APPENDIX ‘A’

BACKGROUND INFORMATION

TREK GEOTECHNICAL
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The City of Winnipeg

Preliminary Engineering Study for Lyndale Drive Retaining Wall – Monck Avenue to Gauvin Street Geotechnical Assessment Report

Prepared for:

Mr. Cam Ward, P.Eng.
The City of Winnipeg
Public Works Department
102 – 1155 Pacific Avenue
Winnipeg, Manitoba
R3E 3P1

Project Number:
0015 014 00

Date:
February 23, 2016

TREK GEOTECHNICAL
Quality Engineering | Valued Relationships

February 23, 2016 Our File No. 0015 014 00

Mr. Cam Ward, P.Eng
The City of Winnipeg
Public Works Department
102 – 1155 Pacific Avenue
Winnipeg, Manitoba
R3E 3P1

RE: Preliminary Engineering Study for Lyndale Drive Retaining Wall – Monck Avenue to Gauvin Street
Geotechnical Assessment Report

TREK Geotechnical Inc. is pleased to submit our Final Report for the Geotechnical Assessment for the above noted project.

Please contact the undersigned if you have any questions. Thank you for the opportunity to serve you on this assignment.

Sincerely,

TREK Geotechnical Inc.
Per:

Michael Van Helden, Ph.D., P.Eng
Principal, Geotechnical Engineer
Tel: 204.975.9433 ext. 102

Encl.

Revision History

Revision No.	Author	Issue Date	Description
0	MVH	February 1, 2016	Draft Report
1	MVH	February 23, 2016	Final Report

Authorization Signatures

PROVINCE OF MANITOBA
2016/02/23
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24729
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Senior Geotechnical Engineer

APEGM
Certificate of Authorization
Trek Geotechnical Inc.
No. 4877 Date: Feb. 23/16

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1.0 Introduction

This report summarizes the results of geotechnical riverbank monitoring and slope stability analysis completed by TREK Geotechnical Inc. (TREK) to evaluate the existing riverbank stability along Lyndale Drive within the study area extending from Monck Avenue to Gauvin Street. TREK was retained by the City of Winnipeg Public Works Department to conduct a preliminary engineering study for the Lyndale Drive retaining wall along this portion of the riverbank. The terms of reference for this work are based on the scope of work identified in TREK's proposal to The City of Winnipeg Public Works Department dated November 2, 2015. TREK was previously engaged by the City to provide preliminary, detailed design and contract administration for emergency riverbank stabilization along Lyndale Drive between Monck Avenue and Avenue Taché, as well as subsequent sub-surface investigations and monitoring within the current study area. TREK has retained numerous sub-consultants for various components of the current assignment, including Bruce Harding Consulting Ltd. (BHC) for river hydraulics and Morrison Hershfield Ltd. (MHL) for structural, municipal and transportation; recommendations provided by BHC and MHL in their separate assessment reports are referenced herein, although these reports are not attached.

2.0 Background

Site History

Lyndale Drive is located along high ground on the outside bend of the Red River which forms a portion of the City's Primary Diking System, Winnipeg's Primary Line of Defence during a flood (Figure 01). The existing timber pile wall along Lyndale Drive was constructed in 1976 to address ongoing riverbank instabilities which threatened the road and dike; the approximate bank crest (head scarps) observed prior to the 1976 wall construction is shown in Figure 01. The wall is approximately 575 m long, extending from just upstream of Gauvin Street to just upstream of Monck Avenue. It consists of 12 m long timber piles driven with their butts to ground (street) level. The riverbank was then excavated on the river side of the piles to a depth of about 2 m and timber lagging was installed. The bank was then regraded to the river at about 5 horizontal to 1 vertical (5H:1V) and riprap was placed along the edge of the river. A network of trench drains was also installed in the regraded portion of the slope to provide for a more rapid run-off of surface water.

In 2000, an extension to the downstream end of the 1976 timber pile wall was added between Monck Avenue and Claremont Avenue (Site WW-2) to mitigate riverbank instabilities reported following the 1997 flood. It was determined by UMA Engineering that the instability of the bank at this location posed an unacceptable level of risk to the road, dike and other infrastructure along the top of bank. It was believed that the next slump block to develop would likely dislodge a section of the road and dike causing extensive damage and severely limiting available stabilization options. The new wall was constructed using longer timber piles driven into the till and was tied back using helical soil anchors and a concrete pile cap was constructed to support a railing. The riverbank was regraded downslope of the wall and riprap was added along the edge of the river. During construction, a decision was made by the City to extend the pile cap 18 m onto the downstream end of the 1976 timber pile wall and add up to 0.5 m of granular fill behind the pile cap to attain drainage towards the street.

<u>2013 Emergency Stabilization Works and Post-Construction Monitoring</u>

Movements of the retaining wall towards the river were observed in April of 2013; about 300 mm of horizontal movement of the top of the wall and 100 mm settlement of the asphalt pavement in the east bound lane of Lyndale Drive were observed. Crack patterns in the pavement indicated the movement had extended north to about the middle of the road and as a result, the east bound lane was closed to traffic. The movements occurred along the downstream end of the 1976 retaining wall, including the 18 m wall section fitted with the concrete pile cap. Emergency riverbank stabilization works consisting of 48 rockfill columns were implemented in the fall of 2013 to address the ongoing movements. Wall deflections and pavement settlement continued as the stabilization works were constructed, however slowed significantly upon completion of the works. The pavement distress and deflected wall are shown in Photo 01. Vibrating-wire pieozmeters and slope inclinometers were installed in TH13-01 and 13-02 at the locations shown in Figure 01.

Photo 01 View Downstream at Retaining Wall Movement and Pavement Subsidence

Following the emergency bank stabilization works, TREK conducted additional sub-surface investigations to install riverbank monitoring instrumentation along the remainder of the 1976 wall, upstream of the emergency stabilization works, in order to characterize the risk of potential riverbank and wall movements in that area. Test holes TH15-03 to TH15-09 were drilled along three cross-sections at the locations shown on Figure 01. Vibrating-wire (VW) piezometers and slope inclinometers (SI) were installed in the test holes to monitor groundwater conditions and riverbank movements.

Instrumentation in both the 2013 stabilized portion and the upstream portion was monitored for a period of two years, concluding in late November 2015 following the fall drawdown event. Monitoring results were summarized in separate letters for the 2013 stabilized and the upstream unstabilized portions of the riverbank, which are attached in Appendix A.

3.0 Site and Sub-surface Conditions

3.1 Soil Stratigraphy

A brief summary of the soil units encountered in previous investigations is provided below. All design interpretations made on the basis of soil stratigraphy should refer to the more detailed information presented on the test hole logs (provided previously). The locations of previous test holes are shown on Figure 01, as well as in four cross-sections (A to D) on Figures 02 to 05. Test hole logs are included in the previous monitoring reports in Appendix A.

In general, the soil stratigraphy consists of thin layers of fill, clay and silt (overall thickness of up to 2 m) in the upper bank area (behind the retaining wall), underlain by a thick layer of high plastic (Lacustrine) clay and compact to dense silt till . The silt till elevation varies across the site, generally rising from about Elev. 214.8 to 215.7 m at Cross-section A (within the 2013 stabilized section) to about Elev 216.8 to 217.8 m at Cross-sections B, C and D.

3.2 Groundwater Conditions

A detailed summary of monitored groundwater conditions was provided in our previous letter reports; a brief overview will be provided herein. It is important to note that the measured piezometric levels are valid at the time they were recorded, and that levels may vary between readings or spatially between piezometers.

Figure 05 shows the monitoring results for all piezometers in both the stabilized and unstabilized portions of the riverbank. The critical period for stability is following the fall drawdown where piezometric levels in the clay and till remain high as the river level falls. Following the fall drawdown events, the piezometric elevation in the till closely follows the river level in the lower bank (VW-7B), but remains about 1 to 1.5 m higher than the river level in the upper bank (VWs 1B & 5B). Similarly, the piezometric elevation in the clay is approximately 1.5 m above the winter river level (VW-7A), whereas the upper bank piezometric elevation in the clay is about 3 to 4 m above river level. Based on these monitoring results, the groundwater flow regime after fall drawdown consists of a downward flow gradient (from the clay to the till) in the upper bank of about 0.4 to 0.7 m of head per metre of depth, with a smaller downward flow gradient in the lower bank of about 0.3 m of head per metre of depth. In comparison of the results for VW-1A/1B with VW-5A/5B, the piezometric levels at Cross-section A appear to be about 0.5 m higher than the level at Cross-section C, but show similar seasonal variations.

3.3 River Morphology

A detailed assessment of river hydraulics has been provided in a separate report by BHC dated January 26, 2016, however a brief discussion of the impacts of channel hydraulics and erosion will be discussed herein.

In general, the outside bends of river meanders experience prolonged erosion and bank loss, whereas inside bends see aggradation (deposition) with the exception being during extreme flood events due to high river velocity profiles. At the current site, a constriction in the upper bank area (Churchill Drive) on the south bank (inside bend) has caused a constriction to flow at high flood stage, which has resulted in down-cutting (scour of the river bottom) within this reach of the river. Six cross-sections of the river were surveyed for ground topography as well as bathymetry, as shown on Figure 06; numbered cross-sections are as referenced in the hydraulics assessment report, whereas the lettered cross-sections correspond to those shown on Figure 01 for the geotechnical assessment. Upstream of the constriction (XS-1), the river bottom is relatively flat at Elev. 219 to 221 m. Proceeding in a downstream direction from XS-4 to XS-10, the river bottom lowers as a result of the flood-stage velocities, down to about Elev. 217 m; this elevation coincides with the approximate till elevation from the test holes. Downstream of the constriction (towards XS-13 and XS-16) the river bottom rises again, almost as high as at the upstream limit. The zone of scour in the river bottom is approximately 100 to 150 m south of the Lyndale Drive retaining wall, or about 50 to 100 mm south of the winter river level shoreline. Given the relative large distance from the shoreline to the scour zone, it is unlikely that the scour in this area is affecting stability of the Lyndale Drive riverbank. Minor erosion of the lower toe of the riverbank slope was noted during the site reconnaissance and in the hydraulics report, at or below about Elev. 223 m; due to the presence of riprap at surface and at shallow depths below ground along the shoreline, it is unclear if the visible erosion had undermined the riprap or if the eroded materials were recent sediments deposited by the river.

3.4 Slope Movement

A detailed summary of slope inclinometer monitoring was provided in our previous letter reports; a brief overview will be provided herein.

This section of the riverbank has been historically prone to riverbank movements in the area down-slope of the current retaining wall. In 1976, the retaining wall was installed upslope of the extent of riverbank movements and the bank was offloaded (flattened) downslope of the wall. The top of bank (slope crest) prior to offloading is shown in Figure 01, based on design drawings for the 1976 retaining wall, which is indicative of the extent of riverbank movements. The existing ground profile prior to offloading is also shown in cross-section on Figures 03 to 05. As shown, the wall is situated approximately 3 to 7 m beyond the 1976 slope crest along sections B and C, whereas significantly more offloading occurred at section D where the wall is situated about 13 m beyond the 1976 slope crest.

Cracking, settlement and translational movement of the pavement surface occurred between Monck Avenue and Avenue Taché in 2013 as a result of deep-seated rotational movement of a riverbank instability down-slope of the 1976 timber pile retaining wall. Based on monitoring and subsequent analysis as part of our previous scope of work, it appears the riverbank instability reduced lateral earth pressure against the retaining wall causing the wall to lean towards the river and mobilize an "active wedge" mode of failure behind the retaining wall. The more recently constructed tied-back (2000) retaining wall remained stable, although the riverbank instability also extended in front of the tied-back wall. As such, it was concluded that the 1976 timber pile wall in this area became unstable due to a lack of toe restraint (the piles were not embedded into till) combined with a lack of tie-back reinforcement.

As summarized in our previous monitoring reports (Appendix A), the rate of inclinometer displacement along cross-section A (SI-1B and SI-2B) has effectively subsided as a result of stabilization works (rockfill columns) implemented in 2013 from Monck to Taché. From 2013 to 2015, and in particular in the fall of 2015, differential shear displacements have been observed in SI-4, SI-6 and SI-7 along cross-sections B and C, which can be attributed to active instabilities in the mid to lower bank areas. Differential displacement over the 2015 fall drawdown were about 45 mm in SI-4, and potentially much larger in SI-7 since the inclinometer could no longer be monitored due to excessive differential movement (*i.e.* sheared off). Shallow displacements were also observed in mid-bank inclinometer SI-6 (cross-section C) that can potentially be due to proximity of a down-slope head scarp. Small displacements attributed to creep movements were observed at a shallow depth in SI-9 (cross-section D) as well as at depths just above the till interface in all lower-bank and mid-bank inclinometers. In the upper bank (SI-5), negligible movements were observed with the exception of tilting in the upper 6 m, possibly due to down-slope creep movements combined with deterioration and deflection of the upper portion of the timber pile retaining wall. No differential movement was observed along cross-section D.

Due to the presence of deep creep movements and active mid to lower bank instabilities, there is a potential for retrogression of the active movements which would potentially impact the stability of the retaining wall and adjacent infrastructure, similar to the event of 2013, although the time frame for this to occur is uncertain. In their structural condition assessment report (submitted separately) dated January 29, 2016, MHL noted a "noteworthy presence of damage in the form of weathering, bleaching, plant rooting, corroded fasteners, splits, checks and decay". The presence of such deterioration in some piles is indicative that the entire wall in general is in that condition. Given the potential for retrogression of riverbank instabilities and the poor condition of the existing retaining wall, there is a clear risk to the roadway and associated infrastructure.

The retaining wall, roadway and associated infrastructure (street lighting and wastewater sewer) within the stretch of Lyndale Drive within the study area are considered to be at risk to continued slope movements. Left unmitigated, these movements may continue until soil strengths are reduced to a point where a larger slope failure can be expected which may impact this critical infrastructure. The magnitude and rates of movements cannot be predicted, however, they are likely to be sensitive to lower river levels (*i.e.* lower river levels will tend to reduce the bank stability). Although differential shear displacement has not been observed at cross-section D, it is unlikely that this section will remain stable for the design life of the replacement structure (75 years) as a result of accumulated plastic (creep) shear strains.

4.0 Slope Stability Analysis

Slope stability analysis was conducted to model the existing stability of the riverbank and determine the need for stabilization works. Cross-sections A, B, C and D are shown in plan on Figure 01 and in section on Figures 02, 03, 04 and 05 respectively. Cross-section A is taken within the 2013 stabilized zone, where observed slope movements have subsided, and therefore was not included in the analysis.

4.1 Numerical Model Description

The stability analysis was conducted using a steady-state FEM seepage model (Seep/W) and a limit-equilibrium slope stability model (Slope/W) from the GeoStudio 2012 software package (Geo-Slope International Inc.). The seepage model was used to incorporate seepage gradients observed in the piezometers into the stability model to calculate factors of safety. The slope stability model used the Morgenstern-Price method of slices with a half-sine interslice force function to calculate factors of safety. Critical local and global slip surfaces were determined using a grid and radius slip surface method.

4.2 Material Properties

The soil units used in the model include the *in-situ* Upper Complex zone (comprising the upper silty clay and silt), lacustrine clay and glacial till. The glacial till layer was included in both the seepage and stability models. The clay-till interface was modeled at the average elevation of the test holes along each cross-section. Table 01 lists the saturated hydraulic conductivity values used for all constituent materials in the seepage model. The hydraulic conductivity for the Lacustrine clay is consistent with typical values for Winnipeg clay. Properties assumed for the till are considered conservative and reflect a compact silt, sand and gravel matrix. Flow in the unsaturated zone was not considered in the model as its effect on the model results would be negligible.

Table 01 Hydraulic Properties used in Seepage Modeling

Soil Description	Hydraulic Conductivity (m/s)
Lacustrine Clay	$1x10^{-9}$
Till	$1x10^{-6}$

Table 02 lists the soil properties used for the soil units in the stability modeling. The lacustrine clay was divided into discrete zones reflective of varying degrees of strain softening due to observed movements. A zone of higher strain softening was assumed down-slope of the 1976 slope crest, since differential displacements outside the limits of the 2013 stabilization works have generally occurred down-slope of this limit. The properties of the down-slope zone were back-analysed along each cross-section to obtain a factor of safety of approximately unity for a slip surface coinciding with observed differential shear displacements. Back-analysed strength parameters were consistent at cross-sections B and C, which also are consistent with previous back-analysis of the 2013 instability, and are considered an upper bound of residual strength parameters for Winnipeg clays. Since recent monitoring observed only creep movements at cross-section D, the 1976 ground profile was used for the back-analysis of a slip surface initiating at the 1976 slope crest. Beyond the 1976 slope crest, a lower degree of strain softening was assumed, reflective of creep movements only; fully-softened strength parameters were assumed in this zone. The properties for the till listed in Table 01 were used in preliminary analysis where circular slip surfaces were considered, however analyses with composite slip surfaces sliding along the clay-till interface were critical. Therefore, the till was modeled as impenetrable in the slope stability analysis reported herein. Since the timber pile wall is not fixed at the toe (i.e. embedded in the till layer) and is not tied back, the wall should not be relied upon for any significant stabilizing resistance. Therefore, the timber pile was not included in the stability model below the down-slope grade.

Table 02 Soil Properties used in Stability Modeling

Soil Description	Unit Weight (kN/m^3)	Cohesion (kPa)	Friction Angle (deg)
Upper Complex	18	0	25
Lacustrine Clay			
- Full-Softened	17	5	17
- Back-Analysis B and C	17	2	12
- Back-Analysis D	17	3	13
Till (composite slip surfaces)	impenetrable		

4.3 Groundwater Conditions

Critical groundwater conditions for the analysis consisted of the winter river level (UWRL) of 222.0 m and a till total head boundary condition of 0.9 m above river level (Elev. 223.5 m), which would occur following fall drawdown of the river from regulated summer levels. A total head of 230 m was applied as a boundary condition along the upper bank ground surface. The selected boundary conditions resulted in good agreement between the steady-state seepage model and the monitored groundwater levels.

4.4 Stability Modeling Results

Table 03 summarizes the stability modeling cases and associated factors of safety calculated using the numerical model for each of the cross-sections. Key cases are discussed in detail in the following sections. Figures showing the stability analysis results for each case have been included in Appendix B, as referenced in Table 03.

Table 03 - Summary of Calculated Factors of Safety

Cross-Section	Geometry Case	River Elevation	Till Piezometric Elevation	Slip Surface	Description	Factor of Safety	Figure No. (Appendix B)
B	Existing Geometry	UWRL 222 m	223.5 m	SS#1	Global minimum FS (mid-bank, back-analysed)	1.05	B-1
				SS#2	Local minimum FS (upper bank, beyond wall)	1.12	
				safety map	observed creep zone	< 1.15	B-2
C	Existing Geometry	UWRL 222 m	223.5 m	SS#1	Global minimum FS (mid-bank, back-analysed)	0.98	B-3
				SS#2	Local minimum FS (upper bank, beyond wall)	1.07	
				safety map	observed creep zone	< 1.18	B-4
D	1976 Geometry	UWRL 222 m	223.5 m	SS#1a	Global minimum FS (mid-bank, back-analysed)	0.98	B-5
	Existing Geometry	UWRL 222 m	223.5 m	SS#1a	1976 Back-analysed	1.18	B-6
				SS#1b	Global minimum FS (mid-bank, back-analysed)	0.96	
				SS#2	Local minimum FS (upper bank, beyond wall)	1.17	
				safety map	observed creep zone	< 1.25	B-7

4.4.1 Cross-sections B and C

The back-analysis of cross-sections B and C resulted in factors of safety between 0.98 and 1.05 on the critical slip surface (SS #1), which closely matched the observed zones of differential shear displacement in the slope inclinometers (Figures B-1 and B-3). The critical upper bank slip surfaces for the two sections (SS #2) had a calculated factor of safety of approximately 1.07 to 1.12 (also shown in Figures B-1 and B-3). The safety map was used to examine the range of factors of safety within the zones of observed creep movement along sections B and C (Figures B-2 and B-4); creep movement along these sections was generally observed where factors of safety were less than about 1.15 to 1.18.

4.4.2 Cross-section D

The back-analysis of cross-section D was conducted on the 1976 slope geometry, and resulted in a calculated factor of safety of 0.98 along the critical slip surface (SS #1a); coincidentally, the slip surface geometry closely matches the zone of creep movements observed in the slope inclinometers (Figure B-5). The existing geometry was subsequently analysed with the current geometry, reflective of significant offloading but also some toe erosion. The factor of safety on the back-analysed slip surface increased to 1.18, while the critical slip surface is located further in the lower bank area with a factor of safety of 0.96 (Figure B-6). Although no differential shear movements have been observed in the lower-bank inclinometer, it is possible that unidentified factors are providing a stabilizing influence that is not captured in the model. Along this section, creep movements of similar magnitude to other cross-sections was observed below about a factor of safety of 1.18 (SS #1a); smaller creep movements observed just above the till layer in the mid-bank inclinometer coincide with factors of safety of about 1.25 or less (Figure B-7).

5.0 Conclusions

Slope stability analysis was used to back-analyse observed zones of differential shear movement from inclinometer data and confirms that the lower to mid-bank stability along this stretch of the riverbank is unstable to marginally stable. The analysis further confirmed that creep movements are occurring, and that further deterioration of the retaining wall (loss of stabilizing support) would result in factors of safety considered to be marginally stable in the upper bank area, thus placing the roadway, dike and utility infrastructure at risk. Stability conditions near the upstream end of the site (cross-section D) are somewhat more favorable than at sections B and C, with calculated factors of safety in the upper bank area that are about 10% higher than at the other two sections. However, due to the presence of creep movements that extend beneath the timber pile retaining wall at all monitoring locations and factors of safety less than typical design criteria of 1.3, it is likely that the riverbank stability will continue to deteriorate as ongoing creep movements result in further strain softening, which will eventually lead to retrogression of slope instabilities and loss of wall stability. Therefore, the results of our assessment and analysis conclude that riverbank stabilization works are required along the entire study area.

6.0 Closure

The geotechnical information provided in this report is in accordance with current engineering principles and practices (Standard of Practice). The findings of this report were based on information provided (field investigation and laboratory testing). Soil conditions are natural deposits that can be highly variable across a site. If subsurface conditions are different than the conditions previously encountered on-site or those presented here, we should be notified to adjust our findings if necessary.

All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work or standard engineering services agreement. If these conditions are not attached, and you are not already in possession of such terms and conditions, contact our office and you will be promptly provided with a copy.

This report has been prepared by TREK Geotechnical Inc. (the Consultant) for the exclusive use of the City of Winnipeg (the Client) and their agents for the work product presented in the report. Any findings or recommendations provided in this report are not to be used or relied upon by any third parties, except as agreed to in writing by the Client and Consultant prior to use.

Figures

TREK GEOTECHNICAL

0015 014 00

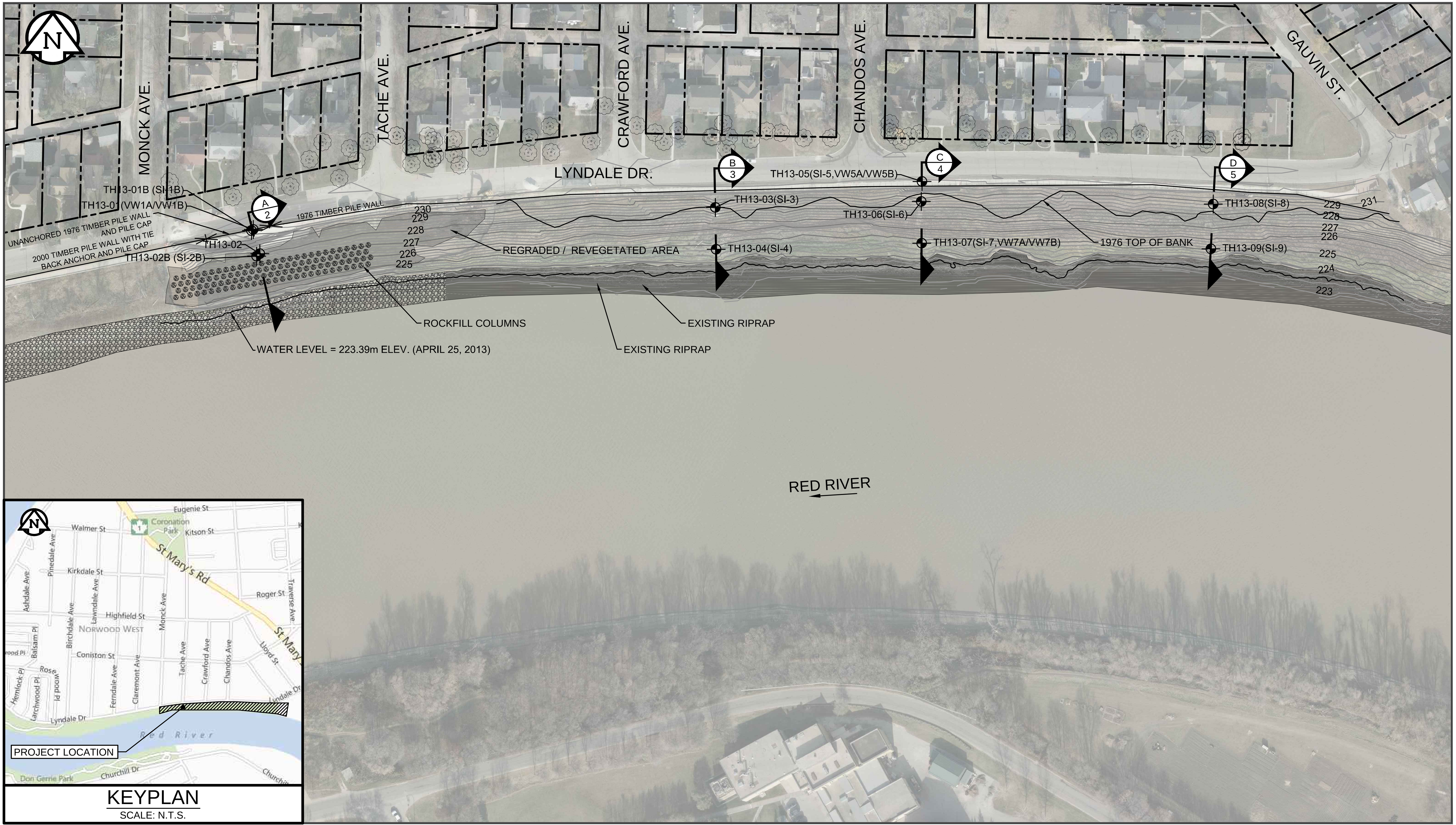
City of Winnipeg

Preliminary Engineering Study for Lyndale Drive Retaining Wall - Monck Ave. to Gauvin St.

Tabloid (279mm x 432mm)

PLOT: 2/23/2016 12:06:47 PM

FILE NAME: FIG 002 2016-02-23 Site Plan 0_I_HA 0015 014 00.dwg



KEYPLAN

SCALE: N.T.S.

0 15 30 45 60m

SCALE : 1:1500 (279mm x 432mm)

LEGEND :

⌖ TEST HOLE (TREK, 2013)

✿ TREE

— - — - APPROXIMATE PROPERTY LINE

NOTES :

1. GROUND SURFACE TOPOGRAPHY BASED ON LIDAR SURVEYS PROVIDED BY CITY OF WINNIPEG.
2. AERIAL IMAGE TAKEN IN 2013 PROVIDED BY CITY OF WINNIPEG
3. SI-1 IN TH13-01 ABANDONED ON OCTOBER 25, 2013
4. SI-2 IN TH13-02 ABANDONED ON NOVEMBER 11, 2013

Figure 01

Site Plan

GEOTECHNICAL

0015 014 00
City of Winnipeg
Preliminary Engineering Study for Lyndale Drive Retaining Wall - Monck Ave. to Gauvin St.

Tabloid (279mm x 432mm)

PLOT: 2/23/2016 12:07:05 PM

FILE NAME: FIG 002 2016-02-23 Site Plan 0_I_HA 0015 014 00.dwg

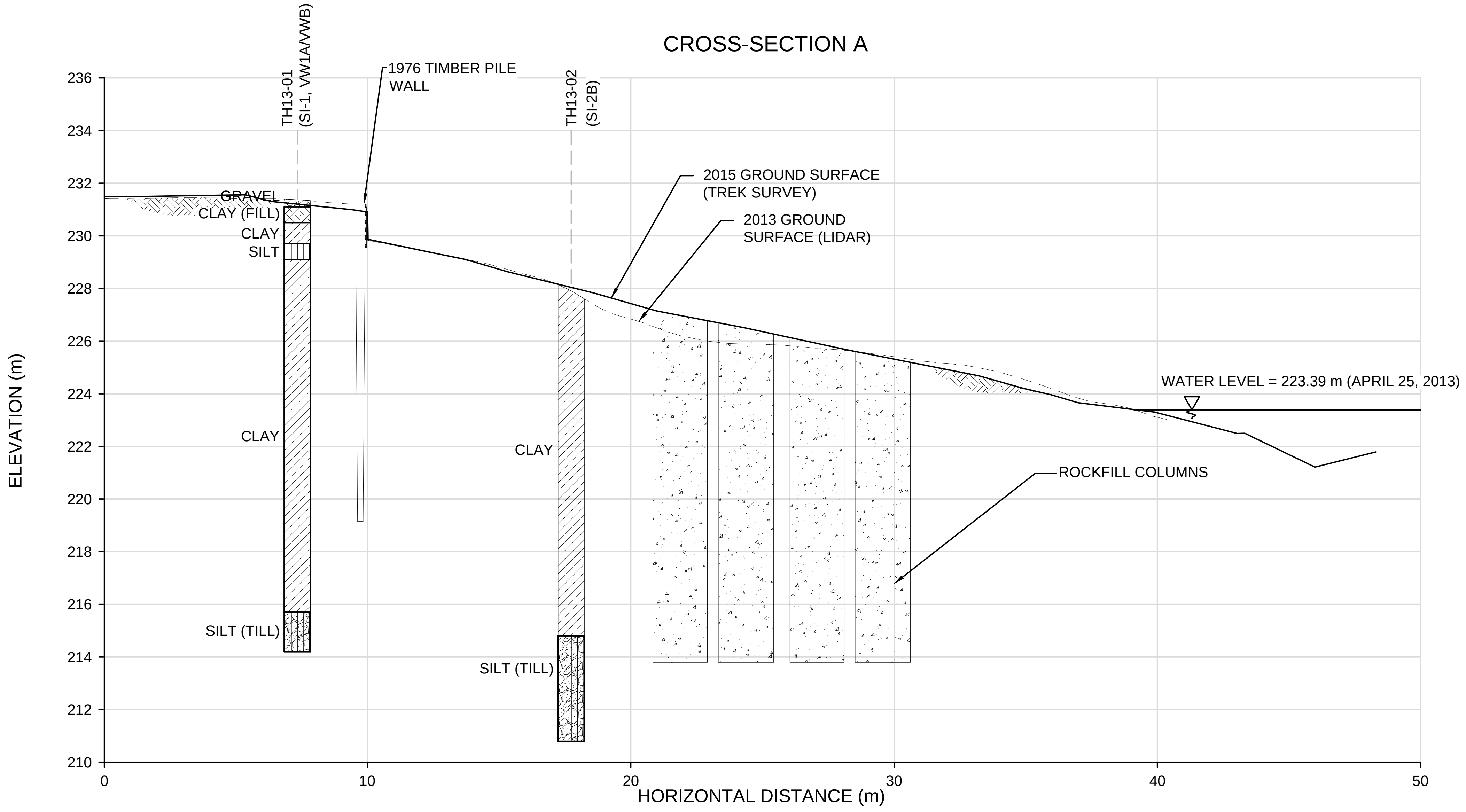


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Figure 02
Cross Section A

Tabloid (279mm x 432mm)
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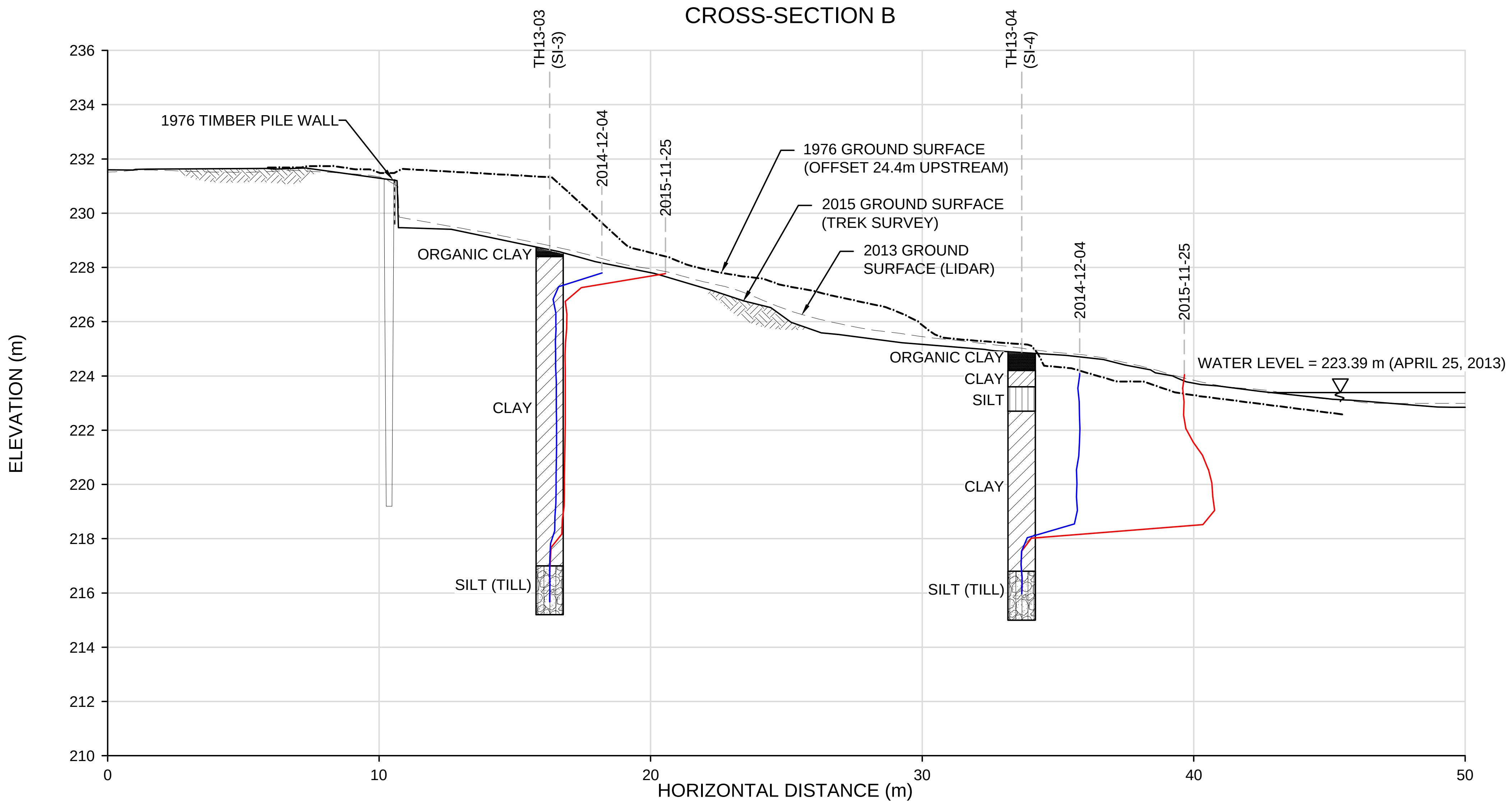

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0 2 4 6 8m
SCALE : 1:200 (279mm x 432mm)

NOTES :

1. SLOPE INCLINOMETER DISPLACEMENT SHOWN FOR NOVEMBER 25, 2015

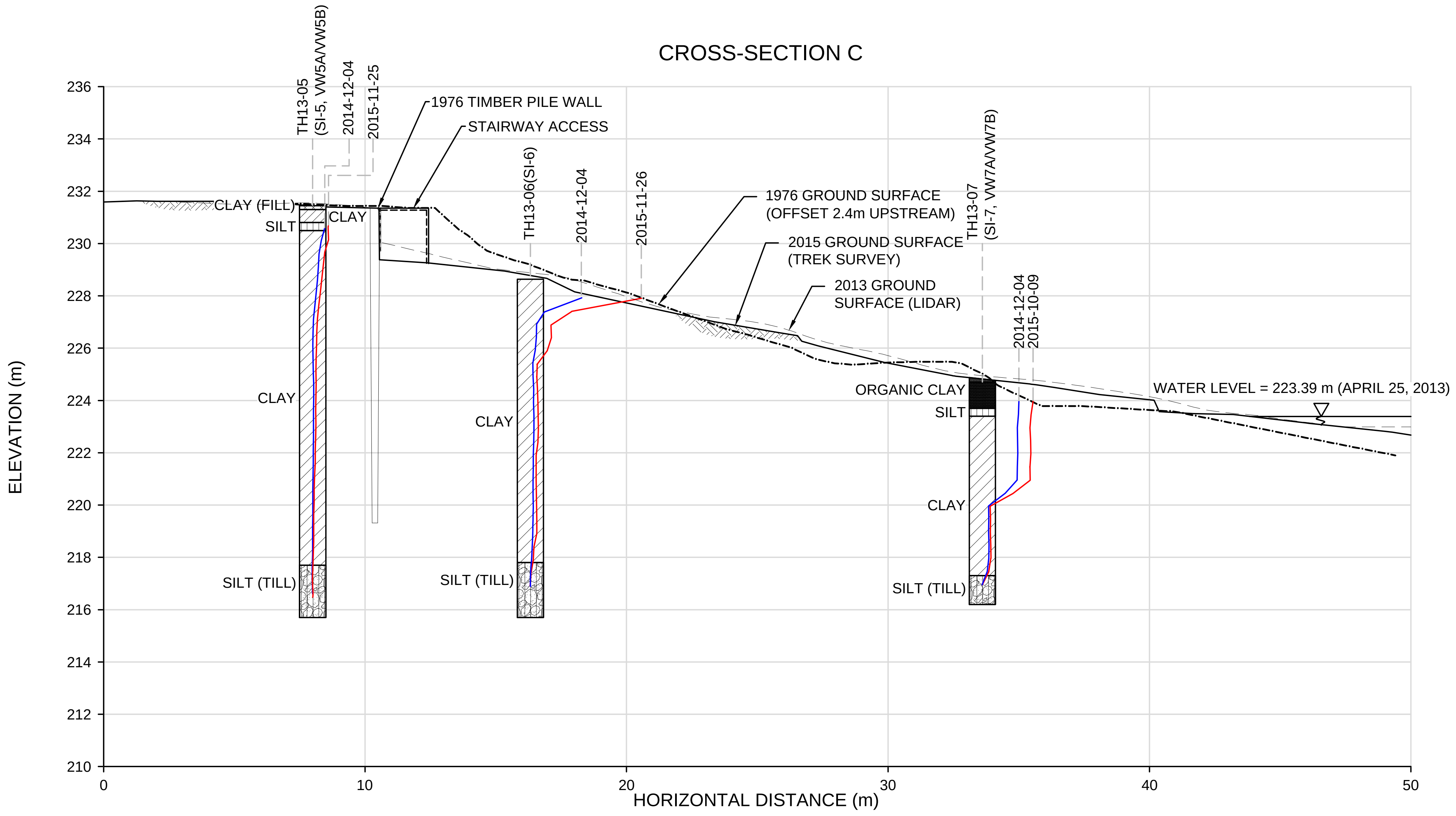
Figure 03
Cross Section B

Tabloid (279mm x 432mm)

PLOT: 2/23/2016 12:07:47 PM

FILE NAME: FIG 002 2016-02-23 Site Plan 0_I_HA 0015 014 00.dwg

CROSS-SECTION C



(HORIZONTAL SCALE FOR SI DISPLACEMENT PLOTS)

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SCALE : 1:2 (279mm x 432mm)

0 2 4 6 8m

SCALE : 1:200 (279mm x 432mm)

NOTES :

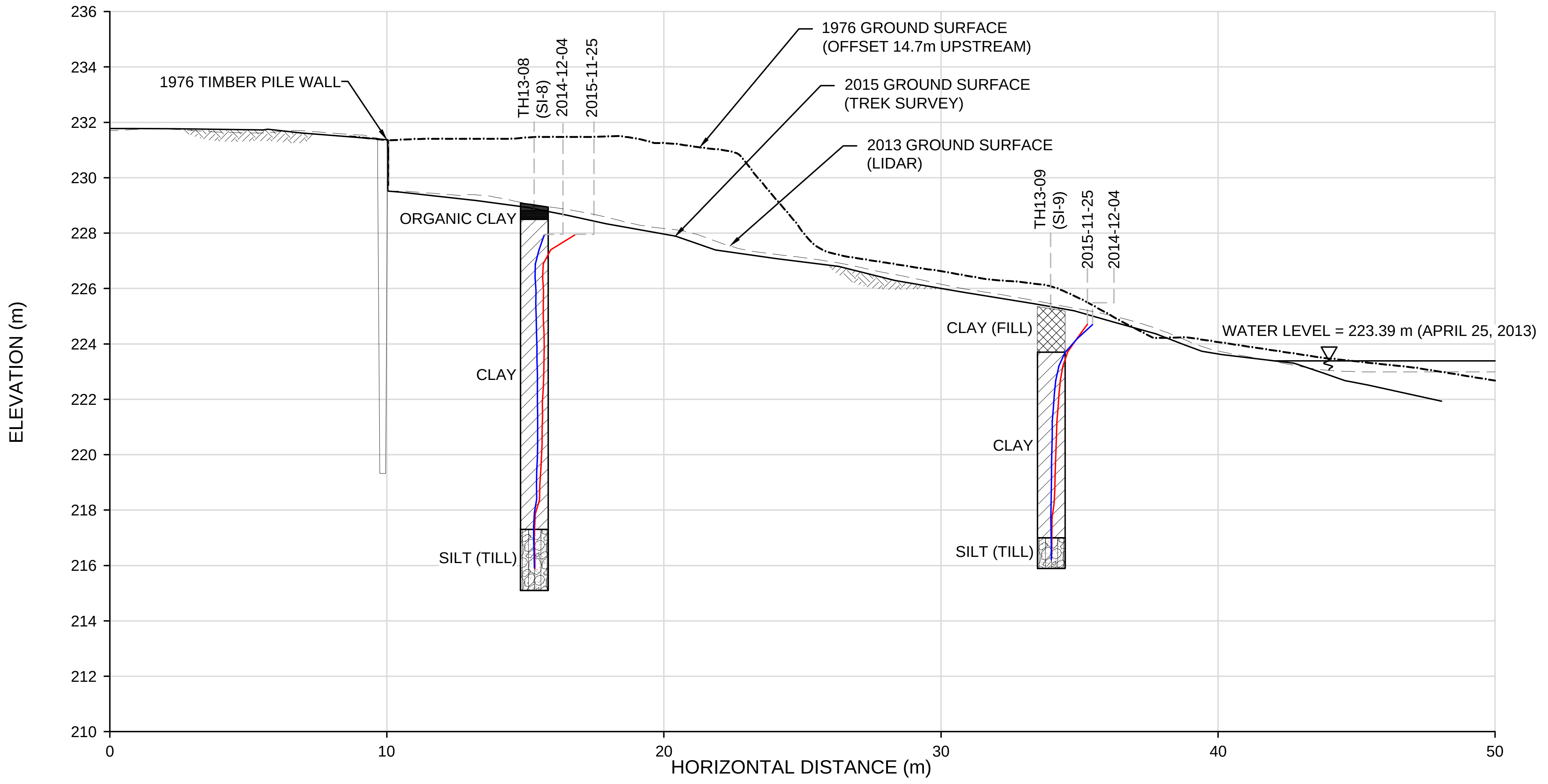
1. SLOPE INCLINOMETER CUMULATIVE DISPLACEMENT SHOWN FOR NOVEMBER 25, 2015 (SI-6) AND OCTOBER 9, 2015 (SI-7).

Figure 04

Cross Section C

Tabloid (279mm x 432mm)
PLOT: 2/23/2016 12:22:40 PM
FILE NAME: FIG 002 2016-02-23 Site Plan 0_I_HA 0015 014 00.dwg

CROSS-SECTION D



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0 2 4 6 8m
SCALE : 1:200 (279mm x 432mm)

NOTES :

1. SLOPE INCLINOMETER DISPLACEMENT SHOWN FOR NOVEMBER 25-26, 2015

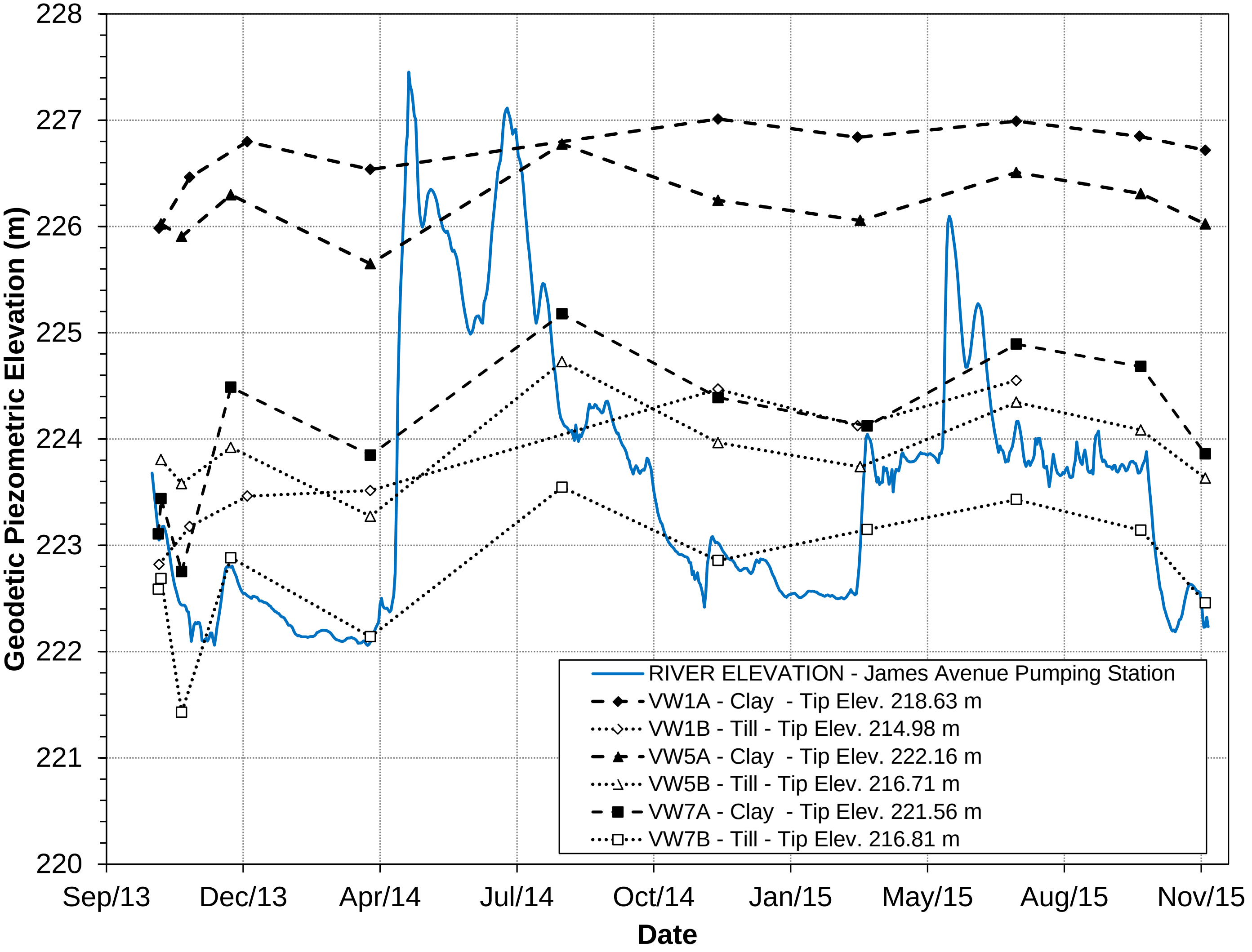


Figure 06 – Piezometer Monitoring Results

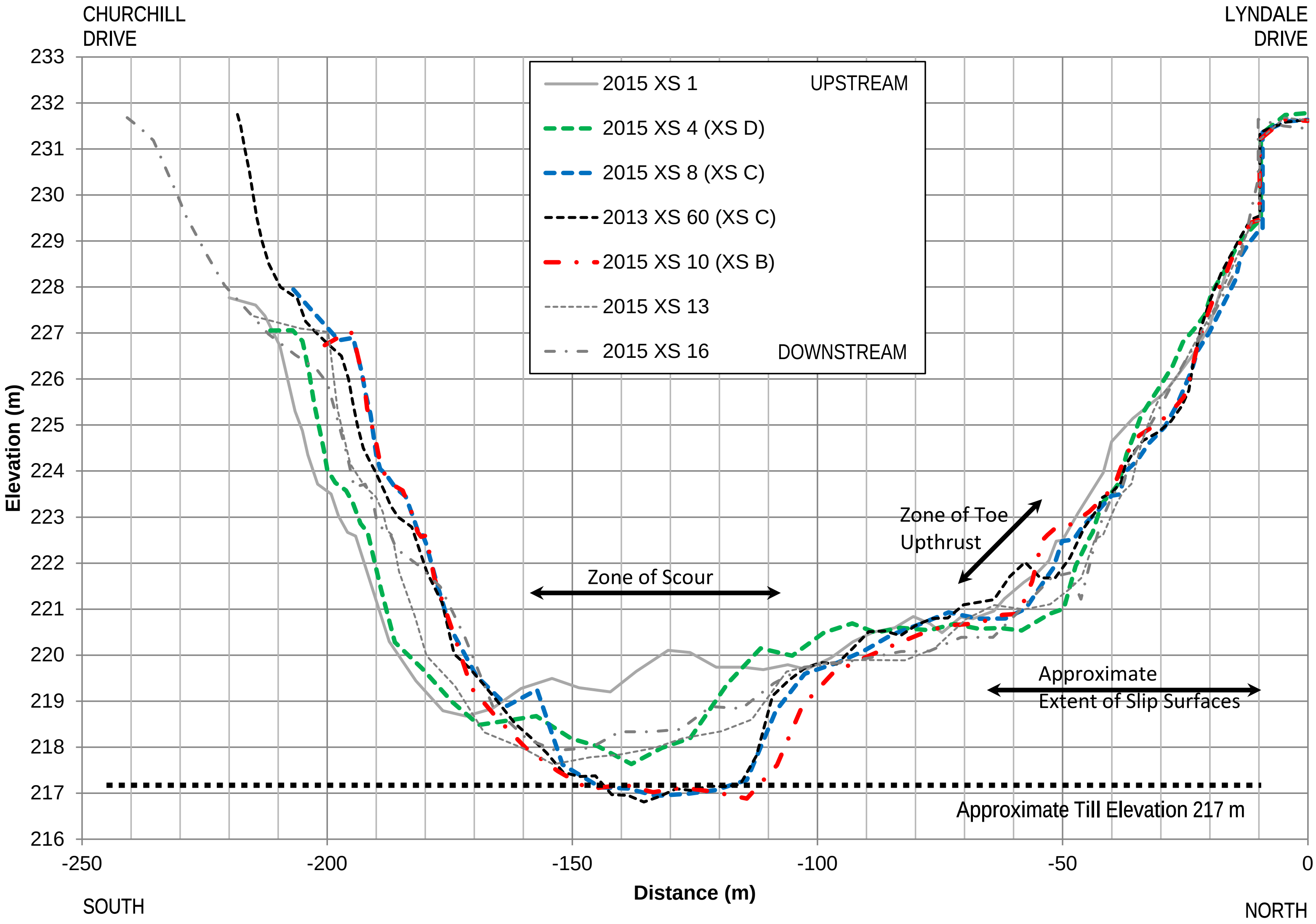


Figure 07 – Comparison of River Cross-Sections

Appendix A – Monitoring Reports

TREK GEOTECHNICAL Quality Engineering | Valued Relationships

February 1, 2015 File No. 0015 008 00

Mr. Kendall Thiessen, P.Eng.
Riverbank Management Engineer
City of Winnipeg, Planning, Property and Development Department
Waterways Section
15 – 30 Fort Street
Winnipeg, MB R3C 4X5

RE Lyndale Drive –Monck Avenue to Avenue Taché
Final 2-year Riverbank Monitoring Summary

Please find enclosed final monitoring results for instrumentation installed along riverbank and retaining wall of Lyndale Drive from Monck Avenue to Avenue Taché. The instrumentation was installed in 2013 as part of emergency riverbank stabilization works along this stretch of the riverbank. Monitoring instrumentation included slope inclinometer casings (SI's) and vibrating-wire piezometers (VW's) along the mid and upper bank areas along one cross-section. Additional instrumentation was installed upstream of the stabilized zone to monitor movements and determine the need for stabilization works along the remainder of the retaining wall. Results of monitoring in the upstream (unstabilized) zone were reported separately and will not be repeated herein.

The test hole locations and types of instrumentation installed are shown on the attached site plan (Figure 1) as well as in cross-section in Figure 02. Figure 1 also shows the limits and types of retaining walls present, including a timber pile wall constructed in 1976 that extends upstream of the 2013 stabilized zone, ending near the intersection of Lyndale Drive and Gauvin Street. Evidence of lower to mid bank movements is apparent at various locations along this stretch of bank, based on visual site inspections and aerial photo review. A deep-seated instability down-slope of the retaining wall triggered a reduction in lateral stability of the retaining wall and a subsequent "active wedge" mechanism of movement behind the retaining wall and into the pavement. As a result, TREK designed and supervised construction of 48 rockfill columns to stabilize the instability. The current letter concludes the 2-year post-construction monitoring program with final monitoring results, which are attached along with test hole logs.

Two slope inclinometers and four vibrating wire piezometers were installed along cross-section A, as outlined in our previous monitoring letter. The upper-bank test hole (TH13-01) was drilled within the boulevard just upslope of the existing timber pile retaining wall, while the mid-bank test hole (TH13-02) was drilled just downslope of the wall and upslope of the access platform excavation for rockfill column installation. Slope inclinometers SI-1 and SI-2 were installed in the test holes. Both inclinometers sheared off due to excessive slope movements and were re-installed near the end of construction of the stabilization works (SI-1B and SI-2B). Baseline readings on the re-installed inclinometers were taken in late October 2013 or early November with up to four to five subsequent monitoring events per year (pre and post spring flood, pre and post fall drawdown, possibly mid-summer or mid-winter events as well). Vibrating-wire piezometer monitoring was also completed at each monitoring event.

Groundwater Monitoring Results

The groundwater monitoring results to date are attached for piezometers VW-1A/1B located in the upper bank area. The piezometers were drawn down due to rockfill column construction and subsequently stabilized over a period of about 1 month. The vibrating wire piezometer installed in the lacustrine clay maintained relatively constant piezometric levels ranging from about Elev. 226.5 m to 227.0 m, or about 4.5 to 5 m above the winter river level. Piezometric levels in the till ranged from about Elev. 223.5 m to 224.5 m in the upper bank (VW-1B) or about 1.5 m to 2 m above the river level. All clay and till piezometers showed higher levels following the spring and summer flooding and lower levels during the winter months. Critical groundwater conditions typically occur during the fall and winter months where the groundwater levels in the bank exceeded the river elevation.

Inclinometer Monitoring Results

Slope inclinometer cumulative displacement profiles as well as displacement rate plots are attached for SI-1 (upper bank) and SI-2 (mid-bank). The year-end cumulative displacement profiles (Dec 2014 and Nov 2015) are also shown on the stratigraphic cross-sections to aid in visualization of slope movements.

Prior to rockfill column construction, horizontal displacement of SI-1 was observed at about Elev. 221 m, which is believed to be close to or just above the tip elevation of the timber piles used to construct the original (1976) retaining wall. From May to early September 2013, about 20 mm of cumulative displacement was observed in SI-1 (average rate of about 5mm per month). As access works and rockfill column installation began, the displacement rate in SI-1 increased with a total of about 100 mm of additional horizontal displacement occurring between September 16th and 23rd, 2013 (rate of about 22 to 30 mm per day). Once rockfill column installation progressed (from west to east) past SI-1, the displacement rate slowed to about 3 to 5 mm per day. Inclinometer displacement rates matched closely with the surface displacement (crack pin) monitoring results during construction. SI-1 was abandoned in late September 2013 with about 135 mm of cumulative displacement at ground surface.

SI-1B was installed in late October immediately adjacent to SI-1 and showed a maximum average displacement rate in November and December 2013 of 3.5 mm per month (measured at the top of the SI casing). In 2014, approximately 4 mm of displacement were observed over the winter months, with about 6 mm of additional movement by the end of the spring flood (August 2014). An additional 7 mm of movement occurred from August to December with negligible movement over the winter months. From March to July of 2015, an additional 5 mm of displacement was observed. During critical conditions for stability, over the 2015 fall drawdown, negligible displacement was observed.

SI-2 was installed near the start of rockfill column installation in late September 2013 and was monitored until late October, at which time it was abandoned due to excessive movements. From late September to early October 2013, about 50 mm of horizontal displacement was observed in SI-2 (average rate of about 3 mm per day). As rockfill column installation progressed, the displacement rate increased to about 26 mm per day with about 60 mm of displacement occurring from October 7th to 9th, 2013. Once rockfill column installation progressed (from west to east) past SI-2, the displacement rate slowed to less than 1 mm per day. SI-2 was abandoned in late October 2013 with about 150 mm of cumulative displacement at ground surface.

SI-2B was installed in early November immediately adjacent to SI-2 and showed a maximum displacement rate of about 2.5 mm per month from November 2013 to January 2014 (total displacement of about 8 to 10 mm) measured at the top of the SI casing. In 2014, approximately 3 mm of movement was observed over the winter months (January to March 2014). Although the SI was not monitored in the summer of 2014, the overall displacement attributed to the spring flood and fall drawdown (combined) in 2014 was approximately 4.5 mm, with an additional 4 mm occurring from December to March while the river was at sustained low levels. In 2015, generally lower displacements were observed with about 2 mm occurring over the spring flood and summer months, and an additional 3.5 mm occurring during the drawdown period. The total displacement observed over the course of flood and drawdown events in 2015 was lower than observed in 2014 (approximately 8 mm in 2014 compared to 5 mm in 2015).

Summary and Discussion

The monitoring results have confirmed that a deep-seated slope instability extending beneath the timber pile wall was responsible for the observed movement of the retaining wall and pavement subsidence. Since construction of the rockfill columns and restoration of the pavement and sidewalk within the failure area, displacements along the pre-existing slip surface have continued, but displacement rates continue to decrease. It is possible that a portion of the upper bank movements can be attributed to deflection of the timber pile wall rather than movement along a deep-seated slip surface. These creep movements are not unexpected and are within the range expected after the construction of slope stabilization works. We are of the opinion that ongoing monitoring is not necessary although minor movements may continue beyond the monitoring period, and that the slope stabilization works are performing as expected.

Please don't hesitate to contact me if have you any questions or require further clarification.

Kind Regards,

TREK Geotechnical
Per:

Michael Van Helden, P.Eng.
Geotechnical Engineer, Tel: 204.975.9433 ext 102

MVH/kms

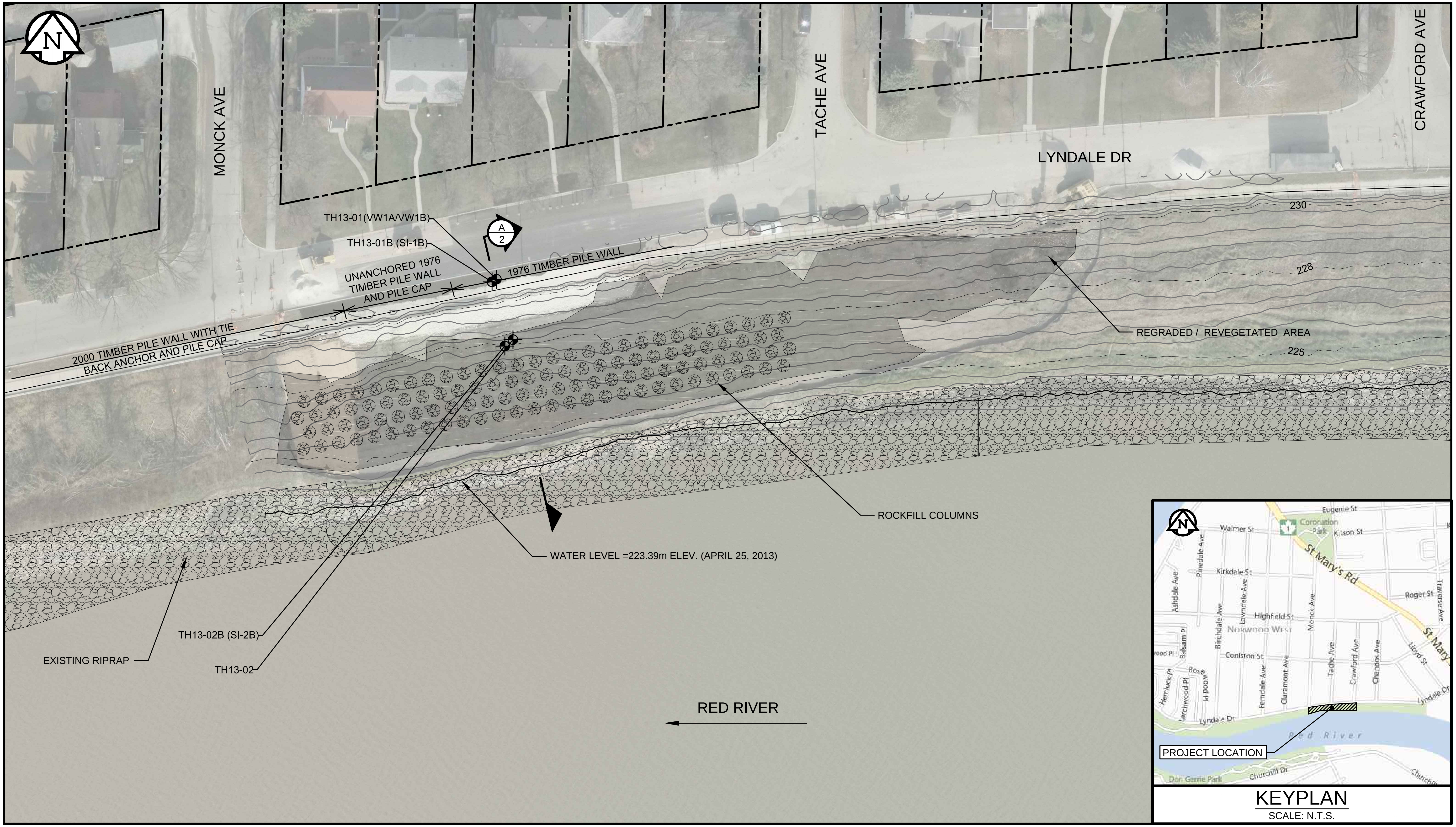
cc. Brad Neirinck, P.Eng., City of Winnipeg Public Works
Ken Skaftfeld, P.Eng., TREK Geotechnical Inc.

Site Plan and Cross-Section

TREK GEOTECHNICAL

0015 008 00
City of Winnipeg
Lyndale Drive Retaining Wall Assessment

Tabloid (279mm x 432mm)
PLOT: 2/3/2015 1:19:45 PM
FILE NAME: FIG 001 2015-02-02 Site Plan 0_H_HA 0015 008.dwg



KEYPLAN
SCALE: N.T.S.

0 6 12 18 24m
SCALE : 1:600 (279mm x 432mm)

LEGEND :

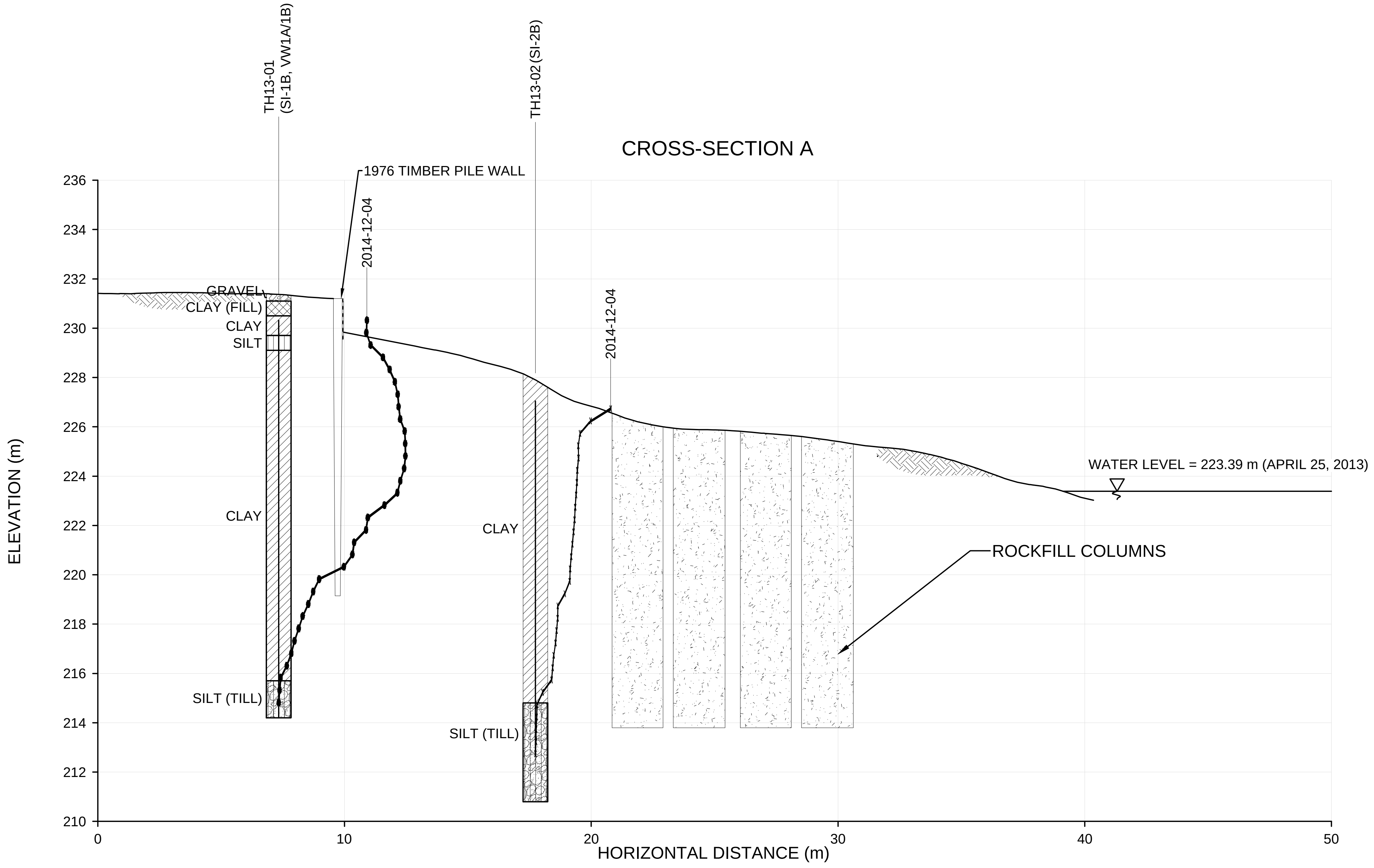
⌖	TEST HOLE (TREK, 2013)
— - - —	APPROXIMATE PROPERTY LINE

NOTES :

1. GROUND SURFACE TOPOGRAPHY BASED ON LIDAR SURVEYS PROVIDED BY CITY OF WINNIPEG.
2. AERIAL IMAGE TAKEN IN 2013 PROVIDED BY CITY OF WINNIPEG
3. SI-1 IN TH13-01 ABANDONED ON OCTOBER 25, 2013
4. SI-2 IN TH13-02 ABANDONED ON NOVEMBER 11, 2013

Figure 01
Site Plan

CROSS-SECTION A



(HORIZONTAL SCALE FOR SI DISPLACEMENT PLOTS)
0 20 40 60 80mm
SCALE : 1:2 (279mm x 432mm)

Tabloid (279mm x 432mm)
PLOT: 2/3/2015 12:25:25 PM
FILE NAME: FIG 001 2015-02-02 Site Plan 0_H_HA 0015 008.dwg

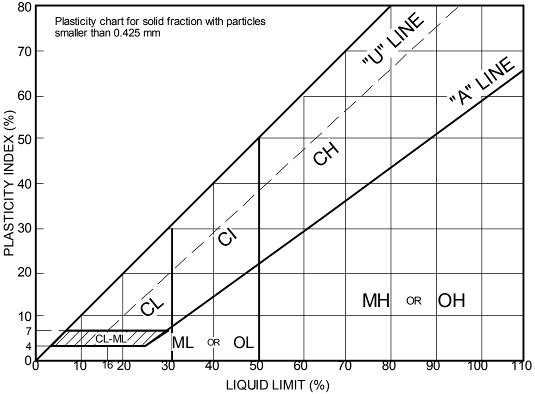
0 2 4 6 8m
SCALE : 1:200 (279mm x 432mm)

Test Hole Logs

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classi-fication	Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW	●	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent...... GW, GP, SW, SP More than 12 percent...... GM, GC, SM, SC 6 to 12 percent...... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	○	Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	◫	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC	▨	Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW	⁘	Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	░	Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	◫	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC	▨	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	▥	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart 		
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	☰	Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH	▥	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts			
			CH	▨	Inorganic clays of high plasticity, fat clays			
			OH	≋	Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt	⁂	Peat and other highly organic soils	Von Post Classification Limit	Strong colour or odour, and often fibrous texture	

Material		Particle Size mm	ASTM Sieve sizes
Sand	Coarse	2.00 to 4.75	#10 to #4
	Medium	0.425 to 2.00	#40 to #10
	Fine	0.075 to 0.425	#200 to #40
Silt or Clay		< 0.075	< #200

Material		Particle Size mm	ASTM Sieve Sizes
Boulders		> 300	> 12 in.
Cobbles		75 to 300	3 in. to 12 in.
Gravel	Coarse	19 to 75	3/4 in. to 3 in.
	Fine	4.75 to 19	#4 to 3/4 in.

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols. For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

■	Asphalt	▧	Bedrock (undifferentiated)	○	Cobbles
⁙	Concrete	▤	Limestone Bedrock	●	Boulders and Cobbles
▩	Fill	☰	Cemented Shale	◫	Silt Till
		▱	Non-Cemented Shale	▨	Clay Till

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD - Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength
VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling
▼ Water Level at End of Drilling
⧩ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

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

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

Sub-Surface Log

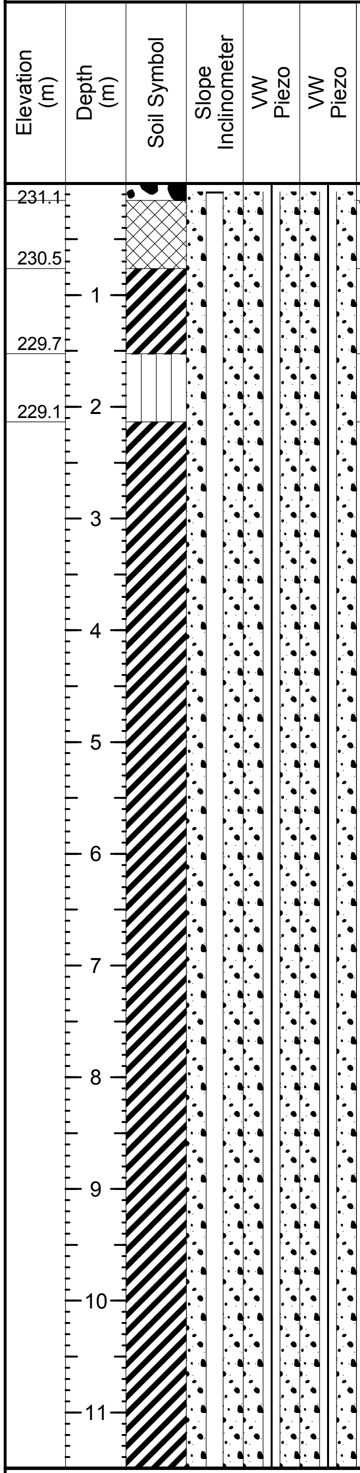
Test Hole TH13-01

Client:	City of Winnipeg - Public Works	**Project Number:**	0015 008 00
Project Name:	Lyndale Drive Retaining Wall Assessment	**Location:**	Lyndale Dr. between Monck Ave. and Gauvin St.
Contractor:	Maple Leaf Drilling	**Ground Elevation:**	231.23 m
Method:	125 mm Solid Stem Auger, Acker MP5-T Track Mount	**Date Drilled:**	6 May 2013

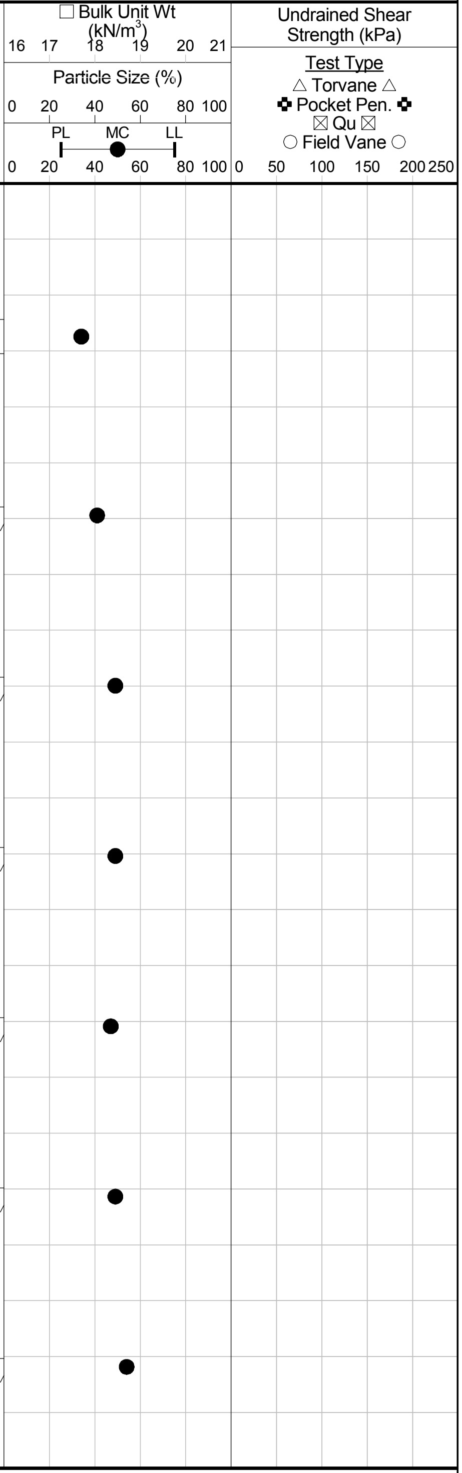
Sample Type: ◢ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) ⧗ Split Barrel (SB) ▯ Core (C)

Particle Size Legend: ▥ Fines ▨ Clay ▥ Silt ⁘ Sand ● Gravel ◌ Cobbles ■ Boulders

Backfill Legend: ■ Bentonite ▩ Cement ▨ Drill Cuttings ⁘ Filter Pack Sand ⁘ Grout ▩ Slough

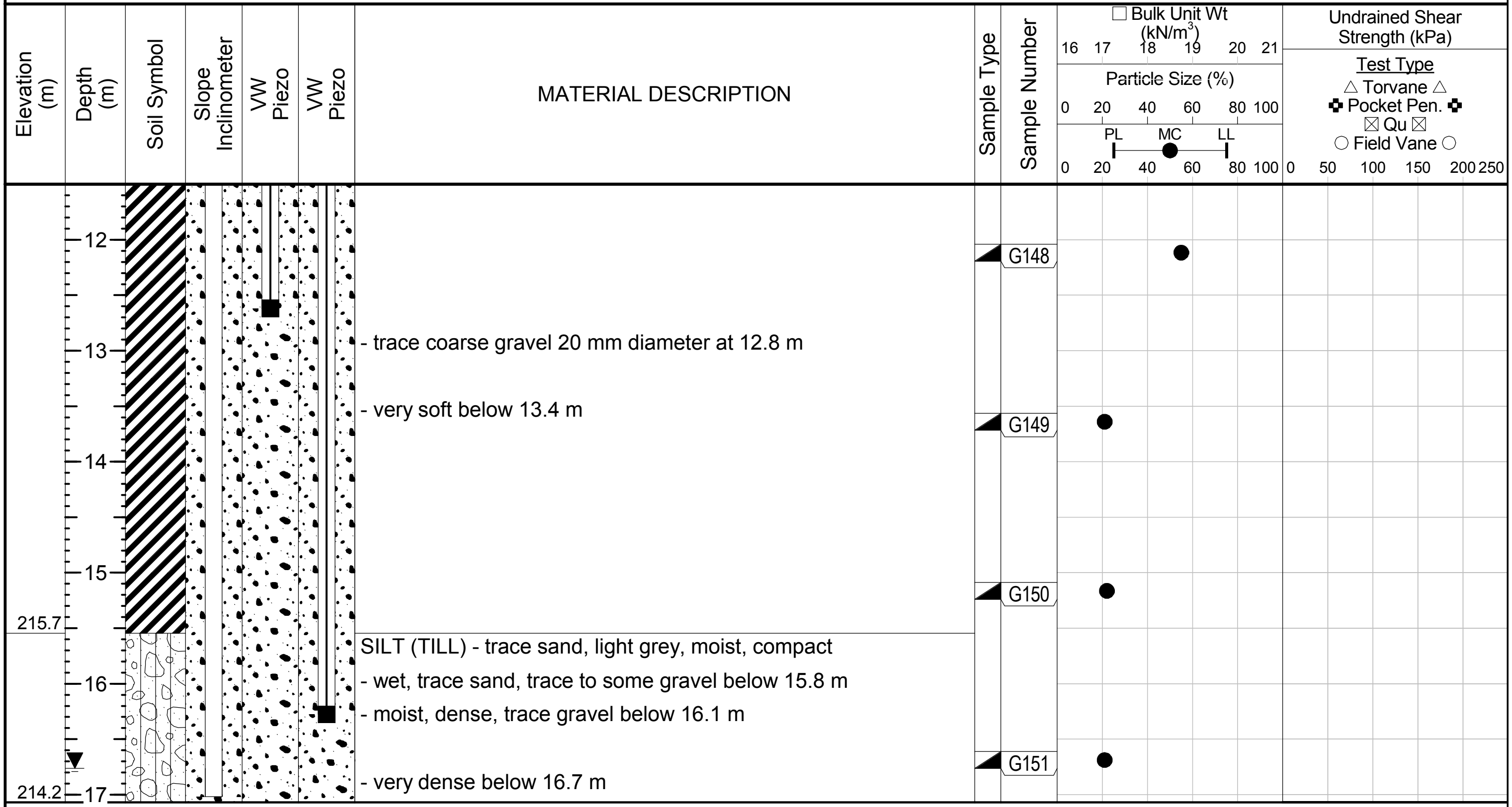


MATERIAL DESCRIPTION	Sample Type	Sample Number
GRAVEL - trace sand, brown, moist, compact		
CLAY (Fill) - silty, trace organics, trace rootlets - black, moist, stiff, high plasticity		
CLAY - silty,trace sand, trace to some light grey silt inclusions - dark brown - moist, firm to stiff, high plasticity	◢	G141
SILT - brown, moist, soft		
CLAY - silty, trace silt inclusions, trace oxidations - brown - moist - firm to stiff, high plasticity	◢	G142
	◢	G143
- firm below 4.6 m		
	◢	G144
- slickensided surface (52 degrees from horizontal) at 6.5 m		
	◢	G145
- trace coarse gravel particle (20 mm diameter), trace oxidations at 7.6 m - trace tan silt inclusions below 7.6 m		
- grey below 8.7 m		
	◢	G146
- trace white precipitates below 9.1 m		
- soft below 9.8 m		
	◢	G147



Logged By: Michael Van Helden **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

Sub-Surface Log



- trace coarse gravel 20 mm diameter at 12.8 m
- very soft below 13.4 m

SILT (TILL) - trace sand, light grey, moist, compact
- wet, trace sand, trace to some gravel below 15.8 m
- moist, dense, trace gravel below 16.1 m
- very dense below 16.7 m

END OF HOLE AT 17.1 m IN SILT TILL
Notes:
1) Power auger refusal (PAR) at 17.1 m
2) Seepage observed below 15.8 m
3) No sloughing observed.
4) Water level at 16.8 m upon completion of drilling.
5) Vibrating wire piezometers VW-1A and VW-1B installed in test hole.
6) Slope inclinometer SI-1B was installed 0.6 m West of TH13-01 on 17/10/13.

Logged By: Michael Van Helden **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

TREK GEOTECHNICAL

Sub-Surface Log

Test Hole TH13-02

Client: City of Winnipeg - Public Works

Project Number: 0015 008 00

Project Name: Lyndale Drive Retaining Wall Assessment

Location: Lyndale Dr. between Monck Ave. and Gauvin St.

Contractor: Maple Leaf Drilling

Ground Elevation: 227.58 m

Method: 125 mm Solid Stem Auger, Acker MP5-T Track Mount

Date Drilled: 19 September 2013

Sample Type: ◢ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) ⧗ Split Barrel (SB) ▮ Core (C)

Particle Size Legend: ▦ Fines ▨ Clay ▥ Silt ⁘ Sand ● Gravel ◌ Cobbles ⬛ Boulders

Elevation (m)	Depth (m)	Soil Symbol	MATERIAL DESCRIPTION	Sample Type	Sample Number	☐ Bulk Unit Wt (kN/m^3) 16 17 18 19 20 21 Particle Size (%) 0 20 40 60 80 100 PL MC LL 0 20 40 60 80 100	Undrained Shear Strength (kPa) Test Type △ Torvane △ ✥ Pocket Pen. ✥ ☒ Qu ☒ ○ Field Vane ○ 0 50 100 150 200 250
		▨	CLAY - silty - brown - moist, firm to stiff - high plasticity				
	1	▨					
	2	▨					
	3	▨					
	4	▨	- mottled brown and grey below 4.0m				
	5	▨	- soft to firm below 5.2m				
	6	▨					
	7	▨					
	8	▨	- trace grey silt till inclusions (<25mm diameter) below 8.2m				
	9	▨					
	10	▨					
	11	▨					

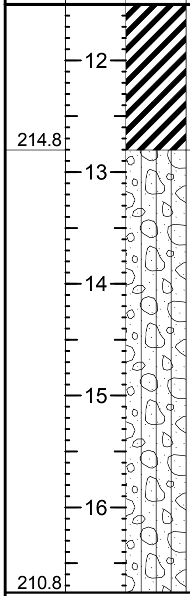
Logged By: Michael Van Helden **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

Sub-Surface Log

Test Hole TH13-02

2 of 2

Elevation (m)	Depth (m)	Soil Symbol	MATERIAL DESCRIPTION	Sample Type	Sample Number	☐ Bulk Unit Wt (kN/m^3) 16 17 18 19 20 21 Particle Size (%) 0 20 40 60 80 100 PL MC LL 0 20 40 60 80 100	Undrained Shear Strength (kPa) Test Type △ Torvane △ ✜ Pocket Pen. ✜ ☒ Qu ☒ ○ Field Vane ○ 0 50 100 150 200 250
214.8			SILT (TILL) - trace to some sand, trace gravel - light grey, moist, loose				
210.8							



END OF HOLE AT 16.8 m IN SILT TILL

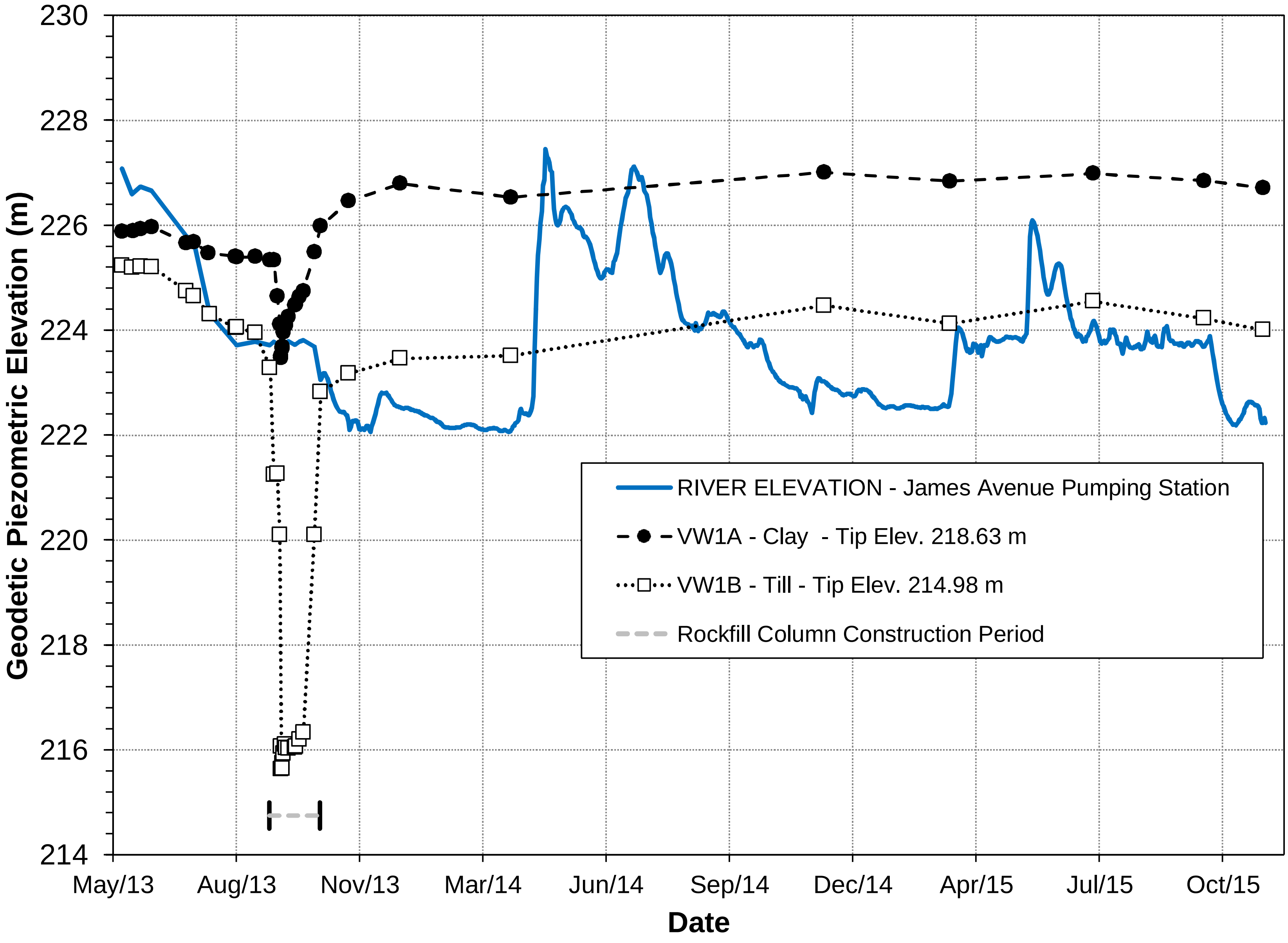
Notes:

1) Drilled to 16.8 m with solid stem then switched to hollow stem with plug to 16.8 for installation.
2) No seepage observed.
3) Sloughing observed below 13.4 m
4) Slope inclinometer SI-02 installed in test hole.
5) SI-02B was installed on 28/10/2013 at TH13-02B which is located mid-bank 1.5 m West and 0.8 m South of TH13-02.

Logged By: Michael Van Helden **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

Piezometers

GROUNDWATER MONITORING REPORT
Lyndale Drive Retaining Wall Assessment
Piezometer Summary Plot (TH13-01)



Z:\Projects\0015 City of Winnipeg\0015 008 00 Lyndale Drive Retaining Wall Assessment\2 Design\2.5 Monitoring\SI and VW's\LYNDAL- VW\Lyndale Drive Vibrating Wires SI_1.xlsx
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Rate Plots

SLOPE INCLINOMETER WORKSHEET

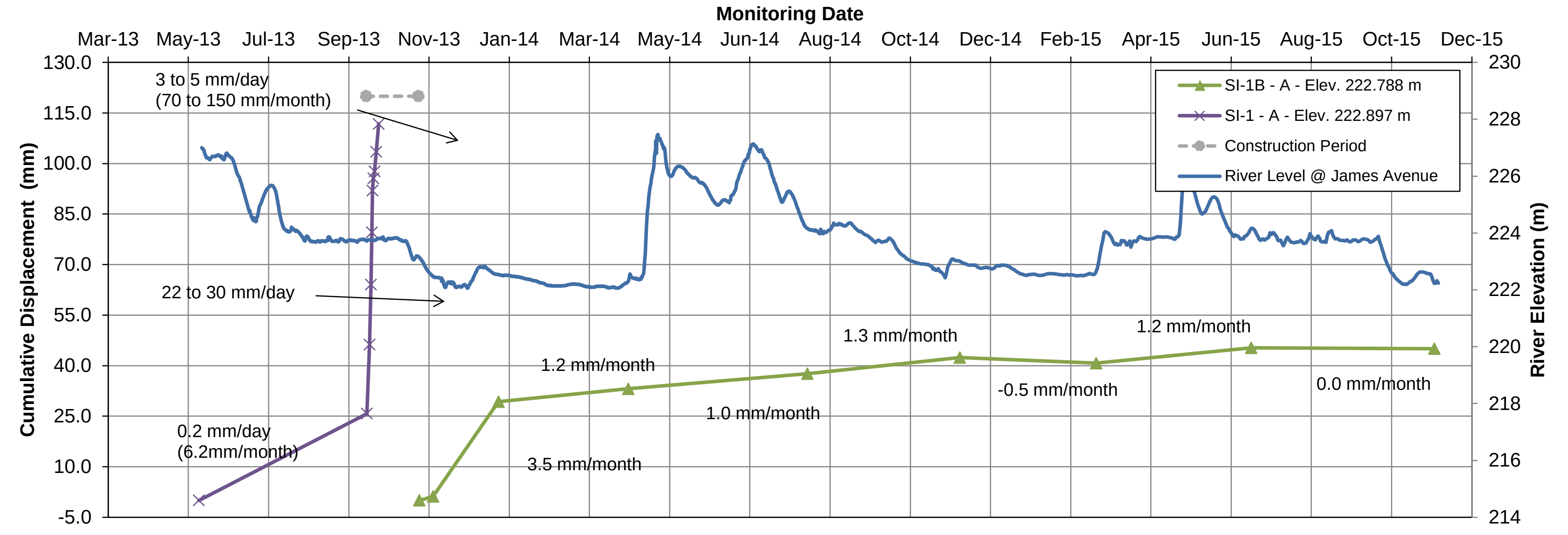
Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Project No.	0015 008 00	Note: Construction Period September to October 2014
Project Title	Lyndale Drive Retaining Wall Assessment	
Client	City of Winnipeg	
Slope Inclinometer No.	SI-1 & SI-1B	

			Cumulative Displacement (mm) vs. Monitoring Date				SI-1 (pre and during construction)						
Elevation Range (m)		Axis	13-May-13	16-Sep-13	18-Sep-13	19-Sep-13	20-Sep-13	20-Sep-13	21-Sep-13	22-Sep-13	23-Sep-13	25-Sep-13	
Upper Movement	222.9	A	0.0	25.8	46.2	64.1	79.6	92.0	95.6	97.7	103.5	111.7	
		B	0.0	4.1	8.3	11.9	13.3	15.0	16.6	16.9	16.0	14.5	
		Resultant	0.0	26.1	47.0	65.2	80.7	93.2	97.0	99.1	104.7	112.7	

			Cumulative Displacement (mm) vs. Monitoring Date				SI-1B (post-construction)						
Elevation Range (m)		Axis	25-Oct-13	5-Nov-13	24-Dec-13	31-Mar-14	12-Aug-14	4-Dec-14	16-Mar-15	10-Jul-15	24-Nov-15		
Upper Movement	222.8	A	0.0	1.2	29.3	33.1	37.6	42.4	40.7	45.3	45.0		
		B	0.0	0.9	35.6	35.7	38.1	37.4	40.3	38.1	40.3		
		Resultant	0.0	1.5	46.1	48.7	53.5	56.6	57.3	59.2	60.4		



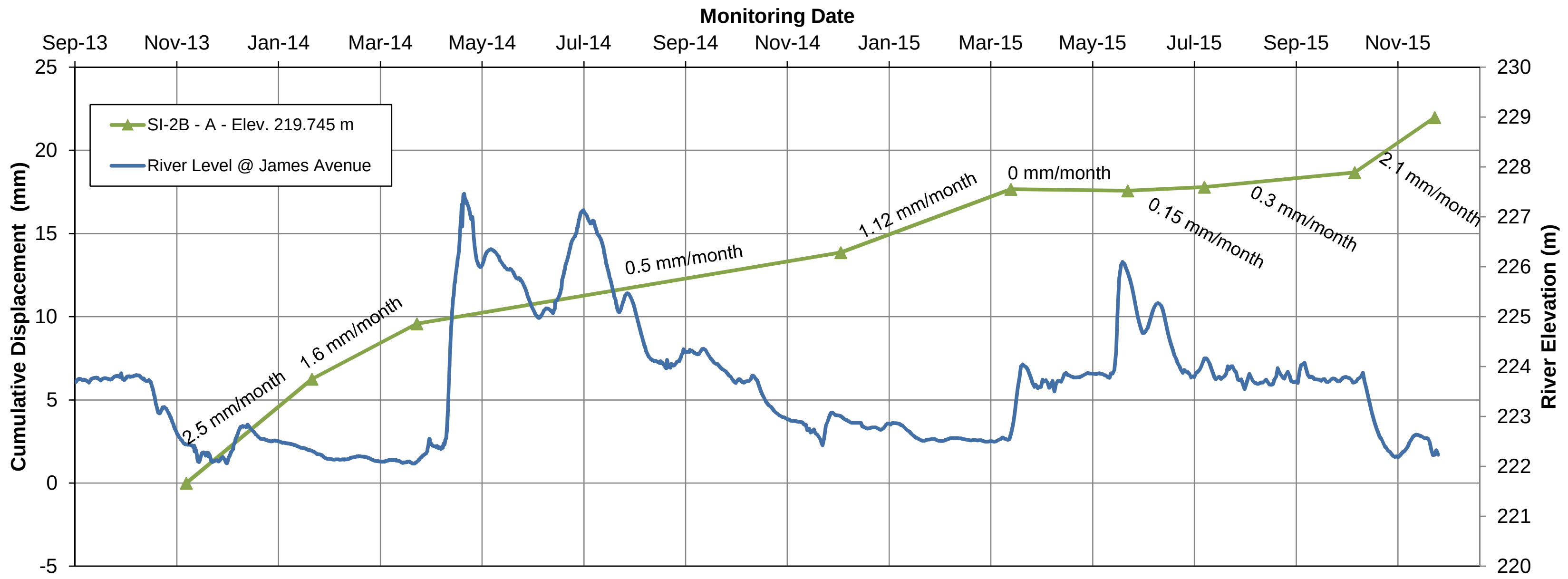
SLOPE INCLINOMETER WORKSHEET

Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-2B

			Cumulative Displacement (mm) vs. Monitoring Date				**SI-2B (post-construction)**						
Elevation Range (m)		**Axis**	**6-Nov-13**	**21-Jan-14**	**25-Mar-14**	**4-Dec-14**	**16-Mar-15**	**25-May-15**	**10-Jul-15**	**8-Oct-15**	**25-Nov-15**		
Upper Movement	219.7	A	0.0	6.3	9.6	13.9	17.7	17.6	17.8	18.7	22.0		
		B	0.0	-0.6	-0.2	-0.2	-0.4	-0.6	-0.8	-2.5	-3.0		
		Resultant	0.0	6.3	9.6	13.9	17.7	17.6	17.8	18.8	22.2		



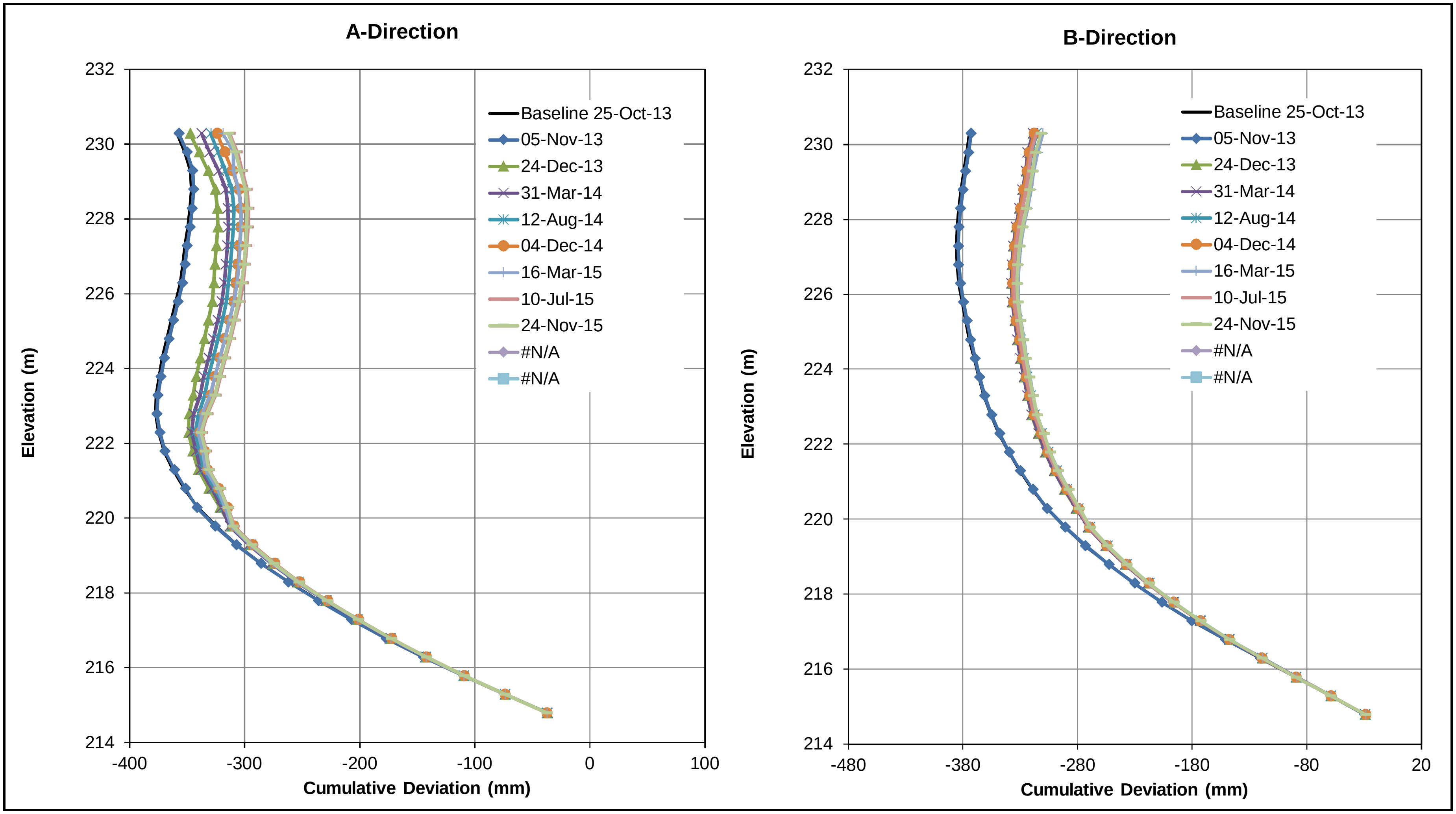
SI-1B

SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-1B

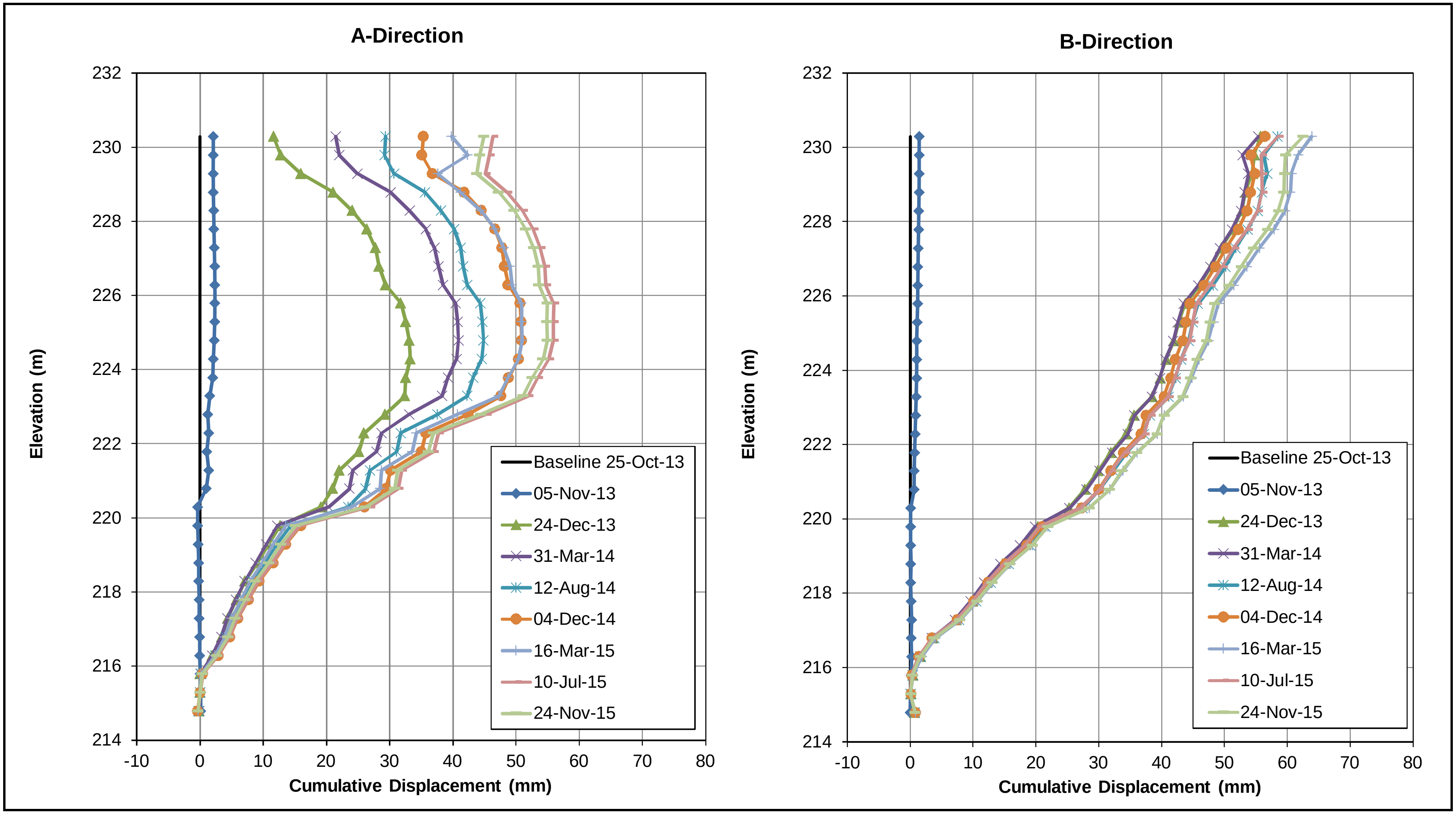


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement in A and B Directions (Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-1B

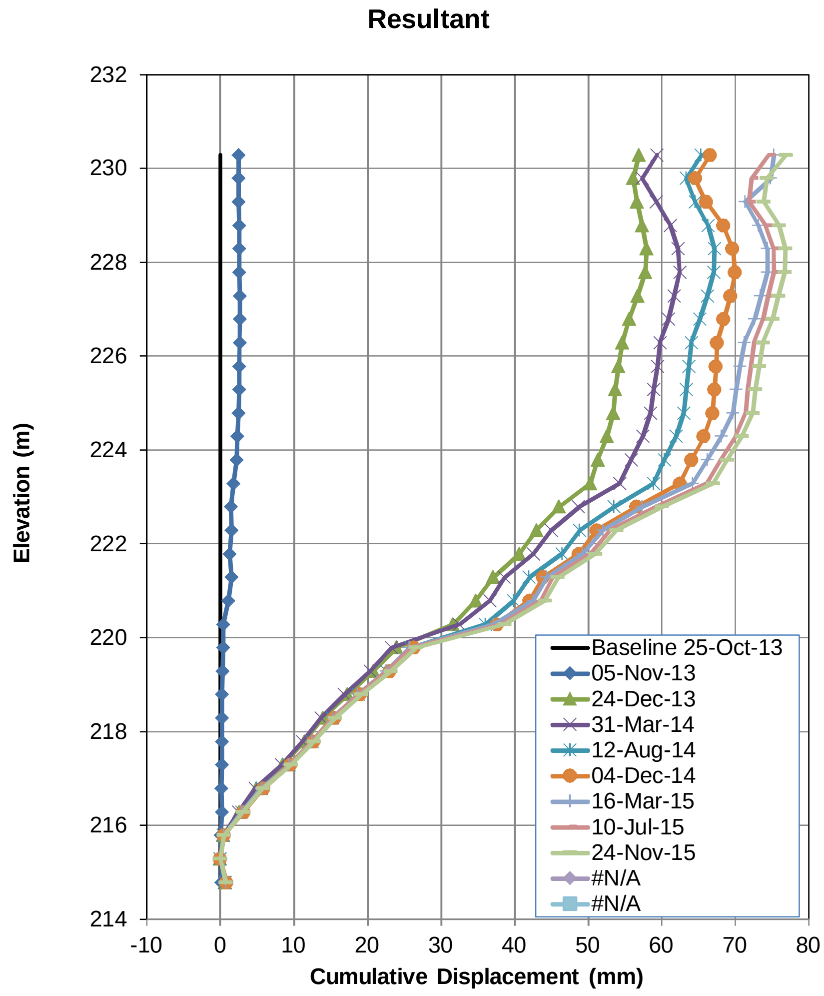


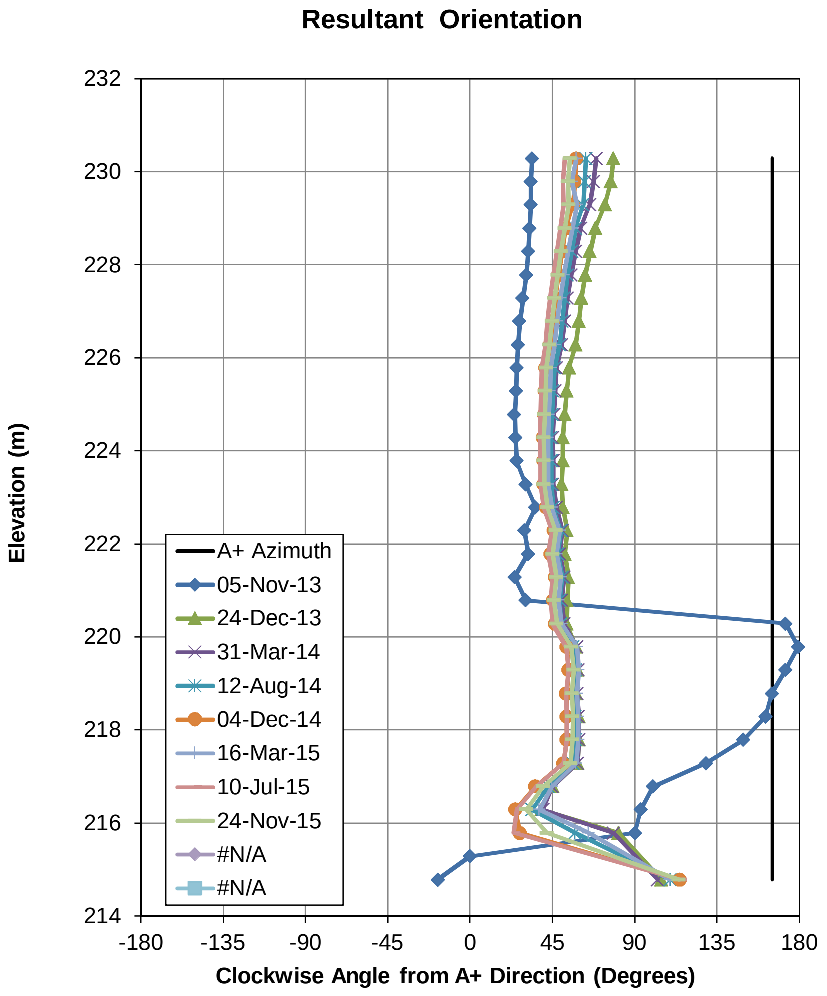
SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-1B


Resultant

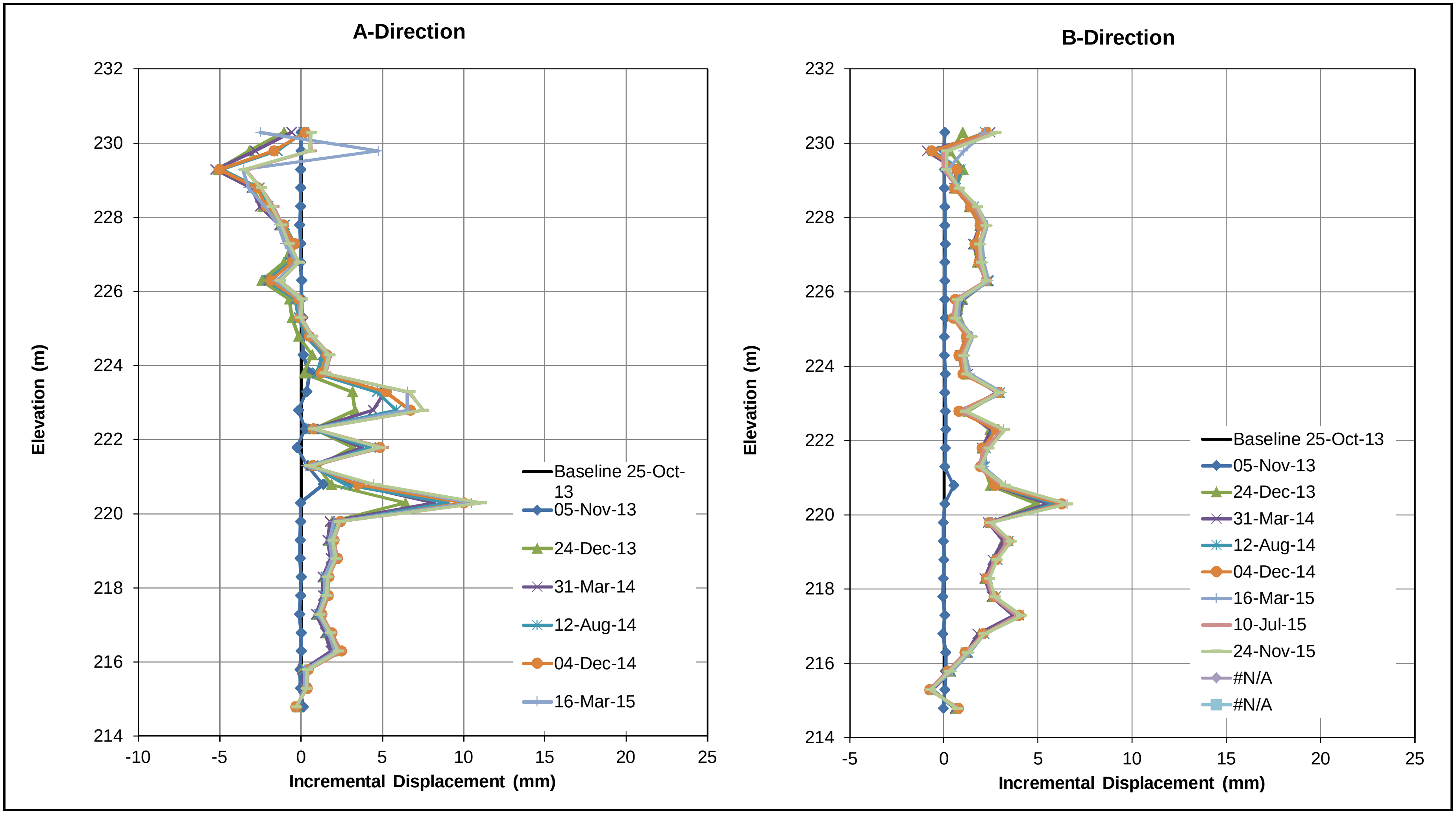

Resultant Orientation

SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

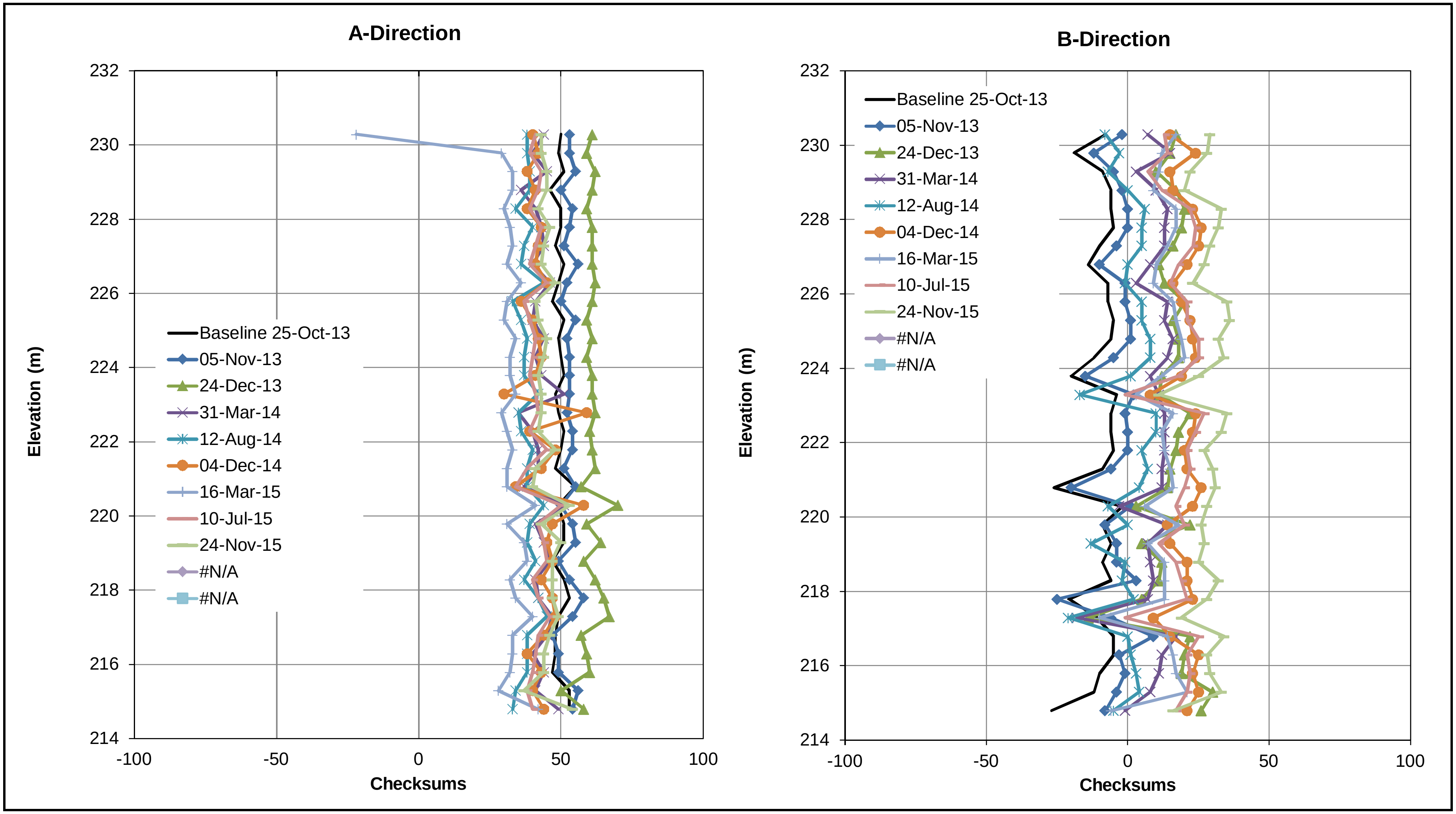
Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-1B



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-1B



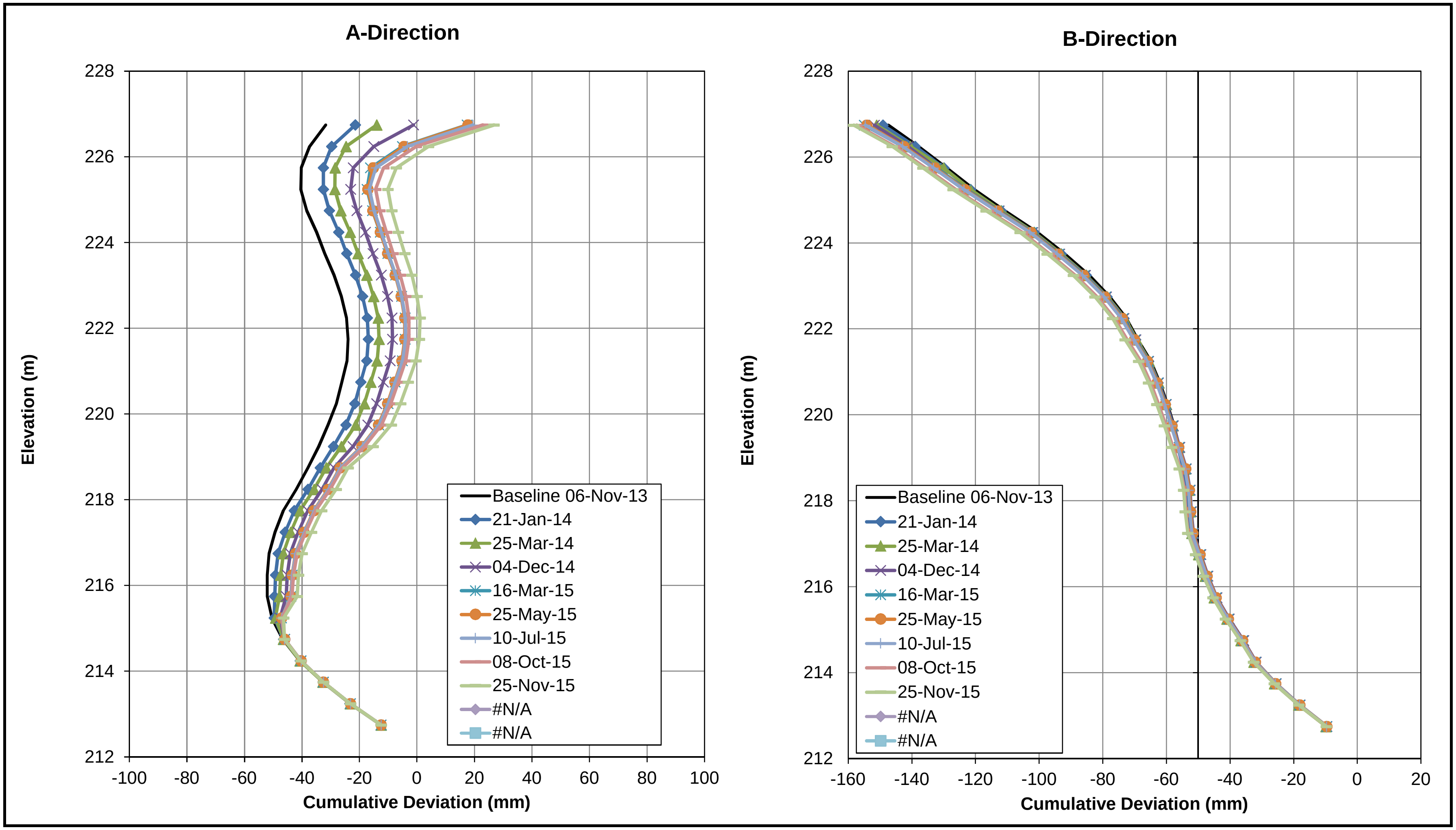
SI-2B

SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-2B

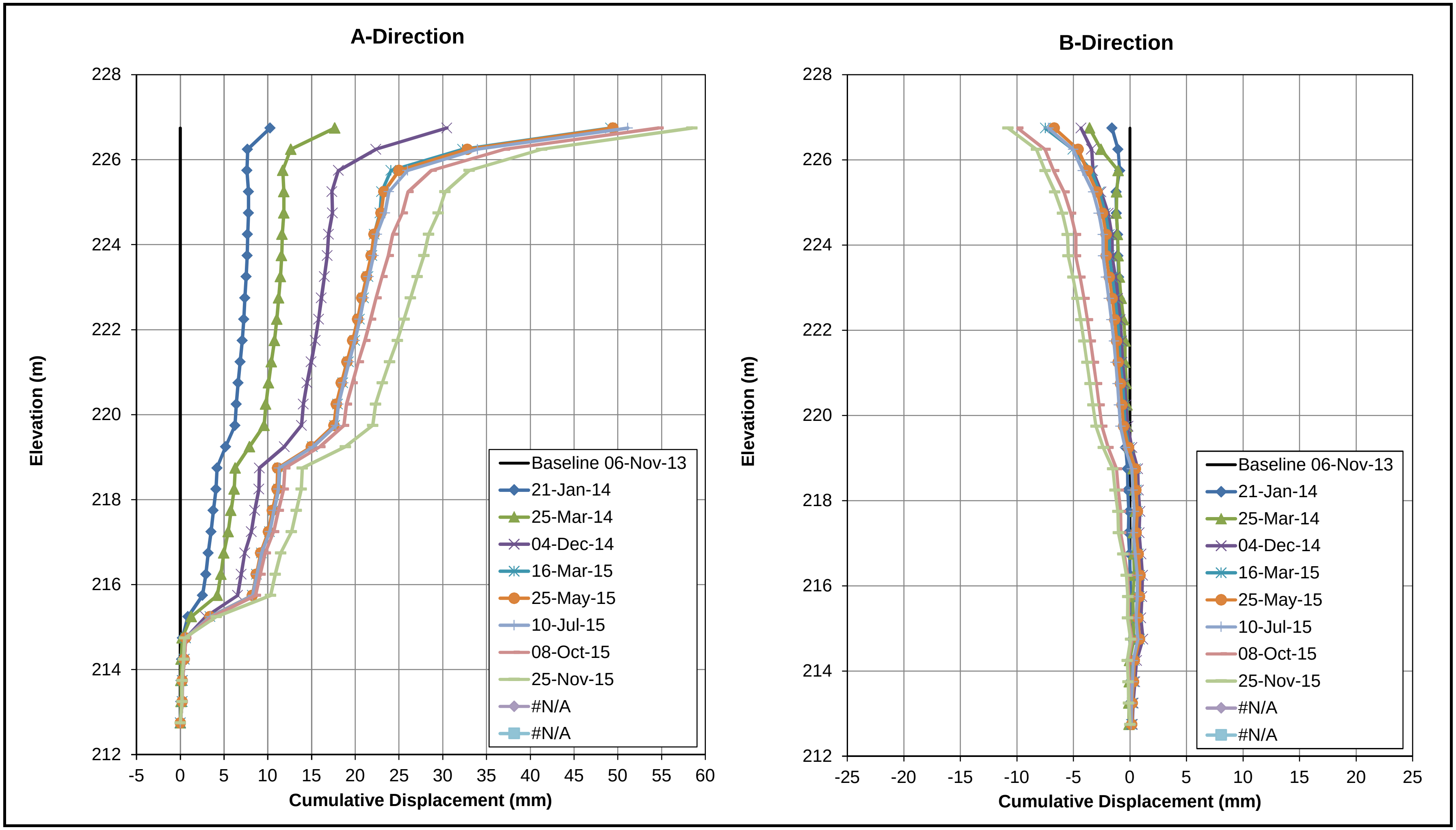


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement in A and B Directions (Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-2B

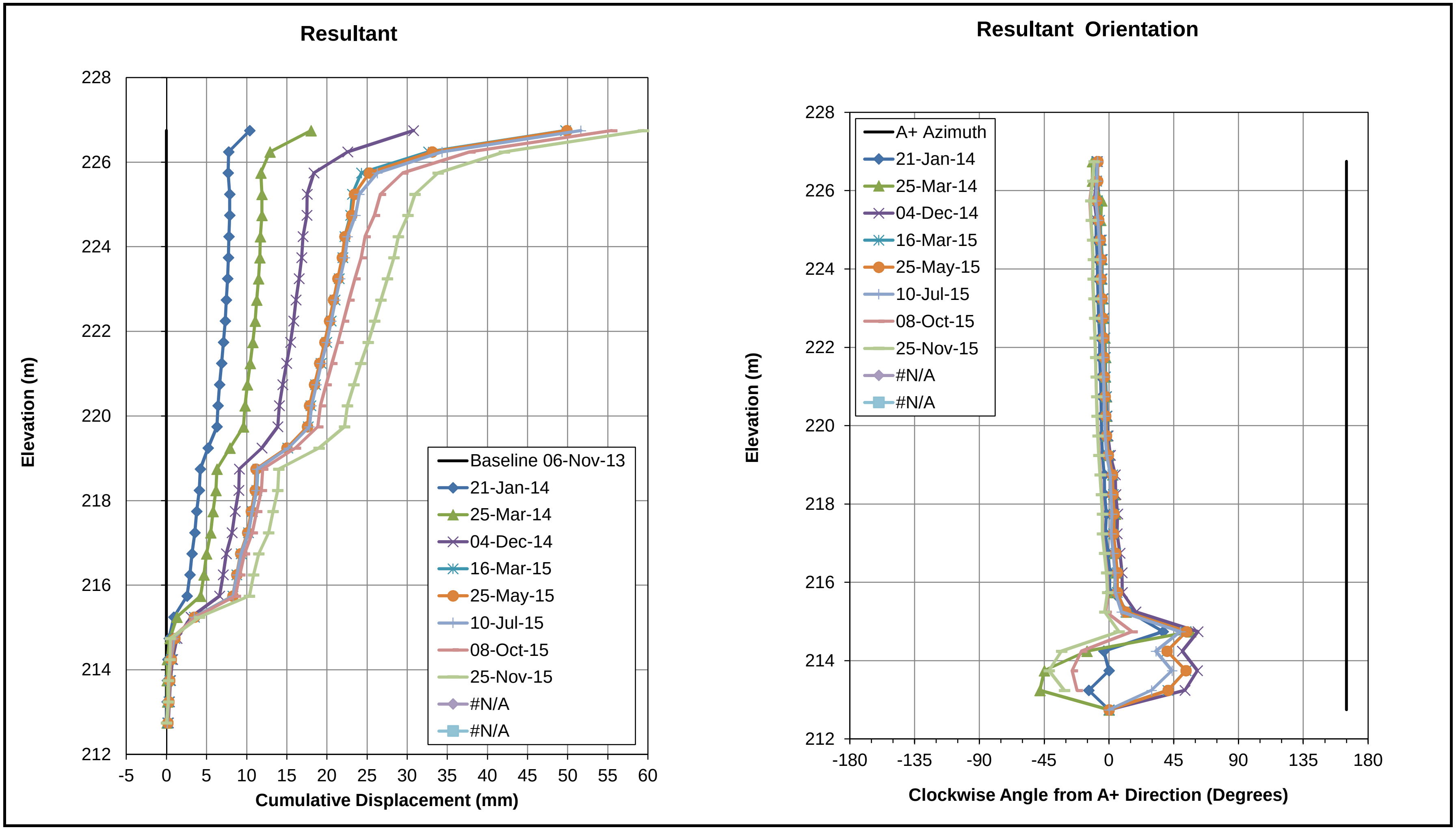


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-2B

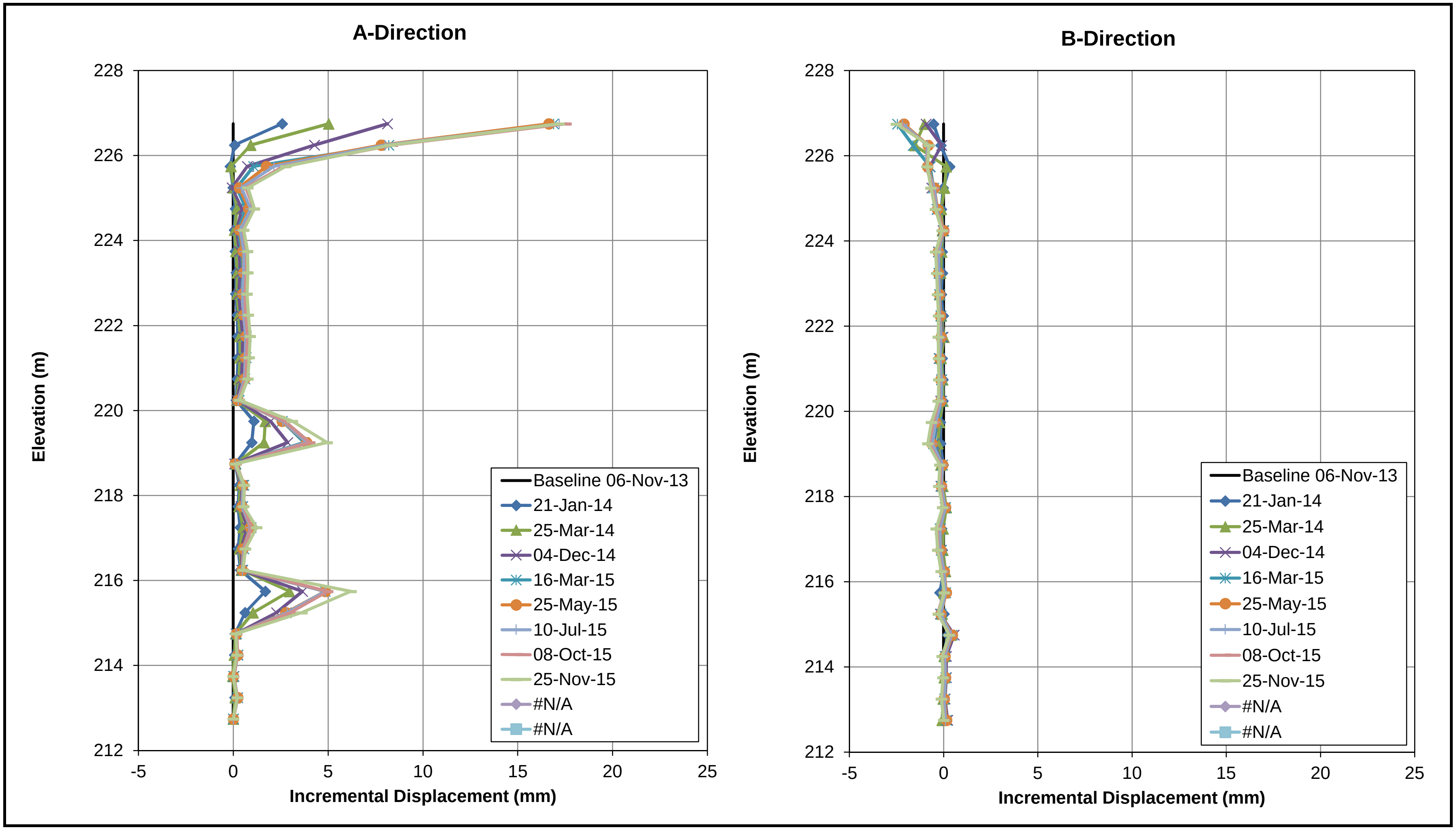


SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

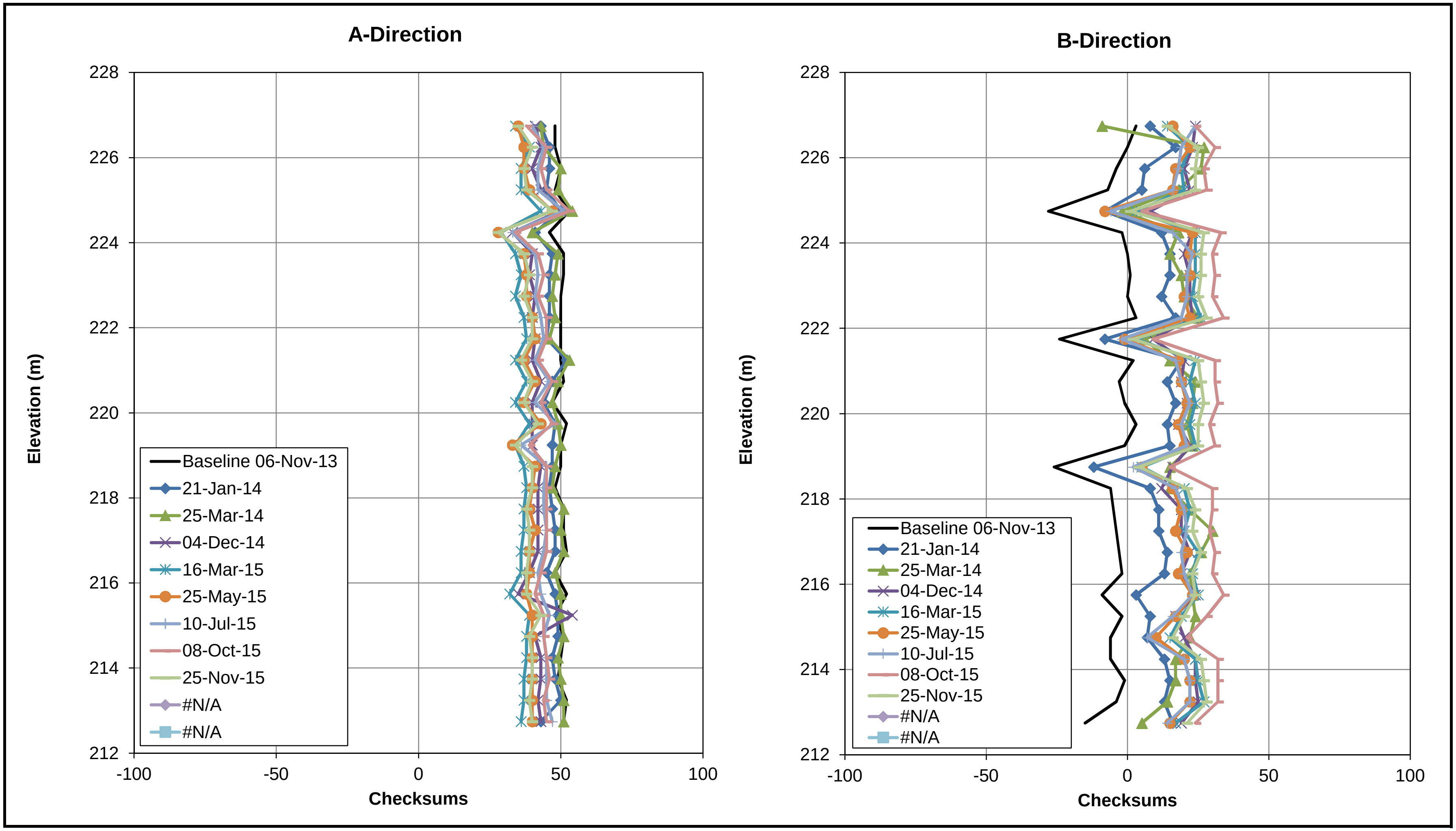
Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-2B



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-2B



TREK GEOTECHNICAL Quality Engineering | Valued Relationships

January 28, 2015 File No. 0015 008 00

Mr. Kendall Thiessen, P.Eng.
Riverbank Management Engineer
City of Winnipeg, Planning, Property and Development Department
Waterways Section
15 – 30 Fort Street
Winnipeg, MB R3C 4X5

RE Lyndale Drive –Ave. Taché to Gauvin St.
Final 2-year Riverbank Monitoring Summary

Please find enclosed final monitoring results for instrumentation installed along riverbank and retaining wall along Lyndale Drive from Avenue Taché to Gauvin Street. The instrumentation was installed in 2013 as part of a riverbank stabilization project from Monck Avenue to Avenue Taché to evaluate the riverbank condition for possible future stabilization works along the stretch of riverbank upstream of the 2013 stabilized zone. Monitoring instrumentation included slope inclinometer casings (SI's) and vibrating-wire piezometers (VW's) along the lower, mid and upper bank areas at three cross-sections within the upstream stretch of bank. Additional instrumentation was installed within the 2013 stabilized zone to monitor movements during construction. Results of monitoring in the 2013 stabilized zone are reported separately and will not be repeated herein.

The test hole locations and types of instrumentation installed are shown on the attached site plan (Figure 1) as well as in cross-section in Figures 02, 03 and 04. Figure 1 also shows the limits and types of retaining walls present, including a timber pile wall constructed in 1976 that extends upstream of the 2013 stabilized zone, ending near the intersection of Lyndale Drive and Gauvin Street. Evidence of lower to mid bank movements is apparent at various locations along this stretch of bank, based on visual site inspections and aerial photo review. The current letter concludes the 2-year monitoring program with final monitoring results, which are attached along with test hole logs.

Seven slope inclinometers and four vibrating wire piezometers were installed along three cross-sections (XS-B to XS-D), as outlined in our previous monitoring letter. The upper-bank test hole (TH13-05) was drilled within the boulevard just upslope of the existing timber pile retaining wall, while mid-bank test holes were drilled just downslope of the wall and lower-bank test holes were drilled along the shoreline. Baseline readings on inclinometers were taken in late October 2013 with up to four to five subsequent monitoring events per year (pre and post spring flood, pre and post fall drawdown, possibly mid-summer or mid-winter events as well). Vibrating-wire piezometer monitoring was also completed at each monitoring event.

Groundwater Monitoring Results

The groundwater monitoring results to date are attached for piezometers VW-5A/5B and VW-7A/7B located in the upper and lower bank areas, respectively. Vibrating wire piezometers installed in the lacustrine clay maintained relatively constant piezometric levels ranging from about Elev. 226.0 m to 226.8 m in the upper bank (VW-5A) or from about Elev. 224 m. to 225.3 m in the lower bank (VW-7A). These levels ranged from about 2 to 4 m above river level in the upper bank, and from about 1 to 2 m above river level in the lower bank with the exception of flood stages when they are lower than the river level.

Piezometric levels in the till ranged from about Elev. 223.2 m to 224.7 m in the upper bank (VW-5B) and from about Elev. 221.5 m to 223.7 in the lower bank (VW-7B). Levels at the top of bank (VW-5B) were typically about 0.8 m to 1.2 m above the river level. At the lower bank area (VW-7B), levels tended to more closely match the river level. The exception to both of these observations is during flood events or regulated summer conditions when river levels are equal to or higher than piezometric levels in the till.

All clay and till piezometers showed higher levels following the spring and summer flooding and lower levels during the winter months. Critical groundwater conditions typically occur during the fall and winter months where the groundwater levels in the bank exceeded the river elevation by up to 1.5 m (till) and 4 m (lacustrine clay).

Inclinometer Monitoring Results

Slope inclinometer cumulative displacement profiles as well as displacement rate plots are attached for all seven SI’s. The year-end cumulative displacement profiles (Dec 2014 and Nov 2015) are also shown on the stratigraphic cross-sections to aid in visualization of slope movements.

Cross Section A

Up until October 8, 2015, about 20 mm of horizontal displacement has been observed at the lower bank area in SI-4 about 1.7 m above the till contact (Elev. 217.0 m). During this period, about 5 mm occurred in proximity to the fall drawdown event in 2014. During the 2015 fall drawdown, an additional 45 mm of displacement occurred, bringing the cumulative displacement on November 25 to 71 mm.

In the mid-bank area at SI-3, about 2 to 3 mm of horizontal displacement was observed about 1.2 m above the till contact (Elev. 216.8 m) likely during the 2014 fall drawdown with an additional 2 mm during the 2015 drawdown event (total to date of 4 mm). About 43 mm of cumulative horizontal displacement has been observed within the upper 0.5 m of SI-3; this is believed to be from environmental effects and not slope movement. Both SI-3 and SI-4 cumulative movement profiles are indicative of shear displacement within the clay just above the till contact, although the magnitudes differ. A comparison of these results indicates that retrogression of riverbank movements towards the retaining wall is occurring although the movements at mid-bank may not not yet be associated with a well defined failure surface; they may be more indicative of creep movements at this location.

Cross Section B

Up until October 9, 2015, horizontal displacements of 17 and 3 mm of horizontal displacement were observed 0.2 m and 3.5 m above the till contact (Elev. 217.5 m and 220.5 m respectively) at SI-7 located in the lower-bank. It appears that a significant portion of the movement occurred in proximity to the 2014 drawdown event and that the shallower movement continued up until the last reading in October 2015. It was not possible to lower the probe past Elev. 221.2 m in late November 2015 suggesting that additional deflections at this depth occurred over the 2015 drawdown event.

Up until November 26, 2015, about 7 and 2 mm of horizontal displacement has been observed at about Elev. 226 m (8.2 m above the till contact) and about 3 mm at Elev. 219 m (1.2 m above the till contact) in SI-6 (mid-bank). Of these total movements, about 1 to 2 mm appears to have occurred over the 2015 drawdown event. The 20 mm of horizontal displacement observed within the upper 0.5 m of SI-6 is believed to be from environmental effects and not slope movement

The upper bank inclinometer (SI-5) has shown negligible displacement below about Elev. 227 m (approx. 3 m below existing ground downslope of wall). Above this elevation, the displacement plot shows a measureable tilt of the casing towards the wall, with about 7 mm of cumulative displacement at ground surface.

The monitoring suggests active movement along two slip surfaces near the toe of the slope (SI-7) and that some acceleration of lower bank movement occurred during the 2015 fall drawdown. Displacements in the mid-bank area (SI-6) indicate this portion of the bank has been impacted by the lower bank movements and creep movements are occurring, although there is no evidence of a well defined failure surface at this location. The upper-bank movements (SI-5) can likely be attributed to deterioration and leaning of the timber pile retaining wall rather than deep-seated riverbank movements.

Cross Section C

Up until November 25, 2015, about 20 mm of horizontal displacement has been observed in the upper 4 m of SI-9 located at the lower-bank. This is not considered indicative of a differential (shear) displacement associated with a deep-seated failure surface but rather may be attributed to shallow translational movement of a layer of fill at this location.

In the mid-bank area, about 3 mm of horizontal displacement has been observed at Elev. 218.5 m (about 1.2 m above till) in SI-8 up until November 25, 2015. Of this total, only about 1 to 2 mm of movement above the till occurred over the 2015 fall drawdown event. Over the same period, about 5mm of near surface displacement attributable to environmental effects has been observed.

The movements measured to date are relatively mall and close to the resolution of the monitoring probe. They do not indicate any active riverbank instabilities at this location, although creep movements may be occurring.

Summary and Discussion

Prior to the construction of the retaining wall and off-loading of the riverbank in 1976, upper bank head scarps accompanied by mid and lower bank instabilities were observed along this stretch of Lyndale Drive. Based on the assumption that the bank downslope of the wall was uniformly graded for off-loading, the uneven slope geometry indicates continued riverbank movements have occurred after this work was done, at least along some stretches. Slope inclinometer monitoring confirms that these movements are ongoing as evidenced by up to 45 mm (or more) of lower-bank displacements and up to 10 mm of mid-slope displacement over a period of two years. While the rate of mid-bank displacement is relatively small, retrogression of active instabilities towards the retaining wall and roadway remains a possibility, however the time frame for this to occur is uncertain. Horizontal displacement upslope of the retaining wall could possibly be attributed to deterioration of the timber piles and leaning of the wall. Significant deterioration of the timber piles was confirmed within the 2013 stabilized zone downstream of the project area and likely applies to the piles within the current section of the bank.

Please don't hesitate to contact me if have you any questions or require further clarification.

Kind Regards,

TREK Geotechnical
Per:

Michael Van Helden, P.Eng.
Geotechnical Engineer, Tel: 204.975.9433 ext 102

MVH/kms

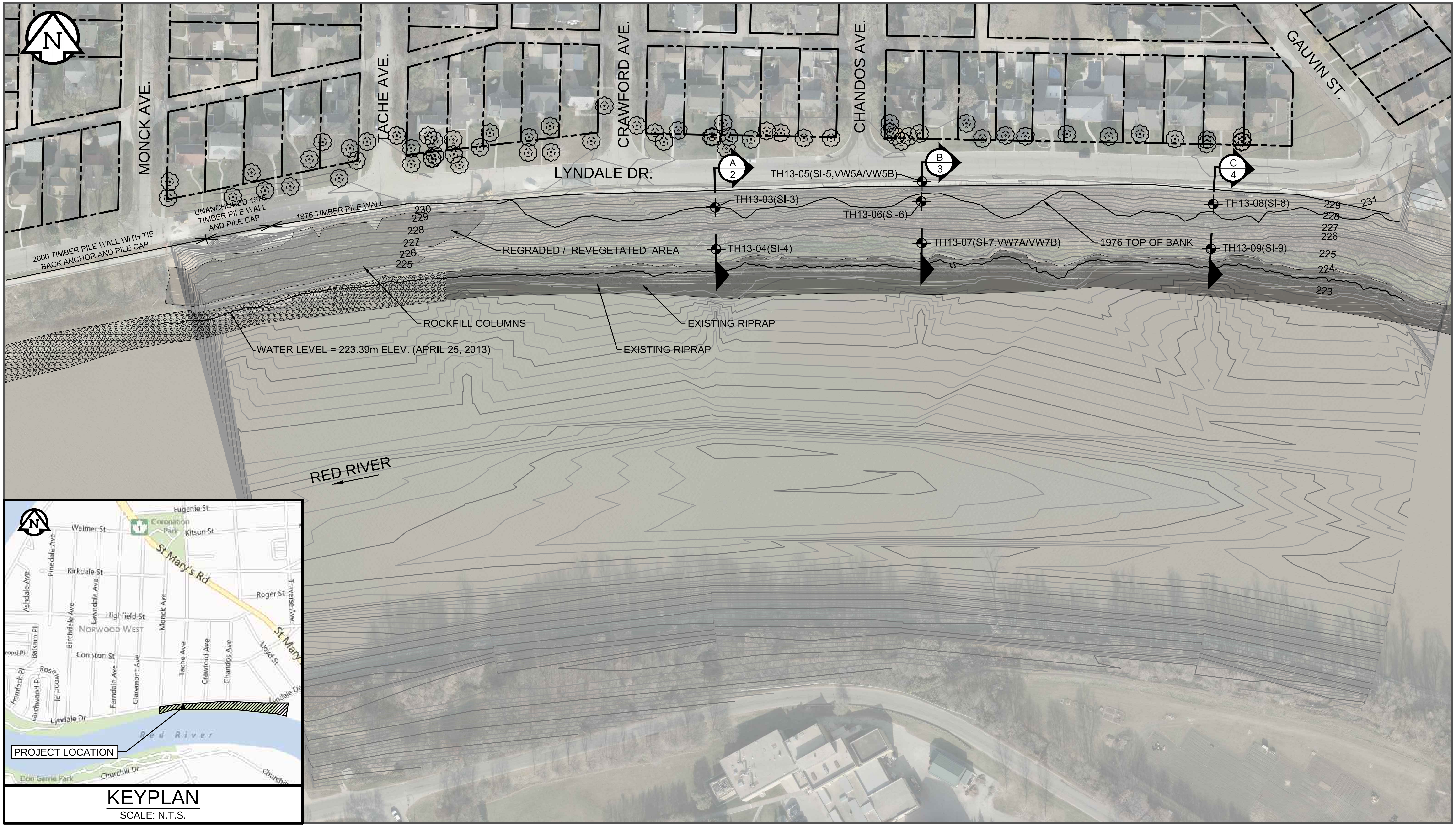
cc. Brad Neirinck, P.Eng., City of Winnipeg Public Works
Ken Skaftfeld, P.Eng., TREK Geotechnical Inc.

Site Plan and Cross-Sections

0015 014 00

City of Winnipeg

Preliminary Engineering Study for Lyndale Drive Retaining Wall - Monck Ave. to Gauvin St.



0 15 30 45 60m

SCALE : 1:1500 (279mm x 432mm)

LEGEND :

⌖ TEST HOLE (TREK, 2013)

✿ TREE

— - — APPROXIMATE PROPERTY LINE

NOTES :

1. GROUND SURFACE TOPOGRAPHY BASED ON LIDAR SURVEYS PROVIDED BY CITY OF WINNIPEG.
2. AERIAL IMAGE TAKEN IN 2013 PROVIDED BY CITY OF WINNIPEG
3. SI-1 IN TH13-01 ABANDONED ON OCTOBER 25, 2013
4. SI-2 IN TH13-02 ABANDONED ON NOVEMBER 11, 2013

Figure 01
Site Plan

Tabloid (279mm x 432mm)

PLOT: 1/28/2016 8:46:35 AM

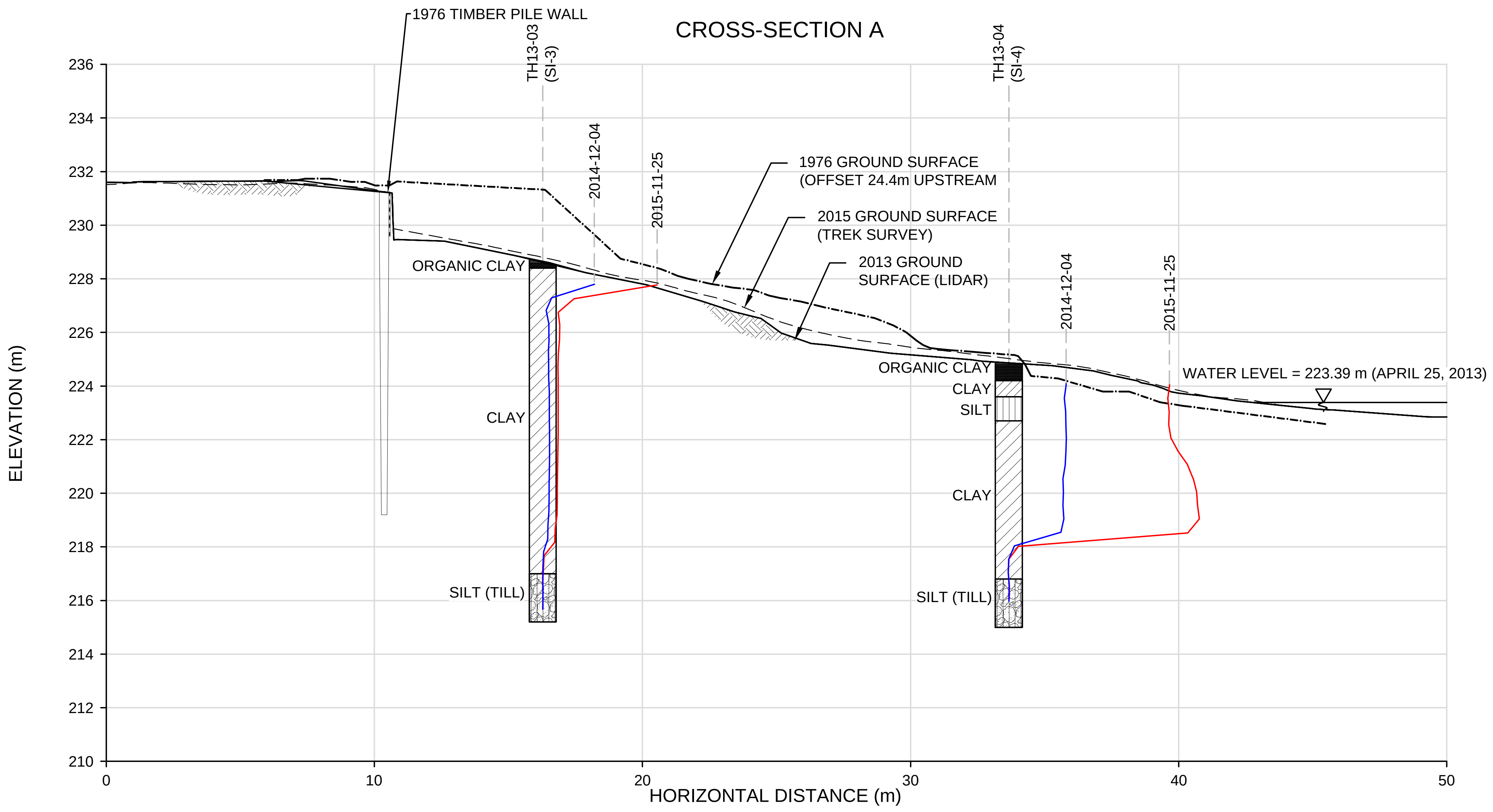
FILE NAME: FIG 002 2016-01-28 Site Plan 0_G_HA 0015 014 00.dwg

0015 014 00
City of Winnipeg
Preliminary Engineering Study for Lyndale Drive Retaining Wall - Monck Ave. to Gauvin St.

Tabloid (279mm x 432mm)

PLOT: 1/28/2016 8:52:43 AM

FILE NAME: FIG 002 2016-01-28 Site Plan 0_G_HA 0015 014 00.dwg



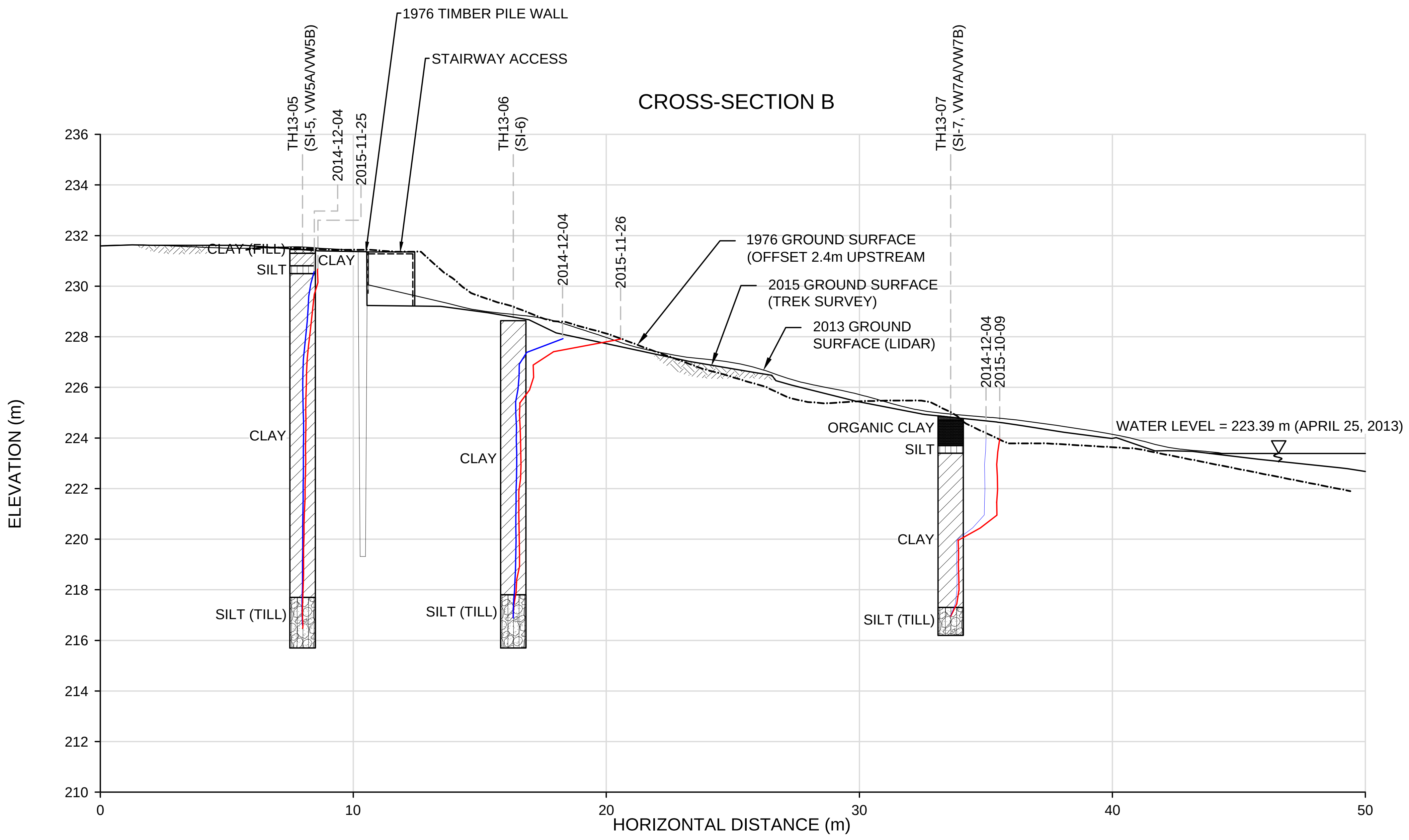
(HORIZONTAL SCALE FOR SI DISPLACEMENT PLOTS)
0 20 40 60 80mm
SCALE : 1:2 (279mm x 432mm)

0 2 4 6 8m
SCALE : 1:200 (279mm x 432mm)

NOTES :

1. SLOPE INCLINOMETER DISPLACEMENT SHOWN FOR NOVEMBER 25, 2015

Figure 02
Cross Section A



(HORIZONTAL SCALE FOR SI DISPLACEMENT PLOTS)
0 20 40 60 80mm
SCALE : 1:2 (279mm x 432mm)

0 2 4 6 8m
SCALE : 1:200 (279mm x 432mm)

NOTES :

1. SLOPE INCLINOMETER CUMULATIVE DISPLACEMENT SHOWN FOR NOVEMBER 25, 2015 (SI-6) AND OCTOBER 9, 2015 (SI-7).

Figure 03
Cross Section B

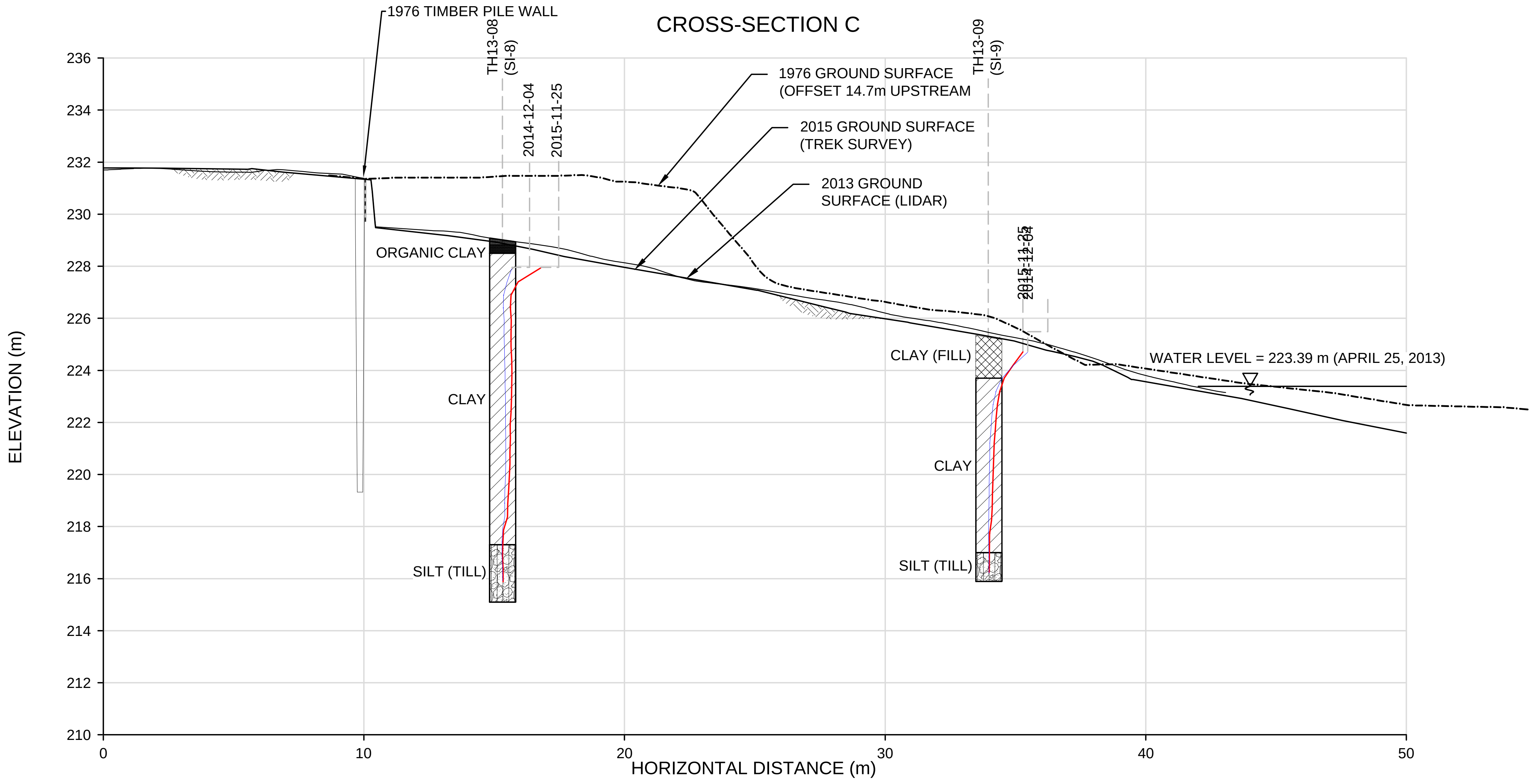
TREK GEOTECHNICAL

0015 014 00
City of Winnipeg
Preliminary Engineering Study for Lyndale Drive Retaining Wall - Monck Ave. to Gauvin St.

Tabloid (279mm x 432mm)

PLOT: 1/28/2016 9:14:48 AM

FILE NAME: FIG 002 2016-01-28 Site Plan 0_G_HA 0015 014 00.dwg



(HORIZONTAL SCALE FOR SI DISPLACEMENT PLOTS)

0 20 40 60 80mm

SCALE : 1:2 (279mm x 432mm)

0 2 4 6 8m

SCALE : 1:200 (279mm x 432mm)

NOTES :

1. SLOPE INCLINOMETER DISPLACEMENT SHOWN FOR NOVEMBER 25-26, 2015

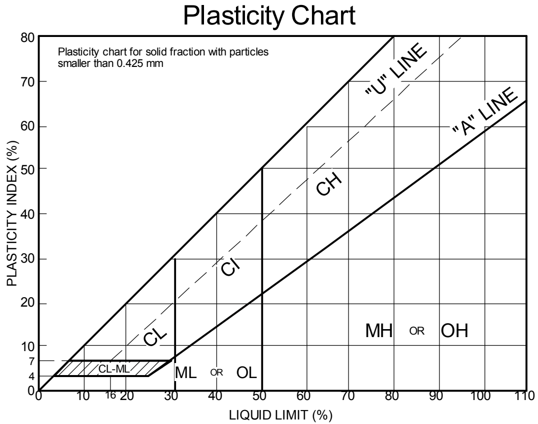
Figure 04
Cross Section C

Test Hole Logs

EXPLANATION OF FIELD AND LABORATORY TESTING

GENERAL NOTES

1. Classifications are based on the United Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.
2. Descriptions on these test hole logs apply only at the specific test hole locations and at the time the test holes were drilled. Variability of soil and groundwater conditions may exist between test hole locations.
3. When the following classification terms are used in this report or test hole logs, the primary and secondary soil fractions may be visually estimated.

Major Divisions			USCS Classi- fication	Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained soils (More than half the material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than 4.75 mm)	Clean gravel (Little or no fines)	GW	■	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain size curve, depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent...... GW, GP, SW, SP More than 12 percent...... GM, GC, SM, SC 6 to 12 percent...... Borderline case4s requiring dual symbols*	$C_U = \frac{D_{60}}{D_{10}}$ greater than 4; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	▢	Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravel with fines (Appreciable amount of fines)	GM	▥	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC	▨	Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than 4.75 mm)	Clean sands (Little or no fines)	SW	⁘	Well-graded sands, gravelly sands, little or no fines		$C_U = \frac{D_{60}}{D_{10}}$ greater than 6; $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	⁚	Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM	▥	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC	▨	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained soils (More than half the material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	▥	Inorganic silts and very fine sands, rock floor, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart  		
			CL	▨	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	▤	Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH	▥	Inorganic silts, micaceous or distomaceous fine sandy or silty soils, organic silts			
			CH	▨	Inorganic clays of high plasticity, fat clays			
			OH	≋	Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt	⁂	Peat and other highly organic soils	Von Post Classification Limit	Strong colour or odour, and often fibrous texture	

Material		Particle Size ASTM Sieve sizes	Particle Size mm
Sand	Coarse	#10 to #4	2.00 to 4.75
	Medium	#40 to #10	0.425 to 2.00
	Fine	#200 to #40	0.075 to 0.425
Silt or Clay		< #200	< 0.075

Material		Particle Size ASTM Sieve Sizes	Particle Size mm
Boulders		> 12 in.	> 300
Cobbles		3 in. to 12 in.	75 to 300
Gravel	Coarse	3/4 in. to 3 in.	19 to 75
	Fine	#4 to 3/4 in.	4.75 to 19

* Borderline classifications used for soils possessing characteristics of two groups are designated by combinations of groups symbols. For example; GW-GC, well-graded gravel-sand mixture with clay binder.

Other Symbol Types

■	Asphalt	▧	Bedrock (undifferentiated)	▢	Cobbles
⁘	Concrete	⊞	Limestone Bedrock	■	Boulders and Cobbles
▩	Fill	▤	Cemented Shale	▥	Silt Till
		▧	Non-Cemented Shale	▨	Clay Till

TREK GEOTECHNICAL

EXPLANATION OF FIELD AND LABORATORY TESTING

LEGEND OF ABBREVIATIONS AND SYMBOLS

LL - Liquid Limit (%)
PL - Plastic Limit (%)
PI - Plasticity Index (%)
MC - Moisture Content (%)
SPT - Standard Penetration Test
RQD - Rock Quality Designation
Qu - Unconfined Compression
Su - Undrained Shear Strength
VW - Vibrating Wire Piezometer
SI - Slope Inclinometer

▽ Water Level at Time of Drilling
▼ Water Level at End of Drilling
⧨ Water Level After Drilling as Indicated on Test Hole Logs

FRACTION OF SECONDARY SOIL CONSTITUENTS ARE BASED ON THE FOLLOWING TERMINOLOGY

TERM	EXAMPLES	PERCENTAGE
and	and CLAY	35 to 50 percent
"y" or "ey"	clayey, silty	20 to 35 percent
some	some silt	10 to 20 percent
trace	trace gravel	1 to 10 percent

TERMS DESCRIBING CONSISTENCY OR COMPACTION CONDITION

The Standard Penetration Test blow count (N) of a non-cohesive soil can be related to compactness condition as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very loose	< 4
Loose	4 to 10
Compact	10 to 30
Dense	30 to 50
Very dense	> 50

The Standard Penetration Test blow count (N) of a cohesive soil can be related to its consistency as follows:

Descriptive Terms	SPT (N) (Blows/300 mm)
Very soft	< 2
Soft	2 to 4
Firm	4 to 8
Stiff	8 to 15
Very stiff	15 to 30
Hard	> 30

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

Descriptive Terms	Undrained Shear Strength (kPa)
Very soft	< 12
Soft	12 to 25
Firm	25 to 50
Stiff	50 to 100
Very stiff	100 to 200
Hard	> 200

TREK GEOTECHNICAL

Sub-Surface Log

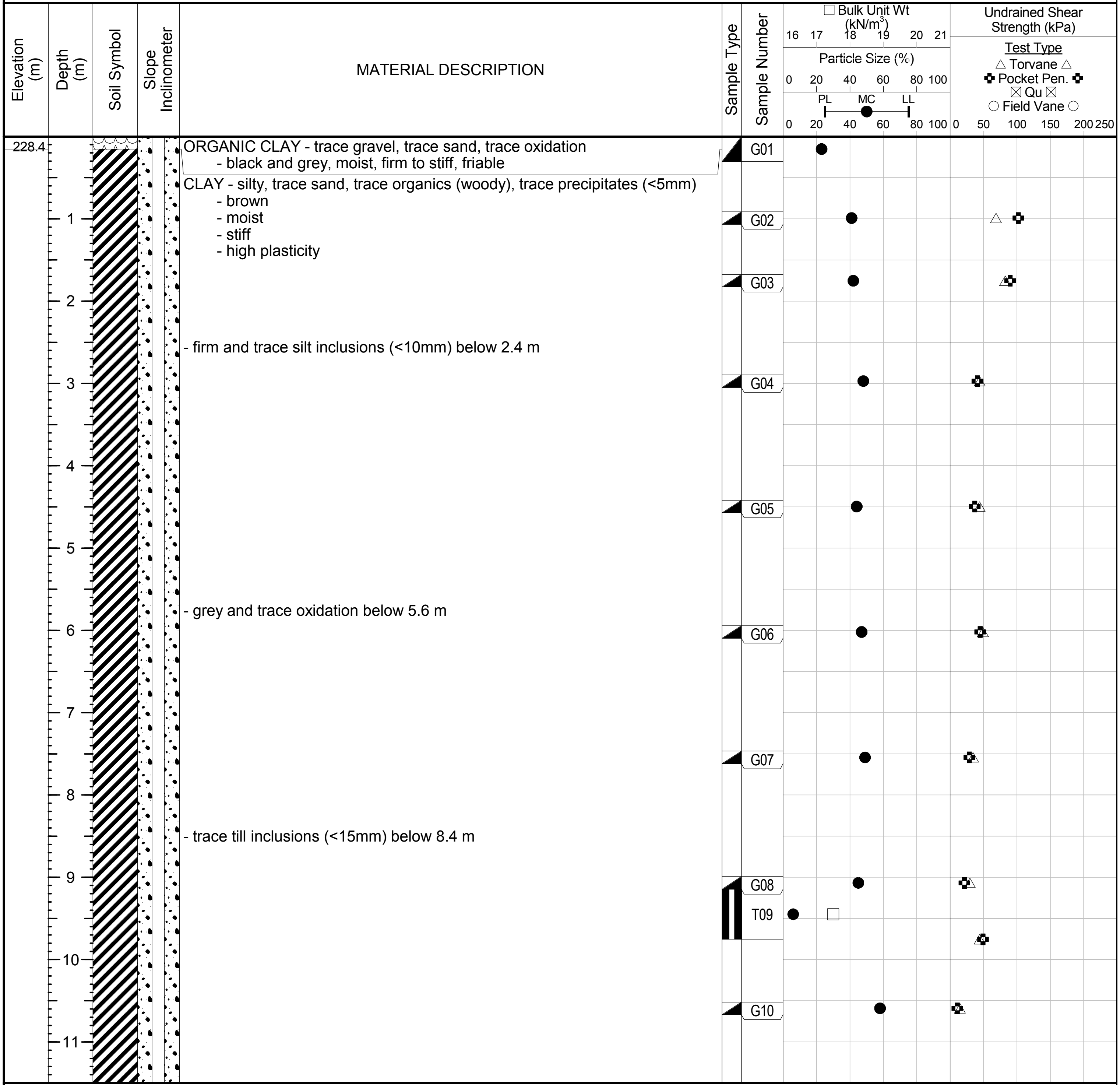
Test Hole TH13-03

Client: City of Winnipeg - Public Works
Project Number: 0015 008 00
Project Name: Lyndale Drive Retaining Wall Assessment
Location: Lyndale Dr. between Monck Ave. and Gauvin St.
Contractor: Maple Leaf Drilling
Ground Elevation: 228.60 m
Method: 125 mm Solid Stem Auger, Acker MP5-T Track Mount
Date Drilled: 15 October 2013

Sample Type: ◩ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) ⧗ Split Barrel (SB) ▮ Core (C)

Particle Size Legend: ▥ Fines ▨ Clay ▥ Silt ▒ Sand ▒ Gravel ▒ Cobbles ■ Boulders

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



ORGANIC CLAY - trace gravel, trace sand, trace oxidation
- black and grey, moist, firm to stiff, friable

CLAY - silty, trace sand, trace organics (woody), trace precipitates (<5mm)
- brown
- moist
- stiff
- high plasticity

- firm and trace silt inclusions (<10mm) below 2.4 m

- grey and trace oxidation below 5.6 m

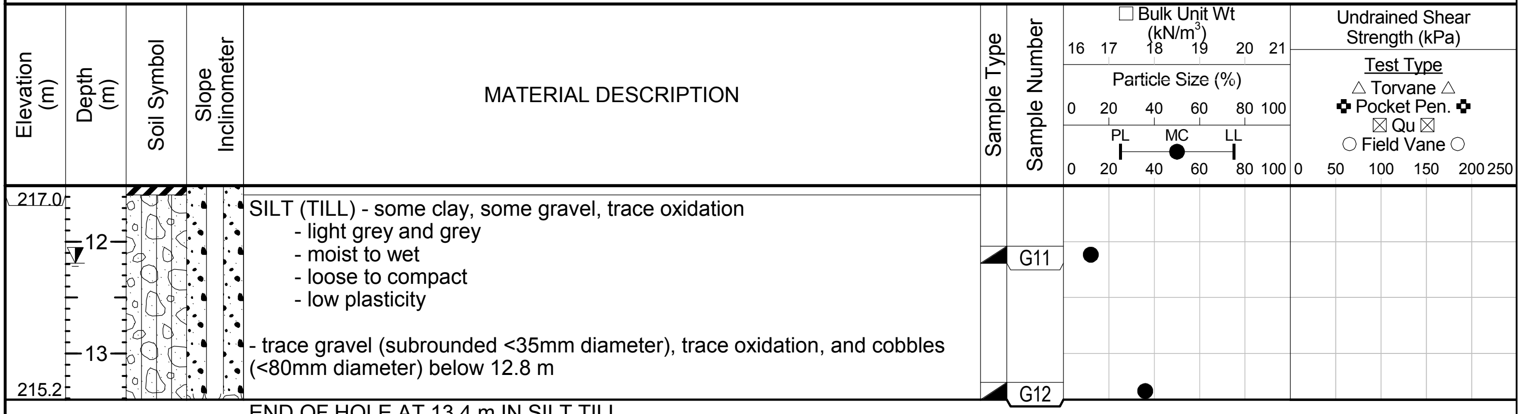
- trace till inclusions (<15mm) below 8.4 m

Logged By: Martial Lemoine **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

Sub-Surface Log

Test Hole TH13-03

2 of 2



SILT (TILL) - some clay, some gravel, trace oxidation
- light grey and grey
- moist to wet
- loose to compact
- low plasticity

- trace gravel (subrounded <35mm diameter), trace oxidation, and cobbles (<80mm diameter) below 12.8 m

END OF HOLE AT 13.4 m IN SILT TILL

Notes:

1) Power auger refusal (PAR) on suspected boulder at 13.4 m.
2) Seepage observed below 11.9 m.
3) No sloughing observed.
4) Water level at 12.2 m upon completion of drilling.
5) Slope inclinometer SI-03 installed in test hole.

Logged By: Martial Lemoine **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

TREK GEOTECHNICAL

Sub-Surface Log

Test Hole TH13-04

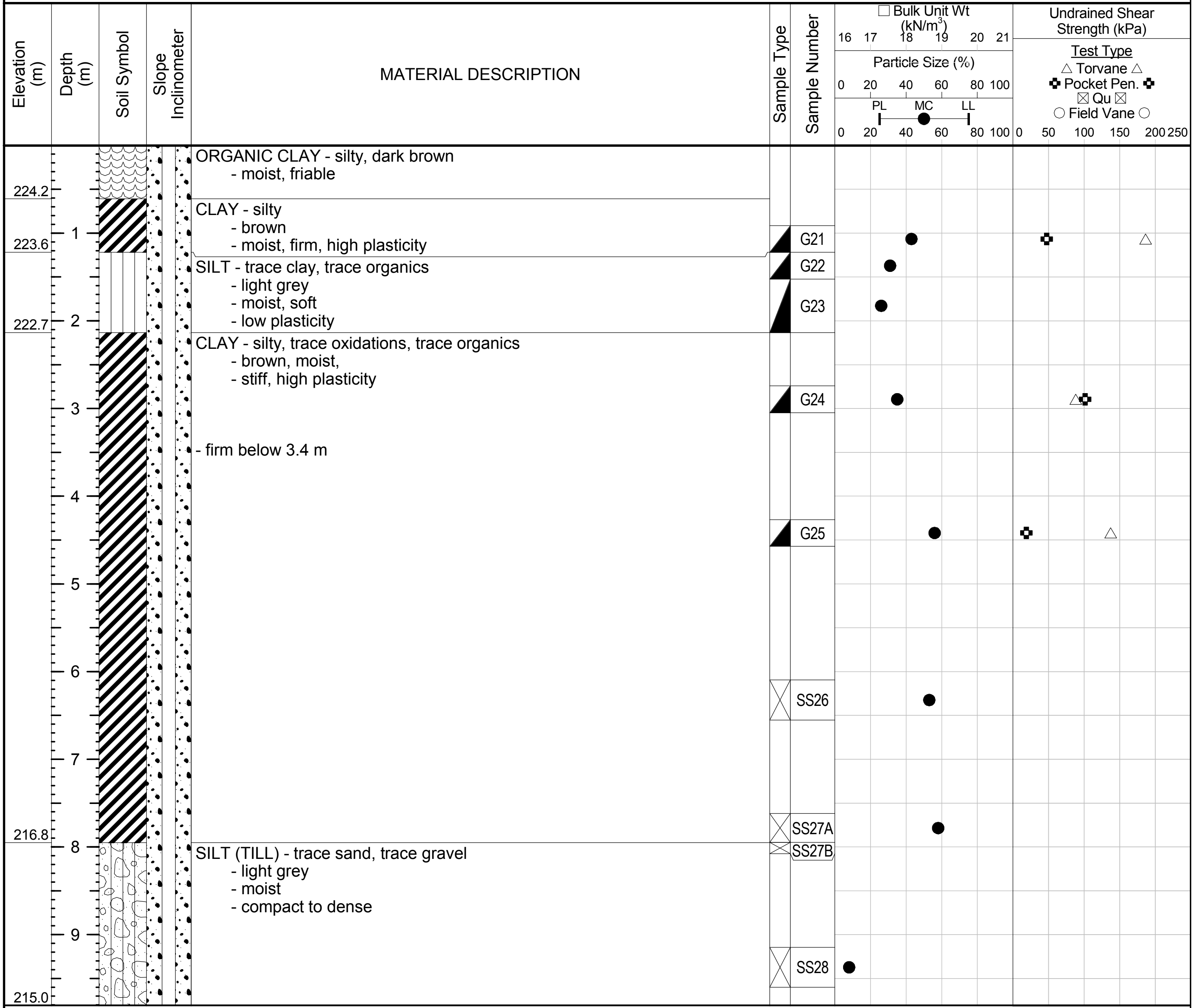
1 of 1

Client: City of Winnipeg - Public Works
Project Number: 0015 008 00
Project Name: Lyndale Drive Retaining Wall Assessment
Location: Lyndale Dr. between Monck Ave. and Gauvin St.
Contractor: Paddock Drilling Ltd.
Ground Elevation: 224.80 m
Method: 125 mm Solid Stem Auger, Acker MP5-T Track Mount
Date Drilled: 15 October 2013

Sample Type: ◪ Grab (G) ◫ Shelby Tube (T) ☒ Split Spoon (SS) ⧗ Split Barrel (SB) ◧ Core (C)

Particle Size Legend: ▥ Fines ▨ Clay ▥ Silt ▒ Sand ▓ Gravel ▧ Cobbles ■ Boulders

Backfill Legend: ■ Bentonite ▩ Cement ▨ Drill Cuttings ▒ Filter Pack Sand ▓ Grout ▧ Slough



Elevation (m)	MATERIAL DESCRIPTION
224.2	ORGANIC CLAY - silty, dark brown - moist, friable
223.6	CLAY - silty - brown - moist, firm, high plasticity
222.7	SILT - trace clay, trace organics - light grey - moist, soft - low plasticity
216.8	CLAY - silty, trace oxidations, trace organics - brown, moist, - stiff, high plasticity - firm below 3.4 m
215.0	SILT (TILL) - trace sand, trace gravel - light grey - moist - compact to dense

Sample Type	Sample Number
◪	G21
◪	G22
◪	G23
◪	G24
◪	G25
☒	SS26
☒	SS27A
☒	SS27B
☒	SS28

END OF HOLE AT 9.8 m IN SILT TILL
Notes:
1) Power auger refusal (PAR) at 9.8 m
2) Solid stem augers were used to 4.6 m depths then switched to hollow stem augers due to sloughing.
3) Seepage observed below 15.8 m
4) Sloughing was observed below 1.2 m
5) Slope inclinometer SI-04 installed in test hole, flush mounted.

Logged By: Michael Van Helden **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

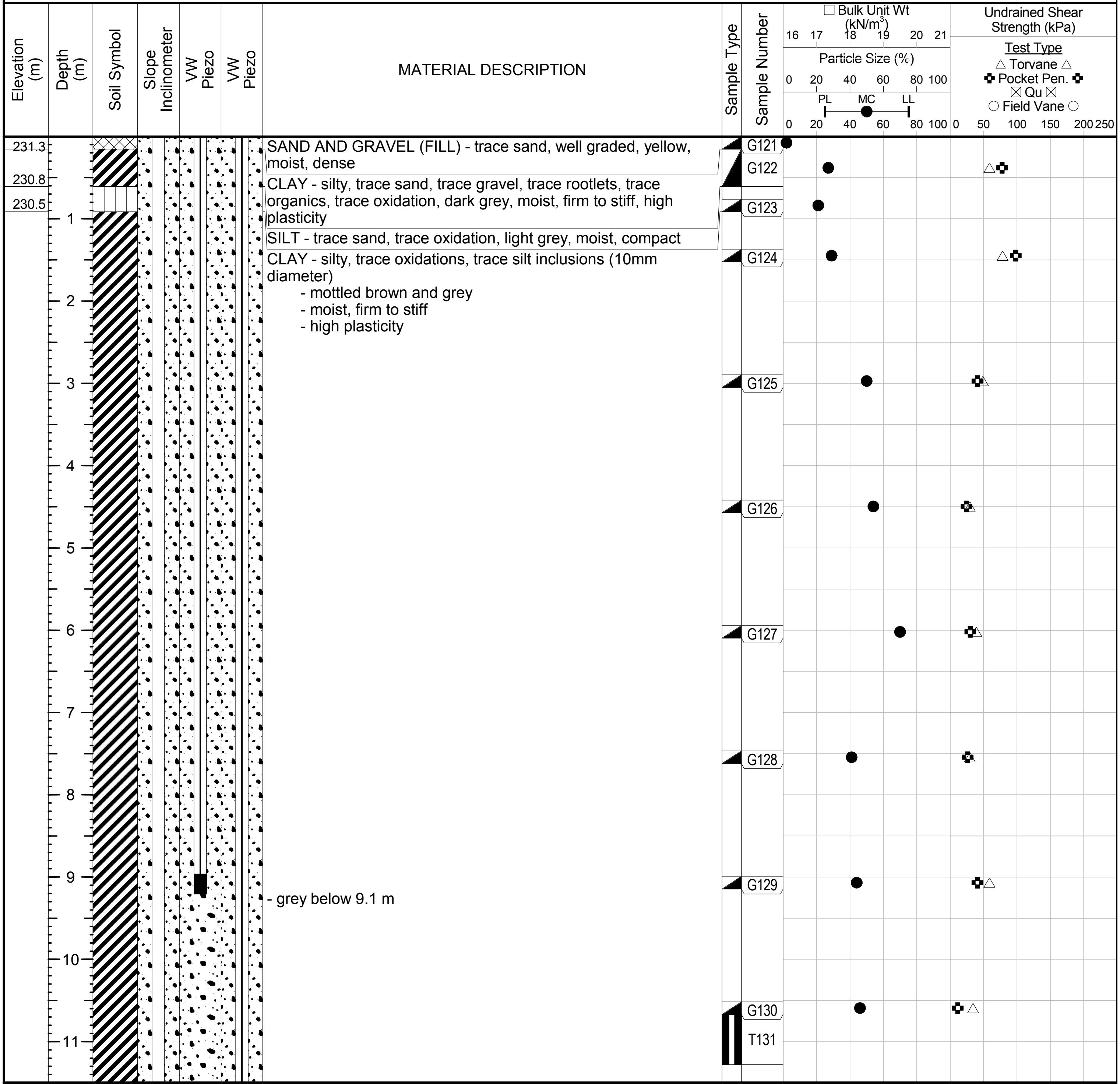
Test Hole TH13-05

1 of 2

Sub-Surface Log

Client: City of Winnipeg - Public Works
Project Number: 0015 008 00
Project Name: Lyndale Drive Retaining Wall Assessment
Location: Lyndale Dr. between Monck Ave. and Gauvin St.
Contractor: Maple Leaf Drilling
Ground Elevation: 231.41 m
Method: 125 mm Solid Stem Auger, Acker MP5-T Track Mount
Date Drilled: 16 October 2013

Sample Type:	Grab (G)	Shelby Tube (T)	Split Spoon (SS)	Split Barrel (SB)	Core (C)		
Particle Size Legend:	Fines	Clay	Silt	Sand	Gravel	Cobbles	Boulders
Backfill Legend:	Bentonite	Cement	Drill Cuttings	Filter Pack Sand	Grout	Slough	



SAND AND GRAVEL (FILL) - trace sand, well graded, yellow, moist, dense

CLAY - silty, trace sand, trace gravel, trace rootlets, trace organics, trace oxidation, dark grey, moist, firm to stiff, high plasticity

SILT - trace sand, trace oxidation, light grey, moist, compact

CLAY - silty, trace oxidations, trace silt inclusions (10mm diameter)
- mottled brown and grey
- moist, firm to stiff
- high plasticity

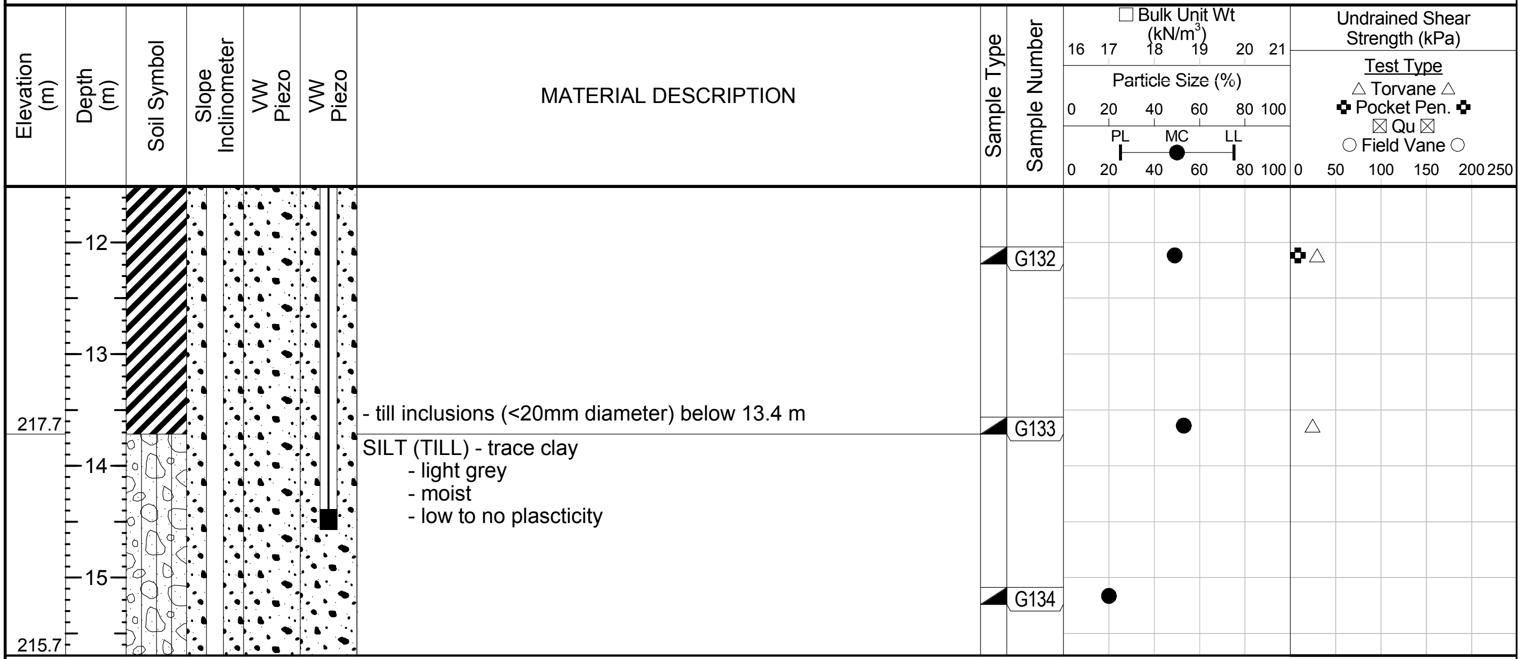
- grey below 9.1 m

Logged By: Martial Lemoine
Reviewed By: Ken Skaftfeld
Project Engineer: Ken Skaftfeld

Sub-Surface Log

Test Hole TH13-05

2 of 2



- till inclusions (<20mm diameter) below 13.4 m

SILT (TILL) - trace clay
- light grey
- moist
- low to no plascticity

END OF HOLE AT 15.7 m IN SILT TILL

Notes:

1) Power auger refusal (PAR) at 15.7 m
2) No seepage observed
3) No sloughing observed.
4) Slope inclinometer SI-05 installed in test hole.
5) Vibrating wire piezometers VW-5A and VW-5B installed on tremie line next to slope inclinometer at depths of 9.1 m and 14.5 m.

Logged By: Martial Lemoine **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

TREK GEOTECHNICAL

Sub-Surface Log

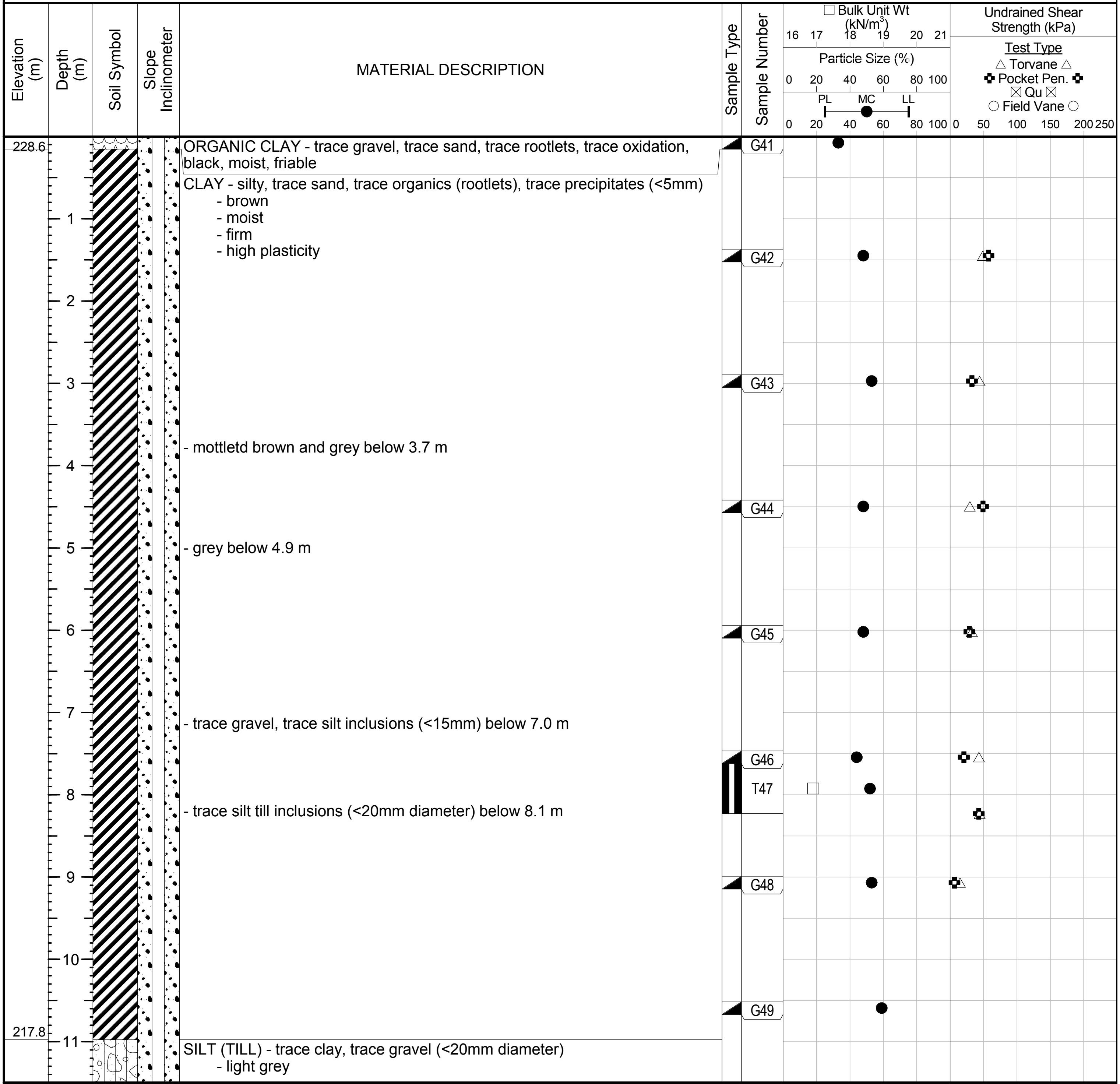
Test Hole TH13-06

Client: City of Winnipeg - Public Works
Project Number: 0015 008 00
Project Name: Lyndale Drive Retaining Wall Assessment
Location: Lyndale Dr. between Monck Ave. and Gauvin St.
Contractor: Maple Leaf Drilling
Ground Elevation: 228.76 m
Method: 125 mm Solid Stem Auger, Acker MP5-T Track Mount
Date Drilled: 16 October 2013

Sample Type: ◣ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) ⧗ Split Barrel (SB) ▯ Core (C)

Particle Size Legend: ▥ Fines ▨ Clay ▥ Silt ⁘ Sand ▚ Gravel ▩ Cobbles ■ Boulders

Backfill Legend: ■ Bentonite ▧ Cement ▨ Drill Cuttings ⁘ Filter Pack Sand ▚ Grout ▩ Slough



ORGANIC CLAY - trace gravel, trace sand, trace rootlets, trace oxidation, black, moist, friable

CLAY - silty, trace sand, trace organics (rootlets), trace precipitates (<5mm)
- brown
- moist
- firm
- high plasticity

- mottletd brown and grey below 3.7 m

- grey below 4.9 m

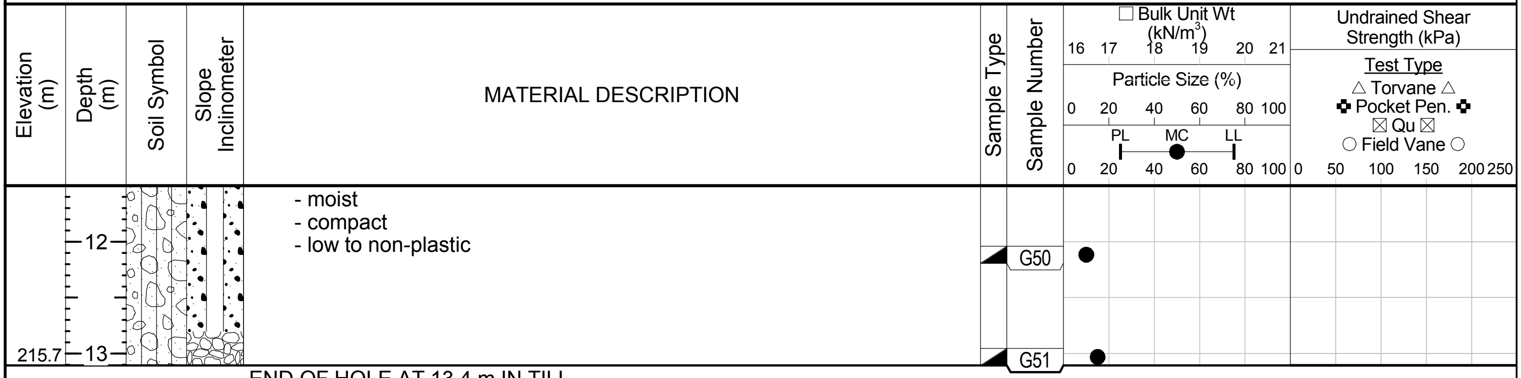
- trace gravel, trace silt inclusions (<15mm) below 7.0 m

- trace silt till inclusions (<20mm diameter) below 8.1 m

SILT (TILL) - trace clay, trace gravel (<20mm diameter)
- light grey

Logged By: Martial Lemoine
Reviewed By: Ken Skaftfeld
Project Engineer: Ken Skaftfeld

Sub-Surface Log



- moist
- compact
- low to non-plastic

END OF HOLE AT 13.4 m IN TILL

Notes:

1) Power auger refusal (PAR) on suspected boulder at 13.4 m.
2) Test hole open to 12.8 m due to sloughing in silt till.
3) No seepage observed.
4) Slope inclinometer SI-06 installed in test hole.

Logged By: Martial Lemoine **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

TREK GEOTECHNICAL

Sub-Surface Log

Test Hole TH13-07

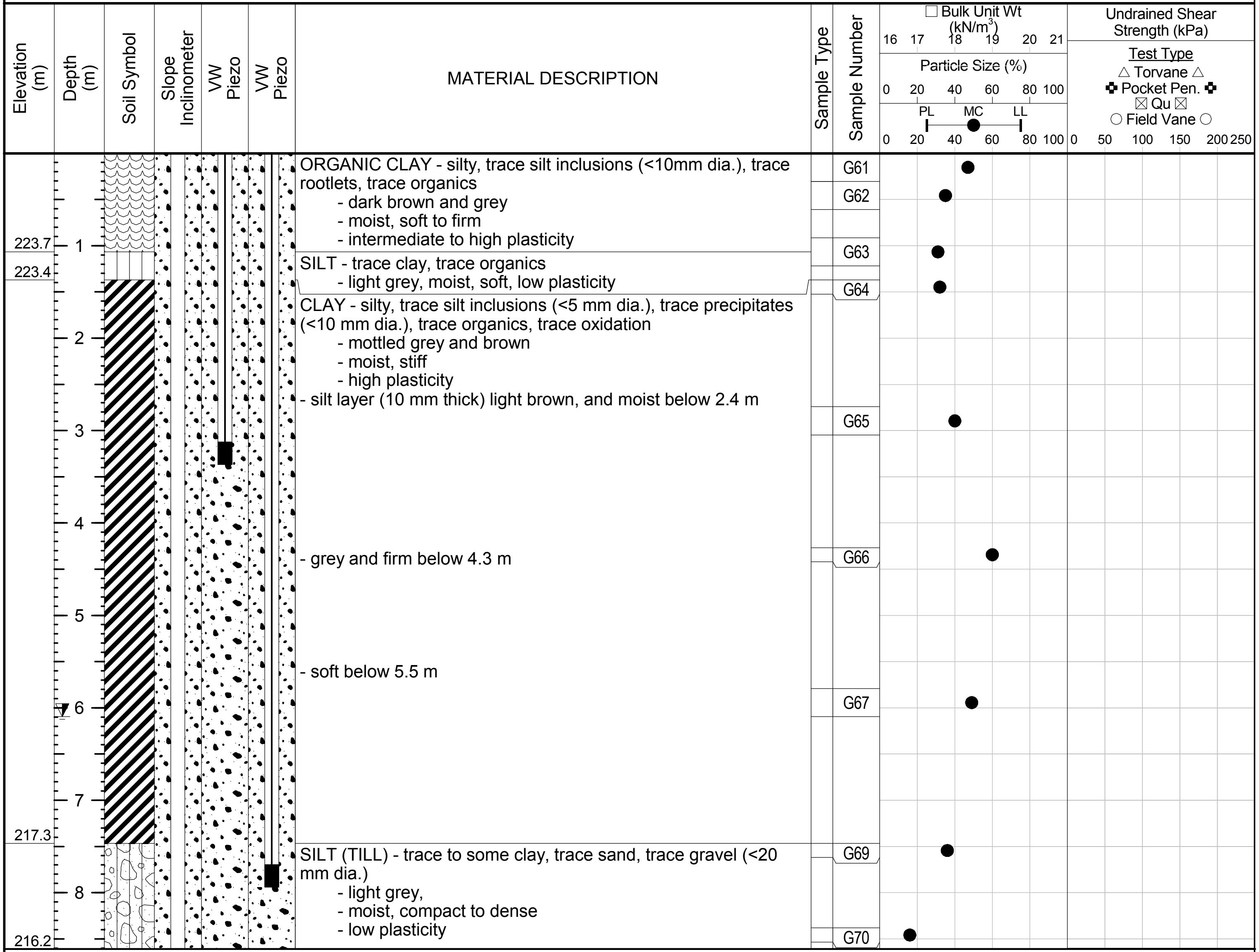
1 of 1

Client:	City of Winnipeg - Public Works	**Project Number:**	0015 008 00
Project Name:	Lyndale Drive Retaining Wall Assessment	**Location:**	Lyndale Dr. between Monck Ave. and Gauvin St.
Contractor:	Paddock Drilling Ltd.	**Ground Elevation:**	224.81 m
Method:	108 mm Solid Stem Auger / Yanmar C25R Rubber Track Mount	**Date Drilled:**	16 October 2013

Sample Type: ◢ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) ⧗ Split Barrel (SB) ▯ Core (C)

Particle Size Legend: ▨ Fines ▨ Clay ▥ Silt ⁘ Sand ● Gravel ○ Cobbles ■ Boulders

Backfill Legend: ■ Bentonite ▩ Cement ▨ Drill Cuttings ░ Filter Pack Sand ⁘ Grout ▩ Slough



ORGANIC CLAY - silty, trace silt inclusions (<10mm dia.), trace rootlets, trace organics
- dark brown and grey
- moist, soft to firm
- intermediate to high plasticity

SILT - trace clay, trace organics
- light grey, moist, soft, low plasticity

CLAY - silty, trace silt inclusions (<5 mm dia.), trace precipitates (<10 mm dia.), trace organics, trace oxidation
- mottled grey and brown
- moist, stiff
- high plasticity

- silt layer (10 mm thick) light brown, and moist below 2.4 m

- grey and firm below 4.3 m

- soft below 5.5 m

SILT (TILL) - trace to some clay, trace sand, trace gravel (<20 mm dia.)
- light grey,
- moist, compact to dense
- low plasticity

END OF HOLE AT 8.5 m IN SILT TILL

Notes:
1) Power auger refusal (PAR) at 8.5 m depth.
2) No seepage or sloughing observed.
3) Open to 7.0 m depth due to squeezing in CLAY.
4) Water level at 6.1 m depth, water from SILT (TILL).
5) Test hole was backfilled with auger cuttings to the surface.
6) TH13-07 lithology based on TH14-07A located 1.2 m at 290 degrees N.

Logged By:	Martial Lemoine	**Reviewed By:**	Ken Skaftfeld	**Project Engineer:**	Ken Skaftfeld

Sub-Surface Log

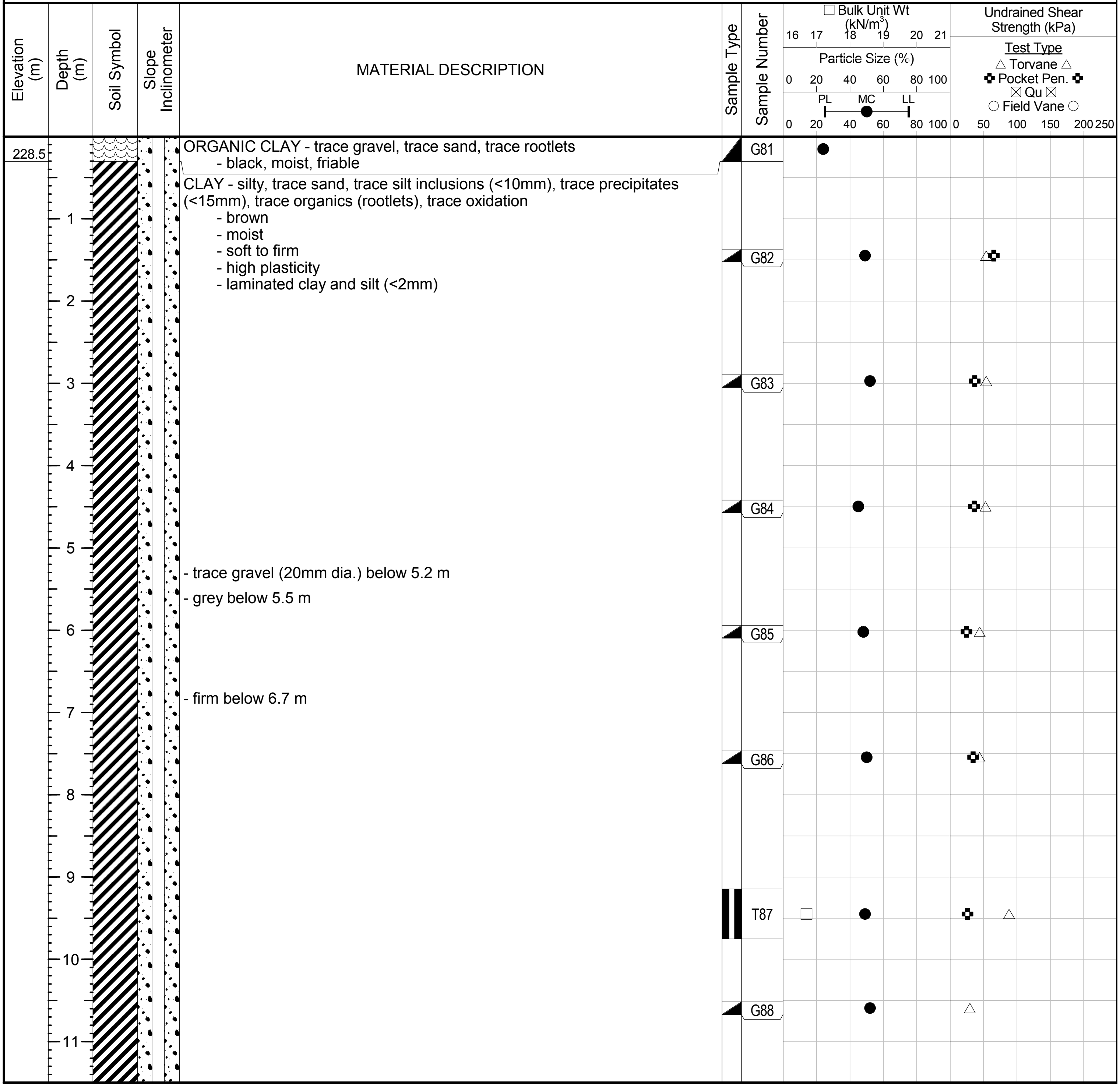
Test Hole TH13-08

Client:	City of Winnipeg - Public Works	**Project Number:**	0015 008 00
Project Name:	Lyndale Drive Retaining Wall Assessment	**Location:**	Lyndale Dr. between Monck Ave. and Gauvin St.
Contractor:	Maple Leaf Drilling	**Ground Elevation:**	228.83 m
Method:	125 mm Solid Stem Auger, Acker MP5-T Track Mount	**Date Drilled:**	16 October 2013

Sample Type: Grab (G) Shelby Tube (T) Split Spoon (SS) Split Barrel (SB) Core (C)

Particle Size Legend: Fines Clay Silt Sand Gravel Cobbles Boulders

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



ORGANIC CLAY - trace gravel, trace sand, trace rootlets
- black, moist, friable

CLAY - silty, trace sand, trace silt inclusions (<10mm), trace precipitates (<15mm), trace organics (rootlets), trace oxidation
- brown
- moist
- soft to firm
- high plasticity
- laminated clay and silt (<2mm)

- trace gravel (20mm dia.) below 5.2 m

- grey below 5.5 m

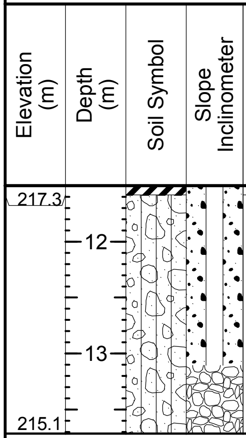
- firm below 6.7 m

Logged By:	Martial Lemoine	**Reviewed By:**	Ken Skaftfeld	**Project Engineer:**	Ken Skaftfeld

Sub-Surface Log

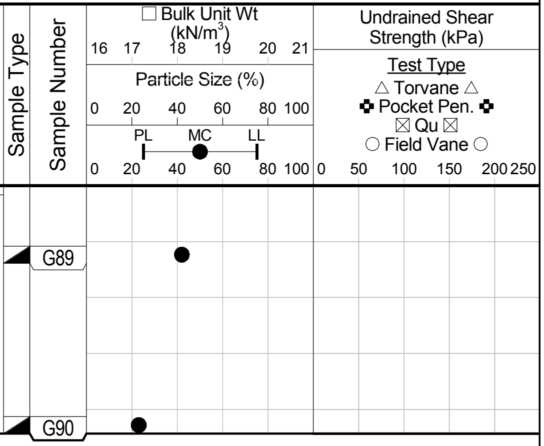
Test Hole TH13-08

2 of 2



MATERIAL DESCRIPTION

SILT (TILL) - trace clay, trace gravel, trace sand
- light grey
- moist
- compact
- low to non-plastic



END OF HOLE AT 13.7 m IN SILT TILL

Notes:

1) Power auger refusal (PAR) at 13.7 m depth.
2) Test hole open to 13.1 m depth due to sloughing.
3) No seepage observed.
4) Slope inclinometer SI-08 installed in test hole.

Logged By: Martial Lemoine **Reviewed By:** Ken Skaftfeld **Project Engineer:** Ken Skaftfeld

Sub-Surface Log

Test Hole TH13-09

1 of 1

Client: City of Winnipeg - Public Works

Project Name: Lyndale Drive Retaining Wall Assessment

Contractor: Paddock Drilling Ltd.

Method: 108 mm Solid Stem Auger / Yanmar C25R Rubber Track Mount

Project Number: 0015 008 00

Location: Lyndale Dr. between Monck Ave. and Gauvin St.

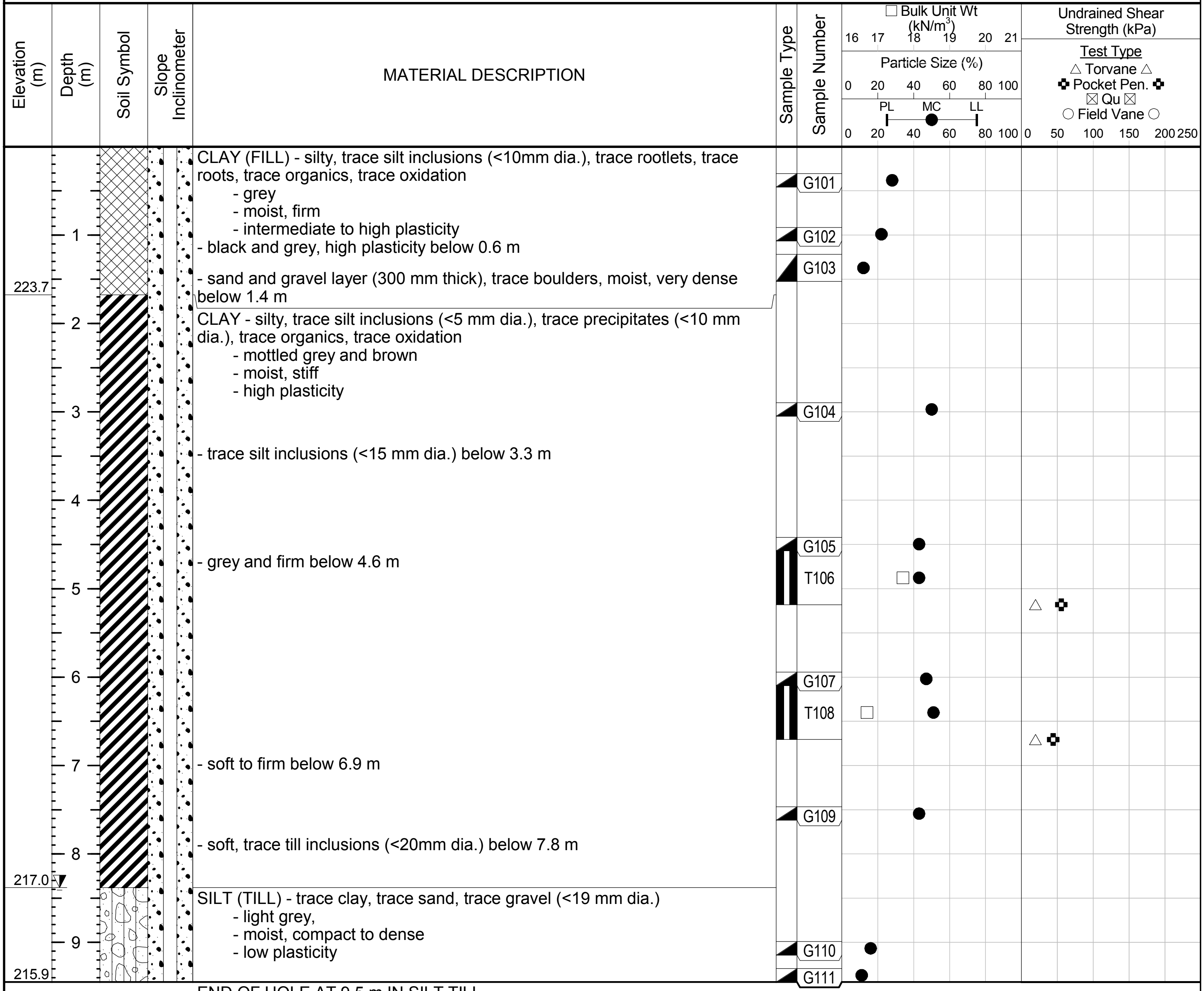
Ground Elevation: 225.39 m

Date Drilled: 16 October 2013

Sample Type: ◪ Grab (G) ▮ Shelby Tube (T) ☒ Split Spoon (SS) ⧗ Split Barrel (SB) ▮ Core (C)

Particle Size Legend: ▨ Fines ▨ Clay ▥ Silt ▒ Sand ▒ Gravel ▒ Cobbles ■ Boulders

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



CLAY (FILL) - silty, trace silt inclusions (<10mm dia.), trace rootlets, trace roots, trace organics, trace oxidation
- grey
- moist, firm
- intermediate to high plasticity

- black and grey, high plasticity below 0.6 m

- sand and gravel layer (300 mm thick), trace boulders, moist, very dense below 1.4 m

CLAY - silty, trace silt inclusions (<5 mm dia.), trace precipitates (<10 mm dia.), trace organics, trace oxidation
- mottled grey and brown
- moist, stiff
- high plasticity

- trace silt inclusions (<15 mm dia.) below 3.3 m

- grey and firm below 4.6 m

- soft to firm below 6.9 m

- soft, trace till inclusions (<20mm dia.) below 7.8 m

SILT (TILL) - trace clay, trace sand, trace gravel (<19 mm dia.)
- light grey,
- moist, compact to dense
- low plasticity

END OF HOLE AT 9.5 m IN SILT TILL
Notes:
1) Power auger refusal (PAR) at 9.5 m
2) No sloughing observed, open to 9.5 m depth.
3) Seepage observed from silt till layer.
4) Water level at 8.4 m depth, water from SILT (TILL).
5) Test hole was backfilled with auger cuttings to the surface.
6) TH13-09 lithology based on TH14-09A located 2.1 m at 300 degrees N.

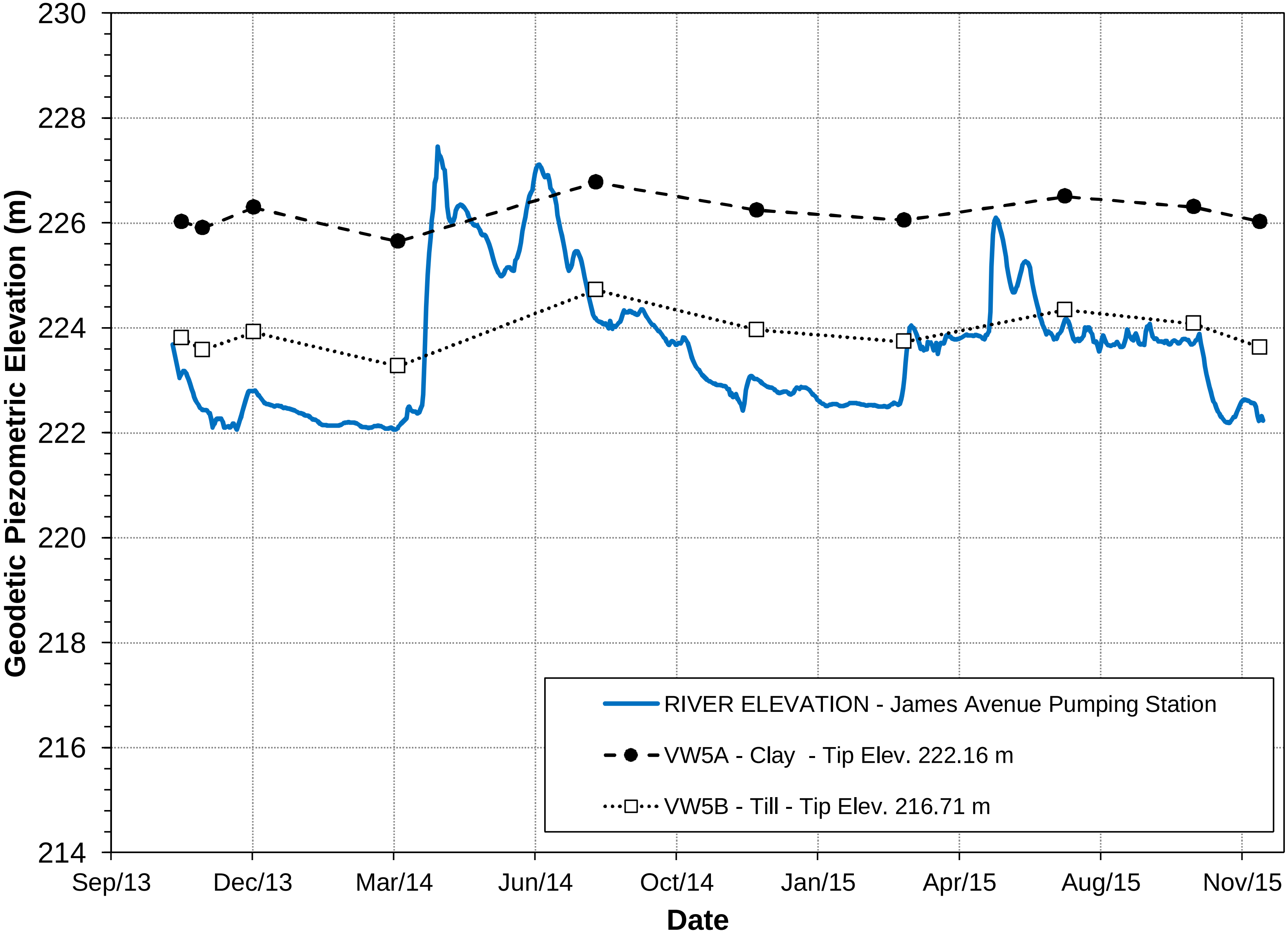
Logged By: Martial Lemoine

Reviewed By: Ken Skaftfeld

Project Engineer: Ken Skaftfeld

Piezometers

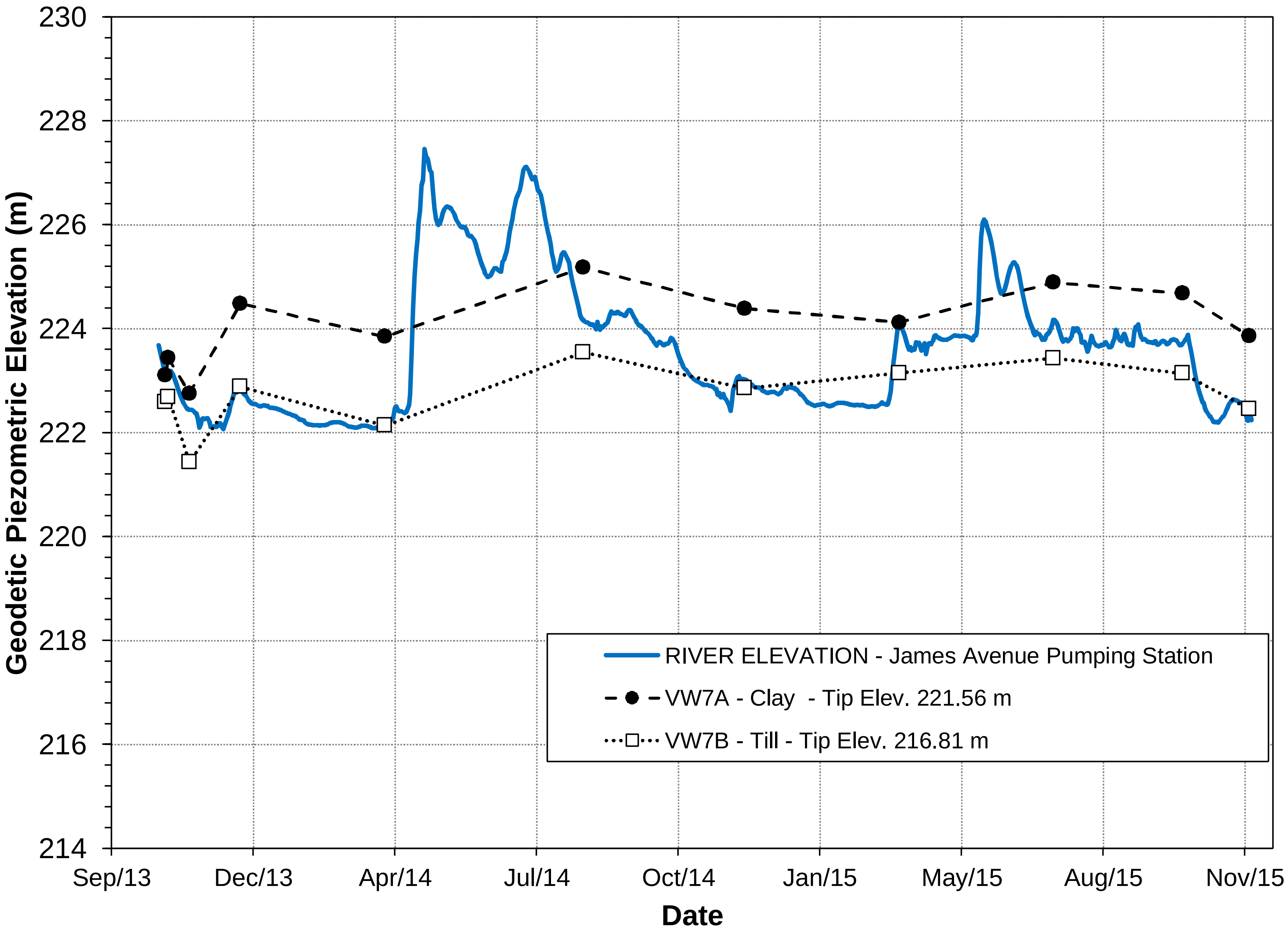
GROUNDWATER MONITORING REPORT
Lyndale Drive Retaining Wall Assessment
Piezometer Summary Plot (TH13-05)



GROUNDWATER MONITORING REPORT

Lyndale Drive Retaining Wall Assessment

Piezometer Summary Plot (TH13-07)



Rate Plots

TREK GEOTECHNICAL

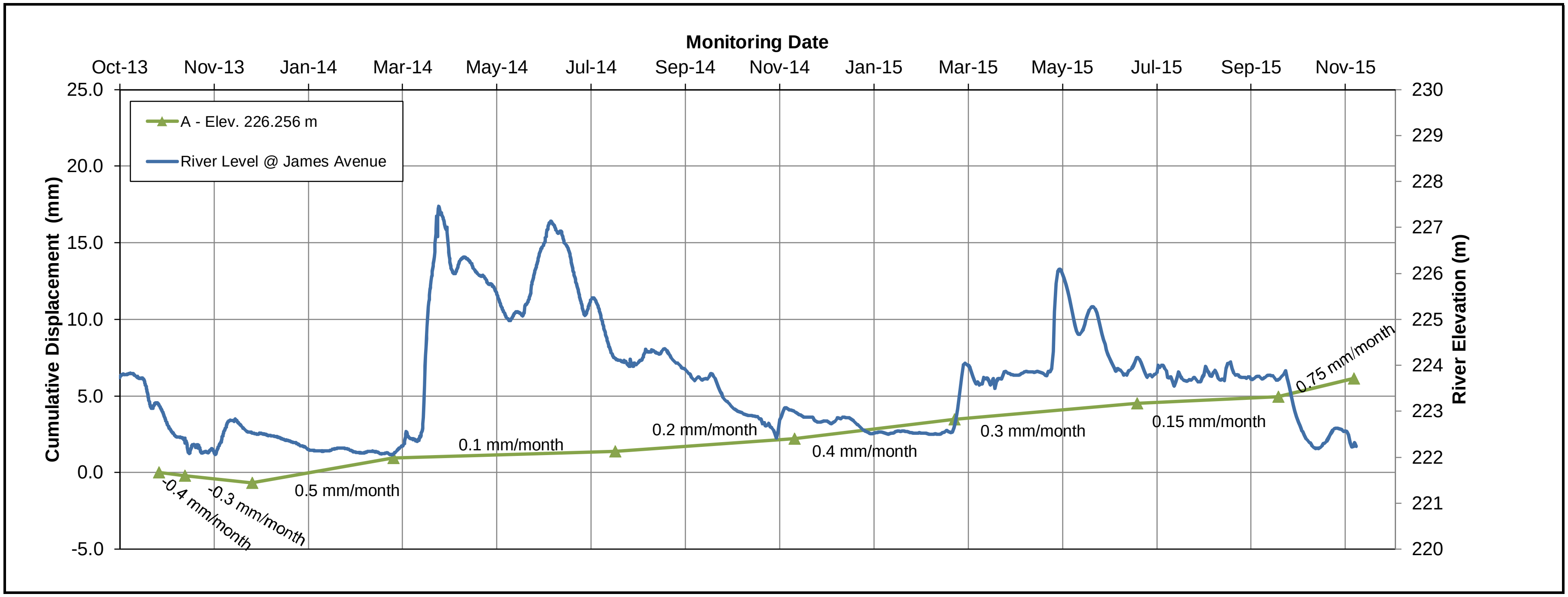
SLOPE INCLINOMETER WORKSHEET

Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-3

			Cumulative Displacement (mm) vs. Monitoring Date										
Elevation Range (m)		**Axis**	**25-Oct-13**	**11-Nov-13**	**24-Dec-13**	**24-Mar-14**	**12-Aug-14**	**4-Dec-14**	**16-Mar-15**	**10-Jul-15**	**8-Oct-15**	**25-Nov-15**	
Bot	226.3	A	0.0	-0.2	-0.7	1.0	1.4	2.2	3.5	4.5	5.0	6.2	
		B	0.0	0.2	0.1	0.1	1.3	0.4	0.0	-0.1	-0.6	-1.4	
		Resultant	0.0	0.3	0.7	1.0	1.9	2.2	3.5	4.5	5.0	6.3	



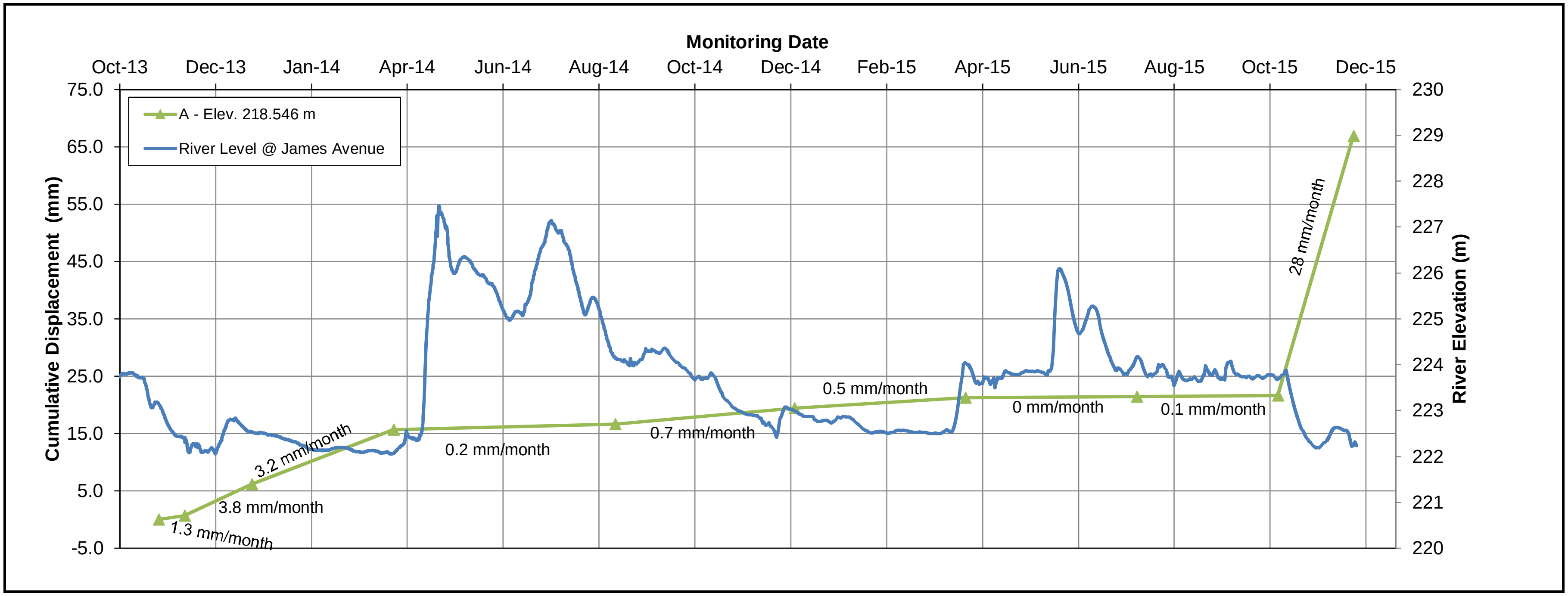
SLOPE INCLINOMETER WORKSHEET

Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-4

			Cumulative Displacement (mm) vs. Monitoring Date										
Elevation Range (m)		**Axis**	**25-Oct-13**	**11-Nov-13**	**24-Dec-13**	**24-Mar-14**	**12-Aug-14**	**4-Dec-14**	**23-Mar-15**	**10-Jul-15**	**8-Oct-15**	**25-Nov-15**	
Mid	218.5	A	0.0	0.7	6.2	15.7	16.6	19.4	21.3	21.4	21.7	66.9	
		B	0.0	0.4	0.4	1.8	1.6	1.8	2.8	2.9	2.9	7.5	
		Resultant	0.0	0.8	6.2	15.8	16.7	19.5	21.5	21.6	21.8	67.3	



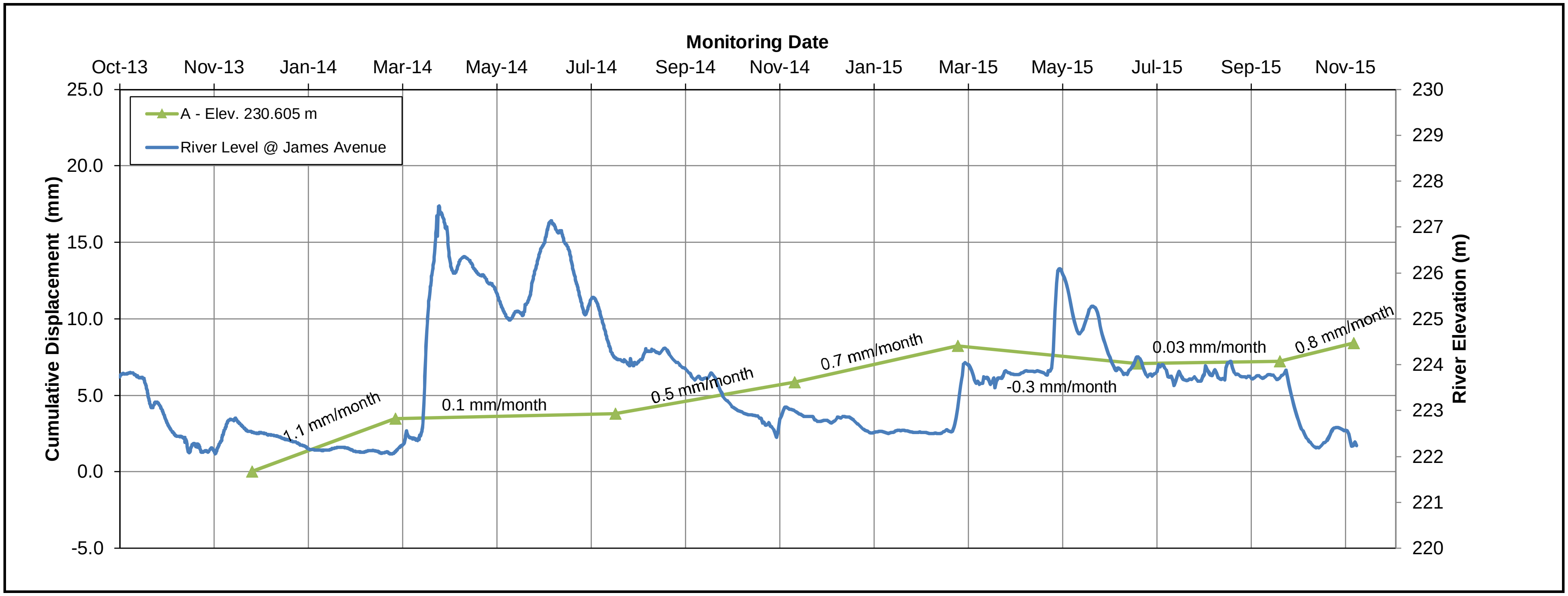
SLOPE INCLINOMETER WORKSHEET

Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-5

			Cumulative Displacement (mm) vs. Monitoring Date										
Elevation Range (m)		**Axis**	**24-Dec-13**	**25-Mar-14**	**12-Aug-14**	**4-Dec-14**	**18-Mar-15**	**10-Jul-15**	**9-Oct-15**	**25-Nov-15**			
Top	230.6	A	0.0	3.5	3.8	5.8	8.2	7.1	7.2	8.4			
		B	0.0	0.4	1.4	1.7	2.4	2.3	1.8	2.4			
		Resultant	0.0	3.5	4.0	6.1	8.6	7.5	7.4	8.7			



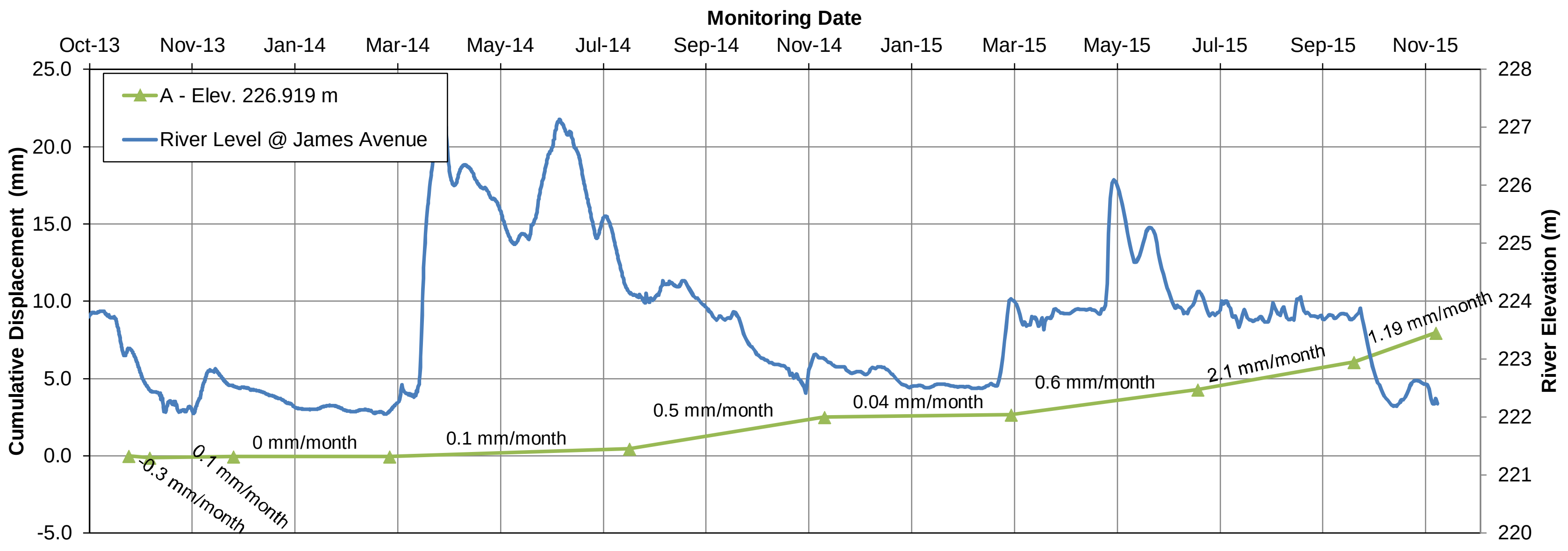
SLOPE INCLINOMETER WORKSHEET

Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-6

			Cumulative Displacement (mm) vs. Monitoring Date										
Elevation Range (m)		**Axis**	**23-Oct-13**	**5-Nov-13**	**24-Dec-13**	**25-Mar-14**	**12-Aug-14**	**4-Dec-14**	**23-Mar-15**	**10-Jul-15**	**9-Oct-15**	**26-Nov-15**	
Top	226.9	A	0.0000	-0.1200	-0.0200	-0.0200	0.5	2.5	2.7	4.3	6.1	8.0	
		B	0.0	-0.2	-0.3	0.0	0.9	0.8	1.0	0.8	1.2	1.6	
		Resultant	0.0	0.2	0.3	0.0	1.0	2.6	2.8	4.4	6.2	8.1	



SLOPE INCLINOMETER WORKSHEET

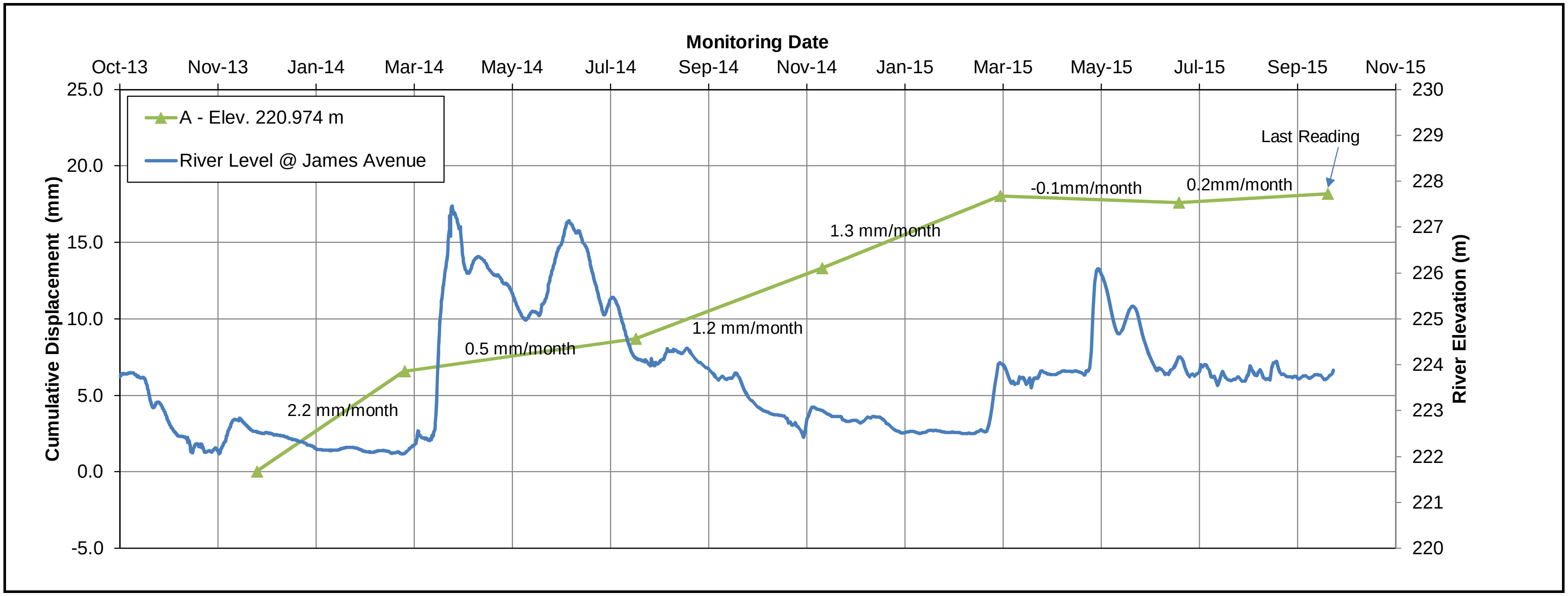
Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Note: SI-7 casing is no longer readable after October 9, 2015

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-7

			Cumulative Displacement (mm) vs. Monitoring Date										
Elevation Range (m)		**Axis**	**23-Dec-13**	**24-Mar-14**	**12-Aug-14**	**4-Dec-14**	**23-Mar-15**	**10-Jul-15**	**9-Oct-15**				
Top	221.0	A	0.0	6.6	8.7	13.3	18.0	17.6	18.2				
		B	0.0	0.0	-1.6	-1.0	-0.4	0.1	-0.6				
		Resultant	0.0	6.6	8.8	13.3	18.0	17.6	18.2				



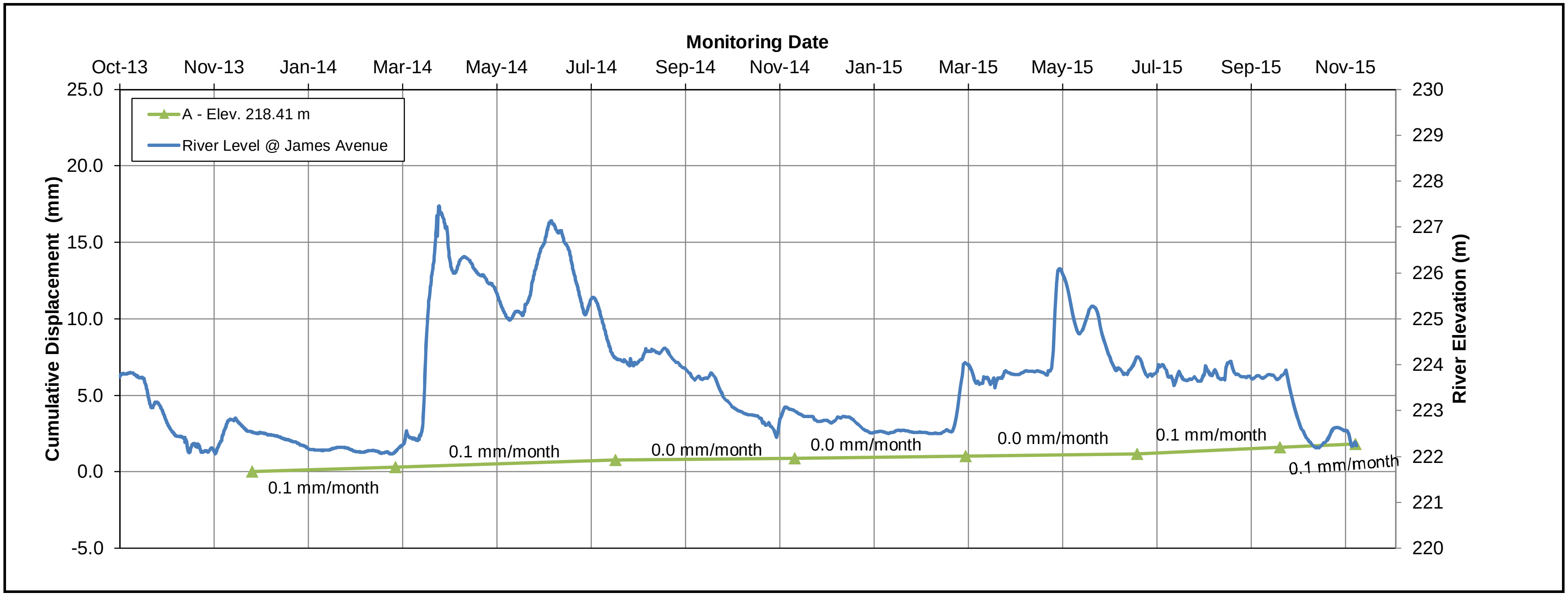
SLOPE INCLINOMETER WORKSHEET

Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-8

			Cumulative Displacement (mm) vs. Monitoring Date										
Elevation Range (m)		Axis	24-Dec-13	25-Mar-14	12-Aug-14	4-Dec-14	23-Mar-15	10-Jul-15	9-Oct-15	26-Nov-15			
Bot	218.4	A	0.0	0.3	0.8	0.9	1.0	1.2	1.6	1.8			
		B	0.0	0.4	1.1	1.2	0.8	1.1	1.3	1.9			
		Resultant	0.0	0.5	1.3	1.5	1.3	1.6	2.0	2.6			



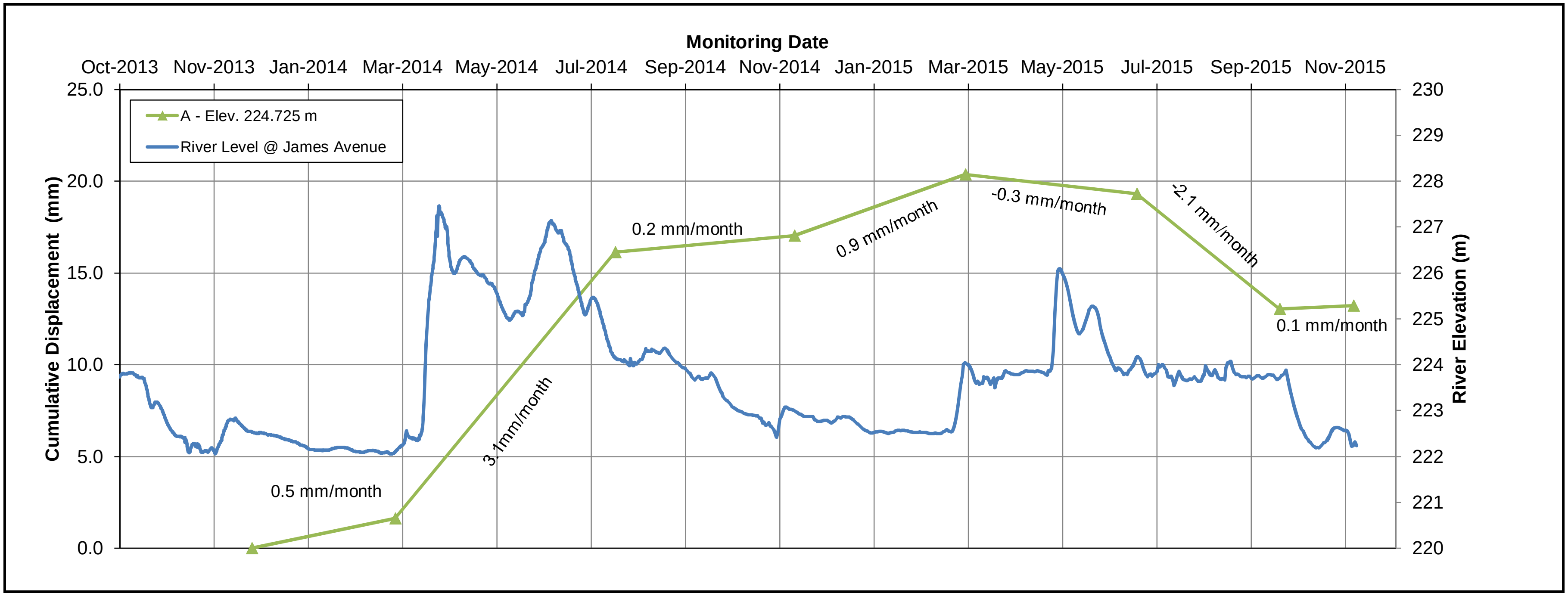
SLOPE INCLINOMETER WORKSHEET

Deflection Rate Plots (All Axes Combined, Relative to Casing Bottom)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-9

			Cumulative Displacement (mm) vs. Monitoring Date										
Elevation Range (m)		**Axis**	**24-Dec-13**	**25-Mar-14**	**12-Aug-14**	**4-Dec-14**	**23-Mar-15**	**10-Jul-15**	**9-Oct-15**	**25-Nov-15**			
Top	224.7	A	0.0	1.6	16.1	17.0	20.4	19.3	13.1	13.2			
		B	0.0	0.4	3.1	1.2	3.9	4.7	1.9	3.8			
		Resultant	0.0	1.7	16.4	17.1	20.7	19.9	13.2	13.7			



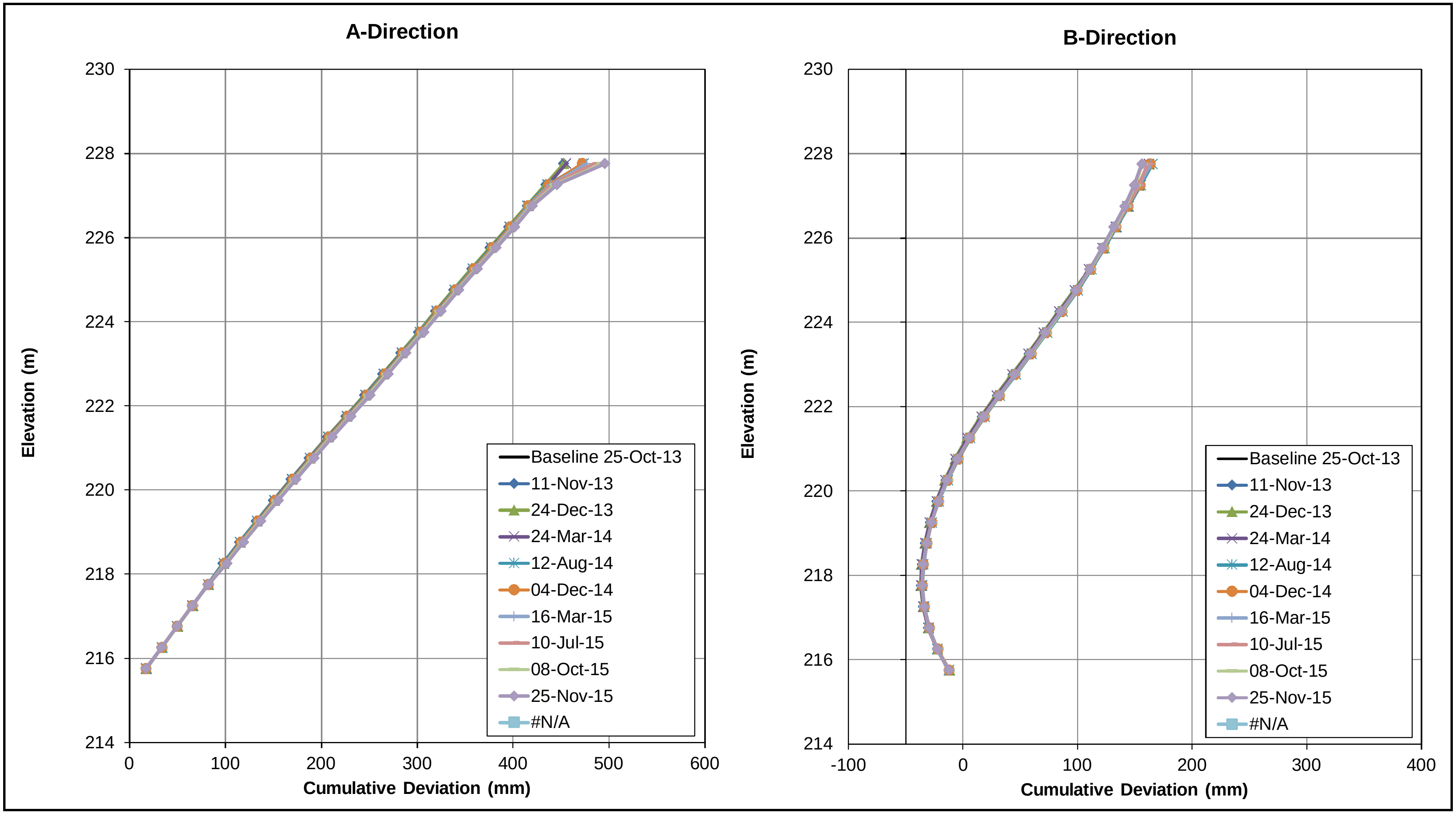
SI-3

SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-3

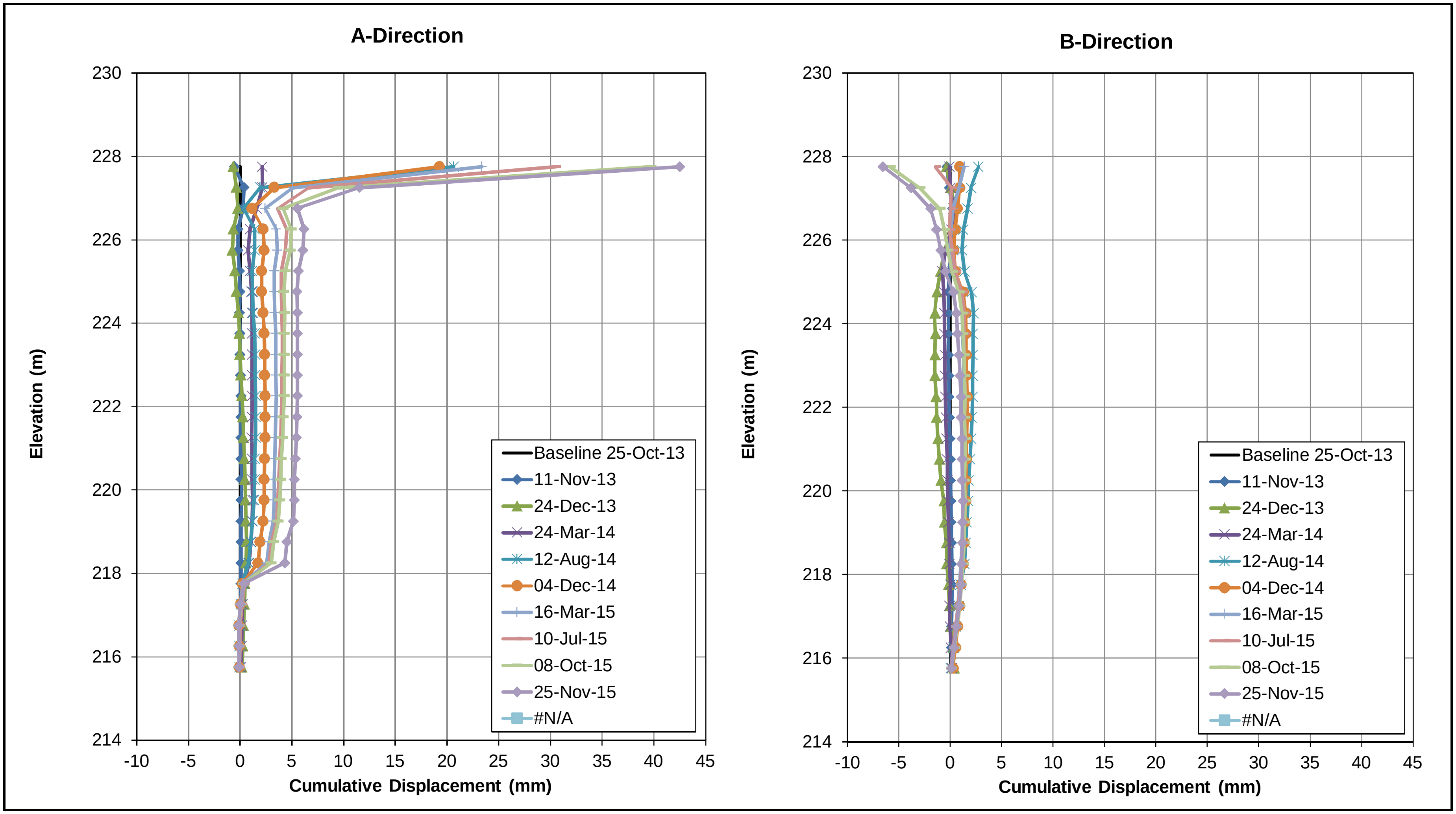


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement in A and B Directions (Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-3

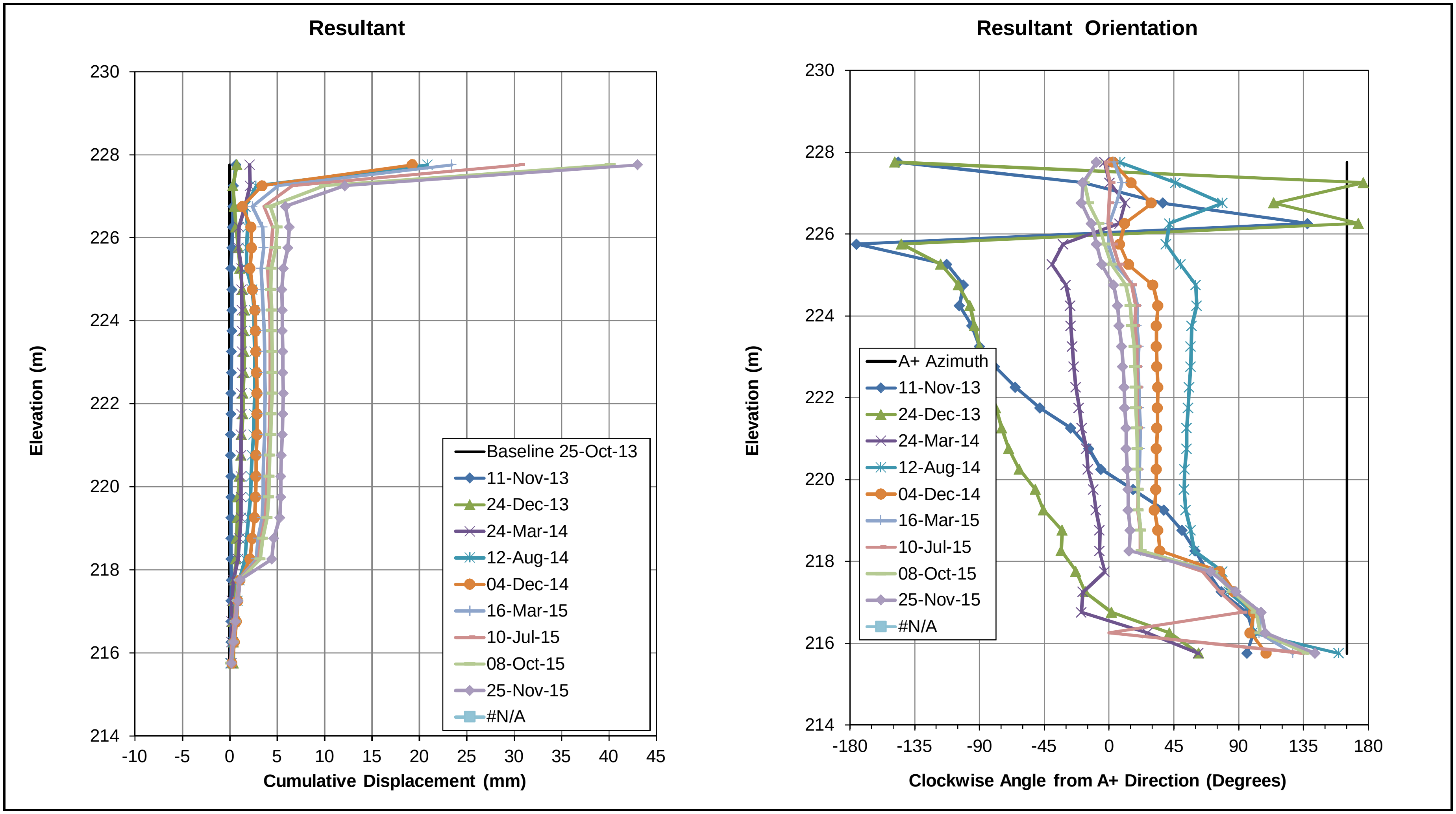


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-3

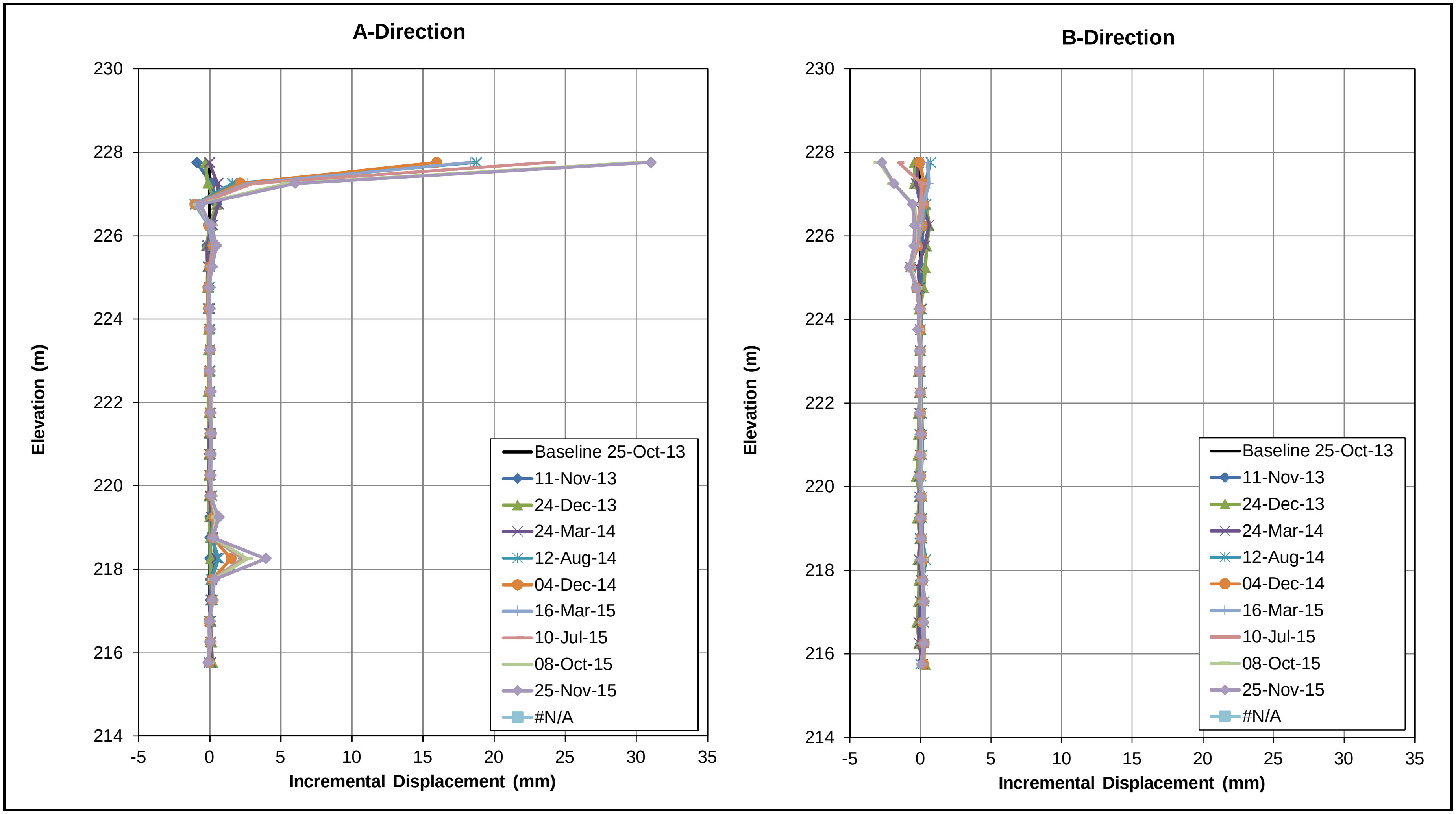


SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-3



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

INSTALLATION DATA

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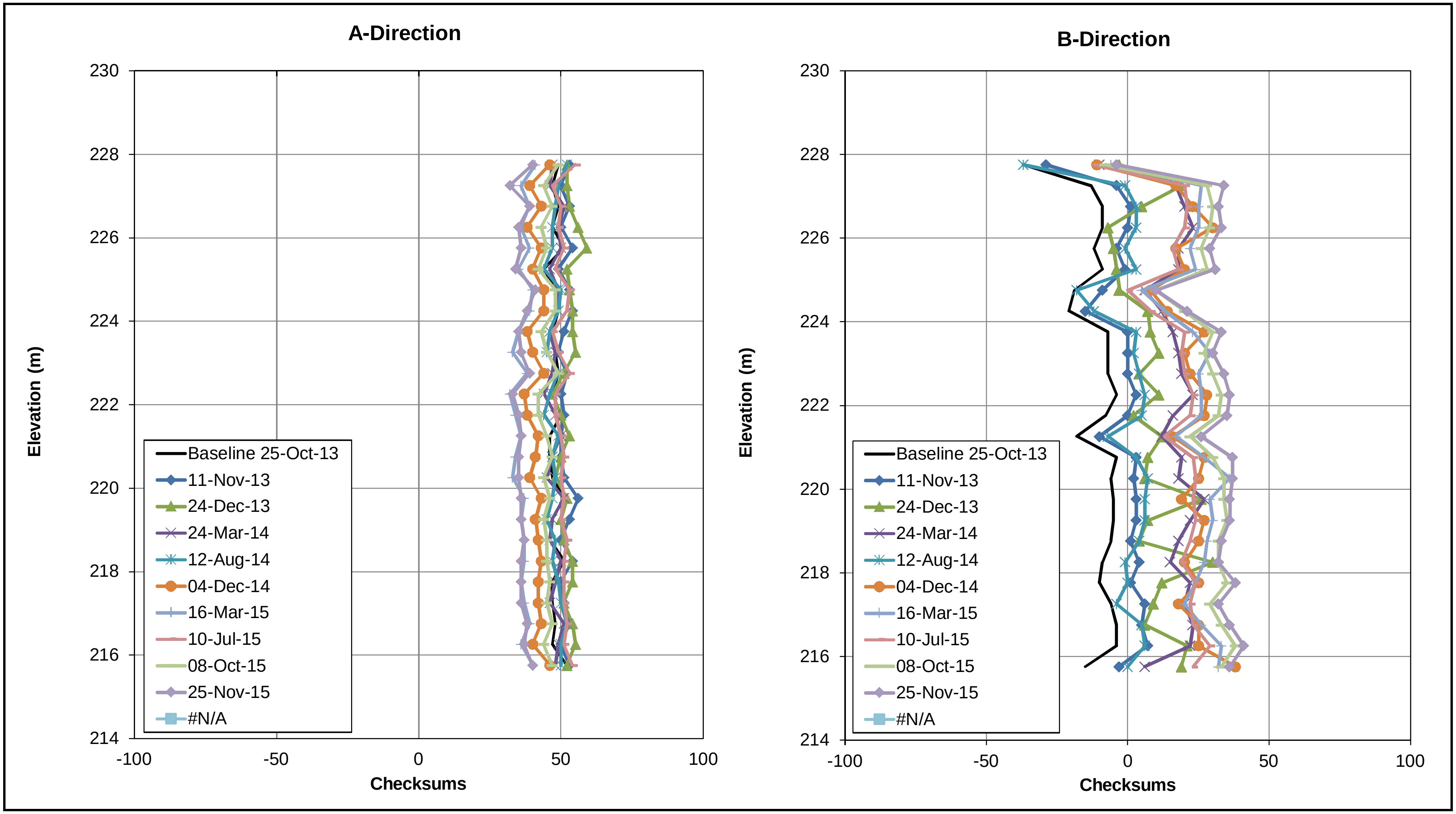
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-3



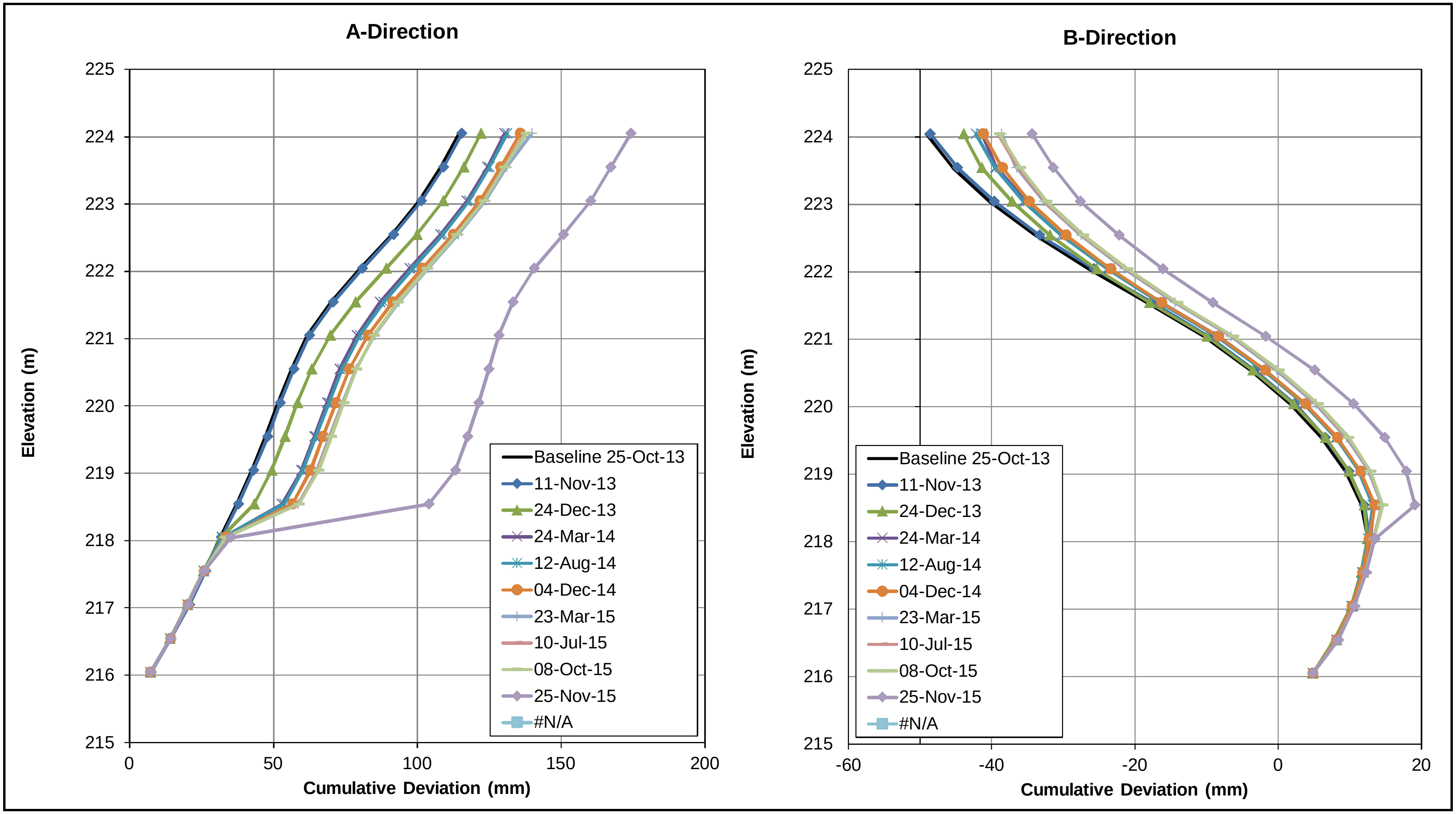
SI-4

SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-4

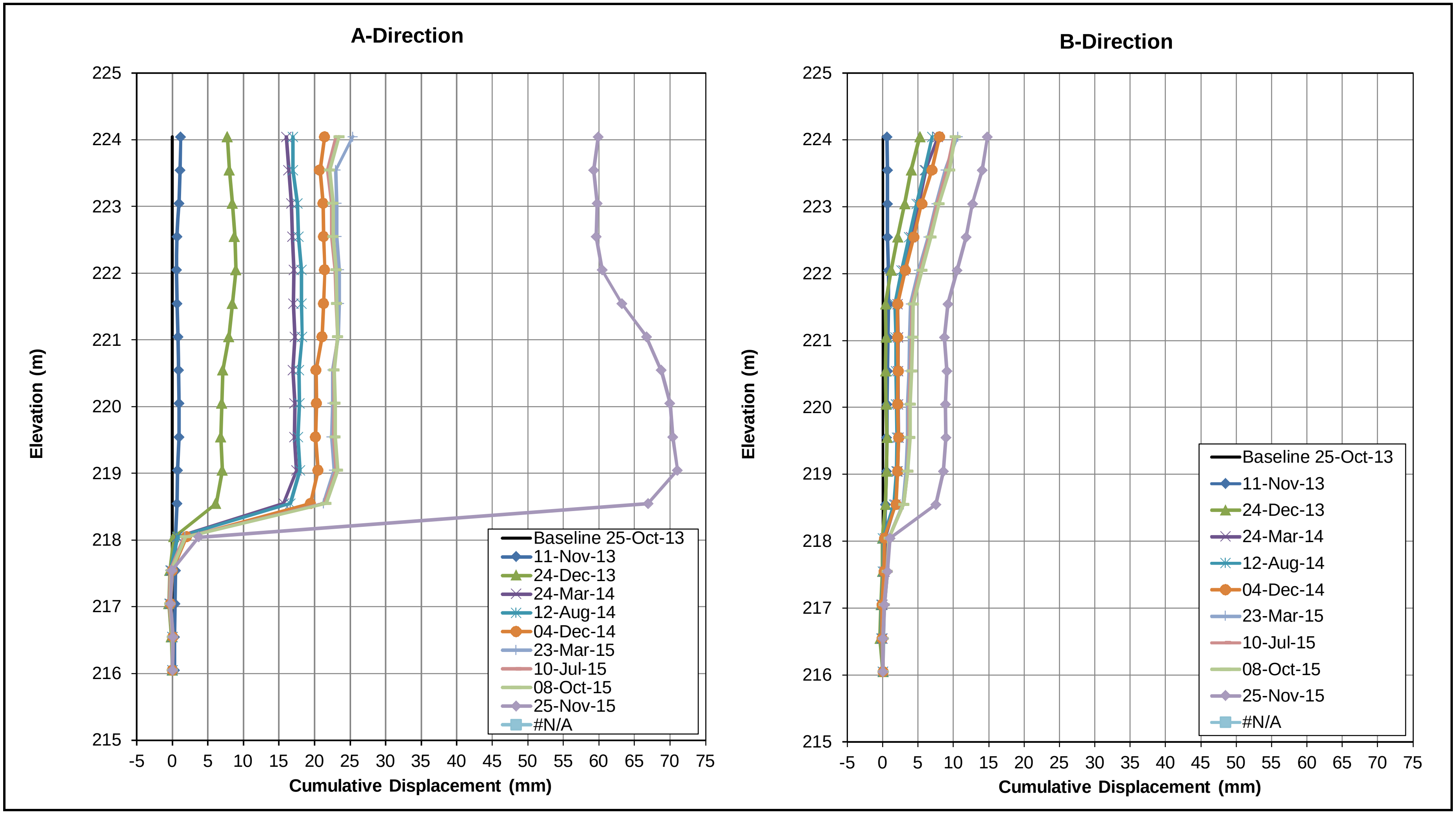


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement in A and B Directions (Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-4



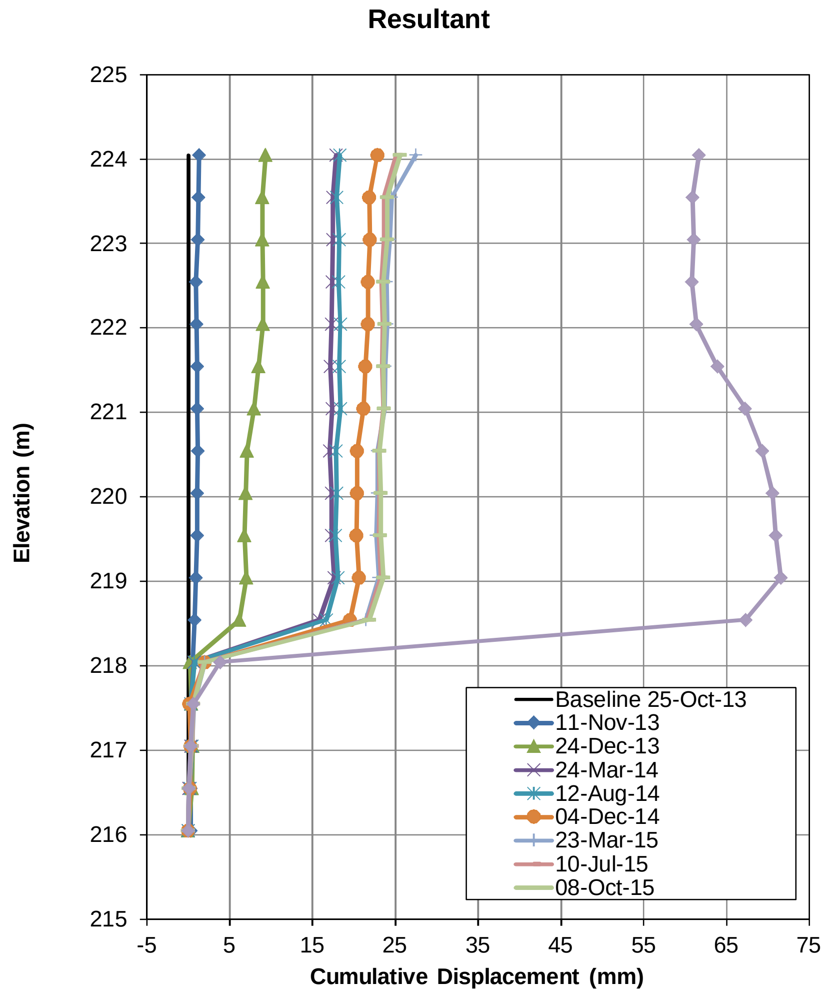
TREK GEOTECHNICAL

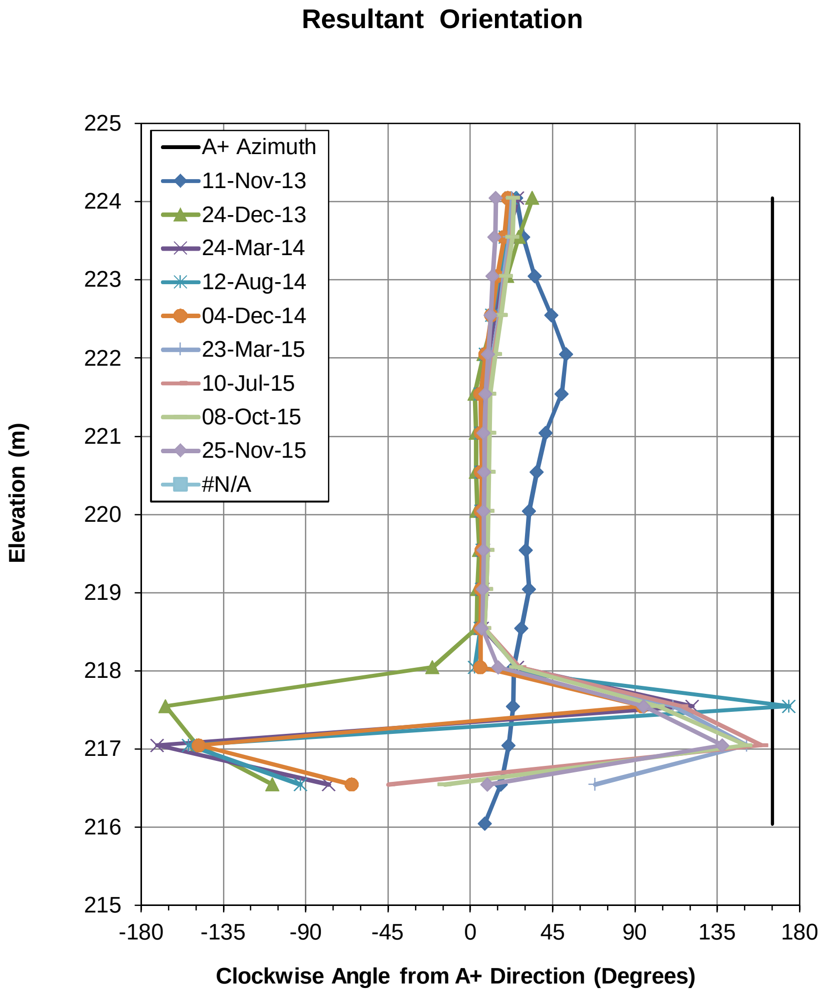
SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-4





SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

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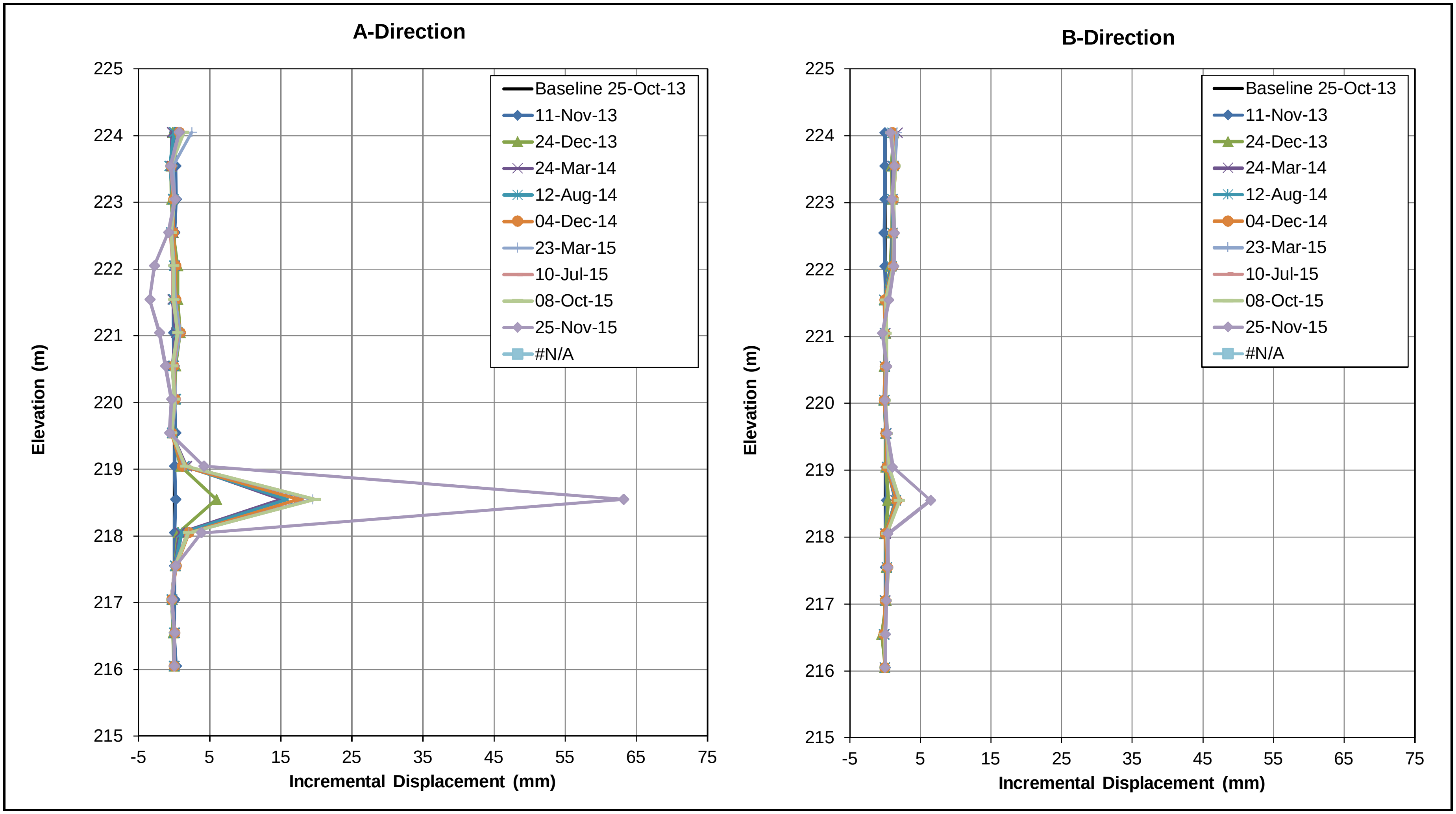
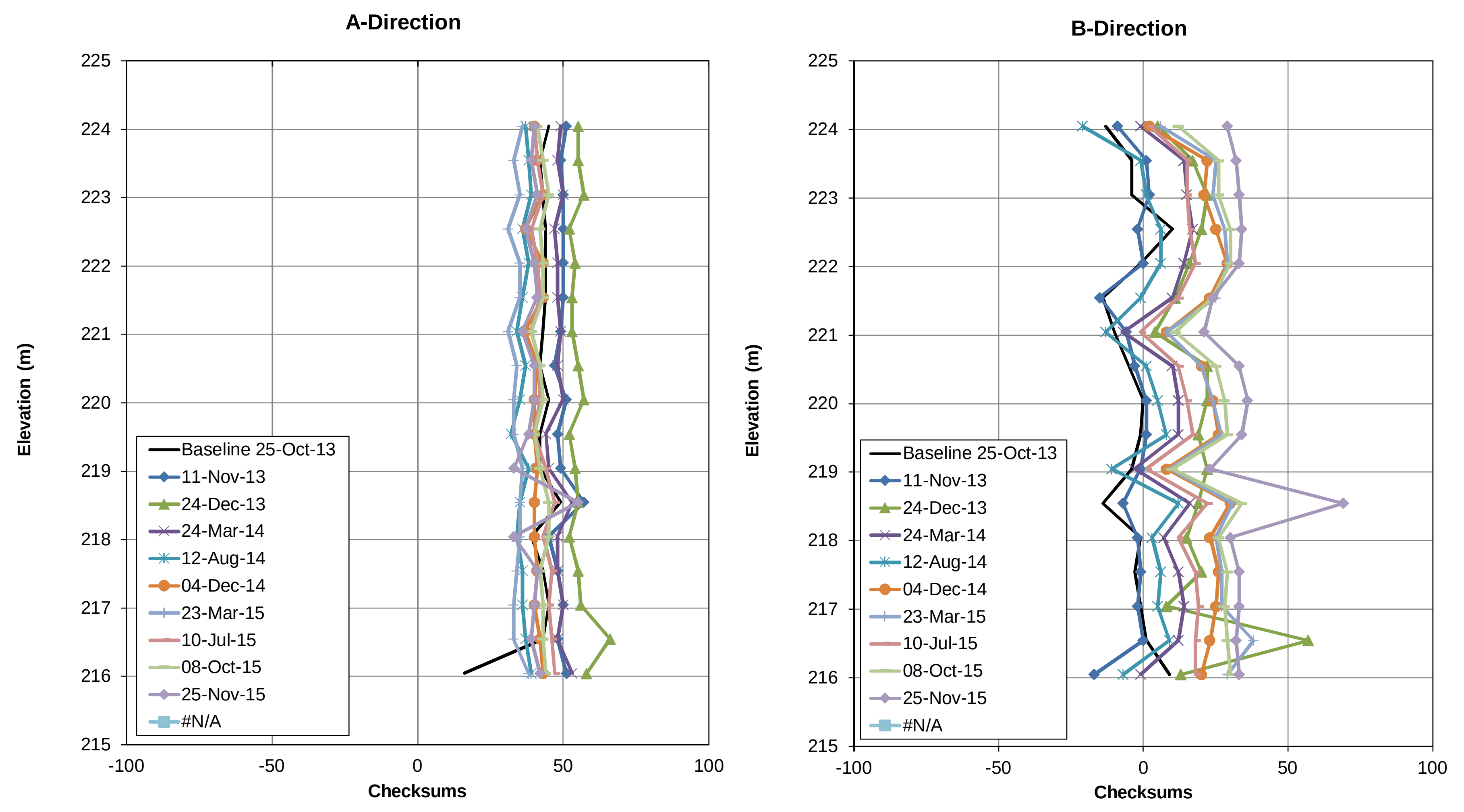
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-4



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-4



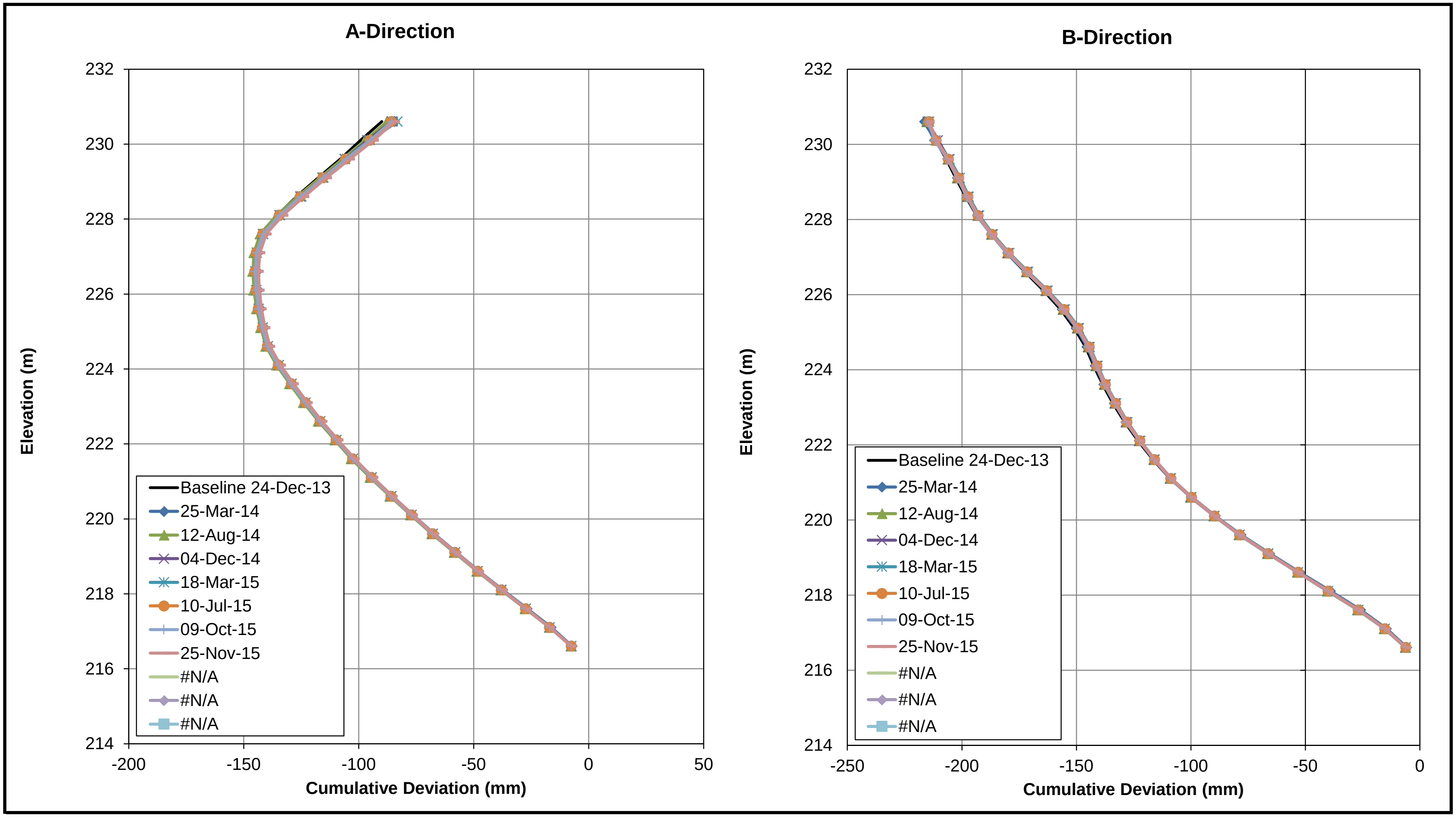
SI-5

SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

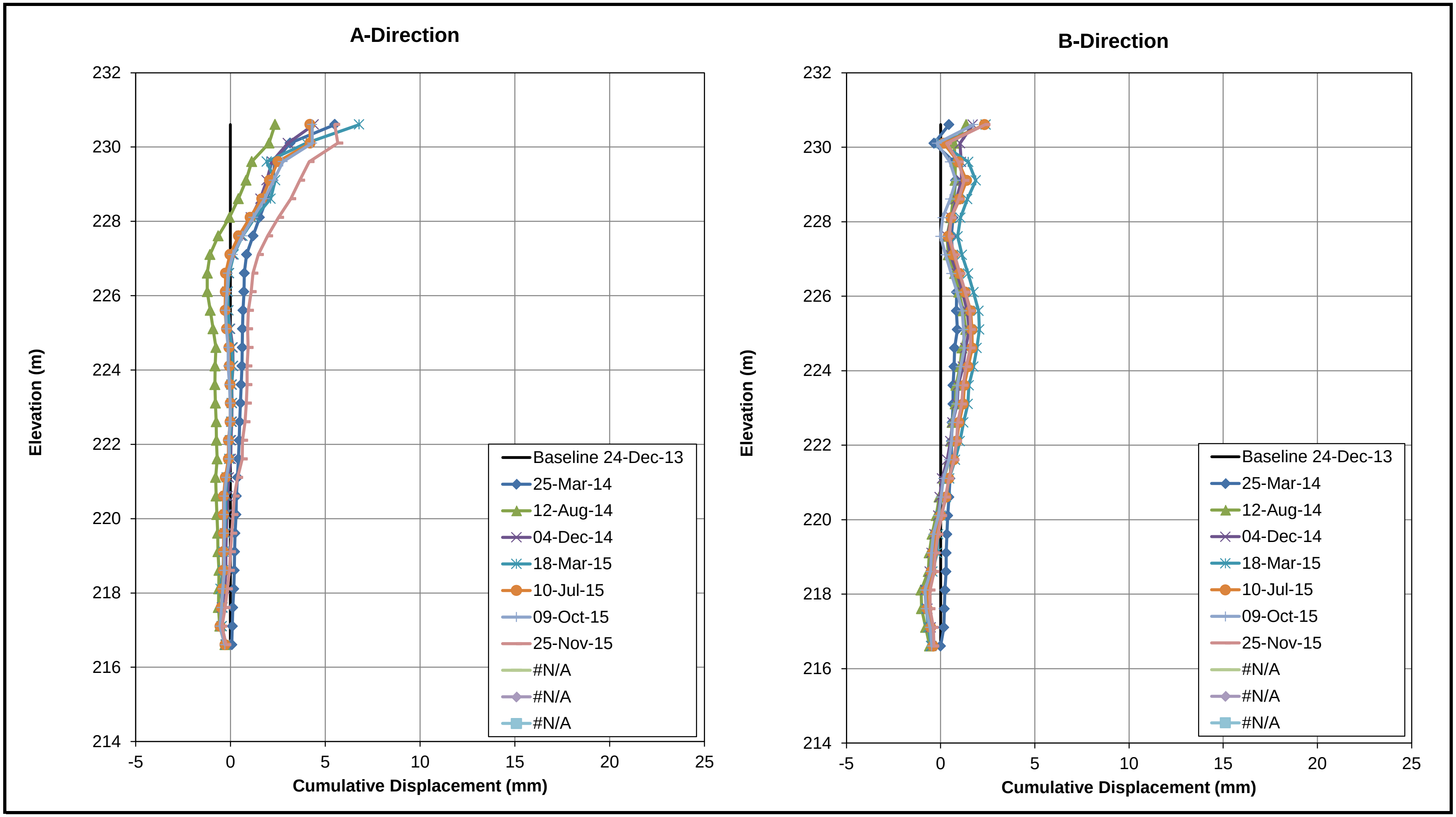
INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-5



INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-5

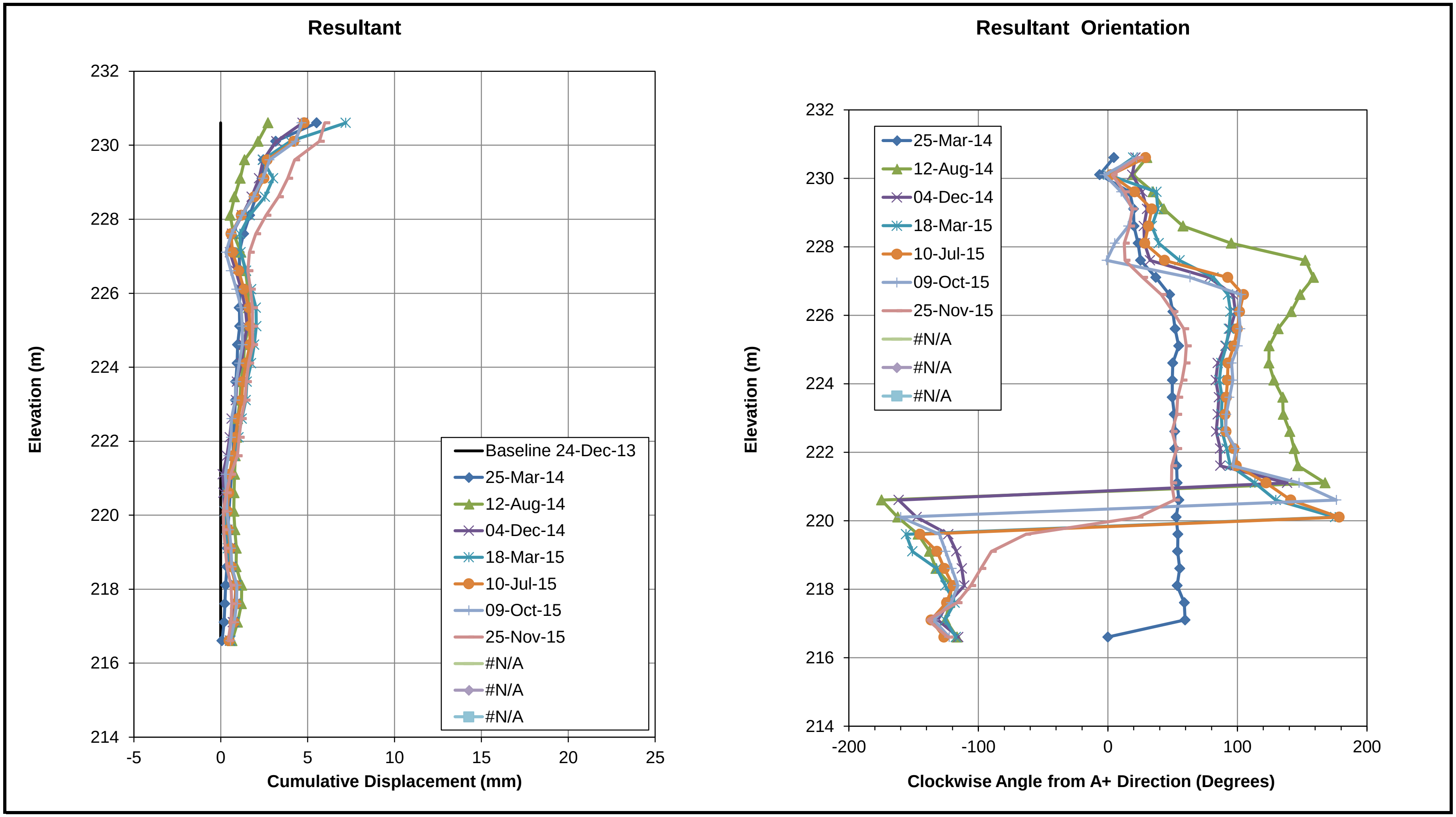


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-5

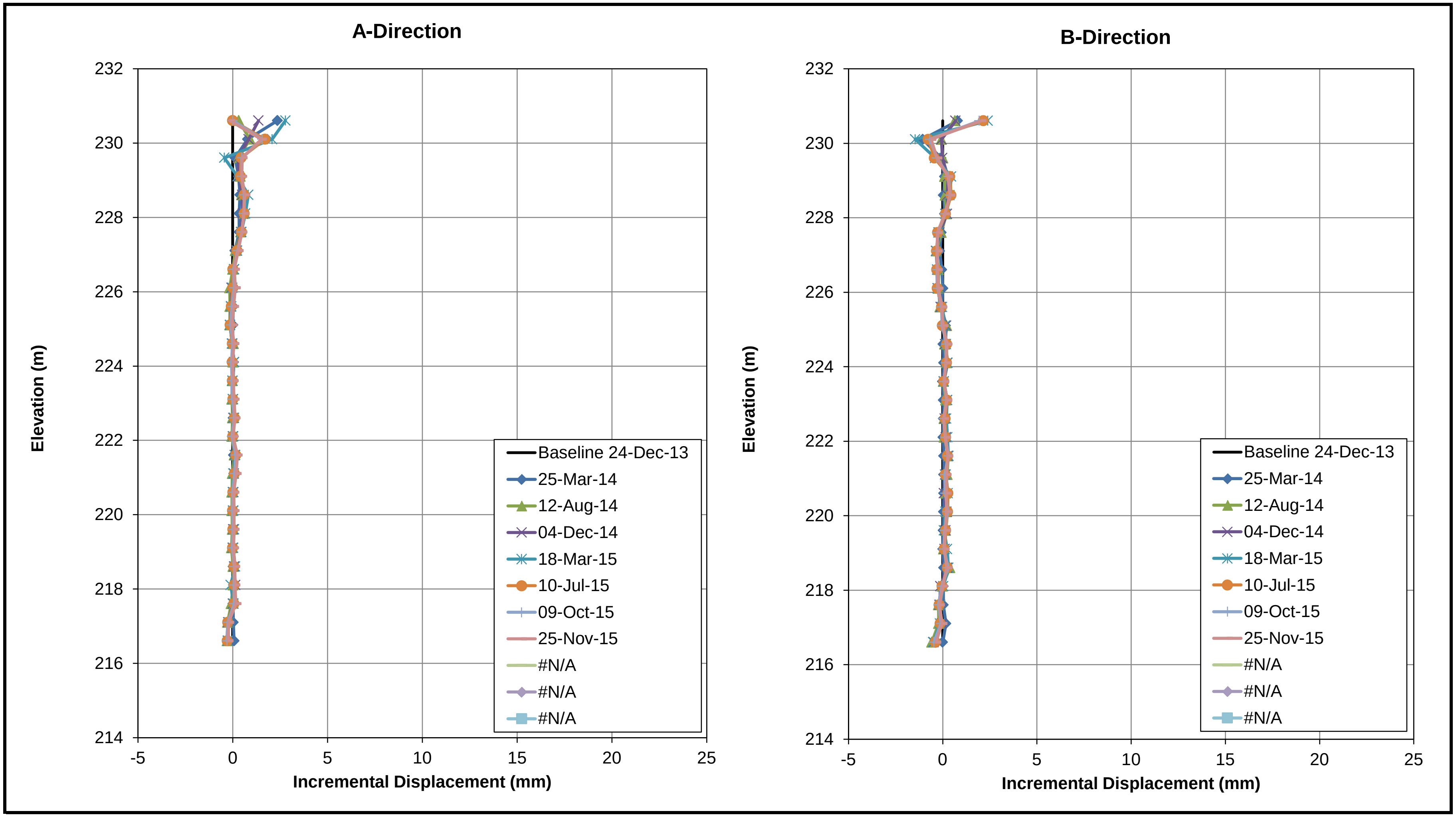


SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

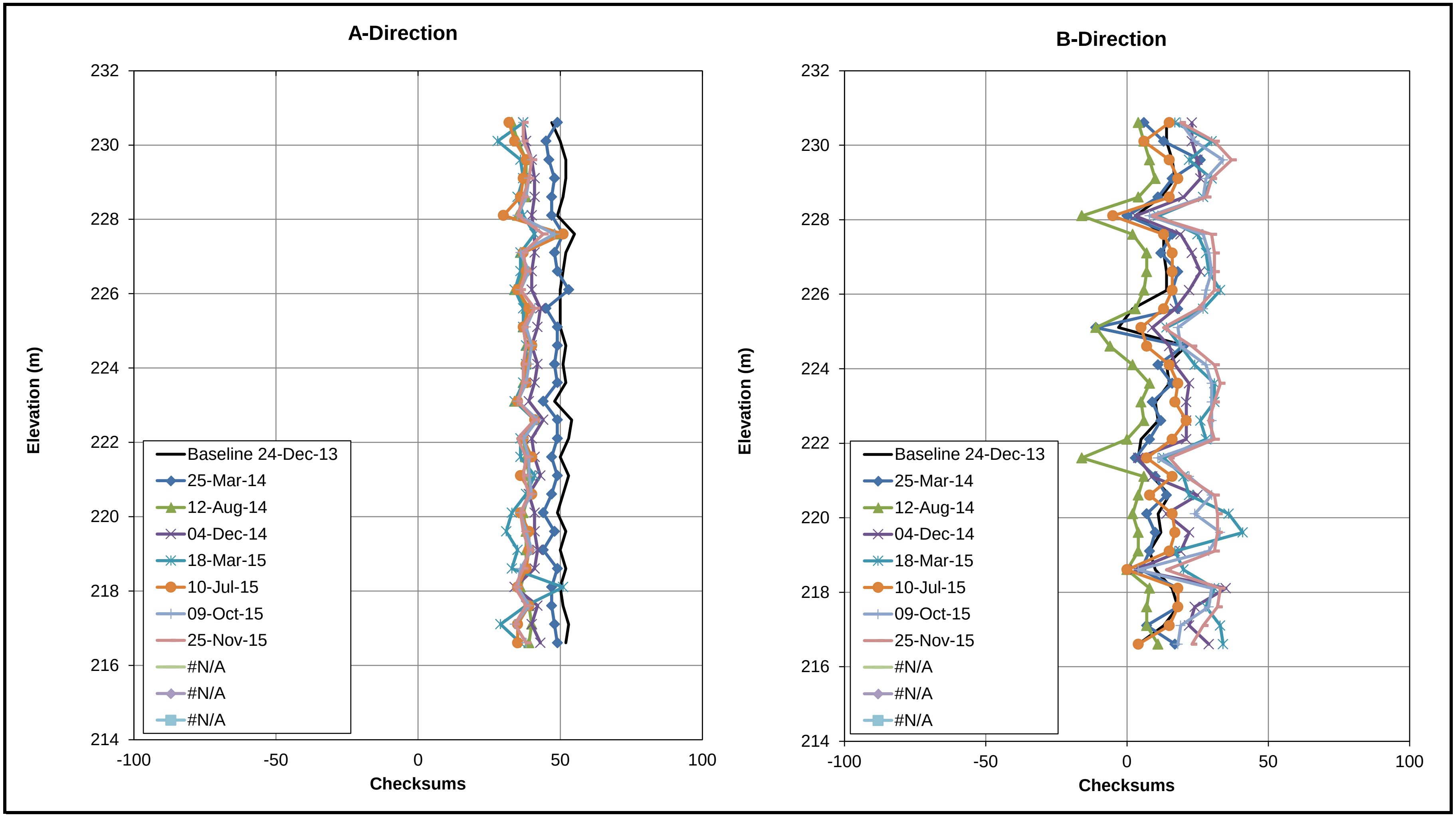
Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-5



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-5



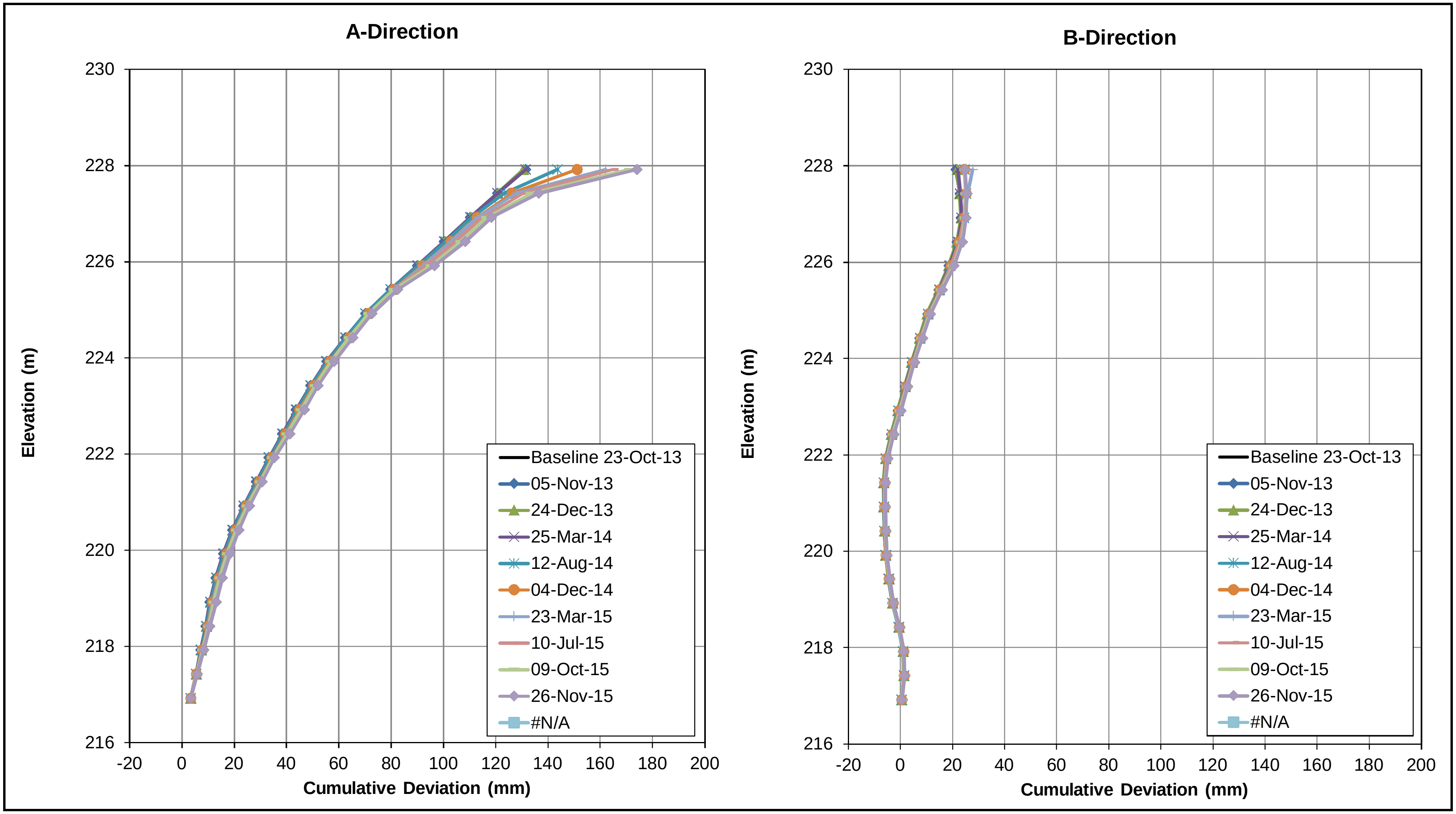
SI-6

SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-6

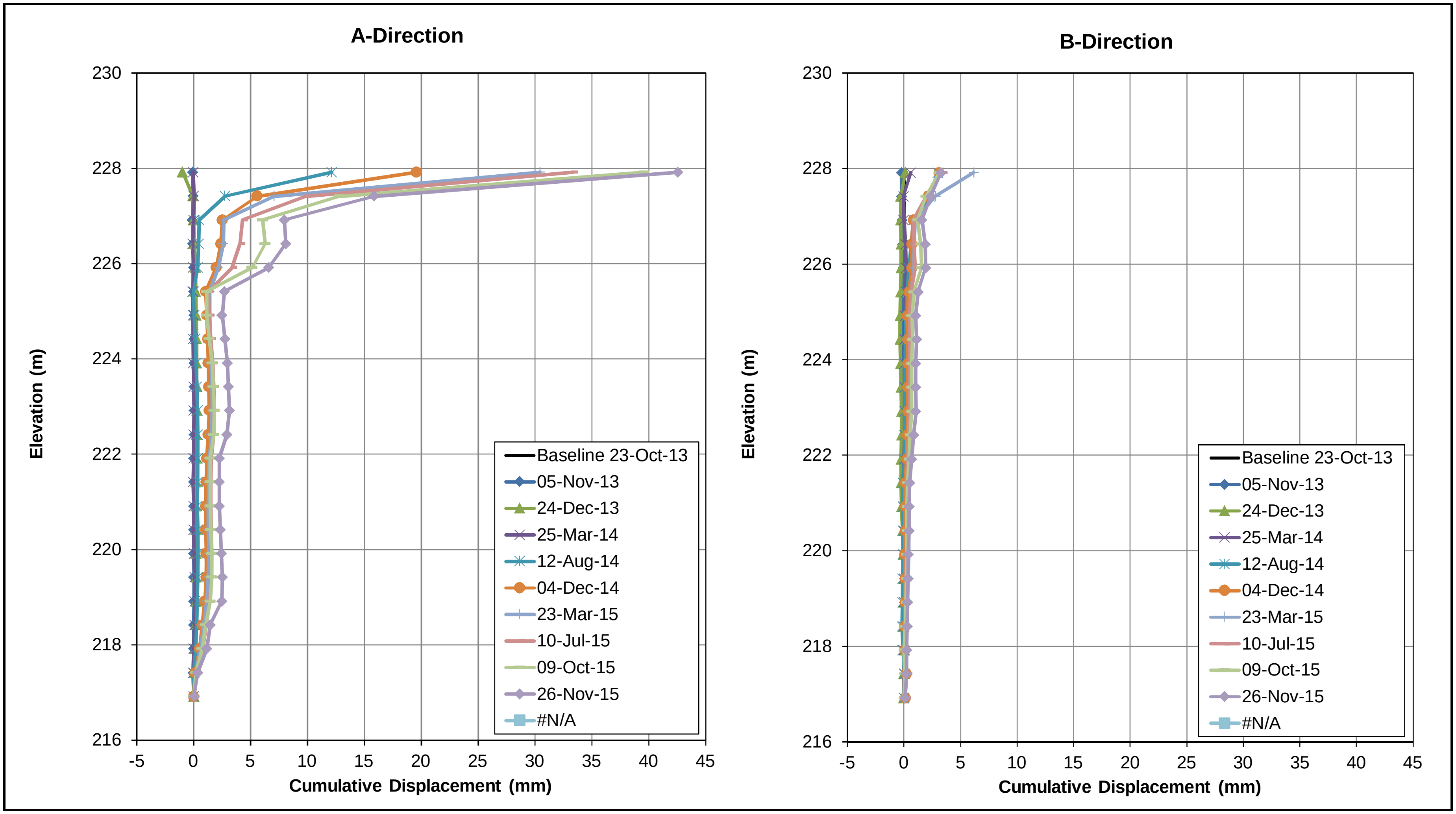


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement in A and B Directions (Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-6

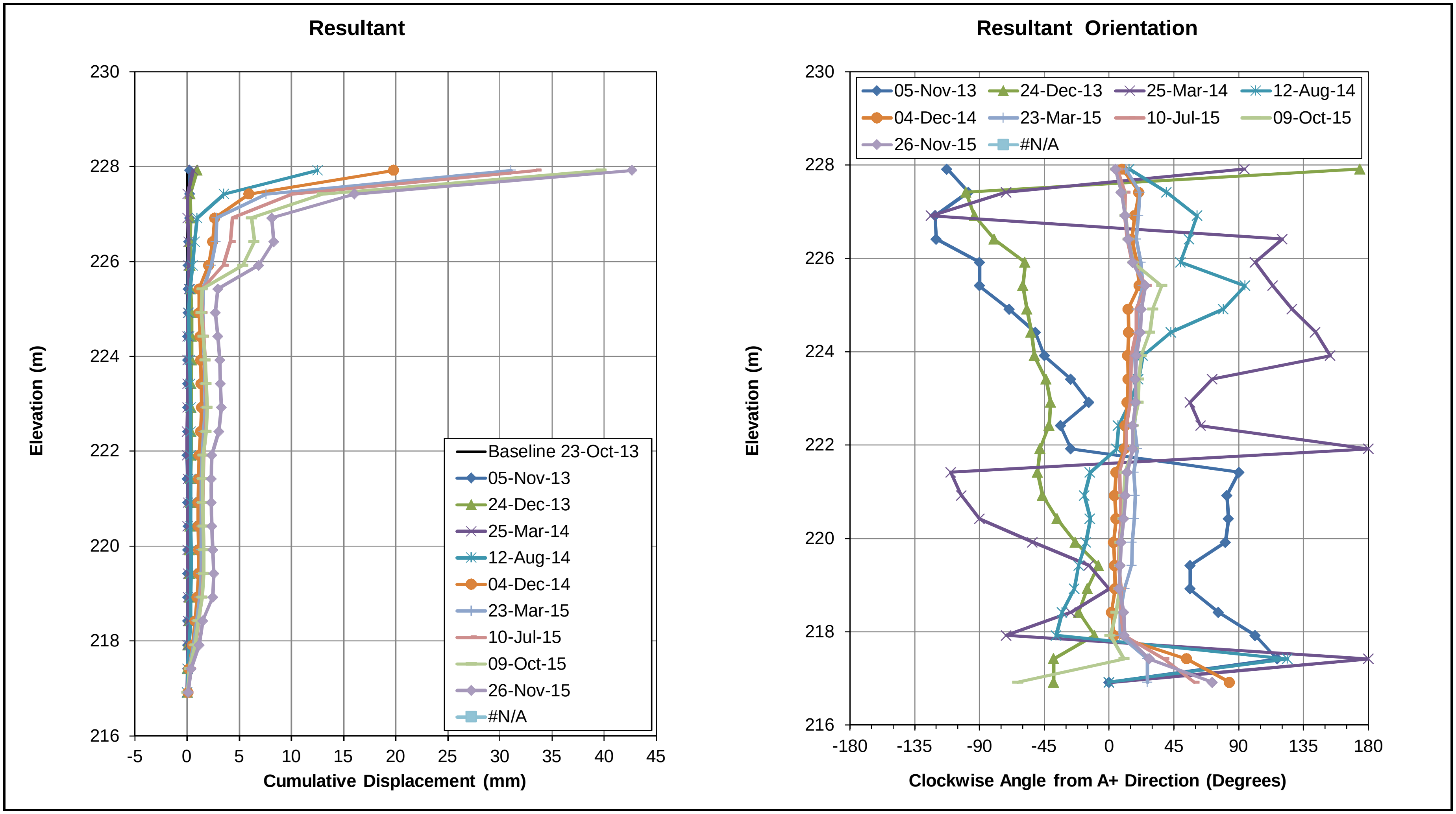


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-6

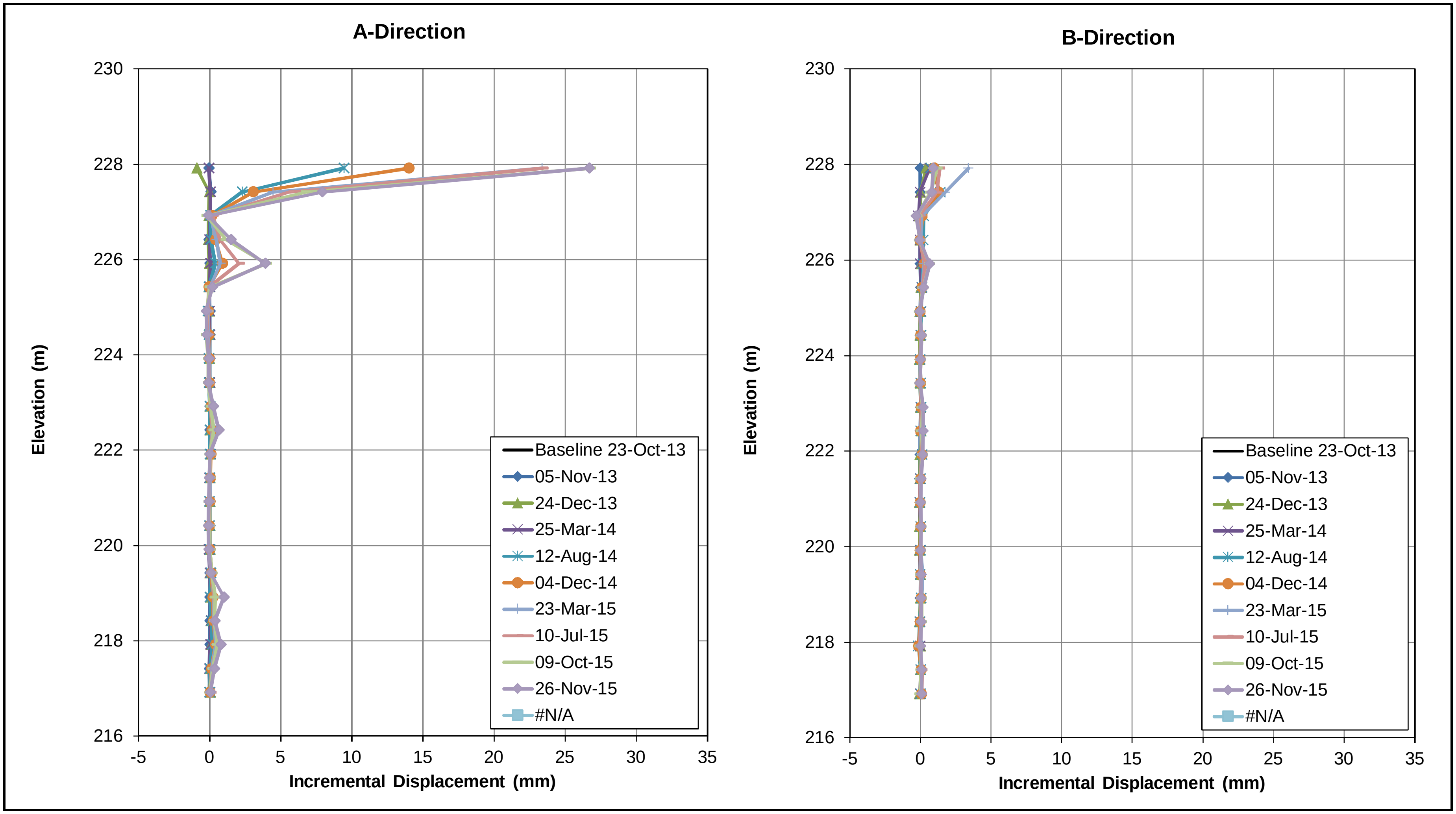


SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-6



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

INSTALLATION DATA	
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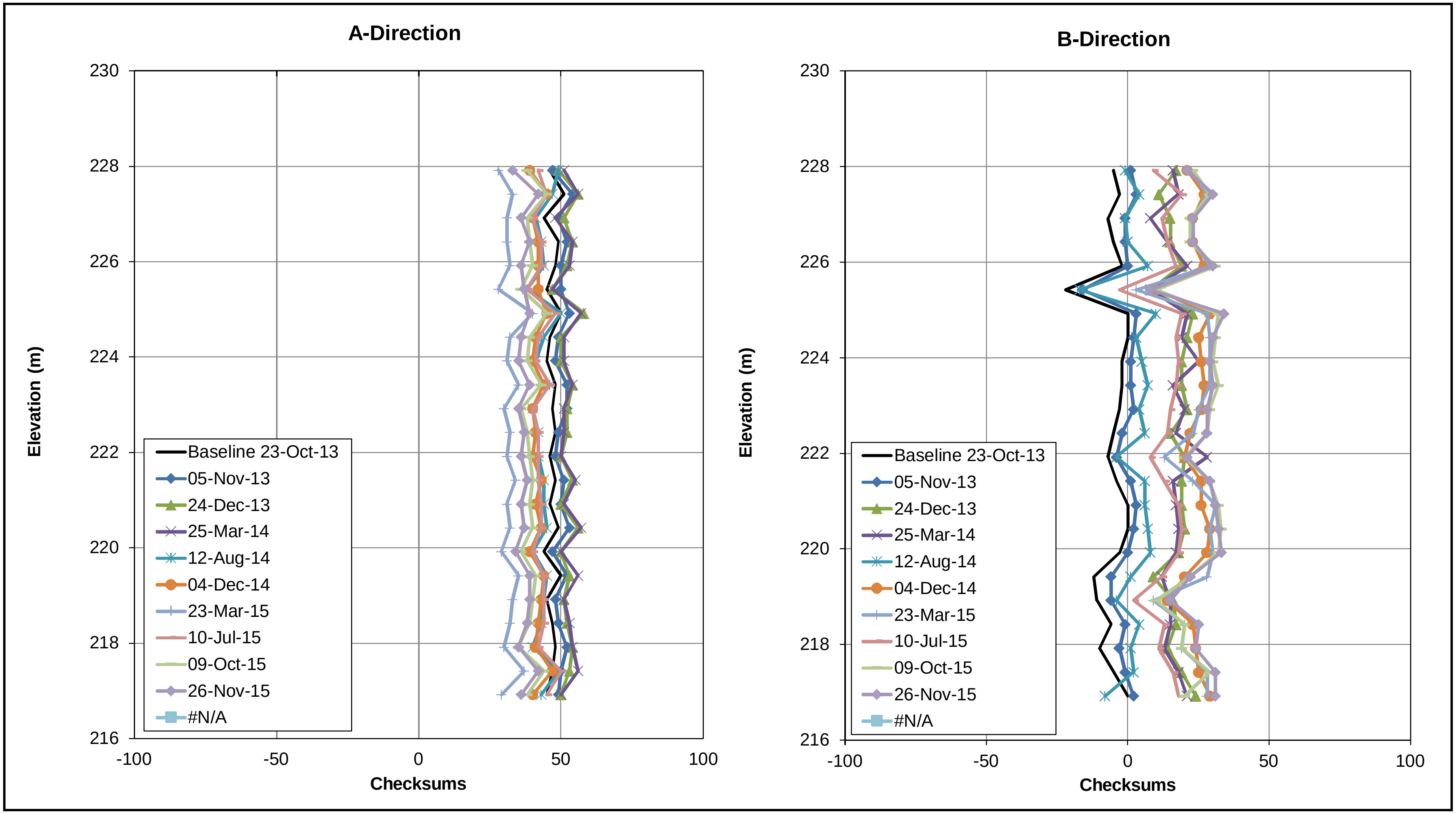
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-6



SI-7

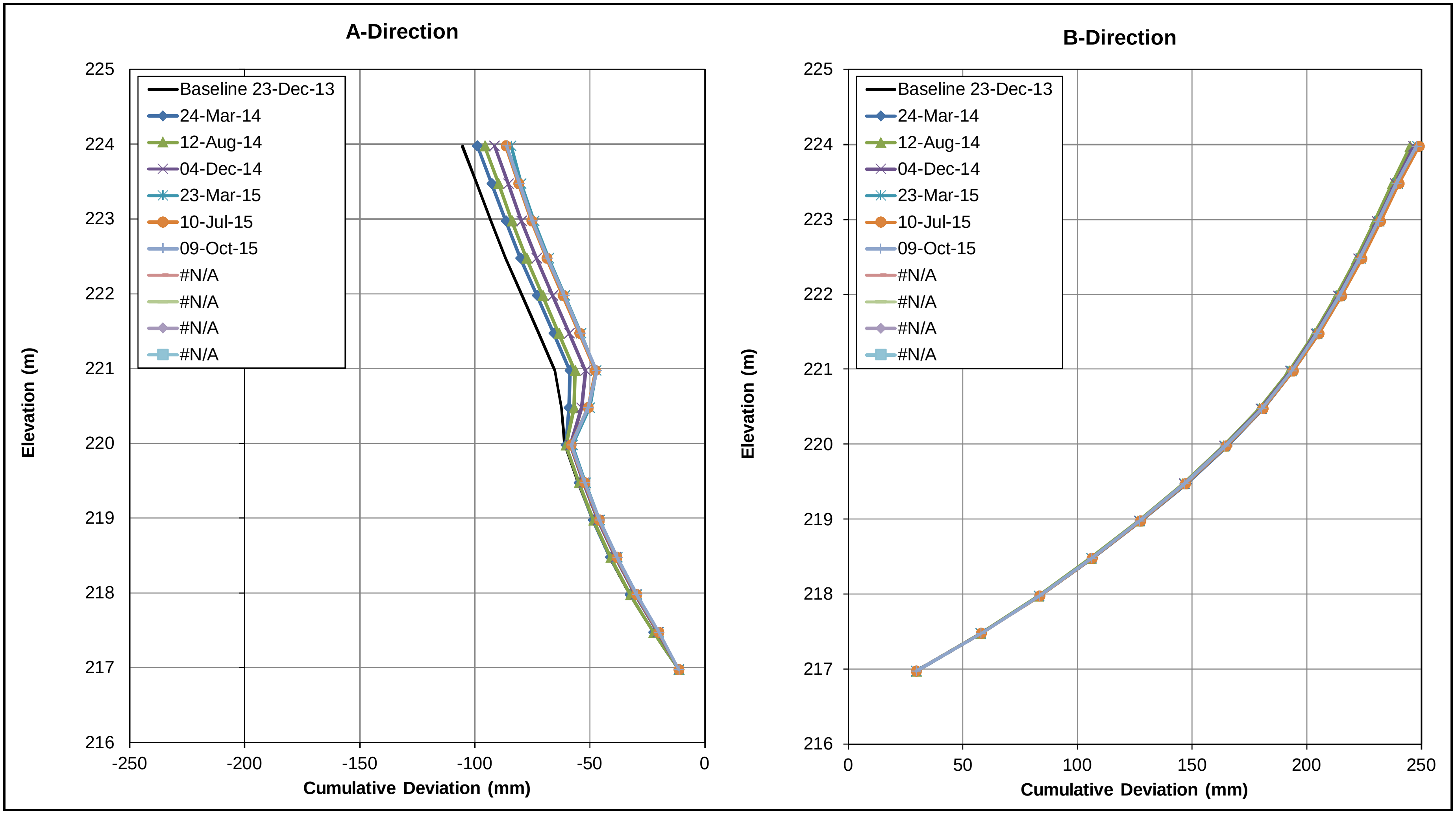
SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

Note: SI-7 casing is no longer readable after October 9, 2015

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-7



SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement in A and B Directions (Movement)

Note: SI-7 casing is no longer readable after October 9, 2015

INSTALLATION DATA	
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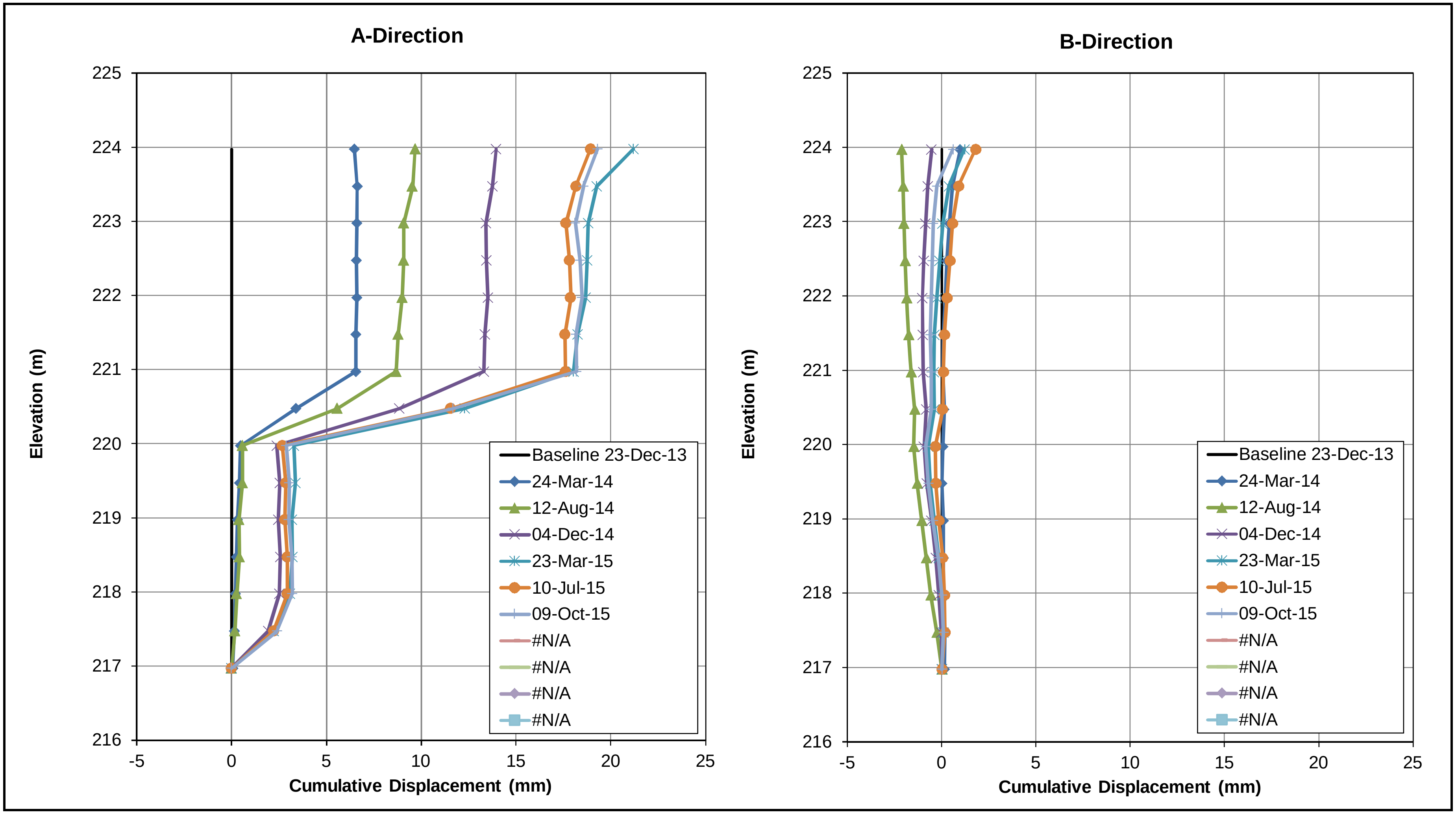
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-7



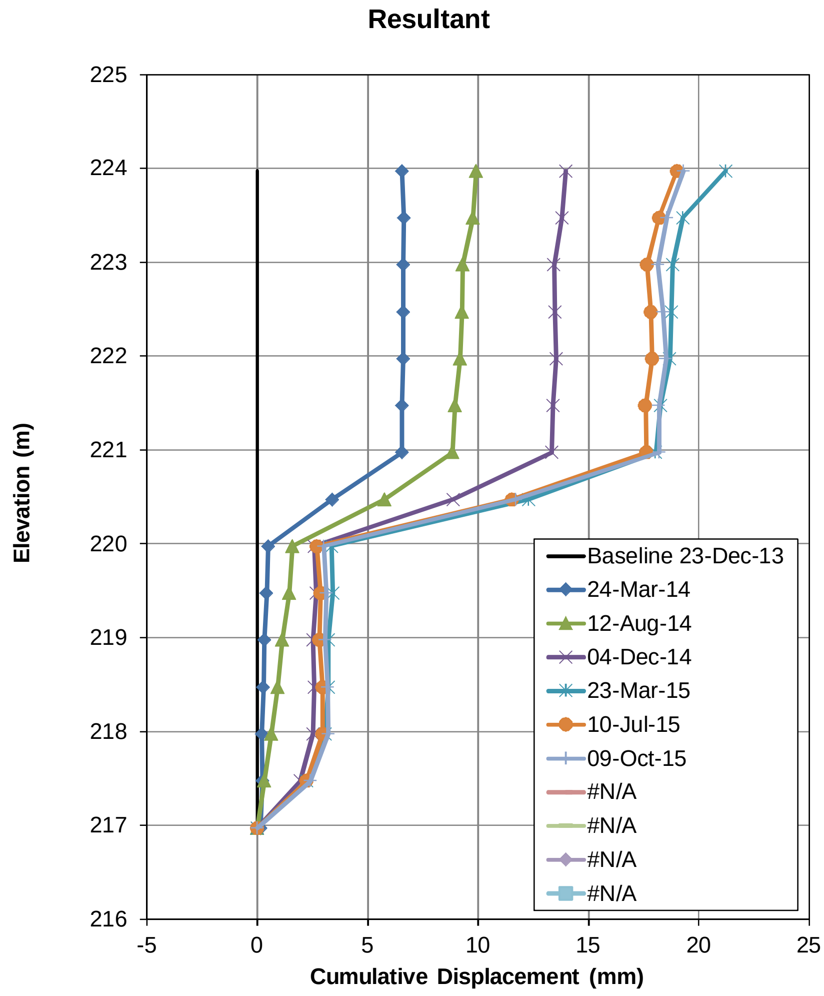
SLOPE INCLINOMETER WORKSHEET

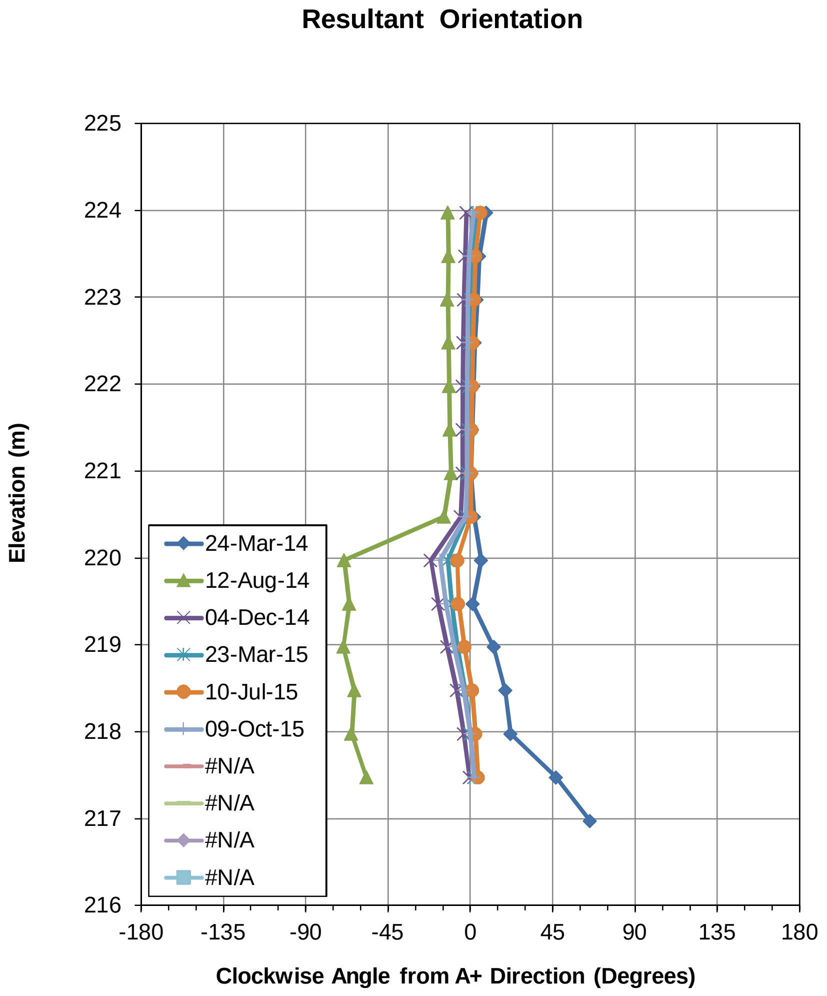
Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

Note: SI-7 casing is no longer readable after October 9, 2015

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-7





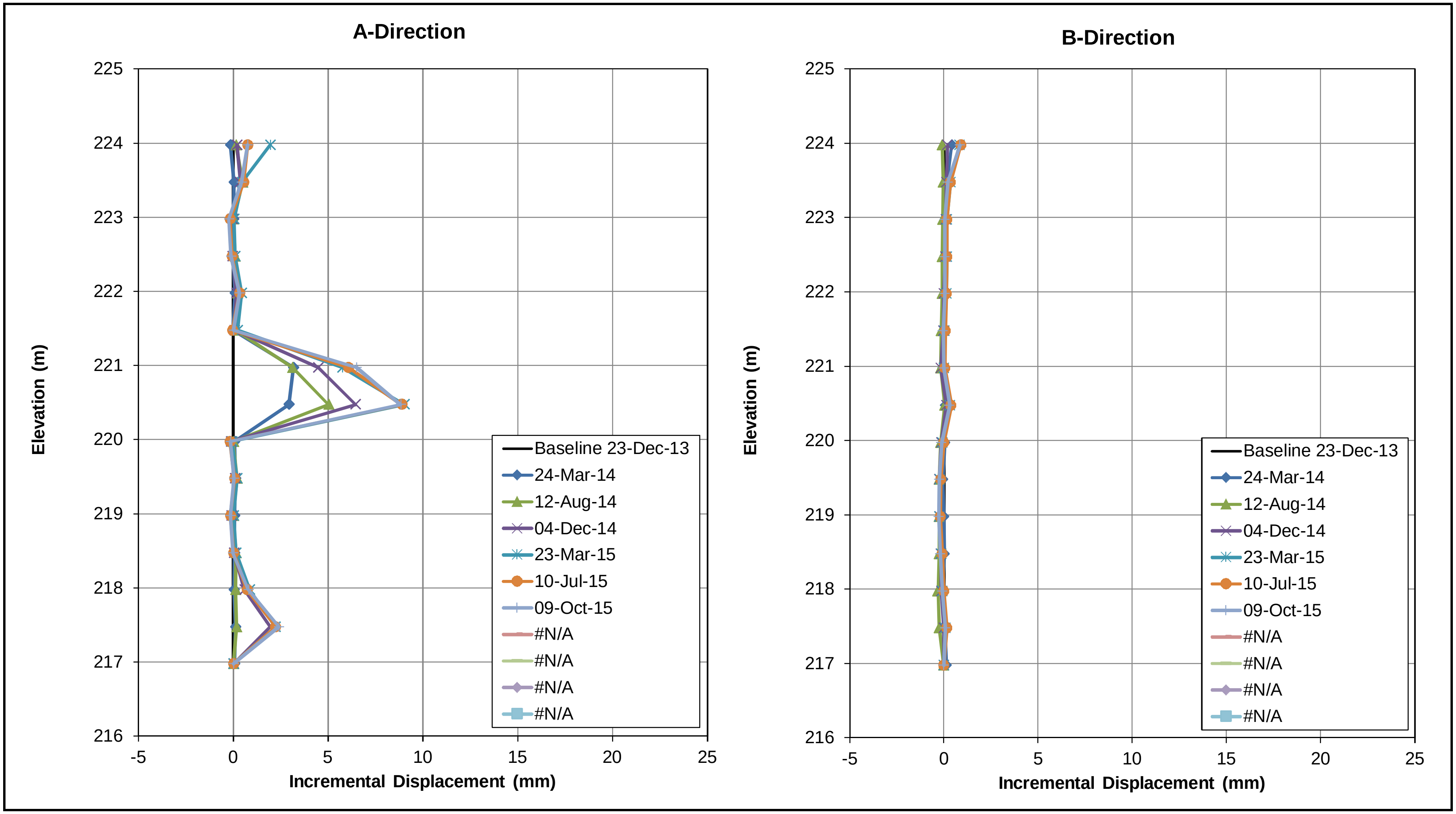
SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

Note: SI-7 casing is no longer readable after October 9, 2015

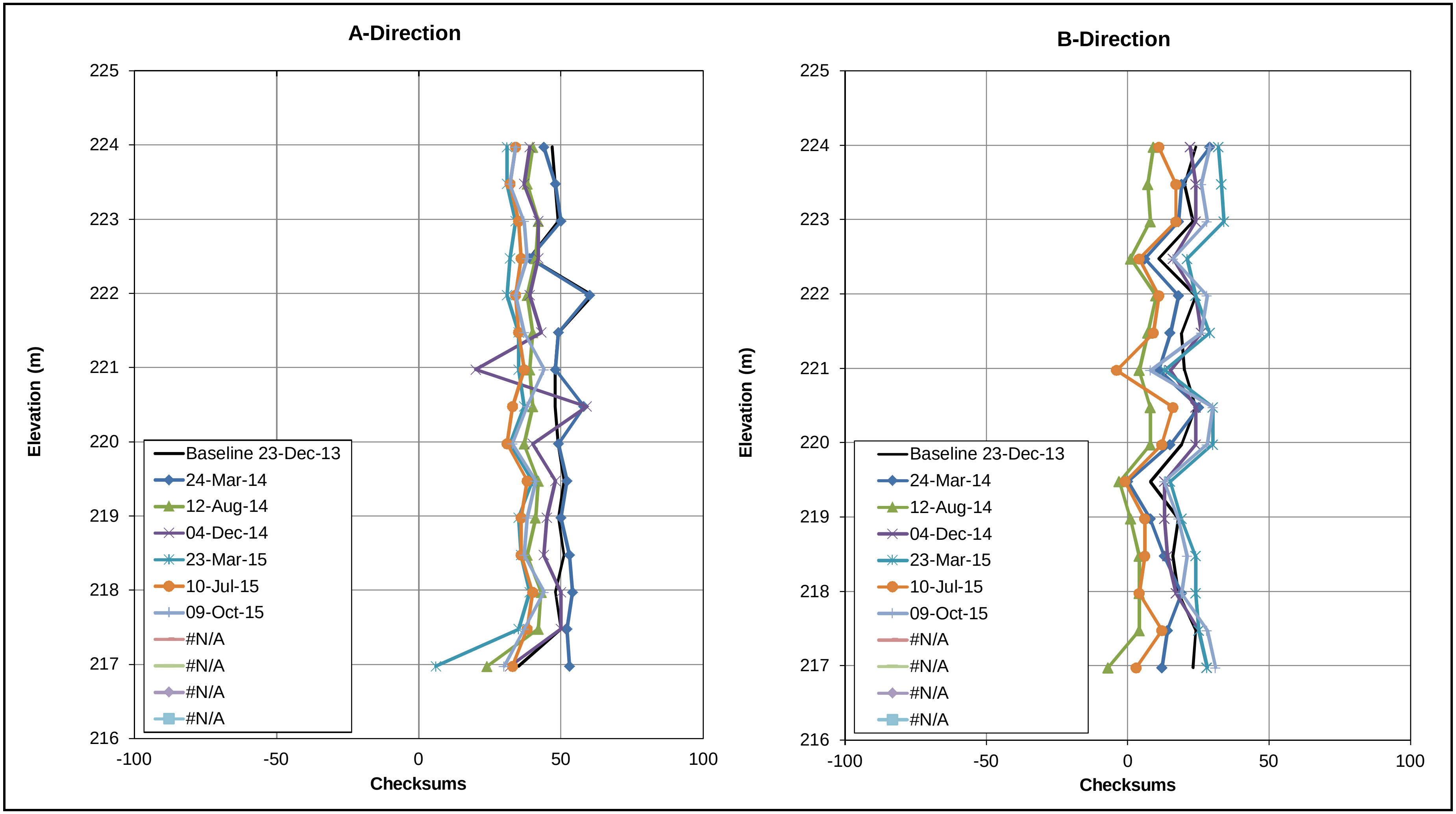
Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-7



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

Note: SI-7 casing is no longer readable after October 9, 2015

INSTALLATION DATA	
Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-7



SI-8

SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

INSTALLATION DATA

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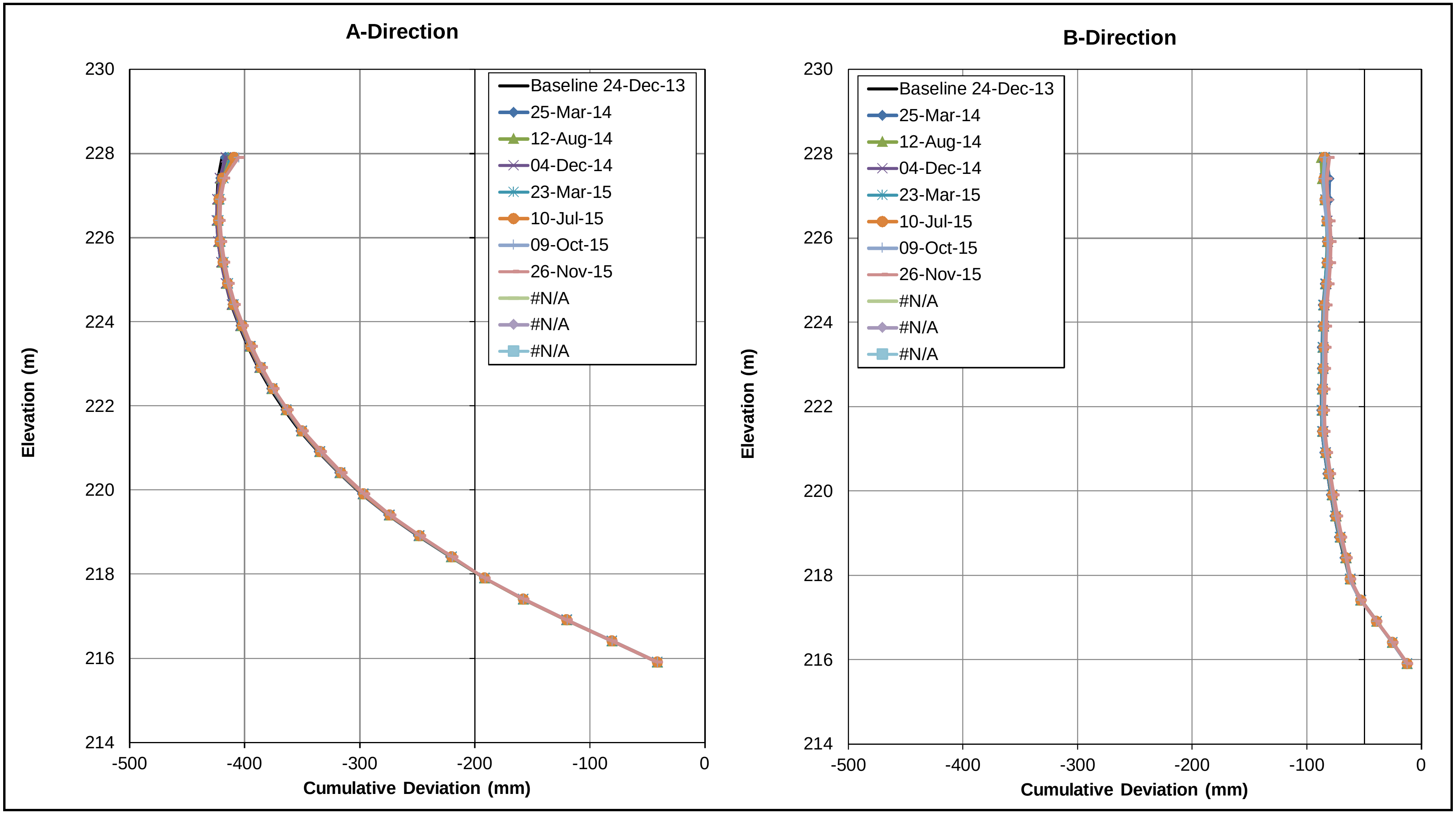
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-8

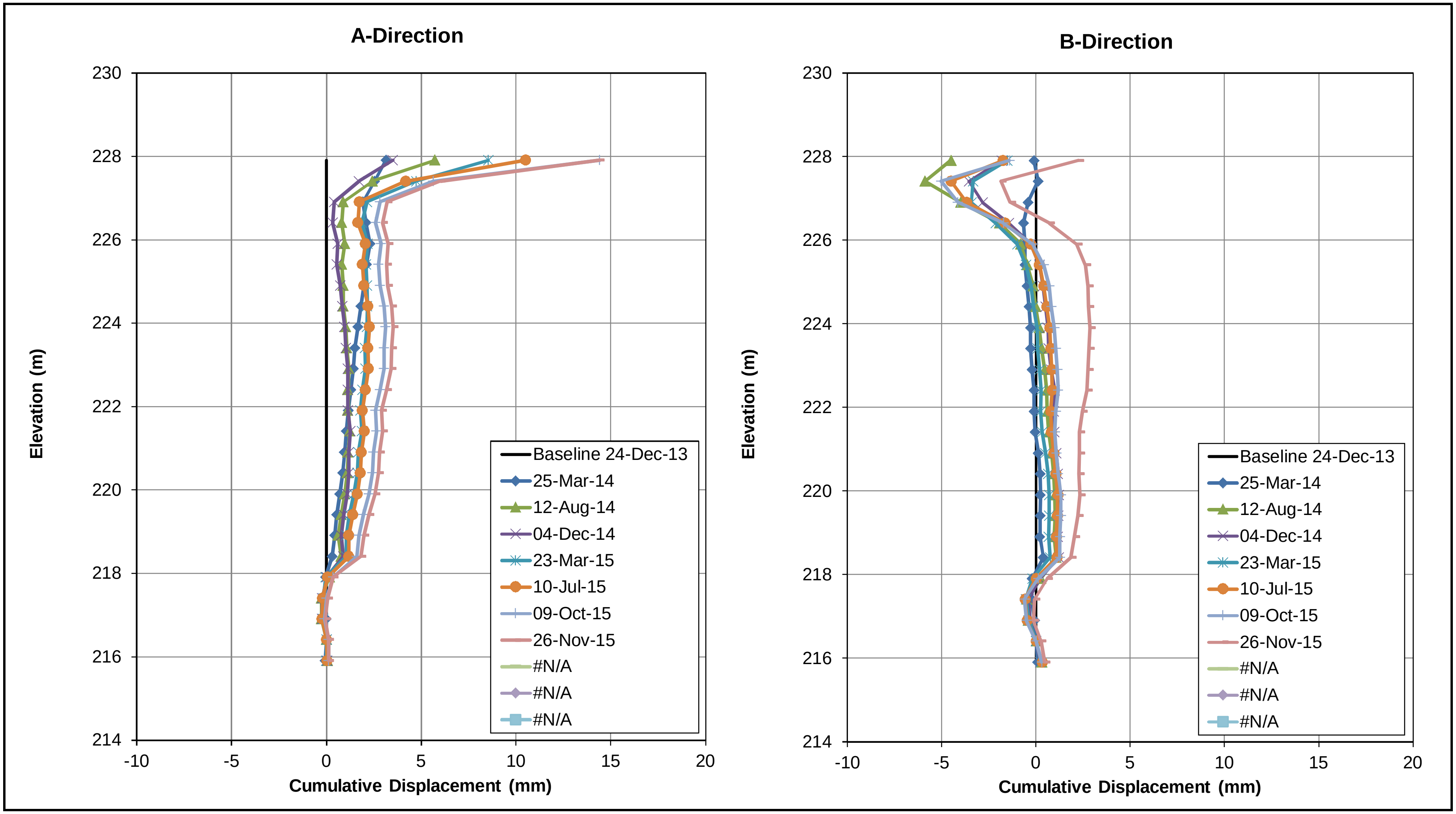


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement in A and B Directions (Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-8



SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

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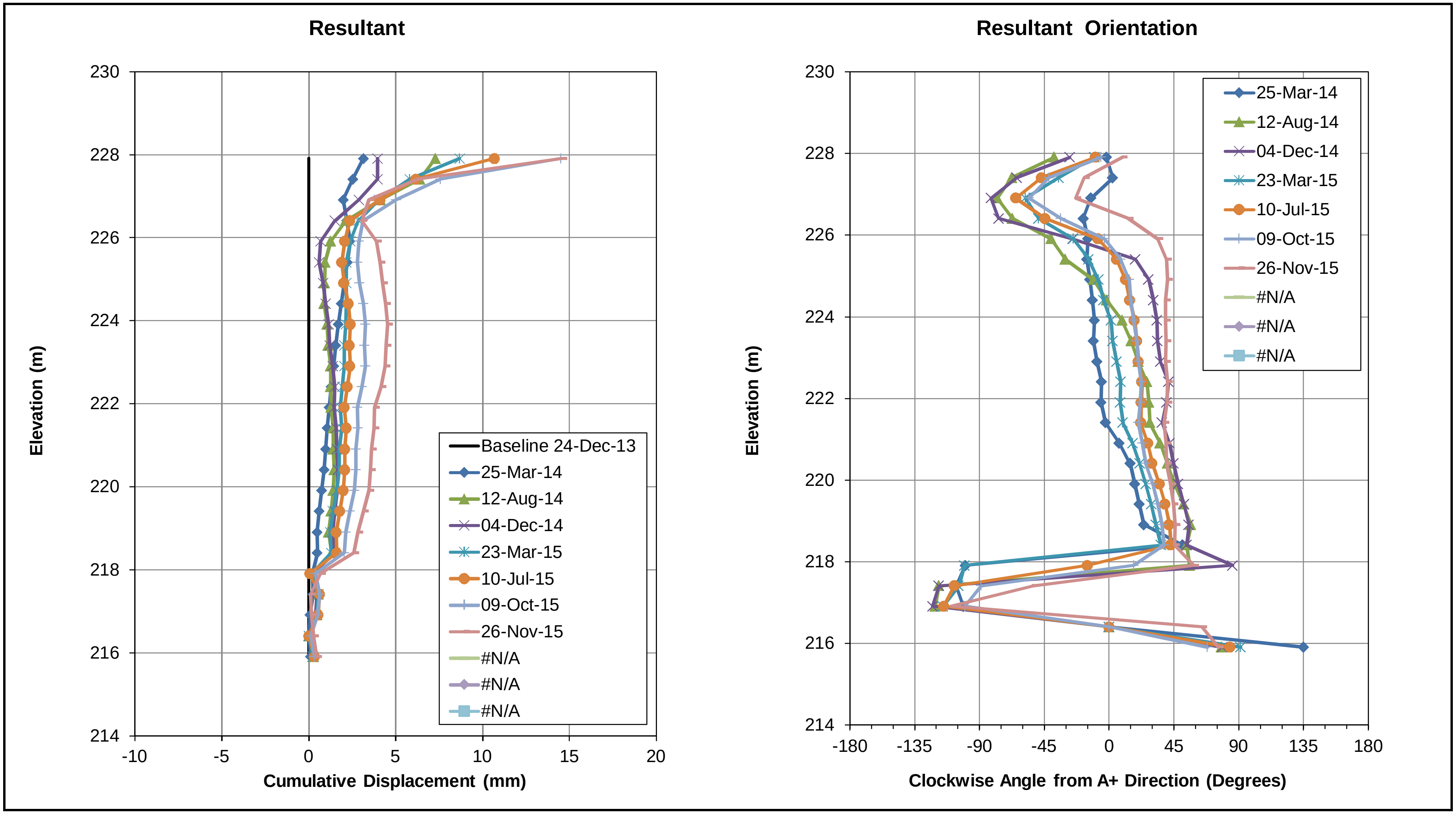
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-8


Resultant

Resultant Orientation

SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

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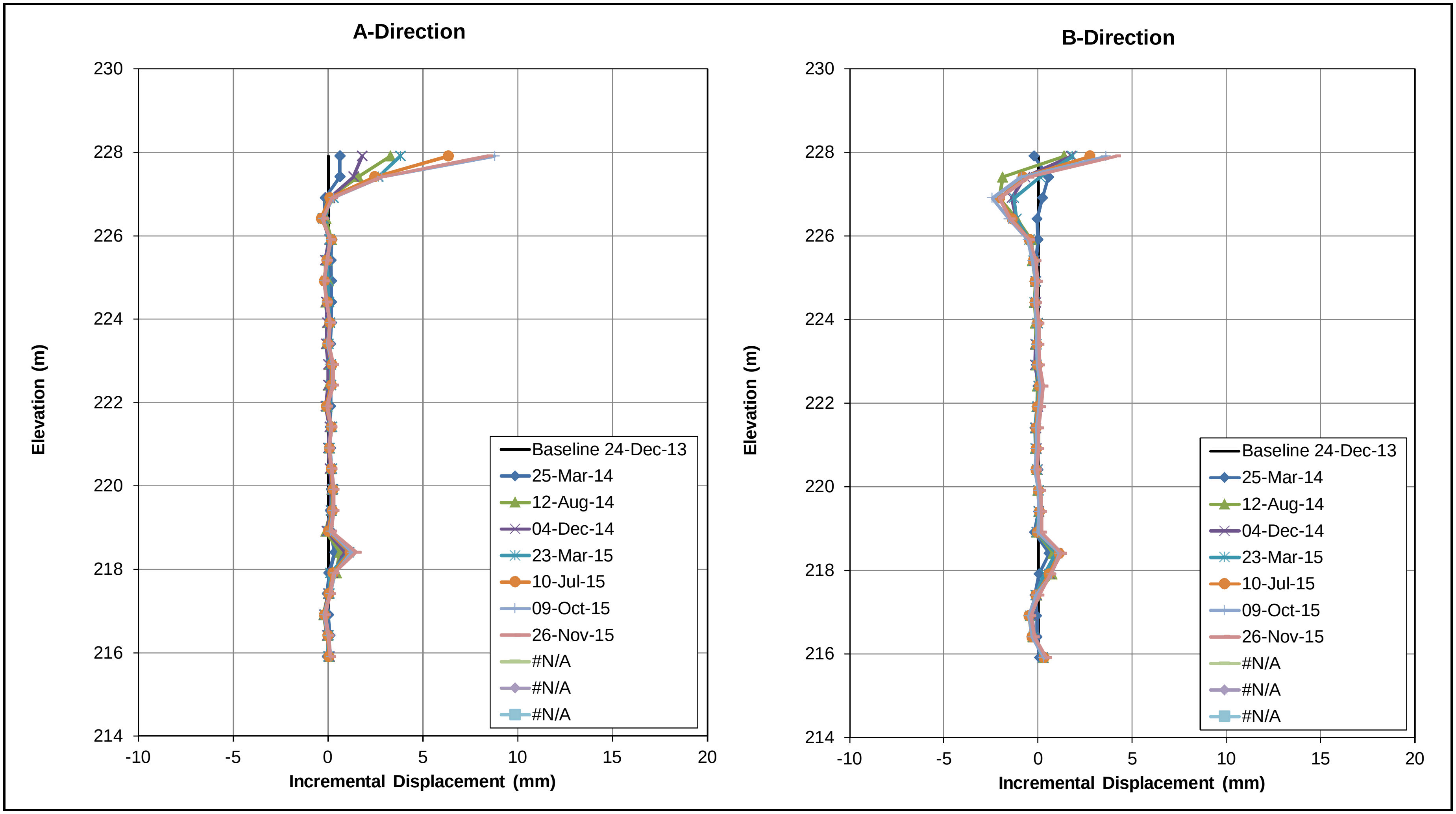
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-8



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

INSTALLATION DATA

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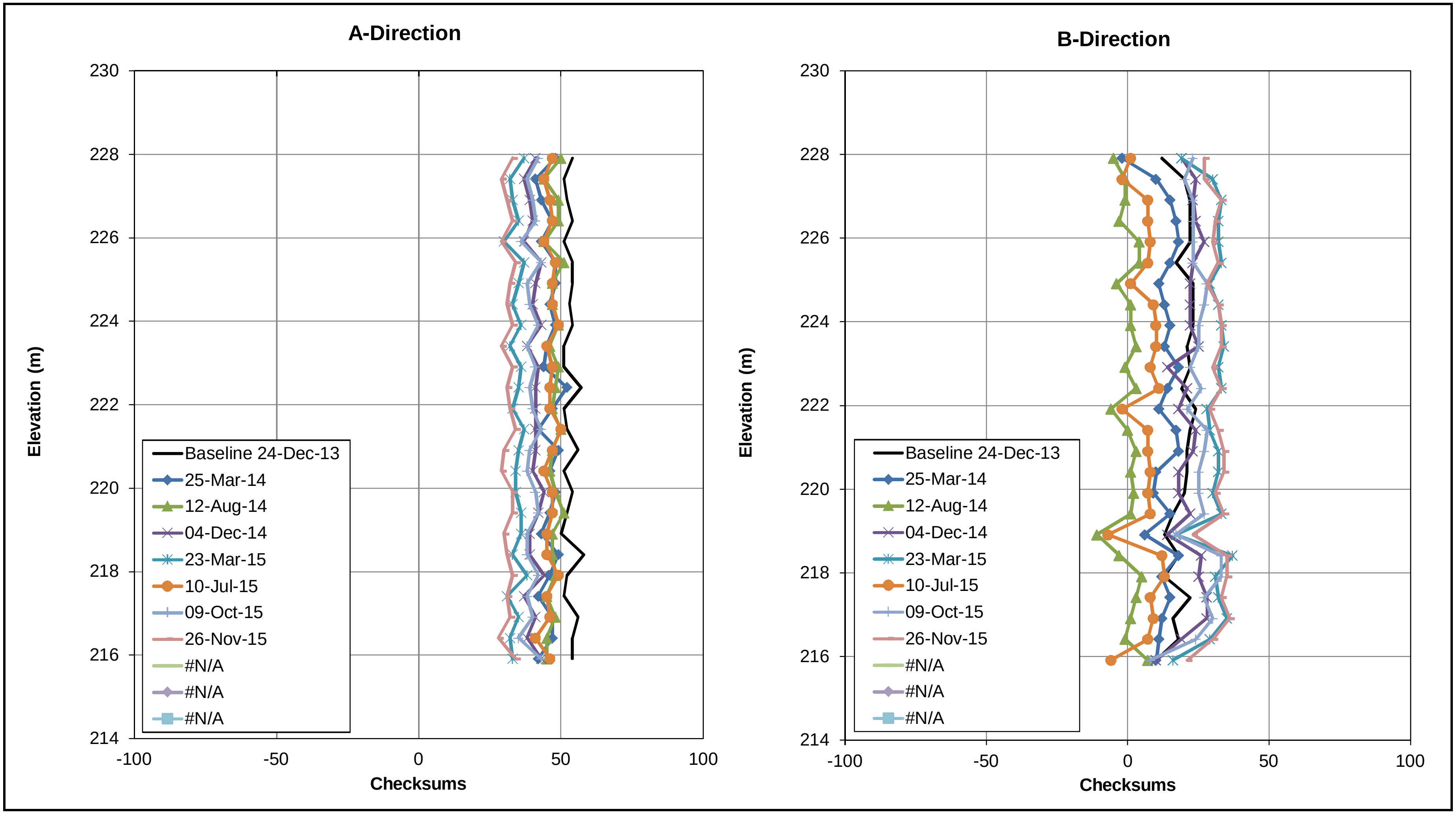
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-8



SI-9

SLOPE INCLINOMETER WORKSHEET

Cumulative Deviation in A and B Directions (Casing Shape)

INSTALLATION DATA

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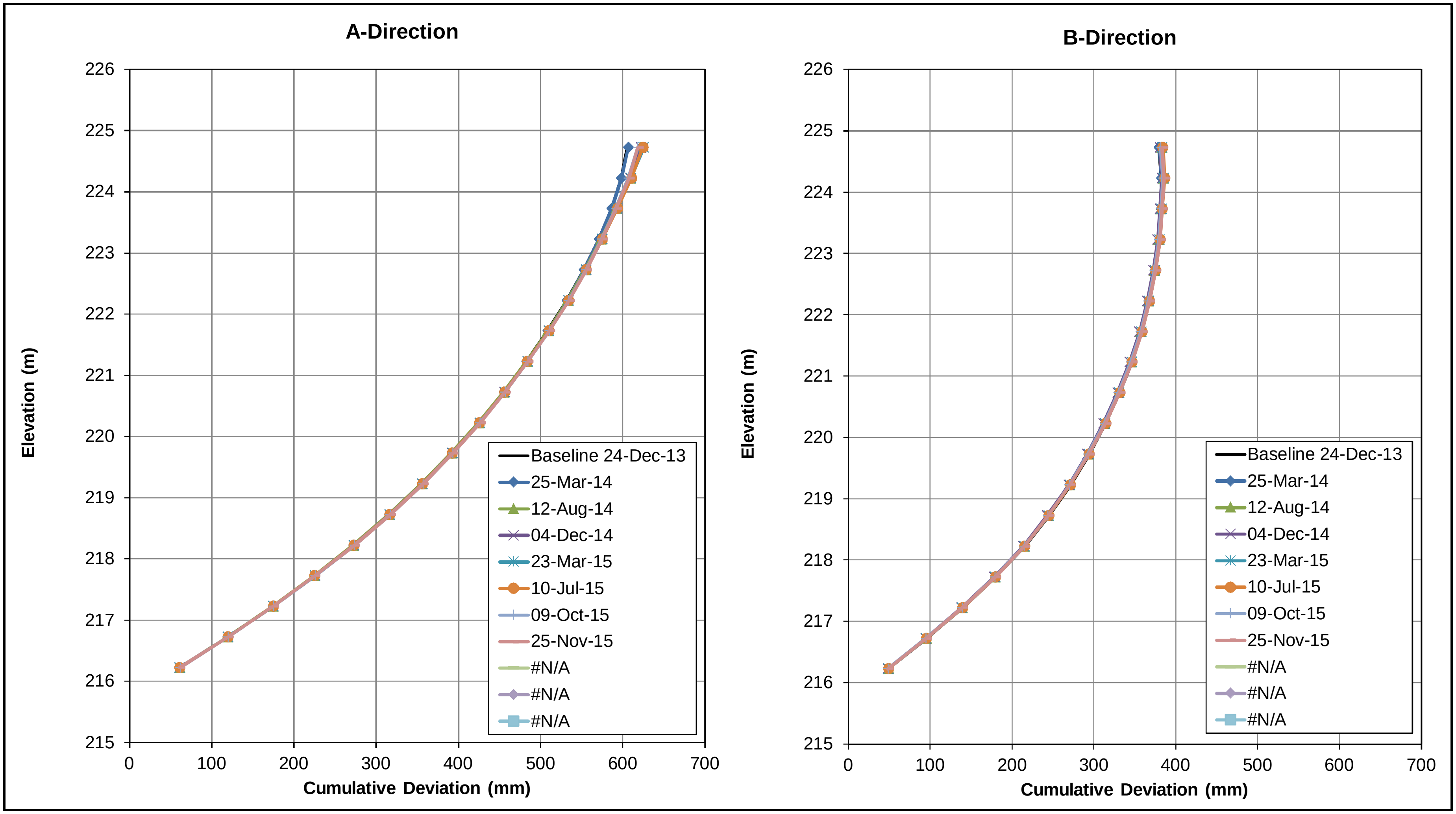
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-9

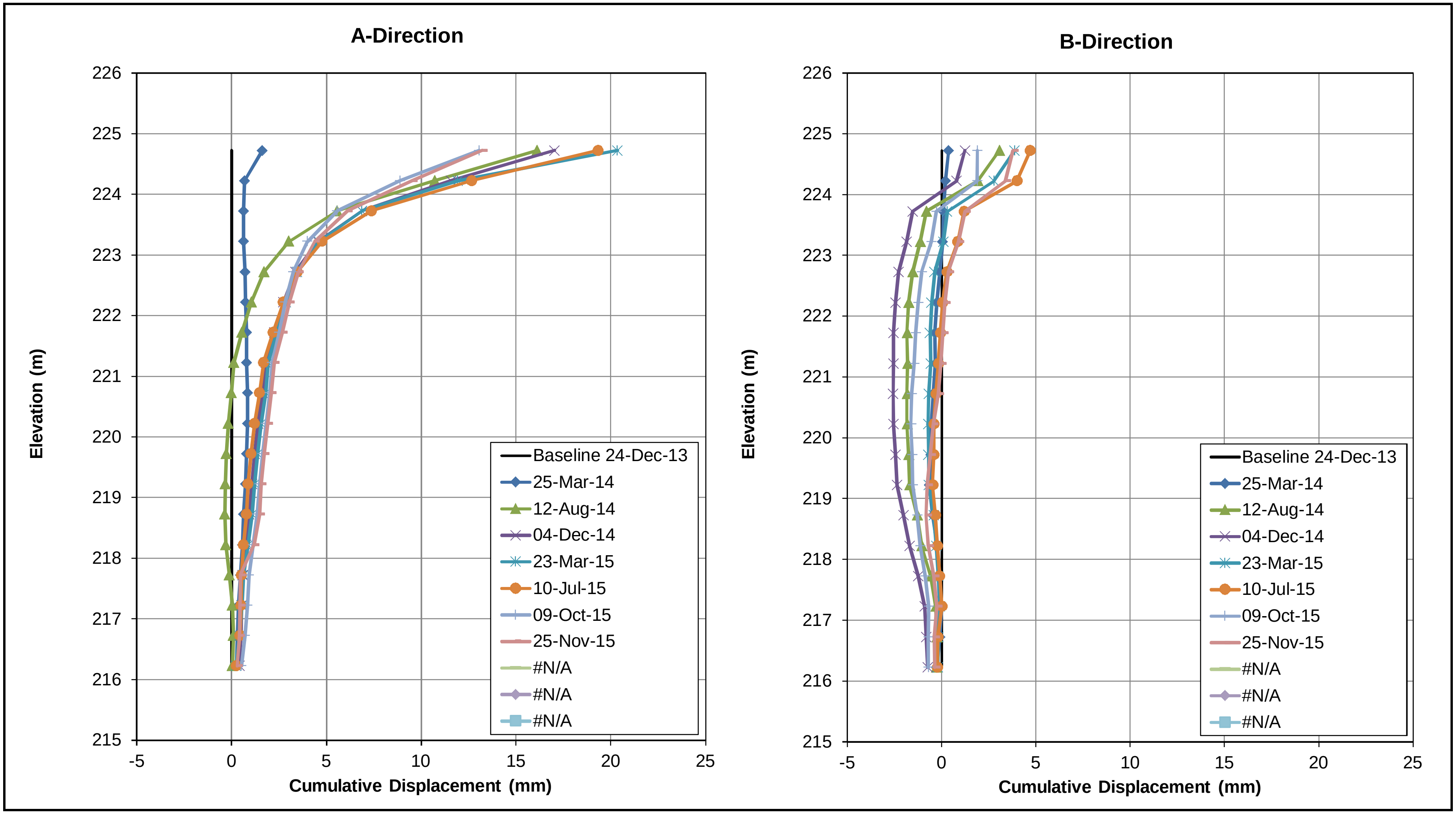


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement in A and B Directions (Movement)

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-9

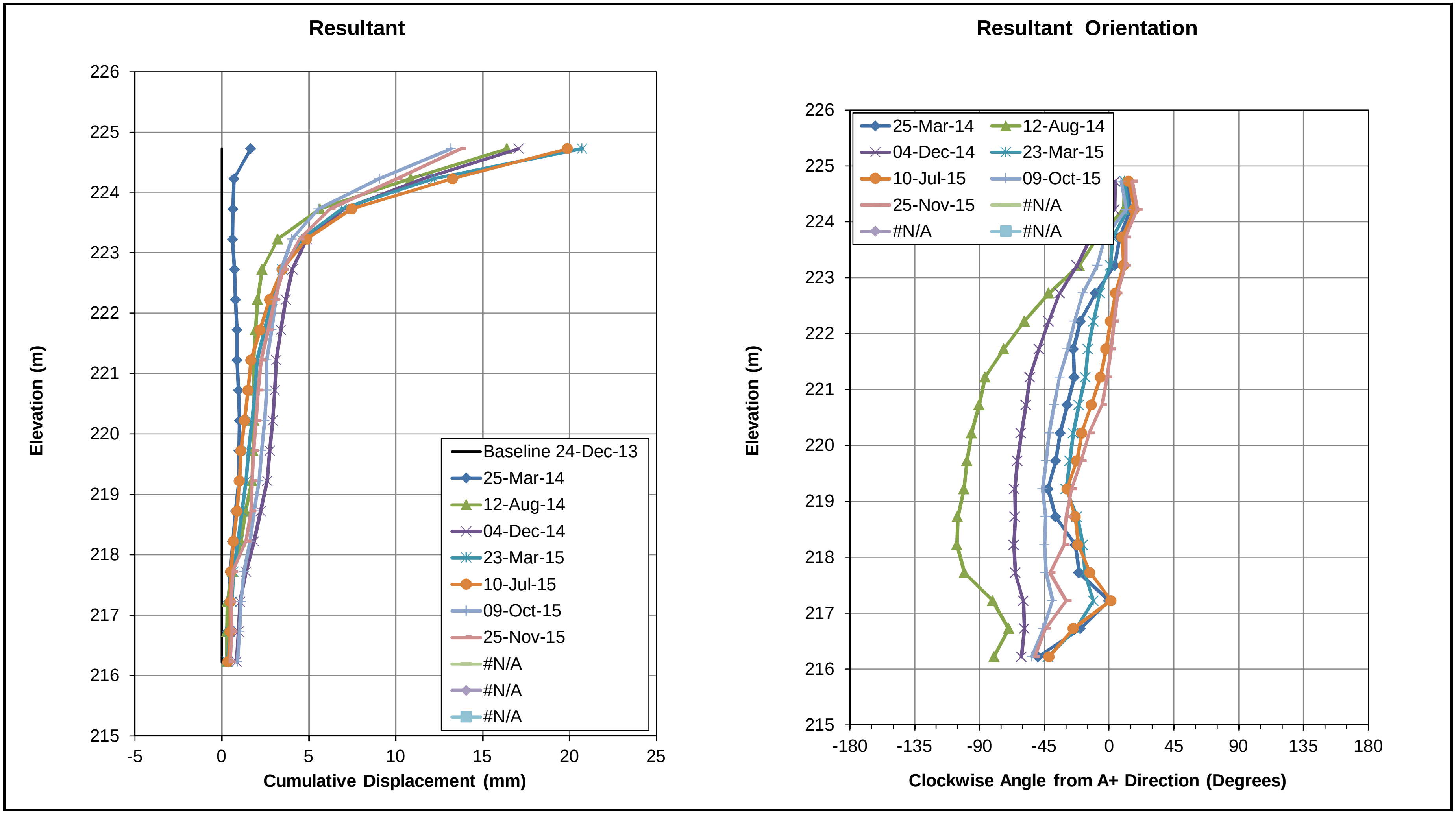


SLOPE INCLINOMETER WORKSHEET

Cumulative Displacement Resultant and Orientation Azimuth

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-9

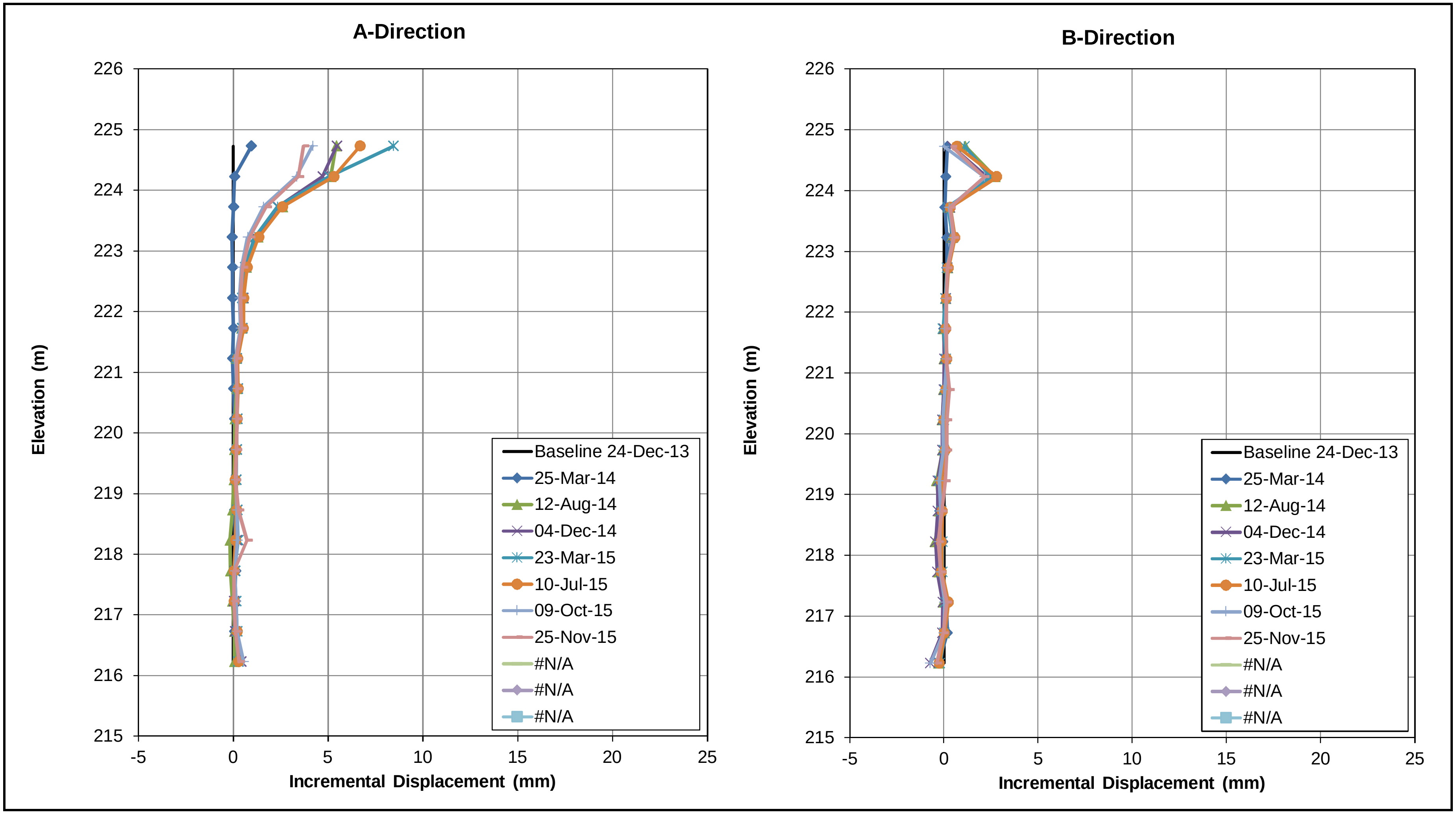


SLOPE INCLINOMETER WORKSHEET

Incremental Displacement in A and B Directions (Zones of Movement)

INSTALLATION DATA

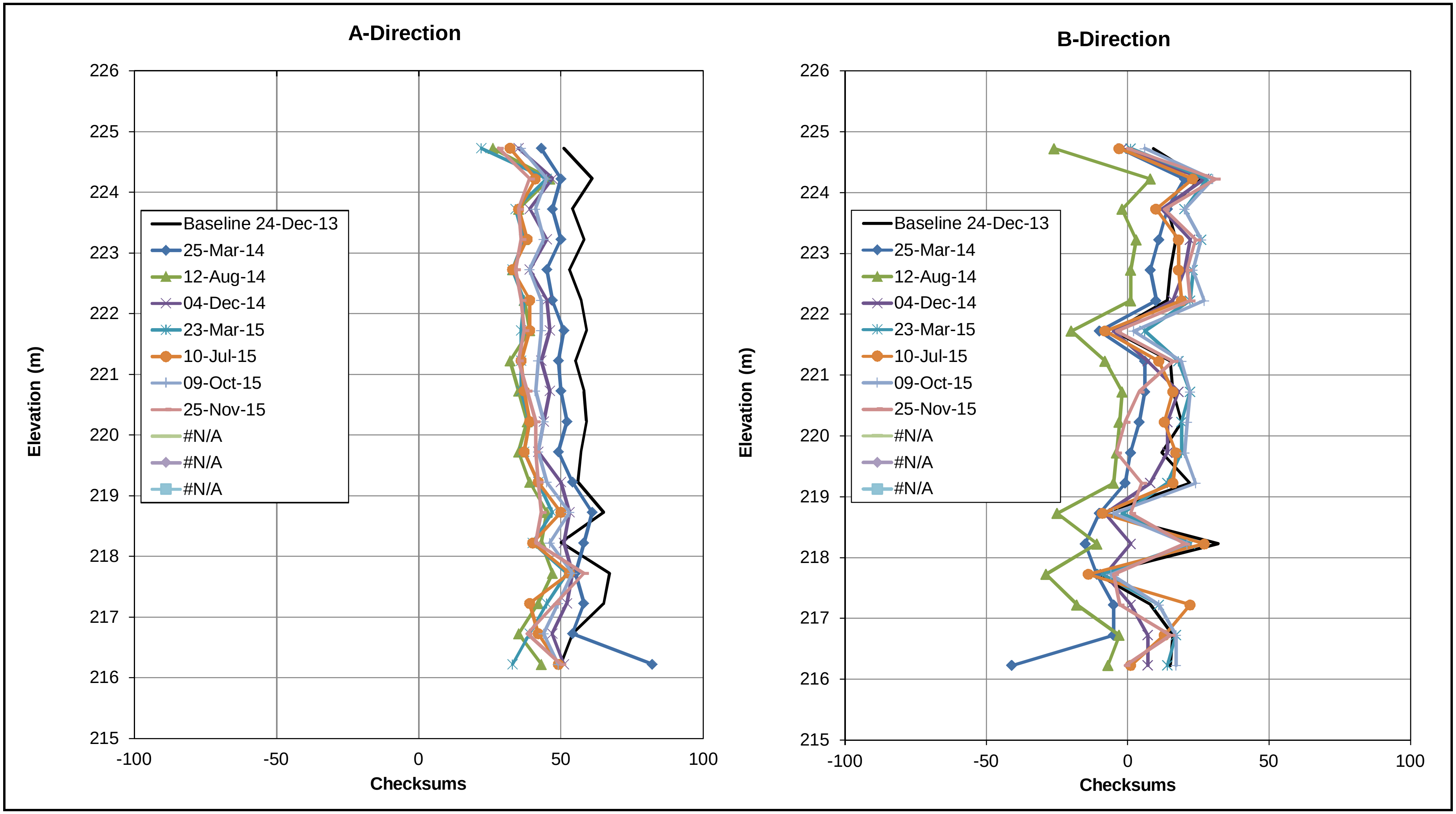
Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-9



SLOPE INCLINOMETER WORKSHEET
Checksums in A and B Directions

INSTALLATION DATA

Project No.	0015 008 00
Project Title	Lyndale Drive Retaining Wall Assessment
Client	City of Winnipeg
Slope Inclinometer No.	SI-9



Appendix B – Slope Stability Analysis Results

0015 014 00
Lyndale Monck to Gauvin

Figure B-1

Back Analysis - Cross Section B

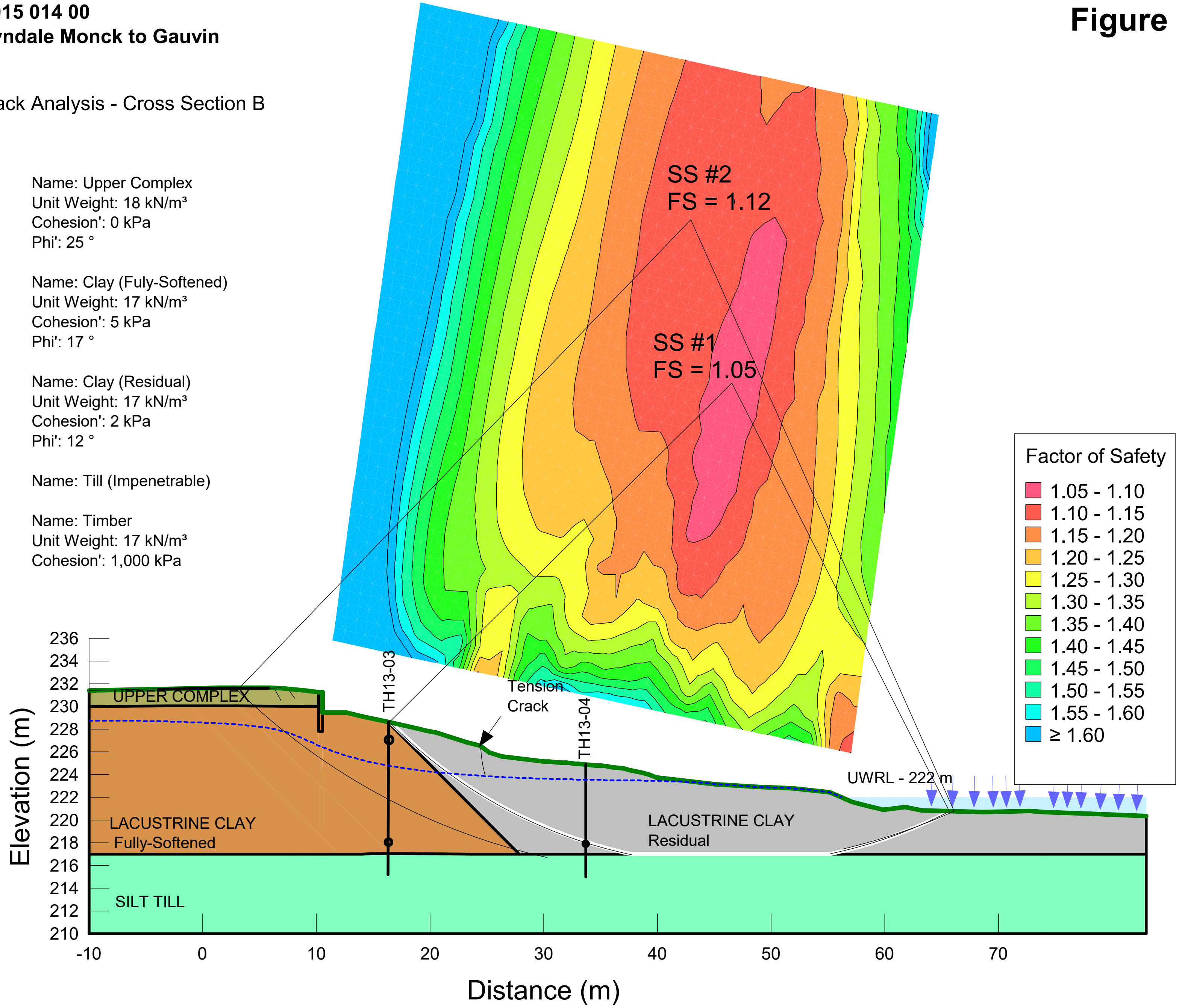
Name: Upper Complex
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 25 °

Name: Clay (Fuly-Softened)
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 17 °

Name: Clay (Residual)
Unit Weight: 17 kN/m³
Cohesion': 2 kPa
Phi': 12 °

Name: Till (Impenetrable)

Name: Timber
Unit Weight: 17 kN/m³
Cohesion': 1,000 kPa



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2016-01-29

0015 014 00
Lyndale Monck to Gauvin

Figure B-2

Back Analysis - Cross Section B

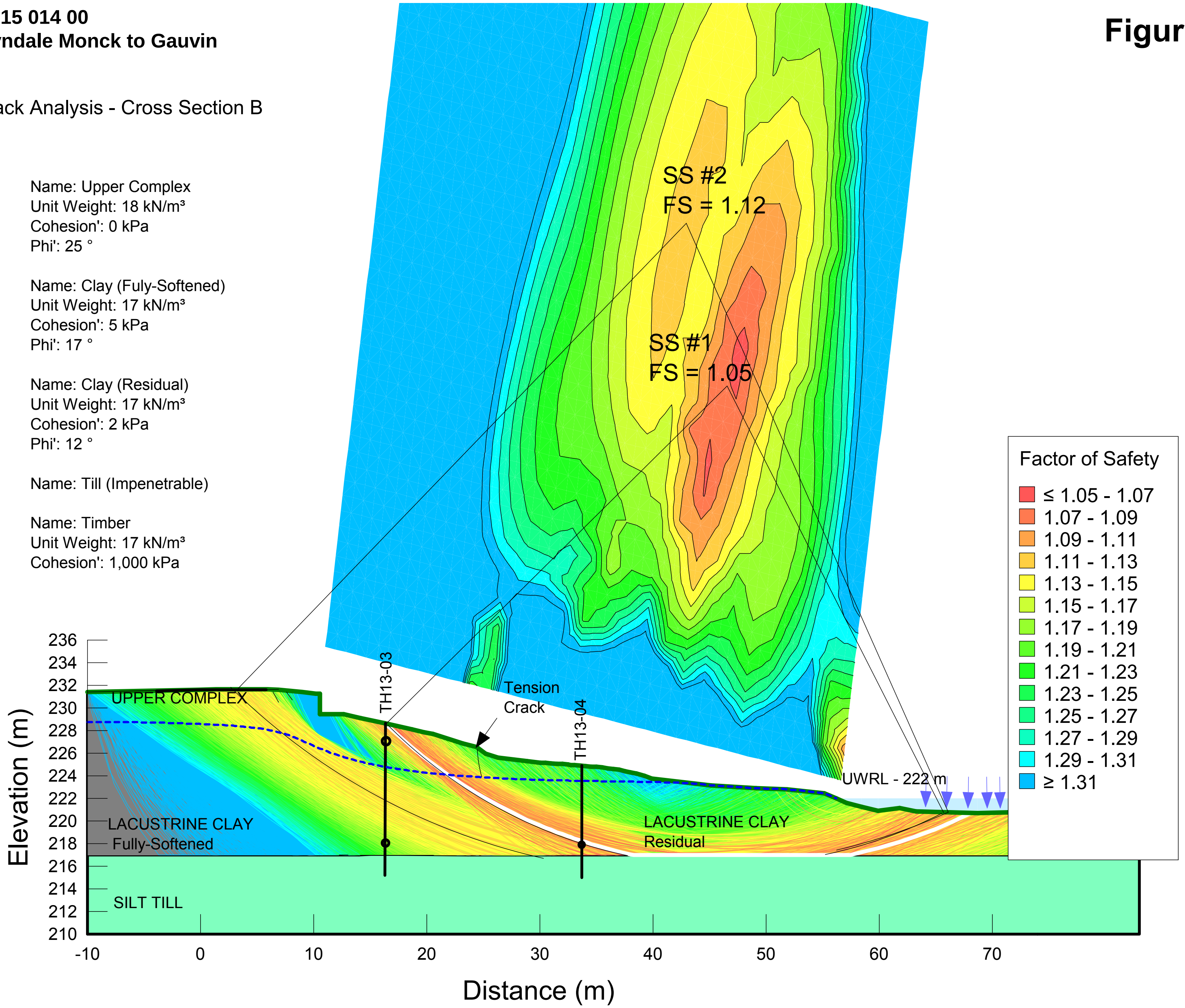
Name: Upper Complex
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 25 °

Name: Clay (Fuly-Softened)
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 17 °

Name: Clay (Residual)
Unit Weight: 17 kN/m³
Cohesion': 2 kPa
Phi': 12 °

Name: Till (Impenetrable)

Name: Timber
Unit Weight: 17 kN/m³
Cohesion': 1,000 kPa



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0015 014 00
Lyndale Monck to Gauvin

Figure B-3

Back Analysis - Cross Section C

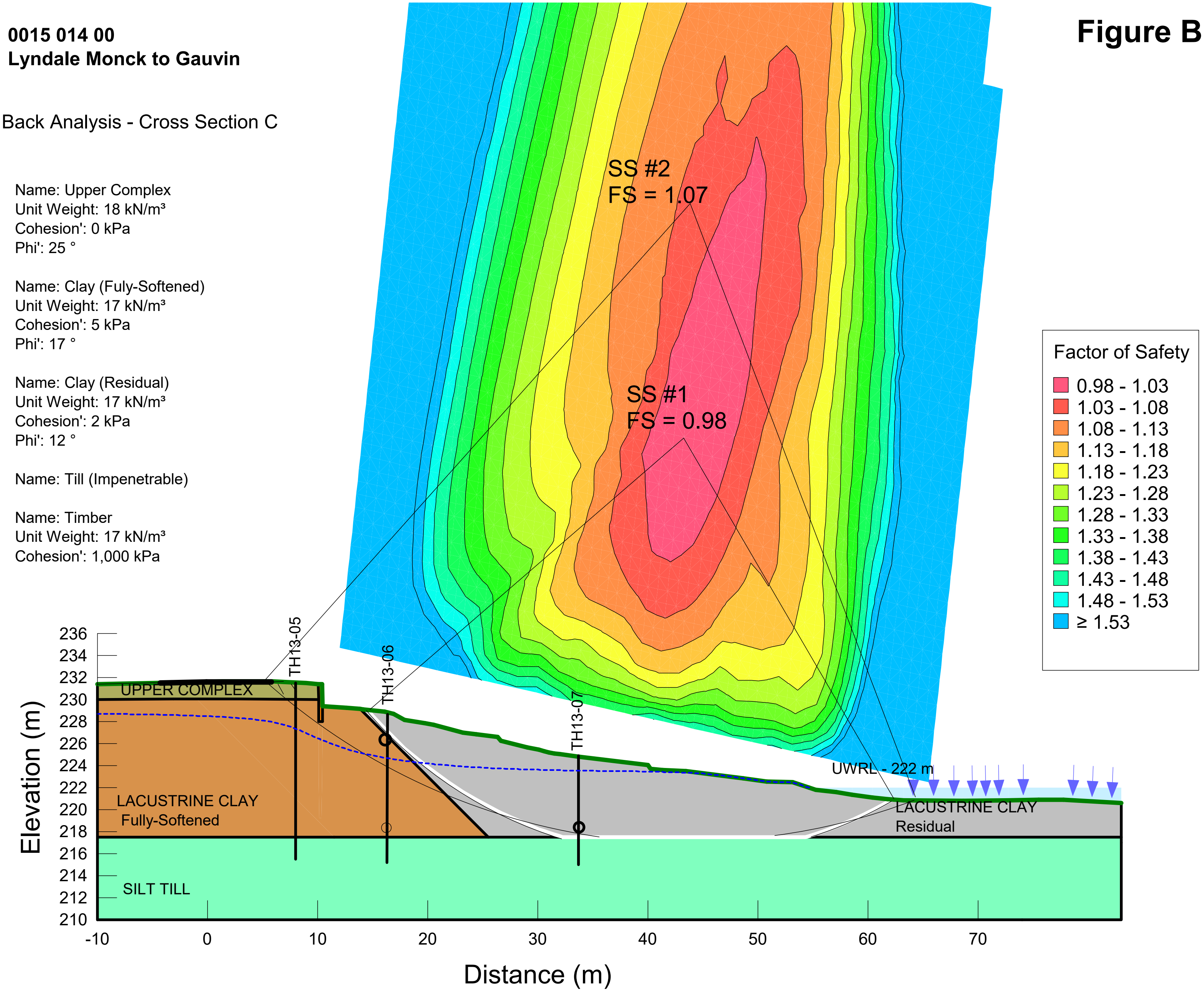
Name: Upper Complex
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 25 °

Name: Clay (Fuly-Softened)
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 17 °

Name: Clay (Residual)
Unit Weight: 17 kN/m³
Cohesion': 2 kPa
Phi': 12 °

Name: Till (Impenetrable)

Name: Timber
Unit Weight: 17 kN/m³
Cohesion': 1,000 kPa



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2016-01-29

0015 014 00
Lyndale Monck to Gauvin

Figure B-4

Back Analysis - Cross Section C

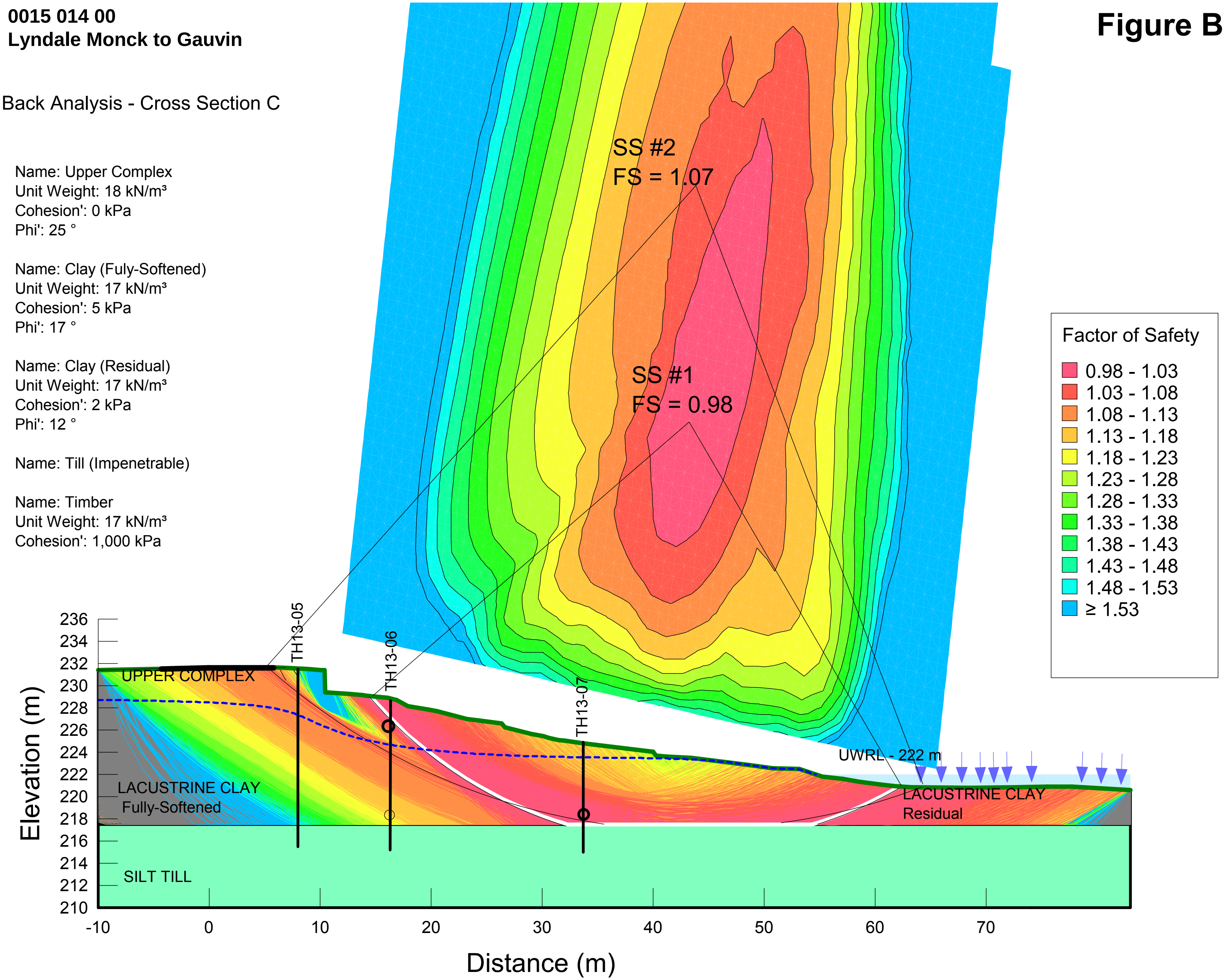
Name: Upper Complex
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 25 °

Name: Clay (Fuly-Softened)
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 17 °

Name: Clay (Residual)
Unit Weight: 17 kN/m³
Cohesion': 2 kPa
Phi': 12 °

Name: Till (Impenetrable)

Name: Timber
Unit Weight: 17 kN/m³
Cohesion': 1,000 kPa



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29/01/2016

0015 014 00
Lyndale Monck to Gauvin

Figure B-5

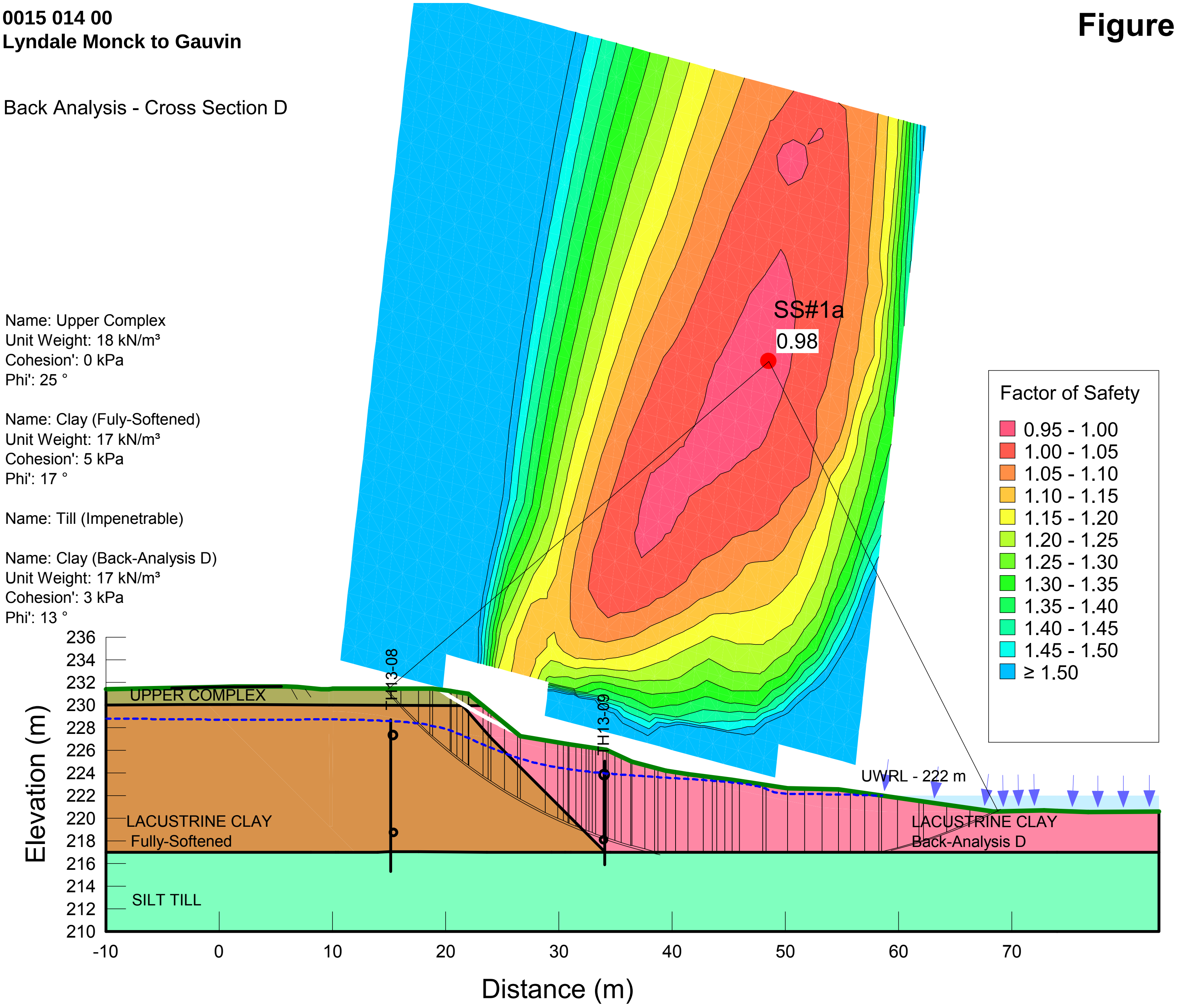
Back Analysis - Cross Section D

Name: Upper Complex
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 25 °

Name: Clay (Fuly-Softened)
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 17 °

Name: Till (Impenetrable)

Name: Clay (Back-Analysis D)
Unit Weight: 17 kN/m³
Cohesion': 3 kPa
Phi': 13 °



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30/01/2016

0015 014 00
Lyndale Monck to Gauvin

Figure B-6

Back Analysis - Cross Section D

Name: Upper Complex
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 25 °

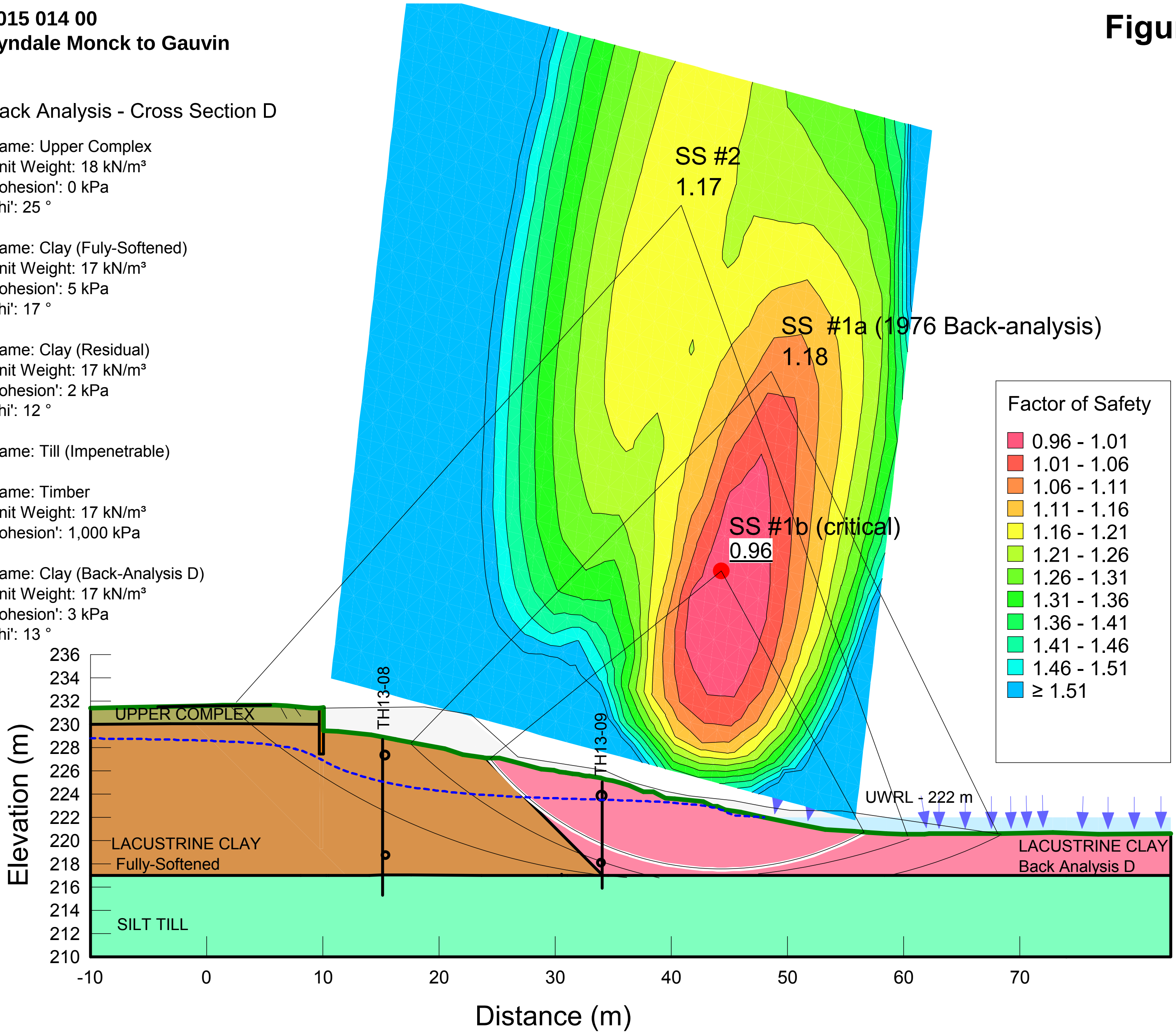
Name: Clay (Fuly-Softened)
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 17 °

Name: Clay (Residual)
Unit Weight: 17 kN/m³
Cohesion': 2 kPa
Phi': 12 °

Name: Till (Impenetrable)

Name: Timber
Unit Weight: 17 kN/m³
Cohesion': 1,000 kPa

Name: Clay (Back-Analysis D)
Unit Weight: 17 kN/m³
Cohesion': 3 kPa
Phi': 13 °



Z:\Projects\0015 City of Winnipeg\0015 014 00 Lyndale Monck to Gauvin\2 Design\2.7 Modelling\Stability\Lyndale 007D.gsz
30/01/2016

0015 014 00
Lyndale Monck to Gauvin

Figure B-7

Back Analysis - Cross Section D

Name: Upper Complex
Unit Weight: 18 kN/m³
Cohesion': 0 kPa
Phi': 25 °

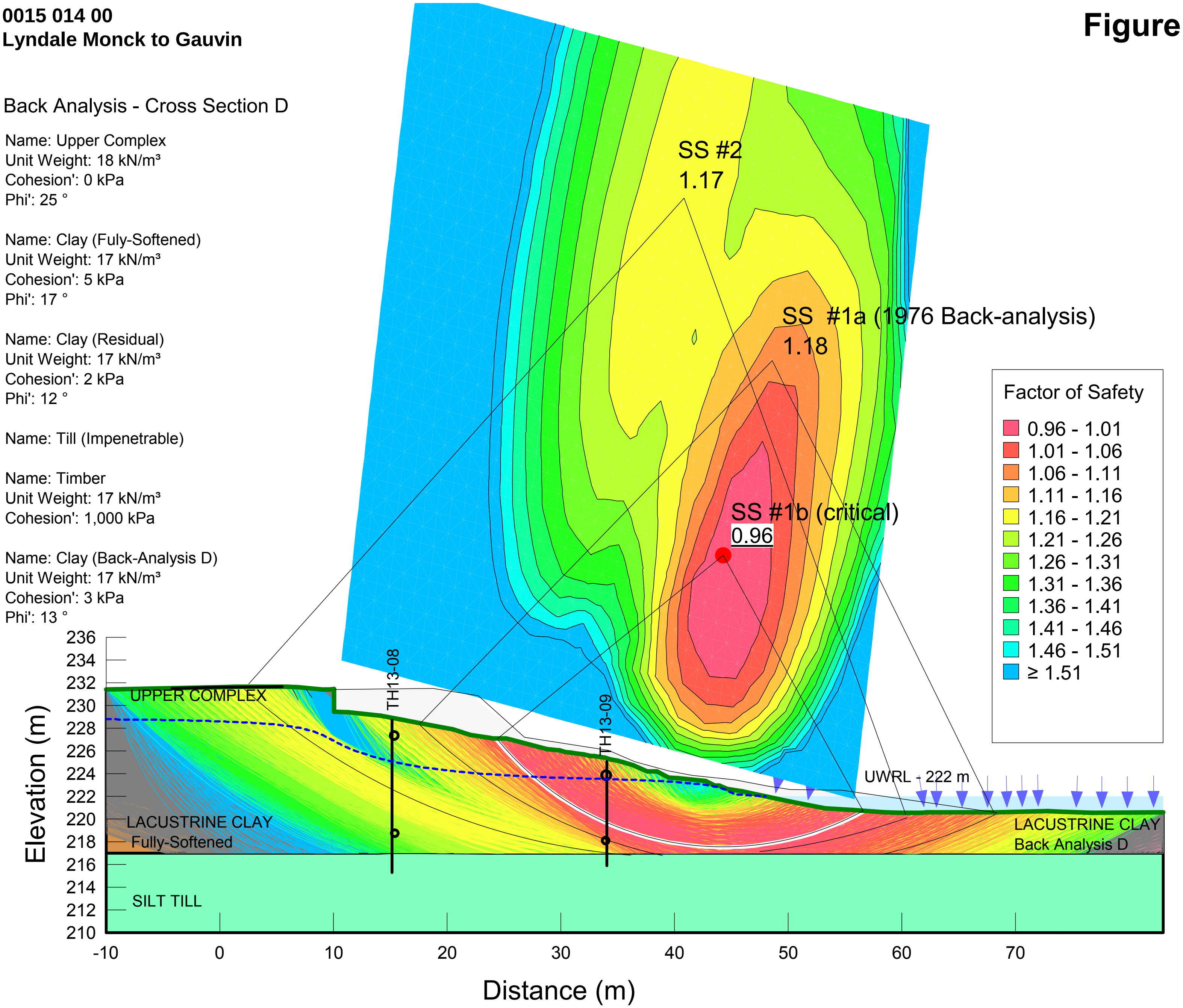
Name: Clay (Fuly-Softened)
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 17 °

Name: Clay (Residual)
Unit Weight: 17 kN/m³
Cohesion': 2 kPa
Phi': 12 °

Name: Till (Impenetrable)

Name: Timber
Unit Weight: 17 kN/m³
Cohesion': 1,000 kPa

Name: Clay (Back-Analysis D)
Unit Weight: 17 kN/m³
Cohesion': 3 kPa
Phi': 13 °



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30/01/2016

Red River - Lyndale Drive Riverbank Stabilization Hydrologic and Hydraulic Assessment

March 2016
Rev 1

City of Winnipeg

Bruce Harding Consulting Ltd

Red River - Lyndale Drive Riverbank Stabilization Hydrologic and Hydraulic Assessment

PROVINCE OF MANITOBA
ORIGINAL
SIGNED BY
W. B. J.
HARDING
Mar 15, 2016
REGISTERED PROFESSIONAL ENGINEER

APEGM
Certificate of Authorization
Bruce Harding Consulting Ltd.
No. 4652 Expiry: April 30, 2016

Prepared by: Bruce Harding, P.Eng.

March 2016
Rev 1

City of Winnipeg

Bruce Harding Consulting Ltd

Table of Contents

1 Introduction

This report summarizes the results of our hydraulic assessment of the Red River at the proposed riverbank stabilization site along Lyndale Drive between Monck Avenue and Gauvin Avenue. The proposed riverbank stabilization measures are to include erosion protection provided by a rock riprap blanket over 470 m of riverbank. The location of the site is indicated on Figure 1.

Pertinent features of the site are as follows:

- Municipality - City of Winnipeg
- Watercourse - Red River
- UTM Coordinates - 635000E, 5526000N (Zone 14)
- City of Winnipeg River Stationing - 35+420 to 35+890

Additional details with respect to the hydraulic assessment of the proposed erosion protection are summarized in the following sections.

2 Red River Hydrology

The hydrology for the Red River is complicated by the operation of the Floodway, which diverts flow around the City of Winnipeg during times of a flood within the Red River Valley. Additionally, the Saint Andrews Lock and Dam, located downstream of Winnipeg, controls river levels through the City of Winnipeg including the Lyndale Drive reach during the open water period. The project site is located upstream of the confluence with the Assiniboine River, however the backwater influence from the combined flows of the two rivers does influence this reach of the Red River.

Manitoba Water Stewardship has developed flood hydrology for the Red River within the City of Winnipeg taking into account recent upgrades to the Floodway. The hydrology derived by Manitoba Water Stewardship is based on a detailed and comprehensive assessment of recorded flows in addition to the incorporation of estimates of extreme historical events. The table from Manitoba Water Stewardship summarizing their assessment is appended for reference. The assessment from Manitoba Water Stewardship has flood hydrology derived for the Red River downstream of the Floodway Inlet and at James Avenue which would be indicative of flood conditions within the Red River throughout the City of Winnipeg. Table 1 summarizes the flood hydrology for the Red River taking into account the flows diverted to the Floodway.

The backwater analyses of the Red River for the project require a discharge for the downstream boundary condition. The discharge required reflects conditions downstream of the Saint Andrews Lock and Dam at the Floodway outlet. The discharge would be approximately equal to the discharge at the Disraeli Bridge when the Floodway is not operating, however this cannot be assumed under flood conditions when total flows are greater than approximately 1100 m^3/s. The discharge has been estimated from the Manitoba Water Stewardship updated hydrology table by summing the Red River at James Avenue discharge and the Floodway discharge. Table 1 summarizes the estimated discharge downstream of the Saint Andrews Lock and Dam.

Table 1
Red River
Flood Hydrology

Flood Event	**Red River at Lyndale Drive * (m^3/s)**	**Red River at James Avenue ** (m^3/s)**	**Red River downstream of St. Andrews Lock and Dam *** (m^3/s)**
50% Flood	824	1005	1005
20% Flood	1179	1361	1597
10% Flood	1283	1401	2033
5% Flood	1334	1453	2597
2% Flood	1688	1810	3452
1% Flood	2168	2292	4225
0.625% (160 Year) Flood	2195	2331	4775

* - Red River downstream of Flood Inlet plus LaSalle River contribution, Manitoba Water Stewardship, Updated Red River Hydrology - February 2010

** - Red River at James Ave, Manitoba Water Stewardship, Updated Red River Hydrology - February 2010

*** - Sum of Red River at James Ave discharge and Floodway discharge, Manitoba Water Stewardship, Updated Red River Hydrology - February 2010

The Red River is controlled by the Saint Andrews Lock and Dam through the City of Winnipeg during the open water period typically between May and October. The target control level is approximately 223.7 m at James Avenue and the water levels are maintained at this level independent of flows in the Red River except under flood conditions. Normal flows during this period are approximately 140 m^3/s at the Lyndale Drive site and 200 m^3/s downstream of the confluence with the Assiniboine River.

3 Hydraulic Assessment – Existing Conditions

The hydraulic conditions within the Red River were assessed to establish the baseline hydraulic regime. A steady-state backwater model of the Red River within the study reach was developed using the US Army Corps of Engineers River Analysis System HEC-RAS model. The HEC-RAS model is a one-dimensional backwater model, which is considered to be the universal standard for computing steady-state water surface profiles. The detailed backwater model extends over approximately 2500 m, including the 470 m reach requiring riverbank erosion protection within the riverbank stabilization project area. The assessment reach would be approximately Sta 33+679 to 36+174 as per City of Winnipeg river stationing. A plan of the study area is shown on Figure 1.

The downstream boundary condition for use in the backwater model was established from results of the calibrated comprehensive HEC-RAS model developed as part of the January 2015 Red River Hydraulic Assessment prepared for the City of Winnipeg[1]. A stage-discharge relationship was developed and used for the downstream boundary conditions of the detailed assessment backwater model for a range of open water flow conditions. The incorporation of the previous comprehensive hydraulic study results combined with the detailed assessment model enabled the accurate estimation of water surface profiles through the study area.

The detailed backwater model was assembled from river cross sections generated from topographic and bathymetric surveys undertaken by GDS Surveys in September 2013, as part of the January 2015 Red River Hydraulic Assessment. Additional topographic and bathymetric surveys within the riverbank stabilization area were undertaken by GDS Surveys in December 2015/January 2016 to provide further detail within the hydraulic model.

The estimated water surface profiles for the Red River for existing conditions are shown on Figure 2. A channel velocity profile plot, shown on Figure 3, is also presented for existing conditions for a range of flow conditions.

It was noted that there is a slightly deeper section at approximately Sta 35+650 which is centred within the Lyndale Drive erosion protection reach. The river velocities are similar to that observed in the river upstream and downstream, however it can be assumed that the channel has scoured this deeper section to achieve equilibrium. It is typical for the deepest

---

[1] "Red River Hydraulic Assessment, Hydraulic Model Update", January 2015, prepared for the City of Winnipeg, Water and Waste Department by Bruce Harding Consulting Ltd.

portion of a river channel to be on the outside of a bend, however the scour is more centred and may be as a result of a possible localized constriction due to the dike (Churchill Drive) protecting the Riverview Health Centre. In general, the outside bends of river meanders experience prolonged erosion and bank loss, whereas inside bends see aggradations (deposition) with the exception of during extreme flood events. The constriction of the river and scour is evident when plotting a sequence of river sections including the upstream limit, at the constriction and at the downstream limit, as shown on Figure 4. Of note, the scour depth as observed within the constriction (Section B-B) is elevation 217.0 m +/- which coincides with the till elevation based on local testhole information. Further scour would most likely be lateral, as opposed to downwards due to the presence of the more erosion resistant till layer. Further review of the sections through the Lyndale Drive reach would also indicate that toe bulges due to slope movements may have occurred but were not apparent based on the survey results.

Irrespective, it is recommended that erosion protection measures along the Lyndale Drive reach not further encroach into the river section. As indicated, the river channel has reached an equilibrium with velocities consistent upstream to downstream. Any further reduction in conveyance due to encroachment would result in scour of the channel, most likely laterally to the south along the shoreline adjacent to the dike on Churchill Drive as the north shore would be rock armored.

4 Hydraulic Assessment – Proposed Erosion Protection Options

The proposed erosion protection measures along Lyndale Drive extends between approximately Monck Avenue and Gauvin Avenue. The erosion protection is to consist of a rock riprap blanket extending over the 470 m length. The proposed erosion protection measures, which include the rock riprap blanket and may include a new retaining wall, would be within the designated Floodway and Floodway Fringe (regulations appended). As such, it is important to minimize any hydraulic impact on water levels or velocities.

Two options for the proposed erosion protection have been developed and assessed. The options proposed are as follows:

Option 1 - Erosion Protection with Retaining Wall

The erosion protection consists of a Class 350 (minimum) rock riprap blanket over approximately 470 m of riverbank. The geometric template for the erosion protection has been selected to closely match the existing site geometry minimizing any encroachment into the river. The erosion protection assumes a 5:1 side slope in conjunction with a new retaining wall to provide the required transition at Lyndale Drive. Class 350 rock would be sufficient to resist the observed velocities, however it is recommended that self launching apron rock be placed at the toe of the slope to minimize toe erosion and the possible reduction in stability of the slope. A self launching apron provides extra rock which will settle/drop into a scoured hole providing continued protection to the toe and upper slope. Velocities and therefore erosive tractive forces are typically higher at the toe of a slope, particularly on an outside river bend, therefore justifying the use of the self launching rock apron at the toe of the slope. As directed by the City of Winnipeg, the top of rock elevation has been selected as the Normal Summer Controlled Level of 223.75 plus 1.0 m which yields an elevation of 224.75. The proposed layout of the erosion protection measures are presented on Figure 1, while typical sections for Option 1 are shown on Figure 5.

With this option, it is proposed that the riverbank be subcut, with the rock placed such that the final rock surface does not extend into the flow, minimizing the hydraulic influence. Placement of rock on the riverbank without subcutting would increase velocities in the river which may result in additional scour. The proposed rock placement, with subcut ensures that any perceived changes to the existing hydraulic regime would be insignificant. The change to river velocity is negligible, with less than a 0.01 m/s increase locally. River velocity profiles for this option relative to existing conditions are presented on Figure 6. Changes to the water surface profile would be imperceptible (less than 2 mm).

Option 2 - Erosion Protection without Retaining Wall

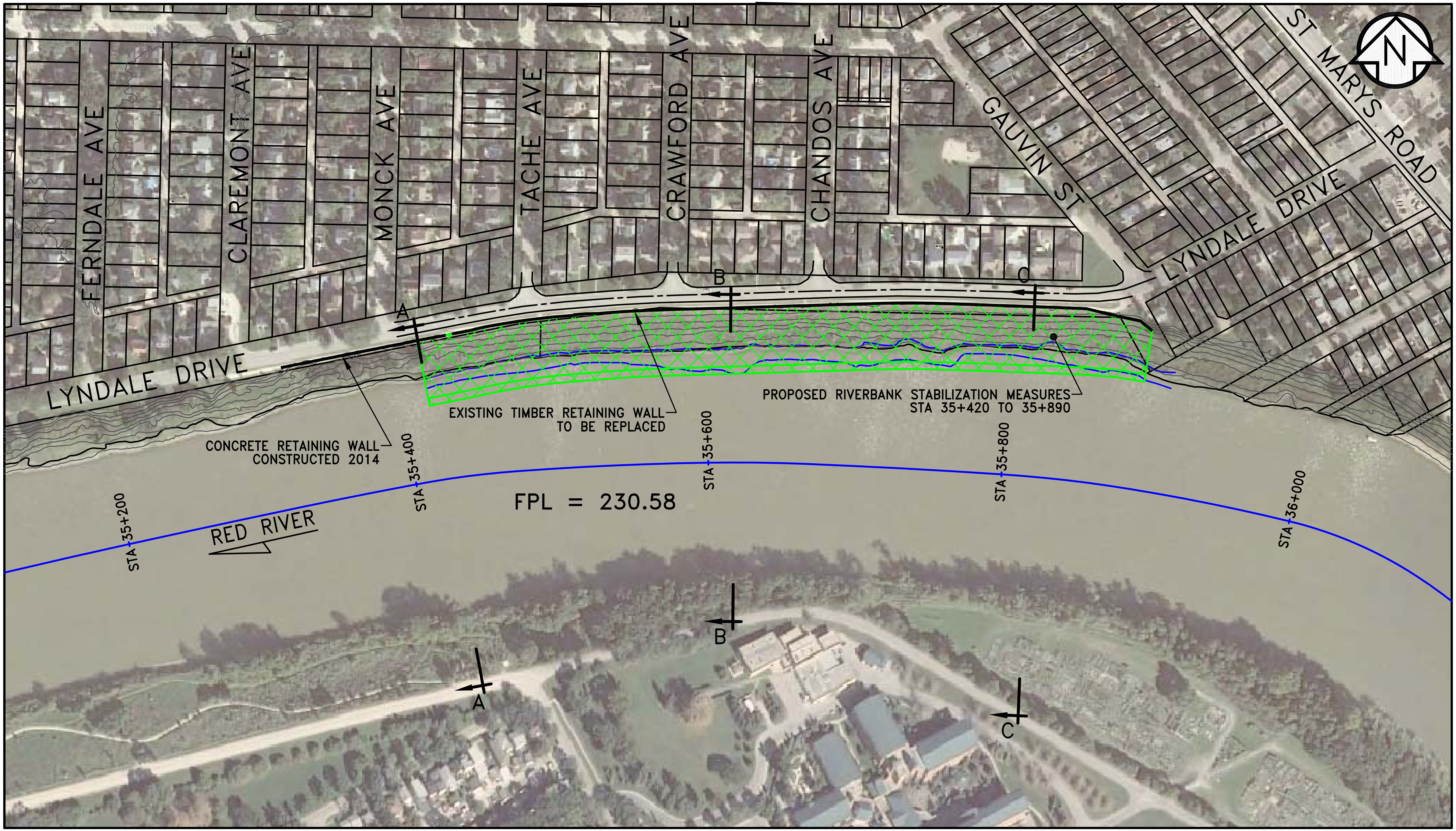
The erosion protection consists of a Class 350 (minimum) rock riprap blanket over approximately 470 m of riverbank. The geometric template for the erosion protection has been selected to closely match the existing toe location, however the side slope will be steepened to 4:1 which eliminates the requirement for a retaining wall at Lyndale Drive. Class 350 rock would be sufficient to resist the observed velocities, however it is recommended that self launching apron rock be placed at the toe of the slope to minimize toe erosion and the possible reduction in stability of the slope. A self launching apron provides extra rock which will settle/drop into a scoured hole providing continued protection to the toe and upper slope. Velocities and therefore erosive tractive forces are typically higher at the toe of a slope, particularly on an outside river bend, therefore justifying the use of the self launching rock apron at the toe of the slope. As directed by the City of Winnipeg, the top of rock elevation has been selected as the Normal Summer Controlled Level of 223.75 plus 1.0 m which yields an elevation of 224.75. The proposed layout of the erosion protection measures are presented on Figure 1, while typical sections for Option 2 are shown on Figure 7.

With this option, fill would have to be placed on the riverbank slope to steepen the slope to 4:1 and to eliminate the requirement for the retaining wall. The toe of the slope would remain at the same location as that of Option 1 and would require some subcutting for the placement of riprap. This option results in encroachment into the river, which will increase river velocities locally by less than a 0.03 m/s which overall on average is not significant. River velocity profiles for this option relative to existing conditions are presented on Figure 6. Changes to the water surface profile would be imperceptible (less than 2 mm).

5 Conclusions and Recommendations

Overall, both erosion protection options have minimal affect on the existing hydraulic regime of the Red River through the Lyndale Drive reach. Option 1 has little to no affect on water levels or river velocities relative to existing conditions as the riverbank remains essentially the same as existing. Option 2 however does require infilling of the riverbank, which although having little affect on water levels, does result in a small increase in river velocities locally. As such, it is recommended that the Option 1 erosion protection measures proposed be considered as part of the overall project.

Figures



SCALE (METRES)

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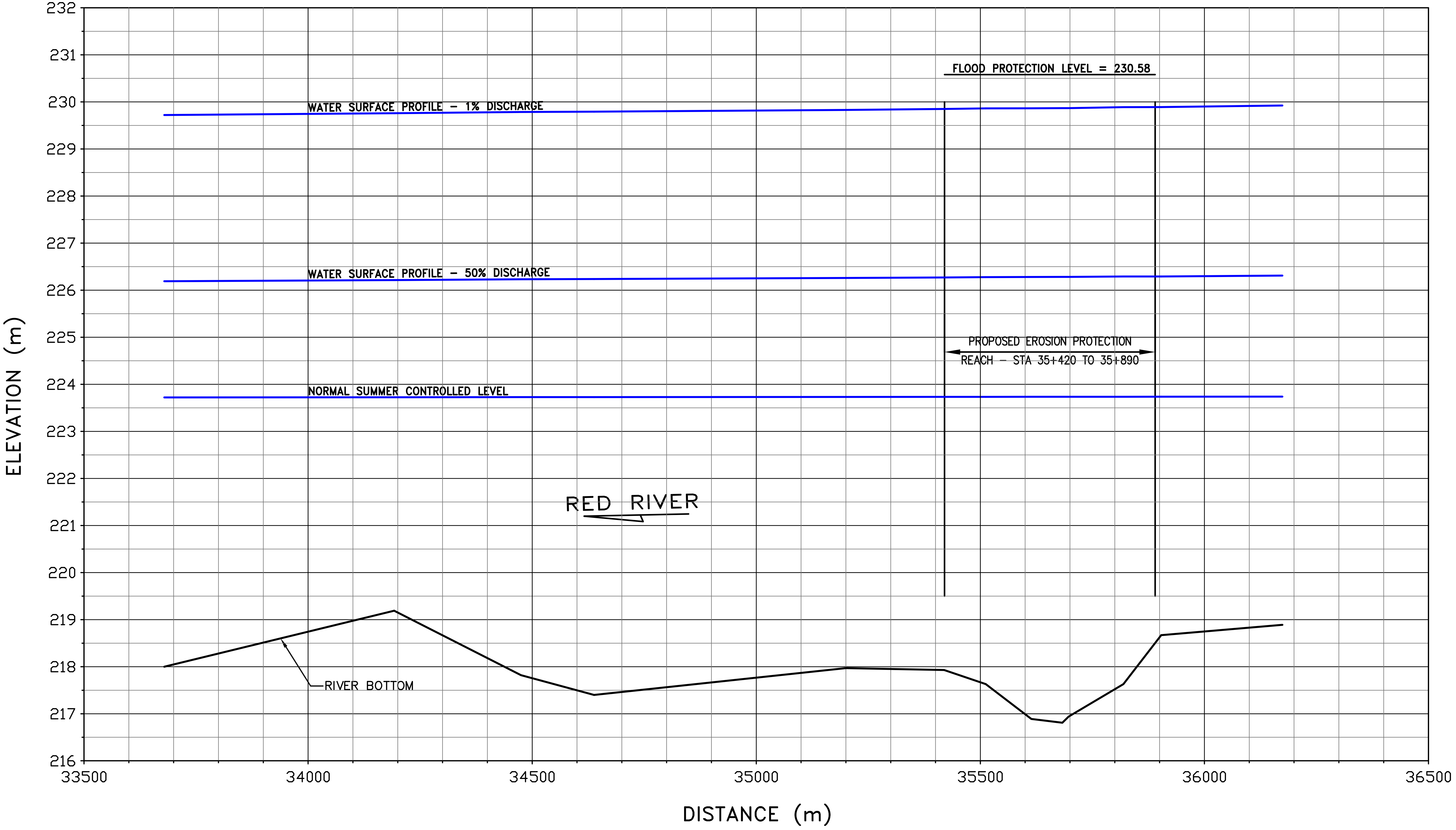
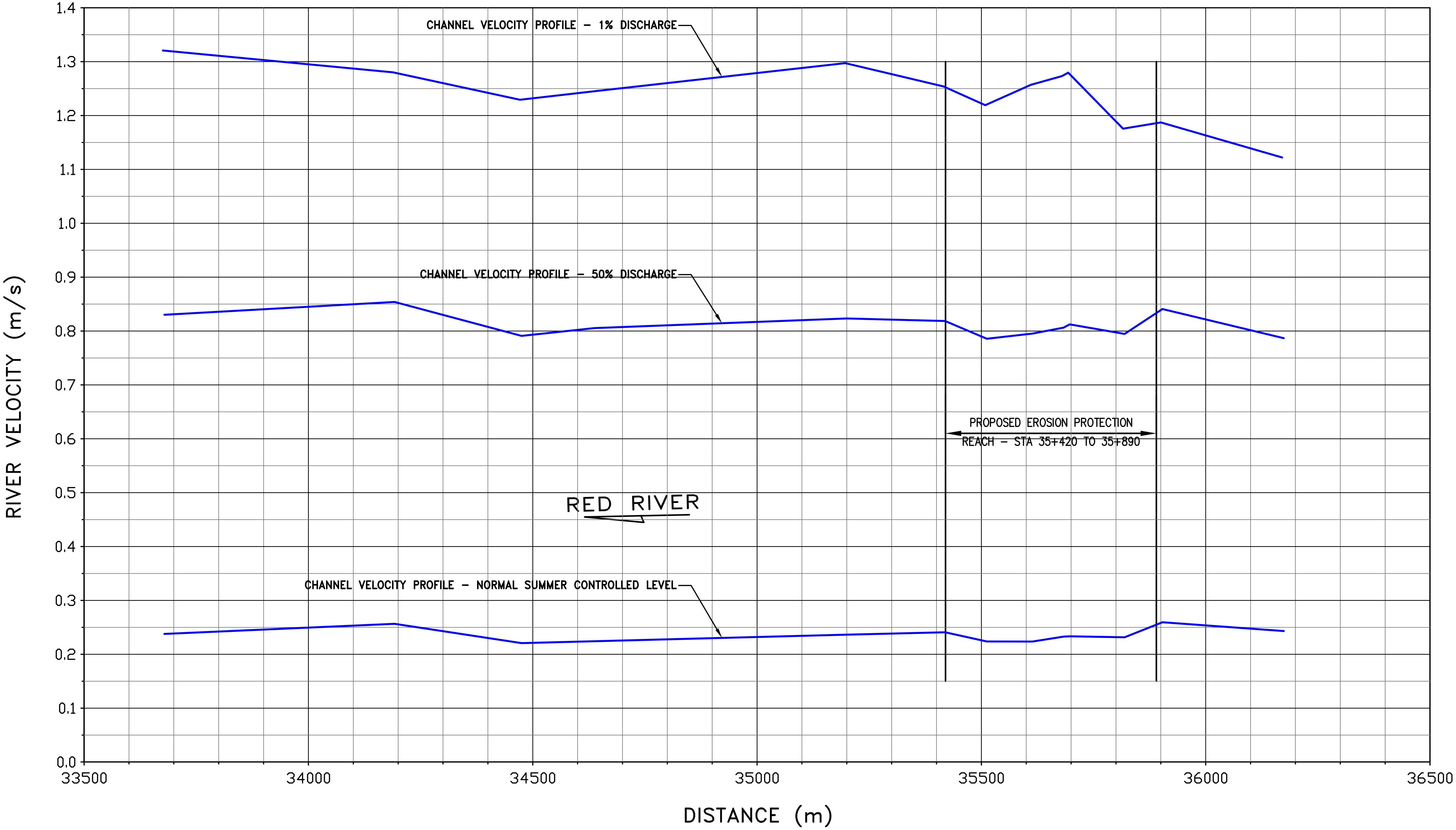
RED RIVER – LYNDALE DRIVE RIVERBANK STABILIZATION
LOCATION PLAN
FIGURE 1



RED RIVER – LYNDALE DRIVE RIVERBANK STABILIZATION
WATER SURFACE PROFILES
EXISTING CONDITIONS
FIGURE 2

NOTES:
1) HEC–RAS MODEL DEVELOPED FROM SEPTEMBER 2013 AND DECEMBER 2015/JANUARY 2016 SURVEY DATA



RED RIVER – LYNDALE DRIVE RIVERBANK STABILIZATION
RIVER VELOCITY PROFILES
EXISTING CONDITIONS
FIGURE 3

NOTES:
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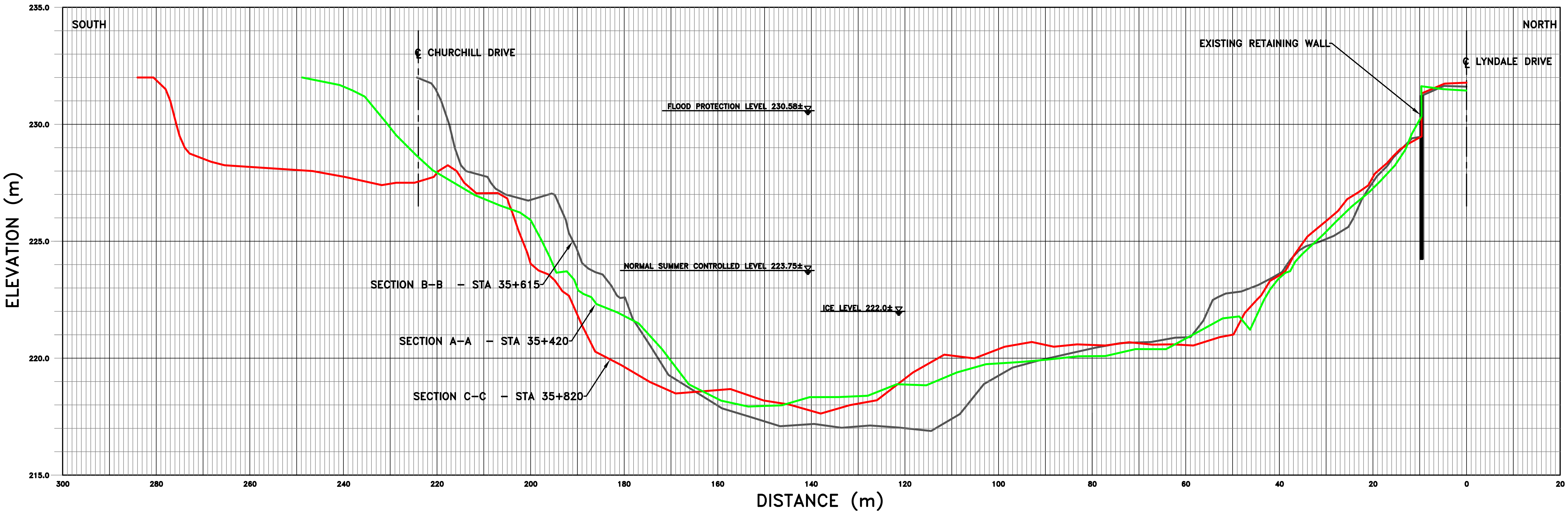
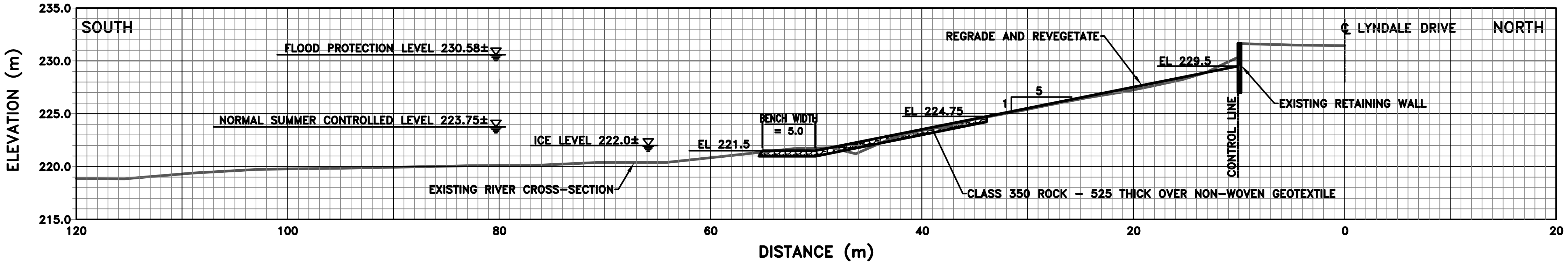


NOTES

1) RIVER SECTIONS REFLECT BATHYMETRIC AND TOPOGRAPHIC SURVEYS UNDERTAKEN IN DECEMBER 2015 & JANUARY 2016 BY GDS SURVEYS

RED RIVER – LYNDALE DRIVE RIVERBANK STABILIZATION
RIVER SECTIONS
FIGURE 4



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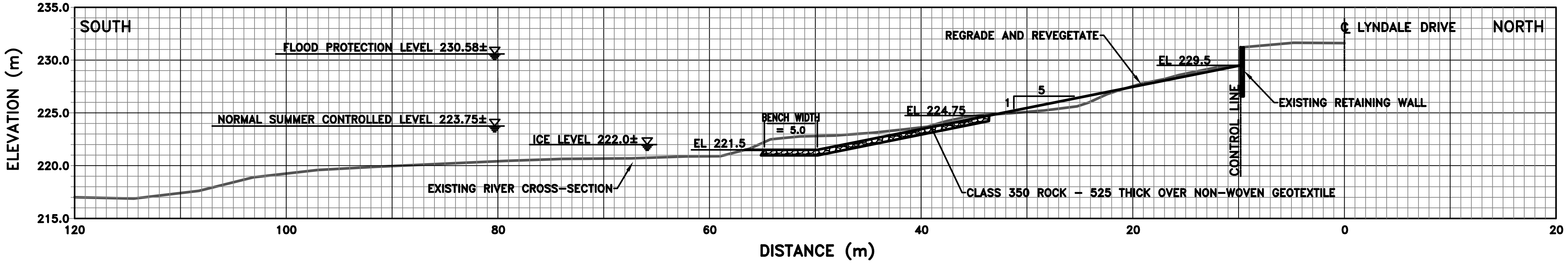

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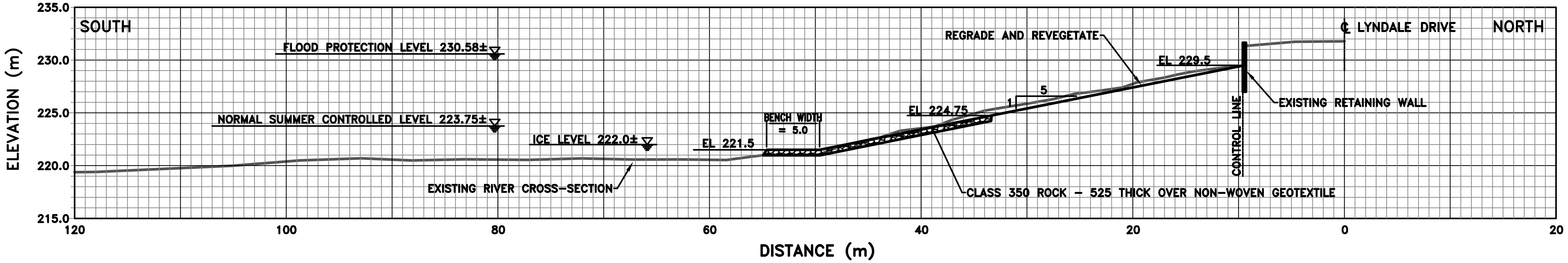
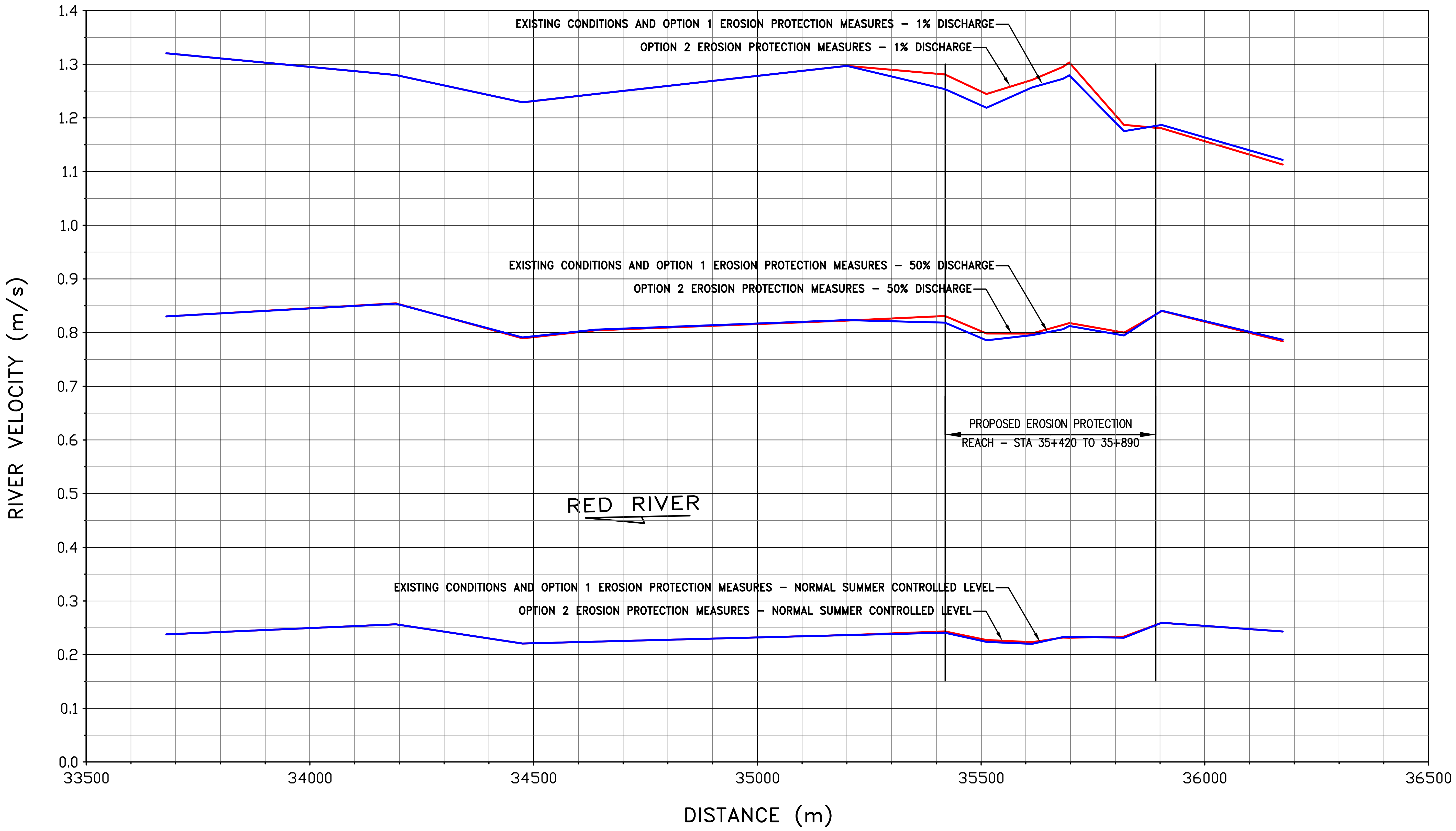


SECTION C–C – STA 35+820
SCALE 1:150

NOTES
1) RIVER SECTIONS REFLECT BATHYMETRIC AND TOPOGRAPHIC SURVEYS UNDERTAKEN IN DECEMBER 2015 & JANUARY 2016 BY GDS SURVEYS

RED RIVER – LYNDALE DRIVE RIVERBANK STABILIZATION
OPTION 1 – PROPOSED RIVERBANK
EROSION PROTECTION SECTIONS
FIGURE 5



RED RIVER – LYNDALE DRIVE RIVERBANK STABILIZATION
RIVER VELOCITY PROFILES
COMPARISON OF OPTIONS
FIGURE 6

NOTES:
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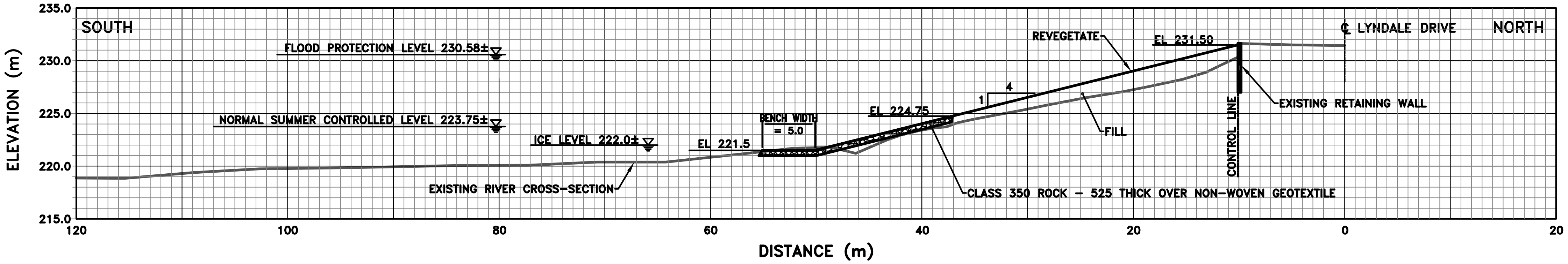

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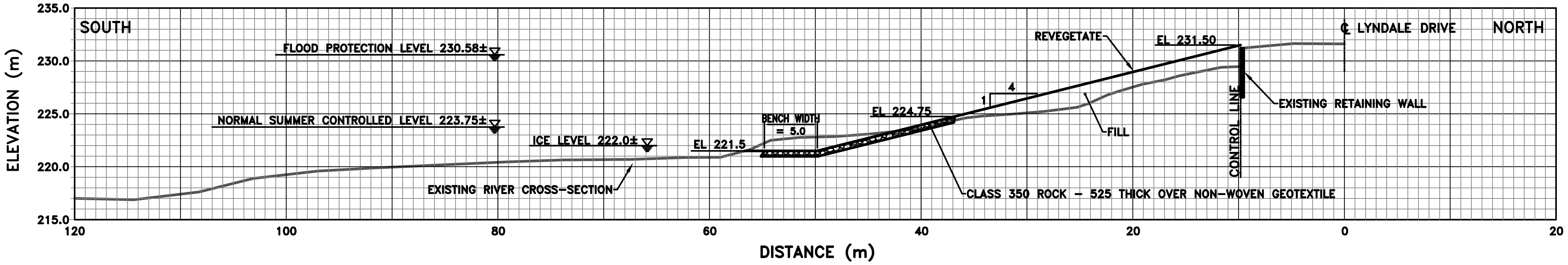

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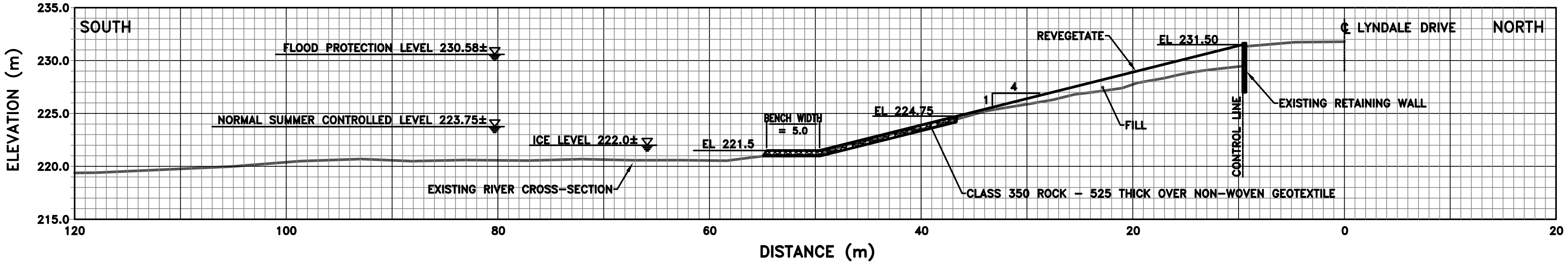

SECTION C–C – STA 35+820
SCALE 1:150

RED RIVER – LYNDALE DRIVE RIVERBANK STABILIZATION
OPTION 2 – PROPOSED RIVERBANK
EROSION PROTECTION SECTIONS
FIGURE 7

NOTES

1) RIVER SECTIONS REFLECT BATHYMETRIC AND TOPOGRAPHIC SURVEYS UNDERTAKEN IN DECEMBER 2015 & JANUARY 2016 BY GDS SURVEYS

Appendix A
Red River Hydrology
February 2010

TABLE 1. RESULTANT FLOWS IN THE CITY OF WINNIPEG FOR DIFFERENT RETURN PERIODS OF ANNUAL EVENTS WITH SHELLMOUTH DAM, PORTAGE DIVERSION AND THE EXPANDED FLOODWAY IN OPERATION

			FLOWS WITHIN THE CITY (CFS)							
RETURN PERIOD OF NATURAL FLOOD CONDITION AT REDWOOD BRIDGE	FLOODWAY INLET (UPSTREAM)	FLOODWAY	D/S of FLOODWAY INLET	LASALLE RIVER	STURGEON CREEK	CONTRIBUTION FROM LOCAL AREA	SEINE RIVER	ASSINIBOINE AT HEADINGLEY	RED RIVER AT JAMES AVE	JAMES AVENUE ELEVATION (CITY OF WPG DATUM)
160 yr	161,000	86,291	74,709	2,800	1,500	450	450	2,400	82,309	24.77
100 yr	142,300	68,254	74,046	2,500	1,400	400	400	2,200	80,946	24.50
50 yr	115,400	58,005	57,395	2,200	1,250	350	350	2,350	63,895	20.64
33 yr	102,300	51,082	51,218	1,900	1,100	300	300	1,900	56,718	18.91
20 yr	85,900	40,397	45,503	1,600	950	250	250	2,750	51,303	17.60
10 yr	66,300	22,313	43,987	1,300	800	200	200	3,000	49,487	17.11
5 yr	48,900	8,353	40,547	1,100	650	150	150	5,450	48,047	16.75
2 yr	28,100	0	28,100	1,000	400	100	100	5,800	35,500	13.47

NOTES:

1. Original flow arrays taken from Kozera 2002 study, which he updated in 2005, and from Warkentin 2007. These have since been modified based on frequency analyses by Kelln and Luo in 2009 and flow arrays provided by Warkentin in 2010.
2. Return periods and natural flows for operation of flood control works taken from frequency curve of natural (unregulated) peak flows for the Red River at Redwood Bridge dated September 2010. Also used was a systematic frequency analysis encompassing recorded and historic flows at Grand Forks, Emerson and Upstream of the Forks described in an e-mail from Kelln to Bowering dated Sept 22, 2004 and filed in 5.5.1 and 11.1. Parts of this analysis were updated by Luo and Kelln in 2009.
3. The Red River Floodway with an expanded capacity of 130,000 cfs at an inlet elevation of 778 feet was used in simulations. The conveyance for the smaller floods was based on the performance of the floodway in the spring 2006. The curve was feathered into the curve provided by KGS in March 2009 at the upper end for higher flows under the expanded floodway. The floodway inlet natural rating curve as developed by Acres (2004) was used in the simulation of Floodway operation.
4. Normal operation of the Portage Diversion was assumed whereby Lake Manitoba is low enough to accommodate Portage Diversion flows as required.
5. Interpolation of values in the table is suggested if values for a return period which is not shown are desired.

6.For the 100-yr and 160-yr conditions, Rule 2 for Red River Floodway operation is in effect. For the 160-yr condition, the inlet level is two feet above the natural level. Therefore, the results shown for this condition should be considered tentative, pending further discussion and analysis.

Appendix B
Floodway Fringe Regulations
City of Winnipeg
266-91

THE CITY OF WINNIPEG CHARTER
(S.M. 2002, c. 39)

Designated Floodway Fringe Area Regulation

Regulation 266/91
Registered December 17, 1991

TABLE OF CONTENTS

Section

CHARTE DE LA VILLE DE WINNIPEG
(c. 39 des L.M. 2002)

Règlement sur la zone limite désignée du canal de dérivation

Règlement 266/91
Date d'enregistrement : le 17 décembre 1991

TABLE DES MATIÈRES

Article

Definitions

1 In this regulation,

"Act" means *The City of Winnipeg Act*; (« *Loi* »)

"accessory structure" means a structure described in section 9; (« construction annexe »)

"Dyking Commissioner" means The Dyking Commissioner appointed under *The Dyking Authority Act*; (« commissaire des digues »)

"flood protection level" means the flood protection level determined under section 4; (« niveau de protection contre les inondations »)

"hazardous material" includes a flammable, explosive or toxic material and a buoyant heavy object; (« matériaux dangereux »)

"minister" means the Minister of Natural Resources; (« ministre »)

"permit" means a permit issued under a by-law passed under subsection 472(1) of the Act; (« permis »)

"structure" means a building, storage tank or drilled well, and includes an addition to any of those things, but does not include

(a) an unenclosed playing field, ice rink or similar open-air structure used for a recreational purpose,

(b) a building that is incidental or subordinate to an open-air structure used for a recreational purpose, including a change room and washroom,

(c) playground equipment,

(d) an unenclosed swimming pool,

(e) a fence,

(f) a storage shed or similar structure under 10m^2, or

(g) an open-air building, including a cattle shed, used for an agricultural purpose. (« construction »)

Définitions

1 Les définitions qui suivent s'appliquent au présent règlement.

« **commissaire des digues** » Le commissaire des digues nommé en vertu de la *Loi sur l'administration des digues*. ("Dyking Commissioner")

« **construction** » Bâtiments, réservoirs de stockage, puits forés et leurs rajouts, à l'exception

a) des terrains de jeu et des patinoires et autres constructions à ciel ouvert du même genre utilisées à des fins récréatives;

b) des bâtiments accessoires ou annexes à une construction à ciel ouvert utilisée à des fins récréatives, notamment les vestiaires et les toilettes;

c) du matériel de terrain de récréation;

d) des piscines non couvertes;

e) des clôtures;

f) des remises ou autres constructions semblables de moins de 10 m^2;

g) des bâtiments à ciel ouvert, y compris les abris à bestiaux, utilisés à des fins agricoles. ("structure")

« **construction annexe** » Construction visée à l'article 9. ("accessory structure")

« ***Loi*** » La *Loi sur la Ville de Winnipeg*. ("Act")

« **matériaux dangereux** » Matériaux inflammables, explosifs ou toxiques et objets lourds flottables. ("hazardous material")

« **ministre** » Le ministre des Ressources naturelles. ("minister")

« **niveau de protection contre les inondations** » Le niveau de protection contre les inondations déterminé conformément à l'article 4. ("flood protection level")

« **permis** » Permis délivré aux termes d'un arrêté pris en vertu du paragraphe 472(1) de la *Loi*. ("permit")

Application

2 This regulation applies in The City of Winnipeg to the designated floodway fringe area and to parcels of land in the designated floodway area that meet the criteria set out in section 494.3(3) of the Act.

Designated areas

3 The designated floodway fringe area and designated floodway area are the floodway fringe and floodway areas identified on the Interim Flood Risk Maps, as designated on February 15, 1980, under the Canada-Manitoba Flood Damage Reduction Agreements, including any amendments thereto, filed at the head office of the Water Resources Branch of the Department of Natural Resources in Winnipeg.

Determination of flood protection level

4 The minister shall determine a flood protection level that is the maximum static water level that occurs during flooding conditions of a certain frequency, as determined by the minister, plus a specific minimum freeboard allowance.

Application to construct

5 An application for a permit to construct a structure shall be made in a form prescribed by council and shall include such of the following information as the designated employee may require:

(a) plans and specifications of the structure;

(b) a plan drawn to scale showing the location of the proposed structure on its site;

(c) a copy of the certificate of title respecting the site;

(d) a plan of survey certified by a Professional Engineer or Manitoba Land Surveyor and referenced to Geodetic Survey of Canada datum showing

(i) the existing and proposed ground elevations on the site where the structure is to be constructed, and

Application

2 Le présent règlement s'applique à la zone limite désignée du canal de dérivation située dans les limites de la Ville de Winnipeg, ainsi qu'aux parcelles de bien-fonds dans la zone désignée du canal de dérivation conformes aux critères énoncés au paragraphe 494.3(3) de la *Loi*.

Zones désignées

3 La zone limite désignée du canal de dérivation et la zone désignée du canal de dérivation constituent la zone limite du canal de dérivation et la zone du canal de dérivation indiquées sur les cartes provisoires des risques d'inondation établies le 15 février 1980 conformément à l'entente Canada-Manitoba modifiée sur la réduction des dommages dûs aux inondations, lesquelles cartes ont été déposées au bureau principal de la Direction des ressources hydriques du ministère des Ressources naturelles à Winnipeg.

Niveau de protection contre les inondations

4 Le ministre détermine le niveau de protection contre les inondations, lequel correspond au niveau statique maximum de l'eau prévu en cas d'inondations survenant à une fréquence reconnue, ainsi qu'il a été déterminé par le ministre, en plus d'une marge minimale pour la hauteur de franc-bord.

Demande de permis de construire

5 Les demandes de permis de construire sont présentées au moyen de la formule prévue à cette fin par le conseil et sont accompagnées des documents énoncés ci-après que l'employé désigné exige :

a) les plans et devis de la construction;

b) un plan à l'échelle indiquant l'endroit où la construction sera située sur l'emplacement;

c) une copie du titre de propriété du bien-fonds;

d) un plan d'arpentage certifié conforme par un ingénieur ou par un arpenteur-géomètre du Manitoba et contenant les renvois aux Levés géodésiques du Canada indiquant

(i) les cotes de nivellement actuelle et projetée de la surface de l'emplacement où la construction sera érigée,

(ii) the floor elevations of the structure;

(e) such other information as the designated employee considers necessary for the purpose of considering the application.

Establishment of reference mark

6(1) Where a permit holder makes a written request for the establishment of a reference mark, a designated employee shall, within 15 days after the receipt of the request, establish a reference mark at or near the site of the structure or proposed structure indicating the flood protection level applicable to the site and structure.

6(2) Upon the written request of a permit holder, a designated employee shall re-establish a reference mark established under subsection (1).

Floodproofing criteria

7(1) Every structure, other than an accessory structure referred to in section 9, shall be constructed on a site raised by fill or supported by piles.

7(2) Where a structure constructed on a site raised by fill has a basement or cellar,

(a) the site shall be raised by impervious fill in accordance with the requirements illustrated in Schedule A;

(b) the elevation of the main floor shall be at least 30 cm above the applicable flood protection level; and

(c) the structure is situated on pervious soil, the design of the structure shall be certified by a Professional Engineer as capable of withstanding hydrostatic and uplift pressures by a static water level at the flood protection level.

(ii) la cote de nivellement du plancher de la construction;

e) les autres renseignements dont l'employé désignée estime devoir tenir compte dans l'examen de la demande.

Établissement d'un niveau repère

6(1) Sur réception d'une demande écrite d'établissement d'un niveau repère présentée par le titulaire d'un permis, l'employé désigné établit, dans les 15 jours qui suivent la réception de la demande, un niveau repère indiquant le niveau de protection contre les inondations à l'emplacement ou près de l'emplacement de la construction ou du projet de construction.

6(2) Sur réception d'une demande écrite présentée par le titulaire d'un permis, l'employé désigné établit de nouveau le niveau repère prévu au paragraphe (1).

Critères de prévention des inondations

7(1) Toutes les constructions, à l'exception des constructions annexes visées à l'article 9, sont érigées sur des emplacements remblayés ou sur pilotis.

7(2) Dans le cas des constructions érigées sur des emplacements remblayés et qui sont dotées d'un sous-sol ou d'une cave :

a) l'emplacement est remblayé au moyen de matériaux de remplissage imperméables, conformément aux exigences indiquées à l'annexe A;

b) la cote de nivellement du rez-de-chaussée est au moins 30 cm au-dessus du niveau de protection contre les inondations;

c) si la construction est érigée sur un sol perméable, un ingénieur doit attester qu'elle est conçue de manière à résister à la pression hydrostatique et à la sous-pression qui s'exercent lorsque le niveau hydrostatique correspond au niveau de protection contre les inondations.

7(3) Where a structure constructed on a site raised by fill has no basement or cellar,

(a) the site shall be raised by fill in accordance with the requirements illustrated in Schedule B;

(b) the elevation of the main floor shall be not less than the applicable flood protection level; and

(c) the top of the fill shall be not more than 30 cm below the applicable flood protection level.

7(4) Where a structure is supported by piles,

(a) the design of the foundation shall be certified by a Professional Engineer;

(b) the structure shall be supported in accordance with the requirements illustrated in Schedule C or an equivalent support system;

(c) the structure shall be so constructed as not to be buoyant when the surface of any flood waters is higher than the bottom of the horizontal members supporting the structure; and

(d) the elevation of a floor containing finished or occupied space shall be at least 1.0 m above the applicable flood protection level.

Additional floodproofing criteria

8 In addition to the floodproofing criteria set out in section 7, every structure, other than an accessory structure referred to in section 9, shall meet the following requirements:

(a) all windows, exterior doors and other exterior openings, including openings between a house and an attached garage, shall be located above the applicable flood protection level;

7(3) Dans le cas des constructions érigées sur un emplacement remblayé et qui ne sont pas dotées d'un sous-sol ou d'une cave :

a) l'emplacement est remblayé conformément aux exigences indiquées à l'annexe B;

b) la cote de nivellement du rez-de-chaussée n'est pas au-dessous du niveau de protection contre les inondations;

c) la surface du remblayage n'est pas plus de 30 cm au-dessous du niveau de protection contre les inondations.

7(4) Dans le cas des constructions érigées sur pilotis :

a) la conception de la fondation est attestée par un ingénieur;

b) les travaux sont effectués conformément aux exigences indiquées à l'annexe C ou à des exigences similaires;

c) la construction est érigée de manière à ce qu'aucune poussée hydrostatique ne soit exercée lorsque la surface des eaux de crues s'élève au-dessus de la face inférieure des membres horizontaux sur lesquels repose la construction;

d) la cote de nivellement du plancher des locaux finis ou occupés est au moins 1,0 mètre au-dessus du niveau de protection contre les inondations.

Critères de prévention additionnels

8 En plus des critères énoncés à l'article 7, toutes les constructions, à l'exception des constructions annexes visées à l'article 9, doivent répondre aux exigences suivantes :

a) les fenêtres, les portes extérieures et les autres ouvertures extérieures, y compris les ouvertures entre une habitation et un garage attenant, sont toutes au-dessus du niveau de protection contre les inondations;

(b) the electrical service and panelboard shall be located above the main floor unless the existing service and panelboard located below the main floor within a structure existing before August 15, 1981 is being replaced or added to in the same location;

(c) the potable water shut-off valve shall be located on the main floor with no take-off fittings on the service pipe side of the valve and shall have a dual check valve type backflow preventer to provide protection against possible contamination of the potable water supply;

(d) if the structure has floor space below the applicable flood protection level, the drain between the structure and a septic or holding tank or a common sanitary sewer line shall have a backwater valve.

Accessory structures

9(1) An accessory structure shall comply with the floodproofing criteria set out in this section.

9(2) Where an accessory structure is a livestock barn, granary, farm machinery shed, attached garage or other building used for the storage of agricultural produce, or a workshop or shed used for the storage of immovable equipment or material or hazardous material,

(a) the floor elevation shall be not more than 30 cm below the applicable flood protection level; and

(b) the elevation of the top of the fill shall be not more than 60 cm below the applicable flood protection level.

9(3) Where an accessory structure is a detached garage,

(a) the floor elevation shall be not more than 1.5 m below the applicable flood protection level;

b) la boîte de dérivation et le tableau de distribution sont installés au-dessus du rez-de-chaussée, à moins qu'il s'agisse remplacer une boîte ou un tableau existant ou d'ajouter une boîte ou un tableau supplémentaire au-dessous du rez-de-chaussée dans une construction érigée avant le 15 août 1981;

c) la soupape d'arrêt d'eau potable se trouve au niveau du rez-de-chaussée, elle ne comporte aucun raccord de prise d'eau en amont et elle est munie d'un dispositif anti-vide à clapet de non-retour double servant à empêcher toute contamination possible de la source d'eau potable;

d) si la construction a une superficie de plancher au-dessous du niveau de protection contre les inondations, le branchement d'égout entre la construction à la fosse septique, le bac à eaux usées ou l'égout sanitaire public doit être muni d'un clapet anti-refoulement.

Constructions annexes

9(1) Les constructions annexes doivent être conformes aux critères de prévention des inondations énoncées dans le présent article.

9(2) Les halles aux bestiaux, les greniers à céréales, les hangars à machines agricoles, les garages attenants ou autres bâtiments servant au stockage de produits agricoles, les ateliers et les remises servant à abriter de l'équipement ou du matériel agricole fixe ou des matières dangereuses doivent satisfaire aux exigences suivantes :

a) la surface du plancher n'est pas plus de 30 cm au-dessous du niveau de protection contre les inondations;

b) la surface du remblai n'est pas plus de 60 cm au-dessous du niveau de protection contre les inondations.

9(3) Si la construction annexe est un garage isolé :

a) la surface du plancher n'est pas plus de 1,5 m au-dessous du niveau de protection contre les inondations;

(b) if constructed of wood, wood by-products or other material susceptible to water damage, the garage shall be supported by a foundation constructed of water resistant material, and the elevation of the top of the foundation shall be not more than 50 cm below the applicable flood protection level; and

(c) any immovable equipment or material or hazardous material stored in the structure shall be stored 1.0 m above the floor level.

9(4) Where an accessory structure is a storage tank for fuel oil, gasoline or any other liquid or solid, the storage tank shall

(a) be designed, and the installation certified, by a Professional Engineer;

(b) be situated above the applicable flood protection level or buried underground;

(c) be anchored so as to prevent flotation; and

(d) have the vent and filler pipes extend above the applicable flood protection level.

9(5) Where an accessory structure is a drilled well, the well casing shall

(a) extend upward at least to the applicable flood protection level; or

(b) be sealed at the top.

Exceptions

10(1) If a designated employee is reasonably satisfied that, because of the size of a building site, compliance with the requirements of Schedule A or B is impossible or impractical, the designated employee

(a) may vary the berm width and side slope requirements of Schedule A or B; and

(b) may require, as a condition of the variance, that retaining walls be constructed and maintained in accordance with the issued permit to ensure slope protection and prevent water run-off on to adjoining property.

b) si le garage a été construit en bois, en produits du bois ou en un autre matériau susceptible de se détériorer sous l'effet de l'eau, sa fondation est en un matériau imperméable et la surface de la fondation n'est pas plus de 50 cm au-dessous du niveau de protection contre les inondations;

c) l'équipement et le matériel fixe ainsi que les matières dangereuses entreposés dans le garage sont placés au moins un mètre au-dessus de la surface du plancher.

9(4) Si la construction annexe est un réservoir de stockage de mazout, d'essence ou de tout autre liquide ou solide, le réservoir :

a) est conçu et son installation est attestée par un ingénieur;

b) est installé au-dessus du niveau de protection contre les inondations ou il est enterré;

c) est assujetti de manière à ne pas pouvoir flotter;

d) est muni de tuyaux de remplissage et d'aération dont l'orifice s'élève au-dessus du niveau de protection contre les inondations.

9(5) Si la construction annexe est un puits foré, l'extrémité supérieure du tubage est, selon le cas :

a) prolongée jusqu'au niveau de protection contre les inondations ou jusqu'à un niveau supérieur;

b) scellée.

Exceptions

10(1) Si l'employé désigné estime, à cause des dimensions de l'emplacement d'une construction, qu'il est impossible ou particulièrement difficile de répondre aux exigences de l'annexe A ou B, il peut :

a) modifier les exigences de l'annexe A ou B en ce qui a trait à la largeur de la risberme et à la pente latérale;

b) exiger, comme condition de la modification, la construction et l'entretien de murs de soutènement en conformité avec le permis délivré afin de maintenir la stabilité de la pente et d'empêcher l'écoulement des eaux sur les biens-fonds contigus.

10(2) If a designated employee is reasonably satisfied that compliance with the floodproofing criteria is impossible or impractical or would result in a structure that would significantly detract in appearance from neighbouring properties, the designated employee may vary the floodproofing criteria in respect of

(a) a new structure to be constructed on one of a small number of remaining building sites, on the only remaining building site or on newly subdivided building sites in an area that is almost fully developed with buildings;

(b) proposed work that constitutes reconstruction of, or an addition or accessory to, a lawfully existing building; or

(c) the replacement of a structure that is destroyed by fire or other peril.

10(3) A designated employee may vary the floodproofing criteria after completion of a foundation by no more than 10 cm in the elevation of foundations, finished floors and fills and in the width of berms.

Private dykes

11 No person shall construct a dyke for flood protection of an existing structure unless it is constructed in accordance with the requirements illustrated in Schedule D.

Protection by primary dykes

12 A structure protected by a primary dyke or an extension of a primary dyke is deemed to comply with the floodproofing criteria.

Criteria for primary dykes

13 A primary dyke and an extension of a primary dyke shall

(a) be located entirely within the floodway fringe area;

10(2) Si l'employé désigné estime qu'une construction ne peut pas ou peut difficilement être érigée conformément aux critères de prévention des inondations ou ne s'harmoniserait pas avec les bâtiments environnants, il peut modifier les critères de prévention des inondations à l'égard des constructions suivantes :

a) une nouvelle construction érigée sur le dernier ou l'un des derniers terrains à bâtir ou sur un terrain nouvellement loti dans un quartier presque complètement aménagé;

b) un projet de reconstruction d'un bâtiment existant ou d'une construction annexe à ce bâtiment;

c) le remplacement d'une construction détruite par le feu ou un autre sinistre.

10(3) L'employé désigné peut modifier de 10 cm au maximum les critères de prévention des inondations d'une fondation déjà construite en ce qui concerne la cote de nivellement des fondations, du plancher fini et de la surface du remblai, ainsi que la largeur de la risberme.

Digues privées

11 Il est interdit d'ériger une digue dans le but de protéger une construction existante contre les inondations à moins que la digue ne soit conforme aux exigences illustrées à l'annexe D.

Digues primaires

12 Les constructions protégées par des digues primaires ou par le prolongement d'une digue primaire sont réputées conformes aux critères de prévention des inondations.

Critères applicables aux digues primaires

13 Les digues primaires et tout prolongement d'une digue primaire doivent répondre aux exigences suivantes :

a) elles sont situées à l'intérieur de la zone limite du canal de dérivation;

(b) be located, designed and constructed to the standard and elevation approved by the city administrator and The Dyking Commissioner but in no case shall the elevation be less than the flood protection level or the top width be less than 9.2 m at the flood protection level;

(c) have adequate permanent works, as approved by the city administrator, for the removal of water as a result of internal drainage and seepage within the protected area; and

(d) have measures, as approved by the city administrator, that are operable during flood conditions to close openings through the primary dyke.

Type of flood protection

14 Where a new structure is proposed for construction, the city administrator and The Dyking Commissioner may determine whether the structure must conform with the floodproofing criteria or the criteria for primary dykes.

Inspection

15 A designated employee may at any stage of, and after the completion of, the construction of a structure make an inspection to determine whether the structure complies with this regulation.

Notice of compliance

16(1) Where a structure described in a permit is completed and inspected, a designated employee shall, upon a request of the owner, issue to the owner a written notice indicating whether the structure complies with this regulation.

16(2) Where a designated employee carries out an inspection under section 15 and determines that the structure does not comply with this regulation, the city may register in the Land Titles Office, in accordance with *The Real Property Act*, a notice to that effect against the land on which the structure is located.

b) elles sont situées, conçues et construites conformément aux normes et aux cotes de nivellement approuvées par l'administrateur de la ville et le commissaire des digues, mais elles ne doivent en aucun cas être moins élevées que le niveau de protection contre les inondations, et la largeur de la digue ne doit pas être inférieure à 9,2 mètre au niveau de protection contre les inondations;

c) elles sont pourvues d'un système de pompage, approuvé par l'administrateur de la ville, pour l'élimination de l'eau qui s'accumule à l'intérieur de la zone protégée par suite du drainage interne;

d) elles sont pourvues de dispositifs, approuvés par l'administrateur de la ville, servant à obstruer, pendant la crue des eaux, les canalisations qui traversent la digue primaire.

Type de protection contre les inondations

14 L'administrateur de la ville et le commissaire des digues peuvent déterminer si une nouvelle construction projetée doit être conforme aux critères de prévention des inondations ou aux critères applicables aux digues primaires.

Inspection

15 L'employé désigné peut procéder à l'inspection d'une construction, à toute étape de son érection ou après son érection, afin de déterminer si elle est conforme au présent règlement.

Avis de conformité

16(1) Après l'érection et l'inspection d'une construction décrite dans un permis, l'employé désigné délivre, au propriétaire qui en fait la demande, un avis écrit indiquant si la construction est conforme ou non au présent règlement.

16(2) Lorsqu'un employé désigné procède à une inspection aux termes de l'article 15 et détermine que la construction n'est pas conforme au présent règlement, la ville peut enregistrer au Bureau des titres fonciers, conformément à la *Loi sur les biens réels*, un avis de non-conformité à l'égard du bien-fonds sur lequel la construction a été érigée.

Building codes, by-laws, regulations and Acts applicable

17 The requirements under this regulation are in addition to requirements under any applicable building code, by-law, regulation or Act of the Legislature.

Repeal

18 Manitoba Regulation 439/88 R is repealed.

Coming into force

19 This regulation comes into force on proclamation of sections 494.3 and 494.4 of *The City of Winnipeg Amendment Act*, S.M. 1991-92, c. 15.

Codes du bâtiment, arrêtés, règlements et lois applicables

17 Les exigences énoncées dans le présent règlement s'ajoutent aux exigences des codes du bâtiment, des arrêtés, des règlements et des lois de l'Assemblée législative applicables.

Abrogation

18 Le *règlement du Manitoba* 439/88 R est abrogé.

Entrée en vigueur

19 Le présent règlement entre en vigueur à la date de proclamation des articles 494.3 et 494.4 de la *Loi modifiant la Loi sur la Ville de Winnipeg*, c. 15 des *L.M. de 1991-92*.

Bruce Harding Consulting Ltd

To	Michael Van Helden, Ph.D., P.Eng. Principal, Trek Geotechnical Inc.	**Date**	June 6, 2016
From	Bruce Harding, P.Eng.	**File**	Trek_8
Subject	Lyndale Drive Riverbank Stabilization Red River Flood Level Probabilities	**cc**	

This memorandum presents the relationship between water level stage and probability of exceedence for the Red River at Lyndale Drive. This memorandum is to be read in conjunction with the March 15, 2016 Hydraulic Report[1] for the Lyndale Drive Riverbank Stabilization project.

The water level stage versus probability relationship was derived utilizing the estimated Red River water levels as a function of flow as computed by the HEC-RAS backwater model. The detailed backwater model extends over approximately 2500 m, including the 470 m reach requiring riverbank erosion protection within the Lyndale Drive riverbank stabilization project area. The downstream boundary condition for use in the backwater model was established from results of the calibrated comprehensive HEC-RAS model developed as part of the January 2015 Red River Hydraulic Assessment prepared for the City of Winnipeg[2].

The flood hydrology utilized for the assessment was provided by Manitoba Water Stewardship. The hydrology for the Red River is complicated by the operation of the Floodway, which diverts flow around the City of Winnipeg during times of a flood within the Red River Valley. Furthermore, the project site is located upstream of the confluence with the Assiniboine River which does backwater this reach of the Red River therefore the combined flows of the two rivers must be taken into account. The hydrology derived by Manitoba Water Stewardship, as summarized in Table 1, is based on a detailed and comprehensive assessment of recorded flows in addition to the incorporation of estimates of extreme historical events. The assessment from Manitoba Water Stewardship has flood hydrology derived for the Red River downstream of the Floodway Inlet and at James Avenue which would be indicative of flood conditions within the Red River throughout the City of Winnipeg.

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[1] “Red River - Lyndale Drive Riverbank Stabilization, Hydrologic and Hydraulic Assessment", March 15, 2016 prepared by Bruce Harding Consulting Ltd. for the City of Winnipeg

[2] "Red River Hydraulic Assessment, Hydraulic Model Update", January 2015, prepared by Bruce Harding Consulting Ltd. for the City of Winnipeg, Water and Waste Department

Table 1
Red River
Flood Hydrology

Flood Event	Red River at Lyndale Drive * (m^3/s)	Red River at James Ave (Downstream Assiniboine River) ** (m^3/s)	Red River downstream of St. Andrews Lock and Dam *** (m^3/s)
50% Flood	824	1005	1005
20% Flood	1179	1361	1597
10% Flood	1283	1401	2033
5% Flood	1334	1453	2597
2% Flood	1688	1810	3452
1% Flood	2168	2292	4225
0.625% (160 Year) Flood	2195	2331	4775

* - Red River downstream of Flood Inlet plus LaSalle River contribution, Manitoba Water Stewardship, Updated Red River Hydrology - February 2010

** - Red River at James Ave, Manitoba Water Stewardship, Updated Red River Hydrology - February 2010

*** - Sum of Red River at James Ave discharge and Floodway discharge, Manitoba Water Stewardship, Updated Red River Hydrology - February 2010

The derived water level stage versus probability relationship is presented on Figure 1 and summarized for a range of conditions in Table 2.

Table 2
Red River
Water Level Stage - Probability

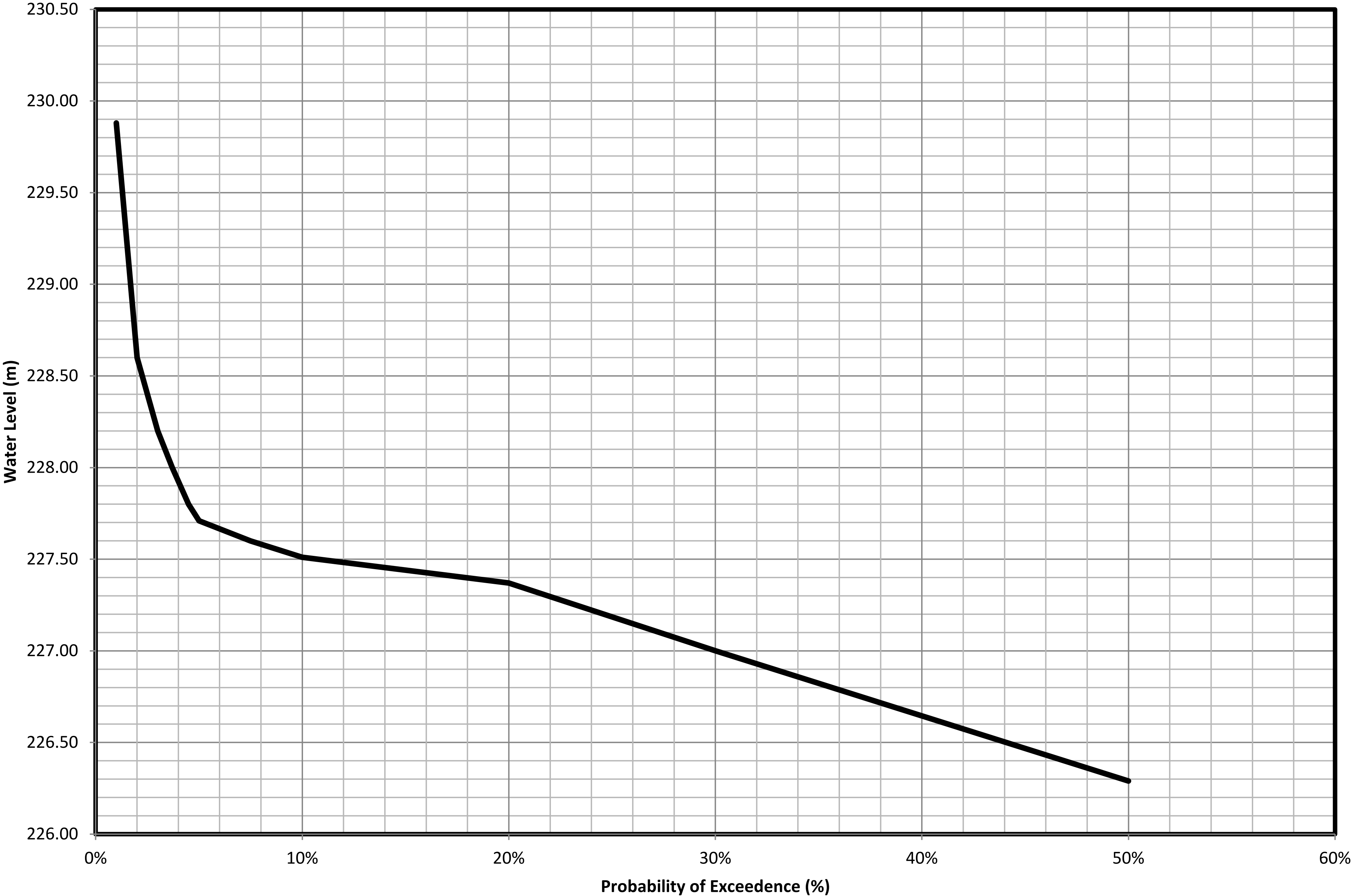
Water Level Stage (m) *	Probability of Exceedence	Return Period (years)
226.3	50%	2
227.0	30%	3
227.4	20%	5
227.5	10%	10
227.6	7.5%	13.5
227.7	5%	20
227.8	4.5%	22
228.0	3.7%	27
228.2	3%	33
228.6	2%	50
229.9	1%	100
230.8	<0.5%	>200

* - Located at Red River Sta 35+697

PROVINCE OF MANITOBA
ORIGINAL
SIGNED BY
W. B. J.
HARDING
June 6, 2016
REGISTERED PROFESSIONAL ENGINEER

APEGM
Certificate of Authorization
Bruce Harding Consulting Ltd.
No. 4652 Expiry: April 30, 2017

Bruce Harding, P.Eng.
Senior Hydraulic Engineer



Red River at Layndale Drive
Water Level versus Probability
Figure 1

NOTE: Water Level referenced to XS 8 at Sta 35+697 along Lyndale Drive