Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries
Study Plan Section 9.12

2014 Study Implementation Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc. and ABR, Inc.

October 2015

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
AEA	Alaska Energy Authority
cfs	cubic feet per second
FA(s)	focus area(s)
FERC	Federal Energy Regulatory Commission
fps	feet per second
ft	feet
GIS	geographic information system
GPS	Global Positioning System
ILP	Integrated Licensing Process
ISR	Initial Study Report
ITU	Integrated Terrain Unit
LiDAR	Light Detection And Ranging. A remote sensing technology that measures distance by illuminating a target with a laser and analyzing the reflected light.
PRM	Project river mile
RM	river mile
RSP	Revised Study Plan
SPD	Study Plan Determination
TM	technical memorandum
USFS	United States Forest Service
USGS	United States Geological Survey
ZHI	zone of hydrologic influence

1. INTRODUCTION

This Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries, Section 9.12 of the Revised Study Plan (RSP) approved by the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241, focuses on the potential effects of Project-induced changes in flow and water surface elevation on free access of fish into, within, and out of suitable habitats in the Upper Susitna River (inundation zone above the Watana Dam site) and the Middle Susitna River (Watana Dam site to the confluence of Chulitna and Talkeetna rivers).

A summary of the development of this study, together with the Alaska Energy Authority's (AEA) implementation of it through the 2013 study season, appears in Part A, Section 1 of the Initial Study Report (ISR) filed with FERC in June 2014. As required under FERC's regulations for the Integrated Licensing Process (ILP), the ISR describes AEA's "overall progress in implementing the study plan and schedule and the data collected, including an explanation of any variance from the study plan and schedule." (18 CFR 5.15(c)(1)). On October 15, 2014, AEA held an ISR meeting for the Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries Study covering the material presented in the June 2014 ISR.

Since filing the ISR in June 2014, AEA has continued to implement the FERC-approved plan for the Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries. For example:

- A technical memorandum (TM) was prepared in November 2014 that presented a proposed final list of fish species to be included in the fish barrier analysis as well as depth, leaping and velocity passage criteria for selected fish species (R2 2014).

- During 2014, additional field surveys included evaluation of potential vertical geologic barriers in six tributaries in the Middle and Upper Susitna River and nine tributary mouth thalweg surveys in Middle Susitna River. All 2014 surveys followed the approach described in the ISR Section 4.5 (AEA 2014) and in the Fish Passage Barrier Assessment Implementation Plan (HDR 2013) using species and passage criteria described in the November 2014 TM (R2 2014). Additional field data in support of this study was collected at modeling sites (ISR Section 4.3.5 [AEA 2014]) by other studies (see ISRs for Study 6.6 Sections 4.1.2.9.2 and 4.1.2.9.3. and Study 8.5 Section 4.3 and 4.6; AEA 2014).

In furtherance of the next round of ISR meetings and FERC's Study Plan Determination (SPD) expected in 2016, this report describes AEA's overall progress in implementing the Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries (Study 9.12) during calendar year 2014. Rather than a comprehensive reporting of all field work, data collection, and data analysis since the beginning of AEA's study program, this report is intended to supplement and update the information presented in Part A of the ISR for the of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries Study through the end of calendar year 2014. It describes the methods and results of the 2014 effort, and includes a discussion of the results achieved.

2. STUDY OBJECTIVES

The overall goal of Study 9.12 is to evaluate the potential effects of Project-induced changes in flow and water surface elevation on free access of fish into, within, and out of suitable habitats in the Upper Susitna River (inundation zone above the Watana Dam site) and the Middle Susitna River (Watana Dam site to the confluence of Chulitna and Talkeetna rivers). This goal is being achieved by meeting the following objectives:

1. Locate and categorize all existing fish passage barriers (e.g., falls, cascades, beaver dams, road or railroad crossings) located in selected tributaries in the Middle and Upper Susitna River.
2. Locate the barriers using a global positioning system (GPS), identify the type (permanent, temporary, seasonal, partial), and characterize the physical nature of any existing fish barriers located within the Project's zone of hydrologic influence (ZHI).
3. Evaluate the potential changes to existing fish barriers (both natural and man-made) located within the Project's ZHI.
4. Evaluate the potential creation of fish passage barriers within existing habitats (tributaries, sloughs, side channels, off-channel habitats) related to future flow conditions, water surface elevations, and sediment transport.

Field activities during 2014 were designed to help meet objectives (1) and (2) and will supply the baseline condition for future evaluations of barrier creation under Objectives 3 and 4.

3. STUDY AREA

The study area includes the mainstem and selected tributaries in the Upper and Middle segments of the Susitna River that would be affected by construction and operation of the Project. For purposes of this study, the study area has been divided into three segments:

- Upper River—Susitna River and selected tributaries within this segment extend from the Proposed Watana Dam site (RM 184 [PRM 187.1]) to the upper extent of the Proposed Watana Reservoir Maximum Pool (PRM 232.5). In tributaries known to support Chinook Salmon, barriers were surveyed to 3,000 ft elevation unless a permanent impassable barrier existed between 2,200 and 3,000 ft elevation. If a barrier existed within this range, surveys stopped at the barrier.
- Middle River—Susitna River and selected tributaries within this segment extend from the Proposed Watana Dam site to the lower extent of Devils Canyon (PRM 153.9). In all tributaries, barriers were surveyed to 3,000 ft elevation or to the first permanent anadromous barrier.
- Middle River below Devils Canyon — Passage study sites in the mainstem Middle River included sloughs, upland sloughs, side channels, and tributary mouths. Passage studies in tributaries to the Middle River included select tributaries and extended from the mouth to include the upper limit of the ZHI for each tributary, The ZHI is defined as a 1.5-year recurrence flow interval (38,500 cubic feet per second [cfs]) at Gold Creek.

4. METHODS

Methods of 2014 activities included the finalization of proposed target fish species and passage criteria, follow-up field assessment at six geologic barriers and field surveys of nine tributary mouths in the Middle Susitna River.

4.1. Fish Species Identification

The methods for selecting the 11 target fish species were detailed in R2's Fish Passage Criteria Technical Memorandum (R2 2014; http://www.susitna-watanahydro.org/wp-content/uploads/2014/11/Barrier-Passage-Criteria-TM-20141110.pdf).

4.2. Passage Criteria for Identified Fish Species

The methods for developing passage criteria for selected target fish species were detailed in R2 (2014; http://www.susitna-watanahydro.org/wp-content/uploads/2014/11/Barrier-Passage-Criteria-TM-20141110.pdf).

4.3. Site Selection

As described in 9.12 ISR Section 4.3 (AEA 2014), site selection for both geologic and tributary mouth field surveys was completed in 2013 for field surveys conducted over 2013 and 2014 study seasons.

4.4. Field Methods

Study methods for field surveys conducted during 2014 varied primarily depending on the type of barrier being assessed. Depth barriers were evaluated at the mouths of tributaries whereas geologic barriers (cascades and waterfalls) were assessed within tributary streams. All surveys were conducted during a low flow window in late September to early October, just prior to freeze up.

4.4.1. Geologic Barriers to Fish Passage

The 2014 surveys of potential geologic barriers consisted of a follow-up to surveys conducted during 2012 and 2013 using the methods described in Study 9.12 Implementation Plan (AEA 2013; http://www.susitna-watanahydro.org/wp-content/uploads/2013/06/2013-06-17-Barrier-Implementation-Plan-Filing.pdf)

Six geologic barriers that had been previously visited and reported as potential barriers were revisited during fall low flow conditions to see if access for measurement would be feasible and, if not, to photo document and further describe each barrier. Aerial surveys were conducted from October 4 to October 10, 2014 and no safe landing zones were located in the vicinity of barriers even under low flow conditions. Conditions at the following six potential barriers and were assessed.

- Upper River

    - PB201.8-A and 201.8-B in Unnamed Tributary 204.5
- Middle River
    - PB152.4-A in Cheechako Creek
    - PB155.3-C in Unnamed Tributary 158.7
    - PB161.5-C in an Unnamed Tributary to Devil Creek
    - PB165.6-A in Unnamed Tributary 169.1

4.4.2. Beaver Dams

As reported in the ISR (Section 4.4.2), field survey data collection on beaver dams in Focus Areas was completed in 2013 for Study 6.6 Section 4.1.2.9.2 (AEA 2014) and aerial surveys of active beaver lodges were completed by the Aquatic Furbearers Study (Study 10.11 Section 5.1). In 2014, AEA completed remote mapping of beaver dams as part of the riparian surveys being conducted by the Riparian Vegetation Study Downstream of the Proposed Susitna-Watana Dam (Study 11.6). All potential beaver dams located between PRM 187.2 and 98 were identified using the methods detailed below. Dams were assigned to one of four structural integrity categories: intact, partial, undetermined, or not intact.

The remote mapping of beaver dams was conducted within the study area for Study 11.6 (PRM 187–29) by a GIS analyst on-screen in *ArcGIS.* Beaver dams were photo-interpreted from and digitized over 1) 4-band Digital Mapping Camera aerial imagery at 1-foot resolution (half-foot for selected areas), and 2) Bare Earth DEM Hillshade from LiDAR. The aerial imagery and LiDAR were both acquired at multiple dates in 2011 by Aerometric (now Quantum Spatial) for the Matanuska-Susitna Borough Imagery and LiDAR project. The Integrated Terrain Unit (ITU) mapping prepared for Study 11.6 (ISR 11.6, Part A, Section 4.3.2) and the beaver colony locations from Study 10.11 (Aquatic Furbearer Abundance & Habitat Use, ISR 10.11, Part A, Section 4.1) were also used as base layers in the mapping of beaver dams.

Beaver dam mapping occurred in two steps. First, to acquire an image library of known beaver structures and the experience to identify beaver structures across the full study area, the analyst assessed the imagery at a scale of 1:3,000 to 1:5,000 in areas with known beaver activity. Areas with known beaver structures were identified based on the beaver colony locations from Study 10.11, beaver dams observed by field personnel working on the Geomorphology Study (Study 6.5) and reported in ISR 6.5 (Table 5.1-4), and from those aquatic geomorphic units in the Study 11.6 ITU mapping with a high likelihood of beaver presence (e.g., Shallow Connected Beaver Pond). Beaver dams were usually found at the 1:3,000 to 1:5,000 scale by finding deep, clear water impoundments or linear features in waterways. LIDAR was used to evaluate the geomorphology of questionable areas (where water impoundments were observed but surface features were difficult to distinguish). Second, the analyst zoomed in (1:1,000 scale) to each area where potential beaver dams were identified during Step 1 and mapped potential beaver dams as line features. Following the initial mapping, the biologist that completed the beaver colony surveys for Study 10.11 reviewed each of the digitized line features. Each digitized line feature was assigned two data attributes, including 1) the likelihood that the digitized line actually represents a beaver dam, and 2) for those digitized lines determined to be a beaver dam, whether or not the dam appeared to be intact or not based on review of the imagery

4.4.3. Passage Conditions in Tributary Mouths

Thalweg profile surveys were conducted from the confluence with the Susitna River upstream to include the tributary mouth for nine Middle River tributaries using methods described in ISR Section 4.4.3. In summary, longitudinal profiles were collected, along with depth and velocity measurements and stream substrate assessments, at each thalweg survey point. The 2014 surveys covered the extent of the tributary delta for all tributaries. Field surveys began with Susitna flows just above 10,600 cfs on September 30 (at the USGS Gold Creek gage 15292000) and concluded with flows below 9,420 cfs on October 4, 2014

Nine Middle River tributary mouths were surveyed for passage conditions and evaluation of current and/or future potential barriers.

- Middle River
  - Tsusena Creek (PRM 184.6)
  - Fog Creek (PRM 179.3)
  - Devil Creek (PRM 164.8)
  - Chinook Creek (PRM 160.5)
  - Cheechako Creek (PRM 155.9)

  Middle River below Devils Canyon
  - Jack Long Creek (PRM 148.3)
  - Little Portage Creek (PRM 121.4)
  - McKenzie Creek (PRM 120.2)
  - Lower McKenzie Creek/Slough (PRM 119.7)

4.4.4. Variances

There were no variances for 2014 beyond those described in the ISR Part C (AEA 2014).

5. RESULTS

Results of 2014 activities included the finalization of proposed target fish species and passage criteria, follow-up field assessment at six geologic barriers and field surveys of nine tributary mouths in the Middle Susitna River.

5.1. Fish species and passage criteria selection

Species- and, where appropriate, life stage-specific criteria have been developed for a list of target species. The criteria will be used to evaluate the potential for these barrier features to impede free passage of fishes among each of the aforementioned habitats. Fish species selection and passage criteria were reported in the Fish Passage Criteria Technical Memorandum filed with FERC November 14, 2014 (R2 2014). The results of the TM are summarized below.

5.1.1. Fish Species Selection

Some fish species in the Susitna River exhibit life history patterns that rely on multiple habitats during freshwater rearing, and therefore, they may be more sensitive to changes in access to side channels, sloughs, and/or tributary habitats. Target species for fish passage barrier analysis was based on passage sensitivity, presence in the Middle and Upper Susitna, and locations of potential barriers (Table 5.1-1). Following the technical team meeting on March 19, 2014, additional species were recommended by licensing participants including Arctic Lamprey, Bering Cisco, Eulachon, Northern Pike, and Humpback Whitefish. AEA examined the distribution of these additional species, and it was determined that both Arctic Lamprey and Humpback Whitefish are present in the Middle River. Thus, these two species were added to the target species list (Table 5.1-1).

The distribution of Bering Cisco and Eulachon were determined to be outside of the study area. In addition, the life history and distribution of these fishes indicate a reliance upon mainstem habitat and/or very large tributaries during their limited time in the Susitna River basin. Consequently, neither Eulachon nor Bering Cisco were added to the target species list for this study.

Northern Pike initially was excluded from the target species list for Study 9.12 due to distribution outside the Study Area; however, based on consultation during the November 2014 Fish Barriers Technical Team Meeting, AEA will evaluate Northern Pike under the modeling component of this study as related to potential effects of Project operation on mainstem flows and migratory conditions, i.e., elimination of mainstem velocity barriers. This modeling will occur with the use of mainstem velocity data collected under Study 8.6 (AEA 2014).

5.1.2. Passage Criteria for the Selected Fish Species

A literature review of passage criteria was conducted for the adult and juvenile life stages of target fish species identified in Table 5.1-1. Salmonid passage criteria are well researched and some criteria exist for all species. Passage criteria for many non-salmonids have not been extensively researched, and in some cases, criteria do not currently exist. Where criteria for selected species were not available, criteria for closely related "surrogate" species were substituted. Basic categories of fish passage criteria evaluated for use in this study include water depth, fish swimming ability (as related to velocity criteria), and fish leaping ability. Depth criteria will be used to assess fish passage into, within, and out of side channels, sloughs, and tributaries. Leaping criteria will be used to evaluate the vertical and horizontal distances fish must leap to pass an isolated geologic barrier. The velocity component of passage at a physical or depth barrier also will be applied where velocity may influence successful passage.

5.1.2.1. Depth Criteria for Adult Upstream Migration and Downstream Migration

Minimum depth criteria for fish passage have been reported for many fish species; although the majority of studies have focused on the design of fish passage structures. The criteria used to assess minimum depth requirements have varied by study, with fish size and life stage. A range of minimum depth criteria from the literature for target fish species and life stages are presented in Table 5.1-2.

5.1.2.2. Leaping Criteria for Adult Upstream Migration

The ability of a fish to pass a vertical barrier is determined by species- and life stage-specific endogenous factors such as burst speed, swimming form, and leaping capability. Exogenous factors include water depth, stream flow, and barrier geometry. Table 5.1-3 presents the leaping criteria from source documents.

Leaping curves and jumping equations assume that the depth of the pool a fish leaps from is adequate for achieving maximum speed at the initiation of the jump. Both a minimum pool depth and the ratio of barrier height to pool depth have been suggested as appropriate metrics by which to evaluate potential for successful passage. These general guidelines were incorporated into the USFS 2001 Aquatic habitat management handbook for the Alaska Region and are presented in Table 5.1-4.

5.1.2.3. Velocity and Gradient Criteria

Velocity can become an effective barrier when flow is concentrated, the length and velocity of the flow field combine to overcome the fish’s swimming ability, and the geometry of the channel does not allow the fish to leap over or otherwise avoid the velocity barrier (R2 Resource Consultants, Inc 2007). In addition to a critical velocity barrier, upstream passage can be limited by the channel gradient over an extended reach if no resting areas are present. Fish passage may occur at steeper gradients over shorter reaches (e.g. > 50 ft at 20 percent gradient for Chinook, Coho and Sockeye Salmon), but the gradient for successful passage decreases with increasing reach length (

Table 5.1-4). Prolonged swimming is an indication of a fish's ability to traverse longer reaches, whereas burst swimming provides an indication of the ability of fish to traverse discrete high velocity areas. We recommend that the high-end of prolonged speed and burst speed are applicable to fish passage in higher velocity and gradient reaches found in Susitna River tributaries. Known species- and life stage-specific prolonged and burst speed values were obtained from the literature are reported in Table 5.1-5.

5.2. Geologic Barriers

5.2.1. Cheechako Creek, PB152.4-A

Cheechako Creek, located on the right bank of the Susitna River at PRM 155.9 was flown from helicopter on October 10, 2014. There was no safe landing site within the vicinity of the potential barrier site that was located approximately one mile upstream from the mouth. The site contained three waterfalls followed by a high gradient reach of boulder dominated cascades. The waterfall located at the upstream end of the reach was estimated at five feet in height and was preceded by a 40 ft long cascade (Figure 5.2-1; upper left). The height of middle waterfall was estimated at 10 ft and below this waterfall the stream dropped into a turbulent pool (Figure 5.2-1; upper right). The lowermost waterfall was estimated at 8 feet in height. Downstream of this lowermost waterfall was a high gradient boulder cascade estimated at 200 ft long (Figure 5.2-1; lower right). The 2012 barrier classification of Potential Fixed Permanent Compound barrier was confirmed. This site could not be confirmed or disproved as a complete barrier to upstream passage of fishes because it could not be measured due to lack of access. The high gradient nature of the habitat downstream of the lower falls indicates that passage for adult salmon at this site is unlikely.

5.2.2. Unnamed Tributary 158.7 (RB), PB155.3-C

The potential barrier was located in an unnamed tributary that flows into the Susitna River at PRM 158.7 on river right. The barrier survey was flown on October 4, 2014. The stream section surveyed contained a continuous steep cascade estimated to be greater than 250 ft long and with a gradient estimated at more than 45 degrees (Figure 5.2-2). The site was re-classified, as a Fixed Permanent Boulder Cascade barrier to upstream fish passage due to excessive gradient.

5.2.3. Unnamed Tributary to Devil Creek, PB161.5-C

The potential barrier was located in an unnamed tributary to Devil Creek approximately 2,000 ft from the tributary confluence with Devil Creek, and approximately one mile from the mouth of Devil Creek. This site contained three waterfalls estimated over ten feet in height with few resting places between waterfalls (Figure 5.2-3). Although a plunge pool was observed below the downstream waterfall, high gradient boulder cascades were observed above and below the multiple waterfalls that would preclude fish passage. The site was re-classified as a Fixed Permanent Compound barrier.

5.2.4. Unnamed Tributary 169.1, PB165.6-A

This potential barrier was located on Unnamed Tributary 169.1 entering the Susitna River on river left. The barrier was approximately 2,000 ft from the tributary mouth. The survey, conducted on October 10, 2014, estimated the waterfall was greater than 12 ft with boulder cascades above and below the waterfall. The gradient of the downstream cascade was 17 percent. The site classification was maintained, Fixed Permanent Compound (Figure 5.2-4); because no ground measurements were possible the site is considered a potential barrier to upstream fish passage.

5.2.5. Unnamed Tributary 204.5, PB201.8-A and PB201.8-B

These potential barriers were located on an unnamed tributary entering the Susitna River on river left. The lowermost barrier was approximately 2,500 ft upstream from the creek mouth. The survey occurred on October 6, 2014. The barriers were approximately 500 ft apart. Under the low flow conditions, the estimated height for the downstream waterfall (PB-204.5A) was 12 ft, while the estimated height for upstream waterfall (PB-204.5B) was 10 ft (Figure 5.2-5). Both of the estimated heights were greater than the previous survey at higher flows. The site was re-classified as a Fixed Seasonal Compound barrier.

5.3. Beaver Dam Survey

Review of remote imagery for approximately 89 miles of the Middle River identified 433 potential beaver dams (Figure 5.3-1). The assessment of structural integrity of the dams identified 164 intact dams, 34 partial dams, and 147 not intact dams. The integrity of 88 dams could not be determined from remote imagery. The dam locations are presented in 19 of the 43 reach maps depicting the results of the review (Appendix A) and these detailed maps also indicate the dams within Focus Areas where field verification occurred as part of Study 6.6. Dam. Heights and status of the field verified dams is reported in Table 5.3-1.

5.4. Tributary Mouth Surveys

5.4.1. Lower McKenzie Creek/Slough (PRM 119.7)

Lower McKenzie Creek/Slough enters into the mainstem Susitna River on the left bank at PRM 119.7. The stream channel was surveyed for a distance of 343.7 ft on September 30, 2014. At the upstream end of the survey, upstream of a culvert under the Alaska Railroad, the stream was flooded by a beaver dam partially blocking the culvert (Figure 5.4-1).

Downstream of the culvert, the stream traversed a large pool (at thalweg station 275.1 ft) then sped up over a shallow riffle (Figure 5.4-2). Overall, substrate downstream of the culvert was dominated by a mixture of cobble, gravel and silt with depths between 0.2 and 3.2 ft (Table 5.4-1). A mainstem gravel bar extended across the creek mouth and separated the creek from the mainstem Susitna River at the low flow condition during surveys (mean daily flow at Gold Creek was 10,609 cfs).

During the survey, survey staff were accompanied by personnel from the Alaska Railroad. They indicated that the beaver would be re-located from this location prior to freeze-up. The geometry and composition of Lower McKenzie Creek/Slough likely will change after removal of the beaver(s).

5.4.2. McKenzie Creek (PRM 120.2)

McKenzie Creek entered the Susitna River on river left at PRM 120.2. The stream channel was surveyed for a distance of 348.8 ft on September 30, 2015 from downstream of the railroad culvert to the mouth. This section of creek was contained within a defined channel as it meandered through a mixed cottonwood and birch stand (Figure 5.4-3). Downstream of the hardwood stand, flow spread out across a small boulder apron just before reaching the Susitna River (Figure 5.4-4). During low Susitna River flow conditions (mean daily flow at Gold Creek USGS gage was 10,609 cfs), the creek mouth was separated from the mainstem flow by a gravel bar. Thalweg substrate was dominated by cobbles and gravel with water depths between 0.3 and 1.0 ft and water velocities averaging 1.4 feet per second (fps) with a maximum of 2.8 fps (Table 5.4-2).

5.4.3. Little Portage Creek (PRM 121.4)

Little Portage Creek was surveyed over a distance of 745.6 ft on September 30, 2014. The stream flowed through a moderate gradient channel and dispersed across a delta before reaching a shallow side channel riffle adjacent to the left bank of the Susitna River. While this riffle was comprised solely of creek flow during the low flow survey conditions it likely becomes submerged by mainstem flows at higher Susitna River flows (Figure 5.4-5, Figure 5.4-6). Substrates were dominated by cobble and gravel and stream depth ranged from 0.25 to 1.10 ft (Table 5.4-3). Water velocity was generally low with an average of 0.8 fps and range of 0.4 to 1.9 fps.

5.4.4. Jack Long Creek (PRM 148.3)

Jack Long Creek entered the Susitna River on river right at PRM 148.3. The stream channel was surveyed over a distance of 297.7 ft on October 1, 2014. At the upstream end of the survey, the channel was distinct with high gradients up to 7.3 percent and large boulders (Figures 5.4-7 and Figure 5.4-8). The stream then dispersed over a large delta dominated by boulder and cobble substrate (Figure 5.4-7) and no defined thalweg was present. Nevertheless, the deepest channel with the majority of the flow was surveyed and this channel extended in the downstream direction of the mainstem Susitna River. Substrate along the entire thalweg survey was dominated by boulder and cobble and channel depths ranged from 0.9 to 2.1 ft (Table 5.4-4). Water velocity averaged 2.8 fps with a maximum of 4.7 fps.

5.4.5. Cheechako Creek (PRM 155.9)

Cheechako Creek joined with the Susitna River on river left at PRM 155.9. Approximately 130 ft of the lower portion of this stream was surveyed on October 2, 2014. The mouth of Cheechako Creek was a high gradient rapid with numerous pools and drops through a large boulder cascade (Figure 5.4-9). Substrate was dominated by boulders and cobbles with a greater proportion of bedrock at the upper survey stations. Flow depths ranged from 1.3 to 2.3 ft (Table

5.4-5). Velocities were consistently high, ranging from 1.3 to 5.0 fps with a mean velocity of 2.7 fps. The channel was incised through an unconsolidated gravel and boulder bank. Overall gradient for the 138.3 feet-long thalweg profile was 5.1 percent with a maximum of 19.3 percent (Figure 5.4-10).

5.4.6. Chinook Creek (PRM 160.5)

Chinook Creek joined the Susitna River on river left at PRM 160.5. The lower section of Chinook Creek was surveyed for 157 ft on October 2, 2014, and consisted of a high gradient rapid with numerous pools and drops among large boulders (Figure 5.4-11). Substrate was dominated by bedrock, boulders and cobbles with flow depths ranging from 1.0 to 2.1 ft. Velocities were consistently high, ranging from 1.8 to 6.7 fps with a mean velocity of 4.3 fps (Table 5.4-6). The channel was incised through an unconsolidated gravel and boulder bank. Overall gradient for the thalweg profile was 4.3 percent (Figure 5.4-12).

5.4.7. Devil Creek (PRM 164.8)

Devil Creek joined the Susitna River on river right at PRM 164.8. The mouth of Devil Creek was surveyed on October 3, 2014, over a distance of 141.9 ft. This section of the creek consisted of a high gradient rapid with a distinct thalweg that ran adjacent to a bedrock wall (Figure 5.4-13). The depth and swiftness of the thalweg prevented survey staff from measuring flow in the deepest channel. As a result, water velocity and depth measurements may underestimate values at the thalweg for some stations. Overall gradient for the thalweg profile was 4.0 percent and the substrate was dominated by bedrock and boulders (Figure 5.4-14). The flow depth ranged from 1.4 to 5.0 ft, and flow velocities were between 1.8 and 7.4 fps with a mean of 4.1 fps (Table 5.4-7).

5.4.8. Fog Creek (PRM 179.3)

Fog Creek joined the Susitna River on river left at PRM 179.3. A distance of 370 ft was surveyed on October 3, 2014. In the mouth of Fog Creek, flow split into two channels across a broad debris fan (Figure 5.4-15). The majority of flow (estimated >90 percent) was contained in the north channel where the survey was conducted. The substrate in this channel was dominated by bedrock and cobble with water depths between 1.1 and 2.4 ft and velocities between 2.7 and 7.4 fps with an average of 5.0 fps (Table 5.4-8). Overall gradient for the thalweg profile was 2.5 percent with a maximum of 12.6 percent (Figure 5.4-16).

5.4.9. Tsusena Creek (PRM 184.6)

Tsusena Creek joined the Susitna River on river right at PRM 184.6. The mouth of Tsusena Creek was surveyed on October 4, 2105, over a distance of 374.8 ft. The stream flowed across a broad alluvial fan consisting of shallow flow over a large extent of the fan as well as within a well-defined thalweg channel (Figure 5.4-17). The substrate was dominated by bedrock and cobble with water depths between 0.95 and 2.8 ft (Table 5.4-9). Average water column velocity ranged from 1.1 to 6.1 fps and the overall gradient along the thalweg length was 1.5 percent with a maximum of 9.4 percent (Figure 5.4-18).

6. DISCUSSION

To date, the Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries has identified target fish species to be evaluated with input from the licensing participants and has proposed velocity, leaping, and depth criteria to use in evaluating species/lifestage specific passage potential. In 2012 through 2014, AEA completed field surveys conducted under this study, including aerial surveys for geologic barriers in all major tributaries in the Upper and Middle River and thalweg surveys of tributary mouths within the Middle River. In addition, field data collection characterization of existing physical barriers within FAs, including beaver dams, and for additional selected tributary mouths outside of FAs has been completed by the Geomorphology Study (Study 6.5) and Instream Flow Study (Study 8.5) and will be used to developed hydraulic and flow-habitat models.

In addition, the Salmon Escapement Study is evaluating the upstream passage of adult salmon through Devils Canyon (Study 9.7). Impacts of changes to barriers will be evaluated in coordination with results from the Geomorphology Modeling Study (Study 8.6) Fish and Aquatic Instream Flow Study (Study 8.5), the Upper and Middle River Fish Distribution and Abundance Studies (Studies 9.5 and 9.6), and the Habitat Characterization and Mapping Study (Study 9.9). Both data collection and model development activities are on track to evaluate the potential effects of Project-induced changes in flow and geomorphology on free access of fish into, within, and out of suitable habitats in the Upper River and the Middle River.

7. CONCLUSION

The Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries has: 1) documented existing barriers present in Middle and Upper Rivers tributaries, 2) characterized the thalweg depths and velocities within selected Middle River Tributary mouths, 3) characterized beaver dams within FAs, 4) conducted consultation with licensing participants on target fish species and passage criteria, and 5) coordinated with interrelated modeling studies. The field data collection efforts for characterizing existing barrier conditions are complete. To evaluate the potential for Project Operations to alter barrier conditions in these areas outputs from modeling efforts will be integrated with the data collected to fully achieve the approved study objectives.

7.1. Decision Points from Study Plan

No decision points beyond those described in Study 9.12 ISR Part C (AEA 2014) have been established.

7.2. Modifications to Study Plan

No modifications to the Study Plan are needed to complete the study and meet Study Plan objectives.

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9. TABLES

Table 5.1-1. Target species list for fish passage barrier evaluation following consultation with licensing participants.

Target Species
Chinook Salmon
Chum Salmon
Coho Salmon
Pink Salmon
Sockeye Salmon
Arctic Grayling
Arctic Lamprey [1]
Burbot
Dolly Varden
Humpback Whitefish[1]
Northern Pike[1,2]
Rainbow Trout

[1] Target species suggested for consideration by licensing participants.
[2] Northern Pike will be evaluated for mainstem velocity barrier.
[3] Bering Cisco and Eulachon were suggested but not added due to distribution and life history characteristics.

Table 5.1-2. Depth criteria required for fish passage as reported in the literature for targeted fish species and adult and juvenile life stages.

Species	Lifestage	Depth Criteria (ft)	References
Arctic Grayling	adult	0.6	ADF&G (2001)
	juvenile	0.4	ADF&G (2001)
Dolly Varden	adult	0.2 - 1.0	ADF&G (2001)
	juvenile	0.2	Bugert et al. (1991)
Chinook Salmon	adult	0.8 - 0.9	CDFG (2013), Thompson (1972)
	juvenile	0.3	CDFG (2013)
Coho Salmon	adult	0.6 - 0.7	CDFG (2013), Thompson (1972)
	juvenile	0.3	CDFG (2013)
Chum Salmon	adult	0.6 - 0.8	CDFG (2013), Thompson (1972),
	juvenile	0.3	CDFG (2013)
Pink Salmon	adult	0.6 - 0.8	CDFG (2013), Thompson (1972),
	juvenile	0.3	NMFS (2008)
Sockeye Salmon	adult	0.6 – 0.7	Bates et al. (2003)
	juvenile	0.3	CDFG (2013)
Rainbow Trout	adult	0.5 - 0.7	Snider (1985), CDFG (2013)
	juvenile	0.3	CDFG (2013)

Note: Northern Pike are being evaluated for velocity and not depth.

Table 5.1-3. Pacific Salmon leaping height capabilities from three sources.

Species	Leaping Height (feet)		
	Powers and Orsborn (1985)[1]	Reiser and Peacock (1985)	USFS (2001)
Dolly Varden	-	-	6.0
Chinook Salmon	7.5	7.9	11.0
Chum Salmon	3.5	4.0	4.0
Coho Salmon	7.5	7.3	11.0
Pink Salmon	3.5	4.0	4.0
Sockeye Salmon	7.5	6.9	10.0

Note: Assumes a trajectory of 80^0 with a condition factor of 1.0. Maximum leaping height is less at a lower trajectory and lower fish condition factor.

Table 5.1-4. Pool depth and channel gradient fish passage criteria for target Salmonids adapted from the Forest Service Handbook 2090.21 Adult Salmonid Migration Blockage Table.

	Species				
Criterion	**Chinook**	**Coho**	**Sockeye**	**Pink/Chum**	**Dolly Varden**
Pool depth A blockage may be presumed if pool depth is less than the following, and the pool is unobstructed by boulders or be bedrock:	1.25 x jump height, except that there is no minimum pool depth for falls: (a)<4 feet (1.2m) in the case of Coho and Steelhead; and (b)<2 feet (0.6m) in the case of other anadromous fish species.				
Steep channel A blockage may be presumed if channel steepness is greater than the following without resting places for fish:	>225 feet (68.6m) @ 12% gradient >100 feet (30.5m) @ 16% gradient >50 feet (15.2m) @ 20% gradient			>100 feet (30.5m) @ 9% gradient	>50 feet (15.2m) @ 30% gradient

Table 5.1-5. Swimming capabilities and velocity criteria for fish passage based literature values for selected fish species and life stages.

Species	Life stage	Prolonged Speed		Burst Speed	
		ft/s	References	ft/s	References
Arctic Grayling	Adult	1.4 - 4.1	Katapodis (1992)	6.9 - 13.9	Bell (1991)
	Juvenile	0.5 - 0.8	Deegan et al. (2005)	NR	NR
Arctic Lamprey	Adult	0.2 - 0.8	[a] Robinson and Bayer (2005), [a] Clemens et al. (2012)	2.5 - 10	[a] Mesa et al. (2003), [a] Keefer et al. (2010)
	Juvenile	0.3 - 0.6	[a]Sutphin and Hueth (2010)	1.0 - 2.5	[a] Sutphin and Hueth (2010)
Burbot	Adult	1.3 - 2.6	Jones et al. (1974), Schwalme et al. (1985)	1.1 - 4.0	Bell (1991)
	Juvenile	1.1 - 1.3	Jones et al. (1974)	NR	NR
Dolly Varden	Adult	2.0 - 3.3	[b]Beamish (1980)	4.2 - 7.5	[b] Mesa et al. (2004)
	Juvenile	0.5-1.6	[c]Mesa et al. (2004)	NR	NR
Humpback Whitefish	Adult	1.0 - 2.3	Jones et al. (1974), Beamish (1980)	3.0 - 4.0	Bell (1991)
	Juvenile	0.2 - 1.3	Jones et al. (1974)	NR	NR
Northern Pike	Adult	1.9 – 2.0	Peake (2008) [d]	5.7 – 17.4[e]	Peake (2008)
	Juvenile	0.4 – 1.2	Peake (2008) [d]	NR	NR
Chinook Salmon	Adult	2.9 - 11.0	Bell (1991)	11.0 - 22.1	Bell (1991)
	Juvenile	0.5 - 0.9	Furniss et al. (2008)	2.0 - 2.3	Randall et al. (1987)
Coho Salmon	Adult	3.1 - 10.9	Lee et al. (2003)	11.7 - 21.0	Bell (1991)
	Juvenile	0.4 - 2.1	Bell (1991)	NR	NR
Chum Salmon	Adult	1.7 - 5.1	Aaserude and Orsborn (1985)	6.0 - 12.6	Powers and Orsborn (1985)
	Juvenile	0.4 - 0.6	Smith and Carpenter (1987)	NR	NR
Pink Salmon	Adult	2.9 - 11.0	Lee et al. (2003), Bell (1991)	11.0 – 21.0	Bell (1991)
	Juvenile	0.4 - 0.5	Smith and Carpenter (1987)	7.7 – 11.0	Powers and Orsborn (1985)

Species	Life stage	Prolonged Speed		Burst Speed	
		ft/s	References	ft/s	References
Sockeye Salmon	Adult	4.0 – 8.8	Bell (1991)	10.0 - 21.9	Bell (1991), Bainbridge (1960)
	Juvenile	1.4 - 2.1	Bell (1991)	NR	NR
Rainbow Trout	Adult	2.1 - 2.6	Furniss et al. (2008)	14.0 - 20.3	Bell (1991)
	Juvenile	1.0 - 2.0	Bainbridge (1960)	2.4 - 7.2	Bainbridge (1960)

[a] Pacific Lamprey is used as a surrogate; [b] Arctic Char is used as a surrogate; [c] Bull Trout is used as a surrogate; [d] Converted from metric UCrit speeds at temperature greater than 12°C; [e] Maximum swimming speed for 20.7 to 35.8 cm Northern Pike at 15°C; [+]for Bull Trout; *NR = no reference available*

Table 5.3-1. Data from field verification of beaver dams in Focus Areas.

Dam ID	Survey Date	Focus Area	Status	Height (ft)	Comments
1	9/14/13	FA-104	Active	5.5	Large beaver dam in upland slough
2	9/ 14/13	FA-104	Undetermined	ND	Beaver pond
3	9/15/13	FA-113	Inactive	ND	Old beaver dam
4	9/16/13	FA-113	Inactive	ND	Abandoned beaver dam that was partially filled in. Raised water table.
5	9/16/13	FA-113	Inactive	ND	Old beaver dam was intact but doesn't appear to be active.
6	9/16/13	FA-115	Active	ND	Beaver dam in upland slough
8	8/26/13	FA-128	Active	ND	Two dam structures located at upstream end of side slough.
7	9/20/13	FA-115	Inactive	5	Old abandoned, breached beaver dam.
9	8/15/13	FA-138	Inactive	ND*	Two points associated with one beaver pond and blown out beaver dam
11	8/14/2013	FA-138	Active	1.5	Two points associated with one beaver dam across a side channel
12	8/14/2013	FA-138	Active	2	Beaver dam at head of coarse riffle
14	8/15/2013	FA-138	Active	3	Downstream end of beaver dam
15	9/21/13	FA-141	Active	3	Beaver dam across upland slough; status uncertain.

Dam ID	Survey Date	Focus Area	Status	Height (ft)	Comments
16	9/21/13	FA-141	Active	4.5	Beaver dam in upland slough.
17	8/17/2013	FA-144	Active	ND	Beaver dam at confluence of side slough and side channel
18	8/18/2013	FA-144	Inactive	0	Old beaver dam at mouth. Flow backed up from beaver dam 17.

*ND = no data

Table 5.4-1. Lower McKenzie Creek/Slough thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	489.2	1.4	0.7	0	0	0	0	100	0
22.4	489.6	1.6	1.2	0	0	60	0	40	0
52.9	490.4	0.6	0.9	0	0	20	0	80	0
81.3	490.4	0.5	1.1	0	0	90	10	0	0
135.5	490.9	0.4	1.4	0	0	20	70	10	0
161.1	491.3	0.3	1.6	0	0	10	90	0	0
193.5	492.2	0.2	1.7	0	0	90	0	10	0
217.8	492.2	0.7	0.9	0	0	20	60	20	0
235.3	492.4	0.5	1.2	0	0	10	80	10	0
252.1	492.0	1.0	0.6	0	0	0	70	30	0
275.1	491.6	1.5	0.7	0	0	10	70	20	0
343.7	494.7	3.2	0.1	NRD	NRD	NRD	NRD	NRD	NRD

Table 5.4-2. McKenzie Creek thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	493.6	0.65	1.0	0	0	0	0	90	10
21.4	495.3	0.45	1.1	0	0	40	50	10	0
41.5	495.8	0.35	1.1	0	0	60	30	0	10
80.7	495.5	0.85	0.7	0	0	40	50	10	0
101.4	495.8	0.65	1.9	0	10	60	20	10	0
118.8	497.2	0.45	1.8	0	0	70	20	10	0
134.8	497.7	0.40	2.8	0	10	50	30	10	0
159.8	499.3	0.60	1.4	0	10	40	40	10	0
176.2	499.6	1.00	1.2	0	20	40	40	0	0
204.8	502.4	0.30	1.3	0	10	50	40	0	0
229.0	502.2	0.40	1.4	0	0	30	60	10	0
265.7	503.2	0.45	1.3	0	0	40	40	20	0
348.8	506.0	0.60	2.4	0	10	50	40	0	0

Table 5.4-3. Little Portage Creek thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	503.8	0.30	0.3	0	0	20	70	10	0
27.1	503.8	0.55	0.6	0	0	30	60	0	10
60.5	504.0	0.45	0.9	0	0	30	50	10	10
113.0	504.5	0.40	0.8	0	0	60	20	10	10
147.7	504.8	0.25	0.7	0	0	30	70	0	0
180.2	505.3	0.30	0.9	0	0	70	30	0	0
210.9	506.0	0.25	0.6	0	0	60	30	0	10
247.3	506.2	0.40	1.0	0	0	70	20	0	10
292.5	506.2	0.45	0.4	0	0	30	50	10	10
327.4	506.1	0.80	0.5	0	0	20	60	10	10
363.8	506.5	0.50	0.9	0	0	60	30	0	10
420.0	506.3	0.80	0.4	0	0	70	20	0	10
475.3	506.2	0.80	0.6	0	0	50	40	0	10
522.9	506.5	0.40	0.6	0	0	50	40	0	10
584.8	506.1	1.10	0.9	0	0	40	40	10	10
609.3	506.6	0.65	0.7	0	0	30	70	0	0
643.7	508.4	0.45	1.1	0	0	70	30	0	0
745.6	512.3	0.65	1.9	0	10	30	60	0	0

Table 5.4-4. Jack Long Creek thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	789.2	1.2	0.2	0	70	20	10	0	0
28.3	790.5	1.0	0.9	0	60	20	10	10	0
41.1	791.5	0.9	3.0	0	70	20	10	0	0
60.1	791.9	1.3	1.2	0	80	20	0	0	0
85.5	792.7	0.9	2.1	0	80	20	0	0	0
101.7	792.9	0.9	3.7	0	90	10	0	0	0
124.4	793.5	1.1	4.7	0	80	10	10	0	0
149.3	793.9	1.0	3.3	0	70	20	10	0	0
168.6	793.8	2.1	4.4	0	90	10	0	0	0
186.2	794.8	1.0	3.7	0	90	10	0	0	0
208.8	795.2	1.1	1.8	0	70	20	10	0	0
227.1	796.0	1.1	4.1	0	70	20	10	0	0
250.1	796.5	1.3	3.9	0	60	20	10	10	0
274.6	796.8	1.3	2.7	0	60	20	10	10	0
297.7	796.1	2.1	2.6	0	50	20	20	10	0

Table 5.4-5. Cheechako Creek thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	968.9	2.20	1.8	0	90	10	0	0	0
12.6	970.1	1.80	1.3	0	90	7	3	0	0
25.0	970.5	2.30	1.3	0	100	0	0	0	0
39.2	972.9	1.75	3.7	0	90	10	0	0	0
60.7	974.2	1.25	5.0	0	95	5	0	0	0
69.1	975.1	1.30	4.6	0	60	35	5	0	0
83.0	974.8	1.70	2.5	0	75	20	5	0	0
94.0	974.8	1.80	2.5	50	40	10	0	0	0
108.9	975.3	1.90	1.8	0	60	30	10	0	0
129.7	976.7	2.00	3.4	30	60	10	0	0	0

Table 5.4-6. Chinook Creek thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	1069.0	1.7	2.1	0	70	25	5	0	0
8.6	1069.9	1.0	4.3	0	50	40	10	0	0
22.6	1070.4	1.1	1.8	0	60	30	10	0	0
34.5	1072.2	1.2	5.2	0	90	10	0	0	0
52.7	1072.9	2.1	2.7	10	70	15	5	0	0
59.1	1073.6	1.8	5.7	10	80	10	0	0	0
65.5	1074.1	1.4	4.9	10	80	10	0	0	0
72.9	1075.3	1.7	5.1	20	75	5	0	0	0
79.0	1076.1	1.2	6.7	50	40	10	0	0	0
85.7	1076.6	1.9	4.1	0	95	5	0	0	0
95.9	1077.5	1.3	3.8	0	50	40	10	0	0
105.4	1077.8	1.3	5.3	0	50	40	10	0	0
111.8	1077.5	1.5	6.4	0	70	20	10	0	0
122.3	1078.7	1.4	5.0	0	80	15	5	0	0
138.5	1079.7	1.3	4.9	0	75	20	5	0	0
157.0	1080.0	1.7	2.9	40	30	20	10	0	0

Table 5.4-7. Devil Creek thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	1200.7	3.3	2.1	20	75	5	0	0	0
7.4	1200.2	3.6	1.8	0	90	10	0	0	0
19.2	1200.7	3.5	2.7	20	75	5	0	0	0
47.1	1201.2	3.5	4.3	0	90	10	0	0	0
64.2	1203.7	1.4	4.8	20	75	5	0	0	0
71.6	1202.3	2.7	2.2	15	85	0	0	0	0
88.1	1204.7	2.4	7.4	40	60	0	0	0	0
96.4	1204.8	2.3	5.9	60	40	0	0	0	0
105.4	1205.7	2.3	4.3	0	85	10	5	0	0
117.7	1206.2	2.7	4.1	60	35	5	0	0	0
141.9	1206.4	2.3	4.9	40	50	10	0	0	0

Table 5.4-8. Fog Creek thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	1372.1	1.2	4.0	0	40	50	10	0	0
18.1	1371.4	2.4	3.8	0	50	40	10	0	0
33.7	1372.2	1.5	6.1	0	50	45	5	0	0
44.4	1372.3	1.4	5.5	0	30	60	10	0	0
53.0	1372.5	1.3	7.4	0	40	50	10	0	0
61.6	1373.1	1.4	6.0	0	40	50	10	0	0
68.9	1373.5	1.5	5.8	0	30	60	10	0	0
74.3	1373.6	1.5	6.9	0	25	70	5	0	0
86.6	1373.7	2.3	3.8	0	60	35	5	0	0
95.1	1374.7	1.6	6.4	0	40	50	10	0	0
102.8	1374.3	2.2	3.2	0	60	35	5	0	0
113.4	1375.7	1.5	5.2	0	45	50	5	0	0
122.3	1376.1	1.1	6.0	0	40	55	5	0	0
133.6	1376.5	1.3	5.3	0	30	60	10	0	0
151.1	1376.9	1.4	3.9	0	20	70	10	0	0
164.3	1376.9	1.6	2.7	0	20	60	20	0	0
186.5	1377.2	1.4	4.4	0	10	70	20	0	0
222.4	1376.9	2.0	5.5	0	30	65	5	0	0
239.1	1376.8	2.2	3.9	0	40	55	5	0	0
330.4	1379.4	2.0	5.1	0	60	35	5	0	0
349.9	1380.0	1.4	4.8	0	50	45	5	0	0
370.0	1380.5	1.4	4.0	0	60	40	0	0	0

Table 5.4-9. Tsusena Creek thalweg characteristics.

Thalweg Station (ft)	Bed Elevation (ft)	Depth (ft)	Velocity (ft/sec)	Bedrock (%)	Boulder (%)	Cobbles (%)	Gravel (%)	Fines (%)	Organics (%)
0.0	1435.6	1.80	3.2	0	50	40	10	0	0
14.5	1436.3	1.20	3.4	0	20	70	10	0	0
28.4	1436.8	0.95	3.6	0	40	50	10	0	0
39.8	1436.7	1.40	4.7	0	30	60	10	0	0
53.1	1437.1	1.60	3.3	0	40	50	10	0	0
64.8	1437.3	1.50	4.7	0	60	30	10	0	0
76.2	1437.9	1.30	5.4	0	70	25	5	0	0
87.1	1438.0	1.70	2.8	0	80	20	0	0	0
100.2	1438.0	1.60	6.1	0	80	20	0	0	0
113.8	1439.2	1.30	4.1	0	75	20	5	0	0
123.7	1440.0	1.50	5.1	0	80	10	10	0	0
142.6	1440.1	1.60	3.5	0	40	50	10	0	0
151.7	1440.3	1.50	5.0	0	70	25	5	0	0
174.8	1440.5	1.40	4.4	0	50	40	10	0	0
185.8	1440.6	1.60	4.9	0	40	55	5	0	0
196.1	1440.9	1.50	3.6	0	50	45	5	0	0
207.5	1441.1	1.70	3.6	0	70	20	10	0	0
219.9	1441.1	1.80	1.8	0	40	50	10	0	0
235.4	1441.2	1.90	2.6	0	30	60	10	0	0
252.3	1440.8	2.40	2.1	0	20	70	10	0	0
332.2	1441.2	2.40	1.1	0	70	20	10	0	0
351.0	1441.1	2.45	2.7	0	70	20	10	0	0
374.8	1441.1	2.80	3.8	0	70	20	10	0	0

10. FIGURES

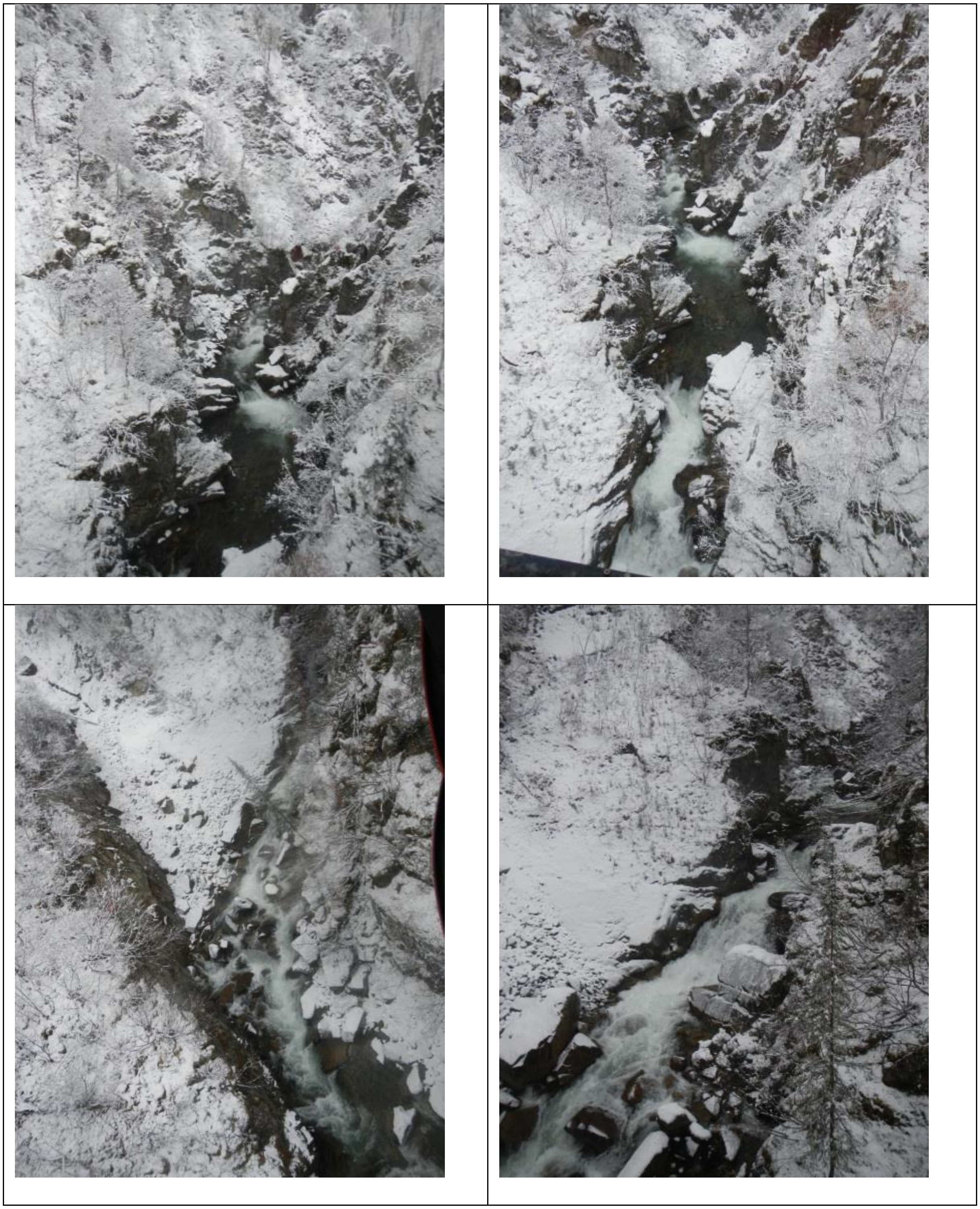

Figure 5.2-1. Photos of PB152.4-A, October 10, 2014. Clockwise from upper left: upper waterfall; middle waterfall; lower waterfall, lower cascade.

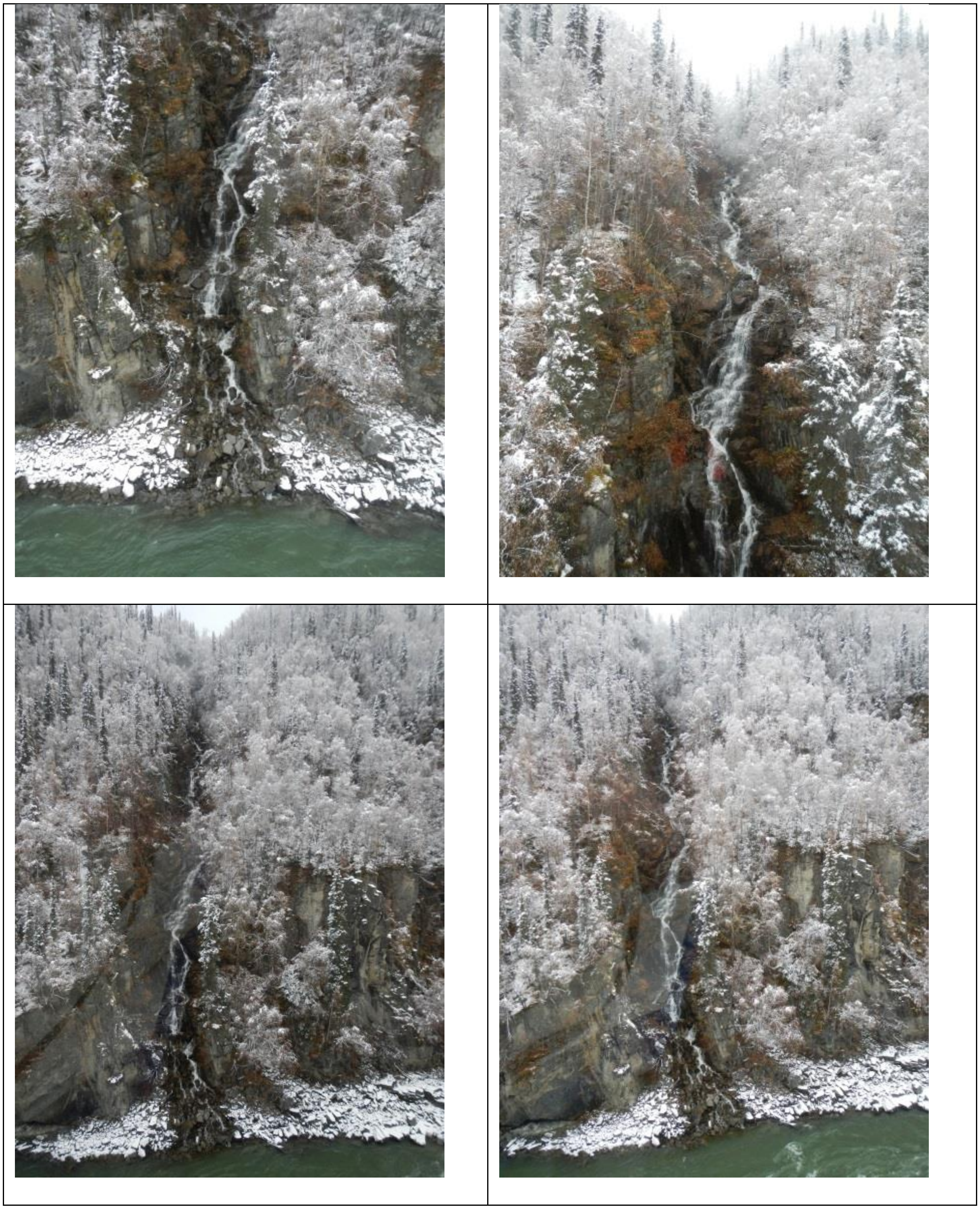

Figure 5.2-2. Photos of PB155.3-C, October 4, 2014. Clockwise from upper left: lower section of cascade; upper section of cascade; full section of cascade view #1; full section of cascade view #2.

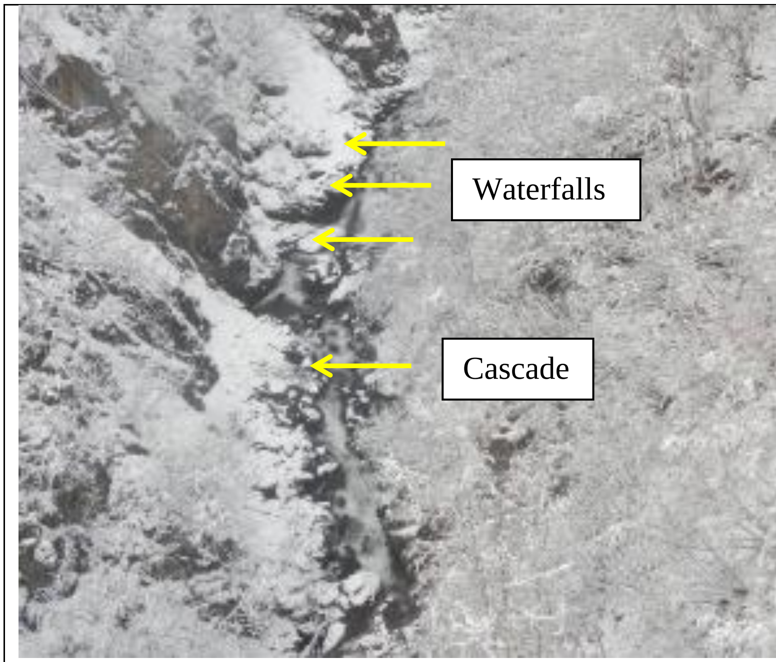

Figure 5.2-3. Photos of PB161.5-C, October 4, 2014. Left panel: view of three waterfalls and downstream cascade; right panel: full waterfall and cascade view.

Figure 5.2-4. Photo of PB165.6-A, October 10, 2014.

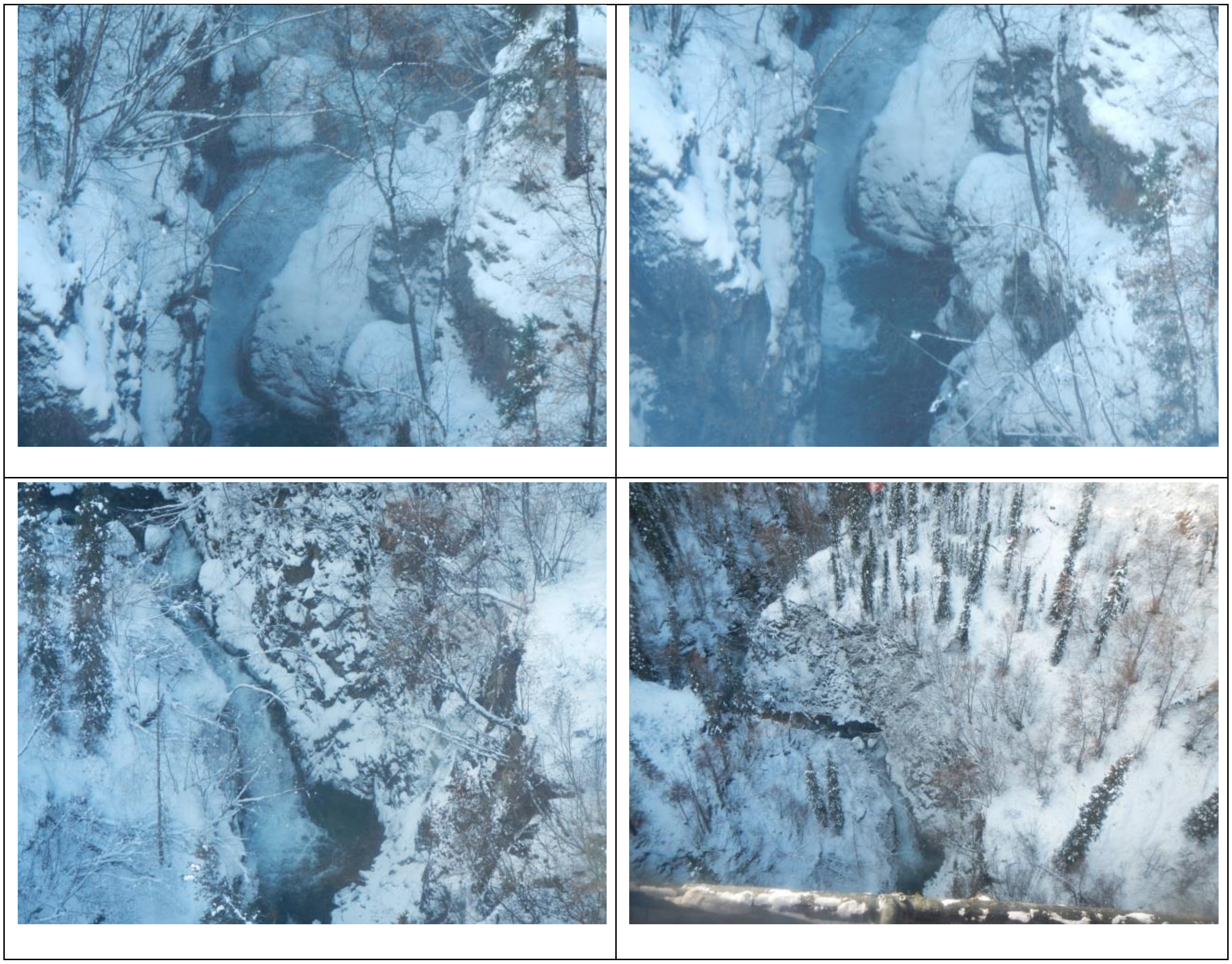

Figure 5.2-5. Photos of PB201.8-A and PB201.8B, October 6, 2014. Clockwise from upper left: barrier PB-204.5A waterfall; barrier PB-204.5A plunge pool; barrier PB204.5B wide view, barrier PB204.5B close view.

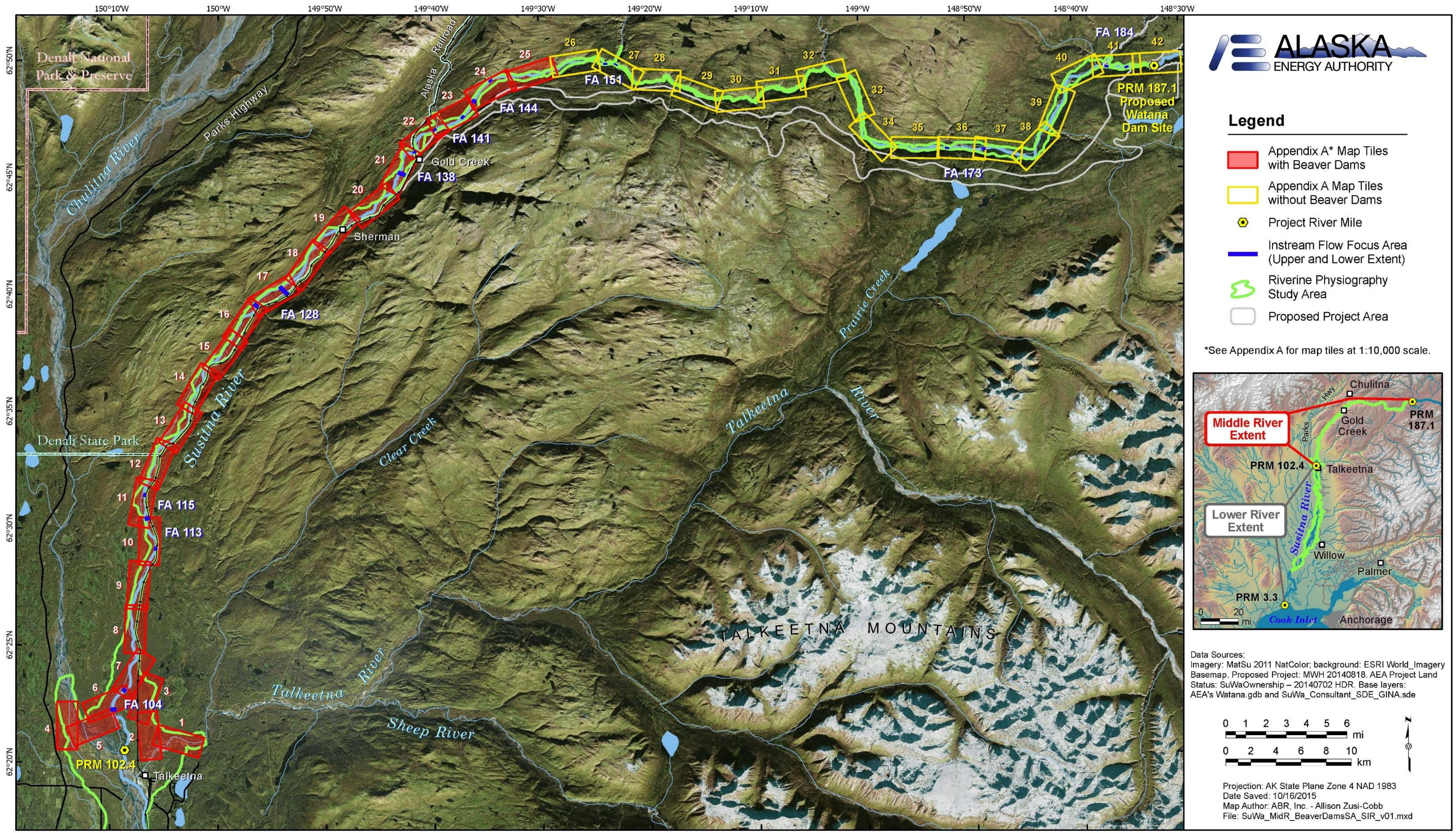

Figure 5.3-1. Overview of 2014 Remote Beaver Dam Mapping.

Figure 5.4-1. Photos of Lower McKenzie Creek/Slough, September 30, 2014. Clockwise from upper left: bottom of creek mouth; upstream view to culvert; culvert and beaver dam; and beaver dam above culvert and upstream of Alaska Railroad tracks.

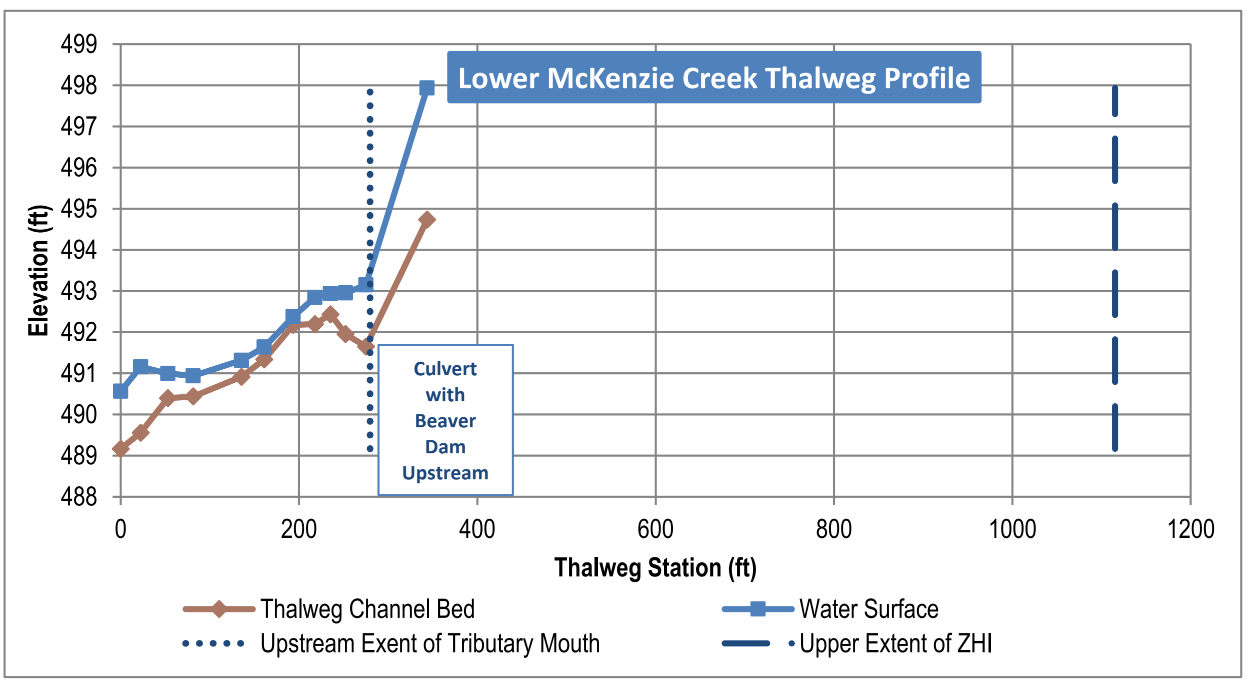

Figure 5.4-2. Lower McKenzie Creek/Slough thalweg profile.

Figure 5.4-3. Photos of McKenzie Creek, September 30, 2014. Clockwise from upper left: bottom of creek mouth and debris apron from mainstem Susitna River; bottom of creek mouth; looking downstream to creek mouth; and looking downstream from Alaska Railroad bridge.

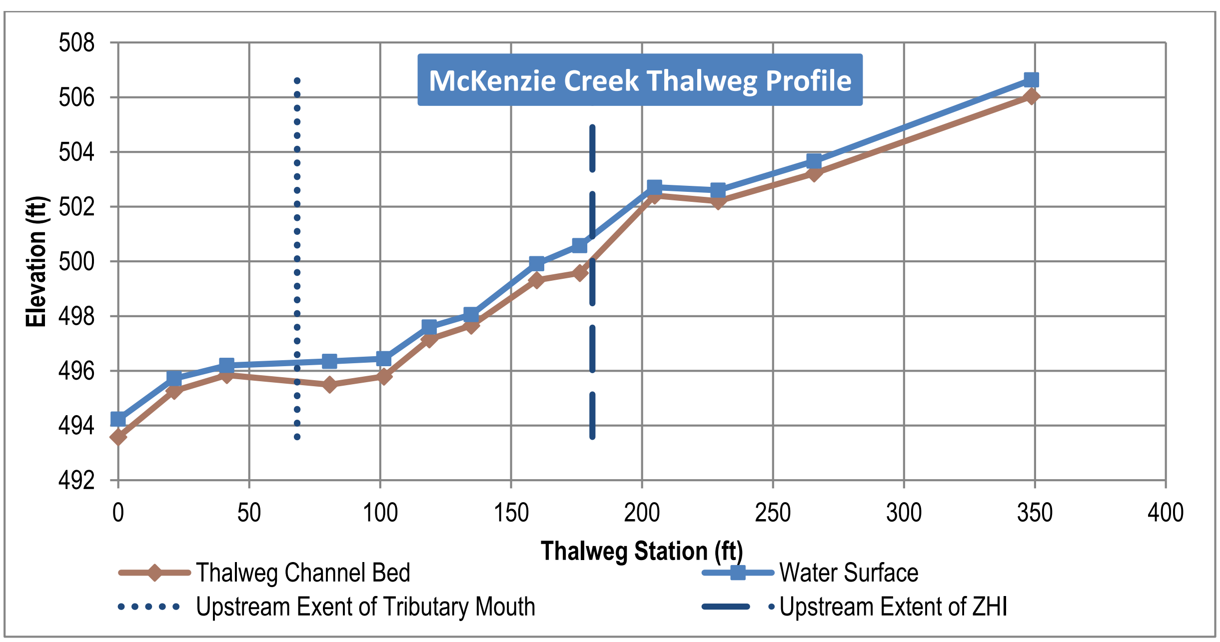

Figure 5.4-4. McKenzie Creek thalweg profile.

Figure 5.4-5. Photos of Little Portage Creek, September 30, 2014. Clockwise from upper left: looking upstream to creek mouth from mainstem Susitna River; creek mouth and debris apron; and looking upstream under Alaska Railroad bridge, looking downstream to creek mouth from Alaska Railroad bridge.

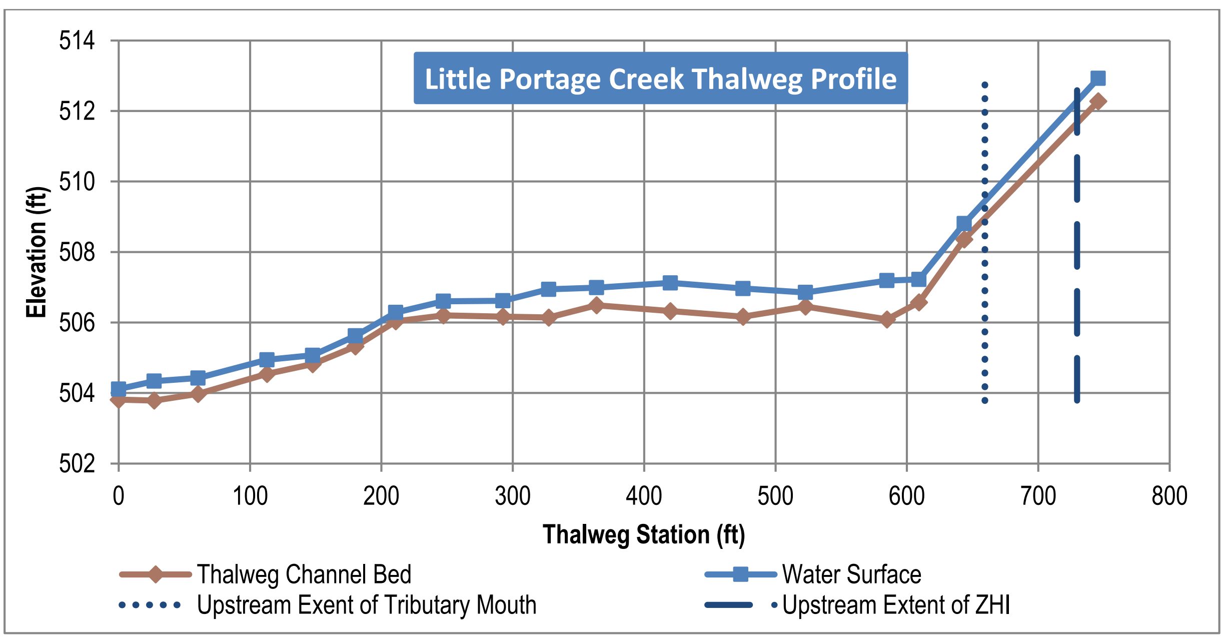

Figure 5.4-6. Little Portage Creek thalweg profile.

Figure 5.4-7. Photos of Jack Long Creek, October 1, 2014. Clockwise from upper left: looking upstream from Susitna River to creek mouth; flow over debris apron; flow above creek mouth; downstream view to creek mouth from top survey station.

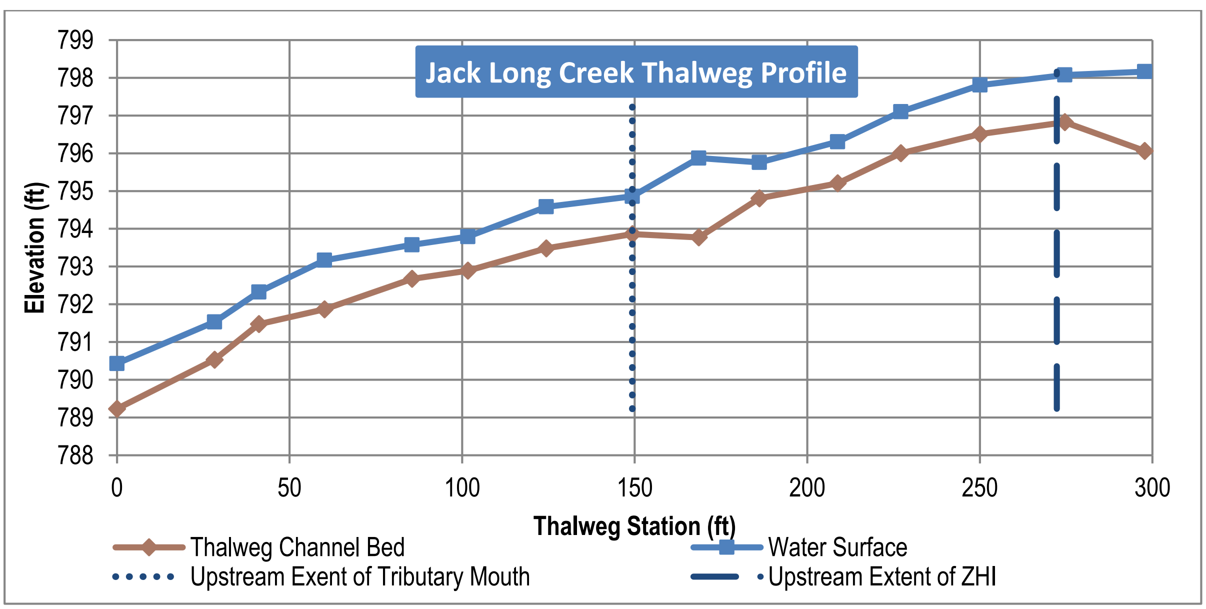

Figure 5.4-8. Jack Long Creek thalweg profile.

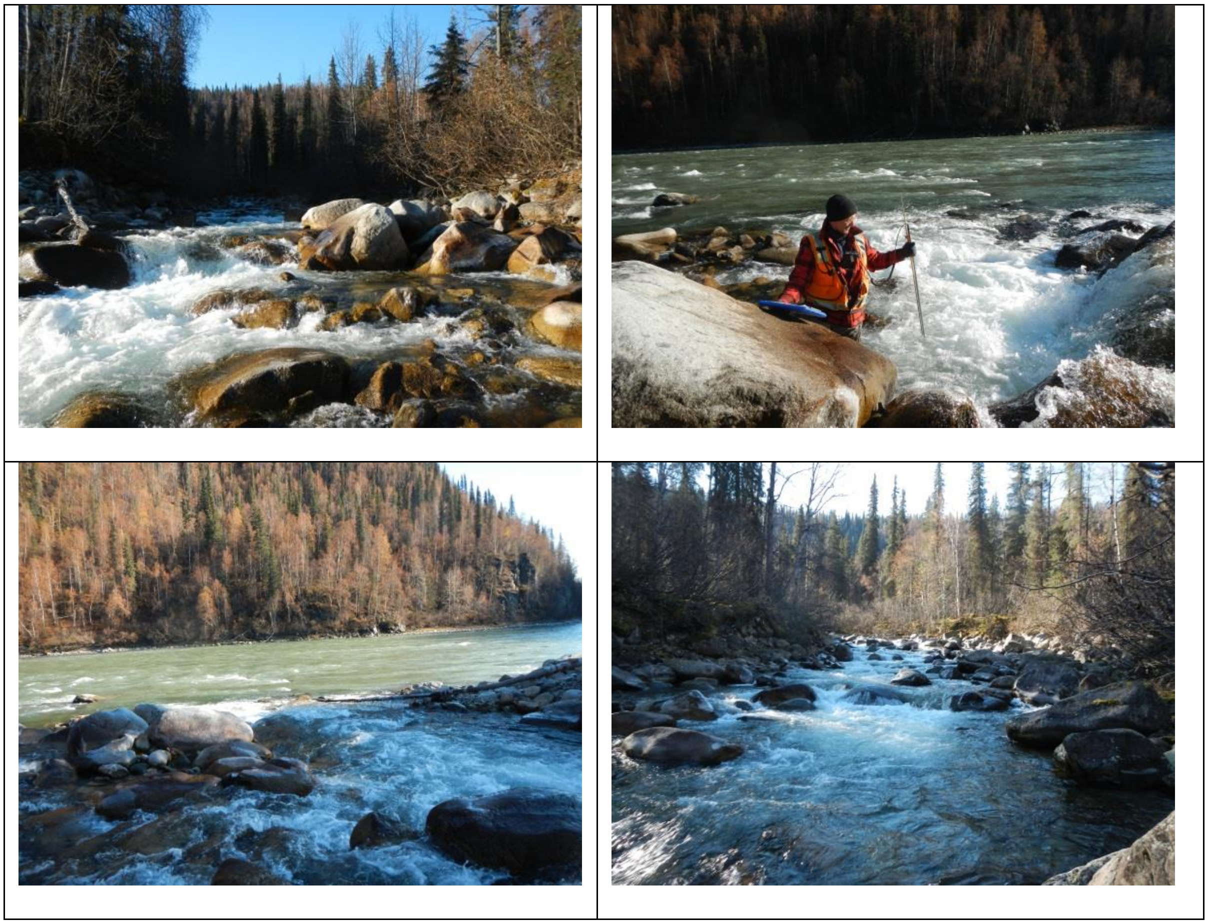

Figure 5.4-9. Photos of Cheechako Creek, October 2, 2014. Clockwise from upper left: bottom of creek mouth; multiple channels through creek mouth; riffle upstream of tributary apron; and looking downstream from top of survey.

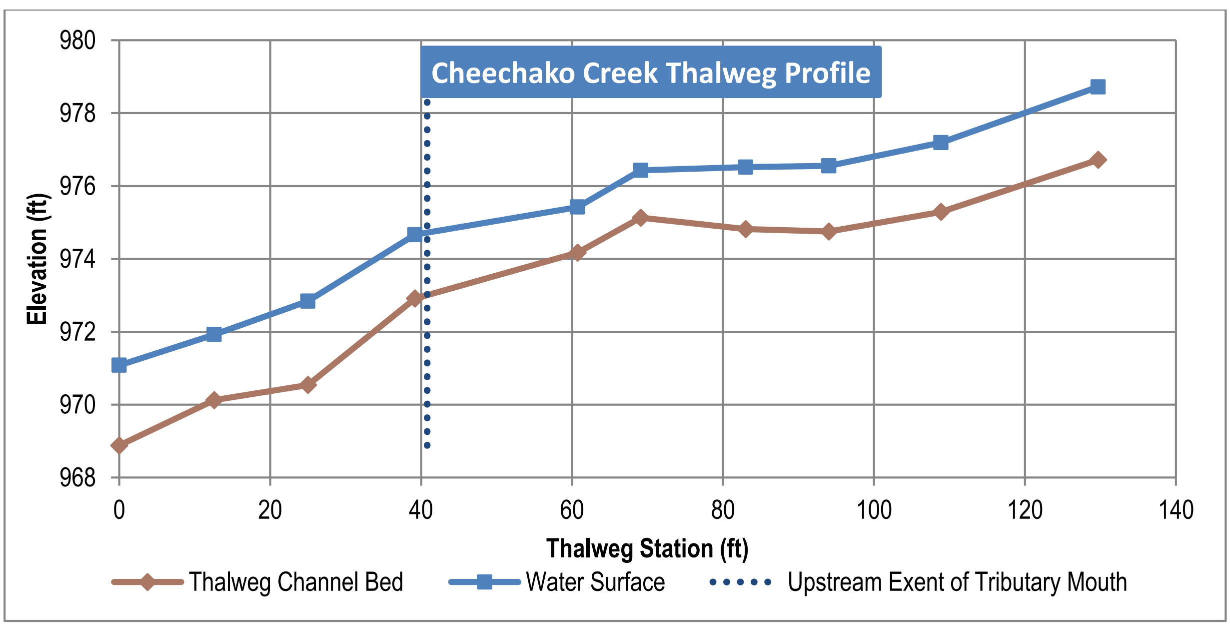

Figure 5.4-10. Cheechako Creek thalweg profile. No ZHI was modeled for Cheechako Creek at the time of the survey.

Figure 5.4-11. Photos of Chinook Creek, October 2, 2014. Clockwise from upper left: bottom of creek mouth from mainstem Susitna River; upstream view from creek mouth; downstream view of creek mouth; downstream view from top survey station.

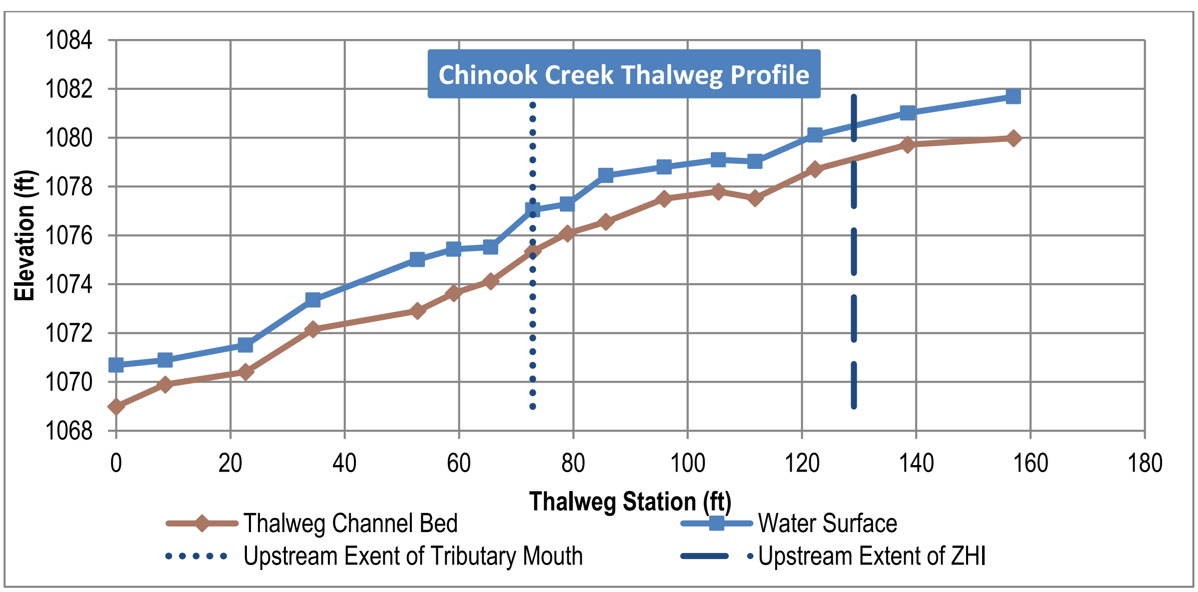

Figure 5.4-12. Chinook Creek thalweg profile.

Figure 5.4-13. Photos of Devil Creek, October 3, 2014. Clockwise from upper left: bottom of creek mouth from mainstem Susitna River; upstream view from creek mouth; downstream view of creek mouth; downstream view from top survey station.

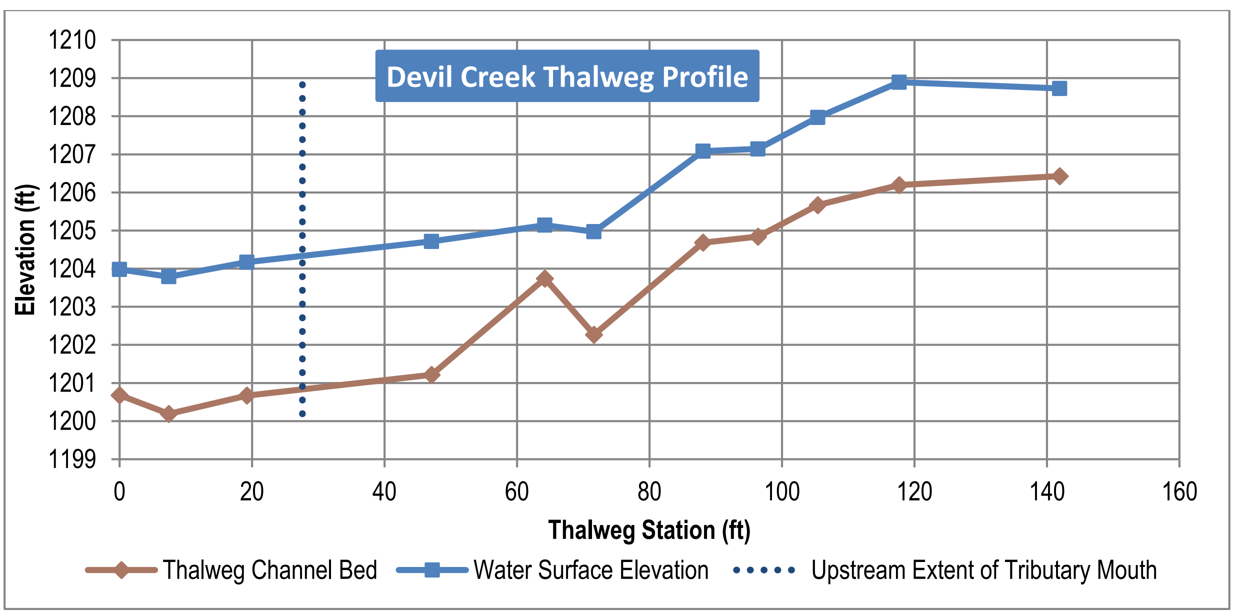

Figure 5.4-14. Devil Creek thalweg profile. No ZHI was modeled for Devil Creek at the time of the survey.

Figure 5.4-15. Photos of Fog Creek, October 3, 2014. Clockwise from upper left: bottom of creek mouth from mainstem Susitna River; view of creek mouth from middle of transect; downstream view from top survey station; aerial view of main surveyed channel and a secondary channel.

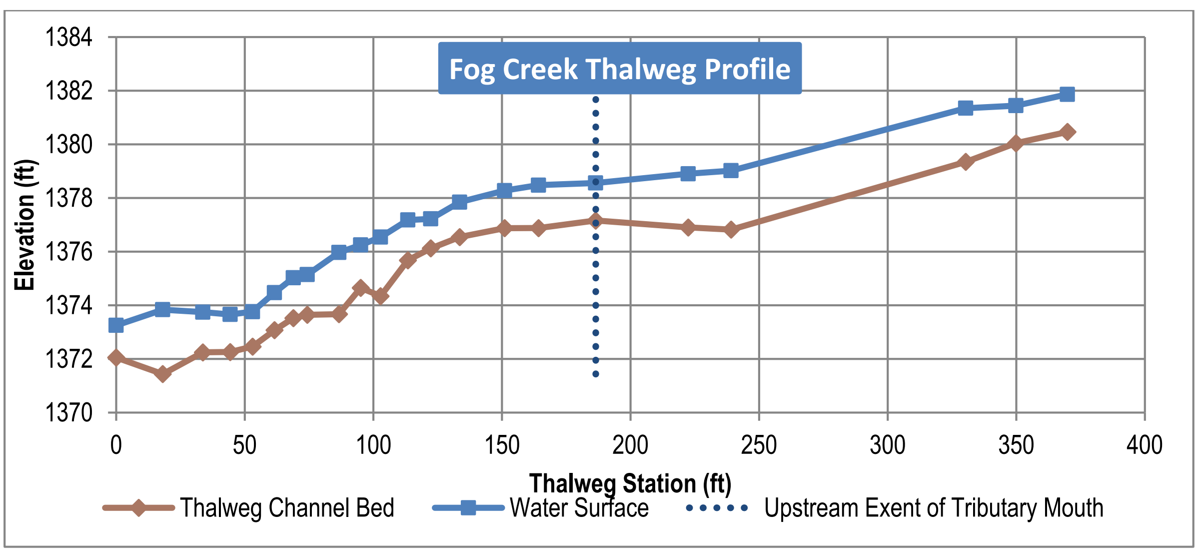

Figure 5.4-16. Fog Creek thalweg profile.

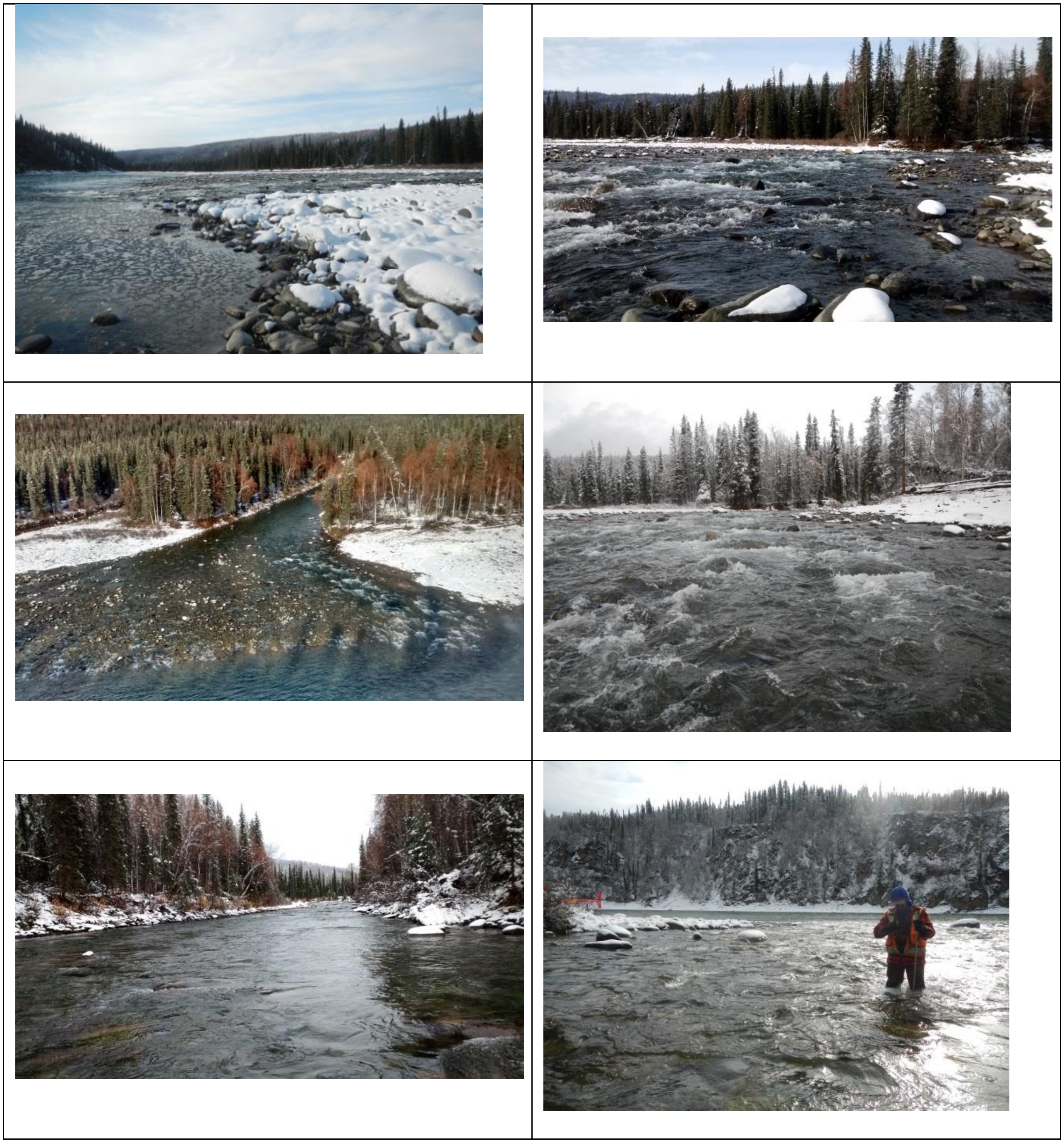

Figure 5.4-17. Photos of Tsusena Creek, October 4, 2014. Clockwise from upper left: bottom of creek looking downstream from mainstem Susitna; upstream view from creek mouth; upstream view above creek mouth; downstream view from top survey station, upstream view from top survey station, aerial view of creek mouth.

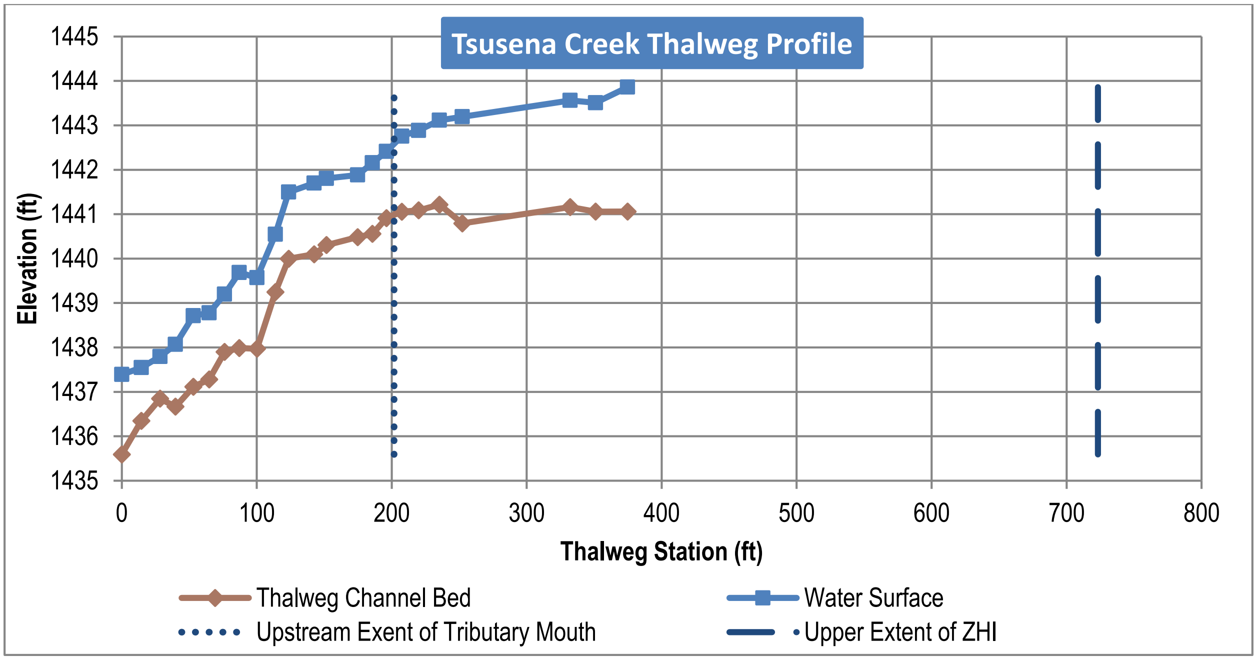

Figure 5.4-18. Tsusena Creek thalweg profile

APPENDIX A: MAPS FROM 2014 REMOTE MAPPING OF BEAVER DAMS