# Hydraulic Modeling and Aquatic Habitat Connectivity Study Report

Bradley Lake Hydroelectric Project
Dixon Diversion

FERC No. P-8221

Prepared for:
**Alaska Energy Authority**

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| 2D | two-dimensional |
| ***A*** | |
| ADF&G | Alaska Department of Fish and Game |
| AEA | Alaska Energy Authority |
| ***B*** | |
| Bradley Lake Project | Bradley Lake Hydroelectric Project |
| ***C*** | |
| cfs | cubic feet per second |
| ***D*** | |
| DEM | digital elevation model |
| DSP | Draft Study Plan |
| ***E*** | |
| EF | East Fork |
| ***F*** | |
| FERC | Federal Energy Regulatory Commission |
| ft/s | feet per second |
| ***H*** | |
| HEC-RAS | Hydrologic Engineering Center’s River Analysis System |
| ***I*** | |
| ICD | Initial Consultation Document |
| ***L*** | |
| LiDAR | light detection and ranging |
| ***M*** | |
| MHW | mean high-tide water |

***O***

| | |
|---|---|
| OCH | off-channel habitat |

***R***

| | |
|---|---|
| R | hydraulic radius |
| RM | River Mile |

***S***

| | |
|---|---|
| S | channel gradient |
| SWE-ELM | Shallow Water Equations, Eulerian-Lagrangian Method |

***U***

| | |
|---|---|
| USACE | United States Army Corps of Engineers |
| USGS | United States Geological Survey |

***W***

| | |
|---|---|
| WDFW | Washington Department of Fish and Wildlife |
| WF | West Fork |
| WSE | water surface elevation |

# 1.0 INTRODUCTION

## 1.1 Background

The Alaska Energy Authority (AEA), licensee and owner of the 120-megawatt Bradley Lake Hydroelectric Project (Bradley Lake Project; Federal Energy Regulatory Commission [FERC] No. P-8221), is pursuing a license amendment to gain authorization to divert seasonal meltwater coming from the Dixon Glacier at the headwaters of the Martin River to the Bradley Lake Project to increase power production. The Bradley Lake Project is located on the Bradley River in the Kenai Peninsula Borough northeast of the town of Homer in southcentral Alaska (Figure 1-1).

AEA filed an Initial Consultation Document (ICD) (AEA 2022a) with FERC on April 27, 2022. The ICD described existing facilities and Bradley Lake Project operations, characterized the affected environment, and described two potential project alternatives for producing energy from Dixon Glacier meltwater. Following the ICD filing, AEA hosted Joint Agency and Public Meetings in Homer, Alaska on June 14, 2022, to discuss the ICD and receive stakeholder input. In November 2022, AEA filed a Draft Study Plan (DSP) (AEA 2022b) with FERC based on the two alternatives that outlined ten studies, including the *Hydraulic Modeling, Geomorphology, and Aquatic Habitat Connectivity Evaluation*. Stakeholders filed comments on the DSP in December 2022. AEA briefly paused the FERC amendment process while it conducted additional feasibility studies and narrowed down the potential project alternatives.

Based on further investigations, AEA decided to move forward with diverting Dixon Glacier meltwater to Bradley Lake (Dixon Diversion Project or Project). The potential Project would include construction of a diversion dam near the toe of the Dixon Glacier; an approximately 4.9-mile-long diversion tunnel bored through the mountain extending from Dixon Glacier to Bradley Lake; diverting water from the Martin River basin to Bradley Lake; approximately 1 mile of new, 16-foot-wide, gravel-surfaced access road from the existing Upper Battle Creek diversion access road to the outlet of the proposed diversion tunnel; and modification of the existing Bradley Lake Dam to raise the maximum normal pool elevation currently at 1,180 feet Bradley Lake Vertical Datum by as much as 7, 14, or 28 feet (1,208 feet elevation). The entire Project would be located on State-owned land.

AEA re-initiated the amendment process in 2024 by hosting public meetings in March and April 2024 to review the selected Project alternative, stakeholder comments on the DSP, and proposed modifications to the DSP. Meeting summaries were posted to AEA's Dixon Diversion Project website at Dixon Diversion Project. This report describes the results of the hydraulic modeling and fish habitat connectivity component of the *Hydraulic Modeling, Geomorphology, and Aquatic Habitat Connectivity Evaluation* completed by Kleinschmidt Associates during 2024. A detailed description of the Martin River morphology and sediment dynamics is presented in the Geomorphology and Sediment Transport Study Report (Watershed GeoDynamics 2025).

## 1.2 Modifications from the Draft Study Plan

The hydraulic modeling and fish habitat connectivity component of the *Hydraulic Modeling, Geomorphology, and Aquatic Habitat Connectivity Evaluation* study was implemented as described in the DSP (AEA 2022b).

## 1.3 Project Nexus

The mainstem Martin River originates from the East Fork Martin River near the toe of the Dixon Glacier, flows north approximately 7 miles, and then flows into the eastern portion of Kachemak Bay (Figure 1-1). The river historically drained from the Dixon Glacier and the Portlock Glacier, but glacial retreat has isolated Portlock Glacier runoff; the Martin River now receives water primarily from the Dixon Glacier (CoastView Science 2019, Freethey and Scully 1980). The headwaters of the Martin River are within the Kenai National Wildlife Refuge, which is south of the proposed Project.

Approximately 3.4 miles downstream of the proposed Dixon diversion dam, after a drop in elevation of approximately 900 feet, the East Fork Martin River is joined by the West Fork Martin River, which is fed by Red Lake (a small lake of approximately 25 acres) that discharges into the Martin River from the southwest.

Downstream of the West Fork and East Fork Martin River confluence, the Martin River is braided and meanders approximately 5 miles, dropping 300 feet in elevation to empty into Kachemak Bay. Historically, the Martin River migrated across the large depositional delta that formed at its mouth. Following a large storm event in late-summer 2023, the lower reach of the Martin River avulsed and began flowing through a series of off-channel mitigation ponds, forming a new outlet into the adjacent unnamed basin to the east before entering Kachemak Bay.


**Figure 1-1 Location of proposed Dixon Diversion Project near Kachemak Bay, Alaska.**

Construction and operation of the Dixon Diversion Project would affect flow, surface water elevation, sediment load and transport, and water depth in the East Fork Martin River and mainstem Martin River downstream from the diversion structure. Flow in the Martin River would be reduced when the Dixon Diversion Project is in operation (May-October), potentially resulting in flow-related changes at tributary confluences and off-channel habitat (OCH) [1] features affecting fish access.

Aquatic habitat connectivity is important for fish species that must migrate within the Martin River and require access to OCH to complete their life cycle. The fish community of the Martin River includes nine documented fish species (AEA 2022a). Within this community, some fish species exhibit life history patterns that rely on multiple habitats during spawning and rearing activities and are thus considered more sensitive to changes in access to OCH. Although all fish species that utilize the Martin River were considered for inclusion, a subset of these species and life stages have been identified as the focus of the aquatic habitat connectivity analysis based on their level of use of the Martin River, migration needs (water depth) and timing, and use of OCH to complete their life history (Table 1-1).

**Table 1-1 List of fish species included in the aquatic habitat connectivity evaluation.**

| Focus Species | Focus Life Stages |
|---|---|
| Coho Salmon | Adult and Juvenile Migration |
| Sockeye Salmon | Adult and Juvenile Migration |
| Dolly Varden | Adult and Juvenile Rearing |

Although the conditions for successful passage vary by species and size of individual fish, there is a general agreement that upstream movement of adult salmon may be impaired when water depths fall below 0.7 feet (Powers and Orsborn 1985, Bjornn and Reiser 1991, R2 Resource Consultants, Inc. 2008). For resident fish species (Dolly Varden) and juvenile salmon, a minimum water depth of 0.3 feet is generally considered necessary to provided unrestricted access to habitat (Bugert et al. 1991, CDFW 2017, ADFG 2001)

To determine water depth at a series of minimum flow releases under consideration by AEA, two-dimensional (2D) numerical hydraulic modeling was used to investigate how fish passage conditions vary. 2D models can simulate the spatial distribution of depth and velocity in streams or rivers and they are frequently used to assess relationships between

[1] Unless otherwise specified, OCH refers to off-channel and tributary habitats.

discharge and parameters of ecological relevance (Elkins et al. 2007, Clark et al. 2008, Harrison et al. 2011, Grantham 2013). Hydraulic model predictions of the spatial distribution of water depths and minimum fish passage criteria were combined to assess habitat connectivity in relation to discharge under three potential flow scenarios: 100 cubic feet per second (cfs), 150 cfs, and 200 cfs.

# 2.0 GOALS AND OBJECTIVES

The goal of this study was to evaluate the effects of the proposed Dixon Diversion Project on water depth and aquatic habitat connectivity within mainstem and off-channels.

The specific objectives of the study were as follows:

- Develop a hydraulic model to predict water depth in mainstem and off-channel connectivity locations under three potential Dixon Diversion Project minimum flow release scenarios – 100 cfs, 150 cfs, and 200 cfs.
- Apply the hydraulic model to estimate the water depth along the mainstem to analyze longitudinal connectivity (i.e., maintain adequate water depths in the main channel of the Martin River).
- Apply the hydraulic model to estimate water depth in the vicinity of the mainstem and OCH locations under the three flow release scenarios.
- Using fish passage depth criteria, evaluate the potential changes to habitat connectivity for adult and juvenile Sockeye Salmon (*Oncorhynchus nerka*), Coho Salmon (*O. kisutch*), and Dolly Varden Trout (*Salvelinus malma*) under each of the minimum flow release scenarios.

# 3.0 STUDY AREA

The study area included the mainstem Martin River and associated OCH connectivity locations from approximately the mean high-tide water (MHW) elevation to the confluence of the West Fork and East Fork of the Martin River. The confluence of the West Fork and East Fork Martin rivers is assumed to define the upstream most extent of salmon migration within the Martin River due to high water velocity, coarse substrate, and lack of suitable spawning habitat. An initial list of eight OCH connectivity locations were identified, shown in pink squares in Figure 3-1. The OCH connectivity locations were selected based on an assumption of likely fish use during the period of anticipated Project operations (May-October).

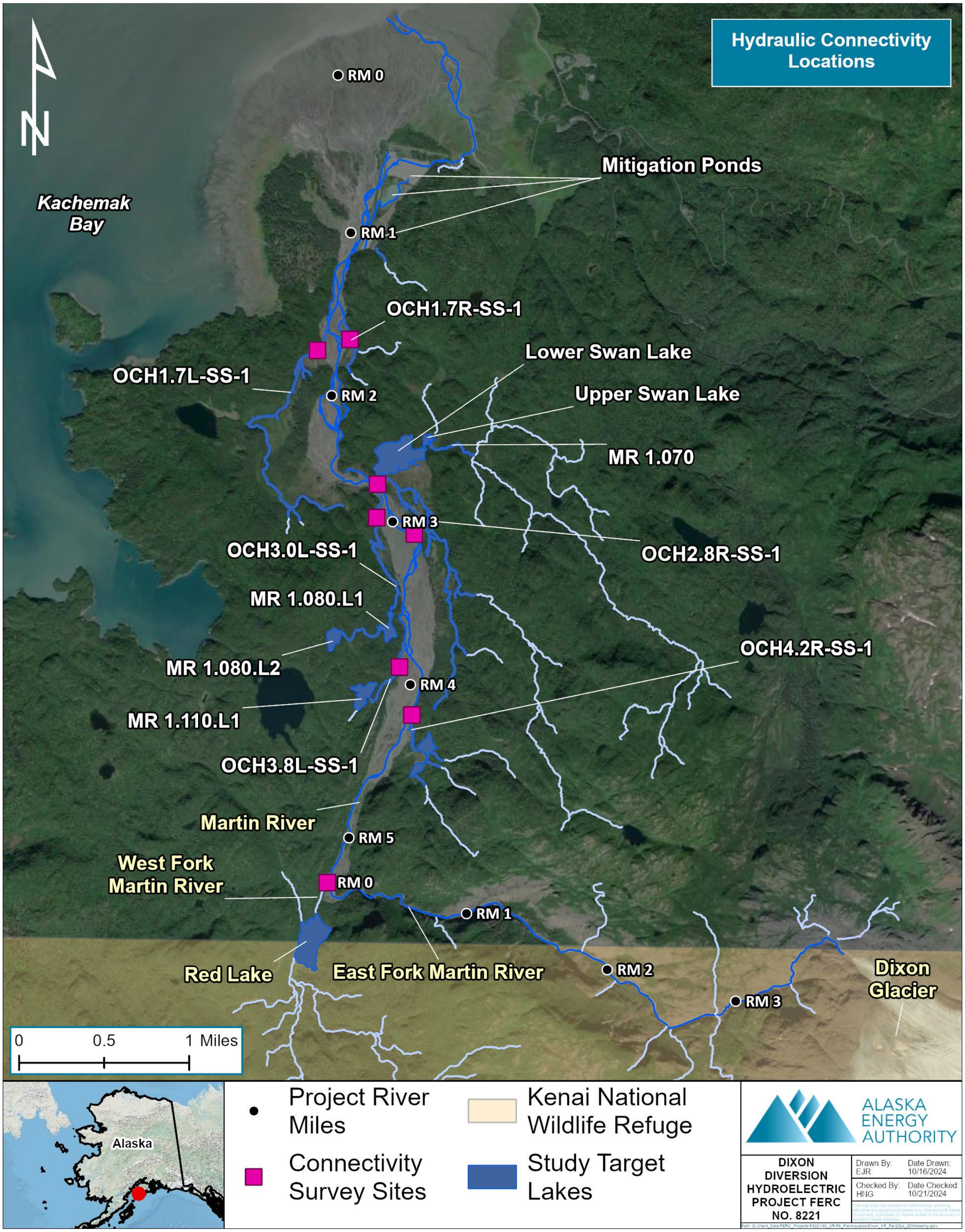


**Figure 3-1 Location of hydraulic connectivity surveys, Martin River, Alaska.**

# 4.0 METHODS

## 4.1 Development of Two-Dimensional Hydraulic Model

A 2D, fixed-bed hydraulic model was used to evaluate potential Project-related fish passage and connectivity effects downstream of the confluence of the East and West forks of the Martin River. Figure 4-1. illustrates the 2D hydraulic model area. The model extent is shown in the irregular orange polygon. The blue segments represent the inflow hydrograph and outflow water surface elevation (WSE) boundaries. The thalweg of the river is delineated in yellow. The four green circles represent stream flow gaging locations. Swan Lake is an off-channel area at approximately river mile (RM) 2.75 on the right side of the channel (looking downstream). The flow gaging station labeled Constriction is the downstream most gage representing flow contributions from the Mid-Reach, West Fork, and East Fork Martin inflow monitoring sites (Figure 4-1).The East Fork Martin River flow gage represents the quantification point flow originating from the Dixon Glacier.

The mainstem Martin River is braided with multiple channels below the West Fork Martin River confluence, but all flows converge as a single channel (Figure 4-1) at the Constriction at approximately RM 1.9.

The following is a list of field data used in the 2D model development that includes data collected during this study and other studies conducted by AEA:

- Aerial photos from May 2 to May 4, 2024 (NV5 2024).
- Digital elevation model (DEM) from the Light Detection and Ranging (LiDAR) flown between May 2 and May 4, 2024 (NV5 2024).
- DOWL ground survey on May 3, 2024.
- DOWL flow measurements on May 3, 2024.
- Kleinschmidt ground survey between May 4 and May 7, 2024.
- Kleinschmidt tributary flow measurements between April 30 and May 7, 2024.
- Watershed GeoDynamics (2025) pebble count survey in April and May 2024.

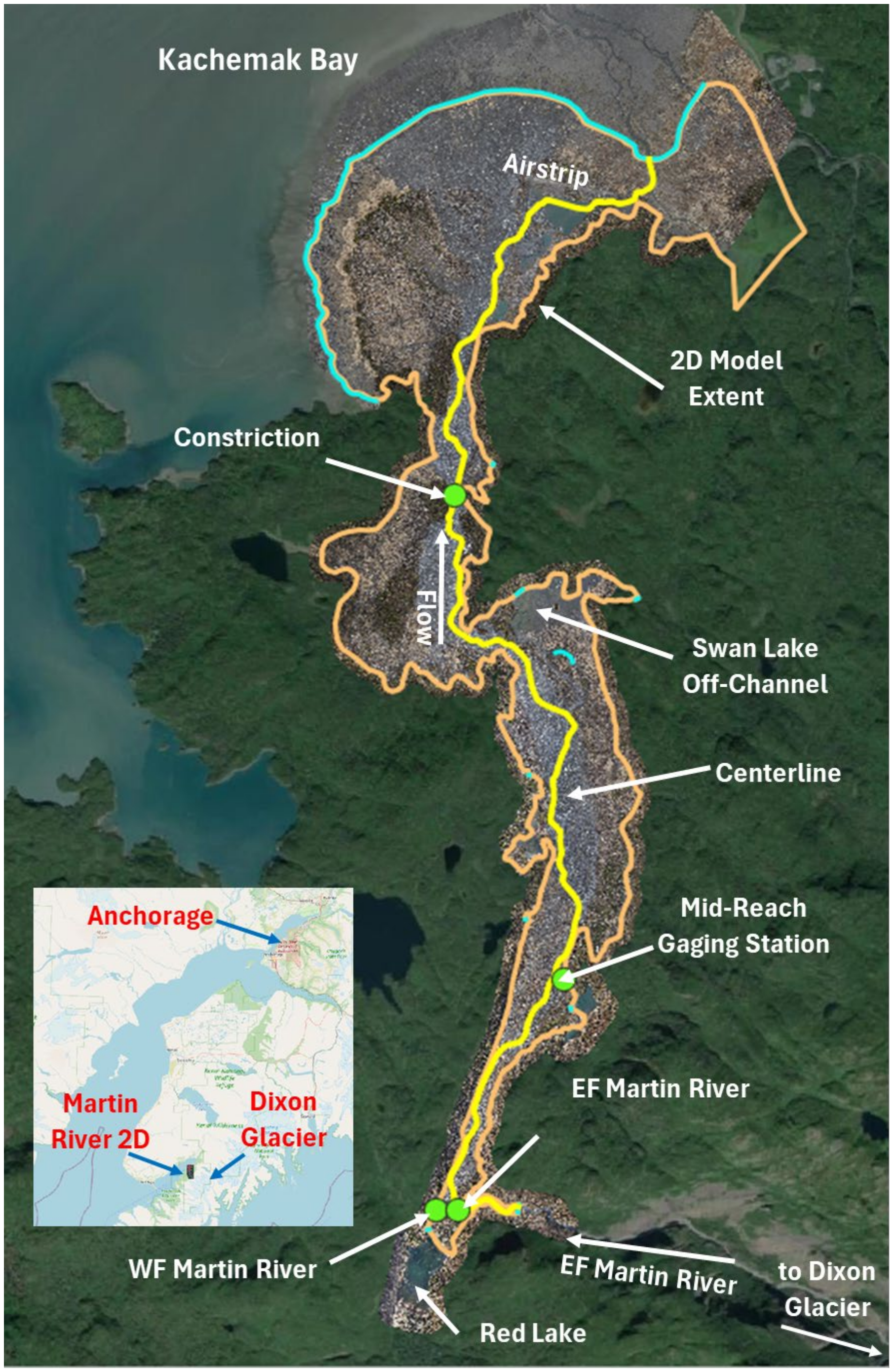


**Figure 4-1 General area of the Martin River 2D hydraulic model.**

### 4.1.1 LiDAR and Topobathymetric Ground Survey

LiDAR were collected in both 2022 and 2024; however, the 2024 survey used water penetrating topobathymetric technology that allowed for high resolution mapping of the complexity of the Martin River channels during low stream flow and clear water conditions. LiDAR and digital aerial imagery were collected simultaneously from May 2 to May 4, 2024 (NV5 2024) for the Martin River valley floor.

### 4.1.2 DEM Creation

The 2024 DEM included the Martin River valley floor (NV5 2024) while the previous LiDAR survey (NV5 2023) included higher elevations within the river basin. The 2024 DEM was merged with 2022 LiDAR for areas above the valley floor, resulting in a combined DEM with 1-foot resolution that covered an extent much larger than the 2D hydraulic model extent.

The elevation datum of the combined DEM was the Bradley Lake Vertical Datum and the horizontal projection was in Alaska State Plane Zone 4. The same elevation datum and projection were used throughout this report unless specified otherwise.

In addition to the elevation from the DEM, DOWL and Kleinschmidt conducted ground elevation surveys during the same period when the bathymetric LiDAR was flown. DOWL surveyed 1,081 points for channel profiles, edge of water and adjacent overbank. Kleinschmidt surveyed 1,094 ground points during a 6-day period from May 2 to May 7, 2024 (Figure 4-2). Comparison of both ground surveys with the DEM indicated the elevation differences were within 0.25 feet for about 85 percent of the points. The comparisons indicated that the 2024 DEM was in general agreement with the ground survey by DOWL and Kleinschmidt, and therefore no modifications were made to the DEM.

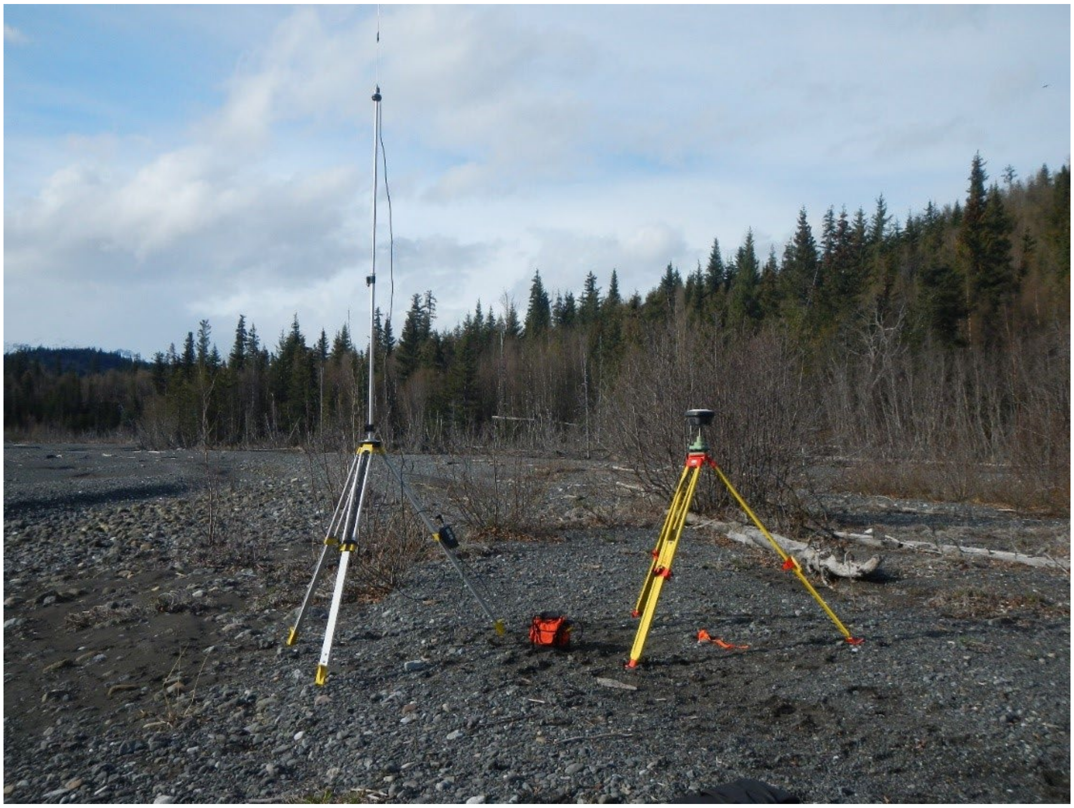

**Figure 4-2 Example of real time kinetic/global positioning system used for ground control surveys of the Martin River.**

### 4.1.3 Channel Substrate

Wolman pebble count surveys were conducted at 21 locations by Watershed GeoDynamics in 2024, including one site on the West Fork Martin River, one site on the East Fork Martin River, and 19 sites on the Martin River. Substrate classes ranged from large cobble in the East Fork Martin River to gravel at the mainstem Constriction (RM 1.9) and below. The variation of substrate sizes was consistent with the slope of the longitudinal bed profile along the East Fork Martin River and mainstem Martin River (Figure 4-3). The slope was relatively steep (2.3 percent) on the East Fork Martin River, gradually decreasing to 1 to 1.5 percent between the West Fork Martin River confluence and the Constriction. Below the Constriction, the slope of the Martin River was 0.7 percent or less (Figure 4-3).

Figure 4-4 shows the longitudinal bed profile of the West Fork Martin River from the Red Lake outlet to the confluence with the Martin River. The channel below the outlet was approximately 1,200-feet-long and the dominant substrate class was cobble (Watershed GeoDynamics 2025). The channel slope varied within this relatively short reach but was relatively gentle in the upstream half at 0.1 to 1.1 percent and relatively steep in the lower half at approximately 2.6 percent.

The pebble count results were used to estimate channel roughness because streambed substrate sizes are an indication of channel bed roughness. A pebble count location was considered representative of bed roughness for a stream length from the midway to its upstream pebble count location to the midway to its downstream pebble count location.

Watershed GeoDynamics (2025) characterized the Martin River valley floor and the surrounding high ground with different geomorphic units to represent different geomorphic types, such as active channels, open water, and vegetation of different canopy types and heights. Those geomorphic units were grouped into 55 land cover types such as active channel, open water, and forest with vegetation of various height categories. Each land cover was then assigned a specific surface roughness in expression of Manning's *n* value based on literature review and the empirical equation described in Section 4.1.5.2.5, *Channel Roughness*.

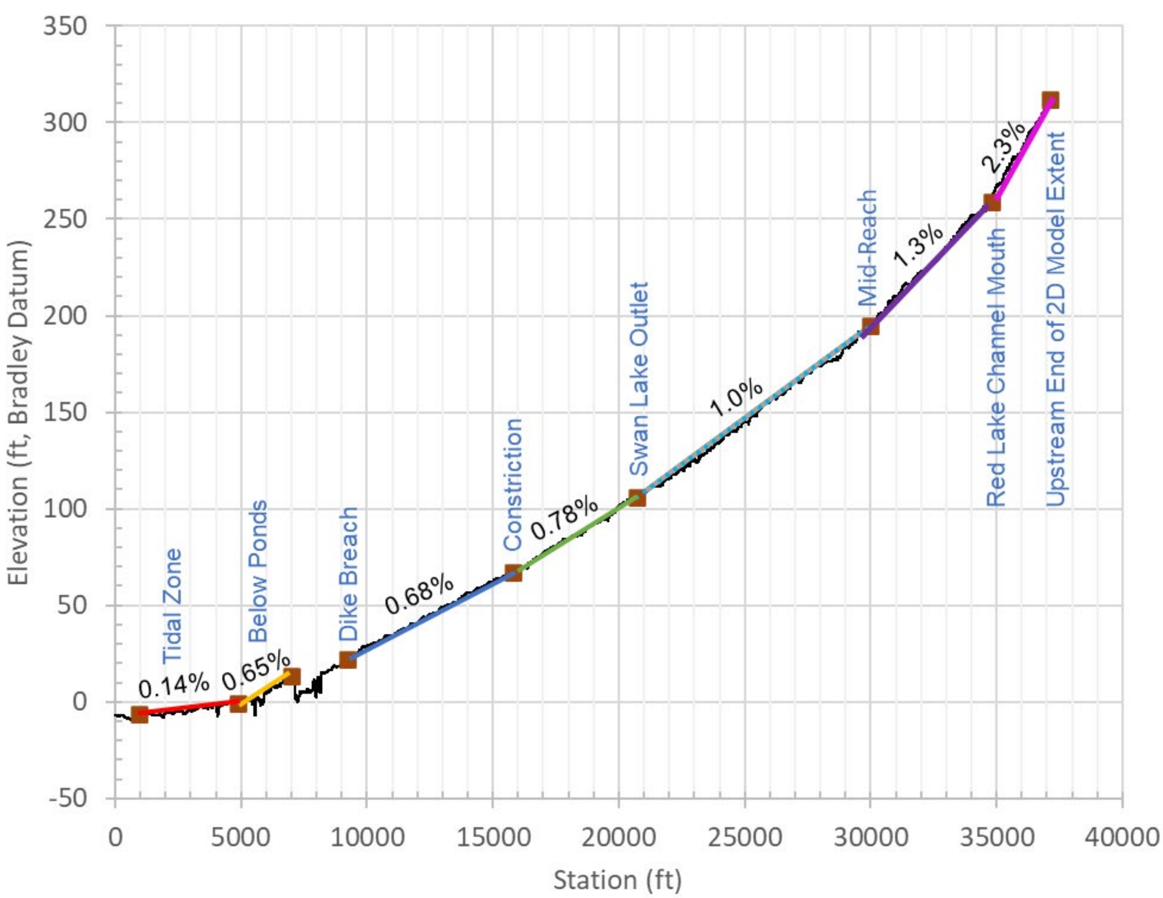


**Figure 4-3 Longitudinal channel profile of the East Fork and Martin Rivers.**

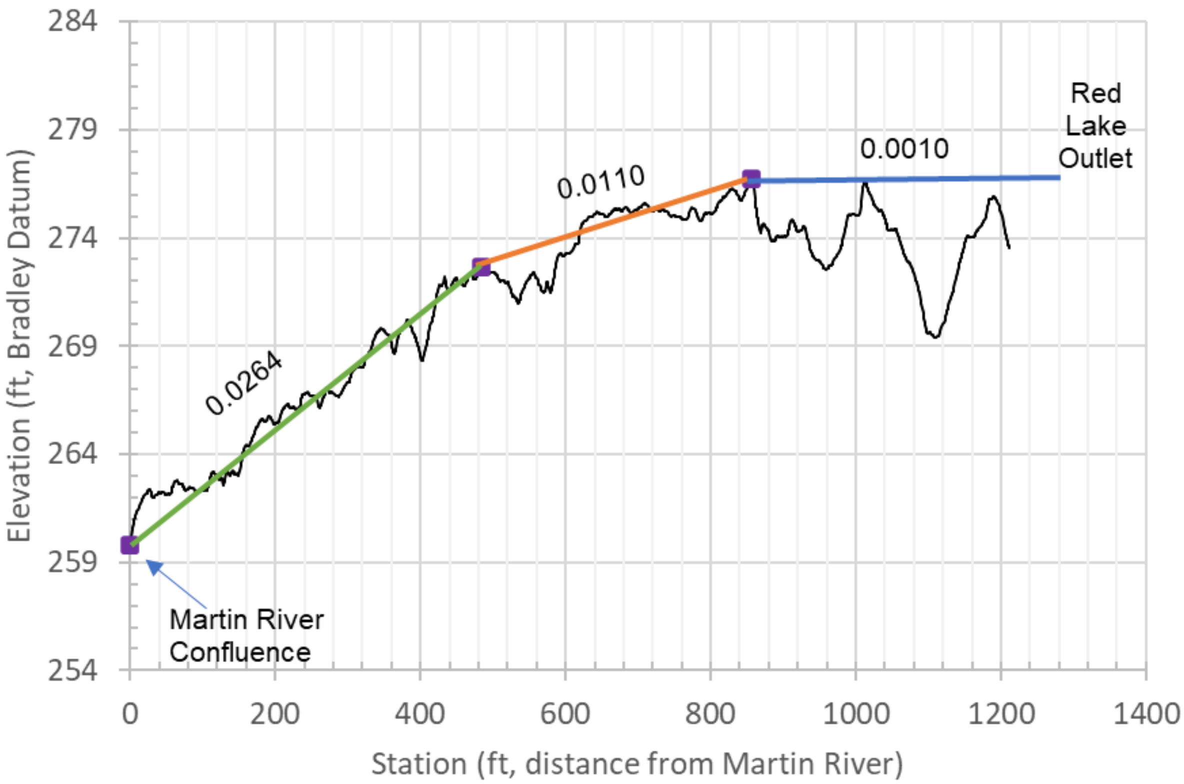


**Figure 4-4 Longitudinal channel profile of the West Fork Martin River.**

### 4.1.4 Hydrology/Flow Measurements

Four gaging stations located within the 2D model extent provided instantaneous WSE or flow records for partial periods in 2023 and 2024. The gages are listed below and illustrated in green circles in Figure 4-1.

- East Fork Martin River gage (EF Martin River RM 0.1).
- West Fork Martin River gage (WF Martin River RM 0.1).
- Mid-Reach gage (located on OCH 4.2R-SS-1 at MR RM 4.2).
- Martin River Constriction gage (MR RM 1.9).

The gage on the East Fork Martin River is operated by the United States Geological Survey (USGS Gage No. 15238951) with only WSE data available. The remaining three gages were operated by AEA, all with WSE and flow data.

Channel flows were measured on May 3, 2024 along transects at the four flow monitoring sites as follows.

- East Fork Martin River: approximately 200 feet upstream of the gaging station.

- West Fork Martin River: immediately adjacent to the gaging station.
- OCH4.2R-SS-1 Mid-Reach: approximately 40 feet upstream of the gaging station.
- Martin River Constriction: approximately 580 feet downstream of the gaging station.

Discharge was also measured at the following six off-channel locations between April 30 and May 7, 2024 (Figure 4-5):

- OCH3.8L-SS-1
- OCH3.0L-SS-1
- OCH2.8R-SS-1
- OCH2.8R-SS-1.060
- MR1.070
- OCH1.7R-SS-1

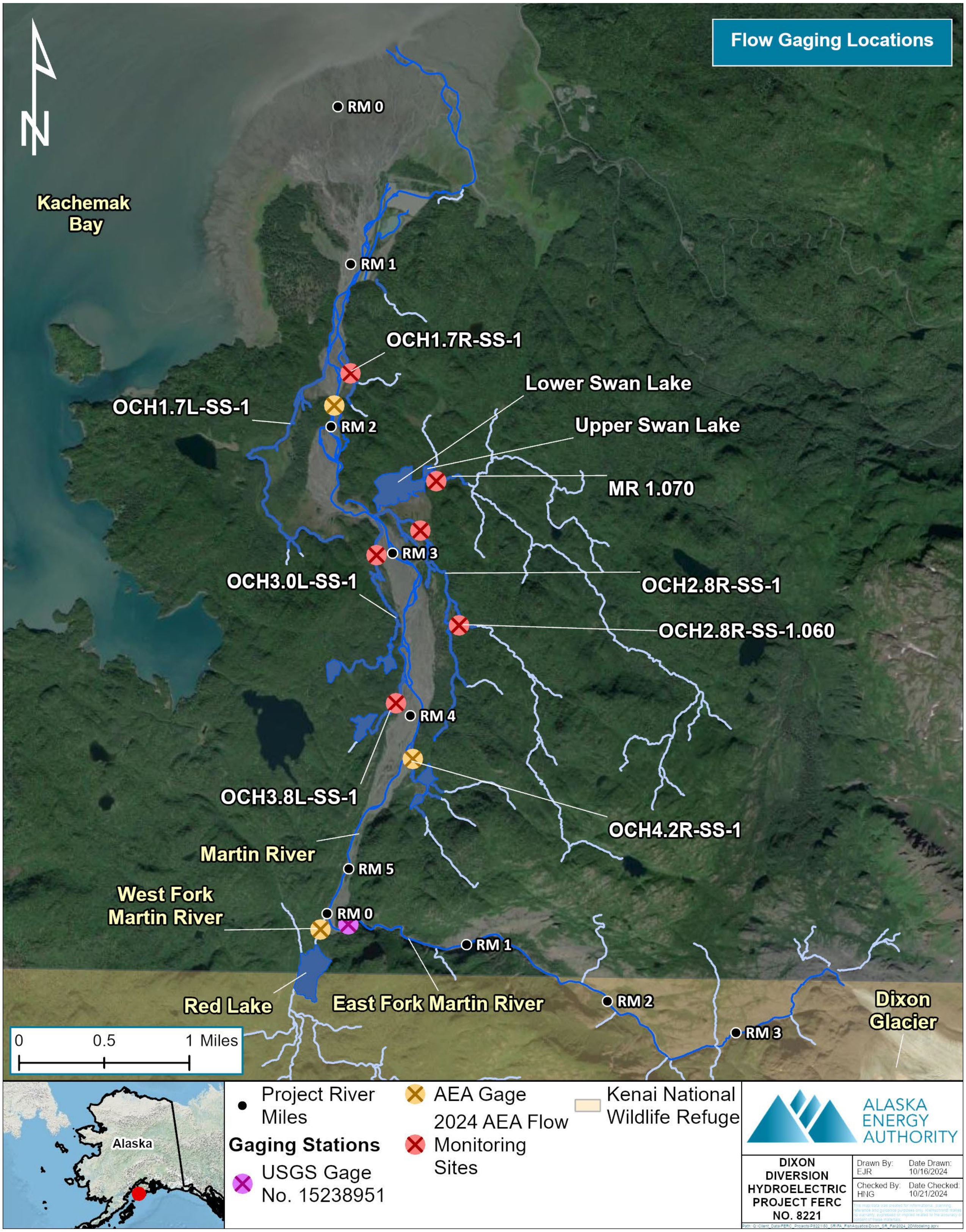


**Figure 4-5 Location of 2024 mainstem Martin River and off-channel flow gaging sites.**

### 4.1.5 Hydraulic Modeling

Hydraulic modeling was conducted using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) Version 6.5, a computer software developed by the U.S. Army Corps of Engineers (USACE 2024) for simulating hydraulics of natural and constructed channels. The model simulation used a 2D depth-averaged, unsteady flow approach with Shallow Water Equations and Eulerian-Lagrangian Method (SWE-ELM) equation set. The model domain, shown as the irregular light-orange color in Figure 4-1, covered an area of approximately 2.84 square miles from about 0.3 miles upstream of the USGS gage on the East Fork Martin River to the outlet of the Red Lake to the beach of Kachemak Bay. No groundwater accretion or depletion was considered in the 2D hydraulic model.

#### 4.1.5.1 Geometry

The model domain was meshed into computational cells of different sizes depending upon local hydraulic conditions. For areas expected to have rapid changing hydraulics, such as major waterways, the cells were generally smaller in size ranging between 5 feet and 8 feet. For areas with slower changing hydraulics, the cell sizes were mostly larger in the range of 30 feet. The mesh network had a total of about 170,000 cells.

Breaklines were used to facilitate mesh network development. A breakline is a line string delineated along the centerline or thalweg of a waterway to help ensure the mesh cells are adequate in size and oriented in the dominant flow direction to better capture the stream hydraulics. A total of 54 breaklines were delineated along the major and tributary channels.

#### 4.1.5.2 Model Calibration

Model calibration consisted of applying measured flows and WSEs on the model boundary with appropriate surface roughness (i.e., Manning's *n* value) for different geomorphic units within the model domain to reproduce the measured hydraulics.

##### 4.1.5.2.1 Boundary Conditions

Boundary conditions are the driving forces of the hydraulics inside the model domain. There were 11 boundary lines set up to account for the discharges and WSE, including: 1) 9 flow hydrograph boundaries for water entering the model domain; 2) 1 artificial flow hydrograph boundary at Swan Lake, an off-channel area near RM 2.75 on the right side of the channel, to help ensure the inflow and outflow of the lake were equal; and 3) an outflow WSE boundary at the downstream end of the model on the beach of Kachemak Bay. Boundary lines are shown in blue in Figure 4-1.

#### 4.1.5.2.2 Inflows

The discharge measured at the four flow monitoring transects on May 3, 2024 were as follows:

- East Fork Martin River: 57 cfs.
- West Fork Martin River: 37 cfs.
- OCH 4.2R-SS-1 Mid-Reach: 2.6 cfs.
- Martin River Constriction: 121 cfs.

Off-channel flow measurements spanned 8 days from April 30 to May 7. Discharge by location is presented below.

- OCH3.8L-SS-1: 0.40 cfs on April 30, 2024.
- OCH3.0L-SS-1: 3.4 cfs on April 30, 2024.
- OCH2.8R-SS-1: 11.2 cfs on May 3, 2024.
- OCH2.8R-SS-1.060: 6.2 cfs on April 30, 2024.
- MR1.070: 17.6 cfs on May 3, 2024.
- OCH1.7R-SS-1: 1.1 cfs on May 7, 2024.

It was not feasible to measure all off-channel flows on May 2, the date most LiDAR was flown. However, mainstem Martin River flow conditions were monitored during the survey period and were relatively stable; thus, it was assumed that tributary discharges remained relatively stable over the 8-day period. Note that OCH2.8R-SS-1.060 was located upstream of OCH2.8R-SS-1, so only the latter was considered in model calibration.

Summing discharge measurements from locations upstream of the Constriction (RM 1.9) resulted in a total discharge estimate at the Constriction of 129.2 cfs. This flow is 8.2 cfs higher than the measured flow of 121 cfs just below the Constriction. The difference may be attributed to the Swan Lake off-channel area that had a potential to mitigate the flow entering and exiting the lake (RM 2.75). As a result, the OCH2.8R-SS-1 flow was changed in the model calibration to 3 cfs from the measured 11.2 cfs to make up the difference in flow at the Constriction.

In addition to the flows listed above, an artificial inflow was applied to Swan Lake. This setup was designed to fill up the lake storage to ensure the combined inflows of MR 1.070 and OCH2.8R-SS-1 matched the outflow at the lake outlet. This artificial inflow estimate was larger in the initial simulation but was reduced to virtually 0 cfs once inflow and outflow were the same. The flows used in the model calibration are summarized in Table 4-1.

**Table 4-1 Flows used in model calibration and application runs.**

| Run | East Fork Martin River | West Fork Martin River | OCH 4.2R-SS-1 Mid-Reach | Other Tributaries Combined | Total Flow at Constriction |
|---|---|---|---|---|---|
| | (cfs) | (cfs) | (cfs) | (cfs) | (cfs) |
| Calibration | 57 | 37 | 2.6 | 24.4[a] | 121 |
| Fall Flow Release | 100 | 1.7[b] | 0.5[b] | 0[c] | 102.2 |
| | 150 | 1.7 | 0.5 | 0 | 152.2 |
| | 200 | 1.7 | 0.5 | 0 | 202.2 |
| Spring Flow Release | 100 | 11.3[d] | 0.6[d] | 8.7[e] | 120.6 |
| | 150 | 11.3 | 0.6 | 8.7 | 170.6 |
| | 200 | 11.3 | 0.6 | 8.7 | 220.6 |

a Included 17.6 cfs from MR1.070; 0.4 cfs from OCH3.8L-SS-1; 3 cfs from OCH2.8R-SS-1; and 3.4 cfs from OCH3.0L-SS-1, measured around the period during the 2024 LiDAR survey.

[b] 7-day low flow during peak fall (September 1 – October 31) spawning period

[c] Assuming no flow from other tributaries in the three fall flow releases modeled.

[d] 7-day low flow during peak spring/summer (June 8-27) spawning period

[e] Estimated combined tributary flow above Constriction, excluding WF Martin River and OCH 4.2R-SS-1, during peak spring (June 8-27) spawning period

#### 4.1.5.2.3 Water Surface Elevations

Measured WSE at the flow transects used in the model calibration are listed below.

1. East Fork Martin River: 283.28 feet. This elevation was measured at the transect located approximately 200 feet upstream of the USGS gage.
2. West Fork Martin River: 276.99 feet. This WSE was measured on the West Fork Martin River flow transect next to the gage.
3. Martin River Constriction: 65.37 feet. This elevation was estimated using the surveyed WSEs at the water edge of the two bounding cross-sections from DOWL's ground survey described in Section 4.1.2, *DTM Creation*. Because the transect was located between the two cross-sections, a linear interpolation of the WSEs of the four water edge points (two on each transect) was used for the WSE of the flow

transect. The upstream cross-section was 201 feet to the transect and the downstream cross-section was 106 feet from the transect.

#### 4.1.5.2.4 Outflow Boundary

An outflow boundary allows water to leave the 2D model area and was set as a fixed WSE on the beach of Kachemak Bay. An elevation of 3.38 feet was estimated to indicate the MHW for the boundary WSE based on the location where the color of the beach changed noticeably per the aerial photos from July 2022 (NV5 2023). This elevation is about 700 feet to the tree line at elevation of approximately 9 to 10 feet. It was not expected that the uncertainty of the boundary condition would significantly affect the hydraulics upstream of the mitigation ponds.

#### 4.1.5.2.5 Channel Roughness

Multiple empirical equations (e.g., Jarrett 1985, Limerinos 1980, Henderson 1966) and publications (e.g., Chow 1959, Arcement and Schneider 1989, Barnes 1967, Warnk 2018, Fasken 1963) were studied to estimate channel roughness (in Manning's *n* values) for different regions of the modeling area. After evaluating all options, it was determined that Jarrett's equation was the most suitable for the Martin River.

Jarrett's equation requires channel gradient (S) and hydraulic radius (R) to estimate Manning's *n*. Because R was not available when starting the calibration, an iterative process was set up to loop calibration runs and R values until the latter became stable.

#### 4.1.5.2.6 Model Calibration Result

The hydraulic model was calibrated to the water surfaces at the three flow-transects: East Fork Martin River, West Fork Martin River, and just below the Martin River Constriction. The calibration errors, the difference between measured WSEs and simulated WSEs, were all very small and no more than 0.02 feet. The small errors suggested the calibrated model was able to adequately reflect the hydraulic conditions of flows of similar magnitude.

- East Fork Martin River flow transect: WSE calibration error was 0.01 feet.
- West Fork Martin River flow transect: WSE calibration error was 0.02 feet.
- Martin River Constriction flow transect: WSE calibration error was 0.00 feet.

Figure 4-6 illustrates the calibrated Manning's *n* values for the model area; the n values by land cover type are presented in Table 4-2. Figure-4-7 and Figure 4-8 show the modeled water depth and velocity maps, respectively. The velocity was generally below 3 feet per second (ft/s) and the water depth was greater than 0.7 feet for most of the mainstem.

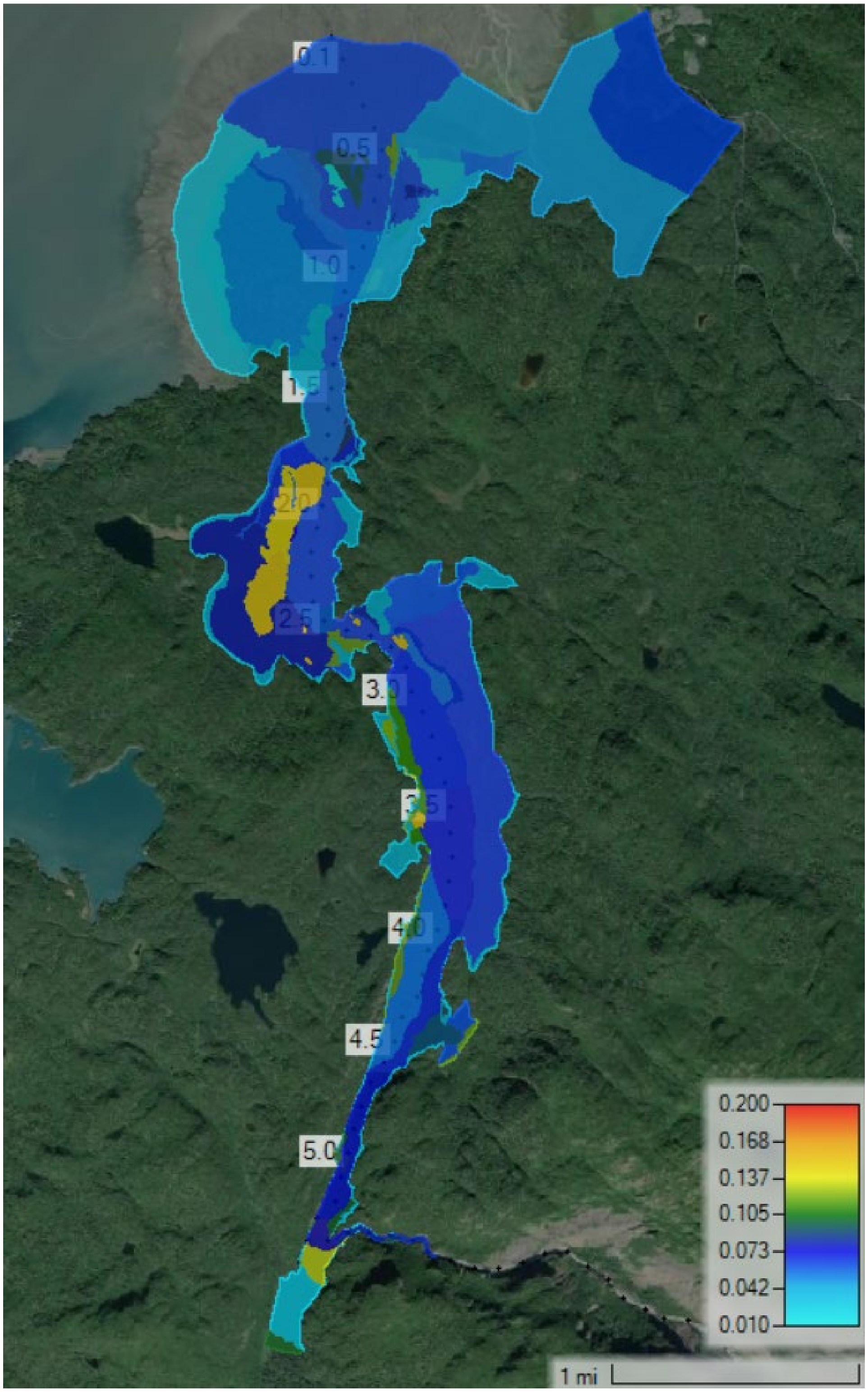


**Figure 4-6 Surface roughness map in Manning's *n* values for the Martin River 2D hydraulic model area.**

**Table 4-2 Manning's *n* values for different land cover types in the Martin River 2D hydraulic model area.**

| Type | Landcover Description | Manning's *n* |
|---|---|---|
| 1 | Upland | 0.15 |
| 2 | Forested to 50+ feet with active channels | 0.045 |
| 3 | Vegetated to 40 feet | 0.12 |
| 4 | Vegetated to 15 feet | 0.09 |
| 5 | Vegetation to 15 feet | 0.09 |
| 6 | Vegetation to 5 feet | 0.075 |
| 7 | Vegetated sparse to 50 feet | 0.11 |
| 8 | Vegetated to 20 feet | 0.10 |
| 9 | Vegetated to 10 feet | 0.08 |
| 10 | Vegetated to 5 feet | 0.075 |
| 11 | Canyon fan; vegetated to 50 feet | 0.13 |
| 12 | Red Lake upstream fan; vegetated to 40 feet | 0.10 |
| 13 | Red Lake | 0.022 |
| 14 | Fan to off-channel area; vegetated to 20 feet | 0.09 |
| 15 | Off-channel open water | 0.055 |
| 16 | Vegetated with clear water channels | 0.06 |
| 17 | Forested with active channels | 0.05 |
| 18 | Tidelands | 0.025 |
| 19 | Off-channel connectivity corridor | 0.04 |
| 20 | Red Lake connectivity corridor-mid | 0.066 |
| 21 | Vegetated to 30 feet | 0.11 |
| 22 | Open water off-channel area | 0.035 |
| 23 | Vegetated to 50 feet | 0.15 |
| 24 | Vegetated sparce to 40 feet | 0.12 |
| 25 | Side channel – active | 0.045 |
| 26 | Older active channel | 0.055 |
| 27 | Vegetated to 15 feet with many small channels | 0.08 |
| 28 | Sparce vegetation | 0.07 |
| 29 | Forested to 50 feet with active channels | 0.055 |
| 30 | Sparce vegetation to 40 feet | 0.012 |
| 31 | Active channel 2024, 07D | 0.064 |
| 32 | Vegetated to 40 feet with many small channels | 0.07 |
| 33 | Active channel 2024, 01D | 0.057 |
| 34 | Active channel 2024, 02 | 0.058 |
| 35 | Active channel 2024, 03 | 0.057 |
| 36 | Active channel 2024, 04 | 0.057 |
| 37 | Active channel 2024, 05D | 0.06 |

| Type | Landcover Description | Manning's *n* |
|---|---|---|
| 38 | Active channel 2024, 06 | 0.064 |
| 39 | Active channel 2024, 07D, side channel | 0.064 |
| 40 | Active channel 2024, 10 | 0.08 |
| 41 | Active channel 2024, 09U | 0.08 |
| 42 | Active channel 2024, 8, side channel | 0.052 |
| 43 | Active channel 2024, 8 | 0.071 |
| 44 | Former pond | 0.03 |
| 45 | Active channel 2024, 01U | 0.054 |
| 46 | Active channel 2024, 05U | 0.059 |
| 47 | Active channel 2024, 07U | 0.066 |
| 48 | Active channel 2024, 09D | 0.072 |
| 49 | Active channel 2024, 00 | 0.045 |
| 50 | Dike | 0.03 |
| 51 | Beach | 0.025 |
| 52 | Semi-forested | 0.065 |
| 53 | Upper pond | 0.025 |
| 54 | Red Lake connectivity corridor_upper | 0.031 |
| 55 | Red Lake connectivity corridor_lower | 0.095 |

The model was run for 16 simulation hours with 1 second computation time interval. The first 4 hours were designed to ramp up inflow hydrographs from very low to the calibration flow, followed by 12 hours of the same flow to ensure the modeled hydraulics reached quasi-steady solution at the end of the simulation. Courant numbers concerning solution accuracy and numerical stability were mostly below 0.5, well below a maximum value of 3.0 in the HEC-RAS manual for the SWE-ELM model solver (USACE 2024).

#### 4.1.5.2.7 Mesh Size Sensitivity

A model run was conducted to assess the sensitivity of the simulated hydraulics to the mesh cell size. The cell size along the main channel centerline was reduced from 5 feet to 3 feet; the size reduction resulted in a WSE difference of about 0.01 feet at the East Fork Martin River, West Fork Martin River, and Martin River Constriction flow transects. This insignificant WSE change suggested the mesh size of 5 feet in the main channel was adequate.

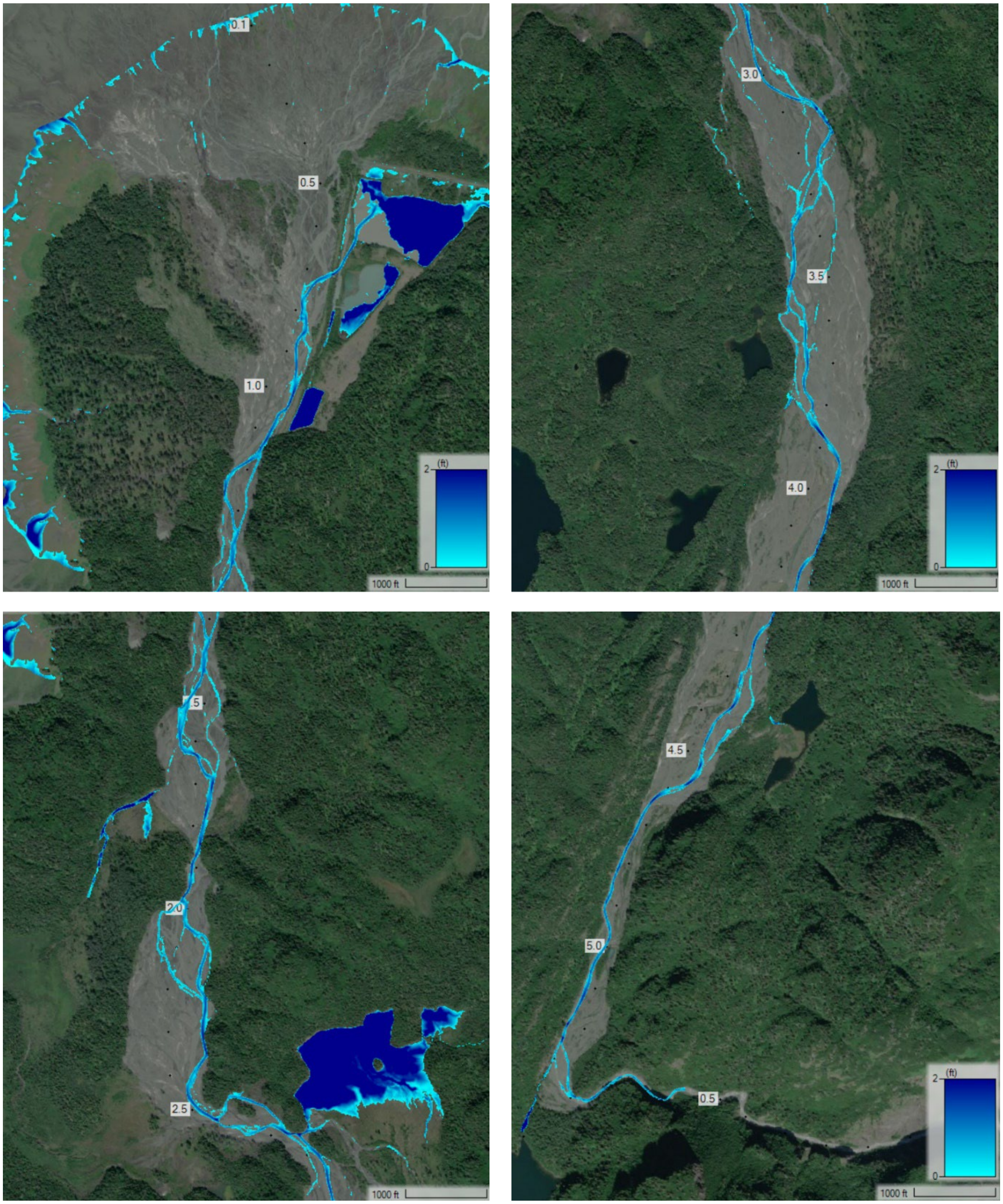


**Figure-4-7 Water depth maps for the model calibration run.**

**Figure 4-7 Notes**: Water depths of 2 feet and greater are shown with the same color (dark blue). The four maps, from top to bottom and left to right, represent the stream's reaches from downstream to upstream. The numbers in white boxes indicate the RM.

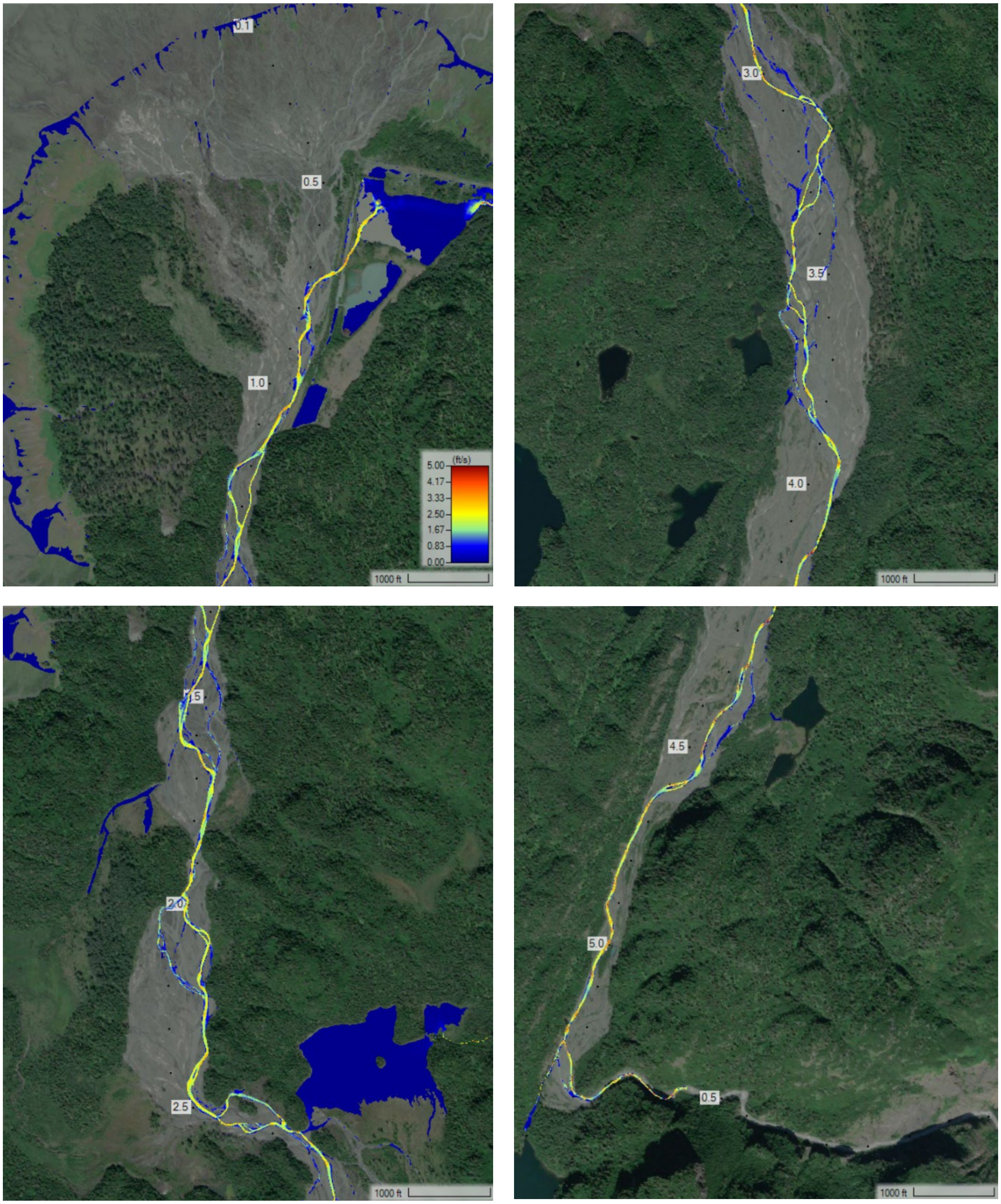


**Figure 4-8 Velocity maps for model calibration run.**

**Figure 4-8 Notes:** Velocity of 5 ft/s and greater is shown with the same color (red). The four maps, from top to bottom and left to right, represent the stream reaches from downstream to upstream. The numbers in white boxes indicate the RM.

#### 4.1.5.3 Hydraulic Model Application

The calibrated model was used to simulate hydraulics for the three flow releases from the East Fork Martin River: 100 cfs, 150 cfs, and 200 cfs. Each flow release was used with the 7-day low flows from the West Fork Martin River and the Martin River Mid-Reach. No other off-channel flows were included in the three model application runs (Table 4-1).

##### 4.1.5.3.1 7-Day Low Flow

Flow records at West Fork Martin River, Mid-Reach, and the Constriction are available for 2023 (Figure 4-9) and 2024 (Figure 4-10). The flows were recorded every 15 minutes and the daily flow was calculated by averaging the flow records of each day. Then, the average flow of 7 consecutive days was calculated for the middle day of the 7 days. The 7-day flow time series was then compared with fish use timing (Section 4.2.1) to determine the lowest flow during the period when fish were present as the 7-day low flow, summarized in Table 4-1.

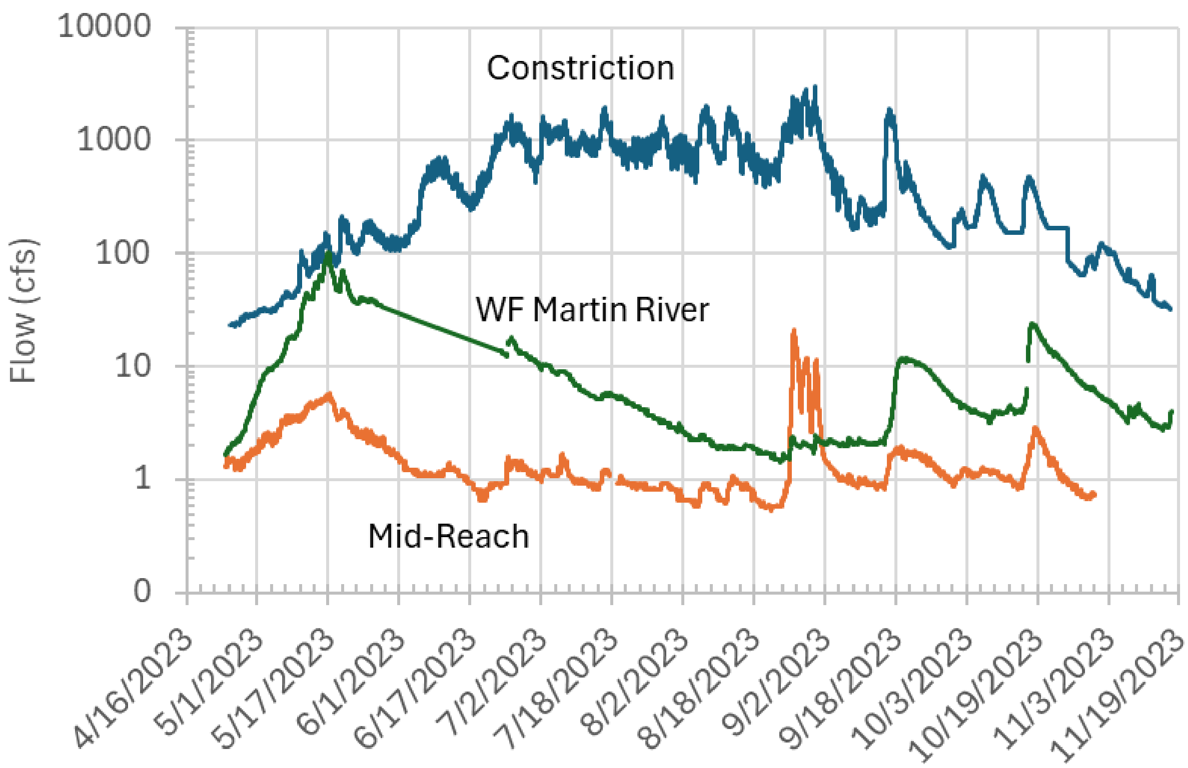


**Figure 4-9 Flow time series for 2023 at West Fork Martin River, Mid Reach, and the Martin River Constriction at RM 1.9.**

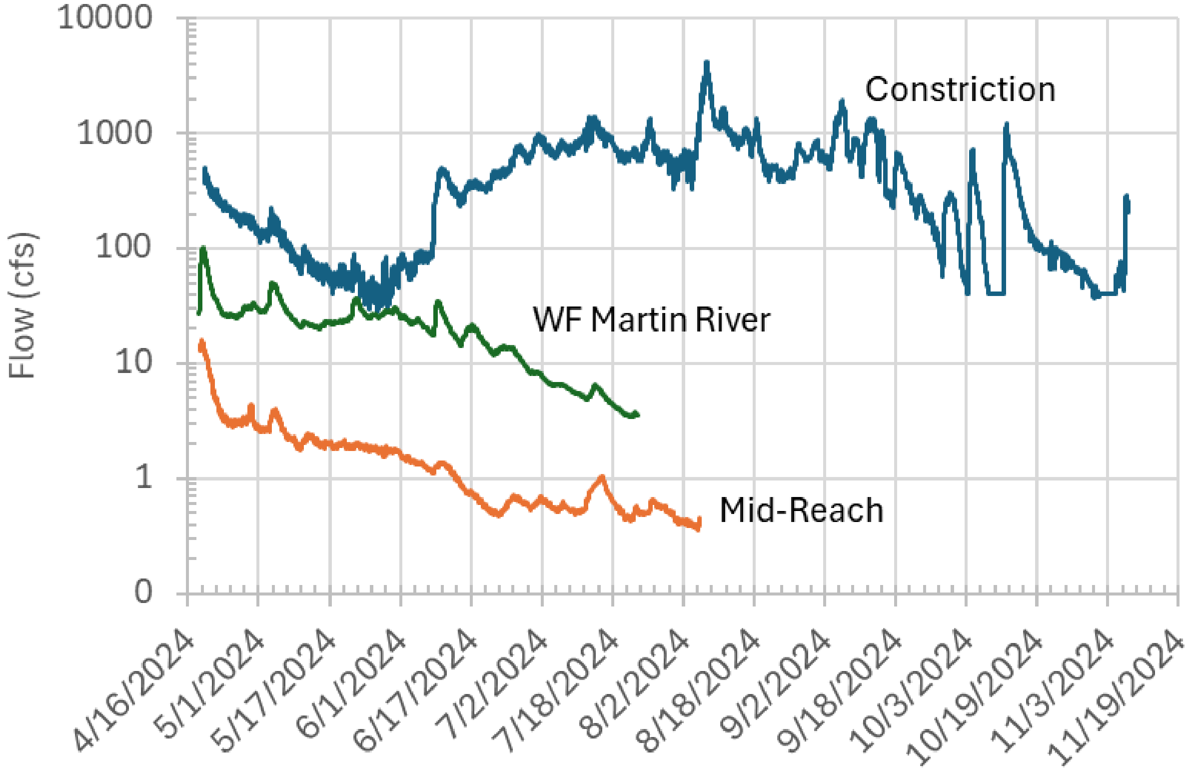


**Figure 4-10 Flow time series for 2024 at West Fork Martin River, Mid Reach, and the Martin River Constriction at RM 1.9.**

Two sets of 7-day low flows were used in the analysis for Fall flow release and Spring flow release.

Fall flow release

- Date range was September and October.
- The 7-day low flow from the West Fork Martin River was 1.7 cfs
- The 7-day low flow from the Mid-Reach (OCH 4.2R-SS-1) was 0.5 cfs from the Mid-Reach
- No flow contribution from any other off-channels or tributaries.

Spring flow release

- Date range was from June 8 to June 27.
- The 7-day low flows for the West Fork Martin River was 11.3 cfs from 2024 flow records
- The 7-day low flow for the Mid-Reach was 0.6 cfs from 2024 flow records.

- Other tributaries were estimated using the ratio of the measured flow (37 cfs) on the West Fork Martin River and the flow (17.6 cfs) measured at MR1.070, both surveyed on May 3, 2024. The ratio (0.476) was applied to tributary flows to the 7-day low flow (11.3 cfs) of the West Fork Martin River. The ratio was applied to the tributary flows in Section 4.1.5.2.2 to estimate the flows for the Spring flow release condition, summarized below.
    - OCH3.8L-SS-1: 0.2 cfs
    - OCH3.0L-SS-1: 1.6 cfs
    - OCH2.8R-SS-1: 1.5 cfs
    - MR1.070: 5.4 cfs
    - OCH1.7R-SS-1: 0.5 cfs.
- The total tributary flow contribution to the mainstem was 21.1 cfs, including West Fork Martin River, Mid-Reach and the 5 off-channels listed above.

## 4.2 Passage Flow/Habitat Connectivity Assessment

Several environmental variables may affect fish passage and connectivity within mainstem and off-channel features. In general, at a given fish passage or habitat connectivity area, the water conditions (primarily depth) interact with conditions of the channel (length and uniformity, substrate size) to characterize the passage conditions that a particular fish encounters. The likelihood of a particular fish successfully navigating through a difficult passage reach will depend on the environmental conditions, timing, and the swimming capabilities of individual fish.

### 4.2.1 Target Fish Species and Periodicity

The fish community of the Martin River includes nine documented fish species (AEA 2022a). Within this community, some fish species exhibit life history patterns that are more sensitive to changes in access to OCH. Although all fish species that use the Martin River were considered, the three primary salmonid species present in the basin (Sockeye Salmon, Coho Salmon, and Dolly Varden) were identified as the focus fish species based on their need to use the Martin River to access tributary and OCH to complete their life history.

The degree to which Martin River flow conditions provided for, or prohibited, aquatic habitat connectivity to the tributary and OCH relates directly to the timing of use by the identified fish species and life stages. Information presented in the ICD (AEA 2022a), fish counts at the West Fork Martin River monitoring station (ADF&G 2024a, 2024b), and 2024 Martin River Aquatic Studies Report results (Kleinschmidt Associates 2025) were used to estimate migration and habitat use timing or periodicity for the target fish species and life stages. Table 4-3 shows the expected timing that target fish species use mainstem, tributary, and OCH for migration, spawning, and/or rearing.

**Table 4-3 Periodicity for target fish species compared to potential releases during operation of the Martin River flow diversion.**

| Life Stage | Species | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | J | F | M | A | May | June | July | August | September | October | N | D |
| Adult Migration | Coho | | | | | | | | | | | | |
| | Sockeye | | | | | | | | | | | | |
| Adult Spawning | Coho | | | | | | | | | | | | |
| | Sockeye | | | | | | | | | | | | |
| | Dolly Varden | | | | | | | | | | | | |
| Rearing (Fry, parr, adult) | Coho | | | | | | | | | | | | |
| | Sockeye | | | | | | | | | | | | |
| | Dolly Varden | | | | | | | | | | | | |
| Minimum Flow 100 cfs | | | | | | | | | 100 cfs min. flow release | | | | |
| Minimum Flow 100 cfs during limited migration | | | | | | | | | 100 cfs flow release | | | | |
| Minimum Flow 150 cfs during migration | | | | | | | 150 cfs min. flow release | | | 150 cfs min. flow release | | | |
| Minimum Flow 200 cfs during migration | | | | | | | 200 cfs min. flow release | | | 200 cfs min. flow release | | | |

## 4.2.2 Habitat Connectivity Criteria

The evaluation of connectivity to off-channel features focused on depth criteria needed to support access to these habitats by adult and juvenile Coho Salmon, Sockeye Salmon, and Dolly Varden. Although high water velocity can be an effective barrier to fish migration, this generally occurs when the entire flow becomes concentrated in a fast chute, the length and speed of which combine to overcome the fish's swimming ability. These conditions are most often encountered at culverts or natural cascades, which are not present within the hydraulic model extent.

Channel gradients at the confluence of the mainstem Martin River and off-channel features are likely not sufficient to create velocity barriers to adult fish or juveniles. For the mainstem channel, the 2D hydraulic model predicted water velocity is within the prolonged swimming capabilities (3-11 ft/s) for adult salmon (Bell 1991, Lee et al. 2003). For these reasons, water velocity was not included in the evaluation of habitat connectivity.

The conditions for successful access to aquatic habitat vary for fish species and fish size (ADF&G 2001, Bates et al. 2003, Bell 1991, California Department of Fish and Wildlife [CDFW] 2017, Powers and Orsborn 1985, Thompson 1972, Washington Department of Fish and Wildlife [WDFW] 2019, Webb 1975). Salmonid passage criteria are well established, and some criteria exist for all salmonid species. After reviewing depth criteria available for Coho Salmon, Sockeye Salmon, and Dolly Varden, a minimum water depth of 0.7 feet was used to assess connectivity to OCH for adult salmon and Dolly Varden and 0.3 feet was used for juvenile salmon and Dolly Varden (Table 4-4). The minimum depth values are intended to provide a conservative approach to assessing the potential flows for a range of fish sizes (e.g., adult salmon, resident and anadromous Dolly Varden) that utilize the Martin River.

**Table 4-4 Depth criteria reported in the literature for selected fish species and life stages.**

| Species | Life Stage | Depth Criteria | |
|---|---|---|---|
| | | Feet | References |
| Dolly Varden | Adult | 0.3-0.6 | ADF&G (2001) |
| | Juvenile | 0.3 | Bugert et al. (1991) |
| Coho Salmon | Adult | 0.6-0.7 | CDFW (2017); Thompson (1972); Everest et al. (1985) |
| | Juvenile | 0.3 | CDFW (2017) |
| Sockeye Salmon | Adult | 0.6-0.7 | Bates et al. (2003); Everest et al. (1985) |
| | Juvenile | 0.3 | CDFW (2017) |
| Salmonids | Adult | 0.6-1.0 | WDFW (2019) |
| Salmon | Adult | 2.5 Times Caudal Fin Height | ADF&G (2001) |

### 4.2.3 Mainstem Habitat Connectivity Assessment

An individual fish moving through the mainstem channel is assumed to follow a continuous path, from the downstream to upstream end of the migration route. Therefore, the most accessible passage route through the river would follow a path of least resistance, where shallower waters are avoided and deeper waters preferred. To identify the assumed migration path, a thalweg (deepest portion of the channel) path was mapped from the downstream to upstream extents of the modeled reaches, including off-channel feature confluences with the mainstem. Transects across the wetted channel and perpendicular to the thalweg were placed at 2-foot increments along the mainstem channel, and the water depths at 1-foot increments across the transect were sampled from the modeled depth. This exercise was repeated for the three flow release scenarios.

The simulated water depths across each transect were evaluated using an approach based, in part, on Thompson’s (1972) passage criteria for adult salmon. Thompson (1972) defined passage criteria for adult salmon (e.g., Coho and Sockeye salmon) as a contiguous water depth of greater than 0.7 feet for at least 10 percent of the wetted channel width and velocities of less than 8 ft/s.

In application of Thompson's method, the length of contiguous mainstem that did not meet the minimum passage criteria was tallied. Although a minimum depth of 0.7 feet is widely recommended to ensure successful fish passage/habitat connectivity, it has been observed that migrating salmon can swim in water shallower than 0.7 feet for a short distance. Unfortunately, there is limited information regarding how far an adult salmon can swim in such conditions. At a minimum, it was assumed that adult Coho and Sockeye salmon are capable of swimming upstream in shallower conditions for a distance of 10 times their average body length. With an average body length of 24 inches, this equates to a channel length of 20 feet.

Using this assumption, three gap length bins were developed for the contiguous thalweg length not meeting the 0.7 feet criteria: 20-39 feet, 40-59 feet, and 60 feet or greater. It was assumed that as the number and length of channel segments that did not meet the passage criteria increases so does the likelihood that connectivity to mainstem and OCH will be restricted.

The number and length of gaps was then used to evaluate fish passage along the channel thalweg. The evaluation was analyzed in a stepwise manner:

1. Determine wetted width of each transect for each modeled flow.
    a) 100 cfs, 150 cfs, 200 cfs.
2. Calculate the contiguous width of each transect that meets or exceeds the minimum passage depth (0.7 feet).
3. Identify transects with <10 percent of contiguous wetted width that meets the passage depth.
4. For the transects identified in step 3, identify the gap greater than 20 feet or with more than 10 contiguous transects.
5. Tally the lengths of the gaps along the thalweg for the three bins:
    a) 20-40 feet.
    b) 41-60 feet.
    c) ≥60 feet.

An assessment of passage flow connectivity requires consideration of not only the spatial hydraulic patterns (e.g., distribution of depths as a function of discharge) but also the temporal dynamics of streamflow. The Martin River is characterized by a highly variable, seasonal (glacial melt), and an interannual hydrograph that influences the timing of fish passage. To evaluate the relationship between Martin River stream flow and migration timing, daily flow values from the Martin River Constriction (RM 1.9) and daily counts of Coho and Sockeye salmon arriving at the Red Lake counting station (WF Martin River) for 2023 and 2024 were compared (Figure 4-11).

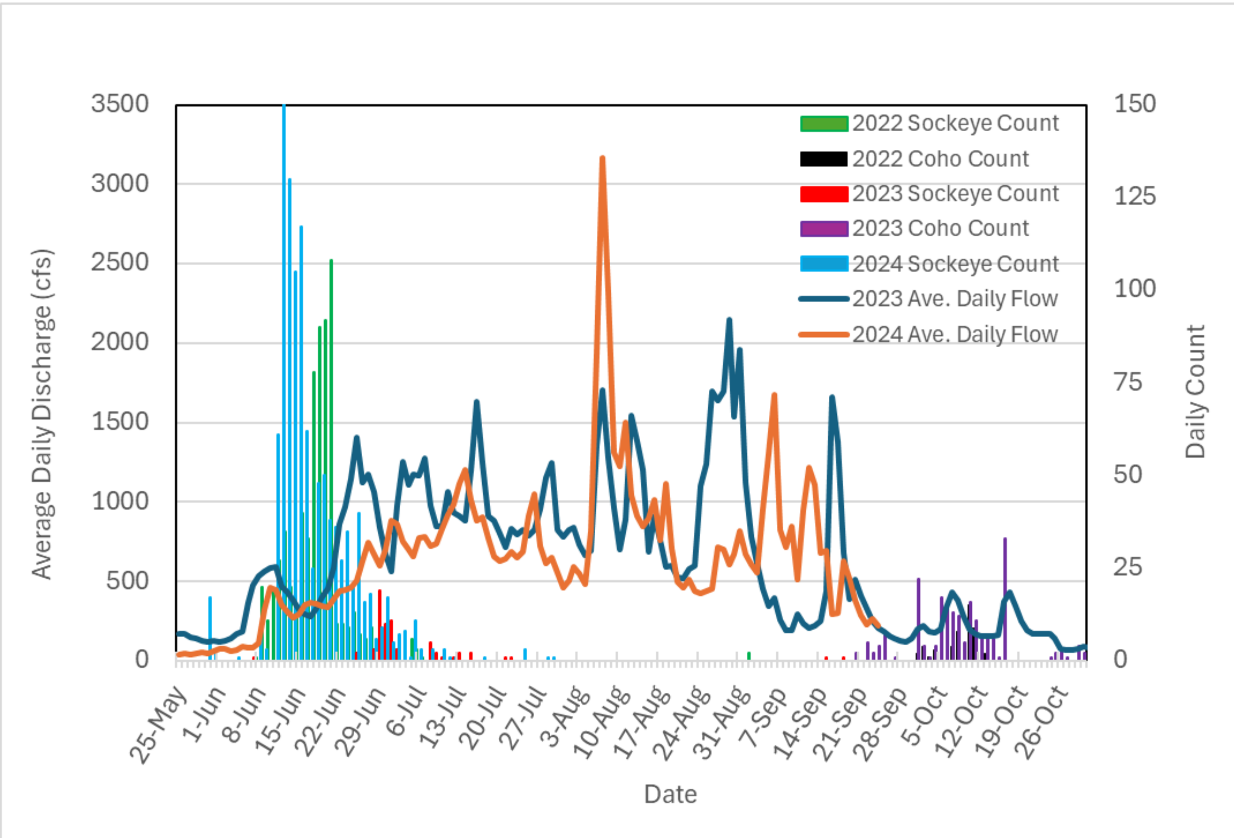


**Figure 4-11 Martin River daily flow values compared to Sockeye and Coho salmon counts from the West Fork Martin River monitoring station for 2023-2024 (Source: ADF&G).**

**Figure 4-11 Note:** The maximum value on the vertical axis for Daily Counts has been reduced to improve resolution. The maximum daily count of Sockeye Salmon in 2024 was 253.

### 4.2.4 Off-Channel Habitat Connectivity Assessment

Researchers observed spawning or juvenile Dolly Varden, Coho Salmon, and Sockeye Salmon in the representative off-channel features modeled for habitat connectivity in 2024 (Kleinschmidt Associates 2025) (Table 4-5). To evaluate connectivity for juvenile fish, the same process for adult/spawning fish was applied but with a minimum water depth of 0.3 feet as the criteria for accessibility.

**Table 4-5 Target fish species distribution documented during spring and fall sampling in 2024 at six off-channel features of the Martin River.**

| OCH Connectivity | Fish Species Use by Life Stage | |
|---|---|---|
| | Juvenile | Adult/Spawning |
| OCH1.7L-SS-1 | Dolly Varden, Coho | None |
| OCH2.8R-SS-1 | Dolly Varden, Coho | Dolly Varden, Coho, Sockeye |
| OCH3.0L-SS-1 | Dolly Varden, Coho | Dolly Varden |
| OCH3.8L-SS-1 | Dolly Varden | None |
| OCH4.2R-SS-1 | Dolly Varden, Coho | None |
| WF Martin River | Dolly Varden, Coho | Dolly Varden, Coho, Sockeye |

# 5.0 RESULTS

## 5.1 Model Application Results

Figure 5-1 and Figure 5-2 show the depth and velocity[2] maps, respectively, for 100 cfs from the East Fork Martin River with tributary flows from the spring flow release in Table 4-1. Figure 5-3 and Figure 5-4 show the depth and velocity maps, respectively, for 150 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1. Figure 5-5 and Figure 5-6 show the depth and velocity maps, respectively, for 200 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1.

Figure 5-7 and Figure 5-8 show the depth and velocity[2] maps, respectively, for 100 cfs from the East Fork Martin River with tributary flows from the spring flow release in Table 4-1. Figure 5-9 and Figure 5-10 show the depth and velocity maps, respectively, for 150 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1. Figure 5-11 and Figure 5-12 show the depth and velocity maps, respectively, for 200 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1.

The flows used in each of the six runs are summarized in Table 4-1.

[2] Mainstem water velocity predictions are presented to ensure that velocity was general well within the range of prolonged swimming capabilities of adult salmon and not barrier to fish migration.

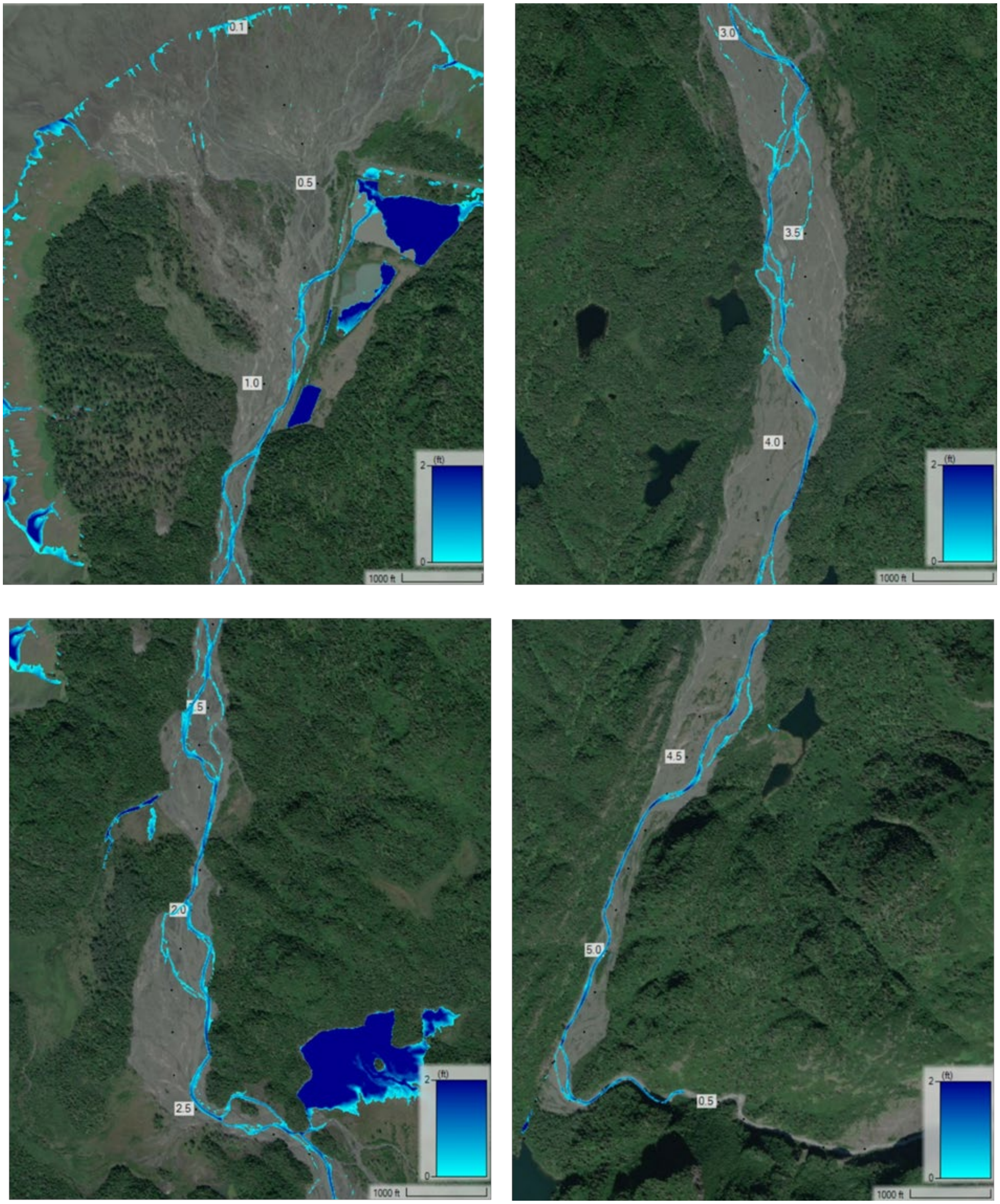


**Figure 5-1 Water depth maps for 100 cfs from East Fork Martin River with tributary flows from the fall flow release in Table 4-1.**

**Figure 5-1 Notes:** Water depths of 2 feet and greater are shown with the same color (dark blue). The four maps, from top to bottom and left to right, represent the stream reach from downstream to upstream. The numbers in white boxes indicate RM.

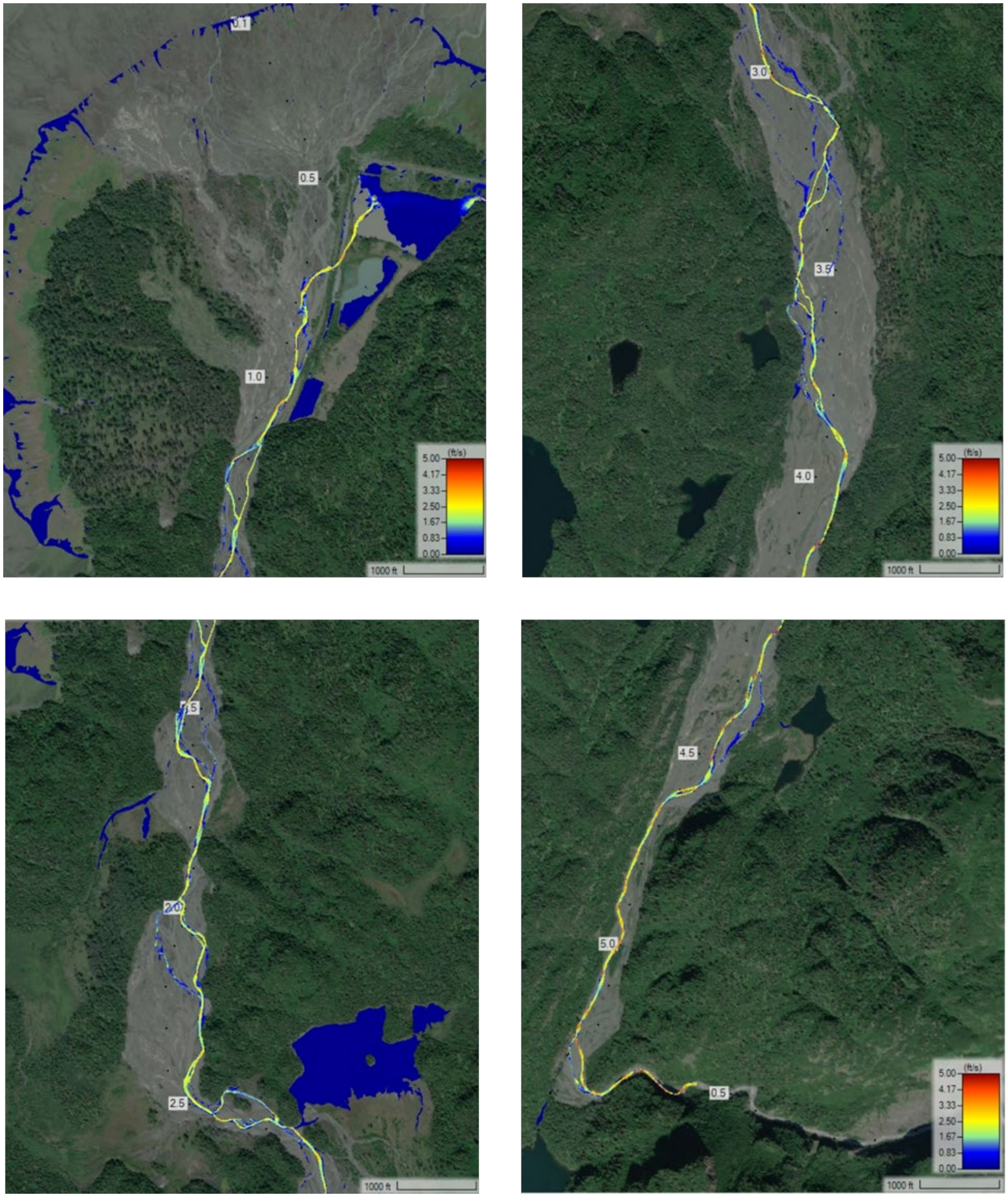


**Figure 5-2 Velocity maps for 100 cfs from East Fork Martin River with tributary flows from the fall flow release in Table 4-1.**

**Figure 5-2 Notes:** Velocity of 5 ft/s and greater is shown with the same color (red). The four maps, from top to bottom and left to right, represent the stream reaches from downstream to upstream. The numbers in white boxes indicate RM.

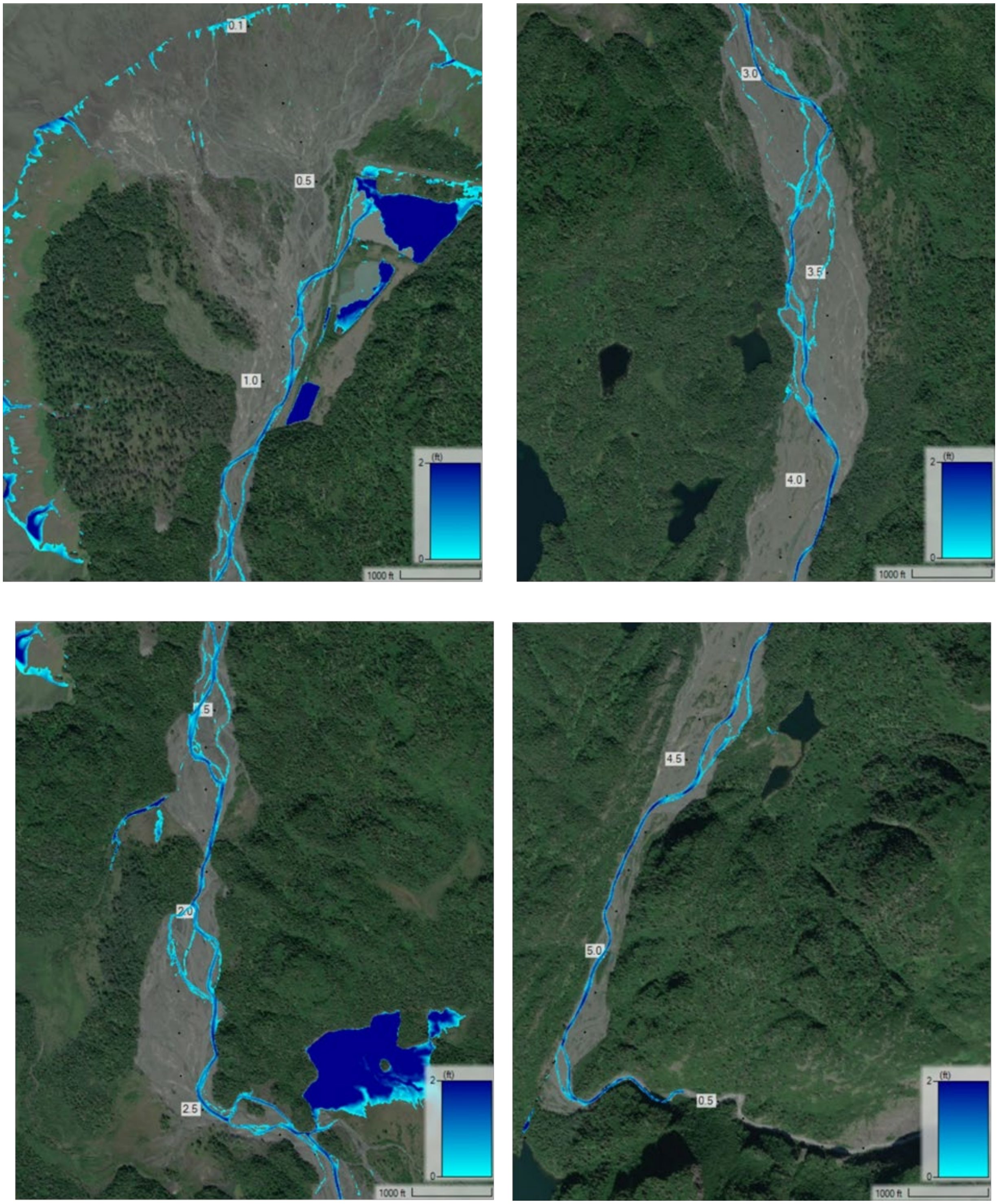


**Figure 5-3 Water depth maps for 150 cfs from East Fork Martin River with tributary flows from the fall flow release in Table 4-1.**

**Figure 5-3 Notes:** Water depths of 2 feet and greater are shown with the same color (dark blue). The four maps, from top to bottom and left to right, represent the stream reach from downstream to upstream. The numbers in white boxes indicate RM.

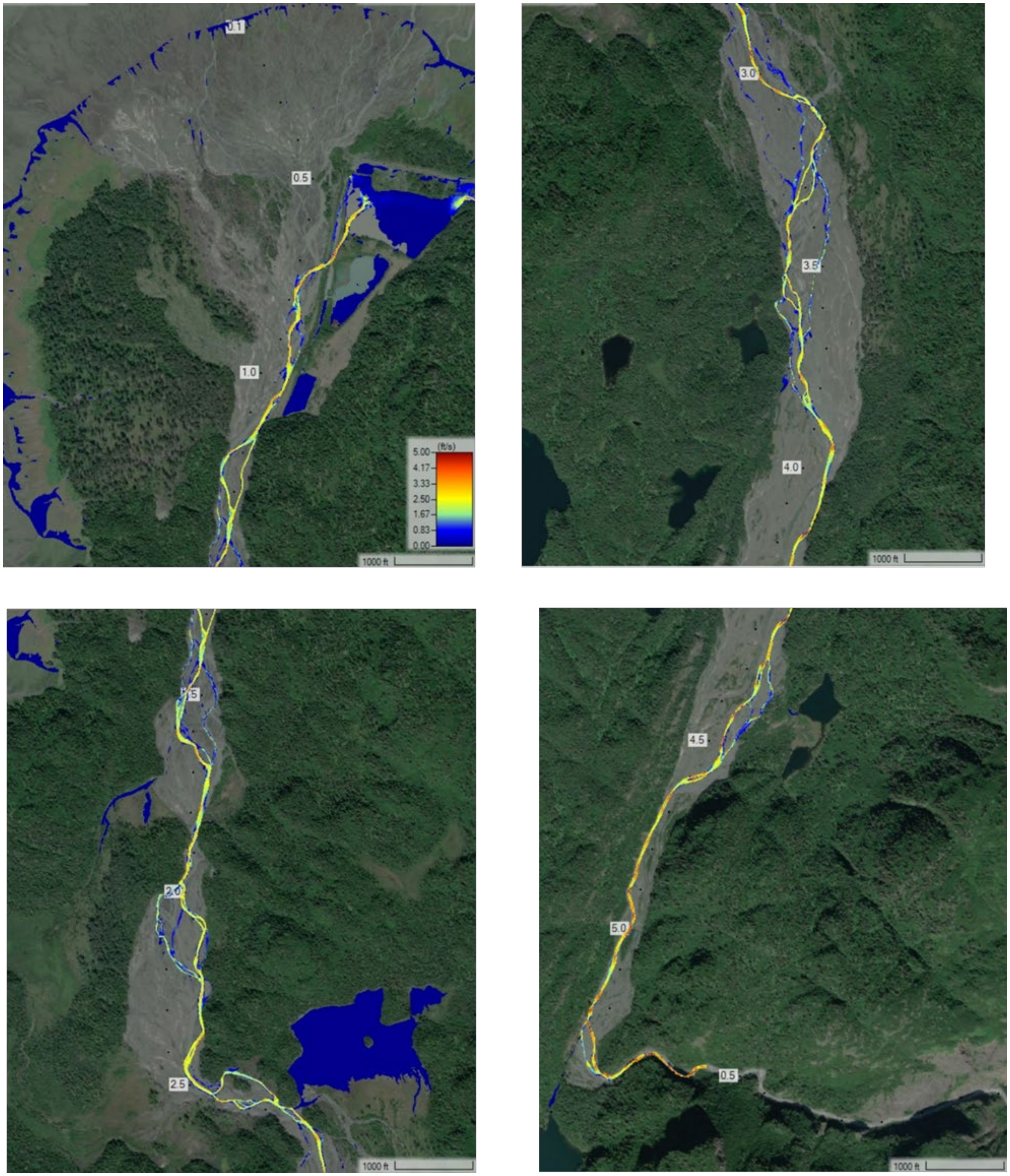


**Figure 5-4 Velocity maps for 150 cfs from East Fork Martin River with tributary flows from the fall flow release in Table 4-1.**

**Figure 5-4 Notes:** Velocity of 5 ft/s and greater is shown with the same color (red). The four maps, from top to bottom and left to right, represent the stream reaches from downstream to upstream. The numbers in white boxes indicate RM.

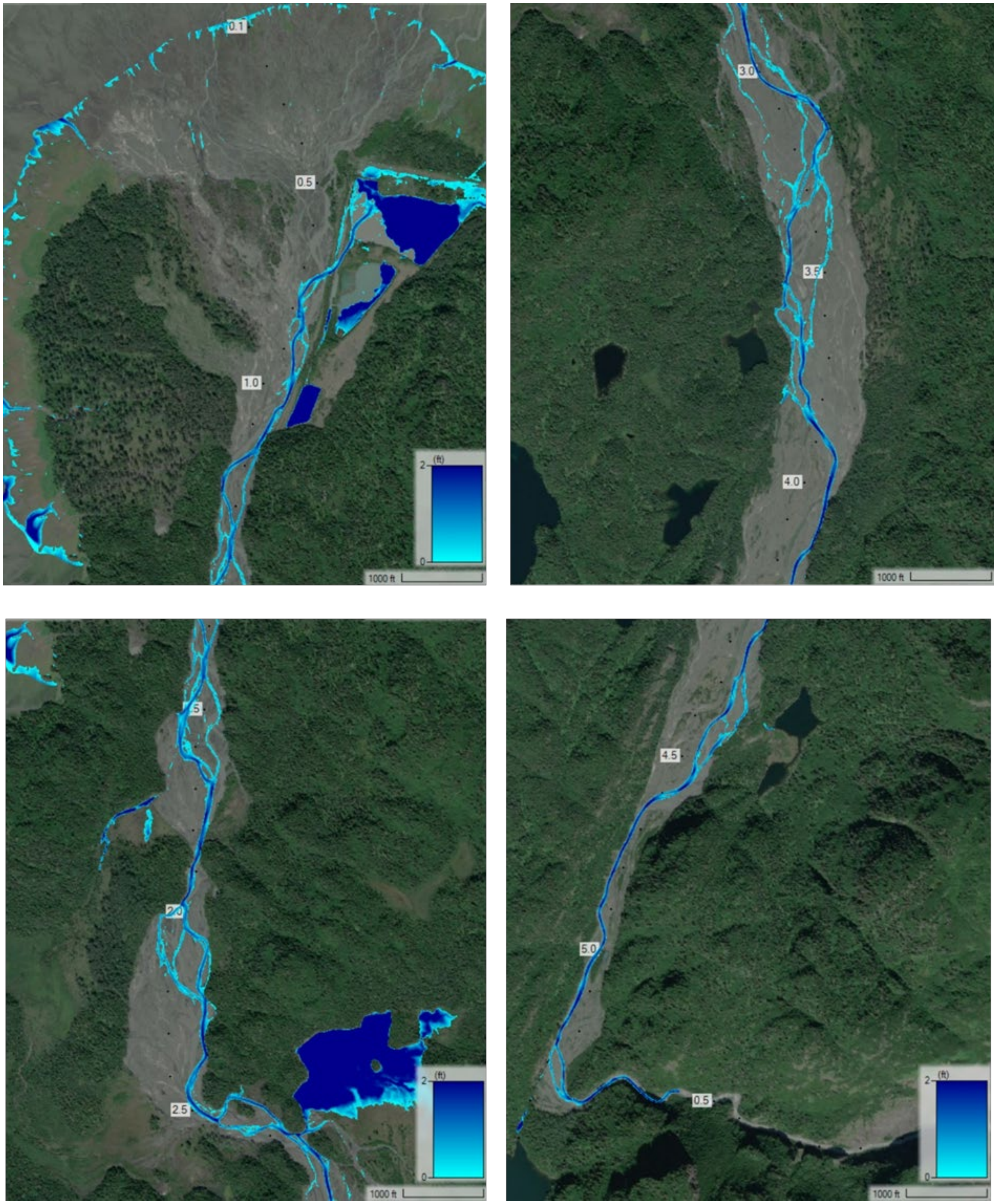


**Figure 5-5 Water depth maps for 200 cfs from East Fork Martin River with tributary flows from the fall flow release in Table 4-1.**

**Figure 5-5 Notes:** Water depths of 2 feet and greater are shown with the same color (dark blue). The four maps, from top to bottom and left to right, represent the stream reach from downstream to upstream. The numbers in white boxes indicate RM.

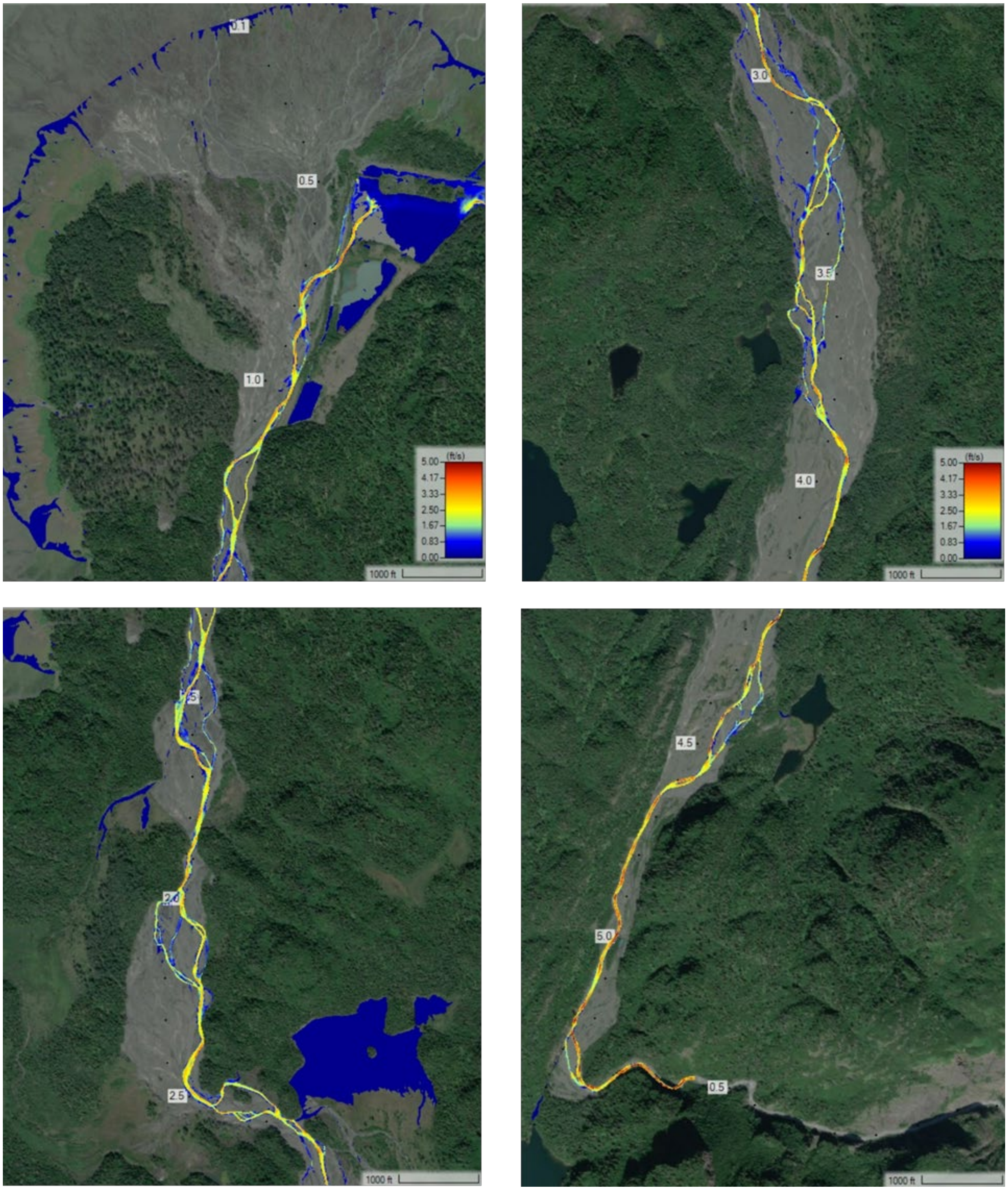


**Figure 5-6 Velocity maps for 200 cfs from East Fork Martin River with tributary flows from the fall flow release in Table 4-1.**

**Figure 5-6 Notes:** Velocity of 5 ft/s and greater is shown with the same color (red). The four maps, from top to bottom and left to right, represent the stream reaches from downstream to upstream. The numbers in white boxes indicate RM.

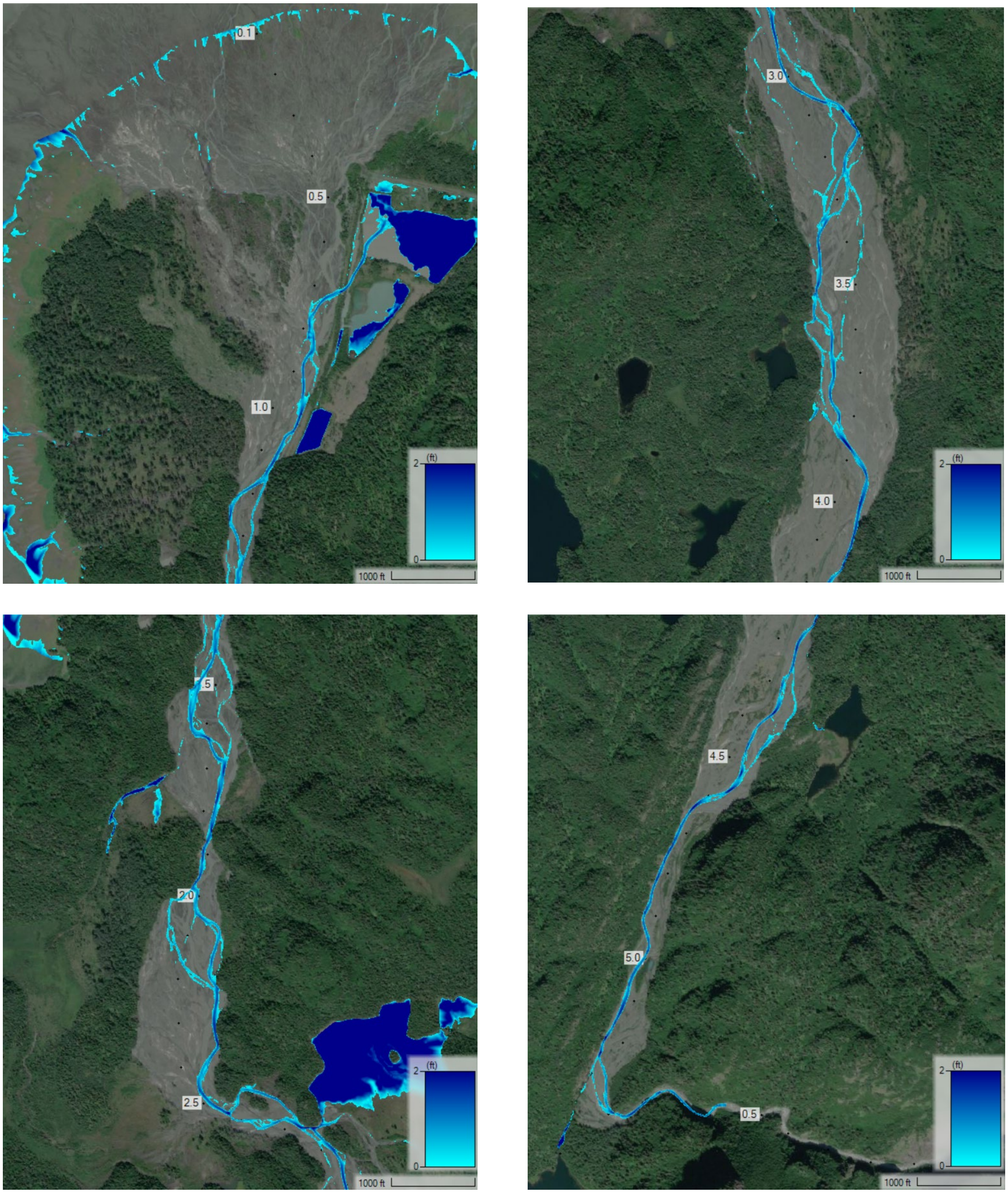


**Figure 5-7 Water depth maps for 100 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1.**

**Figure 5-7 Notes:** Water depths of 2 feet and greater are shown with the same color (dark blue). The four maps, from top to bottom and left to right, represent the stream reach from downstream to upstream. The numbers in white boxes indicate RM.

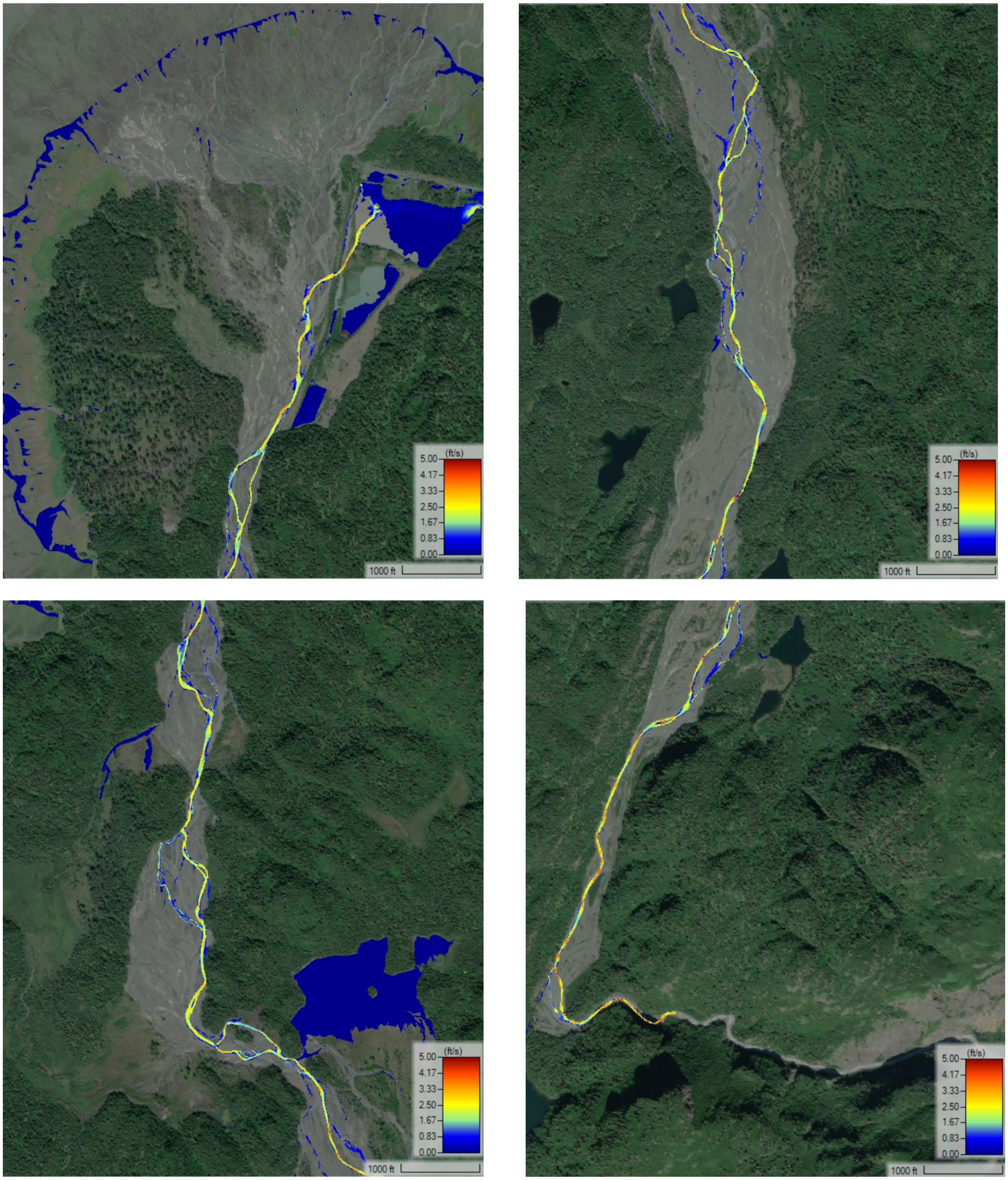


**Figure 5-8 Velocity maps for 100 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1.**

**Figure 5-8 Notes:** Velocity of 5 ft/s and greater is shown with the same color (red). The four maps, from top to bottom and left to right, represent the stream reaches from downstream to upstream. The numbers in white boxes indicate RM.

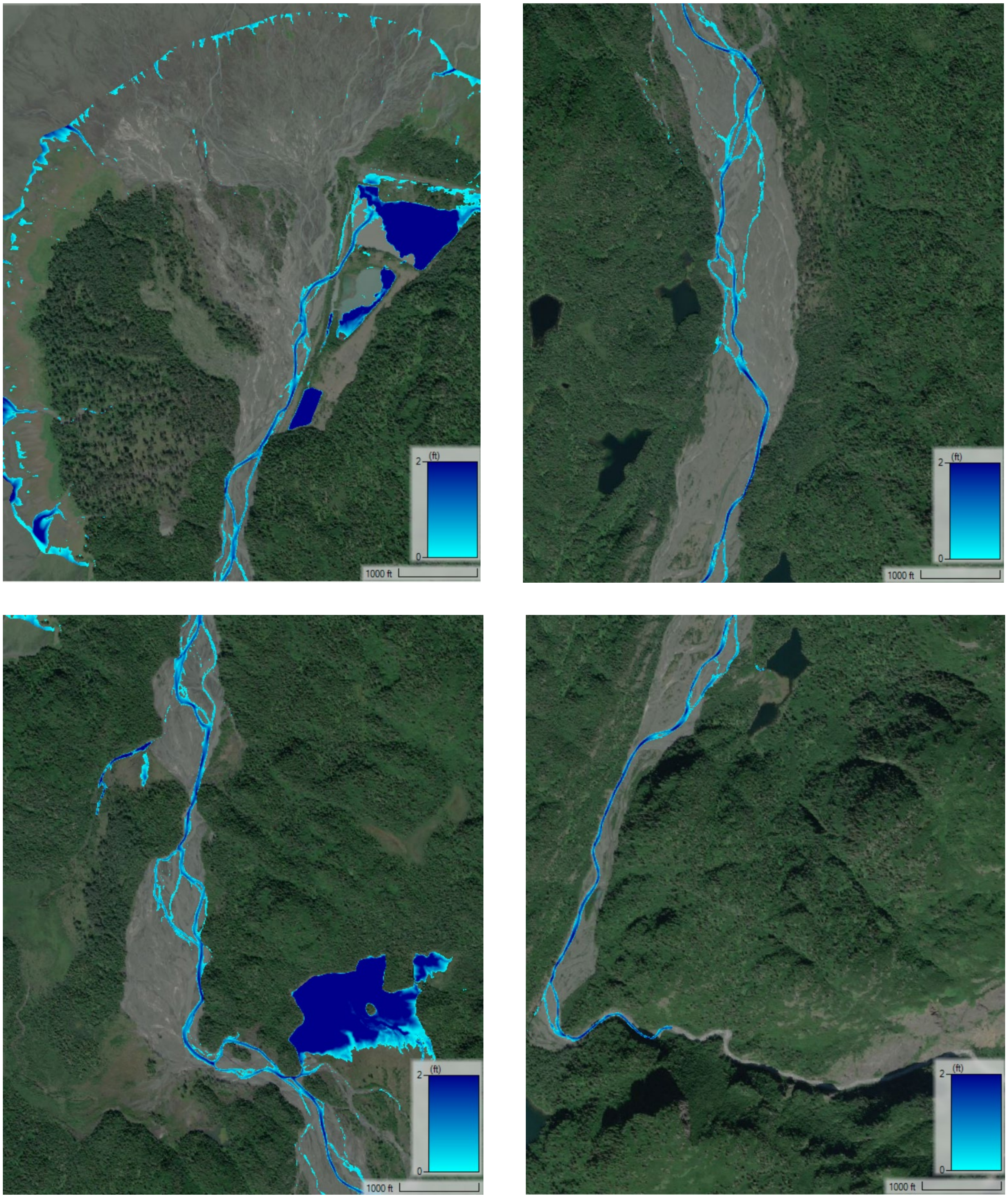


**Figure 5-9 Water depth maps for 150 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1.**

**Figure 5-9 Notes:** Water depths of 2 feet and greater are shown with the same color (dark blue). The four maps, from top to bottom and left to right, represent the stream reach from downstream to upstream. The numbers in white boxes indicate RM.

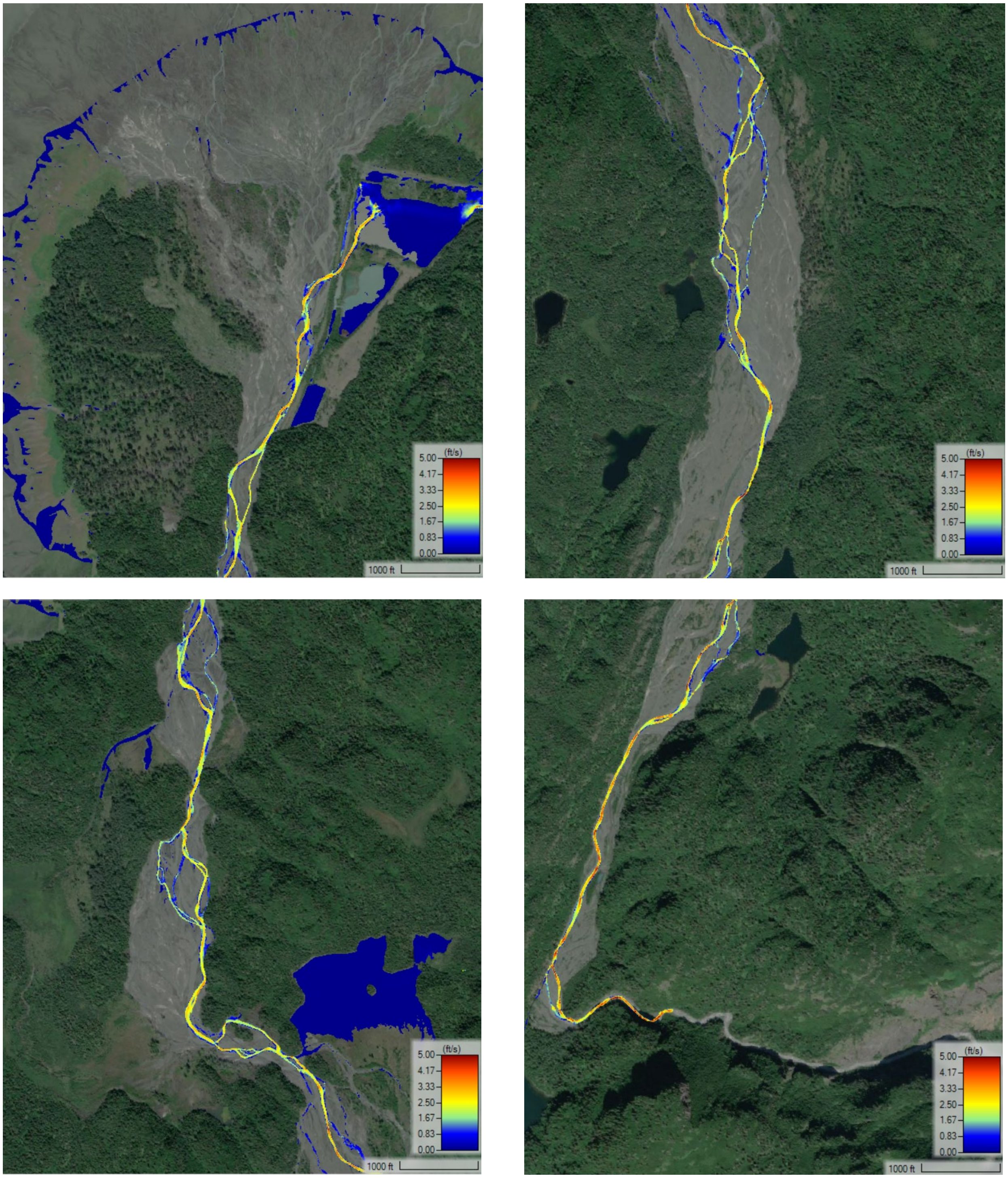


**Figure 5-10 Velocity maps for 150 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1.**

**Figure 5-10 Notes:** Velocity of 5 ft/s and greater is shown with the same color (red). The four maps, from top to bottom and left to right, represent the stream reaches from downstream to upstream. The numbers in white boxes indicate RM.

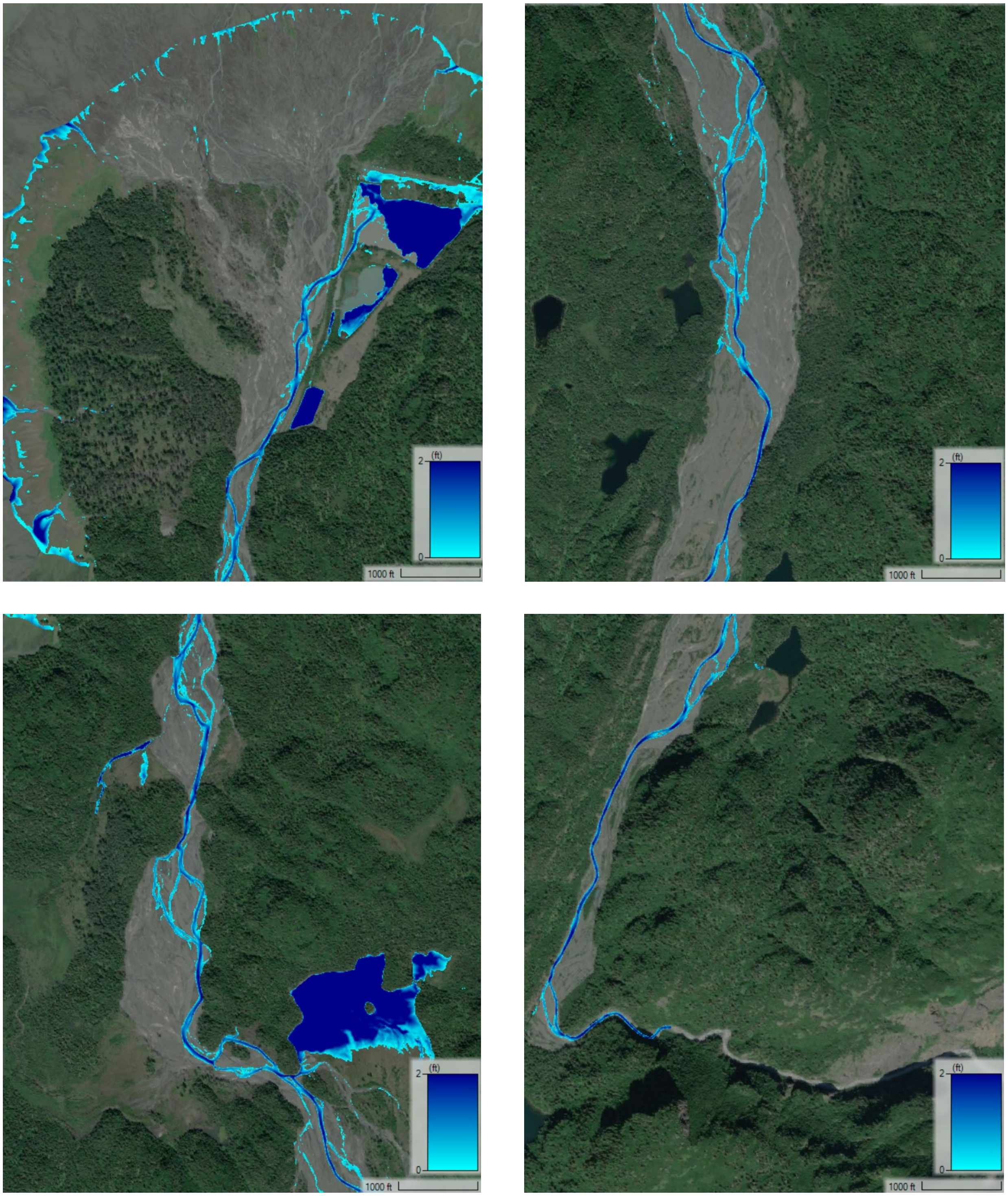


**Figure 5-11 Water depth maps for 200 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1.**

**Figure 5-11 Notes:** Water depths of 2 feet and greater are shown with the same color (dark blue). The four maps, from top to bottom and left to right, represent the stream reach from downstream to upstream. The numbers in white boxes indicate RM.

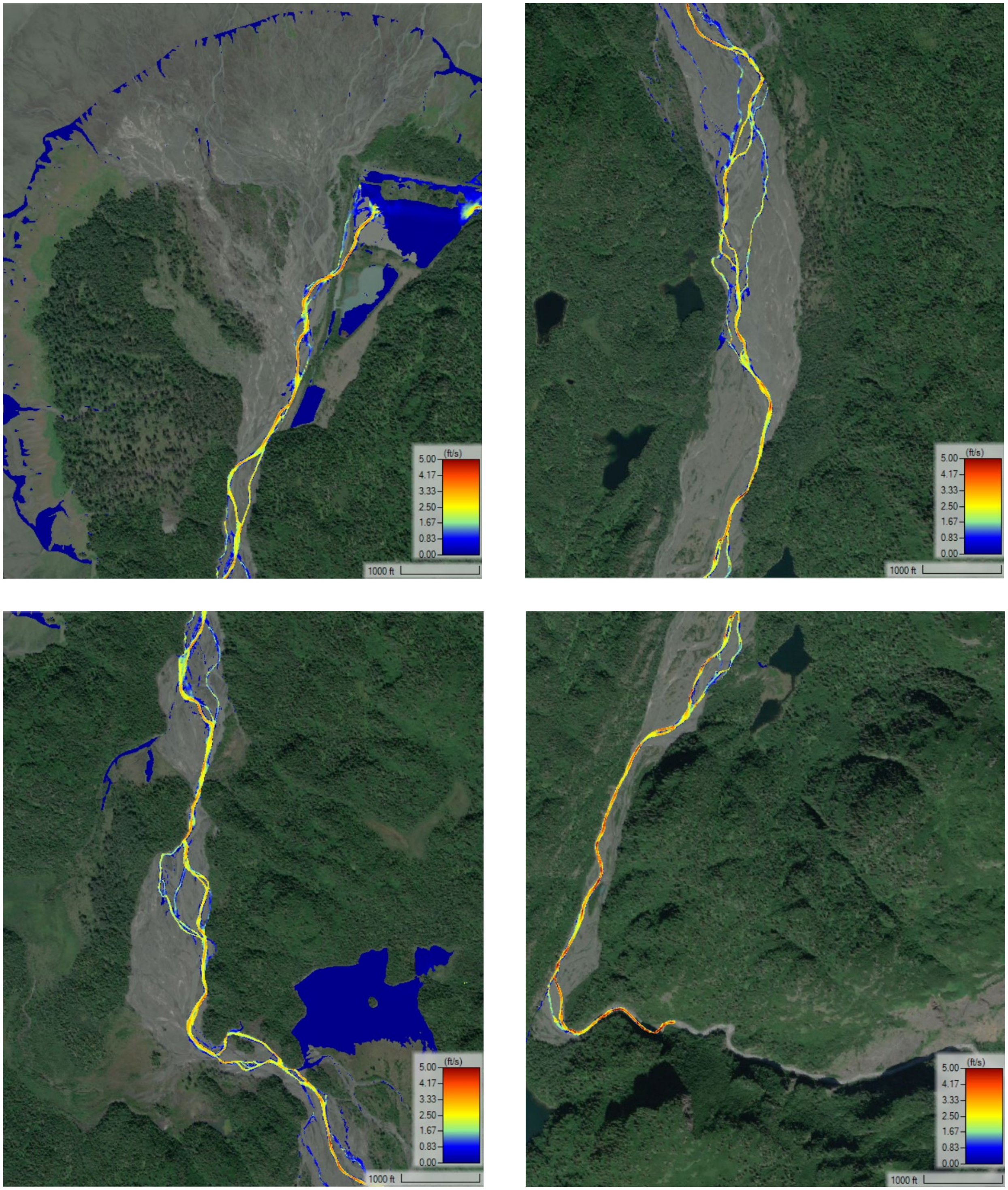


**Figure 5-12 Velocity maps for 200 cfs from East Fork Martin River with tributary flows from the spring flow release in Table 4-1.**

**Figure 5-12 Notes:** Velocity of 5 ft/s and greater is shown with the same color (red). The four maps, from top to bottom and left to right, represent the stream reaches from downstream to upstream. The numbers in white boxes indicate RM.

## 5.2 Fish Passage/Habitat Connectivity

Results of the 2D hydraulic modeling were used to assess how changes in flow interact with local channel morphology to estimate the connectivity between mainstem and OCH within the Martin River for the three minimum flow release scenarios. In general, increasing discharge was associated with an increase in water depth distributions for mainstem and off-channel features. However, there were reach-specific responses to flow that reflect differences in channel morphology of mainstem and off-channel features. Estimates of habitat connectivity for mainstem and OCH are presented separately for each of the minimum flow release scenarios.

### 5.2.1 Mainstem Connectivity

With increasing discharge, the analysis indicated the potential for a reduction in the proportion of the mainstem migration path that may limit or restrict upstream migrating salmon and habitat connectivity (Figure 5-13). The hydraulic model predicted that a minimum flow release of 100 cfs would have the largest number (n=4) of gaps in the predicted migration path. Although most of the predicted gaps at the 100 cfs flow release were relatively short (<40 ft), with only one of the gaps exceeding 40 feet in length. Both the number and length of connectivity gaps decreased at flow releases of 150 cfs (n=2) and 200 cfs (n=1) (Figure 5-14).

The relationship of increased habitat connectivity with increased minimum flow was not evident for all reaches of the mainstem Martin River. At the time of this study, the downstream most section of the Martin River was unconsolidated and lacked a well-defined thalweg as it flows through and exits a series of off-channel mitigation ponds (Figure 5-15). As a result, the wetted width of the channel widens such that increasing flows tend to extend laterally, maintaining relatively shallow water depths that do not meet the minimum depth criteria for any of the potential minimum flow releases.

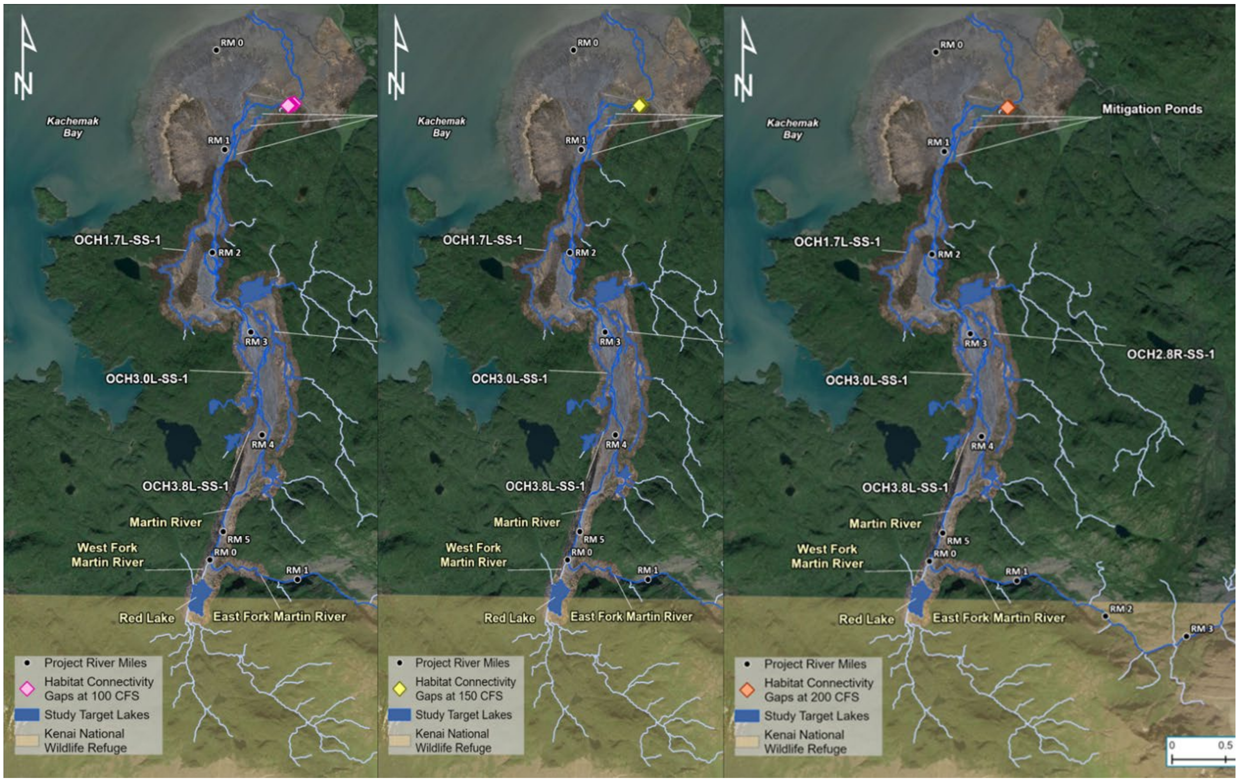


**Figure 5-13 Distribution of gaps (>20ft) in habitat connectivity under three minimum flow release scenarios (100 cfs left, 150 cfs center, 200 cfs right panel) for the mainstem Martin River, Alaska.**

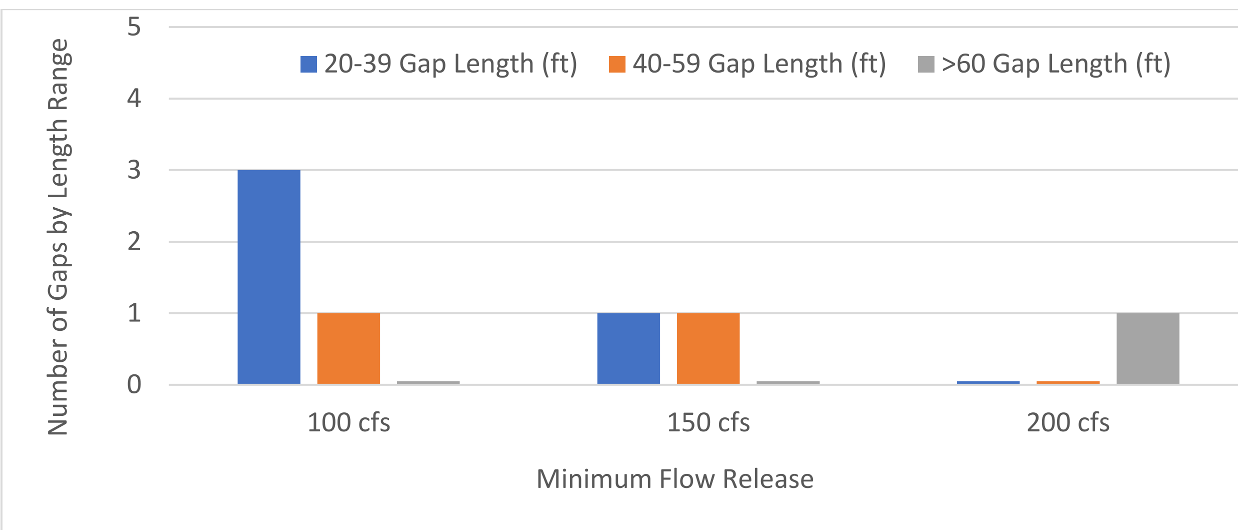


**Figure 5-14 Number and length of gaps in habitat connectivity under three minimum flow release scenarios for the mainstem Martin River, Alaska.**

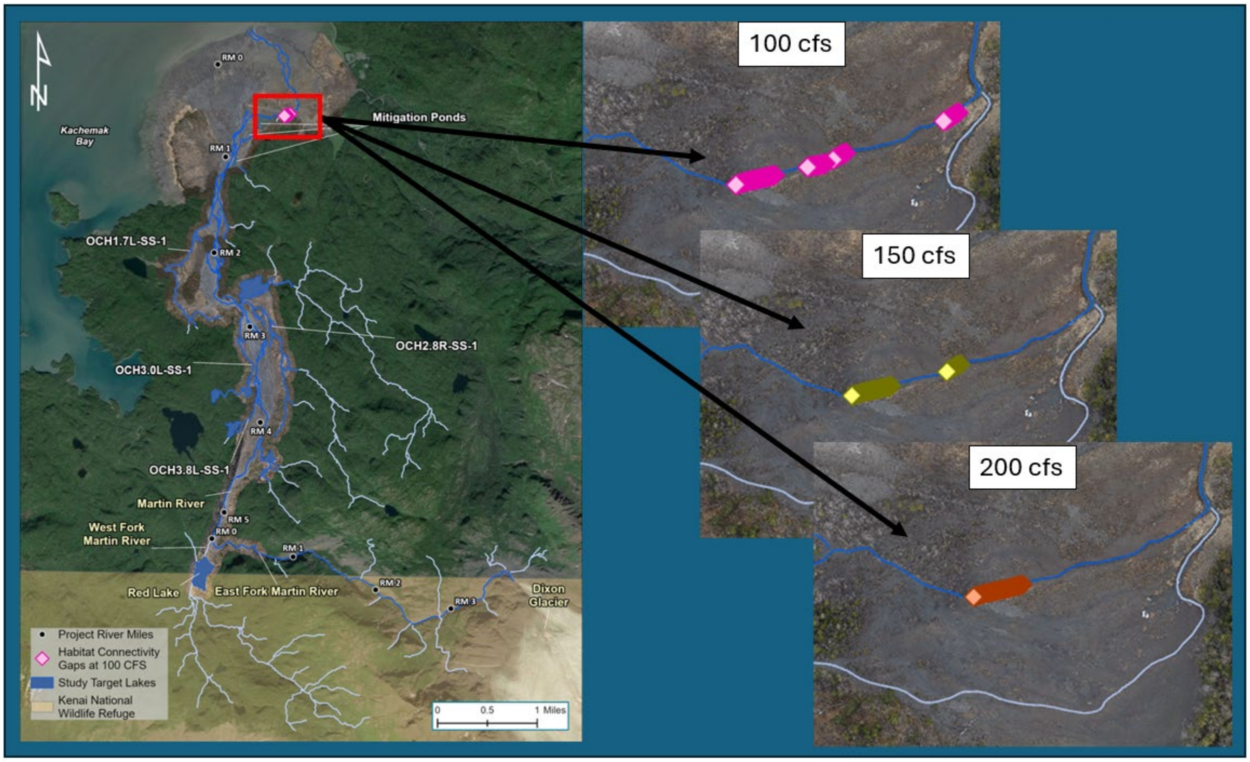


**Figure 5-15 Lowermost reach of the mainstem Martin River where unconsolidated flow results in consistent gaps (pink diamonds 100 cfs, yellow diamonds 150 cfs, orange diamonds 200 cfs) in habitat connectivity under potential flow release scenarios.**

### 5.2.2 OCH Connectivity

Of the eight off-channel connectivity locations included as part of the bathymetric validation ground surveys, six were selected for detailed analysis: OCH1.7L-SS-1, OCH 2.8R-SS-1, OCH3.0L-SS-1, OCH3.8L-SS-1, OCH4.2R-SS-1, and West Fork Martin River (Table 5-1). These locations were selected based on observed fish use and the presence of a well-defined hydraulic connectivity with the Martin River.

For OCH features OCH1.7L-SS-1, OCH2.8R-SS-1, and the West Fork Martin River, the 2D hydraulic model estimated sufficient water depth would be available to provide habitat connectivity under all three minimum flow release scenarios (Table 5-1). This includes the two OCH features (OCH2.8R-SS-1 and West Fork Martin River) that support spawning Dolly Varden, Coho Salmon, and Sockeye Salmon. For the off-channel feature found to support juvenile and adult Dolly Varden and juvenile Coho Salmon (OCH3.0L-SS-1, water depth greater than 0.3 feet was limited until flows reached 150 cfs (Table 5-1). Habitat connectivity for channels OCH 3.8L-SS-1 and OCH4.2R-SS-1 was limited for flows less than

200 cfs (Table 5-1). The minimum flow release of 200 cfs was found to provide water depth greater than the 0.3 and 0.7 feet for all off-channel features.

**Table 5-1 Habitat connectivity results from two water depth criteria under three potential flow release scenarios for the Martin River, Alaska.**

| Habitat Connectivity | Fish Use | | Minimum Flow Release Scenario | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 100 cfs | | 150 cfs | | 200 cfs | |
| | | | Connected at Minimum Depth | | | | | |
| | Juvenile | Spawning | 0.3 feet | 0.7 feet | 0.3 feet | 0.7 feet | 0.3 feet | 0.7 feet |
| OCH1.7L-SS-1 | DV, CO | None | Yes | Yes | Yes | Yes | Yes | Yes |
| **OCH2.8R-SS-1** | **DV, CO, SO** | **DV, CO, SO** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** |
| **OCH3.0L-SS-1** | **DV, CO** | **DV** | **Yes** | **No** | **Yes** | **No** | **Yes** | **Yes** |
| OCH3.8L-SS-1 | DV | None | No | No | No | No | Yes | Yes |
| OCH4.2R-SS-1 | DV, CO | None | No | No | No | No | Yes | Yes |
| **WF Martin River** | **DV, CO, SO** | **DV, CO, SO** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** | **Yes** |

DV=Dolly Varden Trout, CO=Coho Salmon, SO=Sockeye Salmon

# 6.0 DISCUSSION

The Martin River supports multiple resident and migratory fish species that have distinct mainstem and off-channel habitat requirements. Access or connectivity to these habitats is sensitive to temporal and spatial variability in hydrologic conditions (i.e., water depth). High resolution topobathymetric mapping and 2D hydraulic modeling allowed for a “snapshot in time” evaluation of habitat connectivity for the mainstem Martin River and off-channel habitats for three potential minimum flow releases.

Hydraulic modeling demonstrated that the number and length of potential gaps in mainstem habitat connectivity would decrease with increasing flow releases. While fish passage conditions in the mainstem improved with each modeled flow scenario (100, 150, 200 cfs), the hydraulic modeling was not extended to a flow condition that predicted full connectivity throughout the mainstem. At a minimum flow release of 150 cfs, only the lowermost segment of the Martin River did not meet the minimum depth of 0.7 feet. This segment of the lower Martin River is relatively new, created during the summer of 2023 when the Martin River broke through a dike and entered a series of mitigation ponds adjacent to the river. Based on the channel conditions at the time of this study and under the potential flow release scenarios, this area of the Martin River may limit or delay upstream migration by adult salmon at flows up to or in excess of 200 cfs.

However, aerial surveys of the lower Martin River completed during the fall of 2024 indicate that the river channel has consolidated and deepened since the topobathymetric survey of the river was completed in May 2024 (Watershed GeoDynamics 2025). The change in channel morphology of the lower Martin River, as it flows through and out of the off-channel mitigation ponds, is assumed to be a response to large flow events that occurred during the summer of 2024 (i.e., on August 6-7, 2024). Additional site-specific surveys of this section of the Martin River could be used to confirm the interpretation of the aerial images and evaluate 2024 channel changes with respect to habitat connectivity.

The hydrologic connectivity of off-channel features to the mainstem Martin River is influenced by the channel morphology at the connectivity location and the relationship between discharge in the Martin River and from the off-channels. Due to a lack of long-term flow records (summer 2024 only) for most of the off-channel features, a flow of 0.01 cfs was used to estimate the flow contribution for four of the six connectivity points. For the mainstem and off-channel features, longer-term flow monitoring may result in refinement to the flow partitioning used in the 2D hydraulic modeling. Modifications to the daily flow estimates may result in increased water depth and greater connectivity between mainstem and OCH. Additionally, it is assumed that juvenile fish would opportunistically access OCH when flow conditions are suitable (e.g., freshets).

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