

# Susitna-Watana Hydroelectric Project Document ARLIS Uniform Cover Page

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**1.1. Geomorphology Study**

**1.2. Requestor of proposed study**

AEA anticipates resource agencies will request this study.

**1.3. Responses to Study Request Criteria (18 CFR 5.9(b))**

**1.3.1. Describe the goals and objectives of the study proposal and the information to be obtained**

The overall goal of the study is to evaluate the effects of the Project on the geomorphology of the Susitna River. The results of this study, along with results of the Fluvial Geomorphology Study below Susitna-Watana Dam, will be used in combination with geomorphic principles and criteria/thresholds defining probable channel forms to predict the potential for alteration of channel morphology.

Specific objectives of this study are as follows:

1. Geomorphically characterize the Project affected river channels;
2. Empirically characterize the Susitna River sediment supply and transport conditions;
3. Assess channel and study site stability/change (1980s versus current conditions);
4. Characterize the surface area versus flow relationships for riverine habitat types over a range of flows (e.g., 5,100 to 23,000 cfs) in the Middle River;
5. Conduct a reconnaissance level geomorphic assessment of potential Project effects on the Lower River channel;
6. Conduct a reconnaissance level riverine habitat assessment of potential Project effects on the Lower River channel;
7. Characterize the proposed Watana Reservoir geomorphology (changes resulting from conversion of the channel/valley to a reservoir);
8. Assess potential issues related to large woody debris transport and recruitment; and
9. Characterize geomorphic conditions at stream crossings along access road/transmission line alignments;

**1.3.2. If applicable, explain the relevant resource management goals of the agencies and Alaska Native entities with jurisdiction over the resource to be studied**

To be completed by requesting organization.

**1.3.3. If the requester is a not resource agency, explain any relevant public interest considerations in regard to the proposed study**

Fisheries resources are owned by the State of Alaska, and the Project could potentially affect these public interest resources by affecting geomorphologic conditions and, in turn, fish habitat.

**1.3.4. Describe existing information concerning the subject of the study proposal, and the need for additional information**

An analysis of the Middle Susitna River reach 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 River reach 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 River reach between the Yentna River confluence (RM 28.5) and Talkeetna (RM 98) (measured at Sunshine gage 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 River 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 proportion of the various meso-habitat types remain constant within a reach.

Considerable information is available from a variety of sources that will support the development and execution of the General Geomorphology Study. Much of the available information is from the 1980 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 as the Susitna River is a dynamic system and historical data such as cross sections and aerial in many areas will likely have changed considerably since they were collected in the 1980s. However, these data when compared with current information provide valuable tools to understand the behavior and physical processes driving the geomorphology of the Susitna River. 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 for AEA Susitna Water Quality and Sediment Transport Data Gaps Analysis Report (URS 2011).

**1.3.5. Explain any nexus between project operations and effects (direct, indirect, and/or cumulative) on the resource to be studied, and how the study results would inform the development of license requirements**

Construction and operation of the Project as described in the Pre-application Document (PAD; AEA 2011) will affect flow, sediment, and large woody debris (LWD) downstream and upstream of Susitna-Watana Dam. Downstream of the dam (Middle River and Lower River) Project operations have the potential to alter aquatic habitat and channel morphology as a result of changes to flow timing and magnitude, sediment supply and sediment transport capacity, large woody debris (LWD) recruitment and transport. Above the dam (Upper River), Project operations would result in trapping of sediments and LWD, deposition of sediments at tributary mouths, beach formation, and erosion and/or mass wasting of soils within the impoundment.

Construction of project access roads and transmission lines would require stream crossing structures which would have the potential to affect stream geomorphology. The various components of this study will address the extent of the associated project effects and data needed for design of any necessary PM&E measures ~~to minimize effects~~.

**1.3.6. Explain how any proposed study methodology (including any preferred data collection and analysis techniques, or objectively quantified information, and a schedule including appropriate field season(s) and the duration) is consistent with generally accepted practice in the scientific community or, as appropriate, considers relevant tribal values and knowledge**

*1.3.6.1. Study Component G-1.1: Delineate Geomorphically Similar (Homogeneous) River Segments*

The goal of the Delineate Geomorphically Similar (Homogeneous) River Segments study component is to geomorphically characterize the project affected river channels. This effort is being performed as part of the 2012 studies and is also described in the Study plan for G-2S Aquatic Habitat and Geomorphic Mapping of the Middle River Using Aerial Photography. The study area is the length of the Susitna River from its mouth at the Cook Inlet (RM 0), upstream to the Susitna-Watana Dam (RM 184) and upstream of Susitna-Watana Dam including the reservoir inundation zone and on upstream to the Maclaren River confluence. The tributary mouths along the Susitna River and in the reservoir inundation zone potentially affected by the project are also included in the study area.

*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 Instream Flow, Instream Flow Riparian Study, Fish Studies and Ice Processes 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 River (Trihey & Associates 1985) and the Lower River (R&M Consultants, Inc. and Trihey & Associates 1985a).

*Methods*

This effort consists of identification of a geomorphic classification systems and conducting the delineation of geomorphic reaches based on the identified classification system.

Identification of Geomorphic Classification System

The first step in geomorphic reach delineation effort will be the identification of the system to classify and delineate the reaches. 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 will be reviewed and it is anticipated that a specific system will be developed that borrows elements from several classifications system. The classification scheme will consider both form and process. Development of this system will be coordinated with the Instream Flow Study, Instream Flow Riparian Study, Ice Processes Study and Fish Study so it is consistent with their needs. These studies may require further stratification to identify specific conditions of importance to their effort, 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.

### Geomorphic Reach Delineation

The Lower River (RM 0 to RM 98), the Middle River (RM 98 to RM 184) and the Upper River to the Maclaren River confluence (RM 184 to RM 260) will be delineated into large-scale geomorphic river segments (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 purposes of stratifying the river into study segments.

Since there are several studies that will require a reach delineation for planning 2012 field activities, an initial delineation that will be primarily based on readily available information (most recent high quality aerials, bed profile from the 1980s, geomorphic descriptions from the 1980s) will be developed in April 2012. As additional information is developed—such as current aerials and transects—the delineation will be refined and the various morphometric parameters will be determined. Coordination with the River Flow Routing Model Transect Data Collection Study will occur in order to obtain cross-section channel/floodplain data. Coordination with the Instream Flow Study, Instream Flow Riparian Study, Geomorphic Modeling Study and Ice Process Study will occur to ensure that the river stratification is conducted at a scale appropriate for those studies.

A reconnaissance-level site visit of the Susitna River will be conducted that will be coordinated with other studies to take advantage of scheduled boat and helicopter trips as well as opportunities to coordinate with other studies. The Study Lead, Geomorphology Lead and Sediment Transport Modeling Lead, the erosion Study Lead and at least one other senior member of the Geomorphology Study team will participate in the reconnaissance trip. 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 the Geomorphology Study components.

### 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.

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 the USGS.
- Profile of the river (thalweg or water surface)

*1.3.6.2. Study Component G-1.2: Bedload and Suspended Load Data Collection at Tsusena Creek, Gold Creek and Sunshine Gage Stations*

The goal of the Bedload and Suspended Load Data Collection at Tsusena Creek (RM 182), Gold Creek (RM 136) and Sunshine Gage (RM 84) Stations study component is to empirically characterize the Susitna River sediment supply and transport conditions. This effort is being performed by the USGS. The effort described is for 2012 and may be modified in subsequent years 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).

*Existing Information and Need for Additional Information*

The collection of the data described in this study will supplement sediment transport data previously collected in the 1980s. The additional data is needed to determine if historical data can be used to reflect current conditions and to address some of the data gaps identified for AEA Susitna Water Quality and Sediment Transport Data Gaps Analysis Report (URS 2011). This study will provide information on current sediment supply conditions and support determination of project effects on sediment supply. This information will be used by several study components in this study as well as the Geomorphology Modeling below Susitna-Watana Dam Study.

*Methods*

The following scope of work was provided by the USGS to describe the original scope of work:

- Operate and maintain the stream gages;
- Maintain datum at the site;
- Record stage data every 15 minute;
- Make discharge measurements during visits to maintain the stage-discharge rating curve and to define the winter hydrograph;
- Post near real-time stage and discharge data on the USGS web site <http://waterdata.usgs.gov/ak/nwis/>;
- Store the data in the USGS databases;



- Publish the data in our annual Water-Resources Data for the United States report (<http://wdr.water.usgs.gov/>);
- Collect at least 5 suspended sediment samples at Susitna River above Tsusena Creek, at Gold Creek, and at Sunshine during the year for concentration and size analysis;
- Collect at least 5 bed material samples during the year at Susitna River above Tsusena Creek, at Gold Creek, and at Sunshine for bedload transport determination and size analysis;
- 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; and
- Suspended and bedload data, including calculation of sediment transport ratings and daily loads, will be compiled in a technical memorandum delivered to AEA during FFY 2013, and as early as March, 2013, 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 bed load 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 for the Susitna River at Gold Creek and the Susitna River at Sunshine.

The sediment transport data available for the Chulitna and Talkeetna rivers will be reviewed. This will be accomplished using the sampling results collected in 2012, to help determine whether or not the historical rating curves are expected to be accurate. Since current data are not being collected on the Chulitna and Talkeetna rivers, this will primarily be accomplished by developing the mass balance of sediment above three rivers (Gold Creek data) and below (Sunshine data) to estimate the contributions from the Chulitna and Talkeetna Rivers. The estimate based on the mass balance developed from the current data will be compared against estimates based on the historical Chulitna and Talkeetna sediment transport relationships. In addition, the historical Chulitna and Talkeetna sediment transport relationships and their applicability to current conditions will secondarily be evaluated comparing the historical versus new sediment rating curves at Gold Creek and at Sunshine (two locations where new data are being collected in 2012). Based on the results of the effort, a recommend whether or not additional sediment transport sampling is necessary in the Chulitna or Talkeetna rivers will be made.

#### *1.3.6.3. Study Component G-1.3: Sediment Supply and Transport Middle and Lower River*

The goal of the Sediment Supply and Transport Middle and Lower River is to empirically characterize the sediment supply and transport conditions in the Susitna River below Susitna-Watana Dam. The study consists of estimation of sediment supply and transport for the Middle and Lower rivers. The effort for the Lower River will be conducted in 2012 as part of G-S4: Reconnaissance Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel. The remaining efforts (Middle River sediment supply, bed material mobilization and effective discharge) will be conducted in 2013. The study area for this effort is from the Susitna Station Gage (RM 28) to Susitna-Watana Dam (RM 184).

### *Existing Information and Need for Additional Information*

Sediment transport data are available along the mainstem Susitna River and several of the major tributaries between the proposed Susitna-Watana Dam (RM 184) downstream to Susitna Station RM 28) (URS 2011). The Project will reduce sediment supply to the Susitna River as well as alter the timing and magnitude of the flows that transport the sediment downstream. The results of this study component will provide the initial basis for assessing the potential for changes to the Lower River and Middle River sediment balance and the associated changes to geomorphology. The studies will also support G-2: Fluvial Geomorphology Modeling below Susitna-Watana Dam Study through development of sediment supply information that will be required for input to the model.

### *Methods*

The methods are divided into five sections analyses: Lower River Sediment Load, Middle River Sediment Supply, Characterization of Bed Material Mobilization and Effective Discharge and Information Required.

#### Lower River Sediment Load

The sediment transport measurements the USGS has collected, both historical and current, will be used to develop bed load 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. 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). Specifically, the bias can result from the construction of linear least-squares regression relationships of logarithmic transformed concentrations or loads and flows (Walling 1977b, Thomas 1985, Ferguson 1986). Various procedures are available to address the bias, including accounting for seasonal differences in sediment transport, and accounting for hysteresis related to rising and falling limbs of flood hydrographs (Guy 1964, Walling 1974). Koch and Smillie (1986) and Cohn and Gilroy (1991) describe methods of handling the bias correction depending on the expected distribution of errors. The USGS Office of Surface Water (1992) endorsed the recommendations in Cohn and Gilroy (1992) to use 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. 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 total sediment load delivered to the Lower River for pre- and post-Project conditions will be evaluated using the sediment rating curves developed from the historical data for the Sunshine and Susitna Station gaging stations and any new sediment transport data being collected by the USGS under Study G-S1: Determine Bedload and Suspended Sediment Load by Size Fraction at Tsusena Creek, Gold Creek, and Sunshine Gage Stations (if the 2012 data is available from the USGS in time for this analysis). If the 2012 Tsusena Creek data are available, it will be compared against the 2012 Gold Creek data to estimate the sediment inflow between Tsusena and Gold Creek (see "Middle River Sediment Supply" below). This will allow development of a sediment rating curve from the 1985 data for the Susitna at Tsusena Creek (representative of sediment transport at the Susitna-Watana dam site). Similarly, the sediment transport rating curves at Gold Creek, Sunshine and the Chulitna Rivers will be used to determine the combined



sediment contribution of the Talkeetna and other sediment inflows between Gold Creek and Sunshine. Moving downstream, the sediment rating curves at Sunshine, Yentna River and Susitna Station can be used to determine the sediment contribution between Sunshine and Susitna Station.

The rating curves for the mainstem Susitna stations, gaged (tributary stations and those developed for contributing ungaged (in terms of sediment data collection) areas between stations will be used to develop the sediment balance for the pre-Project hydrology for a wet, average and dry year. This will include the contributions from the gaged tributaries and the ungaged contributing areas. The latter will be calculated based on the assumption that the sediment load in the Susitna 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 below the Susitna-Watana Dam (Tsusena Creek) will be reduced by 100 percent for the bed load and 90 percent for the suspended load. This sediment inflow as well as the inflows from the gaged tributaries and the ungaged contributing areas (determined from the pre-Project sediment balance) will be added together to determine the sediment balance for the post-Project condition for representative wet, average and dry years. The overall sediment balance below the dam for the Post-Project condition for representative wet, average and dry years will then be calculated based on adding the gaged and ungaged contributions for the pre-project condition to the reduced sediment below the Susitna-Watana Dam. The results of the pre- and post-Project sediment balance determinations will be used to identify the relative influence of the trapping of sediments in the Susitna Watana reservoir on the overall sediment balance along the Susitna River.

#### Middle River Sediment Supply

The sediment supply inputs in the Middle River downstream of Susitna-Watana Dam will be estimated. Contributions from identified mass wasting locations or tributary sediment sources downstream of the dam will be estimated. Potential procedures to estimate the Middle River sediment supply include: 1) the use of watershed area and regional sediment supply relationships and 2) the determination of the difference between Tsusena Creek and Gold Creek sediment transport. Past USGS sediment data may be available for Indian and Portage Creek which could also be used to assist in the estimation of the Middle River sediment supply inputs.

#### Characterization of Bed Material Mobilization

The approximate discharge that bedload transport begins, incipient motion, in the Susitna River near the dam and at selected locations in the Middle and Lower rivers will be estimated using the USGS empirical sediment rating curves, incipient motion calculations, and field observations. The determination of the discharge at which incipient motion occurs will be used to estimate and compare the frequency, number of days, of bed mobilization for the pre- and post-project condition hydrology. This will be performed on both a monthly and annual basis and 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 ( $\tau_c$ ) to the dimensionless critical shear stress ( $\tau_c^*$ ) and the unit weight of sediment ( $\gamma_s$ ), the unit weight of water ( $\gamma$ ), and the median particle size of the bed material ( $D_{50}$ ). One key limitation of this relation is the specification of  $\tau_c^*$ , for incipient motion, which can range by a factor of three (Buffington and Montgomery 1997). To work around this limitation, Parker

(Parker et. al. 1982) proposed relating the reference Shields stress ( $\tau^*$ ) to the dimensionless transport rate  $W^* = 0.002$ , which represents flow conditions that are just high enough to begin mobilization of the bed material (i.e., incipient motion conditions). For this relationship,  $W^*$  is a function of the unit bed load and the total boundary shear stress, both of which are relatively simple parameters to calculate from field data if bed load and discharge measurements are included.

Consistent with the work of Mueller (Mueller et. al. 2005), bed material mobilization at various locations along the project reach will be characterized using this procedure. Data collected by the USGS, which will include the necessary series of coupled flow and bed load transport measurements, will be used to formulate a series of bed load rating curves. These curves will then provide a basis for estimating  $\tau^*$  that corresponds to a dimensionless transport rate  $W^* = 0.002$  for bed material mobilization.

### Effective Discharge

The concept of effective discharge, as advanced by Wolman and Miller (1960), related 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 transported the most sediment over the long-term, and that these flows were 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.*”

Alluvial rivers adjust their shape in response to flows that transport sediment, and 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 Werner, 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 to 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 size 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 by dividing the range of flows into 30 logarithmic classes (Biedenharn et al., 2000) and then computing the total quantity of bed material load transported by the flows within each class to determine the discharge that transports the most sediment. The total quantity of bed material transport will be based on sediment rating curves developed from the USGS measurements, and multiplying the bed material transport rate for the average discharge in each class by the corresponding duration using information from mean daily flow duration curves. The effective discharge will be determined for both the pre- and post-project conditions.

### Information Required

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

- Current aerial photographs.
- Historical suspended sediment and bed load data for the Susitna River.
- Flow records for the Susitna River.

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

- Suspended and bed load data for the Susitna River at Tsusena Creek and Gold Creek being performed by the USGS.
- Extended flow record for the Susitna River and gaged tributaries within the study area being developed by the USGS.
- Estimated flows for the ungaged tributaries within the study area.
- Extended flow record for the Susitna River and tributaries being developed by the USGS.
- Collection of bed material samples throughout the Middle and Lower Rivers.
- Hydraulic conditions from the Hydraulic Routing Model

#### *1.3.6.4. Study Component G-1.4: Assess Geomorphic Change Middle and Lower Rivers*

The goal of the Assess Geomorphic Change Middle and Lower Rivers study component is to compare existing and 1980s geomorphic feature data from aerial photo analysis to characterize the relative stability of the 1980s study sites and river morphology under unregulated flow conditions. The effort for the Middle River will be conducted in 2012 as part of G-S2: Aquatic Habitat and Geomorphic Mapping of the Middle River Using Aerial Photography and for the Lower River as part of G-S4: Reconnaissance Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel. The study area extends from the mouth of the Susitna River (RM 0) at Cook Inlet to Susitna-Watana Dam (RM 184).

#### *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 River (R&M Consultants, Inc. and Trihey and Associates 1985a). The 1980s Lower River study also included an evaluation of the morphologic stability of islands and side channels by comparing aerial photography between 1951 and 1983. 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 subreaches is required.

Understanding existing geomorphic conditions, 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 may also be used in the Instream Flow Riparian and Ice Processes studies to provide the surface areas of bars likely to become vegetated in the absence of ice-cover formation.

### *Methods*

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

#### Middle River

Coordination with AEA's Spatial Data Contractor to digitize the riverine geomorphic features from RM 98 to RM 150 defined in the 1980s from hard copy maps as found in the Middle River Assessment Report (Trihey & Associates 1985) will occur. Each feature will be a polygon (without slivers). Geomorphic features that are visible between the 1980s and current images, including the main channel, side channels, the presence and extent of mid-channel bars, vegetated bar areas, and changes at tributary deltas will be digitized for a single representative flow. (*Note: the AEA Spatial Data Contractor will complete the digitizing and develop associated metadata for the 1980s digitizing.*) From RM 98 to RM 184 the geomorphic features at a single representative stream flow on the 2012 aerial photographs will also be digitized and delineated using the orthorectified photography and ArcGIS software (each geomorphic feature will be a polygon without slivers. (*Note: the Study Contractor will complete the digitizing and develop associated metadata for the 1980s digitizing.*))

The information developed from digitizing the aeriels will be used to analyze and compare the geomorphology for 1980s and current conditions. From RM 98 to RM 150 GIS software will be used to compare the 2012 versus 1980s total surface area associated with each geomorphic feature. Data results will be compiled into tables and graphs, as appropriate, to show the difference in surfaces area of the feature types between 2012 and the 1980s photography. The lead geomorphologist will provide training to ensure appropriate application of the geomorphic definitions. Since this 34-mile river segment below the proposed Susitna-Watana Dam site (RM 150 to RM 184) was not analyzed in the 1980s, this portion of the river will be a new assessment (2012 photography only) that will not be compared to past studies. However, the methods for analyzing riverine geomorphic features will remain the same.

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 2012. 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. 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 1985 and 2012 could be pertinent if substantial changes in the riverine habitat types (surface area, locations, etc.) were identified during comparison of the 2012 and 1980s photography. 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. If additional analysis is identified, it will be performed under the 2103/2014 studies.

### Lower River

The 36,600 cfs September 6, 1983 set of Lower River aerial photographs and current satellite images or aerial photographs will be obtained to compare historical and present-day channel planform and pattern from RM 28 to RM 99. Planform shifts of the main channel and side channels will be identified between the 1983 and current aerial photography. The three rivers confluence area is also a part of the analysis (extended to RM 99). Geomorphic features that are visible between the 1983 and current images, including the presence and extent of side channels, vegetated bar areas, and changes at tributary deltas will be mapped and characterized. In areas where the mainstem channel consists of a dynamic braid plain mostly void of stabilizing vegetation, the effort will be directed to defining the edges of the active channel rather than detailing the myriad of channels within the active area. Major sloughs and side channel along the lower river margins will be included in the digitizing effort.

The rest of the Lower River effort will be similar to the Middle River. 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. 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. 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 1985 and 2012 could be pertinent if substantial changes in the riverine habitat types (surface area, locations, etc.) were identified during comparison of the 2012 and 1980s photography. 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.

### Information Required

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

- Historical 1980s orthorectified aerial photographs for the Middle and Lower rivers.

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

- Obtain recent or fly 2012 orthorectified aerial photos (or satellite imagery) in the Middle and Lower Rivers at a flow similar to the historic aerials.
- Acquire historic orthorectified aerial photos and digitized geomorphic features from the AEA Spatial Data Contractor (SDC) for the Middle and Lower Rivers for a single discharge.



#### 1.3.6.5. Study Component G-1.5: Riverine Habitat Versus Flow Relationship Middle River

The goal of the Riverine Habitat Versus Flow Relationship Middle River study component is to develop existing and 1980s riverine habitat type area data over a range of flows in order to quantify riverine habitat versus surface area relationships. The study area extends from the three rivers area (RM 98) to Susitna-Watana Dam (RM 184). Up to 20 study sites not exceeding fifty percent of the reach will be studied in the 2012 study G-S2: Aquatic Habitat and Geomorphic Mapping of the Middle River Using Aerial Photography. All or part of the remaining portion may be studied in 2103/2014 depending on the outcome and recommendations from the 2012 study as well as the selection of instream flow study sites.

##### *Existing Information and Need for Additional Information*

Understanding existing geomorphic conditions, how aquatic habitat 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 macro-habitat mapping to support the Instream Flow Study and will be used in the Ice Processes Study to provide the surface areas of bars likely to become vegetated in the absence of ice-cover formation.

##### *Methods*

New aerial photography obtained in 2012 will be combined with 1980s and other information to create a digital, spatial representation (i.e., GIS database) of riverine habitat. The result will be a quantification of the area of the riverine habitat types for three flows conditions for the historical 1980s condition and the current 2012 condition. The results will be presented as riverine habitat versus area relationships for the Middle River, reaches in the Middle River and individual habitat study sites. Comparison between the results from the 1980s and 2012 can be made. The historical information will only be developed for the Reach from RM 98 to RM 150 as the delineation of habitat in the Devil Canyon section, RM 150 to RM 184, was not performed.

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

##### Aerial Photography

New (2012) color aerial photography of the Middle River (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]) will be obtained in order to provide the foundation for the aquatic habitat and geomorphic mapping the Middle River, as well as to provide a resource for other studies.

Three sets of aerial photography will be obtained 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). If hydrologic conditions will not allow obtaining the aerials at 5,100 cfs in 2012, the lowest flow for which aerials can be obtained, either 7,400 cfs or 10,600 cfs, will be substituted.



Determination of the scale of the aerial photography (i.e., flying elevation) and the digital scan resolution will be coordinated with AEA's Spatial Data Contractor, AEA, the Instream Flow Study Lead, and licensing participants. The Geomorphology Study Lead will coordinate with the Spatial Data Contractor who will both obtain (fly) the aerial photography and orthorectify the aerial photography.

The flow record for the previous 10 years at the USGS Gold Creek gage will be reviewed. The river typically rises from about 2,000 cfs to over 15,000 cfs during the ice break-up period in late April to mid-May in a matter of a few days. Because of the influence of ice and ice break-up on water surface elevations during this period, it is unlikely that aerial photographs to make a valid comparison with the 1980s habitat mapping can be collected in the spring. The river does not recede to 12,500 cfs until mid-August to mid-September and to 5,100 cfs until sometime in October. The river is intermittently in the 23,000 cfs range in the June through August timeframe. For developing the schedule, it is assumed that the orthorectified aerial photographs for 23,000 cfs will be available in August 1, 2012, aerials for 12,500 cfs will be available by October 15, 2012, and aerials for 5,100 cfs will be available by November 15, 2012. Analysis of riverine habitat for flows at which aerials are not obtained in 2012 will need to be completed in 2013/2014. It should be noted that snowfall in the project area for 2012 is close to an all-time record, and this may influence the timing and magnitude of the discharges this year. If it does not appear that the Susitna River will recede to 5,100 cfs prior to ice and/or snow cover becoming a potential issue with the quality of the photographs in the fall, a decision will be made to obtain aerial photographs for the low-flow discharge in 2012 at either 7,400 cfs or 10,600 cfs.

#### Digitize Riverine Habitat Types

The Geomorphology Study will coordinate with the Instream Flow Study, the Instream Flow Riparian Study, Ice Processes Study, and other pertinent studies to identify large-scale (typically many miles) aerial photography analysis study reaches for the riverine habitat digitizing. For this initial work, the number of study sites to be analyzed is assumed to not exceed 20 detailed study sites from the 1980s effort or more than 50 percent of the reach. In addition to consideration of habitat and geomorphic characteristics of the reach, a visual qualitative side-by-side comparison of the aerials will be performed to ensure that the selected reaches are also representative of the level of change that has occurred over the period of comparison. Aerial photography will be obtained for the entire reach so that additional areas may be digitized in the future if warranted.

Coordination 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 as found in the Middle River Assessment Report (Trihey & Associates, 1985) will occur. Each habitat type must be a polygon (without slivers). The habitat types were classified into the following categories: main channel, side channel, side sloughs, upland sloughs, and tributary mouths.

Riverine habitat types for the identified study sites will be delineated and digitized from the 2012 aerials at each of the three stream flows used for the 1980s digitizing effort. Sites will include those identified for the 1980s digitization effort as well as up to six additional sites between RM 150 and RM 184, identified in coordination with the Instream Flow Study, the Riparian Instream Flow Study, Ice Processes Study, and other pertinent studies. The habitat types will be digitized from the orthorectified photography using ArcGIS software (each habitat type must be a polygon without slivers). Riverine habitat will be classified using the same classification categories used in the Trihey & Associates study (1985) main channel, side channel, side sloughs, upland

sloughs, and tributary mouths. *Note: the digitizing (and associated metadata) will be completed by Contractor during this study.*

### Riverine Habitat Analysis

The information developed in the previous task will be 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 aeriels. The riverine habitat type surface area versus flow relationships between the 1980s and current conditions will be 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 River.

From RM 98 to RM 150 GIS software will be used to compare the 2012 versus 1980s total surface area associated with each delineated riverine habitat types at each measured flow. Data results will be compiled into tables and graphs, as appropriate, to show the difference in surfaces area of the feature types between 2012 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 will the same approximate flows be compared, but the same definitions will be used for each of the riverine habitat features that are delineated (see above). The lead geomorphologist will provide training to ensure appropriate application of the habitat definitions.

Since the 34-mile river segment below the proposed Susitna-Watana Dam site (RM 150 to RM 184) was not analyzed in the 1980s, this portion of the river will be a new assessment (2012 photography only) that will not be compared to past studies. However, the methods for analyzing riverine habitat types over the range of flows will remain the same as for the downstream reach (23,000 cfs, 12,500 cfs and 5,100 cfs). Because this reach has a high level of lateral and vertical control, the areas associated with riverine habitat types has likely experienced little change. Results of the study component Assess Geomorphic Change will determine whether there has been change in geomorphic features in this portion of the Middle River.

Habitat features will be compared and contrasted quantitatively and a qualitative assessment will be made of the similarity of the sites in 2012 compared to the 1980s in order to assess the stability of the study sites. A decision will also be made as to whether the remaining portions of the Middle River beyond the original selected study sites analyzed in 2012 will be also be digitized and analyzed in 2013/2014.

### Information Required

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

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

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

- Obtain (fly) 2012 orthorectified aerial photos in the Middle River at 5,100, 12,500, and 23,000 cfs (corresponds to 1980s flow).
- Acquire historical 1980s digitized riverine habitat features from the AEA Spatial Data Contractor (SDC) for the Middle River for flows of 5,100, 12,500, and 23,000 cfs.

*1.3.6.6. Study Component G-1.6: Reconnaissance Level Assessment of Project Effects on Lower River Channel*

The goal of the Reconnaissance Level Assessment of Project Effects on Lower River Channel 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 River. The study area for this effort is the Lower River from RM 98 to RM 0. This effort will be conducted in 2012 as part G-S4: Reconnaissance Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel. The results of this effort will help determine what additional analysis of Project effects may be warranted in the Lower River for the 2013/2104 studies.

*Existing Information and Need for Additional Information*

An analysis of the Lower River reach 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 River reach between the Yentna River confluence (RM 28.5) and Talkeetna (RM 98) (measured at Sunshine gage 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 (Trihey and Associates, 1985b). The study contains information regarding 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.

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 will provide the initial basis for assessing the potential for changes to the Lower River reach morphology due to the Project. Additional studies will be planned for 2013-2014 if the results of this study plan identify a potential for important aquatic habitat and channel adjustments in response to the Project.

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

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

### *Methods*

#### Stream Flow Assessment

Pre-Project and available post-Project hydrologic data will be compared. This will include a comparison of the monthly and annual flow duration curves (exceedance pots) and plots/tables of flows by month (maximum, average, median, minimum) for the Susitna River at the Sunshine and Susitna Station gaging stations. 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 will include the extended record being prepared by the United States Geological Survey (USGS).

Using the extended record currently being prepared by the USGS, a flood-frequency and flood-duration analysis for pre- and post-Project annual peak flows will be performed. The flood-frequency analysis will be performed using standard hydrologic practices and guidelines as recommended by USGS (1982).

#### Sediment Transport Assessment

The sediment transport measurements USGS has collected 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). This information will be used to perform an overall sediment balance for both the suspended sediment load and the bed load. The development of this information will be performed in Study G-3: Sediment Supply and Transport Middle and Lower River (see Section 1.3.6.3).

#### Integrate Sediment Transport and Flow Results into Analytical Framework

Based upon the above analyses, an assessment of anticipated Project effects on the Lower River channel type and morphology will be developed. 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 an analytic framework along the longitudinal profile of the river system from the three rivers confluence through Lower River reach will be predicted. The analytical framework developed by Grant et al. (2003) that relies on the dimensionless variables of (1) the ratio of sediment supply below the dam to that above the dam, and (2) the fractional change in frequency of sediment transporting flows will be used to predict the nature and magnitude of the Lower River geomorphic response. Other analytical approaches may be considered to demonstrate potential for geomorphic adjustments in the river reaches due to the Project.

### Information Required

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

- Historical suspended sediment and bed load 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 bed load data for the Susitna River at Tsusena Creek and Gold Creek being performed by the USGS.
- Extended flow record for the Susitna River and gaged tributaries within the study area being developed by the USGS.
- Extended flow record for the Susitna River and tributaries being developed by the USGS

#### *1.3.6.7. Study Component G-1.7: Riverine Habitat Area Versus Flow Lower River*

The objective of the Riverine Habitat Area Versus Flow Lower River study component is to conduct a reconnaissance level assessment of potential for Project effects associated with the change in stage to change Lower River riverine habitat. This effort will be conducted in 2012.

#### *Existing Information and Need for Additional Information*

An analysis of the Lower River reach 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 River reach between the Yentna River confluence (RM 28.5) and Talkeetna (RM 98) (measured at Sunshine gage RM-75) 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 River 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.

#### *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 River under pre- and post-Project flows is warranted for additional flow conditions.

#### Riverine Habitat-Flow Relationship 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 (above) will be developed using the stage-discharge relationships (rating curves) for the Sunshine and Susitna Station gaging



stations. This comparison will include 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. A graphical plot of a representative cross section at each gaging station will be 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.

The availability of USGS winter gage data with respect to discharge and ice elevation/thickness will be investigated. Coordination with the WR-S2: Documentation of Susitna River Ice Breakup and Formation Study will occur to obtain information on ice elevation/thickness, as appropriate. The potential need for an analysis of discharge effects on ice elevation will be identified and conducted, if feasible.

#### 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) will be provided. 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) will also be provided. Data will be summarized with respect to the anticipated pre- and post-Project flow changes, where applicable (see Stream Flow Assessment section above).

#### Site Selection and Stability Assessment

Up to eight sites in the Lower River will be selected from the Yentna to Talkeetna reach map book (R&M Consultants, Inc. and Trihey and Associates 1985a) at the ~36,600 cfs flow at Sunshine Gage to study in 2012. These sites will be selected in coordination with the Instream Flow Study, the Instream Flow Riparian Study, the Ice Processes Study and the stakeholders. A side-by-side comparison of the sites using the 1983 36,600 cfs aerials and the most appropriate current aerials or satellite imagery will be performed to qualitatively assess site stability. Sites which have been substantially reworked by the Susitna River since the 1980s will not be selected for comparison of riverine habitat in the 1980s versus the present. Only sites that have been relatively stable during the period will be selected.

#### 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 will be digitized from the 1985 map book (R&M Consultants, Inc. and Trihey and Associates 1985a) for the selected sites. Each area associated with a habitat type will be a polygon (without slivers). To provide a comparison with current conditions, either recent satellite imagery at a flow similar to 36,600 cfs or aerials obtained in 2012 (if appropriate satellite imagery is not available) will be used to delineate the current wetted areas within the riverine and side-channel habitats for the selected sites.

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 Geomorphic Assessment of Channel Change subtask (see below) 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 River riverine habitat information developed in the 1980s to supplement information being developed in the current Project studies.

Optional: 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 River and results of the Geomorphic Assessment of Channel Change subtask (see below), 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 River 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 Instream Flow Study, Instream Flow Riparian Study, Ice Processes Study, Fish Study and stakeholders. 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. Satellite imagery at similar discharges or new aerial photographs will be obtained (if appropriate satellite imagery is not available). The riverine habitat types 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.

Information Required

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

- Historical 1980s orthorectified aerial photographs for the Lower River.
- 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 G-1.4 Assess Geomorphic Change Middle and Lower Rivers

*1.3.6.8. Study Component G-1.8: Reservoir Geomorphology*

The goal of the Reservoir Geomorphology study component is to characterize changes resulting from conversion of the channel and portions of the river valley to a reservoir. The study area extends from Susitna-Watana Dam (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 5 miles above the reservoir maximum pool ( $\approx$ RM 238). Specific objectives of this study component include:

- 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.

### *Existing Information and Need for Additional Information*

The construction and operation of the proposed Susitna-Watana Project will impound a reservoir for approximately 39 miles upstream from the dam. The reservoir will trap coarse and much of the fine sediment load of the upstream Susitna River that enters the impoundment. The coarse sediment load that enters the reservoir will form a delta where the river enters the reservoir. This material will be re-worked as the reservoir elevation fluctuates seasonally.

Similar to the situation that is expected to occur where the Susitna River enters Watana Reservoir, sediment deposition is expected to occur where tributaries enter the reservoir. The amount and distribution of sediment deposition may impact the connectivity between the reservoir and the tributary channels. The formation of deltas may lead to flows conditions that do not permit upstream fish passage. The reviewed information does not contain data describing the annual loads and the gradations of the sediment that could be transported to and deposited at the mouth of tributaries that enter the reservoir, and therefore this is a data gap.

Operation of the Project would result in seasonal and daily water level fluctuations in the 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 any alterations to project operations or erosion control measures to reduce erosion and mass wasting.

### *Methods*

The methods are divided into three areas: reservoir trap efficiency and sediment accumulation rates, delta formation and reservoir erosion.

#### Reservoir Trap Efficiency and Sediment Accumulation Rates

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

Methods of calculating trapping efficiency to be considered include Churchill (1948), Brune (1953), and Einstein (1965). These methods will provide a basis for estimating the amounts of various size fractions that either pass through or are trapped in the proposed reservoir. Due to the storage capacity of the proposed reservoir, it is reasonable to assume that all sands and coarser size fractions delivered to the reservoir will be trapped. When applied over a long-term horizon, the amount of trapped sediment, coupled with estimates of consolidation (Miller 1953, Lara and Pemberton 1965), can be used to evaluate the impacts of sedimentation on reservoir storage capacity.

#### Delta Formation

While the USGS measurements in Study G-S1 target three locations along the Susitna River, there will be need for sediment transport estimates at additional locations, including ungaged tributaries. Ungaged tributaries that may 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. For example, 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 gradations based on bed material samples can be coupled with selected bed material transport functions to calculate sediment yield rating curves. Long-term flow hydrograph 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. The yield and the topography in the area of the expected delta will provide a basis for characterizing how Project operations affect the formation of deltas. Specifically the physical constraints imposed by Project operations on the topset and foreset slopes of the deltas can be incorporated to simulate growth and development of deltas (USBR 1987, Morris and Fan 1998).

### Reservoir Erosion

Erosion and mass wasting potential will be assessed within the reservoir fluctuation zone and along the shoreline for 100 vertical feet from 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 melting of permafrost.
- Beach/bank development at full pool.
- Erosion by ice movement on the reservoir surface.

The following spatial data will be collected, either from existing data sources or through field mapping:

- Topography (LiDAR).
- Geo-rectified aerial photography.
- Geologic and soil mapping; soil properties of interest include texture, depth, permafrost presence/absence, infiltration capacity, cohesion. Existing mass wasting features will also be mapped on recent (2011) aerial photographs for comparison with 1982 studies.
- Vegetation mapping.

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

- Expected reservoir surface elevation fluctuations (seasonal, daily, maximum hourly lowering rate).

- Expected motorized watercraft recreational use data.
- Daily air temperature (maximum/minimum) and wind (speed, direction) data.
- Expected ice development and movement within the reservoir

The spatial data 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. Possibly use a GIS-based model such as SHALSTAB.
- Surface erosion from sheetwash – estimate surface erosion potential using WEPP and/or RUSLE.
- 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 melting of permafrost – evaluate potential based on soil properties, seasonal reservoir water elevations, and daily max/min 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 Ice Processes Study.

### Information Required

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

- Historical aerial photographs.
- Suspended sediment data for the Susitna River at Vee Canyon (RM 223) and Gold Creek (RM 137).
- Bedload data for the Susitna River at Gold Creek (RM 137).
- Flow records for the Susitna River.
- Topographic mapping including USGS survey quadrangle maps and LiDAR.

- Reconnaissance-level mapping of surficial geology and permafrost in the Watana Reservoir area was done from aerial photographs and limited ground surveys during studies for the original Susitna license (WCC 1982).
- An analysis of the potential for mass wasting was completed (Acres 1982).

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

- Suspended and bed load data for the Susitna River at Tsusena Creek being performed by the USGS.
- Extended flow record for the Susitna River and gaged tributaries within the study area being developed by the USGS.
- Estimated flows for the ungaged tributaries within the study area.
- Estimation of upstream mainstem sediment loads by size fractions.
- Estimation of tributary bed load supply.
- Field observations of the mainstem and tributary confluence areas made during a site reconnaissance.
- Extended flow record for the Susitna River and tributaries being developed by the USGS.
- Vegetation mapping.
- Expected reservoir surface elevation fluctuations (seasonal, daily, maximum hourly lowering rate).
- Expected motorized watercraft recreational use data.
- Daily air temperature (maximum/minimum) and wind (speed, direction) data.
- Expected ice development and movement within the reservoir.

#### 1.3.6.9. Study Component G-1.9: Large Woody Debris

The goal of the Large Woody Debris 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:

- Evaluate large woody debris recruitment in the Middle and Lower River channels (including upstream of Watana Reservoir).
- Characterize the presence, extent, and function of large woody debris downstream of Susitna-Watana Dam.

- Estimate the amount of large woody debris that will be captured in the reservoir and potential downstream effects of project operation.

The study area for the Large Woody Debris Study includes the Susitna River from the mouth to the confluence with the Maclaren River.

#### *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, create and maintain anastomosing channel patterns and side channels (Abbe and Montgomery 1996 and 2003, Fetherston et al. 1995, Montgomery et al. 2003, Dudley et al. 1998). 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 likely plays an important role in island formation and stabilization, as well as side channel and slough avulsion and bank erosion. Construction and operation of the Susitna-Watana project has the potential to change the input, transport, stability, and storage of large woody debris downstream of Susitna-Watana Dam 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 assess the magnitude of these effects. Construction and operation of the Susitna-Watana Project will likely alter large woody debris input and transport downstream of Susitna-Watana Dam. 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 operation on large wood resources. The information can also be used to determine appropriate PM&E measures such as a large woody debris management plan and handling of wood that accumulates in the reservoir.

#### *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 3 rivers junction; between the 3 rivers junction and Devil's Canyon, Devil's Canyon, and upstream of Devil's Canyon. 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 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 that not all wood will be able to be identified on the aerial photographs. As a supplement to large woody information obtained from aerial photographs, a reconnaissance assessment of large woody debris in the Susitna River will be made in coordination with aquatic/riparian habitat mapping in the summer of 2012. This assessment will be useful to direct more detailed field data collection in representative portions of the study area during the 2013-2014 study seasons. The objective of the 2013-2014 field studies will be to verify the large wood data collected from the aerial photographs and to provide more detailed field information on large wood input and storage. 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 (based on diameter, length).
- 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.).
- 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.).
- For log accumulations and jams: key piece size.

The aerial photograph and field inventories of large wood will be used to determine large wood input processes and source areas, 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 Susitna-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. The analysis will require coordination with the geomorphology, sediment transport, ice processes, riparian habitat, aquatic habitat, and instream flow studies.

The results of the large woody debris study will be used to determine appropriate PM&E measures for the project and a large wood management plan.

*1.3.6.10. Study Component G-1.10: Geomorphology of Stream Crossings along Transmission Lines and Access Alignments*

The goal of the Geomorphology of Stream Crossings along Transmission Lines and Access Alignments study is 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.

*Existing Information and Need for Additional Information*

Development of the Susitna-Watana Dam would require road and/or rail transportation from existing roads (either the George Parks Highway or the Denali Highway) 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. The alignments are designated as Denali, Chulitna and Gold Creek. The ADOT&PF evaluated potential access corridors, including the Denali and Chulitna River 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 River 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 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 by:

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

### *Methods*

The following data would be obtained, either from existing sources or from field studies:

- LiDAR or topography at stream crossings.
- Stream characteristics – gradient, substrate size, wetted and bankfull width/depth, large woody debris, Rosgen channel type, and bank erosion would be measured or evaluated for a minimum of 100 feet upstream and downstream of each proposed crossing.
- Crossing design – information on the culvert or bridge characteristics planned at each crossing would be obtained from project engineering designs (HDR 2011).
- Road design – information on the road prism in the vicinity of stream crossings would be obtained from project engineering designs, including surfacing, gradient, expected traffic levels, and road prism width.

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

- Channel morphology, sediment dynamics – the hydraulic characteristics and bedload transport capacity of existing channel and of proposed crossing structures will be computed and compared. Guidelines in the existing stream crossing design MOU 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.

### **1.3.7. Describe considerations of level of effort and cost, as applicable, and why any proposed alternative studies would not be sufficient to meet the stated information needs**

Specific details for the study components will be determined when Study Plans are further developed. Initial planning level estimates of the costs to perform the components of the Geomorphology study are provided in the table below along with the expected quarter the study

will be completed. The total effort for the Geomorphology Study, excluding Sediment Data Collection, is estimated to cost between approximately \$0.8 million and \$1.3 million.

Study Component	Estimated Cost Range	Estimated Completion
Geomorphic River Segment Delineation	\$60k to \$80k	Summer 2012
Sediment Data Collection	USGS will provide	Summer 2012
Sediment Supply and Transport Assessment	\$60k to \$90k	Sum 2012/ Fall 2013 <sup>2</sup>
Geomorphic Change Middle and Lower River	\$80k to \$120k <sup>1</sup>	Summer 2012
Riverine Habitat Middle River	\$200k to \$300k <sup>1</sup>	Winter 2012
Recon Assessment Lower River Project Effects	\$40k to \$60k	Summer 2012
Riverine Habitat Lower River	\$100k to \$150k <sup>1</sup>	Winter 2012
Reservoir Geomorphology	\$140k to \$180k	Spring 2014
Large Woody Debris	\$80k to \$120k	Summer 2014
Geomorphology of Stream Crossings	\$80k to \$140k	Summer 2014

<sup>1</sup> Includes acquisition of orthorectified aerial imagery

<sup>2</sup> Lower River sediment supply and transport to be completed in summer 2012, remainder of study component to be completed by fall 2013

The USGS is developing a cost estimate for the 2012 portion of the study. The data collection effort will be conducted in the late spring and summer of 2012. 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 of 2012. Suspended and bedload data, including calculation of sediment transport ratings and daily loads, will be compiled in a technical memorandum delivered to AEA during FFY 2013, and as early as March, 2013, if possible.

Performing the digitization of the 2012 aerial photography is dependent on the AEA SDC being able to fly the aerials at the appropriate discharge. The only portions of this effort that can be completed in 2012 are for flows for which the current aerial photographs are supplied in orthorectified format by November 15, 2012. The most critical discharge in regard to schedule is the 5,100 cfs since there are years when the Susitna at Gold Creek does not fall to this level until late October or early November.

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