Susitna-Watana Hydroelectric Project Document
ARLIS Uniform Cover Page

Title: Study of fish passage barriers in the middle and upper Susitna River and Susitna tributaries, Study plan Section 9.12 : Final study plan	**SuWa 200**
Author(s) – Personal:	
Author(s) – Corporate: Alaska Energy Authority	
AEA-identified category, if specified: Final study plan	
AEA-identified series, if specified:	
Series (ARLIS-assigned report number): Susitna-Watana Hydroelectric Project document number 200	**Existing numbers on document:**
Published by: [Anchorage : Alaska Energy Authority, 2013]	**Date published:** July 2013
Published for:	**Date or date range of report:**
Volume and/or Part numbers: Study plan Section 9.12	**Final or Draft status, as indicated:**
Document type:	**Pagination:** 30 p.
Related work(s):	**Pages added/changed by ARLIS:**
Notes:	

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

Final Study Plan

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

July 2013

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

On December 14, 2012, Alaska Energy Authority (AEA) filed with the Federal Energy Regulatory Commission (FERC or Commission) its Revised Study Plan (RSP), 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 9.12 provided 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 determination at page B-35 (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.[3] [sic] 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 delta 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 deltas 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 deltas 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 all 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 implementation plan filed with FERC on June 17, 2013. Information in the Implementation Plan supersedes relevant details within this Final Study Plan. Please note that the Implementation Plan includes FERC's request that AEA assess discharge conditions at the streamflow gages established by AEA closest to Devils Canyon and near the dam site.

9.12.1. General Description of the Proposed Study

Construction and operation of the Project will likely affect flow, surface water elevation, sediment load and transport, and water depth in the mainstem channel of the Susitna River at tributary confluences as well as at the inlets and outlets to side channels, sloughs, and various off-channel habitat features both in the area of the inundation upstream from the Watana Dam site and downstream in the Project's potential zone of hydrologic influence (ZHI). These changes in mainstem flow, water elevations, and sediment transport can potentially inhibit fish passage into, within, and out of aquatic habitats. Understanding existing conditions of barriers[1], how those conditions change over a range of stream flows, and the relative importance of habitats upstream of barriers will provide baseline information needed for predicting the likely extent and nature of potential changes to barriers resulting from flow and water elevation changes that will occur due to Project operations.

Environmental variables affecting fish passage in streams are dynamic; therefore, results of this study must be considered representative of only a "snapshot-in-time". The height and configuration of cascades and waterfalls change from season to season with the rise and fall of stream flow, and the feature itself can be present or absent over time with the natural shifting or displacement of keystone rocks or logs. The dynamic alluvial river bed of the mainstem Susitna River also changes with variable flows over time. Thus, the bed elevations into and within sloughs, side channels, and at the mouths of tributaries can change within a year, or perhaps not

[1] The term "barrier" includes both natural and man-made features.

for a decade, or longer. These shifts in bed elevation may change the passage depth conditions, sometimes eliminating and sometimes creating the opportunity for fish passage where it may or may not have previously existed.

Deltas formed at the mouths of tributaries also change in size, height, and composition over time, possibly affecting fish passage into and out of the tributaries. The dynamics of tributary delta formation are primarily a function of tributary sediment load and the erosive power of the mainstem at the tributary mouth. Long-term changes in land use in the tributary watershed, such as increased timber harvest or road building, and changes in the timing and volume of mainstem flow will change tributary mouth passage conditions over time.

This study plan describes a coordinated effort that will be undertaken to identify and evaluate the effects of potential Project-induced changes in water depth and stream bed elevation on fish passage over barriers. Several other fish and aquatic resource studies to be conducted in 2012 and 2013–2014 will be integrated with this passage study to address future Project effects related to flow and sediment transport. This study will describe existing barriers, identify barriers that may be eliminated or created by the Project operation, and will identify potential impacts to fish associated with these anticipated changes. The results will be used to determine what, if any, protection, mitigation, and enhancement measures may be appropriate.

Study Goals and 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 will be 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. Identify and locate using GPS 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 will be met through the use of existing information, consulting with the Fish and Aquatic TWG and other licensing participants, and by using the methods described in the this study plan. In addition, the relationship between discharge conditions at stream gages closest to Devils Canyon and salmon passage will be evaluated as part of FSP 9.7 Salmon Escapement.

9.12.2. Existing Information and Need for Additional Historic Information

Historic information on anadromous fish passage in sloughs and side channels was collected in the 1980s (ADF&G 1984a). These efforts focused on collection of multi-disciplinary data at specific sloughs and side channels (Table 9.12-1).

Studies conducted in the 1980s by ADF&G evaluated passage in side channels and sloughs for six fish species, including chum, Chinook, sockeye, coho, and pink salmon, and Dolly Varden. Chum salmon were used as a surrogate for the other five species. These studies did not address access changes at existing barriers or access into tributaries.

Current information specific to the Susitna River includes aquatic studies being conducted by AEA for Project licensing. Project licensing studies that will support the Fish Passage Barriers Study are described in Section 9.12.7.

The need for additional information regarding potential Project effects on fish passage was identified in the Pre-Application Document (PAD) (AEA 2011):

- **F2:** Potential effect of fluctuating reservoir surface elevations on fish access and movement between the reservoir and its tributaries and habitats.
- **F6:** Potential influence of the proposed Project flow regime and the associated response of tributary mouths on fish movement between the mainstem and tributaries within the Middle River Reach.
- **F7:** Influence of Project-induced changes to mainstem water surface elevations July through September on adult salmon access to upland sloughs, side sloughs, and side channels.

9.12.3. 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 the construction and operation of the Project. For purposes of this study, the study area has been preliminarily divided into two segments:

- Upper River—Susitna River and selected tributaries within this segment up to the 3,000 foot elevation and extending upstream from Watana Dam site (RM 184) to the upper extent of river influenced by Watana Reservoir up to and including the Oshetna River (see Section 9.5, Figure 9.5-1).
- Middle River—Susitna River and selected tributaries within this segment, extending from Watana Dam site to the confluence of the Chulitna River (RM 98). Passage studies in the mainstem Middle Segment will include sloughs, upland sloughs, side channels, and tributary mouths and deltas.

Passage studies in tributaries to the Middle River will include select tributaries and will extend from the mouth to the upper extent of Project hydrologic influence. The upper limit of hydrologic influence will be determined from supporting studies including the Instream Flow Study (Section 8.0) and the Geomorphology Study (Section 6.0), among others.

9.12.4. Study Methods

Study methods will vary primarily depending on the type of barrier being assessed. In this study, depth barriers are more of a concern in sloughs, side channels, and mouths of tributaries. Physical barriers (cascades and waterfalls) are more of a concern within tributaries. Beaver dam barriers can occur in sloughs, side channels, and tributaries. While the specific methods for each barrier type differ, the general study components and steps are similar for locating and assessing the various types of barriers.

Methods for the study of fish passage barriers will likely consist of the following study components (these components will be refined in response to Fish and Aquatic Technical Workgroup [TWG] and licensing participant input):

- 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, as described in Section 9.12.7 and illustrated in Figure 9.12-1.
- Evaluate potential effects of altered fluvial processes on fish passage in sloughs, upland sloughs, side channels, and at tributary mouths.
- Evalutate the potential for impeded movement or “pooling” of fish that could result in increased predation below a barrier[2].

9.12.4.1. Identify Fish Species

The fish community of the Susitna River includes approximately 18 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 9.12-3). A subset of species will be selected to target for the fish passage barrier analysis based on passage sensitivity, the known distribution of the species, and the locations of potential barriers. The species list will be refined in response to input from the Fish and Aquatic TWG and licensing participants.

9.12.4.2. Passage Criteria for the Identified Fish Species

Salmonid passage criteria are well researched and some criteria exist for all species, while passage criteria for many non-salmonids has not been researched and therefore criteria do not curently exist. The need for species-specific passage criteria for different species will depend on the results of consultation with licensing participants. Which criteria are used and whether “surrogate” salmonid species criteria can be substituted for other species will be determined in consultation with licensing partipants.

[2] Methods to evaluate the potential for delayed movement or pooling of fish below a barrier are not provided in this Final Study Plan. These studies would be designed on a barrier-by-barrier basis with input from licenscing participants.

Basic categories of fish passage criteria for use in this study include water depth, water velocity, and fish leaping ability. Depth criteria will establish the minimum water depth and the maximum distance (at the minimum depth) through which a fish can successfully pass. Depth requirements for successful passage increase with an increase in the length of passage. Depth criteria will be used to assess access into, within, and out of side channels, sloughs, and tributaries. The ability of adult fish to enter or exit slough and side channel or tributary habitats from the mainstem Susitna River and access spawning or rearing areas within these habitats is primarily a function of water depth in relation to the length of shallow reaches a fish must navigate (ADF&G 1984b). Velocity criteria pertain to the ability of adult and juvenile fish to swim against the flow, which varies with fish length and, similar to depth, with the distance over which the velocity is maintained.

Leaping criteria will be established 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 may influence successful passage. Velocity criteria will also be applied at chutes. Leaping criteria and velocity criteria will be applied only in tributaries (including their deltas) and at beaver dams.

9.12.4.2.1. 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 1984b). Thompson (1972) involves establishing cross-sectional and water surface elevation transects at one or more locations to represent the shallowest conditions a fish may encounter while moving upstream. Although there is no longitudinal factor measured in this method, one can assume the criterion represents a minimum depth over a relatively short stream distance. With this method, depth criterion for an individual species should be based on literature values and would be determined in consultation with the Fish and Aquatic TWG.

The depth/distance method evaluates fish passage in two dimensions: depth of water and distance of travel required. This method and criteria for select species were developed for the 1980s Susitna River studies to assess passage into and within side channels and sloughs (ADF&G 1984b). One component of the depth/distance method is the development of species-specific fish passage curves that define relationships between passage depth and reach length in different habitats. Parameters that were used in the 1980s to differentiate habitats within channels and side sloughs were channel complexity, substrate, and velocity (ADF&G 1984b).

The resulting ADF&G (1984b) chum salmon passage criteria curves for small substrate and uniform, unobstructed channel are presented in Figure 9.12-2. Chum salmon passage curves for large substrate and non-uniform obstructed channel are presented in Figure 9.12-3. As needed, depth, length, and substrate criteria can be modified for chum and developed for other species as a part of this study with input from licensing participants.

9.12.4.2.2. 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. Their analysis is based on collecting data on barrier geometry and stream hydrology to define the existing hydraulic conditions within the barrier. The hydraulic conditions are compared to known fish capabilities to determine if fish passage is feasible. Predicting successful passage at flows outside of those at the time the data were collected depends on knowing the stage versus discharge or other flow indicators for the site. 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 9.12-4 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. Stuart (1964) suggests a ratio of 1:1.25 (barrier height/leaping pool depth). Reiser and Peacock (1985) also suggest a ratio of 1:1.25 and a pool depth of at least 2.5 meters (8.2 feet). Aaserude (1984) concluded that for optimum leaping conditions the depth of the leaping pool must be on the order of, or greater than, the length of the fish attempting to pass. Because assessment of the leaping pool is fundamental to determining fish passage, leaping pool depth criteria will be investigated as part of the study. The refinement of leaping criteria for use in this study will be determined in consultation with licensing participants.

9.12.4.2.3. Upstream Velocity Criteria

Stream velocities higher than a fishes swimming speed can create barriers to upstream migration. Velocity barriers within the ZHI may currently exist, may be created by Project operation, or existing barriers may be eliminated by the presence of the Project.

If velocity barriers to upstream adult migration currently exist or if they are potentially created by the Project, they would likely only occur in tributaries. Gradients or channel constrictions at the entrances to sloughs and side channels are likely not sufficient to create velocity barriers to adult fish or juveniles with or without the Project.

For juveniles and fry, an exception is at tributary mouths where the tributary may flow over a steep slope just before entering the main channel. Under current conditions, this section of steep slope immediately upstream of the tributary confluence may be inundated at high flow, thereby eliminating any velocity barrier associated with the higher gradient. During some periods of time under Project operation, these steep gradient sections may not be inundated, thereby creating higher velocities, along with shallower depths, at the stream entrance. If these tributaries are utilized by rearing juveniles, the higher velocities may exceed juvenile swim speeds and thereby create a barrier to utilization.

Juvenile salmonid swim speeds have been well researched so there is abundant existing critieria. 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 where velocity criteria do not exist for species of interest.

9.12.4.2.4. Downstream Passage Criteria

In natural systems, a section of very shallow surface flow or dry streambed is the most likely type of barrier to downstream fish migration or movement (beaver dam barriers to downstream migration are discussed in Section 9.12.4.4, Physical Barriers subsection). Although impassable depths can occur in any reach due to large-scale erosion of stream banks or subsurface slow, a more common concern is the deposition of large amounts of cobble and gravel at tributary mouths.

Fish requiring adequate flows for downstream passage in the Susitna River include anadromous juvenile and migratory resident species that move between summer rearing and overwintering habitats. Most research on downstream passage is related to passage at physical structures such as hydroelectric projects, irrigation diversions, and culverts. There is minimal information on depth criteria for downstream passage in natural environments. Alaska requires that passage depth be greater than 2.5 times the depth of a fish's caudal fin (ADF&G and ADOT&PF 2001 as cited in FHWA 2011). Other sources (Powers and Orsborn 1985 and Webb 1975) suggest that only full submergence is necessary. Maine Department of Transportation (2008) suggests 1.5 times the body thickness.

The species, life stage, and respective depth criteria for passage of downstream migrating fish will be determined in collaboration with licensing participants as part of this study.

9.12.4.3. Study Site Selection

Selection of tributaries and tributary mouths for passage study in the Upper River will expand upon the 2012 Upper Susitna River Fish Distribution and Habitat Study.

Upper River 2013–2014 passage studies will supplement the 2012 passage study and include the following:

- Passage studies in any streams or stream segments requiring study that were not completed in 2012.
- Second assessment of barriers identified in 2012 that require confirmation.
- Passage survey within the projected reservoir drawdown (or varial) zone. Selection of tributaries for varial zone passage study will be based on those streams selected for study in 2012 initial surveys.

In the Middle River, tributaries and their mouths and deltas will be selected for passage study as described in the Fish Passage Barriers Implementation plan that was filed with FERC on June 30, 2013.

In the Middle River, the expanse, large number, and complexity of sloughs and side channels will prohibit total coverage of all such potentially affected areas. Thus, sub-sampling of these habitats will be necessary. This study will coordinate with licensing participants, IFS study leads, and geomorphology study leads to identify a subset of tributary mouths, sloughs, and side channels for Focus Areas that represent the range of conditions present in the mainstem Middle River. These intensively studied habitats will likely be located within the ISF Focus Area. Passage into, within, and out of the selected sloughs and side channels can then be modeled to evaluate how Project-induced flow and sedimentation may affect fish passage conditions on a local scale and extrapolated to the larger river segment.

Researchers who conducted the 1980s APA studies encountered a similar dilemma of conducting passage studies in such a large number of off-channel habitats with complex hydrodynamics. Instead of studying all possible passage barriers, a total of 12 slough and side channel sites were selected for passage evaluation studies. These study sites were considered representative of the major slough and side channel spawning areas for chum, sockeye, and pink salmon in the middle reach of the Susitna River.

9.12.4.4. Field Studies

Studies in the Middle River will rely upon data collected as part of IFS and geomorphology studies. However, the need is anticipated to collect additional information at IFS and geomorphology study sites and at additional sites primarily for physical barriers but also for potential depth barriers. The following methods describe field activities to be conducted for this study.

To maximize access to habitats, passage barrier field efforts will be conducted under lower flow conditions. Discharge relationships developed from the routing and IFS studies will enable passage to be analyzed under a wide range of flows. Field data collection methods will vary among physical barriers and depth passage barriers.

Physical Barriers

Physical barriers (geologic and beaver dam barriers) will be assessed by following the methods of Powers and Orsborn (1984). Physical barriers in tributaries and beaver dams in sloughs and side channels will be located by first reviewing existing information including the following:

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

A field survey team of two will walk up tributaries or stream reaches where barriers may be present or where their presence could not be ruled out by existing information. Each potential barrier (including beaver dams) will be assessed in two phases. If a stream feature is a possible obstacle to the species of concern, the geometry of the obstacle will be surveyed including measurements of barrier height, leap distance, and estimated depth of leaping pool at high and low flow. It will be drawn to scale, photographed, and its location fixed with GPS. If the obstacle is clearly not a barrier, its location and basic dimensions will be noted with no further measurements.

If the surveyors have uncertainty regarding the barrier status of an obstacle, a decision tree analysis (URS and HDR 2010) (Figures 9.12-4) will be implemented that is consistent with Powers and Orsborn (1984) and modified as necessary for site-specific species and barrier conditions. Field data forms will be designed around this decision tree. A draft prototype of the field data form is presented in Figure 9.12-6. The final field data form will be developed as part of study planning prior to the 2013 field season.

The barrier analysis decision tree is a step-wise process for evaluating potential barriers in the field. Quantitative metrics are used at each step in the decision tree to identify the impassability of the potential barrier. Decision tree questions logically break down the barrier into its physical component parts, allowing a systematic, repeatable, and comparable evaluation of each potential barrier. An advantage to sequentially evaluating each component of a barrier is that if the answer to the first decision tree question suggests that a barrier is impassable, the evaluation is terminated and additional questions need not be addressed to determine barrier passability.

Beaver dams are built in many shapes and sizes. Most beaver dams stretch from bank to bank and range in height from 2 to 5 feet, but can reach 8 to 10 feet above the tailwater level at low flow. Coho, Chinook, and sockeye can easily leap over a 4-foot-high blockage and a chum or pink can leap over a 2-foot-high blockage if the depth and distance of the leaping pool from the crest of the barrier are within criteria (Powers and Orsborn 1984). Hetrick and Nemeth (2003) found that the early run of coho in Clear and Sandy creeks on the Alaska Peninsula were blocked until the onset of frequent and higher flows in October. Pink and chum salmon appeared to have been blocked from the upper reaches of the stream over their entire run period.

The depth of the leaping pool and its location relative to the crest of the blockage is critical to successful passage by an upstream migrant (Powers and Orsborn 1984). Because beaver dams are temporary structures and there is not a continuous plunge of flow over the crest, scour pools do not generally form below the dam as they would in a free-flowing stream below a cascade or waterfall. At low flow, tailwaters below most beaver dams are shallow relative to dam height.

Not all beaver dams in sloughs and side channels will be surveyed on the ground. All significant beaver dams will be identifiable in high-resolution aerial imagery and will be included on the GIS fish barrier layer and/or the wildlife layer. Beaver dams in sloughs and side channels that are selected as representative passage study sites will be surveyed on the ground. Beaver dams may also be surveyed in high-use salmon spawning areas.

Beaver dams are not typically thought to impede the downstream movement of juvenile fish. In the Black River drainage, Alaska, Brown and Fleener (2001) found that "high flows in the drainage provided multiple opportunities for both juvenile and adult fish to move over beaver dams during the season." In *Beaver Management Guidelines*, Canada Ministry of Environment (2001) states "When water is flowing over the dam, juvenile fish are able to migrate downstream, making use of small rivulets at either end of the dam." Pacific Stream Keepers website on controlling beavers states that "Generally, downstream migrating young salmon are not held back by a beaver dam (Kambietz 2003)."

9.12.4.5. Depth Barriers in Sloughs, Side Channels, Tributaries, and Tributary Deltas

Several environmental variables may affect fish passage in sloughs and side channels and tributary deltas. In general, at a given passage reach the water conditions (primarily depth) interact with conditions of the channel (length and uniformity, substrate size) to characterize the passage conditions that a particular fish encounters when attempting to migrate into, within, and out of a slough, side channel, or tributary delta. The likelihood of a particular fish successfully navigating through a difficult passage reach will depend on the environmental conditions as well as the individual capabilities and condition of the fish.

Depth passage for adults and juveniles in sloughs, upland sloughs, side channels, and at tributary delta mouths will be assessed following methods similar to ADF&G (1984b) and will focus on salmon passage in sloughs, side channels, and tributary deltas. Two-dimensional modeling, not available in the 1980s, may also be applied. Although salmon passage remains a key concern, the passage methods are generally applicable to other species where depth passage criteria are known or can be developed.

Passage reaches in the ADF&G study were evaluated under three types of hydraulic conditions: breaching, backwater, and local discharge. Breaching and backwater analyses were used to evaluate all passage reaches within a study site, whereas the local flow analysis was used to evaluate only a subset of passage reaches that were identified as most problematic for salmon passage (ADF&G 1984b). Length and depth of passage reaches were used as the primary criteria.

To separate the influence of breaching and backwater from local-flow-only conditions, a flow duration curve (based on a 32-year record at the USGS gage near Gold Creek) was developed by ADF&G for the period between August 20 and September 20, the period of time adult salmon would be entering the study sites. These date ranges were based on ADF&G 1981, 1982, and 1983 adult salmon spawner survey data for middle river sloughs and side channels. As part of this study, current information on adult spawner timing will be examined in collaboration with licensing participants. Timing of other species will be examined and applied as determined in consultation with licensing participants.

9.12.4.5.1.1.1. Breaching

The breaching discharge is generally defined as the mainstem discharge at which the overtopping of the head of a side channel or side slough occurs. Sub-definitions of breaching discharge include initial, intermediate, and controlling breaching discharge. The controlling discharge is a higher discharge that directly governs hydraulic characteristics within a slough or side channel. Passage conditions were considered to be successful within a site under controlled breaching conditions (ADF&G 1984b).

9.12.4.5.1.1.2. Backwater

The backwater analysis included an evaluation of all passage reaches that were physically located in areas directly influenced by the rising stage of the mainstem Susitna River at the mouth of each site (backwater area) before breaching occurs. Backwater area is defined as a segment of flowing water in which the depth of water is greater than that which would otherwise exist for a given discharge due to an obstruction (including hydraulic obstruction) downstream of the channel (ADF&G 1984b).

The analysis of backwater effects required stage/discharge relationships at the mouth of the study site plotted over the thalweg bed profile. Generally, passage was determined to be successful when the water surface elevation at the mouth equaled or exceeded the highest point on the thalweg profile plus the threshold passage criteria of 0.41 feet for a small substrate, uniform channel, and 0.54 feet for a large substrate non-uniform passage reach (ADF&G 1984b).

9.12.4.5.1.1.3. Local Flow

The local flow analysis estimated the amount of local flow (flow deriving from upwelling, tributaries, precipitation) required at a study site to provide adequate depth of flow for each passage reach when the reach is not influenced by backwater and breaching effects. Although the database varied for each study site, the general approach required two pieces of information:

- Surveyed cross-sections within each passage reach that represented the most difficult passage condition within the reach
- Stage versus discharge rating curves for each cross-section

These data were analyzed for each passage reach to determine the discharge required to equal or exceed the "passage depth" criteria established for cross-sections. In this report, the passage depth is defined as the depth of water through which a fish must pass in order to proceed upstream. Passage depth for cross-sections was calculated as the average of the mean depth and maximum depth at a transect (ADF&G 1984b). In the ADF&G 1984 study, for successful fish passage the passage depth had to exceed the appropriate threshold passage criteria of 0.41 or 0.54 feet. For juveniles, the species, life stage, and respective depth passage criteria for downstream migrating fish will be determined with input from licensing participants as part of this study.

Two-dimensional modeling and other survey and hydraulic modeling methods, not available in the 1980s, will be applied to collect the same field data. Although salmon passage is a key concern, the passage methods are generally applicable to other species where depth passage criteria are known or can be developed.

Figure 9.12-7 is a flow chart of the methods used by ADF&G (1984b) for evaluating passage in representative sloughs and side channels.

Where necessary to supplement the data collected under the Geomorphology Study, similar data collection methods, as described above for sloughs and side channels, will be applied at tributary mouths and deltas. The thalweg profile from the lowest extent of the delta or tributary flow upstream to and slightly beyond the upper extent of the delta, or tributary mouth, will be surveyed at low flows. Cross-sections will be surveyed at thalweg breakpoints and tributary discharge will be measured. Stage-discharge relationships in the mainstem will be derived from the closest Flow Routing Study transect. If necessary, the stage-discharge rating will be interpolated between the nearest upstream and downstream Flow Routing Study transects. Substrate along the thalweg and uniformity of channel will be recorded. Mainstem water surface elevation will be measured and the site will be photographed. Once analyzed, these data will enable decision-makers to determine the effects of mainstem discharge on fish passage from the mainstem into the selected tributaries.

Changes in the channel morphology may alter the accessibility by important fish species, into, within, and out of important riverine aquatic habitat types such as side channels, sloughs, and tributaries. Analysis of the complex interaction of water and sediment with the channel and floodplain boundaries to evaluate potential Project effects requires development and application of a sediment transport model.

Fluvial processes that may alter access to tributaries, sloughs, and side channels due to the proposed Project will be investigated and evaluated primarily in the Fluvial Geomorphology Study (Section 6.6). The passage study will coordinate and work closely with the Fluvial Geomorphology Study to achieve passage study objectives.

9.12.4.6. Velocity Barriers over Tributary Deltas

Velocity barriers over tributary deltas will be assessed at the same time and use some of the same methods as decribed in Section 9.12.4.5 for depth barriers. Longitudial survey data will be obtained from the depth barrier field studies. Relationships between main channel water surface elevation and the ZHI will be determined during the depth studies as well. Velocity profiles will be obtained across the steepest sections of the reach that are within the ZHI. Velocities will be measured as the main channel flow receeds in order to obtain the highest velocity that is likely to occur within the ZHI with no backwater effect from the main channel. All velocity measurements will target the conditions coincident of migratory timing of target species into the tributaries with modeled main channel flows that would occur under Project operation.

9.12.4.7. 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 is analyzed on a case-by-case basis.

For adult fish passage analyses at physical barriers, the primary factors that must be considered to determine probable passage success are as follows:

- Fish species and respective adult leaping criteria
- Adult migration timing of fish species
- Geometry of the physical barrier
- Estimate of flow range and hydraulics of the barrier present during adult migration timing
- Projected seasonal reservoir elevations (Upper River)

For passage analyses at depth barriers, the primary factors that must be considered to determine probable passage success are as follows:

- Fish species/life stage and respective depth/distance criteria
- Migration timing of fish species/life stage
- Longitudinal and cross-sectional geometry of the passage reach
- Mainstem breaching discharge
- Mainstem backwater discharge

The upper extent of tributary use by target species in the Upper River will be determined by the analysis of physical barriers in tributaries. The immediate effects of the proposed Project on depth passage in the Middle River, due to changes in river hydrology and hydraulics, will be analyzed based on the factors listed above.

Analyses and modeling will involve the integration of flow routing and water surface elevation results with site-specific topographic profile data. Two-dimensional model results from the Instream Flow Study (Section 8.5) will also be used to model depth and velocities in and at the exits of sloughs and side channels at Focus Areas.

Physical barriers will be analyzed on a case-by-case basis according to the methods described in Section 9.12.4.4, Physical Barriers subsection.

9.12.5. Consistency with Generally Accepted Scientific Practice

The study methods presented above are consistent with the study methods commonly followed in investigations of fish passage. These include, but are not limited to, ADF&G (1984b, c, and d), Powers and Orsborn (1984), Powers and Orsborn (1985), Reiser and Peacock (1985), Thompson (1972), URS and HDR (2010), and USFS (2001). Methods are specifically adapted from these and other well-known contemporary researchers in the science of fish passage, as cited in this study plan.

9.12.6. Schedule

This is a multi-year study. Baseline data collection of natural fish passage barriers in Susitna River tributaries between Devils Canyon and the Oshetna River was initiated in 2012. It is anticipated that the 2013–2014 study of Fish Passage Barriers in the Middle and Upper Susitna River and Susitna Tributaries will be completed according to the schedule shown in Table 9.12-5.

9.12.7. Relationship with Other Studies

The Fish Passage Barriers Study is interrelated with eight other Project licensing studies (Figure 9.12-1). This study will rely on data and analyses inputs from six studies conducted in 2012 and upcoming 2013–2014 studies.

The 2012 aquatic habitat and geomorphic mapping of the Middle River using aerial photography (Geomoprphology Study 6.0) will provide a comparison of the habitat mapping conducted in the 1980s with habitat mapping developed at similar discharges in 2012.

Aerial photography at the various flows ((Geomoprphology Study 6.0) will help inform the selection, characterization, and demarcation of Fish Barriers Study sites and help identify breaching flows and the backwater influence on fish passage at the selected passage study sites.

Aerial videography collected as part of the Characterization and Mapping of Aquatic Habitats (Section 9.9) will be used to locate possible physical barriers in sloughs, side channels, and tributaries.

The 2012 river flow routing model data collection study results will be used as needed to simulate various physical and biological processes. The close proximity of the proposed flow routing transect locations to the previous passage study sites (Table 9.12-2) will inform the assessment of the stability of passage conditions over time.

The 2012 Upper Susitna River Fish Distribution and Habitat Study (Section 9.5) will be identifying and characterizing potential fish barriers in tributaries between Devils Canyon and the Oshetna River. The first upstream salmon fish passage barrier encountered in tributaries below approximately 3,000 feet elevation, the highest elevation at which Chinook salmon have been documented, will be located, described, photographed, and measured. Results of the Fish Distribution and Abundance in the Upper River Study (Section 9.5) conducted in 2013–2014 will also be used to evaluate fish use of reaches with barriers.

The Instream Flow Study (Section 8.0) is focused on development of models that can reliably estimate flow-habitat response patterns for different species and life stages of fish and other aquatic biota. In addition, this study will model the effects of flow on passage conditions into and out of specific mainstem habitats. Results of the instream flow model will be integrally linked to the barrier analysis to provide complete coverage of existing and potential future depth barriers as well as to synthesize the relevance of passage condition changes to fish populations in the Middle and Lower Susitna River. Results of the reservoir operations model with scenarios of how Project operation may affect flow and stage level will be used as input to simulate how physical and biological processes may affect passage barriers. Results from the Geomorphology Study (Section 6.0), in particular the outputs from the two-dimensional model at Focus Areas, will be used to predict the potential for alteration of channel morphology that may result in creation of fish passage barriers.

The Fish Passage Barriers Study will provide useful output to two AEA Project studies. Analysis of the potential for creation or alteration of fish passage barriers under Project operations will inform the Instream Flow Study (Section 8.0) and the fish passage feasibility study (Section 9.11). The Fish Passage Barriers Study will synthesize the relevance of geomorphic passage condition changes to fish populations in the Middle and Lower Susitna River.

9.12.8. Level of Effort and Cost

The schedule, staffing, and costs will be detailed as the 2013–2014 Study Plan develops. Total study costs are estimated at $500,000.

9.12.9. Literature Cited

Aaserude, R. G. 1984. New concepts in fishway design. M.S. Thesis, Department of Civil and Environmental Engineering, Washington State University.

ADF&G (Alaska Department of Fish and Game). 1984a. Aquatic habitat and instream flow investigations (May–October, 1983). C.C. Estes and D.S. Vincent-Lang, eds. Chapters 1 - 9. Susitna Hydro Aquatic Studies, Alaska Deptartment of Fish and Game, Anchorage, AK. Report 3. Report for Alaska Power Authority.

— 1984b. Susitna Hydro Aquatic Studies, Report No.3: Aquatic habitat and instream flow investigations, May - October 1983 (Review Draft). Chapter 6: An evaluation of passage conditions for adult salmon in sloughs and side channels of the Middle Susitna River. Prepared for Alaska Power Authority, Anchorage, AK.

—. 1984c Susitna Hydro Aquatic Studies, Report No.3: Aquatic habitat and instream flow investigations, May - October 1983. Chapter 1: Stage and discharge investigations. Prepared for Alaska Power Authority, Anchorage, AK.

—. 1984d. Susitna Hydro Aquatic Studies, Report No.3: Aquatic habitat and instream flow investigations, May - October 1983. Chapter 2: Channel geometry investigations of the Susitna River Basin. Prepared for Alaska Power Authority, Anchorage, AK.

—. 1984e. Susitna Hydro Aquatic Studies, Report No.3: Aquatic habitat and instream flow investigations, May - October 1983 (Draft). Part II, Chapter 37: An evaluation of chum and sockeye salmon spawning habitat in sloughs and side channels of the middle Susitna River. Prepared for Alaska Power Authority, Anchorage, AK.

—. 1984f. Susitna Hydro Aquatic Studies Report, No.1: Adult anadromous fish investigations, May-October, 1983. Prepared for Alaska Power Authority, Anchorage, Alaska

AEA (Alaska Energy Authority). 2011. *Pre-application Document: Susitna-Watana Hydroelectric Project FERC Project No. 14241*. December 2011. Prepared for the Federal Energy Regulatory Commission, Washington DC.

Brown, J. Randy and Craig Fleener, 2001. *Beaver dam influence on fish distribution in lentic and lotic habitats in the Black River drainage, Alaska*.

FHWA (Federal Highway Administration). 2011. *Design for fish passage at roadway-stream crossings: synthesis Report.* http://www.fhwa.dot.gov/engineering/hydraulics/pubs/07033/2.cfm. Accessed on June 6, 2012.

Hetrick, Nicholas, J and Matthew J. Nemeth. 2003. *Survey of coho salmon runs on the Pacific coast of the Alaska Peninsula and Becharof National Wildlife Refuges, 1994 with estimates of escapement for two small streams in 1995 and 1996.* Annual Fisheries Technical Report Number 63. US Fish and Wildlife Service, King Salmon Fish and Wildlife Office, King Salmon, AK.

Kambietz, J. September 18, 2003. *Controlling Beavers*. The Pacific Streamkeepers Federation. http://www.pskf.ca/publications/beavers.htm. Accessed on June 7, 2012.

Maine Department of Transportation. 2008. Waterway and Wildlife Crossing Policy and Design Guide. 3rd Edition, July 2008.

Ministry of Environment, Lands and Parks, Vancouver Island Region. 2001. *Beaver Management Guidelines, Draft, Version 1*. British Columbia, Canada

Powers P. and John Orsborn. 1984. Analysis of barriers to upstream fish migration: An investigation of the physical and biological conditions affecting fish passage success at culverts and waterfalls. Albrook Hydraulic Laboratory, Department of Civil and Environmental Engineering, Washington State University. Project No. 82-14.

Powers, P. D., and J. F. Orsborn. 1985. Analysis of barriers to upstream fish migration, an investigation of the physical and biological conditions affecting fish passage success at culverts and waterfalls. Washington State University, Department of Civil Engineering, Albroook Hydraulics Lab, Pullman, WA.

Reiser, D. W. and R. Peacock. 1985. A technique for assessing upstream fish passage problems at small-scale hydropower developments. Pages 423–432 in F. Olson, R. White, and R. Hamre, editors. *Proceedings of the symposium on small hydropower and fisheries.* American Fisheries Society, Bethesda, Maryland.

Stuart, T. A. 1964. *The leaping behavior of salmon and trout at falls and obstructions*. Department of Agriculture and Fisheries for Scotland, Edinburgh.

Thompson, K. 1972. Determining stream flows for fish life. Presentation at the Pacific Northwest River Basin Commission Instream Flow Requirements Workshop, March 15-16, 1972.

URS and HDR. 2010. Assessment of fish migration at natural barriers in the upper Alameda Creek sub-watershed. A technical memorandum prepared for San Francisco Public Utilities Commission.

USFS (U.S. Forest Service). 2001. *Aquatic habitat management handbook*. U.S. Forest Service, R-10 FSH 2090.21.\, Juneau, Alaska.

Webb, P. W., 1975. Hydrodynamics and Energetics of Fish Propulsion Bulletin 190. Ottawa, Ontario.

9.12.10. Tables

Table 9.12-1. Co-location of 1984 aquatic studies pertinent to fish passage at sloughs and side channels.

Slough or Side Channel Name	River mile[1]	Study Name				
		Salmon Passage	Stage/Q	Channel Geometry	Instream Flow	Adult Salmon Use
Whiskers Creek Slough	101.2	X	X	X		X
Mainstem 2 Side Channel	114.5	X	X	X		X
Slough 8A	125.3	X	X	X	X	X
Slough 9	128.3	X	X	X	X	X
Slough 9A	133.2	X		X		X
Side Channel 10	133.8	X	X	X	X	X
Slough 11	135.3	X	X	X		X
Lower Side Channel 11	136.1				X	X
Upper Side Channel 11	136.2	X	X	X	X	X
Slough 20	140.1	X	X	X		X
Side Channel 21	140.6	X	X	X	X	X
Slough 21	141.8	X	X	X	X	X
Slough 22	144.2	X	X	X		X

Notes:

1. River mile is determined from the most downstream point of the study site
2. ADF&G 1984b
3. ADF&G 1984c
4. ADF&G 1984d
5. ADF&G 1984e
6. ADF&G 1984f

Table 9.12-2. Location of proposed 2012-13 flow routing transect relative to locations of 1984 slough and side channel study sites.

1980s Slough or Side Channel Name	River mile[1]	Salmon Passage Study	River mile[1] Location of Proposed 2012-13 Flow Routing Study Transect
Whiskers Creek Slough	101.2	Yes	101.52
Mainstem 2 Side Channel	114.5	Yes	114.0
Slough 8A	125.3	Yes	124.41/126.11
Slough 9	128.3	Yes	128.66
Slough 9A	133.2	Yes	133.33
Side Channel 10	133.8	Yes	133.3/134.28
Slough 11	135.3	Yes	135.36
Lower Side Channel 11	136.1		136.4
Upper Side Channel 11	136.2	Yes	136.4
Slough 20	140.1	Yes	140.15
Side Channel 21	140.6	Yes	140.83
Slough 21	141.8	Yes	141.49/142.13
Slough 22	144.2	Yes	143.18/144.83

Notes:

1 River miles –based on 1984 river mile index.

Table 9.12-3. Fish and potential fish species within the lower, middle, and upper Susitna River, based on sampling during the 1980s.

Common Name	Scientific Name	Life History	Passage Sensitive
Arctic grayling	*Thymallus arcticus*	Fresh water	X
Dolly Varden	*Salvelinus malma*	Fresh water/ Anadromous	X
Humpback whitefish	*Coregonus pidschian*	Fresh water/ Anadromous	X
Round whitefish	*Prosopium cylindraceum*	Fresh water	X
Burbot	*Lota lota*	Fresh water	X
Longnose sucker	*Catostomus catostomus*	Fresh water	X
Sculpin	*Cottid*	Fresh water/ Marine	--
Eulachon	*Thaleichthys pacificus*	Anadromous	--
Bering cisco	*Coregonus laurettae*	Fresh water/Anadromous	X
Threespine stickleback	*Gasterosteus aculeatus*	Anadromous/Fresh water	X
Arctic lamprey	*Lethenteron japonicum*	Anadromous/Fresh water	X
Chinook salmon	*Oncorhynchus tshawytscha*	Anadromous	X
Coho salmon	*Oncorhynchus kisutch*	Anadromous	X
Chum salmon	*Oncorhynchus keta*	Anadromous	X
Pink salmon	*Oncorhynchus gorbuscha*	Anadromous	X
Sockeye salmon	*Oncorhynchus nerka*	Anadromous	X
Rainbow trout	*Oncorhynchus mykiss*	Fresh water	X
Northern pike	*Esox lucius*	Fresh water	X

Table 9.12-4. Pacific salmon leaping height capabilities from three sources.

Species	Leaping Height (in feet)		
	Powers and Orsborn (1984)[1]	Reiser and Peacock (1985)	USFS (2001)
Chinook	7.5	7.9	11.0
Coho	7.5	7.3	11.0
Sockeye	7.5	6.9	10.0
Pink	3.5	4.0	4.0
Chum	3.5	4.0	4.0

Notes:

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 9.12-5. Schedule for implementation of the Fish Passage Barrier Study.

Activity	2013				2014			
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q
Study Site Selection	—	—	—					
Define Passage Criteria	—	—	—					
Data Collection		—	—					
Initial Study Report				—Δ				
Follow up Data Collection						—	—	
Copordination With Interdependent Studies	—	—	—	—	—	—	—	—
Updated Study Report							—	—▲

9.12.11. Figures

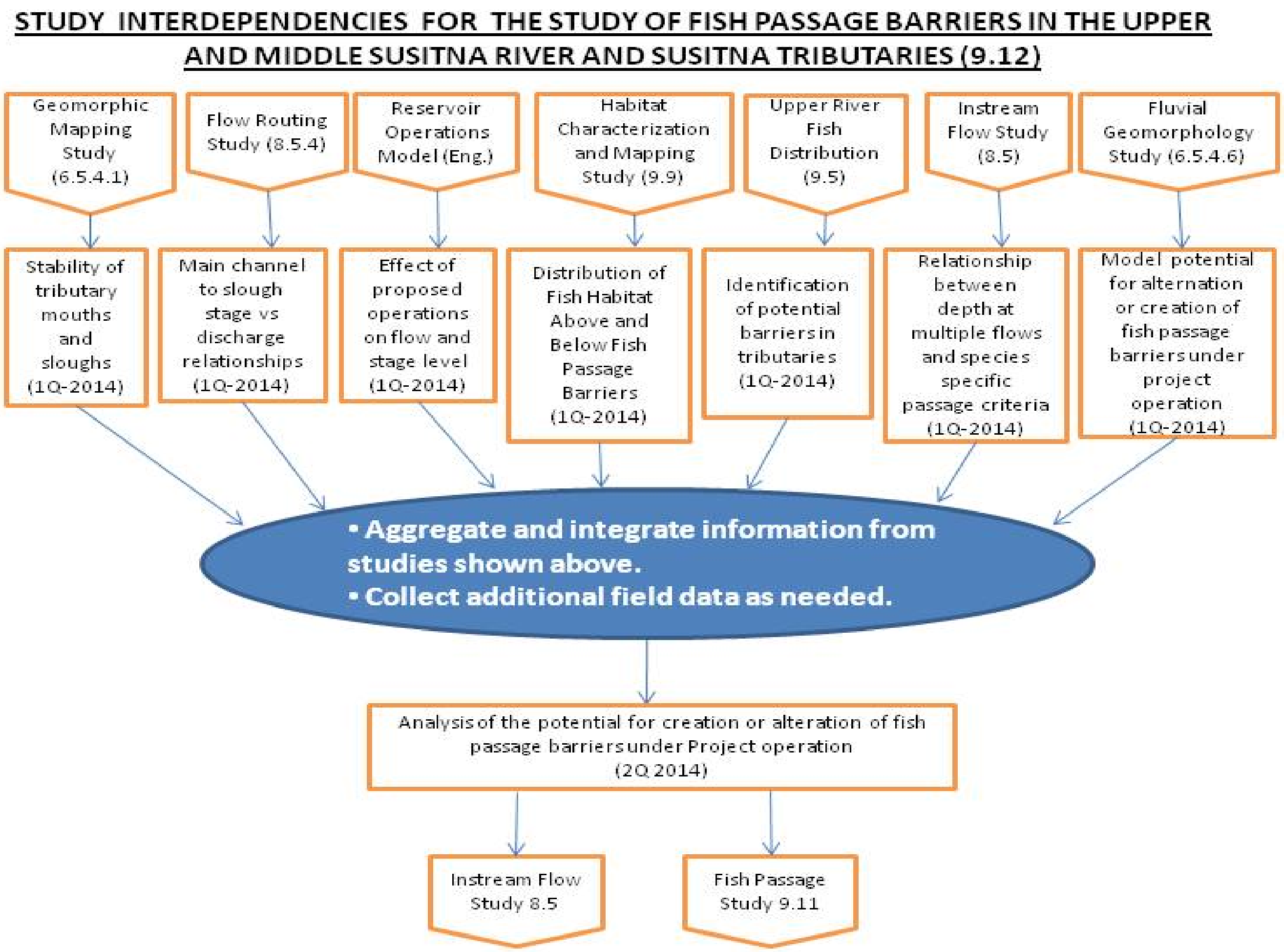


Figure 9.12-1. Study interdependencies for the Fish Passage Barriers Study.

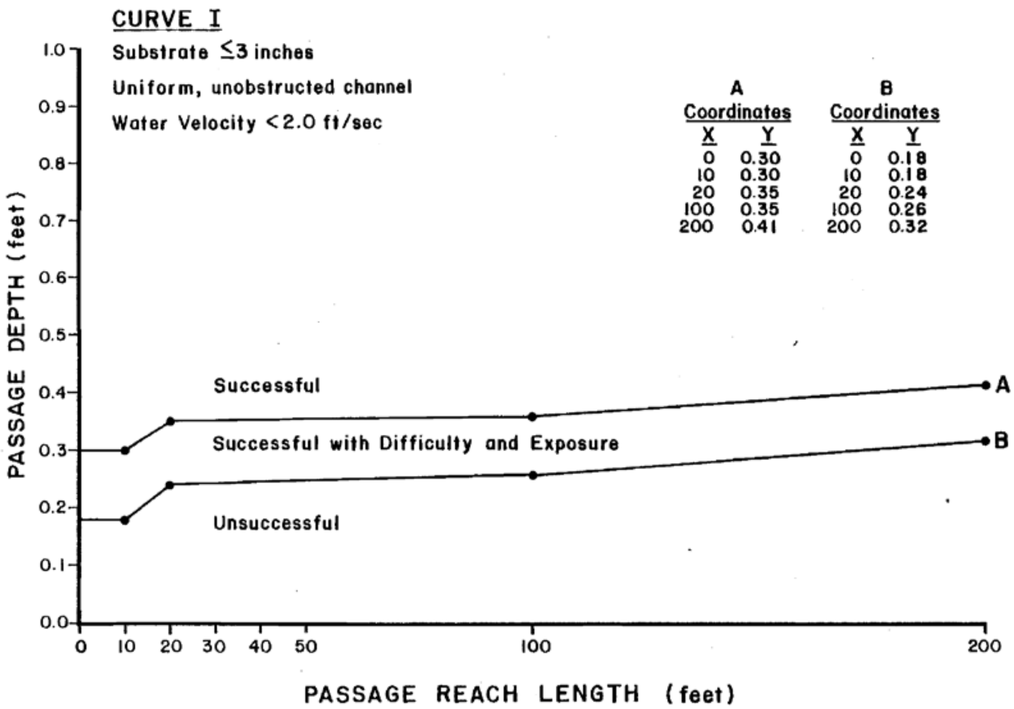


Figure 6-4. Passage depth requirements for chum salmon as a function of passage reach length within sloughs and side channels having substrates less than 3.0 inches in diameter, uniform morphology and water velocities less than 2.0 ft/sec.

Figure 9.12-2. Depth/distance passage criteria for chum salmon in unobstructed uniform channels with smaller substrates. Source ADF&G 1984d.

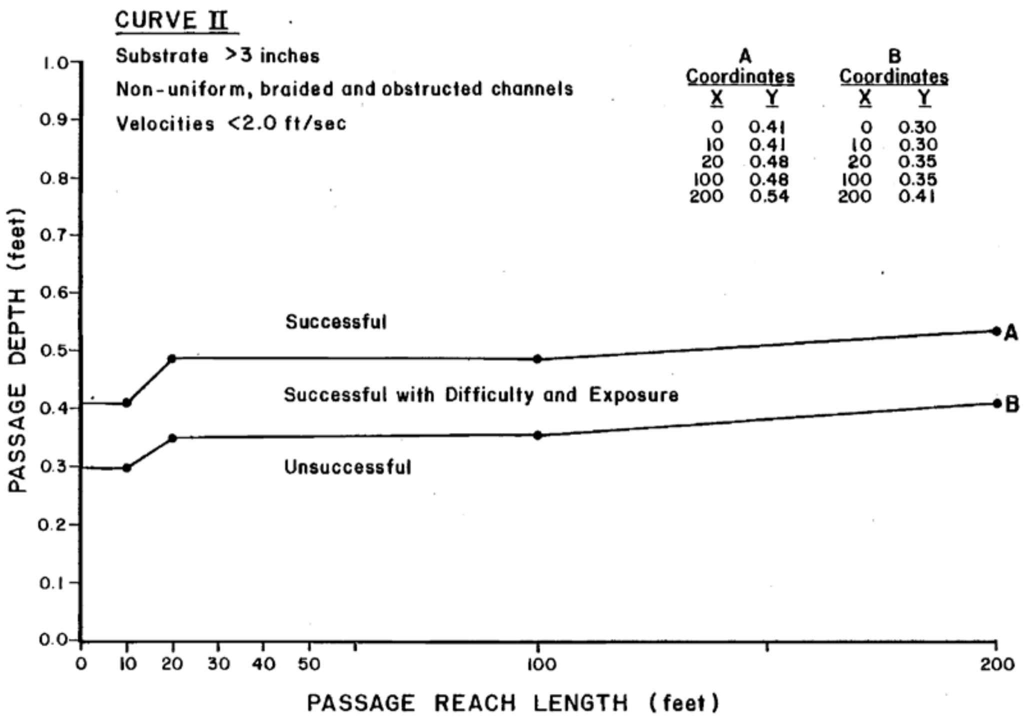
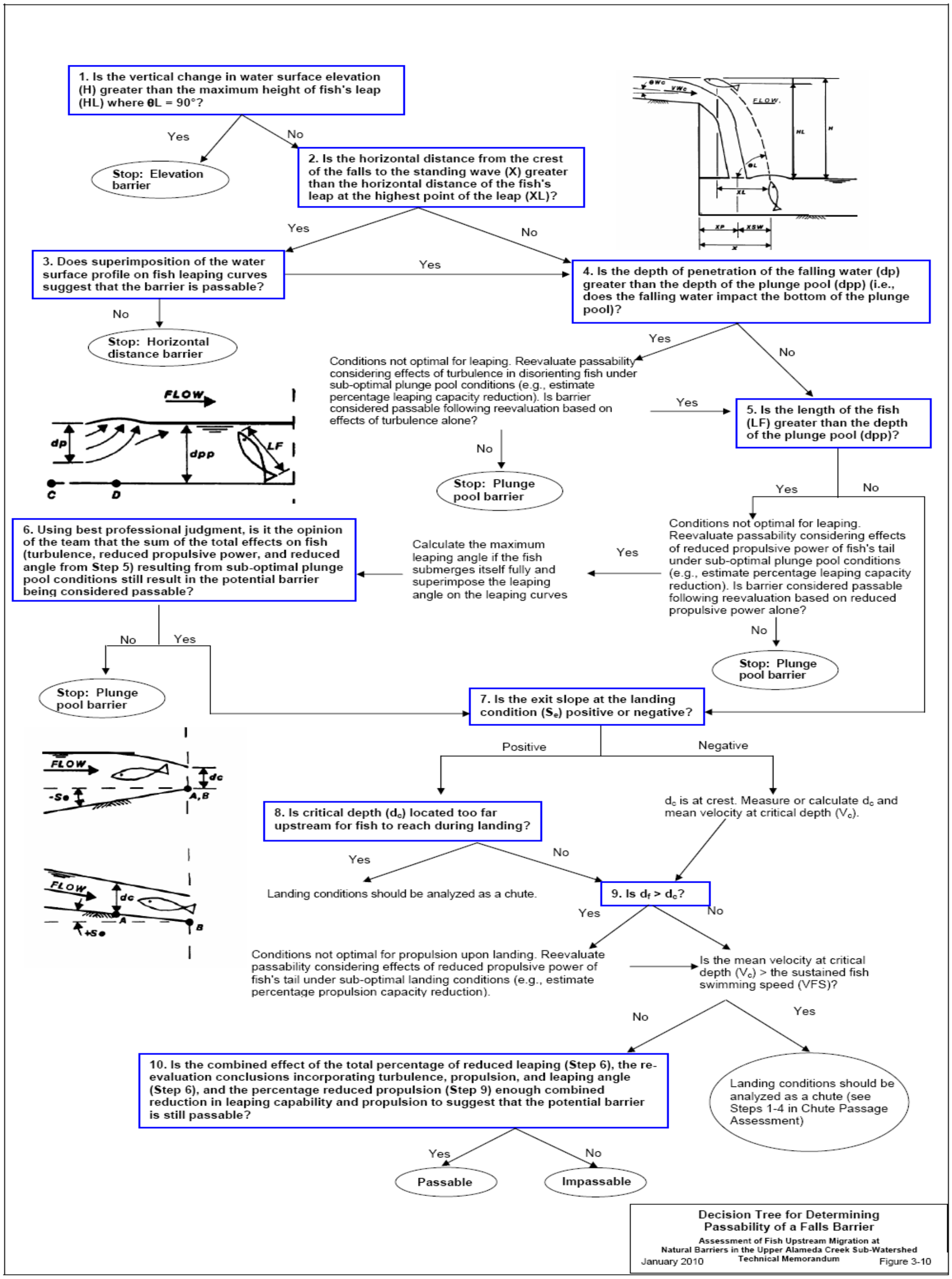


Figure 6-5. Passage depth requirements for chum salmon as a function of passage reach length within sloughs and side channels having substrates greater than 3.0 inches in diameter, non-uniform, braided and obstructed channels and velocities less than 2.0 ft/sec.

Figure 9.12-3. Depth/distance passage criteria for chum salmon in obstructed non-uniform channels with larger substrates. (ADF&G 1984b).



A = point on fish exit bed slope where critical depth occurs;
B = elevation of crest;
C = farthest point upstream on bed of plunge pool;
D = point just downstream of falling water (or standing wave) on bed of plunge pool;
dc = critical depth (point A)
dpp = depth in the plunge pool
dp = depth the falling water plunges
FH = fall height
H = change in water surface elevation
LF = length of fish
Se = fish exit slope
Sp = fish passage slope
X = horizontal distance from the crest (point B) to standing wave (point D)

Figure 9.12-4. Barrier analysis decision tree (URS and HDR 2010).

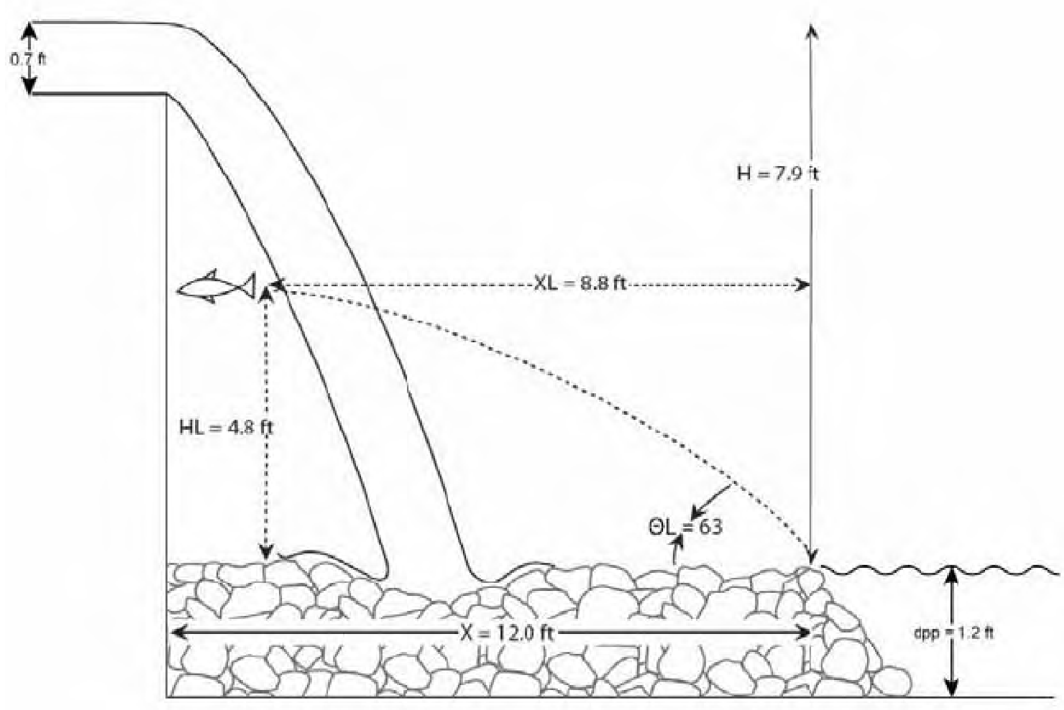


Figure 9.12-5. Example of barrier field drawing with measurement notation (URS and HDR 2010).

Physical Barrier Field Form		
Date:	Stream Name:	Reach Name:
Barrier Number: (numbered sequentially from mouth)	Barrier Location (UTM):	
Estimated Discharge:	Photo Numbers:	
Evaluation Species: Generic Fish		
Leap Height (LH) = 8 ft		
Leap Distance (LX) = 5 ft		
Fish Length (FL) = 2 ft		
Fish Body Depth (d_f) 8 in		
Fish Sustained Swim Speed (VFS) = 6 fps		
Observers:		
Passable/Impassable: Passable		

Decision Tree Step	Determination	Measurement or Judgment Basis for Determination
1	No	H = 5 feet
2	No	X = 4.5 feet
3	Skip	
4	No	dp = 3 ft and dpp = 1 ft
5	No	LF (2 ft) < dp (3 ft)
6	Skip	
7	Positive	Exit slopes up
8	No	d_c is within fishes horizontal leaping distance of 6 ft.
9	No	d_f (8 in)< d_c (12 in)
10	No	All factors suggest barrier is passage

Comments: All factors suggest barrier is passable by (species) at flows present on day of observation……other comments as needed.

Figure 9.12-6. Draft physical barrier field form.

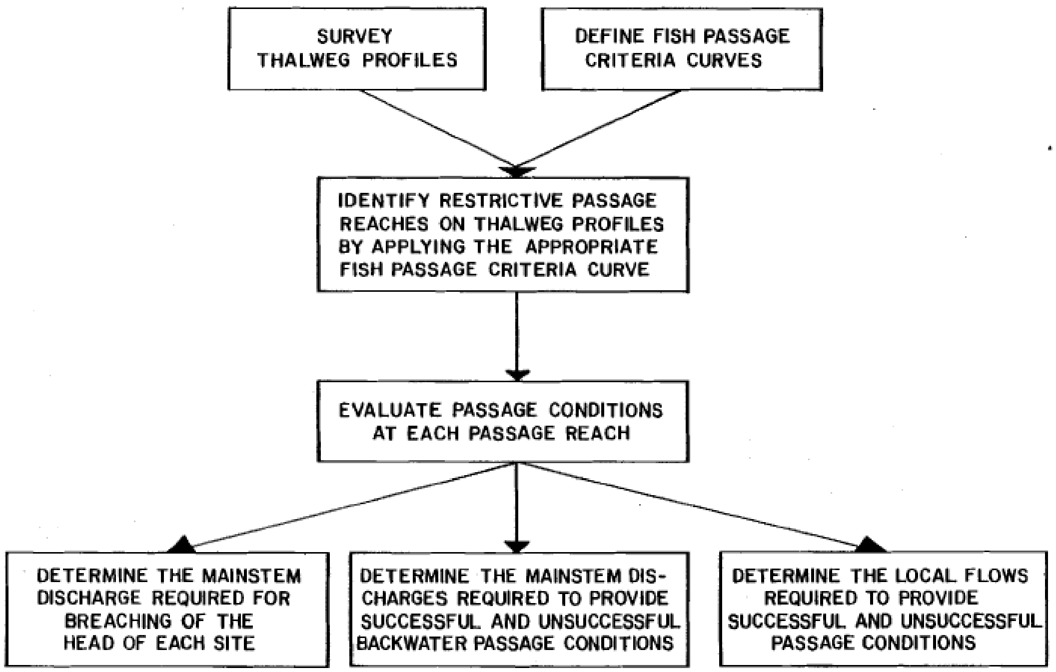


Figure 9.12-7. ADF&G (1984b) flow chart for slough and side channel assessment methods.

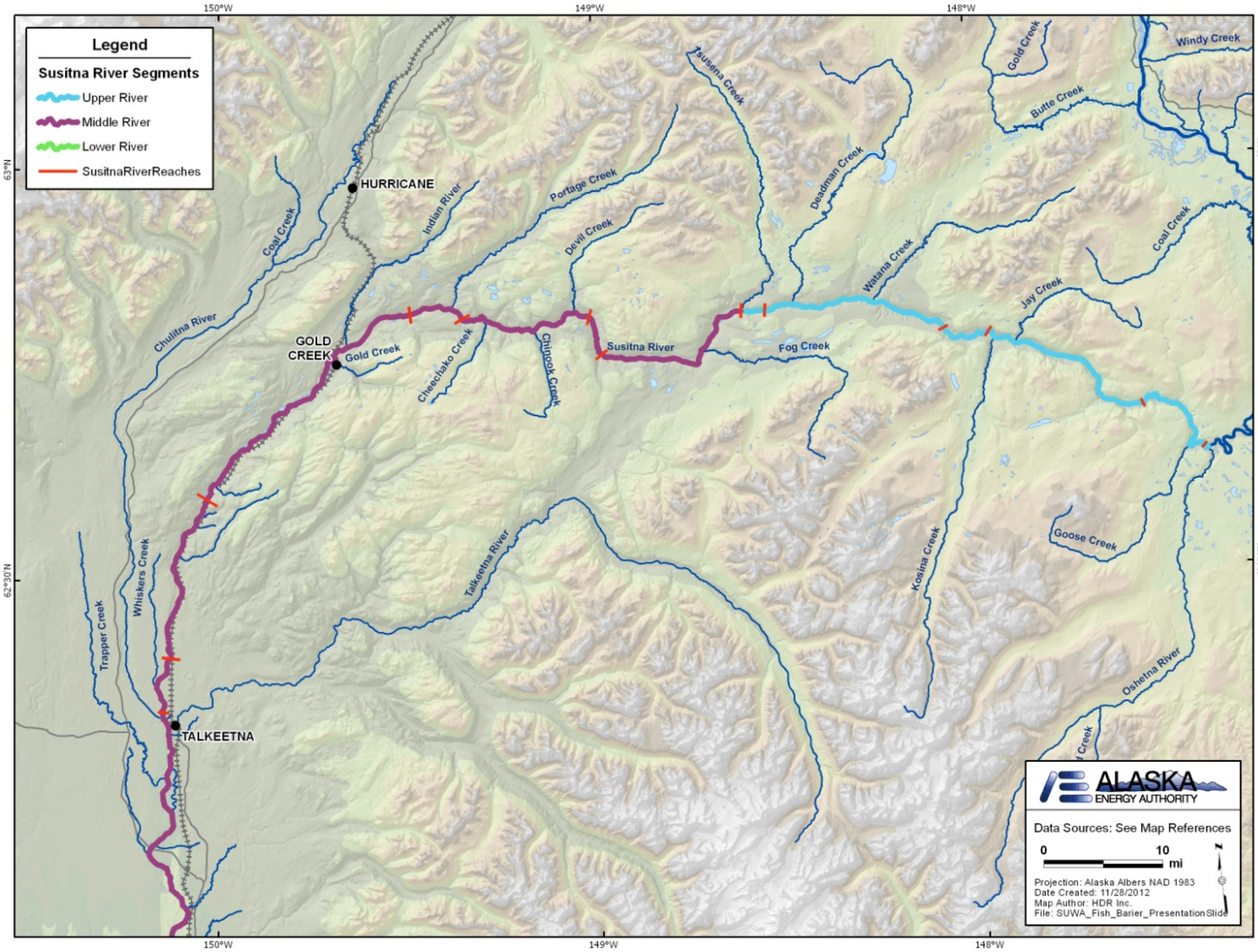


Figure 9.12-8. Study of Fish Passage Barriers in the Middle and Upper Susitna Basin.