Photo source: NHC (5 Dec, 2024)

MF Nooksack Channel Monitoring & Adaptive Management
Year 4 Monitoring

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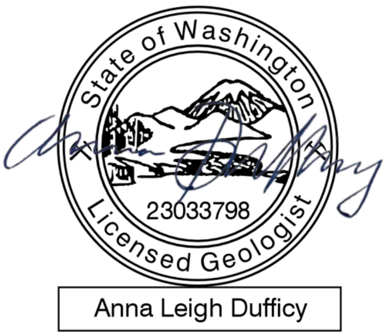

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- Steve Day — Project Engineer, City of Bellingham
- April McEwen — River Restoration Project Manager, American Rivers

The following NHC personnel participated in the study:

- Annie Dufficy — Project Manager and Project Geomorphologist
- Andrew Nelson — Senior Review
- Richard Anderson — Project Field & GIS Support

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

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

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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 was intended to provide passage and restore fish 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). 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 spring 2025, presents results of the year 4 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)

Field tasks completed in the fourth-year monitoring effort and preparation of this report included a survey effort completed with a Terrestrial LiDAR Scanner (TLS) and Unmanned Aerial Vehicle (UAV) and field photo documentation during fall. A new topographic surface was compiled from the survey data to document changes from the as-built condition composite surface of fall 2020.

The focus of this report is to document channel adjustments observed and measured since monitoring began, with particular focus on recent changes since the last topographic survey in 2022. Figure 1.1 illustrates the timing various observations relative to flood pulses and their associated stream power that occurred through the entire monitoring period. Photographic and surveyed documentation of the reach revealed that the channel bed remained mostly stable between 2022 and 2024. The previous year-three report presented a qualitative analysis of the geomorphic changes to the reach between 2022 and 2023, in the second year following the 2021 floods (NHC, 2024). The addition of topographic comparisons in this year-four report was needed to confirm assumptions of stability and provide quantitative metrics for fish passage. This report addresses the previously outlined concerns from prior monitoring reports using updated topographic data, highlights the continued success of the restored main channel, and provides discussion on fish passage.

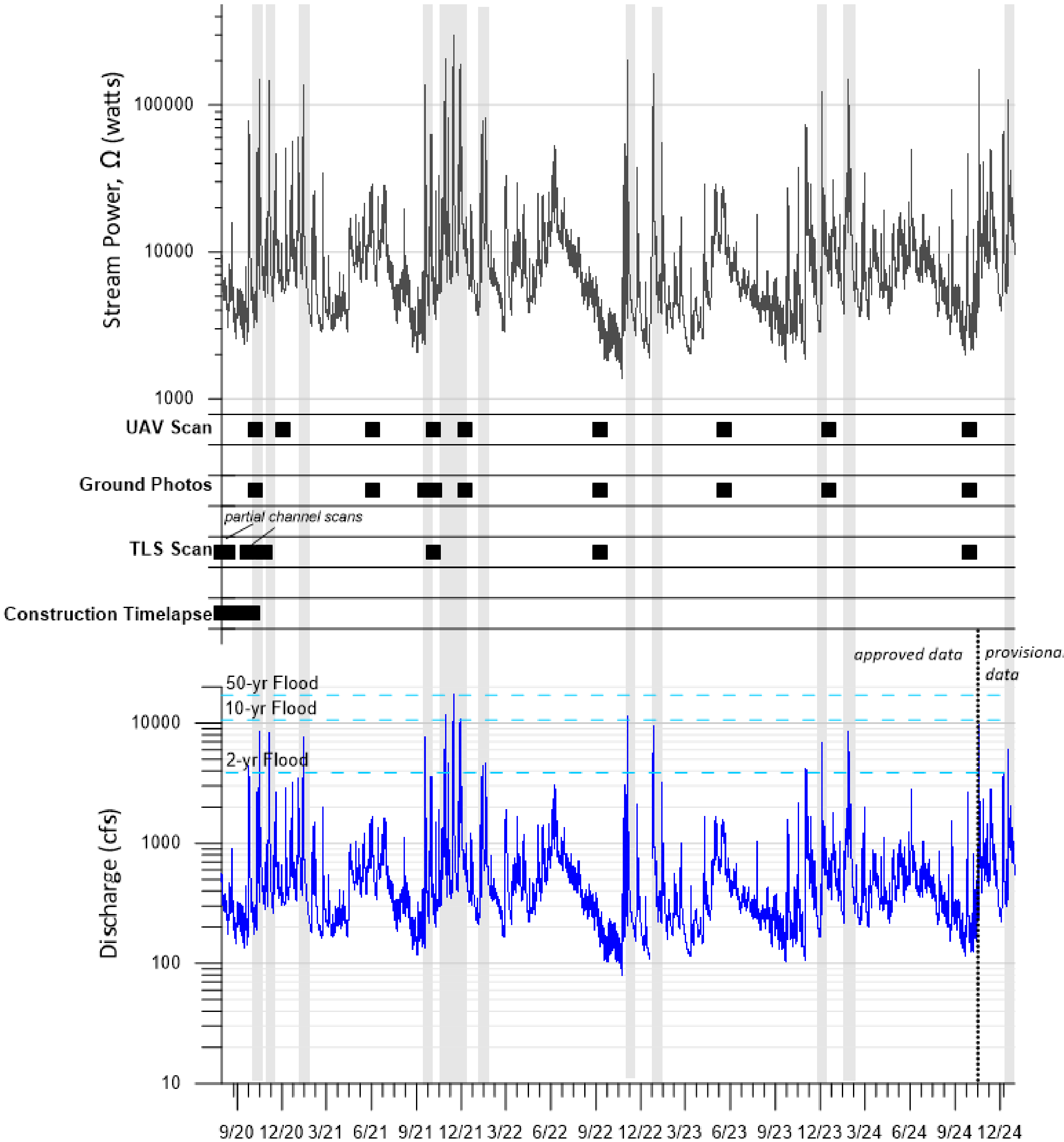

Figure 1.1 Timeline of stream flow, stream power, and observation efforts from August 31, 2019 to December, 2024

This four-year post-construction monitoring report is structured in the same way as previous monitoring reports, with an overall site-scale narrative describing the layout of the monitoring observations, key geomorphic and fish passage observations during the site visits, as well as a quantitative summary of observed changes since monitoring began. It is supported by an appendix of detailed exhibits showing conditions and changes in conditions at each monitoring site visit.

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.

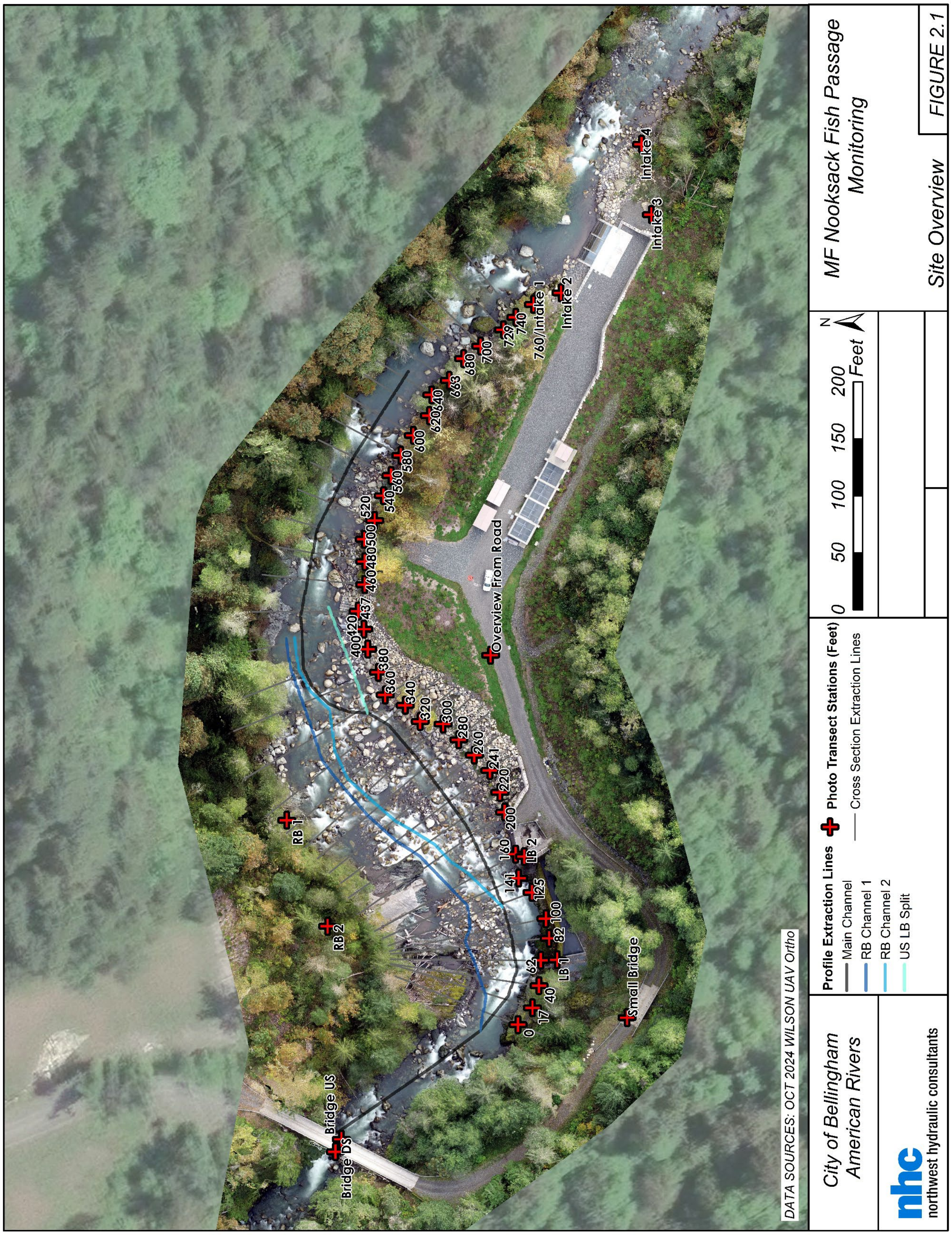

Figure 2.1 Map illustrating monitoring site layout

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, as well as documentation of notable floods (greater than 10-yr event) that occurred during the monitoring period.

Table 2.1 Timing of site visits and observations collected.

Date	Observation Location or Notable Event	Equipment	Approximate Discharge/Flow Condition
Autumn 2020	Whole site	Methods described in NHC (2021)	Observations from 225-650 cfs, high flows up to 8,500 cfs
Winter-Spring 20/21	Moderate flows	NA	4 flow pulses over 2,000 cfs, max flow 7,800 cfs
3 June 2021	Spring high flow observations	Ground-based Photo Documentation, DJI Mavic 2 Pro UAV/UAS System equipped with Hasselblad 20MP Camera	1,200 cfs
17 Sept 2021	Year 1 Photo Documentation	Ground-based Photo Documentation	140-160 cfs
6 Oct 2021	Station 50 to Station 480	Trimble TX-5 Terrestrial 3D Laser Scanner & DJI/Matrice 200 UAV/UAS System equipped with ZenMuse 24MP Camera	275 cfs
8 Oct 2021	Photo documentation points defined in Figure 2.1.	Theodolite App running on iPhone 6s.	225 cfs
15 Nov 2021	> 25 yr RI Flood	NA	17,200 cfs
28 Nov 2021	> 10 yr RI Flood	NA	12,700 cfs
8 Dec 2021	Post-flood photo documentation	Ground-based Photo Documentation, DJI Mavic 2 Pro UAV/UAS System equipped with Hasselblad 20MP Camera	475 cfs
8 Sep 2022	Year 2 Low flow photo documentation	Ground-based Photo Documentation, DJI Mavic 2 Pro UAV/UAS System equipped with Hasselblad 20MP Camera	152 cfs

Date	Observation Location or Notable Event	Equipment	Approximate Discharge/Flow Condition
12 Sep 2022	Year 2 low flow survey	Trimble TX-5 Terrestrial 3D Laser Scanner & DJI/Matrice 200 UAV/UAS System equipped with ZenMuse 24MP Camera	205 cfs
23 May 2023	Year 3 high flow photo documentation	Ground-based Photo Documentation, DJI Mavic 2 Pro UAV/UAS System equipped with Hasselblad 20MP Camera	1,040 cfs
18 Dec 2023	Year 3 low flow photo documentation	Ground-based Photo Documentation, DJI Mavic 2 Pro UAV/UAS System equipped with Hasselblad 20MP Camera	410 cfs
1 Oct 2024	Year 4 low flow survey	Trimble TX-5 Terrestrial 3D Laser Scanner & DJI/Matrice 200 UAV/UAS System equipped with ZenMuse 24MP Camera	160 cfs
5 Dec 2024	Year 4 photo documentation	Ground-based Photo Documentation, DJI Mavic 2 Pro UAV/UAS System equipped with Hasselblad 20MP Camera	300 cfs

3 AS-BUILT THROUGH 2024

3.1 Summary of Past Geomorphic Change Through 2024

Prior to the November 2021 floods, only minor channel adjustments were observed in the observation reach. Most of these changes occurred in the right bank pathways (RB 1 and RB 2), where headcutting was first initiated around Transect 200 but had not propagated upstream to the boulders at the fish bypass pool tailout in October 2021. The restored main channel remained largely unchanged during this time in large part due to the stability of the designed boulder clusters. Significant changes occurred to the channel bed during the November 2021 floods, which exceeded the threshold energy expected to mobilize individual boulders outside of jammed units. These changes are described in detail in NHC (2023, 2024). Boulder transport had notably altered the right bank pathways, midchannel bar and the facility fish bypass outlet pool upstream of the main channel and right bank pathway flow split. In particular, as anticipated in NHC (2021), headcutting continued along the right bank flow pathway, resulting in mobilization of boulders forming the hydraulic control for the fish bypass pool tailout and overall channel lowering. Relatively minor changes had occurred in the restored left bank pathway in comparison, suggesting that the boulder jams effectively held the designed channel in place during the flood. As was described in NHC (2023), channel lowering of this main restored channel did in fact take place, especially upstream near the fish bypass outlet, but most of the clusters remained stable or settled to a more stable position.

Quantitative metrics derived from the Year 4 (October 1, 2024) TLS survey data show that minimal change has occurred in the structure of the channel bed, which can be attributed to the stability of the jamming features formed in the November 2021 floods (Figure 3.1, Figure 3.2). Prior to the November 2021 event, boulders outside of the restored flow path were not organized in stable morphologies such as boulder clusters or jamming arches, which led to the widespread mobilization. Boulder transport of some of the largest grains (estimated D_{84} and above) in the November flood have restructured the bed into a more stable jammed state characteristic of an organized step-pool morphology, increasing the overall stability of the bed compared to the less-organized state present along the right bank flow paths before the November 2021 flood (Church and Zimmermann, 2007; Zimmermann et al., 2010). Minor changes since 2022 can be attributed to small boulder transport from boulders that were not incorporated in the more stable channel-spanning jams and boulder clusters. Errant boulder transport is expected to occur in the treads between step lines until they are stabilized in future jamming configurations.

Readjustment of the main channel has increased the complexity of the reach, increasing the total number of pools and flow pathways. Therefore, the designed jams continue to not only maintain passable slopes, but add stable roughness along the perimeter of the left flow pathway from which new step pool lines can form over time. Additionally, reworking of the previously exposed mid-channel bar now connects the right and main channels at a range of flows, which increases the number of potential fish migration routes. Section 4 discusses the ongoing adjustments of the main channel, as well as the minor changes in the primary fish pathways outlined in NHC (2024).

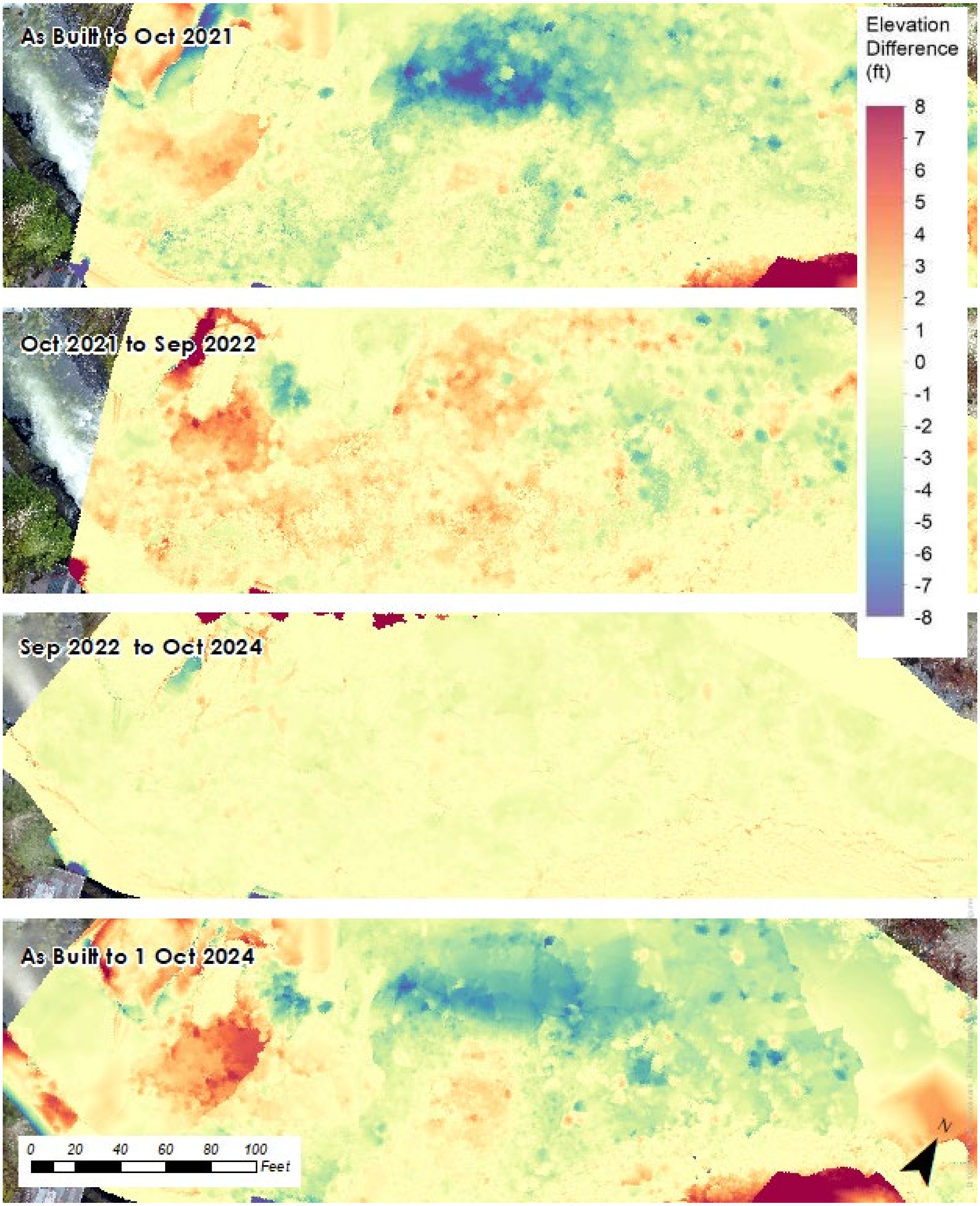

Figure 3.1 DEM surface comparisons showing differences between the design surface and as-built surface (top) and between the as-built surface and subsequent topographic surfaces. Red colors indicate aggradation and blue colors degradation.

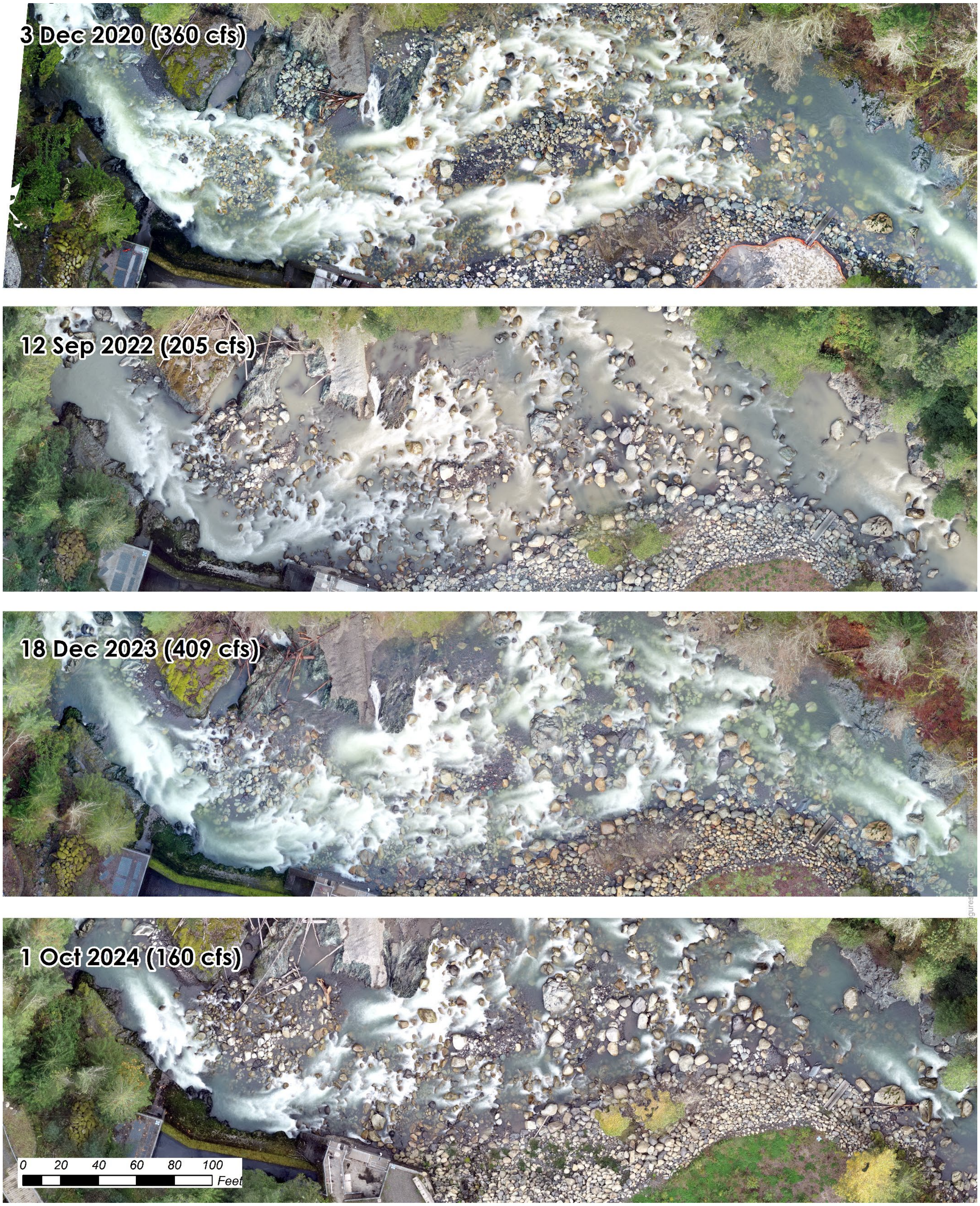

Figure 3.2 Orthomosaic comparisons showing observed channel conditions during monitoring site visits between December 2020 to October 2024.

The relative stability and locations of the designed boulder jams did not change between 2023 and 2024 based on aerial and in-field observations. As discussed in NHC (2023, 2024), the November 2021 floods provided an early opportunity to test the stability and adaptability of the designed channel during a large magnitude event (approaching 50-yr recurrence). Figure 3.3 displays boulder cluster changes within the flow split between station 140 and the fishway at 437 ft. As described in NHC (2023), only two of the boulder clusters completely destabilized from their jammed state during the floods, Jam 5 and Bonus Cluster 2. These clusters (outlined in red in Figure 3.3) are located at the upstream extent of the design channel, suggesting that boulder cluster instability increases upstream with proximity to the pool outlet, between stations 320 and 437. Depth to bedrock increases in the downstream direction, highlighting the importance of downstream buried stabilizing or bracing boulders that could not be constructed in jams over shallow bedrock at the upstream clusters. It should be noted that since initial mobilization in 2021, most of the mobilized boulders in Jam 5 have reorganized into a new stable jam.

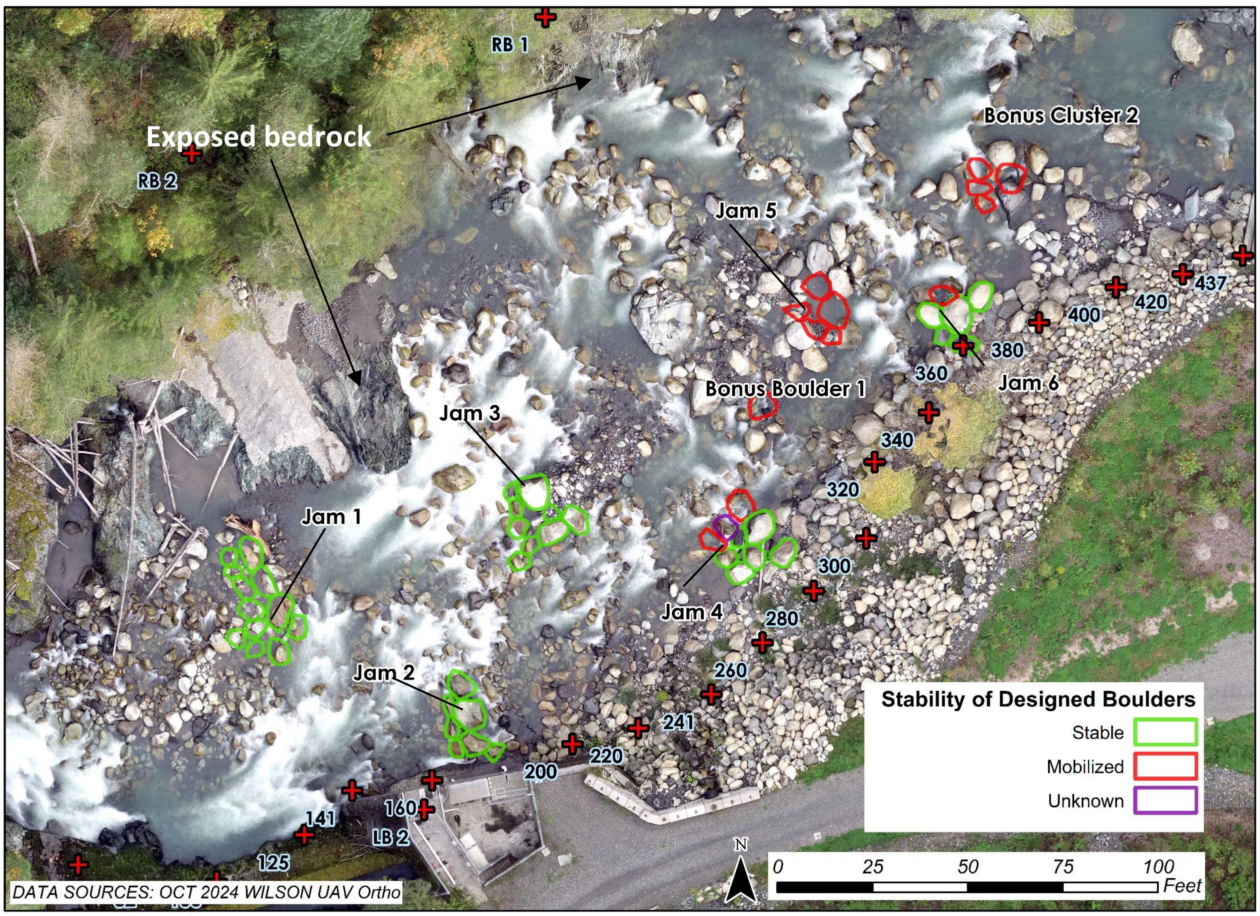

Figure 3.3 October 2024 (160 cfs) orthomosaic documenting relative instability in the restored channel, with engineered boulder cluster jams labeled. Areas of exposed bedrock on the channel bed are also labeled. (Photo: Wilson Engineering)

3.2 Low Flow Fish Passage Conditions Observations

Detailed low flow observations took place in December 2024 after a relatively calm fall (no notable runoff events, Figure 1.1). Observations were conducted at 300 cfs, which is in the lower range of fish passable flows analyzed for the design (R2, 2007). A second rapid site assessment was conducted in February 2025 at 350 cfs, as described in Section 4.5. There were no major concerns regarding fish passage through the observational pathways. The channel bed structure has remained largely stable and unchanged since the December 2023 observations. The widespread regrade and channel lowering through the fish bypass outlet pool was still apparent during low flows, but does not appear to have downcut any further (Figure 3.4), due to the prolonged stability of the boulder line that formed at the downstream end of the bypass pool in November 2021. In 2023 and 2024, the slide outlet remained perched above the water surface during both site visits (300 to 410 cfs), which is within the range of operable flows for the bypass. The step upstream of the fish bypass return pool has not increased in prominence since September 2022, and similar to steps present along the reach upstream, is not interpreted to adversely affect fish passage, as discussed in Section 4. However, more abrasion of the concrete slide has occurred since 2023, exposing additional rebar.

As mentioned in Section 3.2 and NHC (2003, 2024), the reorganization of small to medium-sized boulders across the channel has resulted in the diversification and unification of flow pathways in the previously separated main channel and right flow paths, which remain connected at low flows of at least 300 cfs (Figure 4.2). The simultaneous regrade of both main channel and right channels has prevented the main channel from dewatering at low flows. Therefore, the engineered boulder clusters have worked as designed by adjusting with the lowering channel, maintaining passable slopes in the main channel, and creating stable roughness from which small step arches can build and form new jamming features and pools. The abundance of available pools provides ample resting areas for migrating fish. Boulders near the top of the main channel near the left bank flow split continue to adjust in a favorable way that is allowing more water into the main channel, whereas previous observations in NHC (2023) raised the concern of main channel dewatering. The next section (Section 4) uses quantitative metrics to describe the evolution of the fish passage routes in this area through 2024. Flows along the upstream left bank flow split, which continues to feed water into the main channel, will be monitored at future low-flow observation visits to assess its risk for dewatering as this reach further adjusts.

Figure 3.4 UAV oblique photos showing channel evolution at the pool outlet near Transect 400c between October 2020 (top, 225 cfs), December 2023 (middle, 410 cfs), and December 2024 (bottom, 300 cfs).

View looking upstream ***View looking downstream***

Figure 4.5 Repeat UAV imagery showing low-flow channel comparisons between October 2020 (top) and September 2022 (bottom)

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, 6.6% in the October 2020 TLS derived DEM, 6.3% in the October 2021 UAV TLS DEM, and remained at 6.2% in the September 2022 and October 2024 UAV TLS DEM. The reduction in the average slope through the reach following the November 2021 flood has occurred due to accumulation of sediment deposition in the bed downstream of the regrade reach and headcutting at the upstream side of the regrade reach (Figure 3.1). All these values are below the 7% maximum slope threshold defined in the 1a MAMP decision pathway and trending toward a lesser average slope (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 5.1. Overall, the channel slopes have stabilized since 2022, apart from some deviation in RB 2. Along the main channel, the September 2024 slopes are below 8% for most of its length and similar to the 2022 slopes. The right bank flow paths (RB 1 and RB 2) have remained under 9%, with 2022 and 2024 slopes lower than the previous monitoring periods. The upstream left bank split is less than 200 ft long, but the average slope along that split is 5%. There are no major changes to the channel slope from September 2022 to October 2024 apart from the regrade in the right bank flow paths trending in the direction of shallower overall slopes. The 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.

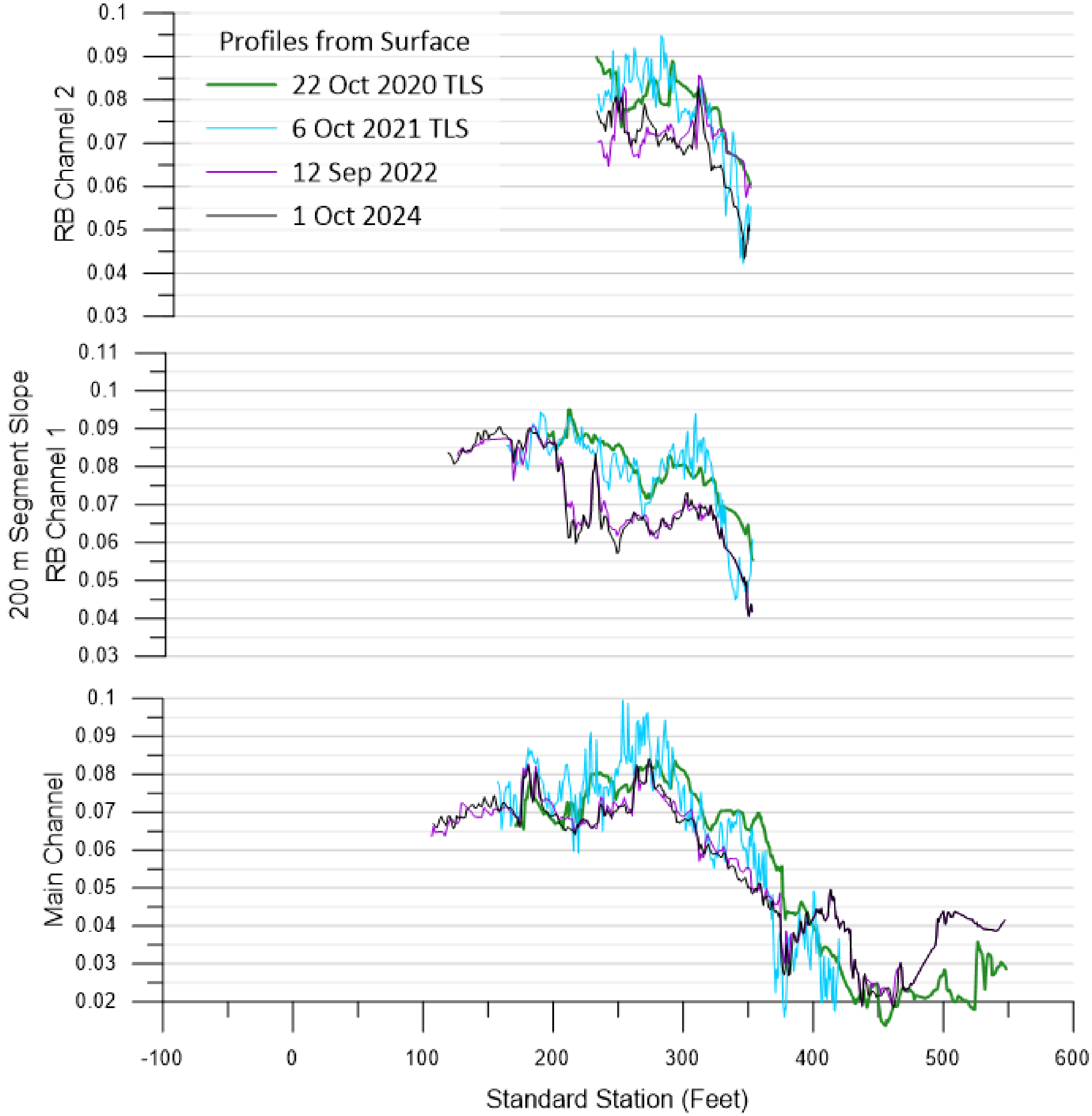

Figure 5.1 Plots showing 200 ft segment average slopes for each monitoring DEM.

The main channel is trending towards shallower slopes between the 280-ft stationing and the 420-ft stationing. This reach of the restored channel coincides with boulder displacement observed in Figure 3.3, and therefore reflects continued channel regrade following bed mobilization and reorganization during the autumn 2021 floods. Just upstream of this reach in the fish bypass return pool the stream is steeper than as-built conditions but still within 2 and 5%. This reach is steeper due to downstream channel bed lowering.

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.

4.3 Longitudinal Profile Metric 3: Step-pool adjustments upstream of the fish bypass return pool

Overall, the moderate degradation of the regrade reach is reducing the average slope and presumably increasing fish passability throughout the project reach (downstream of the fish bypass slide). Given the adjustments, more detailed observations began upstream of the fish bypass to assess potential upstream effects (NHC, 2023). A combination of downstream lowering and sediment transport during the November 2021 floods exposed a boulder step at Transect 480 (step 1), immediately upstream of the fish bypass slide (Figure 5.2). Another step was exposed at Station 580 during the November 2021 flood events (step 2), likely due to a combination of channel bed reorganization and dropping of the low flow water surface elevation (Figure 5.2). Two prominent steps upstream have remained mostly unchanged in morphology at Station 729 (step 3) and Station 760 (step 4) (Figure 4.1, Figure 5.3). To provide a quantitative assessment in addition to the qualitative observations from photos, head drop and average slopes over 20-ft segments were calculated for the reach using both the October 2024 and October 2020 TLS topographic surfaces. At both steps, local slopes approach 15% in the 2024 surface as compared to the 2020 topographic surface, where slopes remain below 10%. These steep steps are separated by long pools and have multiple pathways for fish passage. The average slope of this reach between Station 440 and Station 600 is 7%. The head drops, rounded to the nearest 0.5 ft, were approximately 2.5 ft, 3 ft, 4 ft, and 3 ft across steps 1 through 4, respectively, consistent with the September 2022 values. These drops do not exceed the 5-ft threshold as outlined in the MAMP.

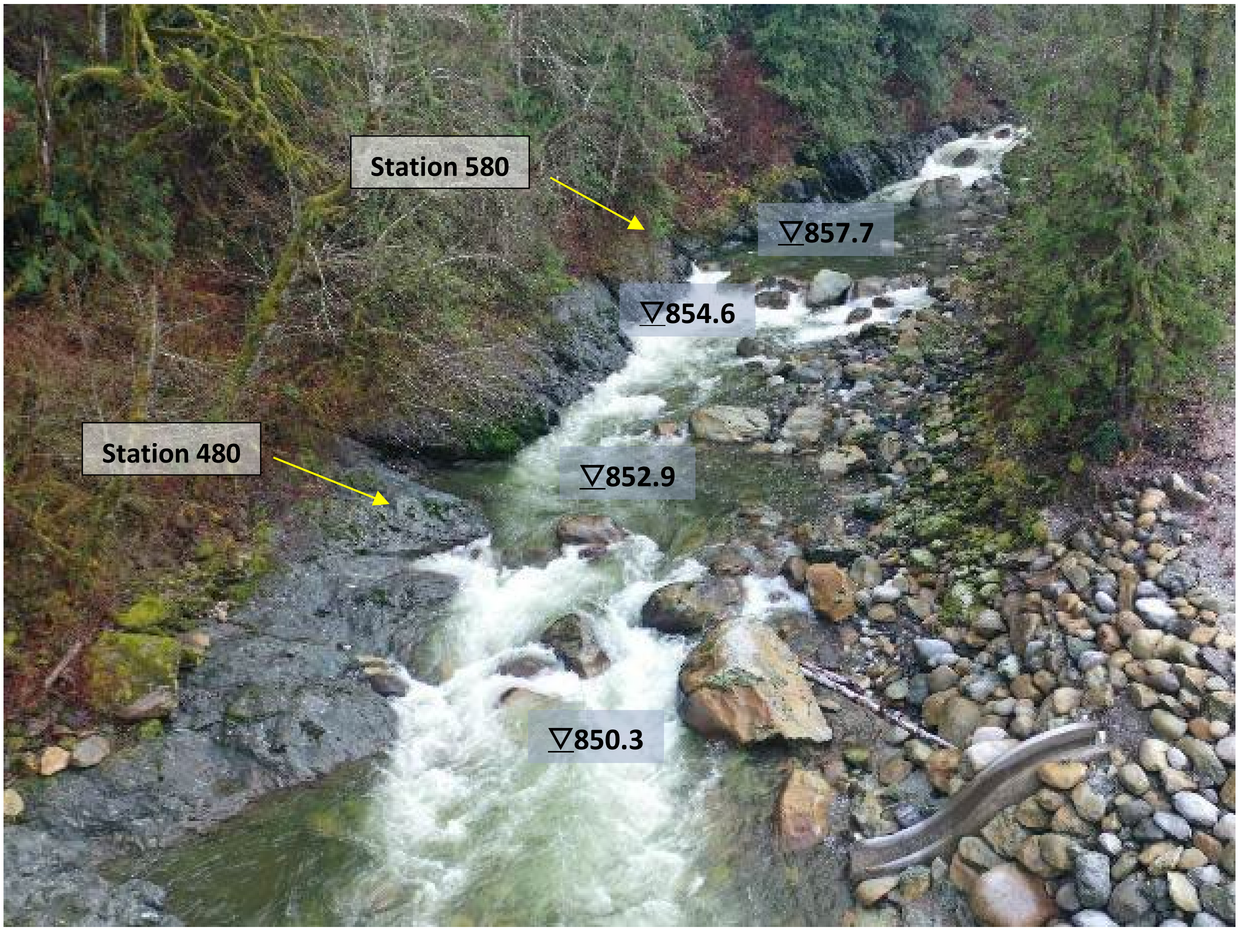

Figure 5.2 View of channel conditions between the fish outlet (Station 437) and Station 580 with water surface elevations extracted from the 2024 TLS scan at prominent channel steps (160 cfs).

Figure 5.3 View of channel conditions between Station 663 (downstream photo extent) to the water intake structure upstream with water surface elevations extracted from 2024 TLS scan at prominent channel steps (160 cfs).

4.4 Cross Section Water Surface Elevation Decrease for September 2022

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. Early on in the monitoring work, significant topographic changes were observed in the secondary right bank flow pathway (RB 1) in comparisons between the as-built DEM and subsequent monitoring (Figure 3.1). While this rapid and ongoing regrade of the secondary right bank flow pathway (RB 1) was expected, the water surface changes exceeded the above outlined thresholds. Therefore, separate values for the water surface were tabulated for the constructed main left bank flow pathway (main channel), 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. The model development and calibration procedure are described in Appendix B of NHC (2021).

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.

Prior to the November 2021 floods, most vertical changes occurred in RB 1, with changes along the dominant main channel flow pathway ranging from +0.55 to -2.0 ft, with nine of twenty-two cross sections exceeding a 1-ft decrease in water surface elevation. Water surface elevations along the regrading secondary right bank flow pathway had decreased by up to 6.8 ft by October 2021 (time of TLS scan), as was anticipated in the design. These results are broadly consistent with the water surface changes observed in the October 2020 TLS scan compared to the as-built model, which is to say that channel adjustments between October 2020 and 2021 were modest.

NHC (2023) documented the WSE comparisons of the post-2021 flood condition. Widespread channel lowering occurred in both the main channel and secondary right bank flow paths. Channel regrade had occurred through the fish bypass outlet pool by 2 to 3 ft, which was confirmed by visual inspection. In the main channel, downcutting greater than 3 ft was most prevalent just downstream of the fish bypass outlet pool (Transect 320 to 400), and was overall more widespread along the right bank. A primary conclusion of NHC (2023) is that with simultaneous lowering in the right pathway and main channel, the main channel has remained lower in elevation than the right flow paths, and is therefore not at immediate risk of dewatering.

Since September 2022, the channel has remained in a mostly stable configuration, as depicted by the minimal change that has occurred between the 2022 and 2024 TLS surveys (average net change of 0.4 ft, Table 5.1). Larger changes in excess of 1 foot occurred in three locations, corresponding to small boulder transport. The primary step lines (largest keystones) have remained in the same configuration, which are controlling the overall water surface elevations of the reach. While small in magnitude, the direction of change is mostly negative (average change of -0.2 ft). The two channels are likely still adjusting but at a much slower rate. The average rate of change between 2022 and 2024 was -0.1 ft per year, as compared to -1.8 ft per year between 2020 (as built) and 2024. While small, a higher magnitude of lowering is occurring downstream of Station 160, which is downstream of the regrade. The average change upstream of Station 160 is less than -0.1 ft per year since 2022, while the average rate of change downstream is -0.25 ft per year. Some amount of change could be from pool scour, as the 2022 TLS survey was conducted after high turbidity events with notable deposits of sand. Likewise, some lowering could have resulted from the change in discharge (170 cfs in 2024 compared to 205 cfs in 2022).

The main channel continues to receive water during low fish passage flows, as confirmed in Section 3. It is assumed that the clusters have readjusted and resettled on the channel bed during the channel lowering, resulting in the preservation of the overall channel grade throughout the reach. This is depicted in Figure 5.1, where despite channel lowering the main channel slopes have stayed relatively consistent. The main channel also remains lower in elevation as both channels adjust. Therefore, there is no imminent risk to the main channel and the overall design is working as planned.

Table 5.1 Comparisons over water surface elevations over time. Modeled water surface for the as-built condition hydraulic model for the corresponding discharge, and interpreted short-term (2022 – 2024) and long-term (as-built – 2024) 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 160 cfs		Observed Water Surface from 2024 (from TLS Surface)		Change from 2022 to 2024		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	MC flow path	RB flow paths
0	827.5	827.5	825.4	825	-0.5	-0.3	-2.1	-2.5
17	827.6	827.6	825.7	825.6	-0.7	-1.5	-1.9	-2
40	827.7	827.8	826.6	825.5	-0.2	-2.1	-1.1	-2.3
62	827.9	828	827.2	827.6	-0.3	-0.7	-0.7	-0.4
82	829.2	829.5	828.2	831.6	-0.3	-0.3	-1	2.1
100	829.8	829.7	829.2	832.8	-0.3	-0.1	-0.6	3.1
125	832.1	829.8	830.2	833.6	-0.4	0.7	-1.9	3.8
141	832.9	833.3	830.7	834	-0.9	-0.2	-2.2	0.7
160	833.8	834.7	832.6	835.2	-0.2	-0.2	-1.2	0.5
200	837.2	835.8	835.7	835.3	-0.3	0.1	-1.5	-0.5
220	838	NA	837.3	837.4	-0.3	0	-0.7	-8.1[1]
241	839.2	NA	838.6	839.8	-0.2	0.3	-0.6	-5.9[1]
260	840.3	NA	839.8	841.9	0.6	0	-0.5	-3.9[1]
280	843.1	NA	841	843.2	-0.2	-0.2	-2.1	-2.7[1]
300	844.7	NA	844.1	843.4	1.8	-0.1	-0.6	-2.9[1]
320	846	NA	843	845.8	0	-0.1	-3	-2.5[1]
340	846.9	849.6	843.5	846	-0.4	-0.2	-3.4	-3.6
360	849.1	850.4	845.5	847.7	-0.4	0.6	-3.6	-2.7
380	851.8	851.9	849.2	849	0	0.1	-2.6	-2.9
400	852.4	852.4	848.9	849	-0.4	-0.1	-3.5	-3.4
420	852.6	852.5	849.6	849.6	-0.2	-0.2	-3	-2.9
437	852.6	NA	850.2	NA	-0.2	NA	-2.4	NA

[1]*Modeled WSE not available for these transect locations. The 2022 TLS surface to As-built WSE comparisons from NHC (2023 were modified by adding the calculated TLS surface comparisons from 2022 to 2024 (columns 6 and 7 in table).*

4.5 Qualitative Evaluation of Fish Passage Conditions

As referenced in earlier reporting (NHC, 2021), typical fish passage design criteria are not readily applicable to natural or restored reaches - similar to the project site - where natural volitional passage is provided by complex in situ channel hydraulics that are controlled by natural geomorphic processes. The wide planform, multiple passage opportunities, and potentially variable fish movement behaviours make it difficult to quantitatively characterize passage conditions.

The site was visited to further evaluate fish passage conditions in April 2024 and February 2025 when flow at the USGS gage was around 250 cfs and 350 cfs, respectively. NHC (2024) outlines how there were no hydraulics within the channel that appeared to preclude volitional upstream passage despite widespread regrade approaching thresholds in the MAMP triggering consideration of adaptive management actions. This was confirmed during the 2025 site assessment during more optimal fish passage flows, which is believed to occur between 300 and 500 cfs. The same general routes appeared passable as depicted in the Year 2 and Year 3 reports (Figure 5.4). Connectivity for adult passage appeared to be highly likely, and different potential swimmable pathways appeared possible for transit of the regraded reach at different flow levels. None of the local head drops were more than about 2 ft in height, with sufficiently deep water at base that steelhead, Chinook, & bull trout could partially swim up the nappe as well. Lowering of the low flow water surface at the upstream end of the regraded reach led to development of larger head drops at existing steps upstream at around stations 480 and 580, but the increased head drops and velocities at the steps were lower than in the unaffected reach between there and the intake, and multiple routes appear passable via a combination of swimming and small leaps (Figure 5.5).

During optimal fish passage flows (300 to 500 cfs), the right bank pathways (RB 1) become fish passable. Prior observations from NHC (2023) made during low flows indicated that turbulent flows along the downstream section of RB 1 were unlikely to be negotiated by upstream migrants as compared to the main channel. During the 2025 site assessment at 350 cfs, the right bank pathways became viable, opening up alternative routes for passage (Figure 5.4). Previously, degradation along the upper portion of both right and left channels had improved fish passage upstream by locally lowering slopes and increasing pool frequency. As noted as a potential outcome in previous reports, the right bank flow path has degraded further and has exposed more of the underlying bedrock. However, it appears from the change detection provided throughout Section 4 that the regrading rate is slowing down, where the right side may be approaching a more stable grade in the future.

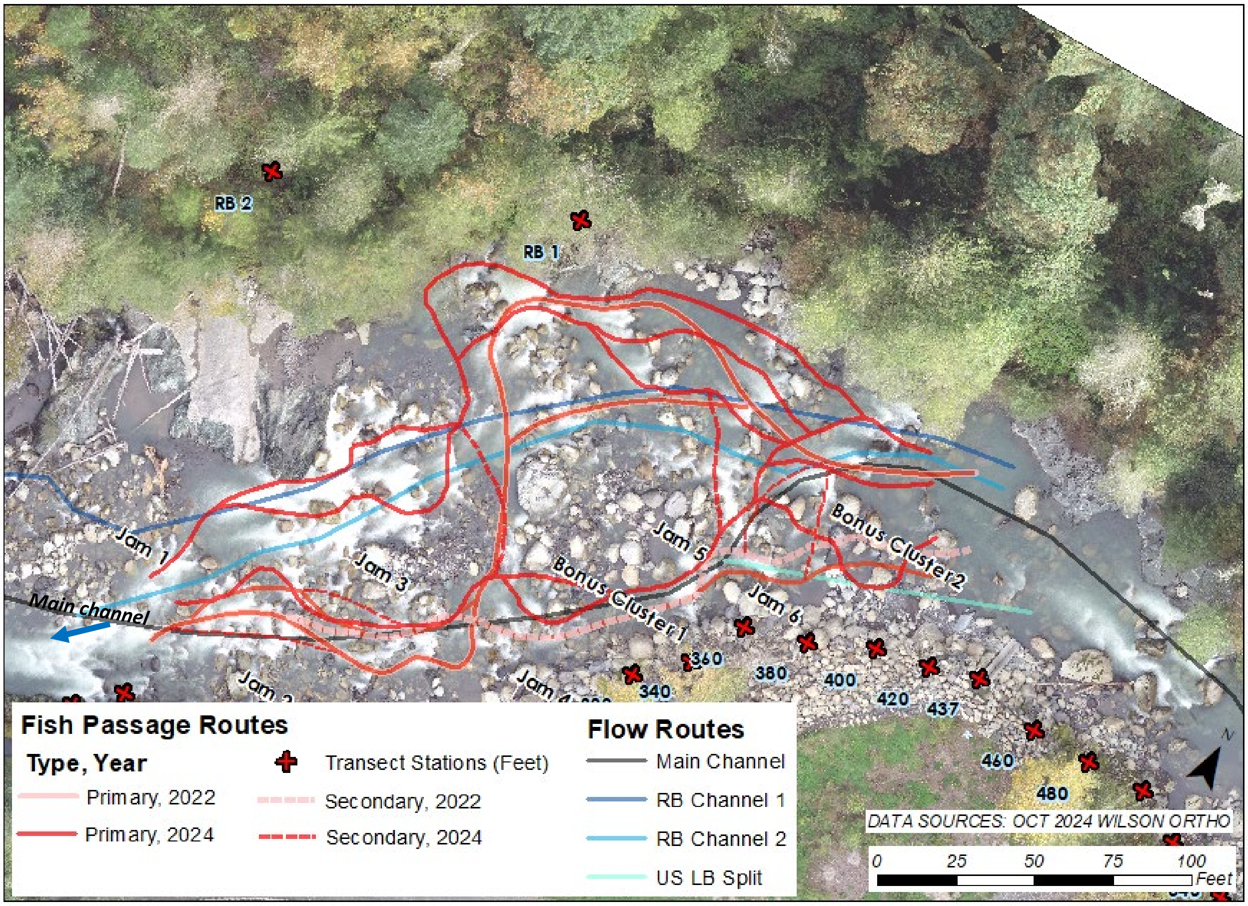

Figure 5.4 Potential upstream passage routes overlaid on October 2024 orthomosaic and relevant monitoring pathways (main channel, RB 1 and RB 2). Solid line = expected primary pathway during lower to mid-flow range; dashed lines = additional routes during mid- and higher flow range. (Photo: Wilson Engineering, 2024)

Figure 5.5 Likely passage routes at the observed flow at steps upstream of the fish outlet slide (December 2024, 300 cfs). Solid lines = expected primary pathway during lower to mid-flow range; dashed lines = additional routes during mid- and higher flow range.

5 SUMMARY & RECOMMENDATIONS

This report documents the results of the geomorphic and topographic surveys for the Year 4 monitoring period of 2024. The primary finding of this assessment is that no meaningful channel bed changes were observed in 2024 compared to the visual observations of 2023 and topographic comparisons of September 2022. While the threshold for channel lowering was exceeded in both observational pathways, channel adjustments do not currently pose risk for fish passage (Table 6.1). Channel adjustments in the form of channel lowering are occurring in both right and main channel flow paths, although the rate of lowering has slowed substantially since 2022. The readjusted bed maintains a slope of less than 8% and is therefore less steep than pre-flood conditions. Additionally, arrangement of the post-flood channel bed has created more potential pathways for fish with more resting pools. The regrade design is therefore working as intended.

Table 6.1 Current performance of project relative to channel monitoring metrics.

Monitoring Technique	Monitoring Metric	Thresholds	Decision Pathway	Status as of December 2024
Photo/Visual Survey	N/A Provides indication of channel changes to inform field work.	N/A	N/A	No evidence of impassable hydraulic conditions. Hydraulics in the fish bypass return pool have changed (roughness has increased and depth has decreased) but has remained consistent since 2022.
Digital Elevation Model Development and Analysis	N/A Provides indication of channel changes to inform field work.	N/A	N/A	The channel bed has remained mostly stable since 2022 apart from large wood. The main channel pathway is currently not at risk of dewatering.
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 flow path and between 7 and 8.5% 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 > 5 ft drop downstream boulder	1. <1 ft decrease (Pass) 2. >1 ft decrease (Monitor/Investigate) 3. >3 ft decrease (Evaluate Adaptive Management Action).	3: Multiple sections along the main flow path exceed 3 ft lowering of the water surface (average of 1.8 ft lowering). Because lowering occurred in main and right flow paths simultaneously, the main channel is currently not at risk of dewatering. Rate of channel bed lowering has slowed since 2022.

As stated in the previous monitoring reports, if this or any subsequent field survey effort identified potential concerns of passage, then NHC would recommend the city consider collecting full ground-based topographic and bathymetric survey of the bed of the wetted channel to combine with the TLS-grade surface representing the subaerially exposed part of the channel and water surface and using this data to assemble an updated hydraulic model to evaluate fish passage flows. Given the lack of observed risk, this action is not recommended at this time. Future monitoring at high and low flows will be necessary to confirm whether fish passage is maintained for the duration of the 10-yr monitoring period, with the option to pursue more detailed data collection and updated modelling if adverse conditions arise. A photo-based monitoring report will be completed in Year 5 after the site visit is completed in 2025.

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MF NOOKSACK CHANNEL MONITORING & ADAPTIVE MANAGEMENT
APPENDIX A
COMPLETE PHOTO DOCUMENTATION AND CROSS SECTION OBSERVATIONS