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Appendix B

Riverbank Slope Stability Report

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August 26, 2019

File No. 143691.6

Tetra Tech Canada Inc.
400 – 161 Portage Avenue East
Winnipeg, MB. R3B 0Y4

Attn: Kirby McRae, P.Eng., Senior Design Lead

Dear Mr. McRae:

RE: City of Winnipeg – Ferry Road and Riverbend CSR Project
Contract 7 Outfall – Riverbank Bank Stability Assessment – Final Draft

As requested, Dyregrov Robinson Inc. (DRI) has undertaken a stability analysis for the proposed Contract 7 outfall into the Assiniboine River. The outfall is a component of the proposed Ferry Road and Riverbend Combined Sewer Relief Project (Contract 7) that will be located in Bourkevale Park. The park is located between Douglas Park Road and Ferry Road in Winnipeg, Manitoba.

Proposed Outfall

The proposed outfall into the Assiniboine River is located at the east end of Bourkevale Park near an existing outfall structure, as illustrated on Figure 1.

The proposed outfall is located at the downstream end of an inside bend along the Assiniboine River. We understand the final alignment of the outfall piping will be located to minimize impacts to mature trees located in the park and along the river bank. The pipe alignment will be perpendicular to the riverbank slope as illustrated on the plan view drawing in Appendix A. The outfall pipe invert will be around elevation 226.2 m and at the upstream end of the outfall pipe, where it connects to the gate chamber structure, it will be at an elevation of 226.4 m. The LDS pipe invert at the upstream end of the gate chamber will be at an elevation of 226.9 m. Erosion protection of the river bank will be provided at the location of the outfall. The drawings attached in Appendix A show the plan and profile views of the proposed pipe alignment.

Subsurface Conditions

The subsurface conditions for the stability modelling work are based on the test holes (TH's 12-4, 12-33 and 12-34) which were drilled in 2012 near the locations illustrated on Figure 1. A copy of the test hole logs are included in Appendix B. The general stratigraphy encountered in the test holes, from local site grade at each test hole, consists of alluvial clay overlying alluvial silty sand and glacial silt till.

Clay soil was encountered near grade and is an alluvial deposit. The thickness of the clay varies with ground surface elevation. The clay is brown in color, moist with a firm to stiff consistency and is of intermediate to high plasticity. The moisture content of the clay is around 30 percent.

A layer of silty sand (alluvial deposit) was encountered beneath the clay at elevations ranging from 223.6 m to 224.8 m. The sand is grey in color and is wet with a loose to compact condition. The moisture content of the sand is around 20 percent.

Glacial silt till was encountered in Test Holes 12-33 and 12-34 at an elevation around 221.2 m. The till in the Winnipeg area is known to be a heterogeneous mixture of sand, gravel, cobble and boulder size materials in a clay and/or silt matrix. The till encountered in the test holes is a light brown (tan) silt till containing some sand and trace gravel. It is dense and dry with moisture contents around 10 percent. Auger refusal was encountered about 0.5 to 1 m into the till deposit at elevations of 220.3 to 220.7 m.

Some seepage and sloughing was observed in the test holes from the silty sand layer. The groundwater level in the sand is likely to be similar to the river level. The groundwater conditions should be expected to vary seasonally, from year to year and possibly as a result of construction activities.

River Bank Stability

The objective of the work was to evaluate the existing stability of the river bank and evaluate if any stabilization measures are required for the proposed outfall. The stability model was prepared using the cross-sections surveyed and provided to DRI by Tetra Tech Canada Inc. (Tetra Tech) and the subsurface conditions encountered in the test holes.

The stability analysis was performed using Geo-Slope International's Slope/W software program. All models were run using the Morgenstern-Price Method with a half-sine side function.

Four cross-sections were surveyed by Tetra Tech, one along the centerline of the proposed outfall (i.e. perpendicular to the riverbank) plus three cross-sections that are parallel to the property lines of the park. Refer to the plan view drawing in Appendix A.

Existing Conditions

The total height of the river bank about 6.5 m and the average slope angle is about 5H:1V. The riverbank has three general areas, the lower bank area along the river, a relatively flat mid-bank area and the upper bank area that blends into prairie level behind the riverbank. The lower bank area is about 2.5 m tall and has a slope that is about 3.5H:1V. The flatter mid-bank area is about 1.2 m tall and 11 m long yielding a slope angle of about 9H:1V. The upper bank is about 3 m tall with a slope angle around 4.75H:1V. The bank is well vegetated with grass and there are no signs of any deep seated movements of the river bank. The lower bank area along the river may have some shallow localized slip surfaces which are likely affected by erosion along the river's edge. There is an existing outfall located about 15 m upstream of the proposed outfall. The general conditions of the riverbank in the vicinity of the outfall are illustrated on Photographs 1 to 4.

Soil Properties

The soil properties used for the stability analysis work are provided in Table 1. The shear strength parameters assigned to the clay and glacial till are conventional shear strength parameters used in Winnipeg for riverbank stability analysis work.

Table 1 – Soil Properties for Stability Analysis

Material	c' (kPa)	Φ' (degrees)	Sat. Unit Weight (kN/m^3)
Clay (alluvial)	5	17	17.0
Sand	0	32	18.5
Glacial Till	5	30	22.0

Groundwater and River Level Conditions

The groundwater level for all layers was assumed to be 1 or 2 m below prairie level at the left hand side of the stability model cross-section. The winter river level was set at 225.57 m based on the ice levels surveyed by Tetra Tech in 2019 and 2014.

Stability Modeling Results

The stability model outputs are provided in Appendix C. The model results for the existing conditions (see Figures C1 and C2, Appendix C) indicate that the factor of safety associated with the global stability of the riverbank is 1.8 for a groundwater level that is 1 m below prairie level and a factor of safety of 1.96 for a groundwater level that is 2 m below prairie level. The corresponding slip surfaces daylight about 32 m behind the point on the lower riverbank that is coincident with a river level of 225.57 m (i.e. approximately 4 m behind the top of bank).

The local slip surface at the toe area of the river bank (see Figures C3 and C4, Appendix C) has a factor of safety of 2.03 for a groundwater level that is 1 m below prairie level and a factor of safety of 2.08 for a groundwater level that is 2 m below prairie level. The slip surfaces daylight about 7 m behind the point on the lower riverbank that is coincident with a river level of 225.57 m (i.e. approximately 3 m behind the top of the lower bank).

Discussion and Recommendations

The results of the stability modeling indicate that the existing stability of the river bank exceeds the typical target levels of safety for design (i.e. factor of safety of 1.5).

Local regrading of the toe area should be included in the final design to reduce the potential for localized failures to develop. A minimum slope angle of 5H:1V is recommended to match the existing average slope angle of the river bank. A slip collar should be provided in the outfall pipe, based on the riverbank cross-section used for the slope stability analysis work, the slip collar should be located about 6 m back from the point on the lower riverbank that is coincident with a river level of 225.57 m.

Some maintenance of the river bank area upstream and downstream of the outfall zone may be required in the future should erosion related (localized) failures develop over time.

It is recommended that one or two test holes be drilled in close proximity to the final outfall location to confirm that the subsurface conditions from the three test holes referenced in this report are representative and to provide local subsurface information for Contractors bidding the outfall construction work.

Closure

This report was prepared based on our understanding of the proposed Contract 7 outfall into the Assiniboine River at Bourkevale Park, the subsurface conditions encountered in the test holes during the geotechnical investigation and the results of the river bank stability analysis. Subsurface conditions are inherently variable and should be expected to vary across the site.

This report was prepared for the exclusive use of The City of Winnipeg and Tetra Tech Canada Inc. for the Contract 7 outfall to be constructed for the Ferry Road and Riverbend CSR Project. The information contained in this report shall not be used by any third parties for any other projects. The findings presented in this report have been prepared in accordance with generally accepted geotechnical engineering principles and practise. No other warranty, expressed or implied, is provided.

Please contact the undersigned if we can be of further assistance.

DYREGROV ROBINSON INC.

Gil Robinson, M.Sc., P.Eng.
President, Senior Geotechnical Engineer
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DYREGROV ROBINSON INC.
CONSULTING GEOTECHNICAL ENGINEERS

Ferry Road and Riverbend CSR – Contract 7 Outfall
Test Hole Location Plan

SCALE:	MADE BY:	CHKD BY:	PROJECT NO.	DATE:	
NTS	GR	CR	143691	August 2019	**Figure 1**

Photograph 1: Upper Riverbank Area Near Proposed Outfall (4.75H:1V slope angle)

Photograph 2: Mid-Riverbank Area Near Proposed Outfall (9H:1V slope angle)

Photograph 3: Lower Riverbank Area Near Proposed Outfall (3.5H:1V slope angle)

Photograph 4: Existing Outfall Located +/-15m Upstream of Proposed Contract 7 Outfall

Appendix A

Contract 7 Outfall Drawings

DES GN S EED 100
STA 1+000.00
B: 1+000.00
1980 3050 CONC 1953
CS 1.5
350 AC 1959
WWS 5.4
NV S
NV W 225.48
48.3
231.00
231.25
231.50
230.75
230.00
229.00
228.00
227.00
226.00
225.00
224.50
224.25
224.00
1+020
1+040
1+060
1+080
1+100
1+110
E: 1+110.00
FLA GATE
SL CE GATE
1309
21.5
STA:1+068.46
OFF:0.62 L

235
234
233
232
231
230
229
228
227
226
225
224
223
222
0+070
0+080
0+090
0+100
0+110
0+120
0+130
0+140
0+150
0+160
0+170
CONCRETE COLLAR
1+15.0
2700Ø GATE CHAMBER MH
1+46.2
LDS BEND
1+59.7
1
5
nswl 226.27
15.00 OF 1350 LDS AT -0.20%
29.60 OF 1050 LDS AT -0.09%
11.84 OF 1050 LDS AT -0.09%
STA:0+100.00
ELEV:226.20
STA:0+144.60
ELEV:226.40
STA:0+147.85
ELEV:226.92

Appendix B

Test Hole Logs

DYREGROV ROBINSON INC. CONSULTING GEOTECHNICAL ENGINEERS	PROJECT #	TEST HOLE NO.
	113324	12-4

PROJECT:	Ferry Road LDS	LOGGED BY:	RB
LOCATION:	AssiniboineAve. At Ferry Rd.	REVIEWED BY:	AOD
CONTRACTOR:	Paddock Drilling Ltd.	DRILL DATE:	April 17, 2012
METHOD:	Acker Soil Sentry - 125 mm SSA	DRILL DEPTH (m):	7.6

DEPTH (m)	ELEVATION (m)	SOIL SYMBOL	SOIL DESCRIPTION	
0.00	230.82		0 - 0.076 m	SAND AND GRAVEL (Fill)
0.50	230.32		0.076 - 0.9 m	CLAY (Fill) - silty, trace sand, trace gravel - dark brown - stiff, moist, high plasticity
1.00	229.82		0.9 - 7.2 m	CLAY (Alluvial) - stratified with silt and sand - brown
1.50	229.32			- stiff, moist, high plasticity
2.00	228.82			- firm below 1.5 m
2.50	228.32			
3.00	227.82			
3.50	227.32			
4.00	226.82			
4.50	226.32			
5.00	225.82			
5.50	225.32			- grey, soft below 5.3 m
6.00	224.82			
6.50	224.32			- decomposed wood between 6.1 and 7.2 m
7.00	223.82			
7.50	223.32		7.2 - 7.6 m	SAND (Alluvial) - silty - grey, compact, wet, - fine to medium grained, poorly graded
8.00	222.82		7.6 m	END OF TEST HOLE AT 7.6 m IN SAND

Notes:
1. Seepage below 7.2 m from sand layer. Water level at 5.5 m 3 minutes after drilling.
2. Sloughing below 7.2 m in sand layer.
3. Test hole backfilled with auger cuttings.

UNDRAINED SHEAR STRENGTH Su	
QU	UNCONFINED COMPRESSION
TV	TORVANE
PP	POCKET PEN.
γ	UNIT WEIGHT

PP = 37 kPa

DYREGROV ROBINSON INC. CONSULTING GEOTECHNICAL ENGINEERS	**PROJECT #** 113324	**TEST HOLE NO.** 12-33

PROJECT:	Ferry Road LDS	**LOGGED BY:**	RB
LOCATION:	Bourkevale Park - Riverbank	**REVIEWED BY:**	AOD
CONTRACTOR:	Paddock Drilling Ltd.	**DRILL DATE:**	May 22, 2012
METHOD:	Acker Soil Sentry - 125 mm SSA	**DRILL DEPTH (m):**	10.4

DEPTH (m)	ELEVATION (m)	SOIL SYMBOL	SOIL DESCRIPTION		SPT (N) (blows / 300 mm)	UNDRAINED SHEAR STRENGTH Su QU UNCONFINED COMPRESSION TV TORVANE PP POCKET PEN. γ UNIT WEIGHT
0.00	231.10		0 - 0.2 m	CLAY (Topsoil) - silty, trace sand, trace rootlets - black, moist		
0.50	230.60		0.2 - 0.5 m	CLAY - silty, brown, stiff, moist, high plasticity		
1.00	230.10		0.5 - 1.5 m	SAND (Alluvial) - silty - brown, dry - fine grained		
1.50	229.60		1.5 - 6.7 m	CLAY (Alluvial) - stratified with silt and sand - brown - firm, moist, intermediate plasticity		
2.00	229.10					
2.50	228.60					
3.00	228.10					TV = 51 kPa PP = 58 kPa
3.50	227.60					
4.00	227.10					
4.50	226.60					
5.00	226.10					
5.50	225.60			- grey below 5.6 m		
6.00	225.10					TV = 35 kPa PP = 25 kPa
6.50	224.60					
7.00	224.10		6.7 - 9.9 m	SAND (Alluvial) - silty - grey - compact, wet - fine to medium grained - poorly graded		
7.50	223.60					
8.00	223.10			- light grey below 7.8 m	11	
8.50	222.60					
9.00	222.10					
9.50	221.60				15	
10.00	221.10		9.9 - 10.4 m	SILT (Till) - some sand, trace gravel - tan - dense, dry		
10.50	220.60		10.4 m	END OF TEST HOLE AT AUGER REFUSAL AT 10.4 m IN SILT TILL Notes: 1. Seepage below 6.1 m from sand layer. 2. Sloughing below 6.7 m in sand layer. 3. Water level at 6.1 m below ground surface immediately after drilling. 4. Sloughing below 6.1 m in sand layer. 5. Test hole backfilled with auger cuttings to 6.1 m and bentonite chips to ground surface.		

DYREGROV ROBINSON INC.
CONSULTING GEOTECHNICAL ENGINEERS

PROJECT #	TEST HOLE NO.
113324	12-34

PROJECT:	Ferry Road LDS	**LOGGED BY:**	RB
LOCATION:	Bourkevale Park - Riverbank	**REVIEWED BY:**	AOD
CONTRACTOR:	Paddock Drilling Ltd.	**DRILL DATE:**	May 22, 2012
METHOD:	Acker Soil Sentry - 125 mm SSA	**DRILL DEPTH (m):**	7.5

DEPTH (m)	ELEVATION (m)	SOIL SYMBOL	SOIL DESCRIPTION	SPT (N) (blows / 300 mm)	PIEZOMETER	UNDRAINED SHEAR STRENGTH Su
0.00	227.83		0 - 0.46 m SAND (Alluvial) - clayey, silty, trace gravel - black, moist			
0.50	227.33		0.46 - 3.0 m CLAY (Alluvial) - stratified with silt and sand - brown			
1.00	226.83		- stiff, moist, intermediate plasticity			
1.50	226.33		- grey, firm, wet below 1.5 m			Qu = 15 kPa TV = 38 kPa PP = 41 kPa γ = 17.4 kN/m³
2.00	225.83					
2.50	225.33					
3.00	224.83		3.0 - 6.6 m SAND (Alluvial) - silty, some gravel - trace cobbles			
3.50	224.33		- grey - loose, wet			
4.00	223.83					
4.50	223.33					
5.00	222.83					
5.50	222.33		- compact below 5.3 m			
6.00	221.83					
6.50	221.33			20		blows per 150 mm
7.00	220.83		6.6 - 7.5 m SILT (Till) - some sand, trace gravel - tan - dense, dry	24		blows per 75 mm refusal to penetration
7.50	220.33					
8.00	219.83		7.5 m END OF TEST HOLE AT AUGER REFUSAL AT 7.5 m IN SILT TILL			

Notes:
1. Seepage below 1.5 m from clay layer. Water level at 2.7 m immediately after drilling.
2. Sloughing below 3.0 m in sand layer.
3. No soil recovery in silt till.
4. Standpipe piezometer with Casagrande tip installed to 6.1 m.
5. Water level measured at 1.33 m below ground surface on June 12, 2012.
6. Test hole backfilled with sand to 5.3 m, bentonite chips to ground surface. Piezometer protected with a flushmount cover.

UNDRAINED SHEAR STRENGTH Su	
QU	UNCONFINED COMPRESSION
TV	TORVANE
PP	POCKET PEN.
γ	UNIT WEIGHT

Appendix C

Stability Modelling Results

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay (alluvial)	Mohr-Coulomb	17	5	17
	Sand	Mohr-Coulomb	18.5	0	32
	Glacial Till	Mohr-Coulomb	22	5	30

GWL = 1 m below grade
Winter River Level = 225.57 m

Figure C1

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay (alluvial)	Mohr-Coulomb	17	5	17
	Sand	Mohr-Coulomb	18.5	0	32
	Glacial Till	Mohr-Coulomb	22	5	30

GWL = 2 m below grade
Winter River Level = 225.57 m

Figure C2

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay (alluvial)	Mohr-Coulomb	17	5	17
	Sand	Mohr-Coulomb	18.5	0	32
	Glacial Till	Mohr-Coulomb	22	5	30

GWL = 1 m below grade
Winter River Level = 225.57 m

Figure C3

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)
	Clay (alluvial)	Mohr-Coulomb	17	5	17
	Sand	Mohr-Coulomb	18.5	0	32
	Glacial Till	Mohr-Coulomb	22	5	30

GWL = 2 m below grade
Winter River Level = 225.57 m

Figure C4