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Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Synthesis of the 1980s Lower Susitna River Segment Aquatic Habitat Information

2012 Study Technical Memorandum

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Tetra Tech, Inc.

March 2013

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	**Definition**
1-D	One-Dimensional
AEA	Alaska Energy Authority
ER	Entrenchment Ratio
FERC	Federal Energy Regulatory Commission
ft/mile	Feet per Mile
IFS	Instream Flow Study
ILP	Integrated Licensing Process
LiDAR	Light Detection and Ranging-based Topography
LR	Lower Susitna River Segment
MC	Multiple Channel Reach Classification
mi	mile(s)
mm	millimeter(s)
MR	Middle Susitna River Segment
NEPA	National Environmental Policy Act
PDF	Portable Document Format
PRM	Project River Mile (the current, Susitna-Watana Project river-mile system)
RM	River Mile (the 1980s Project river-mile system)
SC	Single Channel Reach Classification
UR	Upper Susitna River Segment
USGS	United States Geological Survey

Summary

This effort was designed to identify whether potential Project effects on aquatic habitat and tributary access in the Lower River warranted additional study and, if necessary, help in planning those studies. The analysis utilized information on aquatic habitat from the 1980s report 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). Information was also summarized from the report Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River (R&M Consultants, Inc. and Trihey & Associates. 1985b).

This effort also used results of two other 2012 technical memorandums. The first was the *Stream Flow Assessment* (Tetra Tech 2013a) which was used to identify whether the pre- and post-Project hydrology were sufficiently similar in the 1980s studies to the current Project to allow for application of the results of the 1980s efforts to planning for the 2013-2014 studies. The Stream Flow Assessment also provided the hydrology to evaluate habitat areas for current pre- and post-Project conditions. The second technical memorandum utilized was *Mapping of Aquatic Macrohabitat Types at Selected Sites in the Middle and Lower Susitna River Segments from 1980s and 2012 Aerials* (Tetra Tech 2013c). This information was used to assess geomorphic change at tributary mouths over the past 30 years.

Results of the comparison of the pre- and Post-Project hydrology used in the 1980s reports and for the current Project indicated they are very similar for the adult salmon migration period of May through September. Based on this finding, it was concluded that the potential impacts identified for the 13 tributaries studied in the 1980s relative to salmon spawning access were applicable to planning 2013-2014 studies. The earlier study identified the potential for a moderate reduction in backwater (holding) area at nine out of the 13 tributaries studied. The other four tributaries were identified as having the potential for a slight reduction in tributary mouth backwater habitat area. Applications of the current pre- and post-Project hydrology and habitat versus flow relationships from the 1980s indicated the potential for 19% to 26% average reduction in the holding area at the mouths of the two tributaries evaluated. Of the 13 tributaries studied, four were identified as potentially having problems associated with access by migrating salmon due to reduction in flow depths for the post-Project condition.

In terms of aquatic macrohabitat, application of the habitat area versus flow relationships for the main channel and lateral habitats indicated that the post-Project change in flows would alter habitat area. Over the three sites and eight habitat types assessed, 65 percent of the results showed reduction in wetted surface area under the post-Project condition. Three of the habitat types, main channel, secondary side channel, and tributary mouth showed a decrease at all three sites. The remaining habitat types indicated some instances of increases and some instances of decreases in wetted surface area under post-Project conditions. Based on these results, the further study of potential Project-related changes to aquatic habitat and tributary access conditions in the Lower River is warranted.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process (ILP). The Project is located on the Susitna River, an approximately 300-mile-long river in the South-Central Region of Alaska. The Project's dam site will be located at Project River Mile (PRM) 187.1. The results of this study will provide information that will serve as the basis for the 2013-14 formal study program, Exhibit E of a license application, and FERC's National Environmental Policy Act (NEPA) analysis for the Project license.

This technical memorandum provides the results of Synthesis of the 1980s Aquatic Habitat Information subtask of the Riverine Habitat-Flow Relationship Assessment task within the 2012 study Reconnaissance-Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel (G-S4). This effort summarizes information on aquatic habitat from the 1980s report *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). Information is also summarized from the report *Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River* (R&M Consultants, Inc. and Trihey & Associates 1985b). The information relating aquatic macrohabitat and fish access to flow and river stage in these reports are used along with the results of the 2012 technical memorandum Stream Flow Assessment (Tetra Tech 2013a) to perform an initial identification of potential Project effects in the Lower Susitna River Segment.

The pre-Project hydrology and post-Project hydrology under an operations scenario referred to as Maximum Load Following Operation Scenario 1 (OS-1) are used to perform an initial identification of potential Project effects. These two hydrologic scenarios were analyzed in detail in Tetra Tech (2013a). The Maximum Load Following OS-1 hydrology is a simulated flow record developed with the Project-conditions flow-routing model (MWH 2012) for the same 61-year period as the pre-Project records. Maximum Load Following OS-1 is based on the assumption that the load fluctuation of the entire Railbelt would be provided by the Susitna-Watana Project, and all other sources of electrical power in the Railbelt would be running at base load. This assumed condition is not realistic for an entire year, and the results of this condition should be conservative with respect to assessing downstream impacts of load following.

2. STUDY OBJECTIVES

The effort described in this Technical Memorandum integrates the results of several earlier tasks in the 2012 Reconnaissance-Level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel Study (G-S4) to address several broader study objectives including:

- Assess potential changes to aquatic habitat pre- and post-Project;
- Provide information to assist AEA and licensing participants to develop the 2013-2014 study plans.

3. STUDY AREA

3.1. General

The Susitna River, located in south-central Alaska, drains an area of approximately 20,010 square miles and flows about 320 miles from its headwaters at the Susitna, West Fork Susitna and East Fork Susitna glaciers to the Cook Inlet (USGS 2012). The Susitna River basin is bounded on the west and north by the Alaska Range, on the east by the Talkeetna Mountains and Copper River Lowlands and on the south by Cook Inlet. The highest elevations in the basin are at Mt. McKinley at 20,320 feet while its lowest elevations are at sea level where the river discharges into Cook Inlet. Major tributaries to the Susitna River between the headwaters and Cook Inlet include the Chulitna, Talkeetna and Yentna Rivers that are also glacially fed in their respective headwaters. The basin receives, on average, 35 inches of precipitation annually with average annual air temperatures of approximately 29^{o}F.

3.2. Specific Study Area

For the Susitna-Watana Hydro Project licensing effort the Susitna River from Project River Mile (PRM) 3.3 at Cook Inlet to the Maclaren River confluence at PRM 261.3, the river has been subdivided into three segments (Tetra Tech 2013b) whose general characteristics are governed by the basin geology as described by Wilson et al. (2009). The segments are referred to as the Upper, Middle and Lower Susitna River segments. The study effort presented in this Technical Memorandum is concentrated on the Lower Susitna River Segment. The three segments are identified on Figure 3.2-1 with the associated extents:

- Upper Susitna River Segment: Maclaren River confluence (PRM 261.3) downstream to the proposed Watana Dam site (PRM 187.1),
- Middle Susitna River Segment: Proposed Watana Dam site (PRM 187.1) downstream to the Three Rivers Confluence (PRM 102.4), and
- Lower Susitna River Segment: Three Rivers Confluence (PRM 102.4) downstream to Cook Inlet (PRM 3.3).

The upstream-most segment, referred to as the Upper River (UR), extends from PRM 261.3 to PRM 187.1 at the Watana Dam site. The morphologic characteristics of this segment of the river are dominated by the products of Quaternary-age glaciation. The Middle River (MR) segment extends from the Watana Dam site to the Three Rivers Confluence at about PRM 102.4. The general characteristics of the river in this segment are heavily influenced by bedrock outcrop as well as Quaternary-age glaciations. The Lower River (LR) segment extends from the Three Rivers Confluence (PRM 102.4) to the tidal flats at Cook Inlet (PRM 3.3). The morphologic characteristics of the river in this segment are dominated by the sediment loading from the major tributaries and variable resistance to erosion of the Pleistocene-age, glacially-derived materials including tills (moraines), glacio-fluvial sediments in various elevation outwash-surfaces and glacio-lacustrine sediments that control the width of the valley.

4. METHODS

4.1. Deviations from Study Plan

There were no deviations from the 2012 study plan for Synthesis of the 1980s Lower Susitna River Segment Aquatic Habitat Information presented as part of the 2012 study plan for the Reconnaissance Level Assessment of Potential Channel Change in the Lower Susitna River Segment G-S4.

4.2. Summary of 1980s Studies

In accordance with the 2012 study plan for this task, the two previous studies by R&M Consultants and Trihey & Associates (1985a and 1985b) were obtained and summarized:

- Response of Aquatic Habitat Surface Area to Mainstem Discharge Relationships in the Yentna to Talkeetna Reach of the Susitna River.
- Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River.

The documents were downloaded as electronic documents in the Portable Document Format (PDF) from the Alaska Resources Library & Information Service (ARLIS) online library. These studies compared the surface area for aquatic habitat types for conditions prior to the construction of the Susitna Hydroelectric Project and estimated for post-construction operation conditions (R&M Consultants and Trihey & Associates 1985a) and evaluated Lower Susitna River tributary access for spawning salmon (R&M Consultants and Trihey & Associates 1985b). The tributary access PDF contains 66 pages, and includes 36 figures, 11 photographs, and five tables; and, the habitat surface area PDF contains 201 pages, and includes 15 figures, 49 additional photographs included in two Exhibits, and five tables.

4.3. Hydrologic Information

As part of the larger 2012 study, hydrologic information was developed for completion of the technical memorandum, Stream Flow Assessment (Tetra Tech 2013a). This information included the probability of exceedence for weekly discharge for the Susitna River at Sunshine for both the pre-Project and Maximum Load Following Operation Scenario 1 (OS-1). The hydrologic data developed for the months of May through September are utilized in this technical memorandum for comparison with R&M Consultants and Trihey & Associates (1985b) as part of the Tributary Access analysis.

4.3.1. Average Monthly Flows for the Susitna River at Sunshine

Average monthly flows for the Susitna River at Sunshine for the pre-Project conditions were developed from 61 years of extended record developed by the USGS (2012). Results from the Maximum Load Following OS-1 simulations were utilized to develop average monthly flows for this scenario and are presented in Table I-3 of the Stream Flow Assessment technical memorandum (Tetra Tech 2013a). Changes in discharge for the Maximum Load Following OS-1 scenario are indicated by comparing the monthly 10-, 50-, and 90-percent probability of exceedence discharge values to those of the pre-Project conditions. For the months of June, July, and August the discharges decrease for all three exceedence probabilities for the Maximum Load

Following OS-1 case. For the months of May and September, the 90-percent probability of exceedence discharge values increase for the Maximum Load Following OS-1 scenario compared to the pre-Project conditions, but decrease for the 10- and 50-percent probabilities of exceedence. Increases for the Maximum Load Following OS-1 scenario are indicated for each of these three probabilities of exceedence for the months of October, November, December, January, February, March, and April. The median monthly values are used in this report to determine wetted surface area associated with the aquatic macrohabitat types developed by R&M Consultants and Trihey & Associates (1985a) for the sites Side Channel Complex IV (SC IV-4), Goose Creek, and Willow Creek. The monthly median flow values for the Susitna River at Sunshine for the pre-Project and Maximum Load Following OS-1 conditions are presented in Table 4.3-1.

4.3.2. Weekly Flows for the Susitna River at Sunshine

The 61 years of daily flows for the pre-Project and Maximum Load Following OS-1 conditions for the Susitna River at Sunshine were further processed to provide weekly 10-, 50-, and 90-percent probability of exceedence discharge values for the months of May through September. These months were picked since they represent the primary period of adult salmon migration in the Lower Susitna River (R&M Consultants and Trihey & Associates 1985b). The weekly values were used to extrapolate the Project effects for tributary access indicators from the 1980s study to the current Project based on the similarity of pre- and post-Project hydrology in both studies.

4.3.3. Monthly Stage Change for the Susitna River at Sunshine

The Stream Flow Assessment technical memorandum (Tetra Tech 2013a) includes analysis of probabilities of exceedance for monthly stage values at Sunshine for the pre-Project and Maximum Load Following OS-1 conditions. These values are summarized for the 10-, 50-, and 90-percent probabilities of exceedence for the months of May through September. These values were compared to the results of main channel discharge changes on tributary backwater area presented by R&M Consultants and Trihey & Associates (1985b). The monthly stage exceedance values at Sunshine are presented in Table 4.3-2.

4.4. Habitat Area versus Flow Relationship

The wetted surface area relationships developed by R&M Consultants and Trihey & Associates (1985a) were used for the analysis of pre-Project and Maximum Load Following OS-1 conditions presented here. This was accomplished by log-linearly interpolating wetted surface areas for three sites, SC IV-4, Goose Creek, and Willow Creek, using the median monthly discharge values at Sunshine (Table 4.3-1). In order to expand the range of the discharge and wetted surface area relationships beyond the minimum discharge of 13,900 cfs and maximum discharge 75,200 cfs that were used by R&M Consultants and Trihey & Associates (1985a), the following assumptions were applied:

- Wetted surface areas were assumed to be remain at zero if they were zero for the bounding discharge values of 13,900 and 75,200 cfs;
- Wetted surface areas were assumed to remain constant at the bounding discharge value of 13,900 and 75,200 cfs, if the relationship indicated that wetted surface areas were increasing

with decreasing discharge from 21,100 to 13,900 cfs or were increasing with increasing discharge from 59,100 to 75,200 cfs; and

- Wetted surface areas were assumed to decrease log-linearly for discharge values less than 13,900 cfs and more than 75,200 cfs, if the previous relationship indicated that wetted surface areas were decreasing with decreasing discharge from 21,100 to 13,900 cfs or were decreasing with increasing discharge from 59,100 to 75,200 cfs.

The monthly results were used to aggregate the wetted surface areas associated with each of the habitat types for the pre-Project and Maximum Load Following OS-1 conditions for specific periods. Two periods were used, with the first representing the general open-water period accumulated from for May through September, and the second representing the general ice-affected period accumulated from October through April. It is cautioned that the results presented during the ice-affected months are relative indicators only since the habitat relationships of R&M Consultants and Trihey & Associates (1985a) are based on open-water and the associated hydraulics that help determine the areas are likely substantially different for periods with ice cover. Therefore, the ice-affected period values can be used for relative comparison between the pre-Project and Maximum Load Following OS-1 conditions but should not be used to identify absolute differences in wetted surface areas between conditions.

4.5. Tributaries

Three aspects of the clearwater tributaries were investigated by R&M Consultants and Trihey & Associates (1985b) including tributary backwater surface area, fish access into tributaries, and morphologic stability of tributary mouth access for migrating salmon. These three aspects were utilized in the current study to assess the pre-Project and Maximum Load Following OS-1 conditions. The methods used previously and for the current study for each of these three indicators of access changes are described here.

4.5.1. Tributary Mouth Backwater Areas

The differences in median weekly discharges were used by R&M Consultants and Trihey & Associates (1985b) to describe potential changes in water depth and potential subsequent reductions to backwater areas for tributaries identified as having relatively low stream gradients. The 1980 tributary information along with the 2012 Stream Flow Assessment were applied to make an initial determination of the potential current Project effects on tributary backwater areas. This was accomplished by evaluating the similarities between the 50% exceedence (median) weekly discharge for the pre-Project conditions and the post-Project conditions for the 1980s evaluation and the current effort. Figure 4.2 of R&M Consultants and Trihey & Associates (1985b) presents the pre-Project (referred to as “Natural” on the figure) and the post-Project (Case E-VI, 2020 load) conditions. Figure 4.5-1 presents these 1980s results and current median weekly flows for the pre- and post-Project conditions. The values are very similar and it is concluded that for this initial assessment, tributary access effects related to flow from the 1980s study can serve as a good starting point to identify impacts of the current Project for the purpose of planning studies.

Applying the habitat area versus flow relationships developed in the 1980s (Section 4.4) for tributary mouths, the potential impacts to tributary backwater areas were further quantified in the current study. This quantification was achieved by combining the habitat flow relationships developed by R&M Consultants and Trihey & Associates (1985a) for the period salmon migration from May through September, which was identified by R&M Consultants and Trihey & Associates (1985b), and evaluating those relationships using the median weekly discharge for the current Project effects. The results of this analysis are presented in Section 5.2.

4.5.2. Tributary Access

Tributary access conditions in R&M Consultants and Trihey & Associates (1985b) were evaluated by applying depth criteria. Chinook salmon were used as the limiting condition as they required a minimum depth of 0.8 feet compared to 0.6 for the other four species of salmon (Thompson 1972). Depths at tributary mouth were considered for the identified salmon migration period of May 13 through September 30. It was also found that the depth at the tributary mouth depends on whether the tributary mouth was located directly on the mainstem or on a side channel. In the case of a side channel, the depth at the mouth was highly dependent on whether the head of the side channel was breached or unbreached. In both cases, the depth at the tributary mouth was related to the flow in the Susitna River.

In order to determine if the assessment of Project effects on tributary access could be extrapolated to the current Project for study planning purposes, the comparison of flows between the 1980s pre- and post-Project conditions and the flows for the current pre- and post-Project conditions was made. Review of the weekly median flows for the pre- and post-Project conditions during the period of adult salmon migration in the Lower River used in the 1985 (R&M Consultants and Trihey & Associates 1985) report were compared against the weekly median flows for the pre-Project and Maximum Load Following OS-1 conditions. The comparison of the median weekly flows is provided in Figure 4.5-1. The plots indicate that both the pre- and post-Project condition hydrology from the 1980s study and for the current Project are very similar in terms of median weekly flows for the period from May through September. Based on this information, the results of the access analysis from 1985 were considered to be transferrable to the current Project for study planning purposes.

4.5.3. Tributary Mouth Stability

The 1980s effort evaluated the potential for Project effects on the stability of tributary mouths based on the observed stability of the tributary mouth. It was assumed in R&M Consultants and Trihey & Associates (1985b) that tributaries that were observed to be stable under the existing conditions would be less subject to instabilities from the Project than tributaries that had exhibited dynamic behavior under per-Project conditions. Interpretation of tributary mouth morphologic stability for current conditions was accomplished by summarizing the results of the comparative analysis of 1980s and 2012 aerial photographs described by Tetra Tech (2013c).

5. RESULTS

5.1. Summary of 1980s Information

Information from the two 1980s reports is summarized in this section. The reports summarized are *Response of Aquatic Habitat Surface Area to Mainstem Discharge Relationships in the Yentna to Talkeetna Reach of the Susitna River* (R&M Consultants and Trihey & Associates

1985a) and *Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River* (R&M Consultants and Trihey & Associates 1985b).

5.1.1. Response of Aquatic Habitat Surface Area to Mainstem Discharge Relationships in the Yentna to Talkeetna Reach of the Susitna River (R&M Consultants and Trihey & Associates 1985a)

R&M Consultants and Trihey & Associates (1985a) identified eight sites in the Lower Susitna River that were determined to be representative of the varied channel morphologies and the habitat types mapped on aerial photography. Wetted surface area for each habitat type was determined for five specific flows from Aerials acquired at flows of 75,200 cfs, 59,100 cfs, 36,600 cfs, 21,100 cfs and 13,900 cfs as measured at Sunshine. These sites were:

- Side Channel Complex Segment IV (SC IV-4),
- Willow Creek,
- Caswell Creek,
- Sheep Creek,
- Goose Creek,
- Montana Creek,
- Sunshine Slough, and
- Birch Creek Slough.

The wetted surface areas in each of the sites was classified by eight general aquatic habitat categories that could be identified by physical characteristics, rather than specific biological characteristics or geographical locations, from either aerial reconnaissance or examination of aerial photography. The eight aquatic habitat categories were:

- Mainstem[1],
- Primary Side Channel,
- Secondary Side Channel,
- Turbid Backwater,
- Clearwater,
- Side Slough,
- Tributary Mouth, and
- Tributary.

The descriptions for each of the habitat categories from R&M Consultants and Trihey & Associates (1985a) are included here, with the change of Mainstem to Main Channel for consistency with the Tetra Tech (2013c) terminology.

[1] It should be noted that as part of the work conducted by Tetra Tech for the mapping of aquatic macrohabitat types (Tetra Tech 2013c) the habitat type associated with Mainstem was further defined and rephrased as Main Channel. The use of the term Main Channel is continued within this report and corresponds to the R&M Consultants and Trihey & Associates (1985a) Mainstem habitat type.

Main Channel habitats represent the main river channel, consisting of the thalweg channel, major sub-channels and alluvial island complexes. This habitat type was, in most cases, outside the boundaries of the control areas used to define representative areas.

Primary Side Channel habitats are those channels which normally convey streamflow throughout the entire year. They exhibit characteristics similar to middle Susitna River main channel habitat types, as described by Klinger and Trihey (1984). They are characterized by turbid glacial water, high velocities, and few mid channel gravel bars.

Secondary Side Channel habitats also have turbid water, but exhibit characteristics of the middle river side channels. For example, there are middle channel gravel bars and riffles or water surface features that indicate slower-moving, shallower water.

Turbid Backwater habitats are nonbreached channels containing turbid water. They have non-vegetated upper thalwegs that are overtopped during periods of moderate to high main channel discharge. They represent transitional habitat type between breached secondary side channel habitats and nonbreached clearwater or side slough habitats.

Clearwater habitats are nonbreached channels containing clear water that dewater completely at a main channel discharge of 13,900 cubic feet per second (cfs) or higher. These channels have non-vegetated upper thalwegs that are overtopped during periods of moderate to high main channel discharge. Groundwater and local surface runoff appear to supply water to these areas at main channel flows above 13,900 cfs.

Side Slough habitats contain clear water. Upwelling and local surface runoff appear to supply sufficient clear water to these areas to maintain wetted areas at a main channel discharge of 13,900 cfs. Side Sloughs also have non-vegetated upper thalwegs that are overtopped at moderate to high main channel discharges.

Tributary Mouth habitats are clear water habitats that exist between the downstream extent of a clear water plume and upstream into the tributary, to the upper extent of the backwater influence. The surface area depends on the discharge of both the tributary and main channel.

Tributary habitat exists upstream of the tributary mouth habitat. In this analysis, tributary habitat was measured only to the boundary of the digitized photo enlargement. Tributary habitat may increase dramatically when the tributary flows into a nonbreached side channel and the clear tributary flows through the side channel to join the Susitna River.

The wetted surface area in units of thousand square feet (ft^2x10^3) were measured at each site and for each habitat type for five Susitna River discharge measurements at Sunshine, including 13,900; 21,100; 36,600; 59,100; and 75,200 cfs. These values are presented in Table 3.3 and the surface area response to discharge relationships are plotted in Figures 3.1 through 3.4 of R&M Consultants and Trihey & Associates (1985a). The Willow Creek site information from Figure 3.1 is recreated in this report as Figure 5.1-1.

5.1.2. Assessment of Access by Spawning Salmon into Tributaries of the Lower Susitna River (R&M Consultants and Trihey & Associates 1985b)

R&M Consultants and Trihey & Associates (1985b) identified clearwater tributaries to the Lower Susitna River Segment as the primary salmon spawning areas within the Lower Susitna

Basin and as such carried out analysis to evaluate potential Project impacts on fish access to these clearwater tributaries. Their primary interest was the backwater areas at the tributary mouths. The backwater areas near the mouths of the clearwater tributaries provides lower velocity areas for migrating salmon to hold and rest. The mouths were also the areas that Project-related changes in water surface elevations in the mainstem could affect depths in the tributary mouth and consequently fish access to the tributaries. The 1980s analysis focused on the potential impacts during the months of June through September, as these months comprise the typical period during which adult salmon migrate within the Lower River. Their data indicated peak migration occurs in July and August for sockeye, chum, pink and coho salmon and June to early July for Chinook. Three clearwater tributary evaluation categories were investigated by R&M Consultants and Trihey & Associates (1985b):

- Tributary backwater surface area,
- Fish access into tributaries, and
- Morphologic stability of tributary mouth access for migrating salmon.

R&M Consultants and Trihey & Associates (1985b) assessed possible impacts of with-project conditions on the access of spawning salmon to the tributaries of the Lower Susitna River. The five Pacific salmon species identified as important to the commercial and sport fisheries of Cook Inlet identified were Chinook (Ck), chum (Ch), sockeye (S), pink (P), and coho (Co), and the associated combined migration period for all five of these salmon species was generally defined as June through September. The three evaluation categories were applied to 13 tributaries, including:

- Alexander Creek,
- Deshka River,
- Willow Creek,
- Lower Willow Creek,
- Kashwitna River,
- Caswell Creek,
- Sheep Creek,
- Goose Creek,
- Montana Creek,
- Rabideux Creek,
- Sunshine Creek,
- Birch Creek, and
- Trapper Creek.

R&M Consultants and Trihey & Associates (1985b) generalized post-Project effects compared to pre-Project seasonal discharge patterns for the Lower Susitna River as potentially increasing discharge in late fall and winter seasons, decreasing discharge in the summer season, and resulting in similar discharge in the spring and early fall seasons. These changes in discharge patterns were summarized as potentially causing:

- Decreased size of backwater areas for migrating fish resting and holding at tributary mouths,
- Decreased water depth in tributary mouths that may prevent adult salmon access, and
- Decreased morphologic stability for tributary mouths or adjoining side channels that may inhibit tributary access.

The results of R&M Consultants and Trihey & Associates (1985b) were summarized in Table 4.1 of that report, and this table is recreated in as Table 5.1-1. Additional discussions for each of the three tributary access categories evaluated are presented below.

5.1.2.1. Tributary Mouth Backwater Area (Holding Area)

The tributary backwater areas serve as holding areas for adult salmon. The low gradient tributaries were identified as having the most extensive backwater areas. Caswell Creek and Sheep Creek were selected in the 1985 study as representative of low gradient tributary mouth backwater areas and response curves of water depth to mainstem discharge were developed. Time series plots of water depth versus 50-percent exceedence weekly pre-Project and post-Project (Case E-VI , 2020 load) were developed to identify the degree of change in water depth caused by Project flows. This category was assessed on a semi-qualitative basis with ranked effects for tributary mouth backwater areas rated as moderate change and slight change.

From the analysis several observations were made in R&M Consultants and Trihey & Associates (1985b) on the potential Project effects on the tributary mouth holding areas. The report indicated Project effects vary depending on the season, precipitation, the channel gradient and the location of the channel relative to the mainstem. The reduction in surface area of tributary mouth backwaters was identified as primarily due to a reduction in the length that the backwater extends upstream. As the mainstem stage drops, the location where the tributary flow meets the backwater moves further downstream in the tributary.

Of the 13 tributaries, four were rated as slight change and nine were rated as moderate change as to the potential for reduction in backwater area at the tributary mouth for post-Project conditions. The four tributaries assigned a slight change rating were Montana Creek, Goose Creek, Willow Creek and the Kashwitna River. The nine tributaries assigned a moderate change rating were Trapper Creek, Birch Creek, Sunshine Creek, Rabideux Creek, Sheep Creek, Caswell Creek, Little Willow Creek, Alexander Creek and the Deshka River.

Based on the time series plots of water depth in R&M Consultants and Trihey & Associates (1985b), for June post-Project flows the reduction in the depth for the holding area at Caswell Creek was estimated to be 4.5 to 5.7 feet in the last week in June and 3.5 to 4.1 feet in the last week of August. At Sheep Creek the decreases in post-Project holding area depth was predicted to be 4.0 to 5.4 feet in the last week of June and 3.2 to 3.8 feet in the last week of August.

5.1.2.2. Tributary Access

R&M Consultants and Trihey & Associates (1985b) determined by field observations that tributary access would not be impeded by velocity but could be impeded by depth and channel stability. Depth criteria developed for each species of salmon was used to compare with field observed water depths in tributary mouths, which were noted to depend on the discharge of both the tributary and main channel Susitna River. The report further caveated the measurements for tributary water depths with respect to main channel discharge as being collected during a period of below average tributary flow. Thus, the water depth analysis provided accounts mostly for the impact of main channel discharge on tributary mouth water depths and in turn may have overestimated decreases in depth associated with the post-Project conditions. The study indicated that during the adult salmon migration period (May 13 through September 30) water depths in tributary mouths would equal or exceed 0.8 feet, the minimum depth for adult Chinook passage in Thompson (1972). The depth criterion for the other four species of salmon was identified as 0.6 feet and less restrictive.

For tributary mouths that connected to side channels of the main channel of the Susitna River rather than directly to the main channel of the Susitna River, discharges measured at Sunshine were compared with the elevation needed to provide breached connection between the main channel and the tributary mouth. Changes in backwater depth or side channel breaching flows were used to determine potential Project effects on tributary access by adult salmon in the 1985 study. The discharge of 21,100 cfs at Sunshine was selected as the baseline since it corresponded to the discharge on the date that the aerial photographs, used in the assessment, were acquired. This category was assessed on a semi-qualitative basis with ranked effects for fish access into tributaries at 21,100 cfs rated as "possible problem" and "no problem" based on whether a minimum depth of 0.8 feet was met for a flow of 21,100 cfs.

Goose Creek and Trapper Creek were the only tributaries with minimum water depth at or below the passage criteria in Thompson (1972) at 21,100 cfs based on the text of R&M Consultants and Trihey & Associates (1985b). Each of the tributaries flowed into a side channel that had a berm at its head that was unbreached at 21,100 cfs. The Goose Creek side channels breached at 22,000 cfs and the Goose Creek at 44,000 cfs. For the flows less than the breaching flows, the depths in the backwater holding areas were determined by the tributary flow. The study indicated that during the salmon migration period (May 13 through September 30) water depths in these tributary mouths would equal or exceed 0.8 feet, the minimum depth for adult Chinook passage in Thompson (1972). Table 4.1 in R&M Consultants and Trihey & Associates (1985b) also indicates potential problems for Caswell and Montana Creek under the post-Project condition and 21,100 cfs.

5.1.2.3. Tributary Mouth Morphologic Stability

Tributary mouth morphologic stability from the years 1951 to 1983 was determined by R&M Consultants and Trihey & Associates (1985b) by comparing aerial photographs of the tributary mouths for relative change at the tributaries evaluated. This category was assessed on a semi-qualitative basis which rated morphologic stability of tributary mouths for pre-Project conditions from "good" meaning no change in tributary mouth morphology since 1951, to "fair" meaning some change in tributary mouth morphology since 1951, and to "poor" meaning change in tributary mouth morphology from 1951 to present. Post-Project stability received the same or slightly higher morphologic stability rating based on the reasoning that the Project would not change tributary hydrology or sediment supply and the amount of sediment deposition would remain similar to the pre-Project condition; it would just occur further downstream.

None of the results presented for morphologic stability of tributary mouths by R&M Consultants and Trihey & Associates (1985b) indicated that post-Project conditions would cause a decrease in stability. Of the 13 tributaries, only one, Montana Creek, was rated as poor for tributary mouth morphologic stability under pre-Project conditions. Five were rated as good: Alexander Creek, Willow Creek, Little Willow Creek, Sheep Creek and Sunshine Creek. The remaining seven tributary mouths were rated as having fair morphologic stability for the pre-Project condition. The results provided for five of the tributary mouths suggested that the post-Project conditions would result in improved stability. These tributaries were Caswell Creek, Goose Creek, Montana Creek, Rabideux Creek, and Birch Creek. However, these results were based on comparison of aerial photographs only and not on detailed geomorphic assessment of each tributary and the impacts Project-related changes in main channel Susitna River discharge and associated stages.

5.2. Synthesis of 1980s Information with Current Project Flow Changes

The information from the 1980s habitat flow relationships in the Lower Susitna River (R&M Consultants and Trihey & Associates 1985a) and the assessment of tributary access (R&M Consultants and Trihey & Associates 1985b) was applied along with the changes in flows and river stages that were developed for the current Project in the stream flow assessment (Tetra Tech 2013a) to make initial assessments of potential effects of the current Project.

5.2.1. Habitat Area versus Flow Relationships

The analysis presented uses the previously developed habitat flow relationships (R&M Consultants and Trihey & Associates 1985a) for the purpose of comparing the pre-Project and Maximum Load Following OS-1 conditions. This was accomplished for SC IV-4, Goose Creek, and Willow Creek by following the methodology described in Section 4.4. These three sites were selected from the eight sites with habitat versus flow relationships for several reasons. SC IV-4 was selected since it was the only site without a tributary. Willow Creek was selected since it had the largest tributary mouth backwater area (784,000 sq. ft.), was indicated to not have a possible access problem and was rated as having good morphologic stability in the 1980s study. Goose Creek had a much smaller tributary mouth backwater area (maximum of 141,000 sq. ft.), but it was indicated to possibly have an access problem in the 1980s report and to have only fair morphologic stability. Between the two tributaries selected for further review under the current post-Project conditions, a range of tributary mouth conditions were represented.

The results of the analysis for each of the 12 months of the year for each habitat type are presented in Appendix 1 (Tables 1-1 to 1-3). The results of the analysis for the open water (May through September) and ice affected (October through April) periods for each habitat type are presented in Tables 5.2-1 to 5.2-3 (No primary side channel habitat was present at the three sites for the range of flows investigated so it does not appear on any of the figures, but is identified as have zero wetted surface area in the tables.). Results for each of the 12 months of the year are also presented in Appendix 2 of this report as bar charts for each habitat type and the three sites (Figures 2-1 to 2-7). Bar charts for the open water and ice affected results are presented in Figures 5.2-1 to 5.2-3. Based on these results, a summary of the estimated change from the pre-Project to the Maximum Load Following OS-1 conditions in terms of wetted surface area for each habitat type during the open water and ice affected periods are as follows (The wetted surface area for tributary mouth habitat is discussed in Section 5.2.2.):

Main Channel – Reductions in wetted surface area during the open water period were estimated at each of the three sites, including a 3-percent reduction at SC IV-4, a 3-percent reduction at Willow Creek, and a 26-percent reduction at Goose Creek. Conversely, during the ice affected period an increase in wetted surface area is estimated for each of the three sites, with an increase of 1 percent is indicated for SC IV-4 and 10 percent for Willow Creek. During the ice affected period, there was no estimated wetted surface area for Main Channel habitat for Goose Creek.

Primary Side Channel – There was no estimated wetted surface area computed for primary side channel habitat for either the pre-Project or Maximum Load Following OS-1 conditions for the three sites during the open water period or the ice affected period.

Secondary Side Channel – Reductions were estimated for the open water period for SC IV-4 of 7.9 percent, for Willow Creek of 6.8 percent, and for Goose Creek of 12 percent. Increases were estimated for the ice affected period of 44 percent for SC IV-4, 42 percent for Willow Creek, and 47 percent for Goose Creek.

Turbid Backwater – Reductions in wetted surface area during the open water period were estimated for SC IV-4 as 27 percent, however increases were estimated for both Willow Creek, at 8%, and Goose Creek, at 5 percent. Increases were estimated during the ice affected Period for Willow Creek as 148 percent and for Goose Creek as 93 percent. During the ice affected period, there was no estimated wetted surface area for turbid backwater habitat for SC IV-4.

Clearwater – Increases in wetted surface area during the open water period were estimated for SC IV-4 as 43 percent, for Willow Creek as 10 percent, and for Goose Creek of 36 percent. During the ice affected period, no wetted surface area was predicted for the three sites under the pre-Project conditions or the Maximum Load Following OS-1 conditions.

Side Slough – During the open water period, no wetted surface area was predicted for SC IV-4 or Willow Creek, but for Goose Creek a decrease of 6 percent was predicted. During the ice affected period reductions in wetted surface area were predicted for each of the three sites, as 14 percent for SC IV-4, 14 percent for Willow Creek, and 2 percent for Goose Creek.

Tributary - No wetted surface area was predicted for SC IV-4 for the pre-Project or Maximum Load Following OS-1 conditions for either the open water or ice affected periods. For the open water period, an increase in wetted surface area was predicted for Willow Creek of 14 percent, but a decrease was predicted for Goose Creek of 5 percent. For the ice affected period, reductions were predicted for both Willow Creek and Goose Creek of 1 and 5 percent, respectively.

5.2.2. Tributaries

The results of R&M Consultants and Trihey & Associates (1985b) assessment of access by spawning salmon in the Lower River tributaries were summarized in Table 5.1-1. Comparison of the median weekly flows during the adult salmon migration period, May through September, was made for both the pre- and post-Project conditions for the 1980s study and current Project (Figure 4.5-1). It was determined that both the pre-Project and post-Project hydrology were sufficiently similar that the evaluations for the 1980s report were applicable to the current effort for use in study planning. The results from the 1980s evaluation of the adult salmon access issue were previously presented in section 5.1.2 including summary Table 5.1-1 (reproduced from Table 4.1 of the 1980s report) and will not be repeated in this section. Two additional analyses were conducted to further address the potential effects of the current Project on access related conditions at the tributary mouths and are presented under their evaluation categories.

5.2.2.1. Tributary Mouth Backwater Area (Holding Area)

Holding areas used by migrating adult salmon and associated with the Tributary Backwater area were evaluated by R&M Consultants and Trihey & Associates (1985b) at Caswell Creek and Sheep Creek by comparing anticipated decreases in water depths associated with the with-project discharge. For Caswell Creek, a decrease of 1.2 feet during the last week of June and of 0.6 feet during the last week of August was estimated. For Sheep Creek, a decrease of 1.4 feet during the last week of June and of 0.6 feet during the last week of August was estimated. The stage analysis performed by Tetra Tech (2013a) for the Susitna River at Sunshine comparing the pre-Project and Maximum Load Following OS-1 conditions estimated similar decreases in stage (Table 4.3-2), including for the median monthly discharge a decrease of 1.43 feet in June and of 0.67 feet in August. R&M Consultants and Trihey & Associates (1985b) concluded that these differences would not negatively impact the holding areas of these two tributary mouths.

In order to further estimate potential Project changes to the backwater holding area at the tributary mouths, the wetted surface areas computed for Willow Creek and Goose Creek in Section 5.2.1 of this report were summed for the salmon migration period of May through September for the Tributary Mouth habitat type. These accumulated results are presented in Table 5.2-2 and Figure 5.2-2. Reductions in the tributary mouth wetted surface area were estimated for both Willow Creek and Goose Creek at 26 percent (from 2,286 ft^2x10^3 to 1,697 ft^2x10^3) and 19 percent (from 405 ft^2x10^3 to 329 ft^2x10^3) respectively (Table 5.2-2).

5.2.2.2. Tributary Mouth Morphologic Stability

Tributary mouth morphologic stability from the years 1951 to 1983 was determined by R&M Consultants and Trihey & Associates (1985b) by comparing aerial photographs of the tributary mouths for relative change at the tributaries evaluated. None of results presented for morphologic stability of tributary mouths by R&M Consultants and Trihey & Associates (1985b) indicated that with-project conditions would cause a decrease in stability. The results provided for five of the tributary mouths suggested that the with-project conditions would result in improved stability. However, these results are based on comparison of aerial photographs only and not on detailed geomorphic assessment of each tributary and the impacts alternative main channel Susitna River discharge.

R&M Consultants and Trihey & Associates (1985b) indicated that the tributary mouth of Willow Creek had no change in morphology between 1951 and 1983, and subsequently classified Willow Creek as good for both pre- and -Project conditions. Additionally, it was noted that the mouth of Willow Creek discharges to a side channel, as opposed to directly discharging to the main channel, of the Lower Susitna River. The bulk of the flow in the Susitna River at the Willow Creek site had run along the western edge of this site in 1983. In 2012, the majority of the flow passed through a branch west of the site, so the area classified as main channel in 1983 was classified as secondary side channel in 2012. Though the site has changed since 1983, the tributary mouth has remained stable. However, as is the case at nearly all the tributary mouths, migration of the main channel has the potential to significantly change the characteristics of the tributary mouth area.

The morphologic stability of the tributary mouth for Goose Creek was identified by R&M Consultants and Trihey & Associates (1985b) as being fair under pre-Project conditions and Fair/Good under post-Project conditions, indicating that some changes were observed between

1951 and 1983. Comparison of aerial photographs from 1983 and 2012 indicate that the tributary mouth area for Goose Creek has increased by 29% for a mainstem discharge of 36,600 cfs (1983 area = 52,000 ft^2, 2012 area = 68,000 ft^2) indicating some changes may have occurred at the tributary mouth. Inspection of the aerials reviews more significant change. In the 1983 aerials, the mouth was considered to be at the upstream end of the site where the main channel flowed along the tributary mouth. In the intervening 30 years vegetated islands now separate the mouth of Goose Creek from the main channel. As a result, the mouth of Goose Creek is now in a secondary side channel. In contrast, 3,000 feet downstream, the main channel migrated 400 feet into the site since 1983. In 1983 Goose Creek split with the majority of the going south and discharging into a secondary side channel with a smaller portion taking a much shorter path and discharging into the Susitna River in the main channel at the north end of the site. However, migration of either the main channel or the subsequent side channel at the north end of the site resulting in the capture of the majority of the flow by side channel at the north end of the site. Currently, the tributary mouth is on a completely different side channel than in 1983, over 3,000 feet to the north. The side channel that Goose Creek flowed into in 1983 has evolved into a side slough. This illustrates the potential for the migration of the main channel to affect the conditions at a tributary mouth.

6. SUMMARY AND CONCLUSIONS

This technical memorandum summarizes the analysis performed to assess potential changes to aquatic habitat for pre-Project and Maximum Load Following OS-1 conditions, and to provide information to AEA and licensing participants to assist with the development of the 2013-2014 study plans. This analysis has been accomplished by reviewing assessment work performed previously for the effects of hydropower operations on the Susitna River by R&M Consultants and Trihey & Associates (1985a and 1985b). These previous studies quantified the wetted surface area versus flow relationships for eight habitat types and developed criteria to compare tributary access by migrating salmon for potential post-Project changes to Susitna River discharge.

6.1. Habitat Area versus Flow Relationships

The analysis presented for the three selected sites, SC IV-4, Willow Creek, and Goose Creek in this technical memorandum indicates that there is a potential for impacts for the Maximum Load Following OS-1 conditions to the wetted surface areas of the eight aquatic macrohabitat types assessed, main channel, primary side channel, secondary side channel, turbid backwater, clearwater, side slough, tributary mouth, and tributary. Results are presented for the open water period and the ice affected period, which has less certainty since the efforts conducted do not account for the changes in hydraulics and wetted area that would result from ice cover.

For the three selected sites and eight habitat types, a total of 17 results were possible for the open water period, and there were seven combinations of site and habitat type that had no aquatic habitat for the open water period discharge evaluated using the habitat area versus flow relationships. Of the 17 possible results, 11 indicated potential decreases in wetted surface area, which constitutes 64% of the possible results. Habitat types that indicated potential decreases in wetted surface area for all sites that had habitat present of the type being considered for the median discharge values included main channel, secondary side channel, and tributary mouth. The remaining habitat types indicated both increases and decreases in wetted surface area.

6.2. Tributaries

Comparison of the pre- and post-Project hydrology used in the 1980s with the current hydrology show that both pre- and post-Project flows from the 1980s effort and the current Project are very similar and the results of the earlier study can be used in developing study plans for the 2013-2014 study. The R&M Consultants and Trihey & Associates (1985b) indicated that of the 13 tributaries, four were rated as slight change and nine were rated as moderate change as to the potential for reduction in backwater area at the tributary mouth for post-Project conditions. The four tributaries assigned a slight change rating were Montana Creek, Goose Creek, Willow Creek and the Kashwitna River. The nine tributaries assigned a moderate change rating were Trapper Creek, Birch Creek, Sunshine Creek, Rabideux Creek, Sheep Creek, Caswell Creek, Little Willow Creek, Alexander Creek and the Deshka River. Using current pre- and post-Project hydrology and habitat versus flow relationships from the 1980s (R&M Consultants and Trihey & Associates 1985a), reductions in the tributary mouth wetted surface area were estimated for both Willow Creek and Goose Creek at 26% and 19%, respectively.

Goose Creek and Trapper Creek were the only tributaries with minimum water depth at or below the passage criteria in Thompson (1972) at 21,100 cfs based on the text of R&M Consultants and Trihey & Associates (1985b). The study indicated that during the salmon migration period (May 13 through September 30) water depth would equal or exceed 0.8 feet, the minimum depth for adult Chinook passage in Thompson (1972). R&M Consultants and Trihey & Associates (1985b) also indicated potential problems for Caswell and Montana Creek under the post-Project condition and 21,100 cfs.

None of the results presented for morphologic stability of tributary mouths by R&M Consultants and Trihey & Associates (1985b) indicated that post-Project conditions would cause a decrease in stability. The results provided for five of the tributary mouths suggested that the post-Project conditions would result in improved stability. These tributaries were Caswell Creek, Goose Creek, Montana Creek, Rabideux Creek, and Birch Creek. However, these results were based on comparison of aerial photographs only and not on detailed geomorphic assessment of each tributary and the impacts from Project-related changes in main channel Susitna River discharge and associated stages. The comparison of the 1983 and 2012 mapping of habitat showed that significant changes had occurred at the Goose Creek site (Tetra Tech 2013c) due to changes in the adjacent main channel.

6.3. 2013-2014 Lower River Studies

The results of the assessment presented in this technical memorandum indicate the potential for Project-related effects on the wetted surface area of various habitat types and related to tributary access by spawning salmon. To further quantify the potential Project effects on these aspects of aquatic habitat in the Lower River Segment additional studies have been planned (R2 Resource Consultants 2013). These efforts include instream flow studies in the main channel and lateral habitats at two sites and assessment of access issues at five tributaries to be conducted as part of the Fish and Aquatics Instream Flow Study (IFS). The two instream flow study sites are in the vicinity of Trappers Creek between PRM 97 and PRM 95 in Geomorphic Reach LR-1 and between PRM 65 and PRM 68 in Geomorphic Reach LR-2. The Lower River tributaries to be studied are Trappers Creek (PRM 94.5), Birch Creek (PRM 92.5), Sheep Creek (PRM 69.5), Caswell Creek (PRM 67) and the Deshka River (PRM 45). The open water flow routing model and the one-dimensional sediment transport model will be extended downstream to PRM 29.9. The Riparian IFS has also added a study site in each of the six Lower River geomorphic reaches. Results of the 2013 Lower River studies will be reviewed to determine if additional sampling and analysis should be performed in 2014.

7. REFERENCES

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8. TABLES

Table 4.3-1. Comparisons of median monthly discharge (cfs) for pre-Project and Max LF OS-1 Conditions for the Susitna River at Sunshine.

Average Monthly Discharge (cfs) for the Susitna River at Sunshine											
Oct		Nov		Dec		Jan		Feb		Mar	
Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1
13,600	15,800	6,100	11,600	4,520	11,300	3,700	11,400	3,280	11,700	2,930	9,510
Apr		May		Jun		Jul		Aug		Sep	
Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1
3,520	9,320	31,100	25,900	63,500	48,000	58,600	45,800	52,900	46,000	32,000	31,300

Table 4.3-2. Comparison of monthly stage exceedences (ft) for the pre-Project and Max LF OS-1 Conditions for the Susitna River at Sunshine.

Percentile	May			June			July		
	Pre-Project	Max LF OS-1	Difference	Pre-Project	Max LF OS-1	Difference	Pre-Project	Max LF OS-1	Difference
90%	11.93	12.62	0.69	16.42	15.62	-0.8	16.98	16.07	-0.91
50%	15.37	14.76	-0.61	18.56	17.13	-1.43	18.13	16.92	-1.21
10%	18.76	17.18	-1.58	20.34	18.29	-2.05	19.68	18.08	-1.6

Percentile	August			September		
	Pre-Project	Max LF OS-1	Difference	Pre-Project	Max LF OS-1	Difference
90%	16.13	15.79	-0.34	13.73	13.78	0.05
50%	17.61	16.94	-0.67	15.48	15.39	-0.09
10%	19.23	18.67	-0.56	17.91	17.73	-0.18

Table 5.1-1. Summary of potential effects on the with-Project flows on tributaries of the Lower Susitna River, reproduced from Table 4.1 of R&M Consultants and Trihey & Associates (1985b).

General Tributary Information									Effects of With-Project Flows On					
Tributary	River Mile	Tributary Mouth in		Breaching Discharge at Sunshine (cfs)	Summary of Adult Salmon Usage of Stream Interface Reach 1984(1)		Passage Conditions Near Tributary Mouth		Fish Access Into Tributaries at 21,100 cfs (2)		On Backwater Areas (3)		Morphologic Stability of Tributary Mouth (4)	
		Side Channel	Main Channel		Passage	Spawning	Water Depth (ft)	Discharge at Sunshine (cfs)	Possible Problem	No Problem	Moderate Change	Slight Change	Present	With-Project
Alexander Cr	9.1	X		---	Not Surveyed		--	--		X	X		Good	Good
Deshka R	40.6		X	---	Ch, S, P, Co	--	--	--		X	X		Fair	Fair
Willow Cr	49.1	X		<13,900	S, P, Ch, Co	P, Ch	2.8	18,300		X		X	Good	Good
L Willow Cr	50.5	X		58,000	Ck, S, P, Ch, Co	P	1.5	18,300		X	X		Good	Good
Kashwitna R	61.0	X		---	P, Ch	--	--	--		X		X	Fair	Fair
Caswell Cr	64.0	X		35,000	Ck, S, P, Ch	P, Ch	0.8	21,100	X		X		Fair	Fair/ Good
Sheep Cr	66.1	X		<13,900	S, P, Ch, Co	P	3.0	18,300		X	X		Good	Good
Goose Cr	72.0	X		21,000	Ck, S, P, Ch, Co	P	0.4	--	X			X	Fair	Fair/ Good
Montana Cr	77.0		X	35,000	Ck, P, Ch, Co	P, Ch	1.1	18,300	X			X	Poor	Poor/ Fair
Rabideux Cr	83.1		X	---	Ck, S, P, Ch	--	--	--		X	X		Fair	Good
Sunshine Cr	85.1	X		<13,900	Ck, S, P, Ch	P, Ch	1.5	28,400		X	X		Good	Good
Birch Cr	89.2		X	54,100	Ck, S, P, Ch, Co	P	--	--		X	X		Fair	Fair/ Good
Trapper Cr	91.5	X		44,000	Ck, S, P, Ch, Co	P, Ch	0.6	20,900	X		X		Fair	Fair

Definitions:

1 The interface reach is first third mile from mouth up the tributary. Source Barrett et al. 1985. Ck = chinook, S= sockeye, P = pink, Ch = chum, and Co = coho.

2 Possible Problem - There is the potential for access problems depending on low tributary flows, debris jams, or channel changes.
No Problem - No problem with access currently exists.

3 Moderate Change - The extent of backwater area could be moderately reduced by with-project flows during June and July.
Slight Change - The extent of backwater area could be slightly reduced by with-project flows during June and July

4 Good - No change in tributary mouth morphology since 1951.
Fair - Some change in tributary mouth morphology since 1951.
Poor - Change in tributary mouth morphology from 1951 to present.

Table 5.2-1. SC IV-4 accumulated wetted surface areas (ft^2x10^3) for each habitat type for the Open water period (May-September) and Ice Affected period (October-April) for both the pre-Project and Maximum Load Following OS-1 conditions.

Accumulated wetted surface area (ft^2x10^3) for each habitat type								
	Main Channel		Primary Side Channel		Secondary Side Channel		Turbid Backwater	
Period Accumulated	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**
Open Water (May-Sept)	30,512	29,524	NA[1]	NA	32,724	30,135	914	669
Ice Affected (Oct-Apr)	37,659	38,012	NA	NA	10,882	15,683	0	0
	Clearwater		Side Slough		Tributary Mouth		Tributary	
Period Accumulated	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**
Open Water (May-Sept)	848	1,212	0	0	NA	NA	NA	NA
Ice Affected (Oct-Apr)	0	0	598	514	NA	NA	NA	NA

[1] NA = No aquatic habitat of this type present at this site

Table 5.2-2. Willow Creek accumulated wetted surface areas (ft^2x10^3) for each habitat type for the Open water period (May-September) and Ice Affected period (October-April) for both the pre-Project and Maximum Load Following OS-1 conditions.

Accumulated wetted surface area (ft^2x10^3) for each habitat type								
	Main Channel		Primary Side Channel		Secondary Side Channel		Turbid Backwater	
Period Accumulated	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**
Open Water (May-Sept)	14,518	14,113	NA[1]	NA	55,586	51,825	1,317	1,419
Ice Affected (Oct-Apr)	12,469	13,701	NA	NA	21,699	30,724	134	332
	Clearwater		Side Slough		Tributary Mouth		Tributary	
Period Accumulated	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**	**Pre-Project**	**Max LF OS-1**
Open Water (May-Sept)	754	832	0	0	2,647	2,150	6,228	7,107
Ice Affected (Oct-Apr)	0	0	5,334	4,578	233	622	14,280	14,214

[1] NA = No aquatic habitat of this type present at this site

Table 1.2-3. Goose Creek accumulated wetted surface areas (ft^2x10^3) for each habitat type for the Open water period (May-September) and Ice Affected period (October-April) for both the pre-Project and Maximum Load Following OS-1 conditions.

Accumulated wetted surface area (ft^2x10^3) for each habitat type								
Period Accumulated	Main Channel		Primary Side Channel		Secondary Side Channel		Turbid Backwater	
	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1
Open Water (May-Sept)	24,751	18,234	NA[1]	NA	27,416	24,108	943	991
Ice Affected (Oct-Apr)	0	0	NA	NA	11,793	17,362	42	81
	Clearwater		Side Slough		Tributary Mouth		Tributary	
Period Accumulated	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1	Pre-Project	Max LF OS-1
Open Water (May-Sept)	677	920	1,172	1,104	455	367	2,539	2,417
Ice Affected (Oct-Apr)	0	0	5,257	5,170	0	0	15,820	15,079

[1] NA = No aquatic habitat of this type present at this site

Table 5.2-4. Accumulated wetted surface areas for tributary mouth habitat for the salmonid spawning period (June-September) for Willow Creek and Goose Creek.

Site	Accumulated wetted surface area ($ft^2 x 10^3$) for the salmonid spawning period (June-Sept)	
	Tributary Mouth	
	Pre-Project	Max LF OS-1
Willow Creek	2,286	1,697
Goose Creek	405	329

9. FIGURES

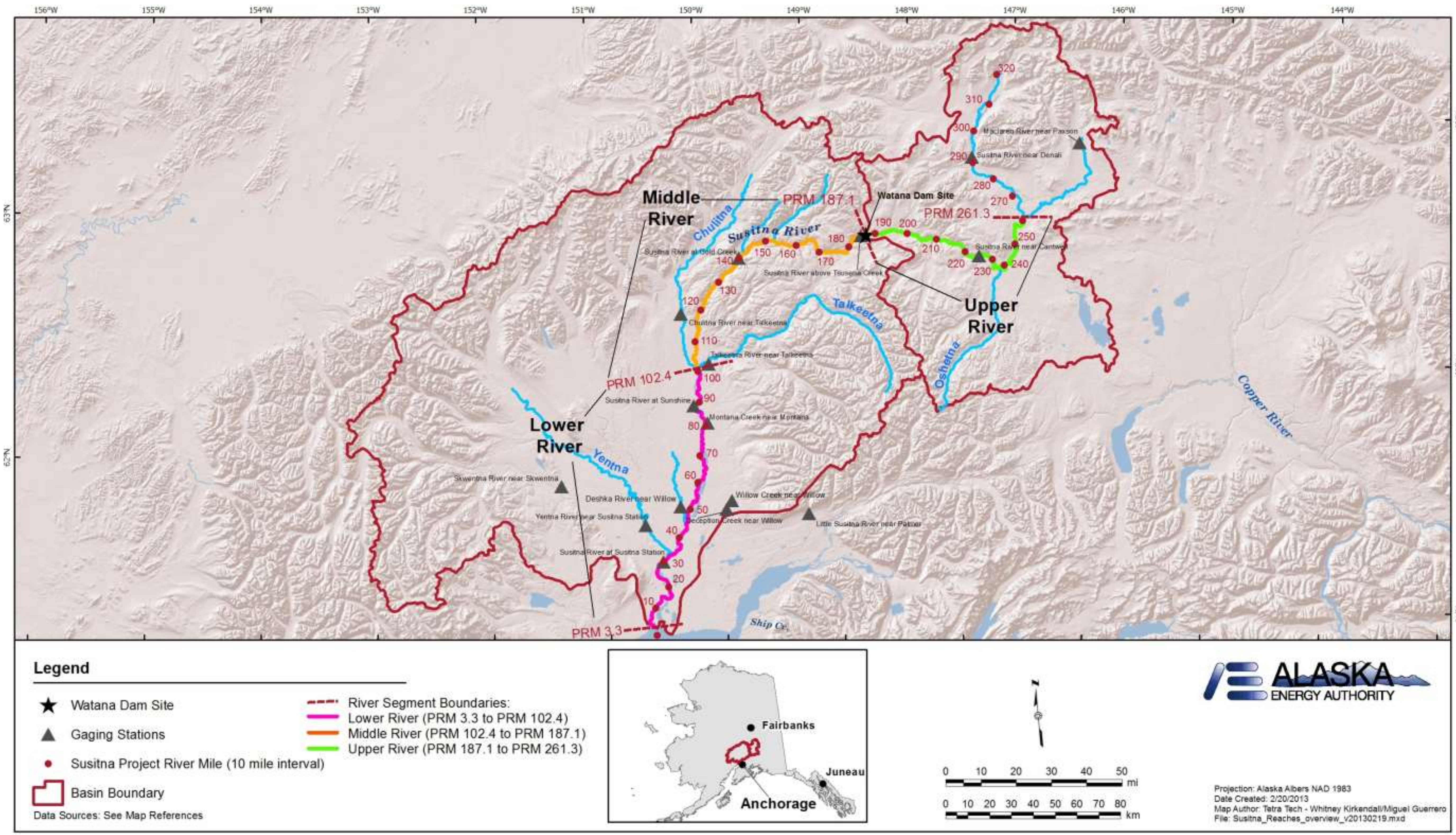

Figure 3.2-1. Susitna River Geomorphology Study Area and Large-scale River Segments.

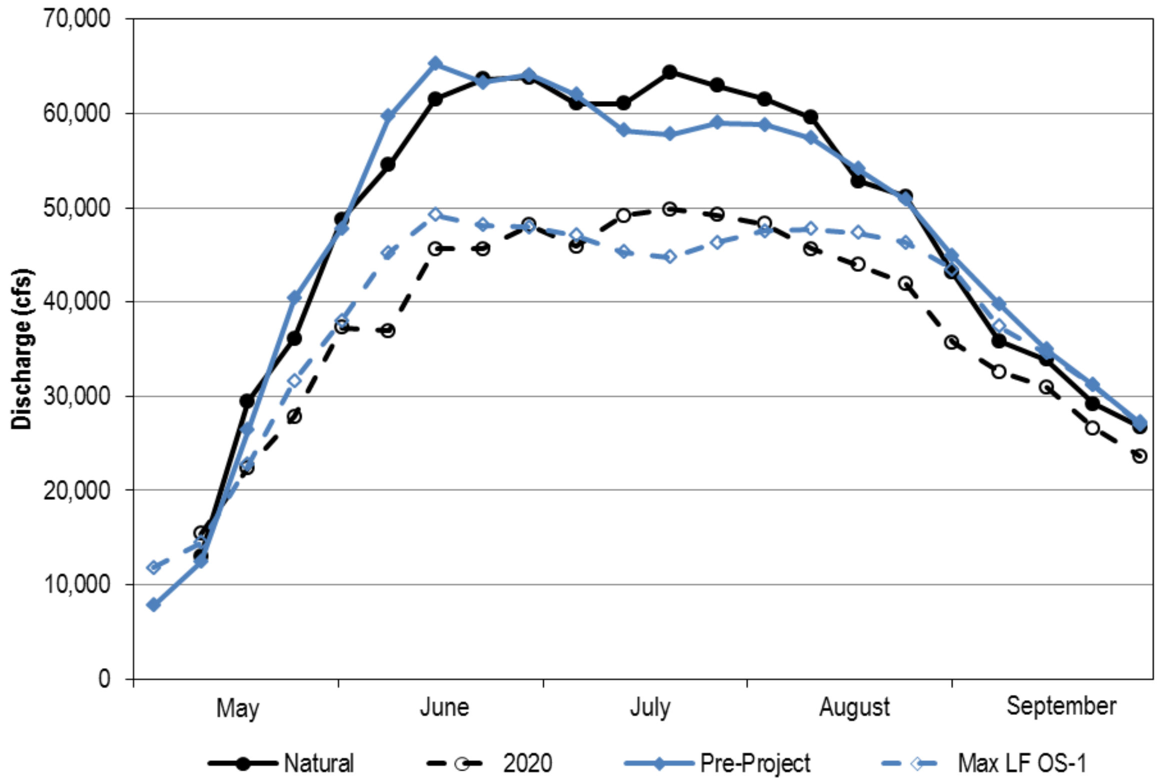

Figure 4.5-1. Comparison of median weekly discharge for the Susitna River at Sunshine for the Natural and 2020 conditions presented in Figure 4.2 of R&M Consultants and Trihey & Associates (1985b) and the pre-Project and Maximum Load Following OS-1 conditions assessed by the 2012 Study.

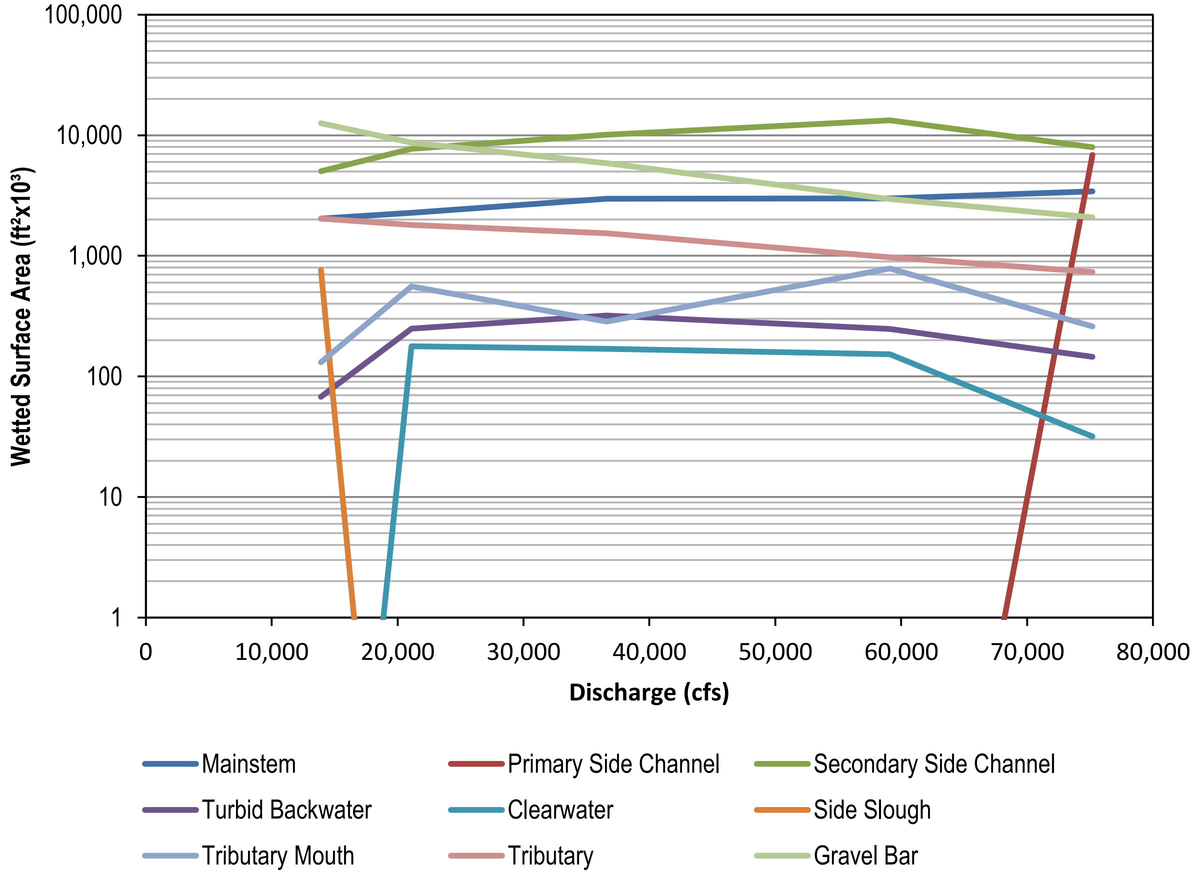

Figure 5.1-1. Wetted surface area ($ft^2 \times 10^3$) response to Susitna River discharge at Sunshine by habitat type for Willow Creek. Reproduced from R&M Consultants and Trihey & Associates (1985a).

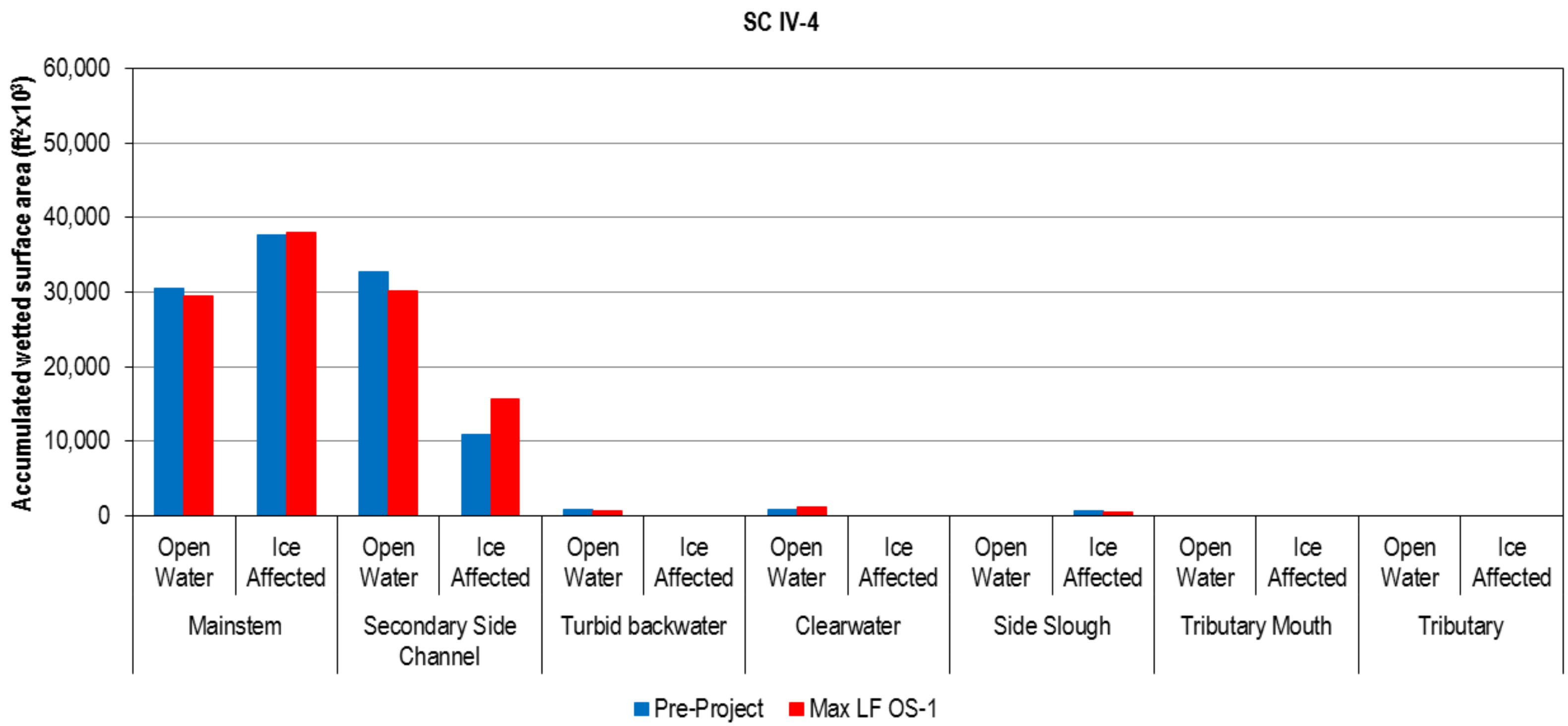

Figure 5.2-1. Accumulated wetted surface area (ft^2x10^3) computed for SC IV-4 for the Open Water period (May-September) and the Ice Affected period (October-April) for the median monthly Sustina River discharge at Sunshine under the pre-Project and Maximum Load Following OS-1 conditions for each habitat type.

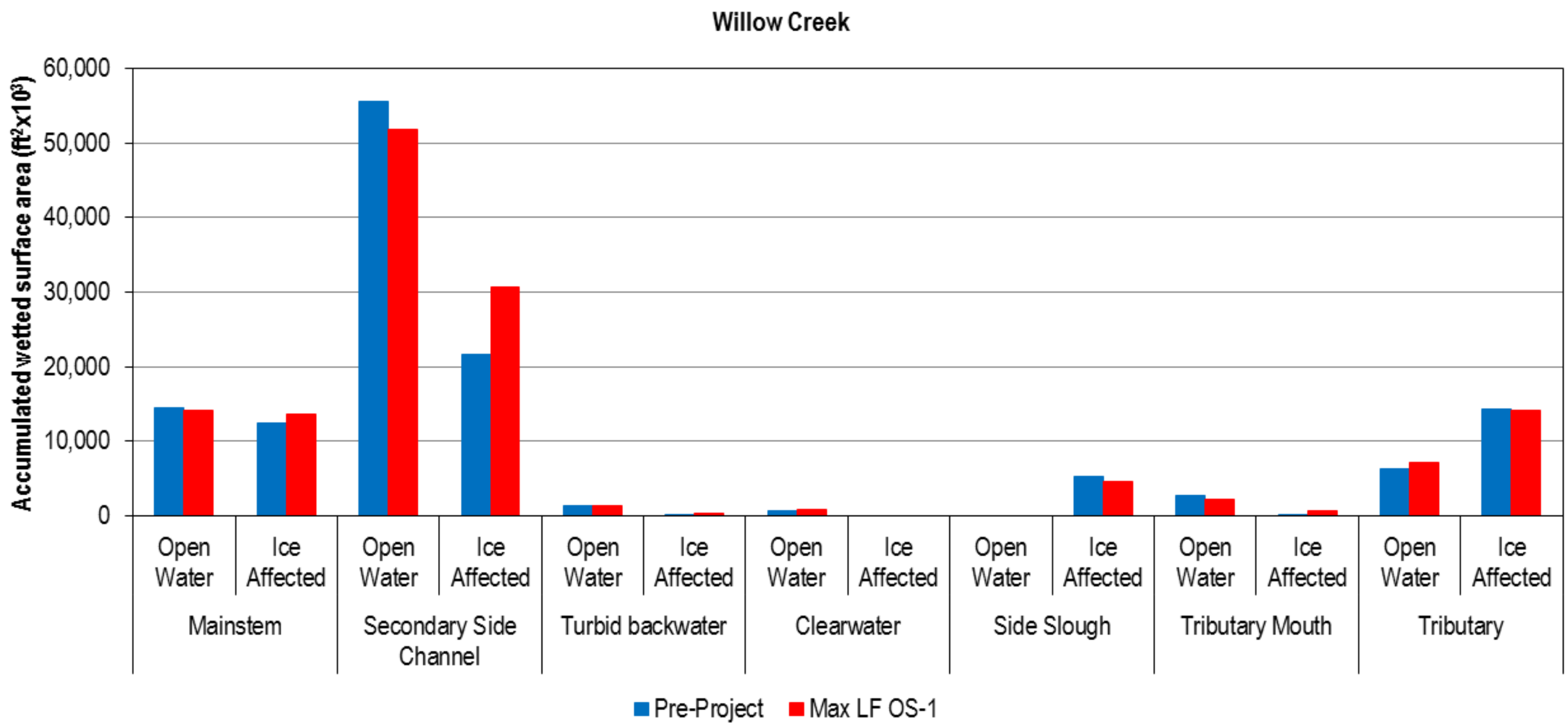

Figure 5.2-2. Accumulated wetted surface area (ft^2x10^3) computed for Willow Creek for the Open Water period (May-September) and the Ice Affected period (October-April) for the median monthly Sustina River discharge at Sunshine under the pre-Project and Maximum Load Following OS-1 conditions for each habitat type.

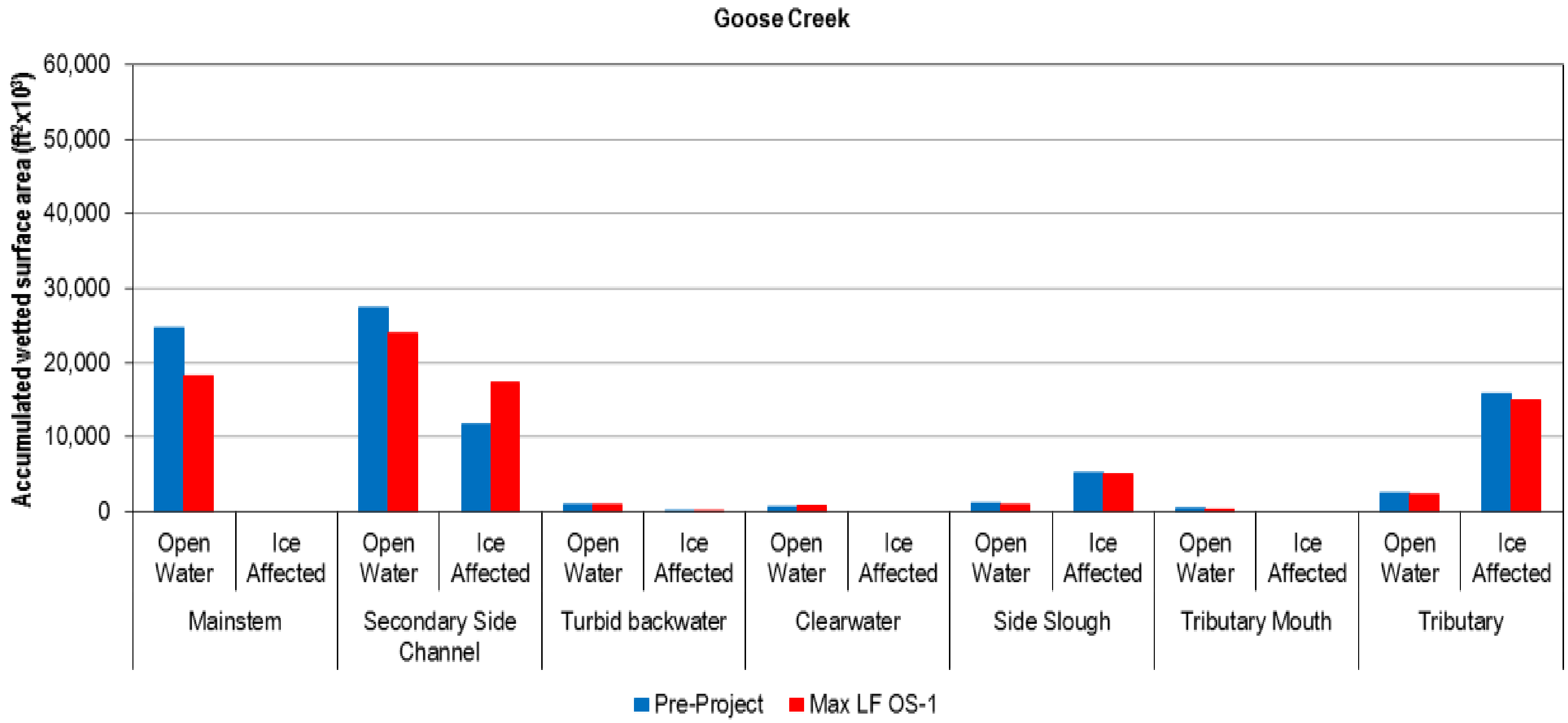

Figure 5.2-3. Accumulated wetted surface area (ft^2x10^3) computed for Goose Creek for the Open Water period (May-September) and the Ice Affected period (October-April) for the median monthly Sustina River discharge at Sunshine under the pre-Project and Maximum Load Following OS-1 conditions for each habitat type.

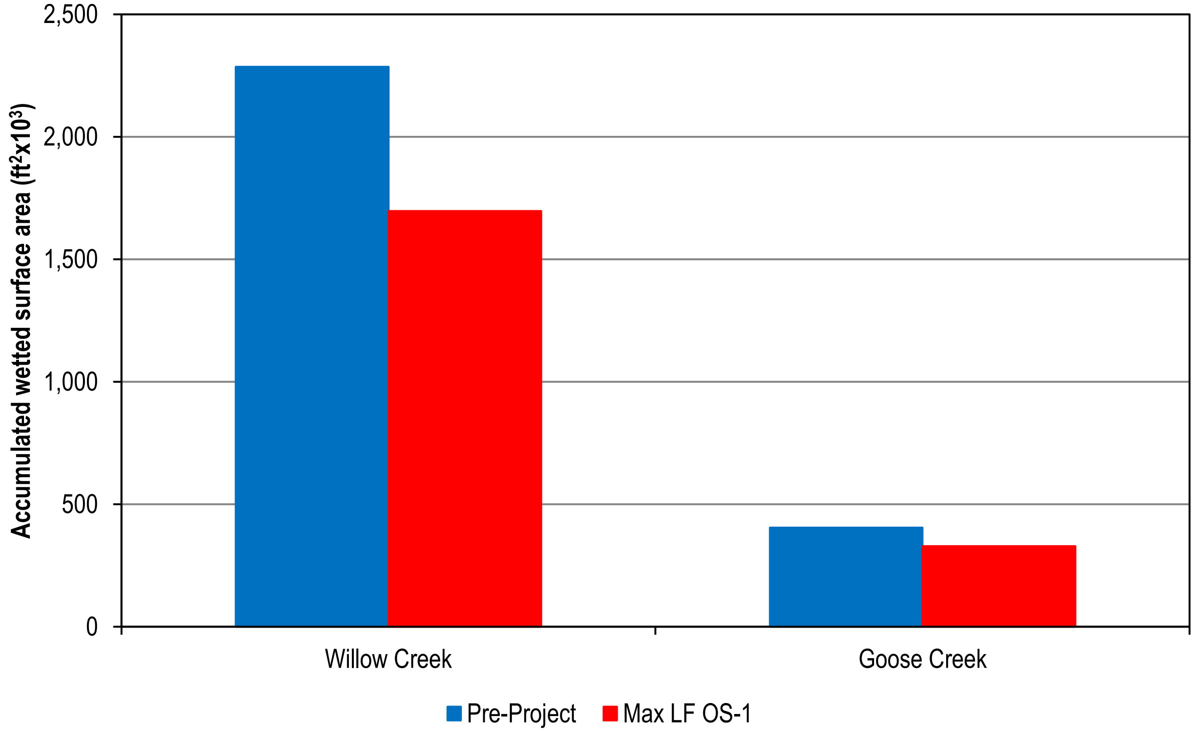

Figure 5.2-4. Accumulated wetted surface area (ft^2x10^3) computed over the salmon migration period (June-September) for the median monthly Sustina River discharge at Sunshine presented for the tributary mouth habitat type for the pre-Project and Maximum Load Following OS-1 conditions at Willow Creek and Goose Creek.