Photo source: Nanaimo River at Morden Colliery Trail, NHC 2022

Morden Colliery Regional Trail – Nanaimo River Pedestrian Bridge
Hydrotechnical Assessment Update

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1 INTRODUCTION

1.1 Project Background

Northwest Hydraulic Consultants Ltd. (NHC) was engaged by Herold Engineering (Herold) on behalf of the Regional District of Nanaimo (RDN) to update the hydrotechnical assessment of the Morden Colliery Regional Trail's (MCRT) proposed pedestrian bridge over the Nanaimo River. The initial hydrotechnical assessment was completed 2014 (NHC, 2014); the RDN is re-visiting the feasibility of the crossing, and so requires an update to that study to evaluate changed conditions.

NHC's scope of work includes the following:

- Update the flood frequency analysis with additional data collected since 2014;
- Develop a climate change allowance and a recommended design discharge for the crossing;
- Run the revised design flows through the existing HEC-RAS model;
- Conduct a field and high-level desktop (satellite imagery) review to assess geomorphic changes to the Nanaimo River in the vicinity of the crossing since the 2014 study;
- Revise the preliminary design parameters presented in the 2014 report based on the updated hydraulics, including design water levels, minimum bridge soffit elevation, and scour depth.

1.2 Limitations

Due to budget constraints, an updated hydraulic model has not been developed. The hydraulic model used for the 2014 study, and in this study is based on the topographic surveys conducted by the BC Ministry of Environment to develop the 1984 floodplain maps of the Nanaimo River (MoE, 1984). The cross-sectional geometry used in the model is therefore 40 years old and does not account for topographic changes due to more recent erosion and deposition. Due to the dynamic nature of rivers, the use of the old model should be considered an approximation of design hydraulics only, only suitable for general feasibility assessment.

As part of this current project, the RDN commissioned a survey of Nanaimo River, focusing on a selection of cross sections taken at the same locations as used in the model from the 1980s. The purpose of the survey is to provide a qualitative comparison of the changes to the cross section geometry in order to better inform potential error in the hydraulic model. The survey was completed on September 20 and 21, 2022 by Bennet Land Surveying Ltd. We conducted a high-level comparison of the surveyed sections and the sections used in the hydraulic model, where available. A comparison of the cross sections is given in Appendix A.

We strongly recommend that an updated hydraulic model be developed using comprehensive and up-to-date channel bathymetry. To support this process, an additional survey beyond the five sections collected in 2022 would be required to capture the level of detail needed near the bridge and at key channel features.

2 PROPOSED CROSSING

The proposed MCRT pedestrian bridge crossing location is shown in Figure 2.1. The trail will be constructed at grade, and will not confine the river during overbank flooding, although the approach trail is likely to be submerged during a large flood. The river crossing is located near the downstream end of an island with mature trees over the Nanaimo River.

Due to the presence of the island, two bridge crossings are required: Bridge 1 from the west bank of the river to the island, and Bridge 2 from the island to the east bank of the river. Two options are being considered for the crossing: Option 1 uses clear span truss bridges, and Option 2 uses suspension bridges, with their supporting towers set back from the river on the floodplain.

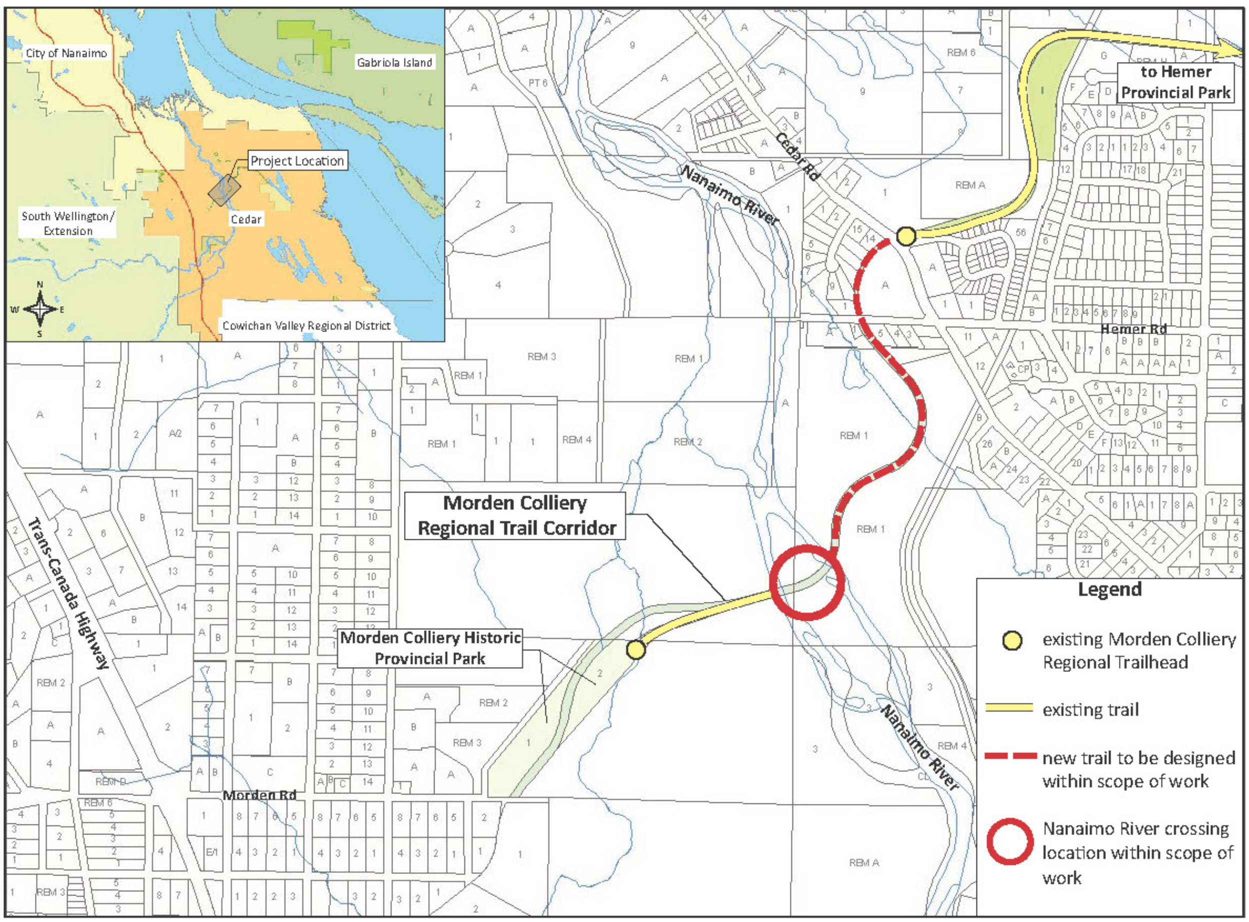

Figure 2.1 Proposed MCRT pedestrian bridge crossing location

3 RIVER CHARACTERISTICS

3.1 Flood Hydrology

3.1.1 Flood Frequency Analysis

The flood frequency analysis conducted during the 2014 study was updated to include additional years of data between 2014 and 2021. The Water Survey of Canada (WSC) has historic data available at three locations upstream of the bridge, summarized in Table 3.1.

Table 3.1 Hydrometric records available near the crossing

Station ID	Station Name	Drainage Area (km^2)	Period of Record	Number of Years of Instantaneous Maximum Discharges
08HB005	Nanaimo River near Extension	645	1913-1963	7
08HB034	Nanaimo River near Cassidy	676	1965-2021	57
08HB003	Haslam Creek near Cassidy	96	1950-1998	5

Notes:

1. Values for 2020 and 2021 from 08HB034 are provisional WSC values, subject to review and adjustment during WSC's QA/QC process. 2022 does not represent a full year of data and was not included.

A similar methodology to that used in the 2014 study was adopted for updating the frequency analysis:

- The combined data record from Nanaimo River near Extension (08HB005) and Nanaimo River near Cassidy (08HB034) was used. Where peak instantaneous values were not available, they were synthetically derived by applying a peaking factor to the recorded maximum daily discharge.
- A 10% increase was applied to the flood quantiles developed from the flood frequency analysis at the Nanaimo River gauges to account for the additional tributary area between the stations and the bridge location. This was based on the review of the data from Haslam Creek near Cassidy (08HB003) in relation to the Nanaimo River stations.

The results of the updated flood frequency analysis are given in

Table 3.2, along with a comparison to the values estimated during the 2014 study. The changes can be attributed primarily to additional years of record in the dataset.

Table 3.2 Updated flood frequency estimates

Return Period (years)	Annual Exceedance Probability (%)	2014 Discharge at Crossing (m^3/s)	Discharge at Gauge (m^3/s)	Discharge at Crossing (m^3/s)	Increase from 2014 Study
2-year	50%	620	560	**620**	0 m^3/s (0.0%)
5-year	20%	860	800	**880**	20 m^3/s (2.3%)
20-year	5%	1170	1080	**1190**	20 m^3/s (1.7%)

Return Period (years)	Annual Exceedance Probability (%)	2014 Discharge at Crossing (m^3/s)	Discharge at Gauge (m^3/s)	Discharge at Crossing (m^3/s)	Increase from 2014 Study
100-year	1%	1460	1350	**1490**	30 m^3/s (2.1%)
200-year	0.5%	1580	1460	**1610**	30 m^3/s (1.9%)

Notes:
1. Values provided in this table **do not** include an allowance for climate change. Refer to Section 3.1.2.

The 2014 study noted that there has not been an extreme flood on the Nanaimo River for over 50 years, with the highest floods in 1980 and 1990 having around 20-year return periods, and the 2007 flood having around a 10-year return period.

Around November 15, 2021, southwestern BC and northwestern Washington were hit with consistent, heavy rainfall over two days, which caused widespread flooding. The preliminary peak discharge measured during this event at the Nanaimo River near Cassidy station was 867 m^3/s, which is between a 5- and 10-year return period event.

3.1.2 Climate Change Allowance

It is important that the design of the bridge consider potential impacts on peak flows due to climate change, as recommended in EGBC and MoTI guidelines (EGBC, 2018, 2020; MoTI, 2016). Based on current projections for Vancouver Island, climate change may result in increased flows at the crossing. A detailed site-specific assessment of potential climate change impacts is beyond the scope of the present study; instead, we reviewed the climate allowances used by NHC on nearby watersheds for recent projects (French Creek, Cowichan River, and the Chemainus River). For each of those projects, a 20% increase in flows was recommended to account for climate change impacts (NHC, 2021b, 2021c, 2021a).

Based on that review, we recommend a 20% increase be applied to the MCRT flows provided in

Table 3.2 to account for the potential impacts of climate change.

3.2 River Levels

Peak river levels and flow on the Nanaimo River tend to occur between October and March, with the lowest water levels occurring in July and August (Figure 3.1). Limited water level data is available from the WSC gauge, and is only provided in a local vertical datum with no conversion to geodetic available. During the recent November 15, 2021 event, peak water levels of 6.3 m (local datum) were recorded (Figure 3.2). Recorded water levels at the time of NHC's site inspection on March 30, 2022 (see Section 3.3) were 1.56 m (local datum). Water levels during the November 2021 event were therefore likely 4.5 to 5.0 m higher than those observed during the inspection.

The 1984 floodplain maps from the BC MoE provide 1 m contours of the flood construction level (FCL) on the Nanaimo River. The FCL represents the 200-year return period estimate at the time, plus a freeboard allowance of 0.3 m. The estimated 200-year and 20-year flood levels (without freeboard) from those maps are approximately 10.7 m and 9.9 m, respectively, just upstream of the site. As noted in the 2014 report, the model was developed in the early 1980s, and so the reliability of the water levels under present conditions is questionable. Updates to the hydraulic model geometry and re-calibration of the hydraulic model would be required to produce updated results.

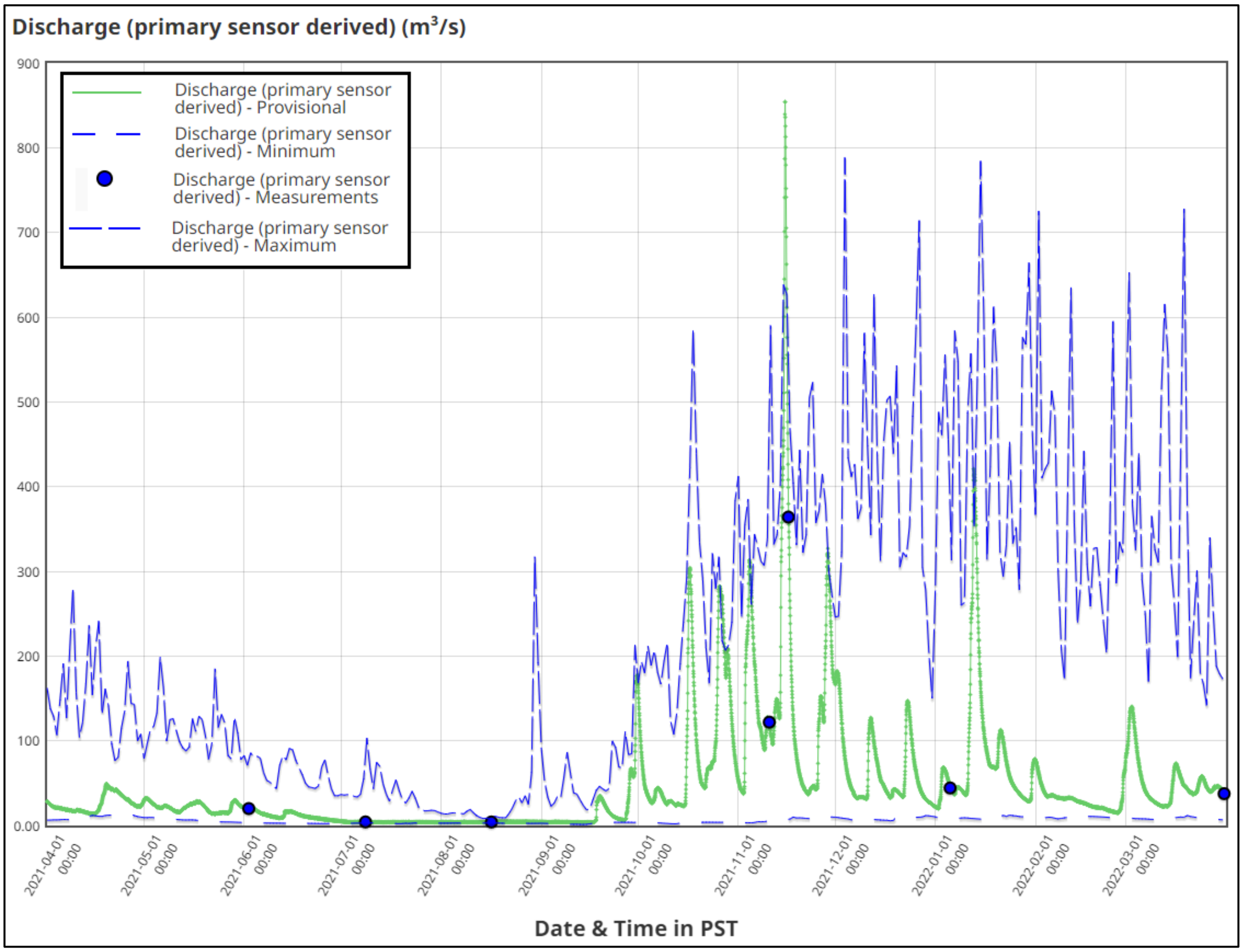

Figure 3.1 Provisional discharge hydrograph for April 1, 2021 to March 31, 2022, including historic maximum and minimum daily values for the Nanaimo River near Cassidy (WSC 08HB034).

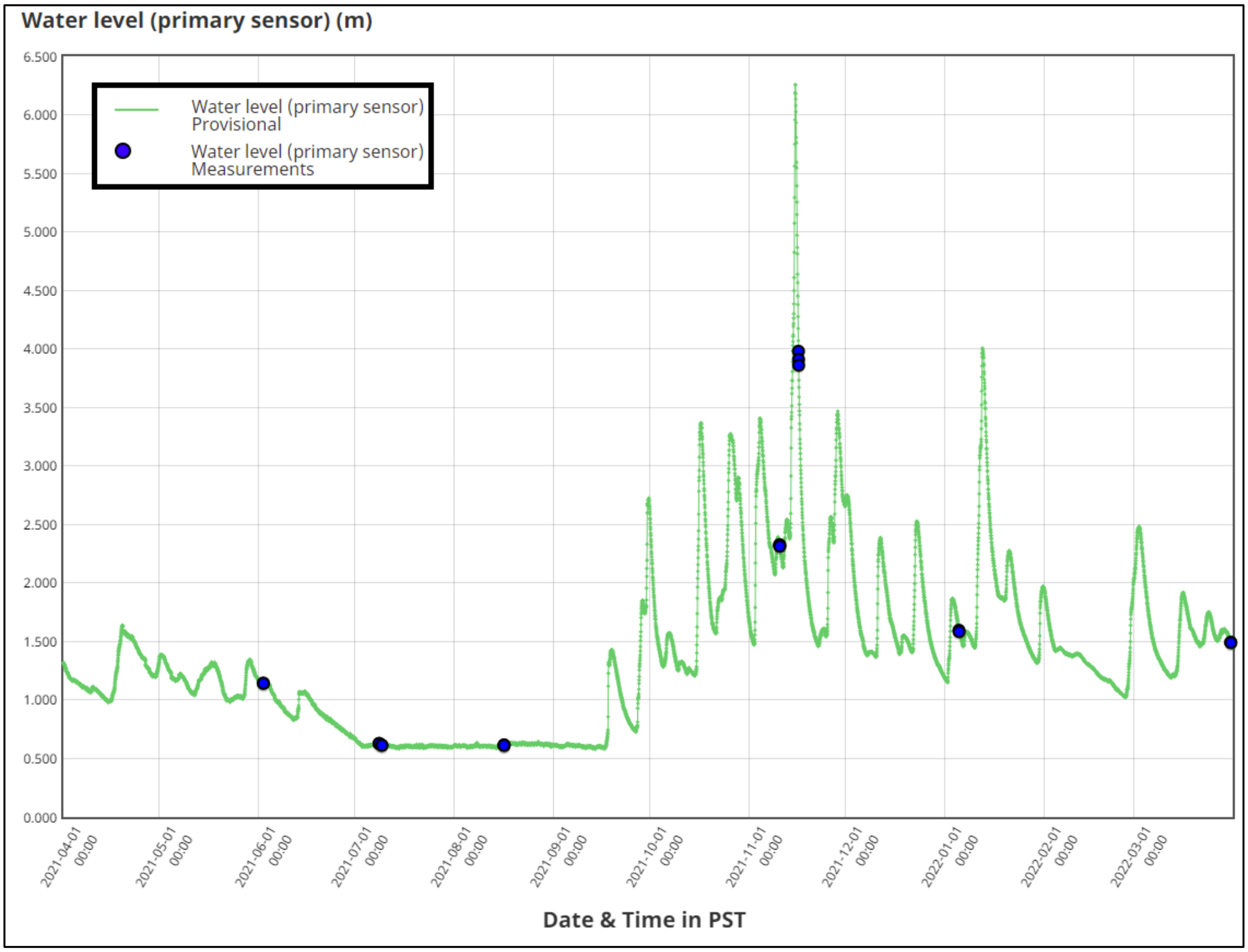

Figure 3.2 Provisional water level hydrograph for April 1, 2021 to March 31, 2022 for the Nanaimo River near Cassidy (WSC 08HB034); water levels are in a local WSC local vertical datum.

3.3 River Morphology

Jason Kindrachuk, P.Eng., and Dave Mclean, P.Eng. from NHC conducted a field review of the crossing on March 30, 2022. Due to high water levels, the center island (island 2 in Figure 3.3) could not be accessed.

The proposed bridge crossing is located approximately 4.7 km upstream of the Nanaimo River estuary tidal flats, and is beyond the limit of direct tidal influence during large floods. The Nanaimo River generally flows in a single, meandering, gravel-bed channel, with occasional divides and splits around vegetated islands. The overall pattern has an irregular 'wandering' appearance. The topography of the Nanaimo River floodplain near the proposed bridge crossings can be seen in Figure 3.3, and illustrates the relatively wide floodplain with historic channel scars. Extensive inundation of the floodplain during large floods can be expected (Figure 3.4).

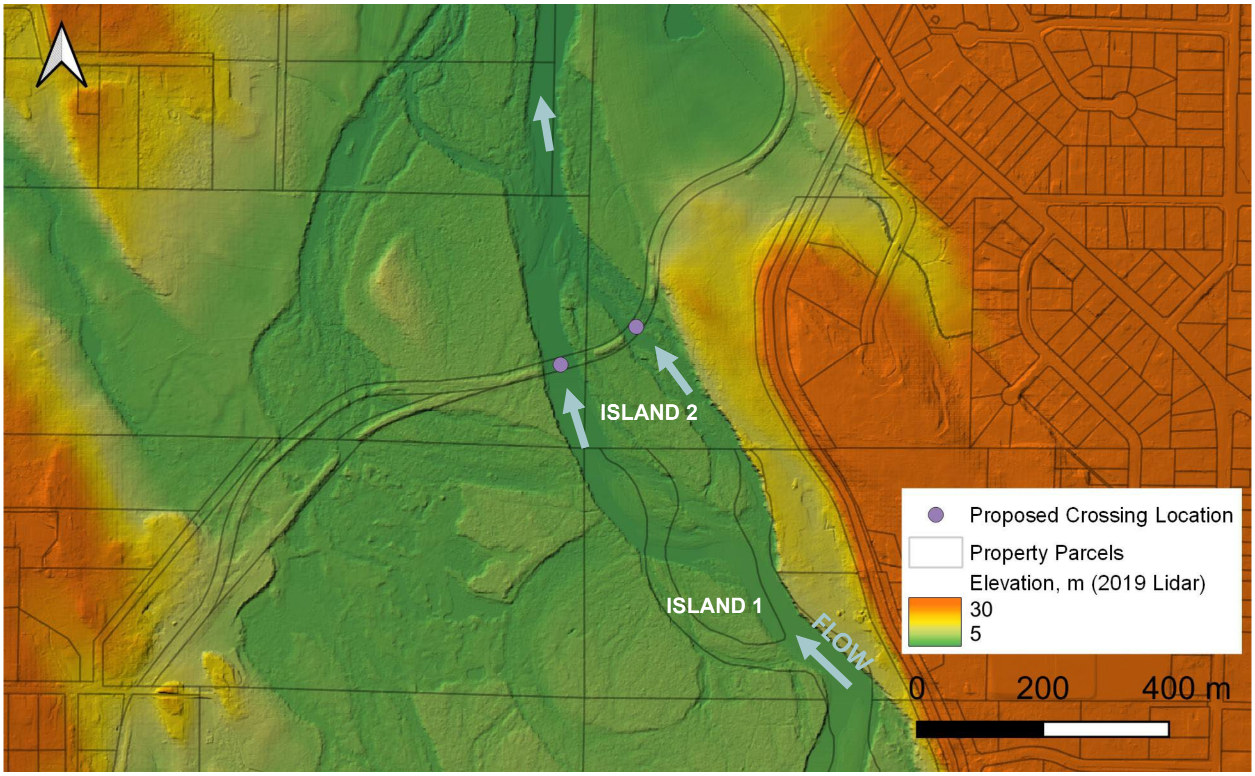

Figure 3.3 Nanaimo River floodplain topography near the proposed bridge sites (2019 lidar).

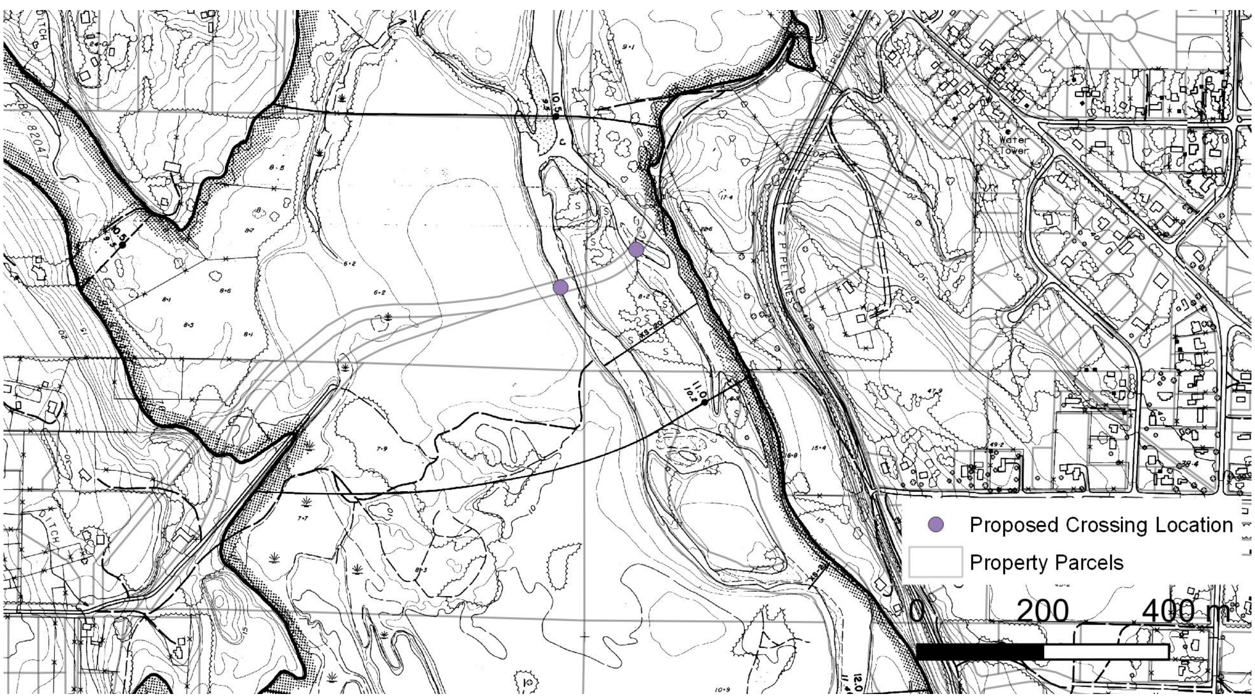

Figure 3.4 MoE floodplain maps with proposed bridge sites overlain. Bold outline is the limit of inundation as shown on those maps (MoE, 1984).

The bed material consists of gravel and sand, with exposed bar sediments having a median grain size of about 50 mm. The river occasionally deflects off bedrock valley walls and flows over bedrock both upstream and downstream of the crossing. Representative bankfull channel characteristics near the crossing are as follows (NHC, 2014):

- Top width: 75 m
- Mean depth: 3.5 m
- Slope: 0.0015 m/m

Near the crossing, the river splits into two channels. The top width of the west channel is approximately 65 m. The top width of the east channel is approximately 50 m, but loses definition, widens, and splits into multiple smaller channels near the location of the bridge crossing.

Figure 3.5 shows the channel alignment in 1968, 1982, 2010, and 2020. For reference, bank lines from 1968 and 2020 are overlain on each image. The 2019 lidar data was used to assist in delineating the 2020 bank lines. There are two prominent islands near the site, island 1, and island 2. The proposed bridges cross the west channel onto island 2, and then from island 2 over the east channel. While the single channel upstream and downstream of the islands, and the main section of the islands themselves have remained relatively stable over the last 52 years, the left[1] bank of the west channel has eroded. This appears to be attributable to the formation of a gravel bar near the head of the island, visible in the 1968 photo (labelled as “A” in the 1968 photo). By 1982, vegetation had begun to establish on the bar, increasing its stability and reducing the proportion of flow directed through the east channel. This resulted in preferential flow through the west channel, which widened the channel by eroding the left bank.

The 2014 NHC report identified a large gravel bar near the head of island 2 (labelled “B” on the 2020 image in Figure 3.5), partially blocking the entrance to the eastern side channel, and deflecting flow in the west channel towards the left bank. The report noted that continued accretion of the bar could induce bank erosion on both sides of the west channel, and promote bank erosion near both ends of the proposed bridge over the west channel.

With continued accumulation of gravel and large woody debris, flow could be forced back through the east channel (NHC, 2014). The 2020 photo shows that vegetation is becoming established on this bar. Over the life of the bridge, an increased proportion of flow may return to the east channel, which would promote bank erosion at the proposed bridge over the east channel beyond what has been experienced in the previous decades. There is a potential for future channel instability and erosion along both banks of the crossing.

[1] Left and right bank refers to the perspective of looking downstream.

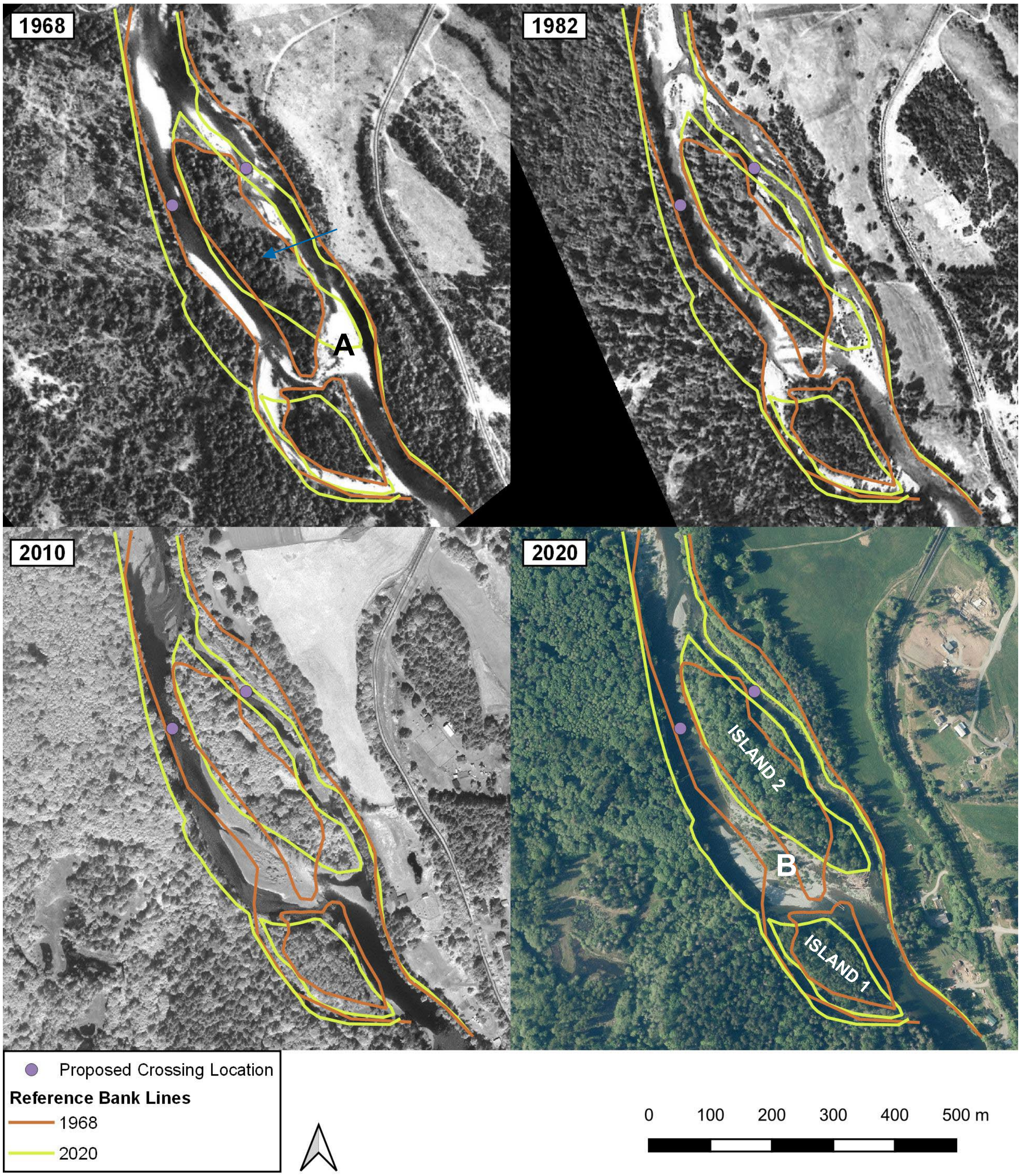

Figure 3.5 Channel changes near crossing, 1968 to 2020.

3.4 River Hydraulics and Scour

The discharges from the updated flood frequency analysis (Section 3.1) were assembled and run through the existing hydraulic model. The hydraulic model was re-compiled into HEC-RAS (v.4.1) software during the 2014 study. The vertical datum is CGVD28.

The revised 200-year discharge is relatively similar to that used in the 2014 study, and the model shows similar results. The additional consideration of climate change increases the flows through the model, and consequently changes velocities and depths. A summary of the model results for the 200-year return period, and the 200-year return period with a climate change allowance, relative to the 2014 study are given in Table 3.3.

Table 3.3 Hydraulic model results using revised discharge estimates

	2014 Study Results	200-year Return Period Results	200-year Return Period with Climate Change Allowance Results
Percentage of flow in the floodplain[1]	15 to 25%	15 to 40%	15 to 40%
Water surface elevation	El. 10.5 m	El. 10.6 m	El. 11.2 m
Mean channel velocity[2]	3.8 m/s	3.9 m/s	3.9 m/s
Bed elevation near the crossing[3]	El. 3.7 m	El. 3.7 m	El. 3.7 m
Flow depth near the crossing	6.6 m	6.6 m	7.3 m

Notes:

2. The percentage of flow in the floodplain varies along the surveyed reach of the Nanaimo River and in some areas may be more or less than the stated approximate range.
3. Highest mean channel velocity in the vicinity of the proposed crossing. Local maximum depth-averaged velocities can be expected to be higher.
4. Bed elevations at the crossing are based on the model geometry near the downstream end of the mid-channel island.

Preliminary estimates of scour potential were made based on the results from the revised 200-year return period, and the 200-year return period with a climate change allowance. The estimates are based on Blench's equation:

$$Y_S = 1.5Z\left(\frac{q^2}{F_b}\right)^{1/3}$$

Where:

Y_s = maximum scour depth at the crossing
Z = empirical scour factor (ratio of maximum to mean depth)
q = discharge intensity per unit width (Q/W)
F_b= bed factor, dependent on bed sediment size and sediment transport rate

The preliminary scour estimates are summarized in Table 3.4, with a comparison to the values from the 2014 study.

Table 3.4 Preliminary scour estimates using revised discharge estimates

	2014 Study Results	200-year Return Period Results	200-year Return Period with Climate Change Allowance Results
Water surface elevation	El. 10.5 m	El. 10.6 m	El. 11.2 m
q	12.5 m^2/s	14.4 m^2/s	16.1 m^2/s
Z	1.7	1.7	1.7
F_b	3.7	4.9	4.9
Y_s	8.8 m	8.8 m	9.5 m
Minimum scoured bed elevation	El. 1.7 m	El. 1.8 m	El. 1.7 m

The revised discharges result in a similar level of scour as suggested in the 2014 study. The additional consideration of climate change results in a lower minimum scoured bed elevation.

4 PRELIMINARY DESIGN PARAMETERS

The BC Ministry of Transportation and Infrastructure (MoTI) recommends using the 200-year return period plus an allowance for climate change in the design of bridges. For 'low volume roads', a 100-year return period can occasionally be adopted. Given the difficulty to access the pedestrian bridge for repairs in the event of a complete or partial failure, we recommend the MCRT pedestrian bridge adopt a 200-year return period plus an allowance for climate change.

This updated study supports the findings from the 2014 assessment that over the life of the bridge, the main channel may switch from one side of the river to the other, and temporarily abandon one of the side channels. Channel shifting and avulsions are likely to be partly controlled by log jam formation. Rather, set back bridge foundations with localized riprap revetments around the base of the bridge towers to withstand submergence during a large flood would be required. An option would be to monitor

This updated study supports the findings from the 2014 assessment that over the life of the bridge (estimated at 30 to 50 years), the main channel may switch from one side of the river to the other and temporarily abandon one of the side channels. Channel shifting and avulsions will be at least in part controlled by log jam formation. Short, localized bank protection is not likely to be effective protection for the bridge, since it can easily be outflanked, and extending the protection far enough upstream that it would be reliably effective is not likely cost effective. Instead, protection should consist of setback bridge foundations with riprap revetments around the base of the bridge towers, capable of withstanding inundation during a large flood.

The design of the tower foundations should consider a future case where the river has eroded its banks and develops deep scour along the base of the structure. In this case, the towers should remain secure against undermining, although the river could still outflank the bridge openings (NHC, 2014).

For the purposes of planning and feasibility, the following hydraulic design parameters are recommended (geodetic elevations are given in CGVD28 vertical datum):

- Design return period = 200-year return period plus climate change allowance
- Design discharge = 1930 m^3/s
- Design water level at crossing = El. 11.2 m
- Minimum freeboard allowance = 1.5 m
- Minimum soffit elevation (underside of bridge) = El. 12.7 m
- Minimum scoured bed elevation at bridge abutments = El. 1.7 m

5 CONCLUSIONS

This report provides an update to the 2014 feasibility-level hydrotechnical assessment for the proposed MCRT pedestrian bridge over the Nanaimo River. Additional hydrotechnical assessment and design services are strongly recommended to confirm the assumptions and support future design stages. These include:

- Update the hydraulic model to include recent channel bathymetry and support improved confidence in the hydraulic calculations. This will require a more comprehensive river survey that includes additional survey around the bridge location and captures key river features.
- Conduct a more thorough geomorphology investigation to understand potential existing and future risks to the bridge site, and predict potential changes to the channel.
- Complete detailed waterway design, including flood level, scour, erosion and debris assessments. Determine erosion protection and / or river training works requirements to achieve a manageable level of risk at the crossing.

Site conditions since the 2014 report have not drastically changed, but the current study supports the findings from the previous assessment that over the life of the bridge, flow may be concentrated in either the west or east channel around the island. Flow through the west channel can contribute to erosion on either the left or right banks. Increased proportion of flow through the east channel could contribute to widening of the channel compared to current conditions. These changes should be considered in the design of the bridge, with the bridge foundations set back from the channel on both the west and east banks.

The recommended minimum soffit elevation has increased from El. 12.2 m in the 2014 study to El. 12.7 m, mainly due to the inclusion of a climate change allowance in the design discharge. With recent and emerging information on potential climate change impacts on flows, it is important to take these changes into account in the bridge hydraulic design.

Additional hydrotechnical design services are recommended for the project. These include a comprehensive, updated river survey; updating the hydraulic model to reflect current bathymetry; a more thorough geomorphology investigation; and detailed waterway design including flood level, scour, and erosion mitigation assessment.

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APPENDIX A

CROSS SECTION COMPARISON:
1984 FLOOD STUDY AND 2022 SURVEY

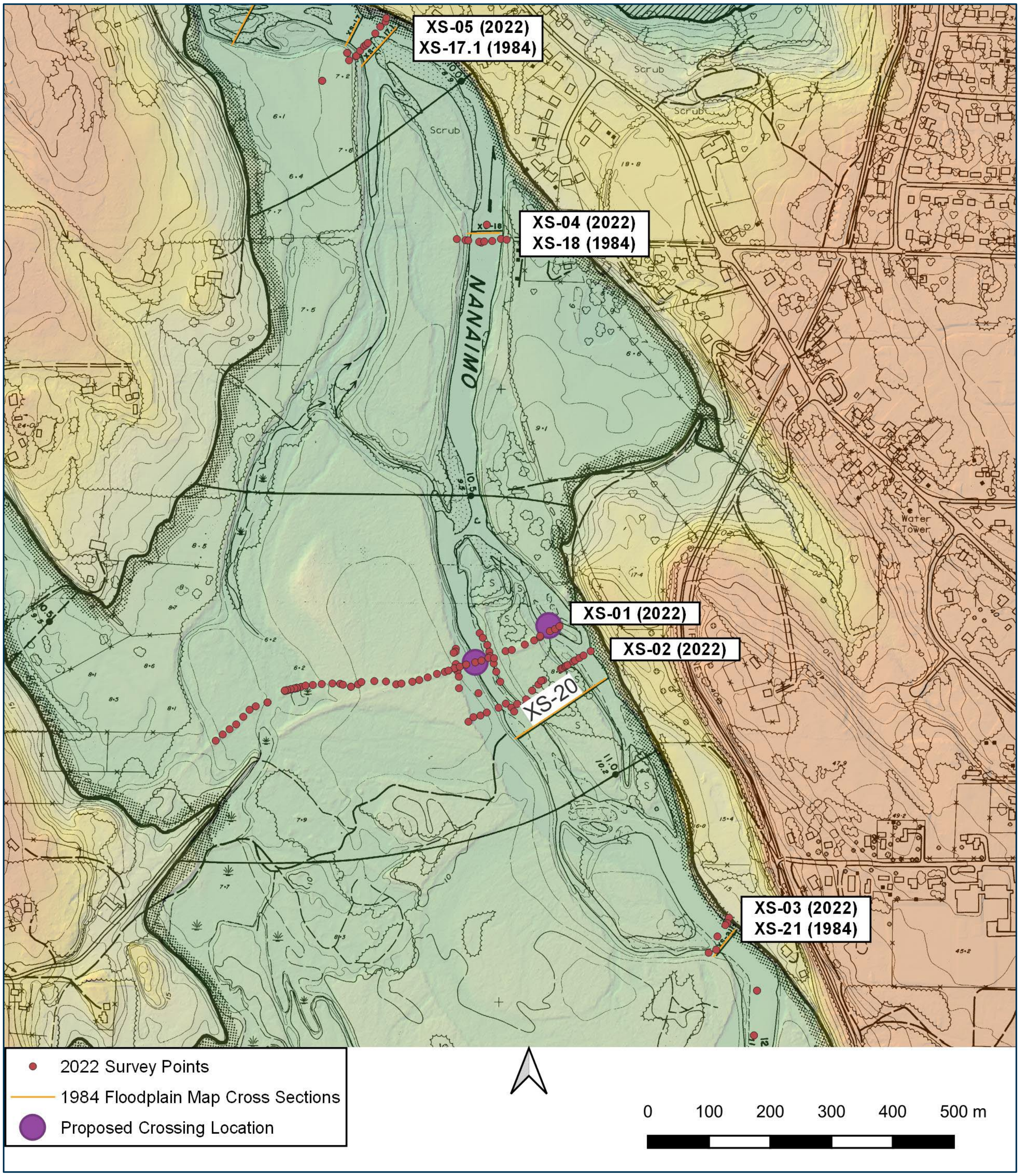

Figure A.1 Location of 2022 survey points in relation to 1984 model sections.

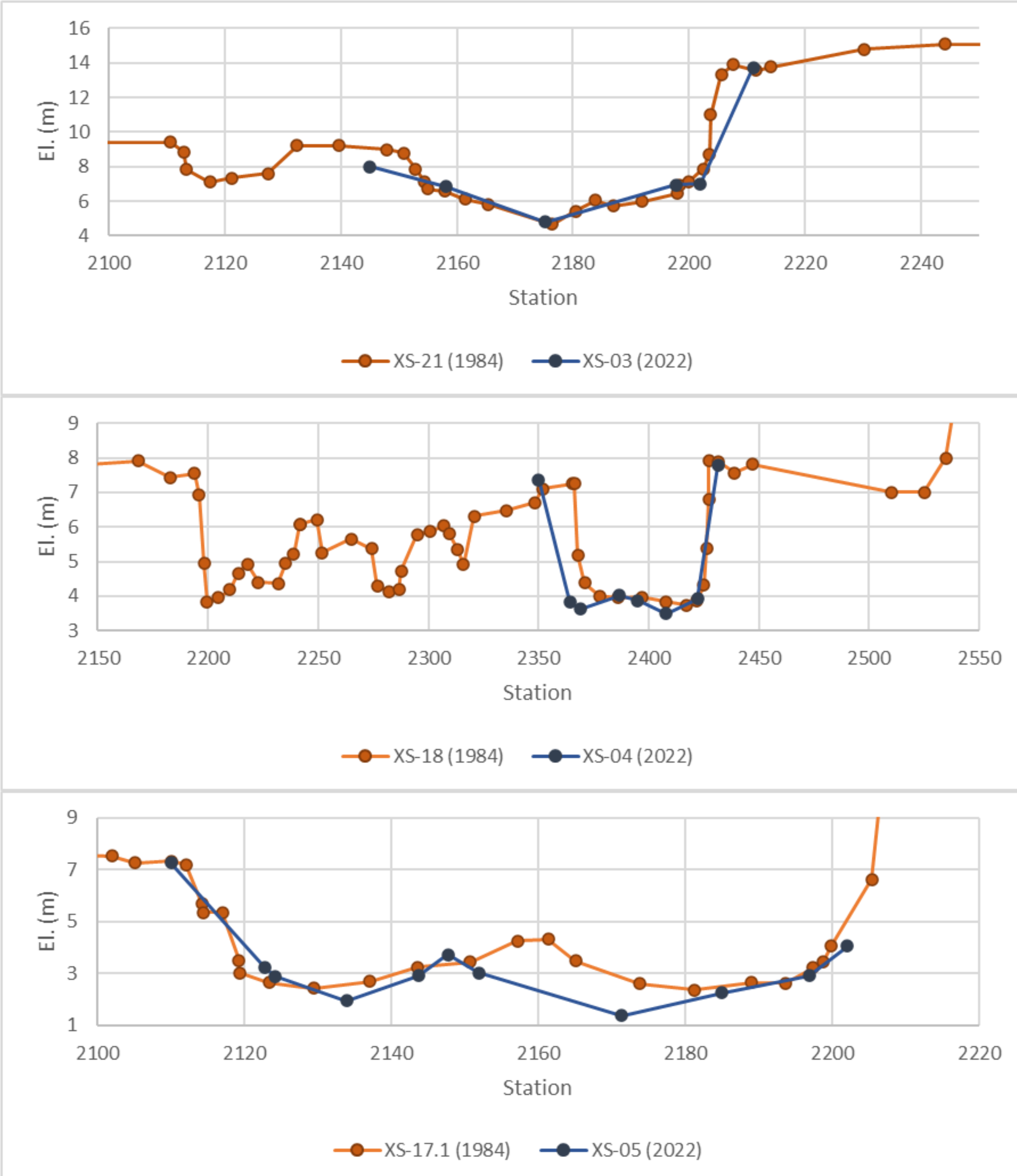

Figure A.2 Cross section comparisons between hydraulic model and 2022 survey. Model cross sections are not geodetic and are manually overlaid for general comparison. Cross sections are left to right looking downstream.

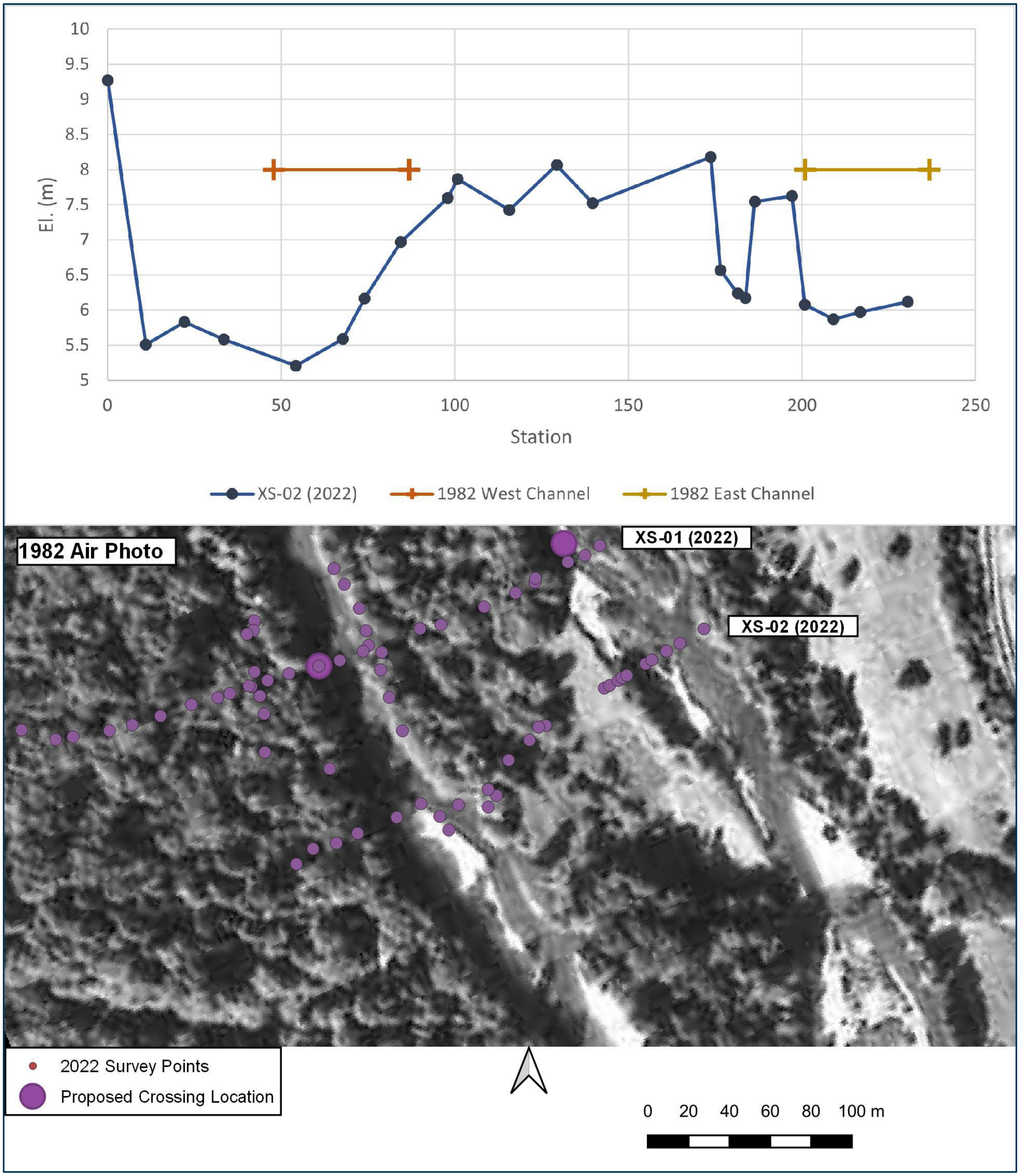

Figure A.3 Location of the west and east side channel in 1982. Top image shows location of left and right banks in 1982, relative to the 2022 cross section. Bottom image shows 2022 survey points overlaid on the 1982 air photo.