JOHN BRUCE PARK
SLOPE STABILITY ASSESSMENT
NEAR 581 ST ANNES'S ROAD
WINNIPEG, MANITOBA

SUBMITTED TO:
McGowan Russell Group
825 St Joseph St
Winnipeg, MB
R2H 0A8

Submitted by:

Amec Foster Wheeler Environment & Infrastructure

A Division of Amec Foster Wheeler Americas Limited

440 Dovercourt Drive
Winnipeg, Manitoba
R3Y 1N4
Canada

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1.0 INTRODUCTION

As authorized by Ms. Susan Russell of McGowan Russell, Amec Foster Wheeler Environment & Infrastructure (Amec Foster Wheeler), a division of Amec Foster Wheeler Americas Limited, has completed a slope stability analyses to evaluate the riverbank erosion protection options to be provided along 75 m of a historically unstable portion of the Seine River located near 581 St. Anne's Road in Winnipeg, Manitoba. The location of the site is presented in Figure 1.

2.0 BACKGROUND INFORMATION

The project site is located along the riverbank of the Seine River. The riverbank shows evidence of erosion at and below the water level that has led to the development of slope instabilities extending to the top of the bank along the majority of the project limits. It was understood that some portions of the site may have been stabilized in the past. A Geotechnical assessment completed for the construction of a bridge south of the site (by others) recommended stabilization of the crossing, further suggesting the area is prone to instabilities.

3.0 SITE VISIT AND RECONNAISSANCE

On 18 June 2016 Amec Foster Wheeler visited the site, as part of the scope of work presented in the proposal to The City of Winnipeg, and complete a detailed site reconnaissance. The project site is located on an outside bend of the Seine River at the back of a group of trailer houses on 581 St Anne's Road. The project site measures about 75 m along the river and the center of the bend coincides approximately with the center of the site. At the time of the site visit, the riverbank was estimated to be about 3 m to 5 m high and measured about 12 m to 15 m from the top of the bank to the water's edge. Riverbank slopes south of the site, beyond the project limits, were relatively flat, but became gradually steeper to slopes about 2H:1V towards the center of the bend and 3H:1V to 4H:1V to the north and south of the center of the bend. To the north, beyond the centre of the bend, and for the rest of the project limits, the riverbank consisted of a backscarp with nearly vertical drops about 1 m to 2 m high followed by a gentle sloping bench extending to the water's edge. At some locations the riverbank downslope from the bench becomes steeper and in some instances almost vertical before reaching the water level.

Two outfalls were noted within the area of the site. One outfall (outfall #1) was towards the south and followed a northerly alignment; while the location of the second outfall (outfall #2) was inferred from the background information to follow a easterly alignment as it was under water at the time of the site visit and also during completion of a topographic survey. Details of the topographic survey are discussed later in this report. At the location of outfall #2 there was strong evidence of erosion and scouring due to river action. Grouted riprap was observed at outfall #1 around and above the top of the pipe, but had been cracked and separate along the top. Riprap was also inferred to be present at outfall #2 based on rock like features detected underwater at the time of the survey.

At the time of the visit the site was well vegetated with tall grass, bushes and trees that ranged in size from small to large (i.e., large trees are referred to trees with a caliper greater than 8"). Most of the treed area is concentrated towards the south end of the project limits. Although the riverbank was well vegetated, there were bare soil areas especially towards the south and within the treed area. Leaning of trees was observed at a few locations, assumed to be caused by movements of the bank, however there was no signs of active movement.

As presented in Figure 2, the group of trailer houses was present south from the center of the bend. A bicycle path was under construction at the time of a site meeting between McGowan Russell, The City of Winnipeg and Amec Foster Wheeler. The bicycle path extended along the top of the bank and measured approximately 2 m wide. Immediately upslope from the location of outfall #2 the bicycle path occupied most of the space available between the rear of the most northern trailer house and the top of the bank.

4.0 TOPOGRAPHIC SURVEY

A limited topographic survey was conducted as part of the scope of work. Sections of the bank were preselected during completion of the site visit and surveyed by a combination of a GPS system and Total Station apparatus. Total Station surveying was required for areas densely treed where GPS signal was not easily obtained. The surveyed cross sections are presented in Figure 2. In addition to surveying of cross sections Amec Foster Wheler identified trees with a caliper greater than 20 cm (8") as requested by the City of Winnipeg. Furthermore, features such as top of the outfall pipes, bicycle path and footprint of the house closest to the top of the bank were also included in the survey and are presented in Figure 2.

5.0 SOIL AND GROUNDWATER CONDITIONS

The soil and groundwater conditions assumed for the site were determined from a previous geotechnical investigation program completed by R.M. Hardy & Associates Ltd (former Amec Foster Wheeler Company) in 1978 as part of the John Bruce Bridge Replacement project. The John Bruce Bridge is located approximately 100 m south from the south end portion of the site (See Figure 1) and at the time of the 1978 investigation, the general soil profile from ground surface consisted of about 1.2 m of clay fill, 1.2 m of silt and about 15 m to 17 m of high plastic clay before reaching the silt till.

The native clay was stiff and brown to about 6 m below ground becoming grey and firm below that depth. Based on observations on completion of drilling it appeared the short term groundwater level in the silt till may have been just above the top of the till surface; while the long term groundwater level in the native clay appeared to have been around 5m below ground based on the moisture profile presented in the test holes logs.

6.0 RIVERBANK SLOPE EVALUATION

6.1 GENERAL DESCRIPTION

The model used to assess the stability of the riverbank slope at the location of the project site was based on the following key components:

a) Surface Conditions:
   - Limited topographic survey data collected by Amec Foster Wheeler, which was used as the basis to determine the model geometry; and
   - Evidence of a previous riverbank failure as noted by the backscarp and benches observed during the site visit.

b) Subsurface conditions;
   - Soil profile identified at the test hole locations completed for the John Bruce Bridge replacement project and interpolated to the project site.

c) River levels and riverbed elevations determined from Survey data collected by Amec Foster Wheeler during the summer of 2016; and

d) Assumed groundwater levels to reflect worst case conditions.

The following sections describe in detail the parameters utilized for the riverbank assessment.

6.1.1 Surface Conditions

The cross sections were selected at the time of the site visit and reconnaissance at locations were signs of previous instabilities had been noted. The cross sections are presented in Figure 2. Initially Amec Foster selected Cross Section A-A as basis for the back-calculation of soil parameters and evaluation of erosion alternatives. However, as requested by McGowan Russell, additional analyses were conducted along Cross Section B-B to evaluate the effects on a section closer to the closest trailer house.

Based on the survey data, the grades within the project site vary between about El. 231 m and El. 226.5 m for the top of the bank and the riverbed, respectively. The river levels at the time of the survey were in the order of El. 227.6 m

6.1.2 Subsurface Conditions

As presented in Section 5.0, soil conditions may consist of high plastic brown clay, low plastic silt, high plastic grey clay and low plastic silt till. For modeling purposes and in order to simplify the simulations, the presence of the shallow silt layer was omitted from the analysis. The stratigraphy for modeling is presented in Figure 3. It is noted that the high plastic brown clay in Figure 3 was divided into two different materials to represent a difference in strength between soils in proximity and away from the riverbank. The grey clay below the bottom of the channel was selected to have post-peak strength only. Further discussion regarding soil strength properties is presented in Section 6.2.

6.1.3 River Water Levels

River levels usually fluctuate through different stages that, depending on the combination with groundwater levels, influence the stability of a riverbank. The Seiner River is relatively shallow along its length. Water levels between 1 m and 1.5 m were measured at the project site at the time of the survey. However, they are deeper at Outfall #2 as the riverbed deepens at that location. The Seine River is not monitored near the project site and therefore historical river water levels are not available for analysis. However, given the Flood Proofing Levels (FPL) provided by the City of Winnipeg, it is likely that the river levels may fluctuate between a maximum of 229.5 m (i.e., the FPL level minus a 0.6 m freeboard) and a near empty river condition (El. 226.7 m at the location of Cross Section A-A). An empty river is a condition that may have occurred in the past based on feedback from Amec Foster Wheler Hydraulic Engineer.

6.1.4 Groundwater Levels

Groundwater levels at the site are expected to be influenced by the fluctuations in river levels and the presence of shallow water bearing layers of silt. Variations in groundwater and river levels give rise to variations in riverbank stability, generally with the most critical conditions (i.e. those conditions giving rise to slope failure) occurring either after the spring flood event of during late fall to early winter. Typically after the spring flooding event the river level recedes to the “normal summer” condition (or “steady-state” condition), but the groundwater conditions in the riverbank remain elevated. The "normal" or "steady state" condition is typically taken to occur during summer when the regulated river level has been established and the groundwater conditions are relatively stable. The late fall or early winter condition occurs when the river levels are low and the riverbank groundwater conditions are above the river level; although it is noted that the water levels in the Seiner River do not fluctuate much

Given the limited data available groundwater levels were assumed to remain high near the FPL to represent a worst case condition with regards to slope stability.

6.2 MODELING APPROACH

Amec Foster Wheeler conducted the stability analyses using the Slope/W module of the computer software Geostudio produced by Geo-Slope International to represent the conditions presented in Section 6.1. All models were evaluated using the Morgenstern-Price method with a half sine variation of inter-slice forces. Circular slip surfaces were considered for the analysis.

6.2.1 Back Analysis of Soil Parameters – Cross Section A-A

Based on the site observations it is not apparent that recent movements have occurred at the site. However, the presence of a backscarp is quite evident, suggesting that slope movements have occurred in the past. Regardless of the site inactivity, it can be reasonably assumed that the backscarp represents a failure zone with a stability of near unity, under worst case operating conditions.

Given the noted site features, Amec Foster Wheeler completed a back-analysis along Cross Section A-A in order to estimate the properties of the soils. A combination of high groundwater (around El. 229 m) and an empty river was selected as the condition that would create the worst case stability state and create an instability as denoted by the back scarp location.

Post peak and residual strengths were assigned to the clays. The use of post peak and residual strengths are common modeling approaches for the shear strengths of soils in close proximity to riverbanks (post-peak) and that have shown past history of movements (residual). The silt till, was neglected from the analysis given the relatively great depth of the silt till with relation to the depth of the channel and the unlikely scenario that critical slip surfaces extend deep to into the silt till. As noted, the possible presence of silt was also discounted in the analysis.

Based on the conditions above and the parameters presented in Table 1, a Factor of Safety (FOS) ~ 0.98 was obtained. A FOS ~ 0.98 is very close to FOS ~ 1.0 (the state of marginal stability) and as such was considered adequate for back-analysis given the historical failures noted. The results are presented in Figure 3.

Table 1 – Summary of Soil Parameters

Soil	Unit Weight γ (kN/m^3)	Cohesion c (kPa)	Friction Angle ϕ (Degrees)
Brown Clay – Post Peak	18	4	15
Brown Clay – Residual	18	1	12.5
Grey Clay – Post Peak	18	4	15

It is noted that the back-calculated shear strength values correlate well with values back-calculated at other riverbank sites and laboratory shear testing completed on similar soils, in particular the residual strength of the clay.

6.2.2 Erosion Protection of Riverbank Slope – Cross Section A-A

Based on the results of the back-analysis of soils properties, slope erosion protection alternatives were evaluated to determine the potential degree of slope improvement for various options. In that regard it is understood that although a certain degree of slope stability is desired, the main erosion protection should not cause any reduction on riverbank stability

A number of options were considered initially that were reduced to a combination of the following:

1. A gabion basket wall placed from the bottom of the riverbed (about El. 226.7 m) up to a minimum El. ~ 227.8 m;
2. A mat of concrete blocks extending from the top of the gabion basket wall up to a minimum El. ~ 228 m;
3. Vegetation establishment for bare areas or replenishment for areas of existing vegetation. Vegetation is to consist of topsoil and seeding within and above the mat of concrete blocks and willow spilling terraces north of the concrete mats.

Results are presented in Figure 4. Results suggest a FOS ~ 1.06 and a net improvement of about 8% in slope stability as compared to the existing slope under worst case conditions.

6.2.3 Erosion Protection of Riverbank Slope – Cross Section B-B

Subsequent to submission of preliminary results along Cross Section A-A, McGowan Russell requested additional analyses to be completed along Cross Section B-B. The purpose of the additional analysis was to evaluate the effects of sub-cutting the top of the bank so that the bicycle path could be re-aligned in order to move away from the trailer house located closest to the bank. This alternative would require placement of a retaining wall to support the soils behind the sub-cut portion of the bank.

Results not presented in this report suggested a net improvement in stability in the order of 1.5% to 7% due to sub-cutting of the top of the bank and although the results suggested an improvement in stability, the alternative was not considered feasible given the risk associated with excavating and placing of a retaining wall in close proximity to the trailer house.

7.0 GENERAL GEOTECHNICAL RECOMMENDATIONS

Based on the proposed erosion protection options evaluated in Section 6.2.2, the following general geotechnical guidelines are provided for construction purposes:

- Prior to installation, the bearing surface of the gabion wall should be prepared so that a uniform surface is obtained. Any organic, soft or weak soils shall be removed and replaced with native or imported competent soil to provide a stable sub-grade;

- Gabion baskets can be either constructed on site or pre-built off site and placed directly on the prepared surface to provide a smooth transition within the riverbank;
- Gabion basket backfill should consist of quarried rock or quarried limestone that is durable and resistant to the action of water and frost;
- Adjacent gabion baskets should be properly secured to reduce the likelihood of displacement;
- Placement of topsoil and seeding should proceed on a prepared surface after placement of the gabion baskets;
- The matt of concrete blocks should be placed directly on the top soil or on areas already vegetated and should be properly overlapped and secured. Overlapping should be both in the direction of the river flow and in the downslope direction.

In addition, the following general geotechnical recommendations are provided to improve the overall performance of the slope:

- The site should be maintained well drained and water should not be allowed to pond and infiltrate the slope soils. Where possible, surface drainage should be diverted away from the slope to prevent for build-up of porewater pressures.
- The presence of vegetation is vital to maintaining the ongoing stability of slopes. In this regard, it is recommended that the existing slopes remain vegetated with minimal disruptions due to the construction activities such as tree and bush removal. Where vegetation needs to be removed, it should be replaced to pre-construction conditions or better.

While the proposed erosion protection alternatives are intended to provide a certain degree of stability improvement, it is noted that some riverbank movements may still occur due to factors unrelated to normal river action (i.e., high groundwater levels, low river levels, severe flooding conditions or a combination thereof). As such some of the erosion protection components may be subject to movement with time unless a more aggressive stabilization program is implemented. As well, some future repairs and upgrades may be necessary.

8.0 CLOSURE

The findings and recommendations of this report were based on interpolation of soil and groundwater conditions observed during completion of a geotechnical investigation completed for the John Bruce Bridge replacement project. If conditions are encountered that appear to be different from those described in this report, or if the assumptions stated herein are not in keeping with the design, this office should be notified in order that the recommendations can be reviewed and adjusted, if necessary.

Soil conditions, by their nature, can be highly variable across a site. The placement of fill and prior construction activities on a site can contribute to the variability especially in near surface soil conditions. A contingency should always be included in any construction budget to allow for the possibility of variation in soil conditions, which may result in modification of the design and construction procedures.

This report has been prepared for the exclusive use of McGowan Russell Group and its agents. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibility of such third parties. Amec Foster Wheeler accepts no responsibility for damages suffered by a third party as a result of decisions made or actions based on this report. It has been prepared in accordance with generally accepted geotechnical engineering practices on similar projects. No other warranty, expressed or implied, is made.

Respectfully submitted,
Amec Foster Wheeler Environment & Infrastructure,
A Division of Amec Foster Wheeler Americas Limited

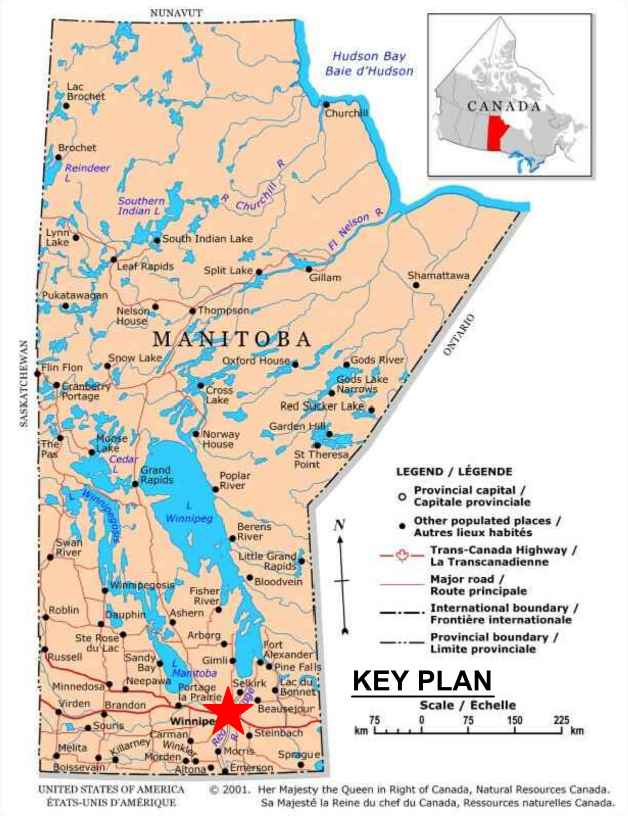
PROVINCE OF MANITOBA
27/10/2016
G. A.
CIRO
Member
30284
REGISTERED PROFESSIONAL ENGINEER

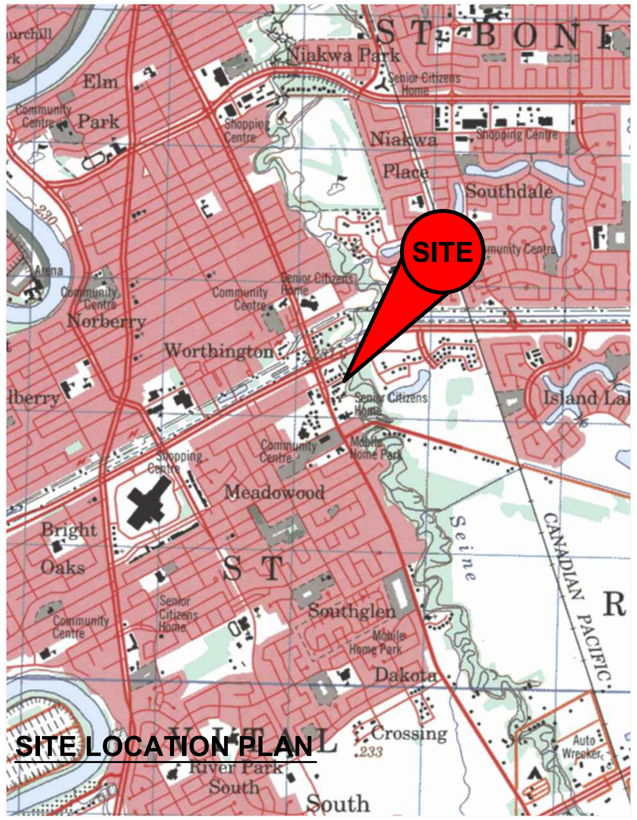
APEGM
Certificate of Authorization
Amec Foster Wheeler Environment & Infrastructure, a Division of Amec Foster Wheeler Americas Limited
No. 6017 Date: 27/10/2016

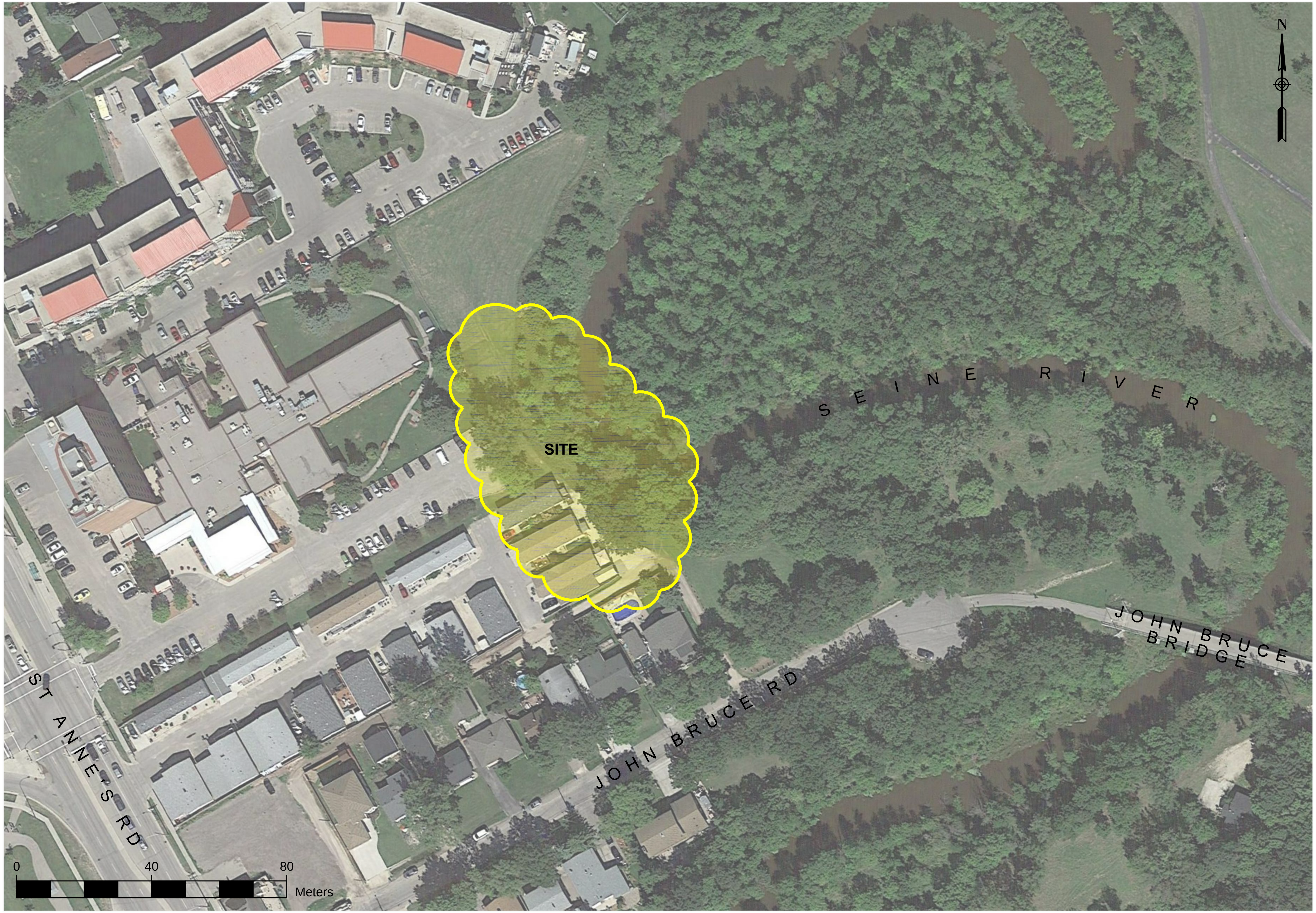
German Ciro, M.Sc., P. Eng
Senior Geotechnical Engineer

Reviewed by:

Harley Pankratz, P.Eng
Area Manager Eastern Prairies and Northern Alberta







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REVISION	BY	DATE
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CLIENT:

McGOWAN RUSSELL GROUP

Amec Foster Wheeler
Environment & Infrastructure
440 DOVERCOURT DRIVE
WINNIPEG, MANITOBA R3Y 1N4
PHONE: 204.488.2997 FAX:204.489.8261

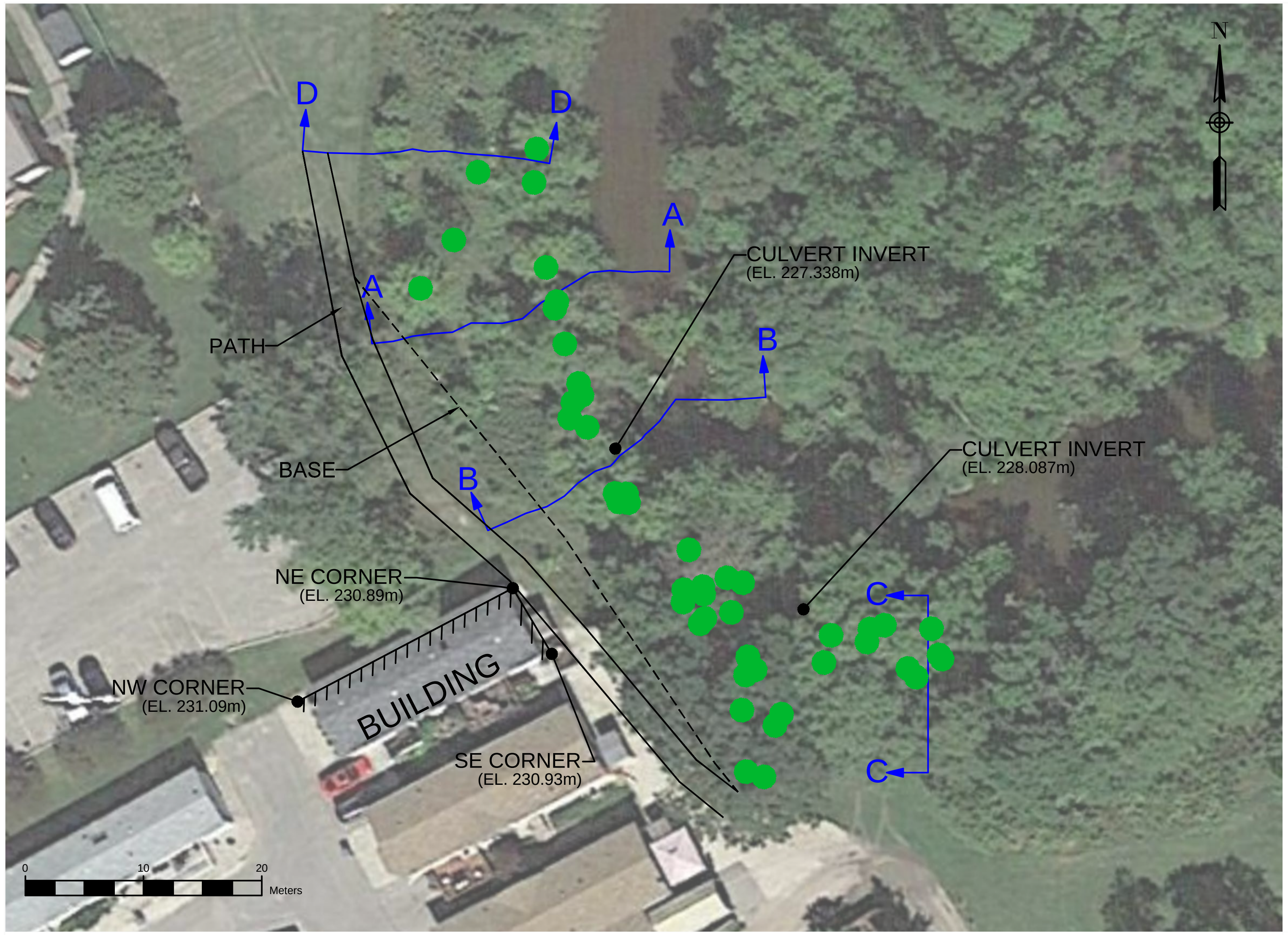
amec foster wheeler

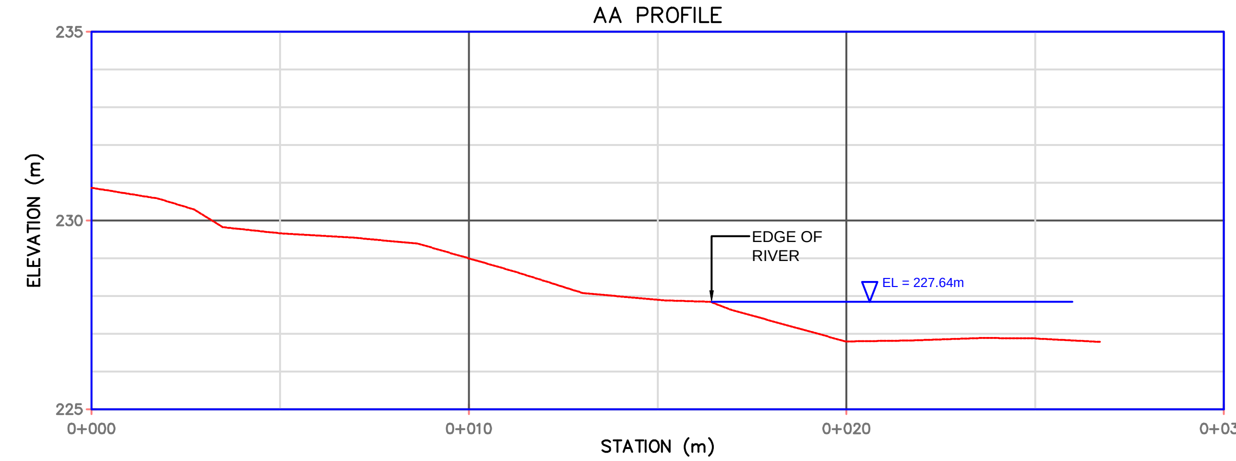
DWN BY: MD
CHK'D BY: GC
DATUM: NAD83
PROJECTION: UTM Zone 14 U
SCALE: AS SHOWN

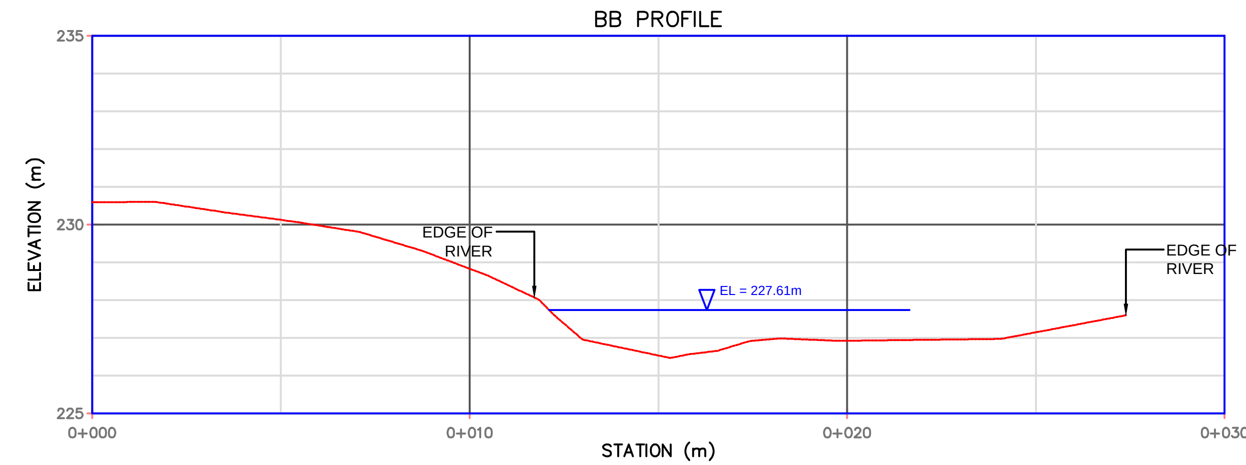
SLOPE STABILITY ASSESSMENT
JOHN BRUCE PARK
SEINE RIVERBANK EROSION PROTECTION PROJECT
WINNIPEG, MANITOBA

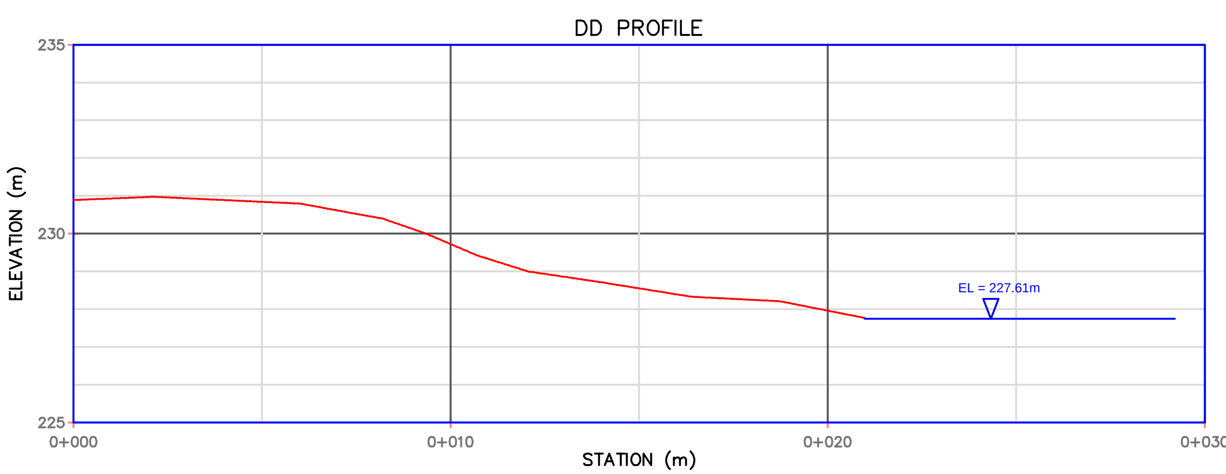
KEY PLAN

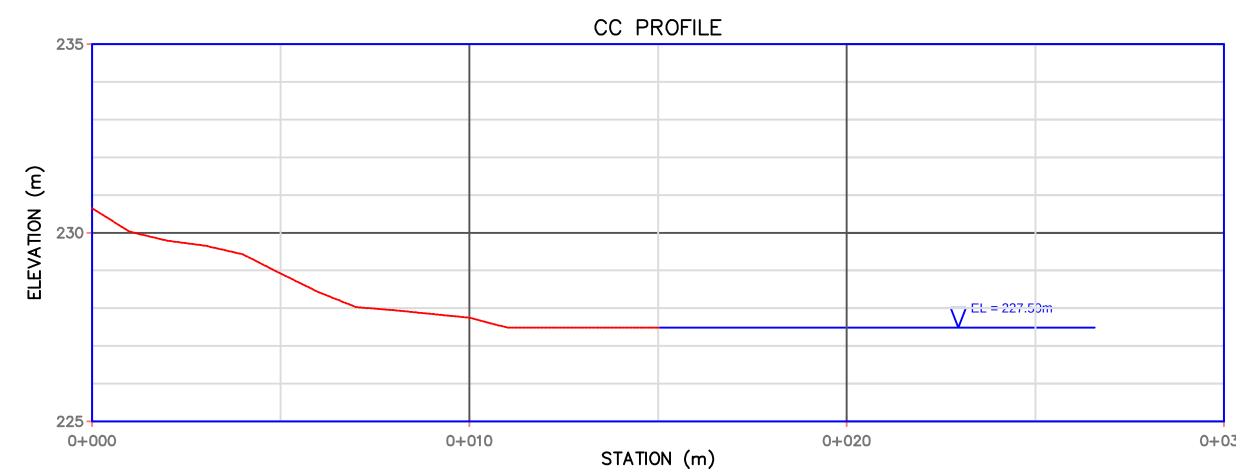
DATE: OCTOBER 2016
PROJECT NO: WX17992
REV. NO.: ---
FIGURE NO: FIGURE 1











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CLIENT:

McGOWAN RUSSELL GROUP

Amec Foster Wheeler
Environment & Infrastructure
440 DOVERCOURT DRIVE
WINNIPEG, MANITOBA R3Y 1N4
PHONE: 204.488.2997 FAX:204.489.8261

amec foster wheeler

DWN BY: MD

CHK'D BY: GC

DATUM: NAD83

PROJECTION: UTM Zone 14 U

SCALE: AS SHOWN

SLOPE STABILITY ASSESSMENT
JOHN BRUCE PARK
SEINE RIVERBANK EROSION PROTECTION PROJECT
WINNIPEG, MANITOBA

SITE PLAN AND CROSS SECTIONS

DATE: OCTOBER 2016

PROJECT NO: WX17992

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FIGURE NO: FIGURE 2

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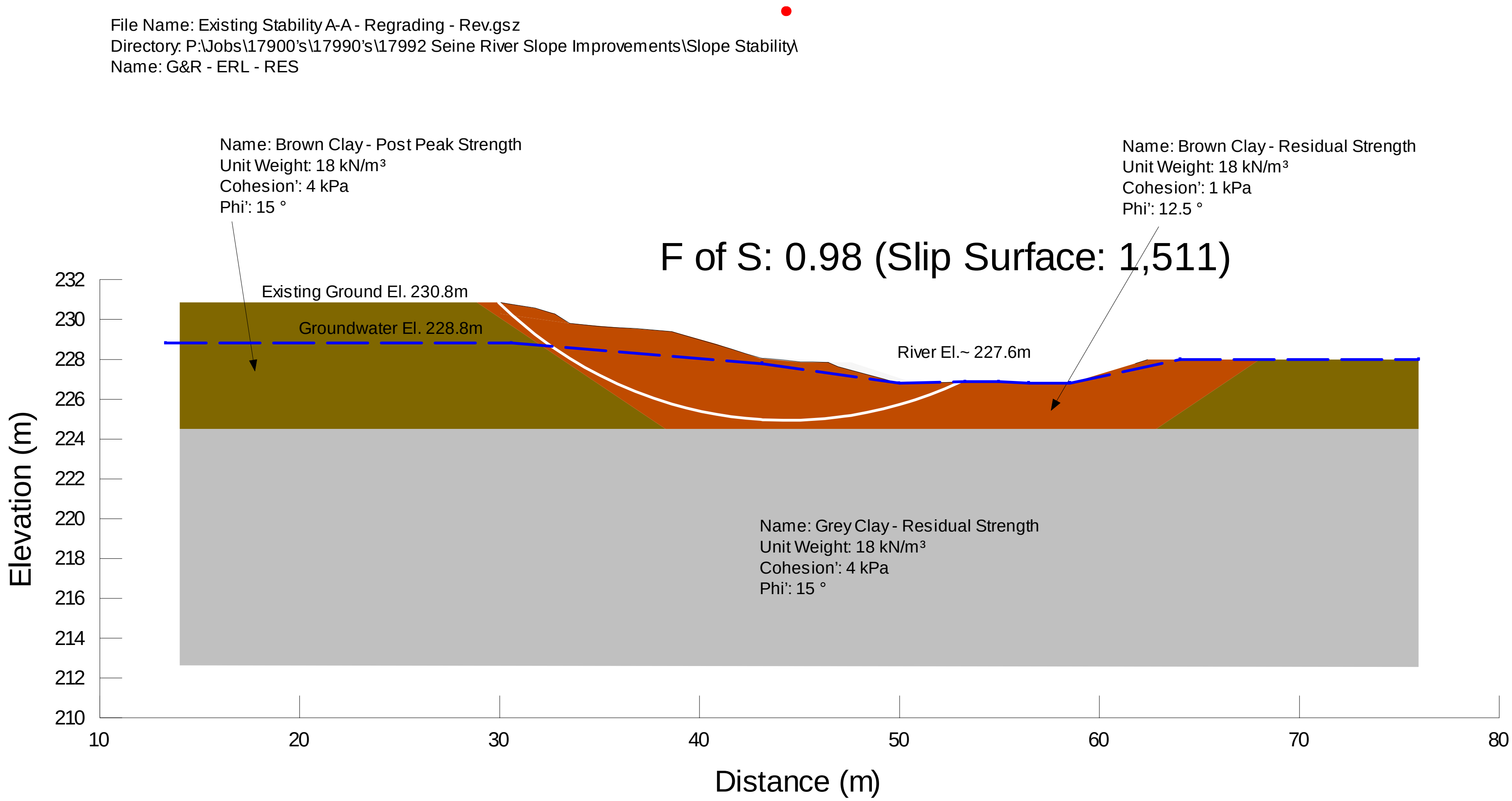

amec foster wheeler	**Client:** **McGOWAN RUSSELL GROUP**	**BACK-ANALYSIS OF SOIL PROPERTIES CROSS SECTION A-A** **SLOPE STABILITY ASSESSMENT JOHN BRUCE PARK WINNIPEG, MANITOBA**	

Project No.:	WX17992
Date:	October 2016
Scale:	As Shown
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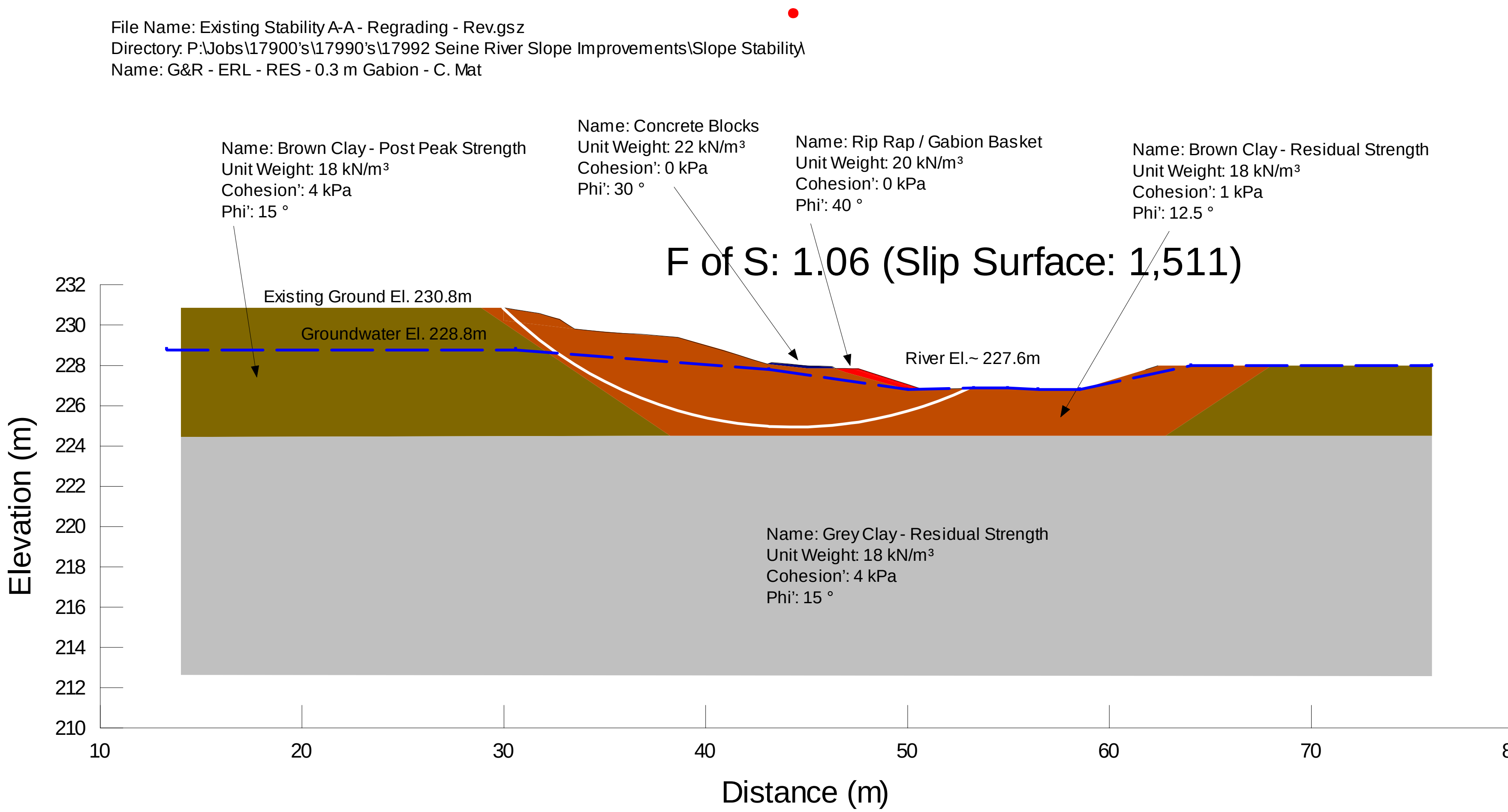
Figure:	3



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EROSION PROTECTION OF RIVERBANK
CROSS SECTION A-A

SLOPE STABILITY ASSESSMENT
JOHN BRUCE PARK
WINNIPEG, MANITOBA

Project No.:	WX17992
Date:	October 2016
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