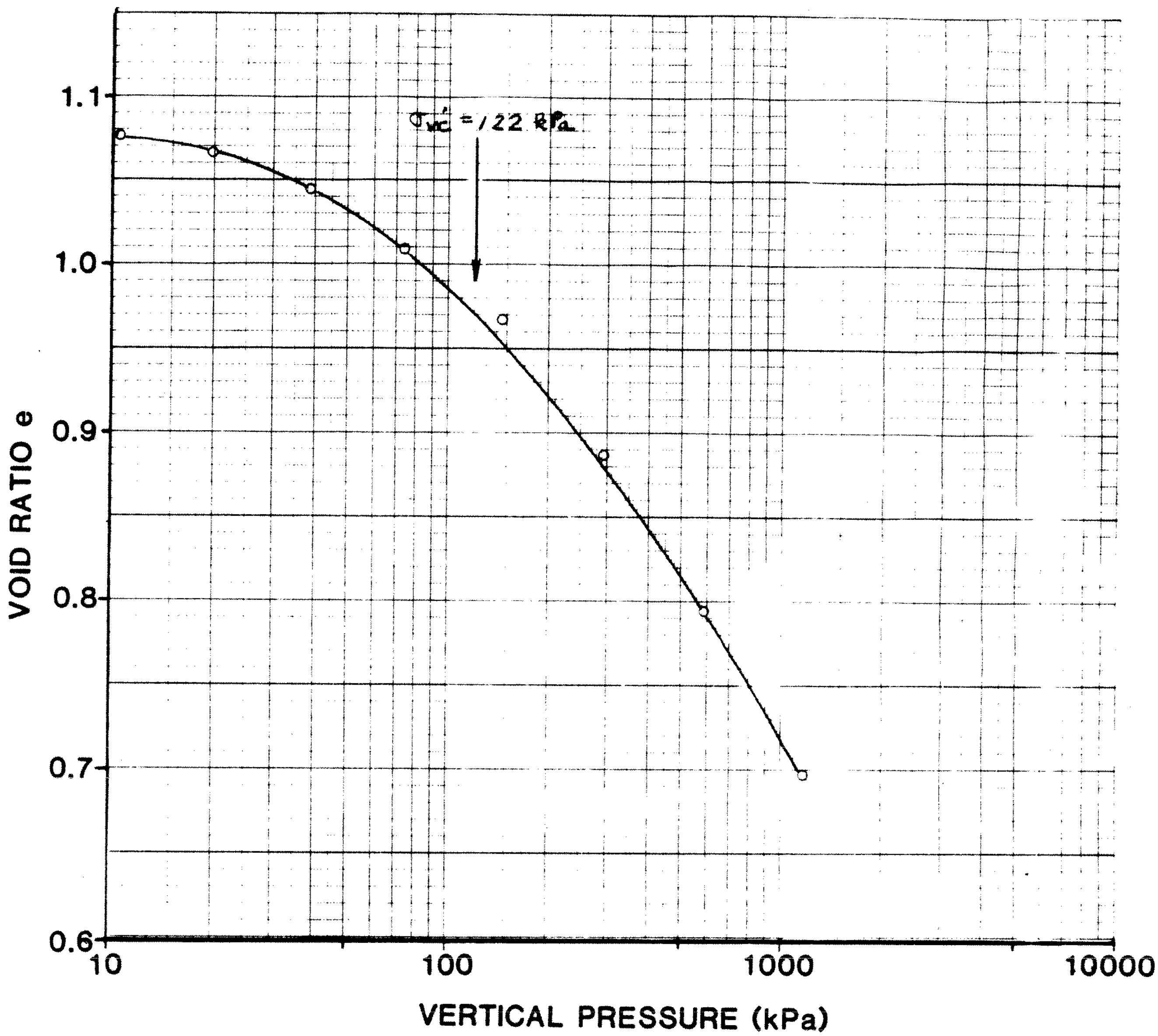
| SCALE | DATE | MADE | CHKD | JOB | FIGURE B7 |
|---|---|---|---|---|---|




**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 |
|---|---|---|---|---|---|

AECOM

# 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

DYREGROV AND BURGESS
FILE NAME: KILDONAN CORRIDOR EAST APPROACH
FILE NUMBER: JOB NO. 87422

RECORD OF DILATOMETER TEST NO. DMT 1
USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE,J-GEO,MARCH 80)
KO IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE,J-GEO,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 | KO | 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 | 72.8 | 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 | 24. | .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 | | 5.40 | 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 |



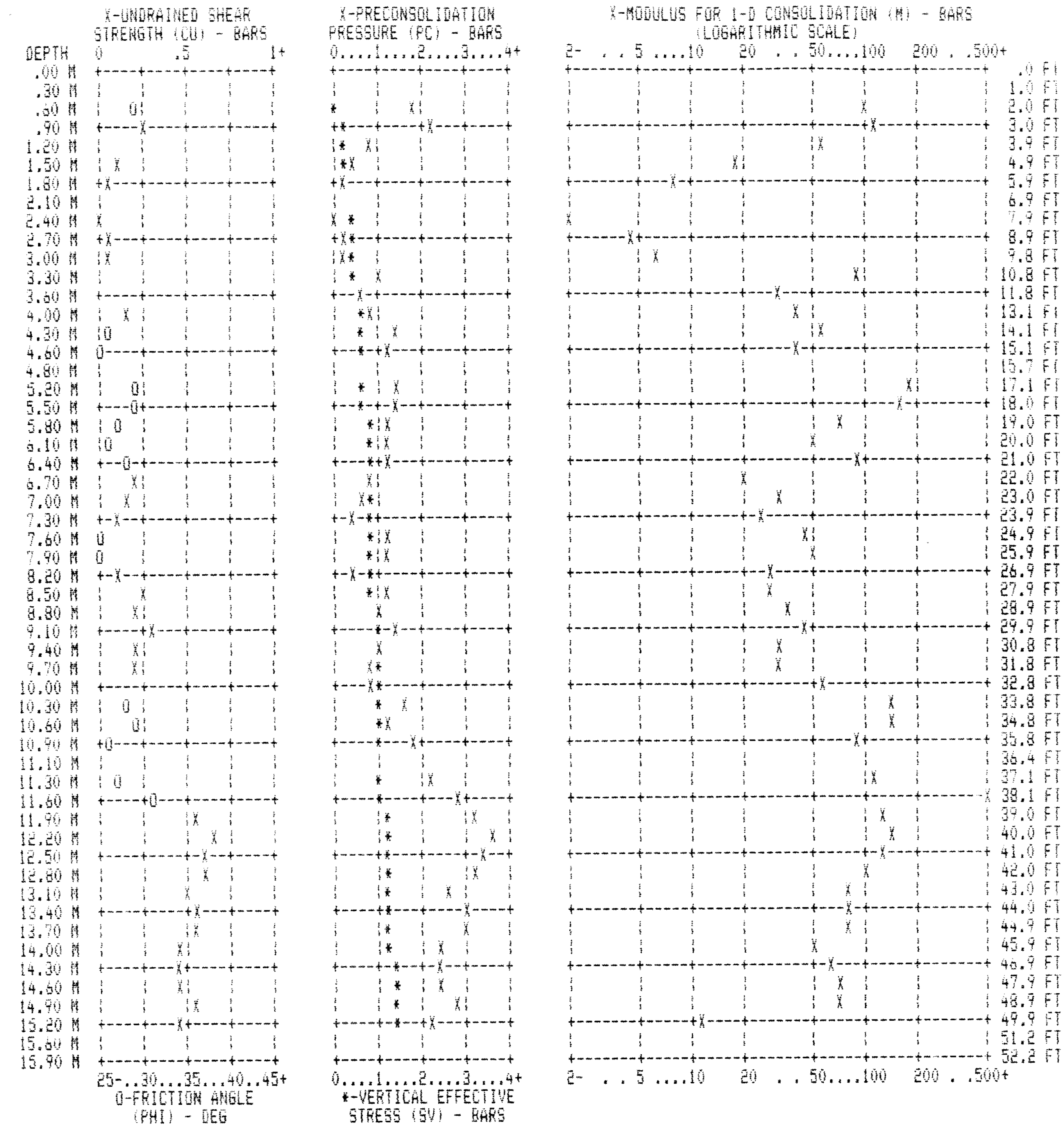
FIG. D1

| Z (M) | THRUST (KG) | A (BAR) | B (BAR) | ED (BAR) | ID | KD | U0 (BAR) | GAMMA (T/M3) | SV (BAR) | PC (BAR) | OCR | K0 | CU (BAR) | PHI (DEG) | M (BAR) | SOIL TYPE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***** | ****** | ***** | ***** | ***** | ***** | ***** | ****** | ****** | ****** | ***** | ***** | ***** | ***** | ***** | ****** | ************ |
| 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



FIG. D2




END OF SOUNDING



FIG. D3

DYREGROV AND BURGESS
FILE NAME: KILDONAN CORRIDOR WEST APPROACH
FILE NUMBER: JOB NO.87422

RECORD OF DILATOMETER TEST NO. DMT 2
USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE,J-GED,MARCH 80)
KO 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 | U0 (BAR) | GAMMA (T/M3) | SV (BAR) | PC (BAR) | OCR | KO | CU (BAR) | PHI (DEG) | M (BAR) | SOIL TYPE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***** | ****** | ***** | ***** | ***** | ***** | ***** | ****** | ****** | ****** | ***** | ***** | ***** | ***** | ***** | ****** | *********** |
| .60 | | 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 | 4.78 | .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 | .648 | 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 | 3.96 | .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 | | 73.2 | CLAY |



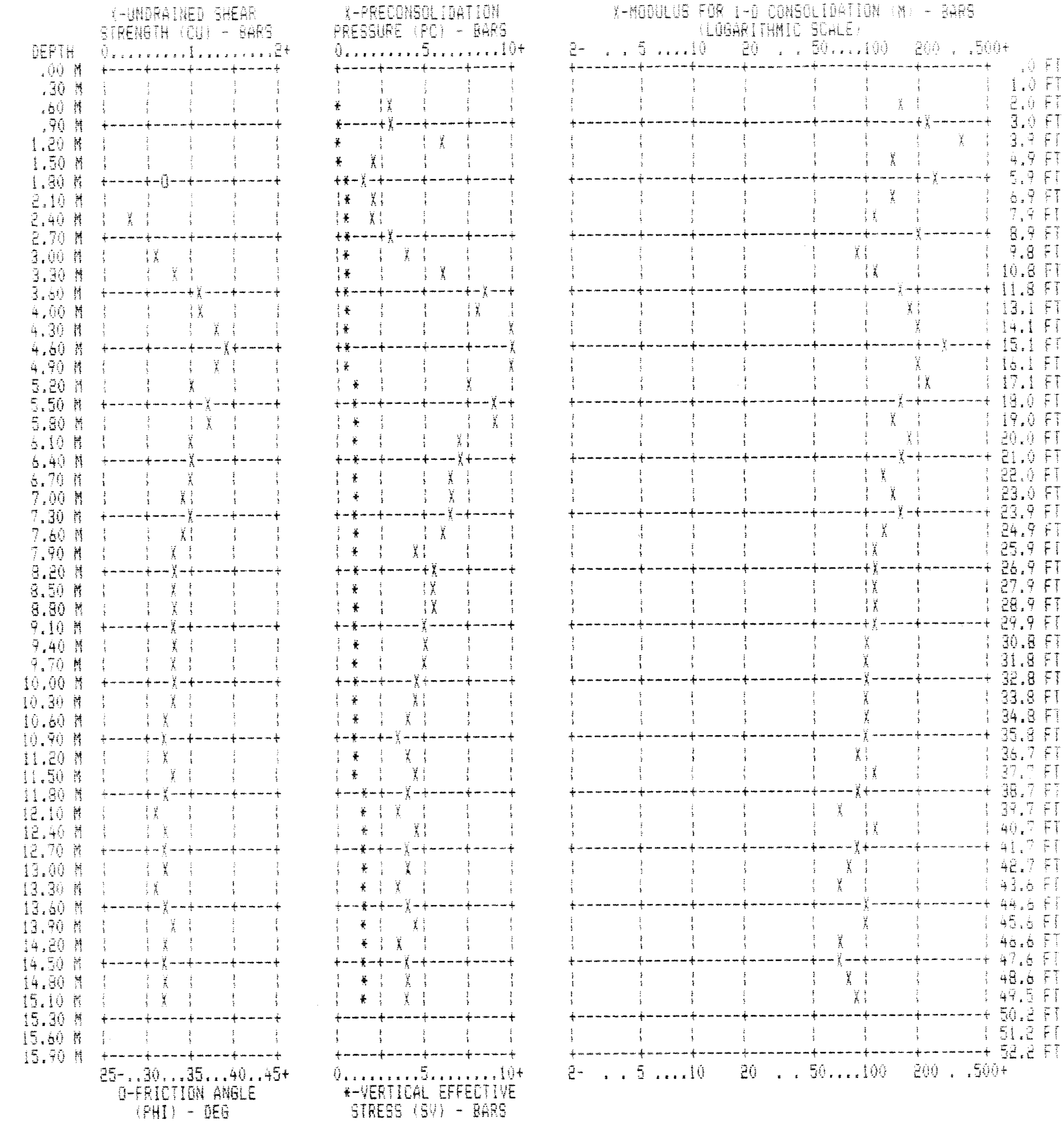
FIG. D4

| Z (M) | THRUST (KG) | A (BAR) | B (BAR) | ED (BAR) | ID | KD | U0 (BAR) | GAMMA (T/M3) | SV (BAR) | PC (BAR) | OCR | KO | CU (BAR) | PHI (DEG) | M (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 | 9.80 | 60. | .31 | 3.63 | 1.089 | 1.800 | 1.528 | 3.87 | 2.53 | .91 | .708 | | 87.9 | CLAY |

END OF SOUNDING



FIG. D5




END OF SOUNDING



FIG. D6

CITY OF WINNIPEG
FILE NAME: KILDONAN CORRIDOR
FILE NUMBER: 87422

RECORD OF DILATOMETER TEST NO. 3
USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE,J-GEO,MARCH 80)
KO IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)
MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE,J-GEO,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

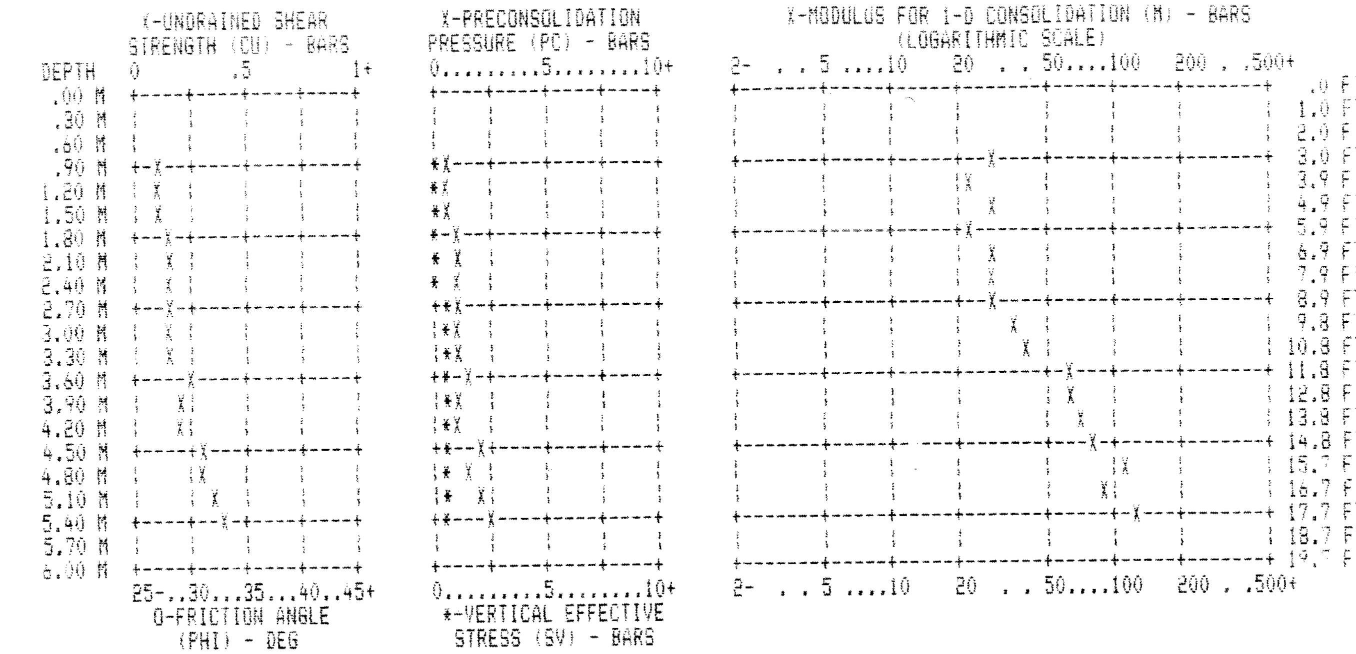
1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H2O UNIT WEIGHT = 1.000 T/M3

| Z (M) | THRUST (KG) | A (BAR) | B (BAR) | ED (BAR) | ID | KD | UO (BAR) | GAMMA (T/M3) | SV (BAR) | PC (BAR) | OCR | KO | 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 | | 1.80 | 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



FIG. D7




END OF SOUNDING



FIG. D8

OYREGROV AND BURGESS
FILE NAME: KILDONAN CORRIDOR
FILE NUMBER: 87422

RECORD OF DILATOMETER TEST NO. 4
USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE,J-GED,MARCH 80)
KO 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

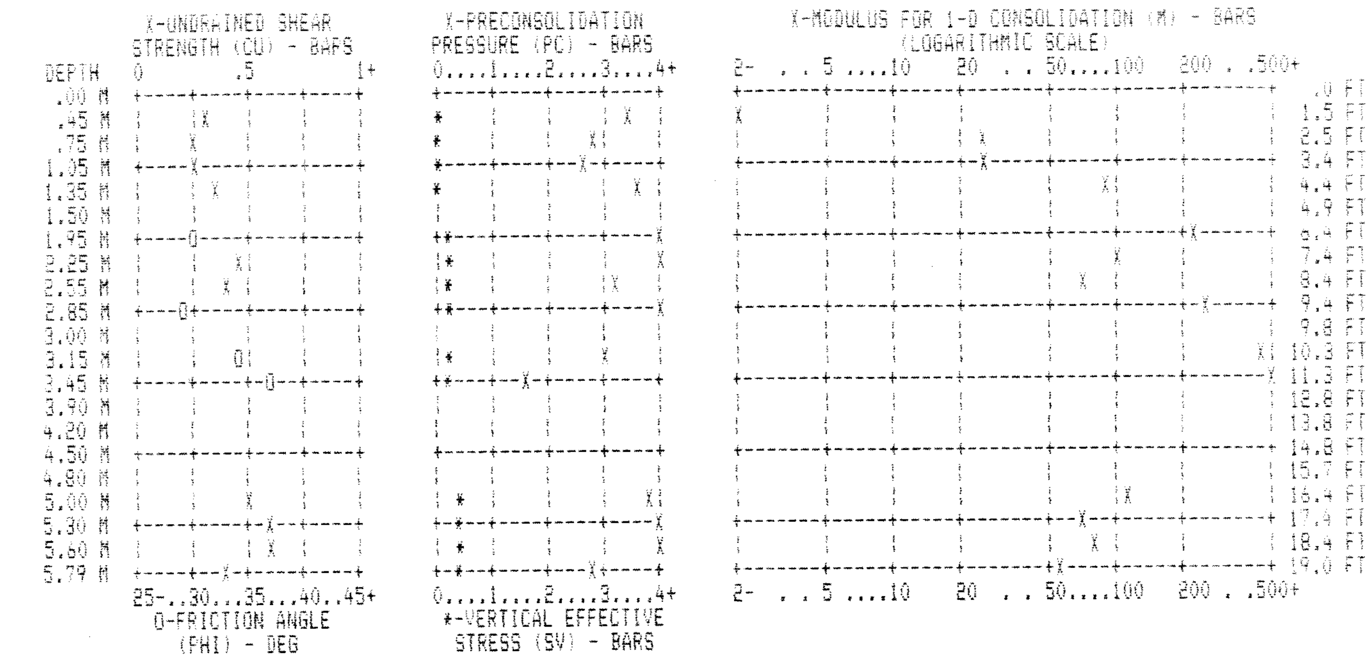
1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H2O UNIT WEIGHT = 1.000 T/M3

| Z (M) | THRUST (KG) | A (BAR) | B (BAR) | ED (BAR) | ID | KD | U0 (BAR) | GAMMA (T/M3) | SV (BAR) | PC (BAR) | OCR | KO | CU (BAR) | PHI (DEG) | M (BAR) | SOIL TYPE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***** | ****** | ***** | ***** | ***** | ***** | ***** | ****** | ****** | ****** | ***** | ***** | ***** | ***** | ***** | ****** | ************ |
| .45 | | 1.10 | 2.20 | 0. | .00 | 44.15 | .208 | 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 | 26. | .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 | | 36.6 | 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 | .413 | | 54.9 | CLAY |

END OF SOUNDING



FIG. D9




END OF SOUNDING



FIG. D 10

MCGREGOR AND BURGESS TEST NO. DMT5

FILE NAME: KILDONAN CORRIDOR

FILE NUMBER: 87422

RECORD OF DILATOMETER TEST NO. DMT5

USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE,J-GEO,MARCH 80)

KO IN SANDS DETERMINED USING SCHMERTMANN METHOD (1983)

MODIFIED MAYNE AND KULHAWY FORMULA USED FOR OCR IN SANDS (ASCE,J-GEO,JUNE 82)

LOCATION: BETWEEN HOLES 14 & 19

PERFORMED - DATE: 30 SEPTEMBER 1987

BY: BURGESS

CALIBRATION INFORMATION:

DELTA A = 1.00 BARS DELTA B = .10 BARS GAGE 0 = .70 BARS GWT DEPTH=-7.60 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 | U0 (BAR) | GAMMA (T/M3) | SV (BAR) | PC (BAR) | OCR | KO | CU (BAR) | PHI (DEG) | M (BAR) | SOIL TYPE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***** | ****** | ***** | ***** | ***** | ***** | ***** | ****** | ****** | ****** | ***** | ***** | ***** | ***** | ***** | ****** | ************ |
| .30 | | 1.50 | 3.20 | 22. | .63 | 49.74 | .775 | 1.600 | .020 | 3.01 | ***** | 4.58 | .244 | | 87.9 | CLAYEY SILT |
| [illegible] | | 2.00 | 3.80 | 26. | .50 | 38.77 | .805 | 1.600 | .038 | 3.84 | ***** | 4.01 | .337 | | [illegible]5.5 | SILT; CLA. |
| [illegible] | | 2.20 | 8.70 | 197. | 4.06 | 23.95 | .834 | 1.800 | .058 | 3.36 | 57.70 | 2.87 | | 39.6 | 654.6 | SAND |

END OF SOUNDING



FIG. D11

```
          X-UNDRAINED SHEAR         X-PRECONSOLIDATION          X-MODULUS FOR 1-D CONSOLIDATION (M) - BARS
          STRENGTH  (CU) - BARS     PRESSURE (PC) - BARS                  LOGARITHMIC SCALE)
DEPTH     0   .1   .2   .3   .4+    0.........1.........2+    2- . . 5 ....10   20 . . 50....100   200 . .500+
 .00 M    +----+----+----+----+     +----+----+----+----+     +-------+-----+-----+-------+-----+-----+-------+   . . FT
 .30 M         :    : (  :    :     *    :    :    :    X     :       :     :     :       :   X :     :       :  1.0 FT
 .60 M    :    :    :    : X  :     *    :    :    :    X     :       .     :     :       :     X     :       :  2.0 FT
 .90 M    +----+----+----O----+     +*---+----+----+----X     +-------+-----+-----+-------+-----+-----+-------X  3.0 FT
          25-..30...35...40..45+    0.........1.........2+    2- . . 5 ....10   20 . . 50....100   200 . .500+
           O-FRICTION ANGLE          *-VERTICAL EFFECTIVE
              (PHI) - DEG              STRESS (SV) - BARS
END OF SOUNDING
```

FIG. D12

DYREGROV AND BURGESS
FILE NAME: KILDONAN CORRIDOR
FILE NUMBER: 87422

RECORD OF DILATOMETER TEST NO. DMT8
USING DATA REDUCTION PROCEDURES IN MARCHETTI (ASCE,J-GED,MARCH 80)
KO 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

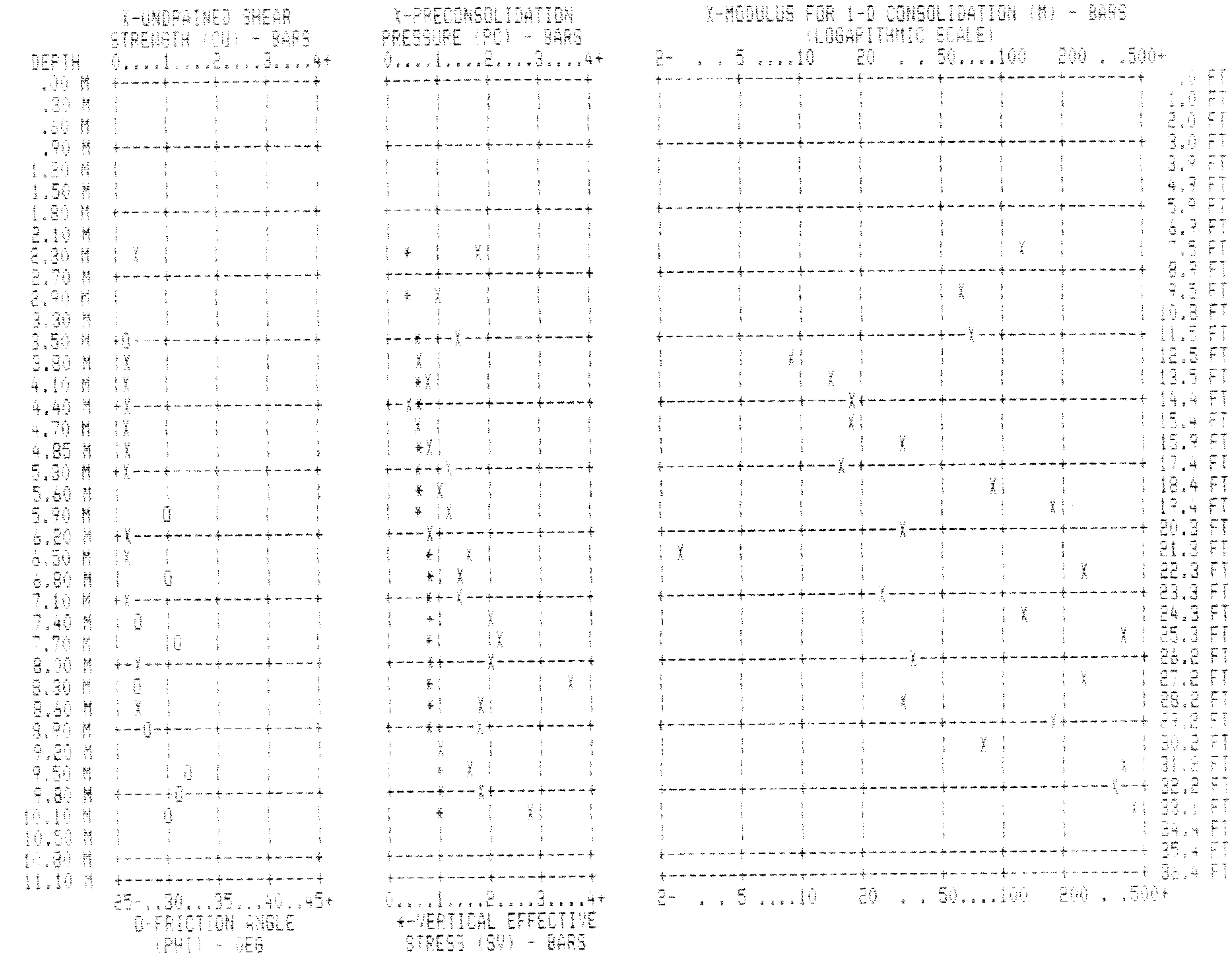
1 BAR = 1.019 KG/CM2 = 1.044 TSF = 14.51 PSI ANALYSIS USES H2O UNIT WEIGHT = 1.000 T/M3

| Z (M) | THRUST (KG) | A (BAR) | B (BAR) | ED (BAR) | ID | KD | UO (BAR) | GAMMA (T/M3) | SV (BAR) | PC (BAR) | OCR | KO | 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 | 1.600 | .499 | .92 | 1.85 | .78 | | | 63.2 | SILT |
| 3.50 | | 1.80 | 4.80 | 64. | 1.30 | 2.58 | .049 | 1.700 | .547 | 1.42 | 2.60 | .78 | | 26.4 | 74.9 | SANDY SILT |
| 3.80 | | 1.60 | 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 | 1.600 | .581 | .80 | 1.37 | .66 | .165 | | 13.5 | CLAY |
| 4.40 | | 1.40 | 3.20 | 20. | .59 | 1.65 | .137 | 1.600 | .599 | .44 | .74 | .44 | .103 | | 17.0 | SILTY CLAY |
| 4.70 | | 1.70 | 3.50 | 20. | .46 | 2.04 | .167 | 1.600 | .616 | .63 | 1.03 | .55 | .139 | | 17.4 | SILTY CLAY |
| 4.85 | | 2.00 | 4.10 | 31. | .58 | 2.44 | .182 | 1.600 | .625 | .85 | 1.36 | .66 | .176 | | 32.7 | SILTY CLAY |
| 5.30 | | 2.40 | 4.00 | 13. | .19 | 2.93 | .226 | 1.600 | .652 | 1.18 | 1.81 | .77 | .231 | | 15.8 | CLAY |
| 5.60 | | 2.40 | 5.60 | 71. | 1.14 | 2.68 | .255 | 1.700 | .671 | 1.06 | 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 | 1.600 | .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 | 1.600 | .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. | 1.34 | 3.98 | .520 | 1.800 | .858 | 3.70 | 4.31 | .93 | | 27.3 | 253.5 | SANDY SILT |
| 8.60 | | 3.60 | 5.50 | 24. | .25 | 3.15 | .550 | 1.600 | .878 | 1.79 | 2.03 | .82 | .341 | | 31.2 | CLAY |
| 8.90 | | 3.00 | 8.60 | 158. | 2.34 | 2.17 | .579 | 1.800 | .899 | 1.80 | 2.00 | .68 | | 28.4 | 175.6 | 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 | 1.900 | .971 | 1.76 | 1.81 | .62 | | 31.2 | 352.7 | SAND |
| 10.10 | | 4.50 | 14.20 | 308. | 2.83 | 3.14 | .697 | 1.900 | .998 | 2.78 | 2.78 | .75 | | 30.3 | 455.9 | SILTY SAND |

END OF SOUNDING



FIG. D13




END OF SOUNDING

FIG. D14