Photo source: NHC (8 Oct. 2020)

MF Nooksack Channel Monitoring & Adaptive Management
As Built Monitoring

Prepared by:

Northwest Hydraulic Consultants Inc.
301 W. Holly Street, Suite U3
Bellingham, WA 98225
Tel: (206) 241-6000
www.nhcweb.com

NHC Project Contact:
Andrew Nelson, M.Sc., LG
Senior Scientist I Associate

Prepared for:

City of Bellingham Public Works
104 W. Magnolia Street, Suite 109
Bellingham, WA 98225

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Prepared by or under the direct supervision of:

State of Washington
3083
Licensed Geologist
Andrew D. Nelson

Andrew D. Nelson

BM Chilibeck

Andrew Nelson, L.G.	Barry Chilibeck, P.Eng.
Associate I Senior Geomorphologist	Principal
Author	Review

Andrew Nelson, LG
Digitally signed by Andrew Nelson, LG
Date: 2021.05.07 09:08:17 -07'00'

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- Steve Day — Project Engineer, City of Bellingham
- April McEwen — River Restoration Project Manager, American Rivers

The following NHC personnel participated in the study:

- Andrew Nelson — Project Manager & Lead Geomorphologist
- Annie Dufficy — Project Geomorphologist
- Jaron Brown — Project Hydraulic Engineer
- Amiana McEwen — Project Hydraulic Engineer
- Barry Chilibeck — Senior Review & Fish Passage Assessment

NHC partnered with Wilson Engineering on the as-built survey and Kleinschmidt R2 for Fish Passage Assessment:

- Tom Brewster — Survey Lead
- Paul DeVries — Fish Passage Assessment

TABLE OF CONTENTS

LIST OF TABLES IN TEXT

LIST OF FIGURES IN TEXT

LIST OF PHOTOS IN TEXT

APPENDICES

1 INTRODUCTION

The City of Bellingham (City), with partner organization American Rivers, removed the City's water diversion dam on the Middle Fork Nooksack River in summer 2020 and restored the river through the previous dam site to a natural historical channel configuration, as part of the Middle Fork Nooksack Fish Passage Project. This will provide passage and restore access to approximately 16 miles of pristine spawning and rearing habitat in the upper Middle Fork Nooksack River for three Endangered Species Act (ESA) listed fish species: spring Chinook salmon (Oncorhynchus tshawytscha), Steelhead (O. mykiss), and Bull Trout (Salvelinus confluentus).

NHC was retained to monitor channel response to the dam removal following the Draft Effectiveness Monitoring and Adaptive Management Plan, or MAMP (City of Bellingham and American Rivers, 2019) (MAMP, City of Bellingham and American Rivers 2019). The purpose of this Plan is to verify that the project meets the intended project goal of restoring the channel to a natural configuration by monitoring the physical river responses that improve fish passage and habitat connectivity. Four key monitoring metrics, outlined in Table 1.1, are the focus. This report, completed following observations of the river through autumn 2020 and published in spring 2021, presents results of the As-built Monitoring completed by NHC, in collaboration with partners Wilson Engineering and Kleinschmidt-R2, to complete this work.

Table 1.1 Key monitoring metrics

Monitoring Technique	Monitoring Metric	Thresholds	Decision Pathway
Photo/Visual Survey	N/A Provides indication of channel changes to inform field work.	N/A	N/A
Digital Elevation Model Development and Analysis	N/A Provides indication of channel changes to inform field work.	N/A	N/A
Channel Longitudinal Profile derived from Digital Elevation Model	Average Water Surface Elevation slope along low flow centerline.	1. >8% average slope over the entire monitoring site length. 2. >12% slope occurring over a 200 ft length within the monitoring site.	1a. <7% Average (Pass) 1b. >7% (Monitor) 2a. >7% in any 200 ft segment (Monitor) 2b. >10% in any 200 ft segment (Evaluate Adaptive Management Action)
Channel Cross Sections derived from Digital Elevation Model	Channel Water Surface Elevation at Minimum Instream Flow.	> 3ft water surface elevation decreases at any channel cross section.	1. <1ft decrease (Pass) 2. >1ft decrease (Monitor/Investigate) 3. >3ft decrease (Evaluate Adaptive Management Action)

Tasks completed in as-built monitoring effort and preparation of this report included several survey efforts completed with a Terrestrial LiDAR Scanner (TLS) or Unmanned Aerial Vehicle (UAV), field photo documentation, assembly of various surfaces into a single composite surface best representing the as-built condition of the channel, and development of a hydraulic model to simulate as-built water surface elevations for a range of flow conditions (so that it will be possible to compare changes in the water surface during subsequent monitoring completed under variable discharge conditions).

Construction of the restored regraded reach of the river channel was completed just before the first high flow pulse (a storm-triggered flow above the late-summer baseflow discharge and potentially capable of modifying the channel boundary). Following this first high flow event, autumn storms came in fast sequence. Therefore, rather than contemporaneously capturing as-built conditions as originally envisioned, survey efforts occurred between the high flow pulses, showing ongoing geomorphic adjustments of the channel in response to the high flow pulses. This results in slightly less comprehensive documentation of the as-built condition than was imagined, but better temporal resolution documenting the initial channel adjustments. Figure 1.1 illustrates the timing of these various observations relative to flood pulses that occurred through the autumn.

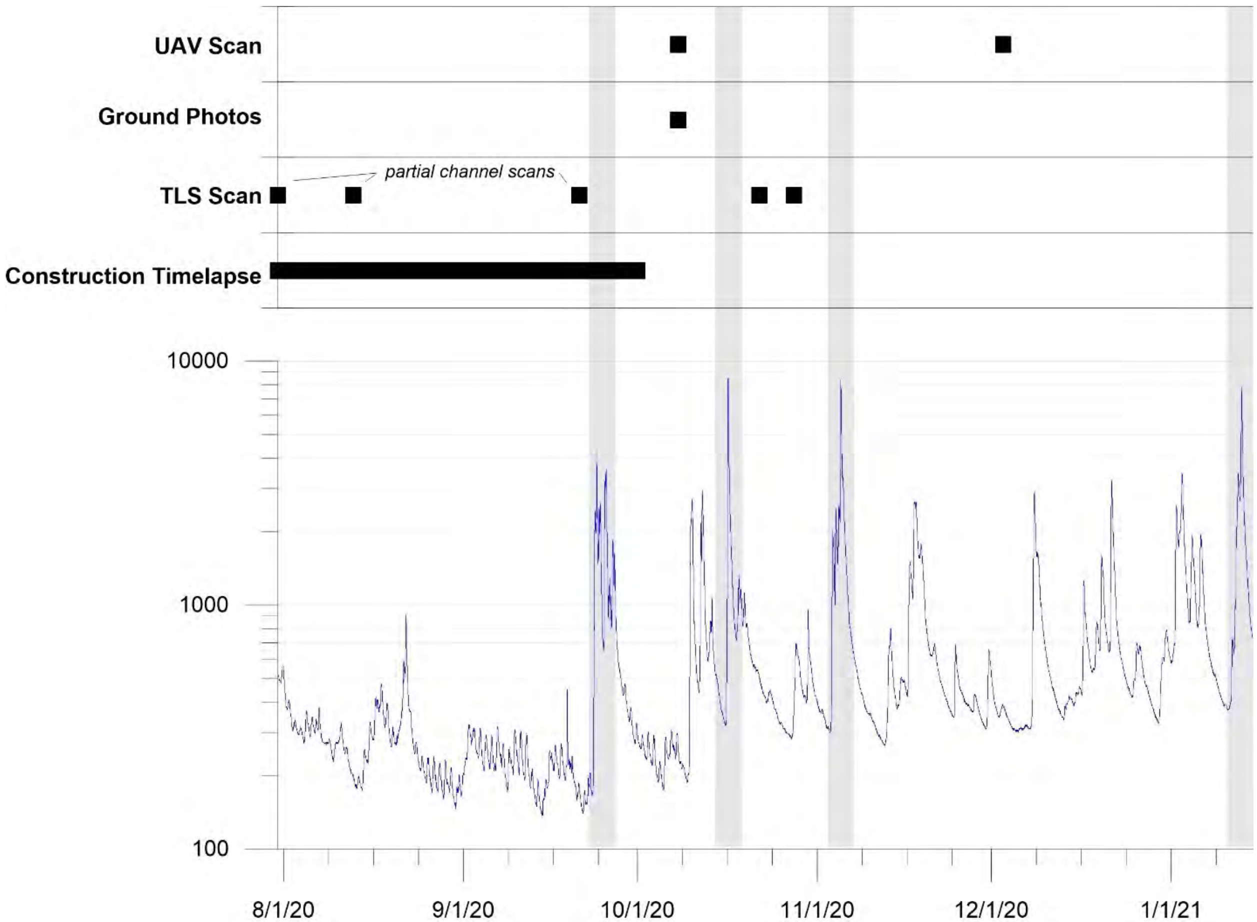

Figure 1.1 Timeline of observation efforts. TLS scans of portions of the restored channel were also completed on 31 July and 13 August as individual segments of that channel were re-watered.

This baseline as-built conditions monitoring report is structured with an overall site-scale narrative describing the layout of the monitoring observations, key observations, and changes observed over the autumn. It is supported by an appendix of detailed exhibits showing conditions and changes in conditions at each monitoring site and an appendix reporting development of the as-built conditions hydraulic model.

2 MONTORING METHODS

2.1 Monitoring Site Layout

Photo documentation and cross section extraction locations were defined at approximately 20 ft intervals (allowing some flexibility to choose good and accessible vantage points) along the left bank of the channel, extending from a point defined as station zero, which is located approximately 200 ft downstream of the historic dam crest , to station 760, which is located approximately 560 ft above the historic dam crest and 55 ft downstream of the new intake, as illustrated in Figure 2.1 (for context, the regraded reach extends from about Station 60 to about Station 400). These are named by the corresponding bank station. In addition, photo documentation points were set at eleven vantage points around the channel; these are given brief descriptive names.

Topographic and profile extraction lines were also laid out on the site to define locations for measuring changes in water surface elevation and profile slope, as also illustrated in Figure 2.1. Topographic cross section extraction lines were laid out crossing the channel at each photo monitoring station. Topographic profile extraction lines were laid out along dominant flow paths that may act as distinct fish passage routes. The measured distances along the bank provide a standardized “stationing” for the whole monitoring area. Because each profile extraction flow path has slightly different lengths than the Bankline, locations along the flow paths are defined by both along-path stations and by standard stationing.

City of Bellingham
American Rivers

nhc
northwest hydraulic consultants

Profile Extraction Lines
- Main Channel
- RB Channel 1
- RB Channel 2
- US LB Split

Photo Transect Stations (Feet)
- Cross Section Extraction Lines

N

0 25 50 75 100 Feet

MF Nooksack Fish Passage Monitoring

SIte Overview

Job: 2005776

DATE: 25-MAR-2021

FIGURE 2.1

2.2 Survey & Documentation Techniques

Two topographic survey techniques were used to define the as-built surface and document subsequent channel changes, photogrammetry from UAV imagery, and TLS scanning. Table 2.1 outlines the timing of survey observations, equipment used, and discharge condition at the time of observation.

Table 2.1 Timing of site visits and observations collected.

Date	Observation Location or Notable Event	Equipment	Approximate Discharge/Flow Condition
31 July 2020	Station 100 to 240, LB Dewatered portion of channel only.	Trimble TX-5 Terrestrial 3D Laser Scanner.	Dewatered
13 Aug 2020	Station 180 to 320, LB Dewatered portion of channel only.		
20 Sept 2020	In water work completed in restoration reach at dam removal location.	NA	NA
21 Sept 2020	Station 320 to 400, LB Dewatered portion of channel only.	Trimble TX-5 Terrestrial 3D Laser Scanner.	Partly Dewatered, unknown discharge through regraded channel. Total discharge 160 cfs.
23 Sept 2020	High flow pulse	NA	4,300 cfs
8 Oct 2020	Station 280 to Station 865	DJI Mavic 2 Pro UAV/UAS System equipped with Hasselblad 20MP Camera.	225 cfs
8 Oct 2020	Photo documentation points defined in Figure 2.1.	Theodolite App running on iPhone 6s.	225 cfs
16 Oct 2020	High flow pulse	NA	8,500 cfs
22 Oct 2020	Station 0 to Station 460	Trimble TX-5 Terrestrial 3D Laser Scanner.	450 cfs
28 Oct 2020	Station 460 to Station 850		650 cfs
05 Nov 2020	High flow pulse	NA	8,000 cfs
3 Dec 2020	Station 100 to Station 965	DJI/Matrice 200 UAV/UAS System equipped with ZenMuse 24MP Camera.	360 cfs

The reference as-built topographic surface was used as the baseline for future channel change observations and hydraulic model development to define the baseline water surface elevation relative to subsequent monitoring efforts. The surface was assembled from a combination of several different Digital Elevation Models (DEMs) representing the as-built conditions immediately following construction (Figure 2.2). Five separate data sources were integrated to produce a terrain covering the model domain representing conditions at the time channel grading work was completed. Topographic sources were selected to best represent conditions visible in time lapse imagery of the site following completion of channel grading work but before the first high flow pulse. These sources included:

- 2013 LiDAR was used for areas outside of the channel and areas of bedrock above the water surface near the channel. These areas are believed to have not changed meaningfully since 2013, except in the area of ongoing grading activity on the left bank floodplain/terrace.
- 2007 ground-based survey of the channel provided by Wilson was used for submerged bathymetry outside of areas of project grading.
- 2020 Wilson TLS scans of the channel through the project area.
    - In the area of project grading, TLS data was gathered during a (mostly) dewatered condition in August and September.
    - Upstream and downstream of the project regrade, TLS data was collected on October 28th, 2020. It only covered the subaerially exposed portion of the channel and was integrated with the 2007 ground-based survey.
- NHC UAV overflight of the project area, completed on October 8, 2020.
- Wilson UAV overflight of the project area, completed on December 3, 2020.

The domain where each of these data sources was used is shown in Figure 2.2. The north portion of the mid-channel bar, between station 240 and 340, was outside of the extent of the dewatered as-built TLS scans, but changed appreciably in the first flow pulse before the Oct 8th UAV overflight. Therefore, no data were available to represent the topography of this area. This hole was filled with simple interpolation unless this interpolation indicated an elevation above the 2013 LiDAR, in which case the lower LiDAR elevation was used. This qualitatively matches topography visible in the reference photo (Photo 2.1) for conditions just before the first high flow pulse, which adjusted the channel morphology (Photo 2.2).

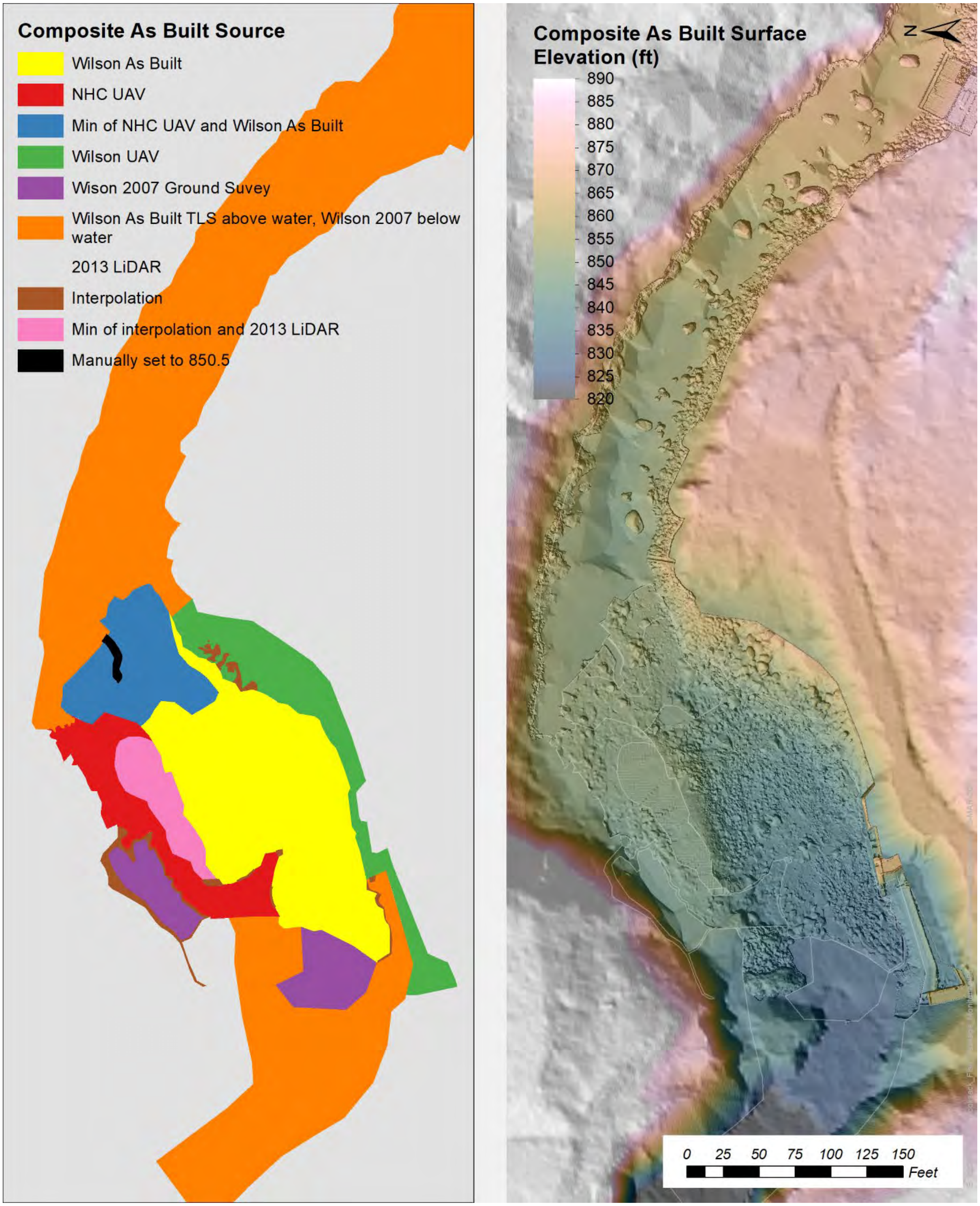

Figure 2.2 Overview of as-built topographic surface and data sources combined to produce the surface.

Photo 2.1 **Image from September 23, 2020 at 7:31 AM PDT showing a flow of approximately 170 cfs used to aid development of the as-built topographic surface and for hydraulic model calibration. Photo provided by American Rivers.**

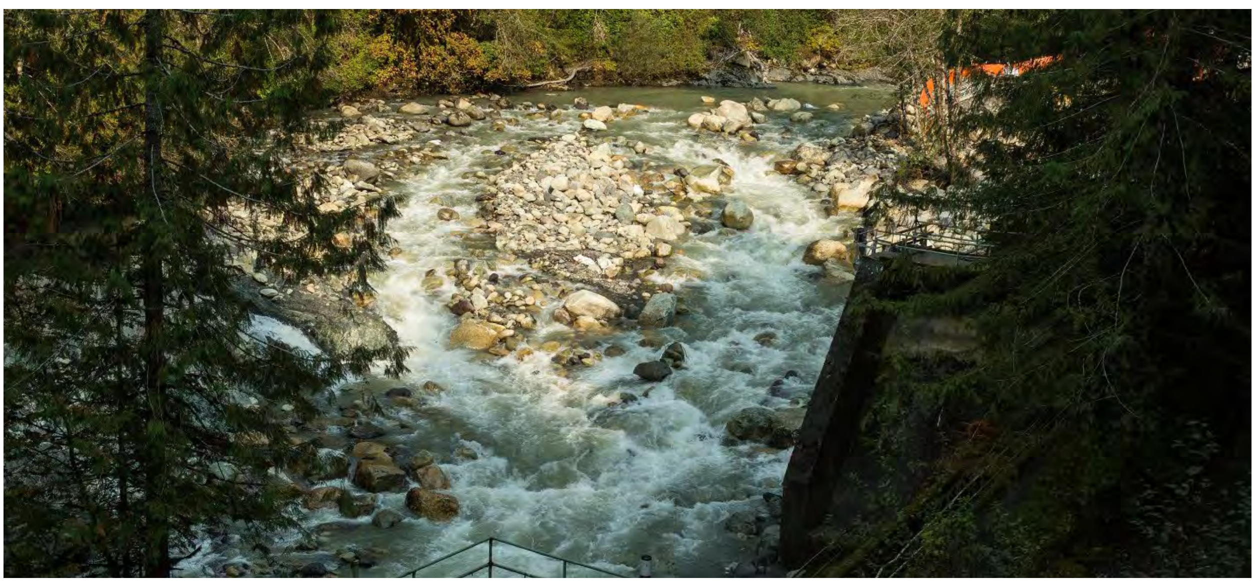

Photo 2.2 **Image from September 30, 2020 at 2:16 PM PDT showing a flow of approximately 275 cfs and development of new mid-river channel. Photo provided by American Rivers.**

3 KEY OBSERVATIONS AND CHANGES OBSERVED OVER AUTUMN 2020

Comparison of the integrated as-built surface with the design channel grading for the project (Figure 3.1 top) indicates that the upstream portion of the channel was built 3 to 4 ft higher than the design and that less material was removed from the right bank portion of the design cut across the mid channel bar than indicated in the design surface. These channel grading revisions performed during construction were made under the direct authorization and observation of the channel design engineer (Paul DeVries).

High flows during autumn 2020 resulted in significant changes in the channel condition through the regraded reach and in the channel immediately downstream of the regraded reach (Figure 3.1). The first flow pulse resulted in scour of a new mid-river channel (Compare Photo 2.1 and Photo 2.2 and changes to 8 October in Figure 3.1), and subsequent flows resulted in continuing deepening of that channel where scour is concentrated in front of a large rock spur and headcutting erosion along the course of the channel towards the fish bypass return pool (compare changes to 8 October, 22 October, and 3 December in Figure 3.1). This channel lowering has removed some of the material along the right bank portion of the design cut that was not removed during construction, but has also removed material from outside (to the north) of the planned excavation area.

Much subtle changes have occurred along the dominant left bank channel where boulder jams were installed to control the grade. The boulder jams have remained stable, though individual overexposed boulders up to 2 m in diameter have shifted and moved short distances (e.g. 3 to 12 m).

Shallow bedrock exposure is believed to be present beneath the right bank channel pathways. Head cutting and down cutting along this path would be expected to continue during future larger flows until such erosion-resistant material is encountered. One concern is that head cutting may propagate to lower the tailout elevation of the fish bypass return pool, diverting low flows away from the designed main channel and increasing step heights above that pool. Continuing monitoring of the head cut development along this path is, therefore, essential; this will continue to be performed as part of future planned monitoring observation work.

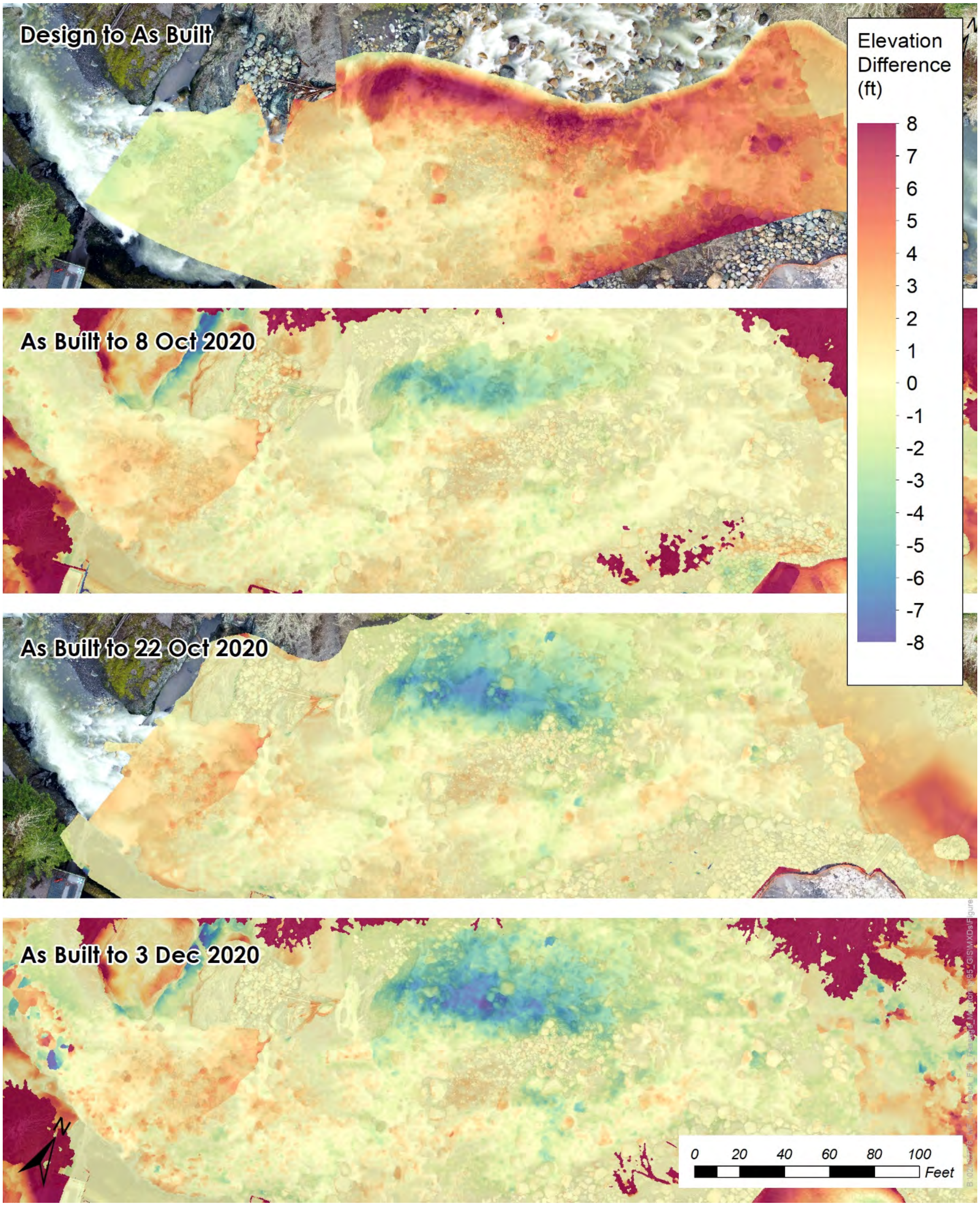

Figure 3.1 DEM surface comparisons showing differences between the design surface and as-built surface (top) and between the as-built surface and subsequent topographic surfaces.

4 PERFORMANCE METRICS

Complete photo documentation and topographic cross section and profiles are plotted in Appendix A. This section summarizes qualitative and quantitative performance metrics defined in the MAMP.

4.1 Longitudinal Profile Metric 1: Average Slope Through Regraded Reach

The average slope between station 60, at about the bottom of the regraded reach, and station 400 at the top of the regraded reach is 6.7% in the composite as-built surface, 6.9% in the October 8 UAV DSM, 6.6% in the TLS derived DEM, and 6.3% in the 3 December UAV DSM. All these values are below the 7% maximum slope threshold defined in the 1a MAMP decision pathway (Table 1.1). Therefore, as indicated by this attribute, the regrade is functioning as intended.

4.2 Longitudinal Profile Metric 2: Average Slope Over Any Individual 200 Ft Segment

Slopes for 200 ft segments were extracted along each profile path outlined in Figure 2.1 and are plotted in Figure 4.1. Along the main channel, the slope is consistently below 8%, except a small area near station 275 that is between 8 and 9%. The right bank flow paths are slightly steeper, with localized areas between 9 and 10%. The upstream left bank split is less than 200 ft long, but the average slope along that split is 5%. All segments are below the action threshold of a 12% slope (Table 1.1) and below the 2b decision pathway threshold of a 10% slope; but several are above the 7% 2b decision pathway indicating continuing monitoring is needed.

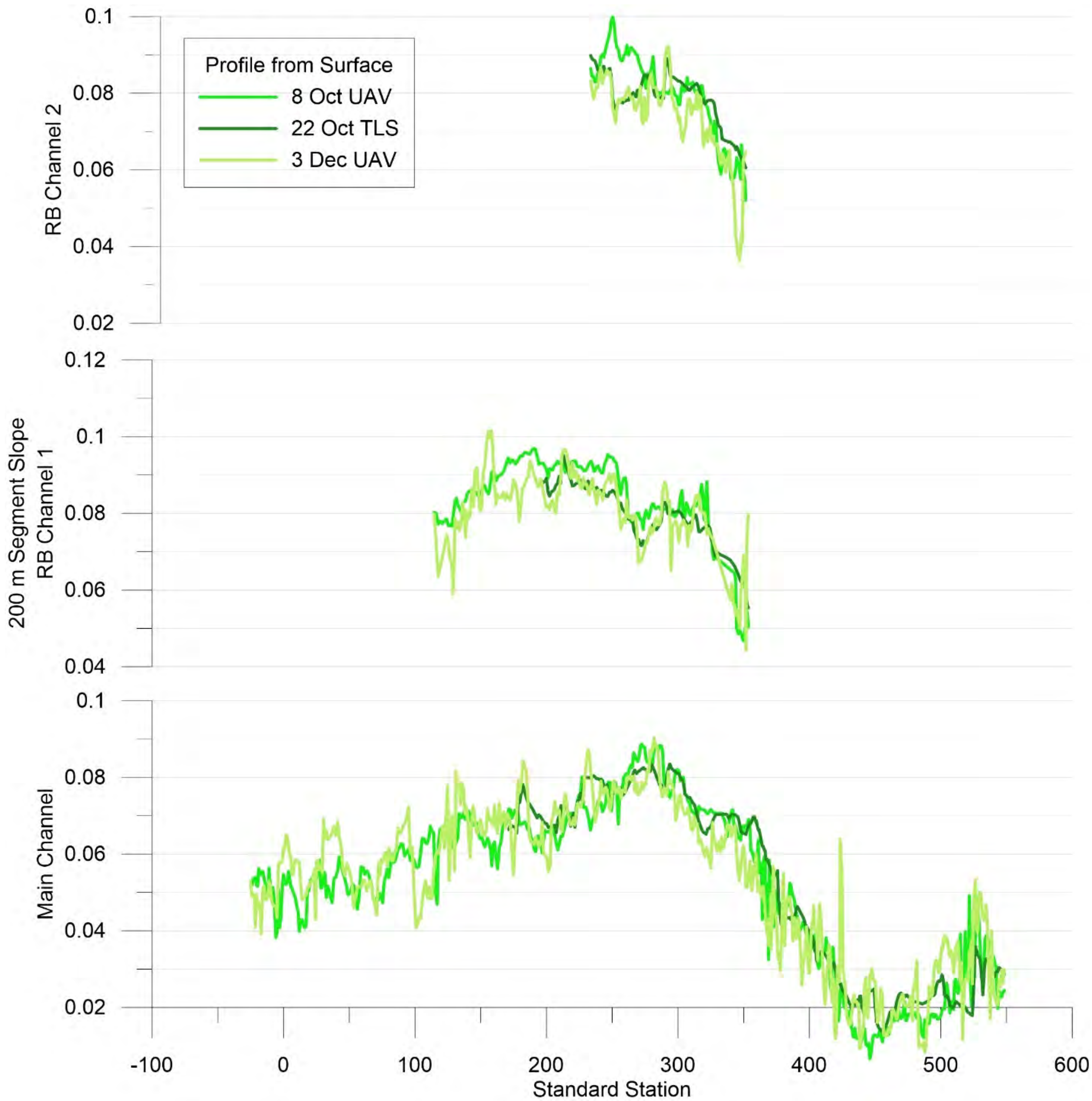

Figure 4.1 Plots showing 200 ft segment average slopes for each monitoring DEM.

4.3 Cross Section Water Surface Elevation Decrease

The performance threshold for water surface elevation decrease at any channel cross section is 3 ft, which triggers evaluation of monitoring or adaptive management actions, with a decision pathway of more than a 1 ft decrease in the water surface elevation triggering further monitoring or investigation. Given significant topographic changes observed in comparisons between the as-built DEM and subsequent monitoring, localized decreases in the water surface elevation exceeding these thresholds are clearly present the secondary right bank flow pathway. Therefore, separate values for the water surface were tabulated for the constructed main left bank flow pathway, which is the primary focus of this monitoring effort and subject of the MAMP and secondary right bank flow pathway.

Because the quantitative target for this metric is change in water surface—which varies with discharge in the river—NHC developed a hydraulic model representing the as-built topographic surface and calibrated this model to images of the channel before the first flood event caused geomorphic change (Photo 2.1). The model development and calibration procedure are described in Appendix B. This model was run for the same discharge as present at the time of survey to provide the baseline for comparison of changes in water surface elevation.

Lateral variability in the water surface, even along individual flow paths, required interpretation to define a specific water surface elevation. This was done by reviewing cross sections extracted from the digital surface model while also reviewing aerial photos to select representative water surface elevations, with preference given to areas of the cross section close to the Main Channel and RB Channel 1 flowlines plotted in Figure 2.1.

These results (Table 4.1) show changes along the dominant Main Channel flow pathway, ranging from +0.4 to -2.0, with nine of twenty-two cross sections exceeding a1 ft decrease in water surface elevation, thus indicating further monitoring or investigation. Water surface elevations along the secondary right bank flow pathway have decreased by up to 6.8 ft as the new right bank channel continues to develop, as was anticipated in the design. Headcutting in this developing channel has not yet propagated to the tailout of the fish bypass return pool at about station 400, and so the Main Channel flow pathway is functioning as intended. Erosion along the right bank flow pathways (RB Channel 1 and RB Channel 2), therefore, does not represent a functional impairment to fish passage or the function of the Main Channel flow pathway as designed. Development and regrading of the right bank flow pathways to a lower slope opens a valuable secondary fish passage route through the regraded reach of channel. However, if erosion propagates to the pool outlet and decreases bed elevation of the right bank flow pathways below the Main Channel flow pathway, then it could result in dewatering of the design flow pathway during low flows. Therefore, continuing sediment mobilization from along the right bank flow pathways requires ongoing monitoring.

Table 4.1 Observed water surface elevations in October 2020 (at time of the TLS observation). Modeled water surface for the as-built condition hydraulic model for the corresponding discharge, and interpreted change in water surface elevation. Cells with blue text exceed the 1 ft trigger for further monitoring or investigation and cells with blue text highlighted in orange exceed the 3 ft water surface difference that triggers evaluation of monitoring or adaptive management if occurring on the Main Channel (MC) flow path.

	Water Surface from As-built Model with 450 cfs		Observed Water Surface 22 Oct. 2020 (from TLS Surface)		Water Surface Change from As-built Condition	
Cross Section	MC flow path	RB Flow Paths	MC flow path	RB Flow Paths	MC flow path	RB flow paths
0	828.1	NA	826.6	NA	-1.5	NA
17	828.3	NA	827.6	NA	-0.7	NA
40	828.4	NA	826.8	NA	-1.6	NA
62	828.6	828.4	829.0	828.1	0.4	-0.3
82	829.6	829.7	829.8	829.2	0.2	-0.5
100	830.1	830.1	830.5	830.1	0.4	0.0
125	832.6	830.2	831.3	831.3	-1.4	1.0
141	833.4	834.0	832.3	833.2	-1.1	-0.8
160	834.3	835.1	833.4	834.2	-0.9	-0.9
200	837.5	836.2	837.2	835.8	-0.3	-0.4
220	838.2	838.3	838.7	836.1	0.5	-2.2
241	839.6	846.1	839.1	839.3	-0.5	-6.8
260	840.6	846.2	839.7	840.2	-0.9	-6.0
280	843.4	847.0	841.9	842.1	-1.5	-4.9
300	845.0	847.1	843.0	843.8	-2.0	-3.3
320	846.3	848.0	844.6	845.6	-1.7	-2.4
340	847.4	849.4	846.0	847.2	-1.4	-2.2
360	848.9	850.7	848.6	849.0	-0.3	-1.7
380	850.9	852.2	850.5	852.4	-0.4	0.2
400	852.4	852.4	851.8	851.9	-0.6	-0.5
420	853.0	NA	851.8	NA	-1.2	NA
437	853.2	NA	853.1	NA	-0.1	NA

4.4 Qualitative Evaluation of Fish Passage Conditions

4.4.1 Fish Passage Hydraulics Design Parameters

It has been generally accepted during planning and design of the project that the primary target species and lifestages for which upstream passage should be feasible in the regraded reach includes adult Chinook Salmon (*Oncorhynchus tschawytscha*), Steelhead (*O. mykiss*), and Bull Trout (*Salvelinus confluentus*) (HDR et al., 2019). A primary design goal was that the resulting upstream passage conditions should at minimum resemble what was present historically in the project reach, and elsewhere farther downstream and upstream, or better, if possible. While this meant that specific fish passage design criteria such as those used in designing fishways were not required to be met during project design, such criteria are appropriate for assessing fish passage conditions in general. If the monitoring data indicate that those criteria are generally met over a range of flows, then it may be concluded that the reach is passable.

Salmon and trout can negotiate difficult passage restrictions by swimming or leaping. The feasibility of upstream fish passage without requiring leaping will be controlled by the availability of passage lanes along the length of the reach with sufficient water depth, suitable velocities over a given distance, and swimming ability. The feasibility of leaping successfully depends on depth of a leaping pool, height of the barrier, depth of receiving water at the top of the head drop, condition of fish, and other factors that are not measured as part of this monitoring program. Thus, this assessment focuses on characterizing swimming restrictions.

Ideally, passage depths for swimming should be deeper than the body depth of the fish, plus a buffer to avoid injury to the belly. For Steelhead and Chinook Salmon, values of 0.7 ft and 1.0 ft respectively are commonly accepted as a minimum criterion for safe natural fish passage depths (although these species are known to move upstream successfully in shallower water; R2 Resource Consultants, 2007). Similar criteria for Bull trout are less well defined, but this species is known to tend to use deeper water areas for holding and are capable of ascending waters where Chinook Salmon can not; so the 1.0 ft depth criterion can also be applied to this species as a screening level criterion.

There are two ways to evaluate upstream passage feasibility in terms of velocity: comparing predicted velocities with (i) fish passage design criteria, and (ii) with reported sustained swimming capabilities. The first comparison is generally indicative of cases where upstream passage is well within the ability of fish without them becoming substantially stressed. The second represents the upper limit of ability to swim at the given velocity for several minutes (Bell, 1991). Fish may become stressed when they encounter velocities near the upper limit, but if the velocity in question is closer to the criterion than the sustained swimming limit, then it may be argued that the reach is passable.

In general, Washington Department of Fish and Wildlife (WDFW) fish passage design criteria range from acceptable velocities of 6 ft/s, 5 ft/s, 4 ft/s, and 3 ft/s for adult Chinook Salmon and Steelhead for culverts with lengths shorter than 60 ft, between 60ft and 100 ft, between 100 ft and 200 ft, and longer than 200 ft, respectively (Barnard et al., 2013). The approximate distance between the downstream sides of boulder jams proposed within the recontoured reach, where resting opportunities are most likely, is specified at about 96 ft in the 60% design plans. Thus the 5 ft/s criterion may be a reasonable test for ease of passage. The higher sustained swimming speed limits for Chinook Salmon and Steelhead are around 11 ft/s and 14 ft/s, respectively (Bell, 1991). These values may represent the high range of successful passage velocities for the most difficult swimming conditions encountered.

4.4.2 As Built Conditions Hydraulics

The as-built hydraulic model was used to explore hydraulic conditions related to fish passage for the as-built channel condition and identify key areas where passage difficulty might be expected. As explained in preceding sections, the bathymetry has changed (through early December 2020), notably along the right bank flow path, but few changes occurred along the dominant left bank flow path. The model, therefore, is inferred to provide a good indication of passage conditions along the left bank flow path. By evaluating the spatial distribution of suitable depths and velocities predicted by the model, it is possible to identify pathways of longitudinal connectivity and specific locations where passage may be difficult in the as-built condition. Interpretation of current (as of early December 2020) passage conditions along the right bank flow path requires more qualitative interpretation because hydraulics in this area have changed appreciably.

Figure 4.2 through Figure 4.5 depict depth and velocity distributions predicted by the model for the approximate as-built terrain in the river regrade reach, over a similar range of flows assessed during design (DeVries, 2018). The velocities are depth averaged and are generally representative of velocities encountered by the target species adults in shallower water and may be higher than encountered by fish swimming along the bottom in deeper water.

Overall, there appears to be hydraulic longitudinal connectivity along both sides of the design channel with periodic refugia of lower velocity along the viable length at all flows modeled (Figure 4.2 through Figure 4.5). Based on depth, passage opportunities presently appear to be available over a wider section of flow for Steelhead than Chinook, and Chinook Salmon upstream passage may be more limited by depth over the 300-600 cfs flow range than at higher flows. There are two steeper locations that presently represent constrained, but passable sections along the Main Channel, and along the actively regrading secondary right bank flow pathways to the North. Both locations will continue to be monitored through the Spring and evaluated in greater detail after their adjustments appear to have completed for the season.

The avulsion of the right bank channel to form the right bank flow pathways (compare Photo 2.1 and Photo 2.2 and see Figure 3.1) has shifted most of the flow in that pathway away from the large shallow and high-velocity step into a much lower slope channel not reflected in the as-built conditions hydraulic model. Although hydraulic conditions in this channel are now precisely known, we interpret—based on the wider channel cross section, lower slope, and higher bed roughness (due to a channel boundary change from rock to boulder)—that hydraulic conditions along the new avulsion pathway of the right bank flowpath are more suitable for fish passage than in the design condition.

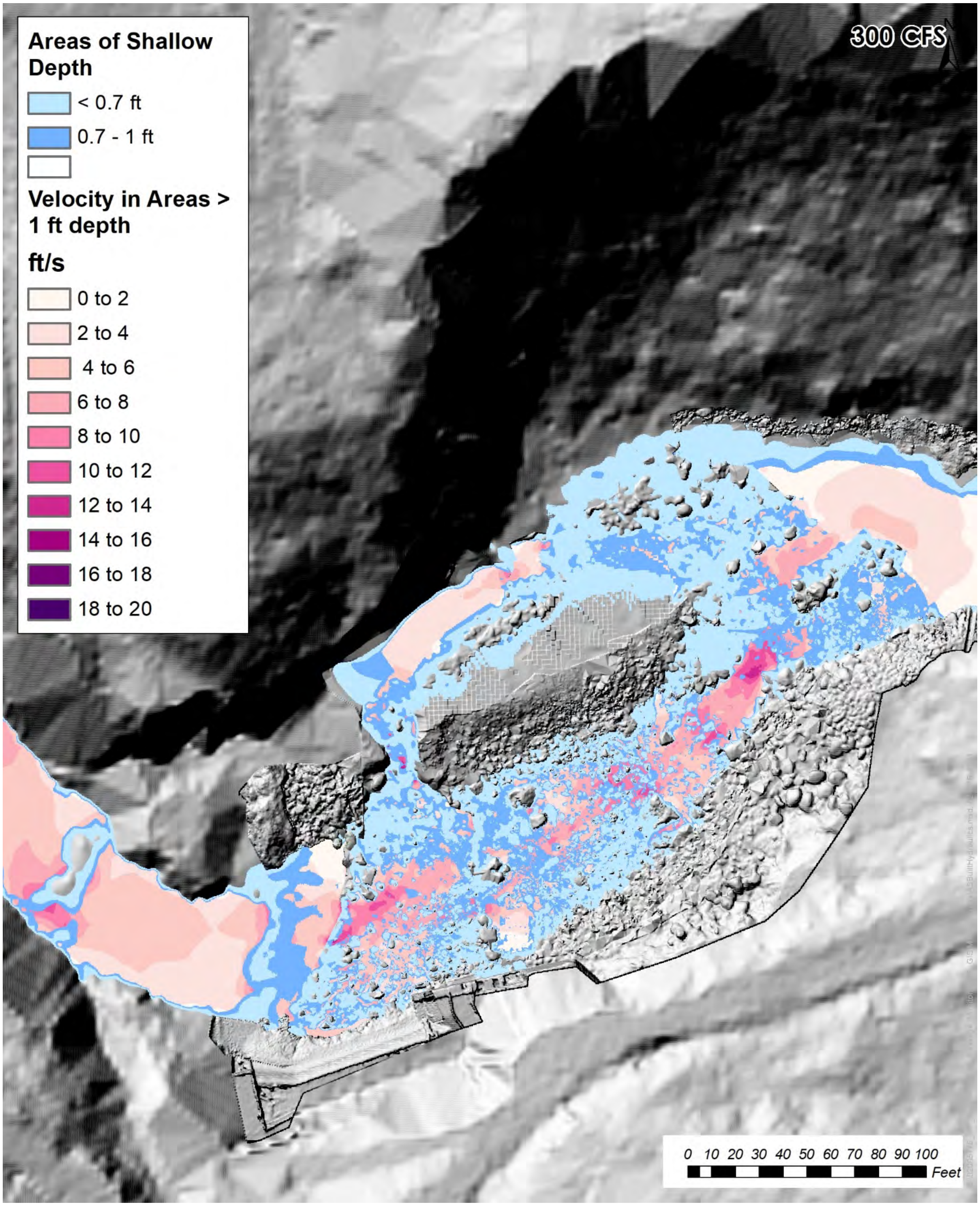

Figure 4.2 As-built hydraulic model results showing areas of shallow inundation and velocity in areas of deeper inundation for a discharge of 300 cfs.

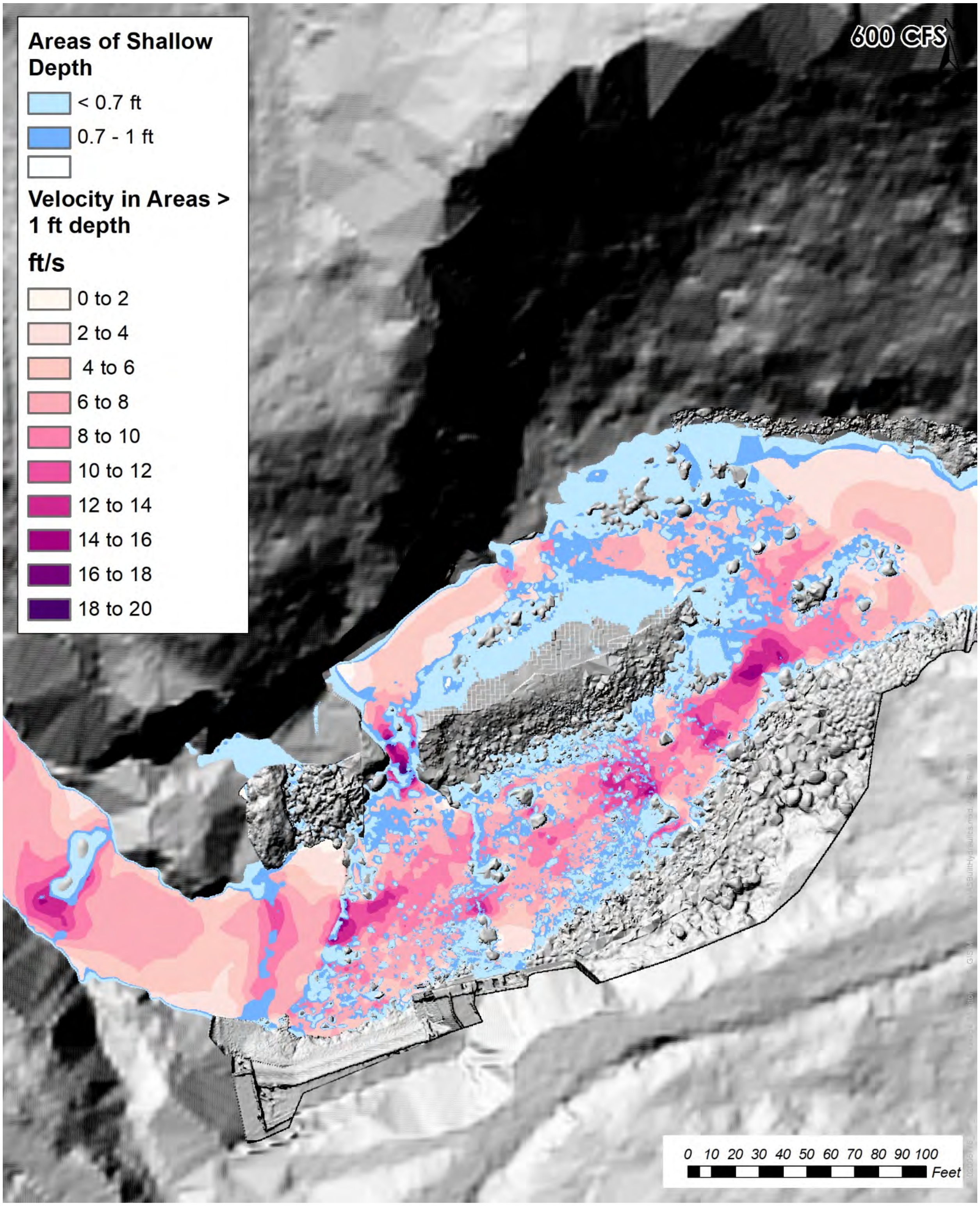

Figure 4.3 As-built hydraulic model results showing areas of shallow inundation and velocity in areas of deeper inundation for a discharge of 600 cfs.

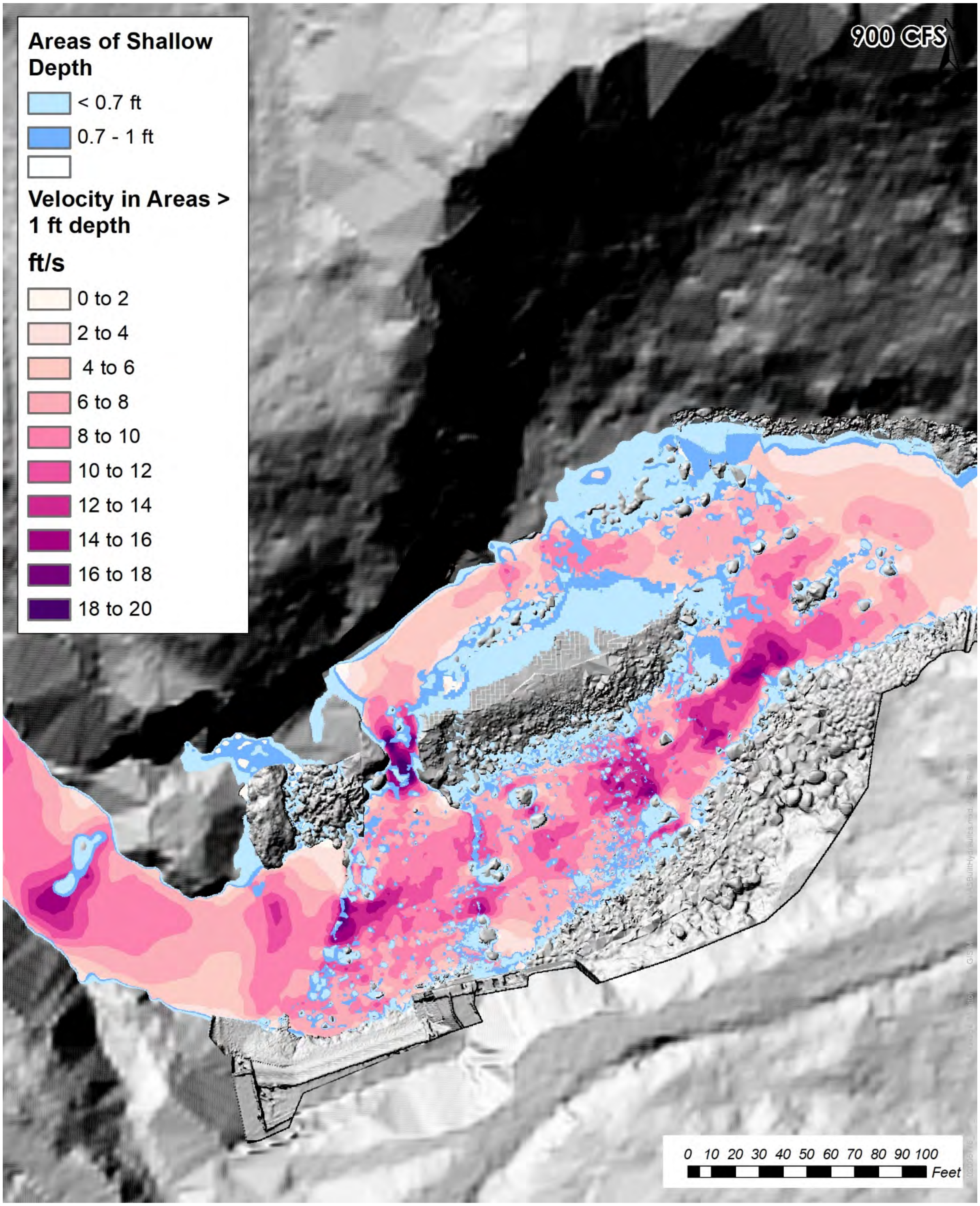

Figure 4.4 As-built hydraulic model results showing areas of shallow inundation and velocity in areas of deeper inundation for a discharge of 900 cfs.

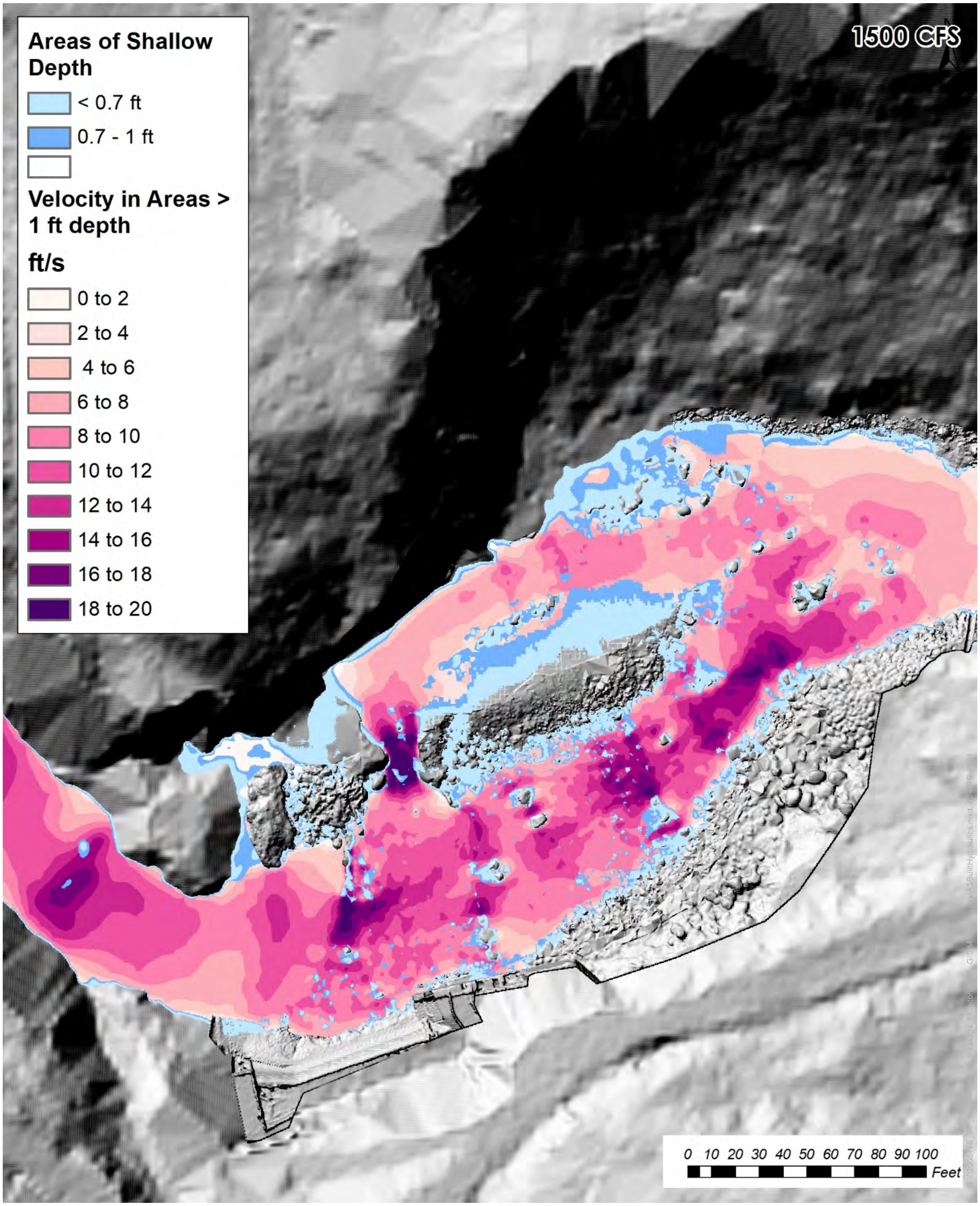

Figure 4.5 As-built hydraulic model results showing areas of shallow inundation and velocity in areas of deeper inundation for a discharge of 1500 cfs.

5 SUMMARY & RECCOMENDATIONS

Several high flows events in autumn 2020 occurred during as-built data collection and resulted in localized sediment mobilization and geomorphic adjustment. Channel longitudinal profiles and water surface changes were identified to exceed thresholds for continuing monitoring in some locations, but do not exceed thresholds that would trigger adaptive management activity (Table 5.1). NHC recommends that the monitoring plan be continued without modification. Any later geomorphic changes that may occur between December 2020 and late summer/early Autumn 2021 will be described in the full first-year monitoring report.

Table 5.1 Current performance of project relative to channel monitoring metrics.

Monitoring Technique	Monitoring Metric	Thresholds	Decision Pathway	Status as of December 2020
Photo/Visual Survey	N/A Provides indication of channel changes to inform field work.	N/A	N/A	No evidence of impassable hydraulic conditions or adverse geomorphic adjustment observed.
Digital Elevation Model Development and Analysis	N/A Provides indication of channel changes to inform field work.	N/A	N/A	Significant erosion along the right bank flow pathway opens additional fish passage routes but could eventually impact hydraulics along the dominant left bank flow path.
Channel Longitudinal Profile derived from Digital Elevation Model	Average water surface elevation slope along low flow centerline.	1. >8% average slope over the entire monitoring site length. 2. >12% slope occurring over a 200 ft length within the monitoring site.	1a. <7% Average (Pass) 1b. >7% (Monitor) 2a. >7% in any 200 ft segment (Monitor) 2b. >10% in any 200 ft segment (Evaluate Adaptive Management Action) .	1a: Pass 2a: Localized 200 ft segments between 7 and 8% slope along main left bank flowpath and between 7 and 10% slope along right bank flow paths.
Channel Cross Sections derived from Digital Elevation Model	Channel water surface elevation at minimum instream flow	> 3 ft water surface elevation decreases at any channel cross section	1. <1 ft decrease (Pass) 2. >1 ft decrease (Monitor/Investigate) 3. >3 ft decrease (Evaluate Adaptive Management Action).	Many individual cross sections exceed 1 ft of apparent decrease in water surface elevation. No sections along the main flow path exceed 3 ft lowering of the water surface.

6 REFERENCES

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MF NOOKSACK CHANNEL MONITORING & ADAPTIVE MANAGEMENTAPPENDIX A

COMPLETE AS BUILT PHOTO DOCUMENTATION AND CROSS SECTION OBSERVATIONS

MF NOOKSACK CHANNEL MONITORING & ADAPTIVE MANAGEMENTAPPENDIX B

AS-BUILT CONDITIONS HYDRAULIC MODEL DEVELOPMENT AND CALIBRATION