Susitna-Watana Hydroelectric Project
(FERC No. 14241)

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

Initial Study Report

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

February 2014 Draft

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LIST OF ACRONYMS, ABBREVIATIONS, AND DEFINITIONS

Abbreviation	Definition
ADF&G	Alaska Department of Fish and Game
AEA	Alaska Energy Authority
ARRC	Alaska Railroad Corporation
cfs	cubic feet per second
CIRWG	Cook Inlet Region Working Group
CP	check point
FA	Focus Area
FERC	Federal Energy Regulatory Commission
GIS	geographic information system
GPS	global positioning system
HSC	Habitat Suitability Criteria
ILP	Integrated Licensing Process
N/A	not applicable or not available
NMFS	National Marine Fisheries Service
PRM	Project River Mile
Project	Susitna-Watana Hydroelectric Project
RM	river mile
ROW	right-of-way
RSP	Revised Study Plan
RTK	Real time kinematic
SPD	study plan determination
TBM	temporary benchmark
TWG	Technical Workgroup
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geologic Survey
ZHI	zone of hydrologic influence

EXECUTIVE SUMMARY

Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries 9.12	
Purpose	Susitna-Watana Hydroelectric Project (Project) construction and operation will affect flow, water depth, surface water elevation, and sediment transport in the mainstem channel, tributary confluences, side channels, and sloughs in both the inundation zone upstream from the proposed dam site and downstream in the zone of Project hydrologic influence. The goal of this study is to evaluate how potential Project-induced changes in flow and sediment transport will affect fish access within and among suitable habitats. Understanding existing barriers, how barrier conditions may change above the dam with inundation, and barrier changes below the dam due to Project operation, will provide information needed for evaluating potential changes in fish access to habitats.
Status	This is an ongoing multi-year study that was initiated in 2012. AEA has made an initial selection of target fish species and passage criteria for consultation with licensing participants, which is currently being reviewed by licensing participants. In 2012 and 2013, field studies of accessible geologic, depth, and velocity barriers on the Upper and Middle Susitna River were completed. Evaluation of barriers within Focus Areas will use forthcoming model outputs from ice-cover and ice-free 2-D hydrologic and geomorphic modeling. Field characterization of remaining barriers will occur in the next year of the study pending land access. In the next year of the study, fish passage criteria will be applied to field- and model-based barrier attributes.
Study Components	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 and characterize the physical nature of any existing fish barriers located within the Project's zone of hydrologic influence (ZHI) downstream from the proposed dam site. 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.

Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries 9.12	
2013 Variances	AEA implemented the methods as described in the Study Plan with the exception of the following variances. The significance of these variances is discussed within the ISR. • Delay in selection of target fish species (ISR Section 4.1.1). • Delay in field surveys of existing barriers on CIRWG and ARRC lands (ISR Section 4.3.5). • Change from field measurements of beaver dam attributes to model-based evaluation (IP Section 4.4.5).
Steps to Complete the Study	As explained in the cover letter to this draft ISR, AEA's plan for completing this study will be included in the final ISR filed with FERC on June 3, 2014.
Highlighted Results and Achievements	In 2012 and 2013, AEA completed aerial surveys for geologic barriers in all major tributaries in the Upper and Middle River. A total of 72 potential barriers were identified and 38 were confirmed as barriers to fish due to height. Within the Middle River, seven tributary mouths were surveyed to document current depth and velocity conditions for fish passage and to collect data for an evaluation of the Project's potential effects. Characterization of existing barriers and evaluation of potential changes to barriers under Project conditions is ongoing and is being coordinated with the Geomorphology Study (Study 6.5), the Ice Processes Study (Study 7.6), and the Flow Routing Study (Study 8.5.4).

1. INTRODUCTION

On December 14, 2012, Alaska Energy Authority (AEA) filed its Revised Study Plan (RSP) with the Federal Energy Regulatory Commission (FERC or Commission) for the Susitna-Watana Hydroelectric Project, FERC Project No. 14241, which included 58 individual study plans (AEA 2012). Included within the RSP was the Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries, Section 9.12. RSP Section 9.12 focuses on the methods for locating, describing, and assessing potential fish passage barriers in the Middle and Upper Susitna River that could be created or eliminated as a result of Project construction and operation. RSP Section 9.12 provides goals, objectives, and proposed methods for identification, classification, measurement, and analysis of potential fish passage barriers.

On February 1, 2013, FERC staff issued its study plan determination (February 1 SPD) for 44 of the 58 studies, approving 31 studies as filed and 13 with modifications. RSP Section 9.12 was one of the 13 approved with modifications. In its February 1 SPD, FERC recommended the following:

> *We recommend that AEA assess discharge conditions at the streamflow gages established by AEA closest to Devils Canyon and near the dam site during the time periods when salmon are documented to successfully pass upstream of the Devils Canyon passage impediment in 2013 and 2014 (via radio-tagging as set forth in study 9.7, salmon escapement), and document the results in the initial and updated study reports.*
>
> *We do not recommend use of any of AEA's criteria set forth in section 9.12.4.4 of the RSP for excluding study sites from the Middle River passage barrier evaluation. Instead, we recommend that AEA prepare and file a detailed plan by no later than June 15, 2013, that provides the additional information described below on implementation of the study within the Middle River study area.*
>
> *1) A specific schedule for completing the following Middle River study components proposed for future development in consultation with the TWG as set forth in section 9.12.4 of the RSP: (a) identifying fish species to be included in the passage barrier study; (b) defining the passage criteria for the identified fish species; (c) selecting the number and location of study sites for each element of study implementation; and (d) filing the results of items (a), (b), and (c).*
>
> *2) A description of how the effects of load-following during the winter ice-cover period on salmonid juvenile and fry passage (e.g., depth, velocity, potential ice blockages) from mainstem into off-channel habitats would be evaluated.*
>
> *3) A description of the specific methods as set forth in section 9.12.4.5 (e.g., 2-dimensional modeling, or other unspecified modeling approach) that would be applied at the off-channel and tributary mouth locations selected for the depth barrier analysis. This would include an explanation of the proposed methods and study sites for the open-water period for adult and juvenile fish, and the ice-cover period for juvenile fish.*

4) A description of a subsample of tributary mouths and off-channel habitat entrances within Middle River focus areas where velocity measurements will be taken to determine if velocity barriers to juvenile salmonids (particularly salmonid fry) would be created at tributary mouths and off-channel habitat entrances by modifications to river stage and discharge through proposed project operations.

5) *Documentation that a draft plan and schedule were provided to FWS, NMFS, and any other TWG participants at least 30 days prior to the due date of the plan and schedule (allowing at least 15 days for comment); a description of how FWS', NMFS', or other TWG participant's comments are incorporated into the final plan; and an explanation for why any of FWS', NMFS', or other TWG participant's comments are not incorporated into the final plan.*

In accordance with the February 1 SPD, on May 15, 2013, AEA provided to U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), and other Technical Work Group participants for comment a Draft Study of Fish Barriers Implementation Plan (Draft Implementation Plan) that was developed to provide responses to the February 1 SPD recommendations. The Draft Implementation Plan was also made available on the Project website (http://www.susitna-watanahydro.org). Consistent with the February 1 SPD, AEA initially allowed 15 days for comment by requesting that all comments be submitted, in writing, by Thursday, May 30, 2013. At the request of NMFS, AEA extended the deadline for comments to June 5, 2013. NMFS and USFWS jointly submitted comments on June 7, 2013. AEA received no other comments on the Draft Implementation Plan. Recommended modifications were addressed in detail in the Study of Fish Barriers Implementation Plan (Implementation Plan) filed with FERC on June 17, 2013.

Following the first study season, FERC's regulations for the Integrated Licensing Process (ILP) require AEA to "prepare and file with the Commission an initial study report describing its 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)). This Initial Study Report (ISR) on the Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries has been prepared in accordance with FERC's ILP regulations and details AEA's status in implementing the study, as set forth in the FERC-approved RSP and as modified by FERC's February 1 SPD, and the Implementation Plan (collectively referred to herein as the "Study Plan").

2. STUDY OBJECTIVES

The goal of this study 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, cascade, beaver dam, road or railroad crossings) located in selected tributaries in the Middle and Upper Susitna River (Middle River tributaries to be determined during study refinement).
2. Locate using geographic information system (GPS), identify the type (permanent, temporary, seasonal, partial), and characterize the physical nature of any existing fish barriers located within the Project's 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.

These objectives are being met through the use of existing information, consulting with the Fish and Aquatic Technical Working Group (TWG) and other licensing participants, and by using the methods described in the Study Plan.

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 (Figure 3-1). For purposes of this study, the study area has been divided into two 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; see Figure 3.1.1). In tributaries known to support Chinook salmon, barriers were surveyed to 3000-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 3000-ft elevation or to the first anadromous barrier.

- Middle River below Devil's Canyon - Passage studies 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 the upper limit of the zone of hydrologic influence (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. [1]

[1] The Study Area has been corrected from the RSP and expanded beyond Middle River tributaries to include sloughs, upland sloughs, and side channels that have been surveyed and will be subject to 2-D modeling as described in ISRs 8.5 and 6.6.

4. METHODS

Study methods varied primarily depending on the type of barrier being assessed. In this study, depth barriers were more of a concern in sloughs, side channels, and mouths of tributaries. Geologic barriers (cascades and waterfalls) were more of a concern within tributaries. Beaver dam barriers occurred in sloughs, side channels, and tributaries. While the specific methods for each barrier type differed, the general study components and steps were similar for locating and assessing the various types of barriers.

Methods for the study of fish passage barriers consisted of the following study components:

- Identify fish species to be included in the passage barrier study.
- Define the passage criteria for the identified fish species.
- Select specific study sites and representative study sites.
- Conduct field studies.
- Coordinate with other interdependent studies and identify modeling needs and outputs from the Fish and Aquatics Instream Flow Study (Study 8.5), the Fluvial Geomorphology Modeling below Watana Dam Study (Study 6.6), and the Ice Processes in the Susitna River Study (Study 7.6) as described in Section 4.5.
- Evaluate potential effects of altered fluvial processes on fish passage in sloughs, upland sloughs, side channels, and at tributary mouths in the Middle River and in tributaries entering the reservoir zone in the Upper River

4.1. Fish Species Identification

AEA implemented the methods for species identification as described in the Study Plan with the exception of the variance explained in Section 4.1.1. The fish community of the Susitna River includes approximately 19 documented fish species. Within this community, some fish species exhibit life history patterns that rely on multiple habitats during freshwater rearing and are thus more sensitive to changes in access to side channels, sloughs, and/or tributary habitats (Table 4.1-1). A subset of species was selected for the fish passage barrier analysis based on passage sensitivity, species distribution, and the locations of potential barriers. Given the interdependencies between the barriers assessment and Instream Flow Study physical habitat data collection, AEA proposed that target species for the fish barrier studies be the same or a subset of those selected for the Fish and Aquatics Instream Flow Study (ISR Study 8.5; Table 4.1-2). For planning purposes, high priority target species proposed in the Fish and Aquatics Instream Flow Study included Chinook, coho, chum, pink and sockeye salmon, rainbow trout, and Arctic grayling. These target species were selected because they are generally considered the most sensitive to habitat loss through manipulation of flows in the Susitna River. All of these species aside from pink salmon have also been identified as target species for the Study of Fish Passage Feasibility at Watana Dam (ISR Study 9.11, Table 4.1-2). Fish passage target species selection was first based on presence of the species in the Upper River, secondly on the following three criteria, and thirdly in consultation with the Fish Passage Technical Team at their

workshop on April 9 and 10, 2013. Aspects of these criteria used by the Fish Passage study team are also useful for selecting target species for passage barrier studies:

- ***The species exhibits migratory behavior*** – Fish passage has a greater importance to species that may exhibit migratory behavior as part of their natural life history compared to fish that exhibit only localized movement, especially when the migration is necessary to complete the life cycle of the species.
- ***The species has high relative abundance*** – Species that are relatively abundant in the Upper River and its tributaries would theoretically utilize fish passage facilities with greater frequency than less abundant species, disregarding other criteria (e.g., migratory behavior).
- ***The species is important to commercial, sport, or subsistence fisheries*** – Species that are harvested in commercial, sport, or subsistence fisheries.

AEA will seek input from the Instream Flow Technical Work Group when finalizing target species and life stages. Information to be discussed during a Technical Team meeting in Q1 of 2013, team members, licensing participants, and AEA will include species and lifestage use of off-channel habitats, seasonal movement into and out of off-channel habitats, and microhabitat (depth and velocity). This information will be used to refine the target species selection.

4.1.1. Variances

The Implementation Plan provided that Fish Species Identification would occur in the third quarter of 2013 (IP Section 7.1.5). Instead, fish species consultation will occur in the next year of the study to coincide with the consultation for Fish Passage Criteria (see Section 4.2). Since decision-making for fish species and fish passage criteria are linked, simultaneous consultation with licensing participants will avoid redundancy. Any changes to the species list will be included in the analysis of fish barriers in the Updated Study Report.

4.2. Passage Criteria for the Identified Fish Species

AEA implemented the methods as described in the Study Plan. Passage criteria are being refined in accordance with approved study methods as outlined in the Implementation Plan (Section 7.1.5). Salmonid passage criteria are well researched and some criteria exist for all species, while passage criteria for many non-salmonids have not been researched and therefore criteria do not currently exist. Which criteria are used and whether "surrogate" salmonid species criteria can be substituted for other species will be determined in consultation with licensing participants in the Fish and Aquatic TWG and Technical Team meetings in the next year of the study.

Basic categories of fish passage criteria for use in this study include water depth, water velocity, and fish leaping ability. Depth criteria will be used to assess access into, within, and out of side channels, sloughs, and tributaries.

Leaping criteria will be reestablished for the vertical and horizontal distances fish must leap to pass a physical barrier. The velocity component of passage at a physical or depth barrier will be applied where velocity influences successful passage. Velocity criteria will also be applied at chutes. Leaping criteria and velocity criteria will be applied only in tributaries (including their mouths) and at beaver dams.

4.2.1. Depth Criteria for Adult Upstream Migration

Existing depth criteria for evaluating fish passage include the transect criteria (Thompson 1972) and the depth/distance criteria (ADF&G 1984a). The resulting ADF&G (1984a) chum salmon passage criteria curves for small substrate and uniform, unobstructed channel are presented in Figure 4.2-1. Chum salmon passage curves for large substrate and non-uniform obstructed channel are presented in Figure 4.2-2. Depth, length, and substrate criteria were modified for chum and developed for other species as a part of this study with input from licensing participants.

4.2.2. 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. Powers and Orsborn (1985) present a detailed analysis of passage at physical barriers to upstream migration by salmon and trout. Powers and Orsborn (1985) present criteria for Chinook, coho, sockeye, pink, and chum salmon passage at waterfalls and cascades. Other sources of leaping height criteria are available from Reiser and Peacock (1985) and the USFS (2001). Table 4.2-1 presents the leaping criteria from the three sources.

Leaping curves and jumping equations assume that the depth of the pool the fish must leap from is adequate. In this study, leaping criteria will be refined in consultation with licensing participants during the TWG and Technical Team meetings in the next year of the study.

4.2.3. Upstream Velocity Criteria

Juvenile salmonid swim speeds have been well researched so there are abundant existing criteria. Swim speed criteria for non-salmonid juveniles have not been well researched and existing criteria are not generally available. Velocity criteria will be determined with input from licensing participants during TWG and Technical Team meetings in the next year of the study in instances where velocity criteria do not exist for species of interest.

4.2.4. Downstream Passage Criteria

The species, life stage, and respective depth criteria for passage of downstream migrating fish will be determined in collaboration with licensing participants during TWG and Technical Team meetings in the next year of study.

4.3. Site Selection

AEA implemented the methods as described in the Study Plan with the exception of the variance explained in Section 4.3.5. Components of study site selection are outlined below.

4.3.1. Upper River Tributaries

Selection of tributaries and tributary mouths for study in 2013 expanded on the 2012 Upper Susitna River Fish Distribution and Habitat Study (HDR Alaska, Inc. 2013). Forty-one

tributaries were selected from the Upper River within the area from the proposed dam site upstream to the Oshetna River and were surveyed for adult salmon passage barriers in 2012 (HDR Alaska, Inc. 2013). Twelve potential barriers were identified, and eight were confirmed as permanent barriers to upstream fish passage (falls and cascades ranged from 11-50 ft) during 2012 surveys (Table 4.3-1). A follow-up of five remaining potential barriers within the inundation zone were conducted by aerial and foot surveys in September 2013 (Figure 4.3-1a).

4.3.2. Middle River Tributaries within and above Devil's Canyon

In 2012, 38 tributaries (study sites) were selected and surveyed for adult salmon passage barriers from PRM 150 to 185, including tributaries draining into Devils Canyon and the uppermost tributary just downstream of the proposed dam site (HDR Alaska, Inc. 2013). Each selected tributary was surveyed for potential barriers up to the first confirmed barrier or to the 3,000-ft elevation, the highest elevation at which salmon had been observed during prior investigations (HDR Alaska, Inc. 2013). Thirty-one potential barriers were identified, and 27 were confirmed as permanent barriers to upstream fish passage during 2012 surveys (Table 4.3-2).

In 2013, Middle River tributary mouths and mouths outside Focus Areas were surveyed for fish barriers (Table 4.3-3). Seven tributaries were surveyed in September 2013, including Gold Creek, Fourth of July Creek, Sherman Creek, Fifth of July Creek, Deadhorse Creek, Lane Creek, and Chase Creek (Figure 4.3-1b). The Geomorphology Study conducted intensive study of seven additional tributary mouths (Figure 4.3-1b).

4.3.3. Middle River below Devil's Canyon

In the Middle River, the expanse, large number, and complexity of sloughs and side channels prohibits total coverage of all such potentially affected areas. Thus, sub-sampling of these habitats was necessary. Based on the Fluvial Geomorphology Modeling Study's 2-D model results (ISR Study 6.6) and the Fish and Aquatic Instream Flow Study's fish observations (ISR Study 8.5), a subset of tributary mouths, sloughs, and side channels will be identified in the next year of the study in accordance with approved study methods.

4.3.4. Lower River

Investigation and evaluation of fish passage barriers in the Lower River will follow a phased approach in which studies of barriers in the Middle River will be used to determine the need and design for barrier studies in the Lower River (FERC 2013). Other studies to be conducted in 2013 that will contribute to determining the need for barrier studies in the Lower River are Fish Distribution and Abundance in the Middle and Lower Rivers (Study 9.6); Fish and Aquatics Instream Flow Study (Study 8.5); Fluvial Geomorphology Modeling Study (Study 6.6); and the Open-water Flow Routing Model (Study 8.5). If 2013 results, as presented in the Initial Study Report, indicate that the Project will cause significant adverse effects on fish passage into tributaries and off-channel habitats in the Middle River, then additional study sites will be added in the Lower River in the next year of study (FERC 2013).

4.3.5. Modeling Sites

As recommended by FERC in HDR Inc.2013, AEA is locating fish passage barrier intensive sampling sites for both the ice-free and ice-cover periods within the selected Focus Areas. Data collection during ice-free conditions occurred in nine of 10 Focus Areas and included a total of 34 side channels, 8 side sloughs (one with a beaver pond), 13 upland sloughs (one with a beaver pond), 2 macrohabitat backwaters, and 10 tributary mouths (Table 4.3-4). Ice-cover modeling will take place in a subset of Focus Areas, including FA-104, FA-113, FA-115, and FA-128 in accordance with approved study methods.

AEA does not propose any data collection or hydrodynamic modeling under this Study. All data collection and hydrodynamic modeling is being conducted as described in the ISRs for the Fluvial Geomorphology Modeling Study (ISR Study 6.6), the Ice Processes in the Susitna River Dam Study (ISR Study 7.6), the Fish and Aquatics Instream Flow Study (ISR Study 8.5), and the Riparian Instream Flow Study (ISR Study 8.6).

4.3.6. Variances

The 2012 Upper Susitna River Fish Distribution and Habitat Study, Study Component 1 of 4, Fish Passage Barriers Assessment technical memorandum identified eight features as potential fish passage barriers in the Middle and Upper River to be targeted for evaluation in 2013 (HDR Alaska, Inc. 2013). However, AEA was not granted access to Cook Inlet Regional Working Group (CIRWG) lands in 2013, which prevented ground access to eight potential barriers within seven streams (Cheechako Creek, Tributary 158.7, Devil Creek, Tributary 169.1, Tributary 189.7, Tributary 197.7, and Tributary 204.5). Nevertheless, the four barriers within the inundation zone of the proposed reservoir in Cheechako Creek, Tributary 158.7, Devil Creek, and Tributary 169.1 were targeted for aerial evaluation to estimate barrier heights using laser rangefinders. The four remaining potential barriers in the middle river will be surveyed in the next year of the study, allowing AEA to meet Objective 1.

Section 7.4.1 of the Implementation Plan summarized the 27 Middle River tributary mouths selected for fish passage barrier investigation. Three tributary mouths within the ARRC right-of-way (ROW) (McKenzie, Lower McKenzie and Little Portage) and nine tributary mouths between Jack Long Creek and Tsusena Creek located within CIRWG lands were not surveyed in 2013. Ground surveys will be conducted at all 12 remaining targeted sites in the next year of the study.

4.4. Field Methods

AEA implemented the methods as described in the Study Plan with the exception of the variance explained in Section 4.4.5.

Studies in the Middle River relied on data collected as part of this study as well as efforts by the Fluvial Geomorphology Modeling Study (ISR Study 6.6) and the Aquatic Furbearer Abundance and Habitat Use Study (ISR Study 10.11).

4.4.1. Geologic Barriers to Fish Passage

Geologic barriers were assessed by following the methods of Powers and Orsborn (1984). Barriers were located by first reviewing existing information including:

- Topographic maps
- Current high-resolution aerial imagery including aerial imagery and LiDAR from the Geomorphic Mapping Study and the 2011 Matanuska-Susitna LiDAR and Imagery Project
- Low elevation aerial video imagery
- Results of the 2012 Upper River Fish Distribution Study
- Results of the Open-water Flow Routing Model Study coupled with the projected effects of proposed Project operations on the zone of hydraulic influence
- Other relevant and available sources

Aerial surveys or a ground survey team examined tributaries or stream reaches where barriers were present or where their presence could not be ruled out by existing information. During ground surveys, tributary barriers were assessed in two phases. If a stream feature was a possible obstacle to the species of concern, the geometry of the obstacle was surveyed including measurements of barrier height, leap distance, and estimated depth of leaping pool at high and low flow. Barriers were drawn to scale, photographed, and their location fixed with GPS. If the obstacle was clearly not a barrier, its location and basic dimensions were noted with no further measurements.

For aerial surveys, the vertical height and horizontal length of each barrier was measured using a Laser Tech Tru Pulse 200 laser rangefinder. The accuracy of the range-finder method was tested prior to the aerial surveys by sighting the range finder to an 8-ft stadia rod. The estimated height from 70 m (230 ft) was consistently within 1 ft. Therefore, aerial estimates of barrier height are ± 1 ft. Ten measurement pairs (top and bottom of barrier) were taken in order to estimate a mean height and length. Site photos were taken by helicopter to supplement the measurements, provide documentation of adjacent reaches, and for follow-up assessment.

If the ground surveyors were uncertain regarding the proposed barrier status of an obstacle, a decision tree analysis (URS and HDR 2010) was implemented that was consistent with Powers and Orsborn (1985) and modified as necessary for site-specific species and barrier conditions.

The barrier analysis decision tree is a step-wise process for evaluating potential barriers in the field. Quantitative metrics were used at each step in the decision tree to identify the impassability of the potential barrier.

4.4.2. Beaver Dams

Aerial surveys of active beaver colonies were conducted by helicopter by the Aquatic Furbearers Study (Study 10.11) between October 1 and 10 in 2013 in accordance with the Barriers Implementation Plan. The Fluvial Geomorphology Modeling Study (ISR Study 6.6) ground-verified 18 beaver dams in Focus Areas (Table 4.1-1). Photographs were taken and dam heights were estimated.

4.4.3. Tributary Mouths

4.4.3.1. Depth

While the Fluvial Geomorphology Modeling Study (ISR Study 6.6) collected bathymetric, substrate, and flow data to support depth barrier analysis within Focus Areas, tributaries outside Focus Areas required additional surveys in 2013. A thalweg profile for seven tributaries outside Focus Areas was surveyed from the confluence of the Susitna River to the top of the ZHI during low flow conditions in late September 2013 (Appendix B). Cross-sections were surveyed at thalweg breakpoints and tributary discharge was measured. Substrate along the thalweg and uniformity of channel were recorded. Mainstem water surface elevation was measured and photographed.

4.4.3.2. Velocity

Velocity barriers over tributary mouths were assessed at the same time and used some of the same methods as described in Section 4.4.3.1 for depth barriers. Field surveys began with Susitna flows just above 16,000 cfs on September 18 (at the USGS Gold Creek gage) and concluded with flows below 12,000 cfs on September 27, 2013. Velocity profiles were obtained across the steepest sections of the reach that was within the ZHI. Velocities were measured as the main channel flow receded to capture the highest velocity within the ZHI without backwater influence from the main channel. All measurements were taken during the migratory timing of target species into the tributaries.

Longitudinal profiles were collected, along with velocity measurements and stream substrate assessments, at each thalweg survey point. Cross-sections were taken to characterize the geometry of the tributary mouth and upstream channels within the 33,500-cfs ZHI. Additional survey points were collected at each site to better define the tributary mouth area, both dry and wet portions, as well as geometry extending into the Susitna River. Control points and temporary benchmarks were established for follow-on survey work, and to tie into existing Project survey. A flow measurement of the tributary was taken at each site to aid in correlation of velocity, depth, and relative flow condition between the Susitna and the tributary itself.

All survey points were electronically collected using a Leica RTK FM rover and base station. This equipment allowed for precise collection of elevation, latitude, and longitude of each survey point, as well as adding a point-specific descriptor, such as thalweg, toe of slope, or water surface elevation. One or more check points (CP) and a temporary benchmark (TBM) were established in the vicinity of each site to document the survey, to provide follow-on reference points for use with a total station or theodolite, and to provide a relatively stable monument to tie into other Project survey data.

4.4.4. Data Analysis

Fish passage is a mechanistic analysis that compares the physical capabilities and periodicity of a fish species or life stage with the environmental variables of the barrier. Each barrier will be analyzed on a case-by-case basis in accordance with approved study methods.

4.4.5. Variances

Section 7.3.2 of the Implementation Plan provided that in addition to photographs and GPS waypoints, the following metrics would be collected during ground surveys of beaver dams: dam height, length, and breadth; the depth of the leaping pool; and observations of possible passageways through or around the dam. However, in 2013, only beaver dam heights and activity status were recorded for ground-surveyed beaver dams. The 2013 surveys will not enable conclusive barrier identification, but will support modeling that will allow barrier evaluation in the next year of the study.

4.5. Modeling Methods

AEA implemented the methods as described in the Study Plan with the no variances. AEA is coordinating with modeling studies—Fluvial Geomorphology Modeling, Study 6.6, and Open-water Flow Routing Model, Study 8.5—to implement the modeling methods as described in the Study Plan. AEA coordinated with hydrology and geomorphology modelers to understand how flow and sediment dynamics will be simulated to estimate current and future barrier conditions for fish passage. Modeling methods are applied in Focus Areas to assess depth and velocity barriers in sloughs, side channels, and mouths of tributaries. Interpretations of model results in proof-of-concept model runs for 1-D and 2-D flow and geomorphic models are to be completed in the next year of the study (Fluvial Geomorphology Modeling, ISR Study 6.6).

4.5.1. Modeling Methods for Ice-free Periods

4.5.1.1. Upper River Tributary Mouths

The Geomorphology Study is estimating the formation of mouths in selected tributaries entering the reservoir zone (Study 6.5, RSP Section 6.5.4.8.2.2). The impact of these mouths on fish movement into and out of the reservoir will be evaluated using fish passage criteria in accordance with approved study methods.

4.5.1.2. Middle River Focus Areas

AEA's fish barrier assessment in Focus Areas is dependent on models developed as part of the ongoing Geomorphology, Instream Flow, and Ice Processes studies. The specific 2-D models are currently being tested by proof-of-concept model runs in FA-104 using either SRH-D, a finite-volume hydrodynamic model, or River2D, a depth-averaged finite-element hydrodynamic model (see ISR Study 6.6). The final decision on model selection depends on the ability of the model to produce representative flow and sediment transport results for existing conditions (Tetra Tech 2013).

The 2-D model, coupled with the flow routing model and the groundwater model, is being assessed to evaluate passage conditions over the full range of pre- and post-Project flow conditions. To the extent possible, passage criteria will be input to the 2-D habitat model, yielding an integrated analysis tool.

4.5.2. Modeling Methods for Ice-cover Periods

AEA is relying on data collected by the intensive, multidisciplinary studies in Focus Areas to evaluate the effects of load-following on juvenile and fry passage at off-channel habitats during the ice-cover period in accordance with approved study methods. AEA does not propose any hydrodynamic or ice modeling under Study 9.12 for this study element. All hydrodynamic or ice modeling will be conducted as described in other ISRs.

4.5.3. Variances

There are no variances to the study plan for Modeling Methods for Ice-free Periods.

5. RESULTS

Results of 2013 field efforts include thalweg surveys of mouths at seven major tributaries in the Middle River, and aerial surveys of five geologic barriers in the Upper River tributaries. AEA has also compiled beaver dam surveys conducted by other studies. Detailed field results are presented in Appendices B and C. Data developed in support of the ISR is available for download at http://gis.suhydro.org/reports/isr (ISR_9_12_BARR_BarrierData).

5.1. Geologic Barriers

Five potential geologic barriers on four streams were surveyed for upstream fish passage in 2013 (Appendix A). Three potential barriers in three unnamed Upper River tributaries (Unnamed Tributary 189.7, Unnamed Tributary 197.7, and Unnamed Tributary 215.2) were classified as permanent fixed barriers because heights were well above the threshold for adult salmon leaping (11 ft) and slopes ranged from 10 to 83 percent. Two additional barriers on Unnamed Tributary 204.5 were classified as potential barriers because heights were between 7.7 and 10.8 feet; however, these barriers also had shallow plunge pools or resting areas that would make adult salmon passage difficult.

5.2. Beaver Dams

In 2013, aerial surveys of the mainstem Susitna River and its tributaries identified 156 beaver colonies, of which 125 were associated with dams (ISR Study 10.11). All 17 beaver dams in the upper River were located in Deadman Creek basin. There were 28 in Middle River tributaries above and within Devils Canyon and 38 in tributaries below. Forty-two were located in the mainstem Middle River. In addition, ground surveys in Middle River Focus Areas 104, 113, 115, 128, 138, 141, and 144 identified 18 beaver dams that ranged in height from 1.5 to 5.5 ft. (ISR Study 6.5). As would be expected some of the Middle River mainstem beaver dams identified by ground and aerial surveys were the same (Figure 5.2-1). Preliminary review of the GIS indicates that 2013 ground surveys identified 8 additional beaver dams that were not documented in the aerial survey for a total count of 50 beaver dams documented in Middle River mainstem in 2013.

5.3. Tributary Mouths

Seven tributary mouths (Gold Creek, Fourth of July Creek, Sherman Creek, Fifth of July Creek, Deadhorse Creek, Lane Creek, and Chase Creek) were surveyed that showed contrasting substrates, channel morphology, water velocities, and thalweg profiles from tributary channels, through the debris apron and into the Susitna channel (Appendix B). The degree to which these tributary mouths are conducive to fish passage will be presented in the Updated Study Report.

6. DISCUSSION

To date, the Study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries has identified a list of potential target fish species to be evaluated with input from the licensing participants. Similarly, a preliminary set of passage criteria for velocity, leaping, and depth criteria has been proposed and a final set of criteria will be selected with input from licensing participants. In 2012 and 2013, AEA completed aerial surveys for geologic barriers in all major tributaries in the Upper and Middle River. Within the ZHI in the Middle River, AEA characterized potential depth and velocity barriers in all accessible tributary mouths. All existing fish barriers not on CIRWG or ARRC lands have been located. Characterization of existing barriers and evaluation of potential changes to barriers under Project conditions is ongoing and coordinated with the Geomorphology Study (Study 6.5), the Ice Processes Study (Study 7.6), and the Flow Routing Study (Study 8.5.4). 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 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).

Field efforts and results reported for 2012 and 2013, in combination with those planned for the next year of the study, 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. Model outputs from the Fluvial Geomorphology Modeling Study (Study 6.6) and Ice Processes (Study 7.6) will be critical to meet the proposed schedule for evaluation of current and future barriers to fish passage.

7. COMPLETING THE STUDY

[As explained in the cover letter to this draft ISR, AEA's plan for completing this study will be included in the final ISR filed with FERC on June 3, 2014.]

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9. TABLES

Table 4.1- 1. HSC curve development priority and fish passage (ISR Study 9.11) priority species list.

Common Name	HSC Low	HSC Moderate	HSC High	PASS
Chinook salmon			X	X
Chum salmon			X	X
Coho salmon			X	X
Pink salmon			X	
Sockeye salmon			X	X
Arctic grayling			X	X
Bering cisco	X			X
Burbot		X		X
Dolly Varden		X	X	X
Eulachon		X		
Lamprey, arctic	X			X
Longnose sucker		X		X
Northern pike	X			
Sculpin	X			
Stickleback, threespine	X			
Trout, lake	X			
Trout, rainbow			X	X
Whitefish, humpback		X	X	X
Whitefish, round	X		X	X

Table 4.2- 1. Pacific salmon leaping height capabilities from three sources.

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

Note:

1 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 4.3- 1. Potential geologic barriers evaluated in the Upper Susitna River in 2013 and in 2012 as reported in HDR Alaska, Inc. 2013

2012 Barrier ID	Tributary PRM	Tributary Name	Survey Year	Location (tributary RM)	Category	Barrier*/Potential Barrier Present	Class	Description
PB186.6-A	189.4	Deadman Creek	2012	0.6	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 50 ft
PB186.9-A	189.7	Unnamed Tributary 189.7	2013	0.4	Permanent	Barrier	Complex Chute	Permanent barrier due to high gradient cascades, and bedrock chutes >29ft
PB194.9-A	197.7	Unnamed Tributary 197.7	2013	1.3	Permanent	Barrier	Multiple Falls	Permanent barrier due to steep gradient boulder cascades and falls > 13ft
PB200.7-A	203.4	Unnamed Tributary 203.4	2012	0.2	Permanent	Barrier	Single Falls	Permanent anadromous barriers with single falls estimated at 10–12 ft
PB200.7-B	203.4	Unnamed Tributary 203.4	2012	0.2	Permanent	Barrier	Single Falls	Permanent anadromous barriers with single falls estimated at 40–50 ft
PB200.7-C	203.4	Unnamed Tributary 203.4	2012	0.2	Permanent	Barrier	Single Falls	Permanent anadromous barriers with single falls estimated at 15–20 ft
PB200.7-D	203.4	Unnamed Tributary 203.4	2012	0.2	Permanent	Barrier	Single Falls	Permanent anadromous barriers with single falls estimated at 11–12 ft
PB200.7-E	203.4	Unnamed Tributary 203.4	2012	0.2	Permanent	Barrier	Single Falls	Permanent anadromous barriers with single falls estimated at 20 ft
PB201.8-A	204.5	Unnamed Tributary 204.5	2013	0.4	Permanent	Potential	Compound	Potential barrier due to steep gradient boulder cascades and falls > 7ft
PB201.8-B	204.5	Unnamed Tributary 204.5	2013	0.6	Permanent	Potential	Compound	Potential barriers due to steep gradient boulder cascades and falls > 10ft
PB213.0-A	215.2	Unnamed Tributary 215.2	2013	0.6	Permanent	Barrier	Compound	Potential barrier due to steep gradient boulder cascades and falls > 60ft
Upper Extent Proposed Watana Reservoir at Low Pool (1850 ft NAVD88, PRM 222.5								
PB226.8-A	228.5	Unnamed Tributary 228.5	2012	0.7	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 60 ft
Upper Extent Proposed Watana Reservoir at Full Pool (2050 ft NAVD88, PRM 232.5								

*Preliminary barrier category based on decision tree using proposed leaping criteria for Chinook salmon (10 ft).

Table 4.3- 2 Potential geologic barriers evaluated in the Middle Susitna River in 2013 and in 2012 as reported in HDR Alaska, Inc. 2013.

2012 Barrier ID	Tributary PRM	Tributary Name	Survey Year	Location (tributary RM)	Category	Barrier*/ Potential Barrier	Class	Description
Middle River Downstream of Devils Canyon								
PB150.1-A	153.7	Unnamed Tributary 153.7	2012	0.1	Permanent	Barrier	Compound	Permanent anadromous barrier with falls > 10 ft. Cascades and chutes upstream and downstream
PB150.2-A	153.8	Unnamed Tributary 153.8	2012	0.2	Permanent	Barrier	Complex Chute	Permanent anadromous barrier due to low flow, high gradient and complex chutes
Middle River Within Devils Canyon								
PB151.0-A	154.6	Unnamed Tributary 154.6	2012	0.1	Permanent	Barrier	Complex Chute	Permanent anadromous barrier due to low flow, high gradient and complex chutes
PB152.0-A	155.4	Unnamed Tributary 155.4	2012	0.5	Permanent	Barrier	Compound	Permanent anadromous barrier with falls > 10 ft, low flow, high gradient, cascades, and complex chutes
PB152.4-A	155.9	Cheechako Creek	2012	2.1	Permanent	Potential	Compound	Potential seasonal barrier due to high gradient boulder cascades falls 3-4 ft, chutes, and high velocity turbulence
PB152.4-B	155.9	Cheechako Creek	2012	2.1	Permanent	Barrier	Multiple Falls	Permanent anadromous barriers (2) with falls > 10 ft and shallow plunge pool
PB152.4-C	155.9	Cheechako Creek	2012	2.1	Permanent	Barrier	Single Falls	Permanent anadromous barrier with waterfall much >10 ft
PB153.4-A	156.8	Unnamed Tributary 156.8	2012	0.3	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 30 ft
PB154.5-A	157.9	Unnamed Tributary 157.9	2012	0.1	Permanent	Barrier	Multiple Falls	Permanent anadromous barrier with high velocity falls > 10 ft
PB154.6-A	158.3	Unnamed Tributary 158.3	2012	0.1	Permanent	Barrier	Complex Chute	Permanent anadromous barrier with high velocity bedrock chutes
PB155.3-A	158.7	Unnamed Tributary 158.7	2012	0.1	Permanent	Barrier	Compound	Permanent anadromous barrier with falls > 10 ft
PB155.3-B	158.7	Unnamed Tributary 158.7	2012	0.1	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls 12–15 ft
PB155.3-C	158.7	Unnamed Tributary 158.7	2012	0.1	Permanent	Potential	Boulder Cascade	Continuous boulder/cascade complex with limited resting areas

2012 Barrier ID	Tributary PRM	Tributary Name	Survey Year	Location (tributary RM)	Category	Barrier*/ Potential Barrier	Class	Description
PB157.0-A	160.5	Chinook Creek	2012	1.3	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 10 ft
PB158.8-A	162.6	Unnamed Tributary 162.6	2012	0.1	Permanent	Barrier	Compound	Permanent anadromous barrier with falls > 30 ft
Middle River Upstream of Devils Canyon Impediment 3								
PB161.5-A	164.8	Devil Creek	2012	1.4	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls estimated at 80–100 ft
PB161.5-B	164.8	Devil Creek	2012	1.4	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls estimated at 40 ft
PB161.5-C	164.8	Devil Creek	2012	1.4	Permanent	Potential	Compound	Chutes and falls with continuous whitewater
PB165.0-A	168.1	Unnamed Tributary 168.1	2012	0.1	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 10 ft
PB165.2-A	168.3	Unnamed Tributary 168.3	2012	0.2	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 10–12 ft
PB165.6-A	169.1	Unnamed Tributary 169.1	2012	1.3	Permanent	Potential	Compound	Potential barrier due to steep gradient boulder cascades and falls to 6 ft with limited resting places and plunge pools
Middle River Upstream of Devils Canyon (PRM 166.1)								
PB168.7-A	172	Unnamed Tributary 172	2012	0.4	Permanent	Barrier	Boulder Cascade	Permanent anadromous barrier with multiple boulder cascades and complex chutes
PB171.0-A	173.8	Unnamed Tributary 173.8	2012	1.4	Permanent	Barrier	Complex Chute	Permanent anadromous barriers due to low flow, high gradient and complex chutes
PB171.0-B	173.8	Unnamed Tributary 173.8	2012	1.4	Permanent	Barrier	Complex Chute	Permanent anadromous barriers due to low flow, high gradient and complex chutes
PB171.0-C	173.8	Unnamed Tributary 173.8	2012	1.4	Permanent	Barrier	Complex Chute	Permanent anadromous barriers due to low flow, high gradient and complex chutes
PB171.0-D	173.8	Unnamed Tributary 173.8	2012	1.4	Permanent	Barrier	Complex Chute	Permanent anadromous barriers due to low flow, high gradient and complex chutes
PB171.3-A	174.3	Unnamed Tributary 174.3	2012	0.1	Permanent	Barrier	Complex Chute	Potential barrier due to complex bedrock chutes
PB173.0-A	175.9	Unnamed	2012	0.2	Permanent	Barrier	Multiple Falls	Permanent anadromous barrier with multiple falls > 6 ft

2012 Barrier ID	Tributary PRM	Tributary Name	Survey Year	Location (tributary RM)	Category	Barrier*/ Potential Barrier	Class	Description
		Tributary 175.9						and limited resting places or plunge pools
PB179.1-A	181.9	Unnamed Tributary 181.9	2012	2.8	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 15 ft
PB181.2-A	184	Unnamed Tributary 184	2012	1.8	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 30 ft
PB181.8-A	184.6	Tsusena Creek	2012	3.8	Permanent	Barrier	Single Falls	Permanent anadromous barrier with falls > 60 ft

*Preliminary barrier category based on decision tree using proposed leaping criteria for Chinook salmon (10 ft).

Table 4.3- 3. Major tributary mouths in the Middle River selected for fish passage barrier investigation in Study

Tributary PRM	Tributary	Focus Area	2013; ISR Study 9.12	Targeted for next year of study; ISR Study 9.12	2013; ISR Study 6.6	Targeted for next year; ISR Study 6.6
Middle River Downstream of Devils Canyon						
105.1	Whiskers Creek	FA-104			X	
110.5	Chase Creek		X			
113.7	Unnamed Tributary 113.7	FA-113			X	
114.9	Slash Creek	FA-113			X	
115	Gash Creek	FA-113			X	
115.4	Unnamed Tributary 115.4	FA-115			n/a*	
117.2	Lane Creek		X+		X+	
119.7	Lower McKenzie Creek			X		
120.2	McKenzie Creek			X		
121.4	Little Portage Creek			X		
124.4	Deadhorse Creek		X			
127.3	Fifth of July Creek		X			
128.1	Skull Creek	FA-128			X	
134.1	Sherman Creek		X			
134.3	Fourth of July Creek		X			
140.1	Gold Creek		X+		X+	
142.1	Indian River	FA-141			X	
144.6	Unnamed Tributary 144.6	FA-144			X	
148.3	Jack Long Creek			X		
152.3	Portage Creek	FA-151				X
Middle River Within Devils Canyon						
155.9	Cheechako Creek			X		
160.5	Chinook Creek			X		
Middle River Upstream of Devils Canyon Impediment 3						
164.8	Devil Creek			X		
Middle River Upstream of Devils Canyon (PRM 166.1)						
173.8	Unnamed Tributary 173.8	FA-173				X
174.3	Unnamed Tributary 174.3	FA-173				X
179.3	Fog Creek			X+		X+
184.6	Tsusena Creek	FA-184		X+		X+

Notes:

* Excluded from modeling in ISR Study 6.6 based on observations during 2013 reconnaissance of low sediment production and absence of a mouth.

\+ Study 9.12 and Study 6.6 surveys on these tributaries are complimentary, focusing on tributary mouth barriers and sediment production zones, respectively.

Table 4.3- 4. Tally of off-channel habitats and tributary mouths in Middle River Focus Areas targeted for data collection to support ice-free modeling by ISR Study 8.5.

Focus Area	Side Channel	Side Slough	Upland Slough	Backwater	Tributary Mouth	Total
FA-104 (Whiskers Slough)	7	2	1		1	11
FA-113 (Oxbow I)	2		1		2	5
FA-115 (Slough 6A)	1		3	1	1	6
FA-128 (Slough 8A)	8	1	1		1	11
FA-138 (Gold Creek)	3	1	2			6
FA-141 (Indian River)	1		1	1	1	4
FA-144 (Slough 21)	6	1	2		1	10
FA-151 (Portage Creek)					1	1
FA-173 (Stephan Lake Complex)	4	3	2		2	11
FA-184 (Watana Dam)	2					2
Total	34	8	13	2	10	67

10. FIGURES

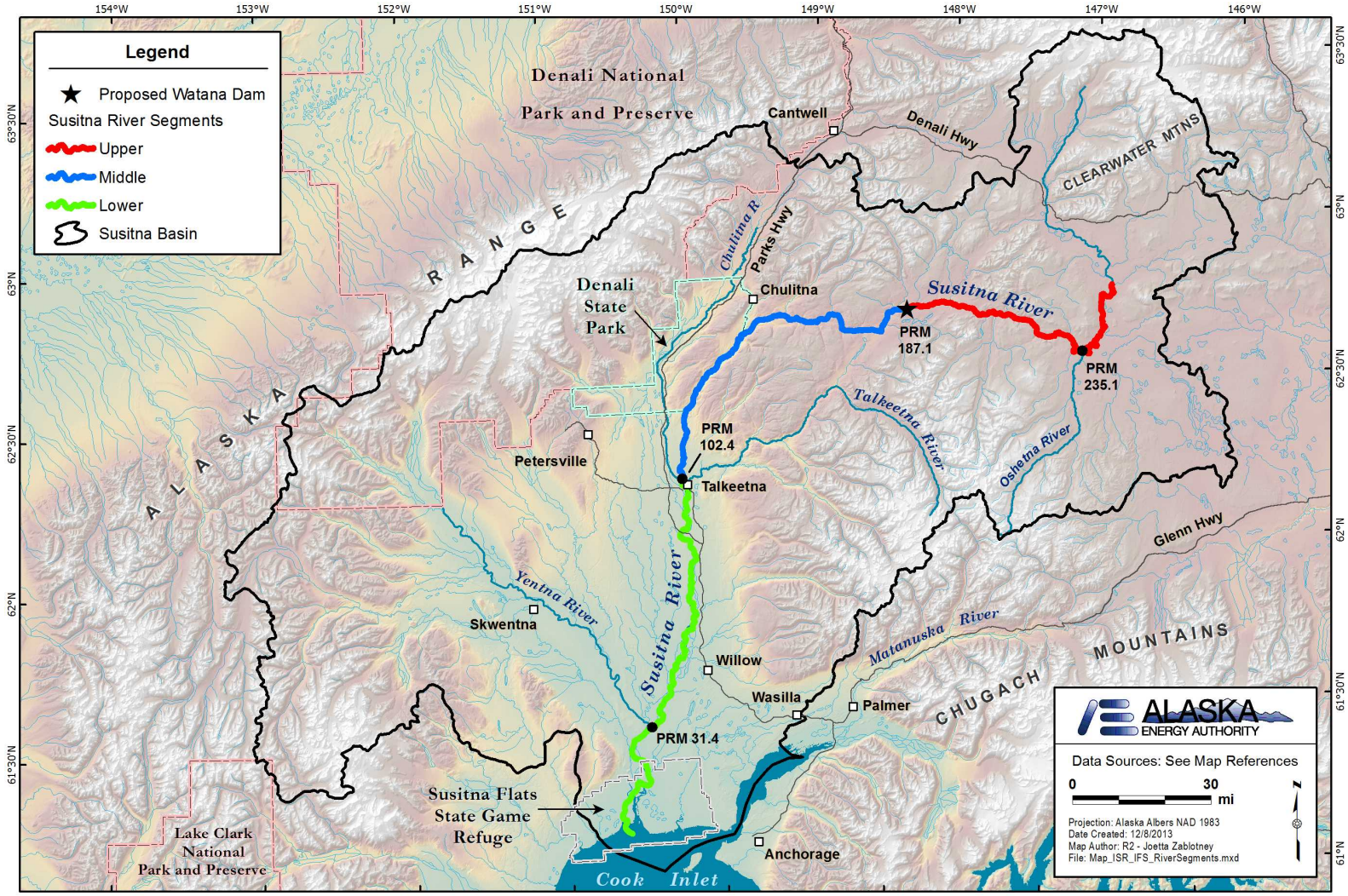

Figure 3- 1. Susitna River Study Area

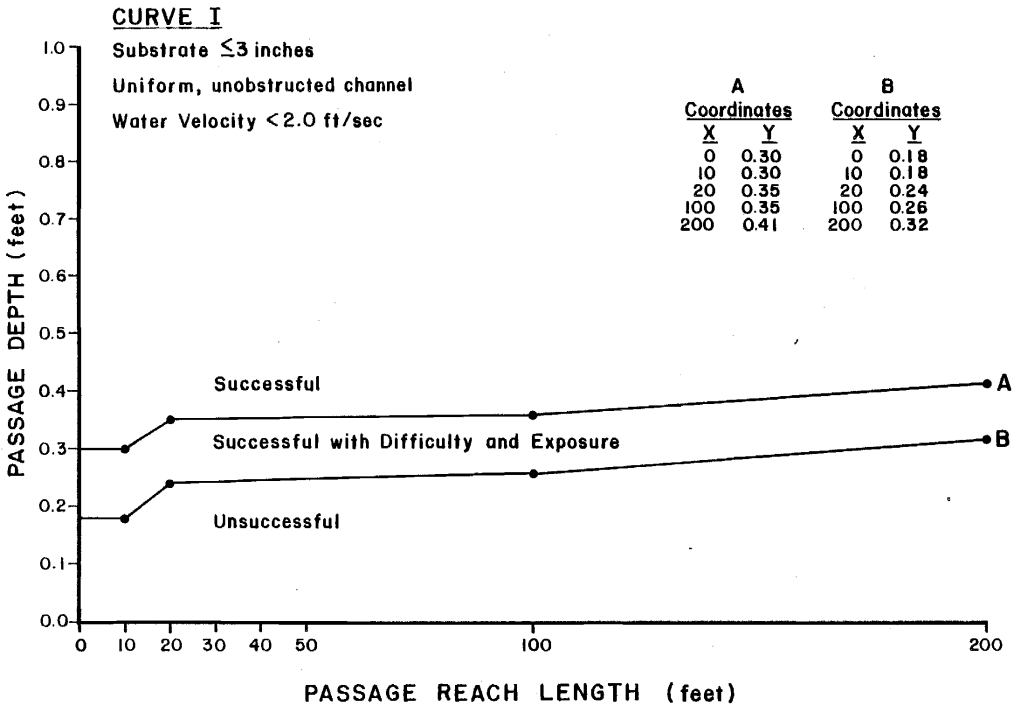

Figure 6-4. Passage depth requirements for chum salmon as a function of passage reach length within sloughs and side channels having substrates less than 3.0 inches in diameter, uniform morphology and water velocities less than 2.0 ft/sec.

Figure 4.2- 1. Depth/distance passage criteria for chum salmon in unobstructed uniform channels with smaller substrates. Source ADF&G 1984b.

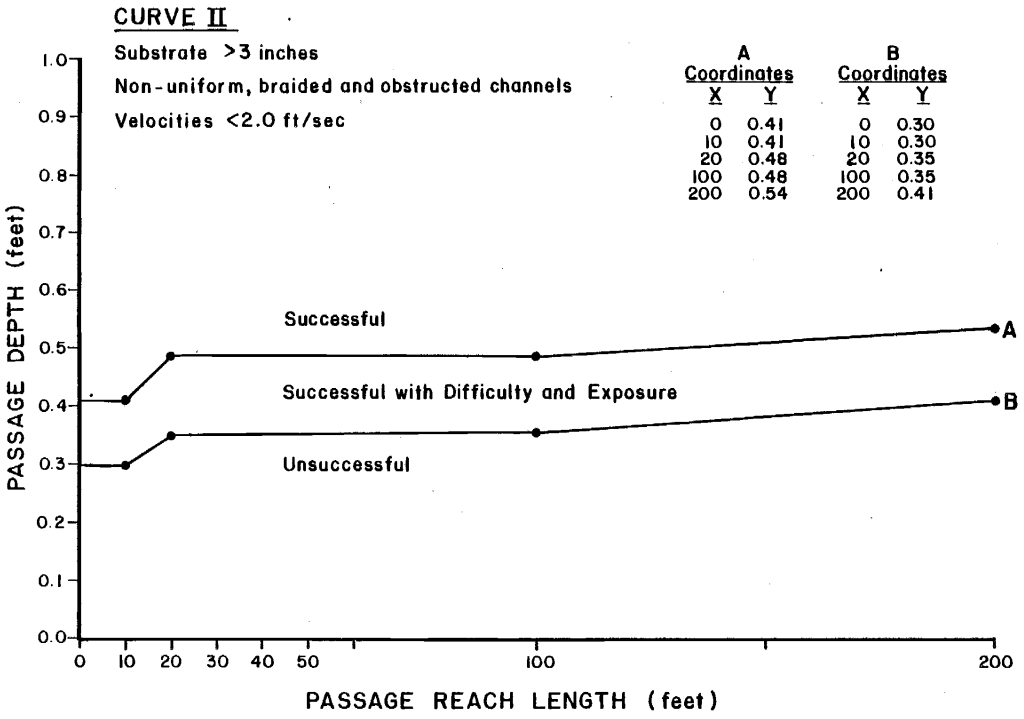

Figure 6-5. Passage depth requirements for chum salmon as a function of passage reach length within sloughs and side channels having substrates greater than 3.0 inches in diameter, non-uniform, braided and obstructed channels and velocities less than 2.0 ft/sec.

Figure 4.2- 2. Depth/distance passage criteria for chum salmon in obstructed non-uniform channels with larger substrates. (ADF&G 1984a).

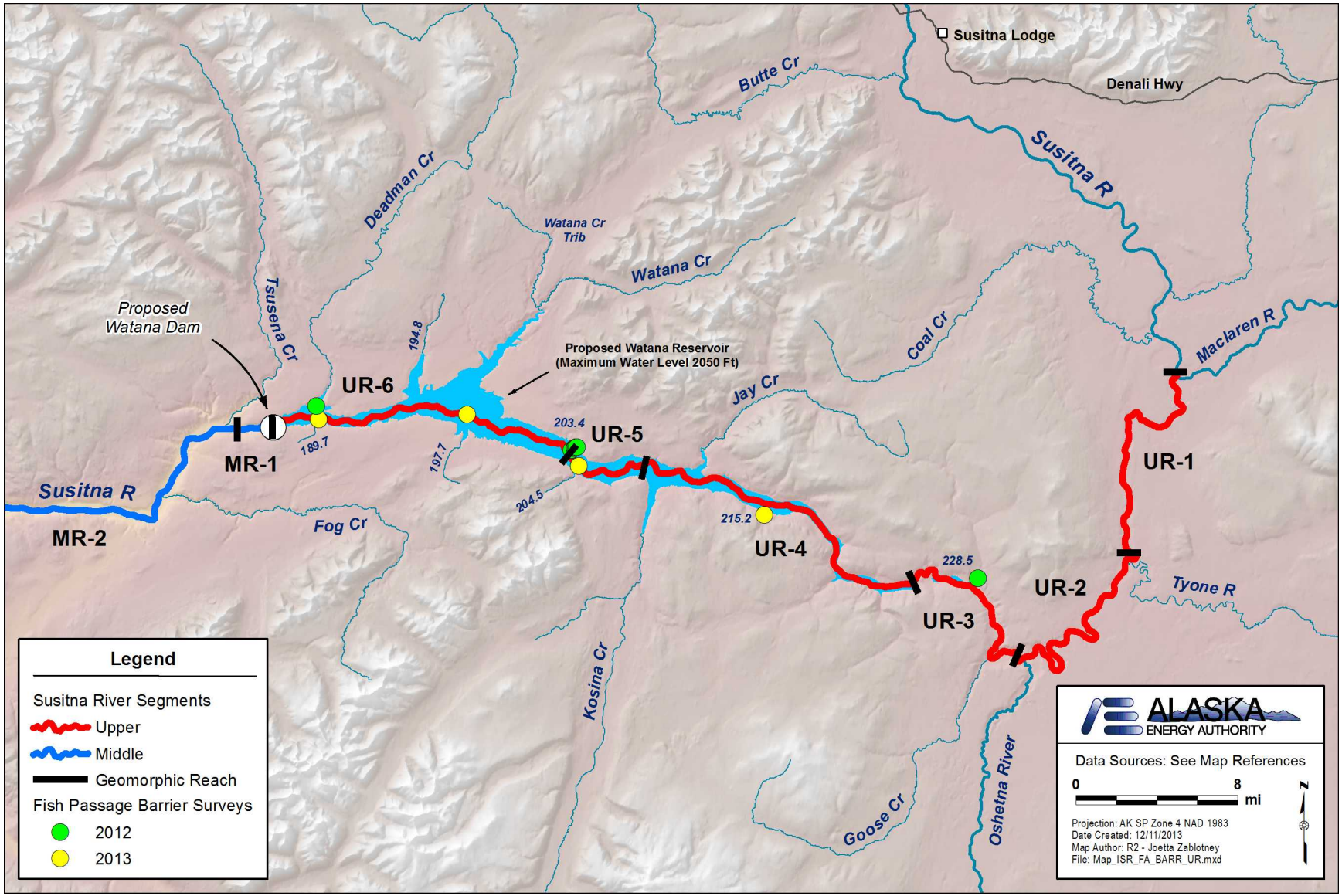

Figure 4.3-1 a. Locations of all Upper River tributaries examined for barrier analysis in 2012 and 2013.

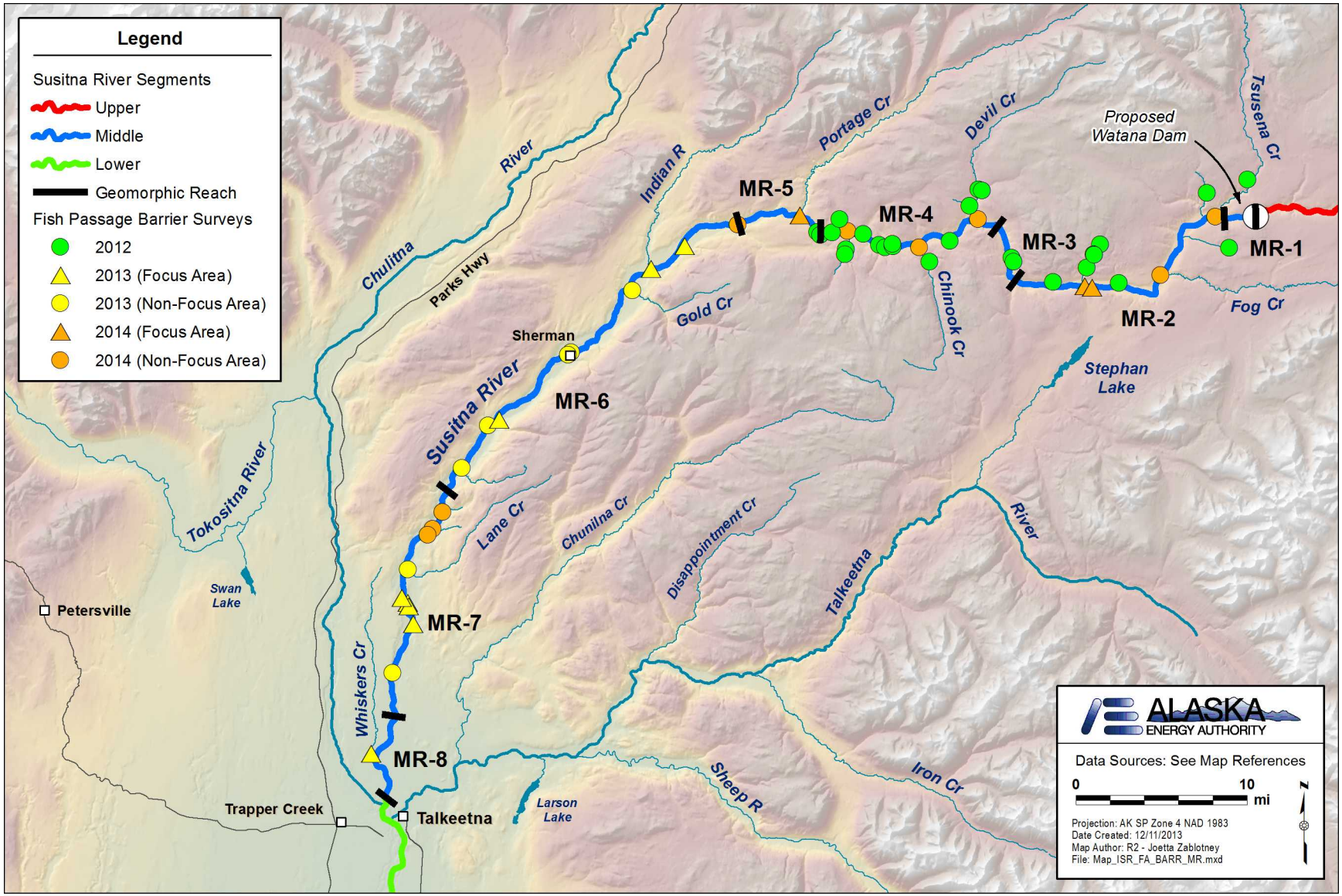

Figure 4.3-1 b. Locations of all Middle River tributary mouths examined in 2013 and planned for the next year of the study.

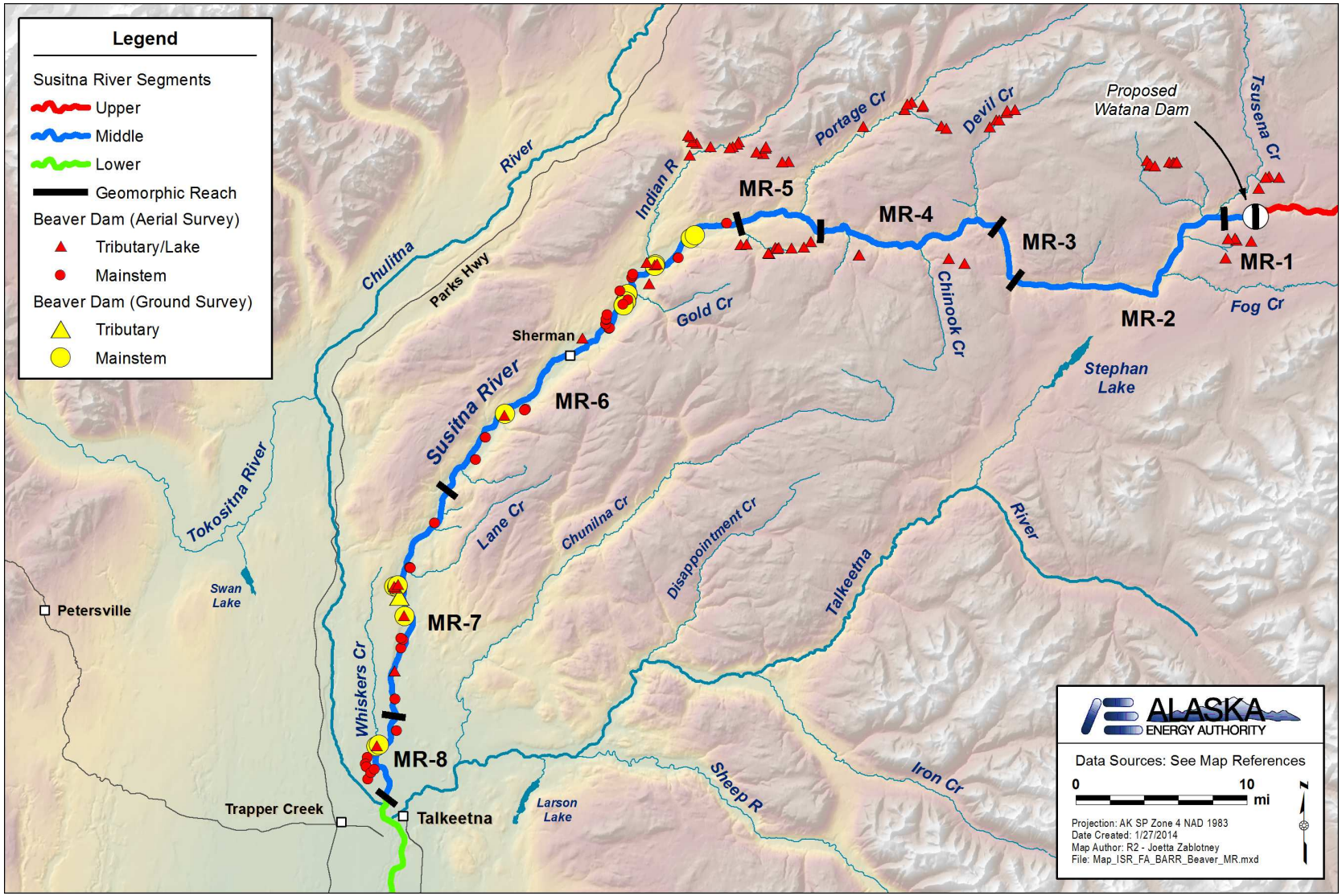

Figure 5.2- 1. Locations of beaver dams identified by aerial and ground surveys in the Middle River.

APPENDIX A: TRIBUTARY GEOLOGIC BARRIERS

[See separate file for Appendix.]

APPENDIX B: MIDDLE RIVER TRIBUATRY DELTA SURVEYS OUTSIDE OF FOCUS AREAS

[See separate file for Appendix.]