ICFM 10
Adapting to Global Change:
Innovative Approaches to Flood Management and Resilience
May 20-22, 2026 | Western University, London, Ontario, Canada

Accounting for Reasonably Plausible Flood Conditions, such as Bridge Obstruction, in Floodplain Mapping

Sophia Eugeni[1], Vanessa McMaster[1], and Dale Muir[1]
Northwest Hydraulic Consultants Ltd., 30 Gostick Place, North Vancouver, Canada[1]
E-mail: SEugeni@nhcwater.com

ABSTRACT

Often, floodplain mapping is based on existing channel conditions, as observed. However, conditions may change during a flood, such as obstruction and sedimentation at bridges, which can substantially increase flood levels for a given flood flow. It is argued that consideration of reasonably plausible flood conditions must be given in the development of floodplain maps. NHC prepared floodplain maps for a 62 km reach of the Salmon River in southern British Columbia, Canada, using a HEC-RAS 2D numerical hydraulic model. The study reach contained 55 bridge crossings. Although channel obstruction can occur at a variety of locations along a channel, such as from slope failure or from debris or ice jams at constrictions, sharp bends or changes in slope, the greatest likelihood and sensitivity to channel obstruction within the study reach were at these bridge crossings. Using this sample project, an investigation into approaches to assess and incorporate the influence of potential obstructions at crossings in floodplain mapping is presented.

KEYWORDS: Floodplain Mapping, Hydraulic Modelling, Bridge Blockage

1 INTRODUCTION

Bridge crossings can influence hydraulic behaviour in a river by introducing substantial hydraulic losses, causing increased upstream flood levels and extents and in some cases attenuating unsteady flows, resulting in measurable reduction in downstream peak flows. These influences are greater when crossings are obstructed. The potential variable condition of bridge crossings and their hydraulic performance during a flood increases uncertainty in flood results, which needs to be accounted for in hydraulic modelling and ultimately in floodplain mapping.

For the purposes of floodplain mapping, bridges are typically modelled without any obstruction and, as such, may underestimate upstream flood levels and extents. During the recent Shuswap Region Floodplain Mapping Project, conducted for the Fraser Basin Council, the impacts of bridge obstruction on floodplain mapping were investigated using a case study analysis of the Salmon River (NHC, 2025).

2 CASE STUDY CONTEXT

The study area is the 62 km long reach of the Salmon River from the town of Falkland to Salmon Arm. The study reach includes 55 bridges (Figure 2.1). Likelihood of obstruction and sensitivity of flood extents to crossing obstruction varied across the set of crossings within the study reach. Some of the structures were well above the channel with a clear span much larger than the channel's width and larger than the length of riparian trees. However, other crossings had multiple piers, trestle support, or relatively low farm-access crossings with little clearance between the soffit and the typical high water level.

Fieldwork for the study included aerial survey, ground survey, and ground observations. These were conducted during the spring of 2023, at which time a flood occurred with a peak flow similar to a five to ten-year average return period event. Flow was obstructed by debris at a number of the structures.

The Railway Bridge (Figure 2.1d) was identified as highly sensitive to obstruction. Accordingly, further analysis was conducted of this structure to quantify the potential impacts of obstruction at this structure on inundation extents and levels.

a) Multi-pier bridge with debris being removed

b) Typical low clearance farm bridge.

c) Low clearance farm bridge experiencing pressurized flow.

d) Wood trestle bridge accumulating debris.

Figure 2.1 Sample of Bridges along the Salmon River

3 APPROACH

Within the context of floodplain maps in British Columbia, Canada, flood levels are calculated for a specific design flood event, typically the 200-year flood event, with a freeboard applied to this level to establish the flood construction level and accompanying flood extents. The freeboard is a vertical allowance used to account for local variations in water level (i.e., surging, superelevation, local turbulence) and uncertainty in the data, analysis, and mapping. This methodology allows the hydrotechnical engineer the ability to establish both expected suitable design conditions – to calculate the 200-year flood level – and the level of uncertainty – to establish a suitable freeboard.

Numerical modelling was used to evaluate the hydraulic response of the channel and floodplain to the hydrologic design event. The same numerical model was used to evaluate the influence of bridge obstructions on flood level and extent to support a quantified assessment of uncertainty. The two-dimensional numerical hydraulic model was developed in HEC-RAS 6.4.1. Three scenarios of bridge obstructions were simulated: clear (0% obstruction), partial obstruction (20% blocked), and near complete blockage (80% blocked).

3.1 Simulation Scenarios

Since the study reach included a large quantity of bridges, it wouldn't be practical to individually assess the sensitivity of the results at each bridge, one by one. Therefore, to understand the range of influence of the crossings on the resulting floodplain maps, obstructions were simulated using the three severities of obstruction at all bridges and then evaluated in greater detail at the crossings identified as probable for obstruction and where flooding is most sensitive to crossing obstruction.

Comparison of flood levels and extents between the clear conditions and the obstructed scenarios enabled identification of the bridges most sensitive to obstruction.

The Railway Bridge was determined to be highly likely to be obstructed given the trestle style of bridge, the observed upstream large overhanging, and in some cases undermined and failing, trees, and extent of debris caused obstruction observed during field investigations. The Railway Bridge was also determined to be highly sensitive to obstruction. The structure spans a localized deeply confined floodplain within a low gradient reach, and as shown through the modelling, slight increases in obstruction can result in large increases in upstream flood level and flood extent. Therefore, the Railway Bridge was one of the bridges where obstructions were further investigated.

3.2 Methods to Simulate Bridge Obstructions at a Single Crossing

Further analysis was conducted at crossings identified as sensitive to obstruction (from model results) and relatively likely to be obstructed (from crossing span, clearance, style, and upstream supply for potential debris recruitment). Debris blockage at hydraulic structures is impactful because it reduces the cross-sectional area in the channel section available to convey streamflow. There are several ways to represent this mechanism in the hydraulic model, such as:

1. Applying the HEC-RAS Floating Pier Debris tool.
2. Extending the bridge abutment from the left or right to narrow the channel section.
3. Extending the bridge abutment from both sides of the channel to narrow the channel section.
4. Lowering the low chord of the bridge deck.
5. Raising the channel bed to reduce the channel cross-section.

The approach(es) selected depends on the style of bridge and expected mechanism of flooding obstruction (e.g., debris, ice, sedimentation).

For Scenario 1: Clear Conditions and the final design scenario for the project, the Railway Bridge was simulated as blocked by 20% to represent existing conditions, as it is never expected to be fully clear of debris. Calibration data was collected for this hydraulic structure, upstream and downstream of the crossing, where the debris obstruction effects were causing a difference in water surface elevation of approximately 1 m. The calibration data was used to validate the application of the floating pier debris tool at this crossing. In the design scenario, the floating pier debris tool was used to simulate the obstruction effects of the debris. This was an example of a structure in the study area which required a detailed assessment of the impacts of obstruction.

However, to assess the model sensitivity to debris obstruction at the hydraulic crossings, the obstructions were simulated as simply and efficiently as possible, for the purpose of evaluating the impact at all bridge locations in the model. It was noted that during the site investigation, the Railway Bridge was blocked from the left bank towards the center of the crossing, with debris floating at the waterline on the upstream side of the bridge. Following this observation, the obstruction modelling Option 2 (as listed above) was used to block the structures from the left bank when debris blockages were applied to bridges in the model, as in Scenario 2 (Expected Conditions) and Scenario 3 (Extreme Conditions) (Figure 3.1).

Since the Railway Bridge had a high sensitivity to blockage, different methods of blocking the bridge were tested and compared. In addition to the floating pier debris tool, blockages from the left bank and both banks were simulated. The results of this analysis are compared in the next section.

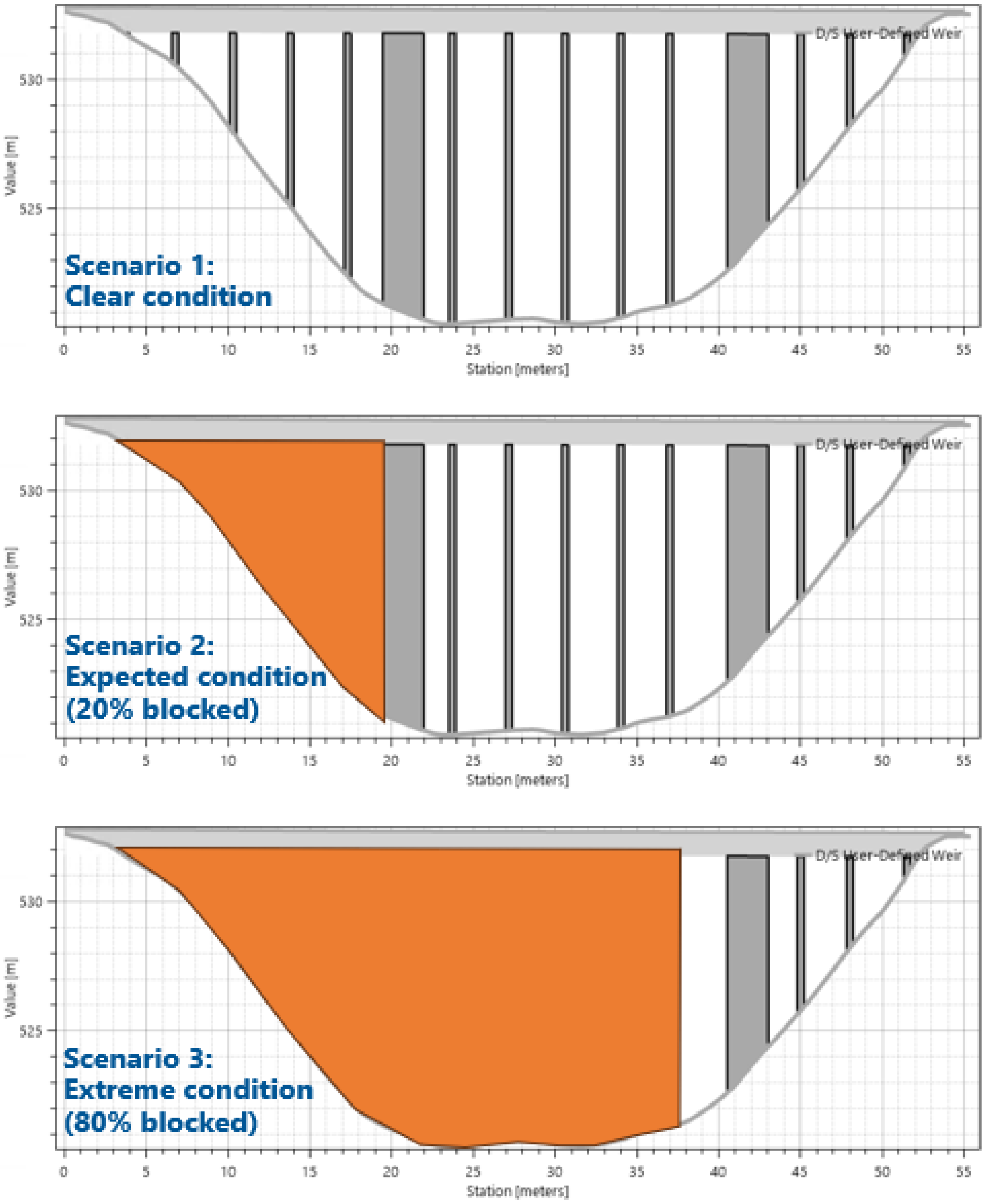

Figure 3.1 Hydraulic Model Bridge Blockage Scenarios presented on the model-simplified Railway Bridge

4 RESULTS

To evaluate the sensitivity of bridges to obstruction, both changes in water surface elevations and inundation extents were compared across the three obstruction simulation scenarios.

The profile plot (Figure 4.1) of the water surface elevations of each simulated scenario demonstrates a noticeable increase from the Scenario 1: Clear Conditions profile at some bridge locations, with a substantial increase in simulated flood water surface elevations at the railway bridge (circled in orange). This increase in water surface elevation indicates that flow is being constricted at these structures.

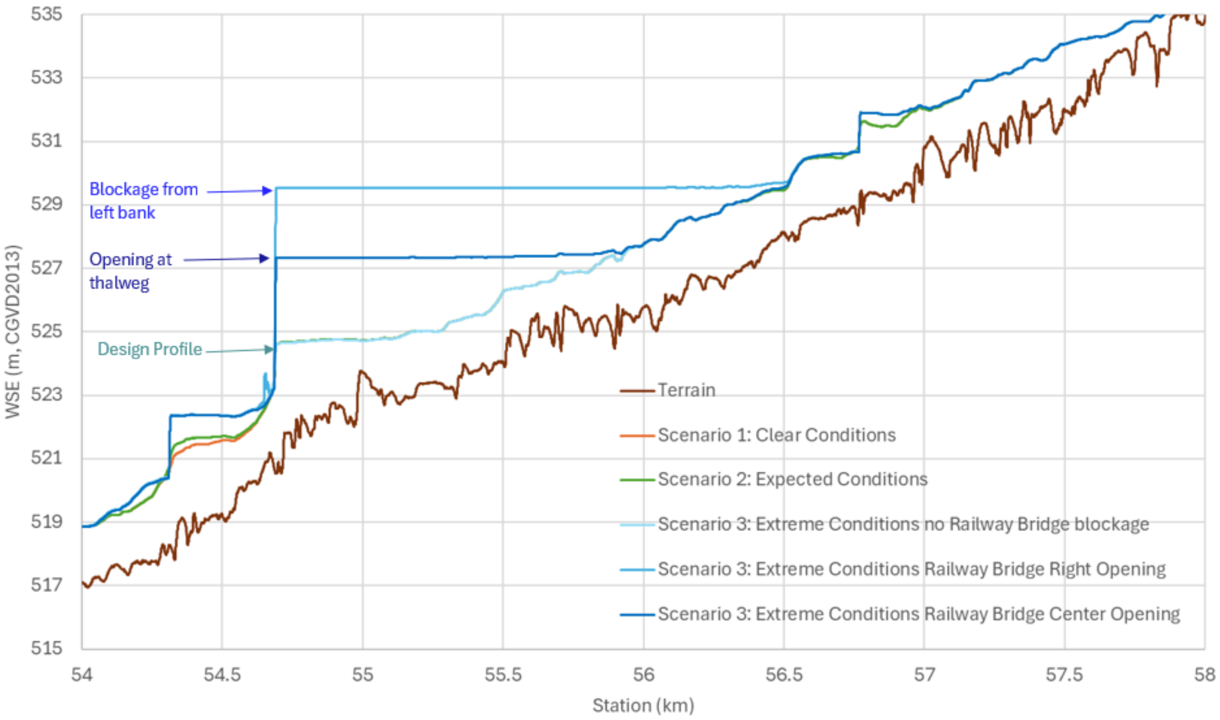

Figure 4.1 Profile plot comparing blockage scenarios at the Railway Bridge.

A closer view of the profile plot (Figure 4.1) at the Railway Bridge emphasizes that the manner in which the bridge is blocked can make a substantial difference in the ability of the crossing to convey flow without influencing hydraulic behaviour. The plot shows the difference between blocking the railway bridge 80% from the left bank versus narrowing the channel from both sides and leaving the thalweg of the channel at the bridge open for conveyance. The difference in modelling blockage technique resulted in a difference in water surface elevations over 2 m upstream of the bridge, and a much farther backwater influence upstream (~ 1 km from the crossing).

The increase in inundation extents once the Railway Bridge is 80% blocked is displayed on the left in Figure 4.2. The backwatering effects caused an increase in inundation extents upstream of the bridge, for over 1 km.

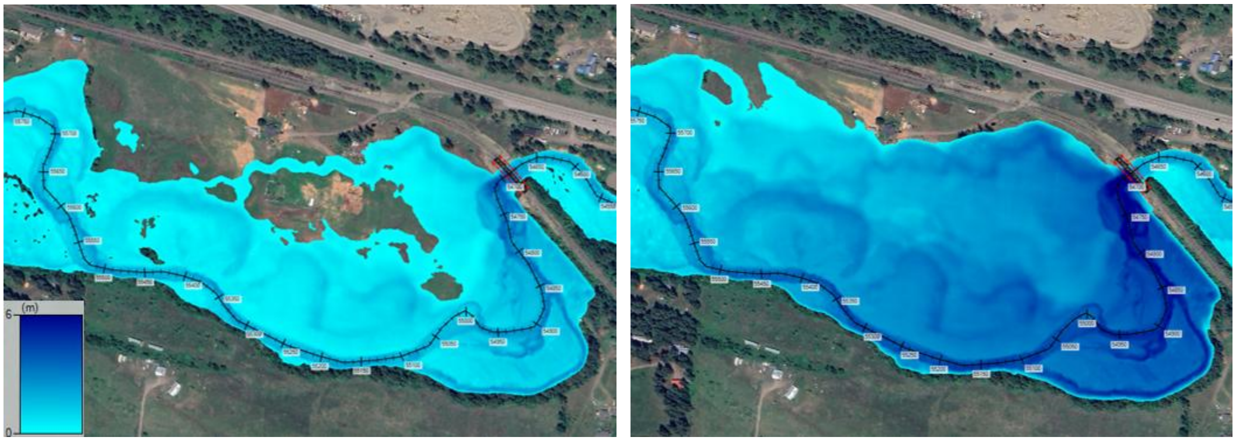

Figure 4.2 Railway Bridge flood extent comparison. Scenario 2: Expected Conditions (left), Scenario 3: Extreme Conditions (right).

The project identified five bridges vulnerable to obstruction along the reach to be investigated individually. Scenario 3: Extreme Conditions was used to compare the increase in blockage depth to a critical increase in depth (study-specific, in this case, 1.5 m was used) from the design scenario to determine which bridges in the study reach would be identified as sensitive to debris blockage.

5 CONCLUSIONS

The blockage scenario comparisons confirmed that bridge obstructions can have substantial impacts (exceeding 1.5 m) on the surrounding flood levels, highlighting the need for consideration during floodplain mapping projects. As was done in this case study, assessing multiple bridge blockages simultaneously is a useful approach to efficiently identify which structures are likely to have a higher flood response to blockage. Once these structures are identified, further analysis can be conducted to evaluate the sensitivity of the surrounding water elevations to blockage at specific structures.

Based on the general level of uncertainty identified at the 55 bridge crossings, a freeboard of 0.6 m was applied to the study. Ultimately, the study demonstrated that the sensitivity of some bridges to obstruction in the floodplain mapping model exceeds the uncertainty accounted for by the freeboard in the project maps. In these situations, rather than overconservatively raising the freeboard for the entire project, the approach of blocking the identified sensitive bridges (as determined by the potential to cause increases in flood level above the design flood event of greater than 1.5 m) in the model accounts for the inherent increase in uncertainty at the structures which are likely to be blocked.

Especially in regions which do not include freeboard in their floodplain maps, the differences caused by bridge obstruction can have implications on results and should be accounted for in floodplain mapping analysis.

6 ACKNOWLEDGEMENTS

The case study project was the Shuswap Region Floodplain Mapping project, which was funded by the Government of Canada and the Province of British Columbia through the Flood Hazard Identification and Mapping Program (FHIMP). It was administered and coordinated by Fraser Basin Council (FBC) and supported by a technical committee including representatives from FBC, Environment and Climate Change Canada (ECCC), Natural Resources Canada (NRCan), and the BC Ministry of Water, Land and Resource Stewardship (WLRS).

REFERENCES

NHC (2025). Shuswap Region Floodplain Maps - Riverine and Coastal Hydraulics. Final Report. Prepared for Fraser Basin Council by Northwest Hydraulic Consultants Ltd., North Vancouver, BC.