KICKING HORSE RIVER
BRIDGES 1 AND 2 REPLACEMENT

HYDROTECHNICAL REPORT
DETAILED DESIGN
TOWN OF GOLDEN, BRITISH COLUMBIA

Version 1.0
December 2022
Project 5635-522

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

KICKING HORSE RIVER BRIDGES 1 AND 2 REPLACEMENT
HYDROTECHNICAL REPORT
DETAILED DESIGN
TOWN OF GOLDEN, BRITISH COLUMBIA

Prepared for:
URBAN SYSTEMS LTD. AND BRITISH COLUMBIA MINISTRY OF TRANSPORTATION AND INFRASTRUCTURE

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DETAILED DESIGN

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Prepared for Urban Systems Ltd. and British Columbia Ministry of Transportation and Infrastructure, December 2022

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DISCLAIMER

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	18-Mar-2021	Draft	5635-522 R 2021-03-18 draft V0.1.docx	50% Functional Design; Issued to clients for review
V0.2	29-Apr-2022	Draft	5635-522 R 2022-04-29 draft V0.2.docx	Update to the 50% Functional Design Issued to clients for review • Updated with comments on V0.1 from B.C. MoTI 2021-05-04 comment resolution sheet. Responses issued to Urban Systems and B.C. MoTI on 2021-05-17. • Updated hydraulic model with 2021 survey data and revised bridge design and pier location. • Updated flood frequency analysis with 2021 maximum annual flow data (no change to design flow). • Winter of 2021/2022 ice jam data incorporated. • Updated river ice crushing force for revised pier location. • Updated the pier scour computations for the revised pier alignment (i.e., from a 15 to 27 degree skew to the flow direction).
V0.3	17-Jun-2022	Draft	5635-522 R 2022-06-16 draft V0.3.docx	100% Functional Design Issued to clients for review • Updated with comments on V0.2 from Mike Sullivan, Hydrotechnical Engineer, of B.C. MoTI received via email on 2022-06-06. Responses provided by Matrix via email on 2022-06-09 and 2022-06-14. • Completed the MoTI Design Criteria Sheet for Climate Change Resilience and included in Appendix C.
V0.4	22-Sep-2022	Draft	5635-522 R 2022-09-22 draft V0.4.docx	50% Detailed Design Issued to clients for review • Updated with comments on V0.3 from Mike Sullivan, Hydrotechnical Engineer, of B.C. MoTI received via email on 2022-07-12. Responses provided by Matrix via email on 2022-09-14. • Refined and updated Bridge 1 south abutment removal and restoration recommendations to optimize project costs as requested during various meetings with MoTI. • MoTI updated Gould's Island Bridge to a low volume road bridge; thus updated Gould's Island Bridge low chord elevation recommendations.
V1.0	9-Dec-2022	Final	5635-522 R 2022-12-09 final V1.0.docx	90% Detailed Design Issued as Final • Updated to address comments on V0.4 from MoTI in the 50% Detailed Design comment resolution sheet, dated September 30, 2022. Responses discussed during a November 16, 2022, call with Matrix and Mike Sullivan, Hydrotechnical Engineer, of B.C. MoTI. Responses provided by Matrix via the comment resolution sheet. • Updated the pier scour computations for the revised pier pile design (i.e., from one row of four 1.5 m diameter circular piles to two rows of eight piles with 0.764 m diameter. No changes were made to the skew of the pier to the flow direction.

EXECUTIVE SUMMARY

Matrix Solutions Inc. prepared this hydrotechnical design report for the replacement of the Highway 95 Bridges 1 and 2 which cross the Kicking Horse River in the town of Golden, British Columbia. Bridge 1 crosses the Kicking Horse River main channel from the north bank to Gould's Island and Bridge 2 crosses the Gould's Island side channel from the island to the south bank. The bridges are owned by the British Columbia Ministry of Transportation and Infrastructure (B.C. MoTI).

Two replacement bridges are proposed:

1. The Highway 95 Bridge: a two-span bridge with a pier located on Gould's Island and a multi-use pathway that will pass under the south bridge approach. The proposed bridge alignment is immediately upstream of the existing bridges and downstream of Canadian Pacific land; thus, the alignment is fixed.

2. The Gould's Island Bridge: a clear-span bridge over the side channel to maintain access to a restaurant and homes on Gould's Island. The bridge will replace the existing Bridge 2 at the same alignment and will be a low-volume structure per the B.C. MoTI supplement to the *Canadian Highway Bridge Design Code*.

The existing bridges were constructed in 1951 (71 years ago). The proposed bridges will have longer spans and will be higher than the existing bridges.

This report provides details of the hydrologic, hydraulic, and geomorphic assessments and the recommended hydrotechnical design parameters for the proposed bridges. This report is based on the following key items:

- 58 years of flow data recorded by the Water Survey of Canada on the Kicking Horse River in the town of Golden
- 34 years of comparative cross-section surveys from 1987 to 2021 along the Kicking Horse River through the town, including at the bridges
- documentation and photographs of the four highest river ice events at the existing bridges
- local river engineering experience along the Kicking Horse River by Matrix since 1999

A summary of the recommended hydrotechnical design criteria is provided in Table i.

TABLE i Summary of Hydrotechnical Design Criteria and Recommended Values

Parameter	Highway 95 Bridge	Gould's Island Bridge
Design Flood and Freeboard		
Flood return period	1:200-year	1:100-year
Instantaneous peak flow[1]	580 m^3/s	545 m^3/s
Instantaneous peak water level	788.9 m	788.7 m
Freeboard	1.5 m	0.8 m
Minimum bridge low chord	790.4 m	789.5 m
Backwater	The bridges will have negligible backwater at the 1:200-year design flow so that flood levels are not increased on the Town of Golden's dikes	
Design River Ice		
Top of ice level	789.6 m	789.5 m
Ice thickness at abutments (ice jam lateral thrust)	2.0 m	2.0 m
Lateral thrust	10 kPa	10 kPa
Ice thickness at pier (ice impact)	0.7 m	n/a
Crushing strength (ice impact)	1,500 kPa	1,500 kPa
Hydraulic Opening		
Type	Two-span (one pier located on Gould's Island)	Clear span
Recommendations	No encroachment of the abutments into the 1:200-year flow area	No reduction of flow area compared to existing Bridge 2
Design Scour		
Main channel scour depth	0.8 m	n/a
Side channel scour depth	0.4 m	0.4 m
Pier scour depth (elevation)	5.3 m depth (783.1 m elevation)	n/a
Erosion and Scour Protection		
Riprap class[2]	250 kg Class (D_{50} = 575 mm)	

Notes:
1 The instantaneous peak design flood flow includes a 25% increase for climate change.
2 The riprap class and median diameter (D_{50}) is per British Columbia Ministry of Transportation and Infrastructure (2020) specification.

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1 INTRODUCTION

Matrix Solutions Inc. prepared this hydrotechnical design report for the replacement of the Highway 95 Bridges 1 and 2 which cross the Kicking Horse River in the town of Golden, British Columbia (see Figures 1 and 2). Bridge 1 crosses the Kicking Horse River main channel from the north bank to Gould's Island and Bridge 2 crosses the Gould's Island side channel from the island to the south bank. The bridges are owned by the British Columbia Ministry of Transportation and Infrastructure (B.C. MoTI).

This report provides details of the hydrologic, hydraulic, and geomorphic assessments and the recommended hydrotechnical design parameters for the bridges including:

- the 1:200-year and 1:100-year design floods and water levels, which include an upward adjustment for potential increase due to climate change
- the design river ice level and forces
- the recommendations for scour and erosion protection
- the recommended minimum bridge low-chord elevations relative to the 1:200-year and 1:100-year design water levels, including consideration for clearances of ice jams, debris, and for navigation

1.1 Existing and Proposed Bridges

The existing and proposed bridge locations are shown on Figures 1 and 2. The existing Bridge 1 is a clear span over the main channel of the river and the existing Bridge 2 is a clear span over the Gould's Island side channel. Bridge 1 and Bridge 2 are connected by a 30 m long built-up section of the highway on Gould's Island. The existing bridges and abutments will be removed.

Two replacement bridges are proposed:

1. The Highway 95 Bridge: a two-span bridge with a pier located on Gould's Island and a multi-use pathway that will pass under south bridge approach. The proposed bridge alignment is immediately upstream of the existing bridges and downstream of Canadian Pacific (CP) land; thus, the alignment is fixed. The bridge will be designed for the 1:200-year design flood per the B.C. MoTI supplement to the *Canadian Highway Bridge Design Code* (CSA 2019).

2. The Gould's Island Bridge: a clear-span bridge over the side channel to maintain access to a restaurant and homes on Gould's Island. The bridge will replace existing Bridge 2 at the same alignment and will be a low-volume (traffic) structure and thus will be designed for the 1:100-year design flood per the B.C. MoTI supplement to the *Canadian Highway Bridge Design Code* (CSA 2019).

The proposed Highway 95 Bridge abutments will be located outside the 1:200-year flood extents, the proposed pier will be located on Gould's Island, and the proposed Gould's Island Bridge will provide at least the same hydraulic opening as the existing Bridge 2.

1.2 River and Site Conditions

Figure 1 depicts the Kicking Horse River drainage basin. The Kicking Horse River originates at Wapta Lake, located immediately west of the continental divide in the Rocky Mountains. At the proposed bridges, the basin has a drainage area of 1,850 km^2. The basin is mountainous and well forested with an average elevation of 1,938 m. About 5% of the basin area is presently glaciated.

From Wapta Lake the Kicking Horse River flows approximately 80 km west to the eastern edge of the town of Golden collecting numerous tributaries along the way (including the Yoho, Emerald, Amiskwi, Otterhead, Ottertail, and Beaverfoot rivers). At the eastern edge of the town, the Kicking Horse River emerges from a narrow canyon and flows 3.5 km through the town to its confluence with the Columbia River. The proposed bridges cross the Kicking Horse River near the centre of town about 1.5 km downstream of the canyon and 2.0 km upstream of the Columbia River.

High water levels on the Kicking Horse River occur during spring freshet due to open-water flooding and in the winter due to ice jams. The town is protected from flooding and ice jams by armoured dikes that extend along both banks of the river though the town including upstream and downstream of the bridges. CP railway tracks are located on the right (north) bank extending upstream from the existing Bridge 1. The CP tracks are adjacent to the dike and at a similar elevation as the top of the adjacent dike.

The Kicking Horse River has been (and is) laterally stable because of the armoured dikes.

2 DESIGN BASIS AND AVAILABLE INFORMATION

2.1 Design Standards and Guidelines

This report is based on the following design standards and guidelines:

- *British Columbia Bridge Standards & Procedures Volume 6 - Hydrotechnical Engineering* (B.C. MoTI 2022a)
  - *Canadian Highway Bridge Design Code* S6-19 (CSA 2019)
  - Transport Association of Canada (TAC) *Guide to Bridge Hydraulics* (TAC 2001)
  - B.C. MoTI *Supplement to CHBDC S6-19* (B.C. MoTI 2022b)
  - B.C. MoTI *Supplement to TAC Geometric Design Guide* (B.C. MoTI 2019)
- B.C. MoTI *Standard Specifications for Highway Construction* (B.C. MoTI 2020)
- British Columbia Ministry of Environment, Lands and Parks (B.C. MELP) *Riprap Design and Construction Guide* (B.C. MELP 2000)
- British Columbia Ministry of Water, Land and Air Protection *Dike Design and Construction Guide Best Management Practices for British Columbia* (B.C. MWLAP 2003)

- The provincial guidelines recommend dikes and their associated erosion protection have a minimum freeboard of 0.6 m above the 1:200-year water level. Whereas it is the Town's goal to have a minimum freeboard of 1.0 m for the dikes in the downtown area, including immediately upstream and downstream of the bridges (Matrix 2014). The higher freeboard goal is to provide additional protection for the high value assets in the area (the downtown and historical buildings) and for ice jams.

The design flood for the proposed Highway 95 Bridge and the Gould's Island Bridge is the maximum instantaneous 1:200-year flood and 1:100-year flood, respectively, including a factor for climate change, per the B.C. MoTI *Supplement to CHBDC S6-19* (B.C. MoTI 2022b). The erosion and scour protection for both bridges is designed for the maximum instantaneous 1:200-year flood, per the British Columbia Ministry of Water, Land and Air Protection *Dike Design and Construction Guide Best Management Practices for British Columbia* (B.C. MWLAP 2003).

Note that in addition to typical approvals, such as approval under the *Canadian Navigable Waters Act*, the project will require approval under the British Columbia *Dike Maintenance Ac*t.

2.2 Available Information

The following information was used for the hydrotechnical assessment:

1. Discharge (58-year record), water level, and ice data (freeze-up and break-up dates) from WSC for the hydrometric station on the Kicking Horse River at Golden (Station 08NA006).

2. Previous hydrologic assessments and flood frequency analysis in 2004 by Hydroconsult EN3 Services Limited (Hydroconsult, now Matrix), and in the 2020 preliminary design report by Associated Engineering (B.C.) Ltd. (Associated Engineering 2020).

3. Survey of the river banks and river bed (bathymetry) and survey of the existing bridges completed by Stantec in September 2020 and provided to Matrix by B.C. MoTI. The bathymetry extends about 200 m upstream and 150 m downstream of the existing bridges. From the survey data the existing Bridge 1 and Bridge 2 low-chord elevations are 788.8 m and 789.2 m, respectively.

4. LiDAR terrain survey and orthophoto completed in 2016 and provided to Matrix by B.C. MoTI. The LiDAR and orthophoto extends along Highway 95 and along the Kicking Horse River about 600 m upstream and 900 m downstream of the existing bridges.

5. LiDAR terrain survey and orthophoto completed on July 20, 2019, and provided to Matrix by the Town of Golden. The LiDAR and orthophoto extend along the Kicking Horse River through the town and include all areas within the town's municipal boundary. There were no differences noted between the 2019 and 2016 LiDAR that would affect the hydrotechnical design of the bridges.

6. Historical Kicking Horse River cross-section data from 1987 to 2021 provided to Matrix by the Town of Golden and in 2020 by the B.C. Ministry of Environment, Land & Parks. Matrix (and formerly Hydroconsult) have completed comparisons of the historical cross-sections since 2002, with the most recent assessment completed with the 2021 surveys (Matrix 2022).

7. The Kicking Horse River open-water hydraulic model that was initially prepared in 1999 by Hydroconsult and has been subsequently reviewed and updated several times with new survey data (Hydroconsult 2004, 1999, Matrix 2014). The model extends 3.5 km upstream from the Columbia River to the mouth of the canyon at the upstream (east) edge of the town. The 2014 model is based on river cross-sections surveyed in 2012 and 2013. The 2014 model was calibrated to observed water levels on the Kicking Horse River between the pedestrian bridge and the existing Bridge 1 during the 2012 flood (about a 1:10-year flood).

8. Data and conclusions on Kicking Horse River ice jams from the 2018 Ice Jam Study that was completed by Matrix for the Town of Golden (Matrix 2018). The study included a summary of historical and recent ice jam records from 1897 to 2018 including photographs of ice jam levels at the existing bridges.

9. Photographs and documentation of MoTI observations of an ice jam that occurred during the 2021/2022 winter. The ice jam occurred on December 31, 2021, and ice levels peaked at the Highway 95 Bridge on January 3, 2022. This was the fourth highest ice jam observed at the bridges.

10. As-built drawings of the existing bridges provided by B.C. MoTI. Construction of the bridges was completed in 1951.

11. Annual inspection reports of the bridges provided to Matrix by B.C. MoTI from 2015 to 2020.

12. Historical construction and dike inspection records including riprap inspections summarized in the *Operation and Maintenance Manual* for the dikes (Matrix 2021).

13. Numerous site visits and site photographs by Matrix (and formerly Hydroconsult) from 1999 to 2022 including observations of the river substrate. Matrix has been involved in river engineering along the Kicking Horse River for more than 20 years including river surveys, hydraulic modelling, river ice engineering, sedimentation studies, hydrotechnical design, construction supervision, and inspection of the pedestrian bridge and dikes for the Town of Golden.

3 HYDROLOGIC ASSESSMENT

3.1 Previous Studies

The following summarizes the previous hydrologic assessments.

Hydroconsult 2004

A comprehensive flood hydrology assessment for the Kicking Horse River was completed in 2004 by Hydroconsult. The assessment included a review of studies completed before 2004, a review of historical floods, and a flood frequency analysis (FFA) of daily annual maximum flows from WSC station 08NA006 Kicking Horse River at Golden (39 years of daily flow data from 1912 to 1918, 1920 to 1922, and 1974 to 2002, of which there were 22 years of instantaneous flow data). The FFA resulted in a 1:200-year daily flood magnitude of 474 m^3/s using the United States flood frequency procedure (USGS 1982). A maximum instantaneous 1:200-year flood magnitude of 504 m^3/s was computed by applying the average instantaneous to daily flow ratio of 1.064. To account for uncertainty and potential climate change, the study recommended a 1:200-year instantaneous flood magnitude of 570 m^3/s, based on the upper 95% confidence interval of the fitted distribution.

Associated Engineering 2020

A hydrotechnical assessment of the Kicking Horse River for the preliminary design of the proposed bridges was completed in 2020 by Associated Engineering. The assessment included a FFA of daily flow from WSC station 08NA006 Kicking Horse River at Golden and an assessment of climate change effects on the 1:200-year flood.

Associated Engineering recommended a 1:200-year maximum daily flood magnitude of 463 m^3/s computed from a 49-year flow record (1912 to 1918, 1920 to 1922, and 1974 to 2012) using the Log Pearson Type III distribution (unknown fitting method). A maximum instantaneous 1:200-year flood magnitude of 495 m^3/s was computed by applying the average instantaneous to daily flow ratio of 1.064.

Climate change factors were computed from daily flow projections by the Pacific Climate Impacts Consortium (PCIC) for Representative Concentration Pathway (RCP) 4.5 and 8.5. The upper factor was computed to be 25% for RCP 8.5 and was recommended for the design. Accordingly, the study recommended a design 1:200-year peak instantaneous flood magnitude of 619 m^3/s.

3.2 Flood Frequency Analysis

Figure 3 summarizes the hydrologic analysis of the Kicking Horse River completed for this hydrotechnical assessment.

For this study, a FFA was completed on daily annual maximum instantaneous flows from WSC station 08NA006 Kicking Horse River at Golden (58 years of daily flow data from 1912 to 1918, 1920 to 1922, and 1974 to 2021, of which there were 41 years of instantaneous flow data). When maximum instantaneous flow was not available, it was estimated by the median ratio of instantaneous to daily flow (1.076) for the floods that had instantaneous flow data. This resulted in a total maximum instantaneous flow record of 58 years of which 17 years (29%) were estimated.

A computed 1:200-year peak instantaneous flood of 463 m^3/s was computed using Hyfran software and the best-fitted Log Pearson Type III (Method of Moments) distribution. This computed value is 6% lower than the value computed by Associated Engineering because of the following:

- This analysis uses all available flow data from 1912 to 2021 (9 more years than Associated Engineering used for their 2020 analysis).

- This analysis used instantaneous flow data rather than daily flow data, which is considered appropriate given that 70% of the available data is instantaneous, and the design flood is instantaneous.

3.3 Potential Effects of Climate Change

The flood history of the Kicking Horse River was reviewed, and no trends were observed in the data (Figure 3).

Uncertainty exists in quantifying the hydrologic response and any potential impact on flood magnitude and timing due to the complex nature and inherent uncertainty in climate change projections. Climate change projections for British Columbia generally predict a 2.8°C increase in average annual temperatures and a 6% to 17% increase in precipitation, with most of the precipitation increase during the winter (EGBC 2018). For large watersheds, flow is expected to increase in the winter, and drier conditions are expected in the summer. For small watersheds, rain-dominated floods are expected with potentially higher peak flows due to increased storm precipitation and intensity. The Kicking Horse River is considered a medium sized watershed. Engineers and Geoscientists of British Columbia (EGBC) currently recommends a 10% climate change factor if no trend in the data is observed, and a 20% climate change factor if an upward trend is observed and if no other information is available such as site-specific flow projections (EGBC 2018).

The PCIC completed a provincial hydrologic model in 2020 that projects future flows based on global climate change model outputs for various emissions scenarios (PCIC 2020). The PCIC hydrologic model provides projected daily flows at selected WSC stations including the Kicking Horse River. A FFA was completed on the historic daily flows (1945 to 2012) and PCIC projected daily flows for the Kicking Horse River at Golden (WSC Station 08NA006) for the moderate and severe emissions scenarios, i.e., RCP 4.5 and 8.5, respectively. Three different timelines were assessed to consider the non-stationarity of the data (the change over time). The climate change factor was computed as the projected flood magnitude increase over the historical daily flood magnitude and the median of the ensemble of model results was computed. The results are shown in Table 1. The median climate change factor for the 1:200-year flood computed from the PCIC projections increases over time to a maximum of 9% and 25% for RCP 4.5 and RCP 8.5, respectively in the 2050 to 2100 period.

TABLE 1 Kicking Horse River Climate Change Factors (Median of the Ensemble of Model Results)

Return Period (year)	Climate Change Factor					
	2020 to 2070		2035 to 2085		2050 to 2100	
	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5	RCP 4.5	RCP 8.5
2	10%	12%	11%	19%	12%	21%
10	10%	12%	9%	18%	13%	21%
20	10%	12%	10%	20%	15%	22%
50	11%	11%	9%	21%	13%	24%
100	8%	12%	6%	20%	10%	25%
200	5%	12%	3%	19%	9%	25%

RCP – Representative Concentration Pathway

A 25% increase to flood magnitudes to account for potential increases to flow due to climate change is recommended for the proposed bridges because it results in a similar 1:200-year design flood discharge (580 m^3/s) compared to the 1:200-year design discharge of the dikes (570 m^3/s). The 25% climate change factor is the most conservative factor computed from PCIC projections and is conservative compared to the 10% to 20% EGBC guidelines. The effect on the design water level for other climate change factors is provided in Section 4.2.

The B.C. MoTI *Design Criteria Sheet for Climate Change Resilience* is provided in Appendix C.

3.4 Flood Magnitudes and Recommended Design Flood

Recommended flood magnitudes used for the hydraulic modelling are summarized in Table 2. The table shows instantaneous flood magnitudes for return periods up to the 1:200-year flood. The recommended 1:200-year, and 1:100-year design flood magnitudes are 580 and 545 m^3/s, respectively, and include the most conservative 25% upward adjustment to account for potential increases due to climate change to year 2100.

TABLE 2 Kicking Horse River Flood Magnitude Estimates

Flood	Instantaneous Flood Flow (m^3/s)[1]
1:2-year	248
1:10-year	340
1:20-year	371
1:50-year	409
1:100-year	436
1:200-year	463
1:100-year design flood	545
1:200-year design flood	580

Note:
1. The 1:200-year and 1:100-year design flood flows include a 25% increase for climate change. Other flood flows were computed from flood records and do not include climate change factors.

4 HYDRAULIC MODELLING

4.1 Model Overview

HEC-RAS hydraulic modelling software (Version 5.0.7; USACE 2016) was used to simulate the Kicking Horse River hydraulics. Two models were created: one for existing bridge conditions and one for proposed bridge conditions.

The hydraulic model and input parameters are summarized below:

- The previous model (Matrix 2014) was updated with the latest survey data from the Town of Golden's sediment monitoring program and the B.C. MoTI bathymetry. One additional section (K4a) was added to the existing and proposed conditions models to accurately represent the proposed Highway 95 Bridge in the new location (see Figure 2).

- The model domain extends about 1,470 m upstream and 2,270 m downstream of the existing bridges along the Kicking Horse River (see Figure 2).

- The existing conditions model includes the existing highway bridges. The bridges have vertical abutment walls with clear span lengths of 42 m and 17 m over the main and side channels of the Kicking Horse River, respectively (measured perpendicular to the flow direction). The expansion and contraction coefficients for the sections immediately upstream and downstream of the bridges were set to values for mild contraction or gradual transitions (i.e., 0.3 and 0.1, respectively).

- The proposed conditions model includes the proposed bridges:

    - The proposed Highway 95 Bridge will have vertical abutment walls located outside the 1:200-year flow area and one pier, with a width of 1.6 m, located on Gould's Island. The bridge has span lengths of 50 m over the main channel (between the north bank and pier) and 22 m over the side channel (between the south bank and the pier), measured perpendicular to the flow direction. The energy balance method was used to model the hydraulic effects of the pier.

    - The proposed Gould's Island Bridge will have vertical abutment walls with a minimum clear-span length of 17 m over the side channel, measured perpendicular to the flow direction.

    - The expansion and contraction coefficients for the sections immediately upstream and downstream of the bridges were set to values for mild contraction or gradual transitions (i.e., 0.3 and 0.1, respectively).

- Manning's channel roughness coefficients (*n*): *n* = 0.035 for the channel from 1,470 upstream to 230 m downstream of the proposed bridges, where the river substrate consists of cobbles and boulders, and *n* = 0.025 from 230 m to 2,270 m downstream of the proposed bridges, where the river substrate consists of sand and gravel. Flood levels are contained within the dikes; therefore, there are no floodplains included in the model along the Kicking Horse River. The roughness coefficients were previously calibrated (Hydroconsult 2004, Matrix 2014), and no change to the river roughness has occurred since then.

- Upstream and downstream boundary conditions were not altered from the 2004 or 2014 models. The downstream boundary condition of the Kicking Horse River is a junction with the Columbia River followed by a normal depth in the Columbia River with an energy grade of 0.1%. The Columbia River has no effect on hydraulics at the existing or proposed bridges because of the distance and river gradient between the bridges and the Columbia River.

- Flow regime: the model was run with a subcritical flow regime for calculations. The Froude number for all the modelled sections is below 1.0, thus the flow is indeed subcritical.

4.2 Sensitivity Analysis

A sensitivity analysis was conducted to determine the effects of changing key model parameters and inputs. The results are summarized in Table 3. The hydraulic model results are not sensitive to the contraction and expansion coefficients because there is minimal encroachment of the existing and proposed bridges into the flow area.

TABLE 3 Kicking Horse River Hydraulic Model Sensitivity Analysis

Parameter	Parameter Variance (or Value)	Effect on 1:200-year Design Flood Level (m)	Effect on 1:200-year Design Flood Mean Channel Velocity (m/s)
Manning roughness coefficient (n)	+20% to -20%	+0.25 to -0.21	-0.29 to +0.29
Contraction/expansion coefficient	+20% to -20%	+0.03 to -0.03	-0.03 to +0.04
Climate change factor			
2050 to 2100 RCP 8.5 (design factor)	25% (580 m^3/s; design flow)	N/A	N/A
2050 to 2100 RCP 4.5	9% (505 m^3/s)	-0.24	-0.17
2020 to 2070 RCP 8.5	12% (519 m^3/s)	-0.19	-0.14
2020 to 2070 RCP 4.5	5% (486 m^3/s)	-0.29	-0.22

RCP – Representative Concentration Pathway

4.3 Results and Design Water Level

Key model results are shown on Figure 4, including the rating curve (water level versus flow) and mean channel velocity at the proposed bridges. Detailed model inputs and outputs are provided in Appendix A. The computed 1:200-year design water level is 788.9 m for the proposed Highway 95 Bridge. The computed 1:100-year design water level is 788.7 m for the proposed Gould's Island Bridge.

The existing bridges cause negligible backwater because they provide a clear span of the dikes over the 1:200-year design flow and the 1:200-year design flow is contained within the dikes. The proposed bridges also will not induce backwater because of the following:

- The proposed Highway 95 Bridge will provide a larger horizontal hydraulic opening over the main channel and side channel than the existing bridges and the abutments will be located outside the 1:200-year design water level. The proposed Gould's Island Bridge will provide at least the same horizontal hydraulic opening as the existing Bridge 2. Both proposed bridges will be higher than the existing bridges.

- The proposed pier is located on Gould's Island. Flow on Gould's Island is already blocked by the existing road fill, vegetation, and high ground elevations on the Island immediately downstream of the pier (see Figure 10).

5 RIVER ICE LEVELS AND FORCES

The following subsections provide an analysis of river ice conditions and the recommended river ice design parameters consisting of the following:

- design river ice level for consideration in determining the low-chord elevation of the proposed bridges
- design river ice forces on the proposed pier and abutments

In 2018, Matrix completed a detailed study of river ice and ice jams on the Kicking Horse River in the town of Golden (Matrix 2018). The following information and river ice analysis are informed by the 2018 study and updated with the B.C. MoTI inspection reports for the bridges from 2015 to 2020 and observations and photographs of the winter of 2021/2022 ice jam (that were not available for the 2018 ice jam study). Key river ice data are summarized on Figures 5 and 6 along with photographs of the bridges during the highest observed ice levels. The high quality and quantity of available ice information is worth noting because this level of documentation for river ice at bridges is not typical.

Freeze-up typically occurs from late October to mid-December and break-up from late February to late April. Ice jams can occur during early winter (freeze-up) or midwinter and consist a mixture of frazil[1] and

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[1] Frazil Ice: Ice that forms in turbulent, fast-moving water that is slightly below freezing; it looks like ice shavings, has a slushy consistency, and tends to group together.

brash[2] ice. Frazil ice has a slushy consistency and a low internal strength (i.e., crushing strength). Brash ice consist of broken-up pieces of solid ice that have a high internal strength. Ice jams can occur during air temperatures of about -30°C based on recorded temperatures in Golden (Matrix 2018).

In Golden, ice jams on the Kicking Horse River can happen suddenly, causing the water level to rise by several metres in a few hours. Afterwards, water and ice levels decrease as the bottom of the ice jam smooths out and the ice becomes more consolidated. Break-up ice jams have not occurred, but movement of ice during break-up could impact the proposed abutments or pier. Break-up can occur quickly, in as little as a day.

5.1 History of Maximum Ice Levels at the Existing Bridges

River ice levels (ice jams) have historically reached the low chord of the existing bridges as described below. Note that these ice jams initiated downstream of the bridges (not on the bridges) followed by continued accumulation of inflowing ice which eventually extended upstream past the bridges. Photographs are shown on Figure 5.

- Ice Jam 1 (second highest ice level at the bridges):
  - The ice jam occurred on January 7, 2005 (winter of 2004/05).
  - The ice jam was preceded by a week of air temperatures dropping from -10°C to -25°C.
  - The ice jam primarily consisted of frazil ice.
  - From photographs, the peak ice level was about 0.3 m above the Bridge 1 low chord. This equates to a peak top of ice elevation of 789.1 m.
  - The ice reportedly impacted the girder of Bridge 1 for "nearly 10 minutes."
- Ice Jam 2 (ice jam of record at the bridges):
  - The ice jam occurred on December 20, 2005 (winter of 2005/06).
  - The ice jam was preceded by a week of air temperatures varying between -5°C to -18°C.
  - The ice jam included numerous solid ice floes (brash ice) near the bridges during the peak of the jam. An inflow of frazil ice continued after the initial ice jam.
  - The B.C. MoTI inspection reports stated that ice levels at the bridges were higher than during Ice Jam 1.
  - The 2015 B.C. MoTI inspection report of Bridge 2 noted a horizontal space between the deck and one girder. The inspection report speculated that this was due to the December 20, 2005, ice jam. The low-chord elevation of Bridge 2 is 789.2 m.

[2] Brash Ice: Accumulation of floating ice made up of fragments; it is the wreckage of other forms of ice.

  - Based on photographs, the peak ice level was about 0.7 m above the Bridge 1 low chord (788.8 m). This equates to a peak top of ice elevation of 789.5 m, which is 0.7 m above the 1:200-year design flood and 0.3 m above the Bridge 2 low chord.
  - Based on photographs of ice remnants after break-up, the ice jam thickness is estimated to have been 2 m.

- Ice Jam 3 (third highest ice level at the bridges and same level as Ice Jam 4):

  - The ice jam occurred on December 2, 2014 (winter of 2014/15).
  - The ice jam was preceded by a week of air temperatures dropping from 0°C to -20°C.
  - The ice jam primarily consisted of frazil ice.
  - Based on photographs, the peak ice level was at the Bridge 1 low chord (788.8 m).

- Ice Jam 4 (third highest ice level at the bridges and same level as Ice Jam 3):

  - The ice jam initially occurred on December 31, 2021 (winter of 2021/22). MoTI reported that the toe of the ice jam was approximately 1.5 km downstream of the bridges.
  - The ice jam was preceded by a week of air temperatures dropping from -4°C to -28°C.
  - From December 31, 2021, to January 3, 2022, MoTI excavated ice from the channel at the toe of the ice jam to provide flow relief. MoTI reported that ice level at the bridges continued to rise at the bridges during this time to a peak level on January 3, 2022, before dropping.
  - The ice jam consisted of brash and frazil ice.
  - Based on photographs, the peak ice level was at the Bridge 1 low chord (788.8 m).

5.2 Maximum River Ice Levels at the WSC Station

Figure 6 shows annual peak river ice levels recorded at the WSC station. Comparing these levels to the maximum river ice level history at the bridges shows that the ice jam levels are not consistent between these two locations. Thus, an analysis of ice jam levels recorded at the WSC station is not applicable to the location of the bridges.

5.3 Design Ice Level

A design top of ice level equal to the ice jam of record (peak ice level of 789.6 m and 789.5 m at the proposed Highway 95 and Gould's Island bridges, respectively) is recommended. Using the ice jam of record as the design ice level is reasonable considering that the bridges have been in place for 71 years; this is common and sound practice for bridges and other river infrastructure.

See Section 8 for the recommended minimum low-chord elevations for the proposed bridges including discussion of clearance of ice levels.

5.4 Design Ice Forces

5.4.1 Thermal Expansion Loading

Thermal expansion loading occurs when a continuous/solid ice sheet is formed between structural elements, such as between bridge piers. Ice jams do not exert thermal expansion loads because they consist of individual ice floes that allow for expansion. Thermal ice cover can form on the river during years when there are no ice jams, but thermal ice loading is not expected on the bridges for the following reasons:

- Solid ice cover on the Kicking Horse River is limited to low river levels below the abutment walls and exposed portion of the pier (i.e., on the riprap or existing banks; see photograph of typical thermal ice cover on Figure 6).

- An ice cover would tend to slide up the shallow and low elevation banks of Gould's Island, lacking a solid surface from which to exert pressure.

5.4.2 Lateral Thrust Due to Arching Ice Jam

The recommended lateral pressure of an ice jam is 10 kPa per the Canadian Highway Bridge Design Code (CSA 2019, Clause 3.12.4).

5.4.3 Ice Impact (Dynamic Force)

Ice impact on the pier can occur during ice jam formation, break-up, or consolidation and movement of the ice jam. The Canadian Highway Bridge Design Code (CSA 2019, Clause 3.12.2.1) recommends the following crushing strengths based on climatic conditions during break-up:

- the ice breaks up at melting temperature and is substantially disintegrated: 400 kPa
- the ice breaks up at melting temperature and is somewhat disintegrated: 700 kPa
- the ice breaks up or ice movement occurs at melting temperature and is internally sound and moving in large pieces: 1,100 kPa
- the ice breaks up or ice movement occurs at temperatures considerably below the melting point of the ice: 1,500 kPa

A crushing strength of 1,500 kPa is recommended for the proposed bridges because brash ice jams can occur during mid-winter at temperatures considerably below the melting point of the ice. The crushing strength is conservative because ice jams consist of a mixture of weak frazil ice and strong brash ice.

5.5 Design Ice Thickness

A design ice thickness of 0.7 m is recommended at the pier for ice impact loading, considering the following:

- At the pier location on Gould's Island, the depth from the design ice level to the existing grade of the island is 0.7 m. The island will be armoured to prevent scour and erosion, preventing ice jam thicknesses greater than 0.7 m contacting the pier (see Section 7).

- Ice floes would have to slide over the surface of the island, which will reduce the force of the ice on the pier (see helicopter photograph of Ice Jam 2 on Figure 5). In addition, the full crushing strength is unlikely to develop across the full ice jam thickness since ice jams are the accumulation of floes of ice which, individually, have a smaller thickness than the ice jam. For example, 0.15 m thick ice floes have been observed (see photograph of typical ice floe thickness on Figure 6). Thus, the design ice thickness and resulting crushing force is considered conservative.

For lateral thrust loading due to an arching ice jam on the abutments, a design ice thickness of 2.0 m is recommended, i.e., the estimated ice jam thickness of the ice jam of record (see Figure 5).

6 AGGRADATION, DEGRADATION, AND SCOUR

6.1 Aggradation and Degradation

Aggradation[3] and degradation[4] are assessed as part of the Town of Golden's ongoing sedimentation monitoring program that includes a comparison of historical Kicking Horse River cross-sections from 1987 to 2021 and is updated herein with 2020 B.C. MoTI bathymetry. The maximum flow during this period was 372 m^3/s in 2007 (see Figure 3). The most recent assessment for the Town was completed using 2021 survey data (Matrix 2022)[5]. Figure 7 shows a comparison of repeated surveys at the existing bridges.

Aggradation and degradation do not occur at the existing and proposed bridges based on the following:

- The riverbed elevation and channel thalweg lateral location have been stable for at least 36 years (the period of cross-section surveys) upstream of, and at, the proposed bridge locations to about 650 m downstream (near 7th Street North; see location plan on Figure 2). The river is subject to

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[3] Aggradation is the long-term process by which streambeds and floodplains are raised in elevation due to the deposition of material eroded and transported from other areas (USBR 1984).

[4] Degradation is the long-term process by which streambeds and floodplains are lowered in elevation due to the removal of material from the streambed by flowing water (USBR 1984).

[5] Note that historically, when deposition reaches a 0.3 m threshold in the gravel bars, the town undertakes dredging to maintain freeboard on the dikes adjacent to the gravel bars (i.e., gravel bar scalping; Matrix 2018).

aggradation further downstream within the gravel bars that extend from near 7th Street North to the Columbia River.

- Deposition within the gravel bars, 650 m downstream, does not affect the design water level at the bridges. The hydraulic model results show there is about a 3.0 m difference in the design water level from the proposed bridges to the top of the gravel bars.

- The river substrate at the proposed bridges consists of large boulders and cobbles that are resistant to scour[6] and degradation. The small variation in the cross-sectional surveys at the bridges is attributed to the large substrate material in this area.

- The river has been confined by the development of the town and by the dikes. The resulting increased velocity has scoured away smaller sediment (smaller than cobbles) from the voids between the larger sediment (boulders and cobbles).

- Although there may be periods where small sediment is deposited near the bridges, such as during the falling limb of flood hydrographs, this smaller sediment will be scoured away during clear-water flow or during the rising limb and peak of flood hydrographs.

6.2 Design Scour

Design scour depths at the proposed bridges were assessed with theoretical scour computations and a field-based assessment based on the repeated surveys, previous site visits, and photographs.

The following is a summary of the field-based assessment:

- The historical surveys show that the channel bed, banks, and thalweg (the thalweg is located in the centre of the main channel) have been stable (see Section 6.1 and Figure 7). The channel is laterally stable because the armoured dikes prevent migration.

- A median bed material size (D_{50}) of 200 mm is estimated for the main channel, which contains large cobbles and boulders based on observations during previous site visits and bathymetric surveys performed by Matrix.

- A median bed material size of 20 mm, corresponding to coarse gravel, is estimated for the side channel from photographs of the side channel (Figure 9) and observations during previous site visits and bathymetric surveys performed by Matrix. This is a conservative estimate because the coarse cobble

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[6] Scour is the enlargement of a flow section by the removal of boundary material through the action of fluid motion during a single discharge event.

visible at the side channel inlet (D_{50} of about 100 mm per Figures 6, 10, and 11) may underlie the surface gravel at the proposed Gould's Island Bridge.

- A median bed material size (D_{50}) of 100 mm is estimated for the pier location from photographs of the side channel inlet and the proposed pier location (Figures 4, 8, and 9).

While there is a low potential for scour at the proposed bridge abutments, riprap protection is recommended and should include a toe trench or launching apron as best practice. Therefore, the theoretical scour for the design flood was computed as summarized in Section 6.2.1.

The computed theoretical scour and recommended design scour depth for the pier is summarized in Section 6.2.2.

6.2.1 Main Channel and Side Channel Scour

The theoretical scour computations were completed for the main channel and side channel using the blench regime depth, clear-water scour, and live-bed scour methods (FHWA 2012). The computations are summarized in Appendix B. The most conservative computed scour depths are 0.8 m in the main channel and 0.4 m in the side channel and were used to determine the design toe trench / launching apron design (see Drawings under separate cover).

6.2.2 Local Pier Scour

Although Gould's Island has been naturally stable for more than the 71-year age of the existing bridges (without riprap protection), construction will disturb the tip of the island, and require removal of large vegetation at the upstream tip and the proposed pier which will change the local flow patterns. This will increase the potential for scour and erosion of the tip of the island including at the pier and nearby infrastructure on the island (i.e., the north approach to the Gould's Island Bridge). A scour hole at the pier could also pose a safety hazard to public walking around the island. Therefore, riprap protection on the tip of Gould's Island and around the pier is recommended.

Riprap will sufficiently protect the tip of the island from scour and erosion but the B.C. Supplement to the CHBDC discourages relying on riprap for scour protection of foundations because they are critical to the bridge's structural integrity. Therefore, the piles for the piers should be conservatively designed to accommodate the computed local pier scour depth. Combining local scour with general (i.e., natural) scour is not applicable at the pier because the pier is located on Gould's Island and not within the channel. The river has been stable and the proposed riprap on the tip of the island will protect against migration of the main or side channel to the pier location.

The theoretical local pier scour was computed as summarized below:

- Pier scour was computed for the proposed pier pile design, consisting of two rows of eight piles, each with a diameter of 0.762 m. See the structural design drawings for details.

- The flow depth upstream of the pier was conservatively set to 2.0 m, corresponding to the depth and velocity from the model results about 20 m upstream from the proposed pier. This is conservative because the maximum depth at the pier is about 0.4 m.

- A scour depth of 5.3 m was computed using the Colorado State University (CSU) equation (FHWA 2012). The calculation used a 27-degree angle of attack (equal to the proposed angle between the pier alignment and flow direction). Applied to the existing ground at the pier location (788.4 m), this equates to a scour elevation of 783.1 m. Note that the CSU method does not depend on the bed material size.

- A scour depth of 2.9 m was computed using the Transportation Association of Canada modified Melville method (TAC 2001). The calculation used a 27-degree angle of attack and conservatively assumed the maximum sediment size factor of 1 (i.e., a bed material D_{50} smaller than 100 mm will not affect the result).

Given the above, a conservative design scour depth and elevation of 5.3 m and 783.1 m respectively are recommended for the pier.

7 SCOUR AND EROSION PROTECTION

The primary goal of the scour and erosion protection design is to provide adequate protection of the bridge integrity. Wherever practical, the design will minimize environmental impacts (e.g., by including vegetation).

The need for, scope, and detail of riprap was determined from:

- a field-based assessment of existing riprap conditions and historical performance of the dikes (completed for previous projects)
- a recognition of the island and bank disturbance that will happen during construction of the proposed bridges and removal of the existing bridges
- a recognition of the importance of bank stability with respect to the integrity of the proposed abutment and pier structures, pile foundations, and roadway approaches

The dikes were historically armoured with a Class II riprap specification (D_{50} of 500 mm [AT 2020]) and more recently with an updated 250 kg Class riprap specification (D_{50} of 575 mm [B.C. MoTI 2020]). From annual dike inspection reports, the existing riprap has performed well in open water and ice jam conditions and has required minimal maintenance (Matrix 2018). Furthermore, the banks upstream and downstream of the existing bridges have been stable because of existing riprap and vegetation.

As a check, the minimum required riprap size was computed using an empirical method developed by the US Army Corps of Engineers (USACE 1991) and recommended in the *Riprap Design and Construction Guide* (B.C. MELP 2000) and Transportation Association of Canada's *Guide to Bridge Hydraulics* (TAC 2001). The computed minimum median riprap diameter was 327 mm for the main channel and 102 mm for the side channel. The calculation input parameters and results are summarized in Table 4.

TABLE 4 Summary of Riprap Computations

Riprap Parameter	Main Channel	Side Channel	Comment
Mean channel velocity, V_{avg} (m/s)	3.2	2.1	From the hydraulic model results.
Depth (m)	4.1	2.5	From the hydraulic model results.
Local depth (m)	3.3	2.0	From the hydraulic model results, measured 20% up from the toe, per USACE 1991.
Bend radius, r (m)	1,000	Straight	Measured from the survey data.
Top width, w (m)	55	20	From the hydraulic model results.
Coefficient of stability, C_s	0.3	0.3	For angular riprap.
Local velocity ratio, depth averaged velocity (V_{ss}) / V_{avg}	1.07	1.0	V_{ss} / V_{avg} = 1.74 - 0.52 log (r/w); for outside bends with r/w < 26; else Vss / Vavg = 1, per USACE 1991.
Vertical velocity distribution coefficient, C_v	1.03	1.0	C_v = 1.28 - 0.2 log (r/w); for outside bends with r/w < 26; else C_v = 1, per USACE 1991.
Thickness coefficient, C_t	1.0	1.0	Per FHWA 2001.
Side slope factor, K	0.9	0.9	For 2H:1V slopes.
Rock density (kg/m^3)	2,500	2,500	Minimum density per B.C. MoTI 2020.
Factor of safety	1.1	1.1	Minimum recommended per FHWA 2001.
Riprap size, D_{50} (mm)	327	102	Computed median diameter (D_{50}).

Based on the above, the following riprap design and scope is recommended:

- Riprap should be installed to protect the proposed bridges and to restore the dikes where they will be disturbed; for example, where the existing bridge abutments are removed from the dikes.
    - The Bridge 1 south abutment is located on Gould's Island. Riprap erosion and scour protection are not required here given that the bank is not a dike and there will be no MoTI infrastructure to protect. The existing bank material near this abutment consists of cobble with a D_{50} of 100 mm, based on photographs and site observations of the bank. After abutment removal, the bank should be restored with cobble with a minimum D_{50} of 100 mm to provide equal or better erosion resistance as compared to the existing bank immediately upstream and downstream of the abutment. Restoration of vegetation above the 1:2-year high water mark should be completed (to be designed by Urban Systems Ltd.).

- For areas to be armoured with riprap, a 250 kg Class riprap size (B.C. MoTI 2020) is recommended based on the history of this size of riprap performing well on the dikes during open-water flood and ice jam conditions and to match the existing riprap on the dikes. The riprap should be installed to a minimum thickness of 1.0 m and at a 2H:1V slope or shallower. The riprap should be placed to the top of the banks/dikes so that the level of flood protection provided by the existing dikes is maintained or improved where existing dikes are disturbed or impacted by the bridge project.

- Either a launching riprap apron[7] or toe trench[8] should be included at the toe of the banks for scour protection as a best practice. A toe trench instead of an apron is generally preferred to reduce the instream footprint of the riprap. In addition, a launching apron may not launch because (a) the project is located on a straight reach of river (i.e., flow velocity at the toe of the bank is not particularly high, as it would be on an outside bend for example), and (b) the riverbed is stable due to the boulder and cobble substrate and as evidenced by cross sectional surveys at the bridge dating back to 1987.

- Riprap should be installed on the tip of Gould's Island and around the pier to ensure the stability of the island is maintained and to provide scour protection for the highway bridge pier and the north approach to the Gould's Island Bridge on the island. The riprap can be covered with salvaged cobble from the excavation of the pier on the island to restore the area to near existing surficial conditions thus maintaining similar fish habitat and natural aesthetics. The finished product should maintain the existing natural grade and therefore will have negligible impacts on flow patterns. The riprap has been designed to extend to the design scour depth along the Gould's Island side channel and to launch to the design scour depth along the main channel.

- At a minimum, riprap should be installed on the north and south banks (i.e., the north and south dikes) where the existing riprap will be removed during construction of the proposed bridges and removal of the existing bridges. The riprap should smoothly transition and tie into existing competent riprap on the dikes at the following locations (based on previous site visits and site photographs on Figures 8 and 9):

    - along the south bank from about 15 m upstream of the proposed Highway 95 Bridge
    - along the south bank from about 20 m downstream of the existing Bridge 2
    - along the north bank immediately downstream of the existing Bridge 1
    - along the north bank immediately upstream of the proposed Highway 95 Bridge

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[7] A launching apron consists of riprap installed on the bed of the river at the toe of the bank and thus projects above the riverbed

[8] A toe trench consists of an excavated trench that is backfilled with riprap. The finished surface of the riprap is approximately flush with the original bed and bank. The toe trench is excavated to the design scour depth or lower.

- Existing riprap along the south bank along the side channel between the proposed bridges is obscured by vegetation and sediment (Photograph 6). Riprap should be installed to protect the bridges here and should extend 10 m from the bridge abutments (about the width of the side channel).

Drawings of the scour and erosion protection are provided under separate cover.

8 FREEBOARD AND CLEARANCE

The following subsections provide a summary of the recommended freeboard, minimum bridge low-chord elevations, and resulting clearances. The recommended minimum bridge low-chord elevations, 1:200-year and 1:100-year design water levels, and design ice levels are shown on a profile along the river and on sections at the proposed bridges on Figures 10 and 11, respectively.

8.1 Freeboard and Minimum Bridge Low-Chord Elevations

8.1.1 Highway 95 Bridge

A freeboard of 1.5 m above the water level computed for the 1:200-year instantaneous peak flow, adjusted for climate change, is recommended for the Highway 95 Bridge considering the following:

- A minimum freeboard of 1.5 m is required for highways per the B.C. MoTI *Supplement S6-19 to the Canadian Highways Bridge Design Code* (B.C. MoTI 2022b).

- A freeboard of 1.5 m is recommended when there are large amounts of logs and uprooted trees per the 2001 TAC guidelines (TAC 2001). At the proposed bridges, the Kicking Horse River is not considered to convey a large volume of woody debris:

  - Most woody debris are expected to be broken up in the upstream canyon, but some logs may be conveyed past the bridges during a flood.

  - Some stranded, broken-up logs have been observed 650 m upstream of the bridges, but log jams on Gould’s Island (including on the proposed pier) are not expected based on site observations (see photographs on Figures 4, 8, and 9).

- A 1.5 m freeboard above the 1:200-year design flood water level will provide sufficient clearance for ice jams. This freeboard will provide 0.8 m clearance above the ice level of record/design ice level (789.6 m at the proposed Highway 95 Bridge).

From a hydrotechnical viewpoint, the recommended freeboard of 1.5 m which results in a minimum low-chord elevation of 790.4 m for the proposed Highway 95 Bridge. For comparison, the existing Bridge 1 and 2 low-chord elevations are 0.0 m and 0.4 m above the design flood, respectively.

8.1.2 Gould's Island Low Volume Road Bridge

A freeboard of 0.8 m above the water level computed for the 1:100-year instantaneous peak flow, adjusted for climate change, is recommended for the Highway 95 Bridge considering the following:

- A minimum of 0.5 m is required for low-volume roads per the B.C. MoTI *Supplement S6-19 to the Canadian Highways Bridge Design Code* (B.C. MoTI 2022b).

- The Kicking Horse River is not considered to convey a large volume of woody debris (see details in Section 8.1.1).

- With a 0.8 m freeboard, the bridge low chord elevation will be equal to the design ice level of 789.5 m which is considered adequate based on the following:

    - The bridge will be conservatively designed to withstand ice impact forces above the design ice level (structural analysis is in progress and additional details, including any additional hydrotechnical input, will be provided under separate cover when completed). The bridge will be constructed with concrete box girders which will provide a smooth and continuous surface under the bridge allowing ice floes to be deflected and transported under the bridge.

    - The design ice level is based on the ice jam of record which impacted the existing bridges, and therefore, ice impact on the Gould's Island Bridge is not expected to cause an increase to ice levels above the design ice level at the Highway 95 Bridge.

From a hydrotechnical viewpoint, the recommended freeboard of 0.8 m results in a minimum low-chord elevation of 789.5 m for the proposed Gould's Island Bridge. For comparison, the proposed low chord elevation is 0.3 m higher than the existing Bridge 2 and is 0.7 m above the 1:200-year design flood of the proposed Highway 95 Bridge. The proposed Gould's Island Bridge will not backwater the proposed Highway 95 Bridge at the 1:100-year or 1:200-year design flood.

8.2 Clearance for Navigation

Figure 11 shows a summary table of the proposed and existing bridge clearances including the existing CP rail bridge for comparison (see Figure 2 for bridge locations). The proposed bridges will improve the vertical navigation clearance compared to the existing bridges. For the minimum recommended low chord elevations:

- The proposed Highway 95 Bridge spans over the main channel and side channel and will provide:

    - 2.0 m clearance to the 1:100-year water level
    - 2.3 m clearance to the 1:20-year water level
    - 2.9 m clearance to the 1:2-year water level
    - 1.6 m more clearance compared to the existing Bridge 1

- The proposed Gould's Island Bridge spans over the side channel only and will provide:
  - 1.2 m clearance to the 1:100-year water level
  - 1.5 m clearance to the 1:20-year water level
  - 2.1 m clearance to the 1:2-year water level
  - 0.3 m more clearance compared to the existing Bridge 2

A vertical clearance of 1.7 m is typically considered adequate for rafts, kayaks, and canoes and is typically measured from the 1:2-year or 1:20-year water level (based on Matrix's experience with Transport Canada applications). In the past, prior to the updated *Navigable Waters Act,* MoTI has used a typical clearance of 1.7 m above the 1:100-year water level (as stated in the MoTI Supplement to the Bridge Code [B.C. MoTI 2022b]). Regardless of the presence of bridges, navigation on the Kicking Horse River during larger floods would be dangerous. Larger vessels are not expected because powered vessels are prohibited on the river per federal regulation (Government of Canada 2021).

With respect to horizontal clearances:

- The proposed Gould's Island Bridge will provide a clear span of the side channel with a horizontal clearance equal to or greater than the existing bridge over the side channel (i.e., greater than the existing 17 m horizontal clearance of existing Bridge 2).

- The proposed Highway 95 Bridge will provide horizontal clearances of 45 m over the main channel and 21 m over the side channel (measured perpendicular to the flow between the banks at the 1:20-year flood level). The bridge will have a single pier, which is located on Gould's Island and is therefore not an obstruction to navigation. For comparison, the existing Bridge 1 and Bridge 2 have horizontal clearances of 42 m and 17 m over the main channel and side channel, respectively (measured perpendicular to the flow).

9 CONSTRUCTION CONDITIONS

Hydrotechnical inputs to construction planning include mean monthly flow and hydrographs of the daily median, maximum, minimum, and quartile flows (the 25% and 75% percentile) as shown on Figure 3. Figure 3 also shows the river ice season and the least risk instream timing window (B.C. MoE 2009). Figures 5 and 6 show a summary of river ice conditions and ice jams. From a flood risk and ice jam viewpoint, the lowest risk is from August to mid-November and in April.

The open-water season typically extends from mid-April to early November.

Freeze-up has occurred as early as October 23 and as late as December 18. Break-up has occurred as early as February 11 and as late as April 27 (Figure 6). The risk of an ice jam occurring is highest from late November to early January. The earliest recorded ice jam was on November 22 and the latest on

January 16. Note that the river ice season can vary significantly from year to year depending on air temperatures.

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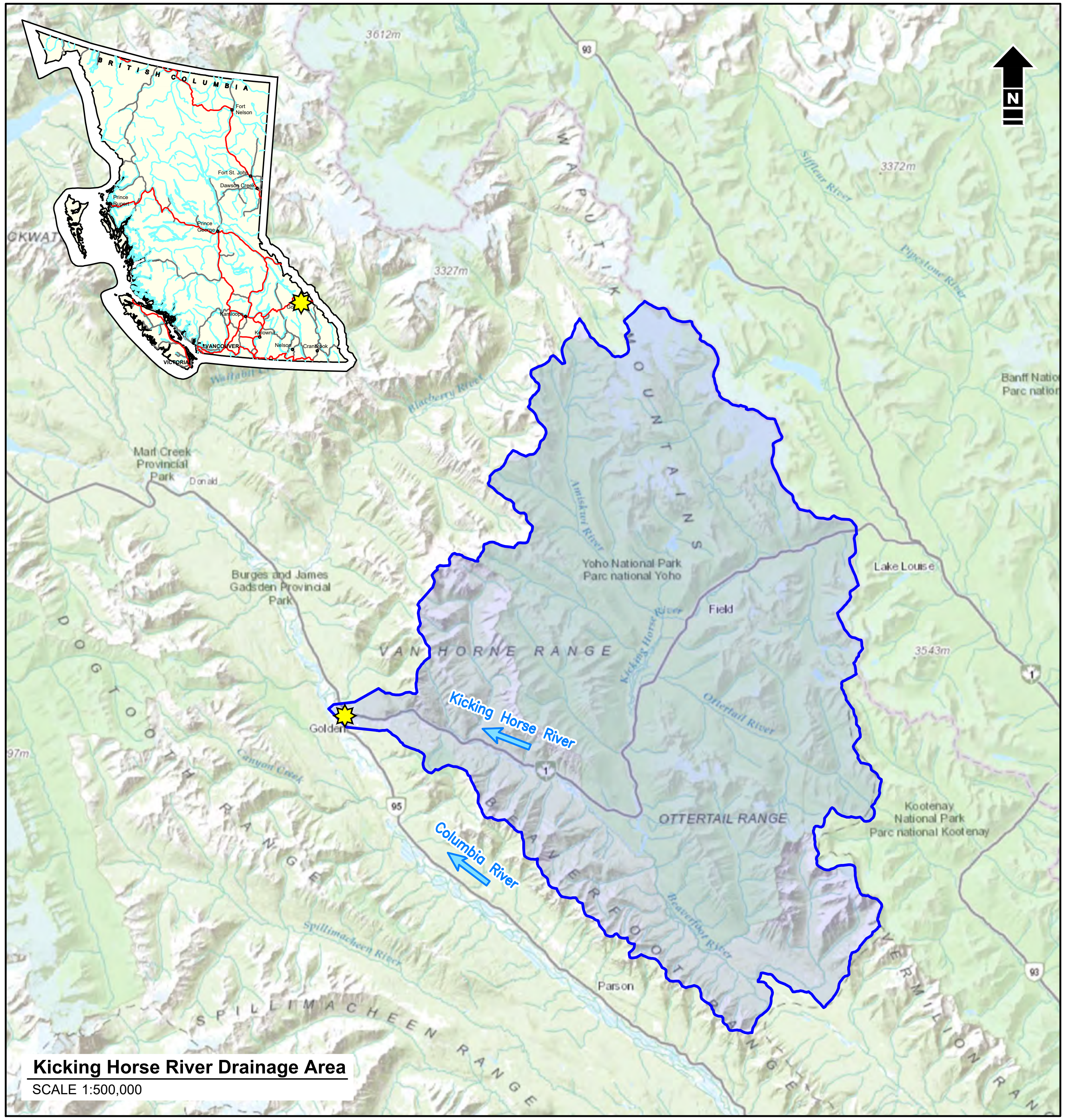

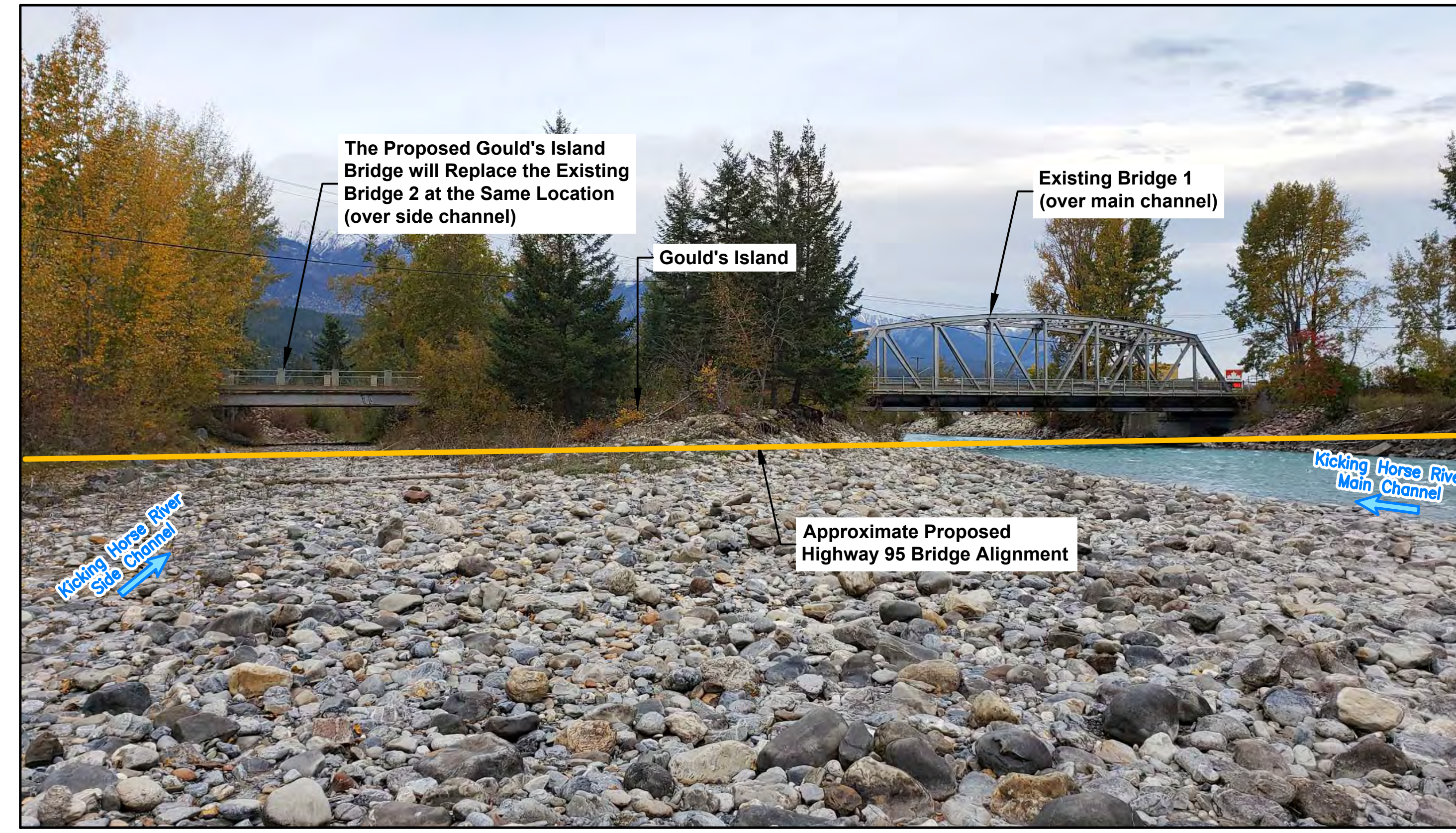

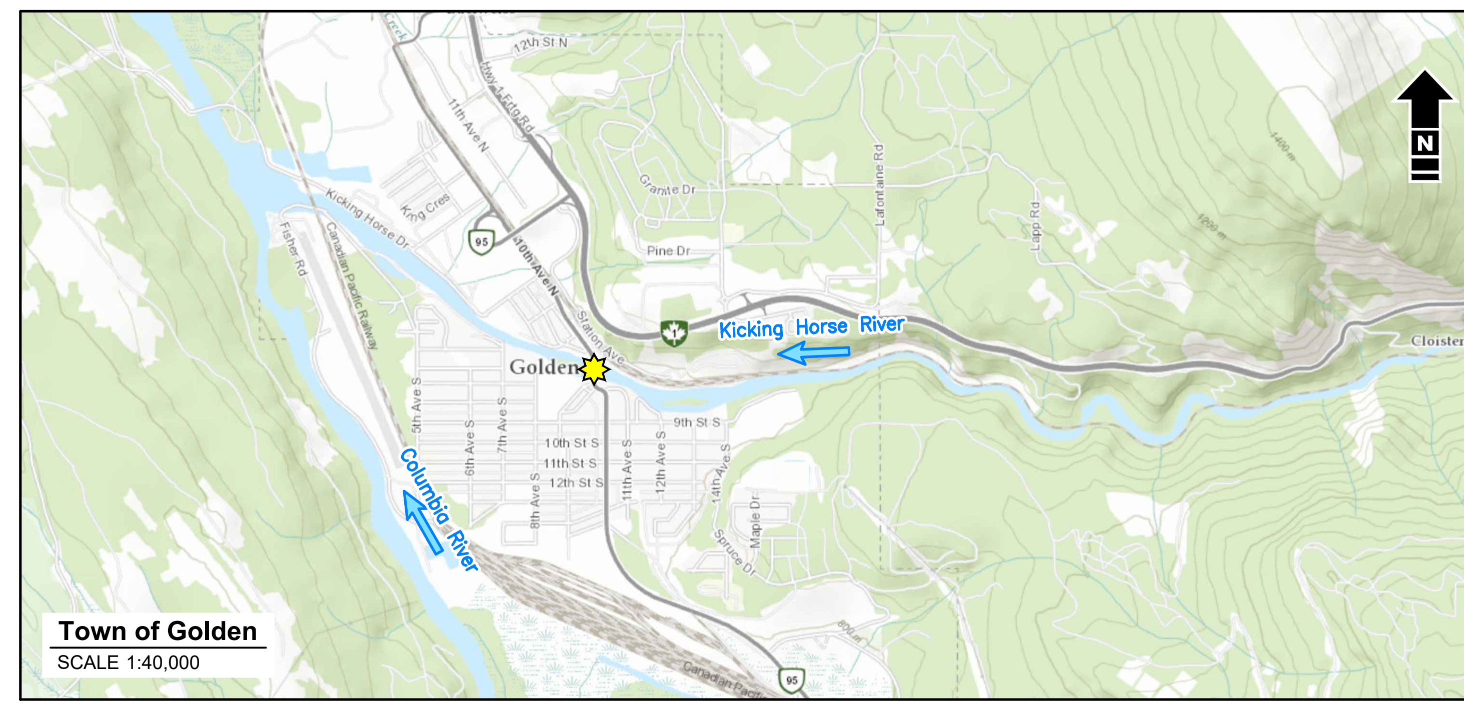

Legend

- Highway 95 Bridges
- Flow Direction
- Kicking Horse River Drainage Area (1,850 km²)

Notes:

1. The existing Highway 95 crossing over the Kicking Horse River consists of two bridges: Bridge 1 over the main channel and Bridge 2 over the side channel. Two replacement bridges are proposed: (1) the Highway 95 bridge over the Kicking Horse River with a pier located on the tip of Gould's Island and (2) the Gould's Island bridge over the side channel to maintain access to buildings on Gould's Island.
2. Figures must be used in conjunction with the attached report and are subject to the limitations and conditions stated in the report.

1 : 40,000 metres (400 0 400 800)

1 : 500,000 metres (5000 0 5000 10000)

NAD 1983 UTM ZONE 11N

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

British Columbia Ministry of Transportation and Infrastructure
Highway 95 Bridges Replacement

Location Plan

Date:	Project:	Submitter:	Reviewer:
April 2022	5635-LP-HWY95	D. Kushner	K. Curtis

Figure 1

References:
1. Basemap and Hydrography from ESRI World Topography Map.
2. Photograph taken by David Kushner, P.Eng., Matrix Solutions Inc. on September 29, 2020.

Cross-section Information

Cross-section	Survey Date	Data Source
K1	2017	ToG Sediment Monitoring Program
K52	2017	ToG Sediment Monitoring Program
K2	2017	ToG Sediment Monitoring Program
K50	2017	ToG Sediment Monitoring Program
K3	2017	ToG Sediment Monitoring Program
K51	2017	ToG Sediment Monitoring Program
K4	2021	ToG Sediment Monitoring Program
K4a*	2020	MoTI Bathymetry
K10	2021	ToG Sediment Monitoring Program
K11	2021	ToG Sediment Monitoring Program
K11b	2021	ToG Sediment Monitoring Program
K5	2021	ToG Sediment Monitoring Program
K61	2013	ToG Sediment Monitoring Program
K6	2021	ToG Sediment Monitoring Program
K6a	2021	ToG Sediment Monitoring Program
K7	2021	ToG Sediment Monitoring Program
K7a	2021	ToG Sediment Monitoring Program
K62	2013	ToG Sediment Monitoring Program
K7b	2021	ToG Sediment Monitoring Program
K8	2021	ToG Sediment Monitoring Program
K53	2021	ToG Sediment Monitoring Program
K54	2021	ToG Sediment Monitoring Program
K54b	2013	ToG Sediment Monitoring Program
K9	2021	ToG Sediment Monitoring Program
K55	2021	ToG Sediment Monitoring Program

* Section K4a was added to the hydraulic model for this study. All other sections were used in the previous model (Matrix 2014).

ToG = Town of Golden
MoTI = British Columbia Ministry of Transportation

Legend

- Flow Direction
- Cross-section (K5) / River Station (1+971)
- Model Cross-sections (see Table of Cross-section Information)
- Proposed Bridges
- River Stationing

Notes:

1. The exact location of the WSC Station prior to 1974 is not known. Its exact location, also within the limits of the town, is not important for this study since there is a negligible change in drainage area throughout the town.
2. Figures must be used in conjunction with the attached report and are subject to the limitations and conditions stated in the report.

References:

1. Historical Cross-sections and photographs from Matrix Solutions Inc., 2021 Update Assessment of Sedimentation on the Kicking Horse River, Town of Golden, January 31, 2022.
2. 2020 bathymetry data provided by British Columbia Ministry of Transportation and Infrastructure.
3. 2019 Orthophoto provided by the Town of Golden.

1 : 3,000 metres (30 0 30 60) UTM83-11

1 : 10,000 metres (100 0 100 200) UTM83-11

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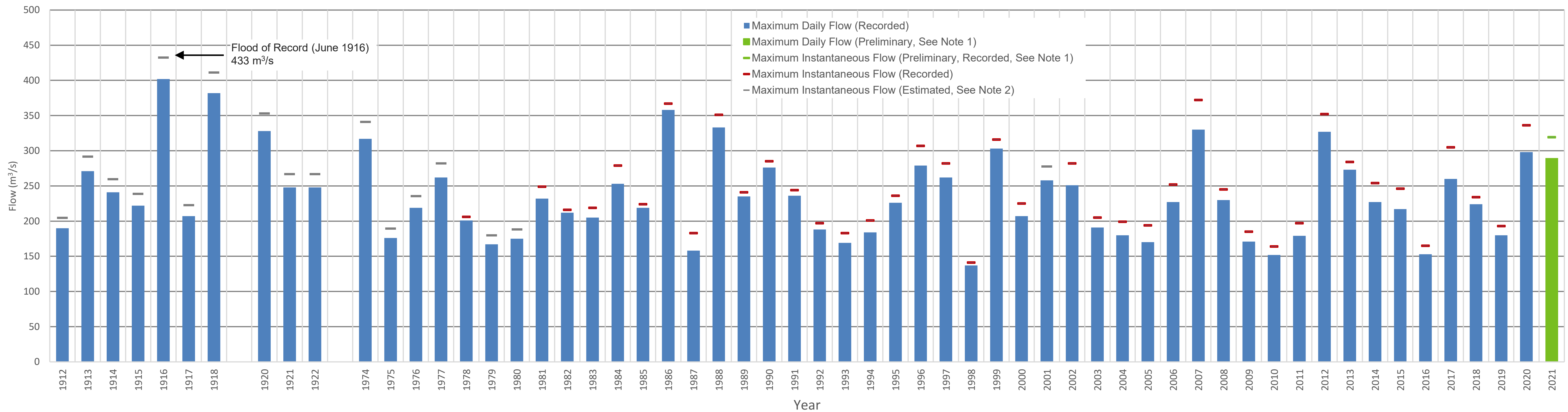
British Columbia Ministry of Transportation and Infrastructure
Highway 95 Bridges Replacement

Kicking Horse River - Plan and Hydraulic Model Sections

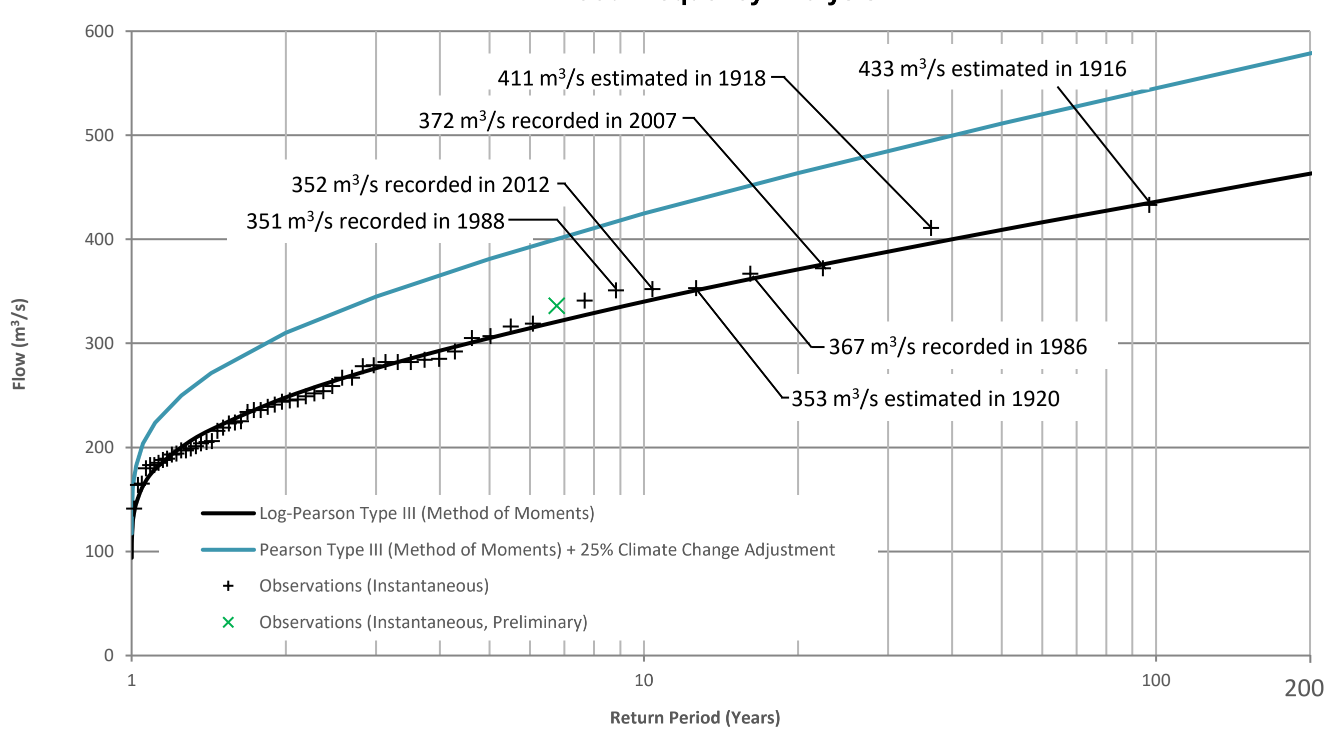
Date:	Project:	Submitter:	Reviewer:
April 2022	5635-SP-HWY95	D. Kushner	K. Curtis

Figure 2

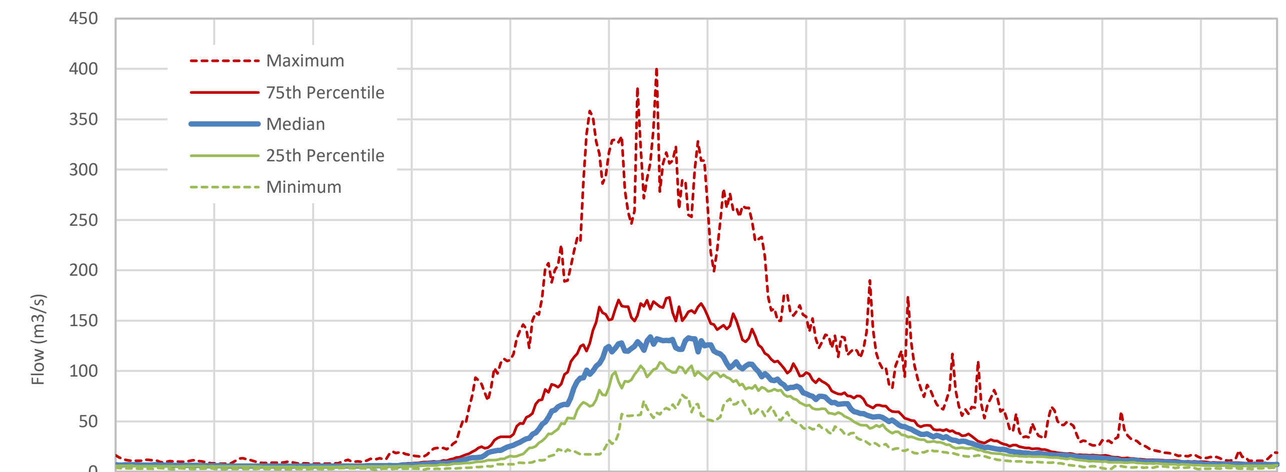
Annual Maximum Daily Average and Instantaneous Flow History



Flood Frequency Analysis



Annual Hydrographs and Monthly Flow Statistics



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min. Monthly[4] Flow	3	3	3	4	20	80	74	48	25	9	6	4
Mean Monthly[4] Flow	6	6	6	13	63	134	115	71	38	20	12	8
Max. Monthly[4] Flow	9	8	11	39	138	200	228	124	75	38	22	12

Typical River Ice Season (Ice Jam Potential) to Early April

High Flow From May to July

From Mid-Nov

See Figures 7 and 8 for Ice Conditions

Period of Least Risk for Instream Works July 16 To Aug 31 (See Note 5)

Flood	Instantaneous Flood Flow (m^3/s)
1:2-year	248
1:10-year	340
1:20-year	371
1:50-year	409
1:100 year	436
1:200-year	463
1:100-year design flood	**545**
1:200-year design flood	**580**

Note: the 1:200-year design flood flow includes a 25% increase for climate change. Other flood flows were computed from historical flood records and do not include climate change factors.

Notes:

1. Flow records are taken from Water Survey of Canada (WSC) hydrometric station 08NA006, located on the Kicking Horse River at the town of Golden. See Figure 2 for locations of the station over the years. Preliminary data from 2021 has not undergone quality control by WSC. There are 58 years of daily flow data from 1912 to 1918, 1920 to 1922, and 1974 to 2021, of which there are 41 years of instantaneous flow data.
2. When not available, maximum instantaneous flow is estimated from daily average flow by applying the median ratio of instantaneous to daily flow (1.076) for the floods that had instantaneous flow data. This results in a total maximum instantaneous flow record of 58 years of which 17 years (29%) were estimated.
3. Flooding typically occurs from May through June.
4. Monthly flow is the average of the daily flows within that month for a given year.
5. From Kootenay region (Region 4) periods of least risk for instream works by fish species, Ministry of Environment of British Columbia, 2009.
6. Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

Matrix Solutions Inc.
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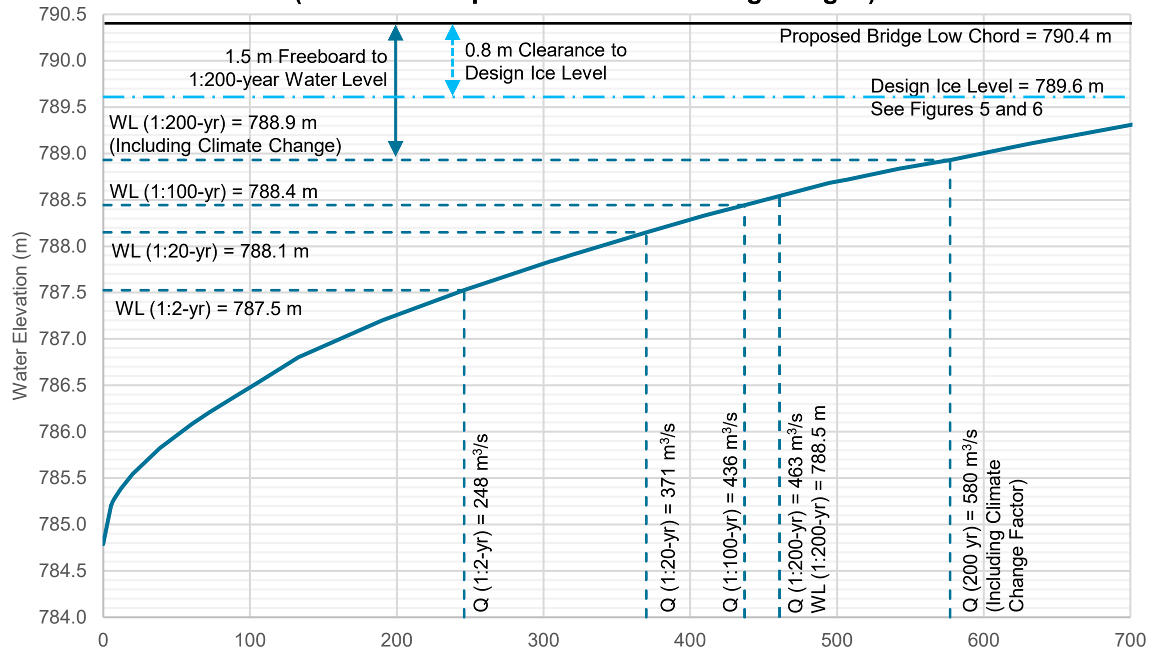
British Columbia Ministry of Transportation and Infrastructure
Highway 95 Bridges Replacement

Kicking Horse River
Hydrologic Analysis

Date:	Project:	Submitter:	Reviewer:
September 2022	5635-HA	K. Seasons	D. Kushner

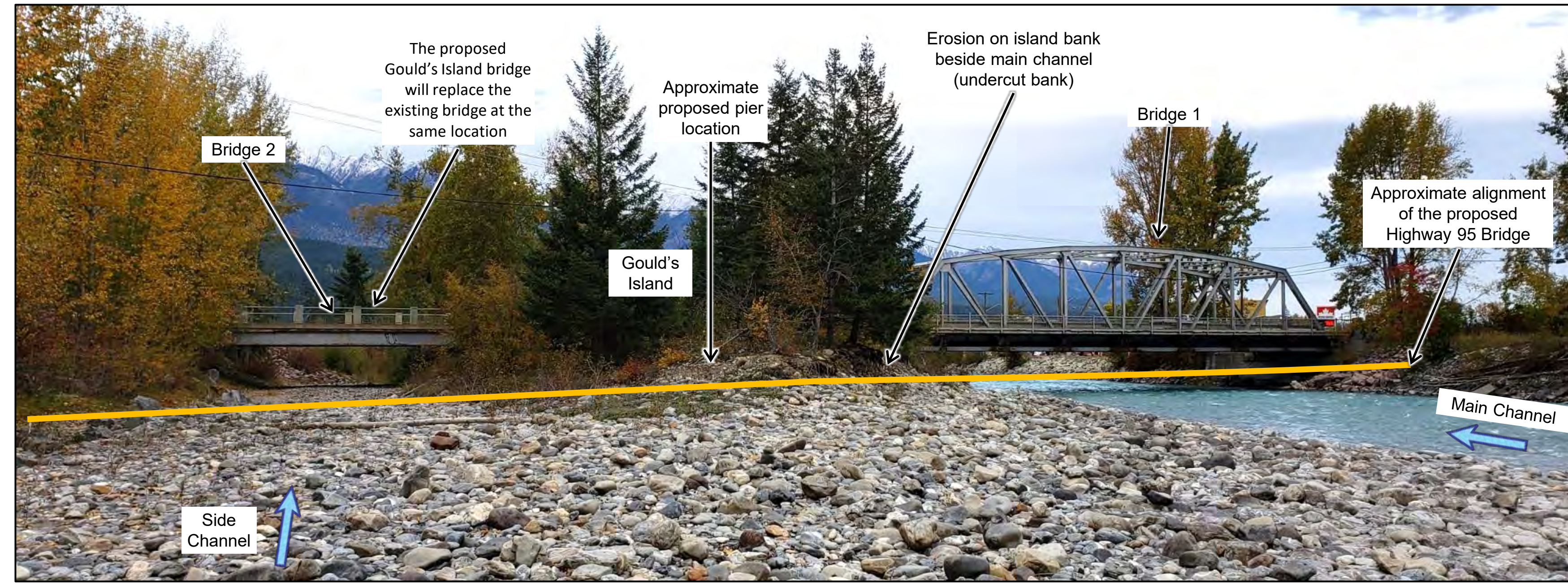
Figure 3

Rating Curve at Proposed Highway 95 Bridge (About 55 m Upstream of the Existing Bridges)



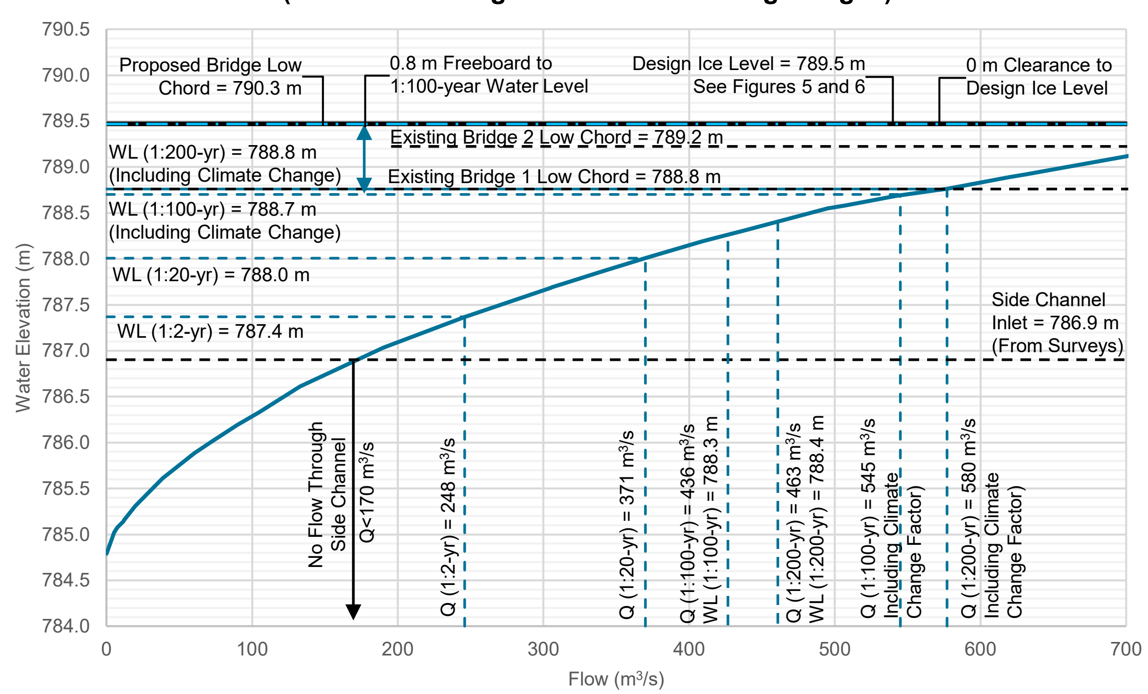
Note: The existing bridge elevations are shown on the Gould's Island Bridge rating curve because the Gould's Island bridge is at the same alignment as the existing bridges.

Existing Bridges



Existing bridges over the main channel and side channel of the Kicking Horse River. Photo by Matrix Solutions Inc. on September 29, 2019.

Rating Curve at Proposed Gould's Island Bridge (At The Same Alignment as the Existing Bridges)



High Water Level From 2012 Flood

Bridge 1 visible in background. The Town of Golden installed rubber dams and jersey barriers to provide temporary additional dike freeboard during the June 2012 flood. Photo taken by the Town of Golden on June 7, 2012.

Example of Woody Debris (On Island 650 m Upstream of the Bridges)

Stranded woody debris. Approximately 700 m upstream of the existing Highway 95 bridges. Photo by Matrix Solutions Inc. on September 1, 2020.

Mean Channel Velocity (m/s)

Flood	Main Channel at Proposed HWY 95 Bridge	Gould's Island Side Channel at Proposed Gould's Island Bridge
1:2-year	2.7	1.6
1:20-year	2.9	2.0
1:200-year design flood	**3.2**	**2.1**

Note: the 1:200-year design flood flow includes a 25% increase for climate change. Other flood flows were computed from flood records and do not include climate change factors.

Legend

Flow Direction

Notes:

1. Rating curves are shown at the upstream sections per Figure 2 for the proposed Highway 95 bridge and Gould's Island bridge crossings.
2. Bridge 1 and Bridge 2 low chord elevations surveyed by Stantec in September 2020.
3. Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

British Columbia Ministry of Transportation and Infrastructure

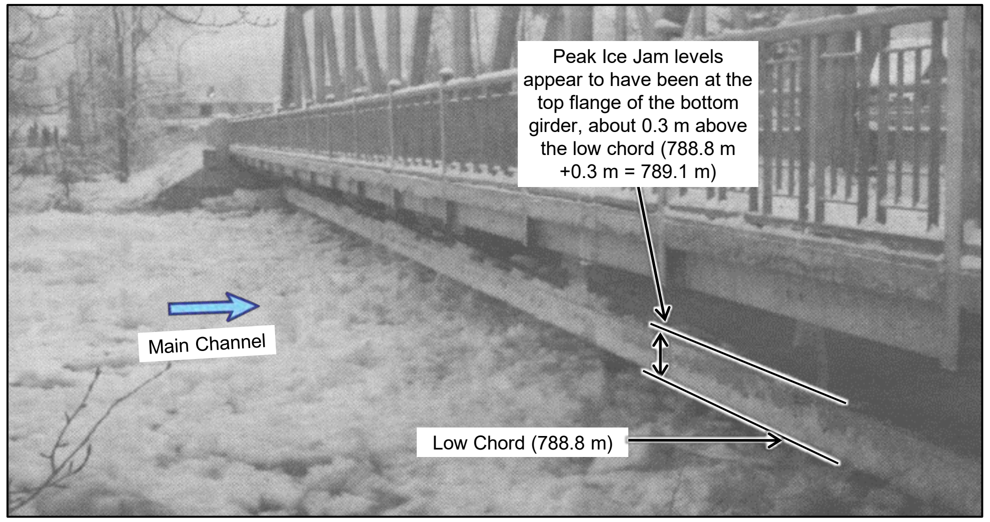
Highway 95 Bridges Replacement

Kicking Horse River
Hydraulic Model Results and Open-Water Photographs

Date:	Project:	Submitter:	Reviewer:
September 2022	5635-HA	K. Seasons	D. Kushner

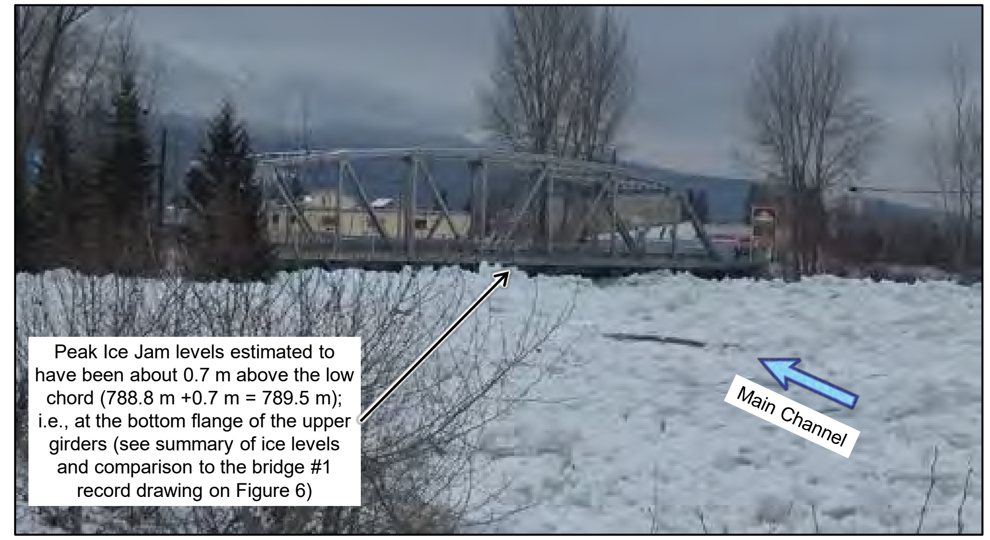
Figure 4

Ice Jam 1
Winter of 2004/05 – January 7, 2005



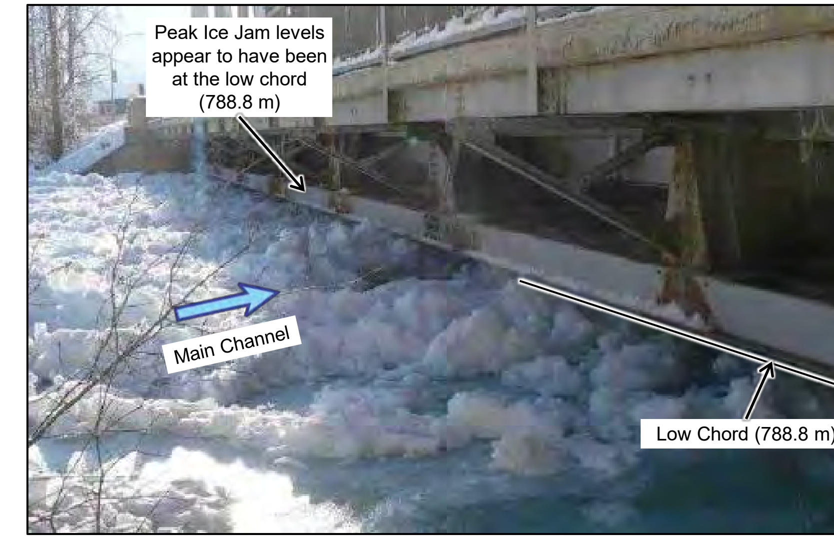
Looking at the upstream edge of Bridge 1. Photo by A. Lewandowski (Golden Star) taken on January 7, 2005 (the same day as the peak of the ice jam). The newspaper caption noted that "ice beat the underside of Golden's main bridge for close to 10 minutes".

Ice Jam 2 – Ice Jam of Record Winter of 2005/06 – December 20, 2005



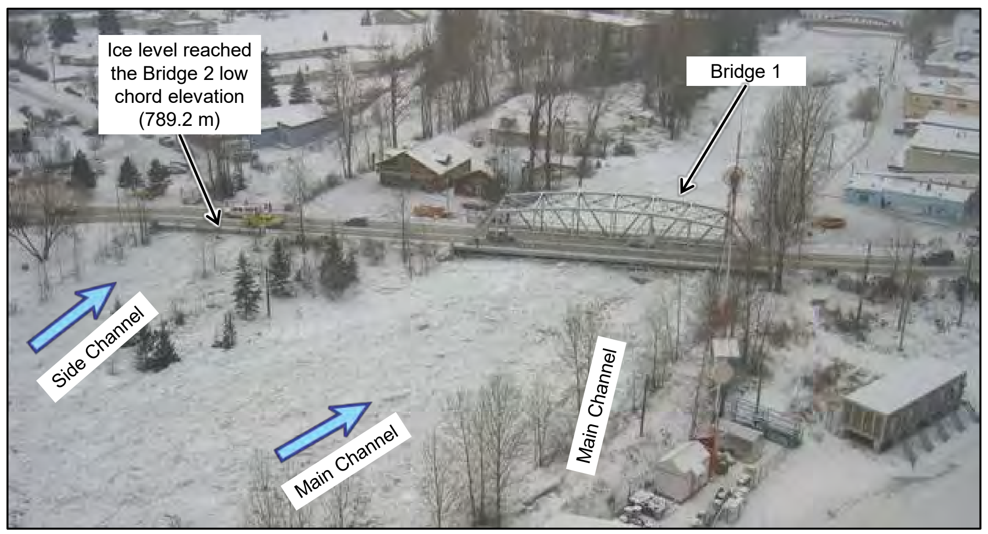
Looking at the upstream edge of Bridge 1. Photo by Paul Doyle, P.Eng. of BC Rivers Consulting (formerly of BC of Ministry of Forests Lands and Resource Development) taken on December 20, 2005 (the same day as the peak of the ice jam).

Ice Jam 3
Winter of 2014/15 – December 2, 2014



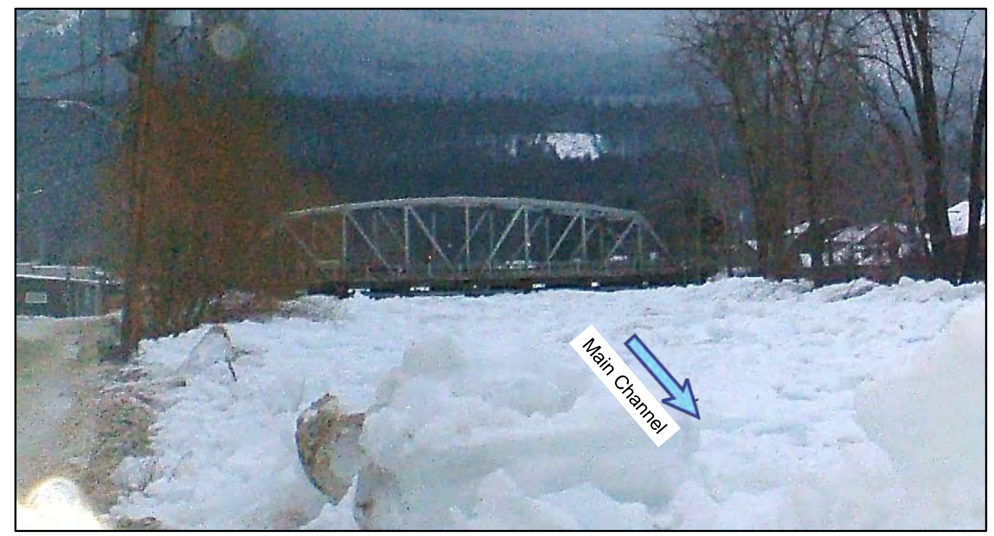
Looking at the upstream edge of Bridge 1. Photo by MoTI taken December 2, 2014 (the same day as the peak of the ice jam)

Ice Jam 2 – Ice Jam of Record
Winter of 2005/06 – December 20, 2005



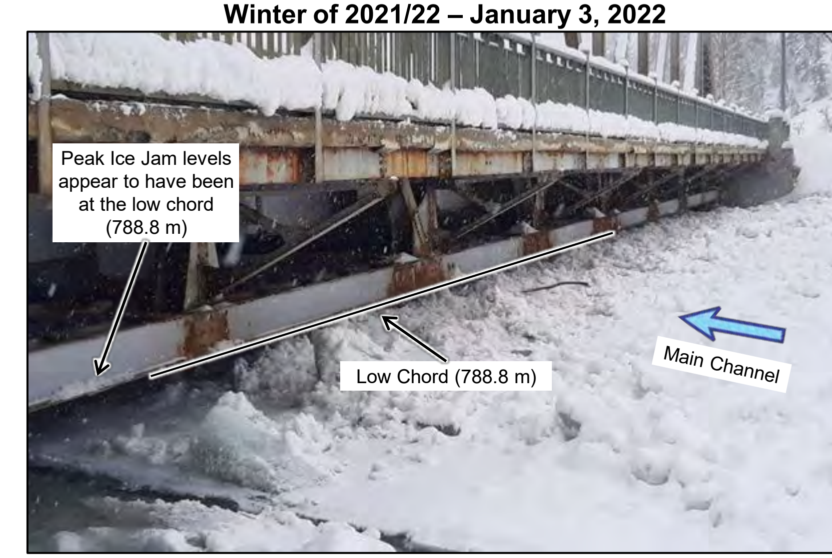
View of the Highway 95 bridges from a helicopter reconnaissance. Photo by Paul Doyle, P.Eng. of BC Rivers Consulting (formerly of BC of Ministry of Forests Lands and Resource Development) taken on December 20, 2005 (the same day as the peak of the ice jam).

Ice Jam 2 – Ice Jam of Record
Winter of 2005/06 – December 20, 2005



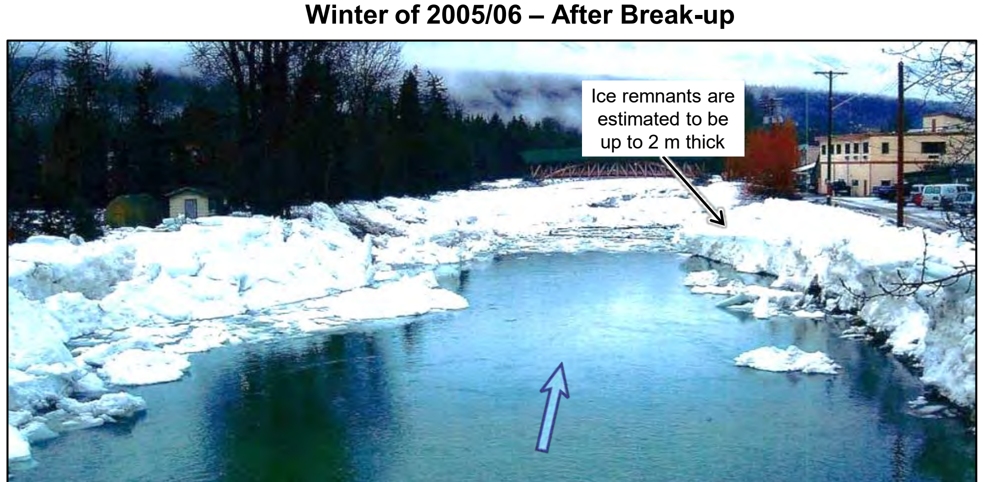
Looking at the downstream edge of Bridge 1. Photo by Paul Doyle, P.Eng. of BC Rivers Consulting (formerly of BC of Ministry of Forests Lands and Resource Development) taken on December 20, 2005 (the same day as the peak of the ice jam).

Ice Jam 4
Winter of 2021/22 – January 3, 2022



Looking at the upstream edge of Bridge 1. Photo by MoTI taken on January 3, 2022 (the same day as the peak of the ice jam). The ice jam initial occurred on December 31, 2021. Ice levels at the bridge rose to a peak on January 3, 2022.

Ice Jam 2 - Ice Jam of Record
Winter of 2005/06 – After Break-up



Looking downstream from Bridge 1. Photo provided by the Town of Golden following the December 20, 2005 ice jam (exact photo date unknown).

Four Highest Ice Levels Observed at The Bridges

Date	Winter of	Ice Jam ID	Peak Ice Level at Bridge 1
January 7, 2005	2004/05	Ice Jam 1	789.1 m
December 20, 2005 (Ice Jam of Record)	2005/06	Ice Jam 2	789.5 m
December 2, 2014	2014/15	Ice Jam 3	788.8 m
January 3, 2022	2021/22	Ice Jam 4	788.8 m

Also see Figure 6 for ice levels compared to the existing bridge cross section.

Notes:
1. This figure shows photographs of the four highest river ice levels observed at the bridges. Notes were added by Matrix Solutions Inc. to the photographs.
2. These ice jams initiated downstream of the bridges (not on the bridges) and extended upstream past the bridges from the accumulation of inflowing ice.
3. The highest ice level (Ice Jam 2) occurred during the December 20, 2005 ice jam event with an estimated ice level of 789.5 m at Bridge 1 (0.7 m above the low chord elevation). This ice jam included brash ice floes which are solid pieces of ice; for example, solid ice that forms along the borders of the river.
4. Bridge 1 and Bridge 2 low chord elevations surveyed by Stantec in September 2020.
5. Also see the summary of river ice levels compared to the Bridge 1 record drawing on Figure 6.
6. Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

Legend
Flow Direction

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

British Columbia Ministry of Transportation and Infrastructure
Highway 95 Bridges Replacement

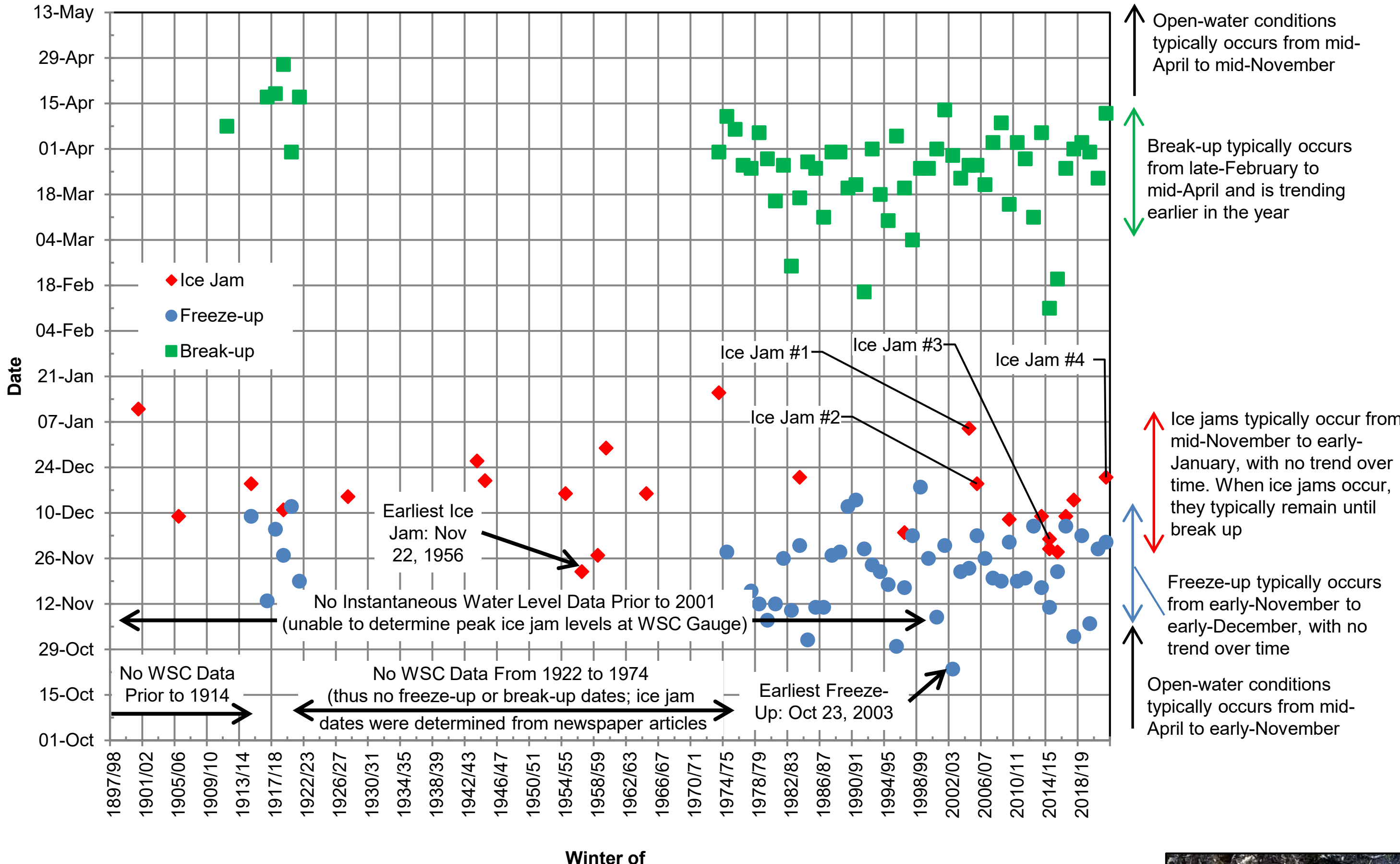
Kicking Horse River Ice Photographs of the Four Highest River Ice Levels Observed at the Bridges

Date:	Project:	Submitter:	Reviewer:
April 2022	5635-HA	K. Seasons	D. Kushner

Figure 5

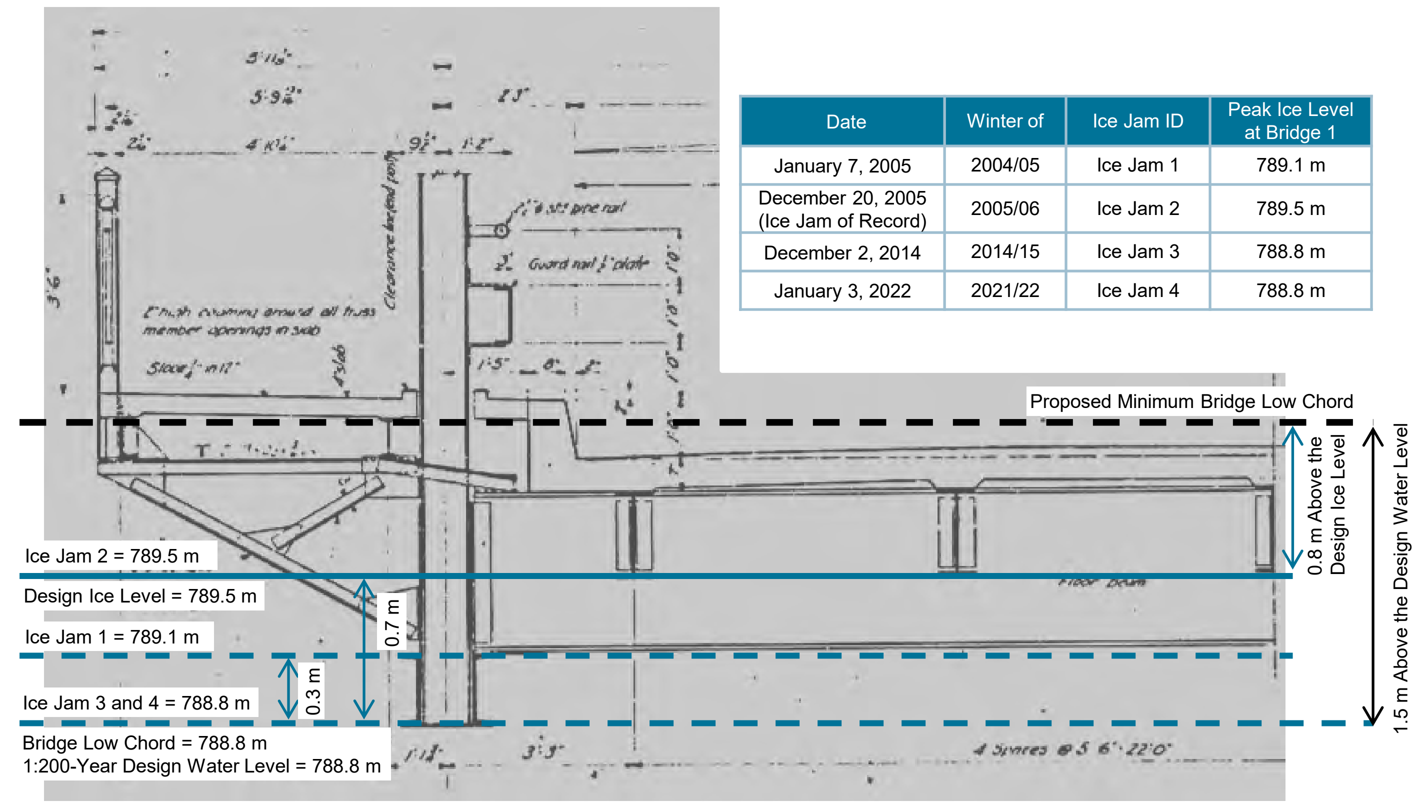
F:\5635\522\2020 HWY 95 Bridge Design\04 Report\90% DD\Figures\Archive\5635-522 Hydrotechnical Figures - HWY 95 Bridge V1.0.pptx

Freeze-Up, Ice Jam, and Break-Up Dates at Water Survey of Canada (WSC) Gauge (See Note 1)

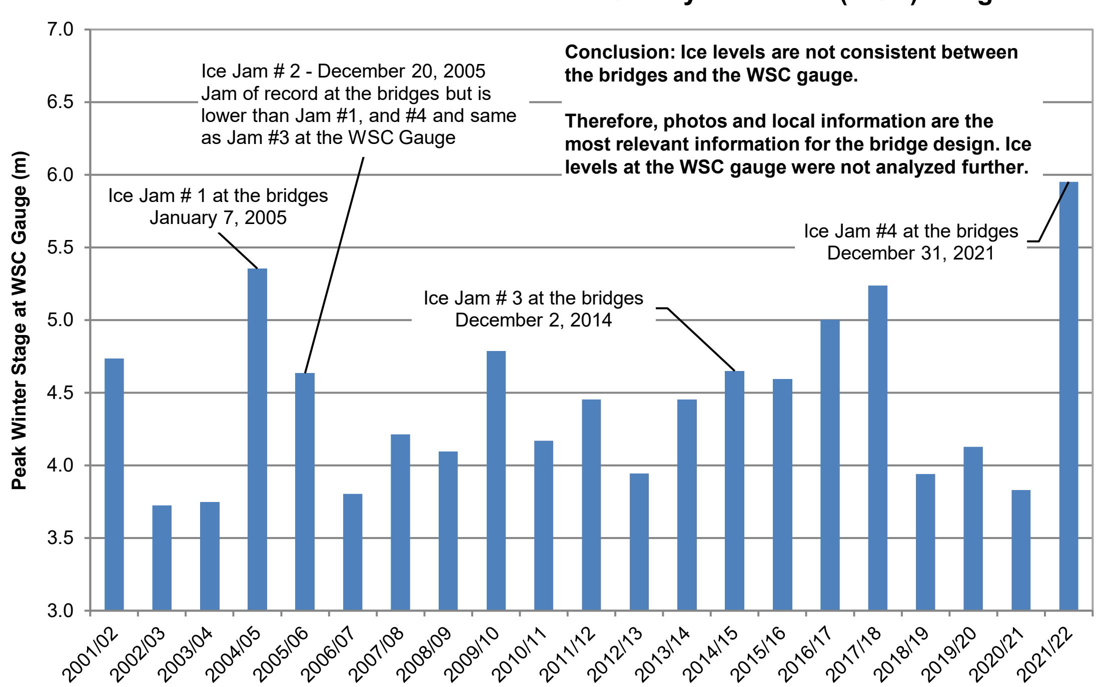


Four Highest Observed River Ice Levels Superimposed on the Bridge 1 Record Drawing

Date	Winter of	Ice Jam ID	Peak Ice Level at Bridge 1
January 7, 2005	2004/05	Ice Jam 1	789.1 m
December 20, 2005 (Ice Jam of Record)	2005/06	Ice Jam 2	789.5 m
December 2, 2014	2014/15	Ice Jam 3	788.8 m
January 3, 2022	2021/22	Ice Jam 4	788.8 m

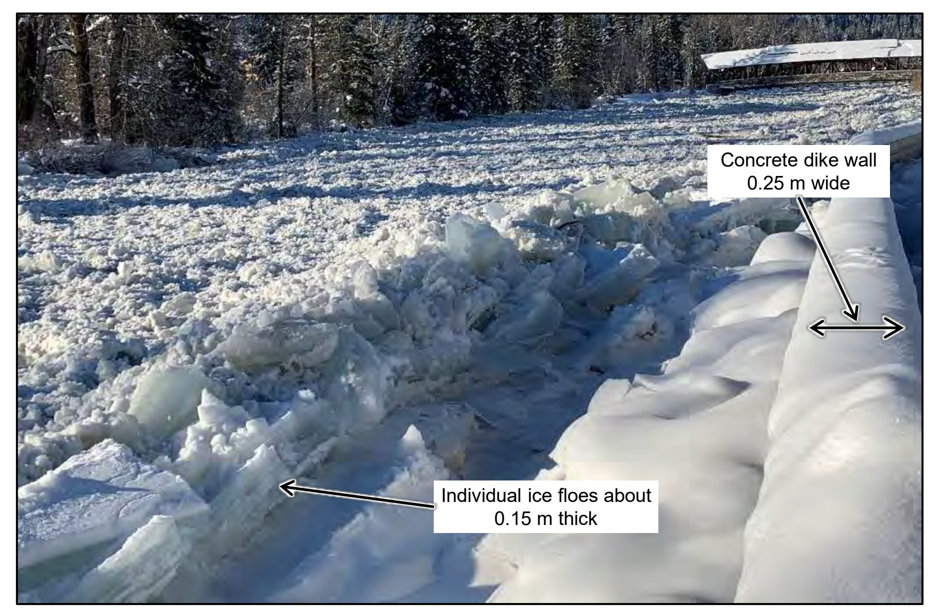


Maximum Annual Ice Levels at Water Survey of Canada (WSC) Gauge



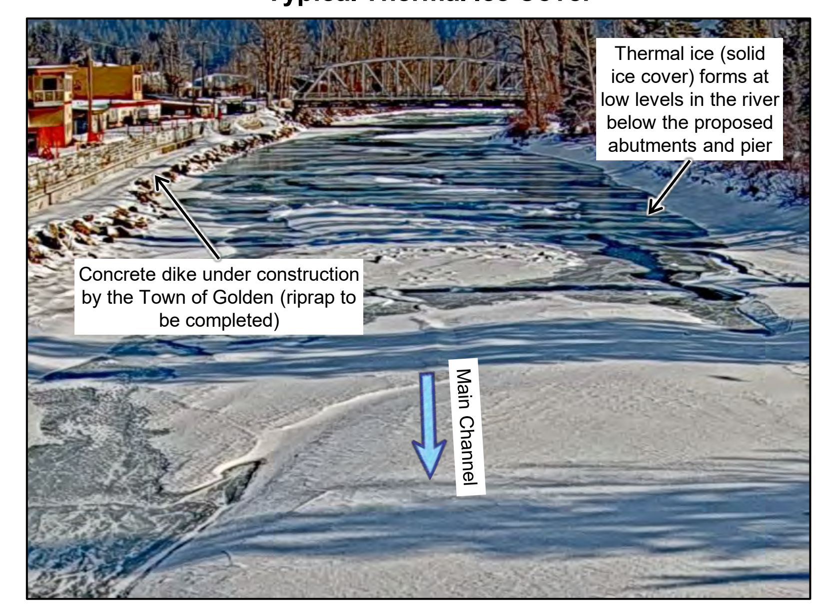
Note: there is no Instantaneous Water Level and thus no peak winter stage data prior to 2001

Typical Ice Floe Thickness



Typical example of ice floe size. Photo taken by MoTI on January 3, 2022.

Typical Thermal Ice Cover



Highway 95 Bridge 1 visible in background. Thermal ice has formed a solid ice cover on the river at low elevation. Photo taken by the Town of Golden on February 8, 2021.

Notes:

1. Freeze-up dates, break-up dates, and peak ice jam levels are from Water Survey of Canada (WSC) hydrometric station 08NA006, located on the Kicking Horse River at the town of Golden. Ice jam dates were determined from the WSC data and newspaper articles per Matrix 2018 *Kicking Horse River Ice Jam Study*.
2. Ice jam levels at Bridge 1 are estimated from the photographs on Figure 5 and scaled on the bridge record drawing relative to the low chord elevation.
3. Bridge 1 low chord elevation surveyed by Stantec in September 2020.
4. Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

Legend

Flow Direction

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

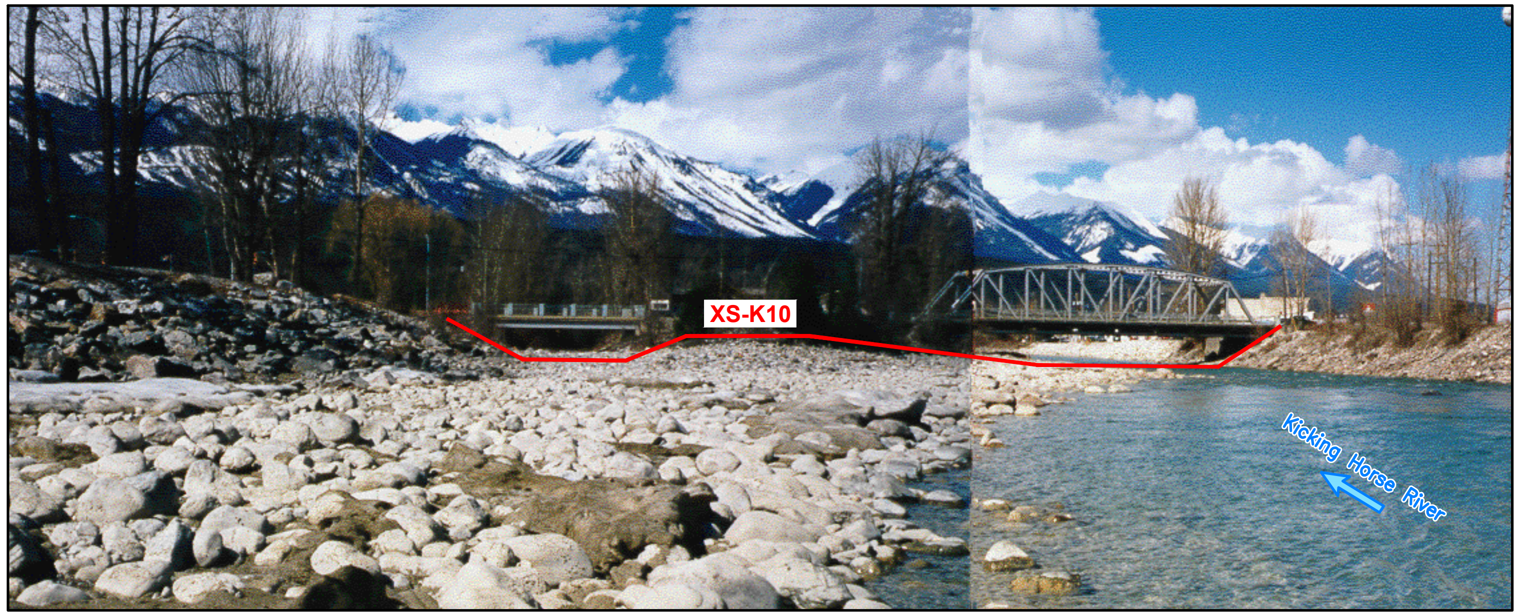
British Columbia Ministry of Transportation and Infrastructure

Highway 95 Bridges Replacement

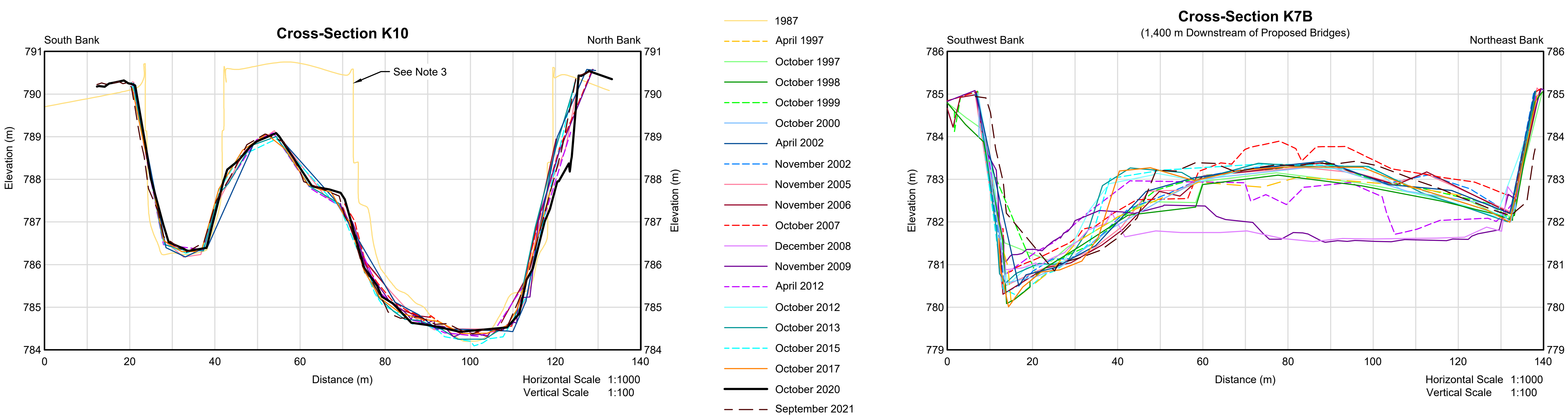
Kicking Horse River
Ice Analysis

Date:	Project:	Submitter:	Reviewer:
December 2022	5635-HA	K. Seasons	D. Kushner

Figure 6



Note: Photo taken looking upstream. Cross sections (below) are looking downstream.



Notes:

1. The comparison of cross-sectional surveys at the bridges (K10) shows that the river bed is stable and not subject to degradation or aggradation upstream of and at the proposed bridge locations to about 650 m downstream (near 7th Street North; see Figure 2). The river is subject to aggradation within the gravel bars (about 650 m downstream of the bridges to the Columbia River) as shown on section K7B.
2. Cross-section locations shown on Figure 2.
3. The April 1997 survey is on / under the bridges. Other surveys were upstream of the bridges.
4. Figures must be used in conjunction with the attached report and are subject to the limitations and conditions stated in the report.

Reference:

1. Historical Cross-sections and photographs from Matrix Solutions Inc., 2021 Update Assessment of Sedimentation on the Kicking Horse River, Town of Golden, January 31, 2022.
2. 2020 cross-section from combined 2016 LiDAR and 2020 survey data provided by Ministry of Transportation and Infrastructure.

1:100 metres
1 0 1 2

1 : 1,000 metres
10 0 10 20

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

British Columbia Ministry of Transportation and Infrastructure
Highway 95 Bridges Replacement

Kicking Horse River
Historical Cross-sections

Date: April 2022	Project: 5635-XS-HWY95	Submitter: D. Kushner	Reviewer: K. Curtis

Figure 7

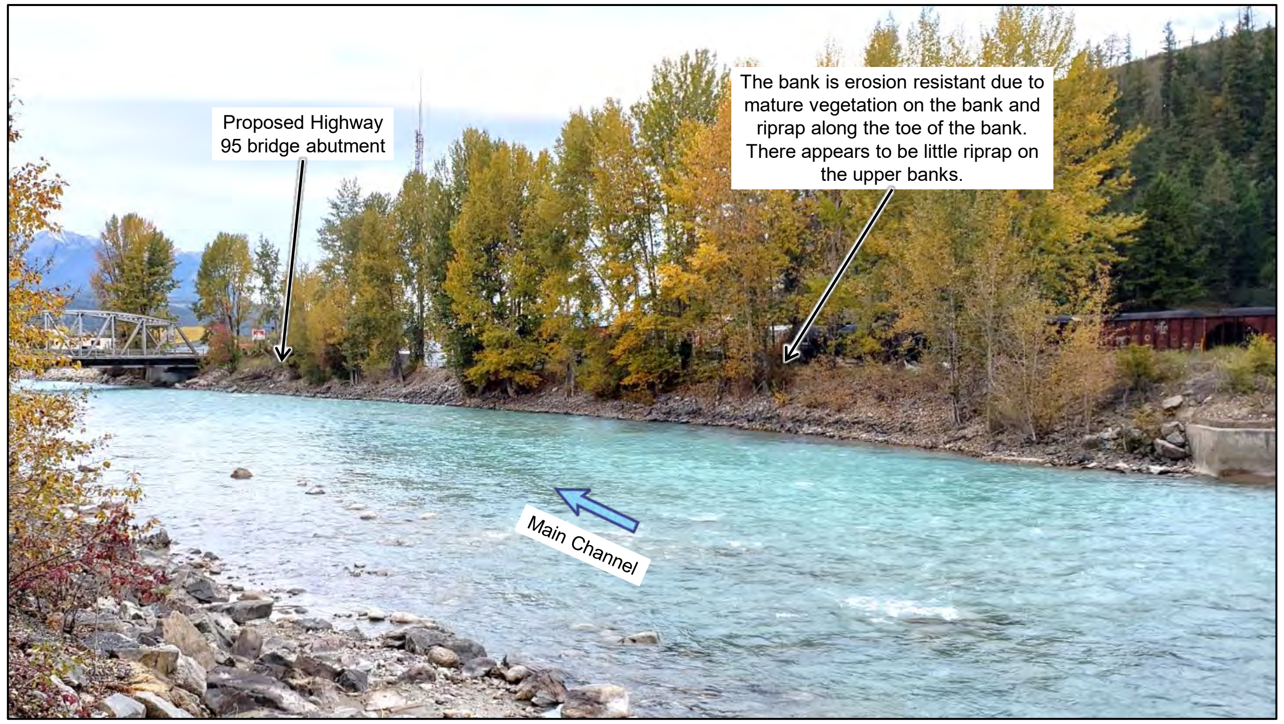


Photo 1: Right (north) bank upstream of Bridge 1. Photo taken September 29, 2019 by Matrix Solutions Inc.

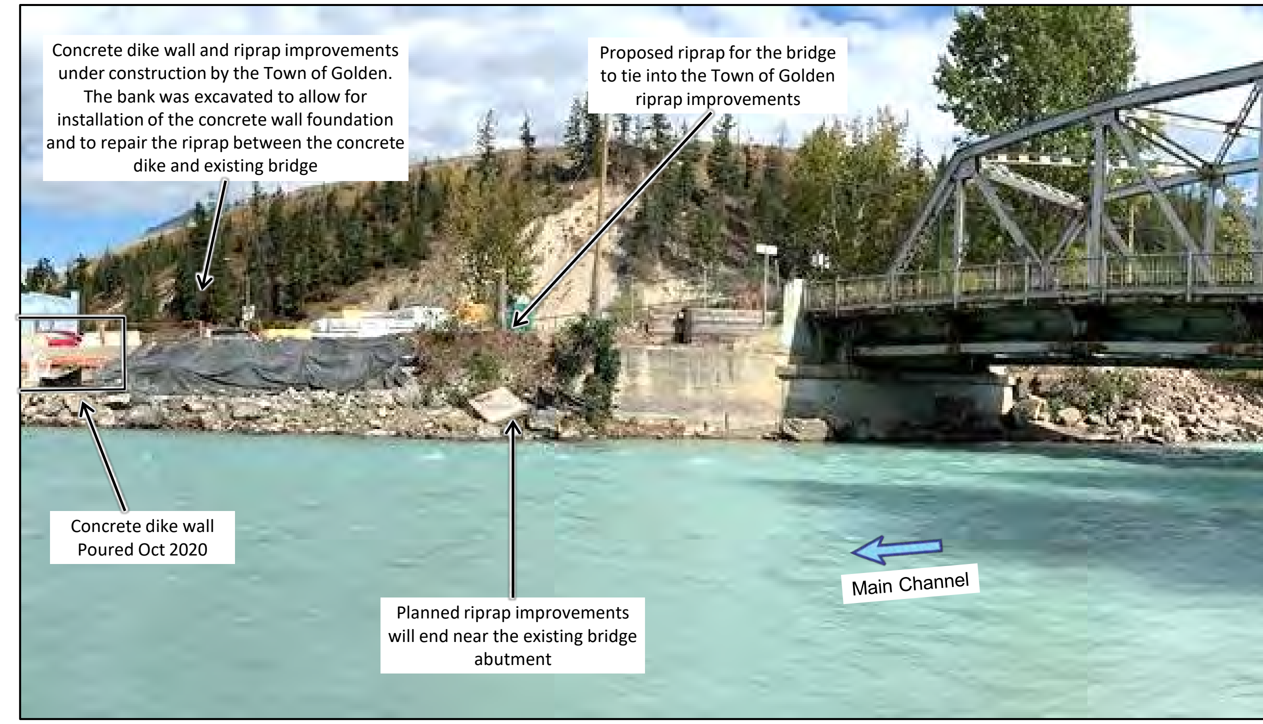


Photo 2: Right (north) bank downstream of Bridge 1. Photo taken on September 09, 2020 by Stantec.

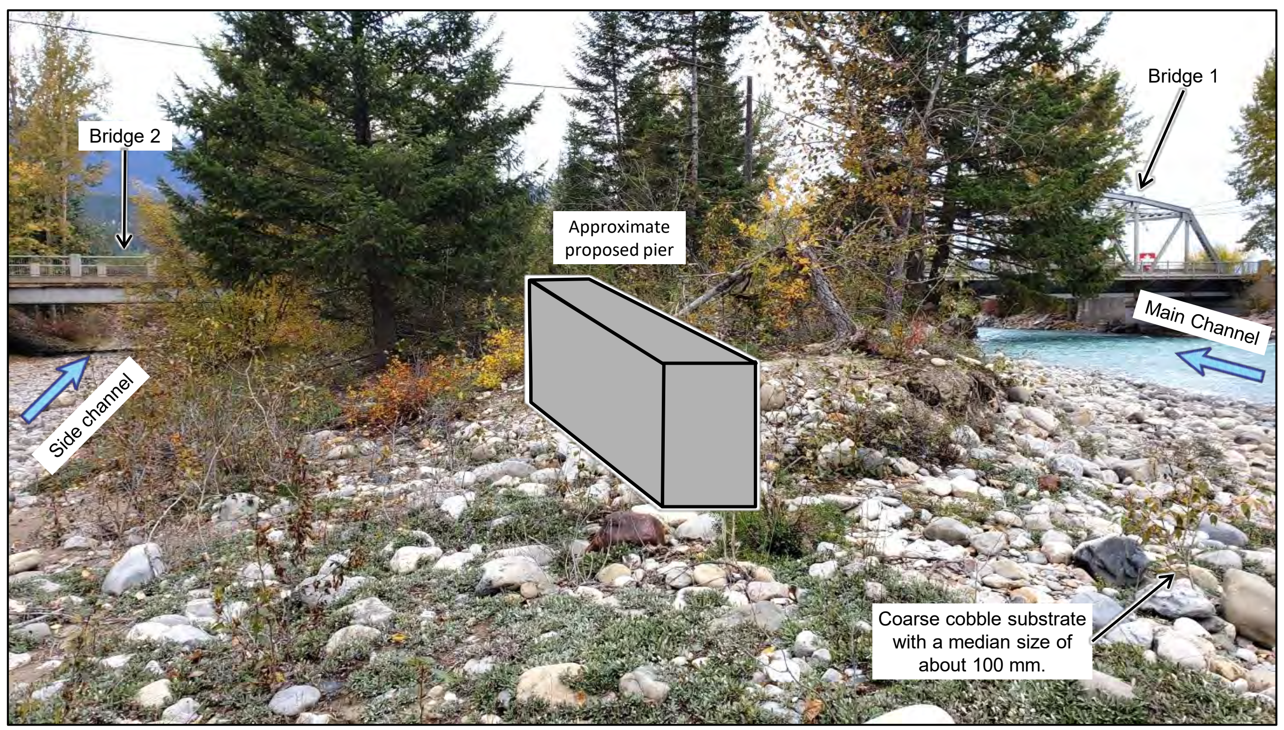


Photo 3: Approximate pier configuration on the upstream tip of Gould's Island. Photo taken on September 29, 2019 by Matrix Solutions Inc.

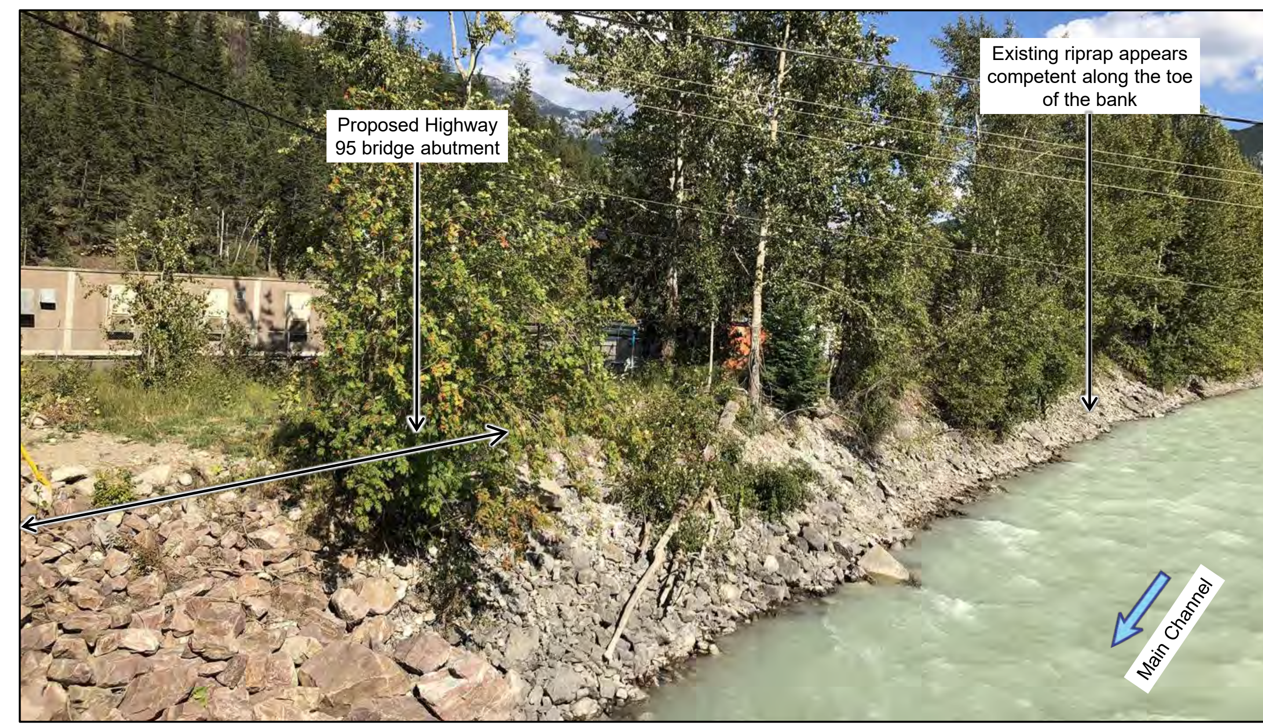


Photo 4: Right (north) bank upstream of Bridge 1. Photo taken on August 27, 2020 by Stantec.

Legend

Flow Direction

Notes:

1. Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

Matrix Solutions Inc.
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British Columbia Ministry of Transportation and Infrastructure

Highway 95 Bridges Replacement

Kicking Horse River Photographs of Existing Banks (1 of 2)

Date:	Project:	Submitter:	Reviewer:
December 2022	5635-HA	K. Seasons	D. Kushner

Figure 8

F:\5635\522\2020 HWY 95 Bridge Design\04 Report\90% DD\Figures\Archive\5635-522 Hydrotechnical Figures - HWY 95 Bridge V1.0.pptx

Photo 5: Downstream of Bridge 2. Photo taken on October 22, 2020 by Stantec.

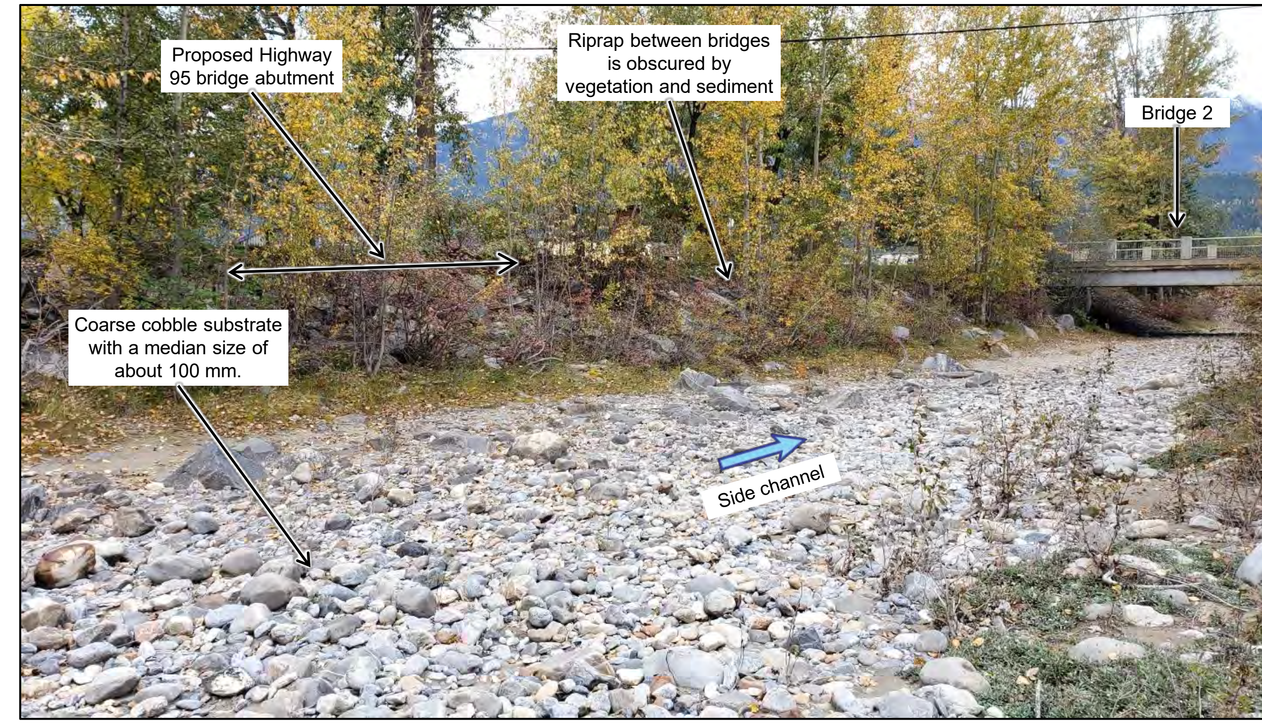


Photo 6: Left (south) bank upstream of Bridge 2 at proposed Highway 95 bridge abutment. Photo taken on September 29, 2019 by Matrix Solutions Inc.

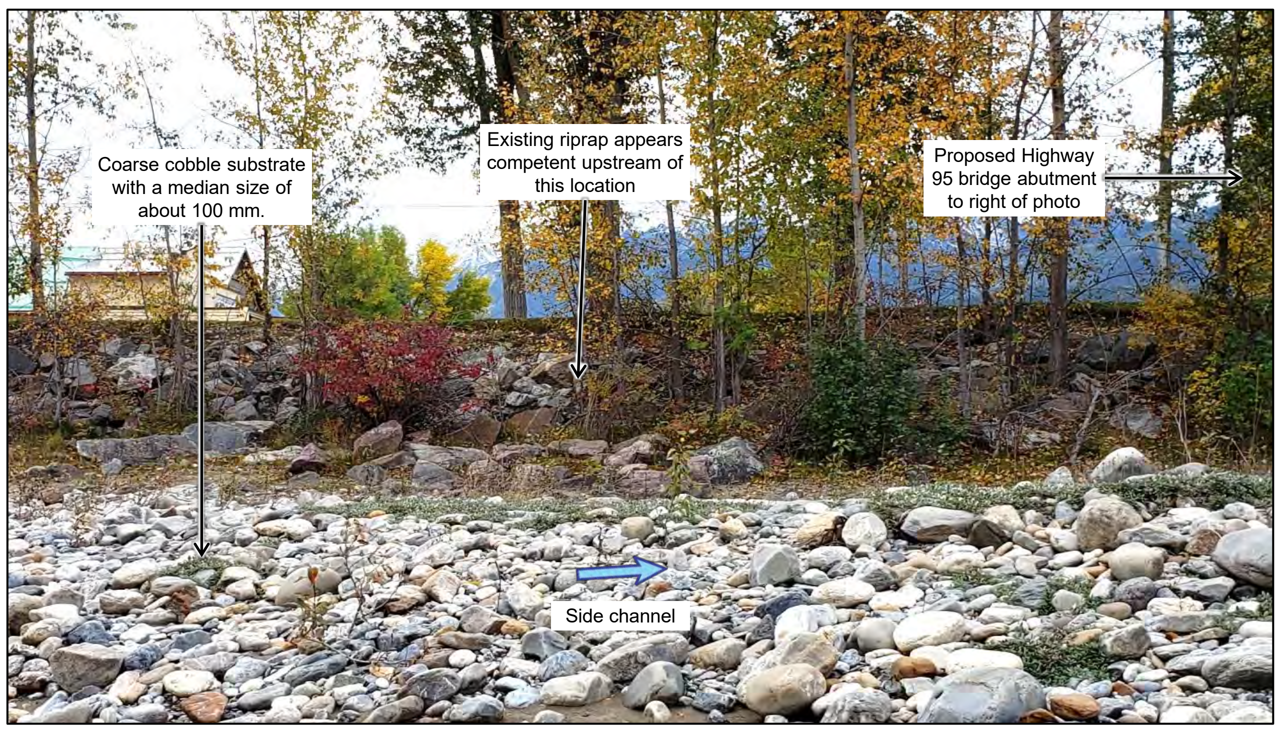


Photo 7: Right (north) bank upstream of Bridge 1. Photo taken on September 29, 2019 by Matrix Solutions Inc.

Photo 8: Left (south) bank upstream of proposed Highway 95 bridge abutment. Photo taken on September 29, 2019 by Matrix Solutions Inc.

Legend

Flow Direction

Notes:

1. Figure(s) must be used in conjunction with the attached report and is subject to the limitations and conditions stated in the report.

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

British Columbia Ministry of Transportation and Infrastructure

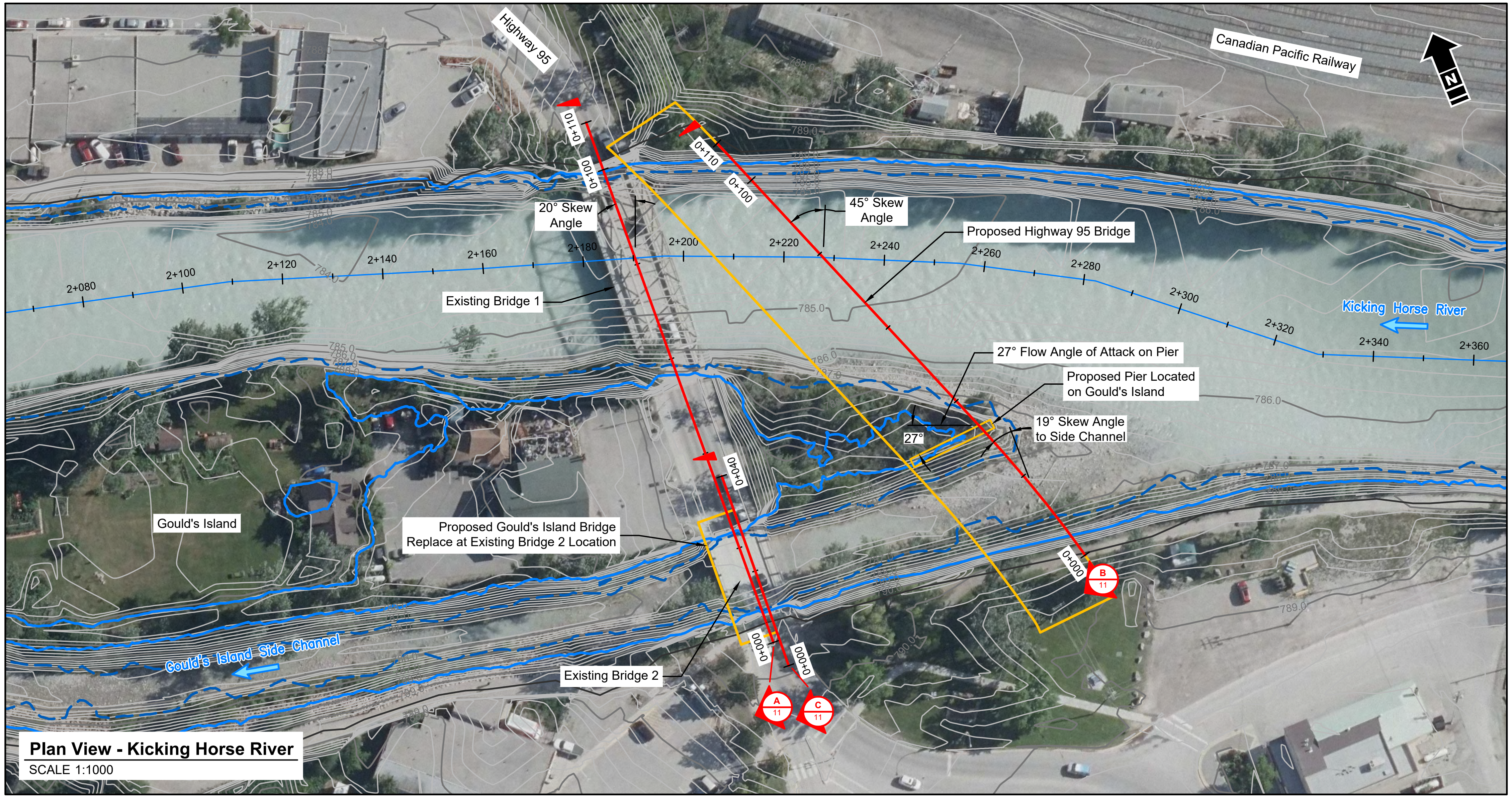
Highway 95 Bridges Replacement

Kicking Horse River Photographs of Existing Banks (2 of 2)

Date:	Project:	Submitter:	Reviewer:
September 2022	5635-HA	K. Seasons	D. Kushner

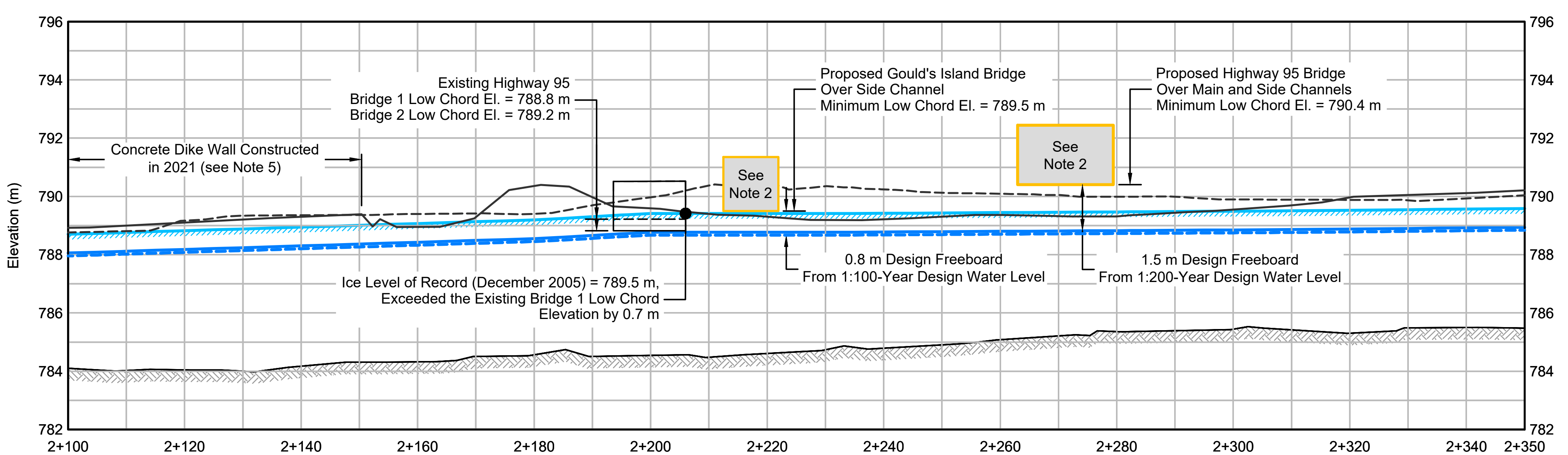
Figure 9

F:\5635\522\2020 HWY 95 Bridge Design\04 Report\90% DD\Figures\Archive\5635-522 Hydrotechnical Figures - HWY 95 Bridge V1.0.pptx



Plan View - Kicking Horse River

SCALE 1:1000



Profile - Kicking Horse River

Horizontal Scale 1:1000
Vertical Scale 1:200

Notes:

1. Existing and proposed water levels were computed by the hydraulic model. The proposed bridges do not cause backwater compared to existing conditions (the existing bridges also cause negligible backwater).
2. Geometry of the proposed bridges to be confirmed in subsequent design phases. Simplified geometry shown herein. The most upstream edge of the bridges are projected onto the profile.
3. Bridge 1 and Bridge 2 low chord elevations surveyed by Stantec in September 2020.
4. The right and left dike crests are projected perpendicular to the Kicking Horse River alignment and therefore are not shown relative to projected bridge locations.
5. The right dike crest shows the constructed top of the concrete wall which was completed by the Town of Golden in May 2021.
6. Figures must be used in conjunction with the attached report and are subject to the limitations and conditions stated in the report.

References:

1. 2019 Orthophoto provided by the Town of Golden.
2. Proposed bridge alignment and pier location from drawing file provided by COWI on April 19, 2022.
3. Existing ground surface (contours and top of dikes) from combined 2016 LiDAR and 2020 survey data provided by British Columbia Ministry of Transportation and Infrastructure unless otherwise noted.
4. Top of Concrete dike wall from "Issued for Record" Drawing by Read Jones Christoffersen dated June 25, 2021.

Legend

- Existing Major Contour (1.0 m interval)
- Existing Minor Contour (0.2 m interval)
- Flow Direction
- River Stationing, Measured from the Confluence of Kicking Horse River and Columbia River
- Proposed Bridge Alignment
- Design Ice Level
- 1:200-year Design Water Level (see Note 1)
- 1:100-year Design Water Level
- 1:20-year Design Water Level
- 1:2-year High Water Mark (see Note 1)
- Right (North) Dike Crest
- Left (South) Dike Crest

1:200 metres 2 0 2 4

1 : 1,000 metres 10 0 10 20

UTM83-11

Matrix Solutions Inc.
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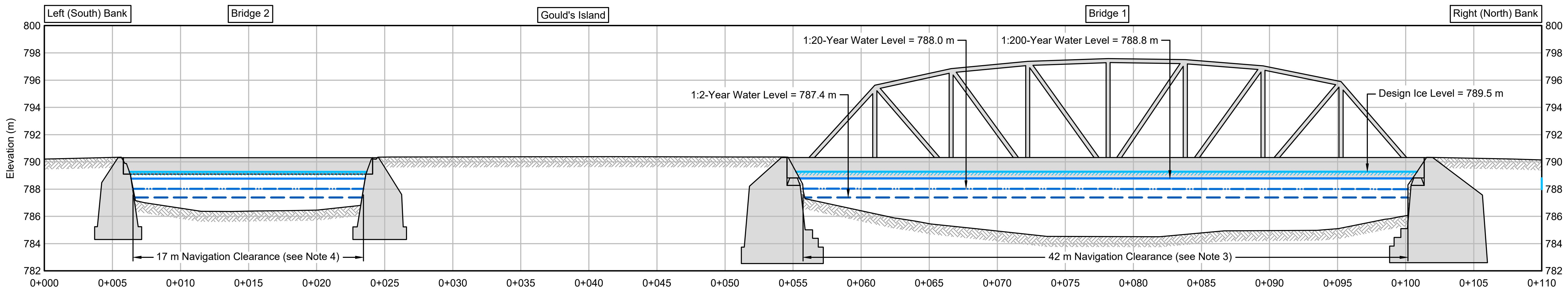
British Columbia Ministry of Transportation and Infrastructure
Highway 95 Bridges Replacement

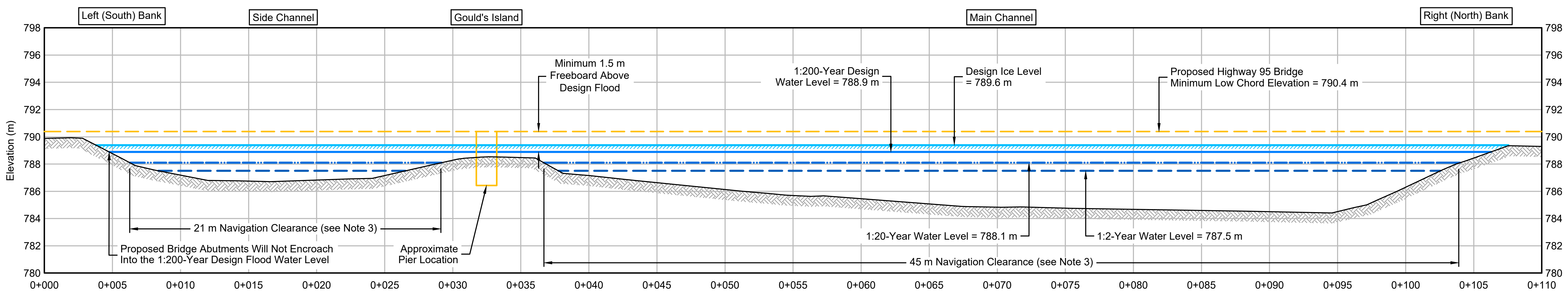
Existing and Proposed Bridges Plan and Profile

Date: September 2022	Project: 5635-SP-HWY95	Submitter: D. Kushner	Reviewer: K. Curtis

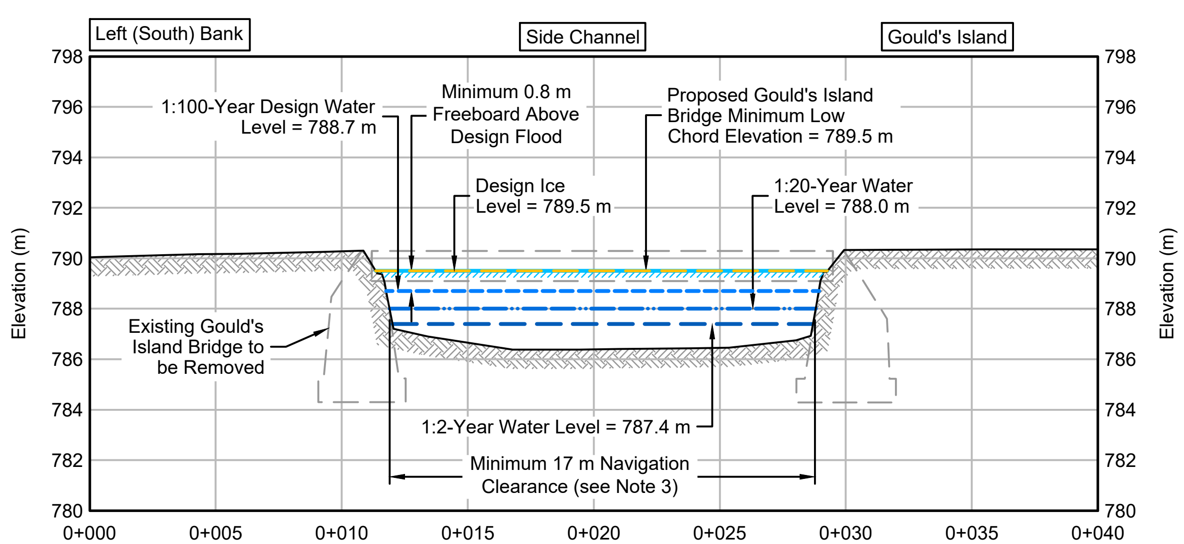
Figure 10



A / 10 **Section - Existing Highway 95 Bridges**
Scale 1:300



B / 10 **Section - Proposed Highway 95 Bridge**
Scale 1:300



C / 10 **Section - Proposed Gould's Island Bridge**
Scale 1:300

	Existing Bridge 1	Existing Bridge 2	Proposed Highway 95 Bridge	Proposed Gould's Island Bridge	CP Rail Bridge[2]
Low Chord Elevation (m)[1]	788.8	789.2	790.4	789.5	785.5
Water Levels (m)[3]					
1:100-Year	788.4	788.4	788.4	788.3	783.7
1:20-Year	788.0	788.0	788.1	788.0	783.5
1:2-Year	787.4	787.4	787.5	787.4	783.0
Clearances (m)[1]					
1:100-Year	0.4	0.8	2.0	1.2	1.8
1:20-Year	0.8	1.2	2.3	1.5	2.0
1:2-Year	1.4	1.8	2.9	2.1	2.5

[1] The table shows the clearances of existing bridges and the minimum low chord elevations and minimum clearances of the proposed bridges.

[2] The CP Rail Bridge clearances are shown for comparison.

[3] The flood water levels shown in the table are computed from historical data and do not include climate change factors, whereas the 1:200-Year and 1:100-Year design floods (shown on the sections) include a 25% climate change factor (increase).

References:

1. Existing ground surface from combined 2016 LiDAR and 2020 survey data provided by Ministry of Transportation and Infrastructure.
2. Existing highway bridge geometry from Government of British Columbia Department of Public Works, Victoria, Drawing No. Bridges 318-8, Revised Sept. 11/51.
3. Proposed bridge pier location from CAD file "BRIDGE 1 GA-1_2022-04-19.dwg" provided by COWI on April 19, 2022.

Notes:

1. Existing and proposed water levels were computed by the hydraulic model. The proposed bridges do not cause backwater compared to existing conditions (the existing bridges also cause negligible backwater).
2. Existing ground surface from combined 2016 LiDAR and 2020 survey data provided by British Columbia Ministry of Transportation and Infrastructure unless otherwise noted.
3. The horizontal clearance is measured perpendicular to the flow; i.e., the horizontal distances on the sections on this drawing were adjusted by the skew angles on Figure 10. The existing Bridge 2 and Proposed Gould's Island Bridge have a skew angle of 0°.
4. Bridge 1 and Bridge 2 low chord elevations surveyed by Stantec in September 2020.
5. Riprap design will be refined in the next stages of design in coordination with the structural and geotechnical engineers.
6. Figures must be used in conjunction with the attached report and are subject to the limitations and conditions stated in the report.

1 : 300 metres

Matrix Solutions Inc.
ENVIRONMENT & ENGINEERING

British Columbia Ministry of Transportation and Infrastructure
Highway 95 Bridges Replacement

Existing and Proposed Bridges Cross-sections and Clearances

Date: September 2022	Project: 5635-SP-HWY95	Submitter: D. Kushner	Reviewer: K. Curtis

Figure 11

APPENDIX A
HEC-RAS Input and Output Data

```
                    HEC-RAS HEC-RAS 5.0.7 March 2019
                     U.S. Army Corps of Engineers
                    Hydrologic Engineering Center
                          609 Second Street
                          Davis, California

            X     X  XXXXXX    XXXX        XXXX       XX      XXXX
            X     X  X        X    X      X   X     X  X    X
            X     X  X        X           X   X    X    X   X
            XXXXXXX  XXXX     X      XXX  XXXX     XXXXXX    XXXX
            X     X  X        X           X  X     X    X        X
            X     X  X        X    X      X   X    X    X        X
            X     X  XXXXXX    XXXX       X    X   X    X   XXXXX
```

****

PROJECT DATA
Project Title: 5635-522 KHR HWY 95 Bridge Model
Project File : 5635-522KHRHModel.prj
Run Date and Time: 2022-06-14 11:32:13 AM

Project in SI units

Project Description:
KHR HWY 95 Bridge Replacement - New Bridges, Sections updated to latest survey data, thalweg adjusted to match actual length

****

PLAN DATA

Plan Title: Final Model - 2022 Updates
Plan File : F:\5635\522\2020 HWY 95 Bridge Design\05 Design\01 HEC-RAS\08 2022 Bridge Updates\5635-522KHRHModel.p54

Geometry Title: Proposed Conditions - 2022 Updates
Geometry File : F:\5635\522\2020 HWY 95 Bridge Design\05 Design\01 HEC-RAS\08 2022 Bridge Updates\5635-522KHRHModel.g18

Flow Title   : Golden Flows 2022
Flow File   : F:\5635\522\2020 HWY 95 Bridge Design\05 Design\01 HEC-RAS\08 2022 Bridge Updates\5635-522KHRHModel.f01

Plan Description:
April 25 - 2022
K. Seasons

5635-522

KHR HWY 95 Bridge Replacement,
Proposed Conditions
New bridge location, vertical datum for all terrain is GVD28.

Model updates include 2021 survey sections, new bridge geometry (pier, clearances).

```
Plan Summary Information:
Number of:  Cross Sections =   31    Multiple Openings  =    0
            Culverts       =    0    Inline Structures  =    0
            Bridges        =    4    Lateral Structures =    0

Computational Information
    Water surface calculation tolerance  =  0.003
    Critical depth calculation tolerance =  0.003
    Maximum number of iterations         =  20
    Maximum difference tolerance         =  0.1
    Flow tolerance factor                =  0.001

Computation Options
    Critical depth computed only where necessary
    Conveyance Calculation Method: At breaks in n values only
    Friction Slope Method:         Average Conveyance
    Computational Flow Regime:     Subcritical Flow
```

****

FLOW DATA

Flow Title: Golden Flows 2022
Flow File : F:\5635\522\2020 HWY 95 Bridge Design\05 Design\01 HEC-RAS\08 2022 Bridge Updates\5635-522KHRHModel.f01

```
Flow Data (m3/s)
*********************************************************************************
*********************************************************************************
*******
* River          Reach           RS      *      2-Yr-Flood      5-Yr-Flood
10-Yr-Flood     20-Yr-Flood     50-Yr-Flood  100 - Yr-Flood    200-Yr Flood
500-Yr Flood *
* Columbia       US              2       *             428             528
    586             638             698             741             777
861 *
* Columbia       Downstream      4       *             673             834
```

```
    937            1035            1159            1255            1347
1493 *
* Thalweg_AllSurveThalweg_AllSurve3583    *            248             305
    340             371             409             436             463
632 *
**********************************************************************************
**********************************************************************************
*******
**********************************************************************************
**********************************************************************************
*******
* River           Reach           RS      *         AE Q200      AE CC Q200MSI Best
Fit Q200     MSI CC Q200  2-Yr Matrix CC 10-Yr Matrix CC 20-Yr Matrix CC 50-Yr
Matrix CC *
* Columbia        US              2       *            777             777
    777             777             428             528             586
638 *
* Columbia        Downstream      4       *           1347            1347
   1347            1347             673             834             937
1035 *
* Thalweg_AllSurveThalweg_AllSurve3583    *            495             619
    465             579             310             425             464
511 *
**********************************************************************************
**********************************************************************************
*******

Boundary Conditions
**********************************************************************************
*********************
* River           Reach           Profile         *            Upstream
     Downstream    *
**********************************************************************************
*********************
* Columbia        Downstream      2-Yr-Flood      *
  Normal S = 0.001 *
* Columbia        Downstream      5-Yr-Flood      *
  Normal S = 0.001 *
* Columbia        Downstream      10-Yr-Flood     *
  Normal S = 0.001 *
* Columbia        Downstream      20-Yr-Flood     *
  Normal S = 0.001 *
* Columbia        Downstream      50-Yr-Flood     *
  Normal S = 0.001 *
**********************************************************************************
*********************

********************************************************************************

GEOMETRY DATA
```

```
Geometry Title: Proposed Conditions - 2022 Updates
Geometry File : F:\5635\522\2020 HWY 95 Bridge Design\05 Design\01 HEC-RAS\08 2022
Bridge Updates\5635-522KHRHModel.g18

Reach Connection Table
**********************************************************************************
* River            Reach            *  Upstream Boundary  * Downstream Boundary *
**********************************************************************************
* Columbia         US               *                     *   Junction          *
* Columbia         Downstream       *   Junction          *                     *
* Thalweg_AllSurve Thalweg_AllSurve *                     *   Junction          *
**********************************************************************************

JUNCTION INFORMATION

Name: Junction
Description:
Energy computation Method

    Length across Junction             Tributary
     River           Reach               River           Reach        Length
Angle
Columbia               US        to Columbia           Downstream      60.92
0
Thalweg_AllSurveThalweg_AllSurve to Columbia           Downstream      149.6
0

CROSS SECTION


RIVER: Columbia
REACH: US                RS: 2

INPUT
Description: X-Section C6b - South of Golden
Station Elevation Data    num=      29
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
*********************************************************************************
    3000  783.763000.079   781.9 3001.25  780.77 3001.71 780.9313003.249  780.23
3005.371  779.233008.361 778.4293009.281 778.3313011.522 778.331 3015.24  778.13
 3020.01  777.883021.601  777.88 3024.46 777.831 3027.13 778.029 3035.01 778.231
 3038.92 778.4293043.458  778.38  3047.4  778.383049.311 778.4813050.569 778.529
3052.389  778.733053.849 778.9293060.021 779.9193062.981   780.73064.542 781.309
3065.752 781.9493065.971 782.2113067.879   782.83072.963 782.781

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    3000    .022    3000    .0223072.963    .022
```

```
Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          30003072.963          109.999     120 124.998            .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
**********************************************************************************
********
* E.G. Elev (m)       *  784.02  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.25  * Wt. n-Val.          *          *   0.022  *
      *
* W.S. Elev (m)       *  783.77  * Reach Len. (m)      *  110.00  *  120.00  *
125.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  336.43  *
      *
* E.G. Slope (m/m)    *0.000331  * Area (m2)           *          *  336.43  *
      *
* Q Total (m3/s)      *  741.00  * Flow (m3/s)         *          *  741.00  *
      *
* Top Width (m)       *   72.96  * Top Width (m)       *          *   72.96  *
      *
* Vel Total (m/s)     *    2.20  * Avg. Vel. (m/s)     *          *    2.20  *
      *
* Max Chl Dpth (m)    *    5.94  * Hydr. Depth (m)     *          *    4.61  *
      *
* Conv. Total (m3/s)  * 40712.8  * Conv. (m3/s)        *          * 40712.8  *
      *
* Length Wtd. (m)     *  120.00  * Wetted Per. (m)     *          *   77.45  *
      *
* Min Ch El (m)       *  777.83  * Shear (N/m2)        *          *   14.11  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *   31.08  *
      *
* Frctn Loss (m)      *    0.04  * Cum Volume (1000 m3) *         *   76.19  *
      *
* C & E Loss (m)      *    0.00  * Cum SA (1000 m2)    *          *    8.77  *
      *
**********************************************************************************
********

Warning: The cross-section end points had to be extended vertically for the
computed water surface.

CROSS SECTION


RIVER: Columbia
REACH: US                 RS: 1

INPUT
Description: X-Section C6 - South of Golden
Station Elevation Data    num=      29
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    3000  783.763000.079   781.9 3001.25  780.77 3001.71 780.9313003.249  780.23
3005.371  779.233008.361 778.4293009.281 778.3313011.522 778.331 3015.24  778.13
 3020.01  777.883021.601  777.88 3024.46 777.831 3027.13 778.029 3035.01 778.231
 3038.92 778.4293043.458  778.38  3047.4  778.383049.311 778.4813050.569 778.529
3052.389  778.733053.849 778.9293060.021 779.9193062.981   780.73064.542 781.309
3065.752 781.9493065.971 782.2113067.879   782.83073.231 782.781

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    3000    .022    3000    .0223073.231    .022

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          30003073.231                0       0       0            .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
**********************************************************************************
********
* E.G. Elev (m)       *  783.98  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.25  * Wt. n-Val.          *          *   0.022  *
      *
* W.S. Elev (m)       *  783.73  * Reach Len. (m)      *   60.92  *   60.92  *
60.92  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  333.39  *
      *
* E.G. Slope (m/m)    *0.000342  * Area (m2)           *          *  333.39  *
      *
* Q Total (m3/s)      *  741.00  * Flow (m3/s)         *          *  741.00  *
      *
* Top Width (m)       *   73.23  * Top Width (m)       *          *   73.23  *
      *
* Vel Total (m/s)     *    2.22  * Avg. Vel. (m/s)     *          *    2.22  *
      *
* Max Chl Dpth (m)    *    5.90  * Hydr. Depth (m)     *          *    4.55  *
      *
* Conv. Total (m3/s)  * 40040.5  * Conv. (m3/s)        *          * 40040.5  *
      *
* Length Wtd. (m)     *   60.92  * Wetted Per. (m)     *          *   77.62  *
      *
* Min Ch El (m)       *  777.83  * Shear (N/m2)        *          *   14.42  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *   32.06  *
      *
* Frctn Loss (m)      *    0.02  * Cum Volume (1000 m3) *         *   36.00  *
      *
```

```
* C & E Loss (m)       *    0.04  * Cum SA (1000 m2)     *          *          *
      *
*********************************************************************************
********

Warning: The cross-section end points had to be extended vertically for the
computed water surface.

CROSS SECTION


RIVER: Columbia
REACH: Downstream         RS: 4

INPUT
Description: K55 (2012)
Station Elevation Data    num=      63
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
******************************************************************************
       0 797.199   4.591 791.504   6.266 790.612   17.89 779.424  32.442  779.32
   40.56 779.902  57.324 779.915  67.941 779.876   75.19 779.682 102.884 780.403
 107.585 780.459 117.242 780.782 118.931 781.055 121.962 780.898 122.528 780.943
 125.444 780.926 128.731 781.171 129.302  781.23 130.581 781.338 130.742 781.316
 131.827 781.657 137.286 781.449  138.65 781.361 139.691 781.274 140.193 781.737
 140.317 781.974 142.626 781.426 143.163 781.005 154.061  780.61 154.748 780.585
 165.261 780.642 167.682 780.985 169.883 780.961 174.989 781.267 179.697 781.584
  182.11 781.616 182.264 781.603 188.488 781.851 191.119 781.929  201.33 781.793
 205.358  781.84 212.164 781.975 229.906 782.371 243.746 782.385 251.287 782.196
 251.387 782.193 261.785  781.65 261.971 781.647 272.607 781.564 288.242  781.12
 288.473 781.127 293.967 781.245 297.782 780.802 297.868 780.805 297.912 780.808
 297.921 780.816 305.839 782.313 319.141 782.712 319.388 782.685 323.283 782.233
 326.589 782.546     329 783.901 329.258 784.046

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .022       0    .022     329    .022

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0     329              354     354     354            .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  783.92  * Element              *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.11  * Wt. n-Val.           *          *   0.022  *
      *
* W.S. Elev (m)        *  783.81  * Reach Len. (m)       *  354.00  *  354.00  *
354.00  *
```

```
* Crit W.S. (m)        *          * Flow Area (m2)       *          *  848.59  *
      *
* E.G. Slope (m/m)     *0.000287  * Area (m2)            *          *  848.59  *
      *
* Q Total (m3/s)       * 1255.00  * Flow (m3/s)          *          * 1255.00  *
      *
* Top Width (m)        *  315.50  * Top Width (m)        *          *  315.50  *
      *
* Vel Total (m/s)      *    1.48  * Avg. Vel. (m/s)      *          *    1.48  *
      *
* Max Chl Dpth (m)     *    4.49  * Hydr. Depth (m)      *          *    2.69  *
      *
* Conv. Total (m3/s)   * 74117.4  * Conv. (m3/s)         *          * 74117.4  *
      *
* Length Wtd. (m)      *  354.00  * Wetted Per. (m)      *          *  318.59  *
      *
* Min Ch El (m)        *  779.32  * Shear (N/m2)         *          *    7.49  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *          *   11.08  *
      *
* Frctn Loss (m)       *    0.18  * Cum Volume (1000 m3) *          *  328.39  *
0.05  *
* C & E Loss (m)       *    0.04  * Cum SA (1000 m2)     *          *  106.90  *
0.26  *
*********************************************************************************
********

Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
Warning: The conveyance ratio (upstream conveyance divided by downstream
conveyance) is less than 0.7 or greater than
         1.4.  This may indicate the need for additional cross sections.

CROSS SECTION


RIVER: Columbia
REACH: Downstream         RS: 3

INPUT
Description: X-Section C7 (2003)
Station Elevation Data    num=      40
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
******************************************************************************
    3000 783.1013001.341 781.449 3003.06 780.069 3004.24 779.959 3008.05  778.56
3011.241  777.563012.439 777.661 3020.15  778.063026.329 778.4593028.819 778.261
3031.041 778.161 3037.92 778.761  3040.1 778.959 3043.87 778.9593045.851 778.859
3052.691 778.4593053.959 778.3593056.339  778.663057.979  778.66 3061.04  778.56
3063.722 778.761 3066.45 778.9593073.481 780.3893076.691 780.971 3080.58 781.111
```

```
3082.369  781.48 3082.89  781.65 3086.99 781.7513089.111 781.2913091.321 781.169
3094.202  781.263096.411   781.93098.691 781.8793104.979 783.2293109.938 782.059
3115.669 782.291 3117.72  783.473126.501 783.5743126.949  783.583129.031 782.729

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    3000    .022    3000    .0223126.501    .022

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          30003126.501              156     156     156             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  783.70  * Element              *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.55  * Wt. n-Val.           *          *   0.022  *
0.022  *
* W.S. Elev (m)        *  783.15  * Reach Len. (m)       *  156.00  *  156.00  *
156.00  *
* Crit W.S. (m)        *          * Flow Area (m2)       *          *  381.62  *
0.21  *
* E.G. Slope (m/m)     *0.001109  * Area (m2)            *          *  381.62  *
0.21  *
* Q Total (m3/s)       * 1255.00  * Flow (m3/s)          *          * 1254.91  *
0.09  *
* Top Width (m)        *  117.45  * Top Width (m)        *          *  116.43  *
1.02  *
* Vel Total (m/s)      *    3.29  * Avg. Vel. (m/s)      *          *    3.29  *
0.41  *
* Max Chl Dpth (m)     *    5.59  * Hydr. Depth (m)      *          *    3.28  *
0.21  *
* Conv. Total (m3/s)   * 37686.5  * Conv. (m3/s)         *          * 37683.9  *
 2.6  *
* Length Wtd. (m)      *  156.00  * Wetted Per. (m)      *          *  119.18  *
1.52  *
* Min Ch El (m)        *  777.56  * Shear (N/m2)         *          *   34.82  *
1.53  *
* Alpha                *    1.00  * Stream Power (N/m s) *          *  114.50  *
0.62  *
* Frctn Loss (m)       *    0.16  * Cum Volume (1000 m3) *          *  110.65  *
0.02  *
* C & E Loss (m)       *    0.00  * Cum SA (1000 m2)     *          *   30.45  *
0.08  *
*********************************************************************************
********

Warning: Divided flow computed for this cross-section.
Warning: The cross-section end points had to be extended vertically for the
```

```
computed water surface.

CROSS SECTION


RIVER: Columbia
REACH: Downstream         RS: 2

INPUT
Description:
Station Elevation Data    num=      48
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    3000  787.173022.001 785.4213023.991  785.143024.241  783.793024.841  783.79
3027.898 781.5013030.051 780.6293032.839  779.243035.951 778.289 3039.38  777.49
 3040.81 777.289 3042.16 777.2893046.961 777.7093050.899  777.743054.541 777.941
3059.061  778.09  3061.6 778.191 3063.63 778.2893066.831 778.8493068.751 778.889
 3072.43  778.74 3075.56 778.7913079.458 778.791 3082.29  778.743083.781 778.791
3084.101 778.8893087.271  779.413090.041   779.3 3093.58 779.599 3097.42 779.861
3102.139 780.0693104.141 780.1513106.951  780.123110.061 780.291 3114.55 780.389
 3116.37  780.483119.601 780.4713121.481 781.0293122.841  781.48 3124.49 782.839
 3126.05  783.19 3126.23  783.793127.059 783.839 3127.15  784.97 3128.47 784.869
 3143.07 784.641 3151.47  784.043179.469 783.909

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    3000    .0223023.991    .022 3128.47    .022

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
      3023.991 3128.47                6       6       6             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  783.53  * Element              *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.59  * Wt. n-Val.           *          *   0.022  *
      *
* W.S. Elev (m)        *  782.94  * Reach Len. (m)       *    1.00  *    1.00  *
1.00  *
* Crit W.S. (m)        *  781.68  * Flow Area (m2)       *          *  369.33  *
      *
* E.G. Slope (m/m)     *0.000992  * Area (m2)            *          *  369.33  *
      *
* Q Total (m3/s)       * 1255.00  * Flow (m3/s)          *          * 1255.00  *
      *
* Top Width (m)        *   98.98  * Top Width (m)        *          *   98.98  *
      *
* Vel Total (m/s)      *    3.40  * Avg. Vel. (m/s)      *          *    3.40  *
```

```
      *
* Max Chl Dpth (m)     *    5.65  * Hydr. Depth (m)      *          *    3.73  *
      *
* Conv. Total (m3/s)   * 39837.5  * Conv. (m3/s)         *          * 39837.5  *
      *
* Length Wtd. (m)      *    1.00  * Wetted Per. (m)      *          *  101.03  *
      *
* Min Ch El (m)        *  777.29  * Shear (N/m2)         *          *   35.58  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *          *  120.89  *
      *
* Frctn Loss (m)       *    0.00  * Cum Volume (1000 m3) *          *   52.07  *
      *
* C & E Loss (m)       *    0.01  * Cum SA (1000 m2)     *          *   13.65  *
      *
***********************************************************************************
********

BRIDGE


RIVER: Columbia
REACH: Downstream         RS: 1.5

INPUT
Description: Columbia River Bridge - SW of Golden
Distance from Upstream XS =       1
Deck/Roadway Width        =   4.999
Weir Coefficient          =    1.44
Upstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
************************************************
    3020   785.4   784.2    3130   785.4   784.2

Upstream Bridge Cross Section Data
Station Elevation Data    num=      48
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    3000  787.173022.001 785.4213023.991  785.143024.241  783.793024.841  783.79
3027.898 781.5013030.051 780.6293032.839  779.243035.951 778.289 3039.38  777.49
 3040.81 777.289 3042.16 777.2893046.961 777.7093050.899  777.743054.541 777.941
3059.061  778.09  3061.6 778.191 3063.63 778.2893066.831 778.8493068.751 778.889
 3072.43  778.74 3075.56 778.7913079.458 778.791 3082.29  778.743083.781 778.791
3084.101 778.8893087.271  779.413090.041   779.3 3093.58 779.599 3097.42 779.861
3102.139 780.0693104.141 780.1513106.951  780.123110.061 780.291 3114.55 780.389
 3116.37  780.483119.601 780.4713121.481 781.0293122.841  781.48 3124.49 782.839
 3126.05  783.19 3126.23  783.793127.059 783.839 3127.15  784.97 3128.47 784.869
 3143.07 784.641 3151.47  784.043179.469 783.909
```

```
Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    3000    .0223023.991    .022 3128.47    .022

Bank Sta: Left   Right    Coeff Contr.   Expan.
      3023.991 3128.47             .1       .3

Downstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
************************************************
    3020   785.4   784.2    3130   785.4   784.2

Downstream Bridge Cross Section Data
Station Elevation Data    num=      55
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    3000 786.881 3023.54 785.3813025.701  785.15    3026 783.781  3026.5 783.812
3028.371  781.483030.051  780.513031.782  779.73 3032.01 780.1813033.059 779.111
 3035.82 778.4813040.459 777.4813042.309 777.179  3045.4 777.231 3046.61  777.28
3047.071 777.081 3048.57 777.039 3049.75  777.283050.771 777.481 3053.99 777.429
3060.491 777.9813064.191 778.4813065.428 778.0813068.409 777.9113071.061 778.279
3076.499 778.6793078.349 778.679 3081.55  778.98 3082.68 779.0813084.939 779.029
3086.021  778.98 3086.13  778.983088.499  778.953091.669 779.0293096.171 779.621
3099.792 779.889 3100.52  779.843102.471 780.1113104.629 780.1813107.899  780.19
3109.219  780.133113.739  780.163117.199 780.3313118.159 780.5013121.161  780.45
3122.719 780.8493123.849 781.4893125.861 782.839 3127.73 783.0493127.769  783.79
3128.659 783.7993128.699     7853130.198   784.93144.701 784.491  3170.2 783.879

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    3000    .0223025.701    .0223130.198    .022

Bank Sta: Left   Right    Coeff Contr.   Expan.
      3025.7013130.198             .1       .3

Upstream Embankment side slope             =    3.73 horiz. to 1.0 vertical
Downstream Embankment side slope           =    3.73 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .95
Elevation at which weir flow begins        =
Energy head used in spillway design        =
Spillway height used in design             =
Weir crest shape                           = Broad Crested

Number of Piers =  4

Pier Data
Pier Station     Upstream=    3040    Downstream=    3040
```

```
Upstream     num=       2
    Width   Elev    Width   Elev
********************************
       1 780.919       1  789.21
Downstream     num=       2
    Width   Elev    Width   Elev
********************************
       1 780.919       1  789.21

Pier Data
Pier Station     Upstream=    3065    Downstream=    3065
Upstream     num=       2
    Width   Elev    Width   Elev
********************************
       1 780.919       1  789.21
Downstream     num=       2
    Width   Elev    Width   Elev
********************************
       1 780.919       1  789.21

Pier Data
Pier Station     Upstream=    3090    Downstream=    3090
Upstream     num=       2
    Width   Elev    Width   Elev
********************************
       1 780.919       1  789.21
Downstream     num=       2
    Width   Elev    Width   Elev
********************************
       1 780.919       1  789.21

Pier Data
Pier Station     Upstream=    3115    Downstream=    3115
Upstream     num=       2
    Width   Elev    Width   Elev
********************************
       1 780.919       1  789.21
Downstream     num=       2
    Width   Elev    Width   Elev
********************************
       1 780.919       1  789.21

Number of Bridge Coefficient Sets =  1

Low Flow Methods and Data
       Energy
Selected Low Flow Methods = Highest Energy Answer

High Flow Method
       Energy Only
```

```
Additional Bridge Parameters
       Add Friction component to Momentum
       Do not add Weight component to Momentum
       Class B flow critical depth computations use critical depth
           inside the bridge at the upstream end
       Criteria to check for pressure flow = Upstream energy grade line

CROSS SECTION


RIVER: Columbia
REACH: Downstream         RS: 1

INPUT
Description: X-Section C57 : Downstream of Bridge (2003)
Station Elevation Data    num=      55
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    3000 786.881 3023.54 785.3813025.701  785.15    3026 783.781  3026.5 783.812
3028.371  781.483030.051  780.513031.782  779.73 3032.01 780.1813033.059 779.111
 3035.82 778.4813040.459 777.4813042.309 777.179  3045.4 777.231 3046.61  777.28
3047.071 777.081 3048.57 777.039 3049.75  777.283050.771 777.481 3053.99 777.429
3060.491 777.9813064.191 778.4813065.428 778.0813068.409 777.9113071.061 778.279
3076.499 778.6793078.349 778.679 3081.55  778.98 3082.68 779.0813084.939 779.029
3086.021  778.98 3086.13  778.983088.499  778.953091.669 779.0293096.171 779.621
3099.792 779.889 3100.52  779.843102.471 780.1113104.629 780.1813107.899  780.19
3109.219  780.133113.739  780.163117.199 780.3313118.159 780.5013121.161  780.45
3122.719 780.8493123.849 781.4893125.861 782.839 3127.73 783.0493127.769  783.79
3128.659 783.7993128.699     7853130.198   784.93144.701 784.491  3170.2 783.879

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    3000    .0223025.701    .0223130.198    .022

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
      3025.7013130.198         130.159 132.161 135.161            .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*******************************************************************************************
********
* E.G. Elev (m)        *  783.47  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.54  * Wt. n-Val.          *          *   0.022  *
      *
* W.S. Elev (m)        *  782.93  * Reach Len. (m)      *  130.16  *  132.16  *
135.16  *
* Crit W.S. (m)        *          * Flow Area (m2)      *          *  386.88  *
      *
```

```
* E.G. Slope (m/m)     *0.000867  * Area (m2)           *         *  386.88  *
      *
* Q Total (m3/s)       * 1255.00  * Flow (m3/s)         *         * 1255.00  *
      *
* Top Width (m)        *   99.49  * Top Width (m)       *         *   99.49  *
      *
* Vel Total (m/s)      *    3.24  * Avg. Vel. (m/s)     *         *    3.24  *
      *
* Max Chl Dpth (m)     *    5.89  * Hydr. Depth (m)     *         *    3.89  *
      *
* Conv. Total (m3/s)   * 42618.4  * Conv. (m3/s)        *         * 42618.4  *
      *
* Length Wtd. (m)      *  132.16  * Wetted Per. (m)     *         *  102.54  *
      *
* Min Ch El (m)        *  777.04  * Shear (N/m2)        *         *   32.08  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *        *  104.07  *
      *
* Frctn Loss (m)       *    0.12  * Cum Volume (1000 m3) *        *   49.94  *
      *
* C & E Loss (m)       *    0.01  * Cum SA (1000 m2)    *         *   13.08  *
      *
*********************************************************************************
********

CROSS SECTION


RIVER: Columbia
REACH: Downstream         RS: 0

INPUT
Description: X-Section C57.0 Downstream X Section C57
Station Elevation Data    num=      55
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
3000.601 786.881 3028.24 785.381 3030.84  785.153031.138 783.7813031.641 783.812
 3033.51  781.483035.189  780.513036.921  779.733037.149 780.1813038.201 779.111
3040.959 778.4813045.601 777.4813047.451 777.1793050.539 777.2313051.749  777.28
3052.209 777.0813053.709 777.0393054.888  777.28 3055.91 777.4813059.131 777.429
 3065.63 777.981 3069.33 778.481 3070.57 778.0813073.552 777.911  3076.2 778.279
3081.641 778.6793083.491 778.6793086.691  778.983087.819 779.0813090.081 779.029
 3091.16  778.98 3091.27  778.983093.641  778.953096.811 779.029 3101.31 779.621
3104.931 779.8893105.659  779.84 3107.61 780.1113109.771 780.1813113.041  780.19
3114.361  780.133118.881  780.163122.341 780.3313123.301 780.501  3126.3  780.45
3127.861 780.8493128.989 781.489    3131 782.8393132.872 783.0493132.911  783.79
3133.801 783.7993133.841     785 3135.34   784.93152.739 784.4913183.341 783.879

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
```

```
************************************************
3000.601    .022 3030.84    .022 3135.34    .022

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
       3030.84 3135.34               0       0       0             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  783.34  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.59  * Wt. n-Val.          *          *   0.022  *
      *
* W.S. Elev (m)        *  782.75  * Reach Len. (m)      *          *          *
      *
* Crit W.S. (m)        *  781.51  * Flow Area (m2)      *          *  368.89  *
      *
* E.G. Slope (m/m)     *0.001000  * Area (m2)           *          *  368.89  *
      *
* Q Total (m3/s)       * 1255.00  * Flow (m3/s)         *          * 1255.00  *
      *
* Top Width (m)        *   98.38  * Top Width (m)       *          *   98.38  *
      *
* Vel Total (m/s)      *    3.40  * Avg. Vel. (m/s)     *          *    3.40  *
      *
* Max Chl Dpth (m)     *    5.71  * Hydr. Depth (m)     *          *    3.75  *
      *
* Conv. Total (m3/s)   * 39686.6  * Conv. (m3/s)        *          * 39686.6  *
      *
* Length Wtd. (m)      *          * Wetted Per. (m)     *          *  101.31  *
      *
* Min Ch El (m)        *  777.04  * Shear (N/m2)        *          *   35.71  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *         *  121.48  *
      *
* Frctn Loss (m)       *          * Cum Volume (1000 m3) *         *          *
      *
* C & E Loss (m)       *          * Cum SA (1000 m2)    *          *          *
      *
*********************************************************************************
********

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 3583

INPUT
Description: X-Section K1 - 2017
```

```
Station Elevation Data    num=      19
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
      10 792.099   11.26 791.726   11.69 791.651   14.44 791.172   14.55 791.156
   16.87 790.812   17.27 790.699    17.9 790.517   32.06 790.571    32.5 790.572
   32.53 790.579   33.43 790.799   35.84 791.337   35.95 791.362   39.01 791.536
   39.11 791.541   39.14 791.555   40.39 791.975   41.69 792.509

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
      10    .032      10    .032   41.69    .032

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
            10   41.69               72      65      59             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)       *  795.95  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    1.21  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)       *  794.75  * Reach Len. (m)      *   72.00  *   65.00  *
59.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  119.26  *
      *
* E.G. Slope (m/m)    *0.005091  * Area (m2)           *          *  119.26  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *   31.69  * Top Width (m)       *          *   31.69  *
      *
* Vel Total (m/s)     *    4.86  * Avg. Vel. (m/s)     *          *    4.86  *
      *
* Max Chl Dpth (m)    *    4.23  * Hydr. Depth (m)     *          *    3.76  *
      *
* Conv. Total (m3/s)  *  8129.1  * Conv. (m3/s)        *          *  8129.1  *
      *
* Length Wtd. (m)     *   65.00  * Wetted Per. (m)     *          *   37.02  *
      *
* Min Ch El (m)       *  790.52  * Shear (N/m2)        *          *  160.82  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *  782.17  *
      *
* Frctn Loss (m)      *    0.30  * Cum Volume (1000 m3) *         *  674.13  *
      *
* C & E Loss (m)      *    0.13  * Cum SA (1000 m2)    *          *  269.11  *
      *
***********************************************************************************
```

```
********

Warning: The cross-section end points had to be extended vertically for the
computed water surface.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 3519

INPUT
Description: X-Section K52 - 2017
Station Elevation Data    num=      21
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
      10 795.494   18.25 791.979   18.76 791.792   19.37 791.566   23.88 791.619
   23.91 791.619   28.59 791.317   28.67 791.313   28.74  791.32   33.35 791.728
   38.96 791.716   40.13 791.713   42.15 791.688   46.92 791.629   53.14 791.623
   53.65 791.623   54.24 791.658   60.45 792.027   64.44 793.552   64.56 793.599
   68.22 796.555

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
      10    .032      10    .032   68.22    .032

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
            10   68.22              381     386     391             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)       *  795.52  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.78  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)       *  794.74  * Reach Len. (m)      *  381.00  *  386.00  *
391.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  148.22  *
      *
* E.G. Slope (m/m)    *0.004241  * Area (m2)           *          *  148.22  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
```

```
      *
* Top Width (m)       *   54.22  * Top Width (m)       *         *   54.22  *
      *
* Vel Total (m/s)     *    3.91  * Avg. Vel. (m/s)     *         *    3.91  *
      *
* Max Chl Dpth (m)    *    3.43  * Hydr. Depth (m)     *         *    2.73  *
      *
* Conv. Total (m3/s)  *  8906.5  * Conv. (m3/s)        *         *  8906.5  *
      *
* Length Wtd. (m)     *  386.00  * Wetted Per. (m)     *         *   55.59  *
      *
* Min Ch El (m)       *  791.31  * Shear (N/m2)        *         *  110.88  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *        *  433.90  *
      *
* Frctn Loss (m)      *    1.98  * Cum Volume (1000 m3) *        *  665.43  *
      *
* C & E Loss (m)      *    0.01  * Cum SA (1000 m2)    *         *  266.32  *
      *
*************************************************************************************
********

Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 3132

INPUT
Description: Section K2 - 2017
Station Elevation Data    num=      23
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
      10 793.638   18.98 791.103   21.42  791.06   26.46 790.969    29.7 790.478
   29.71 790.476   29.74 790.475   36.63 790.341   36.84 790.333   42.68 790.123
   46.26 790.066   49.46 790.016   53.35 789.912   55.18 789.863   55.26 789.863
   60.59 789.849   62.94  789.87   65.39 789.893   69.07 789.788   69.67 789.771
   69.98  789.84   73.64 790.647   81.51 795.604

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
      10    .032      10    .032   81.51    .032

Bank Sta: Left    Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
            10   81.51              385     390     377             .1       .3
```

```
CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*************************************************************************************
********
* E.G. Elev (m)       *  793.54  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.88  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)       *  792.66  * Reach Len. (m)      *  385.00  *  390.00  *
377.00  *
* Crit W.S. (m)       *  792.49  * Flow Area (m2)      *          *  139.45  *
      *
* E.G. Slope (m/m)    *0.006308  * Area (m2)           *          *  139.45  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *   63.35  * Top Width (m)       *          *   63.35  *
      *
* Vel Total (m/s)     *    4.16  * Avg. Vel. (m/s)     *          *    4.16  *
      *
* Max Chl Dpth (m)    *    2.88  * Hydr. Depth (m)     *          *    2.20  *
      *
* Conv. Total (m3/s)  *  7302.4  * Conv. (m3/s)        *          *  7302.4  *
      *
* Length Wtd. (m)     *  390.00  * Wetted Per. (m)     *          *   64.29  *
      *
* Min Ch El (m)       *  789.77  * Shear (N/m2)        *          *  134.19  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *  558.13  *
      *
* Frctn Loss (m)      *    2.31  * Cum Volume (1000 m3) *         *  609.91  *
      *
* C & E Loss (m)      *    0.12  * Cum SA (1000 m2)    *          *  243.63  *
      *
*************************************************************************************
********

Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2742
```

```
INPUT
Description: K50 - 2017
K50
Station Elevation Data    num=      55
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    8.57 791.178    8.76 791.098   13.67 789.033   14.46 788.502   14.52 788.462
   14.78 788.461   18.37 788.451   23.39 788.663   23.65 788.674   23.85  788.68
   27.59 788.803   34.08 789.243   34.27 789.256   34.48 789.252   41.11 789.103
   45.28 788.634   45.52 788.606   45.61 788.626   47.17 788.968   47.74 790.064
   47.77 790.134   48.29 790.141   56.46 790.246   63.47 790.115   63.99 790.105
   64.04 790.016   64.79 788.859   66.23 788.213   66.28 788.187   66.78 788.158
   71.83 787.862   71.99 787.859   75.51 787.792      79 787.943   79.11 787.948
   79.27 787.965   84.62 788.539   84.91 788.578   89.32  789.19  100.48  789.73
   101.1  789.76  107.86  789.41  107.93 789.407  108.02 789.404  117.05 789.062
  117.17 789.053  120.56 788.779  125.54 788.684  125.62 788.682  125.69 788.689
  129.29 789.068   129.4 789.105  130.99 789.652  132.03 791.004  132.07 791.067

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    8.57    .032    8.57    .032  132.07    .032

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          8.57  132.07              217     171     157             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)       *  791.11  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.48  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)       *  790.63  * Reach Len. (m)      *  217.00  *  171.00  *
157.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  188.76  *
      *
* E.G. Slope (m/m)    *0.005564  * Area (m2)           *          *  188.76  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *  121.86  * Top Width (m)       *          *  121.86  *
      *
* Vel Total (m/s)     *    3.07  * Avg. Vel. (m/s)     *          *    3.07  *
      *
* Max Chl Dpth (m)    *    2.84  * Hydr. Depth (m)     *          *    1.55  *
      *
* Conv. Total (m3/s)  *  7775.5  * Conv. (m3/s)        *          *  7775.5  *
      *
* Length Wtd. (m)     *  171.00  * Wetted Per. (m)     *          *  124.72  *
```

```
      *
* Min Ch El (m)       *  787.79  * Shear (N/m2)        *          *   82.58  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *  253.75  *
      *
* Frctn Loss (m)      *    0.47  * Cum Volume (1000 m3) *         *  545.91  *
      *
* C & E Loss (m)      *    0.07  * Cum SA (1000 m2)    *          *  207.51  *
      *
***********************************************************************************
********

Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
Warning: The conveyance ratio (upstream conveyance divided by downstream
conveyance) is less than 0.7 or greater than
         1.4.  This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2571

INPUT
Description: K3/K60 - Oct 2017
Station Elevation Data    num=      36
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
   10.83 790.807   17.16 787.758   20.42 787.698   20.72 787.692   21.22 787.697
   25.95 787.747   30.68 787.838   31.78 787.859   33.49 787.823   39.87  787.69
   43.31 787.611   44.84 787.577   46.66 787.272   47.46 787.136   48.47 787.046
   48.91 787.006   49.87 787.215   51.79  787.64   52.76 788.047   54.32 788.697
   58.74 788.734      70 788.828   84.32 788.644   89.61 787.529   89.84 787.481
    95.3 787.242   95.32 787.241   95.39 787.237  107.47 786.458  112.31 787.004
  112.39 787.013  112.44  787.02  116.12 787.524  116.19 787.545  119.74 788.655
  120.52 789.464

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
   10.83    .032   10.83    .032  120.52    .032

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
         10.83  120.52              133     128     115             .1       .3
```

```
CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)       *  790.57  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.25  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)       *  790.32  * Reach Len. (m)      *  133.00  *  128.00  *
115.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  260.82  *
      *
* E.G. Slope (m/m)    *0.001625  * Area (m2)           *          *  260.82  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *  108.68  * Top Width (m)       *          *  108.68  *
      *
* Vel Total (m/s)     *    2.22  * Avg. Vel. (m/s)     *          *    2.22  *
      *
* Max Chl Dpth (m)    *    3.86  * Hydr. Depth (m)     *          *    2.40  *
      *
* Conv. Total (m3/s)  * 14389.6  * Conv. (m3/s)        *          * 14389.6  *
      *
* Length Wtd. (m)     *  128.00  * Wetted Per. (m)     *          *  111.18  *
      *
* Min Ch El (m)       *  786.46  * Shear (N/m2)        *          *   37.37  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *   83.11  *
      *
* Frctn Loss (m)      *    0.35  * Cum Volume (1000 m3) *         *  507.47  *
      *
* C & E Loss (m)      *    0.08  * Cum SA (1000 m2)    *          *  187.80  *
      *
***********************************************************************************
********

Warning: The cross-section end points had to be extended vertically for the
computed water surface.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
Warning: The conveyance ratio (upstream conveyance divided by downstream
conveyance) is less than 0.7 or greater than
         1.4.  This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION
```

```
RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2443

INPUT
Description: K51 - 2017
Station Elevation Data    num=      21
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    6.02 790.494    7.06 789.916    13.6 786.266   15.38 785.532   15.46 785.498
   15.68   785.5    20.7 785.525   20.91 785.531   23.96 785.614    27.8 785.869
   27.86 785.873   28.51 785.875   32.72 785.884   37.81 786.209   38.56 786.257
   43.74 786.326   44.56 786.337   45.52 786.384   50.77 786.637   54.23 788.564
   55.47  789.26

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    6.02    .032    6.02    .032   55.47    .032

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          6.02   55.47              133     128     115             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)       *  790.14  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    1.03  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)       *  789.11  * Reach Len. (m)      *  133.00  *  128.00  *
115.00  *
* Crit W.S. (m)       *  788.83  * Flow Area (m2)      *          *  128.85  *
      *
* E.G. Slope (m/m)    *0.005602  * Area (m2)           *          *  128.85  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *   46.70  * Top Width (m)       *          *   46.70  *
      *
* Vel Total (m/s)     *    4.50  * Avg. Vel. (m/s)     *          *    4.50  *
      *
* Max Chl Dpth (m)    *    3.61  * Hydr. Depth (m)     *          *    2.76  *
      *
* Conv. Total (m3/s)  *  7749.1  * Conv. (m3/s)        *          *  7749.1  *
      *
* Length Wtd. (m)     *  128.00  * Wetted Per. (m)     *          *   48.26  *
      *
* Min Ch El (m)       *  785.50  * Shear (N/m2)        *          *  146.67  *
      *
```

```
* Alpha               *    1.00  * Stream Power (N/m s) *         *  660.24  *
      *
* Frctn Loss (m)      *    0.51  * Cum Volume (1000 m3) *         *  482.54  *
      *
* C & E Loss (m)      *    0.14  * Cum SA (1000 m2)     *         *  177.85  *
      *
*************************************************************************************
********
```

Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate
the need for additional cross sections.

CROSS SECTION

RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2312

INPUT
Description: K4 - 2021 survey

```
Station Elevation Data    num=      47
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
*********************************************************************************
    4.65 789.776    7.32 789.731    7.35  789.73    7.36 789.728    8.41 789.483
   10.71 788.294   10.71  788.29   10.72 788.289   14.15 787.151   18.52 786.497
   18.87 786.443   19.17 786.434   23.63 786.298    23.9 786.282   27.58 786.063
    30.7 786.069   31.21  786.07   32.18 785.993   35.28 785.749      37 785.645
   38.71 785.542   40.56 785.467   42.44 785.392   43.51 785.326   43.97   785.3
   45.37 785.296   46.64 785.292   49.45 785.346   50.99 785.376   51.67 785.439
   52.82 785.546   53.74  785.51   56.02 785.422   58.69 785.495   60.07 785.533
   61.76 785.616   62.47 785.652   63.88 785.854   66.78 786.254   67.28  786.52
   67.43 786.599   68.18 787.062   71.95 789.452   72.08 789.536   72.11 789.552
   72.13 789.553   74.66 789.656

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
*************************************************
    4.65    .032    4.65    .032   74.66    .032

Bank Sta: Left    Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          4.65   74.66            47.71      50  52.672            .1       .3
```

CROSS SECTION OUTPUT Profile #200-Yr Matrix CC

```
*************************************************************************************
********
* E.G. Elev (m)       *  789.49  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.58  * Wt. n-Val.           *         *   0.032  *
      *
* W.S. Elev (m)       *  788.92  * Reach Len. (m)       *   20.00  *   20.00  *
20.00  *
* Crit W.S. (m)       *  788.14  * Flow Area (m2)       *         *  172.71  *
      *
* E.G. Slope (m/m)    *0.003000  * Area (m2)            *         *  172.71  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)          *         *  580.00  *
      *
* Top Width (m)       *   61.60  * Top Width (m)        *         *   61.60  *
      *
* Vel Total (m/s)     *    3.36  * Avg. Vel. (m/s)      *         *    3.36  *
      *
* Max Chl Dpth (m)    *    3.63  * Hydr. Depth (m)      *         *    2.80  *
      *
* Conv. Total (m3/s)  * 10589.3  * Conv. (m3/s)         *         * 10589.3  *
      *
* Length Wtd. (m)     *   20.00  * Wetted Per. (m)      *         *   62.84  *
      *
* Min Ch El (m)       *  785.29  * Shear (N/m2)         *         *   80.85  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *  271.53  *
      *
* Frctn Loss (m)      *    0.06  * Cum Volume (1000 m3) *         *  463.24  *
      *
* C & E Loss (m)      *    0.04  * Cum SA (1000 m2)     *         *  170.92  *
      *
*************************************************************************************
********
```

BRIDGE

RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2272

INPUT
Description: Internal XS's adjusted to match actual location of bridge K4A

```
Distance from Upstream XS =      20
Deck/Roadway Width        =    15.8
Weir Coefficient          =     1.6
Upstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
************************************************
       0   791.4   790.4     115   791.4   790.4
```

Upstream Bridge Cross Section Data

```
Station Elevation Data    num=      67
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0  790.11   4.203 790.005   5.235 790.006     7.3 790.095   9.365 790.057
   9.913 789.928  10.397 789.792  10.735 789.633  11.429 789.261  12.462 788.675
    13.2 788.226  13.494 788.218  13.992 788.076  14.527 788.028  17.624 786.933
  18.656 786.607  20.595 786.493   24.85 786.452  25.525 786.504  25.882  786.51
  27.947 786.997   28.98   787.3  31.044 787.957  32.041 788.194  33.109 788.609
  34.141 788.858  35.174 789.023  36.206 789.086  37.238 789.069  38.271 788.988
  39.303 788.959  40.335  788.83  41.368 788.828  42.779 788.742  43.433 788.722
  44.423 788.807  45.244 788.747   46.53 788.715  46.888 788.618  47.562  788.47
  48.531  788.48  48.702 788.404  49.627 787.865  53.756 786.809  54.788 786.456
  55.821 786.141  56.853 786.014  60.034 785.503  60.983 785.415  63.047 785.284
  67.177 784.906  68.412 784.863  72.339  784.79  83.695 784.878  88.856 784.855
  89.613 785.052  89.889 785.138  90.921 785.722  91.953 786.253  92.566 786.593
   95.05  788.09  95.907 788.743  96.187 788.923  96.592 789.083  97.115 789.262
   98.84 789.225 104.719 789.225

Manning's n Values        num=       1
     Sta   n Val
****************
       0    .032

Bank Sta: Left   Right    Coeff Contr.   Expan.
             0 104.719             .1       .3

Downstream  Deck/Roadway Coordinates
    num=       2
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
************************************************
       0   791.4   790.4     115   791.4   790.4

Downstream Bridge Cross Section Data
Station Elevation Data    num=      67
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0  790.11   4.203 790.005   5.235 790.006     7.3 790.095   9.365 790.057
   9.913 789.928  10.397 789.792  10.735 789.633  11.429 789.261  12.462 788.675
    13.2 788.226  13.494 788.218  13.992 788.076  14.527 788.028  17.624 786.933
  18.656 786.607  20.595 786.493   24.85 786.452  25.525 786.504  25.882  786.51
  27.947 786.997   28.98   787.3  31.044 787.957  32.041 788.194  33.109 788.609
  34.141 788.858  35.174 789.023  36.206 789.086  37.238 789.069  38.271 788.988
  39.303 788.959  40.335  788.83  41.368 788.828  42.779 788.742  43.433 788.722
  44.423 788.807  45.244 788.747   46.53 788.715  46.888 788.618  47.562  788.47
  48.531  788.48  48.702 788.404  49.627 787.865  53.756 786.809  54.788 786.456
  55.821 786.141  56.853 786.014  60.034 785.503  60.983 785.415  63.047 785.284
  67.177 784.906  68.412 784.863  72.339  784.79  83.695 784.878  88.856 784.855
  89.613 785.052  89.889 785.138  90.921 785.722  91.953 786.253  92.566 786.593
   95.05  788.09  95.907 788.743  96.187 788.923  96.592 789.083  97.115 789.262
   98.84 789.225 104.719 789.225
```

```
Manning's n Values        num=       1
     Sta   n Val
****************
       0    .032

Bank Sta: Left   Right    Coeff Contr.   Expan.
             0 104.719             .1       .3

Upstream Embankment side slope             =       0 horiz. to 1.0 vertical
Downstream Embankment side slope           =       0 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .98
Elevation at which weir flow begins        =
Energy head used in spillway design        =
Spillway height used in design             =
Weir crest shape                           = Broad Crested

Number of Abutments =  2

Abutment Data
Upstream     num=       2
     Sta    Elev     Sta    Elev
********************************
       0   790.4     1.5   790.4
Downstream     num=       2
     Sta    Elev     Sta    Elev
********************************
       0   790.4     1.5   790.4

Abutment Data
Upstream     num=       2
     Sta    Elev     Sta    Elev
********************************
 103.219   790.4 104.719   790.4
Downstream     num=       2
     Sta    Elev     Sta    Elev
********************************
 103.219   790.4 104.719   790.4

Number of Piers =  1

Pier Data
Pier Station     Upstream=    43.3    Downstream=    43.3
Upstream     num=       2
    Width   Elev    Width   Elev
********************************
     1.5     787     1.5     791
Downstream     num=       2
    Width   Elev    Width   Elev
********************************
```

```
     1.5     787     1.5     791

Number of Bridge Coefficient Sets =  1

Low Flow Methods and Data
       Energy
Selected Low Flow Methods = Energy

High Flow Method
       Energy Only

Additional Bridge Parameters
       Add Friction component to Momentum
       Do not add Weight component to Momentum
       Class B flow critical depth computations use critical depth
           inside the bridge at the upstream end
       Criteria to check for pressure flow = Upstream energy grade line

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2219

INPUT
Description: K4A - 2019 MoTI Bath
Station Elevation Data    num=      67
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0  790.11   4.203 790.005   5.235 790.006     7.3 790.095   9.365 790.057
   9.913 789.928  10.397 789.792  10.735 789.633  11.429 789.261  12.462 788.675
    13.2 788.226  13.494 788.218  13.992 788.076  14.527 788.028  17.624 786.933
  18.656 786.607  20.595 786.493   24.85 786.452  25.525 786.504  25.882  786.51
  27.947 786.997   28.98   787.3  31.044 787.957  32.041 788.194  33.109 788.609
  34.141 788.858  35.174 789.023  36.206 789.086  37.238 789.069  38.271 788.988
  39.303 788.959  40.335  788.83  41.368 788.828  42.779 788.742  43.433 788.722
  44.423 788.807  45.244 788.747   46.53 788.715  46.888 788.618  47.562  788.47
  48.531  788.48  48.702 788.404  49.627 787.865  53.756 786.809  54.788 786.456
  55.821 786.141  56.853 786.014  60.034 785.503  60.983 785.415  63.047 785.284
  67.177 784.906  68.412 784.863  72.339  784.79  83.695 784.878  88.856 784.855
  89.613 785.052  89.889 785.138  90.921 785.722  91.953 786.253  92.566 786.593
   95.05  788.09  95.907 788.743  96.187 788.923  96.592 789.083  97.115 789.262
   98.84 789.225 104.719 789.225

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .032       0    .032 104.719    .032

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
```

```
             0 104.719               8    14.5       6             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
********************************************************************************
********
* E.G. Elev (m)       *  789.30  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.50  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)       *  788.81  * Reach Len. (m)      *    2.00  *    2.00  *
2.00  *
* Crit W.S. (m)       *  787.94  * Flow Area (m2)      *          *  185.87  *
      *
* E.G. Slope (m/m)    *0.003147  * Area (m2)           *          *  185.87  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *   75.93  * Top Width (m)       *          *   75.93  *
      *
* Vel Total (m/s)     *    3.12  * Avg. Vel. (m/s)     *          *    3.12  *
      *
* Max Chl Dpth (m)    *    4.02  * Hydr. Depth (m)     *          *    2.45  *
      *
* Conv. Total (m3/s)  * 10339.2  * Conv. (m3/s)        *          * 10339.2  *
      *
* Length Wtd. (m)     *    2.00  * Wetted Per. (m)     *          *   78.26  *
      *
* Min Ch El (m)       *  784.79  * Shear (N/m2)        *          *   73.29  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *  228.70  *
      *
* Frctn Loss (m)      *    0.01  * Cum Volume (1000 m3) *         *  453.79  *
      *
* C & E Loss (m)      *    0.00  * Cum SA (1000 m2)    *          *  167.22  *
      *
********************************************************************************
********

Warning: Divided flow computed for this cross-section.

BRIDGE


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2205

INPUT
Description: Internal XS's not adjusted
Distance from Upstream XS =       2
Deck/Roadway Width        =      10
```

Weir Coefficient = 1.6

Upstream Deck/Roadway Coordinates

num= 6

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord
0	792	790.3	36	792	790.3	36	792	788
46	792	788	46	794	794	105	794	794

Upstream Bridge Cross Section Data

Station Elevation Data num= 67

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	790.11	4.203	790.005	5.235	790.006	7.3	790.095	9.365	790.057
9.913	789.928	10.397	789.792	10.735	789.633	11.429	789.261	12.462	788.675
13.2	788.226	13.494	788.218	13.992	788.076	14.527	788.028	17.624	786.933
18.656	786.607	20.595	786.493	24.85	786.452	25.525	786.504	25.882	786.51
27.947	786.997	28.98	787.3	31.044	787.957	32.041	788.194	33.109	788.609
34.141	788.858	35.174	789.023	36.206	789.086	37.238	789.069	38.271	788.988
39.303	788.959	40.335	788.83	41.368	788.828	42.779	788.742	43.433	788.722
44.423	788.807	45.244	788.747	46.53	788.715	46.888	788.618	47.562	788.47
48.531	788.48	48.702	788.404	49.627	787.865	53.756	786.809	54.788	786.456
55.821	786.141	56.853	786.014	60.034	785.503	60.983	785.415	63.047	785.284
67.177	784.906	68.412	784.863	72.339	784.79	83.695	784.878	88.856	784.855
89.613	785.052	89.889	785.138	90.921	785.722	91.953	786.253	92.566	786.593
95.05	788.09	95.907	788.743	96.187	788.923	96.592	789.083	97.115	789.262
98.84	789.225	104.719	789.225						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.032	0	.032	104.719	.032

Bank Sta: Left	Right	Coeff Contr.	Expan.
0	104.719	.1	.3

Downstream Deck/Roadway Coordinates

num= 6

Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord	Sta	Hi Cord	Lo Cord
0	792	790.3	36	792	790.3	36	792	787
46	792	787	46	794	794	110	794	794

Downstream Bridge Cross Section Data

Station Elevation Data num= 79

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	790.224	1.103	790.26	2.104	790.232	3.104	790.259	4.241	790.264
5.104	790.295	6.105	790.242	7.105	790.266	8.105	790.163	9.105	789.588
10.107	788.984	11.106	788.534	12.106	787.781	14.37	787.255	14.92	786.998
15.67	786.656	17.49	786.528	20.89	786.28	21.82	786.332	25.13	786.519
27.45	787.302	28.05	787.507	30.84	787.975	31.35	788.06	31.98	788.184
35.23	788.814	38.84	789.024	39.48	789.061	43.75	788.882	43.9	788.876
46.9	788.345	47.56	788.232	47.84	788.153	48.57	787.947	53.26	787.756
56.89	787.605	57.68	787.312	58.16	787.141	58.7	787.044	59.65	786.871
61.5	786.257	62.4	785.954	63.91	785.724	64.38	785.655	65.3	785.486
66.93	785.192	67.73	785.034	68.35	784.891	68.93	784.844	69	784.84
69.16	784.833	71.28	784.74	72.99	784.756	75.71	784.781	77.62	784.689
79.48	784.598	80.47	784.604	80.94	784.607	82.34	784.617	85.15	784.475
85.69	784.45	87.95	784.389	88.26	784.38	88.65	784.395	91.54	784.502
94.92	784.453	95.02	784.452	95.02	784.455	95.32	784.55	95.43	784.55
96.38	784.55	98.8	785.106	100.86	785.607	107.75	788.177	109.15	788.697
109.94	789.089	112.55	790.405	113.39	790.437	115.7	790.525		

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
0	.032	0	.032	115.7	.032

Bank Sta: Left	Right	Coeff Contr.	Expan.
0	115.7	.1	.3

Ineffective Flow num= 1

Sta L	Sta R	Elev	Permanent
35.23	44.82	790.95	T

Upstream Embankment side slope = 0 horiz. to 1.0 vertical
Downstream Embankment side slope = 0 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow = .98
Elevation at which weir flow begins =
Energy head used in spillway design =
Spillway height used in design =
Weir crest shape = Broad Crested

Number of Abutments = 2

Abutment Data

Upstream num= 3

Sta	Elev	Sta	Elev	Sta	Elev
6.5	790.3	8.5	790.3	13.5	790.3

Downstream num= 3

Sta	Elev	Sta	Elev	Sta	Elev
5	790.3	7	790.3	11	790.3

Abutment Data

Upstream num= 2

Sta	Elev	Sta	Elev
30.9	790.3	37.5	790.3

Downstream num= 2

```
     Sta    Elev     Sta    Elev
********************************
    30.9   790.3    37.5   790.3

Number of Bridge Coefficient Sets =  1

Low Flow Methods and Data
       Energy
Selected Low Flow Methods = Highest Energy Answer

High Flow Method
       Energy Only

Additional Bridge Parameters
       Add Friction component to Momentum
       Do not add Weight component to Momentum
       Class B flow critical depth computations use critical depth
           inside the bridge at the upstream end
       Criteria to check for pressure flow = Upstream energy grade line

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2198

INPUT
Description: K10 - 2021 survey
Station Elevation Data    num=      79
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0 790.224   1.103  790.26   2.104 790.232   3.104 790.259   4.241 790.264
   5.104 790.295   6.105 790.242   7.105 790.266   8.105 790.163   9.105 789.588
  10.107 788.984  11.106 788.534  12.106 787.781   14.37 787.255   14.92 786.998
   15.67 786.656   17.49 786.528   20.89  786.28   21.82 786.332   25.13 786.519
   27.45 787.302   28.05 787.507   30.84 787.975   31.35  788.06   31.98 788.184
   35.23 788.814   38.84 789.024   39.48 789.061   43.75 788.882    43.9 788.876
    46.9 788.345   47.56 788.232   47.84 788.153   48.57 787.947   53.26 787.756
   56.89 787.605   57.68 787.312   58.16 787.141    58.7 787.044   59.65 786.871
    61.5 786.257    62.4 785.954   63.91 785.724   64.38 785.655    65.3 785.486
   66.93 785.192   67.73 785.034   68.35 784.891   68.93 784.844      69  784.84
   69.16 784.833   71.28  784.74   72.99 784.756   75.71 784.781   77.62 784.689
   79.48 784.598   80.47 784.604   80.94 784.607   82.34 784.617   85.15 784.475
   85.69  784.45   87.95 784.389   88.26  784.38   88.65 784.395   91.54 784.502
   94.92 784.453   95.02 784.452   95.02 784.455   95.32  784.55   95.43  784.55
   96.38  784.55    98.8 785.106  100.86 785.607  107.75 788.177  109.15 788.697
  109.94 789.089  112.55 790.405  113.39 790.437   115.7 790.525

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
```

```
************************************************
       0    .032       0    .032   115.7    .032

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   115.7                8    14.5       6             .1       .3
Ineffective Flow     num=       1
   Sta L   Sta R    Elev  Permanent
   35.23   44.82  790.95       T

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  789.20  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.31  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)        *  788.90  * Reach Len. (m)      *    8.00  *   14.50  *
6.00  *
* Crit W.S. (m)        *          * Flow Area (m2)      *          *  236.14  *
      *
* E.G. Slope (m/m)     *0.001750  * Area (m2)           *          *  236.30  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)        *   92.47  * Top Width (m)       *          *   92.47  *
      *
* Vel Total (m/s)      *    2.46  * Avg. Vel. (m/s)     *          *    2.46  *
      *
* Max Chl Dpth (m)     *    4.52  * Hydr. Depth (m)     *          *    2.63  *
      *
* Conv. Total (m3/s)   * 13866.1  * Conv. (m3/s)        *          * 13866.1  *
      *
* Length Wtd. (m)      *   14.50  * Wetted Per. (m)     *          *   91.68  *
      *
* Min Ch El (m)        *  784.38  * Shear (N/m2)        *          *   44.19  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *         *  108.54  *
      *
* Frctn Loss (m)       *    0.03  * Cum Volume (1000 m3) *         *  450.76  *
      *
* C & E Loss (m)       *    0.03  * Cum SA (1000 m2)    *          *  166.10  *
      *
*********************************************************************************
********

Warning: Divided flow computed for this cross-section.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
```

CROSS SECTION

RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2184

INPUT
Description: Section K11 - 2021 Survey
Station Elevation Data   num=   114

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	789.593	.769	789.641	1.77	789.656	2.771	789.602	4.571	789.63
5.774	789.701	6.775	789.74	7.776	789.742	8.766	789.773	9.745	789.841
10.779	789.882	11.913	789.896	12.961	789.945	15.784	790.024	18.787	790.069
20.79	790.127	22.792	790.206	23.793	790.276	25.795	790.225	27.645	790.239
28.893	790.327	29.799	790.337	30.808	789.721	31.801	789.012	32.889	788.483
33.803	787.89	34.804	787.453	35.805	786.968	36.036	786.901	36.552	786.804
36.806	786.728	38.808	786.641	39.809	786.506	40.81	786.335	41.811	786.32
44.814	786.354	46.126	787.069	46.817	787.423	47.818	787.87	48.622	788.031
48.819	788.018	48.998	788.212	49.671	788.845	49.82	789.004	49.956	789.167
50.719	790.24	50.821	790.362	51.822	790.387	53.824	790.309	58.829	790.316
59.83	790.293	60.831	790.308	61.832	790.371	62.833	790.386	64.835	790.289
68.839	790.277	69.84	790.236	70.647	790.292	71.019	790.297	71.842	790.286
72.844	790.227	73.845	790.286	74.848	790.273	75.891	790.312	76.848	790.323
77.849	790.257	78.85	790.126	79.038	790.048	79.635	789.913	79.851	789.82
80.23	789.779	84.13	787.97	84.68	787.716	84.92	787.688	86.95	787.445
88.55	786.614	89.03	786.35	90.21	786.065	92.01	785.628	95.36	785.182
96.71	785.001	97.41	784.895	98.72	784.691	99.7	784.581	100.54	784.492
101.88	784.505	102.78	784.514	103.25	784.507	104.55	784.485	104.78	784.441
105.58	784.316	108.89	784.275	109.02	784.273	109.05	784.273	110.31	784.241
110.59	784.259	111.6	784.313	113.29	784.484	113.3	784.484	120.09	784.613
120.49	784.693	120.59	784.715	121.08	784.759	122.61	784.901	123.29	785.144
124.57	785.569	126.52	788.704	126.57	788.792	126.59	788.793	126.88	788.812
127.18	788.832	127.19	788.833	127.23	788.861	128.84	790.304		

Manning's n Values   num=   3

Sta	n Val	Sta	n Val	Sta	n Val
0	.032	0	.032	128.84	.032

```
Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0  128.84              147     117     112             .1       .3
Ineffective Flow     num=       1
   Sta L   Sta R    Elev  Permanent
   57.31   68.85  790.72       T
```

CROSS SECTION OUTPUT Profile #200-Yr Matrix CC

```
*****************************************************************************************
********
* E.G. Elev (m)       *  789.14  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.61  * Wt. n-Val.          *          *   0.032  *
      *
* W.S. Elev (m)       *  788.53  * Reach Len. (m)      *  147.00  *  117.00  *
112.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  167.73  *
      *
* E.G. Slope (m/m)    *0.003353  * Area (m2)           *          *  167.73  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *   60.03  * Top Width (m)       *          *   60.03  *
      *
* Vel Total (m/s)     *    3.46  * Avg. Vel. (m/s)     *          *    3.46  *
      *
* Max Chl Dpth (m)    *    4.29  * Hydr. Depth (m)     *          *    2.79  *
      *
* Conv. Total (m3/s)  * 10016.1  * Conv. (m3/s)        *          * 10016.1  *
      *
* Length Wtd. (m)     *  117.00  * Wetted Per. (m)     *          *   63.49  *
      *
* Min Ch El (m)       *  784.24  * Shear (N/m2)        *          *   86.86  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *  300.38  *
      *
* Frctn Loss (m)      *    0.50  * Cum Volume (1000 m3) *         *  447.83  *
      *
* C & E Loss (m)      *    0.02  * Cum SA (1000 m2)    *          *  164.99  *
      *
*****************************************************************************************
********
```

Warning: Divided flow computed for this cross-section.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate
the need for additional cross sections.

CROSS SECTION

RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 2068

INPUT
Description: Section K11b - 2021 Survey
Station Elevation Data   num=   95

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
0	788.793	1.453	788.936	2.461	789.15	4.477	789.159	6.492	789.059
7.5	788.97	9.458	788.593	9.59	788.544	10.524	788.093	11.531	787.811

```
  12.145 787.615  12.539  787.52  13.547 787.236  19.594 785.682  20.602 785.513
  21.609 785.701  23.625 786.256  24.685 786.672  25.641 787.079  26.648 787.242
  27.656 787.635  28.664 787.889  29.672 788.497   30.68 788.533  30.955 788.518
  31.687 788.516  32.695 788.375  34.538 787.866  35.718 787.583  36.726 787.472
  37.734 787.445   39.75 787.425  41.844 787.469  43.781 787.461  45.796 787.411
  47.812 787.439  49.828   787.4  51.843 787.417  52.851 787.441  54.867 787.448
  56.882 787.508   57.89 787.562  58.898 787.669  59.906 787.823  60.913 787.788
  61.921 787.707  62.306 787.698  62.579 787.721  62.929 787.721  63.937 787.921
  64.097 787.924  64.945 787.857  65.889 787.905   66.96 787.932  67.968  787.87
  68.976 787.784  70.991 787.768  71.999  787.78  73.054 787.878  74.015  787.82
  75.023  787.73   76.03 787.508   76.36 787.606   78.28 787.604   79.01 787.603
    79.9 786.876   81.63 785.448   82.01 785.357   86.46 784.291   86.86 784.195
   86.89 784.187   86.94 784.186   90.98 784.127   92.97 784.079   93.57 784.064
   95.67 783.974   95.83 783.967   97.26 783.958   98.97 783.948    99.4 783.944
  103.98 783.893  107.35 783.944   107.6 783.948  107.93 783.973  109.26 784.075
  110.31  784.57  112.16 785.408  113.13 785.945  113.93 786.401  114.71 786.613
  116.46 787.091  118.36 787.422  118.48 787.443  118.51 787.492  118.97 788.353

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .032       0    .032  118.97    .032

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0  118.97               92      97      96             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  788.62  * Element              *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.56  * Wt. n-Val.           *          *   0.032  *
      *
* W.S. Elev (m)        *  788.06  * Reach Len. (m)       *   92.00  *   97.00  *
96.00  *
* Crit W.S. (m)        *          * Flow Area (m2)       *          *  175.42  *
      *
* E.G. Slope (m/m)     *0.005733  * Area (m2)            *          *  175.42  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)          *          *  580.00  *
      *
* Top Width (m)        *  103.30  * Top Width (m)        *          *  103.30  *
      *
* Vel Total (m/s)      *    3.31  * Avg. Vel. (m/s)      *          *    3.31  *
      *
* Max Chl Dpth (m)     *    4.17  * Hydr. Depth (m)      *          *    1.70  *
      *
* Conv. Total (m3/s)   *  7660.0  * Conv. (m3/s)         *          *  7660.0  *
      *
* Length Wtd. (m)      *   97.00  * Wetted Per. (m)      *          *  106.20  *
```

```
      *
* Min Ch El (m)        *  783.89  * Shear (N/m2)         *          *   92.87  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *          *  307.07  *
      *
* Frctn Loss (m)       *    0.32  * Cum Volume (1000 m3) *          *  427.76  *
      *
* C & E Loss (m)       *    0.00  * Cum SA (1000 m2)     *          *  155.44  *
      *
*********************************************************************************
********

Warning: Divided flow computed for this cross-section.
Warning: The conveyance ratio (upstream conveyance divided by downstream
conveyance) is less than 0.7 or greater than
         1.4.  This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 1971

INPUT
Description: K5 - 2021 survey
Station Elevation Data    num=      37
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    6.07 788.626    6.39 788.521       9 787.657   10.93 787.328   20.15 785.777
   20.53 785.114   20.58  785.01   23.24 784.988   27.31 784.953   28.39 785.666
   31.44 787.744    33.8 787.785   34.71   787.8   35.01 787.564   35.89 786.894
   37.61 786.198   39.58 785.358    40.7   785.1   41.62 784.896   44.52 784.193
   44.96 784.086   46.81 784.095   61.77 784.163   63.45 784.086   65.73  783.98
   67.54 784.142   68.47 784.224   70.56 784.136   71.05 784.116   71.52 784.268
   73.53 784.915   77.01 785.909   77.88 786.158   78.55 786.324   82.33 787.242
   82.54 787.998   82.73 788.699

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    6.07    .025    6.07    .025   82.73    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          6.07   82.73              296     292     287             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
```

```
********
* E.G. Elev (m)        *  788.30  * Element              *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.55  * Wt. n-Val.           *          *   0.025  *
      *
* W.S. Elev (m)        *  787.75  * Reach Len. (m)       *  296.00  *  292.00  *
287.00  *
* Crit W.S. (m)        *          * Flow Area (m2)       *          *  176.95  *
      *
* E.G. Slope (m/m)     *0.002099  * Area (m2)            *          *  176.95  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)          *          *  580.00  *
      *
* Top Width (m)        *   70.91  * Top Width (m)        *          *   70.91  *
      *
* Vel Total (m/s)      *    3.28  * Avg. Vel. (m/s)      *          *    3.28  *
      *
* Max Chl Dpth (m)     *    3.77  * Hydr. Depth (m)      *          *    2.50  *
      *
* Conv. Total (m3/s)   * 12659.9  * Conv. (m3/s)         *          * 12659.9  *
      *
* Length Wtd. (m)      *  292.00  * Wetted Per. (m)      *          *   73.97  *
      *
* Min Ch El (m)        *  783.98  * Shear (N/m2)         *          *   49.24  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *          *  161.38  *
      *
* Frctn Loss (m)       *    0.63  * Cum Volume (1000 m3) *          *  410.67  *
      *
* C & E Loss (m)       *    0.01  * Cum SA (1000 m2)     *          *  146.99  *
      *
*********************************************************************************
********

Warning: Divided flow computed for this cross-section.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 1679

INPUT
Description: K61 - Oct 2013
Station Elevation Data    num=      47
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0 787.014   3.701  787.23    4.74  787.29    4.86 787.294    4.98  787.35
    5.02 787.299     5.7 787.083    6.43 786.865   10.63 784.783      12 784.155
   12.08 784.045   12.31 783.737   14.19 783.469   15.34 783.284   17.31 783.353
   19.46 783.429   24.73 783.467   25.41 783.472   27.31 783.457   29.82 783.438
   33.78 783.466   37.48 783.492   43.23 783.518   43.63  783.52   43.99 783.531
   47.64  783.64   48.05 783.884   48.13 783.938   48.29 783.962   49.24 784.131
    49.3 784.178   49.61 784.423   50.52 784.603   51.41 784.777   51.53 784.789
    55.8 785.195   55.94 785.229    57.9 785.649   58.03 785.687   59.71  786.17
   60.84 786.437    61.4 786.581   62.03 786.893   64.15 787.944    64.4 787.941
   64.66 787.938    67.5 787.923

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .025       0    .025    67.5    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0    67.5              209     196     183             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  787.66  * Element              *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.69  * Wt. n-Val.           *          *   0.025  *
      *
* W.S. Elev (m)        *  786.97  * Reach Len. (m)       *  209.00  *  196.00  *
183.00  *
* Crit W.S. (m)        *          * Flow Area (m2)       *          *  158.04  *
      *
* E.G. Slope (m/m)     *0.002188  * Area (m2)            *          *  158.04  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)          *          *  580.00  *
      *
* Top Width (m)        *   56.13  * Top Width (m)        *          *   56.13  *
      *
* Vel Total (m/s)      *    3.67  * Avg. Vel. (m/s)      *          *    3.67  *
      *
* Max Chl Dpth (m)     *    3.69  * Hydr. Depth (m)      *          *    2.82  *
      *
* Conv. Total (m3/s)   * 12399.5  * Conv. (m3/s)         *          * 12399.5  *
      *
* Length Wtd. (m)      *  196.00  * Wetted Per. (m)      *          *   57.53  *
      *
* Min Ch El (m)        *  783.28  * Shear (N/m2)         *          *   58.94  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *          *  216.31  *
      *
* Frctn Loss (m)       *    0.61  * Cum Volume (1000 m3) *          *  361.76  *
      *
```

```
* C & E Loss (m)       *    0.04  * Cum SA (1000 m2)     *          *  128.44  *
      *
*********************************************************************************
********

Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
Warning: The conveyance ratio (upstream conveyance divided by downstream
conveyance) is less than 0.7 or greater than
         1.4.  This may indicate the need for additional cross sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 1483

INPUT
Description: K6 - 2021 survey
Station Elevation Data    num=      39
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    9.01 786.669   10.94 786.639   11.28 786.634   11.45 786.601   12.34 786.427
   15.38 784.754   16.07 784.367   19.88 783.704   21.15 783.488   22.73 783.344
   24.07 783.223   26.28 783.164   28.64 783.101   32.76 783.318   32.97 783.329
   33.19 783.325   35.22 783.289   39.23 783.219   39.67 783.211   39.88 783.217
   42.15 783.278   46.09 783.269   46.48 783.268   46.75 783.278   50.01 783.393
   50.61 783.403   53.43 783.451   55.68 783.441   56.82 783.436   57.66 783.467
   60.45 783.571   62.75 784.043   64.49 784.401   66.61 785.131   66.65 785.146
   66.74   785.2   71.13 787.757   73.27 787.887      74 787.931

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    9.01    .025    9.01    .025      74    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          9.01      74              244     244     245             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  787.01  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    1.13  * Wt. n-Val.          *          *   0.025  *
      *
* W.S. Elev (m)        *  785.88  * Reach Len. (m)      *  244.00  *  244.00  *
245.00  *
* Crit W.S. (m)        *  785.88  * Flow Area (m2)      *          *  123.22  *
      *
* E.G. Slope (m/m)     *0.004776  * Area (m2)           *          *  123.22  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)        *   54.56  * Top Width (m)       *          *   54.56  *
      *
* Vel Total (m/s)      *    4.71  * Avg. Vel. (m/s)     *          *    4.71  *
      *
* Max Chl Dpth (m)     *    2.78  * Hydr. Depth (m)     *          *    2.26  *
      *
* Conv. Total (m3/s)   *  8392.9  * Conv. (m3/s)        *          *  8392.9  *
      *
* Length Wtd. (m)      *  244.00  * Wetted Per. (m)     *          *   55.46  *
      *
* Min Ch El (m)        *  783.10  * Shear (N/m2)        *          *  104.06  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *         *  489.79  *
      *
* Frctn Loss (m)       *    0.92  * Cum Volume (1000 m3) *         *  334.19  *
      *
* C & E Loss (m)       *    0.17  * Cum SA (1000 m2)    *          *  117.59  *
      *
*********************************************************************************
********

Warning: The energy equation could not be balanced within the specified number of
iterations.  The program used critical
         depth for the water surface and continued on with the calculations.
Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.
Warning: During the standard step iterations, when the assumed water surface was
set equal to critical depth, the calculated
         water surface came back below critical depth.  This indicates that there
is not a valid subcritical answer.  The
         program defaulted to critical depth.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 1239
```

```
INPUT
Description: K6A - 2021 Survey
Station Elevation Data    num=      63
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    6.83 786.272    9.59 786.257   11.18 786.249   11.64 786.048   12.35 785.748
   13.42 785.421   15.17 784.912   15.93 784.209   16.14 784.023   17.06 783.691
   19.63 782.758   22.81 782.845      24 782.878   25.91 782.894   29.71 782.927
   30.97  782.96    33.9 783.036   34.59 783.059    38.2  783.19    40.6 783.377
   40.79 783.393   41.11  783.41   45.02 783.619   49.44 783.978   49.46 783.979
   49.52 783.982   54.81 784.207   58.49 784.287   59.58 784.311   62.77 784.398
   64.67  784.45   67.19  784.45   69.95  784.45   74.32  784.42   74.39  784.42
   74.51 784.416   78.57 784.265   79.85 783.963   80.93 783.708   81.74  783.49
   82.62 783.241    85.8 783.005   86.34 782.966   86.81 782.913   89.74 782.579
   92.14 782.188    93.3 781.994   94.61 781.871   94.83 781.851   96.54 781.785
   98.79 781.697   99.35 781.711  101.67 781.772  102.19 782.358     103 783.238
  107.15 785.386  109.02 786.362  109.32 786.456  110.17 786.731  113.07 786.866
  114.88 786.951  119.28  786.95  123.42 786.949

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    6.83    .025    6.83    .025  123.42    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          6.83  123.42               133     133     126             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)       *  785.91  * Element            *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.56  * Wt. n-Val.         *          *   0.025  *
      *
* W.S. Elev (m)       *  785.35  * Reach Len. (m)     *  133.00  *  133.00  *
126.00  *
* Crit W.S. (m)       *          * Flow Area (m2)     *          *  175.22  *
      *
* E.G. Slope (m/m)    *0.003049  * Area (m2)          *          *  175.22  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)        *          *  580.00  *
      *
* Top Width (m)       *   93.44  * Top Width (m)      *          *   93.44  *
      *
* Vel Total (m/s)     *    3.31  * Avg. Vel. (m/s)    *          *    3.31  *
      *
* Max Chl Dpth (m)    *    3.66  * Hydr. Depth (m)    *          *    1.88  *
      *
* Conv. Total (m3/s)  * 10504.5  * Conv. (m3/s)       *          * 10504.5  *
      *
```

```
* Length Wtd. (m)     *  133.00  * Wetted Per. (m)    *          *   95.50  *
      *
* Min Ch El (m)       *  781.70  * Shear (N/m2)       *          *   54.85  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *        *  181.57  *
      *
* Frctn Loss (m)      *    0.30  * Cum Volume (1000 m3) *        *  297.78  *
      *
* C & E Loss (m)      *    0.05  * Cum SA (1000 m2)   *          *   99.54  *
      *
***********************************************************************************
********

Warning: The velocity head has changed by more than 0.5 ft (0.15 m).  This may
indicate the need for additional cross
         sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and
previous cross section.  This may indicate
         the need for additional cross sections.

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 1106

INPUT
Description: K7 - 2021 Survey
Station Elevation Data    num=      51
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    5.75 786.729    8.19 786.702    8.54 786.698   13.46 784.296   14.73 783.675
   14.81 783.638    15.1 783.517   20.54 783.431    21.3 783.419   26.06 783.506
   27.07 783.525   30.02 783.507   31.27   783.5   33.05 783.455   35.83 783.385
   42.09 783.173   42.31 783.166   43.05 783.135   46.82 782.979   49.03 782.928
   50.89 782.886   52.25 782.851   54.83 782.785   58.95 782.808   59.43 782.811
   59.83  782.81   63.41 782.803   63.86 782.802   67.54 782.794   68.61 782.777
   72.55 782.716   75.48 782.621   77.33 782.561   81.58 782.225   82.02  782.19
   83.28 782.188    93.4 782.171   95.23 782.325   96.32 782.417    99.7 782.329
    99.8 782.327   99.86  782.35  102.45 783.401  103.86 784.065  108.95 786.394
  109.39 786.527  109.73 786.631  112.26 786.749  113.63 786.812  120.91 786.857
  121.15 786.859

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    5.75    .025    5.75    .025  121.15    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          5.75  121.15                92      91      87             .1       .3
```

```
CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  785.56  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.40  * Wt. n-Val.          *          *   0.025  *
      *
* W.S. Elev (m)        *  785.16  * Reach Len. (m)      *   92.00  *   91.00  *
87.00  *
* Crit W.S. (m)        *          * Flow Area (m2)      *          *  206.03  *
      *
* E.G. Slope (m/m)     *0.001778  * Area (m2)           *          *  206.03  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)        *   94.55  * Top Width (m)       *          *   94.55  *
      *
* Vel Total (m/s)      *    2.82  * Avg. Vel. (m/s)     *          *    2.82  *
      *
* Max Chl Dpth (m)     *    2.99  * Hydr. Depth (m)     *          *    2.18  *
      *
* Conv. Total (m3/s)   * 13753.4  * Conv. (m3/s)        *          * 13753.4  *
      *
* Length Wtd. (m)      *   91.00  * Wetted Per. (m)     *          *   95.57  *
      *
* Min Ch El (m)        *  782.17  * Shear (N/m2)        *          *   37.60  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *         *  105.84  *
      *
* Frctn Loss (m)       *    0.18  * Cum Volume (1000 m3) *         *  272.43  *
      *
* C & E Loss (m)       *    0.01  * Cum SA (1000 m2)    *          *   87.04  *
      *
*********************************************************************************
********

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 1015

INPUT
Description: K7A - 2021 Survey
Station Elevation Data    num=      55
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
*******************************************************************************
    4.86 786.063    8.27 785.911    8.75  785.89    9.45 785.585   14.76 783.278
   16.51 783.083   16.62 783.071   16.89 783.054   20.56 782.831   22.59 782.909
   26.82  783.07   28.54   783.1   31.35 783.148   32.91 783.676   33.03 783.717
   33.22 783.711   35.95 783.617   36.61  783.54   39.59   783.2   42.42 783.092
   43.52  783.05   44.97  783.07   47.44 783.105   50.14 783.151   51.44 783.174
   52.43  783.18   55.95 783.204   57.04 783.184   60.05 783.128   63.06 782.967
   63.55  782.94   63.77 782.927      66 782.797   66.53 782.723   69.58 782.294
   71.51 781.745   73.03 781.326   75.02 781.212   77.07 781.088    78.9 781.116
   81.25 781.153   82.59 781.244   85.01 781.403   85.84 781.385   89.51 781.301
   89.58  781.33   92.81 782.757   94.99 783.711  100.02 785.952  100.14 785.988
  100.64 786.146  105.17 786.347  105.57 786.365  106.17 786.368  107.11 786.373

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    4.86    .025    4.86    .025  107.11    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          4.86  107.11               112     116     143             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)        *  785.37  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.51  * Wt. n-Val.          *          *   0.025  *
      *
* W.S. Elev (m)        *  784.86  * Reach Len. (m)      *  112.00  *  116.00  *
143.00  *
* Crit W.S. (m)        *          * Flow Area (m2)      *          *  183.83  *
      *
* E.G. Slope (m/m)     *0.002325  * Area (m2)           *          *  183.83  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)        *   86.45  * Top Width (m)       *          *   86.45  *
      *
* Vel Total (m/s)      *    3.16  * Avg. Vel. (m/s)     *          *    3.16  *
      *
* Max Chl Dpth (m)     *    3.77  * Hydr. Depth (m)     *          *    2.13  *
      *
* Conv. Total (m3/s)   * 12027.9  * Conv. (m3/s)        *          * 12027.9  *
      *
* Length Wtd. (m)      *  116.00  * Wetted Per. (m)     *          *   87.87  *
      *
* Min Ch El (m)        *  781.09  * Shear (N/m2)        *          *   47.70  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *         *  150.51  *
      *
* Frctn Loss (m)       *    0.21  * Cum Volume (1000 m3) *         *  254.69  *
      *
* C & E Loss (m)       *    0.05  * Cum SA (1000 m2)    *          *   78.80  *
```

```
      *
*********************************************************************************
********
```

Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross sections.

CROSS SECTION

RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve RS: 899.86

INPUT
Description: K62 - Oct 2013
Station Elevation Data num= 57

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
.91	784.77	1.17	784.774	1.47	784.763	1.78	784.753	1.81	784.752
4.34	784.879	6.23	784.989	7.14	785.038	8.2	785.104	9.16	785.133
10.88	785.185	11.68	785.209	12.13	785.222	12.83	784.842	14.38	784.03
15	782.847	15.38	782.172	15.75	782.068	16.1	781.96	17.01	781.595
18.81	780.79	19.19	780.835	20.28	780.973	23.86	781.161	24.12	781.175
25.77	781.26	25.95	781.27	28.46	781.26	29.08	781.257	31.7	781.048
31.71	781.051	34.29	781.963	36.43	782.105	36.84	782.132	53.72	782.656
55.71	782.718	57.58	782.734	65.07	782.796	70.75	782.835	81.41	782.909
84.3	782.87	90.41	782.787	96.17	782.704	101.86	782.622	102.77	782.544
103.69	782.467	104.66	782.659	105.39	782.806	105.82	783.116	106.8	783.832
107.27	784.159	109.75	785.594	109.85	785.653	109.87	785.666	111.12	785.706
111.83	785.738	112.39	785.759						

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
.91	.025	.91	.025	112.39	.025

```
Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
           .91  112.39              138     127     119             .1       .3
```

CROSS SECTION OUTPUT Profile #200-Yr Matrix CC

```
*********************************************************************************
********
* E.G. Elev (m)        *  785.11  * Element              *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.35  * Wt. n-Val.           *          *   0.025  *
      *
* W.S. Elev (m)        *  784.75  * Reach Len. (m)       *  138.00  *  127.00  *
119.00  *
* Crit W.S. (m)        *          * Flow Area (m2)       *          *  219.84  *
      *
* E.G. Slope (m/m)     *0.001477  * Area (m2)            *          *  219.84  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)          *          *  580.00  *
      *
* Top Width (m)        *   95.39  * Top Width (m)        *          *   95.39  *
      *
* Vel Total (m/s)      *    2.64  * Avg. Vel. (m/s)      *          *    2.64  *
      *
* Max Chl Dpth (m)     *    3.96  * Hydr. Depth (m)      *          *    2.30  *
      *
* Conv. Total (m3/s)   * 15090.6  * Conv. (m3/s)         *          * 15090.6  *
      *
* Length Wtd. (m)      *  127.00  * Wetted Per. (m)      *          *   97.79  *
      *
* Min Ch El (m)        *  780.79  * Shear (N/m2)         *          *   32.57  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *          *   85.92  *
      *
* Frctn Loss (m)       *    0.18  * Cum Volume (1000 m3) *          *  231.28  *
      *
* C & E Loss (m)       *    0.03  * Cum SA (1000 m2)     *          *   68.25  *
      *
*********************************************************************************
********
```

Warning: Divided flow computed for this cross-section.

CROSS SECTION

RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve RS: 772

INPUT
Description: K7B - 2021 Survey
Station Elevation Data num= 76

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
6.64	784.942	8.09	784.921	9.07	784.908	9.37	784.814	10.13	784.561
10.94	784.006	11.36	783.703	12.49	783.204	13.19	782.904	13.46	782.613
13.85	782.205	23.07	781.099	25.15	780.851	25.37	780.889	26.14	781.021
28.37	781.082	31.21	781.163	35.73	781.328	35.98	781.337	36.11	781.346
38.32	781.506	39.99	781.627	40.09	781.634	40.21	781.647	44.56	782.095
48.95	783.191	49.06	783.217	49.14	783.217	50.19	783.211	53.43	783.194
53.69	783.193	54	783.206	58.34	783.392	59.11	783.389	62.88	783.373
64.23	783.317	67.78	783.171	70.72	783.232	72.69	783.273	75.01	783.307
77.15	783.339	79.05	783.331	81.79	783.319	84.14	783.35	86.7	783.384
88.46	783.373	91.19	783.357	95.5	783.418	95.99	783.425	100.56	783.326
100.84	783.32	101.17	783.308	105.54	783.148	106.8	783.1	109.92	782.98

```
  111.82 782.917  114.12 782.838  115.37 782.792  116.23  782.76  117.65 782.699
   120.5 782.577  123.48 782.466  124.51 782.428  125.66 782.382  128.54 782.266
   130.2 782.214  132.29 782.148  134.01 782.298  136.09 782.474  137.42 783.374
  137.69 783.556  138.03 783.712  140.73  784.98  140.89 784.991  144.32 785.224
  149.44 785.241

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    6.64    .025    6.64    .025  149.44    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
          6.64  149.44              133     129     124             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)       *  784.90  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.27  * Wt. n-Val.          *          *   0.025  *
      *
* W.S. Elev (m)       *  784.63  * Reach Len. (m)      *  133.00  *  129.00  *
124.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  251.66  *
      *
* E.G. Slope (m/m)    *0.001400  * Area (m2)           *          *  251.66  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *  130.06  * Top Width (m)       *          *  130.06  *
      *
* Vel Total (m/s)     *    2.30  * Avg. Vel. (m/s)     *          *    2.30  *
      *
* Max Chl Dpth (m)    *    3.78  * Hydr. Depth (m)     *          *    1.93  *
      *
* Conv. Total (m3/s)  * 15501.1  * Conv. (m3/s)        *          * 15501.1  *
      *
* Length Wtd. (m)     *  129.00  * Wetted Per. (m)     *          *  131.70  *
      *
* Min Ch El (m)       *  780.85  * Shear (N/m2)        *          *   26.23  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *   60.46  *
      *
* Frctn Loss (m)      *    0.19  * Cum Volume (1000 m3) *         *  201.34  *
      *
* C & E Loss (m)      *    0.01  * Cum SA (1000 m2)    *          *   53.94  *
      *
*********************************************************************************
********
```

```
CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 643.15

INPUT
Description: K8 - 2021 Survey
Station Elevation Data    num=      67
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0 784.996    1.04 784.966    5.53 784.835    6.87 784.796    7.16 784.733
    8.18 784.526   10.58 783.729   11.08 783.563   11.37 783.403   12.74 782.659
   14.75 782.201   15.03 782.135   16.91 781.697   18.44 781.339   19.03 781.072
   20.39 780.453   21.37 780.498   25.15 780.671   30.43 781.131   31.32 781.207
   35.49 780.833   35.52  780.83   35.71 780.842   39.63 781.105   41.02 781.073
   46.24 780.953   49.62 781.188   50.55 781.252   51.65 781.509    54.3  782.12
   56.63 782.342   58.88 782.561   62.85 782.706   63.13 782.716   63.32 782.723
   67.32 782.869   71.25 782.896   71.47 782.897   71.68 782.893   75.38  782.82
   78.89 782.943   79.62 782.969   80.55 783.032   83.87 783.257   86.17  783.25
   88.35 783.243   91.81 783.216   92.49 783.211   93.61 783.196   96.92 783.153
   98.14 783.087  100.68 782.947  101.77 782.874  104.05  782.72  106.28 782.568
  107.97 782.452  109.36 782.366  110.98 782.265  111.93 782.486  112.83 782.693
  113.17 782.945  113.58 783.233   116.5 784.634  117.32 784.891  120.08 785.145
  123.38 785.128  125.58 785.116

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .025       0    .025  125.58    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0  125.58              148     179     194             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
*********************************************************************************
********
* E.G. Elev (m)       *  784.71  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.33  * Wt. n-Val.          *          *   0.025  *
      *
* W.S. Elev (m)       *  784.38  * Reach Len. (m)      *  148.00  *  179.00  *
194.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  229.47  *
      *
* E.G. Slope (m/m)    *0.001476  * Area (m2)           *          *  229.47  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *  107.37  * Top Width (m)       *          *  107.37  *
```

```
      *
* Vel Total (m/s)      *    2.53  * Avg. Vel. (m/s)      *          *    2.53  *
      *
* Max Chl Dpth (m)     *    3.93  * Hydr. Depth (m)      *          *    2.14  *
      *
* Conv. Total (m3/s)   * 15095.6  * Conv. (m3/s)         *          * 15095.6  *
      *
* Length Wtd. (m)      *  179.00  * Wetted Per. (m)      *          *  108.80  *
      *
* Min Ch El (m)        *  780.45  * Shear (N/m2)         *          *   30.53  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *          *   77.18  *
      *
* Frctn Loss (m)       *    0.30  * Cum Volume (1000 m3) *          *  170.30  *
      *
* C & E Loss (m)       *    0.02  * Cum SA (1000 m2)     *          *   38.62  *
      *
**********************************************************************************
********
```

Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
sections.
Warning: The energy loss was greater than 1.0 ft (0.3 m). between the current and previous cross section. This may indicate
the need for additional cross sections.

CROSS SECTION

RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 463.66

INPUT
Description: K53 - 2021 Survey

```
Station Elevation Data    num=      63
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0 787.085     .88  787.05    1.34 787.034     2.1 786.979    3.28 786.921
    4.76 786.839    6.56 786.087     9.3 784.904   10.33 784.777   11.07  784.69
    11.9  784.59   13.05 784.456   15.78 783.677   15.91  783.64   16.99 783.195
   19.07 782.335   19.17 782.327   20.84 782.201   26.96 782.033   27.43  782.02
   27.48 782.018   27.75  782.01   31.08 781.907   31.72 781.888   32.84 781.856
   35.28 781.788   37.93 781.705   38.33 781.692   38.54 781.682   40.73 781.575
   43.44 781.499    45.4 781.444    46.5  781.42   48.31  781.38   51.03 781.605
   51.64 781.656   52.13 781.574   55.09 781.082   57.63 781.104   57.68 781.104
   57.76 781.101   61.46 780.983   62.14 780.907   63.27  780.78    64.8 780.682
   66.12 780.593   68.31 780.488   70.79 780.369   72.77 780.412   74.33 780.445
   74.92 780.525   76.05 780.679   78.35 780.523   79.64 780.434   80.62 780.526
      84 780.845   84.67 781.075   87.72 782.129   89.08 782.965   89.37 783.147
   90.15 783.401   93.97 784.657   98.65 784.683

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .025       0    .025   98.65    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0   98.65                3      54      69             .1       .3
```

CROSS SECTION OUTPUT Profile #200-Yr Matrix CC

```
**********************************************************************************
********
* E.G. Elev (m)        *  784.39  * Element              *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.51  * Wt. n-Val.           *          *   0.025  *
      *
* W.S. Elev (m)        *  783.88  * Reach Len. (m)       *    3.00  *   54.00  *
69.00  *
* Crit W.S. (m)        *          * Flow Area (m2)       *          *  183.96  *
      *
* E.G. Slope (m/m)     *0.001966  * Area (m2)            *          *  183.96  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)          *          *  580.00  *
      *
* Top Width (m)        *   76.55  * Top Width (m)        *          *   76.55  *
      *
* Vel Total (m/s)      *    3.15  * Avg. Vel. (m/s)      *          *    3.15  *
      *
* Max Chl Dpth (m)     *    3.51  * Hydr. Depth (m)      *          *    2.40  *
      *
* Conv. Total (m3/s)   * 13081.9  * Conv. (m3/s)         *          * 13081.9  *
      *
* Length Wtd. (m)      *   54.00  * Wetted Per. (m)      *          *   77.61  *
      *
* Min Ch El (m)        *  780.37  * Shear (N/m2)         *          *   45.69  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *          *  144.06  *
      *
* Frctn Loss (m)       *    0.07  * Cum Volume (1000 m3) *          *  133.30  *
      *
* C & E Loss (m)       *    0.07  * Cum SA (1000 m2)     *          *   22.16  *
      *
**********************************************************************************
********
```

Warning: The velocity head has changed by more than 0.5 ft (0.15 m). This may indicate the need for additional cross
sections.

```
CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 410.07

INPUT
Description: K54 - 2021 Survey
Station Elevation Data    num=      59
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0 786.883     .37 786.872    1.65 786.797    2.07 786.786    2.72 786.749
    4.91 785.937    7.65 784.927   10.34  784.64   11.59 784.505   14.76 784.193
   15.24 784.148   16.27 783.821    18.4 783.147   20.23 782.891   22.43 782.576
   25.08 781.978   25.18 781.955   25.29 781.956    28.7 781.988   29.13 781.993
   32.81 782.038   33.44 782.048   35.43 782.077   37.94 782.074   39.39 782.072
   40.96 782.039   46.72 781.919   49.37 781.904   50.16 781.899   53.34 781.829
   54.14 781.811   55.03 781.812   57.56 781.814   60.21 781.662   61.66 781.579
   64.07 781.519   65.42 781.486   68.21 781.378   68.96 781.349   69.83 781.309
   72.33 781.197   74.38 781.101   75.38 781.055   78.93  780.84   84.93 780.476
   95.97 779.978      98 779.886   99.31 779.995  105.44  780.51  107.43  781.15
  107.85 781.288  108.87  781.44  112.87 782.034  119.37 784.117  121.52 784.804
  121.63 784.722  122.49 784.104  124.92  784.27  130.37 784.639

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .025       0    .025  130.37    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0  130.37               18      18      18             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)        *  784.24  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.27  * Wt. n-Val.          *          *   0.025  *
      *
* W.S. Elev (m)        *  783.98  * Reach Len. (m)      *    2.00  *    2.00  *
2.00  *
* Crit W.S. (m)        *  782.91  * Flow Area (m2)      *          *  254.25  *
      *
* E.G. Slope (m/m)     *0.000987  * Area (m2)           *          *  254.25  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)        *  103.16  * Top Width (m)       *          *  103.16  *
      *
* Vel Total (m/s)      *    2.28  * Avg. Vel. (m/s)     *          *    2.28  *
```

```
      *
* Max Chl Dpth (m)     *    4.09  * Hydr. Depth (m)     *          *    2.46  *
      *
* Conv. Total (m3/s)   * 18461.6  * Conv. (m3/s)        *          * 18461.6  *
      *
* Length Wtd. (m)      *    2.00  * Wetted Per. (m)     *          *  103.95  *
      *
* Min Ch El (m)        *  779.89  * Shear (N/m2)        *          *   23.67  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *         *   54.00  *
      *
* Frctn Loss (m)       *    0.00  * Cum Volume (1000 m3) *         *  121.47  *
      *
* C & E Loss (m)       *    0.01  * Cum SA (1000 m2)    *          *   17.31  *
      *
***********************************************************************************
********

BRIDGE


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 409

INPUT
Description:
Distance from Upstream XS =   1.999
Deck/Roadway Width        =    13.5
Weir Coefficient          =     1.4
Upstream  Deck/Roadway Coordinates
    num=      4
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
************************************************************************
       0  788.45  784.68       0  788.45  785.55     150  788.45  785.55
     150  788.45  784.54

Upstream Bridge Cross Section Data
Station Elevation Data    num=      59
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0 786.883     .37 786.872    1.65 786.797    2.07 786.786    2.72 786.749
    4.91 785.937    7.65 784.927   10.34  784.64   11.59 784.505   14.76 784.193
   15.24 784.148   16.27 783.821    18.4 783.147   20.23 782.891   22.43 782.576
   25.08 781.978   25.18 781.955   25.29 781.956    28.7 781.988   29.13 781.993
   32.81 782.038   33.44 782.048   35.43 782.077   37.94 782.074   39.39 782.072
   40.96 782.039   46.72 781.919   49.37 781.904   50.16 781.899   53.34 781.829
   54.14 781.811   55.03 781.812   57.56 781.814   60.21 781.662   61.66 781.579
   64.07 781.519   65.42 781.486   68.21 781.378   68.96 781.349   69.83 781.309
   72.33 781.197   74.38 781.101   75.38 781.055   78.93  780.84   84.93 780.476
   95.97 779.978      98 779.886   99.31 779.995  105.44  780.51  107.43  781.15
```

```
  107.85 781.288  108.87  781.44  112.87 782.034  119.37 784.117  121.52 784.804
  121.63 784.722  122.49 784.104  124.92  784.27  130.37 784.639

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .025       0    .025  130.37    .025

Bank Sta: Left   Right    Coeff Contr.   Expan.
             0  130.37             .1       .3

Downstream  Deck/Roadway Coordinates
    num=       4
     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord     Sta Hi Cord Lo Cord
************************************************************************
       0  788.45  784.68       0  788.45  785.55     150  788.45  785.55
     150  788.45  784.54

Downstream Bridge Cross Section Data
Station Elevation Data    num=      36
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0 786.874     .06 786.874     .14 786.873    1.71 786.277    5.45 784.859
   10.05 784.549   10.09 784.546   10.19 784.522   21.37 781.889    24.3 782.157
   24.34  782.16   24.39  782.16   28.43 782.186   60.31 781.655   61.01 781.643
   81.39 780.719   81.95 780.693   87.12 780.377   87.27 780.368   87.66 780.366
  101.29 780.292  101.31   780.3  102.15 780.561  102.52 780.695  103.84 781.176
  107.05 781.537  108.07 781.651  111.39  782.95  111.51 782.998  114.83 783.535
  114.95 783.555  115.07 783.599   118.4 784.794  118.85  784.78  119.89 784.749
  119.96 784.749

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .025       0    .025  119.96    .025

Bank Sta: Left   Right    Coeff Contr.   Expan.
             0  119.96             .1       .3

Upstream Embankment side slope             =       2 horiz. to 1.0 vertical
Downstream Embankment side slope           =       2 horiz. to 1.0 vertical
Maximum allowable submergence for weir flow =     .98
Elevation at which weir flow begins        =
Energy head used in spillway design        =
Spillway height used in design             =
Weir crest shape                           = Broad Crested

Number of Piers =  3

Pier Data
```

```
Pier Station     Upstream=   28.43    Downstream=   28.43
Upstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
   2.624 776.118   2.624 778.249   2.624 780.099   2.624     786
Downstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
   2.624 776.118   2.624 778.249   2.624 780.099   2.624     786

Pier Data
Pier Station     Upstream=   60.43    Downstream=   60.43
Upstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
   2.624 776.118   2.624 778.249   2.624 780.099   2.624     786
Downstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
   2.624 776.118   2.624 778.249   2.624 780.099   2.624     786

Pier Data
Pier Station     Upstream=   93.29    Downstream=   93.29
Upstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
   2.624 776.118   2.624 777.581   2.624 779.849   2.624     786
Downstream     num=       4
    Width   Elev    Width   Elev    Width   Elev    Width   Elev
****************************************************************
   2.624 776.118   2.624 777.581   2.624 779.849   2.624     786

Number of Bridge Coefficient Sets =  1

Low Flow Methods and Data
       Energy
Selected Low Flow Methods = Highest Energy Answer

High Flow Method
       Energy Only

Additional Bridge Parameters
       Add Friction component to Momentum
       Do not add Weight component to Momentum
       Class B flow critical depth computations use critical depth
           inside the bridge at the upstream end
       Criteria to check for pressure flow = Upstream energy grade line

CROSS SECTION
```

```
RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 392

INPUT
Description: K54b - Oct 2013
Station Elevation Data    num=      36
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
       0 786.874     .06 786.874     .14 786.873    1.71 786.277    5.45 784.859
   10.05 784.549   10.09 784.546   10.19 784.522   21.37 781.889    24.3 782.157
   24.34  782.16   24.39  782.16   28.43 782.186   60.31 781.655   61.01 781.643
   81.39 780.719   81.95 780.693   87.12 780.377   87.27 780.368   87.66 780.366
  101.29 780.292  101.31   780.3  102.15 780.561  102.52 780.695  103.84 781.176
  107.05 781.537  108.07 781.651  111.39  782.95  111.51 782.998  114.83 783.535
  114.95 783.555  115.07 783.599   118.4 784.794  118.85  784.78  119.89 784.749
  119.96 784.749

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
       0    .025       0    .025  119.96    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
             0  119.96              117     117     113            .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)       *  784.18  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)        *    0.31  * Wt. n-Val.          *          *   0.025  *
      *
* W.S. Elev (m)       *  783.86  * Reach Len. (m)      *  117.00  *  117.00  *
113.00  *
* Crit W.S. (m)       *          * Flow Area (m2)      *          *  233.39  *
      *
* E.G. Slope (m/m)    *0.001307  * Area (m2)           *          *  233.39  *
      *
* Q Total (m3/s)      *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)       *  102.80  * Top Width (m)       *          *  102.80  *
      *
* Vel Total (m/s)     *    2.49  * Avg. Vel. (m/s)     *          *    2.49  *
      *
* Max Chl Dpth (m)    *    3.57  * Hydr. Depth (m)     *          *    2.27  *
      *
* Conv. Total (m3/s)  * 16042.4  * Conv. (m3/s)        *          * 16042.4  *
      *
* Length Wtd. (m)     *  117.00  * Wetted Per. (m)     *          *  103.61  *
```

```
      *
* Min Ch El (m)       *  780.29  * Shear (N/m2)        *          *   28.87  *
      *
* Alpha               *    1.00  * Stream Power (N/m s) *         *   71.76  *
      *
* Frctn Loss (m)      *    0.13  * Cum Volume (1000 m3) *         *  117.51  *
      *
* C & E Loss (m)      *    0.04  * Cum SA (1000 m2)    *          *   15.59  *
      *
***********************************************************************************
********

CROSS SECTION


RIVER: Thalweg_AllSurve
REACH: Thalweg_AllSurve   RS: 274.99

INPUT
Description: K9 - 2021 Survey
Station Elevation Data    num=      96
     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev     Sta    Elev
********************************************************************************
    1.07 784.742    7.67 784.792    8.08 784.795    8.11 784.795    8.54 784.798
    9.36 784.565   11.62 783.925   12.74 783.481   16.08 782.164   18.53 782.089
   19.97 782.045   21.39  782.21   23.55 782.461   25.45 782.432    26.9  782.41
    28.4 782.338   30.51 782.236   32.14 782.205   34.54  782.16   37.71 782.123
    38.7 782.112   39.52 782.115   42.72 782.125    43.8 782.122   47.38 782.111
   49.27 782.574   49.37 782.598   49.55 782.611   52.68 782.834   56.34 782.812
    57.6 782.805   59.17 782.757   63.72  782.62   65.03 782.666   69.05 782.806
   72.73 782.476   72.78 782.471   72.98 782.495   75.92 782.848   76.52 782.841
   79.52 782.809    83.7 782.629   83.93 782.619   84.73 782.595   88.49  782.48
   89.79 782.438   93.94 782.304   99.82  782.14  101.34 782.098  102.12 782.074
  105.96 781.953  107.03 782.009  110.64   782.2  116.16 782.102  116.47 782.096
   116.5 782.093  118.05 781.946  119.02 781.841  121.07 781.619  123.41 781.231
  124.35  781.07  127.17 780.909  128.37 780.841  130.84 780.824  133.32 780.808
  136.77 780.965  137.72 781.009  138.74 780.971  143.09 780.809  143.91 780.816
  146.17 780.835  146.54 780.865  146.78 780.884   147.8 780.891  150.53 780.912
  151.83 780.907  153.45   780.9  153.63  780.95  153.99 781.056  154.64 780.991
  156.71 780.786  162.46 781.226  163.22 781.284  165.57 780.678   166.1 780.541
  166.23 780.569  172.08 781.919  174.73 783.374  175.84 783.986  176.09 783.995
  179.39 784.112  181.29 784.818     182 785.084  182.38 785.111  183.33 785.179
   184.8 785.147

Manning's n Values        num=       3
     Sta   n Val     Sta   n Val     Sta   n Val
************************************************
    1.07    .025    1.07    .025   184.8    .025

Bank Sta: Left   Right    Lengths: Left Channel   Right     Coeff Contr.   Expan.
```

```
          1.07   184.8                0       0       0             .1       .3

CROSS SECTION OUTPUT  Profile #200-Yr Matrix CC
***********************************************************************************
********
* E.G. Elev (m)        *  784.00  * Element             *  Left OB *  Channel *
Right OB *
* Vel Head (m)         *    0.19  * Wt. n-Val.          *          *   0.025  *
      *
* W.S. Elev (m)        *  783.82  * Reach Len. (m)      *  149.60  *  149.60  *
149.60  *
* Crit W.S. (m)        *          * Flow Area (m2)      *          *  302.93  *
      *
* E.G. Slope (m/m)     *0.001019  * Area (m2)           *          *  302.93  *
      *
* Q Total (m3/s)       *  580.00  * Flow (m3/s)         *          *  580.00  *
      *
* Top Width (m)        *  163.64  * Top Width (m)       *          *  163.64  *
      *
* Vel Total (m/s)      *    1.91  * Avg. Vel. (m/s)     *          *    1.91  *
      *
* Max Chl Dpth (m)     *    3.27  * Hydr. Depth (m)     *          *    1.85  *
      *
* Conv. Total (m3/s)   * 18168.8  * Conv. (m3/s)        *          * 18168.8  *
      *
* Length Wtd. (m)      *  149.60  * Wetted Per. (m)     *          *  164.99  *
      *
* Min Ch El (m)        *  780.54  * Shear (N/m2)        *          *   18.35  *
      *
* Alpha                *    1.00  * Stream Power (N/m s) *         *   35.13  *
      *
* Frctn Loss (m)       *    0.06  * Cum Volume (1000 m3) *         *   86.13  *
      *
* C & E Loss (m)       *    0.02  * Cum SA (1000 m2)    *          *          *
      *
***********************************************************************************
********

********************************************************************************

SUMMARY OF MANNING'S N VALUES

River:Columbia
*****************************************************************
*     Reach      *   River Sta.   *   n1    *   n2    *   n3    *
*****************************************************************
*US              *    2           *     .022*     .022*     .022*
*US              *    1           *     .022*     .022*     .022*
*Downstream      *    4           *     .022*     .022*     .022*
*Downstream      *    3           *     .022*     .022*     .022*
*Downstream      *    2           *     .022*     .022*     .022*
*Downstream      *    1.5         *Bridge   *         *         *
*Downstream      *    1           *     .022*     .022*     .022*
*Downstream      *    0           *     .022*     .022*     .022*
*****************************************************************

River:Thalweg_AllSurve
*****************************************************************
*     Reach      *   River Sta.   *   n1    *   n2    *   n3    *
*****************************************************************
*Thalweg_AllSurve*    3583        *     .032*     .032*     .032*
*Thalweg_AllSurve*    3519        *     .032*     .032*     .032*
*Thalweg_AllSurve*    3132        *     .032*     .032*     .032*
*Thalweg_AllSurve*    2742        *     .032*     .032*     .032*
*Thalweg_AllSurve*    2571        *     .032*     .032*     .032*
*Thalweg_AllSurve*    2443        *     .032*     .032*     .032*
*Thalweg_AllSurve*    2312        *     .032*     .032*     .032*
*Thalweg_AllSurve*    2272        *Bridge   *         *         *
*Thalweg_AllSurve*    2219        *     .032*     .032*     .032*
*Thalweg_AllSurve*    2205        *Bridge   *         *         *
*Thalweg_AllSurve*    2198        *     .032*     .032*     .032*
*Thalweg_AllSurve*    2184        *     .032*     .032*     .032*
*Thalweg_AllSurve*    2068        *     .032*     .032*     .032*
*Thalweg_AllSurve*    1971        *     .025*     .025*     .025*
*Thalweg_AllSurve*    1679        *     .025*     .025*     .025*
*Thalweg_AllSurve*    1483        *     .025*     .025*     .025*
*Thalweg_AllSurve*    1239        *     .025*     .025*     .025*
*Thalweg_AllSurve*    1106        *     .025*     .025*     .025*
*Thalweg_AllSurve*    1015        *     .025*     .025*     .025*
*Thalweg_AllSurve*    899.86      *     .025*     .025*     .025*
*Thalweg_AllSurve*    772         *     .025*     .025*     .025*
*Thalweg_AllSurve*    643.15      *     .025*     .025*     .025*
*Thalweg_AllSurve*    463.66      *     .025*     .025*     .025*
*Thalweg_AllSurve*    410.07      *     .025*     .025*     .025*
*Thalweg_AllSurve*    409         *Bridge   *         *         *
*Thalweg_AllSurve*    392         *     .025*     .025*     .025*
*Thalweg_AllSurve*    274.99      *     .025*     .025*     .025*
*****************************************************************

********************************************************************************

SUMMARY OF REACH LENGTHS

River: Columbia
*****************************************************************
*     Reach      *   River Sta.   *  Left   * Channel *  Right  *
*****************************************************************
*US              *    2           *  109.999*      120*  124.998*
*US              *    1           *        0*        0*        0*
*Downstream      *    4           *      354*      354*      354*
```

```
*Downstream      *    3           *      156*      156*      156*
*Downstream      *    2           *        6*        6*        6*
*Downstream      *    1.5         *Bridge   *         *         *
*Downstream      *    1           *  130.159*  132.161*  135.161*
*Downstream      *    0           *        0*        0*        0*
*****************************************************************

River: Thalweg_AllSurve
*****************************************************************
*     Reach      *   River Sta.   *  Left    * Channel *  Right  *
*****************************************************************
*Thalweg_AllSurve*    3583        *       72*       65*       59*
*Thalweg_AllSurve*    3519        *      381*      386*      391*
*Thalweg_AllSurve*    3132        *      385*      390*      377*
*Thalweg_AllSurve*    2742        *      217*      171*      157*
*Thalweg_AllSurve*    2571        *      133*      128*      115*
*Thalweg_AllSurve*    2443        *      133*      128*      115*
*Thalweg_AllSurve*    2312        *    47.71*       50*   52.672*
*Thalweg_AllSurve*    2272        *Bridge   *         *         *
*Thalweg_AllSurve*    2219        *        8*     14.5*        6*
*Thalweg_AllSurve*    2205        *Bridge   *         *         *
*Thalweg_AllSurve*    2198        *        8*     14.5*        6*
*Thalweg_AllSurve*    2184        *      147*      117*      112*
*Thalweg_AllSurve*    2068        *       92*       97*       96*
*Thalweg_AllSurve*    1971        *      296*      292*      287*
*Thalweg_AllSurve*    1679        *      209*      196*      183*
*Thalweg_AllSurve*    1483        *      244*      244*      245*
*Thalweg_AllSurve*    1239        *      133*      133*      126*
*Thalweg_AllSurve*    1106        *       92*       91*       87*
*Thalweg_AllSurve*    1015        *      112*      116*      143*
*Thalweg_AllSurve*    899.86      *      138*      127*      119*
*Thalweg_AllSurve*    772         *      133*      129*      124*
*Thalweg_AllSurve*    643.15      *      148*      179*      194*
*Thalweg_AllSurve*    463.66      *        3*       54*       69*
*Thalweg_AllSurve*    410.07      *       18*       18*       18*
*Thalweg_AllSurve*    409         *Bridge   *         *         *
*Thalweg_AllSurve*    392         *      117*      117*      113*
*Thalweg_AllSurve*    274.99      *        0*        0*        0*
*****************************************************************

********************************************************************************

SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: Columbia

*******************************************************
*     Reach      *   River Sta.   * Contr.  * Expan.  *
*******************************************************
*US              *    2       *       .1*       .3*
*US              *    1       *       .1*       .3*
```

```
*Downstream      *    4       *       .1*       .3*
*Downstream      *    3       *       .1*       .3*
*Downstream      *    2       *       .1*       .3*
*Downstream      *    1.5     *Bridge   *         *
*Downstream      *    1       *       .1*       .3*
*Downstream      *    0       *       .1*       .3*
*******************************************************
River: Thalweg_AllSurve

*******************************************************
*     Reach      *   River Sta.   * Contr.  * Expan.  *
*******************************************************
*Thalweg_AllSurve*    3583    *       .1*       .3*
*Thalweg_AllSurve*    3519    *       .1*       .3*
*Thalweg_AllSurve*    3132    *       .1*       .3*
*Thalweg_AllSurve*    2742    *       .1*       .3*
*Thalweg_AllSurve*    2571    *       .1*       .3*
*Thalweg_AllSurve*    2443    *       .1*       .3*
*Thalweg_AllSurve*    2312    *       .1*       .3*
*Thalweg_AllSurve*    2272    *Bridge   *         *
*Thalweg_AllSurve*    2219    *       .1*       .3*
*Thalweg_AllSurve*    2205    *Bridge   *         *
*Thalweg_AllSurve*    2198    *       .1*       .3*
*Thalweg_AllSurve*    2184    *       .1*       .3*
*Thalweg_AllSurve*    2068    *       .1*       .3*
*Thalweg_AllSurve*    1971    *       .1*       .3*
*Thalweg_AllSurve*    1679    *       .1*       .3*
*Thalweg_AllSurve*    1483    *       .1*       .3*
*Thalweg_AllSurve*    1239    *       .1*       .3*
*Thalweg_AllSurve*    1106    *       .1*       .3*
*Thalweg_AllSurve*    1015    *       .1*       .3*
*Thalweg_AllSurve*    899.86  *       .1*       .3*
*Thalweg_AllSurve*    772     *       .1*       .3*
*Thalweg_AllSurve*    643.15  *       .1*       .3*
*Thalweg_AllSurve*    463.66  *       .1*       .3*
*Thalweg_AllSurve*    410.07  *       .1*       .3*
*Thalweg_AllSurve*    409     *Bridge   *         *
*Thalweg_AllSurve*    392     *       .1*       .3*
*Thalweg_AllSurve*    274.99  *       .1*       .3*
*******************************************************

Profile Output Table - Standard Table 1
*********************************************************************************
*********************************************************************************
***************************
* River            * Reach            * River Sta   * Profile          * Q Total *
Min Ch El * W.S. Elev * Crit W.S. * E.G. Elev * E.G. Slope * Vel Chnl * Flow Area *
Top Width * Froude # Chl *
*                  *                  *             *                  *  (m3/s) *
     (m) *       (m) *       (m) *       (m) *      (m/m) *    (m/s) *      (m2) *
```

```
     (m) *              *
**********************************************************************************
**********************************************************************************
***************************
* Thalweg_AllSurve * Thalweg_AllSurve * 3583        * 200-Yr Matrix CC *  580.00 *
  790.52 *   794.747 *           *   795.953 *   0.005091 *     4.86 *    119.26 *
   31.69 *         0.80 *
* Thalweg_AllSurve * Thalweg_AllSurve * 3519        * 200-Yr Matrix CC *  580.00 *
  791.31 *   794.744 *           *   795.524 *   0.004241 *     3.91 *    148.22 *
   54.22 *         0.76 *
* Thalweg_AllSurve * Thalweg_AllSurve * 3132        * 200-Yr Matrix CC *  580.00 *
  789.77 *   792.655 *    792.49 *   793.537 *   0.006308 *     4.16 *    139.45 *
   63.35 *         0.90 *
* Thalweg_AllSurve * Thalweg_AllSurve * 2742        * 200-Yr Matrix CC *  580.00 *
  787.79 *   790.628 *           *   791.109 *   0.005564 *     3.07 *    188.76 *
  121.86 *         0.79 *
* Thalweg_AllSurve * Thalweg_AllSurve * 2571        * 200-Yr Matrix CC *  580.00 *
  786.46 *   790.320 *           *   790.572 *   0.001625 *     2.22 *    260.82 *
  108.68 *         0.46 *
* Thalweg_AllSurve * Thalweg_AllSurve * 2443        * 200-Yr Matrix CC *  580.00 *
  785.50 *   789.109 *    788.83 *   790.142 *   0.005602 *     4.50 *    128.85 *
   46.70 *         0.87 *
* Thalweg_AllSurve * Thalweg_AllSurve * 2312        * 200-Yr Matrix CC *  580.00 *
  785.29 *   788.917 *    788.14 *   789.492 *   0.003000 *     3.36 *    172.71 *
   61.60 *         0.64 *
* Thalweg_AllSurve * Thalweg_AllSurve * 2272        *                  *  Bridge *
         *           *           *           *            *          *           *
         *              *
* Thalweg_AllSurve * Thalweg_AllSurve * 2219        * 200-Yr Matrix CC *  580.00 *
  784.79 *   788.806 *    787.94 *   789.302 *   0.003147 *     3.12 *    185.87 *
   75.93 *         0.64 *
* Thalweg_AllSurve * Thalweg_AllSurve * 2205        *                  *  Bridge *
         *           *           *           *            *          *           *
         *              *
* Thalweg_AllSurve * Thalweg_AllSurve * 2198        * 200-Yr Matrix CC *  580.00 *
  784.38 *   788.896 *           *   789.204 *   0.001750 *     2.46 *    236.14 *
   92.47 *         0.48 *
* Thalweg_AllSurve * Thalweg_AllSurve * 2184        * 200-Yr Matrix CC *  580.00 *
  784.24 *   788.530 *           *   789.139 *   0.003353 *     3.46 *    167.73 *
   60.03 *         0.66 *
* Thalweg_AllSurve * Thalweg_AllSurve * 2068        * 200-Yr Matrix CC *  580.00 *
  783.89 *   788.062 *           *   788.620 *   0.005733 *     3.31 *    175.42 *
  103.30 *         0.81 *
* Thalweg_AllSurve * Thalweg_AllSurve * 1971        * 200-Yr Matrix CC *  580.00 *
  783.98 *   787.752 *           *   788.300 *   0.002099 *     3.28 *    176.95 *
   70.91 *         0.66 *
* Thalweg_AllSurve * Thalweg_AllSurve * 1679        * 200-Yr Matrix CC *  580.00 *
  783.28 *   786.973 *           *   787.660 *   0.002188 *     3.67 *    158.04 *
   56.13 *         0.70 *
* Thalweg_AllSurve * Thalweg_AllSurve * 1483        * 200-Yr Matrix CC *  580.00 *
```

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  783.10 *   785.876 *    785.88 *   787.006 *   0.004776 *     4.71 *    123.22 *
   54.56 *         1.00 *
* Thalweg_AllSurve * Thalweg_AllSurve * 1239        * 200-Yr Matrix CC *  580.00 *
  781.70 *   785.354 *           *   785.913 *   0.003049 *     3.31 *    175.22 *
   93.44 *         0.77 *
* Thalweg_AllSurve * Thalweg_AllSurve * 1106        * 200-Yr Matrix CC *  580.00 *
  782.17 *   785.158 *           *   785.562 *   0.001778 *     2.82 *    206.03 *
   94.55 *         0.61 *
* Thalweg_AllSurve * Thalweg_AllSurve * 1015        * 200-Yr Matrix CC *  580.00 *
  781.09 *   784.860 *           *   785.367 *   0.002325 *     3.16 *    183.83 *
   86.45 *         0.69 *
* Thalweg_AllSurve * Thalweg_AllSurve * 899.86      * 200-Yr Matrix CC *  580.00 *
  780.79 *   784.754 *           *   785.109 *   0.001477 *     2.64 *    219.84 *
   95.39 *         0.55 *
* Thalweg_AllSurve * Thalweg_AllSurve * 772         * 200-Yr Matrix CC *  580.00 *
  780.85 *   784.630 *           *   784.901 *   0.001400 *     2.30 *    251.66 *
  130.06 *         0.53 *
* Thalweg_AllSurve * Thalweg_AllSurve * 643.15      * 200-Yr Matrix CC *  580.00 *
  780.45 *   784.384 *           *   784.710 *   0.001476 *     2.53 *    229.47 *
  107.37 *         0.55 *
* Thalweg_AllSurve * Thalweg_AllSurve * 463.66      * 200-Yr Matrix CC *  580.00 *
  780.37 *   783.882 *           *   784.388 *   0.001966 *     3.15 *    183.96 *
   76.55 *         0.65 *
* Thalweg_AllSurve * Thalweg_AllSurve * 410.07      * 200-Yr Matrix CC *  580.00 *
  779.89 *   783.977 *    782.91 *   784.243 *   0.000987 *     2.28 *    254.25 *
  103.16 *         0.46 *
* Thalweg_AllSurve * Thalweg_AllSurve * 409         *                  *  Bridge *
         *           *           *           *            *          *           *
         *              *
* Thalweg_AllSurve * Thalweg_AllSurve * 392         * 200-Yr Matrix CC *  580.00 *
  780.29 *   783.861 *           *   784.176 *   0.001307 *     2.49 *    233.39 *
  102.80 *         0.53 *
* Thalweg_AllSurve * Thalweg_AllSurve * 274.99      * 200-Yr Matrix CC *  580.00 *
  780.54 *   783.816 *           *   784.003 *   0.001019 *     1.91 *    302.93 *
  163.64 *         0.45 *
* Columbia         * US               * 2           * 200-Yr Matrix CC *  741.00 *
  777.83 *   783.775 *           *   784.022 *   0.000331 *     2.20 *    336.43 *
   72.96 *         0.33 *
* Columbia         * US               * 1           * 200-Yr Matrix CC *  741.00 *
  777.83 *   783.730 *           *   783.982 *   0.000342 *     2.22 *    333.39 *
   73.23 *         0.33 *
* Columbia         * Downstream       * 4           * 200-Yr Matrix CC * 1255.00 *
  779.32 *   783.809 *           *   783.921 *   0.000287 *     1.48 *    848.59 *
  315.50 *         0.29 *
* Columbia         * Downstream       * 3           * 200-Yr Matrix CC * 1255.00 *
  777.56 *   783.147 *           *   783.698 *   0.001109 *     3.29 *    381.84 *
  117.45 *         0.58 *
* Columbia         * Downstream       * 2           * 200-Yr Matrix CC * 1255.00 *
  777.29 *   782.942 *    781.68 *   783.531 *   0.000992 *     3.40 *    369.33 *
   98.98 *         0.56 *
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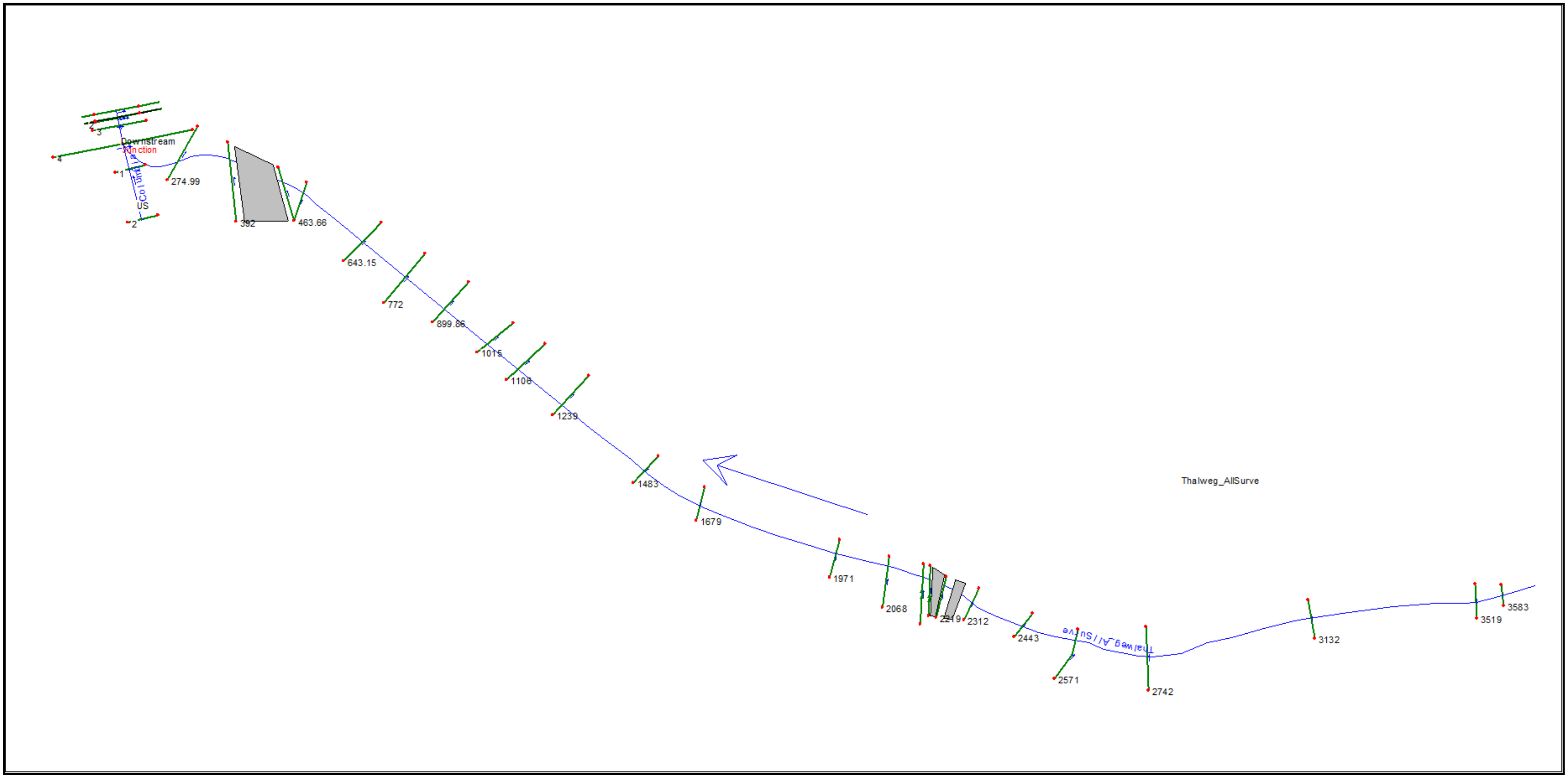
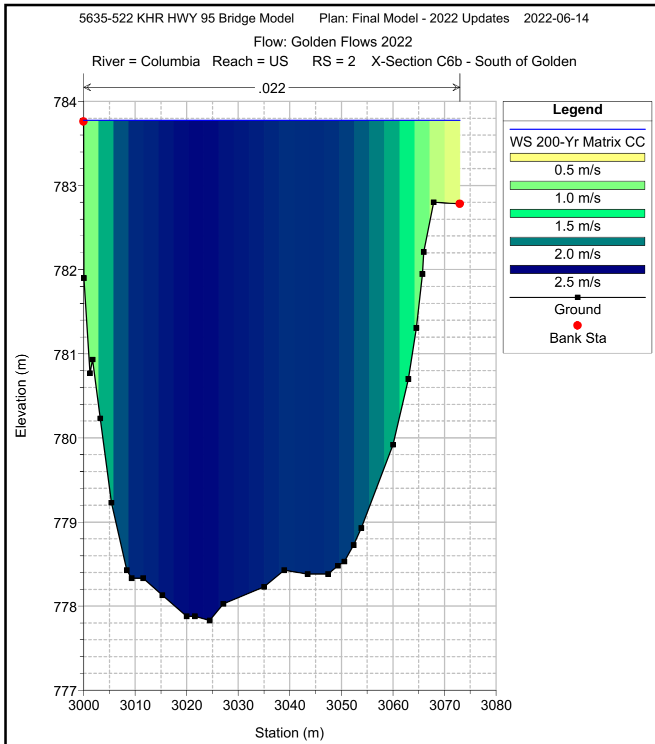
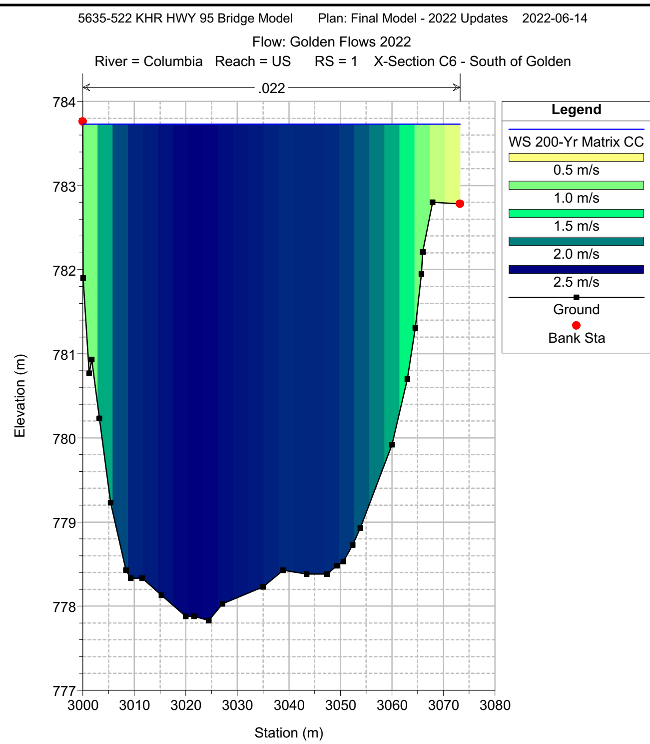
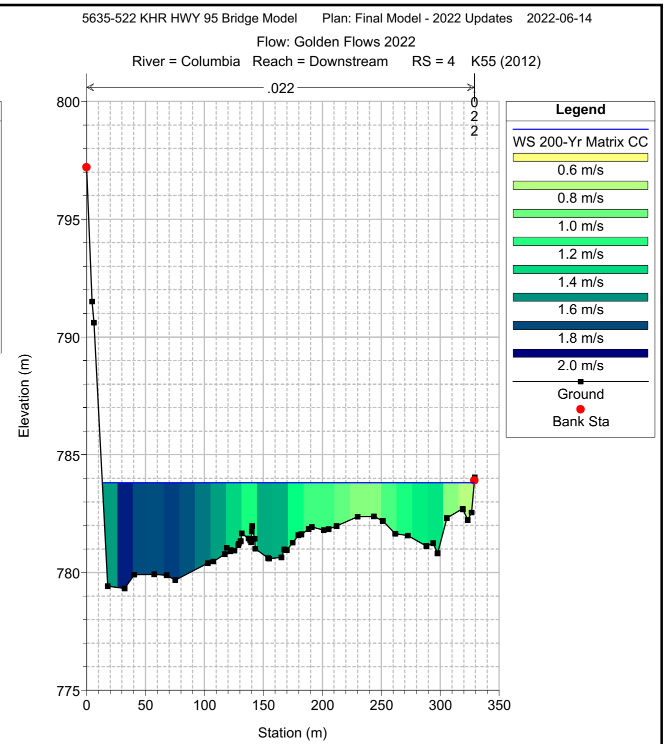
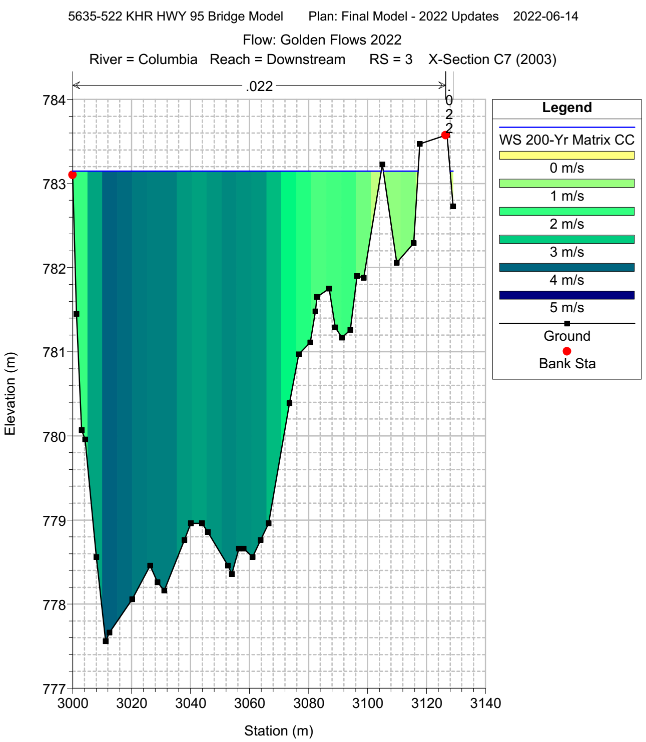
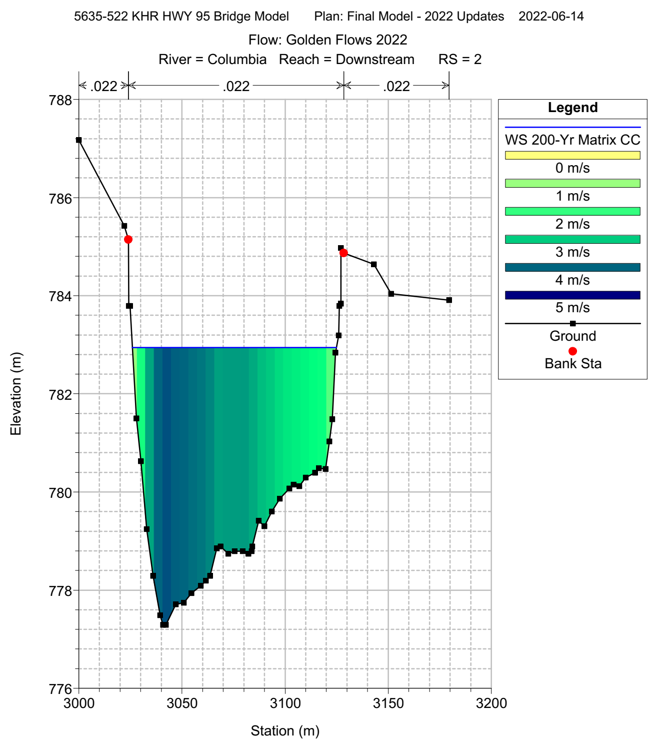

Downstream
Junction
US
274.99
392
463.66
643.15
772
899.86
1015
1106
1239
1483
1679
1971
2068
2219
2312
2443
2571
2742
3132
3519
3583
Thalweg_AllSurve

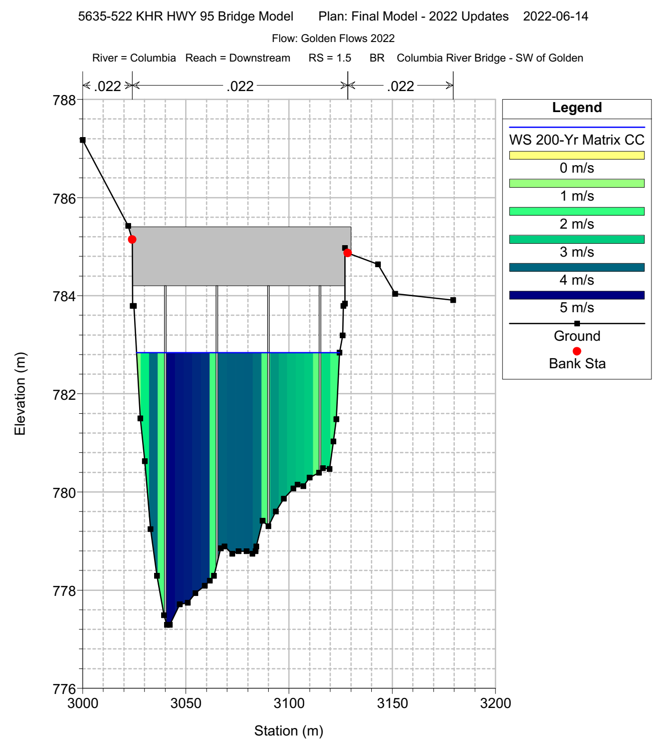

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = US RS = 2 X-Section C6b - South of Golden
.022
Legend
WS 200-Yr Matrix CC
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Bank Sta
Elevation (m)
777
778
779
780
781
782
783
784
Station (m)
3000
3010
3020
3030
3040
3050
3060
3070
3080

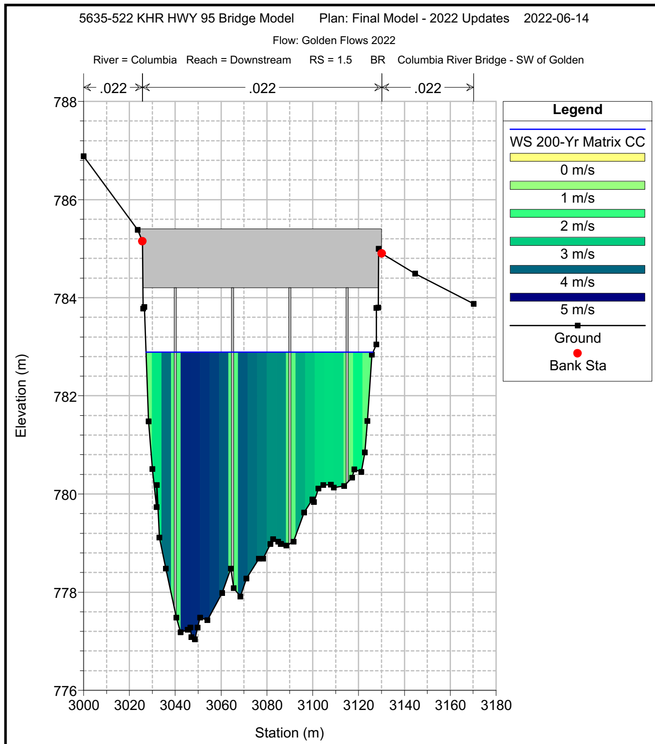

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = US RS = 1 X-Section C6 - South of Golden
.022
Legend
WS 200-Yr Matrix CC
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Bank Sta
Elevation (m)
777
778
779
780
781
782
783
784
Station (m)
3000
3010
3020
3030
3040
3050
3060
3070
3080

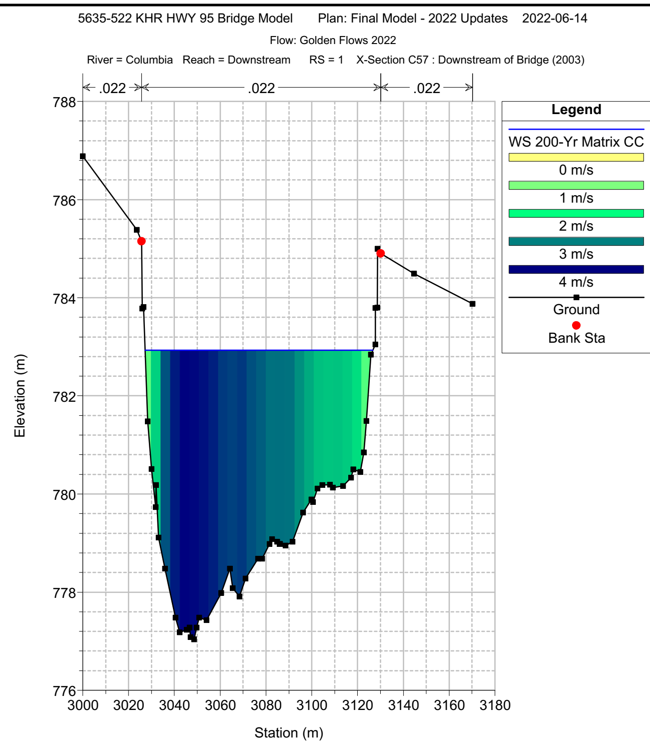

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = Downstream RS = 4 K55 (2012)
.022
0
2
2
Legend
WS 200-Yr Matrix CC
0.6 m/s
0.8 m/s
1.0 m/s
1.2 m/s
1.4 m/s
1.6 m/s
1.8 m/s
2.0 m/s
Ground
Bank Sta
Elevation (m)
775
780
785
790
795
800
Station (m)
0
50
100
150
200
250
300
350

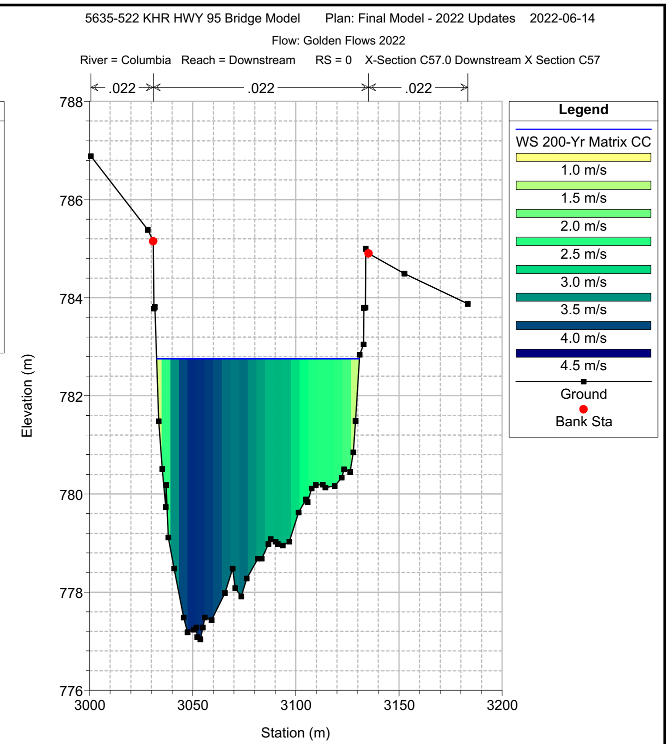

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = Downstream RS = 3 X-Section C7 (2003)
.022
0
2
2
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
777
778
779
780
781
782
783
784
Station (m)
3000
3020
3040
3060
3080
3100
3120
3140

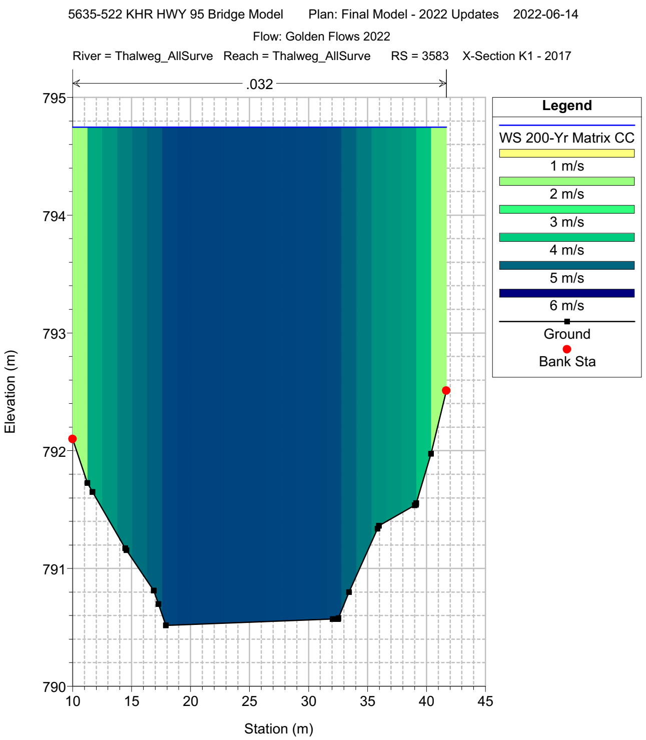

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = Downstream RS = 2
.022
.022
.022
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
776
778
780
782
784
786
788
Station (m)
3000
3050
3100
3150
3200

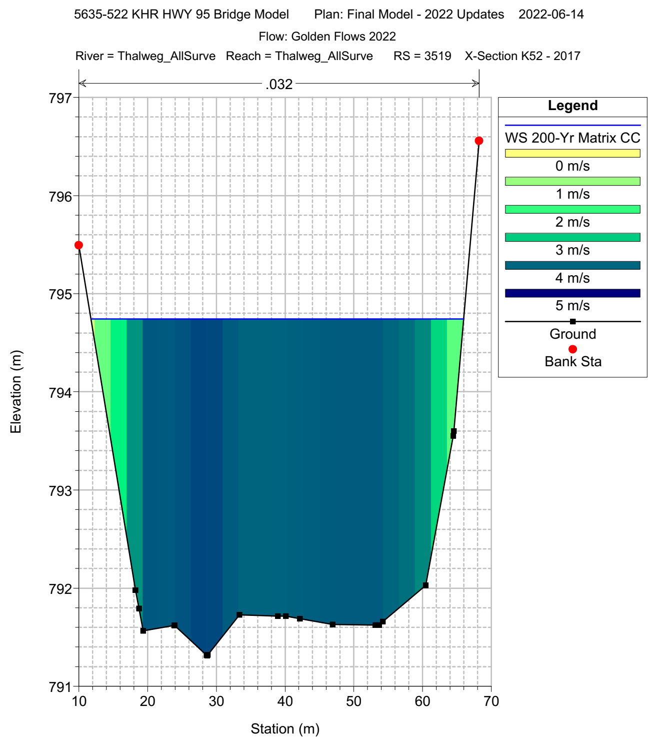

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = Downstream RS = 1.5 BR Columbia River Bridge - SW of Golden
.022
.022
.022
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
776
778
780
782
784
786
788
Station (m)
3000
3050
3100
3150
3200

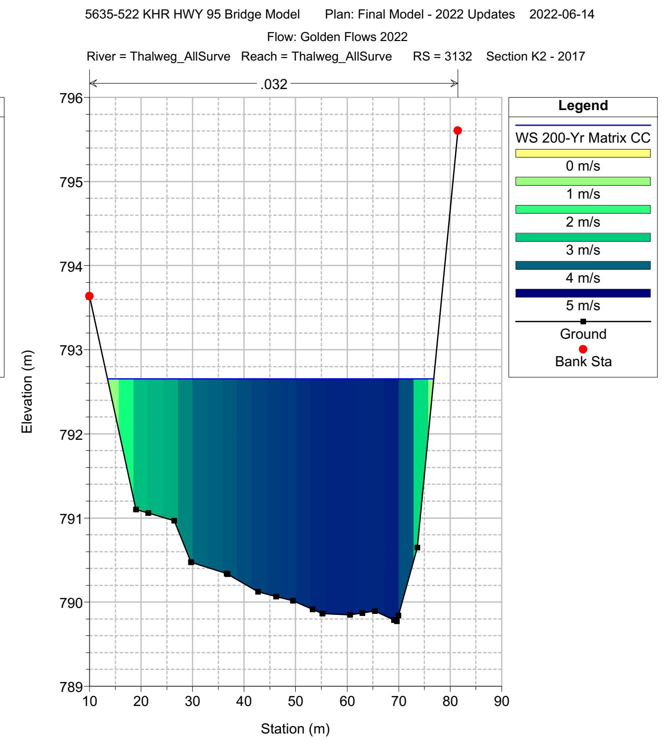

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = Downstream RS = 1.5 BR Columbia River Bridge - SW of Golden
.022
.022
.022
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = Downstream RS = 1 X-Section C57 : Downstream of Bridge (2003)
.022
.022
.022
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

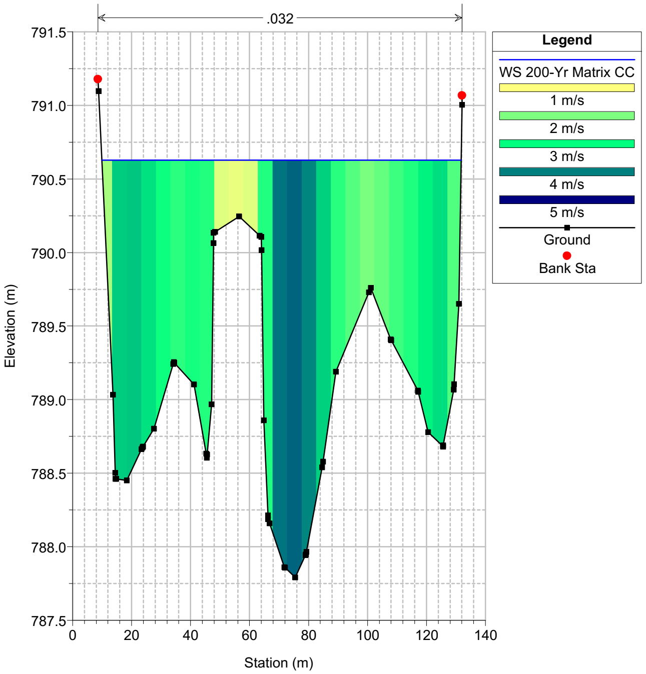

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Columbia Reach = Downstream RS = 0 X-Section C57.0 Downstream X Section C57
.022
.022
.022
Legend
WS 200-Yr Matrix CC
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
4.0 m/s
4.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve Reach = Thalweg_AllSurve RS = 3583 X-Section K1 - 2017
.032
Legend
WS 200-Yr Matrix CC
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
6 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

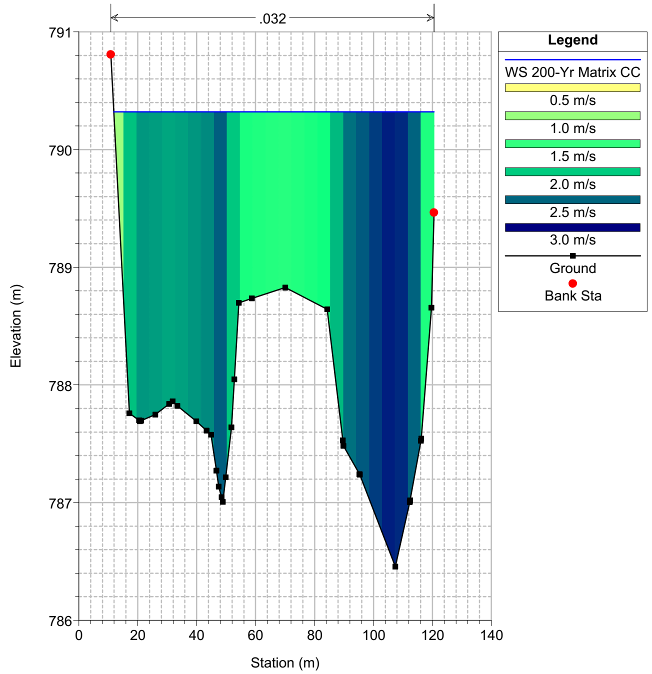

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve Reach = Thalweg_AllSurve RS = 3519 X-Section K52 - 2017
.032
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve Reach = Thalweg_AllSurve RS = 3132 Section K2 - 2017
.032
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

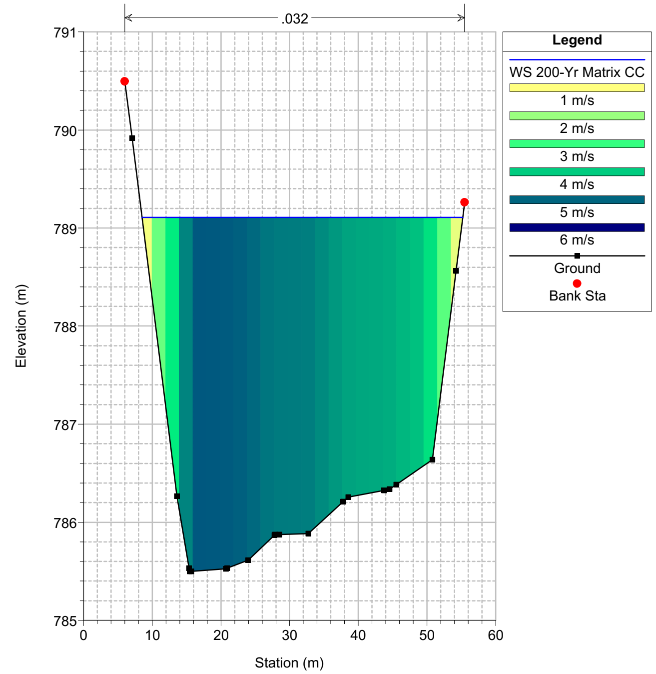
5635-522 KHR HWY 95 Bridge Model   Plan: Final Model - 2022 Updates   2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve   Reach = Thalweg_AllSurve   RS = 2742   K50 - 2017



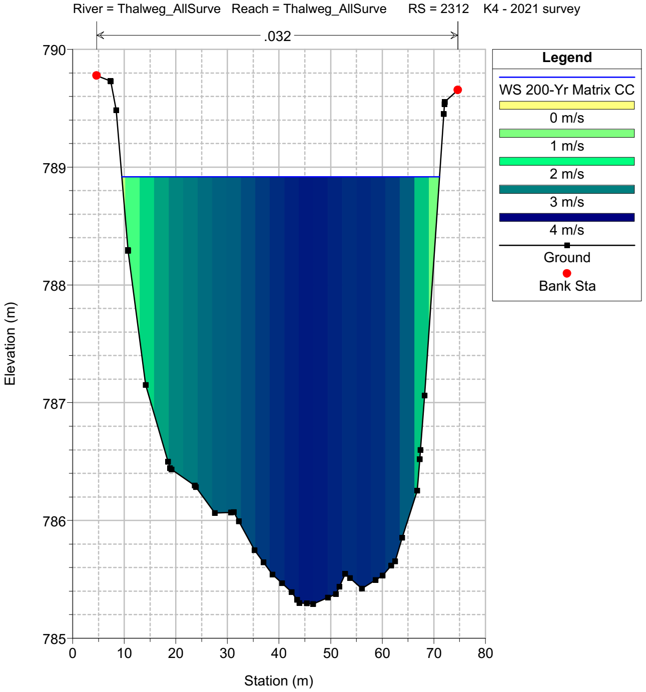
5635-522 KHR HWY 95 Bridge Model   Plan: Final Model - 2022 Updates   2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve   Reach = Thalweg_AllSurve   RS = 2571   K3/K60 - Oct 2017



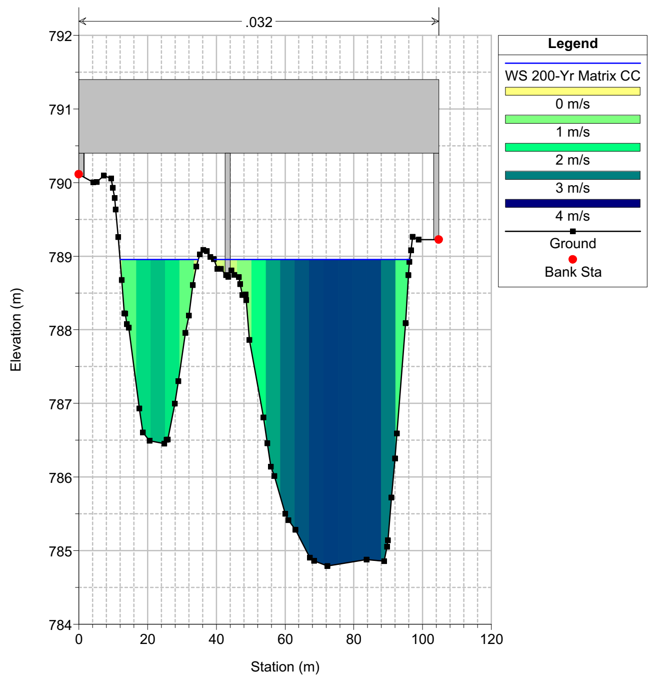
5635-522 KHR HWY 95 Bridge Model   Plan: Final Model - 2022 Updates   2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve   Reach = Thalweg_AllSurve   RS = 2443   K51 - 2017



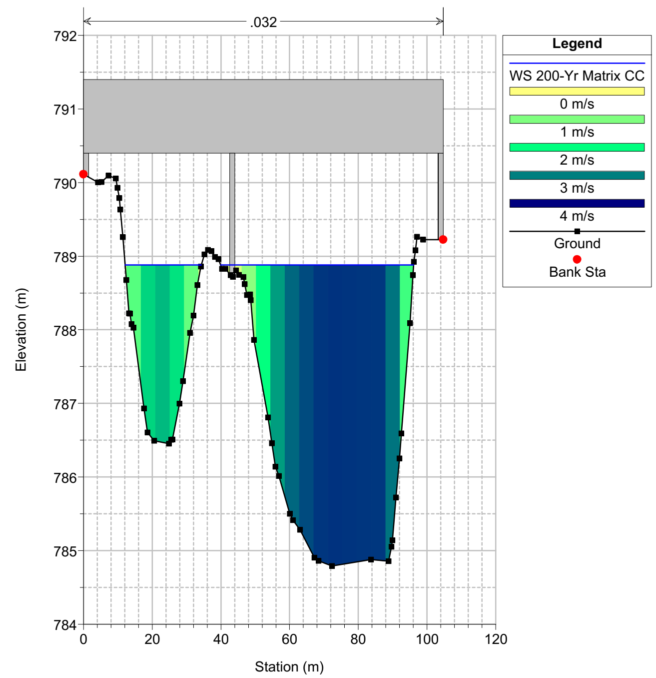
5635-522 KHR HWY 95 Bridge Model   Plan: Final Model - 2022 Updates   2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve   Reach = Thalweg_AllSurve   RS = 2312   K4 - 2021 survey

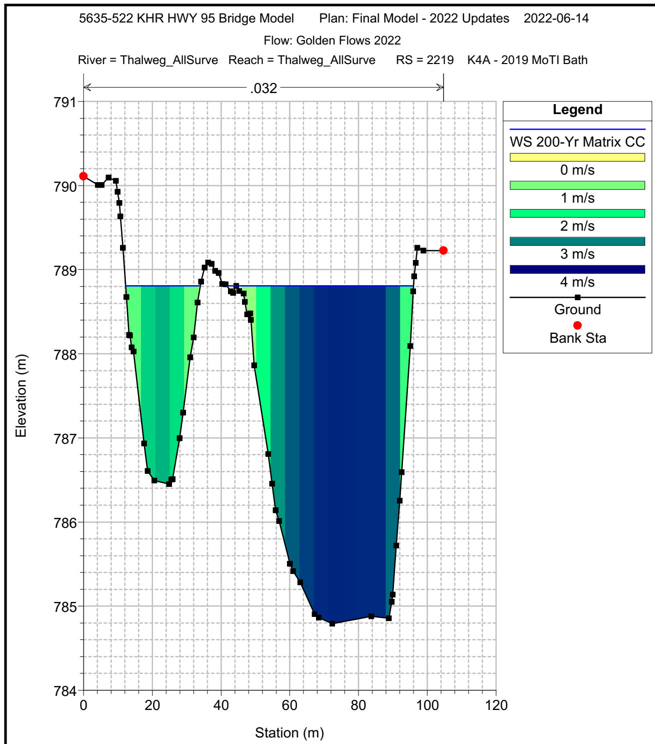


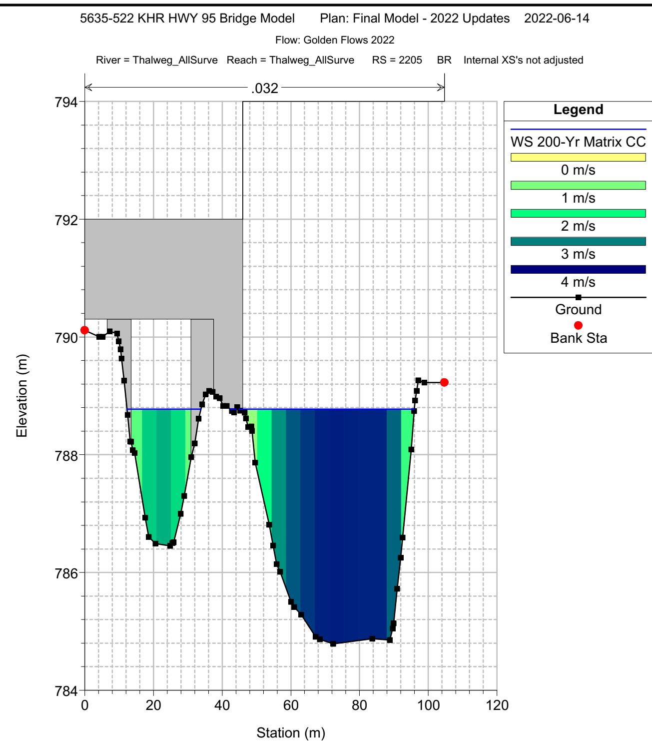
5635-522 KHR HWY 95 Bridge Model   Plan: Final Model - 2022 Updates   2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve   Reach = Thalweg_AllSurve   RS = 2272   BR   Internal XS's adjusted to match actual location of bridge K4A

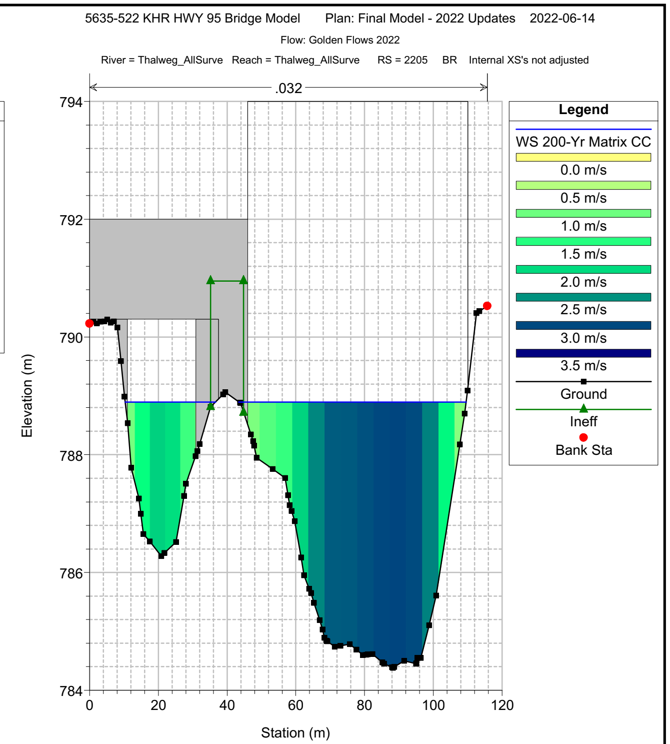


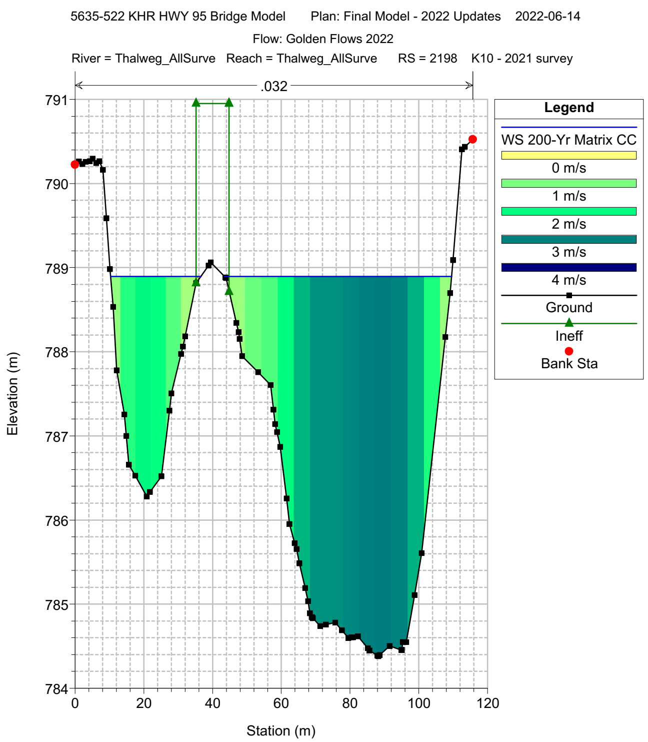
5635-522 KHR HWY 95 Bridge Model   Plan: Final Model - 2022 Updates   2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve   Reach = Thalweg_AllSurve   RS = 2272   BR   Internal XS's adjusted to match actual location of bridge K4A

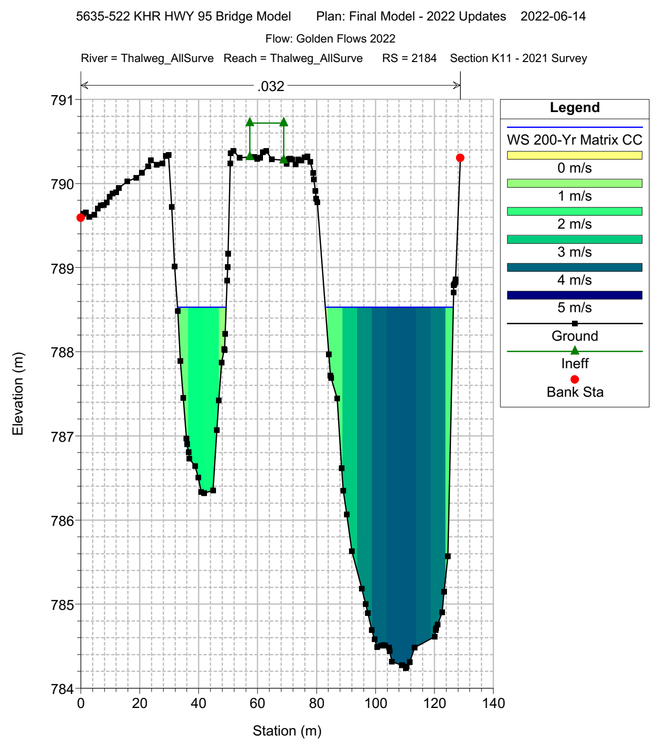


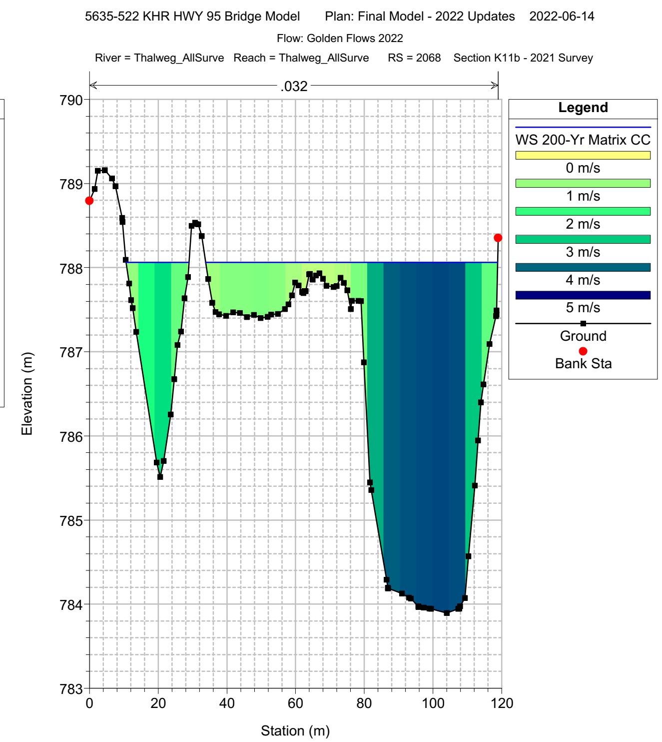

5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve Reach = Thalweg_AllSurve RS = 2219 K4A - 2019 MoTI Bath
.032
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve Reach = Thalweg_AllSurve RS = 2205 BR Internal XS's not adjusted
.032
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve Reach = Thalweg_AllSurve RS = 2205 BR Internal XS's not adjusted
.032
Legend
WS 200-Yr Matrix CC
0.0 m/s
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve Reach = Thalweg_AllSurve RS = 2198 K10 - 2021 survey
.032
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
River = Thalweg_AllSurve Reach = Thalweg_AllSurve RS = 2184 Section K11 - 2021 Survey
.032
Legend
WS 200-Yr Matrix CC
0 m/s
1 m/s
2 m/s
3 m/s
4 m/s
5 m/s
Ground
Ineff
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
Flow: Golden Flows 2022
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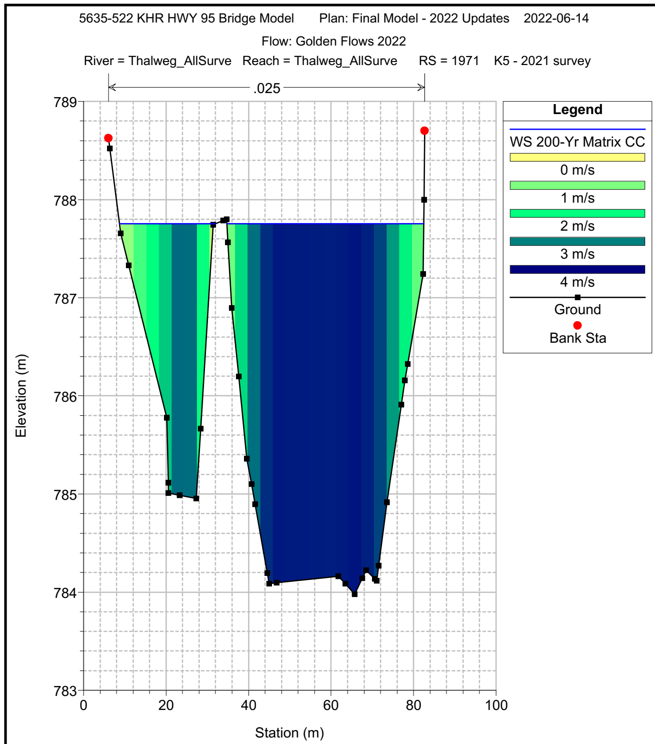
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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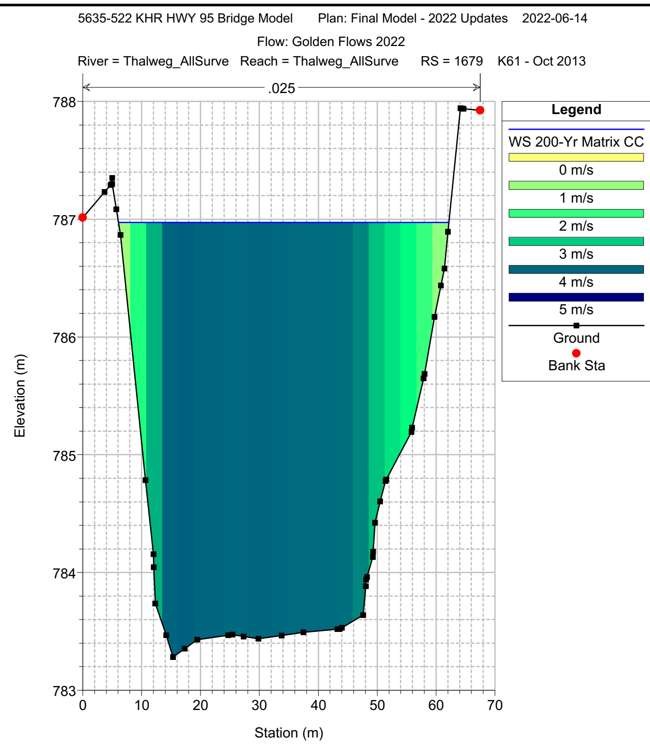
3 m/s
4 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
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Legend
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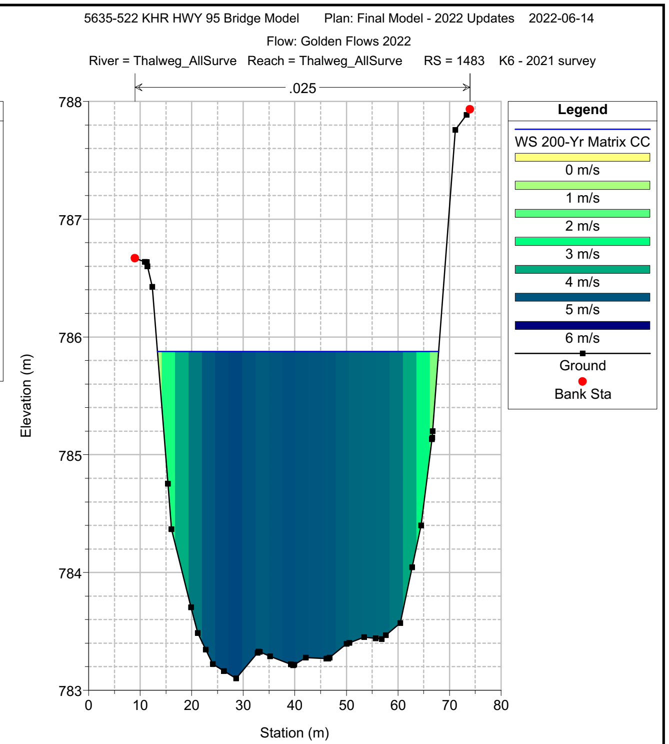
4 m/s
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
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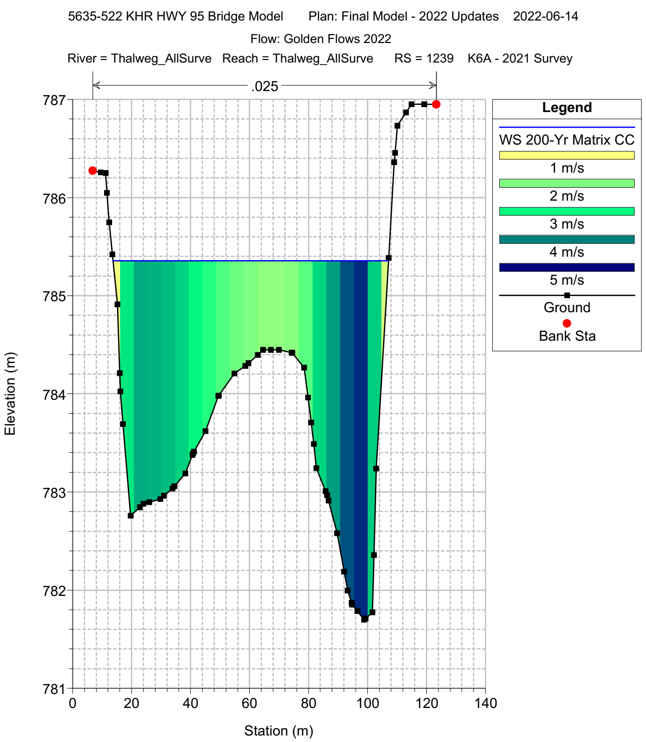
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
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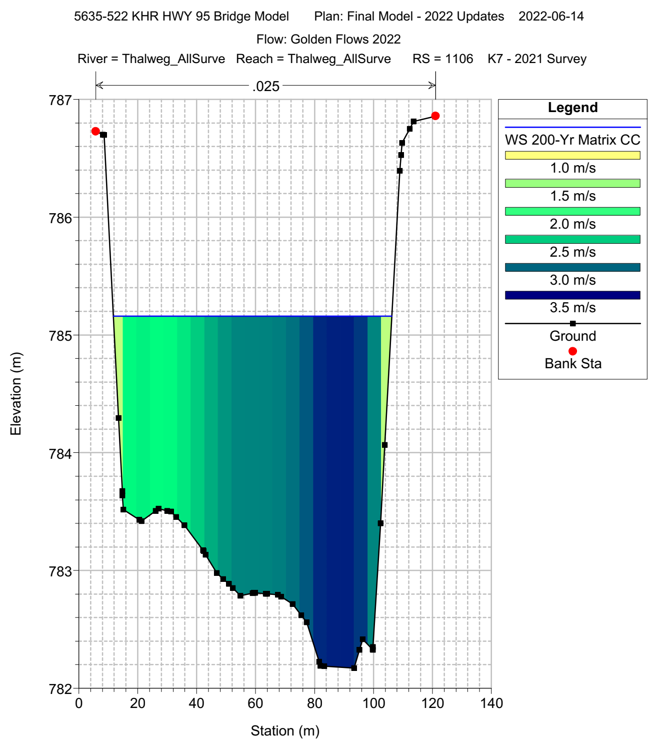
Bank Sta
Elevation (m)
Station (m)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.025
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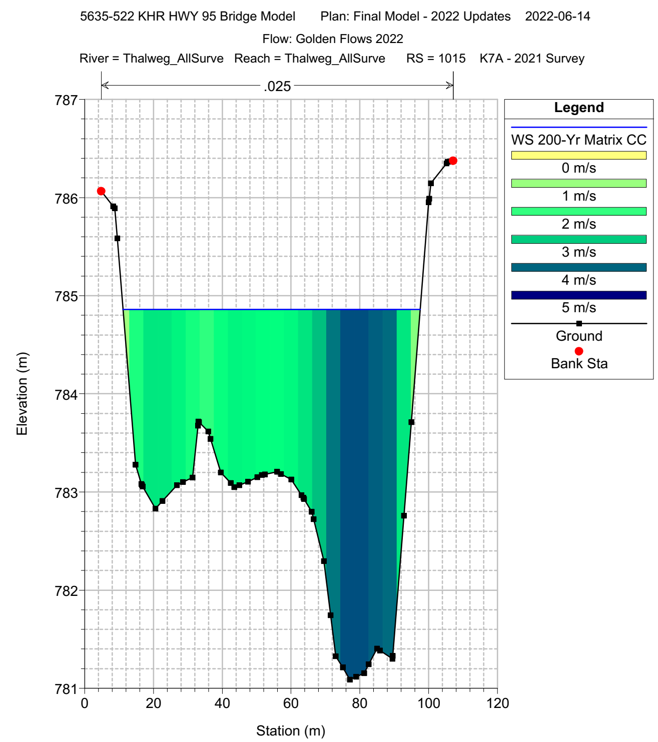
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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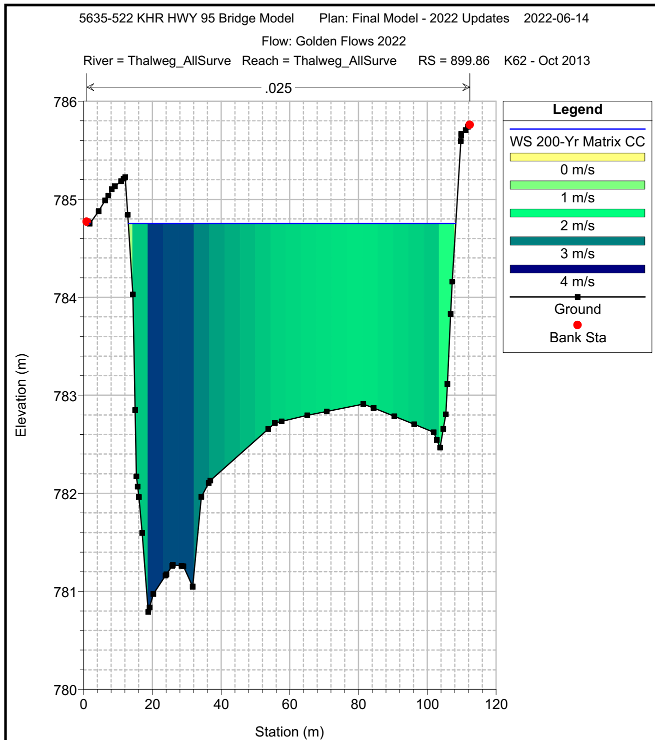
5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Ground
Bank Sta
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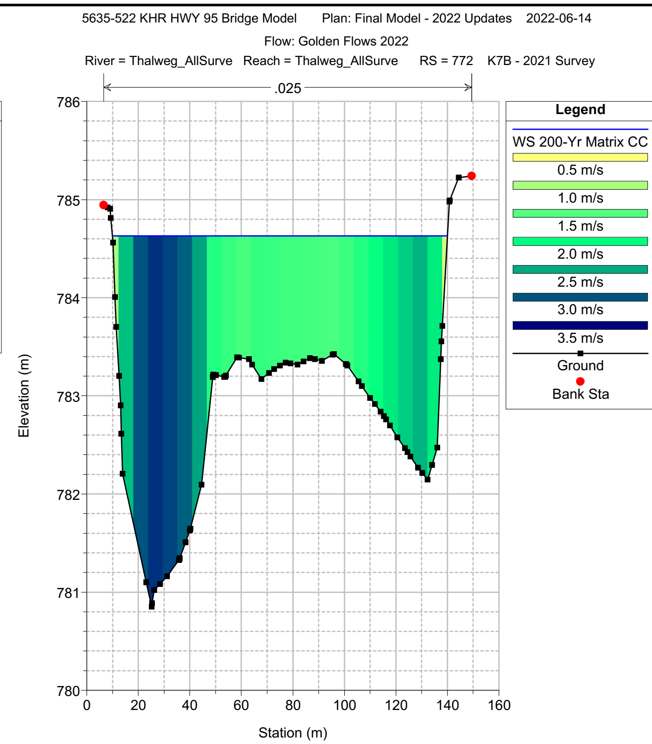
Station (m)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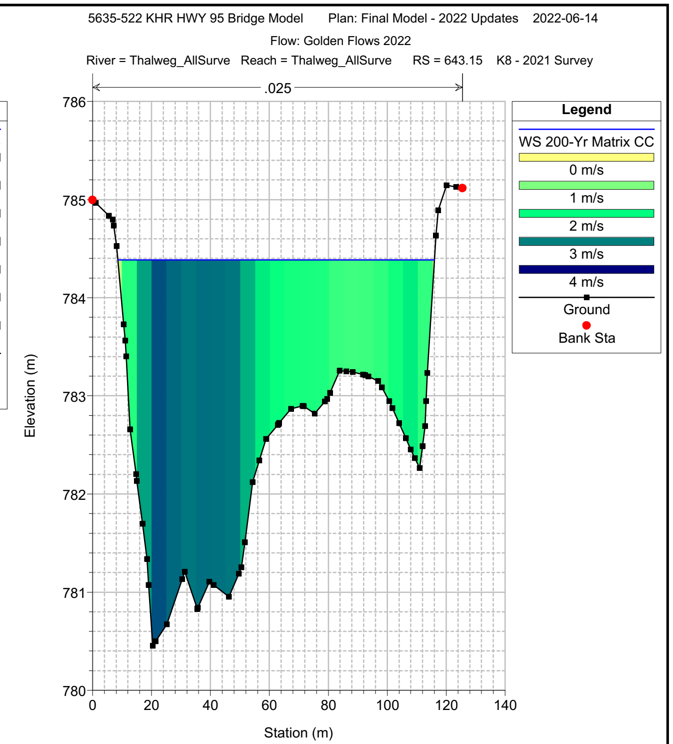
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
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.025
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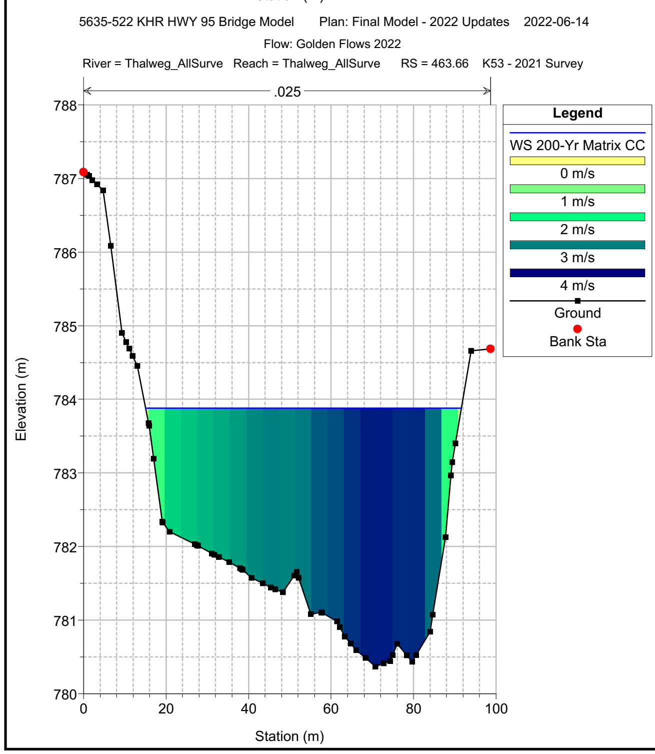
4 m/s
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
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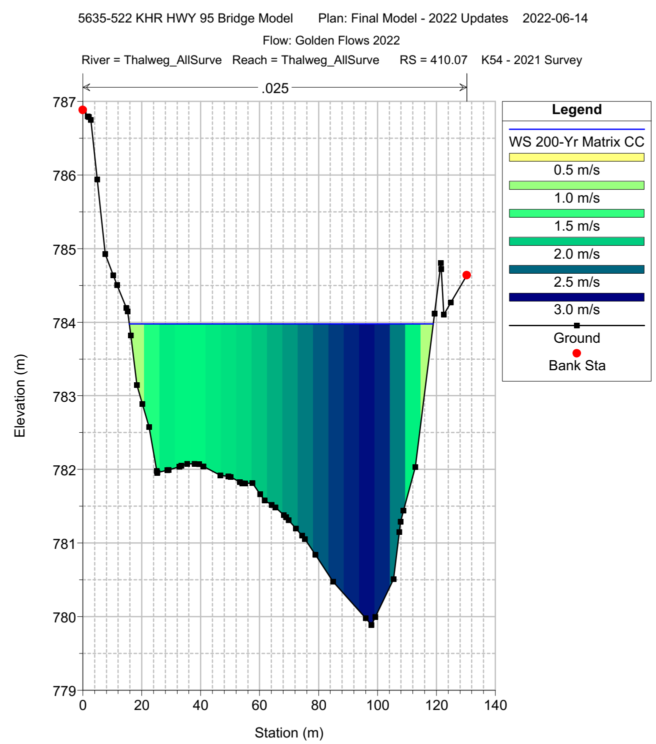
Ground
Bank Sta
Elevation (m)
Station (m)


5635-522 KHR HWY 95 Bridge Model Plan: Final Model - 2022 Updates 2022-06-14
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.025
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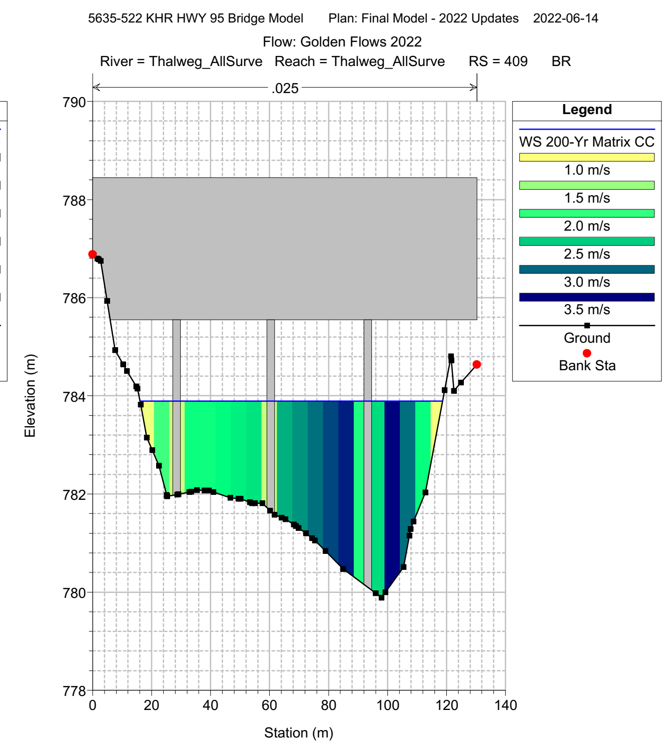
2.5 m/s
3.0 m/s
Ground
Bank Sta
Elevation (m)
Station (m)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Legend
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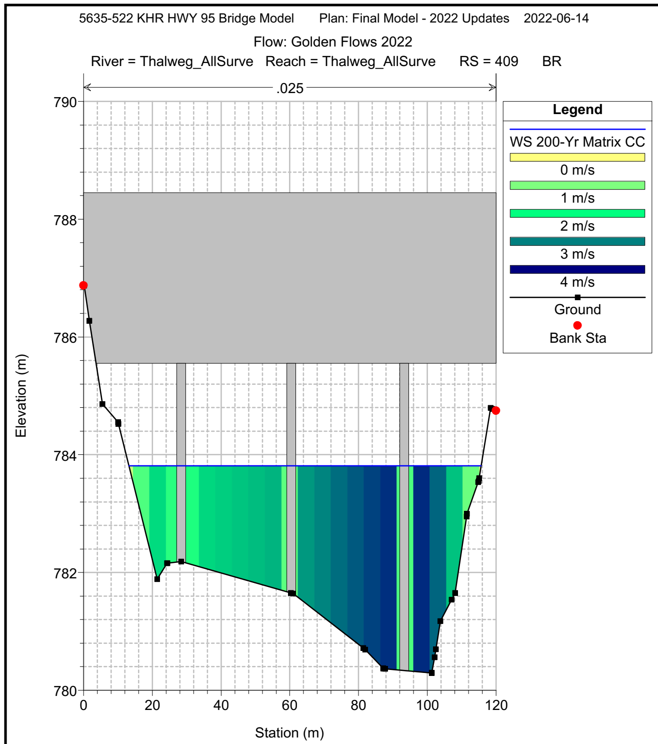
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
3.0 m/s
3.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)



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Legend
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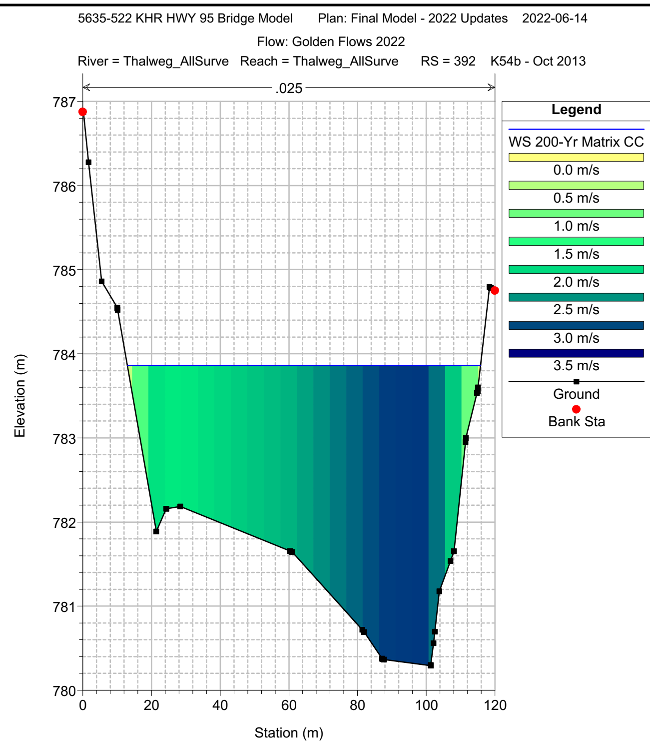
Ground
Bank Sta
Elevation (m)
Station (m)



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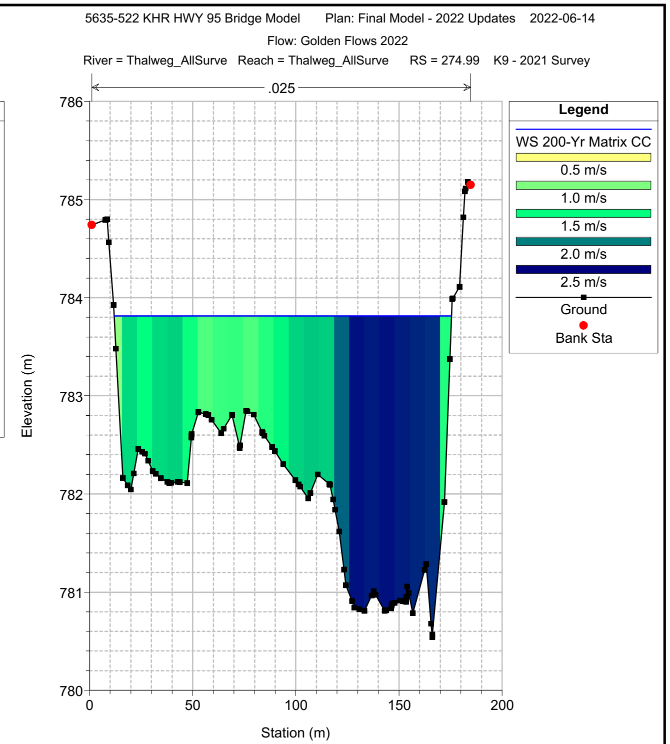
Ground
Bank Sta
Elevation (m)
Station (m)



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.025
Legend
WS 200-Yr Matrix CC
0.5 m/s
1.0 m/s
1.5 m/s
2.0 m/s
2.5 m/s
Ground
Bank Sta
Elevation (m)
Station (m)

```
* Columbia         * Downstream       * 1.5         *                  *  Bridge *
         *           *           *           *            *          *           *
         *              *
* Columbia         * Downstream       * 1           * 200-Yr Matrix CC * 1255.00 *
  777.04 *   782.933 *           *   783.469 *   0.000867 *     3.24 *    386.88 *
   99.49 *         0.53 *
* Columbia         * Downstream       * 0           * 200-Yr Matrix CC * 1255.00 *
  777.04 *   782.751 *    781.51 *   783.341 *   0.001000 *     3.40 *    368.89 *
   98.38 *         0.56 *
***************************************************************************************
***************************************************************************************
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APPENDIX B
Scour Calculations

APPENDIX B1
Channel Scour

APPENDIX B1

CHANNEL SCOUR CALCULATIONS SUMMARY

Scour Calculation	Main Channel	Side Channel	Comment
Median bed material size (mm)	200	20	From the field-based assessment.
Thalweg elevation (m)	784.8	786.4	From the survey data at the proposed Highway 95 and Gould's Island bridges, respectively.
Design flow (m^3/s)	500	77	Portion of the flow in the main channel and side channel, respectively. From the hydraulic model results.
Flow depth (m)	4.1	2.5	From the hydraulic model results.
Mean channel velocity (m/s)	3.2	2.1	From the hydraulic model results.
Competent velocity (m/s)[1]	4.4	1.8	Main channel: competent velocity is greater than the mean channel velocity; thus clear-water scour is applicable, per FHWA (2012). Side Channel: competent velocity is less than the mean channel velocity; thus, live-bed scour is applicable, per FHWA (2012).
Blench regime scour depth below the water level (m)[1,2]	3.7	2.2	Main Channel: Blench regime depth is less than the flow depth. Side Channel: Blench regime depth is less than the flow depth.
Scour elevation computed from Blench with a Z-factor (depth[3]) (m)	784.1 (0.7)	786.0 (0.4)	Computed with a Z-factor of 1.3 for minimal bends.
Clear-water scour elevation (depth[3]) (m)[1]	784.0 (0.8)	n/a	From the competent velocity results, clear-water scour is not applicable to the side channel.
Live-bed scour elevation (depth[3]) (m)[1]	n/a	786.2 (0.2)	From the competent velocity results, live-bed scour is not appliable to the main channel.

1 *Hydraulic Engineering Circular No. 18. Evaluating Scour at Bridges Fifth Edition* (FHWA 2012).
2 G*uide to Bridge Hydraulics 2nd Edition (*TAC 2001*)*
3 Scour depths are below the thalweg unless otherwise noted.
n/a - not applicable
FHWA – Federal Highway Administration

REFERENCES

Federal Highway Administration (FHWA). 2012. *Evaluating Scour at Bridges: Fifth Edition*. US Department of Transportation. Fort Collins, Colorado. April 2012.

Transportation Association of Canada (TAC). 2001. *Guide to Bridge Hydraulics*. Second Edition. June 15, 2001.

Design Flow, Q	500	m^3/s	1:200-year design flood in main channel
Top width, W	48.9	m	At bridge section
q (Q/W)	10.22	$m^3/s/m$	
D50	200	mm	Estimated based on site visits and bathymetric surveys performed by Matrix
D50	0.66	ft	
Fb_0	2.03	m/s^2	Blench's Zero Bed factor (from chart, based on D50)
Fb_0	6.66	ft/s^2	
Regime depth, yf	3.7	m	TAC 2001 $y_f = (q_f^2/F_{b0})^{1/3}$
Z-factor	1.3		Varies from 1.25 to 2.75 (TAC 2001). Selected value is for a mild bend and is consistent with previous analysis by Associated Engineering
Depth of scour, ys	4.8	m	below water surface
Q200 WS EL	788.9	m	Bridge section (from HEC-RAS model)
Thalweg EL	784.8	m	Bridge section (from HEC-RAS model)
Depth of Q200	4.1	m	Q200 WS EL - Thalweg EL
Depth of scour	0.7	m	below thalweg

Input Values

Computed Values

Sensitivity Analysis

		Depth of Scour Below Thalweg (m)		
	Z-factor:	1.25	**1.3**	1.4
D50 (mm)	Fb_0 (m/s^2)			
50	1.45	1.1	1.3	1.7
100	1.70	0.8	1.0	1.4
200	2.03	0.6	**0.7**	1.1
500	2.50	0.2	0.4	0.8
1,000	2.90	0.0	0.2	0.5

Bold = computed scour for selected D50 and Z-factor

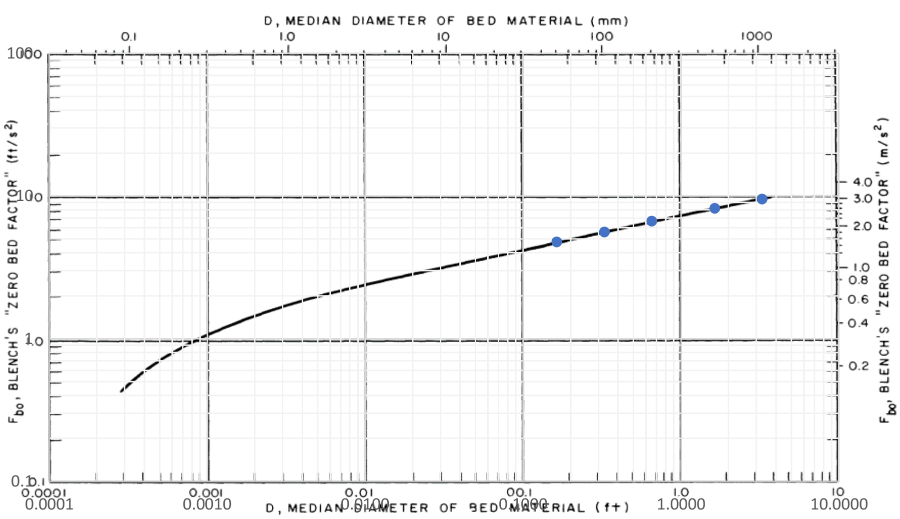

CHART FOR ESTIMATING F_{bo} (AFTER BLENCH)

Figure 9. - Chart for estimating F_{bo} (after Blench, 1969).

References

1. Transportation Association of Canada (TAC). 2001. Guide to Bridge Hydraulics. Second Edition.

2. U.S. Department of the Interior Bureau of Reclamation (USBR). 1984. Computing Degradation and Local Scour. Technical Guideline for Bureau of Reclamation.

PROJECT	KHR HWY 95 Bridge Replacement	BY	K.Seasons
		DATE	15-Mar-21
SUBJECT	Blench Scour Calculation - Side Channel	CHK	D. Kushner
		PAGE	1 of 1

Design Flow, Q	77	m^3/s	1:200-year design flood in side channel	Input Values
Top width, W	22.5	m	From bridge section (from HEC-RAS model)	Computed Values
q (Q/W)	3.42	$m^3/s/m$		
D50	20	mm	Estimated based on site reconnaissance and photos	
D50	0.07	ft		
Fb_0	1.15	m/s^2	Blench's Zero Bed factor (from chart, based on D50)	
Fb_0	3.77	ft/s^2		
Regime depth, yf	2.2	m	TAC 2001 $y_f = (q_f^2/F_{b0})^{1/3}$	
Z-factor	1.3		Varies from 1.25 to 2.75 (TAC 2001). Selected value is for a mild bend and is consistent with previous analysis by Associated Engineering	
Depth of scour, ys	2.8	m	Below water surface	
Q200 WS EL	788.8	m	Bridge section (from HEC-RAS model)	
Thalweg EL	786.4	m	Bridge section (from HEC-RAS model)	
Depth of Q200	2.4	m	Q200 WS EL - Thalweg EL	
Depth of scour	0.4	m	Below thalweg	

Sensitivity Analysis

		Depth of Scour Below Thalweg (m)		
	Z-factor:	1.25	**1.3**	1.4
D50 (mm)	Fb_0 (m/s^2)			
10	1	0.4	0.6	0.8
15	1.10	0.3	0.5	0.7
20	1.15	0.3	**0.4**	0.6
30	1.30	0.2	0.3	0.5
50	1.45	0.1	0.2	0.4

Bold = computed scour for selected D50 and Z-factor

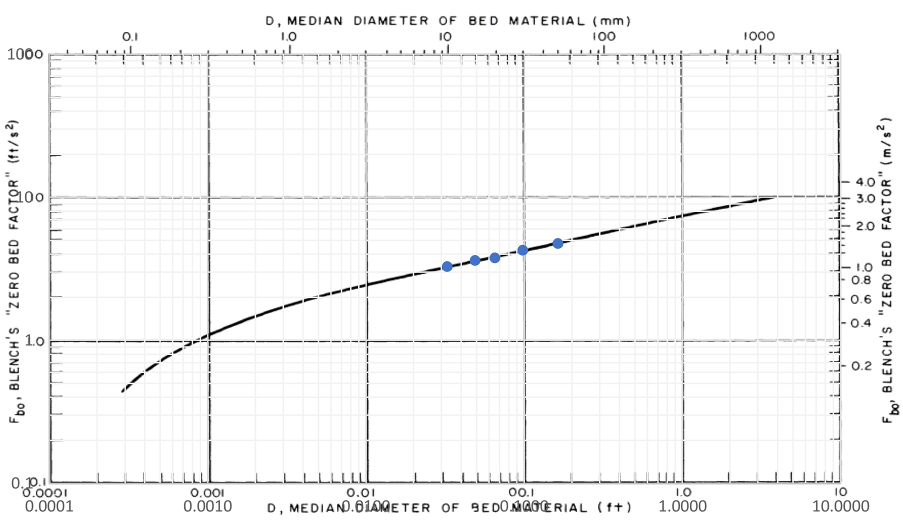

CHART FOR ESTIMATING F_{bo} (AFTER BLENCH)

Figure 9. - Chart for estimating F_{bo} (after Blench, 1969).

References

1. Transportation Association of Canada (TAC). 2001. Guide to Bridge Hydraulics. Second Edition.

2. U.S. Department of the Interior Bureau of Reclamation (USBR). 1984. Computing Degradation and Local Scour. Technical Guideline for Bureau of Reclamation.

PROJECT	KHR HWY 95 Bridge Replacement	BY	K.Seasons
SUBJECT	Competent Velocity Calculation - Main Channel	DATE	15-Mar-21
		CHK	D. Kushner
		PAGE	1 of 1

Design Flow, Q	500	m^3/s	1:200-year design flood in main channel
D50	200	mm	Estimated based on site visits and bathymetric surveys performed by Matrix
D50	0.200	m	
Constant, Ku	6.19	m	FHWA HEC18 2012

Input Values
Computed Values

Top width, W	48.9	m	At US bridge section in main channel
Design Flow Area, A	157.8	m^2	At US bridge section in main channel
Channel Bottom Width, Wb	22	m	At US bridge section in main channel
Flow Velocity, V	3.17	m/s	HEC-RAS Model, velocity in main channel
Average depth of flow, y1	3.23	m	A / W
Competent Velocity, Vc	4.40	m/s	Vc > V, thus clear-water scour governs; FHWA HEC18 2012

$$V_c = K_u\, y_1^{1/6}\, D_{50}^{1/3}$$

Sensitivity Analysis

D50 (mm)	Vc (m/s)	Scour Condition
100	3.49	Clear-Water
200	**4.40**	Clear-Water
500	5.97	Clear-Water
1,000	7.52	Clear-Water

Bold = computed competent velocity for selected D50

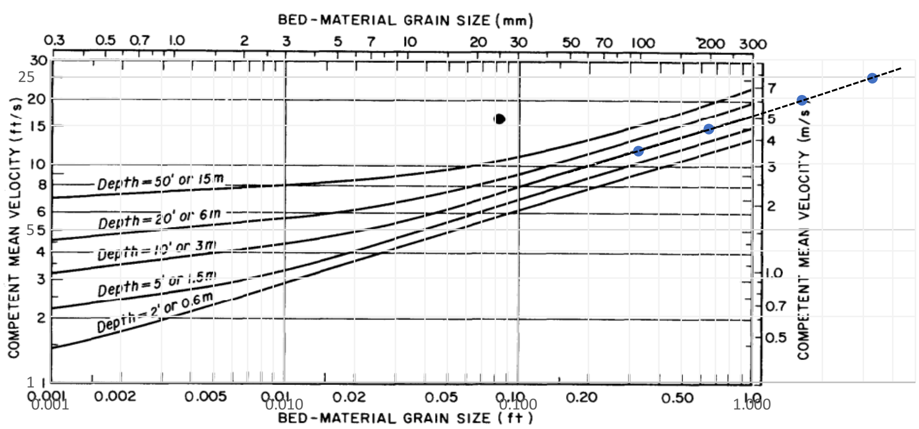

Figure 12. - Suggested competent mean velocities for significant bed movement of cohesionless materials, in terms of grain size and depth of flow (after Neill, 1973).

References

1. U.S. Department of Transportation Federal Highway Administration (FHWA). 2012. HEC-18 Evaluating Scour at bridges Fifth Edition.

	PROJECT	KHR HWY 95 Bridge Replacement	BY	K.Seasons
			DATE	15-Mar-21
	SUBJECT	Competent Velocity Calculation - Side Channel	CHK	D. Kushner
			PAGE	1 of 1

Design Flow, Q	77 m^3/s	1:200-year design flood in side channel	
D50	20 mm	Estimated based on site reconnaissance and photos	
D50	0.020 m		
Constant, Ku	6.19 m	FHWA HEC18 2012	Input Values
			Computed Values

Top width, W	22.5 m	At US bridge section in side channel	
Design Flow Area, A	36.3 m^2	At US bridge section in side channel	
Channel Bottom Width, Wb	7.5 m	At US bridge section in side channel	
Flow Velocity, V	2.10 m/s	HEC-RAS Model, avg velocity in side channel	
Average depth of flow, y1	1.61 m	A / W	
Competent Velocity, Vc	1.82 m/s	Vc < V, thus live-bed scour governs; FHWA HEC18 2012	$V_c = K_u\, y_1^{1/6}\, D_{50}^{1/3}$

Sensitivity Analysis

D50 (mm)	Vc (m/s)	Scour Condition
10	1.4	Live-Bed
15	1.7	Live-Bed
20	**1.8**	Live-Bed
30	2.1	Live-Bed

Bold = computed competent velocity for selected D50

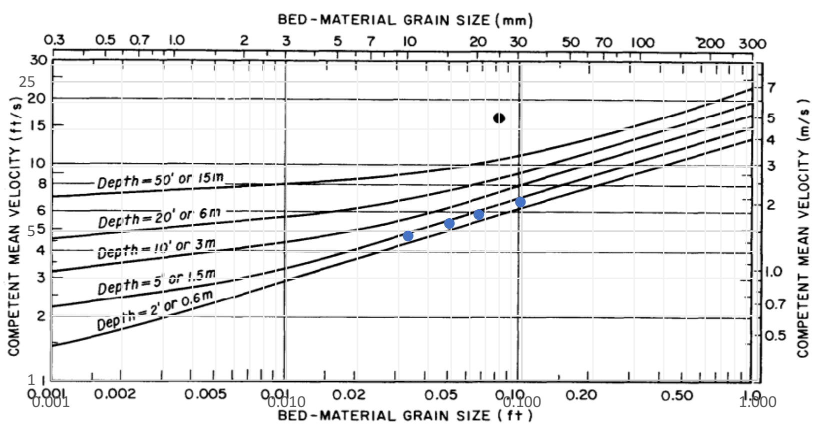

Figure 12. - Suggested competent mean velocities for significant bed movement of cohesionless materials, in terms of grain size and depth of flow (after Neill, 1973).

References

1. U.S. Department of Transportation Federal Highway Administration (FHWA). 2012. HEC-18 Evaluating Scour at bridges Fifth Edition.

PROJECT	KHR HWY 95 Bridge Replacement	BY	K.Seasons
SUBJECT	Clear-Water Contraction Scour Calculation - Main Channel	DATE	15-Mar-21
		CHK	D. Kushner
		PAGE	1 of 1

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2}\right]^{3/7} \quad (6.4)$$

$$y_s = y_2 - y_o = \text{(average contraction scour depth)} \quad (6.5)$$

where:

- y_2 = Average equilibrium depth in the contracted section after contraction scour, ft (m)
- Q = Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft^3/s (m^3/s)
- D_m = Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in the contracted section, ft (m)
- D_{50} = Median diameter of bed material, ft (m)
- W = Bottom width of the contracted section less pier widths, ft (m)
- y_o = Average existing depth in the contracted section, ft (m)
- K_u = 0.0077 English units
- K_u = 0.025 SI units

FHWA HEC18 2012 equation for clear-water contraction scour

Input Values

Computed Values

Design Flow, Q	500	m^3/s	1:200-year design flood in main channel
D50	200	mm	Estimated based on site visits and bathymetric surveys performed by Matrix
D50	0.200	m	
Dm	0.250	m	
Constant, Ku	0.025	m	
Top width, W	48.9	m	Bridge section in the main channel
Design Flow Area, A	157.8	m^2	Bridge section in the main channel
Channel Bottom Width, Wb	25	m	Bridge Section in the main channel
Average depth of flow, y_0	3.23	m	FWA HEC18 2012
Average Equilibrium Depth, y_2	3.99	m	
Scoured Depth, ds	0.76	m	(+ve = scour, -ve = no scour)

Sensitivity Analysis

D50 (mm)	Scoured Depth, ds (m)
100	1.6
200	**0.8**
500	0.0
1,000	0.0

Bold = computed scour for selected D50

References

1. U.S. Department of Transportation Federal Highway Administration (FHWA). 2012. HEC-18 Evaluating Scour at bridges Fifth Edition.

$$y_2 = \left[\frac{K_u Q^2}{D_m^{2/3} W^2}\right]^{3/7} \quad (6.4)$$

$$y_s = y_2 - y_o = \text{(average contraction scour depth)} \quad (6.5)$$

where:

y_2 = Average equilibrium depth in the contracted section after contraction scour, ft (m)
Q = Discharge through the bridge or on the set-back overbank area at the bridge associated with the width W, ft³/s (m³/s)
D_m = Diameter of the smallest nontransportable particle in the bed material (1.25 D_{50}) in the contracted section, ft (m)
D_{50} = Median diameter of bed material, ft (m)
W = Bottom width of the contracted section less pier widths, ft (m)
y_o = Average existing depth in the contracted section, ft (m)
K_u = 0.0077 English units
K_u = 0.025 SI units

FHWA HEC18 2012 equation for clear-water contraction scour

Input Values
Computed Values

Design Flow, Q	77	m^3/s	1:200-year design flood in side channel
D50	20	mm	Estimated based on site reconnaissance and photos
D50	0.020	m	
Dm	0.025	m	
Constant, Ku	0.025	m	
Top width, W	22.5	m	At US bridge section in side channel
Design Flow Area, A	36.3	m^2	At US bridge section in side channel
Channel Bottom Width, Wb	7.5	m	At US bridge section in side channel
Average depth of flow, y_0	1.61	m	FWA HEC18 2012
Average Equilibrium Depth, y_2	4.35	m	
Scoured Depth, ds	2.73	m	(+ve = scour, -ve = no scour)

Sensitivity Analysis

D50 (mm)	Scoured Depth, ds (m)
10	N/A, Live-Bed Governs
15	N/A, Live-Bed Governs
20	N/A, Live-Bed Governs
30	2.3
50	1.7

Bold = computed scour for selected D50

Note: A D50 of 20 mm is recommended for the side channel. Thus, live-bed scour governs. Clear-water scour would govern for D50 > 25 mm and is shown on this page for comparison purposes only.

References

1. U.S. Department of Transportation Federal Highway Administration (FHWA). 2012. HEC-18 Evaluating Scour at bridges Fifth Edition.

$$\frac{y_2}{y_1} = \left(\frac{Q_2}{Q_1}\right)^{6/7} \left(\frac{W_1}{W_2}\right)^{k_1} \left(\frac{n_2}{n_1}\right)^{k_2} \quad (C.1)$$

$y_s = y_2 - y_o$ = (Average scour depth)

where:

- y_1 = Average depth in the upstream main channel, m
- y_2 = Average depth in the contracted section, m
- y_o = Existing depth in the contracted section before scour, m
- Q_1 = Flow in the upstream channel transporting sediment, m^3/s
- Q_2 = Flow in the contracted channel, m^3/s. Often this is equal to the total discharge unless the total flood flow is reduced by relief bridges, water overtopping the approach roadway, or in the setback area
- W_1 = Bottom width of the upstream main channel, m
- W_2 = Bottom width of main channel in the contracted section, m
- n_1 = Manning n for upstream main channel
- n_2 = Manning n for contracted section
- k_1 & k_2 = Exponents determined below depending on the mode of bed material transport
- V_* = $(gyS_1)^{1/2}$ shear velocity in the upstream section, m/s
- T = Median fall velocity of the bed material based on the D_{50}, m/s (see Figure 6.8 in Chapter 6)
- g = Acceleration of gravity (9.81 m/s^2)
- S_1 = Slope of energy grade line of main channel, m/m
- D_{50} = Median diameter of the bed material, m

V_*/T	k_1	k_2	Mode of Bed Material Transport
<0.50	0.59	0.066	Mostly contact bed material discharge
0.50 to 2.0	0.64	0.21	Some suspended bed material discharge
>2.0	0.69	0.37	Mostly suspended bed material discharge

A HEC18 2012
ition for live-bed
raction scour

t Values
puted Values

Average depth in main channel, y1	1.82	m	
Average depth in the contracted section, y2	2.00	m	
Existing depth in the contracted section before scour, y0	2.5	m	From modelled US bridge section
Q1, flow in main channel upstream of bridge, not including overbank flows	77	m^3/s	1:200-year design flood in side channel
Q2, total flow going through the bridge opening	77	m^3/s	No floodplains, so Q1 = Q2
Bottom width of the upstream channel, W1	20	m	From model
Bottom width in the contracted section, W2	17	m	From model
Manning n for upstream main channel, n1	0.032		
Manning n for contracted section, n2	0.032		
Top width, W	20	m	From modelled section upstream of bridge
Design Flow Area, A	36.3	m^2	From modelled section upstream of bridge
D50	20	mm	Estimated based on site visits and bathymetric surveys performed by Matrix
D50	0.02	m	
Average scour depth, ys	0.18	m	

Vdot/T	0.49	
Vdot	0.245	
T (m/s)	0.5	Extrapolated from Fig 6.8
g (m/s2)	9.81	
y1 (m)	1.82	
S1 (m/m)	0.003	From modelled section upstream of bridge
k1	0.59	
k2	0.21	

Sensitivity Analysis

D50 (mm)	k1	Scour Depth (m)
10	0.64	0.20
15	0.64	0.20
20	**0.59**	**0.18**
30	0.59	0.18

Bold = computed scour for selected D50

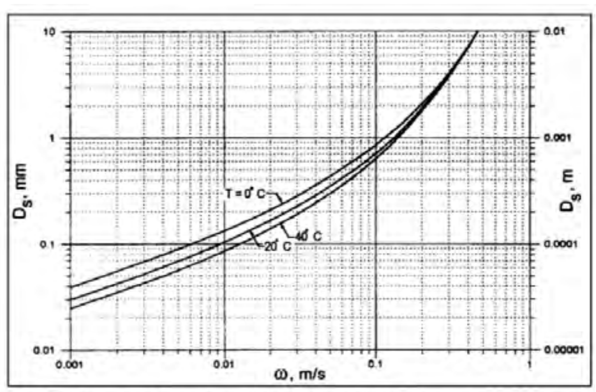

Figure 6.8. Fall velocity of sand-sized particles with specific gravity of 2.65 in metric units.

References

1. U.S. Department of Transportation Federal Highway Administration (FHWA). 2012. HEC-18 Evaluating Scour at bridges Fifth Edition.

APPENDIX B2
Pier Scour

$$\frac{y_s}{y_1} = 2.0\, K_1\, K_2\, K_3 \left(\frac{a}{y_1}\right)^{0.65} Fr_1^{0.43} \quad (7.1)$$

As a Rule of Thumb, the maximum scour depth for round nose piers aligned with the flow is:

$y_s \leq 2.4$ times the pier width (a) for $Fr \leq 0.8$ (7.2)
$y_s \leq 3.0$ times the pier width (a) for $Fr > 0.8$

In terms of y_s/a, Equation 7.1 is:

$$\frac{y_s}{a} = 2.0\, K_1\, K_2\, K_3 \left(\frac{y_1}{a}\right)^{0.35} Fr_1^{0.43} \quad (7.3)$$

where:

- y_s = Scour depth, ft (m)
- y_1 = Flow depth directly upstream of the pier, ft (m)
- K_1 = Correction factor for pier nose shape from Figure 7.3 and Table 7.1
- K_2 = Correction factor for angle of attack of flow from Table 7.2 or Equation 7.4
- K_3 = Correction factor for bed condition from Table 7.3
- a = Pier width, ft (m)
- L = Length of pier, ft (m)
- Fr_1 = Froude Number directly upstream of the pier = $V_1/(gy_1)^{1/2}$
- V_1 = Mean velocity of flow directly upstream of the pier, ft/s (m/s)
- g = Acceleration of gravity (32.2 ft/s^2) (9.81 m/s^2)

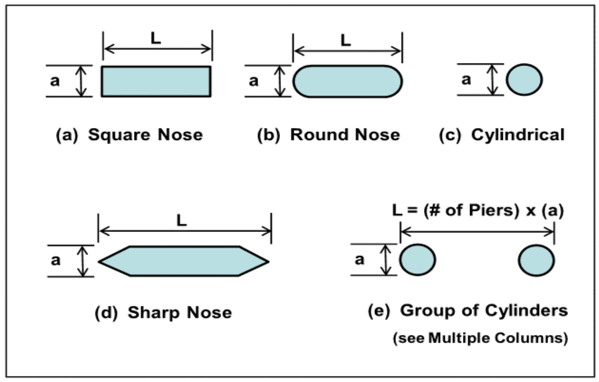

Figure 7.3. Common pier shapes.

Input Values
Computed Values

y1, flow depth upstream of the pier	2	m	From the HEC-RAS Model, about 20 m upstream of the pier
K1, Correction factor	1		Circular piles
K2, Correction factor	2.67		
θ, Angle of attack	27	Degrees	
L	6.10	m	
a, Pier width	0.76	m	
L/a	8		
# of rows	2		
# of piers per row	8		
K3, Correction Factor	1.1		Clear-water scour
Fr, Froude number	0.67		From section upstream of bridge
ys, scour depth	5.28	m	

Table 7.3. Increase in Equilibrium Pier Scour Depths, K_3, for Bed Condition.

Bed Condition	Dune Height ft	K_3
Clear-Water Scour	N/A	1.1
Plane bed and Antidune flow	N/A	1.1
Small Dunes	10 > H ≥ 2	1.1
Medium Dunes	30 > H ≥ 10	1.2 to 1.1
Large Dunes	H ≥ 30	1.3

Sensitivity Analysis

Flow Depth Upstream of Pier (m)	Scoured Depth, ys (m)
1	4.1
2	**5.3**
3	6.1

Bold = computed scour for selected depth of flow

The correction factor, K_2, for angle of attack of the flow, 2, is calculated using the following equation:

$$K_2 = \left(\cos\theta + \frac{L}{a}\sin\theta\right)^{0.65} \quad (7.4)$$

If L/a is larger than 12, use L/a = 12 as a maximum in Equation 7.4 and Table 7.2. Table 7.2 illustrates the magnitude of the effect of the angle of attack on local pier scour.

Table 7.1. Correction Factor, K_1, for Pier Nose Shape.

Shape of Pier Nose	K_1
(a) Square nose	1.1
(b) Round nose	1.0
(c) Circular cylinder	1.0
(d) Group of cylinders	1.0
(e) Sharp nose	0.9

Table 7.2. Correction Factor, K_2, for Angle of Attack, 2, of the Flow.

Angle	L/a=4	L/a=8	L/a=12
0	1.0	1.0	1.0
15	1.5	2.0	2.5
30	2.0	2.75	3.5
45	2.3	3.3	4.3
90	2.5	3.9	5.0

Angle = skew angle of flow
L = length of pier

References

1. U.S. Department of Transportation Federal Highway Administration (FHWA). 2012. HEC-18 Evaluating Scour at bridges Fifth Edition.

PROJECT	KHR HWY 95 Bridge Replacement	BY	K.Seasons
SUBJECT	Local Pier Scour (TAC Melville Equation)	DATE	02-Dec-22
		CHK	D. Kushner
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Pier Diameter, b	0.76	m		Input Values
Number of Piers Per Row, n	8	m		Computed Values
Equivalent Pier Length, L = b x n	6.1	m	From HEC-RAS model, about 20 m upstream of pier	
Depth of flow usptream of pier, y	2	m	From bridge section (from HEC-RAS model)	
Median Bed Material Size, d50	100	mm	Estimated based on site reconnaissance and photos	
b/d50	8			
L/d50	61			
L/b	8			
Flow intensity factor, K_I	1		Envelope value of 1 recommended, TAC 2001	
Sediment Size Factor K_d	1		Per Figure 4.19; 1 for L/d50 > 25	
Shape Factor, K_s	1		Per Table 4.3	
Alignment Factor, K_θ	1.9		Per Table 4.4 for θ = 27 degrees	
Scour depth, ds	2.9		TAC 2001 $ds = 1.5bK_IK_dK_sK_\theta(y/b)^{0.3}$	

Figure 4.19 Melville's sediment size factor K_d

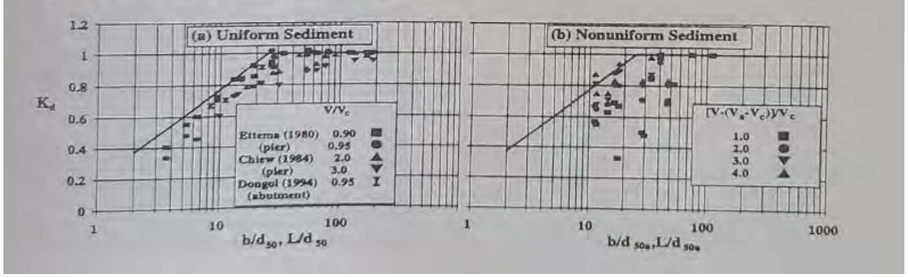

Table 4.3 Melville's shape factors (K_s) for piers and abutments

Foundation type (1)	Shape (2)	K_s (3)
Pier	Circular cylinder	1.0
	Round nosed	1.0
	Square nosed	1.1
	Sharp nosed	0.9
Abutment	Vertical wall	1.0
	Wing wall	0.75
	Spill through 0.5:1 (H:V)	0.6
	Spill through 1:1	0.5
	Spill through 1.5:1	0.45

Table 4.4 Melville's flow alignment factor K_θ

Foundation type	Length to width L/b	Values of K_θ							
		θ = 0	15°	30°	45°	60°	90°	120°	150°
Pier	4	1.0	1.5	2.0	2.3	-	2.5	-	-
	8	1.0	2.0	2.75	3.3	-	3.9	-	-
	12	1.0	2.5	3.5	4.3	-	5.0	-	-
Abutement	-	-	-	0.9	-	0.97	1.0	1.06	1.08

Sensitivity Analysis

Flow Depth Upstream of Pier (m)	Scoured Depth, ds (m)
1	2.4
2	**2.9**
3	3.3

Bold = computed scour for selected depth of flow

References

1. Transportation Association of Canada (TAC). 2001. Guide to Bridge Hydraulics. Second Edition.

APPENDIX C
Design Criteria Sheet for Climate Change Resilience

Design Criteria Sheet for Climate Change Resilience

Highway Infrastructure Engineering Design and Climate Change Adaptation
BC Ministry of Transportation and Infrastructure

Project: *Kicking Horse River Bridges 1 and 2 Replacement*
Type of work: *Bridge replacement for the Kicking Horse River in Golden, British Columbia*
Location: *Town of Golden, British Columbia*
Discipline: *Hydrotechnical*

Design Component	Design Life or Return Period	Design Criteria + (Units)	Design Value Without Climate Change	Change in Design Value from Future Climate	Design Value Including Climate Change	Adaptation Cost Estimate ($)	Comments/Notes/Deviations/ Variances
Bridge	200 yr Return Period	Flow Rate (m^3/s)	463	+25%	580 (rounded from 578.75)	$0	The increased design flow rate results in a 0.4 m higher design water level; however, the bridge low chord elevation is also governed by the design ice level thus there is negligible adaptation cost.

Explanatory Notes / Discussion:
The bridge design flow return period is per the BC MoTI Supplement to the Canadian Highway Design Bridge Code. The design flood value without climate change is computed using a single station hydrology analysis consisting of 58 years of daily flow data.

The PCIC completed a provincial hydrologic model in 2020 that projects future flows based on global climate change model outputs for various emissions scenarios. The PCIC hydrologic model provides projected daily flows at selected WSC stations including the Kicking Horse River. A FFA was completed on the historic daily flows (1945 to 2012) and PCIC projected daily flows for the Kicking Horse River at Golden (WSC Station 08NA006) for the moderate and severe emissions scenarios, i.e., RCP 4.5 and 8.5, respectively. The climate change factor was computed as the projected flood magnitude increase over the historical daily flood magnitude and the median of the ensemble of model results was computed. The median climate change factor for the 1:200-year flood computed from the PCIC projections is 9% and 25% for RCP 4.5 and RCP 8.5, respectively in the 2050 to 2100 period.

A 25% increase to flood magnitudes to account for potential increases to flow due to climate change is recommended for the proposed bridges because it results in a similar design flood discharge (580 m^3/s) compared to the 1:200-year design discharge of the dikes (570 m^3/s). The 25% climate change factor is the most conservative factor computed from PCIC projections and is conservative compared to the 10% to 20% EGBC guidelines.

See the Hydrotechnical Report for further details.

Recommended by: Engineer of Record: David Kushner
(Print Name / Provide Seal & Signature)

PROFESSIONAL PROVINCE OF D. N. KUSHNER # 42649 BRITISH COLUMBIA ENGINEER
December 9 2022

Date: June 17, 2022

Engineering Firm: Matrix Solutions Inc.

Accepted by BCMoTI Consultant Liaison: ____________________
(For External Design)

Deviations and Variances Approved by the Chief Engineer: ____________________
Program Contact: Chief Engineer BCMoTI