Methow River Reach Assessment

Appendix D| Hydraulic Model

METHOW RIVER (RM 40.6 – 62.3)

May 2026

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1 Introduction

A hydraulic analysis of the Methow River was conducted as part of the reach assessment. This analysis includes a preliminary-level 2-dimensional (2-D) hydraulic model of Reaches 1 to 16 of the assessment area (RM 40.6 to 62.2). The hydraulic model is used to understand general hydraulic characteristics of the river at a range of high flows, including stream energy (e.g. velocity), floodplain inundation patterns, and the effects of human and natural features on streamflow patterns. Model results were used to support the geomorphological interpretations that are included in the main document.

2 Hydraulic Model Methodology

The hydraulic model was developed in the U.S. Army Corps of Engineers HEC-RAS 6.6 software (USACE, 2024), which can compute hydraulic properties related to the physical processes governing water flow through natural rivers and other channels. Characteristics of the Methow River, such as regions of high sinuosity, multiple regions of split flow, and a wide and complex floodplain, make it a good candidate for a 2-D model, as such features are difficult to accurately model using a 1-dimensional model. The model was developed for existing conditions to assess the current channel and floodplain dynamics, as well as to assess the impacts of a range of flows on the landscape. This model only accounts for surface water flows and does not include groundwater inputs. This document describes parameterization, assumptions, and set up of the hydraulic model. Results are depicted and described in Section 3.

2.1 MODEL SETUP

2.1.1 Model Terrain

A digital terrain model (DTM) was created using publicly available LiDAR data. The LiDAR dataset includes topographic and bathymetric data from 2018 and 2022 (NV5 Geospatial, 2022; WGS, 2020), respectively, and is believed to be a sufficient representation of the Methow River's riverbed and surrounding terrain for this analysis. Bathymetric LiDAR uses refracted green laser returns to capture terrain details below water during the LiDAR flights. However, factors such as thick aquatic vegetation, algal growth, high turbidity, and pool depth can affect the accuracy of bathymetric LiDAR. More detailed bathymetric and topographic surveys would be needed to support site-specific project design work.

2.1.2 Model Domain and Geometry

The model's domain extends from RM 63, just downstream of the Early Winters Creek and Methow River Confluence, to RM 39.1, approximately 2.5 miles downstream of the Twisp River confluence near Twisp, WA (Figure 1). The computational mesh consists of grid cells ranging from 10-50 feet, with the smallest grid cells utilized to provide higher resolution results closer to the channel and terrain features of interest (Figure 2). To save hours to days of run time, channel cell size ranged between 10x10 and 30x30 ft, whereas much of the floodplain is made up of 50x50 ft cells. Larger cells on the floodplain can sometimes result in overestimation of flow inundation if cells span across high ground areas that would be a flow barrier. Breaklines were added along topographic high points to align cell faces along high ground to improve the representation of the underlying terrain and to limit this "leaking" effect, but there can still be some overestimation of floodplain inundation in some areas. Breaklines are also added along the channel to force cell alignment perpendicular to flow, improving efficiency and accuracy.

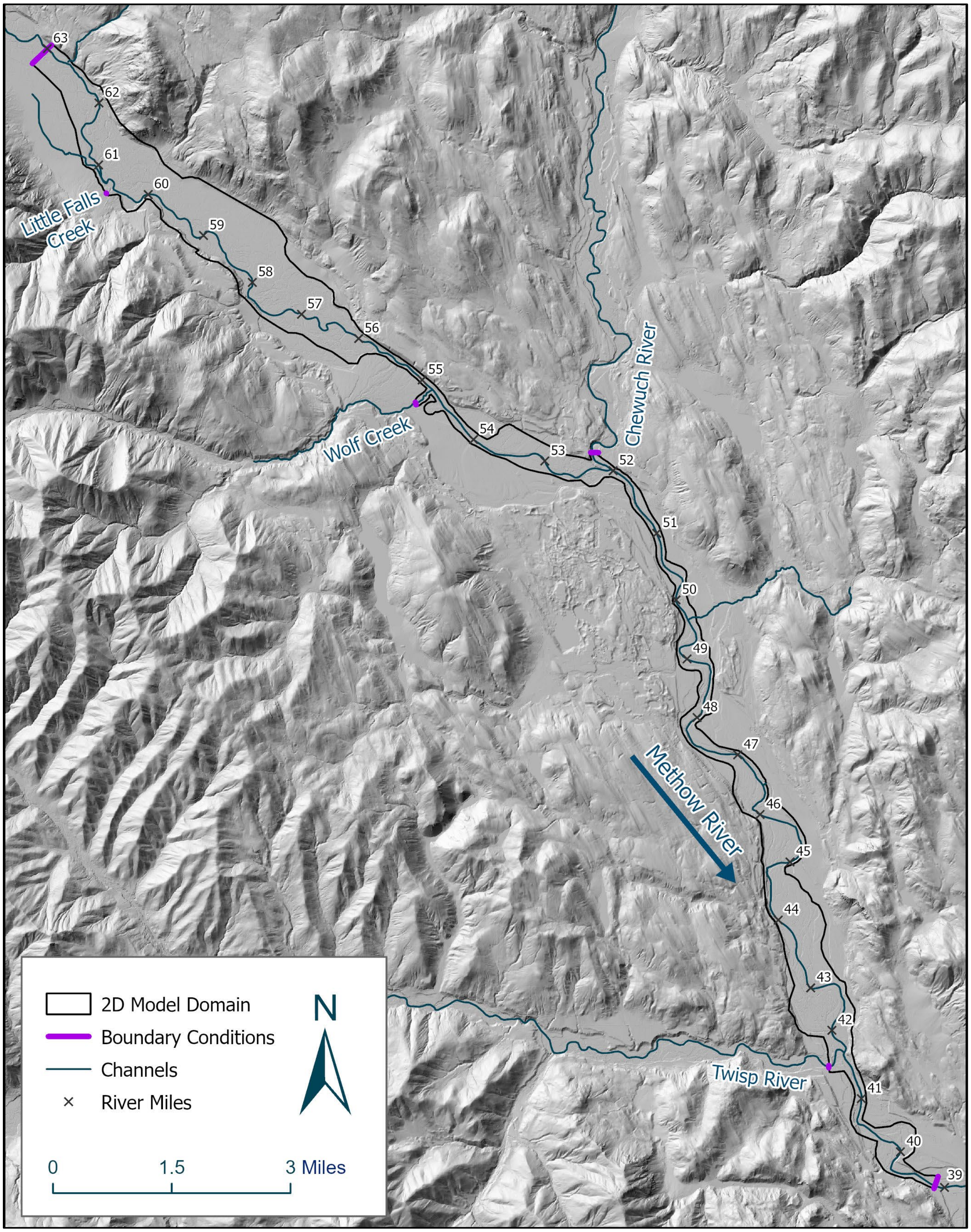

Figure 1. 2D model domain for the Methow River showing tributaries included in the model and model external boundary locations.

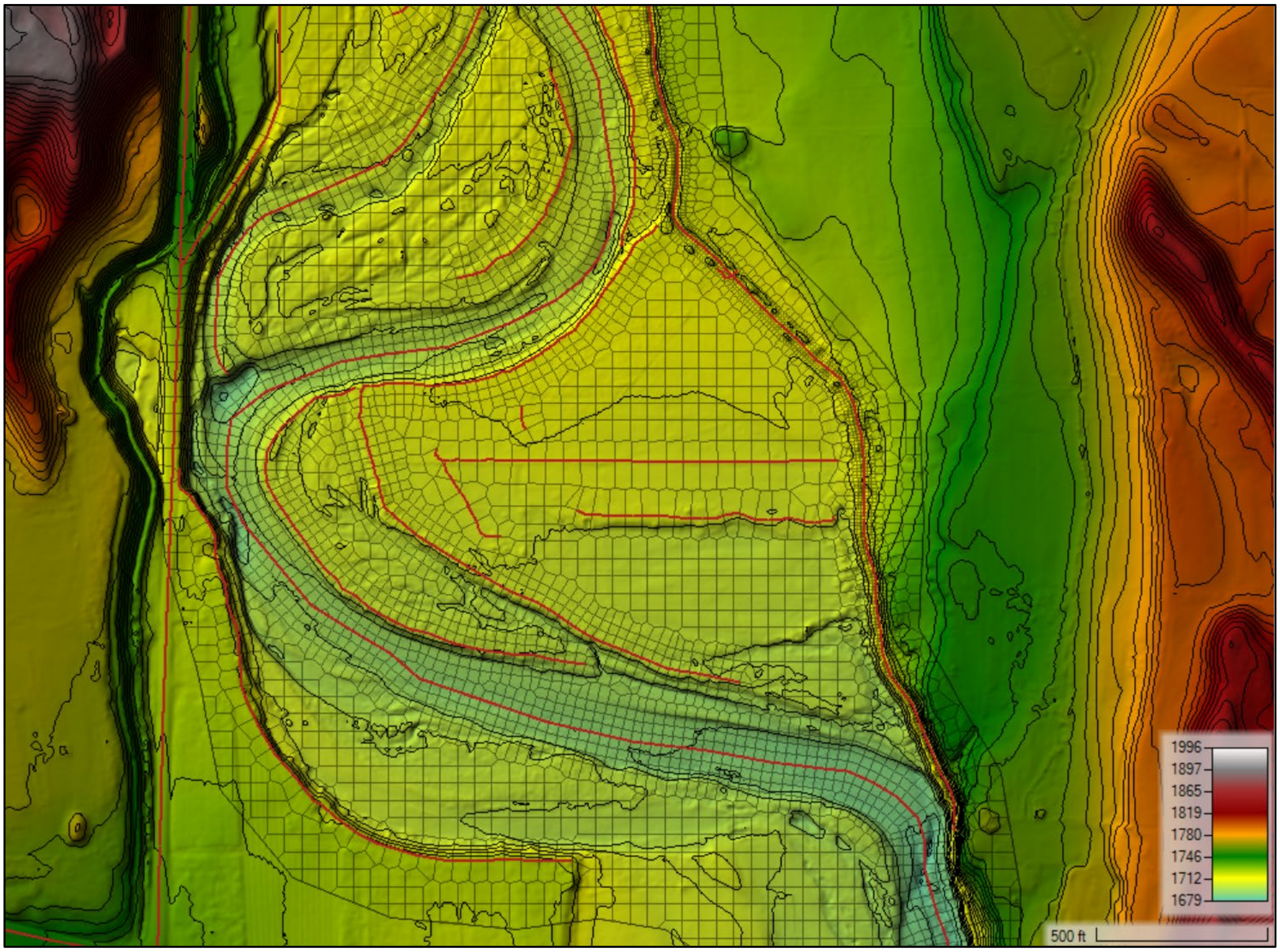

Figure 2. Representative computational mesh in the model domain (with 5 ft contours shown). Grid cells within the channel have a nominal size of 20-30 ft, while the outer floodplain cells are 50 ft. Breaklines (seen in red) are enforced along the channels and high ground features to align cell faces perpendicular to the prominent flow direction.

2.1.3 Bridges and Water Control Structures

Although there are bridges that cross the Methow River within the assessment area, bridge surveys were not performed and therefore no bridges were included in the model. Most bridges in this region are high and likely have relatively minor or insignificant effects at the reach-scale at the flows used in the model. In addition, water control structures in the project area were deemed to be adequately represented by the LiDAR-based model terrain for this preliminary analysis. Future design-level modeling will likely require survey of bridges and water control structures.

2.2 MODEL INPUTS

2.2.1 Model Roughness

A spatially varying Manning's n layer was developed using ArcGIS tools to represent hydraulic roughness throughout the model domain. The roughness layer was developed using a vegetation height layer created by subtracting the LiDAR bare ground layer (DTM) from the LiDAR first return layer (Digital Surface Model) and reclassifying these data to approximate vegetation communities by canopy height that would be represented by different Manning's n values (Figure 3). These data were supplemented with hand-digitized polygons, representing more discrete features such as creek and river channels. A table of Manning's n coefficients and their associated classifications is provided in Table 1. Assumed channel roughness coefficients range from 0.035 across most of the reach to 0.04 in turbulent sections where the channel slope is steeper. Floodplain roughness coefficients range from 0.02 to 0.65.

Table 1. Roughness coefficients (Manning's n values) utilized in the preliminary existing conditions modeling.

Area Description	Roughness Coefficient (Manning's n Value)
Methow River Channel	0.035
Methow River Channel (Turbulent Areas)	0.04
Side Channels	0.04
Tributary Channels	0.045
Road	0.02
Bare Ground (<0.5 ft)	0.03
Grassy Sparse Vegetation (0.5-4 ft)	0.04
Small Tree Forest (4-30 ft)	0.055
Tall Tree Forest (>30 ft)	0.065

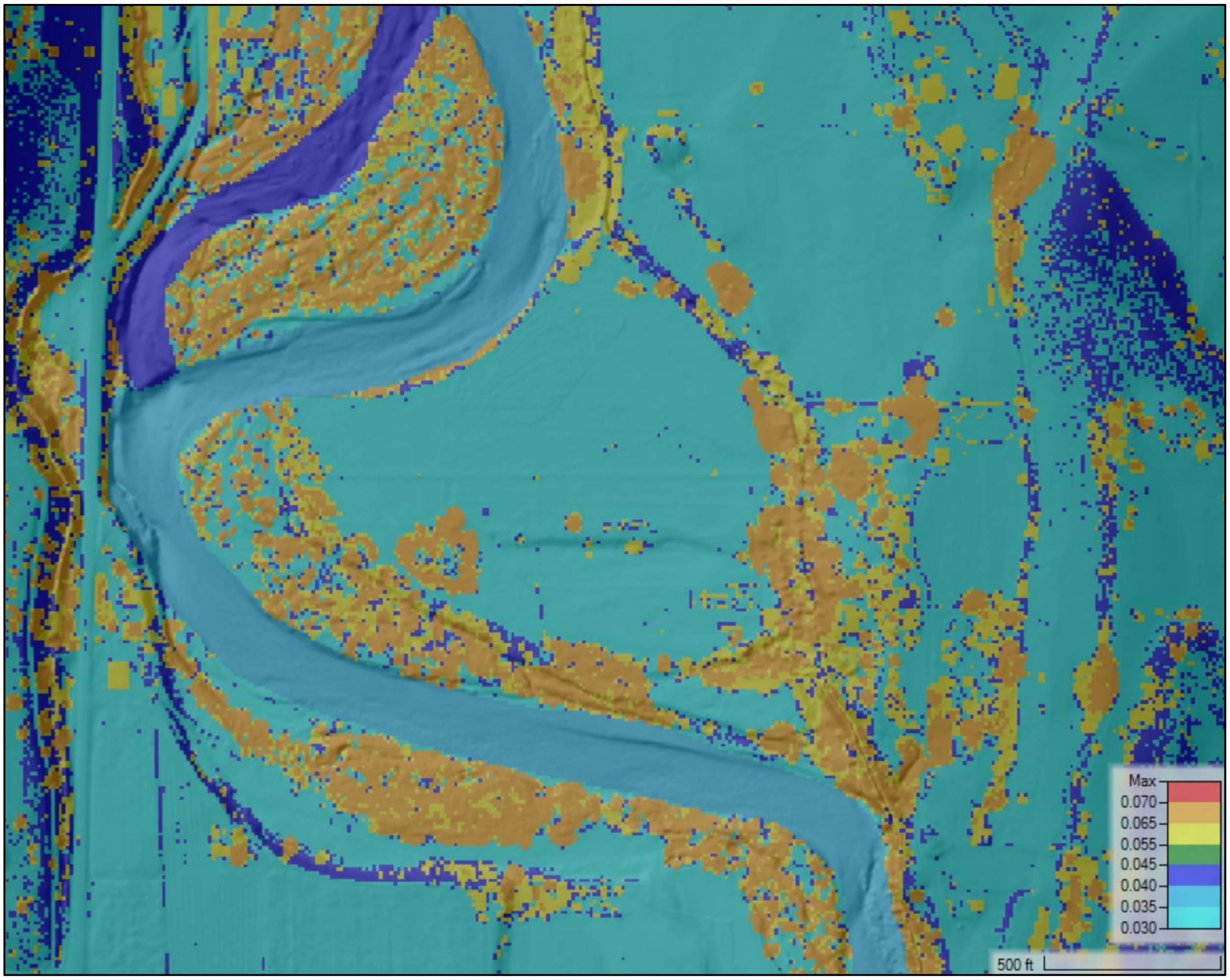

Figure 3. Representative depiction of roughness regions assigned to the existing conditions Methow River model.

2.2.2 Model Hydrology

The hydrologic inputs for the Methow River model were calculated by performing hydrologic analyses using data from several sources. Three USGS gages were used: Methow River above Goat Creek near Mazama, WA (USGS 12447383), Methow River at Winthrop, WA (USGS 12448500), and Methow River at Twisp, WA (USGS 12449500).

The Methow River above Goat Creek gage is located just under 3-miles upstream of the assessment area and has a period of record from 1991 to present. Due to its proximity to the upstream extent of the assessment area, this gage was used to estimate peak flows for the upstream extent of the model. The Methow River at Winthrop gage is located near the mid-point of the assessment area, just downstream of the Chewuch River confluence; it has a period of record from 1990 to present. This gage was used in combination with the upstream gage to estimate tributary inputs for peak flows of interest between the upstream extent and Winthrop. The Methow River at Twisp gage is located near the downstream extent of the assessment area, just downstream of the Twisp River confluence; it has a period of record from 1920 to present; however, there is a large gap in the data from 1965 to 1990. This gage was used in combination with the upstream gage to estimate tributary inputs for peak flows of interest between Winthrop and Twisp.

A flood frequency analysis was conducted for each USGS gage in HEC-SSP using the methods in Bulletin 17C to estimate peak flows (USACE, 2023). The Mastin et al. (2017) Equation 11 was used to weight the results by drainage area to estimate peak flows at the upstream extent of the project area (RM 62.2) based on the Methow at Goat Creek gage and the downstream extent of the project area (RM 40.6) based on the Methow at Twisp gage. The difference in flow between the upstream and downstream extents was further subdivided and apportioned to tributaries using Mastin et. Al. Equation 11 to estimate tributary contributions (Table 2) (2017). Drainage areas were determined using the USGS StreamStats Program (USGS, 2022). Originally, Little Falls Creek, Wolf Creek, Chewuch River, Bear Creek, Thompson Creek, Davis Creek, and Twisp River were all identified as tributaries of interest for this model. However, limitations in the LiDAR data at the Bear Creek, Thompson Creek, and Davis Creek confluences made flow input boundary conditions difficult to add for these tributaries, so these flows were rolled into the discharge estimate for the Chewuch River.

Table 2. Modeled flow events for the Methow River and tributaries used in hydraulic modeling.

Flow Event	Methow River Upstream Discharge (cfs)	Little Falls Creek (cfs)	Wolf Creek (cfs)	Chewuch River (cfs)	Twisp River (cfs)
2 - year	5,860	70	380	3,820	1,080
5 - year	7,750	110	610	6,140	1,310
10 - year	8,940	140	780	7,770	1,440
25 - year	10,400	180	1,000	9,930	1,580
50 - year	11,450	210	1,170	11,590	1,660
100 - year	12,490	240	1,340	13,280	1,720

The hydraulic model was used to evaluate existing conditions at flow events ranging from the 2-year to the 100-year recurrence interval floods (Table 2). A synthetic hydrograph containing inflows of interest was used as the model input hydrograph to simulate steady-state flow conditions for the peak flows, where the discharge of interest remains constant long enough to allow the model to reach a state of equilibrium. Allowing the model to reach a steady state during large flood events may overestimate flooding results, as floodplain storage areas throughout the model domain must reach capacity for the outflow of the model to reach steady-state conditions. In reality, this may not occur during short-duration events. However, it is a safe assumption for longer-duration events and is a more conservative (i.e., more likely to predict larger flooding extents) approach that was deemed appropriate for this preliminary-level model.

2.2.3 Model Boundary Conditions

The upstream boundary condition was set to the "Methow River Upstream Discharge" flows in Table 2, with an assumed Energy Grade Line slope of 0.004 based on the terrain at the location of the upstream boundary, which estimates the energy loss across the boundary condition. Each of the four tributaries, Little Falls Creek, Wolf Creek, Chewuch River, and Twisp River were also added to the model as external boundary conditions with their own hydrograph and energy slopes estimated based on the channel bed slope from the LiDAR-based terrain, and with peak flow timings corresponding to the mainstem Methow

River peak flows. The downstream boundary of the model is a normal depth boundary condition with an assumed Energy Grade Line slope of 0.004 based on the terrain at the location of the boundary.

2.3 MODEL CALIBRATION AND VERIFICATION

Calibration and verification of the 2D hydraulic model was performed based on field surveyed water surface elevation (WSE) data and stage data available from the USGS Methow River at Winthrop gage (USGS 12448500). A comparison between the modeled WSEs at the Winthrop gage location and corresponding daily average discharge and stage measurements from the Methow at Winthrop USGS gage at various flows was used to calibrate the roughness values of the Methow River channel in the model. At the selected roughness values in the model (see Section 2.2.1), WSE results were both higher and lower than USGS gage data at different flows, however these differences fell within a reasonable range, with an average difference of approximately 0.25 feet. Table 3 summarizes the comparison of the simulated WSEs and the Methow River at Winthrop gage data. The selected roughness values were also checked against WSEs collected during a survey conducted by Inter-Fluve in June of 2020 (between RM 42 and 43). The Methow River at Winthrop gage had a daily average flow of approximately 2,970 cfs at the time of the survey, and model results at this flow and location approximately matched the surveyed WSE (differences of less than 1 foot).

Table 3. Methow River WSE comparison for final model at the Methow River at Winthrop USGS gage station location.

Date of Flow	Flow at Methow at Winthrop Gage (cfs)	Methow at Winthrop Gage WSE (ft NAVD88)	Model WSE (ft NAVD88)	Difference (ft)
6/20/2002	4,170	1,735.9	1,735.5	-0.379
5/9/2013	10,100	1,738.8	1,738.5	-0.379
5/15/2018	14,700	1,739.9	1,740.3	0.351
5/18/2006	17,700	1,740.7	1,741.3	0.541
5/10/2018	20,300	1,741.4	1,742.1	0.631
5/31/1972	24,400	1,743.0	1,743.2	0.131

3 Summary of Hydraulic Model Results

The results of the Methow River model were used to assess channel hydraulics and floodplain dynamics. A wide range of flows were run in the model (2, 5, 10, 20, 50, and 100-year recurrence interval flood events). The 2-year and 100-year results are presented below. These flows were selected for inclusion because the 2-year flood represents a common high flow event and the 100-year represents an uncommon, very large flood with regulatory implications.

3.1 MODELED VELOCITY AND DEPTH RESULTS

Modeled velocity results for the 2-year and 100-year floods are included below in Figures 4 and 5. Modeled depth results for the 2-year and 100-year floods are shown in Figures 6 and 7.

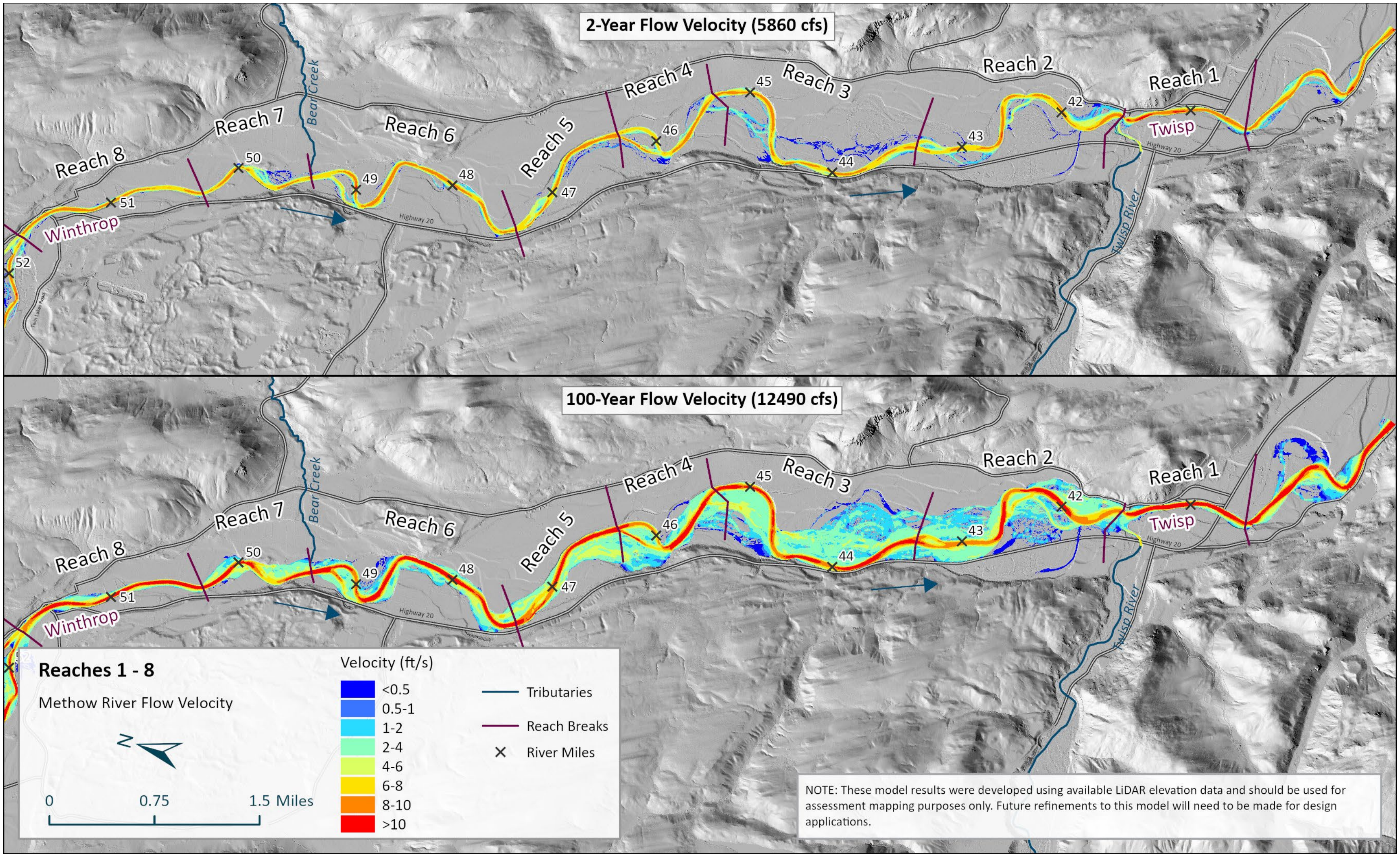

Figure 4. Modeled 2-year flood and 100-year flood velocities for reaches 1 to 8, labeled with the Methow River flowrate at the upstream end of the model.

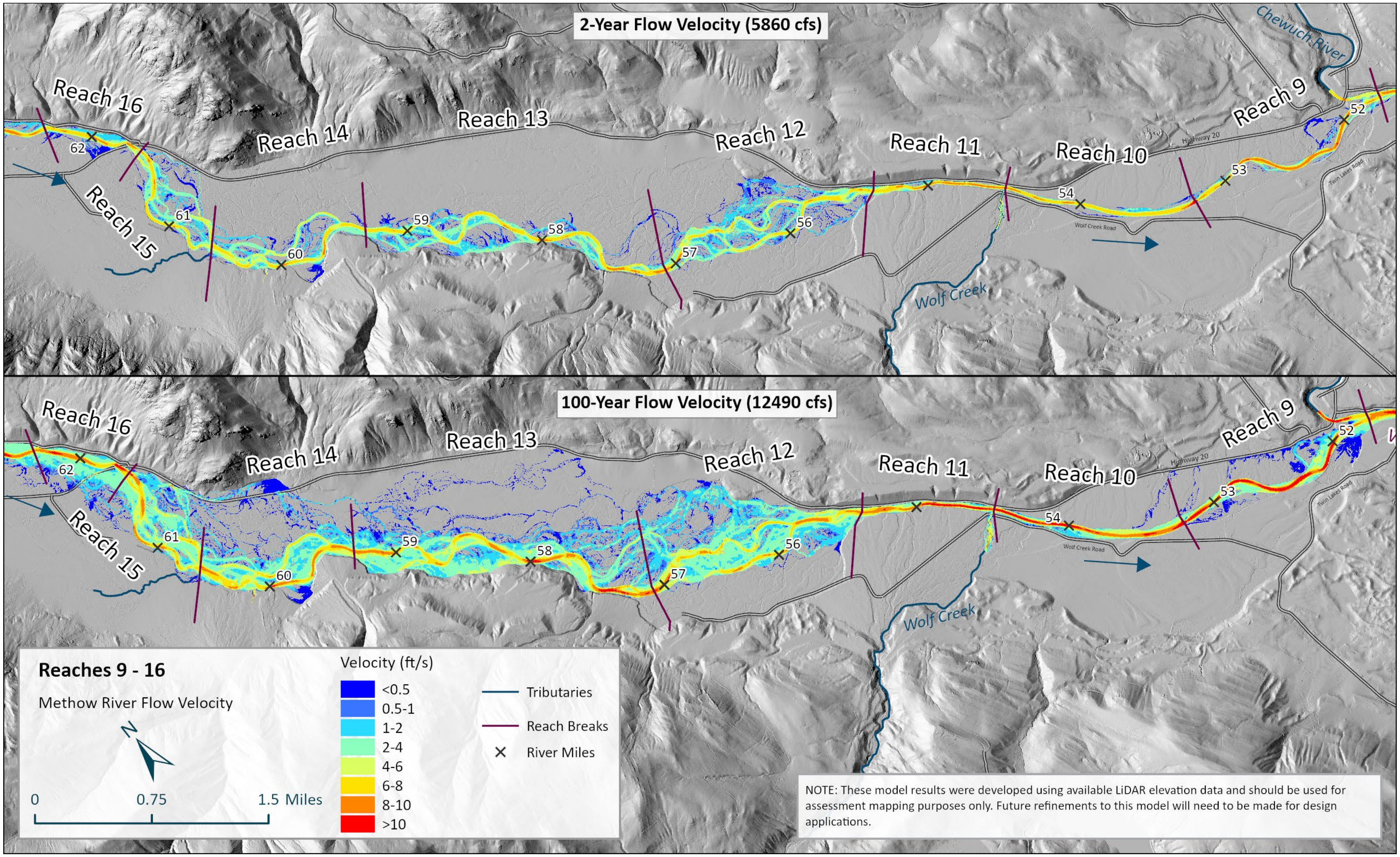

Figure 5. Modeled 2-year flood and 100-year flood velocities for reaches 9 to 16, labeled with the Methow River flowrate at the upstream end of the model.

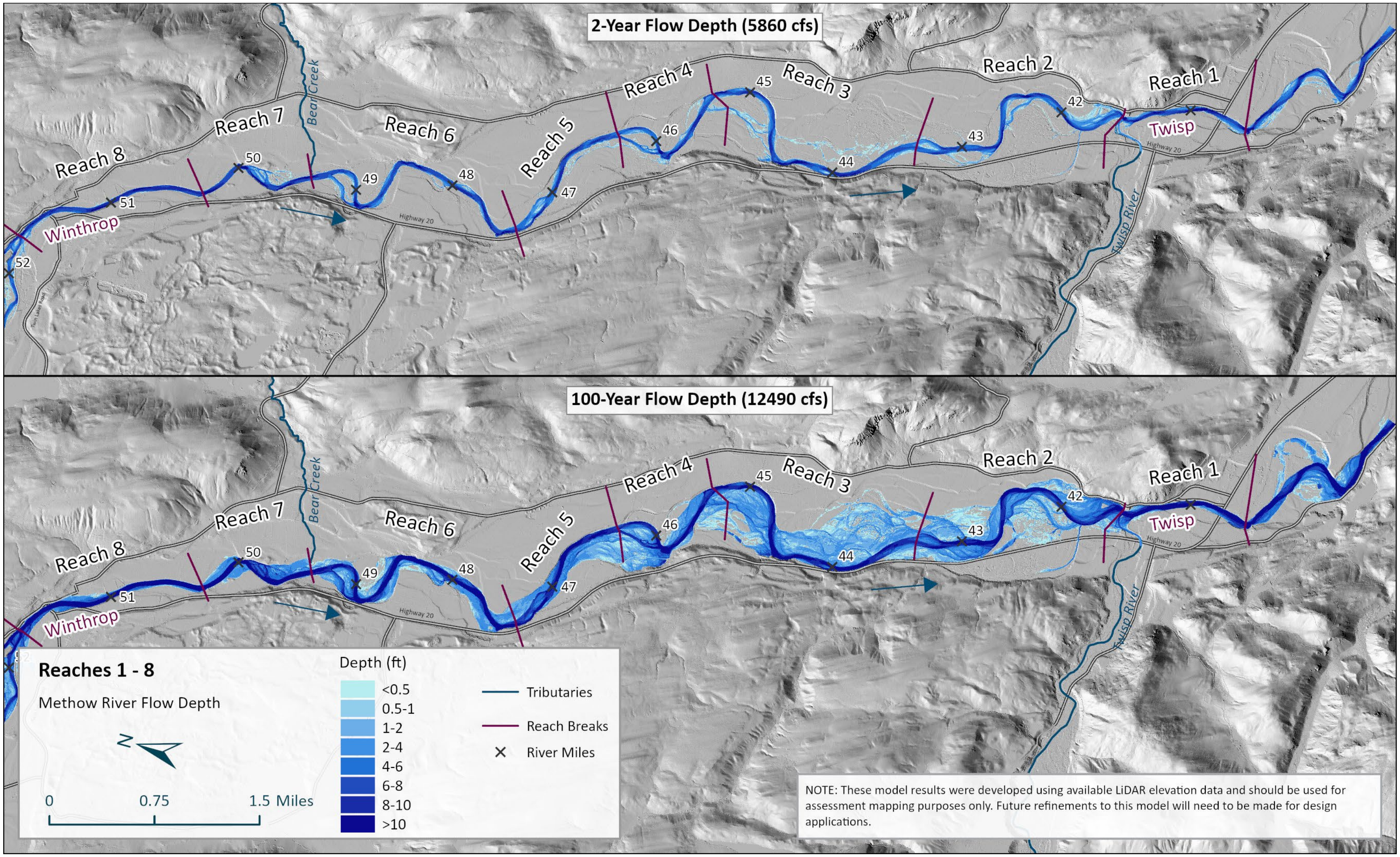

Figure 6. Modeled 2-year flood and 100-year flood depths for reaches 1 to 8, labeled with the Methow River flowrate at the upstream end of the model.

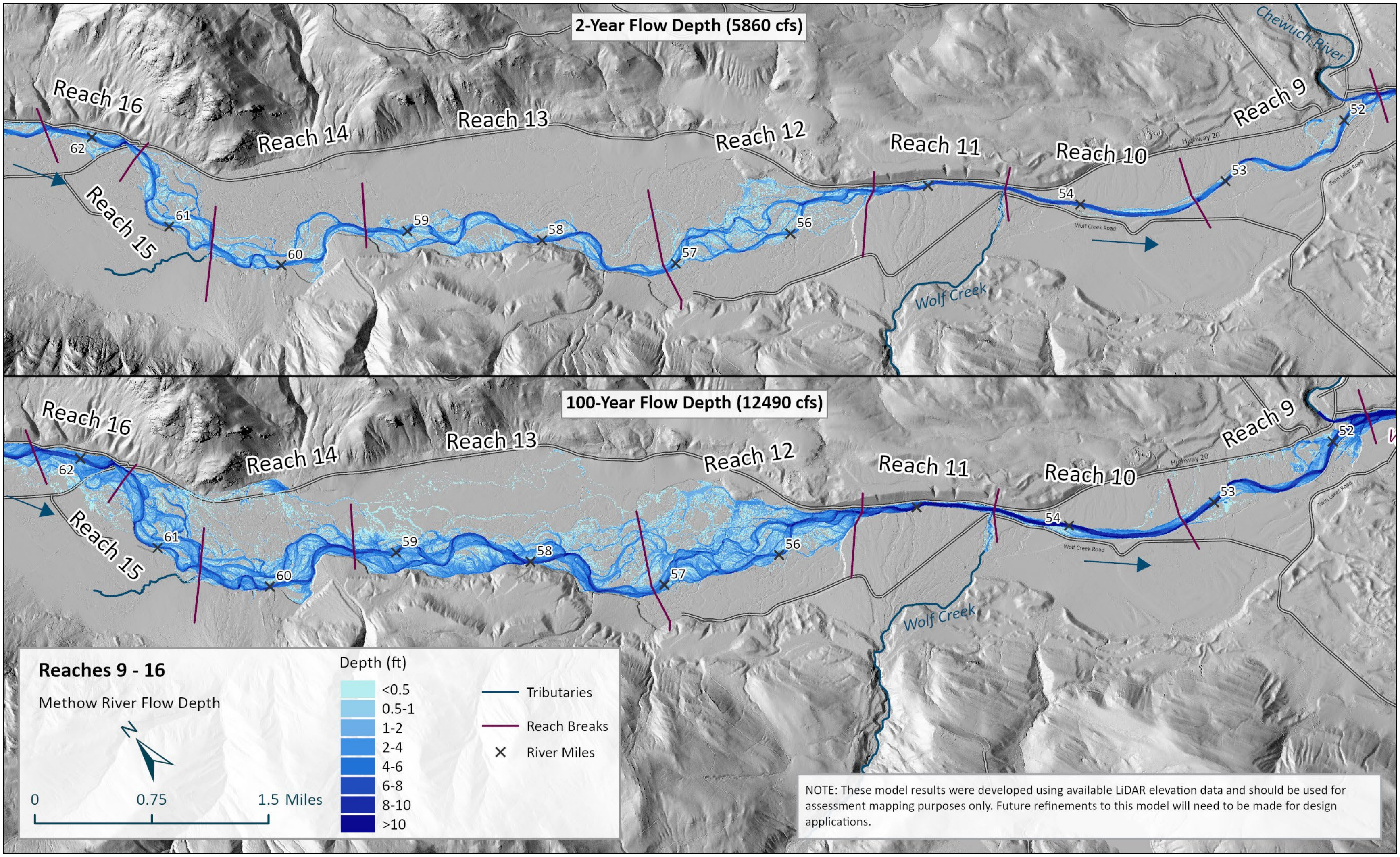

Figure 7. Modeled 2-year flood and 100-year flood depths for reaches 9 to 16, labeled with the Methow River flowrate at the upstream end of the model.

3.2 MODEL RESULTS DISCUSSION

3.2.1 Model Results Overview

Based on the preliminary model results presented here, the degree of floodplain inundation varies throughout the assessment area. In the 2-year modeled flood, most of the flow is contained within the mainstem channel in reaches 1 -- 11, with depths generally between 4 and 10 feet and velocities generally between 6 and 10 feet per second (fps). However, some side channel activation is depicted in the modeled 2-year event in reaches 2, 3, 4, and 6, as well as other small pockets of floodplain inundation. In reaches 12 -- 16, there is more floodplain inundation and several wetted side channels in the modeled 2-year flood. Main channel depths the upstream reaches ranges from 4 to 8 feet and velocities rarely exceeding 8 feet per second (fps). Side channel velocities are between 2 and 8 fps, with several showing velocities of 6 to 8 fps. Surrounding floodplain flow velocities are typically less than 1 fps. In the modeled 100-year flood, there is varied floodplain inundation throughout the assessment area, with extensive inundation in all reaches except 8 -- 11, (near Winthrop). Floodplains are inundated with 2-4 feet of water across much of the assessment area at the modeled 100-year flood. In addition, there are increases in depth and velocity in the main channel across the assessment area, especially in reaches 1 -- 11 where depths exceed 10 feet and velocities exceed 10 fps.

The model results indicate very little infrastructure impacts at the 2-year flood, with only a few rural roads inundated in reaches 12 to 16. However, the modeled 100-year flood results show various impacts to infrastructure. Washington State Route 20 is located within the floodplain and crosses the Methow River, Twisp River, and Chewuch River. At all crossings in the assessment area, including the Methow River (in reaches 1, 8, and 16), the Twisp River (Reach 1), a small ground water flow channel (Reach 2), and the Chewuch River (Reach 9), the abutment elevations from the LiDAR do not appear to overtop. However, the flow does spill over State Route 20 at several locations in reaches 14, 15, and 16. Other bridges in the project area include Spring Creek Bridge crossing at Winthrop in Reach 8 and the Wolf Creek Road bridge crossing over Wolf Creek in Reach 11, neither of which show the LiDAR abutments being overtopped. 100-year flood results show the Old Twisp Highway South overtopped in Reach 4 and several structures being impacted in reaches 9, 12, 14, and 15, as well as surrounding small or rural roads.

3.2.2 Model Results Considerations

This preliminary model was built using readily available data for the key terrain and hydrology inputs for the assessment area. Although these data are informative, they lack the detail to be the sole basis to design restoration projects. Future restoration projects will need to conduct additional surveys and other analyses to provide more accurate and precise data to support restoration design. Bathymetric surveys should be conducted to confirm that the available bathymetric LiDAR sufficiently represents the Methow River channel and major side-channels that contribute to conveyance. Topographic surveys should be conducted to assess infrastructure that may be affected by a given project. The several bridge crossings within the assessment area should be surveyed and further evaluated to assess how they impact surrounding flow and inundation. Upon reviewing model results with the reach assessment survey teams, it was noted that the model estimated greater floodplain inundation on river right in reaches 3 and 9 and on river left in Reach 16 than was observed during the surveys based on flood level indicators.

Although the model was refined at these locations, it still predicted greater inundation than expected. This may be due to the available LiDAR data not being fully representative of channel bathymetry, flood control structures (e.g. levees), or other features, again emphasizing the need for more detailed survey to support project design.

Although there are several long-term gages in the Methow River watershed, there remain large hydrology data gaps. The model included only the four largest tributaries to the Methow River within the assessment area. However, there are many smaller tributaries that flow into the Methow River throughout the assessment area. In addition, this model does not include groundwater inputs, nor the infiltration of surface water into soil on the floodplain. According to observations made by reach assessment survey teams, this lack of groundwater input likely underestimates the inundation extent in some locations.

4 References

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