INSTREAM FLOW MODEL DEVELOPMENT STUDY
INTERIM REPORT

ATTACHMENT G

SUMMARY OF SKAGIT RIVER CHANNEL MIGRATION DESKTOP ANALYSIS MEMORANDUM

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nhc
northwest hydraulic consultants

MEMORANDUM

To: **Project File** Date: March 2022

NHC Ref. No. 2003536

From: Andrew Nelson, LG – NHC
Chris Long, PE – NHC

Re: Summary of Skagit River Channel Migration Desktop Analysis

1 INTRODUCTION

Northwest Hydraulic Consultants (NHC) completed a desktop bankline mapping exercise and analysis of planform morphodynamics of the Skagit River between Project River Mile (PRM) 65 and 78 (the subject reach) over the period between 2015 and 2019. This reach was selected because it is downstream of the Cascade River confluence, where lateral channel mobility is generally understood to be higher than upstream. This desktop analysis was conducted to help better understand preliminary observations of differences between survey data collected during summer/autumn 2020 and 2017 bathymetric LiDAR and corroborated by survey data collected in March 2021. These surveys were performed as part of data collection during Low (August 2020), Moderate (October 2020), and High (March 2021) calibration discharges in support of Upper Skagit Hydraulic Model calibration (NHC 2022a, 2022b and 2022c, as attached to the FA-02 Instream Flow Model Development Study Interim Report). Observations of areas of geomorphic change observable in the planform morphodynamics also indicate areas where vertical bed changes are also occurring. This is important because NHC is calibrating a two-dimensional (2-D) hydraulic model that utilizes the 2017 bathymetric LiDAR with water surface elevation, flow depth, and flow velocity measurements collected in 2020 and 2021. Localized velocities and flow depths for the same discharge should be expected to differ between 2017 and 2020/21 in areas where the channel geometry has changed or is dynamic. The dynamic nature of channel geometry means precise calibration utilizing 2020/21 observations should not be expected in some areas of the channel (discussed further in the conclusions section below). This memorandum describes the methods employed to document locations of geomorphic change between 2017 and 2020/21. The subject reach includes the locations of calibration transects K, L, O, and P.

2 METHODOLOGY

2.1 Planform Morphology

NHC reviewed aerial photos consisting of U.S. Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) imagery from 2015, 2017, and 2019 (Table 1) to delineate the low-flow channel planform morphology for the subject reach. This review included delineation of the active channel, which was defined as the area where the combination of flow and sediment transport intensity and inundation duration prevent establishment of perennial vegetation. The active channel was then subdivided into the wetted channel at the time of aerial photo acquisition (wet), areas of bare sediment (bars), and areas with dense accumulations of large wood (wood). A relatively large flood (daily average flow of 43,780 cfs for the Skagit River downstream of the confluence with Cascade River) occurred on November 23, 2017, after the 2017 imagery and LiDAR was acquired. This likely affected changes in the channel geometry between the 2017 and 2019 images. The period prior to this event was relatively hydrologically quiescent (Figure 1).

Table 1. Dates of NAIP aerial photo acquisition, corresponding flow conditions and image resolution.

Image Acquisition Date	Coverage (PRM)	Coincident Discharge Below Cascade R. Confluence	Resolution	95% absolute accuracy confidence level for rectification
29 Sept. 2015	65-78	4,800 cfs	1 m (3.3 ft)	6 m (20 ft)
27 Sept. 2017	65-73.5	3,960 cfs	1 m (3.3 ft)	4 m (13 ft)
3 Oct. 2017	73.5-78	3,880 cfs	1 m (3.3 ft)	4 m (13 ft)
7 Aug 2019	65-78	3,280 cfs	0.6 m (2.0 ft)	4 m (13 ft)

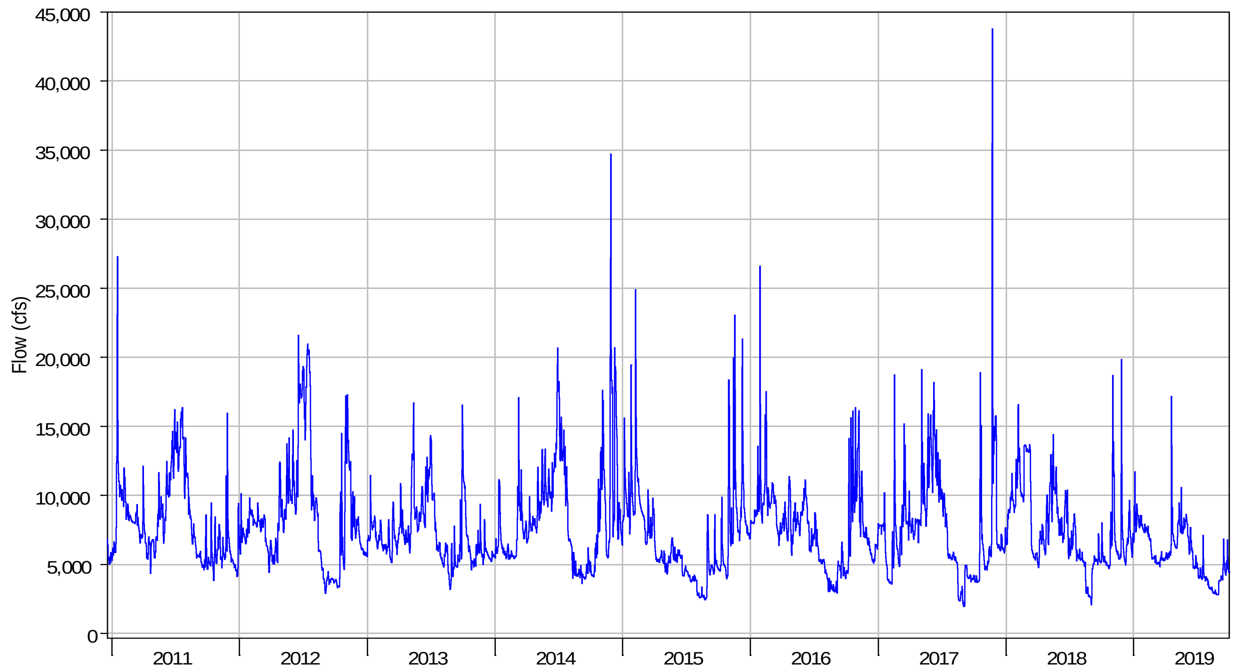


Figure 1. Daily flows for the Skagit River below the Cascade River confluence for the period preceding and between aerial photos analyzed.

The delineation was completed at an on-screen scale ranging from 1:2,000 to 1:4,000. The edge of the active channel was delineated based on the visible position of the bankline in gaps between overhanging vegetation or at the position of the interpreted center of trees in areas with overhanging vegetation. The characteristic diameter of tree canopies along the bank lines is 5 to 10 m. When the imagery rectification accuracy, uncertainty related to vegetation, and scale of the delineation are considered together, the accuracy of the bankline delineations is believed to be on the order of 10 m or better. To reduce the occurrence of false positive indications of geomorphic change, the most recent (2019) and highest resolution bank lines were delineated first and then modified only in areas where the bankline had visibly changed when compared against the earlier images.

2.2 Transect K, L, O, and P Comparison

Localized imagery collected from an unmanned aerial vehicle (UAV) contemporaneous with the August 2020 flow velocity and depth measurements was available at the transect locations. The UAV imagery did not include ground control points, and so its horizontal geolocation accuracy was low relative to the NAIP imagery (probably similar to typical Differential Global Positioning System (DGPS) accuracy on the order of 15-35 ft). Therefore, NHC manually georeferenced the mosaicked imagery to recognizable control points in the 2019 NAIP image, which brought the two datasets into close alignment (probably to within about 5 ft). This alignment is acceptable considering the precision of the techniques used in this analysis. The NAIP-based bankline delineations for 2017 and 2019 were then plotted against the 2020 images (and images directly compared) to observe localized areas of notable morphologic change.

Topobathymetry was also collected approximately 200 feet upstream and downstream of select transects using the SonTek M9 ADCP during the High calibration discharge field data collection effort (March 1-4, 2021) and a single beam CEE ECHO during the Low calibration discharge field data collection effort (August 23-28, 2020). Surveyed topobathymetric data was compared to the 2017 Quantum Spatial LiDAR elevation (Quantum Spatial 2017) at all locations that do not fall in a LiDAR void area. The distribution of the elevation differences is shown in Appendix D.

3 RESULTS

3.1 Reach Scale Planform Morphology

The subject reach included both very stable areas and areas of clear change in the channel morphology (Figure 2). Complete bankline delineations, maps of historical channel occupancy duration, and timing of inferred change in the extent of the active channel are included in Appendix A, Appendix B, and Appendix C, respectively.

The planform geometry was extremely stable (very little detectible change in active channel extent) between PRM 73.5 and 77 (Figure 2 and Appendices Panel 4), which is a transport reach with few depositional features. The bar complex at PRM 73-73.5 was an area with moderate changes (Appendices Panel 3) mostly related to closure of side channels on either side of the river due to vertical accretion and vegetation establishment, but also included localized cut bank erosion.

Just downstream, around PRM 72.5, cut bank erosion and point bar deposition are both occurring in the bend immediately upstream of the Washington State Department of Transportation (WSDOT) Milepost (MP) 101 riverbank protection project and along the channel just downstream of the project. Erosion upstream of the project appears to be down valley meander migration, while the pattern of erosion downstream of the project suggests the channel is dynamically adjusting.

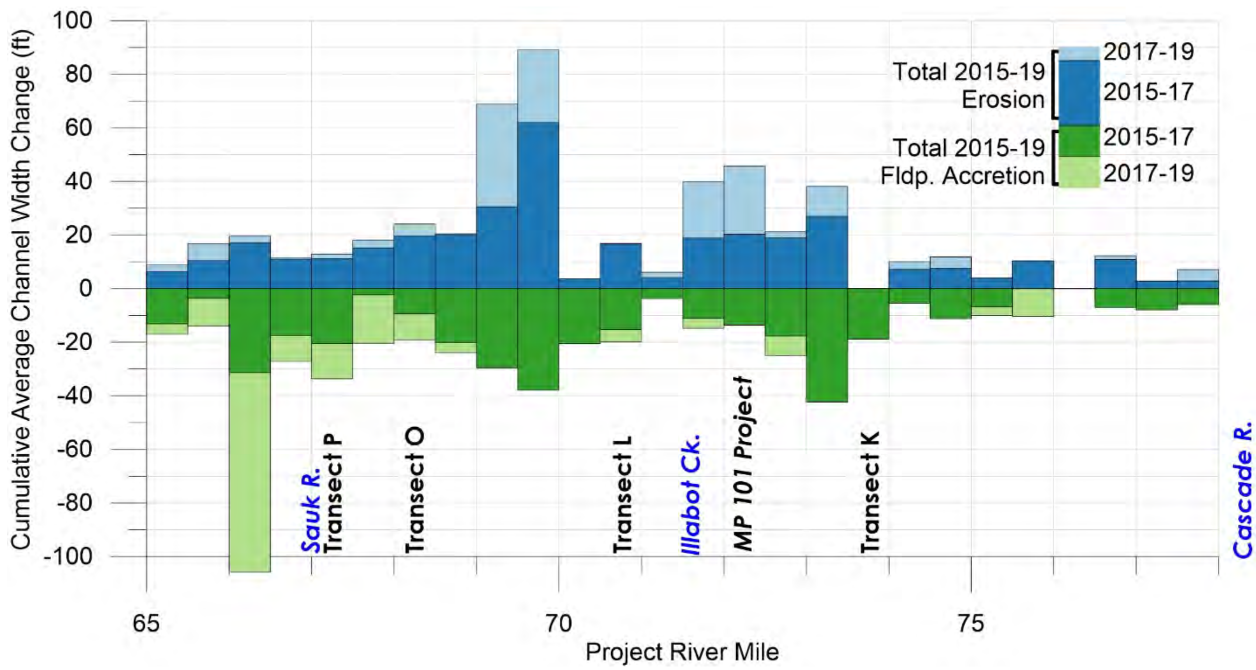


Figure 2. Areas of observed bank erosion and floodplain accretion indicating general pattern of geomorphic change through the subject reach.

The area with the most dynamic planform geometry extends from the Sauk River upstream to PRM 70 (Appendices Panel 2). Changes occurring in this area include meander amplification, down valley meander translation, and the formation and closure of side channels. Substantial change in the localized bar configuration occurred at the Sauk River confluence (Appendices Panel 2), but there was little change in the active channel extent except for the emergence and enlargement of some vegetated island features within the large left bank confluence bar complex.

3.2 Transect K, L, O, and P Bankline Comparison

More detailed comparison of the bankline delineations at the calibration transect locations and 2020 imagery (Figure 3 through Figure 6), indicates that planform geomorphic changes at transects K, L, O, and P has been relatively subtle.

Very little change has occurred at Transect K (Figure 3), where changes in the extent of exposed sediment along the banklines (e.g., Locations A and B) likely reflect differences in discharge. Reorganization of the delta-bar complex at Location C is interpreted to be meaningful geomorphic change that would alter localized hydraulics. The bar complex downstream of this transect at approximately PRM 73-73.4 has been dynamic between 2017 and 2019. Changes in this bar complex have the potential to affect the downstream backwater hydraulic control at the location of the calibration transect.

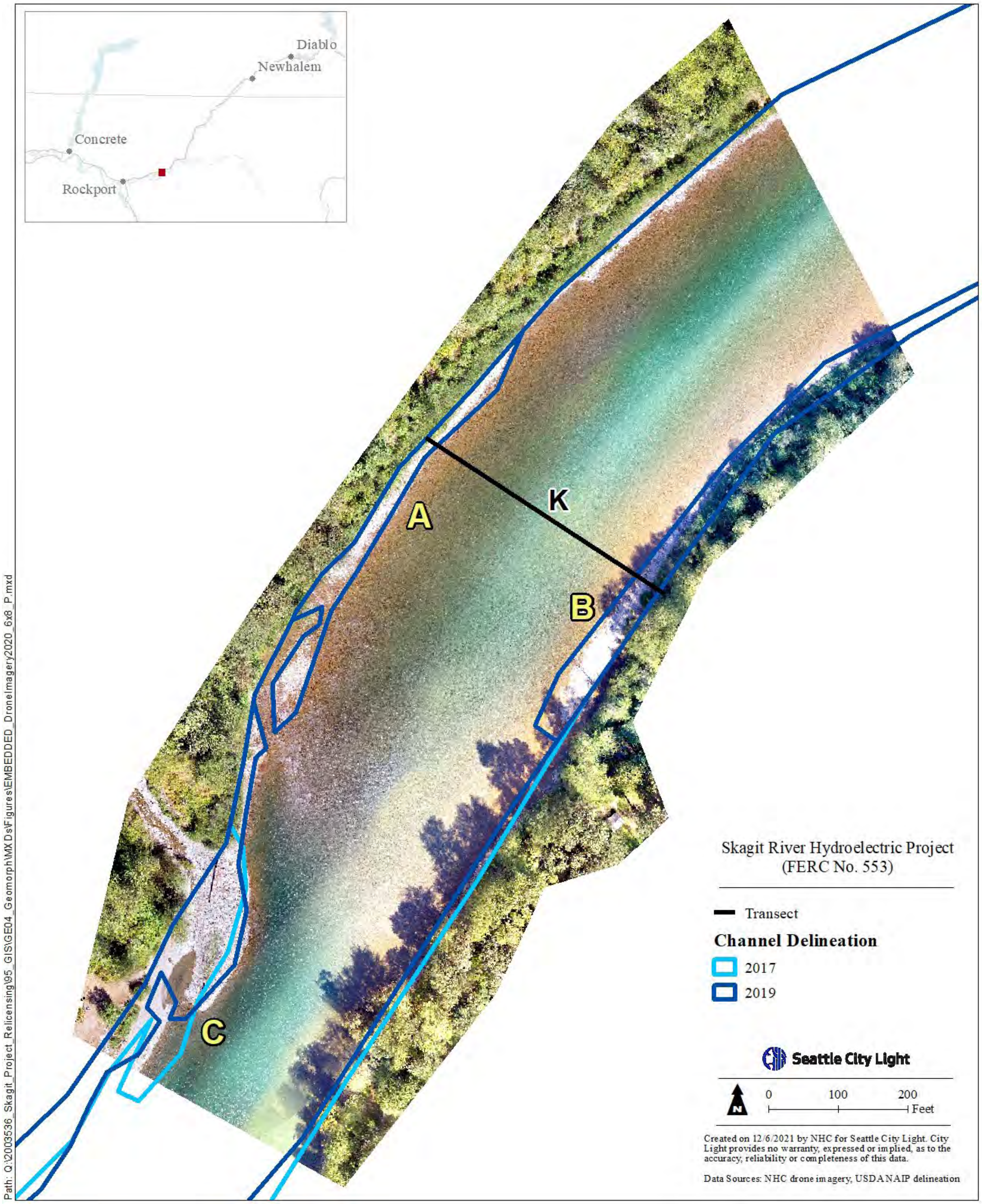


Figure 3. Comparison of channel delineation from NAIP 2017 and 2019 images with August 2020 UAV image at location of Transect K.

At Transect L (Figure 4), apparent changes in the bankline positions (e.g., Locations A and B) are within the georeferencing and bankline delineation precision. Localized changes have occurred where a cluster of large wood was—probably temporarily—retained on the bar upstream of the island (Location C) resulting in formation of a scour hole upstream of the rootward and sediment accumulation downstream in the hydraulic shadow and in the bar complex at the outlet of the side channel (Location D). Visibility of the side channel in the imagery is not sufficient to infer whether localized geomorphic changes that would affect the hydraulics in the side channel have occurred. Apparent growth of the bar downstream of the side channel confluence (Location E) could be due to either meaningful geomorphic change or variability in river stage. The upstream and riverward edge of the bar south of the island (Location F) appear to have contracted slightly. The interpreted thalweg position at the riffle downstream of this transect location has changed, as have conditions at the bar complex near PRM 70. As with changes at Transect K, these could impact backwater hydraulic control over conditions at the calibration transect.

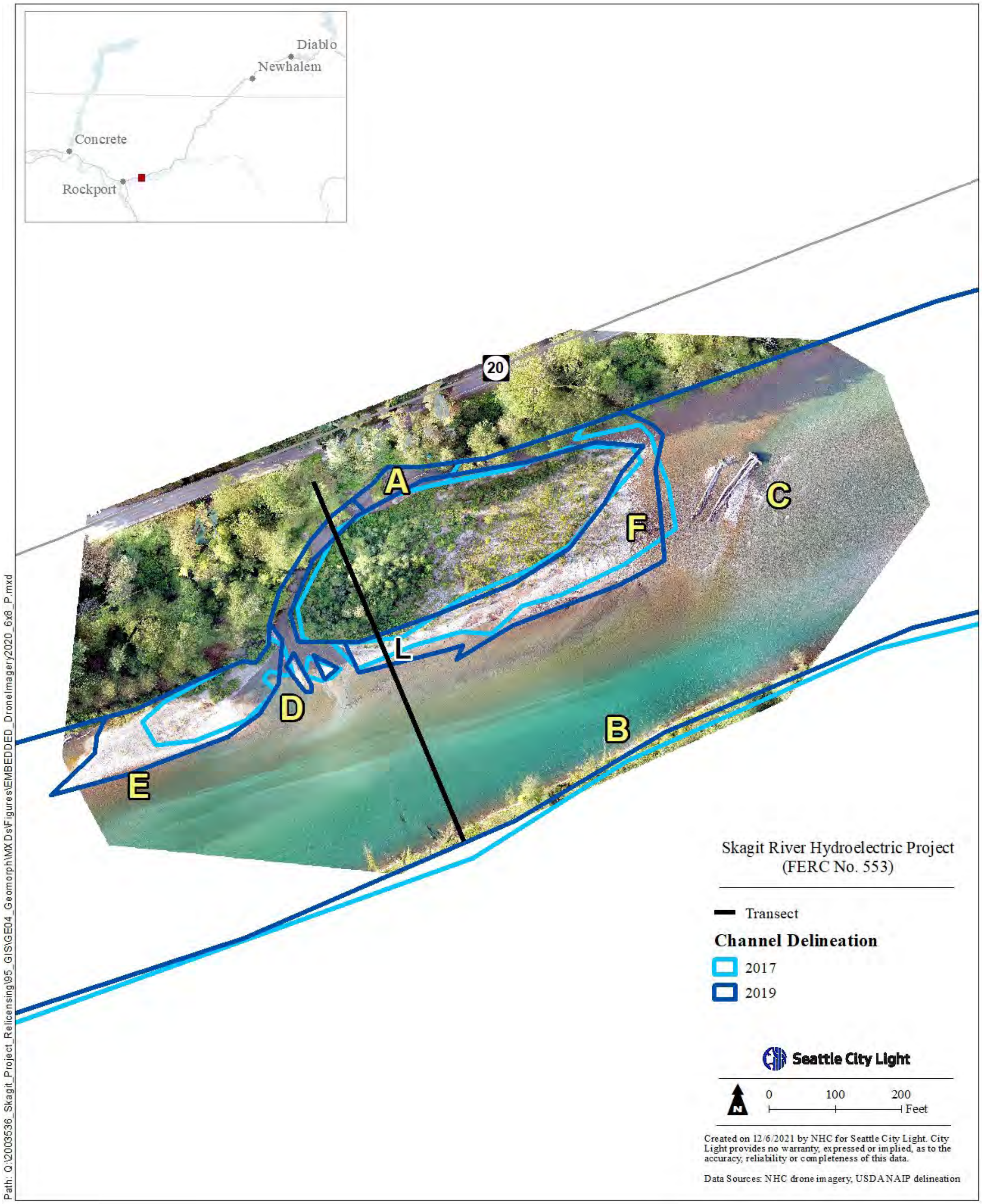


Figure 4. Comparison of channel delineation from NAIP 2017 and 2019 images with August 2020 UAV image at location of Transect L.

Transect O (Figure 5) is in the relatively geomorphically-dynamic zone upstream of the Sauk River confluence (Figure 2), but changes within the extent of the 2020 UAV image are subtle. There is little change in the edge of the active channel (e.g., Locations A and B) or in the geometry of the channel bifurcation (Location C). The Location D bar slip-face in the side channel changed between 2017 and 2019, and between 2019 and 2020, indicating it is a geomorphically dynamic feature. Localized bar configurations on either side of the side channel near Location E have also changed. It is unclear whether changes in the extent of bars on either side of the main channel (Locations G and F) are due to variable stage or small geomorphic changes. Changes in the channel configuration upstream of the area covered by the 2020 UAV image (see appendices) may also influence the hydraulics at the transect location.

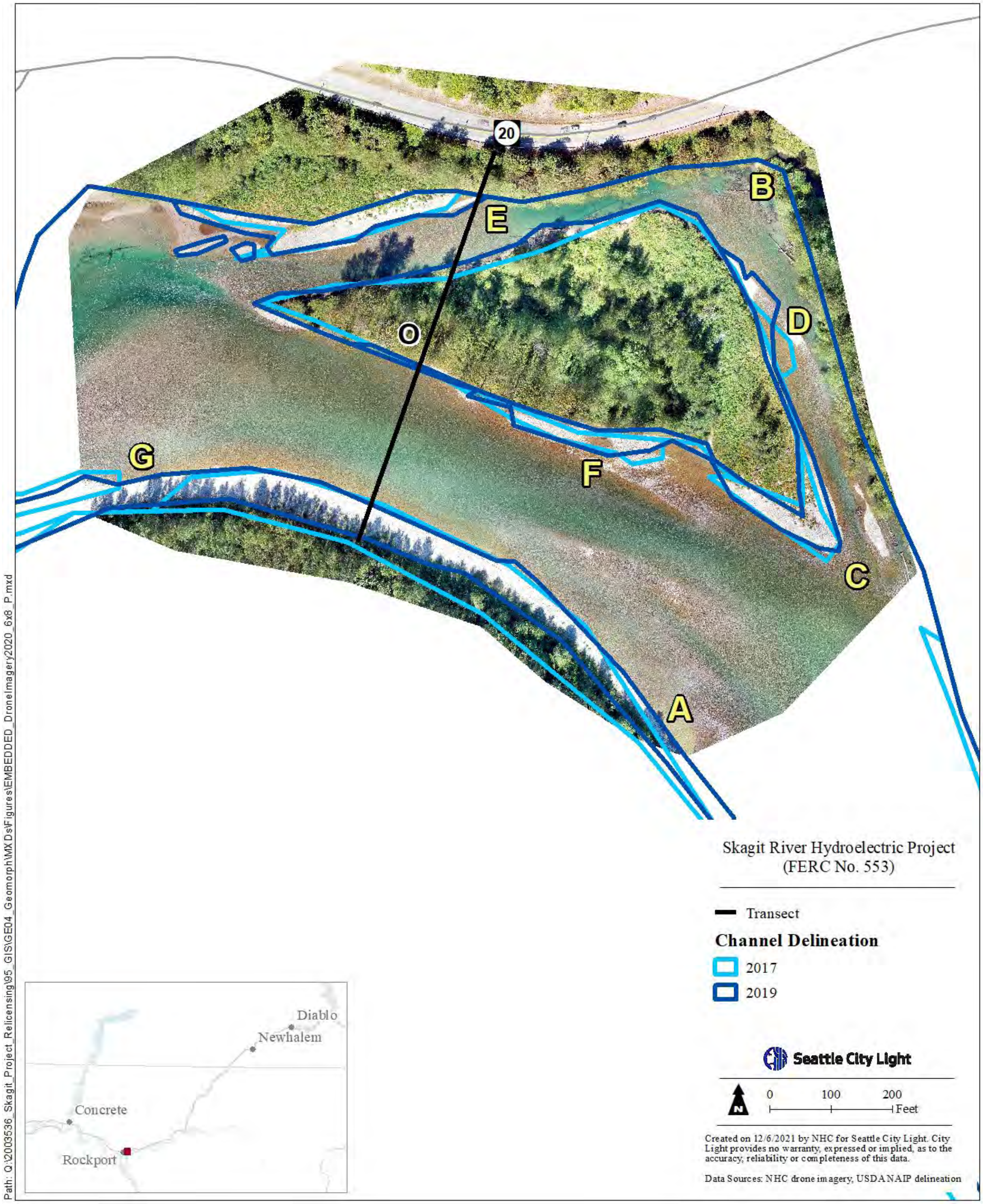


Figure 5. Comparison of channel delineation from NAIP 2017 and 2019 images with August 2020 UAV image at location of Transect O.

Transect P is located at the confluence of a significant (75 ft wide) side channel and the mainstem at the upstream edge of the Sauk River confluence delta. This is an area of substantial reach-scale geomorphic change, due to transient storage of sediment deposited by the Sauk River. In addition, the bar complex at the head of the side channel appears to be dynamic, suggesting the flow partition between the side channel and the main channel may be somewhat unstable. Notwithstanding variability in these potential upstream and downstream controls on the local hydraulics, local features appear to have been generally stable at the location of this transect between 2017 and 2020 (Figure 6). The most notable planform change detectable in the aerial imagery is at Location A, where vegetation is progressively encroaching onto the bar. The waterward edges of bars (Locations B-D) appear to have been very stable. The large wood jam at the side channel confluence was separately delineated in the 2019 aerial photo, but not in the 2017 photo. Careful comparison of the two photos indicates that the wood was present in 2017 and that only localized reorganization (movement of a few individual pieces) appears to have occurred. The thalweg position at this transect was mapped as having shifted between 2017 and 2020 (see Appendices), but high turbidity in the 2019 image due to Sauk River inflows reduces confidence in the thalweg mapping for that year at this location. Qualitative comparison of apparent water depths between the 2017 image and 2020 image does not indicate a large difference in the thalweg position.

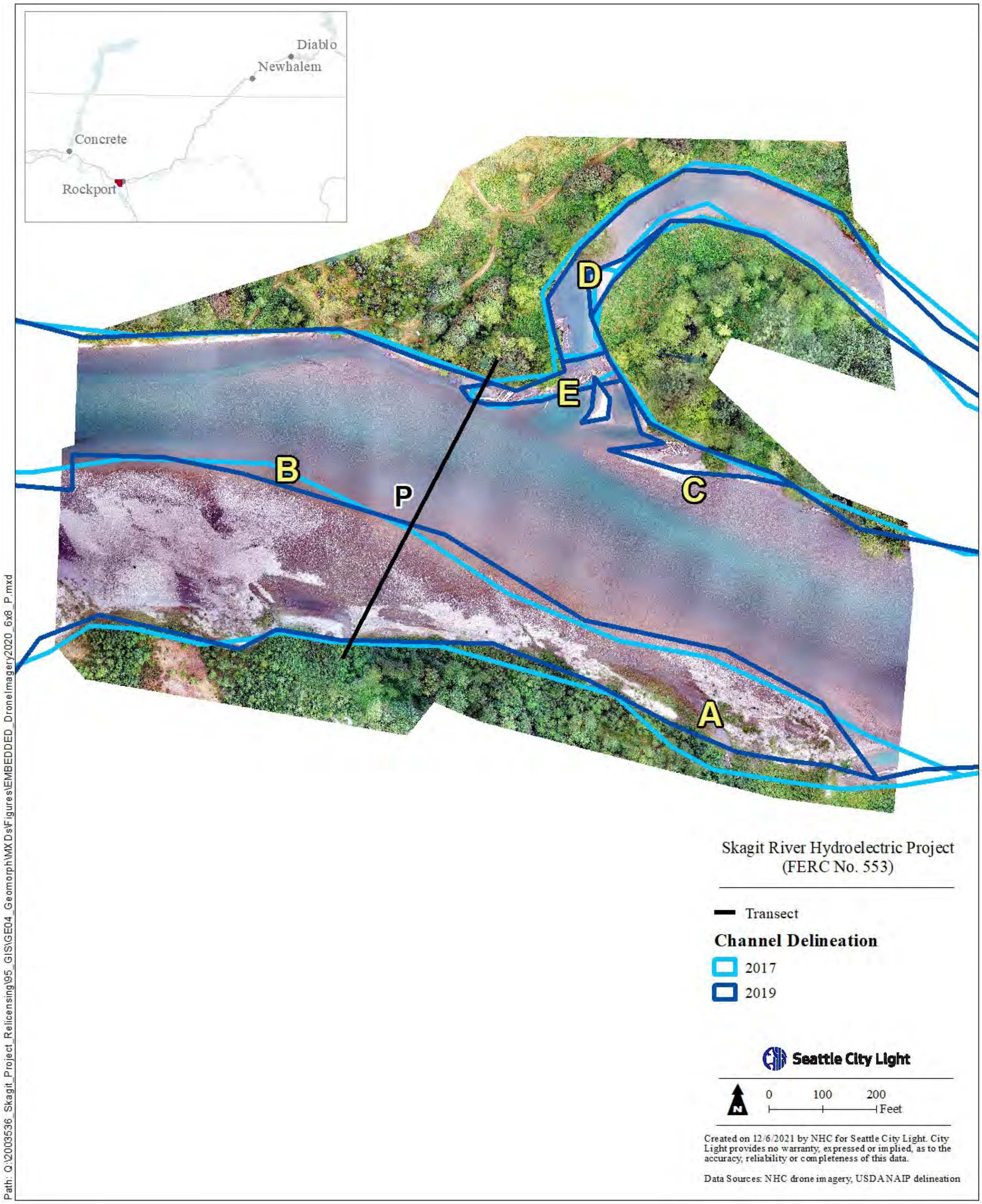


Figure 6. Comparison of channel delineation from NAIP 2017 and 2019 images with August 2020 UAV image at location of Transect P.

3.3 Transect K, L, O, and P Topobathymetry Comparison

Topobathymetry collected during the High calibration discharge field data collection event (March 2021) and Low calibration discharge field data collection effort (August 2020) was compared to the 2017 Quantum Spatial LiDAR where overlapping. The difference in surveyed and LiDAR elevations is documented in Appendix D.

Topobathymetric data comparison of points around Transect K using data collected during the low-flow data-collection event shows an even distribution centered around a median difference of 0.0 feet and mean difference of 0.03 feet, with a standard deviation of 0.30 feet. This supports the bankline assessment that Transect K is relatively stable.

Bed elevation comparison at Transect L surveyed during the High calibration discharge field data collection event show a mean and median difference of 0.38 feet and 0.39 feet, respectively, between surveyed and LiDAR elevations. However, this trend appears to be influenced by depositional features along the right bank, whereas main channel elevations remained similar. Furthermore, the spatial variability is limited by the void in the LiDAR through the thalweg of the channel, possibly biasing the average elevation difference.

The mean and median differences between surveyed and LiDAR elevation at Transect O are 0.07 and 0.05 feet, respectively, with a standard deviation of 0.51 feet. There is evidence of some shifts in bed elevation near the upstream and downstream end of the reach, especially near the left bank bar; however, main channel values are consistent with LiDAR elevations.

At Transect P, topobathymetry differences from the High calibration discharge field data collection event show a mean and median difference of -0.06 feet and -0.18 feet, respectively, whereas the mean and median difference from the Low calibration discharge field monitoring event is 0.44 feet and 0.40 feet. The standard deviation of comparison points for the Low and High calibration discharge field monitoring events is 0.51 feet and 0.72 feet, respectively. The statistical difference between the two surveys is likely due to the different spatial extents of the surveys: the High calibration discharge field data collection event survey extended both farther upstream and farther downstream than the Low calibration discharge field data collection event survey. Both surveys show some channel shifts, especially at the downstream end of the reach and along the right bank. This could be a result of flow from the side channel and the presence of the large wood jam upstream.

4 CONCLUSION

This investigation of channel planform dynamics between PRM 65 and 78 demonstrates that the Skagit River has been generally stable upstream of PRM 74 between 2017 and 2019, while the reach downstream of PRM 74 has been much more dynamic. The planform changes observable in aerial photos indicate that underlying topographic and bathymetric changes have also occurred. Such changes are typical in alluvial rivers.

Topography and bathymetry are amongst the most fundamental controls on channel hydraulics; thus changes in the topography between the time of collection of survey data used in development of the Upper Skagit Hydraulic Model and the measurement of calibration hydraulic conditions imply that perfect hydraulic model calibration should not be expected: an accurate hydraulic model representing conditions in 2017 would be different from an accurate model representing conditions in 2020, which would be different from one representing conditions in 2021.

Similar changes in planform should be expected to continue in the future. Because the channel has been much more stable upstream of PRM 74 compared to downstream of PRM 74, substantially better calibration should be expected upstream. In a geomorphically-dynamic reach, precise hydraulic model calibration would require contemporaneous topographic surface information and calibration data— this is not practical given the desire to use a single model topographic surface with a range of flows and the need for calibration information over a range of flow conditions which only exist 6-12 months distant from one another in time. However, neither is a precise hydraulic model calibration possible given uncertainties in instrumentation and GPS satellites, natural and random turbulence in the water, continual changes in channel topography, and the limitations of a two-dimensional, depth-averaged hydraulic model (or any numerical model). Ultimately the model's ability to report the river's depth and velocity for given flows will be demonstrated through performance statistics of the calibrated model. Given the uncertainties in hydraulic model calibration that exist irrespective of a topographic surface that pre-dates the monitoring period by three or four years, the Upper Skagit Hydraulic Model is expected to calibrate sufficiently to evaluate instream flows. Application of a topographic surface that pre-dates calibration observations by several years and vice-versa, is standard in hydraulic modeling because of practicalities previously stated and the error-band that we are operating in, not to mention uncertainties associated with the biologic criteria coupled with the hydraulic output.

The calibration transects downstream of PRM 74 tend to be in localized areas of greater stability than the surrounding channel (Figure 2). As noted for the specific transects in Section 3, reach-scale changes in the topography and bathymetry can affect localized hydraulics by changing the flow distribution across the channel cross section upstream and by changing tailwater hydraulic conditions downstream of the transect location. Further localized changes described in Section 3 should be expected to alter localized hydraulics (e.g., within 10 to 100 feet of the changed features). The planform change observations described here do not provide adequately specific information on the topographic changes they signal to quantitatively predict their impact on model calibration. Rather, they should be used as an interpretive tool to discern underlying mechanistic reasons for incongruence between model predictions and calibration data in areas where the planform is known to have changed.

This reach of the river likely will continue to be dynamic in the future; therefore, the Upper Skagit Hydraulic Model should be seen as a tool to define a representative condition to be used for relative comparisons of alternative flow regimes, and not thought of as a precise representation of the range of likely future conditions.

Based on the surveys of calibration transects K, L, O, and P from August 2020 and March 2021, the average difference between surveyed and LiDAR elevation at all transects is less than the 95 percent confidence vertical accuracy of the LiDAR (0.540 feet). Transect K appears to be relatively stable, however transects L, O, and P, show local- to reach-scale vertical change that could impact transect calibration.

5 REFERENCES

Northwest Hydraulic Consultants (NHC). 2022a. Summary of Skagit River data collection for lowest calibration discharge. Technical Memorandum. March 2022.

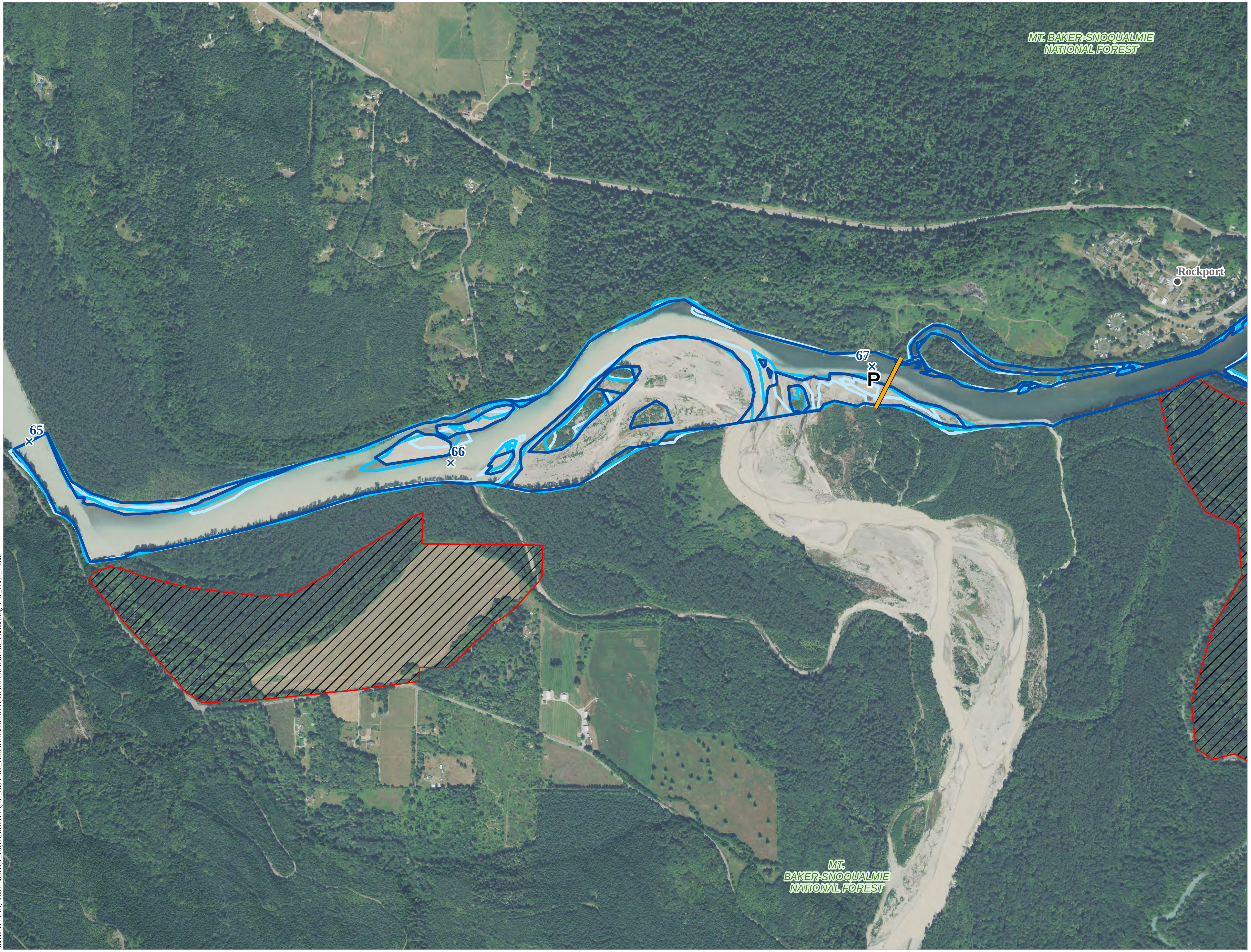
Northwest Hydraulic Consultants (NHC). 2022b. Summary of Skagit River data collection for moderate calibration discharge. Technical Memorandum. March 2022.

Northwest Hydraulic Consultants (NHC). 2022c. Summary of Skagit River data collection for high calibration discharge. Technical Memorandum. March 2022.

Quantum Spatial. 2017. Skagit topobathy, Washington. Topobathymetric LiDAR technical data report. Report prepared for Skagit River System Cooperative. July 21, 2017.

APPENDIX A

Bankline Delineation



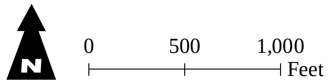
BANKLINE DELINEATIONS PANEL 1

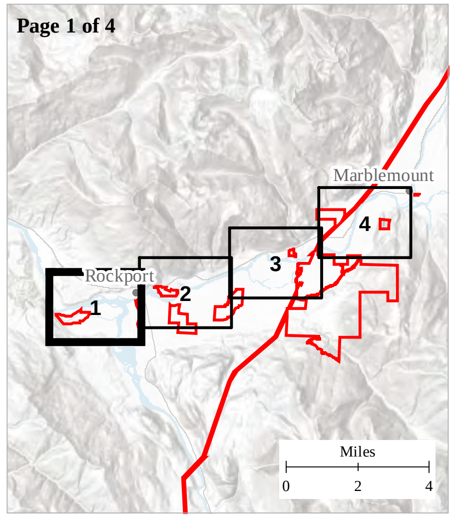
Legend

- FERC Project Boundary
- Mitigation Parcel
- Project River Mile
- Calibration Transect

Channel Delineation

- 2015
- 2017
- 2019





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Data Source: USDA NAIP Orthoimagery (2015, 2017, 2019)

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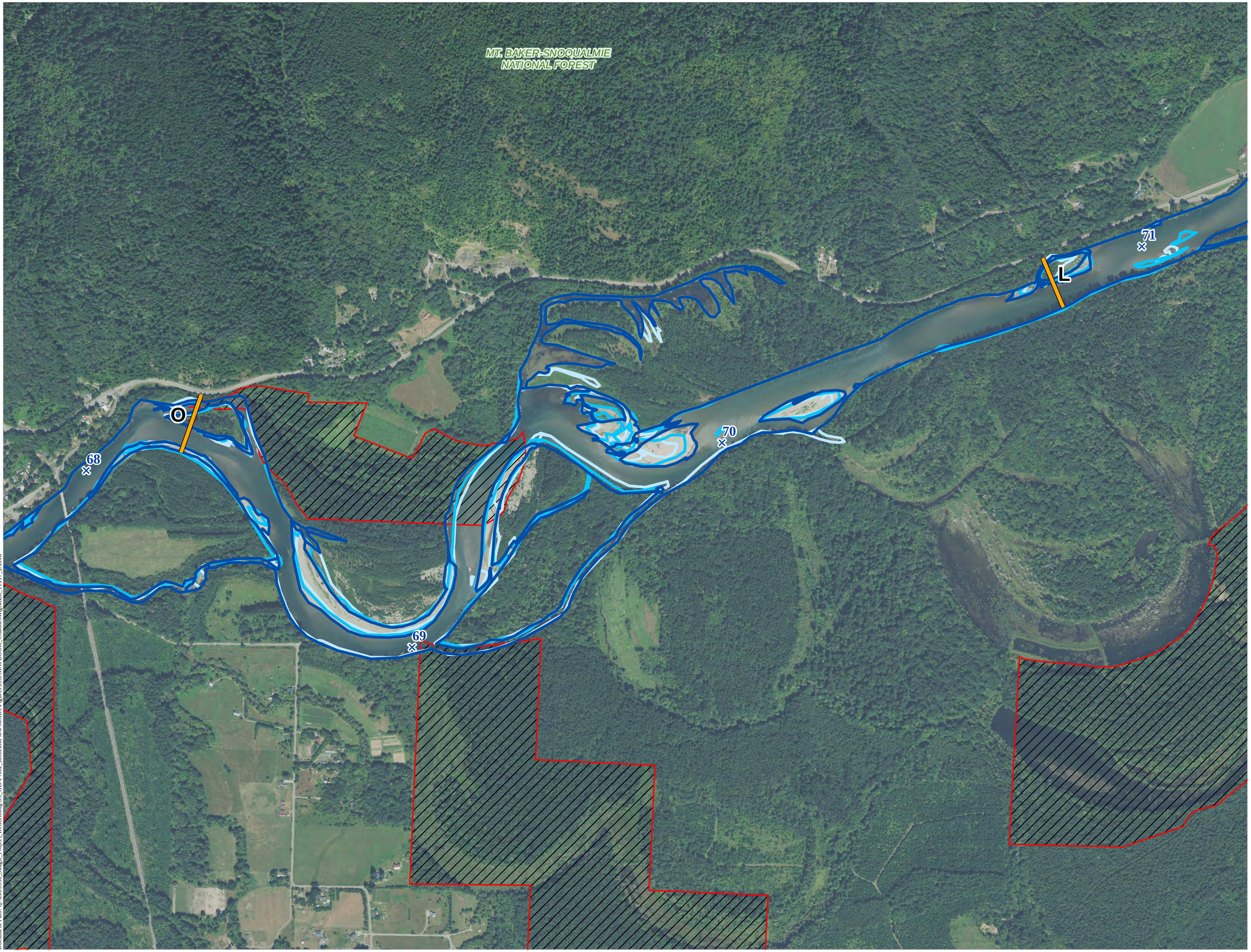


BANKLINE DELINEATIONS PANEL 2

Legend

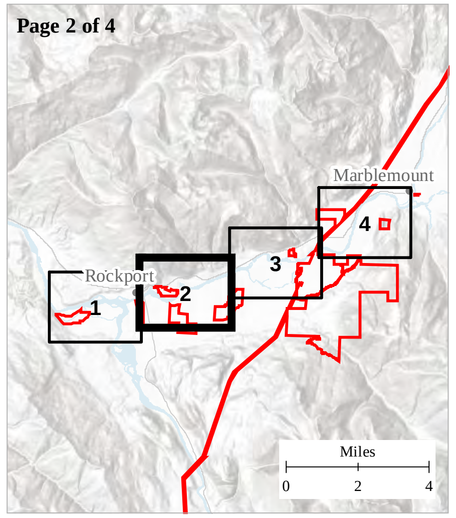
- FERC Project Boundary
- Mitigation Parcel
- Project River Mile
- Calibration Transect

Channel Delineation

- 2015
- 2017
- 2019

N

0 500 1,000
Feet



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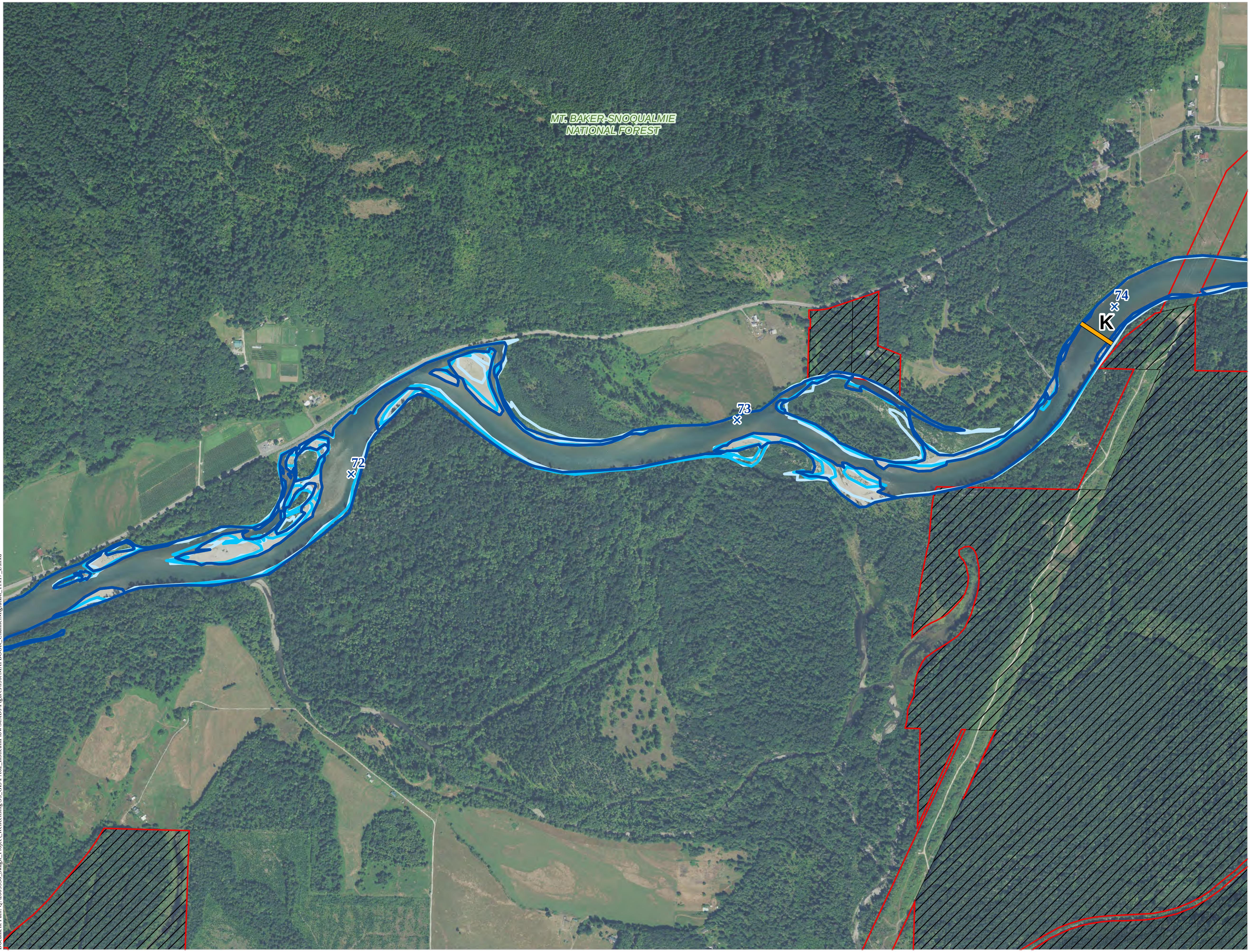


BANKLINE DELINEATIONS PANEL 3

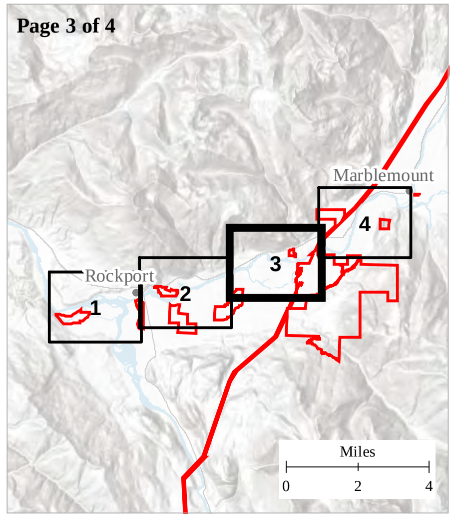
Legend

- FERC Project Boundary
- Mitigation Parcel
- × Project River Mile
- Calibration Transect

Channel Delineation

- 2015
- 2017
- 2019

0 500 1,000 Feet



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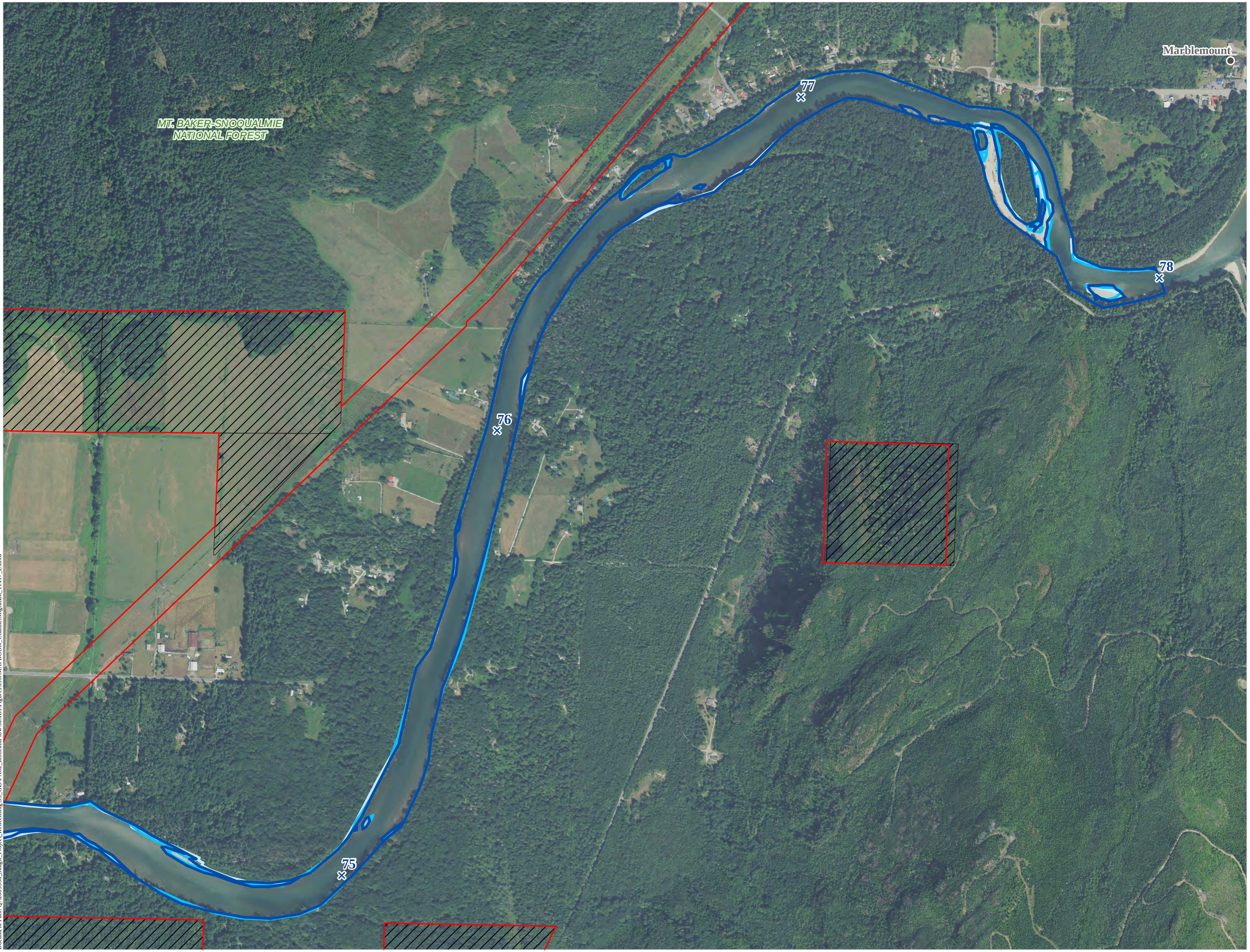


BANKLINE DELINEATIONS PANEL 4

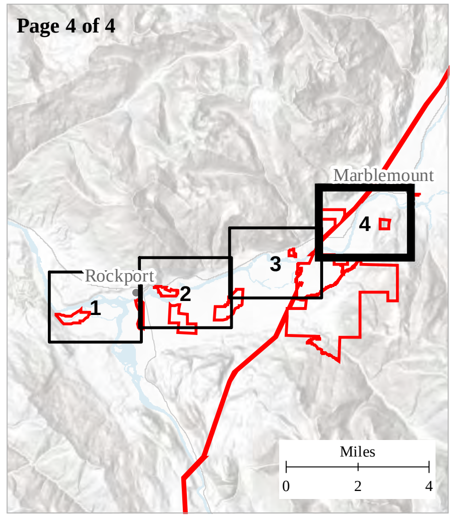
Legend

- FERC Project Boundary
- Mitigation Parcel
- Project River Mile
- Calibration Transect

Channel Delineation

- 2015
- 2017
- 2019

0 500 1,000 Feet



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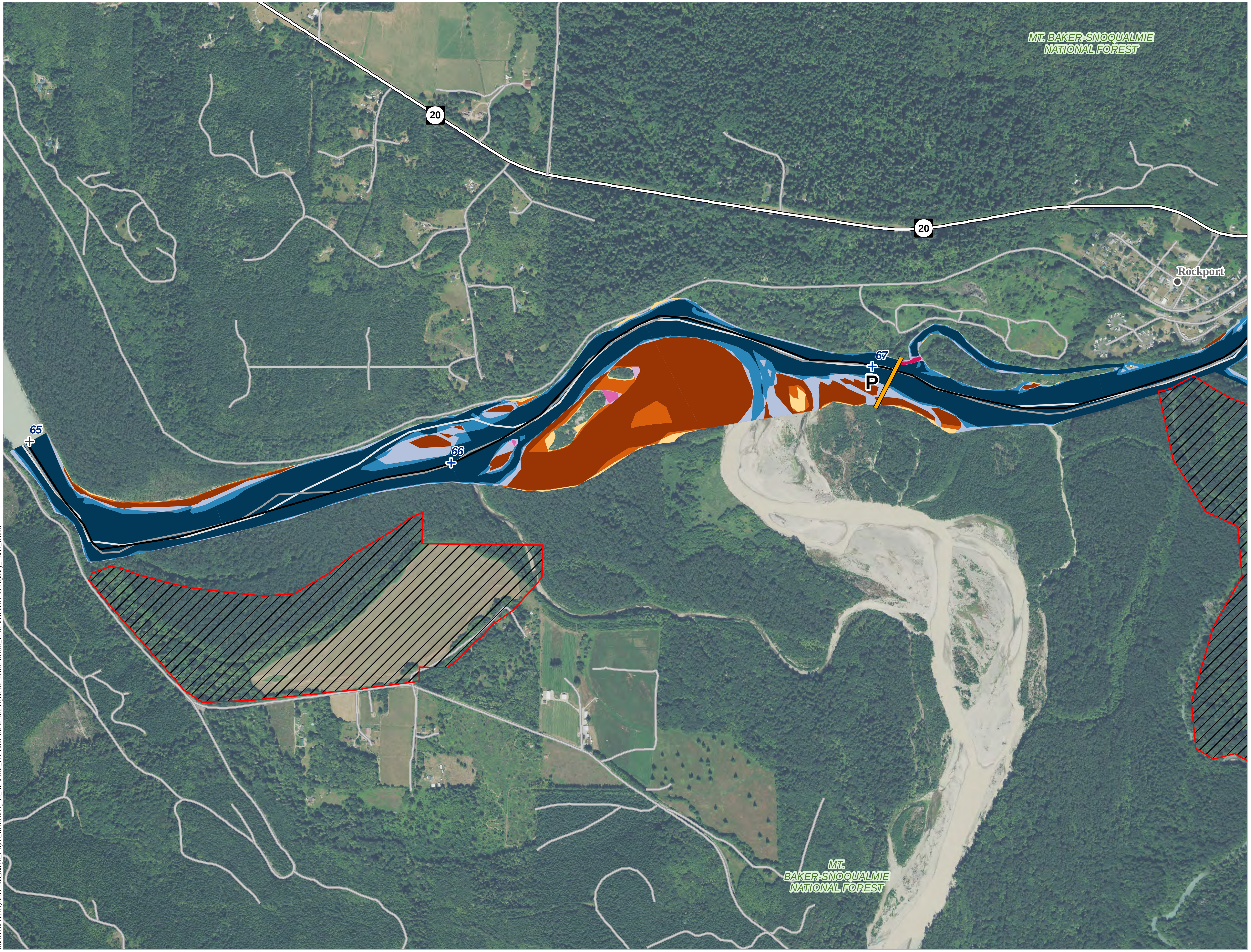
APPENDIX B

Historical Channel Occupancy Duration



HISTORICAL CHANNEL OCCUPANCY PANEL 1

FERC Project Boundary
Mitigation Parcel
Project River Mile
Calibration Transect

Aerial Image Delineated Thalweg

2015
2017
2019

Duration Wood (years)

2
4
6

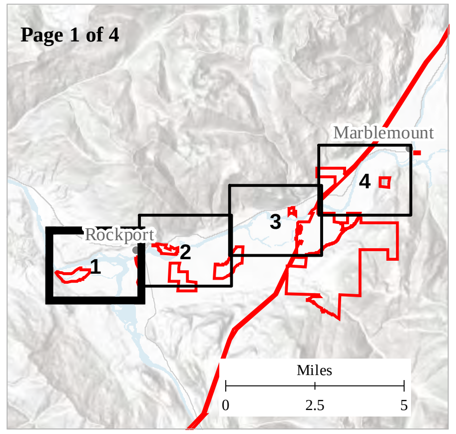
Duration Wet (years) of areas never classified as wood

2
4
6

Duration Bar (years) of areas never classified as wood or wet

2
4
6

0 500 1,000 Feet



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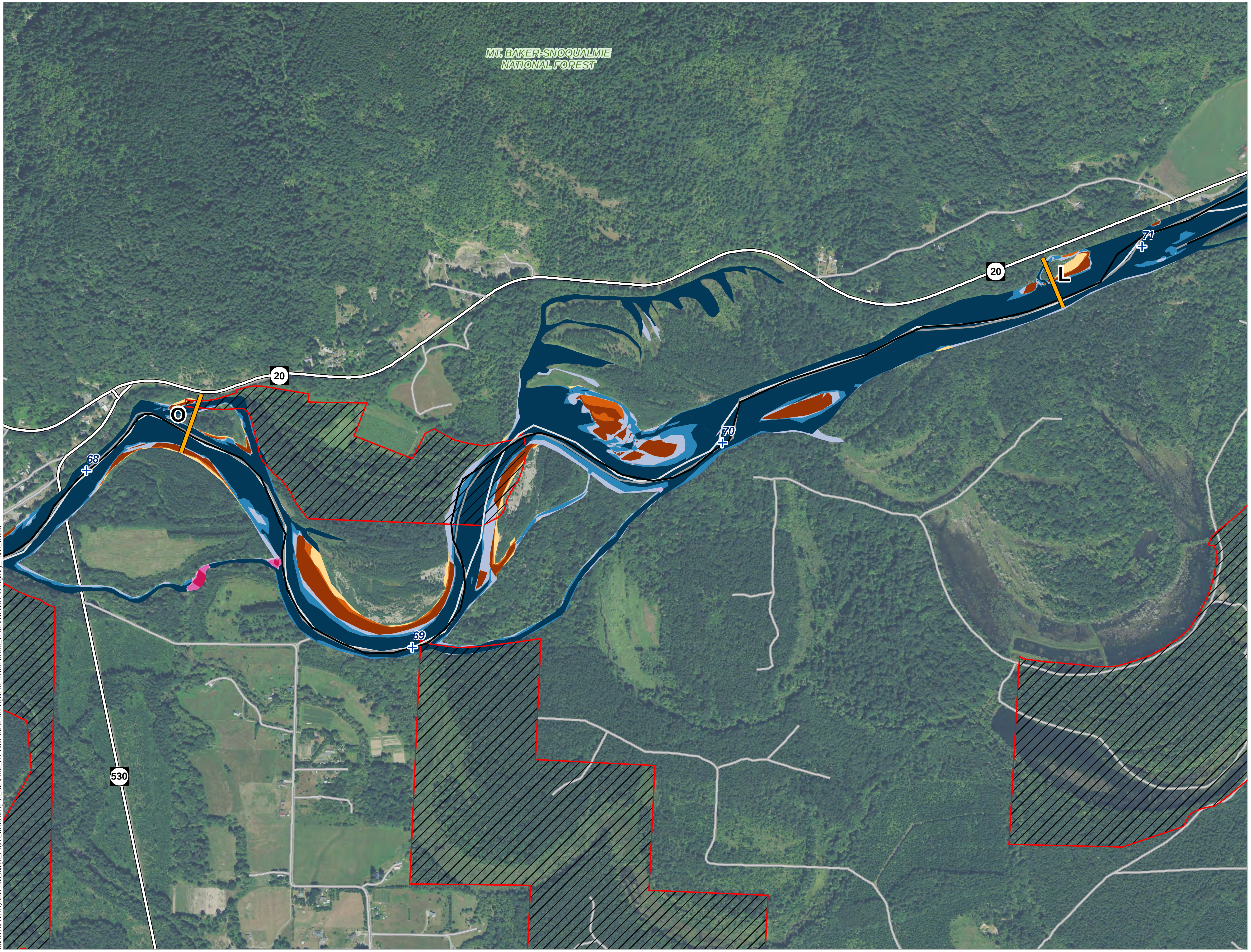


HISTORICAL CHANNEL OCCUPANCY PANEL 2

FERC Project Boundary
Mitigation Parcel
Project River Mile
Calibration Transect

Aerial Image Delineated Thalweg

2015
2017
2019

Duration Wood (years)

2
4
6

Duration Wet (years) of areas never classified as wood

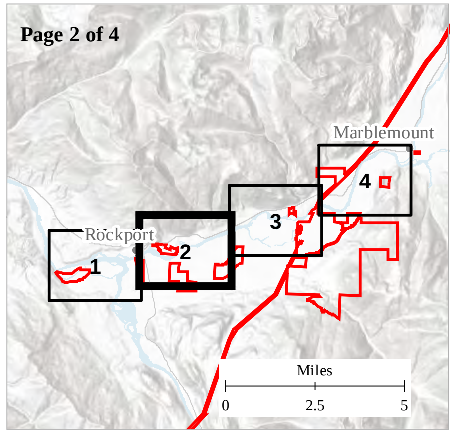
2
4
6

Duration Bar (years) of areas never classifed as wood or wet

2
4
6

N

0 500 1,000 Feet



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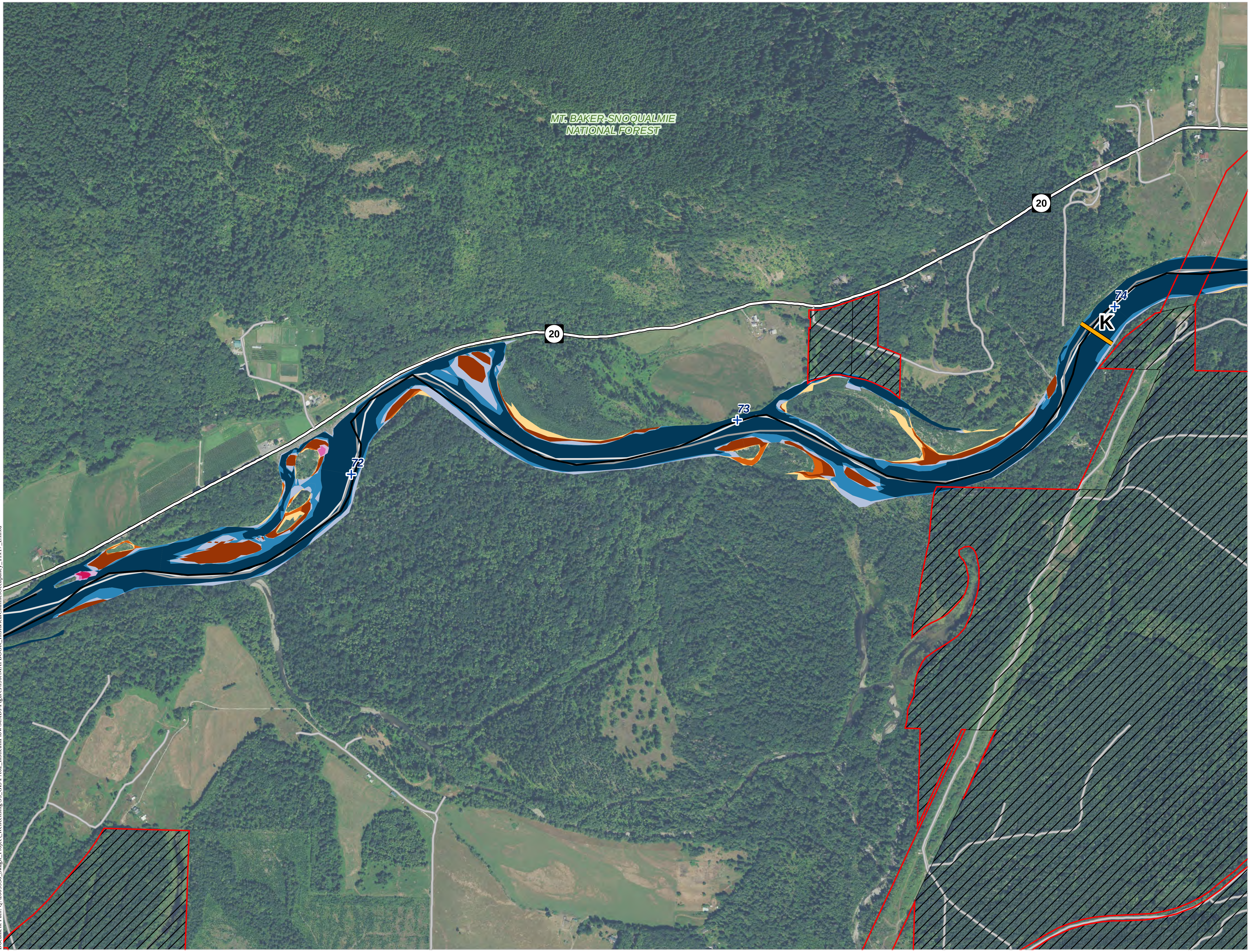


HISTORICAL CHANNEL OCCUPANCY PANEL 3

FERC Project Boundary
Mitigation Parcel
Project River Mile
Calibration Transect

Aerial Image Delineated Thalweg

2015
2017
2019

Duration Wood (years)

2
4
6

Duration Wet (years) of areas never classified as wood

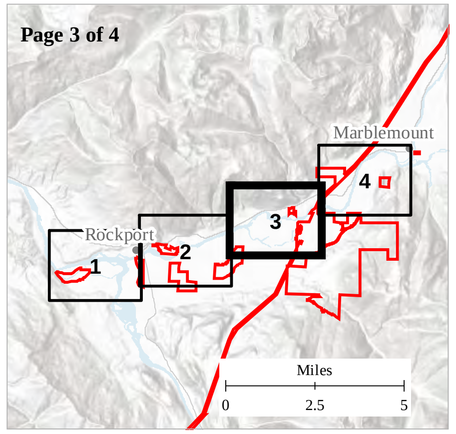
2
4
6

Duration Bar (years) of areas never classifed as wood or wet

2
4
6

N

0 500 1,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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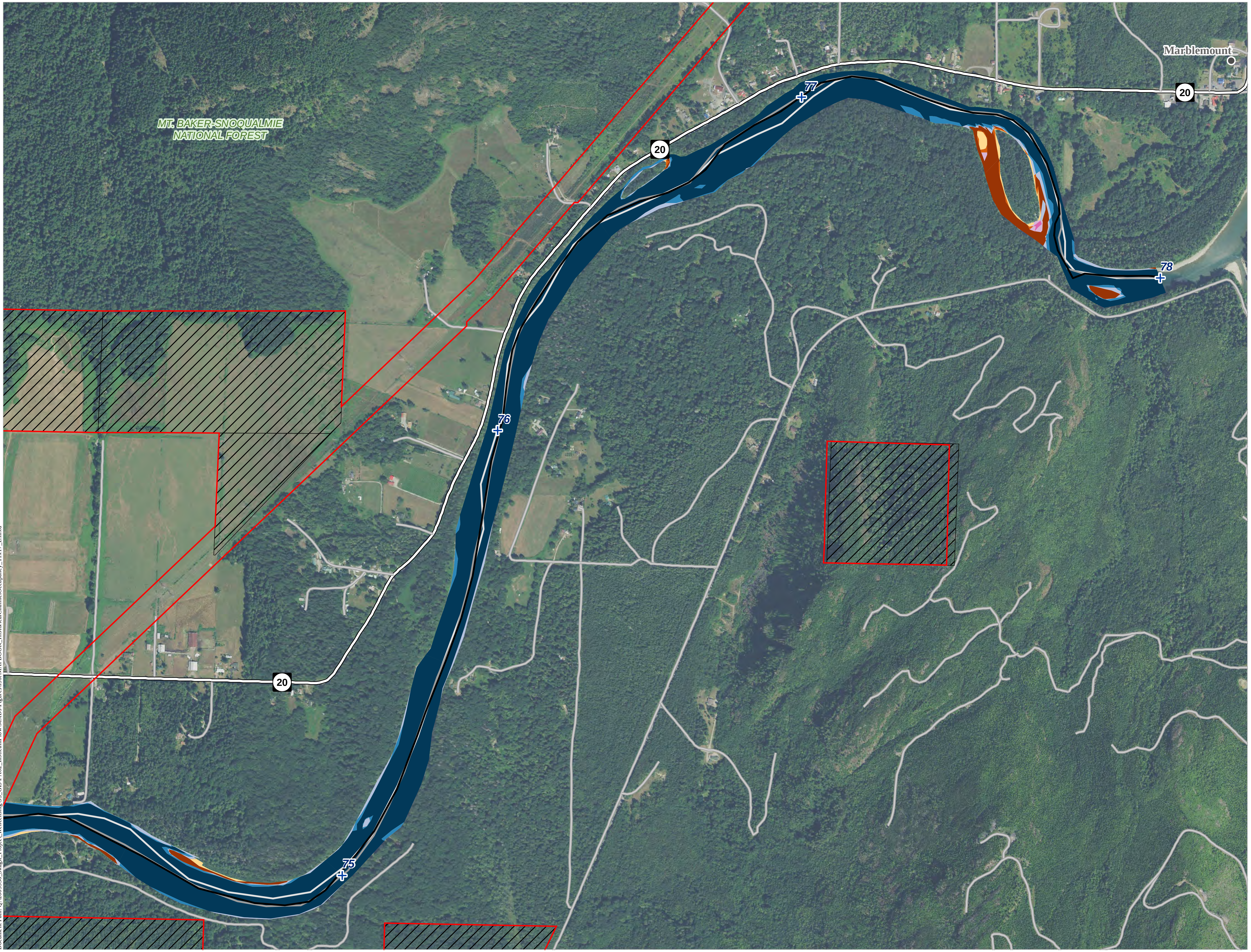
Data Source: USDA NAIP Orthoimagery (2015, 2017, 2019)



HISTORICAL CHANNEL OCCUPANCY PANEL 4

- FERC Project Boundary
- Mitigation Parcel
- Project River Mile
- Calibration Transect

Aerial Image Delineated Thalweg

- 2015
- 2017
- 2019

Duration Wood (years)

- 2
- 4
- 6

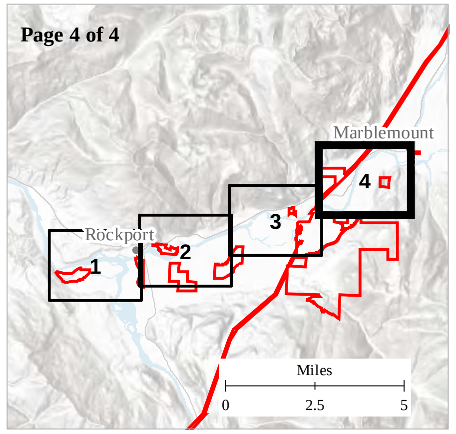
Duration Wet (years) of areas never classified as wood

- 2
- 4
- 6

Duration Bar (years) of areas never classifed as wood or wet

- 2
- 4
- 6

0 500 1,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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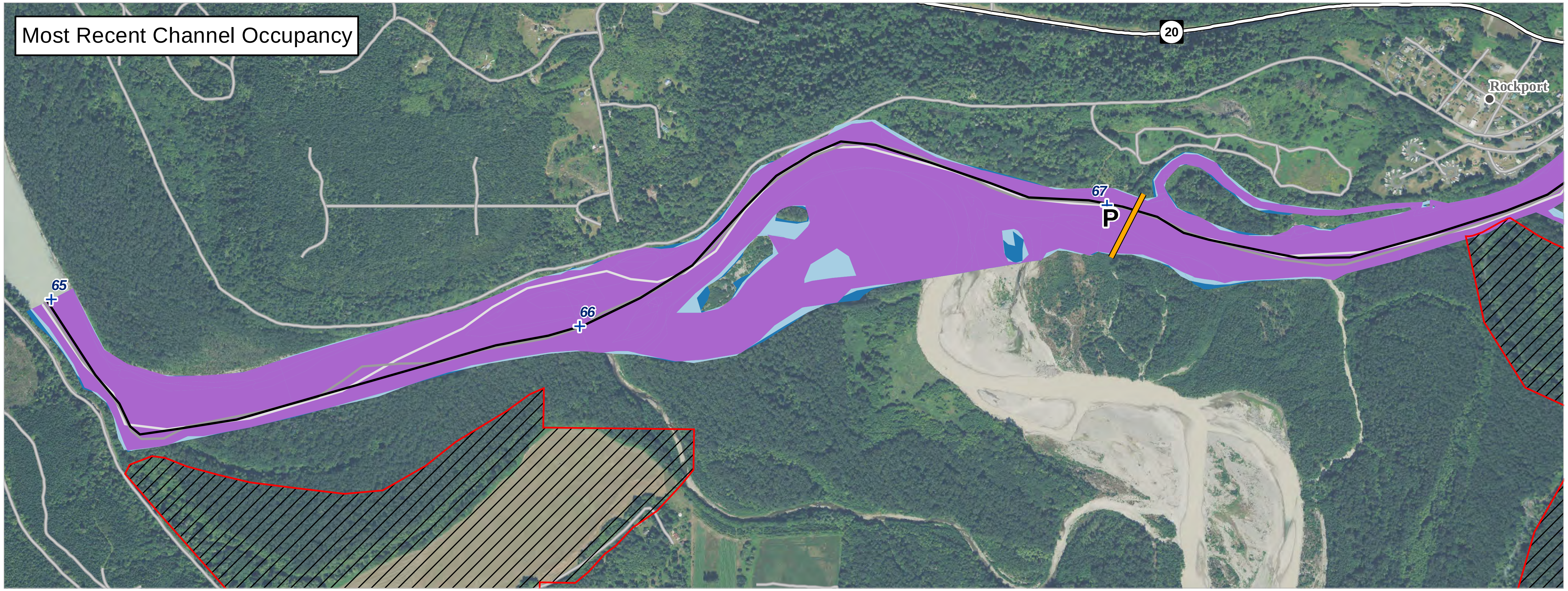
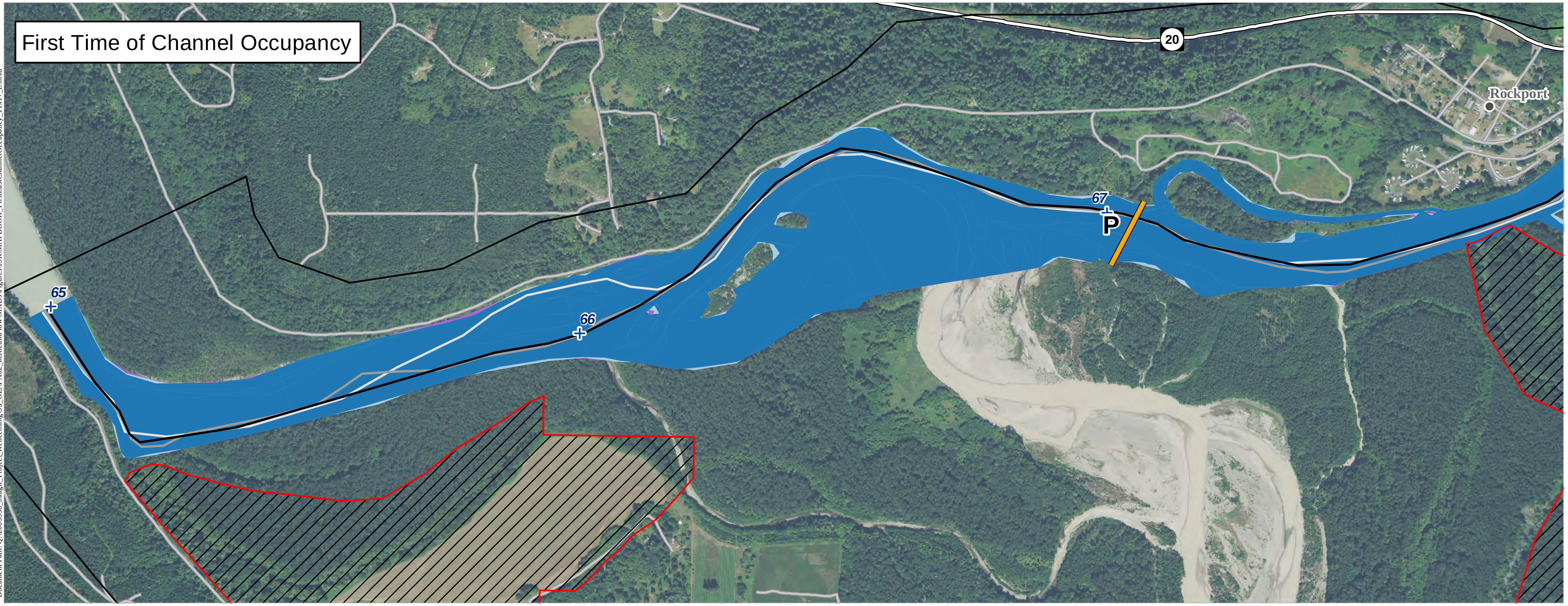
Data Source: USDA NAIP Orthoimagery (2015, 2017, 2019)

Document Path: Q:\2003536_Skagit_Project_Relicensing\95_GIS\FA02_InstreamFlow\MXDs\Figures\ISR\MAPBOOK_HistoricalChannelOccupancy_11x17_L.mxd

APPENDIX C

Bank Erosion and Floodplain Accretion





CHANNEL OCCUPANCY PANEL 1

FERC Project Boundary
Mitigation Parcel
Project River Mile
Calibration Transect

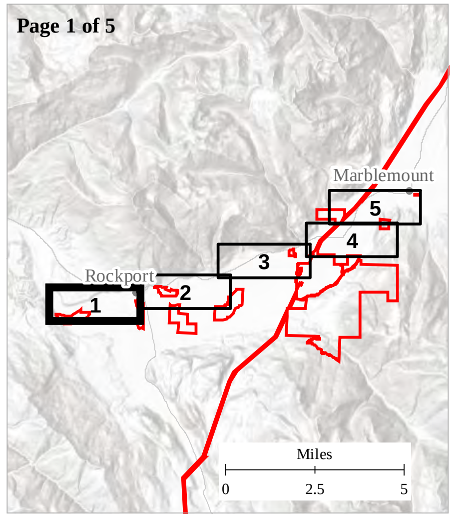
Aerial Image Delineated Thalweg

2015
2017
2019

Channel Occupancy

2015
2017
2019

0 500 1,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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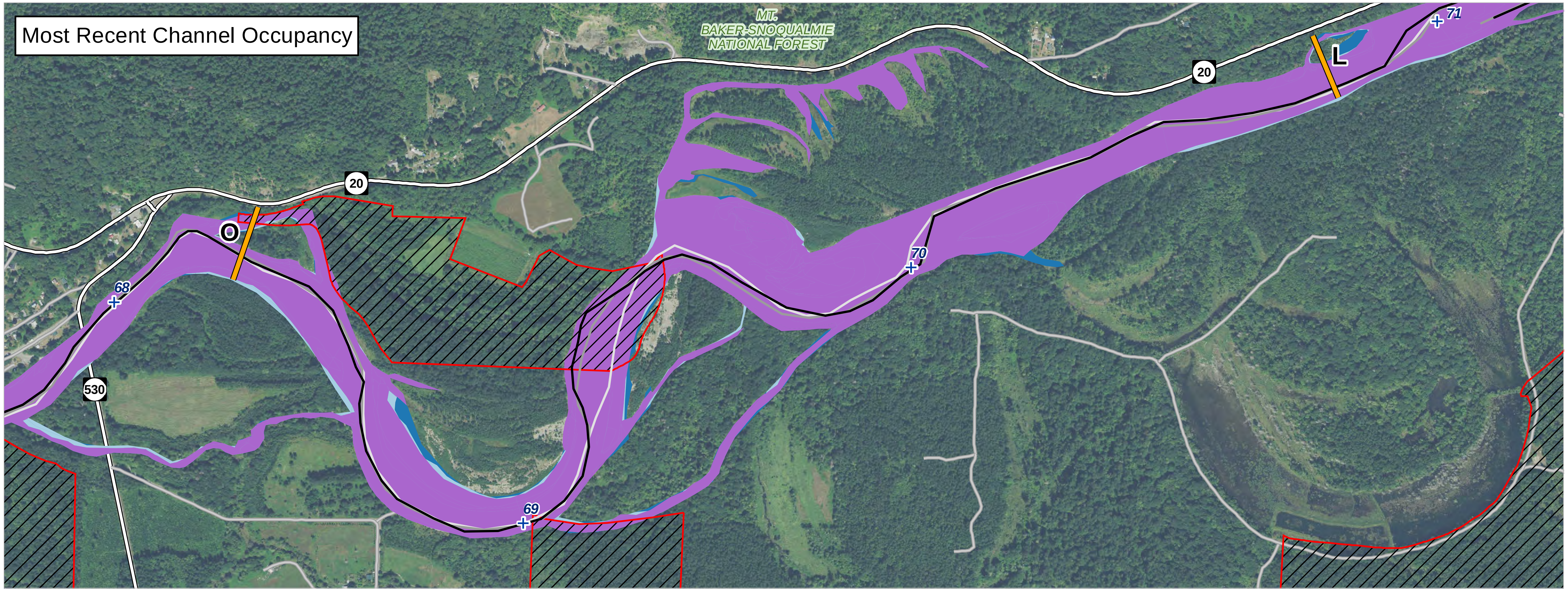
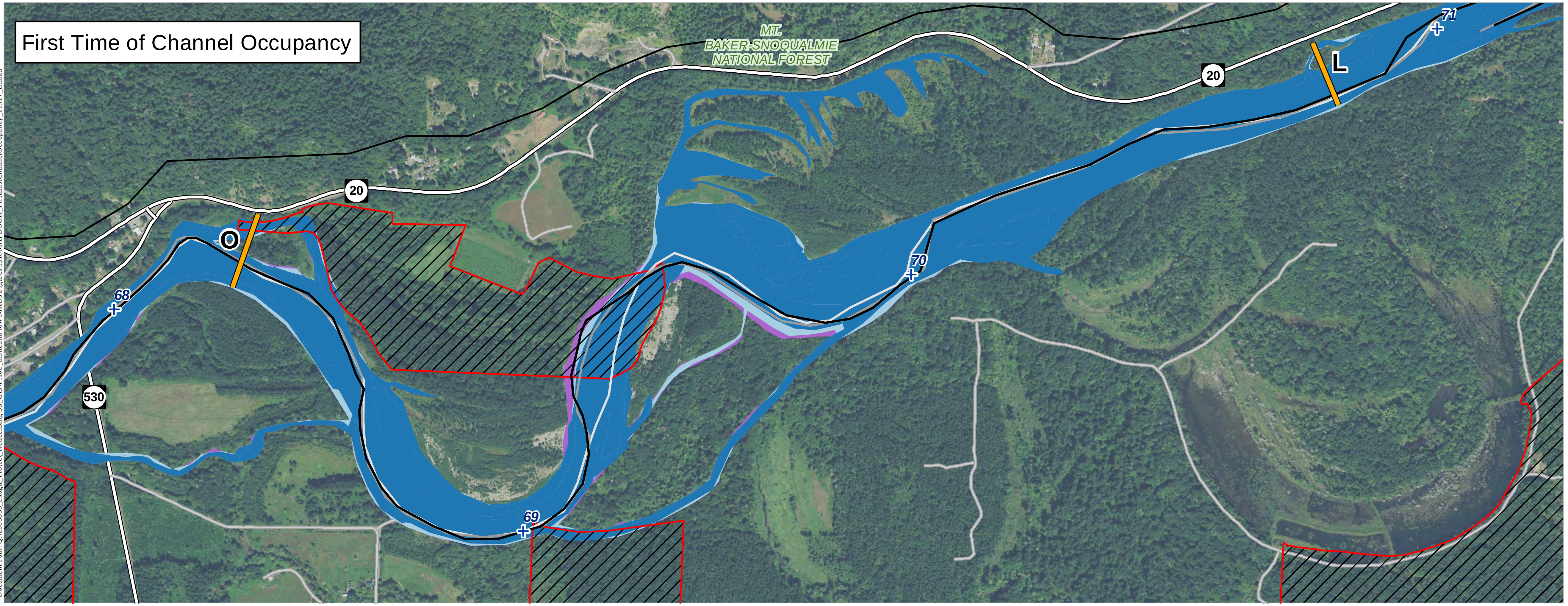
Data Source: USDA NAIP Orthoimagery (2015, 2017, 2019), Northwest Hydraulic Consultants (2021)

Document Path: Q:\2003536_Skagit_Project_Relicensing\95_GIS\FA02_InstreamFlow\MXDs\Figures\ISR\MAPBOOK_FirstLastChannelOccupancy_11x17_L.mxd





CHANNEL OCCUPANCY PANEL 2

FERC Project Boundary
Mitigation Parcel
Project River Mile
Calibration Transect

Aerial Image Delineated Thalweg

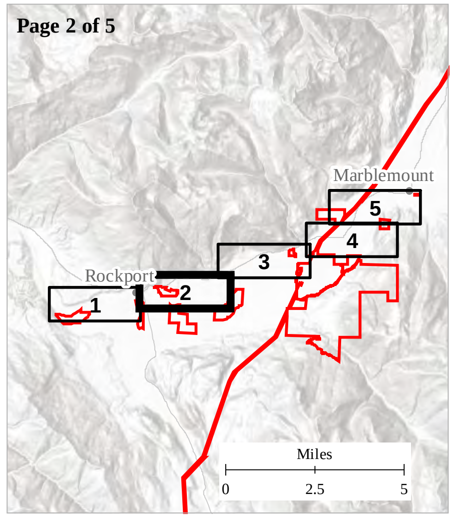
2015
2017
2019

Channel Occupancy

2015
2017
2019

N

0 500 1,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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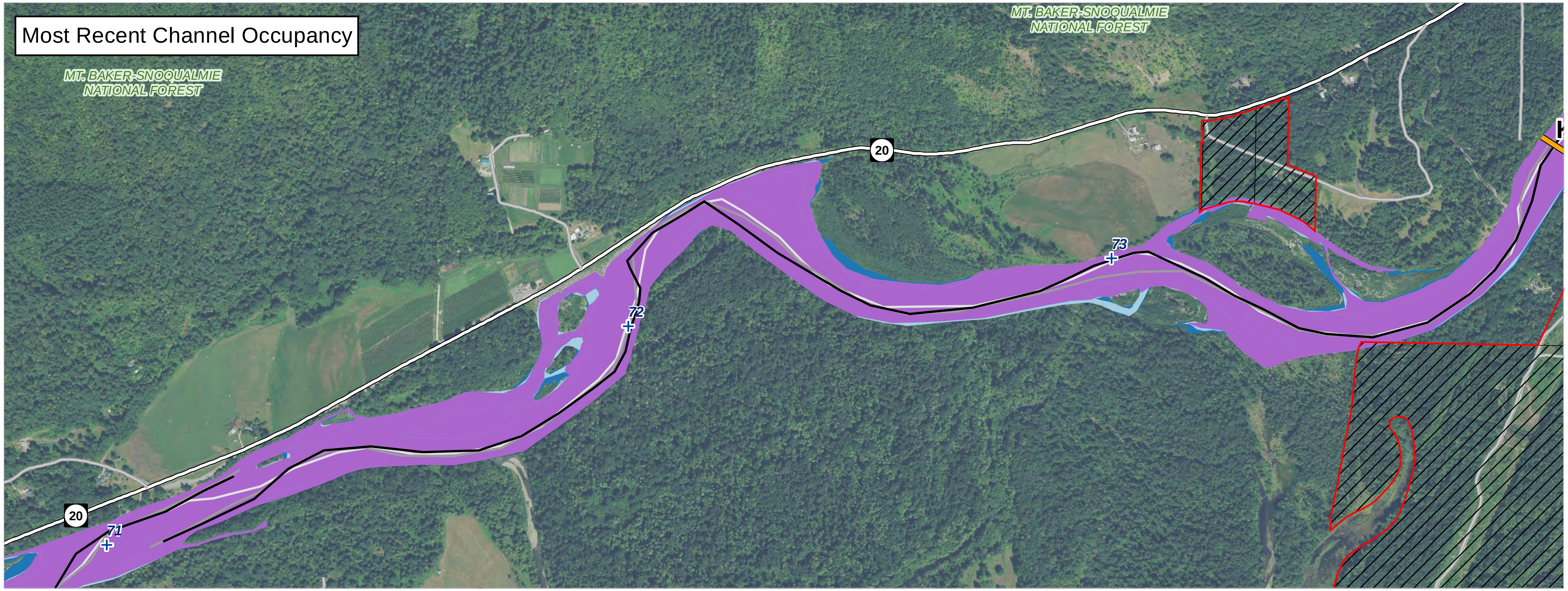
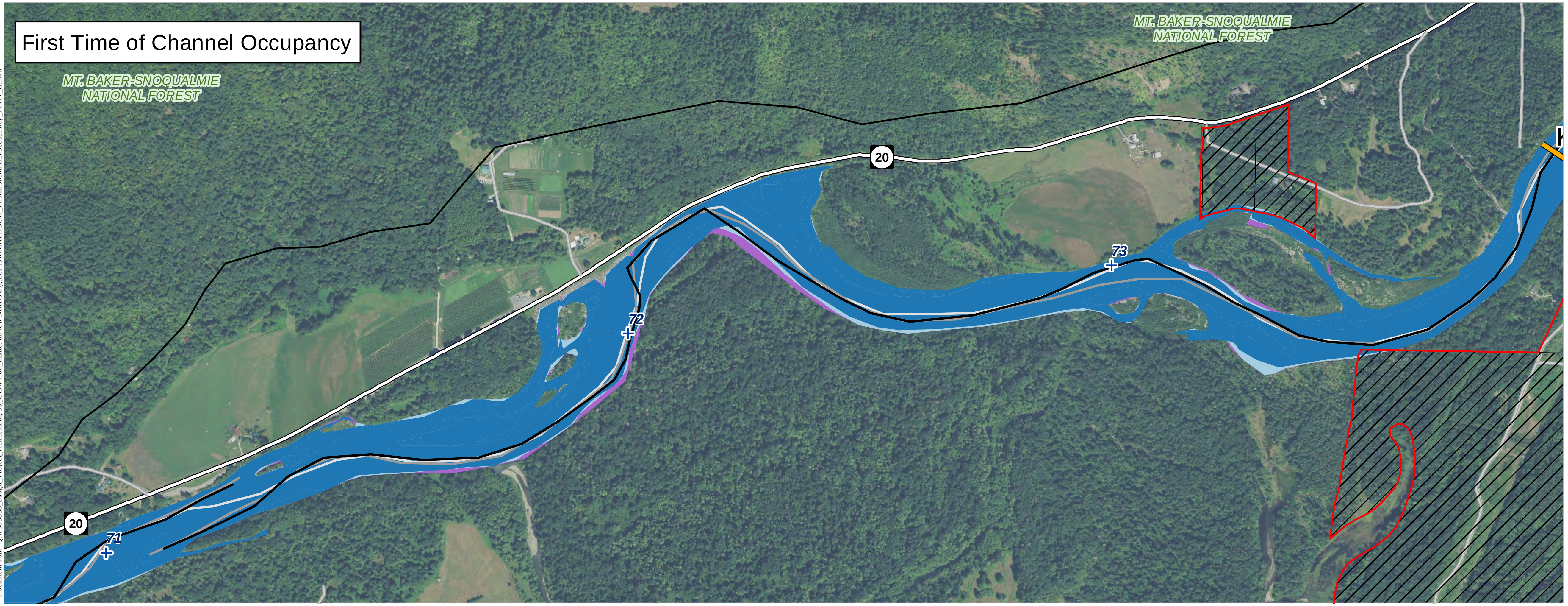
Data Source: USDA NAIP Orthoimagery (2015, 2017, 2019), Northwest Hydraulic Consultants (2021)

Document Path: Q:\2003536_Skagit_Project_Relicensing\95_GIS\FA02_InstreamFlow\MXDs\Figures\ISR\MAPBOOK_FirstLastChannelOccupancy_11x17_L.mxd

CHANNEL OCCUPANCY PANEL 3





- FERC Project Boundary
- Mitigation Parcel
- Project River Mile
- Calibration Transect

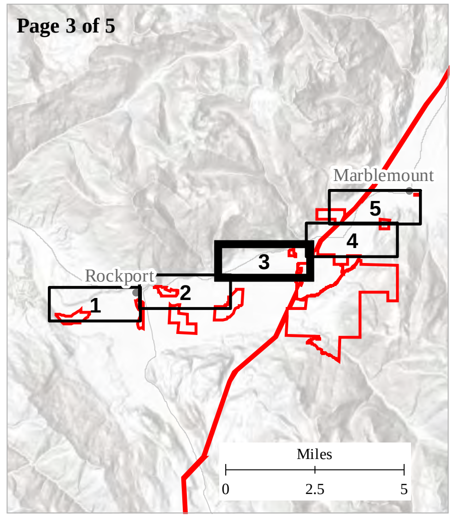
Aerial Image Delineated Thalweg

- 2015
- 2017
- 2019

Channel Occupancy

- 2015
- 2017
- 2019

0 500 1,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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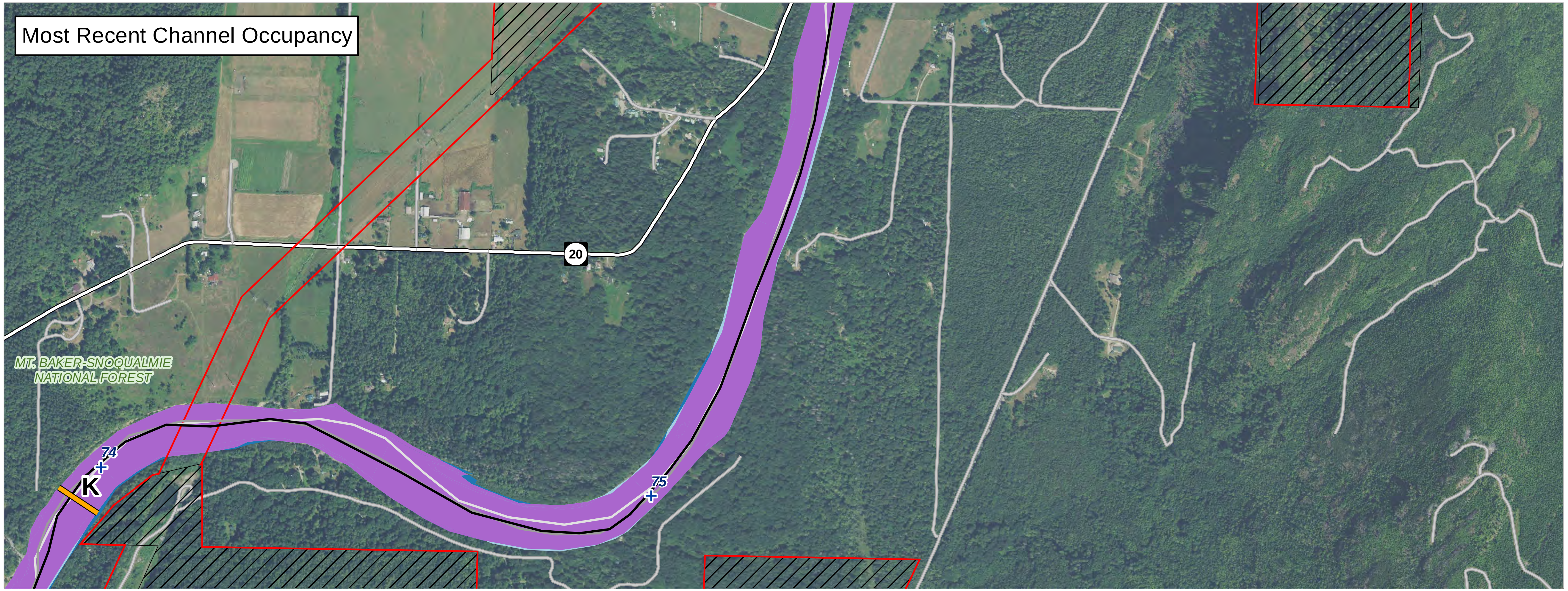
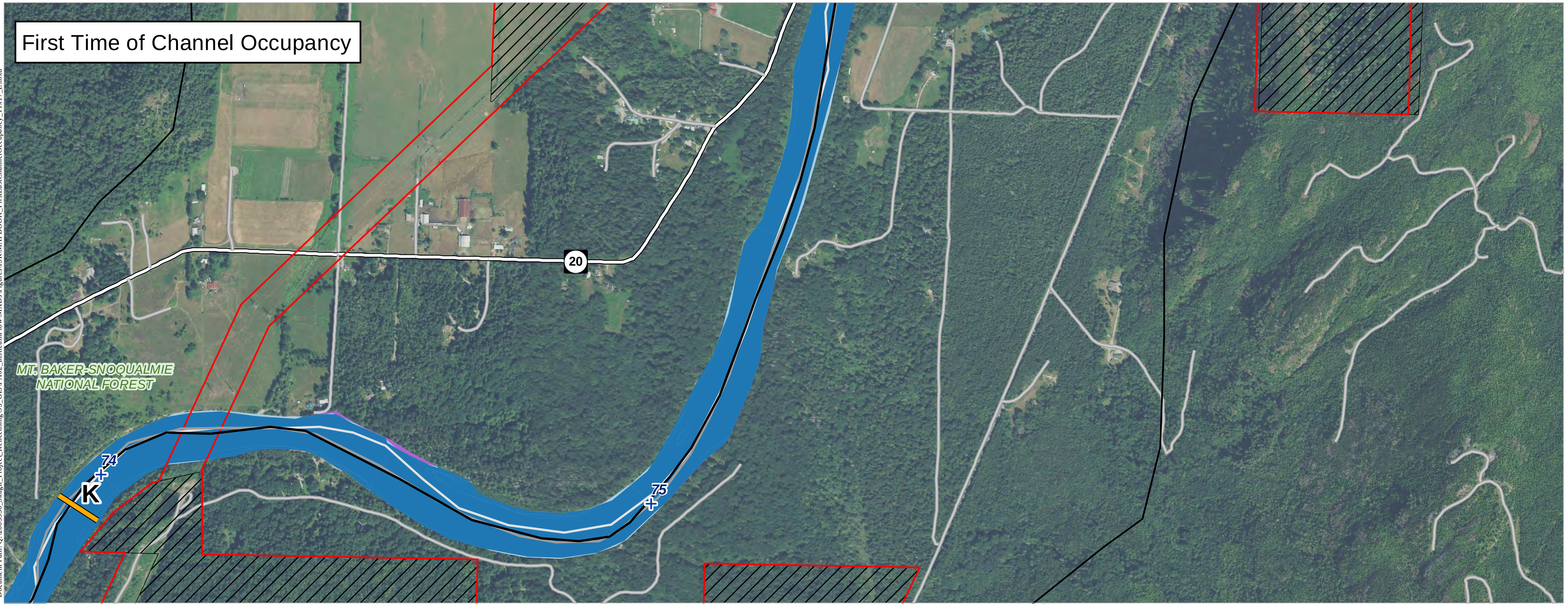
Data Source: USDA NAIP Orthoimagery (2015, 2017, 2019), Northwest Hydraulic Consultants (2021)

Document Path: Q:\2003536_Skagit_Project_Relicensing\95_GIS\FA02_InstreamFlow\MXDs\Figures\ISR\MAPBOOK_FirstLastChannelOccupancy_11x17_L.mxd





CHANNEL OCCUPANCY PANEL 4

FERC Project Boundary
Mitigation Parcel
Project River Mile
Calibration Transect

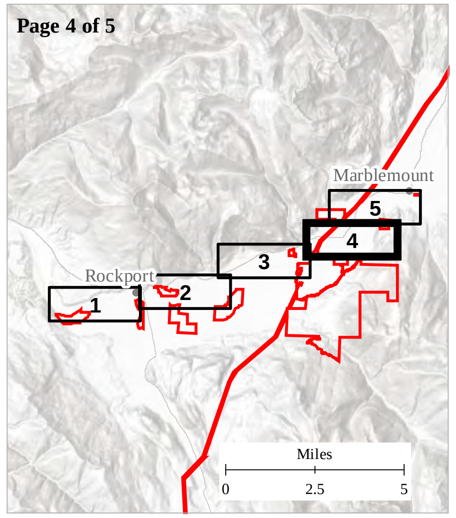
Aerial Image Delineated Thalweg

2015
2017
2019

Channel Occupancy

2015
2017
2019

0 500 1,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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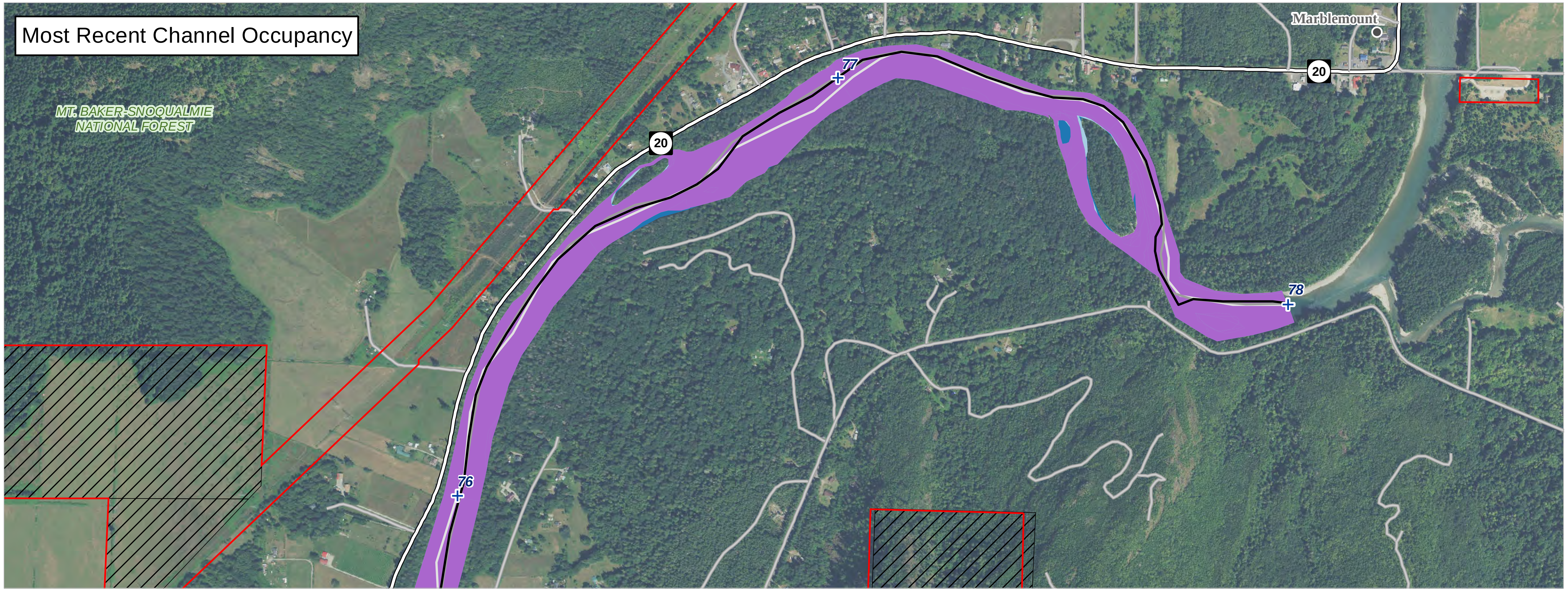
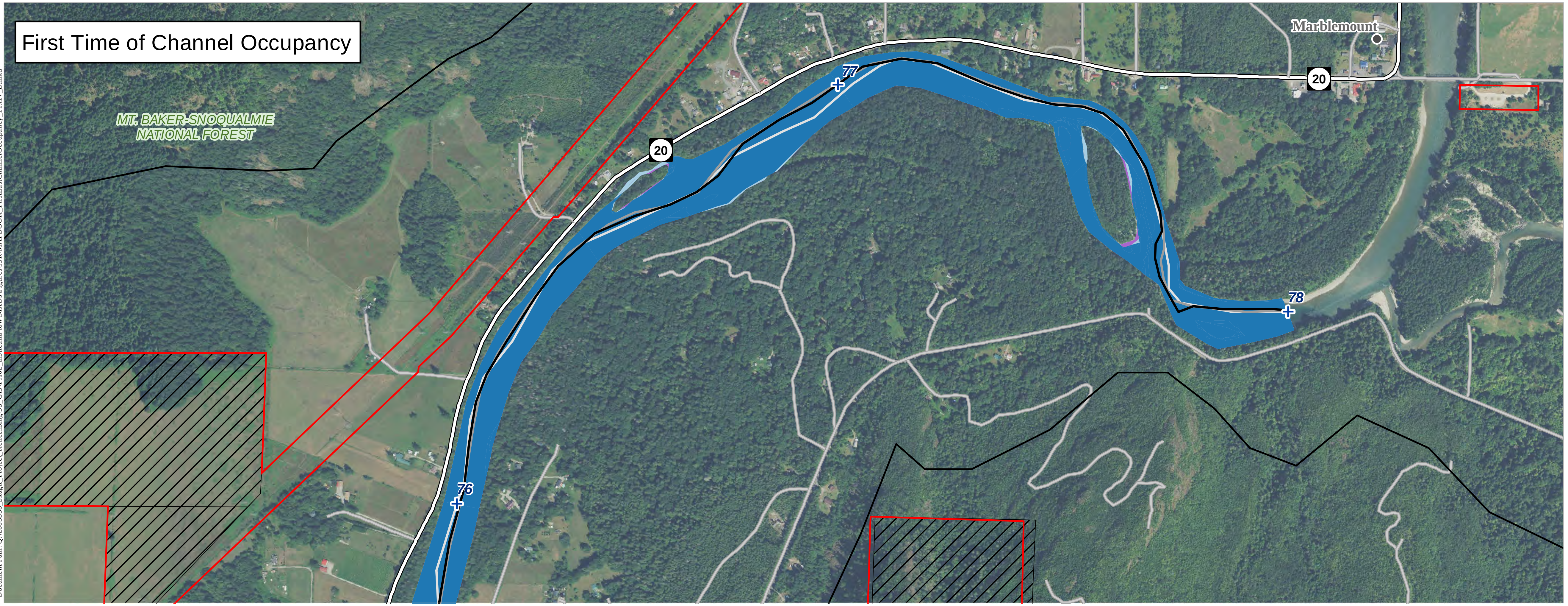
Data Source: USDA NAIP Orthoimagery (2015, 2017, 2019), Northwest Hydraulic Consultants (2021)

Document Path: Q:\2003536_Skagit_Project_Relicensing\95_GIS\FA02_InstreamFlow\MXDs\Figures\ISR\MAPBOOK_FirstLastChannelOccupancy_11x17_L.mxd





CHANNEL OCCUPANCY PANEL 5

FERC Project Boundary
Mitigation Parcel
Project River Mile
Calibration Transect

Aerial Image Delineated Thalweg

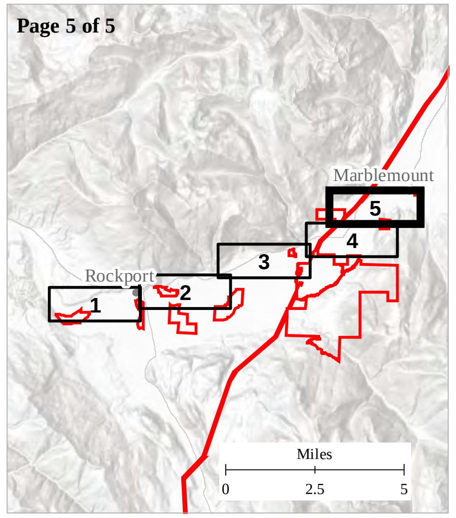
2015
2017
2019

Channel Occupancy

2015
2017
2019

N

0 500 1,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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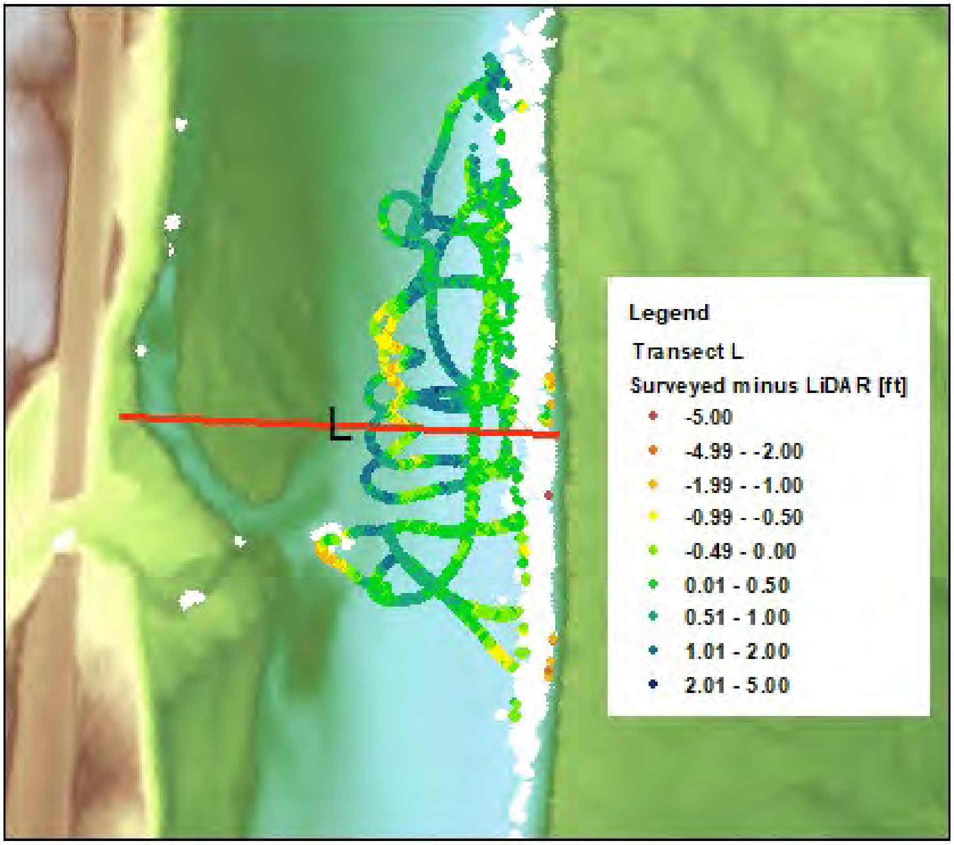
Data Source: USDA NAIP Orthoimagery (2015, 2017, 2019), Northwest Hydraulic Consultants (2021)

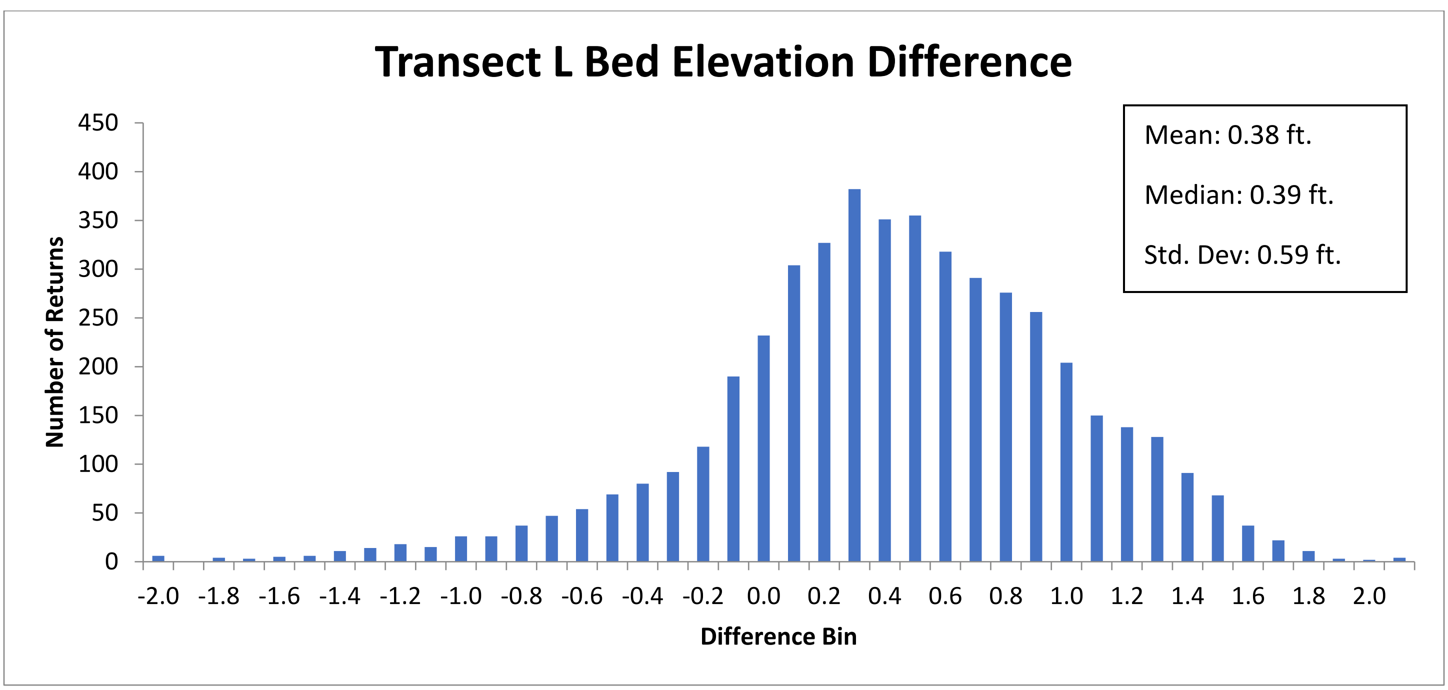
APPENDIX D

Transect Bathymetry Comparison

Transect L – High Discharge Survey

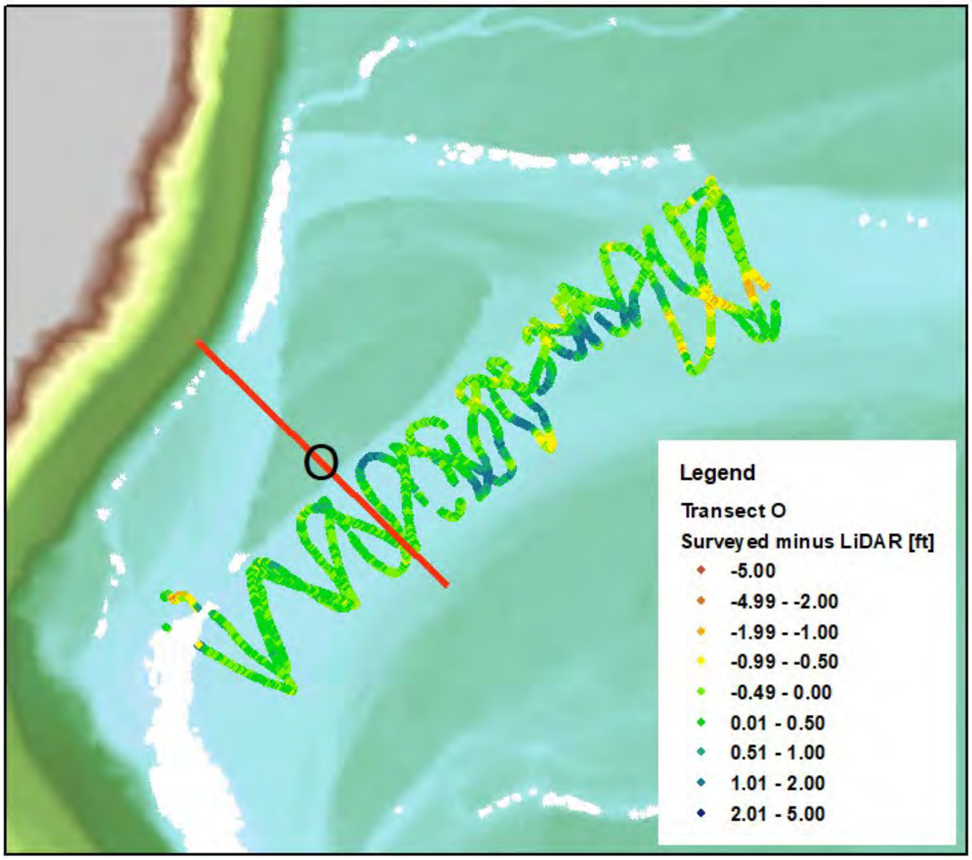
- Located within 2017 Quantum Spatial topobathy surface
- 4771/6158 (77.5%) of survey points fell within topobathy surface, 22.5% fell within a void
- Positive values in the histogram mean surveyed elevation higher than LiDAR elevation

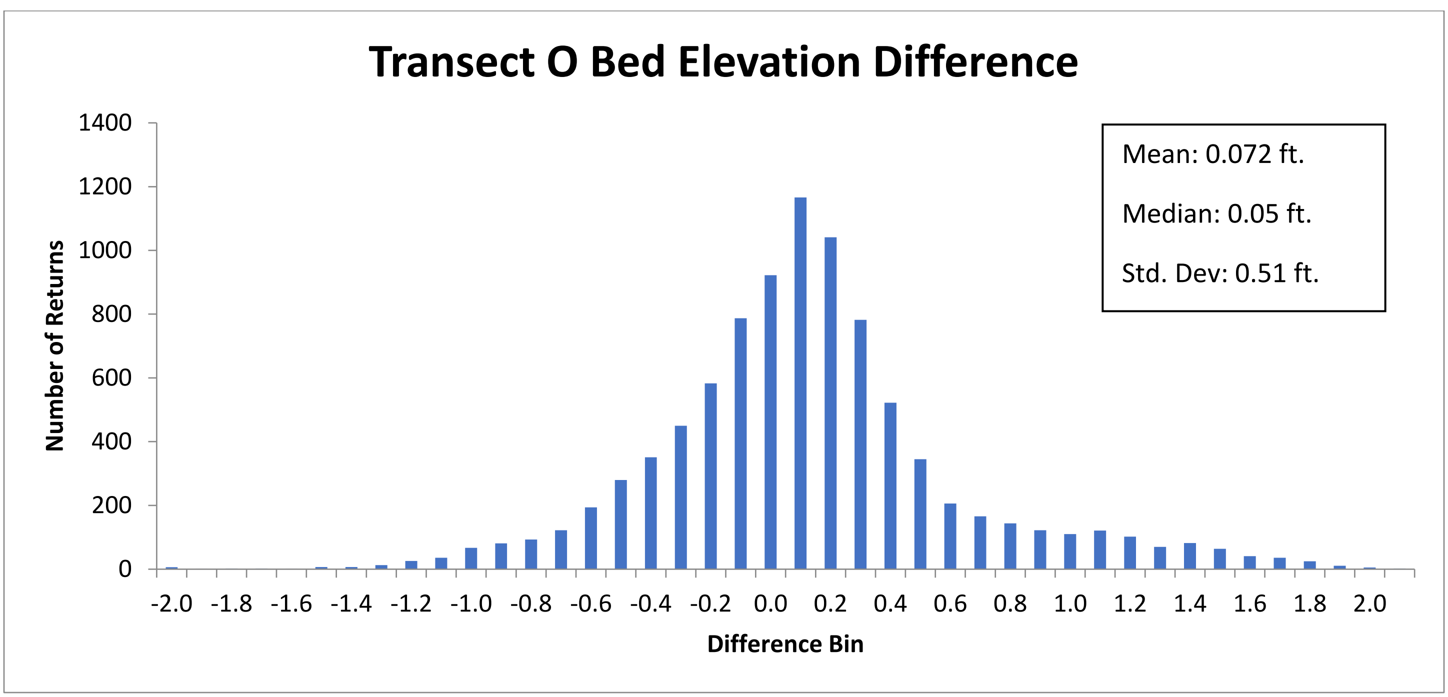




Transect O – High Discharge Survey

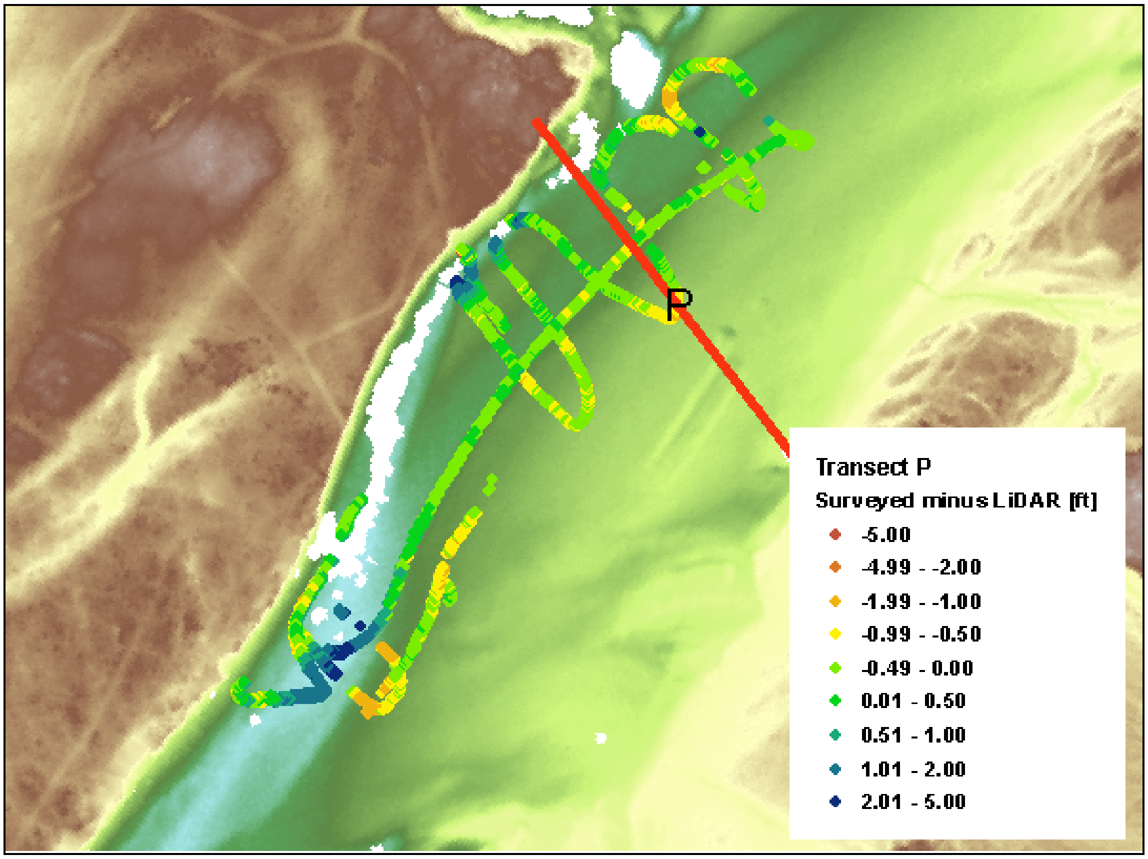
- Located within 2017 Quantum Spatial topobathy surface
- 9194/9322 (98.6%) of survey points fell within topobathy surface, 1.4% fell within a void
- Positive values in the histogram mean surveyed elevation higher than LiDAR elevation

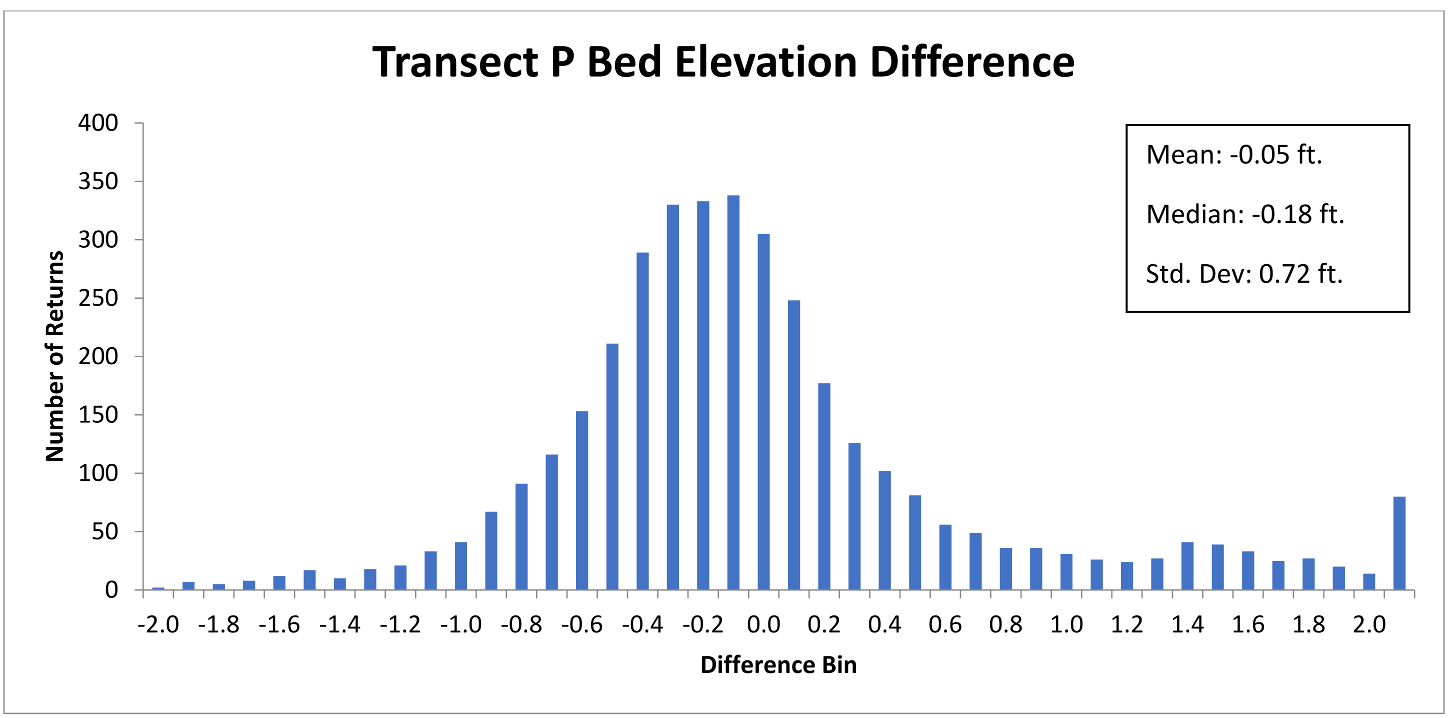




Transect P – High Discharge Survey

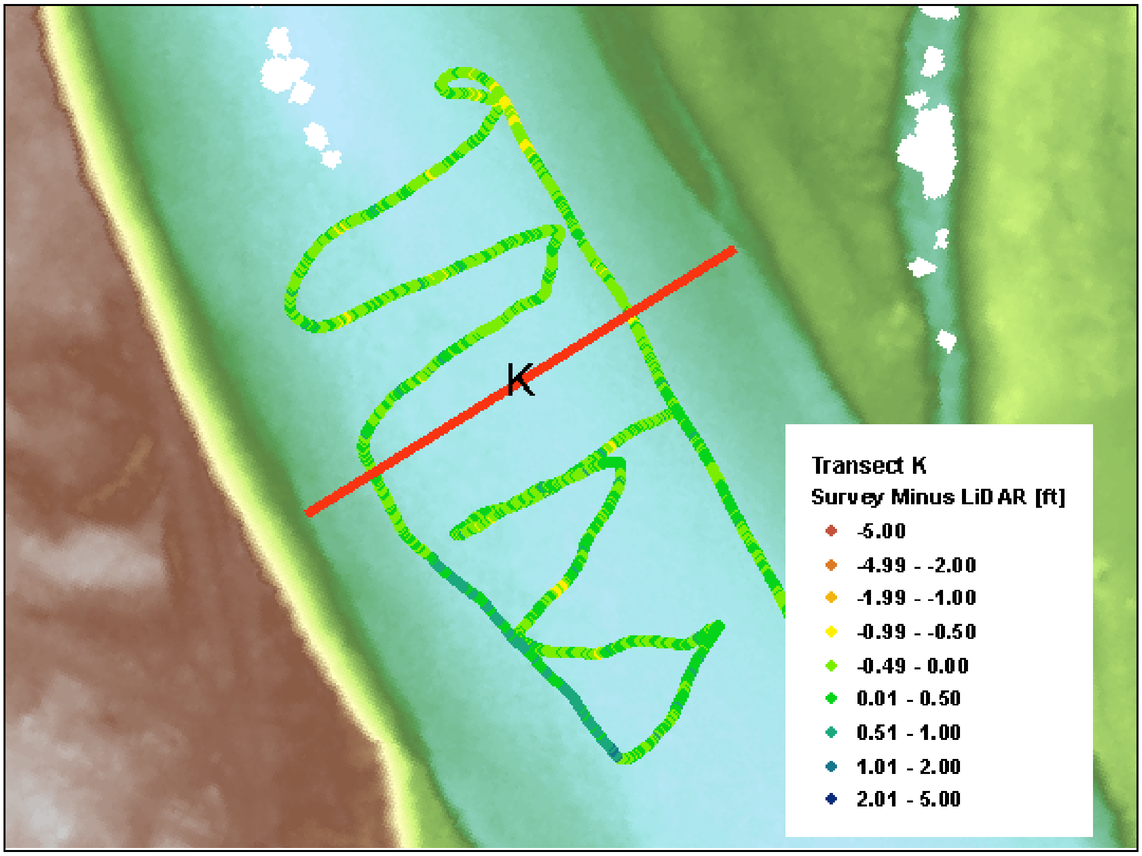
- Located within 2017 Quantum Spatial topobathy surface
- 3705/3957 (93.6%) of survey points fell within topobathy surface, 6.4% fell within a void
- Positive values in the histogram mean surveyed elevation higher than LiDAR elevation

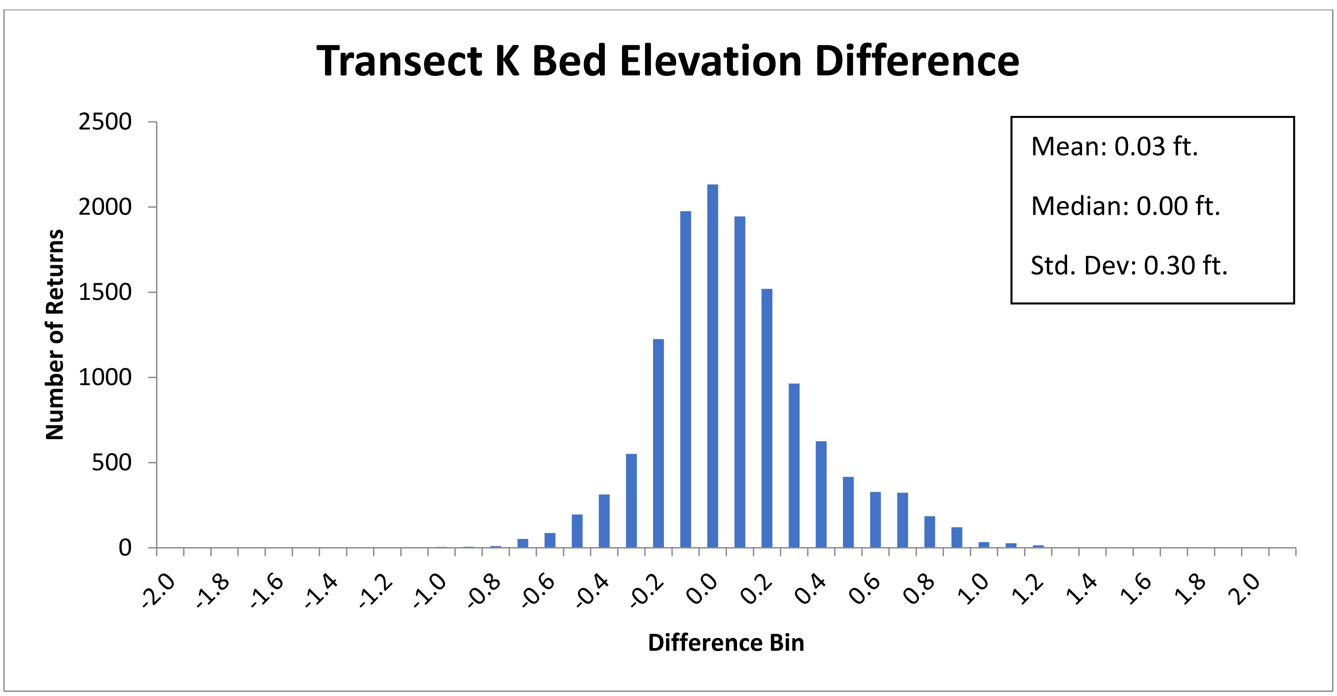




Transect K – Low Discharge

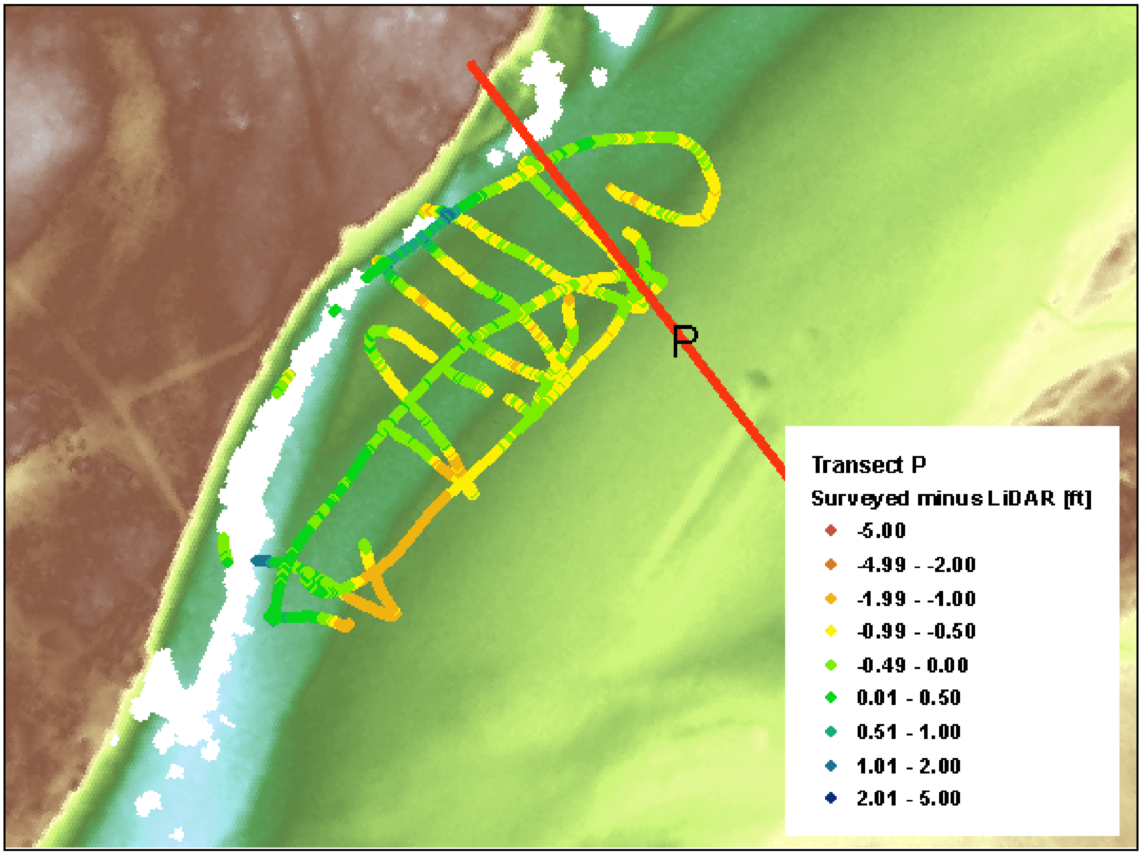
- Located within 2017 Quantum Spatial topobathy surface
- 13057/13057 (100%) of survey points fell within topobathy surface, 0.0% fell within a void
- Positive values in the histogram mean surveyed elevation higher than LiDAR elevation

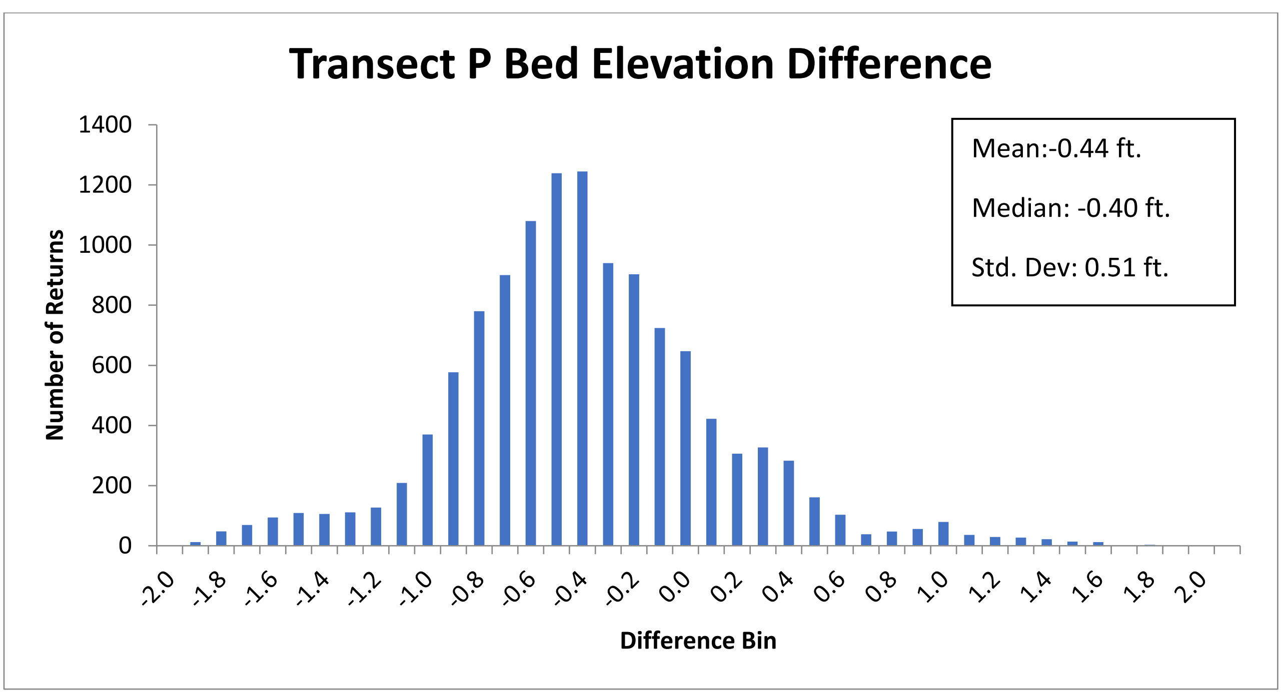




Transect P – Low Discharge

- Located within 2017 Quantum Spatial topobathy surface
- 12257/13067 (93.8%) of survey points fell within topobathy surface, 6.2% fell within a void
- Positive values in the histogram mean surveyed elevation higher than LiDAR elevation





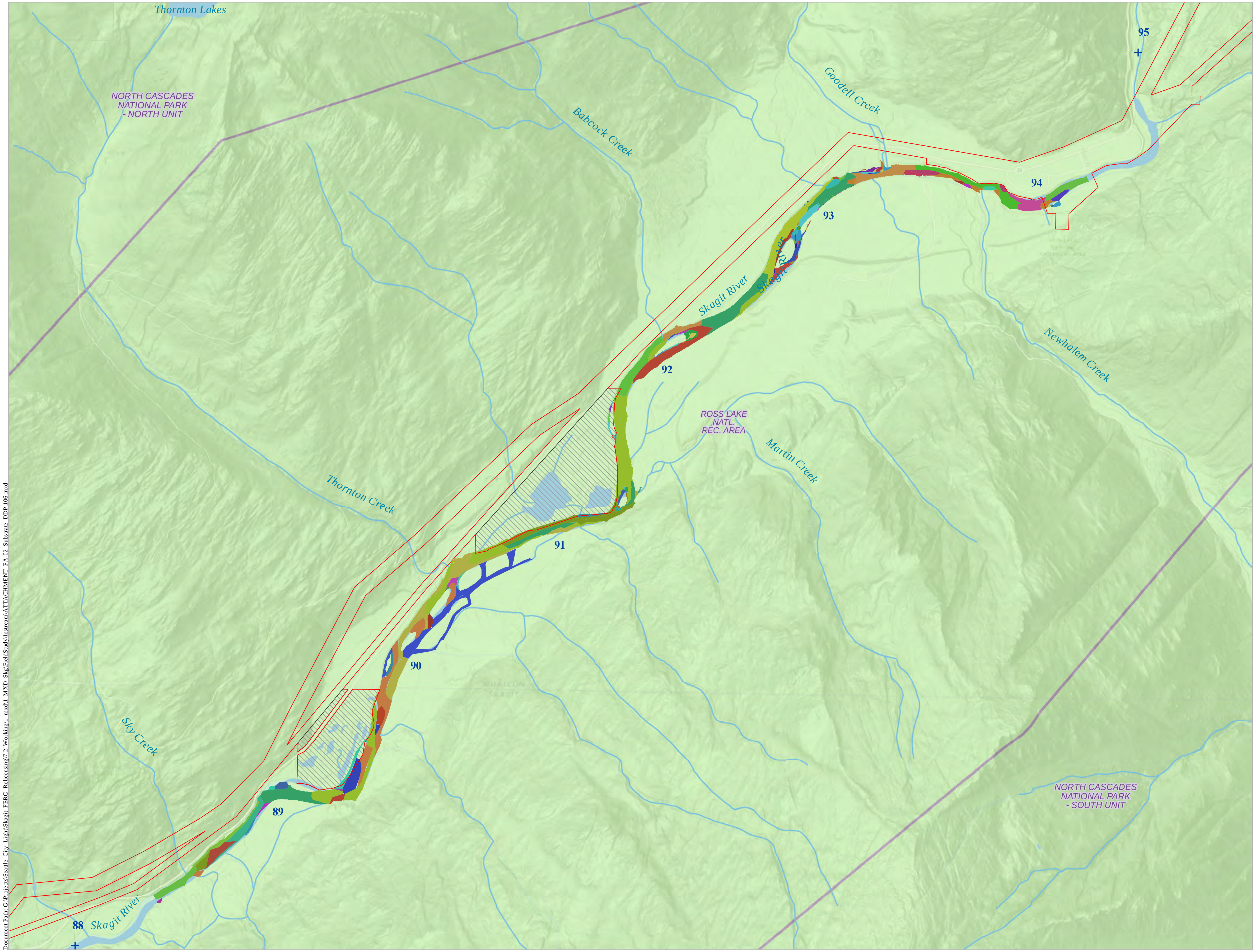
INSTREAM FLOW MODEL DEVELOPMENT STUDY
INTERIM REPORT

ATTACHMENT H

SUBSTRATE AND COVER MAPBOOK

The following substrate and cover maps show substrate and cover codes per Washington State's Instream Flow Study Guidelines (Beecher et al. 2016). Details on the coding system are provided in Section 4.2.4 of the preceding report text.

With respect to substrate codes, the guidelines stipulate use of dominant and subdominant substrate combinations that result in numerous possible substrate codes. The polygon visual attributes in the following substrate maps and the corresponding legend were selected to highlight the detail resulting from mapping efforts, while also condensing results to a point that is reasonable for an informed review of a large 2-D instream flow study area.



Document Path: G:\Projects\Seattle_City_Light\Skagit_FERC_Relicensing\7.2_Working\1_mxd\1_MXD_Skg\FieldStudy\Instream\ATTACHMENT_FA-02_Substrate_DDP_106.mxd

FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – SUBSTRATE

FERC Project Boundary
Mitigation Parcel
Project River Miles (PRM)

Substrate Coding

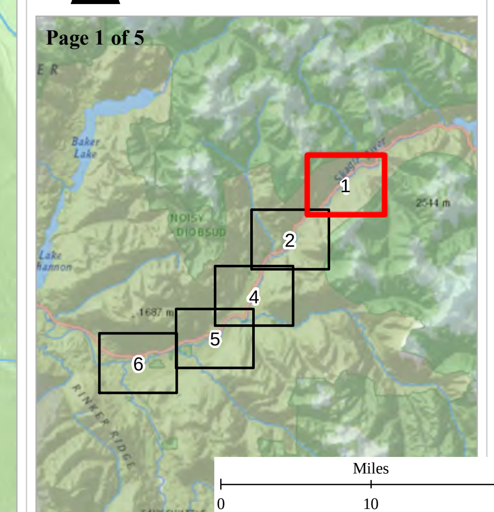
74.6	23	28.9	45.50	56.5	67	78.8
76.6	23.5	32.5	45.6	56.6	67.5	78.9
11.5	23.6	32.6	45.7	56.7	67.6	8
11.5*	23.7	32.7	45.8	56.8	67.7	81
12	23.8	32.8	45.9	56.9	67.8	81.9
12.3	23.9	32.9	46.5	57	67.9	82.6
12.5	24	34.5	46.6	57.5	67:6	82.7
12.6	24.5	34.6	46.7	57.7	68	82.8
12.7	24.6	34.7	46.8	57.8	68.6	82.9
12.8	24.7	34.8	47.6	58.6	68.7	85.7
12.9	24.8	34.9	47.8	58.7	68.8	85.9
13.9	24.9	35.4	51	58.8	7	86
14.7	25	35.6	51.7	61.5	71.6	86.6
14.8	25..9	35.7	51.8	61.7	72.5	86.7
15.7	25.3	35.8	52	61.8	72.6	86.8
15.8	25.5	36.6	52.4	62	72.7	87
15.9	25.6	36.7	52.5	62.5	72.8	87.5
16.6	25.7	36.8	52.6	62.6	74.6	87.6
16.7	25.8	37.6	52.7	62.7	74.7	87.7
16.8	25.9	37.8	52.8	62.8	75	87.8
16.9	26	42	52.9	63.5	75.5	87.9
17.7	26.5	42.5	53	63.7	75.6	88.5
17.8	26.6	42.6	53.5	63.8	75.7	88.9
17.9	26.7	42.7	53.6	64	76	89.5
18.8	26.8	42.9	53.7	64.5	76.5	89.6
18.9	26.9	43.4	54	64.6	76.6	89.8
19.9	27	43.5	54.4	64.7	76.7	89.9
21	27.6	43.6	54.5	64.8	76.8	9
21.5	27.7	43.7	54.6	65	76.9	98.6
21.6	27.8	43.8	54.7	65.5	78	98.8
21.7	27.9	43.9	54.8	65.6	78.4	98.9
21.8	28.6	45	54.9	65.7	78.5	99.5
21.9	28.7	45.3	56	65.8	78.6	
22.5	28.8	45.5	56.4	65.9	78.7	

Land Ownership

National Park / National Recreation Area Boundary

N

0 1,000 2,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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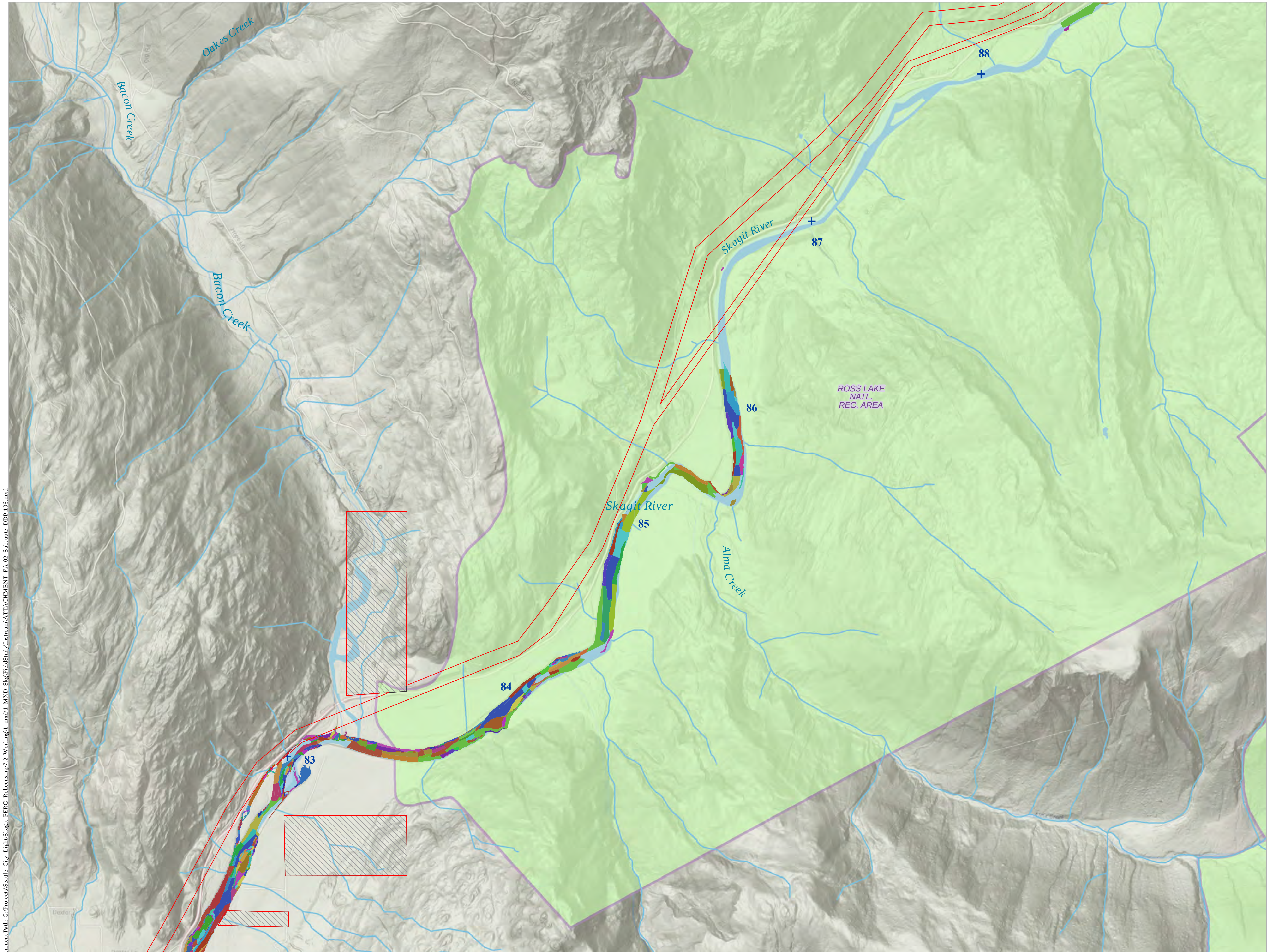
Data Source: Substrate - HDR.



FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – SUBSTRATE

FERC Project Boundary
Mitigation Parcel
+ Project River Miles (PRM)

Substrate Coding

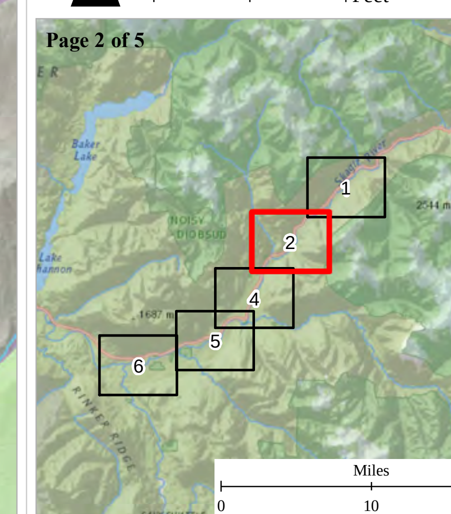
74.6	23	28.9	45.50	56.5	67	78.8
76.6	23.5	32.5	45.6	56.6	67.5	78.9
11.5	23.6	32.6	45.7	56.7	67.6	8
11.5*	23.7	32.7	45.8	56.8	67.7	81
12	23.8	32.8	45.9	56.9	67.8	81.9
12.3	23.9	32.9	46.5	57	67.9	82.6
12.5	24	34.5	46.6	57.5	67:6	82.7
12.6	24.5	34.6	46.7	57.7	68	82.8
12.7	24.6	34.7	46.8	57.8	68.6	82.9
12.8	24.7	34.8	47.6	58.6	68.7	85.7
12.9	24.8	34.9	47.8	58.7	68.8	85.9
13.9	24.9	35.4	51	58.8	7	86
14.7	25	35.6	51.7	61.5	71.6	86.6
14.8	25..9	35.7	51.8	61.7	72.5	86.7
15.7	25.3	35.8	52	61.8	72.6	86.8
15.8	25.5	36.6	52.4	62	72.7	87
15.9	25.6	36.7	52.5	62.5	72.8	87.5
16.6	25.7	36.8	52.6	62.6	74.6	87.6
16.7	25.8	37.6	52.7	62.7	74.7	87.7
16.8	25.9	37.8	52.8	62.8	75	87.8
16.9	26	42	52.9	63.5	75.5	87.9
17.7	26.5	42.5	53	63.7	75.6	88.5
17.8	26.6	42.6	53.5	63.8	75.7	88.9
17.9	26.7	42.7	53.6	64	76	89.5
18.8	26.8	42.9	53.7	64.5	76.5	89.6
18.9	26.9	43.4	54	64.6	76.6	89.8
19.9	27	43.5	54.4	64.7	76.7	89.9
21	27.6	43.6	54.5	64.8	76.8	9
21.5	27.7	43.7	54.6	65	76.9	98.6
21.6	27.8	43.8	54.7	65.5	78	98.8
21.7	27.9	43.9	54.8	65.6	78.4	98.9
21.8	28.6	45	54.9	65.7	78.5	99.5
21.9	28.7	45.3	56	65.8	78.6	
22.5	28.8	45.5	56.4	65.9	78.7	

Land Ownership

National Park / National Recreation Area Boundary

N

0 1,000 2,000 Feet



Seattle City Light

SKAGIT RIVER HYDROELECTRIC PROJECT (FERC NO. 553)

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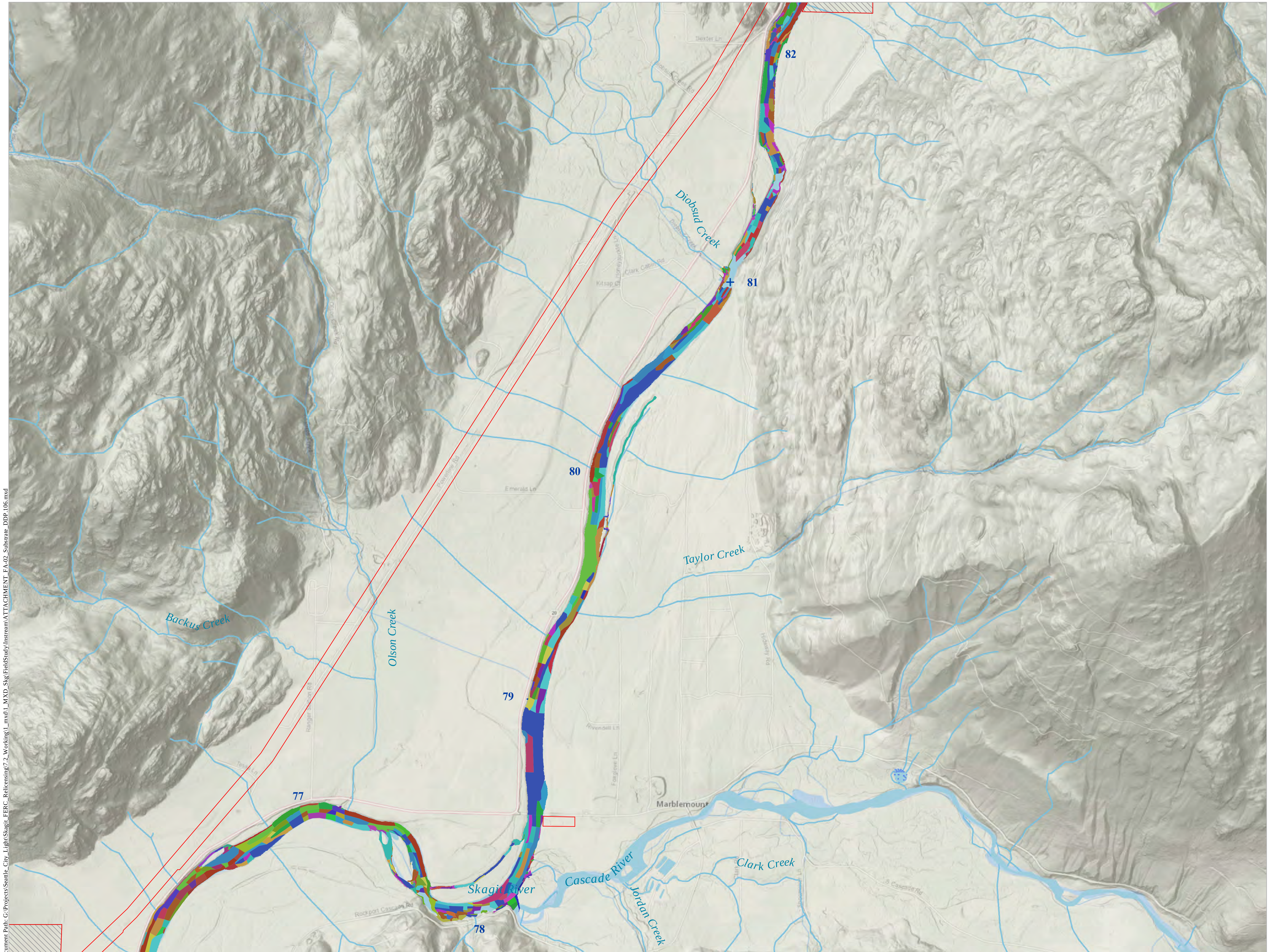
Data Source: Substrate - HDR.

Document Path: G:\Projects\Seattle_City_Light\Skagit_FERC_Relicensing\7.2_Working\1_mxd\1_MXD_Skg\FieldStudy\Instream\ATTACHMENT_FA-02_Substrate_DDP_106.mxd



FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – SUBSTRATE

FERC Project Boundary
Mitigation Parcel
+ Project River Miles (PRM)

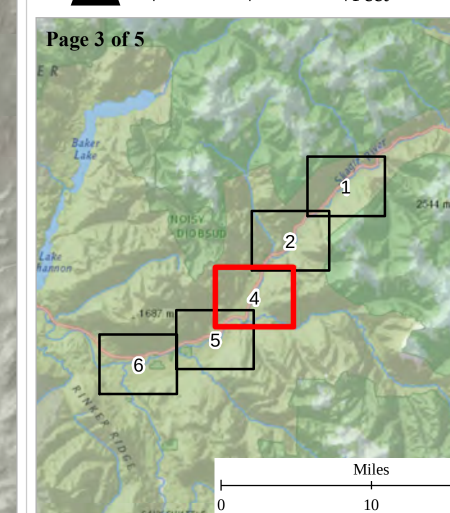
Substrate Coding

74.6	23	28.9	45.50	56.5	67	78.8
76.6	23.5	32.5	45.6	56.6	67.5	78.9
11.5	23.6	32.6	45.7	56.7	67.6	8
11.5*	23.7	32.7	45.8	56.8	67.7	81
12	23.8	32.8	45.9	56.9	67.8	81.9
12.3	23.9	32.9	46.5	57	67.9	82.6
12.5	24	34.5	46.6	57.5	67:6	82.7
12.6	24.5	34.6	46.7	57.7	68	82.8
12.7	24.6	34.7	46.8	57.8	68.6	82.9
12.8	24.7	34.8	47.6	58.6	68.7	85.7
12.9	24.8	34.9	47.8	58.7	68.8	85.9
13.9	24.9	35.4	51	58.8	7	86
14.7	25	35.6	51.7	61.5	71.6	86.6
14.8	25..9	35.7	51.8	61.7	72.5	86.7
15.7	25.3	35.8	52	61.8	72.6	86.8
15.8	25.5	36.6	52.4	62	72.7	87
15.9	25.6	36.7	52.5	62.5	72.8	87.5
16.6	25.7	36.8	52.6	62.6	74.6	87.6
16.7	25.8	37.6	52.7	62.7	74.7	87.7
16.8	25.9	37.8	52.8	62.8	75	87.8
16.9	26	42	52.9	63.5	75.5	87.9
17.7	26.5	42.5	53	63.7	75.6	88.5
17.8	26.6	42.6	53.5	63.8	75.7	88.9
17.9	26.7	42.7	53.6	64	76	89.5
18.8	26.8	42.9	53.7	64.5	76.5	89.6
18.9	26.9	43.4	54	64.6	76.6	89.8
19.9	27	43.5	54.4	64.7	76.7	89.9
21	27.6	43.6	54.5	64.8	76.8	9
21.5	27.7	43.7	54.6	65	76.9	98.6
21.6	27.8	43.8	54.7	65.5	78	98.8
21.7	27.9	43.9	54.8	65.6	78.4	98.9
21.8	28.6	45	54.9	65.7	78.5	99.5
21.9	28.7	45.3	56	65.8	78.6	
22.5	28.8	45.5	56.4	65.9	78.7	

Land Ownership

National Park / National Recreation Area Boundary

0 1,000 2,000 Feet



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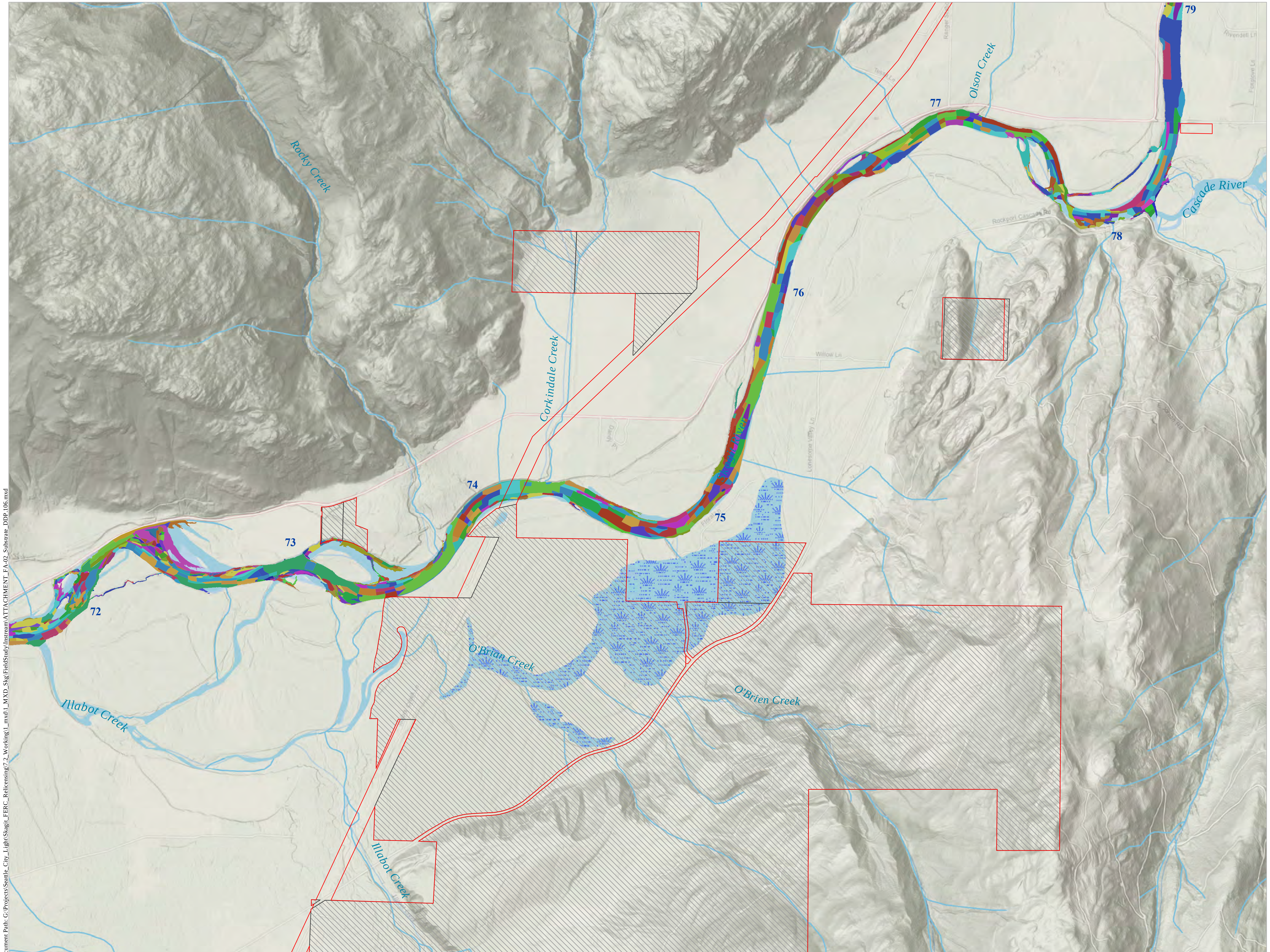


FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – SUBSTRATE

FERC Project Boundary
Mitigation Parcel
Project River Miles (PRM)

Substrate Coding

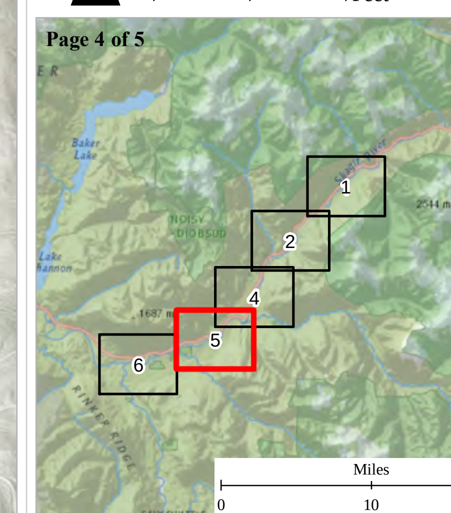
74.6	23	28.9	45.50	56.5	67	78.8
76.6	23.5	32.5	45.6	56.6	67.5	78.9
11.5	23.6	32.6	45.7	56.7	67.6	8
11.5*	23.7	32.7	45.8	56.8	67.7	81
12	23.8	32.8	45.9	56.9	67.8	81.9
12.3	23.9	32.9	46.5	57	67.9	82.6
12.5	24	34.5	46.6	57.5	67:6	82.7
12.6	24.5	34.6	46.7	57.7	68	82.8
12.7	24.6	34.7	46.8	57.8	68.6	82.9
12.8	24.7	34.8	47.6	58.6	68.7	85.7
12.9	24.8	34.9	47.8	58.7	68.8	85.9
13.9	24.9	35.4	51	58.8	7	86
14.7	25	35.6	51.7	61.5	71.6	86.6
14.8	25..9	35.7	51.8	61.7	72.5	86.7
15.7	25.3	35.8	52	61.8	72.6	86.8
15.8	25.5	36.6	52.4	62	72.7	87
15.9	25.6	36.7	52.5	62.5	72.8	87.5
16.6	25.7	36.8	52.6	62.6	74.6	87.6
16.7	25.8	37.6	52.7	62.7	74.7	87.7
16.8	25.9	37.8	52.8	62.8	75	87.8
16.9	26	42	52.9	63.5	75.5	87.9
17.7	26.5	42.5	53	63.7	75.6	88.5
17.8	26.6	42.6	53.5	63.8	75.7	88.9
17.9	26.7	42.7	53.6	64	76	89.5
18.8	26.8	42.9	53.7	64.5	76.5	89.6
18.9	26.9	43.4	54	64.6	76.6	89.8
19.9	27	43.5	54.4	64.7	76.7	89.9
21	27.6	43.6	54.5	64.8	76.8	9
21.5	27.7	43.7	54.6	65	76.9	98.6
21.6	27.8	43.8	54.7	65.5	78	98.8
21.7	27.9	43.9	54.8	65.6	78.4	98.9
21.8	28.6	45	54.9	65.7	78.5	99.5
21.9	28.7	45.3	56	65.8	78.6	
22.5	28.8	45.5	56.4	65.9	78.7	

Land Ownership

National Park / National Recreation Area Boundary

N

0 1,000 2,000 Feet



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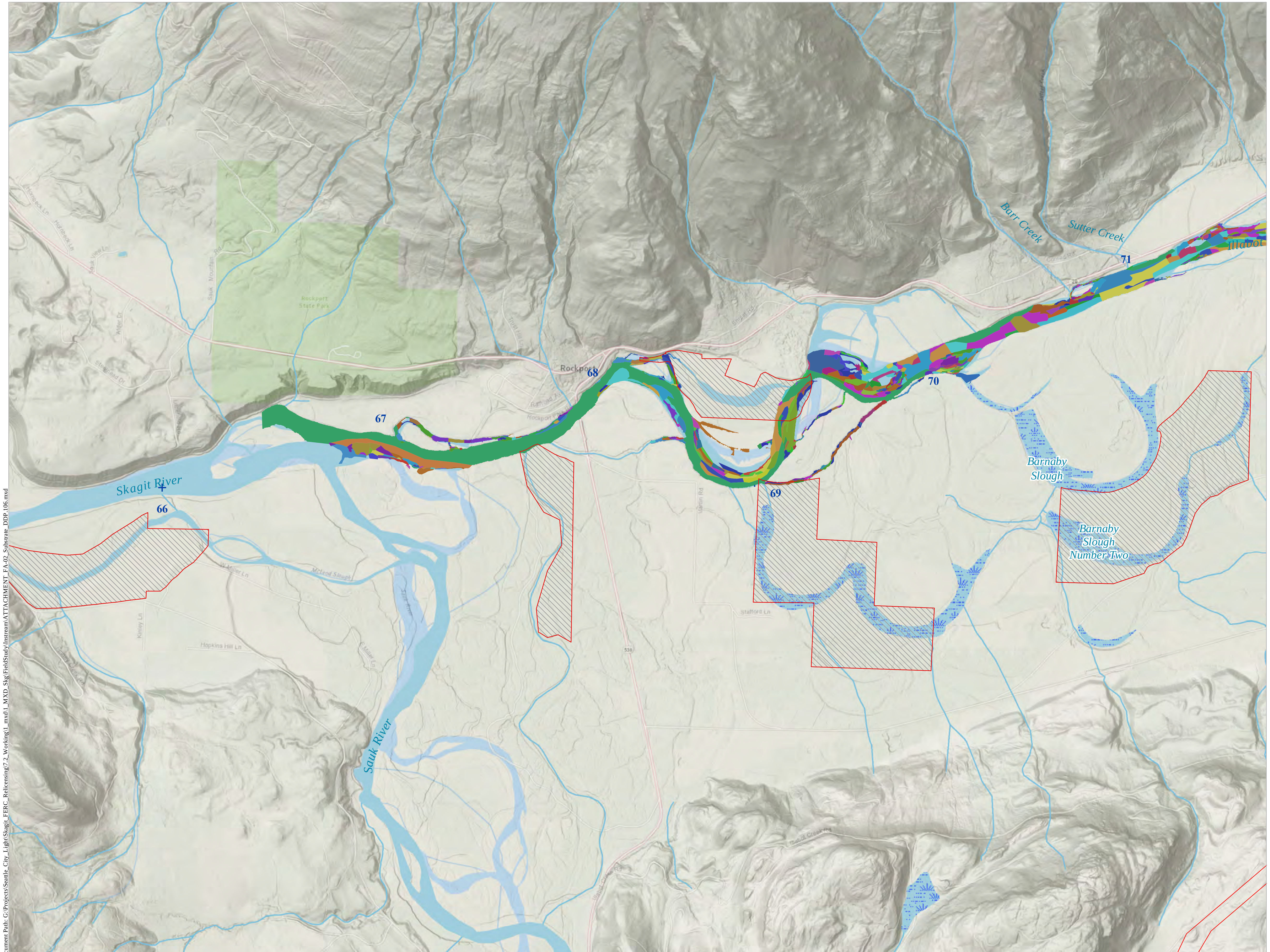

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FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – SUBSTRATE

FERC Project Boundary
Mitigation Parcel
+ Project River Miles (PRM)

Substrate Coding

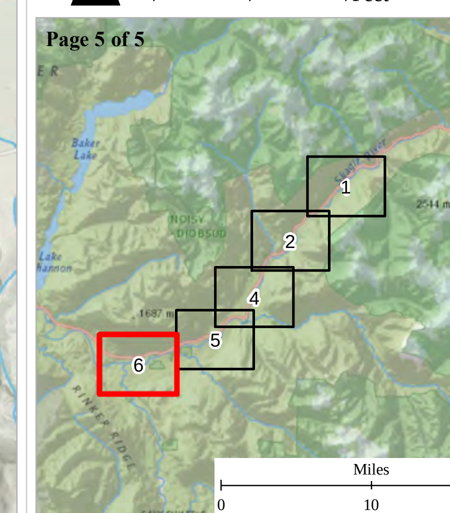
74.6	23	28.9	45.50	56.5	67	78.8
76.6	23.5	32.5	45.6	56.6	67.5	78.9
11.5	23.6	32.6	45.7	56.7	67.6	8
11.5*	23.7	32.7	45.8	56.8	67.7	81
12	23.8	32.8	45.9	56.9	67.8	81.9
12.3	23.9	32.9	46.5	57	67.9	82.6
12.5	24	34.5	46.6	57.5	67:6	82.7
12.6	24.5	34.6	46.7	57.7	68	82.8
12.7	24.6	34.7	46.8	57.8	68.6	82.9
12.8	24.7	34.8	47.6	58.6	68.7	85.7
12.9	24.8	34.9	47.8	58.7	68.8	85.9
13.9	24.9	35.4	51	58.8	7	86
14.7	25	35.6	51.7	61.5	71.6	86.6
14.8	25..9	35.7	51.8	61.7	72.5	86.7
15.7	25.3	35.8	52	61.8	72.6	86.8
15.8	25.5	36.6	52.4	62	72.7	87
15.9	25.6	36.7	52.5	62.5	72.8	87.5
16.6	25.7	36.8	52.6	62.6	74.6	87.6
16.7	25.8	37.6	52.7	62.7	74.7	87.7
16.8	25.9	37.8	52.8	62.8	75	87.8
16.9	26	42	52.9	63.5	75.5	87.9
17.7	26.5	42.5	53	63.7	75.6	88.5
17.8	26.6	42.6	53.5	63.8	75.7	88.9
17.9	26.7	42.7	53.6	64	76	89.5
18.8	26.8	42.9	53.7	64.5	76.5	89.6
18.9	26.9	43.4	54	64.6	76.6	89.8
19.9	27	43.5	54.4	64.7	76.7	89.9
21	27.6	43.6	54.5	64.8	76.8	9
21.5	27.7	43.7	54.6	65	76.9	98.6
21.6	27.8	43.8	54.7	65.5	78	98.8
21.7	27.9	43.9	54.8	65.6	78.4	98.9
21.8	28.6	45	54.9	65.7	78.5	99.5
21.9	28.7	45.3	56	65.8	78.6	
22.5	28.8	45.5	56.4	65.9	78.7	

Land Ownership

National Park / National Recreation Area Boundary

N

0 1,000 2,000 Feet



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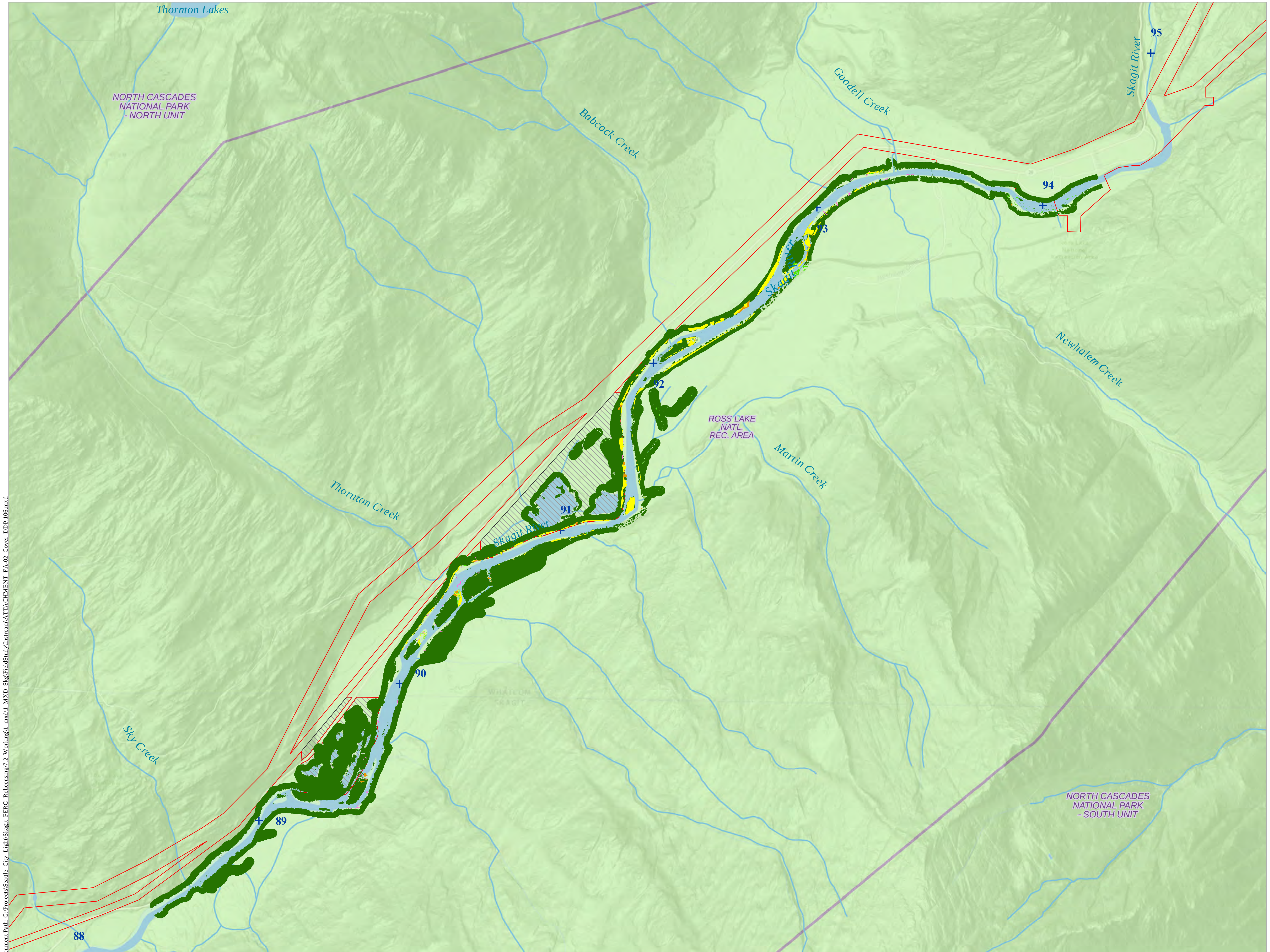


FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – COVER

FERC Project Boundary

Mitigation Parcel

+ Project River Miles (PRM)

Cover Code

00.2

00.3

00.4

00.5

00.8

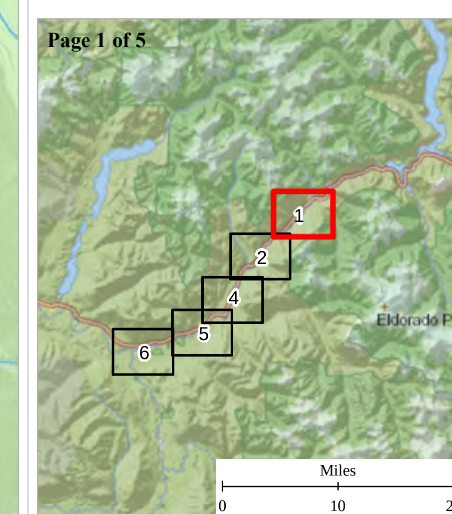
00.9

Land Ownership

National Park / National Recreation Area Boundary

N

0 1,000 2,000 Feet



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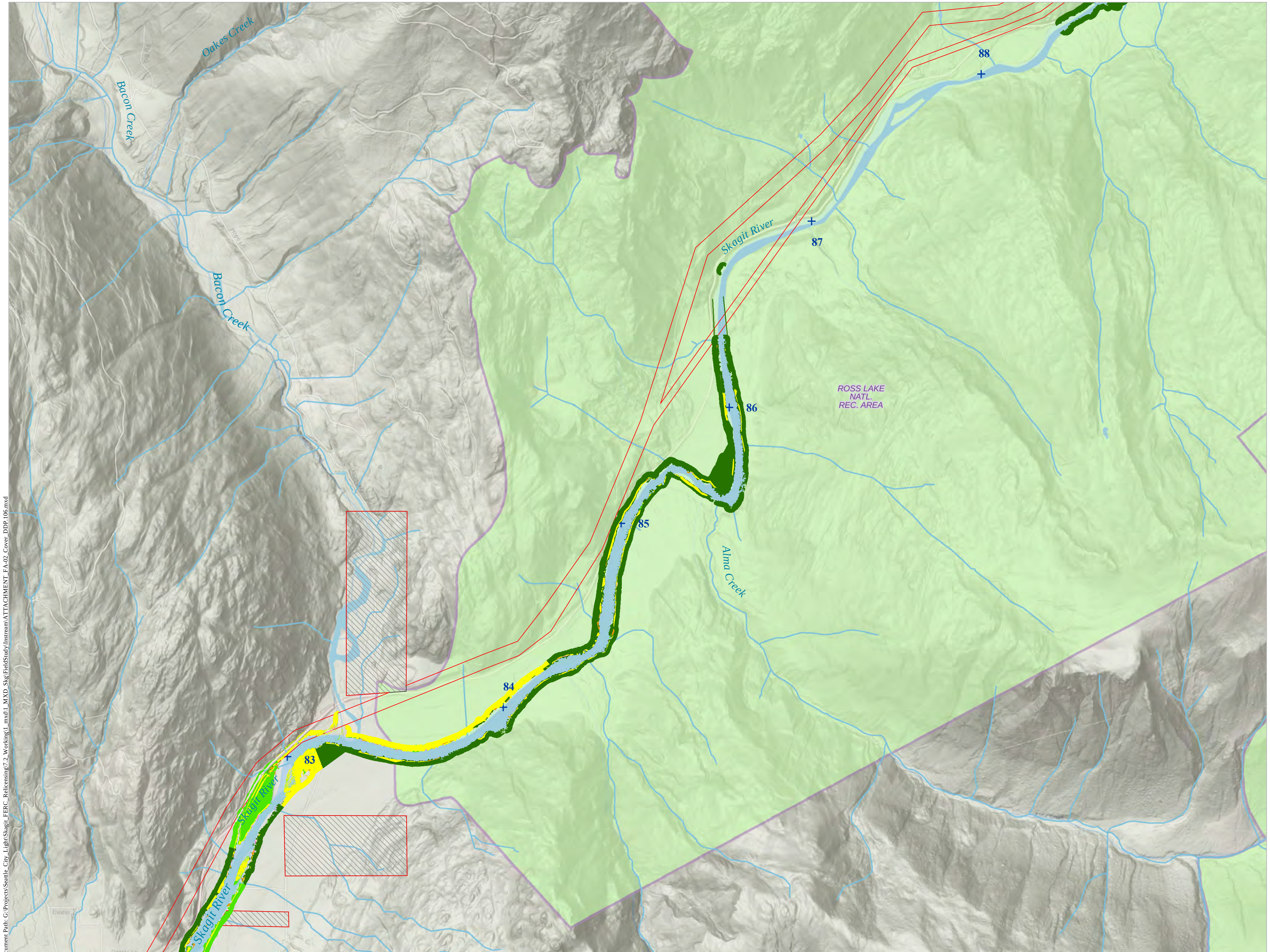


FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – COVER

FERC Project Boundary

Mitigation Parcel

+ Project River Miles (PRM)

Cover Code

00.2

00.3

00.4

00.5

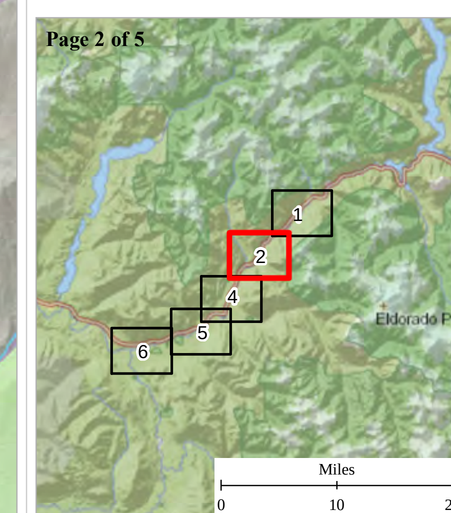
00.8

00.9

Land Ownership

National Park / National Recreation Area Boundary

0 1,000 2,000 Feet



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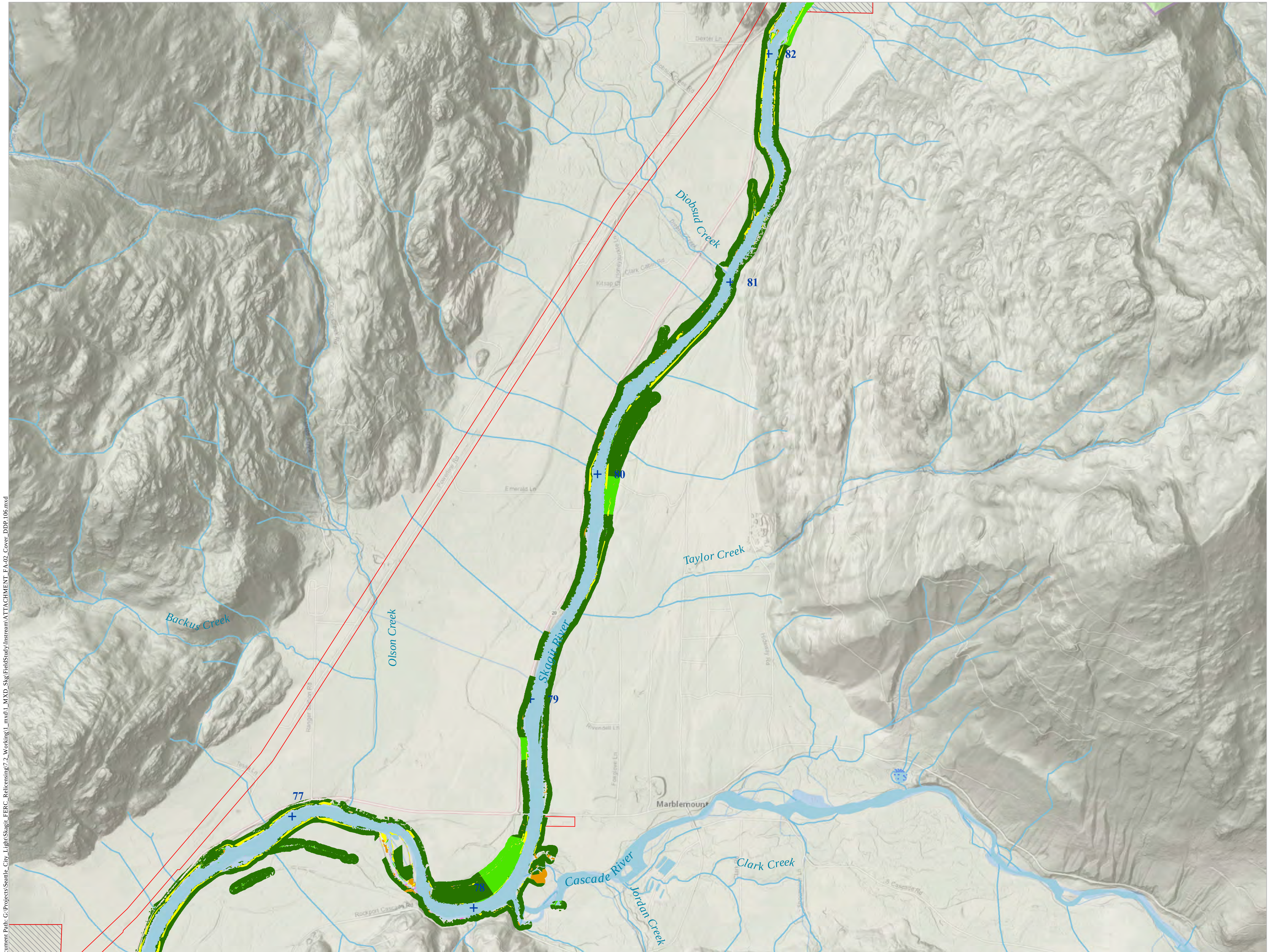
FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – COVER



FERC Project Boundary

Mitigation Parcel

Project River Miles (PRM)

Cover Code

00.2

00.3

00.4

00.5

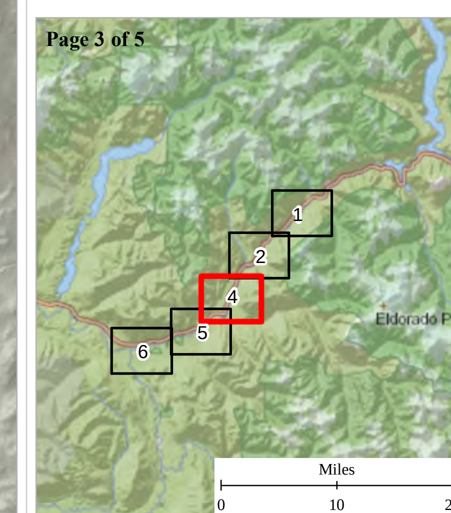
00.8

00.9

Land Ownership

National Park / National Recreation Area Boundary

0 1,000 2,000 Feet



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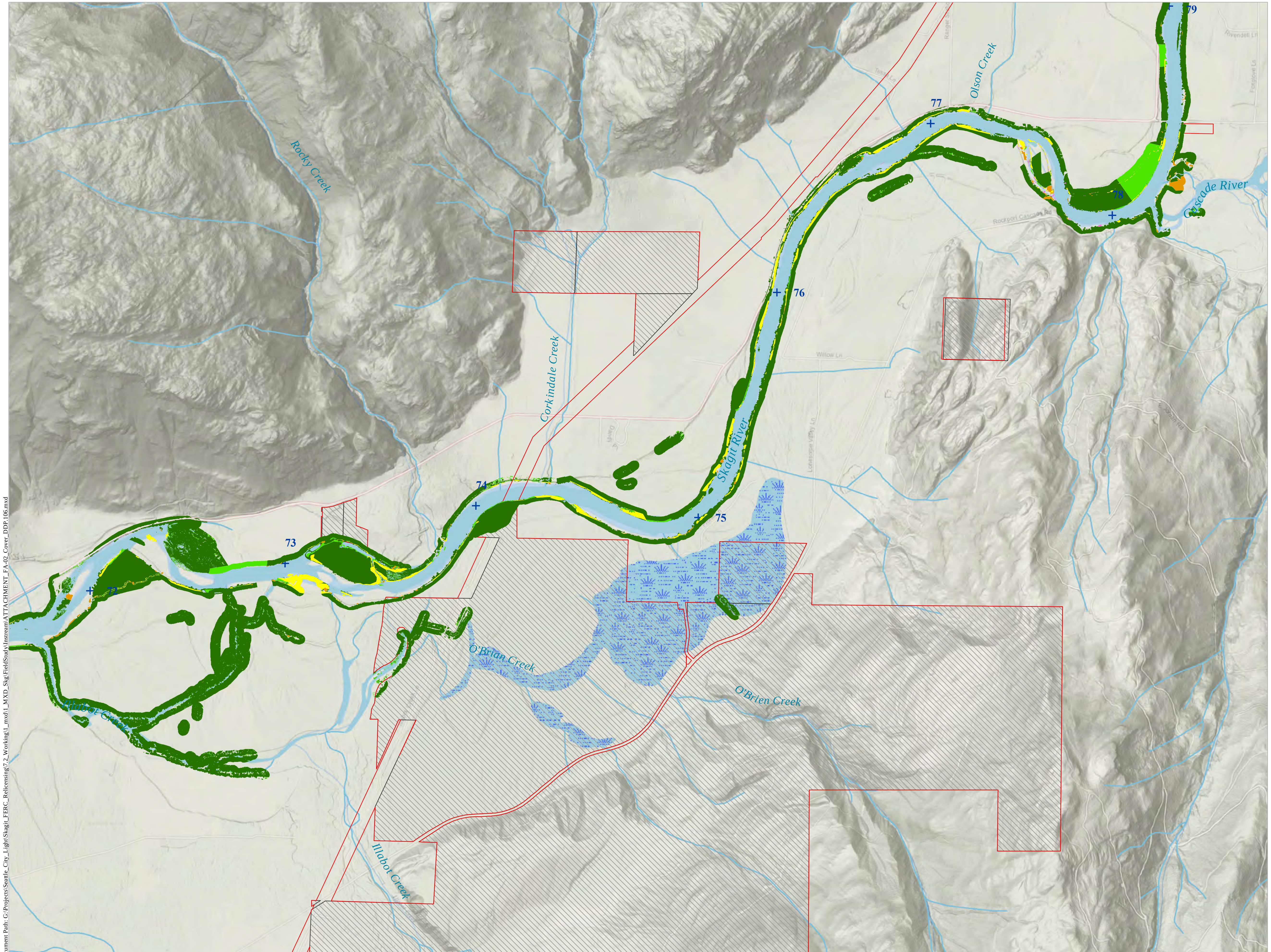


FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – COVER

FERC Project Boundary
Mitigation Parcel
+ Project River Miles (PRM)

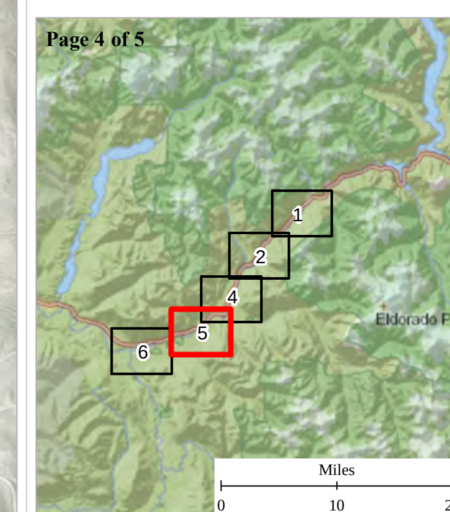
Cover Code

00.2
00.3
00.4
00.5
00.8
00.9

Land Ownership

National Park / National Recreation Area Boundary

0 1,000 2,000 Feet



Seattle City Light

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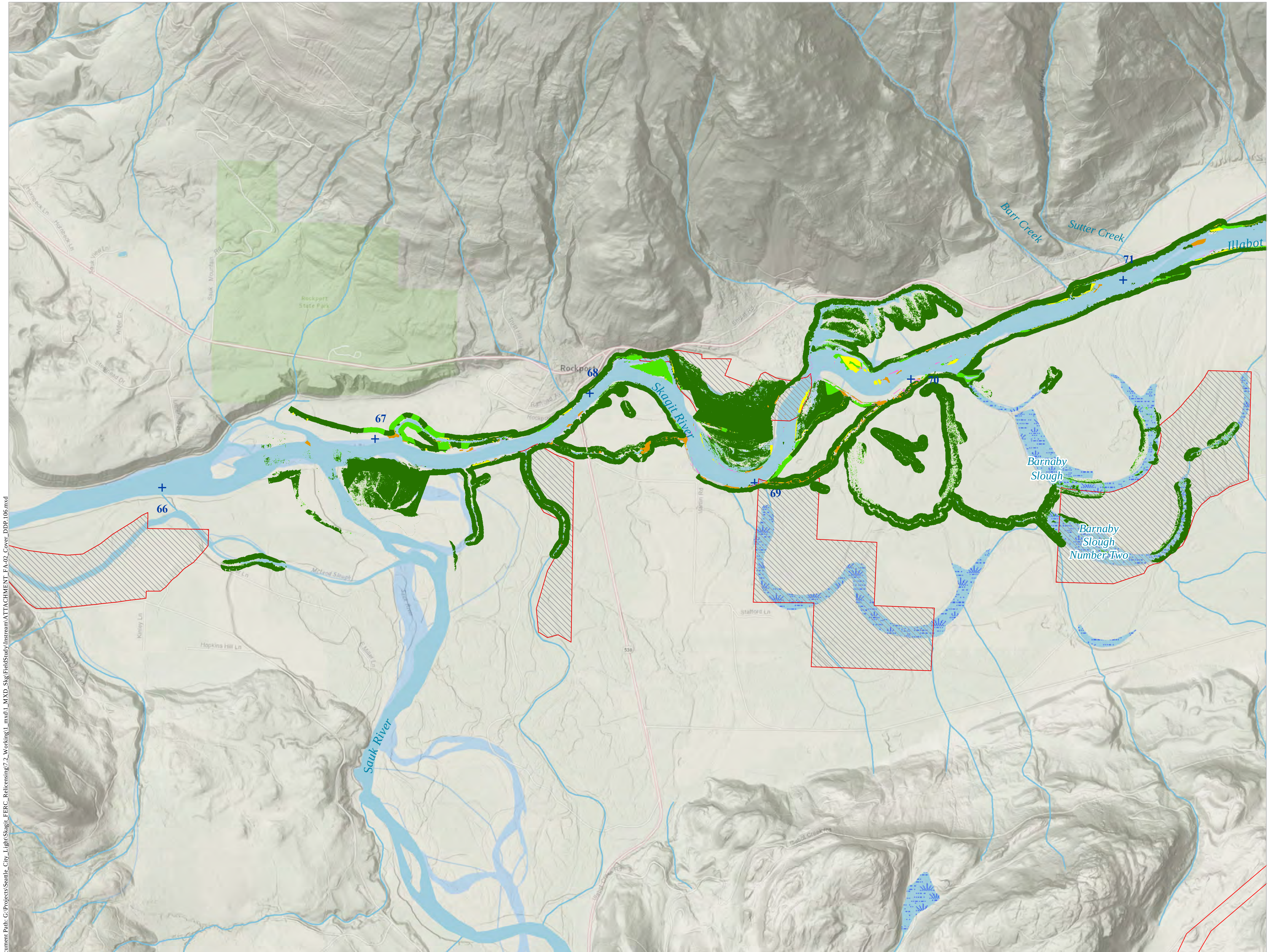


FA-02 INSTREAM FLOW MODEL DEVELOPMENT STUDY – COVER

FERC Project Boundary

Mitigation Parcel

+ Project River Miles (PRM)

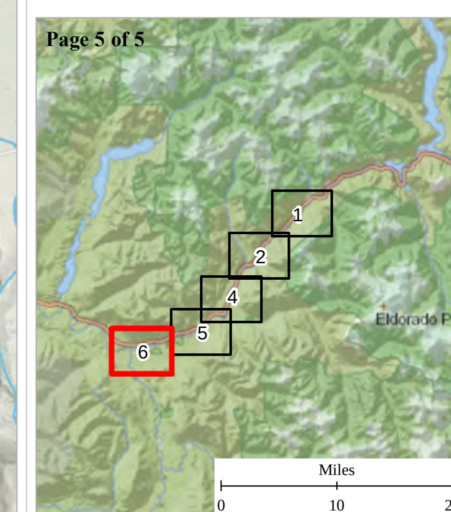
Cover Code

- 00.2
- 00.3
- 00.4
- 00.5
- 00.8
- 00.9

Land Ownership

National Park / National Recreation Area Boundary

0 1,000 2,000 Feet



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INSTREAM FLOW MODEL DEVELOPMENT STUDY
INTERIM REPORT

ATTACHMENT I

PRELIMINARY MODEL CALIBRATION RESULTS MEMORANDUM

Memo

Date:	March 2022
Project:	Skagit River Project FERC Relicensing
To:	Project File, NHC
From:	Tyler Rockhill, PE –NHC Chris Long, PE – NHC
Subject:	FA-02 Instream Flow Model Development Study - Preliminary Hydraulic Model Calibration Results

1.0 INTRODUCTION

In support of the FA-02 Instream Flow Model Development Study for the Skagit Hydroelectric Project Federal Energy Regulatory Commission Relicensing, Northwest Hydraulic Consultants (NHC) performed statistical analysis of model performance by comparing simulated data from preliminary calibration of the Upper Skagit Hydraulic Model against observed data collected during Low (August 2020), Moderate (October 2020) and High (March 2021) calibration discharge field monitoring events (NHC 2022a, 2022b, 2022c, as attached to the FA-02 Instream Flow Model Development Study Report [Attachments A, B and C]). Statistical analysis of model performance includes longitudinal water surface elevation (WSE) and depth components and transect velocity and depth components.

2.0 MODEL PERFORMANCE METRICS

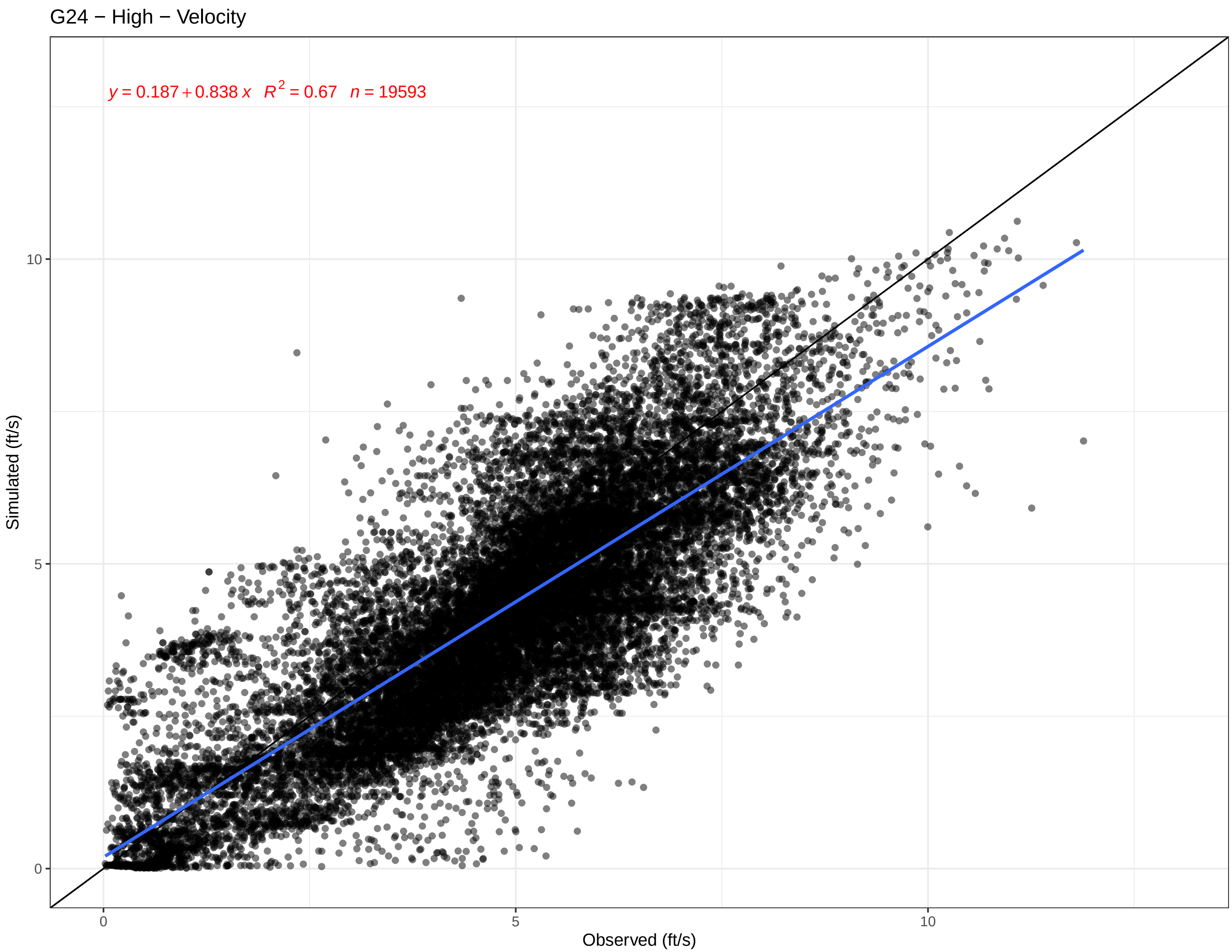
Model performance metrics are documented for the current Upper Skagit Hydraulic Model iteration – G24 – as of December 2021 for the Low, Moderate, and High calibration discharge field monitoring events (August 2020, October 2020, and March 2021, respectively). Model performance output titles follow the format of G24 – "Calibration Discharge Events" – "Parameter". The parameters analyzed include depth and velocity at transects and depth and WSE for longitudinal profiles. For linear regression plots, the Y-Intercept, R^2, and slope of linear regression line, and number of points compared are included. For each calibration discharge event, transect comparisons are shown in entirety and shown discretized by transect. Longitudinal profile comparisons are also shown in entirety and discretized by reach. Model performance metrics included are listed below:

3.0 REFERENCES

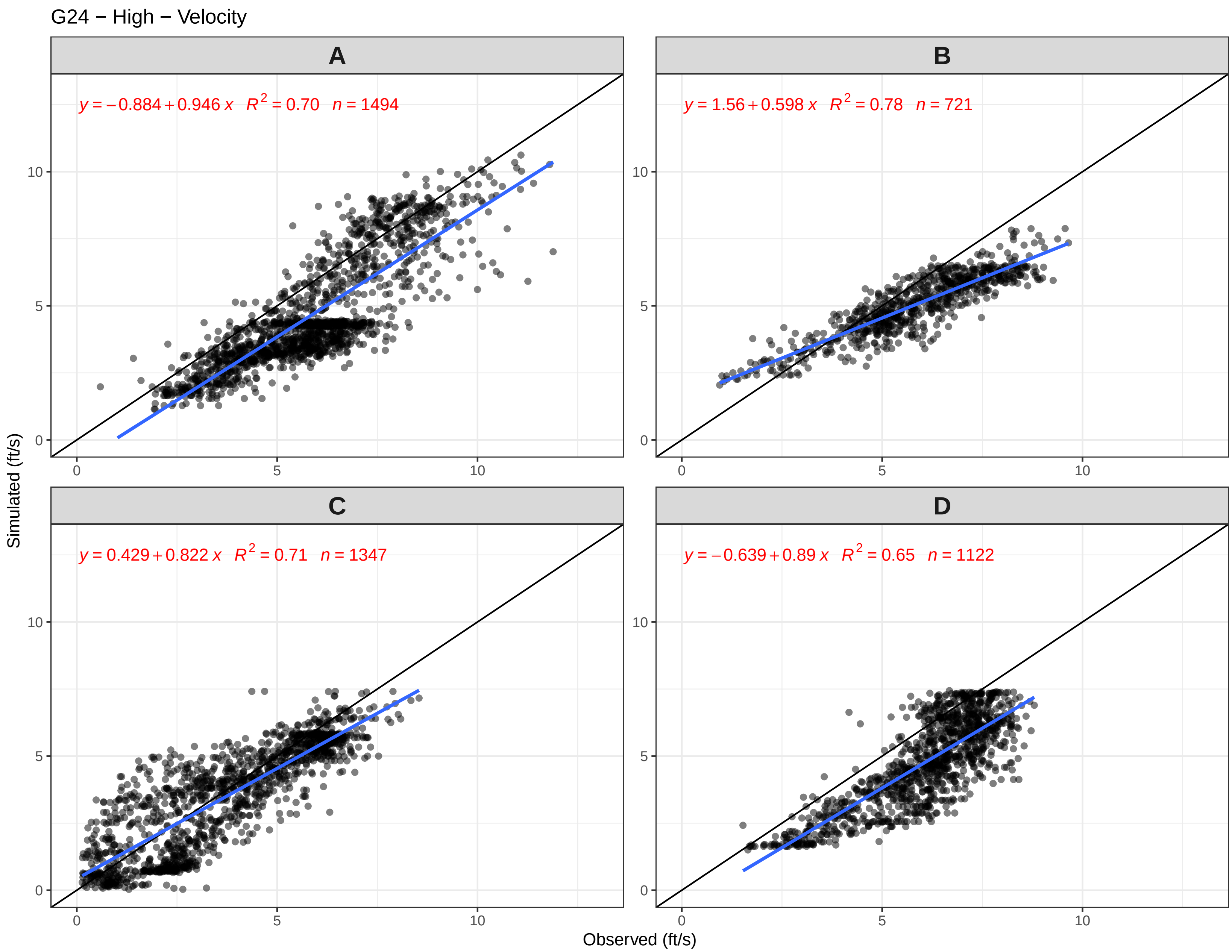
Northwest Hydraulic Consultants (NHC). 2022a. Summary of Skagit River data collection for lowest calibration discharge. Technical Memorandum. March 2022.

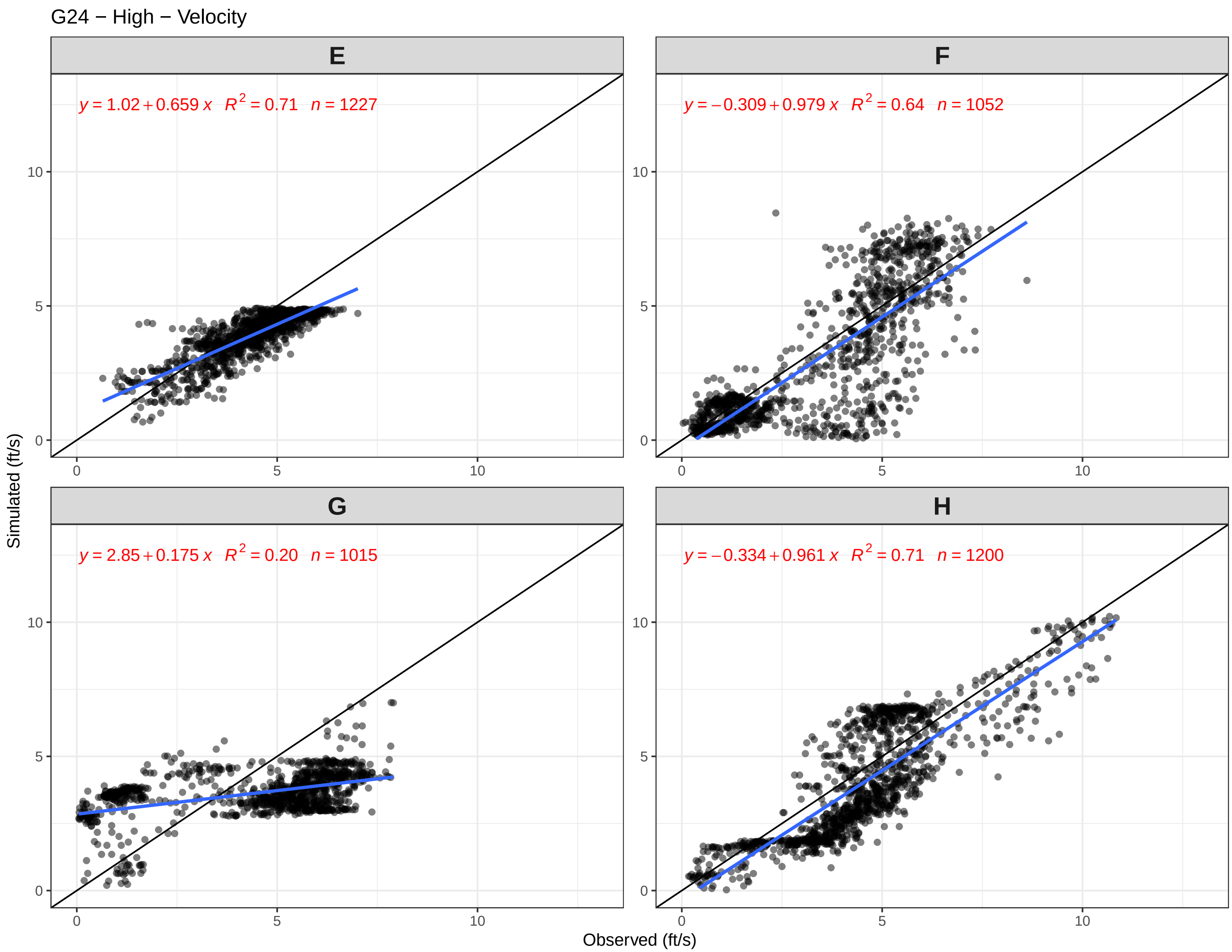
Northwest Hydraulic Consultants (NHC). 2022b. Summary of Skagit River data collection for moderate calibration discharge. Technical Memorandum. March 2022.

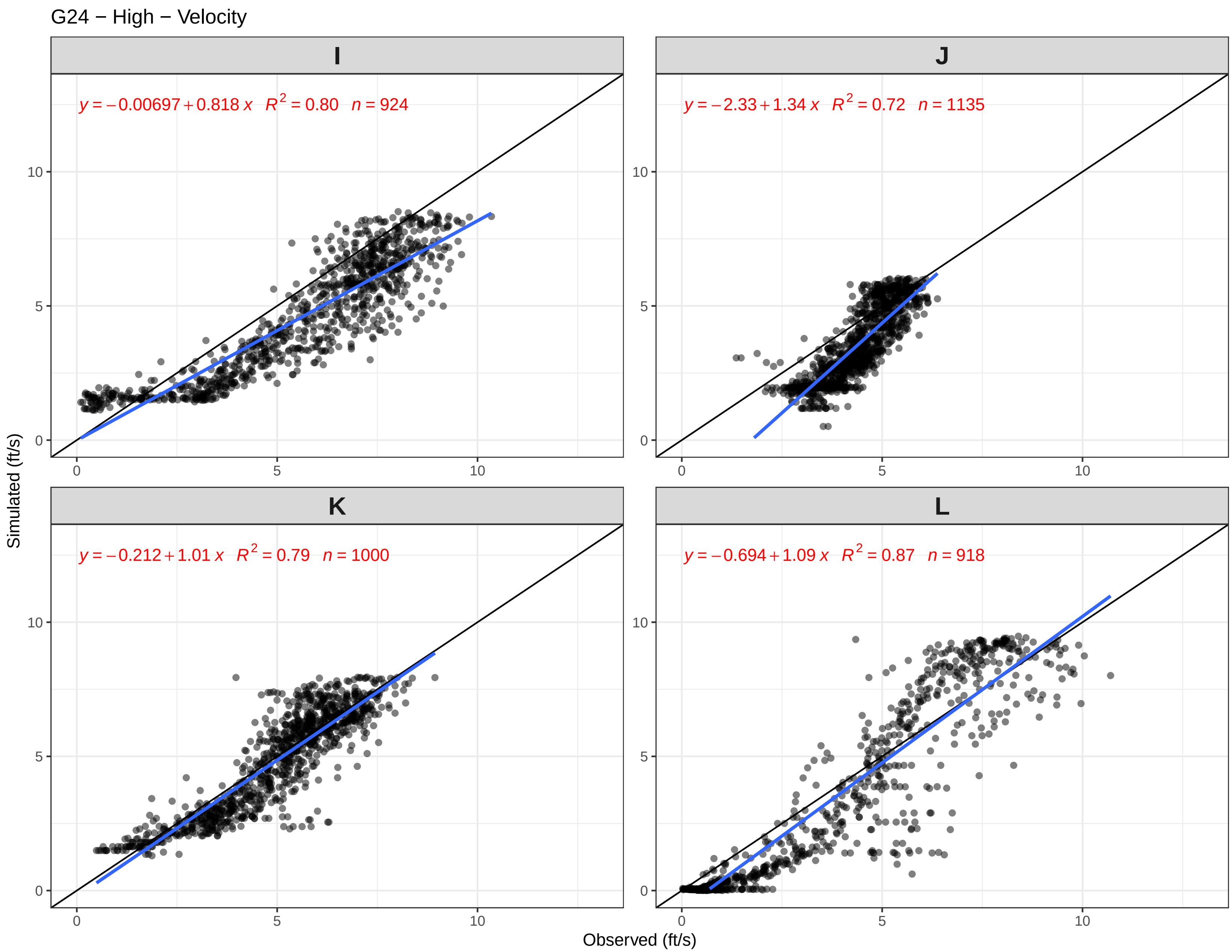
Northwest Hydraulic Consultants (NHC). 2022c. Summary of Skagit River data collection for high calibration discharge. Technical Memorandum. March 2022.



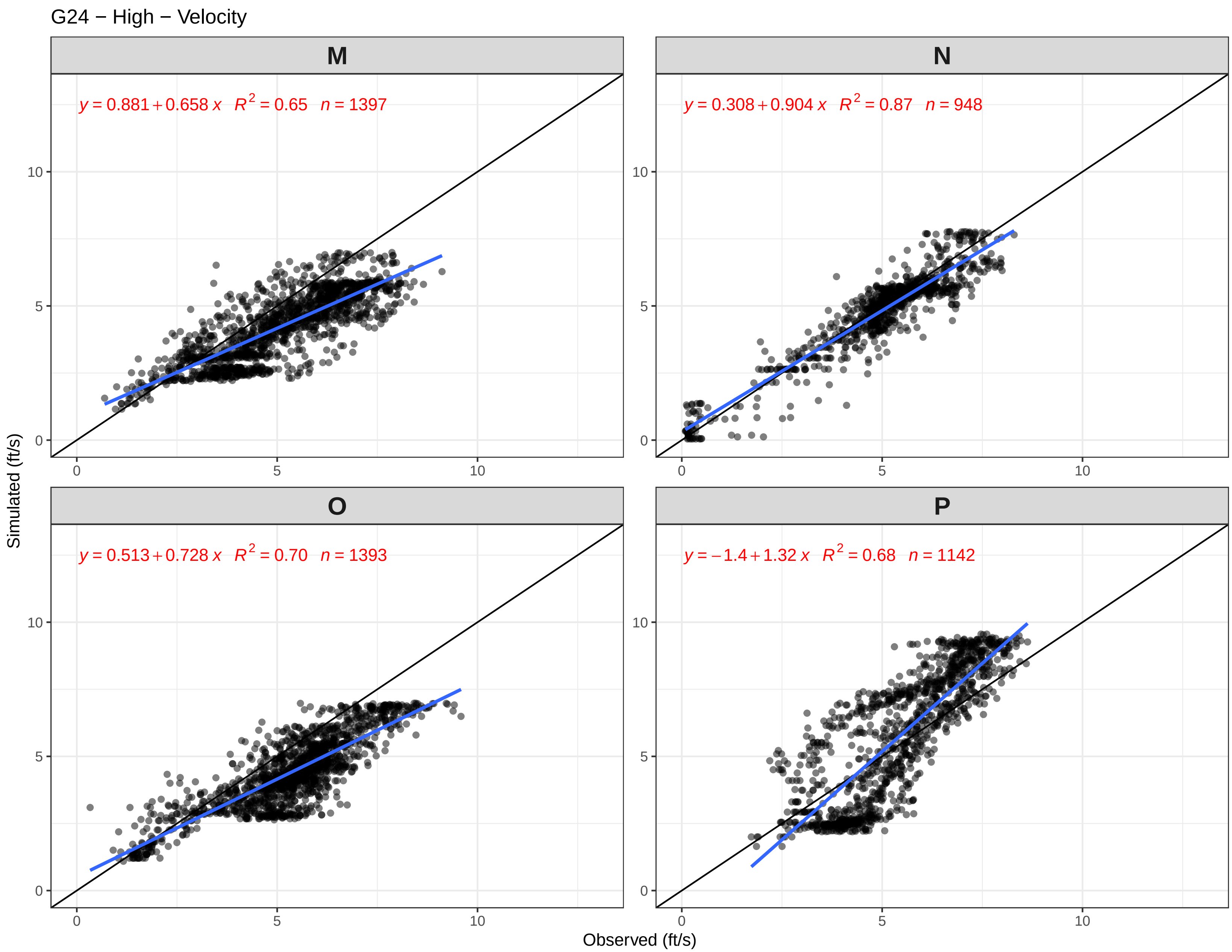
G24 − High − Velocity
y = 0.187 + 0.838 x   R^2 = 0.67   n = 19593
Simulated (ft/s)
Observed (ft/s)
0
5
10
0
5
10

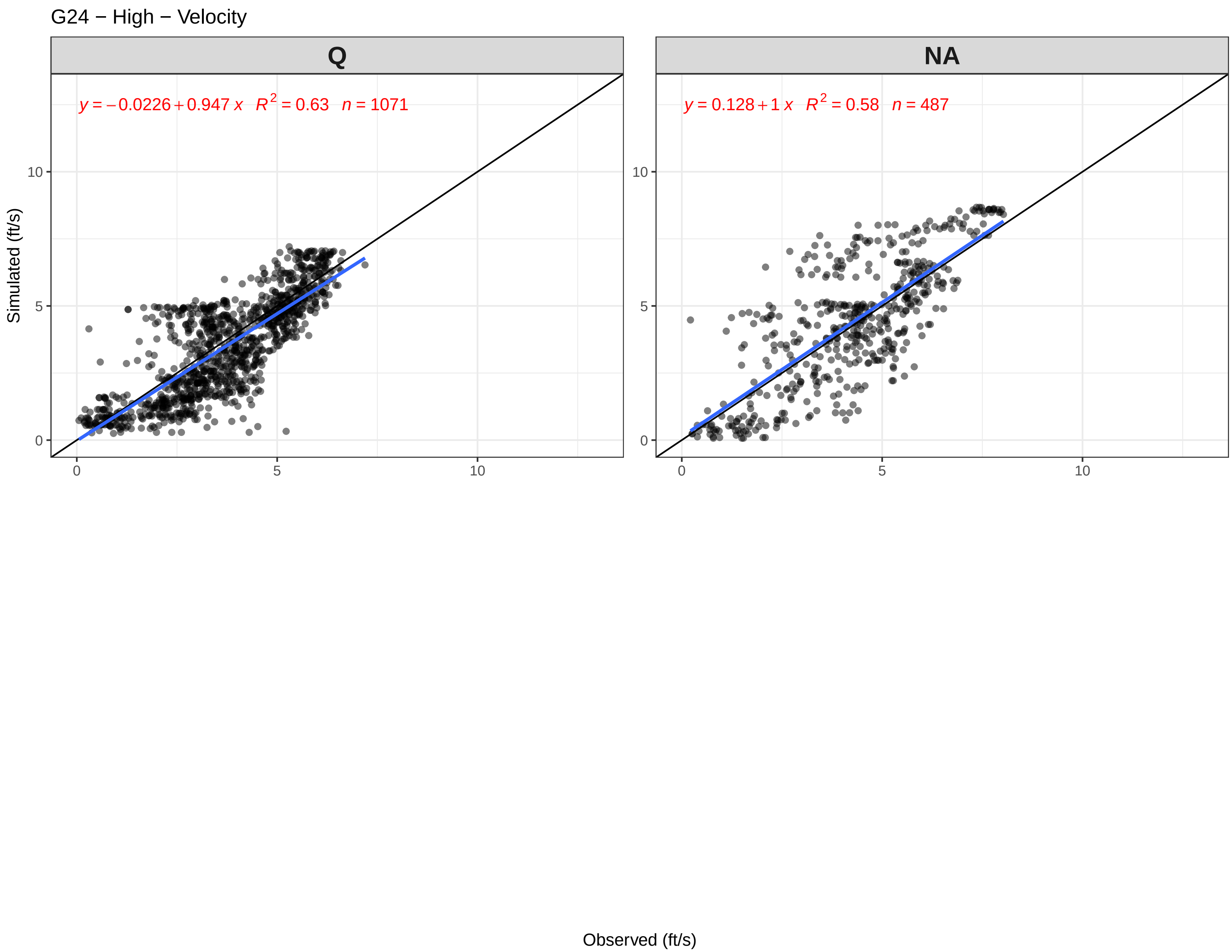

G24 − High − Velocity
A
y = −0.884 + 0.946 x   R^2 = 0.70   n = 1494
B
y = 1.56 + 0.598 x   R^2 = 0.78   n = 721
C
y = 0.429 + 0.822 x   R^2 = 0.71   n = 1347
D
y = −0.639 + 0.89 x   R^2 = 0.65   n = 1122
Simulated (ft/s)
Observed (ft/s)
0
5
10

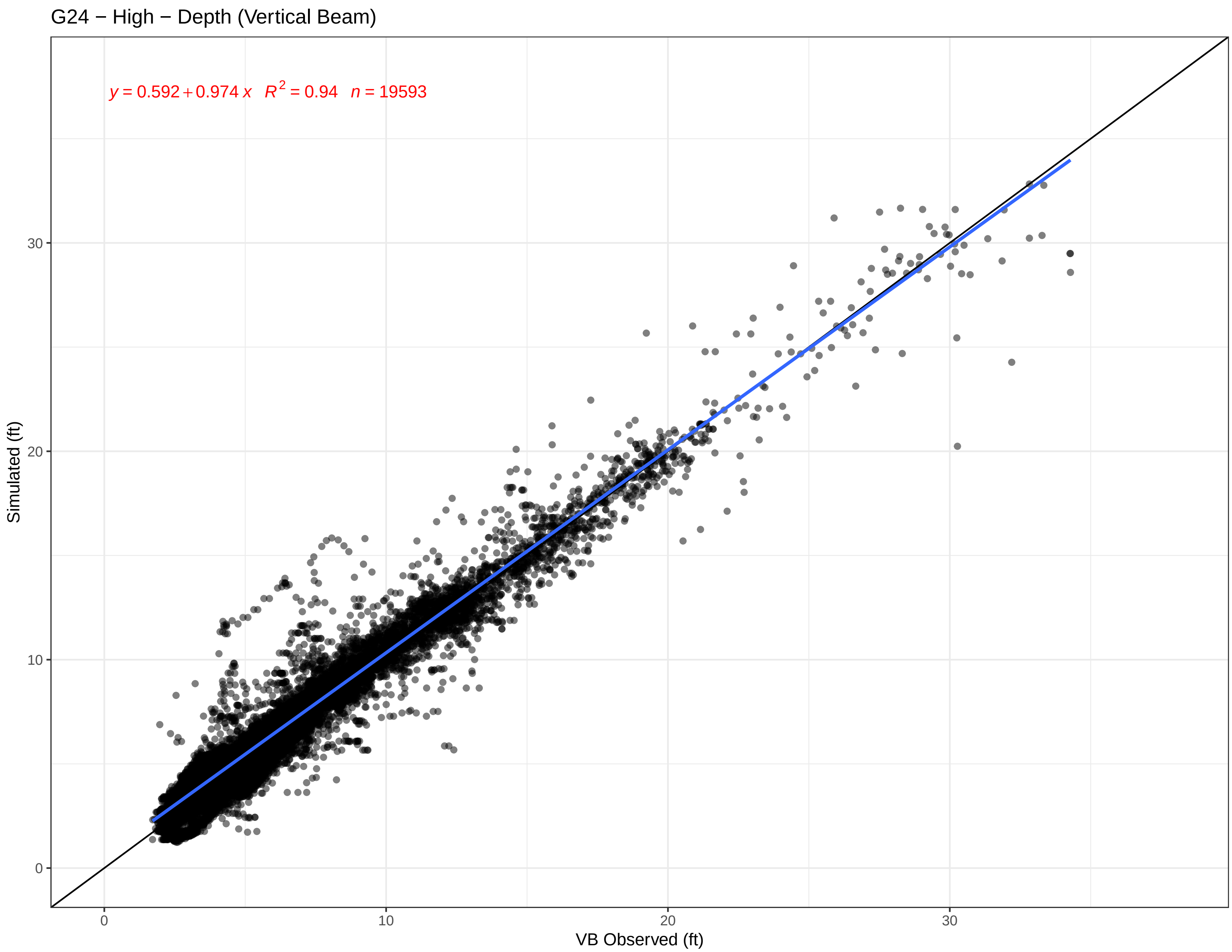

G24 − High − Velocity
E
$y = 1.02 + 0.659\,x \quad R^2 = 0.71 \quad n = 1227$
F
$y = -0.309 + 0.979\,x \quad R^2 = 0.64 \quad n = 1052$
G
$y = 2.85 + 0.175\,x \quad R^2 = 0.20 \quad n = 1015$
H
$y = -0.334 + 0.961\,x \quad R^2 = 0.71 \quad n = 1200$
Simulated (ft/s)
Observed (ft/s)
0
5
10



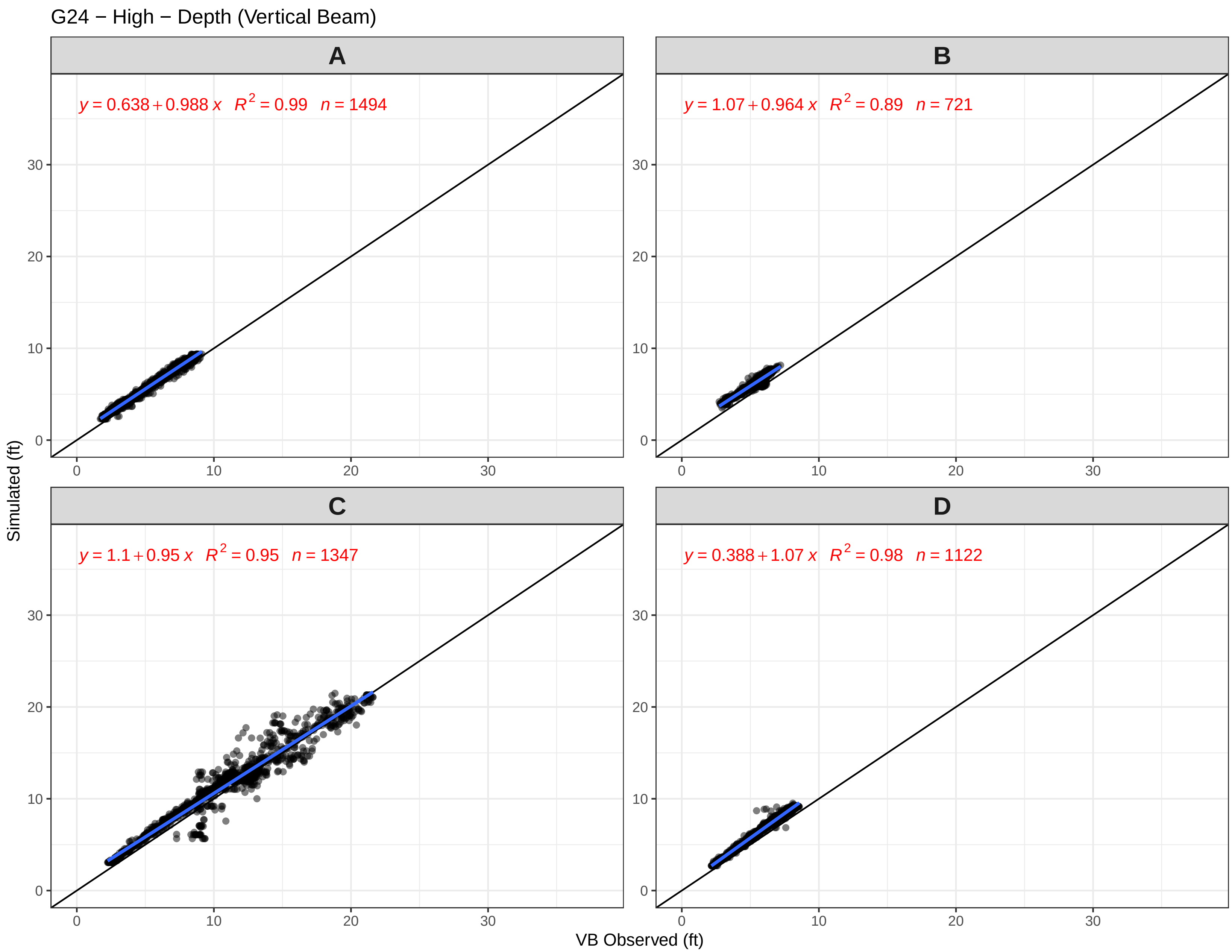
G24 − High − Velocity
I
y = −0.00697 + 0.818 x R2 = 0.80 n = 924
J
y = −2.33 + 1.34 x R2 = 0.72 n = 1135
K
y = −0.212 + 1.01 x R2 = 0.79 n = 1000
L
y = −0.694 + 1.09 x R2 = 0.87 n = 918
Simulated (ft/s)
Observed (ft/s)

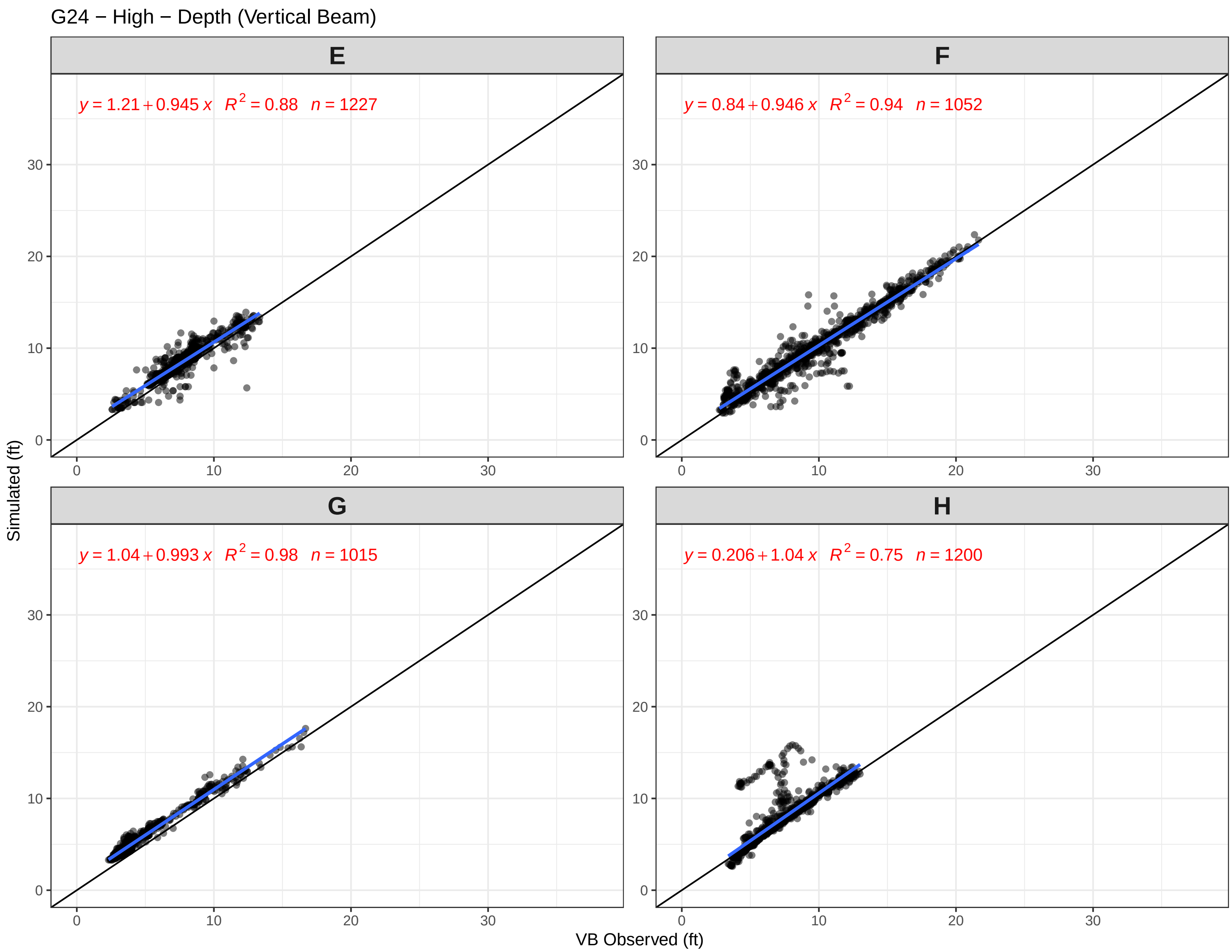

G24 − High − Velocity
M
y = 0.881 + 0.658 x   R² = 0.65   n = 1397
N
y = 0.308 + 0.904 x   R² = 0.87   n = 948
O
y = 0.513 + 0.728 x   R² = 0.70   n = 1393
P
y = −1.4 + 1.32 x   R² = 0.68   n = 1142
Simulated (ft/s)
Observed (ft/s)
0
5
10


G24 − High − Velocity
Q
NA
y = −0.0226 + 0.947 x   R2 = 0.63   n = 1071
y = 0.128 + 1 x   R2 = 0.58   n = 487
Simulated (ft/s)
Observed (ft/s)
0
5
10

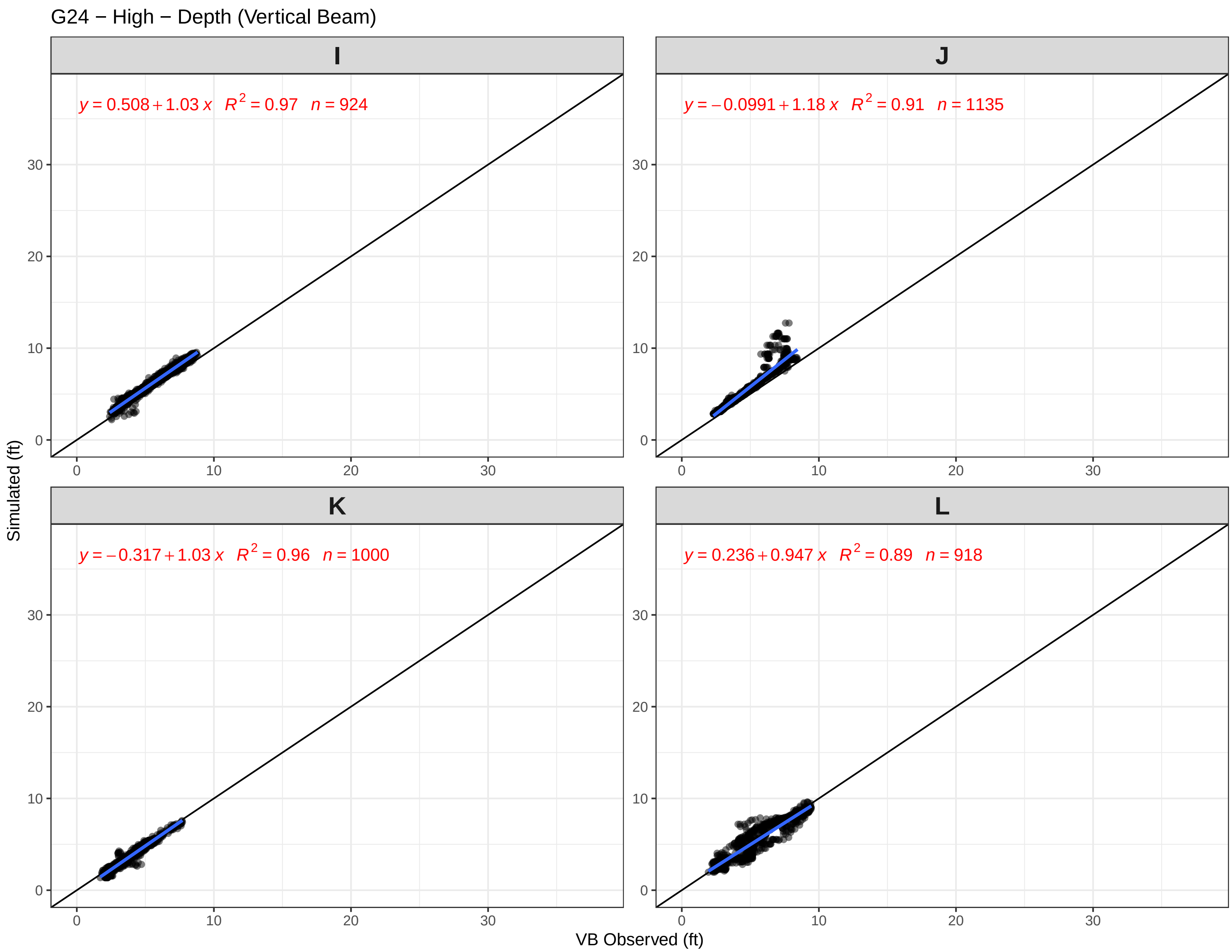


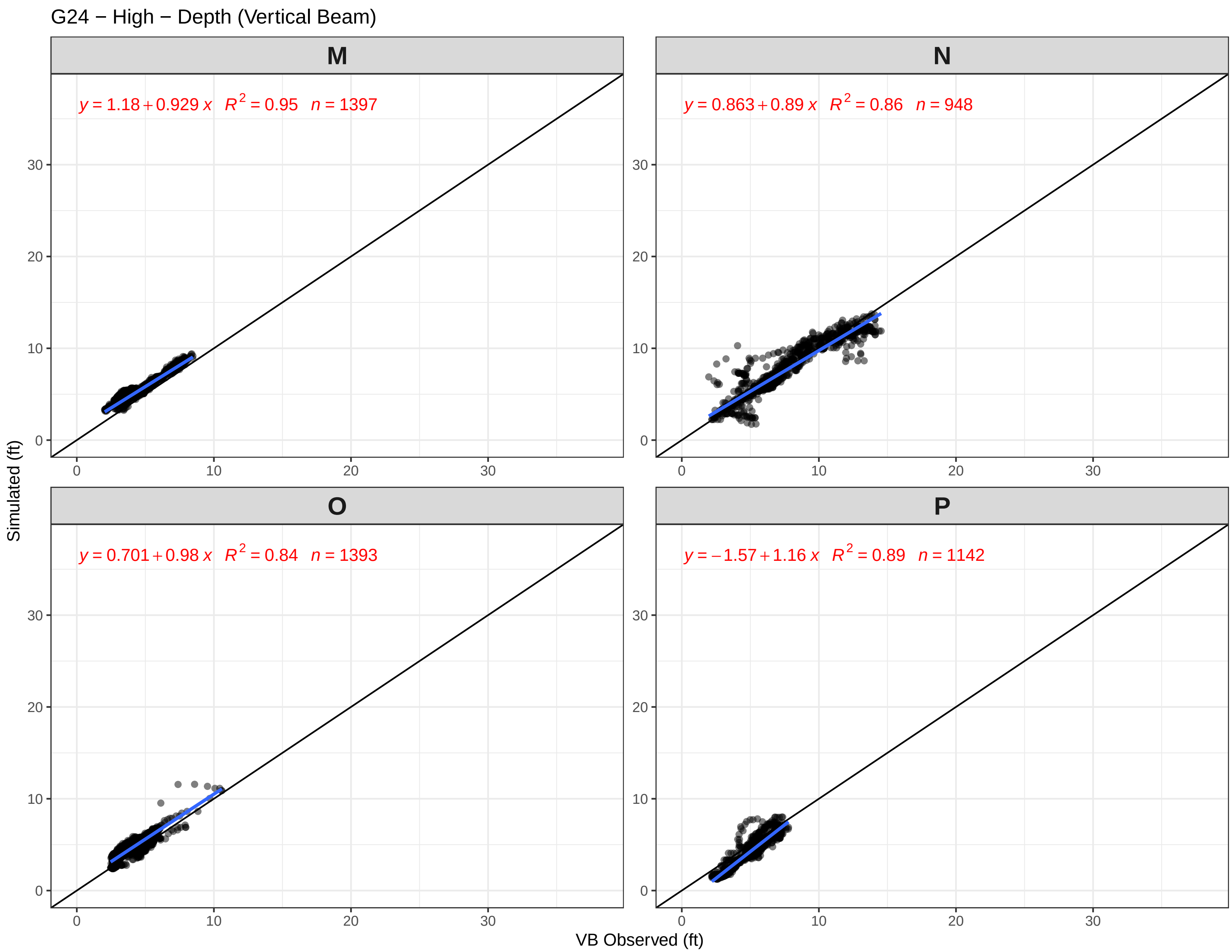
G24 − High − Depth (Vertical Beam)
$y = 0.592 + 0.974\,x \quad R^2 = 0.94 \quad n = 19593$
Simulated (ft)
VB Observed (ft)
0
10
20
30
0
10
20
30


G24 − High − Depth (Vertical Beam)
A
$y = 0.638 + 0.988\,x$ $R^2 = 0.99$ $n = 1494$
B
$y = 1.07 + 0.964\,x$ $R^2 = 0.89$ $n = 721$
C
$y = 1.1 + 0.95\,x$ $R^2 = 0.95$ $n = 1347$
D
$y = 0.388 + 1.07\,x$ $R^2 = 0.98$ $n = 1122$
Simulated (ft)
VB Observed (ft)
0
10
20
30

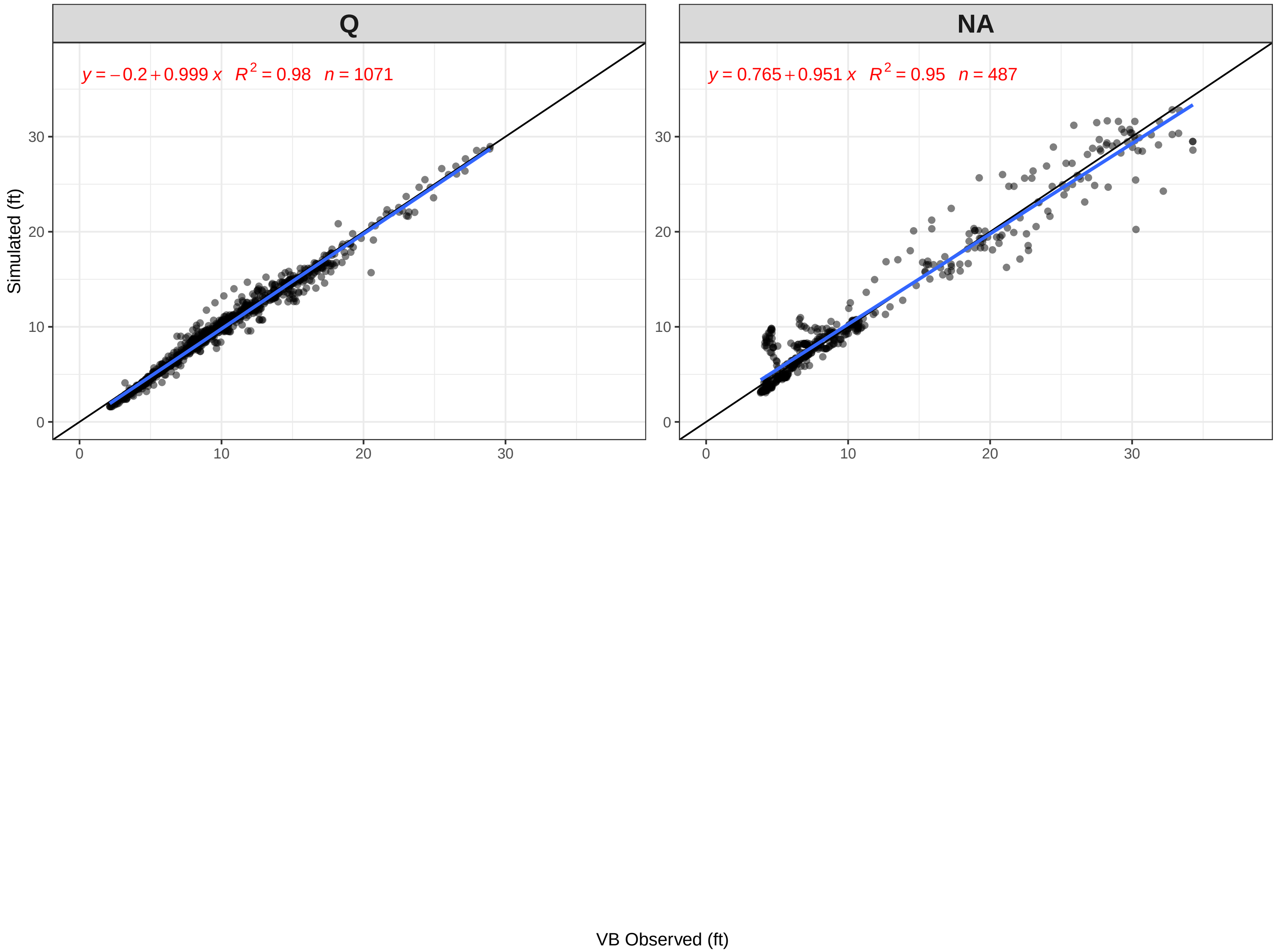


G24 − High − Depth (Vertical Beam)
E
$y = 1.21 + 0.945\,x \quad R^2 = 0.88 \quad n = 1227$
F
$y = 0.84 + 0.946\,x \quad R^2 = 0.94 \quad n = 1052$
G
$y = 1.04 + 0.993\,x \quad R^2 = 0.98 \quad n = 1015$
H
$y = 0.206 + 1.04\,x \quad R^2 = 0.75 \quad n = 1200$
Simulated (ft)
VB Observed (ft)
0
10
20
30

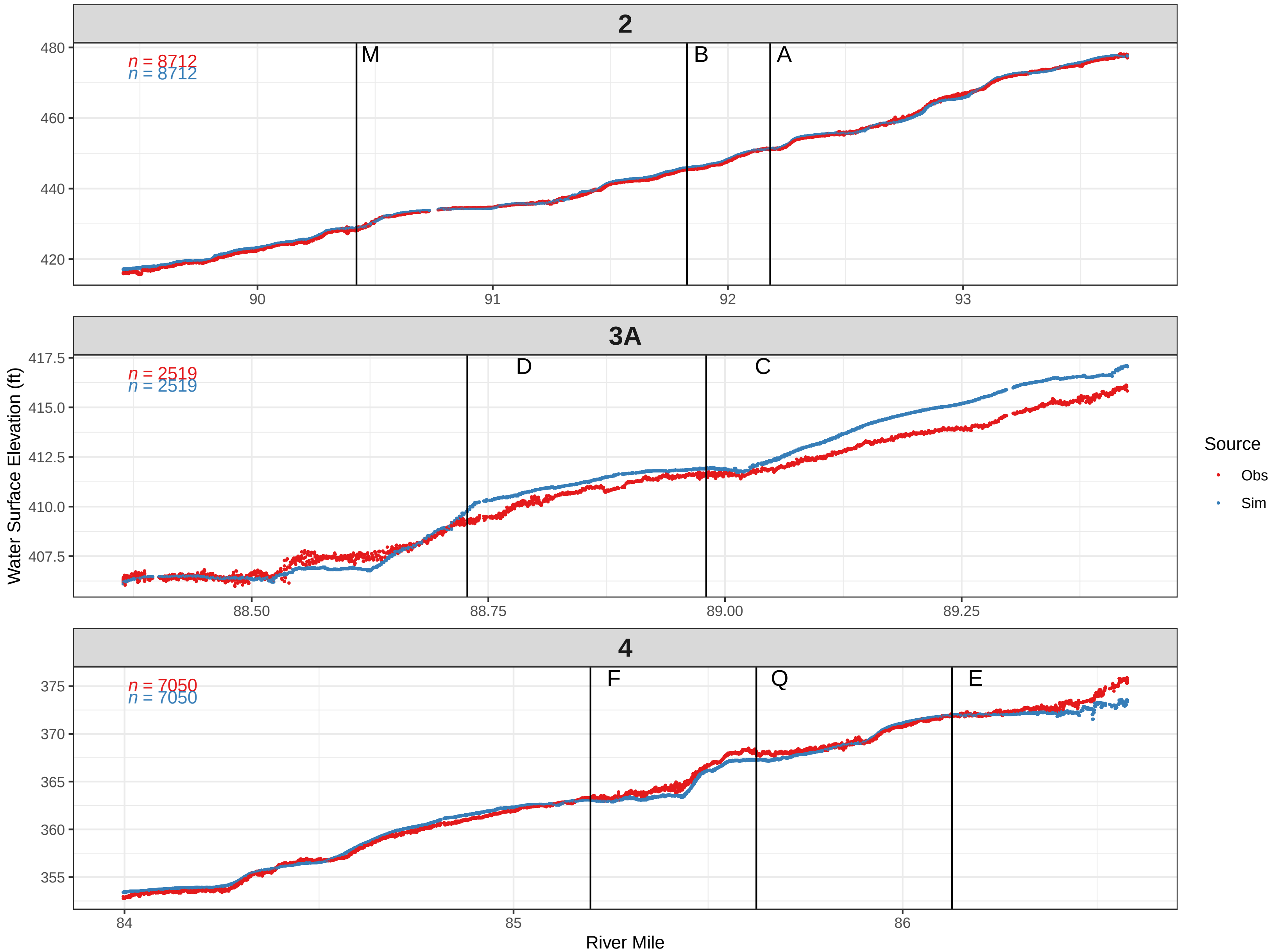

G24 − High − Depth (Vertical Beam)
I
J
K
L
y = 0.508 + 1.03 x R^2 = 0.97 n = 924
y = −0.0991 + 1.18 x R^2 = 0.91 n = 1135
y = −0.317 + 1.03 x R^2 = 0.96 n = 1000
y = 0.236 + 0.947 x R^2 = 0.89 n = 918
Simulated (ft)
VB Observed (ft)
0
10
20
30

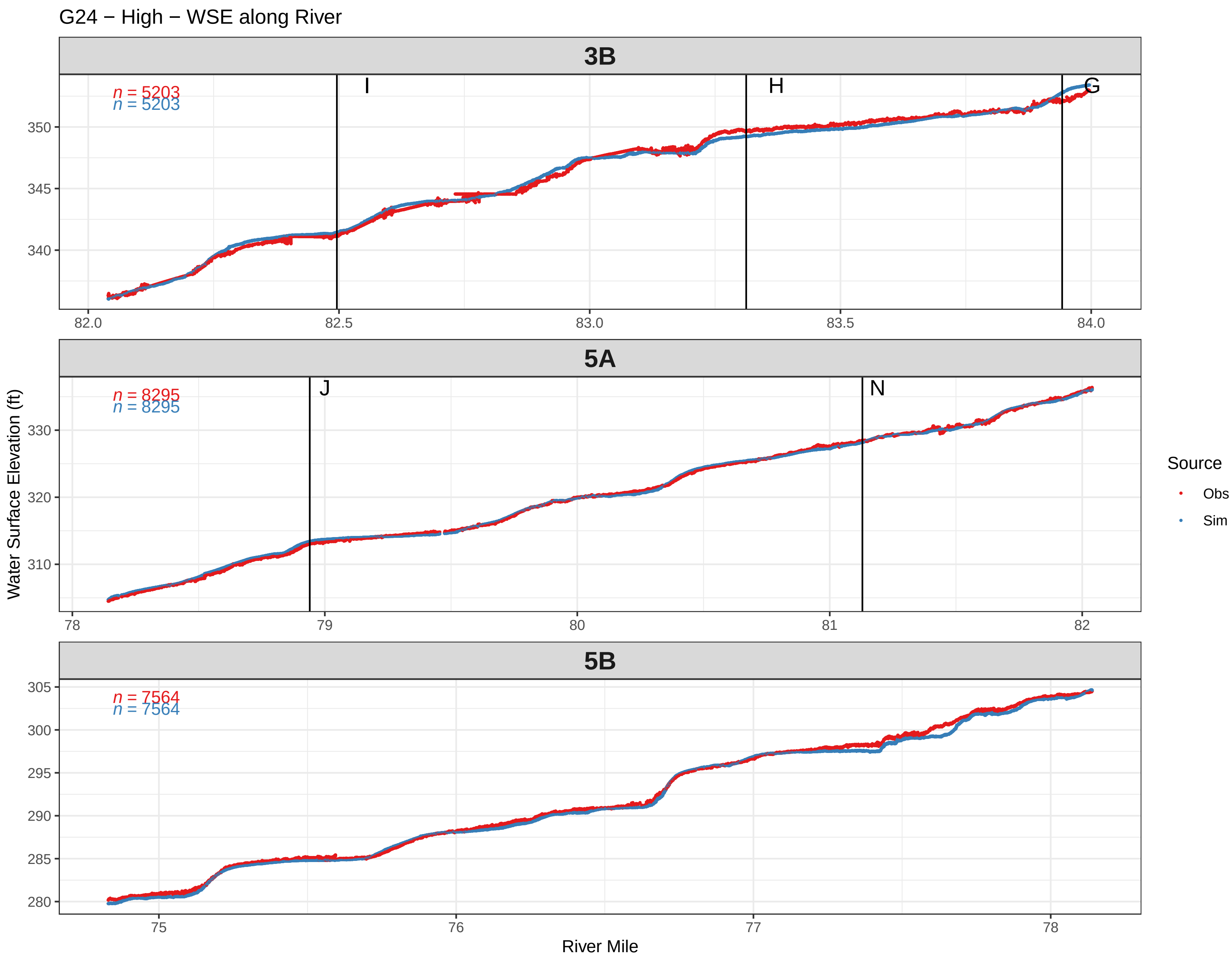

G24 − High − Depth (Vertical Beam)
M
N
O
P
y = 1.18 + 0.929 x   R^2 = 0.95   n = 1397
y = 0.863 + 0.89 x   R^2 = 0.86   n = 948
y = 0.701 + 0.98 x   R^2 = 0.84   n = 1393
y = −1.57 + 1.16 x   R^2 = 0.89   n = 1142
Simulated (ft)
VB Observed (ft)
0
10
20
30

G24 − High − Depth (Vertical Beam)



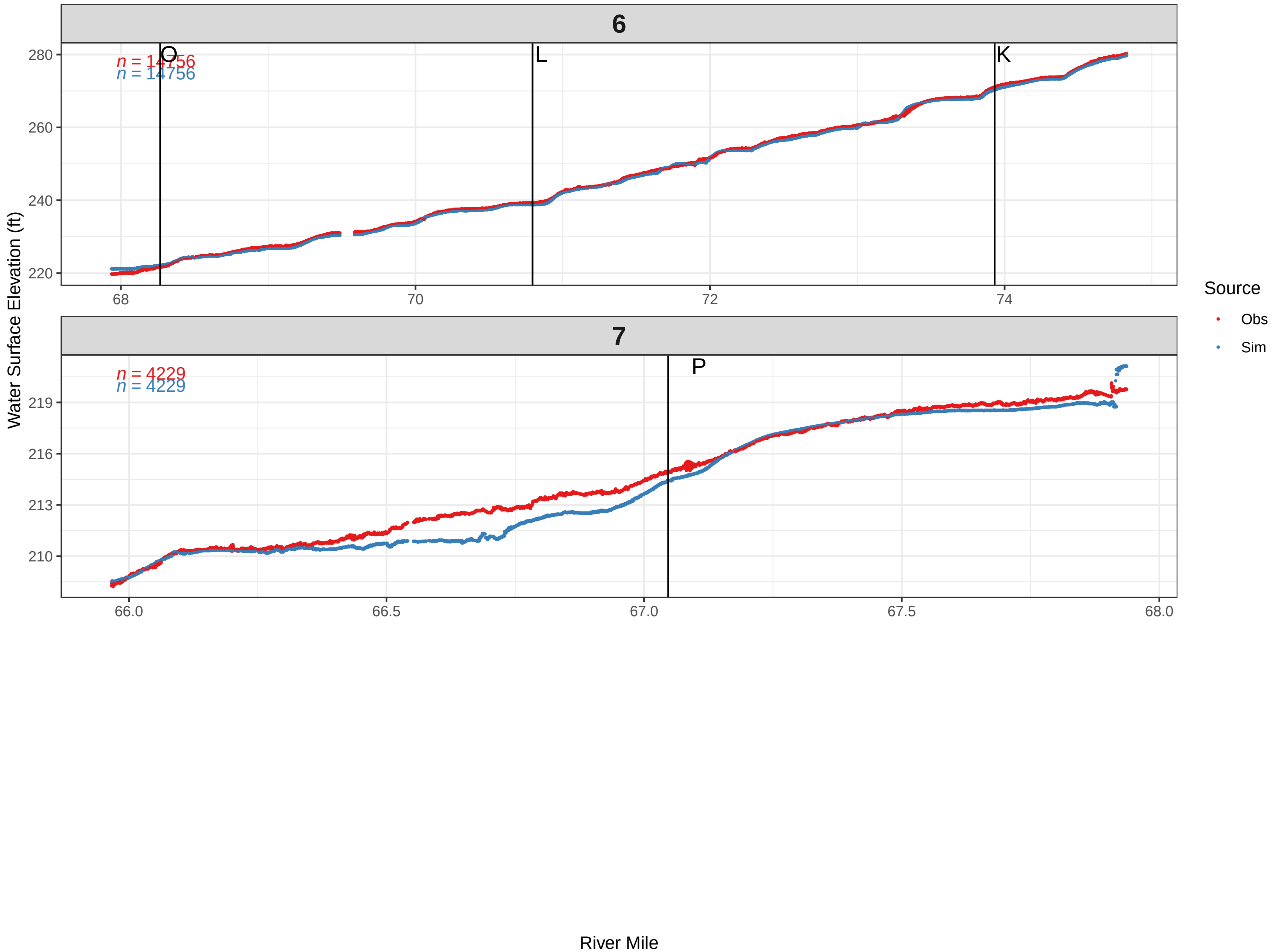
G24 − High − WSE along River

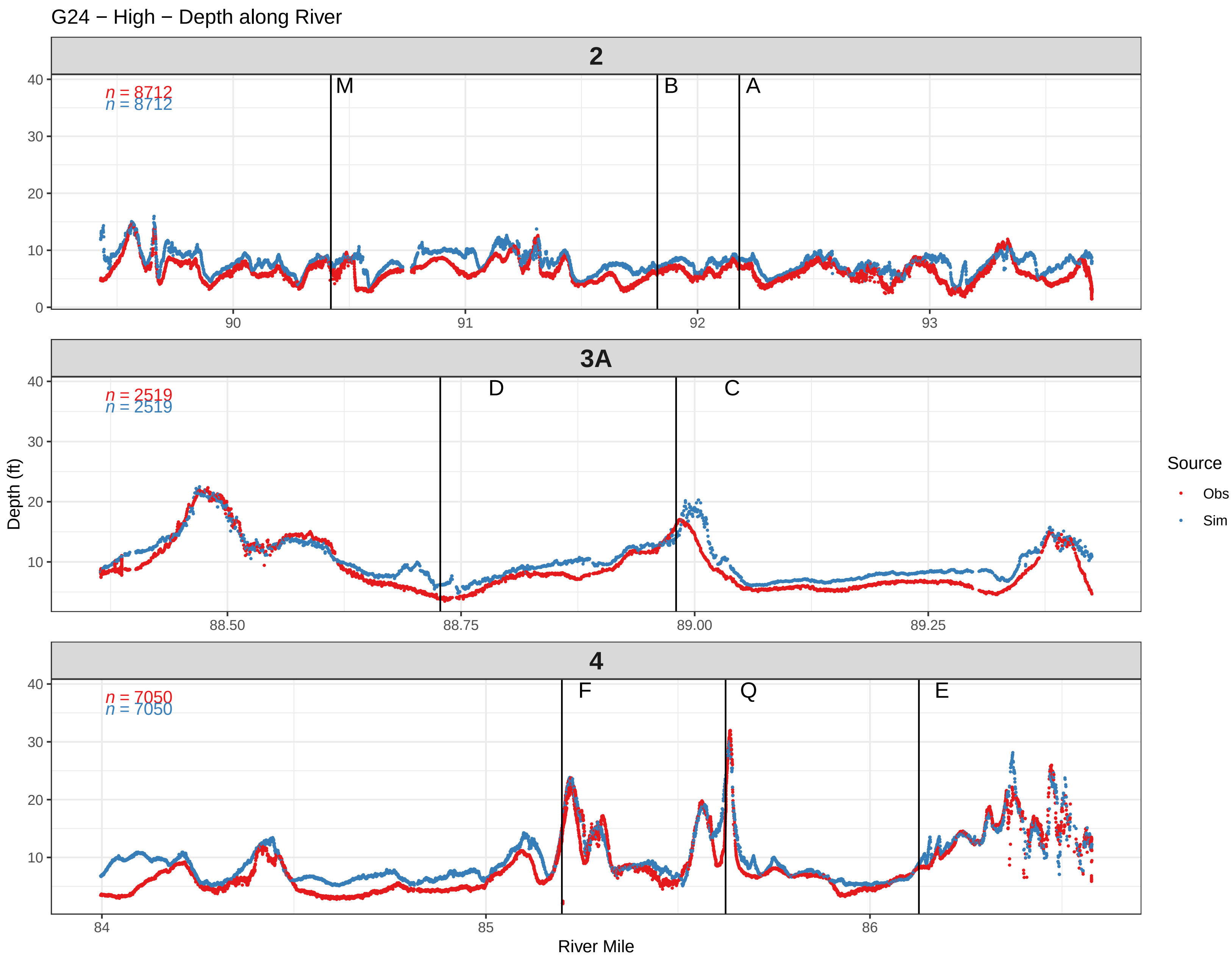




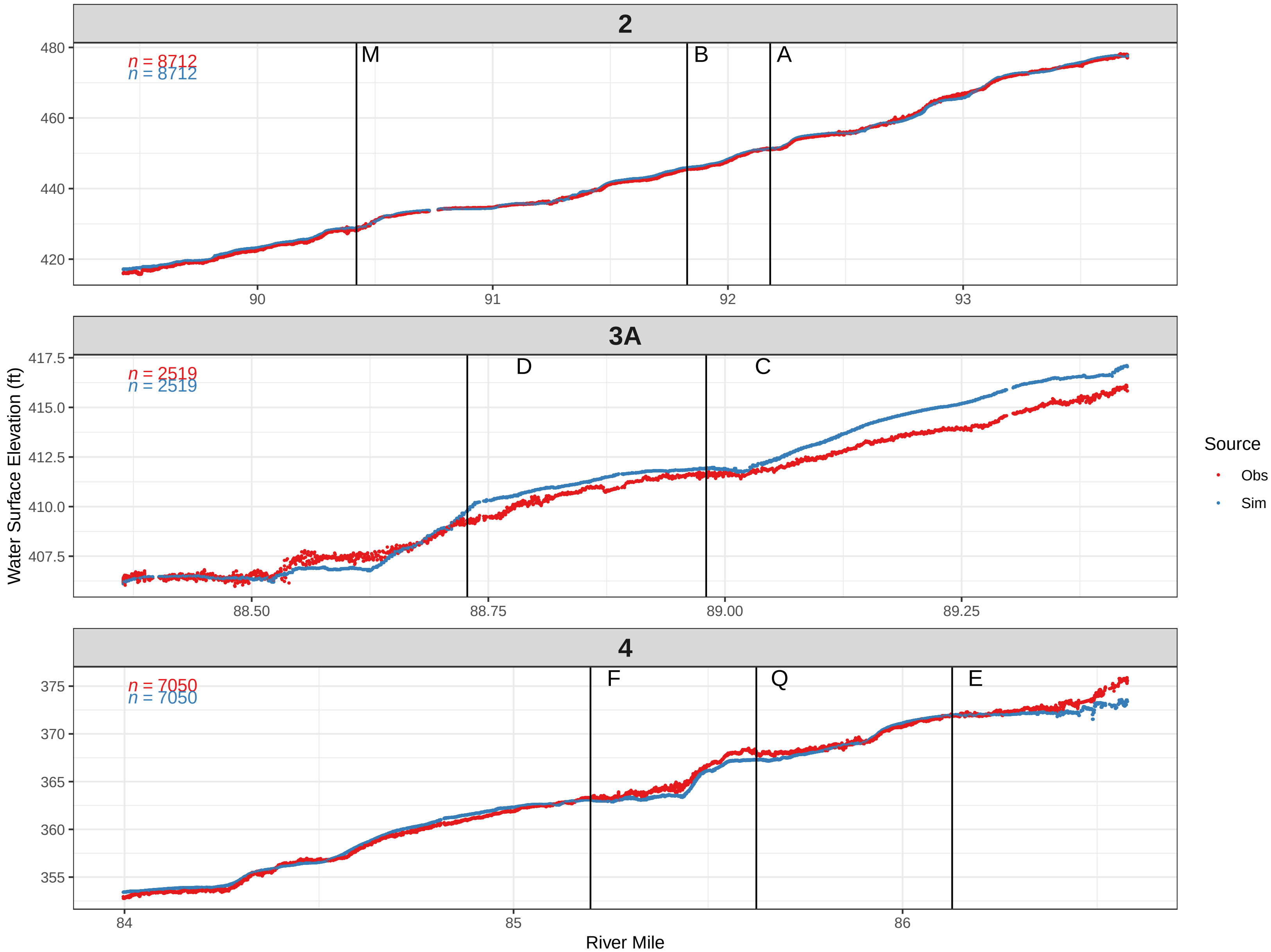
G24 − High − WSE along River
3B
5A
5B
n = 5203
n = 5203
n = 8295
n = 8295
n = 7564
n = 7564
I
H
G
J
N
Water Surface Elevation (ft)
River Mile
Source
Obs
Sim

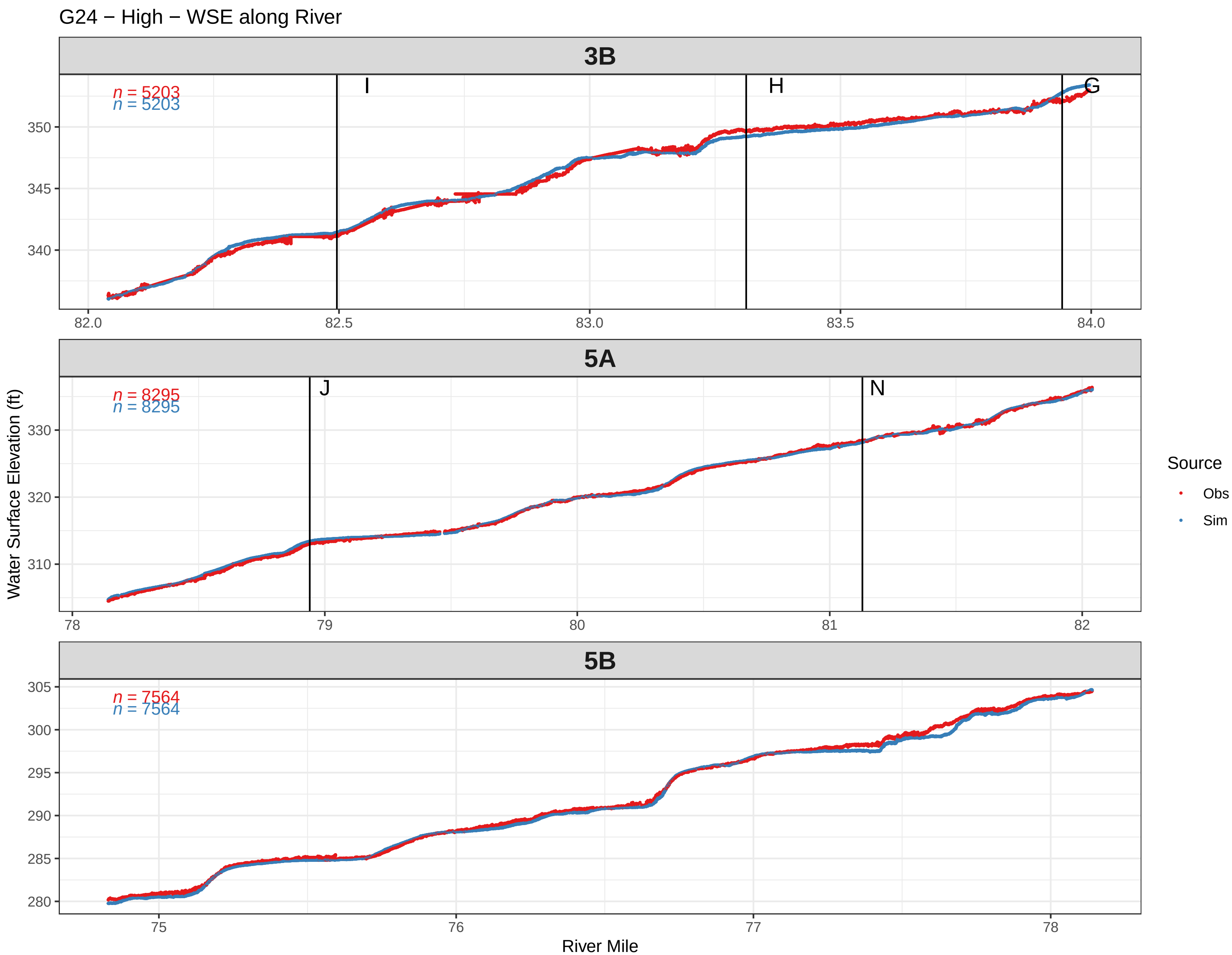
G24 − High − WSE along River



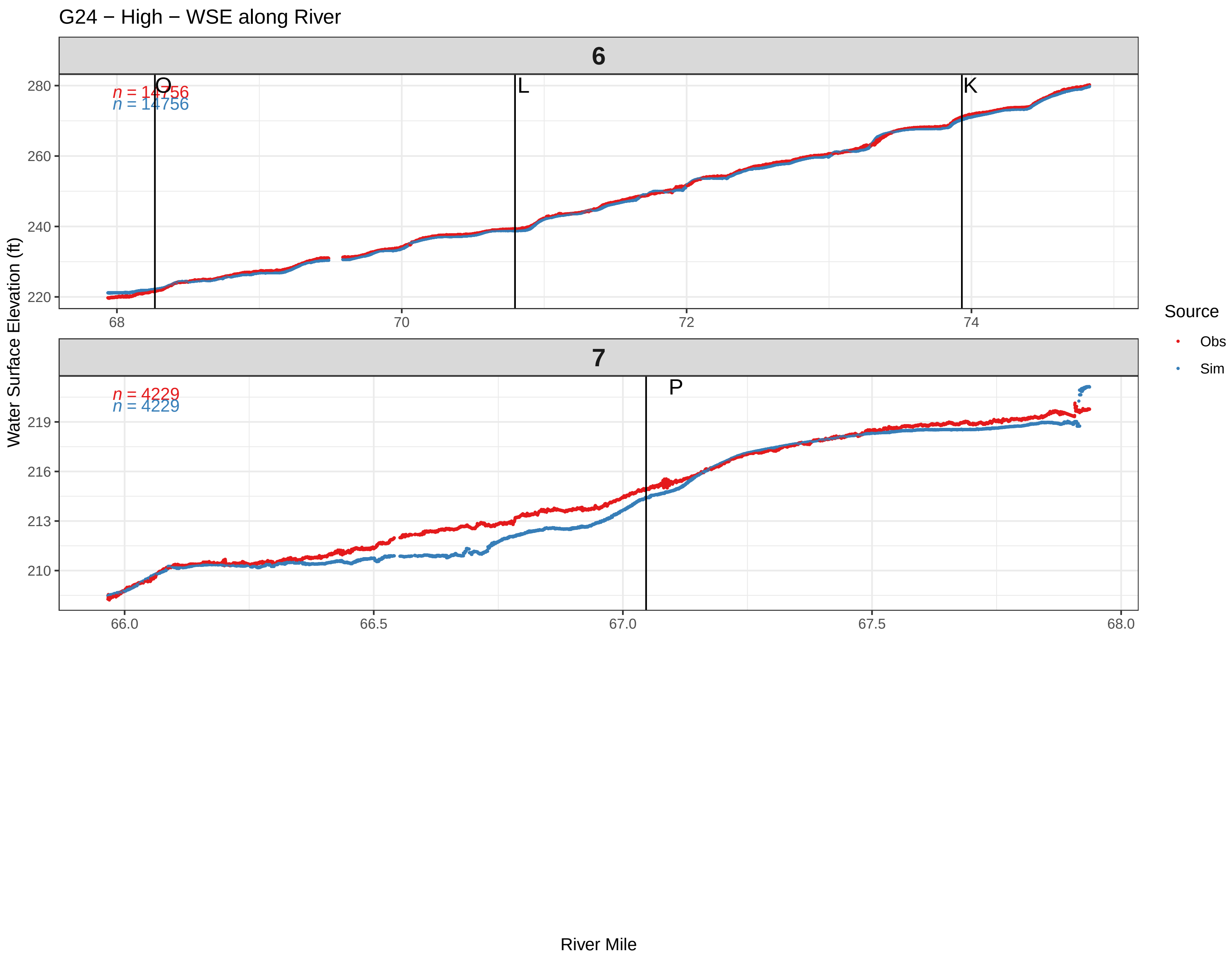

G24 − High − Depth along River
2
n = 8712
n = 8712
M
B
A
3A
n = 2519
n = 2519
D
C
4
n = 7050
n = 7050
F
Q
E
Depth (ft)
River Mile
Source
Obs
Sim

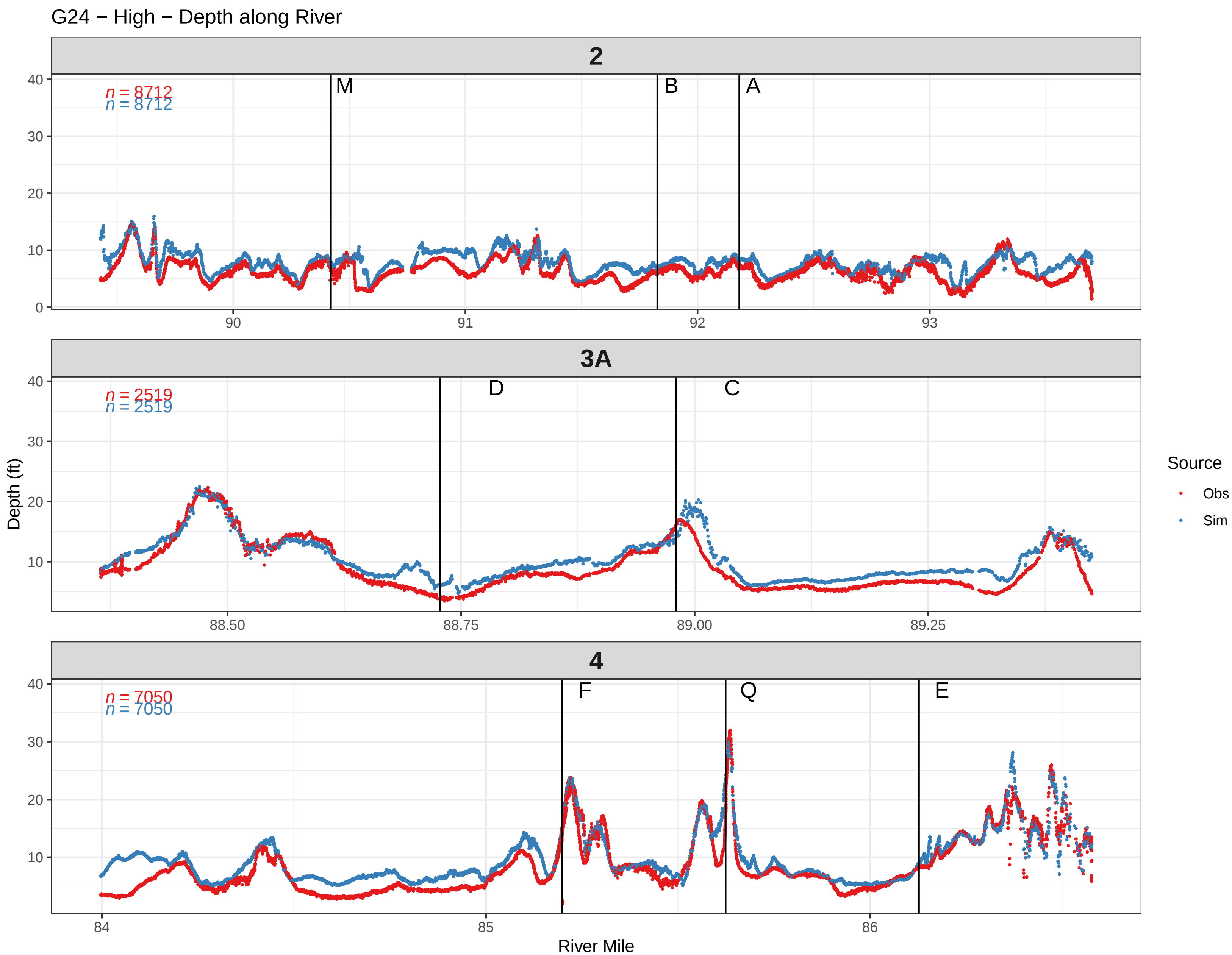
G24 − High − WSE along River



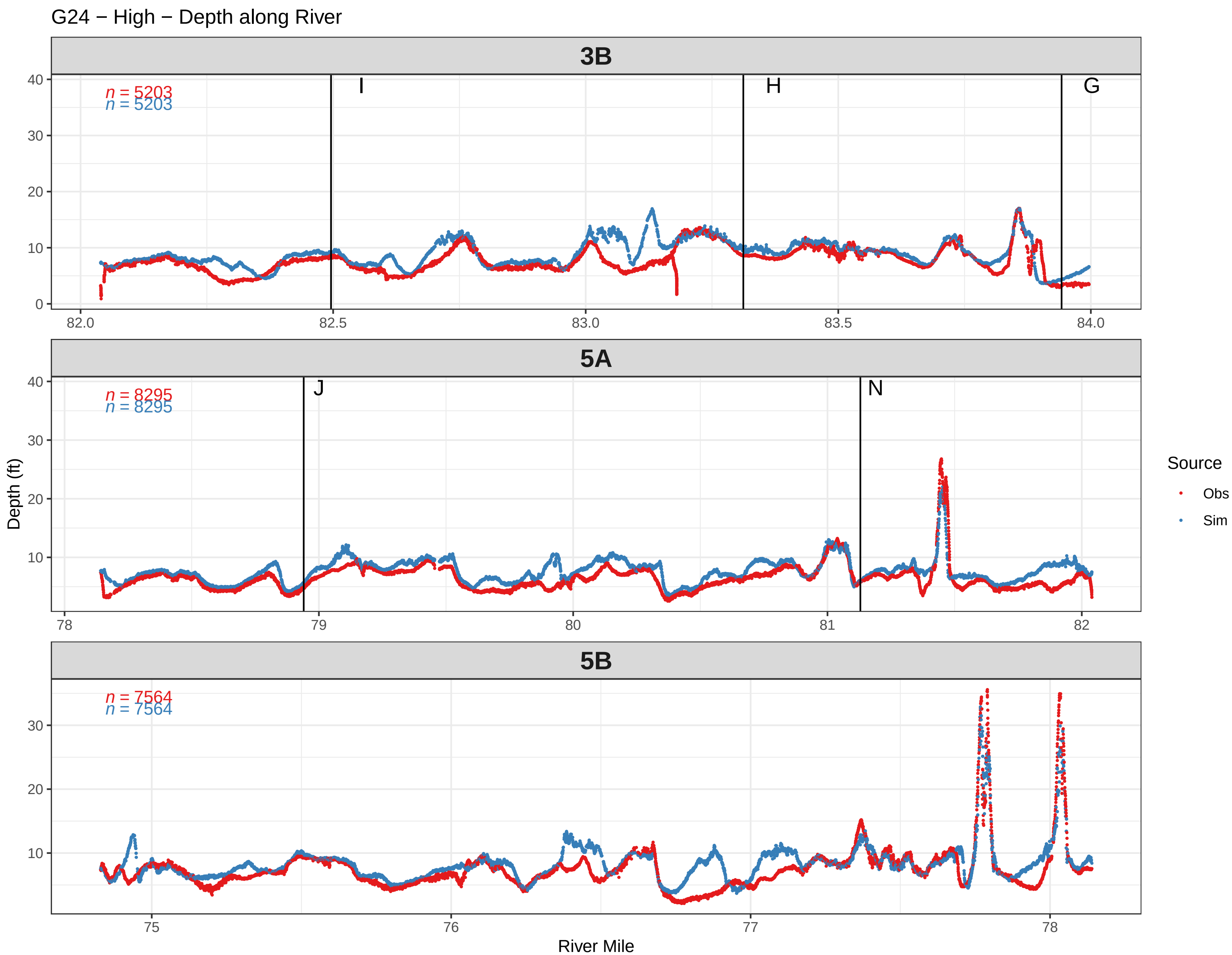


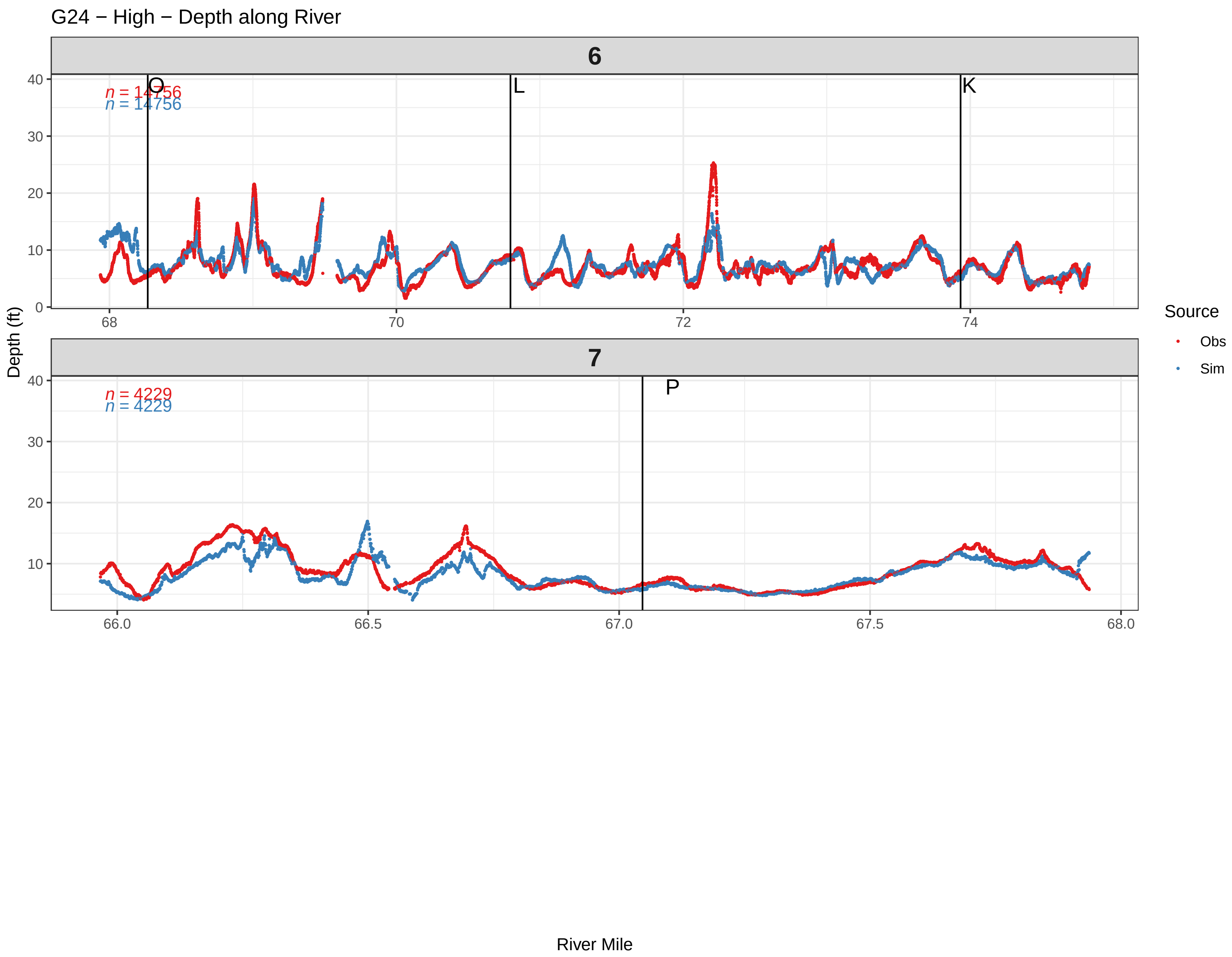
G24 − High − WSE along River
3B
5A
5B
n = 5203
n = 5203
n = 8295
n = 8295
n = 7564
n = 7564
I
H
G
J
N
Water Surface Elevation (ft)
River Mile
Source
Obs
Sim


G24 − High − WSE along River
6
7
n = 14756
n = 14756
n = 4229
n = 4229
O
L
K
P
Water Surface Elevation (ft)
River Mile
Source
Obs
Sim
280
260
240
220
68
70
72
74
219
216
213
210
66.0
66.5
67.0
67.5
68.0

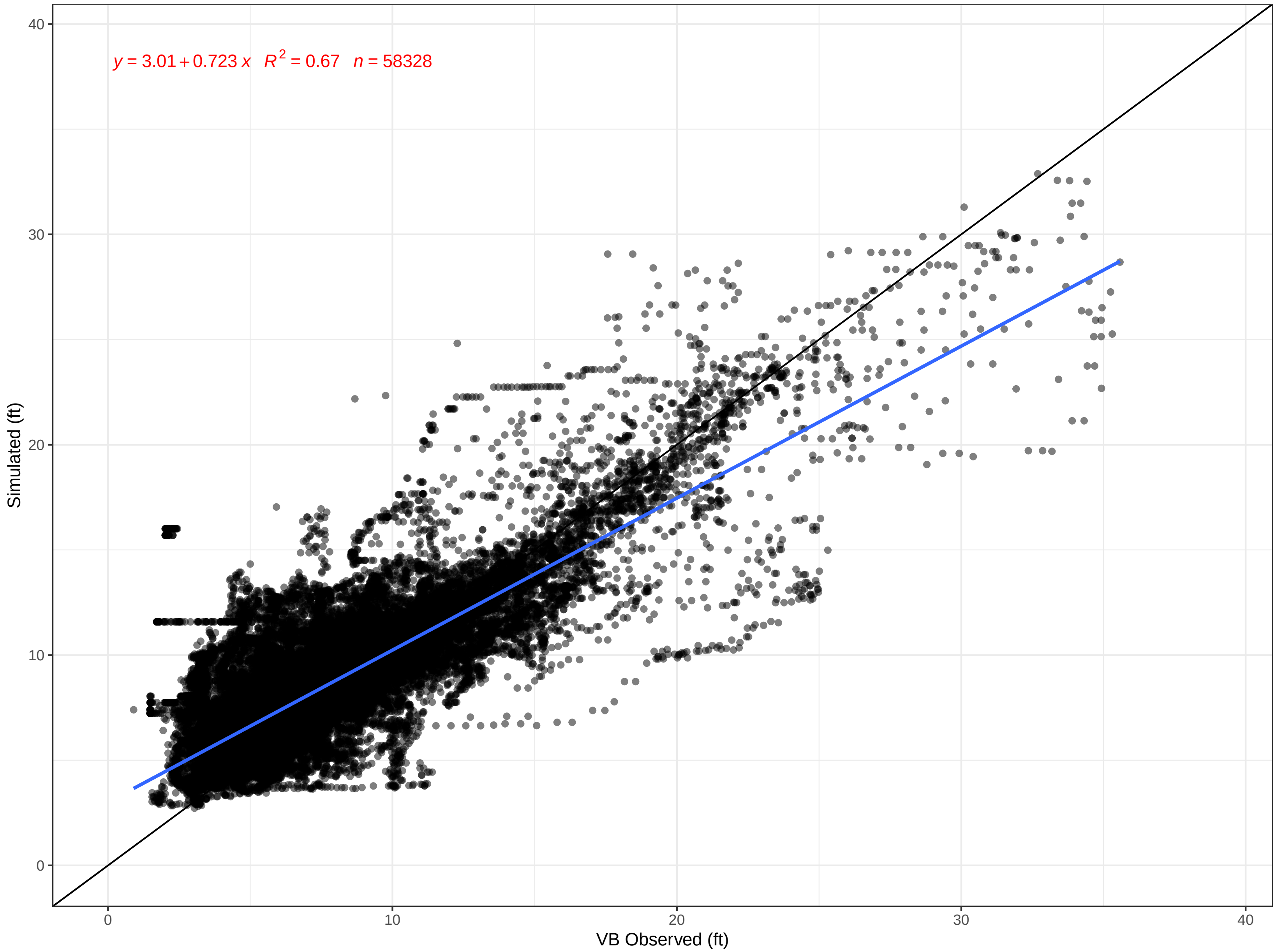


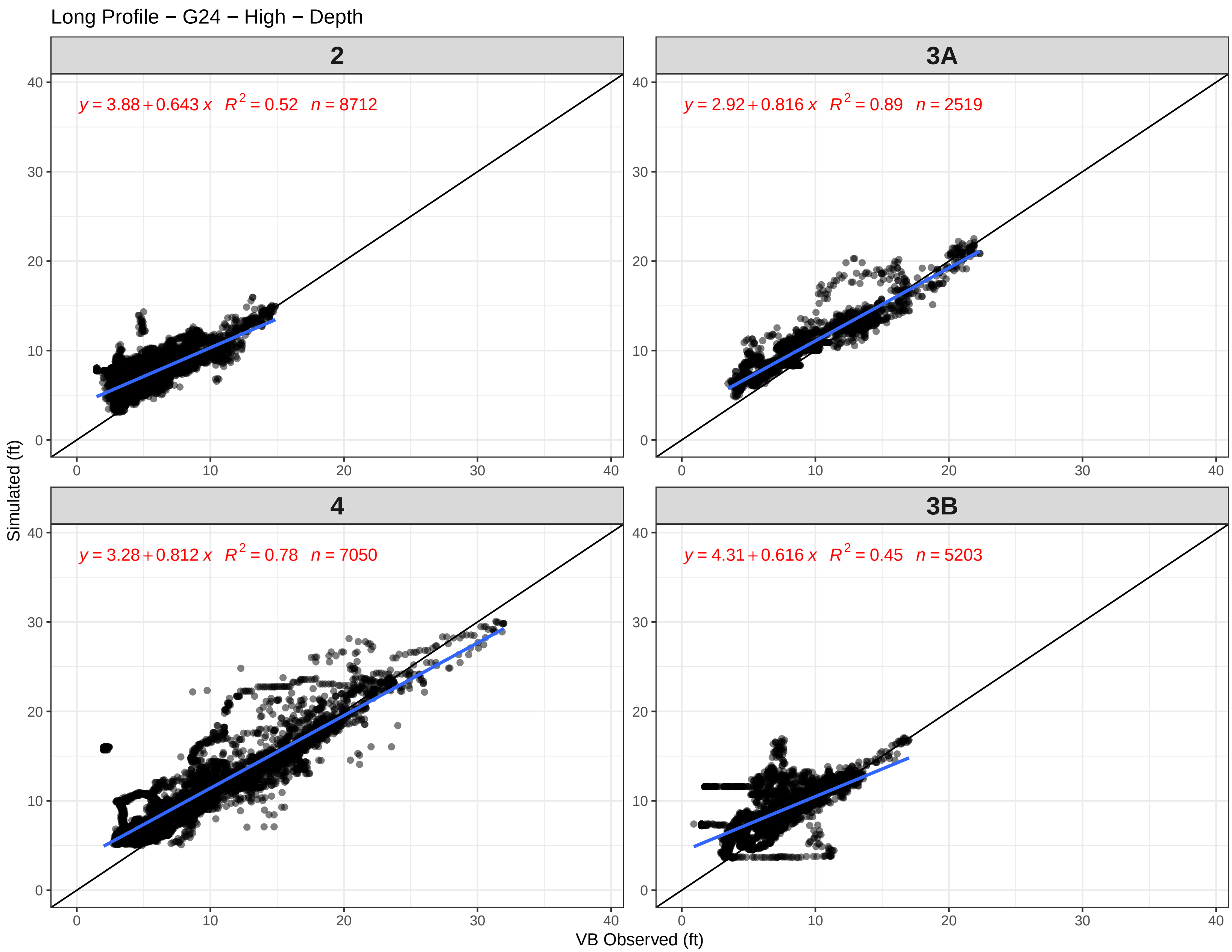
G24 − High − Depth along River
2
M
B
A
n = 8712
n = 8712
40
30
20
10
0
90
91
92
93
3A
D
C
n = 2519
n = 2519
40
30
20
10
88.50
88.75
89.00
89.25
4
F
Q
E
n = 7050
n = 7050
40
30
20
10
84
85
86
Depth (ft)
River Mile
Source
Obs
Sim


G24 − High − Depth along River
3B
5A
5B
I
H
G
J
N
n = 5203
n = 5203
n = 8295
n = 8295
n = 7564
n = 7564
Depth (ft)
River Mile
Source
Obs
Sim

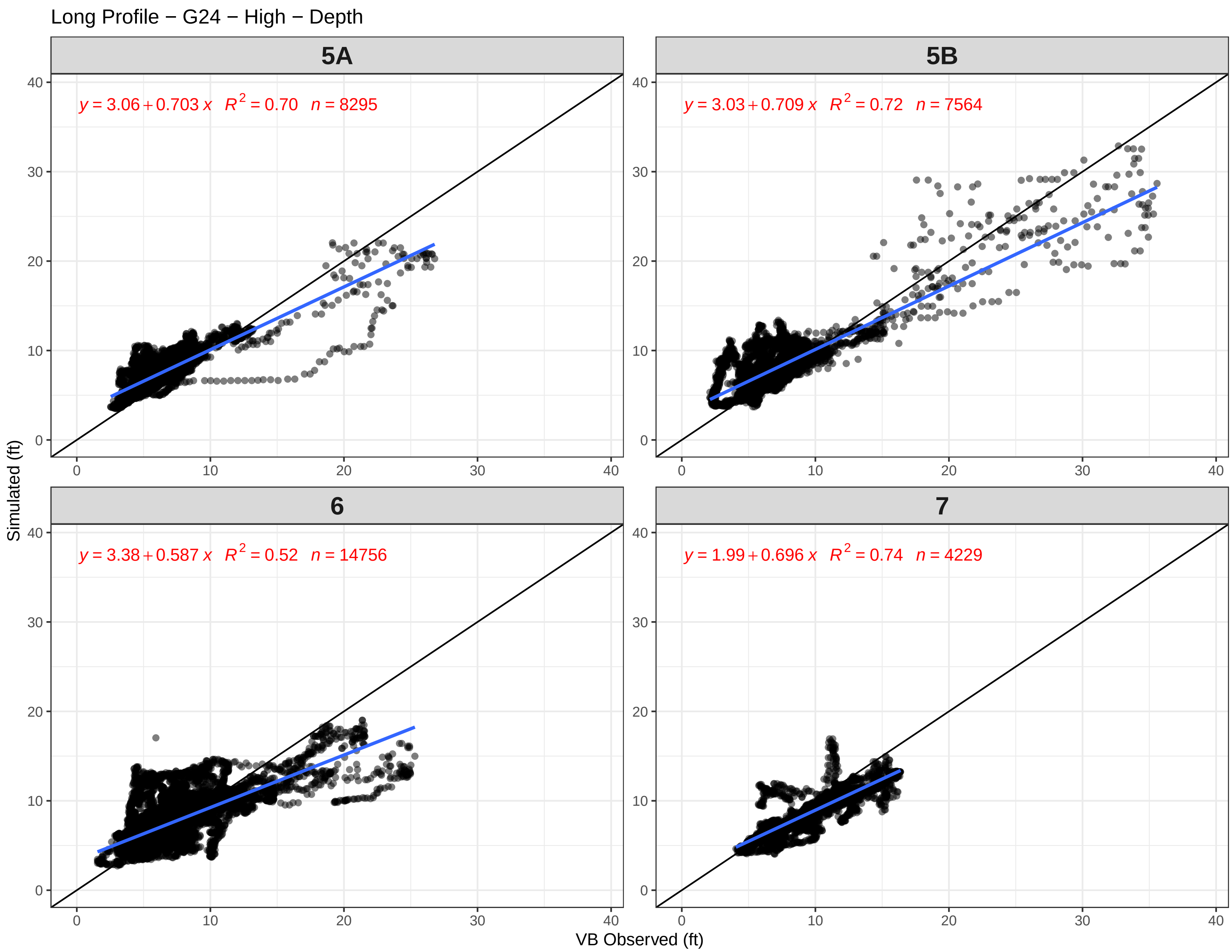

G24 − High − Depth along River
6
7
n = 14756
n = 14756
n = 4229
n = 4229
O
L
K
P
Depth (ft)
River Mile
Source
Obs
Sim

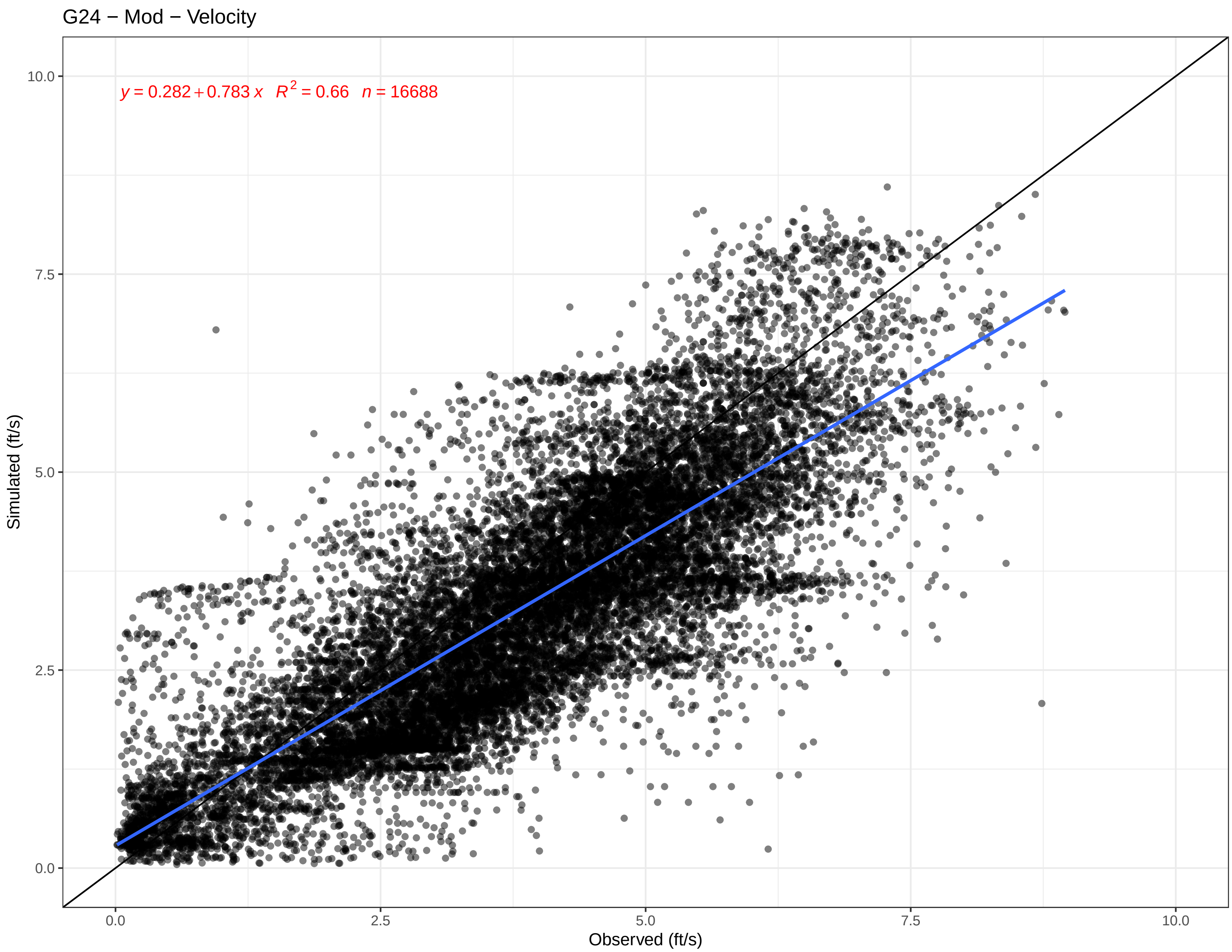
Long Profile − G24 − High − Depth



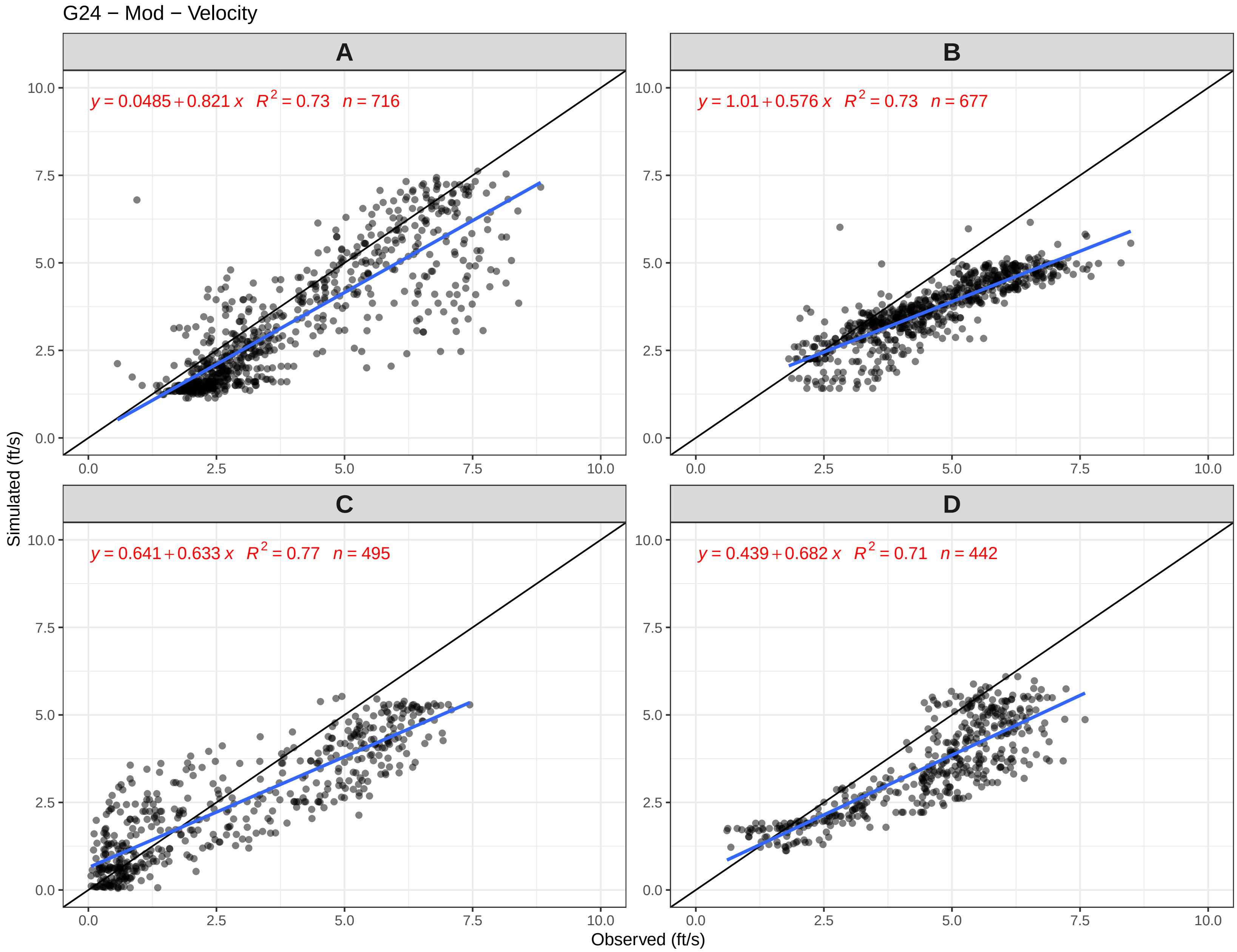


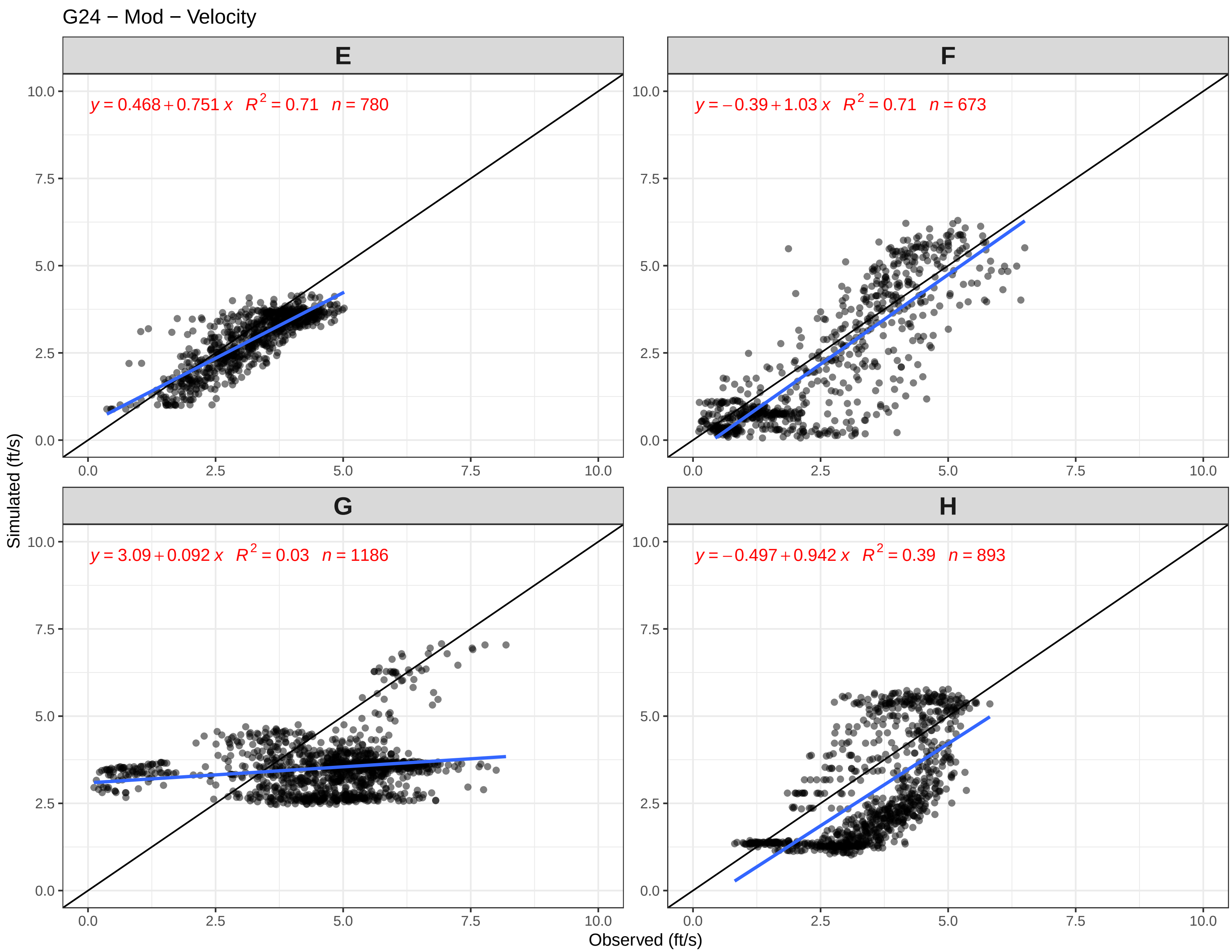
Long Profile − G24 − High − Depth
2
$y = 3.88 + 0.643\,x$ $R^2 = 0.52$ $n = 8712$
3A
$y = 2.92 + 0.816\,x$ $R^2 = 0.89$ $n = 2519$
4
$y = 3.28 + 0.812\,x$ $R^2 = 0.78$ $n = 7050$
3B
$y = 4.31 + 0.616\,x$ $R^2 = 0.45$ $n = 5203$
Simulated (ft)
VB Observed (ft)
0
10
20
30
40


Long Profile − G24 − High − Depth
5A
$y = 3.06 + 0.703\,x$ $R^2 = 0.70$ $n = 8295$
5B
$y = 3.03 + 0.709\,x$ $R^2 = 0.72$ $n = 7564$
6
$y = 3.38 + 0.587\,x$ $R^2 = 0.52$ $n = 14756$
7
$y = 1.99 + 0.696\,x$ $R^2 = 0.74$ $n = 4229$
Simulated (ft)
VB Observed (ft)
0
10
20
30
40

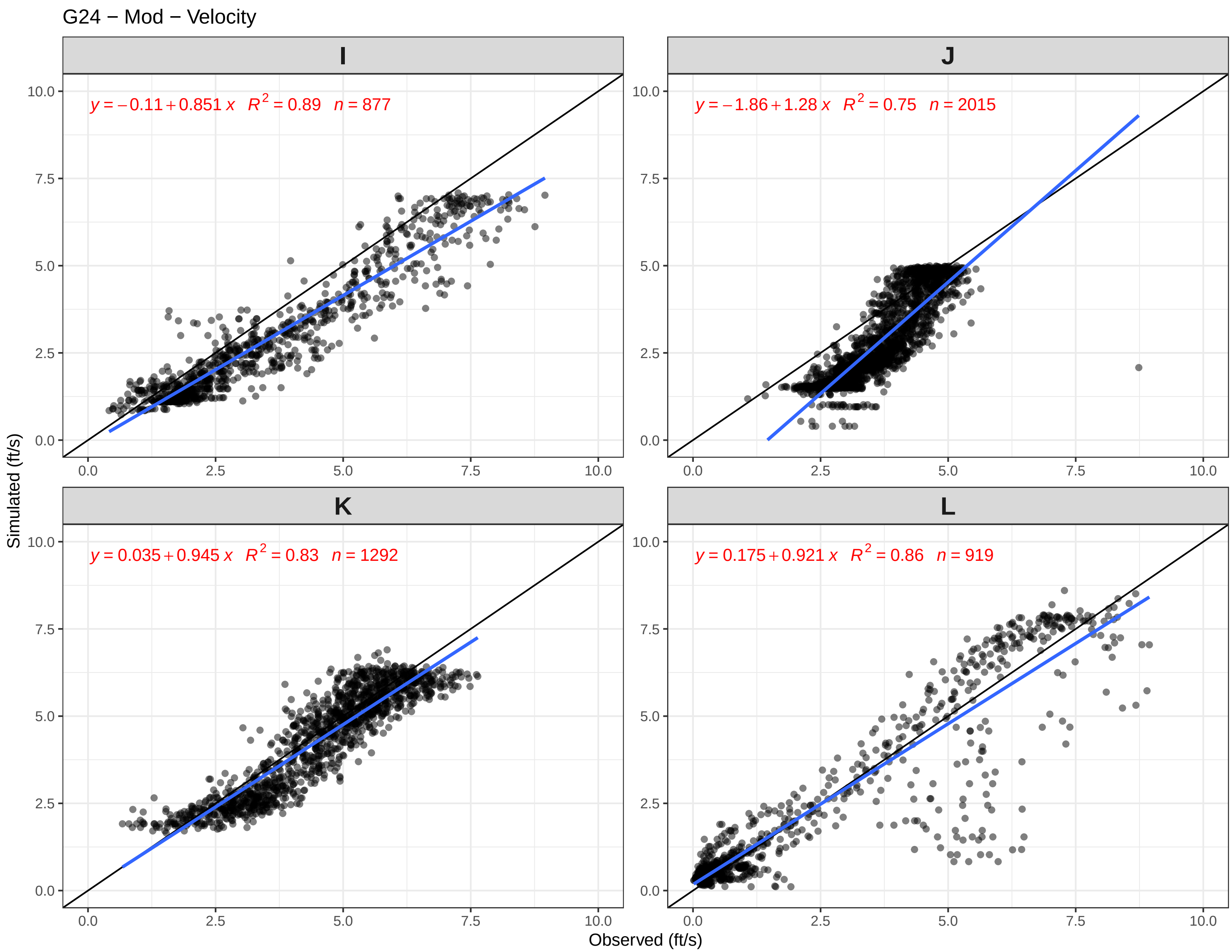


G24 − Mod − Velocity
y = 0.282 + 0.783 x   R² = 0.66   n = 16688
10.0
7.5
5.0
2.5
0.0
Simulated (ft/s)
0.0
2.5
5.0
7.5
10.0
Observed (ft/s)

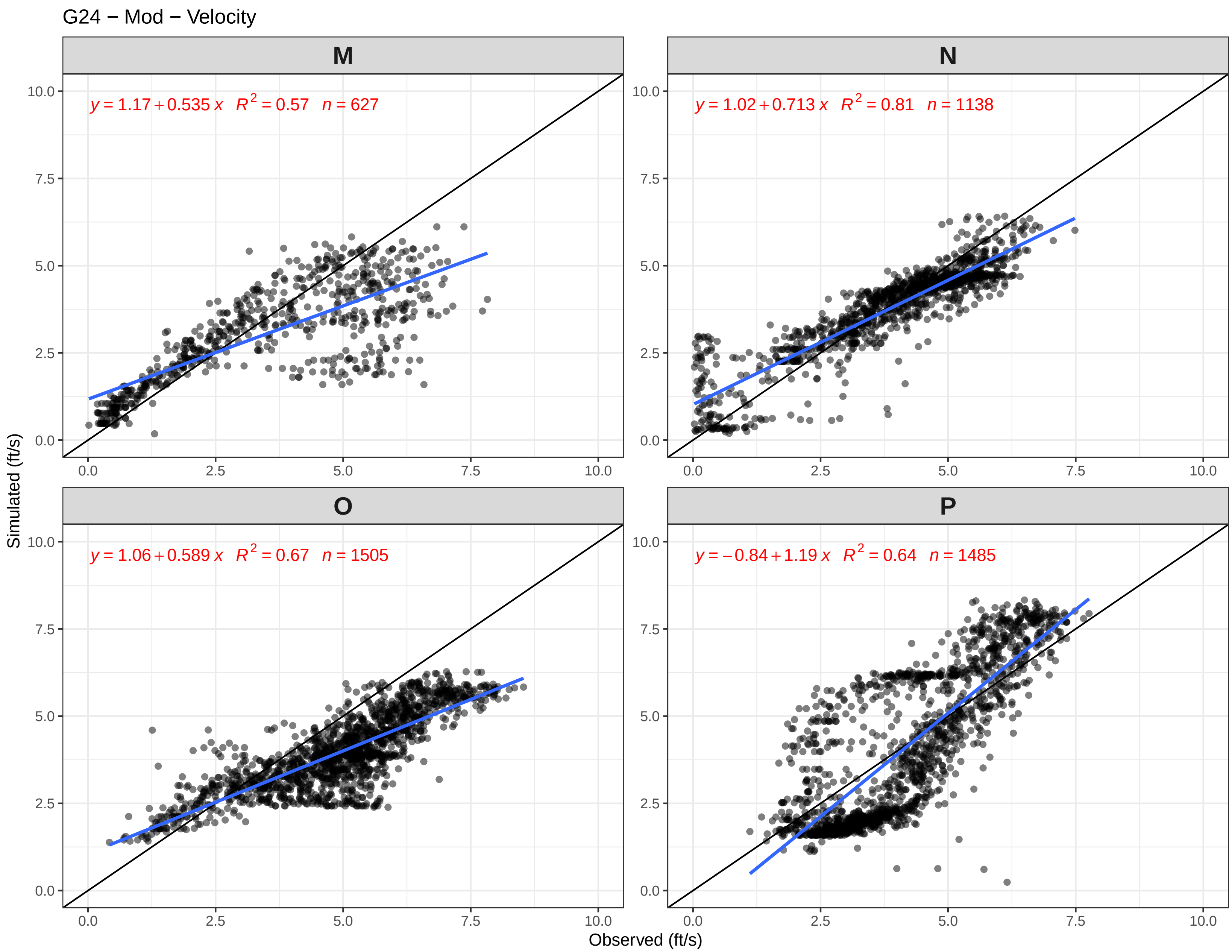

G24 − Mod − Velocity
A
y = 0.0485 + 0.821 x R2 = 0.73 n = 716
B
y = 1.01 + 0.576 x R2 = 0.73 n = 677
C
y = 0.641 + 0.633 x R2 = 0.77 n = 495
D
y = 0.439 + 0.682 x R2 = 0.71 n = 442
Simulated (ft/s)
Observed (ft/s)
0.0
2.5
5.0
7.5
10.0



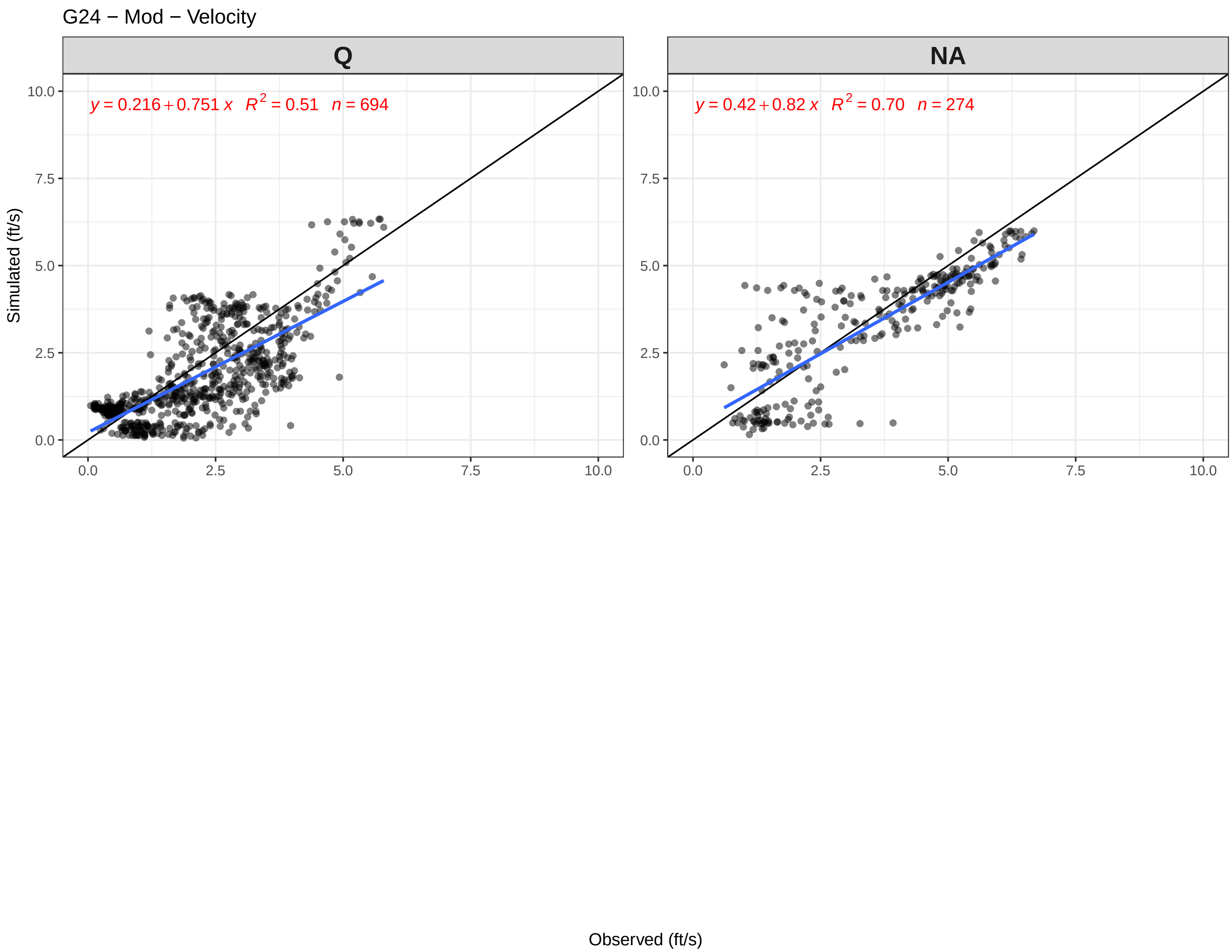
G24 − Mod − Velocity
E
F
G
H
y = 0.468 + 0.751 x R² = 0.71 n = 780
y = −0.39 + 1.03 x R² = 0.71 n = 673
y = 3.09 + 0.092 x R² = 0.03 n = 1186
y = −0.497 + 0.942 x R² = 0.39 n = 893
Simulated (ft/s)
Observed (ft/s)
0.0
2.5
5.0
7.5
10.0



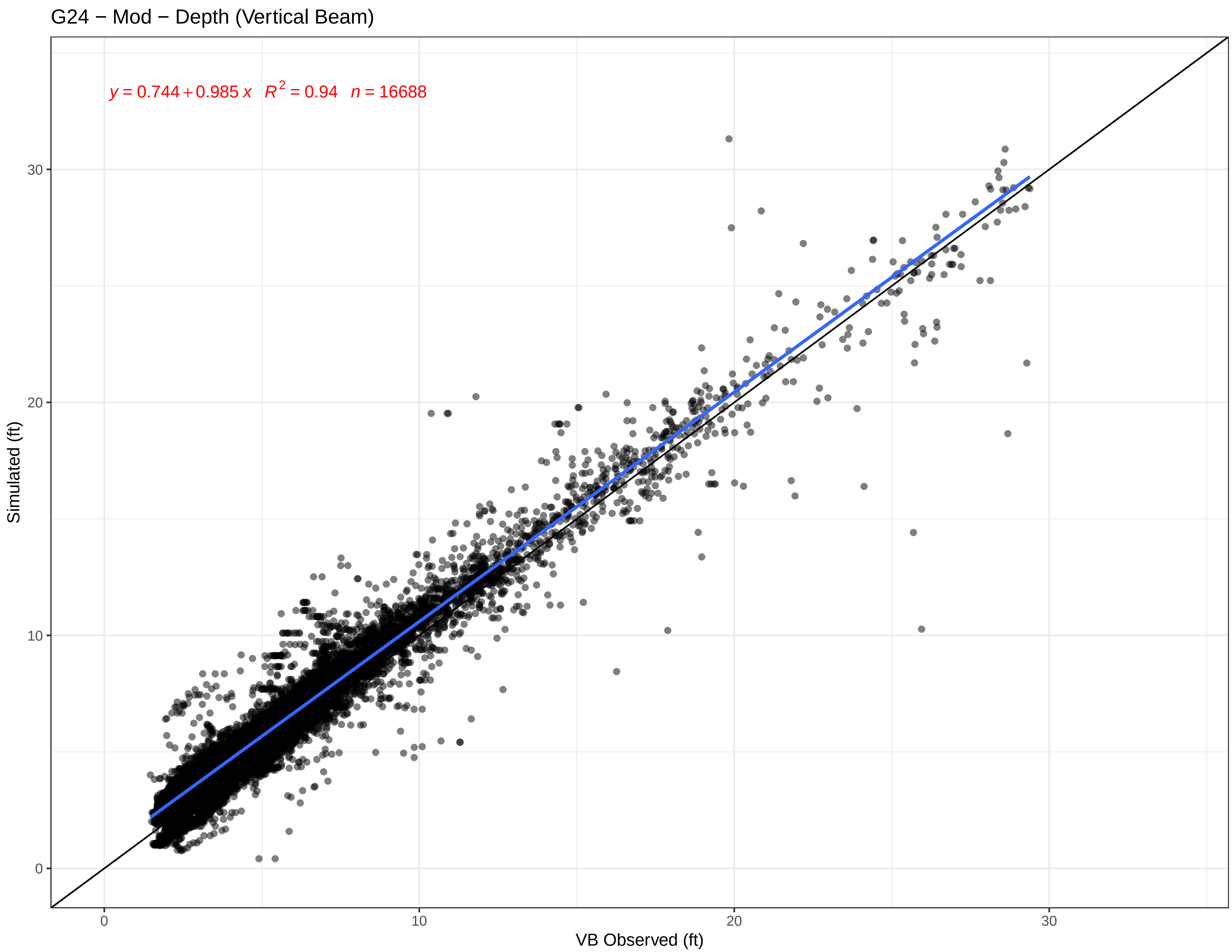
G24 − Mod − Velocity
I
$y = -0.11 + 0.851\,x$ $R^2 = 0.89$ $n = 877$
J
$y = -1.86 + 1.28\,x$ $R^2 = 0.75$ $n = 2015$
K
$y = 0.035 + 0.945\,x$ $R^2 = 0.83$ $n = 1292$
L
$y = 0.175 + 0.921\,x$ $R^2 = 0.86$ $n = 919$
Simulated (ft/s)
Observed (ft/s)
0.0
2.5
5.0
7.5
10.0



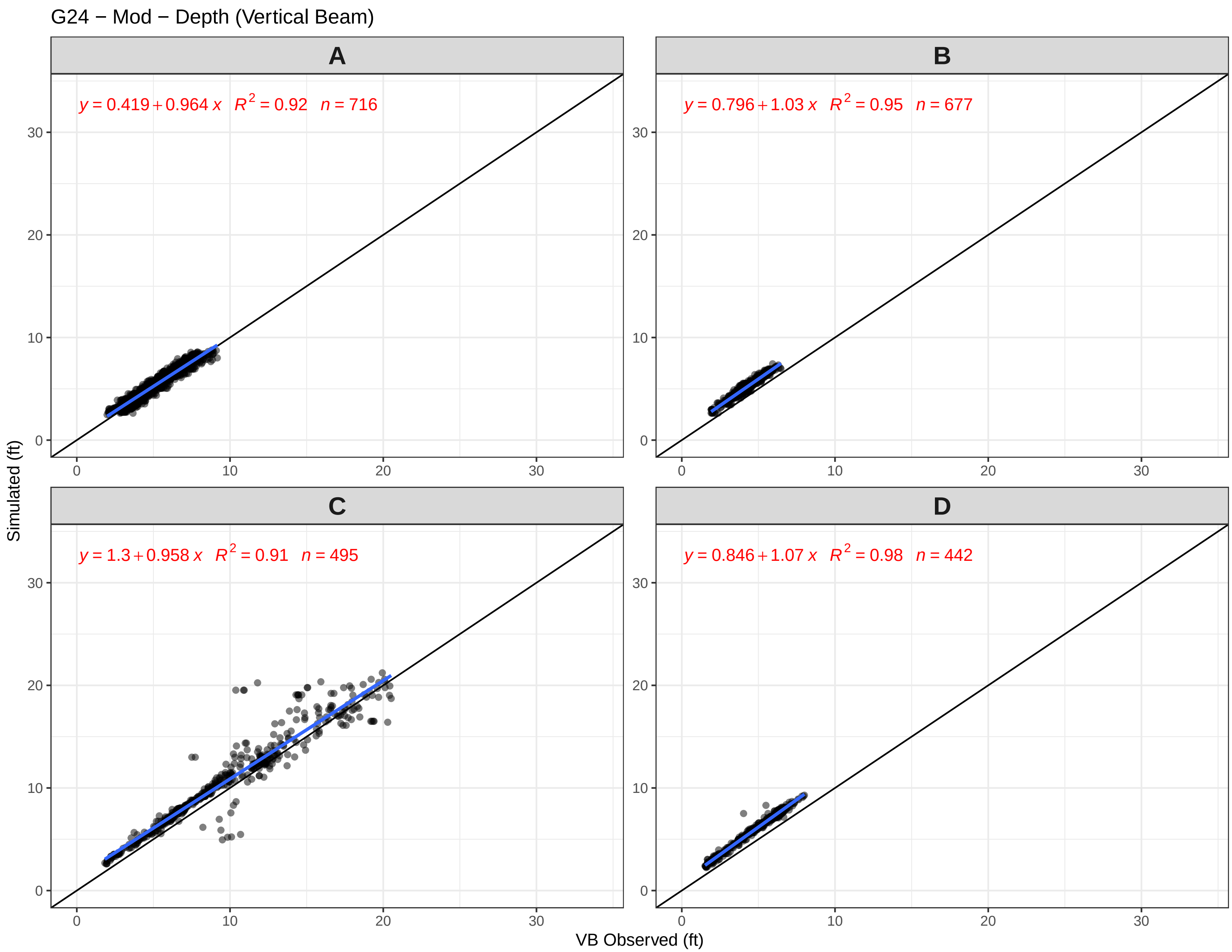
G24 − Mod − Velocity
M
N
O
P
y = 1.17 + 0.535 x   R^2 = 0.57   n = 627
y = 1.02 + 0.713 x   R^2 = 0.81   n = 1138
y = 1.06 + 0.589 x   R^2 = 0.67   n = 1505
y = −0.84 + 1.19 x   R^2 = 0.64   n = 1485
Simulated (ft/s)
Observed (ft/s)
0.0
2.5
5.0
7.5
10.0



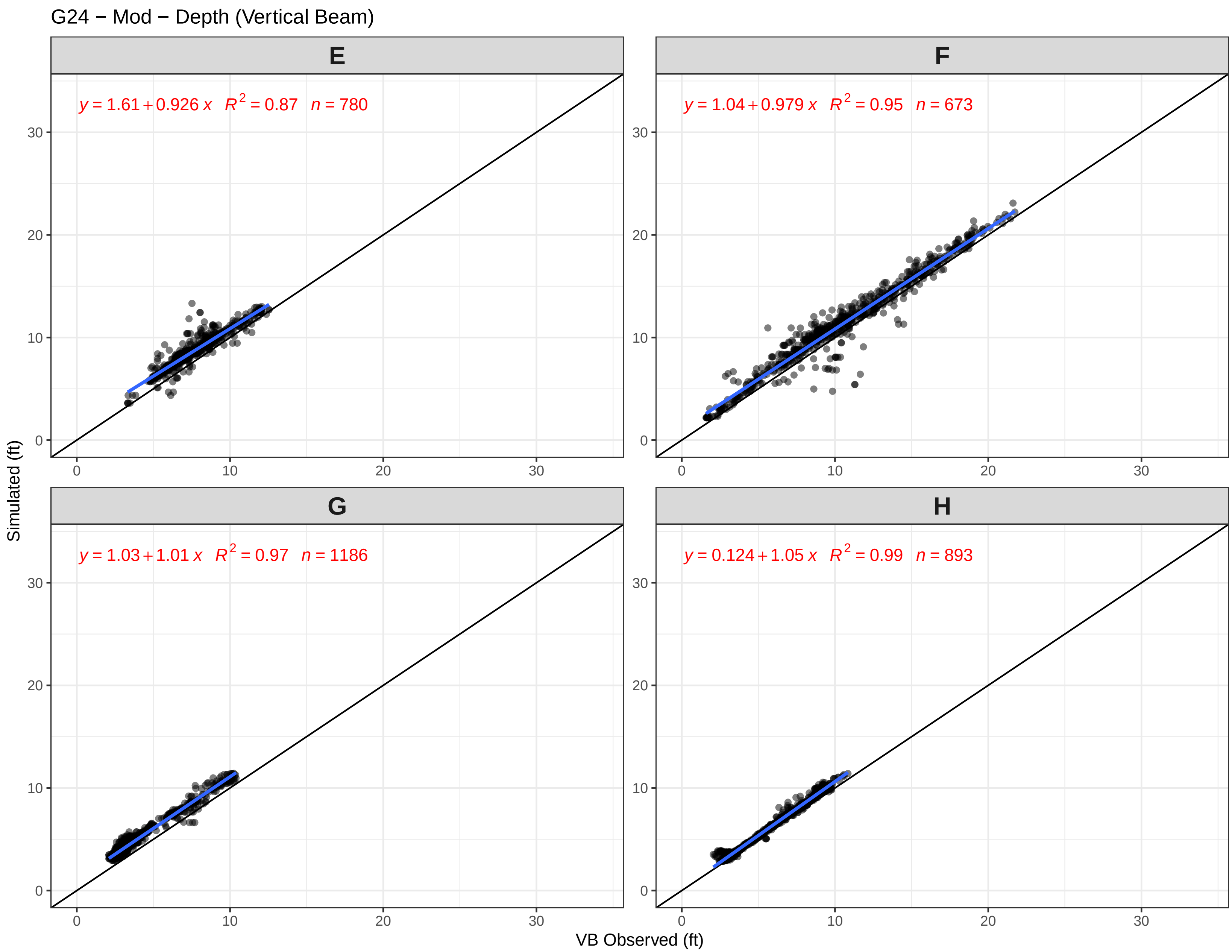
G24 − Mod − Velocity
Q
NA
y = 0.216 + 0.751 x   R^2 = 0.51   n = 694
y = 0.42 + 0.82 x   R^2 = 0.70   n = 274
Simulated (ft/s)
Observed (ft/s)
0.0
2.5
5.0
7.5
10.0

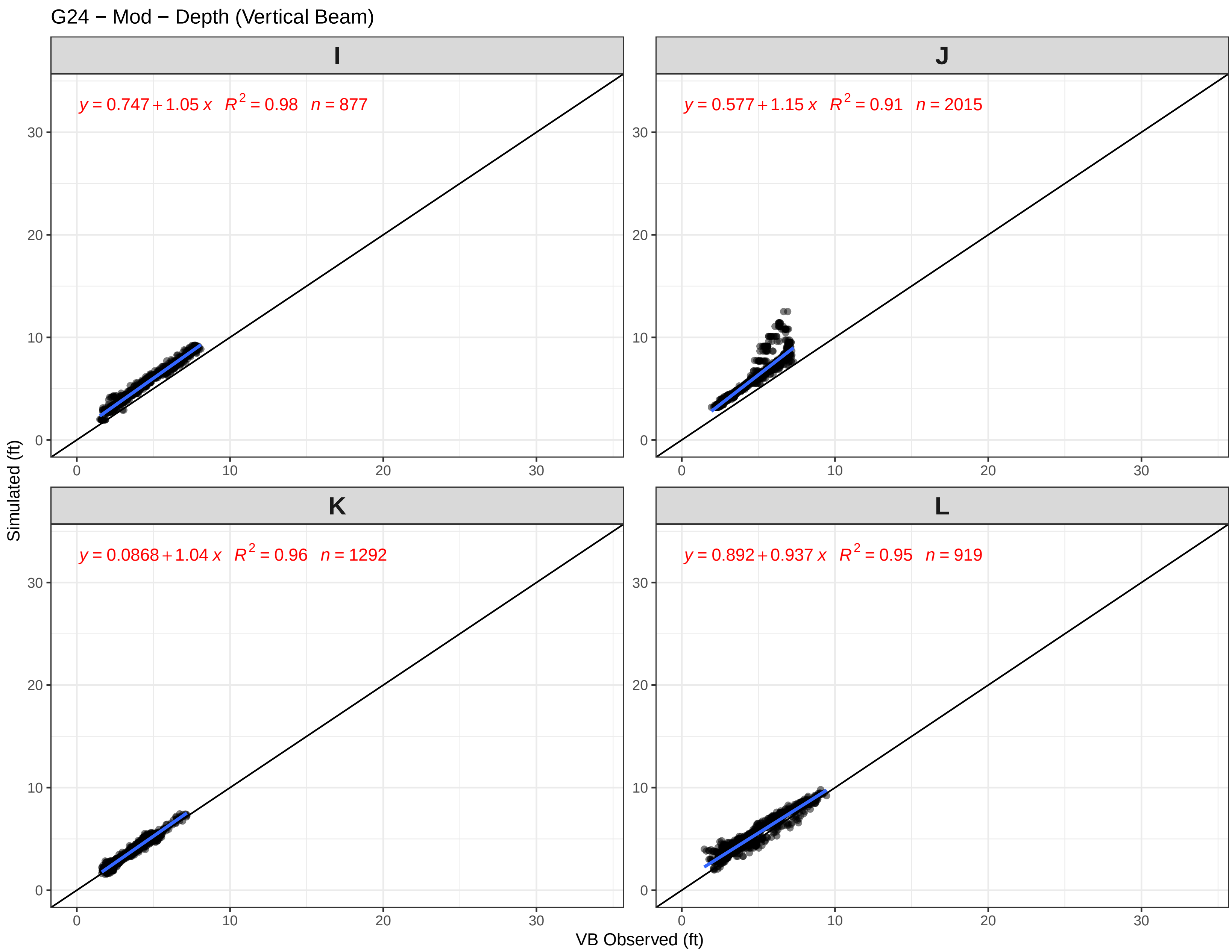


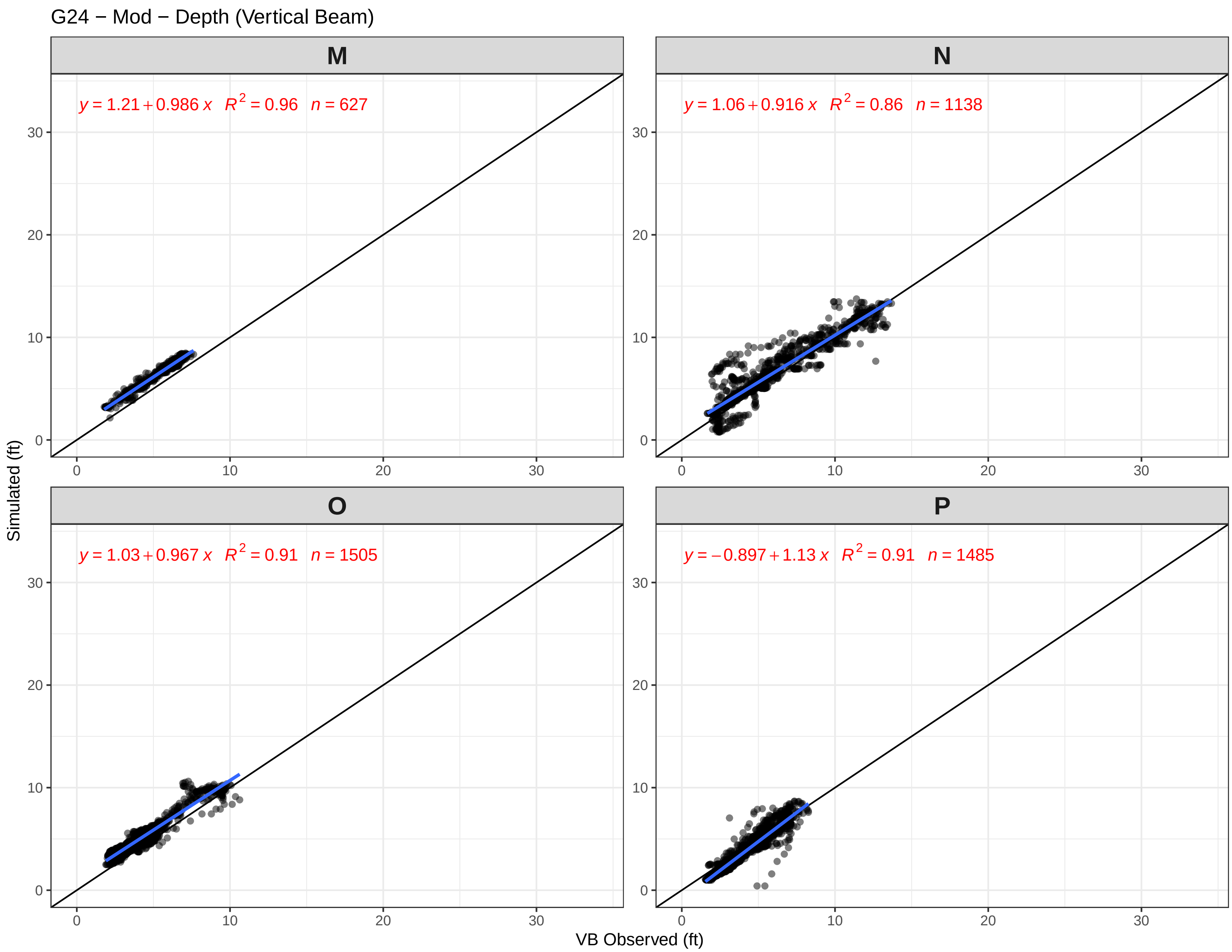
G24 − Mod − Depth (Vertical Beam)
$y = 0.744 + 0.985\,x \quad R^2 = 0.94 \quad n = 16688$
Simulated (ft)
VB Observed (ft)
0
10
20
30
0
10
20
30



G24 − Mod − Depth (Vertical Beam)
A
$y = 0.419 + 0.964\,x$ $R^2 = 0.92$ $n = 716$
B
$y = 0.796 + 1.03\,x$ $R^2 = 0.95$ $n = 677$
C
$y = 1.3 + 0.958\,x$ $R^2 = 0.91$ $n = 495$
D
$y = 0.846 + 1.07\,x$ $R^2 = 0.98$ $n = 442$
Simulated (ft)
VB Observed (ft)
0
10
20
30

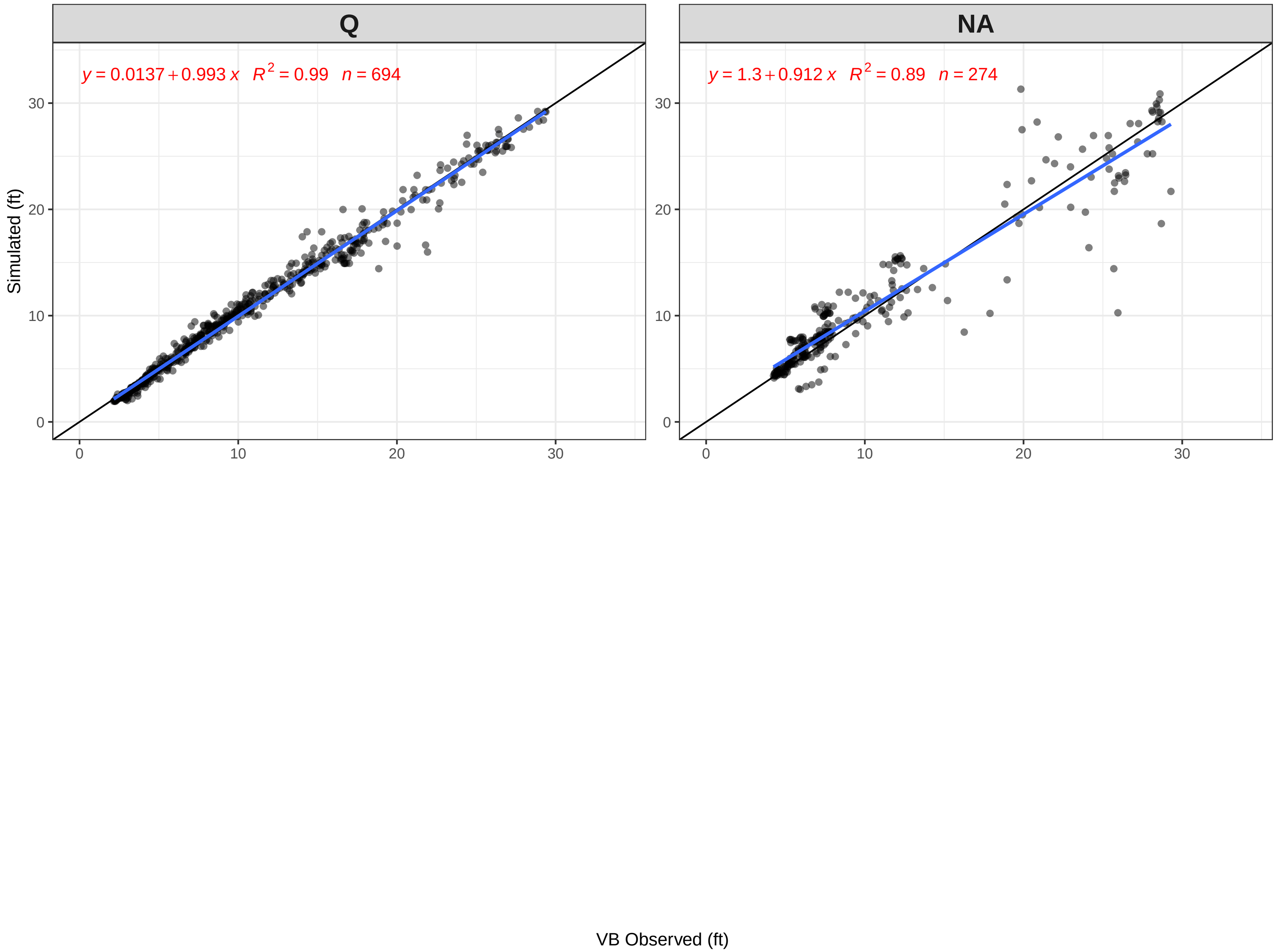

G24 − Mod − Depth (Vertical Beam)
E
y = 1.61 + 0.926 x R2 = 0.87 n = 780
F
y = 1.04 + 0.979 x R2 = 0.95 n = 673
G
y = 1.03 + 1.01 x R2 = 0.97 n = 1186
H
y = 0.124 + 1.05 x R2 = 0.99 n = 893
Simulated (ft)
VB Observed (ft)
0
10
20
30

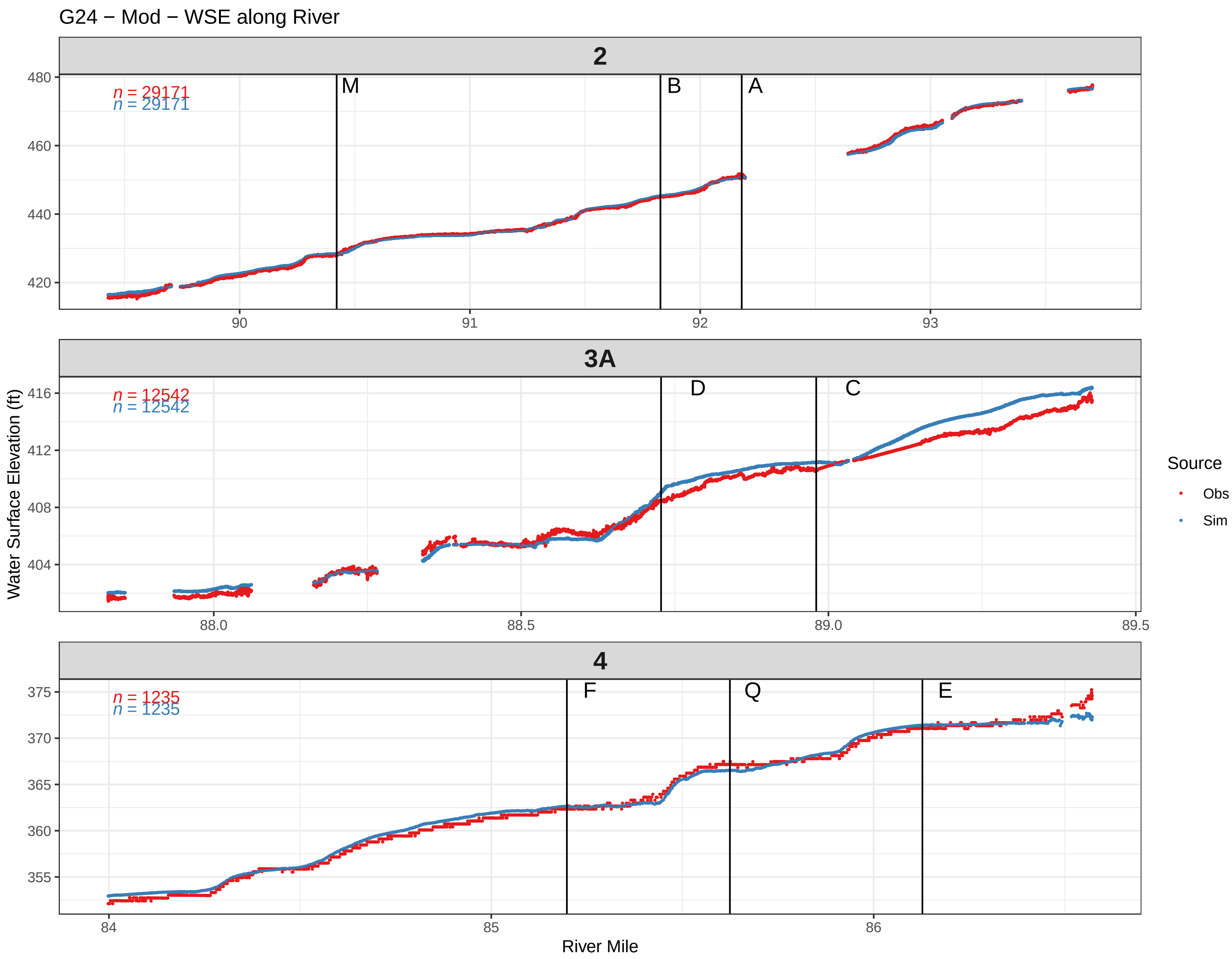

G24 − Mod − Depth (Vertical Beam)
I
y = 0.747 + 1.05 x   R² = 0.98   n = 877
J
y = 0.577 + 1.15 x   R² = 0.91   n = 2015
K
y = 0.0868 + 1.04 x   R² = 0.96   n = 1292
L
y = 0.892 + 0.937 x   R² = 0.95   n = 919
Simulated (ft)
VB Observed (ft)
0
10
20
30



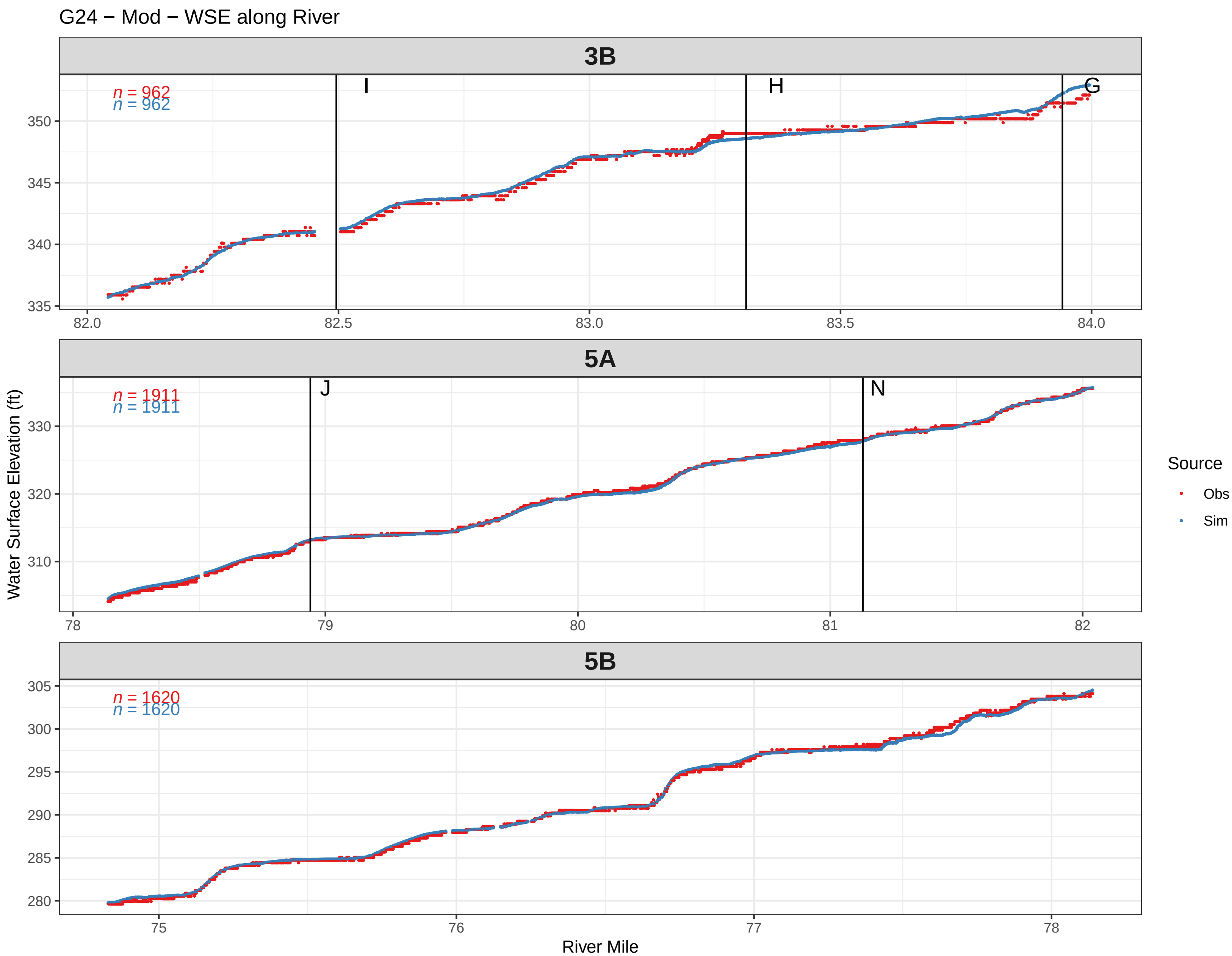
G24 − Mod − Depth (Vertical Beam)
M
y = 1.21 + 0.986 x   R^2 = 0.96   n = 627
N
y = 1.06 + 0.916 x   R^2 = 0.86   n = 1138
O
y = 1.03 + 0.967 x   R^2 = 0.91   n = 1505
P
y = −0.897 + 1.13 x   R^2 = 0.91   n = 1485
Simulated (ft)
VB Observed (ft)
0
10
20
30

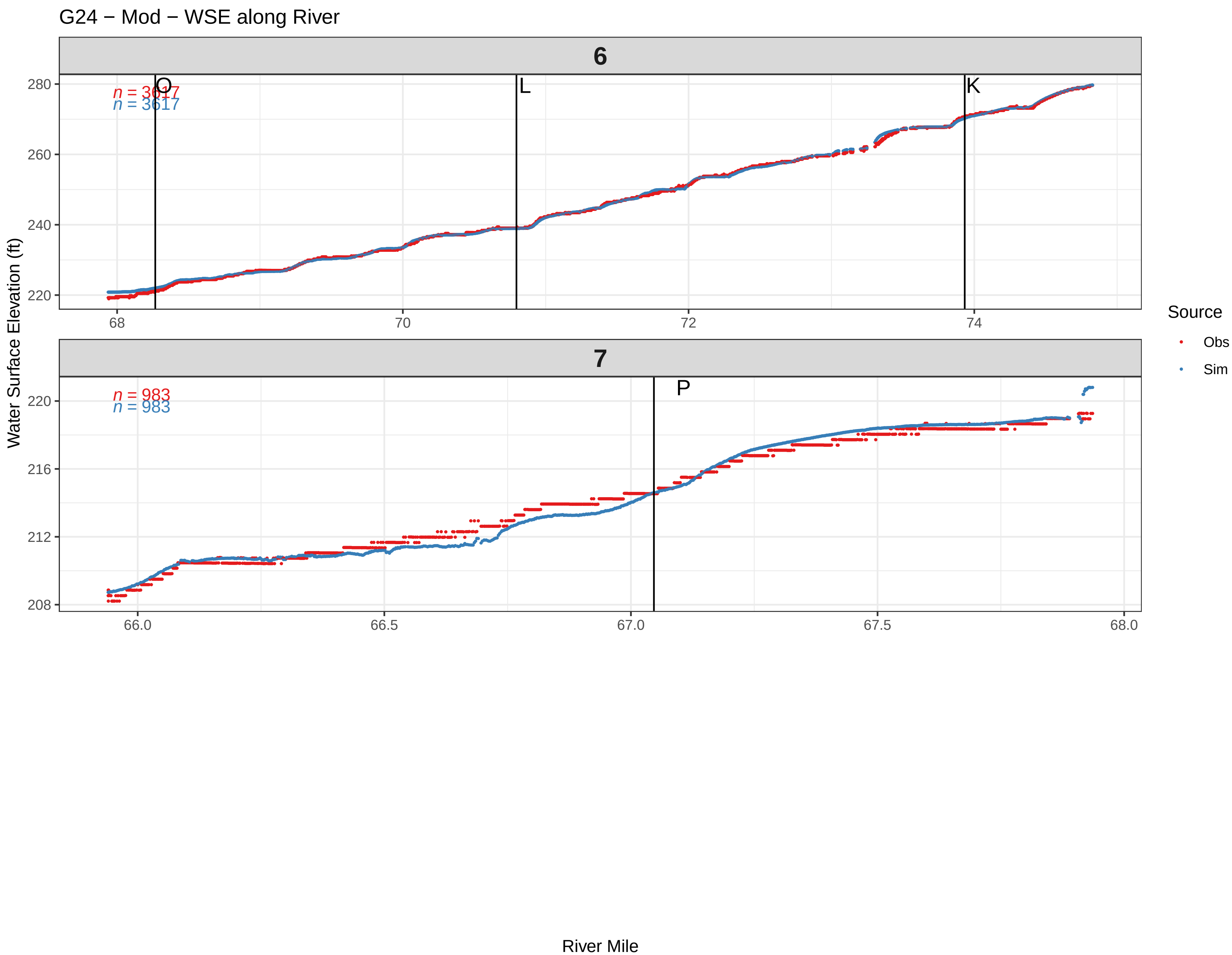
G24 − Mod − Depth (Vertical Beam)



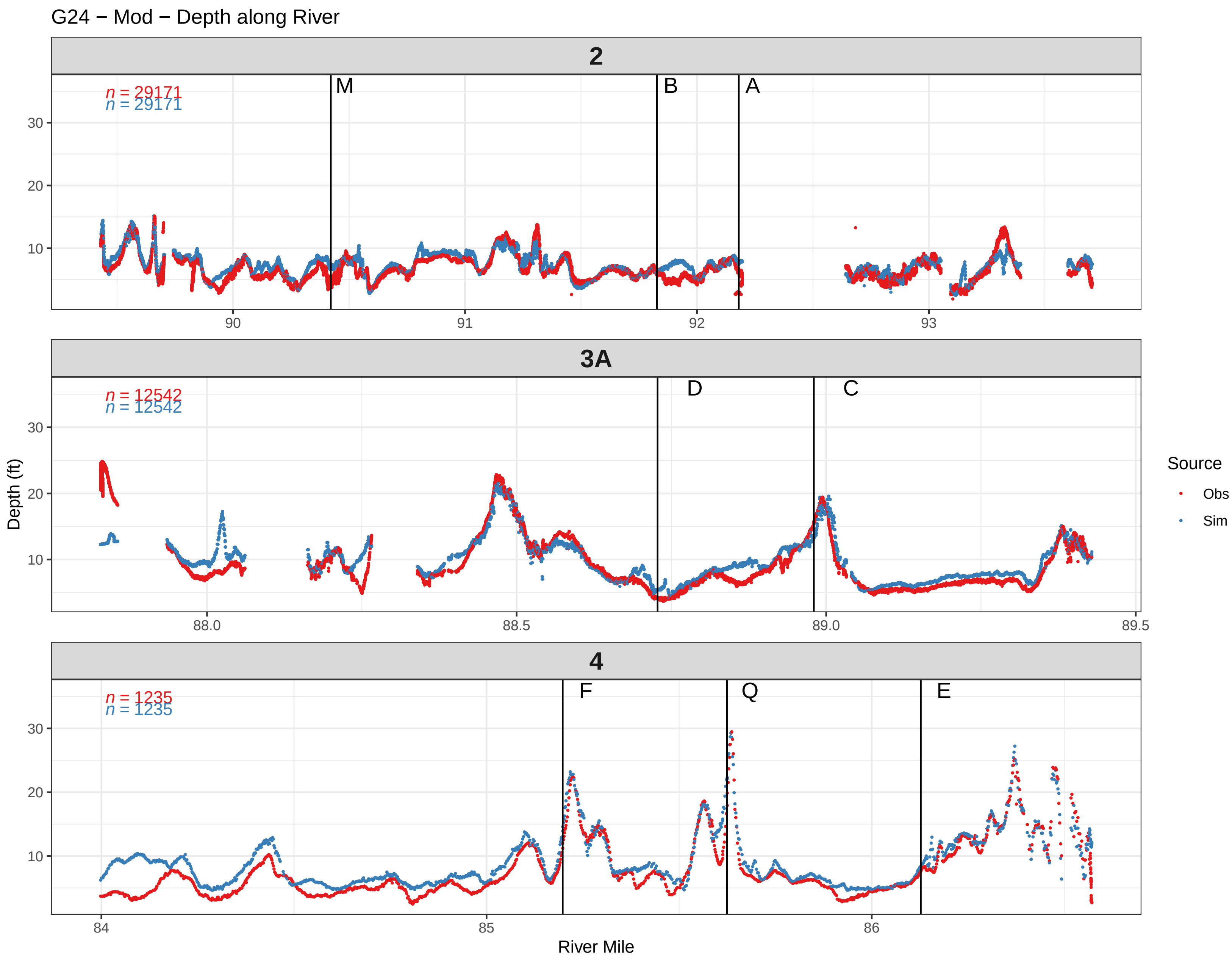


G24 − Mod − WSE along River
2
M
B
A
n = 29171
n = 29171
3A
D
C
n = 12542
n = 12542
4
F
Q
E
n = 1235
n = 1235
Water Surface Elevation (ft)
River Mile
Source
Obs
Sim

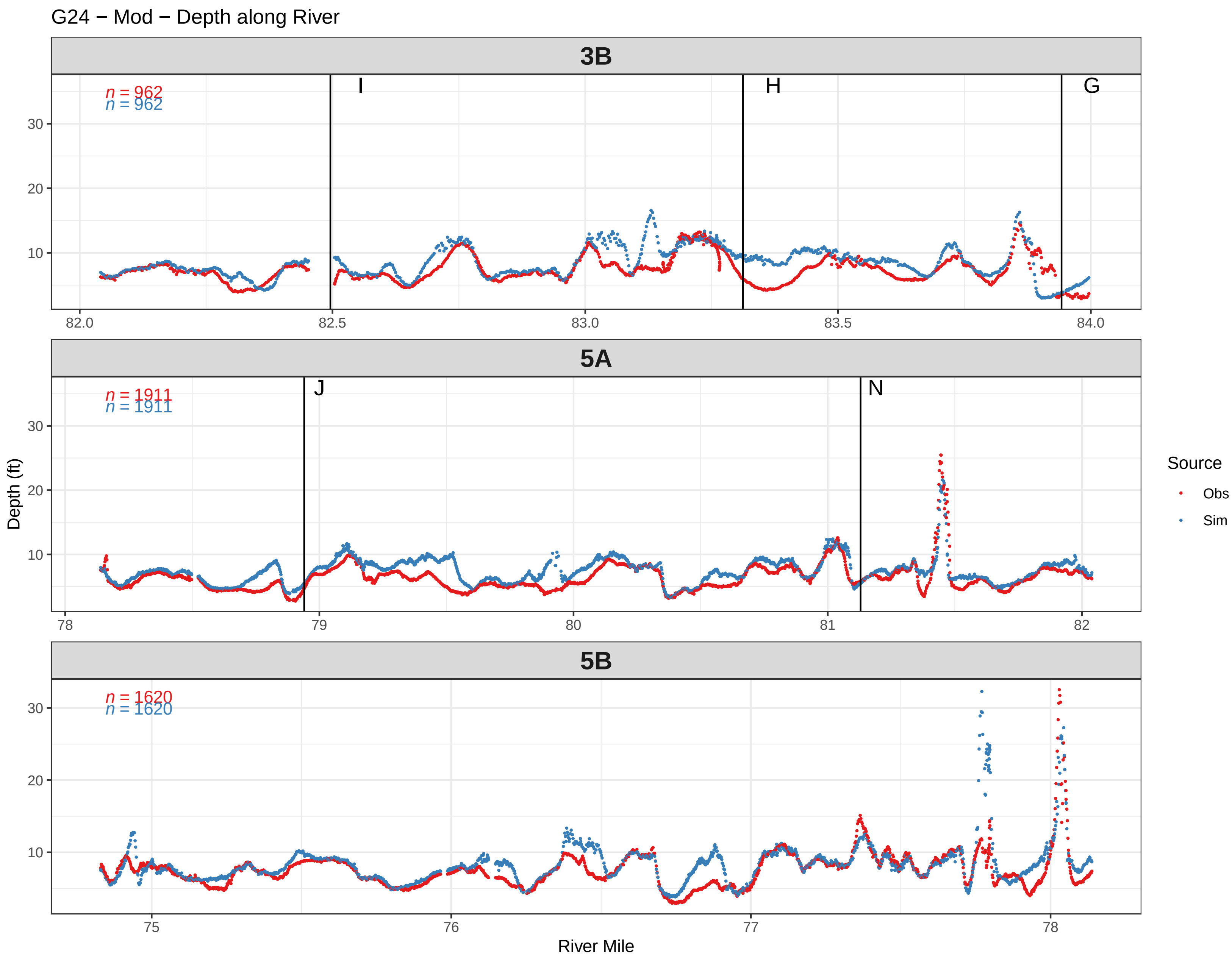

G24 − Mod − WSE along River
3B
n = 962
n = 962
I
H
G
350
345
340
335
82.0
82.5
83.0
83.5
84.0
5A
n = 1911
n = 1911
J
N
330
320
310
78
79
80
81
82
5B
n = 1620
n = 1620
305
300
295
290
285
280
75
76
77
78
Water Surface Elevation (ft)
River Mile
Source
Obs
Sim



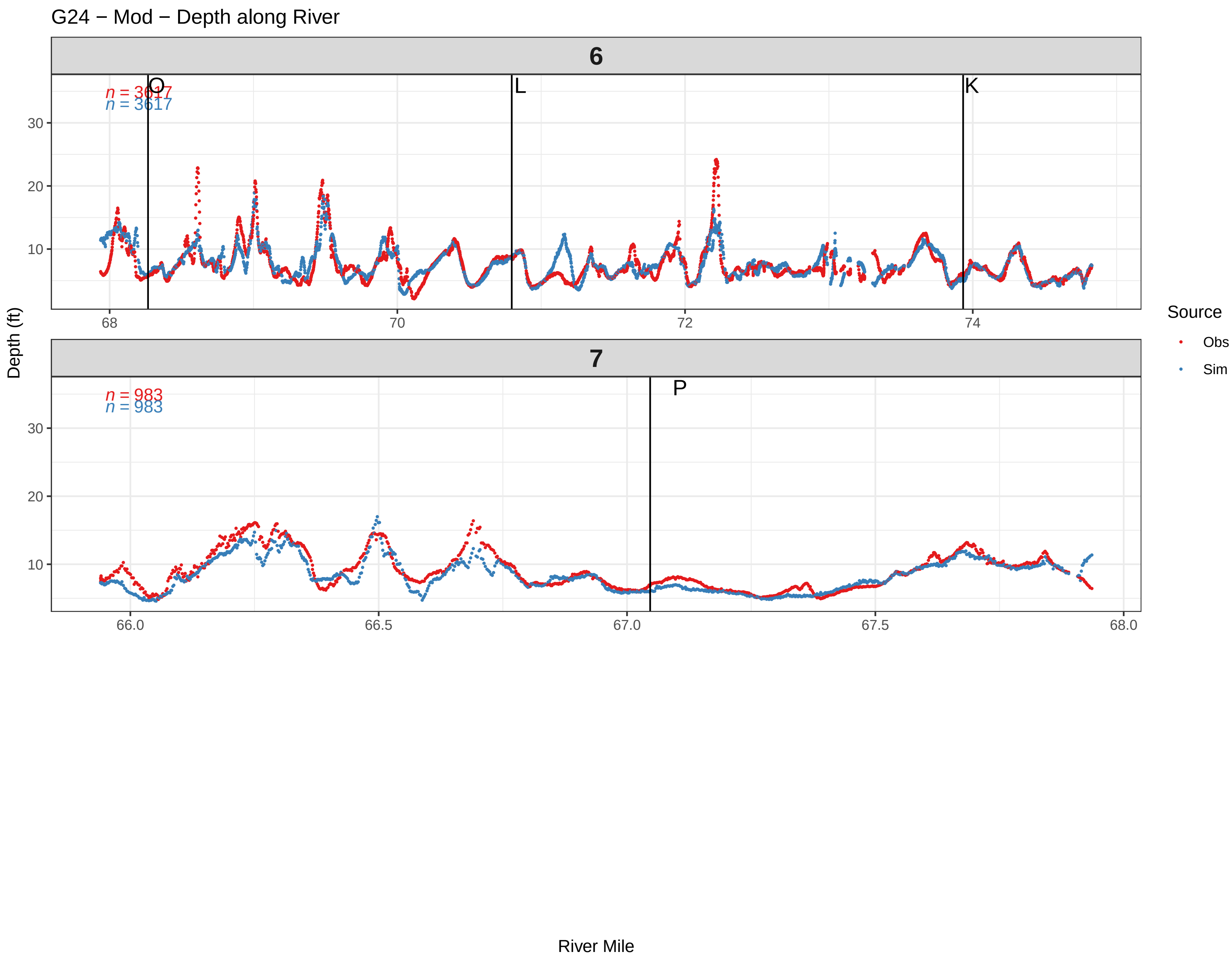
G24 − Mod − WSE along River
6
7
n = 3617
n = 3617
n = 983
n = 983
O
L
K
P
Water Surface Elevation (ft)
River Mile
Source
Obs
Sim



G24 − Mod − Depth along River
2
n = 29171
n = 29171
M
B
A
30
20
10
90
91
92
93
3A
n = 12542
n = 12542
D
C
88.0
88.5
89.0
89.5
4
n = 1235
n = 1235
F
Q
E
84
85
86
Depth (ft)
River Mile
Source
Obs
Sim

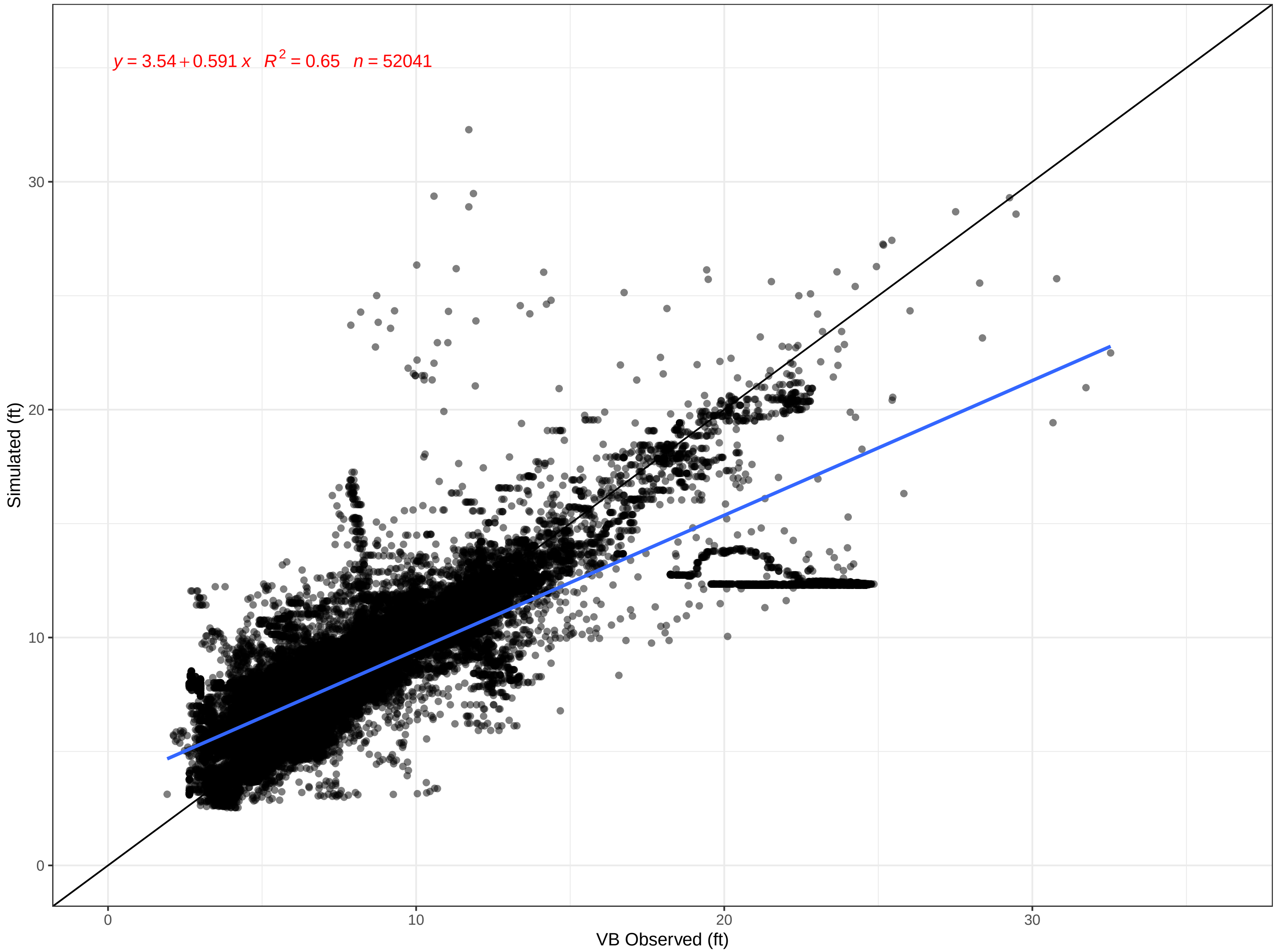


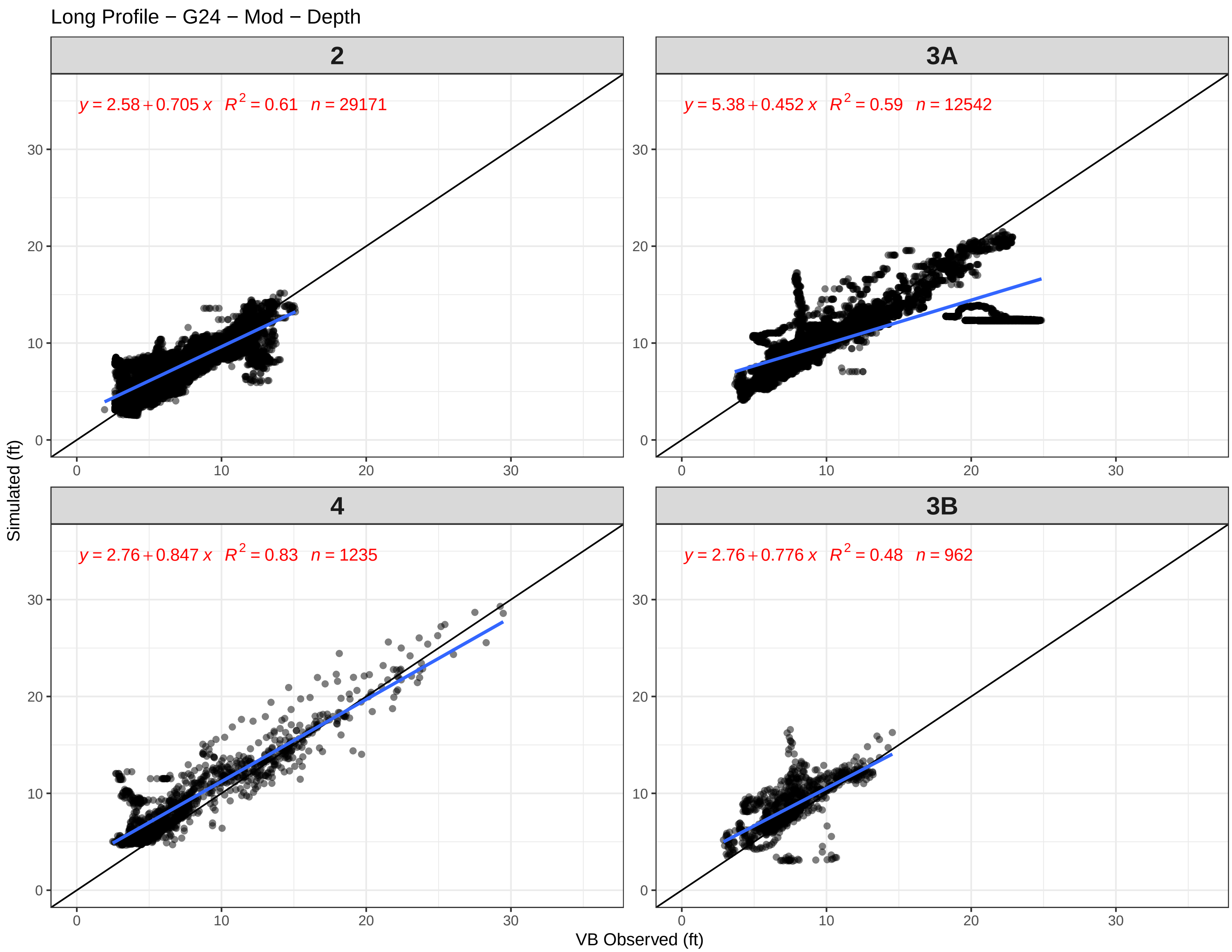
G24 − Mod − Depth along River
3B
n = 962
n = 962
I
H
G
5A
n = 1911
n = 1911
J
N
5B
n = 1620
n = 1620
Depth (ft)
River Mile
Source
Obs
Sim

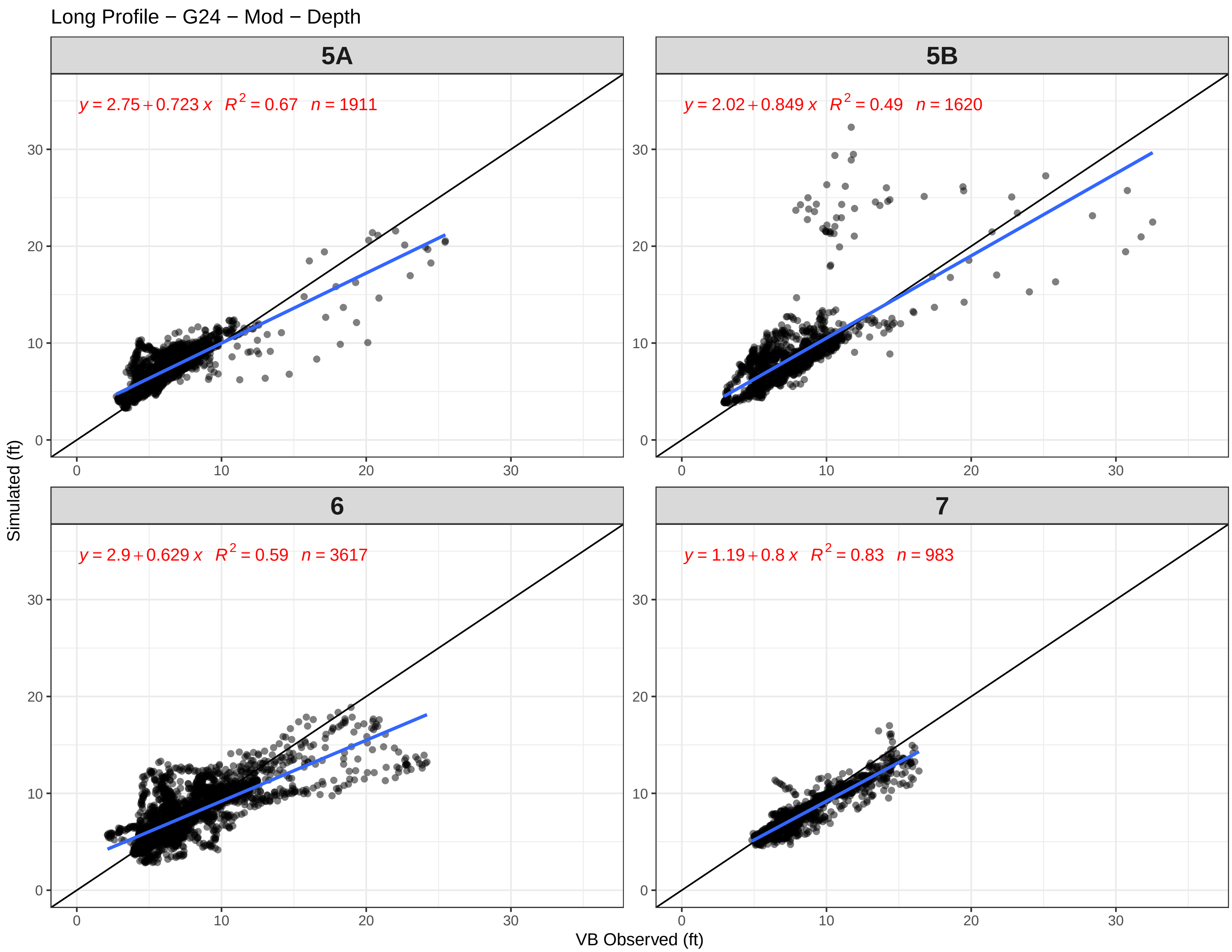


G24 − Mod − Depth along River
6
O
L
K
n = 3617
n = 3617
30
20
10
68
70
72
74
7
P
n = 983
n = 983
30
20
10
66.0
66.5
67.0
67.5
68.0
Depth (ft)
River Mile
Source
Obs
Sim

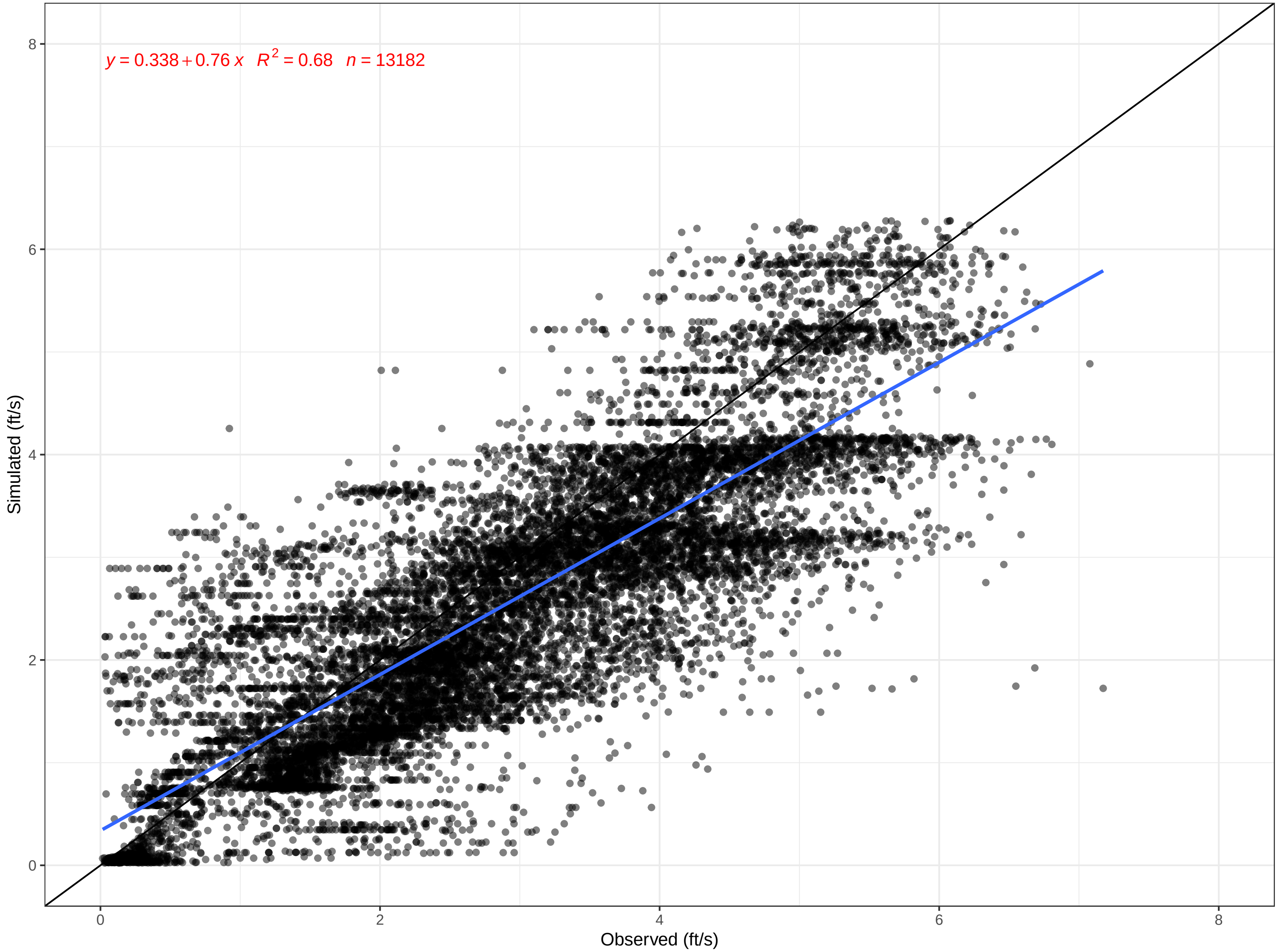
Long Profile − G24 − Mod − Depth

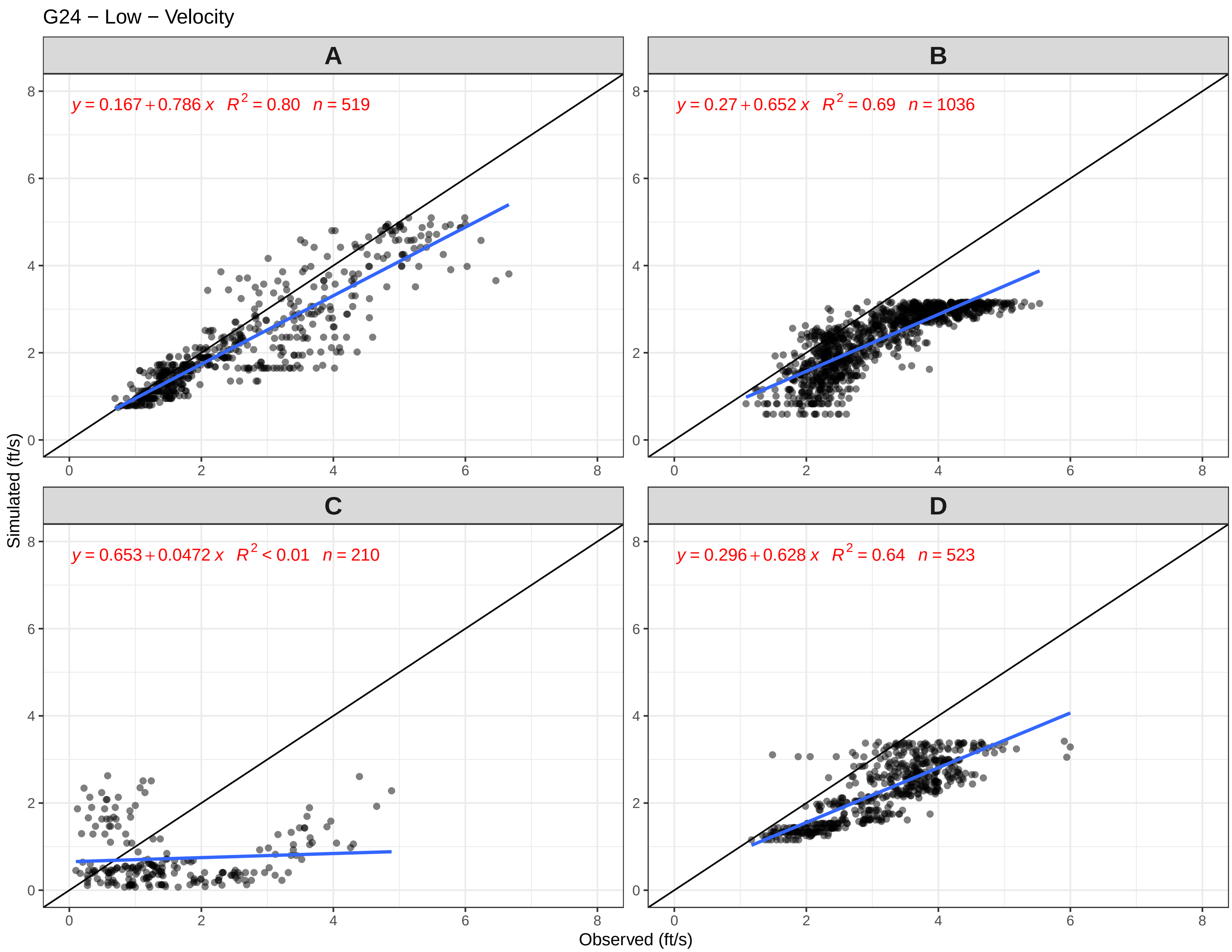


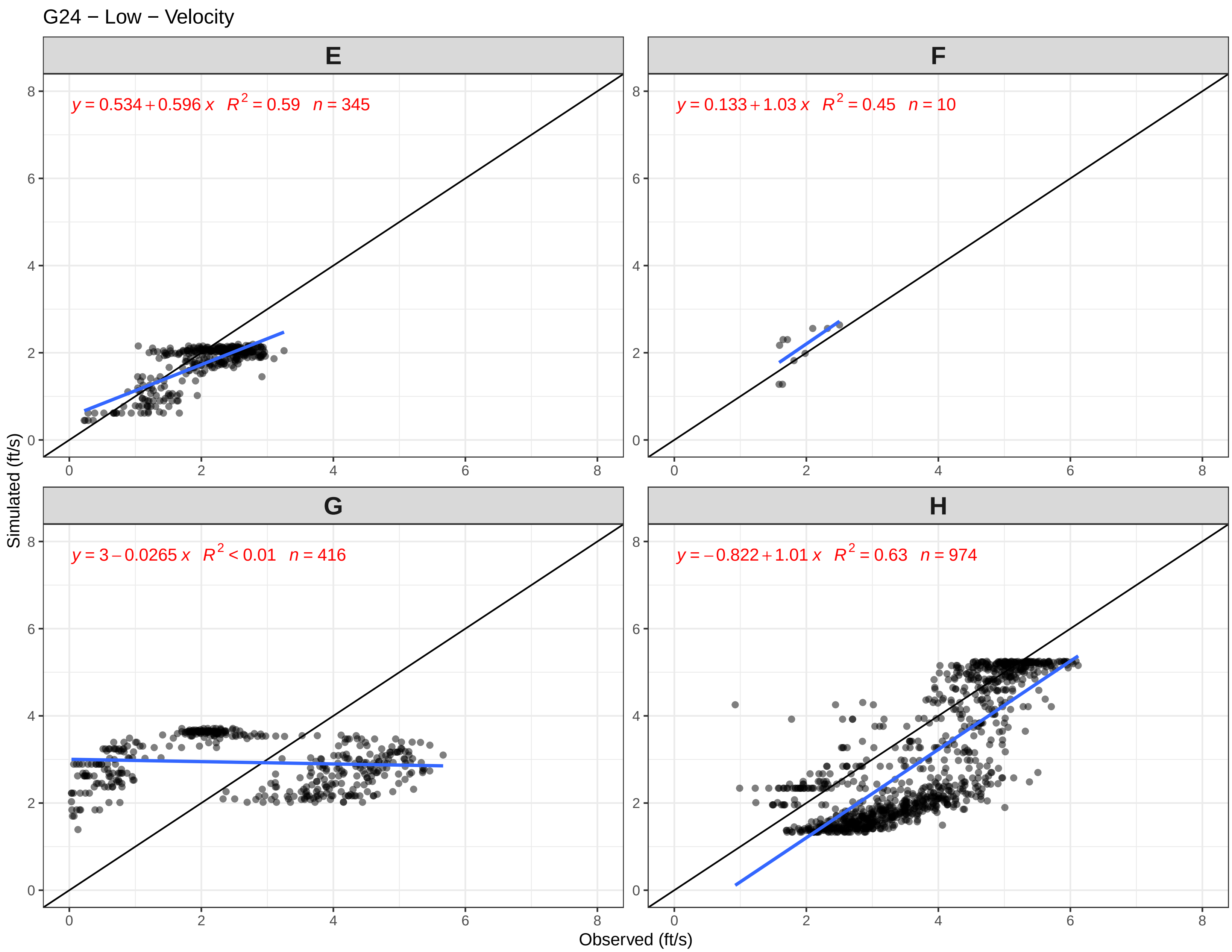

Long Profile − G24 − Mod − Depth
2
y = 2.58 + 0.705 x   R^2 = 0.61   n = 29171
3A
y = 5.38 + 0.452 x   R^2 = 0.59   n = 12542
4
y = 2.76 + 0.847 x   R^2 = 0.83   n = 1235
3B
y = 2.76 + 0.776 x   R^2 = 0.48   n = 962
0
10
20
30
Simulated (ft)
VB Observed (ft)


Long Profile − G24 − Mod − Depth
5A
$y = 2.75 + 0.723\,x$ $R^2 = 0.67$ $n = 1911$
5B
$y = 2.02 + 0.849\,x$ $R^2 = 0.49$ $n = 1620$
6
$y = 2.9 + 0.629\,x$ $R^2 = 0.59$ $n = 3617$
7
$y = 1.19 + 0.8\,x$ $R^2 = 0.83$ $n = 983$
Simulated (ft)
VB Observed (ft)
0
10
20
30

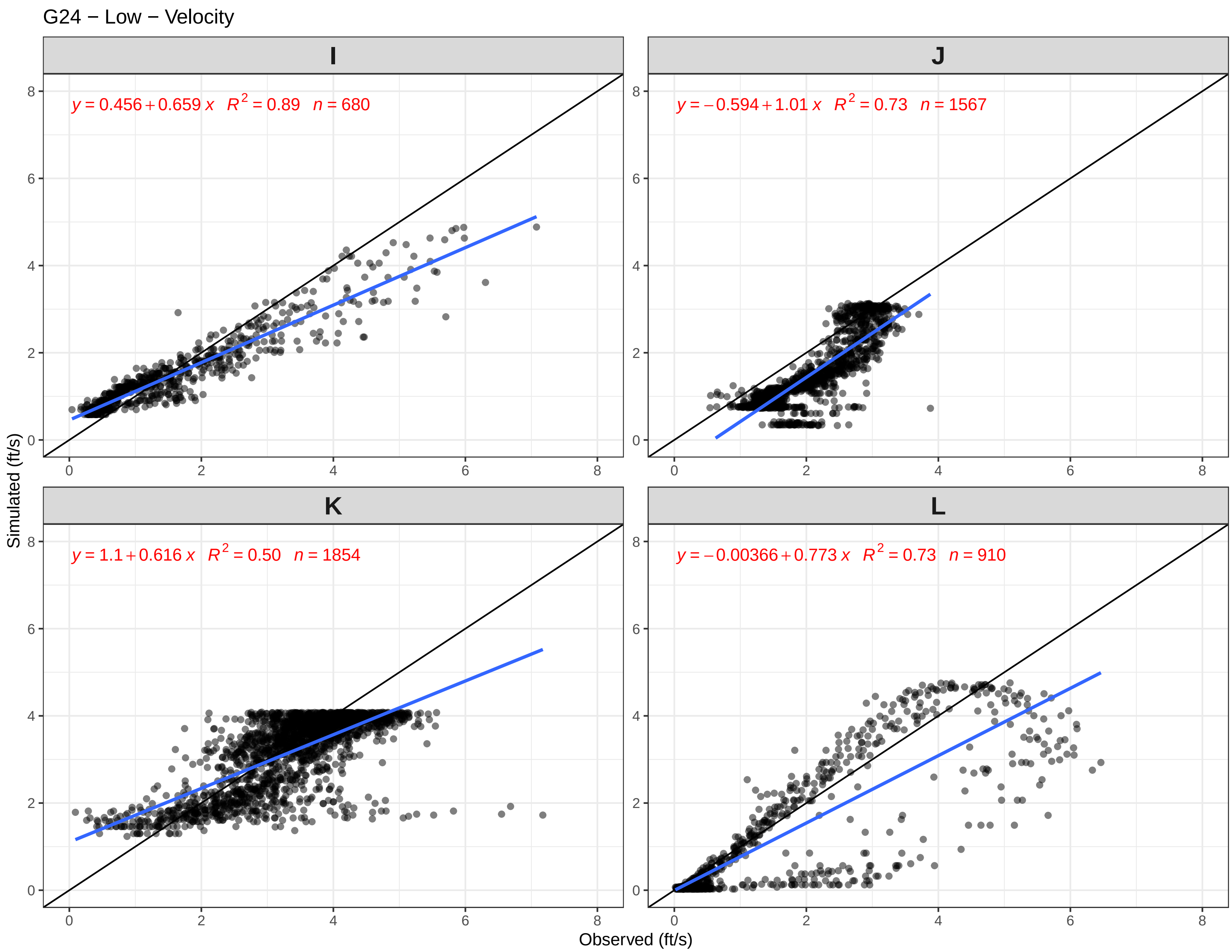
G24 − Low − Velocity



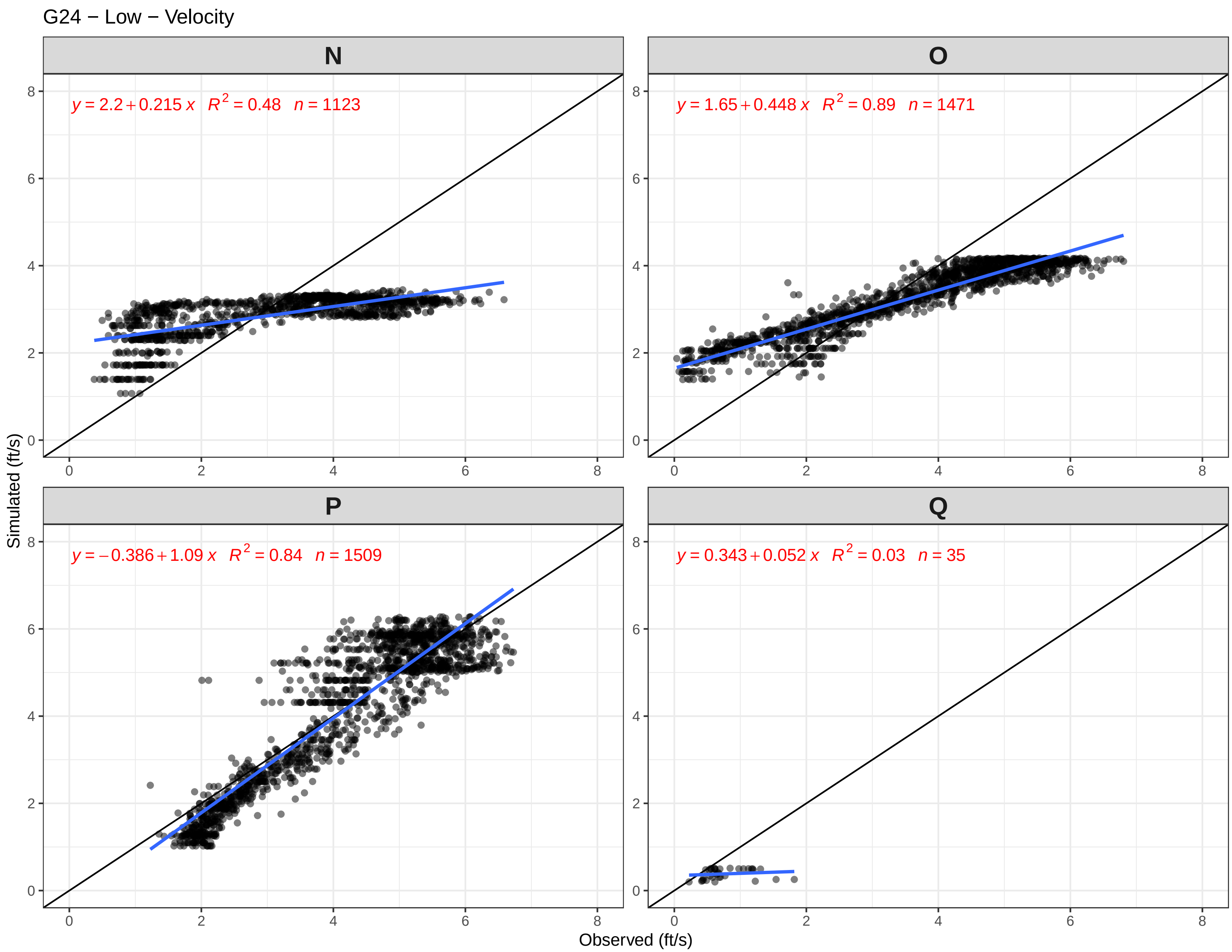

G24 − Low − Velocity
A
B
C
D
y = 0.167 + 0.786 x   R^2 = 0.80   n = 519
y = 0.27 + 0.652 x   R^2 = 0.69   n = 1036
y = 0.653 + 0.0472 x   R^2 < 0.01   n = 210
y = 0.296 + 0.628 x   R^2 = 0.64   n = 523
Simulated (ft/s)
Observed (ft/s)



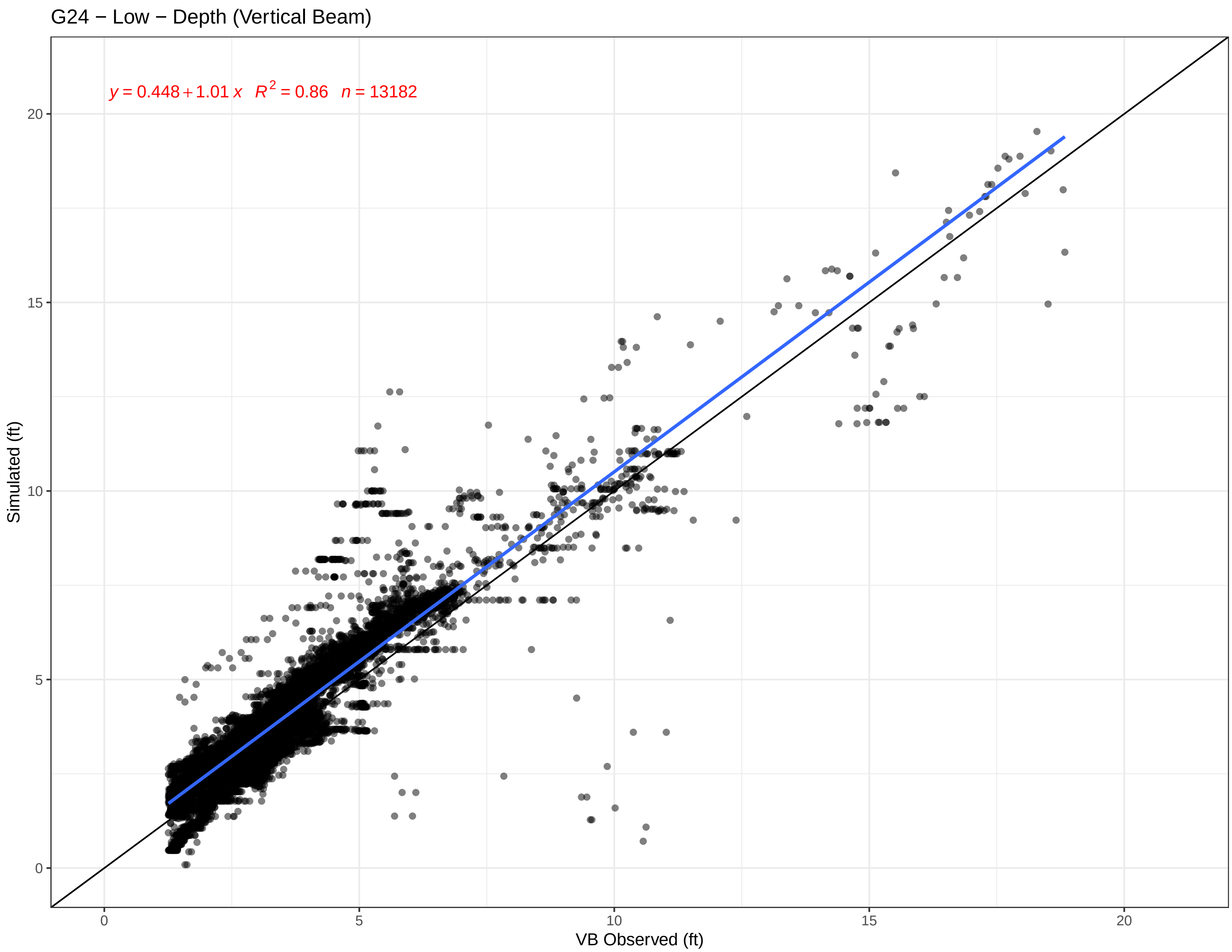
G24 − Low − Velocity
E
$y = 0.534 + 0.596\,x \quad R^2 = 0.59 \quad n = 345$
F
$y = 0.133 + 1.03\,x \quad R^2 = 0.45 \quad n = 10$
G
$y = 3 - 0.0265\,x \quad R^2 < 0.01 \quad n = 416$
H
$y = -0.822 + 1.01\,x \quad R^2 = 0.63 \quad n = 974$
Simulated (ft/s)
Observed (ft/s)



G24 − Low − Velocity
I
$y = 0.456 + 0.659\,x$ $R^2 = 0.89$ $n = 680$
J
$y = -0.594 + 1.01\,x$ $R^2 = 0.73$ $n = 1567$
K
$y = 1.1 + 0.616\,x$ $R^2 = 0.50$ $n = 1854$
L
$y = -0.00366 + 0.773\,x$ $R^2 = 0.73$ $n = 910$
Simulated (ft/s)
Observed (ft/s)

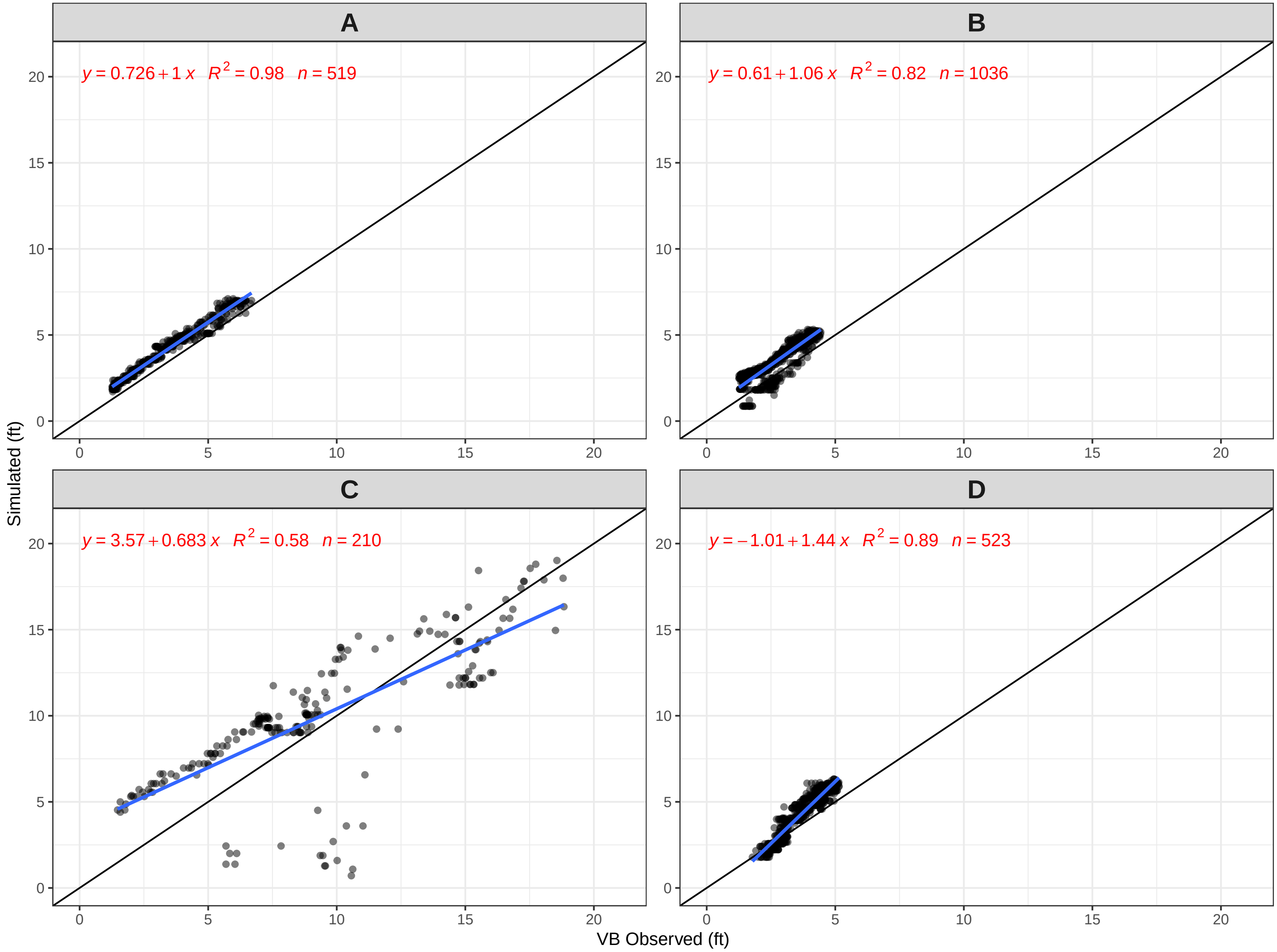


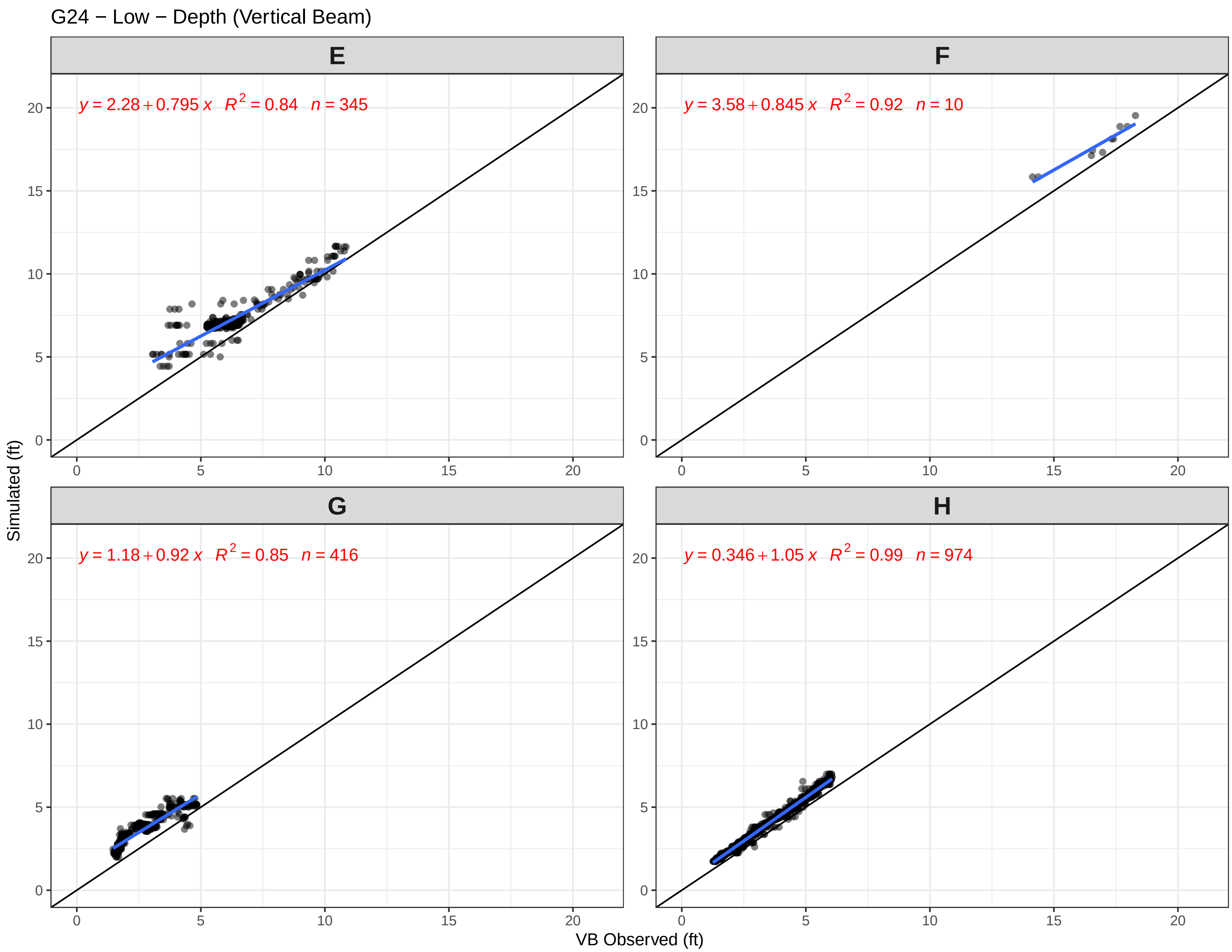
G24 − Low − Velocity
N
y = 2.2 + 0.215 x R^2 = 0.48 n = 1123
O
y = 1.65 + 0.448 x R^2 = 0.89 n = 1471
P
y = −0.386 + 1.09 x R^2 = 0.84 n = 1509
Q
y = 0.343 + 0.052 x R^2 = 0.03 n = 35
Simulated (ft/s)
Observed (ft/s)
0
2
4
6
8



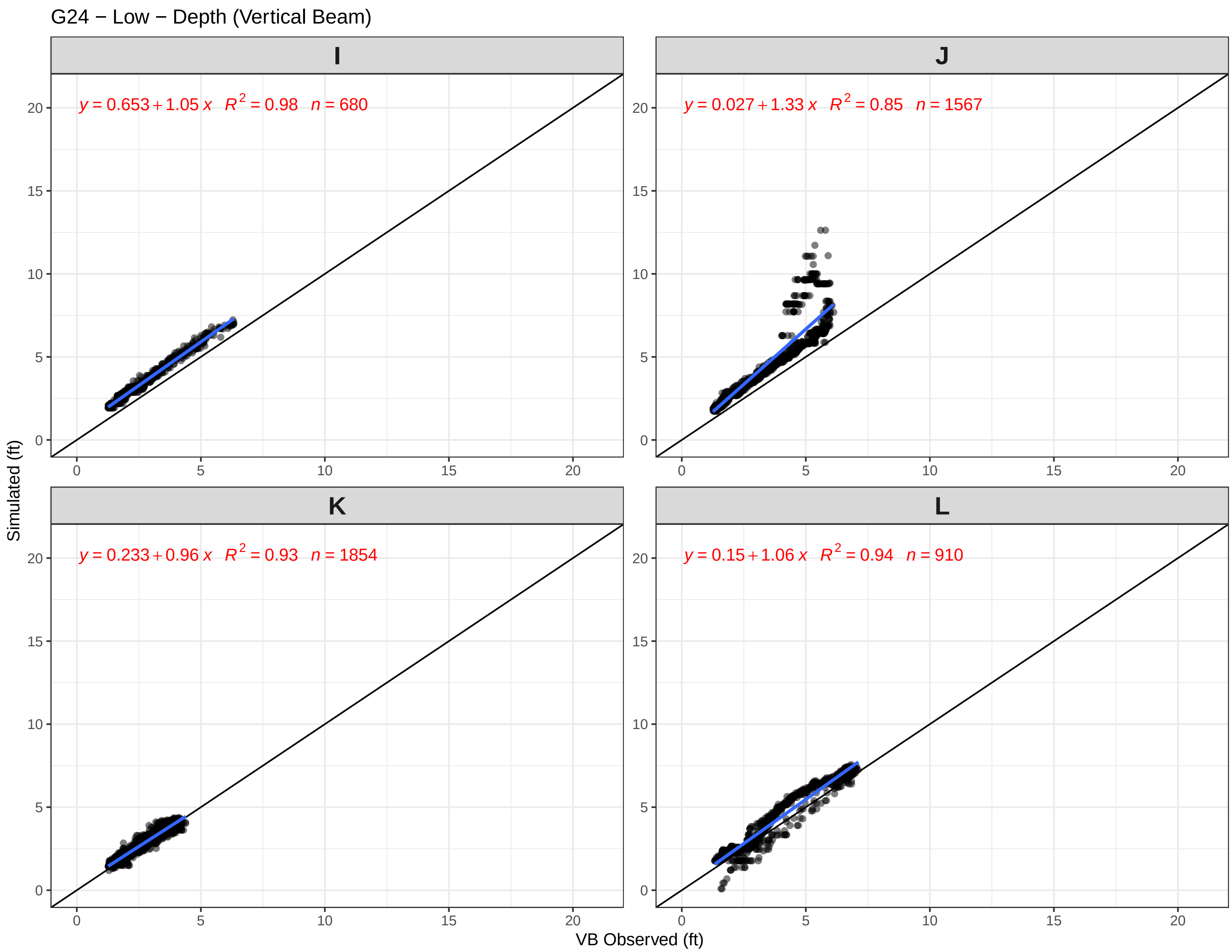
G24 − Low − Depth (Vertical Beam)
y = 0.448 + 1.01 x   R^2 = 0.86   n = 13182
Simulated (ft)
VB Observed (ft)
0
5
10
15
20

G24 − Low − Depth (Vertical Beam)

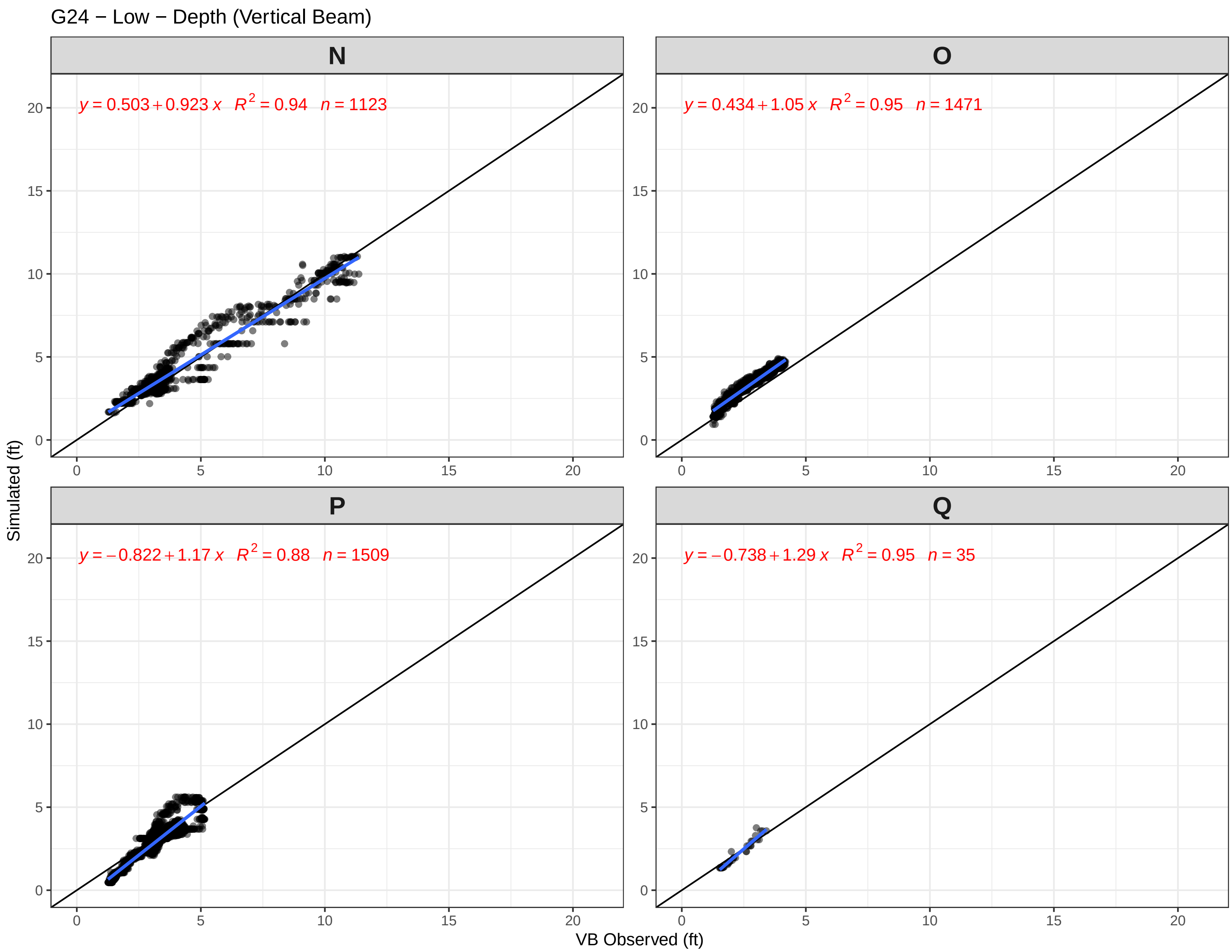


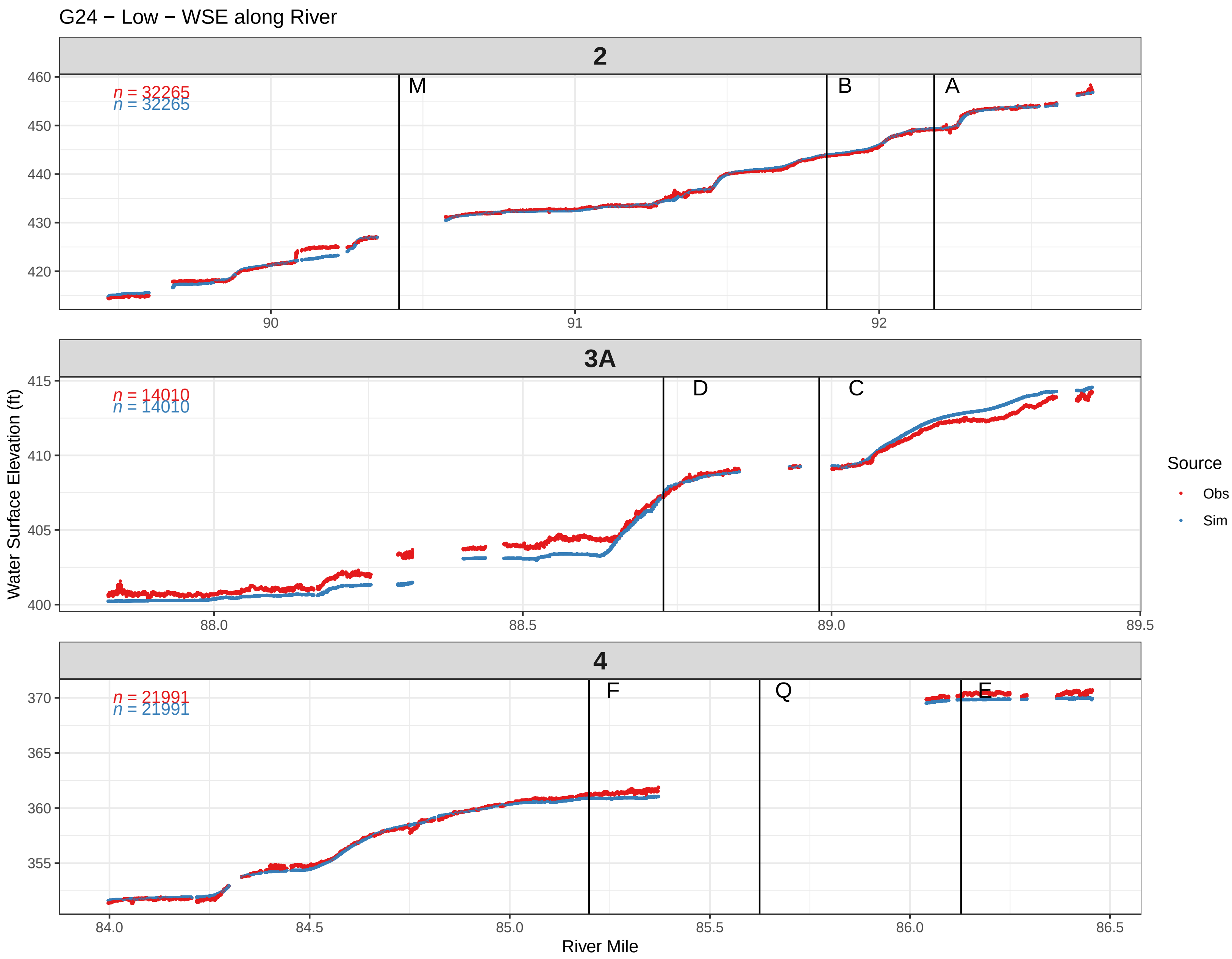


G24 − Low − Depth (Vertical Beam)
E
$y = 2.28 + 0.795\,x \quad R^2 = 0.84 \quad n = 345$
F
$y = 3.58 + 0.845\,x \quad R^2 = 0.92 \quad n = 10$
G
$y = 1.18 + 0.92\,x \quad R^2 = 0.85 \quad n = 416$
H
$y = 0.346 + 1.05\,x \quad R^2 = 0.99 \quad n = 974$
Simulated (ft)
VB Observed (ft)

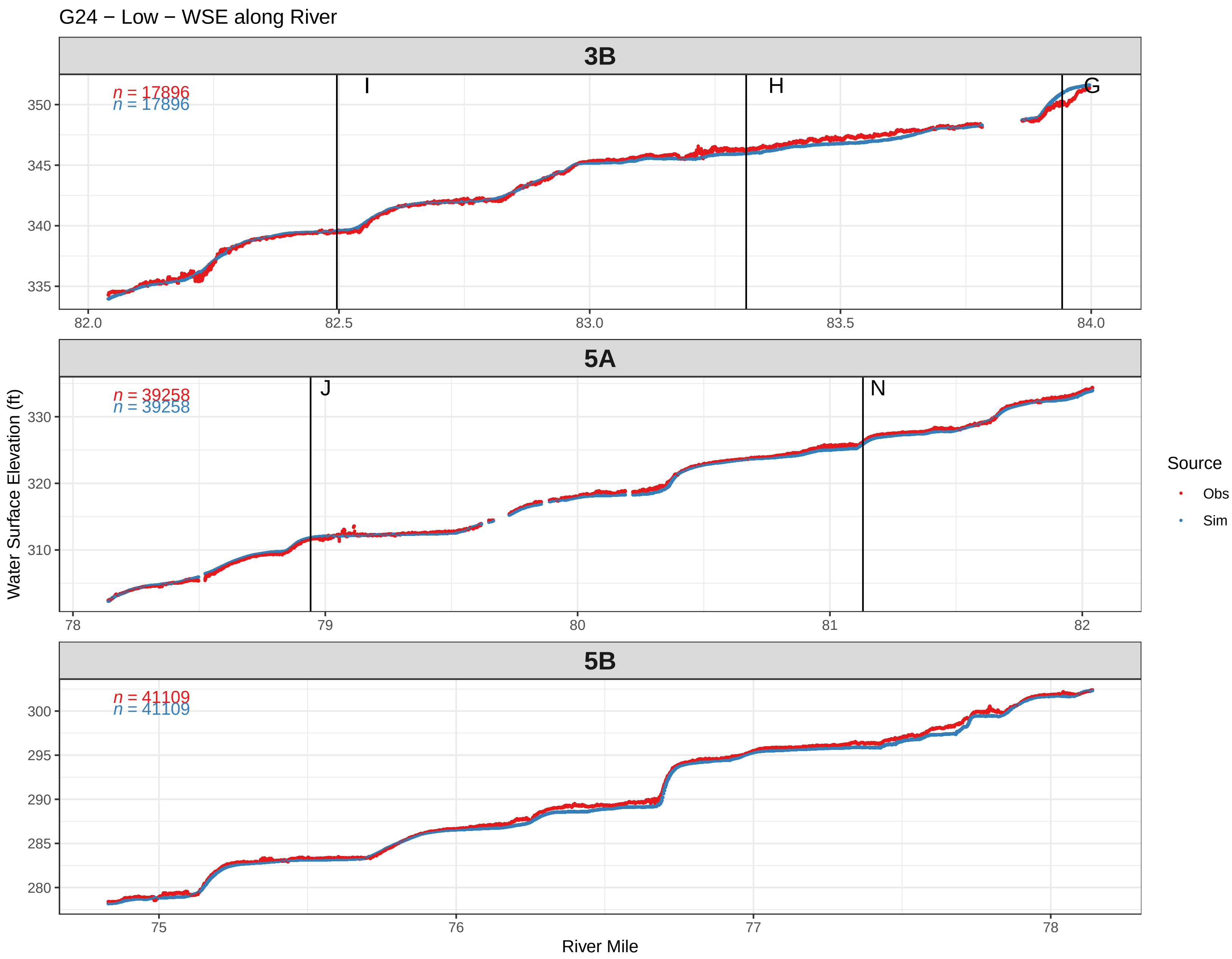


G24 − Low − Depth (Vertical Beam)
I
J
K
L
y = 0.653 + 1.05 x   R2 = 0.98   n = 680
y = 0.027 + 1.33 x   R2 = 0.85   n = 1567
y = 0.233 + 0.96 x   R2 = 0.93   n = 1854
y = 0.15 + 1.06 x   R2 = 0.94   n = 910
Simulated (ft)
VB Observed (ft)
0
5
10
15
20

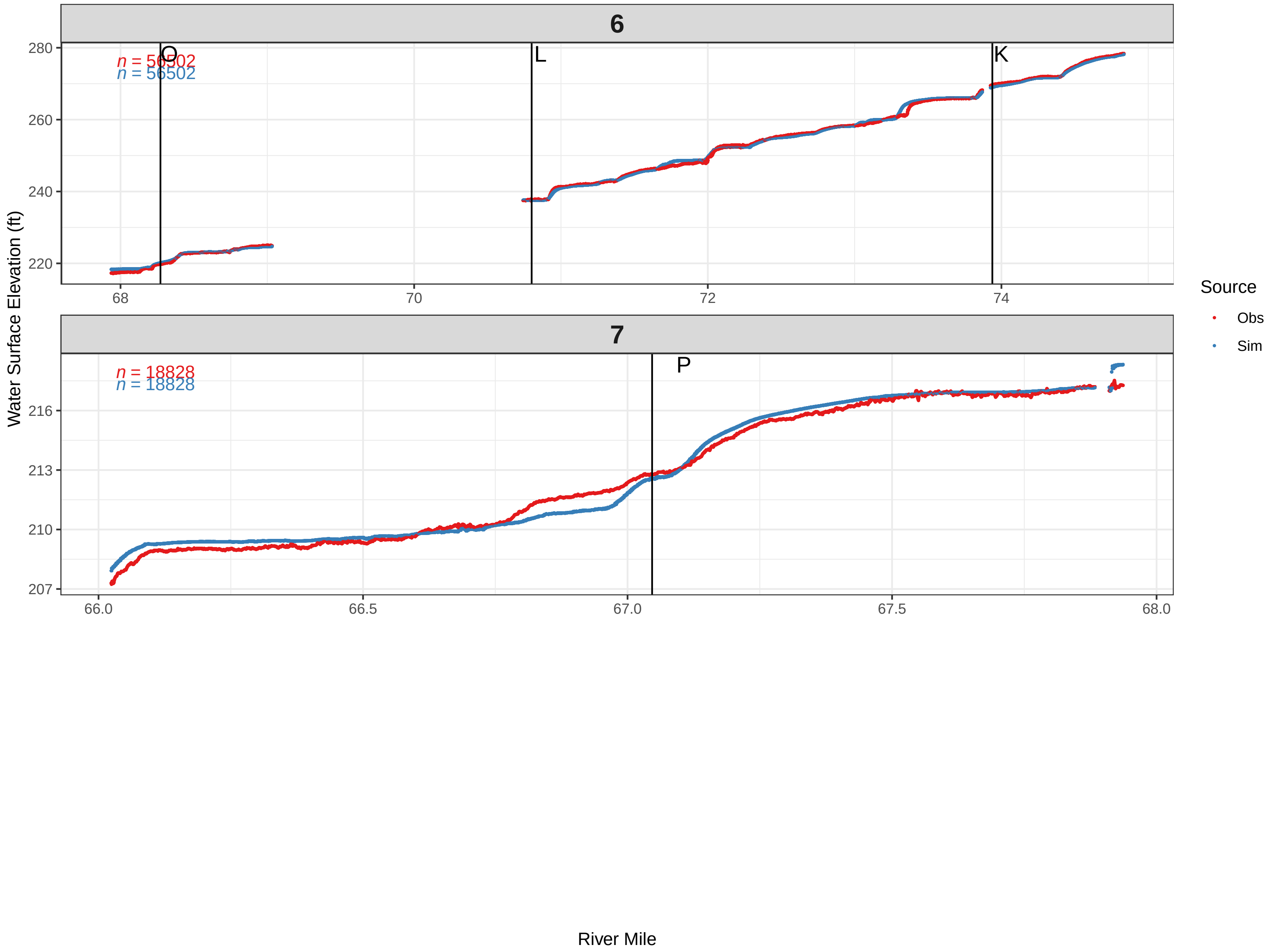

G24 − Low − Depth (Vertical Beam)
N
y = 0.503 + 0.923 x R2 = 0.94 n = 1123
O
y = 0.434 + 1.05 x R2 = 0.95 n = 1471
P
y = −0.822 + 1.17 x R2 = 0.88 n = 1509
Q
y = −0.738 + 1.29 x R2 = 0.95 n = 35
Simulated (ft)
VB Observed (ft)
0
5
10
15
20



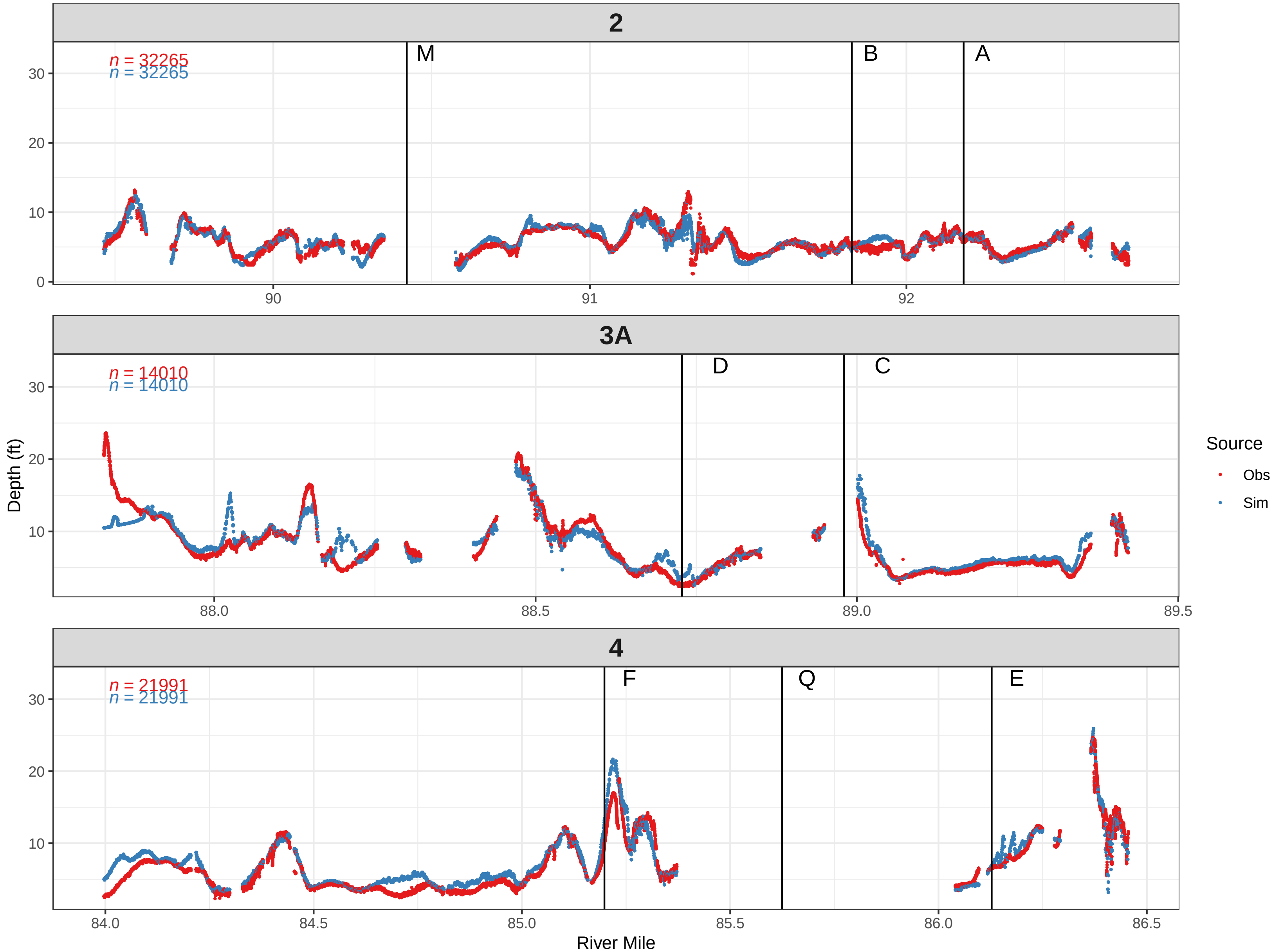
G24 − Low − WSE along River
2
n = 32265
n = 32265
M
B
A
460
450
440
430
420
90
91
92
3A
n = 14010
n = 14010
D
C
415
410
405
400
88.0
88.5
89.0
89.5
4
n = 21991
n = 21991
F
Q
E
370
365
360
355
84.0
84.5
85.0
85.5
86.0
86.5
Water Surface Elevation (ft)
River Mile
Source
Obs
Sim


G24 − Low − WSE along River
3B
n = 17896
n = 17896
I
H
G
350
345
340
335
82.0
82.5
83.0
83.5
84.0
5A
n = 39258
n = 39258
J
N
330
320
310
78
79
80
81
82
5B
n = 41109
n = 41109
300
295
290
285
280
75
76
77
78
Water Surface Elevation (ft)
River Mile
Source
Obs
Sim

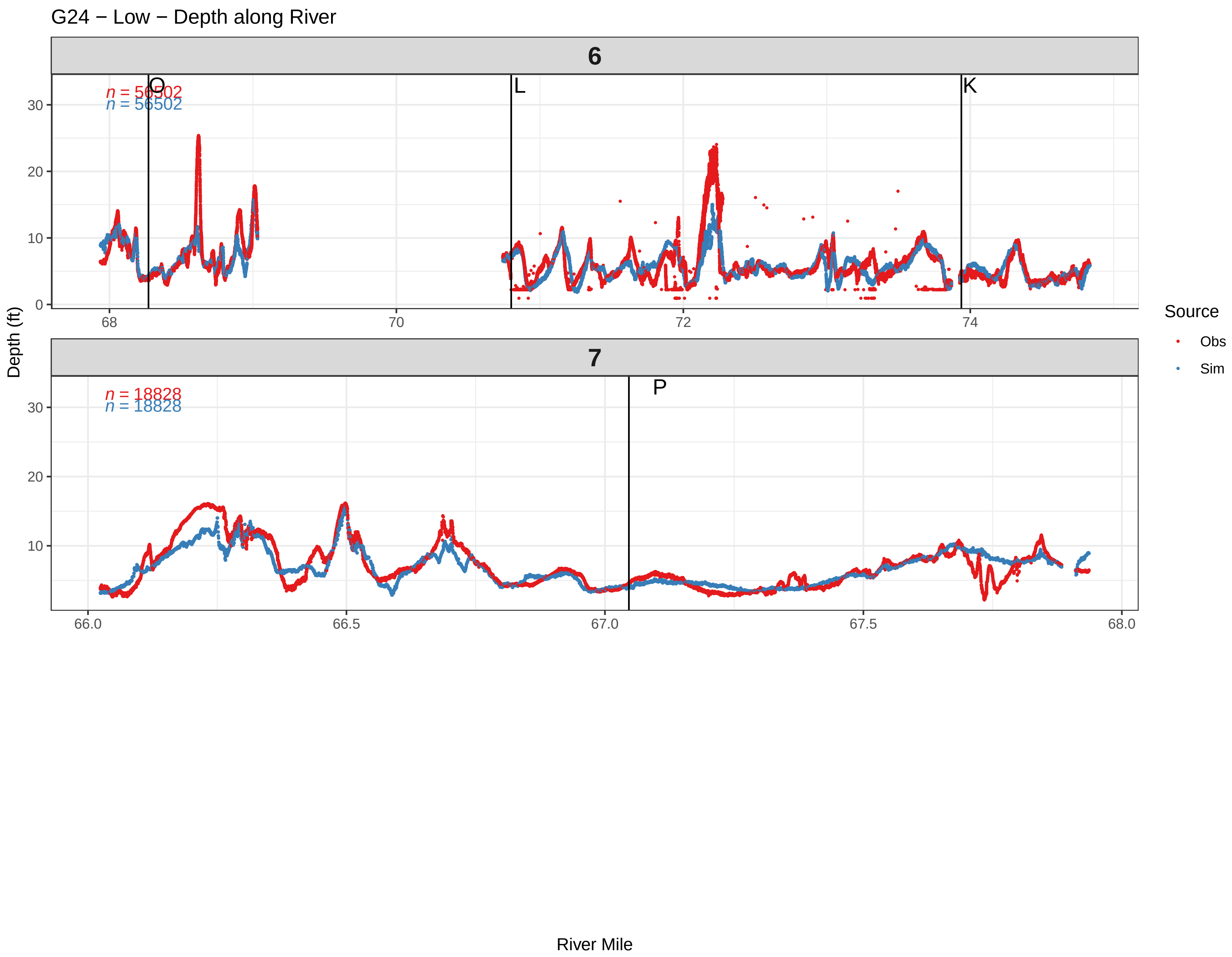
G24 − Low − WSE along River

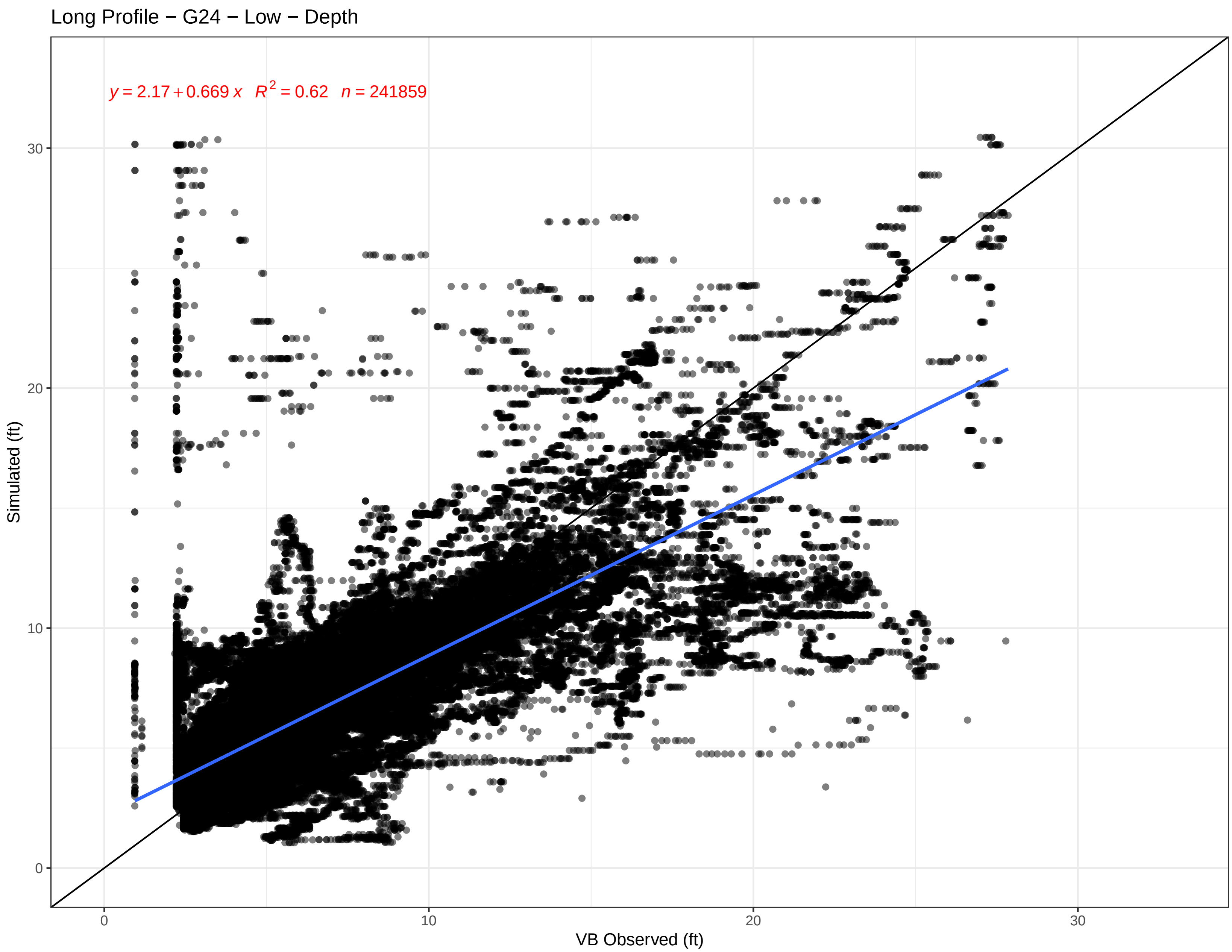


G24 − Low − Depth along River

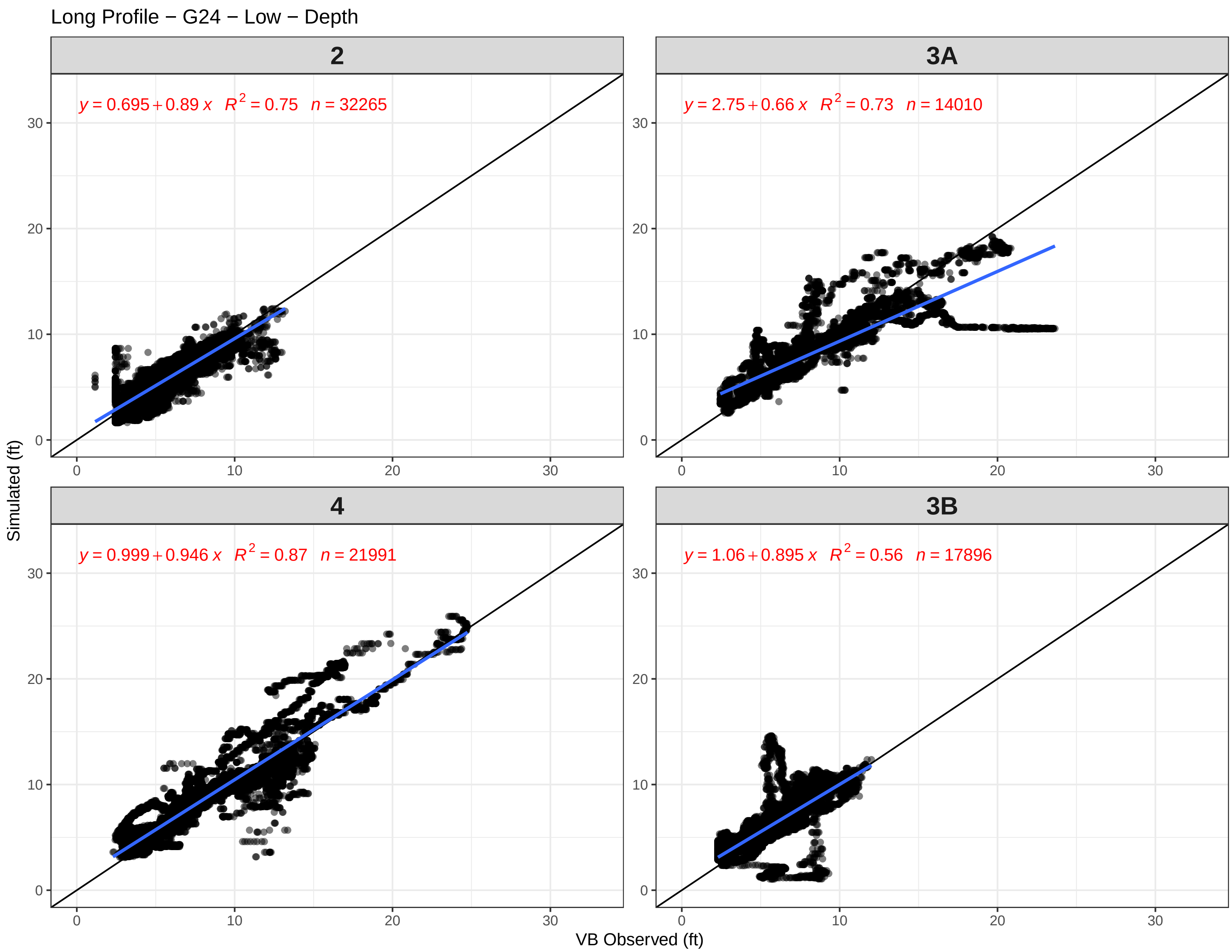


G24 − Low − Depth along River

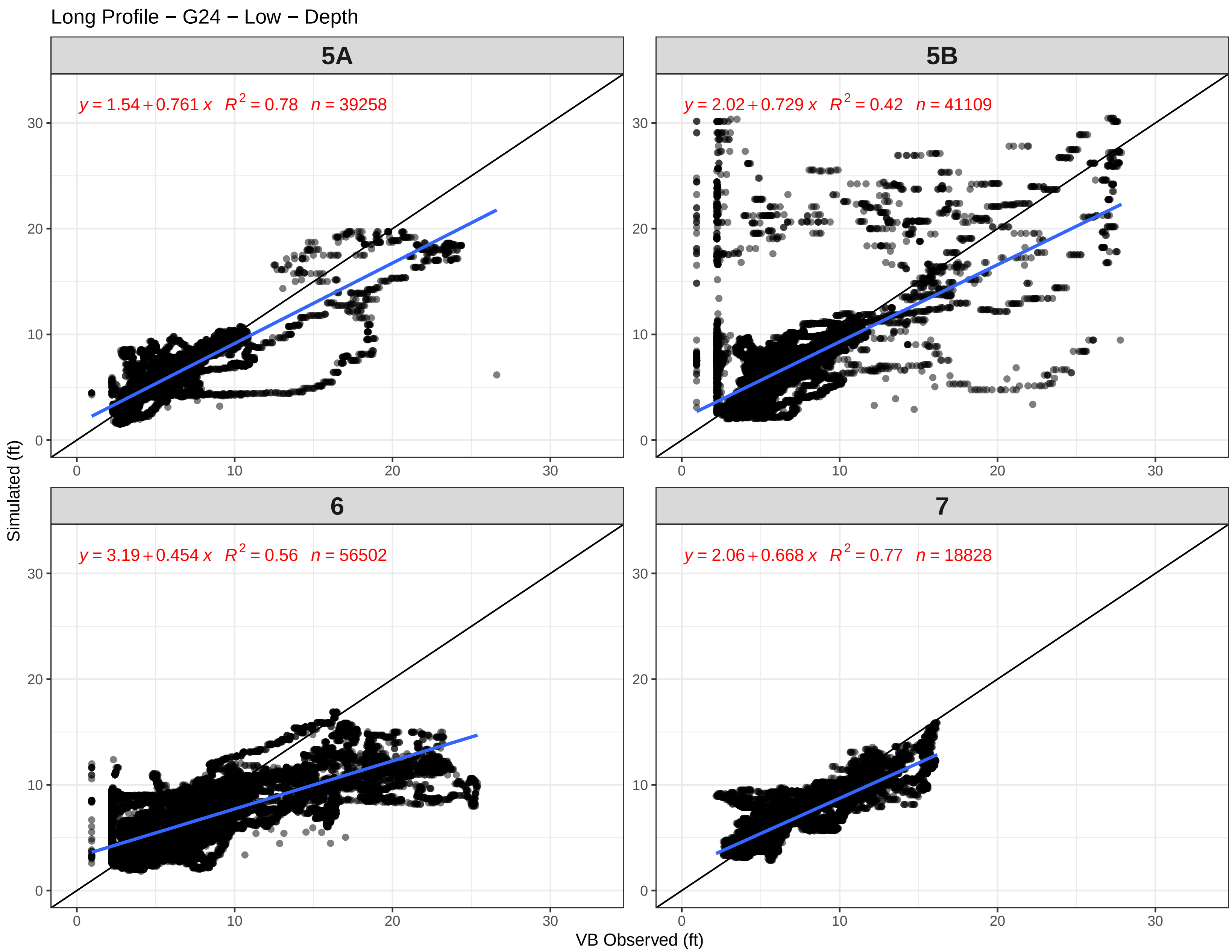

G24 − Low − Depth along River
6
n = 56502
n = 56502
O
L
K
7
n = 18828
n = 18828
P
Depth (ft)
River Mile
Source
Obs
Sim



Long Profile − G24 − Low − Depth
y = 2.17 + 0.669 x   R^2 = 0.62   n = 241859
Simulated (ft)
VB Observed (ft)
0
10
20
30
0
10
20
30



Long Profile − G24 − Low − Depth
2
3A
4
3B
$y = 0.695 + 0.89\,x \quad R^2 = 0.75 \quad n = 32265$
$y = 2.75 + 0.66\,x \quad R^2 = 0.73 \quad n = 14010$
$y = 0.999 + 0.946\,x \quad R^2 = 0.87 \quad n = 21991$
$y = 1.06 + 0.895\,x \quad R^2 = 0.56 \quad n = 17896$
Simulated (ft)
VB Observed (ft)
0
10
20
30



Long Profile − G24 − Low − Depth
5A
y = 1.54 + 0.761 x   R^2 = 0.78   n = 39258
5B
y = 2.02 + 0.729 x   R^2 = 0.42   n = 41109
6
y = 3.19 + 0.454 x   R^2 = 0.56   n = 56502
7
y = 2.06 + 0.668 x   R^2 = 0.77   n = 18828
Simulated (ft)
VB Observed (ft)
0
10
20
30

INSTREAM FLOW MODEL DEVELOPMENT STUDY
INTERIM REPORT

ATTACHMENT J

HABITAT SUITABILITY CRITERIA – 2021 FIELD VALIDATION DATA SUMMARY

Memo

Date:	March 2022
Project:	Skagit River Hydroelectric Project FERC No. 553
To:	Erin Lowery, Seattle City Light (City Light)
From:	Ty Ziegler, HDR Engineering, Inc.
Subject:	Habitat Suitability Criteria – 2021 Field Validation Activities and Data Summary

1.0 INTRODUCTION

To support the development, evaluation and selection of habitat suitability criteria (HSC) for use in the Skagit River Hydroelectric Project FERC relicensing FA-02 Instream Flow Model Development and FA-05 Skagit River Gorge Bypass Reach Hydraulic and Instream Flow Model Development studies, City Light, in collaboration with licensing participants (LP), conducted field validation studies in 2021 on the Skagit River between the Gorge Powerhouse (at Newhalem, Washington) and the Sauk River confluence (near Rockport, Washington) for species and life stages listed in Table 1.

Table 1. Target species and life stages selected for field validation studies in 2021.

Target Species	Life Stage	Field Validation Period
Steelhead (*Oncorhynchus mykiss*)	Spawning	Spring
	Juvenile	Summer / Fall
Chinook Salmon (*Oncorhynchus tshawytscha*)	Spawning	Fall / Winter
	Juvenile	Summer / Fall
Pink Salmon (*Oncorhynchus gorbuscha*)	Spawning	Fall / Winter
Bull Trout (*Salvelinus confluentus*)	Juvenile	Summer / Fall

2.0 METHODS

Generally, field validation data collection consisted of observing fish and/or redds and recording water depth and velocity, substrate type, and cover type at each location. Meridian Environmental, Inc. (Meridian) collected field observation data for the target species spawning life stage (i.e., adults) and Natural Systems Design (NSD) collected field observation data for the target juvenile life stage. Methods used for spawning and juvenile data collection are provided below.

2.1 Spawning Life Stage

Meridian collected field validation data during the spring and fall of 2021. Surveys were conducted via jet boat to collect field validation data for the target species – spawning steelhead, Chinook Salmon, and Pink Salmon. Surveys were conducted at nine sites on the Skagit River between the Gorge Powerhouse and the Sauk River confluence. Boating observations were conducted in an upstream direction at each survey area. The steelhead spawning survey was conducted on May 20 and May 26, 2021 and the Chinook Salmon and Pink Salmon spawning surveys were conducted on October 7 and October 13, 2021. During each survey event, a two-person field crew attempted to locate all new and existing (i.e., previously recorded) redds over a broad range of depths, velocities, and substrate types. At each location a target species and/or active redd was observed, the water depth, velocity at 60 percent depth, dominant and subdominant substrate size (i.e., visual estimate of approximately one square foot area at the head of the redd), cover classification and distance to nearest cover type, distance from redd to bank, date and time, and Global Positioning System (GPS) location were measured and recorded. Substrate sizes and stream cover classifications (provided in Table 2) followed the coding system described in the Washington Department of Fish and Wildlife (WDFW) and Washington State Department of Ecology (Ecology) Instream Flow Study Guidelines (Beecher et al. 2016).

2.2 Juvenile Life Stage

NSD collected field validation data during the summer and early fall of 2021. Snorkel surveys were conducted to observe fish and collect validation data for target species – juvenile steelhead, Chinook Salmon, and Bull Trout. Snorkel surveys were conducted at 25 sites within side channels and mainstem edges on the Skagit River between the Gorge Powerhouse and the Sauk River confluence. The surveys took place over nine days between August 24 – October 1, 2021. Side channel sites sampled were located in areas where other non-relicensing-related fisheries studies have been conducted (O'Neal et al. 2022, in preparation). Mainstem sites were selected using a Generalized Random Tessellation Stratified (GRTS) sample draw.

Snorkeling was conducted in an upstream direction at each site. At each location a target species was observed, the water depth, velocity at 60 percent depth, dominant and subdominant substrate size, cover classification, date and time, and GPS location were measured and recorded. Similar to the spawning surveys, substrate sizes and stream cover classifications followed the Washington State Instream Flow Study Guidelines provided in Table 2 (Beecher et al. 2016).

Table 2. Washington State Instream Flow Study Guidelines substrate and cover codes.

Substrate Code	Type of Substrate	Cover Code	Type of Cover
1	Silt, clay, or organic	00.1	Undercut bank
2	Sand	00.2	Overhanging vegetation near or touching water[1]
3	Small Gravel (0.1 - 0.5 inches)	00.3	Rootwad (including partly undercut)
4	Medium Gravel (0.5 - 1.5 inches)	00.4	Log jam/submerged brush pile
5	Large Gravel (1.5 - 3 inches)	00.5	Log(s) parallel to bank
6	Small Cobble (3 - 6 inches)	00.6	Aquatic vegetation
7	Large Cobble (6 - 12 inches)	00.7	Short (<1-foot [ft]) terrestrial grass
8	Boulder (>12 inches)	00.8	Tall (>3-ft) dense grass[2]
9	Bedrock	00.9	Vegetation >3 vertical ft above stage of zero flow

1 This includes low tree branches (<3 vertical ft above water surface elevation at stage of zero flow) and bushes overhanging the bank-full water's edge.

2 This category refers to stout, almost bushy type grasses such as reed canary grass up to the bank-full water's edge.

3.0 RESULTS

A summary of field observation results is provided in Table 3 for each target species spawning life stage and in Table 4 for each target species juvenile life stage.

3.1 Spawning Life Stage

A total of 19 steelhead spawning observations were made at seven locations during the May 20 and 26, 2021 data collection events. Most of the observations consisted of newly created redds and actively spawning steelhead at three locations. The median spawning depth was just over 2 ft (28.4 inches) and the median spawning velocity was 2.54 feet/second (ft/s). Dominant substrate categories ranged between small gravel and small cobble.

A total of 31 Chinook Salmon spawning observations were made at five locations during the October 7 and 13, 2021 data collection events. The median spawning depth was just over 2 ft (27.6 inches) and the median spawning velocity was 3.01 ft/s. Dominant substrate categories ranged between medium gravel and large cobble.

A total of 31 Pink Salmon spawning observations were made at two locations during the October 7 and 13, 2021 data collection events. The median spawning depth was 16.4 inches and the median spawning velocity was 1.91 ft/s. Dominant substrate categories ranged between sand and small cobble.

3.2 Juvenile Life Stage

A total of 116 steelhead juvenile observations were made during the August 24 – October 1, 2021 data collection period. The majority of observations (103) were fish with lengths between 50 – 140 millimeters (mm). The remaining 13 observations were larger fish, with lengths ranging from 150 – 350 mm. The median depth for the smaller juvenile observations was 17.3 inches and for the larger juveniles, the median depth was approximately twice that, at 35.4 inches. Measured velocities for all steelhead juvenile observations were relatively low (median velocities for both size ranges were less than 0.2 ft/s). Dominant substrate categories covered a wide range from silt/sand up to boulder. The majority of steelhead juvenile observations were near cover (107 out of 116). The predominant cover types were logs, log jams, and aquatic vegetation.

A total of 41 chinook juvenile observations were made during the August 24 – October 1, 2021 data collection period. Observed fish ranged from 60 – 100 mm in length with a median of 70 mm. The median depth was 21.6 inches and the median velocity was 0.16 ft/s. Dominant substrate categories ranged from silt/sand up to large cobble. Observed cover was predominantly undercut banks, logs, and log jams.

A total of 4 bull trout juvenile observations were made during the August 24 – October 1, 2021 data collection period. Three of the four observations were fish with lengths ranging from 150 – 250 mm, which are considered sub-adults. The remaining one observation was a juvenile with a length of 130 mm. The larger fish were observed in deeper water (median = 53.1 inches) compared to the smaller fish observation (depth = 29.1 inches). Median velocity for the larger fish observations was 0.0 ft/s and for the smaller fish observation was 0.13 ft/s. Dominant substrate categories ranged from medium gravel to boulder. Observed cover was either 'no cover' or logs and log jams.

4.0 SUMMARY AND CONCLUSIONS

Spawning and juvenile field observation data collected during 2021 were reviewed by the Skagit HSC Technical Group which was comprised of LPs, City Light, and Consultant Team members knowledgeable about HSC and its use in instream flow habitat modeling. While the HSC Technical Group determined that not enough field observation data was collected to support development of new Type 3 HSC curves[1], the data that was collected is consistent with existing WDFW/Ecology Type 3 curves (Beecher et al. 2016), as well as the HSC curves used in City Light's Skagit River Effective Spawning Habitat Model for the target spawning and juvenile species.

5.0 REFERENCES

Beecher, H., Caldwell, B., and J. Pacheco. 2016. Instream flow study guidelines, technical and habitat suitability issues including fish preference curves. Washington Department of Fish and Wildlife (WDFW) and Washington State Department of Ecology (Ecology). March 9, 2016. 84 pp.

O'Neal, J., et al. 2022 (in preparation). Stream type juvenile Chinook Phase 3 Study.

[1] Type 3 HSC curves are based on data from locations where target species are observed or collected under a variety of conditions to remove environmental bias. As a result, Type 3 curves are commonly referred to as preference curves.

Table 3. Skagit River Habitat Suitability Criteria Field Validation Study – 2021 Summary (Spawning).

Species	Spawning Period	Data Collection Period	Number of Observations by Reach										Depth (inches)		Velocity (ft/s)		Dominant Substrate Codes
			Wash Eddy	Buller	Sutter	Ponder Roses	Cascadia	Diobsud	Marble Island	Taylor	Moses	Total Observations	Range	Median	Range	Median	
Steelhead	**Spring**	May 20 - 26, 2021	8	5	1	2	--	1	--	1	1	19	13 - 54	28.4	2.14 - 3.59	2.54	3, 4, 5, 6
Chinook Salmon	**Fall/Winter**	Oct 7 - 13, 2021	--	--	--	--	15	3	2	4	7	31	8 - 50	27.6	1.27 - 5.06	3.01	4, 5, 6, 7
Pink Salmon	**Fall/Winter**	Oct 7 - 13, 2021	--	--	--	--	--	21	10	--	--	31	4 - 49	16.4	0.64 - 4.02	1.91	2, 3, 4, 5, 6

Source: Field data collected by Meridian Environmental, Inc. (note cover codes are not used in habitat modeling for the spawning life stage).

Table 4. Skagit River Habitat Suitability Criteria Field Validation Study – 2021 Summary (Juvenile).

Species	Life Stage	Data Collection Period	Number of Observations			Fish Length (mm)		Depth (inches)		Velocity (ft/s)		Dominant Substrate Codes	Cover Codes
			Side Channel	Mainstem	Total	Range	Median	Range	Median	Range	Median		
Steelhead	**Juvenile**	Aug 24 - Oct 1, 2021	46	57	103	50 - 140	70	7 - 51	17.3	0.00 - 1.38	0.16	1 - 7	00.0 - 00.6
	Juvenile		13	0	13	150 - 350	200	16 - 59	35.4	0.00 - 1.18	0.03	1, 2, 4, 6, 7, 8	00.0 - 00.5
Chinook Salmon	**Juvenile**		10	31	41	60 - 100	70	9 - 51	21.6	0.00 - 0.72	0.16	1 - 7	00.0 - 00.5
Bull Trout	**Juvenile**		1	0	1	130	130	29	29.1	0.13	0.13	6	00.4
	Sub-adult		3	0	3	150 - 250	200	42 - 98	53.1	0.00 - 0.03	0.00	4, 7, 8	00.0 and 00.5

Source: Field data collected by Natural Systems Design.

INSTREAM FLOW MODEL DEVELOPMENT STUDY
INTERIM REPORT

ATTACHMENT K

HABITAT SUITABILITY CRITERIA CURVES

Substrate/cover codes for all species and life stages modeled will use the WDFW/Ecology substrate/cover coding system provided in Table K-1.

Table K-1. Generic Substrate/Cover Codes and Preference Values[1] (Beecher et al. 2016).

Code	Type of Cover Note: Cover Codes are not used for Spawning	Salmon & Trout Rearing	Whitefish Rearing	
		Juvenile & Resident Adult	Juvenile	Adult
00.1	Undercut bank	1.00	1.00	1.00
00.2	Overhanging vegetation near or touching water[2]	1.00	1.00	1.00
00.3	Rootwad (including partly undercut)	1.00	1.00	1.00
00.4	Log jam/submerged brush pile	1.00	1.00	1.00
00.5	Log(s) parallel to bank	0.80	0.80	0.80
00.6	Aquatic vegetation	0.80	0.80	0.80
00.7	Short (<1 ft) terrestrial grass	0.10	0.10	0.10
00.8	Tall (>3 ft) dense grass[3]	0.70	0.70	0.10
00.9	Vegetation >3 vertical ft above SZF	0.20	0.20	0.20

Code	Type of Substrate	Spawning					Salmon & Trout Rearing	Whitefish Rearing	
		Salmon	Steelhead[4]	Resident Trout	Native Char[5]	Whitefish	Juvenile & Resident Adult	Juvenile	Adult
1	Silt, clay, or organic	0.00	0.00	0.00	0.00	0.00	0.10	0.38	0.15
2	Sand	0.00	0.00	0.00	0.00	0.00	0.10	0.38	0.15
3	Small Gravel (0.1 - 0.5")	0.30	0.50	0.80	1.00	1.00	0.10	0.74	0.76
4	Medium Gravel (0.5 - 1.5")	1.00	1.00	1.00	1.00	1.00	0.30	0.88	0.91
5	Large Gravel (1.5 - 3")	1.00	1.00	0.80	1.00	1.00	0.30	0.88	0.91
6	Small Cobble (3 - 6")	1.00	1.00	0.50	0.70	1.00	0.50	1.00	1.00
7	Large Cobble (6 - 12")	0.50	0.30	0.00	0.70	0.50	0.70	1.00	1.00
8	Boulder (>12")	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00
9	Bedrock	0.00	0.00	0.00	0.00	0.00	0.30	0.50	0.30

1 This table reflects average values for the listed species. Site specific preferences would supersede this table.
2 This includes low tree branches (<3 vertical ft. above WSE at SZF) and bushes overhanging the bank-full water’s edge.
3 This category refers to stout, almost bushy type grasses such as reed canary grass up to the bank-full water’s edge.
4 This category includes intermountain and coastal cutthroat (*Oncorhynchus clarki*).
5 This category includes Bull Trout (*Salvelinus confluentus*) and Dolly Varden (*S. malma*).

Skagit River Habitat Suitability Criteria

HSC Technical Group

Skagit River Habitat Suitability Criteria (HSC) Licensing Participant (LP) Workshops began in May 2021. After the June and July 2021 Workshops, a recommendation was made to form a smaller technical group of people knowledgable about HSC and its use in instream flow habitat modeling. In August 2021, the HSC Technical Group was formed and comprised of LPs, Seattle City Light, and Consultant Team members. The HSC Technical Group met a total of 10 times (approximately bi-weekly) from August 2021 through January 2022. The HSC Technical Group's objective was to gather and review available HSC information relevant to the Skagit River and develop a step-wise process to evaluate and ultimately propose recommended HSC curves for each species and life stage being considered for habitat modeling on the Skagit mainstem and bypass reach. In addition, the HSC Technical Group evaluated 2021 field validation data collected on the Skagit River (see below) as well as additional studies that were included in updated WDFW/Ecology Type 3 HSC curves for Bull Trout juveniles and Cutthroat Trout juveniles.

HSC Background

As a starting point for the HSC curve selection (and in some cases development) process, an HSC library was assembled consisting of curves from City Light's existing effective spawning habitat (ESH) model, Washington State's Instream Flow Study Guidelines (Beecher et al. 2016), curves from other west coast region instream flow studies for rivers comparable in size to the Skagit River, and literature from other relevant studies and research.

HSC curves are often referred to by "type," which indicates the basis of the curves (Bovee 1986). Type 1 curves are based on general life history and professional judgement with little or no empirical data. Type 2 curves are based on data from locations where target species are observed or collected. Commonly referred to as utilization (or use) curves, Type 2 curves can be biased by a limited range of hydraulic conditions that were available at the time the target species were observed. Type 3 curves are based on data from locations where target species are observed or collected under a variety of conditions to remove environmental bias. Type 3 curves include measurements of "available" habitat (at the time the discrete observation data were collected) which are used to adjust utilization data to become "preference curves". Type 3 curves tend to be less site-specific than Type 2 curves and can be applied more broadly.

The HSC List tab provides a list of species and life stages to be considered for modeling. They are grouped based on the availability and type of existing HSC curves as described below.

HSC Groups

Group A includes species and life stages where HSC curves are available from both the Skagit ESH model and WDFW/Ecology Type 3 curves. With the exception of Chum Salmon spawning, field validation studies were conducted in 2021 to collect additional site-specific data (i.e., depth, velocity, substrate, and cover) for Group A species and life stages. These data were used qualitatively to support decisions on HSC curve selection and/or modification.

Group B originally consisted of two species and life stages where both Skagit-specific Type 2 curves (i.e., based on Skagit River field observation data) and WDFW/Ecoloty Type 3 curves were available (i.e., Chum spawning and Pink spawning). Early in the HSC evaluation process the larger LP team recommended adding these two species to Group A as there was interest in collecting additional field observation data during the 2021 field validation study efforts. Moving these two species/life stages into Group A effectively eliminated Group B.

Group C includes species and life stages where HSC curves are not available from the ESH model but are available as WDFW/Ecology Type 3 curves. The Type 3 curves will be used as a default unless field validation studies conducted for Group A provide information that a modification of the WDFW/Ecology Type 3 curves is warranted to better represent site-specific observations on the Skagit River.

Group D HSC curves are not available from either the ESH model, or WDFW/Ecology. For these species and life stages, available HSC curves from other instream flow studies were used as a surrogate and/or consensus curves were developed in collaboration with LPs by modifying available HSC curves. In some cases, literature was available to support development of HSC consensus curves.

Group E consists of the fry life stage for several species. Instead of modeling individual fry species, consensus curves were developed for generic salmonid fry.

Group F surrogate HSC curves were not available, so consensus curves were developed based on literature review.

2021 Field Validation Studies

During the first HSC Workshop on May 12, 2021, LPs discussed and ultimately recommended collecting field validation data (i.e., observatons of fish and/or redds) on the Skagit River to support the HSC evaluation and selection process. Target species and number of observations during the 2021 study period were: spawning life stage [Steelhead (19), Chinook (31), Pink (31), and Chum (NA)] and juvenile life stage [Steelhead (116), Chinook (41), and Bull Trout (4)]. Note due to unseasonably high flows and turbid water conditions during the late-fall/early-winter period, field validation data collection efforts for Chum spawning were not conducted.

HSC Evlauation Process

Based on WDFW/Ecology policy, the statewide Type 3 curves are prefered unless:

a) Enough site-specific, Type 3 data can be found or collected to develop new HSC curves, or
b) Enough site-specific Type 3 data can be collected in the field to use as a rationale for adjusting the statewide Type 3 curves, or
c) Type 3 curves from another source can be found and determined to be equal to, or more representative than, the statewide Type 3 curves.

Skagit River Habitat Suitability Criteria

HSC curves used in the current ESH model are based on a variety of Type 1 and Type 2 data sources. For example, HSC curves for Steelhead, Chinook, Pink, and Chum spawning life stage are based on hundreds of Skagit-specific field observation data from Crumley and Stober 1984, and considered to be Type 2 curves (attempts to locate detailed field observation data from the studies were unsuccessful). Data collected during the 2021 HSC field validation effort for these four species (spawning life stage) were determined to be insufficient to create new Type 3 curves. However, these data (i.e., observations of redds or fish) were reviewed by the HSC Technical Group and were determined to be consistent with the ESH and statewide HSC curves. Other HSC curves used in the ESH model are based on Type 1 and Type 2 curves from other (non-Skagit) data sources and are considered to be a hybrid of Type 1-2 curves. As a result, in most cases, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves for Skagit River habitat modeling purposes when available.

When WDFW/Ecology Type 3 curves were not available, the HSC Technical Group typically recommended a) curves from other surrogate species with statewide Type 3 curves, b) Type 2 curves from other studies, or c) developed consensus curves from available and relevant literature.

Skagit River Habitat Suitability Criteria (HSC) Summary					
				WDFW/Ecology Guidelines (Beecher et al. 2016) or other reference	
Species	**Life Stage**	**HSC Group**	**HSC Status**	**Substrate**	**Cover**
Steelhead	spawning	A	WDFW/Ecology Type 3 curves	Table 4	N/A
	adult holding	D	WDFW/Ecology Type 3 curves for RBT adult/rearing	Table 3	Table 3
	juvenile	A	WDFW/Ecology Type 3 curves	Table 3	Table 3
Chinook Salmon	spawning	A	WDFW/Ecology Type 3 curves	Table 2	N/A
	juvenile			Table 3	Table 3
	fry	E	ESH Model Type 2 curves	ESH Model	N/A
Pink Salmon	spawning	A	WDFW/Ecology Type 3 curves	Table 2	N/A
Chum Salmon	spawning	A	WDFW/Ecology Type 3 curves	Table 2	N/A
	fry	E	Fraser River Type 2 curves	Fraser River (Rempel et al. 2012)	N/A
Coho Salmon	spawning	C	WDFW/Ecology Type 3 curves	Table 2	N/A
	juvenile	D	ESH Model Type 2 curves	ESH Model	Table 3
	fry	E	ESH Model Type 2 curves	ESH Model	N/A
Sockeye Salmon	spawning	C	WDFW/Ecology Type 3 curves	Table 2	N/A
Rainbow Trout	spawning	C	WDFW/Ecology Type 3 curves	Table 5	N/A
	adult rearing			Table 3	Table 3
	juvenile			Table 3	Table 3
	fry	E	ESH Model Type 2 curves	ESH Model	N/A
Bull Trout/ Dolly Varden	spawning	C	WDFW/Ecology Type 3 curves	Table 6	N/A
	juvenile	A		Table 3	Table 3
	fry	E	ESH Model Type 2 curves	ESH Model	N/A
Trout	spawning	F	Proposed consensus curves developed	Table 6	N/A
Cutthroat Trout	spawning	C	WDFW/Ecology Type 3 curves	Table 5	N/A
	adult	D	Use WDFW/Ecology Type 3 curve for Cutthroat juvenile	Table 3	Table 3
	juvenile	C	WDFW/Ecology Type 3 curves	Table 3	Table 3
	fry	E	ESH Model Type 2 curves	ESH Model	N/A
Sea-Run Cutthroat Trout	spawning	D	Proposed consensus curves developed	Table 5	N/A
Mountain Whitefish	spawning	C	WDFW/Ecology Type 3 curves	Table 7	N/A
	adult rearing			Table 8	Table 1
	juvenile			Table 9	Table 1
	fry	E	ESH Model Type 2 curves	ESH Model	N/A
Pacific Lamprey	spawning	D	Proposed consensus curves developed	Vadas 2021	N/A
	juvenile rearing				

Skagit River Habitat Suitability Criteria (HSC) Summary					
				WDFW/Ecology Guidelines (Beecher et al. 2016) or other reference	
Species	**Life Stage**	**HSC Group**	**HSC Status**	**Substrate**	**Cover**
Western Brook Lamprey	spawning	F	Proposed consensus curves developed	Vadas 2021	N/A
Western River Lamprey	spawning	F	Proposed consensus curves developed	Vadas 2021	N/A
Salish Sucker	spawning	F	Proposed consensus curves developed	Pearson 2003	N/A
	juvenile rearing				Pearson 2003
White Sturgeon	spawning	F	Proposed consensus curves developed	Sacramento River (Gard 1996)	N/A

Steelhead

Spawning (Group A)

Steelhead spawning HSC curves from several sources were evaluated including WDFW/Ecology (Type 3; 108 redds), the ESH model (Skagit River-specific Type 2; 305 redds), and the Trinity River (Type 2). It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when available unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. The statewide curves are based on analysis from 6 studies and 108 redds [Rock Creek (WRIA 31), Cedar (2 studies) and Sultan rivers and Chelan Fish Channel (2 studies)] (Beecher et al. 2016). Field validation studies conducted on the Skagit River during 2021 resulted in an additional 19 redd observations. These data were reviewed by the HSC Technical Group and were determined to be consistent with the ESH and statewide HSC curves (i.e., observation data points were generally captured within the defined area under the HSC depth and velocity curves). As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves.

Adult Holding (Group D)

WDFW/Ecology HSC curves for Steelhead adult holding are not available and the ESH model HSC curves are not based on Skagit-specific field observation data (hybrid Type 1-2). As a result, the WDFW/Ecology Type 3 HSC curves for resident Rainbow Trout adult rearing are proposed to represent Steelhead adult. The Rainbow Trout adult rearing curves are based on anlaysis from 15 studies totalling 638 fish observations [mostly streams west of the Cascades, but includes Yakima River, upper Mill Creek (WRIA 32), and Douglas Creek (WRIA 44)] (Beecher et al. 2016).

Juvenile (Group A)

Steelhead juvenile HSC curves from several sources were evaluated including WDFW/Ecology (Type 3; 1,954 fish observations), the ESH model (hybrid Type 1-2), and the Trinity River (Type 2). It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when available unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. The statewide curves are based on analysis from 32 studies and 1,954 fish observatons (from multiple Washington streams of differing sizes and stream types) (Beecher et al. 2016). Field validation studies conducted on the Skagit River during 2021 resulted in an additional 116 fish observations. These data were reviewed by the HSC Technical Group and were determined to be consistent with the ESH and statewide HSC curves (i.e., observation data points were generally captured within the defined area under the HSC depth and velocity curves). As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves.

Additional Notes

There is no clear biological evidence that depth becomes a limiting factor for adult and juvenile Steelhead. Therefore, the HSC Technical Group recommended that once depth reaches 3.85 ft (1.0 preference) for adult and 2.65 ft (1.0 preference) for juvenile, it be considered "non-limiting" in the HSC depth curves.

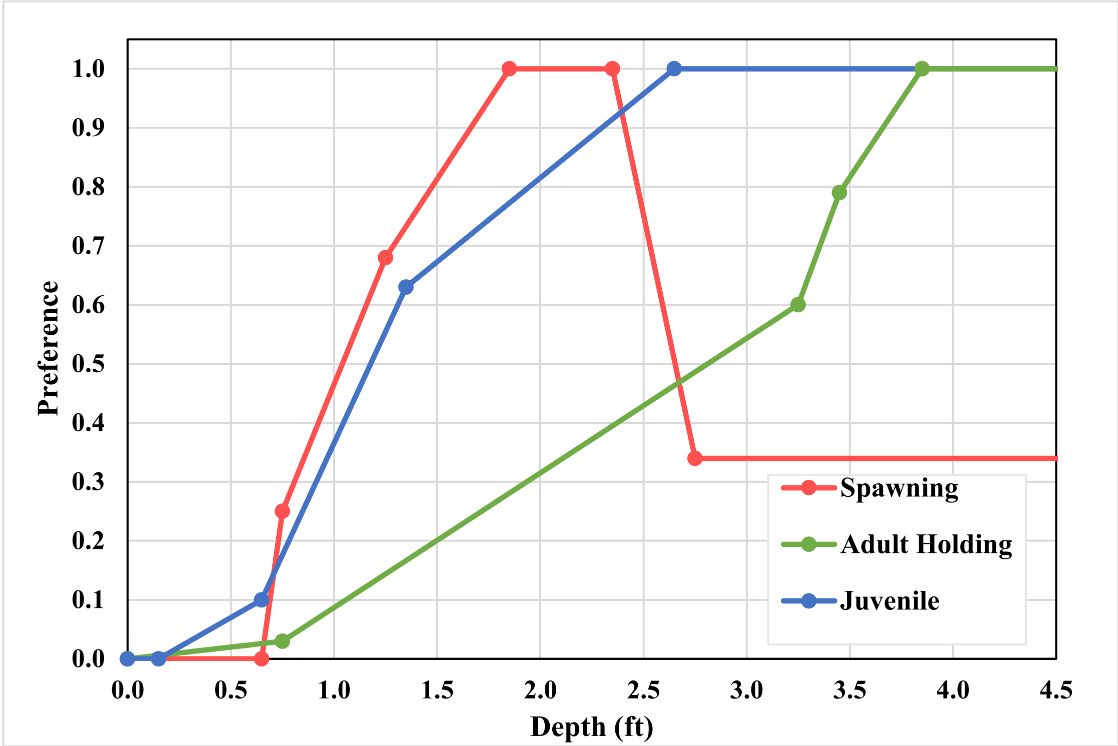
Steelhead

References

WDFW/Ecology: spawning, adult, and juvenile (Beecher et al. 2016)
ESH model: spawning (Crumley and Stober 1984); adult (Bovee 1978); juvenile (Crumley and Stober 1984; Bovee 1978)
Trinity River: spawning, adult, and juvenile (Hampton et al. 1997)
Fraser River: juvenile (Rempel et al. 2012)
Klamath River: juvenile (Hardy and Addley 2001)
McKenzie River: juvenile (Hardin-Davis 1990)

Steelhead

Depth Preference Curves

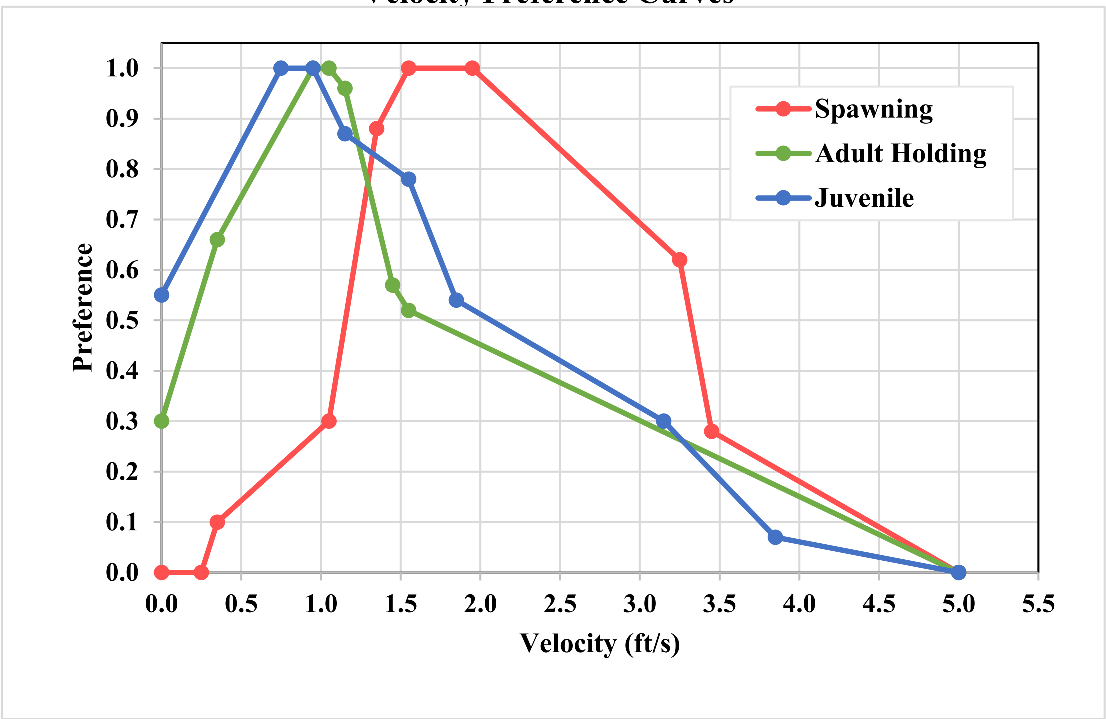


Spawning	
Depth (ft)	Preference
0.00	0.00
0.65	0.00
0.75	0.25
1.25	0.68
1.85	1.00
2.35	1.00
2.75	0.34
99.00	0.34

Adult Holding	
Depth (ft)	Preference
0.00	0.00
0.75	0.03
3.25	0.60
3.45	0.79
3.85	1.00
99.00	1.00

Juvenile	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.65	0.10
1.35	0.63
2.65	1.00
99.00	1.00

Steelhead



Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.25	0.00
0.35	0.10
1.05	0.30
1.35	0.88
1.55	1.00
1.95	1.00
3.25	0.62
3.45	0.28
5.00	0.00

Adult Holding	
Velocity (ft/s)	Preference
0.00	0.30
0.35	0.66
0.95	1.00
1.05	1.00
1.15	0.96
1.45	0.57
1.55	0.52
5.00	0.00

Juvenile	
Velocity (ft/s)	Preference
0.00	0.55
0.75	1.00
0.95	1.00
1.15	0.87
1.55	0.78
1.85	0.54
3.15	0.30
3.85	0.07
5.00	0.00

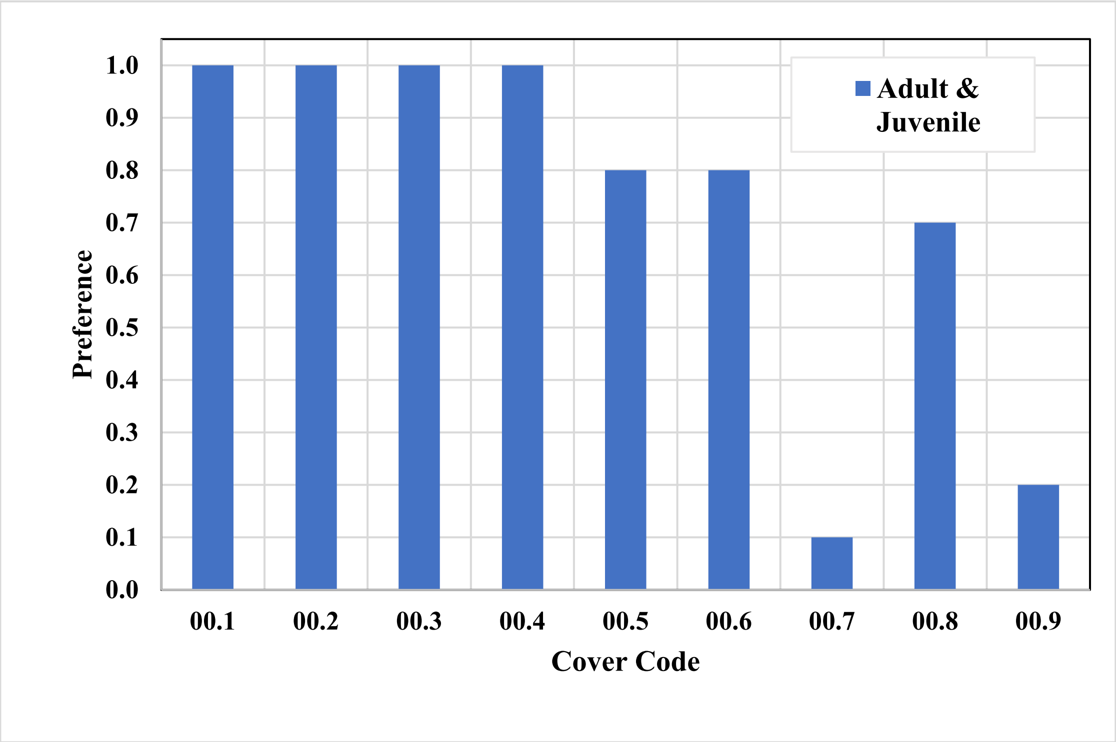
Steelhead

Substrate Preference Criteria

For Steelhead Spawning Substrate Preference, use Table 4 (Beecher et al. 2016)

For Steelhead Juvenile and Resident Adult Substrate and Cover Preference, use Table 3 (Beecher et al. 2016)

Steelhead
Cover Preference



Code	Type of Cover Note: cover codes are not used for spawning life stage	Adult & Juvenile Preference
00.1	Undercut bank	1.00
00.2	Overhanging vegetation near or touching water	1.00
00.3	Rootwad (including parly undercut)	1.00
00.4	Log jam/submerged brush pile	1.00
00.5	Log(s) parallel to bank	0.80
00.6	Aquatic vegetation	0.80
00.7	Short (<1 ft) terrestrial grass	0.10
00.8	Tall (>3 ft) dense grass	0.70
00.9	Vegetation >3 vertical ft above SZF	0.20

Source: Table 3, Beecher et al. 2016

Chinook Salmon

Spawning (Group A)

Chinook spawning HSC curves from several sources were evaluated including WDFW/Ecology (Type 3; 440 redds), the ESH model (Skagit River-specific Type 2; 436 redds), and the Klamath and Trinity rivers (both Type 2). Two sets of WDFW/Ecology Type 3 curves are available; one is recommended for large rivers (examples include the Skagit and Snohomish rivers) and the other is recommended for the Columbia and Snake rivers (Beecher et al. 2016). It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when available unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves for large rivers. Field validation studies conducted on the Skagit River during 2021 resulted in an additional 31 redd observations. These data were reviewed by the HSC Technical Group and were determined to be consistent with both the ESH and statewide HSC curves (i.e., observation data points were generally captured within the defined area under the HSC depth and velocity curves). As a result, the recommended HSC curves for use in the habitat modeling are the large river WDFW/Ecology Type 3 HSC curves.

Juvenile (Group A)

Chinook juvenile HSC curves from several sources were evaluated including WDFW/Ecology (Type 3; 5,615 fish) and the Klamath and Trinity rivers (both Type 2). No curves were available from the ESH model. It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when available unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. The statewide curves are based on analysis from 9 studies totaling 5,615 fish observations (Dungeness, Chiwawa, Mad & Similkameen, and Tucannon rivers and Kendall Creek (Beecher et al. 2016). Kendall Creek was a utilization study with 5,055 fish observations (Beecher et al. 2016). Field validation studies conducted on the Skagit River during 2021 resulted in an additional 41 fish observations. These data were reviewed by the HSC Technical Group and were determined to be consistent with the statewide HSC curves (i.e., observation data points were generally captured within the defined area under the HSC depth and velocity curves). As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves.

Fry (Group E)

Type 3 HSC curves are not available from WDFW/Ecology as the salmonid fry life stage is not commonly modeled in instream flow studies. However, habitat results for the fry life stage are of interest on the Skagit River in evaluating the relationship between flow and available habitat along the stream margins/shoreline areas as well as off-channel habitats that may be activated during higher flow events. As a result, the HSC Technical Group recommended using existing Type 2 fry curves when available. For Chinook fry, the HSC Technical Group reviewed existing Type 2 curves used in the ESH model (FRI and WDF) as well as the Trinity River. The velocity curves used in the ESH model are based velocity HSC for Rainbow Trout juvenile which are likely too high for Chinook fry. Therefore, the HSC Technical Group recommended using the Type 2 depth and velocity fry curves from the Trinity River study. Habitat cover preference information was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

Additional Notes

There is no clear biological evidence that depth becomes a limiting factor for juvenile Chinook salmon. Therefore, the HSC Technical Group recommended that once depth reaches 2.45 ft (1.0 preference), it be considered "non-limiting" in the HSC depth curve.

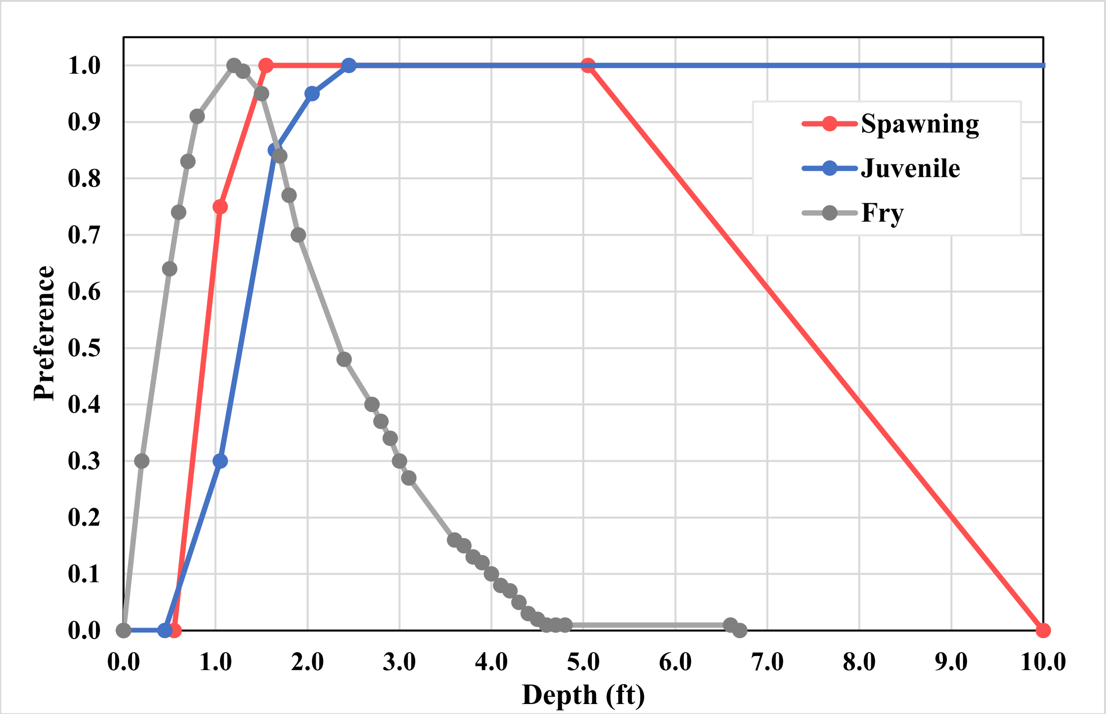
Chinook Salmon

References

WDFW/Ecology: spawning and juvenile (Beecher et al. 2016)
ESH model: spawning and fry (Crumley and Stober 1984; FRI and WDF)
Trinity River: spawning, juvenile, and fry (Hampton et al. 1997)
Klamath River: spawning and juvenile (Hardin et al. 2005; Hardy and Addley 2001)
Fraser River: juvenile (Rempel et al. 2012)

Chinook Salmon

Depth Preference Curves



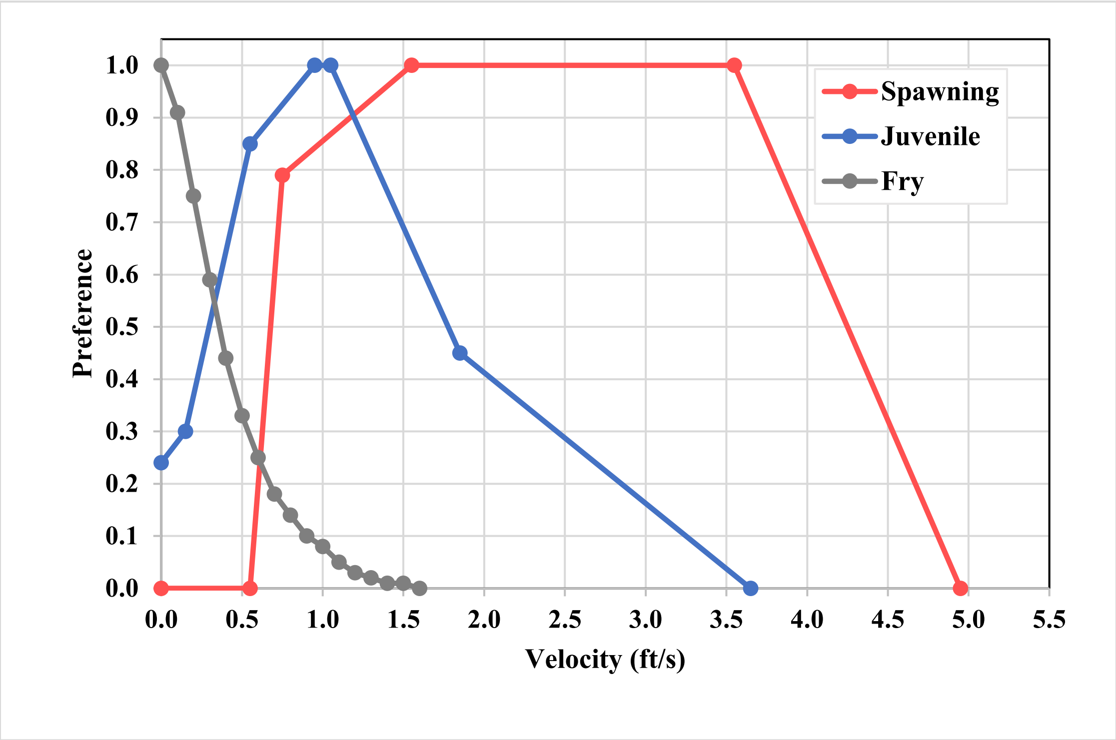
Spawning	
Depth (ft)	Preference
0.00	0.00
0.55	0.00
1.05	0.75
1.55	1.00
5.05	1.00
10.00	0.00

Juvenile	
Depth (ft)	Preference
0.00	0.00
0.45	0.00
1.05	0.30
1.65	0.85
2.05	0.95
2.45	1.00
99.00	1.00

Fry	
Depth (ft)	Preference
0.00	0.00
0.20	0.30
0.50	0.64
0.60	0.74
0.70	0.83
0.80	0.91
1.20	1.00
1.30	0.99
1.50	0.95
1.70	0.84
1.80	0.77
1.90	0.70
2.40	0.48
2.70	0.40
2.80	0.37
2.90	0.34
3.00	0.30
3.10	0.27
3.60	0.16
3.70	0.15
3.80	0.13
3.90	0.12
4.00	0.10
4.10	0.08
4.20	0.07
4.30	0.05
4.40	0.03
4.50	0.02
4.60	0.01
4.70	0.01
4.80	0.01
6.60	0.01
6.70	0.00

Chinook Salmon

Velocity Preference Curves



Fry	
Velocity (ft/s)	Preference
0.00	1.00
0.10	0.91
0.20	0.75
0.30	0.59
0.40	0.44
0.50	0.33
0.60	0.25
0.70	0.18
0.80	0.14
0.90	0.10
1.00	0.08
1.10	0.05
1.20	0.03
1.30	0.02
1.40	0.01
1.50	0.01
1.60	0.00

Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.55	0.00
0.75	0.79
1.55	1.00
3.55	1.00
4.95	0.00

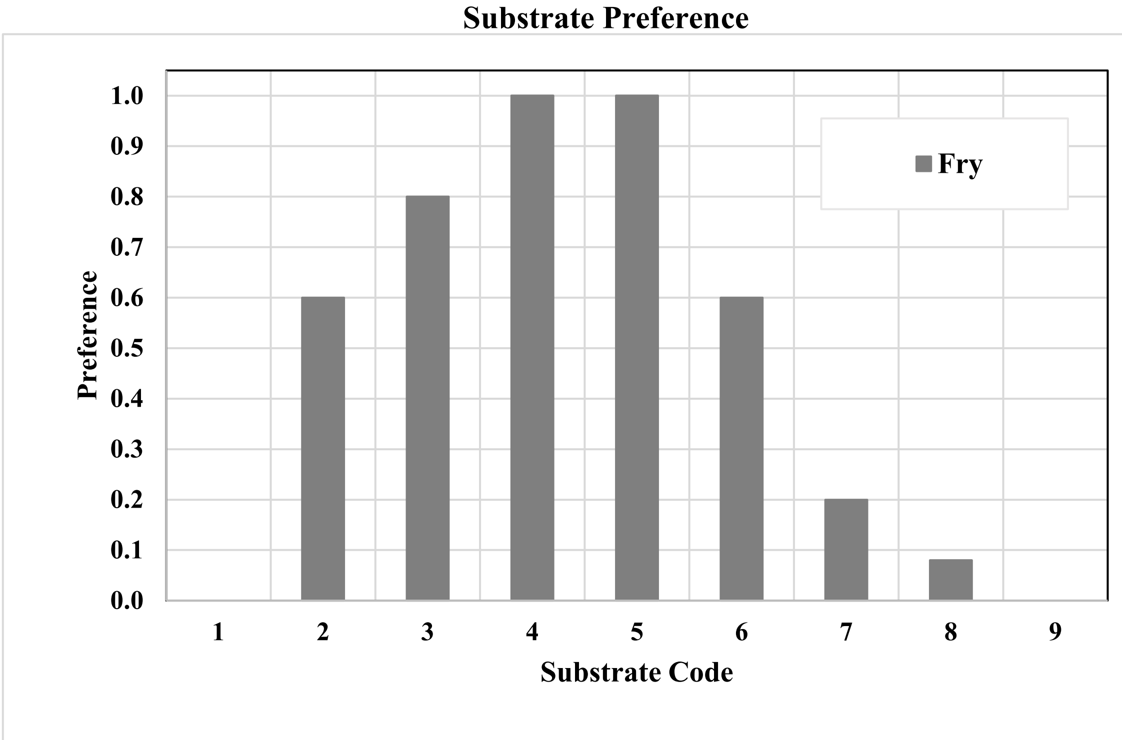
Juvenile	
Velocity (ft/s)	Preference
0.00	0.24
0.15	0.30
0.55	0.85
0.95	1.00
1.05	1.00
1.85	0.45
3.65	0.00

Chinook Salmon

Substrate Preference Criteria

For Chinook Salmon Spawning Substrate Preference, use Table 2 (Beecher et al. 2016)
For Chinook Salmon Juvenile Substrate and Cover Preference, use Table 3 (Beecher et al. 2016)
For Chinook Salmon Fry Substrate Preference, use data from the ESH Model

Chinook Salmon

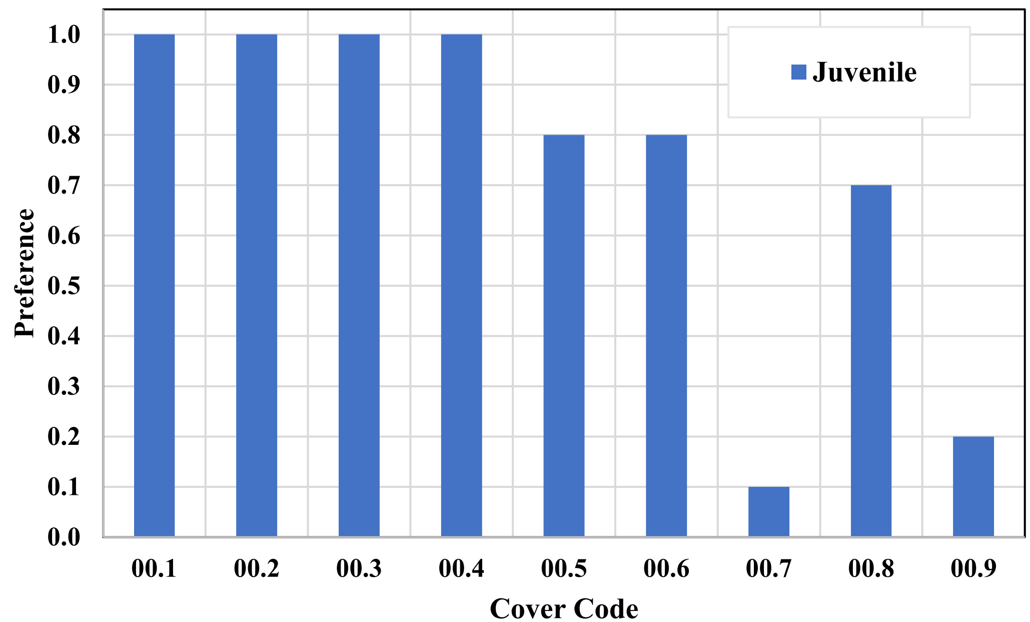


Sustrate Code	Substrate Type	Fry Preference
1	Silt, Clay, or Organic	0.00
2	Sand	0.60
3	Small Gravel (0.1-0.5")	0.80
4	Med Gravel (0.5-1.5")	1.00
5	Large Gravel (1.5-3.0")	1.00
6	Small Cobble (3.0-6.0")	0.60
7	Large Cobble (6.0-12")	0.20
8	Boulder (>12")	0.08
9	Bedrock	0.00

Source: ESH Model

Chinook Salmon

Cover Preference



Code	Type of Cover Note: cover codes are not used for spawning life	Juvenile Preference
00.1	Undercut bank	1.00
00.2	Overhanging vegetation near or touching water	1.00
00.3	Rootwad (including parly undercut)	1.00
00.4	Log jam/submerged brush pile	1.00
00.5	Log(s) parallel to bank	0.80
00.6	Aquatic vegetation	0.80
00.7	Short (<1 ft) terrestrial grass	0.10
00.8	Tall (>3 ft) dense grass	0.70
00.9	Vegetation >3 vertical ft above SZF	0.20

Source: Table 3, Beecher et al. 2016

Pink Salmon

Spawning (Group A)

Pink spawning HSC curves from WDFW/Ecology (Type 3; 104 redds) and the ESH model (Skagit River-specific Type 2; 347 redds) were evaluated by the HSC Technical Group. It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when avaiailable unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. Field validation studies conducted on the Skagit River during 2021 resulted in an additional 31 redd observations. These data were reviewed by the HSC Technical Group and were determined to be consistent with both the ESH and statewide HSC curves (i.e., observation data points were generally captured within the defined area under the HSC depth and velocity curves). The statewide curves are based on data from 6 studies and 104 redds [Squire Creek/North Fork Stillaguamish, Dosewallips (3 studies), and Duckabush (2 studies) rivers] (Beecher et al. 2016). As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves.

Additional Notes

There is no clear biological evidence that depth becomes a limiting factor for spawning Pink salmon. Therefore, the HSC Technical Group recommended that once depth reaches 1.35 ft (0.30 preference), it be considered "non-limiting" in the HSC depth curve.

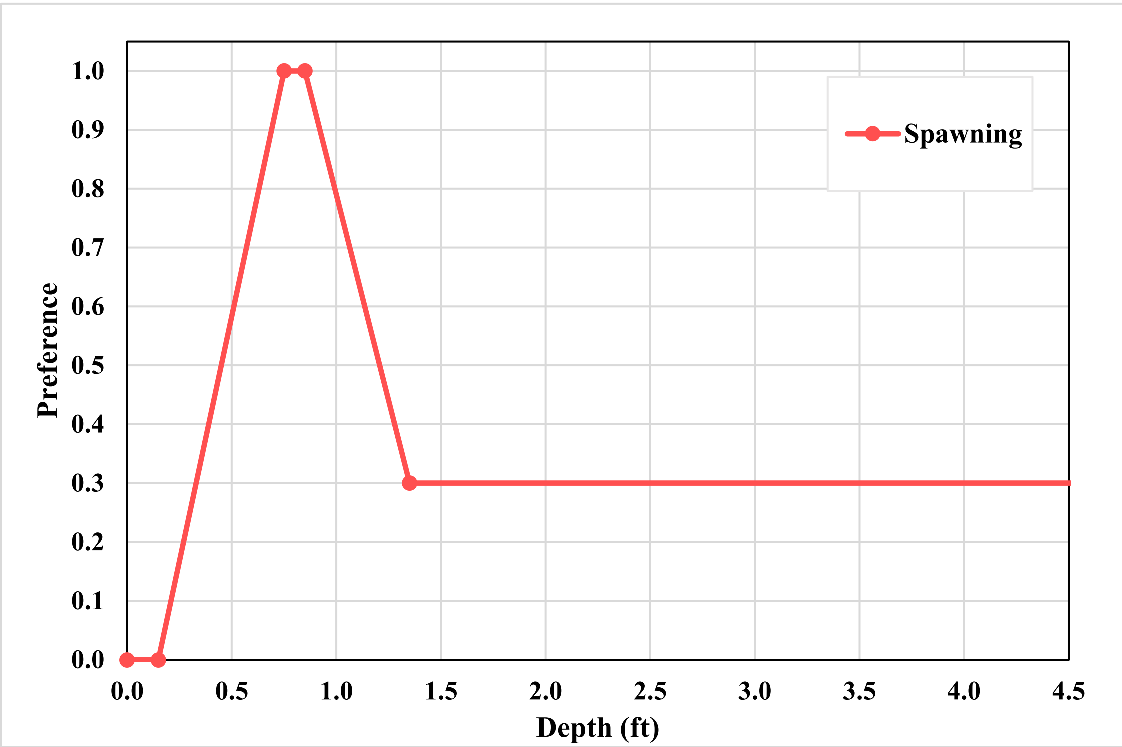
Pink salmon is an "ocean-type" rearing species, therefore, juvenile HSC curves are not recommended for habitat modeling in the Skagit River. However, the HSC Technical Group has developed a set of "generic salmonid fry" HSC curves based on an evaluation of HSC currently used in the ESH model for several salmonid species (see Fry tab in this spreadsheet). The generic salmonid fry HSC curves will be used to evaluate potential fry habitat along stream margins and side-channel areas.

References

WDFW/Ecology: spawning (Beecher et al. 2016)
ESH model: spawning (Crumley and Stober 1984)

Pink Salmon

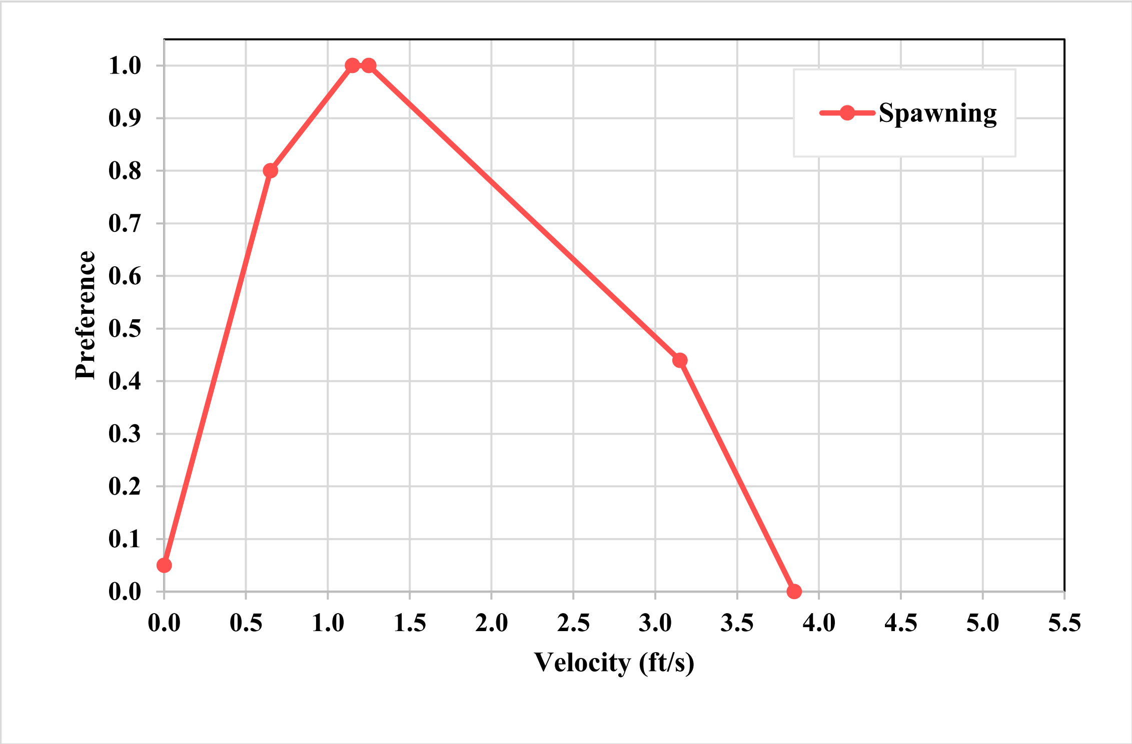
Depth Preference Curves



Spawning	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.75	1.00
0.85	1.00
1.35	0.30
99.00	0.30

Pink Salmon

Velocity Preference Curves



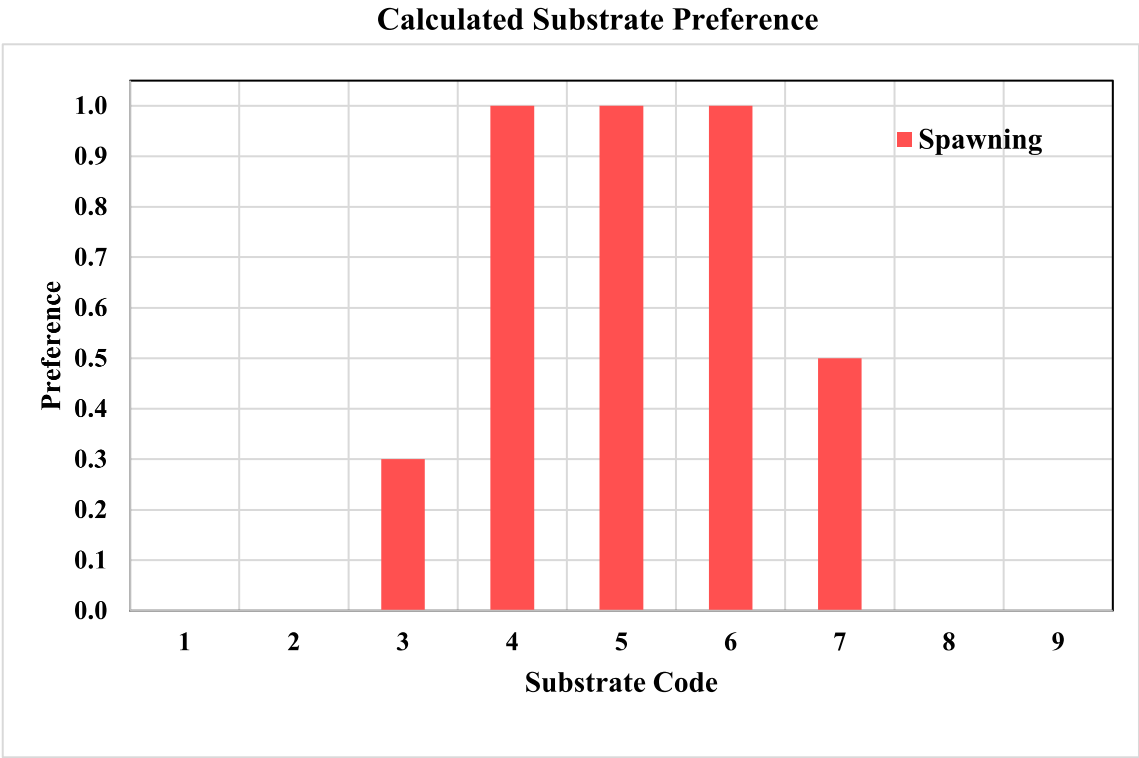
Spawning	
Velocity (ft/s)	Preference
0.00	0.05
0.65	0.80
1.15	1.00
1.25	1.00
3.15	0.44
3.85	0.00

Pink Salmon

Substrate Preference Criteria

For Pink Salmon Spawning Substrate Preference, use Table 2 (Beecher et al. 2016)

Pink Salmon



Sustrate Code	Substrate Type	Spawning Preference
1	Silt, Clay, or Organic	0.0
2	Sand	0.0
3	Small Gravel (0.1-0.5")	0.3
4	Med Gravel (0.5-1.5")	1.0
5	Large Gravel (1.5-3.0")	1.0
6	Small Cobble (3.0-6.0")	1.0
7	Large Cobble (6.0-12")	0.5
8	Boulder (>12")	0.0
9	Bedrock	0.0

Source: Table 12, Beecher et al. 2016

Chum Salmon

Spawning (Group A)

Chum spawning HSC curves from WDFW/Ecology (Type 3; 225 redds) and the ESH model (Skagit River-specific Type 2; 251 redds) were evaluated by the HSC Technical Group. It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when avaiailable unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. The statewide curves are based on data from 16 studies and 225 redds [Hill Creek, Kennedy Creek (3 studies), Duckabush (9 studies) and Dosewallips rivers (3 studies)] (Beecher et al. 2016). As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves.

Fry (Group E)

Type 3 curves are not available from WDFW/Ecology or the ESH model for Chum fry. As a result, the proposed HSC curves are based on information from a juvenile fish habitat survey on the Lower Fraser River (Rempel et al. 2012). The authors noted that the HSC curves are consistent with the Type 2 curves proposed by Hale et al. (1985). Habitat cover preference information was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

Additional Notes

The 2021 HSC field validation study included spawning Chum as a target species. However, due to unseasonably high flows on the Skagit River (and poor visibility conditions due to turbidity) during Chum spawning window (i.e., late-fall/early-winter), field observations were not possible.

There is no clear biological evidence that depth becomes a limiting factor for the fry and spawning life stages. Therefore, the HSC Technical Group recommended that once depth reaches 1.31 ft (1.0 preference) for fry and 2.65 ft (0.17 preference) for spawning, it be considered "non-limiting" in the HSC depth curves.

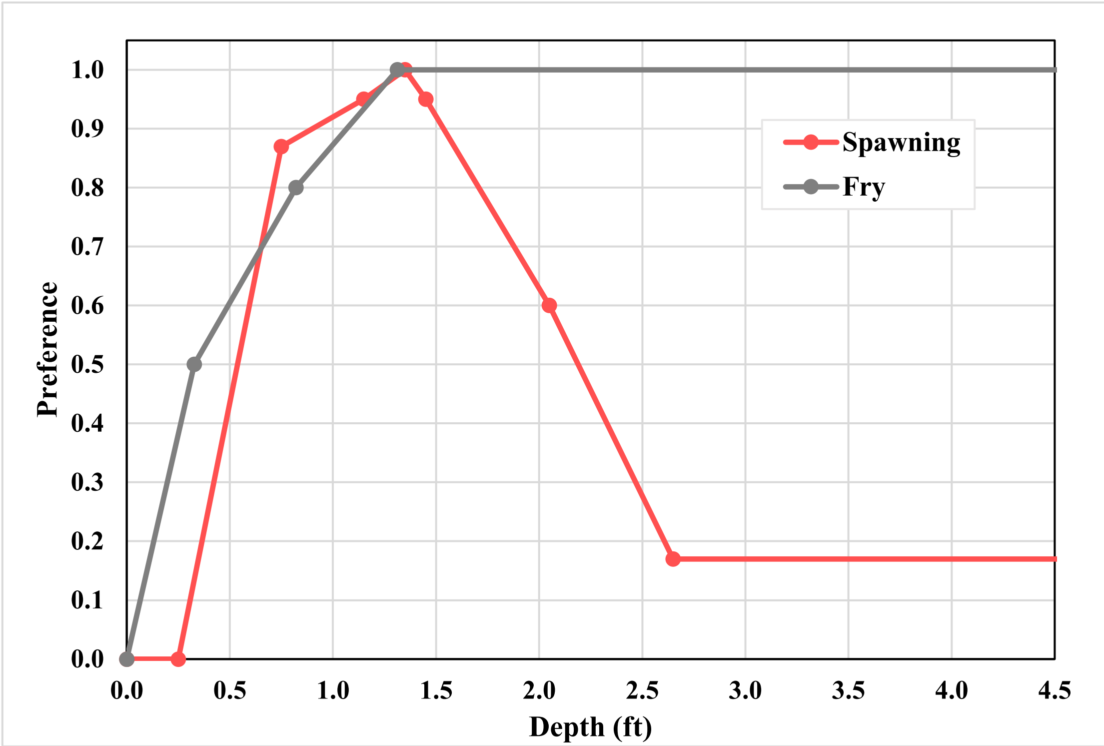
Chum salmon is an "ocean-type" rearing species, therefore, juvenile HSC curves are not recommended for habitat modeling in the Skagit River. However, the HSC Technical Group has developed a set of "generic salmonid fry" HSC curves based on an evaluation of HSC currently used in the ESH model for several salmonid species (see Fry tab in this spreadsheet). The generic salmonid fry HSC curves will be used to evaluate potential fry habitat along stream margins and side-channel areas.

References

WDFW/Ecology: spawning (Beecher et al. 2016)
ESH model: spawning (Crumley and Stober 1984)
Fraser River: spawning and fry (Rempel et al. 2012)

Chum Salmon

Depth Preference Curves

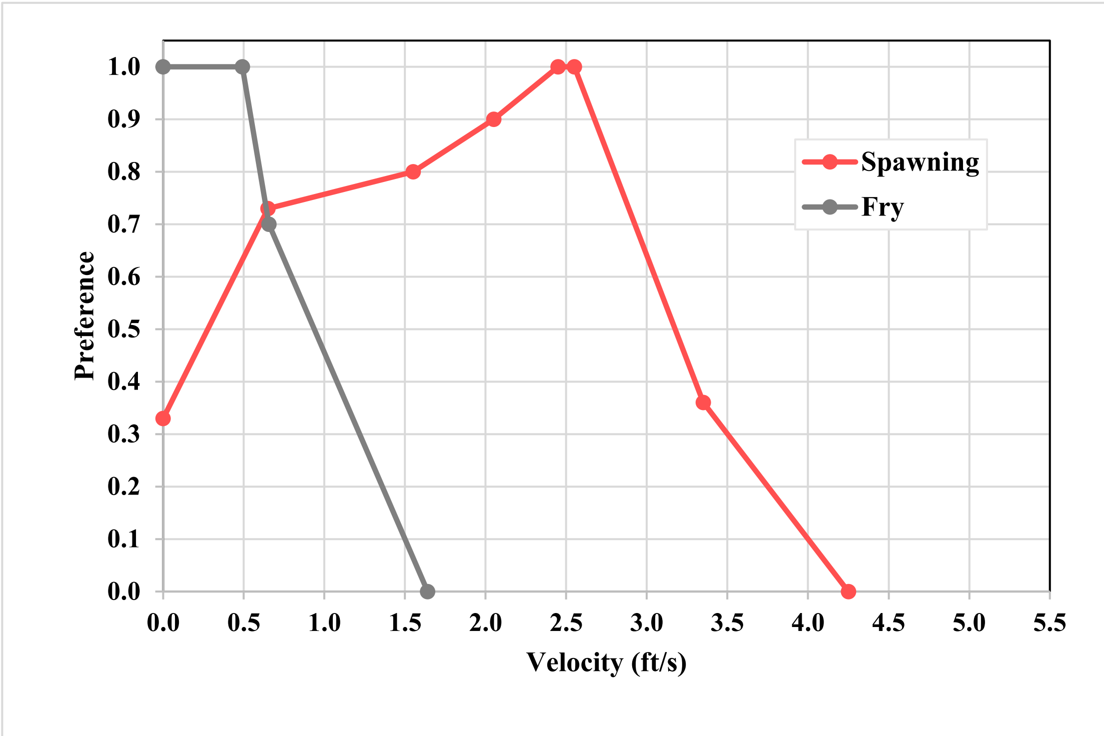


Spawning	
Depth (ft)	Preference
0.00	0.00
0.25	0.00
0.75	0.87
1.15	0.95
1.35	1.00
1.45	0.95
2.05	0.60
2.65	0.17
99.00	0.17

Fry	
Depth (ft)	Preference
0.00	0.00
0.33	0.50
0.82	0.80
1.31	1.00
99.00	1.00

Chum Salmon

Velocity Preference Curves



Spawning	
Velocity (ft/s)	Preference
0.00	0.33
0.65	0.73
1.55	0.80
2.05	0.90
2.45	1.00
2.55	1.00
3.35	0.36
4.25	0.00

Fry	
Velocity (ft/s)	Preference
0.00	1.00
0.49	1.00
0.66	0.70
1.64	0.00

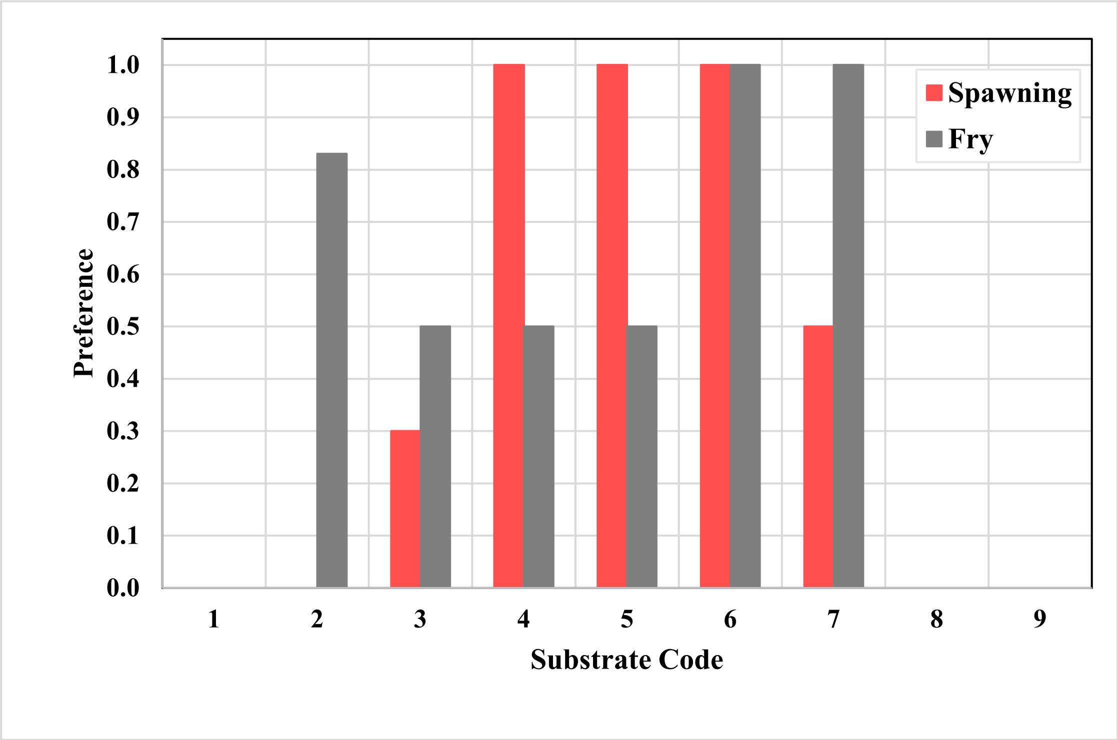
Chum Salmon

Substrate Preference Criteria

For Chum Salmon Spawning Substrate Preference, use Table 2 (Beecher et al. 2016)
For Chum Salmon Fry Substrate Preference, use Rempel et al. 2012

Chum Salmon

Substrate Preference



Sustrate Code	Substrate Type	Spawning Preference	Fry Preference
1	Silt, Clay, or Organic	0.0	0.0
2	Sand	0.0	0.8
3	Small Gravel (0.1-0.5")	0.3	0.5
4	Med Gravel (0.5-1.5")	1.0	0.5
5	Large Gravel (1.5-3.0")	1.0	0.5
6	Small Cobble (3.0-6.0")	1.0	1.0
7	Large Cobble (6.0-12")	0.5	1.0
8	Boulder (>12")	0.0	0.0
9	Bedrock	0.0	0.0

Source: Spawning (Table 10, Beecher et al. 2016); Fry (Rempel et al. 2012)

Coho Salmon

Spawning (Group C)

Coho spawning HSC curves from several sources were evaluated including WDFW/Ecology (Type 3; 66 redds), the ESH model (hybrid Type 1-2), and the Trinity River (Type 2). It is WDFW/Ecology's preference to use statewide Type 3 HSC curves when available unless additional site-specific field observation is collected on the Skagit River in sufficient numbers to revisit, and potentially revise, the statewide curves. The statewide HSC curves are based on data from 5 studies and 66 redds (Fletcher Canyon and Irely creeks, and Humptulips and Dewatto rivers). As a result, the proposed habitat modeling approach is to use the existing WDFW/Ecology Type 3 HSC curves.

Juvenile (Group D)

The WDFW/Ecology Instream Flow Study Guidelines are periodically updated with best available data.Versions of the WDFW/Ecology Instream Flow Study Guidelines prior to 2013 provided default Coho juvenile depth and velocity HSC curves developed in earlier studies (Beecher et al. 2002). Subsequent research has shown that the stream flow relating to peak Coho rearing habitat did not resemble the stream flow relating to increased Coho salmon production (Beecher et al. 2010). Based on this, WDFW/Ecology removed the statewide Coho juvenile HSC curves from subsequent versions (Beecher et al. 2013; Beecher et al. 2016).

HSC curves from the ESH model (Type 2) and the Trinity River (Type 2) were evaluated by the HSC Technical Group. While the ESH curves are not based on Skagit-specific field observation data, the HSC Technical Group recommended their use primarily because there is a history of using these curves for Skagit River habitat modeling purposes.

Fry (Group E)

Type 3 HSC curves are not available from WDFW/Ecology as the salmonid fry life stage is not commonly modeled in instream flow studies. However, habitat results for the fry life stage are of interest on the Skagit River in evaluating the relationship between flow and available habitat along the stream margins/shoreline areas as well as off-channel habitats that may be activated during higher flow events. As a result, the HSC Technical Group recommended using existing Type 2 fry curves when available. For Coho fry, the HSC Technical Group reviewed existing Type 2 curves used in the ESH model (Crumley and Stober 1984) as well as the Trinity River with a recommendation to use the ESH model curves for habitat modeling purposes. Habitat cover preference information was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

Additional Notes

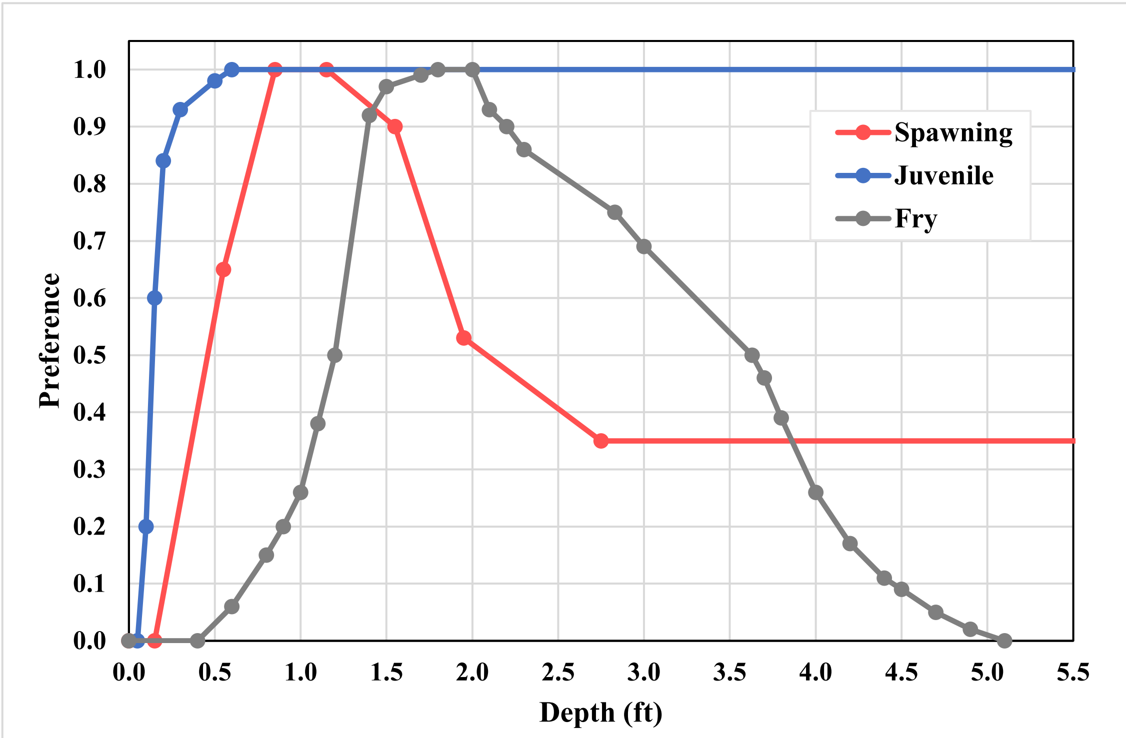
There is no clear biological evidence that depth becomes a limiting factor for spawning and juvenile Coho salmon. Therefore, the HSC Technical Group recommended that once depth reaches 2.75 ft (0.35 preference) for spawning and 2.0 ft (1.0 preference) for juvenile, it be considered "non-limiting" in the HSC depth curves.

References

WDFW/Ecology: spawning (Beecher et al. 2016)
ESH model: spawning, juvenile, and fry (Wampler 1980; Bovee 1978; Crumley and Stober 1984)
Trinity River: spawning, juvenile, and fry (Hampton et al. 1997)

Coho Salmon

Depth Preference Curves



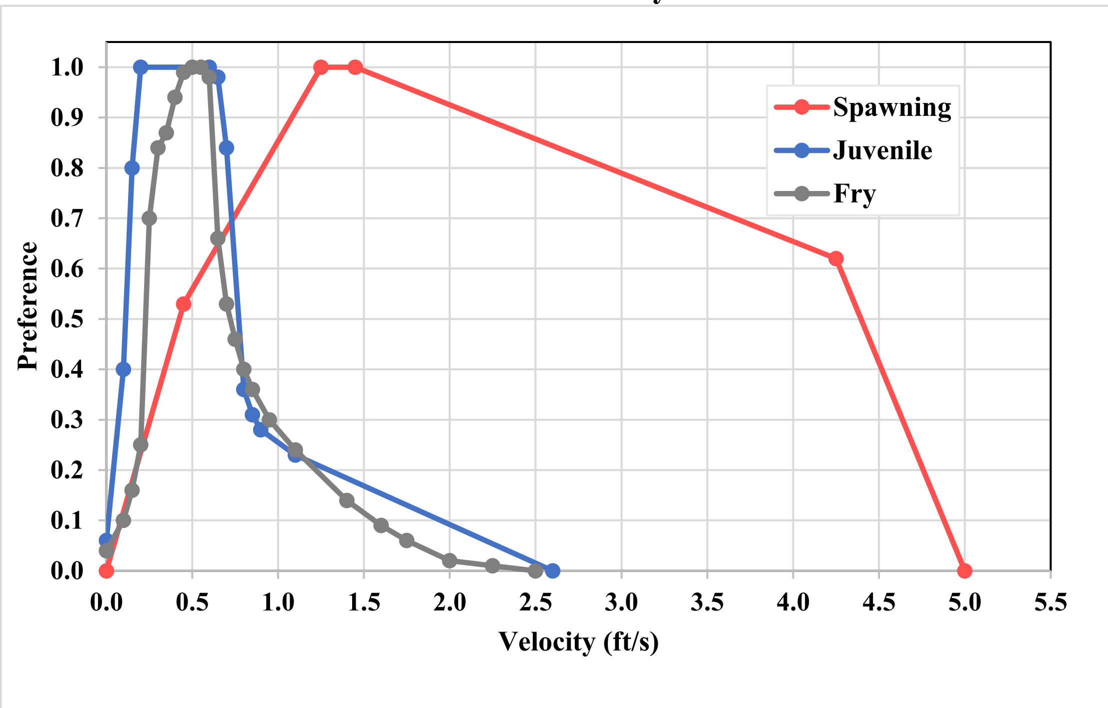
Fry	
Depth (ft)	Preference
0.00	0.00
0.40	0.00
0.60	0.06
0.80	0.15
0.90	0.20
1.00	0.26
1.10	0.38
1.20	0.50
1.40	0.92
1.50	0.97
1.70	0.99
1.80	1.00
2.00	1.00
2.10	0.93
2.20	0.90
2.30	0.86
2.83	0.75
3.00	0.69
3.63	0.50
3.70	0.46
3.80	0.39
4.00	0.26
4.20	0.17
4.40	0.11
4.50	0.09
4.70	0.05
4.90	0.02
5.10	0.00

Spawning	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.55	0.65
0.85	1.00
1.15	1.00
1.55	0.90
1.95	0.53
2.75	0.35
99.00	0.35

Juvenile	
Depth (ft)	Preference
0.05	0.00
0.10	0.20
0.15	0.60
0.20	0.84
0.30	0.93
0.50	0.98
0.60	1.00
99.00	1.00

Coho Salmon

Velocity Preference Curves



Fry	
Velocity (ft/s)	Preference
0.00	0.04
0.10	0.10
0.15	0.16
0.20	0.25
0.25	0.70
0.30	0.84
0.35	0.87
0.40	0.94
0.45	0.99
0.50	1.00
0.55	1.00
0.60	0.98
0.65	0.66
0.70	0.53
0.75	0.46
0.80	0.40
0.85	0.36
0.95	0.30
1.10	0.24
1.40	0.14
1.60	0.09
1.75	0.06
2.00	0.02
2.25	0.01
2.50	0.00

Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.45	0.53
1.25	1.00
1.45	1.00
4.25	0.62
5.00	0.00

Juvenile	
Velocity	Preference
0.00	0.06
0.10	0.40
0.15	0.80
0.20	1.00
0.60	1.00
0.65	0.98
0.70	0.84
0.80	0.36
0.85	0.31
0.90	0.28
1.10	0.23
2.60	0.00

Coho Salmon

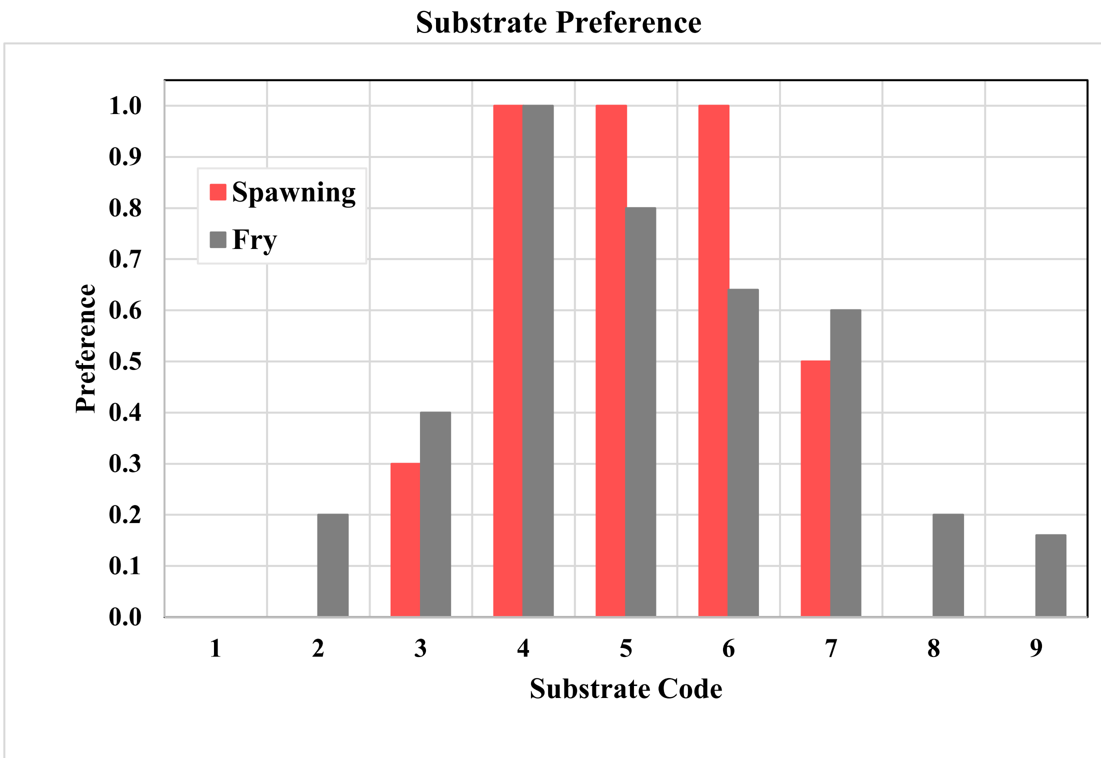
Substrate Preference Criteria

For Coho Salmon Spawning Substrate Preference, use Table 2 (Beecher et al. 2016)

For Coho Salmon Juvenile Substrate and Cover Preference, use Table 3 (Beecher et al. 2016)

For Coho Salmon Fry Substrate Preference, use data from the ESH Model

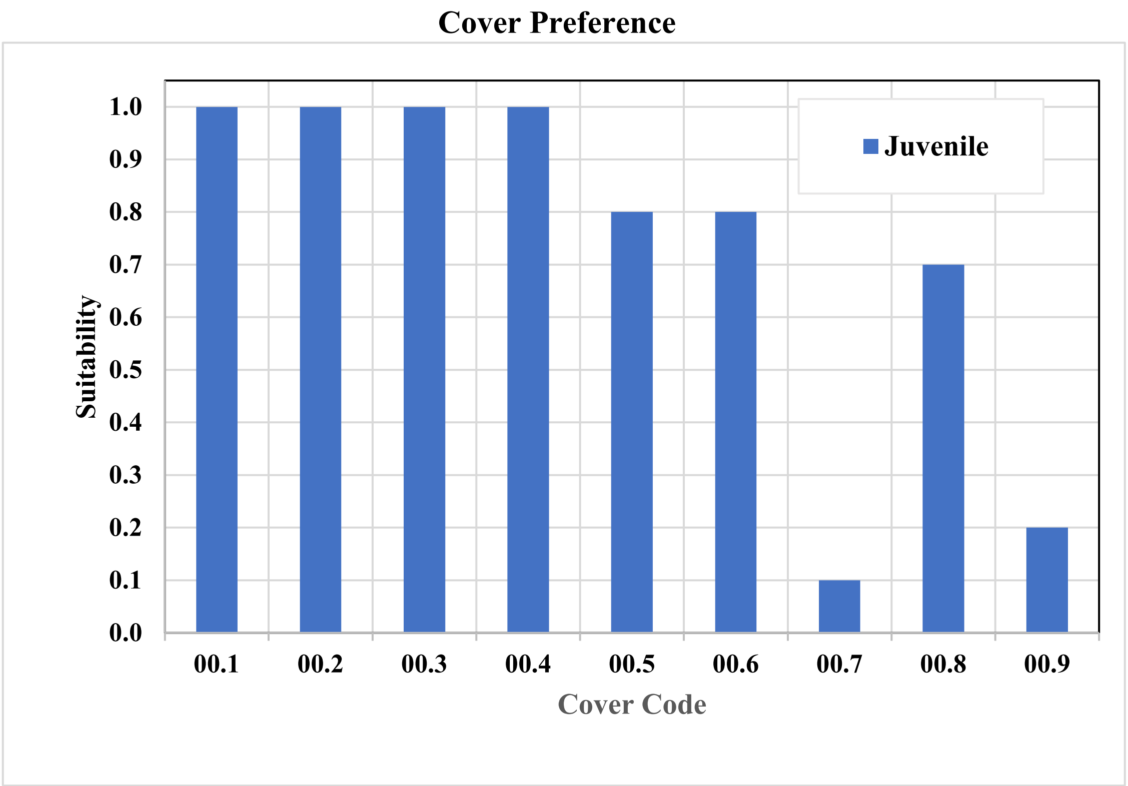
Coho Salmon



Sustrate Code	Substrate Type	Spawning Preference	Fry Preference
1	Silt, Clay, or Organic	0.0	0.00
2	Sand	0.0	0.20
3	Small Gravel (0.1-0.5")	0.3	0.40
4	Med Gravel (0.5-1.5")	1.0	1.00
5	Large Gravel (1.5-3.0")	1.0	0.80
6	Small Cobble (3.0-6.0")	1.0	0.64
7	Large Cobble (6.0-12")	0.5	0.60
8	Boulder (>12")	0.0	0.20
9	Bedrock	0.0	0.16

Source: Spawning (Table 11, Beecher et al. 2016); Fry (ESH Model)

Coho Salmon



Code	Type of Cover Note: Cover Codes are not used for Spawning life stage	Juvenile Preference
00.1	Undercut bank	1.00
00.2	Overhanging vegetation near or touching water	1.00
00.3	Rootwad (including parly undercut)	1.00
00.4	Log jam/submerged brush pile	1.00
00.5	Log(s) parallel to bank	0.80
00.6	Aquatic vegetation	0.80
00.7	Short (<1 ft) terrestrial grass	0.10
00.8	Tall (>3 ft) dense grass	0.70
00.9	Vegetation >3 vertical ft above SZF	0.20

Source: Table 3, Beecher et al. 2016

Sockeye Salmon

Spawning (Group C)

For Sockeye spawning, only Type 3 HSC curves from WDFW/Ecology were evaluated by the HSC Technical Group as ESH curves are not available. It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when available unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. The statewide curves are based on data from 4 studies and 1,053 redds [Cedar River (3 studies) and Big Creek (Quinault basin)] (Beecher et al. 2016). As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves.

Additional Notes

There is no clear biological evidence that depth becomes a limiting factor for spawning Sockeye salmon. Therefore, the HSC Technical Group recommended that once depth reaches 1.55 ft (0.45 preference), it be considered "non-limiting" in the HSC depth curve.

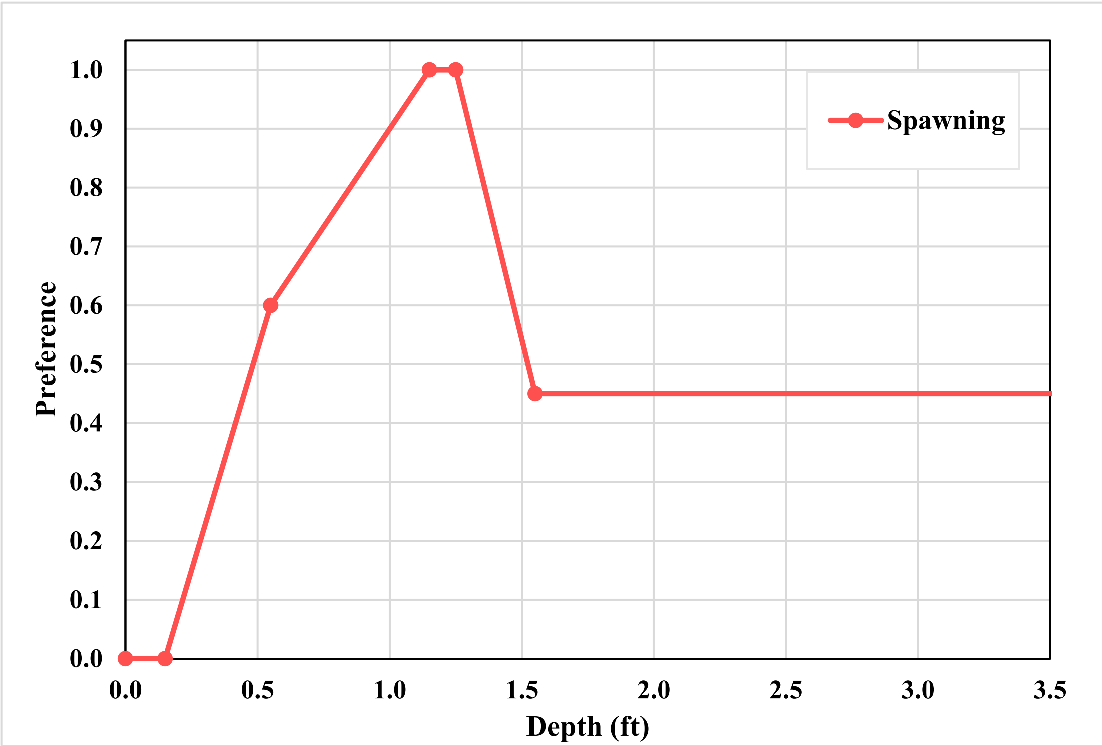
Sockeye salmon is an "ocean-type" rearing species, therefore, juvenile HSC curves are not recommended for habitat modeling in the Skagit River. However, the HSC Technical Group has developed a set of "generic salmonid fry" HSC curves based on an evaluation of HSC currently used in the ESH model for several salmonid species (see Fry tab in this spreadsheet). The generic salmonid fry HSC curves will be used to evaluate potential fry habitat along stream margins and side-channel areas.

References

WDFW/Ecology: spawning (Beecher et al. 2016)
Fraser River: spawning (Rempel et al. 2012)

Sockeye Salmon

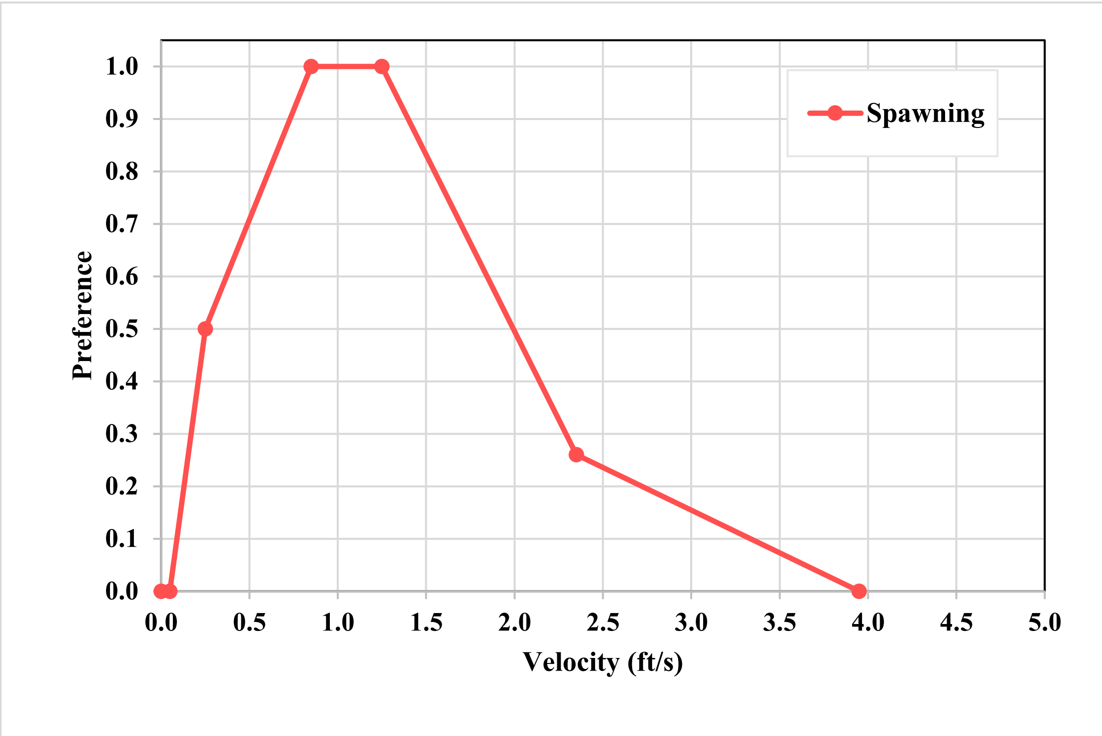
Depth Preference Curves



Spawning	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.55	0.60
1.15	1.00
1.25	1.00
1.55	0.45
99.00	0.45

Sockeye Salmon

Velocity Preference Curves



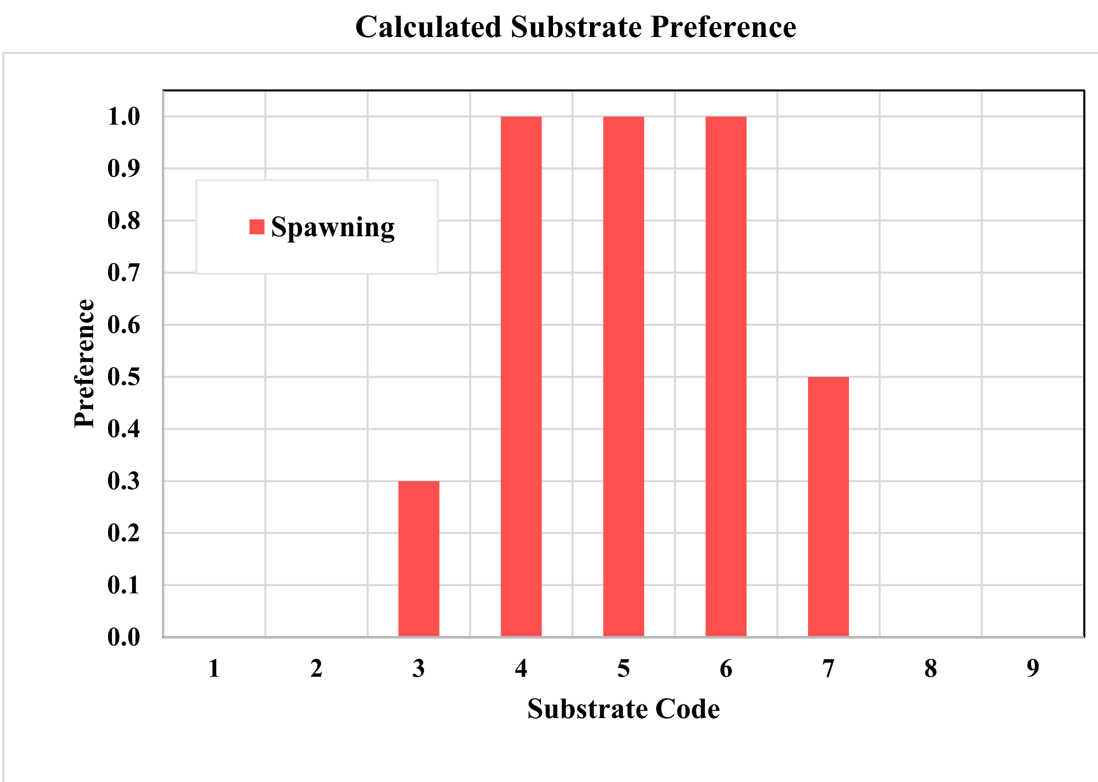
Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.05	0.00
0.25	0.50
0.85	1.00
1.25	1.00
2.35	0.26
3.95	0.00

Sockeye Salmon

Substrate Preference Criteria

For Sockeye Salmon Spawning Substrate Preference, use Table 2 (Beecher et al. 2016)

Sockeye Salmon



Sustrate Code	Substrate Type	Spawning Preference
1	Silt, Clay, or Organic	0.0
2	Sand	0.0
3	Small Gravel (0.1-0.5")	0.3
4	Med Gravel (0.5-1.5")	1.0
5	Large Gravel (1.5-3.0")	1.0
6	Small Cobble (3.0-6.0")	1.0
7	Large Cobble (6.0-12")	0.5
8	Boulder (>12")	0.0
9	Bedrock	0.0

Source: Table 13, Beecher et al. 2016

Rainbow Trout

General Approach

For Rainbow Trout spawning, adult rearing, and juvenile life stages, HSC curves from WDFW/Ecology (Type 3), the ESH model (hybrid Type 1-2), and the Fraser River (Type 2, juvenile only) were evaluated by the HSC Technical Group. It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when avaiailable unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves for all three Rainbow Trout life stages. Information specific to each life stage is provided below.

Spawning (Group C)

The WDFW/Ecology Type 3 HSC curves for Rainbow Trout spawning are based on analysis from 2 studies and 27 redds (from the upper Lake and Muller creeks) (Beecher et al. 2016).

Adult Rearing (Group C)

The WDFW/Ecology Type 3 HSC curves for Rainbow Trout adult rearing are based on anlaysis from 15 studies and 638 fish observations [mostly streams west of the Cascades, but includes Yakima River, upper Mill Creek (WRIA 32), and Douglas Creek (WRIA 44)] (Beecher et al. 2016).

Juvenile (Group C)

The WDFW/Ecology Type 3 HSC curves are based on analysis from 32 studies and 1,954 fish observations (from multiple Washington streams of differing sizes and stream types) (Beecher et al. 2016).

Fry (Group E)

Type 3 HSC curves are not available from WDFW/Ecology as the salmonid fry life stage is not commonly modeled in instream flow studies. However, habitat results for the fry life stage are of interest on the Skagit River in evaluating the relationship between flow and available habitat along the stream margins/shoreline areas as well as off-channel habitats that may be activated during higher flow events. As a result, the HSC Technical Group recommended using existing Type 2 fry curves when available. For Rainbow Trout fry, the HSC Technical Group reviewed existing Type 2 curves used in the ESH model (Bovee 1978) as well as the Fraser River with a recommendation to use the ESH model curves for habitat modeling purposes. Habitat cover preference information was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

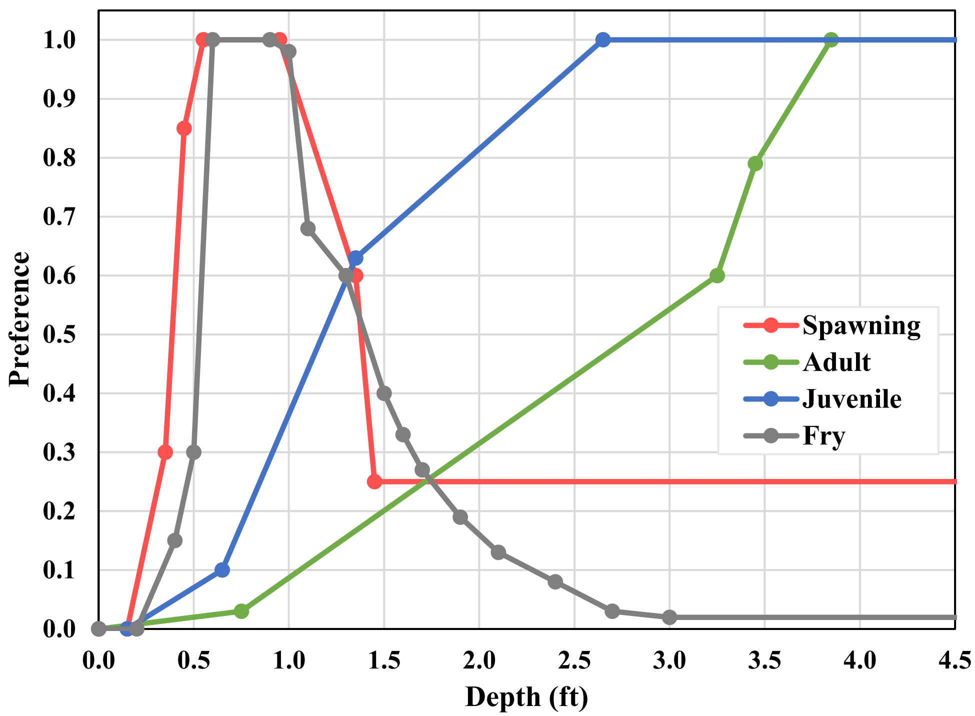
Additional Notes

There is no clear biological evidence that depth becomes a limiting factor for spawning, adult, and juvenile Rainbow Trout. Therefore, the HSC Technical Group recommended that once depth reaches 1.45 ft for spawning (0.25 preference), 3.85 ft (1.0 preference) for adult, and 2.65 ft (1.0 preference) for juvenile, it be considered "non-limiting" in the HSC depth curves.

References

WDFW/Ecology: spawning, adult rearing, and juvenile (Beecher et al. 2016)
ESH model: spawning and fry (Bovee 1978); adult and juvenile (Bovee 1978; Crumley and Stober 1984)
Fraser River: juvenile and fry (Rempel et al. 2012)
Klamath River: spawning, adult, and juvenile (Allen DATE)
McKenzie River: spawning, adult, and juvenile (Hardin-Davis 1990)

Rainbow Trout
Depth Preference Curves



Fry	
Depth (ft)	Preference
0.00	0.00
0.20	0.00
0.40	0.15
0.50	0.30
0.60	1.00
0.90	1.00
1.00	0.98
1.10	0.68
1.30	0.60
1.50	0.40
1.60	0.33
1.70	0.27
1.90	0.19
2.10	0.13
2.40	0.08
2.70	0.03
3.00	0.02
5.00	0.02
6.00	0.02
100.00	0.02

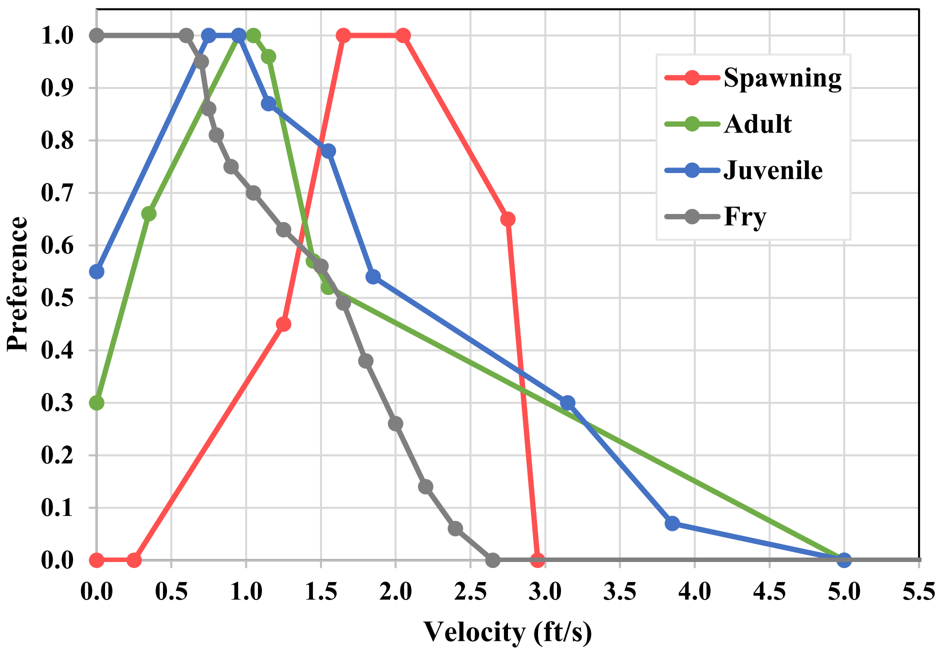
Spawning	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.35	0.30
0.45	0.85
0.55	1.00
0.95	1.00
1.35	0.60
1.45	0.25
99.00	0.25

Adult	
Depth (ft)	Preference
0.00	0.00
0.75	0.03
3.25	0.60
3.45	0.79
3.85	1.00
99.00	1.00

Juvenile	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.65	0.10
1.35	0.63
2.65	1.00
99.00	1.00

Rainbow Trout

Velocity Preference Curves



Fry	
Velocity (ft/s)	Preference
0.00	1.00
0.60	1.00
0.70	0.95
0.75	0.86
0.80	0.81
0.90	0.75
1.05	0.70
1.25	0.63
1.50	0.56
1.65	0.49
1.80	0.38
2.00	0.26
2.20	0.14
2.40	0.06
2.65	0.00
100.00	0.00

Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.25	0.00
1.25	0.45
1.65	1.00
2.05	1.00
2.75	0.65
2.95	0.00

Adult	
Velocity (ft/s)	Preference
0.00	0.30
0.35	0.66
0.95	1.00
1.05	1.00
1.15	0.96
1.45	0.57
1.55	0.52
5.00	0.00

Juvenile	
Velocity (ft/s)	Preference
0.00	0.55
0.75	1.00
0.95	1.00
1.15	0.87
1.55	0.78
1.85	0.54
3.15	0.30
3.85	0.07
5.00	0.00

Rainbow Trout

Substrate Preference Criteria

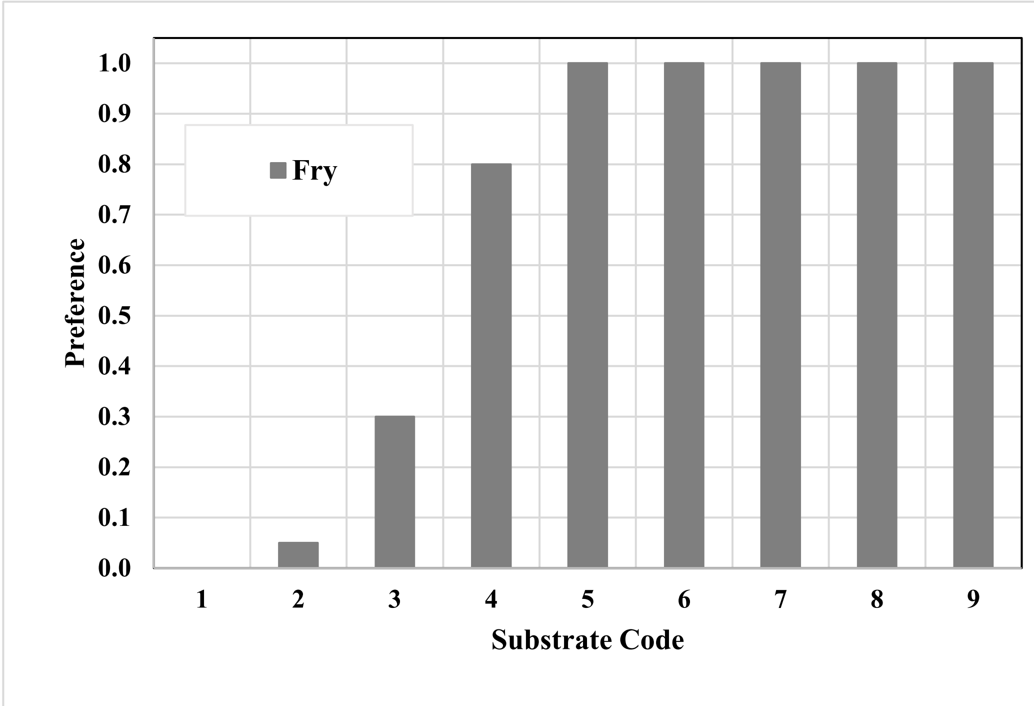
For Rainbow Trout Spawning Substrate Preference, use Table 5 (Beecher et al. 2016)

For Rainbow Trout Adult Rearing and Juvenile Substrate and Cover Preference, use Table 3 (Beecher et al. 2016)

For Rainbow Trout Fry Substrate Preference, use data from the ESH Model

Rainbow Trout

Substrate Preference

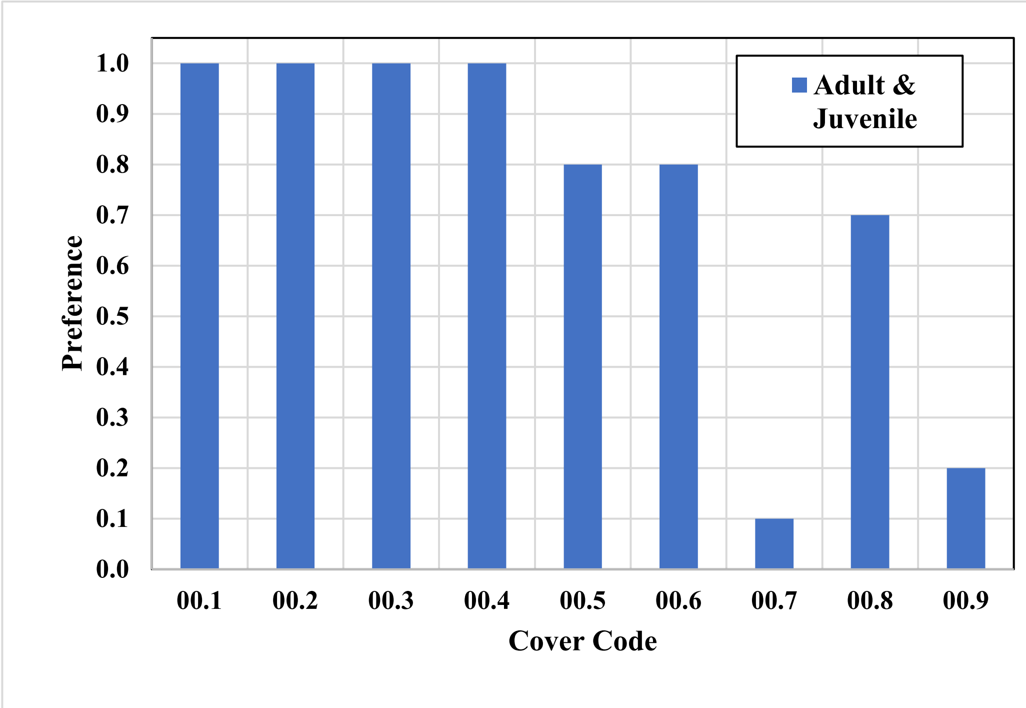


Sustrate Code	Substrate Type	Fry Preference
1	Silt, Clay, or Organic	0.00
2	Sand	0.05
3	Small Gravel (0.1-0.5")	0.30
4	Med Gravel (0.5-1.5")	0.80
5	Large Gravel (1.5-3.0")	1.00
6	Small Cobble (3.0-6.0")	1.00
7	Large Cobble (6.0-12")	1.00
8	Boulder (>12")	1.00
9	Bedrock	1.00

Source: ESH Model

Rainbow Trout

Cover Preference Criteria



Code	Type of Cover Note: Cover Codes are not used for Spawning life stage	Adult & Juvenile Preference
00.1	Undercut bank	1.00
00.2	Overhanging vegetation near or touching water	1.00
00.3	Rootwad (including parly undercut)	1.00
00.4	Log jam/submerged brush pile	1.00
00.5	Log(s) parallel to bank	0.80
00.6	Aquatic vegetation	0.80
00.7	Short (<1 ft) terrestrial grass	0.10
00.8	Tall (>3 ft) dense grass	0.70
00.9	Vegetation >3 vertical ft above SZF	0.20

Source: Table 3, Beecher et al. 2016

Bull Trout and Dolly Varden

General Approach

For Bull Trout and Dolly Varden spawning and juvenile life stages, HSC curves from WDFW/Ecology (Type 3) and the ESH model (hybrid Type 1-2) were evaluated by the HSC Technical Group. It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when avaiailable unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves for Bull Trout and Dolly Varden spawning and juvenile life stages. Information specific to each life stage is provided below.

Spawning (Group C)

The WDFW/Ecology Type 3 HSC curves for Bull Trout and Dolly Varden spawning are based on analysis from 8 studies and 122 redds [WRIA 7, WRIA 38, WRIA 45 95), and WRIA 46] (Beecher et al. 2016).

Juvenile (Group A)

The WDFW/Ecology Type 3 HSC curves for Bull Trout and Dolly Varden spawning provided in Beecher et al. 2016 were updated in December 2021 and are now based on anlaysis from 11 studies totalling 127 fish observations [from the Mad, Chiwawa (2 studies), Dungeness, Tucannon, and Kachess rivers; Rock, Early Winters, Phelps, Troublesome, and Box Canyon creeks] (Beecher et al. 2016, Granger 2021). The WDFW/Ecology Instream Flow Guidelines are in the process of being updated and the revised Bull Trout and Dolly Varden juvenile HSC curves will be included in the updated 2022 report. Field validation studies conducted on the Skagit River during 2021 resulted in an additional 4 fish observations (not included in the 2021 update to the HSC curves). Data from these 4 fish observations was reviewed by the HSC Technical Group and were determined to be consistent with both the ESH model and statewide HSC curves (i.e., observation data points were generally captured within the defined area under the HSC depth and velocity curves).

Fry (Group E)

Type 3 HSC curves are not available from WDFW/Ecology as the salmonid fry life stage is not commonly modeled in instream flow studies. However, habitat results for the fry life stage are of interest on the Skagit River in evaluating the relationship between flow and available habitat along the stream margins/shoreline areas as well as off-channel habitats that may be activated during higher flow events. As a result, the HSC Technical Group recommended using existing Type 2 fry curves when available. For Bull Trout and Dolly Varden fry, the HSC Technical Group recommended using the existing Type 2 curves from the ESH model which are based on data from the Arctic Environmental Information and Data Center (1981). Habitat cover preference information was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

Additional Notes

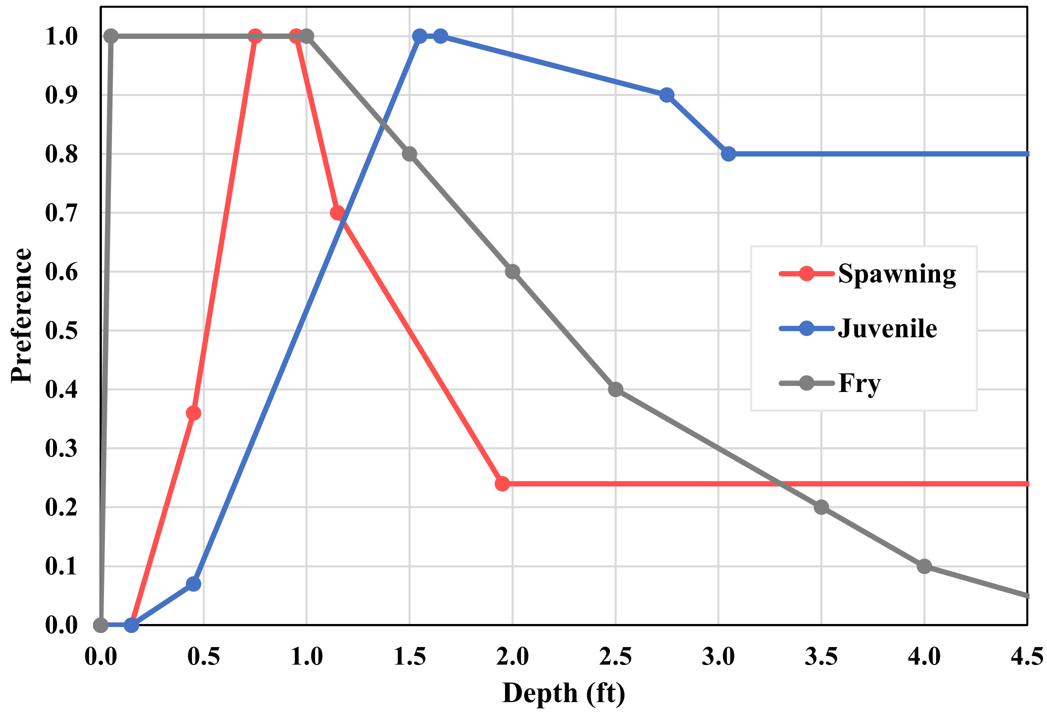
There is no clear biological evidence that depth becomes a limiting factor for spawning and juvenile Bull Trout and Dolly Varden. Therefore, the HSC Technical Group recommended that once depth reaches 1.95 ft (0.24 preference) for spawning and 3.05 ft (0.80 preference) for juvenile, it be considered "non-limiting" in the HSC depth curves.

References

WDFW/Ecology: spawning (Beecher et al. 2016); juvenile (Granger 2021 provisional data)
ESH model: spawning and juvenile (Crumley and Stober 1984); fry (AEIDC 1981)

Bull Trout and Dolly Varden

Depth Preference Curves



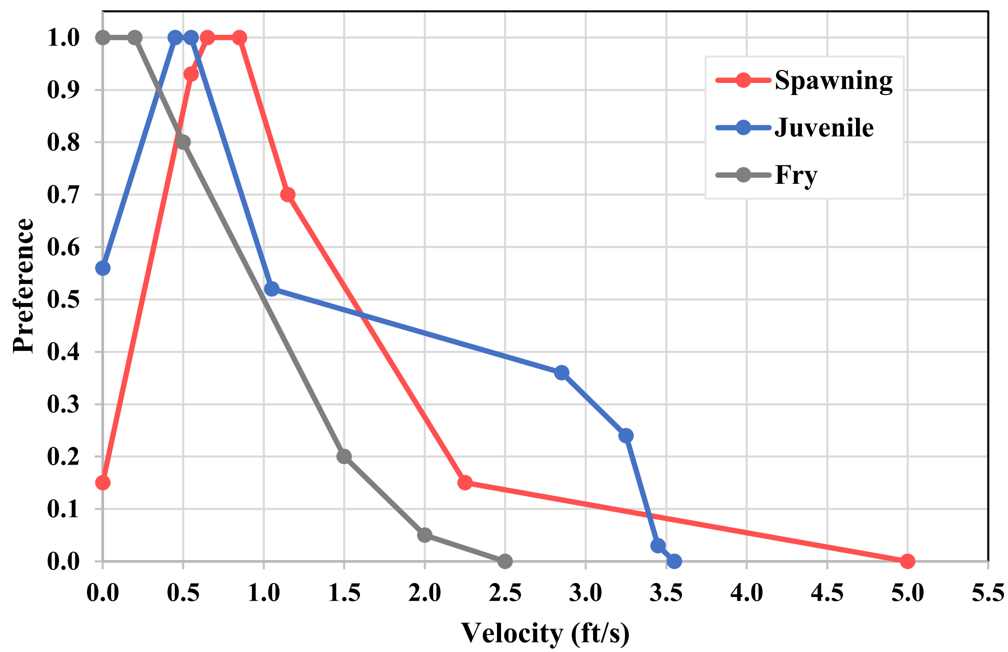
Spawning	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.45	0.36
0.75	1.00
0.95	1.00
1.15	0.70
1.95	0.24
99.00	0.24

Juvenile	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.45	0.07
1.55	1.00
1.65	1.00
2.75	0.90
3.05	0.80
99.00	0.80

Fry	
Depth (ft)	Preference
0.00	0.00
0.05	1.00
1.00	1.00
1.50	0.80
2.00	0.60
2.50	0.40
3.50	0.20
4.00	0.10
5.00	0.00
100.00	0.00

Bull Trout and Dolly Varden

Velocity Preference Curves



Spawning	
Velocity (ft/s)	Preference
0.00	0.15
0.55	0.93
0.65	1.00
0.85	1.00
1.15	0.70
2.25	0.15
5.00	0.00

Juvenile	
Velocity (ft/s)	Preference
0.00	0.56
0.45	1.00
0.55	1.00
1.05	0.52
2.85	0.36
3.25	0.24
3.45	0.03
3.55	0.00

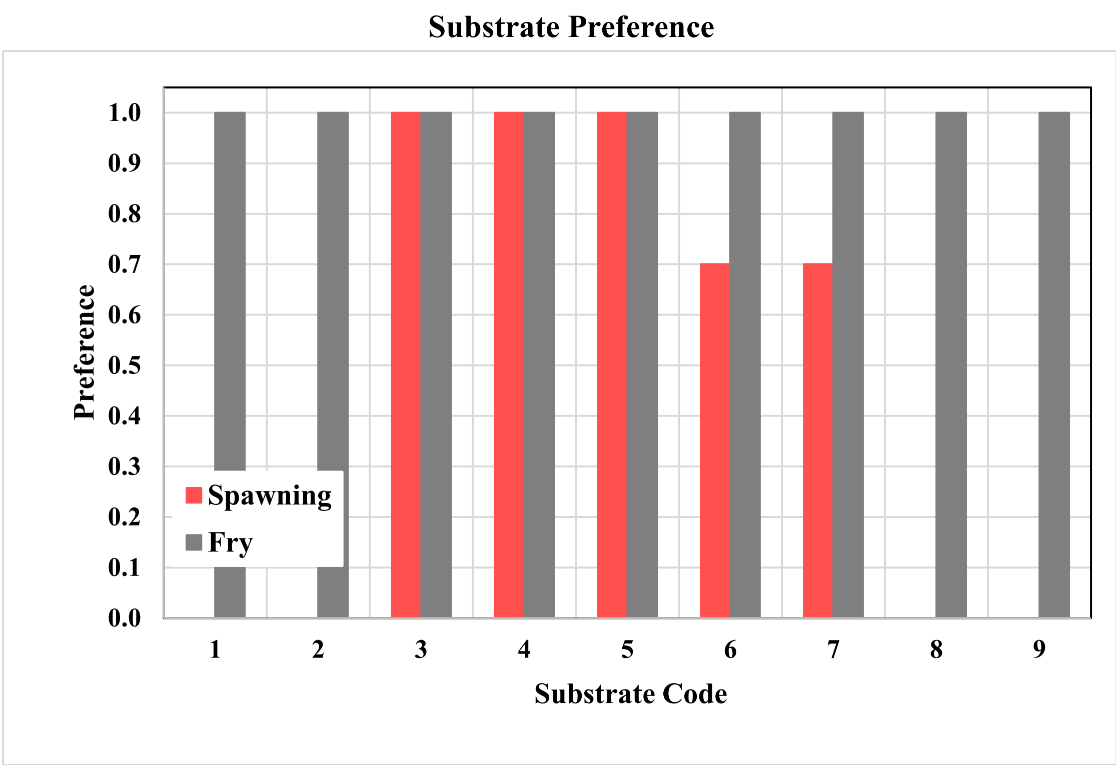
Fry	
Velocity (ft/s)	Preference
0.00	1.00
0.20	1.00
0.50	0.80
1.50	0.20
2.00	0.05
2.50	0.00

Bull Trout and Dolly Varden

Substrate Preference Criteria

For Bull Trout and Dolly Varden Spawning Substrate Preference, use Table 6 (Beecher et al. 2016)
For Bull Trout and Dolly Varden Juvenile Substrate and Cover Preference, use Table 3 (Beecher et al. 2016)
For Bull Trout and Dolly Varden Fry Substrate Preference, use data from the ESH Model

Bull Trout and Dolly Varden

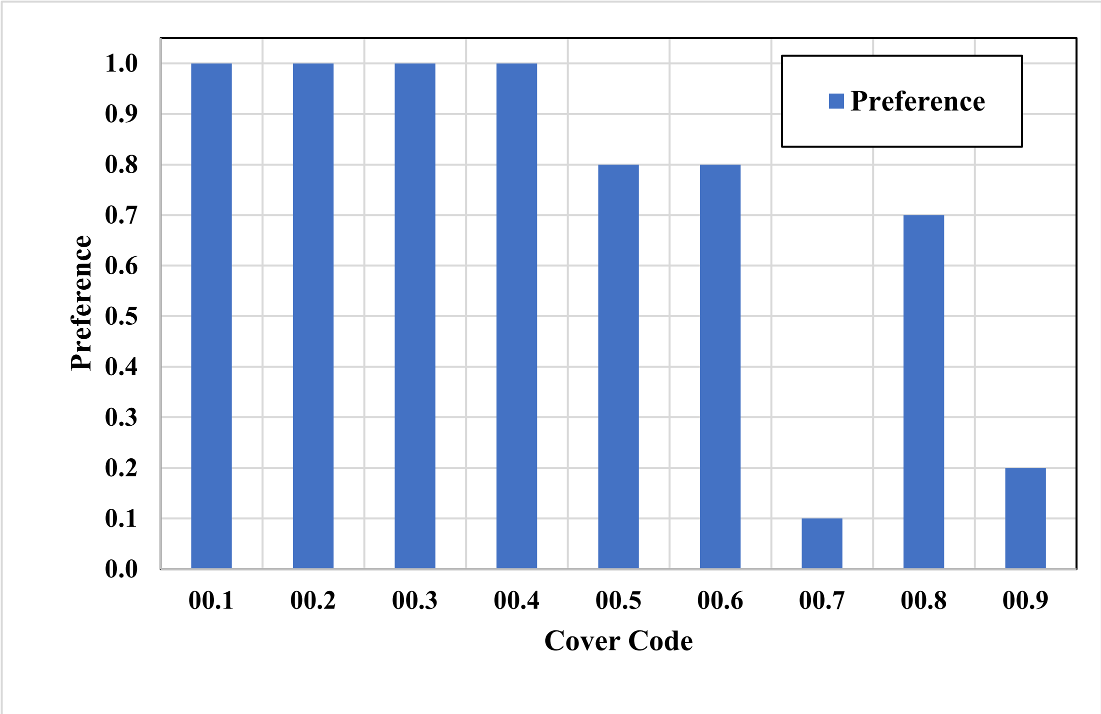


Sustrate Code	Substrate Type	Spawning Preference	Fry Preference
1	Silt, Clay, or Organic	0.00	1.00
2	Sand	0.00	1.00
3	Small Gravel (0.1-0.5")	1.00	1.00
4	Med Gravel (0.5-1.5")	1.00	1.00
5	Large Gravel (1.5-3.0")	1.00	1.00
6	Small Cobble (3.0-6.0")	0.70	1.00
7	Large Cobble (6.0-12")	0.70	1.00
8	Boulder (>12")	0.00	1.00
9	Bedrock	0.00	1.00

Source: Spawning (Table 14, Beecher et al. 2016); Fry (ESH Model)

Bull Trout and Dolly Varden

Cover Preference



Code	Type of Cover Note: Cover Codes are not used for Spawning life stage	Juvenile Preference
00.1	Undercut bank	1.00
00.2	Overhanging vegetation near or touching water	1.00
00.3	Rootwad (including parly undercut)	1.00
00.4	Log jam/submerged brush pile	1.00
00.5	Log(s) parallel to bank	0.80
00.6	Aquatic vegetation	0.80
00.7	Short (<1 ft) terrestrial grass	0.10
00.8	Tall (>3 ft) dense grass	0.70
00.9	Vegetation >3 vertical ft above SZF	0.20

Source: Table 3, Beecher et al. 2016

Sea-Run Bull Trout

Spawning (Group F)

WDFW/Ecology Type 3 HSC curves are not available and Sea-Run Bull Trout spawning HSC curves are not included in the ESH model. The HSC Technical Group reviewed HSC curves from other studies and developed proposed consensus curves using that information. The other available studies included the Cedar, Yakima, and Wenatchee Rivers in Washington State; the Chowade River, Kemess Creek, and Duncan River in British Columbia; and Smith-Dorrien Creek in Alberta. The general approach was to envelop the depth and velocity HSC curves from the other studies.

Additional Notes

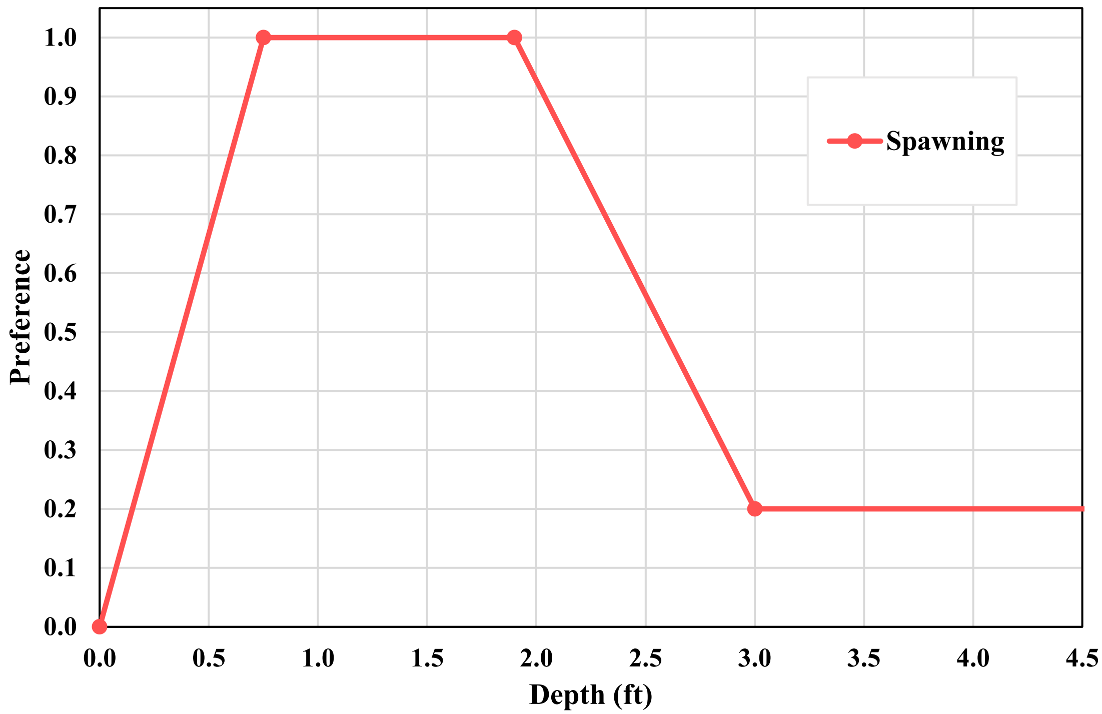
There is no clear biological evidence that depth becomes a limiting factor for spawning Sea-run Bull Trout. Therefore, the HSC Technical Group recommended that once depth reaches 3.0 ft (0.20 preference), it be considered "non-limiting" in the HSC depth curve.

References

Cedar River (Reiser et al. 1997)
Yakima and Wenatchee rivers (Sexauer 1994)
Chowade, British Columbia (Baxter 1995)
Kemess Creek, British Columbia (Bustard and Royea 1995)
Duncan River, British Columbia (O'Brien 1996)
Smith-Dorrien Creek, Alberta (Stelfox and Egan 1995)

Sea-Run Bull Trout

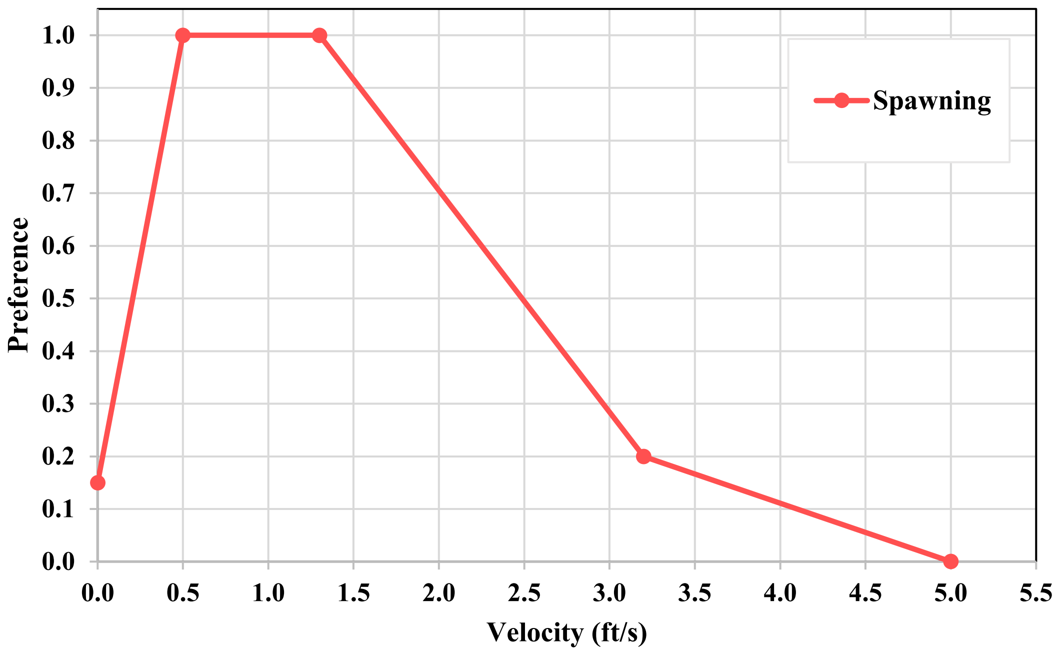
Depth Preference Curves



Spawning	
Depth (ft)	Preference
0.00	0.00
0.75	1.00
1.90	1.00
3.00	0.20
99.00	0.20

Sea-Run Bull Trout

Velocity Preference Curves



Spawning	
Velocity (ft/s)	Preference
0.00	0.15
0.50	1.00
1.30	1.00
3.20	0.20
5.00	0.00

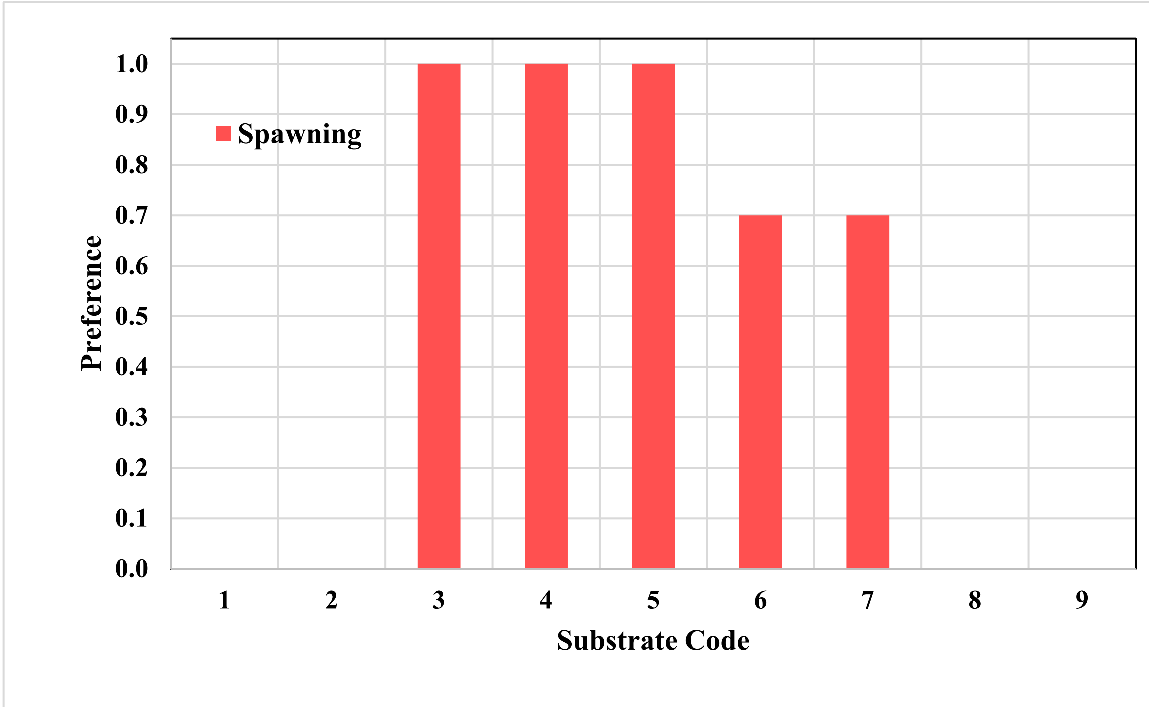
Sea-Run Bull Trout

Substrate Preference Criteria

For Sea-Run Bull Trout Spawning Substrate Preference, use Table 6 (Beecher et al. 2016)

Sea-Run Bull Trout

Calculated Substrate Preference



Sustrate Code	Substrate Type	Spawning Preference
1	Silt, Clay, or Organic	0.0
2	Sand	0.0
3	Small Gravel (0.1-0.5")	1.0
4	Med Gravel (0.5-1.5")	1.0
5	Large Gravel (1.5-3.0")	1.0
6	Small Cobble (3.0-6.0")	0.7
7	Large Cobble (6.0-12")	0.7
8	Boulder (>12")	0.0
9	Bedrock	0.0

Source: Table 14, Beecher et al. 2016

Cutthroat Trout

General Approach
For Cutthroat Trout spawning and juvenile life stages, HSC curves from WDFW/Ecology (Type 3) and the ESH model (hybrid Type 1-2) were evaluated by the HSC Technical Group. It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when avaiailable unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves for Cutthroat Trout life stages. Information specific to each life stage is provided below.

Spawning (Group C)
The WDFW/Ecology Type 3 HSC curves for Cutthroat Trout spawning are based on analysis from 7 studies and 123 redds [from the Irely (4 studies) and Skookum (3 studies) creeks] (Beecher et al. 2016).

Adult (Group D)
WDFW/Ecology Type 3 HSC surves are not available for the Cutthroat Trout adult life stage and the ESH model curves are Type 2. Therefore, the HSC Technical Group recommended using the WDFW/Ecology Type 3 HSC curves for Cutthorat Trout juvenile (see below) to also represent the adult life stage.

Juvenile (Group C)
The WDFW/Ecology Type 3 HSC curves for Cutthroat Trout juvenile provided in Beecher et al. 2016 were updated in 2021 and are now based on analysis from 11 studies and 518 fish observations [from the Ohanapecosh and Kachess rivers; Warm, Grade, Martin, Olson, Perry (2 studies), Skookum, Box Canyon, and Mineral creeks] (Beecher et al. 2016, Granger 2021). The WDFW/Ecology Instream Flow Guidelines are in the process of being updated and the revised Cutthroat Trout juvenile HSC curves will be included in the updated 2022 report.

Fry (Group E)

Type 3 HSC curves are not available from WDFW/Ecology as the salmonid fry life stage is not commonly modeled in instream flow studies. However, habitat results for the fry life stage are of interest on the Skagit River in evaluating the relationship between flow and available habitat along the stream margins/shoreline areas as well as off-channel habitats that may be activated during higher flow events. As a result, the HSC Technical Group recommended using existing Type 2 fry curves when available. For Cutthroat Trout fry, the HSC Technical Group recommended using the existing Type 2 curves from the ESH model (Bovee 1978). Habitat cover preference information was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

Additional Notes
There is no clear biological evidence that depth becomes a limiting factor for spawning, adult, and juvenile Cutthroat Trout. Therefore, the HSC Technical Group recommended that once depth reaches 1.55 ft (0.25 preference) for spawning and 4.25 ft (0.50 preference) for adult and juvenile, it be considered "non-limiting" in the HSC depth curve.

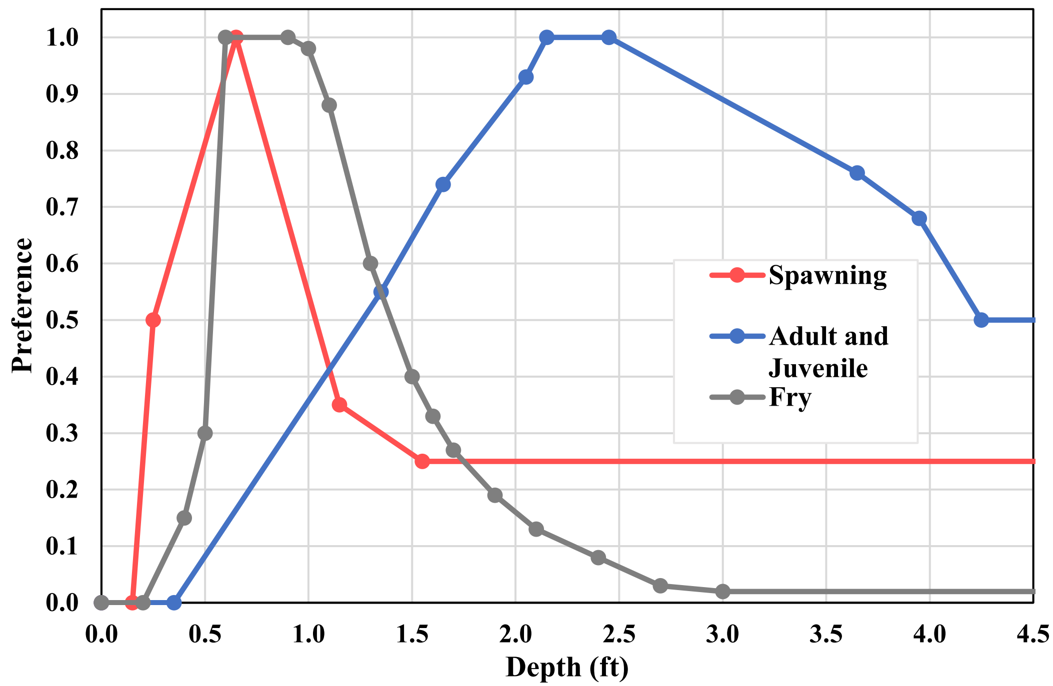
Cutthroat Trout

References

WDFW/Ecology: spawning and adult (Beecher et al. 2016); juvenile (Granger 2021 provisional data)
ESH model: spawning, adult, juvenile, and fry (Bovee 1978; Crumley and Stober 1984)
Additional sources of information:
Hickman and Raleigh 1982; Katopodis and Gervais 2016; Skookum Creek (Losee et al. 2016)

Cutthroat Trout

Depth Preference Curves



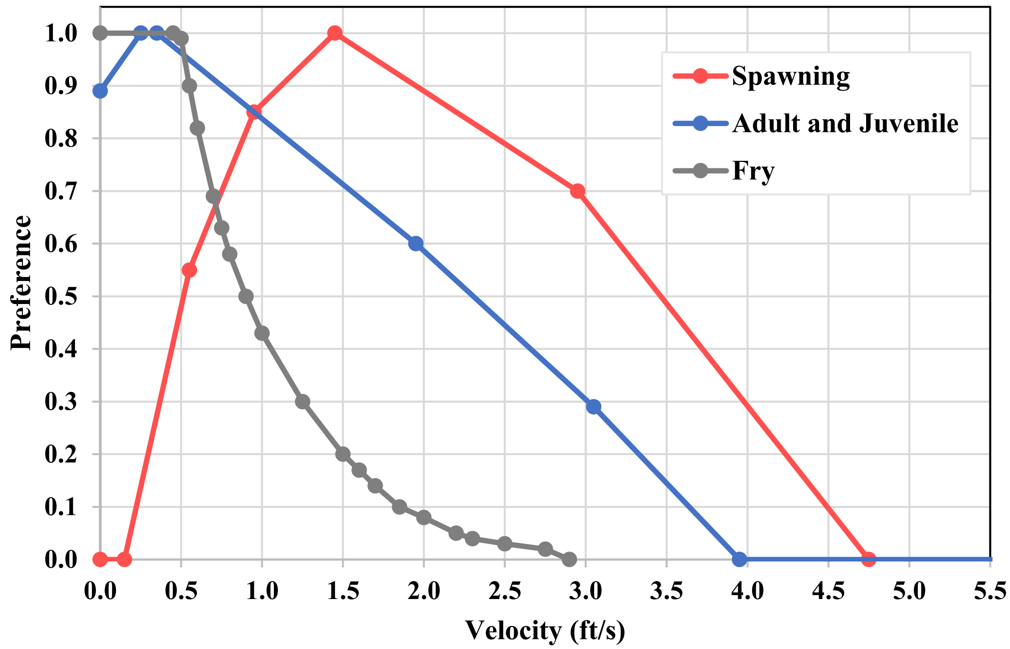
Fry	
Depth (ft)	Preference
0.00	0.00
0.20	0.00
0.40	0.15
0.50	0.30
0.60	1.00
0.90	1.00
1.00	0.98
1.10	0.88
1.30	0.60
1.50	0.40
1.60	0.33
1.70	0.27
1.90	0.19
2.10	0.13
2.40	0.08
2.70	0.03
3.00	0.02
5.00	0.02
6.00	0.02
100.00	0.02

Spawning	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.25	0.50
0.65	1.00
1.15	0.35
1.55	0.25
99.00	0.25

Adult and Juvenile	
Depth (ft)	Preference
0.00	0.00
0.35	0.00
1.35	0.55
1.65	0.74
2.05	0.93
2.15	1.00
2.45	1.00
3.65	0.76
3.95	0.68
4.25	0.50
99.00	0.50

Cutthroat Trout

Velocity Preference Curves



Fry	
Velocity (ft/s)	Preference
0.00	1.00
0.45	1.00
0.50	0.99
0.55	0.90
0.60	0.82
0.70	0.69
0.75	0.63
0.80	0.58
0.90	0.50
1.00	0.43
1.25	0.30
1.50	0.20
1.60	0.17
1.70	0.14
1.85	0.10
2.00	0.08
2.20	0.05
2.30	0.04
2.50	0.03
2.75	0.02
2.90	0.00

Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.15	0.00
0.55	0.55
0.95	0.85
1.45	1.00
2.95	0.70
4.75	0.00

Adult and Juvenile	
Velocity (ft/s)	Preference
0.00	0.89
0.25	1.00
0.35	1.00
1.95	0.60
3.05	0.29
3.95	0.00
99.00	0.00

Cutthroat Trout

Substrate Preference Criteria

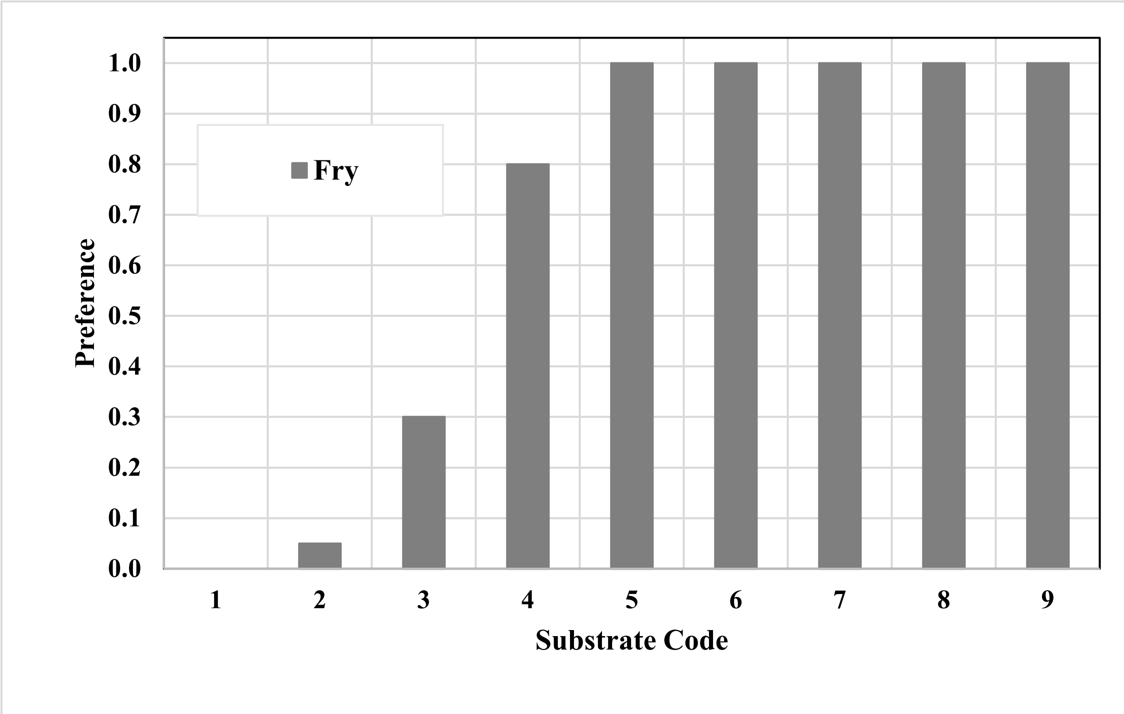
For Cutthroat Trout Spawning Substrate Preference, use Table 5 (Beecher et al. 2016)

For Cutthroat Trout Adult and Juvenile Substrate and Cover Preference, use Table 3 (Beecher et al. 2016)

For Cutthroat Trout Fry Substrate Preference, use data from the ESH Model

Cutthroat Trout

Substrate Preference

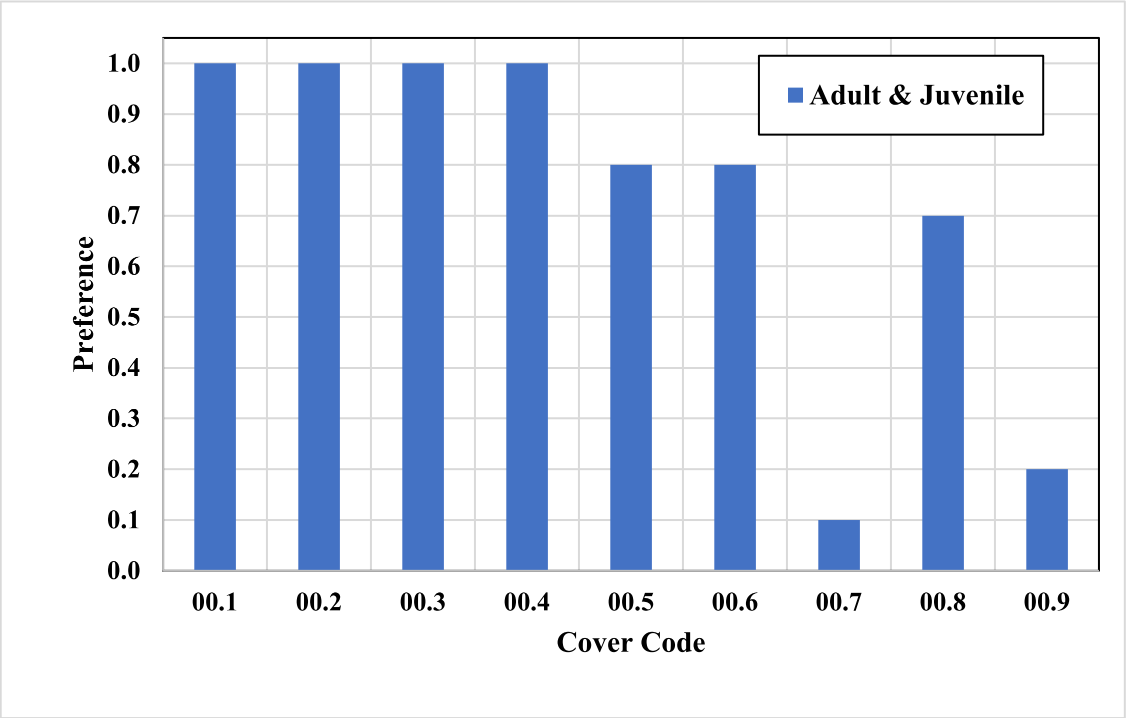


Sustrate Code	Substrate Type	Fry Preference
1	Silt, Clay, or Organic	0.00
2	Sand	0.05
3	Small Gravel (0.1-0.5")	0.30
4	Med Gravel (0.5-1.5")	0.80
5	Large Gravel (1.5-3.0")	1.00
6	Small Cobble (3.0-6.0")	1.00
7	Large Cobble (6.0-12")	1.00
8	Boulder (>12")	1.00
9	Bedrock	1.00

Source: ESH Model

Cutthroat Trout

Cover Preference



Code	Type of Cover Note: Cover Codes are not used for Spawning life stage	Adult & Juvenile Preference
00.1	Undercut bank	1.00
00.2	Overhanging vegetation near or touching water	1.00
00.3	Rootwad (including parly undercut)	1.00
00.4	Log jam/submerged brush pile	1.00
00.5	Log(s) parallel to bank	0.80
00.6	Aquatic vegetation	0.80
00.7	Short (<1 ft) terrestrial grass	0.10
00.8	Tall (>3 ft) dense grass	0.70
00.9	Vegetation >3 vertical ft above SZF	0.20

Source: Table 3, Beecher et al. 2016

Sea-Run Cutthroat Trout

Spawning (Group D)

For Sea-run Cutthroat Trout, HSC curves from several soucres were evaluated by the HSC Technical Group including WDFW/Ecology curves for Cutthroat Trout spawning (Type 3; 66 redds), curves used in the ESH model (hybrid Type 1-2), and Skookum Creek, WA (Losee et al. 2016). While it is WDFW/Ecology's preference to use statewide Type 3 HSC curves when available, for Sea-run Cutthorat Trout, the HSC Technical Group developed proposed consensus curves that basically envelop the WDFW/Ecology Type 3 curve for Cutthroat Trout spawning, but with a little broading of the peak preference range for both the depth and velocity HSC curves.

Additional Notes

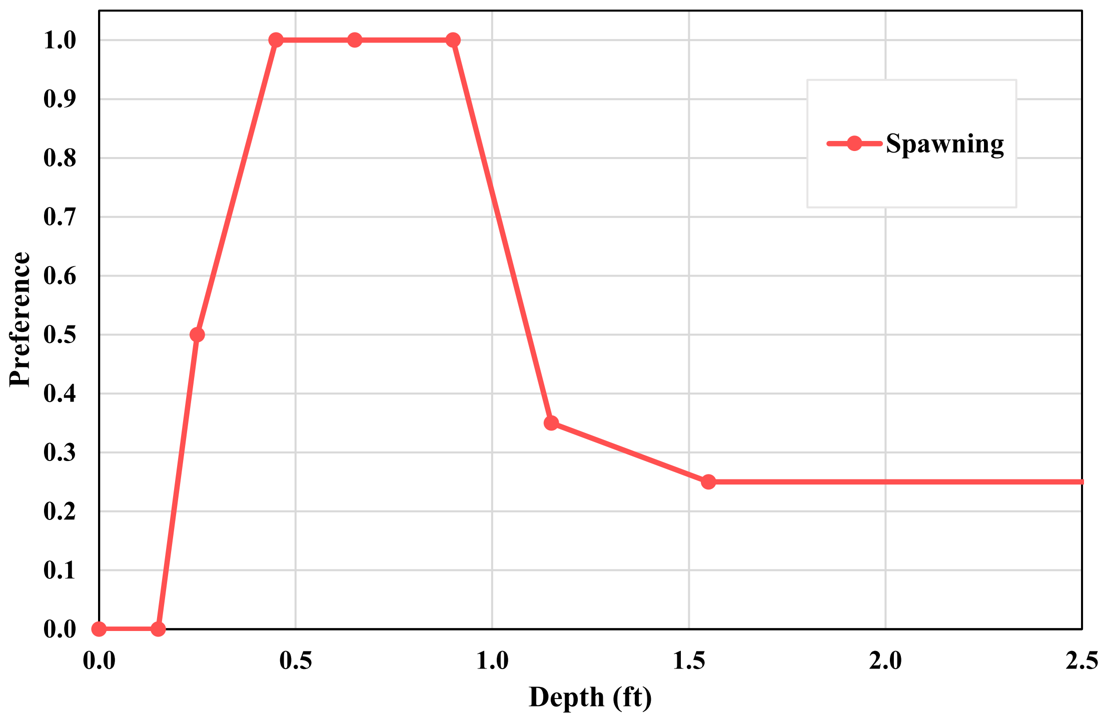
There is no clear biological evidence that depth becomes a limiting factor for spawning Sea-run Cutthroat Trout. Therefore, the HSC Technical Group recommended that once depth reaches 1.55 ft (0.25 preference), it be considered "non-limiting" in the HSC depth curve.

References

WDFW/Ecology: spawning (Beecher et al. 2016)
ESH model: spawning (Crumley and Stober 1984)
Additional sources of information:
Skookum Creek (Losee et al. 2016)
(Hickman and Raleigh 1982)
(Katopodis and Gervais 2016)

Sea-Run Cutthroat Trout

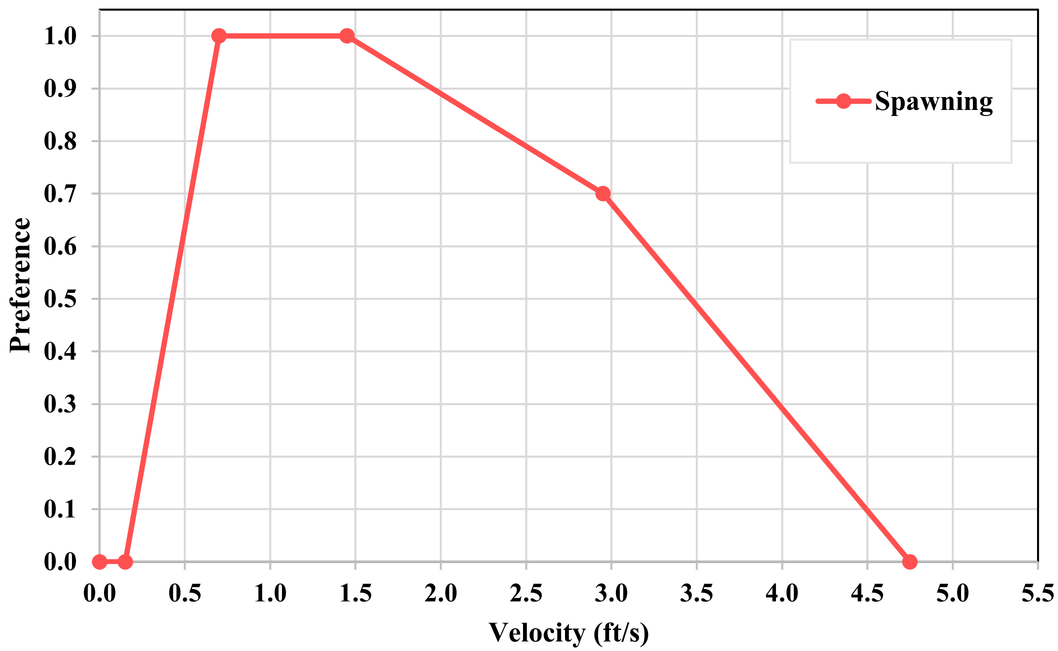
Depth Preference Curves



Spawning	
Depth (ft)	Preference
0.00	0.00
0.15	0.00
0.25	0.50
0.45	1.00
0.65	1.00
0.90	1.00
1.15	0.35
1.55	0.25
99	0.25

Sea-Run Cutthroat Trout

Velocity Preference Curves



Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.15	0.00
0.70	1.00
1.45	1.00
2.95	0.70
4.75	0.00

Substrate Preference Criteria

For Sea-Run Cutthorat Trout Spawning Substrate Preference, use Table 5 (Beecher et al. 2016)

Mountain Whitefish

General Approach

For Mountain Whitefish spawning, adult, and juvenile life stages, HSC curves from WDFW/Ecology (Type 3), the ESH model (hybrid Type 1-2), and the Fraser River (Type 2, juvenile only) were evaluated by the HSC Technical Group. It is WDFW/Ecology's preference to use the statewide Type 3 HSC curves when avaiailable unless additional site-specific field observation data is collected on the Skagit River in sufficient numbers to revisit, and possibly revise, the statewide curves. As a result, the recommended habitat modeling approach is to use the WDFW/Ecology Type 3 HSC curves for all three Mountain Whitefish life stages. Information specific to each life stage is provided below.

Spawning (Group C)

The WDFW/Ecology Type 3 HSC curves for Mountain Whitefish spawning are based on a composite of 8 Canadian studies totalling 3,789 fish observations [from the Oldman, Bow, Sheep, Kananaskis, Red Deer (2), and Highwood rivers] (Beecher et al. 2016).

Adult Rearing (Group C)

The WDFW/Ecology Type 3 HSC curves for Mountain Whitefish adult rearing are based on a composite of 8 Canadian studies totalling 1,616 fish observations [from the Oldman, Bow, Sheep, Kananaskis, Red Deer (2 studies), Highwood, and Fraser rivers] (Beecher et al. 2016).

Juvenile (Group C)

The WDFW/Ecology Type 3 HSC curves for Mountain Whitefish juvenile are based on a composite of 6 Canadian studies totalling 2,306 fish observations (from the Oldman, Bow, Kananaskis, Red Deer, Highwood, and Fraser rivers) (Beecher et al. 2016).

Fry (Group E)

Type 3 HSC curves are not available from WDFW/Ecology as the salmonid fry life stage is not commonly modeled in instream flow studies. However, habitat results for the fry life stage are of interest on the Skagit River in evaluating the relationship between flow and available habitat along the stream margins/shoreline areas as well as off-channel habitats that may be activated during higher flow events. As a result, the HSC Technical Group recommended using existing Type 2 fry curves when available. For Mountain Whitefish fry, the HSC Technical Group reviewed existing Type 2 curves used in the ESH model (Bovee 1978) as well as the Fraser River with a recommendation to use the ESH model curves for habitat modeling purposes. Habitat cover preference information was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

Additional Notes

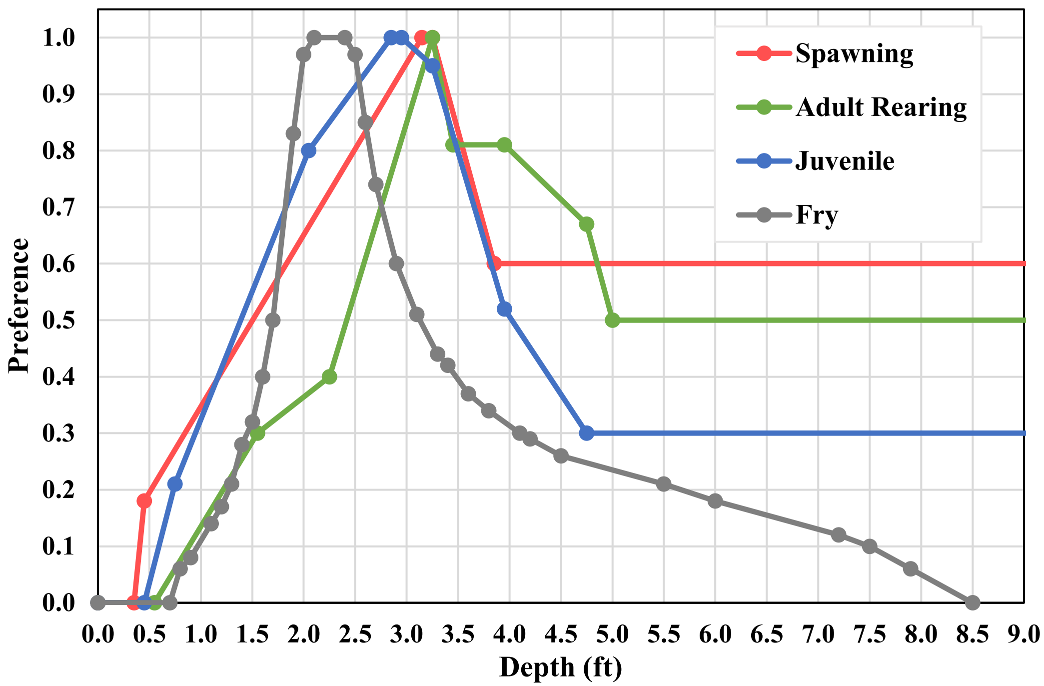
There is no clear biological evidence that depth becomes a limiting factor for spawning, adult rearing, and juvenile Mountain Whitefish. Therefore, the HSC Technical Group recommended that once depth reaches 3.85 ft for spawning (0.60 preference), 5.0 ft (0.50 preference) for adult rearing, and 4.75 ft (0.30 preference) for juvenile, it be considered "non-limiting" in the HSC depth curves.

References

WDFW/Ecology: spawning, adult rearing, and juvenile (Beecher et al. 2016)
ESH model: spawning and fry (Bovee 1978); adult and juvenile (Bovee 1978; Crumley and Stober 1984)
Fraser River: juvenile and fry (Rempel et al. 2012)

Mountain Whitefish

Depth Preference Curves



Spawning	
Depth (ft)	Preference
0.00	0.00
0.35	0.00
0.45	0.18
3.15	1.00
3.25	1.00
3.85	0.60
99.00	0.60

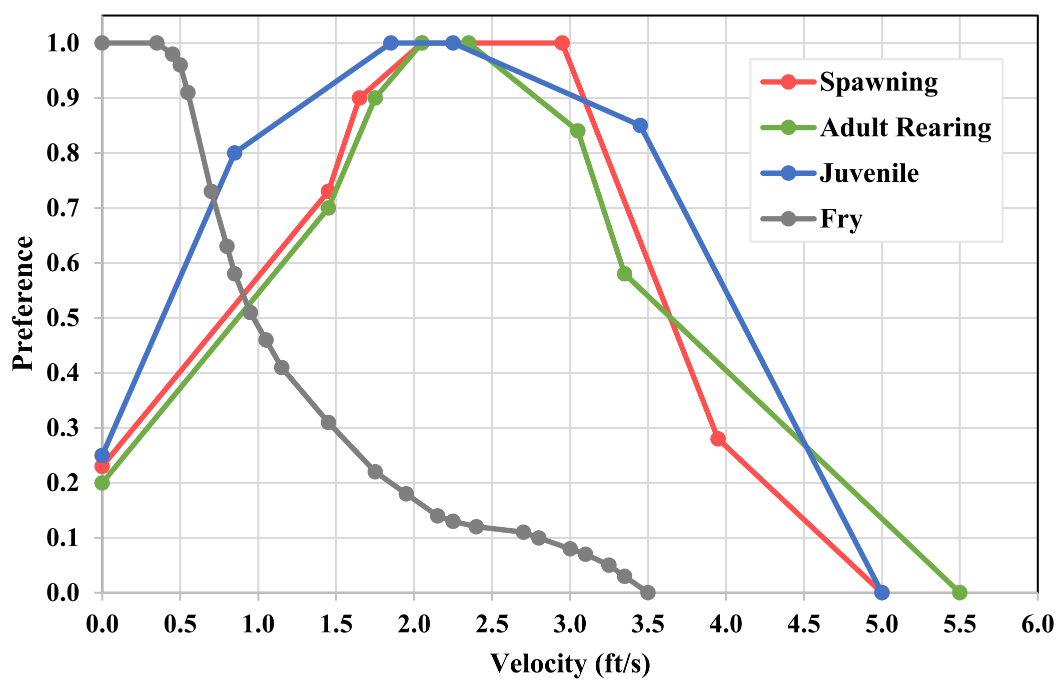
Adult Rearing	
Depth (ft)	Preference
0.00	0.00
0.55	0.00
1.55	0.30
2.25	0.40
3.25	1.00
3.45	0.81
3.95	0.81
4.75	0.67
5.00	0.50
99.00	0.50

Juvenile	
Depth (ft)	Preference
0.00	0.00
0.45	0.00
0.75	0.21
2.05	0.80
2.85	1.00
2.95	1.00
3.25	0.95
3.95	0.52
4.75	0.30
99.00	0.30

Fry	
Depth (ft)	Preference
0.00	0.00
0.70	0.00
0.80	0.06
0.90	0.08
1.10	0.14
1.20	0.17
1.30	0.21
1.40	0.28
1.50	0.32
1.60	0.40
1.70	0.50
1.90	0.83
2.00	0.97
2.10	1.00
2.40	1.00
2.50	0.97
2.60	0.85
2.70	0.74
2.90	0.60
3.10	0.51
3.30	0.44
3.40	0.42
3.60	0.37
3.80	0.34
4.10	0.30
4.20	0.29
4.50	0.26
5.50	0.21
6.00	0.18
7.20	0.12
7.50	0.10
7.90	0.06
8.50	0.00

Mountain Whitefish

Velocity Preference Curves



Fry	
Velocity (ft/s)	Preference
0.00	1.00
0.35	1.00
0.45	0.98
0.50	0.96
0.55	0.91
0.70	0.73
0.80	0.63
0.85	0.58
0.95	0.51
1.05	0.46
1.15	0.41
1.45	0.31
1.75	0.22
1.95	0.18
2.15	0.14
2.25	0.13
2.40	0.12
2.70	0.11
2.80	0.10
3.00	0.08
3.10	0.07
3.25	0.05
3.35	0.03
3.50	0.00

Spawning	
Velocity (ft/s)	Preference
0.00	0.23
1.45	0.73
1.65	0.90
2.05	1.00
2.95	1.00
3.95	0.28
5.00	0.00

Adult Rearing	
Velocity (ft/s)	Preference
0.00	0.20
1.45	0.70
1.75	0.90
2.05	1.00
2.35	1.00
3.05	0.84
3.35	0.58
5.50	0.00

Juvenile	
Velocity (ft/s)	Preference
0.00	0.25
0.85	0.80
1.85	1.00
2.25	1.00
3.45	0.85
5.00	0.00

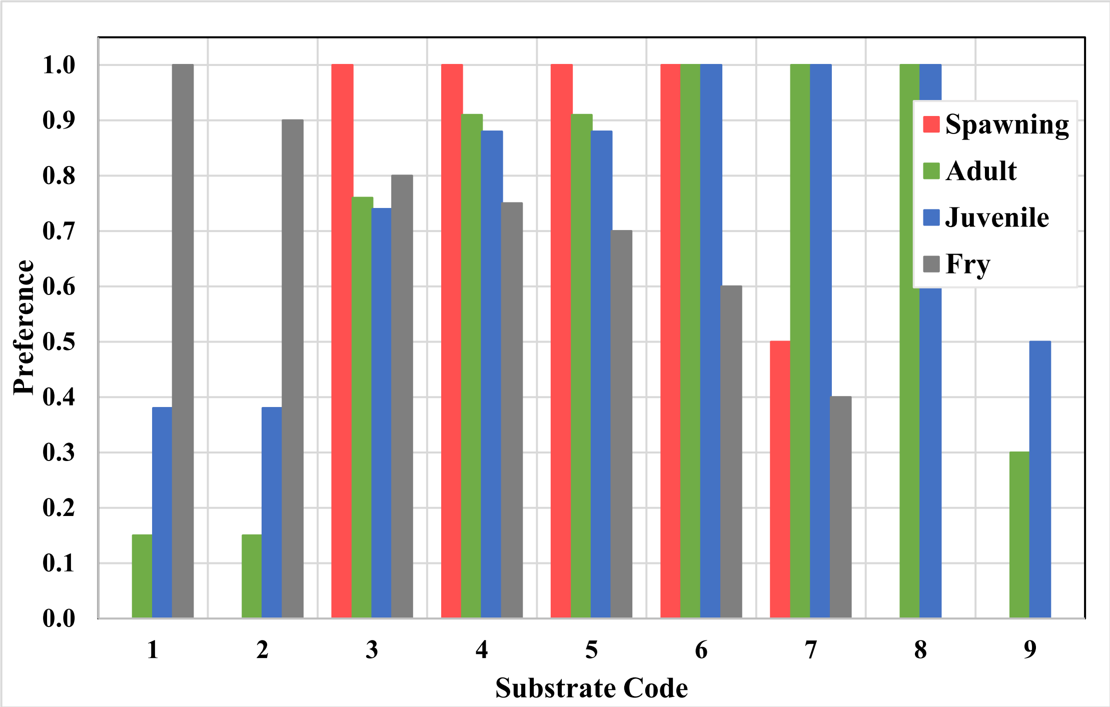
Mountain Whitefish

Substrate Preference Criteria

For Mountain Whitefish Spawning Substrate Preference, use Table 7 (Beecher et al. 2016)
For Mountain Whitefish Adult Rearing Substrate Preference, use Table 8 (Beecher et al. 2016)
For Mountain Whitefish Juvenile Substrate Preference, use Table 9 (Beecher et al. 2016)
For Mountain Whitefish Fry Substrate Preference, use data from the ESH Model

Mountain Whitefish

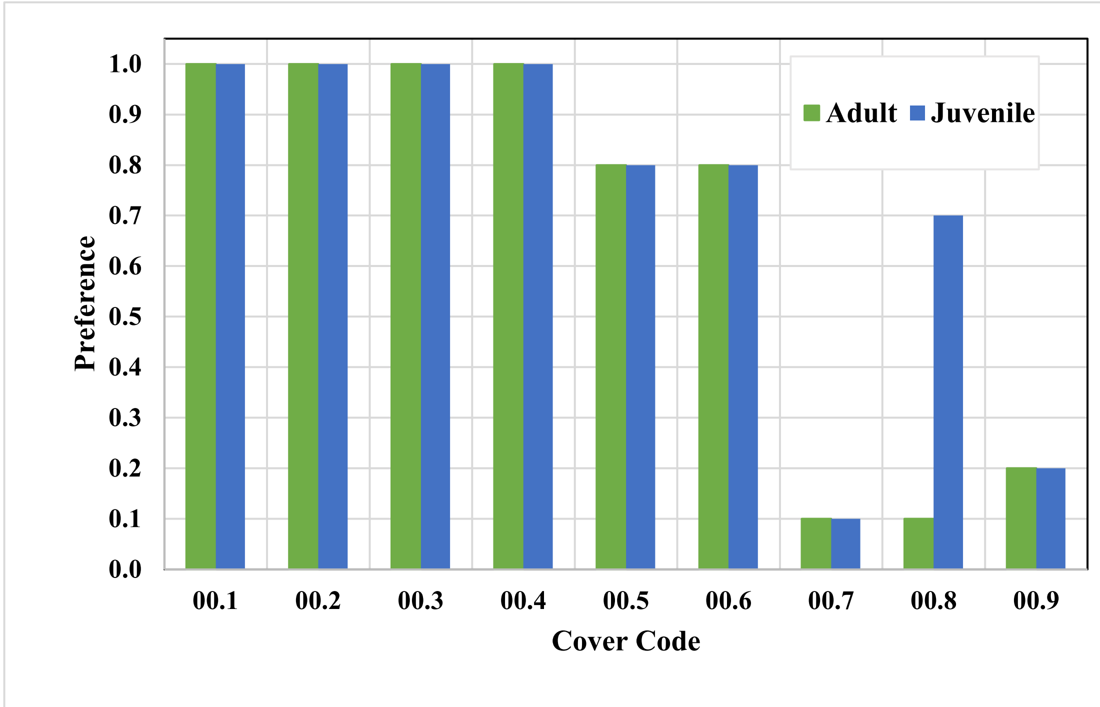
Substrate Preference



Sustrate Code	Substrate Type	Spawning	Adult	Juvenile	Fry
1	Silt, Clay, or Organic	0.00	0.15	0.38	1.00
2	Sand	0.00	0.15	0.38	0.90
3	Small Gravel (0.1-0.5")	1.00	0.76	0.74	0.80
4	Med Gravel (0.5-1.5")	1.00	0.91	0.88	0.75
5	Large Gravel (1.5-3.0")	1.00	0.91	0.88	0.70
6	Small Cobble (3.0-6.0")	1.00	1.00	1.00	0.60
7	Large Cobble (6.0-12")	0.50	1.00	1.00	0.40
8	Boulder (>12")	0.00	1.00	1.00	0.00
9	Bedrock	0.00	0.30	0.50	0.00
Source: Beecher et al. 2016		Table 15	Table 16	Table 17	ESH Model

Mountain Whitefish

Cover Preference



Code	Type of Cover Note: Cover Codes are not used for Spawning life stage	Adult Preference	Juvenile Preference
00.1	Undercut bank	1.00	1.00
00.2	Overhanging vegetation near or touching water	1.00	1.00
00.3	Rootwad (including parly undercut)	1.00	1.00
00.4	Log jam/submerged brush pile	1.00	1.00
00.5	Log(s) parallel to bank	0.80	0.80
00.6	Aquatic vegetation	0.80	0.80
00.7	Short (<1 ft) terrestrial grass	0.10	0.10
00.8	Tall (>3 ft) dense grass	0.10	0.70
00.9	Vegetation >3 vertical ft above SZF	0.20	0.20

Source: Table 1, Beecher et al. 2016

Pacific Lamprey

Spawning (Group D)

WDFW/Ecology HSC curves are not available and Pacific Lamprey HSC curves are not included in the ESH model. The HSC Technical Group reviewed HSC curves from other studies and developed proposed consensus curves using that information. The proposed consensus curves envelop depth and velocity preferences from studies on the Lower Merced and Chehalis Rivers and Vadas 2021 literature with a recommended extension of suboptimal preference (i.e., preference = 0.5) depth to 7 ft made by Ralph Lampman (a lamprey research biologist at Yakama Nation Fisheries in Prosser, WA).

Juvenile Rearing (Group D)

WDFW/Ecology HSC curves are not available and Pacific Lamprey HSC curves are not included in the ESH model. The HSC Technical Group reviewed HSC curves from other studies and developed proposed consensus curves using that information. The proposed consensus curves envelop depth and velocity preferences from studies on the Chehalis River (Winkowksi and Kendall 2018) and Vadas 2021 literature. Note due to uncertainty about maximum depth and velocity preferences, both HSC curves have been extended to infinity at a preference of 0.1.

Additional Notes

There is no clear biological evidence that depth becomes a limiting factor for spawning and juvenile rearing Pacific Lamprey. Therefore, the HSC Technical Group recommended that once depth reaches 9.0 ft for spawning (0.10 preference) and 5.0 ft (0.10 preference) for juvenile rearing, it be considered "non-limiting" in the HSC depth curves.

Habitat cover preference information for Pacific Lamprey was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

References

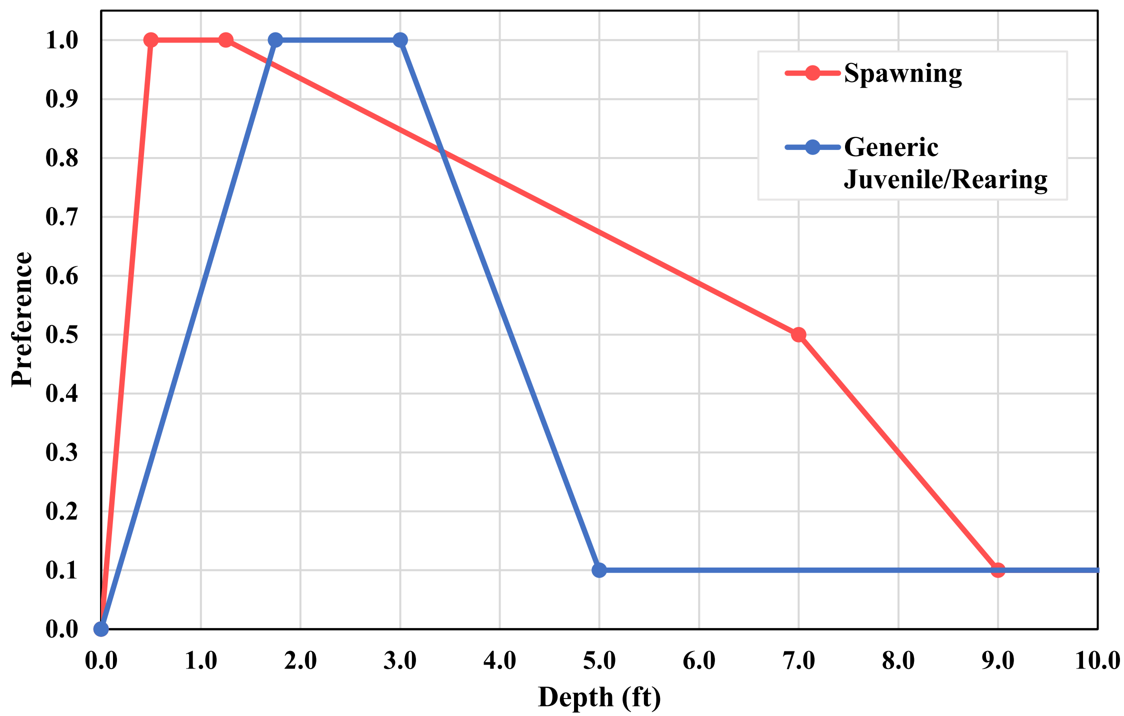
West-coast lamprey species based on literature review of West Fork Hoquiam River, Chehalis River basin and Trapp Creek, Washington and Nichola/coastal Salmon River, British Columbia (Vadas 2000, 2013, and 2021)

Chehalis River, Washington (Winkowski and Kendall 2018)

Additional data source:
Smith River, Oregon (Gunckel et al. 2006)

Pacific Lamprey

Depth Preference Curves

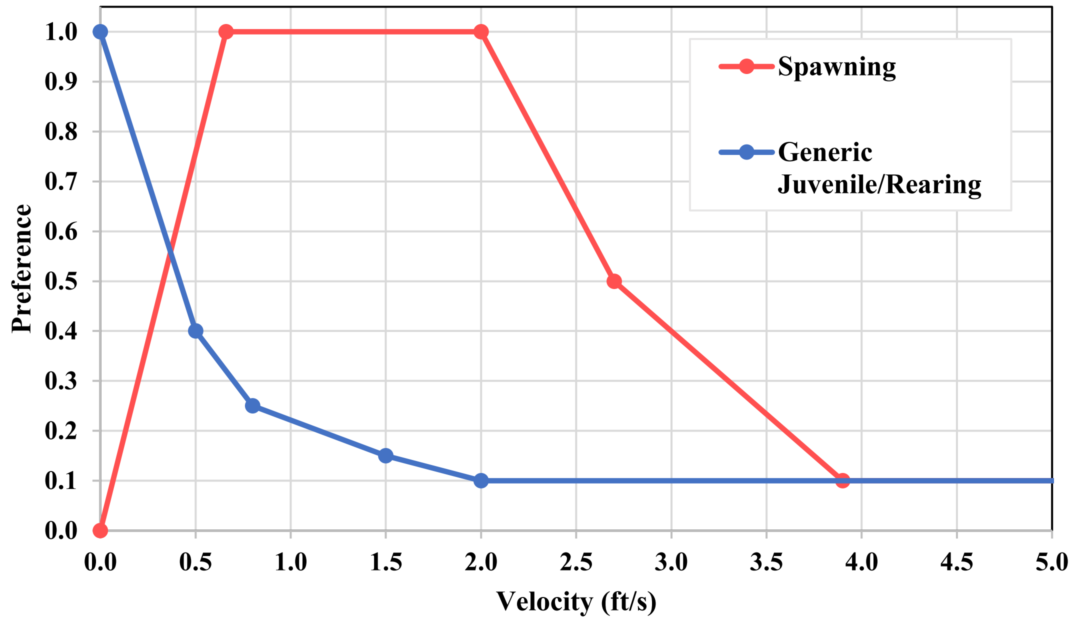


Spawning	
Depth (ft)	Preference
0.00	0.00
0.50	1.00
1.25	1.00
7.00	0.50
9.00	0.10
99.00	0.10

Generic	
Depth (ft)	Preference
0.00	0.00
1.75	1.00
3.00	1.00
5.00	0.10
99.00	0.10

Pacific Lamprey

Velocity Preference Curves

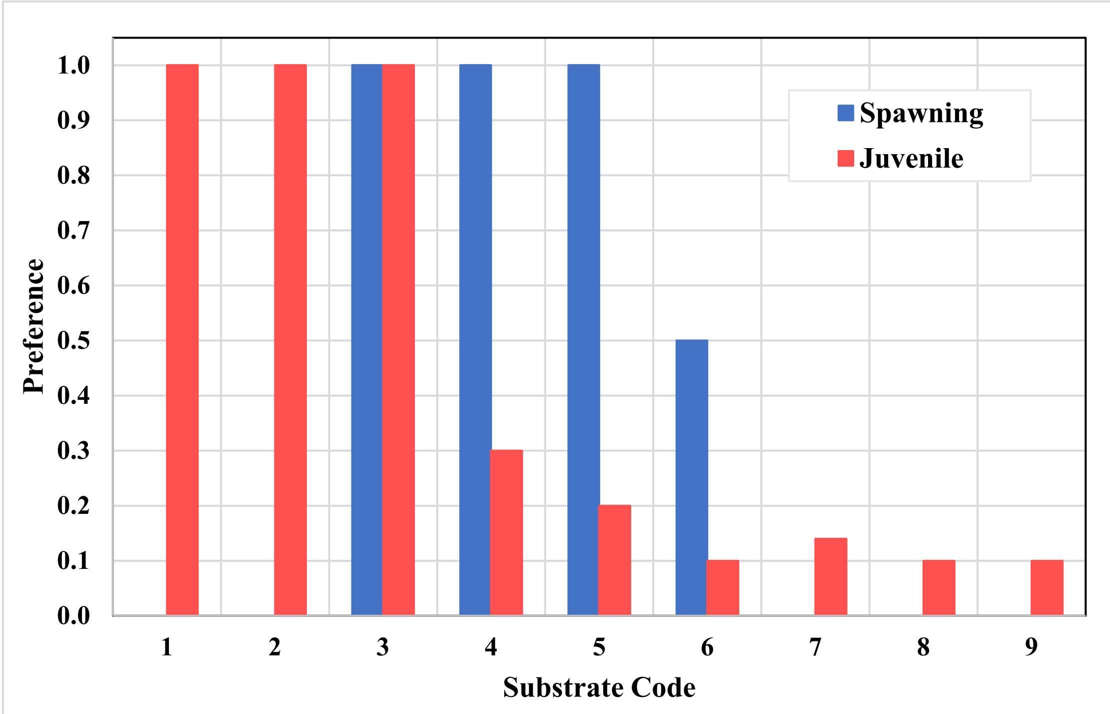


Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.66	1.00
2.00	1.00
2.70	0.50
3.90	0.10
99.00	0.10

Generic	
Velocity (ft/s)	Preference
0.00	1.00
0.50	0.40
0.80	0.25
1.50	0.15
2.00	0.10
99.00	0.10

Pacific Lamprey

Substrate Preference



Sustrate Code	Substrate Type	Spawning Preference	Juvenile Preference
1	Silt, Clay, or Organic	0.0	1.0
2	Sand	0.0	1.0
3	Small Gravel (0.1-0.5")	1.0	1.0
4	Med Gravel (0.5-1.5")	1.0	0.3
5	Large Gravel (1.5-3.0")	1.0	0.2
6	Small Cobble (3.0-6.0")	0.5	0.1
7	Large Cobble (6.0-12")	0.0	0.1
8	Boulder (>12")	0.0	0.1
9	Bedrock	0.0	0.1

Source: Vadas 2021

Western Brook & Western River Lamprey

Western Brook Lamprey Spawning (Group F)

WDFW/Ecology HSC curves are not available and Western Brook Lamprey HSC curves are not included in the ESH model. The HSC Technical Group reviewed HSC curves from other studies and developed proposed consensus curves using that information. The proposed consensus curve is based on research and literature review by Vadas (2000, 2013, and 2021) which includes data from the West Fork Hoquiam River, WA; Nichola/coastal Salmon River, BC; Trapp Creek, WA, and Chehalis River basin, WA.

Western River Lamprey Spawning (Group F)

WDFW/Ecology HSC curves are not available and Western River Lamprey HSC curves are not included in the ESH model. The HSC Technical Group reviewed HSC curves from other studies and developed proposed consensus curves using that information. The proposed consensus curve is based on Vadas 2021 which includes data from the West Fork Hoquiam River, WA; Nichola/coastal Salmon River, BC; Trapp Creek, WA, and Chehalis River basin, WA.

Additional Notes

There is no clear biological evidence that depth becomes a limiting factor for spawning Western Brook Lamprey and Western River Lamprey. Therefore, the HSC Technical Group recommended that once depth reaches 1.40 ft for Western Brooke Lamprey (0.10 preference) and 1.80 ft (0.10 preference) for Western River Lamprey, it be considered "non-limiting" in the HSC depth curves.

Habitat cover preference information for Western Brook Lamprey and Western River Lamprey was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

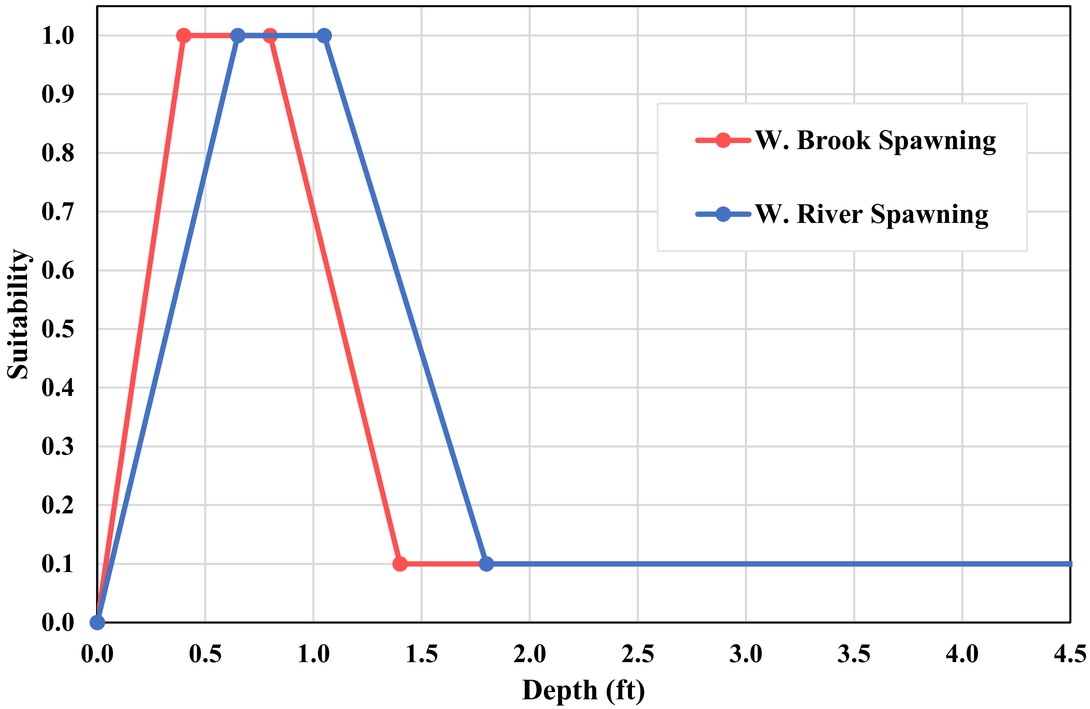
References

West-coast lamprey species based on literature review of West Fork Hoquiam River, Chehalis River basin and Trapp Creek, Washington and Nichola/coastal Salmon River, British Columbia (Vadas 2000, 2013, and 2021)

Additional data source:
(Gunckel et al. 2006)

Western Brook & Western River Lamprey

Depth Preference Curves

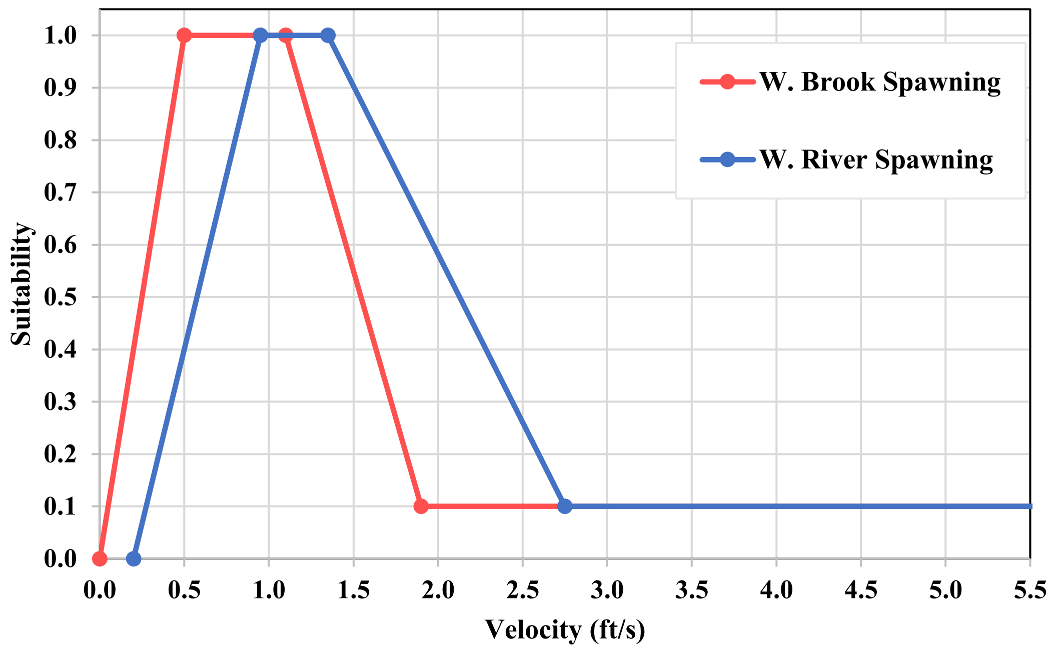


W. Brook Spawning	
Depth (ft)	Preference
0.00	0.00
0.40	1.00
0.80	1.00
1.40	0.10
99.00	0.10

W. River Spawning	
Depth (ft)	Preference
0.00	0.00
0.65	1.00
1.05	1.00
1.80	0.10
99.00	0.10

Western Brook & Western River Lamprey

Velocity Preference Curves

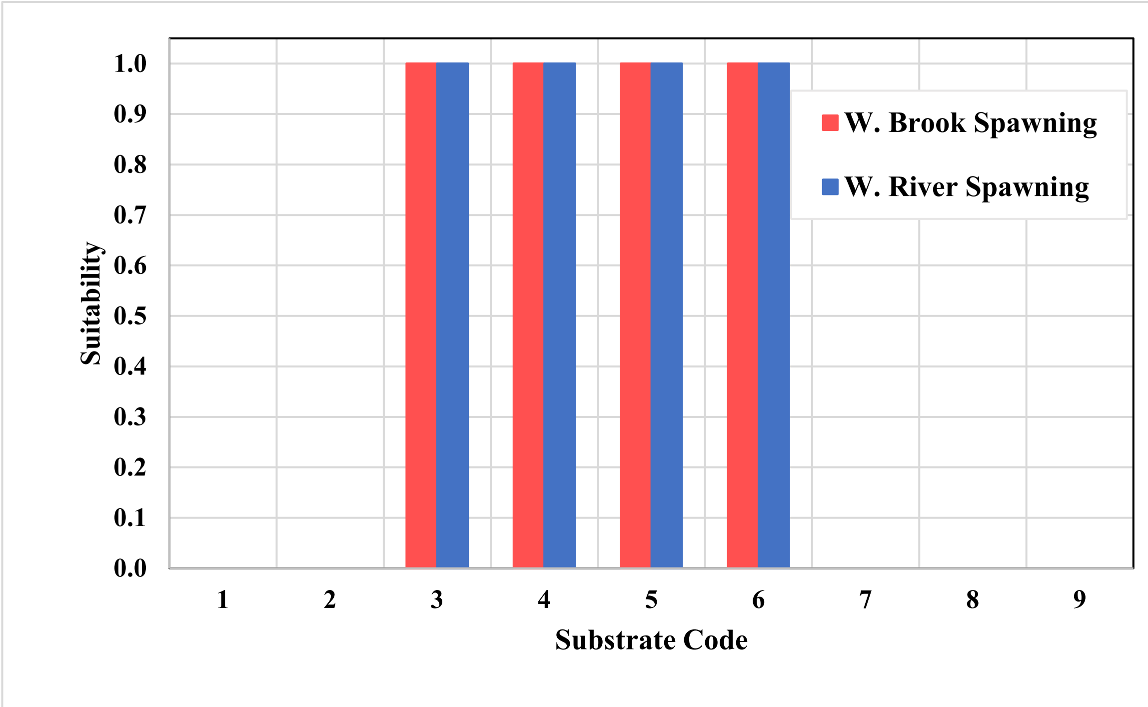


W. Brook Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.50	1.00
1.10	1.00
1.90	0.10
99.00	0.10

W. River Spawning	
Velocity (ft/s)	Preference
0.20	0.00
0.95	1.00
1.35	1.00
2.75	0.10
99.00	0.10

Western Brook & Western River Lamprey

Substrate Preference Criteria



Sustrate Code	Substrate Type	W. Brook Preference	W. River Preference
1	Silt, Clay, or Organic	0.0	0.0
2	Sand	0.0	0.0
3	Small Gravel (0.1-0.5")	1.0	1.0
4	Med Gravel (0.5-1.5")	1.0	1.0
5	Large Gravel (1.5-3.0")	1.0	1.0
6	Small Cobble (3.0-6.0")	1.0	1.0
7	Large Cobble (6.0-12")	0.0	0.0
8	Boulder (>12")	0.0	0.0
9	Bedrock	0.0	0.0

Source: Vadas 2021

Salish Sucker

Spawning (Group F)

WDFW/Ecology HSC curves are not available and Sailish Sucker spawning HSC curves are not included in the ESH model. The HSC Technical Group reviewed literature and HSC data from several sources in Washington State and western Canada (see references cited below). The proposed consensus curves are largely based on research performed by Pearson et al. (2000 and 2003) with a slightly broader peak depth preference that extends an additional 0.5 ft from 2.0 ft to 2.5 ft and a slightly broader peak velocity preference that extends an additional 0.35 ft/s from 1.65 ft/s to 2.0 ft/s.

Juvenile Rearing (Group F)

WDFW/Ecology HSC curves are not available and Sailish Sucker juvenile rearing HSC curves are not included in the ESH model. The HSC Technical Group reviewed literature and HSC data from several sources in Washington State and western Canada (see references cited below). The proposed consensus curves are largely based on research performed by Pearson et al. (2000 and 2003) with a slightly broader peak depth preference range and slightly extended sub-optimal velocity preference range.

Additional Notes

There is no clear biological evidence that depth becomes a limiting factor for juvenile rearing Salish Sucker. Therefore, the HSC Technical Group recommended that once depth reaches 3.0 ft (0.50 preference) for juvenile rearing, it be considered "non-limiting" in the HSC depth curves.

Habitat cover preference information for Sailish Sucker spawning life stage was not available from literature, so this physical attribute will be removed from the habitat modeling process (i.e., habitat model results will be based on depth, velocity, and substrate preferences).

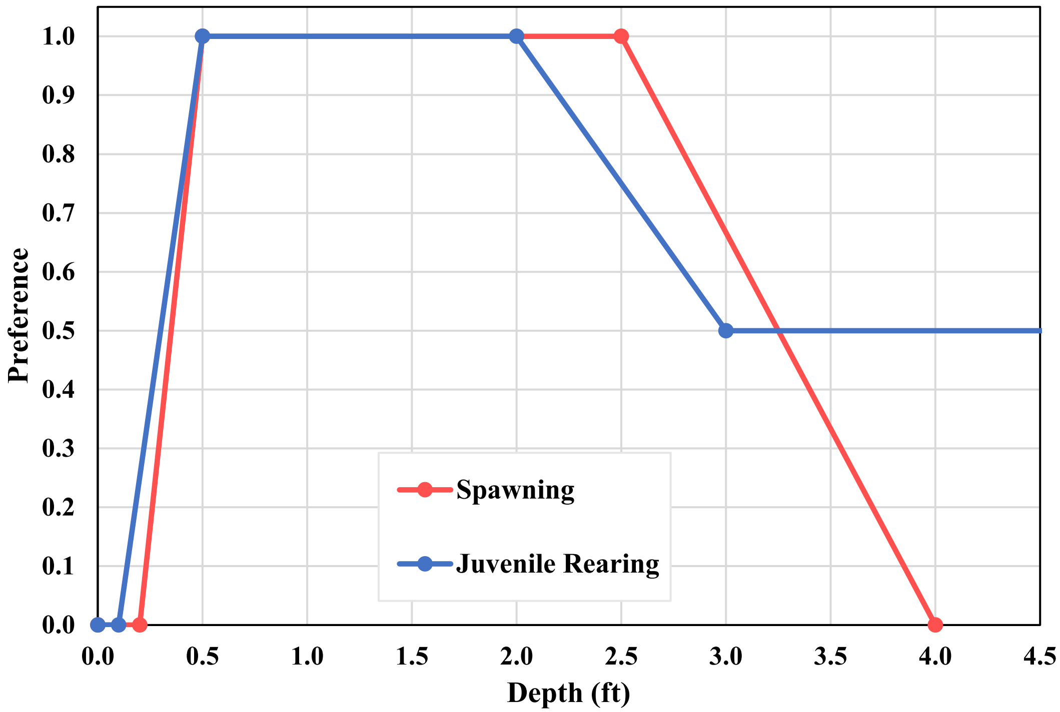
References

Consensus HSC curves: (Pearson et al. 2000 and 2003)

Additional sources of information:
COSEWIC 2012
McPhail 1986
Washington Department of Fish and Wildlife 2015

Salish Sucker

Depth Preference Curves

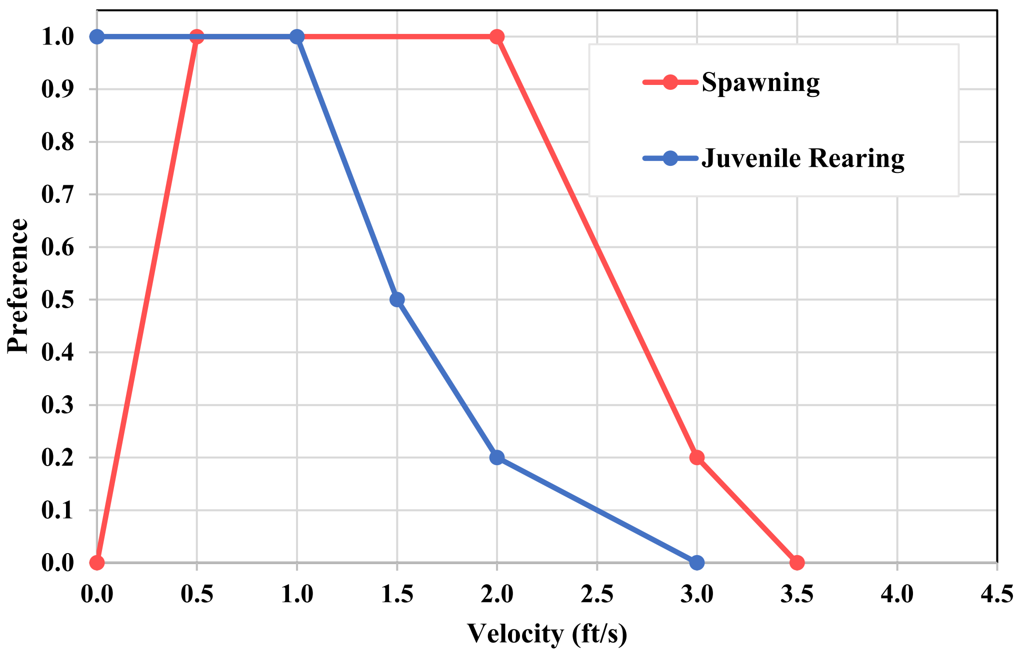


Spawning	
Depth (ft)	Preference
0.00	0.00
0.20	0.00
0.50	1.00
2.50	1.00
4.00	0.00

Juvenile Rearing	
Depth (ft)	Preference
0.00	0.00
0.10	0.00
0.50	1.00
2.00	1.00
3.00	0.50
99.00	0.50

Salish Sucker

Velocity Preference Curves

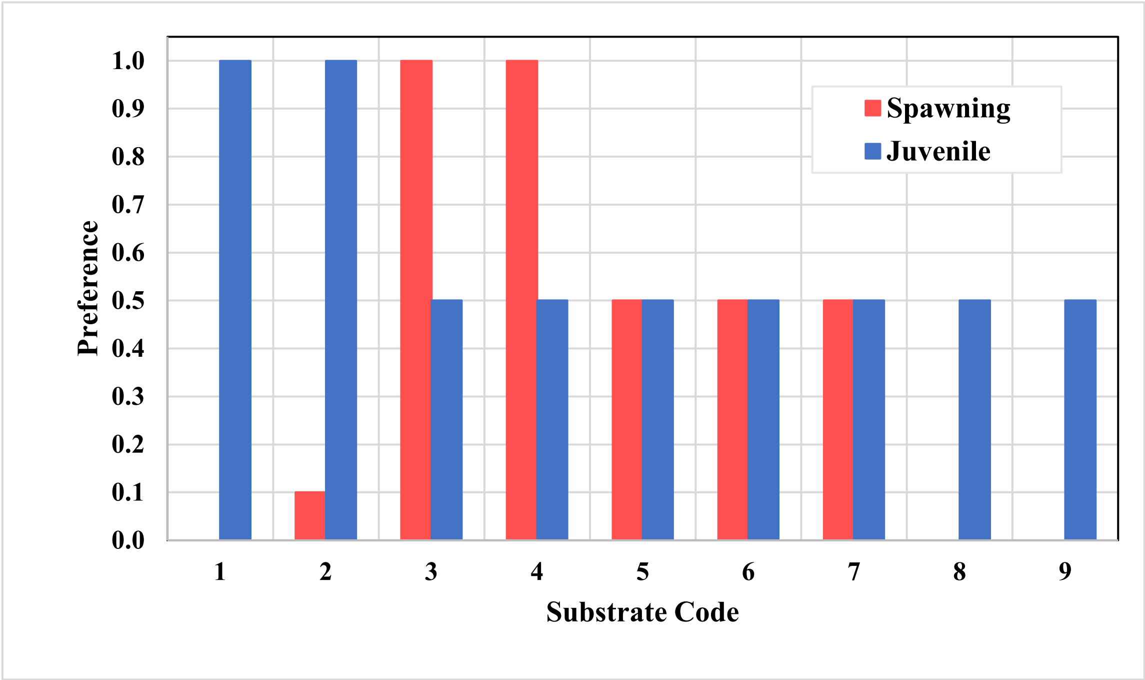


Spawning	
Velocity (ft/s)	Preference
0.00	0.00
0.50	1.00
2.00	1.00
3.00	0.20
3.50	0.00

Juvenile Rearing	
Velocity (ft/s)	Preference
0.00	1.00
1.00	1.00
1.50	0.50
2.00	0.20
3.00	0.00

Salish Sucker

Substrate Preference

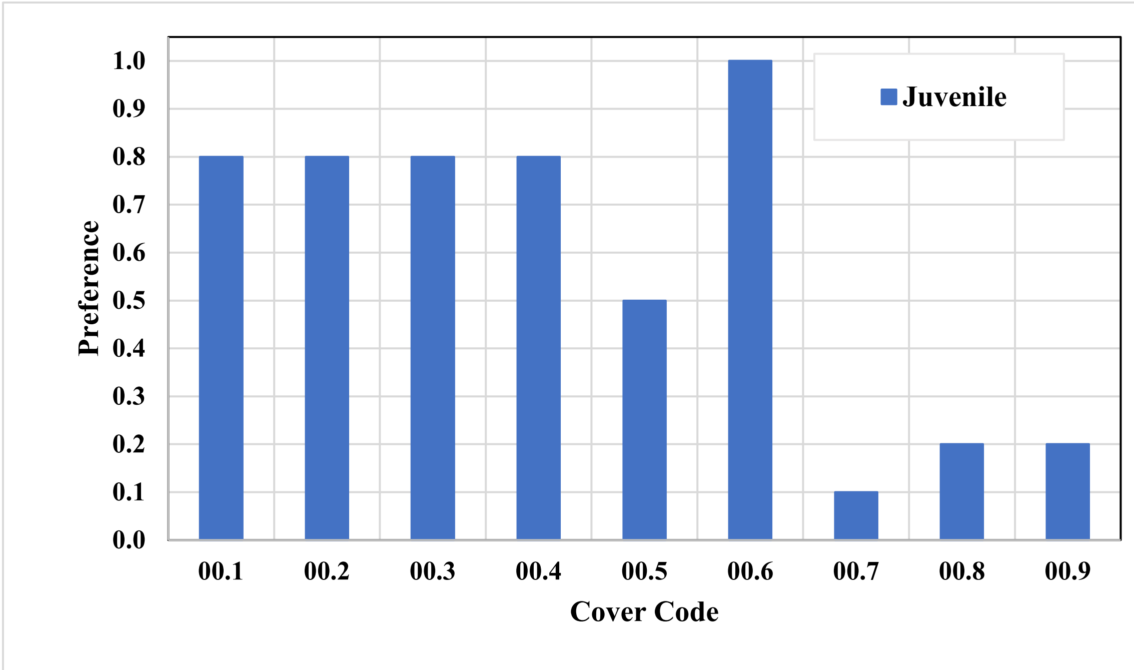


Sustrate Code	Substrate Type	Spawning Preference	Juvenile Preference
1	Silt, Clay, or Organic	0.0	1.0
2	Sand	0.1	1.0
3	Small Gravel (0.1-0.5")	1.0	0.5
4	Med Gravel (0.5-1.5")	1.0	0.5
5	Large Gravel (1.5-3.0")	0.5	0.5
6	Small Cobble (3.0-6.0")	0.5	0.5
7	Large Cobble (6.0-12")	0.5	0.5
8	Boulder (>12")	0.0	0.5
9	Bedrock	0.0	0.5

Source: Pearson et al. 2003

Salish Sucker

Cover Preference



Code	Type of Cover Note: Cover Codes are not used for Spawning	Juvenile Preference
00.1	Undercut bank	0.80
00.2	Overhanging vegetation near or touching	0.80
00.3	Rootwad (including parly undercut)	0.80
00.4	Log jam/submerged brush pile	0.80
00.5	Log(s) parallel to bank	0.50
00.6	Aquatic vegetation	1.00
00.7	Short (<1 ft) terrestrial grass	0.10
00.8	Tall (>3 ft) dense grass	0.20
00.9	Vegetation >3 vertical ft above SZF	0.20

Source: Pearson et al. 2003

White Sturgeon

Spawning (Group F)

WDFW/Ecology HSC curves are not available and White Sturgeon HSC curves are not included in the ESH model. The HSC Technical Group reviewed HSC curves from studies on the Columbia River, WA and Sacramento River, CA. The HSC Technical Group considered the Sacramento River curves to be more representative of the Skagit River as these two rivers are more comparable in size compared to the Columbia River which is much larger; albeit, both sets of HSC curves are similar. As a result, the Sacramento River HSC curves are recommended for habitat modeling.

Additional Notes

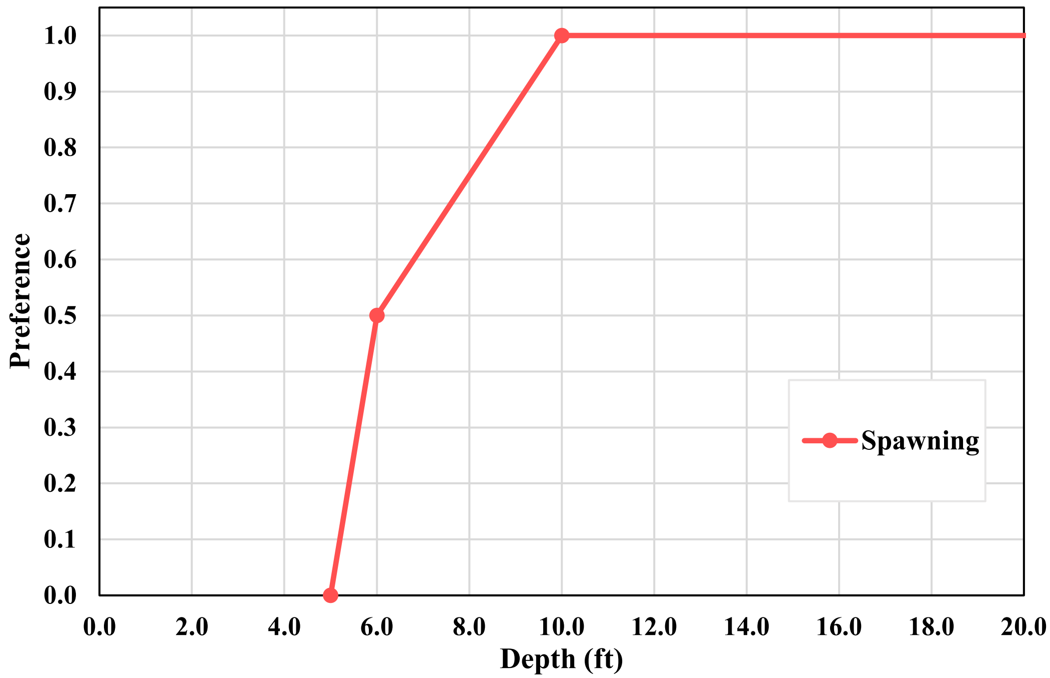
There is no clear biological evidence that depth becomes a limiting factor for spawning White Sturgeon. Therefore, the Sacramento River HSC depth curve is considered to be "non-limiting" once depth reaches 10.0 ft (1.0 preference).

References

Sacramento River: spawning (Gard 1996)

White Sturgeon

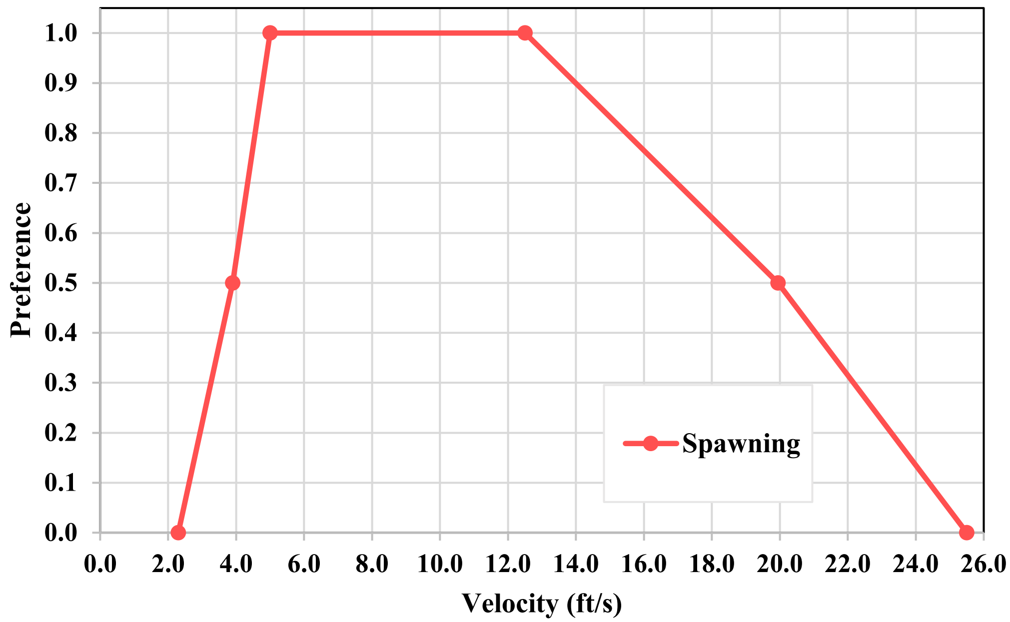
Depth Preference Curves



Spawning	
Depth (ft)	Preference
5.00	0.00
6.00	0.50
10.00	1.00
99.00	1.00

White Sturgeon

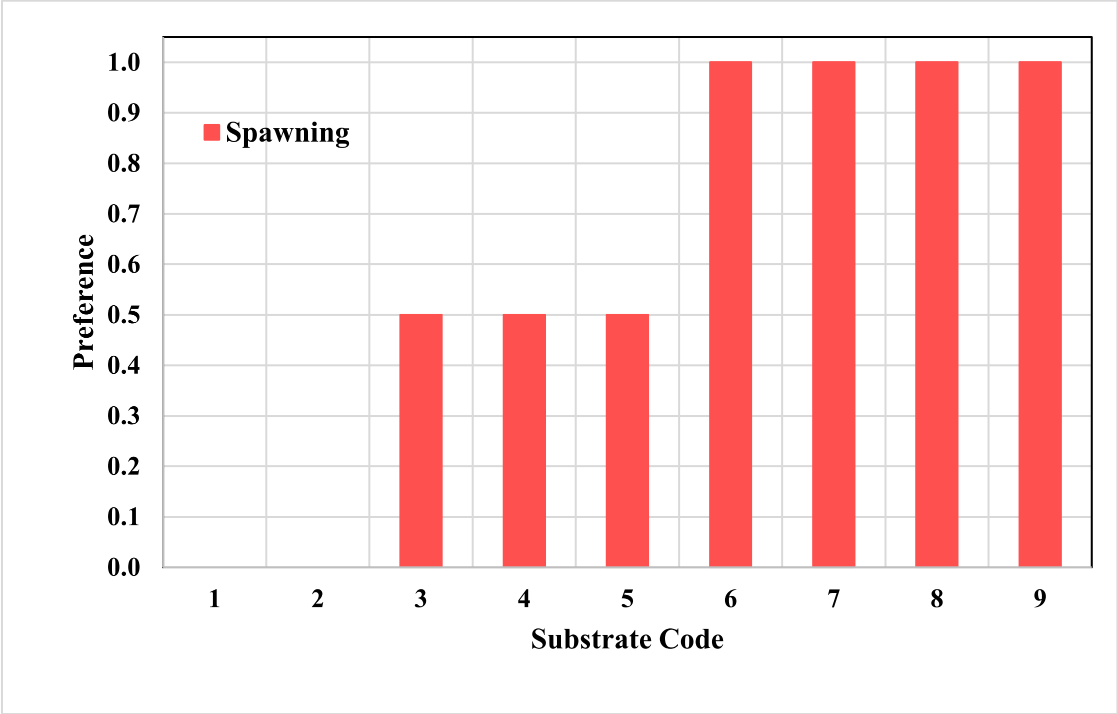
Velocity Preference Curves



Spawning	
Velocity (ft/s)	Preference
2.30	0.00
3.90	0.50
5.00	1.00
12.50	1.00
19.95	0.50
25.50	0.00

White Sturgeon

Substrate Preference Criteria



Sustrate Code	Substrate Type	Spawning Preference
1	Silt, Clay, or Organic	0.0
2	Sand	0.0
3	Small Gravel (0.1-0.5")	0.5
4	Med Gravel (0.5-1.5")	0.5
5	Large Gravel (1.5-3.0")	0.5
6	Small Cobble (3.0-6.0")	1.0
7	Large Cobble (6.0-12")	1.0
8	Boulder (>12")	1.0
9	Bedrock	1.0

Source: Gard 1996

REFERENCE LIST used for Skagit River HSC review and development

1 Baxter, J.S. 1995. Chowade River bull trout studies (1995): habitat and population assessment. Report to Ministry of Environment, Lands and Parks (Fort St John), Fisheries Branch, British Columbia, 108 pages.

2 Beecher, H. A., B. A. Caldwell, and S. B. DeMond. 2002. Evaluation of depth, velocity, substrate, and cover preferences of juvenile coho salmon (Oncorhynchus kisutch) in Washington streams. North American Journal of Fisheries Management 22 (3): 785-795. (Beecher et al. 2002)

3 Beecher, H. A., B. A. Caldwell, S. B. DeMond, D. Seiler, and S. N. Boessow. 2010. An empirical assessment of PHABSIM using long-term monitoring of coho salmon smolt production in Bingham Creek, Washington. NAJFM 30:6, 1529-1543. (Beecher et al. 2010)

Beecher, H. A., B. A. Caldwell, and J. Pacheco. 2013. Instream Flow Study Guidelines. Technical and Habitat Suitability Issues Including Fish Preference Curves. Washington Dept. of Fish and Wildlife and Washing State Dept. of Ecology. Updated April 1, 2013.

4 Beecher, H. A., B. A. Caldwell, and J. Pacheco. 2016. Instream Flow Study Guidelines. Technical and Habitat Suitability Issues Including Fish Preference Curves. Washington Dept. of Fish and Wildlife and Washing State Dept. of Ecology. Updated March 9, 2016.

5 Bovee, K.D. 1978. Probability of use criteria for the family Salmonidae. Instream Flow Information Paper No. 4. U.S. Fish Wildl. Serv. FWS/OBS-78/07.

6 Bovee, K.D. 1986. Development and Evaluation of Habitat Suitability Criteria for Use in the Intream Flow Incremental Methodology. Instream Flow Information Paper No. 21. U.S. Fish Wildl. Serv. FWS/OBS-86/7.

7 Bustard, D. and D. Royea. 1995. Kemess South Gold-Copper Project 1994 Fisheries Study. Report of Dave Bustard and Associates and Hallem Knight Piesold Limited to El Condor resources Limited and St. Phillips Resources Incorporated, Vancouver, British Columbia.

8 COSEWIC 2012. Assessment and update status report on the Salish Sucker *Catostomus* sp. in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 36 pages.

9 Crumley, S.C., and Q.J. Stober 1984. Skagit River interim agreement. Volume 1: Instream flow habitat analysis. Appendices. Final Report for Seattle City Light. 1332 pages.

Additional sources relied upon by Crumley and Stober:

10 AEIDC Arctic Environmental Information and Data Center 1981. An assessment of environmental effects of construction and operation of the Terror Lake hydroelectric facility, Kodiak, Alaska.

11 FRI Fisheries Research Institute, University of Washington. Data only (no

12 WDF Washington State Department of Fisheries. 1977. Salmon spawning groud data report. Progress Report 17. 346 pp.

13 WDF Washington State Department of Fisheries. 1982. Puget Sound salmon spawning groud data report. Water resource inventory areas 1 - 19 for escapement years 1978 - 1981. Progress Report 175. 574 pp.

14 WDF Washington State Department of Fisheries. 1983. Puget Sound salmon spawning groud data report. Water resource inventory areas 1 - 19 for escapement years 1982 - 1983. Progress Report 194. 157 pp.

15 WDG Washington State Game Department. 1980. Steelhead program progress report. April 1, 1980 - June 30, 1980. Cooperative agreement numbers 14-16-0001-5776FS, 14-16-0001-6345IFC between the United States Fish and Wildlife Service and the Washington State Game Department. 217 pp.

16 Gard, M. 1996. Sacramento River White sturgeon spawning criteria. USFWS. Ecological Services. Sacramento Field Office. 13 p.

REFERENCE LIST used for Skagit River HSC review and development

17 Granger, R. 2021. Updated HSC curves for Bull Trout and Dolly Varden juvenile and Cutthroat Trout juvenile. Personnal communication (email). Received 12/28/2021.

18 Gunckel, S, Jones, K., and Jacobs, S. 2006. Spawning distribution and habitat use of adult Pacific and western brook lampreys in Smith River, Oregon.

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TABLE 1. Generic Cover/Substrate Codes and Preference Value[1] (Beecher et al. 2016)

Code	Type of Cover Note: Cover Codes are not used for Spawning	Salmon & Trout Rearing	Whitefish Rearing	
		Juvenile & Resident Adult	Juvenile	Adult
00.1	Undercut bank	1.00	1.00	1.00
00.2	Overhanging vegetation near or touching water2	1.00	1.00	1.00
00.3	Rootwad (including parly undercut)	1.00	1.00	1.00
00.4	Log jam/submerged brush pile	1.00	1.00	1.00
00.5	Log(s) parallel to bank	0.80	0.80	0.80
00.6	Aquatic vegetation	0.80	0.80	0.80
00.7	Short (<1 ft) terrestrial grass	0.10	0.10	0.10
00.8	Tall (>3 ft) dense grass[3]	0.70	0.70	0.10
00.9	Vegetation >3 vertical ft above SZF	0.20	0.20	0.20

Code	Type of Substrate	Spawning					Salmon & Trout Rearing	Whitefish Rearing	
		Salmon	Steelhead[4]	Resident Trout	Native Char[5]	Whitefish	Juvenile & Resident Adult	Juvenile	Adult
1	Silt, clay, or organic	0.00	0.00	0.00	0.00	0.00	0.10	0.38	0.15
2	Sand	0.00	0.00	0.00	0.00	0.00	0.10	0.38	0.15
3	Sm Gravel (0.1 - 0.5")	0.30	0.50	0.80	1.00	1.00	0.10	0.74	0.76
4	Med Gravel (0.5 - 1.5")	1.00	1.00	1.00	1.00	1.00	0.30	0.88	0.91
5	Lrg Gravel (1.5 - 3")	1.00	1.00	0.80	1.00	1.00	0.30	0.88	0.91
6	Sm Cobble (3 - 6")	1.00	1.00	0.50	0.70	1.00	0.50	1.00	1.00
7	Lrg Cobble (6 - 12")	0.50	0.30	0.00	0.70	0.50	0.70	1.00	1.00
8	Boulder (>12")	0.00	0.00	0.00	0.00	0.00	1.00	1.00	1.00
9	Bedrock	0.00	0.00	0.00	0.00	0.00	0.30	0.50	0.30

Notes:

1. This table reflects average values for the listed species. Site specific preferences would supersede this table.
2. This includes low tree branches (<3 vertical ft. above water surface elevation at stage of zero flow (SZF)) and bushes overhanging the bank-full water's edge.
3. This category refers to stout, almost bushy type grasses such as reed canary grass up to the bank-full water's edge.
4. This category includes intermountain and coastal cutthroat (*Oncorhynchus clarki*).
5. This category includes Bull Trout (*Salvelinus confluentus*) and Dolly Varden (*S. malma*).

TABLE 2. Generic Salmon Spawning Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.0	Cover codes are not factors for spawning habitat		
00.1			
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.00	0.00	0.00
13.9	0.00	0.30	0.00*
17.9	0.00	0.30	0.00*
18.5	0.00	0.00	0.00
21.5	0.00	0.00	0.00
23.9	0.00	0.30	0.00*
27.9	0.00	0.50	0.00*
28.5	0.00	0.00	0.00
29.9	0.00	0.00	0.00
31.5	0.30	0.00	0.00*
31.7	0.30	0.00	0.00*
31.8	0.30	0.00	0.24
31.9	0.30	0.00	0.27
32.5	0.30	0.00	0.00*
32.7	0.30	0.00	0.00*
32.8	0.30	0.00	0.24
32.9	0.30	0.00	0.27
33.9	0.30	0.30	0.30
34.5	0.30	1.00	0.65
34.9	0.30	1.00	0.37
35.5	0.30	1.00	0.65
35.9	0.30	1.00	0.37
36.5	0.30	1.00	0.65
36.9	0.30	1.00	0.37
37.5	0.30	0.50	0.40
37.9	0.30	0.50	0.32
38.5	0.30	0.00	0.15
38.9	0.30	0.00	0.27
39.5	0.30	0.00	0.00*
39.9	0.30	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	0.30	0.65
43.9	1.00	0.30	0.93
44.9	1.00	1.00	1.00
46.9	1.00	1.00	1.00
47.5	1.00	0.50	0.75
47.9	1.00	0.50	0.95
48.5	1.00	0.00	0.5
48.9	1.00	0.00	0.9
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	1.00	0.00	0.00*
51.7	1.00	0.00	0.00*
51.8	1.00	0.00	0.80
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.00*
52.7	1.00	0.00	0.00*
52.8	1.00	0.00	0.80
52.9	1.00	0.00	0.90
53.5	1.00	0.30	0.65
53.9	1.00	0.30	0.93
54.5	1.00	1.00	1.00
56.9	1.00	1.00	1.00
57.5	1.00	0.50	0.75
57.9	1.00	0.50	0.95
58.5	1.00	0.00	0.5
58.9	1.00	0.00	0.9
59.5	1.00	0.00	0.00*
59.9	1.00	0.00	0.00*

[1] Assume straight line between codes. Values are derived from RP equation (see pg. 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).
* Asterisk indicated deviation from the RP formula.

Table 2 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
61.5	1.00	0.00	0.00*
61.7	1.00	0.00	0.00*
61.8	1.00	0.00	0.80
61.9	1.00	0.00	0.90
62.5	1.00	0.00	0.00*
62.7	1.00	0.00	0.00*
62.8	1.00	0.00	0.80
62.9	1.00	0.00	0.90
63.5	1.00	0.30	0.65
63.9	1.00	0.30	0.93
64.5	1.00	1.00	1.00
66.9	1.00	1.00	1.00
67.5	1.00	0.50	0.75
67.9	1.00	0.50	0.95
68.5	1.00	0.00	0.50
68.9	1.00	0.00	0.90
69.5	1.00	0.00	0.00*
71.7	0.50	0.00	0.00*
71.8	0.50	0.00	0.40
71.9	0.50	0.00	0.45
72.5	0.50	0.00	0.00*
72.7	0.50	0.00	0.00*
72.8	0.50	0.00	0.40
72.9	0.50	0.00	0.45
73.5	0.50	0.30	0.40
73.9	0.50	0.30	0.48
74.5	0.50	1.00	0.75
74.9	0.50	1.00	0.55
75.5	0.50	1.00	0.75
75.9	0.50	1.00	0.55
76.5	0.50	1.00	0.75
76.9	0.50	1.00	0.55
77.9	0.50	0.50	0.50
78.5	0.50	0.00	0.25
78.9	0.50	0.00	0.45
79.5	0.50	0.00	0.00*
79.9	0.50	0.00	0.00*
81.5	0.00	0.00	0.00
82.9	0.00	0.00	0.00
83.5	0.00	0.30	0.00*
87.9	0.00	0.50	0.00*
88.9	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	0.30	0.00*
97.9	0.00	0.50	0.00*
98.5	0.00	0.00	0.00
99.9	0.00	0.00	0.00

TABLE 3. Generic Juvenile & Resident Adult Salmon and Trout Cover/Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.1	a & b values are not used to determine cover preference		1.00
00.2			1.00
00.3			1.00
00.4			1.00
00.5			0.80
00.6			0.80
00.7			0.10
00.8			0.70
00.9			0.20
11.9[2]	0.10	0.10	0.10
13.9	0.10	0.10	0.10
14.5	0.10	0.30	0.20
14.9	0.10	0.30	0.12
15.5	0.10	0.30	0.20
15.9	0.10	0.30	0.12
16.5	0.10	0.50	0.30
16.9	0.10	0.50	0.14
17.5	0.10	0.70	0.40
17.9	0.10	0.70	0.16
18.5	0.10	1.00	1.00*
18.9	0.10	1.00	1.00*
19.5	0.10	0.30	0.20
19.9	0.10	0.30	0.12
21.5	0.10	0.10	0.10
23.9	0.10	0.10	0.10
24.5	0.10	0.30	0.20
24.9	0.10	0.30	0.12
25.5	0.10	0.30	0.20
25.9	0.10	0.30	0.12
26.5	0.10	0.50	0.30
26.9	0.10	0.50	0.14
27.5	0.10	0.70	0.40
27.9	0.10	0.70	0.16
28.5	0.10	1.00	1.00*
28.9	0.10	1.00	1.00*
29.5	0.10	0.30	0.20
29.9	0.10	0.30	0.12
31.5	0.10	0.10	0.10
33.9	0.10	0.10	0.10
34.5	0.10	0.30	0.20
34.9	0.10	0.30	0.12
35.5	0.10	0.30	0.20
35.9	0.10	0.30	0.12
36.5	0.10	0.50	0.30
36.9	0.10	0.50	0.14
37.5	0.10	0.70	0.40
37.9	0.10	0.70	0.16
38.5	0.10	1.00	1.00*
38.9	0.10	1.00	1.00*
39.5	0.10	0.30	0.20
39.9	0.10	0.30	0.12
41.5	0.30	0.10	0.20
41.9	0.30	0.10	0.28
42.5	0.30	0.10	0.20
42.9	0.30	0.10	0.28
43.5	0.30	0.10	0.20
43.9	0.30	0.10	0.28
44.9	0.30	0.30	0.30
45.9	0.30	0.30	0.30
46.5	0.30	0.50	0.40
46.9	0.30	0.50	0.32
47.5	0.30	0.70	0.50
47.9	0.30	0.70	0.34
48.5	0.30	1.00	1.00*
48.9	0.30	1.00	1.00*
49.5	0.30	0.30	0.30
49.9	0.30	0.30	0.30
51.5	0.30	0.10	0.20
51.9	0.30	0.10	0.28
52.5	0.30	0.10	0.20
52.9	0.30	0.10	0.28
53.5	0.30	0.10	0.20
53.9	0.30	0.10	0.28
54.5	0.30	0.30	0.30
55.9	0.30	0.30	0.30
56.5	0.30	0.50	0.40
56.9	0.30	0.50	0.32
57.5	0.30	0.70	0.50
57.9	0.30	0.70	0.34

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* Asterisk indicated deviation from the RP formula.

Table 3 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
58.5	0.30	1.00	1.00*
58.9	0.30	1.00	1.00*
59.5	0.30	0.30	0.30
59.9	0.30	0.30	0.30
61.5	0.50	0.10	0.30
61.9	0.50	0.10	0.46
62.5	0.50	0.10	0.30
62.9	0.50	0.10	0.46
63.5	0.50	0.10	0.30
63.9	0.50	0.10	0.46
64.5	0.50	0.30	0.40
64.9	0.50	0.30	0.48
65.5	0.50	0.30	0.40
65.9	0.50	0.30	0.48
66.9	0.50	0.50	0.50
67.5	0.50	0.70	0.60
67.9	0.50	0.70	0.52
68.5	0.50	1.00	1.00*
68.9	0.50	1.00	1.00*
69.5	0.50	0.30	0.40
69.9	0.50	0.30	0.48
71.5	0.70	0.10	0.40
71.9	0.70	0.10	0.64
72.5	0.70	0.10	0.40
72.9	0.70	0.10	0.64
73.5	0.70	0.10	0.40
73.9	0.70	0.10	0.64
74.5	0.70	0.30	0.50
74.9	0.70	0.30	0.66
75.5	0.70	0.30	0.50
75.9	0.70	0.30	0.66
76.5	0.70	0.50	0.60
76.9	0.70	0.50	0.68
77.9	0.70	0.70	0.70
78.5	0.70	1.00	1.00*
78.9	0.70	1.00	1.00*
79.5	0.70	0.30	0.50
79.9	0.70	0.30	0.66
81.5	1.00	0.10	1.00*
87.9	1.00	0.70	1.00*
88.9	1.00	1.00	1.00
89.5	1.00	0.30	1.00*
89.9	1.00	0.30	1.00*
91.5	0.30	0.10	0.20
91.9	0.30	0.10	0.28
92.5	0.30	0.10	0.20
92.9	0.30	0.10	0.28
93.5	0.30	0.10	0.20
93.9	0.30	0.10	0.28
94.5	0.30	0.30	0.30
95.9	0.30	0.30	0.30
96.5	0.30	0.50	0.40
96.9	0.30	0.50	0.32
97.5	0.30	0.70	0.50
97.9	0.30	0.70	0.34
98.5	0.30	1.00	1.00*
98.9	0.30	1.00	1.00*
99.9	0.30	0.30	0.30

TABLE 4. Steelhead (Oncorhynchus mykiss) Spawning Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.0	Cover codes are not factors for spawning habitat		
00.1			
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.00	0.00	0.00
13.9	0.00	0.50	0.00*
14.5	0.00	1.00	0.00*
16.9	0.00	1.00	0.00*
17.5	0.00	0.30	0.00*
17.9	0.00	0.30	0.00*
18.5	0.00	0.00	0.00
21.5	0.00	0.00	0.00
23.9	0.00	0.50	0.00*
27.9	0.00	0.30	0.00*
28.5	0.00	0.00	0.00
29.9	0.00	0.00	0.00
31.5	0.50	0.00	0.00*
31.7	0.50	0.00	0.00*
31.8	0.50	0.00	0.40
31.9	0.50	0.00	0.45
32.5	0.50	0.00	0.00*
32.7	0.50	0.00	0.00*
32.8	0.50	0.00	0.40
32.9	0.50	0.00	0.45
33.9	0.50	0.50	0.50
34.5	0.50	1.00	0.75
34.9	0.50	1.00	0.55
35.5	0.50	1.00	0.75
35.9	0.50	1.00	0.55
36.5	0.50	1.00	0.75
36.9	0.50	1.00	0.55
37.5	0.50	0.30	0.40
37.9	0.50	0.30	0.48
38.5	0.50	0.00	0.00*
38.9	0.50	0.00	0.00*
39.5	0.50	0.00	0.00*
39.9	0.50	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	0.50	0.75
43.9	1.00	0.50	0.95
44.9	1.00	1.00	1.00
46.9	1.00	1.00	1.00
47.5	1.00	0.30	0.65
47.9	1.00	0.30	0.93
48.5	1.00	0.00	0.00*
48.9	1.00	0.00	0.00*
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	1.00	0.00	0.00*
51.7	1.00	0.00	0.00*
51.8	1.00	0.00	0.80
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.00*
52.7	1.00	0.00	0.00*
52.8	1.00	0.00	0.80
52.9	1.00	0.00	0.90
53.5	1.00	0.50	0.75
53.9	1.00	0.50	0.95
54.5	1.00	1.00	1.00
56.9	1.00	1.00	1.00
57.5	1.00	0.30	0.65
57.9	1.00	0.30	0.93

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).
* Asterisk indicated deviation from the RP formula.

Table 4 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
58.5	1.00	0.00	0.00*
58.9	1.00	0.00	0.00*
59.5	1.00	0.00	0.00*
59.9	1.00	0.00	0.00*
61.5	1.00	0.00	0.00*
61.7	1.00	0.00	0.00*
61.8	1.00	0.00	0.80
61.9	1.00	0.00	0.90
62.5	1.00	0.00	0.00*
62.7	1.00	0.00	0.00*
62.8	1.00	0.00	0.80
62.9	1.00	0.00	0.90
63.5	1.00	0.50	0.75
63.9	1.00	0.50	0.95
64.5	1.00	1.00	1.00
66.9	1.00	1.00	1.00
67.5	1.00	0.30	0.65
67.9	1.00	0.30	0.93
68.5	1.00	0.00	0.00*
68.9	1.00	0.00	0.00*
69.5	1.00	0.00	0.00*
69.9	1.00	0.00	0.00*
71.5	0.30	0.00	0.00*
71.7	0.30	0.00	0.00*
71.8	0.30	0.00	0.24
71.9	0.30	0.00	0.27
72.5	0.30	0.00	0.00*
72.7	0.30	0.00	0.00*
72.8	0.30	0.00	0.24
72.9	0.30	0.00	0.27
73.5	0.30	0.50	0.40
73.9	0.30	0.50	0.32
74.5	0.30	1.00	0.65
74.9	0.30	1.00	0.37
75.5	0.30	1.00	0.65
75.9	0.30	1.00	0.37
76.5	0.30	1.00	0.65
76.9	0.30	1.00	0.37
77.9	0.30	0.30	0.30
78.5	0.30	0.00	0.00*
78.9	0.30	0.00	0.00*
79.5	0.30	0.00	0.00*
79.9	0.30	0.00	0.00*
81.5	0.00	0.00	0.00*
82.9	0.00	0.00	0.00*
83.5	0.00	0.50	0.00*
83.9	0.00	0.50	0.00*
84.5	0.00	1.00	0.00*
86.9	0.00	1.00	0.00*
87.5	0.00	0.30	0.00*
87.9	0.00	0.30	0.00*
88.5	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	0.50	0.00*
93.9	0.00	0.50	0.00*
94.5	0.00	1.00	0.00*
96.9	0.00	1.00	0.00*
97.5	0.00	0.30	0.00*
97.9	0.00	0.30	0.00*
98.5	0.00	0.00	0.00
99.9	0.00	0.00	0.00

TABLE 5. Generic Trout Spawning Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.1	Cover codes are not factors for spawning habitat		
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.00	0.00	0.00
13.9	0.00	0.80	0.00*
14.5	0.00	1.00	0.00*
14.9	0.00	1.00	0.00*
15.5	0.00	0.80	0.00*
15.9	0.00	0.80	0.00*
16.5	0.00	0.50	0.00*
16.9	0.00	0.50	0.00*
17.5	0.00	0.00	0.00
21.5	0.00	0.00	0.00
23.9	0.00	0.80	0.00*
24.5	0.00	1.00	0.00*
24.9	0.00	1.00	0.00*
25.5	0.00	0.80	0.00*
25.9	0.00	0.80	0.00*
26.5	0.00	0.50	0.00*
26.9	0.00	0.50	0.00*
27.5	0.00	0.00	0.00
29.9	0.00	0.00	0.00
31.5	0.80	0.00	0.00*
31.7	0.80	0.00	0.00*
31.8	0.80	0.00	0.64
31.9	0.80	0.00	0.72
32.5	0.80	0.00	0.00*
32.7	0.80	0.00	0.00*
32.8	0.80	0.00	0.64
32.9	0.80	0.00	0.72
33.9	0.80	0.80	0.80
34.5	0.80	1.00	0.90
34.9	0.80	1.00	0.82
35.5	0.80	0.80	0.80
35.9	0.80	0.80	0.80
36.5	0.80	0.50	0.65
36.9	0.80	0.50	0.77
37.5	0.80	0.00	0.00*
37.9	0.80	0.00	0.00*
38.5	0.80	0.00	0.00*
38.9	0.80	0.00	0.00*
39.5	0.80	0.00	0.00*
39.9	0.80	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	0.80	0.90
43.9	1.00	0.80	0.98
44.9	1.00	1.00	1.00
45.5	1.00	0.80	0.90
45.9	1.00	0.80	0.98
46.5	1.00	0.50	0.75
46.9	1.00	0.50	0.95
47.5	1.00	0.00	0.00*
47.9	1.00	0.00	0.00*
48.5	1.00	0.00	0.00*
48.9	1.00	0.00	0.00*
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	0.80	0.00	0.00*
51.7	0.80	0.00	0.00*
51.8	0.80	0.00	0.64
51.9	0.80	0.00	0.72
52.5	0.80	0.00	0.00*
52.7	0.80	0.00	0.00*
52.8	0.80	0.00	0.64
52.9	0.80	0.00	0.72
53.5	0.80	0.80	0.80
53.9	0.80	0.80	0.80

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* Asterisk indicated deviation from the RP formula.

TABLE 5 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
54.5	0.80	1.00	0.90
54.9	0.80	1.00	0.82
55.9	0.80	0.80	0.80
56.5	0.80	0.50	0.65
56.9	0.80	0.50	0.77
57.5	0.80	0.00	0.00*
57.9	0.80	0.00	0.00*
58.5	0.80	0.00	0.00*
58.9	0.80	0.00	0.00*
59.5	0.80	0.00	0.00*
59.9	0.80	0.00	0.00*
61.5	0.50	0.00	0.00*
61.7	0.50	0.00	0.00*
61.8	0.50	0.00	0.40
61.9	0.50	0.00	0.45
62.5	0.50	0.00	0.00*
62.7	0.50	0.00	0.00*
62.8	0.50	0.00	0.40
62.9	0.50	0.00	0.45
63.5	0.50	0.80	0.65
63.9	0.50	0.80	0.53
64.5	0.50	1.00	0.75
64.9	0.50	1.00	0.55
65.5	0.50	0.80	0.65
65.9	0.50	0.80	0.53
66.9	0.50	0.50	0.50
67.5	0.50	0.00	0.00*
67.9	0.50	0.00	0.00*
68.5	0.50	0.00	0.00*
68.9	0.50	0.00	0.00*
69.5	0.50	0.00	0.00*
69.9	0.50	0.00	0.00*
71.5	0.00	0.00	0.00
72.9	0.00	0.00	0.00
73.5	0.00	0.80	0.00*
73.9	0.00	0.80	0.00*
74.5	0.00	1.00	0.00*
74.9	0.00	1.00	0.00*
75.5	0.00	0.80	0.00*
75.9	0.00	0.80	0.00*
76.5	0.00	0.50	0.00*
76.9	0.00	0.50	0.00*
77.9	0.00	0.00	0.00
82.9	0.00	0.00	0.00
83.5	0.00	0.80	0.00*
83.9	0.00	0.80	0.00*
84.5	0.00	1.00	0.00*
84.9	0.00	1.00	0.00*
85.5	0.00	0.80	0.00*
85.9	0.00	0.80	0.00*
86.5	0.00	0.50	0.00*
86.9	0.00	0.50	0.00*
87.5	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	0.80	0.00*
93.9	0.00	0.80	0.00*
94.5	0.00	1.00	0.00*
94.9	0.00	1.00	0.00*
95.5	0.00	0.80	0.00*
95.9	0.00	0.80	0.00*
96.5	0.00	0.50	0.00*
96.9	0.00	0.50	0.00*
97.5	0.00	0.00	0.00
99.9	0.00	0.00	0.00

TABLE 6. Bull Trout (Salvelinus confluentus) and Dolly Varden (S. malma) Spawning Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.1	Cover codes are not factors for spawning habitat		
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.00	0.00	0.00
31.7	1.00	0.00	0.00*
31.8	1.00	0.00	0.80
31.9	1.00	0.00	0.90
32.5	1.00	0.00	0.00*
32.7	1.00	0.00	0.00*
32.8	1.00	0.00	0.80
32.9	1.00	0.00	0.90
33.9	1.00	1.00	1.00
35.9	1.00	1.00	1.00
36.5	1.00	0.70	0.85
36.9	1.00	0.70	0.97
37.5	1.00	0.70	0.85
37.9	1.00	0.70	0.97
38.5	1.00	0.00	0.50
38.9	1.00	0.00	0.90
39.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	1.00	1.00
45.9	1.00	1.00	1.00
46.5	1.00	0.70	0.85
46.9	1.00	0.70	0.97
47.5	1.00	0.70	0.85
47.9	1.00	0.70	0.97
48.5	1.00	0.00	0.50
48.9	1.00	0.00	0.90
49.5	1.00	0.00	0.00*
51.7	1.00	0.00	0.00*
51.8	1.00	0.00	0.80
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.00*
52.7	1.00	0.00	0.00*
52.8	1.00	0.00	0.80
52.9	1.00	0.00	0.90
53.5	1.00	1.00	1.00
55.9	1.00	1.00	1.00
56.5	1.00	0.70	0.85
56.9	1.00	0.70	0.97
57.5	1.00	0.70	0.85
57.9	1.00	0.70	0.97
58.5	1.00	0.70	0.85
58.9	1.00	0.70	0.97
59.5	1.00	0.00	0.00*
61.7	0.70	0.00	0.00*
61.8	0.70	0.00	0.56
61.9	0.70	0.00	0.63
62.5	0.70	0.00	0.00*
62.7	0.70	0.00	0.00*
62.8	0.70	0.00	0.56
62.9	0.70	0.00	0.63
63.5	0.70	1.00	0.85
63.9	0.70	1.00	0.73
64.5	0.70	1.00	0.85
64.9	0.70	1.00	0.73
65.5	0.70	1.00	0.85
65.9	0.70	1.00	0.73
66.9	0.70	0.70	0.70
67.9	0.70	0.70	0.70
68.5	0.70	0.00	0.35
68.9	0.70	0.00	0.63
69.5	0.70	0.00	0.00*

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 20).
* Asterisk indicated deviation form RP formula.

Table 6 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
71.7	0.70	0.00	0.00*
71.8	0.70	0.00	0.56
71.9	0.70	0.00	0.63
72.5	0.70	0.00	0.00*
72.7	0.70	0.00	0.00*
72.8	0.70	0.00	0.56
72.9	0.70	0.00	0.63
73.5	0.70	1.00	0.85
73.9	0.70	1.00	0.73
74.5	0.70	1.00	0.85
74.9	0.70	1.00	0.73
75.5	0.70	1.00	0.85
75.9	0.70	1.00	0.73
76.5	0.70	0.70	0.70
76.9	0.70	0.70	0.70
77.9	0.70	0.70	0.70
78.5	0.70	0.00	0.35
78.9	0.70	0.00	0.63
79.5	0.70	0.00	0.00*
82.9	0.00	0.00	0.00*
83.5	0.00	1.00	0.50
83.9	0.00	1.00	0.10
84.5	0.00	1.00	0.50
84.9	0.00	1.00	0.10
85.5	0.00	1.00	0.50
85.9	0.00	1.00	0.10
86.5	0.00	0.70	0.35
86.9	0.00	0.70	0.07
87.5	0.00	0.70	0.35
87.9	0.00	0.70	0.07
88.9	0.00	0.00	0.00
93.5	0.00	0.00	0.00*
97.9	0.00	1.00	0.00*
99.9	0.00	0.00	0.00

TABLE 7. Mountain Whitefish (*Prosopium williamsoni*) Spawning Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.1	Cover codes are not factors for spawning habitat		
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.0	0.0	0.0
21.9	0.00	0.00	0.00
31.5	1.00	0.00	0.50
31.9	1.00	0.00	0.90
32.5	1.00	0.00	0.50
32.9	1.00	0.00	0.90
33.9	1.00	1.00	1.00
36.9	1.00	1.00	1.00
37.5	1.00	0.50	0.75
37.9	1.00	0.50	0.95
38.5	1.00	0.00	0.50
38.9	1.00	0.00	0.90
39.5	1.00	0.00	0.50
39.9	1.00	0.00	0.90
41.5	1.00	0.00	0.50
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.50
42.9	1.00	0.00	0.90
43.5	1.00	1.00	1.00
46.9	1.00	1.00	1.00
47.5	1.00	0.50	0.75
47.9	1.00	0.50	0.95
48.5	1.00	0.00	0.50
48.9	1.00	0.00	0.90
49.5	1.00	0.00	0.50
49.9	1.00	0.00	0.90
51.5	1.00	0.00	0.50
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.50
52.9	1.00	0.00	0.90
53.5	1.00	1.00	1.00
56.9	1.00	1.00	1.00
57.5	1.00	0.50	0.75
57.9	1.00	0.50	0.95
58.5	1.00	0.00	0.50
58.9	1.00	0.00	0.90
59.5	1.00	0.00	0.50
59.9	1.00	0.00	0.90
61.5	1.00	0.00	0.50
61.9	1.00	0.00	0.90
62.5	1.00	0.00	0.50
62.9	1.00	0.00	0.90
63.5	1.00	1.00	1.00
66.9	1.00	1.00	1.00
67.5	1.00	0.50	0.75
67.9	1.00	0.50	0.95
68.5	1.00	0.00	0.50
68.9	1.00	0.00	0.90
69.5	1.00	0.00	0.50
69.9	1.00	0.00	0.90
71.5	0.50	0.00	0.25
71.9	0.50	0.00	0.45
72.5	0.50	0.00	0.25
72.9	0.50	0.00	0.45
73.5	0.50	1.00	0.75
73.9	0.50	1.00	0.55
74.5	0.50	1.00	0.75
74.9	0.50	1.00	0.55
75.5	0.50	1.00	0.75
75.9	0.50	1.00	0.55
76.5	0.50	1.00	0.75
76.9	0.50	1.00	0.55
77.9	0.50	0.50	0.50
78.5	0.50	0.00	0.25
78.9	0.50	0.00	0.45
79.5	0.50	0.00	0.25
79.9	0.50	0.00	0.45

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* Asterisk indicated deviation from the RP formula.

Table 7 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
81.5	0.00	0.00	0.00
82.9	0.00	0.00	0.00
83.5	0.00	1.00	0.50
83.9	0.00	1.00	0.10
84.5	0.00	1.00	0.50
84.9	0.00	1.00	0.10
85.5	0.00	1.00	0.50
85.9	0.00	1.00	0.10
86.5	0.00	1.00	0.50
86.9	0.00	1.00	0.10
87.5	0.00	1.00	0.50
87.9	0.00	1.00	0.10
88.9	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	1.00	0.50
93.9	0.00	1.00	0.10
94.5	0.00	1.00	0.50
94.9	0.00	1.00	0.10
95.5	0.00	1.00	0.50
95.9	0.00	1.00	0.10
96.5	0.00	1.00	0.50
96.9	0.00	1.00	0.10
97.5	0.00	1.00	0.50
97.9	0.00	1.00	0.10
98.5	0.00	0.00	0.00
99.9	0.00	0.00	0.00

TABLE 8. Mountain Whitefish Adult Rearing Cover/Substrate Preference [1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference	
00.1	a & b values are not used to determine cover preference		1.0	1.00
00.2			1.0	1.00
00.3			1.0	1.00
00.4			1.0	1.00
00.5			0.8	0.80
00.6			0.8	0.80
00.7			0.1	0.10
00.8			0.1	0.70
00.9			0.2	0.20
11.9[2]	0.15	0.15	0.15	
12.9	0.15	0.15	0.15	
13.5	0.15	0.76	0.46	
13.9	0.15	0.76	0.21	
14.5	0.15	0.91	0.53	
14.9	0.15	0.91	0.23	
15.5	0.15	0.91	0.53	
15.9	0.15	0.91	0.23	
16.5	0.15	1.0	0.58	
16.9	0.15	1.0	0.24	
17.5	0.15	1.0	0.58	
17.9	0.15	1.0	0.24	
18.5	0.15	1.0	0.58	
18.9	0.15	1.0	0.24	
19.5	0.15	0.30	0.23	
19.9	0.15	0.30	0.17	
21.5	0.15	0.15	0.15	
22.9	0.15	0.15	0.15	
23.5	0.15	0.76	0.46	
23.9	0.15	0.76	0.21	
24.5	0.15	0.91	0.53	
24.9	0.15	0.91	0.23	
25.5	0.15	0.91	0.53	
25.9	0.15	0.91	0.23	
26.5	0.15	1.00	0.58	
26.9	0.15	1.00	0.24	
27.5	0.15	1.00	0.58	
27.9	0.15	1.00	0.24	
28.5	0.15	1.00	0.58	
28.9	0.15	1.00	0.24	
29.5	0.15	0.30	0.23	
29.9	0.15	0.30	0.17	
31.5	0.76	0.15	0.46	
31.9	0.76	0.15	0.70	
32.5	0.76	0.15	0.46	
32.9	0.76	0.15	0.70	
33.9	0.76	0.76	0.76	
34.5	0.76	0.91	0.84	
34.9	0.76	0.91	0.78	
35.5	0.76	0.91	0.84	
35.9	0.76	0.91	0.78	
36.5	0.76	1.0	0.88	
36.9	0.76	1.0	0.78	
37.5	0.76	1.0	0.88	
37.9	0.76	1.0	0.78	
38.5	0.76	1.0	0.88	
38.9	0.76	1.0	0.78	
39.5	0.76	0.30	0.53	
39.9	0.76	0.30	0.71	
41.5	0.91	0.15	0.53	
41.9	0.91	0.15	0.83	
42.5	0.91	0.15	0.53	
42.9	0.91	0.15	0.83	
43.5	0.91	0.76	0.84	
43.9	0.91	0.76	0.90	
44.9	0.91	0.91	0.91	
45.9	0.91	0.91	0.91	
46.5	0.91	1.0	0.96	
46.9	0.91	1.0	0.92	
47.5	0.91	1.0	0.96	
47.9	0.91	1.0	0.92	
48.5	0.91	1.0	0.96	
48.9	0.91	1.0	0.92	
49.5	0.91	0.30	0.61	
49.9	0.91	0.30	0.85	
51.5	0.91	0.15	0.53	
51.9	0.91	0.15	0.83	
52.5	0.91	0.15	0.53	
52.9	0.91	0.15	0.83	
53.5	0.91	0.76	0.84	
53.9	0.91	0.76	0.90	
54.5	0.91	0.91	0.91	
55.9	0.91	0.91	0.91	
56.5	0.91	1.0	0.96	
56.9	0.91	1.0	0.92	

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* Asterisk indicated deviation from the RP formula.

Table 8 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
57.5	0.91	1.0	0.96
57.9	0.91	1.0	0.92
58.5	0.91	1.0	0.96
58.9	0.91	1.0	0.92
59.5	0.91	0.30	0.61
59.9	0.91	0.30	0.85
61.5	1.0	0.15	0.58
61.9	1.0	0.15	0.92
62.5	1.0	0.15	0.58
62.9	1.0	0.15	0.92
63.5	1.0	0.76	0.88
63.9	1.0	0.76	0.98
64.5	1.0	0.91	0.96
64.9	1.0	0.91	0.99
65.5	1.0	0.91	0.96
65.9	1.0	0.91	0.99
66.9	1.0	1.0	1.00
68.9	1.0	1.0	1.00
69.5	1.0	0.30	0.65
69.9	1.0	0.30	0.93
71.5	1.0	0.15	0.58
71.9	1.0	0.15	0.92
72.5	1.0	0.15	0.58
72.9	1.0	0.15	0.92
73.5	1.0	0.76	0.88
73.9	1.0	0.76	0.98
74.5	1.0	0.91	0.96
74.9	1.0	0.91	0.99
75.5	1.0	0.91	0.96
75.9	1.0	0.91	0.99
76.5	1.0	1.0	1.00
78.9	1.0	1.0	1.00
79.5	1.0	0.30	0.65
79.9	1.0	0.30	0.93
81.5	1.0	0.15	0.58
81.9	1.0	0.15	0.92
82.5	1.0	0.15	0.58
82.9	1.0	0.15	0.92
83.5	1.0	0.76	0.88
83.9	1.0	0.76	0.98
84.5	1.0	0.91	0.96
84.9	1.0	0.91	0.99
85.5	1.0	0.91	0.96
85.9	1.0	0.91	0.99
86.5	1.0	1.0	1.00
88.9	1.0	1.0	1.00
89.5	1.0	0.30	0.65
89.9	1.0	0.30	0.93
91.5	0.30	0.15	0.23
91.9	0.30	0.15	0.29
92.5	0.30	0.15	0.23
92.9	0.30	0.15	0.29
93.5	0.30	0.76	0.53
93.9	0.30	0.76	0.35
94.5	0.30	0.91	0.61
94.9	0.30	0.91	0.36
95.5	0.30	0.91	0.61
95.9	0.30	0.91	0.36
96.5	0.30	1.0	0.65
96.9	0.30	1.0	0.37
97.5	0.30	1.0	0.65
97.9	0.30	1.0	0.37
98.5	0.30	1.0	0.65
98.9	0.30	1.0	0.37
99.9	0.30	0.30	0.30

TABLE 9. Mountain Whitefish Juvenile Rearing Cover/Substrate Preference [1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference	
00.1	a & b values are not used to determine cover preference		1.00	1.00
00.2			1.00	1.00
00.3			1.00	1.00
00.4			1.00	1.00
00.5			0.80	0.80
00.6			0.80	0.80
00.7			0.10	0.10
00.8			0.70	0.70
00.9			0.20	0.20
11.9[2]	0.38	0.38	0.38	
12.9	0.38	0.38	0.38	
13.5	0.38	0.74	0.56	
13.9	0.38	0.74	0.42	
14.5	0.38	0.88	0.63	
14.9	0.38	0.88	0.43	
15.5	0.38	0.88	0.63	
15.9	0.38	0.88	0.43	
16.5	0.38	1.0	0.69	
16.9	0.38	1.0	0.44	
17.5	0.38	1.0	0.69	
17.9	0.38	1.0	0.44	
18.5	0.38	1.0	0.69	
18.9	0.38	1.0	0.44	
19.5	0.38	0.50	0.44	
19.9	0.38	0.50	0.39	
21.5	0.38	0.38	0.38	
22.9	0.38	0.38	0.38	
23.5	0.38	0.74	0.56	
23.9	0.38	0.74	0.42	
24.5	0.38	0.88	0.63	
24.9	0.38	0.88	0.43	
25.5	0.38	0.88	0.63	
25.9	0.38	0.88	0.43	
26.5	0.38	1.0	0.69	
26.9	0.38	1.0	0.44	
27.5	0.38	1.0	0.69	
27.9	0.38	1.0	0.44	
28.5	0.38	1.0	0.69	
28.9	0.38	1.0	0.44	
29.5	0.38	0.50	0.44	
29.9	0.38	0.50	0.39	
31.5	0.74	0.38	0.56	
31.9	0.74	0.38	0.70	
32.5	0.74	0.38	0.56	
32.9	0.74	0.38	0.70	
33.9	0.74	0.74	0.74	
34.5	0.74	0.88	0.81	
34.9	0.74	0.88	0.75	
35.5	0.74	0.88	0.81	
35.9	0.74	0.88	0.75	
36.5	0.74	1.0	0.87	
36.9	0.74	1.0	0.77	
37.5	0.74	1.0	0.87	
37.9	0.74	1.0	0.77	
38.5	0.74	1.0	0.87	
38.9	0.74	1.0	0.77	
39.5	0.74	0.50	0.62	
39.9	0.74	0.50	0.72	
41.5	0.88	0.38	0.63	
41.9	0.88	0.38	0.83	
42.5	0.88	0.38	0.63	
42.9	0.88	0.38	0.83	
43.5	0.88	0.74	0.81	
43.9	0.88	0.74	0.87	
44.9	0.88	0.88	0.88	
45.9	0.88	0.88	0.88	
46.5	0.88	1.0	0.94	
46.9	0.88	1.0	0.89	
47.5	0.88	1.0	0.94	
47.9	0.88	1.0	0.89	
48.5	0.88	1.0	0.94	
48.9	0.88	1.0	0.89	
49.5	0.88	0.50	0.69	
49.9	0.88	0.50	0.84	
51.5	0.88	0.38	0.63	
51.9	0.88	0.38	0.83	
52.5	0.88	0.38	0.63	
52.9	0.88	0.38	0.83	
53.5	0.88	0.74	0.81	
53.9	0.88	0.74	0.87	
54.5	0.88	0.88	0.88	
55.9	0.88	0.88	0.88	
56.5	0.88	1.0	0.94	
56.9	0.88	1.0	0.89	

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).
* Asterisk indicated deviation from the RP formula.

Table 9 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
57.5	0.88	1.0	0.94
57.9	0.88	1.0	0.89
58.5	0.88	1.0	0.94
58.9	0.88	1.0	0.89
59.5	0.88	0.50	0.69
59.9	0.88	0.50	0.84
61.5	1.0	0.38	0.69
61.9	1.0	0.38	0.94
62.5	1.0	0.38	0.69
62.9	1.0	0.38	0.94
63.5	1.0	0.74	0.87
63.9	1.0	0.74	0.97
64.5	1.0	0.88	0.94
64.9	1.0	0.88	0.99
65.5	1.0	0.88	0.94
65.9	1.0	0.88	0.99
66.9	1.0	1.0	1.00
68.9	1.0	1.0	1.00
69.5	1.0	0.50	0.75
69.9	1.0	0.50	0.95
71.5	1.0	0.38	0.69
71.9	1.0	0.38	0.94
72.5	1.0	0.38	0.69
72.9	1.0	0.38	0.94
73.5	1.0	0.74	0.87
73.9	1.0	0.74	0.97
74.5	1.0	0.88	0.94
74.9	1.0	0.88	0.99
75.5	1.0	0.88	0.94
75.9	1.0	0.88	0.99
76.5	1.0	1.0	1.00
78.9	1.0	1.0	1.00
79.5	1.0	0.5	0.75
79.9	1.0	0.5	0.95
81.5	1.0	0.38	0.69
81.9	1.0	0.38	0.94
82.5	1.0	0.38	0.69
82.9	1.0	0.38	0.94
83.5	1.0	0.74	0.87
83.9	1.0	0.74	0.97
84.5	1.0	0.88	0.94
84.9	1.0	0.88	0.99
85.5	1.0	0.88	0.94
85.9	1.0	0.88	0.99
86.5	1.0	1.0	1.00
88.9	1.0	1.0	1.00
89.5	1.0	0.5	0.75
89.9	1.0	0.5	0.95
91.5	0.50	0.38	0.44
91.9	0.50	0.38	0.49
92.5	0.50	0.38	0.44
92.9	0.50	0.38	0.49
93.5	0.50	0.74	0.62
93.9	0.50	0.74	0.52
94.5	0.50	0.88	0.69
94.9	0.50	0.88	0.54
95.5	0.50	0.88	0.69
95.9	0.50	0.88	0.54
96.5	0.50	1.0	0.75
96.9	0.50	1.0	0.55
97.5	0.50	1.0	0.75
97.9	0.50	1.0	0.55
98.5	0.50	1.0	0.75
98.9	0.50	1.0	0.55
99.9	0.50	0.5	0.50