APPENDIX 'A'

TACHE PROMENADE – RED RIVER HYDROLOGIC AND HYDRAULIC ASSESSMENT

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City of Winnipeg

Tache Promenade - Red River
Hydrologic and Hydraulic Assessment

Prepared for:

Cameron Ward, P.Eng.
Engineering Division
Public Works Department
City of Winnipeg

Project Number:
0015 021 00

Date:
October 4, 2017
Rev 1

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Quality Engineering | Valued Relationships

October 4, 2017

Our File No. 0015 021 00

Mr. Cameron Ward, P.Eng.
Engineering Division
Public Works Department
City of Winnipeg

RE: Tache Promenade - Red River
Hydrologic and Hydraulic Assessment

TREK Geotechnical Inc. is pleased to submit our Final Report for the Hydrologic and Hydraulic 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:

Jim Friesen, P.Eng
Manager, Water Resources Engineering
Tel: 204.975.9454

Encl.

Revision History

Revision No.	Author	Issue Date	Description
0	BH	June 21, 2017	Draft Report
1	BH	October 4, 2017	Final Report

Authorization Signatures

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APEGM
Certificate of Authorization
Trek Geotechnical Inc.
No. 4877 Date:___________

Table of Contents

Figures

Site Photos

List of Appendices

1.0 Introduction

This report summarizes the results of our hydraulic assessment of the Red River along Tache Avenue required as part of the Tache Promenade Project. The Tache Promenade Project includes riverbank stabilization measures in addition to erosion protection provided by a rock riprap blanket over a total of approximately 265 m of riverbank. Additionally, an elevated viewing platform, referred to as the Treetop Outlook, will also be constructed along the riverbank within the project area. The hydraulic influence of the erosion protection measures and the proposed outlook will require hydraulic assessment in addition to the requirements for recommendations for hydraulic design. 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 - 634630E, 5527990N (Zone 14)
- City of Winnipeg River Stationing - 32+105 to 32+450

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

2.0 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. The project site is located immediately downstream of the confluence with the Assiniboine River, therefore the combined flow of the two rivers has to be take into consideration. Additionally, the Saint Andrews Lock and Dam, located downstream of Winnipeg, controls river levels through the City of Winnipeg including the Tache Avenue reach during the open water period.

The annual flood hydrology, based on annual peak flows, has been developed as part of the hydrologic assessment. It was requested that hydrologic analyses be completed for specific seasons including summer, fall and winter periods as summarized in the following sections. Additionally monthly average hydrology is presented for reference.

2.1 Annual Flood Hydrology

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 summarizing the hydrology is appended for reference. The assessment from Manitoba Water Stewardship has flood hydrology derived for the Red River at James Avenue which would be indicative of spring flood conditions within the Red River throughout the City of Winnipeg. Table 1 summarizes the annual 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 project site when the Floodway is not operating, however this cannot be assumed under flood conditions when total flows are higher 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 which reflects total combined Red River flows after the confluence with the Floodway.

Table 1
Red River
Annual Flood Hydrology (Spring)

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

* - 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

2.2 Seasonal Hydrology

The hydrology to estimate seasonal flows outside of the spring period, were estimated using hydrologic records available from Water Survey of Canada for the Red River near Lockport (05OJ010) gauge. The records were sorted into 3 distinct seasons - Summer (July 1 to September 30th), Fall (October 1st to November 30th) and Winter (December 1st to February 28th) - with frequency analysis on the annual peaks within those seasons. It has been assumed that the flows recorded at Lockport would reflect flows at Tache Promenade, except in cases where the Floodway is in operation with total flows exceeding approximately 1100 m^3/s. Table 2 summarizes the hydrologic estimates.

Table 2
Red River
Seasonal Flood Hydrology

Probability	Red River at Tache Promenade (m^3/s)	Red River downstream of St. Andrews Lock and Dam ** (m^3/s)
Summer - July 1 to September 30		
50%	362	362
20%	733	733
10%	1040 *	1089
5%	1300 *	1512
2%	1430 *	2276
1%	1580 *	2979
0.5%	2045 *	3846
Fall - October 1 to November 30		
50%	138	138
20%	254	254
10%	356	356
5%	475	475
2%	665	665
1%	837	837
0.5%	1039	1039
Winter - December 1 to February 28		
50%	75	75
20%	124	124
10%	163	163
5%	204	204
2%	270	270
1%	325	325
0.5%	386	386

* - Floodway operational for total flows at Lockport (05OJ010) exceeding approximately 1100 m^3/s. Floodway diverted around Winnipeg have been estimated with flows reflecting conditions at Tache Promenade.

** - Based on seasonal frequency analysis for streamflow records at WSC gauge Red River near Lockport - 05OJ010.

2.3 Monthly Average Hydrology

Monthly average hydrology has been derived for the Red River at Tache Promenade using hydrologic records available from Water Survey of Canada for the Red River near Lockport (05OJ010) gauge. The monthly estimates assume that the Floodway is not operational, as the flows remain below the 1100 m^3/s limit where diversion typically is initiated, therefore the Lockport flow estimates would reflect conditions at Tache Promenade. Table 3 summarizes the monthly average flow estimates.

Table 3
Red River
Average Monthly Flows

Month	Red River at Tache Promenade * (m^3/s)
January	57
February	53
March	144
April	780
May	647
June	394
July	332
August	162
September	119
October	110
November	110
December	72

* - Based on analysis of streamflow records at WSC gauge Red River near Lockport - 05OJ010.

3.0 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 1900 m, including the reach which requires riverbank erosion protection within the project area. The assessment reach would be approximately Sta 31+132 (James Avenue Pumping Station) upstream to 33+011 (Norwood Bridge) 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]. The incorporation of the previous comprehensive hydraulic study results combined with the detailed assessment model enabled the accurate estimation of water surface profiles within the study area for a wide range of flow conditions.

The framework for the detailed backwater model, to allow for the assessment within the project area, was the hydraulic model developed for the January 2015 Red River Hydraulic Assessment. The sections within the detailed backwater model were from either:

- the 2015 hydraulic model of the Red River. These particular sections were assembled from bathymetric surveys undertaken by GDS Surveys in September 2013 and topography collected as part of the 2012 LiDAR survey
- additional sections developed using the bathymetric data collected by North-South Consultants Inc in June 2017, collected as part of their substrate mapping . The 2012 LiDAR data was utilized to detail the riverbank topography for the additional sections.

The estimated water surface profiles for the Red River for existing conditions are shown on Figure 2. A channel velocity profile plot, as shown on Figure 3, is also presented for existing conditions for a range of flow conditions. It is noted that the channel velocities within the reach are relatively high, but typical for the lower reach of the Red River. It is was noted that sections of rock rap armouring exist along the riverbank within the project area, however it is not continuous and that these gaps in the protection should be addressed. On that basis, a continuous blanket of rock riprap protection is recommended however encroachment of the rock should be limited to minimize changes to the existing hydraulic regime.

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.*

4.0 Hydraulic Assessment - Proposed Erosion Protection

The erosion protection measures proposed along Tache Avenue, near the Tache Dock, are to augment the existing erosion protection measures and to form a continuous blanket throughout the project area.. The erosion protection measures, as shown on Figure 1. are proposed to consist of a rock riprap blanket placed in two locations with an approximately 90 m length of rock riprap blanket placed north of the Tache Dock, and an approximately 175 m length of rock riprap blanket placed south of the Tache Dock. These proposed rock riprap blankets would be located within the designated Floodway and Floodway Fringe (as shown in Appendix B), therefore it is important to minimize any hydraulic impact on water levels or velocities.

The erosion protection consists of a Class 450 (minimum) rock riprap blanket over a total of approximately 265 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 an approximate slope of a 5.5:1 on the finished rock riprap blanket, transitioning to the existing rock riprap. The proposed rock riprap blanket has been detailed with a continuous even surface complete with smooth transitions at the end of each length of blanket to minimize turbulence and deposition/erosion issues. Typical sections are shown on Figure 4.

The rock proposed would be sufficient to resist the observed velocities, however it is recommended that a 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 in the event of riverbed scour. Velocities and therefore erosive tractive forces are typically highest 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.

The change to river velocity is negligible, with less than a 0.03 m/s increase locally. River velocity profiles for this option relative to existing conditions are presented on Figure 5. Changes to the water surface profile would be imperceptible.

5.0 Treetop Lookout - Hydraulic Assessment

The Treetop Outlook as proposed consists of a narrow elevated walkway overtop of the riverbank as shown on Figure 1. The structure would be founded on multiple round piers along the structure length. The base of the piers would be submerged under high flows and elevated river level conditions, however the deck would be set to be well clear of flood levels. In general, the structure is located in a very low velocity zone and would have an unperceivable influence on river hydraulics. The structure would extend beyond the Floodway Line, where development is typically not permitted as it potentially has a negative effect on river hydraulics and may exacerbate flooding and erosion concerns. However, the structure with its minimal pier footprint and raised decking, as noted, will not be of concern to river hydraulics. The design of the structure however, should ensure that sufficient deck clearance is provided and that the piers can adequately resist ice loading. The following sections detail the hydraulic and ice loading design requirements.

5.1 Hydraulic Design Requirements

The underside of girder for the proposed deck should be set to ensure that it remains well above river flood levels. It is proposed that the underside of deck be set as a minimum at the Flood Protection Level, which is approximately 230.39 m at this location. It would be preferable to provide additional freeboard above this level, however it was noted that Tache Avenue at this location is at approximately elevation 230.0 m, which already results in the necessity for a transition from the Tache Avenue sideway to the higher Treetop Lookout structure. Additional freeboard would only result in a much larger transition. Keep in perspective that the 1% river level has been estimated to be elevation 229.55 m, providing approximately 0.85 m of clearance/freeboard to the minimum underside of girder elevation.

The piers should be round to minimize hydraulic effects and possible turbulence. It is also recommended that a blanket of rock riprap (Class 350) be placed around the perimeter of each pile to ensure that the riverbank at the pier base does not scour.

5.2 Ice Loading Design Requirements

There are several modes of interaction between ice and river piers that have the potential to develop forces which have to be taken into consideration in the design of a pier. The possible modes of ice interaction on the piers may include:

- Dynamic forces due to moving sheets or floes of ice being carried by river currents.
- Static pressure due to thermal expansion movements of the ice cover.
- Pressures resulting from the formation of a hanging ice dam or by an ice jam
- Vertical loading resulting from the adhesion of ice to the pier in waters with fluctuating water level.

Ice loadings acting on the Tree Top Lookout piers are most likely not as a result of direct impacts, as the piers are set back on the riverbank within the trees and in the lower velocity fringe. Nonetheless, ice impact loading should be taken into consideration. However, based on observations, it is judged that lateral loading acting on the piers due to the formation of ice jams within the river, which are prevalent during breakup through this reach of the river, can induce significant loads on the piers with ice being pushed up the riverbank. These ice jam conditions and resultant lateral pushes were observed during the April 2009 flood event when the ice breakup was severe. Of note, the trees remain intact within the proposed location of the Treetop Lookout, which indicates that the forces were not severe enough to shear the trees, however every ice breakup is different and conditions can vary considerably. On that basis, the structure should be assessed for the possibility of significant ice loads whether from ice floe impacts or due to ice jam forces.

5.2.1 Dynamic Ice Forces

Dynamic forces occur when a moving ice floe strikes a pier. Forces imposed by the ice floe on a pier are dependent on the size of the individual ice floes (thickness, width and length), the internal strength of the ice and the geometry of the pier nose. For larger rivers, like the Red River, the governing ice loads are typically due to the river ice characteristics under crushing and bending/flexure.

The effective ice strength varies depending on the air temperatures and the integrity of the ice cover. Section 3.12 – *Ice Loads* of the Canadian Highway Bridge Design Code[2] will be referenced to estimate the ice loading forces for the design of the piers. The code provides guidelines for estimating the effective crushing strength of the ice cover (Section 3.12.2.1). The value which best reflects the effective crushing ice strength is (b) “the ice breaks up at melting temperature and is somewhat disintegrated: 700 kPa”. The thickness of the ice cover has been assumed to be limited to 900 mm, although locally thinner and thicker sections could exist depending on the severity of the winter, the snow cover and flows throughout the winter period. A 900 mm thickness would be considered the upper limit for average river ice thickness within this reach of the Red River. The code provides equations for the estimation of the horizontal forces computed by both crushing and bending modes. The governing ice loading force, F, will be the smaller of either of these two estimates as the ice will fail in either crushing or flexure modes once it reaches the smaller of these two loadings.

The code recommends that the acting ice load or impact force for piers be assessed for the two load cases as indicated. The ice in the Red River typical begins to breakup around elevation 14 to 15 ft James Avenue which is approximately equal to the ground level beneath the Treetop Lookout (226.5 m +/-). Note however, higher breakup conditions have been observed (2009), where ice breakup was initiated around 18 ft James Avenue which would have the area around the Treetop Lookup piers submerged and the potential for ice extending into overbank area beneath the Treetop Lookout.

2 “Canadian Highway Bridge Design Code”, Canadian Standards Association, November 2006, Section 3.12

The resultant dynamic ice force should be applied at a given elevation which corresponds to the water level at the time of estimated breakup. The required water level elevation and top of ice elevation at the Treetop Lookout piers has been estimated to be 227.8 m (19 ft James Avenue + datum adjustment + water surface gradient = 19 ft +727.6 ft + 0.7 ft = 747.3ft = 227.8 m) . The elevation to apply the force can be taken as the centre of the ice cover which is approximately 227.35 m. Corresponding river channel velocities are estimated at 1.5 m/s, however velocities within the river overbank area would be much lower, estimated to be less than 0.5 m/s.

The potential for dynamic loading on the piers exists, however there are many factors which influence whether the ice will contact the pier. These factors include:

- Water level during ice breakup/movement. The water level at the time the ice floes are passing the structure may influence where the ice floes go and whether the floes will simply ground into the riverbank.
- Whether shore fast ice exists which will deflect the ice out and away from the piers.
- The existence of trees which may deflect the ice out and away from the piers.

Regardless, the potential for dynamic loads on the piers exists and measures must be taken by either ensuring the structure is robust enough to resist the entire load or by providing a mechanism for reducing the load on the pier itself. The use of round piers should be considered with either a sloping apron base or mounded rock riprap at ground level to reduce ice forces by forcing the ice up and minimizing the load transfer to the pier. Mounded riprap set at approximately elevation 227.4 m, has the advantage of acting as a buffer, absorbing the impact as the rock is not rigid and can yield. Displaced rock can be repaired as required as part of regular maintenance.

5.2.2 Static Ice Forces

Thermal expansion of an ice cover can induce significant loading on piers if the loading is unbalanced, acting only on one side. Generally thermal expansion is of greater concern within a lake environment where the ice is constrained on one shoreline and expands laterally out from the shore. The ice cover throughout the winter, at the project site, typically remains well below elevation 224.0 m, which is below the base elevation of the proposed Treetop Lookout piers and therefore the ice cover would not impart any static ice forces on the piers.

5.2.3 Ice Jam Forces

Dynamic forces occur when moving ice jams and hanging ice dams shed their internal forces to the river banks, to islands or to obstructions like piers within a river. The code provides guidance with respect to estimating the loading of an ice jam on the piers. As indicated, ice jams have been observed at this location and must be taken into consideration. The pier configuration is different than a typical bridge configuration, however the lateral forces would be similar. The higher estimate (10 kPa) of ice jam load acting on a pier has been selected to be representative of site conditions. The ice jam pressure of 10 kPa would be applied over the thickness of the ice jam and pier width from one direction only, however this force can be applied over a range of directions around the outside face of the pier towards the river. The estimated ice jam thickness is 1500 mm which would be assumed at a water level and corresponding ice surface elevation of 227.8 m.

5.2.4 Ice Adhesion Forces

Ice adhesion is generally of concern in areas where rapidly varying water levels can occur such as below a hydroelectric development during ice formation periods. River flows and corresponding water levels within the Red River throughout the winter period, do recede during and after freezup and then remain relatively stable through the winter. Note however that the base of the piers as proposed would typically be above river levels during that period. As such, no significant vertical loadings on the piers due to ice formation are anticipated.

6.0 Probabilistic River Levels

Water level estimates based on the probabilistic flows, as presented in Section 2, have been generated using a combination of the 2015 comprehensive hydraulic model results (downstream boundary conditions) and the detailed Tache Promenade hydraulic model results.

The operation of the Floodway has been taken into consideration in terms of flows through the City (as discussed in Section 2) and for establishing the downstream boundary conditions. It has been assumed that the Floodway would be operational when total flows are in excess of 1100 m^3/s.

During the navigation period (open water period typically from June to September inclusive) and when flows permit, the Red River through Winnipeg is controlled by the Saint Andrews Lock and Dam. 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. The water levels as presented reflect these operational conditions. Additionally, the water level estimate during the winter period were developed assuming an consistent ice cover over the Red River, which results in a slight increase in water level relative to open water conditions.

The probabilistic water level estimates at Tache Promenade are presented in Table 4. For reference, Table 5 summarizes monthly water level estimates at Tache Promenade.

Table 4
Red River
Probabilistic Water Levels at Tache Promenade

Probability	Annual Flood (m)	Summer July 1 to September 30 (m)	Fall October 1 to November 30) (m)	Winter December 1 to February 28 ** (m)
50%	226.09	224.20 *	222.18	222.48
20%	227.13	225.18	222.99	223.02
10%	227.26	226.20	223.57	223.37
5%	227.44	226.96	224.14	223.70
2%	228.43	227.36	224.93	224.17
1%	229.56	227.82	225.54	224.52

* - Assumes that Red River is controlled by St Andrews Lock and Dam
** - Water level estimates assume an ice cover on the river

Table 5
Red River
Average Monthly Levels at Tache Promenade

Month	Red River at Tache Promenade (m)
January	222.24 *
February	222.18 *
March	223.21 *
April	225.34
May	224.86
June	224.30 **
July	224.10 **
August	223.70 **
September	223.70 **
October	221.94
November	221.94
December	222.44 *

* - Water level estimate assumes an ice cover on the river

** - Assumes that Red River is controlled by St Andrews Lock and Dam

7.0 Conclusions and Recommendations

It is recommended that a continuous rock riprap blanket be provided for erosion protection along the riverbank within the project area, with the new rock placement into a sub-cut riverbank for minimal river section encroachment and tying into the existing rock riprap. Overall, the proposed erosion protection measures will have minimal affect on the existing hydraulic regime of the Red River throughout this reach. Additionally, the Treetop Lookout as proposed would have little to no influence on river hydraulics however, special consideration for ice loading and hydraulics must be taken into consideration during the design of the structure.

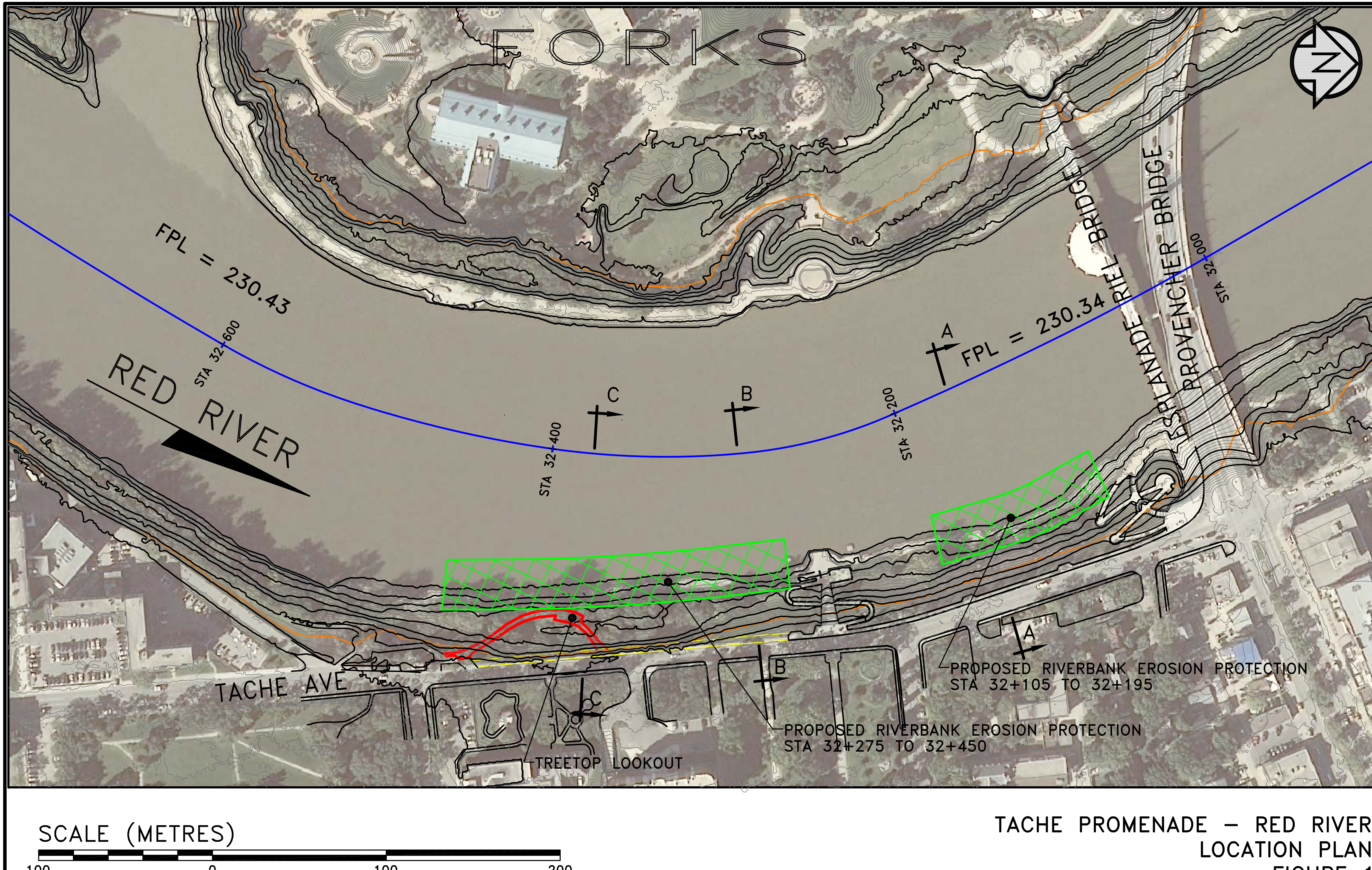
8.0 Closure

The technical 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 collected by TREK during recent field surveys and provided by the City of Winnipeg. Hydrotechnical analysis is based on environmental characteristics assumed to extend uniformly throughout the contributing area and watershed-scale, temporally-discrete hydrologic events.

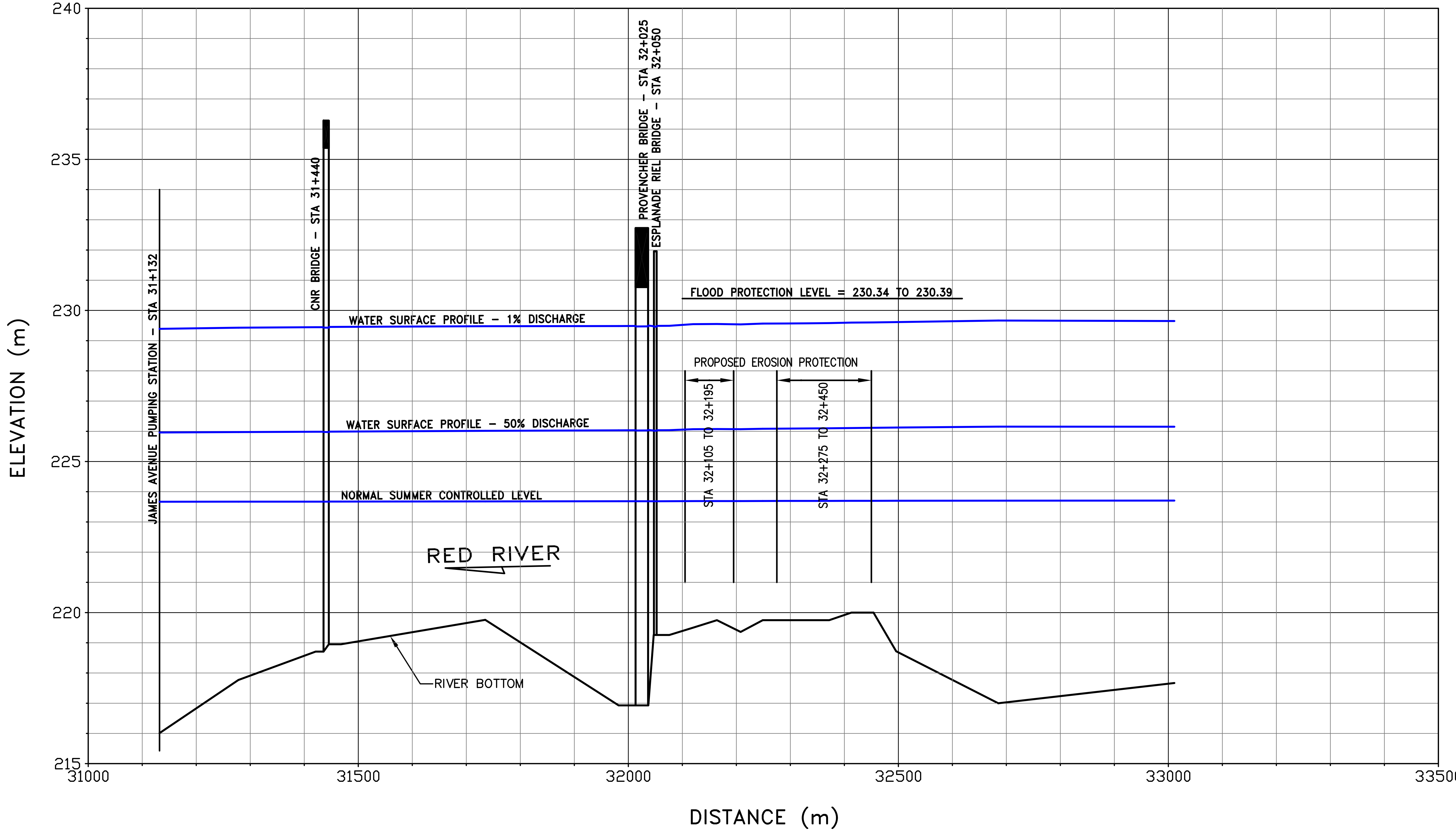
All information provided in this report is subject to our standard terms and conditions for engineering services, a copy of which is provided to each of our clients with the original scope of work, or a mutually executed standard engineering services agreement. If these conditions are not attached, and 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 relied upon by any third parties, except as agreed to in writing by the Client and Consultant prior to use.

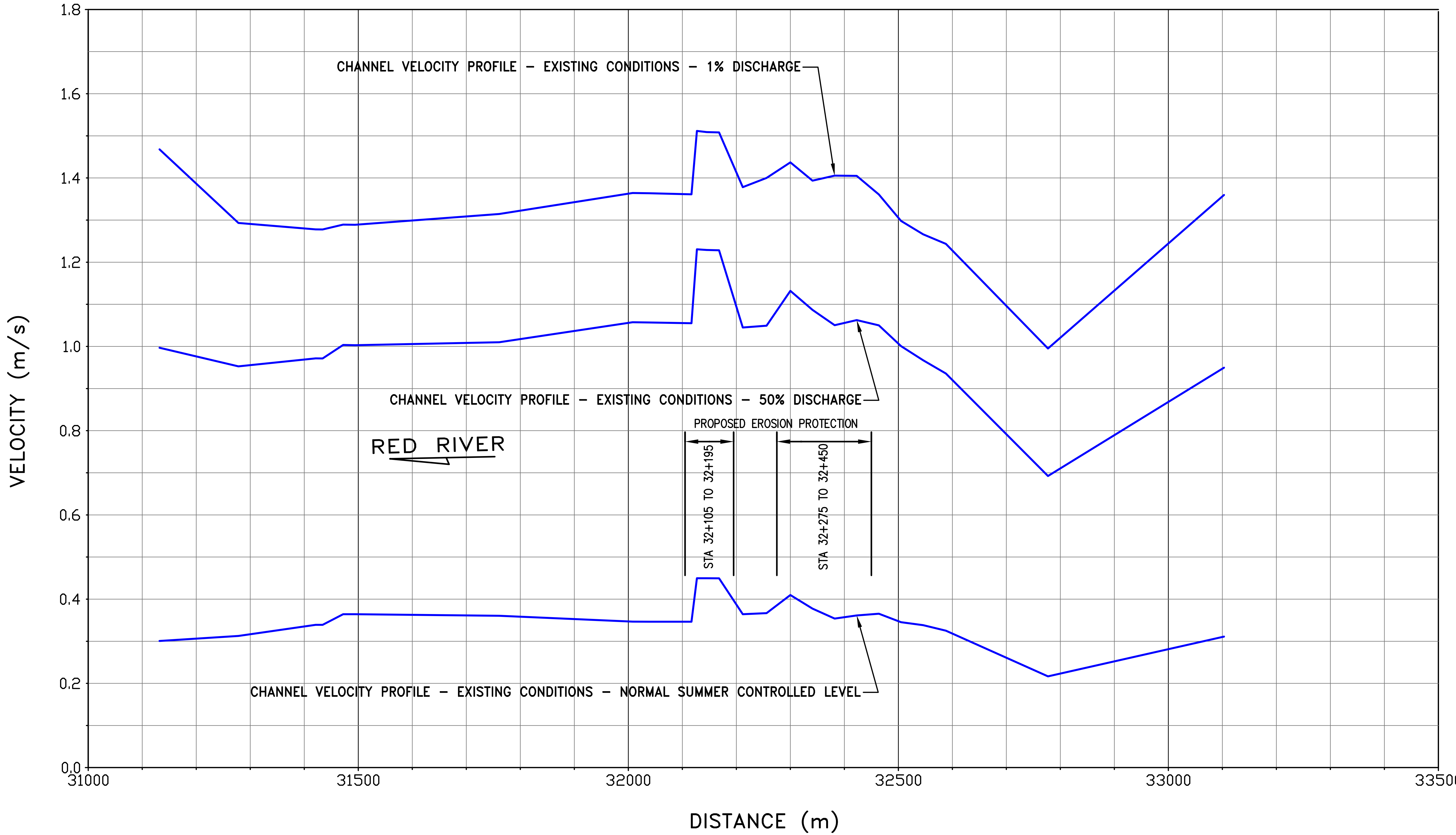
Figures



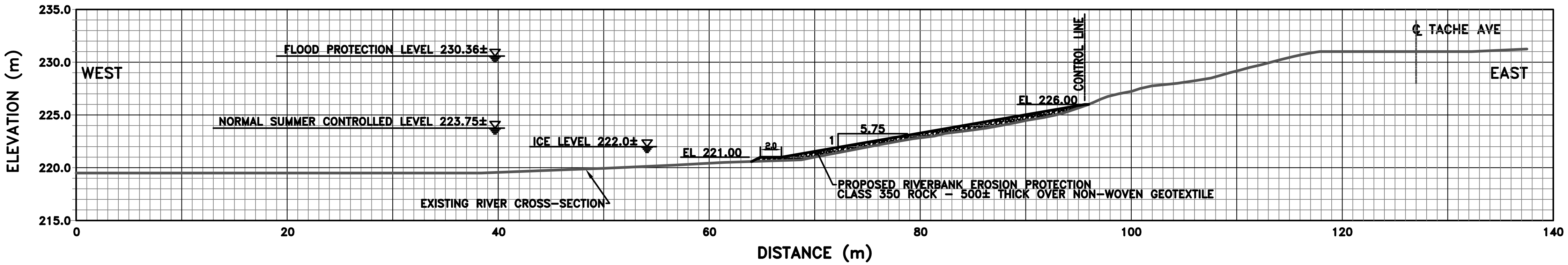
TACHE PROMENADE – RED RIVER
LOCATION PLAN
FIGURE 1



TACHE PROMENADE – RED RIVER
WATER SURFACE PROFILES
EXISTING CONDITIONS
FIGURE 2



TACHE PROMENADE – RED RIVER
RIVER VELOCITY PROFILES
EXISTING CONDITIONS
FIGURE 3



SECTION A–A – STA 32+164
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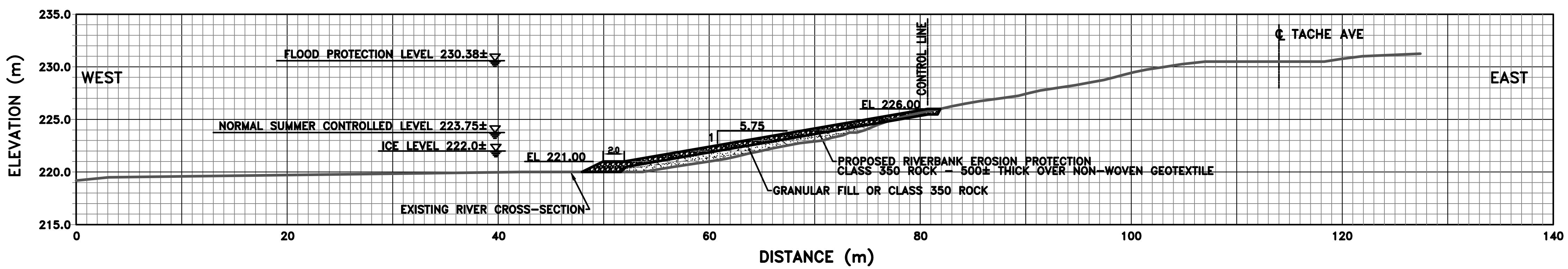

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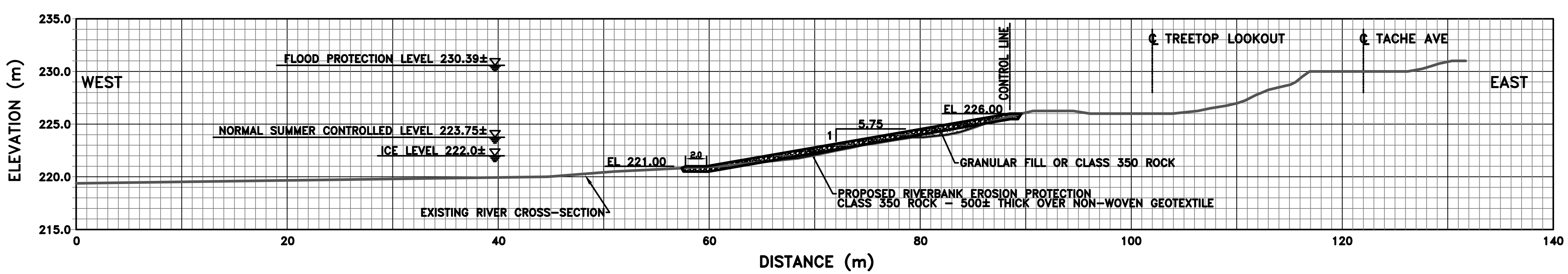

SECTION C–C – STA 32+372
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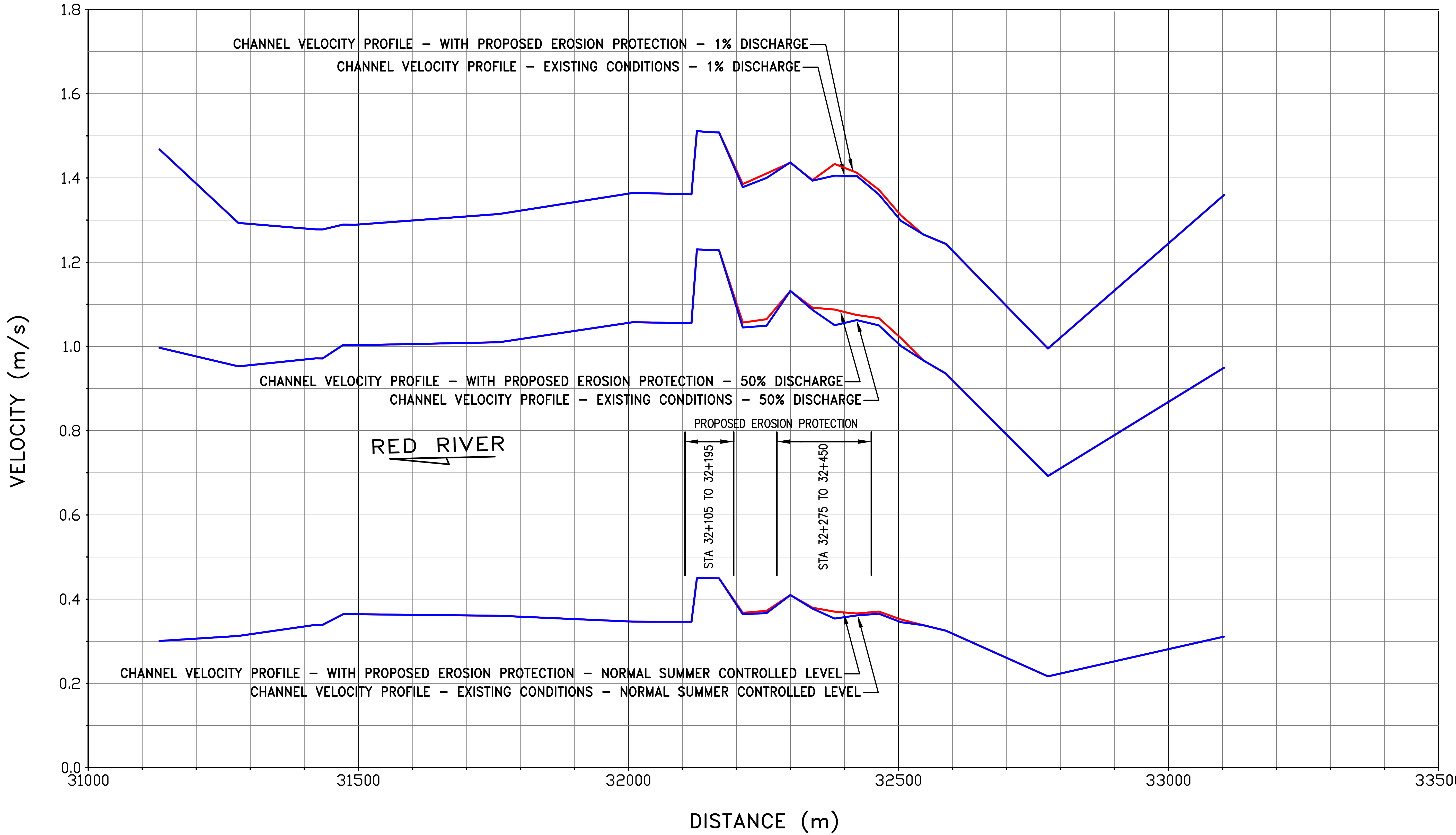
NOTES
1) RIVER SECTIONS REFLECT BATHYMETRIC SURVEYS UNDERTAKEN BY NORTH–SOUTH (JUNE 2017) AND LIDAR (2013)

TACHE PROMENADE – RED RIVER
PROPOSED RIVERBANK
EROSION PROTECTION SECTIONS
FIGURE 4



TACHE PROMENADE – RED RIVER
RIVER VELOCITY PROFILES
EXISTING VERSUS PROPOSED CONDITIONS
FIGURE 5

Site Photos

Photo 1 - Red River east riverbank - looking downstream near Sta 32+150

Photo 2 - Red River east riverbank - looking upstream near Sta 32+150

All photos taken May 29, 2017

Photo 3 - Red River east riverbank - looking upstream near Sta 32+300

Photo 4 - Red River east riverbank - looking downstream near Sta 32+450

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

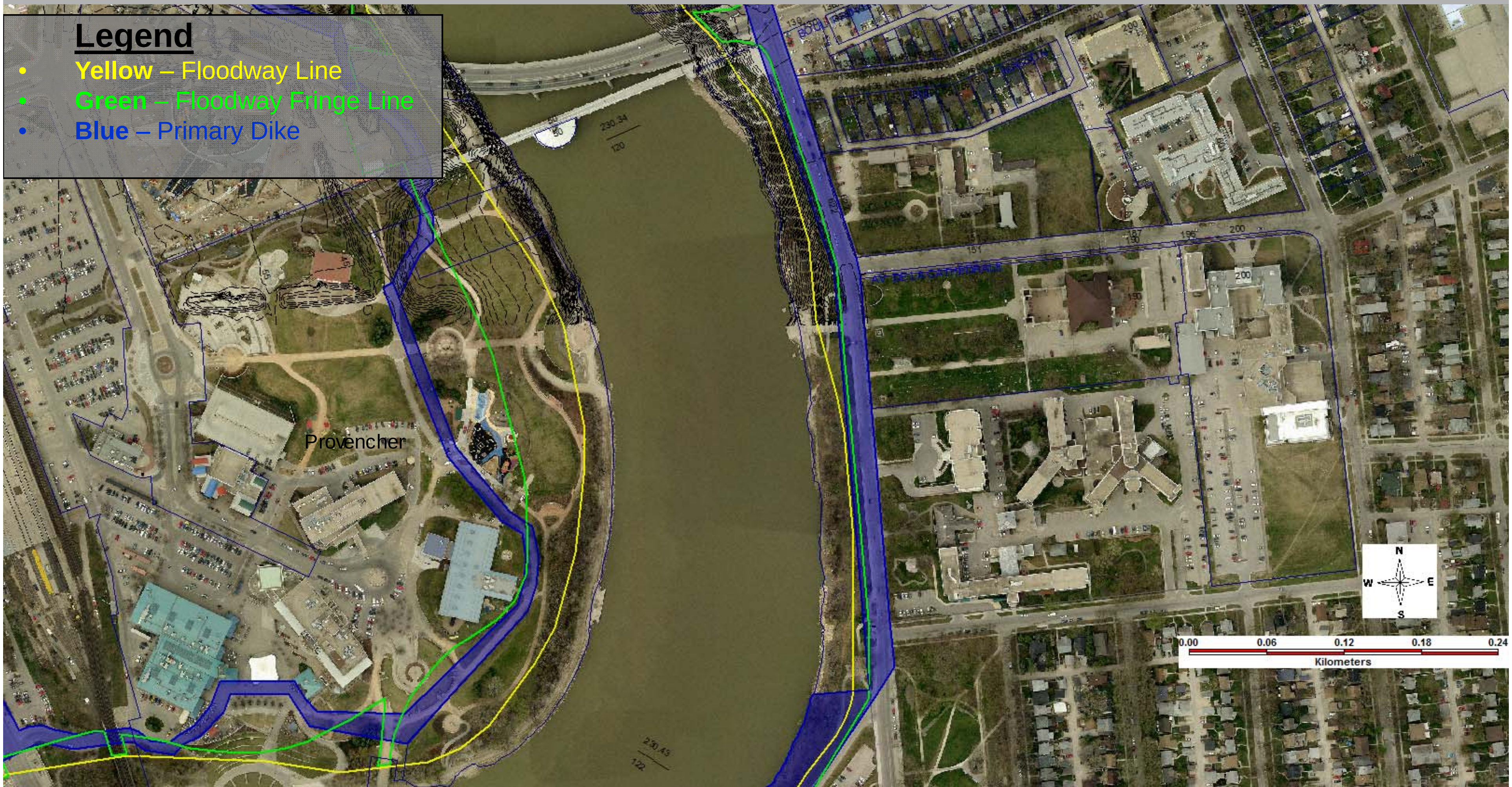
NOTES:

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 – Flood Protection Level Map
City of Winnipeg

Tache between Provencher Bridge and Main St Bridge - Section 1



•This lot is located in the Floodway and Floodway Fringe area. Any new development is governed by Manitoba Regulation 266/91 and the City of Winnipeg Charter. No development is allowed in the "Floodway Zone", the area between the Floodway line and the river. This lot is **outside the Primary Line of Defence (PLD)** and must be developed at or above the **Flood Protection Level (FPL),** which varies and must be interpolated from the elevations on the river above, and must conform to Regulation 266/91. See attached regulation.