Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Geomorphology Study
Study Plan Section 6.5

Final Study Plan

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

July 2013

6.5. Geomorphology Study

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 Geomorphology Study, Section 6.5. RSP Section 6.5 focuses on characterizing the geomorphology of the Susitna River and evaluating the effects of the Project on the geomorphology and dynamics of the river.

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. On April 1, 2013 FERC issued its study plan determination (April 1 SPD) for the remaining 14 studies; approving one study as filed and 13 with modifications. RSP Section 6.5 was the one study approved with no modifications in FERC's April 1 SPD. As such, in finalizing and issuancing Final Study Plan Section 6.5, AEA has made no modifications to to this study from its Revised Study Plan.

6.5.1. General Description of the Proposed Study

6.5.1.1. Study Goals and Objectives

The overall goal of the Geomorphology Study is to characterize the geomorphology of the Susitna River, and to evaluate the effects of the Project on the geomorphology and dynamics of the river by predicting the trend and magnitude of geomorphic response. This will inform the analysis of potential Project-induced impacts to aquatic habitats. The results of this study, along with results of the Fluvial Geomorphology Modeling below Susitna-Watana Dam Study, will be used in combination with geomorphic principles and criteria/thresholds defining probable channel forms to predict the potential for alteration of channel morphology from Project operation. This information will be used to assist in determining whether protection, mitigation, or enhancement measures may be needed, and if so, what those measures may be. More specific goals of the Geomorphology Study are as follows:

- Determine how the river system functions under existing conditions.
- Determine how the current system forms and maintains a range of aquatic and channel margin habitats.
- Identify the magnitudes of changes in the controlling variables and how these will affect existing channel morphology in the identified reaches downstream of the dam and in the areas upstream of the dam affected by the reservoir.
- In an integrated effort with the Fluvial Geomorphology Modeling Study (Section 6.6) determine the likely changes to existing habitats through time and space.

In order to achieve the study goals, the following objectives are required:

- Geomorphically characterize the Project-affected river channels and floodplain including:
    - Delineate the Susitna River into geomorphically similar reaches.
    - Characterize and map relic geomorphic forms from past glaciation and debris flow events.

  - Characterize and map the geology of the Susitna River, identifying controlling features to channel and floodplain geomorphology.
  - Identify and describe the primary geomorphic processes that create, influence, and maintain mapped geomorphic features.
- Collect sediment transport data to supplement historical data to support the characterization of Susitna River sediment supply and transport.
- Determine sediment supply and transport in Middle and Lower Susitna River Segments.
- Assess geomorphic stability/change Middle and Lower Susitna River Segments.
- Characterize the surface area versus flow relationships for riverine macrohabitat types (1980s main channel, side channel, side sloughs, upland sloughs, tributaries and tributary mouths) over a range of flows in the Middle Susitna River Segment.
- Conduct a reconnaissance-level geomorphic assessment of potential Project effects on the Lower and Middle Susitna River Segments considering Project-related changes to stream flow and sediment supply and a conceptual framework for geomorphic reach response.
- Conduct a phased characterization of the surface area versus flow relationships for riverine macrohabitat types in the Lower Susitna River Segment including:
  - Delineation of aquatic macrohabitat per 1980s definitions for selected sites.
  - Comparison of 1980s versus existing macrohabitat areas and selected sites.
  - Estimate potential change in macrohabitat areas base on initial estimates of change in stage from Project operations.
  - Optional – If Focus Areas are extended into the Lower Susitna River Segment, perform development of macrohabitat wetted area versus flow relationships for additional sites and flows.
- Characterize the proposed Watana Reservoir geomorphology and changes resulting from conversion of the channel/valley to a reservoir.
- Assess large woody debris transport and recruitment, their influence on geomorphic forms and, in conjunction with the Fluvial Geomorphology Modeling Study, effects related to the Project.
- Characterize geomorphic conditions at stream crossings along access road/transmission line alignments.
- Integration with the Fluvial Geomorphology Modeling Study to develop estimates of Project effects on the creation and maintenance of the geomorphic features that comprise important aquatic and riparian macrohabitats and other key habitat indicators, with particular focus on side channels, side sloughs, and upland sloughs.

6.5.2. Existing Information and Need for Additional Information

An analysis of the Middle Susitna River Segment geomorphology and how aquatic habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (Trihey & Associates 1985). The AEA Susitna Water Quality and

Sediment Transport Data Gap Analysis Report (URS 2011) states that "if additional information is collected, the existing information could provide a reference for evaluating temporal and spatial changes within the various reaches of the Susitna River." The gap analysis emphasizes that it is important to determine if the conditions represented by the data collected in the 1980s are still representative of current conditions and that at least a baseline comparison of current and 1980s-era morphological characteristics in each of the identified sub-reaches is required.

An analysis of the lower Susitna River Segment and how riverine habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (R&M Consultants, Inc. and Trihey & Associates 1985a). This study evaluated the response of riverine aquatic habitat to flows in the Lower Susitna River Segment between the Yentna River confluence (river mile [RM] 28.5) and Talkeetna (RM 98) (measured at Sunshine gage near RM 84) ranging from 13,900 cfs to 75,200 cfs. The study also included an evaluation of the morphologic stability of islands and side channels by comparing aerial photography between 1951 and 1983. As with the Middle Susitna River Segment information, it is important to determine if the conditions represented by the 1980s data are representative of current conditions. Such a comparison should include not only an identification of change, but should consider if the relative proportions of the various mesohabitat types have remained constant within a reach. If the relative proportions of the various mesohabitat types have remained constant in the various reaches, it provides a reasonable basis for using the 1980s data.

Considerable information is available from a variety of sources that will support the development and execution of the Geomorphology Study. Much of the available information is from the 1980s studies associated with the earlier efforts to develop the Susitna Hydroelectric Project (FERC No. 7114). In some cases, the older information will need to be replaced or supplemented with newer information because the Susitna River is a dynamic system and historical data such as cross-sections and aerial images in many areas will likely have changed considerably since they were collected in the 1980s. However, when compared with current information, these data provide valuable tools to understand the behavior and physical processes driving the geomorphology of the Susitna River. Comparability of the two sets of data will indicate that the fundamental relationships between channel form and fluvial process have remained constant and thus provide a basis for using the historical data. Additional data and analyses are needed to determine if historical data can be used to reflect current conditions and to address some of the data gaps identified in the AEA Susitna Water Quality and Sediment Transport Data Gaps Analysis Report (URS 2011). A more specific description of existing information and the need for additional information for each geomorphology study component are provided in the appropriate sections below.

6.5.3. Study Area

The study area for the Geomorphology Study is the Susitna River from its confluence with the Maclaren River (RM 260) downstream to the mouth at Cook Inlet (RM 0). The study area has been divided into three large-scale river segments:

- Upper Susitna River Segment: Maclaren River confluence (RM 260) downstream to the proposed Watana Dam site (RM 184).
- Middle Susitna River Segment: Proposed Watana Dam site (RM 184) downstream to the Three Rivers Confluence (RM 98).

- Lower Susitna River Segment: Three Rivers Confluence (RM 98) downstream to Cook Inlet (RM 0).

Each of the 11 study components that make up the Geomorphology Study has a component-specific study area often related to the three large-scale river segments identified above. The study area and river segments are shown on Figure 6.5-1. Identification of the study area that each study component addresses is provided in the discussion of each study component in Section 6.5.4, Study Methods.

6.5.4. Study Methods

The methods for each of the 11 Geomorphology Study components are presented in this section.

6.5.4.1. Study Component: Delineate Geomorphically Similar (Homogeneous) Reaches and Characterize the Geomorphology of the Susitna River

The goal of this study component is to geomorphically characterize the Project-affected river channels including determination of geomorphically similar reaches. Portions of this effort were performed in 2012 including development of the geomorphic classification system and initial delineation of geomorphic reaches. The study area is the length of the Susitna River from its mouth at Cook Inlet (RM 0), upstream to the proposed Watana Dam site (RM 184), and upstream of the proposed Watana Dam site, including the reservoir inundation zone and on upstream to the Maclaren River confluence (RM 260). The tributary mouths along the Susitna River and in the reservoir inundation zone that may be affected by the Project are also included in the study area.

One of the major factors that is relevant to the geomorphic characterization and subsequent classification of the Susitna River and the potential for the Project to affect geomorphology, and hence habitat, is changes in the volume of sediment in storage within discrete types of storage units, that can generally be separated into mid-channel and bank-attached units. Storage of sediment for varying durations within discreet types of storage zones is an integral part of any fluvial system (Schumm 1977; Montgomery and Buffington 1993). The types of sediment storage units and the rates of change within the storage zones provide a measure of the sediment flux within the system (Harvey et al. 2003; Harvey and Trabant 2006). Order-of-magnitude changes in sediment storage within a given reach of the river, or for the river as a whole, as well as the rates of change in the various types of sediment storage zones can be assessed by GIS-based comparisons of time-sequential aerial photography. Suitable aerial photography appears to be available for the 1950s, 1980s, and the present (2012).

On the Susitna River, the end members of a continuum could include long-duration sediment storage in vegetated islands and floodplains that persist for multiple decades at one end and short-duration sediment storage in braid bars that change on an almost daily basis at the other end of the continuum. Sediment storage is directly incorporated into the preliminary geomorphic classification developed for the Susitna River (Section 6.5.4.1.2.2.1). Within single channel (SC) reaches, sediment storage zones include unvegetated mid-channel bars, vegetated islands, and discontinuous and continuous vegetated floodplain segments. Within multiple channel (MC) reaches, sediment storage zones include unvegetated braid bars, vegetated islands, and floodplains.

6.5.4.1.1. Existing Information and Need for Additional Information

This effort will support the understanding of the conditions in the Susitna River by applying a geomorphic classification system based on form and process. It will also support efforts by other studies, including the Fish and Aquatics Instream Flow (Section 8.5), Riparian Instream Flow (Section 8.6), Characterization and Mapping of Aquatic Habitats (Section 9.9), and Ice Processes (Section 7.6) studies by providing a basis to stratify the river into reaches based on current morphology and their potential sensitivity to the Project. A delineation of the Susitna River into reaches was performed in the 1980s for the Middle Susitna River Segment (Trihey & Associates 1985) and the Lower Susitna River Segment(R&M Consultants, Inc. and Trihey & Associates 1985a).

6.5.4.1.2. Methods

This effort consists of identification of a geomorphic classification system, conducting the delineation of geomorphic reaches based on the identified classification system and characterization of the geomorphology of the Susitna River.

6.5.4.1.2.1. Identification and Development of Geomorphic Classification System

The first step in the geomorphic reach delineation effort is the identification of the system to be used to classify and delineate the reaches. Classification of the river segments is required to provide a basis for communication among the various disciplines and to identify relatively homogeneous river segments that can then be used as a basis for extrapolation of results and findings from more spatially-limited studies. Numerous river classifications exist (Leopold and Wolman 1957; Schumm 1963, 1968; Mollard 1973; Kellerhals et al. 1976; Brice 1981; Mosley 1987; Rosgen 1994, 1996; Thorne 1997; Montgomery and Buffington 1997; Vandenberghe 2001), but no single classification has been developed that meets the needs of all investigators. Several factors have prevented the achievement of an ideal geomorphic stream classification, and foremost among these has been the variability and complexity of rivers and streams (Mosley 1987; Juracek and Fitzpatrick 2003). Problems associated with the use of existing morphology as a basis for extrapolation (Schumm 1991) further complicates the ability to develop a robust classification (Juracek and Fitzpatrick 2003). For purposes of classifying the Susitna River, available classification systems are being reviewed, and a specific system is being developed that borrows elements from several classification systems. The classification scheme considers both form and process. Development of this system is being coordinated with the Fish and Aquatics Instream Flow Study (FA-IFS) (Section 8.5, Riparian Instream Flow Study (R-IFS) (Section 8.56, Ice Processes (Section 7.6), and Characterization and mapping of Aquatic Habitats (Section 9.9) so it is consistent with their needs. These studies may require further stratification to identify specific conditions of importance to their efforts, in which case these studies will further divide the river into subreaches. However, the overall reach delineations developed in the Geomorphology Study will be used consistently across all studies requiring geomorphic reach delineations.

6.5.4.1.2.2. Geomorphic Reach Delineation

The Lower Susitna River Segment (RM 0 to RM 98), the Middle Susitna River Segment (RM 98 to RM 184), and the Upper Susitna River Segment to the Maclaren River confluence (RM 184 to

RM 260) will be delineated into large-scale geomorphic reaches (a few to many miles) with relatively homogeneous characteristics, including channel width, entrenchment, ratio, sinuosity, slope, geology/bed material, single/multiple channel, braiding index, and hydrology (inflow from major tributaries) for the purpose of stratifying the river into study segments. Stratification of the river into relatively homogeneous reaches will permit extrapolation of the results of sampled data at representative sites within the individual reaches.

Because there are several studies that required reach delineation for planning 2012 field activities, an initial delineation primarily based on readily available information (most recent high-quality aerials, bed profile from the 1980s, geomorphic descriptions from the 1980s, and geologic mapping) was developed in April 2012. As additional information is developed, such as current aerial photographs and transects, the delineation will be refined and the various morphometric parameters will be included in the delineation. Coordination with the Mainstem (Open-water) Flow Routing Model (Section 8.5.4.3) Study is being conducted to obtain cross-section channel/floodplain data. Coordination with the Fish and Aquatics Instream Flow Study (FA-IFS)(Section 8.5), Riparian Instream Flow Study (R-IFS)(Section 8.6), Fluvial Geomorphic Modeling Study, and Ice Processes in the Susitna River Study (Ice Processes Study) (Section 7.6) is being conducted to ensure that the river stratification is performed at a scale appropriate for those studies.

A reconnaissance-level site visit of the Susitna River was conducted for a portion of the Susitna River in October, 2012. A more complete reconnaissance will be conducted in early 2013 after break-up. The 2012 reconnaissance was coordinated with other studies to provide an opportunity for multidisciplinary interaction. Representatives from the Fish and Aquatics Instream Flow Study (Section 8.5), Riparian Instream Flow Study (Section 8.6), Riparian Vegetation Study Downstream of Susitna-Watana Dam Study (Section 11.6) and Groundwater Study (Section 7.5) participated in the 2012 reconnaissance. The 2013 reconnaissance will take a similar multidisciplinary approach. For the 2013 reconnaissance it is anticipated that the Geomorphology Study team will be joined by representatives from the FA-IFS (Section 8.5), R-IFS (Section 8.6), Ice Processes Study (Section 7.6), and Characterization and Mapping of Aquatic Habitats Study (Section 9.9). The purpose of this site visit will be to provide key team members an overview of the river system. This will be extremely useful for all components of the geomorphology studies because it will permit team members to verify on the ground assessments that have been made from remotely sensed information.

6.5.4.1.2.2.1. Initial Geomorphic Reach Classification System

Classification of the identified Upper, Middle and Lower Susitna River Segments into reasonably homogeneous reaches is required to provide a basis for extrapolation of the results of process-based analyses of existing conditions and predictions of likely geomorphic changes in response to the Project at selected study locations to those reaches. To support development of study plans for a variety of resource areas, an initial reach classification was performed with the information available in 2012. This classification will be reviewed and updated in 2013 if necessary as new information from the Geomorphology Study and Fluvial Geomorphology Modeling Study, as well as several other studies, becomes available. The initial geomorphic reach classification scheme is described below.

From a practical viewpoint, Schumm (2005) has suggested that rivers and streams can be divided into two principal types: regime and non-regime. Regime channels, which are defined as those that flow on and in sediments transported by the river during the present hydrologic regime, and whose morphology is controlled primarily by the interactions of the flow regime and the sediment supply (Leopold et al. 1964; Schumm 1977), can be further subdivided on the basis of patterns (straight, meandering, wandering, braided, anastomosing). Non-regime channels can be further subdivided into constrained, where the form of the channel is forced by non-alluvial factors such as bedrock, colluvium, glacial deposits or extreme flood deposits (Montgomery and Buffington 1997; Tinker and Wohl 1998; O'Connor and Grant 2003), or unstable, which can include degrading (Schumm et al. 1984; Darby and Simon 1999), aggrading (Schumm 1977) or avulsing (Schumm et al. 2000) channels.

Based on Schumm's (2005) classification scheme, the factors used in the initial geomorphic classification of the individual reaches of the Susitna River include the following:

1. Channel planform (single channel: straight, meandering; multiple channels: braided, anastomosing) – identified from topographic mapping, aerial photography
2. Constraints (bedrock, colluvium, moraines, alluvial fans, glaciolacustrine and glaciofluvial sediments) – identified from geologic mapping
3. Confinement (width of the floodplain and modern alluvium in relation to the width of the active channel(s)) – identified from geologic mapping, Light Detection and Ranging (LiDAR) based topography, hydraulic modeling
4. Gradient and bed materials – derived from various sources of survey data, 1980s data

Based on available information, the individual reaches within the three river segments were classified as follows:

Single Channel (SC):
SC1– Laterally confined with no sediment storage in bars, islands, or floodplain
SC2 – Laterally confined with limited sediment storage in mid-channel bars and non-continuous bank-attached floodplain segments
SC3 – Laterally confined with sediment storage in mid-channel bars, vegetated islands, and continuous floodplain segments

Multiple Channels (MC):
MC1 – Moderately wide floodplain with significant sediment storage in braid bars and vegetated islands
MC2 – Wide floodplain with significant sediment storage in braid bars and vegetated islands
MC3 – Wide floodplain width with vegetated floodplain segments separated by anastomosed channels with downstream base level controls
MC4 – Delta distributary channels

6.5.4.1.2.2.2. Initial Geomorphic Delineation

Application of the classification scheme described above to the three river segments of the study area resulted in the geomorphic reaches and reach types presented in Table 6.5-1. Maps showing the geomorphic reaches are presented on Figure 6.5-2, 6.5-3, and 6.5-4 for the Upper, Middle, and Lower Susitna River segments, respectively. The Upper Susitna River Segment was divided into six reaches, with three reaches identified as SC1 reach type and three geomorphic reaches identified as SC2 reach type. The Middle Susitna River Segment was divided into eight reaches with one geomorphic reach classified as SC1 (Devils Canyon), five as SC2, one as SC3, and one as MC1/SC2 geomorphic reach types. The latter designation represents the fact that the downstream most geomorphic reach of the Middle Susitna River Segment, MR-8, is a transition reach from a single channel to multiple channel. The Lower Susitna River Segment was divided into six reaches with the upper two reaches classified as MC1, the next two reaches classified as MC3, the fifth reach classified as SC2, and the downstream-most reach classified as MC4.

It should be kept in mind that as more information becomes available, the geomorphic reach delineations and classifications will be reevaluated and adjusted if necessary.

6.5.4.1.2.3. Geomorphic Characterization of the Susitna River

Based on information collected and developed in support of the reach delineation (Section 6.5.4.1.2.1), mapping of current and historical (1980s and 1950s) fluvial geomorphic features (Section 6.5.4.4) and as part of the field studies conducted in the Fluvial Geomorphology Modeling Study (Section 6.6.4.1.2.9), the geomorphology of the Middle and Lower Susitna River Segments will be characterized. The characterization will be directed toward identifying processes and controls that create, influence and maintain the fluvial geomorphic features that comprise the river and floodplain and represent the important aquatic habitats that may be affected by the Project. The role of large woody debris, ice processes, floodplain vegetation and extreme events as well as the more typical hydrologic events and sediment loading will be considered in development of the understanding of the processes that create and influence the geomorphic features of the Susitna River. Of particular importance will be the features that represent both the within-channel (bars, islands, side channels) and the off-channel macrohabitats (side channels, side sloughs and upland sloughs) and the meso- and micro-scale habitats within these features.

Using the available geologic mapping, topographic mapping, recent (2012) and historical (1980s and 1950s) aerial photographs and the 2011 Mat-Su LiDAR in conjunction with fieldwork conducted in 2013 during the Focus Area fieldwork the following will be mapped and characterized:

- Geology of the Susitna River corridor with identification of controlling features such as locations where the river is laterally confined or vertically controlled
- Relic geomorphic forms from past glaciation, paleofloods and debris flow events with particular attention paid to coarse grained deposits that can serve as lateral or vertical controls
- Identify from aerials and aerial reconnaissance major locations of recent and historic mass wasting
- Overlay the mapping of areas of frequent ice jam events from the Ice Processes Study (Section 7.6)
- Identification of coarse deposits at tributary confluences that may influence the profile of the Susitna River

Using this information as well as thalweg profiles generated from the cross-section and bathymetric surveys performed in 2012 and 2013, aerial photo analysis of channel change from the 1950s to 2012, bed material sampling, floodplain soil profiles, LWD mapping and characterization, dating of floodplain surfaces, an understanding of the fluvial processes that govern the behavior of the Middle and Lower Susitna River will be developed. This understanding will be reviewed and updated as various study results are made available. This would include information such as determination of flows required for bed material mobilization, effective discharge, comparison of 1980s and current cross-section profiles, sediment balance, and 1-D bed evolution modeling, This will provide a basis for developing a thorough understanding of the current river system dynamics and thus the framework for interpreting potential Project effects which will be derived from the results of modeling and other analyses that reflect the changes in the hydrologic and sediment supply regimes due to construction and operation of the Project.

6.5.4.1.2.4. Information Required

The following available existing information will be needed to conduct this study:

- Historical aerial photographs
- Information on bed material size
- Location and extent of lateral and vertical geologic controls
- Drainage areas of major tributaries
- Topographic mapping, including USGS survey quadrangle maps and LiDAR
- Geologic mapping
- 1980s cross-sections

The following additional information will need to be obtained to conduct this study:

- Current high resolution aerial photography
- Field observations made during a site reconnaissance
- Extended flow record for the Susitna River and tributaries being developed by USGS
- Current cross-sections
- Profile of the river (thalweg or water surface)
- Field data collected in the Fluvial Modeling Geomorphology Study

6.5.4.1.3. Study Products

The results of the Delineate Geomorphically Similar Reaches study component will be included in the Geomorphology Report. Information provided will include the following:

- A geomorphic classification system developed specifically for the Susitna River that considers both form and physical processes.

- A delineation of the Susitna River into reaches of similar geomorphic characteristics, which has been coordinated with other relevant studies (FA-IFS (Section 8.5), R-IFS (Section 8.6), Ice Processes (Section 7.6), and Characterization and Mapping of Habitat (Section 9.9) studies). The delineation will include broad large-scale reaches and further delineation into sub-reaches.
- Tables of morphometric parameters describing the physical characteristics of each reach developed from the analysis of aerial photographs, LiDAR, bed profiles, bed material samples, geologic mapping, and transect surveys.

In addition, an ArcGIS shapefile will be provided with the following information:

- Mapping of the segments and reaches overlaid on recent aerial photography and topographic mapping.

6.5.4.2. Study Component: Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations on the Susitna River, Chulitna River near Talkeetna and the Talkeetna River near Talkeetna

The goal of this study component is to empirically characterize the Susitna River sediment supply and transport conditions. This effort is being performed by USGS. The effort described is for 2012 and 2013. The effort in 2013 may be modified in 2013 based on experience gained from the 2012 work. The study covers the Susitna River from RM 84 (Sunshine Station) upstream to RM 182 (Tsusena Gage) and the Chulitna River and Talkeetna Rivers near their confluences with the Susitna River. Figure 6.5-5 identifies the location of the study gages and other existing and historical USGS gages in the Susitna River basin. The collection of the sediment transport data was completed in 2012 per the 2012 study plan. The data will be available from the USGS in early 2013. The Talkeetna River near Talkeetna was added for 2013 after review of 1980s data and after comments from agency review of the PSP. Suspended sediment and flow were collected at the Talkeetna by the USGS as part of the USGS National monitoring network.

6.5.4.2.1. Existing Information and Need for Additional Information

The collection of the data described in this study component will supplement sediment transport data collected in the 1980s. The additional data are needed to determine if historical data can be used to reflect current conditions or if there have been shifts in the rating curves that might be related to climate change, glacial surges, or other as yet unidentified causes and to address some of the data gaps identified in the Susitna Water Quality and Sediment Transport Data Gaps Analysis Report (URS 2011).

The USGS published a summary report on sediment transport data collected in the 1980s (USGS 1987). The data collected includes suspended sediment measurements and bedload measurements for the Susitna River near Talkeetna, Susitna River at Sunshine, Susitna River at Susitna Station, Chulitna River near Talkeetna, Talkeetna River near Talkeetna, and Yentna River near Susitna Station. The suspended load is divided into a silt/clay component and a sand component. The bedload transport is divided into two fractions: sand and gravel. The report also presents rating curves developed from data collected between 1981 through 1985. The

USGS estimated the annual sediment load for Water Year 1985 for the various components of the sediment load by applying the rating curves to the mean daily flow record.

Table 6.5-2 presents the sediment loads estimated by the USGS for Water Year 1985 (October 1984 through September 1985). This information suggests that the Chulitna River contributes the majority of the sediment load at the Three Rivers Confluence. The relative contributions are 61 percent for the Chulitna River, 25 percent for the Susitna River, and 14 percent for the Talkeetna River. Of note is the relatively small amount of the gravel load contributed by the Susitna River to the Three Rivers Confluence (about 4 percent, compared to 83 percent from the Chulitna River and 13 percent from the Talkeetna River, based on the 1985 data).

This study will provide information on current transport conditions and support assessment of Project effects on sediment supply. Sediment data derived from the gages will be used to provide sediment inputs at model boundaries. This information will be used by several study components in this study as well as the Fluvial Geomorphology Modeling below Watana Dam Study.

6.5.4.2.2. Methods

The following scope of work was provided by USGS:

- Operate and maintain the stream gages.
- Maintain datum at the site.
- Record stage data every 15 minutes.
- Make discharge measurements during visits to maintain the stage-discharge rating curve and to define the winter hydrograph.
- Store the data in USGS databases.
- Collect at least five suspended sediment samples at Susitna River above Tsusena Creek, at Gold Creek, and at Sunshine; the Chulitna River near Talkeetna and the Talkeetna River near Talkeetna during the year for concentration and size analysis (collect in 2012 and 2013).
- Collect at least five bed material samples during the year at Susitna River above Tsusena Creek, at Gold Creek, and at Sunshine; and the Chulitna River near Talkeetna for bedload transport determination and size analysis (collect in 2012 and 2013, except Talkeetna River near Talkeetna will be collected in 2013 only).
- Collect at least five bedload samples during the year at Susitna River at Gold Creek, Susitna River at Sunshine, Susitna River above Tsusena Creek, and the Chulitna River near Talkeetna for bedload transport determination and size analysis (collect in 2012 and 2013, except Talkeetna River near Talkeetna will be collected in 2013 only).
- Operate and maintain the stream gages at the Susitna River near Denali and the Chulitna River near Talkeetna (2012 and 2013).
- Operate a stage-only gage at a site upstream from Deadman Creek. Logistics at this site may preclude continuous operation or telemetry of the information (2012 and 2013).

- Compile suspended and bedload data, including calculation of sediment transport ratings and daily loads, in a technical memorandum delivered to AEA during federal fiscal year (FFY) 2013 for the 2012 data and FFY 2014 for the 2013 data, and as early as March of the following year, if possible. Provisional results from sampling will be available as soon as lab data are available. Provisional results from sediment load computations will be made available as soon as possible.

The bedload and suspended sediment data will be combined with existing rating curves to identify the differences and similarities between the historical and current data sets. This information will be used to evaluate whether the historical data sets are representative of current conditions in the Susitna River at Gold Creek, the Susitna River at Sunshine, the Chulitna River near Talkeetna and the Talkeetna River near Talkeetna. If the historical data are not representative of current conditions, a decision will be made as to whether the 1980s data may be adjusted or shifted to represent current conditions or whether only the current data should be used in developing sediment transport relationships.

Based on review of the 1980s sediment transport data, including the information previously presented in Table 6.5-2, the Talkeetna River is a significant source of sediment to the Lower Susitna River Segment. Therefore, collection of sediment transport data for the Talkeetna River near Talkeetna will be conducted in 2013. This will allow for better understanding of the sediment transport balance in Geomorphic Reach LR-1 (the portion of the Susitna River between the Three Rivers Confluence and Sunshine Station).

6.5.4.2.3. Study Products

The results of the Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations on the Susitna River, and Chulitna River near Talkeetna and the Talkeetna River near Talkeetna and Sunshine gage stations study component will be included in the Geomorphology Report. Information provided will include the following:

- Calculation of discharge, suspended sediment discharge, and bedload discharge.
- Tabulation of all discharge, suspended sediment, bedload, and bed material sampling results.
- Data sheets reflecting field measurements.
- Comparison of historical and 2012 sediment transport measurements to determine if historical sediment transport rating curves can be expected to accurately represent current conditions.
- Narrative on data collection activities including description of methods, any difficulties encountered, and recommendations for data collection in 2013.
- Posting of near real-time stage and discharge data on the USGS website: http://waterdata.usgs.gov/ak/nwis/.
- Publication of the data in the USGS annual Water-Resources Data for the United States report (http://wdr.water.usgs.gov/).

In addition, an ArcGIS shapefile will be provided with the following information:

- Location of gage stations and measurement transects (if different from gage location).

6.5.4.3. Study Component: Sediment Supply and Transport Middle and Lower Susitna River Segments

The objective of this study component is to characterize the sediment supply and transport conditions in the Susitna River between the proposed Watana Dam site (RM 184) and the Susitna Station gage (RM 28). This includes the mainstem Susitna River and its tributaries. The Three Rivers Confluence (RM 98) separates the Middle Susitna River Segment from the Lower Susitna River Segment. Initial estimates for the Lower Susitna River Segment Sediment Balance are being developed in 2012 as part of the Reconnaissance-Level Assessment of Project Effects on Lower and Middle Susitna River Segment (Section 6.5.4.6). The remaining efforts, which include refined estimates of the Middle Susitna River Segment sediment balance, bed material mobilization, and effective discharge, will be conducted in 2013. The 2013 effort will provide estimates of sediment supply that will be used in the bed evolution modeling efforts described in Section 6.6.

6.5.4.3.1. Existing Information and Need for Additional Information

The Project will reduce sediment supply to the reach of the Susitna River downstream from the dam, and will also alter the timing and magnitude of the flows that transport the sediment. Information provided in the Pre-Application Document (PAD) (AEA 2011) suggests that peak flows may be reduced in magnitude and occur later in the season, and the flows will tend to be higher during the non-peak flow season under Project conditions. Sediment transport data are available along the mainstem Susitna River and several of the major tributaries between the proposed Watana Dam site (RM 184) and Susitna Station (RM 28) (URS 2011) that can be used to perform an initial evaluation of the sediment balance along the study reach under existing conditions. The results of this study component will provide the initial basis for assessing the potential for changes to the Middle and Lower Susitna River segments' sediment balance, and the associated changes to geomorphology, because it will permit quantification of the magnitude in the reduction of sediment supply below the dam. The studies will also support the Fluvial Geomorphology Modeling below Watana Dam Study through development of sediment supply information that will be required as input to the model.

6.5.4.3.2. Methods

The methods section is divided into five subsections: (1) Initial Lower Susitna River Segment Sediment Balance, (2) Middle Susitna River Segment Sediment Balance, (3) Characterization of Bed Material Mobilization, (4) Effective Discharge, and (5) Information Required.

Development of the sediment balance for both the Lower Susitna River Segment (RM 98 to RM 28) and Middle Susitna River Segment (RM 184 to RM 98) will consider various techniques to characterize the sediment supply to each reach, the sediment transport capacity through the reaches, and deposition/storage within the reaches. Sources of sediment supply are expected to include the mainstem Susitna River, contributing tributaries, and identified locations of mass wasting. Potential procedures to estimate sediment supply include the use of regional sediment supply relationships (e.g., regression equations based on watershed area) and calculation of differences in sediment loads between gaging stations. While it is recognized that the gages are spatially separated, the comparison of the loads at the gages will permit an assessment of whether there is significant storage or loss of sediment between gages. If the data indicate that there is little difference between the gages, then it can be reasonably concluded that there is sufficient supply of sediment within the reach between gages to support an assumption of transport capacity limitation rather than supply limitation. The sediment transport measurements collected by USGS, both historical and current, will be used to develop bedload and suspended load rating curves to facilitate translation of the periodic instantaneous measurements into yields over longer durations (e.g., monthly, seasonal, and annual). Since gradations of transported material will be available, the data will allow for differentiation of transport by size fraction.

The sediment balance will be quantified by developing sediment load versus water discharge rating curves for each portion of the sediment load (i.e., wash load, total bed material load, bedload) using the available data or transport capacity calculations based on the hydraulic modeling results, as appropriate. The rating curves will then be integrated over the relevant hydrographs to estimate the total sediment load, and the resulting total sediment loads will then be compared to determine if each segment of the reach between the locations represented by the rating curves is net aggradational (i.e., more sediment is delivered to the reach than is carried past the downstream boundary) or degradational (i.e., more sediment is carried out of the reach than is delivered from upstream and lateral sources).

Previous studies have documented the potential for bias in suspended load rating curves due to scatter in the relationship between sediment concentration or load and flow (Walling 1977a). Part of the scatter is often caused by hysteresis in the sediment load versus discharge relationship, where the loads on the rising limb are higher than on the falling limb due to availability of material and coarsening of the surface layer during the high-flow portion of the hydrograph (Topping et al. 2010). Bias is also introduced in performing linear least-squares regressions using logarithmically-transformed data and then back-transforming the predicted sediment loads to their arithmetic values (Walling 1977b; Thomas 1985; Ferguson 1986, Koch and Smillie 1986). The hysteresis effect can be accounted for by applying separate (or perhaps, shifting) rating curves through rising and falling limbs of flood hydrographs (Guy 1964; Walling 1974; Wright et al. 2010). Bias in the regression equations can be removed using the Minimum Variance Unbiased Estimator (MVUE) bias correction for normally distributed errors, or the Smearing Estimator (Duan 1983) when a non-normal error distribution is identified. These methods were recommended by Cohn and Gilroy (1991) and have been endorsed by the USGS Office of Surface Water (1992). Once the sediment measurements are available for review, the potential for bias in the sediment rating curves will be considered and addressed as appropriate.

The rating curves for the mainstem Susitna stations, for gaged tributary stations, and those developed for contributing ungaged areas between stations will be used to develop the sediment balance for the pre-Project hydrology for representative wet, average, and dry years and warm and cold Pacific Decadal Oscillation (PDO) phases. (The inclusion of the warm and cold PDO phases was requested by NOAA-NMFS and USFWS in the May 31, 2012, study requests; the rationale for the request was discussed at the June 14, 2012, Water Resources TWG meeting and it was agreed that the PDO phases would be included in the suite of representative annual hydrologic conditions.) The sediment balance will be calculated based on the assumption that the sediment load in the Susitna River is currently in a state of equilibrium. To develop the sediment balance for the post-Project condition, the historical (pre-Project) sediment rating curve developed for the river immediately below the Watana Dam site (Tsusena Creek) will be reduced by 100 percent for the bedload and 90 percent for the suspended load on a preliminary basis. If the reservoir trap efficiency analysis discussed below indicates that a substantially different amount of sediment will pass through the reservoir, the sediment load curves will be adjusted accordingly.

6.5.4.3.2.1. Initial Sediment Balance (Lower Susitna River Segment)

The primary purpose of the Initial Sediment Balance evaluation for the Lower Susitna River Segment performed in 2012 is to help evaluate the potential for the Project to alter sediment transport conditions and channel response in the Lower Susitna River Segment. The results of this evaluation will provide the basis for assessing the need to perform additional 1-D and 2-D modeling and other studies related to potential channel change downstream from RM 75. The Lower Susitna River Segment Sediment Balance depends on the sediment supply from the Middle Susitna River Segment of the Susitna, the Chulitna and Talkeetna rivers, and other local tributaries along the reach, and the transport capacity along the reach. The total sediment supply to the Lower Susitna River Segment under pre-Project conditions is being evaluated using the sediment rating curves developed from the historical data (and 2012 data, if available) for the Susitna River at Gold Creek and near Talkeetna gages on the mainstem, and the below canyon near Talkeetna and near Talkeetna gages on the Chulitna and Talkeetna rivers, respectively. The historical rating curves for the Sunshine and Susitna Station gages, updated with any new sediment transport data collected by USGS under the Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations on the Susitna River, the Chulitna River near Talkeetna and the Talkeetna River near Talkeetna (Section 6.5.4.2), are being used to estimate the sediment loads in the river in the vicinity of RM 84 and RM 26.

6.5.4.3.2.2. Middle Susitna River Segment Sediment Balance

A more detailed sediment balance will also be developed in 2013 for the Middle Susitna River Segment between the proposed Watana Dam site (RM 184) and the Three Rivers Confluence (RM 98/98.5) using the available data, and when available, the hydraulic and sediment transport modeling results for this portion of the study reach. Estimates of the contributions to the sediment supply from the Upper Susitna River Segment identified mass wasting locations, bank erosion, and contributing tributaries downstream of the dam will be an important aspect of this analysis. An estimate of the volume of sediment from bank erosion will be made utilizing a comparison of the channel location and area developed in the Assess Geomorphic Change Middle and Lower Susitna River Segments study component (see Section 6.5.4.4) and comparison of cross-sections surveyed in the 1980s and in 2012. The cross-sections may also be used to determine if there has been a loss or gain in sediment supply from aggradation or degradation of the bed in the Middle Susitna River Segment. Tributary sediment loading will be estimated as part of the Fluvial Geomorphology Modeling Study (see Section 6.6.4.1.2.6).

Potential procedures to estimate the Middle Susitna River Segment sediment supply include the use of watershed area and regional sediment supply relationships and the determination of the differences on a seasonal or annual basis between the sediment loads estimated for the Susitna River at the Tsusena Creek and Gold Creek gage locations. Past USGS sediment data may be available for Indian River and Portage Creek, which could also be used to assist in the estimation of the Middle Susitna River Segment sediment supply inputs. If data being collected by USGS for the Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations on the Susitna River, the Chulitna River near Talkeetna, and the Talkeetna River near Talkeetna are available in time for this analysis, the 2012 data from

Tsusena Creek will be compared to the 2012 Gold Creek data to estimate the sediment inflow between these two locations. This will allow development of a sediment rating curve from the 1985 data for the Susitna River at Tsusena Creek (representative of sediment transport at the Watana Dam site).

6.5.4.3.2.3. Characterization of Bed Material Mobilization

Bedload transport, particularly for the gravel and cobble size-fractions, is the key process that determines the dynamic behavior of the river bed both in the mainstem and in the side channel that is important to fish habitat. In coarse-grained rivers such as the Susitna River, a coarse surface layer is present that is typically not mobile over the full range of flows; thus, significant bedload transport does not occur. An important part of the geomorphology study will involve quantification of the range of flows over which bed mobilization occurs, and the potential change in duration of those flows under Project conditions. The approximate discharge at which bedload mobilization begins in the Susitna River near the proposed dam and at selected locations in the Middle and Lower Susitna River Segments will be estimated using the USGS empirical sediment rating curves, incipient motion calculations (i.e., estimates of the critical discharge at which bed material begins to mobilize), and field observations. The resulting estimates of the critical discharge will be used to assess the frequency and duration of bed mobilization under the pre- and post-Project condition hydrology. This will be performed on both a monthly and annual basis at the selected locations for a range of flow years.

The concept of incipient motion as advanced by Shields (1936) relates the critical shear stress for particle motion (τ_c) to the dimensionless critical shear stress (τ^*_c) and the unit weight of sediment (γ_s), the unit weight of water (γ), and the median particle size of the bed material (D_{50}). One key limitation of this relation is the specification of τ^*_c (often referred to as the Shields parameter), which can range by a factor of three (Buffington and Montgomery 1997). The large range in published values for τ^*_c is caused largely by the difficulty in defining and identifying when bed material motion actually begins. To work around this limitation, Parker (Parker et al. 1982) defined a reference Shields stress (τ^*_r) that corresponds to a dimensionless transport rate $W^* = 0.002$, corresponding to a very low, but measurable transport rate. For this relationship, W^* is a function of the unit bedload and the total boundary shear stress, both of which are relatively simple parameters to calculate from field data if bedload and discharge measurements are included. (In the NOAA-NMFS and USFWS Study Plan Requests, it was proposed that the bed material mobilization analysis be calibrated based on the use of tracers. This topic was discussed at the Water Resources TWG held on June 14, 2012. AEA's consultants indicated that the use of tracers in a large river such as the Susitna would not be practical due to the difficulty in locating the tracers after mobilization. Therefore, the use of tracers is not included in the proposed study plan.)

Another limitation of the original Shields equation is that is does not consider hiding effects in substrate with a broad range of particle sizes. Hiding effects result in mobilization of the larger particles at lower shear stresses than would occur in uniform-sized substrate. This is due to the larger substrate projecting farther into the flow than if they were surrounded by similarly sized particles. Conversely, the smaller particles are mobilized at higher-than-expected shear stresses because they are sheltered by the larger particles. Meyer-Peter, Muller, and Einstein recognized this effect in developing their original bedload transport equations, and numerous researchers have continued to evaluate and provide relationships that account for this effect (Parker et al, 1982; Andrews 1978; Neill 1969; and many others). In a general sense, these relationships indicate that the original Shields equation only applies directly to the median (D_{50}) substrate size, and the substrate mixture is effectively immobile at shear stresses less than that required to mobilize the median size. These relationships do, however, indicate varying degrees of selective transport in which at least some of the finer particles mobilize at shear stresses less than that required to mobilize the median size. The strength of this effect is marginally different among the different relationships, most likely due to difference in the specific characteristics of material used to develop them. For purposes of this study, the Parker et al. (1982) relationship will most likely be used because it applies to relatively clean (i.e., low percentages of sand and finer material) gravel and cobble substrate. If it is found that the substrate in specific areas contains more than about 20 percent sand, the Wilcock and Crowe (2003) relationship will be used because it takes into account effects of large amounts of sand in increasing the mobility of the gravel/cobble fraction.

Because of the uncertainty in defining appropriate values of the Shields critical shear stress for the median particles size, bed material mobilization at various locations along the study reach will be characterized using the reference shear approach of Parker, following the methods of Mueller et al. (2005). Data collected by USGS, which will include the necessary series of coupled flow and bedload transport measurements, will be used to formulate a series of bedload rating curves. These curves will then provide a basis for estimating τ^* that corresponds to a dimensionless transport rate $W^* = 0.002$ for bed material mobilization.

6.5.4.3.2.4. Effective Discharge

The concept of effective discharge, as advanced by Wolman and Miller (1960), relates the frequency and magnitude of various discharges to their ability to do geomorphic work by transporting sediment. They concluded that events of moderate magnitude and frequency transport the most sediment over the long-term, and these flows are the most effective in forming and maintaining the planform and geometry of the channel. Andrews (1980) defined the effective discharge as "*the increment of discharge that transports the largest fraction of the annual sediment load over a period of years.*"

Estimates of the potential change in effective discharge between historic and post-Project conditions provides a basis for predicting whether the bankfull channel capacity will change due to the Project, and if so, the likely trajectory and magnitude of the changes. The concept of effective discharge, as advanced by Wolman and Miller (1960), relates the frequency and magnitude of various discharges to their ability to do geomorphic work by transporting sediment. They concluded that events of moderate magnitude and frequency transport the most sediment over the long-term, and these flows are the most effective in forming and maintaining the planform and geometry of the channel.

Alluvial rivers adjust their shape in response to flows that transport sediment. Numerous authors have attempted to relate the effective discharge to the concepts of dominant discharge, channel-forming discharge, and bankfull discharge, and it is often assumed that these discharges are roughly equivalent and correspond to approximately the mean annual flood peak (Benson and Thomas 1966; Pickup 1976; Pickup and Warner 1976; Andrews 1980, 1986; Nolan et al. 1987; Andrews and Nankervis 1995). Quantification of the range of flows that transport the most sediment provides useful information to assess the current state of adjustment of the channel and to evaluate the potential effects of increased discharge and sediment delivery on channel behavior. Although various investigators have used only the suspended sediment load and the total sediment load to compute the effective discharge, the bed material load should generally be used when evaluating the linkage between sediment loads and channel morphology because it is the bed material load that has the most influence on the morphology of the channel (Schumm 1963; Biedenharn et al. 2000).

For purposes of this study, the effective discharge will be computed for the Susitna River below Tsusena Creek, at Gold Creek, and at Sunshine. This will be performed by dividing the full range of flows at each location into at least 30 logarithmic classes (Biedenharn et al. 2000) and then computing the sediment transport capacity at the average discharge within each flow class using the previously described rating curves. The bed material transport in each flow class over the long-term will be determined by multiplying the individual transport rates by the corresponding flow duration, which is derived from mean daily flow duration curves. The effective discharge is the flow, or range of flows, where the incremental bed material transport is greatest. Effective discharges will be determined for both the pre- and post-Project conditions. If the post-Project value is lower than the pre-Project value, it provides an indication that the morphology of the channel will change because there is a reasonably well identified relationship between the effective discharge and the size of the channel.

6.5.4.3.2.5. Information Required

The following available existing information will be needed to conduct this study:

- Current and historical aerial photographs.
- Historical suspended sediment and bedload data for the Susitna River and contributing tributaries.
- Flow records for the Susitna River and contributing tributaries.

The following additional information will need to be obtained to conduct this study:

- Suspended and bedload data for the Susitna River at Tsusena Creek and Gold Creek being performed by USGS.
- Extended flow record for the Susitna River and gaged tributaries within the study area being developed by USGS.
- Estimated flows for the ungaged tributaries within the study area.
- Extended flow records for the Susitna River and tributaries being developed by USGS.
- Collection of bed material samples throughout the Middle and Lower River Segments, as well as contributing tributaries.
- Hydraulic conditions in the Susitna River from the Hydraulic Routing Model.
- Surveys of channel geometry for contributing tributaries to simulate hydraulic conditions.

6.5.4.3.3. Study Products

The results of the Sediment Supply and Transport Middle and Lower Susitna River Segments study component will be included in the Geomorphology Report. Information provided will include the following:

- Tabular and graphical summary of available discharge and sediment transport data.
- Description of procedures used to develop sediment transport rating curves from suspended load and bedload data, including development of curves for specific sediment size-classes.
- Graphical and numerical relationships for sediment discharge rating curves.
- Narrative describing procedures used to perform effective discharge and bed mobilization calculations.
- Determination of total sediment load delivered to the Susitna River for pre- and post-Project conditions (the latter based on preliminary assumption that 100 percent bedload and 90 percent of suspended load will be trapped behind the Project dam; this estimate can be refined if the trap efficiency analysis indicates substantially different results).
- Estimate of Middle Susitna River Segment sediment supply inputs from local tributaries and other sources.
- Tabular and graphical representation and comparison of the duration and frequency of bed material mobilization in the Middle and Lower Susitna River Segments for pre- and post-Project conditions.
- Estimates of the effective discharge for the pre- and post-Project conditions, and the likely effects on channel morphology.
- Estimates of the overall sediment transport balance along the reach and the likely effects on channel morphology, particularly with respect to aggradation/degradation trends and changes in braiding potential. In reaches with net sediment deficit, results from the bed mobilization analysis will also be considered in assessing degradation tendencies.

6.5.4.4. Study Component: Assess Geomorphic Change Middle and Lower Susitna River Segments

The goal of this study component is to compare existing, 1980s and 1950s geomorphic feature data from aerial photo analysis to characterize channel stability and change and the distribution of geomorphic features under unregulated flow conditions. The effort will include use of the best available aerial photographs from the 1950s to provide a longer range assessment of channel change. The acquisition of the current aerials for the Middle Susitna River Segment was initiated in 2012 as part of the Aquatic Habitat and Geomorphic Mapping of the Middle Susitna River Segment Using Aerial Photography study (Section 6.5.4.5) and for the Lower Susitna River Segment as part of the Riverine Habitat Area versus Flow Lower Susitna River Segment (Section 6.5.4.7). Digitization of the geomorphic features from the 1980s and 2012 aerial, determination of geomorphic feature areas, and qualitative assessment of channel change were conducted in 2012 for the flows that aerials could be obtained. Due to a combination of weather and flows conditions, not all aerials originally planned for acquisition in 2012 were obtained. The acquisition of the aerials is discussed further in Sections 6.5.4.4.2.1 and 6.5.4.4.2.2. The remainder of the effort described will be conducted in 2013. The study area extends from the mouth of the Susitna River (RM 0) at Cook Inlet to the proposed Watana Dam site (RM 184).

6.5.4.4.1. Existing Information and Need for Additional Information

An analysis of the Middle Susitna River Reach geomorphology and how aquatic habitat conditions changed over a range of stream flows was performed in the 1980s using aerial photographic analysis (Trihey & Associates 1985). A similar analysis was performed for the Lower Susitna River Segment (R&M Consultants, Inc. and Trihey & Associates 1985a). The1980s Lower Susitna River Segment study also included an evaluation of the morphologic stability of islands and side channels by comparing aerial photography between 1951 and 1983. An analysis of channel changes of the Middle River was presented in *Geomorphic Change in the Middle Susitna River Since 1949* (Labelle et al. 1985). In this document, aerial photographs and other data from the late 1940s through the early 1980s was evaluated to determine historical change in the Middle Susitna River Segment including the important off-channel macrohabitats identified in the 1980s studies (side channels, side sloughs, and upland sloughs).

The AEA Susitna Water Quality and Sediment Transport Data Gap Analysis Report (URS 2011) states that "if additional information is collected, the existing information could provide a reference for evaluating temporal and spatial changes within the various reaches of the Susitna River." The gap analysis emphasizes that it is important to determine if the conditions represented by the data collected in the 1980s are still representative of current conditions and that at least a baseline comparison of current and 1980s-era morphological characteristics in each of the identified sub-reaches is required.

Understanding existing geomorphic conditions and how laterally stable/unstable the channels have been over recent decades provides a baseline set of information needed to provide a context for predicting the likely extent and nature of potential changes that will occur due to the Project. Results of this study may also be used in the Riparian Instream Flow (Section 8.6) and Ice Processes (Section 7.6) studies to provide the surface areas of bars likely to become vegetated in the absence of ice-cover formation. This would be accomplished by evaluating the areas of exposed bars within river segments over a range of flows and developing exposed bar area discharge curves that could then be used to assess the impacts of the Project flows on bar inundation by both flows and ice. Increases in areas that would be both inundation- and ice-free are likely to permit vegetation establishment and persistence.

Determination of the rate that area occupied by the channel is converted to floodplain and islands, and area occupied by floodplain and islands is converted to channel will provide information useful in identifying LWD recruitment rates and characterizing floodplain dynamics important to the Riparian Instream Flow Study (Section 8.6). Therefore, a "turnover" analysis is included as part of this study component.

6.5.4.4.2. Methods

This study component has been divided into the Middle and Lower Susitna River Segments because the available information differs. The analysis of geomorphic change will be conducted for a single representative discharge.

6.5.4.4.2.1. Middle Susitna River Segment

The orthorectified digital images of the historical 1983 black and white aerial photographs for the Middle River at a flow of 12,500 cfs were acquired for the area from RM 98 to RM 150 (RM 150 was the limit of the coverage from the 1980s effort). Additional historical aerials were acquired to allow delineation of the geomorphic features from RM 150 to 184. The September 6, 1983, aerials flown at a flow of 12,500 cfs, as measured at the Gold Creek Gage, were used for the historical condition. From RM 98 to RM 150, color aerials from July 19–20, 1980, at flows ranging between 31,800 and 35,900 cfs (as measured at Gold Creek), not collected as part of the original Susitna Project effort, were used to digitize geomorphic features from RM 150 to RM 184. The 1980s orthorectified digital images of historical aerials were also acquired for the Upper River from RM 184 to RM 260. The aerials from RM 184 to RM 252 were from the same July19–20, 1980 acquisition as the RM 150 to RM 184 aerials. From RM 252 to RM 260, color aerials from August 24, 1981 were obtained. The flow at Gold Creek on this date was 35,000 cfs.

Acquisition of the 2012 aerials was targeted at a flow of 12,500 cfs; however, due to a combination of late season high flows and poor weather, the actual 2012 aerials were collected at flows of 13,300 cfs for RM 98 to RM 135 and 18,100 cfs for RM 136 to RM 184. Table 6.5-3 summarizes the 2012 aerial photo data collection effort for the Lower, Middle, and Upper Susitna River segments and indicates the RMs and discharges at which various sets of photos were obtained. The higher flow for the RM 136 to RM 184 should not create problems with digitizing geomorphic features, except that the areas of the gravel bars will require adjustment prior to comparison with 1980s information for use in 2013. Completion of aerial collection at the targeted flows will be performed in 2013, so the final information is expected to be based on flows closer to the target of 12,500 cfs.

In 2012, for the both the 1983 and 2012 aerials, each feature was digitized as a polygon (without slivers) using ArcGIS software. Associated metadata were developed for both sets of digitized geomorphic features. The primary geomorphic features that are visible between the 1980s and current images, including the main channel, side channels, and sloughs were digitized from the aerial database just described. In addition, the presence and extent of mid-channel bars, vegetated bar areas, and changes at tributary deltas were digitized.

The information developed from digitizing the aerials is being used to analyze and compare the geomorphology for 1980s and current conditions. From RM 98 to RM 184, Geographic Information System (GIS) software is being used to compare the 2012 versus 1980s total surface area associated with each geomorphic feature. Results will be compiled into tables and graphs, as appropriate, to show the difference in surface areas of the feature types between 2012 and the 1980s photography. The lead geomorphologist has trained the staff performing the digitization to ensure appropriate application of the geomorphic definitions. Since this 34-mile river segment below the proposed Watana Dam site (RM 150 to RM 184) was not analyzed in the 1980s, the historical aerials are at a higher discharge, 30,000 cfs compared to 12,500 cfs, and the area of exposed gravel will not be comparable to the 2012 aerials at a lower flow without adjustment. It may be more appropriate to compare this 1980s RM 150 to RM 184 information with the results of the 2012 aerials collected at 23,200 cfs. A final decision on the 2012 aerials used from RM 150 to 184 for comparison with the 1980s will be made in 2013 after the 2013 supplemental aerial photo acquisition effort is conducted. (The 2013 supplemental aerial photo acquisition effort will be performed to fill in flow rates and areas that were scheduled for collection in 2012 but were not collected due to a combination of weather and flow conditions.)

In 2013, orthorectified digital versions of historical 1950s aerials will be acquired and the geomorphic features digitized. Acquisition of these aerials and performing the effort is dependent on locating a set of historical aerials from the 1950s or early 1960s that are of sufficient quality to provide for meaningful comparison between the other two datasets (1980s and current).

The change in channel planform over the length of the river (main channel location, side channel location, bars, channel and side channel width, channel and side channel location) will first be qualitatively assessed between the 1980s and 2012. This will be performed to assist in selection of the proposed Focus Areas. The geomorphic reach delineations will be reviewed in terms of the information on channel change and geomorphic reach limits adjusted if necessary to properly characterize channel stability. Reaches will be identified that are relatively stable versus those that are more dynamic. Reaches that would be most susceptible to channel change (e.g., width or planform change) with changes in the flow or sediment regime resulting from the Project or Project operations will be qualitatively identified because these are currently the most dynamic.

In 2013, a quantitative evaluation of channel change in the Middle River will be performed by conducting a “turnover” analysis (Note: the turnover analysis was added to the RSP as a result of comments on the PSP from the EPA submitted November 14, 2012). The digitized maps of the geomorphic features will be used to determine how much of the area covered by water in the 1950s and 1980s is land in 2012 versus still covered by water, taking into account river stage for the aerials not collected at ~12,500 cfs, and how much of the area covered by water today was land versus covered by water in the 1980s and 1950s. This analysis will be performed on a geomorphic reach basis. This information will be used to calculate a “turnover rate” (water to land and land to water, in acres per year) for each reach, for the periods between the 1950s and the1980s, and between the 1980s and 2012 aerial imagery. The resulting reach-scale data will be used to define the reach-scale turnover rate values. The resulting quantitative data on turnover rate will be compared with hydrologic conditions, events at upstream glaciers, and other potential factors such as the occurrence of earthquakes to determine potential differences in the turnover rates from the two periods. Spatially, the turnover rates will be compared between reaches and channel types to determine if there is a difference in turnover between the various reaches and associated channel types.

Depending upon the results of the riverine geomorphic analysis, additional historical photographic analysis may be requested as part of future geomorphic studies, but this additional analysis is not included at this time. Additional analysis of historical aerial photographs and the corresponding flows that occurred between 1950s and 2012 could be pertinent if substantial changes in the riverine habitat types (surface area, locations, etc.) are identified during comparison of the 2012, 1980s, and 1950s photography. A decision on whether to acquire additional aerials will be made in Q4 2013. While the long-term changes in river morphology are the result of a range of flows, if significant changes are identified between pairs of aerial photographs, review of the hydrologic record frequently identifies events that are more than likely to have been morphogenetically significant. This type of additional aerial photo analysis could provide more specific information on the flow magnitude(s) and other conditions (for example, ice formation) that may cause substantial geomorphic channel adjustments.

6.5.4.4.2.2. Lower Susitna River Segment

In 2012, orthorectified digital images of the 36,600-cfs (as measured at Sunshine Station) September 6, 1983, set of Lower Susitna River Segment aerial photographs were obtained for the Lower Susitna River Segment from RM 0 to RM 98. Acquisition of 2012 aerials for the Lower Susitna River Segment at a targeted flow of approximately 36,600 cfs was planned. Due to a combination of weather and flows conditions, the Lower River aerials were acquired at several different times for flows ranging from 38,100 cfs to 46,900 cfs. For determining geomorphic features, these flows are considered to be within the target range.

The extent of the side channels, main channel, anabranches and braid plain in the Lower Susitna River Segment, including the Three Rivers Confluence area, were digitized for both the 1980s and 2012 aerials. Planform shifts of the main channel and side channels are being identified between the 1983 and current aerial photography. This work was performed in 2012 to help in confirmation or adjustment of the downstream study limit for the Fluvial Modeling Geomorphology Study. Geomorphic features that are visible between the 1983 and 2012 images, including the presence and extent of individual side channels, side channel complexes, vegetated islands or bar complexes, and tributary deltas, were mapped and characterized. In areas where the mainstem channel consists of a dynamic braid plain mostly void of stabilizing vegetation, the effort was directed at defining the edges of the active channel rather than detailing the myriad of channels within the active area. Portions of the area within the braid plain were identified as bar island complexes and side channel complexes. Major sloughs and side channels along the Lower Susitna River Segment margins were included in the digitizing effort.

In 2013, orthorectified digital versions of historical 1950s aerials will be acquired and the geomorphic features digitized. Acquisition of these aerials and performing the effort is dependent on locating a set of historical aerials from the 1950s or early 1960s that are of sufficient quality to provide for meaningful comparison between the other two datasets (1980s and current). The geomorphic change over the length of the river (main channel location, side channel location, bars, channel and side channel width, channel and side channel location) will be qualitatively assessed between the 1980s and current conditions. Reaches will be identified that are relatively stable versus those that are more dynamic. Reaches that would be most susceptible to channel change (e.g., width or planform change) with changes in the flow or sediment regime resulting from the Project or Project operations will be qualitatively identified.

In 2013, a quantitative evaluation of channel change in the Lower River will be performed by conducting a “turnover” analysis (Note: the turnover analysis was added to the RSP as a result of comments on the PSP from the EPA submitted November 14, 2012). The digitized maps of the geomorphic features will be used to determine how much of the area covered by water in the 1950s and 1980s is land in 2012 versus still covered by water, taking into account river stage for the aerials not collected at ~36,600 cfs, and how much of the area covered by water today was land versus covered by water in the 1980s and 1950s. This analysis will be performed on a geomorphic reach basis. This information will be used to calculate a “turnover rate” (water to land and land to water, in acres per year) for each reach for the periods between the 1950s and the1980s, and between the 1980s and 2012 aerial imagery. The resulting reach-scale data will be used to define the reach-scale turnover rate values. The resulting quantitative data on turnover rate will be compared with hydrologic conditions, events at upstream glaciers, and other potential factors such as the occurrence of earthquakes to determine potential differences in the turnover rates from the two periods. Spatially, the turnover rates will be compared between reaches and channel types to determine if there is a difference in turnover between the various reaches and associated channel types.

Depending on the results of the riverine geomorphic analysis, additional historical photographic analysis may be requested as part of future geomorphic studies, but this additional analysis is not included at this time. Additional analysis of historical aerial photographs and the corresponding flows that occurred between the 1950s and 2012 could be pertinent if substantial changes in the riverine habitat types (surface area, locations, etc.) are identified during comparison of the 2012, 1980s and 1950s photography. While the long-term changes in river morphology are the result of a range of flows, if significant changes are identified between pairs of aerial photographs, review of the hydrologic record frequently identifies events that are more than likely to have been morphogenetically significant. This type of additional aerial photo analysis could provide more specific information on the flow magnitude(s) and other conditions (for example, ice formation) that may cause substantial geomorphic channel adjustments. A decision on whether to acquire additional aerials will be made in Q4 2013.

6.5.4.4.2.3. Information Required

The following available existing information will be needed to conduct this study:

- Historical 1980s orthorectified aerial photographs for the Middle and Lower Susitna River Segments.
- Historical 1950s orthorectified aerial photographs for the Middle and Lower Susitna River Segments.

The following additional information will be needed to conduct this study:

- Obtain recent or develop 2012 orthorectified aerial photos in the Middle and Lower Susitna River Segments at a flow similar to the historic aerials (12,500 cfs Middle Susitna River Segment and 36,600 cfs Lower Susitna River Segment) (acquired in 2012).
- Supplemental aerials Middle River to be collected in 2013 for any areas with gaps in 2012 coverage at the 12,500 cfs target flow.

6.5.4.4.3. Study Products

The results of the Assess Geomorphic Change Middle and Lower Susitna River Segment component will be included in the Geomorphology Report. Information provided will include the following (Note: 1950s products are dependent on suitable aerials being available from the 1950s):

- Maps showing riverine geomorphic features outlined in the Middle and Lower Susitna River Segments for the 1950s, 1980s, and 2012 for flows of approximately 12,500 cfs and 36,600 cfs, respectively.
- Maps showing the distribution of all riverine geomorphic features for the three dates and for the Middle and Lower Susitna River Segments.
- Overlay map of 1950s, 1980s, and 2012 riverine geomorphic features to qualitatively assess the level of change in the channel morphology over the past three decades.

- Tabular and graphical representation of the areas for each riverine geomorphic feature type by geomorphic reaches within the Middle and Lower Susitna River Segments.
- Qualitative assessment of the level of geomorphic change within each geomorphic reach over the lengths of the Middle and Lower Susitna River Segments including identification of stable versus non-stable areas.
- Quantitative assessment of geomorphic change based on conducting a turnover rate analysis identifying the area of channel converted to land and land converted to channel for the periods of 1950s to 1980s and 1980s to 2012.

In addition, an ArcGIS shapefile will be provided with the following information:

- 1950s, 1980s, and 2012 orthorectified aerial imagery on GIS layer for the Middle and Lower Susitna River Segments.
- Digitized polygons for each riverine habitat feature type in the Middle and Lower Susitna River Segments.

6.5.4.5. Study Component: Riverine Habitat versus Flow Relationship Middle Susitna River Segment

The goal of this study component is to delineate existing and 1980s riverine macrohabitat types and develop wetted habitat area data over a range of flows to quantify riverine macrohabitat surface area versus flow relationships. The habitat areas will be determined for the riverine macrohabitats as defined in the 1980s (main channel, side channel, side slough, upland slough, tributary mouth and tributary).

It is noted that the macrohabitats being delineated in this study component is one of five levels of nested and tiered habitat classification being applied to the Middle Susitna River Segment. The system is presented in Table 9.9-4 of the Characterization and Mapping of Aquatic Habitats (Section 9.9). The classification levels include rivers segment, geomorphic reach, macrohabitats, mesohabitat, and edge habitat. The Geomorphology Study has defined the Susitna River segments and geomorphic reaches. The effort in this section will map approximately 50 percent of the macrohabitat in the Middle River. The results will be provided to the habitat characterization study (Section 9.9) to add macrohabitat subcategories not defined in the 1980s classification scheme. These include split main channel, multiple split main channel, backwater, and beaver complex. The habitat characterization study (Section 9.9) will also conduct the mapping for the fourth and fifth levels of the classification scheme.

The study area extends from the Three Rivers Confluence area (RM 98) to the Watana Dam site (RM 184). Sixteen study sites representing approximately 50 percent of the river studied in the 1980s were studied in the 2012 study. Due to a combination of weather and flow conditions, not all aerials intended to be acquired in 2012 were flown (Table 6.4-3 summaries the 2012 aerial photo acquisition). Therefore, development of the riverine habitat area versus flow relationships for the current condition will continue into 2013. The 2012 effort does supply the information necessary for reach stratification and selection of proposed Focus Areas in the Middle River. Additionally, all or part of the remaining portion of the Middle Susitna River Segment may be studied in 2013–2014, depending on the outcome and recommendations from the 2012 study as well as the finalization of instream flow Focus Areas.

6.5.4.5.1. Existing Information and Need for Additional Information

An analysis of the Middle Susitna River Segment and how riverine habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (Trihey & Associates 1985). This study evaluated the response of riverine aquatic habitat to flows in the Middle Susitna River Segment between the Three Rivers Confluence (RM 98) and Devils Canyon (RM 150) ranging from 5,100 cfs to 23,000 cfs (measured at Gold Creek gage [approximately RM 134]).

Understanding existing geomorphic conditions, how aquatic macrohabitat changes over a range of stream flows, and how stable/unstable the geomorphic conditions have been over recent decades provides a baseline set of information needed to provide a context for predicting the likely extent and nature of potential changes that will occur due to the Project. Results of this study will also provide the basis for macrohabitat mapping to support the Fish and Aquatics Instream Flow Study (Section 8.5) and will be used in the Ice Processes Study (Section 7.6) to provide the surface areas of bars likely to become vegetated in the absence of ice-cover formation.

6.5.4.5.2. Methods

Aerial photography obtained in 2012 were combined with 1980s and other information to create a digital, spatial representation (i.e., GIS database) of riverine habitat. The result was intended to be a quantification of the area of the riverine habitat types for three flow conditions for the historical 1980s condition and the current 2012 condition. Due to a combination of weather and flow conditions, only portions of two out of the three flows were collected (aerials for high and medium flows were collected, but no aerial low flows were collected). A supplemental data collection effort will be conducted in 2013 to complete the acquisition of aerials for all three flows for the entire Middle Susitna River Segment.

The results for the information available in 2012 will be analyzed and presented in January 2013 as riverine habitat versus area relationships at three spatial levels: for the Middle Susitna River Segment, for the geomorphic reaches in the Middle Susitna River Segment, and for individual habitat study sites (This includes all ten proposed Focus Areas and seven additional sites studied in the 1980s that are not proposed Focus Areas). Comparison between the results from the 1980s and 2012 are being made. The historical information is only being developed for the reach from RM 98 to RM 150 because the delineation of habitat in the Devils Canyon section, RM 150 to RM 184, was not performed in the 1980s.

The methods for this study component have been divided into three tasks: aerial photography, digitize riverine habitat types, and riverine habitat analysis.

6.5.4.5.2.1. Aerial Photography

Portions of new color aerial photography of the Middle Susitna River Segment (RM 98 to RM 184) at stream flows corresponding to those analyzed in the Trihey & Associates study (1985) (stream flow at the Gold Creek gage [15292000]) were obtained in 2012 to provide the foundation for the aquatic habitat and geomorphic mapping of the Middle Susitna River Segment, as well as to provide a resource for other studies. The aerials collected included RM 98 to RM 107 at 23,200 cfs, RM 98 to RM 135 at 13,300 cfs, and RM 136 to RM 184 at 18,100 cfs.

It was the intent of the study plan to obtain three sets of aerial photography in 2012 at the following approximate discharges: 23,000 cfs; 12,500 cfs; and 5,100 cfs. (Note: seven sets of aerial photographs were flown and evaluated in the 1985 study at the stream flows of 5,100 cfs; 7,400 cfs; 10,600 cfs; 12,500 cfs; 16,000 cfs; 18,000 cfs; and 23,000 cfs). The combination of weather conditions and river flows only allowed the 23,000 cfs and a portion of the 12,500 cfs set of aerials to be collected in 2012. No aerials were obtained for the lowest flow of 5,100 cfs as ice and snow cover formed prior to the Susitna River dropping to this level. In order to provide a complete set of current aerial imagery, the 23,000 cfs aerials were collected for the entire study are from RM 0 to RM 260. The aerial photography was collected in 2012 at a scale of 1:12,000 and with a pixel resolution of 1 foot or better. Images to be collected in 2013 will be flown at the same scale and resolution. The flow levels intended to be collected in 2013 will be the remainder of the 12,500 cfs acquisition and all of the 5,100 cfs acquisition. If weather and discharge conditions have not occurred that allowed for collection of the aerials at the specified discharges by September 1 of 2013, a more opportunistic approach to obtaining the aerials will be instituted and alternate flows may be substituted for the 12,500 cfs and 5,100 cfs discharges to insure that a medium and low flow set of images are collected by the end of 2013.

Digital orthorectified images of the 1980s 12,500 cfs aerial photos will be obtained to serve as the base map for overlaying the digitized riverine habitat types from the1980s map book (Trihey and Associates 1985).

6.5.4.5.2.2. Digitize Riverine Habitat Types

For the 2012 effort, 17 study sites totaling 26.3 river miles were selected from the 1980s effort The 17 sites represent over 50 percent of the 49 miles (RM 100 to RM 149) of the Middle Susitna River Segment with aquatic habitat delineated in the 1980s. The selected sites are listed in Table 6.5-4. Selection of the sites was based on consideration of habitat and geomorphic characteristics of the reach and a visual qualitative side-by-side comparison of the aerials to ensure that the selected reaches were also representative of the level of change that has occurred over the period of comparison. The sites include the seven proposed Focus Areas, as identified in Section 6.6.1.2.4, in this portion of the Middle Susitna River Segment. Aerial photography for both 1980s and present condition was obtained for the entire reach so that additional areas may be digitized in the future if warranted.

The Middle Susitna River Segment upstream of RM 150 was not studied in the 1980s; however, the current habitat features are to be delineated on 50 percent of the portion of the Segment encompassing Geomorphic Reaches MR-1 and MR-2. Six sites were selected, representing a variety of conditions and totaling 9.0 miles of the total 17.5 miles of combined Geomorphic Reaches MR-1 and MR-2. These sites include three proposed Focus Areas identified in Section 6.6.4.1.2.4. and represent approximately 50 percent of Geomorphic Reaches MR-1 and MR-2.

Coordination has occurred and will continue to occur with AEA's Spatial Data Contractor to digitize (within the aerial photography analysis study reaches) the riverine habitat types from RM 98 to RM 150 defined in the 1980s from hard copy maps found in the Middle Susitna River Segment Assessment Report (Trihey & Associates 1985). Each habitat type has been digitized as a polygon (without slivers). The digitized habitat types are overlaid on a digital orthorectified image of the 1980s 12,500 cfs black and white aerial. The habitat types were classified into the following categories: main channel, side channel, side sloughs, upland sloughs, and tributary mouths.

In 2012, riverine habitat types for the identified study sites were delineated and digitized from the 2012 aerials at the selected 23,000 cfs and for portions sites of the 12,500 cfs. Sites included the 17 sites identified for the 1980s digitization effort as well as six additional sites between RM 166.5 and RM 184, identified in coordination with the FA-IFS (Section 8.5), the R-IFS (Section 8.6), Ice Processes Study (Section 7.6), and other pertinent studies. The habitat types were digitized from the orthorectified photography using ArcGIS software (each habitat type must be a polygon without slivers). Riverine habitat was classified using the same classification categories used in the Trihey & Associates study (1985) main channel, side channel, side sloughs, upland sloughs, and tributary mouths.

In 2013, the digitization of the riverine habitat types and determination of the areas will be completed. This will include acquisition of the remaining portions of the 12,500 cfs and all of the 5,100 cfs orthorectified aerial photos.

6.5.4.5.2.3. Riverine Habitat Analysis

The information developed in the previous task are being used to develop relationships for riverine habitat versus flow for the specified reaches and habitat study sites. The relationships will be developed for both 1980s and 2012 and 2013 aerials. The riverine habitat type surface area versus flow relationships between the 1980s and current conditions are being compared at both a site and reach scale to determine if changes in the relationships have occurred. The comparison can only be performed for a portion of the reach, since the 1980s study did not cover the entire Middle Susitna River Segment. This effort will be completed in December 2012 and reported on in January 2012 for the 23,000 cfs and the portion of the 12,500 cfs aerials collected in 2012.

From RM 98 to RM 150, GIS software was used to compare the 2012/2013 versus 1980s total surface area associated with each delineated riverine habitat type at each measured flow. Results are being compiled into tables and graphs, as appropriate, to show the difference in surfaces area of the feature types between 2012/2013 and the 1980s photography and to show the change in riverine habitat types versus flow. To ensure accurate comparison to the 1980s data set, not only are the same approximate flows be compared, but the same definitions are being used for each of the riverine habitat features that are delineated (see above). The Lead Geomorphologist has provided training to the staff performing the delineation to ensure appropriate application of the habitat definitions.

Since the 34-mile river segment below the proposed Watana Dam site (RM 150 to RM 184) was not analyzed in the 1980s, this portion of the river is a new assessment (2012/2013 photography only) that will not be compared to past studies. However, the methods for analyzing riverine habitat types over the range of flows remain the same as for the downstream reach (23,000 cfs; 12,500 cfs; and 5,100 cfs). For Geomorphic Reaches MR-3 and MR-4, which include Devils Canyon and the river immediately upstream, no habitat sites have been selected for study. This reach has a high level of lateral and vertical control, the areas associated with riverine habitat types have likely experienced little change. Results of the study component Assess Geomorphic Change Middle and Lower Susitna River Segments (Section 6.5.4.4) will determine whether there has been change in geomorphic features in this portion of the Middle Susitna River Segment.

Habitat features are being compared and contrasted quantitatively and a qualitative assessment will be made of the similarity of the sites in 2012/2013 compared to the 1980s in order to assess the stability of the study sites. The results for the sites with 2012 aerials will be reported on in January 2013. A decision will also be made as to whether the remaining portions of the Middle Susitna River Segment, beyond the original selected study sites analyzed in 2012, will be digitized and analyzed in 2013–2014.

6.5.4.5.2.4. Information Required

The following available existing information will be needed to conduct this study:

- Historical 1980s orthorectified aerial photographs for the Middle Susitna River Segment.
- USGS flow records for the past 10 years for the Susitna River at Gold Creek.

The following additional information will be needed to conduct this study:

- Obtain (fly) 2012/2013 orthorectified aerial photos in the Middle Susitna River Segment at 5,100; 12,500; and 23,000 cfs (corresponds to 1980s flow) (partially completed in 2012).
- Obtain orthorectified digital images of 1980s black and white aerial photos in the Middle Susitna River Segment at 12,500 cfs base map aerial (completed in 2012).

6.5.4.5.3. Study Products

The results of the Riverine Habitat Versus Flow Relationship Middle Susitna River Segment component will be included in the Geomorphology Report. Information provided will include the following:

- Tabulation of the riverine habitat types versus flow on a reach and individual site basis for the 1980s and 2012/2013 conditions.
- Graphical representation of the riverine habitat type area versus flow relationships by reaches for both the 1980s and 2012/2013 data.
- Assessment of the change and similarity in riverine habitat types between the 1980s and 2012 and conclusions on site stability to aid the Instream Flow Study in site selection and determination of the applicability of the 1980s data to represent current conditions.

In addition, an ArcGIS shapefile will be provided with the following information:

- Orthorectified 2012/2013 aerial imagery of the Middle Susitna River Segment at 5,100 cfs; 12,500 cfs; and 23,000 cfs.
- Orthorectified 1983 aerial imagery of the Middle Susitna River Segment from RM 98 to RM 150 at 12,500 cfs.
- Digitized polygons representing the 1980s riverine habitat types for the Middle Susitna River Segment at 5,100 cfs; 12,600 cfs; and 23,000 cfs from RM 98 to RM 150 (Middle Susitna River Segment below Devils Canyon).
- Digitized polygons representing the current (2012/2013) riverine habitat types for the Middle Susitna River Segment at 5,100 cfs; 12,500 cfs; and 23,000 cfs from RM 98 to

RM 150 (Middle Susitna River Segment below Devils Canyon) and RM 150 to 184 (Middle Susitna River Segment in Devils Canyon and above Devils Canyon).

6.5.4.6. Study Component: Reconnaissance-Level Assessment of Project Effects on Lower and Middle Susitna River Segments

The goal of the Reconnaissance-Level Assessment of Project Effects on Lower and Middle Susitna River Segments study component is to utilize comparison of pre- and post-Project flows and sediment transport conditions to estimate the likelihood for potential post-Project channel change in the Lower and Middle Susitna River Segments. The study area for this effort is the Lower Susitna River Segment from RM 98 to RM 0 and the Middle Susitna River Segment from RM 184 to RM 98. The initial effort involves the Lower River and was started in 2012 and will be completed in early 2013. The results of this effort will help determine what additional analysis of Project effects may be warranted in the Lower Susitna River Segment for the 2013–2014 studies. The initial Middle River assessment will be performed in Q3 2013. Continued application of the framework to both the Lower and Middle Susitna River segments as additional information on with-Project hydrology, sediment transport, and the geomorphology of the system are developed by the various studies will provide additional context for identification of Project effects including interpretation of and integration with the Fluvial Geomorphology Modeling Study results.

6.5.4.6.1. Existing Information and Need for Additional Information

An analysis of the Lower Susitna River Segment and how riverine habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (R&M Consultants, Inc. and Trihey and Associates 1985a). This study evaluated the response of riverine aquatic habitat to flows in the Lower Susitna River Segment reach between the Yentna River confluence (RM 28.5) and Talkeetna (RM 98) (measured at Sunshine gage [approximately RM 84]) ranging from 13,900 cfs to 75,200 cfs. The study also included an evaluation of the morphologic stability of islands and side channels by comparing aerial photography between 1951 and 1983.

In another study, 13 tributaries to the lower Susitna River were evaluated for access by spawning salmon under existing and with proposed stream flows for the original hydroelectric project (R&M Consultants, Inc. and Trihey and Associates 1985b). The study contains information regarding fish run timing, mainstem and tributary hydrology, and morphology. Based on the results of this study, it was concluded that passage for adult salmon was not restricted under natural flow conditions nor was it expected to become restricted under the proposed Project operations.

An analysis of channel changes of the Middle River was presented in *Geomorphic Change in the Middle Susitna River Since 1949* (Labelle et al. 1985). In this document, aerial photographs and other data from the late 1940s through the early 1980s was evaluated to determine historical change in the Middle Susitna River Segment including the important off-channel macrohabitats identified in the 1980s studies (side channels, side sloughs, and upland sloughs).

The AEA Susitna Water Quality and Sediment Transport Data Gap Analysis Report (URS 2011) states that "if additional information is collected, the existing information could provide a reference for evaluating temporal and spatial changes within the various reaches of the Susitna

River." The gap analysis emphasizes that it is important to determine if the conditions represented by the data collected in the 1980s are still representative of current conditions, and that at least a baseline comparison of current and 1980s morphological characteristics in each of the identified subreaches is required.

Results of this study in Q1 of 2013 will provide the initial basis for assessing the potential for changes to the Lower Susitna River Segment reach morphology due to the Project in order to help inform the evaluation of the downstream limit for the Fluvial Geomorphology Modeling Study. Additional studies will be planned for 2013–2014 to continue further downstream in the Lower River if the results of this study identify a potential for important aquatic habitat and channel adjustments in response to the Project below RM 84. In addition to providing the initial assessment for informing the evaluation of the downstream limit for the Fluvial Geomorphology Modeling Study, the assessments presented in this study component will also assist in the overall evaluation of Project effects. This is why the effort was extended upstream to include the Middle Susitna River Segment in response to comments filed November 14, 2012 by NMFS and USFWS on the PSP (NMFS and USFWS).

The Stream Flow Assessment portion of this study component includes a concurrent flow and stage analysis for the Susitna River in the area of the Talkeetna and Chulitna confluences. This analysis was added in response to a comment filed November 14, 2012 on the PSP concerning the potential for Project to affect erosion in the area of the Town of Talkeetna (Teich, Cathy).

Issues associated with geomorphic resources in the Lower and Middle Susitna River Segments for which information appears to be insufficient were identified in the PAD (AEA 2011), including the following:

- G16: Potential effects of reduced sediment load and changes to sediment transport as a result of Project operations within the Lower Susitna River Segment.
- F19: The degree to which Project operations affect flow regimes, sediment transport, temperature, and water quality that result in changes to seasonal availability and quality of aquatic habitats, including primary and secondary productivity.

6.5.4.6.2. Methods

6.5.4.6.2.1. Stream Flow Assessment

Pre-Project and available post-Project hydrologic data are being compared in 2012 and the results will be reported on in January 2013. This includes a comparison of the monthly and annual flow duration curves (exceedance plots) and plots/tables of flows by month (maximum, average, median, minimum) for the Susitna River at Gold Creek, Susitna River at the Sunshine and Susitna Station gaging stations. These analyses are being conducted for the major tributaries provided in the extended record including the Chulitna River near Talkeetna, the Talkeetna River near Talkeetna, and the Yentna River near Susitna Station. In 2013, additional hydrologic indicators may be used to further illustrate and quantify the comparison between pre- and post-Project stream flows. The pre-Project data analysis includes the 61-year extended record prepared by USGS. The post-Project condition is based on initial runs of the Operations Model and the Initial Flow Routing Model developed by the engineering studies. The Operations Model provides Project releases and the routing model provides estimates of hourly flow and stage from the base of the dam at RM 184 to the downstream limit of the model near RM 84.

Using the extended record currently prepared by USGS, a flood-frequency and flood-duration analysis for pre- and post-Project annual peak flows is being performed. The flood-frequency analysis is being performed using standard hydrologic practices and guidelines as recommended by USGS (1982). The pre-Project analysis was completed in November 2012 and the post-Project analysis will be completed by the end of December 2012. The results of both analyses were be compared and reported on in January 2013.

A concurrent flow and stage analysis will be conducted in Q4 of 2013 to determine the potential for Project-induced changes in flows and stage on the Susitna River that may have the potential to alter the erosion patterns in the area of the town of Talkeetna. A technical memorandum will be prepared identifying the analysis procedures and results. If this initial analysis indicates that the changes in flows and stage on the Susitna River may be sufficient to alter the flow patterns during peak flows on the Talkeetna and Chulitna rivers, then a plan will be developed to further study this potential Project effect in 2014. It is expected that if implemented, this additional effort would include extending a branch of the Mainstem (Open-water) Flow Routing Model up the Talkeetna River and possibly the Chulitna River. As part of this effort, 2012 aerial photos acquired prior to the September 2012 high flows and after the high flows will be evaluated to determine the extent of erosion from the September 2012 high flow event. This aerial photo comparison will provide an indication of current erosion that is typical of a high flow event for pre-Project conditions.

6.5.4.6.2.2. Sediment Transport Assessment

The sediment transport data collected by USGS (See Section 6.5.4.2) are used to develop bedload, total bed material, and wash load rating curves to facilitate translation of the periodic instantaneous measurements into yields over longer durations (e.g., monthly, seasonal, and annual). This information is being used to perform an overall sediment balance for each component of the sediment load. This information will be developed as part of the Sediment Supply and Transport Middle and Lower Susitna River Segment study (see Section 6.5.4.3). The initial sediment balance will be completed in December 2012 and reported on in January 2013 to inform the review of the downstream study limit (See Section 6.6.3.2) with more detailed work effort conducted throughout 2013 and 2014 to support the Fluvial Geomorphology Modeling Study (Section 6.6).

6.5.4.6.2.3. Integrate Sediment Transport and Flow Results into Conceptual Framework for Identification of Geomorphic Reach Response

Prediction of Project-induced changes to river morphology in an alluvial river is fundamentally based on the magnitudes and directions of change in the driving variables, hydrology, and sediment supply. Initial, qualitative assessment of change can be based on Lane's (1955) equality:

$Q_w.S \sim Q_s.D_{50}$,

where Q_w is the flow, S is the slope, Q_s is the sediment transport and D_{50} is the median size of the bed material. A change in any one of the variables will require a change in the others to maintain the balance.

Use of the expansion of Lane's relation by Schumm (1977) allows the response to the changes in driving variables to be expressed in terms of channel morphometric parameters such as channel width (b), depth (d), slope (S), meander wavelength (λ), width-depth ratio (F) and sinuosity (P). For example, a potential range of changes in response to the Project in the vicinity of the Three Rivers Confluence where flows will be reduced and sediment supply could be effectively increased could be expressed as follows:

$Q_w^-, Q_s^+ \sim b^\pm, d^-, \lambda^\pm, S^+, P^-, F^+$

where + represents an increase, – represents a decrease and ± represents indeterminacy.

Application of these qualitative relations assumes that the river is alluvial and that the form and characteristics of the channel are the result only of the interaction of the flows and the sediment load. Where non-fluvial factors such as bedrock outcrop or coarse-grained paleo-flood deposits limit the adjustability of the channel, the ability to predict the direction and magnitude of channel change in response to changes in the water and sediment load below dams is reduced (Miller 1995; Grant and Swanson 1995; Grant et al. 2003).

Using the data developed for the pre- and post-Project flood frequency, flood duration, and sediment load, the geomorphic response of the Susitna River in a conceptual framework along the longitudinal profile of the river system from the Lower and Middle Susitna River Segments will be predicted. The work will be initially performed for the Lower River Segment and completed in January of 2013 in order to support evaluation of the downstream study limit for the Fluvial Geomorphology Modeling Study (Section 6.6.3.2). The initial effort on the Middle River will be performed in Q3 of 2013. The conceptual framework developed by Grant et al. (2003) that relies on the dimensionless variables of the ratio of sediment supply below the dam to that above the dam and the fractional change in frequency of sediment transporting flows is being used to predict the nature and magnitude of the response of the geomorphic reaches in the Lower and Middle Susitna River Segments. Other analytical approaches are also being considered to evaluate potential for geomorphic adjustments of the reaches in the river segments due to the Project. These include an evaluation of morphologic changes based on changes to the degree and intensity of braiding using Germanoski's (1989) modified braiding index (MBI) that has been used to predict channel responses to anthropomorphically-induced changes in Alaskan, glacial-fed rivers including the Toklat, Robertson, and Gerstle Rivers (Germanoski 2001). As demonstrated by Germanoski and Schumm (1993), Germanoski and Harvey (1993), and Harvey and Trabant (2006), the following are the expected directions of responses in the MBI values to significant changes in bed material gradation and sediment supply:

- If the D50 increases and there is a supply of sediment, then MBI increases.
- If the D50 increases and there is a significant decrease in the supply of sediment, then MBI decreases.
- If the bed aggrades, then MBI increases.
- If the bed degrades, then MBI decreases.

Specific MBI values for braided reaches of the Susitna River under existing conditions are being developed from aerial photography, and the likely changes in values in response to the Project will be assessed. Prediction of the direction, if not the magnitude of changes, provide useful information for assessing likely Project effects on geomorphic features that form instream habitats. It also provides context to assist in interpreting and assessing the validity of results from the bed evolution models and other analytical tools.

6.5.4.6.2.4. Literature Review on Downstream Effects of Dams

To assist in the assessment of potential Project effects on the geomorphology of the Susitna River, a search and review of literature on the downstream effects of dams will be conducted. There is considerable literature on this topic for dams within the United States as well as around the world. Grant et al. (2003) identified in the previous section in one such reference, with others including, but not limited to Sabo et al. (2012), Clipperton et al. (2003), Schmidt and Wilcock (2000), Shields et al. (2000), Freidman et al. (1998), Collier et al. (1996), and Williams and Wolman (1984). Efforts will be made to locate information on specific dams within the region and in other similar cold region environments around the world. Information could be used to extend or complement field studies as well as reduce the uncertainty associated with study results and conclusions.

6.5.4.6.2.5. Information Required

The following available existing information will be needed to conduct this study:

- Historical suspended sediment and bedload data for the Susitna River.
- Flow records for the Susitna River.
- Characterization of bed material from previous studies.

The following additional information will need to be obtained to conduct this study:

- Suspended and bedload data for the Susitna River at Tsusena Creek and Gold Creek being performed by USGS.
- Extended flow record for the Susitna River and gaged tributaries within the study area being developed by USGS.
- Channel morphologic data for existing conditions including, width, depth, width/depth ratios, and MBIs.

6.5.4.6.3. Study Products

The results of the Reconnaissance-Level Assessment of Project Effects on Lower Susitna River Segment Channel Sediment component will be included in the Geomorphology Report. Information provided will include the following:

- Pre- and post-Project comparison of hydrologic parameters for the Susitna River at Sunshine and at Susitna Station, including:
  - Monthly and annual flow duration curves
  - Annual peak flow frequency
  - Monthly flow statistics (maximum, average, median, minimum)
- Summary of changes in sediment transport for pre- and post-Project conditions in the Lower Susitna River Segment.
- Results of the assessment of anticipated Project effects on the Lower Susitna River Segment based on the analytical framework in Grant et al. (2003) and other indicators of potential channel change such as the MBI by Germanoski (1989).

6.5.4.7. Study Component: Riverine Habitat Area versus Flow Lower Susitna River Segment

The goal of this study component is to conduct an initial assessment of the potential for Project effects associated with changes in stage to alter Lower Susitna River Segment riverine habitat. This effort was conducted in 2012. If the decision is made to continue detailed studies of Project effects into the Lower Susitna River, then this effort will be expanded to include mapping of the 1980s aquatic macrohabitat type in the Lower Susitna River Segment and the development of the wetted macrohabitat versus flow relationships.

6.5.4.7.1. Existing Information and Need for Additional Information

An analysis of the Lower Susitna River Segment and how riverine habitat conditions change over a range of stream flows was performed in the 1980s using aerial photographic analysis (R&M Consultants, Inc. and Trihey and Associates 1985a). This study evaluated the response of riverine aquatic habitat to flows in the Lower Susitna River Segment reach between the Yentna River confluence (RM 28.5) and Talkeetna (RM 98) (measured at Sunshine gage at approximately RM 84) ranging from 13,900 cfs to 75,200 cfs. Results of this study will provide the initial basis for assessing the potential for changes to the Lower Susitna River Segment reach morphology due to the Project. Additional studies will be planned for 2013–2014 if the results of this study and other studies identify a potential for important aquatic habitat and channel adjustments in response to the Project.

6.5.4.7.2. Methods

This study component is divided into three tasks: Riverine Habitat-Flow Relationship Assessment, Synthesis of the 1980s Aquatic Habitat Information, and Contingency Analysis to Compare Wetted Channel Area. The third task is optional and dependent on a determination if comparison of riverine habitat in the Lower Susitna River Segment under pre- and post-Project flows is warranted for additional flow conditions and determination of whether aquatic resource studies need to be continued further downstream in the Lower Susitna River Segment.

6.5.4.7.2.1. Change in River Stage Assessment

A tabular and graphical comparison of the change in water surface elevations associated with the results of the pre- and post-Project stream flow assessment (Section 6.5.6.2.1) was developed using the stage-discharge relationships (rating curves) for the Sunshine and Susitna Station gaging stations. This comparison included monthly and annual stage duration curves (exceedance plots) and plots/tables of stage by month (maximum, average, median, minimum). Additional parameters to describe and compare the pre- and post-Project water surface elevations may be performed in 2013. A graphical plot of a representative cross-section at each gaging station was developed with a summary of the changes in stage (water surface elevation) for the two flow regimes. If possible, the location of the active channel and the floodplain will also be identified on the cross-section. Changes in stage will be related to exposure of bars through the previously developed bar area discharge curves, thereby providing the link between both vegetation and ice impact assessments. The stage change information was also used to estimate and compare the areas of the various riverine habitat types for the existing and with-Project conditions over a range of flow frequencies.

The availability of USGS winter gage data with respect to discharge and ice elevation/thickness was investigated. Coordination with the Ice Processes (Section 7.6) occurred to obtain information on ice elevation/thickness. This information was summarized and will be analyzed in Q1 2013 to make an initial assessment of discharge effects on ice elevation.

6.5.4.7.2.2. Synthesis of the 1980s Aquatic Habitat Information

A synthesis/summary of the 1980s Response of Aquatic Habitat Surface Area to Mainstem Discharge Relationships in the Yentna to Talkeetna Reach of the Susitna River (R&M Consultants, Inc. and Trihey & Associates 1985a) was performed and will be provided with the January 2013 technical memorandum. A synthesis/summary of the Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River (R&M Consultants, Inc. and Trihey & Associates, 1985b) was also performed and will be included in the January 2103 technical memorandum. Data have been summarized with respect to the anticipated pre- and post-Project flow changes, where applicable.

6.5.4.7.2.3. Site Selection and Stability Assessment

Five sites in the Lower Susitna River Segment were selected from the Yentna to Talkeetna reach map book (R&M Consultants, Inc. and Trihey and Associates 1985a) at the approximately 36,600 cfs flow at Sunshine Gage to study in 2012. These sites were selected in coordination with the FA-IFS and the R-IFS. A side-by-side comparison of the sites using the 1983 36,600-cfs aerials and the 2011 aerials from the Mat-Su Borough LiDAR project were used to qualitatively assess site stability. Only sites that had been relatively stable during the period from the 1980s to present were selected. The five sites selected were: Side Channel IV-4 (SC IV-4), Willow Creek (SC III-1), Goose Creek (SC II-4), Montana Creek (SC II-1) and Sunshine Slough (SC I-5).

6.5.4.7.2.4. Aerial Photography Analysis, Riverine Habitat Study Sites (RM 28 to RM 98)

Using GIS and the September 6, 1983 aerials for the 36,600-cfs flow, mainstem and side channel riverine habitat was digitized from the 1985 map book (R&M Consultants, Inc. and Trihey & Associates 1985a) for the selected sites. Each area associated with a habitat type was digitized as a polygon (without slivers). To provide a comparison with current conditions, aerials flown at approximately 36,600 cfs were obtained (actual flows ranged from 38,100 cfs to 46,900 cfs). The current wetted areas of the riverine habitat types, as defined in the 1980s analysis, were delineated for the selected sites.

In January 2013, the difference in wetted surface area of the main channel and side channel riverine habitats (as defined in R&M Consultants, Inc. and Trihey & Associates 1985a) will be compared between the 1983 and current conditions. The areas of the riverine habitat types, along with the initial 2012 results of the Assess Geomorphic Change Middle and Lower Susitna River Segments study component (Section 6.5.4.4), will be compared and contrasted quantitatively, and a qualitative assessment will be made of the similarity of the 1980s sites compared to the 2012 sites. The assessment of site stability will help determine the applicability of Lower Susitna River Segment riverine habitat information developed in the 1980s to supplement information being developed in the current Project studies.

6.5.4.7.2.5. Additional Aerial Photography Analysis, Riverine Habitat Study Sites (RM 28 to RM 98)

Based on the results of the comparison of riverine habitat areas at the selected study sites for the Lower Susitna River Segment and results of the Assess Geomorphic Change Middle and Lower Susitna River Segments study component (Section 6.5.4.4), a determination of whether to perform a similar effort and comparison for up to two additional discharges will be made (discharges corresponding to the analysis of wetted habitat areas in the Lower Susitna River Segment include 75,200 cfs; 59,100 cfs; 36,600 cfs; 21,100 cfs; and 13,900 cfs). This decision will be made in coordination with the FA-IFS (Section 8.5), R-IFS (Section 8.6), Ice Processes Study (Section 7.6), Characterization and Mapping of Aquatic Habitats Study (Section 9.9), and licensing participants.

If the decision is made to analyze riverine habitat at two additional discharges, the flows will be selected and the associated habitat areas digitized from the 1985 map book. New aerial photographs will be obtained at the selected discharges. If a decision is made to extend studies further downstream in the Lower Susitna River Segment, additional sites for delineation may be selected. The process, schedule, and criteria for extending the studies further in the Lower Susitna River Segment is described in Section 6.6.3.2 based on geomorphic criteria and in Section 8.5.3 based on results of the Mainstem (Open-water) Flow Routing Model. The geomorphic criteria will be evaluated in Q1 2013 and again in Q1 2014. The Mainstem Flow Routing Model trigger will be evaluated in Q1 2013.

The riverine habitat types at the selected sites will be delineated and digitized on these images to represent the current condition. The difference in wetted surface area of the main channel and side channel riverine habitats will be compared between the 1983 and current conditions for the two additional discharges. Additional sites for delineation of existing aquatic macrohabitat beyond those identified in the 1980s may be included in the optional effort if results of the interim flow and fish and aquatics studies require this information. (The USFWS Study Plan Request included digitizing the riverine habitat types for three flows in the Lower Susitna River Segment. This topic was discussed at the Water Resources TWG meeting held on June 14, 2012. It was explained that the current proposal by AEA is to digitize riverine habitat for a single flow in 2012, then based on decisions on whether to continue Focus Area studies into the Lower Susitna River Segment and how far those studies would be carried downstream, the optional aerial photo analysis identified in this task would be performed in 2013. USFWS agreed at the meeting that this approach was appropriate.)

6.5.4.7.2.6. Information Required

The following available existing information will be needed to conduct this study:

- Historical 1980s orthorectified aerial photographs for the Lower Susitna River Segment.
- USGS flow record for the Sunshine and Susitna Station gages including measurement notes, rating curves, stage shifts, cross-sections, and information on ice thickness.

The following additional information will need to be obtained to conduct this study:

- Results of Study Component, Assess Geomorphic Change Middle and Lower Susitna River Segments (Section 6.5.4.4).

6.5.4.7.3. Study Products

The results of the Riverine Habitat Area versus Flow Lower Susitna River Segment component will be included in the Geomorphology Report. Information provided will include the following:

- Comparison of pre- and post-Project stage at the Susitna River at Sunshine and the Susitna Station gages associated with the flow duration curves (monthly and annual) and monthly statistics.
- Summary of available USGS measurements of ice elevation/thickness to identify the need to perform analysis of the discharge effect on ice elevation.
- Narrative describing the synthesis of the 1980s aquatic habitat versus flow relationships and the anticipated post-Project flow changes.
- Results for the selected flow of the comparison of the riverine habitat areas, by type, for the selected sites for 1980s and current aerial imagery.

In addition, an ArcGIS shapefile will be provided with the following information:

- Digitized polygons of the 1980s and current riverine habitat surface areas at the selected sites.

6.5.4.8. Study Component: Reservoir Geomorphology

The goal of this study component is to characterize changes resulting from conversion of the channel and portions of the river valley to a reservoir. For the majority of this study component (Sections 6.5.4.8.2.1, 6.5.4.8.2.2 and 6.5.8.4.3) the study area extends from the proposed Watana Dam site (RM 184) upstream to include the reservoir inundation zone and the portion of the river potentially affected by backwater and delta formation in the river, which is currently assumed to correspond to approximately five miles above the reservoir maximum pool (at approximately RM 238). This portion of the proposed study area is shown in Figure 6.5-6. For the Bank and Boat Wave Erosion downstream of Watana Dam (Section 6.5.4.8.2.4) portion of the study component, the study area extends from the proposed Watana Dam (RM 184) downstream to the Three Rivers Confluence (RM 98). This study area corresponds to the entire Middle Susitna River Segment. Specific objectives of the Reservoir Geomorphology study component include the following:

- Estimate reservoir sediment trap efficiency and reservoir longevity.
- Estimate the Susitna River and inflow tributary delta formation with respect to potential effects on upstream fish passage.
- Estimate erosion and beach formation in the Watana Reservoir drawdown zone and shoreline area.
- Evaluate the resistance of the Susitna River banks to boat wave erosion under Project operations and if the assessment indicates the lower portion of the bank is not sufficiently armored and/or boat activity may cause an increase in erosion of the upper part of the bank, the magnitude of the potential effects will be estimated.

6.5.4.8.1. Existing Information and Need for Additional Information

Construction and operation of the proposed Project will impound a reservoir for approximately 41.5 miles upstream from the dam. The reservoir will likely trap essentially all of the coarse sediment load and much of the fine sediment load that enters the impoundment from the upstream Susitna River. The coarse sediment load will form a delta at the head of the reservoir that will be re-worked by seasonal fluctuations of the reservoir elevation.

Similar to the mainstem Susitna River delta at the head of the reservoir, deltas of varying size will likely form where tributaries enter the reservoir. The amount and distribution of sediment deposits may affect the connectivity of the surface flows between the reservoir and the tributary channels, which may, in turn, block fish passage into the tributaries. The available information does not contain data describing the magnitude and size distribution of the annual sediment loads from the tributaries that enter the reservoir, a potentially significant data gap.

Operation of the Project would result in seasonal and daily water-level fluctuations in Watana Reservoir, which will result in beach formation and erosion and/or mass wasting of soils within the impoundment. The results of the erosion potential portion of this study will provide information on the extent of these processes and the potential for alterations to Project operations or erosion control measures to reduce erosion and mass wasting.

6.5.4.8.2. Methods

The methods are divided into three areas: reservoir trap efficiency and sediment accumulation rates, delta formation, and reservoir erosion. (In the Study Plan comments, NOAA-NMFS and USFWS requested that a description of reservoir sediment removal procedures be included in the Geomorphology effort. At the Water Resources TWG meeting held June 14, 2012, AEA's consultants indicated that there are no plans for removal of sediment deposited in the reservoir because no feasible procedures for accomplishing this on a large reservoir with a substantial permanent pool currently exist. The reservoir will have a finite life as a result of sedimentation and this will be estimated as part of the Reservoir Geomorphology study component.

6.5.4.8.2.1. Reservoir Trap Efficiency and Sediment Accumulation Rates

Inflowing sediment loads from the mainstem Susitna River will be determined by integrating the bedload and suspended load equations developed for the Susitna River at Tsusena Creek over the extended hydrologic record for the Susitna River. Due to the short record at this station, the information collected at Vee Canyon and the bedload and suspended load data collected at Gold Creek will be used to further refine Tsusena sediment rating curves. The methods described in the Empirically Characterize Susitna River Sediment Supply and Transport study component will be used to develop the incoming sediment load.

Sediment loading from the significant tributaries within the reservoir may also affect reservoir life. The reservoir tributary loading will be accounted for in the sediment load data collected for the Susitna River at Tsusena Creek. Similarly, if the sediment loading from the reservoir perimeter is substantial, it will be incorporated into the analysis. Potential additional sediment loading resulting from glacial surge will be investigated in the Glacier and Runoff Changes Study (Section 7.7.4.4, Analyze Potential Changes in Sediment Delivery to Watana Reservoir). If this investigation indicates that the increased sediment load can actually be delivered in substantial quantities to Watana Reservoir, more detailed analyses of the increased loading will be performed and a sediment loading scenario accounting for glacial surge will be added to the reservoir trap efficiency and sediment accumulation analysis. This would include an estimate of the reduction in reservoir life that could result from sediment loading associated with periodic glacial surges.

Due to the relatively large storage capacity of the proposed reservoir, it is reasonable to assume that all sand and coarser sediment size fractions delivered to the reservoir will be trapped, while a substantial amount of the fine-grained, colloidal sediments associated primarily with glacial outwash will pass through the reservoir into the downstream river. When applied over a long-term horizon, the amount of trapped sediment can be used to evaluate the impacts of sedimentation on reservoir storage capacity. If the analysis indicates that a substantial amount of fine sediment will deposit in the reservoir, consolidation of the deposits will also be considered in the analysis. (Note that consolidation of sands and gravels is minimal.) Potential methods for estimating the trap efficiency of the fine sediment include the relationships from Einstein (1965) and Li and Shen (1975). The latter method may be the most appropriate because it accounts for the tendency of suspended particles to be carried upward in the water column due to turbulence. Estimates of the trap efficiency for the fine sediment will be made using the Brune (1953) method. The Brune (1953) method that was recommended by Strand and Pemberton (1987) for use in large or normally-ponded reservoirs (Morris et al. 2007) can be used to check the reasonableness of results obtained from the other methods, although this method does not provide a means of separating the behavior of different particle sizes in the inflowing load. Chen (1975) may also be another method to check the reasonableness of the trap efficiency determination. The Churchill (1948) method is also commonly used to estimate reservoir trap efficiency; however, this method is more applicable for settling basins, small reservoirs, and flood-retarding structures and should probably not be used for this study. The proposed methods will provide a basis for estimating the quantity of the various size fractions that either pass through or are trapped in the reservoir. If the initial analyses indicate that a more sophisticated approach is necessary to obtain reasonable trap efficiencies, consideration will be given to using a numerical model such as Environmental Fluid Dynamics Code (EFDC) (Hamrick 1992) model to refine the estimates.

6.5.4.8.2.2. Delta Formation

Estimation of the formation of deltas on the mainstem Susitna River and its tributaries as they enter the proposed Watana Reservoir will require estimation of sediment load. Although the USGS measurements in the Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek, and Sunshine Gage Stations study component target three locations along the Susitna River, sediment transport estimates will be needed at additional locations, including ungaged tributaries. Because of the potential impacts on fish movement into the tributaries, ungaged tributaries that require study will be identified in coordination with the Fish studies. In these locations, reconnaissance will be performed to characterize the sediment transport regime and to identify appropriate methods of calculating yields. In cases where bed material delivery to the proposed reservoir could produce deltas with the potential to affect upstream fish migration, surveys of tributary channel geometry and bed material gradations based on samples collected during the reconnaissance will be coupled with selected bed material transport functions to calculate sediment yield rating curves. Long-term flow hydrographs synthesized for the ungaged tributaries will be needed from other studies for each of the selected tributaries to calculate sediment yields. Alternate approaches to quantifying sediment yield, such as previous studies of regional sediment yields (Guymon 1974) may also be considered.

To estimate the development of the deltas, the sediment yield results can be coupled with the physical constraints imposed by Project operations (i.e., variation in lake levels) on the topset and foreset slopes of the deltas to simulate growth and development of deltas throughout the period of the license (USBR 1987; Morris and Fan 1998). The volume of sediments deposited will be distributed within the topographic constraints of the reservoir fluctuation zone identified for the period when mainstem and tributaries are delivering significant sediment load. Consideration will be given to which portion of the sediment load would form the delta deposits based on settling characteristics.

6.5.4.8.2.3. Reservoir Erosion

Erosion and mass wasting potential will be assessed within the reservoir fluctuation zone and along the shoreline for 100 vertical feet above the proposed full pool elevation. The following potential erosion processes will be evaluated:

- Mass wasting.
- Surface erosion from sheetwash.
- Wave erosion (wind and boat wakes if motorized boat recreation is permitted).
- Solifluction, freeze-thaw, and thawing of permafrost.
- Beach/bank development at full pool.
- Erosion by ice movement on the reservoir surface.

The following existing spatial data will be collected:

- Topography (LiDAR as available).
- Geo-rectified aerial photography and recent stereo pairs to evaluate existing mass wasting sites.
- Geologic and soil mapping, including work done for the Susitna Hydroelectric Project (Acres 1982) and subsequent mapping by USGS and the Alaska Division of Geologic and Geophysical Surveys. This task will be coordinated with the Geology and Soils Study.
- Vegetation mapping; this task will be coordinated with the Botanical Resources Study.

In addition, the following information will be obtained from other resource study leads:

- Expected reservoir surface elevation fluctuations (seasonal, daily, maximum hourly lowering rate) from the Project Operation Study.
- Expected motorized watercraft recreational use data (if any, from the Recreation and Aesthetic Resources Study).
- Daily air temperature (maximum/minimum) and wind (speed, direction) data from the Water Quality Modeling Study (Section 5.6).

- Expected ice development and movement within the reservoir from the Ice Processes Study (Section 7.6).

The existing spatial data will be evaluated to determine if sufficient geologic and soil data are available to evaluate erosion and mass wasting potential. The mass wasting work will be coordinated with the Geology and Soils Study and geotechnical investigations of the dam site and reservoir area that are planned under the geotechnical exploration and testing program. The geotechnical investigations for the dam site and reservoir will cover large, deep rotational and block failures; the Reservoir Erosion Study will cover shallow translational slides (added in response to the FERC comment letter dated May 31, 2012). The initial investigation will be completed by spring 2013. If additional soil/geologic mapping or data on soil characteristics are needed, field mapping and sample collection will occur during summer 2013 in coordination with the Geology and Soils, and Geotechnical studies. This work could include mapping or collection of soil properties of interest in representative areas, including soil texture, depth, permafrost presence/absence, infiltration capacity, and cohesion.

The spatial data (topography, geology, soils, vegetation) will be used to prepare an erosion and mass wasting hazard map of the reservoir shoreline and inundation area. Areas with similar slope, soil, aspect, and potential wave fetch will be delineated. Areas above and below the full pool elevation will be mapped separately.

The erosion potential for representative erosion/mass wasting hazard polygons will be evaluated as follows:

- Mass wasting – evaluate potential for mass wasting based on slope gradient, soil properties, and anticipated pore pressures/fluctuations. This work will be carried out in coordination with the geotechnical investigation of the dam site and reservoir area. A GIS-based model such as SHALSTAB may be used to analyze shallow translational slides if sufficient data exist.
- Surface erosion from sheetwash – estimate surface erosion potential using WEPP and/or RUSLE.
- Wind (aeolian) erosion from exposed reservoir and delta surfaces and the floodplain downstream of Watana Dam – evaluate using the USDA-NRCS WEQ (Wind Erosion Equation) or WEPS (Wind Erosion Production System) to provide information on dust production for the recreation and aesthetics studies (in response to request by USDOI-NPS in a letter dated May 24, 2012).
- Wave erosion (wind and boat wakes if motorized boat recreation is permitted) – estimate erosive energy of waves based on methods in Finlayson (2006) and Sherwood (2006).
- Solifluction, freeze-thaw, and thawing of permafrost – evaluate potential based on soil properties, seasonal reservoir water elevations, and daily maximum/minimum temperatures.
- Beach/bank development at full pool – use the beach development model in Penner (Penner 1993; Penner and Boals 2000).
- Erosion by ice movement on the reservoir surface – evaluate potential for ice erosion based on reservoir elevation and coordination with the Ice Processes Study (Section 7.6).

6.5.4.8.2.4. Bank and Boat Wave Erosion downstream of Watana Dam

It has been suggested that Project operations may cause increased bank erosion, i.e., cumulative to ongoing erosion associated with boat waves, particularly during load-following operations. (This effort was added based on requests from the agencies at the Water Resources TWG meeting on June 14, 2012.) Load-following will primarily occur during the winter months when flows are relatively low (in the range of 5,000 cfs to 14,500 cfs). Boat activity is relatively infrequent (or not present due to ice conditions) during this period; thus, cumulative impacts of these two processes are very unlikely. Based on preliminary information, it appears that the lower portion of the bank that would be affected by the load-following operations is well armored with cobble-sized material; thus, additional erosion due to the load-following alone is unlikely. The Project may reduce flows and the associated river stage during the runoff period in late spring and summer. During the initial phases of the study, data will be collected to assess the amount of armoring of the portion of the banks that will be affected by load-following to assess whether or not bank erosion in this zone is likely. In addition, the bank material characteristics in the range of stages during the periods of frequent boat activity will be assessed under existing conditions and Project operations to determine if changes associated with the Project could cause an increase in bank erosion. If the information indicates the lower portion of the bank is not sufficiently armored and/or boat activity may cause an increase in erosion of the upper part of the bank, the magnitude of the potential effects will be investigated. Factors that may be considered include the following:

- The potential effects of rapid changes in stage, and the associated pore-water pressures on bank stability during the load-following period.
- The typical wave climate and frequency of use of the types of boats that operate in the reach (it is assumed that the boat types and frequency of use will be available from the Recreation studies).
- The change in erosion potential associated with the boat waves due to the change in stage under Project operations during the period of primary boat activity.

6.5.4.8.3. Study Products

The results of the Reservoir Geomorphology component will be included in the Geomorphology Report. Information provided will include the following:

- Determination of average annual trap efficiencies for sediment by general size characterization (clays, silts, sands, and gravels).
- Estimate of average annual sediment loading to the reservoir from the potential primary sources including the upstream Susitna River, reservoir tributaries, and shoreline erosion.
- Estimate of reservoir life based on extrapolation of the sedimentation rate.
- Sediment outflow rating curves to serve as downstream supply for the Fluvial Geomorphology Modeling Study.
- Discussion of the tributary delta formation processes and characterization of the estimated size, vertical extent, and morphology (topset and foreset slopes) of the deltas at the selected tributary mouths.

- Discussion of potential erosion areas within the proposed reservoir, including erosion type, relative erosion potential, Project-related factors affecting erosion, and potential mitigation measures.
- Map showing reservoir erosion hazard areas (completed in coordination with the Geology and Soils and Geotechnical studies).

In addition, an ArcGIS shapefile will be provided with the following information:

- Identification of all tributaries studied for potential tributary delta formation.
- Estimated footprint of delta formation for the selected tributaries.
- Reservoir erosion hazard map units.

6.5.4.9. Study Component: Large Woody Debris

The goal of this study component is to assess the potential for Project construction and operations to affect the input, transport, and storage of large woody debris in the Susitna River. Specific objectives include the following:

- Evaluation of large woody debris recruitment in the Middle and Lower Susitna River Segments' channels (including upstream of Watana Reservoir).
- Characterization of the presence, extent, and function of large woody debris downstream of the Watana Dam site.
- Estimation of the amount of large woody debris that will be captured in the reservoir and potential downstream effects of Project operation.
- Work in conjunction with the Fluvial Geomorphology Modeling Study to estimate potential Project effects on large woody debris recruitment and associated changes in the processes that create and influence the geomorphic features linked to important aquatic habitats of the Middle and Lower Susitna River Segments.

The study area for the Large Woody Debris study component includes the Susitna River from the mouth (RM 0) upstream to the confluence with the Maclaren River (RM 260).

6.5.4.9.1. Existing Information and Need for Additional Information

The role of large woody debris in the development of channel morphology and aquatic habitat has been widely studied in meandering and anastomosing channels. Large wood and wood jams can create pool habitat, affect mid-channel island and bar development, and create and maintain anastomosing channel patterns and side channels (Abbe and Montgomery 1996, 2003; Fetherston et al. 1995; Montgomery et al. 2003; Dudley et al. 1998; Collins et al. 2012). In addition, large wood can provide cover and holding habitat for fish and help create habitat and hydraulic diversity (summary in Durst and Ferguson 2000). Despite the wealth of large woody debris research, little is known of the role of large woody debris in the morphology and aquatic biology of braided, glacial rivers. Large woody debris may play a role in island formation and stabilization, as well as side channel and slough avulsion and bank erosion, although the role of large woody debris in altering hydraulics in the lower Susitna River may be limited due to the size of the river (J. Mouw, ADF&G, personal communication, May 14, 2012).

Construction and operation of the Project has the potential to change the input, transport, stability, and storage of large woody debris downstream of the Watana Dam site by changes to the flow regime, ice processes, and riparian stand development, and interruption of wood transport through the reservoir. An assessment of the source, transport, and storage of large woody debris in the Susitna River and the role of large woody debris in channel form and aquatic habitat is needed to evaluate the magnitude of these effects. Construction and operation of the Project will likely alter large woody debris input and transport downstream of the Watana Dam site. An assessment of the source, transport, and storage of large woody debris in the Susitna River and the role of large woody debris in channel form and aquatic habitat would provide data on the current status of large wood in the river which, in conjunction with data from the studies of hydrology, geomorphology, riparian and aquatic habitat, and ice processes, would be used to determine the potential effects of Project operations on large wood resources. The information can also be used to determine whether protection, mitigation and enhancement (PM&E) measures are necessary, such as a large woody debris management plan and handling of wood that accumulates in the reservoir.

6.5.4.9.2. Methods

Available recent and historic high-resolution aerial photography will be used to assess large woody debris characteristics in the Susitna River between the mouth and the Maclaren River. It is anticipated that large woody debris input, transport, and storage characteristics will vary along the length of the river. Four reaches have been initially delineated with distinct characteristics: downstream of the Three Rivers Confluence; between the Three Rivers Confluence and Devils Canyon; Devils Canyon; and upstream of Devils Canyon. However, the Geomorphic Reaches delineated in the Delineate Geomorphically Similar (Homogenous) Reaches (Section 6.5.4.1) study component will be used as a basis for final reach determination.

Large woody debris will be inventoried to the extent practical on the aerial photographs. Information regarding the sources of large woody debris, locations of large woody debris in the river channel, and the relationship of large woody debris to channel or slough habitat and geomorphic features will be collected and correlated with bank erosion and riparian vegetation mapping from the geomorphology mapping and riparian habitat mapping studies to identify potential recruitment methods (Mouw 2011; Ott et al. 2001). If adequate historic aerial photographs are available, the stability of large wood pieces and jams between photo years will be assessed in representative areas of the river.

It is likely not possible to identify all wood on the aerial photographs. As a supplement to large woody debris information obtained from aerial photographs, a reconnaissance assessment of large woody debris in the Susitna River between the proposed Watana Dam Site and Willow was made in coordination with aquatic/riparian habitat mapping June 2012. This assessment suggested that the primary large woody debris input mechanisms in the Middle Susitna River are wind throw, wind snap, ice snap, and bank erosion. Wood was observed in association with scour pool, islands heads, side channels, and channel margins. The Chulitna River appears to provide a large amount of woody debris to the Susitna River downstream from Three Rivers, where the Susitna becomes braided with both stable, racked log jams and single non-stable piece of wood.

Field studies of large woody debris will take place during 2013–2014 to (1) verify the large wood data collected from the aerial photographs at 4–5 representative sites in each of the four reaches discussed above, and (2) provide more detailed field information on large wood input, stable/key piece size, large wood/aquatic habitat function, and large wood stability in the river within each of the Focus Areas. It is anticipated that the following types of large woody debris data will be collected as part of a field inventory of large wood in 2013–2014:

- GPS location (to correlate with geomorphology, aquatic, and riparian habitat mapping from other studies).
- Wood size class (diameter, length, volume).
- Root wad status of attachment.
- Single piece, accumulation, or log jam.
- Decay class.
- Species if known.
- Input mechanism if known (windthrow, bank erosion, ice processes, etc.).
- Channel location (side; mid channel; side channel inlet, middle, outlet; associated with island or bar – and where on island or bar, etc.).
- Wood orientation in channel.
- In wetted or bankfull channel or potential input (leaning over bankfull channel).
- Function (scour pool, bar forming, island forming, side channel inlet protection, bank protection, aquatic cover, etc.) and associated geomorphic features.
- For log accumulations and jams: key piece size.
- Area/grain size of any associated sediment deposits.

The aerial photograph and field inventories of large wood will be used to determine large wood input processes, large wood transport and storage, and how large wood is functioning in the Susitna River to influence geomorphic, riparian, and aquatic habitat processes. Based on estimated large wood input and transport upstream of the Watana Dam site, the potential effects of reservoir operation on trapping upstream large wood will be assessed. In addition, the potential for operation of the Project to alter large wood input and transport downstream of the dam site will be analyzed. Modeling of the interaction between large woody debris and bedload transport/geomorphic processes will take place at selected Focus Areas utilizing the 2-D models described in Section 6.6. The analysis will require coordination with other geomorphology component studies, and the sediment transport, ice processes, riparian habitat, aquatic habitat, and instream flow studies.

6.5.4.9.3. Study Products

The results of the large woody debris component will be included in the Geomorphology Report. Information provided will include the following:

- Existing large woody debris input mechanisms and source areas.
- Existing large woody debris loading by geomorphic zone.

- Observations and discussion of how large woody debris is currently functioning in the Susitna River, including a discussion of interactions with riparian and aquatic/fish habitat, geomorphic processes (sediment transport/channel forming processes), ice processes, and flows.
- Discussion of potential for Project construction and operation to affect large woody debris input and transport in the Susitna River.
- Map showing current large woody debris loading.

In addition, an ArcGIS shapefile will be provided with the following information:

- Location of large woody debris mapped from aerial photographs and during field visits.

6.5.4.10. Study Component: Geomorphology of Stream Crossings along Transmission Lines and Access Alignments

The goals of this study component are to characterize the existing geomorphic conditions at stream crossings along access road/transmission line alignments and to determine potential geomorphic changes resulting from construction, operation, and maintenance of the roads and stream crossing structures.

6.5.4.10.1. Existing Information and Need for Additional Information

Development of the Watana Dam will require road transportation from either the Denali Highway or the railroad near Gold Creek or Chulitna to the dam site as well as a transmission line from the powerhouse to an existing transmission line intertie. Construction, use, and maintenance of the roads and transmission lines have the potential to affect stream geomorphology if stream crossing structures constrict flow or alter transport of sediment or large wood, or if sediment is delivered to the streams from erosion of the road prism.

Three different access/transmission alignments are currently being considered (Figure 6.5-7). Work currently underway may refine or change the number of alignments that are finally considered for the project, and may include upgrades to existing road systems (e.g., Denali Highway). The Geomorphology of Stream Crossings along Transmission Lines and Access Alignments study area will include the corridors that are under consideration at the beginning of the study work in 2013.

The three alignments currently under consideration are designated as Denali, Chulitna, and Gold Creek. The Alaska Department of Transportation and Public Facilities (ADOT&PF) evaluated potential access corridors, including the Denali and Chulitna options (HDR 2011). The analysis considered the number of stream crossings as one criterion, among many others, during the screening process, but a detailed analysis of the geomorphic effects of the stream crossings on bedload transport, large woody debris, and channel functions was not conducted.

A road in the Denali alignment would cross Seattle Creek and Brushkana Creek, two major drainages within the Nenana River watershed, and Deadman Creek within the Susitna River watershed. A road in this alignment would require a total of 15 stream crossings. A Gold Creek access alignment would require 23 stream crossings. The major streams that would be crossed by the Gold Creek access alignment include Gold Creek, Fog Creek, and Cheechako Creek. Smaller streams crossed include tributaries to Prairee and Jack Long creeks, and a number of unnamed tributaries to the Susitna River. A road in the Chulitna alignment would require about 30 stream crossings including the Indian River, and Thoroughfare, Portage, Devils, Tsusena, and Deadman creeks. The Chulitna alignment would also cross 10 small, unnamed tributaries of Portage Creek, three small tributaries of Devils Creek, seven smaller tributaries to the Upper Susitna River Segment, and two tributaries of Tsusena Creek. Construction of Project access roads and transmission lines would require stream crossing structures. Stream crossing structures have the potential to affect stream geomorphology in the following ways:

- Altering hydraulics upstream and downstream of the crossing if flow is constricted. This can lead to sediment deposition upstream of the crossing or bank erosion/channel incision downstream.
- Altering migration of streams across a floodplain.
- Inhibiting movement of large woody debris.
- Increasing sediment delivered to a stream if road erosion is occurring near stream crossings.

Data collected during this study will help determine the potential for proposed stream crossings to affect stream hydraulics, morphology, sediment transport, and large woody debris transport. This analysis will also provide data needed for design of appropriate stream crossing structures and PM&E measures to minimize effects.

6.5.4.10.2. Methods

The following data would be obtained from existing sources:

- Topography at stream crossings.
- Aerial photography of stream crossings.
- Crossing design – information on the culvert or bridge characteristics planned at each crossing will be obtained from Project engineering designs (HDR 2011 and subsequent reports).
- Road design – information on the proposed road prism in the vicinity of stream crossings will be obtained from Project engineering designs, including surfacing, gradient, expected traffic levels, and road prism width.

A field assessment of each stream crossing along routes being considered will be made during the summer of 2013. Fieldwork will be carried out in conjunction with the Aquatic Resources Study (Access Alignment, Transmission Alignment and Construction Area component), if possible. The following geomorphic information will be collected for each stream crossing:

- Stream characteristics – gradient, wetted and bankfull width, and depth.
- Substrate characteristics – existing substrate size and description of relative sediment loading (based on field evidence of fresh deposits, large gravel bars, etc.).
- Existing large woody debris size and loading.
- Geomorphic channel type (Rosgen classification is recommended by USFS in its study request dated May 31, 2012) and confinement.

- Existing and potential for bank erosion will be measured or evaluated for a minimum of 100 feet upstream and downstream of each proposed crossing.
- Potential for channel migration will be evaluated from aerial photographs if available, supplemented by field/aerial observations.

The potential effects of stream crossings on geomorphology will be analyzed based on stream characteristics and the proposed design of crossing structures. The evaluation will include the following:

- Channel morphology, sediment dynamics – the hydraulic characteristics and bedload transport capacity of existing channel and of proposed crossing structures will be estimated and compared. Guidelines in the existing stream crossing design Memorandum of Agreement (MOA) will be considered (ADOT&PF 2001).
- Channel migration zone – the existing channel migration zone will be mapped for alluvial channels that show evidence of migration across the floodplain. Effects of proposed crossing structures on channel migration will be analyzed.
- Large woody debris transport – potential effects on large woody debris transport will be evaluated based on channel crossing type and width. The potential for culvert plugging will be ranked based on observed large woody debris size in the stream and proposed culvert size.
- Erosion and delivery of road sediment to stream – erosion from any unpaved roads will be estimated using the WEPP or SEDMODL algorithms. Wind (aeolian) erosion from unsurfaced areas (roads, parking areas, airstrip, etc.) will be evaluated using the U.S. Environmental Protection Agency (EPA) methodology (AP-42) to provide information on dust production for the recreation and aesthetics studies. (This effort was added in response to a request by USDOI-NPS in a letter dated May 24, 2012.)

6.5.4.10.3. Study Products

The results of the Geomorphology of Stream Crossings along Transmission Lines and Access Alignments component will be included in the Geomorphology Report. This will include a discussion of the potential effects of road/transmission alignments on the following:

- Channel migration zones (potential effects of crossings on stream and vice versa)
- Channel aggradation/erosion upstream and downstream of crossing
- Blocking large woody debris transport
- Increased turbidity/sediment input to streams

6.5.4.11. Study Component: Integration of Fluvial Geomorphology Modeling with the Geomorphology Study

The Geomorphology and Fluvial Geomorphology Modeling studies are inextricably linked, and in reality, should be viewed as a single, integrated study. The efforts of the Geomorphology Study identify the specific geomorphic (and habitat-related) processes that require further quantification, identify a significant portion of the data needs, and provides the basic information and context for performing the Fluvial Geomorphology Modeling Study. During the Fluvial Geomorphology Modeling Study, results from the Geomorphology Study will be used in conjunction with knowledge of the specific needs of the other resource teams to ensure that the models are developed in an appropriate manner to address the key issues and to provide a reality check on the model results. After completion of the modeling, the study team will use the results from both studies in an integrated manner to provide interpretations with respect to the issues that must be addressed, including predictions of potential changes to key geomorphic features that comprise the aquatic and riparian habitat. This information will be provided to the other resource teams for use in their evaluation of potential Project effects.

6.5.4.11.1. Existing Information and Need for Additional Information

The existing information required for this study component was previously described above under the other ten components of the Geomorphology Study, and includes the results from those study components.

6.5.4.11.2. Methods

Results from the previously described Geomorphology Study components will be compiled and used by the Fluvial Geomorphology Modeling Study team to guide development of the models and interpretation of the model results. During the modeling phase, close coordination will occur between the two teams, and with the other resource teams, to insure that the relevant information is being used in an appropriate manner and that the results being obtained from the baseline models are consistent with the observed behavior of the river. Since there will be considerable overlap between the Geomorphology and Fluvial Geomorphology teams, this coordination between these two teams will be seamless and ongoing throughout the study.

Specific aspects of the Geomorphology Study that will be used to guide development of the models and interpretation of the model results for the Fluvial Geomorphology Modeling Study, particularly as they relate to the habitat indicators, include the following:

- The reach delineations under Section 6.5.4.1 will define and provide descriptions of the geomorphically- and ecologically-significant macro-scale characteristics of each segment of the study reach. As described in Section 6.6, the 1-D bed evolution model will be used to quantify the reach-scale hydraulic and sediment transport conditions in the study reach over the range of flows for both existing and Project conditions to expand and refine these descriptions. The initial descriptions will guide development of the model, specifically by defining geomorphically similar reaches where model input parameters such as bed material gradations and hydraulic roughness coefficients are similar. The descriptions will also guide interpretation of the model results by defining reaches where the responses to Project actions are expected to be similar, providing a framework for evaluating and summarizing reach-scale processes that affect geomorphic features and associated habitat.
- The bedload and suspended sediment load data being collected by the USGS under Section 6.5.4.2 will be used to calibrate and verify the predicted transport rates in the bed evolution model, and to assess the natural variability in transport rates on a seasonal and annual basis under existing and historic conditions.

- Data from the Sediment Supply and Transport Study Component (Section 6.5.4.3) will provide tributary sediment input boundary conditions for both the existing and project conditions the bed evolution models.
- Results from the Assess Geomorphic Change Study Component (Section 6.5.4.4) will be used to provide a macro-scale understanding of the changes in geomorphic and habitat features over the past several decades. In particular, the Turnover Rate analysis that is part of this study component will provide a measure of the lateral sediment input to the mainstem due to bank and bar erosion.
- The stream flow analysis under the Reconnaissance-level Assessment of Project Effects study component (Section 6.5.4.6) will provide a basis for assessing seasonal and annual hydrologic variability under existing and Project conditions to guide both development of the hydrologic input data for the bed evolution model, and interpretation of the temporal variability in model results, particularly for the long-term model runs. The sediment transport analysis portion of this study component will be used to ensure that baseline model results accurately reflect the historic and existing sediment balance along the study reach.
- Information from the Large Woody Debris study component (Section 6.5.4.7) will be considered in establishing channel roughness parameters for the hydraulic model, and if appropriate, significant LWD clusters will be considered in establishing the local erodibility of banklines along the project reach.
- Sediment trap efficiency results from the Reservoir Geomorphology Study Component (Section 6.5.4.8) will provide the upstream sediment input boundary conditions for the Project-conditions bed evolution model.

6.5.4.11.3. Study Products

The following specific items will be provided from this study to assist the Fluvial Geomorphology Modeling Study and other resources teams with their analysis. A detailed description of how the results from the Geomorphology and Fluvial Geomorphology Modeling Studies will be integrated, and specifically, how the modeling results will be used to update and refine the Geomorphology Study results is presented in Section 6.6.4.3.

- Reach delineations, description of key geomorphic attributes and characterization of the geomorphology of the Susitna River.
- Identification of processes that create and influence the geomorphic features that help comprise the aquatic and riparian habitat.
- Bedload and suspended sediment load rating curves at key gages (Gold Creek/above Talkeetna, Tsusena Creek (if available), Chulitna River above Talkeetna, Talkeetna River near Talkeetna, Sunshine, Susitna Station) based on USGS field data. Separate curves will be developed for each of the following sediment size ranges:
    - Gravel/cobble bedload
    - Sand bedload
    - Suspended sand load

  - Wash load.

- Estimates of annual load of each of the above sediment size ranges passing each gage for the extended flow record under existing and Project conditions.
- Summary of key changes in geomorphic features/units (i.e., island/bar evolution, main channel width and form, bank erosion, changes in side channels, side sloughs, upland sloughs) based on historical aerial photography.
- Estimates of historic LWD loading rates from upstream and lateral sources.
- Estimates of trap efficiency of the proposed reservoir.

6.5.5. Consistency with Generally Accepted Scientific Practice

The methods described for geomorphology are similar to those used for other recent hydroelectric project licensing procedures and follow current scientific literature (see Literature Cited, Section 6.5.8).

- The Geomorphic Classification component will use a combination of the numerous river classifications that currently exist (Leopold and Wolman 1957; Schumm 1963, 1968; Mollard 1973; Kellerhals et al. 1976; Brice 1981; Mosley 1987; Rosgen 1994, 1996; Thorne 1997; Montgomery and Buffington 1997; Vandenberghe 2001).
- The Bedload and Suspended Load Data Collection component will be conducted by USGS using its currently accepted field methods.
- The Sediment Supply and Transport in the Middle and Lower Susitna River Segments component will use published USGS sediment and flow data and USGS-endorsed correction factors to develop rating curves (Cohn and Gilroy 1991; Duan 1983). Bed mobilization and effective discharge will be computed using currently recognized methods (Mueller et al. 2005; Biedenharn et al. 2000).
- The Geomorphic Change Analysis and Habitat versus Flow components will use geo-rectified aerial and satellite images to compare the river between years and flows. These methods are widely used to compare changes in river systems.
- The Reconnaissance-Level Assessment of Geomorphic Change in the Lower Susitna River Segment will utilize published USGS flow and sediment data and the analytical framework developed by Grant et al. (2003).
- The Reservoir Geomorphology Study will use several widely-accepted methods to calculate sediment trap efficiency (Churchill 1948; Brune 1953; Einstein 1965; Miller 1953; Lara and Pemberton 1965; Chen 1975). The delta formation study will use methods developed and applied at similar projects (e.g., Boundary Hydroelectric Project, FERC 2144) to analyze delta formation. Reservoir erosion will use models and analysis methods developed and widely used for either general erosion (e.g., SHALSTAB, WEPP/RUSLE) or for reservoir-based beach development (Penner 1993; Penner and Boals 2000).
- The Large Woody Debris Study component and large wood inventory will be based on widely used methods (Schuett-Hames et al. 1999).

- The Geomorphology of Stream Crossings along Transmission and Access Alignments component will use guidelines from the existing stream crossing design MOU (ADOT&PF 2001) along with site-specific analyses of channel dynamics.

6.5.6. Schedule

The schedule for conducting the Geomorphology Study is presented in Table 6.5-5. The Geomorphology Study includes several efforts that were conducted in 2012. This included both analysis and field efforts. One of the two field efforts in the Geomorphology Study is the USGS data collection effort (Section 6.5.4.2). It was conducted in the late spring and summer of 2012. A total of five sets of sediment transport data were collected at the Susitna River above Tsusena Creek, Susitna River near Talkeetna (substituted for Gold Creek), and the Susitna River at Sunshine and four sets on the Chulitna River below canyon. Provisional results of the data collection effort will be delivered to the other studies as soon as they are available from the lab during fall 2012. Suspended and bedload data, including calculation of sediment transport ratings and daily loads, will be compiled in a technical memorandum delivered early in 2013.

The other primary 2012 field effort in the Geomorphology Study is the collection of aerial photographs (Sections 6.5.4.4 for Lower Susitna River Segment and 6.5.4.5 for Middle Susitna River Segment). Collection of aerial photographs was included in the 2012 effort to support the digitization of aquatic habitat types, geomorphic features and to access channel change. This information in turn helps support the site selection process for other studies. Due to the combination of weather and flow conditions during 2012, only the 23,00cfs aerial photography was acquired in 2012. Performing the digitization of the 2012 aerial photography was dependent on the AEA SDC being able to fly the aerials at the appropriate discharge. The remainder of the effort—12,500 cfs and 5,100 cfs aerial photography—will be collected in 2013. Consequently, only the digitization of the aquatic habitat features associated with the 23,000 cfs flow was performed in 2012. Therefore, 2012 study products only include the 23,000 cfs condition. The acquisition, digitization and analysis work associated with the 12,500 and 5,100 cfs flows will be performed in 2013.

The other study components in the Geomorphology Study that include 2012 efforts are Delineation of Geomorphically Similar River Segments (Section 6.5.4.1), Sediment Supply and Transport Middle and Lower Susitna River Segments (Section 6.5.4.3), Reconnaissance-Level Assessment of the Project Effects on the Lower River Channel (Section 6.5.4.6) and Riverine Habitat Versus Flow Lower River Segment. The 2012 portion of the geomorphic reach delineation has been completed and is summarized in this document (Section 6.5.4.1). Continued refinement and determination of morphometric parameters for the reaches will be ongoing in 2013 as additional information becomes available. The remaining three efforts require information from the operations modeling (Engineering Study) consisting of downstream flows and stages associated with Project operations. This information was available the end of November 2012. Therefore, completion of the identified 2012 efforts has been delayed until January and early February of 2013. The delivery of these 2012 study results in this timeframe will allow their use in the collaborative process that will occur in Q1 and early Q2 of 2013 associated with vetting the selection of the proposed Focus Areas and in evaluating the need to extend detailed ISF and Geomorphology Study limits further downstream in the Lower Susitna River Segment.

Table 6.5-3 shows the schedule for the performance and completion of the Geomorphology Study. This schedule shows components of the Geomorphology Study that have early component performed in 2012 or early 2013 (in the case of studies that have been delayed per the discussion in the previous paragraph) and then a second effort that is performed in late 2013 and 2014. This is due to the 2012 efforts being conducted with best available information to provide primarily results to inform the development and execution of other studies. The 2013 effort also includes optional aerial photograph acquisition in the Lower River and assisted mapping of macrohabitat types if studies are extended into the Lower River. The subsequent 2013 and 2014 efforts are performed to incorporate additional information collected in 2013 and to assess the effects of altered sediment supply and flow regimes for the alterative operational scenarios.

The Initial Study Report (ISR) and the Updated Study Report (USR) explaining the actions taken and data collected to date will be due within one and two years, respectively, of FERC's Study Plan Determination.

6.5.7. Relationship with Other Studies

A flow chart (Figure 6.5-8) describes study interdependencies and outlines the information and products required from other studies and the timing of delivery to successfully complete the Geomorphology Study on schedule. In the study interdependencies chart, the studies providing input are listed in the five sided boxes at the top of the chart. The corresponding Sections are provided in parentheses. The rectangular boxes below the five sided boxes list the major information and products that the other studies will provide to the Geomorphology Study. The primary studies that the Geomorphology Study will require information from and the associated information are listed below and in Table 6.5-6.

- Mainstem (Open-water) Flow Routing Study (Section 8.5.4.3)
  - Current and historical cross-sections
  - Thalweg Profile
  - Results of flow routing to Sunshine Station
- Fluvial Geomorphology Modeling Study (Section 6.6)
  - Bed material sizes
  - Geomorphic field assessment and observations
  - Geomorphic feature mapping at Focus Areas
- Ice Processes Study (Section 7.6)
  - Ice effects on banks, side channels, bed scouring and river stage
- Riparian Instream Flow Study (Section 8.6)
  - Riparian/floodplain sedimentation rates
  - Dating of surfaces
  - Floodplain soil profiles and depth
- Reservoir Operations Modeling (Engineering)

  - Results of operations modeling
- Water Modeling Quality Study (Section 5.6)
  - Reservoir sediment trap efficiency for alternative scenarios

Studies that are considered secondary sources of to the Geomorphology Study information include the Geology and Soils Characterization Study (Section 4.5), and Riparian Vegetation Study Downstream of the Proposed Susitna-Watana Dam (Section 11.6). The USGS will provide the extended hydrologic record for 11 gage locations for a period of 61 years. This information will be used as the hydrologic record for analysis of existing stream flow characteristics and will also provide the flows to be used by the Reservoir Operations Study (Engineering) and the Mainstem (Open-water) Flow Routing Study (Section 8.5.4.3) to generate flow conditions in the Middle and Lower River Segments for the with-Project conditions.

In the chart, the timing of delivery of each type of information or study product to the Geomorphology study is provided in parentheses by quarter and year. For example, "(Q4-12)" indicates the information will be provided in the fourth quarter of 2012. Table 6.5-6 provides these interdependencies in tabular form including the study providing the information or product and which area of the Geomorphology Study requires the information or product and the timing.

The chart indicates which areas of the Geomorphology Study require the information. The Geomorphology Study areas are identified in the blue ellipses. To simplify the chart, study components have been lumped into areas. The study components associated with each area identified in the blue ellipses are listed below.

<u>Geomorphic reach classification and delineation:</u>

- Delineate geomorphically similar (homogeneous) reaches (Section 6.5.4.1)

<u>Aerial photo analysis of geomorphic features and riverine habitat:</u>

- Riverine habitat versus flow relationship Middle Susitna River Segment (Section 6.5.4.5)
- Riverine habitat area versus flow Lower Susitna River Segment (Section 6.5.4.7)

<u>Geomorphic assessment:</u>

- Bedload and suspended load data collection (Section 6.5.4.2)
- Sediment supply and transport Middle and Lower Susitna River Segments (Section6.5.4.3)
- Assess geomorphic change Middle and Lower Susitna River Segments (Section 6.5.4.4)
- Reconnaissance-level assessment of project effects on Lower and Middle Susitna River Segment channel (Section 6.5.4.6)
- Reservoir geomorphology (Section 6.5.4.8)
- Large woody debris (Section 6.5.4.9)
- Geomorphology of stream crossings along transmission lines and access alignments (Section 6.5.4.10)

The chart also shows products and information the Geomorphology Study will provide to other studies and the timing of their delivery. Table 6.5-7 provides these study interdependencies in tabular form including the area of the Geomorphology Study providing the information and which study requires the information or study product. In the flow chart the products and information the Geomorphology Study will provide are identified in the rectangles below the study area ellipses. The quarter and year that the products and information will be provided to other studies is indicated in the parentheses adjacent to each item. At the bottom of the chart, the studies that require the information from the Geomorphology Study are listed in the five sided boxes. Included in parentheses adjacent to each study is the section of the RSP that the product or information will support. The primary studies requiring information from the Geomorphology Study and the associated information they will require are listed below. The information they will require is identified in Table 6.5-7 (Note: Tables 6.6-6 and 6.6-7 provide a detailed list of 1-D and 2-D model output and other information the Fluvial Geomorphology Modeling and Geomorphology Studies will provide to other studies):

- Fish and Aquatics Instream Flow Study Fish (Section 8.5)
- Riparian Instream Flow Study (Section 8.6)
- Fluvial Geomorphology Modeling Study (Section 6.6)
- Characterization and Mapping of Aquatic Habitats Study (Section 9.9)
- Aesthetic Resources Study (Section 12.6)
- River Recreation Flow and Access Study (Section 12.7)

In addition to these studies, other studies may utilize input from the Geomorphology Study to help identify their downstream study limits.

6.5.8. 2012 Study Efforts

The Geomorphology Study (Section 6.5) has several study components that include 2012 study efforts to help prepare or refine various aspects of the Study Plans. Table 6.5-8 lists these study components, the portions of the studies that support development of the study plan, and the aspect of the study plan they support. These 2012 efforts were intended to be completed by November 2012 to provide support for the Study Plan development; however, several circumstances have resulted in portions of the efforts not being completed in November 2012. Table 6.5-8 also identifies efforts completed in time to fully support development of the study plan and which were partially completed. Efforts not fully completed prior to filing of the study plan, will be completed in December 2012 and reported on in January 2013. The results of the 2012 Geomorphology Study will support Water Resources Technical Workgroup (TWG) meetings to be held in February and March 2013 involving review and finalization of the proposed Focus Areas and the downstream study limit.

6.5.9. Level of Effort and Cost

Initial planning level estimates of the costs to perform the components of the Geomorphology Study are provided in Table 6.5-9. The total effort for the Geomorphology Study, including Component 2, Sediment Data Collection, to be performed by the USGS, is estimated to cost between approximately $1.6 and $2.1 million.

6.5.10. Literature Cited

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6.5.11. Tables

Table 6.5-1. Initial geomorphic reach classifications.

Reach Designation	Upstream Limit RM)	Down- stream Limit (RM)	Reach Classifi-cation	Slope (ft/mi)	Lateral Constraints
Upper Susitna River Segment (UR)					
UR-1	260	248	SC2	NA	Quaternary Basin Fill
UR-2	248	233	SC1	NA	Quaternary Basin Fill
UR-3	233	223	SC1	NA	Quaternary Basin Fill
UR-4	223	206	SC2	NA	Granodiorite
UR-5	206	201	SC1	NA	Quaternary Basin Fill
UR-6	201	184	SC2	NA	Quaternary Basin Fill
Middle Susitna River Segment (MR)					
MR-1	184	182	SC2	9	Gneiss
MR-2	182	166.5	SC2	10	Quaternary Basin Fill
MR-3	166.5	163	SC2	17	Granites
MR-4	163	150	SC1	30	Granites
MR-5	150	145	SC2	12	Moraine and Turbidites
MR-6	145	119	SC3	10	Moraines
MR-7	119	104	SC2	8	Moraines
MR-8	104	98.5	MC1/SC2	8	Holocene Lacustrine and Alluvial Terrace deposits (Reach is a transition from SC2 to MC1 as the Three Rivers Confluence is approached)
Lower Susitna River Segment (LR)					
LR-1	98.5	84	MC1	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-2	84	61	MC1	5	Upper Pleistocene Outwash, Moraine and Lacustrine deposits
LR-3	61	40.5	MC3	4	Glaciolacustrine and Moraine deposits
LR-4	40.5	28	MC3	2	Glaciolacustrine and Moraine deposits
LR-5	28	20	SC2	2	Glaciolacustrine and Moraine deposits
LR-6	20	0	MC4	1.4	Glaciolacustrine and Holocene Estuarine deposits

Table 6.5-2. Estimated Water Year 1985 annual sediment loads for the Susitna River and major tributaries (based on USGS 1987).

Gage Station	Drainage Area (sq. mi.)	Annual Water Yield (ac.ft.)	Estimated Annual Sediment Load (million tons)			
			Silt and Clay	Sand	Gravel	Total
Susitna River near Talkeetna	6,320	6,720,000	1.79	1.48	0.019	3.29
Chulitna River near Talkeetna	2,580	6,122,000	4.46	2.99	0.355	7.81
Talkeetna River near Talkeetna	2,006	3,083,000	0.81	0.90	0.054	1.76
Total of the three stations near Talkeetna	10,906	15,925,000	7.06	5.37	0.430	12.9
Susitna River at Sunshine	11,100	17,600,000	8.94	6.03	0.155	15.1
Difference (Sunshine minus near Talkeetna stations)	194	1,675,000	1.88	0.66	-0.275	2.20

Table 6.5-3. Summary of 2012 aerial photo acquisition for the Upper, Middle, and Lower Susitna River segments.

Aerial Coverage (RM)		Date	Discharge Target (cfs)		Actual Discharge (cfs)	
From	To		Gold Creek	Sunshine Station	Gold Creek	Sunshine Station
Upper River						
241	184	09/30/2012	NA[1]	---	18,100	---
264	224	10/20/2012	NA[1]	---	5,000	---
Middle River						
107	98.5	07/27/2012	23,000	---	23,200	---
135	98.5	09/10/2012	12,500	---	13,300	---
136	184	9/30/2012	12,500	---	18,100	---
Lower River						
98.5	54	07/27/2012	---	59,100	---	54,000
98.5	74	09/10/2012	---	36,600	---	38,100
74	0	09/30 - 10/01/2012[2]	---	36,600	---	41,700 to 46,900
18	1	10/10/2012	---	59,100	---	53,700
68	30	10/10/2012	---	59,100	---	53,700

Notes:

1 Aerials are only being used for delineation of geomorphic features and channel change in the Upper River, target flow not required
2 Due to cloud cover, this set of aerials is a combination of photos from 9/30/2012 and 10/01/2012

Table 6.5-4. Middle Susitna River Segment aquatic habitat sites from 1980s to be digitized.

Site Name	River Mile (RM)		Length (Miles)
	Downstream RM	Upstream RM	
Whiskers Slough[1]	100.7	102.0	1.3
Slough 4	105.0	106.5	1.5
Slough 5	107.0	108.5	1.5
Slough 6A[1]	112.0	113.0	1.0
Slough 8	113.4	115.4	2.0
Oxbow II	118.5	120.5	2.0
Slough 8A[1]	124.3	126.6	2.3
Slough 9	128.0	129.5	1.5
Side Channel 10A	131.0	132.8	1.8
Side Channel 10	133.0	134.3	1.3
Slough 11[1]	134.3	136.8	2.5
Gold Creek	136.8	138.3	1.5
Indian River	138.5	139.5	1.0
Slough 21[1]	140.0	142.6	2.6
Slough 22	144.0	145.0	1.0
Fat Canoe Island	146.5	147.5	1.0
Portage Creek[1]	148.3	148.8	0.5
MR-2 Narrow[1,2]	168.5	170.0	1.5
MR-2 Wide[1,2]	170.7	172.5	1.8
MR-2 Straight[2]	173.2	174.9	1.7
MR-2 Tributary[2]	176.0	176.8	0.8
MR-2 Island Bend[2]	178.1	180.3	2.2
Below Dam[1,2]	182.0	183.0	1.0
TOTAL LENGTH	-	-	35.3

<u>Notes:</u>

1 Proposed Focus Area (see Section6.6.4.1.2.4 and Table 6.6-5)

2 Site not studied in the 1980s

Table 6.5-5. Schedule for implementation of the Geomorphology Study.

Activity	2012				2013				2014				2015	
	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1 Q	2 Q	3 Q	4 Q	1Q	2Q
Develop Geomorphic Classification System / Finalize Classification System		—	—	—	—●									
Initial Geomorphic Reach Delineation / Finalize Delineation			—●			—	—●							
Identify and Map Paleo Geomorphic Features and Geology / Field Verify			—	—	—	/ —	—●							
Determine Morphometric Parameters (sinuosity, slope, topwidth, etc…)			—	—	—	—	—●							
Identify Key Governing Geomorphic Processes			—	—	—	—	—●							
Acquire Aerial Photo / Complete Aerial Acquisition (not Completed in 2012)			—	—	/	—	—	—						
Digitize 1980s Habitat and Geomorphic Features			—	—●			—	—●						
Digitize 2012 Habitat and Geomorphic Features / Complete Habitat Effort			—	—	●	/	—	—●						
Assess Habitat Area Change 1980s to 2012				—	—●			—	—●					
Assess Channel Change 1980s to 2012				—	—●			—	—●					
Initial Flow Assessment / Final Flow Assessment			—	—	● /	—	—	—	—	—	—	—●		
Determine Effective Discharge and Characterization of Bed Mobilization						—	—	—	—	—	—	—●		
Initial Sediment Balance / Detailed Sediment Balance for Modeling			—	—	● /	—	—	—	—	—	—	—●		
Recon. Level Assess. of Potential L. and M. Susitna River Segment Change				—	—●	—	—●		—	—	—	—●		
Optional 2013 aerial photo and macrohabitat mapping – Lower River						—	—	—	●					
Large Woody Debris						—	—	—	—	—	—●			
Reservoir Geomorphology						—	—	—	—	—	—●			
Geomorphology of Stream X-ings along Access & Transmission Line Corridor						—	—	—	—	—	—●			
Integration with & Support of Interpreting Fluv. Geomorph. Modeling Results					—	—	—	—	—	—	—	—●		
Initial Study Report /Updated Study Report									—Δ			—	—▲	

Legend:
- —— Planned Activity
- ● Technical Memorandum or Interim Product
- Δ Initial Study Report
- ▲ Updated Study Report

Table 6.5-6. Information and products required by the Geomorphology Study from other studies.

Source of Product or Information	Information or Product to be Provided	Timing
Information or Products Required for: Geomorphic Reach Classification and Delineation		
Mainstem (Open-water) Flow Routing Model (Section 8.5.4.3)	Current and historical cross-sections	Q4-12
	Thalweg profile	Q4-12
Fluvial Geomorphology Modeling Study (Section 6.6.4.1.2.8)	Bed material sizes	Q3-13
External: GINA / Mat-Su Borough	LiDAR	Q4-12
Internal: Geomorphology Study (Sections 6.5.4.5 & 6.5.4 .7)	1980s and 2012 aerials	Q4-12 & Q4-13
Information or Products Required for: Aerial Photo Analysis of Geomorphic Features and Riverine Habitat		
Mainstem (Open-water) Flow Routing Model (Section 8.5.4.3)	Current cross-sections	Q4-12
Internal: Geomorphology Study (Sections 6.5.4.5 & 6.5.4.7)	1980s and 2012 aerials	Q4-12 & Q4-13
Trihey & Associates 1985	1980s habitat mapping Middle Susitna River Segment	Q4-12
R&M Consultants, Inc., and Trihey and Associates 1985a)	1980s habitat mapping Lower Susitna River Segment	Q4-12
Information or Products Required for: Geomorphic Assessment		
External: USGS	USGS extended flow record	Q3-12
	USGS sediment transport data 1980s and 2012	Q4-12
Mainstem (Open-water) Flow Routing (Section 8.5.4.3)	Results of operations modeling - preliminary	Q4-12
	Results of operations modeling – alternative scenarios	Q4-14
	Results of flow routing to Sunshine Station - Preliminary	Q4-12
	Results of flow routing to Sunshine Station – Alternative Scenarios	Q4-14
Internal: Geomorphology Study Model (Section 6.5.4.8..2.1)	Initial estimates of reservoir sediment trap efficiency	Q3-13
Water Quality Modeling Study (Section 5.6)	Reservoir sediment trap efficiency for alt. scenarios	Q2-14
Ice Processes Study (Section 7.6)	Ice effects on: banks, side channels, scouring and stage	Q1-14
Geology & Soils Characterization Study (Section 4.5)	Soils and mass wasting in reservoir area	Q1-14
Riparian Vegetation Study Downstream of the Proposed Susitna-Watana Dam Study (Section 11.6)	Vegetation mapping in the reservoir area	Q1-14
Recreation Resources Study (Section 12.5)	Expected boat use in the reservoir and river	Q2-14

Table 6.5-7. Information and products the Geomorphology Study will provide to other studies.

<table>
<tr><th>Study the Product or Information is Provided to</th><th>Information or Product to be Provided</th><th>Timing</th></tr>
<tr><td colspan="3">Information or Products Provided by: Geomorphic Reach Classification and Delineation</td></tr>
<tr><td rowspan="4">Fish and Aquatics Instream Flow Study (Section 8.5)
Riparian Instream Flow Study (Section 8.6)
Characterization and Mapping of Aquatic Habitats (Section 9.9)
Fluvial Geomorphology Modeling Study (Section 6.6)</td><td>Initial geomorphic reach delineation</td><td>Q4-12</td></tr>
<tr><td>Final geomorphic reach delineation</td><td>Q4-13</td></tr>
<tr><td>Collaboration on Focus Area selection</td><td>Q4-13</td></tr>
<tr><td>Morphometric parameters</td><td>Q1-13</td></tr>
<tr><td colspan="3">Information or Products Provided by: Aerial Photo Analysis of Geomorphic Features and Riverine Habitat</td></tr>
<tr><td rowspan="6">Fish and Aquatics Instream Flow Study (Section 8.5)
Riparian Instream Flow Study (Section 8.6)
Characterization and Mapping of Aquatic Habitats (Section 9.9)
Fluvial Geomorphology Modeling Study (Section 6.6)</td><td>Digitized 2012 riverine habitat areas –Middle River</td><td rowspan="5">Q4-12 & Q4-13</td></tr>
<tr><td>Digitized 2013 riverine habitats – Middle River</td></tr>
<tr><td>Optional 2013 riverine habitat areas – Lower River</td></tr>
<tr><td>Digitized 1980s habitat areas</td></tr>
<tr><td>Habitat stability 1980s to 2012</td></tr>
<tr><td>Chanel Change 1980s to 2012 / geomorphic features</td><td>Q1-13</td></tr>
<tr><td colspan="3">Information or Products Provided by: Geomorphic Assessment</td></tr>
<tr><td rowspan="2">Fish and Aquatics Instream Flow Study (Section 8.5)
Riparian Instream Flow Study (Section 8.6)
Characterization and Mapping of Aquatic Habitats (Section 9.9)
Fluvial Geomorphology Modeling Study (Section 8.6)
River Recreation Flow & Access Study (Section 12.7)</td><td>Reconnaissance level assessment of potential channel change in the Lower Susitna River Segment</td><td>Q1-13</td></tr>
<tr><td>LWD Study</td><td>Q3-14</td></tr>
<tr><td rowspan="4">Fluvial Geomorphology Modeling Study (Section 6.6)
Fish and Aquatics Instream Flow Study (Section 8.5)
Riparian Instream Flow Study (Section 8.6)</td><td>Flow assessment (flood frequency and flow duration)</td><td>Q1-13 & Q-14</td></tr>
<tr><td>Characterization of bed mobilization</td><td rowspan="2">Q4-13 & Q4-14</td></tr>
<tr><td>Effective discharge determination</td></tr>
<tr><td>Sediment transport assessment and balance</td><td>Q4-12 & Q4-13</td></tr>
<tr><td>Fluvial Geomorphology Modeling Study (Section 6.6)</td><td rowspan="4">Reservoir geomorphology and tributary deltas</td><td rowspan="4">Q3-14</td></tr>
<tr><td>Fish and Aquatics Instream Flow Study (Section 8.5)</td></tr>
<tr><td>Riparian Instream Flow Study (Section 8.6)</td></tr>
<tr><td>Characterization and Mapping of Aquatic Habitats (Section 9.9)</td></tr>
<tr><td>Aesthetic Resources Study (Section 12.6)</td><td>Aeolian transport of dust</td><td>Q3-14</td></tr>
<tr><td>Fluvial Geomorphology Modeling Study (Section 6.6)</td><td rowspan="2">Identifications of key physical processes</td><td rowspan="2">Q2-13 & Q4-13</td></tr>
<tr><td>Riparian Instream Flow Study (Section 8.6)</td></tr>
<tr><td>Fluvial Geomorphology Modeling Study (Section 6.6)</td><td rowspan="4">Integration with Fluvial Geomorphology Modeling Study (see Tables 6.6-6 and 6.6-7 for detailed list of information)</td><td rowspan="4">Q4-14</td></tr>
<tr><td>Fish and Aquatics Instream Flow Study (Section 8.5)</td></tr>
<tr><td>Riparian Instream Flow Study (Section 8.6)</td></tr>
<tr><td>River Recreation Flow & Access Study (Section 12.7)</td></tr>
</table>

Table 6.5-8. Summary of 2012 Geomorphology Study efforts to support preparation and refinement of the Study Plan.

Study Component	Portion of Study Component of Interest	Aspect of Study Plan Preparation or Refinement Supported	Status
Delineate Geomorphically Similar (Homogenous) Reaches and Characterize the Geomorphology of the Susitna River (Section 6.5.4.1)	Initial geomorphic reach delineation	Part of classification system used to stratify study area for various study site selection efforts	Yes
Sediment Supply and Transport Middle and Lower Susitna River Segments (Section 6.5.4.3)	Initial sediment balance for the Lower River for pre- and post-Project conditions	Part of criteria to identify downstream limit of studies in the Lower Susitna River Segment	Completed pre-Project condition Developing with-Project 1/13[1]
Assess Geomorphic Change in the Middle and Lower Susitna River Segments (Section 6.5.4.4)	Site stability in the Middle Susitna River Segment	Site selection in the Middle River Segment, applicability of 1980s data	Products in review 1/13[1]
	Channel change in the Lower River Susitna River Segment	Downstream study limit in the Lower River, applicability of 1980s data	Products in review 1/13[1]
Reconnaissance-Level Assessment of Project Effects on the Lower and Middle Susitna River Segments (Section 6.5.4.6)	Initial assessment of potential Project effects on the geomorphology of the Lower Susitna River Segment	Downstream study limit in the Lower River	Awaiting with-Project hydrology and sediment transport assessments 1/13[1]
Riverine Habitat Area versus Flow Lower Susitna River Segment (Section 6.5.4.7)	Initial assessment of potential Project effects on habitat area vs. flow relationships	Downstream study limit in the Lower River	Finalizing analysis 1/13[1]

Notes:

1 Technical work will be completed by end of December 2012 and reported on in January 2013

Table 6.5-9. Geomorphology Study costs.

Study Component	Estimated Cost Range
1 Geomorphic River Segment Delineation	\$60,000 to \$80,000
2 Sediment Data Collection	\$450,000 to \$600,000
3 Sediment Supply and Transport Assessment	\$80,000 to \$110,000
4 Geomorphic Change Middle and Lower Susitna River Segments	\$180,000 to \$240,000[1]
5 Riverine Habitat Middle Susitna River Segment	\$200,000 to \$300,000[1]
6 Recon Assessment Lower Susitna River Segment Project Effects	\$80,000 to \$100,000
7 Riverine Habitat Lower Susitna River Segment	\$100,000 to \$150,000[1]
8 Reservoir Geomorphology	\$140,000 to \$180,000
9 Large Woody Debris	\$100,000 to \$130,000
10 Geomorphology of Stream Crossings	\$80,000 to \$140,000
11 Integration Fluvial Geomorphology Modeling with the Geomorphology Study	\$50,000 to \$60,000

[1] Includes acquisition of orthorectified aerial imagery

6.5.12. Figures

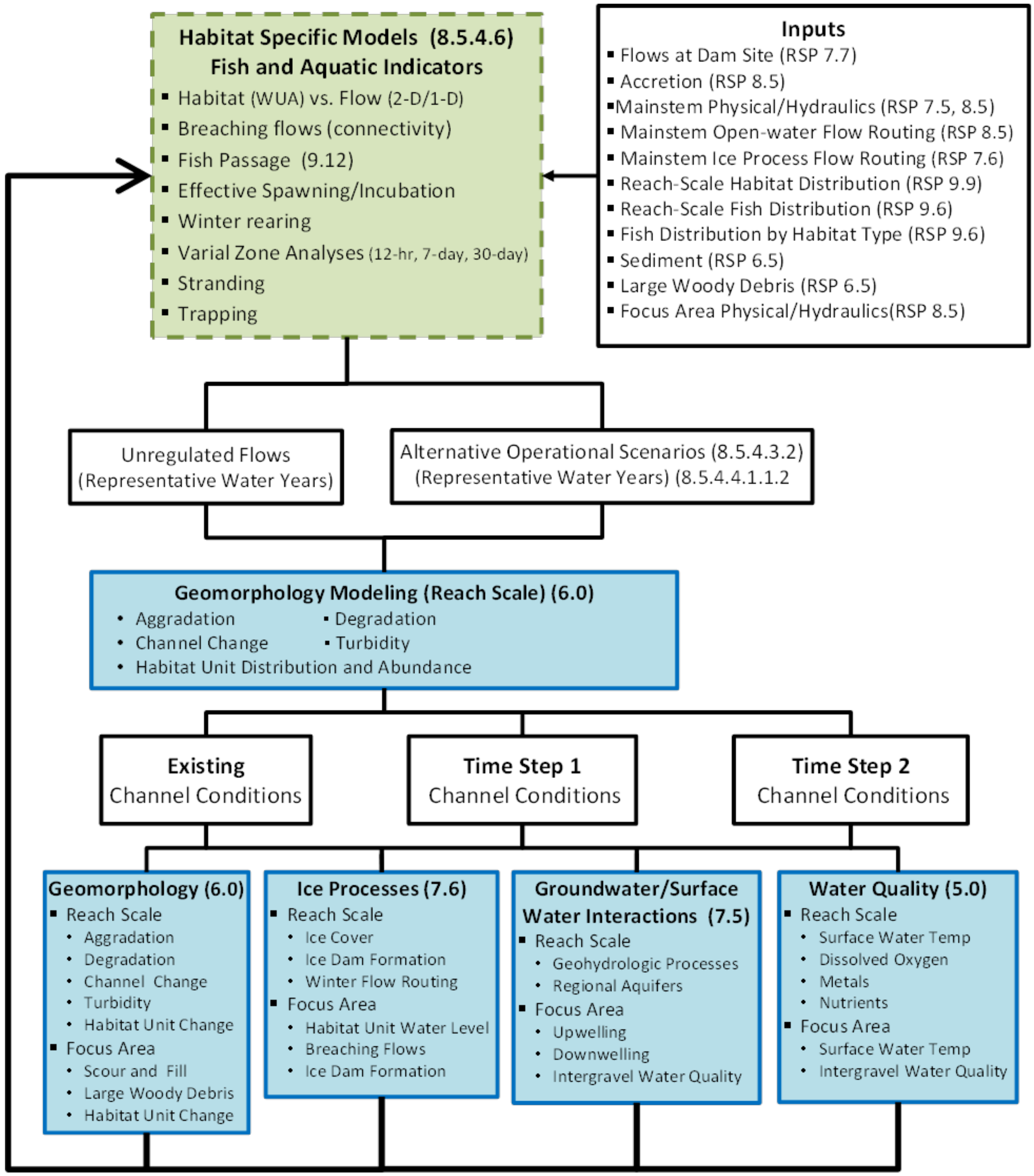

Figure 6.1-1. Conceptual framework for the Susitna-Watana Instream Flow Study depicting integration of habitat specific models and riverine processes to support integrated resource analyses; and integration of riverine processes to develop fish and aquatic habitat specific models.

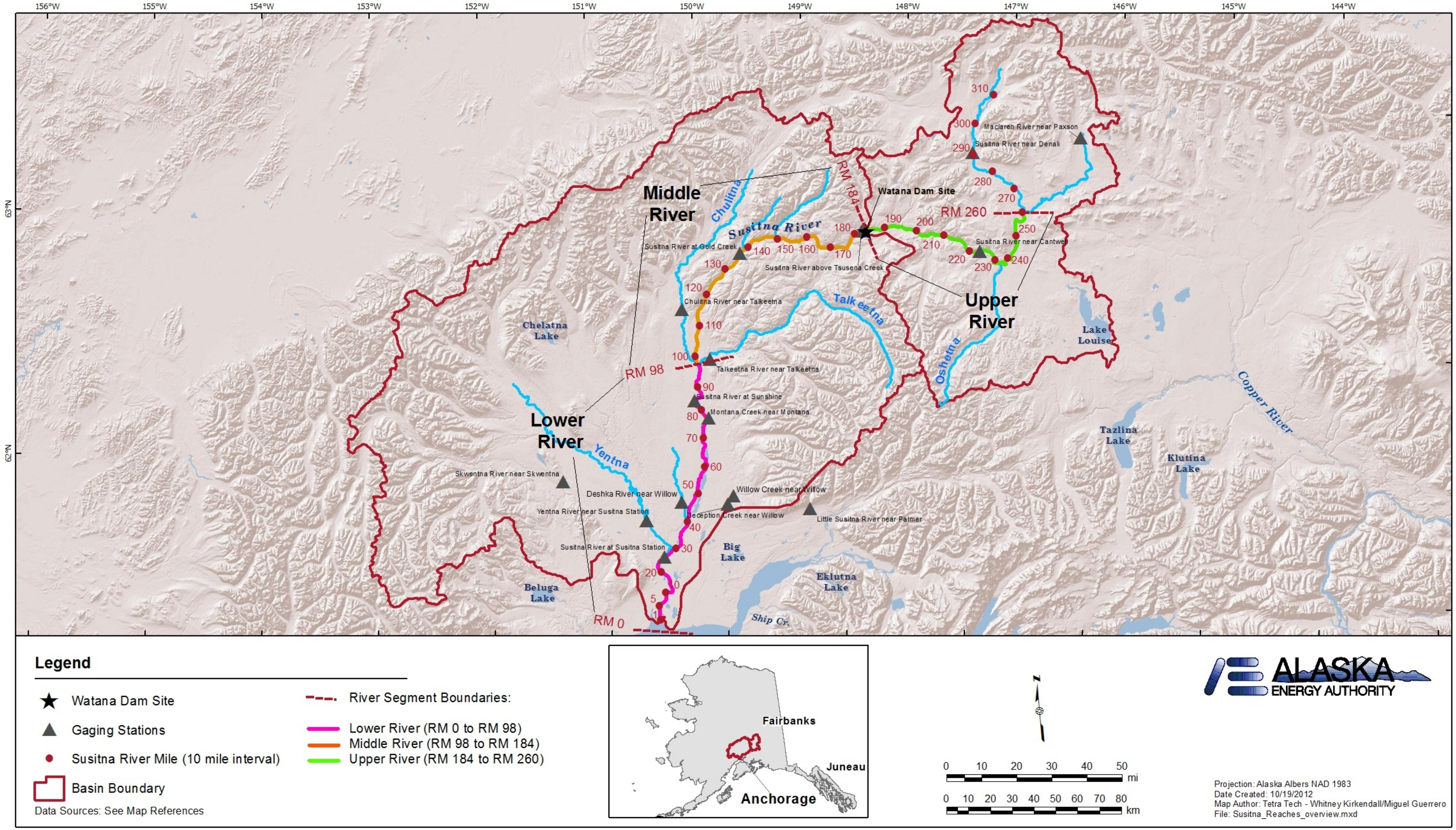

Figure 6.5-1. Susitna River Geomorphology study area and large-scale river segments.

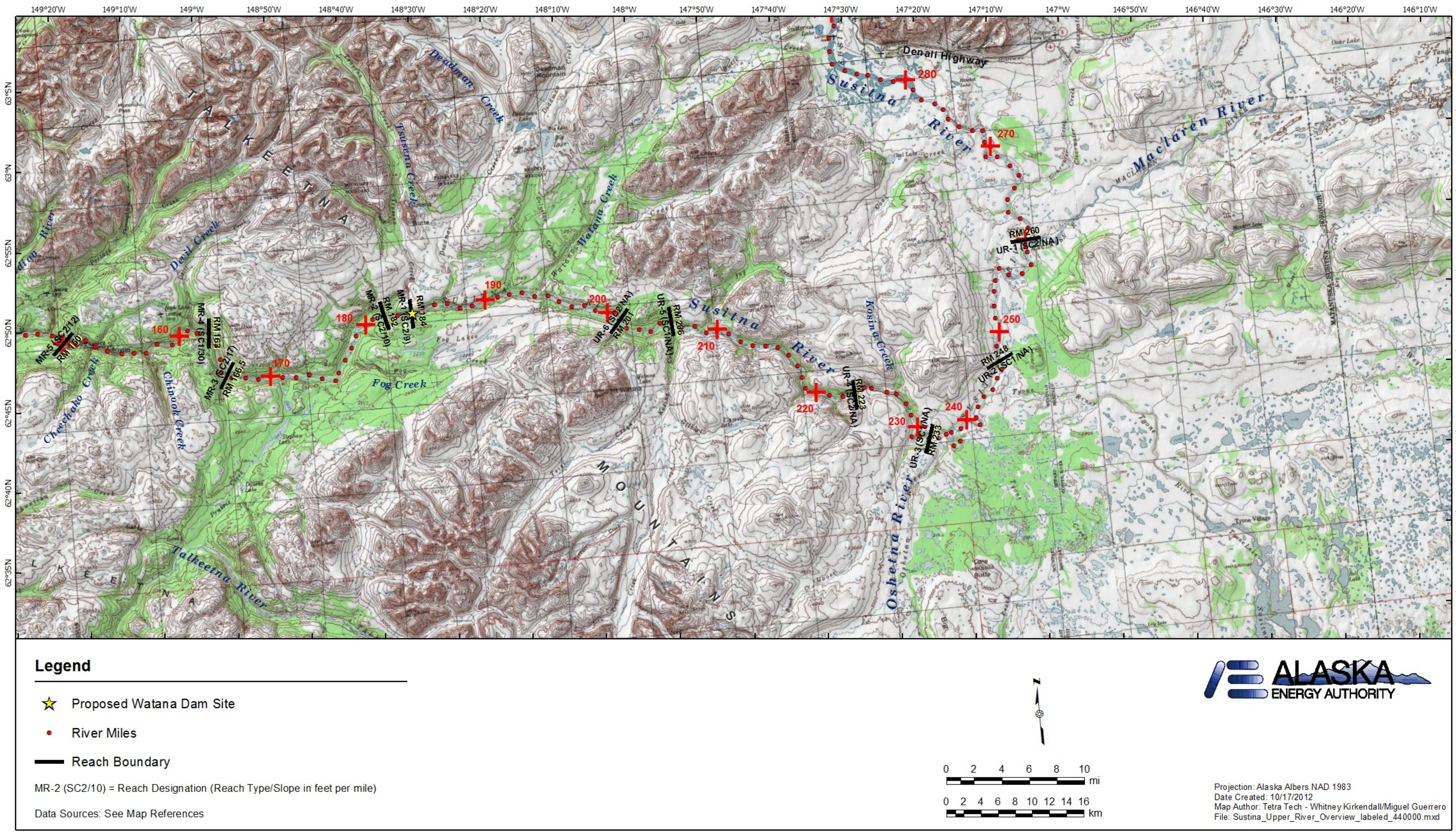

Figure 6.5-2. Upper Susitna River Segment geomorphic reaches.

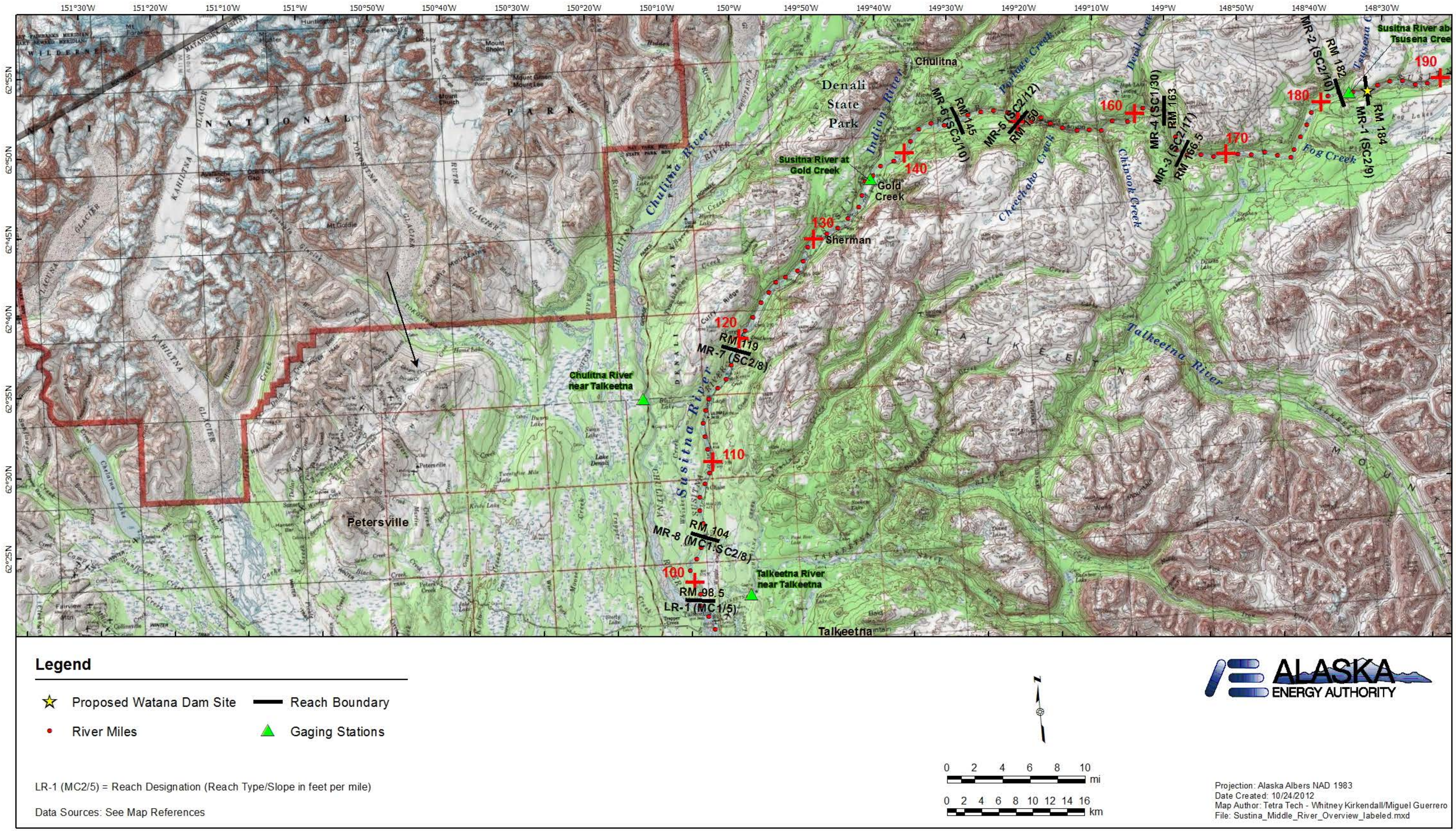

Figure 6.5-3. Middle Susitna River Segment geomorphic reaches.

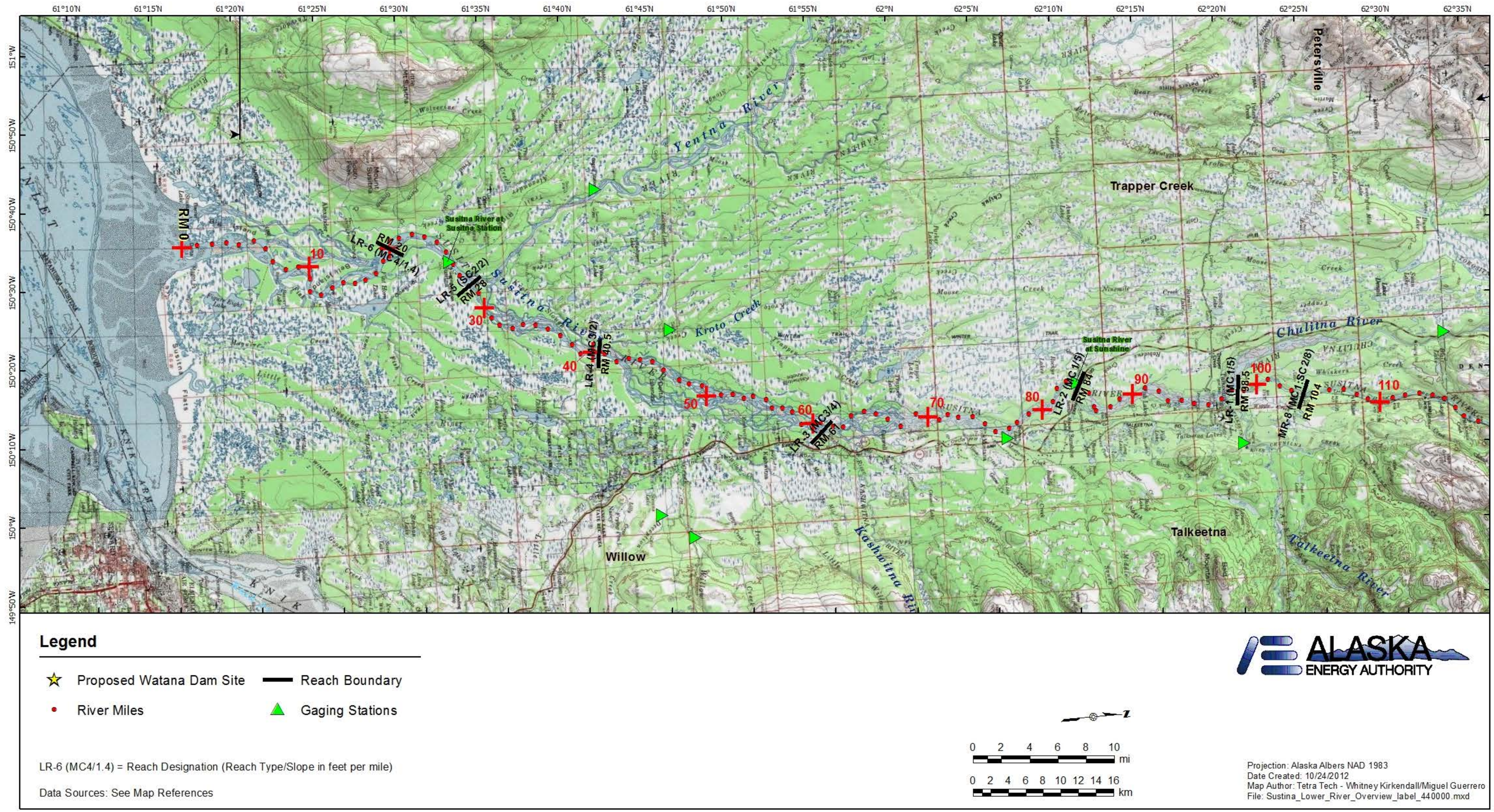

Figure 6.5-4. Lower Susitna River Segment geomorphic reaches.

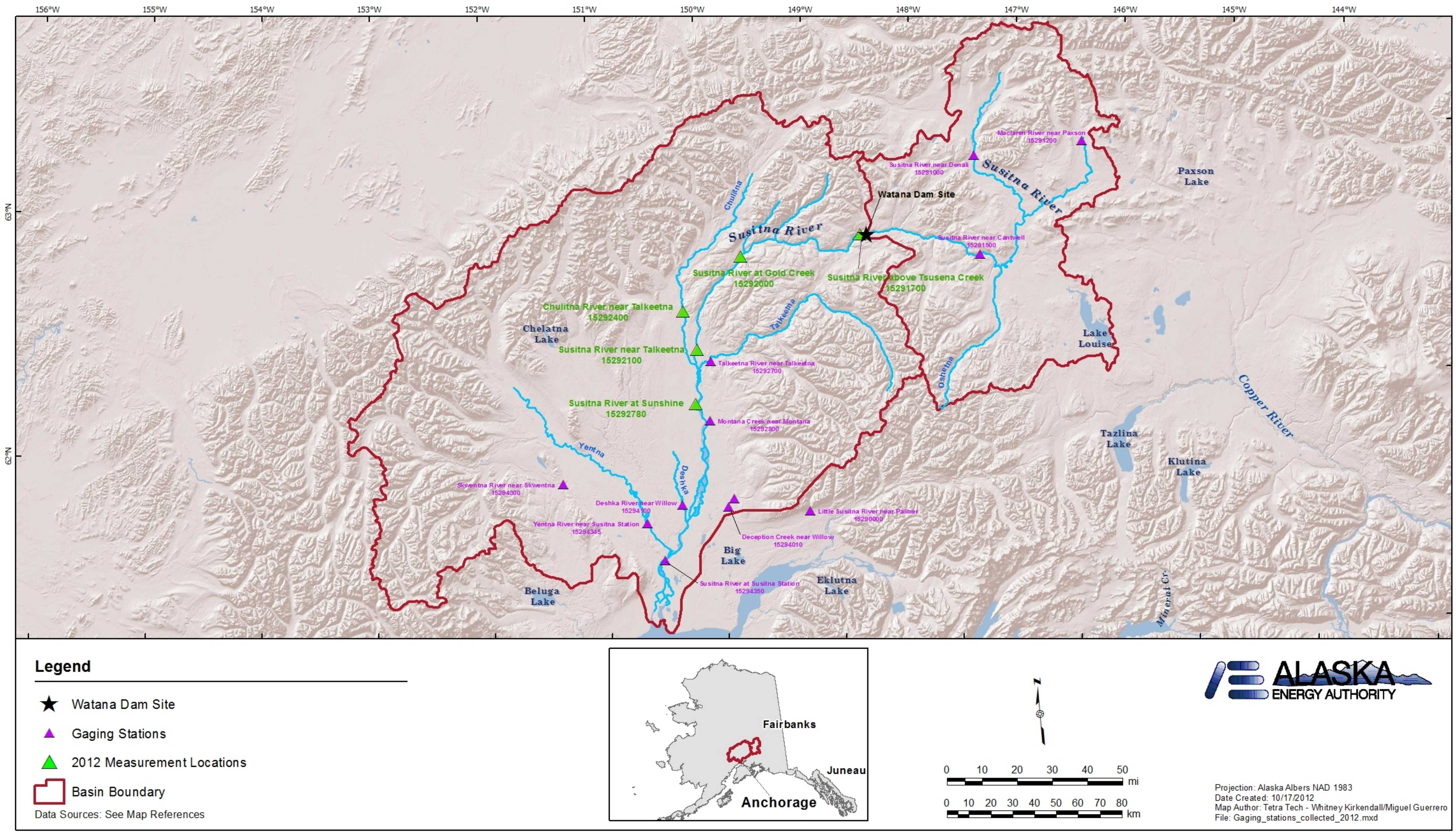

Figure 6.5-5. USGS Susitna River basin gaging stations and 2012 measurement locations.

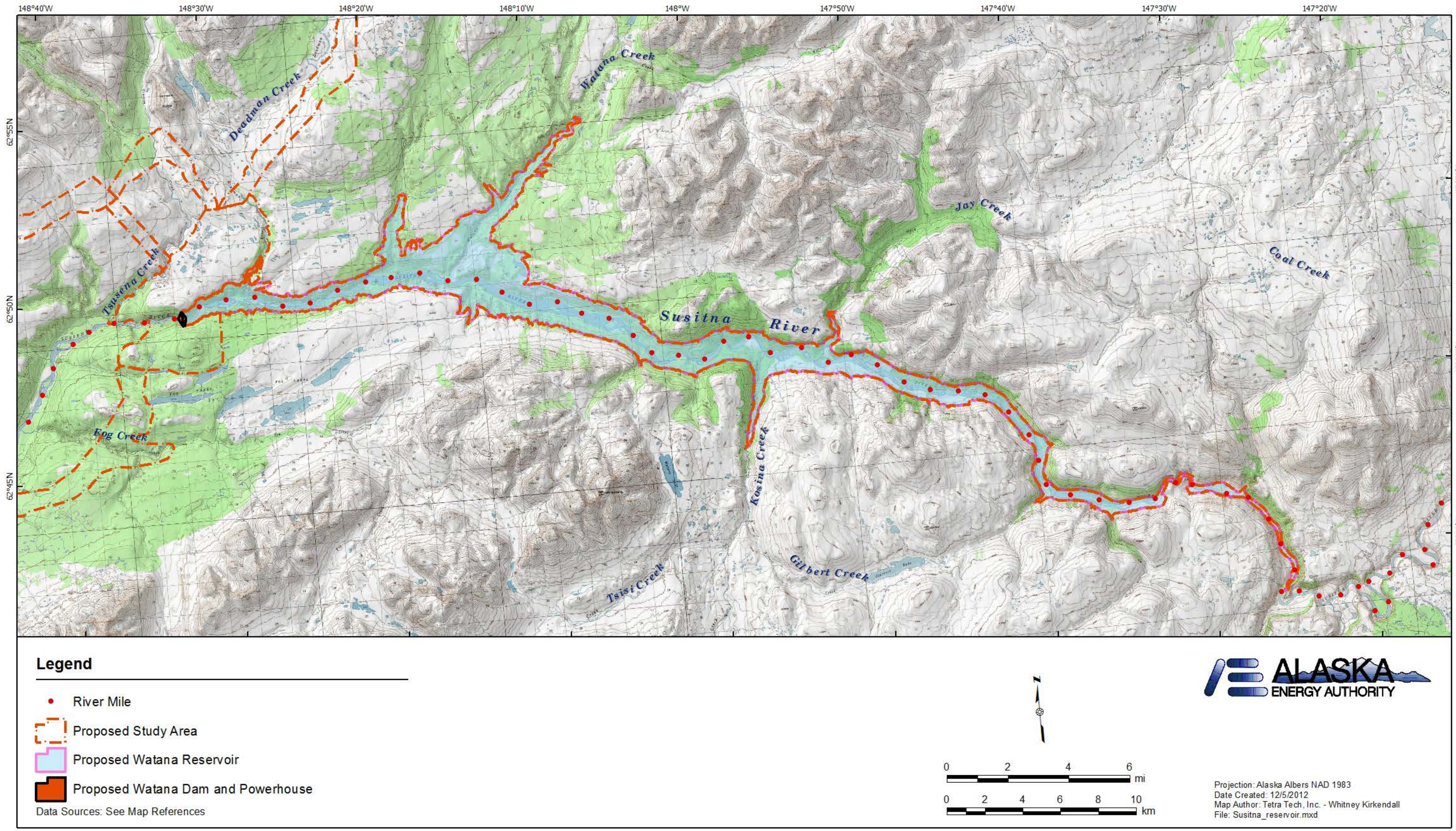

Figure 6.5-6. Susitna-Watana Geomorphology Study reservoir geomorphology study area.

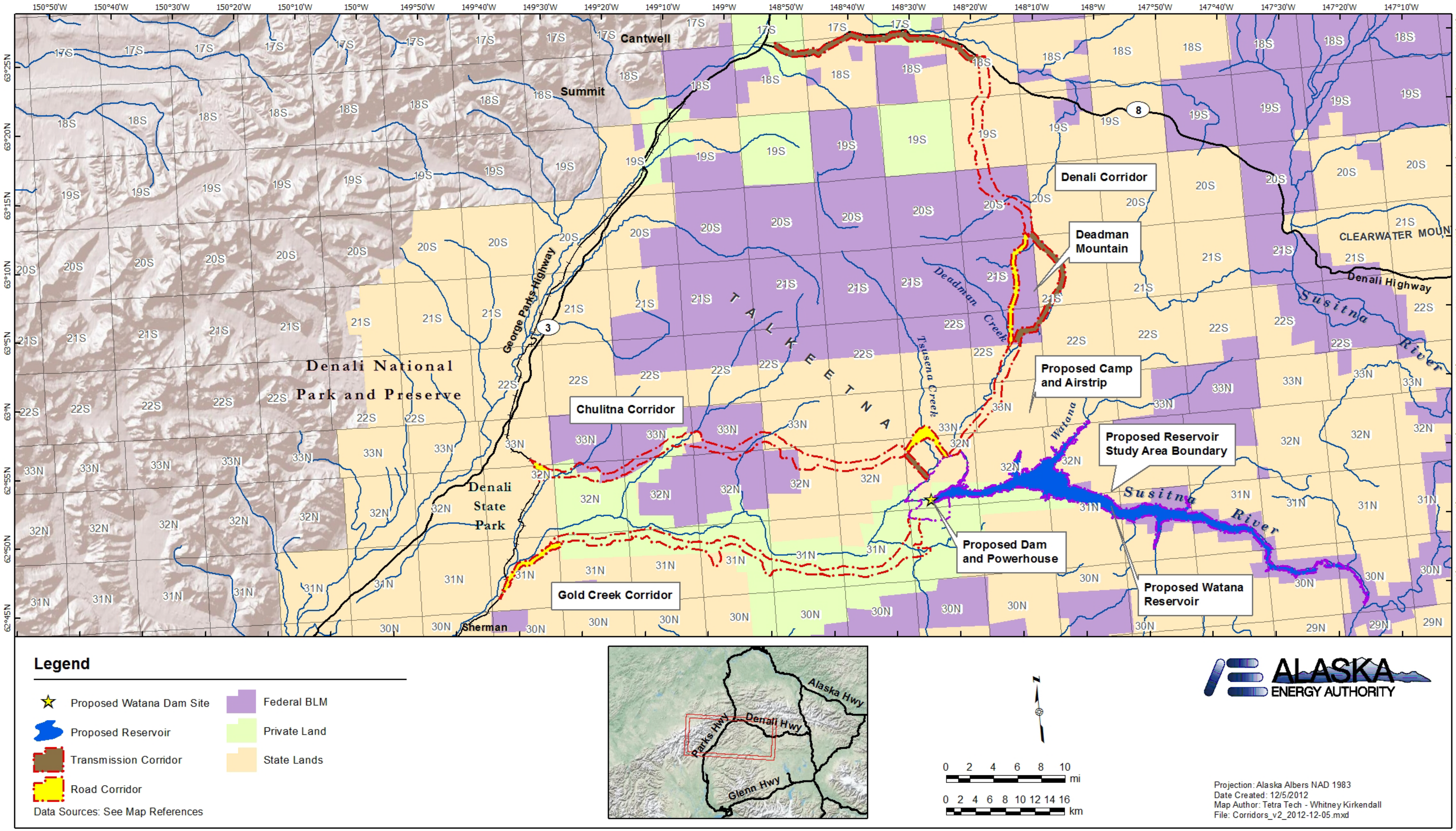

Figure 6.5-7. Susitna-Watana access corridors.

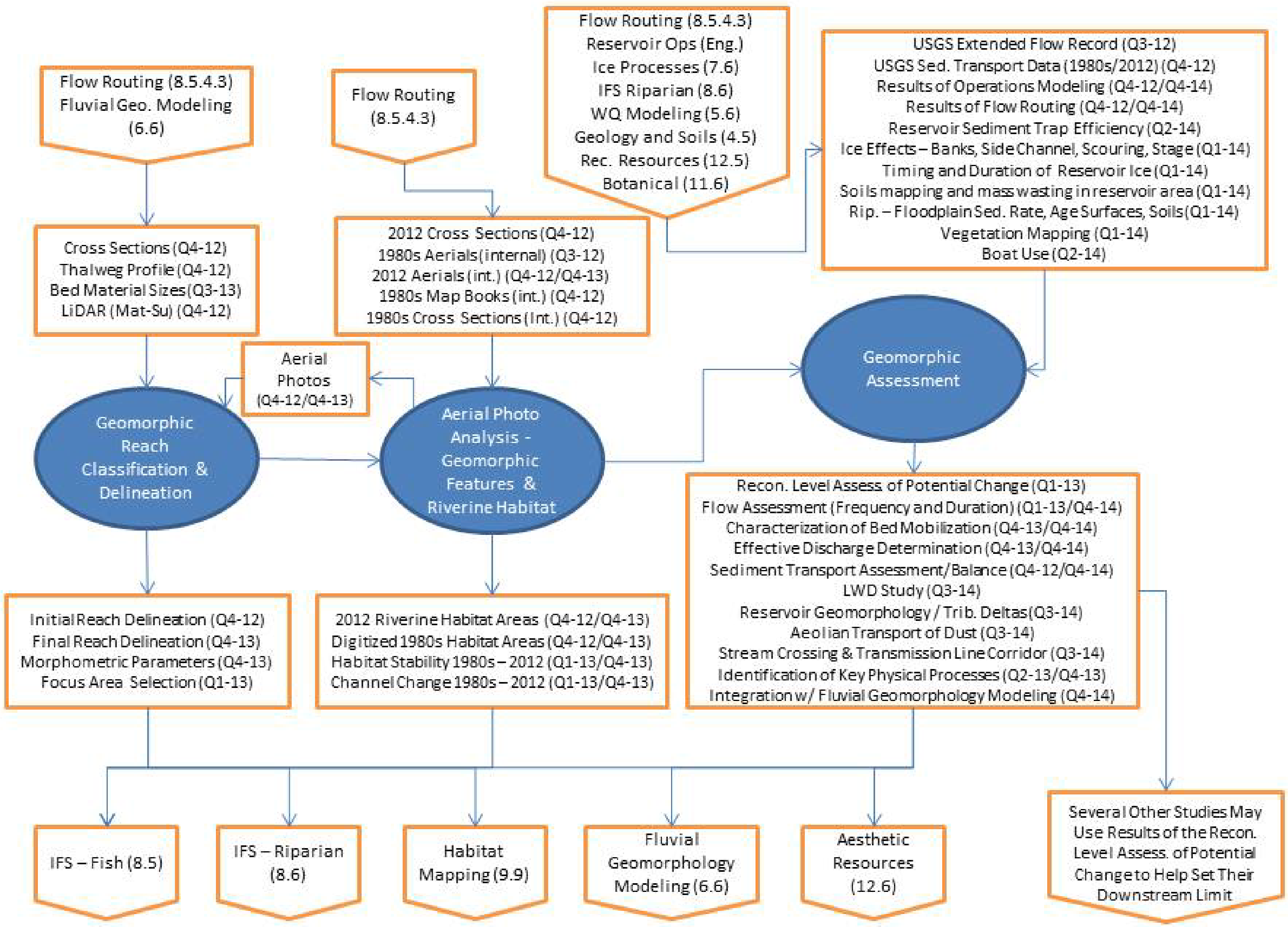

Figure 6.5-8. Study interdependencies for the Geomorphology Study.