TETRA TECH

INTERNAL MEMO

ISSUED FOR USE

To:	Kirby McRae	**Date:**	June 11, 2021
c:		**Memo No.:**	
From:	Brent Horning	**File:**	705-1000120300, Task 600.02
Subject:	Ferry Road Piezometer Hydraulic Conductivity Testing		

1.0 PROJECT BACKGROUND

In order to assess the potential for groundwater inflow into proposed future excavation works for a water and sewer line replacement, hydraulic conductivity analyses were performed at six (6) locations using the piezometers previously installed for geotechnical investigation of the proposed routing. These piezometers were installed along Rutland Street, running north from the Assiniboine River to Silver Avenue. A site plan showing the approximate piezometer locations is provided as Figure 1, attached.

The piezometers consist of 25 mm diameter PVC casings with 300 mm long perforated sections. Five of the piezometers were installed in the overburden, either a soft clay or silt till, at depths of 6.7 m below grade (mbg) to 11.2 mbg. The sixth piezometer was installed in the carbonate bedrock at a depth of 15.5 m below grade. Details relating to the screen section placement are provided in Table 1, attached. Borehole logs showing the stratigraphy encountered and the well construction as prepared by Dyregrov Robinson are included in Appendix A.

2.0 METHODOLOGY

On May 25 and 26, 2020, falling head slug tests were performed on each of the six piezometers, as described below.

- The static water level was measured using an electronic water level meter in relation to top of casing.
- A data logging pressure transducer set to record at two second intervals was placed approximately 0.5 m below the static water level.
- Approximately 4 L of clean tap water was poured into the well casing to create a sudden increase in the water level in the piezometer
- The rate of water drainage through the well screen to restore the water level to its original elevation was recorded by the pressure transducer and confirmed by periodic manual measurements.
- The transducer record was analysed using the AquiferTest Pro software to produce a hydraulic conductivity value for the materials adjacent to the well screen in each location.

Tetra Tech Canada Inc.
400-161 Portage Avenue East
Winnipeg, MB R3B 0Y4
Tel 204.954.6800 Fax 204.988.0546

3.0 FIELD OBSERVATIONS

Measurement of static water levels in the piezometers completed in the overburden found the water levels to be between 3.25 mbg and 3.53 mbg near the Assiniboine River shoreline, and between 6.45 mbg and 6.94 mbg further inland. Calculation of the associated groundwater elevations showed a variation of between 228.66 m above sea level (ASL) in the northern most piezometer (TH19-240) and 225.37 m ASL in the southern piezometer (TH19-147). The associated groundwater flow direction in the overburden unit is therefore anticipated to be southerly.

The groundwater in the bedrock piezometer (TH19-173) was measured as 7.65 mbg, with a calculated elevation of 227.51 m ASL. With only one measurement point, the potential groundwater flow direction in the carbonate bedrock cannot be determined. It is however noted that the water level in the bedrock is at a lower elevation that the water level in the closest overburden piezometer (TH19-240), suggesting a downward groundwater flow direction between these units.

Depth to groundwater measurements and calculated groundwater elevations are presented in Table 1, attached.

Upon introduction of the clean water into the piezometer casing it was noted that the water dissipated relatively quickly in each of the six piezometers, confirming that the water was being forced out into the surrounding water bearing unit adjacent to the screen section. Review of the piezometer construction details showed that for four of the six piezometers, the static water level was above any sand backfill installed around the screen section, ensuring it was saturated prior to the introduction of water into the piezometer. For the two piezometers located closest to the river (TH19-147 and TH19-148), the sand backfill extended above the static water level, suggesting the possibility that some of the water being introduced in to the casing would infill the sand fill, possibly influencing the initial results of the hydraulic conductivity assessment.

4.0 FALLING HEAD TEST ANALYSIS

Based on the well construction and stratigraphic conditions present, the Hvorselv method of hydraulic conductivity analysis was considered to be appropriate. This method involves the plotting the rate of variation in water level recovery over time in an effort to produce a straight-line semi-log plot. The water level recovery plots are provided in Appendix B. A summary of the resulting hydraulic conductivity values is included in Table 1.

Review of the groundwater level recovery curves found each of the five piezometers completed in the overburden to show a relative consistent pattern with at least two notable recovery stages. The initial straight line portion, extending over between 2 minutes and 10 minutes following water addition is considered to be representative of the hydraulic conductivity of the unit adjacent to the screen section. The secondary straight line portion of the slope is representative of the presence of a boundary condition, most commonly a hydraulic connection with adjacent stratigraphic units. For those two piezometers in which initial saturation of the sand pack adjacent to the piezometer was possibly anticipated (TH19-147 and TH19-148), some initial curve variation was noted, but was of limited duration so is not expected to have impacted the hydraulic conductivity value calculations.

In four of the five overburden piezometers, the initial hydraulic conductivity values were relatively consistent, ranging in value from 3.6×10^{-6} m/s to 8.9×10^{-6} m/s. In the fifth overburden piezometer (TH19-240, located furthest inland), the hydraulic conductivity was lower, with a value of 8.0×10^{-7} m/s. All of these values are consistent with a primarily silt with sand soil condition, as reported in the borehole logs.

In each of the five piezometers completed in the overburden, the secondary slope is representative of an increased hydraulic conductivity. Again the range of hydraulic conductivity is fairly consistent in four of the piezometers, being between 1.3×10^{-5} m/s to 3.6×10^{-5} m/s. The conductivity in the northern most piezometer (TH19-240) is again notable lower at 2.5 x 10^{-6} m/s. These values are still consistent with a silt with sand, but would suggest an increasing sand content.

Review of the groundwater level recovery plot for the piezometer completed in the bedrock (TH19-173) shows a single straight line plot, terminating upon recovery to the original static water level. The calculated hydraulic conductivity of the carbonate bedrock in this location is 3.2 x 10^{-5} m/s, consistent with a fractured or karstic carbonate rock condition, as noted in the associated borehole log.

5.0 DISCUSSION/ CONCLUSIONS

Hydraulic conductivity testing of the piezometers installed in the overburden suggests that these soils show a variable hydraulic conductivity due to interconnectivity between layers or over lateral extension. The hydraulic conductivities in the saturated overburden extending from the Assiniboine River northward to at least Bruce Avenue, showed an initial average hydraulic conductivity of 6.0 x 10^{-6} m/s, increasing to an average of 2.5 x 10^{-5} m/s. In the vicinity of Ness avenue, the overburden showed a lower hydraulic conductivity of 8.0 x 10^{-7} m/s to 2.5 x 10^{-6} m/s.

The higher range of secondary hydraulic conductivity values for the overburden units is similar to that calculated for the carbonate bedrock unit (3.2 x 10^{-5} m/s), suggesting this may be the source of the boundary condition observed in each of the overburden falling head tests.

6.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of the City of Winnipeg and their agents. Tetra Tech Canada Inc. (Tetra Tech) does not accept any responsibility for the accuracy of any of the data, the analysis, or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than the City of Winnipeg, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this document is subject to the Limitations on the Use of this Document attached in the Appendix or Contractual Terms and Conditions executed by both parties.

7.0 CLOSURE

We trust this memo meets your present requirements. If you have any questions or comments, please contact the undersigned.

Respectfully submitted,
Tetra Tech Canada Inc.

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Prepared by:
Brent Horning, P.Eng.
Sr. Environmental Engineer
Direct Line: 204.954.6860
Email: Brent.Horning@tetratech.com

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Reviewed by:
Ryan Wizbicki, P.Eng.
Manager – Environmental Services
Direct Line: 204.954.6930
Email: Ryan.Wizbicki@tetratech.com

BH/
Attachments

PROVINCE OF MANITOBA
B.K. HORNING
Member
7802
REGISTERED PROFESSIONAL ENGINEER
Jun 14/21

ENGINEERS GEOSCIENTISTS MANITOBA
Certificate of Authorization
Tetra Tech Canada Inc.
No. 6499

FIGURES

REFERENCE DRAWINGS: MAPQUEST street map

TETRA TECH

NO.	DATE	DESCRIPTION	ISSUED BY

REVISIONS / ISSUE

AUTHORIZED BY:

DATE 11-06-2021

CLIENT DRAWING NO.

CLIENT

THE CITY OF WINNIPEG

DRAWING DESCRIPTION

FIGURE 1: GENERAL PIEZOMETER LOCATION PLAN
FERRY ROAD PIEZOMETER HYDRAULIC CONDUCTIVITY TESTING

DESIGNED BY: BKH	DRAWN BY: BKH	DRAWING NO.	REV.
REVIEWED BY:	SCALE: As Shown	705-10001203A00-SKT-V0005	00

TABLES

Table 1
Summary of Hydraulic Conductivty Test Results
Ferry Road Piezometer Hydraulic Conductivity Testing
City of Winnipeg

Piezometer No.	Ground Surface Elevation [a]	Screen Section Depth		Material Adjacent to Screen Section	Static Water Level [b]		Initial Hydraulic Conductivity	Secondary Hydraulic Conductivity
	m Above Sea Level	m below grade	m Above Sea Level		m below grade	m Above Sea Level	m/ sec	m/ sec
TH19-147	228.619	6.1 - 6.4	222.2 - 222.5	Silt (Till)	3.25	225.37	7.0×10^{-6}	3.0×10^{-5}
TH19-148	230.566	6.1 - 6.4	224.2 - 224.5	Clay (Alluvial) underlain by Sand (alluvial)	3.53	227.04	3.6×10^{-6}	3.6×10^{-5}
TH19-155	233.629	12.0 - 12.3	221.3 - 221.6	Silt (Till)	6.59	227.04	4.5×10^{-6}	1.3×10^{-5}
TH19-173	235.159	15.2 - 15.5	219.7 - 220.0	Bedrock (Dolomite)	7.65	227.51	3.2×10^{-5}	Not Present
TH19-239	234.083	10.7 - 11.0	223.1 - 223.4	Silt (Till)	6.94	227.14	8.9×10^{-6}	2.2×10^{-5}
TH19-240	235.111	9.1 - 9.4	225.7 - 226.0	Silt (Till)	6.45	228.66	8.0×10^{-7}	2.5×10^{-6}

Note: [a] Elevations based on Dyregrov Robinson Inc. well logs.
[b] Water levels measured on May 25 and 26, 2020.

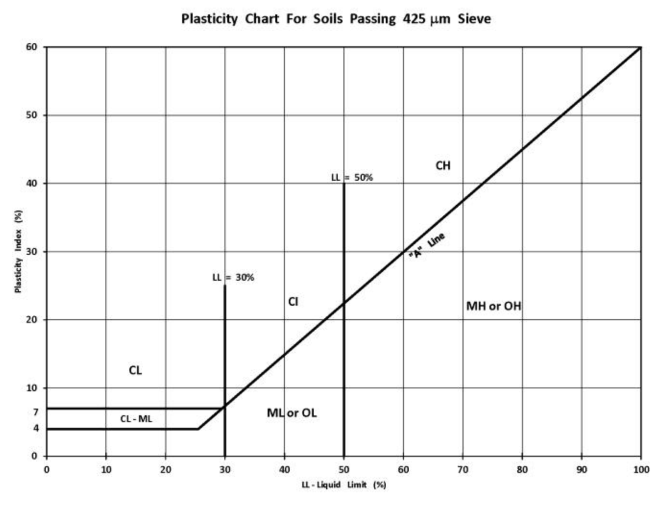
APPENDIX A

DYREGROV ROBINSON BOREHOLE LOGS

EXPLANATION OF TERMS & SYMBOLS

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

	Asphalt		Glacial Till		Bedrock (Igneous)	
	Concrete		Clay Shale		Bedrock (Limestone)	DYREGROV ROBINSON INC. CONSULTING GEOTECHNICAL ENGINEERS
	Fill				Bedrock (Undifferentiated)	



FRACTION		**PARTICLE SIZE** (mm) Min.	Max.
Boulders		>300	
Cobbles		75	300
Gravel	Coarse	19	75
	Fine	4.75	19
Sand	Coarse	2.0	4.75
	Medium	0.425	2.0
	Fine	0.075	0.425
Silt (non-plastic) or Clay (plastic)		< 0.075 mm	

RELATIVE PROPORTIONS (by weight) Percent	Descriptor
>35%	main fraction
35 - 50	"and"
20 – 35	Adjective e.g. silty, clayey
10 – 20	"some"
1 - 10	"trace"

Soil Classification Example

Clay 50% (main fraction), Silt 25%, Sand 17%, Gravel 8%

Clay – silty, some sand, trace gravel

TERMS and SYMBOLS

Laboratory and field tests are identified as follows:

Unconfined Comp.: undrained shear strength (kPa or psf) derived from unconfined compression testing.

Torvane: undrained shear strength (kPa or psf) measured using a Torvane

Pocket Pen.: undrained shear strength (kPa or psf) measured using a pocket penetrometer.

Unit Weight bulk unit weight of soil or rock (kN/m^3 or pcf).

SPT – N Standard Penetration Test: The number of blows (N) required to drive a 51 mm O.D. split barrel sampler 300 mm into the soil using a 63.5 kg hammer with a free fall drop height of 760 mm.

DCPT Dynamic Cone Penetration Test. The number of blows (N) required to drive a 50 mm diameter cone 300 mm into the soil using a 63.5 kg hammer with a free fall drop height of 760 mm.

M/C insitu soil moisture content in percent

PL Plastic limit, moisture content in percent

LL Liquid limit, moisture content in percent

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

Su (kPa)	Su (psf)	CONSISTENCY
<12	250	very soft
12 – 25	250 – 525	soft
25 – 50	525 – 1050	firm
50 – 100	1050 – 2100	stiff
100 – 200	2100 – 4200	very stiff
200	4200	hard

The SPT - N of non-cohesive soil is related to compactness condition as follows:

N – Blows / 300 mm	COMPACTNESS
0 - 4	very loose
4 - 10	loose
10 - 30	compact
30 - 50	dense
50 +	very dense

References:

ASTM D2487 – Classification of Soils For Engineering Purposes (Unified Soil Classification System)

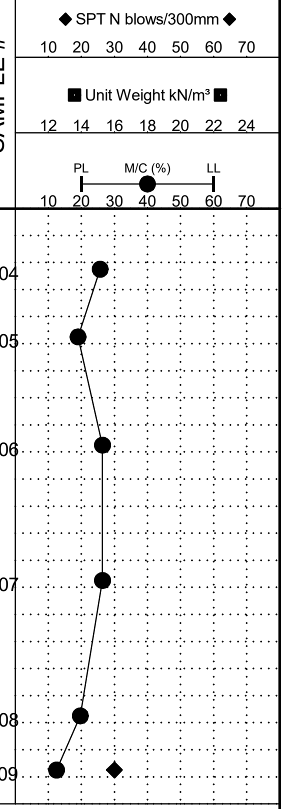
Canadian Foundation Engineering Manual, 4th Edition, Canadian Geotechnical Society, 2006

PROJECT: Ferry Rd. & Riverbend CSR - Rutland Trunk Sewer	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **19-147**
LOCATION: UTM 14U: 5526115 m N, 627781 m E		PROJECT NO.: 143691
CONTRACTOR: Paddock Drilling Ltd.	METHOD: ACKER SS Drill Rig w/125 mm SS & 200mm HS Augers	ELEVATION (m): 228.619

SAMPLE TYPE: GRAB, SHELBY TUBE, SPLIT SPOON, BULK, NO RECOVERY, CORE

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

ELEVATION (m)	DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #
228.6–226.4	0–2.2	CLAY (ALLUVIAL) - silty, trace sand - brown - dry to moist - intermediate plasticity - some silt below 1 m	GRAB GRAB	G304 G305
226.4–224.0	2.2–4.6	SILT (ALLUVIAL) - some clay, some sand - brown - moist, loose - grey and wet below 4 m	GRAB GRAB	G306 G307
224.0–222.0	4.6–6.7	SILT (TILL) - trace sand, trace gravel - grey, wet, loose - compact and moist below 5.5 m - dense at 6 m	GRAB SPLIT SPOON	G308 S309



END OF TEST HOLE AT 6.7 m IN SILT(TILL) (AUGER REFUSAL)
NOTES:
1. Some sloughing and seepage observed at 4 m.
2. After drilling to 5.8 m, hole caved to 4 m.
Switched to hollow stem (HS) augers at 5.8 m.
3. 25 mm PVC Standpipe piezometer w/ Cassagrande tip installed 6.7 m b/l grade.
Top of pipe (T.O.P) 0.91 m above grade.

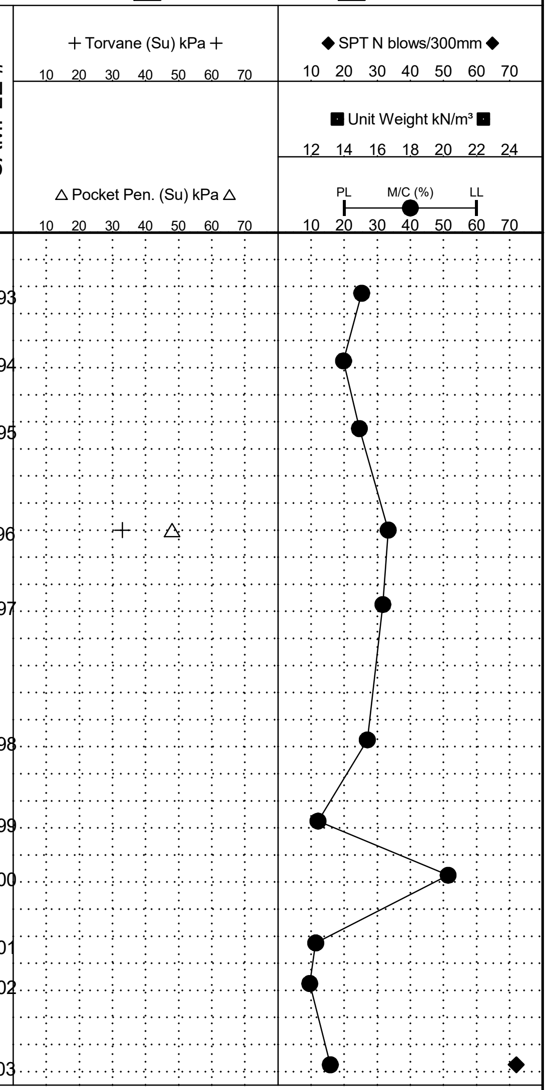
Water levels:
September 23, 2019: 3.93 m below T.O.P. - Ground water elevation - 225.60 m
November 13, 2019: 2.70 m below T.O.P. - Ground water elevation - 226.83 m

DYREGROV ROBINSON INC. Consulting Geotechnical Engineers	LOGGED BY: CR	COMPLETION DEPTH: 6.71 m
	REVIEWED BY: DRAFT	COMPLETION DATE: 30-7-19
	PROJECT ENGINEER: Gil Robinson	Page 1 of 1

PROJECT: Ferry Rd. & Riverbend CSR - Rutland Trunk Sewer	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **19-148**
LOCATION: UTM 14U: 5526210 m N, 627763 m E		PROJECT NO.: 143691
CONTRACTOR: Paddock Drilling Ltd.	METHOD: ACKER SS Drill Rig w/125 mm SS & 200mm HS Augers	ELEVATION (m): 230.566

SAMPLE TYPE	GRAB	SHELBY TUBE	SPLIT SPOON	BULK	NO RECOVERY	CORE
BACKFILL TYPE	BENTONITE	GRAVEL	SLOUGH	GROUT	CUTTINGS	SAND

ELEVATION (m)	DEPTH (m)	SLOTTED PIEZOMETER	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #
230 – 221	0 – 9.6			TOPSOIL (150 mm thick) - black, dry		
				CLAY (Alluvial) - some silt to silty - black with trace organics to 1.5 m - dry to moist - brown below 1.5 m - moist, stiff bvecoming firm below 3 m - intermediate to high plasticity (variable) - wet sand lense at 5.2 m - grey, wet, soft below 5.2 m	GRAB GRAB GRAB SHELBY TUBE GRAB GRAB	G293 G294 G295 T296 G297 G298
				SAND (Alluvial) - brown, wet, loose, coarse grained	GRAB	G299
				CLAY (Glaciolacustrine) - silty - grey - moist, firm to stiff, high plasticity	GRAB	G300
				SILT (TILL) - trace sand, trace gravel - grey, wet, loose becoming moist and dense to very dense at 9 m	GRAB GRAB SPLIT SPOON	G301 G302 S303



END OF TEST HOLE AT 9.6 m IN SILT(TILL) (AUGER REFUSAL)

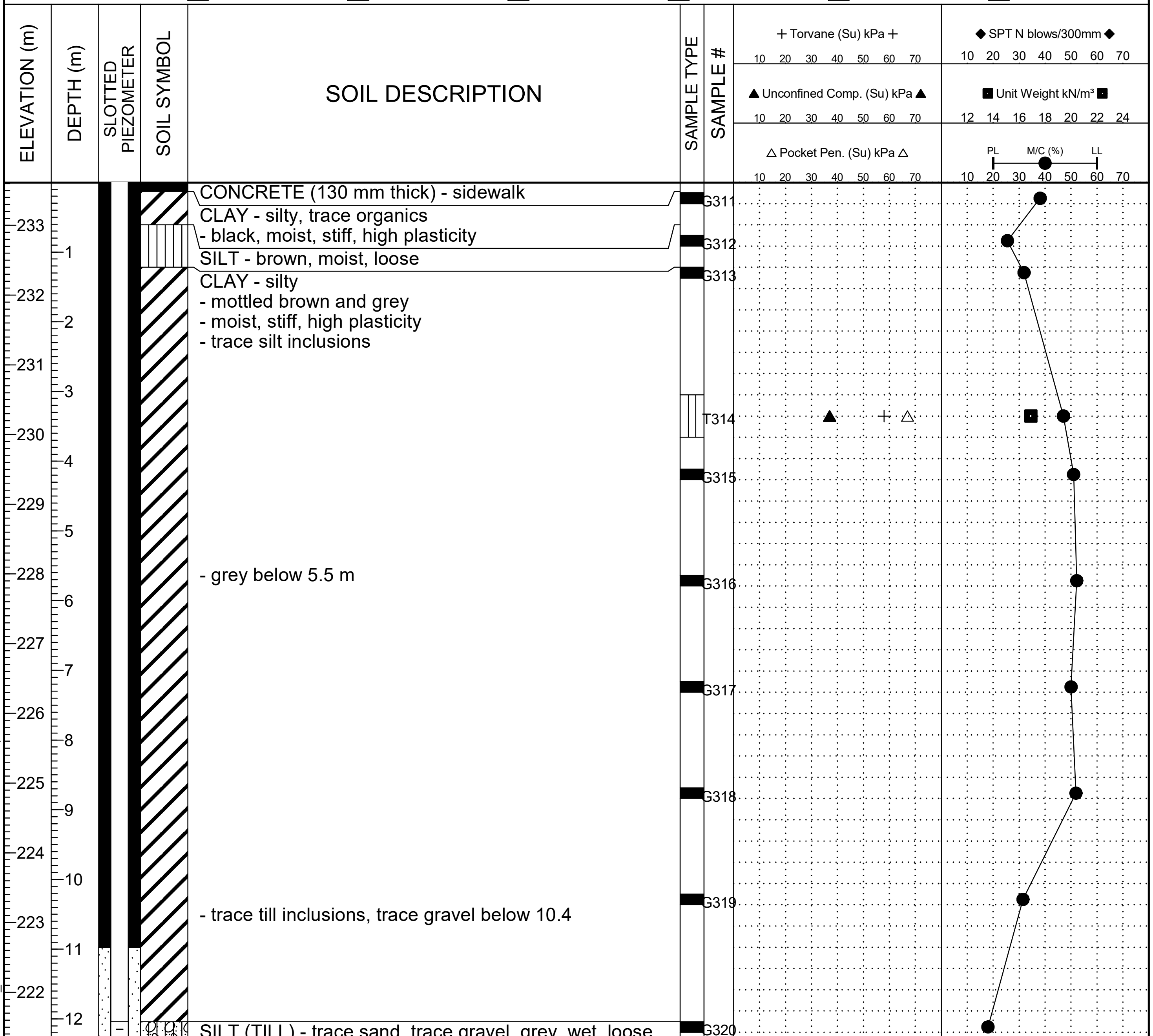
NOTES:
1. Some sloughing and seepage observed.
2. After drilling to 8.8 m, hole caved to 5 m.
   Switched to hollow stem (HS) augers at 8.8 m.
4. 25 mm PVC Standpipe piezometer w/ Cassagrande tip installed 6.4 m b/l grade.
Top of pipe (T.O.P) 0.05 m below grade.
Water levels:
September 23, 2019: 4.13 m below T.O.P. - Ground water elevation at 226.436 m
November 13, 2019: 3.52 m below T.O.P. - Ground water elevation at 227.046 m

DYREGROV ROBINSON INC. Consulting Geotechnical Engineers	LOGGED BY: CR	COMPLETION DEPTH: 9.60 m
	REVIEWED BY: DRAFT	COMPLETION DATE: 29-7-19
	PROJECT ENGINEER: Gil Robinson	

PROJECT: Ferry Rd. & Riverbend CSR - Rutland Trunk Sewer	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **19-155**
LOCATION: UTM 14U: 5526690 m N, 627784 m E		PROJECT NO.: 143691
CONTRACTOR: Paddock Drilling Ltd.	METHOD: ACKER SS Drill w/125 mm SS Augers	ELEVATION (m): 233.629

SAMPLE TYPE: GRAB, SHELBY TUBE, SPLIT SPOON, BULK, NO RECOVERY, CORE

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



CONCRETE (130 mm thick) - sidewalk

CLAY - silty, trace organics
- black, moist, stiff, high plasticity

SILT - brown, moist, loose

CLAY - silty
- mottled brown and grey
- moist, stiff, high plasticity
- trace silt inclusions

- grey below 5.5 m

- trace till inclusions, trace gravel below 10.4

SILT (TILL) - trace sand, trace gravel, grey, wet, loose

END OF TEST HOLE AT 12.3 m IN SILT(TILL)
NOTES:
1. No sloughing or seepage observed during drilling.
2. 25 mm PVC Standpipe piezometer w/ Cassagrande tip installed 12.3 m b/l grade.
Top of pipe (T.O.P) 0.075 m below grade.
Water levels:
September 23, 2019: 7.27 m below T.O.P. - Ground water elevation at 226.284 m
November 13, 2019: 5.10 m below T.O.P. - Ground water elevation at 228.454 m

BH GEOTECH PLOTS-AUGUST 2013 143691.7_RUTLAND TRUNK_GINT.GPJ DATA TEMPLATE - AUGUST 2, 2013.GDT 26-2-20

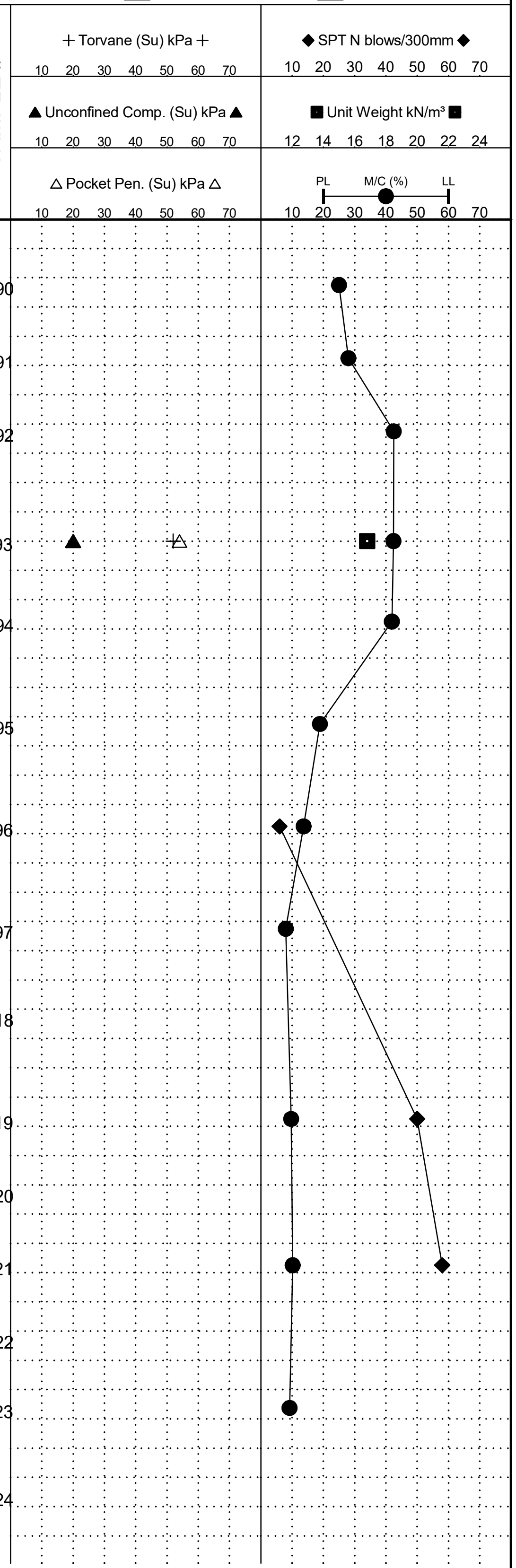
DYREGROV ROBINSON INC. Consulting Geotechnical Engineers	LOGGED BY: CR	COMPLETION DEPTH: 12.34 m
	REVIEWED BY: DRAFT	COMPLETION DATE: 30-7-19
	PROJECT ENGINEER: Gil Robinson	Page 1 of 1

PROJECT: Ferry Rd. & Riverbend CSR - Rutland Trunk Sewer	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **19-173**
LOCATION: UTM 14U: 5527675 m N, 627822 m E		PROJECT NO.: 143691
CONTRACTOR: Paddock Drilling Ltd.	METHOD: ACKER MP8 Drill w/125 mm SS Augers & HQ coring	ELEVATION (m): 235.159

SAMPLE TYPE: GRAB, SHELBY TUBE, SPLIT SPOON, BULK, NO RECOVERY, CORE

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

ELEVATION (m)	DEPTH (m)	SOIL DESCRIPTION	SAMPLE #
235	0	TOPSOIL (75 mm thick) - black, moist	
		CLAY - silty - black with trace organics to 1.8 m - mottled brown / grey below 1.8 m - moist, stiff, high plasticity - trace silt inclusions	G490, G491, G492, T493, G494
230	5	SILT (TILL) - trace sand, trace gravel - grey - moist to wet, loose - moist, dense to very dense below 7 m	G495, S496
228	7	S497) SPT stopped, sampler bouncing after 50 blows & 150 mm penetration	S497, C518, S519, C520, S521, C522
223	12	S523) SPT stopped, sampler bouncing after 39 blows for 380 mm penetration	S523, C524



DYREGROV ROBINSON INC. Consulting Geotechnical Engineers	LOGGED BY: CR	COMPLETION DEPTH: 15.54 m
	REVIEWED BY: DRAFT	COMPLETION DATE: 15-8-19
	PROJECT ENGINEER: Gil Robinson	

PROJECT: Ferry Rd. & Riverbend CSR - Rutland Trunk Sewer	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **19-173**
LOCATION: UTM 14U: 5527675 m N, 627822 m E		PROJECT NO.: 143691
CONTRACTOR: Paddock Drilling Ltd.	METHOD: ACKER MP8 Drill w/125 mm SS Augers & HQ coring	ELEVATION (m): 235.159

SAMPLE TYPE: GRAB, SHELBY TUBE, SPLIT SPOON, BULK, NO RECOVERY, CORE

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

ELEVATION (m)	DEPTH (m)	SLOTTED PIEZOMETER	SOIL SYMBOL	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #	+ Torvane (Su) kPa + / ▲ Unconfined Comp. (Su) kPa ▲ / △ Pocket Pen. (Su) kPa △ (10 20 30 40 50 60 70)	◆ SPT N blows/300mm ◆ (10 20 30 40 50 60 70) / ■ Unit Weight kN/m³ ■ (12 14 16 18 20 22 24) / PL M/C (%) LL (10 20 30 40 50 60 70)
221, 220	15			BEDROCK - Red River Formation, Upper Fort Garry Member (dolomite) - poor to good quality, good below 14 m - whitish grey color, strong to very strong - horizontal and vertical fractures - close to moderately close discontinuity spacing - gapped to open joint apeture, evidence of water flow (Class 3) - 3 mm thick clay filling at 13.7 m and 13.9 m - trace small vugs (< 0.5mm) *continued from previous page*	CORE	C525		

END OF TEST HOLE AT 15.5 m IN BEDROCK
Notes:
1. No sloughing or seepage observed during driling with augers.
2. Upon completion of drilling with augers, test hole open to 7.5 m b/l grade, dry.
3. Auger refusal occured at 7.5 m, switched to HQ coring with casing advancer.
4. 25 mm PVC Standpipe piezometer w/ Cassagrande tip installed 15.5 m b/l grade.
Top of pipe (T.O.P) 0.05 m below grade.
Water levels:
September 23, 2019: 8.43 m below T.O.P. - Ground water elevation at 226.679 m
November 13, 2019: 6.44 m below T.O.P. - Ground water elevation at 228.669 m

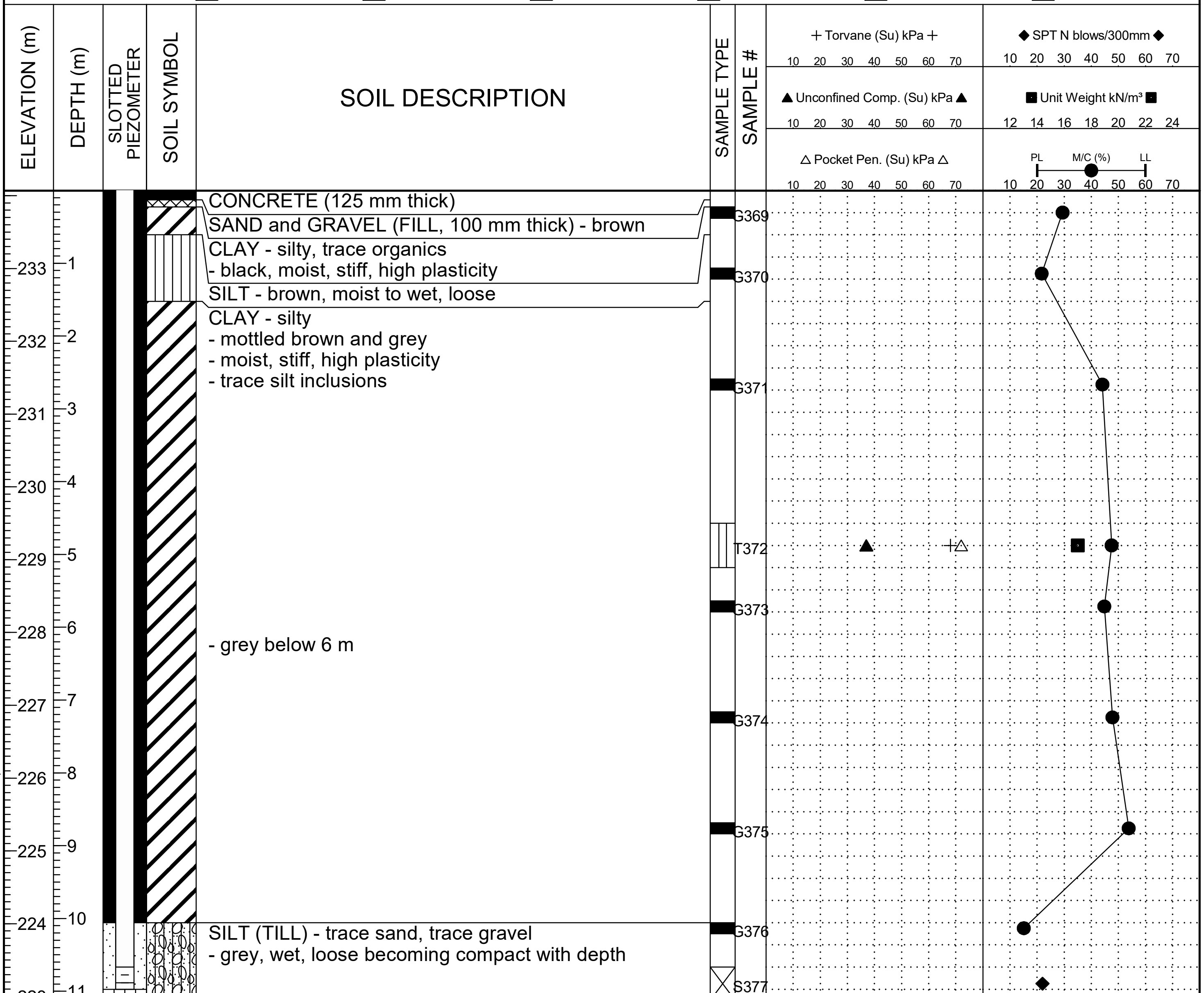
DYREGROV ROBINSON INC.
Consulting Geotechnical Engineers

LOGGED BY: CR	COMPLETION DEPTH: 15.54 m
REVIEWED BY: DRAFT	COMPLETION DATE: 15-8-19
PROJECT ENGINEER: Gil Robinson	Page 2 of 2

PROJECT: Ferry Rd. & Riverbend CSR - Rutland Trunk Sewer	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **19-239**
LOCATION: UTM 14U: 5526983 m N, 627796 m E		PROJECT NO.: 143691
CONTRACTOR: Paddock Drilling Ltd.	METHOD: ACKER SS Drill w/125 mm SS Augers	ELEVATION (m): 234.083

SAMPLE TYPE	GRAB	SHELBY TUBE	SPLIT SPOON	BULK	NO RECOVERY	CORE
BACKFILL TYPE	BENTONITE	GRAVEL	SLOUGH	GROUT	CUTTINGS	SAND

ELEVATION (m)	DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #
234.083	0	CONCRETE (125 mm thick)		
		SAND and GRAVEL (FILL, 100 mm thick) - brown	GRAB	G369
		CLAY - silty, trace organics - black, moist, stiff, high plasticity	GRAB	G370
		SILT - brown, moist to wet, loose		
		CLAY - silty - mottled brown and grey - moist, stiff, high plasticity - trace silt inclusions	GRAB	G371
			SHELBY TUBE	T372
			GRAB	G373
		- grey below 6 m	GRAB	G374
			GRAB	G375
		SILT (TILL) - trace sand, trace gravel - grey, wet, loose becoming compact with depth	GRAB	G376
			SPLIT SPOON	S377



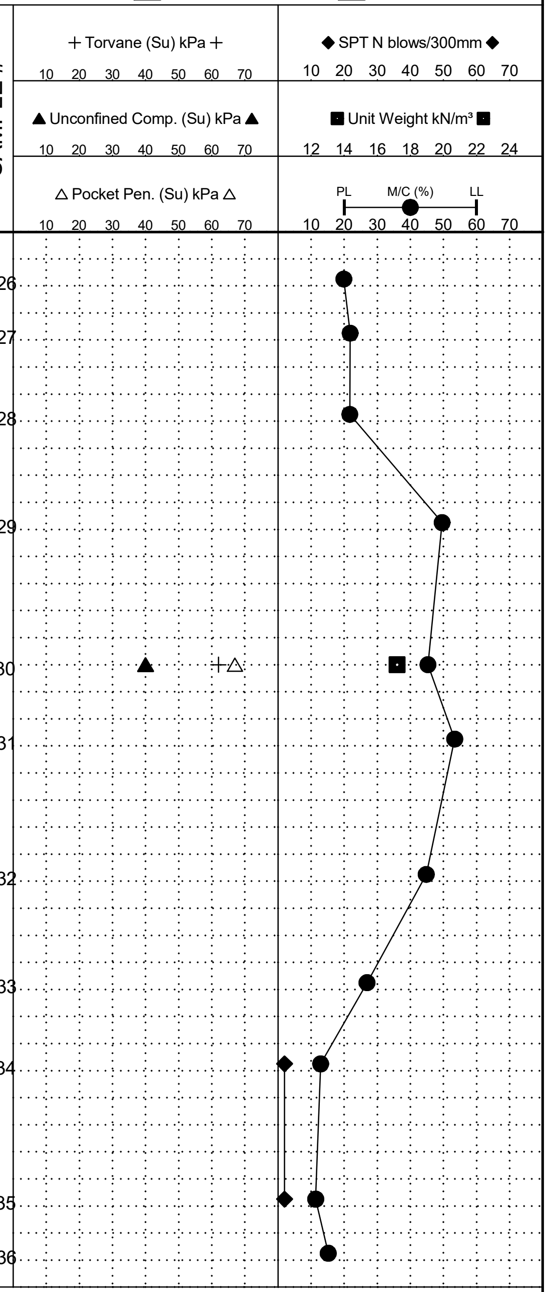
END OF TEST HOLE AT 11.2 m IN SILT(TILL) (AUGER REFUSAL)
NOTES:
1. Some sloughing and seepage observed silt layer 0.6 m.
2. Upon completion of drilling, test hole open to 11 m b/l grade, water level 7.9 m b/l grade.
4. 25 mm PVC Standpipe piezometer w/ Cassagrande tip installed 11 m b/l grade.
Top of pipe (T.O.P) 0.05 m below grade.
Water levels:
September 23, 2019: 7.66 m below T.O.P. - Ground water elevation at 226.373 m
November 13, 2019: 5.50 m below T.O.P. - Ground water elevation at 228.533 m

DYREGROV ROBINSON INC. Consulting Geotechnical Engineers	LOGGED BY: CR	COMPLETION DEPTH: 11.13 m
	REVIEWED BY: DRAFT	COMPLETION DATE: 1-8-19
	PROJECT ENGINEER: Gil Robinson	Page 1 of 1

PROJECT: Ferry Rd. & Riverbend CSR - Rutland Trunk Sewer	CLIENT: Tetra Tech Canada Inc.	TEST HOLE NO: **19-240**
LOCATION: UTM 14U: 5527295 m N, 627808 m E		PROJECT NO.: 143691
CONTRACTOR: Paddock Drilling Ltd.	METHOD: ACKER SS Drill w/125 mm SS Augers	ELEVATION (m): 235.111

SAMPLE TYPE	GRAB	SHELBY TUBE	SPLIT SPOON	BULK	NO RECOVERY	CORE
BACKFILL TYPE	BENTONITE	GRAVEL	SLOUGH	GROUT	CUTTINGS	SAND

ELEVATION (m)	DEPTH (m)	SOIL DESCRIPTION	SAMPLE TYPE	SAMPLE #
235	0	CLAY - silty, trace organics - black, moist, stiff		
		SILT - brown - moist, loose	GRAB	G426
234	1		GRAB	G427
233	2		GRAB	G428
		CLAY - silty - mottled brown and grey - moist, stiff, high plasticity - trace silt inclusions		
232	3		GRAB	G429
231	4			
230	5	- trace sand, trace gravel below 5 m	SHELBY TUBE	T430
		- grey, wet below 5.5 m	GRAB	G431
229	6			
228	7		GRAB	G432
227	8		GRAB	G433
226	9	SILT (TILL) - trace clay, trace sand, trace gravel - grey - wet, loose	SPLIT SPOON	S434
225	10			
224	11		SPLIT SPOON	S435
		- SPT attempted after refusal, no penetration sampler bouncing	GRAB	G436



END OF TEST HOLE AT 11.2 m IN SILT(TILL) (AUGER REFUSAL)
NOTES:
1. Sloughing observed from silt till layer below 9.4 m.
2. No seepage observed during drilling.
3. Upon completion of drilling test hole open to 9.4 m, dry.
4. 25 mm PVC Standpipe piezometer w/ Cassagrande tip installed 9.4 m b/l grade.
Top of pipe (T.O.P) 0.05 m below grade.
Water levels:
September 23, 2019: 8.45 m below T.O.P. - Ground water elevation at 226.611 m
November 13, 2019: 7.80 m below T.O.P. - Ground water elevation at 227.261 m

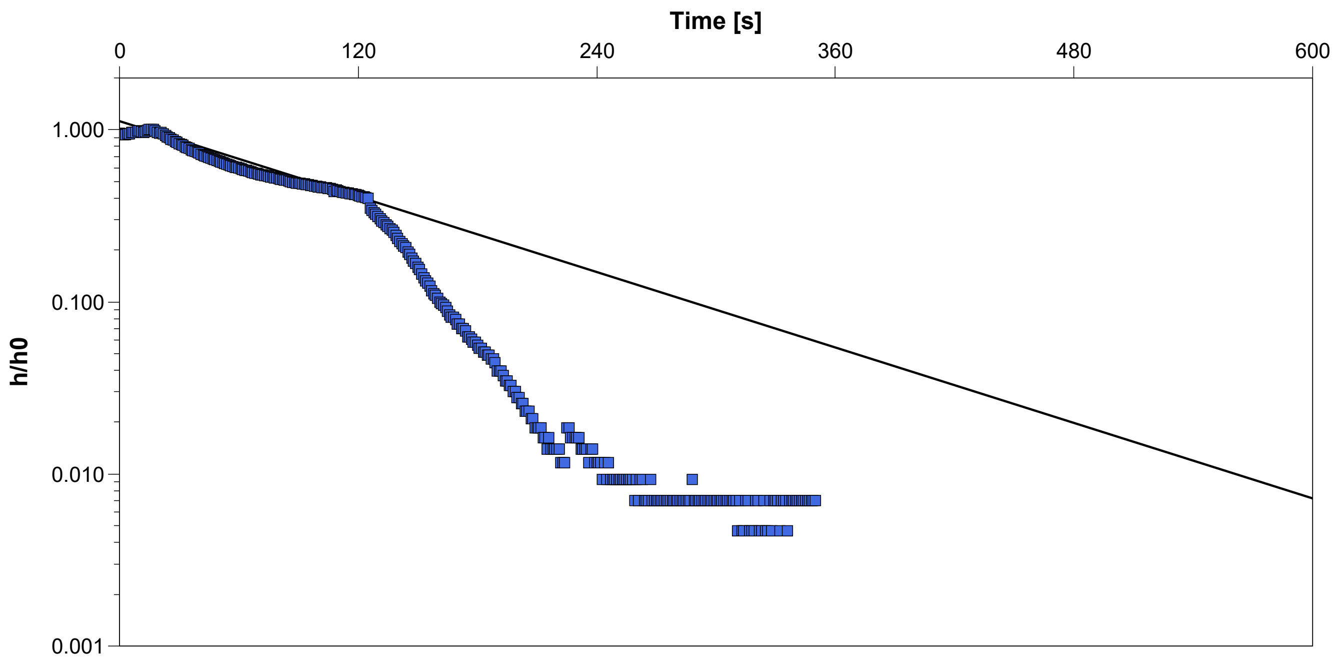
DYREGROV ROBINSON INC. Consulting Geotechnical Engineers	LOGGED BY: CR	COMPLETION DEPTH: 11.89 m
	REVIEWED BY: DRAFT	COMPLETION DATE: 2-8-19
	PROJECT ENGINEER: Gil Robinson	Page 1 of 1

APPENDIX B

HYDRAULIC CONDUCTIVITY GRAPHS

Slug Test Analysis Report	
TETRA TECH	Project: Ferry Road Sewer Line Upgrade
	Number: 705-1000120300
	Client: City of Winnipeg

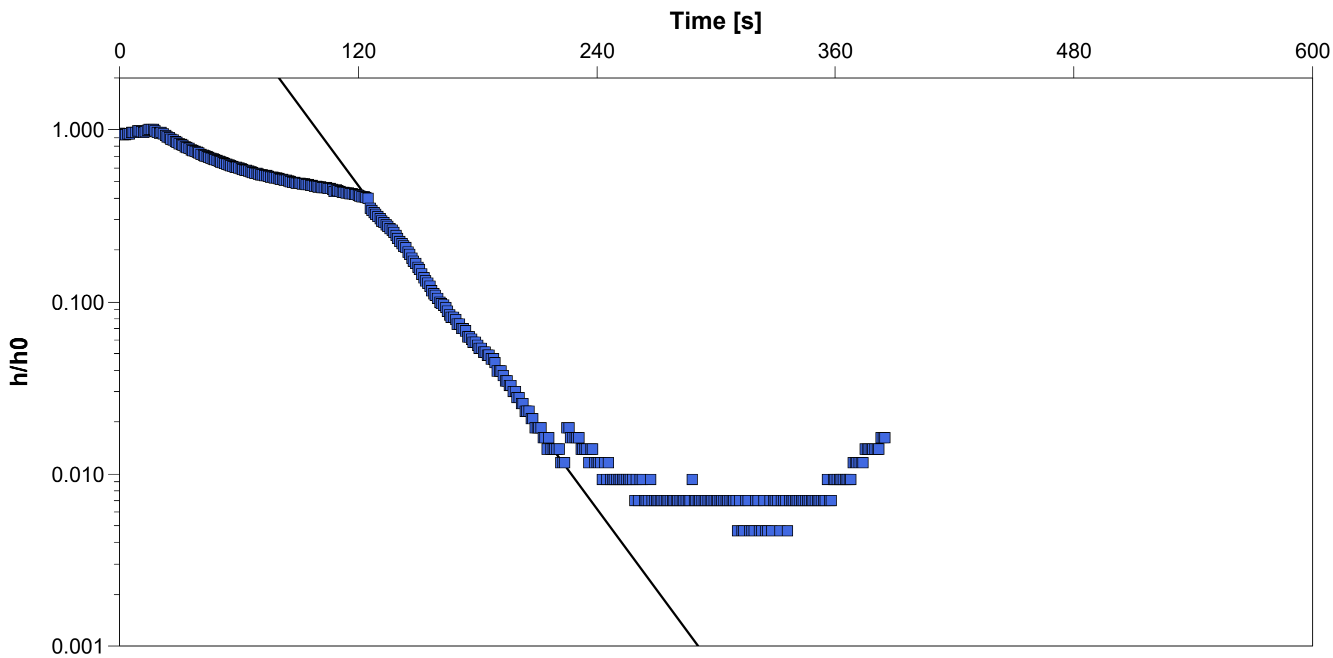
Location: Ferry Road, Winnipeg	Slug Test: TH19-147 Falling Head	Test Well: TH19-147
Test Conducted by: M. Randell		Test Date: 2020-05-25
Analysis Performed by:	TH19-147 Falling Head	Analysis Date: 2020-07-21
Aquifer Thickness: 10.00 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-147	7.00×10^{-6}	

TETRA TECH		**Slug Test Analysis Report**
		Project: Ferry Road Sewer Line Upgrade
		Number: 705-1000120300
		Client: City of Winnipeg
Location: Ferry Road, Winnipeg	Slug Test: TH19-147 Falling Head	Test Well: TH19-147
Test Conducted by: M. Randell		Test Date: 2020-05-25
Analysis Performed by:	TH19-147 Falling Head- Secondary	Analysis Date: 2020-06-11
Aquifer Thickness: 10.00 m		

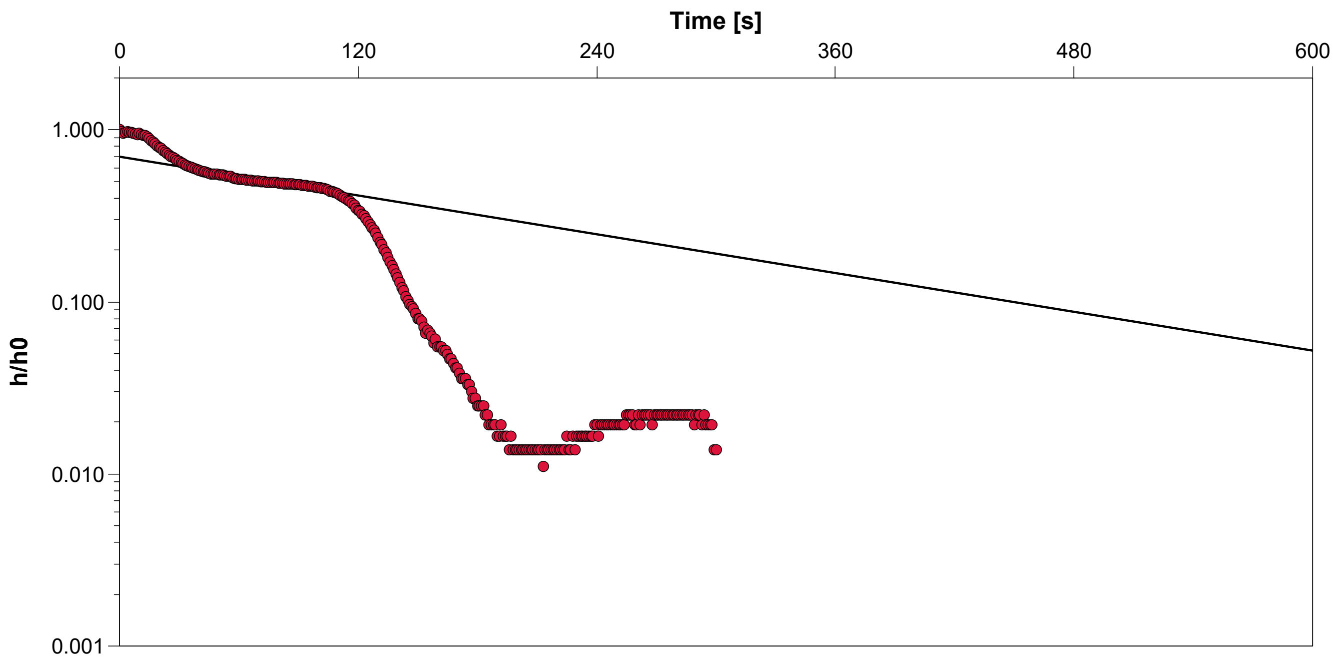


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-147	3.00×10^{-5}	

TETRA TECH	**Slug Test Analysis Report**
	Project: Ferry Road Sewer Line Upgrade
	Number: 705-1000120300
	Client: City of Winnipeg

Location: Ferry Road, Winnipeg	Slug Test: TH19-148 falling Head	Test Well: TH19-148
Test Conducted by:		Test Date: 2020-06-11
Analysis Performed by:	TH19-148 Falling Head	Analysis Date: 2020-07-21
Aquifer Thickness: 10.00 m		

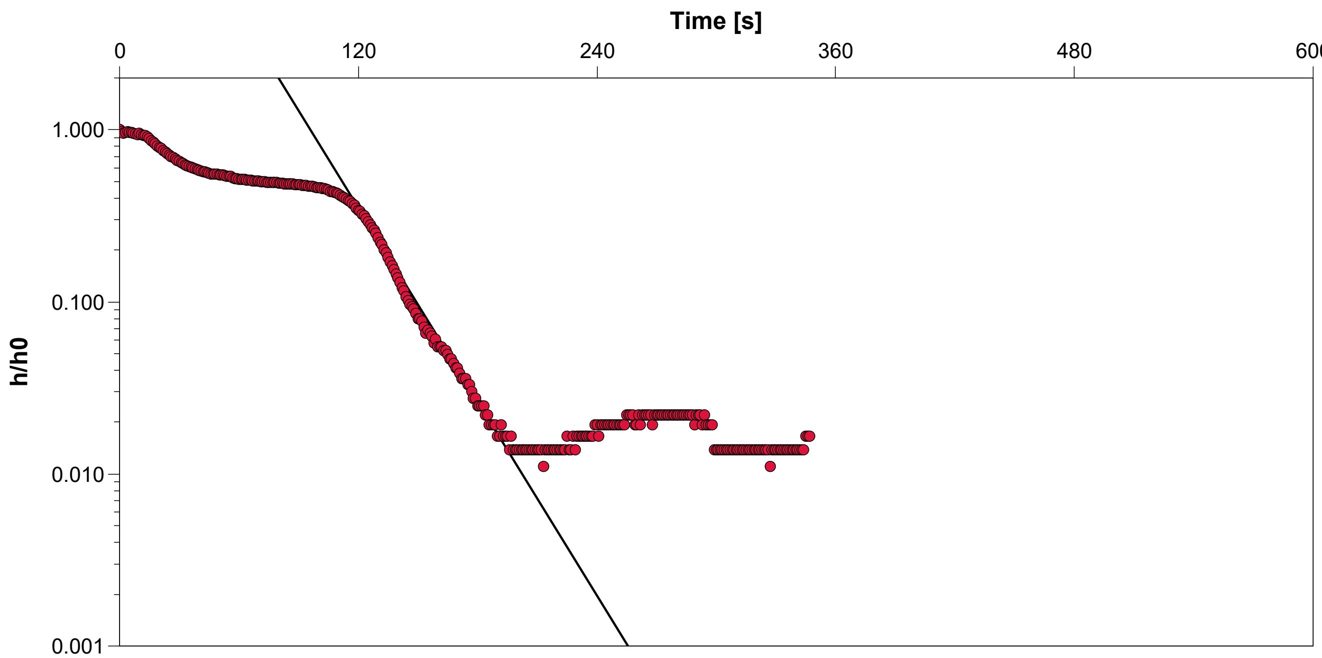


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-148	3.60×10^{-6}	

TETRA TECH	**Slug Test Analysis Report**
	Project: Ferry Road Sewer Line Upgrade
	Number: 705-1000120300
	Client: City of Winnipeg

Location: Ferry Road, Winnipeg	Slug Test: TH19-148 falling Head	Test Well: TH19-148
Test Conducted by:		Test Date: 2020-06-11
Analysis Performed by:	TH19-148 Falling Head - Secondary	Analysis Date: 2020-06-11
Aquifer Thickness: 10.00 m		

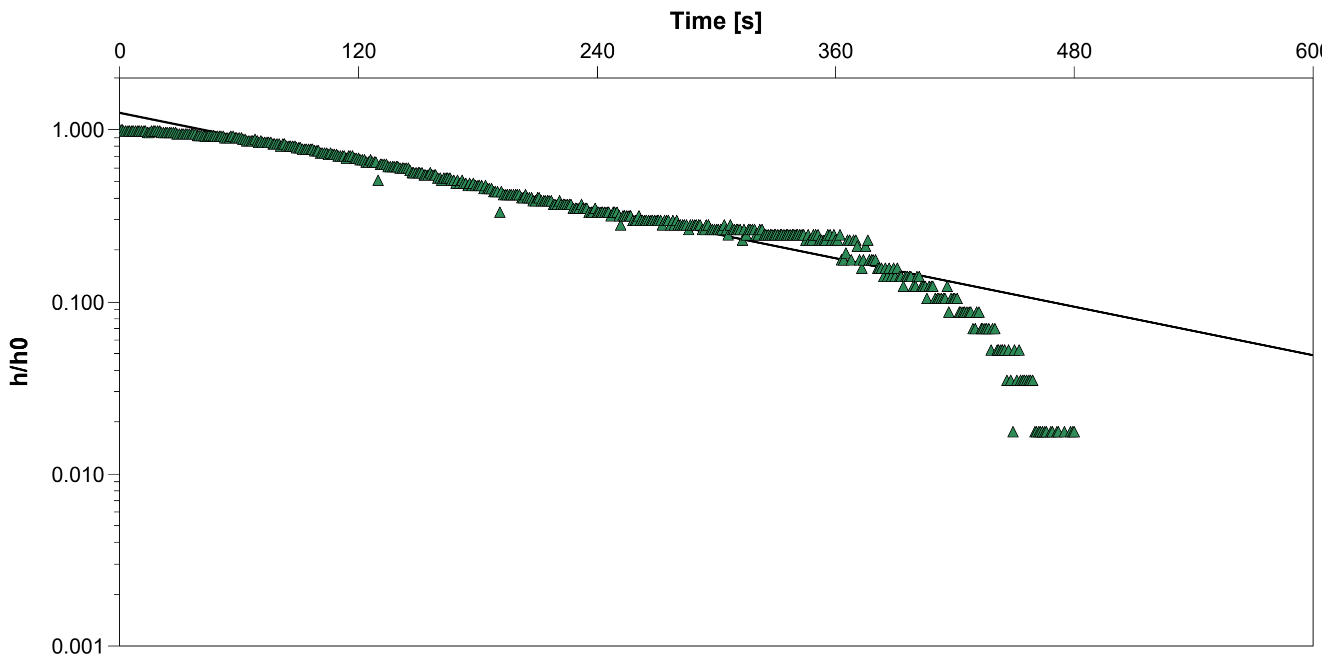


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-148	3.60×10^{-5}	

Slug Test Analysis Report	
TETRA TECH	Project: Ferry Road Sewer Line Upgrade
	Number: 705-1000120300
	Client: City of Winnipeg

Location: Ferry Road, Winnipeg	Slug Test: TH19-155 All Data	Test Well: TH19-155
Test Conducted by: M. Randell		Test Date: 2020-05-25
Analysis Performed by:	TH18-155 Falling Head	Analysis Date: 2020-07-21
Aquifer Thickness: 10.00 m		

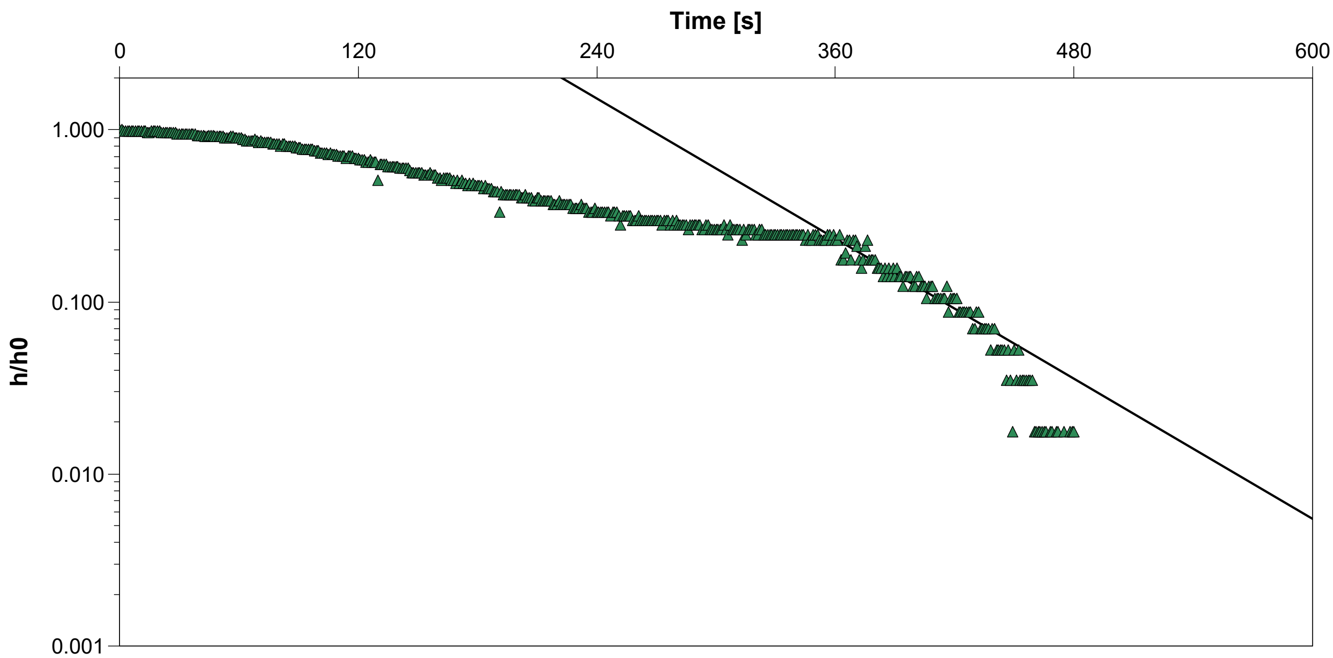


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-155	4.50×10^{-6}	

	Slug Test Analysis Report
	Project: Ferry Road Sewer Line Upgrade
	Number: 705-1000120300
	Client: City of Winnipeg

Location: Ferry Road, Winnipeg	Slug Test: TH19-155 All Data	Test Well: TH19-155
Test Conducted by: M. Randell		Test Date: 2020-05-25
Analysis Performed by:	TH19-155 Falling Head - Secondary	Analysis Date: 2020-07-21
Aquifer Thickness: 10.00 m		

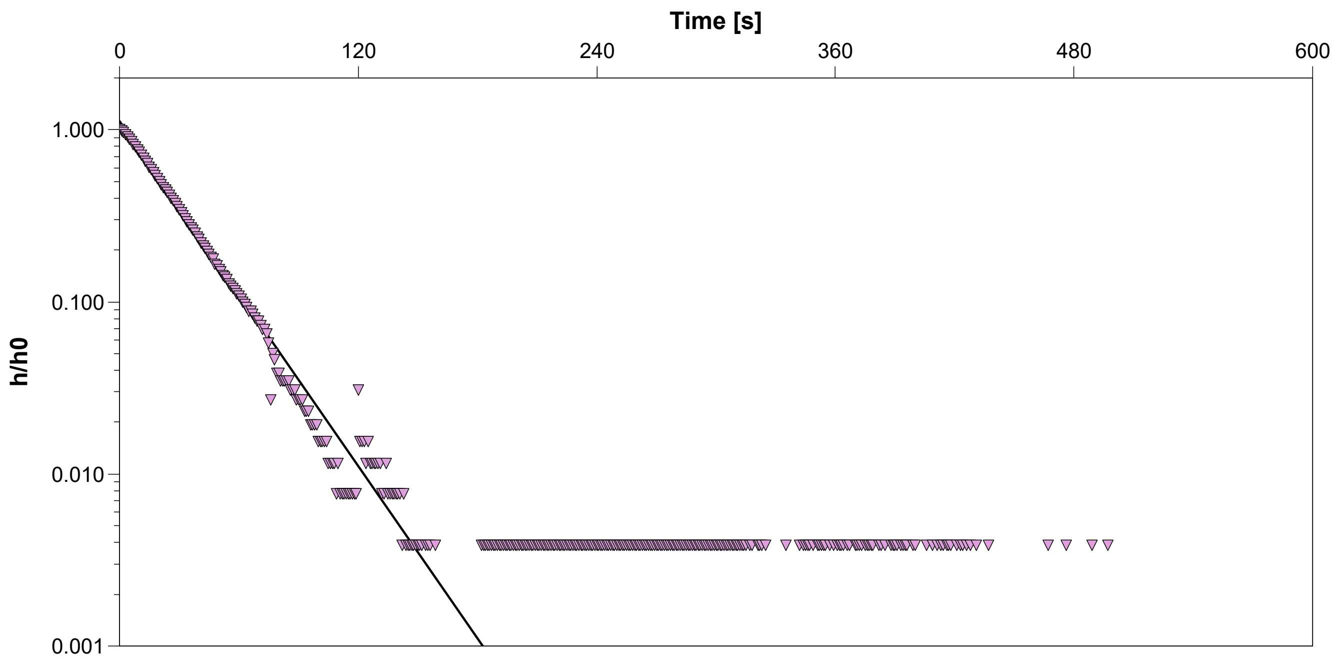


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-155	1.30×10^{-5}	

TETRA TECH	**Slug Test Analysis Report**
	Project: Ferry Road Sewer Line Upgrade
	Number: 705-1000120300
	Client: City of Winnipeg

Location: Ferry Road, Winnipeg	Slug Test: TH19-173 falling 1	Test Well: TH19-173
Test Conducted by:		Test Date: 2020-06-11
Analysis Performed by:	TH19-173 Falling Head	Analysis Date: 2020-06-11
Aquifer Thickness:		

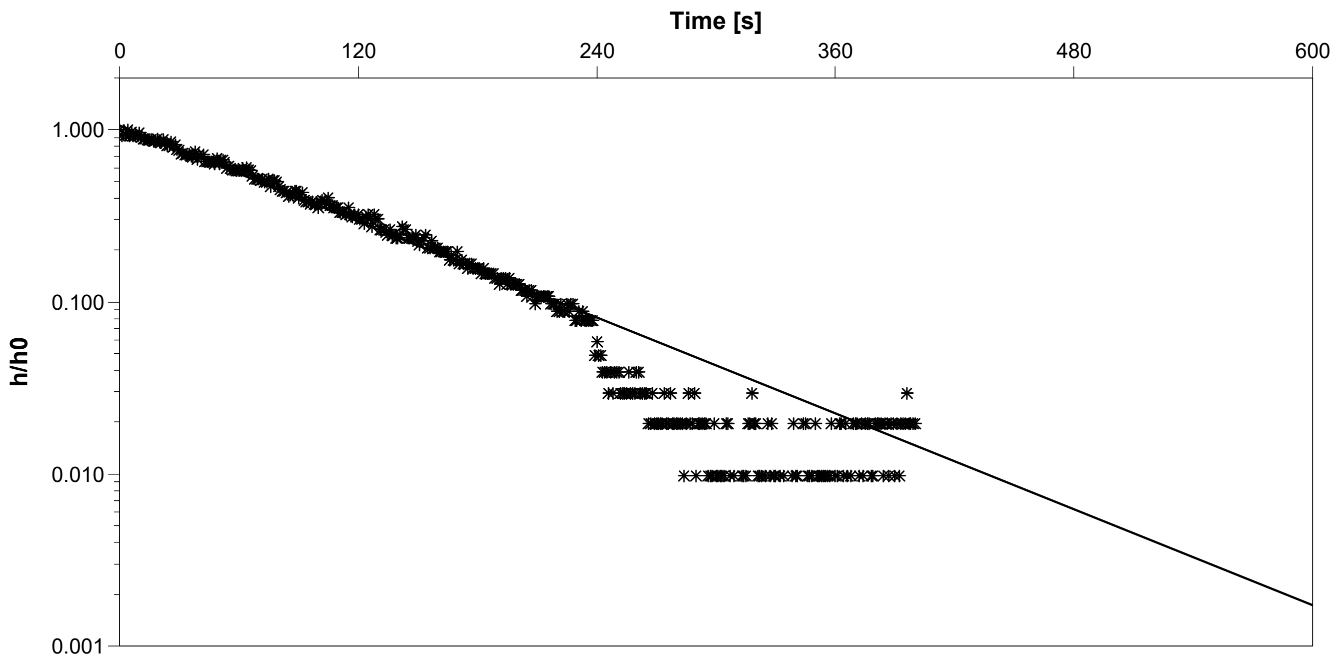


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-173	3.20×10^{-5}	

TETRA TECH	**Slug Test Analysis Report**
	Project: Ferry Road Sewer Line Upgrade
	Number: 705-1000120300
	Client: City of Winnipeg

Location: Ferry Road, Winnipeg	Slug Test: TH19-239 Falling	Test Well: TH19-239
Test Conducted by:		Test Date: 2020-06-11
Analysis Performed by:	TH19-239 Falling Head	Analysis Date: 2020-06-11
Aquifer Thickness: 10.00 m		

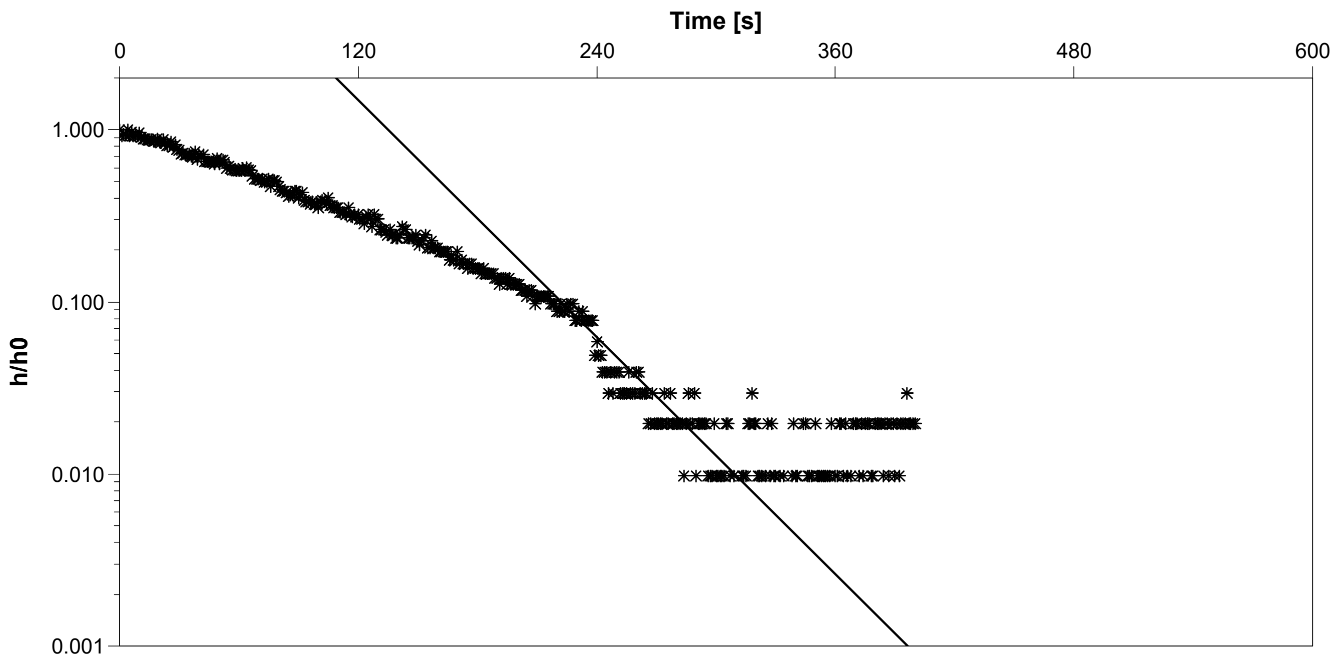


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-239	8.90×10^{-6}	

TETRA TECH	**Slug Test Analysis Report**
	Project: Ferry Road Sewer Line Upgrade
	Number: 705-1000120300
	Client: City of Winnipeg

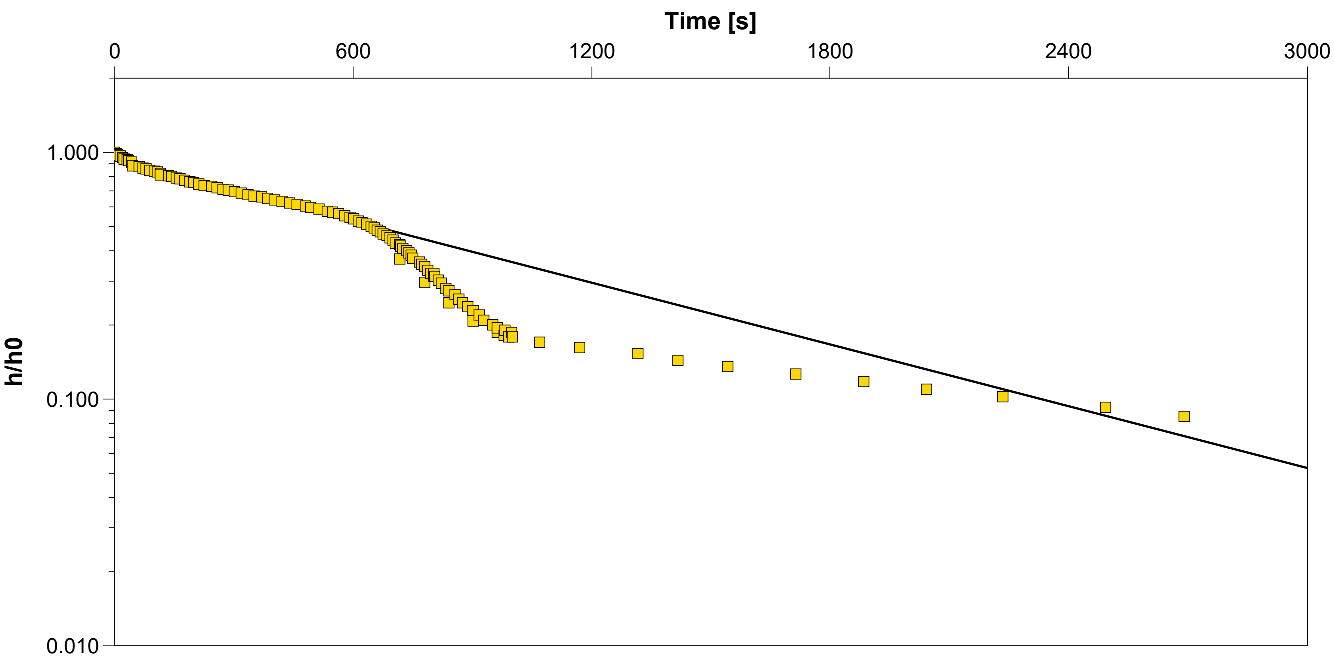
Location: Ferry Road, Winnipeg	Slug Test: TH19-239 Falling	Test Well: TH19-239
Test Conducted by:		Test Date: 2020-06-11
Analysis Performed by:	TH19-239 Falling - Secondary	Analysis Date: 2020-07-22
Aquifer Thickness: 10.00 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-239	2.20×10^{-5}	

TETRA TECH		**Slug Test Analysis Report**
		Project: Ferry Road Sewer Line Upgrade
		Number: 705-1000120300
		Client: City of Winnipeg
Location: Ferry Road, Winnipeg	Slug Test: TH19-240 Falling	Test Well: TH19-240
Test Conducted by:		Test Date: 2020-06-11
Analysis Performed by:	TH19-240 Falling Head	Analysis Date: 2020-06-11
Aquifer Thickness: 10.00 m		

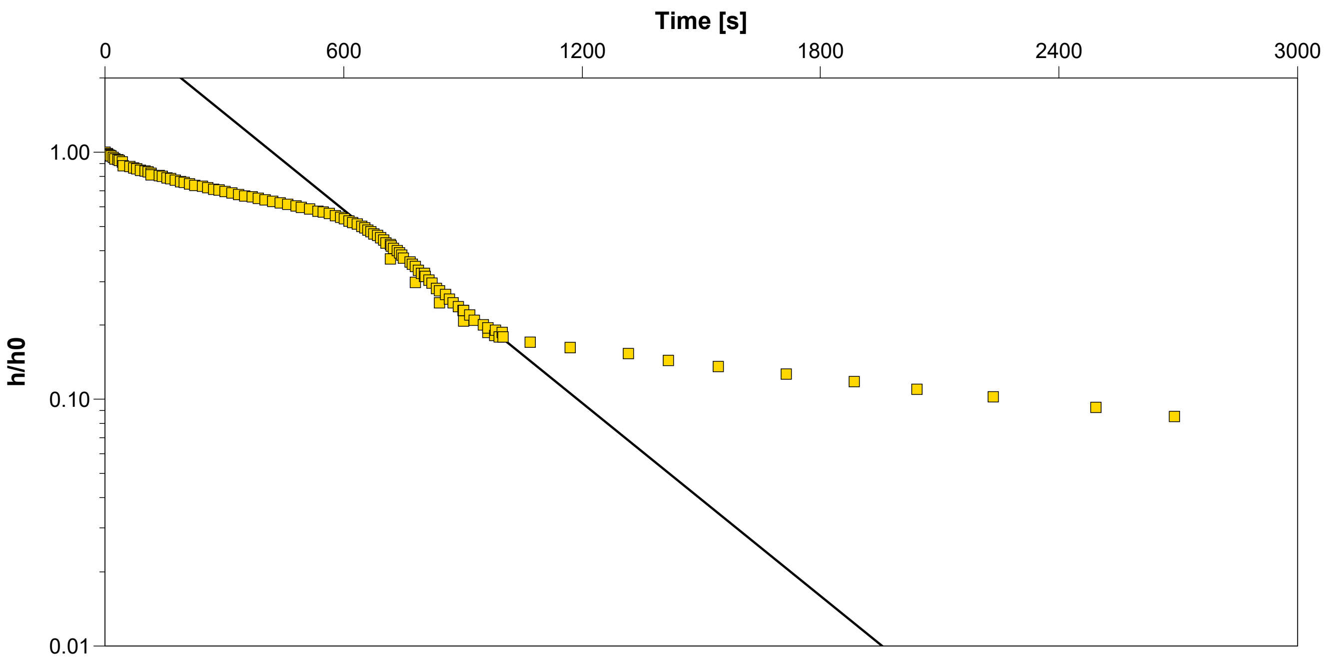


Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-240	8.00×10^{-7}	

Slug Test Analysis Report	
Project: Ferry Road Sewer Line Upgrade	
Number: 705-1000120300	
Client: City of Winnipeg	

Location: Ferry Road, Winnipeg	Slug Test: TH19-240 Falling	Test Well: TH19-240
Test Conducted by:		Test Date: 2020-06-11
Analysis Performed by:	TH19-240 Falling Head - Secondary	Analysis Date: 2020-07-21
Aquifer Thickness: 10.00 m		



Calculation using Hvorslev

Observation Well	Hydraulic Conductivity [m/s]	
TH19-240	2.50×10^{-6}	