APPENDIX 'H'

2016 HYDROLOGIC AND HYDRAULIC ASSESSMENT

Seine River at Fermor Avenue
Bridge Crossing Replacement
Hydrologic and Hydraulic Assessment

May 2016

City of Winnipeg
Public Works

Bruce Harding Consulting Ltd

Seine River at Fermor Avenue
Bridge Replacement
Hydrologic and Hydraulic Assessment

PROVINCE OF MANITOBA
ORIGINAL
SIGNED BY
W. B. J.
HARDING
May 26, 2016
REGISTERED PROFESSIONAL ENGINEER

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

Prepared by: Bruce Harding, P.Eng.

May 2016

City of Winnipeg
Public Works

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1 Introduction

This report summarizes the results of our hydrologic analysis and hydraulic assessment of the Seine River for the replacement of the Fermor Avenue Bridge crossing in the City of Winnipeg. The location of the site is indicated on Figure 1. The existing three span bridge crossing has reached the end of its service life and requires replacement.

Pertinent features of the site are as follows:

- Jurisdiction - City of Winnipeg
- Watercourse - Seine River
- Flow Direction - Southeast
- Designation of Drain Map - No. 9
- UTM Coordinates - 636930E, 5524575N (Zone 14)

Fisheries and Oceans Canada has indicated that this reach of the Seine River near the site has Type A – complex habitat with indicator species[1] (refer to appended map) , therefore the design of the proposed crossings will adhere to the Manitoba Stream Crossing Guidelines[2] with respect to providing fish passage.

For this assessment it has been assumed that the waterway would be navigable therefore any proposed crossing will be subject to the specific requirements for vertical and horizontal clearances under the Navigable Water Protection Act. Note however that a request to Transport Canada to determine navigability for this location has not been undertaken to date.

The existing bridge crossing has been proposed to be replaced with twinned three span bridge structures on the same alignment. Additional details with respect to the hydrologic assessment and the hydraulic sizing of the replacement structure options are summarized in the following sections.

1 "Fish Habitat Classification for Manitoba Agricultural Watersheds", Map 062H14, March 2008, Fisheries and Oceans Canada.
2 "Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat", Manitoba Natural Resources –Fisheries Department and the Canadian Department of Fisheries and Oceans, May 1996.

2 Hydrology

2.1 Flood Hydrology

The Seine River watershed, which has a total drainage area of approximately 1470 km^2, is heavily regulated by diversions and as such the hydrology of the river is significantly altered particularly within the City of Winnipeg. The diversion of the Seine River flows at the Floodway has the most influence on the hydrology of the waterway through the City of Winnipeg. The flows into the City are restricted to the conveyance capacity of the Floodway inverted siphon, which has been estimated to be approximately 4.2 m^3/s. Additional inputs into the Seine River within the City occur from the Floodway downstream to the Red River from lateral drains, including the Navin Drain Bibeau Drain and Dugald Drain, along with numerous storm sewer outfalls.

The flood hydrology for the Seine River, downstream through the City was interpreted from the "Seine River Hydrology Study" Report[3] and the "Seine River, Riffle Site Development Plan" Report[4]. Table 1 summarizes the hydrology for the Seine River from the Floodway downstream to the Red River.

Table 1
Seine River - City of Winnipeg Reach
Flood Hydrology Estimates

Location	50% Discharge (m^3/s)	10% Discharge (m^3/s)	1% Discharge (m^3/s)
Seine River Siphon (Floodway)	4.2	4.2	4.2
At Prairie Grove Road	6.8	8.5	12.0
At Creek Bend Road	7.4	9.3	15.6
AtSouth Glen Boulevard	7.9	9.9	17.0
At Navin Drain (Fermor Avenue reach)	**10.8**	**13.6**	**21.2**
At Bibeau Drain	13.6	17.0	24.1

The 1% flood discharge of 21.2 m^3/s will be selected as the design discharge for the Fermor Avenue crossing replacement.

3 "Seine River Hydrology Study", for the City of Winnipeg prepared by Acres Consulting Services, 1978
4 "Seine River, Riffle Site Development Plan, Technical Report" for Save or Seine prepared by Denis Andrews Consulting. March 2000

2.2 Red River Backwater Influence

The backwater effect due to elevated levels on the Red River, have a large influence on the hydraulics of the Seine River including the hydraulics of the river at Fermor Avenue. The backwater influence from the Red River can extend as far upstream as the Perimeter Highway (PTH 101) as observed during the 1997 Flood. On that basis, the hydraulics of the Seine River will be assessed over a range of backwater conditions due to elevated Red River levels from the normal summer (controlled) levels of 223.8 m or 6.7 ft James Avenue Pumping Station Datum (JAPSD) up to the Flood Protection Level of 230.0 m or 27 ft JAPSD.

3 Hydraulic Assessment – Existing Conditions

The existing Fermor Avenue crossing of the Seine River is a three span 55 m long concrete girder bridge. The bridge is located at the end of a meander bend, with the channel skewed approximately 12^{o}, however the bridge is unskewed. The proposed roadway upgrades for Fermor Avenue, in addition to the fact that the existing bridge has reached the end of its service life, warrants replacement of the structure.

The Seine River within the study reach is for the most part a natural channel; however the river has been greatly impacted by urban development and transportation infrastructure. The main channel of the river is heavily meandering with a well defined main channel, with a predominately silty clay bottom. The channel grade through the study reach is approximately 0.08%. The overbank area is heavily vegetated with trees, bushes and shrubs. Although the Seine River through the City of Winnipeg does not experience severe flooding due to the diversion at the Floodway, the river does get affected by the backwater influence from elevated Red River levels during flood, which results in flooding into the overbank area. Photographs of the Seine River and the Fermor Avenue bridge are appended for reference.

A hydraulic assessment of the Seine River within the project area was undertaken to determine the hydraulic characteristics of the waterway and downstream structures which influence the hydraulics of the river and the Fermor Avenue bridge crossing. An existing HEC-RAS model of the Seine River previously developed for other hydraulic studies was used for the assessment. The steady-state backwater model of the Seine 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 backwater model extends approximately 26 km upstream from the Red River to the Floodway. The existing backwater model was assembled from cross-sections, channel profiles and details of the crossing structures surveyed by Acres Consulting (1978), Denis Andrews Consulting (2002), Bruce Harding Consulting (2005/2006), and GDS Surveys (2011). The model was further updated with additional detailed surveys within the Fermor Avenue study reach by GDS Surveys (May 2016).

The backwater model has been developed to the level of detail required to estimate the relative effect of the proposed replacement crossing at Fermor Avenue. The hydraulic parameters typically required for calibration within this lower reach, such as channel roughness, are within the standard range expected for the Seine River.

The estimated water surface profiles for the Seine River within the study area under existing conditions (circa May 2016), with the existing Fermor Avenue bridge structure are shown on Figure 2. Table 2 summarizes the hydraulic assessment for the existing Fermor Avenue bridge.

Table 2
Seine River at Fermor Avenue
Hydraulic Summary for Existing Bridge

Probability	Discharge (m^3/s)	Water Level Downstream of Crossing (m)	Water Level Upstream of Crossing (m)	Headloss (m)	Clearance to Underside of Girder * (m)	Bridge Opening Velocities (m/s)
Low Red River Levels (no backwater)						
50% Discharge	10.8	226.99	227.01	<0.05	4.19	0.55
10% Discharge	13.6	227.22	227.24	<0.05	6.96	0.55
1% Discharge	21.2	227.54	227.57	<0.05	3.63	0.65
Elevated Red River Levels (backwatered) - assumes 50% Discharge						
12' JAPSD**	10.8	227.03	227.05	<0.05	4.15	0.55
18' JAPSD**	10.8	227.47	227.48	<0.05	3.72	0.35
24.5' JAPSD**	10.8	229.24	229.24	<0.05	1.96	0.10
Elevated Red River Levels (backwatered) - assumes Flood Protection Level of 230.0						
50% Discharge	10.8	230.03	230.03	<0.05	1.17	0.10
1% Discharge	21.2	230.09	230.09	<0.05	1.11	0.15

* - underside of girder at approximately el 231.2 m

** - Red River at junction with Seine River referenced to James Avenue Pump Station Datum (JAPSD) of 727.586 ft

4 Hydraulic Assessment – Proposed Crossing Replacement

4.1 General

The existing bridge crossing has been proposed to be replaced with twinned three span bridge structures on the same alignment The proposed replacement crossings will continue to be bridge structures due to the site geometry and the flow conditions observed at this location, with the centre span clearing the main channel of the Seine River.

4.2 Hydraulic and Regulatory Design Criteria

The hydraulic design criterion selected for the replacement crossing is as follows:

- Design discharge – governing condition with either :
  - 1% discharge with low Red River levels (no backwater)
  - 1% discharge with Red River at Flood Protection Level (FPL) at 230.0 resulting in a backwater condition.
- Maximum headloss of 0.3 m during the passage of the design discharge. Due to the close proximity of these two structures, the headloss would the total due to both structures.
- Bridge opening velocities less than 1.5 m/s for discharges up to the design discharge
- Underside of girder elevation to remain minimum of 0.3 m above water surface during passage of design discharge.

The Seine River has been judged to be navigable by Transport Canada; therefore any proposed crossing will be subject to the specific requirements for vertical and horizontal clearances under the Navigable Water Protection Act. The following vertical and horizontal clearances for small watercraft (canoes, kayaks, etc.) were assumed to be provided:

- Provide a minimum vertical clearance of 1.5 m from the underside of girder to the water surface corresponding to the 50% (Q2) discharge.
- Provide a minimum clear horizontal width of 3 m within the bridge opening at the water surface corresponding to the 50% (Q2) discharge.

Bridge structures do not typically require the same strict limiting velocity requirements for fish passage as those of culvert type structures. The shape of the bridge opening with sloping banks at the abutments, provides lower velocity fringe zones to permit upstream fish passage. As such, the requirement for limiting velocity is typically not applied except under extenuating circumstances. On that basis, there are no concerns or design requirements with respect to fish passage with a bridge structure at this location.

4.3 Replacement Structures

It is proposed that the existing bridge be replaced with twinned structures, dividing the east and westbound lanes of traffic. The proposed replacement structures for this site are as follows:

- Three span 52 m long bridges. The 52 m long bridges consist of 15.6 m long approach spans with a 20.8 m long centre span.
- The proposed structures would be constructed without skew and would be offset slightly south and 2.4 m west relative to the existing bridge.
- The proposed underside of girder elevation of 231.2 has been selected to approximately match the existing underside of girder elevation. Typically a bridge is not lowered relative to the existing structures, however if judged necessary, then the minimum underside of girder elevation that should be considered would be 230.4 m.
- The proposed replacement structures will require the removal of the existing bridge and abutments. The channel slopes (headslopes) upstream, beneath the bridge and downstream, will be excavated with a slope of 4:1 extending down from the abutments to the channel base. The channel base and slopes would be armoured with a 0.525 m thickness of Class 350 rock placed over non-woven geotextile. The channel base would be reshaped with a width of 7.0 m and a finished elevation of 224.9.
- Rock armour to extend 10 m upstream and downstream of the outside faces of the replacement bridge structures.
- Channel reshaping to extend 24 m upstream and 47 m downstream of the outside faces of the replacement bridge structures.
- Refer to the detail sketches of the proposed bridge structure on Figures 3 and 4.

The backwater model of the Seine River was modified to incorporate the proposed bridge replacement structure. The estimated water surface profiles for the Seine River with the proposed replacement bridge structures are shown on Figure 5 while Table 3 summarizes the hydraulic assessment.

The proposed bridge structure length/configuration is governed primarily by standard bridge configurations for the site geometry and design discharge water level and not headloss or velocity. A slightly shorter bridge could be considered, however non-standard abutments and side slopes would be required which have a higher cost and may not be acceptable with respect to geotechnical stability.

Table 3
Seine River at Fermor Avenue
Hydraulic Summary for 52 m long 3 span Twin Span Bridges

Probability	Discharge (m^3/s)	Water Level Downstream of WBL Bridge (m)	Water Level Upstream of EBL Bridge (m)	Headloss (m)	Clearance to Underside of Girder * (m)	Bridge Opening Velocities (m/s)
Low Red River Levels (no backwater)						
50% Discharge	10.8	226.99	227.01	<0.05	4.19	0.35
10% Discharge	13.6	227.24	227.24	<0.05	3.96	0.4
1% Discharge	21.2	227.56	227.57	<0.05	3.63	0.45
Elevated Red River Levels (backwatered) - assumes 50% Discharge						
12' JAPSD**	10.8	227.04	227.05	<0.05	4.15	0.35
18' JAPSD**	10.8	227.47	227.48	<0.05	3.72	0.25
24.5' JAPSD**	10.8	229.24	229.24	<0.05	1.96	0.10
Elevated Red River Levels (backwatered) - assumes Flood Protection Level of 230.0						
50% Discharge	10.8	230.03	230.03	<0.05	1.17	0.10
1% Discharge	21.2	230.09	230.09	<0.05	1.11	0.15

* - underside of girder at approximately el 231.2 m

** - Red River at junction with Seine River reference to James Avenue Pump Station Datum of 727.586 ft

4.4 Erosion Control Measures

The velocities within the bridge opening of the proposed twinned bridge structures at Fermor Avenue and the reshaping of the channel will not adversely alter the hydraulics of the river. Velocities are not high, generally less than 0.6 m/s. As such, the requirements for the rock armoring within the bridge opening are not excessive. The proposed Class 350 rock will be more than adequate to resist erosive forces within the bridge opening for the velocities that would be encountered.

Note however there are areas along the meander bend adjacent to Fermor which have steep slopes and evidence of slope failures, Rock armouring may be necessary at these locations to minimize toe erosion which may be reducing slope stability.

5 Other Considerations

Best Management Practices for working near waterways including the appropriate implementation of sediment and erosion control measures should be followed. Exposed slopes not covered with rock should be revegetated and covered with erosion control blanket. Construction activities within the river shall not take place between April 1 and June 15 of any given year. An Environmental Management Plan should be prepared which details the specific environmental management requirements and sediment and erosion control.

Water management during construction can be an important aspect of any project and may influence the cost and scheduling for crossing replacement. Elevated water levels at the bridge would occur as a result of: increased flows in the Seine River during the spring runoff period and following a heavy summer rainfall event; or from the backwater influence of the Red River when that river is under flood which is typically a spring condition however summer flooding is not uncommon. Construction should take place in the late fall and winter period when the potential for runoff is reduced thereby minimizing water management requirements. All instream work should be completed no later than March 15th, with the schedule showing the majority of instream work completed by early March. Although minimal, flows continue throughout the winter and should be considered as part of the water management plan with appropriate measures taken to deal with the flow.

6 Ice Loadings

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

Section 3.12 – *Ice Loads* of the Canadian Highway Bridge Design Code[5] will be referenced to develop ice loading forces for the design of the piers.

6.1 Dynamic Ice Forces

Dynamic forces occur when a moving ice floe strikes a bridge 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 smaller rivers, like the Seine River, the governing ice loads are typically due to crushing and bending/flexure. Note however, the ice and resultant loadings that have been observed on the Seine River would not be excessive due to the reduced flows (upstream diversion) and the heavily meandering nature of the river which breaks up the ice floes.

The effective ice strength varies depending on the air temperatures and the integrity of the ice cover. 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 750 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 750 mm thickness would be considered the upper limit on average for ice thickness within the 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.

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

The code recommends that the acting ice load or impact force for piers parallel to the flow, as would exist at the Fermor Avenue Bridge, be assessed for two load cases as indicated. During breakup, the ice would be confined to the main river channel which would be in alignment with the proposed bridge and the piers.

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 Fermor Avenue Bridges has been estimated to be 227.2 m. The elevation to apply the force can be taken as the centre of the ice cover which is approximately 226.8 m. Corresponding bridge opening velocities are estimated at 0.5 m/s.

Any remedial measures required for the piers should incorporate a rounded or bullet-shaped nose as that form reduces the ice loadings relative to pointed angular noses. The sloping of the upstream face of the pier can also decrease ice loadings by reducing the force necessary to fail the ice by flexure; however this may only be an advantage when the crushing strength is relatively high, however a sensitivity on the slope angle should be assessed to determine if a design advantage exists.

6.2 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 limited ice cover within the proposed bridge opening would not be large enough to generate sufficient static ice forces which would result in an imbalance in forces, therefore no allowance for static forces will be assumed.

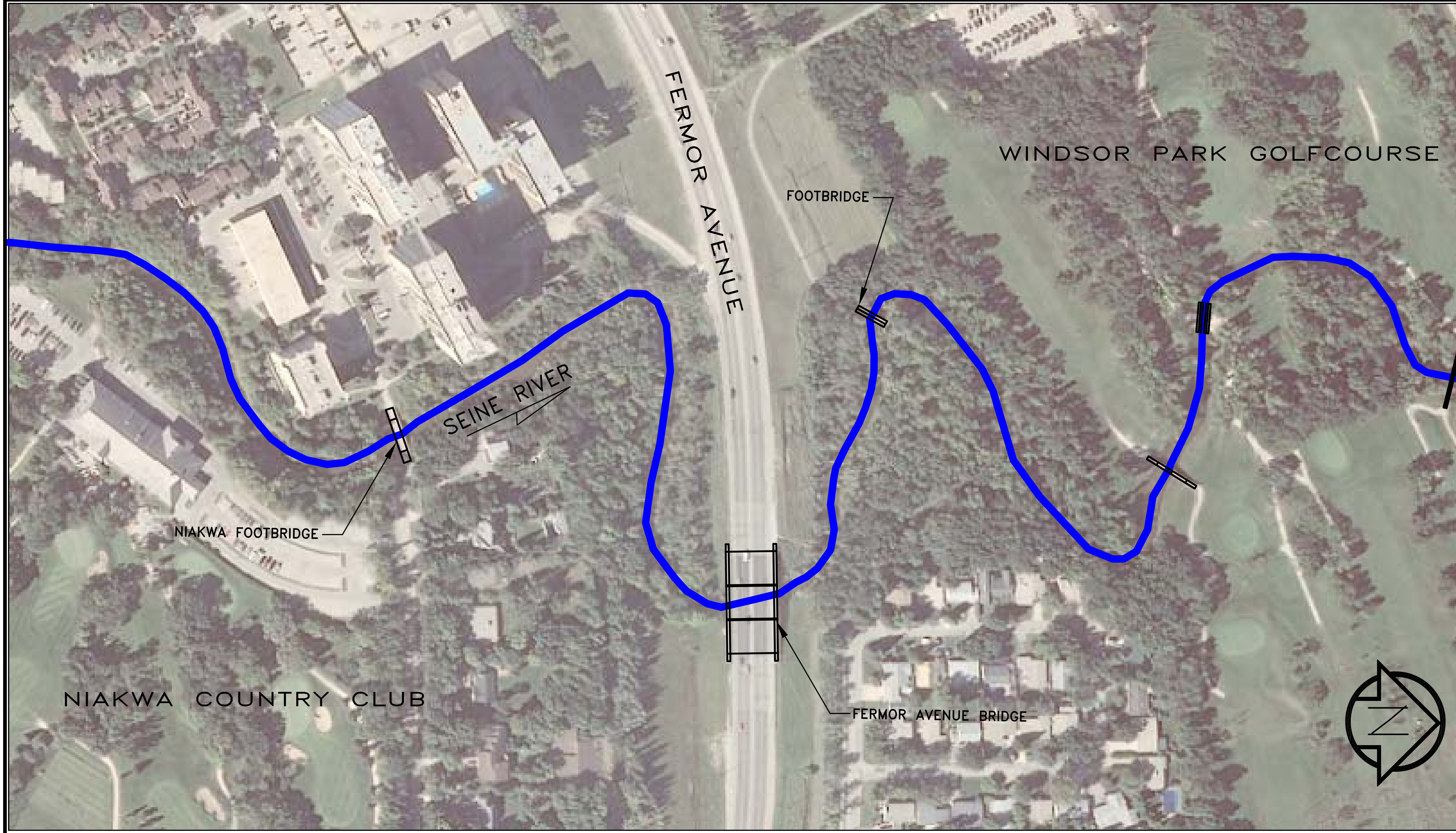
6.3 Ice Jam Forces

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 bridge piers within a river. The code provides guidance with respect to estimating the loading of an ice jam on the bridge piers. For clear openings between piers less than 30 m, a pressure of 10 kPa can be assumed which acts on either one of the lateral faces or the upstream face of the pier over the thickness of the ice jam. Ice jams at this location would be unlikely, again due to the diversion of flows, however the sensitivity of the pier loadings should be assessed for a nominal ice jam thickness. The estimated ice jam thickness is 1000 mm which would be assumed at a water level and corresponding ice surface elevation of 227.2 m.

6.4 Ice Adhesion Forces

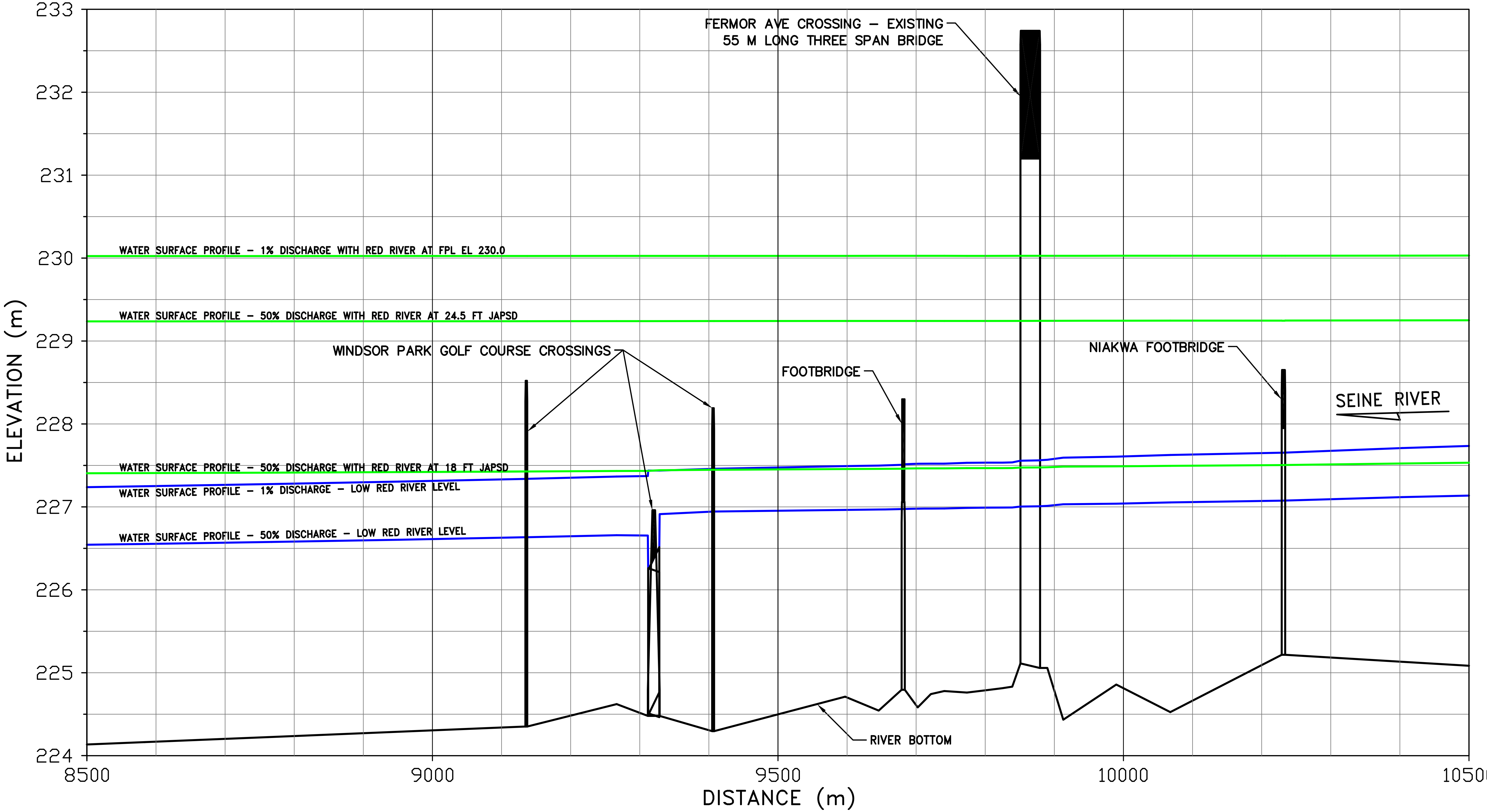
Ice adhesion is generally of concern in areas where rapidly varying water levels can occur such as below a hydroelectric development during ice formation periods. River flows and corresponding water levels within the Seine River throughout the winter period remain relatively stable and would not typically result in significant vertical loadings.

Figures



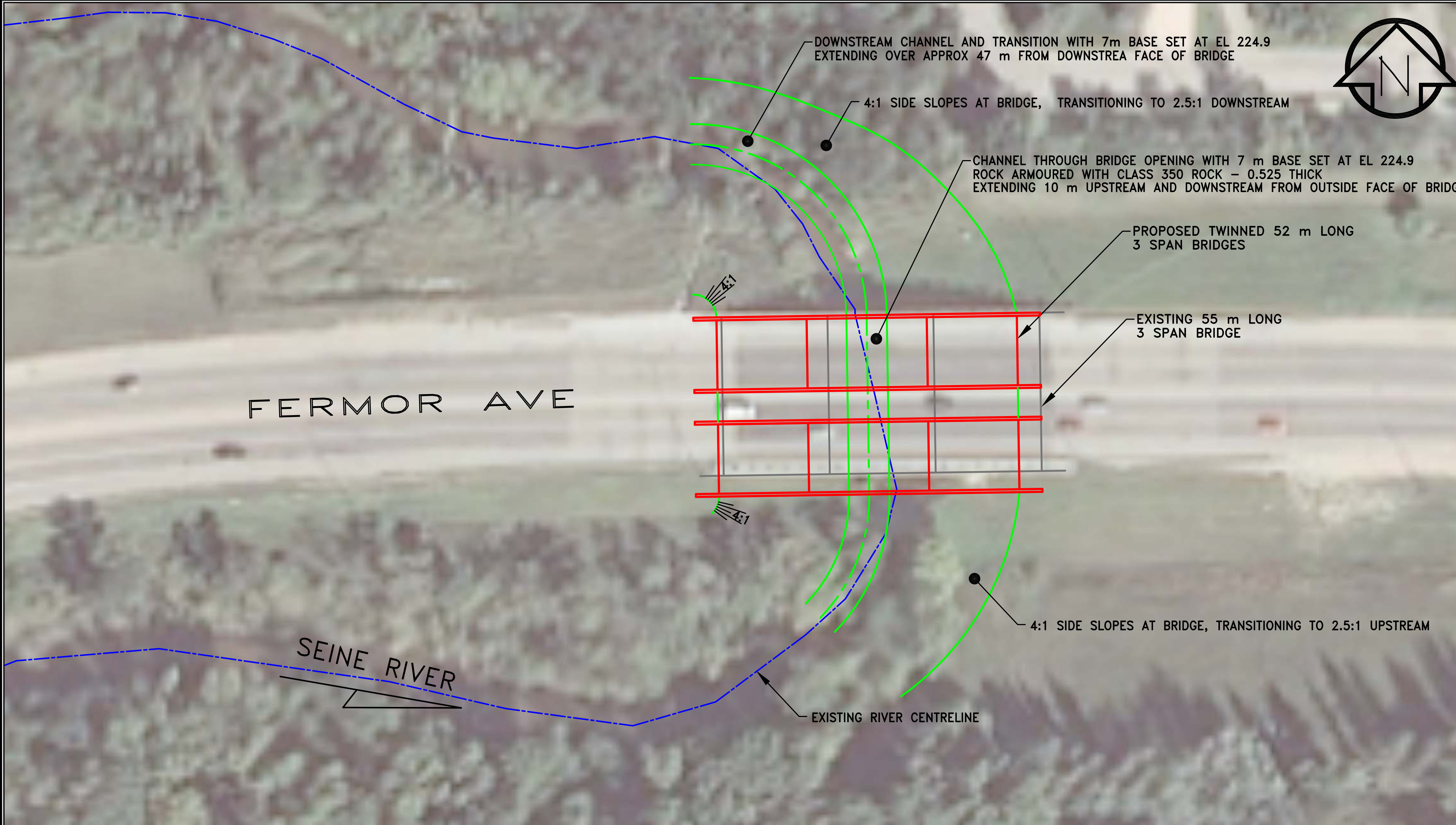
SCALE
100 0 100 200

SEINE RIVER AT FERMOR AVENUE
CROSSING ASSESSMENT AND REPLACEMENT
LOCATION PLAN
FIGURE 1



NOTES:
1) HEC-RAS MODEL DEVELOPED FROM COMPREHENSIVE SEINE RIVER MODEL WITH ADDITIONAL DETAILED SECTIONS WITHIN PROJECT AREA SURVEYED MAY 2016
2) WATER SURFACE PROFILES REFLECT HYDRAULIC CONDITIONS WITH EXISTING 55 M LONG THREE SPAN CONCRETE BRIDGE AT FERMOR AVENUE

SEINE RIVER AT FERMOR AVENUE
WATER SURFACE PROFILES
EXISTING CONDITIONS
FIGURE 2

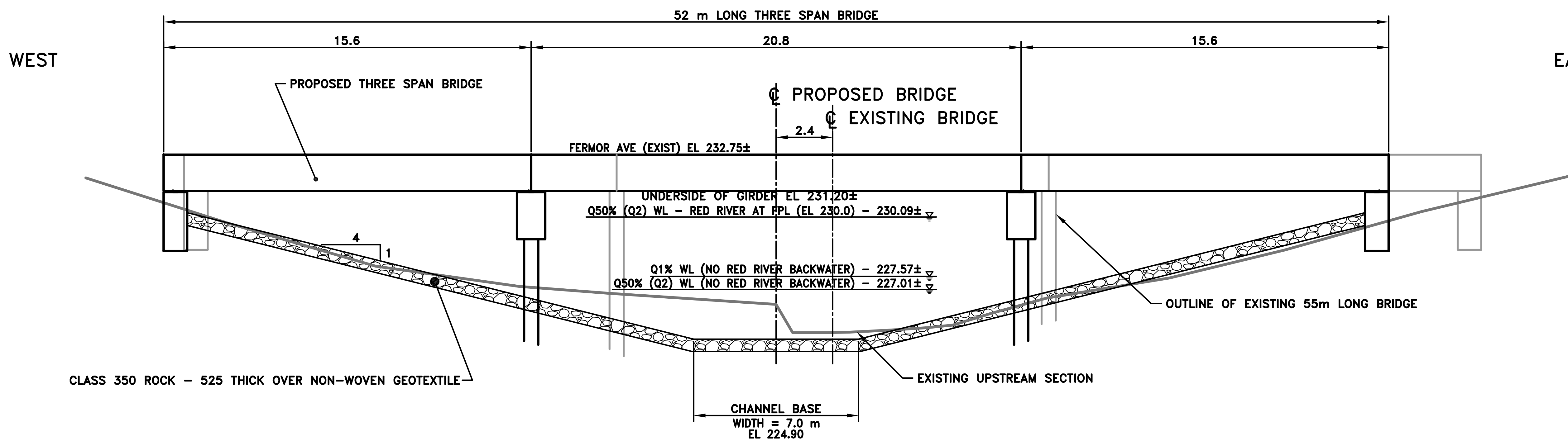


SCALE

25 0 25 50

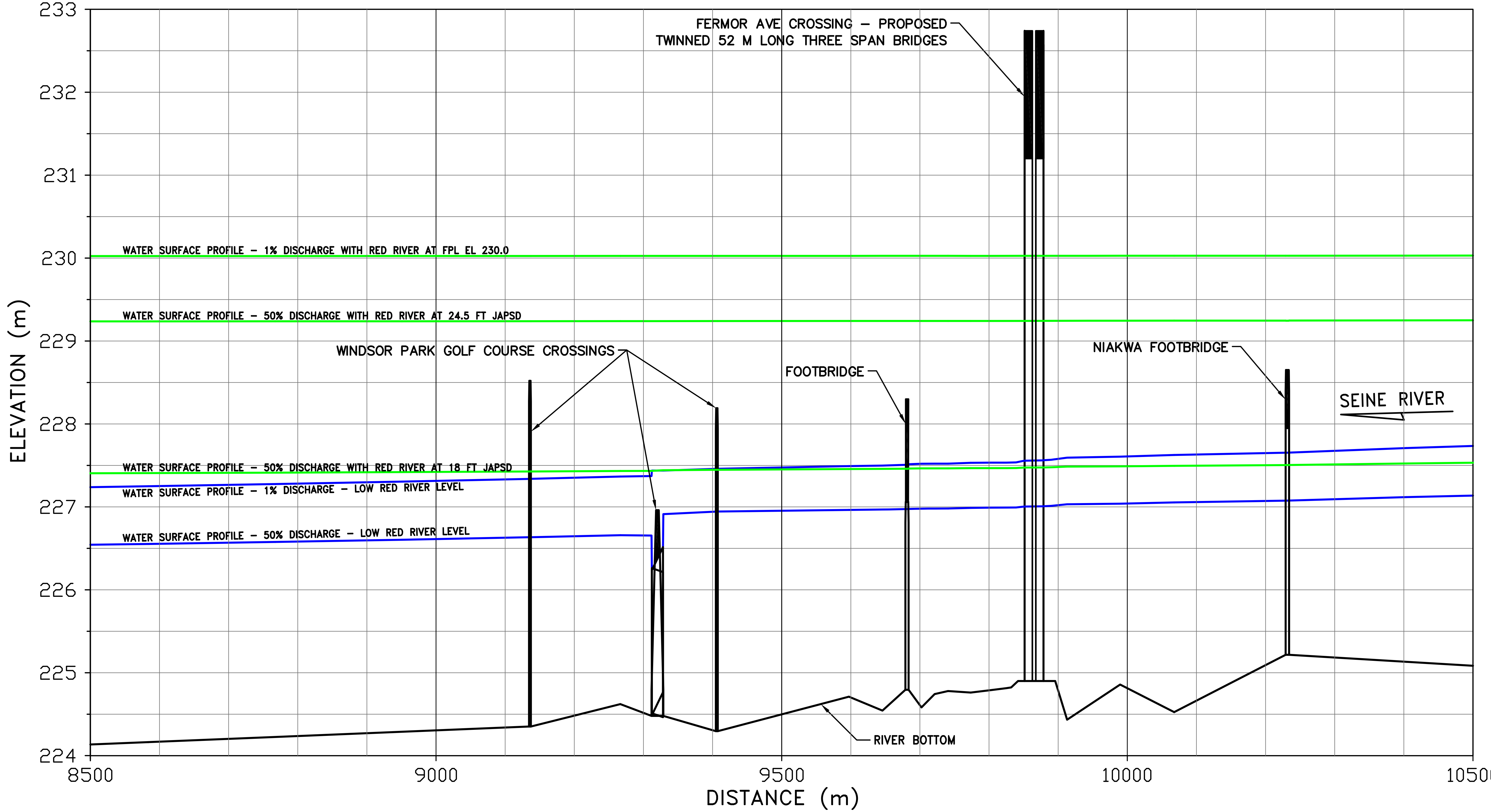
SEINE RIVER AT FERMOR AVE
PROPOSED TWINNED BRIDGES
LAYOUT
FIGURE 3

TWINNED 3 SPAN 52 m LONG BRIDGES



UPSTREAM ELEVATION – EASTBOUND LANE BRIDGE

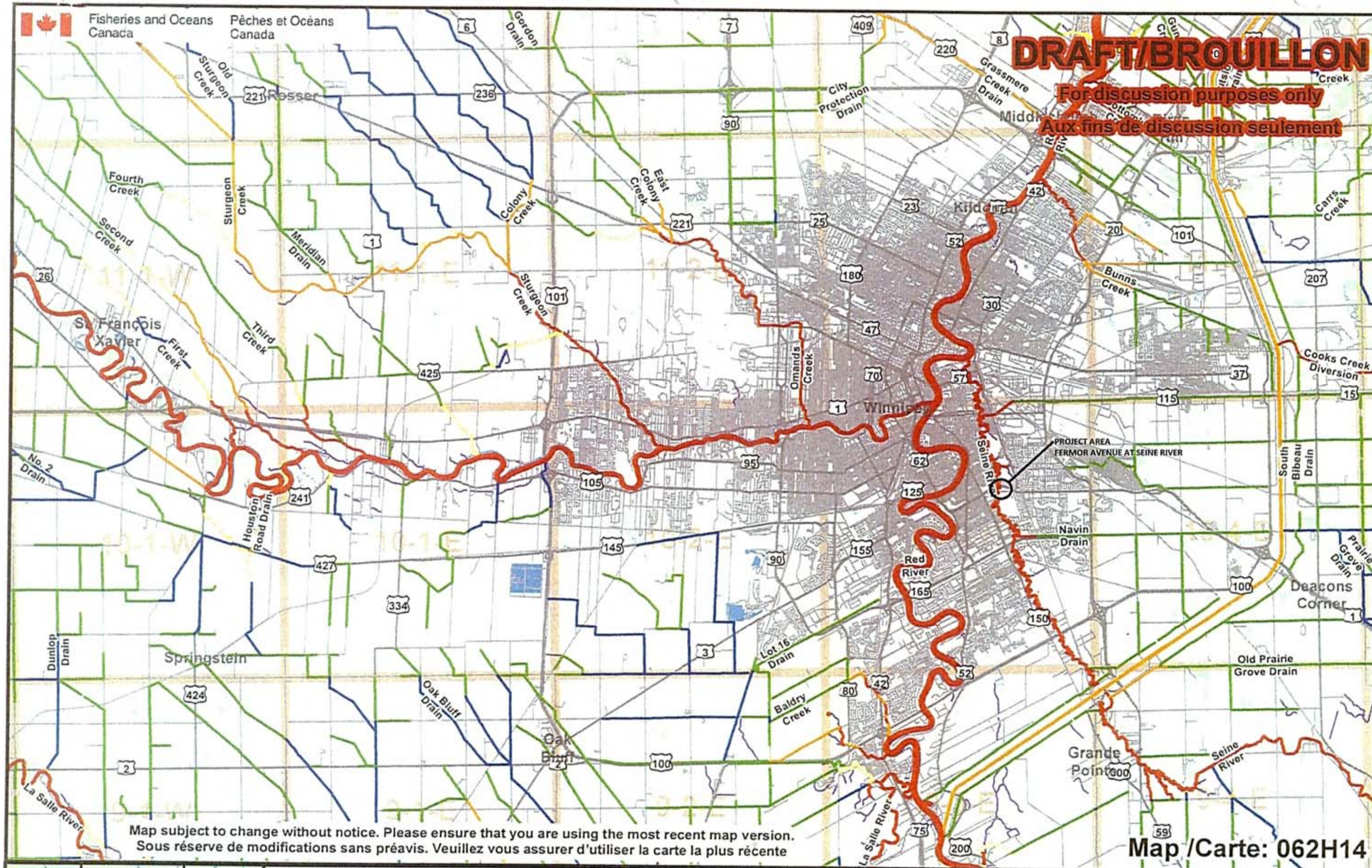
SEINE RIVER AT FERMOR AVE
PROPOSED TWINNED BRIDGES
UPSTREAM ELEVATION
FIGURE 4



NOTES:
1) HEC-RAS MODEL DEVELOPED FROM COMPREHENSIVE SEINE RIVER MODEL WITH ADDITIONAL DETAILED SECTIONS WITHIN PROJECT AREA SURVEYED MAY 2016
2) WATER SURFACE PROFILES REFLECT HYDRAULIC CONDITIONS WITH PROPOSED TWINNED 52 M LONG THREE SPAN BRIDGES AT FERMOR AVENUE

SEINE RIVER AT FERMOR AVENUE
WATER SURFACE PROFILES
PROPOSED REPLACEMENT CROSSING
FIGURE 5

Appendix A
Fish Habitat Classification Map



062I04	062I03	062I02
062H13	062H14	062H15
062H12	062H11	062H10

Kilometers 0 1 2 4 6 8 10 Kilomètres

Miles 0 1 2 4 6 Milles

Map not to be used for navigation/
Ne pas utiliser pour la navigation

Habitat Type/ Type d'habitat	Color/ Couleur
A	
B	
C	
D	
E	
Unclassified/ Non classifié	

Fish Habitat Classification for Manitoba Agricultural Watersheds/ Classification de l'habitat du poisson par rapport aux bassins hydrographiques agricoles au Manitoba

Version 1.0

Valid until March 31, 2008
Valide jusqu'au 31 mars 2008

Canada

Appendix B
Photographs

Seine River at Fermor – Crossing Replacement

Photo No. 1 Seine River downstream of Fermor Avenue Crossing

Photo No. 2 Downstream side of Fermor Avenue Crossing

All photographs taken May 4, 2016

Photo No. 3 Upstream side of Fermor Avenue Crossing

Photo No. 4 Seine River upstream of Fermor Avenue Crossing