NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING
FINAL REPORT

Prepared for:

Alberta

10 April 2020

NHC Ref. No. 1003870

nhc
northwest hydraulic consultants
water resource specialists

NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

FINAL REPORT

Prepared for:

Alberta Environment and Parks
Edmonton, Alberta

Prepared by:

Northwest Hydraulic Consultants Ltd.
Edmonton, Alberta

10 April 2020

NHC Ref No. 1003870

APEGA Permit to Practice - P654

Prepared by:

Dan Healy, PhD, PEng
Principal

Reviewed by:

Gary Van Der Vinne, MSc, PEng
Principal

DISCLAIMER

This report has been prepared by Northwest Hydraulic Consultants Ltd. (NHC) in accordance with generally accepted engineering practices, for the benefit of Alberta Environment and Parks for specific application to the North Saskatchewan River Hazard Study in Alberta. The information and data contained herein represent the best professional judgment of NHC, based on the knowledge and information available to NHC at the time of preparation.

Except as required by law, this report and the information and data contained herein are to be treated as confidential and may be used and relied upon only by Alberta Environment and Parks, its officers and employees. NHC denies any liability whatsoever to other parties who may obtain access to this report for any injury, loss or damage suffered by such parties arising from their use of, or reliance upon, this report or any of its contents.

EXECUTIVE SUMMARY

Alberta Environment and Parks retained Northwest Hydraulic Consultants Ltd. in June 2018 to complete a river hazard study for the North Saskatchewan River. The 111 km long study reach includes the Town of Devon, the City of Edmonton, the City of Fort Saskatchewan and surrounding areas of Parkland County, Leduc County, Strathcona County, and Sturgeon County. The study is being conducted under the provincial Flood Hazard Identification Program; the overall objectives are to enhance public safety and to reduce future flood damages and disaster assistance costs.

The North Saskatchewan River Hazard Study is comprised of eight major project components and this report summarizes the work of the third and fourth components – ***Hydraulic Model Creation and Calibration*** and ***Open Water Flood Inundation Mapping***. These two components included the development of a calibrated hydraulic model, a model sensitivity analysis, computation of flood levels, and flood inundation mapping.

The hydraulic model (the model) was calibrated by adjusting channel roughness so that the computed flood levels matched well with the observed 1986 flood levels. Computed water levels were consistent with water levels collected by NHC during the 2018 cross survey and the model also computed water levels that agreed with those published by Water Survey Canada at the *North Saskatchewan River at Edmonton* gauging station.

Water surface profiles were calculated for 13 flood scenarios representing the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year open water flood events. There is no evidence in the systematic flood record for significant flooding due to ice jams, and thus ice jam flood scenarios were not calculated for this study. The computed flood levels were used to determine the extent of inundation for each of the respective flood scenarios and are presented as a set of flood inundation maps for each scenario (the flood inundation map library). This library is intended primarily for stakeholders to use in emergency response planning and preparation.

CREDITS AND ACKNOWLEDGEMENTS

Northwest Hydraulic Consultants Ltd. would like to express appreciation to Alberta Environment and Parks for initiating this project, making extensive background information available, and providing the project team with valuable technical input throughout the project. Mr. James Choles managed and directed the North Saskatchewan River Hazard Study on behalf of Alberta Environment and Parks.

The following NHC personnel were part of the study team and participated in this study component:

- Dan Healy (Project Manager and Hydraulic Modelling Lead) provided the overall direction of the hazard study and was the technical lead for this study component. He was the primary author of this report and was responsible for model development and application.
- Rebecca Himsl (GIS Analyst) created the mapping products and developed the associated digital asset deliverables (including the inundation map libraries).
- Makamum Mahmood (Project Engineer) provided support in hydraulic model development, flood history documentation, and cataloguing of the model results.
- Gary Van der Vinne (Technical Reviewer) provided technical review.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

1.1 Study Background

The North Saskatchewan River Hazard Study was initiated by Alberta Environment and Parks (AEP) to identify and assess river and flood hazards along the North Saskatchewan River, within the Town of Devon, City of Edmonton, City of Fort Saskatchewan, and surrounding areas of Parkland County, Leduc County, Strathcona County, and Sturgeon County. This study was undertaken as part of the Flood Hazard Identification Program (FHIP). The goals of FHIP include the enhancement of public safety and reduction of future flood damages through the identification of river and flood hazards. Project stakeholders include the provincial government, local authorities, and the public.

This flood hazard study is larger in scope and scale than the three previous studies of the North Saskatchewan in and near Edmonton by Philips Planning & Engineering Limited (1994), I.D. Group (Alberta) Inc. and CartoLogix Corporation (1995), and Northwest Hydraulic Consultants Ltd. (2007). The first study reach extended from the city limits of Fort Saskatchewan upstream to the High Level Bridge in Edmonton. The second study extended from the High Level Bridge upstream to the southwest boundary of Edmonton. The third study included these two reaches plus an additional 17 km upstream to Devon and an additional 18 km through Fort Saskatchewan.

This study is comprised of the eight major components:

1) Survey and Base Data Collection
2) Open Water Hydrology Assessment
3) Hydraulic Model Creation and Calibration
4) Open Water Flood Inundation Map Production
5) Open Water Flood Hazard Identification
6) Governing Flood Hazard Map Production
7) Flood Risk Assessment and Inventory
8) Channel Stability Investigation

Reporting and associated deliverables were prepared separately for each.

1.2 Objectives

This report summarizes the work of components three and four: ***Hydraulic Model Creation and Calibration,*** and ***Open Water Flood Inundation Map Production***. The following primary tasks, services, and deliverables are associated with this report:

- Documentation of the open water flood history.
- Creation, calibration, and validation of a HEC-RAS hydraulic model for the study reach.

- Application of the HEC-RAS model for computation of the selected return-period flood water level profiles along the study reach.
- A sensitivity analysis on key model input parameters.
- Production of flood inundation maps.

The development of the hydraulic model and the production of the inundation maps are foundational to the overall study and are required for the identification of flood hazard areas along the study reach.

1.3 Study Area and Reach

Figure 1 depicts the location and boundaries of the river hazard study area and the upstream watershed. The study reach includes 111 km of the North Saskatchewan River from the western edge of quarter section boundary 32-50-26-W4 to the eastern edge of 35-56-21-W4. The study reach extends along the Town of Devon, City of Edmonton, City of Fort Saskatchewan, Parkland County, Leduc County, Strathcona County, and Sturgeon County. Additional river cross sections were surveyed beyond the study boundaries to facilitate hydraulic modelling and inundation mapping near the study area limits.

The contributing watershed covers a total area of about 32,900 km^2, extending from the headwaters of the North Saskatchewan River in the Rocky Mountains to the downstream boundary of the river hazard study area. High flows along this reach are typically dominated by snowmelt in the spring and early summer. Larger floods typically occur when snowmelt coincides with major rainfall events in the foothills.

The following characterization of the study reach is based on prior investigation by Kellerhals, Neill, and Bray (1972). The main channel of the North Saskatchewan River through the study reach can be characterized as an entrenched channel that cuts through a moderately forested valley of lacustrine origin. At the upstream end of the study reach between the Devon and Fort Saskatchewan, the channel has an irregular meandering pattern. Downstream of Fort Saskatchewan, the channel pattern is relatively straight. Throughout the study reach, point bars and side bars are observed within the active channel. The river has an overall slope of 0.00035 m/m. River bed material consists of a shallow gravel layer over easily erodible shale. The channel banks consist of silt over gravel on erodible bedrock.

2 FLOOD HISTORY

A description of local flood history has been prepared to provide context for the hydraulic model creation and calibration. The flood history documentation includes observational information and historical records for open water and ice jam flooding. **Appendix A** provides photography documenting historic and recorded floods**.**

2.1 Open Water Floods

2.1.1 Historic and Observed Open Water Floods

Water Survey Canada (WSC) began systematic gauging of the North Saskatchewan River in 1911. Prior to this, flood events occurred in 1820, 1825, 1827, 1829, 1832, 1833, 1850, 1857, 1862, 1863, 1864, 1866, 1884, and 1889. Descriptions of these historic floods have been summarized by others in previous hydrological studies (AENV 1981 and 1990). **Table 1** provides excerpts for the more notable historic floods from these prior studies.

Table 1 Historic and observed open water floods

Date	Details
1825	One of the earliest historic flood events occurred during the summer of 1825. Previous investigators found accounts of flood events in the Hudson's Bay Company archives (AENV 1990). These indicate that the entire plain surrounding the Fort in Ross Flats (now Rossdale) flooded and everyone left the Fort to wait out the flood for several days. The flood damaged the buildings and gardens. An entry in the *Lesser Slave Lake Journal* in fall 1825 made reference to the flood at Edmonton House, noting that "*the River was higher this June than has been known for the last 30 Years it rose at the Fort upwards of 18 feet they Had to abandon the Fort with Goods which they embarked in a Boat in the Fort the water rising three feet in the Houses*" (AENV 1990).
1829	Destruction and subsequent relocation of the Fort to higher ground has been attributed to the flood of 1829. The following recounts the descriptions found by previous investigators (AENV 1990). *"Fort Edmonton has a fine commanding situation, on an almost perpendicular part of the bank of about 200 feet in height; it formerly stood a little lower down the stream, about a furlong from its present position where the bank is not so much elevated, but a remarkable flood in the year 1829 destroyed the establishment which was then removed to its present site."*
17-19 August 1899	The Low Level Bridge was under construction during the 1899 flood and the *Edmonton Bulletin* (1899) reported that the river rose in response to heavy rainfall which resulted in overtopping of the bridge pier caps and abutment seats. The August 1899 flood is the largest flood in historic records prior to the 1915 flood. Flows peaked at an estimated 5100 m^3/s as water levels rose to an elevation of 620.19 m at the Low Level Bridge crossing site. The proposed design elevations of the bridge piers were subsequently raised 2.44 m (AENV 1981). **Appendix A** includes some of the photographs taken during the 1899 flood.
1900	Limited descriptive accounts of the 1900 flood are available in previous studies. Water levels at the gauge reached 11.55 m and WSC reported an estimated peak discharge of 4250 m^3/s.

2.1.2 Recent and Recorded Open Water Floods

The following recounts the major recent and recorded floods (1915, 1972 and 1986) occurring on the North Saskatchewan River at Edmonton.

June 1915 Flood

The flood of 27-29 June 1915 is the largest flood of record for the North Saskatchewan River at Edmonton. The peak discharge was estimated at 5800 m^3/s on 28 June 1915 by Water Survey Canada (WSC). At that time, the direct flood damages to public and private property were estimated to between $500,000 and $750,000. The communities of Fraser Flats (now Riverdale), Ross Flats (now Rossdale), and Gallagher Flats (now Cloverdale) were all inundated. Many homes were destroyed, approximately 800 families rendered homeless, and the Edmonton Lumber Company mill washed away. Two hundred families were relocated to a designated flood relief centre in Gallagher Flats, but soon after had to be relocated again when the relief centre flooded. *History of Floods in the North Saskatchewan River Basin* (AENV 1981) well documents the 1915 flood, and the City of Edmonton website provides the following chronology of this event (City of Edmonton n.d.).

- On June 27th, an Edmonton businessman, John Walter, was awakened at 2 AM by a telephone call from Rocky Mountain House warning him that the river was rising there. In Edmonton, the river began to rise at 6 AM and the Mayor was notified. The police and fire departments issued a flood warning and prepared for evacuation. By 6 PM, floodwaters spilled over the river banks into the floodplain inundating nearby homes.
- On June 28th, the North Saskatchewan River had risen to 17 feet (5.2 m) at the gauge; by 3:30 AM it was rising approximately 1 foot (0.3 m) every hour. At 11 AM, the City issued calls for help with evacuation efforts as river levels rose to 24 feet (7.32 m) – the Low Level Bridge was now closed. By 10 PM, Edmonton's power plant was flooded, and by 11:30 PM the pumping plant was closed – meaning power and treated water were no longer available (*Edmonton Bulletin* June 29th, 1915).
- By early morning of June 29th, the North Saskatchewan peaked at 45 feet (13.72 m) above the low water mark. By 10:30 PM that day, power was restored.
- On June 30th, river levels started to subside and unfiltered water was supplied to residents; a boil water advisory continued (*Edmonton Bulletin* July 1st, 1915).
- By July 2nd, most of those impacted by the flood were expected to return to their homes shortly (*Edmonton Bulletin* July 2nd, 1915).

Appendix A includes several photographs taken during the 1915 flood.

June 1972 Flood

In June 1972, intense rainfall in the foothills region resulted in flooding throughout the study reach. Several climate stations reported rainfall from 100 to 150 mm in less than 48 hours (AENV, 1981). On June 27th, the WSC gauge at Edmonton recorded a peak instantaneous discharge of 3200 m^3/s. Reported flood damages were very minimal – some gardens and lawns were inundated in Rossdale, Riverdale, and Cloverdale (AENV 1981). **Appendix A** includes several photographs taken during the 1972 flood.

July 1986 Flood

The 1986 flood is the largest flood recorded since completion of the Brazeau and Bighorn Dam Projects. On July 19th, the WSC gauge at Edmonton reported a peak discharge of 4520 m^3/s. Areas adjacent to the river banks in the Riverdale, Rossdale, and Cloverdale communities were inundated and basements flooded. Total costs resulting from flood damage were estimated at $40 million (*Edmonton Journal*, July 1st, 1986). High water levels were identified and surveyed by the Province after the flood. This well-documented flood was used to calibrate the hydraulic model of the current study. **Appendix A** includes several photographs taken during the 1986 flood.

Table 2 lists the measured peak discharge rates, as reported by WSC for the Edmonton gauge (North Saskatchewan River at Edmonton, 05DF001), for the largest recorded open water flood events. The three floods described above are listed, plus the high water events of 1923, 1944, 1952, 1954, 1990, 2005, and 2013.

2.2 Ice Jam Floods

There is no evidence in the systematic flood record for significant flooding due to ice jams. One historical account attributed Ross Flats flooding to accumulated river ice, and further suggested that the relocation of Edmonton House to higher ground was motivated by ice-related flooding (*Edmonton Bulletin* August 21st, 1899; AENV 1990).

Table 2 Peak discharges for recent and recorded open water floods – North Saskatchewan River at Edmonton (05DF001)

Date	Peak discharge (m^3/s)*
29 June 1915	5,800
25 June 1923	2,820
16 June 1944	3,570
25 June 1952	3,740
8 June 1954	3,340
27 June 1972	3,200
6 July 1982	2,030
19 July 1986	4,520
4 July 1990	2,660
21 June 2005	2,270 (maximum average daily)**
23 June 2013	2,850

Notes: *Peak discharge is denoted as the *maximum instantaneous discharge* in the published WSC record. **The 2005 peak discharge value is missing from the published record.

3 AVAILABLE DATA

The key data used to develop and calibrate the hydraulic model included the high-resolution digital terrain model (DTM), recent aerial imagery (OGL 2019), the surveyed cross section geometry, surveyed highwater marks, and the stage discharge relationship (rating curve) at the WSC gauge in Edmonton. Additional information such as past studies, flood photography, recent aerial imagery, and existing hydraulic models also informed model development and calibration. The data available for this study is summarized below.

3.1 Hydrology Summary

In accordance with the terms of reference and FHIP guidelines, flood frequency water level profiles must be calculated using naturalized flood frequency discharges, which were estimated under a separate study component documented in the ***Open Water Hydrology Assessment*** study report (NHC 2020a). **Table 3** summarizes the flood frequency values for both the naturalized and regulated flow conditions. Regulated values are provided for comparison. Flood level profiles were computed for all return periods listed in the table (2-year through 1000-year return period floods).

Table 3 Flood frequency estimates for North Saskatchewan River at Edmonton, above Whitemud Creek, and below Sturgeon River

Return Period (Years)	Annual Probability of Exceedance (%)	Naturalized Flow (m^3/s)		Regulated Flow (m^3/s)	
		Value	95% Confidence Limits	Value	95% Confidence Limits
1000	0.10	7,330	6,730 - 8,070	6,460	5,210 - 8,450
750	0.13	7,060	6,490 - 7,770	6,140	4,970 - 7,990
500	0.20	6,670	6,140 - 7,330	5,710	4,660 - 7,360
350	0.29	6,340	5,840 - 6,960	5,340	4,390 - 6,830
200	0.50	5,800	5,350 - 6,350	4,790	3,970 - 6,040
100	1.0	5,130	4,750 - 5,610	4,140	3,480 - 5,130
75	1.3	4,860	4,500 - 5,310	3,890	3,290 - 4,780
50	2.0	4,470	4,140 - 4,870	3,540	3,020 - 4,300
35	2.9	4,130	3,830 - 4,490	3,240	2,780 - 3,900
20	5	3,580	3,330 - 3,880	2,790	2,430 - 3,300
10	10	2,910	2,710 - 3,140	2,260	2,000 - 2,620
5	20	2,220	2,060 - 2,410	1,750	1,570 - 1,980
2	50	1,300	1,130 - 1,460	1,070	972 - 1,190

Table 4 shows adopted flood frequency values alongside those estimated by previous studies, for comparison purposes. Current flood frequency estimates are slightly less than those of the previous studies. These small differences are largely attributable to the longer record available to the current study's frequency analysis.

Table 4 Comparison with previous flood frequency estimates for North Saskatchewan River at Edmonton

Return Period (Years)	Peak Instantaneous Discharge (m^3/s)			
	Current Study for Naturalized Flows	NHC (2007)	AENV (1990)	AENV (1988)
1000	7,330	7,540	-	-
750	7,060	-	-	-
500	6,670	6,810	-	-
350	6,340	-	-	-
200	5,800	5,850	5,960	-
100	5,130	5,140	5,270	5,340
75	4,860	-	-	-
50	4,470	4,430	4,570	4,630
35	4,130	-	-	-
20	3,580	3,520	3,640	-
10	2,910	2,840	2,940	-
5	2,220	2,160	2,230	2,270
2	1,300	1,260	1,270	-

3.2 Digital Terrain Model Data

A digital terrain model (DTM) based on airborne LiDAR data was supplied by AEP for this study. The DTM was developed from data collected by Airborne Imaging (Airborne Imaging 2019). A complete description of the digital terrain model data, including a comparison to ground survey data, is provided in the ***Survey and Base Data Collection*** study report (NHC 2020b).

3.3 Survey Data

The majority of the survey program was conducted during the summer of 2018 and is documented in the ***Survey and Base Data Collection*** study report (NHC 2020b). The hydraulic model geometry was developed from river bathymetry data, bank survey data, and bridge opening geometry survey data. Ground control points were also established during the survey program to validate the DTM. The DTM was used to inform the geometry of cross sections through the floodplain, beyond the extent of the river bathymetry and bank survey data.

A total of 245 surveyed cross sections were used to model the channel geometry along the 114 km reach of the North Saskatchewan River extending from 4 km upstream of the Hwy 60 crossing at Devon downstream past Edmonton and on to about 30 km downstream of Fort Saskatchewan, just below Vinca Bridge (Hwy 28 crossing). The river cross sections were located so as to adequately resolve variations in river geometry (width, depth, and slope), channel pattern, and islands. The average distance between cross sections was about 500 m. Cross sections near bridges were surveyed approximately one channel

width upstream and downstream of the bridge faces – additional sections were surveyed immediately upstream and downstream of bridges to facilitate the calculation of the energy losses at bridges. Bridge survey data was collected to define the model inputs for bridge opening and pier geometry.

3.4 Existing Hydraulic Models

Existing hydraulic models for portions of the study reach were developed by others from survey data collected during prior studies. These models were created using HEC-RAS under the following previous studies.

- North Saskatchewan River at Edmonton Flood Risk Mapping Study (Phase I - Lower Reach). Philips Planning & Engineering Limited (1994).
- North Saskatchewan River at Edmonton Flood Risk Mapping Study (Phase II - Upper Reach). I.D. Group (Alberta) Inc. and Cartologix Corporation (1995).
- North Saskatchewan River Flood Risk Mapping Study Devon to Fort Saskatchewan (Excluding Edmonton). Northwest Hydraulic Consultants Ltd. (2007).

The domain of the current model extends a short distance upstream and about 15 km downstream of the combined domain of models developed under the three previous studies. Model parameters from the previous studies were referenced during the development and calibration of the current hydraulic model.

3.5 Highwater Marks

A highwater mark (HWM) survey documents the highest water levels experienced along the river during the passage of a flood event. Typically, the observations are taken not long after the passage of the flood while evidence of the highest water level experienced at the HWM location remains apparent. The HWM survey data collected from the 1986 flood was examined for this study.

Table 5 lists the HWM elevation values reported for the 1986 flood and **Figure 2** depicts their locations along the river. The locations were initially digitized from observation locations indicated on maps included within the HWM report (AENV 1987). These locations were further adjusted based on the available information specific to each HWM observation site (e.g. site photographs and/or remarks on their location with respect to prominent features, such as bridges or buildings). Each HWM location was then assigned a river station value representative of its location alongside the model channel centerline; that is, the streamwise distance from the downstream model boundary. At several HWM locations the reported elevation values were suspiciously higher or lower in relation to neighbouring HWMs. It is plausible that the reported elevation value at these locations is in error or the streamwise location could not be accurately deduced from the information available in the HWM reporting – these locations were denoted as “suspect” in **Table 5**.

Table 5 1986 highwater mark summary

Highwater Mark ID	Reported Location Description	River Station (m)	HWM Elevation (m)	Remark
86-NS-11.A	15 m d/s old bridge	110025.69	638.97	suspect
86-NS-11.B	50 m d/s old bridge	109990.69	638.53	suspect
86-NS-11.1	Intake Site 1-4, TAU Mile 25.1	109728.08	637.69	
86-NS-11.2	Intake Site 1-6, TAU Mile 24.9	109325.47	637.41	
86-NS-11.3.A	Intake Site 1-7, TAU Mile, RB	109092.39	636.08	suspect
86-NS-11.3.B	Intake Site 1-7, TAU Mile, LB	109086.71	637.09	
86-NS-11.4	Devon Golf Course, Cross Section 7U	105788.40	635.35	
86-NS-11.5	Lions Park near Devon, 86-NS-PG2	105786.04	636.32	suspect
86-NS-11.6	Gravel Pit, Cross Section 6-U	104007.96	636.70	suspect
86-NS-11.7	Reclaimed Gravel Pit, Cross Section 5-U	101916.67	635.20	suspect
86-NS-11.8	Rabbit Hill Ski Resort	99747.73	633.10	
86-NS-11.9	Reclaimed Gravel Pit, Cross Section 4-U	98890.91	631.52	
86-NS-11.10	Cross Section 3-U	96911.48	630.39	suspect
86-NS-11.11	Cross Section 2-U	94345.07	630.49	
86-NS-11.12	Cross Section 1-U, Windermere Golf Course	92229.65	629.77	
86-NS-11.13	Windermere Golf Course, 86-NS-PG4	91859.22	629.79	
86-NS-11.14	E.L. Smith Water Treatment Plant	85907.06	627.80	
86-NS-11.15	Terwilliger Park (NW) 86-NS-PG6.1	84282.91	627.15	
86-NS-11.16	Terwilliger Pak (East Side), 86-NS-PG7.1	82549.00	626.62	
86-NS-11.16.1	L.B. near boat launch at Fort Edmonton Park	79169.37	625.07	
86-NS-11.17.A	Quesnell Bridge, RB U/S of bridge	77544.09	624.74	
86-NS-11.17.B	Quesnell Bridge, 86-NS-PG9, LB D/S of bridge	77490.85	624.73	
86-NS-11.18	Fox Drive Bridge over Whitemud Creek	77182.62	624.64	
86-NS-11.19	Laurier Park Boat Launch, 86-NS-PG11	75694.91	624.14	
86-NS-11.20	Hawrelak Park at pumphouse, near turnaround in road	73631.10	623.43	
86-NS-11.21.A	Groat Bridge, bridge centreline	71460.02	622.88	
86-NS-11.21.B	Groat Bridge, 30m D/S bridge centreline	71415.80	622.86	
86-NS-11.22	Along River Rd by fruit sellers, opposite biological sciences building	70426.76	622.69	
86-NS-11.23.B	High Level Bridge, 86-NS-PG15, 5m D/S	69454.20	622.40	
86-NS-11.23.A	High Level Bridge, 86-NS-PG15, 5m U/S	69408.47	622.44	
86-NS-11.24	105th St Bridge, 86-NS-11.24, U/S of bridge	68785.91	622.20	

Notes: LB and RB denote left bank and right bank; U/S and D/S denote upstream and downstream; and, suspect denotes elevation or location values that are likely in error.

Table 5 1986 highwater mark summary (continued)

Highwater Mark ID	Reported Location Description	River Station (m)	HWM Elevation (m)	Remark
86-NS-11.25	Edmonton Fire Training boat Launch, 86-NS-PG17	67955.95	621.91	
86-NS-11.26	Rossdale, 86-NS-PG18, In front of 9542-100 St	67488.77	621.65	
86-NS-11.27	Rossdale, 86-NS-PG19 at 97 Ave and 100St	67278.11	621.52	
86-NS-11.28	James MacDonald Bridge, U/S on LB	67061.67	621.48	
86-NS-11.29	Low Level Bridge, 86-NS-PG21, U/S of bridge in front of WSC gauge	66829.07	621.34	
86-NS-11.30	50m west of pedestrian overpass on 998 Ave near Muttart Conservatory	66116.27	620.82	
86-NS-11.31	Cloverdale, 86-NS-PG23, Centreline 98 Ave and 94 St	65682.54	620.74	
86-NS-11.32	92 St and Cameron Ave along LB, South of street sign	65654.37	620.79	
86-NS-11.33	Riverdale, Centreline 91 St and 98 Ave, 86-NS-PG24	65405.60	620.73	
86-NS-11.34.A	5m U/S of bridge	64114.25	620.20	
86-NS-11.34.B	5m D/S of bridge	64090.06	620.41	
86-NS-11.35	Grierson Park along LB, LSD 3-10-53-24-W4, 86-NS-SV3	63046.21	619.33	
86-NS-11.36.A	U/S of Capilano Bridge pier on LB, 86-NS-SV3A	61514.38	618.94	
86-NS-11.36.B	D/S of Capilano Bridge pier, 86-NS-SV3A	61482.72	618.86	
86-NS-11.37	Across from 6607 Capilano Crescent, 86-NS-SV4	60740.37	618.19	
86-NS-11.38.A	U/S of 50 St pedestrian bridge on RB, 86-NS-SV5	59940.79	618.44	
86-NS-11.38.B	D/S of 50 St pedestrian bridge, on RB, 86-NS-SV5	59926.49	618.43	
86-NS-11.39	West end of Goldbar Park, 86-NS-SV6, end of path	58910.83	617.81	
86-NS-11.40	Pedestrian bridge connecting Goldbar and Rundle parks, RB,86-NS-SV7	58171.04	617.93	
86-NS-11.41	Rundle Park, approx midway between pedestrian bridges	56753.50	617.11	
86-NS-11.42	Strathcona pedestrian bridge along LB, 86-NS-SV9	55744.77	616.64	

Notes: LB and RB denote left bank and right bank; U/S and D/S denote upstream and downstream; and, suspect denotes elevation or location values that are likely in error.

Table 5 1986 highwater mark summary (continued)

Highwater Mark ID	Reported Location Description	River Station (m)	HWM Elevation (m)	Remark
86-NS-11.43	D/S on CNR bridge along RB, 86-NS-SV9A	54464.50	616.16	
86-NS-11.44	NW corner of Cloverbar Power Plant, on RB	52821.75	615.02	
86-NS-11.45	Cloverbar dump, 86-NS-13PS, under transmission lines	49184.55	613.96	
86-NS-11.46	Concrete pumphouse for Capital City Sewage Treatment plant, 86-NS-SV11	42865.63	611.58	
86-NS-11.47	Centreline of Point Aux Pins Creek confluence, near road, 86-NS-16PS	36302.88	608.64	
86-NS-11.48	NW 25-54-23-W4, 1982 HWM: 82-NS-23	30795.19	608.62	suspect
86-NS-12.A	10m U/S Fort Saskatchewan bridge, 86-NS-18-PS	28928.75	605.45	
86-NS-12.B	10m D/S from Fort Saskatchewan bridge, 86-NS-18-PS	28899.79	605.38	
86-NS-12.1	Fort Saskatchewan Ferry along right bank, 86-NS-19PS	27046.99	604.99	
86-NS-12.2	NW-10-55-22-W4, 86-NS-20PS	22965.75	603.44	
86-NS-12.3	SW-23-55-22-W4, 86-NS-21PS	21401.64	602.57	
86-NS-12.4	Outfall site along RB,SE 36-55-22-W4, 86-NS-22PS	16967.68	600.84	
86-NS-12.5	Intake Site, SW 7-56-21-W4, 86-NS-23PS	13779.53	599.19	
86-NS-12.6	Water intake, NE-8-56-21-W4, 86-NS-24PS	11058.44	598.17	
86-NS-13	10m U/S of NW corner of Vinca bridge, 86-NS-25PS	246.65	593.82	

Notes: LB and RB denote left bank and right bank; U/S and D/S denote upstream and downstream; and suspect denotes elevation or location values that are likely in error.

3.6 Gauge Data and Rating Curves

WSC Gauge 05DF001 North Saskatchewan River at Edmonton, is the lone streamflow gauge located within the study reach. The relationship between stage (or height) and discharge at the gauging station is determined by WSC, based on recorded stage and direct discharge measurements. This relationship is represented by a curve fit through the observed data, commonly called a rating curve. When new direct discharge measurements are added to the dataset, the curve is updated. The rating curve relationship allows for discharge (streamflow) to be estimated from the recorded gauge height. **Figure 3** plots published rating curves for the North Saskatchewan River at Edmonton.

3.7 Flood Photography

Aerial photography was acquired close in time to the 1986 flood peak by AEP. AEP provided digital scans of this imagery to NHC for this study. These aerial images were referenced during model development and model calibration. The extent of inundation depicted in the flood photography helped to align model cross sections through overbank areas, and allowed flood mapping inundation extents to be qualitatively assessed.

4 RIVER AND VALLEY FEATURES

This section summarizes the descriptions of the river and valley features from the three previous studies of the North Saskatchewan River in and near Edmonton (Philips Planning & Engineering Limited 1994; I.D. Group (Alberta) Inc. and Cartologix Corporation 1995; and NHC 2007). Context for the river reach studied here is available in Kellerhals, Neill, and Bray (1972). This early work documents the geomorphic and hydraulic characteristics of Alberta rivers including the North Saskatchewan.

4.1 Channel Characteristics

From Devon downstream to and through Edmonton, the river channel is entrenched within a relatively narrow winding valley. Through this upper reach, the channel has a slightly irregular meandering to straight irregular pattern. In northeast Edmonton, between Sherwood Park and Fort Saskatchewan, the channel flows through a notably wider floodplain, through a few wide meanders confined by valley walls and terraces. At Fort Saskatchewan, the channel returns to a more narrow floodplain, straightening and following a slightly irregular pattern confined by terraces and valley walls. Through the lower reaches, the valley is considerably straighter.

Channel bank materials vary with location, comprising mostly lacustrine and aeolian deposits, till, alluvial sands and gravels, and some moderately erodible bedrock.

In the upper reaches, bed materials are mostly coarser gravels, tending towards sands and gravels in the lower reaches. In some areas of downtown Edmonton, the channel encounters bedrock.

4.2 Floodplain Characteristics

In the upper reach around Devon, valley width is fairly constant at about 500 m, becoming more variable (600 m to 1200 m) just west of Edmonton and through most of the city. In northeastern Edmonton, the valley widens considerably to over 2000 m, narrowing again to a width of 500 m to 800 m at Fort Saskatchewan through to the end of the study reach. Valley walls are mostly moderately forested, excepting area of little to no vegetation on steep slopes. In rural areas, the valley flats are occupied by a mix of forest, moderate vegetation, and some cultivation; in urban areas, they contain a mix of forested parks, grassed areas, and some built-up / developed areas.

4.3 Bridge Crossings

Table 6 lists the 29 bridge crossings along the study reach. At the time of writing, the Tawatina bridge was under construction – geometry for this bridge relied on information from design drawings. Bridge information is documented in the ***Survey and Base Data Collection*** study report (NHC 2020b).

Table 6 Bridge crossings along study reach

Bridge ID	Crossing Description	River Station (m)
Devon Bridge SB	Highway 60 Southbound	110023.00
Devon Bridge NB	Highway 60 Northbound	109998.20
SW Henday Bridge SB	Southwest Anthony Henday Southbound	88248.69
SW Henday Bridge NB	Southwest Anthony Henday Northbound	88202.25
Terwillegar Park Footbridge	Pedestrian Crossing	81947.70
Fort Edmonton Park Footbridge	Pedestrian Crossing	79858.22
Quesnell Bridge	Whitemud Drive	77536.41
Laurier Park Footbridge	Pedestrian Crossing	74442.40
Groat Bridge	Groat Road	71467.34
Menzies Bridge	Capital Line LRT	69503.73
High Level Bridge	109 Street	69433.41
Walterdale Bridge	105 Street	68781.72
James MacDonald Bridge	98 Avenue	67076.04
Low Level Bridge	Connors Road	66821.10
Tawatina Bridge	Valley Line Southeast LRT	66112.31
Dawson Bridge	Rowland Road	64108.25
Capilano Bridge	Wayne Gretzky Drive	61510.46
Capilano Park Footbridge	Pedestrian Crossing	59939.45
Ainsworth Dyer Footbridge	Pedestrian Crossing	58164.93
Rundle Park Footbridge	Pedestrian Crossing	55733.80
Beverly Bridge	Highway 16 Eastbound	54764.91
Cloverbar Bridge	Highway 16 Westbound	54619.54
CN Rail Cloverbar Bridge	CN Rail	54488.64
NE Henday Bridge SB	Northeast Anthony Henday Southbound	49842.51
NE Henday Bridge NB	Northeast Anthony Henday Northbound	49798.61
Abandoned Piers	Abandoned Rail	29453.15
Highway 15 Bridge	Highway 15	28920.56
CN Rail Fort Saskatchewan Bridge	CN Rail	21168.86
Vinca Bridge	Highway 38	231.02

4.4 Other Features

The ***Flood Risk Inventory and Assessment*** study report (NHC 2020c) provides detailed information on the nature and extent of development along the river valley. A brief overview of this information is provided here, followed by a list of main features of interest, ordered from upstream to downstream, grouped by administrative boundaries.

River valley development above and below Edmonton consists of parks, recreational facilities, industrial areas, and limited residential development. Within Edmonton, river valley development comprises parks, golf courses, industrial areas, residential development, a water treatment plant, a sewage treatment plant, storm outfalls, and several water intakes. Several larger tributaries enter the study reach, including Whitemud Creek, Blackmud Creek, Oldman Creek, and the Sturgeon River. The following lists developments of interest along the study reach.

Parkland County / Leduc County / Devon: Riverside RV Park, Cotton Tail Corner Park, McCargar's Bluff, Devon Golf Course, Blackhawk Golf Club, Devon Voyageur Park, Devon Water Treatment Plant, Devon Lions Campground, Battery Creek Ravine.

Edmonton upstream of the Low Level Bridge: Shalom Park Water Ski Site, Rabbit Hill Snow Resort, Keswick Park, Gurthrie Ravine, Windermere Golf Course, Big Island Park, River Ridge Golf & Country Club, Windermere Park, Heath Road Park, EL Smith Water Treatment Plant, Terwillegar Park, Cameron Ravine, Wedgewood Ravine, Oleskiw Park, Edmonton Country Club, Centennial Park, Fort Edmonton Park, Patricia Ravine, Rio Park, Whitemud Equestrian Park, Buena Vista Park, Hawrelak Park, Mackenzie Ravine, MacKinnon Ravine, Royal Mayfair Golf Club, Government Hill Park, Emily Murphy Park, Victoria Golf Course, University Alberta (water intake), Royal Glenora Club, Rossdale Water Treatment Plant, Kinsmen Park, Queen Elizabeth Park, Irene Parlby Park, Nellie McClung Park, Rossdale Park.

Edmonton downstream of Low Level Bridge: Louise McKinney Riverfront Park, Henrietta Muir Edwards Park, Muttart Conservatory, Edmonton River Boat, Gallagher Hill Park, George F. Hustler Memorial Plaza, Alan Stein Park, Riverdale Park, Forest Heights Park, Dawson Park, Riverside Golf Course, Kinnaird Park, Highlands Golf Club, Capilano Park, Floden Park, Goldbar Wastewater Treatment Plant, Goldbar Park, Goldbar Wastewater Treatment Plant, Strathcona Refinery, Strathcona Science Provincial Park, Hermitage Park, Eco Industrial Business Park, Cloverbar Energy Centre, Cloverbar Sand and Gravel, Edmonton Waste Management Centre, Raven Crest Golf and Country Club, Our Lady Queen of Peace Ranch, The Quarry Golf Course, Riverbend Gardens, Tribend Ranch.

Strathcona County / Sturgeon County / Fort Saskatchewan: Legends Golf and Country Club, Alberta Capital Region Wastewater Commission, North Strathcona Regional Park, DOW Ball Fields, Wetlands Conservation Area, Chabot Park, Peter Ream Park, Turner Park, Agrium, Dow Chemical, Keyera, Plains Midstream, Manderley Turf Products, Inter Pipeline, Shell Scotford, Pembina, Access Pipeline, North West, Viridian.

5 MODEL CONSTRUCTION

5.1 HEC-RAS Program

The U.S. Army Corps of Engineers *Hydrologic Engineering Center-River Analysis System* (HEC-RAS) computer program (Version 5.0.7, March 2019) was used to calculate the flood levels along the study reach. The basic inputs required by HEC-RAS are a series of cross sections with known distances between sections, roughness coefficients for the channel, overbank areas for each cross section, inflow discharge at the upstream limits of each reach, and a prescribed water level at the downstream outflow boundary.

5.1.1 Theoretical Aspects

HEC-RAS can perform one-dimensional (1D), two-dimensional (2D), or combined 1D and 2D hydraulic calculations for a network of channels and hydraulic structures. For this study, a 1D model was constructed to calculate water surface profiles for steady-state gradually varied flow. The computational procedure for steady flow calculations is based on the solution of the 1D energy equation. Energy losses between river sections are calculated as friction losses (using Manning's equation) and as expansion / contraction losses. The momentum equation is used by the model for rapidly varied flow conditions, for hydraulics through bridges, and for evaluating water surface profiles at stream junctions.

The analytical approach employed by HEC-RAS has the following assumptions and potential limitations:

- Flow is gradually varied and boundary friction losses between cross sections are estimated by Manning's equation using section-average parameters.
- Geometry is assumed to be fixed; thus potential changes in channel and floodplain geometry occurring during a flood are not accounted for.
- Each model cross section is apportioned into three separate conveyance components representing the main channel, left overbank, and right overbank, with a constant water level assumed across all three components.
- Flow is one-dimensional.

5.1.2 General Model Setup

Geometric Layout

The approach followed to develop key components of the model geometric layout was:

- The channel centreline was defined along the middle of the main channel and was digitized using ArcGIS tools and visual referencing of the DTM and aerial imagery. A single continuous centreline was created to represent the model reach.

- Flow paths were created coincident with the river centerline and along the left and right floodplains, representing the length of the main channel, left overbank, and right overbank flow paths. Distances between cross sections were measured along flow path lines. The model requires these distances for estimating energy losses between cross sections within the main channel and the left and right overbank areas.
- Model cross section transects were digitized at each surveyed cross section as follows. First, a main channel portion was digitized across the main channel overtop of the surveyed channel and bank point data. Then, the main channel portion was extended left and right across the floodplain (overbank areas) and up the valley walls. The overbank portions were aligned perpendicular to the anticipated path of the floodplain flows and were projected far enough to extend beyond the 1000-year flood inundation extents. Cross section elevation values from the survey point data were projected onto the cross section lines using the HEC-GeoRAS GIS toolset through a conflation process. Elevations in the overbank areas were determined by extracting elevation values from the underlying DTM along the cross section polylines.
- The location of the left and right banks (denoted as bank stations) were determined by inspection of the cross section geometry and examining DTM channel geometry. Bank stations demarcate the extents of the modelled left overbank, main channel, and modelled right overbank portions of cross sections.

Channel and Overbank Roughness

Manning's roughness values were used to simulate roughness in the modelled reaches. At each cross section, roughness was varied horizontally across the channel, to represent changes in river and floodplain characteristics. A minimum of three roughness values (at least one channel and two overbank values) were used within each cross section. The number of roughness values used was dependent on the complexity of the channel and the presence of distinct features, such as islands and side channels.

Manning's roughness is an empirical coefficient used to account for energy losses due a combination of factors including surface roughness and channel sinuosity. Manning's *roughness* also varies somewhat with discharge. For this study, the calibrated Manning's roughness values were held constant for the full range of design flood discharges. The Manning's roughness values adopted for the present study are discussed further in a subsequent section on model calibration.

Expansion and Contraction Coefficients

To account for the effect of flow contraction or expansion losses on the energy balance between successive cross sections, HEC-RAS multiplies the absolute difference in velocity head by a coefficient. These coefficients range from 0.10 for gradual transitions to 0.80 for abrupt transitions (Brunner, 2016).

Boundary Conditions

Boundary conditions were required at the model inflow and outflow boundaries. At the downstream boundary, a normal depth water level approximation was assigned as the boundary condition. The slope used for calculating normal depth was set to 0.00028 m/m. This value approximates the slope of the energy grade line near the downstream boundary.

5.2 Geometric Database

All the HEC-RAS model geometry components are contained in the geometric database that is one of the study's electronic deliverables. These components include points and polylines representing model cross section plan geometries, flow paths, bank stations, and bridge locations. Components were developed using the ArcGIS geospatial analysis tool, and further refined using the HEC-GeoRAS toolbox and HEC-RAS geometry editor. The contents of the geometric database and the model geometry development methodology are described in the following sections.

5.2.1 Cross Section Data

Appendix B contains elevation, survey, and other data derived from the NHC surveys for each model cross section. These cross section data sets included the combined DTM, topographic survey, and hydrographic survey data.

5.2.2 Bridges

The modelled reach includes 39 bridge crossings (**Table 6** and **Appendix C**). Each bridge structure's alignment and location was established in ArcGIS. Bridge cross sections include approach roadways and abutments in the left and right overbanks, bridge piers, and bridge deck high and low chord profiles. Approach roadway profiles are based on extracted DTM elevation data supplemented with data from bridge drawings. Abutment geometry, piers, and high and low chords were determined from surveyed data and/or drawings. Model bridge geometry was checked against design drawings, available AT bridge file records, and other information as available. Pier losses were estimated with the Yarnell equation under low flow conditions, and with the energy equation under high flow conditions.

5.3 Model Calibration

5.3.1 Methodology

Calibration parameters. Model calibration involves choosing values for model parameters such that modelled water levels simulate the levels observed in actual flood events. Calibrated parameters include:

- Manning's roughness coefficient for the channel and floodplain.

- Friction slope associated with the downstream normal depth boundary condition.
- Ineffective flow areas.
- Expansion and contraction coefficients.

The primary calibration parameter is the channel Manning's roughness.

Roughness calibration challenges and limitations. These include:

- Accuracy of highwater mark elevations.
- Improper identification of highwater marks.
- Uncertainties in estimates of flood peak discharge.
- Presence of a hydraulic control between model cross sections.

Main channel Manning's roughness. The general calibration approach was to adjust Manning's *roughness* values such that simulated water levels matched well with observed water levels for the adopted high flow calibration event (1986 flood). The adjustments were made on a reach-averaged basis by visual comparison of computed and observed water levels. A single calibrated model representing both high and low flow conditions was created. Multiple models for different flow scenarios is generally not a desirable outcome for FHIP studies as they can present operational challenges to potential future users.

Overbank / floodplain roughness. Land cover type was used to help characterize roughness in the floodplain areas (model overbanks). **Table 7** describes the three different land cover types identified for this study. Manning's roughness values attributed to each type are consistent with the three previous studies of the North Saskatchewan in and near Edmonton (Philips Planning & Engineering Limited 1994; I.D. Group (Alberta) Inc. and Cartologix Corporation 1995; and NHC 2007).

Table 7 Description of floodplain land cover types within the study reach

Land cover type	Manning's Roughness, n	Description
Light to medium vegetation	0.055	Agricultural crops, pastureland, parks, and golf courses, short to tall grasses, and light vegetation.
Medium to dense vegetation	0.070	Medium to dense vegetation including forested areas with medium to large size trees.
Developed urban areas	0.080	Urban development (residential and commercial) with buildings of varying size and density.

Land cover type was determined by visual inspection of aerial imagery. At each cross section, a qualitative visual assessment was made to determine the dominant land cover type within the upstream and downstream left and right overbank inundated areas identified from preliminary model and flood

mapping results. Manning's *roughness* values were then assigned to left and right overbanks according to the respective values listed in **Table 7**. It was assumed that these values were appropriate for the full range of discharge scenarios. The assigned values were consistent with the three previous studies.

5.3.2 High Flow Calibration

The July 1986 flood event was used for high flow calibration by the current study and the three previous studies. This is the largest flood event on record having well-documented highwater mark data, which extends along the entire study reach. The 1986 estimated peak discharge was 4520 m^3/s; this value exceeds the 50-year flood discharge but falls short of the 75-year discharge.

The calibration results are illustrated by the comparison of the simulated water surface elevations with the observed highwater mark elevations. **Figure 4** shows a comparison between the simulated water surface profile and the observed highwater mark elevations for the July 1986 flood. **Table 8** tabulates a summary of the comparison. Excluding HWM locations deemed to be *suspect*, computed water levels were on average 0.03 m above observed 1986 flood event highwater marks. The average absolute difference between computed and observed highwater marks was 0.11 m; the largest positive difference was 0.43 m, and largest negative difference was -0.39 m.

A rating curve simulated using the high flow calibration was compared to the published rating curves for the WSC gauge for North Saskatchewan River at Edmonton (05DF001) located just upstream of the Low Level Bridge. The simulated curve compared well to the published curves (**Figure 3)**. The simulated curve envelopes most of observations, up to the 1986 flood event. Above the 1986 flood, the simulated curve follows the most recent projected rating curves. The 1915 flood level is underestimated by the simulated curve; the most recent rating curves also underestimate it.

Table 8 Calibration results for North Saskatchewan River - July 1986 flood event

Highwater Mark ID	River Station (m)	Observed HWM Elevation (m)	Computed Elevation (m)	Computed minus Observed (m)	Remark
86-NS-11.A	110025.69	638.97	638.00	-0.97	suspect
86-NS-11.B	109990.69	638.53	637.94	-0.59	suspect
86-NS-11.1	109728.08	637.69	637.72	0.03	
86-NS-11.2	109325.47	637.41	637.46	0.05	
86-NS-11.3.A	109092.39	636.08	637.35	1.27	suspect
86-NS-11.3.B	109086.71	637.09	637.35	0.26	
86-NS-11.4	105788.40	635.35	635.58	0.23	
86-NS-11.5	105786.04	636.32	635.58	-0.74	suspect
86-NS-11.6	104007.96	636.70	634.69	-2.01	suspect
86-NS-11.7	101916.67	635.20	633.74	-1.46	suspect
86-NS-11.8	99747.73	633.10	632.86	-0.24	
86-NS-11.9	98890.91	631.52	632.47	0.95	suspect
86-NS-11.10	96911.48	630.39	631.53	1.14	suspect
86-NS-11.11	94345.07	630.49	630.46	-0.03	
86-NS-11.12	92229.65	629.77	629.71	-0.06	
86-NS-11.13	91859.22	629.79	629.68	-0.11	
86-NS-11.14	85907.06	627.80	627.79	-0.01	
86-NS-11.15	84282.91	627.15	627.13	-0.02	
86-NS-11.16	82549.00	626.62	626.67	0.05	
86-NS-11.16.1	79169.37	625.07	625.13	0.06	
86-NS-11.17.A	77544.09	624.74	624.74	0.00	
86-NS-11.17.B	77490.85	624.73	624.72	-0.01	
86-NS-11.18	77182.62	624.64	624.67	0.03	
86-NS-11.19	75694.91	624.14	624.18	0.04	
86-NS-11.20	73631.10	623.43	623.57	0.14	
86-NS-11.21.A	71460.02	622.88	622.91	0.03	
86-NS-11.21.B	71415.80	622.86	622.89	0.03	
86-NS-11.22	70426.76	622.69	622.66	-0.03	
86-NS-11.23.B	69454.20	622.40	622.55	0.15	
86-NS-11.23.A	69408.47	622.44	622.49	0.05	
86-NS-11.24	68785.91	622.20	622.19	-0.01	
86-NS-11.25	67955.95	621.91	621.79	-0.13	
86-NS-11.26	67488.77	621.65	621.67	0.02	

Note: suspect denotes that the elevation or location for the HWM observation is likely in error.

Table 8 Calibration results for North Saskatchewan River - July 1986 flood event (continued)

Highwater Mark ID	River Station (m)	Observed HWM Elevation (m)	Computed Elevation (m)	Computed minus Observed (m)	Remark
86-NS-11.27	67278.11	621.52	621.62	0.10	
86-NS-11.28	67061.67	621.48	621.64	0.16	
86-NS-11.29	66829.07	621.34	621.42	0.08	
86-NS-11.30	66116.27	620.82	620.75	-0.07	
86-NS-11.31	65682.54	620.74	620.72	-0.02	
86-NS-11.32	65654.37	620.79	620.71	-0.08	
86-NS-11.33	65405.60	620.73	620.58	-0.15	
86-NS-11.34.A	64114.25	620.20	620.05	-0.15	
86-NS-11.34.B	64090.06	620.41	620.02	-0.39	
86-NS-11.35	63046.21	619.33	619.38	0.05	
86-NS-11.36.A	61514.38	618.94	618.91	-0.03	
86-NS-11.36.B	61482.72	618.86	618.88	0.02	
86-NS-11.37	60740.37	618.19	618.62	0.43	
86-NS-11.38.A	59940.79	618.44	618.43	-0.01	
86-NS-11.38.B	59926.49	618.43	618.41	-0.02	
86-NS-11.39	58910.83	617.81	618.07	0.26	
86-NS-11.40	58171.04	617.93	617.90	-0.03	
86-NS-11.41	56753.50	617.11	617.00	-0.11	
86-NS-11.42	55744.77	616.64	616.72	0.08	
86-NS-11.43	54464.50	616.16	616.16	0.00	
86-NS-11.44	52821.75	615.02	615.26	0.24	
86-NS-11.45	49184.55	613.96	613.93	-0.03	
86-NS-11.46	42865.63	611.58	611.33	-0.25	
86-NS-11.47	36302.88	608.64	608.77	0.13	
86-NS-11.48	30795.19	608.62	606.47	-2.15	suspect
86-NS-12.A	28928.75	605.45	605.73	0.28	
86-NS-12.B	28899.79	605.38	605.71	0.33	
86-NS-12.1	27046.99	604.99	604.98	-0.01	
86-NS-12.2	22965.75	603.44	603.24	-0.20	
86-NS-12.3	21401.64	602.57	602.45	-0.12	
86-NS-12.4	16967.68	600.84	600.76	-0.08	
86-NS-12.5	13779.53	599.19	599.23	0.04	
86-NS-12.6	11058.44	598.17	598.13	-0.04	
86-NS-13	246.65	593.82	593.81	-0.01	

Note: suspect denotes that the elevation or location for the HWM observation is likely in error.

5.3.3 Comparison of High Flow Calibrated Model Run at Low Flow to Low Flow Observations

The model was not calibrated to a low flow event. The high flow calibrated model was, however, run using the 2018 river survey measurements, which were collected during a low flow condition, to determine if the adopted Manning's roughness value was also valid for lower flows.

Table 9 summarizes the 2018 recorded flows. Cross sections are grouped by survey date. For each section, the average, minimum, and maximum discharge on the day of survey are listed because discharge fluctuated on a daily basis due to the effects of hydropower production upstream. Daily averages were calculated as the arithmetic mean of discharge values recorded during the 24 hours of each date.

Table 9 Recorded discharges during 2018 cross section survey – North Saskatchewan River at Edmonton (05DF001)

Cross Sections	Survey Date	Discharge (m^3/s)		
		Minimum	Average	Maximum
XS-245 to XS-228	31-Jul-18	185	253	319
XS-227 to XS-219	1-Aug-18	193	247	295
XS-218 to XS-200	8-Aug-18	166	231	295
XS-200 to XS-180	7-Aug-18	188	240	278
XS-179 to XS-162	2-Aug-18	155	220	305
XS-161 to XS-141	1-Aug-18	193	247	295
XS-140 to XS-123	31-Jul-18	185	253	319
XS-122 to XS-108	27-Jul-18	251	305	365
XS-107 to XS-091	26-Jul-18	265	331	398
XS-092 to XS-076	25-Jul-18	263	344	398
XS-075 to XS-060	24-Jul-18	362	378	395
XS-059 to XS-049	23-Jul-18	368	390	414
XS-048 to XS-040	18-Jul-18	239	264	289
XS-039 to XS-026	17-Jul-18	274	348	443
XS-025 to XS-013	13-Jul-18	300	379	518
XS-012 to XS-001	16-Jul-18	393	419	443

The calibrated model was then tested under three flow conditions corresponding to the minimum, average, and maximum daily flows listed in **Table 9**. A single steady-state flow file was created for each flow condition, where model discharges were adjusted along the reach according to sub-reach as listed in the table. Discharge was changed at the location of the most upstream cross section within a single row of the table. **Figure 5** plots the comparison of simulated water surface profiles for the three flow conditions and 2018 surveyed water levels at each cross section. Visual comparison of computed and

surveyed water levels indicates that the adopted high flow Manning's roughness value appears to provide a reasonable simulation for low flows.

This low flow comparative assessment was approximate, so differences between computed and surveyed water levels were not quantified. A more rigorous estimate of discharges associated with each flow condition, and possibly unsteady flow simulations, would be required to warrant numerical comparison of computed and observed values.

5.4 Model Parameters and Options

The following sections describe the key model parameters and options adopted in the calibrated HEC-RAS model. These include Manning's roughness values for channel and overbank areas; contraction and expansion loss coefficients; and ineffective areas.

5.4.1 Manning's Roughness Values

Computations in HEC-RAS are based on quantifying the friction loss between cross sections using Manning's roughness equation. The Manning's roughness coefficient is a parameter that accounts for losses attributed to river bottom material size and shape, floodplain conditions, and variations in the general river planform. A description of the channel and floodplain roughness values adopted in the model follows.

Channel Roughness

Table 10 summarizes calibrated channel roughness along the study reach for the high flow model calibration. Calibrated channel roughness values, n were adjusted on a reach-averaged basis. Calibrated channel roughness values gradually vary from n = 0.025 in the lower reaches to n = 0.029 in the upper reaches. Calibrated values were consistent with roughness values estimated by the three previous studies of the North Saskatchewan in and near Edmonton (Philips Planning & Engineering Limited 1994, I.D. Group (Alberta) Inc. and CartoLogix Corporation 1995, and Northwest Hydraulic Consultants Ltd. 2007).

Overbank Roughness

Overbank roughness varied from reach to reach according to the land cover types listed in **Table 7**. **Appendix B** lists the prescribed values for each cross section.

5.4.2 Expansion and Contraction Coefficients

To account for the effect of flow contraction and expansion losses on the energy balance between successive cross sections, HEC-RAS multiplies the absolute difference in velocity head by a coefficient. The default values of 0.1 and 0.3 (for expansion and contraction coefficients) were utilized throughout

the entire model domain, excepting cross sections located at the bridge crossings. At these cross sections, expansion and contraction coefficients were increased to 0.3 and 0.5, respectively.

Table 10 Calibrated Manning's roughness values for main channel

Cross Sections	Description	Manning's Roughness, n
XS-245 to XS-181 (113925.9 m to 81037.88 m)	The upper reach has the largest bed material and the most steep bed slope. A number of islands and large channel bars are present in this reach.	0.029
XS-180 & XS-179 (80207 m to 79861.91 m)	Transition between upstream and downstream reaches.	0.028
XS-178 to XS-153 (79845.91 m to 69440.75 m)	Channel begins to flatten out and narrow somewhat. Planform is a regular meander of near constant width with no islands.	0.027
XS-152 (69408.42 m)	Transition between upstream and downstream reaches.	0.028
XS-151 to XS-128 (69126.02 m to 62738.11 m)	The observed HWMs suggest that Manning's *roughness* values here may be higher here than adjacent reaches. Therefore a higher roughness value was chosen here to match observed HWMs and the WSC gauge rating curve. Higher roughness in this reach may be somewhat attributable to its relatively tight bends and occasional encounter with bedrock.	0.029
XS-127 (62176.15 m)	Transition between upstream and downstream reaches.	0.028
XS-126 to XS-097 (61674.38 m to 52899.12 m)	Through this reach, the river has an irregular straight channel pattern.	0.027
XS-096 to XS-075 (52136.59 m to 40863.20 m)	This reach begins slightly downstream of the Sturgeon River confluence. It is slightly wider than neighbouring reaches. The channel winds through a few regular wide meanders.	0.026
XS-074 to XS-001 (40013.82 m to 0.00 m)	The lowest reach has the mildest slope of the study reaches, and a straight channel of near constant channel width.	0.025

5.4.3 Ineffective Flow Areas

Ineffective Flow Areas

Ineffective flow areas were specified at cross sections in the HEC-RAS model based on a review of local terrain and floodplain features at and between cross sections. Ineffective flow areas can be specified

within portions of cross sections where the downstream velocity is expected to be close to or equal to zero (Brunner, 2016).

In the model, permanent and non-permanent ineffective flow areas may be specified. Permanent ineffective flow areas are ineffective at all water surface elevations, whereas temporary ineffective flow areas become effective above a defined elevation. For this study, only permanent ineffective flow areas were specified. Non-permanent areas often produce the undesirable result of computed high flood magnitude water level profiles dipping below computed lower flood magnitude water level profiles.

Permanent ineffective flow areas were used to account for flow patterns influenced by nearby bridge abutments and roadway embankments crossing the floodplain. These types of obstructions tend to direct flows towards the bridge opening. Several site-specific factors were taken into account when configuring ineffective flow areas at bridges in the study area, including: distance from the cross section to the bridge, terrain features, and bridge geometry.

5.4.4 Flow Splits, Islands and Diversions

The study reaches were adequately represented without flow splits around islands. Where a cross section intersected an island, the HEC-RAS model assumed equal water levels on both sides of the island based on the composite channel conveyance properties and computed energy losses. The validity of this assumption increases as flood magnitudes increase beyond the point where the island is inundated.

Diversions may include avulsion channels or flow paths along a portion of the study reach that reduce total main channel discharge there. There were no such diversions encountered within the study area; all flood flows were confined to the cross sections modelled along the study reach.

5.5 Flood Frequency Profiles

The calibrated hydraulic model was used to generate flood frequency profiles for the thirteen naturalized open water floods of varying magnitude listed in **Table 3. Appendix D** lists the computed flood frequency water levels at each cross section. **Figure 6** displays these results.

5.6 Model Sensitivity

Varying the downstream boundary condition and Manning's roughness changes computed water levels, and consequently flood depths and inundation limits. The sensitivity of computed water levels to these variations were evaluated to gain an indication of model error range and to identify the relative sensitivity to each parameter. The 100-year flood was used as the baseline for this sensitivity analyses. A summary of the sensitivity analysis results is provided in the following sections. **Appendix E** provides detailed tabulated results.

5.6.1 Downstream Boundary Condition

A starting water surface elevation at the downstream boundary is necessary for the HEC-RAS model to begin calculations. The adopted downstream boundary condition was based on a normal depth approximation, where the starting water level was calculated by Manning's equation with a specified energy slope equal to 0.00028 m/m. At the 100-year flood frequency discharge, this resulted in a starting water surface elevation of 594.73 m at the downstream boundary. The downstream boundary condition was adjusted to test changes of about ±0.5 m in the downstream water surface elevation. This was achieved by adjusting the specified energy slopes to 0.00035 m/m (~0.5 m decrease to 594.24 m) and 0.00023 m/m (~0.5 m increase to 595.18 m).

The results are listed in **Appendix E** and the resulting water surface elevation profiles shown in **Figure 7**. Departures of the computed water surface elevations from the baseline condition steadily decrease to below 0.1 m about 9,000 m upstream of the boundary condition (near cross section XS-018). Beyond about 23,000 m (near cross section XS-043) computed water surface elevations are effectively independent of the downstream boundary condition – the response of the computed water level here to boundary level variations is indiscernible.

5.6.2 Manning's Roughness Values

Channel Roughness

Calibrated channel Manning's *roughness* values vary from the lower to the upper reaches, from 0.025 to 0.029 progressively. To test the sensitivity of computed water levels to channel roughness, these values were adjusted ±15%. **Appendix E** lists the results of these tests and **Figure 8** shows the resulting water levels. A 15% increase (decrease) in main channel roughness results in an average water level increase (decrease) of 0.62 m (-0.67 m) along the study reach. **Table 11** lists statistics on the differences.

Overbank Roughness

Sensitivity of computed 100-year flood levels was tested with a ±20% variation in overbank roughness. Overbank roughness was varied by a larger percent than channel roughness to reflect the potentially greater uncertainty in overbank roughness. **Appendix E** tabulates the results and **Figure 9** . displays the resulting water levels. The computed water levels are not very sensitive to variations in overbank roughness. A 20% increase (decrease) in overbank roughness corresponds to a water level increase (decrease) along the study reach of 0.01 m (-0.02 m) on average. **Table 11** lists statistics on the differences.

Table 11 Sensitivity analysis results for variation in channel roughness

Sensitivity Parameter	Difference from Baseline Profile (m)			
	Lower Roughness		Higher Roughness	
	Maximum	Average	Maximum	Average
Channel Roughness	-0.79	-0.67	0.73	0.62
Overbank Roughness	-0.07	-0.03	0.05	0.02

6 FLOOD INUNDATION MAPS

Flood inundation mapping provides a visual display of areas that could be underwater in one or more flood scenarios. For this study, one flood inundation map series was created for each flood frequency return period; there are 13 map series, with return periods ranging from 2 to 1000-years. **Appendix F** contains the flood inundation maps. The following sections describe the flood inundation map production process.

6.1 Methodology

The flood inundation maps were created in five steps:

1. A water surface elevation (WSE) triangular irregular network (TIN) is created, representing a contiguous flood level profile along the modelled river reaches.
2. A WSE grid with the same grid geometry as the underlying DTM is generated. Elevation values are assigned to each grid cell, based on the corresponding WSE TIN value.
3. A depth grid, having the same grid geometry as the WSE grid, is generated by subtracting DTM elevation values from the corresponding WSE grid value.
4. Inundation polygons are generated from the positive depths. Negative depths indicating dry cells are assigned a *NoData* value. Inundation polygons are further processed by smoothing and removing "isolated" wetted areas not directly inundated and "holes" (very small dry areas).
5. WSE and depth grids are clipped to the inundation extent using the inundation polygons.

The WSE TINs, WSE and depth grids, and the inundation polygons were created using standard ArcGIS tool sets, and are stored in a conventional Esri file format.

6.1.1 Direct Flood Inundation Areas

Direct flood inundation areas are identified as either within the actively-flowing river channel, or as flooded overbank areas connected to the channel. Extensive flooded overbank areas connected directly to the channel via a distinct overtopping point are identified, and each such area's water level is adjusted to equal the water level at its overtopping point. Generally speaking, this procedure reduces (increases) the extent of an inundated area that is upstream (downstream) of its overtopping point.

Also identified as direct flood inundation areas are flooded areas behind railroad embankments as these are assumed to be permeable; and areas directly connected by a culvert to the channel.

6.2 Flood Impacts

The impacts of flooding on developed areas and infrastructure is evident in the flood inundation mapping libraries (**Appendix F**). **Table 13** lists flood impacted areas, and provides an overview of flood magnitude ranges for residential, commercial, industrial, and other notable facilities. The Table lists areas from upstream to downstream, with left (right) floodplain areas on the left (right) side of the Table. The middle of the Table shows the cross section numbers nearest to each flooded area to assist in cross-referencing with the inundation mapping libraries. The grey shaded boxes provide a graphical display of the approximate range of flood frequency magnitudes impacting each area.

Impacts to bridges are illustrated in the computed flood level frequency profiles where low chord and high chord elevations are indicated on the profile plots (**Figure 6**). Up to and including the calculated 1,000-year flood level, no flood exceeds the high chord elevation of any bridge. The low chord elevation of some bridges (e.g. Walterdale Bridge, Low Level Bridge, Dawson Bridge, and the pedestrian bridge under the NE Anthony Henday Bridge) is exceeded by the 200-year and greater return period flood scenarios.

The ***Flood Risk Inventory and Assessment Study Report*** (NHC 2020c) provides additional detailed information on flood impacts to developed areas and bridges.

Table 12 Overview of the range of flood magnitudes for areas impacted by flooding

Impacted Areas along Left Floodplain													Cross Section Reference	Impacted Areas along Right Floodplain											
2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR		2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR
Riverside RV Park													XS-245													
					50	75	100	200	350	500	750	1K														
Grand River Valley Estates													XS-242													
					50	75	100	200	350	500	750	1K														
													XS-235	Devon Voyageur Park											
																10	20	35	50	75	100	200	350	500	750	1K
													XS-229	Devon Golf Course											
																	20	35	50	75	100	200	350	500	750	1K
													XS-227	Devon Lions Campground											
																10	20	35	50	75	100	200	350	500	750	1K
													XS-220	Rabbit Hill Snow Resort & Shalom Park											
																	20	35	50	75	100	200	350	500	750	1K
Blackhawk Golf Club													XS-217													
		10	20	35	50	75	100	200	350	500	750	1K														
													XS-206	Windermere Golf & Country Club											
																10	20	35	50	75	100	200	350	500	750	1K
Big Island Park													XS-204													
2	5	10	20	35	50	75	100	200	350	500	750	1K														
													XS-202	River Ridge Golf & Country Club											
																10	20	35	50	75	100	200	350	500	750	1K
EL Smith Water Treatment Plant													XS-193	Terwillegar Park											
						75	100	200	350	500	750	1K			5	10	20	35	50	75	100	200	350	500	750	1K

Note: shaded areas indicate the flood frequencies impacting the respective area.

Table 13 Overview of the range of flood magnitudes for areas impacted by flooding (continued)

Impacted Areas along Left Floodplain													Cross Section Reference	Impacted Areas along Right Floodplain											
2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR		2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR
													XS-177	Fort Edmonton Park												
																						200	350	500	750	1K
Sir Wilfrid Laurier Park													XS-170	Whitemud Equestrian Park												
						75	100	200	350	500	750	1K											350	500	750	1K
Buena Vista Park													XS-168													
						75	100	200	350	500	750	1K															
													XS-164	Hawrelak Park												
																							350	500	750	1K
													XS-162	Royal Mayfair Golf Club												
																					100	200	350	500	750	1K
Victoria Golf Course / Victoria Park													XS-158	Emily Murphy Park												
								200	350	500	750	1K								75	100	200	350	500	750	1K
Royal Glenora Club													XS-156													
								200	350	500	750	1K															
													XS-151	Kinsmen Park												
																				75	100	200	350	500	750	1K
Rossdale Water Treatment Plant													XS-149	Kinsmen Outdoor Pool & Sports Centre												
												1K										200	350	500	750	1K
Fire Station No. 21													XS-147													
								200	350	500	750	1K															
Rossdale													XS-145													
				35	50	75	100	200	350	500	750	1K															

Note: shaded areas indicate the flood frequencies impacting the respective area.

Table 13 Overview of the range of flood magnitudes for areas impacted by flooding (continued)

Impacted Areas along Left Floodplain													Cross Section Reference	Impacted Areas along Right Floodplain											
2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR		2-YR	5-YR	10-YR	20-YR	35-YR	50-YR	75-YR	100-YR	200-YR	350-YR	500-YR	750-YR	1000-YR
Louise McKinney Riverfront Park													XS-140	Cloverdale												
		10	20	35	50	75	100	200	350	500	750	1K								75	100	200	350	500	750	1K
Riverdale													XS-136													
			20	35	50	75	100	200	350	500	750	1K														
Dawson Park													XS-130	Riverside Golf Course												
								200	350	500	750	1K							50	75	100	200	350	500	750	1K
Highlands Golf Club													XS-126													
					50	75	100	200	350	500	750	1K														
													XS-118	Gold Bar Wastewater Treatment Plant												
																							350	500	750	1K
Rundle Park													XS-116	Gold Bar Park												
			20	35	50	75	100	200	350	500	750	1K											350	500	750	1K
Hermitage Park													XS-099													
		10	20	35	50	75	100	200	350	500	750	1K														
													XS-080	Legends Golf and Country Club												
																	20	35	50	75	100	200	350	500	750	1K
The Quarry Golf Course													XS-078	Capital Region Wastewater Commission												
						75	100	200	350	500	750	1K										200	350	500	750	1K
													XS-062	West Rivers Edge Park												
																										1K
													XS-060	Chabot Park												
																							350	500	750	1K
Lamoureux													XS-051													
									350	500	750	1K														

7 CONCLUSIONS

The objectives of this study were to assess river flood-related hazards along the North Saskatchewan River. Municipalities affected by flooding in the study area include Devon, Parkland County, Edmonton, Strathcona County, Sturgeon County, and Fort Saskatchewan. This report summarizes the work of the **Hydraulic Model Creation and Calibration and Open Water Flood Map Production** study component. A numerical model was developed using the HEC-RAS computer program distributed and maintained by the U.S. Army Corps of Engineers Hydraulic Engineering Center. River bathymetry and digital terrain data from the **Survey and Base Data Collection** component as well as flood frequency estimates from the **Open Water Hydrology Assessment** component were used to develop, calibrate, and apply the open water hydraulic model as described throughout this report. The reports for the two previous work components mentioned above should also be read in conjunction with this report, as they provide additional pertinent background information.

A number of open water floods have occurred on the North Saskatchewan River. The largest recorded flood event occurred on 28 June 1915 (peak discharge 5,800 m^3/s). The most significant flood in recent memory occurred on June 27th 1986. Highwater elevations were recorded just after the 1986 flood peak discharge (3200 m^3/s) had passed; these data were used to calibrate the hydraulic model. Water levels computed by the calibrated model were about 0.03 m above the observed high water elevations in the 1986 event.

Water surface profiles were calculated for the 2-, 5-, 10-, 20-, 35-, 50-, 75-, 100-, 200-, 350-, 500-, 750-, and 1000-year flood frequency return period discharges. All bridges along the study reach are above the computed 100-year flood level. The low chord of a few bridges are impacted by the 200-year flood level while most bridges remain above computed flood levels up to the 1000-year flood magnitude.

Flood inundation maps were created for all of the 13 flood frequency magnitudes and organized together into a single flood inundation map library.

8 REFERENCES

AENV. 1981. History of Floods in the North Saskatchewan River Basin. Environmental Engineering Support Services, Technical Services Division, Alberta Environment, January 1981.

AENV. 1987. 1986 highwater mark report. Water Resource Management Services, Technical Services Division, Alberta Department of the Environment, June 1987.

AENV. 1988. North Saskatchewan River, Fort Saskatchewan to Devon, Water Surface Profiles and Location Plans. River Engineering Branch, Alberta Environment, March 1988.

AENV. 1990. Flood Frequency Analysis-North Saskatchewan River at Edmonton. Water Resources Management Services, Technical Services Division, Hydrology Branch, Alberta Environment, November 1990.

Airborne Imaging. 2019. North Saskatchewan River and Red Deer River LiDAR Acquisition and Processing – 2018.

Brunner, G. 2016. HEC-RAS River Analysis System Hydraulic Reference Manual. Version 5.0. Hydrologic Engineering Center, U.S. Army Corps of Engineers. Davis, California, February 2016.

City of Edmonton. (n.d.). The Flood. Retrieved September 2019 from https://www.edmonton.ca/city_government/edmonton_archives/the-flood.aspx.

Edmonton Bulletin. 1899. The Deluge. *Edmonton Bulletin*, August 21st, 1899.

Edmonton Bulletin. 1915. Work of Relief Went on All Day without Stop. *Edmonton Bulletin*, June 29th, 1915.

Edmonton Bulletin. 1915. Power Plant in Danger. *Edmonton Bulletin*, June 29th, 1915.

Edmonton Bulletin. 1915. Boil the Water. *Edmonton Bulletin*, July 1st, 1915.

Edmonton Bulletin. 1915. Flood Victims Back in Homes. *Edmonton Bulletin,* July 2nd, 1915.

Edmonton Journal. 1986. Hundreds Flee Flooded River. *Edmonton Journal,* July 19th, 1986.

I.D. Group (Alberta) Inc. and Cartologix Corporation. 1995. North Saskatchewan River at Edmonton Flood Risk Mapping Study (Phase II - Upper Reach).

Kellerhals, R., Neil, C. and Bray, D. 1972. Hydraulic and Geomorphic Characteristics of Rivers in Alberta. Research Council of Alberta. Edmonton, AB. 1972

Northwest Hydraulic Consultants Ltd. 2007. North Saskatchewan River Flood Risk Mapping Study Devon to Fort Saskatchewan (Excluding Edmonton) Alberta Flood Risk Mapping Program.

Northwest Hydraulic Consultants Ltd. 2020a. North Saskatchewan River Hazard Study – Open Water Hydrology Assessment Report. Report for Alberta Environment and Parks.

Northwest Hydraulic Consultants Ltd. 2020b. North Saskatchewan River Hazard Study – Survey and Base Data Collection Report. Report for Alberta Environment and Parks.

Northwest Hydraulic Consultants Ltd. 2020c. North Saskatchewan River Hazard Study – Flood Risk Inventory and Assessment Report. Report for Alberta Environment and Parks.

OGL Engineering Ltd. 2019. Aerial imagery acquisition memo (*Untitled document*). Imagery acquired on 27 May 2019.

Philips Planning & Engineering Limited. 1994. North Saskatchewan River at Edmonton Flood Risk Mapping Study (Phase I - Lower Reach).

FIGURES

North Saskatchewan River

GIBBONS

BRUDERHEIM

STURGEON COUNTY

FORT SASKATCHEWAN

ST. ALBERT

SPRUCE GROVE

STONY PLAIN

PARKLAND COUNTY

EDMONTON

05DF001

SHERWOOD PARK

STRATHCONA COUNTY

LAMONT COUNTY

BEAVER COUNTY

LEDUC COUNTY

BEAUMONT

DEVON

HWY 2

HWY 2A

HWY 44

HWY 16

HWY 14

North Saskatchewan River Basin

SCALE - 1:3,500,000

0 50 100 KM

N

DRAFT

WSC GAUGE STATION

FLOW DIRECTION

STUDY REACH

MUNICIPAL BOUNDARY

DATA SOURCES: Basemap from Esri & NRCAN.

SCALE - 1:300,000

0 2 4 6 8 10 12 KM

N

Coordinate System: NAD 1983 CSRS 3TM 114
Vertical Datum: CGVD28 HTv2.0; Units: Metres

Job: 1003870 Date: 10-APR-2020

NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

STUDY AREA

FIGURE 1

Alberta

nhc northwest hydraulic consultants

PARKLAND COUNTY

DEVON BRIDGE NB

DEVON BRIDGE SB

North Saskatchewan River

Study Limit

113000 m

112000 m

111000 m

110000 m

109000 m

108000 m

107000 m

106000 m

105000 m

104000 m

103000 m

102000 m

101000 m

100000 m

TOWN OF DEVON

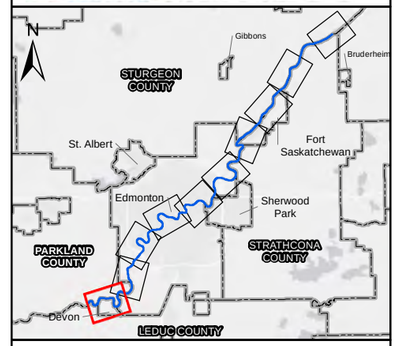
LEDUC COUNTY

CITY OF EDMONTON

Edmonton South West

Alberta

nhc
northwest hydraulic consultants



- 1986 HIGHWATER MARK
- FLOW DIRECTION
- STUDY REACH
- BRIDGE
- STUDY LIMIT
- MODEL CROSS SECTION
- MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000

0 200 400 800 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	REH	PGV

Job: 1003870	Date: 10-APR-2020

NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

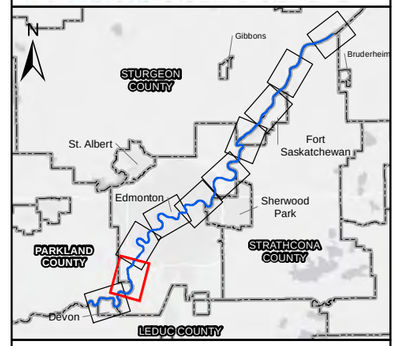
HIGHWATER MARK LOCATIONS

SHEET 1 OF 10	*FIGURE 2*

P:\Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd

Alberta

nhc
northwest hydraulic consultants



- 1986 HIGHWATER MARK
- FLOW DIRECTION
- STUDY REACH
- BRIDGE
- STUDY LIMIT
- MODEL CROSS SECTION
- MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000

0 200 400 800 M

N

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	REH	PGV

Job: 1003870	Date: 10-APR-2020

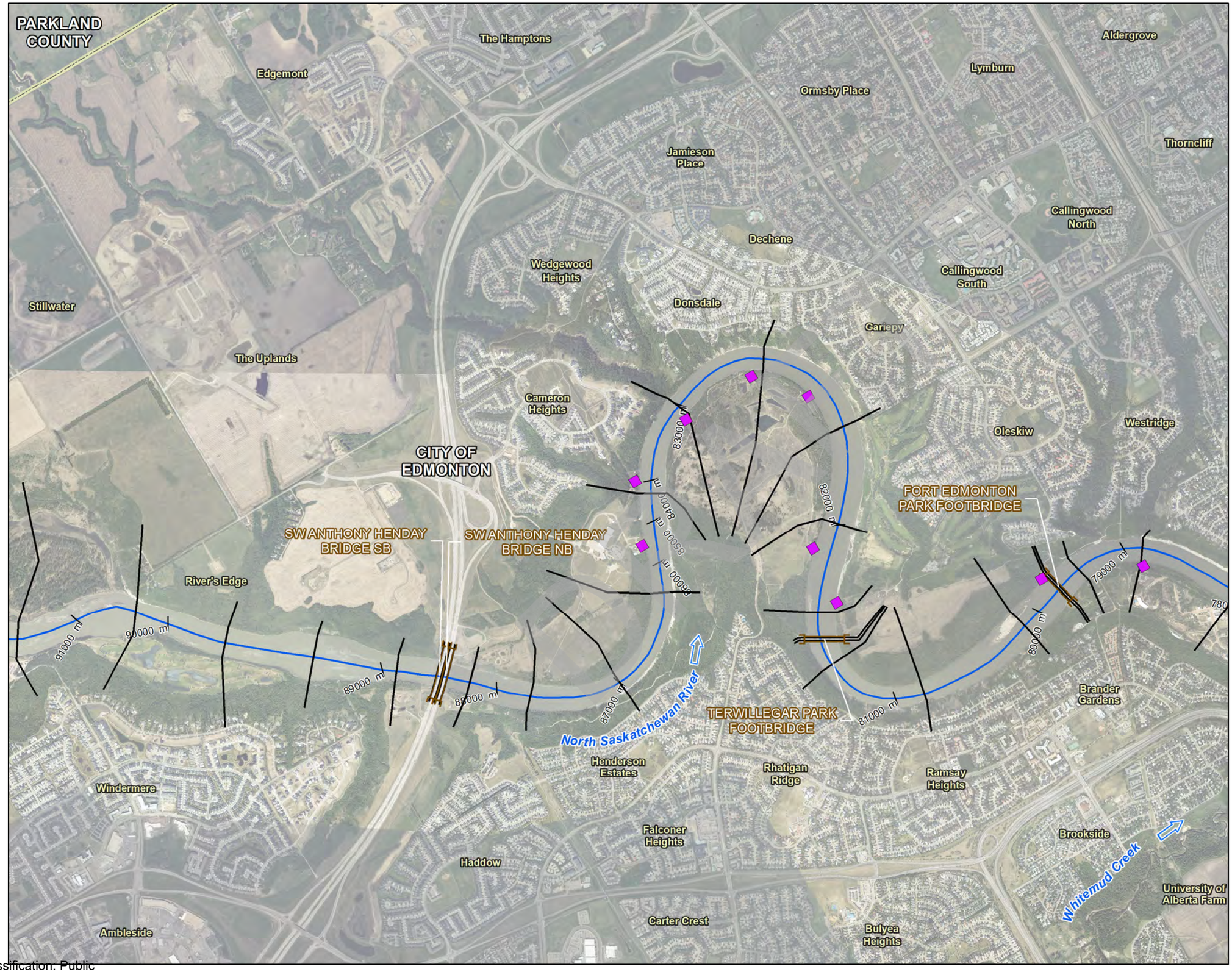
NORTH SASKATCHEWAN RIVER HAZARD STUDY

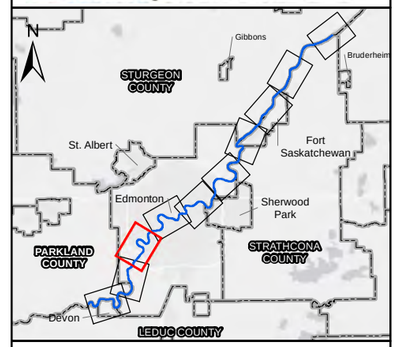
HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS

SHEET 2 OF 10	FIGURE 2

P:_Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd, REH





1986 HIGHWATER MARK

FLOW DIRECTION

STUDY REACH

BRIDGE

STUDY LIMIT

MODEL CROSS SECTION

MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000

0 200 400 800 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	REH	PGV

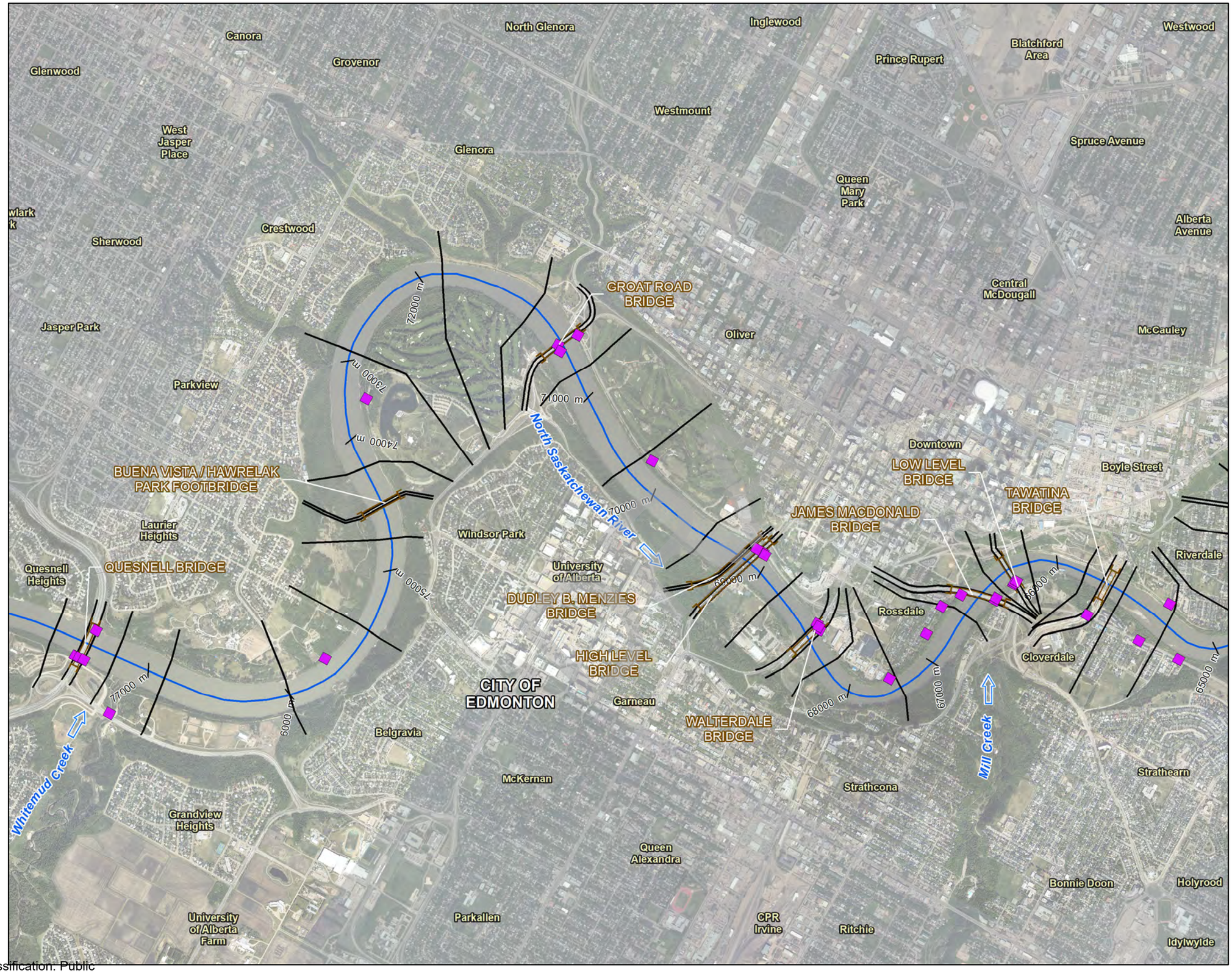
Job: 1003870 | Date: 10-APR-2020

NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

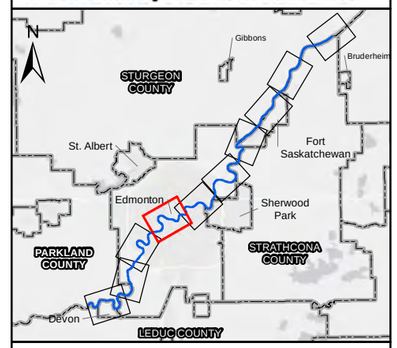
HIGHWATER MARK LOCATIONS

SHEET 3 OF 10 | *FIGURE 2*



Alberta

nhc
northwest hydraulic consultants



1986 HIGHWATER MARK
FLOW DIRECTION
STUDY REACH
BRIDGE
STUDY LIMIT
MODEL CROSS SECTION
MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000
0 200 400 800 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	REH	PGV

Job: 1003870 | Date: 10-APR-2020

NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

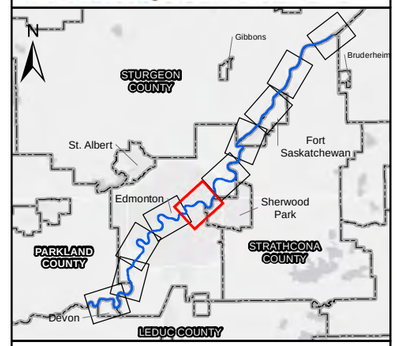
HIGHWATER MARK LOCATIONS

SHEET 4 OF 10 | *FIGURE 2*

REH, P:_Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd

Alberta

nhc
northwest hydraulic consultants



- 1986 HIGHWATER MARK
- FLOW DIRECTION
- STUDY REACH
- BRIDGE
- STUDY LIMIT
- MODEL CROSS SECTION
- MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000

0 200 400 800 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	REH	PGV

Job: 1003870	Date: 10-APR-2020

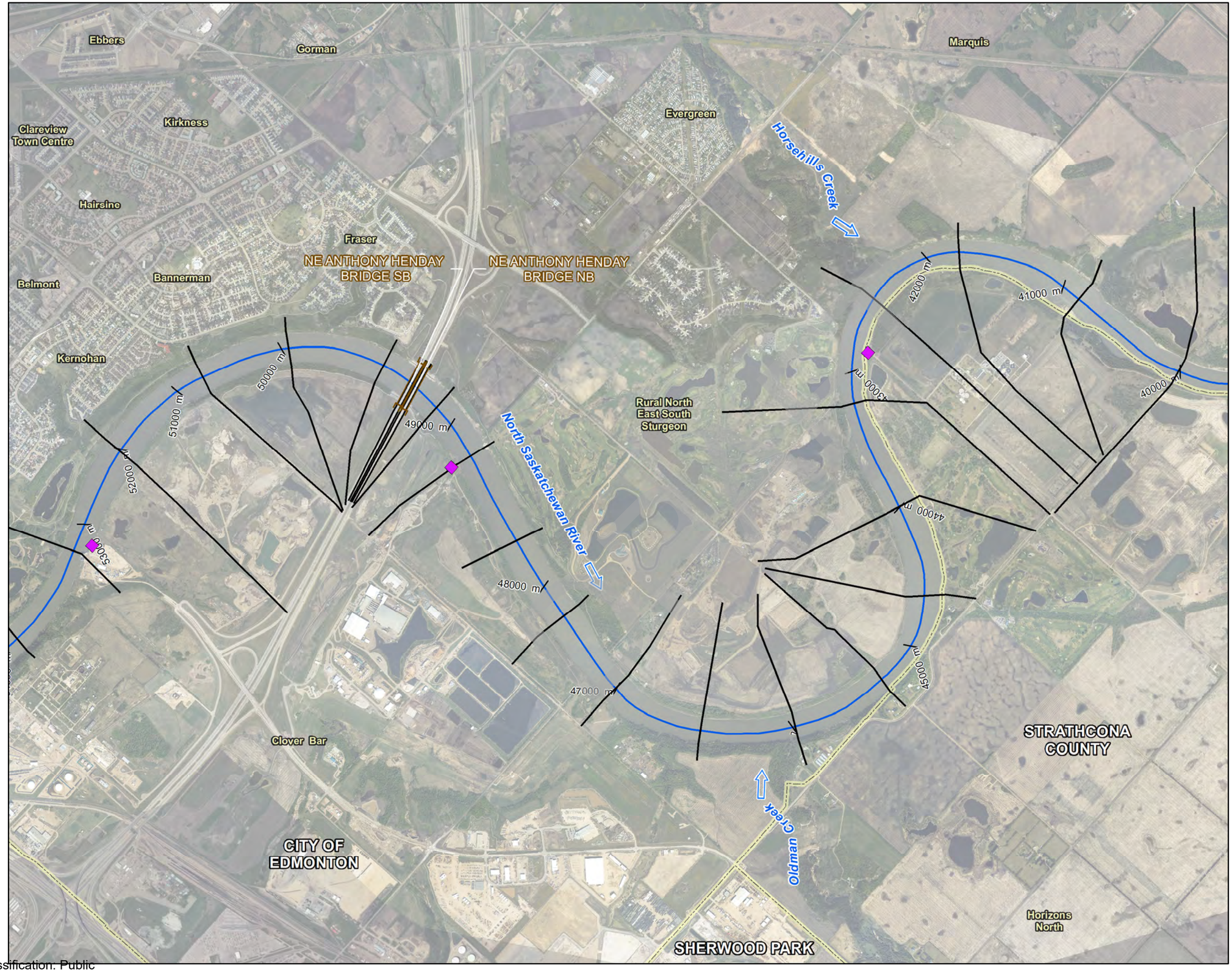
NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS

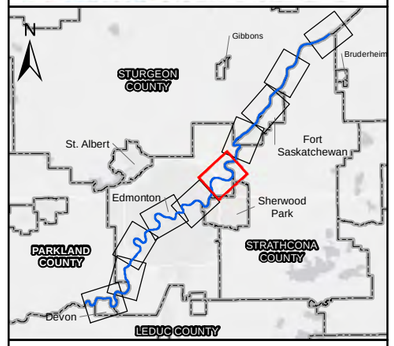
SHEET 5 OF 10	*FIGURE 2*

REH, P:_Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd



Alberta

nhc
northwest hydraulic consultants



- 1986 HIGHWATER MARK
- FLOW DIRECTION
- STUDY REACH
- BRIDGE
- STUDY LIMIT
- MODEL CROSS SECTION
- MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000

0 200 400 800 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	GIS	Reviewer
DJH	REH	PGV

Job: 1003870	Date: 10-APR-2020

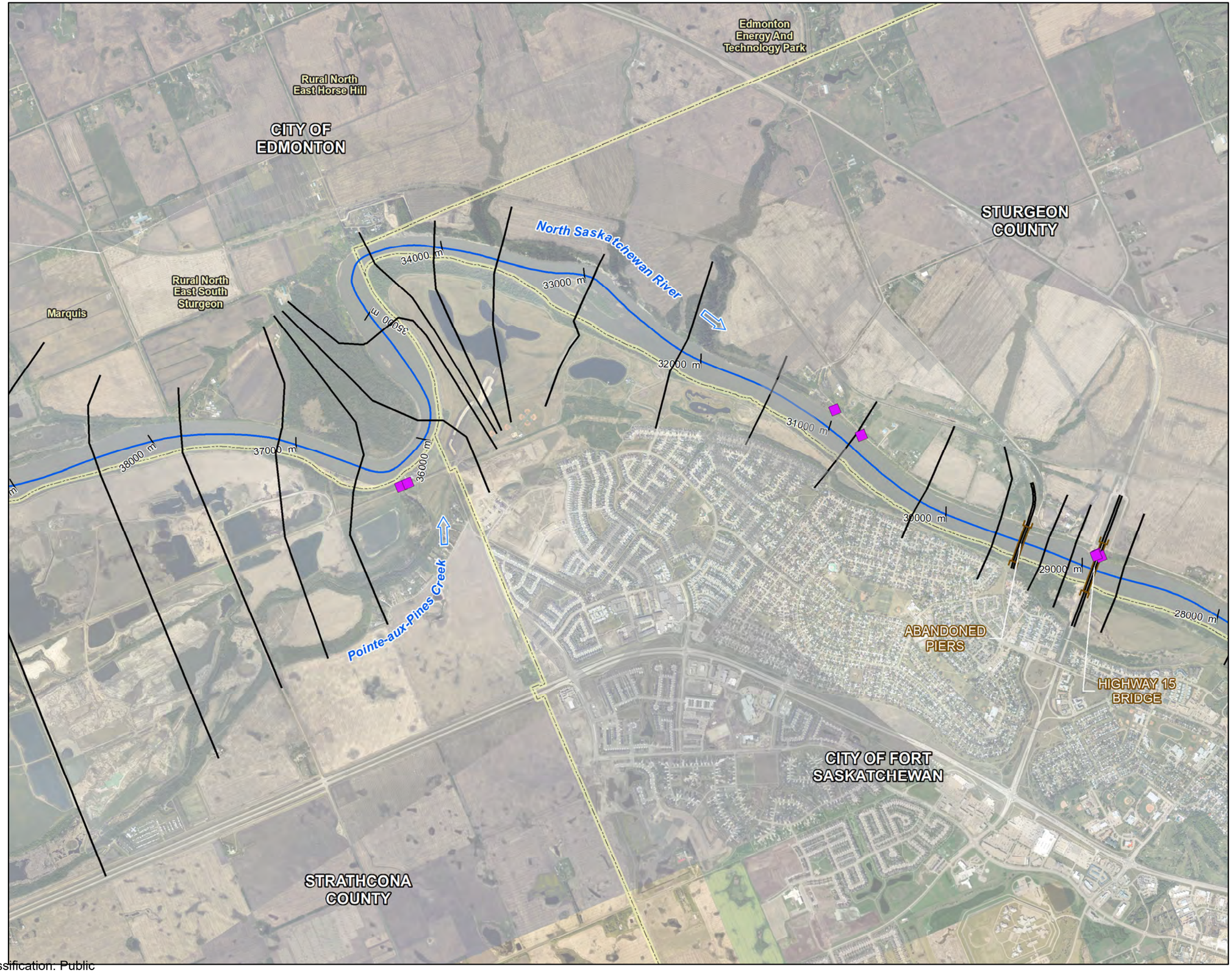
NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS

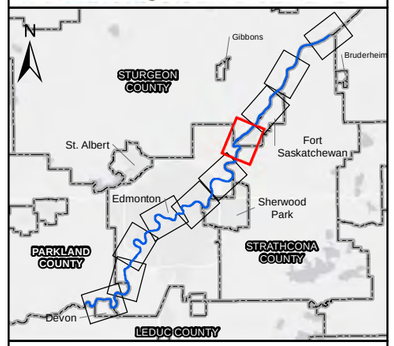
SHEET 6 OF 10	FIGURE 2

REH, P:_Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd



Alberta

nhc
northwest hydraulic consultants



- 1986 HIGHWATER MARK
- FLOW DIRECTION
- STUDY REACH
- BRIDGE
- STUDY LIMIT
- MODEL CROSS SECTION
- MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000

0 200 400 800 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	REH	PGV

Job: 1003870	Date: 10-APR-2020

NORTH SASKATCHEWAN
RIVER HAZARD STUDY

HYDRAULIC MODELLING AND
FLOOD INUNDATION MAPPING

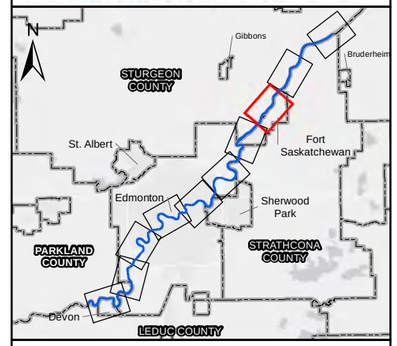
HIGHWATER MARK LOCATIONS

SHEET 7 OF 10	*FIGURE 2*

REH, P:_Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd

Alberta

nhc
northwest hydraulic consultants



- 1986 HIGHWATER MARK
- FLOW DIRECTION
- STUDY REACH
- BRIDGE
- STUDY LIMIT
- MODEL CROSS SECTION
- MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000

0 200 400 800 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	REH	PGV

Job: 1003870	Date: 10-APR-2020

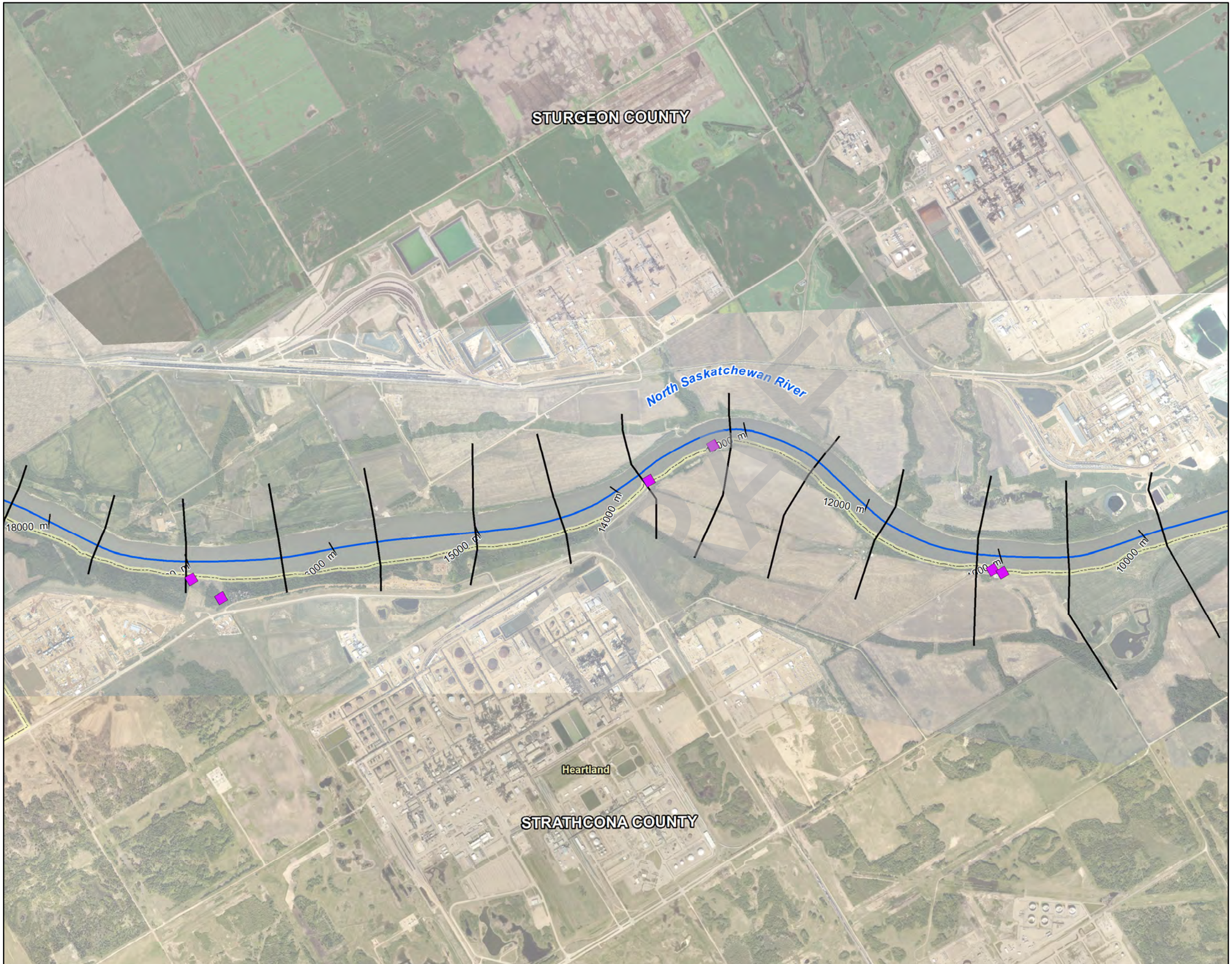
NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS

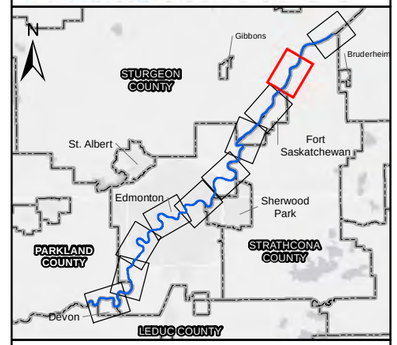
SHEET 8 OF 10	*FIGURE 2*

REH, P:_Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd



Alberta

nhc
northwest hydraulic consultants



1986 HIGHWATER MARK
FLOW DIRECTION
STUDY REACH
BRIDGE
STUDY LIMIT
MODEL CROSS SECTION
MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000
0 200 400 800 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	REH	PGV

Job: 1003870	Date: 10-APR-2020

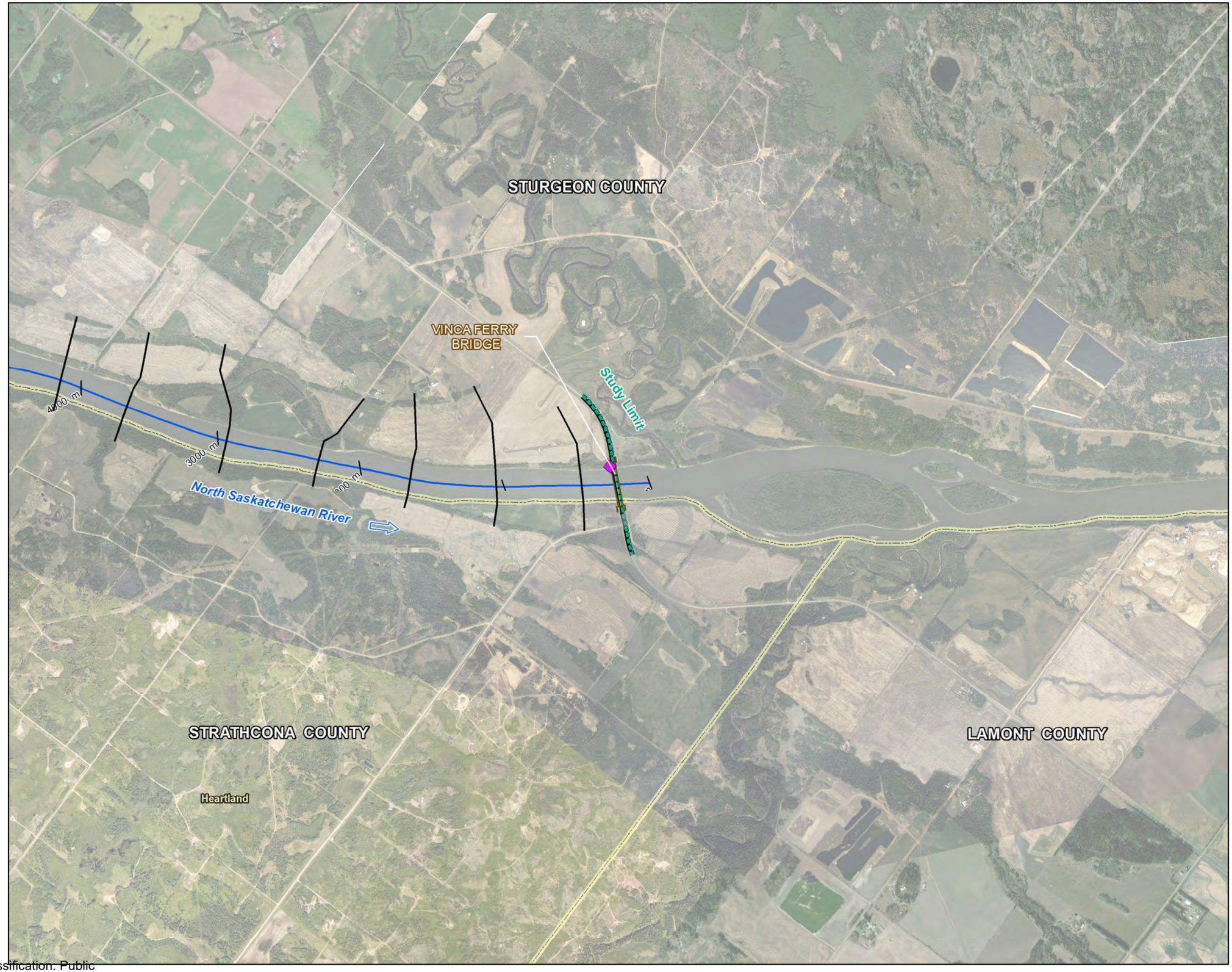
NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS

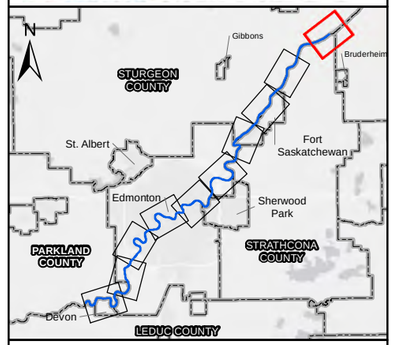
SHEET 9 OF 10	*FIGURE 2*

REH_P:_Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd



Alberta

nhc
northwest hydraulic consultants



- 1986 HIGHWATER MARK
- FLOW DIRECTION
- STUDY REACH
- BRIDGE
- STUDY LIMIT
- MODEL CROSS SECTION
- MUNICIPAL BOUNDARY

DATA SOURCES: Basemap imagery from Alberta Environment and Parks supplemented by Esri World Imagery; Highwater marks from Alberta Environment and Parks.

SCALE - 1:25,000

0 200 400 800 M

Coordinate System: NAD 1983 CSRS 3TM 114; Vertical Datum: CGVD28 HTv2.0; Units: Metres

Engineer	*GIS*	*Reviewer*
DJH	REH	PGV

Job: 1003870	Date: 10-APR-2020

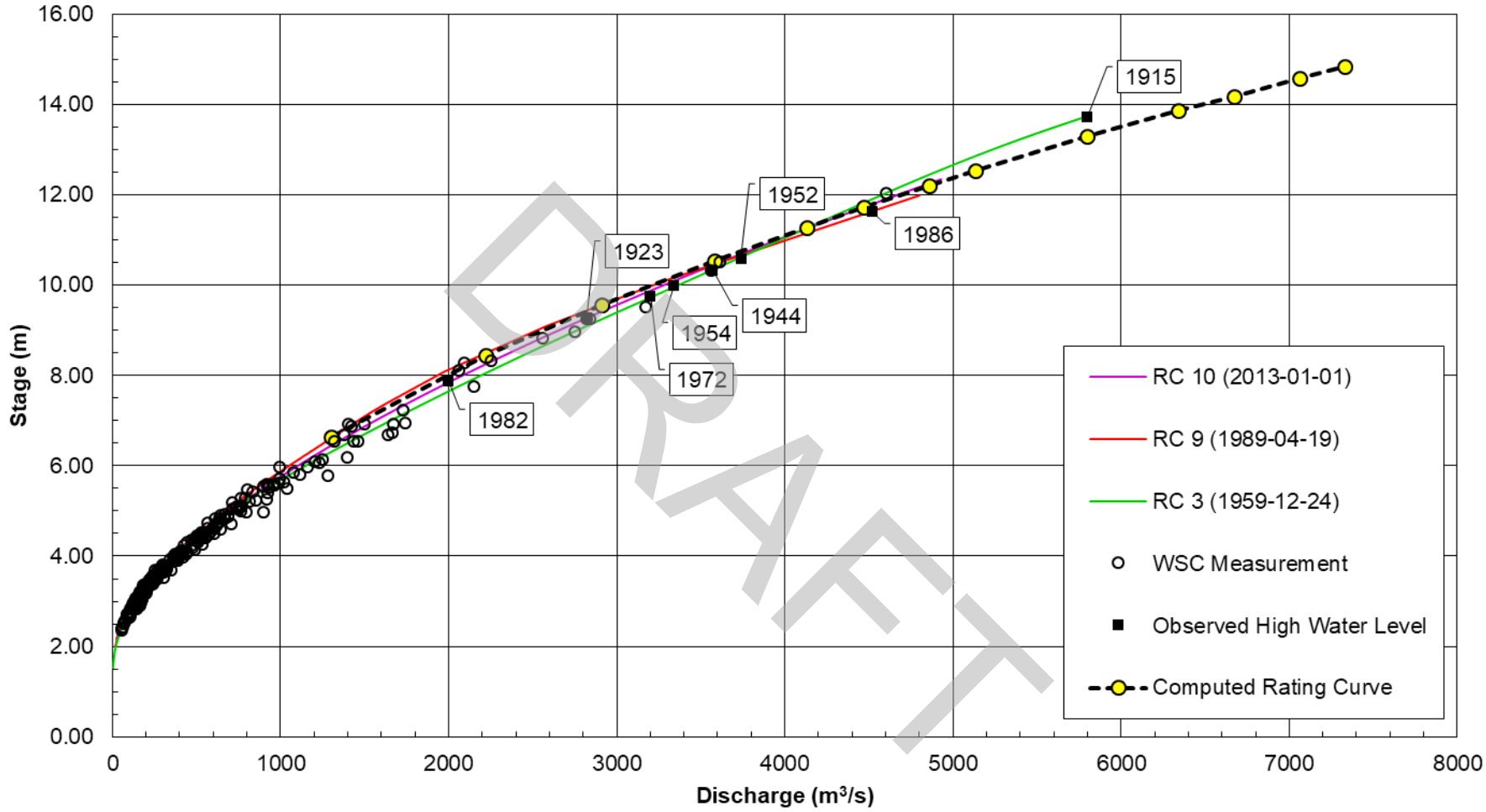
NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING AND FLOOD INUNDATION MAPPING

HIGHWATER MARK LOCATIONS

SHEET 10 OF 10	*FIGURE 2*

REH, P:_Projects (Active)\1003870 North Sask River Hazard Study\300 Hydraulic Model Creation and Calibration\GIS\1003870_REH_HWM_R0.mxd



Alberta Government

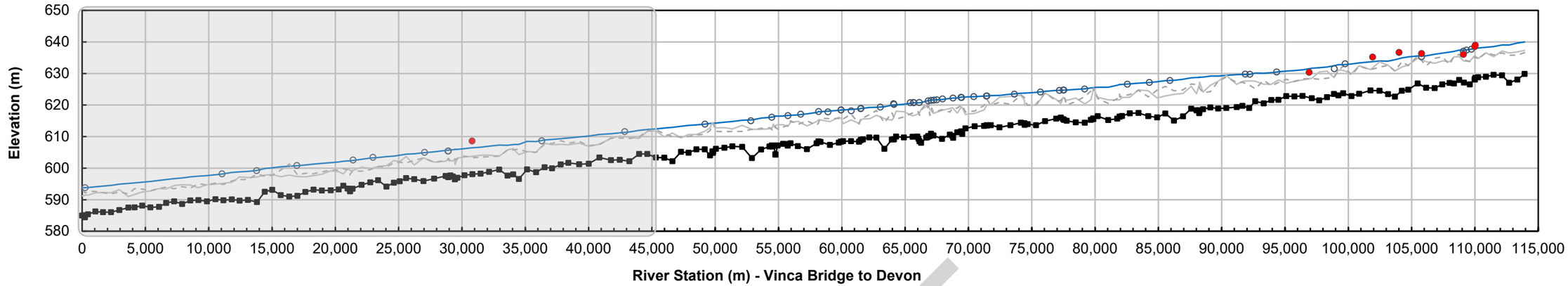
nhc northwest hydraulic consultants

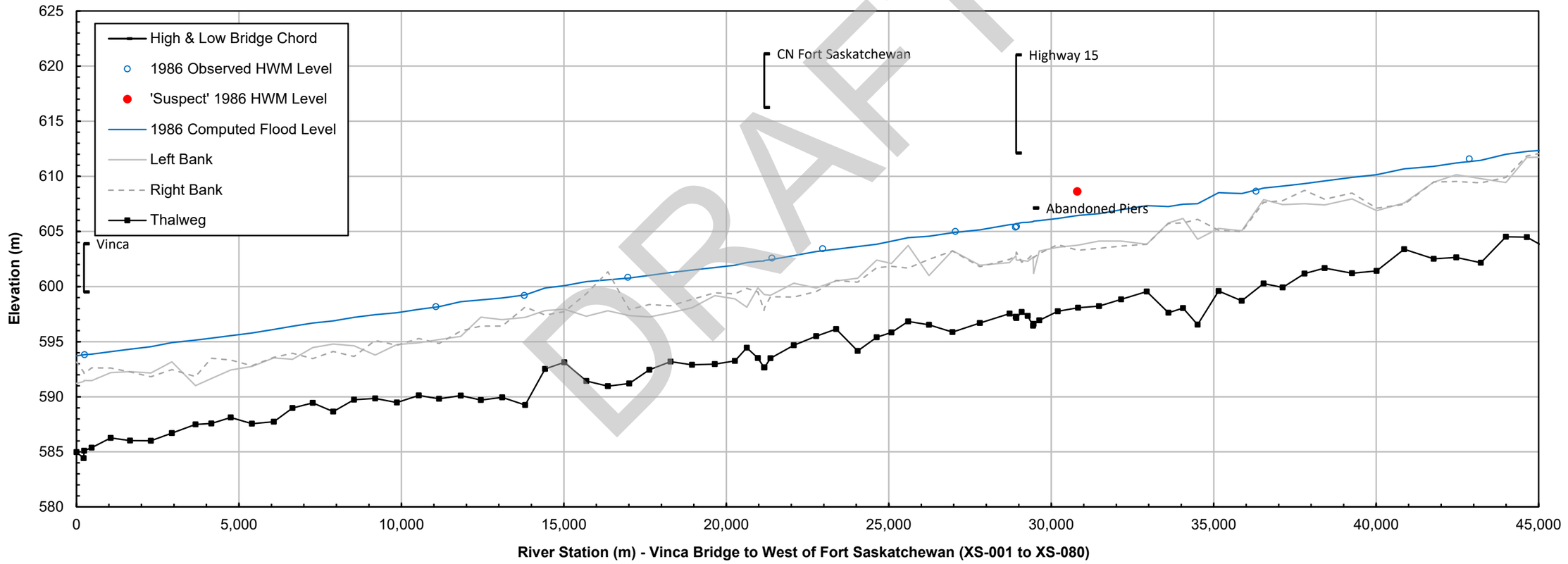
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING
COMPARISON BETWEEN COMPUTED AND REPORTED WSC RATING CURVE DATA 05DF001 NORTH SASKATCHEWAN RIVER AT EDMONTON

Project No.: 1003870

Date: 10-Apr-2020

FIGURE 3





Alberta Government

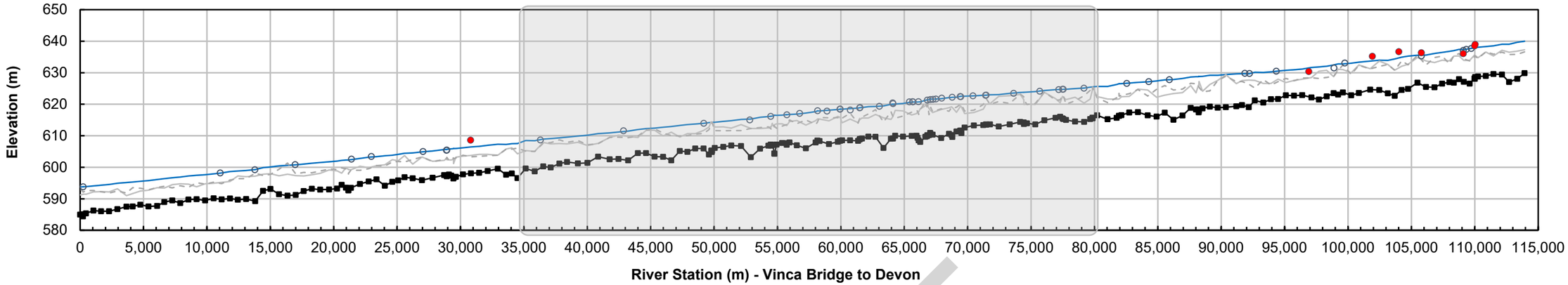
nhc northwest hydraulic consultants

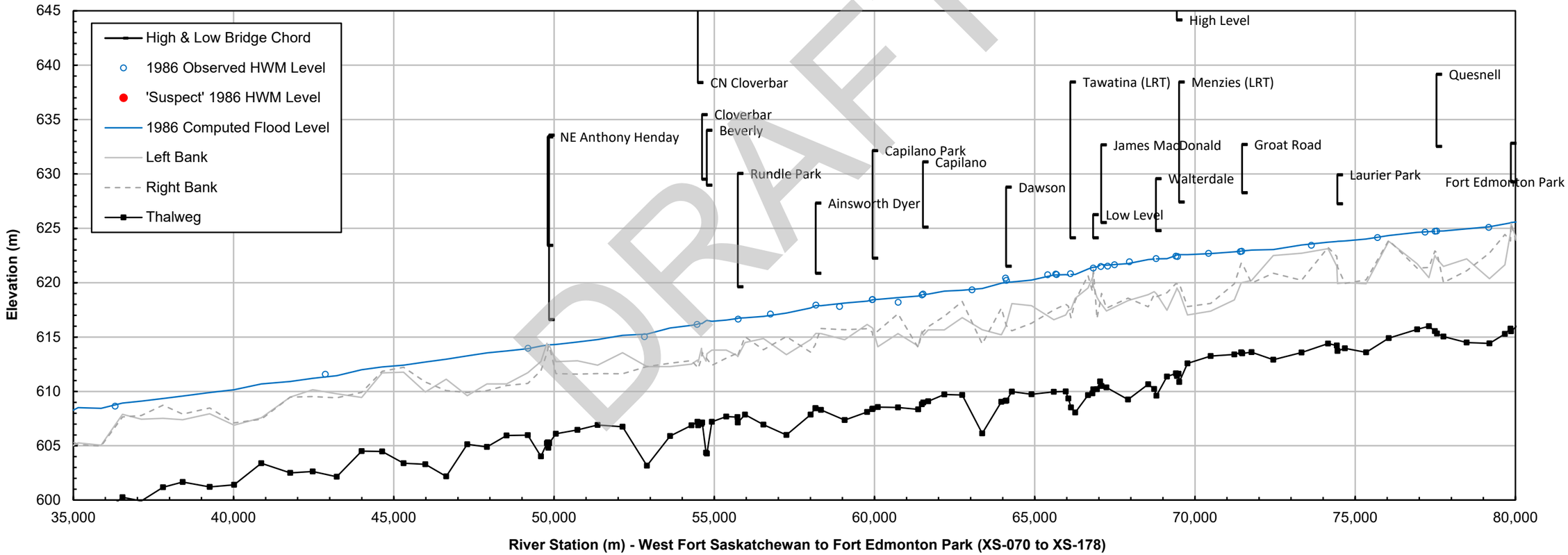
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED VS OBSERVED WATER LEVELS 1986 FLOOD

Project No. 1003870 | *Date: 10-Apr-2020*

FIGURE 4a





Alberta Government

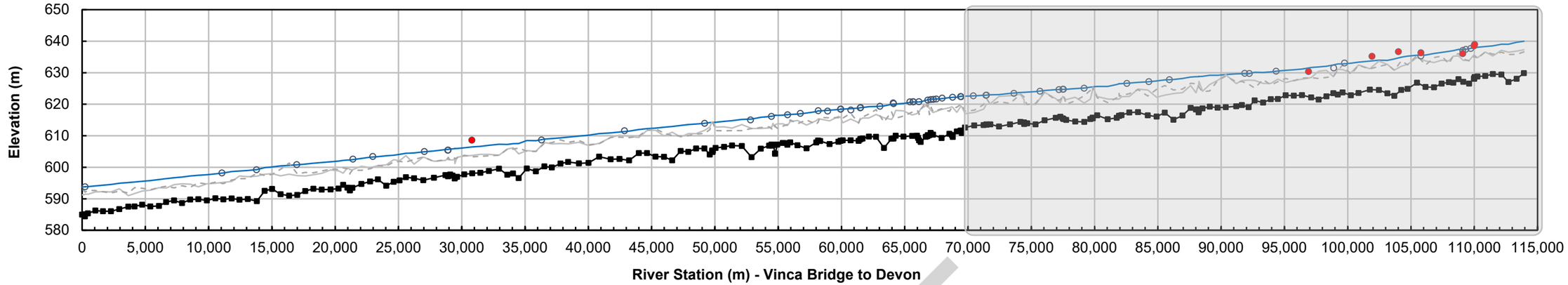
nhc northwest hydraulic consultants

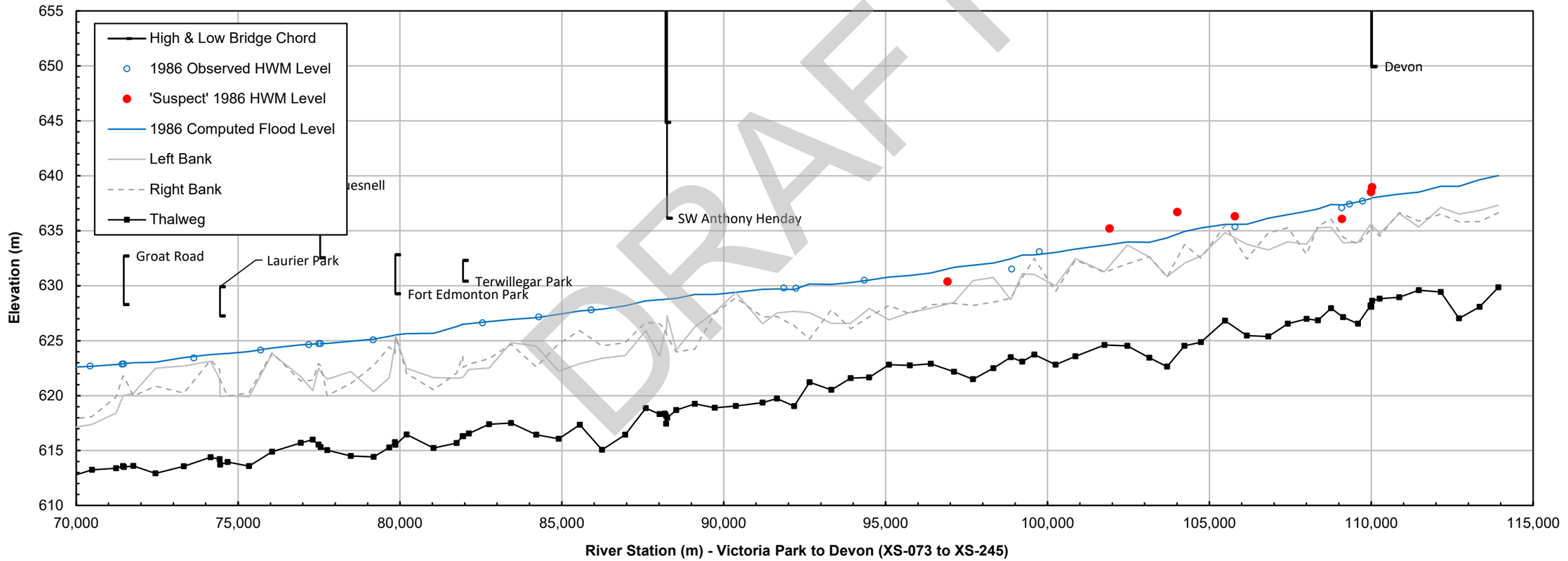
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED VS OBSERVED WATER LEVELS
1986 FLOOD

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 4b





Alberta Government

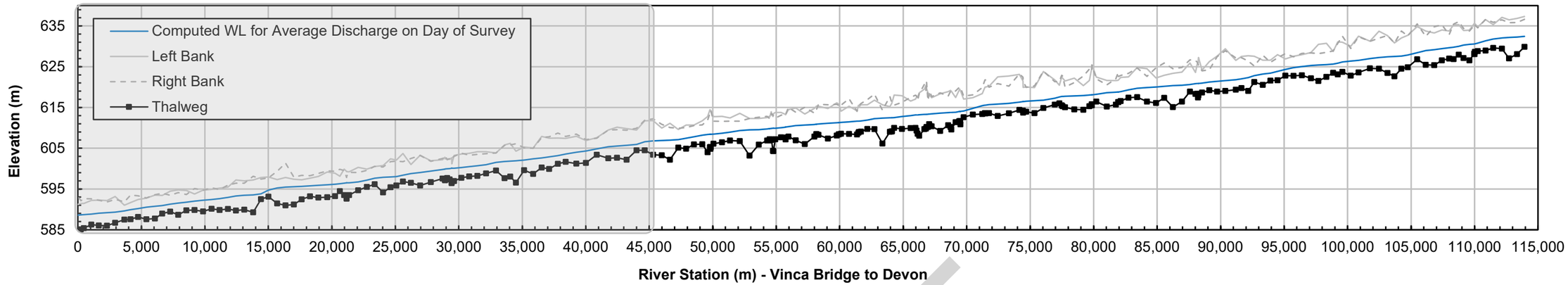
nhc northwest hydraulic consultants

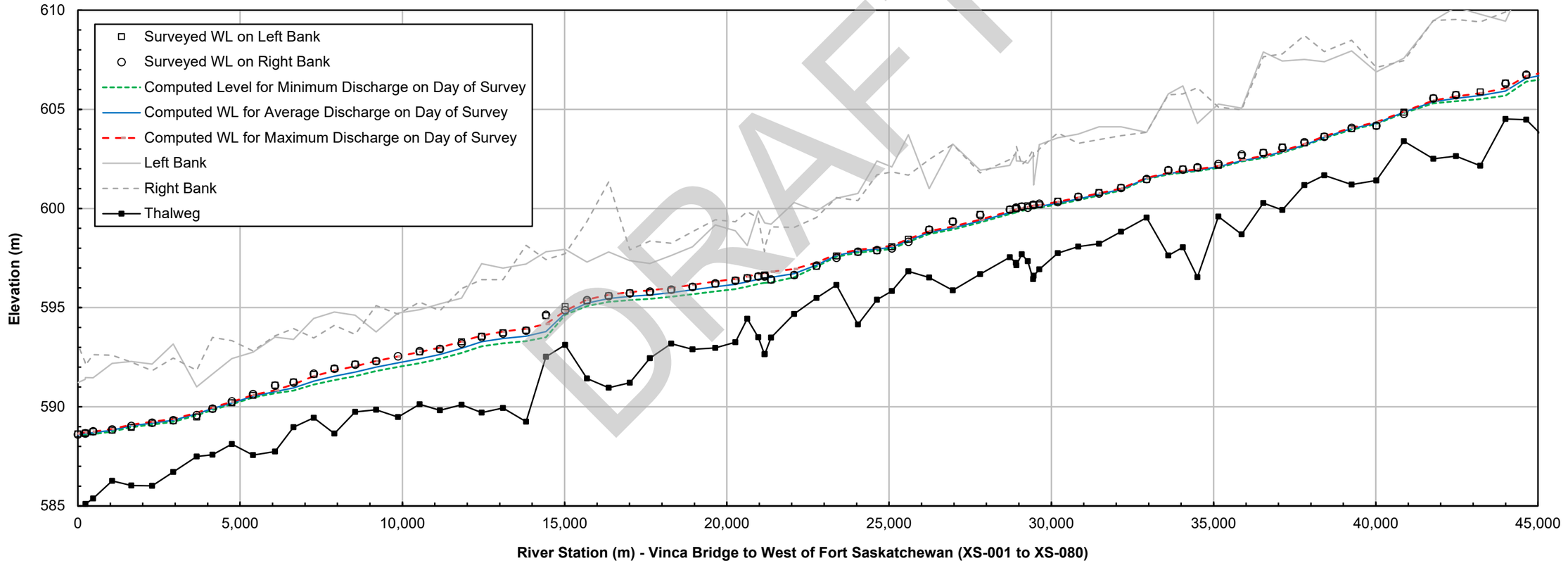
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED VS OBSERVED WATER LEVELS
1986 FLOOD

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 4c





Alberta Government

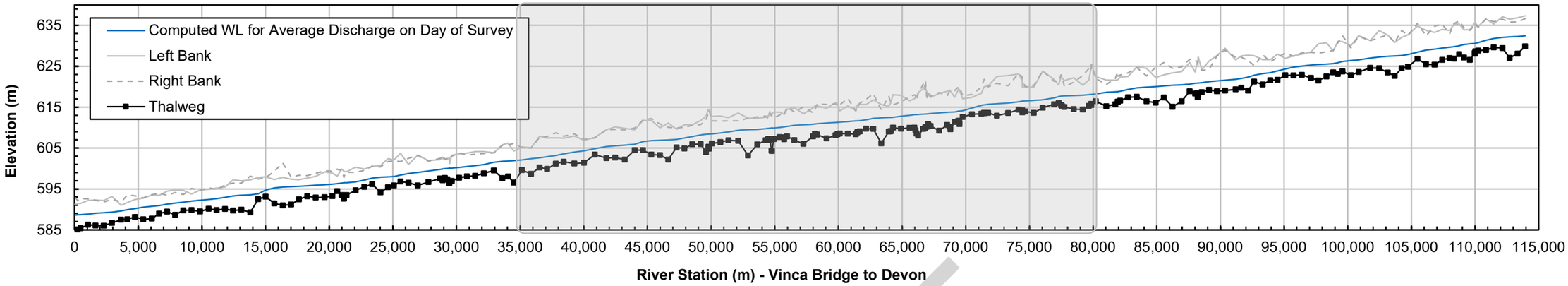
nhc northwest hydraulic consultants

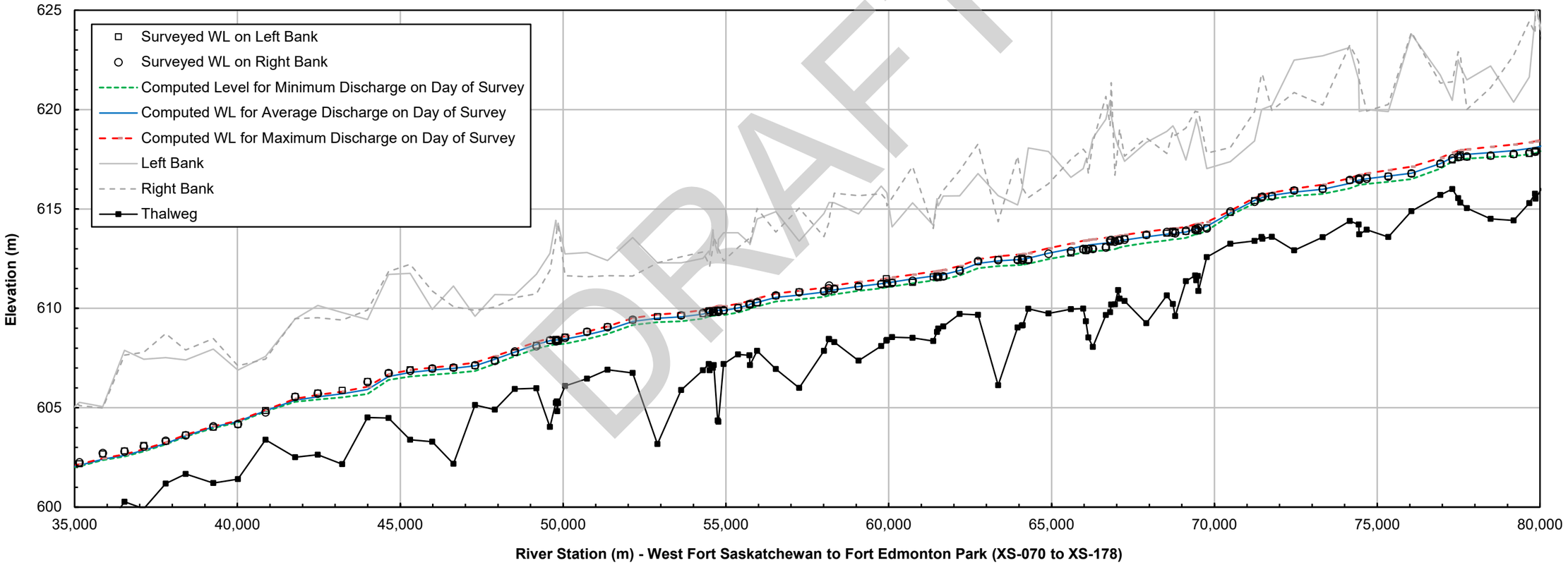
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED VS OBSERVED WATER LEVELS
2018 BATHYMETRY SURVEY

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 5a





Alberta Government

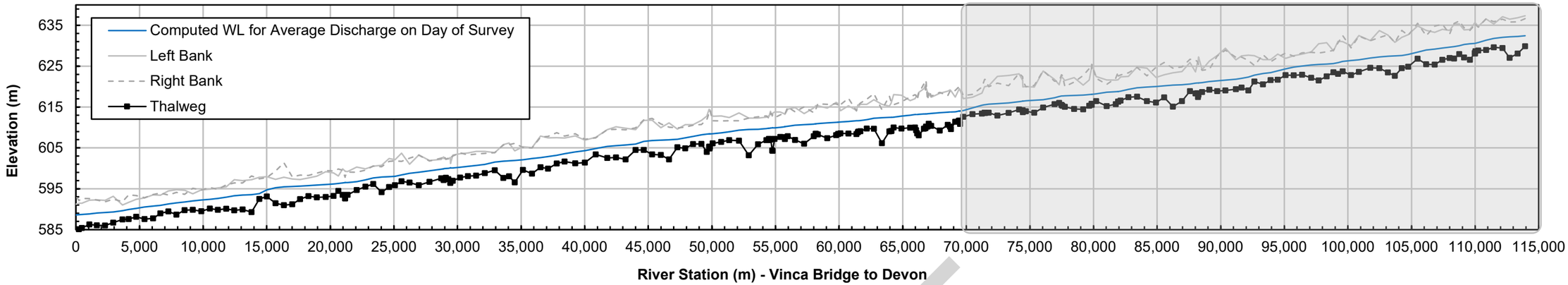
nhc northwest hydraulic consultants

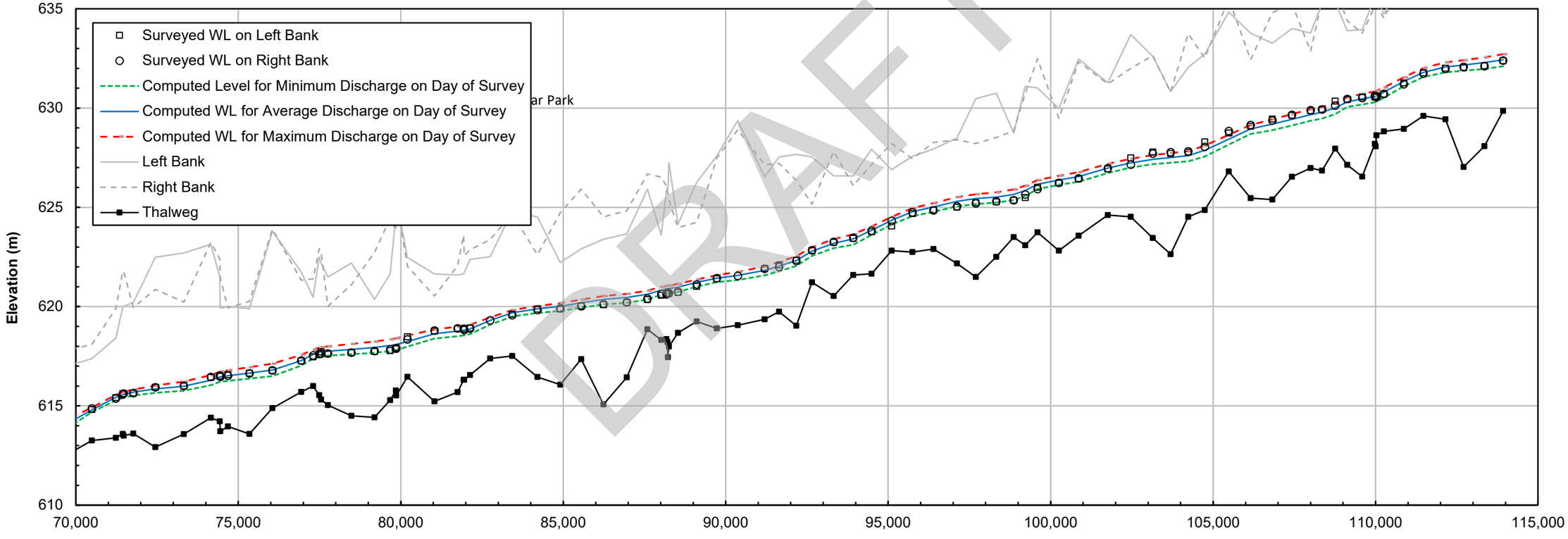
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED VS OBSERVED WATER LEVELS
2018 BATHYMETRY SURVEY

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 5b





Alberta Government

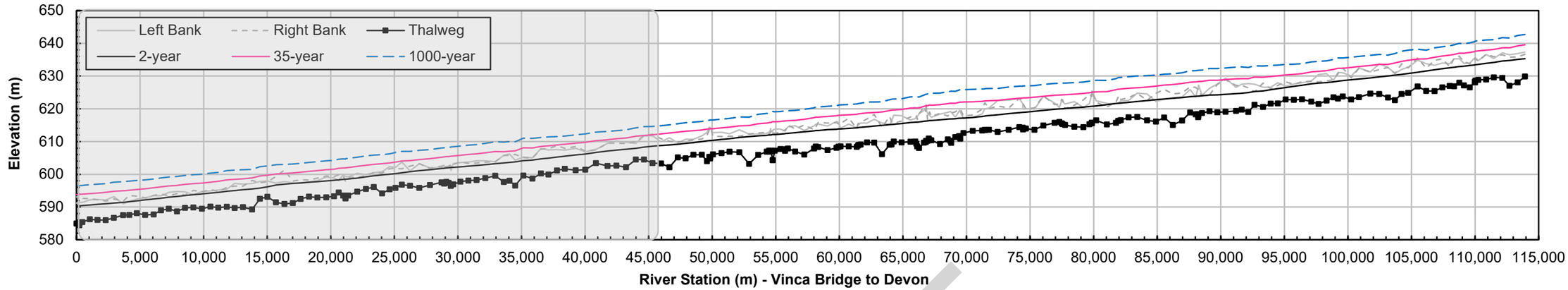
nhc northwest hydraulic consultants

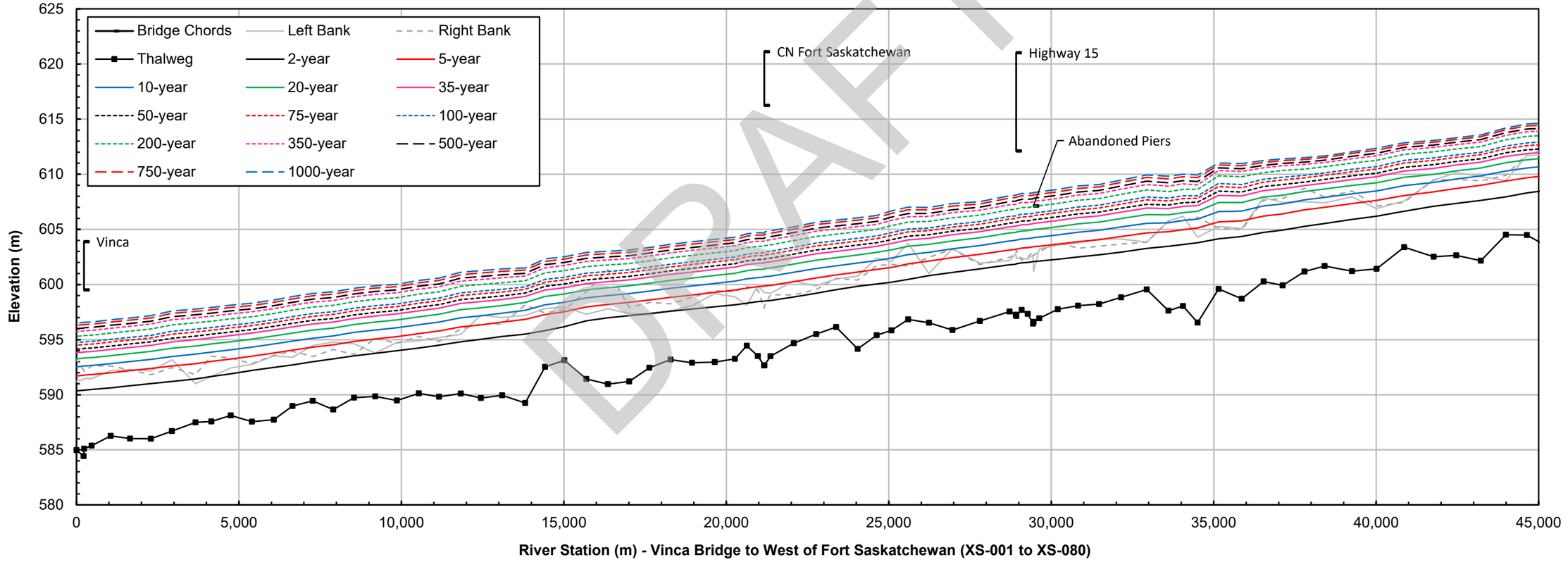
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED VS OBSERVED WATER LEVELS
2018 BATHYMETRY SURVEY

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 5c





Alberta Government

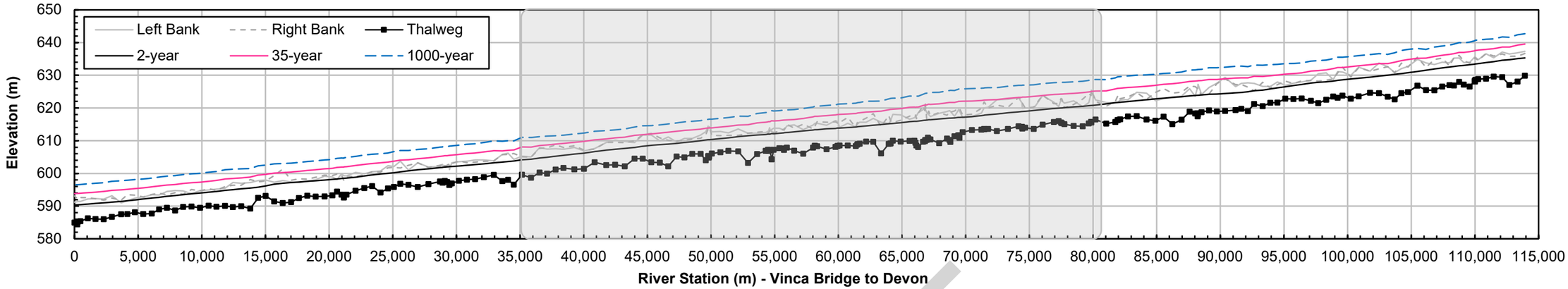
nhc northwest hydraulic consultants

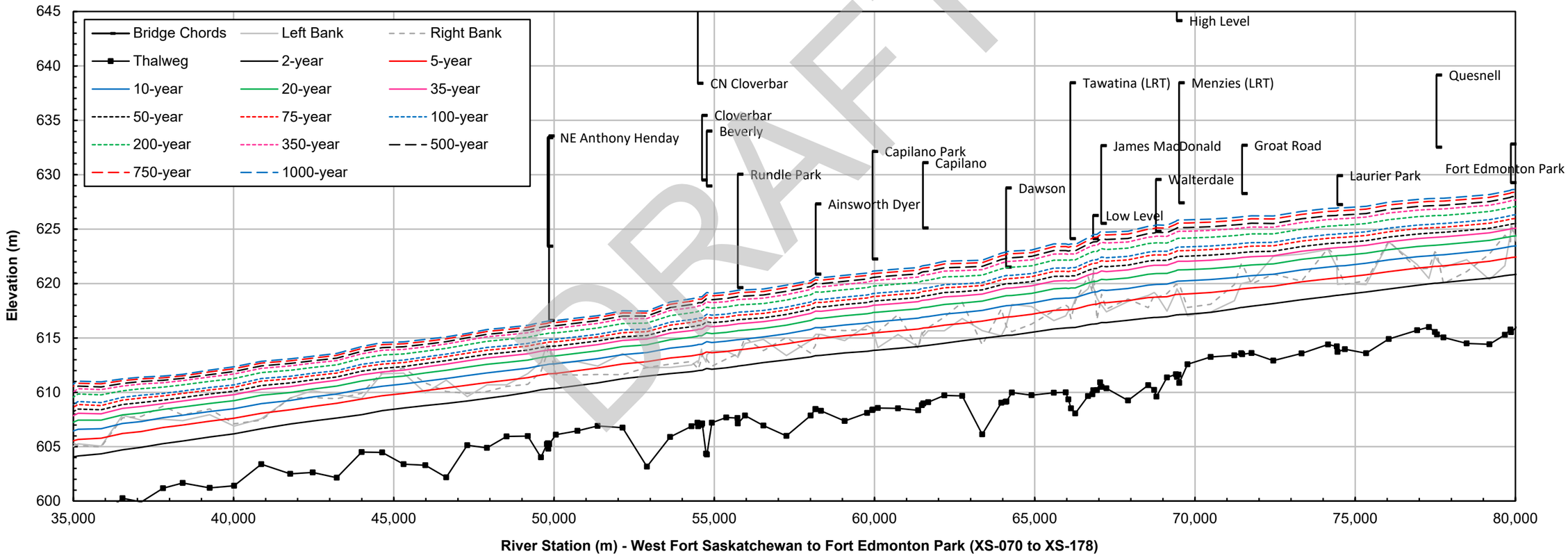
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED FLOOD FREQUENCY PROFILES

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 6a





Alberta Government

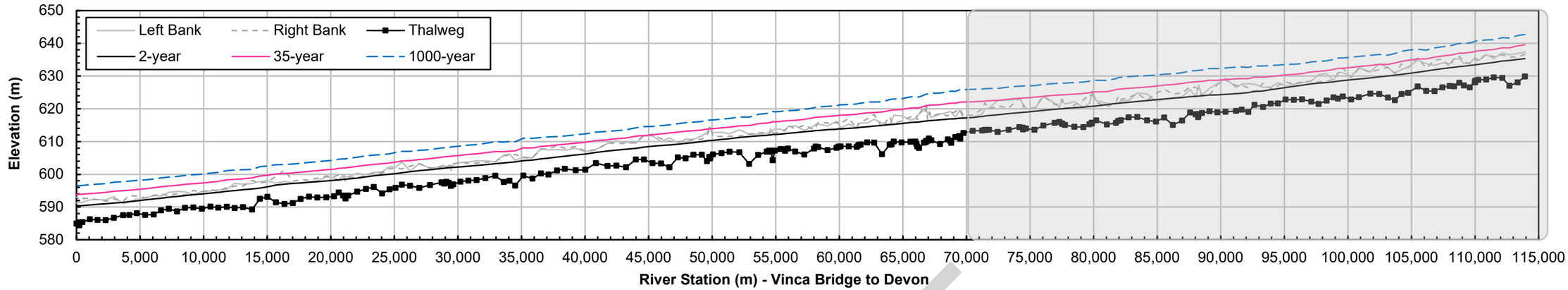
nhc northwest hydraulic consultants

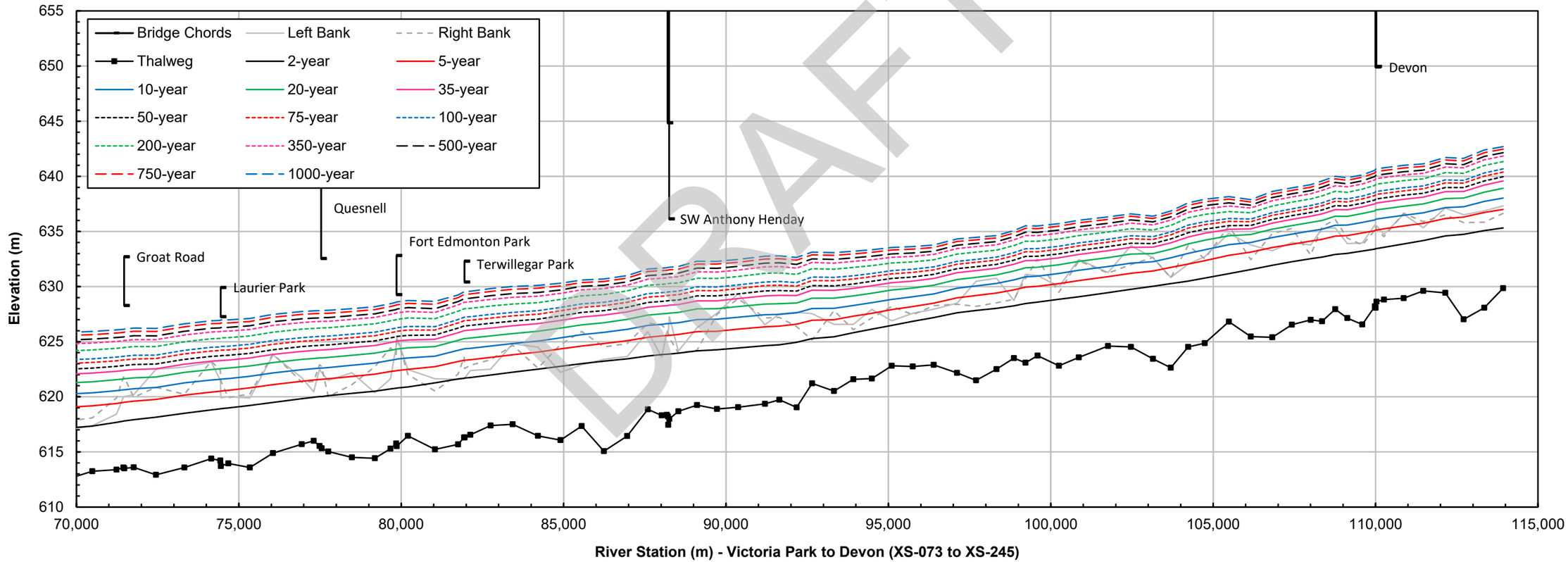
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED FLOOD FREQUENCY PROFILES

Project No. 1003870 | *Date: 10-Apr-2020*

FIGURE 6b





Alberta Government

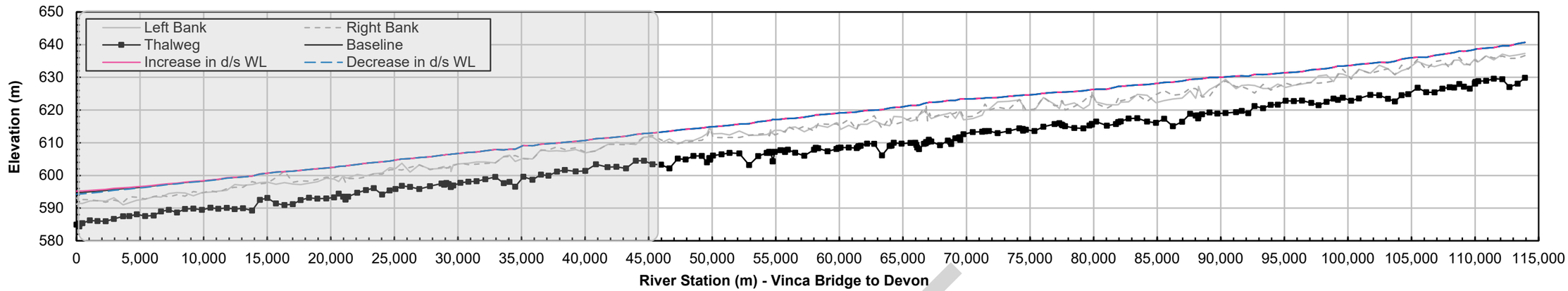
nhc northwest hydraulic consultants

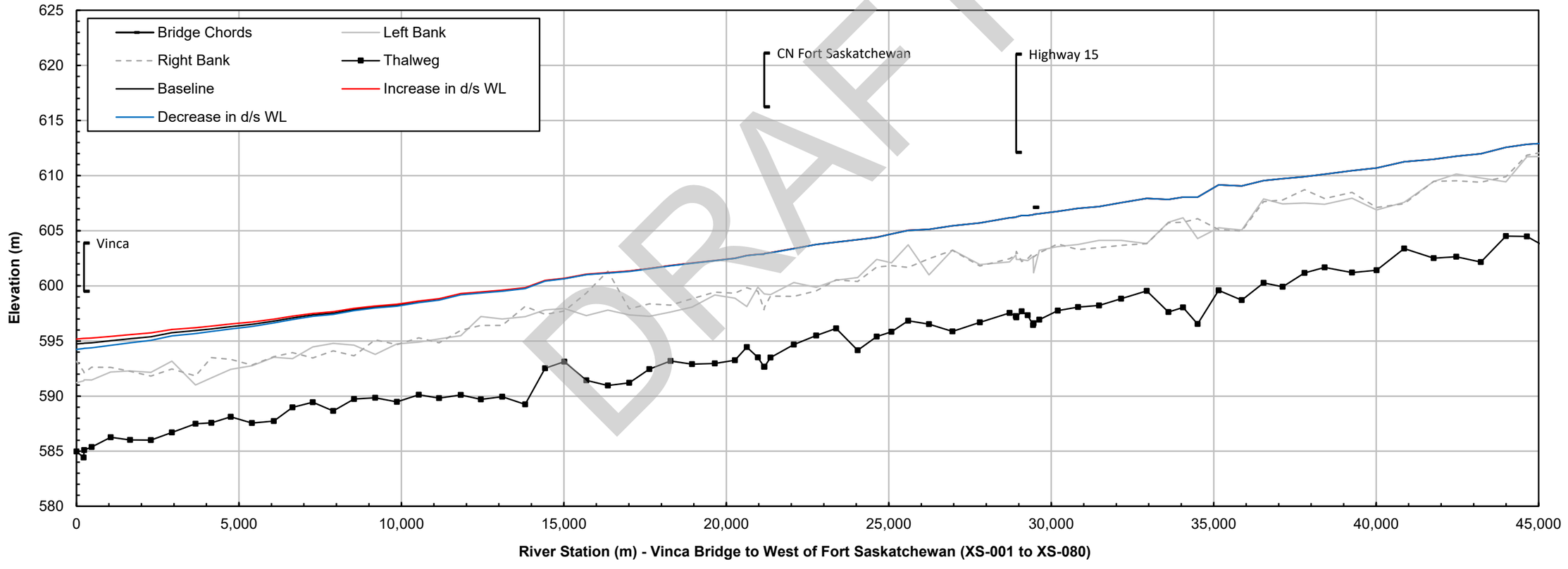
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

COMPUTED FLOOD FREQUENCY PROFILES

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 6c





Alberta Government

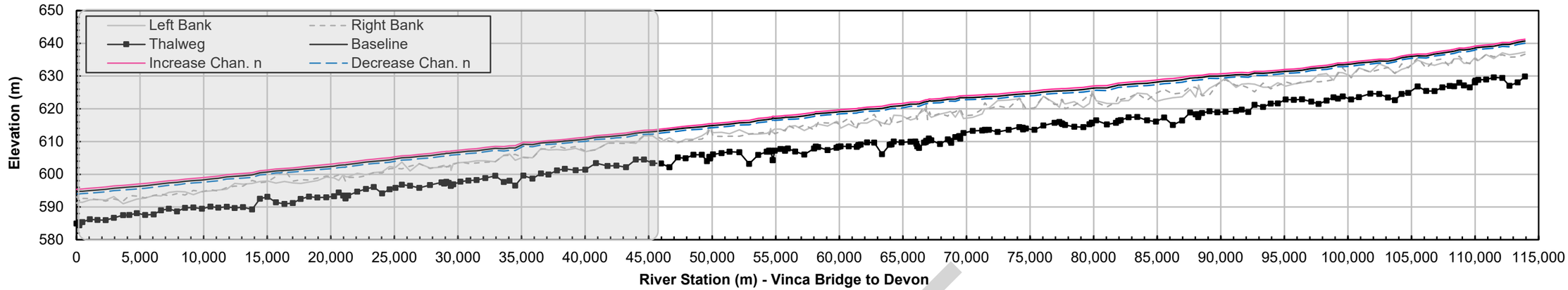
nhc northwest hydraulic consultants

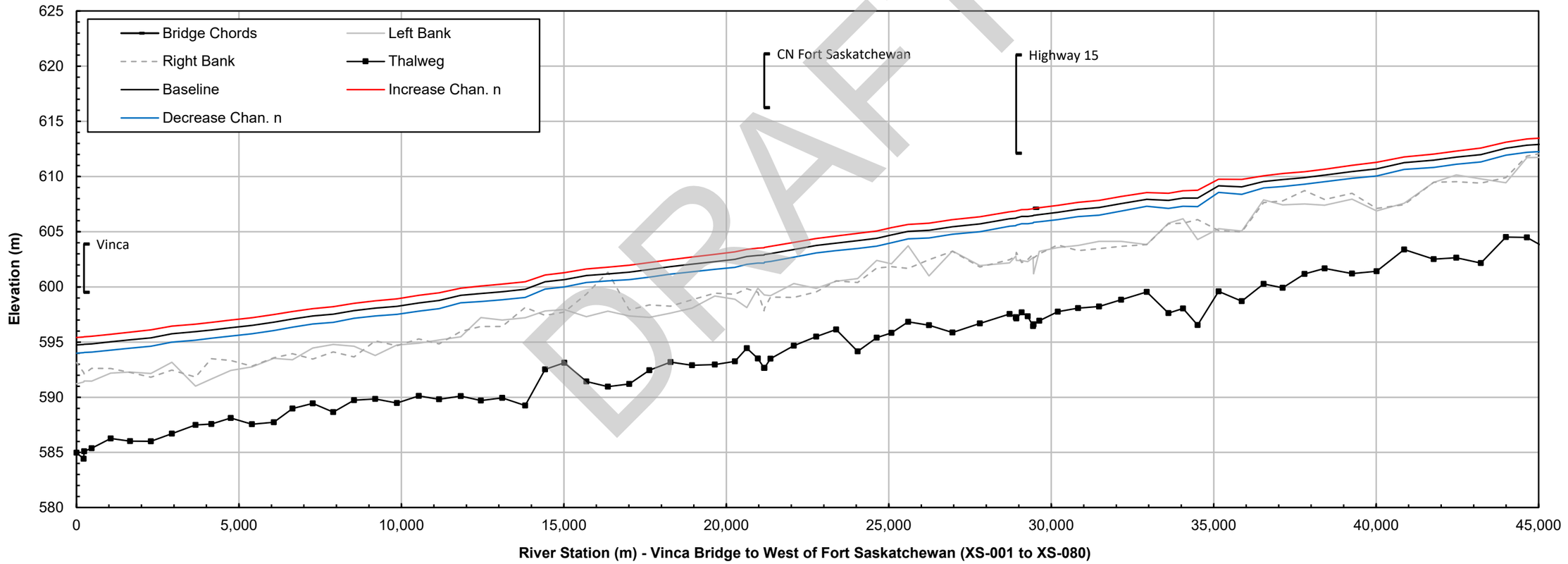
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

SENSITIVITY OF THE COMPUTED 100-YEAR WATER SURFACE PROFILE TO CHANGES IN THE DOWNSTREAM BOUNDARY CONDITION

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 7





Alberta Government

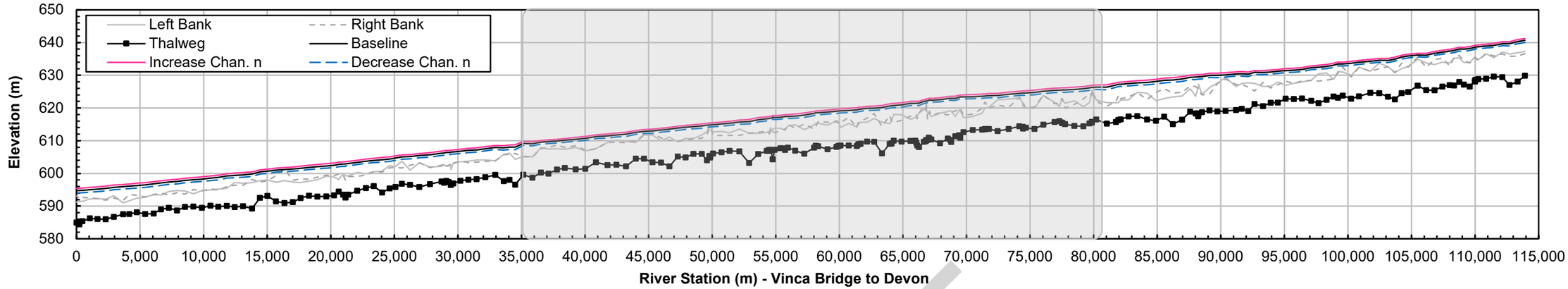
nhc northwest hydraulic consultants

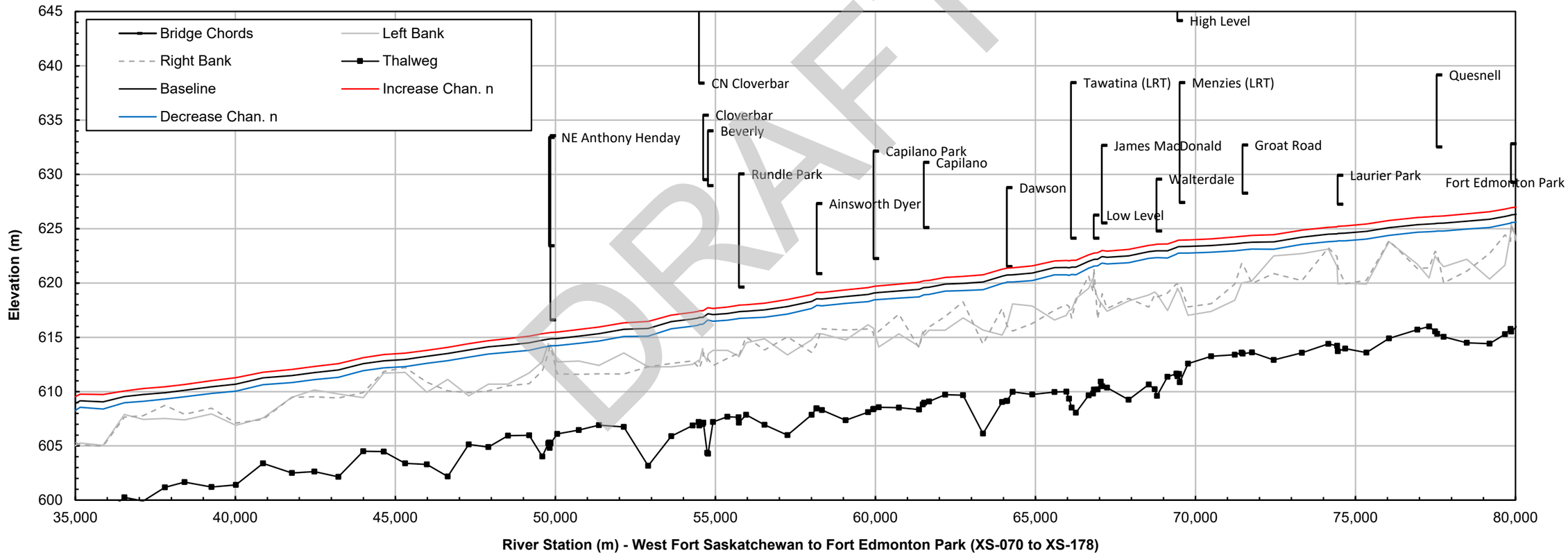
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

SENSITIVITY OF THE COMPUTED 100-YEAR WATER SURFACE PROFILE TO CHANGES IN THE MAIN CHANNEL ROUGHNESS

Project No. 1003870 | *Date: 10-Apr-2020*

FIGURE 8a





Alberta Government

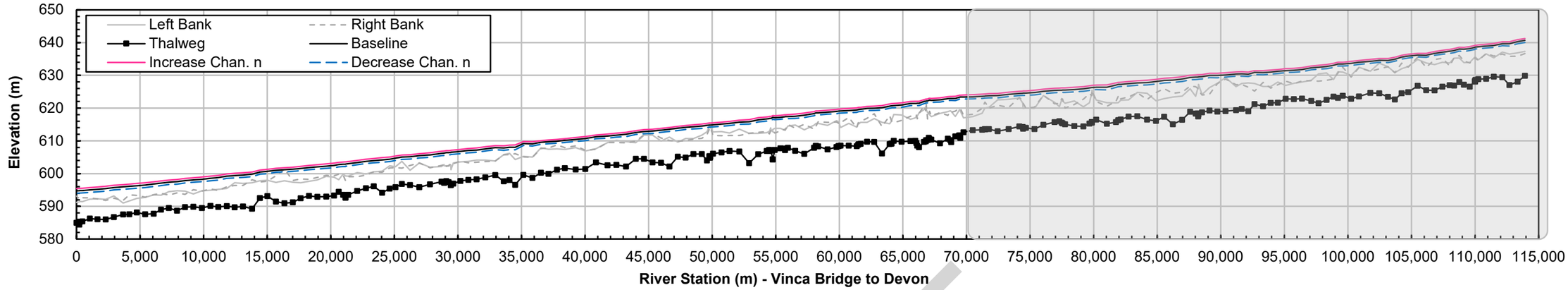
nhc northwest hydraulic consultants

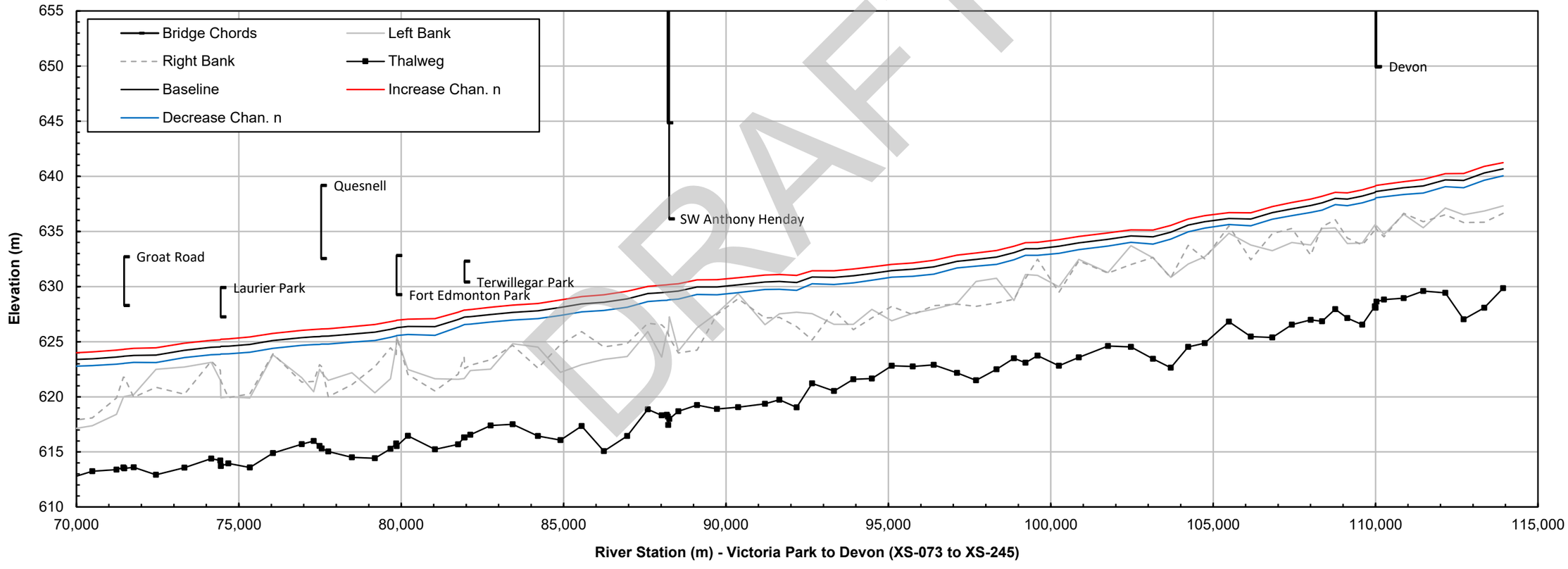
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

SENSITIVITY OF THE COMPUTED 100-YEAR WATER SURFACE PROFILE TO CHANGES IN THE MAIN CHANNEL ROUGHNESS

Project No. 1003870 | *Date: 10-Apr-2020*

FIGURE 8b





Alberta Government

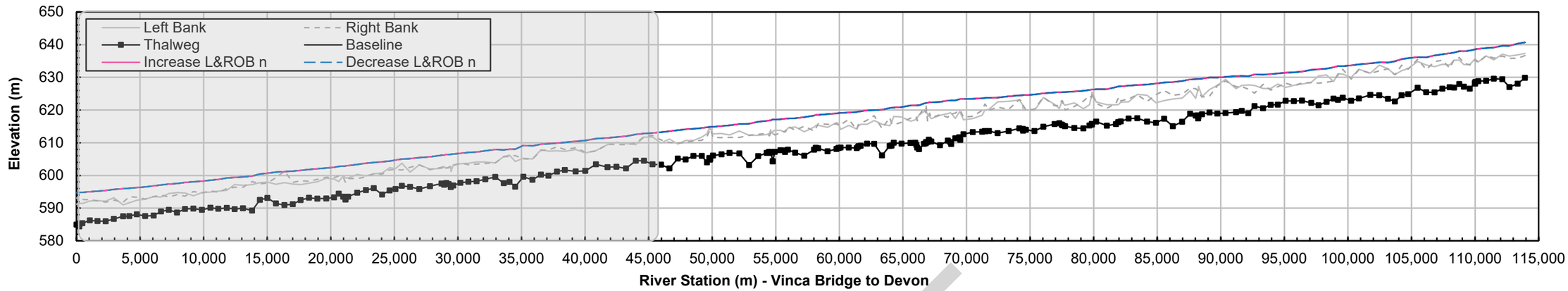
nhc
northwest hydraulic consultants

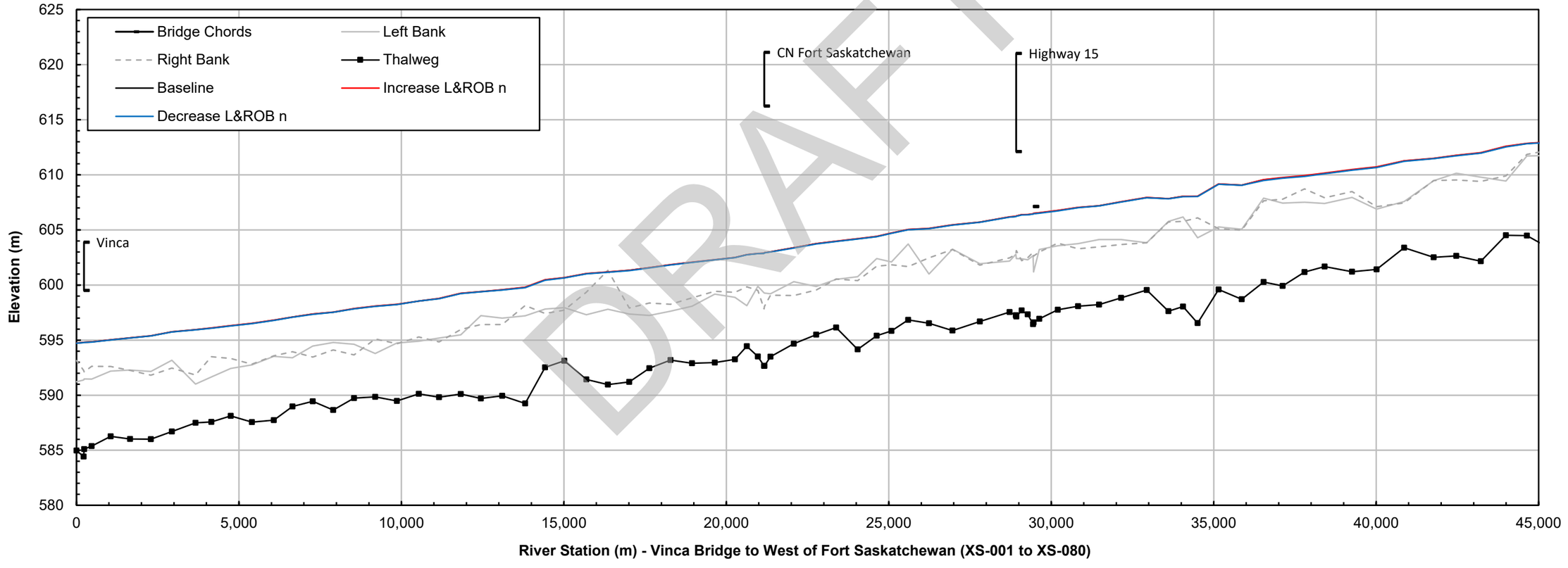
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

SENSITIVITY OF THE COMPUTED 100-YEAR WATER SURFACE PROFILE TO CHANGES IN THE MAIN CHANNEL ROUGHNESS

Project No. 1003870 | *Date: 10-Apr-2020*

FIGURE 8c





Alberta Government

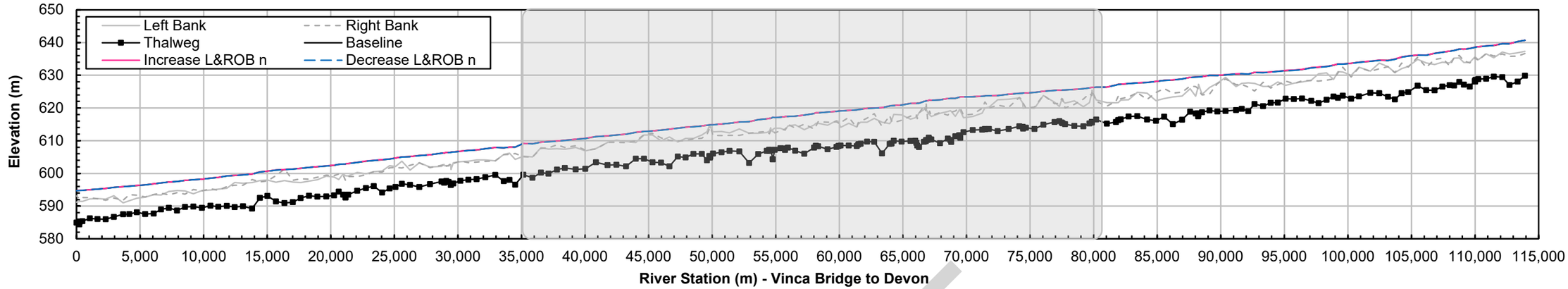
nhc northwest hydraulic consultants

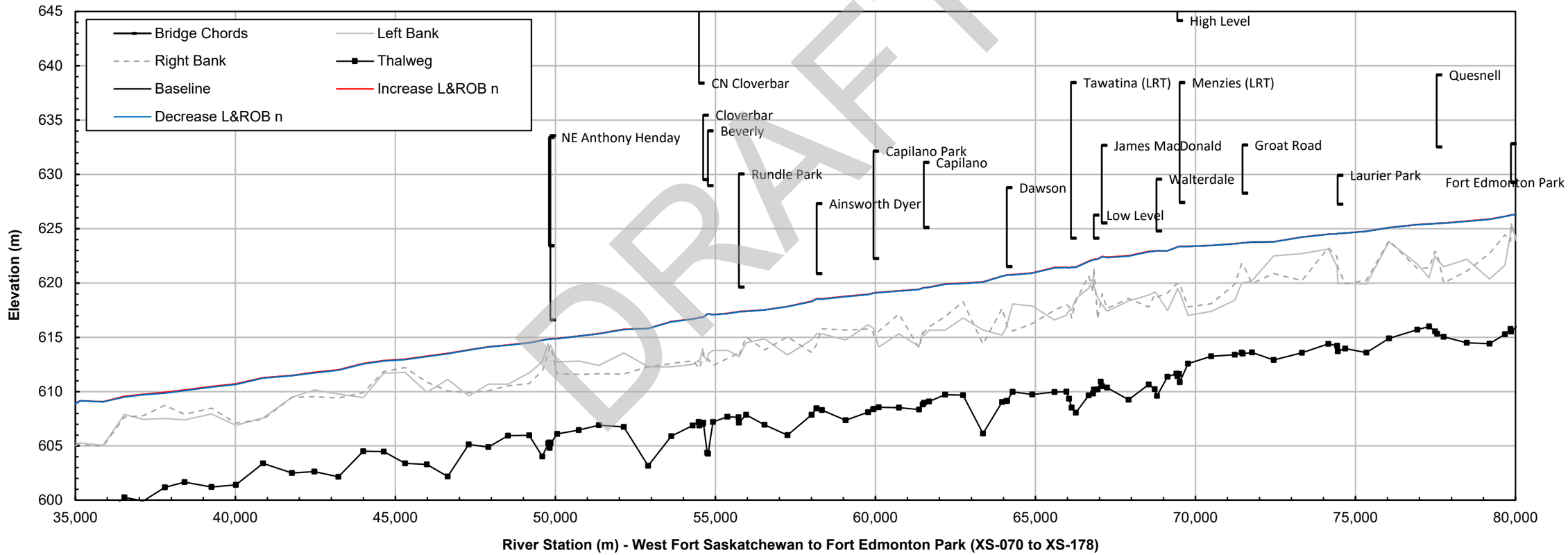
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

SENSITIVITY OF THE COMPUTED 100-YEAR WATER SURFACE PROFILE TO CHANGES IN THE OVERBANK ROUGHNESS

Project No. 1003870 | *Date: 10-Apr-2020*

FIGURE 9a





Alberta Government

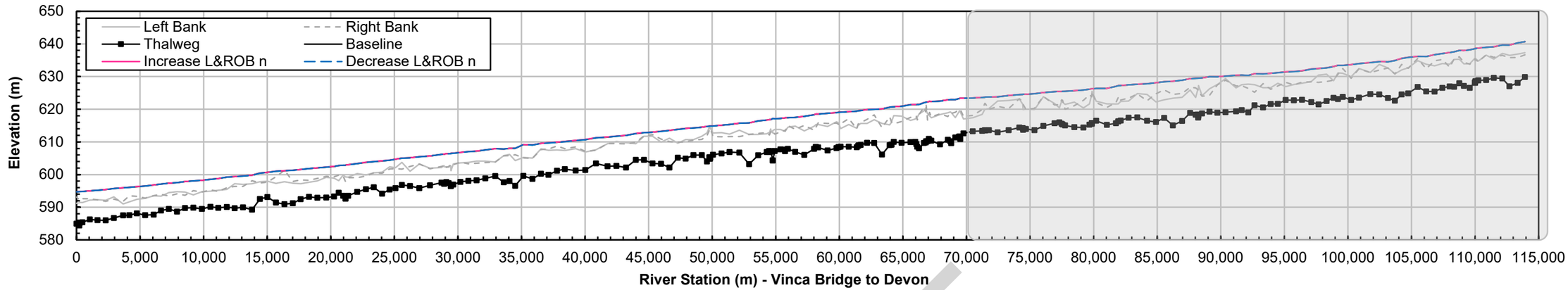
nhc northwest hydraulic consultants

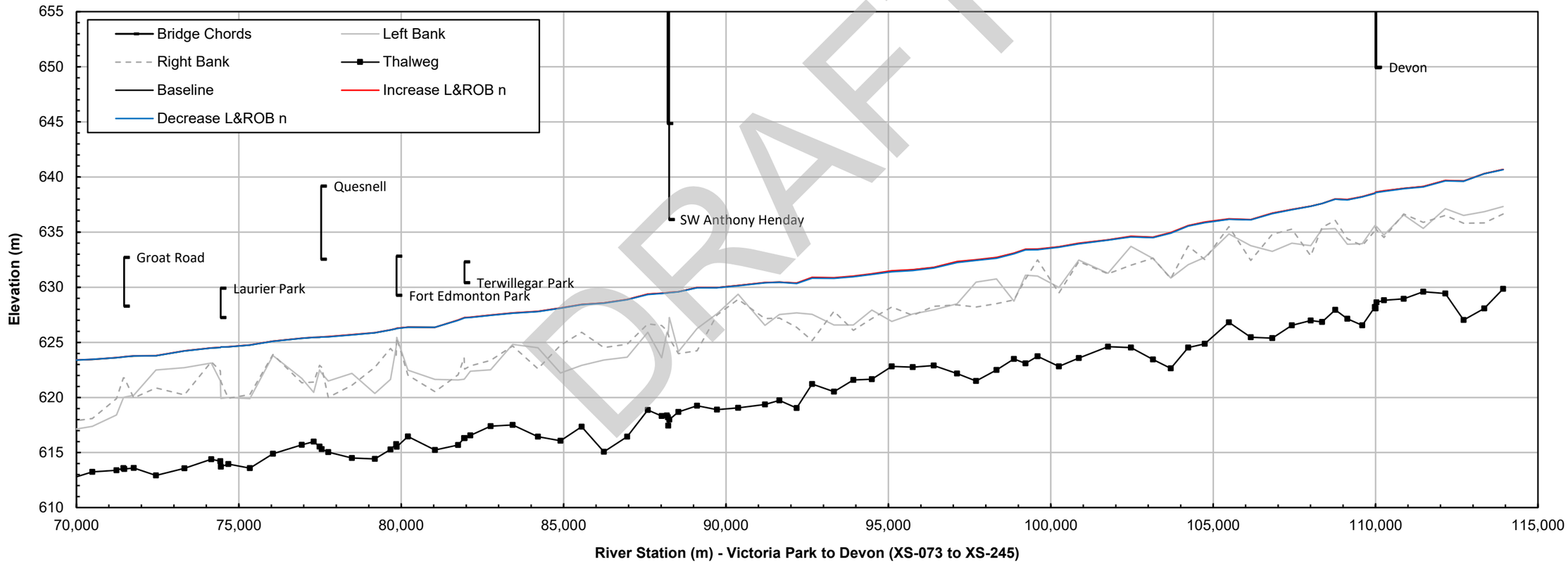
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

SENSITIVITY OF THE COMPUTED 100-YEAR WATER SURFACE PROFILE TO CHANGES IN THE OVERBANK ROUGHNESS

Project No. 1003870 | *Date: 10-Apr-2020*

FIGURE 9b





Alberta Government

nhc northwest hydraulic consultants

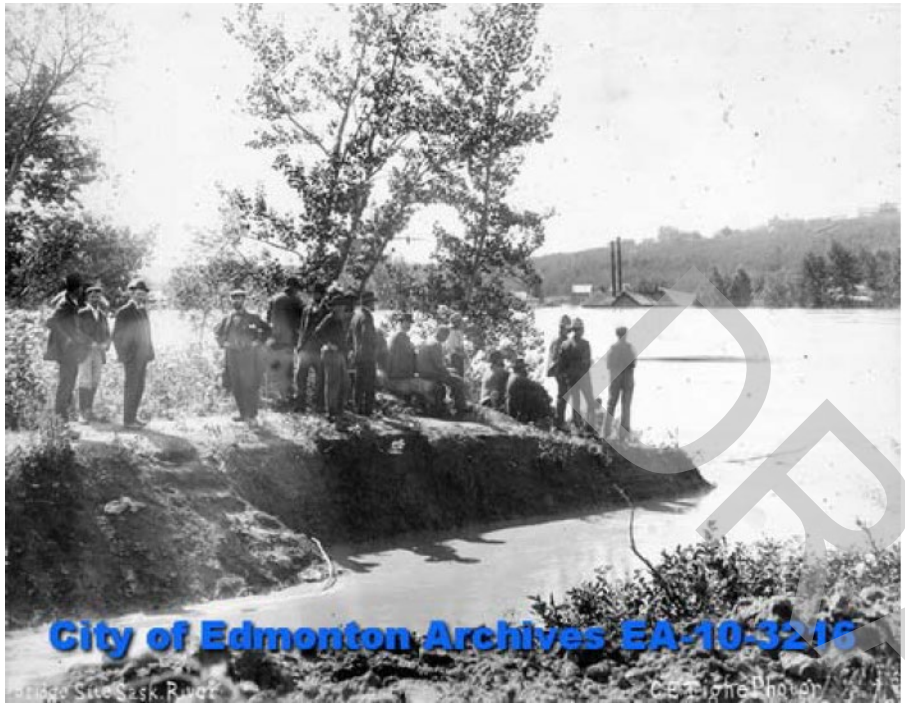
NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

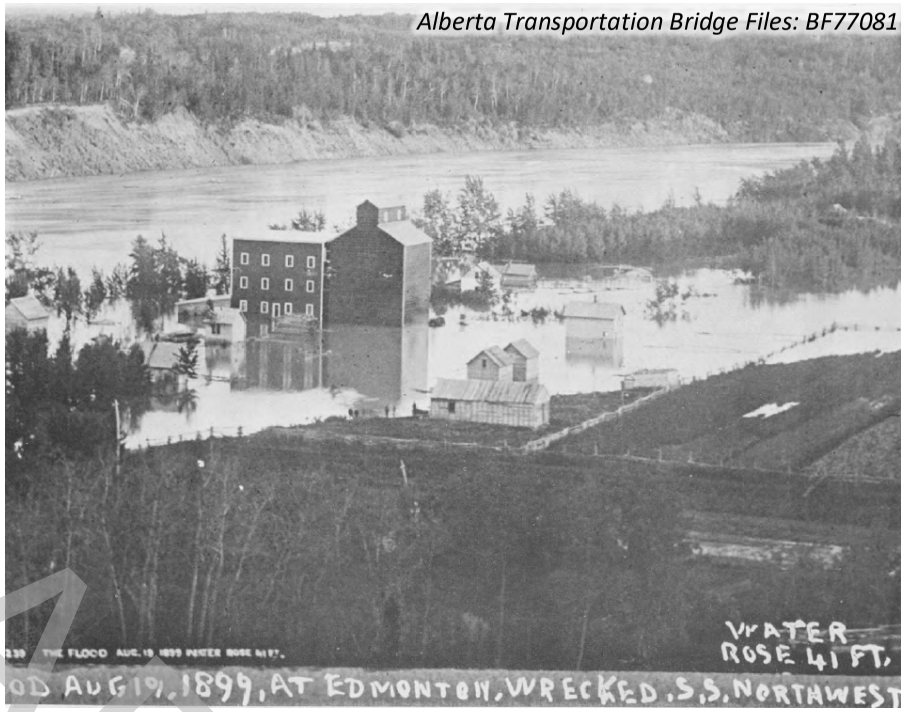
SENSITIVITY OF THE COMPUTED 100-YEAR WATER SURFACE PROFILE TO CHANGES IN THE OVERBANK ROUGHNESS

Project No. 1003870 | Date: 10-Apr-2020

FIGURE 9c

APPENDIX A
HISTORICAL FLOOD PHOTOGRAPHS

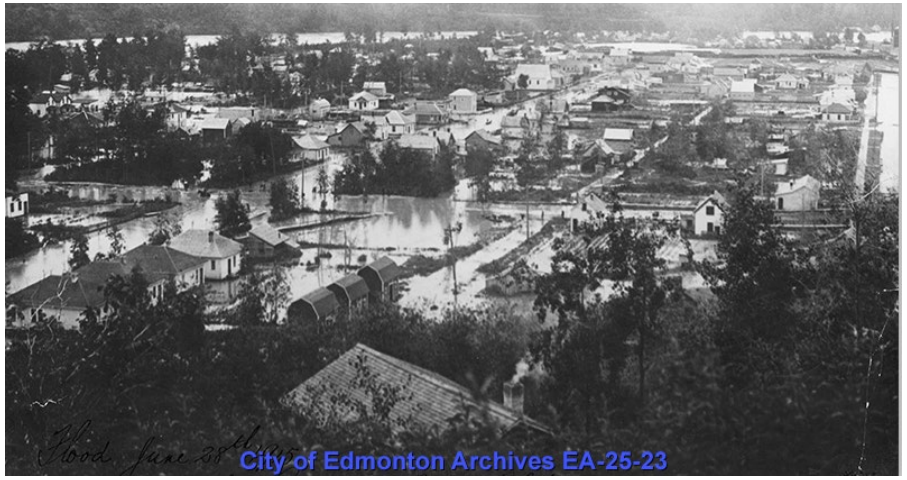


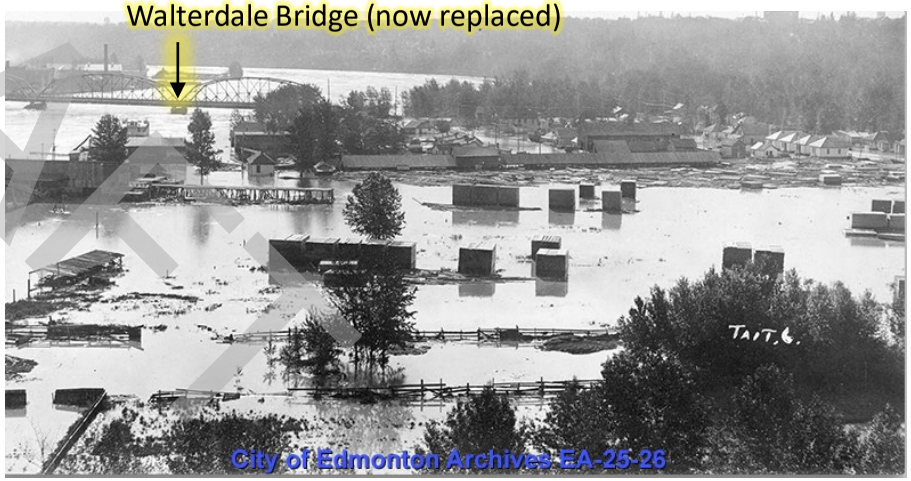


Notes:
1. (Left) Looking southwest towards Rossdale Power Plant from right abutment of Low Level Bridge. Buildings, bridge piers and abutment were submerged (August 18, 1899).
2. (Right) The North Saskatchewan River rose 41 ft (12.5 m) during the 1899 flood (August 19, 1899).

nhc northwest hydraulic consultants

ALBERTA ENVIRONMENT AND PARKS		
NORTH SASKATCHEWAN RIVER HAZARD STUDY *HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING* **HISTORICAL OPEN WATER FLOOD (1899)**		
1003870	10 APR 2020	**FIGURE A-1**





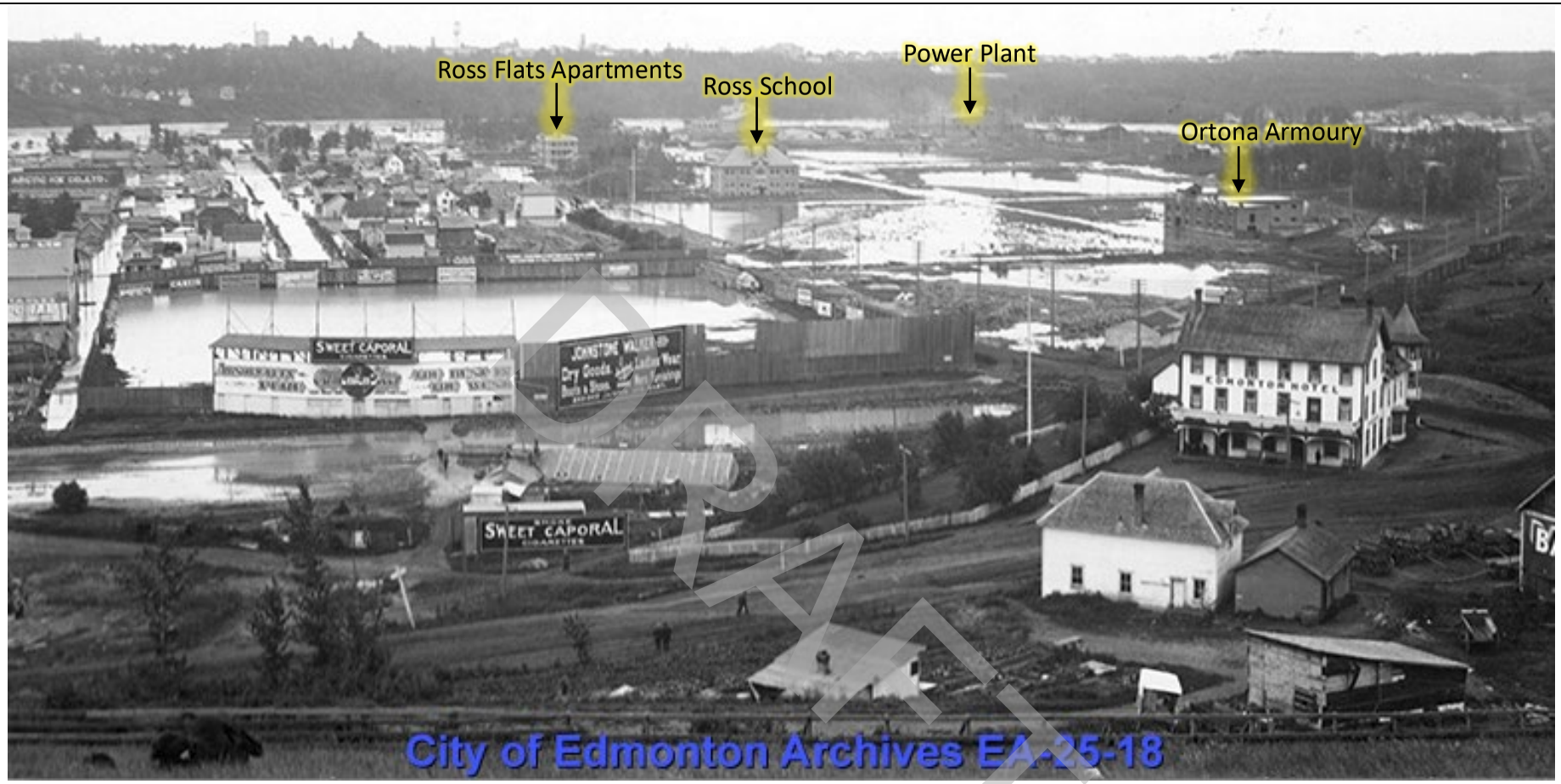
Notes:
1. (Left) Flooding in Gallagher Flats (now Cloverdale). Looking north across 98 Avenue at 92 Street.
2. (Top Right) Flooding in Fraser's Flats (now Riverdale).
3. (Bottom Right) Flooding in Walterdale Flats. Almost every house was affected in the Walterdale Flats and 50 to 60 families were evacuated.

nhc northwest hydraulic consultants

ALBERTA ENVIRONMENT AND PARKS

NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING
HISTORICAL OPEN WATER FLOOD (1915)

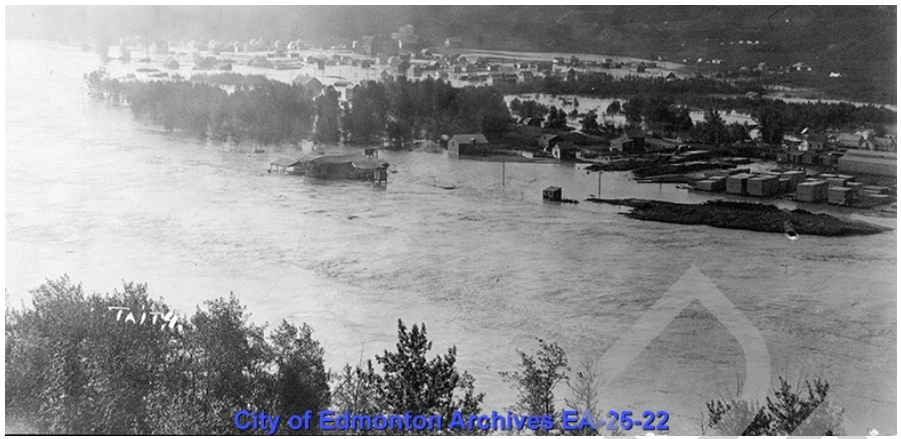
1003870	10 APR 2020	**FIGURE A-2**

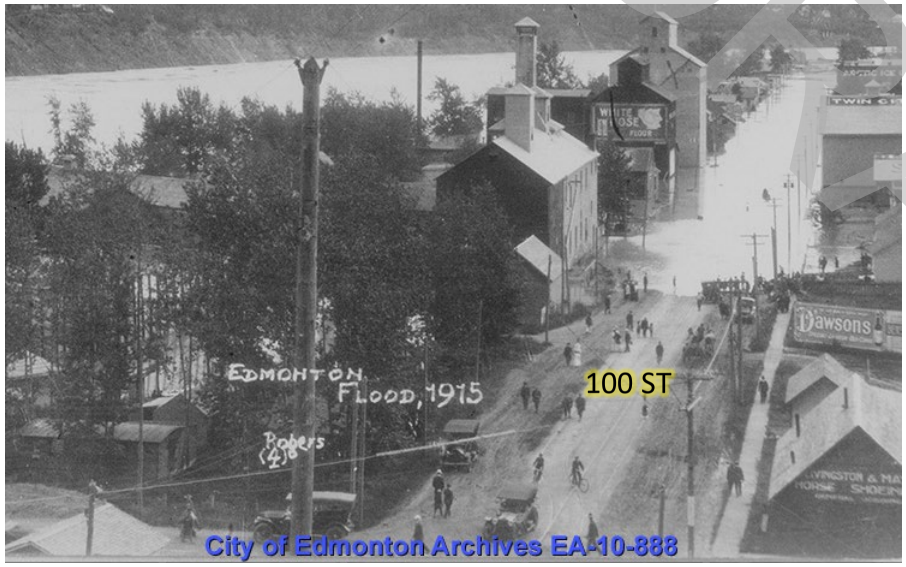


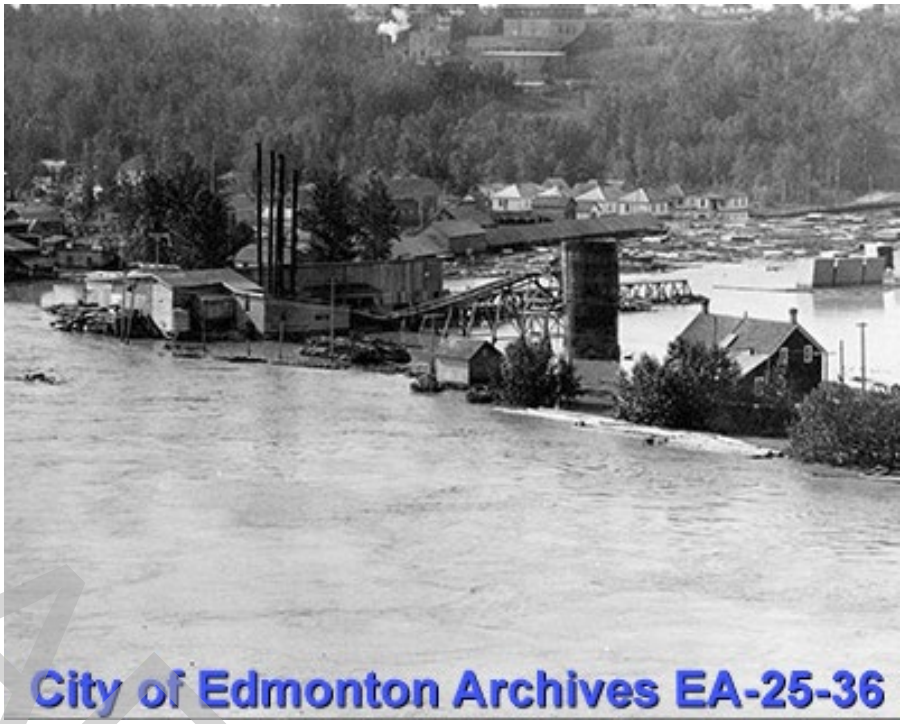
Notes: 1. Flooding in Ross Flats (now Rossdale). Looking south from Macdonald Drive Promenade.

nhc northwest hydraulic consultants

ALBERTA ENVIRONMENT AND PARKS		
NORTH SASKATCHEWAN RIVER HAZARD STUDY *HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING* **HISTORICAL OPEN WATER FLOOD (1915)**		
1003870	10 APR 2020	**FIGURE A-3**







Notes:
1. (Top Left) Looking downstream across Walterdale Flats. Gallagher Flats (now Cloverdale) in far background.
2. (Bottom Left) Flooding along 100 Street.
3. (Right) Flooding at John Walter's lumber mill.

nhc northwest hydraulic consultants

ALBERTA ENVIRONMENT AND PARKS

NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

HISTORICAL OPEN WATER FLOOD (1915)

1003870	10 APR 2020	**FIGURE A-4**

Notes: 1. (Left) CNR freight car parked on the Low Level Bridge.
2. (Right) Daring observer standing on floating debris on downstream side of the Low Level Bridge.

nhc northwest hydraulic consultants

ALBERTA ENVIRONMENT AND PARKS

NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING
HISTORICAL OPEN WATER FLOOD (1915)

1003870	10 APR 2020	**FIGURE A-5**

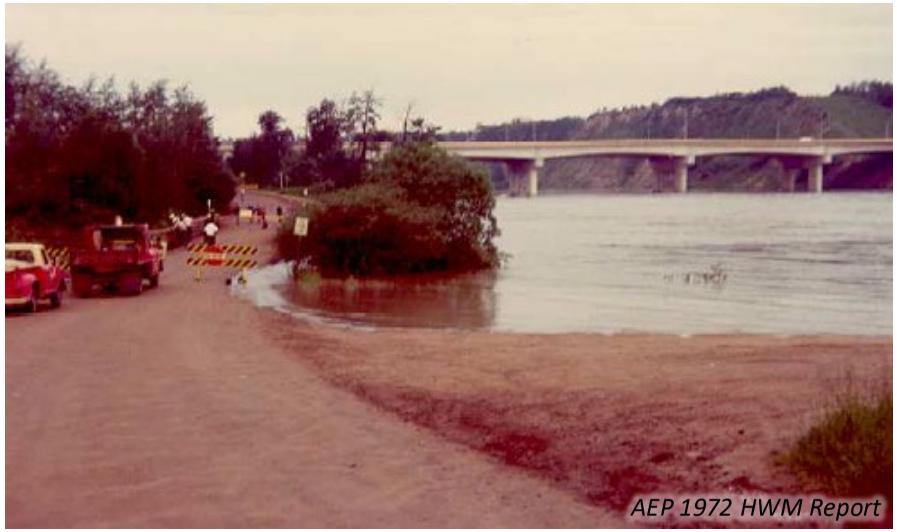
Notes: 1. (Left) Flooding at Victoria Park.
2. (Right) Flooding at Campbell & Ottewell Mill, Twin City Ice Co., and Edmonton Brewery.

nhc northwest hydraulic consultants

ALBERTA ENVIRONMENT AND PARKS

NORTH SASKATCHEWAN RIVER HAZARD STUDY
HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING
HISTORICAL OPEN WATER FLOOD (1915)

1003870	10 APR 2020	**FIGURE A-6**



Notes:

1. (Top left) Flooding at Windermere Golf and Country Club. Image looking downstream along the right bank where flood water was entering the golf course.
2. (Top right) Flooding downstream of Quesnel Bridge.
3. (Bottom left) Flooding in Riverdale upstream of Dawson Bridge. Looking south from the corner of 102 Avenue and 87 Street.
4. (Bottom right) Fort Saskatchewan Bridge.

nhc northwest hydraulic consultants

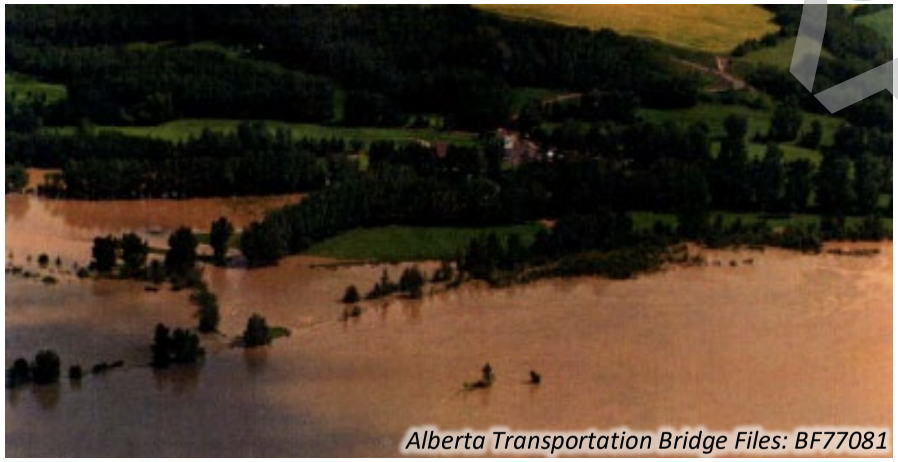
ALBERTA ENVIRONMENT AND PARKS

NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

HISTORICAL OPEN WATER FLOOD (1972)

1003870	10 APR 2020	**FIGURE A-7**



Notes:

1. (Top left) Flooding in Riverdale – 87th Street and 101 A Avenue.
2. (Right) Flood backwater up Whitemud Creek.
3. (Bottom left) Flooding at Windermere Golf and Country Club.

nhc northwest hydraulic consultants

ALBERTA ENVIRONMENT AND PARKS

NORTH SASKATCHEWAN RIVER HAZARD STUDY

HYDRAULIC MODELLING & FLOOD INUNDATION MAPPING

HISTORICAL OPEN WATER FLOOD (1986)

1003870	10 APR 2020	**FIGURE A-8**

APPENDIX B
MODEL CROSS SECTION DATA

Cross Section	River Station (m)	Min Bed Elv. (m)	Channel Width (m)	Manning's n Values		
				Left	Main	Right
XS-245	113925.90	629.85	180	0.055	0.029	0.055
XS-244	113347.40	628.08	151	0.070	0.029	0.055
XS-243	112709.50	627.03	131	0.070	0.029	0.055
XS-242	112148.30	629.43	209	0.055	0.029	0.070
XS-241	111469.50	629.60	175	0.055	0.029	0.070
XS-240	110867.80	628.95	207	0.055	0.029	0.070
XS-239	110258.10	628.82	206	0.055	0.029	0.070
XS-238	110028.40	628.63	214	0.070	0.029	0.070
XS-237	110003.40	628.07	220	0.070	0.029	0.070
XS-236	109978.30	628.20	218	0.070	0.029	0.070
XS-235	109590.20	626.55	168	0.070	0.029	0.070
XS-234	109130.10	627.14	171	0.070	0.029	0.070
XS-233	108756.30	627.95	244	0.070	0.029	0.070
XS-232	108353.80	626.85	157	0.070	0.029	0.070
XS-231	108000.20	626.98	170	0.070	0.029	0.070
XS-230	107424.30	626.54	179	0.070	0.029	0.070
XS-229	106821.70	625.39	185	0.070	0.029	0.055
XS-228	106156.90	625.46	156	0.070	0.029	0.070
XS-227	105483.40	626.81	396	0.070	0.029	0.080
XS-226	104742.30	624.86	389	0.070	0.029	0.070
XS-225	104231.70	624.52	278	0.070	0.029	0.070
XS-224	103691.40	622.64	148	0.055	0.029	0.070
XS-223	103146.80	623.45	150	0.070	0.029	0.070
XS-222	102467.20	624.52	347	0.070	0.029	0.070
XS-221	101759.50	624.61	230	0.070	0.029	0.055
XS-220	100863.50	623.57	239	0.070	0.029	0.055
XS-219	100252.20	622.82	194	0.070	0.029	0.055
XS-218	99594.20	623.74	235	0.070	0.029	0.055
XS-217	99221.64	623.09	311	0.070	0.029	0.070
XS-216	98864.05	623.50	200	0.055	0.029	0.070
XS-215	98325.86	622.50	173	0.055	0.029	0.070
XS-214	97698.93	621.49	196	0.055	0.029	0.070
XS-213	97115.77	622.17	236	0.055	0.029	0.070
XS-212	96394.77	622.90	183	0.070	0.029	0.070
XS-211	95747.41	622.75	226	0.070	0.029	0.070
XS-210	95104.69	622.82	326	0.070	0.029	0.070
XS-209	94489.34	621.65	232	0.070	0.029	0.070
XS-208	93922.47	621.59	220	0.055	0.029	0.070

Cross Section	River Station (m)	Min Bed Elv. (m)	Channel Width (m)	Manning's n Values		
				Left	Main	Right
XS-207	93323.98	620.53	262	0.070	0.029	0.070
XS-206	92653.69	621.22	490	0.070	0.029	0.055
XS-205	92172.40	619.04	174	0.070	0.029	0.055
XS-204	91643.14	619.74	205	0.070	0.029	0.055
XS-203	91198.32	619.36	276	0.070	0.029	0.070
XS-202	90371.64	619.06	240	0.070	0.029	0.055
XS-201	89723.91	618.90	224	0.070	0.029	0.055
XS-200	89108.68	619.25	333	0.070	0.029	0.070
XS-199	88532.08	618.68	181	0.070	0.029	0.070
XS-198	88253.47	617.99	198	0.070	0.029	0.070
XS-197	88219.44	617.45	194	0.070	0.029	0.070
XS-196	88208.26	618.21	194	0.070	0.029	0.070
XS-195	88178.25	618.36	195	0.070	0.029	0.070
XS-194	88019.10	618.32	193	0.055	0.029	0.055
XS-193	87591.62	618.86	216	0.055	0.029	0.070
XS-192	86955.53	616.44	145	0.070	0.029	0.070
XS-191	86239.82	615.07	145	0.070	0.029	0.070
XS-190	85554.21	617.35	186	0.070	0.029	0.070
XS-189	84906.53	616.07	171	0.070	0.029	0.055
XS-188	84206.12	616.45	173	0.070	0.029	0.055
XS-187	83428.95	617.51	223	0.070	0.029	0.055
XS-186	82749.63	617.39	221	0.070	0.029	0.055
XS-185	82129.57	616.55	213	0.070	0.029	0.070
XS-184	81952.76	616.31	208	0.070	0.029	0.070
XS-183	81934.67	616.31	209	0.070	0.029	0.070
XS-182	81749.65	615.69	170	0.070	0.029	0.070
XS-181	81037.88	615.23	131	0.070	0.029	0.070
XS-180	80207.00	616.46	262	0.070	0.028	0.070
XS-179	79861.91	615.52	241	0.070	0.028	0.070
XS-178	79845.91	615.77	233	0.070	0.027	0.070
XS-177	79671.26	615.29	205	0.070	0.027	0.070
XS-176	79189.96	614.42	189	0.070	0.027	0.070
XS-175	78479.98	614.50	190	0.070	0.027	0.070
XS-174	77755.85	615.04	202	0.070	0.027	0.070
XS-173	77551.43	615.32	229	0.070	0.027	0.070
XS-172	77487.37	615.54	237	0.070	0.027	0.070
XS-171	77302.26	616.00	252	0.070	0.027	0.070
XS-170	76934.93	615.70	256	0.070	0.027	0.055

Cross Section	River Station (m)	Min Bed Elv. (m)	Channel Width (m)	Manning's n Values		
				Left	Main	Right
XS-169	76048.58	614.89	231	0.055	0.027	0.070
XS-168	75341.23	613.59	175	0.070	0.027	0.070
XS-167	74678.51	613.96	190	0.055	0.027	0.070
XS-166	74447.05	613.72	215	0.070	0.027	0.070
XS-165	74429.04	614.22	221	0.070	0.027	0.070
XS-164	74153.50	614.40	256	0.070	0.027	0.055
XS-163	73324.63	613.58	212	0.070	0.027	0.055
XS-162	72447.05	612.92	175	0.055	0.027	0.055
XS-161	71765.96	613.60	244	0.055	0.027	0.055
XS-160	71474.21	613.50	241	0.055	0.027	0.055
XS-159	71443.92	613.59	247	0.055	0.027	0.070
XS-158	71230.52	613.39	238	0.055	0.027	0.070
XS-157	70490.60	613.25	225	0.055	0.027	0.070
XS-156	69766.72	612.58	240	0.070	0.027	0.070
XS-155	69508.13	610.87	263	0.080	0.027	0.070
XS-154	69489.65	611.63	256	0.070	0.027	0.070
XS-153	69440.75	611.41	244	0.070	0.027	0.070
XS-152	69408.42	611.65	232	0.070	0.028	0.070
XS-151	69126.02	611.37	171	0.070	0.029	0.055
XS-150	68798.57	609.61	200	0.070	0.029	0.070
XS-149	68725.75	610.22	198	0.080	0.029	0.070
XS-148	68538.78	610.65	195	0.080	0.029	0.070
XS-147	67911.63	609.25	149	0.080	0.029	0.070
XS-146	67239.21	610.37	180	0.080	0.029	0.070
XS-145	67085.80	610.49	234	0.070	0.029	0.070
XS-144	67041.75	610.92	219	0.070	0.029	0.070
XS-143	66944.45	610.20	177	0.070	0.029	0.070
XS-142	66829.07	610.19	198	0.070	0.029	0.070
XS-141	66797.01	609.81	193	0.070	0.029	0.070
XS-140	66663.69	609.66	169	0.070	0.029	0.070
XS-139	66264.02	608.06	128	0.070	0.029	0.070
XS-138	66132.32	608.53	135	0.070	0.029	0.080
XS-137	66054.77	609.35	155	0.070	0.029	0.080
XS-136	65968.72	609.99	178	0.080	0.029	0.080
XS-135	65594.35	609.96	218	0.080	0.029	0.080
XS-134	64902.41	609.74	159	0.080	0.029	0.070
XS-133	64285.15	609.98	192	0.080	0.029	0.070
XS-132	64114.25	609.15	194	0.080	0.029	0.070

Cross Section	River Station (m)	Min Bed Elv. (m)	Channel Width (m)	Manning's n Values		
				Left	Main	Right
XS-131	64088.24	609.13	200	0.080	0.029	0.070
XS-130	63957.07	609.04	182	0.070	0.029	0.055
XS-129	63358.94	606.13	133	0.070	0.029	0.055
XS-128	62738.11	609.67	198	0.070	0.029	0.055
XS-127	62176.15	609.72	264	0.055	0.028	0.070
XS-126	61674.38	609.09	199	0.055	0.027	0.070
XS-125	61520.62	608.98	192	0.055	0.027	0.070
XS-124	61480.22	608.81	193	0.055	0.027	0.070
XS-123	61365.59	608.35	173	0.055	0.027	0.070
XS-122	60734.08	608.52	195	0.055	0.027	0.070
XS-121	60103.41	608.55	207	0.070	0.027	0.070
XS-120	59943.01	608.41	210	0.070	0.027	0.080
XS-119	59928.97	608.37	208	0.070	0.027	0.080
XS-118	59770.01	608.10	197	0.070	0.027	0.080
XS-117	59071.03	607.37	194	0.070	0.027	0.080
XS-116	58328.16	608.30	208	0.055	0.027	0.070
XS-115	58168.08	608.44	233	0.055	0.027	0.070
XS-114	58156.05	608.46	236	0.055	0.027	0.070
XS-113	58009.17	607.86	195	0.055	0.027	0.070
XS-112	57249.07	606.00	152	0.055	0.027	0.070
XS-111	56531.61	606.95	168	0.055	0.027	0.070
XS-110	55959.75	607.86	228	0.070	0.027	0.070
XS-109	55737.30	607.14	226	0.070	0.027	0.070
XS-108	55723.29	607.64	230	0.070	0.027	0.070
XS-107	55373.45	607.68	216	0.070	0.027	0.055
XS-106	54926.37	607.20	221	0.070	0.027	0.055
XS-105	54770.85	604.29	222	0.070	0.027	0.070
XS-104	54745.55	604.36	218	0.070	0.027	0.070
XS-103	54625.54	607.14	217	0.070	0.027	0.070
XS-102	54601.45	607.01	213	0.070	0.027	0.070
XS-101	54498.21	606.88	223	0.070	0.027	0.070
XS-100	54476.03	607.20	236	0.070	0.027	0.070
XS-099	54290.64	606.88	234	0.070	0.027	0.070
XS-098	53623.91	605.89	202	0.055	0.027	0.070
XS-097	52899.12	603.17	144	0.055	0.027	0.055
XS-096	52136.59	606.75	254	0.070	0.026	0.055
XS-095	51361.43	606.91	220	0.070	0.026	0.055
XS-094	50732.05	606.46	226	0.070	0.026	0.055

Cross Section	River Station (m)	Min Bed Elv. (m)	Channel Width (m)	Manning's n Values		
				Left	Main	Right
XS-093	50059.53	606.10	234	0.070	0.026	0.055
XS-092	49849.74	605.23	252	0.070	0.026	0.055
XS-091	49821.43	604.82	251	0.070	0.026	0.055
XS-090	49805.56	605.32	251	0.070	0.026	0.055
XS-089	49777.12	605.24	249	0.070	0.026	0.055
XS-088	49592.88	604.03	242	0.070	0.026	0.055
XS-087	49181.89	605.98	226	0.070	0.026	0.055
XS-086	48518.80	605.94	237	0.070	0.026	0.070
XS-085	47906.11	604.90	249	0.070	0.026	0.070
XS-084	47294.37	605.14	216	0.055	0.026	0.070
XS-083	46633.48	602.18	203	0.055	0.026	0.070
XS-082	45984.16	603.29	195	0.055	0.026	0.070
XS-081	45305.53	603.39	199	0.055	0.026	0.070
XS-080	44638.14	604.48	261	0.055	0.026	0.055
XS-079	43994.80	604.51	246	0.055	0.026	0.055
XS-078	43217.95	602.16	172	0.055	0.026	0.055
XS-077	42467.22	602.64	231	0.055	0.026	0.055
XS-076	41770.57	602.51	213	0.055	0.026	0.055
XS-075	40863.20	603.39	288	0.055	0.026	0.055
XS-074	40013.82	601.41	191	0.055	0.025	0.055
XS-073	39256.42	601.21	217	0.055	0.025	0.055
XS-072	38412.44	601.67	222	0.070	0.025	0.055
XS-071	37797.09	601.18	214	0.055	0.025	0.055
XS-070	37120.66	599.92	230	0.055	0.025	0.055
XS-069	36534.02	600.27	252	0.070	0.025	0.055
XS-068	35863.70	598.70	159	0.070	0.025	0.055
XS-067	35148.61	599.59	270	0.070	0.025	0.055
XS-066	34502.66	596.54	128	0.070	0.025	0.055
XS-065	34055.15	598.04	174	0.055	0.025	0.055
XS-064	33606.53	597.63	173	0.055	0.025	0.055
XS-063	32938.86	599.54	383	0.055	0.025	0.055
XS-062	32150.13	598.83	238	0.055	0.025	0.055
XS-061	31470.43	598.22	197	0.055	0.025	0.055
XS-060	30826.06	598.08	229	0.055	0.025	0.055
XS-059	30199.04	597.75	209	0.055	0.025	0.070
XS-058	29631.55	596.93	207	0.055	0.025	0.070
XS-057	29454.00	596.61	194	0.055	0.025	0.070
XS-056	29440.00	596.44	205	0.055	0.025	0.070

Cross Section	River Station (m)	Min Bed Elv. (m)	Channel Width (m)	Manning's n Values		
				Left	Main	Right
XS-055	29275.33	597.34	214	0.055	0.025	0.070
XS-054	29088.41	597.69	235	0.055	0.025	0.055
XS-053	28923.56	597.14	219	0.055	0.025	0.055
XS-052	28907.56	597.26	230	0.055	0.025	0.055
XS-051	28718.56	597.54	225	0.055	0.025	0.055
XS-050	27805.42	596.69	196	0.055	0.025	0.055
XS-049	26962.15	595.87	248	0.055	0.025	0.055
XS-048	26237.08	596.52	224	0.070	0.025	0.055
XS-047	25596.20	596.83	266	0.070	0.025	0.055
XS-046	25084.20	595.84	175	0.070	0.025	0.055
XS-045	24626.28	595.40	200	0.070	0.025	0.055
XS-044	24039.88	594.15	198	0.070	0.025	0.055
XS-043	23377.35	596.14	237	0.070	0.025	0.055
XS-042	22763.99	595.49	240	0.055	0.025	0.070
XS-041	22074.10	594.68	206	0.055	0.025	0.070
XS-040	21361.38	593.49	183	0.055	0.025	0.055
XS-039	21171.43	592.66	174	0.055	0.025	0.055
XS-038	21161.43	592.65	174	0.055	0.025	0.055
XS-037	20969.79	593.51	215	0.070	0.025	0.055
XS-036	20630.58	594.44	226	0.070	0.025	0.055
XS-035	20262.90	593.26	199	0.070	0.025	0.055
XS-034	19643.18	592.97	210	0.055	0.025	0.070
XS-033	18942.99	592.90	222	0.070	0.025	0.070
XS-032	18284.24	593.18	222	0.070	0.025	0.070
XS-031	17629.36	592.45	216	0.070	0.025	0.070
XS-030	17010.11	591.21	208	0.055	0.025	0.070
XS-029	16356.71	590.96	266	0.055	0.025	0.070
XS-028	15692.60	591.43	318	0.055	0.025	0.070
XS-027	15015.99	593.12	266	0.055	0.025	0.070
XS-026	14424.59	592.52	247	0.055	0.025	0.070
XS-025	13810.13	589.25	168	0.055	0.025	0.055
XS-024	13102.02	589.94	180	0.070	0.025	0.055
XS-023	12445.42	589.71	203	0.070	0.025	0.055
XS-022	11827.03	590.10	266	0.070	0.025	0.055
XS-021	11158.90	589.82	193	0.055	0.025	0.055
XS-020	10534.33	590.13	209	0.070	0.025	0.055
XS-019	9862.57	589.48	204	0.070	0.025	0.055
XS-018	9191.96	589.85	243	0.070	0.025	0.055

Cross Section	River Station (m)	Min Bed Elv. (m)	Channel Width (m)	Manning's n Values		
				Left	Main	Right
XS-017	8543.36	589.74	241	0.070	0.025	0.070
XS-016	7903.68	588.65	210	0.055	0.025	0.070
XS-015	7270.37	589.45	255	0.070	0.025	0.070
XS-014	6647.24	588.97	237	0.070	0.025	0.055
XS-013	6074.52	587.74	211	0.070	0.025	0.055
XS-012	5397.17	587.56	207	0.070	0.025	0.055
XS-011	4745.18	588.12	229	0.055	0.025	0.070
XS-010	4150.78	587.58	228	0.055	0.025	0.070
XS-009	3661.96	587.49	227	0.055	0.025	0.070
XS-008	2937.02	586.71	237	0.070	0.025	0.070
XS-007	2289.74	586.01	191	0.070	0.025	0.070
XS-006	1648.82	586.03	222	0.055	0.025	0.070
XS-005	1053.63	586.26	239	0.055	0.025	0.070
XS-004	467.71	585.38	222	0.055	0.025	0.070
XS-003	234.05	585.10	240	0.055	0.025	0.070
XS-002	220.92	584.43	241	0.055	0.025	0.070
XS-001	0.00	584.97	256	0.055	0.025	0.070

APPENDIX C
MODEL BRIDGE DATA

Bridge Name	River Station (m)	Municipality	AT Bridge File No.	City Edmonton File No.	Span (m)	Deck Width (m)	Number of Piers	Peir Width (m)	Min. Chord Elv. (m)		Modelling Approach	
									Top	Bottom	Low Flow	High Flow
Devon Bridge SB	110023.00	Parkland	BF73694		320	13	3	2.2-2.5	661.860	649.960	Yarnell	Energy
Devon Bridge NB	109998.20	Parkland	BF73694		320	14	3	2.2-2.5	661.830	649.920	Yarnell	Energy
SW Henday Bridge SB	88248.69	Edmonton	BF85014		360	14	3	2.5	655.960	636.140	Yarnell	Energy
SW Henday Bridge NB	88202.25	Edmonton	BF85014		360	14	3	2.5-4.3	655.960	644.850	Yarnell	Energy
Terwillegar Park Footbridge	81947.70	Edmonton		B434	262	5	2	1.6-3.0	632.300	630.420	Yarnell	Energy
Fort Edmonton Park Footbridge	79858.22	Edmonton	BF85308	B400	245	6	2	2-3.4	632.820	629.270	Yarnell	Energy
Quesnell Bridge	77536.41	Edmonton	BF74523	B101	313	46	5	2.1-2.4	639.170	632.540	Yarnell	Energy
Laurier Park Footbridge	74442.40	Edmonton	BF82235	B281	276	6	4	3	629.920	627.260	Yarnell	Energy
Groat Bridge	71467.34	Edmonton	BF74030	B059	289	18	6	1.7-2.3	632.710	628.280	Yarnell	Energy
Menzies Bridge	69503.73	Edmonton	BF82063	B235	561	10	6	3-4	638.450	627.410	Yarnell	Energy
High Level Bridge	69433.41	Edmonton	BF2400	B007	740	10	4	3.5-6.5	664.790	644.160	Yarnell	Energy
Walterdale Bridge	68781.72	Edmonton	BF20000	B435	230	25	0	N/A	629.560	624.780	Yarnell	Energy
James MacDonald Bridge	67076.04	Edmonton	BF6903	B125	324	29	5	1.7-4.5	632.670	625.530	Yarnell	Energy
Low Level Bridge	66821.10	Edmonton	BF551	B551	212	22	3	2.8-4.4	626.260	624.120	Yarnell	Energy
Tawatina Bridge	66112.31	Edmonton	BF82189	B156	210	6	2	2.5-3.1	638.460	624.120	Yarnell	Energy
Dawson Bridge	64108.25	Edmonton	BF7178	B005	236	13	4	2-4	628.790	621.520	Yarnell	Energy
Capilano Bridge	61510.46	Edmonton	BF76741	B112	291	29	4	2-2.6	631.120	625.110	Yarnell	Energy
Capilano Park Footbridge	59939.45	Edmonton	BF82186	B153	275	5	4	2	632.150	622.260	Yarnell	Energy
Ainsworth Dyer Footbridge	58164.93	Strathcona	BF82193	B158	281	5	4	2	627.320	620.870	Yarnell	Energy
Rundle Park Footbridge	55733.80	Strathcona	BF82188	B155	336	6	5	2	630.040	619.620	Yarnell	Energy
Beverly Bridge	54764.91	Edmonton	BF77132	B143	320	19	4	2.4-2.7	634.010	628.960	Yarnell	Energy
Cloverbar Bridge	54619.54	Edmonton	BF2032	B292	320	18	4	1.7-3.3	635.460	629.520	Yarnell	Energy
CN Rail Cloverbar Bridge	54488.64	Edmonton			504	6	4	3.3-5.8	651.310	638.410	Yarnell	Energy
NE Henday Bridge SB	49842.51	Edmonton	BF77081		304	21	3	2.5	633.570	616.610	Yarnell	Energy
NE Henday Bridge NB	49798.61	Edmonton	BF77081		304	21	3	2.5-3.5	633.410	623.440	Yarnell	Energy
Abandoned Bridge	29453.15	Ft. Sask.			N/A	2	5	2.4-3.9	607.130	607.130	Yarnell	Energy
Highway 15 Bridge	28920.56	Ft. Sask.	BF 74452		358	10	7	1.5-2.4	621.020	612.110	Yarnell	Energy
CN Rail Fort Saskatchewan Bridge	21168.86	Ft. Sask.			279	6	5	2.0-2.5	621.120	616.250	Yarnell	Energy
Vinca Bridge	231.02	Strathcona	BF74233		287	10	4	1.4-1.7	603.890	599.520	Yarnell	Energy

APPENDIX D
FLOOD FREQUENCY WATER LEVELS

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-245	113925.9	635.31	637.00	638.03	638.91	639.57	639.96	640.39	640.68	641.34	641.84	642.14	642.47	642.69
XS-244	113347.4	635.07	636.72	637.72	638.56	639.20	639.58	640.01	640.30	640.98	641.50	641.81	642.15	642.38
XS-243	112709.5	634.74	636.30	637.23	638.03	638.63	638.98	639.38	639.63	640.27	640.77	641.06	641.40	641.63
XS-242	112148.3	634.59	636.18	637.15	637.98	638.61	638.98	639.40	639.67	640.33	640.84	641.14	641.48	641.71
XS-241	111469.5	634.17	635.74	636.69	637.50	638.11	638.46	638.86	639.13	639.77	640.27	640.56	640.90	641.13
XS-240	110867.8	633.87	635.49	636.46	637.29	637.91	638.28	638.68	638.96	639.61	640.12	640.42	640.76	640.99
XS-239	110258.1	633.56	635.23	636.22	637.05	637.68	638.05	638.45	638.73	639.38	639.89	640.19	640.53	640.77
XS-238	110028.4	633.45	635.13	636.12	636.96	637.58	637.95	638.36	638.63	639.28	639.79	640.09	640.43	640.67
XS-237	110003.4	633.44	635.12	636.11	636.94	637.56	637.93	638.34	638.61	639.26	639.77	640.07	640.40	640.64
XS-236	109978.3	633.39	635.06	636.04	636.87	637.49	637.85	638.26	638.53	639.18	639.68	639.98	640.31	640.54
XS-235	109590.2	633.22	634.86	635.82	636.62	637.22	637.56	637.95	638.21	638.83	639.31	639.59	639.91	640.13
XS-234	109130.1	633.01	634.63	635.58	636.37	636.96	637.30	637.68	637.94	638.55	639.04	639.32	639.64	639.86
XS-233	108756.3	632.91	634.58	635.56	636.38	636.98	637.34	637.73	638.00	638.64	639.14	639.44	639.77	640.00
XS-232	108353.8	632.67	634.28	635.20	636.00	636.59	636.94	637.33	637.59	638.22	638.72	639.02	639.34	639.57
XS-231	108000.2	632.52	634.12	635.04	635.82	636.39	636.72	637.10	637.35	637.95	638.42	638.70	639.02	639.24
XS-230	107424.3	632.25	633.84	634.76	635.53	636.09	636.43	636.79	637.05	637.65	638.13	638.42	638.73	638.95
XS-229	106821.7	631.93	633.54	634.45	635.21	635.76	636.09	636.46	636.71	637.31	637.79	638.07	638.39	638.62
XS-228	106156.9	631.54	633.13	634.00	634.72	635.24	635.55	635.89	636.13	636.69	637.13	637.38	637.68	637.89
XS-227	105483.4	631.17	632.83	633.80	634.61	635.19	635.53	635.92	636.18	636.81	637.30	637.59	637.93	638.16
XS-226	104742.3	630.77	632.35	633.34	634.21	634.83	635.20	635.61	635.89	636.55	637.05	637.35	637.69	637.92
XS-225	104231.7	630.50	632.05	633.01	633.87	634.50	634.88	635.30	635.58	636.24	636.74	637.03	637.37	637.60
XS-224	103691.4	630.27	631.73	632.61	633.38	633.97	634.31	634.69	634.94	635.55	636.03	636.31	636.63	636.85
XS-223	103146.8	630.03	631.41	632.25	633.00	633.57	633.90	634.27	634.52	635.12	635.59	635.86	636.18	636.39
XS-222	102467.2	629.75	631.21	632.13	632.94	633.56	633.93	634.33	634.60	635.25	635.75	636.04	636.38	636.60
XS-221	101759.5	629.44	630.89	631.81	632.63	633.25	633.62	634.02	634.29	634.94	635.45	635.74	636.09	636.31
XS-220	100863.5	629.08	630.54	631.47	632.29	632.92	633.29	633.69	633.97	634.63	635.14	635.43	635.78	636.01
XS-219	100252.2	628.85	630.27	631.18	631.98	632.61	632.97	633.38	633.66	634.32	634.83	635.13	635.48	635.71
XS-218	99594.2	628.59	630.03	630.94	631.75	632.38	632.75	633.16	633.44	634.10	634.62	634.92	635.26	635.49
XS-217	99221.64	628.46	629.94	630.88	631.71	632.35	632.73	633.15	633.43	634.10	634.63	634.93	635.28	635.51

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-216	98864.05	628.25	629.70	630.60	631.41	632.03	632.39	632.80	633.07	633.72	634.23	634.52	634.85	635.07
XS-215	98325.86	628.02	629.41	630.28	631.06	631.66	632.01	632.40	632.67	633.30	633.79	634.08	634.41	634.62
XS-214	97698.93	627.83	629.19	630.06	630.84	631.44	631.80	632.20	632.47	633.12	633.62	633.91	634.24	634.46
XS-213	97115.77	627.62	628.98	629.85	630.64	631.25	631.62	632.02	632.29	632.95	633.45	633.75	634.09	634.31
XS-212	96394.77	627.18	628.49	629.34	630.12	630.74	631.10	631.51	631.78	632.43	632.92	633.21	633.55	633.77
XS-211	95747.41	626.85	628.19	629.07	629.87	630.50	630.87	631.29	631.57	632.24	632.74	633.04	633.39	633.62
XS-210	95104.69	626.48	627.91	628.84	629.69	630.35	630.73	631.16	631.45	632.14	632.66	632.97	633.32	633.55
XS-209	94489.34	626.13	627.58	628.54	629.40	630.07	630.47	630.90	631.19	631.90	632.43	632.75	633.10	633.34
XS-208	93922.47	625.82	627.31	628.28	629.15	629.83	630.23	630.68	630.98	631.73	632.28	632.60	632.97	633.21
XS-207	93323.98	625.45	627.00	628.03	628.94	629.65	630.06	630.52	630.83	631.58	632.13	632.46	632.83	633.07
XS-206	92653.69	625.28	626.94	628.01	628.95	629.67	630.09	630.55	630.87	631.62	632.18	632.51	632.88	633.12
XS-205	92172.4	624.95	626.59	627.62	628.51	629.18	629.59	630.05	630.36	631.10	631.67	632.01	632.39	632.64
XS-204	91643.14	624.72	626.41	627.48	628.45	629.20	629.64	630.13	630.46	631.23	631.81	632.16	632.53	632.78
XS-203	91198.32	624.63	626.34	627.44	628.41	629.16	629.60	630.09	630.42	631.20	631.78	632.12	632.50	632.75
XS-202	90371.64	624.43	626.14	627.22	628.18	628.91	629.34	629.82	630.15	630.92	631.50	631.84	632.21	632.46
XS-201	89723.91	624.26	625.95	627.04	627.99	628.71	629.15	629.63	629.96	630.74	631.32	631.66	632.04	632.29
XS-200	89108.68	624.17	625.91	627.01	627.97	628.71	629.15	629.64	629.97	630.75	631.33	631.67	632.05	632.30
XS-199	88532.08	623.96	625.65	626.72	627.65	628.37	628.79	629.27	629.59	630.34	630.89	631.22	631.58	631.81
XS-198	88253.47	623.88	625.58	626.65	627.59	628.31	628.73	629.20	629.52	630.28	630.84	631.16	631.52	631.76
XS-197	88219.44	623.88	625.57	626.64	627.58	628.29	628.72	629.19	629.51	630.26	630.82	631.14	631.50	631.74
XS-196	88208.26	623.87	625.56	626.63	627.57	628.29	628.71	629.18	629.50	630.26	630.81	631.14	631.50	631.73
XS-195	88178.25	623.87	625.56	626.63	627.56	628.27	628.70	629.17	629.49	630.24	630.79	631.12	631.48	631.71
XS-194	88019.1	623.83	625.52	626.58	627.52	628.23	628.66	629.13	629.45	630.20	630.75	631.08	631.44	631.67
XS-193	87591.62	623.70	625.40	626.47	627.41	628.13	628.56	629.04	629.36	630.12	630.67	631.00	631.36	631.59
XS-192	86955.53	623.45	625.09	626.12	627.02	627.71	628.12	628.58	628.89	629.61	630.13	630.43	630.77	631.00
XS-191	86239.82	623.23	624.83	625.84	626.72	627.41	627.81	628.26	628.57	629.28	629.82	630.12	630.46	630.69
XS-190	85554.21	623.01	624.60	625.63	626.53	627.23	627.65	628.11	628.43	629.16	629.71	630.02	630.36	630.59
XS-189	84906.53	622.76	624.34	625.35	626.24	626.93	627.34	627.80	628.11	628.84	629.38	629.69	630.06	630.30
XS-188	84206.12	622.50	624.06	625.06	625.94	626.63	627.04	627.50	627.81	628.54	629.12	629.46	629.85	630.11

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-187	83428.95	622.23	623.81	624.83	625.74	626.45	626.87	627.34	627.66	628.42	629.02	629.36	629.75	630.01
XS-186	82749.63	621.98	623.57	624.61	625.53	626.24	626.67	627.14	627.47	628.24	628.83	629.17	629.55	629.81
XS-185	82129.57	621.75	623.36	624.40	625.33	626.05	626.47	626.95	627.27	628.03	628.62	628.95	629.33	629.58
XS-184	81952.76	621.70	623.31	624.36	625.29	626.01	626.43	626.91	627.23	627.99	628.58	628.91	629.29	629.54
XS-183	81934.67	621.69	623.31	624.35	625.28	626.00	626.42	626.90	627.22	627.98	628.57	628.90	629.28	629.52
XS-182	81749.65	621.62	623.20	624.21	625.12	625.82	626.23	626.70	627.01	627.76	628.33	628.64	629.00	629.23
XS-181	81037.88	621.27	622.74	623.69	624.55	625.21	625.61	626.05	626.36	627.09	627.66	628.00	628.39	628.65
XS-180	80207	620.90	622.49	623.52	624.44	625.15	625.58	626.05	626.38	627.15	627.74	628.09	628.48	628.74
XS-179	79861.91	620.79	622.38	623.42	624.33	625.05	625.47	625.94	626.27	627.03	627.62	627.96	628.35	628.61
XS-178	79845.91	620.78	622.37	623.40	624.31	625.02	625.44	625.91	626.24	627.00	627.59	627.92	628.31	628.57
XS-177	79671.26	620.72	622.29	623.31	624.22	624.92	625.34	625.81	626.13	626.89	627.47	627.81	628.19	628.45
XS-176	79189.96	620.50	622.05	623.06	623.96	624.66	625.08	625.54	625.87	626.62	627.20	627.53	627.91	628.17
XS-175	78479.98	620.31	621.84	622.86	623.77	624.47	624.89	625.36	625.69	626.44	627.03	627.36	627.74	628.00
XS-174	77755.85	620.10	621.63	622.65	623.57	624.28	624.70	625.18	625.51	626.26	626.85	627.19	627.58	627.84
XS-173	77551.43	620.03	621.58	622.61	623.53	624.25	624.68	625.15	625.49	626.25	626.84	627.18	627.57	627.83
XS-172	77487.37	620.03	621.57	622.60	623.52	624.24	624.66	625.14	625.47	626.24	626.83	627.16	627.56	627.82
XS-171	77302.26	619.96	621.52	622.55	623.48	624.20	624.63	625.11	625.44	626.21	626.81	627.14	627.54	627.80
XS-170	76934.93	619.83	621.41	622.46	623.40	624.12	624.55	625.04	625.37	626.14	626.74	627.08	627.47	627.73
XS-169	76048.58	619.49	621.10	622.17	623.11	623.84	624.27	624.76	625.10	625.87	626.48	626.82	627.22	627.48
XS-168	75341.23	619.22	620.81	621.86	622.79	623.52	623.94	624.42	624.76	625.52	626.11	626.44	626.83	627.10
XS-167	74678.51	618.99	620.58	621.65	622.60	623.33	623.76	624.25	624.59	625.36	625.96	626.30	626.70	626.97
XS-166	74447.05	618.92	620.53	621.61	622.56	623.30	623.74	624.23	624.57	625.35	625.95	626.29	626.70	626.97
XS-165	74429.04	618.91	620.51	621.59	622.54	623.28	623.72	624.20	624.53	625.30	625.91	626.25	626.66	626.93
XS-164	74153.5	618.81	620.43	621.52	622.48	623.23	623.67	624.16	624.49	625.27	625.88	626.22	626.63	626.90
XS-163	73324.63	618.51	620.15	621.26	622.22	622.96	623.40	623.90	624.22	625.00	625.61	625.95	626.35	626.62
XS-162	72447.05	618.15	619.76	620.85	621.80	622.54	622.97	623.47	623.79	624.56	625.18	625.52	625.93	626.20
XS-161	71765.96	617.92	619.60	620.73	621.71	622.47	622.92	623.43	623.76	624.56	625.19	625.54	625.95	626.23
XS-160	71474.21	617.81	619.51	620.64	621.63	622.40	622.85	623.35	623.69	624.48	625.11	625.45	625.87	626.14
XS-159	71443.92	617.80	619.49	620.63	621.62	622.38	622.83	623.34	623.67	624.46	625.09	625.43	625.85	626.12

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-158	71230.52	617.68	619.40	620.55	621.55	622.31	622.77	623.27	623.61	624.40	625.03	625.38	625.79	626.07
XS-157	70490.6	617.35	619.18	620.36	621.37	622.15	622.61	623.12	623.45	624.25	624.88	625.23	625.64	625.92
XS-156	69766.72	617.17	619.05	620.25	621.27	622.05	622.51	623.03	623.37	624.17	624.80	625.15	625.57	625.85
XS-155	69508.13	617.14	619.02	620.23	621.26	622.04	622.50	623.02	623.36	624.16	624.80	625.15	625.57	625.84
XS-154	69489.65	617.13	619.02	620.23	621.25	622.04	622.50	623.01	623.35	624.16	624.79	625.14	625.56	625.83
XS-153	69440.75	617.12	619.00	620.20	621.23	622.01	622.47	622.99	623.32	624.12	624.76	625.11	625.52	625.80
XS-152	69408.42	617.11	618.99	620.17	621.18	621.96	622.42	622.93	623.27	624.06	624.69	625.04	625.45	625.72
XS-151	69126.02	616.95	618.79	619.94	620.93	621.69	622.13	622.63	622.96	623.72	624.34	624.68	625.09	625.36
XS-150	68798.57	616.89	618.75	619.91	620.91	621.68	622.13	622.63	622.96	623.74	624.36	624.70	625.11	625.38
XS-149	68725.75	616.89	618.74	619.90	620.90	621.67	622.12	622.62	622.95	623.72	624.31	624.65	625.06	625.32
XS-148	68538.78	616.84	618.70	619.85	620.85	621.61	622.06	622.56	622.89	623.67	624.25	624.59	624.99	625.25
XS-147	67911.63	616.62	618.43	619.55	620.52	621.26	621.69	622.18	622.50	623.25	623.82	624.15	624.55	624.81
XS-146	67239.21	616.41	618.23	619.37	620.35	621.10	621.55	622.04	622.36	623.13	623.72	624.05	624.47	624.73
XS-145	67085.8	616.41	618.25	619.40	620.39	621.15	621.60	622.10	622.43	623.20	623.79	624.13	624.54	624.81
XS-144	67041.75	616.38	618.21	619.35	620.34	621.10	621.54	622.04	622.37	623.14	623.72	624.06	624.47	624.74
XS-143	66944.45	616.30	618.11	619.23	620.20	620.95	621.38	621.88	622.19	622.95	623.52	623.85	624.25	624.51
XS-142	66829.07	616.27	618.08	619.21	620.18	620.92	621.36	621.85	622.17	622.93	623.50	623.82	624.23	624.49
XS-141	66797.01	616.27	618.06	619.19	620.16	620.90	621.34	621.83	622.15	622.90	623.47	623.79	624.16	624.41
XS-140	66663.69	616.20	617.98	619.08	620.04	620.77	621.20	621.68	622.00	622.74	623.30	623.61	623.97	624.21
XS-139	66264.02	615.97	617.65	618.70	619.60	620.30	620.70	621.16	621.46	622.17	622.70	623.01	623.35	623.58
XS-138	66132.32	615.94	617.63	618.68	619.59	620.29	620.70	621.15	621.46	622.18	622.73	623.04	623.40	623.64
XS-137	66054.77	615.93	617.60	618.65	619.55	620.24	620.65	621.10	621.40	622.12	622.67	622.98	623.34	623.58
XS-136	65968.72	615.91	617.60	618.66	619.57	620.27	620.68	621.13	621.44	622.16	622.72	623.03	623.40	623.64
XS-135	65594.35	615.82	617.53	618.60	619.52	620.23	620.65	621.11	621.41	622.15	622.71	623.03	623.39	623.64
XS-134	64902.41	615.51	617.17	618.20	619.10	619.78	620.18	620.62	620.92	621.63	622.18	622.49	622.84	623.08
XS-133	64285.15	615.26	616.94	617.99	618.90	619.60	620.00	620.46	620.76	621.49	622.05	622.37	622.74	622.98
XS-132	64114.25	615.23	616.92	617.97	618.88	619.58	619.99	620.44	620.74	621.47	622.02	622.34	622.70	622.94
XS-131	64088.24	615.22	616.90	617.95	618.86	619.56	619.97	620.42	620.72	621.44	621.98	622.29	622.64	622.88
XS-130	63957.07	615.17	616.84	617.88	618.79	619.48	619.88	620.33	620.63	621.35	621.88	622.20	622.55	622.78

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-129	63358.94	614.96	616.55	617.53	618.38	619.03	619.41	619.82	620.10	620.77	621.27	621.57	621.91	622.15
XS-128	62738.11	614.73	616.33	617.33	618.20	618.87	619.26	619.69	619.97	620.66	621.19	621.50	621.85	622.09
XS-127	62176.15	614.51	616.17	617.19	618.08	618.77	619.17	619.61	619.90	620.61	621.14	621.45	621.81	622.05
XS-126	61674.38	614.32	615.95	616.96	617.84	618.51	618.90	619.32	619.61	620.30	620.82	621.12	621.46	621.70
XS-125	61520.62	614.27	615.91	616.92	617.79	618.46	618.85	619.28	619.57	620.26	620.78	621.07	621.42	621.65
XS-124	61480.22	614.26	615.89	616.90	617.77	618.44	618.82	619.25	619.54	620.22	620.74	621.04	621.38	621.61
XS-123	61365.59	614.20	615.82	616.81	617.67	618.33	618.71	619.13	619.41	620.09	620.59	620.88	621.23	621.46
XS-122	60734.08	614.04	615.66	616.66	617.52	618.18	618.56	618.99	619.27	619.95	620.45	620.75	621.09	621.33
XS-121	60103.41	613.88	615.50	616.50	617.37	618.03	618.42	618.84	619.12	619.81	620.31	620.61	620.95	621.18
XS-120	59943.01	613.85	615.46	616.46	617.33	617.99	618.37	618.80	619.08	619.76	620.26	620.56	620.90	621.14
XS-119	59928.97	613.84	615.45	616.45	617.31	617.97	618.36	618.78	619.06	619.74	620.25	620.54	620.88	621.11
XS-118	59770.01	613.77	615.37	616.36	617.22	617.87	618.25	618.67	618.95	619.62	620.12	620.41	620.74	620.96
XS-117	59071.03	613.62	615.21	616.19	617.04	617.69	618.07	618.48	618.76	619.43	619.92	620.21	620.54	620.76
XS-116	58328.16	613.39	614.96	615.95	616.80	617.45	617.83	618.25	618.53	619.20	619.69	619.98	620.31	620.53
XS-115	58168.08	613.37	614.96	615.95	616.80	617.46	617.85	618.27	618.55	619.22	619.72	620.01	620.34	620.57
XS-114	58156.05	613.37	614.95	615.94	616.79	617.45	617.83	618.25	618.53	619.21	619.70	619.99	620.33	620.55
XS-113	58009.17	613.26	614.81	615.78	616.61	617.26	617.63	618.04	618.31	618.97	619.45	619.73	620.06	620.27
XS-112	57249.07	612.98	614.46	615.39	616.18	616.79	617.16	617.56	617.83	618.48	618.98	619.28	619.62	619.85
XS-111	56531.61	612.74	614.18	615.09	615.88	616.49	616.85	617.25	617.52	618.15	618.65	618.94	619.27	619.49
XS-110	55959.75	612.50	613.97	614.90	615.72	616.35	616.72	617.13	617.40	618.06	618.56	618.85	619.19	619.41
XS-109	55737.3	612.42	613.90	614.84	615.67	616.30	616.67	617.09	617.37	618.03	618.53	618.82	619.16	619.39
XS-108	55723.29	612.39	613.89	614.83	615.65	616.28	616.66	617.07	617.35	618.01	618.51	618.81	619.14	619.37
XS-107	55373.45	612.26	613.76	614.70	615.51	616.14	616.51	616.92	617.19	617.85	618.34	618.63	618.97	619.19
XS-106	54926.37	612.13	613.64	614.58	615.40	616.03	616.40	616.81	617.09	617.74	618.23	618.52	618.86	619.08
XS-105	54770.85	612.18	613.70	614.65	615.47	616.10	616.48	616.89	617.17	617.82	618.32	618.62	618.95	619.17
XS-104	54745.55	612.17	613.68	614.63	615.45	616.08	616.45	616.86	617.13	617.78	618.28	618.57	618.90	619.12
XS-103	54625.54	612.03	613.51	614.43	615.22	615.84	616.20	616.60	616.87	617.51	617.99	618.27	618.60	618.81
XS-102	54601.45	612.03	613.49	614.41	615.20	615.82	616.18	616.58	616.84	617.47	617.96	618.24	618.56	618.77
XS-101	54498.21	612.00	613.47	614.39	615.19	615.80	616.16	616.57	616.83	617.47	617.95	618.23	618.56	618.77

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-100	54476.03	611.98	613.44	614.36	615.15	615.76	616.12	616.52	616.78	617.41	617.89	618.17	618.49	618.70
XS-099	54290.64	611.89	613.35	614.27	615.06	615.67	616.03	616.43	616.69	617.32	617.79	618.07	618.39	618.60
XS-098	53623.91	611.72	613.16	614.06	614.84	615.44	615.79	616.18	616.44	617.05	617.52	617.79	618.10	618.31
XS-097	52899.12	611.49	612.82	613.65	614.36	614.90	615.22	615.58	615.81	616.37	616.78	617.01	617.28	617.46
XS-096	52136.59	611.25	612.60	613.46	614.20	614.77	615.11	615.48	615.73	616.32	616.76	617.01	617.30	617.49
XS-095	51361.43	610.87	612.23	613.09	613.82	614.38	614.72	615.09	615.34	615.91	616.34	616.59	616.87	617.05
XS-094	50732.05	610.62	611.99	612.86	613.59	614.16	614.50	614.87	615.11	615.69	616.12	616.36	616.64	616.83
XS-093	50059.53	610.37	611.74	612.62	613.35	613.92	614.26	614.64	614.88	615.46	615.89	616.13	616.41	616.59
XS-092	49849.74	610.33	611.71	612.59	613.32	613.90	614.24	614.62	614.86	615.45	615.87	616.12	616.40	616.58
XS-091	49821.43	610.33	611.71	612.58	613.31	613.89	614.23	614.60	614.85	615.43	615.86	616.10	616.38	616.56
XS-090	49805.56	610.32	611.70	612.57	613.30	613.88	614.22	614.60	614.84	615.42	615.85	616.09	616.37	616.55
XS-089	49777.12	610.30	611.67	612.54	613.29	613.87	614.20	614.58	614.83	615.40	615.83	616.07	616.34	616.53
XS-088	49592.88	610.23	611.59	612.46	613.21	613.79	614.12	614.50	614.74	615.32	615.74	615.98	616.25	616.43
XS-087	49181.89	609.99	611.35	612.22	612.97	613.54	613.88	614.25	614.49	615.06	615.48	615.71	615.98	616.16
XS-086	48518.8	609.69	611.10	611.99	612.75	613.33	613.67	614.04	614.29	614.86	615.27	615.50	615.77	615.94
XS-085	47906.11	609.45	610.89	611.79	612.57	613.15	613.49	613.87	614.12	614.69	615.10	615.33	615.59	615.77
XS-084	47294.37	609.20	610.65	611.55	612.31	612.89	613.22	613.59	613.83	614.38	614.78	615.01	615.25	615.42
XS-083	46633.48	608.98	610.39	611.27	612.02	612.59	612.92	613.28	613.51	614.05	614.44	614.66	614.91	615.09
XS-082	45984.16	608.78	610.16	611.03	611.78	612.34	612.66	613.02	613.25	613.78	614.18	614.42	614.68	614.86
XS-081	45305.53	608.56	609.90	610.76	611.50	612.04	612.36	612.73	612.96	613.53	613.95	614.19	614.46	614.64
XS-080	44638.14	608.31	609.68	610.56	611.31	611.87	612.21	612.59	612.84	613.43	613.86	614.10	614.38	614.57
XS-079	43994.8	607.95	609.38	610.29	611.05	611.61	611.95	612.33	612.57	613.13	613.54	613.77	614.03	614.20
XS-078	43217.95	607.63	609.00	609.85	610.57	611.10	611.41	611.77	611.99	612.52	612.92	613.14	613.40	613.57
XS-077	42467.22	607.36	608.71	609.57	610.30	610.84	611.16	611.53	611.75	612.29	612.68	612.90	613.14	613.31
XS-076	41770.57	607.09	608.40	609.25	609.98	610.53	610.87	611.25	611.48	612.03	612.43	612.65	612.90	613.07
XS-075	40863.2	606.65	608.07	608.96	609.73	610.29	610.63	611.02	611.26	611.81	612.21	612.43	612.68	612.85
XS-074	40013.82	606.19	607.62	608.49	609.23	609.78	610.10	610.46	610.69	611.26	611.68	611.91	612.17	612.35
XS-073	39256.42	605.90	607.34	608.23	608.98	609.52	609.85	610.22	610.45	611.01	611.41	611.63	611.88	612.04
XS-072	38412.44	605.53	607.00	607.90	608.66	609.20	609.53	609.90	610.13	610.68	611.07	611.28	611.51	611.66

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-071	37797.09	605.28	606.77	607.67	608.43	608.96	609.29	609.67	609.90	610.47	610.88	611.10	611.34	611.50
XS-070	37120.66	604.94	606.40	607.31	608.10	608.70	609.06	609.48	609.73	610.33	610.77	610.99	611.24	611.40
XS-069	36534.02	604.72	606.21	607.13	607.93	608.52	608.88	609.29	609.54	610.14	610.58	610.81	611.07	611.24
XS-068	35863.7	604.35	605.78	606.66	607.44	608.03	608.39	608.78	609.06	609.77	610.25	610.50	610.78	610.96
XS-067	35148.61	604.15	605.67	606.61	607.44	608.08	608.46	608.88	609.16	609.85	610.33	610.58	610.84	611.02
XS-066	34502.66	603.78	605.13	605.94	606.64	607.16	607.47	607.82	608.05	608.63	609.03	609.33	609.69	609.93
XS-065	34055.15	603.62	604.97	605.80	606.52	607.08	607.41	607.79	608.04	608.63	609.12	609.42	609.77	610.00
XS-064	33606.53	603.46	604.78	605.59	606.32	606.88	607.21	607.58	607.83	608.42	608.92	609.23	609.58	609.82
XS-063	32938.86	603.27	604.68	605.55	606.33	606.93	607.28	607.68	607.94	608.58	609.07	609.37	609.71	609.93
XS-062	32150.13	602.94	604.35	605.22	605.98	606.56	606.91	607.29	607.55	608.17	608.64	608.93	609.25	609.47
XS-061	31470.43	602.69	604.07	604.92	605.66	606.23	606.56	606.94	607.19	607.79	608.25	608.53	608.85	609.06
XS-060	30826.06	602.49	603.88	604.74	605.49	606.06	606.40	606.78	607.03	607.64	608.11	608.39	608.71	608.93
XS-059	30199.04	602.29	603.66	604.50	605.24	605.80	606.14	606.51	606.76	607.36	607.81	608.09	608.41	608.62
XS-058	29631.55	602.12	603.47	604.30	605.03	605.60	605.93	606.30	606.55	607.14	607.60	607.88	608.20	608.41
XS-057	29454	602.08	603.43	604.26	604.99	605.55	605.88	606.25	606.49	607.09	607.54	607.82	608.13	608.34
XS-056	29440	602.07	603.41	604.23	604.96	605.51	605.84	606.21	606.45	607.04	607.50	607.78	608.10	608.31
XS-055	29275.33	602.00	603.33	604.16	604.88	605.44	605.77	606.14	606.39	606.98	607.44	607.73	608.05	608.26
XS-054	29088.41	601.96	603.30	604.13	604.86	605.42	605.76	606.13	606.38	606.98	607.44	607.73	608.05	608.26
XS-053	28923.56	601.88	603.21	604.03	604.75	605.31	605.64	606.01	606.26	606.86	607.32	607.60	607.92	608.13
XS-052	28907.56	601.84	603.19	604.01	604.73	605.29	605.62	605.98	606.23	606.82	607.28	607.56	607.88	608.09
XS-051	28718.56	601.78	603.13	603.95	604.68	605.23	605.56	605.93	606.18	606.77	607.23	607.51	607.83	608.05
XS-050	27805.42	601.42	602.74	603.53	604.24	604.78	605.10	605.46	605.70	606.29	606.74	607.01	607.31	607.52
XS-049	26962.15	601.10	602.43	603.24	603.95	604.51	604.84	605.20	605.45	606.05	606.51	606.78	607.11	607.33
XS-048	26237.08	600.80	602.12	602.92	603.64	604.19	604.52	604.88	605.13	605.72	606.18	606.45	606.77	606.98
XS-047	25596.2	600.47	601.86	602.71	603.46	604.04	604.39	604.77	605.03	605.66	606.15	606.44	606.78	607.01
XS-046	25084.2	600.20	601.55	602.40	603.15	603.72	604.07	604.45	604.71	605.33	605.82	606.11	606.45	606.68
XS-045	24626.28	600.04	601.36	602.18	602.91	603.46	603.79	604.16	604.40	604.99	605.45	605.72	606.04	606.25
XS-044	24039.88	599.83	601.13	601.95	602.68	603.24	603.57	603.94	604.19	604.78	605.25	605.52	605.83	606.04
XS-043	23377.35	599.53	600.86	601.69	602.43	603.00	603.34	603.71	603.96	604.57	605.03	605.31	605.63	605.84

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-042	22763.99	599.21	600.59	601.45	602.20	602.78	603.12	603.50	603.75	604.36	604.83	605.11	605.43	605.65
XS-041	22074.1	598.86	600.26	601.11	601.85	602.42	602.76	603.13	603.38	603.98	604.44	604.71	605.02	605.23
XS-040	21361.38	598.55	599.92	600.76	601.50	602.06	602.39	602.76	603.01	603.60	604.06	604.34	604.65	604.87
XS-039	21171.43	598.50	599.87	600.70	601.43	601.99	602.32	602.68	602.93	603.52	603.97	604.24	604.55	604.76
XS-038	21161.43	598.49	599.85	600.67	601.39	601.95	602.27	602.63	602.88	603.46	603.91	604.17	604.48	604.68
XS-037	20969.79	598.44	599.80	600.63	601.37	601.92	602.25	602.62	602.86	603.45	603.91	604.17	604.48	604.69
XS-036	20630.58	598.31	599.68	600.51	601.25	601.81	602.14	602.51	602.75	603.34	603.80	604.07	604.38	604.59
XS-035	20262.9	598.16	599.49	600.30	601.02	601.57	601.89	602.25	602.49	603.07	603.52	603.78	604.08	604.29
XS-034	19643.18	597.98	599.28	600.10	600.82	601.37	601.69	602.05	602.29	602.87	603.32	603.58	603.89	604.09
XS-033	18942.99	597.77	599.05	599.86	600.58	601.13	601.46	601.82	602.06	602.64	603.09	603.36	603.66	603.87
XS-032	18284.24	597.57	598.84	599.65	600.36	600.91	601.24	601.59	601.84	602.42	602.87	603.13	603.43	603.64
XS-031	17629.36	597.36	598.60	599.40	600.11	600.65	600.97	601.33	601.57	602.14	602.58	602.85	603.15	603.35
XS-030	17010.11	597.18	598.39	599.18	599.88	600.42	600.74	601.09	601.33	601.90	602.35	602.61	602.91	603.12
XS-029	16356.71	596.98	598.19	598.99	599.70	600.25	600.58	600.94	601.18	601.77	602.22	602.49	602.80	603.01
XS-028	15692.6	596.70	597.96	598.78	599.52	600.08	600.41	600.78	601.03	601.63	602.09	602.37	602.68	602.90
XS-027	15015.99	596.18	597.53	598.39	599.14	599.71	600.05	600.42	600.66	601.26	601.72	602.00	602.31	602.52
XS-026	14424.59	595.81	597.27	598.15	598.92	599.50	599.84	600.21	600.46	601.06	601.52	601.80	602.10	602.32
XS-025	13810.13	595.49	596.84	597.66	598.37	598.91	599.22	599.56	599.79	600.34	600.77	601.02	601.30	601.50
XS-024	13102.02	595.28	596.59	597.40	598.10	598.64	598.96	599.32	599.56	600.15	600.61	600.88	601.19	601.41
XS-023	12445.42	595.03	596.34	597.15	597.88	598.44	598.78	599.15	599.40	599.99	600.45	600.73	601.05	601.26
XS-022	11827.03	594.80	596.15	596.98	597.72	598.29	598.62	598.99	599.24	599.84	600.30	600.58	600.89	601.11
XS-021	11158.9	594.49	595.79	596.60	597.31	597.85	598.17	598.53	598.77	599.34	599.78	600.05	600.36	600.57
XS-020	10534.33	594.24	595.54	596.35	597.06	597.61	597.94	598.30	598.55	599.13	599.58	599.85	600.16	600.37
XS-019	9862.57	593.99	595.27	596.08	596.78	597.33	597.64	598.00	598.24	598.81	599.25	599.51	599.81	600.02
XS-018	9191.96	593.76	595.06	595.87	596.59	597.14	597.47	597.83	598.08	598.66	599.11	599.37	599.68	599.89
XS-017	8543.36	593.52	594.83	595.65	596.37	596.92	597.24	597.61	597.85	598.43	598.88	599.14	599.45	599.66
XS-016	7903.68	593.25	594.53	595.34	596.05	596.60	596.92	597.28	597.53	598.11	598.55	598.82	599.12	599.34
XS-015	7270.37	592.99	594.31	595.13	595.86	596.42	596.75	597.11	597.36	597.95	598.40	598.67	598.98	599.19
XS-014	6647.24	592.71	594.04	594.86	595.59	596.15	596.48	596.84	597.09	597.67	598.12	598.39	598.69	598.90

Cross Section	River Station (m)	Flood Return Period and Discharge (m^3/s)												
		2-year	5-year	10-year	20-year	35-year	50-year	75-year	100-year	200-year	350-year	500-year	750-year	1000-year
		1300	2220	2910	3580	4130	4470	4860	5130	5800	6340	6670	7060	7330
		Water Surface Elevation (m)												
XS-013	6074.52	592.48	593.79	594.61	595.33	595.88	596.20	596.56	596.80	597.37	597.81	598.07	598.38	598.59
XS-012	5397.17	592.20	593.50	594.32	595.04	595.59	595.91	596.27	596.51	597.08	597.53	597.79	598.09	598.30
XS-011	4745.18	591.89	593.23	594.07	594.80	595.36	595.69	596.06	596.30	596.89	597.34	597.61	597.91	598.12
XS-010	4150.78	591.66	593.02	593.86	594.60	595.16	595.49	595.85	596.09	596.68	597.13	597.40	597.71	597.92
XS-009	3661.96	591.43	592.82	593.68	594.42	594.99	595.32	595.69	595.94	596.53	596.98	597.25	597.56	597.77
XS-008	2937.02	591.20	592.61	593.47	594.22	594.79	595.13	595.50	595.75	596.34	596.80	597.08	597.39	597.60
XS-007	2289.74	591.01	592.38	593.21	593.93	594.48	594.80	595.15	595.39	595.97	596.41	596.67	596.97	597.17
XS-006	1648.82	590.82	592.18	593.01	593.73	594.28	594.60	594.96	595.20	595.77	596.21	596.47	596.77	596.97
XS-005	1053.63	590.62	591.99	592.82	593.55	594.10	594.42	594.78	595.02	595.59	596.03	596.30	596.60	596.80
XS-004	467.71	590.47	591.83	592.65	593.37	593.92	594.24	594.59	594.83	595.40	595.84	596.10	596.40	596.60
XS-003	234.05	590.42	591.78	592.60	593.33	593.88	594.20	594.56	594.80	595.37	595.81	596.07	596.37	596.57
XS-002	220.92	590.42	591.77	592.60	593.32	593.87	594.19	594.54	594.78	595.35	595.79	596.05	596.35	596.55
XS-001	0	590.35	591.70	592.53	593.26	593.81	594.13	594.49	594.73	595.30	595.74	596.00	596.30	596.51

APPENDIX E
SENSITIVITY ANALYSIS RESULTS

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-245	113925.9	640.68	640.68	640.68	0.00	0.00	641.24	640.05	0.56	-0.63	640.70	640.66	0.02	-0.02
XS-244	113347.4	640.30	640.30	640.30	0.00	0.00	640.90	639.64	0.60	-0.66	640.31	640.29	0.01	-0.01
XS-243	112709.5	639.63	639.63	639.63	0.00	0.00	640.26	638.96	0.63	-0.67	639.64	639.61	0.01	-0.02
XS-242	112148.3	639.67	639.67	639.67	0.00	0.00	640.24	639.07	0.57	-0.60	639.69	639.65	0.02	-0.02
XS-241	111469.5	639.13	639.13	639.13	0.00	0.00	639.72	638.49	0.59	-0.64	639.15	639.10	0.02	-0.03
XS-240	110867.8	638.96	638.96	638.96	0.00	0.00	639.51	638.36	0.55	-0.60	638.97	638.93	0.01	-0.03
XS-239	110258.1	638.73	638.73	638.73	0.00	0.00	639.27	638.14	0.54	-0.59	638.75	638.70	0.02	-0.03
XS-238	110028.4	638.63	638.63	638.63	0.00	0.00	639.17	638.06	0.54	-0.57	638.65	638.60	0.02	-0.03
XS-237	110003.4	638.61	638.61	638.61	0.00	0.00	639.15	638.03	0.54	-0.58	638.63	638.58	0.02	-0.03
XS-236	109978.3	638.53	638.53	638.53	0.00	0.00	639.09	637.93	0.56	-0.60	638.55	638.50	0.02	-0.03
XS-235	109590.2	638.21	638.21	638.21	0.00	0.00	638.78	637.60	0.57	-0.61	638.23	638.19	0.02	-0.02
XS-234	109130.1	637.94	637.94	637.94	0.00	0.00	638.50	637.33	0.56	-0.61	637.96	637.91	0.02	-0.03
XS-233	108756.3	638.00	638.00	638.00	0.00	0.00	638.54	637.43	0.54	-0.57	638.02	637.98	0.02	-0.02
XS-232	108353.8	637.59	637.59	637.59	0.00	0.00	638.19	636.93	0.60	-0.66	637.59	637.60	0.00	0.01
XS-231	108000.2	637.35	637.35	637.35	0.00	0.00	637.93	636.72	0.58	-0.63	637.36	637.33	0.01	-0.02
XS-230	107424.3	637.05	637.05	637.05	0.00	0.00	637.62	636.43	0.57	-0.62	637.06	637.03	0.01	-0.02
XS-229	106821.7	636.71	636.71	636.71	0.00	0.00	637.26	636.11	0.55	-0.60	636.73	636.68	0.02	-0.03
XS-228	106156.9	636.13	636.13	636.13	0.00	0.00	636.69	635.51	0.56	-0.62	636.14	636.11	0.01	-0.02
XS-227	105483.4	636.18	636.18	636.18	0.00	0.00	636.71	635.62	0.53	-0.56	636.20	636.16	0.02	-0.02
XS-226	104742.3	635.89	635.89	635.89	0.00	0.00	636.43	635.30	0.54	-0.59	635.91	635.86	0.02	-0.03
XS-225	104231.7	635.58	635.58	635.58	0.00	0.00	636.13	634.97	0.55	-0.61	635.60	635.55	0.02	-0.03
XS-224	103691.4	634.94	634.94	634.94	0.00	0.00	635.54	634.30	0.60	-0.64	634.96	634.90	0.02	-0.04
XS-223	103146.8	634.52	634.52	634.52	0.00	0.00	635.13	633.86	0.61	-0.66	634.54	634.49	0.02	-0.03
XS-222	102467.2	634.60	634.60	634.60	0.00	0.00	635.15	634.01	0.55	-0.59	634.63	634.56	0.03	-0.04
XS-221	101759.5	634.29	634.29	634.29	0.00	0.00	634.87	633.67	0.58	-0.62	634.31	634.27	0.02	-0.02
XS-220	100863.5	633.97	633.97	633.97	0.00	0.00	634.54	633.35	0.57	-0.62	633.99	633.94	0.02	-0.03
XS-219	100252.2	633.66	633.66	633.66	0.00	0.00	634.25	633.02	0.59	-0.64	633.68	633.63	0.02	-0.03
XS-218	99594.2	633.44	633.44	633.44	0.00	0.00	634.01	632.83	0.57	-0.61	633.46	633.40	0.02	-0.04

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-217	99221.64	633.43	633.43	633.43	0.00	0.00	633.98	632.84	0.55	-0.59	633.45	633.39	0.02	-0.04
XS-216	98864.05	633.07	633.07	633.07	0.00	0.00	633.66	632.44	0.59	-0.63	633.09	633.03	0.02	-0.04
XS-215	98325.86	632.67	632.67	632.67	0.00	0.00	633.27	632.02	0.60	-0.65	632.70	632.63	0.03	-0.04
XS-214	97698.93	632.47	632.47	632.47	0.00	0.00	633.05	631.85	0.58	-0.62	632.50	632.43	0.03	-0.04
XS-213	97115.77	632.29	632.29	632.29	0.00	0.00	632.85	631.69	0.56	-0.60	632.33	632.24	0.04	-0.05
XS-212	96394.77	631.78	631.78	631.78	0.00	0.00	632.38	631.12	0.60	-0.66	631.80	631.74	0.02	-0.04
XS-211	95747.41	631.57	631.57	631.57	0.00	0.00	632.15	630.94	0.58	-0.63	631.60	631.52	0.03	-0.05
XS-210	95104.69	631.45	631.45	631.45	0.00	0.00	632.01	630.85	0.56	-0.60	631.49	631.40	0.04	-0.05
XS-209	94489.34	631.19	631.19	631.19	0.00	0.00	631.78	630.57	0.59	-0.62	631.22	631.15	0.03	-0.04
XS-208	93922.47	630.98	630.98	630.98	0.00	0.00	631.60	630.33	0.62	-0.65	631.01	630.95	0.03	-0.03
XS-207	93323.98	630.83	630.83	630.83	0.00	0.00	631.44	630.19	0.61	-0.64	630.86	630.80	0.03	-0.03
XS-206	92653.69	630.87	630.87	630.87	0.00	0.00	631.44	630.26	0.57	-0.61	630.90	630.82	0.03	-0.05
XS-205	92172.4	630.36	630.36	630.36	0.00	0.00	631.01	629.65	0.65	-0.71	630.39	630.33	0.03	-0.03
XS-204	91643.14	630.46	630.46	630.46	0.00	0.00	631.10	629.76	0.64	-0.70	630.46	630.44	0.00	-0.02
XS-203	91198.32	630.42	630.42	630.42	0.00	0.00	631.05	629.74	0.63	-0.68	630.43	630.40	0.01	-0.02
XS-202	90371.64	630.15	630.15	630.15	0.00	0.00	630.80	629.45	0.65	-0.70	630.16	630.13	0.01	-0.02
XS-201	89723.91	629.96	629.96	629.96	0.00	0.00	630.62	629.25	0.66	-0.71	629.97	629.94	0.01	-0.02
XS-200	89108.68	629.97	629.97	629.97	0.00	0.00	630.61	629.29	0.64	-0.68	629.98	629.95	0.01	-0.02
XS-199	88532.08	629.59	629.59	629.59	0.00	0.00	630.26	628.86	0.67	-0.73	629.60	629.57	0.01	-0.02
XS-198	88253.47	629.52	629.52	629.52	0.00	0.00	630.19	628.81	0.67	-0.71	629.54	629.50	0.02	-0.02
XS-197	88219.44	629.51	629.51	629.51	0.00	0.00	630.18	628.79	0.67	-0.72	629.52	629.49	0.01	-0.02
XS-196	88208.26	629.50	629.50	629.50	0.00	0.00	630.17	628.78	0.67	-0.72	629.52	629.48	0.02	-0.02
XS-195	88178.25	629.49	629.49	629.49	0.00	0.00	630.16	628.76	0.67	-0.73	629.50	629.47	0.01	-0.02
XS-194	88019.1	629.45	629.45	629.45	0.00	0.00	630.12	628.73	0.67	-0.72	629.46	629.43	0.01	-0.02
XS-193	87591.62	629.36	629.36	629.36	0.00	0.00	630.02	628.64	0.66	-0.72	629.38	629.34	0.02	-0.02
XS-192	86955.53	628.89	628.89	628.89	0.00	0.00	629.58	628.13	0.69	-0.76	628.90	628.87	0.01	-0.02
XS-191	86239.82	628.57	628.57	628.57	0.00	0.00	629.25	627.83	0.68	-0.74	628.58	628.55	0.01	-0.02
XS-190	85554.21	628.43	628.43	628.43	0.00	0.00	629.09	627.70	0.66	-0.73	628.44	628.41	0.01	-0.02

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-189	84906.53	628.11	628.11	628.11	0.00	0.00	628.78	627.38	0.67	-0.73	628.12	628.10	0.01	-0.01
XS-188	84206.12	627.81	627.81	627.81	0.00	0.00	628.47	627.09	0.66	-0.72	627.82	627.79	0.01	-0.02
XS-187	83428.95	627.66	627.66	627.66	0.00	0.00	628.32	626.96	0.66	-0.70	627.68	627.64	0.02	-0.02
XS-186	82749.63	627.47	627.47	627.47	0.00	0.00	628.12	626.78	0.65	-0.69	627.48	627.45	0.01	-0.02
XS-185	82129.57	627.27	627.27	627.27	0.00	0.00	627.92	626.59	0.65	-0.68	627.29	627.26	0.02	-0.01
XS-184	81952.76	627.23	627.23	627.23	0.00	0.00	627.87	626.56	0.64	-0.67	627.25	627.22	0.02	-0.01
XS-183	81934.67	627.22	627.22	627.22	0.00	0.00	627.86	626.54	0.64	-0.68	627.24	627.21	0.02	-0.01
XS-182	81749.65	627.01	627.01	627.01	0.00	0.00	627.67	626.31	0.66	-0.70	627.03	627.00	0.02	-0.01
XS-181	81037.88	626.36	626.36	626.36	0.00	0.00	627.09	625.57	0.73	-0.79	626.37	626.36	0.01	0.00
XS-180	80207	626.38	626.38	626.38	0.00	0.00	627.05	625.66	0.67	-0.72	626.39	626.37	0.01	-0.01
XS-179	79861.91	626.27	626.27	626.27	0.00	0.00	626.94	625.56	0.67	-0.71	626.28	626.26	0.01	-0.01
XS-178	79845.91	626.24	626.24	626.24	0.00	0.00	626.91	625.52	0.67	-0.72	626.25	626.23	0.01	-0.01
XS-177	79671.26	626.13	626.13	626.13	0.00	0.00	626.81	625.40	0.68	-0.73	626.14	626.12	0.01	-0.01
XS-176	79189.96	625.87	625.87	625.87	0.00	0.00	626.56	625.11	0.69	-0.76	625.88	625.86	0.01	-0.01
XS-175	78479.98	625.69	625.69	625.69	0.00	0.00	626.37	624.96	0.68	-0.73	625.70	625.68	0.01	-0.01
XS-174	77755.85	625.51	625.51	625.51	0.00	0.00	626.17	624.79	0.66	-0.72	625.52	625.50	0.01	-0.01
XS-173	77551.43	625.49	625.49	625.49	0.00	0.00	626.15	624.78	0.66	-0.71	625.50	625.48	0.01	-0.01
XS-172	77487.37	625.47	625.47	625.47	0.00	0.00	626.14	624.76	0.67	-0.71	625.48	625.47	0.01	0.00
XS-171	77302.26	625.44	625.44	625.44	0.00	0.00	626.10	624.73	0.66	-0.71	625.46	625.44	0.02	0.00
XS-170	76934.93	625.37	625.37	625.37	0.00	0.00	626.03	624.67	0.66	-0.70	625.38	625.37	0.01	0.00
XS-169	76048.58	625.10	625.10	625.10	0.00	0.00	625.76	624.39	0.66	-0.71	625.11	625.09	0.01	-0.01
XS-168	75341.23	624.76	624.76	624.76	0.00	0.00	625.43	624.04	0.67	-0.72	624.77	624.76	0.01	0.00
XS-167	74678.51	624.59	624.59	624.59	0.00	0.00	625.25	623.89	0.66	-0.70	624.60	624.59	0.01	0.00
XS-166	74447.05	624.57	624.57	624.57	0.00	0.00	625.22	623.88	0.65	-0.69	624.58	624.57	0.01	0.00
XS-165	74429.04	624.53	624.53	624.53	0.00	0.00	625.18	623.85	0.65	-0.68	624.54	624.53	0.01	0.00
XS-164	74153.5	624.49	624.49	624.49	0.00	0.00	625.13	623.81	0.64	-0.68	624.50	624.48	0.01	-0.01
XS-163	73324.63	624.22	624.22	624.22	0.00	0.00	624.87	623.56	0.65	-0.66	624.24	624.22	0.02	0.00
XS-162	72447.05	623.79	623.79	623.79	0.00	0.00	624.45	623.11	0.66	-0.68	623.80	623.79	0.01	0.00

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-161	71765.96	623.76	623.76	623.76	0.00	0.00	624.39	623.12	0.63	-0.64	623.78	623.77	0.02	0.01
XS-160	71474.21	623.69	623.69	623.69	0.00	0.00	624.31	623.05	0.62	-0.64	623.70	623.69	0.01	0.00
XS-159	71443.92	623.67	623.67	623.67	0.00	0.00	624.30	623.03	0.63	-0.64	623.69	623.67	0.02	0.00
XS-158	71230.52	623.61	623.61	623.61	0.00	0.00	624.24	622.97	0.63	-0.64	623.62	623.61	0.01	0.00
XS-157	70490.6	623.45	623.45	623.45	0.00	0.00	624.07	622.83	0.62	-0.62	623.47	623.46	0.02	0.01
XS-156	69766.72	623.37	623.37	623.37	0.00	0.00	623.97	622.76	0.60	-0.61	623.38	623.37	0.01	0.00
XS-155	69508.13	623.36	623.36	623.36	0.00	0.00	623.95	622.76	0.59	-0.60	623.38	623.36	0.02	0.00
XS-154	69489.65	623.35	623.35	623.35	0.00	0.00	623.95	622.75	0.60	-0.60	623.37	623.36	0.02	0.01
XS-153	69440.75	623.32	623.32	623.32	0.00	0.00	623.92	622.72	0.60	-0.60	623.34	623.33	0.02	0.01
XS-152	69408.42	623.27	623.27	623.27	0.00	0.00	623.87	622.66	0.60	-0.61	623.28	623.27	0.01	0.00
XS-151	69126.02	622.96	622.96	622.96	0.00	0.00	623.59	622.31	0.63	-0.65	622.97	622.96	0.01	0.00
XS-150	68798.57	622.96	622.96	622.96	0.00	0.00	623.57	622.34	0.61	-0.62	622.98	622.97	0.02	0.01
XS-149	68725.75	622.95	622.95	622.95	0.00	0.00	623.53	622.32	0.58	-0.63	622.96	622.92	0.01	-0.03
XS-148	68538.78	622.89	622.89	622.89	0.00	0.00	623.47	622.27	0.58	-0.62	622.91	622.87	0.02	-0.02
XS-147	67911.63	622.50	622.50	622.50	0.00	0.00	623.09	621.86	0.59	-0.64	622.52	622.47	0.02	-0.03
XS-146	67239.21	622.36	622.36	622.36	0.00	0.00	622.94	621.75	0.58	-0.61	622.38	622.34	0.02	-0.02
XS-145	67085.8	622.43	622.43	622.43	0.00	0.00	622.99	621.84	0.56	-0.59	622.45	622.41	0.02	-0.02
XS-144	67041.75	622.37	622.37	622.37	0.00	0.00	622.93	621.77	0.56	-0.60	622.38	622.34	0.01	-0.03
XS-143	66944.45	622.19	622.19	622.19	0.00	0.00	622.78	621.57	0.59	-0.62	622.21	622.17	0.02	-0.02
XS-142	66829.07	622.17	622.17	622.17	0.00	0.00	622.75	621.56	0.58	-0.61	622.19	622.15	0.02	-0.02
XS-141	66797.01	622.15	622.15	622.15	0.00	0.00	622.73	621.52	0.58	-0.63	622.16	622.12	0.01	-0.03
XS-140	66663.69	622.00	622.00	622.00	0.00	0.00	622.59	621.36	0.59	-0.64	622.01	621.97	0.01	-0.03
XS-139	66264.02	621.46	621.46	621.46	0.00	0.00	622.10	620.76	0.64	-0.70	621.47	621.43	0.01	-0.03
XS-138	66132.32	621.46	621.46	621.46	0.00	0.00	622.09	620.78	0.63	-0.68	621.47	621.43	0.01	-0.03
XS-137	66054.77	621.40	621.40	621.40	0.00	0.00	622.05	620.71	0.65	-0.69	621.42	621.38	0.02	-0.02
XS-136	65968.72	621.44	621.44	621.44	0.00	0.00	622.07	620.76	0.63	-0.68	621.45	621.41	0.01	-0.03
XS-135	65594.35	621.41	621.41	621.41	0.00	0.00	622.03	620.76	0.62	-0.65	621.43	621.39	0.02	-0.02
XS-134	64902.41	620.92	620.92	620.92	0.00	0.00	621.57	620.22	0.65	-0.70	620.93	620.90	0.01	-0.02

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-133	64285.15	620.76	620.76	620.76	0.00	0.00	621.40	620.09	0.64	-0.67	620.77	620.74	0.01	-0.02
XS-132	64114.25	620.74	620.74	620.74	0.00	0.00	621.37	620.09	0.63	-0.65	620.76	620.72	0.02	-0.02
XS-131	64088.24	620.72	620.72	620.72	0.00	0.00	621.35	620.05	0.63	-0.67	620.73	620.70	0.01	-0.02
XS-130	63957.07	620.63	620.63	620.63	0.00	0.00	621.27	619.96	0.64	-0.67	620.64	620.62	0.01	-0.01
XS-129	63358.94	620.10	620.10	620.10	0.00	0.00	620.76	619.39	0.66	-0.71	620.11	620.08	0.01	-0.02
XS-128	62738.11	619.97	619.97	619.97	0.00	0.00	620.61	619.30	0.64	-0.67	619.99	619.95	0.02	-0.02
XS-127	62176.15	619.90	619.90	619.90	0.00	0.00	620.52	619.25	0.62	-0.65	619.92	619.88	0.02	-0.02
XS-126	61674.38	619.61	619.61	619.61	0.00	0.00	620.24	618.95	0.63	-0.66	619.63	619.59	0.02	-0.02
XS-125	61520.62	619.57	619.57	619.57	0.00	0.00	620.20	618.91	0.63	-0.66	619.58	619.55	0.01	-0.02
XS-124	61480.22	619.54	619.54	619.54	0.00	0.00	620.17	618.87	0.63	-0.67	619.55	619.52	0.01	-0.02
XS-123	61365.59	619.41	619.41	619.41	0.00	0.00	620.07	618.72	0.66	-0.69	619.42	619.40	0.01	-0.01
XS-122	60734.08	619.27	619.27	619.27	0.00	0.00	619.90	618.61	0.63	-0.66	619.28	619.25	0.01	-0.02
XS-121	60103.41	619.12	619.12	619.12	0.00	0.00	619.74	618.48	0.62	-0.64	619.14	619.11	0.02	-0.01
XS-120	59943.01	619.08	619.08	619.08	0.00	0.00	619.69	618.44	0.61	-0.64	619.09	619.06	0.01	-0.02
XS-119	59928.97	619.06	619.06	619.06	0.00	0.00	619.68	618.42	0.62	-0.64	619.08	619.04	0.02	-0.02
XS-118	59770.01	618.95	618.95	618.95	0.00	0.00	619.58	618.29	0.63	-0.66	618.96	618.93	0.01	-0.02
XS-117	59071.03	618.76	618.76	618.76	0.00	0.00	619.37	618.13	0.61	-0.63	618.78	618.74	0.02	-0.02
XS-116	58328.16	618.53	618.53	618.53	0.00	0.00	619.13	617.90	0.60	-0.63	618.55	618.51	0.02	-0.02
XS-115	58168.08	618.55	618.55	618.55	0.00	0.00	619.13	617.94	0.58	-0.61	618.56	618.52	0.01	-0.03
XS-114	58156.05	618.53	618.53	618.53	0.00	0.00	619.12	617.92	0.59	-0.61	618.55	618.51	0.02	-0.02
XS-113	58009.17	618.31	618.31	618.31	0.00	0.00	618.93	617.66	0.62	-0.65	618.33	618.29	0.02	-0.02
XS-112	57249.07	617.83	617.83	617.83	0.00	0.00	618.48	617.14	0.65	-0.69	617.84	617.82	0.01	-0.01
XS-111	56531.61	617.52	617.52	617.52	0.00	0.00	618.14	616.85	0.62	-0.67	617.53	617.51	0.01	-0.01
XS-110	55959.75	617.40	617.40	617.40	0.00	0.00	618.00	616.77	0.60	-0.63	617.42	617.39	0.02	-0.01
XS-109	55737.3	617.37	617.37	617.37	0.00	0.00	617.96	616.74	0.59	-0.63	617.38	617.35	0.01	-0.02
XS-108	55723.29	617.35	617.35	617.35	0.00	0.00	617.94	616.72	0.59	-0.63	617.36	617.34	0.01	-0.01
XS-107	55373.45	617.19	617.19	617.19	0.00	0.00	617.79	616.57	0.60	-0.62	617.20	617.18	0.01	-0.01
XS-106	54926.37	617.09	617.09	617.09	0.00	0.00	617.66	616.48	0.57	-0.61	617.10	617.07	0.01	-0.02

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-105	54770.85	617.17	617.17	617.17	0.00	0.00	617.72	616.59	0.55	-0.58	617.18	617.15	0.01	-0.02
XS-104	54745.55	617.13	617.13	617.13	0.00	0.00	617.69	616.55	0.56	-0.58	617.14	617.12	0.01	-0.01
XS-103	54625.54	616.87	616.87	616.87	0.00	0.00	617.47	616.23	0.60	-0.64	616.88	616.85	0.01	-0.02
XS-102	54601.45	616.84	616.84	616.84	0.00	0.00	617.45	616.20	0.61	-0.64	616.85	616.83	0.01	-0.01
XS-101	54498.21	616.83	616.83	616.83	0.00	0.00	617.44	616.19	0.61	-0.64	616.84	616.82	0.01	-0.01
XS-100	54476.03	616.78	616.78	616.78	0.00	0.00	617.40	616.12	0.62	-0.66	616.79	616.77	0.01	-0.01
XS-099	54290.64	616.69	616.69	616.69	0.00	0.00	617.31	616.02	0.62	-0.67	616.70	616.68	0.01	-0.01
XS-098	53623.91	616.44	616.44	616.44	0.00	0.00	617.05	615.78	0.61	-0.66	616.45	616.42	0.01	-0.02
XS-097	52899.12	615.81	615.81	615.81	0.00	0.00	616.46	615.10	0.65	-0.71	615.82	615.80	0.01	-0.01
XS-096	52136.59	615.73	615.73	615.73	0.00	0.00	616.33	615.07	0.60	-0.66	615.74	615.71	0.01	-0.02
XS-095	51361.43	615.34	615.34	615.34	0.00	0.00	615.95	614.65	0.61	-0.69	615.35	615.32	0.01	-0.02
XS-094	50732.05	615.11	615.11	615.11	0.00	0.00	615.72	614.45	0.61	-0.66	615.13	615.10	0.02	-0.01
XS-093	50059.53	614.88	614.88	614.88	0.00	0.00	615.48	614.23	0.60	-0.65	614.90	614.87	0.02	-0.01
XS-092	49849.74	614.86	614.86	614.86	0.00	0.00	615.44	614.22	0.58	-0.64	614.88	614.85	0.02	-0.01
XS-091	49821.43	614.85	614.85	614.85	0.00	0.00	615.43	614.20	0.58	-0.65	614.86	614.83	0.01	-0.02
XS-090	49805.56	614.84	614.84	614.84	0.00	0.00	615.42	614.20	0.58	-0.64	614.86	614.82	0.02	-0.02
XS-089	49777.12	614.83	614.83	614.83	0.00	0.00	615.41	614.17	0.58	-0.66	614.84	614.81	0.01	-0.02
XS-088	49592.88	614.74	614.74	614.74	0.00	0.00	615.33	614.08	0.59	-0.66	614.76	614.72	0.02	-0.02
XS-087	49181.89	614.49	614.49	614.49	0.00	0.00	615.10	613.80	0.61	-0.69	614.51	614.48	0.02	-0.01
XS-086	48518.8	614.29	614.29	614.29	0.00	0.00	614.88	613.62	0.59	-0.67	614.30	614.27	0.01	-0.02
XS-085	47906.11	614.12	614.12	614.12	0.00	0.00	614.69	613.46	0.57	-0.66	614.13	614.10	0.01	-0.02
XS-084	47294.37	613.83	613.83	613.83	0.00	0.00	614.41	613.17	0.58	-0.66	613.85	613.81	0.02	-0.02
XS-083	46633.48	613.51	613.51	613.51	0.00	0.00	614.08	612.85	0.57	-0.66	613.53	613.48	0.02	-0.03
XS-082	45984.16	613.25	613.25	613.25	0.00	0.00	613.80	612.60	0.55	-0.65	613.27	613.22	0.02	-0.03
XS-081	45305.53	612.96	612.96	612.96	0.00	0.00	613.54	612.30	0.58	-0.66	612.99	612.94	0.03	-0.02
XS-080	44638.14	612.84	612.84	612.84	0.00	0.00	613.41	612.19	0.57	-0.65	612.86	612.82	0.02	-0.02
XS-079	43994.8	612.57	612.57	612.57	0.00	0.00	613.12	611.93	0.55	-0.64	612.59	612.54	0.02	-0.03
XS-078	43217.95	611.99	611.99	611.99	0.00	0.00	612.58	611.32	0.59	-0.67	612.01	611.96	0.02	-0.03

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-077	42467.22	611.75	611.75	611.75	0.00	0.00	612.31	611.11	0.56	-0.64	611.78	611.72	0.03	-0.03
XS-076	41770.57	611.48	611.48	611.48	0.00	0.00	612.04	610.83	0.56	-0.65	611.50	611.46	0.02	-0.02
XS-075	40863.2	611.26	611.26	611.26	0.00	0.00	611.78	610.64	0.52	-0.62	611.28	611.23	0.02	-0.03
XS-074	40013.82	610.69	610.69	610.69	0.00	0.00	611.29	610.04	0.60	-0.65	610.72	610.66	0.03	-0.03
XS-073	39256.42	610.45	610.45	610.45	0.00	0.00	611.01	609.83	0.56	-0.62	610.48	610.42	0.03	-0.03
XS-072	38412.44	610.13	610.13	610.13	0.00	0.00	610.66	609.53	0.53	-0.60	610.16	610.09	0.03	-0.04
XS-071	37797.09	609.90	609.90	609.90	0.00	0.00	610.44	609.31	0.54	-0.59	609.94	609.85	0.04	-0.05
XS-070	37120.66	609.73	609.73	609.73	0.00	0.00	610.28	609.10	0.55	-0.63	609.75	609.70	0.02	-0.03
XS-069	36534.02	609.54	609.54	609.54	0.00	0.00	610.06	608.97	0.52	-0.57	609.57	609.49	0.03	-0.05
XS-068	35863.7	609.06	609.06	609.06	0.00	0.00	609.74	608.39	0.68	-0.67	609.07	609.05	0.01	-0.01
XS-067	35148.61	609.16	609.16	609.16	0.00	0.00	609.76	608.56	0.60	-0.60	609.17	609.15	0.01	-0.01
XS-066	34502.66	608.05	608.05	608.05	0.00	0.00	608.76	607.27	0.71	-0.78	608.06	608.03	0.01	-0.02
XS-065	34055.15	608.04	608.04	608.04	0.00	0.00	608.71	607.30	0.67	-0.74	608.04	608.02	0.00	-0.02
XS-064	33606.53	607.83	607.83	607.83	0.00	0.00	608.49	607.11	0.66	-0.72	607.83	607.82	0.00	-0.01
XS-063	32938.86	607.94	607.94	607.94	0.00	0.00	608.55	607.30	0.61	-0.64	607.95	607.92	0.01	-0.02
XS-062	32150.13	607.55	607.55	607.55	0.00	0.00	608.19	606.87	0.64	-0.68	607.56	607.53	0.01	-0.02
XS-061	31470.43	607.19	607.19	607.19	0.00	0.00	607.84	606.50	0.65	-0.69	607.20	607.17	0.01	-0.02
XS-060	30826.06	607.03	607.03	607.03	0.00	0.00	607.66	606.37	0.63	-0.66	607.05	607.01	0.02	-0.02
XS-059	30199.04	606.76	606.76	606.76	0.00	0.00	607.39	606.10	0.63	-0.66	606.77	606.73	0.01	-0.03
XS-058	29631.55	606.55	606.55	606.55	0.00	0.00	607.17	605.90	0.62	-0.65	606.56	606.52	0.01	-0.03
XS-057	29454	606.49	606.50	606.49	0.01	0.00	607.11	605.85	0.62	-0.64	606.51	606.47	0.02	-0.02
XS-056	29440	606.45	606.45	606.45	0.00	0.00	607.08	605.79	0.63	-0.66	606.47	606.43	0.02	-0.02
XS-055	29275.33	606.39	606.39	606.39	0.00	0.00	607.02	605.72	0.63	-0.67	606.40	606.37	0.01	-0.02
XS-054	29088.41	606.38	606.38	606.38	0.00	0.00	607.00	605.72	0.62	-0.66	606.39	606.36	0.01	-0.02
XS-053	28923.56	606.26	606.26	606.26	0.00	0.00	606.89	605.59	0.63	-0.67	606.27	606.24	0.01	-0.02
XS-052	28907.56	606.23	606.23	606.23	0.00	0.00	606.87	605.54	0.64	-0.69	606.24	606.21	0.01	-0.02
XS-051	28718.56	606.18	606.18	606.18	0.00	0.00	606.81	605.50	0.63	-0.68	606.19	606.16	0.01	-0.02
XS-050	27805.42	605.70	605.71	605.70	0.01	0.00	606.36	604.99	0.66	-0.71	605.71	605.69	0.01	-0.01

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-049	26962.15	605.45	605.45	605.45	0.00	0.00	606.09	604.77	0.64	-0.68	605.46	605.43	0.01	-0.02
XS-048	26237.08	605.13	605.13	605.13	0.00	0.00	605.77	604.44	0.64	-0.69	605.14	605.11	0.01	-0.02
XS-047	25596.2	605.03	605.04	605.03	0.01	0.00	605.66	604.36	0.63	-0.67	605.05	605.02	0.02	-0.01
XS-046	25084.2	604.71	604.71	604.70	0.00	-0.01	605.37	603.99	0.66	-0.72	604.72	604.69	0.01	-0.02
XS-045	24626.28	604.40	604.41	604.40	0.01	0.00	605.06	603.69	0.66	-0.71	604.42	604.38	0.02	-0.02
XS-044	24039.88	604.19	604.19	604.19	0.00	0.00	604.85	603.48	0.66	-0.71	604.20	604.18	0.01	-0.01
XS-043	23377.35	603.96	603.97	603.96	0.01	0.00	604.61	603.28	0.65	-0.68	603.98	603.95	0.02	-0.01
XS-042	22763.99	603.75	603.76	603.75	0.01	0.00	604.39	603.07	0.64	-0.68	603.76	603.73	0.01	-0.02
XS-041	22074.1	603.38	603.39	603.37	0.01	-0.01	604.03	602.69	0.65	-0.69	603.39	603.36	0.01	-0.02
XS-040	21361.38	603.01	603.01	603.00	0.00	-0.01	603.67	602.30	0.66	-0.71	603.01	602.99	0.00	-0.02
XS-039	21171.43	602.93	602.94	602.92	0.01	-0.01	603.58	602.24	0.65	-0.69	602.94	602.92	0.01	-0.01
XS-038	21161.43	602.88	602.89	602.87	0.01	-0.01	603.55	602.16	0.67	-0.72	602.88	602.87	0.00	-0.01
XS-037	20969.79	602.86	602.87	602.86	0.01	0.00	603.52	602.16	0.66	-0.70	602.87	602.85	0.01	-0.01
XS-036	20630.58	602.75	602.76	602.74	0.01	-0.01	603.40	602.05	0.65	-0.70	602.76	602.74	0.01	-0.01
XS-035	20262.9	602.49	602.51	602.49	0.02	0.00	603.17	601.77	0.68	-0.72	602.50	602.48	0.01	-0.01
XS-034	19643.18	602.29	602.31	602.28	0.02	-0.01	602.95	601.59	0.66	-0.70	602.30	602.28	0.01	-0.01
XS-033	18942.99	602.06	602.07	602.05	0.01	-0.01	602.71	601.37	0.65	-0.69	602.07	602.04	0.01	-0.02
XS-032	18284.24	601.84	601.85	601.82	0.01	-0.02	602.47	601.16	0.63	-0.68	601.85	601.82	0.01	-0.02
XS-031	17629.36	601.57	601.58	601.55	0.01	-0.02	602.20	600.89	0.63	-0.68	601.58	601.55	0.01	-0.02
XS-030	17010.11	601.33	601.35	601.31	0.02	-0.02	601.96	600.66	0.63	-0.67	601.34	601.31	0.01	-0.02
XS-029	16356.71	601.18	601.20	601.16	0.02	-0.02	601.79	600.54	0.61	-0.64	601.19	601.16	0.01	-0.02
XS-028	15692.6	601.03	601.06	601.01	0.03	-0.02	601.63	600.40	0.60	-0.63	601.05	601.01	0.02	-0.02
XS-027	15015.99	600.66	600.69	600.64	0.03	-0.02	601.29	600.00	0.63	-0.66	600.68	600.64	0.02	-0.02
XS-026	14424.59	600.46	600.49	600.43	0.03	-0.03	601.08	599.81	0.62	-0.65	600.48	600.43	0.02	-0.03
XS-025	13810.13	599.79	599.83	599.76	0.04	-0.03	600.47	599.05	0.68	-0.74	599.81	599.76	0.02	-0.03
XS-024	13102.02	599.56	599.61	599.52	0.05	-0.04	600.25	598.83	0.69	-0.73	599.58	599.54	0.02	-0.02
XS-023	12445.42	599.40	599.45	599.35	0.05	-0.05	600.07	598.67	0.67	-0.73	599.40	599.39	0.00	-0.01
XS-022	11827.03	599.24	599.30	599.19	0.06	-0.05	599.89	598.56	0.65	-0.68	599.26	599.22	0.02	-0.02

Cross Section	River Station (m)	Summary of Sensitivity Analysis Results											
		Baseline WSE (m)	Downstream Boundary Condition				Channel Roughness				Overbank Roughness			
			Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)		Computed Water Surface Elevation (m)		Difference from Baseline (m)	
			increase WL 0.5 m	decrease WL 0.5 m	increase WL 0.5 m	decrease WL 0.5 m	increase by 15%	decrease by 15%	increase by 15%	decrease by 15%	increase by 20%	decrease by 20%	increase by 20%	decrease by 20%
XS-021	11158.9	598.77	598.84	598.71	0.07	-0.06	599.46	598.02	0.69	-0.75	598.78	598.76	0.01	-0.01
XS-020	10534.33	598.55	598.63	598.48	0.08	-0.07	599.23	597.80	0.68	-0.75	598.55	598.54	0.00	-0.01
XS-019	9862.57	598.24	598.33	598.16	0.09	-0.08	598.92	597.51	0.68	-0.73	598.25	598.22	0.01	-0.02
XS-018	9191.96	598.08	598.18	597.99	0.10	-0.09	598.74	597.37	0.66	-0.71	598.09	598.06	0.01	-0.02
XS-017	8543.36	597.85	597.96	597.76	0.11	-0.09	598.51	597.15	0.66	-0.70	597.87	597.83	0.02	-0.02
XS-016	7903.68	597.53	597.66	597.42	0.13	-0.11	598.21	596.78	0.68	-0.75	597.54	597.52	0.01	-0.01
XS-015	7270.37	597.36	597.50	597.24	0.14	-0.12	598.03	596.64	0.67	-0.72	597.37	597.34	0.01	-0.02
XS-014	6647.24	597.09	597.25	596.95	0.16	-0.14	597.77	596.35	0.68	-0.74	597.10	597.07	0.01	-0.02
XS-013	6074.52	596.80	596.98	596.64	0.18	-0.16	597.49	596.05	0.69	-0.75	596.81	596.78	0.01	-0.02
XS-012	5397.17	596.51	596.72	596.32	0.21	-0.19	597.21	595.75	0.70	-0.76	596.52	596.49	0.01	-0.02
XS-011	4745.18	596.30	596.54	596.09	0.24	-0.21	597.00	595.54	0.70	-0.76	596.31	596.29	0.01	-0.01
XS-010	4150.78	596.09	596.35	595.86	0.26	-0.23	596.78	595.35	0.69	-0.74	596.10	596.08	0.01	-0.01
XS-009	3661.96	595.94	596.21	595.68	0.27	-0.26	596.63	595.18	0.69	-0.76	595.94	595.93	0.00	-0.01
XS-008	2937.02	595.75	596.05	595.46	0.30	-0.29	596.44	595.00	0.69	-0.75	595.75	595.74	0.00	-0.01
XS-007	2289.74	595.39	595.74	595.06	0.35	-0.33	596.10	594.63	0.71	-0.76	595.40	595.39	0.01	0.00
XS-006	1648.82	595.20	595.57	594.83	0.37	-0.37	595.90	594.44	0.70	-0.76	595.21	595.19	0.01	-0.01
XS-005	1053.63	595.02	595.42	594.61	0.40	-0.41	595.71	594.27	0.69	-0.75	595.03	595.01	0.01	-0.01
XS-004	467.71	594.83	595.27	594.38	0.44	-0.45	595.52	594.09	0.69	-0.74	594.84	594.82	0.01	-0.01
XS-003	234.05	594.80	595.24	594.33	0.44	-0.47	595.48	594.06	0.68	-0.74	594.80	594.78	0.00	-0.02
XS-002	220.92	594.78	595.23	594.31	0.45	-0.47	595.47	594.04	0.69	-0.74	594.79	594.77	0.01	-0.01
XS-001	0	594.73	595.18	594.24	0.45	-0.49	595.41	593.99	0.68	-0.74	594.74	594.72	0.01	-0.01
Maximum Difference from Baseline					**0.45**	**-0.49**			**0.73**	**-0.79**			**0.04**	**-0.05**
Average Difference from Baseline					**0.02**	**-0.02**			**0.62**	**-0.67**			**0.01**	**-0.02**

APPENDIX F
OPEN WATER FLOOD INUNDATION MAP LIBRARY

(PROVIDED UNDER SEPARATE COVER)

nhc
northwest hydraulic consultants
water resource specialists