KGS
GROUP

ASSOCIATED ENGINEERING LTD.

Newton Ave Forcemain Red River Crossing
2021 Preliminary
Geotechnical Investigation Report

Final:
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KGS Group Project:
21-3913-001

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STATEMENT OF LIMITATIONS AND CONDITIONS

Limitations

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

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

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Geotechnical Investigation Statement of Limitations

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

1.0 INTRODUCTION

Associated Engineering (AE) was retained by the City of Winnipeg to complete the preliminary design for the Newton Ave Force Main Red River crossing replacement. KGS Group provided the geotechnical engineering support for the work.

The overall objective of the project is to complete the preliminary engineering required to create and evaluate options for the replacement of the dual 350 mm force main crossing between Fraser's Grove Park and Newton Avenue / Scotia Street. The geotechnical investigation program was designed to determine the riverbank stratigraphy and evaluate the competency of the underlying bedrock including strength, hardness, extent of fracture, water bearing potential and rock quality designation index. This approach will assist in evaluating the remedial alternatives and suitability of the bedrock for the horizontal directional drilling (HDD) and microtunneling options to facilitate the preliminary design of crossing.

2.0 REGIONAL GEOLOGICAL SETTING

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

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

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

3.0 2021 FIELD INVESTIGATION PROGRAM

The geotechnical field investigation program was developed to meet the objectives stated in Section 1.0 of this report.

3.1 Test Hole Drilling and Soil Sampling

The test hole drilling and sampling program was completed by KGS Group from August 4 to 12, 2021. A total of four (4) test holes were advanced into bedrock to investigate the subsurface stratigraphic conditions and evaluate the suitability of the bedrock for Horizontal Directional Drilling (HDD), one (1) on the west side of the Red River, one (1) within the river and two (2) on the east side of the Red River. The locations of the test holes are shown on Figure 1. The information obtained from the drilling investigation in conjunction with the seismic refraction surveys was used to developed profile to facilitate the preliminary design of the river crossing.

Maple Leaf Drilling of Winnipeg, Manitoba provided the drilling services using a track mounted drill rig. Soil samples were collected at intervals of 1.5 m (5 ft.) or at any changes in soil strata encountered during drilling. The soil samples were visually inspected for material type and classified according to the Modified Unified Soil Classification System (USCS).

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

3.2 Laboratory Testing

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

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

These mechanical properties of the bedrock are required to adequately evaluate potential construction risks, tooling, and costs for horizontal directional drilling and microtunneling options.

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

3.3 Groundwater Monitoring

A total of two (2) standpipes were installed at the site, one (1) in the till and one (1) in the bedrock. Details of the standpipe piezometer installations are included on the test hole logs in Appendix A.

3.4 Geophysical Investigation

KGS Group retained the services of Frontier Geoscience Inc. to complete seismic refraction surveys along the two (2) preferred alignments on August 10 and 11, 2021. The primary objective of the geophysical survey was to obtain estimates of the depth to till and bedrock along the preferred alignments. The locations of the seismic lines are shown on Figure 1. The results of the seismic refraction survey are included in the Seismic Refraction Survey Report included in Appendix C.

FIGURE 1: TEST HOLE AND SEISMIC REFRACTION SURVEY LOCATIONS

4.0 FIELD INVESTIGATION RESULTS

4.1 Subsurface Characterization

The stratigraphy at the site is described in this section and is based on the exploratory test holes, seismic refraction surveys and our understanding of the general site geology.

The approximate stratigraphic boundaries shown on the test hole logs were inferred from soil observed during the drilling. The engineering characteristics of the subsurface materials are described in the following sub-sections. The soil classification is based on visual examination.

In general, the stratigraphy consists of alluvium soils over lacustrine clay, glacial silt till and limestone bedrock. The following sections describe the soil and the bedrock encountered during the geotechnical drilling investigation.

4.1.1 TOPSOIL

Topsoil was encountered at ground surface in test holes TH21-01, TH21-03 and TH21-04 and was generally less than 300mm thick. The topsoil was black in colour and dry at the time of drilling

4.1.2 FILL

Silty sand fill was observed in test hole TH21-01 from elevation 228.1 to 227.7 m. The silty sand fill was brown in colour, dry, loose in density, and contained medium to coarse grained sand.

4.1.3 ALLUVIUM SOILS

Alluvium soils ranging from sandy clay to sand was observed in test holes TH21-01, TH21-03 and TH21-04 at elevations ranging from 226.8 to 227.7 m and extending to elevations ranging from 211.6 to 219.0 m.

Silty sand was observed in test hole TH21-03 from elevation 226.8 to 225.6 m and in test hole TH21-04 from elevation 227.1 to 226.4 m. The silty sand was brown in colour, dry, loose in density, and contained some silt.

Sandy clay was observed in test hole TH21-01, TH21-03 and TH21-04 from elevations 214.7 to 226.7 m. The sandy clay was brown in color, damp, soft to stiff in consistency, of low to intermediate plasticity. The torvanes within the sandy clay ranged from 10 to 100 kPa and generally decreased with depth.

Clayey sand was encountered in test hole TH21-01, TH21-03 and TH21-04 from elevations 213.4 to 224.4 m. The clayey sand was brown in colour, moist to wet, loose in density and contained fine grained sand. It was noted that there was interlayered sand and clay throughout the layer.

Sandy silt was encountered in test hole TH21-04 from elevation 226.4 to 225.7 m. The sandy silt was brown in colour, damp, of low plasticity, and contained some fine grained sand lens.

Sand was encountered in test hole TH21-01 from elevation 220.6 to 219.0 m and in test hole TH21-03 from elevation 222.3 to 221.5 m. The sand was brown to grey in colour, moist to wet, compact in density, and contained trace silt.

Alluvial clay (CI to CL) was encountered in test holes TH21-03 and TH21-04 from elevation 219.0 to 217.7 m, and 216.5 to 214.9 m respectively. The clay was grey in colour, moist, soft to firm in consistency, of low to intermediate plasticity, and contained trace sand. The torvanes in the clay ranged from 10 to 45 kPa.

Silt was observed at the base of the Red River in the test hole drilled in the river, TH21-02. The silt was grey, wet, very soft in consistency, and contained fine grained gravel. The silt was observed from elevation 217.7 to 216.6 m.

A sand and gravel layer was encountered in test hole TH21-04 from elevation 213.4 to 211.5 m. The sand and gravel was grey in colour, moist to wet and dense.

4.1.4 LACUSTRINE CLAY

Lacustrine clay was encountered in test holes TH21-01, to TH21-03 overlying the silt till at elevations ranging from 213.6 to 219.0 m. The clay ranged in thickness from 0.6 to 6.1 m. The clay was typically brown to grey in colour, damp to moist, firm to stiff in consistency and of high plasticity. In general, the consistency of the clay decreased with depth. The material contained trace to some silt nodules. Fine to coarse grained gravel and boulders were encountered in the grey clay near the till interface. The undrained shear strength of the clay deposit, as determined using a field Torvane on disturbed samples, ranged from 30 to 80 kPa, generally decreasing with depth.

4.1.5 GLACIAL SILT TILL

Glacial silt till was encountered below the clay and sand with gravel at elevations ranging from 211.6 to 212.9 m in the test holes. The glacial till ranged in thickness from 3.1 to 5.8 m. The silt till was brown in colour, damp to moist, compact to very dense and contained some fine to coarse grained gravel and some fine to coarse grained sand.

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

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

Cobbles and Boulders

In KGS Group's experience, sporadic irregular zones or cobbles and/or boulders have been encountered within the till deposits such as those at this site. These zones can cause difficulties during construction.

4.1.6 BEDROCK

The limestone bedrock in the area of the project site is Selkirk member of the Red River Formation. The Selkirk member typically is medium strength with compressive strengths that vary from 30 to 40 MPa. The Young's modulus (E) generally ranges from 15 to 25 GPa (University of Manitoba, 1983). The bulk modulus (k) typically ranges from 40 to 50 GPa, and the shear modulus ranges from 5 to 10 GPa.

Based on the borehole drilling, bedrock was encountered below the silt till at elevations ranging from 207.1 to 209.7 m. However, the seismic refraction survey suggest that top of bedrock may be lower on the east side of the river, at an elevation of approximately El. 198 m along the proposed alignment. The core samples retrieved from the borehole and the seismic survey indicate that the quality of the bedrock is generally better on the east side of the river compared to the west especially near the upper section above elevation El. 202 m. The estimated bulk compressive wave velocity (Vp)for the upper bedrock is 4100 m/s and 3200 m/s on the east side and west side, respectively. These estimated velocities suggest that the bedrock is more fractured on the west side as indicated by the RQD values presented in Figure 2.

The bedrock consists of limestone and mottled limestone. Dolomite was observed in test hole TH21-01 from elevation 208.0 to 209.7 m. The measured RQD of the bedrock with elevation is shown Figure 2 below, and a historgram with he RQD distribution is shown on Figure 3.

FIGURE 2: BEDROCK RQD WITH ELEVATION

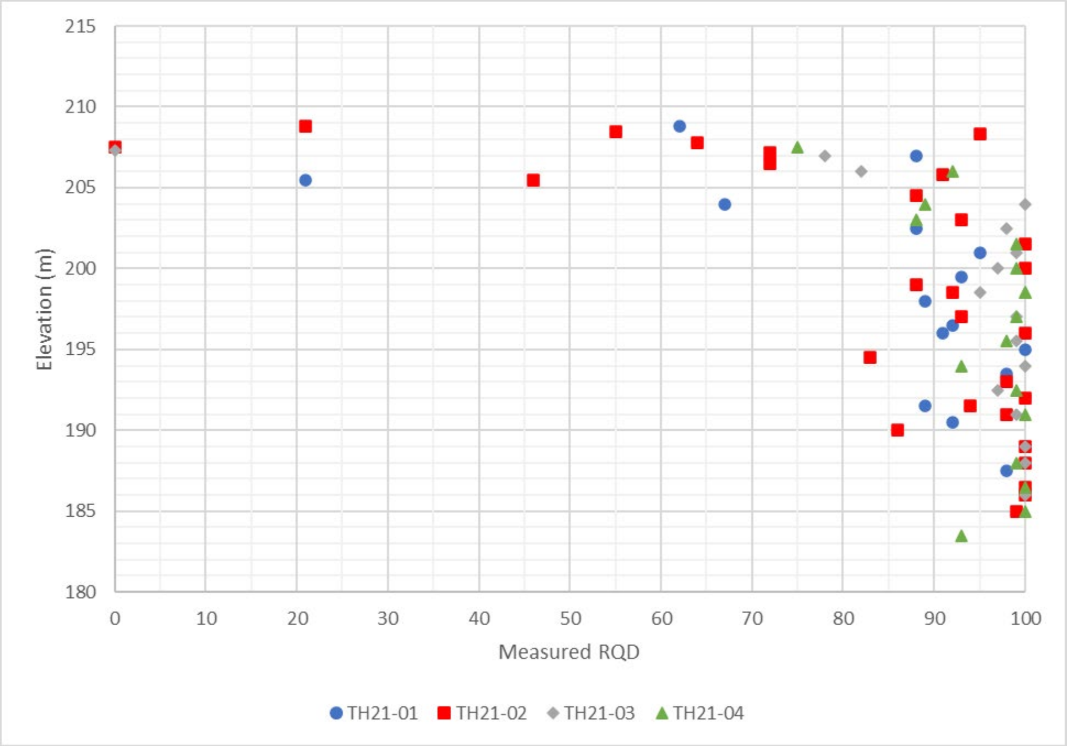
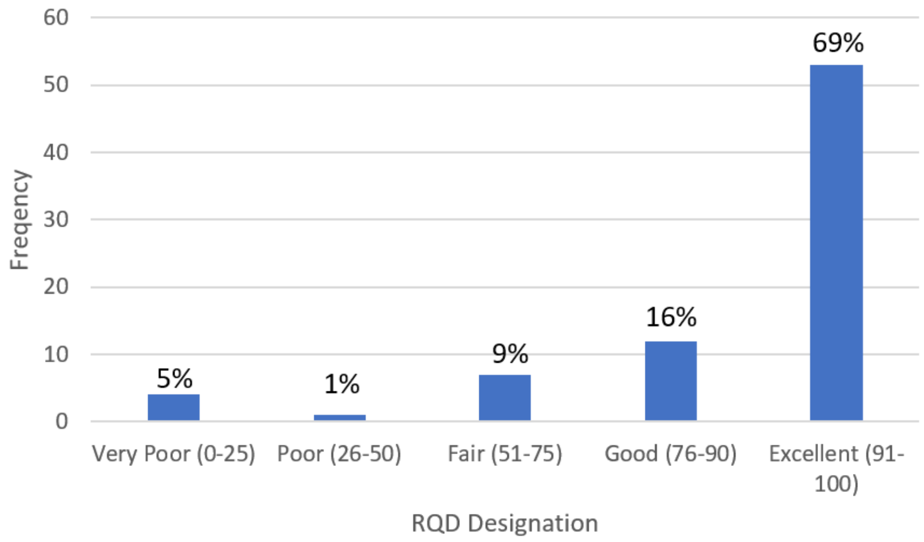


FIGURE 3: HISTOGRAM OF DISTRIBUTION OF RQD WITHIN TEST HOLES



The dolomite was brown in colour, and fine grained. Weaker fractured rock with closely spaced joints was generally observed above elevation 208 m. Shale was observed at elevation 208.0 m. The rock quality designation (RQD) of the dolomite was 62, classifying the rock as fair.

Limestone was generally encountered below elevations of 208.0. The limestone was white to grey colour, and medium grained. A soft clay seam 50 mm thick was observed in test hole TH21-01 at elevation 207.0 m. In some sections of the core, multiple closely spaced breaks were observed along the bedding planes. Three (3) open joints were observed in test hole TH21-02 at elevations ranging from 208.6 to 207.5 m. The RQD of the limestone ranged from 21 to 91. In general, the RQD was greater than 80 below elevation 205 m, classifying the rock as good to excellent.

Mottled limestone was encountered in all of the test holes at elevations ranging from 203.7 to 207.9 m and extending to the end of the test holes. The mottled limestone was mottled white, brown and grey in colour, medium grained and strong. The jointing was moderate to wide spaced. Weak zones of soft clay seams up to 50 mm were noted within the mottled limestone in test hole TH21-01 from elevation 203.3 to 197 m. The RQD of the mottled limestone ranged from 75 to 100, generally increasing with depth. In general, the RQD was greater than 90 below elevation 197 m, classifying the bedrock as excellent.

Laboratory testing was completed on two (2) mottled limestone bedrock samples from test hole TH21-01, at elevations 200.5 and 202.7 m. The compressive strength was measured to be 14.4 and 28.4 MPa, the Young's Modulus was measured to be 12.0 and 19.3 GPa and the Shear Modulus was calculated to be 5.4 and 12.2 GPa in the upper and lower samples respectively.

The origin of the opening in limestone rock, which has apparently become infilled with alluvial clay from the river, could be the result of erosion of rock material which might have been sheared and weakened (from faulting) or a zone containing erodible material. Once the weaker rock has been eroded, the opening could become filled with alluvium (clay) washed in by fluvial processes over time.

4.2 Groundwater Monitoring

Two (2) standpipe piezometers were installed as part of the 2021 geotechnical investigation. The installation details for the standpipes are included on the test hole logs included in Appendix A. Since installation, groundwater monitoring has been completed twice. The measured groundwater levels are listed below in Table 1.

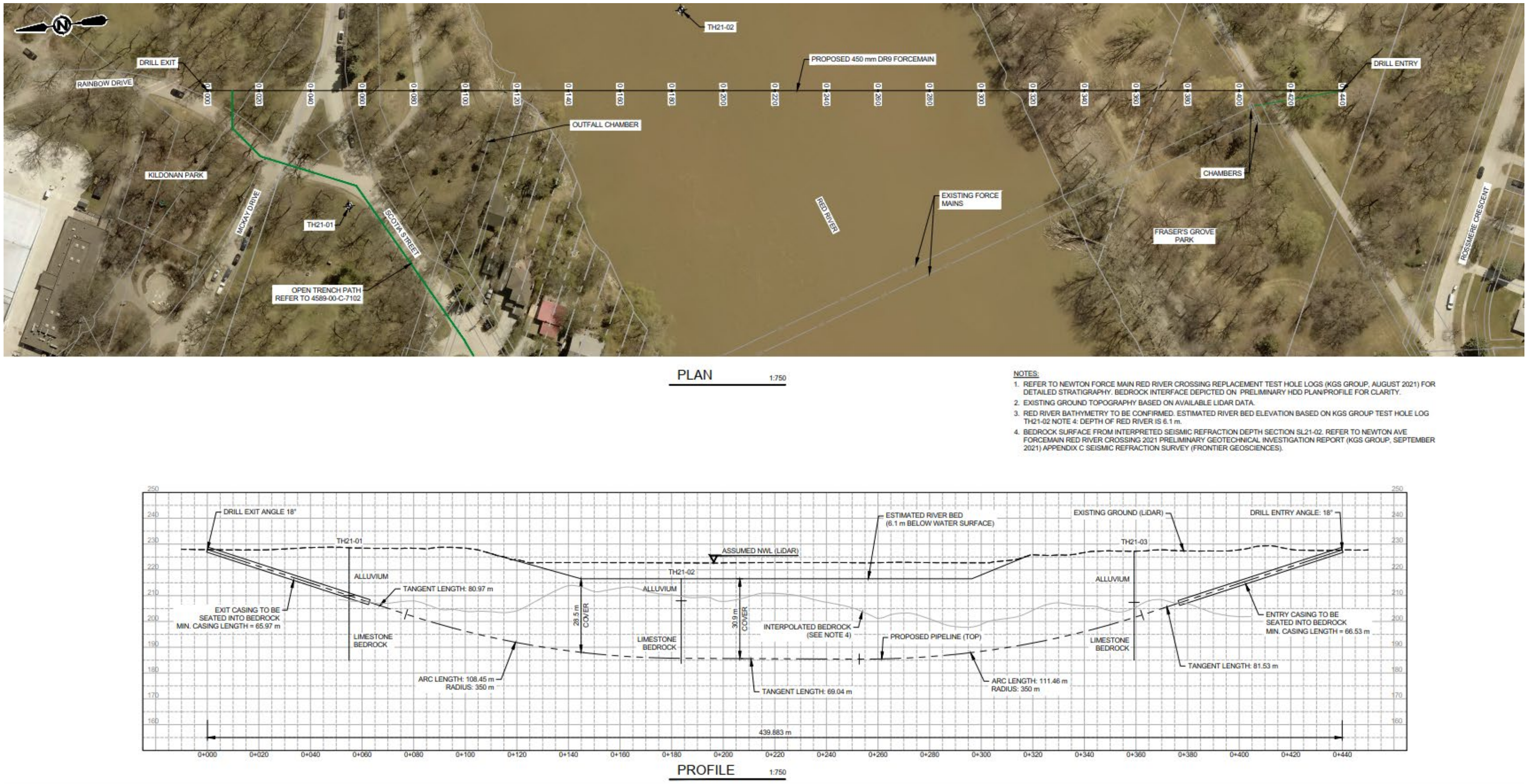
TABLE 1: GROUNDWATER MONITORING RESULTS

Test Hole ID	TH21-01	TH21-03
Ground Elevation (m)	228.19	227.14
Piezometer Type	Standpipe	Standpipe
Tip Elevation (m)	211.4	205.74
Monitoring Zone	Glacial Till	Bedrock
Date		
9/10/2021	222.3	222.7
10/28/2021	223.4	223.2

5.0 PROPOSED PIPE BOREPATH

Figure 4 shows preliminary borepath for the proposed pipeline. The drill entry will be east of Kildonan Drive in Fraser’s Grove Park, and the exit will be located west of the intersection of Rainbow Drive and Scotia Street in Kildonan Park. The borepath will enter and exit at an angle of 18 degrees, with a minimum elevation of approximately 185 m.

FIGURE 4: CONCEPT LEVEL BOREPATH



NOTES:

1. REFER TO NEWTON FORCE MAIN RED RIVER CROSSING REPLACEMENT TEST HOLE LOGS (KGS GROUP, AUGUST 2021) FOR DETAILED STRATIGRAPHY. BEDROCK INTERFACE DEPICTED ON PRELIMINARY HDD PLAN/PROFILE FOR CLARITY.
2. EXISTING GROUND TOPOGRAPHY BASED ON AVAILABLE LIDAR DATA.
3. RED RIVER BATHYMETRY TO BE CONFIRMED. ESTIMATED RIVER BED ELEVATION BASED ON KGS GROUP TEST HOLE LOG TH21-02 NOTE 4: DEPTH OF RED RIVER IS 6.1 m.
4. BEDROCK SURFACE FROM INTERPRETED SEISMIC REFRACTION DEPTH SECTION SL21-02. REFER TO NEWTON AVE FORCEMAIN RED RIVER CROSSING 2021 PRELIMINARY GEOTECHNICAL INVESTIGATION REPORT (KGS GROUP, SEPTEMBER 2021) APPENDIX C SEISMIC REFRACTION SURVEY (FRONTIER GEOSCIENCES).

6.0 PRELIMINARY RIVERBANK SLOPE STABILITY

6.1 Visual Inspection

As part of the field investigation, a visual inspection of the riverbank was completed for the east and west riverbanks. The site is located at the start of a gradual bend in the river, with the west side of the river being on the inside of the bend and the east side on the outside as shown on Figure 4. Erosion is typically observed on the outside bend of rivers.

FIGURE 5: SITE LOCATION

The east side of the riverbank is approximately 8 m high with benches at approximately elevations 222.5 and 225.9 m. These elevations generally coincide with approximate average summer river level and ordinary high water level (2-year flood level), respectively. The slope of the riverbank at the top of bank above the upper bench at EL. 225.9 m was approximately 3H:1V, from the upper bench to lower bench the slope was approximately 3.5H:1V and below the lower bench to the bottom of channel the slope was approximately 8H:1V. The benching and shallow slope of the riverbank suggests historical erosion along this segment of the river.

At the time of the site inspection there were no visual signs of deep-seated slope movement including slumps, sloughing, headscraps, or tension cracking. The downstream slope was vegetated with tall grass and shrubs and mature trees at the top of the bank. Photos of east bank are shown below.

PHOTO 1: EAST RIVERBANK LOOKING SOUTH

PHOTO 2: EAST RIVERBANK LOOKING SOUTH

The west side of the riverbank is approximately 10 m high with a bench at approximate the normal summer water level (El. 222.5 m). The slope of the riverbank above to the bench was at a slope of approximately 4H:1V and the lower slope to the channel was approximately 5H:1V. The riverbank slope flattens downstream of the site. An existing headscrap was observed downstream of the outfall pipe during the site inspection. At the time of the site inspection, no additional visual signs of deep seated slope instability such as slumps, sloughing, headscraps, or tension cracking with exception of the historical headscrap downstream were noted. The downstream slope was vegetated with tall grass and shrubs and mature trees at the top of the bank. Photos of the west bank are shown below.

PHOTO 3: WEST RIVERBANK LOOKING WEST

PHOTO 4: WEST RIVERBANK LOOKING SOUTH (UPSTREAM OF OUTLET)

PHOTO 5: WEST RIVERBANK LOOKING NORTH NOTE HISTORICAL HEADSCRAP

6.2 Preliminary Slope Stability Analysis

KGS Group completed limit equilibrium (LE) slope stability analyses to determine the current stability of the riverbank on both sides of the proposed crossing. The slope stability analysis approach incorporates LE techniques based on two-dimensional slope stability analysis using SLOPE/W software by Geo-Slope International Ltd. The Morgenstern-Price method of analysis was employed for the slope stability assessment using the LE method. This method considers both shear and normal interslice forces, and it satisfies both moment and force equilibrium.

The estimated target factor of safety generally reflects the uncertainty in the input parameters used in the slope stability analysis and the potential impacts that the failure of the riverbank may have on adjoining infrastructure. In general, riverbanks with a minimum factor of safety greater than 1.3 are considered to be relatively stable, however movements are possible. Riverbanks with a minimum factor of safety greater than 1.5 are unlikely to experience ground movements.

6.2.1 REPRESENTATIVE STRATIGRAPHIC SECTIONS

Two (2) cross-sections were analyzed, one (1) on the east side and one (1) on the west side of the Red River at the proposed crossing to evaluate the stability of the riverbanks. The riverbank geometry was obtained from LiDAR data provided by the City of Winnipeg and the soil stratigraphy was developed from the test hole drilling and seismic refraction survey results. The cross sections for the slope stability analysis are shown in Figures 6 and 7 below.

FIGURE 6: EAST RIVERBANK SIMPLIFIED STRATIGRAPHY

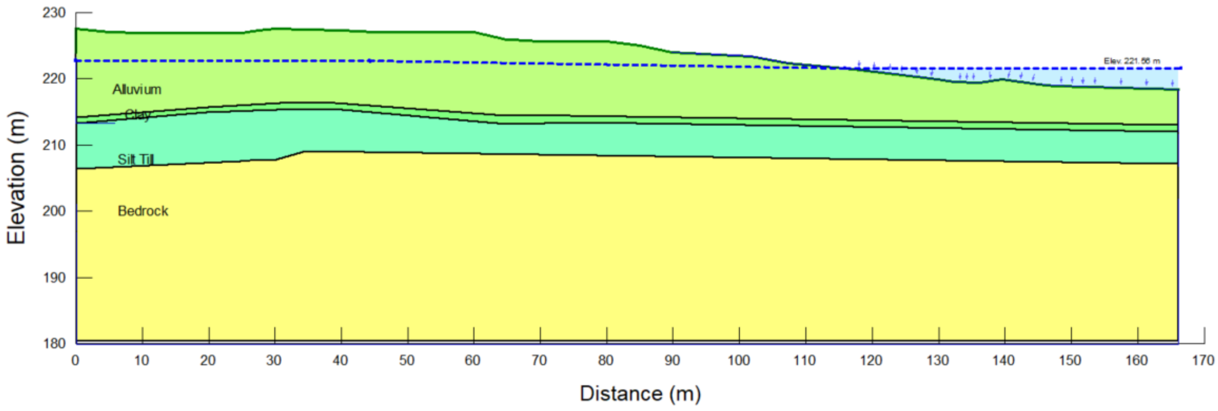
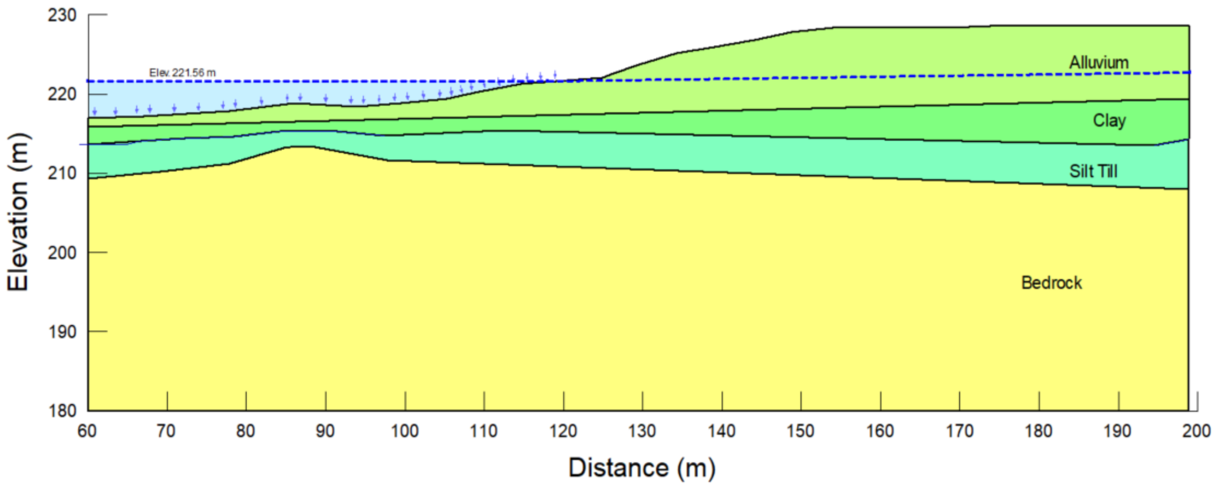


FIGURE 7: WEST RIVERBANK SIMPLIFIED STRATIGRAPHY



6.2.2 SOIL MATERIAL PARAMETERS

The soil strength parameters for the subsurface soils in these analyses were based on the observations from the field investigation and our experience with the native soils in the area. The average soil strength parameters assigned to the various materials for the slope stability analyses are summarized in Table 2. The shear strength parameters used for the alluvium soils have been reduced from typical strengths for this material in Winnipeg to account for the weaker and lower strength zones present within the deposits. The shear strength parameters used for the alluvium soils are considered to be representative of the average strength of the layer.

TABLE 2: SLOPE STABILITY ANALYSIS MATERIAL PARAMETERS

Soil Type	Unit Weight (kN/m³)	Effective / Apparent Cohesion (kPa)	Friction Angle (°)
Alluvium soils	18	2	20
Clay	18	5	14
Till	20	2	30
Bedrock	Impenetrable		

6.2.3 GROUND WATER AND RIVER LEVELS

The groundwater levels adopted for the stability analysis model were based on the recorded groundwater levels obtained from the newly installed standpipe piezometers and the river water levels are typical levels for the Red River outlined below:

- Average Winter River Level = 221.56 m

- Average Summer River Level = 222.57 m
- Ordinary high-water level (2 year flood) = 225.92 m

The reported river levels consider average summer and winter flows over the last 20 years. The ordinary high-water level is estimated based on a two year flood on the Red and Assiniboine River.

Two (2) groundwater and river level combinations were analyzed in the slope stability models:

Case 1: Long-Term Condition – The groundwater level was assumed to be at elevation 223.4 m and the river level was assumed to be at the average winter level.

Case 2: Short-Term Condition – The groundwater level was assumed to coincide with the ordinary high-water level and the river level was the average winter river level.

6.3 Slope Stability Results

The stability analysis was completed on both sides of the Red River along the proposed pipe alignment to determine the minimum factor of safety (FOS = 1.5). The analysis indicated the in general the estimated factor of safety for the riverbanks is equal to or greater than 1.5. The typical potential slip surfaces for the riverbanks are shown on the figures below. The proposed entry and exit location for the new forcemain will be located beyond the potential slip surfaces shown below.

Based on the visual inspection, the east riverbank has benching and shallow slopes which suggests historical erosion along this segment of the river. Additionally, it is located on an outside bend which are known to be susceptible to erosion. No erosion protection was observed along the east shoreline during the visual inspection. It is recommended that a riprap blanket be placed in the lower bank area within the normal summer river level range to minimize the potential for toe erosion which will result in a reduction in the stability over time. The riprap blanket should extend a minimum of 1.5 m above and below the normal summer river level.

FIGURE 8: EAST RIVERBANK TYPICAL SLIP SURFACE

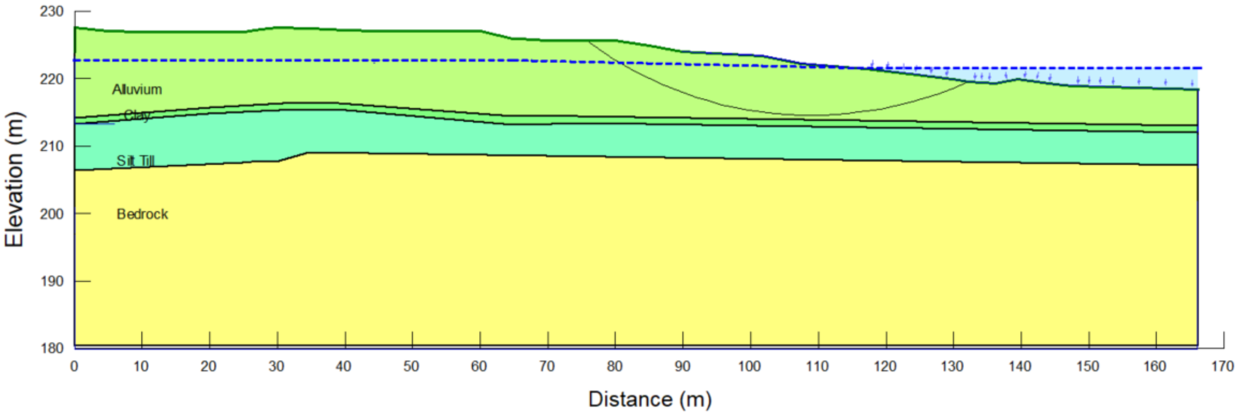
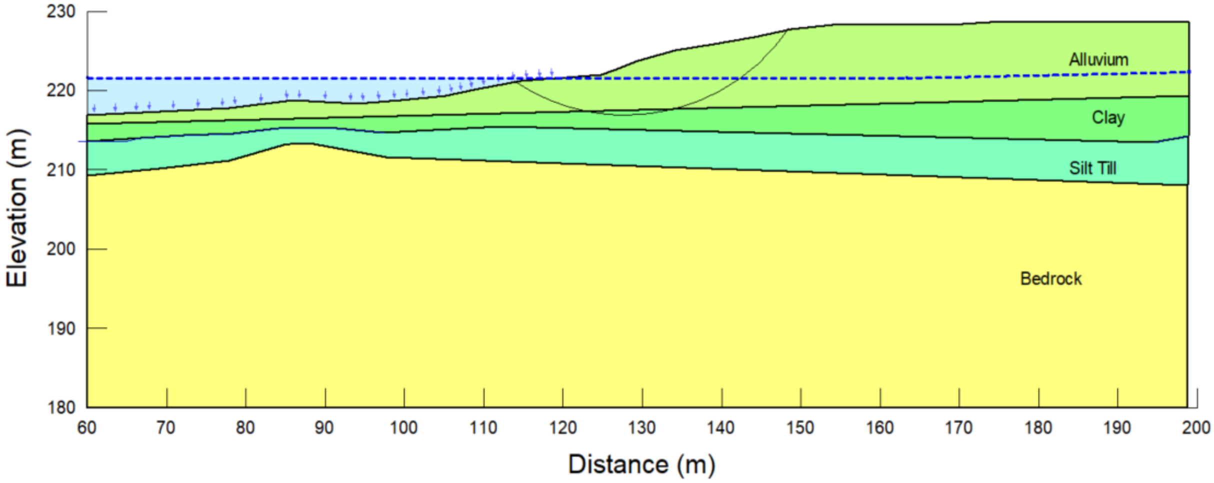


FIGURE 9: WEST RIVERBANK TYPICAL SLIP SURFACE



7.0 CONSTRUCTION CONSIDERATIONS

7.1 Bedrock Quality and Trenchless Pipe Installation

Rock Quality Designation (RQD) of the limestone bedrock is generally between 75% and 100% indicating typically good rock quality. The limestone bedrock joints/fractures can result in migration of drilling fluid (loss of circulation) and instability of the borehole. The possible occurrence of cobbles and boulders within glacial till soils above the bedrock is another fissure that could provide paths for fluid to migrate out of the borepath. However, this risk may be mitigated by using drilling additives to consolidate and reduce the permeability of joints and fractures.

Karst openings are commonly encountered in limestone and dolomite formations around Winnipeg; these features are results of bedrock solution processes and can also be a source of loss of circulation and mud control problems. However, no extensive karst features that would be of concern were observed in any of the boreholes that were drilled at the site.

Both horizontal directional drilling and microtunneling are feasible trenchless installation methods at the site based on the strength, hardness and quality of the bedrock.

7.2 Temporary Excavations

Temporary excavations will be required for the construction of the proposed pipeline and associated infrastructure. All excavation work will be required to be performed in accordance with the Workplace Safety and Health Act and Manitoba Workplace Safety and Health Regulation.

Excavations adjacent to existing infrastructure including structures, roads and utilities will require temporary shoring or bracing to minimize ground movement. Excavations deeper than 1.5 m are required to be designed and approved prior to construction by an experienced Professional Engineer with expertise in Geotechnical Engineering.

For design purposes the soils may be assigned active, passive and at-rest lateral earth pressure coefficients as shown in Table 3.

TABLE 3: LATERAL EARTH PRESSURE COEFFICIENTS

Material	Unit Weight (kN/m^3)	ϕ'	K_a	K_o	K_p
Alluvium soils	18	20	0.49	0.66	2.04
Clay	18	14	0.61	0.75	1.63
Till	20	30	0.33	0.50	3.00
Well Graded Compacted Granular Fill	18	35°	0.27	0.43	3.70

7.3 Impacts on Existing Infrastructure

Some degree of movement, settlement, heave and lateral movement, will be expected during the construction of the pipeline and the associated structures. The Contractor shall be required to undertake the work in a manner which maintains movements around the perimeter of the excavation and of utilities, roadways, and buildings within the established acceptable limits to be determined during the detailed design.

All excavation and shoring system should be designed by a professional engineer with extensive relevant experienced and the works must be inspected and certified by the same professional engineer to verify that the temporary structure has been installed according to the design.

7.4 Impact of Groundwater and Dewatering

The groundwater level in the till and bedrock was observed to be at approximate elevations 223.4 and 223.2 m respectively. These levels are expected to fluctuate with the river level. In KGS Group's experience, zones of cobbles, boulders and/or granular layers are known to exist within till deposits. These zones should be expected to be water bearing, which may cause difficulties with open cut excavation for vertical shafts.

8.0 CLOSURE

The geotechnical investigation conducted by KGS Group describes the overburden deposits and bedrock stratigraphy along the proposed alignment based on the information from the test holes and seismic refraction survey. This report presented the geotechnical engineer's best judgement of the subsurface and ground conditions anticipated to be encountered across the project site. While the actual conditions encountered in the field are expected to be within the range of the conditions discussed in this document, the spatial variability of subsurface conditions that could be encountered may be more complex than the simplified interpretation presented in this report.

It is recommended that a geotechnical baseline report (GBR) be prepared as part of the detailed design phase of work. The GBR will be used to establish the geotechnical conditions anticipated to be encountered during construction and set the basis of tender assumptions during bidding for the work.

9.0 REFERENCES

Department of geological Engineering, The University of Manitoba, Geological Engineering Report for Urban Development of Winnipeg, February 1983.

APPENDIX A

Test Hole Logs

KGS GROUP

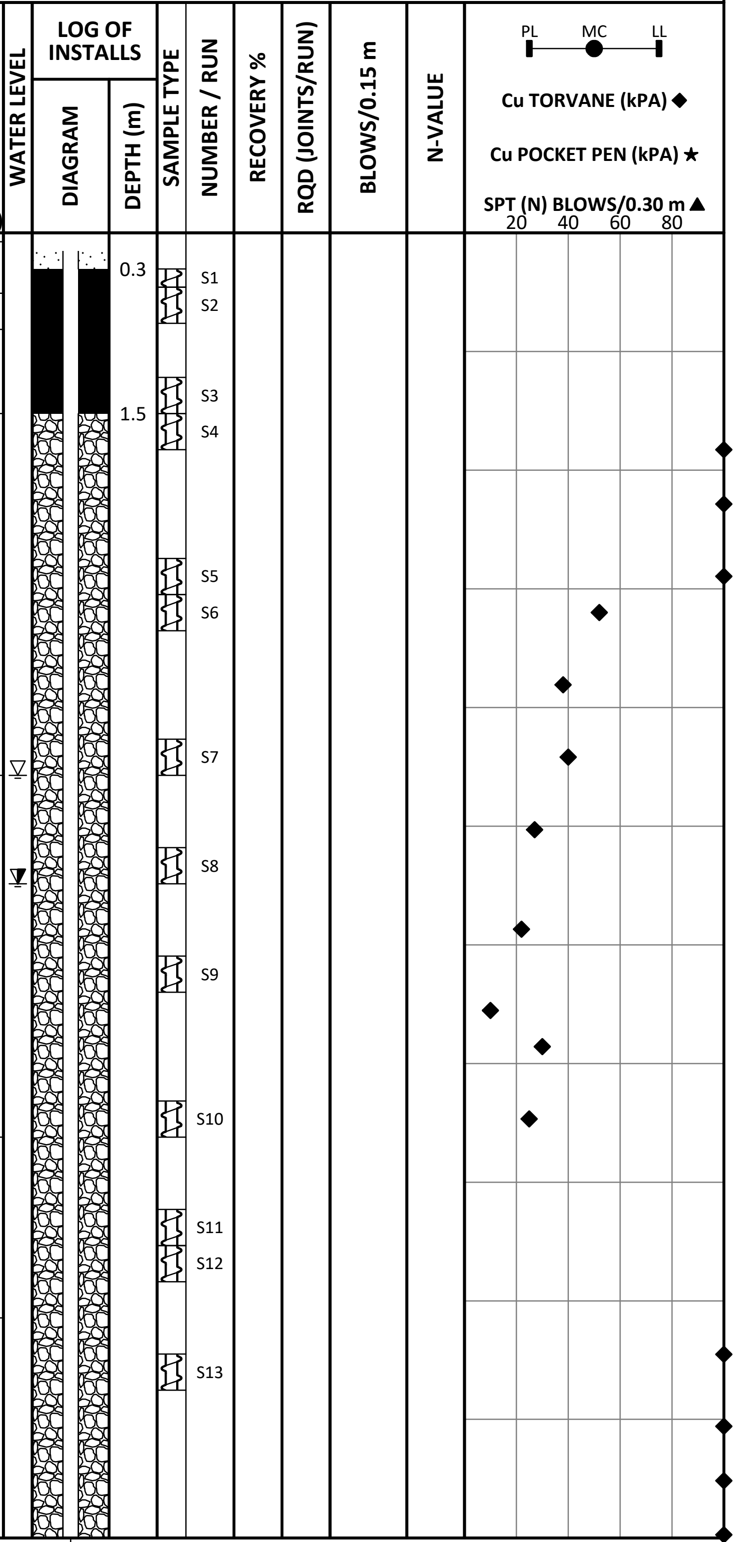
TEST HOLE LOG

HOLE NO.
TH21-01

SHEET 1 of 4

CLIENT	**ASSOCIATED ENGINEERING ALBERTA LTD.**	**PROJECT NO.**	21-3913-001
PROJECT	**Newton Force Main Red River Crossing Replacement**	**SURFACE ELEV.**	228.19 m
LOCATION	Winnipeg, MB	**TOC STICK-UP / ELEV.**	-0.10 m / 228.09 m (Standpipe)
DESCRIPTION	Scotia Street at Rainbow Drive (Kildonan Park)	**DATE DRILLED**	8-9-2021
DRILL RIG / HAMMER	Acker Renegade Track Mounted Drill Rig with Auto-Hammer	**UTM (m)**	N 5,533,809 E 636,141
METHOD(S)	0.0 m to 16.6 m: 100 mm ø SSA - switched due to encountering dense till 16.6 m to 43.2 m: Triple Tube, HQ Core		

ELEV (m)	DESCRIPTION AND CLASSIFICATION
228.1	**TOPSOIL** - Black, dry.
227.7	**SILTY SAND FILL (SM)** - Brown, dry, loose, fine grained, with silt, some medium to coarse grained sand.
227.4	**POORLY GRADED SAND (SP)** - Light brown, dry, loose, fine grained, trace medium grained sand.
226.7	**SILTY SAND (SM)** - Brown, dry, loose, fine grained, with silt, trace rootlets.
	SANDY CLAY (CL) - Brown, damp, stiff, low plasticity, minor oxidation , trace gypsum, trace oxidation. - Intermediate plasticity below 2.4 m. - Trace black organic pockets/lenses below 2.7 m. - Damp to moist, high plasticity, no gypsum, no oxidation below 3.0 m. - Firm below 3.4 m.
223.6	**CLAYEY SAND (SC)** - Brown, moist to wet, loose, fine grained, interlayered sand/clay throughout.
220.6	**POORLY GRADED SAND (SP)** - Grey, moist to wet, compact, fine to medium grained, trace silt, trace shells. - Medium to coarse grained sand below 8.5 m.
219.0	**CLAY (CH)** - Grey, moist, stiff, high plasticity, trace medium to coarse grained sand, trace fine grained gravel. - No sand or gravel below 10.1 m.



WATER LEVELS
▽ **During Drilling** 4.57 m on 8-9-2021 During Drilling
▼ **Remeasured/Static During Drilling** 5.49 m on 8-13-2021 CS Standpipe

CONTRACTOR
Maple Leaf Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
J. MACLENNAN

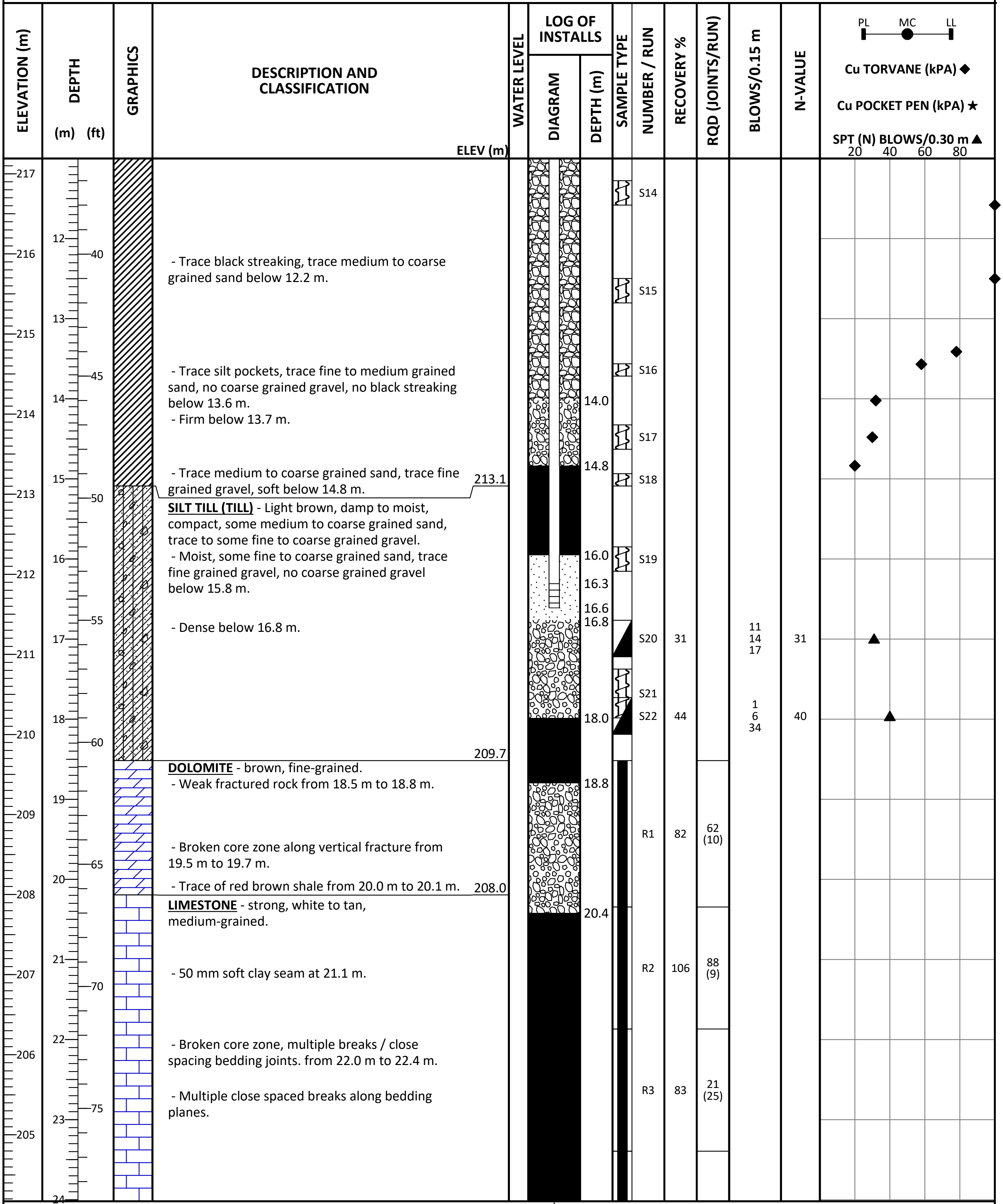
DATE
10-25-2021

KGS GROUP

TEST HOLE LOG

HOLE NO.
TH21-01

SHEET 2 of 4



DESCRIPTION AND CLASSIFICATION — ELEV (m)

- Trace black streaking, trace medium to coarse grained sand below 12.2 m.
- Trace silt pockets, trace fine to medium grained sand, no coarse grained gravel, no black streaking below 13.6 m.
- Firm below 13.7 m.
- Trace medium to coarse grained sand, trace fine grained gravel, soft below 14.8 m.

213.1

SILT TILL (TILL) - Light brown, damp to moist, compact, some medium to coarse grained sand, trace to some fine to coarse grained gravel.
- Moist, some fine to coarse grained sand, trace fine grained gravel, no coarse grained gravel below 15.8 m.
- Dense below 16.8 m.

209.7

DOLOMITE - brown, fine-grained.
- Weak fractured rock from 18.5 m to 18.8 m.
- Broken core zone along vertical fracture from 19.5 m to 19.7 m.
- Trace of red brown shale from 20.0 m to 20.1 m.

208.0

LIMESTONE - strong, white to tan, medium-grained.
- 50 mm soft clay seam at 21.1 m.
- Broken core zone, multiple breaks / close spacing bedding joints. from 22.0 m to 22.4 m.
- Multiple close spaced breaks along bedding planes.

NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE
S14				
S15				
S16				
S17				
S18				
S19				
S20	31		11 14 17	31
S21				
S22	44		1 6 34	40
R1	82	62 (10)		
R2	106	88 (9)		
R3	83	21 (25)		

WATER LEVELS
∇ **During Drilling** 4.57 m on 8-9-2021 During Drilling
▼ **Remeasured/Static** During Drilling 5.49 m on 8-13-2021 CS Standpipe

CONTRACTOR
Maple Leaf Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
J. MACLENNAN

DATE
10-25-2021

TEST HOLE LOG

HOLE NO.
TH21-01

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEV (m)	WATER LEVEL	LOG OF INSTALLS DIAGRAM	LOG OF INSTALLS DEPTH (m)	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPA) ◆ Cu POCKET PEN (kPA) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80
204	80								R4	98	67 (18)			
			MOTTLED LIMESTONE - strong, mottled brown, white and grey, medium-grained. - trace nodules from 24.5 m to 25.2 m. - 25 mm open joint at 24.8 m. - Compressive strength is 14.4 MPa, Young's Modulus is 12.0 GPa and Poisson's ratio is 0.13 at 25.2 m.	203.7										
203	25								R5	93	88 (8)			
202	26 / 85													
201	27 / 90								R6	95	95 (11)			
200	28		- Compressive strength is 28.4 MPa, Young's Modulus is 19.3 GPa and Poisson's ratio is 0.16 at 27.6 m.											
199	29 / 95								R7	100	93 (10)			
			- 50 mm soft clay seam at 29.5 m.											
198	30 / 100								R8	100	89 (6)			
197	31		- 7 mm clay seam at 31.1 m. - Moderate to wide space joints, trace vugs below 31.2 m.											
196	32 / 105								R9	100	92 (7)			
195	33 / 110								R10	100	100 (6)			
194	34													
193	35 / 115								R11	98	98 (2)			
192	36 / 120								R12	100	89 (11)			
	37													

WATER LEVELS ▽ **During Drilling** 4.57 m on 8-9-2021 During Drilling
▼ **Remeasured/Static** 5.49 m on 8-13-2021 CS Standpipe
During Drilling

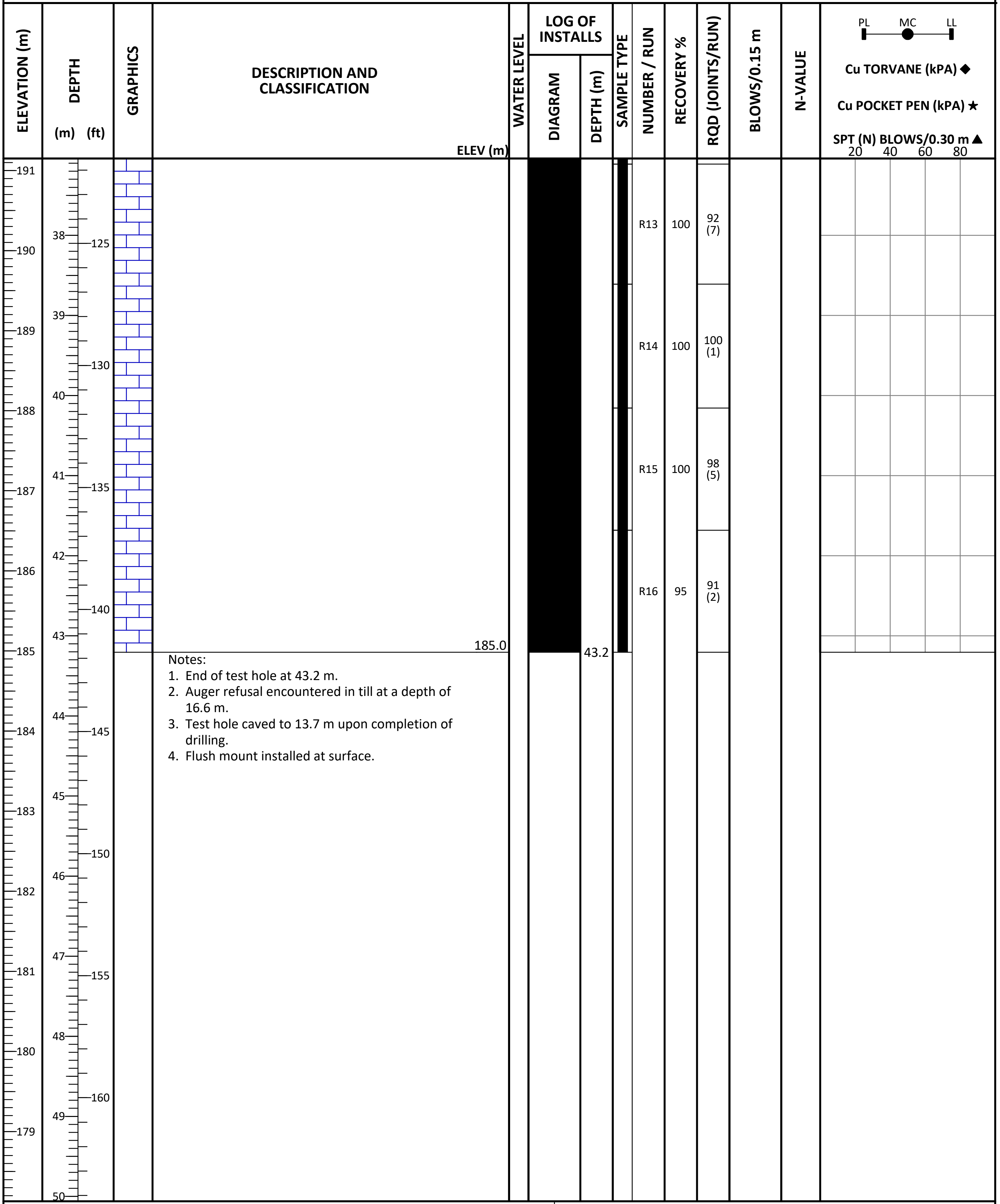
CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

KGS GROUP

TEST HOLE LOG

HOLE NO.
TH21-01

SHEET 4 of 4



NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)
R13	100	92 (7)
R14	100	100 (1)
R15	100	98 (5)
R16	95	91 (2)

Notes:
1. End of test hole at 43.2 m.
2. Auger refusal encountered in till at a depth of 16.6 m.
3. Test hole caved to 13.7 m upon completion of drilling.
4. Flush mount installed at surface.

WATER LEVELS ⊻ **During Drilling** 4.57 m on 8-9-2021 During Drilling
⊻ **Remeasured/Static** 5.49 m on 8-13-2021 CS Standpipe
During Drilling

CONTRACTOR
Maple Leaf Drilling Ltd.

INSPECTOR
C. FRIESEN

APPROVED
J. MACLENNAN

DATE
10-25-2021

KGS GROUP

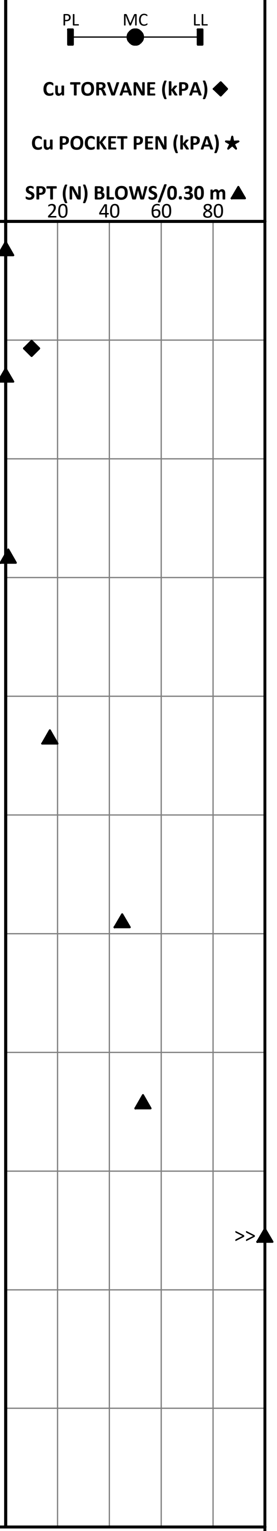
TEST HOLE LOG

HOLE NO.
TH21-02

SHEET 1 of 3

CLIENT	**ASSOCIATED ENGINEERING ALBERTA LTD.**	**PROJECT NO.**	21-3913-001
PROJECT	**Newton Force Main Red River Crossing Replacement**	**SURFACE ELEV.**	217.70 m
LOCATION	Winnipeg, MB	**DATE DRILLED**	8-4-2021
DESCRIPTION	Center of Red River	**UTM (m)**	N 5,533,672 E 636,201
DRILL RIG / HAMMER	B20 Portable Drill Rig with Winch Drop Hammer		
METHOD(S)	0.0 m to 8.6 m: Water Rotary - switched due to encountering bedrock 8.6 m to 33.8 m: Triple Tube, NQ Core		

DESCRIPTION AND CLASSIFICATION	ELEV (m)	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE
SILT (ML) - Dark grey, wet, very loose, non-plastic, with fine grained gravel, trace organic odour.		S1	33		2 0 0	0
CLAY (CI) - Grey, wet, very soft, intermediate plasticity, trace silt, trace shells.	216.6	S2	22		1 0 0	0
			0		1 0 1	1
SILT TILL (TILL) - Light brown, wet, compact, trace fine to coarse grained sand, trace fine to coarse grained gravel.	213.6	S3	44		10 6 11	17
- Harder drilling below 5.5 m. - Dense below 5.7 m.		S4	6		22 26 19	45
- Fine to coarse grained gravel in SPT sampler at 7.2 m. - Very dense below 7.2 m.		S5	11		26 26 27	53
LIMESTONE - strong, white to grey, massive.	209.1	S6	100		60/ 90mm	+100
- Weak altered zone from 8.6 m to 9.4 m.		R1	67	21 (2)		
- Close spaced fractures from 9.4 m to 10.3 m.		R2	77	55 (1)		
		R3	95	95 (1)		
		R4	100	64 (2)		
		R5	100	0 (1)		
- Close to moderate spaced joints, three open joints observed from 10.3 m to 12.5 m.		R6	100	72 (10)		



WATER LEVELS

CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **G. BAKER/C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

TEST HOLE LOG

HOLE NO.
TH21-02

SHEET 2 of 3

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEV (m)	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPA) ◆ Cu POCKET PEN (kPA) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80

Elevation (m): 206, 205, 204, 203, 202, 201, 200, 199, 198, 197, 196, 195, 194

Depth (m): 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24

Depth (ft): 40, 45, 50, 55, 60, 65, 70, 75

- Weak fracture at 12.2 m.

205.2

MOTTLED LIMESTONE - strong, mottled white to grey, moderate to wide spaced joints, trace vugs.
- Occasional nodules from 12.5 m to 14.5 m.

NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)
R7	100	72 (8)
R8	100	91 (2)
R9	100	46 (6)
R10	100	88 (8)
R11	100	93 (6)
R12	100	100 (4)
R13	100	100 (2)
R14	100	88 (2)
R15	100	92 (7)
R16	93	93 (5)
R17	100	100 (3)
R18	83	83 (1)

WATER LEVELS

CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **G. BAKER/C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	DESCRIPTION AND CLASSIFICATION	ELEV (m)	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE
					R19	100	98 (4)		
193	25	80			R20	100	100 (3)		
192	26	85			R21	94	94 (1)		
191	27				R22	98	98 (3)		
190	28	90			R23	86	86 (1)		
189	29	95			R24	100	100 (2)		
188	30				R25	100	100 (1)		
187	31	100			R26	100	100 (1)		
186	32	105			R27	100	99 (1)		
185					R28	100	100 (0)		
	33				R29	99	99 (1)		
184		110		183.9					
183	34								
182	35	115							
181	36	120							
	37								

PL MC LL
Cu TORVANE (kPA) ◆
Cu POCKET PEN (kPA) ★
SPT (N) BLOWS/0.30 m ▲
20 40 60 80

Notes:
1. End of test hole at 33.8 m.
2. Test hole backfilled with grout.
3. Grout mix consisted of 1 part cement, 0.75 part bentonite, 5.7 part water.
4. Depth of Red River is 6.1m.

WATER LEVELS

CONTRACTOR
Maple Leaf Drilling Ltd.

INSPECTOR
G. BAKER/C. FRIESEN

APPROVED
J. MACLENNAN

DATE
10-25-2021

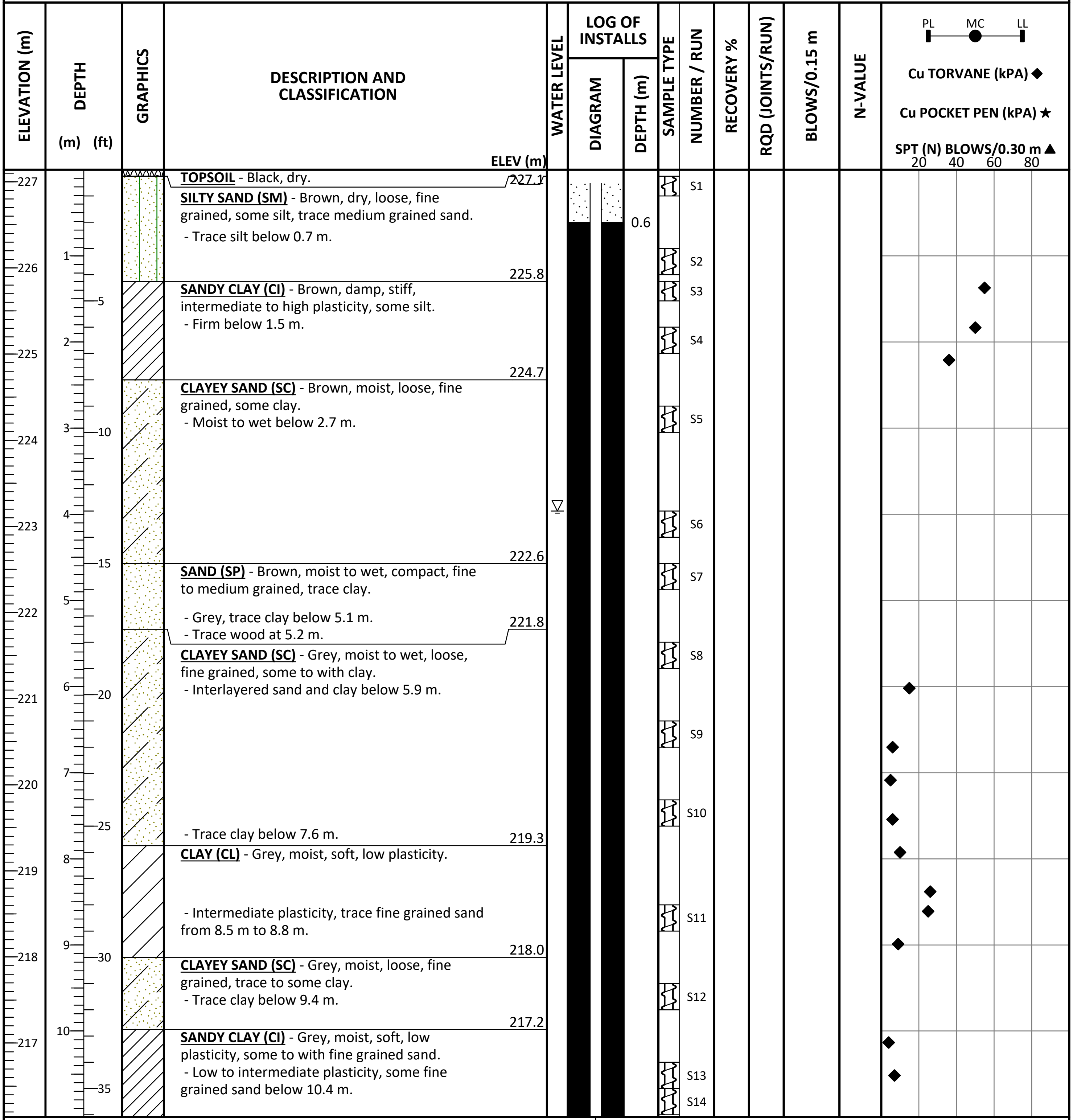
KGS GROUP

TEST HOLE LOG

HOLE NO.
TH21-03

SHEET 1 of 4

CLIENT	**ASSOCIATED ENGINEERING ALBERTA LTD.**	**PROJECT NO.**	21-3913-001
PROJECT	**Newton Force Main Red River Crossing Replacement**	**SURFACE ELEV.**	227.14 m
LOCATION	Winnipeg, MB	**TOC STICK-UP / ELEV.**	-0.10 m / 227.04 m (Standpipe)
DESCRIPTION	Kildonan Drive at Larchdale Crescent (Fraser's Grove Park)	**DATE DRILLED**	8-12-2021
DRILL RIG / HAMMER	Acker Renegade Track Mounted Drill Rig with Auto-Hammer	**UTM (m)**	N 5,533,496 E 636,194
METHOD(S)	0.0 m to 18.3 m: 125 mm ø SSA - switched due to sloughing 18.3 m to 41.7 m: Triple Tube, HQ Core		



DESCRIPTION AND CLASSIFICATION	ELEV (m)
TOPSOIL - Black, dry.	227.1
SILTY SAND (SM) - Brown, dry, loose, fine grained, some silt, trace medium grained sand. - Trace silt below 0.7 m.	225.8
SANDY CLAY (CI) - Brown, damp, stiff, intermediate to high plasticity, some silt. - Firm below 1.5 m.	224.7
CLAYEY SAND (SC) - Brown, moist, loose, fine grained, some clay. - Moist to wet below 2.7 m.	222.6
SAND (SP) - Brown, moist to wet, compact, fine to medium grained, trace clay. - Grey, trace clay below 5.1 m. - Trace wood at 5.2 m.	221.8
CLAYEY SAND (SC) - Grey, moist to wet, loose, fine grained, some to with clay. - Interlayered sand and clay below 5.9 m. - Trace clay below 7.6 m.	219.3
CLAY (CL) - Grey, moist, soft, low plasticity. - Intermediate plasticity, trace fine grained sand from 8.5 m to 8.8 m.	218.0
CLAYEY SAND (SC) - Grey, moist, loose, fine grained, trace to some clay. - Trace clay below 9.4 m.	217.2
SANDY CLAY (CI) - Grey, moist, soft, low plasticity, some to with fine grained sand. - Low to intermediate plasticity, some fine grained sand below 10.4 m.	

WATER LEVELS	⊻ **During Drilling** During Drilling	3.96 m on 8-12-2021 During Drilling	CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **C. FRIESEN**
			APPROVED J. MACLENNAN	DATE 10-25-2021

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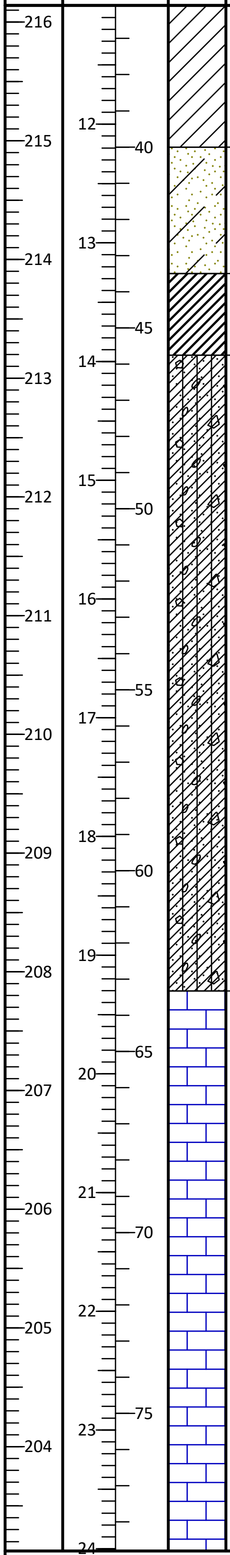
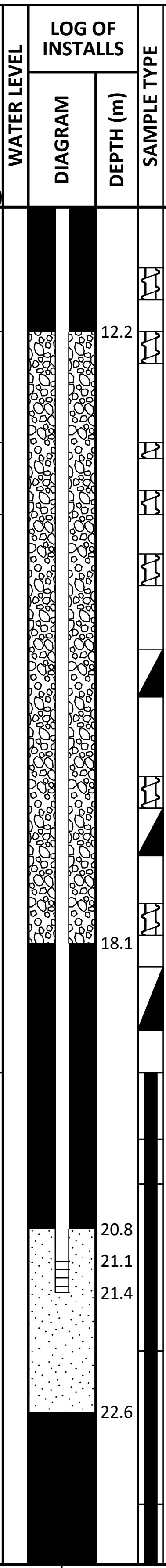
TEST HOLE LOG

HOLE NO.
TH21-03

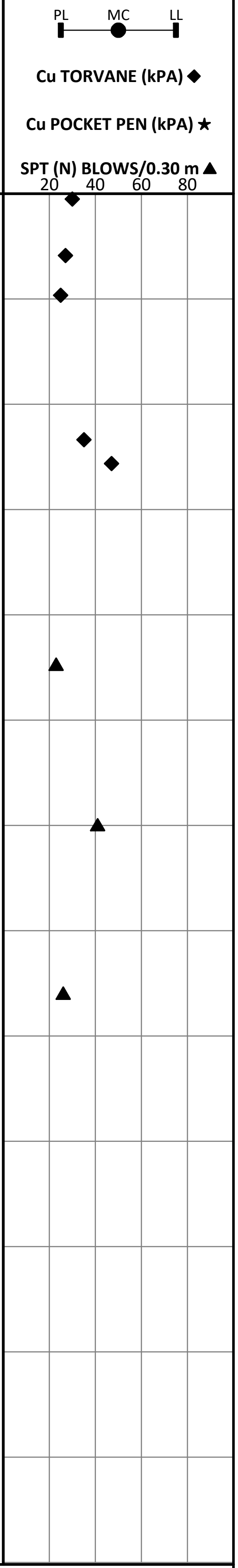
SHEET 2 of 4

ELEVATION (m)	DESCRIPTION AND CLASSIFICATION	ELEV (m)
216 – 214.9	- Intermediate to high plasticity, firm below 11.0 m. - Trace to some fine grained sand below 11.3 m.	214.9
214.9 – 213.9	**CLAYEY SAND (SC)** - Grey, moist, loose, fine to medium grained, some clay.	213.9
213.9 – 213.2	**CLAY (CH)** - Greyish brown, moist, firm, high plasticity, trace silt nodules, some fine to medium grained sand. - Trace coarse grained sand, trace fine grained gravel below 13.9 m.	213.2
213.2 – 207.8	**SILT TILL (TILL)** - Light brown, moist, compact, some fine to coarse grained sand, trace fine to coarse grained gravel. - With coarse grained sand below 14.6 m. - Broken gravel in SPT sampler at 16.8 m. - Some fine to coarse grained gravel below 16.8 m.	207.8
207.8 –	**MOTTLED LIMESTONE** - grey to light yellow brown, Moderate to wide spaced joints. - Highly fractured limestone from 19.3 m to 19.9 m. - Vugs from 22.9 m to 23.8 m. - Softer to 23.4 m. - Softer at 23.8 m.	





NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE
S15				
S16				
S17				
S18				
S19				
S20	72		8 10 13	23
S21				
S22	42		44 29 12	41
S23				
S24	42		14 13 13 13	26
R1	48	0		
R2	100	78 (3)		
R3	97	82 (11)		
R4	100	100 (4)		



WATER LEVELS ⊻ **During Drilling** 3.96 m on 8-12-2021 During Drilling
During Drilling

CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

TEST HOLE LOG

HOLE NO.
TH21-03

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE
203		80	R5	100	98 (4)		
202	25		R6	100	99 (7)		
201	26	85					
200	27	90	R7	97	97 (0)		
199	28		R8	100	95 (5)		
198	29	95					
197	30	100	R9	100	99 (3)		
196	31						
195	32	105	R10	99	99 (3)		
194	33	110	R11	100	100 (1)		
193	34						
192	35	115	R12	99	97 (3)		
191	36	120	R13	100	99 (3)		
	37						

DESCRIPTION AND CLASSIFICATION — ELEV (m)

- Grey to white, moderate to wide spaced joints. from 31.5 m to 41.7 m.

- Mottled grey to brown below 32.4 m.

- Trace vugs from 34.1 m to 36.3 m.

WATER LEVEL | LOG OF INSTALLS: DIAGRAM, DEPTH (m) | SAMPLE TYPE

PL — MC — LL
Cu TORVANE (kPA) ◆
Cu POCKET PEN (kPA) ★
SPT (N) BLOWS/0.30 m ▲
20 40 60 80

WATER LEVELS ⊻ **During Drilling** 3.96 m on 8-12-2021 During Drilling
During Drilling

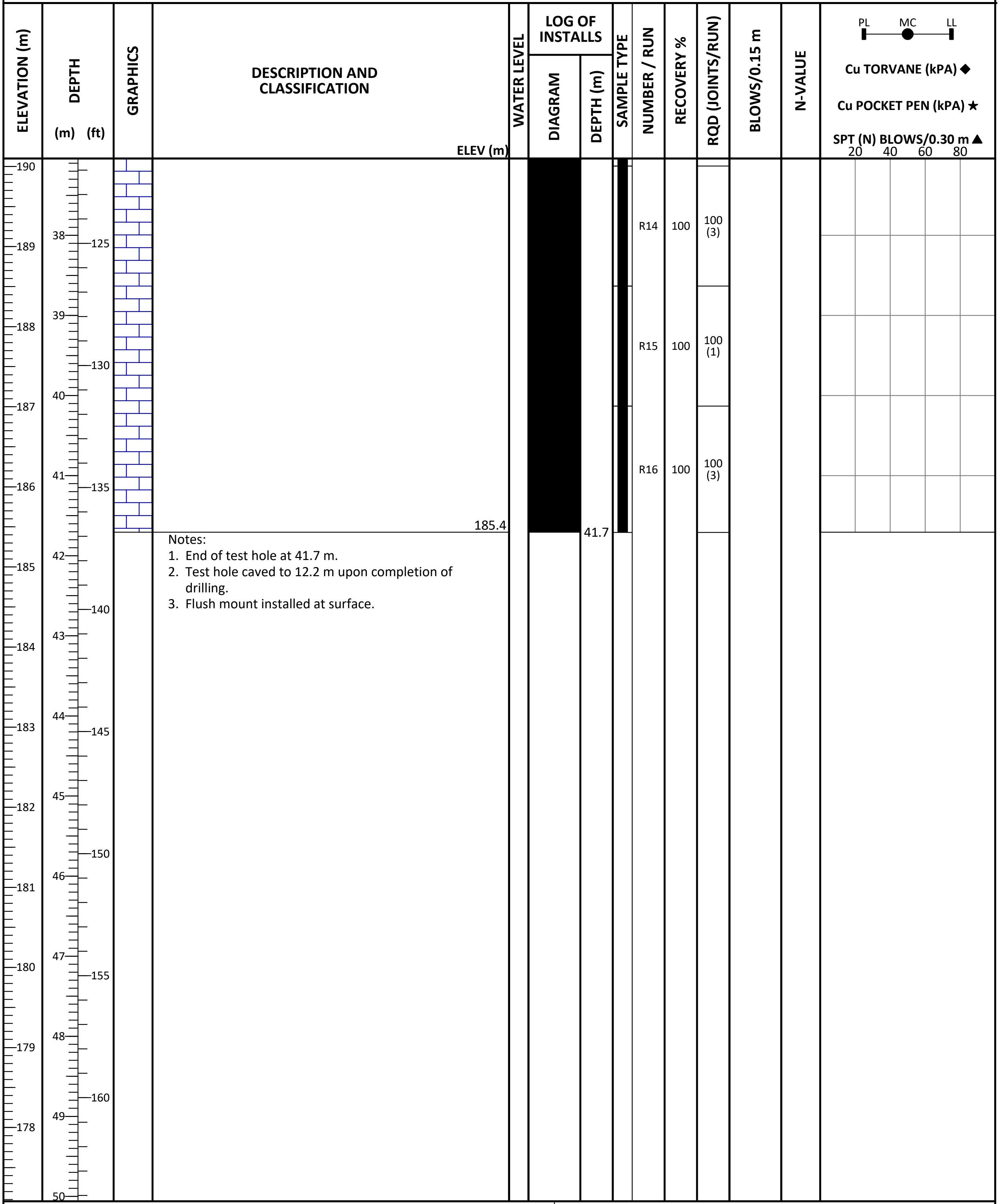
CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

KGS
GROUP

TEST HOLE LOG

HOLE NO.
TH21-03

SHEET 4 of 4



NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)
R14	100	100 (3)
R15	100	100 (1)
R16	100	100 (3)

185.4 | 41.7

Notes:
1. End of test hole at 41.7 m.
2. Test hole caved to 12.2 m upon completion of drilling.
3. Flush mount installed at surface.

WATER LEVELS ▽ **During Drilling** 3.96 m on 8-12-2021 During Drilling
During Drilling

CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

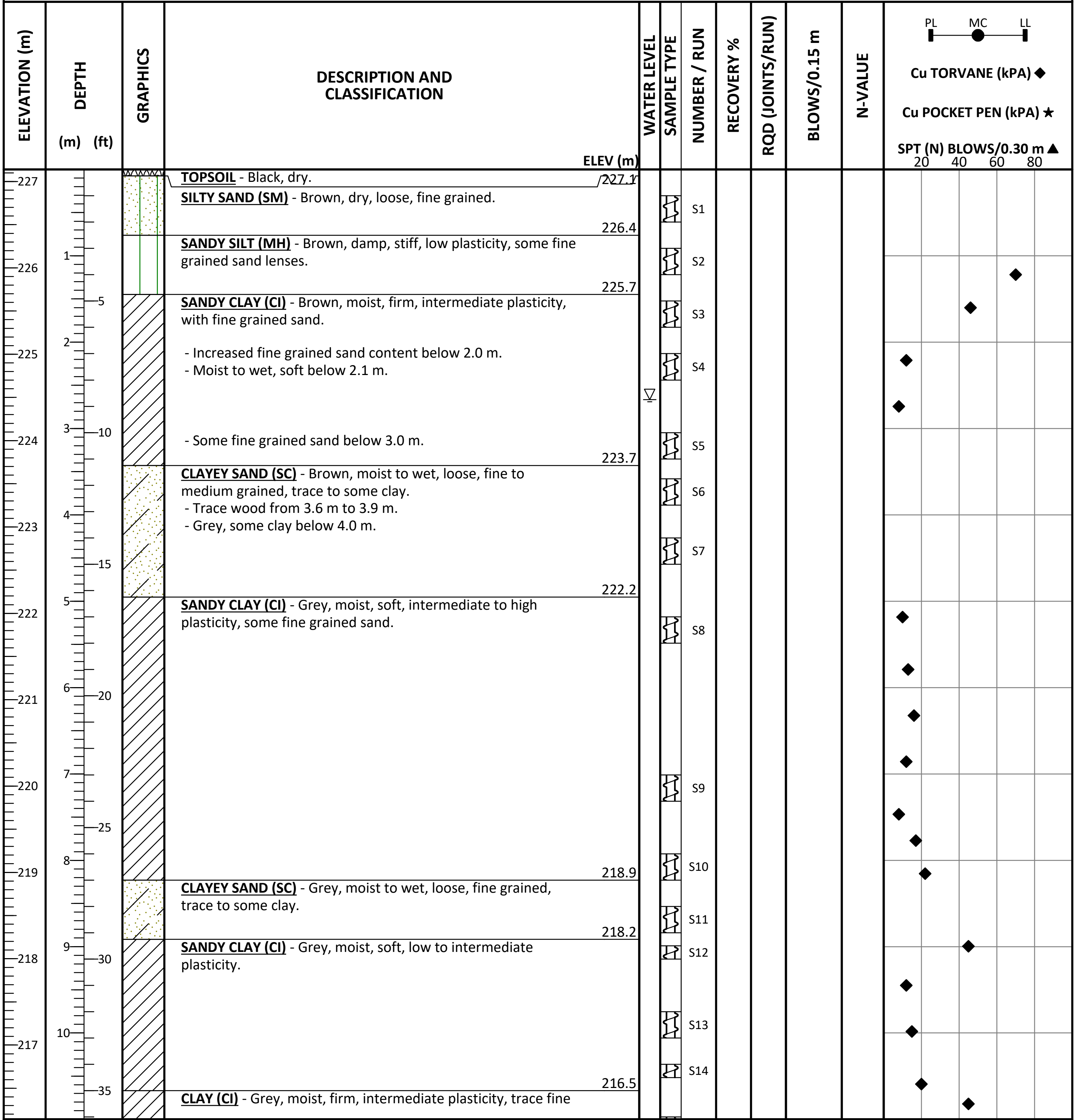
KGS GROUP

TEST HOLE LOG

HOLE NO.
TH21-04

SHEET 1 of 4

CLIENT	**ASSOCIATED ENGINEERING ALBERTA LTD.**	**PROJECT NO.**	21-3913-001
PROJECT	**Newton Force Main Red River Crossing Replacement**	**SURFACE ELEV.**	227.14 m
LOCATION	Winnipeg, MB	**DATE DRILLED**	8-11-2021
DESCRIPTION	Kildonan Drive at Rowandale Crescent (Fraser's Grove Park)	**UTM (m)**	N 5,533,587 E 636,371
DRILL RIG / HAMMER	Acker Renegade Track Mounted Drill Rig with Auto-Hammer		
METHOD(S)	0.0 m to 18.3 m: 125 mm ø SSA - switched due to sloughing 18.3 m to 44.7 m: Triple Tube, HQ Core		



DESCRIPTION AND CLASSIFICATION — ELEV (m)

TOPSOIL - Black, dry. — 227.1

SILTY SAND (SM) - Brown, dry, loose, fine grained. — 226.4

SANDY SILT (MH) - Brown, damp, stiff, low plasticity, some fine grained sand lenses. — 225.7

SANDY CLAY (CI) - Brown, moist, firm, intermediate plasticity, with fine grained sand.

- Increased fine grained sand content below 2.0 m.
- Moist to wet, soft below 2.1 m.

- Some fine grained sand below 3.0 m.

223.7

CLAYEY SAND (SC) - Brown, moist to wet, loose, fine to medium grained, trace to some clay.

- Trace wood from 3.6 m to 3.9 m.
- Grey, some clay below 4.0 m.

222.2

SANDY CLAY (CI) - Grey, moist, soft, intermediate to high plasticity, some fine grained sand.

218.9

CLAYEY SAND (SC) - Grey, moist to wet, loose, fine grained, trace to some clay.

218.2

SANDY CLAY (CI) - Grey, moist, soft, low to intermediate plasticity.

216.5

CLAY (CI) - Grey, moist, firm, intermediate plasticity, trace fine

WATER LEVELS	⊻ **During Drilling** During Drilling	2.67 m on 8-11-2021 During Drilling	
CONTRACTOR **Maple Leaf Drilling Ltd.**		INSPECTOR **C. FRIESEN**	
APPROVED J. MACLENNAN		DATE 10-25-2021	

KGS GROUP

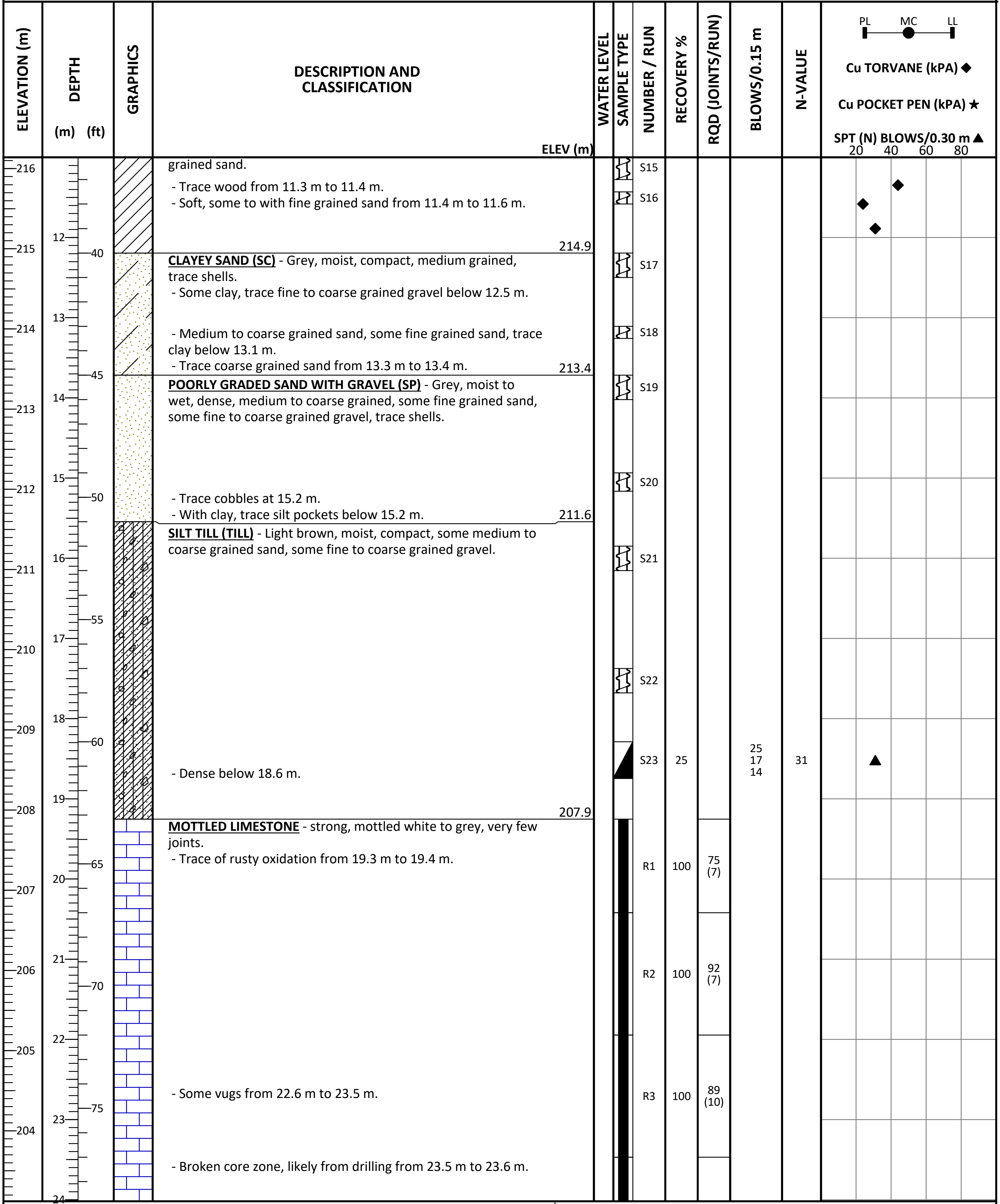
TEST HOLE LOG

HOLE NO.
TH21-04

SHEET 2 of 4

ELEV (m)	DESCRIPTION AND CLASSIFICATION
	grained sand. - Trace wood from 11.3 m to 11.4 m. - Soft, some to with fine grained sand from 11.4 m to 11.6 m.
214.9	**CLAYEY SAND (SC)** - Grey, moist, compact, medium grained, trace shells. - Some clay, trace fine to coarse grained gravel below 12.5 m. - Medium to coarse grained sand, some fine grained sand, trace clay below 13.1 m. - Trace coarse grained sand from 13.3 m to 13.4 m.
213.4	**POORLY GRADED SAND WITH GRAVEL (SP)** - Grey, moist to wet, dense, medium to coarse grained, some fine grained sand, some fine to coarse grained gravel, trace shells. - Trace cobbles at 15.2 m. - With clay, trace silt pockets below 15.2 m.
211.6	**SILT TILL (TILL)** - Light brown, moist, compact, some medium to coarse grained sand, some fine to coarse grained gravel. - Dense below 18.6 m.
207.9	**MOTTLED LIMESTONE** - strong, mottled white to grey, very few joints. - Trace of rusty oxidation from 19.3 m to 19.4 m. - Some vugs from 22.6 m to 23.5 m. - Broken core zone, likely from drilling from 23.5 m to 23.6 m.

NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE
S15				
S16				
S17				
S18				
S19				
S20				
S21				
S22				
S23	25		25 17 14	31
R1	100	75 (7)		
R2	100	92 (7)		
R3	100	89 (10)		



WATER LEVELS	⊻ **During Drilling** During Drilling	2.67 m on 8-11-2021 During Drilling

CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

KGS GROUP

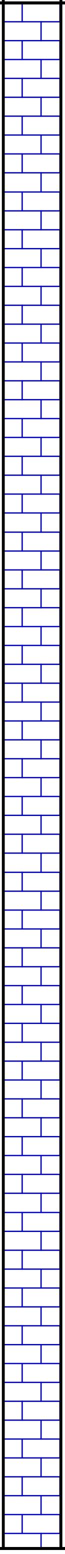
TEST HOLE LOG

HOLE NO.
TH21-04

SHEET 3 of 4

ELEVATION (m)	DEPTH (m)	DEPTH (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	WATER LEVEL	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL; Cu TORVANE (kPA) ◆; Cu POCKET PEN (kPA) ★; SPT (N) BLOWS/0.30 m ▲ 20 40 60 80
203		80					R4	100	88 (3)			
202	25						R5	99	99 (5)			
201	26	85										
200	27	90					R6	99	99 (4)			
199	28						R7	100	100 (4)			
198	29	95		- Finer grained section from 29.6 m to 31.7 m.								
197	30	100					R8	100	99 (5)			
196	31											
195	32	105		- Mottled brown, medium grained, trace of vugs with no alterations associated in the vuggy areas from 31.7 m to 44.7 m.			R9	99	98 (6)			
194	33	110					R10	100	93 (7)			
193	34											
192	35	115					R11	99	99 (2)			
191	36	120					R12	100	100 (1)			
	37											

ELEV (m)



WATER LEVELS ∇ **During Drilling** 2.67 m on 8-11-2021 During Drilling
During Drilling

CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

KGS
GROUP

TEST HOLE LOG

HOLE NO.
TH21-04

SHEET 4 of 4

ELEVATION (m)	DEPTH (m) (ft)	GRAPHICS	DESCRIPTION AND CLASSIFICATION	ELEV (m)	WATER LEVEL	SAMPLE TYPE	NUMBER / RUN	RECOVERY %	RQD (JOINTS/RUN)	BLOWS/0.15 m	N-VALUE	PL MC LL Cu TORVANE (kPA) ◆ Cu POCKET PEN (kPA) ★ SPT (N) BLOWS/0.30 m ▲ 20 40 60 80
190–189	38 / 125						R13	100	100 (2)			
188	39 / 130		- Large piece of coral at 39.1 m.				R14	99	99 (2)			
187–186	40–41 / 135						R15	100	100 (2)			
185	42 / 140						R16	100	100 (1)			
184–183	43–44 / 145			182.4			R17	100	93 (4)			

Elevation scale (m): 190, 189, 188, 187, 186, 185, 184, 183, 182, 181, 180, 179, 178

Depth scale (m): 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50

Depth scale (ft): 125, 130, 135, 140, 145, 150, 155, 160

Notes:
1. End of test hole at 44.7 m.
2. Test hole backfilled with grout.
3. Grout mix consisted of 1 part cement, 0.4 part bentonite, 3.3 part water.
4. Backfilled testhole with bentonite grout mixture to 1.8m.
5. Grout level dropped to 2.9m overnight. Topped up hole with bentonite chips to grade.

WATER LEVELS ▽ **During Drilling** 2.67 m on 8-11-2021 During Drilling
During Drilling

CONTRACTOR **Maple Leaf Drilling Ltd.**	INSPECTOR **C. FRIESEN**
APPROVED J. MACLENNAN	DATE 10-25-2021

APPENDIX B

Photographs

Photo 1: TH21-01, Depth: 60’9” to 71’4.5”

Photo 2: TH21-01, Depth: 71’4.5” to 81’9”

Photo 3: TH21-01, Depth: 81’9” to 91’9”

Photo 4: TH21-01, Depth: 91’9” to 101’9”

Photo 5: TH21-01, Depth: 101’9” to 116’9”

Photo 6: TH21-01, Depth: 111’6.5” to 126’8”

Photo 7: TH21-01, Depth: 120’2.5” to 136’9”

Photo 8: TH21-01, Depth: 129’1” to 141’9” (End of Hole)

Photo 1: TH21-02, Depth: 28’2” to 40’10”

Photo 2: TH21-02, Depth: 40’10” to 55’9”

Photo 3: TH21-02, Depth: 55’9” to 70’9”

Photo 4: TH21-02, Depth: 70’9” to 82’2”

Photo 5: TH21-02, Depth: 82’2” to 95’11”

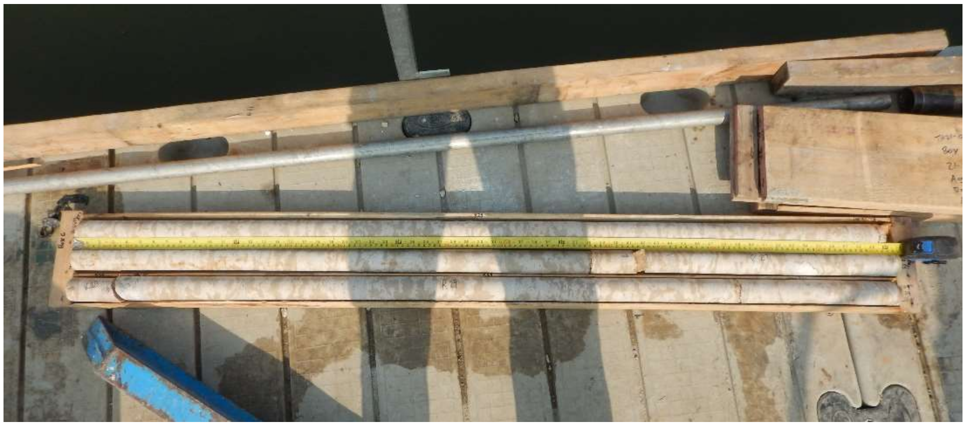


Photo 6: TH21-02, Depth: 95’11” to 110’9” (End of Hole)

Photo 1: TH21-03, Depth: 63'4" to 81'11"

Photo 2: TH21-03, Depth: 73'10.75" to 96'10"

Photo 3: TH21-03, Depth: 92’10.5” to 111’11”

Photo 4: TH21-03, Depth: 111’11” to 121’10”

Photo 5: TH21-03, Depth: 121'10" to 131'8"

Photo 6: TH21-03, Depth: 131'8" to 136'10" (End of Hole)

Photo 1: TH21-04, Depth: 63’2” to 81’10”

Photo 2: TH21-04, Depth: 72’9” to 91’10”

Photo 3: TH21-04, Depth: 91’10” to 106’11”

Photo 4: TH21-04, Depth: 101’6.25” to 116’11”

Photo 5: TH21-04, Depth: 110’11” to 126’11”

Photo 6: TH21-04, Depth: 120’9.5” to 136’9”

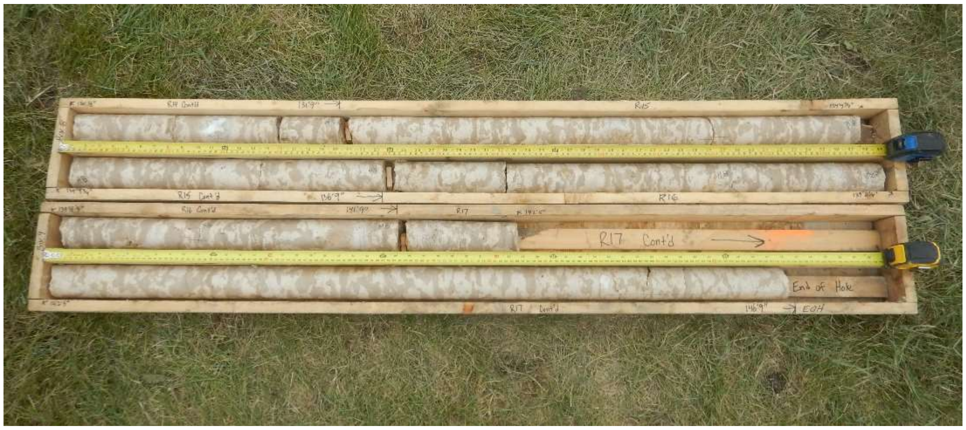


Photo 7: TH21-04, Depth: 130’0.5” to 146’9” (End of Hole)

APPENDIX C

Seismic Refraction Survey

FRONTIER GEOSCIENCES INC.

SEISMIC REFRACTION SURVEY REPORT NEWTON FORCE MAIN RED RIVER CROSSING WINNIPEG, MB

Submitted to:

KGS Group

October 26, 2021

Authors:

Sean Henry, B.Sc.

Caitlin Gugins, P.Geo.

Project: FGI-1743

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CHANGE LOG

Version	Date of Issue	Changes
Draft	Sept. 6, 2021	Draft Report for Review
Final	Oct. 26, 2021	Final Report – updated Figures 3 and 4, discussion updated

Table of Contents

Illustrations

1. Introduction

During the period of August 10 and 11, 2021, Frontier Geosciences Inc. carried out a seismic refraction investigation for KGS Group, in Winnipeg, MB. The survey area is located across the Red River, near Newton Ave. A Survey Location Plan of the area is shown at a scale of 1:50,0000 in Figure 1 in the Appendix.

The purpose of the geophysical survey was to obtain overburden and bedrock compressional wave velocity information, in support of the Newton Force Main Red River Crossing Replacement project. A total of 705 metres of seismic refraction data was collected along two separate seismic lines. A Site Plan showing the locations of the lines is presented at a 1:2,000 scale in Figure 2, in the Appendix.

Example of Survey Setup at the River's Edge

2. Seismic Refraction Survey

2.1 Terrestrial Refraction Survey

2.1.1 Survey Equipment

The seismic refraction investigation was carried out using a Geometric Geode, 24 channel, signal enhancement seismograph and Oyo Geospace 10 Hz geophones. Geophone intervals along the multicored seismic cable were maintained at 5 metres, in order to ensure high resolution data of subsurface layering. Seismic energy was provided from a Buffalo gun, shotgun source firing 8 gauge, blank, shotgun shells into hand-excavated shotholes. Shot initiation or zero time was established by metal to metal contact of a striking hammer contacting the firing pin of the shotgun.

2.1.2 Survey Procedure

For each spread, the seismic cable was stretched out in a straight line and the geophones implanted in the soil. Up to seven separate 'shots' were then initiated: one at either end of the geophone array, up to three at intermediate locations along the seismic cable, and two off each end of the line, to ensure adequate coverage of the subsurface. The shots were triggered individually and arrival times for each geophone were recorded digitally in the seismograph. For quality assurance, field inspection of raw data after each shot was carried out, with additional shots recorded if first arrivals were unclear.

Throughout the survey, notes were recorded regarding seismic line positions in relation to topographic and geological features. Relative elevations along the seismic lines were recorded by chain and inclinometer and referenced to handheld GPS measurements.

2.2 Overwater Refraction Survey

2.2.1 Survey Equipment

The overwater seismic refraction surveying was carried out with two, land-based, Geode seismographs and up to twenty-four geophones, together with a waterborne airgun energy source. A small Bolt airgun was used which released 10 cubic inches of compressed air into the river. A Gisco seismic radio trigger in the survey boat was used to initiate recordings at the two, shore-based seismographs.

2.2.2 Survey Procedure

In operation, the 'shooting' boat was manoeuvred in-line with the recording stations and the seismic source was lowered to just above the river bottom then initiated. The recording stations were automatically triggered by a radio link between the shooting vessel and recording seismographs. Accurate positioning of the shooting vessel was determined with a handheld GPS receiver. With numerous shot locations spanning the breadth of the lake, detailed travel time data was established similar to land-based operations. Water depths were recorded at each 'shooting' station.

2.3 Seismic Refraction Interpretive Method

The final interpretation of the seismic data was arrived at using the method of differences technique. This method utilizes the time taken to travel to a geophone from shotpoints located to either side of the geophone. Velocities are calculated as the slope of first break pick times and geophone distances. When there is a significant change in slope a new velocity is calculated and assigned to the new layer. Basal velocities are calculated by the arrivals of off-end shots, where picked arrivals are refracted from the basal layer. Each geophone is assigned a velocity and time for each layer. Using the total time, a small vertical time is computed which represents the time taken to travel from the refractor up to the ground surface. This time is then multiplied by the velocity of each overburden layer to obtain the thickness of each layer at that point. The thicknesses are splined along the seismic line to create a continuous boundary between layers.

3. Geophysical Results

3.1 General

The interpreted results of the seismic refraction lines are illustrated in profile in Figures 3 and 4, at a scale of 1:500, in the Appendix. The seismic velocity layer interfaces are marked on the seismic profiles in blue, purple and red. The interface line colours are not a specific velocity contour, but rather the interpreted discrete boundary above which velocities are defined within a certain range and below which velocities are within a significantly increased velocity range.

Seismic Shotgun Operation on Terrestrial Lines

3.2 Discussion

The results of the seismic refraction survey indicate the area is underlain by up to four distinct velocity layers. The two seismic profiles display a surficial layer with a range of compressional wave velocities between 360 m/s and 450 m/s. This velocity range is indicative of unconsolidated materials such as loose, dry to damp sands, silts and clays. This layer averages approximately 3.8 metres in thickness and reaches a maximum of approximately 6.2 metres along line SL21-02 near station 338N. This surficial layer is absent across the river.

Underlying the surficial layer is an upper intermediate layer with an interpreted compressional wave velocity range between 1000 m/s and 1400 m/s, consistent with drillhole intersections of moist to wet, sands and clays. Layer thicknesses vary significantly across the survey lines, from a minimum of around 2.7 metres surrounding station 188N on line SL21-02, while reaching a maximum of over 15 metres near station 90NW on line SL21-01.

Underlying the upper intermediate layer is a lower intermediate velocity layer with a narrow compressional wave velocity range of 1600 m/s to 1750 m/s. These velocities are consistent with a more compact material, such as the silt till layer encountered in the drillholes. The greatest calculated thicknesses for this layer is approximately 11 m occurring at the beginning of line SL21-02, and thinning to 1.5 metres near station 264N on line SL21-02. While identifiable over the terrestrial portions this layer was not as apparent over the coarser cross river portions of the lines, likely due to it's thickness relative to depth. As a result, the depth for this layer was interpolated along the river bottom, and therefore it's thickness has a higher level of uncertainty underneath the river.

The basal layer with compressional wave velocities of 3250 m/s to 4100 m/s is the interpreted competent bedrock surface. These high velocities are consistent with nearby borehole logs encountering limestone, with higher velocities in this range indicative of a lesser degree of weathering and/or fracturing. Depths to the interpreted bedrock surface range from around 5.5 metres underlying the river near station 240N on line SL21-02 to a maximum of 26 metres at station 100NW on line SL21-01.

4. Limitations

The depths to subsurface boundaries derived from seismic refraction surveys are generally accepted as accurate to within ten percent of the true depths to the boundaries, below 10 metres. Above 10 metres, the accuracy of seismic refraction data is approximately +/- 1.5 metres due mainly to the greater statistical error in determining the upper velocity layers from fewer data points. In some cases, unusual geological conditions may produce false or misleading data points with the result that computed depths to subsurface boundaries may be less accurate. In seismic refraction surveying difficulties with a 'hidden layer' or a velocity inversion may produce erroneous depths. The first condition is caused by the inability to detect the existence of a layer because of insufficient velocity contrasts or layer thicknesses. A velocity inversion exists when an underlying layer has a lower velocity than the layer directly above it. The interpreted depths shown on drawings are to the closest interface location, which may not be vertically below the measurement point if the refractor dip direction departs significantly from the survey line location. Structural discontinuities occurring on a scale less than the geophone spacing or isolated boulders would go undetected in the interpretation of the data. The seismic refraction method may not detect a narrow canyon-like feature incised into bedrock, if the canyon width is narrow relative to the depth of burial of the feature.

Due to the method constraints of the overwater seismic refraction surveying, there is limited data on the velocities and depths of the overburden materials on the overwater profile. As a result, overburden velocities and bedrock depth errors may be greater than fifteen percent on the overwater segments of refraction lines.

The information in this report is based upon geophysical measurements and field procedures and our interpretation of the data. The results are interpretive in nature and are considered to be a reasonably accurate representation of existing subsurface conditions within the limitations of the seismic refraction method.

For: Frontier Geosciences Inc.

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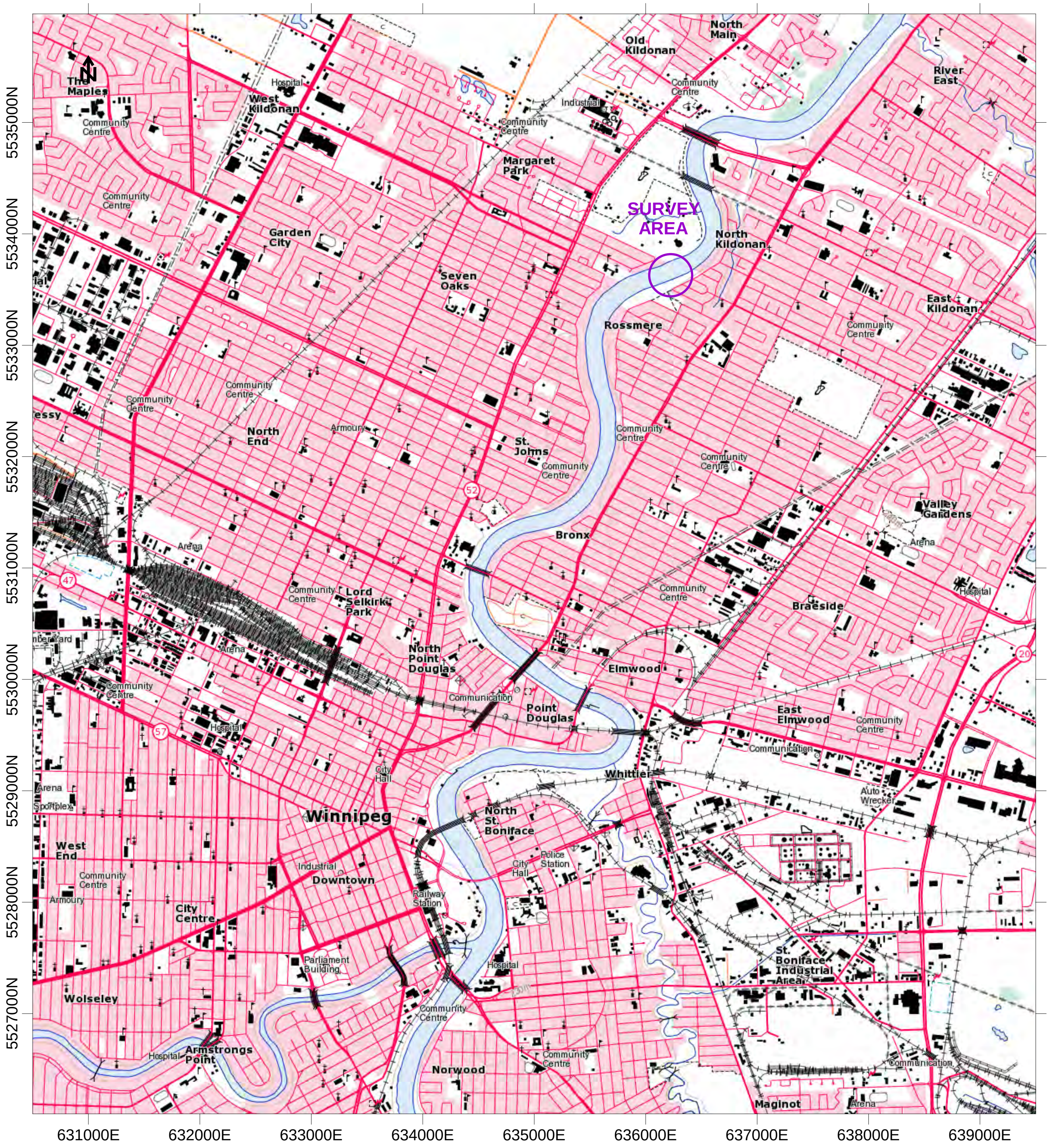
Caitlin Gugins, P.Geo.

PROVINCE OF MANITOBA
C.M.
GUGINS
Member
46920G
REGISTERED PROFESSIONAL GEOSCIENTIST

Oct 26, 2021

APPENDIX



0 0.5 1 1.5 2

KILOMETRES

NATURAL RESOURCES CANADA
TOPORAMA MAPSHEET 62H14
UTM NAD83 ZONE 14

KGS GROUP

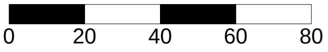
NEWTON FORCE MAIN
RED RIVER CROSSING REPLACEMENT

SEISMIC REFRACTION SURVEY

SURVEY LOCATION PLAN

FRONTIER GEOSCIENCES INC.

DATE: AUG. 2021	SCALE 1:50,000	FIG. 1



METRES

GOVERNMENT OF MANITOBA IMAGERY
UTM NAD83 ZONE 14

KGS GROUP

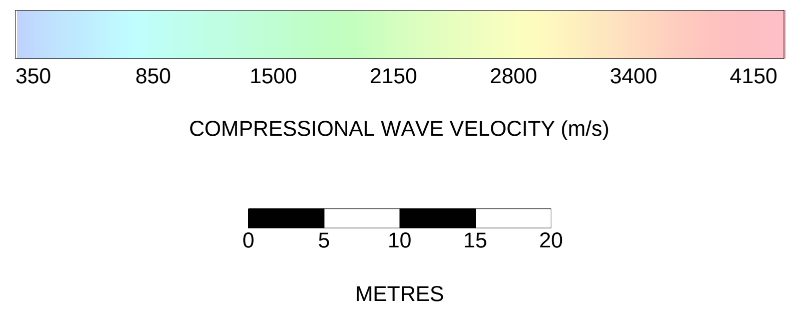
NEWTON FORCE MAIN
RED RIVER CROSSING REPLACEMENT

SEISMIC REFRACTION SURVEY

SITE PLAN

FRONTIER GEOSCIENCES INC.

DATE: AUG. 2021	SCALE 1:2,000	FIG. 2



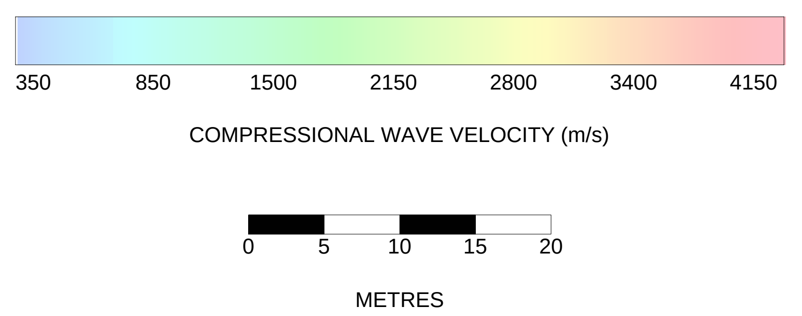
KGS GROUP
NEWTON FORCE MAIN
RED RIVER CROSSING REPLACEMENT

SEISMIC REFRACTION SURVEY

INTERPRETED SEISMIC REFRACTION
DEPTH SECTION
SL21-01

FRONTIER GEOSCIENCES INC.

DATE: AUG. 2021 | SCALE 1:500 | FIG. 3



KGS GROUP
NEWTON FORCE MAIN
RED RIVER CROSSING REPLACEMENT

SEISMIC REFRACTION SURVEY

INTERPRETED SEISMIC REFRACTION
DEPTH SECTION
SL21-02

FRONTIER GEOSCIENCES INC.

DATE: AUG. 2021
SCALE 1:500
FIG. 4

KGS
GROUP

Experience in Action