Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fish and Aquatics Instream Flow Study
Study Plan Section 8.5

Initial Study Report
Part C: Executive Summary and Section 7

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants, Inc.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

EXECUTIVE SUMMARY

Fish and Aquatics Instream Flow Study 8.5	
Purpose	The objective of the Fish and Aquatics Instream Flow Study (IFS) is to characterize and evaluate the potential operational flow-induced effects of the proposed Project on fish habitat below the proposed Project dam. The focus of implementation of this study is on establishing a set of analytical tools/models based on site-specific channel and hydraulic data that can be used for defining existing conditions (i.e., without Project) and how these resources and processes will respond to alternative Project operational scenarios.
Status	The IFS study, which consists of eight study components, was initiated in 2013 in accordance with the Study Plan and resulted in the selection of study areas and study sites that are being used across resource disciplines, as well as the collection of substantial field data (including completion of pilot winter fish studies) that will be used in evaluating flow related effects of the Project on fish habitats. In addition, Version 1 (developed in 2013) and Version 2 (developed in 2014) of the Open-water Flow Routing Model have been developed and used by a number of resource disciplines for planning studies and defining the downstream extent of Project effects. The IFS study team is currently analyzing data, developing habitat – flow models, continuing to refine the Open-water Flow Routing Model, and preparing to continue data collection efforts in 2014 and 2015.
Study Components	The IFS study includes the following components as described in the Study Plan: 1) IFS Analytical Framework 2) River Stratification and Study Area Selection 3) Hydrologic Data Analysis 4) Reservoir Operations and Open-water Flow Routing Model\ 5) Habitat Suitability Criteria Development 6) Habitat-Specific Model Development 7) Temporal and Spatial Habitat Analyses 8) Instream Flow Study Integration
2013 Variances	While land access was not available for the three upper Focus Areas adjacent to Cook Inlet Regional Working Group (CIRWG) lands in 2013, this was not considered a variance because this study was designed to collect data over multiple years. Alaska Energy Authority (AEA) implemented the methods as described in the Study Plan with the exception of the following variances:

Fish and Aquatics Instream Flow Study 8.5	
	The Study Plan indicated 13 mainstem water-level recording stations would be maintained in 2013 (RSP Section 8.5.4.3.1). After calibration and validation of the Version 1 Open-water Flow Routing Model, and in response to land owner access issues, five stations were not maintained in 2013 (ISR Study 8.5, Section 4.4.2).
	The Study Plan indicated continuous stage measurements would be collected in the mainstem (RSP Section 8.5.4.3.1). Due to ice damage, flooding and land access issues, some short and long-term data gaps of water stage exist for eight hydrology locations (ISR Study 8.5, Section 4.3.2).
	The Study Plan indicated continuous gaging would be installed at Fog Creek and Portage Creek (RSP Section 8.5.4.4.1.1). Due to land access issues, these were not installed in 2013 (ISR Study 8.5, Section 4.3.2).
	The Study Plan indicated that specific representative years and the duration of the continuous flow record would be selected by AEA in consultation with the TWG in Q3 2013 (RSP Section 8.5.4.4.1.2). This selection was discussed at the November 13-15, 2013 Riverine Modelers meeting and Q4 2013 TWG meeting. (ISR Study 8.5, Section 4.3.2). The recommended representative years and the rationale for selection were presented at the April 15-17, 2014 Proof of Concept meeting and described in ISR Study 8.5, Appendix J.
	The Study Plan indicated that hydrologic parameters for IHA analysis would be developed in consultation with the TWG in Q3 2013 and interim results of IHA-type analysis would be presented in the ISR (RSP Section 8.5.4.4.1.3). A description of the initial proposed methodology is provided in ISR Study 8.5, Section 5.3, and Section 7.3 and will undergo continued discussion and coordination with the TWG (ISR Study 8.5, Section 4.3.2). An Instream Flow Study (IFS) Technical Team (TT) meeting occurred on March 21, 2014 which reviewed candidate metrics and proposed analysis for IHA and EFC.
	The Study Plan indicated that HSC sample sites would be stratified and randomly selected from within the Middle River Segment and Lower River Segment (RSP Section 8.5.4.5.1.1.3). Due to access restrictions, the Middle River Segment was limited to habitat areas between Portage Creek and Three Rivers Confluence. Due to flow related delays in completing the habitat mapping surveys and the desire to focus sampling in 2013 on the Middle River, the Lower River segment was not sampled (ISR Study 8.5, Section 4.5.2).
	The Study Plan indicated spawning redd dimensions would be collected (RSP Sections 8.5.4.5.1.1.4 and 8.5.4.5.1.1.5). These were collected in 2012 but in

Fish and Aquatics Instream Flow Study 8.5	
	2013 deemed unnecessary for developing evaluation metrics (ISR Study 8.5, Section 4.5.2).
	The Study Plan indicated that substrate size (dominant, sub-dominant, and percent dominant) would be characterized in accordance with a Wentworth grain size scale modified to reflect English units (RSP Sections 8.5.4.5.1.1.4, 8.5.4.5.1.1.5, 8.5.4.5.1.1.6.1, and 8.5.4.6.1.2.4). Field personnel found it impracticable to attempt to accurately differentiate gravel composition into three size classes in turbid water conditions and used two instead (ISR Study 8.5, Section 4.5.2).
	The Study Plan indicated that location in water column, focal point and mean column velocity would be measured using a Price AA current meter (RSP Section 8.5.4.5.1.1.6.1). Most fish captures occurred using electrofishing, seining or a combination of the two methods which precluded the identification of fish focal point position within the water column (ISR Study 8.5, Section 4.5.2).
	The Study Plan indicated that mesohabitat type would be recorded for fish observation/capture points (RSP Section 8.5.4.5.1.1.6.1). However, this was not done during the field surveys but will be completed after the mesohabitat mapping task is complete by applying GIS data layers containing the location of HSC fish use observations (ISR Study 8.5, Section 4.5.2) to denote mesohabitat types
	The Study Plan indicated that field surveys would be conducted at potential stranding and trapping areas on an opportunistic basis following up to three flow reduction events during 2013 (RSP Section 8.5.4.5.1.2.2). The need for these studies will be discussed with the TWG.
	The Study Plan indicated that 2012-2013 winter study results would be distributed to the TWG by Q3 2013 (RSP Section 8.5.4.5.1.2.1). The results were presented and discussed during an IFS TT meeting in March 2014 (ISR Study 8.5, Section 4.5.2, Appendix L).
	The Study Plan indicated that macroinvertebrate sampling would occur at six stations, each with three sites (one mainstem site and two off-channel sites associated with the mainstem site), for a total of 18 sites (RSP Section 8.5.4.5.1.2.3). This sampling occurred at five stations on the Susitna River, each station with three to five sites (establishing sites at all macrohabitat types present within the station), for a total of 20 sites (ISR Study 8.5, Section 4.5.2).

Fish and Aquatics Instream Flow Study 8.5	
	The Study Plan indicated the Deshka River Chinook salmon and Yentna River sockeye salmon datasets would be examined for flow-dependent biological cues (RSP Section 8.5.4.5.1.3). Mainly due to lack of the necessary data, the Deshka River and the Yentna River were not used for this study. Through further discussions with ADF&G, the Taku River and Stikine River Chinook salmon stocks were selected (ISR Study 8.5, Section 4.5.2).
	The Study Plan indicated that additional variables would be compared to fish distribution and abundance: surface flow and groundwater exchange fluxes, dissolved oxygen (intergravel and surface water), macronutrients, temperature (intergravel and surface water), pH, dissolved organic carbon, alkalinity, and Chlorophyll-a. Depending on these relationships, additional HSC preference curves may be needed (FERC 2013b [FERC April 1 SPD, page B-85]). Most of the data necessary to complete this analysis is still being processed and/or undergoing quality assurance checks and is not available at this time (ISR Study 8.5, Section 4.5.2, and Section 7.5.1.2.1).
	The Study Plan indicated that five tributary mouths, including Sheep Creek and Caswell Creek, would be investigated as part of the Lower River studies (R2 2013b [Technical Memorandum, Selection of Focus Areas and Study Sites in the Middle and Lower Susitna River for Instream Flow and Joint Resource Studies – 2013 and 2014]). Two of the five sites identified for study in 2013 were not completed and were deferred to the next study year in order to evaluate the effectiveness of the model outputs from the other three sites and evaluate the need for additional sites (ISR Study 8.5, Section 4.6.2).
	The Study Plan indicated that an evaluation of the representativeness of the Lower River study areas was to occur by Q4 2013 (R2 2013b [Technical Memorandum, Selection of Focus Areas and Study Sites in the Middle and Lower Susitna River for Instream Flow and Joint Resource Studies – 2013 and 2014]). This task was completed as part of the IFS TT POC Meetings, April 15-17, 2014; ISR Study 8.5, Section 7.6.
	The Study Plan indicated that the final approach and details concerning methods for conducting temporal analysis and Project operational scenarios would be discussed with the TWG in Q4 2013 (RSP Section 8.5.4.7.1.1). The general approaches to be used for the spatial analysis of the fish habitat models and the temporal analysis for the different resource models were discussed as part of the November 13-15, 2013 Instream Flow Study Technical Team Riverine Modelers meeting. More details concerning these methods are provided in this ISR and AEA is planning on finalizing the methods in 2014, in accordance with the Study Plan schedule; AEA demonstrate the application of the temporal methods and presented options for the spatial analysis during the IFS TT POC Meetings, April 15-17, 2014

Fish and Aquatics Instream Flow Study 8.5	
	(ISR Study 8.5, Section 4.7.2, Section 7.7).
Steps to Complete the Study	AEA's plans for completing this study include the continued collection and analysis of data and information that will be used in development of the different resource models, and specifically the habitat-flow models. In addition, AEA will finalize methods for the temporal and spatial analysis of information, as well as the Decision Support System. More details are provided below by study component. Additional hydrology data will continue to be collected in 2014 and 2015. The 2014 data collection effort will focus on mainstem hydrology stations, mainstem transect data needed fill data gaps in the Open-water Flow Routing Model, tributary gage data, and completion of focus area data gaps for sites collected in 2014. These data will be used to refine and complete Version 3 of the Open-water Flow Routing Model. Version 3 will incorporate diurnal fluctuations, new floodplain geometry if available, and adjusted tributary inflows based on measured data. 2015 data collection will focus on the Lower River transects and Focus Area measurements needed on CIRWG lands. IHA and EFC parameters will continue to be reviewed with the Agencies and will be finalized prior to completion of Version 3 of the Open-water Flow Routing model. AEA plans to complete development of HSC/HSI curves/models for the Middle and Lower River segments of the river. Additionally, two years of study (2014 and 2015) are proposed for CIRWG lands that were inaccessible during the 2013 field season (FA-151 (Portage Creek), FA-173 (Stephan Lake Complex, and FA-184 (Watana Dam)). Steps that will be completed in 2014 include: • Conduct sampling in representative habitat types in the lower segment of the Susitna River in association with Trapper, Birch, Sheep, and Caswell creeks. • Conduct sampling in FA-151 (Portage Creek), FA-173 (Stephan Lake Complex), and FA-184 (Watana Dam). Conduct sampling in the Middle River Segment in areas with known fish use. • Conduct opportunistic aquatic biota stranding and trapping surveys. • Continue development of site-specific HSC preference curves. • Complete exploratory analysis of relationships between microhabitat use and fish abundance utilizing data from FDA, Water Quality, and Groundwater studies. • Distribute draft species and life stage specific periodicity tables for the high and moderate priority fish species. • Finalize list of species and life stages for which HSC curves will be developed and the types of curves (preference, utilization, bianary)

Fish and Aquatics Instream Flow Study 8.5	
	needed for each. • Distribute draft findings from 2014 Winter Studies. • Distribute draft HSC/HSI curves for macroinvertebrates and algae • In preparation for 2015 Winter Studies, install continuous stage and water quality (temperature and dissolved oxygen) monitoring sensors in FA-104, FA-128 and FA-138. Steps that will be completed in 2015 include: • Conduct sampling in representative habitat types in the lower segment of the Susitna River in association with Trapper, Birch, Sheep, and Caswell creeks. • Conduct sampling in FA-151 (Portage Creek), FA-173 (Stephan Lake Complex), and FA-184 (Watana Dam). • Distribute final species and life stage specific periodicity tables for use in habitat modeling. • Conduct Winter Studies including monitoring stage and water qaulity data at main channel and off-channel sites in FA-104, FA-128 and FA-138. • Conduct winter sampling including fish observation, capture, and monitoromg using electrofishing and underwater video to discern seasonal habitat use patterns. • Distribute draft findings from 2015 Winter Studies. • Develop final HSC/HSI curves for use as part of habitat modeling. AEA will also continue working on the development of habitat-specific models in both the Upper River and Lower River segments during 2014 and 2015. In the Middle River Segment, this will include: • Finalization of 2-D hydraulic models in each of the seven Focus Areas that were surveyed between PRM 104 and PRM 145 in 2013 (FA-104 [Whiskers Slough], FA-113 [Oxbow 1], FA-115 [Slough 6A], FA-128 [Slough 8A], FA-138 [Gold Creek], FA-141 [Indian River], and FA-144 [Slough 21]) as needed to provide inputs into the fish habitat modeling. • Finalization of the Visual Basic (VB) models and associated GIS tools for each of the seven Focus Areas to allow computation of HSC/HSI habitat based metrics at the macrohabitat and Focus Area scale under different flow conditions (ISR Study 8.5, Section 5.6.4.1). • Continued development and refinement of the Effective Spawning/Incubation model as described in ISR Study 8.5, Section 5.6.4.2, and presented during the IFS-TT POC meetings on April 15-17, 2014. • Continued development and refinement of the Salmonid Rearing

Fish and Aquatics Instream Flow Study 8.5	
	Habitat Model as presented during the IFS-TT POC meetings on April 15-17, 2014. • Development of varial zone models for each of the seven Focus Areas (RSP Section 8.5.4.6.1.6) • Collection of bathymetric and hydraulic data in the remaining three Focus Areas, including FA-151 (Portage Creek), FA-173 (Stephan Lake Complex) and FA-184 (Watana Dam Site) as necessary to develop either 2-D and/or 1-D hydraulic models to conduct fish habitat modeling. • Collection of substrate and cover data within the remaining three Focus Areas (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex] and FA-184 [Watana Dam Site]). • Development of hydraulic models (either 2-D or 1-D) and habitat models for the remaining three Focus Areas (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex] and FA-184 [Watana Dam Site]). • Development of varial zone models for the remaining three Focus Areas (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex] and FA-184 [Watana Dam Site]). • Collection of single transect data at selected cross-sections in the Middle River Segment as needed to support development of the OWFRM and other resource models. For the Lower River Segment this will include: • Finalization of the open-water hydraulic model calibration of the LR-1 fish habitat sites from field data collected in 2013; • Identification of transect locations within targeted habitats for reach LR-2 in the vicinity of Sheep Creek and Caswell Creek; • Collection of open-water field data in 2015 to support fish habitat modeling at LR-2 fish habitat sites; • Finalization of open-water hydraulic model calibration of the LR-2 fish habitat sites from field data collected in 2015;Identification of priority species, life stages and periodicity for LR-1 and LR-2 to use for HSC curve development to apply to the fish habitat modeling; • Calculation of weighted useable area (WUA) curves for each lower river fish habitat site in LR-1 and LR-2 using calibrated PHABSIM models; • Calculation of WUA time series of open-water habitat for LR-1 and LR-2 sites based on species and life stage periodicity for existing conditions and project flow scenarios; • open-water hydraulic model calibration of the Deshka River confluence site; • development of timing windows for fish passage for priority species within the Deshka River;

Fish and Aquatics Instream Flow Study 8.5	
	• development of depth and velocity criteria for defining breaching, fish passage and connectivity conditions for the Deshka River confluence; and, • Calculation of fish passage probabilities and percentage of time open-water connectivity is maintained to identify changes to timing, frequency or duration of conditions. And finally, AEA will continue in 2014 and 2015 to work on development and finalization of methods for completing both the temporal and spatial analyses of data as described in ISR Study 8.5, Section 7.7., and in parallel, will be working in collaboration with the licensing participants in developing the Decision Support System that will be used for evaluating overall Project effects across resource disciplines and user groups.
Highlighted Results and Achievements	In 2013, the major field efforts were associated with collection of HSC/ HSI fish habitat data (winter and open-water periods), mainstem Susitna and tributary hydrology data, bathymetry and topographic data, and characterization of substrates.
	Major activities completed in 2013 related to development of HSC curves included selection of target species and life stages, development of draft HSC curves using existing information, selection of HSC sampling locations, collection of microhabitat use and availability data for the target fish species, development of histograms displaying frequency of use for different microhabitat variables, and preliminary development of microhabitat preference curves. A total of 68 HSC data collection sites were randomly selected for collection of HSC field data to quantify microhabitat use by spawning and freshwater 'rearing' (juvenile resident or anadromous fish) or 'holding' (adult resident fish) life stages of target fish species. During each survey, both microhabitat utilization (water depth, velocity, substrate composition, turbidity, and cover) and availability data were collected during each sampling event Habitat measurements were collected for four different life history stages (spawning, juvenile, fry, and adult) and twelve different fish species: Chinook, sockeye, chum, coho, and pink salmon; rainbow trout; Arctic grayling; Arctic lamprey; Dolly Varden char; whitefish; longnose sucker; and burbot. A total of 1,433 observations of site-specific habitat use was recorded during 2013 HSC surveys of the Middle Susitna River. A total of 3,297 measurements of habitat availability was collected from within each of the seven Focus Areas and from additional areas located outside of the Focus Areas. Collection of habitat availability data allows modeling of fish presence/absence as a function of single or multiple parameters (e.g., water depth, velocity, cover, water quality, temperature, and groundwater upwelling) using availability measurements at locations of where fish were not observed, and utilization measurements as locations where fish were

Fish and Aquatics Instream Flow Study 8.5	
	observed.
	Pilot winter studies were initiated during 2012–2013 to monitor water quality and stage conditions at salmon spawning locations and to record fish habitat use. The 2012–2013 pilot study was conducted at two areas in the Middle River Segment that contain a diversity of habitat types with groundwater influence, that have documented fish utilization, and that are accessible to and from Talkeetna during winter. Water quality and water level sampling sites for the 2012–2013 IFS winter studies were selected using a stratified approach. Whiskers Slough and Slough 8A study areas were stratified by macrohabitat type (e.g., main channel, side slough, tributary) and areas of known fish utilization. A total of nine water quality and water level monitoring sites was selected in FA-104 in areas of known or suspected groundwater upwelling; bank seepage and lateral intergravel flow from the main channel; mixing between upwelling and bank seepage; no intergravel discharge; fish spawning; and the Susitna River main channel. In FA-128, intergravel water quality and surface water level monitoring occurred in Slough 8A and an unnamed upland slough. Sites used for fish observation in each Focus Area consisted of open water and ice-covered areas in side slough, upland slough, and tributary habitats, while fish capture efforts occurred entirely in open water areas in side channel, side slough, and upland slough habitats.
	Hydrology data collected in 2012 and 2013 were used in development of Version 2 of the Open-water Flow Routing Model. Hydrology data collection included streamflow and/or water surface elevation measurements at 13 mainstem sites in 2012 and 8 mainstem sites in 2013. Streamflow, water surface elevation, or bathymetry data were also collected at 167 mainstem transects over both the 2012 and 2013 field seasons. These data were used in refining the Open-water Flow Routing Model. Hydrology data were also collected at 13 tributary sites in 2013.
	Bathymetric, ADCP, and substrate characterization surveys were completed for seven of the ten Focus Areas; data will be used in development of a 2-D hydraulic model that will be used in a PHABSIM related analysis to develop habitat-flow relationships for target fish species and life stages. Surveys in the Lower River Segment consisted of the collection of field data at 1-D single transect locations that will be used for defining habitat-flow relationships. Lower River field data collection during 2013 consisted of three site visits (June, August and September) at the LR-1 fish habitat sites to coincide with high, moderate and low flow conditions. Channel geometry and water levels were collected at the Deshka River confluence site as part of the geomorphology component (Study 5.6).

Fish and Aquatics Instream Flow Study 8.5	
	Preliminary hydraulic model calibrations using HEC-RAS were completed for two of the Lower River fish habitat sites located in LR-1 to provide analysis to be presented at the proof-of-concept meetings. The hydraulic modeling results were imported into PHABSIM and an example of the habitat modeling output was generated using available habitat suitability criteria. Examples of weighted useable area and a habitat time series analysis were presented at the proof-of-concept meeting.
	Analysis of data collected in 2013 is ongoing and is focused on development of different models that will be used for evaluating fish habitat-flow relationships, as well as developing plans for continuing data collection and analysis for the next year of study.
	HSC/HSI activities included the selection of target species and life stages, development of draft HSC curves using existing information, selection of HSC sampling locations, collection of microhabitat use and availability data for the target fish species, development of histograms displaying frequency of use for different microhabitat variables, and preliminary development of microhabitat preference curves. A total of 68 HSC data collection sites were randomly selected for collection of HSC field data to quantify microhabitat use by spawning and freshwater 'rearing' (juvenile resident or anadromous fish) or 'holding' (adult resident fish) life stages of target fish species. During each survey, both microhabitat utilization (water depth, velocity, substrate composition, turbidity, and cover) and availability data were collected during each sampling event. Habitat measurements were collected for four different life history stages (spawning, juvenile, fry, and adult) and twelve different fish species: Chinook, sockeye, chum, coho, and pink salmon; rainbow trout; Arctic grayling; Arctic lamprey; Dolly Varden char; whitefish; longnose sucker; and burbot. A total of 1,433 observations of site-specific habitat use was recorded during 2013 HSC surveys of the Middle Susitna River. A total of 3,297 measurements of habitat availability was collected from within each of the seven Focus Areas and from additional areas located outside of the Focus Areas. Pilot winter studies were also initiated during 2012–2013 to monitor water quality and stage conditions at salmon spawning locations and to record fish habitat use.
	Hydrology data collected in 2012 and 2013 were used in development of Version 2 of the Open-water Flow Routing Model. Hydrology data collection included streamflow and/or water surface elevation measurements at 13 mainstem sites in 2012 and 8 mainstem sites in 2013. Streamflow, water surface elevation, or bathymetry data were also collected at 167 mainstem transects over both the 2012 and 2013 field seasons. These data were used in refining the Open-water Flow Routing Model. Hydrology data were also

Fish and Aquatics Instream Flow Study 8.5	
	collected at 13 tributary sites in 2013.
	Bathymetric, ADCP, and substrate characterization surveys were completed for seven of the ten Focus Areas; data will be used in development of a 2-D hydraulic model that will be used in a PHABSIM related analysis to develop habitat-flow relationships for target fish species and life stages. Surveys in the Lower River Segment consisted of the collection of field data at 1-D single transect locations that will be used for defining habitat-flow relationships. Lower River field data collection during 2013 consisted of three site visits (June, August and September) to coincide with high, moderate and low flow conditions.
	Analysis of data collected in 2013 is ongoing and is focused on development of different models that will be used for evaluating fish habitat-flow relationships, as well as developing plans for continuing data collection and analysis for the next year of study.

7. COMPLETING THE STUDY

The steps for completing this study will will consist of the following components:

- IFS Analytical Framework (ISR Study 8.5, Section 7.1)
- River Stratification and Study Area Selection (ISR Study 8.5, Section 7.2)
- Hydrologic Data Analysis (ISR Study 8.5, Section 7.3)
- Reservoir Operations and Open-water Flow Routing (ISR Study 8.5, Section 7.4)
- Habitat Suitability Criteria Development (ISR Study 8.5, Section 7.5)
- Habitat-Specific Model Development (ISR Study 8.5, Section 7.6)
- Temporal and Spatial Habitat Analyses (ISR Study 8.5, Section 7.7)
- Instream Flow Study Integration (ISR Study 8.5, Section 7.8)

Details concerning each of these components including proposed methodologies to complete the study are provided below.

7.1. IFS Analytical Framework

7.1.1. Proposed Methodologies and Modifications

To complete this study component, AEA will implement the methods in RSP Section 8.5.4.1 with no modifications. These activities include:

- Adherence to the overall Analytical Framework for the Project as depicted in Figure 8.5-10 of RSP Section 8.5.4.1. That framework includes development and linking of a Reservoir Operations Model and Open-water Flow Routing Model with a series of habitat and riverine process models that are designed to evaluate the effects of different Project operational scenarios on fish habitat (Study 8.5), water quality (Study 5.6), sediment transport (Study 6.6), ice processes (Study 7.6), groundwater (Study 7.5), and riparian vegetation (Study 8.6). The framework also includes an Integrated Resource Analysis consisting of a Decision Support System (DSS) (see ISR Study 8.5, Section 7.8) that will be used to assess and compare Project effects across resource disciplines and between different user groups.
- Continuation of periodic Technical Working Group (TWG) and Technical Team (TT) meetings as needed to provide project technical updates and address specific technical issues (RSP Section 8.5.4.1).

7.1.1.1. Decision Points from Study Plan

There were no decision points in the FERC-approved Study Plan to be evaluated for this study component following the completion of 2013 work.

7.1.1.2. Modifications to Study Plan

No modifications to the Study Plan are needed to complete this study component and meet Study Plan objectives.

7.1.2. Schedule

In general, the schedule for completing the FERC-approved Study Plan is dependent upon several factors, including Project funding levels authorized by the Alaska State Legislature, availability of required data inputs from one individual study to another, unexpected weather delays, the short duration of the summer field season in Alaska, and other events outside the reasonable control of AEA. For these reasons, the Study Plan implementation schedule is subject to change, although at this time AEA expects to complete the FERC-approved Study Plan through the filing of the Updated Study Report by February 1, 2016, in accordance with the ILP schedule issued by FERC on January 28, 2014.

The IFS Analytical Framework outlines the process to guide implementation of the Study Plan. The schedule of activities associated with each component are described in their respective sections.

7.1.3. Conclusion

The Analytical Framework represents a measurement-oriented approach for assessing the relationship of hydrologic and geomorphic variables to the biological and ecological resources of concern. The Analytical Framework was developed and implemented in 2013 in accordance with the Study Plan (RSP Section 8.5.4.1), and will continue in 2014 and 2015 to provide guidance for developing and integrating resource specific models that will meet the objectives of the Study Plan.

7.2. River Stratification and Study Area Selection

7.2.1. Proposed Methodologies and Modifications

To complete this study component, AEA will implement the methods in RSP Section 8.5.4.2 with no modifications.. These activities include reviewing, and refining the size or number of study areas identified in the Study Plan.

7.2.1.1. Decision Points from Study Plan

RSP Section 8.5.4.1 provided that AEA would utilize an adaptive management approach in the site selection process for the Middle River segment. This specifically stated that “ The data and information collected in 2013 from this study and other related investigations ….would be reviewed, and necessary refinements to existing sites made or new sites added to the studies completed in 2014.” AEA completed detailed surveys and data collection activities in seven Focus Areas below Devils Canyon in 2013: FA-104 (Whiskers Slough), FA-113 (Oxbow 1), FA-115 (Slough 6A), FA-128 (Slough 8A), FA-138 (Gold Creek), FA-141 (Indian River), and FA-144 (Slough 21).

As part of a review of 2013 data collection activities, AEA is reviewing the sufficiency of the existing data sets collected at the seven Focus Areas for adequately evaluating Project effects. Based on that review, AEA will assess, first, the overall need for completing IFS related studies in the remaining three Focus Areas, and secondly, the extent and level of detail required in each of the remaining Focus Areas to address the overall study objectives.

Based on the results of this ongoing review process, in 2014, AEA may modify the number of Focus Areas (and/or sites) that will be sampled and/or the sampling methods that would be applied to the Focus Areas. AEA will seek the input of the TWG prior to making such modifications.

7.2.1.2. Modifications to Study Plan

At this time, no modifications to the Study Plan are needed to complete this study component and meet Study Plan objectives.

7.2.2. Schedule

In general, the schedule for completing the FERC-approved Study Plan is dependent upon several factors, including Project funding levels authorized by the Alaska State Legislature, availability of required data inputs from one individual study to another, unexpected weather delays, the short duration of the summer field season in Alaska, and other events outside the reasonable control of AEA. For these reasons, the Study Plan implementation schedule is subject to change, although at this time AEA expects to complete the FERC-approved Study Plan through the filing of the Updated Study Report by February 1, 2016, in accordance with the ILP schedule issued by FERC on January 28, 2014.

With regard to this specific study component, AEA expects to complete data collection in both the 2014 and 2015 study seasons, which will be reported in the USR. AEA is currently reviewing and prioritizing model development needs and plans to collect additional channel and hydraulic data during 2014 including:

- Real time kinematic surveys at Focus Areas measured in 2013 to fill in localized areas of sparse elevation data points;
- Water surface elevation measurements in main channel and lateral habitats;
- Continued stage and flow measurements in tributaries entering Focus Areas; and
- Continued stage, flow and water temperature measurements at Focus Area features exhibiting groundwater/surface water interactions.

7.2.3. Conclusion

The River Stratification and Study Area Selection process for the Project has been largely completed. However, depending on the results of the 2013 data and model review, some refinements may be made regarding the overall number of Focus Areas that will be surveyed and/or the sampling and modeling methods that will be applied. Likewise, specific locations of study sites and transects in LR-2 of the Lower River Segment will be selected and surveyed in

2015 (see ISR Study 8.5, Section 7.2.2). In combination, the Focus Areas and study sites that were selected and measured in 2013, along with those that will be established and surveyed in 2014 and 2015 will provide a wide range of habitat types from which data have been and will be collected. Those data sets are being and will be used in the development of resource specific models that will be applied in evaluating potential Project effects that will meet the overall objectives of the Study Plan.

7.3. Hydrologic Data Analysis

7.3.1. Proposed Methodologies and Modifications

To complete this study component, AEA will implement the methods in RSP Section 8.5.4.3 and Section 8.5.4.4 except as described below in Sections 7.3.1.6 and 7.3.1.7. These activities are described below and include:

- Mainstem data collection

  Data collection on the mainstem Susitna River will continue in both 2014 and 2015. Similar to previous data collection efforts, additional data collection will include maintenance of hydrology stations, collection of bathymetry transect data, collection of flow/WSE/bathymetry transect data, and collection of data at Focus Areas. Additional bathymetry transect data will to be collected in 2014 and 2015 with approximately 60 additional transects targeted for data collection. Data collection in 2014 will focus on filling data gaps needed for the Open-Water Flow Routing Model as well as collecting any remaining transects needed in the Middle River Segment. Data collection in 2015 will focus on remaining transects needed in the Lower River Segment. Other data collection efforts in 2014 will focus on filling any data gaps identified in the lower seven Focus Areas that were measured in 2013. Additional data collection will occur in the three Focus Areas located on CIRWG lands (i.e., FA-151 [Portage Creek], FA-173 [Stephan Lake Complex], and FA-184 [Watana Dam]) with data collection activities occurring in 2014 or 2015.

- Tributary data collection

  Tributary gaging sites established in 2013 will continue to be monitored in 2014. Additional gaging sites will be established in 2014 and include Portage Creek, Fog Creek, Tsusena Creek, Sheep Creek, and Caswell Creek. While AEA intends to complete all tributary data collection in 2014; equipment malfunctions or other factors may lead to some tributary data collection efforts in the 2015 study season.

- Winter gaging

  Winter gaging was conducted in the winters of both 2012-2013 and 2013-2014. All data collection is complete and will be reported in the USR.

- Representative Years

  Three years were proposed as representative of wet, average, and dry conditions. These three years are 1981 (wet/warm), 1985 (average), and 1976 (dry/cold). These years were selected collaboratively between Geomorphology (Study 6.6), IFS (Study 8.5), and

Ice Processes (Study 7.6) resource needs. The technical rationale for selection of these years was discussed during the IFS-TT POC meetings on April 15-17, 2014 (Tetra Tech et al. 2014) and is provided in ISR Study 8.5, Appendix J and also in ISR Study 6.6 Appendix E of the Geomorphology ISR. Final selection of representative years will be identified prior to the USR with input from the TWG and other resource disciplines.

- Indicators of Hydrologic Alteration and Environmental Flow Components

The objectives of the IHA/EFC analyses (RSP Section 8.5.4.4.1.3) centers on those hydrologic parameters that can capture the ecologically relevant events and/or time periods for the Susitna River (i.e., adult migration, spawning, egg incubation, juvenile rearing, outmigration, etc.). In total, the traditional IHA/EFC approach consists of 67 parameters.

AEA is also considering other hydrologic metrics that can be calculated on an hourly basis as a means to evaluate potential load-following that could occur under Project operations. Traditional IHA/EFC parameters are based on daily average flow values that would not be sensitive to hourly flow changes associated with load following. As a result, a set of metrics are being considered that can characterize both high and low flows, as well as the variability in flows on an hourly basis. This set of metrics has the additional benefit of simplifying the analysis to a readily understandable and meaningful number of parameters, reducing the complications that can arrive from attempting to consider all 67 traditional IHA/EFC parameters.

AEA has identified the following candidate metrics (some of which could be computed on a daily basis from the IHA, or otherwise calculated outside of the IHA on an hourly basis) for assessing load-following impacts:

Annual Low Flows

- 7-day minimum
- Baseflow
- Number of low pulses
- Duration of low pulses

Annual High Flows

- Maximum 1-hour flow
- Number of high pulses
- Duration of high pulses
- Number of freshets (where the average daily flow is greater than 1.5 times the average flow of the previous 3 days)

Seasonal Flow Variability

- Monthly flow medians

- Monthly 2-day minimum
- Monthly 2-day maximum

These metrics were presented and discussed at the March 21, 2014 TWG meeting. (AEA 2014a). AEA will utilize the results from Version 3 of the Open-water Flow Routing Model (available in 2015) for the IHA analysis.

In order to compare and contrast the existing (i.e., unregulated) flow regime with Project regulated flow regimes, AEA will consider the selected IHA-type parameters on the basis of their individual magnitude (especially for defining baseline conditions and the acceptable range of variation); other parameters will be evaluated based on the relative change. The hydrologic alteration factor (HAF) is defined as a dimensionless, normalized version of a given IHA-type parameter (Hilgert et al. 2008), and can be expressed as:

$$(run\ (regulated)\ value - unregulated\ value)/unregulated\ value$$

With the HAF, an end user can more effectively quantify the alteration a test flow regime would create upon a given parameter compared to another.

The HAF would be reported individually for each selected parameter, for each of the representative years (i.e., wet – 1981, average – 1985, dry – 1976 [see ISR Study 8.5, Section 7.3.1.2.4; Appendix J]). If it is necessary to further aggregate a given parameter, an overall hydrologic alteration index (HAI) can be computed as the sum of the absolute values of the hydrologic alteration factor for each of the representative years, with each HAF multiplied by a weighting factor for the given representative year that represents the likelihood of that type of year occurring (Hilgert et al. 2008). As such, the HAI provides one value that represents the hydrologic alteration quantified by a given parameter for the range of climatic conditions that could be expected to occur in any given year.

Lastly, to understand the potential hydrologic alteration caused by the Susitna-Watana Project on a spatial scale, AEA proposes that the analysis be completed at the following locations in the Susitna River, where the extended period of record flow data are available (see ISR Study 8.5, Section 4.3):

— Gold Creek (USGS Gage No. 15292000) – Middle Susitna River and the first location downstream of the proposed dam where period of record is available. Site is directly applicable, comparable, and relatable to other studies.
— Sunshine (USGS Gage No. 15292780) – includes the influence of the Chulitna and Talkeetna Rivers, can measure how much the Project effects are attenuated by this additional inflow.
— Susitna Station (USGS Gage No. 15294350) – includes the influence of the Deshka and Yentna Rivers, which collectively contribute a large percentage of flow measured at the Susitna Station. It would be expected that Project effects are minimal here as quantified by the IHA-type analysis.

Altogether, the proposed IHA/EFC based analysis will provide an effective quantification of hydrologic alteration on a temporal and spatial scale, and over a range of climatic conditions as defined by the selected representative years. Data collected in 2013 for these activities are summarized in ISR Study 8.5, Appendix K (Hydrology and Version 2 Open-water Flow Routing Model).

7.3.1.1. Decision Points from Study Plan

There were no decision points in the FERC-approved Study Plan to be evaluated for this study component following the completion of 2013 work.

7.3.1.2. Modifications to Study Plan

7.3.1.2.1. Mainstem Data Collection

The Study Plan (RSP Section 8.5.4.3.1) identified that 13 hydrology stations will be maintained in 2013 and 2014. However, several of the original hydrology stations established in 2012 will be discontinued in 2014. For instance, ESS60 (PRM 168.1) and ESS35 (PRM 102.1) were located in active channels that were not ideal for rating curve development and neither of them is a priority from a modeling perspective. At least six of the original hydrology stations will be maintained in 2014 for water level and temperature (ESS80 [PRM 225.0]; ESS70 [PRM 187.2]; ESS65 [PRM 176.5]; ESS55 [PRM 152.1]; ESS40 [PRM 107.1]; ESS30 [PRM 98.4]) . All of the other remaining hydrology stations will be maintained for air temperature and camera images. In addition to maintaining water level recording at a minimum of six of the original hydrology stations, additional water-level recording stations will be maintained in 2014 to address the specific needs of the fish habitat modeling efforts. For instance, during 2013, water level recording stations were installed in the mainstem Susitna River near the confluence of Trapper Creek (PRM 94.5), Birch Creek (PRM 92.5) and the Deshka River (PRM 45.0) and will be maintained during 2014. Additional water-level recording stations will be installed and maintained in 2014 in the mainstem Susitna River near the confluence of Sheep Creek (PRM 69.5) and Caswell Creeks (PRM 67). Additional water-level recording stations will be installed and maintained in the mainstem SusitnatRiver in 2014 as needed to provide calibration data for Middle River Focus Areas. Priority stations were identified during discussions among IFS (Study 8.5), water quality (Study 5.6), ice processes (Study 7.6), geomorphology (Study 6.6), and groundwater (Study 7.5) study leads with AEA. Maintenance of continued sites for the real-time reporting network in 2014 will follow details outlined in the Study Plan (RSP Section 8.5.4.4.1) and include data collection of water temperature, stage level, photographs, and meteorological information. The necessity of maintaining water-level recording and other hydrologic data during the 2015 field season will be evaluated at the end of 2014.

While water-level recording will not be continued at all 13 of the hydrology stations installed in 2012, data will be available at more than 13 mainstem water-level recording stations during some or all of 2014. Given the availability of complete data sets at seven locations (three ESS stations and four USGS stations), and additional water-level recording stations installed in response to data needs at fish habitat Focus Areas and Lower River study sites, sufficient hydrology data will be available to achieve Study Plan objectives.

7.3.1.2.2. Tributary Data Collection

To complete the tributary gaging tasks associated with this study component, AEA will implement the methods in the Study Plan (RSP Section 8.5.4.4.1). The RSP states that gaging stations will be added at selected tributaries to help provide additional hydrologic analysis for hydrologic and fisheries studies. These tributaries will include Fog Creek, Portage Creek, and Indian River. These gaging stations were intended to be installed in spring 2013 to help measure the spring snowmelt peaks. Hydrology gages were not installed at Fog Creek and Portage Creek in 2013 due to land access issues. Gaging of Fog Creek and Portage Creek is scheduled for 2014. The delay in installing gages at Fog and Portage creeks will not significantly affect use of the data to achieve Study Plan objectives.

7.3.1.2.3. Winter Gaging

AEA will implement the methods in the Study Plan (RSP Section 8.5.4.4.1) with no modifications.

7.3.1.2.4. Representative Years

RSP Section 8.5.4.4.1.2 identifies that five representative years will be selected that represent, wet, average, and dry conditions, and warm and cool Pacific Decadal Oscillation phases in 2013. The topic of representative years was discussed at the November 13-15, 2013 IFS-TT Riverine Modelers Meeting, the Q4 2013 TWG meeting, and at the IFS-TT POC Meeting on April 15-17, 2014. AEA proposed 1981(wet/warm), 1985 (average), and 1976 (dry/cold) as representative years; a final decision on representative years will be made in 2014. This delay in selection of representative years will not affect the ability to meet Study Plan objectives.

7.3.1.2.5. Indicators of Hydrologic Alteration and Environmental Flow Components

IHA/EFC-type analyses will be used as indicators of Project effects by comparing hydrologic statistics describing Existing Conditions and Project operational scenarios. The RSP states that select hydrologic parameters, considered to be ecologically relevant to Susitna River resources, will be developed in consultation with the TWG in 2013, and that interim results of the IHA-type analyses will be presented in the ISR. AEA proposed a list of IHA/EFC metrics at the March 21, 2014 TWG meeting. Final metrics will be developed with input from the TWG and other resource disciplines after Version 3 of the Open-water Flow Routing Model is available in 2015. The Open-water Flow Routing Model will translate hourly Project dam releases to downstream stations and is integral to conducting IHA/EFC-type analyses. A fully developed methodology will be available for use prior to the USR.

7.3.2. Schedule

With regard to this specific study component, AEA expects to complete data collection in the 2014 and 2015 study seasons, which will be reported in the USR. Although 167 mainstem Susitna River transects were measured in 2012 and 2013, measurement of over 60 additional mainstem transects will be collected in 2014 or 2015. Additional Middle River transect data will collected in 2014, and Lower River Segment transect data collected in 2015. AEA is currently reviewing and prioritizing model development needs and plans to collect additional channel and hydraulic data during 2014 including:

- Real time kinematic surveys at Focus Areas measured in 2013 to fill in localized areas of sparse elevation data points;
- Water surface elevation measurements in main channel and lateral habitats;
- Continued stage and flow measurements in tributaries entering Focus Areas;
- Continued stage, flow and water temperature measurements at Focus Area features exhibiting groundwater/surface water interactions; and
- Collection of data within FA-144 (Portage Creek) that was previously inaccessible due to CIRWG lands access permit issues.

Mainstem hydrology and tributary gaging stations are targeted for completion in 2014. Consistent with data collection procedures described in the RSP (Section 8.5.4.4), additional mainstem transect and tributary hydrology data collection will include maintenance of hydrology stations, collection of bathymetry transect data, collection of flow/WSE/bathymetry transect data, and collection of data at Focus Areas. Tributary gaging sites established in 2013 will continue to be monitored in 2014. Additional gaging sites will be established in 2014 and include Portage Creek, Fog Creek, Tsusena Creek, Sheep Creek, and Caswell Creek. IFS (Study 8.5) and Ice Processes (Study 7.6) resource studies will evaluate the existing winter gaging data in consultation with AEA to determine if additional data in 2014-2015 is warranted. A final decision on representative years will be made with input from the TWG and other resource disciplines in 2014. AEA proposed a list of IHA/EFC metrics at the March 21, 2014 TWG meeting and final metrics will be developed with input from the TWG and other resource disciplines after Version 3 of the Open-water Flow Routing Model is available in 2015.

Any remaining data collection will occur in 2015.

7.3.3. Conclusion

The collection and analysis of hydrologic data will continue in 2014 and 2015 in accordance with the Study Plan. This will include collection of water level and discharge data at both mainstem and tributaries using previously applied methods. In addition, bathymetric and ADCP data will be collected at mainstem transects, from three Focus Areas in the Middle River Segment, as well as from the Single Transect locations in the Lower River Segment in LR-2. No changes from the Study Plan were necessary for field data collection procedures for mainstem transect data, tributary measurements, or winter gaging. Changes to the mainstem hydrology stations in 2013 (as described in ISR Study 8.5, Section 4.3.2) and as planned in 2014 (as described in ISR Study 8.5, Section 7.3.1.1) were made to reflect actual application of these data to modeling and other efforts. As such, completion of the data collection efforts and hydrologic analyses described above will achieve the objectives of this study component in support of the IFS Study Plan.

7.4. Reservoir Operations and Open-water Flow Routing Modeling

7.4.1. Proposed Methodologies and Modifications

To complete this study component, AEA will implement the methods in the Study Plan except as described below in Sections 7.4.1.3 and 7.4.1.4. Activities needed to complete this study component include:

- Reservoir Operations Modeling (RSP Section 8.5.4.3)

  In 2014-2015, the reservoir operations will be simulated under conditions as described in the Study Plan (RSP Section 8.5.4.3.2). During the IFS-TT POC meetings on April 15-17, 2014, the results of Operational Scenario OS-1b were used to demonstrate riverine process and fish habitat modeling procedures and linkages. The OS-1b scenario represented a worst case load following condition (AEA 2014b). During the meeting it was suggested that AEA consider an intermediate Operational Scenario that simulates potential ramping rates and other environmental constraints. For each scenario, the Reservoir Operations Model will be used to generate total reservoir outflow on an hourly basis that will be provided to the downstream Open-water Flow Routing Model.

- Open-water Flow Routing Model (RSP Section 8.5.4.3)

  Methods and results of Version 2 of the Open-water Flow Routing Model can be found in ISR Study 8.5, Appendix K. Refinements to the model will continue in 2014 and 2015. Additional data will be collected at mainstem transects in both 2014 and 2015 (see above at Section 7.3).

7.4.1.1. Decision Points from Study Plan

RSP Section 8.5 provided that AEA would make a decision regarding whether extension of the Open-water Flow Routing Model ("OWFRM") below PRM 80 would be necessary based on results of Version 1 of the Open-water Flow Routing Model. In 2013, AEA determined, with input from the TWG and other resource disciplines, to extend the model downstream to PRM 29.9. During 2013, AEA collected additional data in the Lower River downstream to PRM 29.9. These data were incorporated into the model as described in ISR Study 8.5, Appendix K Hydrology and Version 2 Open-water Flow Routing Model.

There were no other decision points in the FERC-approved Study Plan to be evaluated for this study component following the completion of 2013 work.

7.4.1.2. Modifications to Study Plan

No modifications to the Study Plan are needed to complete the modeling for this study component and meet Study Plan objectives.

7.4.2. Schedule

With regard to this specific study component, AEA expects to complete data collection and modeling in both the 2014 and 2015 study seasons, which will be reported in the USR. Data collection in 2014 will focus on filling data gaps needed for the Open-Water Flow Routing Model as well as collecting any remaining transects needed in the Middle River Segment. Data collection in 2015 will focus on remaining transects needed in the Lower River Segment. Once data collection efforts are complete, refinements will continue on Version 3 of the Open-water Flow Routing Model. The following changes will be made to Version 3 of the model:

- Additional transect data collected will be included;
- If needed, the floodplain geometry will be updated;
- Additional Q:WSE pairs will be used for calibration;
- Diurnal fluctuations will be incorporated to both the calibration period and the 61-year period of record; and
- Lateral inflows will be updated with more recent synthesized tributary flows that have been adjusted based on data collected in 2013 and 2014.

7.4.3. Conclusion

The Reservoir Operations Model will be simulated under conditions outlined in the Study Plan and the Open-water Flow Routing Model will continue to be refined based on additional efforts in 2014 and 2015. These two models, in combination with those specific to Geomorphology (Study 6.6), Ice Processes (Study 7.6), Water Quality (Study 5.6), Groundwater (Study 7.5) and habitat modeling (Study 8.5), as well as data and information provided from other Study 8.5 components, and information from FDA (Study 9.6), River Productivity (Study 9.8) and Fish Passage barriers (Study 9.12) will provide analytical tools and data to address the objectives of the Study Plan.

7.5. Habitat Suitability Criteria Development

7.5.1. Proposed Methodologies and Modifications

The 2014-2015 HSC/HSI studies will be a continuation of studies conducted during 2012 and 2013. These studies will be performed in conjunction with Fish Distribution and Abundance (Studies 9.5 and 9.6) and Groundwater studies (Study 7.5) and will be coordinated with River Productivity (Study 9.8), and Water Quality (Study 5.6) resource disciplines.

To complete this study component, AEA will implement the methods in the Study Plan. These activities will include studies that will be completed during both open-water conditions as well as the winter period during ice-covered conditions. Studies conducted during the open-water period will occur largely as described above in Section 4.5.1 and will include:

- Lower River Segment HSC/HSI sampling. The FERC-approved Study Plan states "sample sites will be stratified and randomly selected from within the Middle River

Segment and Lower River Segment." AEA will apply a similar stratified random sampling approach as used in 2013, and will extend the HSC/HSI sampling to the Lower River Segment. AEA will collect microhabitat use and availability data from representative habitat types in association with Trapper, Birch, Sheep, and Caswell creeks.

- Middle River Segment HSC/HSI sampling. AEA will conduct HSC/HSI sampling in the three Focus Areas (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex], and FA-184 [Watana Dam]) in the Middle River Segment that were not measured in 2013 with sampling conducted using a similar stratified random sampling approach as used in 2013. AEA will also collect microhabitat use and availability data from representative habitat types from within each of the three Focus Areas.
- Middle River Segment HSC/HSI sampling. AEA will conduct HSC/HSI sampling in areas outside of the Focus Areas that are known to be used by fry, juvenile, and adult life stages of high and moderate priority fish species. These areas will be identified based on results from the FDA Study 9.6, information obtained from the 1980s studies, as well as anecdotal information, knowledge, and insight provided by local residents and people who have worked or recreated on the Susitna River. This effort will include the collection of microhabitat use and availability data.
- Development of site-specific HSC preference curves. Utilizing habitat use and availability data collected in 2013 and 2014, AEA will continue with data analysis and development of site-specific HSC curves for high and moderate priority species and life stages. Data collected in 2013 and 2014 will be combined using logistic regression modeling to develop microhabitat preference curves (see ISR Study 8.5, Appendix M for a description of HSC/HSI data collection efforts completed in 2012 and 2013 and the statistical methods being applied to the data).
- Stranding and trapping surveys. AEA will complete opportunistic stranding and trapping surveys in 2014 and 2015. These efforts will be coordinated with the Early Life History (Study 9.6), Fish Distribution and Abundance (Study 9.6), River Productivity (Study 9.8), and HSC/HSI (Study 8.5) surveys. Each field crew will note the date, location, species and number of fish observed, and if the fish were either stranded (completely out of the water) or trapped (isolated pool). This information will be used to determine the extent of stranding or trapping of juvenile fish under natural conditions in the Susitna River. As discussed during the May 17, 2013 TWG meeting and again noted during the IFS-TT POC meetings on April 15-17, 2014, lacking site-specific standing and trapping data, fall-back ramping rate criteria developed in Washington State (Hunter 1992) will be used during the effects analyses (Table 7.5-1).
- Relationship between fish microhabitat use and fish abundance. As described in ISR Study 8.5, Section 4.5.1.15 and in accordance with the April 1, 2013 Study Plan Determination (FERC 2013b), AEA will evaluate whether there are any relationships between fish distribution and abundance and any of the following microhabitat variables (surface flow and groundwater exchange fluxes, dissolved oxygen (intergravel and surface water), macronutrients, temperature (intergravel and surface water), pH, dissolved organic carbon, alkalinity, and chlorophyll-a). Specific details of this analysis are provided in ISR Study 8.5, Section 7.5.1.2.

The 2014-2015 HSC/HSI winter studies will be a continuation of the studies initiated in 2012-2013 (Pilot Winter Study) and conducted in 2013-2014 (see ISR Study 8.5, Section 4.5.1.10 and Appendix L). The studies will be conducted as a coordinated effort with the FDA (Study 9.6) and groundwater (Study 7.5) winter studies programs. The studies will be conducted based on the methods stated in the Study Plan, with no modifications. Specific tasks that will be conducted during the 2014-2015 HSC/HSI winter studies include:

- Stage and water temperature data (surface and intergravel) will be continuously monitored at main channel and off-channel sites in the three Focus Areas (FA-104 [Whiskers Slough], FA-128 [Slough 8A], and FA-138 [Gold Creek]). Monitoring sites within each FA will be distributed among habitat types, at locations of known salmon spawning, and at sites with and without groundwater influence.
- Intergravel dissolved oxygen will be continuously recorded at a minimum of two of the Focus Area sites within known salmon spawning locations.
- Fish observation and capture efforts will be performed at available habitat types in each of three Middle River Focus Areas (FA-104 [Whiskers Slough], FA-128 [Slough 8A], and FA-138 [Gold Creek]); additional sites outside of these Focus Areas will be sampled based on observed fish distribution, site access, weather conditions and personnel safety.
- Fish activity and behavior will be monitored using underwater video equipment to discern potential patterns in activity related to diurnal and seasonal periodicity and/or habitat (e.g., side channel, side slough).
- Site-specific habitat suitability criteria (HSC) data for juvenile and adult fish will be collected or recorded using electrofish capture methods in open-water areas and underwater video in ice covered habitats.
- Instantaneous surface water quality measurements (temperature, dissolved oxygen, specific conductance) will be recorded in association with maintenance of continuous stage and water quality monitoring sites and fish observation and capture efforts.

7.5.1.1. Decision Points from Study Plan

There were no decision points in the FERC-approved Study Plan to be evaluated for this study following completion of 2013 work.

7.5.1.2. Modifications to Study Plan

7.5.1.2.1. Relationship between Microhabitat Use and Fish Abundance

In their SPD (FERC 2013b [FERC April 1, 2013 SPD, page B—85]) FERC recommended that AEA file with the ISR the results of analyses to determine whether a relationship between specific microhabitat variables and fish abundance is evident. These microhabitat variables include: surface flow and groundwater exchange fluxes, dissolved oxygen (intergravel and surface water), macronutrients, temperature (intergravel and surface water), pH, dissolved organic carbon, alkalinity, and Chlorophyll-a. Depending on the results of the analysis, additional HSC/HSI curves may be needed. Most of the data necessary to complete these analyses are still being processed and/or undergoing quality assurance checks; these analyses could not be completed and included in the ISR (Section 4.5.2 above). Nevertheless, AEA did initiate this task in 2013 and proposes to complete the initial analysis in 2014. This change in schedule is not expected to adversely impact achieving Project objectives. Details regarding the proposed methods for completing this analysis are described below.

AEA will complete the initial analysis of microhabitat use and fish abundance in 2014. As a first step, sampling locations for available finalized fish abundance and microhabitat data will be grouped on a relevant time scale for each variable. The temporal extent to which data will be compared will be dependent on the variability in water quality and flow conditions during and around the time in which the data were collected. For example, since DO can vary based on water temperature and flow, only DO and fish abundance data that were collected under similar conditions and time frames can be compared. Temporal groupings for microhabitat and fish abundance data will then be spatially overlaid on Focus Area maps and data points that were within a reasonable spatial distance (e.g., nearest neighbor) of fish sampling locations grouped and given a unique group identifier. In this way, only those data that were collected from similar locations and at similar times will be used as part of the relationship analysis.

Once the data are matched in space and time, multivariate analyses will be used to determine if patterns in fish abundance and any of the available microhabitat variables are evident. If there are strong correlates or relationships detected between a specific variable and a fish abundance parameter, univariate inspection of the variable will be performed including frequency distribution and tests for significant differences. However, correlations among environmental variables are common, and do not imply causation. In addition to basic correlation, there are other important considerations relevant to determining as to whether additional HSC/HSI variables should be developed for use in the IFS modeling. These include: 1) considerations are whether the inclusion of these variables improves the predictions of fish habitat use; 2) whether these variables are impacted by changes to the flow regime of the system; and 3) whether the current models have the we have the current ability to predict or evaluate model these changes in these variables. Additional consideration and interpretation of the relationships between fish distribution and abundance preference and each of the habitat variables discussed here will be reviewed and presented during the ISR review meeting.

7.5.2. Schedule

With regard to this specific study component, AEA expects to complete data collection in both the 2014 and 2015 study seasons, which will be reported in the USR. Specific activities planned for 2014 include:

- Conduct HSC/HSI sampling in representative habitat types in the Lower River Segment of the Susitna River in association with Trapper, Birch, Sheep, and Caswell creeks.
- Conduct HSC/HSI sampling in the Middle River Segment within FA-151 (Portage Creek), FA-173 (Stephan Lake Complex), and FA-184 (Watana Dam).
- Conduct HSC/HSI sampling in the Middle River Segment in areas with known fish use by high and moderate priority fish species.
- Conduct opportunistic aquatic biota stranding and trapping surveys.

- Continue analysis of data and development of site-specific HSC/HSI preference curves.
- Complete exploratory analysis of relationships between microhabitat use and fish abundance utilizing data from FDA (Study 9.6), Water Quality (Study 5.6), and Groundwater (Study 7.5) studies.
- Prepare list of species and life stages for which HSC curves will be developed and the types of curves (preference, utilization, binary) that may be developed for each.
- Prepare species and life stage specific periodicity tables for the high and moderate priority fish species.
- Prepare a Technical Memorandum describing findings from the 2013-2014 Winter Studies.
- Prepare HSC/HSI curves for macroinvertebrates and algae.
- In preparation for 2014-2015 Winter Studies, install continuous stage and water quality (temperature and dissolved oxygen) monitoring sensors in the three Focus Areas (FA-104 [Whiskers Slough], FA-128 [Slough 8A], and FA-138 [Gold Creek]).

AEA plans to complete all remaining data collection and analysis for this study in 2015; specific activities include:

- Conduct HSC/HSI sampling in representative habitat types in the Lower River Segment of the Susitna River in association with Trapper, Birch, Sheep, and Caswell creeks.
- Conduct HSC/HSI sampling in the Middle River Segment within FA-151 (Portage Creek), FA-173 (Stephan Lake Complex), and FA-184 (Watana Dam).
- Prepare final species and life stage specific periodicity tables for use in habitat modeling.
- Complete 2014-2015 winter studies in Focus Areas FA-104 (Whiskers Slough), FA-128 (Slough 8A) and FA-138 (Gold Creek) including monitoring stage and water quality data, and HSC/HSI sampling consisting of fish capture and observations using electrofishing and underwater video to discern seasonal habitat use patterns.
- Prepare findings from the 2014-2015 Winter Studies for inclusion in the USR.
- Develop final HSC/HSI curves for use as part of habitat modeling.

7.5.3. Conclusion

The combination of HSC/HSI studies completed in 2012, 2013 and those proposed for 2014 and 2015, coupled with results provided from FDA (Study 9.6), Groundwater (Study 7.5), and Water Quality (Study 5.6) will provide a robust data set from which to develop species and life stage specific HSC/HSI models that can be applied to habitat – flow models for evaluating Project effects. The schedule modification described in Section 7.5.1.2 remains consistent with the objectives of this study and is not expected to adversely impact achieving Project objectives since there will be adequate time for agency review and comment prior to data collection in 2015.

7.6. Habitat-Specific Model Development

7.6.1. Proposed Methodologies and Modifications

To complete the Middle River Segment FA-IFS study component, AEA will implement the methods in the Study Plan (RSP Section 8.5.4.6) and as described above in Section 4.6 and 5.6 with no modifications. These activities include:

- Finalize development of 2-D hydraulic models in each of the seven Focus Areas that were surveyed between PRM 104 and PRM 145 in 2013 (FA-104 [Whiskers Slough], FA-113 [Oxbow 1], FA-115 [Slough 6A], FA-128 [Slough 8A], FA-138 [Gold Creek], FA-141 [Indian River], and FA-144 [Slough 21]) as needed to provide inputs into the fish habitat modeling. AEA has selected the SRH-2D hydraulic model for modeling habitats during open-water conditions, and River2D during ice-covered periods (see ISR Study 6.6, Attachment A).
- Finalize development of Visual Basic (VB) models and associated GIS tools for each of the seven Focus Areas to allow computation of HSC/HSI habitat based metrics at the macrohabitat and Focus Area scale under different flow conditions(ISR Study 8.5, Section 5.6.4.1).
- Continued development and refinement of the Effective Spawning/Incubation model as described above in Section 5.6.4.2, and presented during the IFS-TT POC meetings on April 15-17, 2014.
- Continued development and refinement of the Salmonid Rearing Habitat Model as cited in RSP Section 8.5.4.6.1.4 and presented during the IFS-TT POC meetings on April 15-17, 2014.
- Development of varial zone models for each of the seven Focus Areas (RSP Section 8.5.4.6.1.6).
- Collection of bathymetric and hydraulic data in the remaining three Focus Areas(see RSP Section 8.5.4.4.1.1):FA-151 (Portage Creek), FA-173 (Stephan Lake Complex) and FA-184 (Watana Dam Site) as necessary to develop either 2-D and/or 1-D hydraulic models to conduct fish habitat modeling.
- Collection of substrate and cover data within the remaining three Focus Areas (RSP Section 8.5.4.4.1.1) (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex] and FA-184 [Watana Dam Site]).
- Development of hydraulic models (either 2-D or 1-D) and habitat models for the remaining three Focus Areas (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex] and FA-184 [Watana Dam Site]) (RSP Section 8.5.4.6).
- Development of varial zone models for the remaining three Focus Areas (FA-151 [Portage Creek], FA-173 [Stephan Lake Complex] and FA-184 [Watana Dam Site]) (RSP Section 8.5.4.6.1.6).

- Collection of single transect data at selected cross-sections in the Middle River Segment as needed to support development of the OWFRM and other resource models (RSP Section 8.5.4.6.1.2).

To complete the Lower River Segment FA-IFS study component, AEA will implement the methods in the Study Plan (see Section 4.2 of Attachment C filed in March 2013; R2 2013b) except as described below in Sections 7.6.1.1 and 7.6.1.2. These activities include:

- Final open-water hydraulic model calibration of the LR-1 fish habitat sites from field data collected in 2013(RSP Section 8.5.4.6.1.3);
- Identification of transect locations within targeted main channel habitats for reach LR-2 in the vicinity of Caswell Creek near PRM 67 and at the tributary mouths of Caswell Creek and Sheep Creek RSP Section 8.5.4.2.1.2);;
- Collection of open-water field data in 2015 to support fish habitat modeling at LR-2 fish habitat sites RSP Section 8.5.4.6.1.2;
- Open-water hydraulic model calibration of the LR-2 fish habitat sites from field data collected in 2015 RSP Section 8.5.4.6.1.3;
- Identification of priority species, life stages and periodicity for LR-1 and LR-2 to use for HSC curve development to apply to the fish habitat modeling (RSP Section 8.5.4.5.1.3);
- Calculation of weighted useable area (WUA) curves for each lower river fish habitat site in LR-1 and LR-2 using calibrated PHABSIM models(RSP Section 8.5.4.6.1.4);
- Calculation of WUA time series of open-water habitat for LR-1 and LR-2 sites based on species and life stage periodicity for existing conditions and project flow scenarios(RSP Section 8.5.4.6.1.4);
- Open-water hydraulic model calibration of the Deshka River confluence site(RSP Section 8.5.4.6.1.4);
- Development of timing windows for fish passage for priority species within the Deshka River(RSP Section 8.5.4.5.1.3);
- Development of depth and velocity criteria for defining breaching, fish passage and connectivity conditions for the Deshka River confluence(RSP Section 8.5.4.5.1.1); and,
- Calculation of fish passage probabilities and percentage of time open-water connectivity is maintained to identify changes to timing, frequency or duration of conditions(RSP Section 8.5.4.6.1.7).

7.6.1.1. Decision Points from Study Plan

As described in RSP Section 8.5.4.2.1.2 and elaborated in Section 4.6.2 of Attachment C in the March 2013 filing (R2 2013b), two study areas, one in each of LR-1 and LR-2, including five tributary mouths were selected to evaluate Project effects as the focus of the Lower River Segment IFS study. The March 2013 filing provided that AEA would evaluate the feasibility of measuring and modeling of hydraulic conditions in the Lower River and would make a decision as to the need for additional sites or data requirements based on the 2013 results. In 2013, AEA collected data within LR-1 and completed preliminary model calibrations as described in ISR Study 8.5, Section 4.6 and Appendix G. Additional preliminary habitat model development was completed and presented at the IFS-TT POC meetings on April 17, 2014, as further described in ISR Study 8.5, Appendix O. Preliminary model calibrations were successful and the example habitat modeling presented at the POC demonstrated that an evaluation of Project operation effects on open-water fish habitat using single-transect PHABSIM modeling will be feasible.

Based on the success of the 2013 data collection efforts and the preliminary modeling results, field data collection within LR-2 at the remaining main channel study area in the vicinity of Caswell Creek around PRM 67 and the two remaining tributary sites at Caswell Creek and Sheep Creek will proceed in 2015. Field data collection, hydraulic and habitat modeling will proceed using the same methods as described in ISR Study 8.5, Section 4.6. The example habitat modelling presented in ISR Study 8.5, Appendix O indicates relatively small changes to open-water habitat conditions would be predicted based on preliminary analysis. No additional IFS study sites in the Lower River outside of the approved Study Plan are proposed.

7.6.1.2. Modifications to Study Plan

As described in ISR Section 4.6.2, AEA is deferring LR-2 field studies from 2013 to 2015. This schedule modification for completing the Study Plan for the Lower River Segment will not impact AEA's ability to meet the objectives of the Study Plan. All other methods for Lower River fish habitat modeling will remain unchanged from the methods described in RSP Sections 8.5.4.2 through 8.5.4.7).

7.6.2. Schedule

With regard to this specific study component, AEA expects to conduct data collection and analysis in both the 2014 and 2015 study seasons, which will be reported in the USR.

With respect to the Middle River Segment FA-IFS habitat modeling, AEA anticipates that the 2-D hydraulic models and the VB habitat models for the seven Focus Areas measured in 2013 will be developed in 2014. The corresponding Effective Spawning/Incubation models and Salmonid Rearing models will likewise be developed in 2014. Field data collection activities will occur in 2014 and 2015, and will include data collection within or adjacent to CIRWG lands. Hydraulic and habitat models for the remaining three Middle River Focus Areas will be developed in 2015.

For the Lower River Segment FA-IFS habitat modeling, the open-water hydraulic calibration for the LR-1 fish habitat study sites will be completed in 2014. AEA expects the selection of fish habitat transects and collection of field data for LR-2 in the vicinity of Sheep Creek and Caswell Creek will be completed in 2015. Final hydraulic model calibration and habitat modeling for the LR-1 and LR-2 sites and the Deshka River confluence will be completed following the 2015 field season and reported in the USR.

7.6.3. Conclusion

The development of the habitat specific models described for the Middle River Segment will be completed in accordance with the methods described in RSP Section 8.5.4.6 and in Attachment C to the approved Study Plan, and as further described in ISR Study 8.5, Section 5.6. These models, in combination with data from other FA-IFS study components, as well as models and data provided from the Geomorphology Study (Study 6.6), Water Quality Study (Study 5.6), Groundwater Study (Study 7.5), Ice Processes (Study 7.6), Fish Passage Barriers Study (Study 9.12), and River Productivity Study (Study 9.8) will be used to compute a variety of habitat metrics that will be used to evaluate Project effects on fish habitats within the Middle River Segment. Implementation procedures and example fish habitat moeling results were described during the IFS-TT POC meetings on April 15-17, 2014 (AEA 2014b) and are summarized in ISR Study 8.5, Appendix N.

Specific to the Lower River Segment, the studies completed in 2013 and proposed in 2015 will achieve the approved Study Plan objectives. Project effects to open-water fish habitat conditions will be assessed at five tributary mouth sites; Birch Creek and Trapper Creek in LR-1, Sheep Creek and Caswell Creek in LR-2, and the Deshka River in LR-4. Additional Lower River fish IFS sites being assessed are main channel habitats in the vicinity of Trapper Creek near PRM 94.5 within LR-1 and main channel habitats in the vicinity of Caswell Creek near PRM 67. The assessment of changes to fish habitat in the Lower River under Project operations will be conducted using weighted useable area (WUA) curves generated from single transect PHABSIM modeling following the conceptual approach described in RSP Section RSP Section 8.5.4.2 through 8.5.4.7 and presented at the IFS-TT POC meetings on April 15-17, 2014 (ISR Study 8.5, Appendix O).

These fish habitat modeling procures will be integrated with the results of other resource specific studies to provide a strong foundation of analytical tools to evaluate Project effects and meet the objectives of the Study Plan.

7.7. Temporal and Spatial Habitat Analyses

7.7.1. Proposed Methodologies and Modifications

To complete this study component, AEA will implement the methods in the Study Plan except as described in ISR Study 8.5, Section7.7.1.2. These activities include:

- Development of methods to complete a Temporal Analysis that allows for an evaluation of spatially explicit habitat changes over time (RSP Section 8.5.4.7.1.1); and
- Development of methods to complete a Spatial Analysis that allows for the expansion or extrapolation of habitat-flow relationships developed from one location to unmeasured or non-modeled locations (RSP Section 8.5.4.7.1.2).

7.7.1.1.1. Temporal Analysis

The general methods and approach AEA proposes to utilize for completing the temporal habitat analysis remain largely as described in RSP Section 8.5.4.7.1.1. This will include varial zone analysis, effective spawning/incubation habitat analysis, analysis of rearing habitats, breaching flow analysis, and analysis of other riverine processes (e.g., water quality, sediment deposition, ice) that may directly influence fish habitats. Many of these were discussed during the IFS-TT Riverine Modelers meetings on November 13-15, 2013 with more details provided during the IFS-TT POC meetings on April 15-17, 2014 (AEA 2014b).

The temporal analysis will involve the integration of hydrology (see Section 4.3 above), Project operations (see Section 4.4 above), the mainstem Open-water Flow Routing Model (ISR Study 8.5, Section 4.4), the River1D Ice Processes Model (Study 7.6), the EFDC Riverine Water Quality Model (Study 5.6), and the various habitat-flow response models (ISR Study 8.5, Section 4.6) to project spatially explicit habitat changes over time. Several analytical tools will be utilized for evaluating Project effects on a temporal basis. This will include development and completion of habitat-time series that represent habitat amounts resulting from flow conditions occurring over different time steps (e.g., daily, weekly, monthly), as well as separate analyses (varial zone analysis) that address effects of rapidly changing flows (e.g., hourly) on habitat availability and suitability. During the IFS-TT POC meetings on April 15-17, 2014, specific examples of time series analysis were displayed for many of the resource models, including the habitat models being developed for the Lower River segment. Analysis of modeling results by hydrologic time periods (e.g., ice-free periods and ice-covered periods), representative Water Year types (e.g., 1976 – dry and cold, 1981 – wet and warm, 1985 – average) (see ISR Study 8.5, Appendix J), and biologically sensitive periods (e.g., migration, spawning, incubation, rearing) will allow for the quantification of Project operational effects.

7.7.1.1.2. Spatial Analysis

How data and habitat-flow relationships developed from one location relate to other non-modeled locations is the focus of the spatial analysis. This analysis is crucial to providing an overall understanding of how Project operations may affect habitats and riverine processes on a system-wide basis and will feed directly into the Study Integration and development of a Decision Support System (see Section 4.8 and Section 7.8).

AEA provided background information on the spatial habitat analysis that was proposed as part of the 1980s studies in RSP Section 8.5.4.7.1.2. While informative, the methods described in the RSP were specific to the types of instream flow related data that had been collected during the 1980s studies and therefore were not directly applicable to employing a 2-D modeling, Focus Area approach for the Middle River Segment (See Section 5.2 above). AEA is proposing to apply a spatial expansion approach that will be founded on the geomorphic strata and macro-habitat mapping of the Middle River segment both within and outside of the Focus Areas. Development of habitat-flow relationships for specific macro-habitat types (e.g., side channel, side slough) from one area should then, with appropriate weighting adjustments for dimensional differences and other distinguishing factors, be expandable to non-modeled areas containing similar characteristics.

AEA provided and discussed several options for expansion of habitat-modeling results with agencies and stakeholders during the IFS-TT riverine modelers meetings on November 13-15, 2013 (see Figure 7.7-1). These were evaluated further and four options were discussed in more detail during the IFS-TT POC Meeting on April 15-17, 2014 (AEA 2014b). These included; 1) Linear distance; 2) Macrohabitat linear distance; 3) Macrohabitat area; and 4) Macrohabitat weighted by fish use. Some of the technical considerations related to each option include:

- Linear distance:
    - Simplest method

  - Assumes Focus Areas are accurately mapped and are proportionally representative of all habitats in a Geomorphic Reach
  - Assumes effects of flow are similar throughout reach
  - Some uncertainty in thalweg length estimates
- Microhabitat linear distance:
  - More complex
  - Assumes Focus Area and non-Focus Area macrohabitats are accurately mapped
  - Assumes dimensions of Focus Area macrohabitats are representative of macrohabitats in geomorphic reach
  - Assumes effects of flow are similar throughout reach
  - Some uncertainty in length estimates for each macrohabitat
- Macrohabitat area:
  - Requires detailed GIS work on entire Middle River
  - Assumes all macrohabitat are accurately area mapped
  - Assumes proportionality of area is similar across different flow levels
  - Assumes effects of flow on macrohabitats are similar throughout the geomorphic reach
  - Some uncertainty in area estimates for each habitat
- Macrohabitat area weighted by fish use:
  - Most complex – spatial expansion plus development of fish use weighting functions
  - Requires detailed GIS work on entire Middle River
  - Assumes all macrohabitat are accurately area mapped
  - Assumes proportionality of area is similar across different flow levels
  - Assumes suitable habitat in high-use macrohabitat type is more valuable than suitable habitat in low-use macrohabitat type
  - HSC process already considers weightings

In the simplest approach, i.e., Linear Distance, the expansion can be made based on scaling the amount of Weighted Usable Area (WUA) or other habitat metric available within a given Focus Area (or combination of Focus Areas within a geomorphic reach) to the entire geomorphic reach at a specific flow. This approach assumes that the mix of different habitat types represented and modeled within the overall Focus Area is representative of other areas outside of the Focus Areas. Given that the lengths of the Focus Areas represent from 9.1 percent to 40 percent of the entire length of the eight Middle River Segment geomorphic reaches, AEA believes this is a reasonable assumption (Table 7.7-1). However, this will be tested further based on the results of the habitat mapping (Study 9.9). This expansion approach would result in applying a habitat-flow relationship from one or more Focus Areas within a geomorphic reach to the entire geomorphic reach. Proportionally weighting these relationships by the specific lengths of each geomorphic reach and then summing the relationships would result in a composited habitat-flow relationship for the entire Middle River Segment. This relationship could then be used to evaluate Project operations.

The Macrohabitat Linear Distance option represents a refinement to this approach and would involve basing the expansion on the macrohabitat mapping of the river and applying the composited WUA relationships derived in the different macrohabitat types within a Focus Area to other macrohabitat types outside of the Focus Area within each of the geomorphic reaches. The objective would be to derive habitat-flow relationships (by species and life stage) for a given geomorphic reach based on Focus Area-specific habitat-flow relationships by macrohabitat type weighted by the percentages of the reach (based on lineal distance) containing each macrohabitat type (as determined from habitat mapping) (Study 9.9). This latter step will then result in a composited habitat-flow relationship that considers all macrohabitat types within a given geomorphic reach. Further compositing of relationships for all geomorphic reaches (with consideration for flow accretion, etc.) will allow for the derivation of habitat-flow relationships (by species and life stage) for the entire Middle River Segment of the Susitna River.

The third option, Macrohabitat Area follows the same general procedures as the Macrohabitat distance option, but in this case, the macrohabitat mapping would need to be completed on an area rather than linear basis. This would require detailed GIS work on the entire Middle River segment to compute areas for each macrohabitat unit based on a specific flow condition; e.g., bankfull – width.

A further refinement of this or the Macrohabitat Linear Distance approach is the Macrohabitat Weighted by Fish Use approach. In this case, the approach would incorporate information on fish distribution and include weighting factors ascribed to certain Focus Areas and/or lengths of river that reflect fish use and abundance (based on Fish Distribution and Abundance studies, Study 9.6) and that would factor into the proportional weighting; i.e., one Focus Area may be weighted higher than another one in the same geomorphic reach based on some fish use factor of fish abundance, and/or certain lengths or areas of the river may be weighted higher due to known fish distribution and abundance.

The merits and assumptions associated with each of these approaches were discussed during the IFS-TT POC meetings on April 15-17, 2014 and although no single option was selected, there was general agreement that the approach involving weightings based on fish use was not appropriate since the HSC analysis was already addressing fish habitat preferences.

The results of the temporal and spatial analyses will include tabular listings of habitat indicator values under existing and alternative flow regimes. Model results will be developed for representative hydrologic conditions (See Section 4.4 above) and a multi-year, continuous hydrologic record to evaluate annual variations in indicator values. The availability of indicator values over a multi-year record will support sensitivity analyses of the habitat indicators used to evaluate proposed reservoir operations. Sensitivity analyses of individual components of the habitat modeling efforts are a standard technique in model construction, calibration, and assessment and are envisioned as implicit steps in the IFS.

Integrating the level of uncertainty in the various model components will provide an overall understanding of the robustness of individual habitat indicators such as those reflected in the HSC and HSI metrics. AEA has also been exploring options for addressing uncertainty as part of the different models and metrics. Uncertainty was recently discussed during the Decision Support Systems (DSS) presentation during the IFS-TT Riverine Modelers meeting on November 13-15, 2013, and is described further in Section 5.8 above.

7.7.1.2. Decision Points from Study Plan

RSP Section 8.5.4.7.1.3 noted that decisions on the final approaches for temporal and spatial analysis were to be provided in the ISR. As described in Section 7.7.1.3, these decisions were deferred to 2015.

7.7.1.3. Modifications to Study Plan

Temporal analyses include extrapolating the results of 2-D modeling of Focus Area fish habitats from existing conditions (i.e., License Year 0) to future conditions (i.e. Years 25 and 50). Spatial analyses include applying 1-D and 2-D fish habitat model results from modeled to non-modeled areas. General approaches for temporal and spatial analysis were discussed during the November 13-15, 2013 IFS TT Riverine Modelers Meeting (AEA 2013), and were more specifically described during the IFS TT POC meeting on April 15-17, 2014 (AEA 2014b). The final approaches for both the temporal and spatial analysis were to be provided in the ISR (RSP Section 8.5.4.7.1.3); and while discussion occurred during implementation of the Study Plan in 2013 and early 2014, decisions on the final approaches were deferred to 2015.

7.7.2. Schedule

Discussion of temporal and spatial approaches to extraploting fish habitat modeling will continue in 2014; however, decisions regarding the final procedures will be made with input from the TWG and other resource disciplines in 2015 when final fish habitat modeling results will be available.

7.7.3. Conclusion

The temporal and spatial habitat analysis will, in combination with the results of other resource specific studies, provide a strong foundation of information and analytical tools from which to evaluate Project effects over a wide range of operational conditions and address the study objectives.

7.8. Instream Flow Study Integration

7.8.1. Proposed Methodologies and Modifications

To complete this study component, AEA will implement the methods in the Study Plan. The general methods and approach AEA will utilize for completing the instream flow study integration remain as described in RSP Section 8.5.4.8. These methods include the selection of indicator variables or evaluation metrics for each resource area as well as the development of a final integrated Decision Support System (DSS) to assist in the interpretation and evaluation of the multitude of study results in preparation for evaluating Project effects. During 2013, the study integration process was more clearly defined. Proposed evaluation metrics and options for the DSS were discussed during the IFS-TT Riverine Modelers meetings on November 13-15, 2013 (AEA 2013), and a summary is provided below.

The general concepts behind and examples of DSS were provided as background in the Study Plan. The following sections present: planned DSS methods and rationale for selection; an assessment of how uncertainty can be integrated into DSS; and preliminary evaluation metrics that can be used in a DSS framework.

7.8.1.1.1. DSS Methods

The DSS developed for the Susitna River will form the primary tool for instream flow study integration. A DSS is a framework for evaluating options based on values. The options in this case are Project operational scenarios, while values will be expressed as a list of temporally and spatially explicit evaluation metrics that describe the most important resources potentially impacted by Project operations. These evaluation metrics will come from all study disciplines described in this ISR. The example matrix in Table 7.8-1 was developed for illustration purposes and lists potential indicator variables in a variety of resource categories.

A DSS is also a form of structured decision-making (see, for example, Conroy and Peterson 2013), which requires explicit quantifiable objectives and management alternatives (operational scenarios), as well as a process to evaluate objectives for each operational scenario. For the Susitna-Watana Hydroelectric Project, the objectives will be to optimize the most important evaluation metrics relevant to each study discipline. For example, one objective will likely be to maximize the area of spawning habitat for selected anadromous fish species. Another will be to maximize energy output. It is unlikely that any single operational scenario will succeed in optimizing all evaluation metrics across all disciplines, and therefore, an integrated objective may be to select the scenario that provides the best possible outcome for the full set of metrics.

AEA plans to use a matrix approach for the Susitna River DSS. As described in the Study Plan (RSP Section 8.5.4.8.1), the matrix approach has been used in previous FERC licensing projects, and is the most efficient and flexible approach for Project decision making. The basic elements of the matrix approach are:

- The development of temporally and spatially explicit evaluation metrics for each study discipline, which form the basis of comparisons among operational scenarios.
- The estimation of values for the evaluation metrics under existing conditions and under any proposed operational scenarios, which is accomplished using methods described under each resource discipline in this ISR.

The matrix of evaluation metrics under different scenarios provides the basis for decisions on the relative merits of each scenario.

AEA will continue to evaluate the details of the matrix method approach in 2014 with input from the TWG. Additional elements that will be considered for inclusion in the matrix approach include:

1) Multi-criteria methods to integrate outcomes across evaluation metrics;
2) Software to provide an automated portable tool for multiple users to evaluate impacts based on differing assumptions; and
3) Uncertainty analysis.

Multiple Criteria Methods

Multiple criteria methods, such as metric weighting or decision rules, provide a means to find a single "optimal" outcome across a suite of metrics. One option would be to simply weight all evaluation metrics equally and select the operational scenario that results in the highest number of positive outcomes or the lowest number of negative outcomes across all metrics. Alternatively, some metrics could be weighted more heavily, perhaps double-weighting metrics involving anadromous fish habitat. Srdjevic et al. (2003) used an objective entropy weighting method to evaluate large numbers of water management scenarios from a decision matrix.

Decision-rule-based methods are an alternative to criteria weighting. An example would be to maximize estimated power generation given that flow does not fall below a minimum threshold during the juvenile anadromous fish-rearing season. With the number of evaluation metrics anticipated for this project, these types of decision rules could become very complex.

For this project, AEA does not intend to use multiple criteria methods due to the complexities of agreement on the relative importance of metrics or of building coherent decision rules across multiple disciplines. Instead, the acceptability of the operational scenario for each evaluation metric will be considered individually. It will therefore be important to limit the evaluation metrics included in the DSS to key metrics that decisions should be based upon. Otherwise, the decision process could become intractable.

DSS Software

Software that could be implemented to automate the matrix DSS approach is best exemplified by the USGS-developed DSS programs. Since their most recent published work discussed in the Study Plan (RSP Section 8.5.4.8.1), the USGS has further refined the DSS for the Delaware River. This more recent version (Riverine Environmental Flow Decision Support System [REFDSS]) has not yet been completed or published, but was presented at the IFS-TT Riverine Modelers Meeting November 13-15, 2013 (Holmquist-Johnson et al. 2013). The USGS has changed the software platform to make the system more transferable among river systems, as well as added a GIS interface to increase the spatially explicit graphing capabilities of the program. Modeling runs for all flow scenarios are completed outside of the program and results can be accessed and manipulated within the REFDSS program. The program allows the user to select a flow scenario and evaluation metrics (from those included in the program) and view a user-specific set of outputs, including graphs and decision matrices. Some model parameters, such as the HSC curve, can be changed by the user.

The advantages of this type of REFDSS system over the simple matrix methods mainly relate to automation and portability. These two features are not requirements of the DSS for the Susitna River, but would be desirable if they could be developed within the IFS Project schedule. The full complement of the USGS DSS has been under development for at least 10 years, so it will not be possible to develop such a system from start to finish for the Susitna River. However, if the REFDSS program were to be made available so it could be readily adapted to the Susitna River, it may be possible to implement something similar for this project. At this time, AEA is not anticipating that this type of automated portable software will be developed for the project. However, AEA will continue discussions with the USGS in 2014 since there may be elements of the REFDSS that can be integrated into the matrix method.

Uncertainty in DSS

Typical instream flow studies do not include an explicit analysis of uncertainty. Rather, temporal variability is considered in the analysis by including the entire available flow record (e.g., from the previous 50 years) and spatial variability is considered by the selection of multiple representative reaches. Because the choice among operational scenarios is based on a relative comparison of evaluation metrics for a set of different flow conditions, it is assumed that uncertainty would impact the results for each scenario in a similar way. In that case, uncertainty would not impact the ultimate decision. Although this is likely often true, it may not be true in all cases. Therefore, a more explicit consideration of uncertainty may be warranted.

Decision analysis is a well-developed field of study that has been used in multiple natural resources studies for structured decision-making under uncertainty (Conroy and Peterson 2013). For example, Alexander et al. (2006) used decision analysis to estimate the optimal spawning flow for Columbia River mountain whitefish from the Hugh Keenleyside Dam in British Columbia. Also, a complex decision analysis was used for the Plan for Analyzing and Testing Hypotheses, a multiagency research program designed to identify and resolve uncertainties surrounding recovery of threatened Snake River Chinook salmon and steelhead (Peters and Marmorek 2000).

Formal decision analysis differs from the DSS methods discussed above in that there are multiple estimates for each evaluation metric under each operational scenario. Each estimate derives from a different set of alternative “states of nature” or assumptions. For example, one assumption could be that the next 50 years will be similar in overall flow scenarios to the past 50 years. A different assumption might be that the next 50 years will be comprised of wetter years with earlier ice melt conditions. Using decision analysis, evaluation metrics would then be integrated over the range of possible assumptions prior to decision-making.

The integration of uncertainty as described above requires relative likelihoods for the different assumptions; the set of results for each evaluation metric are weighted using these likelihoods or probabilities. Using the example above, if the two 50-year flow assumptions were considered equally likely, then the ultimate evaluation metric would be the simple average of the evaluation metrics under each assumption. If one was considered twice as likely, the ultimate evaluation metric would be a weighted average, with the more likely alternative weighted by 2/3 and the less likely alternative weighted by 1/3.

The probabilities used to weight alternative assumptions can be assigned based on past observation, confidence intervals on parameters, best professional judgment, or consensus. Although this probability assignment may in some cases seem subjective, it is important to note that methods without uncertainty consideration are ultimately assigning 100 percent probability to a single outcome and 0 percent to all other outcomes. Allowing any positive probability on alternative assumptions provides a consideration of uncertainty.

The majority of Project evaluation metrics will be based on a hierarchical combination of inputs from multiple riverine resource studies. The selection and calibration of this information will be based on assumptions and uncertainties that are specific to each resource discipline. Lack of perfect knowledge for some parameters or assumptions may have no impact on evaluation metrics and effects analyses, while other information gaps could have large impacts. Based on the complexities of multiple models being used in sequence to estimate evaluation metrics and the time and effort needed to perform model runs under alternate scenarios, it will not be possible to incorporate all assumption uncertainties into the Project DSS. However, AEA is considering the feasibility of and methods for incorporating several key uncertainties associated with each riverine resource analysis.

7.8.1.1.2. Evaluation Metrics

As discussed above, evaluation metrics will be developed and used in a DSS framework to compare operational scenarios for each study discipline. In 2013, this process was begun for endpoints related to anadromous fish habitat. The following five draft key evaluation metrics were discussed during the IFS-TT Riverine Modelers Meeting on November 13-15, 2014 (AEA 2013) and are proposed for anadromous fish habitat. These will be evaluated for different species and life stages as necessary.

1) Weighted usable area of habitat in the Middle and Lower River for effective spawning through emergence (see Section 4.6 above for details on this metric)
2) Weighted usable area in the Middle and Lower River for juvenile rearing during open-water and ice cover time periods
3) Timing/intensity/duration of spring ice breakup
4) Area of lateral habitats in the Middle and Lower River that support juvenile outmigration
5) Area of lateral habitats in the Middle and Lower River that is accessible during adult migration (access into lateral spawning habitats, including mainstem river passage within and through Devils Canyon)

Table 7.8-2 provides an example of a portion of an evaluation matrix including these five metrics for instream flow.

Draft process flow charts have been developed for key questions related to these five metrics and are displayed in Figure 7.8-1 through Figure 7.8-5. These flow charts detail the planned flow of information for estimating each evaluation metric in a single Focus Area. They will be modified and refined as the work develops on study integration. These flow charts will be important components of the study integration to provide transparency to the process of estimating evaluation metrics. They are also important precursors to any consideration of uncertainty which may be included in the study integration.

7.8.1.2. Decision Points from Study Plan

There were no decision points in the FERC-approved Study Plan to be evaluated for this study component following the completion of 2013 work.

7.8.1.3. Modifications to Study Plan

No modifications the Study plan are needed to complete the Study components and meet Study Plan objectives.

7.8.2. Schedule

Development of the DSS was initiated in 2013 and will continue in 2014 and 2015 in collaboration with the TWG. As stated in the Study Plan (RSP Section 8.5.4.8.2), a summary of these study integration efforts will be included in the USR. The USR summary will include the results of three planned efforts, as follows.

1) Identification of key evaluation metrics for all study disciplines.

   In 2013, five evaluation metrics were proposed for anadromous fish habitat and discussed during the IFS-TT Riverine Modelers Meeting on November 13-15, 2013 (AEA 2013). In 2014, evaluation metrics for fish habitat will be refined, and evaluation metrics for all study disciplines will be identified. The evaluation metrics will be finalized in 2015 with input from the TWG.

2) Development of flow charts describing processes for estimating the evaluation metrics.

   In 2013, draft process flow charts for five proposed evaluation metrics were created. The modeling and data information flow has been and will continue to be updated in 2014, and the flow charts will be updated to reflect the current processes. Also in 2014, draft process flow charts for additional evaluation metrics will be created. Process flow charts for all evaluation metrics will be completed in 2015.

3) Identification of key uncertainties and processes for addressing those uncertainties in the DSS.

   In 2014, AEA study leads will identify key uncertainties in the modeling and data analysis steps reflected in the process flow charts for each evaluation metric. The process for incorporating these uncertainties into the DSS will be further developed. Final identification of included uncertainties and final methods for incorporating these uncertainties into the DSS will be completed in 2015.

7.8.3. Conclusion

The efforts and TWG collaborations conducted in 2013 and planned for 2014-2015 will result in a DSS process that will be used to assist scenario evaluations in support of the License Application and to achieve the objectives of the approved Study Plan (see RSP Section 8.5.4.8).

7.9. Literature Cited

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7.10. Tables

Table 7.5-1. Seasonal daylight and night downramping guidelines (Hunter 1992).

Season	Daylight Rates*	Night Rates
February 16 to June 15 (salmon fry)	No Ramping	2 inches/hour
June 16 to October 31 (steelhead and trout fry)	1 inch/hour	1 inch/hour
November 1 to February 15	2 inches/hour	2 inches/hour

Notes:

* Daylight is defined as 1 hour before sunrise to 1 hour after sunset.

Table 7.7-1. Lengths of final Focus Areas as proportion of each Geomorphic Reach.

Geomorphic Reach	Geomorphic Reach			Current Focus Area				Revised Focus Area Length as % of Geomorphic Reach
	Start	End	Length	ID	Start	End	Length	
MR-1	187.1	184.6	2.5	184	185.7	184.7	1	40%
MR-2	184.6	169.6	15	173	175.4	173.6	1.8	12%
MR-5	153.9	148.4	5.5	151	152.3	151.8	0.5	9.1%
MR-6	148.4	122.7	25.7	144	145.7	144.4	1.3	23%
				141	143.4	141.8	1.6	
				138	140	138.5	1.5	
				128	129.7	128.1	1.6	
MR-7	122.7	107.8	14.9	115	116.5	115.3	1.2	19%
				113	115.3	113.6	1.7	
MR-8	107.8	102.4	5.4	104	106	104.8	1.2	22%

Table 7.8-1. Conceptual Comparison of Multiple Resource Indicators of the Effects of Alternative Operational Scenarios (OS) for the Susitna-Watana Hydroelectric Project.

Indicators to be coordinated with resource-specific working groups.

(Indicators provided for illustration purposes only)

		Existing Conditions (EC-01)	Scenario 1 (Ver. 1/20/15) (OS-01)	Scenario 2 (Ver. 02/14/15) (OS-02)	Scenario 3 (Ver. 02/14/15) (OS-03)
Run Description	Average monthly MIF(cfs)				
	Max generation Nov-Mar (cfs)				
	Min generation Nov-Mar (cfs)				
	Max generation Apr-Oct (cfs)				
	Min generation Apr-Oct (cfs)				
	Ramping Rates				
	Evaluation Indicators				
Pow er	Weighted average generation Nov-Mar (MWh)⑤				
	Weighted average generation Apr-Oct (MWh)⑤				
	Weighted annual dependable capacity (MWh)⑤				
Hydrologic	Max 1-day flow (cfs) wet / avg/dry	wet / avg / dry	wet / avg/ dry	wet / avg / dry	wet / avg / dry
	Min 2-day low, Nov-Mar (cfs)				
	Min 2-day low Jul-May as% of 2-day max Jul-Sep				
	Freshets (Apr-Jun)[Qc]>1.5*[Q_{C-1}+Q_{C-2}+Q_{C-3}]/3				
	Water Particle Travel Time, 25% exceedance, Apr-Jun				
	Other IHA statistics				
Reservoir	Average reservoir volume (KAF)	wet / avg /dry	wet / avg / dry	wet / avg / dry	wet / avg / dry
	Min 2-day reservoir volume (KAF)				
	Weighted annual euphotic zone (KAF)				
	Other Biological/recreation indicators				
Ramping	Weighted avg annual total, Middle Susitna, reach-averaged (ra) downramping events >1-inch per hour⑤				
	Weighted average annual total, Middle Susitna, reach-averaged downramping events > 2-inch per hour⑤				
	Weighted average annual total, Middle Susitna, reach-averaged downramping events > 4-inches per hour ⑤				
Varial Zone	Median annual, MS, reach-averaged (ra) channel width-ft ⑤				
	Total varial zone, MS, 12-hr/12-hr, ra, median annual channel width-ft ⑤				
	Total varial zone, MS, 12-hr/7-day, ra, median annual channel width-ft ⑤				
	Total varial zone, MS, 12-hr/30-day, ra, median annual channel width-ft ⑤				

Evaluation Indicators *(Indicators provided for illustration purposes only)*		Existing Conditions(EC-01)	Scenario 1 (Ver. 1/20/15) (OS-01)	Scenario 2 (Ver. 02/14/15) (OS-02)	Scenario 3 (Ver. 02/14/15) (OS-03)
Potential Salmon Habitat	Chum spawning habitat, Devils Canyon to 3 Rivers (DCto3R) reach-averaged(ra), **gross channel width,** (ft)⑤				
	Chum **effective spawning/incubation,** DCto3R-reach-averaged (ra), channel width accounting for dewatering, groundwater/surface water interactions, water quality effects, **net width** (ft)⑤				
	Coho effective spawning/incubation, DCto3R-ra, **net width**, (ft)⑤				
	Sockeye effective spawning and incubation, DCto3R-ra, slough/side channel, **net width** (ft)⑤				
	Pink effective spawning/incubation, DCto3R-ra, slough/side channel, **net width** (ft)⑤				
	Coho juvenile habitat, open-water, DCto3R-ra, channel width(ft) ⑤				
	Coho juvenile habitat, ice-period, DCto3R-ra, channel width(ft) ⑤				
	Chinook juvenile habitat, ice-period, DCto3R-ra, slough/side channel width(ft) ⑤				
Other Fish	Grayling average minimum spawning, Watana Dam to Devils Canyon (DtoDC), reach averaged WUA, (ft^2)⑤				
	Northern pike effective spawning and incubation, DCto3R-reach averaged slough/side channel net width (ft)⑤				
Riparian	Wet meadow area, reach averaged, DC to 3R, post-licensing yrs 10-20 (acres)⑤				
	Scrub thickets, reach averaged, DC to 3R, post-licensing yrs 10-20 (acres)⑤				
	Floodplain plant community colonization area, reach averaged, DC to 3R, post-licensing yrs 10-20 (acres)⑤				
	Other riparian indicators				
Recreation	Devils Canyon to 3R, tour boat accessible, May to Sep (days)				
	Three Rivers to Sunshine, days channel exceeds minimum boating depth, May to Sep				
	Devils Canyon to 3 R, upstream extent of January ice cover for snow machine travel				
	Other recreation/access indicators				
Other Aquatics	Other potential indicators of Project effects such as: ▫ minimum slough area, ▫ percent of river length mobilized-D_{25} ▫ downstream extent of ice-free zone, ▫ 30-day wetted euphotic streambed, ▫ other reaches, seasons, life stages, mesohabitats to be determined in consultation with TWG				

Notes:

1 Average of five select years weighted by likelihood of occurrence (Dry Year* 0.077, Somewhat Dry Year* 0.231, Average Year * 0.462, Somewhat Wet Year * 0.115, Wet Year*0.115) (values are for illustration purposes only)

Table 7.8-2. EXAMPLE Subset of an Evaluation Matrix for the Decision Support System.

Resource Area	Temporal Scale	Spatial Scale	Evaluation Metrics		Existing Conditions	OS1	OS2	OS3
Anadromous Fish	Averaged over expected 50 year flow	Middle River	Effective spawning/ incubation habitat area	Coho				
				Chum				
				Chinook				
				Sockeye				
			Juvenile rearing habitat area sustained over rearing period	Coho				
				Chum				
				Chinook				
				Sockeye				
			Juvenile outmigration habitat area					
			Adult migration habitat area					
Ice processes	Median date at year 50	n/a	Timing of ice breakup					

7.11. Figures

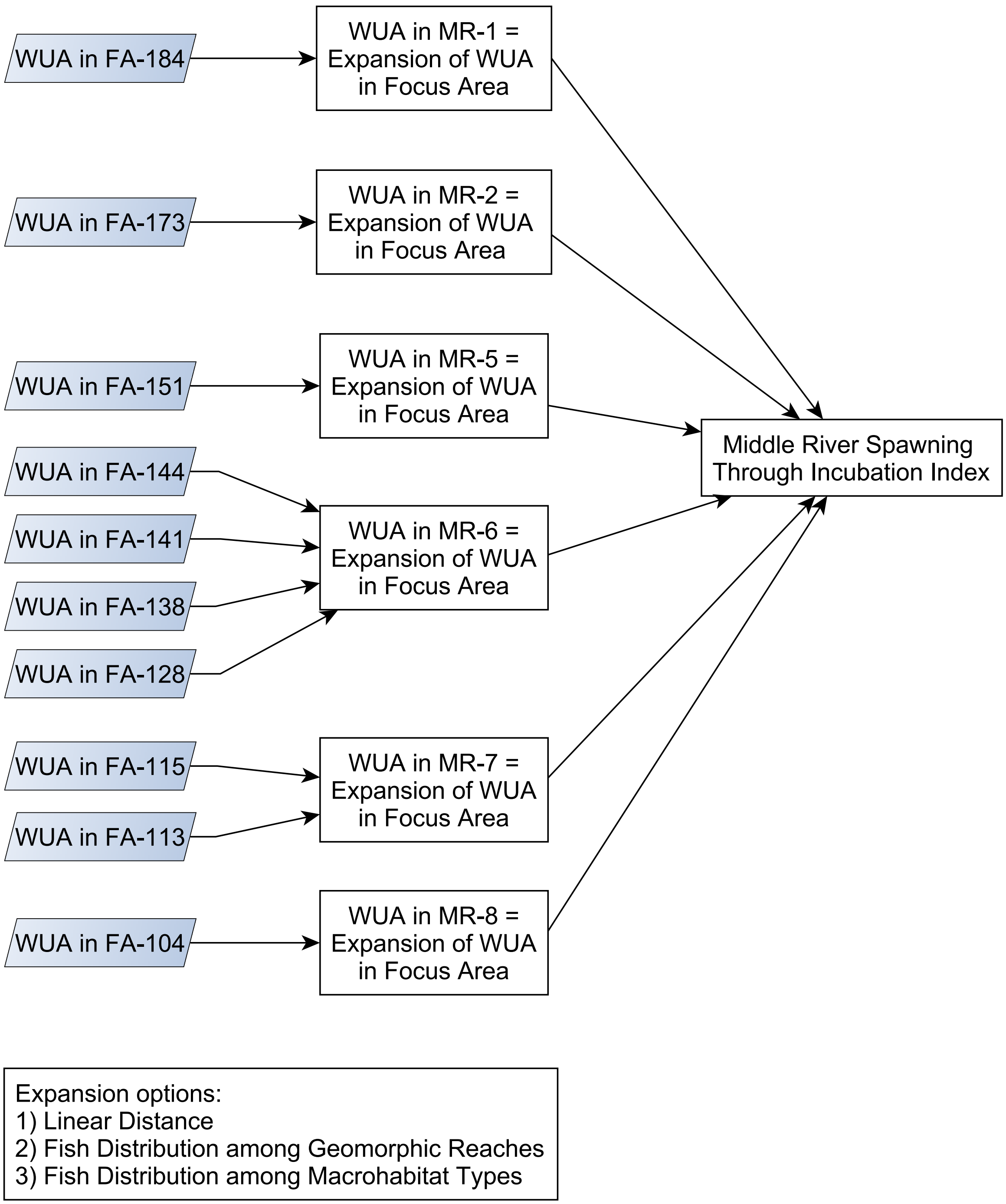

Figure 7.7-1. Potential approaches for spatial expansion of habitat-flow relationships to other areas within the Middle River Segment of the Susitna River. The three expansion options listed represent base options; these can be combined or further refined to consider specific habitat features of the Focus Areas (FA) (e.g., main channel, side channel, side slough, etc.). The final approach will be developed in consultation with the TWG in Q1 2014.

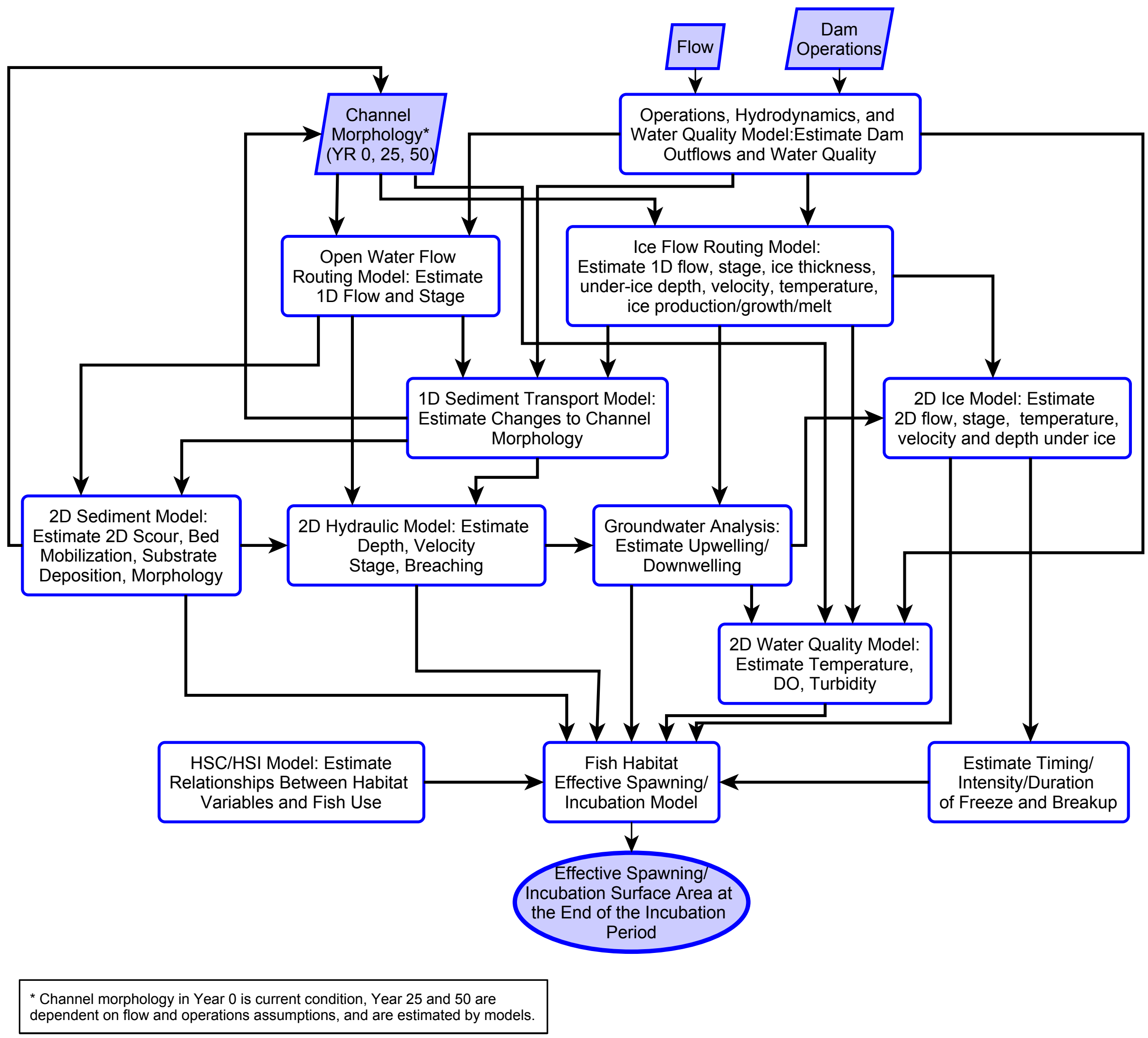

Figure 7.8-1. Process flow chart showing the steps in developing the evaluation metric for Effective Spawning/Incubation Habitat in one Focus Area.

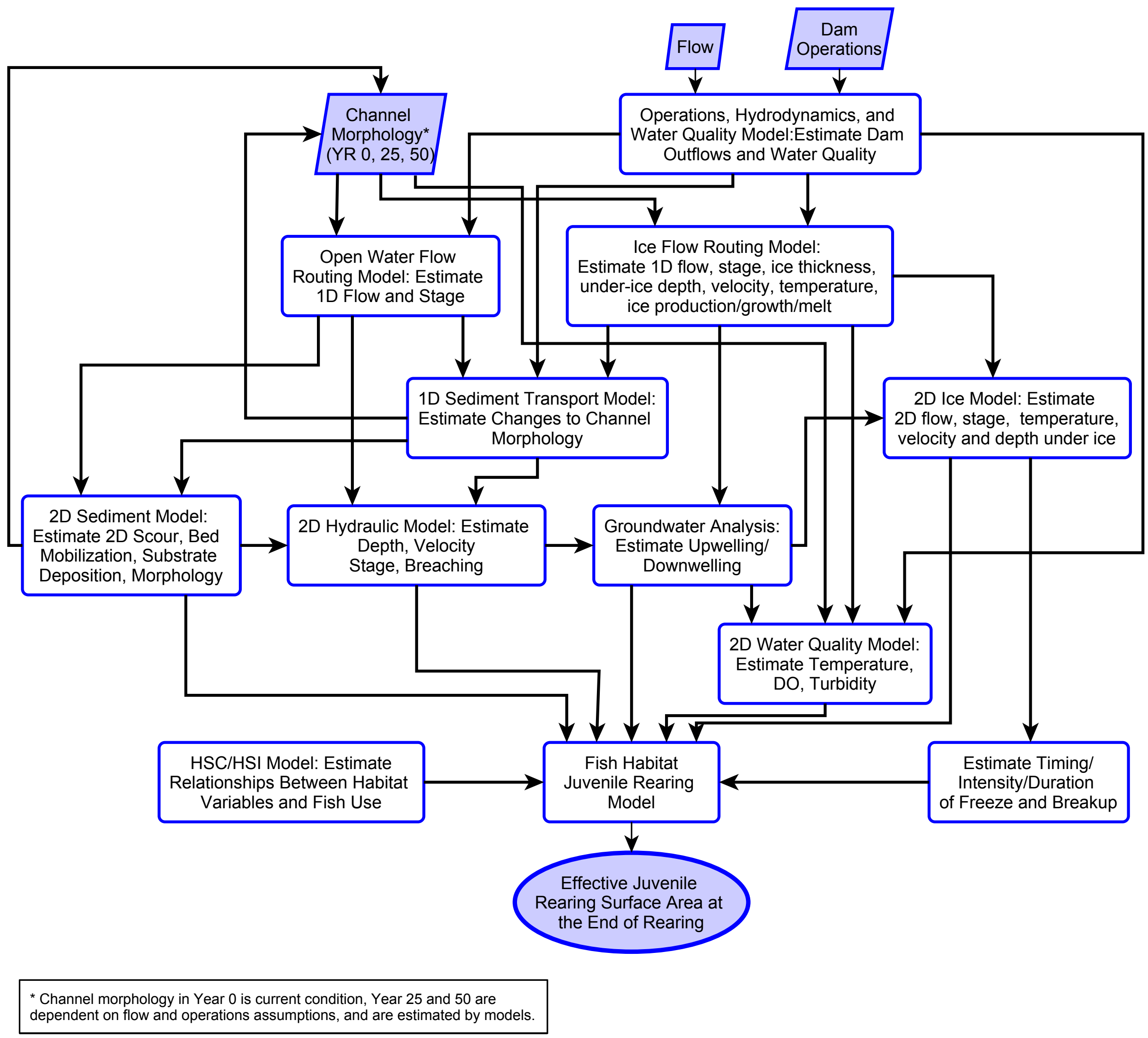

Figure 7.8-2. Process flow chart showing the steps in developing the evaluation metric for juvenile rearing habitat in one Focus Area.

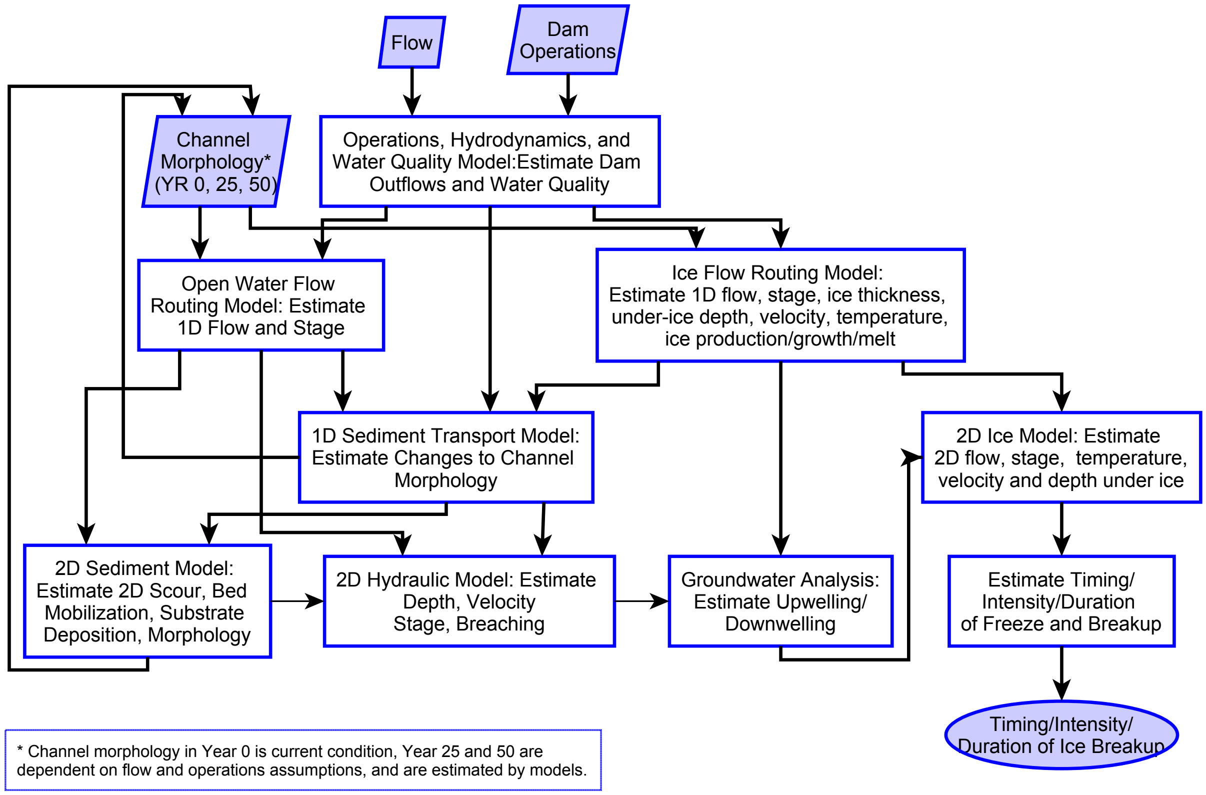

Figure 7.8-3. Process flow chart showing the steps in developing the evaluation metric for ice breakup timing.

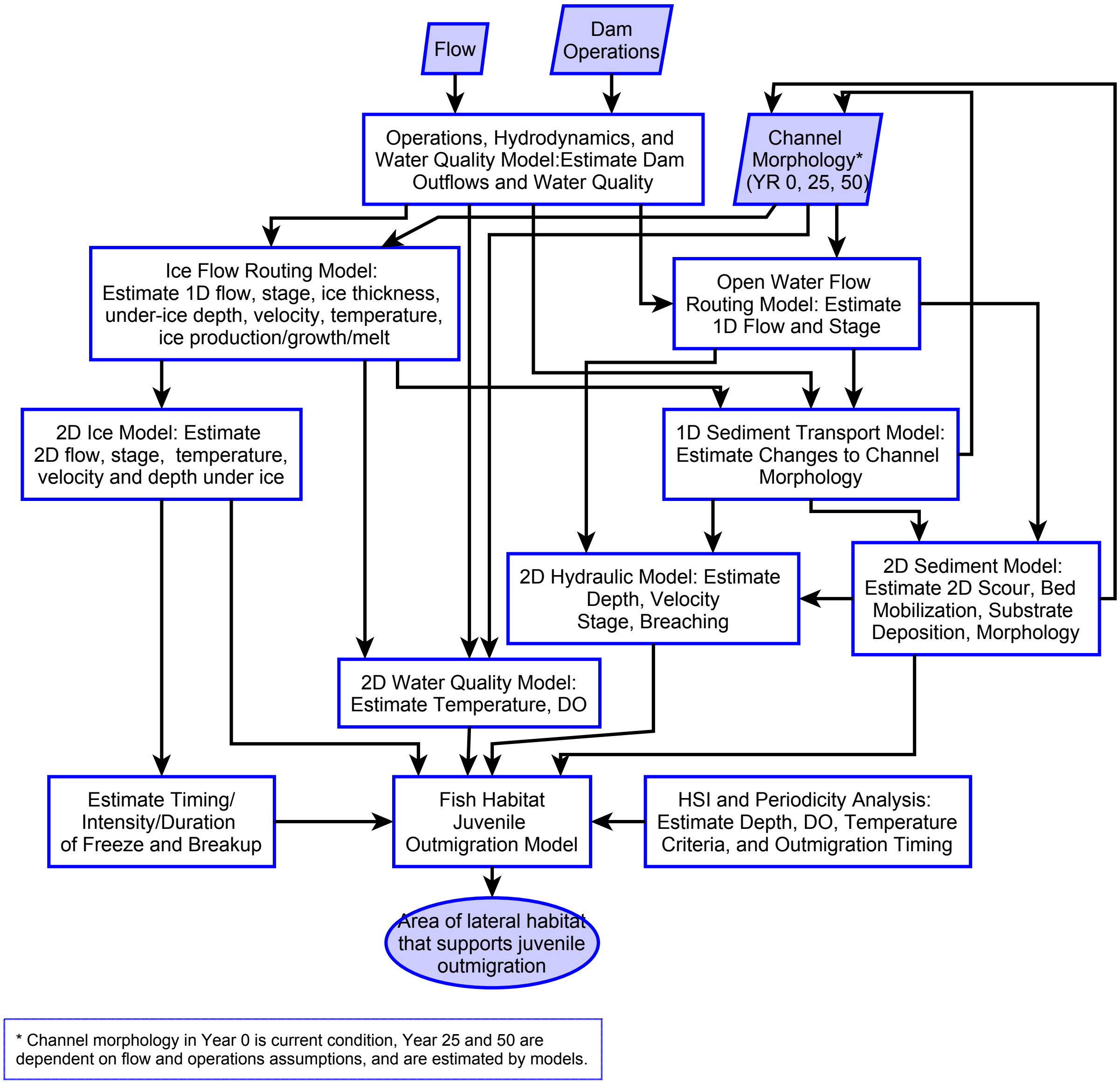

Figure 7.8-4. Process flow chart showing the steps in developing the evaluation metric for juvenile outmigration habitat.

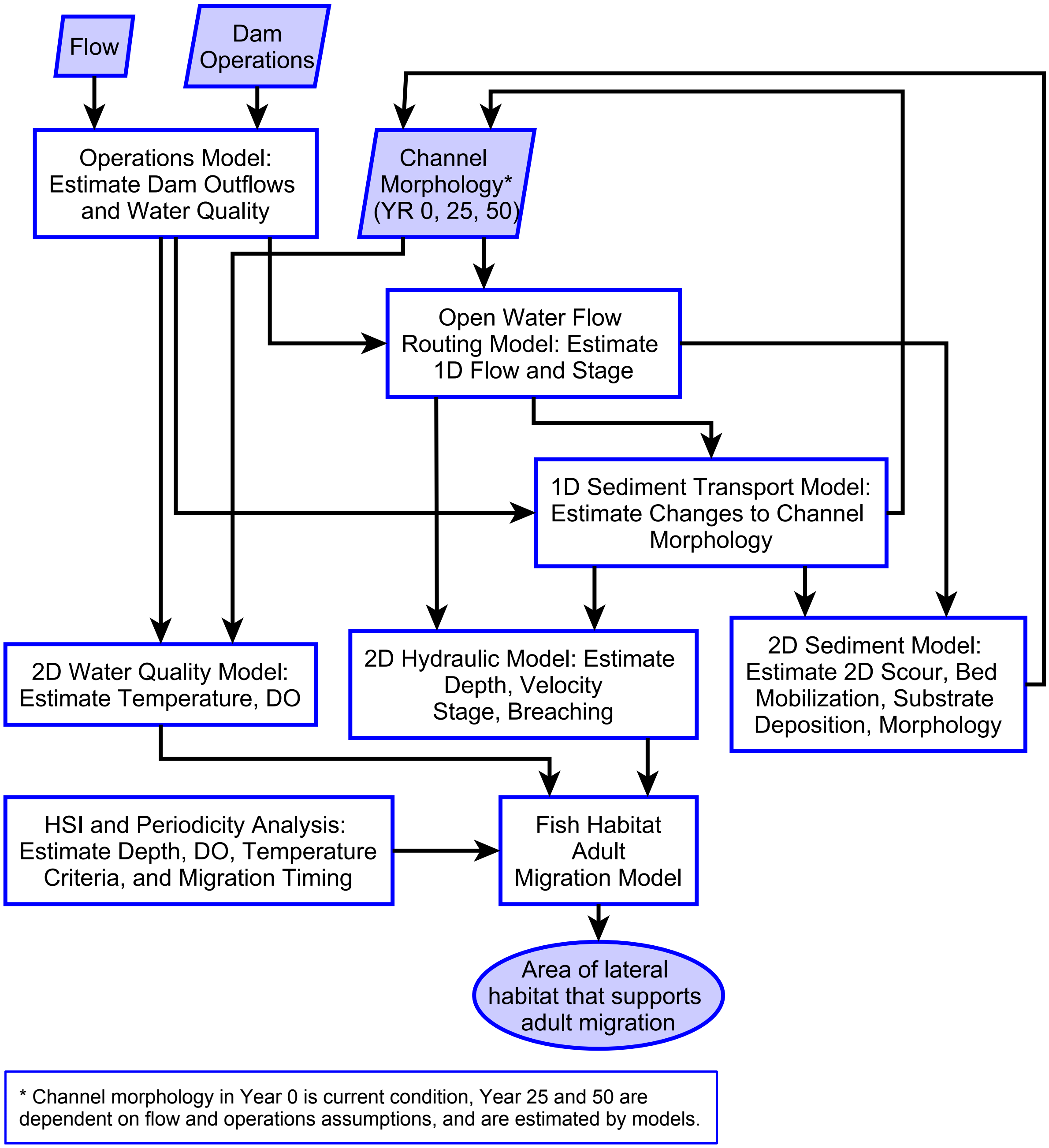

Figure 7.8-5. Process flow chart showing the steps in developing the evaluation metric for adult migration habitat.

PART C - APPENDIX J: REPRESENTATIVE YEARS

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fish and Aquatics Instream Flow Study (8.5)

Initial Study Report
Part C - Appendix J
Representative Years

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

R2 Resource Consultants

Miller Ecological Consultants

Tetra Tech

HDR

GW Scientific

Montgomery Watson Harza

June 2014

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
AEA	Alaska Energy Authority
AFDD	Accumulated Freezing Degree Days
ATDD	Accumulated Thawing Degree Days
IFS	Instream Flow
ISR	Initial Study Report
PDO	Pacific Decadal Oscillation
RSP	Revised Study Plan

1. INTRODUCTION

Revised Study Plan (RSP) Section 8.5.4.4.1.2 stated that five representative years would be selected for analysis that represent wet, average, and dry conditions, and warm and cold Pacific Decadal Oscillation (PDO) phases so that Project effects for various project alternatives can be evaluated under a range of climatic and hydrologic conditions. In addition, a multi-year continuous flow record will be evaluated to identify year-to-year variations independent of average, wet, or dry conditions. This appendix summarizes the process Alaska Energy Authority (AEA) has applied in selecting a final set of representative years for analysis. The process involved considerations and analyses provided by three resource areas including Fluvial Geomorphology (Study 6.6), Instream Flow (Study 8.5), and Ice Processes (Study 7.6). These three resource areas were involved because the Fluvial Geomorphology studies need years selected that are representative of conditions during the open-water period, the Ice Processes studies need years selected that are representative of conditions during the ice cover period, and the Instream Flow Studies (IFS) need years selected that are representative of conditions during both periods. Thus, it was important to bring together all three resource needs in the selection process.

2. GEOMORPHOLOGY ANALYSIS

Geomorphology conducted an analysis to evaluate and recommend representative years for wet, average, and dry conditions and warm and cold PDO phases. Details of this analysis are provided in Appendix E of ISR Study 6.6 Fluvial Geomorphology Modeling. Importantly, the geomorphology analysis relative to PDO found that none of the Gold Creek summer flow conditions were significantly different between warm and cool PDO, even when extreme high and low flows were included in the analysis. The analysis concluded that from a geomorphological perspective, there was no evidence to support further differentiating year types by PDO since it does not produce geomorphically discernible conditions. As a result, Geomorphology recommended three candidate representative years – 1981 for wet conditions, 1985 for average conditions, and 1950 for dry conditions. The hydrographs and flow duration curves of the three years selected by Geomorphology are provided in Figure 1. The Instream Flow and Ice Processes studies evaluated these recommendations based on factors important to their studies.

3. INSTREAM FLOW ANALYSIS

Instream Flow studies evaluated the same 50-year period identified in Appendix E of ISR Study 6.6 Fluvial Geomorphology Modeling from a fish habitat perspective. A 12-month and 5-month frequency analysis was performed to evaluate years. This analysis compared and ranked months for either the 12-month or 5-month period for the 50-year record by both average flow and the range in flows. The monthly hydrographs of the four potential years for each of the wet, average, and dry conditions are shown on a linear scale in Figure 2. These hydrographs and the ranking analysis were used to evaluate each year.

The IFS representative years work found agreement on the preference for 1981 as representative of a wet year and 1985 as representative of an average year. However, the IFS analysis indicated a different year, 1970, would be a better representation of dry conditions than 1950, from a fish habitat perspective since it had both low fall and winter flows.

4. ICE PROCESSES ANALYSIS

The Ice Processes study also evaluated representative years. The Ice Processes study reviewed years in terms of when freeze up occurred, how long freeze-up lasted, the accumulated freezing degree days (AFDD), the accumulated thawing degree days (ATDD), the amount of winter precipitation, and the snow depth. Four years (1976, 1970, 1985, and 1981) were evaluated and are described in detail below, with a comparison to 2013. The AFDD and ATDD for these four years are provided in Figure 3.

The year 1976 was characterized as a cold dry year. It was the 8th coldest year for AFDD at 1795°C-days. It had an early freeze-up that was short in duration. Winter precipitation (i.e., between October 18, 1975 and April 7, 1976) was 6.71 inches. Very little snow occurred early in the winter, but the snow depth on March 14, 1976 was 52 inches.

The year 1970 was characterized as a warm dry year. It was the 6th warmest for AFDD at 899°C-days. Freeze up was very late, but long in duration. Winter precipitation (i.e., between October 20, 1969 and March 13, 1970) was 4.37 inches. The snow depth on February 2, 1970 was 18 inches.

The year 1985 was characterized as an average cold year. It was the 35th coldest and 28th warmest for AFDD at 1263°C-days. This year had a median freeze-up date of average duration. Winter precipitation (i.e., between October 18, 1984 and April 7, 1985) was 11.12 inches. The snow depth on March 12, 1985 was 62 inches.

The year 1981 was characterized as a warm, but not too wet winter. It was the 7th warmest for AFDD at 908°C-days, and had a very late, long duration freeze-up. Winter precipitation (i.e., between October 26, 1980 and March 8, 1981) was 5.81 inches. The snow depth on February 28, 1981 was 26 inches.

For comparative purposes, 2013 was considered a massive breakup year. It had warmer than average AFDD at 1151°C-days. It had an average to late freeze-up of long duration, breakup was also late occurring from May 25 to 29, 2013. Winter precipitation (i.e., October 14, 2012 to April 18, 2013) was 8.22 inches. The snow depth on March 25, 2013 was 41 inches.

Overall, Ice Processes concluded that wet, average, and dry designations don't work well to represent winter periods. Instead cold, average, and warm conditions are more representative of the issues that need to be addressed from an ice processes perspective. This analysis was in agreement on 1981 as representative of a "warm" year for Ice Processes (corresponding to a wet year for the Geomorphology and IFS studies) and 1985 as representative of an average year. However, instead of 1970 which IFS had suggested was representative of dry conditions, the Ice Processes recommended 1976 as representative of a dry cold year.

5. SUMMARY AND SELECTION OF REPRESENTATIVE YEARS

Based on the analyses completed by the Geomorphology, Instream Flow, and Ice Processes studies, representative years were selected as 1981 (wet/warm), 1985 (average), and 1976 (dry/cold). As noted above, additional years to reflect warm and cold PDO periods were not included since results of the comparisons of hydrographs, flow duration curves and the statistical comparisons did not support making this distinction (Appendix E of ISR Study 6.6 Fluvial Geomorphology Modeling). These three years (1981, 1985, and 1976) represent a range of climatic and hydrologic conditions that are meaningful from a geomorphology, instream flow, and ice processes perspective and are the representative years that will be used to evaluate and compare existing and Project operational scenarios.

6. FIGURES

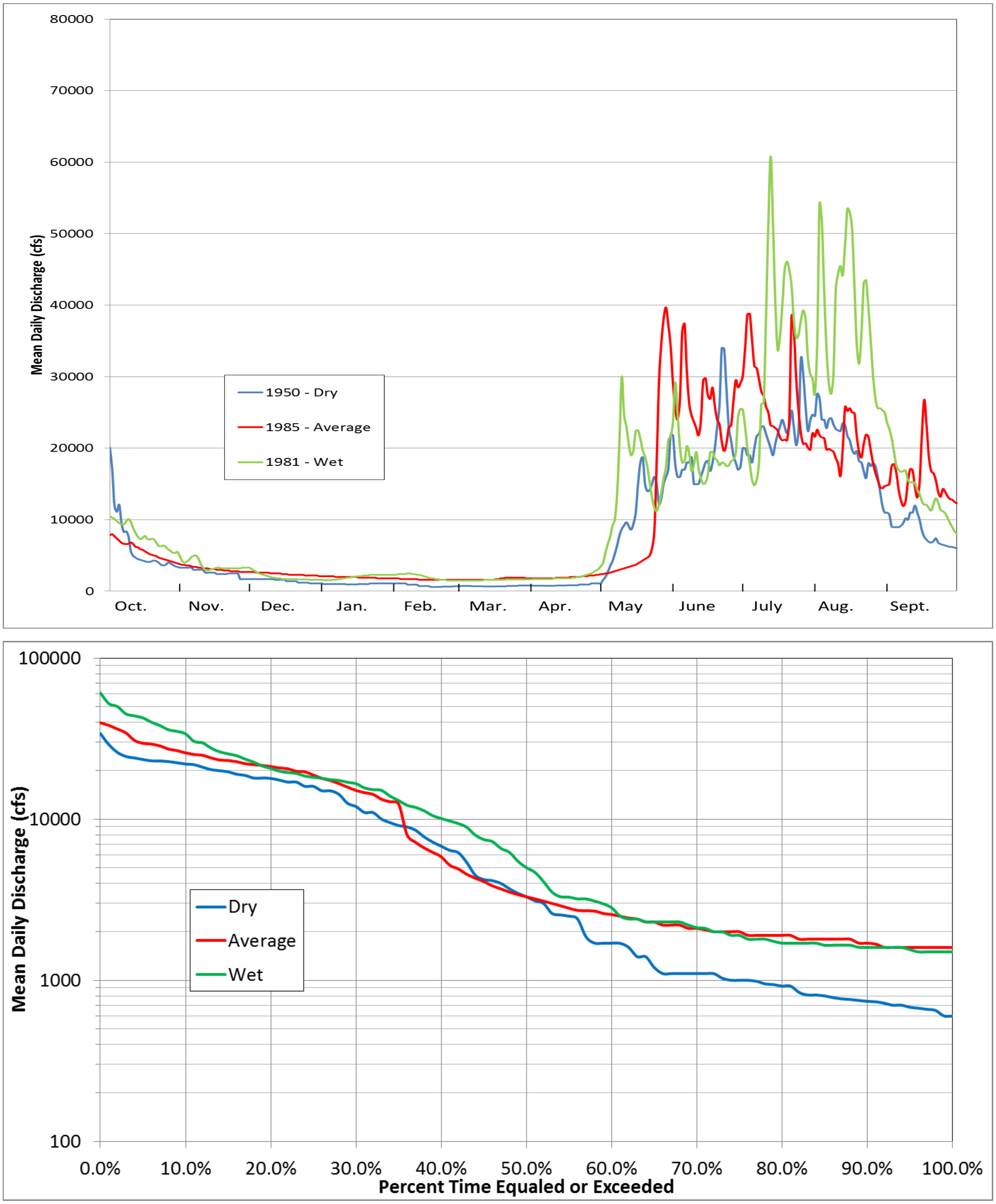

Figure 1. Geomorphology recommended wet (1981), average (1985), and dry (1950) representative years annual hydrographs (upper) and flow duration curves (lower).

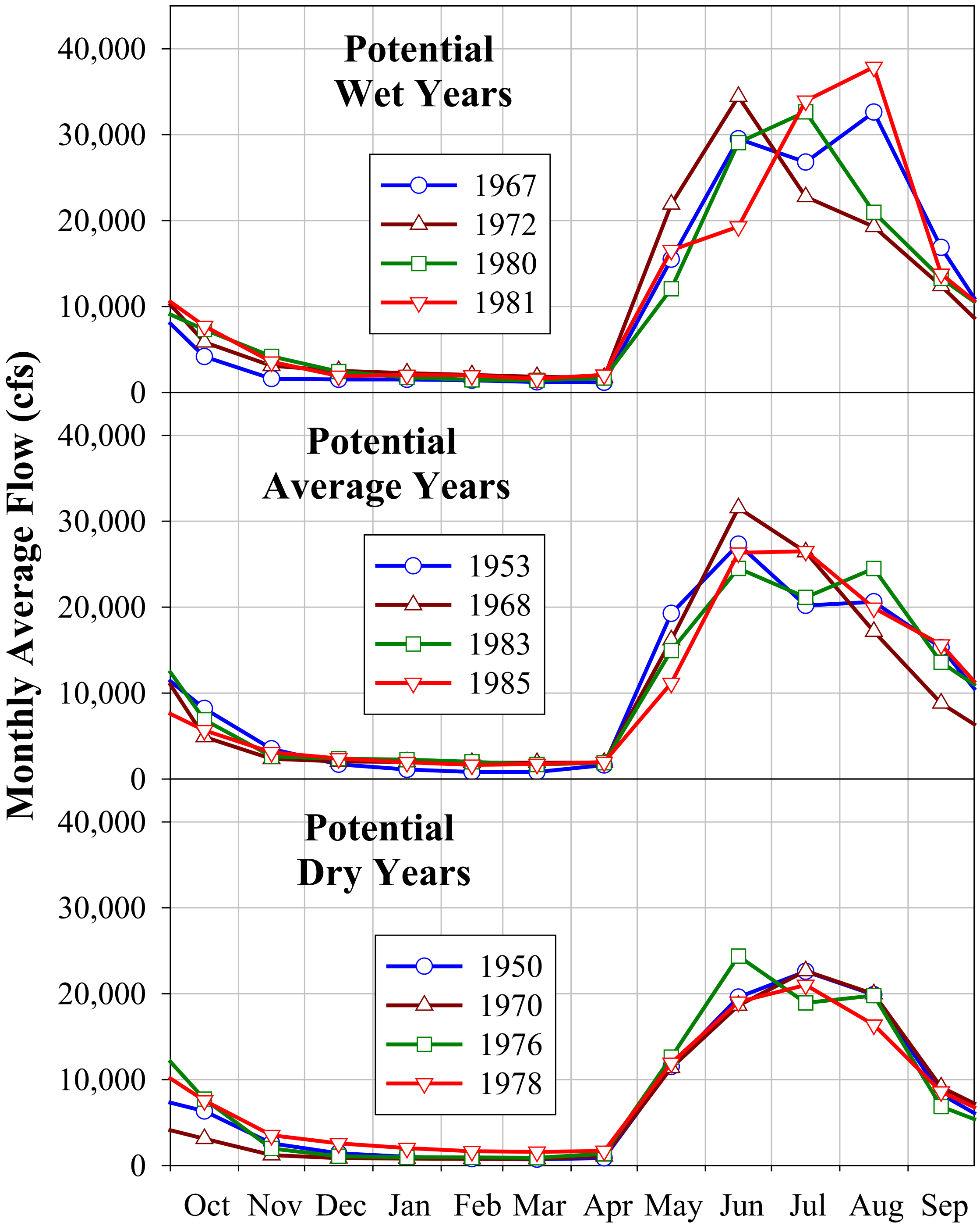

Figure 2. Monthly average flow for potential wet, average, and dry representative years, as evaluated by the Instream Flow Study. IFS recommended 1981 for wet, 1985 for average, and 1970 for dry year conditions

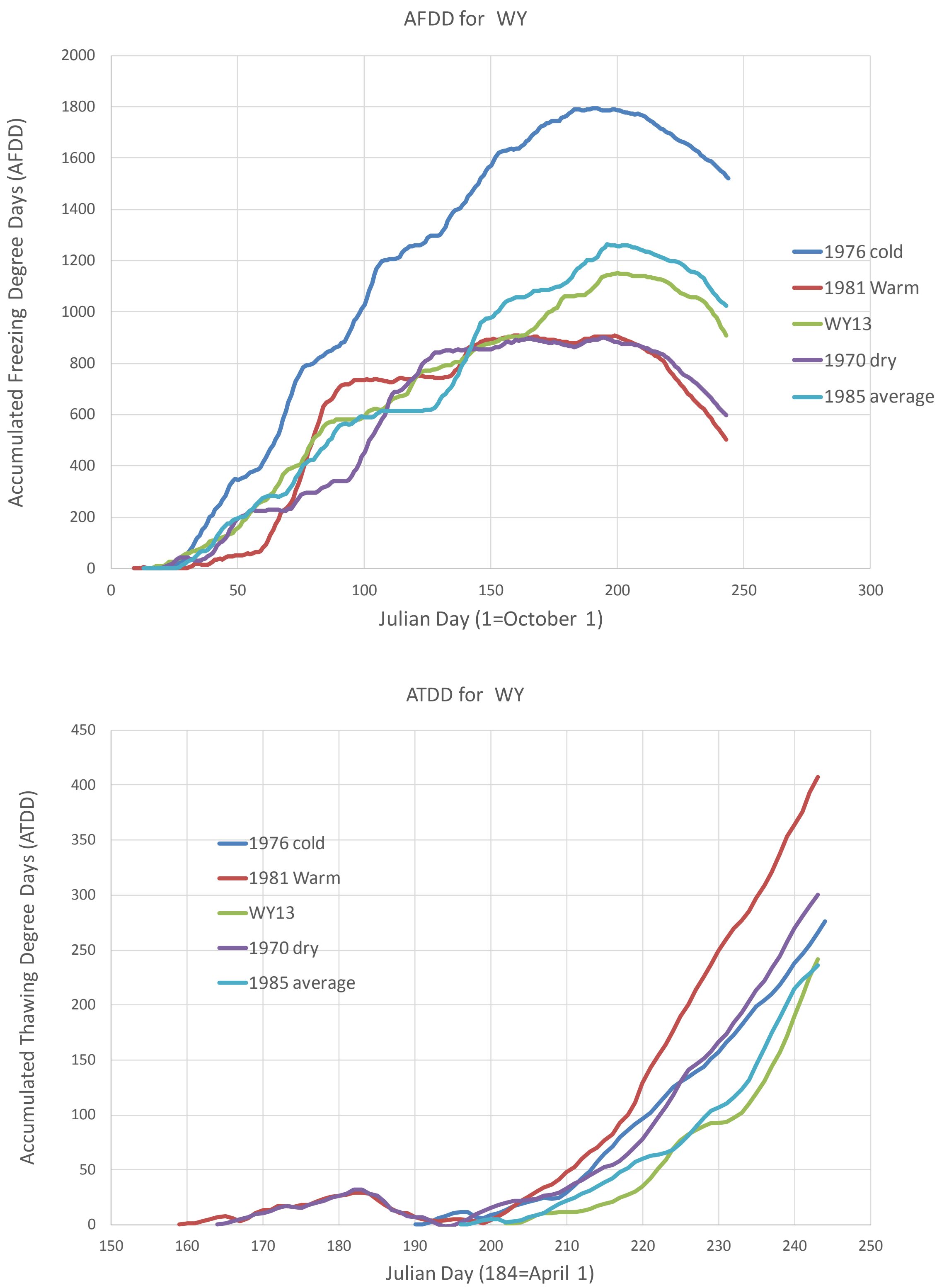

Figure 3. Accumulated freezing degree days (top) and accumulated thawing degree days (bottom) for representative years (1970, 1976, 1981, 1985, and WY13) evaluated by Ice Processes. Ice Processes recommended 1976 for dry/cold conditions, 1981 for wet/ warm conditions, and 1985 for average conditions.

PART C - APPENDIX K: HYDROLOGY AND VERSION 2 OPEN-WATER FLOW ROUTING MODEL

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Fish and Aquatics Instream Flow Study
Study Plan Section 8.5

Initial Study Report
Part C - Appendix K
Hydrology and Version 2
Open-water Flow Routing Model

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

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June 2014

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
ADCP	Acoustic Doppler Current Profiler
Alluvial	Relating to, composed of, or found in alluvium.
AEA	Alaska Energy Authority
AT	air temperature
Bank	The sloping land bordering a stream channel that forms the usual boundaries of a channel. The bank has a steeper slope than the bottom of the channel and is usually steeper than the land surrounding the channel.
Calibration	In the context of hydrologic modeling, calibration is the process of adjusting input variables to minimize the error between predicted and observed water surface elevations or other hydrologic parameters.
cfs	cubic feet per second
Channel	A natural or artificial watercourse that continuously or intermittently contains water, with definite bed and banks that confine all but overbank stream flows.
Confluence	The junction of two or more rivers or streams.
COV	coefficient of variation
Cross-section	A plane across a river or stream channel perpendicular to the direction of water flow.
Datum	A geometric plane of known or arbitrary elevation used as a point of reference to determine the elevation, or change of elevation, of another plane (see gage datum).
Depth	Water depth at the measuring point (station).
Devils Canyon	Located at approximately Susitna River Mile (RM) 150-161, Devils Canyon contains four sets of turbulent rapids rated collectively as Class VI. This feature is a partial fish barrier because of high water velocity.
Discharge	The rate of stream flow or the volume of water flowing at a location within a specified time interval.
Drainage area	The total land area draining to any point in a stream. Also called catchment area, watershed, and basin.
El.	Elevation
FERC	Federal Energy Regulatory Commission
Floodplain	1. The area along waterways that is subject to periodic inundation by out-of-bank flows. 2. The area adjoining a water body that becomes inundated during periods of over-bank flooding and that is given rigorous legal definition in regulatory programs. 3. Land beyond a stream channel that forms the perimeter for the maximum probability flood. 4. A relatively flat strip of land bordering a stream that is formed by sediment deposition. 5. A deposit of alluvium that covers a valley flat from lateral erosion of meandering streams and rivers.
fps	feet per second
ft	Feet
Gaging station	A specific site on a stream where systematic observations of stream flow or other hydrologic data are obtained.

Abbreviation	Definition
Geomorphic reach	Level two tier of the habitat classification system. Separates major hydraulic segments into unique reaches based on the channel's geomorphic characteristic.
Geomorphology	The scientific study of landforms and the processes that shape them.
GIS	Geographic Information System. An integrated collection of computer software and data used to view and manage information about geographic places, analyze spatial relationships, and model spatial processes.
GPS	Global Positioning System. A system of radio-emitting and -receiving satellites used for determining positions on the earth.
Gradient	The rate of change of any characteristic, expressed per unit of length (see Slope). May also apply to longitudinal succession of biological communities.
Groundwater (GW)	In the broadest sense, all subsurface water; more commonly that part of the subsurface water in the saturated zone.
HEC-RAS	hydraulic flow-routing model
Hydrograph	A graph showing stage, flow, velocity, or other property of water with respect to time.
Hydraulic model	A computer model of a segment of river used to evaluate stream flow characteristics over a range of flows.
Ice cover	A significant expanse of ice of any form on the surface of a body of water.
Ice-free	No floating ice present.
ILP	Integrated Licensing Process
LiDAR	Light Detection and Ranging. An optical remote sensing technology that can measure the distance to a target; can be used to create a topographic map.
Main channel	For habitat classification system: a single dominant main channel. Also, the primary downstream segment of a river, as contrasted to its tributaries.
Mainstem	Mainstem refers to the primary river corridor, as contrasted to its tributaries. Mainstem habitats include the main channel, split main channels, side channels, tributary mouths, and off-channel habitats.
Manning's equation	V = 1.486 R2/3S1/2/n in English units (V = R2/3S1/2/n in SI units) where V = mean flow velocity, R = hydraulic radius, and S = hydraulic slope; n is a coefficient of roughness.
mph	miles per hour
N/A	not applicable *or* not available
NAVD	North American Vertical Datum, 1988
NEPA	National Environmental Policy Act
No.	Number
NSRS	National Spatial Reference System
ºC	degrees Celsius
OHW	ordinary high water
Open lead	Elongated opening in the ice cover caused by water current (velocity lead) or warm water (thermal lead).
Period of record	The length of time for which data for an environmental variable has been collected on a regular and continuous basis.
PRM	Project River Mile

Abbreviation	Definition
Project	Susitna-Watana Hydroelectric Project
Q	Hydrological abbreviation for discharge, usually presented as cfs (cubic feet per second) or cms (cubic meters per second). Flow (discharge at a cross-section).
QC	quality assurance, quality control
Reservoir	A body of water, either natural or artificial, that is used to manipulate flow or store water for future use.
Riparian	Pertaining to anything connected with or adjacent to the bank of a stream or other body of water.
River mile	The distance of a point on a river measured in miles from the river's mouth along the low-water channel.
RTK	Real time kinematic, in reference to a GPS survey method.
s	Second
Side channel	Lateral channel with an axis of flow roughly parallel to the mainstem, which is fed by water from the mainstem; a braid of a river with flow appreciably lower than the main channel. Side channel habitat may exist either in well-defined secondary (overflow) channels, or in poorly defined watercourses flowing through partially submerged gravel bars and islands along the margins of the mainstem.
Slope	The inclination or gradient from the horizontal of a line or surface.
Slough	A widely used term for wetland environment in a channel or series of shallow lakes where water is stagnant or may flow slowly on a seasonal basis. Also known as a stream distributary or anabranch.
Stage	The distance of the water surface in a river above a known datum.
Stage-discharge relationship	The relation between the water-surface elevation, termed stage (gage height), and the volume of water flowing in a channel per unit time.
Thalweg	A continuous line that defines the deepest channel of a watercourse.
Three Rivers Confluence	The confluence of the Susitna, Chulitna, and Talkeetna rivers at Susitna River Mile (RM) 98.5 represents the downstream end of the Middle River and the upstream end of the Upper River.
Tributary	A stream feeding, joining, or flowing into a larger stream (at any point along its course or into a lake). Synonyms: feeder stream, side stream.
TWG	Technical Workgroup
USACE	U.S. Army Corps of Engineers
USGS	DOI, Geological Survey
Watana Dam	The dam proposed by the Susitna-Watana Hydroelectric project. The approximately 750-foot-high Watana Dam (as measured from sound bedrock) would be located at river mile (RM) 184 on the Susitna River.
Water slope	Change in water surface elevation per unit distance.
Wetted channel width (wetted Perimeter)	The length of the wetted contact between a stream of flowing water and the stream bottom in a plane at right angles to the direction of flow.
WT	water temperature
WSE	Water surface elevation

1. INTRODUCTION AND STUDY GOALS

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). 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) 187.2. The results of this study and of other proposed studies will provide information needed to support the FERC's National Environmental Policy Act (NEPA) analysis for the Project license.

Project operations will cause hourly, daily, and seasonal changes in the Susitna River flows downstream of the proposed dam as compared to existing conditions. Seasonally, Project operations will likely include storing water during the snowmelt season (May through August) and releasing it during the winter (October through April) (AEA 2011). This would reduce flows downstream of the proposed dam site from May through August and increase flows October through April.

In addition to these seasonal changes, the Project may be operated in a load-following mode. Daily load-following operations will typically release higher volumes of water during peak-load hours, and lower volumes of water during off-peak hours. Flow fluctuations that originate at the powerhouse will travel downstream and attenuate, or dampen, as they travel downstream. The waves created by load following operations will affect the aquatic habitat of the Susitna River downstream from the powerhouse, especially along the margins of the river that are exposed to daily cycles of inundation and dewatering (i.e., the varial zone).

Flow releases from the Project are the result of hydropower rules that specify minimum flow releases needed from a Project powerhouse to meet a power generation requirement and schedule. In addition, flow releases are constrained by assumed flow requirements to protect non-power resources such as fish and aquatic habitats. A HEC-ResSim model (U.S. Army Corps of Engineers 2007) was developed for the Susitna River downstream from the Watana Dam (MWH 2012). The HEC-ResSim model was used to simulate flow and stage hydrographs downstream from the Watana Dam site under Pre-Project and Post-Project conditions.

In an effort to meet multiple resource interests, available resources under existing conditions will be analyzed in comparison to alternative operational scenarios. To analyze the impacts of alternative Project operational scenarios on habitats downstream of the Watana Dam site, an Open-water Flow Routing Model will be used to translate the effects of changes in flow associated with Project operations to downstream Susitna River locations.

In support of the Open-water Flow Routing Model, as well as other studies, a variety of streamflow gaging studies have been implemented for the Susitna River area. Thirteen gaging stations were established on the mainstem Susitna River in 2012. The gaging stations will be used to monitor stage and flow under summer, ice-free conditions and to monitor water pressure under winter ice-covered conditions. These stations were set up to measure and record stage in real time every 15 minutes. The stations record additional measurements including water temperature and camera images of the river conditions (summer and winter). Eight of the original 13 sites were identified as high priority for monitoring in 2013. Priority was based in part upon their locations in the river, the stability of the channel proximal to the stations, and accessibility. Other sites were considered low priority due to location or erosional changes in the channel profile during 2013 and as a result contain data gaps. Plans are underway to continue the mainstem gaging program in 2014. The mainstem data will be used to calibrate and validate the flow routing models and provide data supporting other studies.

In addition to mainstem gaging, gages were established on select tributaries of the Susitna River in 2013. These gages were established to measure streamflow during the open-water period from approximately May or June through September or October. Plans are in development to continue tributary gaging in 2014. Once the tributary data collection has been completed, the flow estimates developed for ungaged tributaries will be refined based on flows measured in those tributaries in 2013 and 2014.

In addition to open-water season gaging, a winter gaging program was first implemented in 2013 and continued in 2014. Periodic winter discharge measurements (January and March/April) were completed at selected mainstem and tributary gaging stations in the winter, and will provide valuable information for understanding hydraulic conditions in the river during a season when groundwater plays a more prominent role in aquatic habitat functions. Where applicable, these data will also be used in the Open-water Flow Routing Model to refine tributary inflows or enhance understanding of mainstem flows. Winter flow measurements will also be used to help develop the Ice Processes Model and supporting analyses.

Initial results from the flow routing model will be used to assess the magnitude, timing, and frequency of hourly flow and stage changes associated with proposed load-following operations during ice-free periods (May 23 to October 27). Results of the Open-water Flow Routing Model will also be used to evaluate downstream changes in flow and stage associated with reduced Project flow releases during the open-water portions of the reservoir refill period. The HEC-RAS model can be used to provide a time history of flow releases from the dam and to predict the flow and stage history at each of the downstream cross-sections. These predicted flow and stage responses can then be evaluated at multiple levels to assess the impacts to aquatic habitat.

Output from the Open-water Flow Routing Model will provide the fundamental input data to a suite of habitat-specific and riverine process-specific models that will be used to describe how the existing flow regime relates to and has influenced various resource elements (e.g., salmonid spawning and rearing habitats and the accessibility to these habitats in the mainstem, side channels, sloughs, and tributary deltas; invertebrate habitat; sediment transport processes; ice dynamics; large woody debris (LWD); the health and composition of the riparian zone). These same models will likewise be used to evaluate resource responses under existing conditions and under alternative Project operational scenarios, again via output from the routing models. As an unsteady flow model, the routing models will be capable of providing flow and water surface elevation information at each location on an hourly basis and therefore Project effects on flow can be evaluated on multiple time steps (hourly, daily, and monthly) as necessary to evaluate different resource elements.

2. PROJECT SETTING

During the 1980s studies, the Susitna River was characterized into three river segments extending above and below the two proposed dam sites. After researching potential Project configurations, AEA is proposing a single dam configuration at the Watana Dam site at PRM

187.2. The proposed study characterizes the Susitna River as three segments (Figure 2.1-1). The Upper River Segment represents that portion of the watershed above the Watana Dam site at PRM 187.2, the Middle River Segment extends from PRM 187.2 downstream to the Three Rivers Confluence at PRM 101, and the Lower River Segment extends from the Three Rivers Confluence to Cook Inlet (Figure 2.1-1). The study area for these analyses extends from the Watana Dam site at PRM 187.2 on the Susitna River downstream to PRM 29.9 (downstream from the Yentna River confluence).

3. SUMMARY OF EXISTING INFORMATION

3.1. 1980s Information Review

A one-dimensional, steady-state hydraulic model (HEC-2, U.S. Army Corps of Engineers 1976) was initially developed for the Susitna River in the 1980s by R&M Consultants (1982). Two reaches were modeled: one below Devils Canyon, and the other above Devils Canyon.

The reach below Devils Canyon extended from the confluence with the Chulitna River to the downstream end of Devils Canyon. The reach below Devils Canyon consisted of 66 cross-sections of the Susitna River. These cross-sections were surveyed just prior to and during freeze-up in the fall of 1980.

The reach above Devils Canyon consisted of 23 cross-sections of the Susitna River. This reach extended from the confluence with Devil Creek (about 23 miles downstream from the proposed Watana Dam site) to the confluence with Deadman Creek (about 2 miles upstream from the proposed Watana Dam site). These cross-sections were surveyed in March 1981 by drilling holes through the ice.

Water surface elevations were monitored at eight sites in the reach below Devils Canyon for flows ranging from 9,700 to 52,000 cfs as measured at the Gold Creek gage. Water surface elevations were monitored at four sites in the reach above Devils Canyon for flows ranging from 8,100 to 46,400 cfs as measured at the Watana gage. While water surface elevations were monitored at eight sites downstream from Devils Canyon and four sites above Devils Canyon, concurrent flow measurements were not made at those 12 locations. Flows were estimated at those 12 sites from flows measured at the Watana and Gold Creek gages, with a drainage area correction applied. With these measured water surface elevations and estimated flows, the HEC-2 model was calibrated to simulate water surface elevations that were mostly within plus or minus 0.5 feet of the observed water surface elevations.

The HEC-2 model that was originally developed by R&M Consultants (1982) was then modified by the Harza-EBASCO Susitna Joint Venture (1984). The focus of the work by the Harza-EBASCO Susitna Joint Venture was on the reach below Devils Canyon. The length of this reach was extended downstream to Sunshine Gage, and the total number of cross-sections was increased from 66 to 107. The HEC-2 model developed by the Harza-EBASCO Susitna Joint Venture was then recalibrated to simulate water surface elevations that were mostly within plus or minus 0.5 feet of the observed water surface elevations.

3.2. USGS Hydrologic Records

Available stage and flow measurements were obtained from the U.S. Geological Survey (USGS) for the following gaging stations:

- Susitna River at Cantwell, USGS 15291500
- Susitna River above Tsusena Creek, USGS 15291700
- Susitna River at Gold Creek, USGS 15292000
- Chulitna River near Talkeetna, USGS 15292400
- Talkeetna River near Talkeetna, USGS 15292700
- Susitna River at Sunshine, USGS 15292780
- Yentna River near Susitna Station, USGS 15294345
- Susitna River at Susitna Station, USGS 15294350

The locations of these gaging stations are show in Figure 3.2-1. Available data from these eight gaging stations were used to synthesize flows in the Susitna River at the proposed dam site and to calculate downstream lateral inflows for both the calibration period used for the Open-water Flow Routing Model (July 28 to August 3, 2013) and for the 61-year period of record adopted for this project (October 1, 1949 to September 30, 2010).

4. OPEN-WATER FLOW ROUTING MODEL DEVELOPMENT PROCESS

Results and documentation of Version 1 of the Open-water Flow Routing Model were completed in January 2013 (R2 et al. 2013). This version of the model extended from the Dam Site at PRM 187.2 downstream to PRM 80.0 (about 23 miles downstream from the confluence with the Chulitna River). Version 1 of the model relied on data collected during the 2012 summer field season and included data from 88 surveyed river cross-sections. For numerical stability under unsteady conditions, additional river cross-sections were interpolated at 1,000-foot intervals. Interpolated river cross-sections were also necessary to route flows through Devils Canyon, a 14-mile-long reach of the Susitna River where for safety reasons no cross-sections were surveyed. The model was calibrated under steady-state conditions using 170 pairs of flow/water surface elevations available at the 88 cross-sections. Flow hydrographs measured in 2012 by the USGS were used to calibrate the flow routing model under unsteady-state conditions for the period from August 11-17, 2012 when significant diurnal fluctuations were observed in the USGS gages above Tsusena Creek, at Gold Creek, and at Sunshine. Ungaged lateral accretion flows were estimated using the difference between USGS gage data and by accounting for travel time through the Susitna River. The model was used to assess potential project impacts during an average year (January 1, 1984 to December 31, 1984). Hourly flow records were not available for this period and no attempts were made to account for diurnal glacial melt fluctuations in Version 1. During this average year, it was assumed that there was no ice cover during the flow routing simulations. Results obtained during ice-affected conditions may differ from the results obtained from these simulations.

Version 2 of the Open-water Flow Routing Model was completed in 2014 and is documented herein. This version of the model relies on river cross-sections surveyed in 2012 and 2013, on 383 flow/water surface elevation pairs, and on LiDAR surveys of the floodplain in 2011. The model was extended downstream from PRM 80.0 to PRM 29.9. Results from Version 1 of the model showed that project effects were still observed at the lower extent at PRM 80.0. As a result, the decision was made to extend the model further downstream. PRM 29.9 was selected since this location has a USGS gage, which would be necessary for model calibration, and locations further downstream would be affected by tidal fluctuations. This change required gage data from two additional USGS gaging stations, Yentna River near Susitna Station and Susitna River near Susitna Station, to be used in calibration and validation. Similar to Version 1, the Devils Canyon bathymetry was estimated. Cross sectional data were extended into the floodplain at all transects using the overbank geometry derived from the Matanuska-Susitna (MatSu) LiDAR mapping collected in 2011 and indexed to the NAVD88 (feet) in 2013. Lateral tributary inflows were calculated based on drainage area for 60 individual subbasins. Hourly flow records for the 61-year period of record were obtained for gages and periods when they were available. While hourly diurnal fluctuations have not been estimated for remaining gages and periods, they are planned to be available in 2014. Version 2 of the model is not applicable during ice-covered conditions, which has been defined from October 28^{th} through May 22^{nd}.

Version 3 of the Open-water Flow Routing Model will be completed in 2015. This submittal will be the final version and will include additional transect and Q-WSE pair data collected in 2014, revisions to tributary lateral inflows based on streamflow gaging data, LiDAR data collected in 2014, and incorporation of diurnal fluctuations. Table 4-1 summarizes the three versions of the model and their similarities and differences.

5. METHODS

5.1. Mainstem Field Data Collection

Over the three field seasons (2011, 2012, and 2013), several types of field data have been collected on the mainstem of the Susitna River. They have been divided into three groups:

1) ESS Transects and Stage Recording Measurements (2012 and 2013)
2) Bathymetry-WSE Transects (2012 and 2013)
3) Q-WSE-Bathymetry Transects (2012 and 2013)
4) LiDAR surveys (2011 and 2013)

The methods for these field efforts are slightly different between the two years and can be found in the following documents:

- ISR Section 8.5.4.3 Hydrologic Data Analysis
- ISR Section 8.5 Appendix A (Hydrologic Methods)
- ISR Section 8.5 Appendix C (Moving Boat ADCP Measurements)

- R2 et al. 2013 Appendix 1 – WR-S1 Reservoir and River Flow Routing Model Transect Data Collection Study

The detailed methodologies from each of these documents are not repeated in the subsections below, but the type of data is summarized briefly.

5.1.1. ESS Transects and Stage Recording Measurements

Together with water temperature and meteorological data, continuous stage measurements were recorded at AEA hydrology stations at 15-minute intervals and made available to studies via the real-time reporting data network. Periodic water elevation surveys were conducted along with discharge measurements. The water levels allow the conversion of the pressure transducer data to surface-water elevation in Project vertical datum standards. The hydrology stations were operated throughout the year to support both summer (open-water) and winter (ice-cover) study needs for the IFS and other studies.

5.1.2. Q-WSE-Bathymetry Transects

Streamflow, water surface elevation, and bathymetry data were collected on many mainstem transects in both 2012 and 2013. Cross-sections of the Susitna River were surveyed between PRM 29.9 and PRM 187.2. Methods for collecting the 2012 field data are described in Appendix 1 of the R2 et al. 2013 report and methods for collecting the 2013 field data are described in ISR Study 8.5, Appendix C (Moving Boat ADCP Measurements). The open-water flow routing model relied on the flow measurements and concurrent water surface elevation surveys at the river cross-sections. The Q-WSE pairs collected are provided in Table 5.1-1. This table summarizes all available Q-WSE pairs by low, medium, and high flows and by PRM. There are 383 Q-WSE pairs available with 214 from measured Q-WSE data. The remaining pairs are discussed in the section below.

5.1.3. Bathymetry-WSE Transects

In some cases, only bathymetry and WSE data were collected at mainstem cross sections. Similar to the other mainstem cross sections referenced above, methods are described in Appendix 1 of the R2 el al. 2013 report and ISR Study 8.5, Appendix C (Moving Boat ADCP Measurements). When Bathymetry-WSE only data were collected, streamflow was estimated from the flow measurement of a nearby transect collected on the same day or from USGS gage data. Of the 383 Q-WSE pairs available, 169 were from bathymetry/WSE only transects where the Q was estimated. It should be noted that in some cases Q-WSE-bathymetry data were collected at a transect, while on another date only WSE-bathymetry data were collected. The estimated Q-WSE pairs are also provided in Table 5.1-1.

5.2. Tributary Gaging Data Collection

Twelve tributary gaging stations were installed at selected tributaries in 2013 to provide additional data for hydrologic and fisheries studies. Ten of the twelve stations have continuous recording pressure transducers and two had spot discharge measurements collected. Details concerning the installation, monitoring, and data analysis procedures of the tributary gages are presented in ISR Study 8.5, Appendix A.

5.3. Winter Gaging Data Collection

5.3.1. Tributary Measurements

5.3.1.1. Dye dilution discharge measurements

Dye dilution measurements were performed on Skull Creek on January 20 and April 20, 2014, as well as at Gash Creek on January 26, 2014. The dye dilution measurements were performed by injecting a known quantity of dye and measuring dye concentrations downstream of a mixing zone. A 4.8% solution of Sulphorhodamine B was used as the tracer, in slugs ranging from four to eight milliliters (ml) each. The dye slugs were mixed with 5 gallons of stream water before injection. Dye concentrations were measured using a GGUN-FL24 fluorometer manufactured by Albilia Co. of Neuchatel, Switzerland. The fluorometer measures dye concentrations based on fluorescence upon exposure to monochromatic light. Turbidity and organics interfere with the light source, decreasing the instrument's sensitivity.

The fluorometer was calibrated by recording the fluorescence signal in a 50 ug/L solution of stream water at stream temperature. The 50 ug/L solution was prepared using serial dilutions prepared with a pipette and a volumetric flask. After calibrating the instrument, the background signal was recorded, followed by slug injection. Slug injection was repeated after the fluorescence signal returned to background.

Discharge was calculated by equating the injected mass of dye with the integral of concentration vs. time. After subtracting the background signal, dye concentration is calculated from the fluorescence signal based on the instrument's response to the 50 ug/L calibration standard. An Excel spreadsheet was used to perform the discharge calculations.

5.3.1.2. Volumetric method

One tributary, Slash Creek, was measured using the volumetric method on January 22 and April 1, 2014. The tributary was measured at a perched culvert. A bucket was inserted below the culvert to catch the flowing water and the time to fill the bucket was recorded. Several measurements were made and the discharge was calculated as the volume divided by the time to fill.

5.3.1.3. Current meter method

The remaining tributaries were measured using a current meter during the periods January 18-27, and March 22-April 3, 2014. Discharge measurements were performed using Price AA current meters deployed on sectional rods through 8-inch ice auger holes if ice was present. All stations, depths, times, and meter revolutions were recorded on Aquacalc Pro Plus dataloggers. After entering the station, depth, and ice draft, the Aquacalc computes sectional rod depth settings corresponding to 20, 60, and 80 percent of the effective depth (0.2D, 0.6D, and 0.8D, respectively). Where the effective depth was greater than 2.5 feet, the velocity was measured at both 0.2D and 0.8D. Where the effective depth was less than 2.5 feet, velocities were only measured at 0.6D. An ice correction factor of 0.92 was used to adjust the velocity for those measurements conducted under ice at 0.6D. An ice correction factor was not used for measurements conducted in open-water or for those measured at the 0.2 depth and 0.8 depth locations (Rantz 1982).

5.3.2. Mainstem Discharge Measurements

Mainstem discharge measurements were conducted on January 23-24 and March 27-April 1, 2014. The January measurements included four gaging stations between Devils Canyon and the three rivers confluence (ESS40, 45, 50, and 55). In addition to these four stations, the March/April measurements included two stations above Devils Canyon (ESS65 and 70). Although the March/April measurements were co-located with January measurements at ESS45 and ESS55, an intermediate layer of broken ice precluded co-located measurements at ESS50. Ice degradation and flooding precluded co-located measurements at ESS40, but a nearby location was selected by USGS for a March 27 ADCP measurement (USGS No. 15292100). After re-drilling the auger holes, the April 1 ESS40 measurement was performed at the USGS measurement location. A partial measurement was completed at the January ESS50 location before broken ice compromised instrument retrieval. As a result, the March ESS50 measurement was relocated about 500 feet upstream of the January measurement location.

The January measurements followed a week of unseasonably warm temperatures resulting in snowmelt and expansion of open-water leads on the mainstem Susitna. In many cases, open velocity leads were connected by depressed areas of thin ice with swift flow underneath. Ice drilling results indicated that beneath the surface ice layer, more than half of the cross-section was occupied by frazil, and that flow was concentrated in narrow conduits. Depressions in the ice surface suggested that the conduits formed at higher flow, and that the ice surface sagged as flow declined underneath. Co-located cross sections indicate that most of the frazil remained stationary between January and March, while ice surface elevations declined by as much as 2.5 feet. Minor erosion of the frazil margins is apparent at all three co-located sections, which may have caused a slight change in flow angle at ESS45.

Discharge measurements were performed using Price AA current meters deployed on sectional rods through 8-inch ice auger holes. All stations, depths, times, and meter revolutions were recorded on Aquacalc Pro Plus dataloggers. After entering the station, depth, and ice draft, the Aquacalc computes sectional rod depth settings corresponding to 20, 60, and 80 percent of the effective depth (0.2D, 0.6D, and 0.8D, respectively). Because many of the vertical velocity profiles were asymmetrical, velocities were usually recorded at all three depths. Where the effective depth was less than 2.5 feet, velocities were only measured at 0.6D.

Upon completing river-wide velocity measurements, the Aquacalc logger computes the proportion of flow in each partial vertical section. Based on these results, additional holes were drilled between partial vertical sections containing more than 10% of the total flow.

In addition to water surface elevations at the gaging stations, the location and elevation of each auger hole was surveyed using RTK GPS methods. The depth of solid ice and frazil were measured with the sectional rod, using the current meter to confirm zones of flowing water.

The Aquacalc logger computes velocity using linear rating equations for various meters. The slope of the polyethylene bucket rating equation is 2.145, and the offset is 0.02 (USGS 1985). These coefficients are specified in the Aquacalc logger files, as well as depths, meter revolutions and measurement times. If flow is irregular or the electrical connection is faulty, no velocity will be recorded. For three measurements at ESS45 on January 24, 2014, manual meter readings (revolutions vs. time) were required due to signal interference.

The Aquacalc depth and velocity data were exported to Excel for discharge computations and database entry. Errors such as missing velocities and blocked verticals were added from the field notes. The average velocity for each partial vertical section was computed as:

$$v = \frac{C_{ice} * v_{0.6} + \frac{v_{0.2} + v_{0.8}}{2}}{2}$$

where: C_{ice} = ice correction factor for the 0.6D depth (0.92)

As recommended by Rantz (1982), an ice correction factor of 0.92 was applied to the 0.6D velocity measurements. If no ice was present, the ice correction factor was set to 1.0.

5.4. Open-water Flow Routing Model

5.4.1. Model Inputs

5.4.1.1. Cross Sections

A combination of data sources were utilized to construct cross sections for the Open-water Flow Routing Model. Cross sections can be broken down into “in-channel” and “overbank” portions. The in-channel cross sectional geometry consists of the wetted river channel itself plus the adjacent riverbanks, just extending into the floodplain. Overbank geometry generally refers to the river floodplain, extending up the valley walls far beyond any potential flood elevations.

5.4.1.1.1. In-Channel Geometry

The in-channel geometry was derived by data collected by Brailey Hydrologic and Geovera during the 2012 and 2013 field seasons. Brailey Hydrologic collected the underwater bathymetry from ADCP and/or bathymetric depth sounder measurements. Geovera measured the remaining (dry) portions of the within-channel profile using RTK surveying methods, along with the water surface elevation. Geovera then merged the wetted and dry survey data together to create a full collection of points for each cross sectional profile. These points were then aligned and projected to the Open-water Flow Routing Model transect lines, and a horizontal distance (station) value was calculated and assigned to each point. This results in each cross section defined by ordered pairs of station and elevation points, as shown in Figure 5.4-1. The left and right side of each cross-section is based on looking in the downstream direction.

For the majority of cross sections that have split (or side) channels, the water surface elevation of the main channel differed from the secondary channels. One-dimensional flow routing models assume a flat water surface across a cross section, and thus cannot account for these differences. Therefore, to properly simulate the conveyance of water in the HEC-RAS model, transects with multiple channels had to be altered in order to maintain the correct cross sectional flow area. This was accomplished by shifting the water surface and bathymetry in the secondary channels up or down in order to match the water surface in each secondary channel with the water surface elevation of the main channel, with each secondary channel receiving a unique shift. Most often, only the wetted portion of a secondary channel required shifting. However, there were cases where the shifting of secondary channels was large enough to significantly and erroneously alter the dry topography of a transect. In this case, other portions of the transect were shifted appropriately to maintain a realistic cross sectional profile. Figure 5.4-2 shows an example cross section that required shifting of both underwater bathymetry and dry topography. Of the 167 total cross sections, 81 required a shift to the wetted bathymetry of the side channel(s), 27 required shifting to both wetted bathymetry and dry topography, and 59 required no shifting.

5.4.1.1.2. Overbank Geometry

The overbank geometry was derived from the Matanuska-Susitna (MatSu) LiDAR mapping collected in 2011 and indexed to the NAVD88 (feet) in 2013. These data were merged with the field-surveyed geometry by Tetra Tech. Each surveyed point was projected onto the transect line and a horizontal station value was determined. The merged geometry at each cross section was carefully reviewed to ensure (1) all appropriate surveyed points were included, (2) alternate alignments or extraneous points were excluded, (3) transitions between the surveyed points and the LiDAR-derived points were reasonable, and (4) projections, particularly near dog-legs in the cross sections were appropriate. In the process of merging, Tetra Tech filtered some of the in-channel points.

Since the Open-water Flow Routing Model focuses mainly on within-channel streamflows, it was important to maintain the integrity of the within-channel geometry. As a result, R2 did not adopt the merged Tetra Tech cross section, but instead decided to merge the full in-channel cross sectional profile (as described above) with a filtered LiDAR profile.

In most instances, the number of points of the R2 merged cross section exceeded the maximum possible geometry points that can be included in HEC-RAS. As a result, the LiDAR imagery had to be filtered down to a fewer number of points. To do this, R2 used the cross section points filter program within HEC-RAS. This program filters the cross sectional points to a user specified number based on minimizing the change in cross sectional area. This filtering method drops out one point at a time until the cross section is down to the user-desired number of points. The decision process for dropping a point is to find the point in the cross section that will cause the area of the cross section to change the least (USACE 2010a).

In general, R2 adopted Tetra Tech's cut line and compared the final R2 merged cross section with the Tetra Tech cross section to make sure they were consistent. There were a few instances where the cross section was slightly different due to different methods of merging the in-channel and overbank profiles, but in general, cross sections were the same. An example merged cross section is shown in Figure 5.4-3.

5.4.1.1.3. Devils Canyon

For reasons of safety, no mainstem transect data were collected in the Devils Canyon reach (PRM 154.6-166.9). Instead, cross sectional profiles were estimated using the 2011 LiDAR topography data and a rectangular conveyance channel provided by HDR. The size of the rectangular channel was calculated using Manning's equation and assumptions of the flow, water surface elevation, and Manning's n on the date of the LiDAR images. An example cross sectional profile created for PRM 164.9 located within the Devils Canyon reach is provided in Figure 5.4-4.

5.4.1.2. Hydrology

5.4.1.2.1. Hydrologic Record and Representative Years

Efforts in 2012 already established the 61-year period extending from Water Years 1950 through 2010 (October 1, 1949 to September 30, 2010) as the hydrologic period of record for the Project. This record was based on a series of USGS gages in the Susitna River Basin that were measured over different time periods which were extended to cover the 61-year period by synthesizing the missing daily flow records to fill in the gaps (Curran 2012). The HEC-RAS model was also set up to simulate conditions over this same period.

Work was also completed in 2013 on selecting representative years to reflect wet, average, and dry conditions and warm and cool Pacific Decadal Oscillations (ISR Study 6.6 Appendix E Evaluation of 50-year Simulation Period, Pacific Decadal Oscillation, and Selection of Representative Annual Hydrographs). For Version 2 of the Open-water Flow Routing Model, two representative years were used for evaluation of Post-Project conditions. These include water years 1976 (dry) and 1981 (wet). In order to capture a full spawning incubation cycle, a 15-month period was simulated starting three months prior to the beginning of the water year (i.e., July 1, 1975 to September 30, 1976 and July 1, 1980 to September 30, 1981).

5.4.1.2.2. Mainstem

The HEC-ResSim model was used to simulate flow and stage hydrographs downstream from the Watana Dam site under Pre-Project and Post-Project conditions (MWH 2014). The Post-Project condition is referred to as the Maximum Load Following Operations Scenario 1b (OS-1b). It is based on the assumption that the entire load fluctuation of the entire Railbelt would be provided by the Susitna-Watana Project, and that 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. OS-1b is similar to OS-1, but was extended to the 61-year period of record where previously OS-1 was only simulated for water year 1984. In addition, this scenario includes a dry water year rule curve that reduces generation in dry years. It also includes eight fixed-cone outlet valves each at 4,000 cfs for a total of 32,000 cfs. Finally, an updated reservoir storage-elevation curve was used to create OS-1b.

The two scenarios (i.e., Pre-Project and OS-1b) represent different flow hydrograph releases from Watana Dam and were used as input to the flow routing model (Figure 5.4-5). With the Maximum Load Following OS-1b, higher flows would generally be released during winter, and lower flows would be released during the spring and summer until the reservoir fills to capacity. During periods when the reservoir is not full, flow releases with Maximum Load Following OS-1 would exhibit daily and weekly flow fluctuations in response to power generation requirements.

5.4.1.2.3. Flows in Susitna River at the Dam Site

Daily flows in the Susitna River at the dam site were estimated for the 61-year period of record from daily flows in the Susitna River at Gold Creek (drainage Area = 6,160 square miles) and from daily flows in the Susitna River at Cantwell (drainage Area = 4,140 square miles). Daily flows at the dam site (drainage area = 5,180 square miles) were estimated through drainage area interpolation. The daily flows were then converted to hourly flows in a manner as illustrated in Figure 5.4-6. With the hourly flow hydrograph, the daily average was preserved each day, and the hourly flow hydrograph was smooth and continuous.

5.4.1.2.4. Lateral Inflows

Downstream lateral inflows were calculated first on a daily basis, and then on an hourly basis in a manner as illustrated in Figure 5.4-6. With the hourly flow hydrograph, the daily average was preserved each day, and the hourly flow hydrograph was smooth and continuous. Historical hourly flow records from USGS gaging stations were incorporated when and where they were available. For periods and locations where they were not available, potential diurnal flow fluctuations were not synthesized in this version of the hydrology.

The accretion calculations relied on daily flow records for the 61-year period of record for three USGS gages on the Susitna River and three USGS gages on tributaries to the Susitna River. Daily flow hydrographs for these gages for the two representative simulation periods (i.e., 1976 and 1981) are provided in Figures 5.4-7 and 5.4-8. Figure 5.4-7 presents the three gages on the mainstem while Figure 5.4-8 presents the three gages available for the tributaries.

Daily accretion was calculated for three sections of the Susitna River: from the Dam Site to Gold Creek gage; from Gold Creek gage to Sunshine gage; and from Sunshine gage to Susitna Station gage. In some cases, gage data either did not add up or did not make sense. For example, sometimes flow at Sunshine gage was smaller than the sum of the upstream gages (i.e., Susitna River at Gold Creek, Talkeetna River, and Chulitna River).

During the month of July 1967, the average flow at Sunshine gage was 66,600 cfs. The combined flow from the Susitna River at Gold Creek, the Chulitna River, and the Talkeetna River was 75,000 cfs. The total ungaged tributary inflow was 8,400 cfs. So, a method was devised to prevent the generation of negative accretion flows.

In the reach from the dam site to Gold Creek gage, the daily flows at the dam site and at Gold Creek gage were used to derive the coefficients a and b on a monthly basis for the following equation:

$$Q_{dam\ site} = a * {Q_{Gold\ Creek}}^{b}$$

The monthly coefficients a and b are shown in Table 5.4-1. The total daily accretion flow in this reach was then calculated as follows:

$$Q_{ungaged\ accretion} = Q_{Gold\ Creek} - a * {Q_{Gold\ Creek}}^{b}$$

This equation was used to derive daily accretion flows in the reach from the dam site to Gold Creek gage from the daily flows at Gold Creek gage.

In the reach from Gold Creek gage to Sunshine gage, long term average monthly accretion flows were calculated from the 61-year period of record using the following equation:

$$Q_{ungaged\ accretion} = Q_{Sunshine} - Q_{Gold\ Creek} - Q_{Chulinta} - Q_{Talkeetna}$$

The long-term average monthly accretion flows were divided by long-term average monthly flows at Gold Creek gage to derive monthly flow ratios (f_r). Monthly flow ratios are listed in Table 5.4-1. The monthly flow ratios were converted to daily flow ratios (shown in Figure 5.4-9) to allow a continuous transition from the end of one month to the beginning of the next month.

Daily ungaged accretion flows in the reach from Gold Creek gage to Sunshine gage were determined from the daily flows at Gold Creek gage using the following equation:

$$Q_{ungaged\ accretion} = f_r\ Q_{Gold\ Creek}$$

Similarly, in the reach from Sunshine gage to Susitna Station gage, long-term average monthly accretion flows were calculated from the 61-year period of record using the following equation:

$$Q_{ungaged\ accretion} = Q_{Susitna\ Station} - Q_{Sunshine} - Q_{Yentna}$$

The long-term average monthly accretion flows were divided by long term average monthly flows at Sunshine gage to derive monthly flow ratios (f_r). Monthly flow ratios are listed in Table 5.4-1. The monthly flow ratios were converted to daily flow ratios to allow a continuous transition from the end of one month to the beginning of the next month. Daily ungaged accretion flows in the reach from Gold Creek gage to Sunshine gage were determined from the daily flows at Gold Creek gage using the following equation:

$$Q_{ungaged\ accretion} = f_r\ Q_{Sunshine}$$

Once the total ungaged accretion within each reach was estimated, it was distributed to multiple subbasins based on the drainage area of each subbasin. Lateral inflows were calculated for 25 subbasins within the lower section, for 15 subbasins within the mid section, and for 19 subbasins within the upper section. The daily values for each subbasin were then converted to hourly values using the same method as illustrated in Figure 5.4-6. Wherever possible, measured values were incorporated into the synthesized values. The only measured data available for any of the 59 subbasins was for the Talkeetna River (USGS 15292700) between 1992 and 2010. 15-minute data were available from USGS for select periods between 1992 and 2010 (mainly summer months) for this site. Hourly data were extracted from the 15-minute data and then used in place of the synthesized data. The hourly lateral inflows for all subbasins were made available to other resource studies.

In order to reduce the effort of incorporating the lateral inflows from all 59 subasins into the HEC-RAS model, the hourly flow records were combined and reduced to 13 reaches. Table 5.4-2 summarizes each of these reaches and includes information on the number of subbasins, the associated PRMs, and how the lateral inflows for the reach were incorporated into the Open-water Flow Routing Model. The lateral inflows were incorporated either as a tributary or as a uniform lateral inflow that is distributed proportional to PRM from one point to the next. Figures 5.4-10 through 5.4-12 show the lateral inflows by reach for each of the two representative years evaluated. Version 3 of the Open-water Flow Routing Model will incorporate adjustments to these lateral inflows based on gage data collected in 2013 and 2014.

5.4.1.3. Roughness Coefficients

Another input into the HEC-RAS model is the Manning's *n* roughness coefficient. The selection of an appropriate Manning's n is important to the accuracy of the computed water surface profiles. The value of Manning's n is highly variable and depends on a number of factors including surface roughness; vegetation; channel irregularities; channel alignment; scour and deposition; obstructions; size and shape of the channel; stage and discharge; seasonal changes; temperature; and suspended material and bedload (USACE 2010b).

Manning's *n* needs to be specified for each cross section. Site photographs as well as other field data are used to select an appropriate value. If necessary, the HEC-RAS model has the capability of automatically varying Manning's "n" with stage by the equivalent roughness option, as well as the capability of varying Manning's "n" on a seasonal basis.

5.4.1.4. Expansion/Contraction Loss Coefficients

The Manning's n roughness coefficient is used by HEC-RAS to account for frictional loss coefficients. Another form of energy loss is associated with expansion or contraction. The default values for expansion and contraction in HEC-RAS are 0.3 and 0.1, respectively.

5.4.2. Model Development and Calibration

Steady state flow models are used to estimate flow and water surface elevations in a river system provided that flows are stable or changing relatively slowly. For instance, a steady state model can be used to calculate daily flows at downstream locations or when modeling daily habitat time series as part of an instream flow study. However, if flows are fluctuating on an hourly basis, an unsteady flow model is needed to accurately represent how downstream reaches of a river will respond to upstream flow changes. For instance, determining flow and water surface elevations at downstream locations must take into account the travel speed and attenuation of the downstream wave caused by a hydropower project operating in load-following mode. If a downstream tributary exhibits hourly flow fluctuations because of glacial runoff, an unsteady flow routing model is needed to integrate the hourly tributary fluctuations into hourly mainstem flow fluctuations downstream of the tributary confluence.

The foundation of the Instream Flow Study (IFS) analyses rests with the development of the Susitna River Mainstem Flow Routing Models (MFRM) (HEC-RAS, Ice Processes Model) that will provide hourly flow and water surface elevation data at numerous locations longitudinally distributed throughout the length of the river downstream of the proposed dam site.

A longitudinal thalweg profile of the Susitna River was developed from the 167 cross-sections that were surveyed in 2012 and 2013 (Figure 5.4-13). The channel gradient was steepest through Devils Canyon (0.6%). Downstream from Devils Canyon there is a gradual reduction in channel gradient as would be expected.

5.4.2.1. Steady-State Model Calibration

The HEC-RAS flow routing model was first calibrated under steady-state conditions using over 375 pairs of flow/water surface elevation measurements/estimates obtained at the 167 transects collected in 2012 and 2013. The relative magnitude of these flow measurements was assessed by using the concurrent flows in the Susitna River at Gold Creek (USGS 15292000) and Susitna River at Sunshine (USGS 15292780) as a common reference point (see Figures 5.4-14 and 5.4-15). Transects upstream of PRM 102.5 were assessed using the Susitna River at Gold Creek gage as shown in Figure 5.4-14 while transects downstream of PRM 102.5 were assessed using the Susitna River at Sunshine gage as shown in Figure 5.4-15. Flows at transects compared to the Susitna River at Gold Creek were considered high if the flow was greater than 24,000 cfs, medium if they were between 17,700 cfs and 24,000 cfs, and low if they were less than 17,700 cfs. Flows at transects compared to the Susitna River at Sunshine Gage were considered high if the flow was greater than 60,600 cfs, medium if they were between 45,500 cfs and 60,600 cfs, and low if they were less than 45,500 cfs.

In all, there was good coverage at low, medium, and high flows for the transects in the upper section that were compared to the Susitna River at Gold Creek gage. In this section, all three flows had 80-83% of the flows measured or estimated. There was excellent coverage in the mid flow range for transects in the lower section that were compared to the Susitna River at Sunshine gage. In this section, the mid range flow had 94% of the flows measured or estimated while the low and high flow ranges had only 56-57% of the flows measured or estimated.

In 2012, the cross-sections were measured during three field trips intended to capture high-flow, medium-flow, and low-flow conditions. The first two trips were intended to measure medium and high flow conditions during late June-early July and August, but rapidly changing flows made it difficult to predict the timing of target flow conditions. The low-flow trip that began on September 14 was interrupted by a 25-year flood event that required evacuation of the field team on September 20. Work resumed on September 29, but was suspended on October 6 when a second late fall storm resulted in unseasonably high flows. A final attempt commenced on October 15, but abundant river ice and slush pans precluded accurate flow measurements.

Additional data were collected throughout the field season in 2013 to fill in any data gaps and to extend the model downstream to PRM 29.9. A very high spring flood occurred in June 2013. For this event, the streamflow at Susitna River at Gold Creek (Gage #15292000) reached 90,700 cfs on June 2, 2013.

The HEC-RAS model was calibrated under steady-state conditions. Under the subcritical flow conditions found in the Susitna River, the water surface elevation at a given cross-section is controlled primarily by the shape and water surface elevation of the next downstream cross-section, and to a lesser extent by roughness coefficients (Manning's n) and expansion/contraction loss coefficients.

If the Devils Canyon reach is excluded, the Susitna River drops about 1,030 feet in elevation between the dam site and Susitna Station Gage. The average drop in elevation between consecutive surveyed cross-section is 6 feet. This drop in elevation is relatively large. The HEC-RAS model has a QA/QC feature that checks the difference in elevation between consecutive cross-sections. If the difference exceeds 1 foot, the model suggests that the addition of interpolated cross-sections should be considered.

With this in mind, and for reasons of numerical stability under unsteady flow conditions, cross-sections were interpolated at distances of about 1,000 feet apart. If Devils Canyon reach is excluded, a total of 703 cross-sections were interpolated in the model. With these additional cross-sections, the average drop in elevation between consecutive cross-sections was about 1 foot.

At the downstream end of the study reach (PRM 29.9), the boundary condition was based on the stage/discharge rating curve of the Susitna River at the USGS gage at Susitna Station. Unsteady flow calibration progressed in the downstream to upstream direction. At each cross-section the Manning's n roughness coefficient was adjusted within the main channel portion of each cross section within the range shown in Figure 5.4-16, with the goal of matching surveyed water surface elevations to within 0.2 feet (approximately the level of accuracy needed for fish habitat analyses). If this level of accuracy could not be obtained by adjusting Manning's n, then a hydraulic control cross-section was inserted 1,000 feet downstream from the cross-section by copying the cross-section, and adjusting the elevation and width of the inserted cross-section as necessary to meet the calibration goal. Additional interpolated cross-sections were interpolated automatically at 1,000-foot intervals. During this process, no modifications were made to the actual surveyed cross-sections.

Higher Manning's n roughness coefficients, ranging from 0.04 to 0.05, were assumed in Devils Canyon in the mains channel portion of each cross section to account for increased roughness in this portion of the Susitna River. While calibration flows were not high enough to inundate the adjacent floodplain, Manning's n was assumed to be 0.07 in the left and right overbank portions of each cross section for this version of the open-water flow routing model. Expansion/contraction loss coefficients were assumed to be 0.3 and 0.1, respectively, at all of the cross sections

To illustrate this process, the calibration at PRM 186.2 is shown herein. The initial step in calibration was to adjust Manning's n within the range shown in Figure 5.4-16. This range shows a trend of increasing Manning's n associated with steeper gradients in the upstream direction of the Susitna River. A best-fit calibration using Manning's "n" (with no interpolated cross-sections) is shown in Figure 5.4-17. At the highest measured flow, the simulated water surface elevation is about 1 foot higher than the surveyed water surface elevation. This level of accuracy would not be suitable for fish habitat analyses.

The simulated water surface elevation was higher than the observed water surface elevation at the highest measured flow, and the simulated water surface elevation was lower than the observed water surface elevation at the lowest measured flow. This suggests that there is a wide hydraulic control cross-section between the surveyed cross sections at PRM 186.2 and 185.5. The aerial photograph in Figure 5.4-18 shows that the river is wider in between the cross-sections at PRM 186.2 and 185.5.

To improve the calibration and obtain the level of accuracy needed for fish habitat studies, a hydraulic control cross section was inserted 1,000 feet downstream from the surveyed cross section at PRM 186.2. The hydraulic control cross section was constructed by copying the cross-section at PRM 186.2. The copied cross-section was then increased in elevation by 2.6 ft, and increased in width by a factor of 2.0, using features built in to the HEC-RAS model. This synthesized cross section is shown in Figure 5.4-19. Additional interpolated cross sections were added between the synthesized cross section and the surveyed cross section at PRM 185.5. During this process, no modifications were made to the surveyed cross sections at PRM 186.2 and 185.5. Results of process are shown in Figure 5.4-20. The simulated water surface elevation match the surveyed water surface elevation to within 0.2 ft, suitable for fish habitat analyses. The model was calibrated to this level of accuracy for flows up to 24,500 cfs. This flow was measured on June 18, 2012. The corresponding flow at Gold Creek gage was 32,800 cfs, a flow that is exceeded 4% of the time.

A similar procedure was followed at PRM 140.0, located about 100 feet upstream from Gold Creek gage, as shown in Figure 5.4-21. The surveyed water surface elevations were slightly higher than the water surface elevations from the USGS stage/discharge rating curve at Gold Creek gage, as would be expected. Initial attempts to calibrate the model at PRM 140.0 suggested that a wide hydraulic control cross-sections would be needed. After adding this hydraulic control, the simulated water surface elevations matched the observed water surface elevation to within 0.2 feet, and the shape of the simulated stage/discharge rating curve was similar to the shape of the USGS stage/discharge rating curve at Gold Creek gage. The model was calibrated to this level of accuracy at PRM 140.0 for flows up to 30,400 cfs, a flow that is exceeded about 5% of the time.

5.4.2.2. Unsteady-State Model Calibration

Flow hydrographs measured in 2013 by the U.S. Geological Survey were used to calibrate the flow routing model under unsteady-state conditions. The locations of these gaging stations are shown in Figure 3.2-1 and include the seven gages described in Section 3.2. Hydrology data for the period from July 28 to August 3, 2013 were selected for model calibration. This period was selected because there was a distinct pattern of diurnal flow pulses associated with glacial melt. Flows from this period are provided in Figure 5.4-22 for the mainstem sites and Figure 5.4-23 for the tributary sites.

In order to calibrate the model, accretion estimates were calculated for the calibration period (July 28 to August 3, 2013). Similar to the 61-year accretion calculations described above, accretion for the calibration period was calculated for the sections of the river from the Dam Site to Gold Creek, Gold Creek to Sunshine, and Sunshine to Susitna Station. However, for the calibration period, accretion calculations were done slightly differently for each of these three sections. In general, the flow from the upper location to the lower location was routed through the HEC-RAS model assuming no accretion. The difference between the flows measured at the USGS gage at the downstream end of each reach and the flows routed from the upstream end of each reach to the downstream end of each reach using the HEC-RAS model was used to calculate accretion at the lower end of the section as well as travel times between different locations. A summary of the travel times extracted from the HEC-RAS model and used the analyses is provided in Table 5.4-3. Specific calculations for each of the three reaches between the major gages are provided below.

The accretion between the Dam Site and Gold Creek was calculated by using the HEC-RAS model to route the hourly flows from the Dam Site to Gold Creek assuming no accretion. The difference between the hourly flows at Gold Creek and the hourly flows for the Dam Site routed to Gold Creek was assumed to be the accretion in this section. This accretion was apportioned to each of the subbasins based on drainage area and lumped into the same reaches as outlined in Table 5.4-2. A travel time shift was applied to the accretion value for each reach to move the flows from the Gold Creek location where they were predicted to the mid-point of the reach where they were incorporated into the model. Similar to the 61-year accretion methodology, lateral inflows were incorporated into the HEC-RAS model as either a tributary point source or a uniform lateral inflow. The lateral inflows for reaches 1 and 2 located within in the section from the Dam Site to Gold Creek both before and after the travel time shifts are provided in Figure 5.4-24. These ungaged accretion hydrographs have diurnal fluctuations, similar to the measured flows on the mainstem Susitna River.

The accretion between Gold Creek and Sunshine was calculated by using the HEC-RAS model to route the hourly flows at Gold Creek to the Sunshine location assuming no accretion. These model results were reviewed to estimate pulse travel times between different locations. Based on these travel times the hourly flows from the Chulitna and Talkeetna Rivers were routed from their gage location downstream to Sunshine. Again, because gage data did not always add up, an adjustment factor method was applied. Long-term average flows from the 61-year period of record were calculated for the Chulitna River, the Talkeetna River, and the Susitna River at Sunshine gage. These long term averages were used to determine what percentages of the total flow in the Susitna River at Sunshine comes from the Chulitna and Talkeetna rivers. These percentages were used to adjust the flow hydrographs from the Chulitna and Talkeetna rivers. The accretion between Gold Creek and Sunshine was then calculated as:

$$Q_{Sunshine} - Q_{Adj,\ Chulitna} - Q_{Adj,\ Talkeetna} - Q_{Gold}$$

These accretion values were apportioned to all of the subbasins within the section, combined into their reach groups, and shifted back upstream to the mid-point of the reach. The lateral inflows for reaches 3 through 7a located within the section from Gold Creek to Sunshine both before and after the travel time shifts are provided in Figure 5.4-25. These ungaged accretion hydrographs have diurnal fluctuations, similar to the measured flows on the mainstem Susitna River

A similar process was used to estimate accretion for the calibration period for the Sunshine to Susitna Station reach. The lateral inflows for reaches 7a through 13 located within the section from Sunshine to Susitna Station both before and after the travel time shifts are provided in Figure 5.4-26. These ungaged accretion hydrographs have diurnal fluctuations, similar to the measured flows on the mainstem Susitna River.

The total travel time from the dam site to the USGS Gage at Susitna Station is almost 2 days (46.5 hours from Table 5.4-3). The average wave speed from the dam site to Gold Creek gage is 6.9 mph. In the next reach, Gold Creek gage to Sunshine gage, the average wave speed is 3.9 mph. From Sunshine gage to Susitna Station gage, the average wave speed is 2.2 mph. While there was not much flow attenuation between the dam site and Sunshine gage, there was noticeable attenuation between Sunshine gage and Susitna Station gage. The amplitude of diurnal pulses was reduced by 50% between Sunshine gage and Susitna Station gage.

5.4.3. Model Validation

The flow routing model, calibrated under steady- and unsteady-state conditions, was then validated using the available hydrologic data set for the 1976 and 1981 simulation periods. The USGS gage data for the validation period were discussed in Sections 5.4.1.2.3 and 5.4.1.2.4. Input to the model is shown in Figures 5.4-5, 5.4-8, 5.4-10, 5.4-11, and 5.4-12. Validation consisted of comparing simulated versus measured hydrographs in the Susitna River at Gold Creek, Sunshine, and Susitna Station. Measured hydrographs at these three locations are shown in Figure 5.4-7. Flows observed in both years cover a wide range with the flows during the wet year (1981) having almost twice as much water as during the dry year (1976).

5.4.4. Assessment of Potential Downstream Stage Changes

Potential downstream changes in flow and water surface elevations were assessed by comparing Pre-Project conditions with the Maximum Load Following OS-1b conditions for calendar year 1976 and 1981. The simulated flows were obtained from MWH and were used as the boundary condition for operation of the Open-water Flow Routing Model.

6. RESULTS

6.1. Mainstem Field Data Collection

Stage hydrographs at the 13-mainstem gaging stations are provided in Figures 6.1-1 through 6.1-4. These figures are in reference to project datum and compare stage at all sites. Stage and flow hydrographs measured at the ESS gaging stations will be used in calibration and/or validation of Version 3 of the Open-water Flow Routing Model. In addition to continuous gage data, transect data were collected in both 2012 and 2013. These data are summarized in Table 6.1-1. This table provides information on the PRM, date sampled, measured WSE, measured streamflow, and any other pertinent information for each of the transects measured in 2013 and 2014. Note that the WSEs provided in the table reflect WSEs in the mainstem and represent what was used for calibration of the Open-water Flow Routing Model. Other side channel WSEs may also be available for select locations, but are not provided within.

6.2. Tributary Gaging Data Collection

In general, tributary gaging data were collected on three field visits in 2013. The data collected in 2013 is summarized in Table 6.2-1. This table includes information on the date visited, measured streamflow, and measured staff gage. Continuous pressure transducer data were also collected and will be used to develop the hourly streamflow record after the rating curves have been finalized. Rating curves will be finalized after the additional 2014 data collection is complete. The pressure transducer data and the rating curve for the site will be used to develop an hourly streamflow record. These tributary gaging data will be used to refine and improve the lateral inflow estimates used in the Open-water Flow Routing Model.

6.3. Winter Gaging Data Collection

Winter gaging data collected in January and March/April of 2014 are summarized in Table 6.3-1. This table includes the sites and dates visited, measurement method, and streamflow measurement.

During the second visit to Skull Creek for winter gaging (April 2, 2014), it was discovered that the first dye tracer measurement (January 20, 2014) was unknowingly conducted at a location of split channel flow, and neglected to measure both channels. The measurement location was moved to a single channel for the April 2, 2014 measurement. Therefore, the first measurement is biased low compared to the second.

For the mainstem discharge measurements, plots were made showing the measurement cross sections (see Attachment 1). These plots depict areas/depth of solid ice, frazil ice, and free flowing water, as well as the locations and magnitude of measured velocities.

At the ESS45 mainstem measurement site, portions of ice on the right margin of the flow area had been scoured out when the March 31 measurement was made (see Attachment 1). It appears as if this caused high flow angles along the right margin, which are not accounted for by the Price AA current meter since it records the maximum velocity regardless of flow direction. Therefore, the March 31 flow measurement is likely biased high compared to the next nearest stations (ESS40 and 50).

6.4. Open-water Flow Routing Model

6.4.1. Steady-State Model Calibration

The HEC-RAS model was calibrated under steady-state conditions to calculate water surface elevations to within plus or minus 0.2 feet of the observed water surface elevation for the transects upstream of the three rivers confluence and 0.25 feet of the observed water surface elevation for the transects downstream of the three rivers confluence. Almost all of the calculated water surface elevations fell within this target range. However, a few were slightly outside of this range.

A summary of the Manning's "n" coefficients that were used for model calibration is presented in Figure 6.4-1. The Manning's "n" coefficients ranged from 0.028 to 0.05. These values are within the range of values determined in the 1980s studies, and are reasonable values for a river as large as the Susitna River. There was a gradual trend of decreasing roughness from upstream to downstream as would normally be expected.

The HEC-RAS model was calibrated up to flows that would be exceeded about 5% of the time. The performance of the model at higher flows was assessed from measurements made during a flood that occurred in September 2012. On September 21, 2012, the flow at the USGS Gage at Gold Creek peaked at 72,900 cfs, and the corresponding water surface elevation was 697.5 ft NAVD 88. This flow would be exceeded about once every 20 years on average. The HEC-RAS cross section at PRM 140.0 is located about 100 feet upstream from the USGS Gage at Gold Creek, and water surfaces measured at this location are about 0.2 feet higher than the water surfaces measured at the USGS Gage at Gold Creek. From the HEC-RAS model, the water surface elevation at PRM 140.0 is 698.0 feet NAVD 88 when the flow is 72,900 cfs, and the corresponding water surface elevation at the USGS Gage at Gold Creek is estimated to be 697.8 feet NAVD 88, within 0.3 feet of the measured stage at the USGS Gage.

During the September 2012 flood, water surface elevations were also measured at ESS50, located at PRM 124.1. The peak recorded stage was 535.30 feet NAVD 88. The peak flow at ESS50 was estimated to be 73,900 cfs by applying a drainage ratio adjustment to the peak flow measured at the USGS Gage at Gold Creek. From the HEC-RAS model, the water surface elevation at ESS50 was estimated to be 534.8 feet NAVD 88, within 0.5 feet of the measured stage.

Water surface elevations were also measured at ESS45 (PRM 116.6) during the September 2012 flood. The peak recorded stage at this location was 474.4 feet NAVD 88. By applying a drainage ratio adjustment to the peak flow at the USGS Gage at Gold Creek, the peak flow at ESS45 was estimated to be 74,300 cfs. From the HEC-RAS model, the water surface elevation at ESS45 was estimated to be 474.3 feet NAVD 88, within 0.1 feet of the measured stage.

6.4.2. Unsteady-State Model Calibration

A comparison of measured and simulated hydrographs in the Susitna River at Gold Creek (USGS 15292000) is shown in Figure 6.4-2, in the Susitna River at Sunshine (USGS 15292780) in Figure 6.4-3, and in the Susitna River at Susitna Station in Figure 6.4-4. Excellent agreement was found at Gold Creek and Sunhsine, and good agreement was found at Susitna Station.

Collecting additional hydrologic data in 2014 and modeling refinements in 2015 will further improve model calibration.

6.4.3. Model Validation

The calibrated model was then used to analyze the 1976 and 1981 simulation periods. A comparison of measured and simulated hydrographs for this validation period is shown in Figure 6.4-5 for the Susitna River at Gold Creek (USGS 15292000), Figure 6.4-6 for the Susitna River at Sunshine (USGS 15292780), and Figure 6.4-7 for the Susitna River at Susitna Station (USGS 15294350). Good agreement was found between measured and simulated hydrographs at all three locations over a wide range of flow conditions.

6.4.4. Assessment of Potential Downstream Stage Changes

The calibrated model was then used to assess downstream stage changes associated with Pre-Project and Maximum Load Following OS-1b scenarios for simulation periods 1976 (dry) and 1981 (wet). Predicted stage and flow hydrographs are shown for the entire simulation period in the Susitna River just below Watana Dam site in Figures 6.4-8 and 6.4-9. These results show a reduction of water level during the summer of as much as 6.4 feet in a dry year and 9.7 feet in a wet year.

Hourly fluctuations are difficult to discern from these plots so detailed information for select periods are also provided in Figures 6.4-10 and 6.4-11. These figures show the predicted stage and flow hydrographs for the weeks of August 1-8, 1976 and July 12-19, 1981 in the Susitna River below Watana Dam site. Pre-Project conditions simulated at the various gaging locations do not account for potential diurnal fluctuations associated with summer-time glacial melt. When considering the open-water period from the representative dry and wet water years (5/23/76-9/30/76 and 5/23/81-9/30/81, respectively), the hourly stage fluctuations within each day associated with Pre-Project conditions range from zero to 1.0 feet under dry conditions, and zero to 1.8 feet under wet conditions. For Maximum Load Following OS-1b, the hourly stage fluctuations within each day may range from zero to 2.1 feet under dry conditions and zero to 8.0 feet under wet conditions.

Predicted stage and flow hydrographs are shown for the entire simulation period in the Susitna River at Gold Creek (USGS 15292000) in Figures 6.4-12 and 6.4-13, respectively. These results show a reduction of water level during the summer of as much as 4.1 feet in a dry year and 5.7 feet in a wet year. Predicted stage and flow hydrographs are shown for the weeks of August 1 to August 8, 1976 and July 12 to July 19, 1981 in the Susitna River at Gold Creek (USGS 15292000) in Figures 6.4-14 and 6.4-15, respectively. For the open-water periods, the hourly stage fluctuations within each day associated with Pre-Project conditions range from zero to 1.0 feet under dry conditions, and zero to 1.8 feet under wet conditions. For Maximum Load Following OS-1b, the hourly stage fluctuations within each day may range from zero to 1.4 feet under dry conditions and zero to 4.1 feet under wet conditions.

To help aide in the quantification of downstream changes, a monthly variability analysis was conducted for both the dry (1976) and wet (1981) years. First, the hourly results from the calibrated model for both scenarios were extracted and the daily maximum, average (mean), minimum, standard deviation, and range (i.e., daily max minus daily min) calculated. For the months with a full month's worth of data (i.e., June through September), the monthly median of each of these values was determined. Table 6.4-1 summarizes the results of this analysis for the Susitna River at Gold Creek (USGS 15292000) for 1976 and 1981, and select data are plotted in Figure 6.4-16. These results suggest a two-foot reduction in stage for most of the summer during a dry year and a reduction of up to three feet during a wet year. Note that the wet year shows a higher reduction in July, but a lower reduction in the remaining months of the summer.

Predicted stage and flow hydrographs are shown for the entire simulation period in the Susitna River at Sunshine (USGS 15292780) in Figures 6.4-17 and 6.4-18, respectively. These results show a reduction of daily average water level during the summer of as much as 2.0 feet in a dry year and 2.7 feet in a wet year. Predicted stage and flow hydrographs are shown for the weeks of August 1 to August 8, 1976 and July 12 to July 19, 1981 in the Susitna River at Sunshine (USGS 15292000) in Figures 6.4-19 and 6.4-20, respectively. For the open-water periods, the hourly stage fluctuations within each day associated with Pre-Project conditions range from zero to 1.1 feet under dry conditions, and zero to 3.8 feet under wet conditions. For Maximum Load Following OS-1b, the hourly stage fluctuations within each day may range from zero to 1.0 feet under dry conditions and zero to 4.0 feet under wet conditions.

The results of the monthly variability analysis for the Susitna River at Sunshine (USGS 15292780) are summarized in Table 6.4-2, and select data are plotted in Figure 6.4-21. These results suggest stage reductions of greater than one foot under the OS-1b simulations. The range of modeled stage under OS-1b is reduced as compared to the Gold Creek location because of the contribution of flow and influence of the Chulitna and Talkeetna Rivers.

Predicted stage and flow hydrographs are shown for the entire simulation period in the Susitna River at Susitna Station (USGS 15294350) in Figures 6.4-22 and 6.4-23, respectively. These results show a reduction of water level in the summer of as much as 1.5 feet in a dry year and 2.1 feet in a wet year. Predicted stage and flow hydrographs are shown for the weeks of August 1 to August 8, 1976 and July 12 to July 19, 1981 in the Susitna River at Susitna Station (USGS 15293450) in Figures 6.4-24 and 6.4-25, respectively. For the open-water periods, the hourly stage fluctuations within each day associated with Pre-Project conditions range from zero to 3.1 feet under dry conditions, and zero to 4.4 feet under wet conditions. For Maximum Load Following OS-1b, the hourly stage fluctuations within each day may range from zero to 3.1 feet under dry conditions and zero to 4.3 feet under wet conditions.

The results of the monthly variability analysis for the Susitna River at Susitna Station (USGS 15294350) are summarized in Table 6.4-3, and select data are plotted in Figure 6.4-26. Again, stage fluctuations are reduced as compared to the Sunshine location because of the influence of the Yentna and Deshka Rivers.

Figures 6.4-27 through 6.4-29 were prepared to help illustrate the differences between Pre-Project and Maximum Load Following OS-1b conditions. These figures show the shape of the cross section and WSEs associated with Pre-Project and Maximum Load Following OS-1b conditions on select dates in 1976 and 1981. Dates were selected to illustrate periods with significant differences in WSE. The thickness of each water surface elevation line was scaled to represent the range between minimum and maximum water surface elevation each day. The figures were prepared for cross sections located near USGS gaging locations including Gold Creek (15292000), Sunshine (15292780), and Susitna Station (15294350).

6.4.5. Assessment of Potential Downstream Changes at FA 128

The calibrated model was also used to assess stage and flow changes at Focus Areas associated with Pre-Project and Maximum Load Following OS-1b scenarios for simulation periods 1976 (dry) and 1981 (wet). Predicted stage and flow hydrographs are shown for the entire simulation periods in the Susitna River at the upstream end of FA-128 in Figures 6.4-30 and 6.4-31. Predicted flow and stage hydrographs are shown for the weeks of August 1 to August 8, 1976 and July 12 to July 19, 1981 in the Susitna River at the upstream end of FA-128 in Figures 6.4-32 and 6.4-33, respectively.

6.4.6. Future Improvements to the Model

The flow routing model described in this technical memo represents Version 2. The model in its present form is adequate to provide information to support decisions on proof of concept, help schedule field studies targeting specific flow and stage conditions, and identify 2014 data needs to improve model accuracy. This model will continue to be refined and improved based on field data collected in 2014. As described in RSP Table 8.5-14, this Version 2 (refined draft) of the Open-water Flow Routing Model was available for review and use in study efforts in 2014. Additional data needs will be identified in 2014 and field data collected in 2014. Hydrologic data that may be collected in 2014 include additional transect cross-sectional profiles, additional discharge/water level data pairs, and hourly stage data from main channel and tributary locations. A refined version of the Open-water Flow Routing Model will be developed in 2014 incorporating available additional data. Major changes in the mainstem Open-water Flow Routing Model results are not anticipated as a result of the additional data collected in 2014. However, the additional data and model refinements will improve the accuracy of hourly flow and stage simulations at complex channel features and within instream flow sampling and modeling areas.

Version 3 of this model to be developed and distributed for review in 2015 will incorporate the following additional information:

- Tributary flow measurements collected in 2013 and 2014 will be used to help estimate lateral accretion flows.
- Additional pairs of flow/water surface elevations will be made which will be used to help improve the steady-state calibration.
- The model will incorporate additional cross-sections if available through implementation of the geomorphology study (RSP Section 6.6).
- Diurnal glacial melt fluctuations will be incorporated into the summer hydrographs.

7. LITERATURE CITED

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8. TABLES

Table 4-1. Comparison of the three versions of the Open-water Flow Routing Model.

Model Component	Version 1	Version 2	Version 3
Extent	PRM 80-187.2	PRM 29.9-187.2	PRM 29.9-187.2
Number of Cross Sections	88	167	212
WSE/Q Measurements	120	387	486
Accretion	Hourly	Hourly	Hourly
Diurnal Fluctuations	None	Measured where and when available, not estimated for missing gaps	Complete
Floodplain coverage	None	Extended using 2011 and 2013 LiDAR	Extended using 2011, 2013 and 2014 LiDAR
Calibration/Validation Data	6 gages 15291500 15291700 15292000 15292780 15292400 15292700	8 gages 15291500 15291700 15292000 15292780 15294350 15292400 15292700 15294345	8 gages 15291500 15291700 15292000 15292780 15294350 15292400 15292700 15294345

Table 5.1-1. Summary of low, medium, and high flow measurements collected in 2012 and 2013 on mainstem transects of the Susitna River. ✓WSE and estimated streamflow ✓✓WSE and measured streamflow.

PRM	Low	Medium	High	PRM	Low	Medium	High
187.2		✓✓	✓✓	143	✓✓	✓	✓✓
186.2	✓✓	✓✓	✓✓	142.2	✓✓	✓✓	✓✓
185.5	✓✓	✓✓	✓✓	141.9	✓✓	✓	✓✓
185.2	✓✓	✓✓	✓✓	141.7	✓✓	✓	✓✓
184.9	✓✓	✓✓	✓✓	141.2		✓	✓
184.4	✓✓		✓✓	140.8		✓	✓
183.3	✓✓		✓✓	140.5		✓	✓
182.9	✓✓		✓✓	140	✓✓	✓	✓✓
181.6	✓✓		✓✓	139.8	✓✓	✓	✓✓
179.5	✓✓		✓✓	139	✓✓		✓✓
178.5	✓✓		✓✓	138.7	✓✓	✓	✓✓
176.5	✓✓		✓✓	138.4		✓	✓
174.9	✓✓		✓✓	138.1	✓✓	✓	✓✓
173.1	✓✓		✓✓	137.6	✓✓	✓	✓✓
170.1	✓✓		✓✓	137.2		✓	✓
168.1	✓✓	✓✓	✓✓	136.7	✓✓	✓✓	✓✓
153.7	✓✓		✓✓	136.2	✓✓	✓✓	✓✓
152.9	✓✓		✓✓	135.6	✓	✓	✓
152.1	✓✓	✓✓	✓✓	135	✓✓	✓✓	✓✓
151.1	✓✓	✓✓	✓✓	134.7	✓	✓	✓
148.3	✓✓	✓✓	✓✓	134.3	✓✓	✓	✓✓
146.6	✓	✓✓	✓✓	134.1	✓✓	✓	✓✓
146.1		✓	✓	133.8	✓✓	✓	✓✓
145.7	✓✓	✓✓	✓✓	133.3	✓✓	✓	✓✓
145.5	✓✓	✓	✓✓	132.6	✓✓	✓	✓✓
144.9	✓✓	✓✓	✓✓	132	✓	✓	✓
144.3	✓✓	✓	✓✓	131.4	✓✓	✓	✓✓
143.9		✓	✓	130.9	✓	✓	✓
143.5	✓✓	✓✓	✓✓	130.4	✓	✓	✓
129.7	✓✓		✓✓	113.1		✓✓	
128.1	✓✓	✓	✓✓	112.5		✓	
127.8	✓			111.9	✓✓	✓	✓✓
126.8	✓✓	✓✓	✓✓	110.5	✓✓	✓	✓✓
126.4	✓			109		✓✓	
126.1	✓✓	✓	✓✓	108.3		✓✓	✓
125.8	✓✓			107.8		✓✓	
125.4	✓✓	✓	✓✓	107.1	✓✓	✓✓	✓✓
124.9	✓✓			106.6		✓✓	
124.5	✓✓			106.1	✓✓	✓✓	✓
124.1	✓✓	✓✓	✓✓	105.3	✓✓	✓	✓
123.7	✓✓	✓✓	✓	104.7	✓✓		
123.2		✓		104.1	✓✓	✓	✓
122.7	✓✓	✓✓	✓	103.5	✓✓	✓	✓
122.6	✓✓	✓✓	✓	102.7	✓✓	✓	✓✓

PRM	Low	Medium	High	PRM	Low	Medium	High
122.1		✓		102.1		✓	
121.4		✓		101.4	✓	✓	
120.7	✓✓	✓✓	✓	100.7		✓	✓
120.3		✓		99.9		✓✓	✓
119.9	✓✓	✓✓	✓	98.4	✓✓	✓✓	
118.9		✓		97	✓	✓✓	
118.4	✓✓	✓✓	✓	96.2		✓✓	✓
117.9		✓✓		94.8		✓✓	✓
117.4	✓✓	✓✓	✓	94		✓	✓
117		✓✓		93.2		✓	✓
116.6	✓✓	✓✓	✓✓	92.3		✓	✓
116.3	✓✓	✓✓	✓✓	91.6	✓✓	✓	
115.7	✓✓	✓✓	✓✓	91	✓✓	✓	
115.4	✓✓	✓✓	✓✓	90.2		✓✓	✓
114.4	✓✓	✓✓	✓✓	89.5		✓	✓
113.6	✓✓	✓✓	✓✓	88.4	✓✓	✓✓	
88		✓✓	✓	49	✓✓	✓	✓
87.6		✓✓	✓	47.9		✓	
87.1	✓✓	✓✓		47.1		✓	
86.3	✓	✓✓		46.3	✓	✓	✓
85.4	✓✓	✓		45.6	✓	✓	
84.4	✓✓	✓		44.5	✓	✓	✓
83	✓✓	✓		41.3	✓	✓	
82.3	✓✓	✓		40.4	✓✓	✓	
81.4		✓	✓	39.5	✓✓	✓	✓
80.7		✓	✓	38.3		✓	
80	✓✓	✓✓		36.4	✓✓	✓	
79		✓✓	✓	34.8	✓✓	✓	✓
78	✓	✓✓	✓	33.7		✓	
77			✓	32.4		✓	
75.9	✓	✓✓	✓	31.6		✓	
75			✓	29.9	✓	✓	✓
74.1		✓✓	✓				
73.1	✓	✓✓	✓				
71	✓	✓✓	✓				
69.2	✓	✓	✓				
68.2		✓					
67.2	✓	✓✓					
66.1		✓✓					
64.6	✓	✓	✓				
62.7	✓	✓	✓				
60.3	✓	✓	✓				
59.1			✓				
57.8	✓	✓	✓				
55.4	✓	✓	✓				
54.2	✓	✓✓	✓				

PRM	Low	Medium	High	PRM	Low	Medium	High
52.1			✓				

Table 5.4-1. Monthly power coefficients and flow ratios used to derived ungaged accretion flows in three reaches of the Susitna River

Month	Dam site to Gold Creek		Gold Creek to Sunshine	Sunshine to Susitna Station
	a	b	Flow Ratio	Flow Ratio
January	0.840	0.993	0.107	0.314
February	0.849	0.991	0.099	0.359
March	0.839	0.993	0.070	0.390
April	0.800	1.000	0.141	0.368
May	0.869	0.994	0.285	0.178
June	0.930	0.988	0.196	0.089
July	1.004	0.982	0.126	0.186
August	0.958	0.986	0.142	0.216
September	0.743	1.010	0.189	0.287
October	0.756	1.007	0.159	0.421
November	0.769	1.006	0.148	0.393
December	0.884	0.987	0.135	0.306

Table 5.4-2. Summary of lateral inflow reaches included in the Open-water Flow Routing Model.

Reach	Upstream PRM	Downstream PRM	Number of Subbasins	HEC-RAS inflow type
1	Dam Site	179.3	6	Uniform Lateral Inflow
2	179.3	140.1	13	Uniform Lateral Inflow
3	140.0	102.4	5	Uniform Lateral Inflow
4	Chulitna River		1	Tributary
5	102.4	100.3	1	Uniform Lateral Inflow
6	Talkeetna River		1	Tributary
7a	100.3	87.9	7	Uniform Lateral Inflow
7b	87.9	64.7	11	Uniform Lateral Inflow
8	Kashwitna River		1	Tributary
9	64.7	44.9	7	Uniform Lateral Inflow
10	Deshka River		1	Tributary
11	44.9	31.4	3	Uniform Lateral Inflow
12	Yentna River		1	Tributary
13	31.4	29.9	1	Uniform Lateral Inflow

Table 5.4-3. Summary of travel times used in calibration period accretion calculations.

Reach	Upstream End		Downstream End		Travel Time (hr)
	PRM	Description	PRM	Description	
Dam Site to Gold Creek	187.2	Dam Site	184.9	USGS Gage above Tsusena Creek	0.33
	184.9	USGS Gage above Tsusena Creek	183.25	Middle of Reach 1	0.24
	183.25	Middle of Reach 1	159.65	Middle of Reach 2	3.42
	159.65	Middle of Reach 2	140	USGS Gage at Gold Creek	2.84
				Dam Site to USGS Gage at Gold Creek Total	6.83
Gold Creek to Sunshine	140	USGS Gage at Gold Creek	121.2	Middle of Reach 3	4.12
	121.2	Middle of Reach 3	102.4	Confluence with Chulitna River	4.12
	102.4	Confluence with Chulitna River	101.35	Middle of Reach 5	0.38
	101.35	Middle of Reach 5	100.3	Confluence with Talkeetna River	0.38
	100.3	Confluence with Talkeetna River	94.1	Middle of Reach 7a	2.25
	94.1	Middle of Reach 7a	87.9	USGS Gage at Sunshine	2.25
				USGS Gage at Gold Creek to USGS Gage at Sunshine Total	13.50
Sunshine to Susitna Station	87.9	USGS Gage at Sunshine	76.3	Middle of Reach 7b	5.24
	76.3	Middle of Reach 7b	64.7	Confluence with Kashwitna River	5.24
	64.7	Confluence with Kashwitna River	54.8	Middle of Reach 9	4.47
	54.8	Middle of Reach 9	44.9	Confluence with Deshka River	4.47
	44.9	Confluence with Deshka River	38.15	Middle of Reach 11	3.05
	38.15	Middle of Reach 11	31.4	Confluence with Yentna River	3.05
	31.4	Confluence with Yentna River	30.65	Middle of Reach 13	0.34
	30.65	Middle of Reach 13	29.9	USGS Gage at Susitna Station	0.34
				USGS Gage at Sunshine to USGS Gage at Susitna Station Total	26.20
				Dam Site to USGS Gage at Susitna Station Total	46.53

Table 6.1-1. Susitna River transect data collected in 2012 and 2013

UPPER RIVER (PRM 261.3 - 187.1)

Project River	XS Profile	XS Profile	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013				
Mile (PRM)	/Bathy Date	/Bathy Date 2	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
225.0	NA		6/14/2012	17:57	26,900	Good	NA	8/9/2012	15:03	11,300	Excellent	NA	10/18/2012	NA	WSE only[5]		1906.26						8/8/2013	15:05	11,900	Excellent	NA	9/3/2013	13:32	14,700	Good	NA
187.2	6/17/2012		6/17/2012	16:30	27,700	Poor	1466.42	8/6/2012	16:13	14,700	Good	1464.09	9/15/2012	13:17	7,840	Good	1461.81															

MIDDLE RIVER (PRM 187.1 - 102.4)

Project River	XS Profile	XS Profile	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013				
Mile (PRM)	/Bathy Date	/Bathy Date 2	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
186.2	6/18/2012		6/18/2012	14:13	24,500	Good	1458.50	8/6/2012	17:05	14,400	Good	1457.07	9/15/2012	14:05	7,630	Excellent	1455.36															
185.5	6/18/2012		6/18/2012	16:10	25,400	Good	1452.14	8/6/2012	17:17	WSE only[5]		1450.52	9/15/2012	14:28	WSE only[5]		1449.17															
185.2	6/19/2012		6/19/2012	13:00	26,700	Good	1449.28	8/6/2012	17:43	WSE only[5]		1447.37	9/15/2012	14:57	WSE only[5]		1445.92															
184.9	6/19/2012		6/19/2012	15:49	27,600	Good	1446.04	8/6/2012	18:24	14,200	Excellent	1443.72	9/15/2012	14:57	7,710	Excellent	1442.10															
184.4	6/19/2012		6/19/2012	16:51	27,900	Fair	1440.48	8/7/2012	12:38	14,800	Good	1437.43	9/15/2012	15:52	8,350	Good	1435.55															
183.3	6/20/2012		6/20/2012	13:19	29,400	Fair	1424.86	8/7/2012	13:35	14,200	Excellent	1422.91	9/15/2012	16:41	8,310	Excellent	1421.75															
182.9	6/20/2012		6/20/2012	16:01	29,200	Good	1418.25	8/7/2012	13:40	WSE only[5]		1416.49	9/15/2012	17:10	WSE only[5]		1415.30															
181.6	6/20/2012		6/20/2012	17:56	29,600	Excellent	1402.27	8/7/2012	14:44	14,700	Good	1400.11	9/15/2012	17:55	8,690	Good	1398.98															
179.5	6/21/2012		6/21/2012	12:28	30,900	Fair	1381.40	8/7/2012	15:41	14,300	Excellent	1377.74	9/14/2012	17:05	8,360	Good	1375.79															
178.5	6/16/2012		6/16/2012	18:35	29,800	Good	1370.75	8/7/2012	16:37	14,800	Excellent	1367.82	9/14/2012	17:47	8,740	Good	1366.14															
176.5	6/21/2012		6/21/2012	14:40	31,200	Excellent	1346.56	8/8/2012	12:07	14,600	Excellent	1344.03	9/16/2012	14:50	10,800	Excellent	1343.18															
174.9	6/21/2012		6/21/2012	16:12	31,200	Good	1329.91	8/8/2012	13:22	WSE only[5]		1327.53	9/16/2012	16:00	WSE only[5]		1326.88															
173.1	6/21/2012		6/21/2012	17:39	30,600	Good	1310.65	8/8/2012	14:28	WSE only[5]		1307.89	9/16/2012	16:29	11,100	Excellent	1306.82															
170.1	6/22/2012		6/22/2012	12:56	31,100	Good	1285.05	8/8/2012	15:16	14,600	Excellent	1282.38	9/16/2012	17:33	11,100	Excellent	1281.59															
168.1	6/22/2012		6/22/2012	14:33	32,300	Good	1259.50	8/8/2012	16:03	14,700	Excellent	1256.43	9/17/2012	15:19	14,600	Good	1256.46															
153.7	6/25/2012		6/25/2012	17:15	32,200	Good	862.57	8/10/2012	15:03	14,600	Excellent	858.93																				
152.9	6/26/2012		6/26/2012	13:43	30,500	Fair	853.72	8/10/2012	15:14	WSE only[5]		850.17																				
152.1	6/26/2012	9/29/2012	6/26/2012	15:38	30,000	Good	843.65	8/10/2012	16:07	15,400	Good	840.96	9/29/2012	15:20	18,500	Good	841.61															
151.1	6/25/2012		6/25/2012	14:00	33,200	Good	832.09	8/10/2012	17:32	WSE only[5]		827.79	9/29/2012	15:59	WSE only[5]		829.13															
148.3	6/26/2012		6/26/2012	18:24	32,100	Good	796.39	8/10/2012	18:03	14,900	Excellent	793.54	9/29/2012	NA	WSE only[5]		794.00															
146.6	6/27/2012		6/27/2012	12:24	31,000	Fair	773.49	8/12/2012	12:54	WSE only[5]		771.94	9/29/2012	16:36	WSE only[5]		772.02															
146.1	8/3/2013																						8/3/2013	12:30	WSE only[5]		766.45	9/5/2013	13:09	WSE only[5]		767.62
145.7	6/27/2012	9/29/2012	6/27/2012	13:51	31,400	Fair	761.96	8/12/2012	13:12	17,400	Excellent	759.65	9/29/2012	16:51	18,100	Good	759.86	6/20/2013	14:42	WSE only[5]		761.43						9/7/2013	13:18	WSE only[5]		760.93
145.5	6/27/2012		6/27/2012	14:40	31,900	Fair	760.04	8/12/2012	13:53	WSE only[5]		757.93						6/20/2013	12:10	WSE only[5]		758.22	8/3/2013	9:38	WSE only[5]		758.57	9/5/2013	13:33	WSE only[5]		760.03
144.9	6/27/2012		6/27/2012	17:01	31,900	Fair	751.50	8/12/2012	14:11	WSE only[5]		749.46	9/29/2012	17:15	WSE only[5]		749.80	6/20/2013	16:12	WSE only[5]		751.24										
144.3	6/27/2012		6/27/2012	18:50	31,100	Good	742.52	8/12/2012	14:32	WSE only[5]		740.68											8/3/2013 8/15/2013	16:25 15:28	WSE only[5] WSE only[5]		740.93 740.77	9/5/2013	9:21	WSE only[5]		742.36
143.9	8/3/2013																						8/3/2013	15:44	WSE only[5]		736.31	9/5/2013	14:16	WSE only[5]		737.47
143.5	6/28/2012		6/28/2012	12:17	30,300	Excellent	732.35	8/12/2012	14:58	17,000	Excellent	730.64	9/29/2012	17:26	WSE only[5]		730.72	7/30/2013	16:16	WSE only[5]		730.63										
143.0	6/28/2012		6/28/2012	13:53	29,500	Good	725.04	8/12/2012	15:40	WSE only[5]		723.49						6/23/2013	14:30	WSE only[5]		725.33	8/4/2013	14:34	WSE only[5]		725.07	9/5/2013	15:16	WSE only[5]		726.11
142.2	6/28/2012	9/29/2012	6/28/2012	15:15	29,800	Good	716.41	8/12/2012	16:29	16,800	Excellent	714.51	9/29/2012	17:45	18,300	Excellent	714.78											9/8/2013	14:53	WSE only[5]		716.21
141.9	6/28/2012		6/28/2012	16:27	30,600	Good	712.88	8/12/2012	17:13	16,800	Excellent	710.84						6/22/2013	17:50	WSE only[5]		712.34	8/4/2013	15:21	WSE only[5]		711.25	9/5/2013	15:39	WSE only[5]		712.73
141.7	6/28/2012		6/28/2012	17:41	30,600	Excellent	711.43	8/12/2012	17:13	WSE only[5]		709.09											8/4/2013	15:44	WSE only[5]		710.00	9/5/2013	15:53	WSE only[5]		711.76
141.2	8/4/2013																						8/4/2013	17:16	WSE only[5]		703.48	9/6/2013	11:27	WSE only[5]		705.26
140.8	8/4/2013																						8/4/2013	18:41	WSE only[5]		700.72	9/6/2013	11:39	WSE only[5]		702.23
140.5	8/5/2013																						8/5/2013	10:55	WSE only[5]		696.94	9/6/2013	12:31	WSE only[5]		698.50
140.0	6/29/2012	9/30/2012	6/29/2012	14:48	30,400	Excellent	693.77	8/13/2012	12:54	16,400	Excellent	691.69	9/30/2012	13:56	17,600	Good	691.94						8/5/2013	12:08	WSE only[5]		692.12	9/6/2013	12:29	WSE only[5]		693.56
139.8	6/29/2012		6/29/2012	16:21	29,100	Excellent	691.34	8/13/2012	13:10	WSE only[5]		689.07											8/5/2013 8/10/2013	12:30 15:03	WSE only[5] WSE only[5]		689.52 688.92	9/6/2013	12:39	WSE only[5]		691.01
139.0	6/30/2012		6/30/2012	13:56	28,000	Good	679.92	8/13/2012	13:58	16,400	Good	678.26	9/30/2012	14:26	WSE only[5]		678.50	6/7/2013 6/25/2013 7/28/2013	11:39 11:11 14:59	WSE only[5] WSE only[5] WSE only[5]		680.77 678.93 678.28	8/10/2013	15:40	15,900	Excellent	678.03	9/6/2013	12:50	WSE only[5]		679.90
138.7	6/30/2012		6/30/2012	14:51	28,200	Excellent	678.08	8/13/2012	14:48	16,300	Excellent	677.07											8/5/2013 8/10/2013	12:50 15:48	WSE only[5] WSE only[5]		677.46 677.06	9/6/2013	13:15	WSE only[5]		678.55
138.4	8/5/2013																						8/5/2013	15:34	WSE only[5]		673.21	9/6/2013	13:27	WSE only[5]		674.41

MIDDLE RIVER (PRM 187.1 - 102.4)

Project River	XS Profile	XS Profile	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013				
Mile (PRM)	/Bathy Date	/Bathy Date 2	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
138.1	6/30/2012		6/30/2012	16:33	28,200	Good	670.43	8/13/2012	15:07	WSE only[5]		669.00	9/30/2012	14:52	WSE only[5]		669.36						8/5/2013	13:21	WSE only[5]		669.70	9/6/2013	9:10	WSE only[5]		670.74
																							8/10/2013	16:12	WSE only[5]		669.46					
137.6	6/30/2012	9/30/2012	6/30/2012	18:13	27,900	Good	664.17	8/13/2012	16:14	16,400	Excellent	662.67	9/30/2012	15:00	17,400	Excellent	662.58						8/10/2013	16:51	15,700	Excellent	662.13	9/6/2013	14:20	WSE only[5]		663.95
137.2	8/5/2013																						8/5/2013	17:22	WSE only[5]		658.44	9/6/2013	17:07	WSE only[5]		659.83
136.7	7/1/2012		7/1/2012	13:35	26,800	Good	654.82	8/13/2012	16:34	WSE only[5]		653.46											8/5/2013	17:54	WSE only[5]		653.47	9/6/2013	17:21	WSE only[5]		654.78
136.2	7/1/2012		7/1/2012	16:06	26,900	Good	648.86	8/13/2012	17:06	WSE only[5]		648.12											8/6/2013	11:24	WSE only[5]		648.21	9/6/2013	17:36	WSE only[5]		649.06
135.6	8/6/2013																						8/6/2013	12:54	WSE only[5]		640.17	9/6/2013	17:51	WSE only[5]		641.23
135.0	7/1/2012		7/1/2012	18:33	26,500	Excellent	634.86	8/13/2012	17:41	15,600	Excellent	632.97											8/6/2013	13:39	WSE only[5]		633.09	9/6/2013	18:04	WSE only[5]		635.01
134.7	8/6/2013																						8/6/2013	15:31	WSE only[5]		631.40	9/6/2013	18:14	WSE only[5]		632.73
134.3	7/2/2012	10/1/2012	7/2/2012	12:16	25,500	Good	627.51	8/13/2012	18:21	WSE only[5]		625.41	10/1/2012	13:40	15,600	Excellent	625.68						8/6/2013	14:45	WSE only[5]		625.99	9/6/2013	18:24	WSE only[5]		628.13
134.1	7/2/2012		7/2/2012	13:18	26,200	Good	625.74	8/14/2012	13:14	16,500	Excellent	624.10											8/7/2013	10:45	WSE only[5]		623.64	9/12/2013	13:24	WSE only[5]		626.31
133.8	7/2/2012		7/2/2012	14:30	25,700	Good	623.51	8/14/2012	14:05	16,300	Excellent	622.22											8/7/2013	11:01	WSE only[5]		622.05	9/12/2013	13:35	WSE only[5]		624.06
133.3	7/2/2012		7/2/2012	16:22	25,700	Excellent	618.46	8/14/2012	14:41	WSE only[5]		617.34											8/7/2013	5:45	WSE only[5]		618.23	9/12/2013	13:52	WSE only[5]		618.70
132.6	7/2/2012		7/2/2012	17:57	25,000	Excellent	609.97	8/14/2012	15:17	16,000	Good	608.67											8/7/2013	12:00	WSE only[5]		608.61	9/12/2013	14:09	WSE only[5]		610.90
132.0	8/7/2013																						8/7/2013	13:18	WSE only[5]		601.78	9/12/2013	14:25	WSE only[5]		604.41
131.4	7/3/2012		7/3/2012	15:27	28,600	Good	598.37	8/14/2012	16:05	WSE only[5]		597.82											8/7/2013	14:34	WSE only[5]		597.89	9/10/2013	14:29	WSE only[5]		598.97
130.9	8/8/2013																						8/8/2013	13:27	WSE only[5]		592.37	9/10/2013	13:57	WSE only[5]		592.97
130.4	8/9/2013																						8/9/2013	6:49	WSE only[5]		585.67	9/10/2013	13:11	WSE only[5]		587.41
129.7	7/3/2012	10/1/2012	7/3/2012	17:33	28,200	Good	580.58	8/14/2012	17:00	16,300	Excellent	578.98	10/1/2012	16:16	15,700	Excellent	579.02	6/27/2013	11:38	WSE only[5]		580.28						9/10/2013	11:43	WSE only[5]		580.53
128.1	7/4/2012		7/4/2012	15:40	26,700	Good	564.50	8/15/2012	12:50	15,900	Excellent	563.54											8/9/2013	15:02	WSE only[5]		562.69					
127.8	8/9/2013																						8/9/2013	15:44	WSE only[5]		560.66					
126.8	7/4/2012	10/1/2012	7/4/2012	17:22	27,600	Excellent	552.41	8/15/2012	13:40	16,100	Excellent	550.87	10/1/2012	17:02	15,600	Excellent	551.04	7/9/2013	13:24	23,100	Good	552.15	8/11/2013	12:26	16,200	Excellent	550.96	9/12/2013	16:52	31,100	Good	552.79
126.4	8/10/2013																						8/10/2013	13:58	WSE only[5]		547.78					
126.1	7/5/2012		7/5/2012	14:24	27,200	Good	546.88	8/15/2012	13:41	WSE only[5]		545.26											8/11/2013	12:48	WSE only[5]		544.76					
125.8	8/11/2013																						8/11/2013	14:10	WSE only[5]		543.45					
125.4	7/5/2012		7/5/2012	16:38	26,400	Excellent	541.32	8/15/2012	14:12	WSE only[5]		540.09											8/10/2013	15:15	WSE only[5]		540.55					
124.9	8/11/2013																						8/11/2013	12:56	WSE only[5]		535.81					
124.5	8/11/2013																						8/11/2013	14:57	WSE only[5]		531.40					
124.1	7/5/2012	10/1/2012	7/5/2012	18:11	26,100	Good	530.43	8/15/2012	14:27	16,200	Excellent	529.24	10/1/2012	17:42	15,600	Good	529.40	7/9/2013	14:14	22,500	Good	530.21	8/11/2013	13:32	16,600	Excellent	529.32	9/10/2013	13:51	WSE only[5]		530.81
																												9/12/2013	17:41	30,600	Good	531.16
123.7	7/6/2012		7/6/2012	12:18	23,900	Excellent	527.93	8/15/2012	15:54	WSE only[5]		527.43											8/11/2013	16:15	WSE only[5]		528.09	9/10/2013	11:38	WSE only[5]		528.61
123.2	8/12/2013																						8/12/2013	12:45	WSE only[5]		521.89					
122.7	7/6/2012		7/6/2012	14:23	23,300	Excellent	518.91	8/15/2012	17:15	WSE only[5]		517.91											8/12/2013	1:09	WSE only[5]		518.85	9/9/2013	15:48	WSE only[5]		520.10
122.6	7/6/2012		7/6/2012	15:59	22,900	Good	517.85	8/15/2012	16:13	16,300	Excellent	516.97											8/12/2013	12:26	WSE only[5]		517.56	9/9/2013	15:33	WSE only[5]		518.69
122.1	8/12/2013																						8/12/2013	6:30	WSE only[5]		512.92					
121.4	8/12/2013																						8/12/2013	15:04	WSE only[5]		508.79					
120.7	7/6/2012		7/6/2012	17:19	22,700	Good	502.03	8/15/2012	17:27	WSE only[5]		501.13											8/12/2013	16:34	WSE only[5]		502.32	9/9/2013	15:18	WSE only[5]		503.32
120.3	8/12/2013																						8/12/2013	8:40	WSE only[5]		498.48					
119.9	7/7/2012	10/3/2012	7/7/2012	12:19	20,700	Excellent	495.29	8/16/2012	12:54	16,000	Excellent	494.37	10/3/2012	14:47	14,000	Excellent	493.97	7/9/2013	17:10	22,700	Excellent	495.34	8/14/2013	11:38	WSE only[5]		494.54	9/9/2013	9:59	WSE only[5]		496.49
118.9	8/14/2013																						8/14/2013	12:06	WSE only[5]		489.01					
118.4	7/7/2012		7/7/2012	14:06	20,700	Excellent	485.32	8/16/2012	13:04	WSE only[5]		484.18	10/3/2012	14:39	WSE only[5]		484.62						8/14/2013	13:27	WSE only[5]		484.58	9/9/2013	13:45	WSE only[5]		486.42
117.9	8/14/2013																						8/14/2013	14:11	WSE only[5]		481.58					
117.4	7/7/2012		7/7/2012	16:15	20,700	Excellent	477.82	8/16/2012	13:39	WSE only[5]		477.21											8/14/2013	16:10	WSE only[5]		477.65	9/9/2013	13:18	WSE only[5]		478.57
117.0	8/14/2013																						8/14/2013	14:37	WSE only[5]		471.85					
116.6	7/7/2012		7/7/2012	17:36	20,700	Excellent	468.98	8/16/2012	14:15	16,100	Excellent	468.16	10/3/2012	15:53	14,300	Excellent	467.97	7/9/2013	15:55	22,900	Excellent	469.33	8/14/2013	14:00	18,100	Excellent	468.71	9/9/2013	12:31	WSE only[5]		470.52
																												9/13/2013	12:05	30,800	Good	470.62
116.3	7/8/2012		7/8/2012	12:42	23,800	Excellent	467.39	8/16/2012	14:49	WSE only[5]		466.24						7/23/2013	10:40	WSE only[5]		466.98	8/14/2013	12:50	WSE only[5]		466.79					
115.7	7/8/2012		7/8/2012	14:05	25,000	Excellent	461.95	8/16/2012	15:17	WSE only[5]		461.01											8/14/2013	12:30	WSE only[5]		461.83					
115.4	7/8/2012		7/8/2012	16:13	26,000	Excellent	458.41	8/16/2012	15:44	WSE only[5]		456.99						7/5/2013	15:46	WSE only[5]		457.29	8/14/2013	12:17	WSE only[5]		457.30					
																		7/23/2013	15:20	WSE only[5]		457.50										
114.4	7/8/2012		7/8/2012	18:29	25,900	Excellent	450.21	8/16/2012	16:07	WSE only[5]		448.97											8/13/2013	16:01	WSE only[5]		449.42					
																							8/14/2013	16:25	WSE only[5]		449.39					
113.6	7/9/2012	10/3/2012	7/9/2012	14:23	28,300	Excellent	444.75	8/16/2012	16:38	16,300	Excellent	443.10	10/3/2012	16:41	13,500	Excellent	442.90						8/14/2013	12:48	WSE only[5]		443.28					
																							8/14/2013	16:12	18,100	Excellent	443.45					

MIDDLE RIVER (PRM 187.1 - 102.4)

Project River	XS Profile	XS Profile	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013				
Mile (PRM)	/Bathy Date	/Bathy Date 2	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
113.1	8/15/2013																						8/14/2013 8/15/2013	17:30 11:00	WSE only[5] WSE only[5]		439.27 438.67					
112.5	8/15/2013																						8/15/2013	13:07	WSE only[5]		432.60					
111.9	7/9/2012		7/9/2012	15:23	28,300	Good	429.73	8/17/2012	14:02	WSE only[5]		427.98											8/15/2013	14:05	WSE only[5]		428.51					
110.5	7/9/2012	10/3/2012	7/9/2012	16:46	28,800	Good	417.55	8/17/2012	14:57	15,300	Excellent	415.70	10/3/2012	17:33	14,200	Excellent	415.49						8/15/2013	14:32	WSE only[5]		416.25					
109.0	8/15/2013																						8/15/2013	14:13	WSE only[5]		403.26					
108.3	8/18/2012							8/17/2012	17:55	16,400	Good	396.50											8/15/2013	13:23	WSE only[5]		397.46	9/7/2013	13:51	WSE only[5]		398.01
107.8	8/15/2013																						8/15/2013	12:56	WSE only[5]		391.77					
107.1	7/9/2012		7/9/2012	18:26	28,400	Good	387.63	8/18/2012	13:12	15,500	Excellent	385.44	10/4/2012	14:10	14,600	Excellent	385.12	7/11/2013	16:50	19,700	Excellent	385.92	8/15/2013	15:53	18,900	Excellent	385.64	9/7/2013 9/15/2013	12:57 12:09	WSE only[5] 21,700	 Excellent	387.46 386.36
106.6	8/15/2013																						8/15/2013	10:49	WSE only[5]		382.41					
106.1	8/18/2012							8/18/2012	14:22	15,300	Excellent	377.95	10/4/2012	14:26	WSE only[5]		377.75						8/15/2013	10:08	WSE only[5]		378.31	9/7/2013	12:40	WSE only[5]		380.10
105.3	8/18/2012							8/18/2012	15:52	15,400	Excellent	372.01											8/16/2013	10:05	WSE only[5]		372.44	9/7/2013	23:05	WSE only[5]		374.10
104.7	8/18/2012							8/18/2012	17:48	15,400	Excellent	367.05	10/4/2012	14:58	WSE only[5]		366.93						8/16/2013	10:29	WSE only[5]		367.15					
104.1	8/19/2012							8/19/2012	12:49	15,300	Excellent	364.79											8/16/2013	10:56	WSE only[5]		365.31	9/6/2013	12:10	WSE only[5]		366.38
103.5	10/1/2012												10/4/2012	16:49	14,600	Excellent	359.89						8/16/2013	11:24	WSE only[5]		359.88	9/6/2013	11:54	WSE only[5]		361.21
102.7	7/10/2012		7/10/2012	13:53	26,600	Good	352.87	8/19/2012	15:05	WSE only[5]		351.70											8/16/2013	10:32	WSE only[5]		352.66					

LOWER RIVER (PRM 102.4 - 3.3)

Project River	XS Profile	XS Profile	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013				
Mile (PRM)	/Bathy Date	/Bathy Date 2	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
102.1	8/16/2013																						8/16/2013	14:11	WSE only[5]		348.19					
101.4	7/10/2012	10/15/2012	7/10/2012	16:28	WSE only[5]		346.09	8/19/2012	15:54	WSE only[5]		344.82	10/15/2012	15:31	WSE only[5]		344.68															
100.7	6/10/13 - 6/11/13, 7/17/2013																	6/10/2013 7/17/2013	6:10 14:28	WSE only[5] WSE only[5]		341.09 342.11	8/1/2013	14:00	WSE only[5]		341.54					
99.9	6/10/13 - 6/11/13, 7/17/2013																	6/10/2013 6/11/2013	15:53 11:57	WSE only[5] WSE only[5]		337.43 338.15	8/1/2013	14:55	WSE only[5]		336.51					
98.4	7/11/2012	10/5/2012	7/11/2012	14:09	46,500	Good	326.86	8/20/2012	14:51	40,600	Good	326.37	10/5/2012	14:37	39,100	Excellent	326.08						8/1/2013	15:15	WSE only[5]		327.62					
97.0	7/11/2012		7/11/2012	18:27	45,100	Good	318.49	8/20/2012	17:03	40,300	Excellent	318.38	10/5/2012	15:18	WSE only[5]		318.21						8/1/2013	15:55	WSE only[5]		319.19					
96.2	6/12/2013																	6/12/2013	11:06	WSE only[5]		315.50	8/1/2013	16:23	WSE only[5]		315.28					
94.8	6/12/2013, 7/18/2013																	6/12/2013 7/18/2013	12:29 10:30	WSE only[5] WSE only[5]		307.57 305.77	8/1/2013 8/2/2013	15:40 11:49	53,800 WSE only[5]	Good [4] 	306.38 306.16					
94.0	6/13/2013																	6/13/2013 7/18/2013	13:02 10:58	WSE only[5] WSE only[5]		301.54 300.72										
93.2	6/13/2013																	6/13/2013	15:42	WSE only[5]		297.59	8/2/2013	12:21	WSE only[5]		296.23					
92.3	6/13/2013, 7/18/2013																	6/13/2013 7/18/2013	5:36 7:01	WSE only[5] WSE only[5]		292.79 291.17	8/2/2013	14:08	WSE only[5]		291.73					
91.6	8/21/2012							8/21/2012	14:55	46,300	Excellent	285.74											8/2/2013	16:27	WSE only[5]		286.54					
91.0	7/12/2012		7/12/2012	15:39	43,900	Good	282.34	8/21/2012	16:51	46,200	Excellent	282.34											8/2/2013	16:40	WSE only[5]		283.58					
90.2	6/14/2013																	6/14/2013	13:24	WSE only[5]		280.51	8/3/2013	13:00	51,900	Good [4]	279.73					
89.5	6/14/2013																	6/14/2013 7/18/2013	7:30 15:36	WSE only[5] WSE only[5]		276.16 274.24	8/2/2013	17:01	WSE only[5]		275.58					
88.4	8/22/2012							8/22/2012	15:01	41,700	Excellent	268.25											8/3/2013	11:00	WSE only[5]		269.39					
88.0	6/15/2013																	6/15/2013	11:18	WSE only[5]		268.19	8/3/2013	13:20	WSE only[5]		266.71					
87.6	6/15/2013																	6/15/2013	13:29	WSE only[5]		267.00	8/3/2013	16:23	52,700	Excellent	265.99					
87.1	7/12/2012		7/12/2012	18:00	42,600	Excellent	263.24	8/22/2012	17:33	WSE only[5]		262.89											8/3/2013	14:17	WSE only[5]		264.23					
86.3	7/13/2012		7/13/2012	13:13	41,900	Excellent	258.59	8/22/2012	17:54	WSE only[5]		258.39											8/3/2013	16:33	WSE only[5]		259.92					
85.4	8/22/2012							8/22/2012	18:01	40,500	Excellent	255.18											8/3/2013	17:10	WSE only[5]		256.22					
84.4	8/23/2012							8/23/2012	15:16	37,000	Good	251.19											8/3/2013	17:00	WSE only[5]		252.05					
83.0	7/13/2012		7/13/2012	16:09	42,000	Excellent	245.29	8/23/2012	16:33	WSE only[5]		244.93											8/4/2013	14:30	WSE only[5]		245.63					
82.3	8/23/2012							8/23/2012	17:52	37,900	Good	241.19											8/4/2013	14:00	WSE only[5]		242.01					
81.4	6/16/2013																	6/16/2013	11:47	WSE only[5]		238.57	8/4/2013	13:33	WSE only[5]		237.22					
80.7	6/16/2013																	6/16/2013	13:44	WSE only[5]		235.84	8/4/2013	11:02	WSE only[5]		234.64					
80.0	8/24/2012							8/24/2012	15:07	36,600	Excellent	229.51											8/4/2013	12:56	WSE only[5]		230.55					

LOWER RIVER (PRM 102.4 - 3.3)

Project River	XS Profile	XS Profile	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013				
Mile (PRM)	/Bathy Date	/Bathy Date 2	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
79.0	6/17/2013																	6/17/2013	12:21	WSE only[5]		226.66	8/4/2013	12:33	WSE only[5]		225.93					
78.0	6/17/2013																	6/17/2013	13:38	WSE only[5]		221.54	8/4/2013	12:32	52,100	Good [4]	220.90	9/20/2013	16:59	WSE only[5]		219.48
77.0	6/18/2013																	6/18/2013	10:08	WSE only[5]		215.46										
75.9	6/18/2013, 8/20/2013																	6/18/2013	8:33	WSE only[5]		209.14	8/5/2013 8/20/2013	12:40 6:05	WSE only[5] WSE only[5]		207.19 208.22	9/20/2013	15:49	WSE only[5]		206.23
75.0	6/19/2013																	6/19/2013	12:07	WSE only[5]		205.04										
74.1	6/19/2013, 8/20/2013																	6/19/2013	14:29	WSE only[5]		200.98	8/5/2013 8/20/2013	13:12 13:02	WSE only[5] WSE only[5]		199.62 199.48					
73.1	6/20/2013																	6/20/2013	13:54	WSE only[5]		194.77	8/5/2013	13:28	51,100	Good [4]	193.41	9/20/2013	14:43	WSE only[5]		192.32
71.0	6/20-6/22, 8/26/2013																	6/20/2013 6/21/2013	15:12 13:41	WSE only[5] WSE only[5]		182.36 182.89	8/26/2013	16:06	WSE only[5]		181.26	9/20/2013	9:14	WSE only[5]		180.38
69.2	6/23/2013																	6/23/2013	12:38	WSE only[5]		171.39	8/5/2013	16:09	WSE only[5]		170.71	9/20/2013	13:07	WSE only[5]		170.12
68.2	6/24/2013- 6/25/2013																	6/25/2013	0:48	WSE only[5]		166.79	8/5/2013	16:54	WSE only[5]		166.43					
67.2	6/25/2013																	6/25/2013	13:02	WSE only[5]		161.48	8/6&7/201	NA	45,400	Fair [4]	160.18	9/20/2013	12:42	WSE only[5]		159.69
66.1	6/25/2013- 6/26/2013																	6/25/2013	15:09	WSE only[5]		155.90	8/6/2013	12:46	WSE only[5]		155.12					
64.6	6/26/2013																	6/27/2013	13:41	WSE only[5]		150.46	8/6/2013	13:30	WSE only[5]		149.75	9/20/2013	11:51	WSE only[5]		148.97
62.7	6/27/2013																	6/27/2013	12:17	WSE only[5]		141.33	8/6/2013	13:57	WSE only[5]		141.07	9/20/2013	11:31	WSE only[5]		139.84
60.3	6/27/2013																	6/27/2013	13:39	WSE only[5]		131.89	8/6/2013	14:51	WSE only[5]		130.95	9/18/2013	12:28	WSE only[5]		130.98
59.1	6/28/2013																	6/28/2013	11:35	WSE only[5]		126.07										
57.8	6/28/2013																	6/28/2013	9:55	WSE only[5]		120.33	8/6/2013 8/27/2013	15:19 13:40	WSE only[5] WSE only[5]		119.04 119.21	9/18/2013	8:56	WSE only[5]		118.63
55.4	6/29/2013																	6/29/2013	12:48	WSE only[5]		110.65	8/27/2013	14:37	WSE only[5]		109.84	9/18/2013	13:52	WSE only[5]		109.09
54.2	6/30/2013																	6/30/2013	8:51	WSE only[5]		104.51	8/27/2013	15:54	WSE only[5]		102.80	9/16&17/201 9/18/2013	NA 9:26	50,600 WSE only[5]	Fair [4]	103.00 102.48
52.1	7/2/2013 - 7/3/2013																	7/2/2013 7/3/2013	16:39 12:52	WSE only[5] WSE only[5]		96.88 98.97	8/28/2013	16:14	WSE only[5]		94.06					
49.0	7/4/2013, 7/6/2013																	7/4/2013	12:26	WSE only[5]		83.55	8/28/2013	14:49	WSE only[5]		82.58	9/12/2013 9/18/2013	14:08 12:26	WSE only[5] 44,100	Good [4]	84.95 82.72
47.9	7/4/2013, 7/6/2013																	7/4/2013	14:34	WSE only[5]		79.97	8/28/2013	14:27	WSE only[5]		79.22					
47.1	7/5/2013																	7/5/2013	12:38	WSE only[5]		77.10	8/28/2013	14:12	WSE only[5]		76.06					
46.3	7/5/2013, 7/7/2013																	7/5/2013 7/7/2013	11:21 11:02	WSE only[5] WSE only[5]		72.84 72.15	8/28/2013	17:01	WSE only[5]		72.16	9/12/2013 9/18/2013	14:46 11:07	WSE only[5] WSE only[5]		76.91 71.93
45.6	7/7/2013																	7/7/2013	12:13	WSE only[5]		71.35	8/29/2013	12:25	WSE only[5]		71.59					
44.5	7/7/2013																	7/7/2013	13:42	WSE only[5]		68.30	8/29/2013	13:00	WSE only[5]		68.73	9/12/2013 9/18/2013	15:28 11:24	WSE only[5] WSE only[5]		72.70 68.28
41.3	7/8/2013																	7/8/2013	12:41	WSE only[5]		61.84	8/29/2013	14:40	WSE only[5]		62.10					
40.4	7/8/13 -																	7/8/2013	13:07	WSE only[5]		60.14	8/29/2013	14:20	WSE only[5]		60.76	9/19/2013	12:34	44,500	Good [4]	60.03
39.5	7/10/13 - 7/12/2013																	7/10/2013	15:10	WSE only[5]		58.48	8/29/2013	14:55	WSE only[5]		58.71	9/12/2013 9/19/2013	15:55 8:37	WSE only[5] WSE only[5]		61.22 58.11
38.3	7/11/13 - 7/13/2013																	7/12/2013 7/18/2013	12:46 15:43	WSE only[5] WSE only[5]		55.34 55.56	8/29/2013	15:15	WSE only[5]		55.49					
36.4	7/11/2013 - 7/13/2013																	7/13/2013	2:18	WSE only[5]		50.82	8/30/2013	14:30	WSE only[5]		51.05	9/20/2013	13:17	40,900	Good [4]	50.05
34.8	7/14/2013																	7/14/2013	12:57	WSE only[5]		47.35						9/12/2013 9/15/2013 9/19/2013 9/21/2013	16:24 14:58 13:00 12:18	WSE only[5] WSE only[5] WSE only[5] 38,100	Excellent [4]	52.09 47.76 46.79 46.15
33.7	7/14/2013																	7/14/2013	14:13	WSE only[5]		46.41	8/30/2013	13:30	WSE only[5]		46.17					
32.4	7/15/2013																	7/15/2013	10:58	WSE only[5]		45.33	8/30/2013	12:56	WSE only[5]		45.03					
31.6	7/15/2013																	7/15/2013	13:24	WSE only[5]		44.64										

LOWER RIVER (PRM 102.4 - 3.3)

Project River Mile (PRM)	XS Profile /Bathy Date	XS Profile /Bathy Date 2	June/July 2012					August 2012					September/October 2012					June/July 2013					August 2013					September/October 2013				
			Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs[1]	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]	Date	Time	Q, cfs	Q Rating[2]	WSE[3]
29.9	7/15/2013												9/11/2012	15:05	WSE only[5]		40.16	7/15/2013	13:18	WSE only[5]		42.42	8/30/2013	12:31	WSE only[5]		41.43	9/9/2013	17:19	WSE only[5]		46.03
																												9/19/2013	9:42	WSE only[5]		40.65

[1] Data approved by HDR Alaska, Inc. (See HDR, 2013)

[2] Q measurement rated according to guidance of U.S. Geological Survey, Office of Surface Water (see USGS OSW, 2012)

[3] WSE = water surface elevation (feet, NAVD 88). WSE was measured during, or within 2 hours of, the flow measurement, typically at left and right banks of all channels . The average WSE of the main channel is reported here.

[4] 2013 multiple channel measurement. Q rating methodology adapted for summing multiple channel Q measurements (see ISR Section 8.5, Appendix C)

[5] Only water surface elevation (WSE) was measured at these cross sections. Flows to be estimated by interpolating/synthesizing from nearby stations.

Not measured concurrently with Q (or reasonably close in time). Pairing of Q and WSE may not be appropriate.

Known channel change affects WSE measurements.

In post processing transects for calibration, the designation of the main channel was changed. Therefore, by the new designation, these WSE measurements are on a side chai

Following the 2012 flood, measurements show noteworthy change in the channel cross section. The post flood bathymetry has been adopted, therefore these measurements **might not** reflect the current channel geometry.

Table 6.2-1. Tributary gaging streamflow and staff gage measurements collected in 2013.

Location	Field Visit 1 (Jun/Jul)			Field Visit 2 (Aug)			Unscheduled Field Visit			Field Visit 3 (Sep/Oct)		
	Date	Q (cfs)	SG (ft)	Date	Q (cfs)	SG (ft)	Date	Q (cfs)	SG (ft)	Date	Q (cfs)	SG (ft)
Oshetna River[1]	7/13/2013		1.55	8/9/2013	604.7	1.42	9/3/2013	1000	2.2	9/26/2013		1.44
Kosina Creek	7/13/2013	620	1.46	8/7/2013	610	1.38				9/26/2013		1.53
Unnamed Tributary 144.6	7/12/2013	0.33	NA	8/7/2013	0	NA	9/15/2013	17.9	NA	9/26/2013	12.2	NA
Indian River	7/11/2013	231.5	1.61	8/9/2013	136.8	1.28				9/28/2013	286.3	1.68
Skull Creek	7/12/2013	7.4	0.96	8/8/2013	2.5	0.75	9/13/2013	48.5	1.6	9/29/2013	13.7	1.15
Gash Creek	6/16/2013	2.4	1.12	8/8/2013	2.9	1.00				9/29/2103	5.3	1.13
Slash Creek	6/16/2013	0.17	NA	8/8/2013	0.031	NA				9/29/2013	0.28	NA
Unnamed Tributary 113.7	6/16/2013	2.3	1.26	8/8/2013	0.3	1.00				9/29/2013	4.9	1.42
Whiskers Creek	6/22/2013	17.6	1.99	8/6/2013	5.7	1.75	9/11/2013	147.7	3.59	9/30/2013	39.3	2.41
Trapper Creek	6/17/2103	31.7	1.26	8/6/2013	10.8	1.01				9/30/2013	89.7	1.7
Birch Creek	7/14/2013	35.1	1.85	8/9/2013	23.9	1.76				9/27/2013	82.3	2.33
Deshka River[2]	7/15/2013	317.4	95.45	8/10/2013	245	95.3				9/27/2013		98.41

Note:

1 Note that discharge measurements collected for the Oshetna River were measured on different dates than when surveying and data downloading occurred.

2 Note that no staff gage was installed at the Deshka River site so the staff gage reading is the measured water surface elevation.

Table 6.3-1: Winter gaging 2014 field measurements.

Location	1st Field Visit			2nd Field Visit		
	Date	Method	Discharge (cfs)	Date	Method	Discharge (cfs)
Tributaries Sites						
Oshetna	Not measured during 1st visit			3/25/2014	Current Meter	101.2
Kosina	Not measured during 1st visit			3/26/2014	Current Meter	79.6
Unnamed Trib 144.5	1/20/2014	NA	Dry	Not measured during 2nd visit		
Indian River	1/19/2014	Current Meter	43.3	3/24/2014	Current Meter	33.6
Skull Creek	1/20/2014	Dye Tracer	0.9	4/2/2014	Dye Tracer	1.2
Gash Creek	1/26/2014	Dye Tracer	5.9	4/3/2014	Current Meter	1.9
Slash Creek	1/22/2014	Volumetric	0.2	4/1/2014	Volumetric	0.1
Unnamed Tributary 113.7	1/27/2014	Current Meter	3.3	3/26/2014	Current Meter	0.4
Whiskers Creek	1/22/2014	Current Meter	8.8	4/1/2014	Current Meter	4.3
Trapper Creek	1/22/2014	Current Meter	16.2	4/2/2014	Current Meter	6.1
Birch Creek	1/21/2014	Current Meter	22	4/3/2014	Current Meter	23.8
Sheep Creek	1/21/2014	Current Meter	75.5	3/22/2014	Current Meter	43.4
Caswell Creek	1/18/2014	Current Meter	23.5	3/22/2014	Current Meter	16.3
Deshka River	1/27/2014	Current Meter	998.3	3/23/2014	Current Meter	216
Mainstem Sites						
ESS70	Not measured during 1st visit			3/28/2014	Current Meter	1146.2
ESS65	Not measured during 1st visit			3/27/2014	Current Meter	1231.1
ESS55	1/25/2014	Current Meter	2246.8	3/29/2014	Current Meter	1364.1
ESS50	1/23/2014	Current Meter	2458.8	3/31/2014	Current Meter	1392.0
ESS45	1/24/2014	Current Meter	2539.2	3/31/2014	Current Meter	1637.6
ESS40	1/26/2014	Current Meter	2615.0	4/1/2014	Current Meter	1537.0

Table 6.4-1: Monthly median of simulated stage (ft, NAVD 88) for Susitna River at Gold Creek (USGS 15292000) with and without project for 1976 (representative dry year, top) and 1981 (representative wet year, bottom).

	Existing Conditions					OS-1b				
Month	Daily max	Daily Avg	Daily Min	Daily StDev	Daily Range	Daily max	Daily Avg	Daily Min	Daily StDev	Daily Range
Jun-76	693.18	692.88	692.66	0.05	0.16	690.46	690.14	690.08	0.14	0.51
Jul-76	692.07	692.03	691.90	0.04	0.13	690.20	690.05	690.02	0.05	0.18
Aug-76	692.25	692.21	692.14	0.07	0.20	690.22	690.07	690.04	0.05	0.18
Sep-76	689.47	689.40	689.32	0.03	0.11	689.77	689.44	689.19	0.16	0.48
Jun-81	692.19	692.13	692.03	0.05	0.17	690.51	690.31	690.23	0.07	0.25
Jul-81	694.86	694.52	694.39	0.11	0.35	691.17	690.80	690.38	0.27	0.80
Aug-81	695.06	694.61	694.25	0.12	0.39	695.44	694.94	694.36	0.14	0.39
Sep-81	691.17	691.11	691.01	0.04	0.11	691.71	690.95	690.10	0.45	1.28

Table 6.4-2: Monthly median of simulated stage (ft, NAVD 88) for Susitna River at Sunshine (USGS 15292780) with and without project for 1976 (representative dry year, top) and 1981 (representative wet year, bottom).

	Existing Conditions					OS-1b				
Month	Daily max	Daily Avg	Daily Min	Daily StDev	Daily Range	Daily max	Daily Avg	Daily Min	Daily StDev	Daily Range
Jun-76	267.57	267.31	267.01	0.09	0.27	266.00	265.87	265.73	0.12	0.35
Jul-76	266.75	266.63	266.46	0.08	0.26	265.82	265.63	265.44	0.09	0.29
Aug-76	267.13	267.00	266.96	0.09	0.30	265.91	265.77	265.62	0.09	0.28
Sep-76	262.35	262.22	262.10	0.05	0.16	262.43	262.26	262.16	0.09	0.30
Jun-81	266.69	266.59	266.51	0.05	0.14	265.73	265.66	265.57	0.04	0.13
Jul-81	270.02	269.84	269.67	0.11	0.33	268.71	268.41	268.15	0.15	0.53
Aug-81	269.79	269.43	268.98	0.18	0.54	269.70	269.27	269.03	0.17	0.56
Sep-81	264.20	264.11	264.02	0.07	0.22	264.50	264.22	263.73	0.22	0.67

Table 6.4-3: Monthly median of simulated stage (ft, NAVD 88) for Susitna River at Susitna Station (USGS 15294350) with and without project for 1976 (representative dry year, top) and 1981 (representative wet year, bottom).

	Existing Conditions					OS-1b				
Month	Daily max	Daily Avg	Daily Min	Daily StDev	Daily Range	Daily max	Daily Avg	Daily Min	Daily StDev	Daily Range
Jun-76	43.08	42.81	42.71	0.12	0.41	41.92	41.69	41.41	0.12	0.36
Jul-76	43.14	42.94	42.70	0.15	0.45	42.28	42.08	41.88	0.14	0.44
Aug-76	42.70	42.54	42.38	0.14	0.42	41.75	41.43	41.18	0.12	0.39
Sep-76	36.63	36.32	36.13	0.11	0.35	36.66	36.40	36.21	0.12	0.35
Jun-81	43.64	43.56	43.31	0.07	0.22	42.73	42.48	42.27	0.06	0.19
Jul-81	47.85	47.40	47.20	0.15	0.48	46.94	46.61	46.41	0.14	0.51
Aug-81	46.49	46.00	45.77	0.19	0.61	46.64	46.01	45.85	0.18	0.57
Sep-81	38.96	38.82	38.62	0.11	0.35	38.90	38.74	38.65	0.12	0.43

9. FIGURES

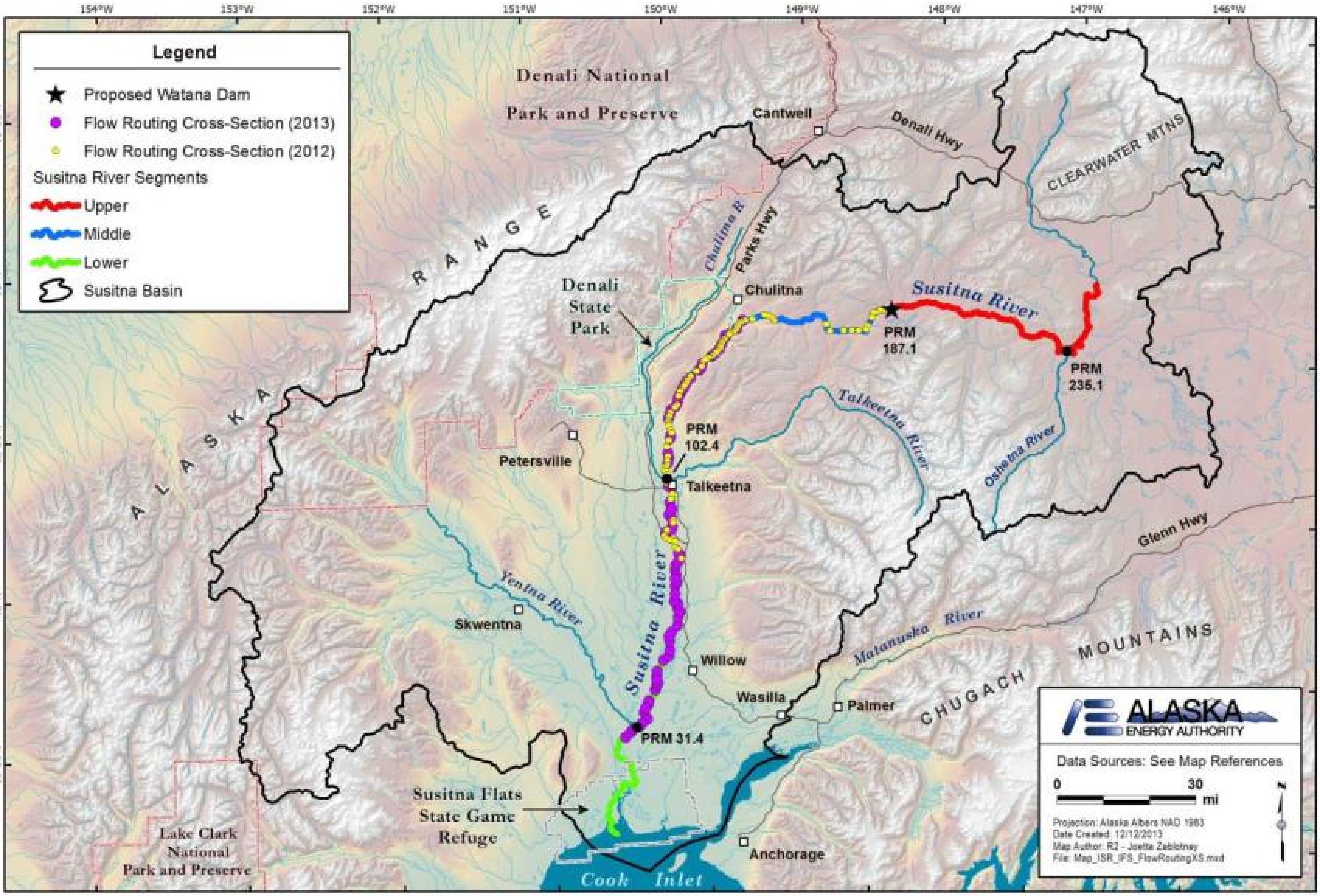


Figure 2.1-1. Map depicting the Upper, Middle and Lower Segments of the Susitna River potentially influenced by the Susitna-Watana Hydroelectric Project, and the locations of the cross-sections of the Susitna River surveyed in 2012 and 2013.

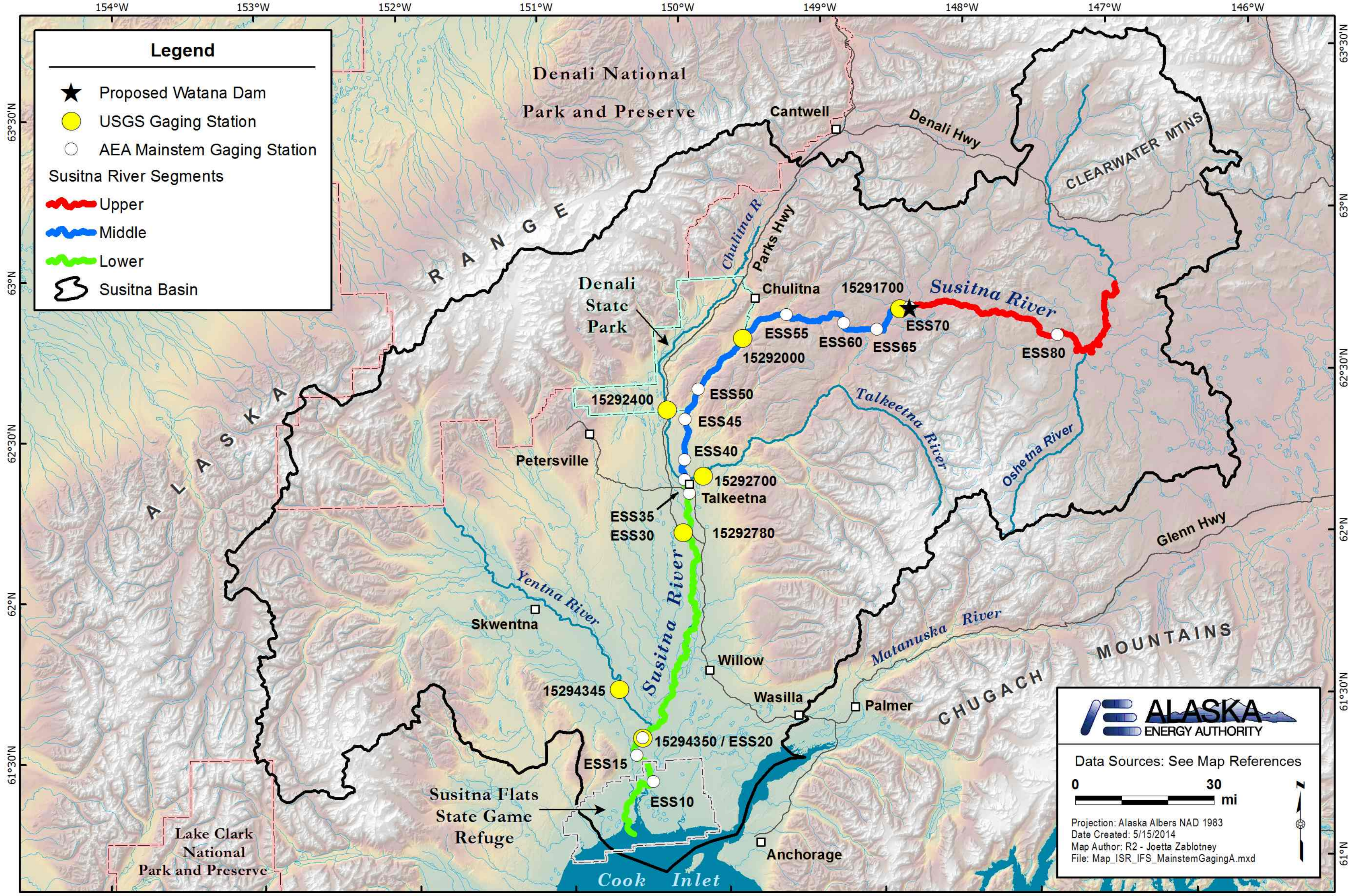


Figure 3.2-1. Locations of USGS gages on the Susitna River and its tributaries.

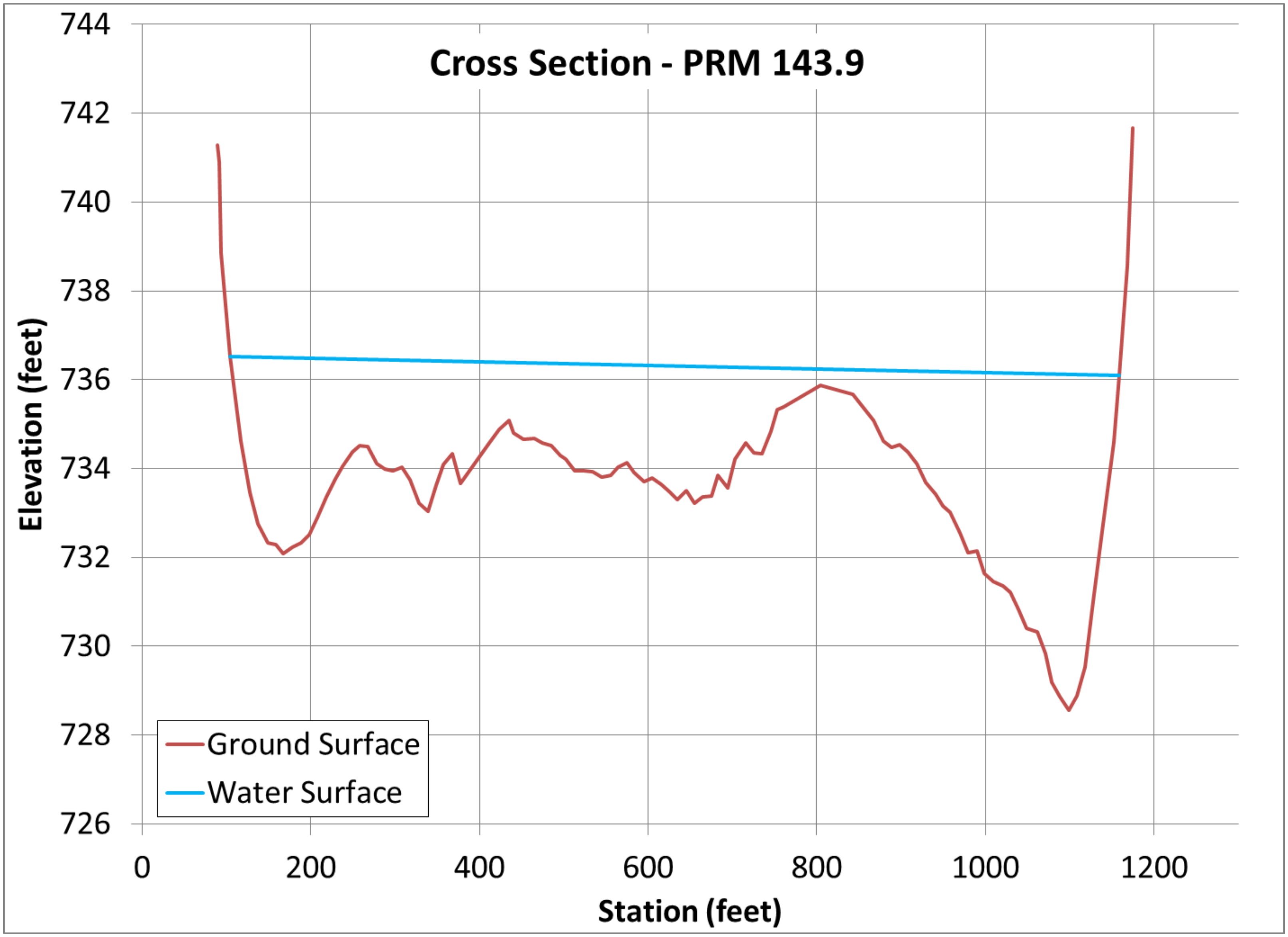


Figure 5.4-1: Example cross section from in-channel measurements.

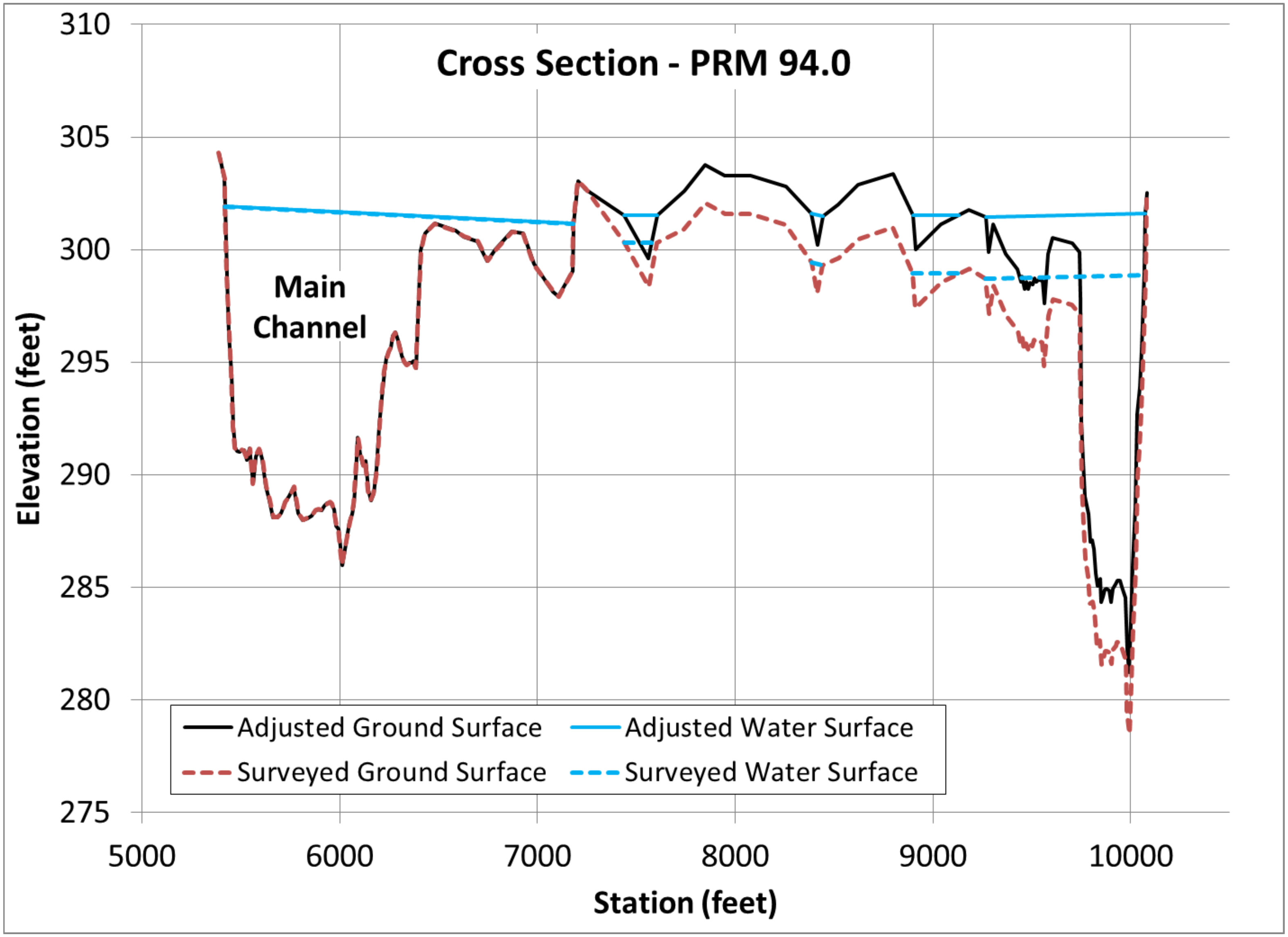


Figure 5.4-2: Example cross section from in-channel measurements that required secondary channel shifting to match the WSE of the main channel. In this case, note how both wetted and dry portions of the transect required shifting.

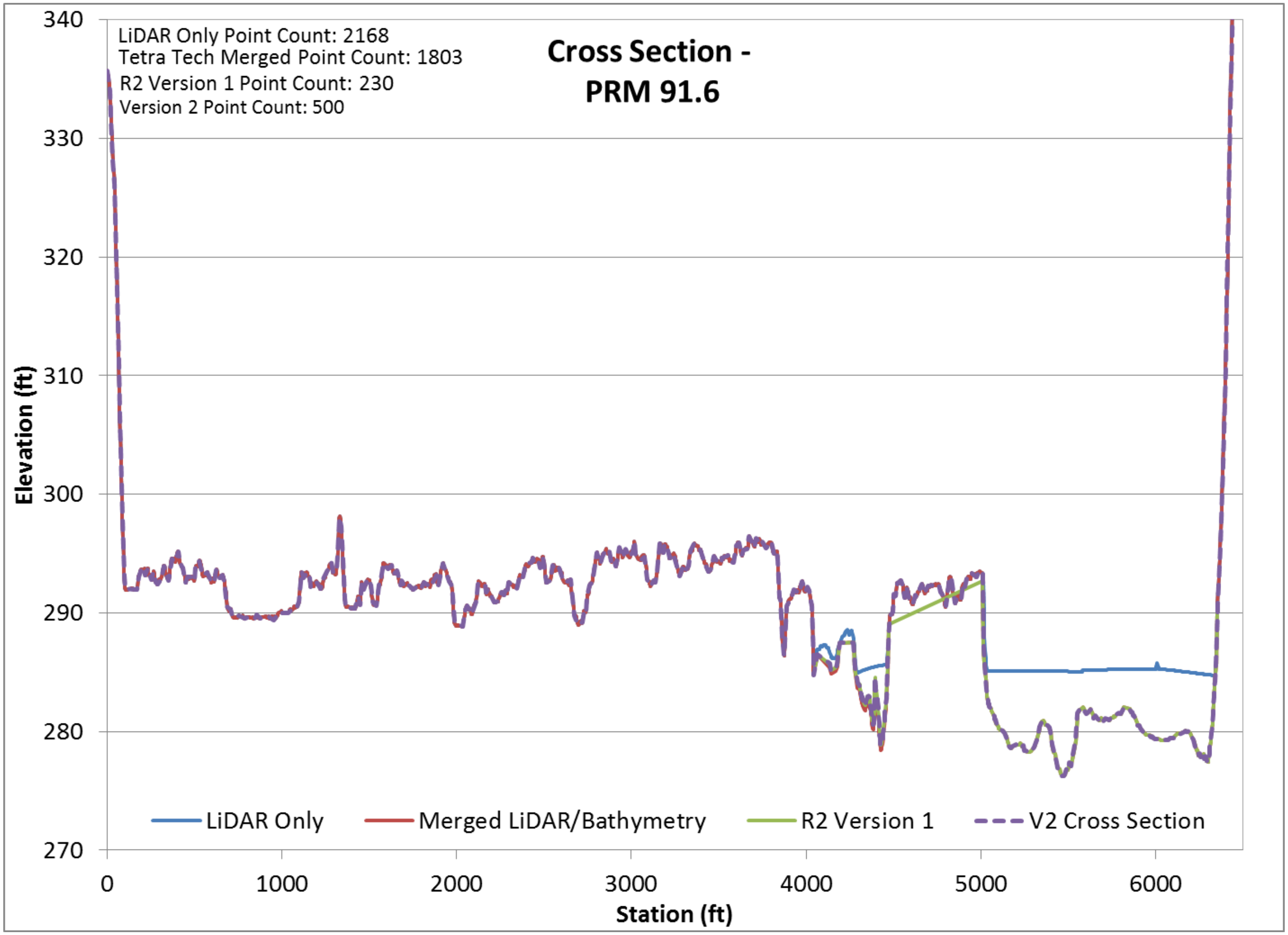


Figure 5.4-3. Example merged in-channel and overbank cross sectional profile for PRM 91.6.

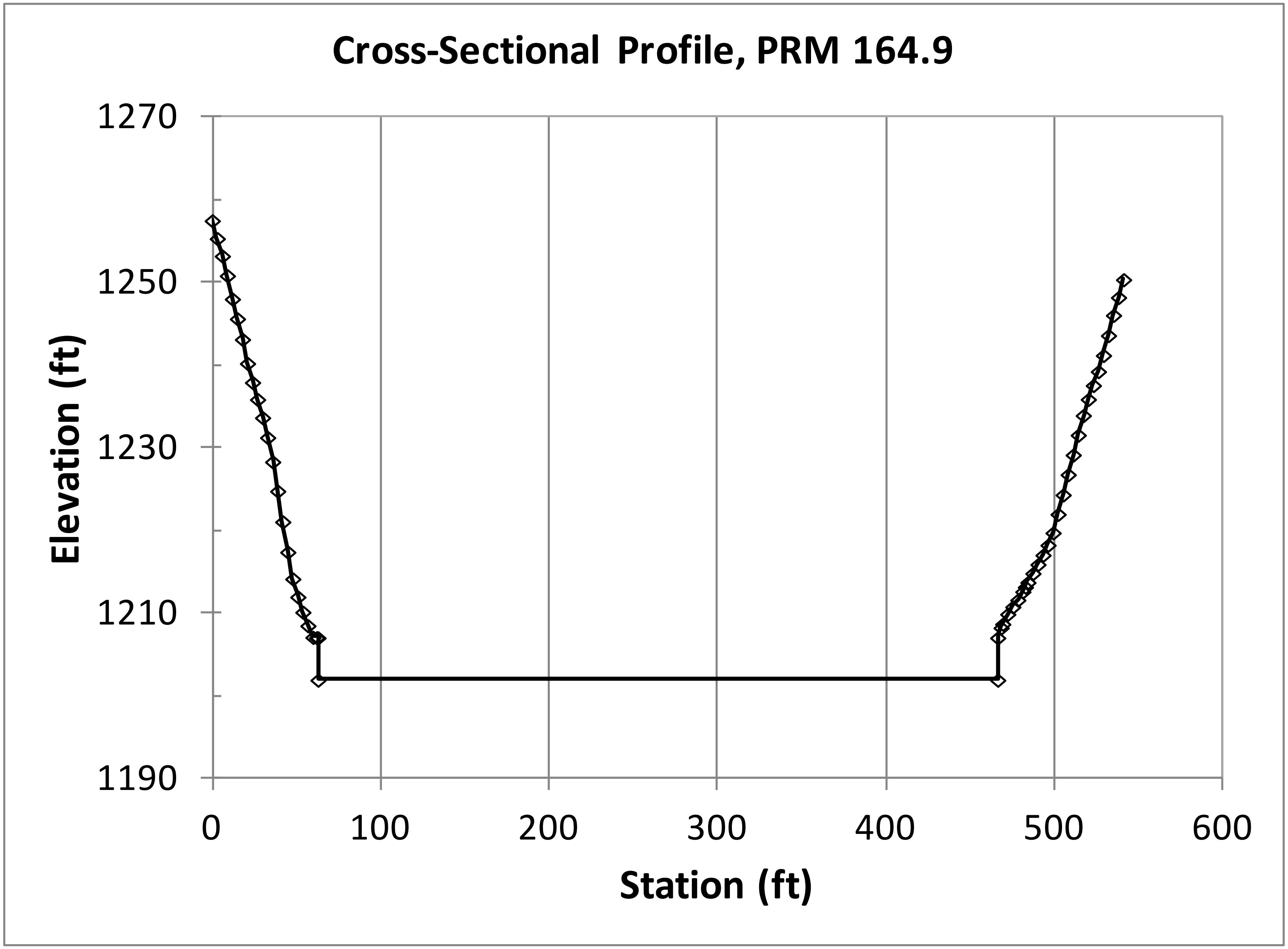
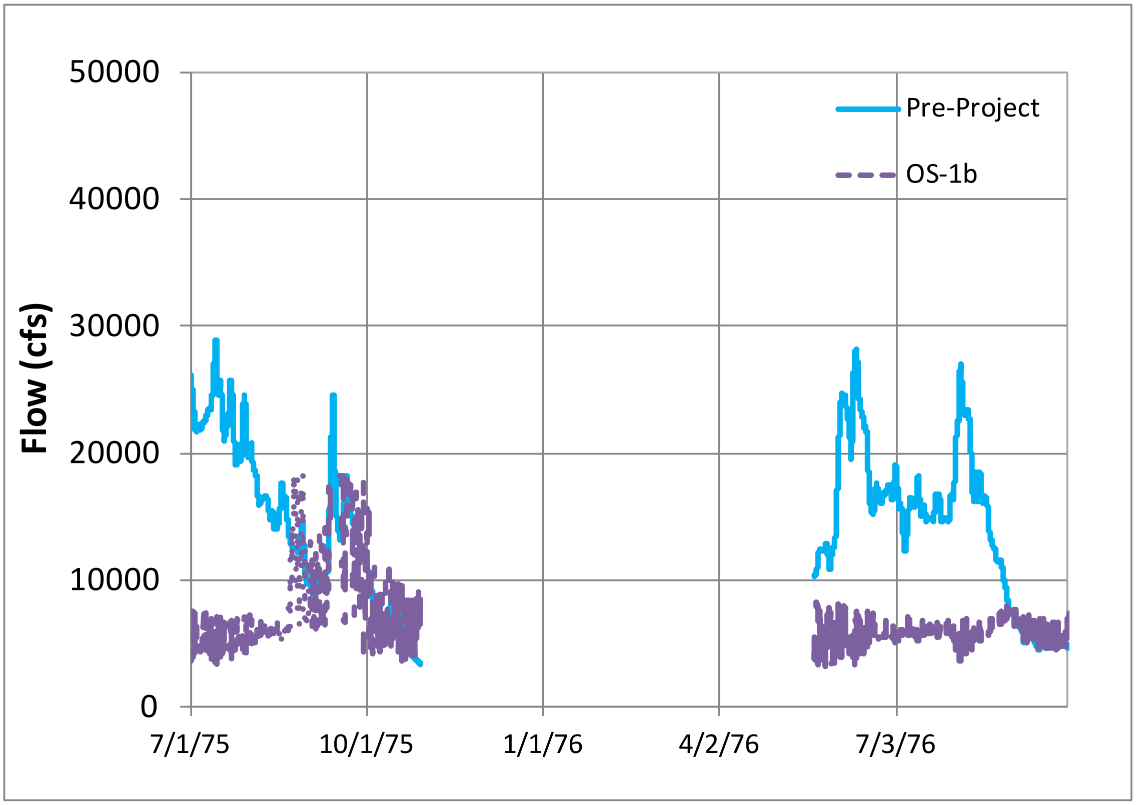


Figure 5.4-4. Example cross sectional profile created for Devils Canyon at PRM 164.9.



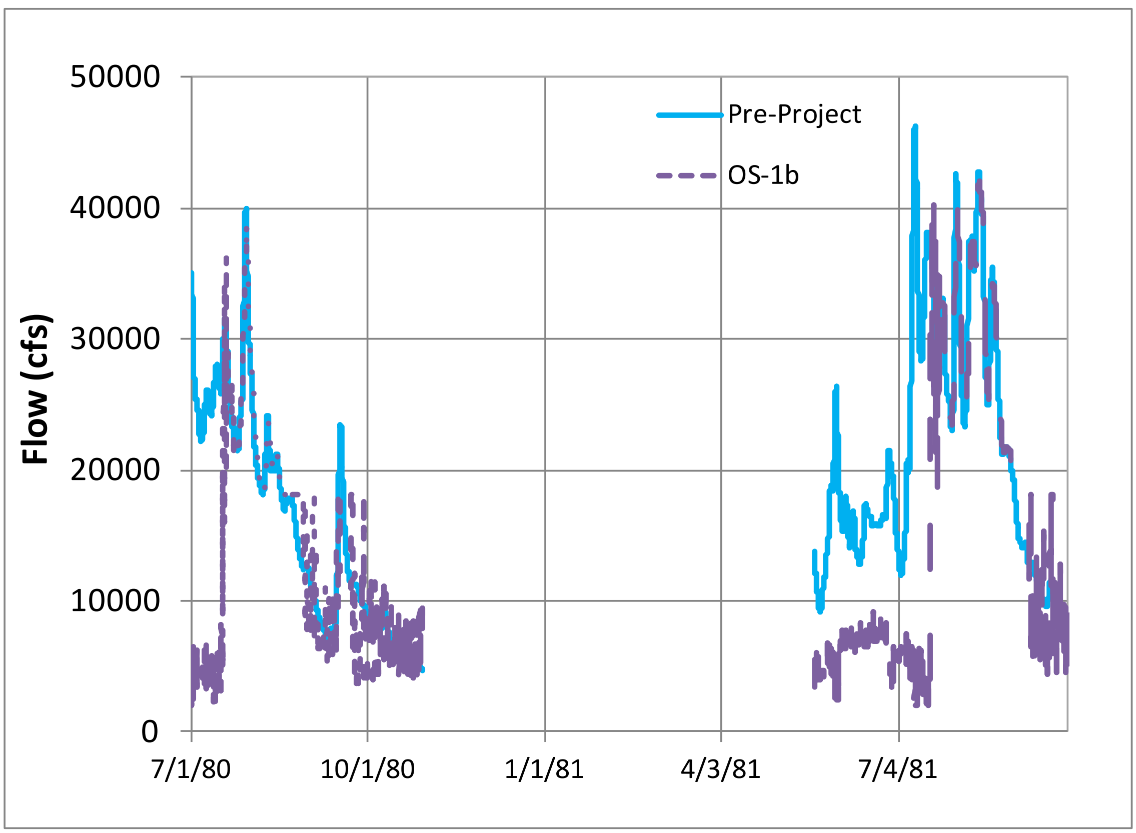


Figure 5.4-5. Flow releases from Watana Dam site, input to the flow routing model for the Pre-Project and Maximum Load Following OS-1b scenarios during simulation period 1976 (top, dry) and 1981 (bottom, wet).

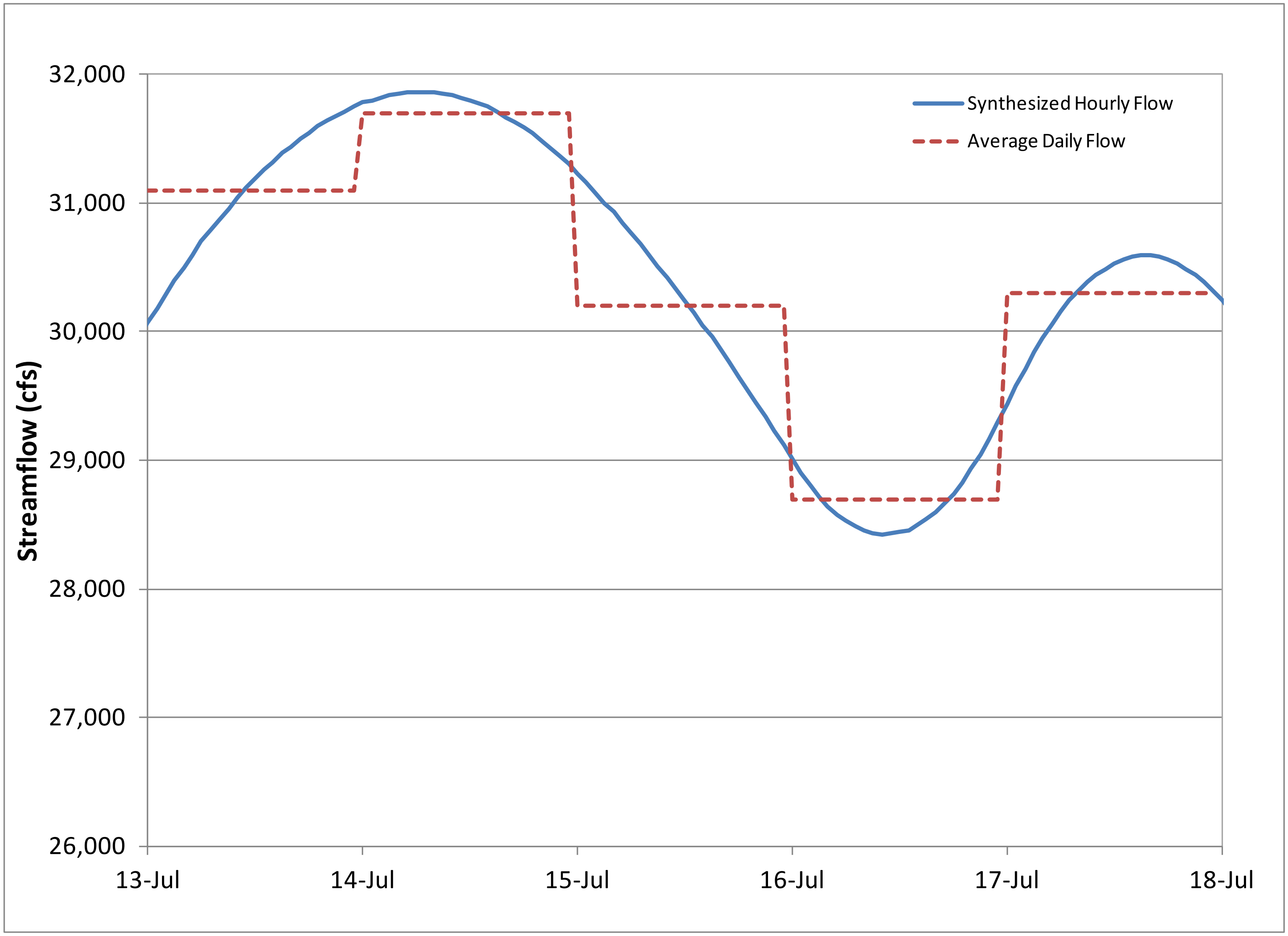


Figure 5.4-6. Illustration of hourly flow hydrograph, synthesized from available daily flows. The synthesized hourly flow hydrograph does not account for potential diurnal variation associated with glacial melt.

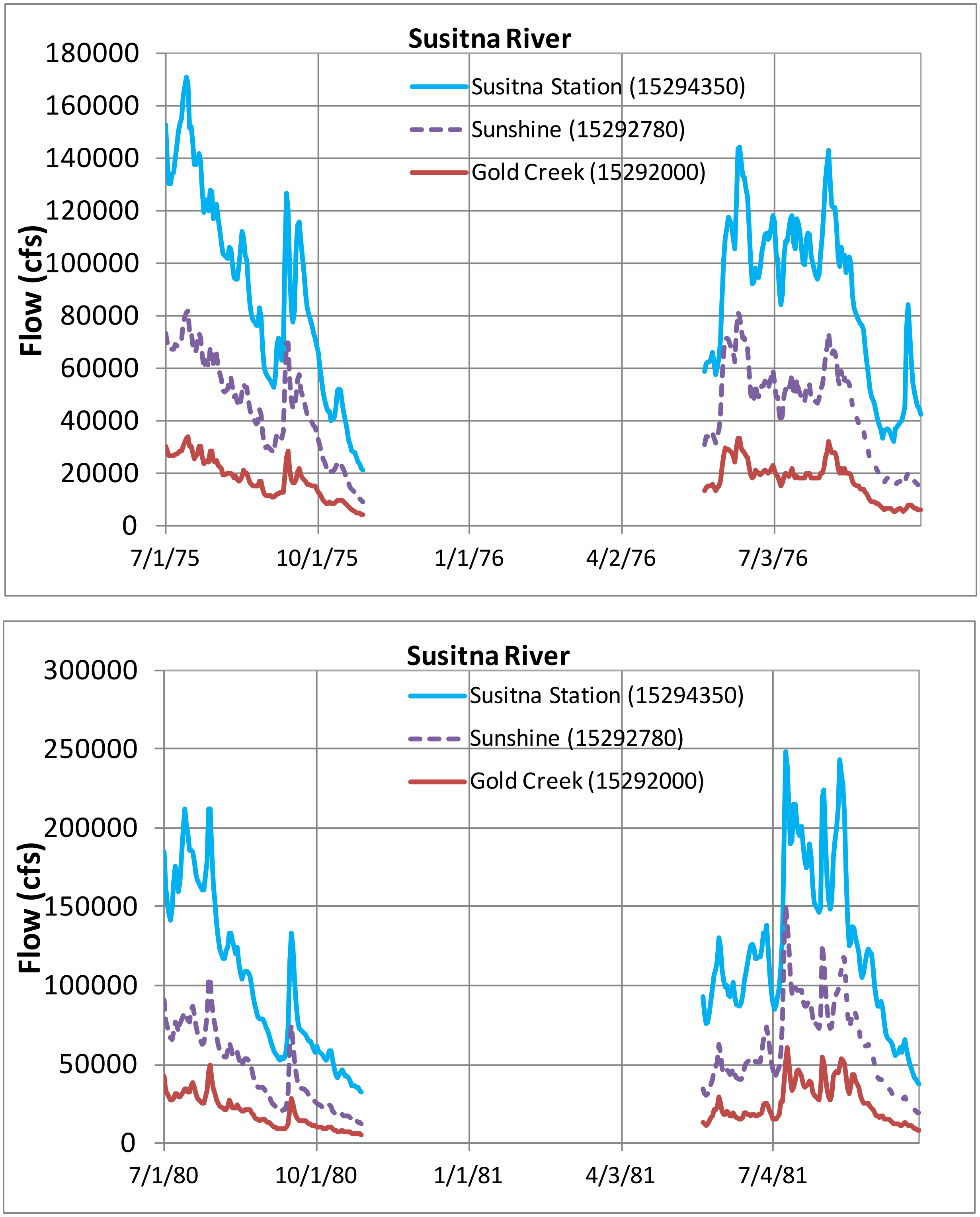


Figure 5.4-7. Daily flow hydrographs reported by the U.S. Geological Survey in the Susitna River at Sunshine (Gage 15292780) at Gold Creek (Gage 15292000), and above Tsusena Creek (USGS 15291700) during water year 1976 (top, dry) and 1981 (bottom, wet).

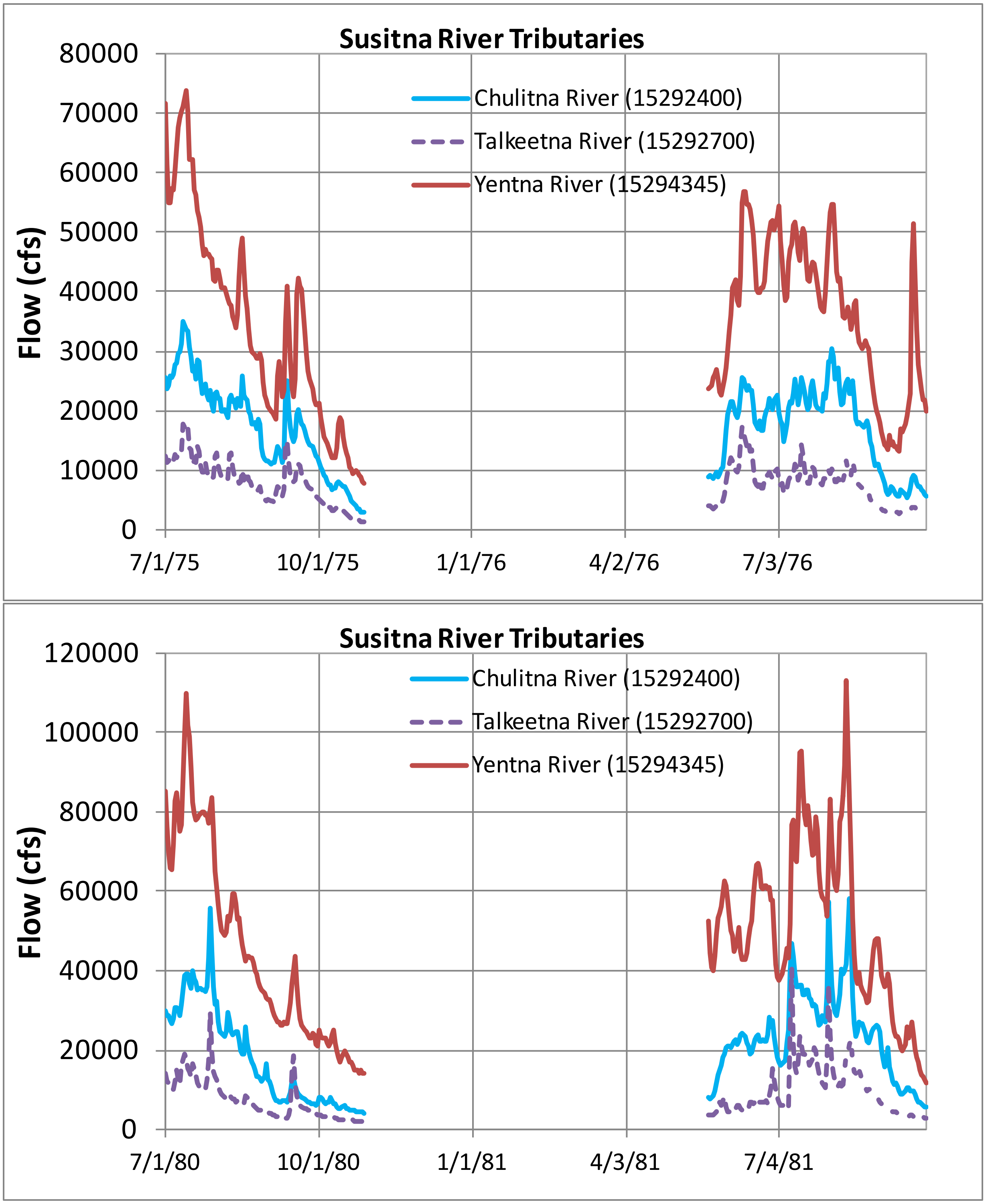


Figure 5.4-8. Daily flow hydrographs reported by the U.S. Geological Survey in the Choline River near Talkeetna (Gage 15292400), in the Talkeetna River near Talkeetna (USGS 15292700), and in the Yentna River near Susitna Station (USGS 15294345) for 1976 (top, dry) and 1981 (bottom, wet).

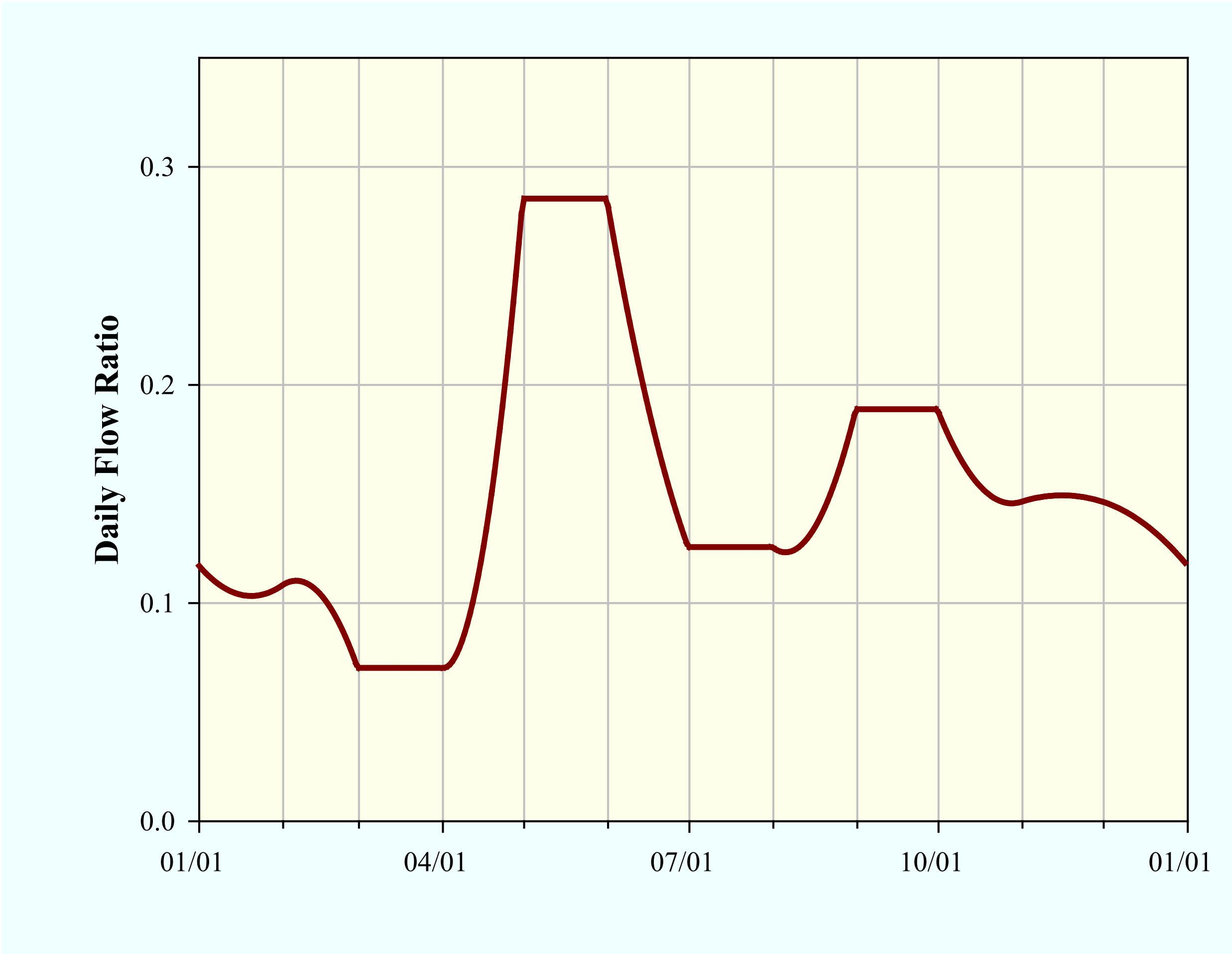
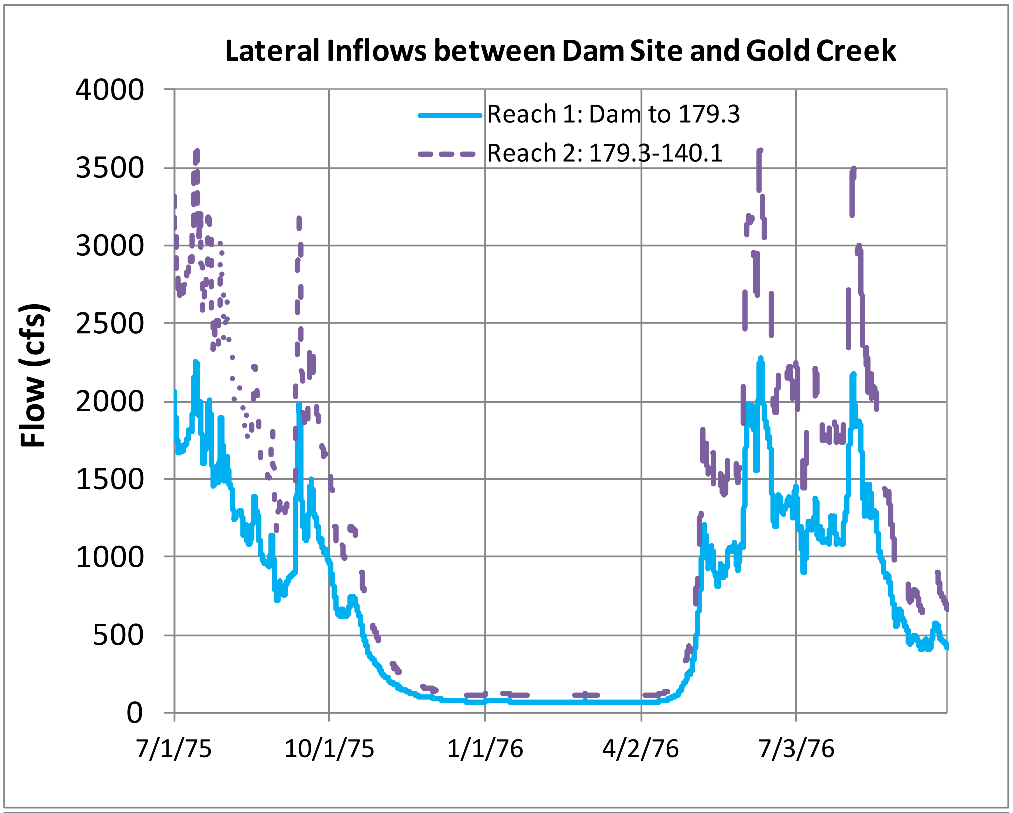


Figure 5.4-9. Ratio of ungaged accretion flow in the Susitna River between Gold Creek gage and Sunshine Gage to the flow at Gold Creek gage, used to derive daily ungaged accretion flows from the daily flows at Gold Creek gage.



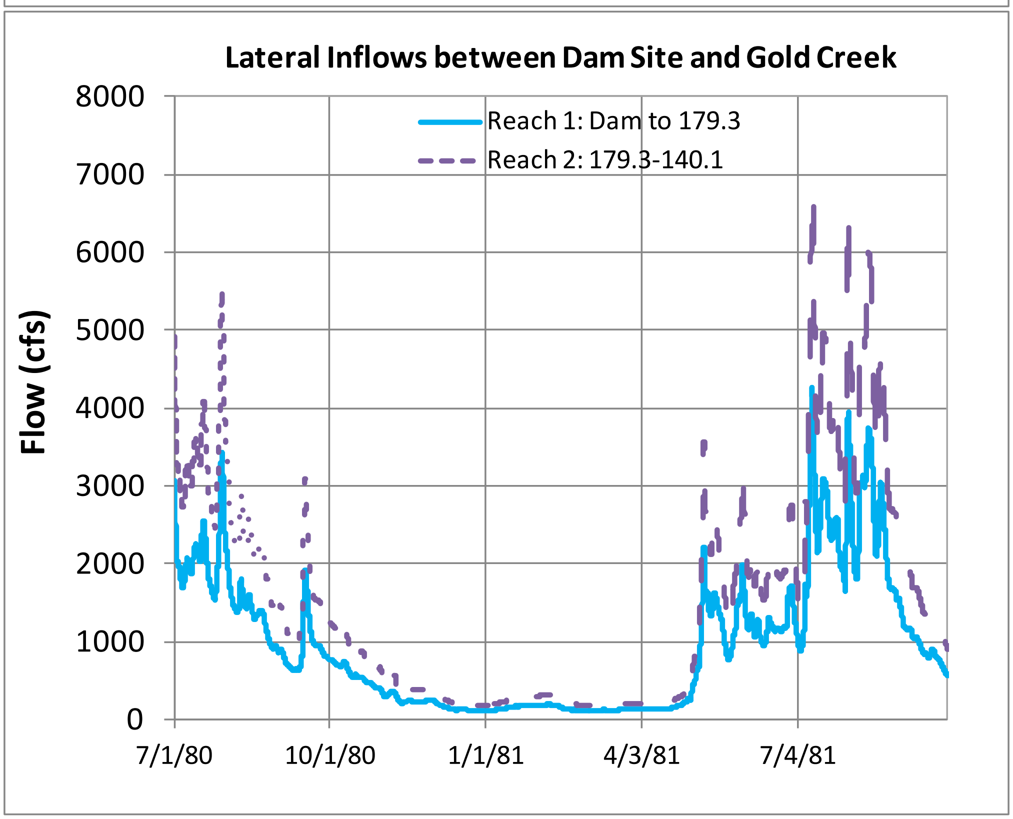


Figure 5.4-10. Hourly flow hydrographs for lateral inflow reaches 1 and 2 between PRM 140.0 and 187.1 for 1976 (top, dry) and 1981 (bottom, wet).

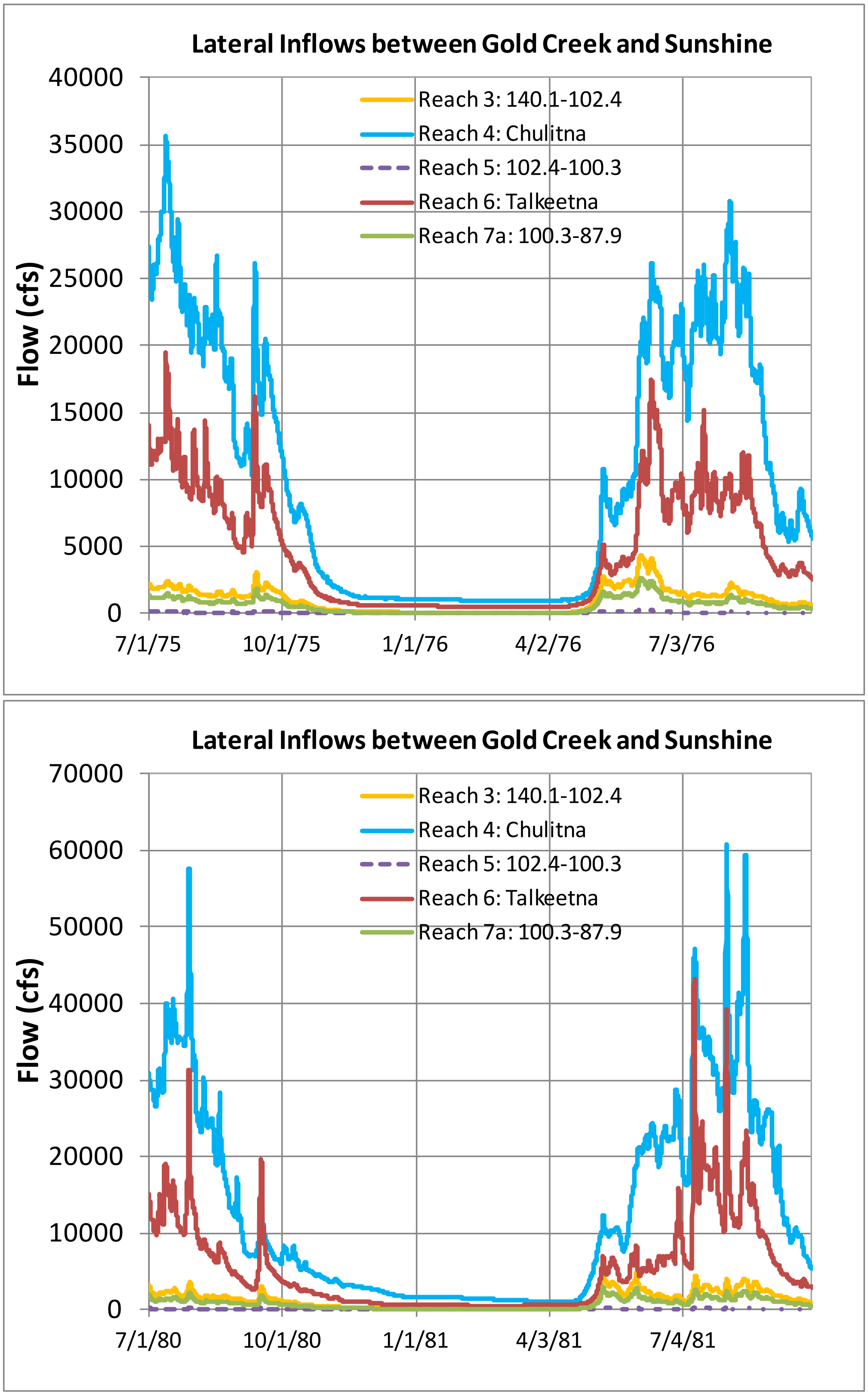
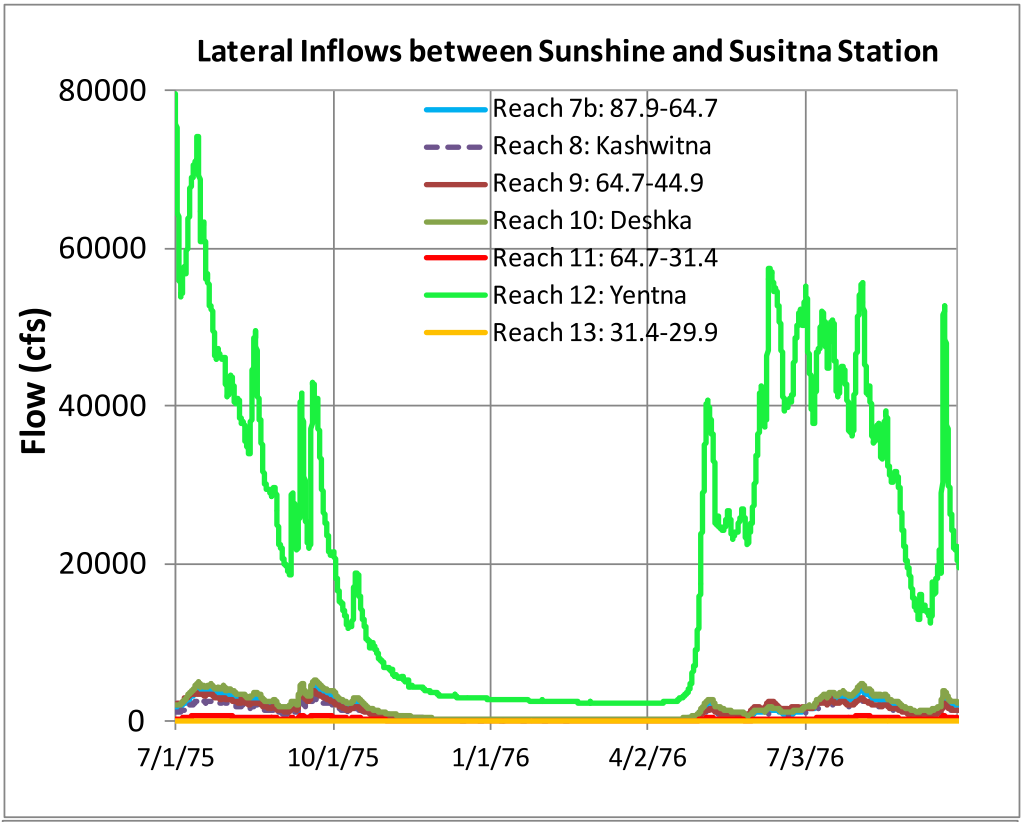


Figure 5.4-11. Hourly flow hydrographs for lateral inflow reaches 3-7a between PRM 87.9 and 140.0 for 1976 (top, dry) and 1981 (bottom, wet).



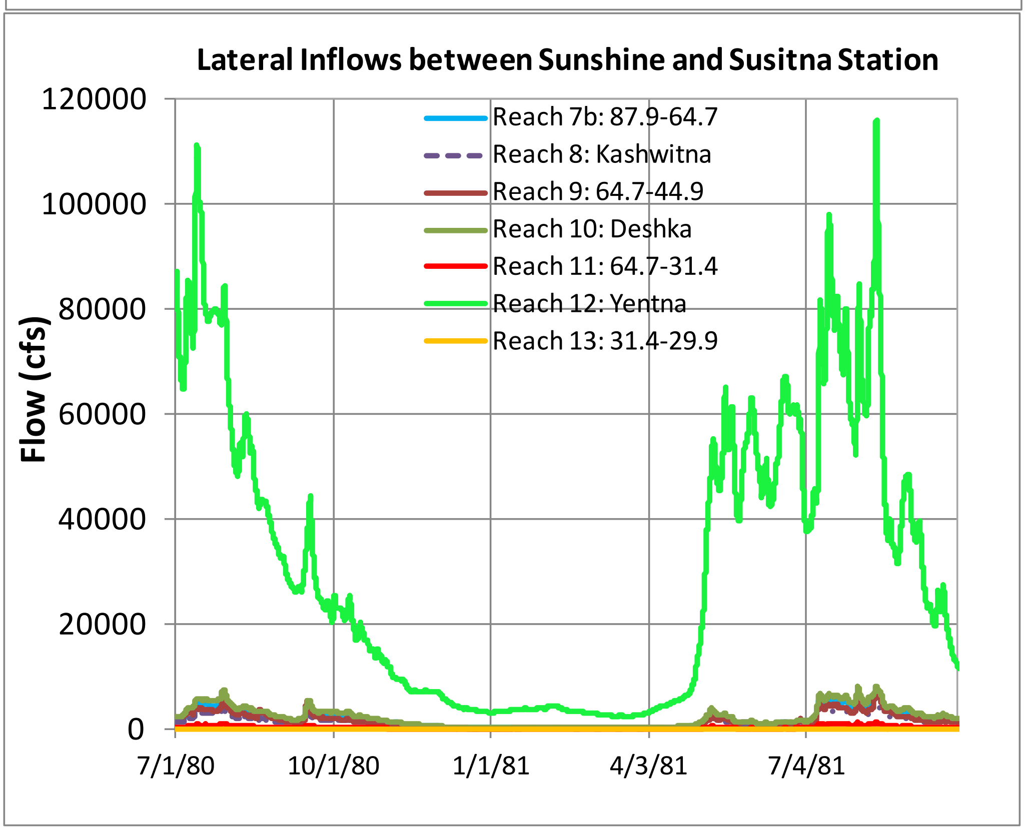


Figure 5.4-12. Hourly flow hydrographs for lateral inflow reaches 7b and 13 between PRM 87.9 and 29.9 for 1976 (top, dry) and 1981 (bottom, wet).

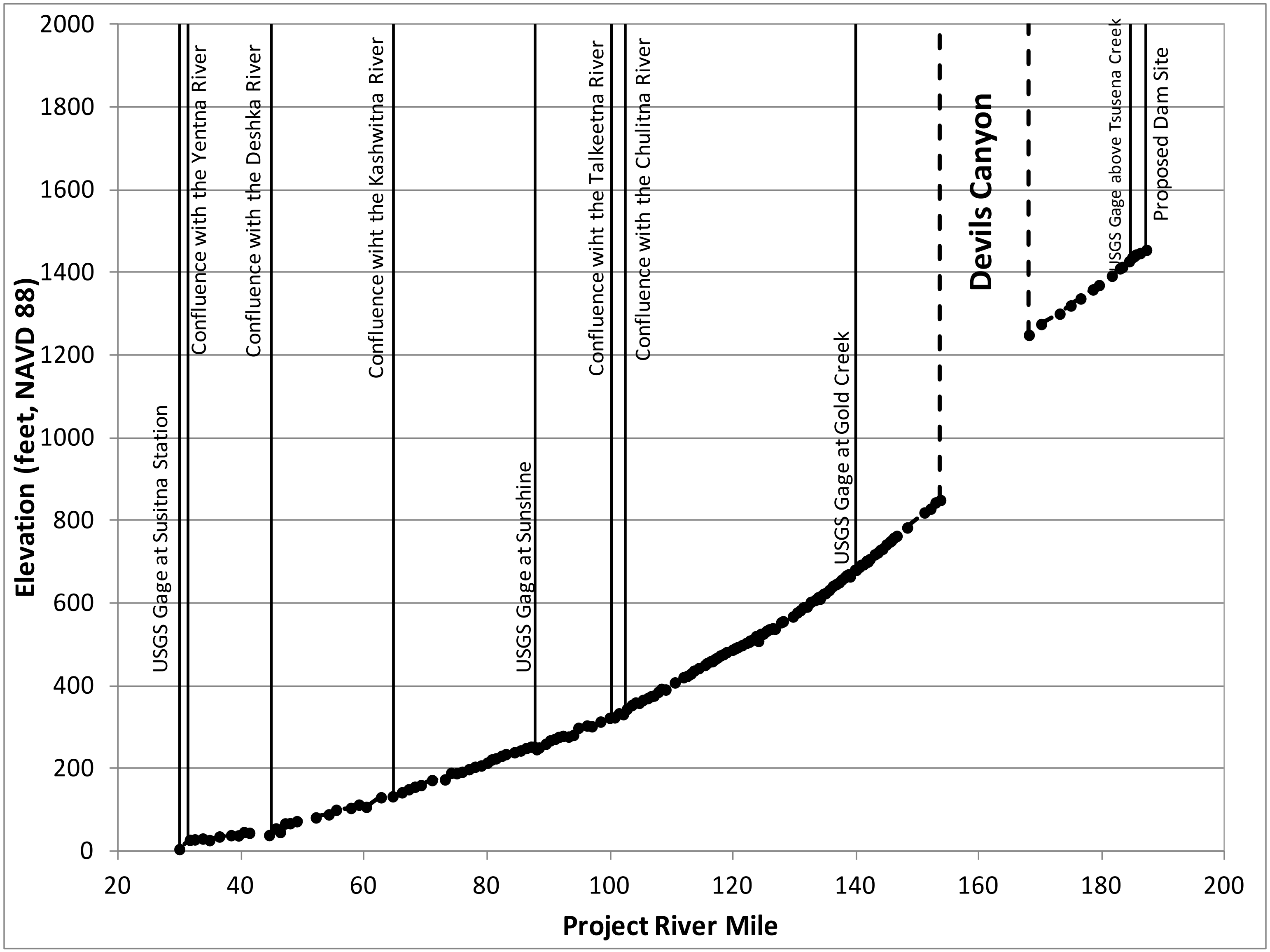


Figure 5.4-13. Longitudinal thalweg profile of the Susitna River extending from PRM 29.9 to PRM 187.2.

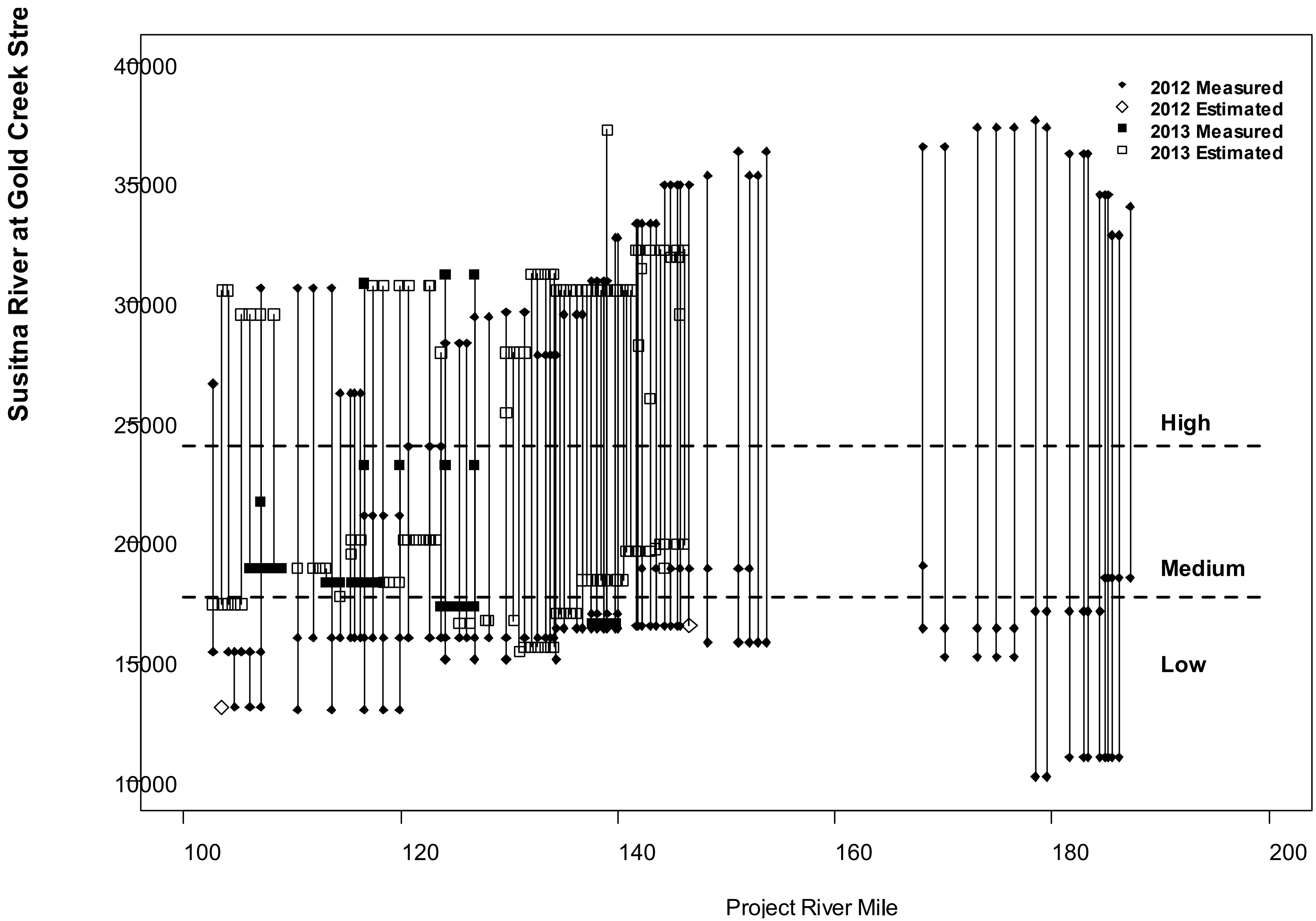


Figure 5.4-14. Locations of flow measurements in the upper Susitna River in 2012 and 2013, and classification of flows as low, medium, or high based on concurrent measurements in the Susitna River at Gold Creek (USGS 15292000).

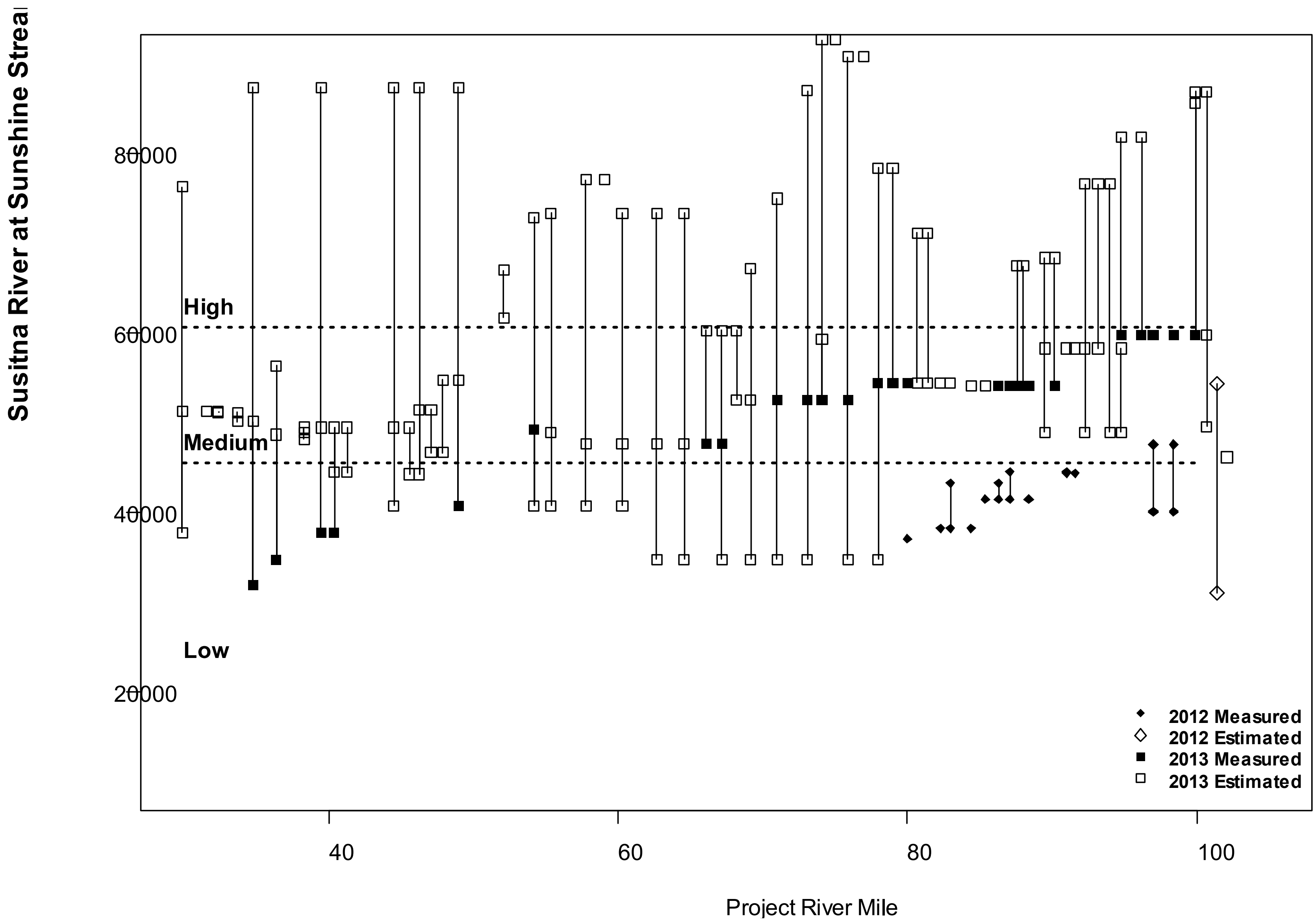


Figure 5.4-15. Locations of flow measurements in the lower Susitna River in 2012 and 2013, and classification of flows as low, medium, or high based on concurrent measurements in the Susitna River at Sunshine (USGS 15292780).

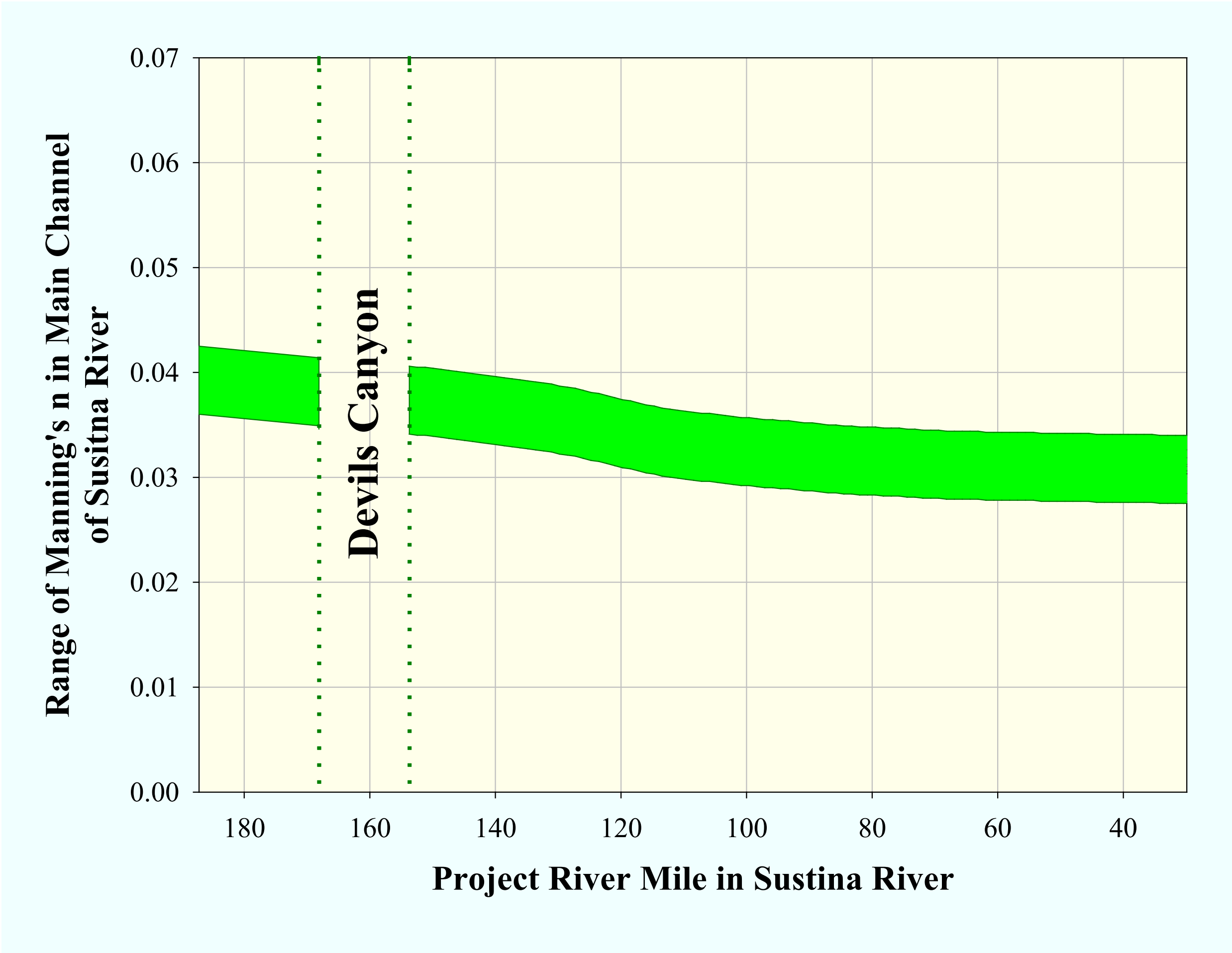


Figure 5.4-16. Range of Manning's n roughness coefficients used for the main channel of the Susitna River between the dam site (PRM 187.2) and Susitna Station gage (PRM 29.9), excluding the Devils Canyon reach.

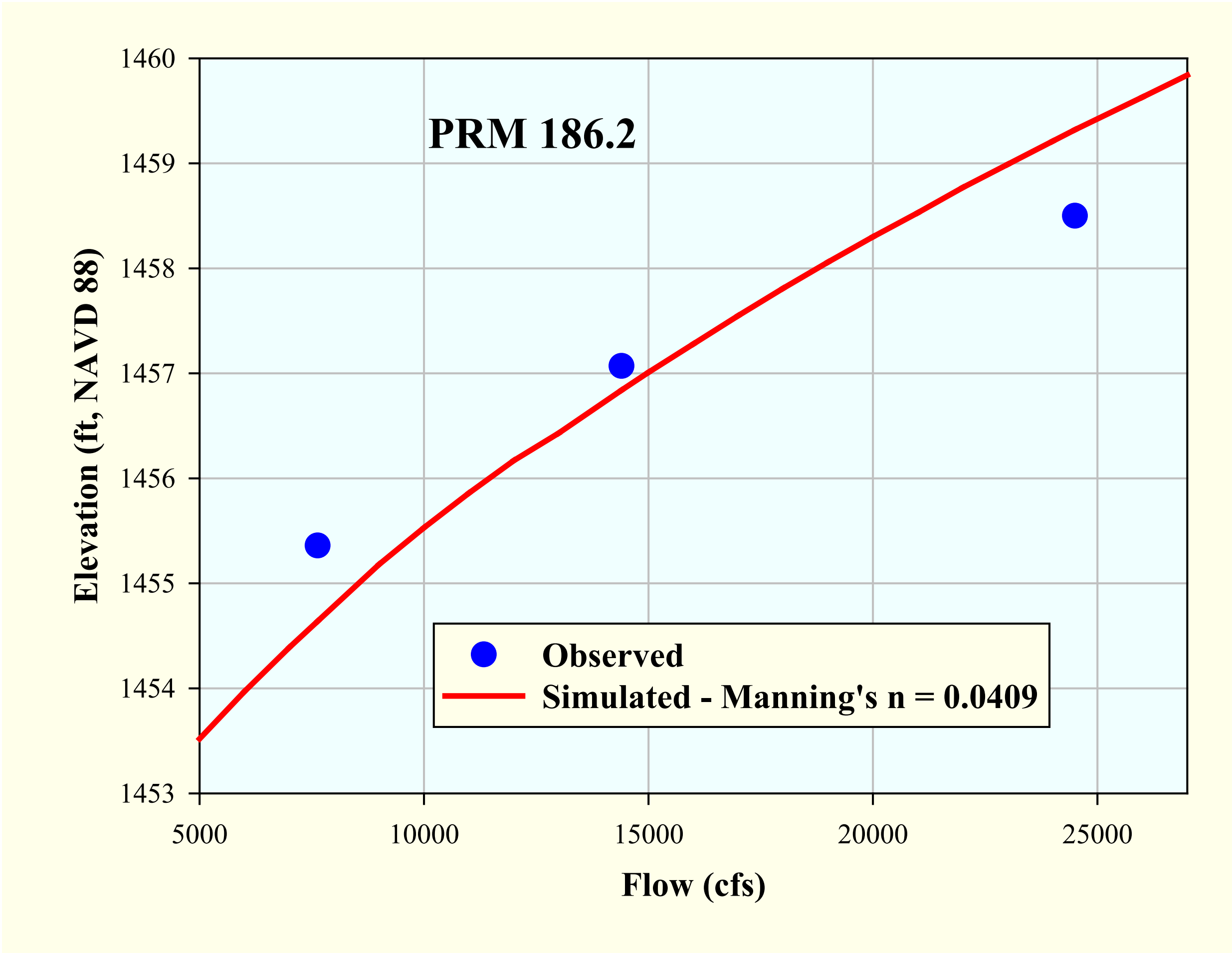


Figure 5.4-17. Comparison of observed water surface elevations at PRM 186.2 by only adjusting Manning's n (with no interpolated cross-sections).

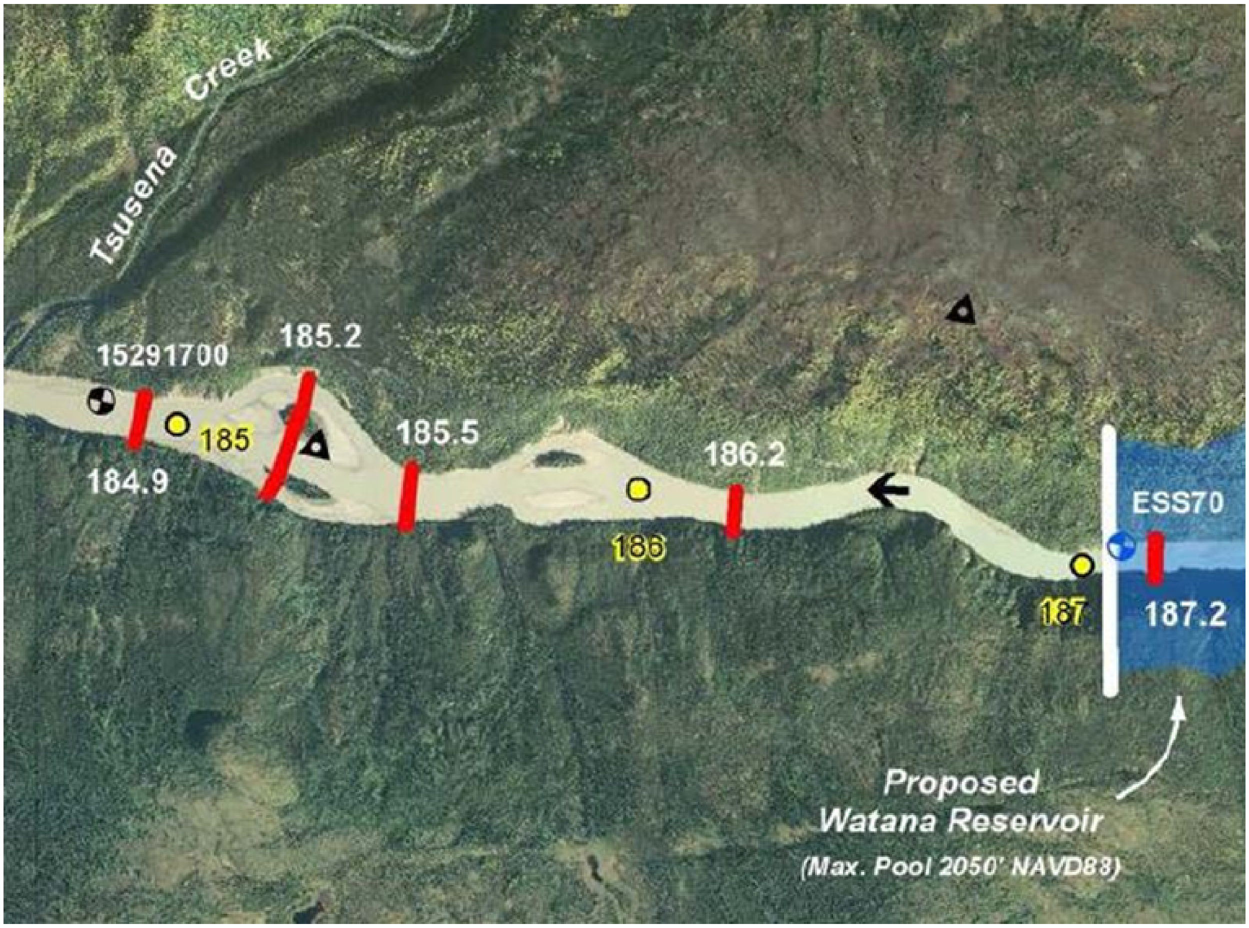


Figure 5.4-18. The Susitna River at PRM 186.2 and PRM 185.5, and the wider portion of the river between those two locations.

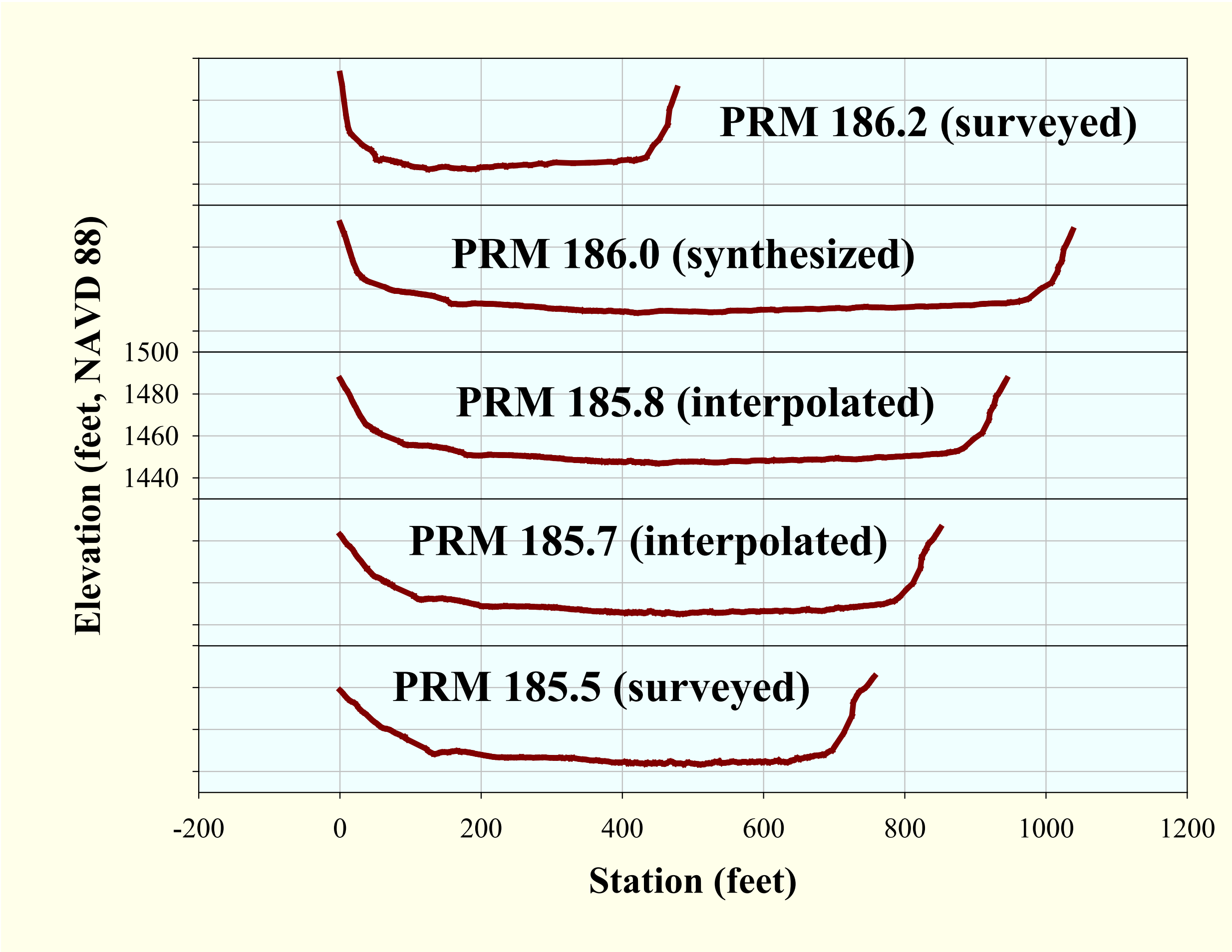


Figure 5.4-19. Surveyed cross-sections in the Susitna River at PRM 186.2 and 185.5, synthesized hydraulic control cross section at PRM 186.0, and interpolated cross sections at PRM 185.8 and 186.7.

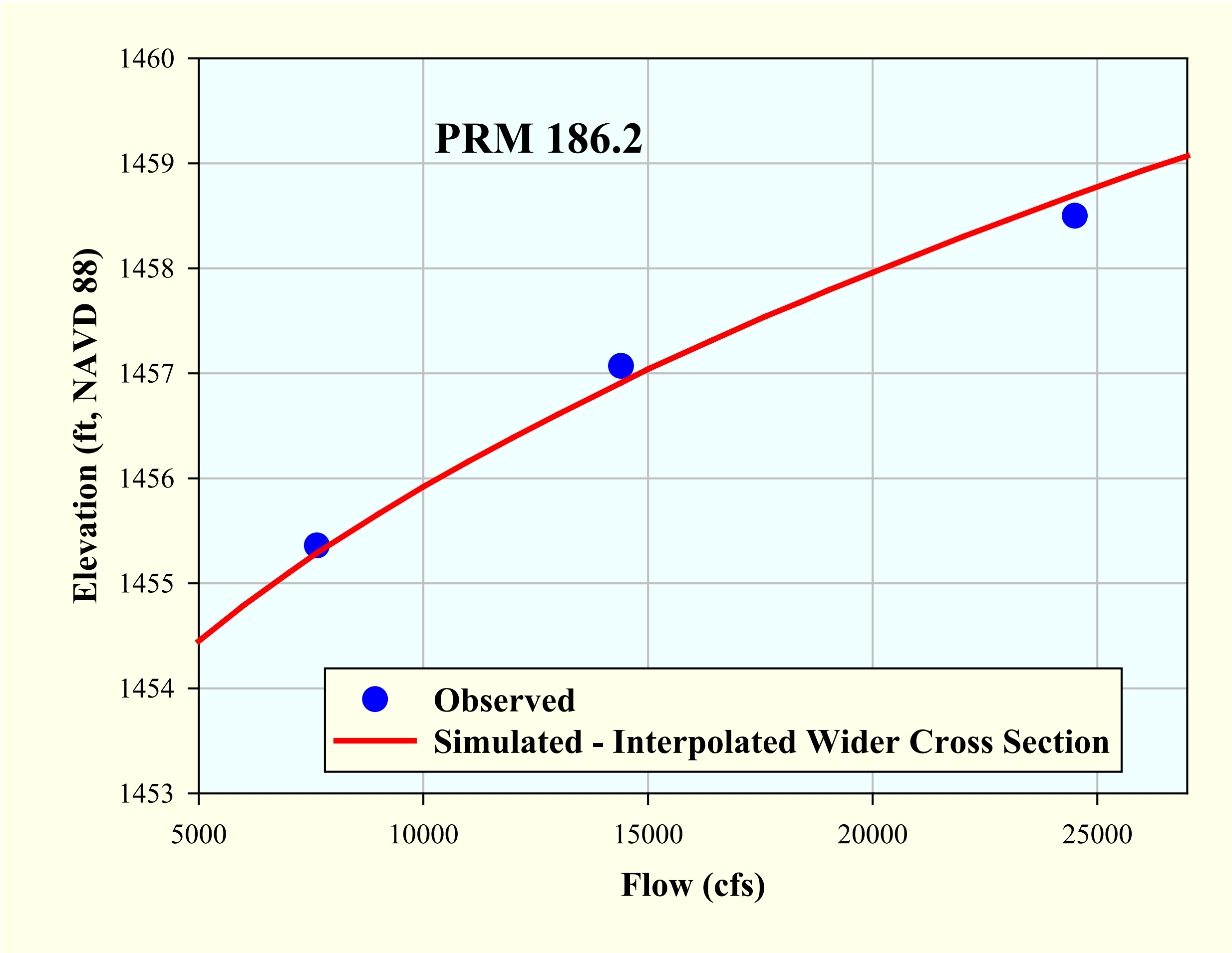


Figure 5.4-20. Comparison of observed water surface elevations at PRM 186.2 with simulated water surface elevations by using a wide hydraulic control cross section.

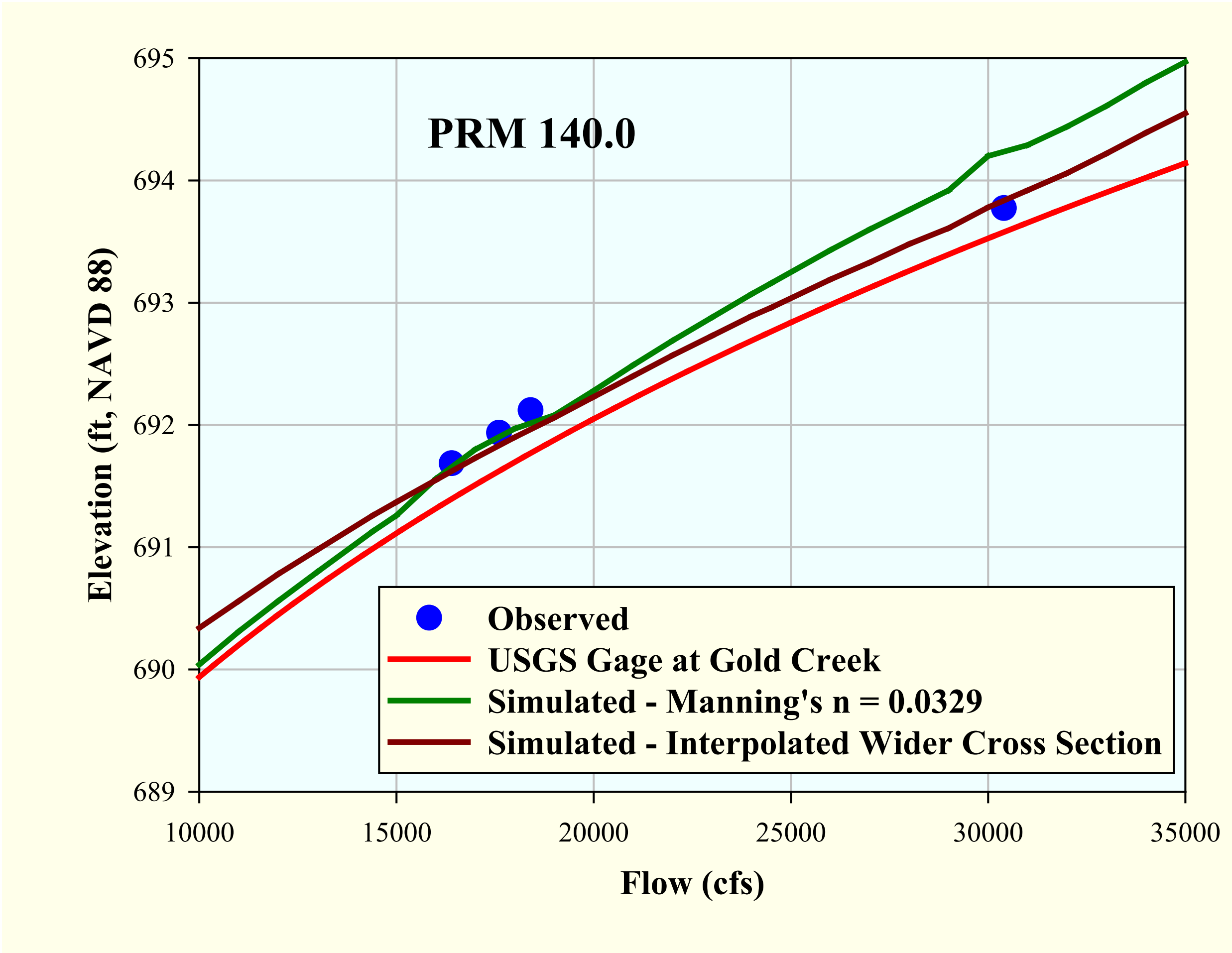


Figure 5.4-21. Observed water surface elevations at PRM 140.0 (located 100 ft upstream from Gold Creek gage), the USGS stage/discharge rating curve at Gold Creek gage, simulated water surface elevations by adjusting Manning's n (with no interpolated cross sections), and simulated water surface elevations using a wide hydraulic control cross-section.

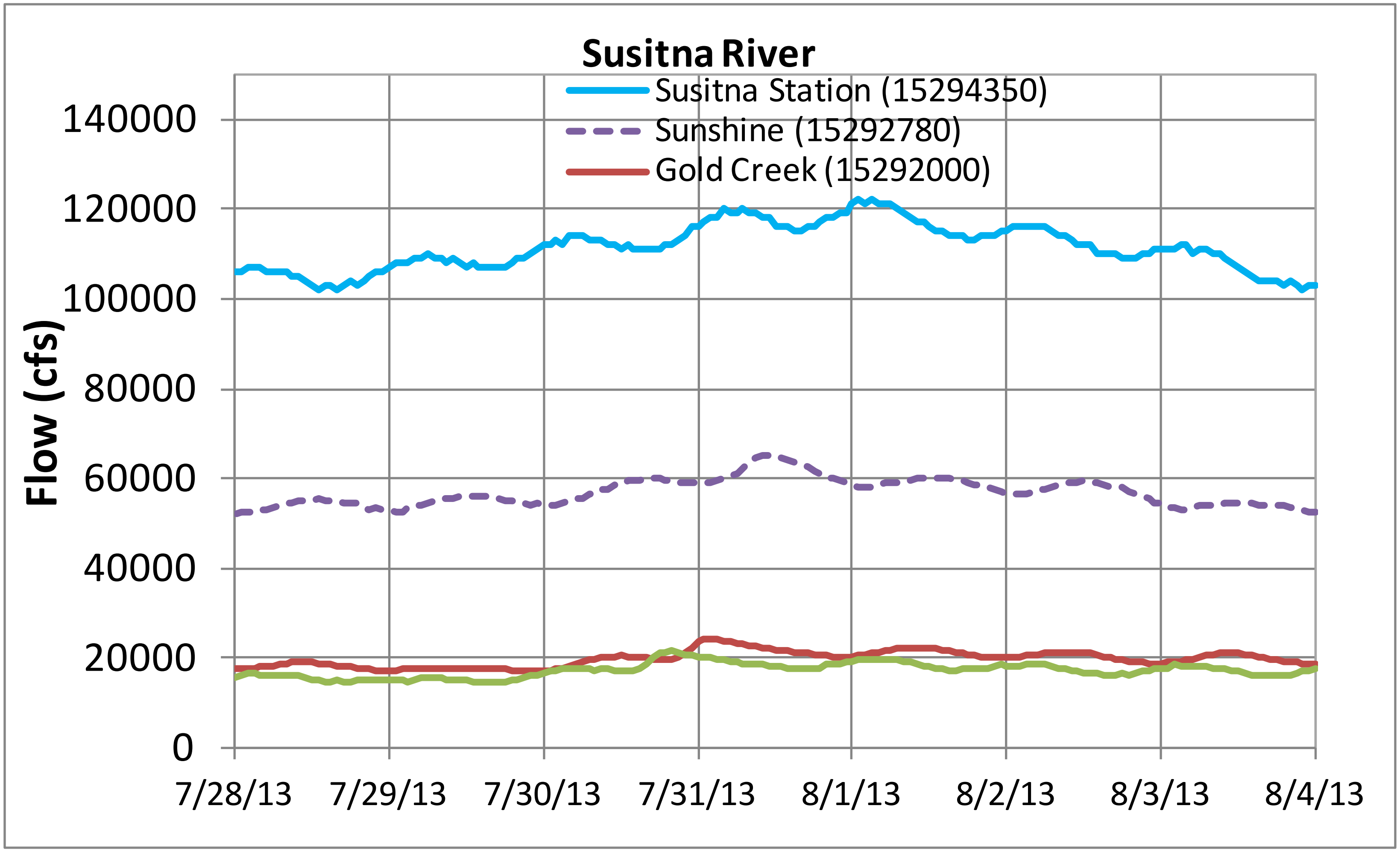


Figure 5.4-22. Flow hydrographs measured at 15-minute intervals by the U.S. Geological Survey in the Susitna River at Susitna Station (Gage 15294345), at Sunshine (Gage 15292780), at Gold Creek (Gage 15292000), and above Tsusena Creek (USGS 15291700) during the period from July 28 to August 3, 2013 when there were diurnal pulses associated with glacial melt.

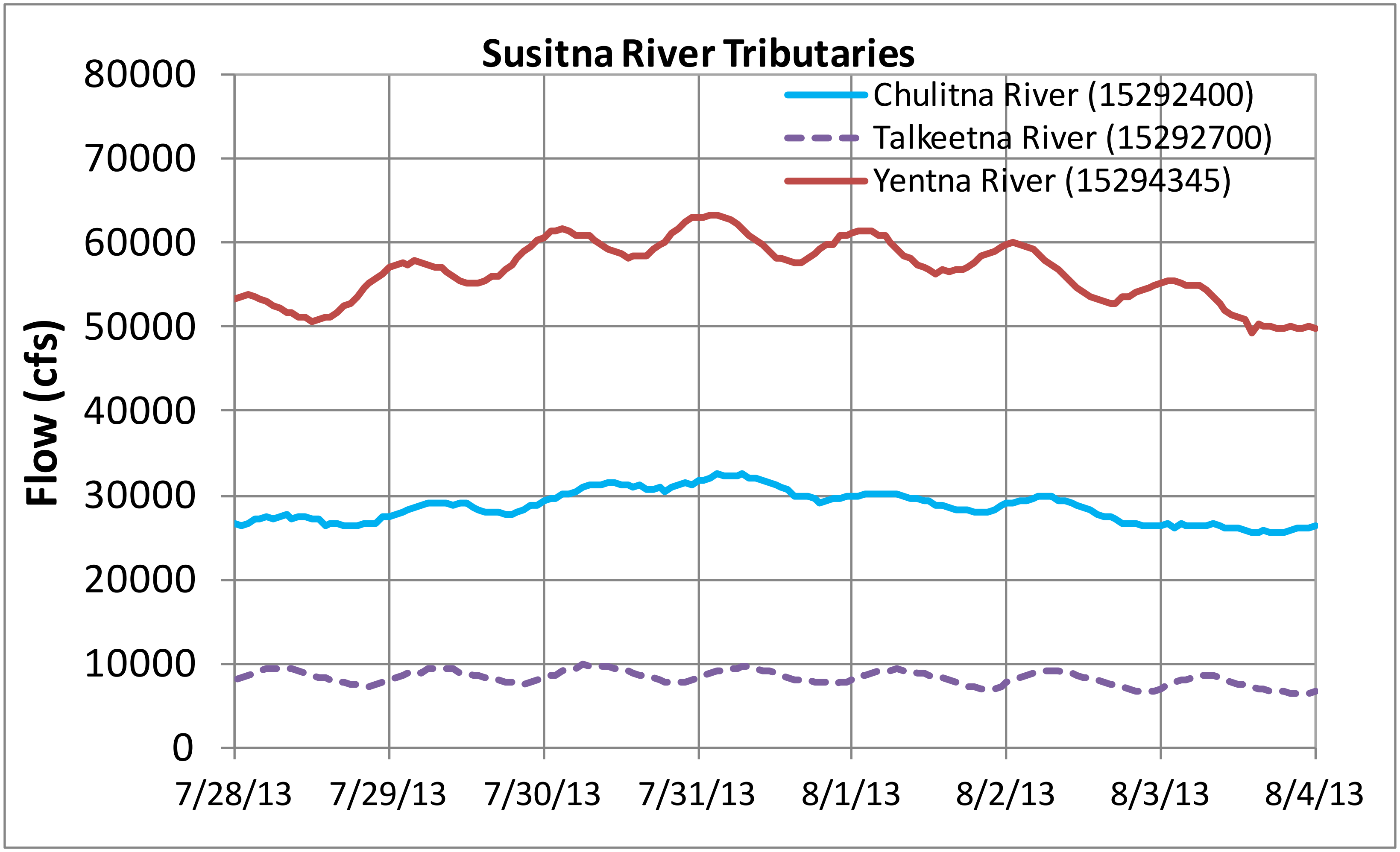


Figure 5.4-23. Flow hydrographs measured at 15-minute intervals by the U.S. Geological Survey in the Chulitna River near Talkeetna (Gage 15292400), Talkeetna River near Talkeetna (USGS 15292700), and Yentna River (USGS 15294345) during the period from July 28 to August 3, 2013 when there were diurnal pulses associated with glacial melt.

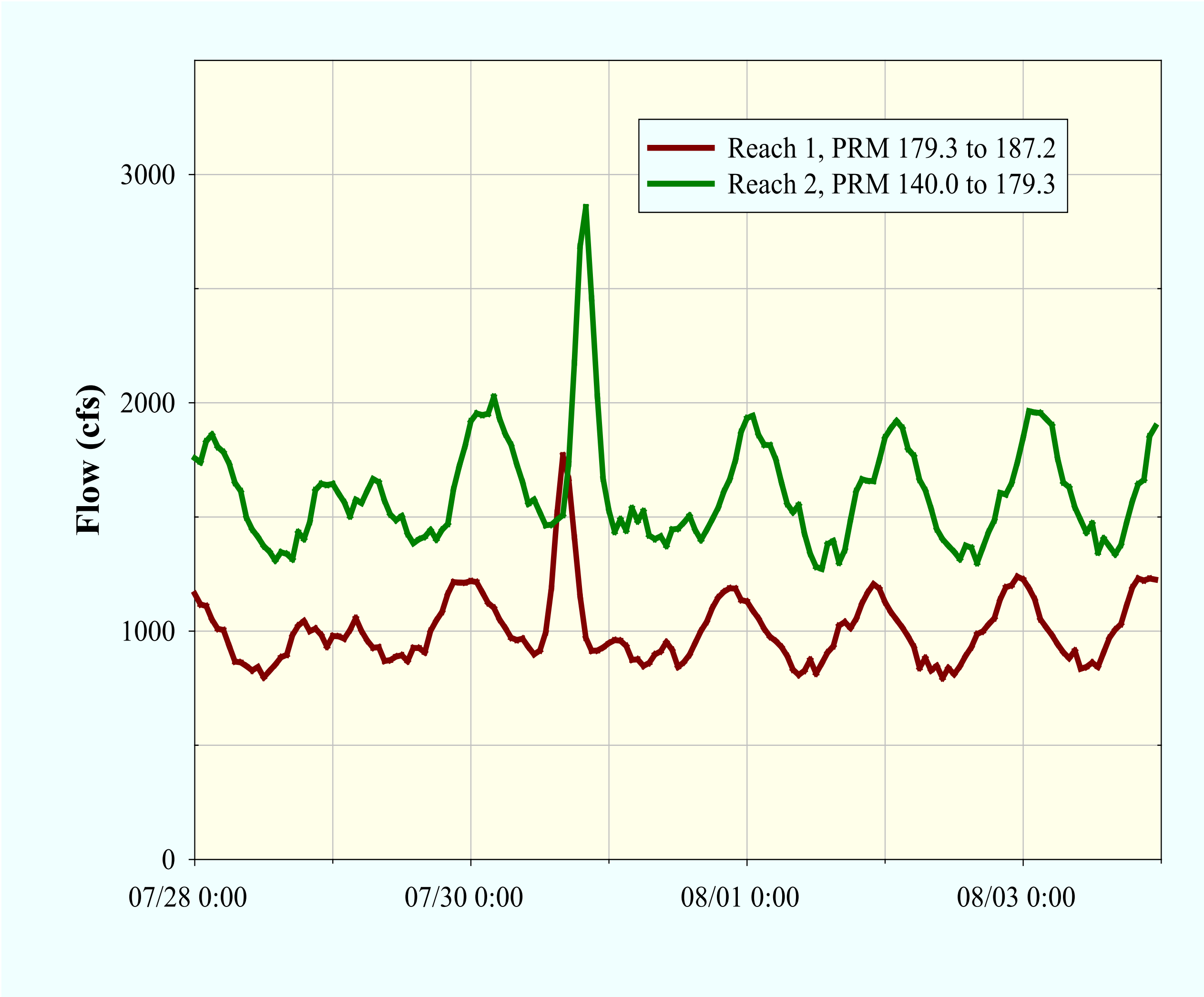


Figure 5.4-24. Ungaged lateral inflow hydrographs to the Susitna River in Reaches 1 and 2 between the Dam Site and Gold Creek during the week of July 28 to August 3, 2013.

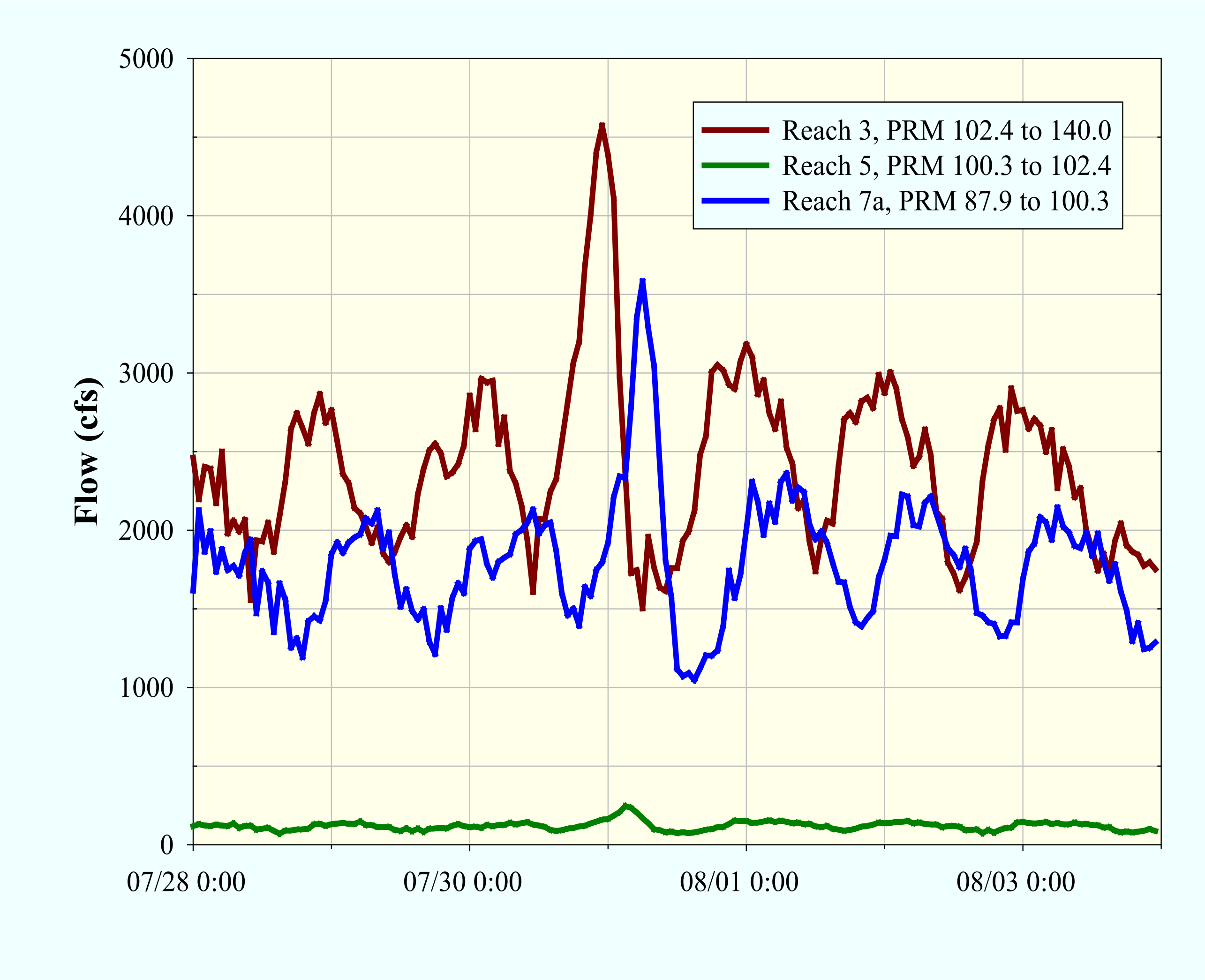


Figure 5.4-25. Ungaged lateral inflow hydrographs to the Susitna River in Reaches 3 through 7a between Gold Creek and Sunshine during the week of July 28 to August 3, 2013.

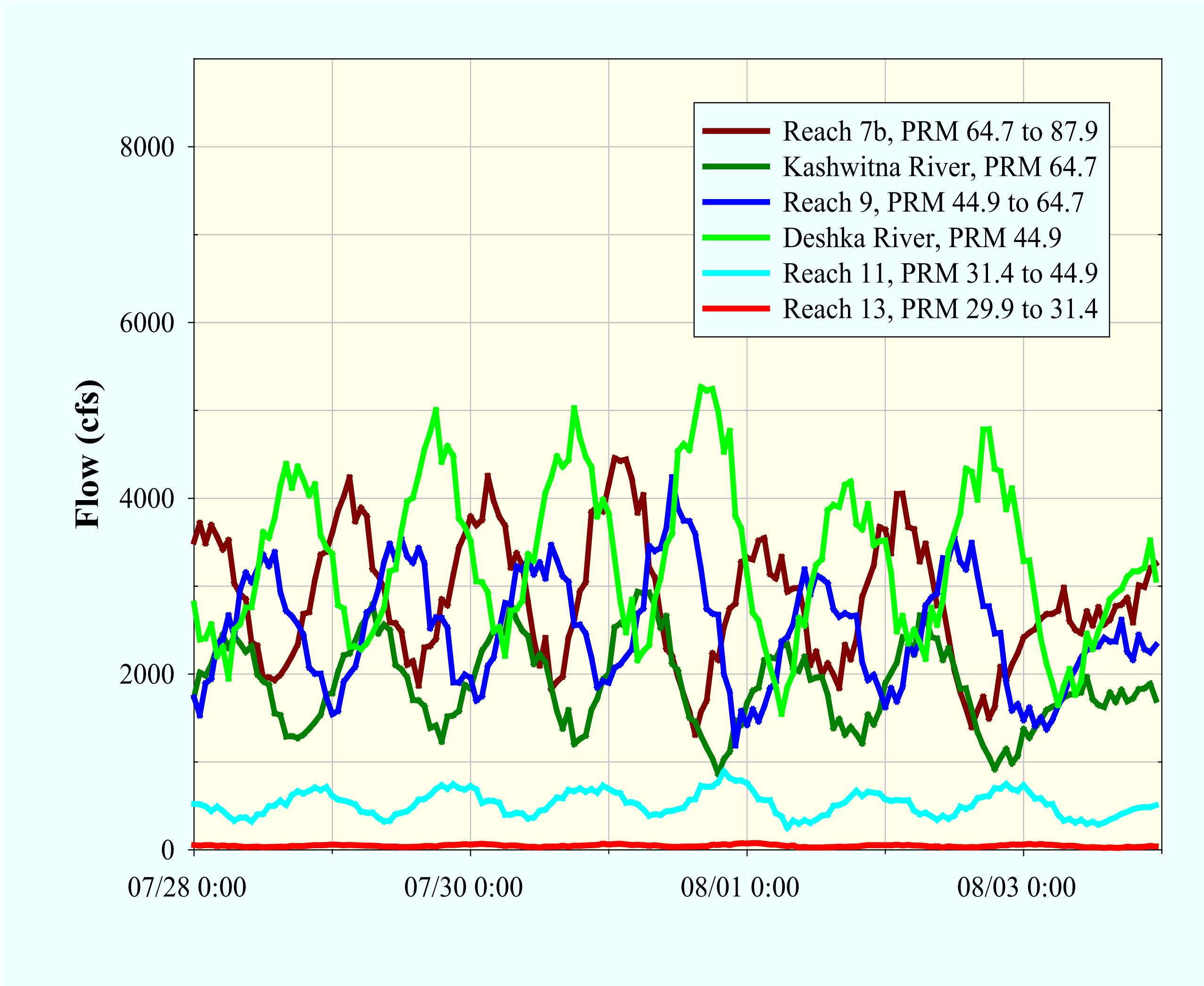


Figure 5.4-26. Ungaged lateral inflow hydrographs to the Susitna River in Reaches 7b through 13 between Sunshine and Susitna Station during the week of July 28 to August 3, 2013.

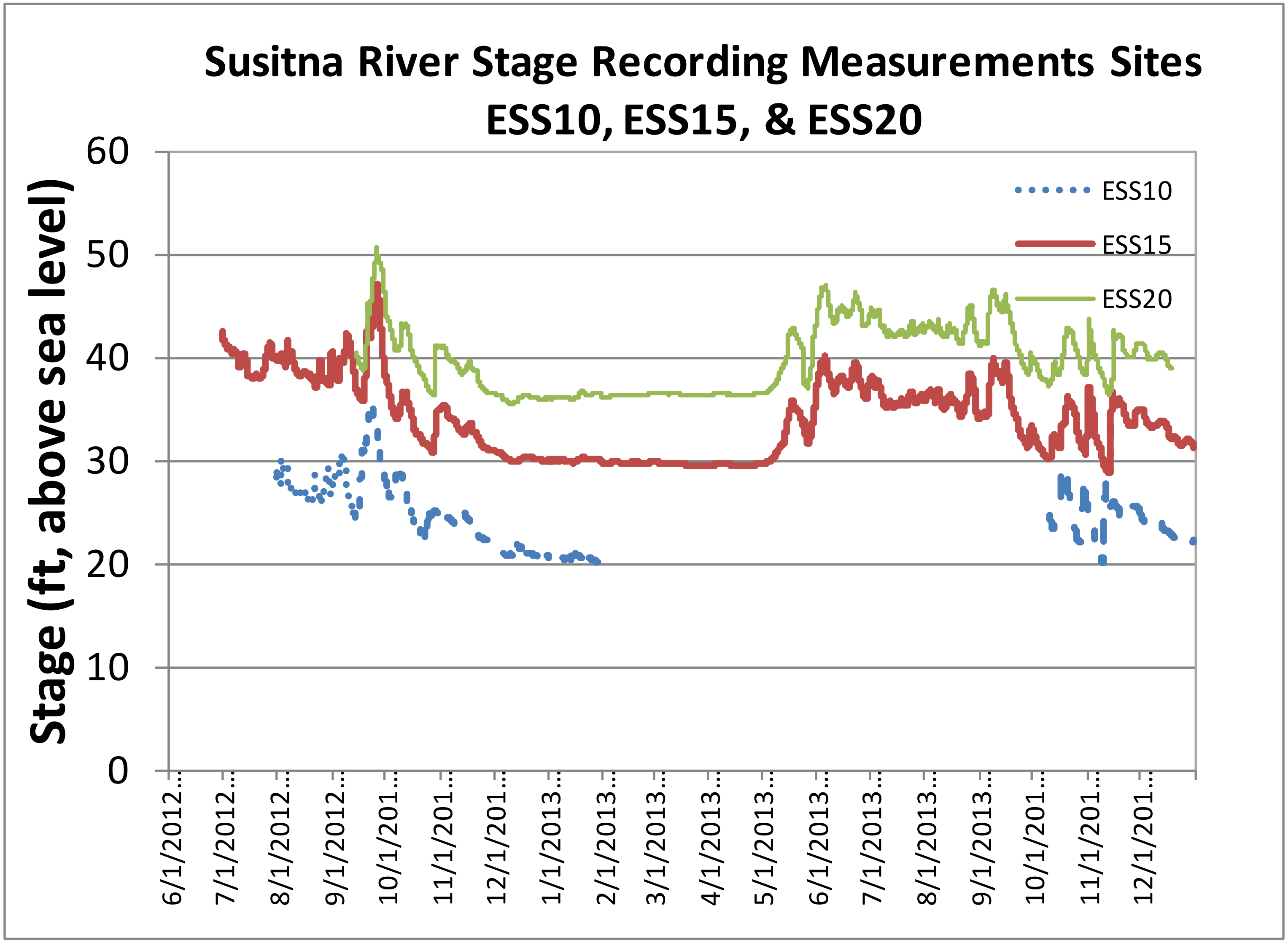


Figure 6.1-1. Stage hydrographs measured at sites ESS10, ESS15, and ESS20 between June 2012 and December 2013.

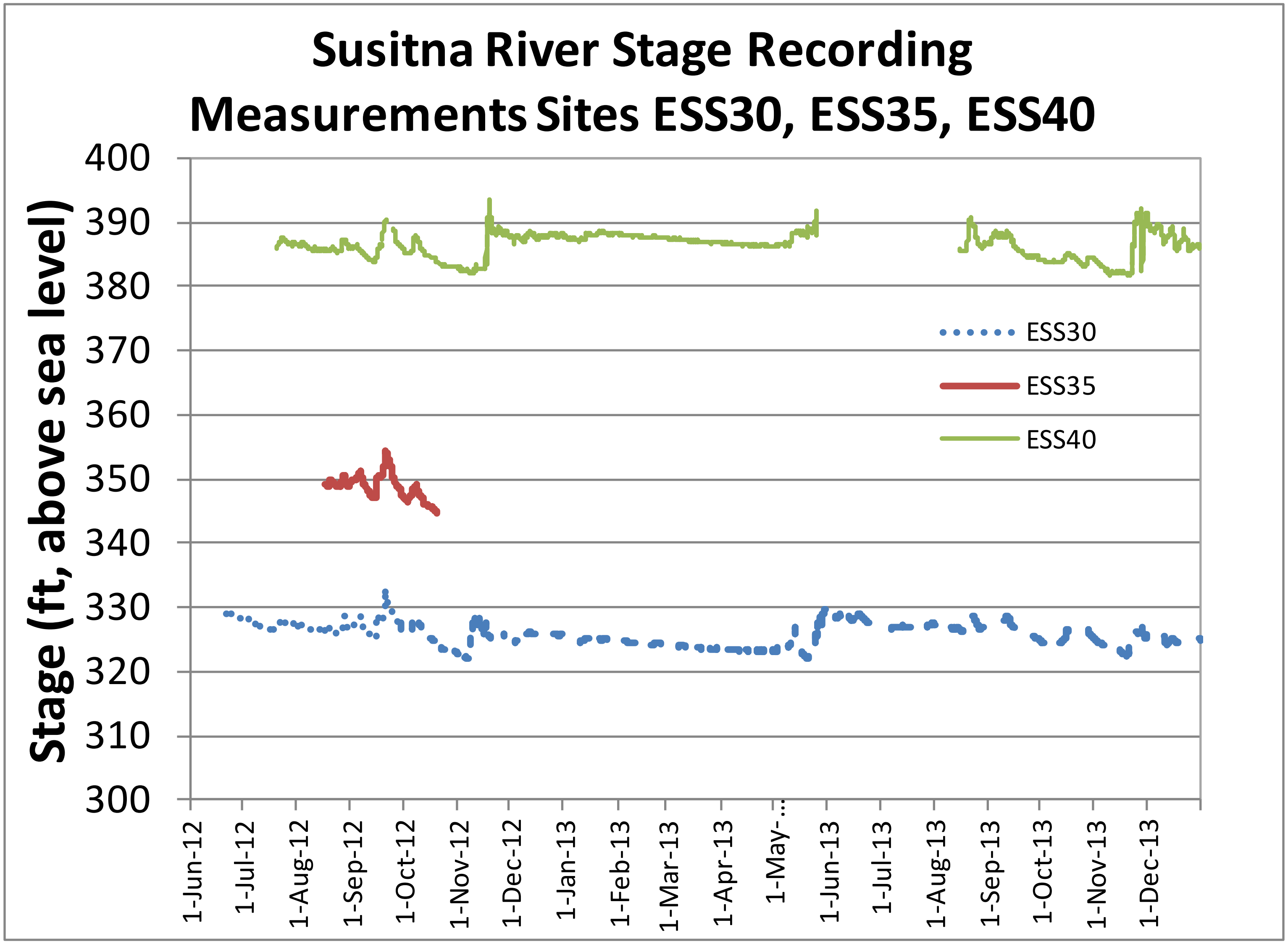


Figure 6.1-2. Stage hydrographs measured at sites ESS30, ESS35, and ESS40 between June 2012 and December 2013.

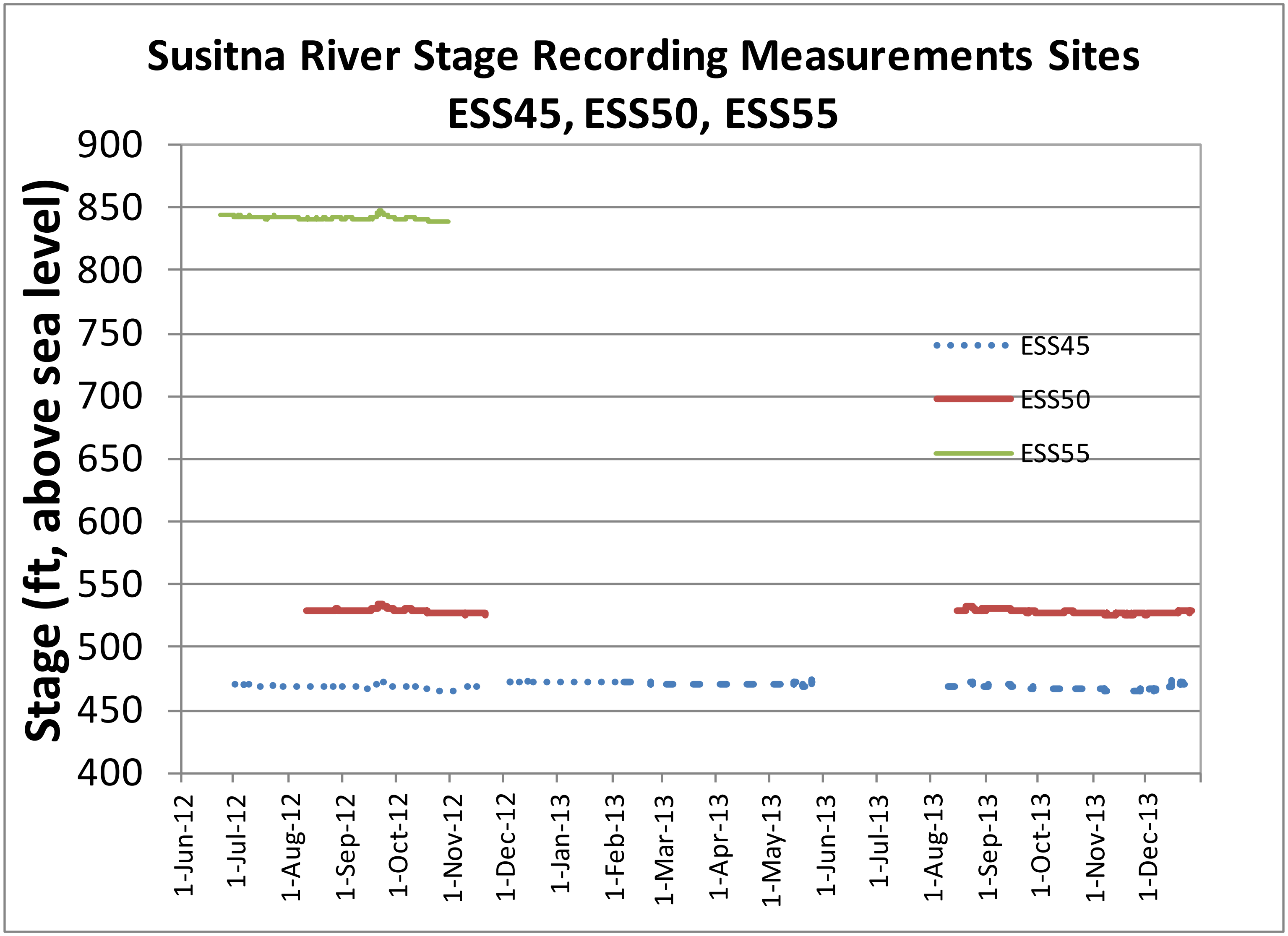


Figure 6.1-3. Stage hydrographs measured at sites ESS45, ESS50, and ESS55 between June 2012 and December 2013.

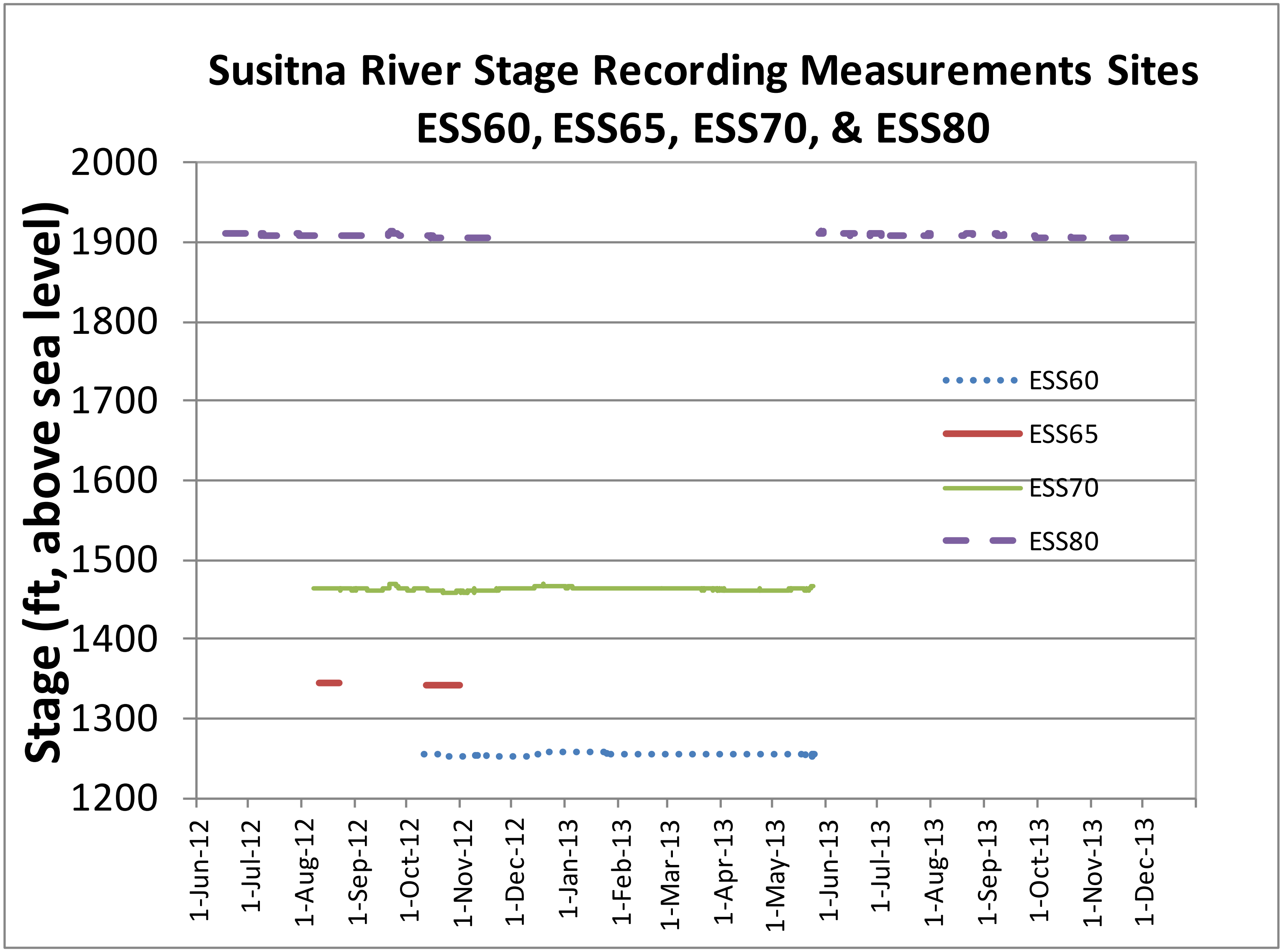


Figure 6.1-4. Stage hydrographs measured at sites ESS60, ESS65, ESS70, and ESS80 between June 2012 and December 2013.

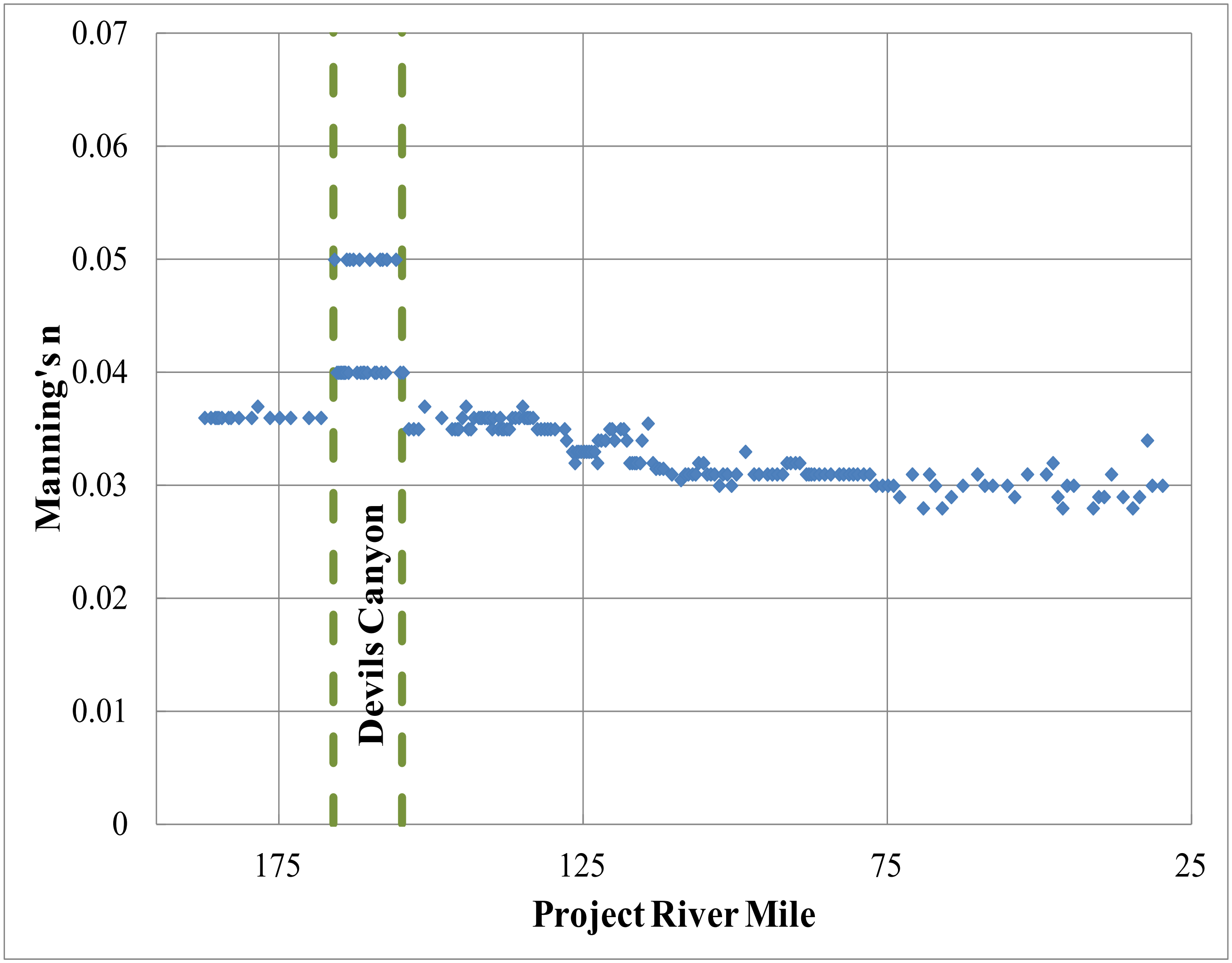


Figure 6.4-1. Manning's n channel roughness coefficients derived from steady-state calibration of flow routing model for 167 cross-sections of the Susitna River surveyed in 2012 and 2013.

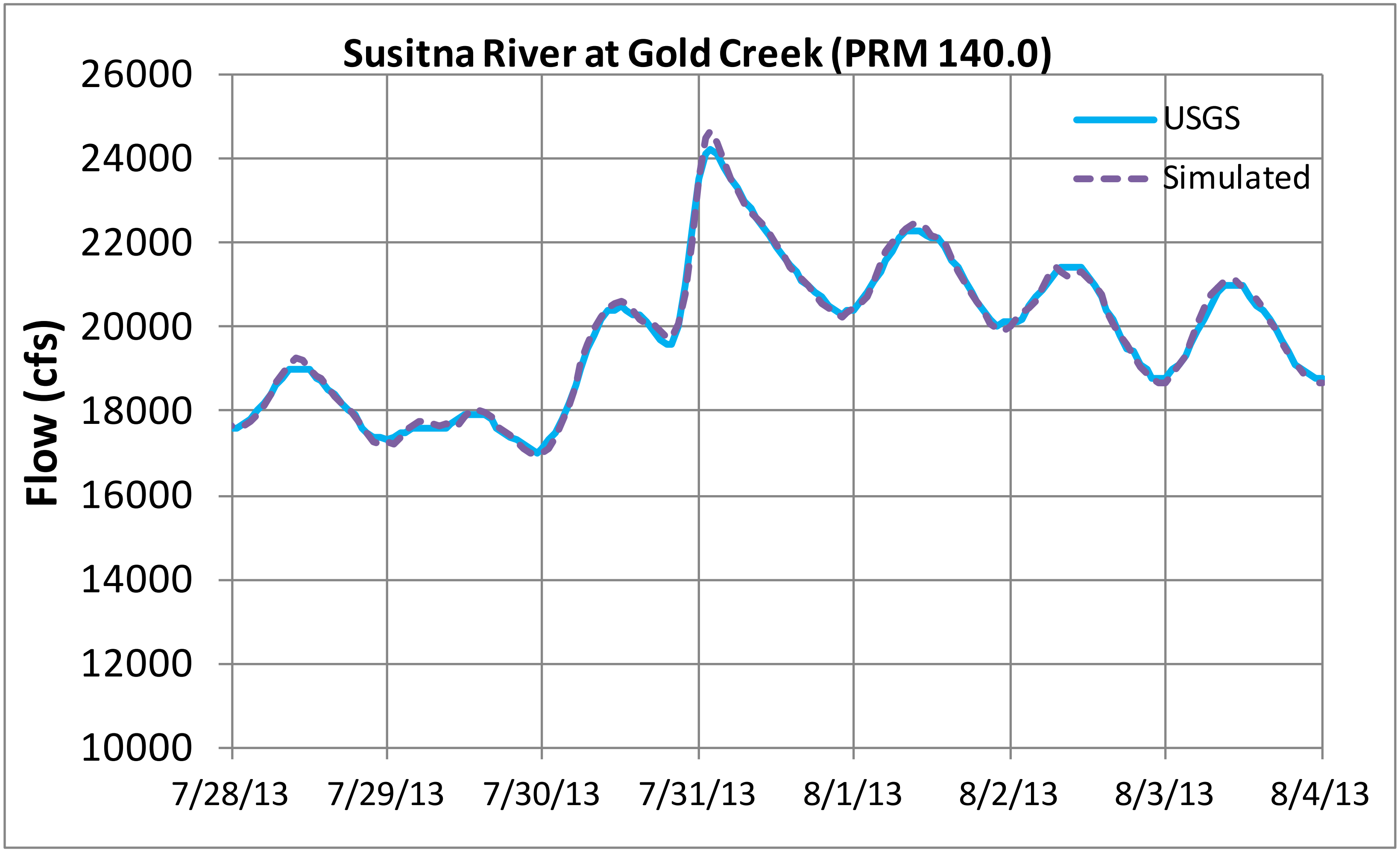


Figure 6.4-2. Comparison of measured versus simulated flow hydrographs in the Susitna River at Gold Creek (USGS 15292000) during the period from July 28 to August 3, 2013 when there were distinct diurnal flow fluctuations associated with glacial melt.

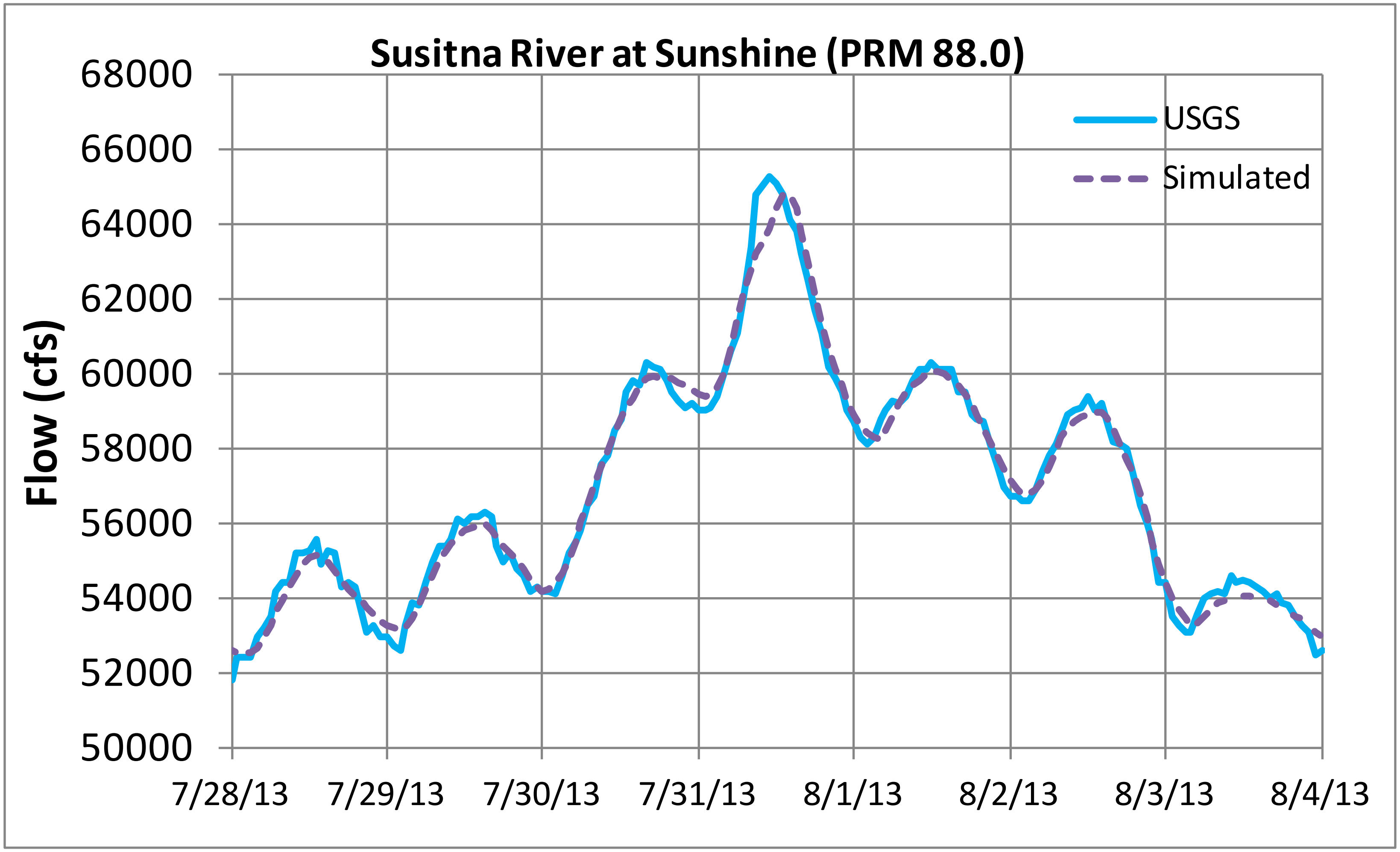


Figure 6.4-3. Comparison of measured versus simulated flow hydrographs in the Susitna River at Sunshine (USGS 15292780) during the period from July 28 to August 3, 2013 when there were distinct diurnal flow fluctuations associated with glacial melt.

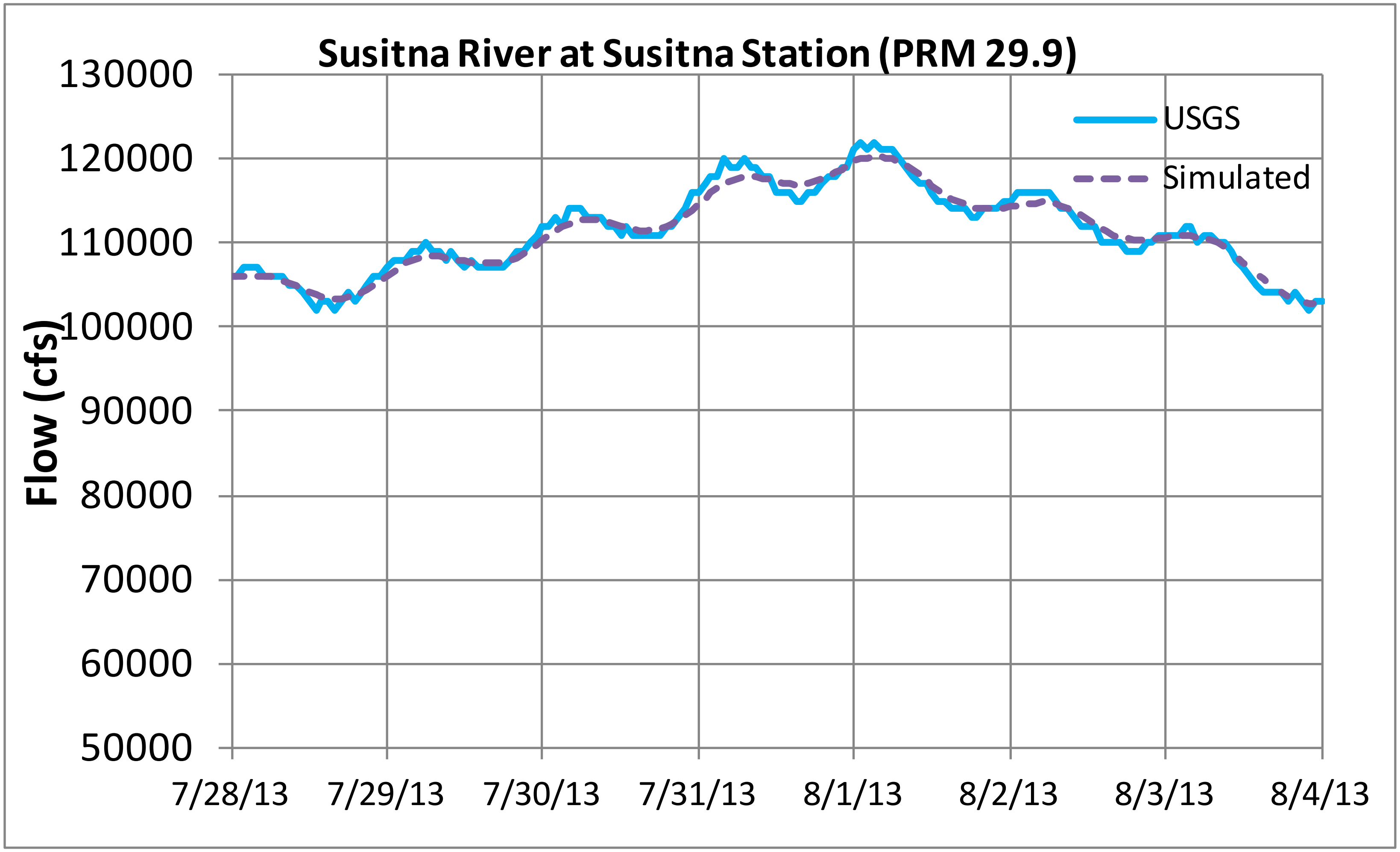
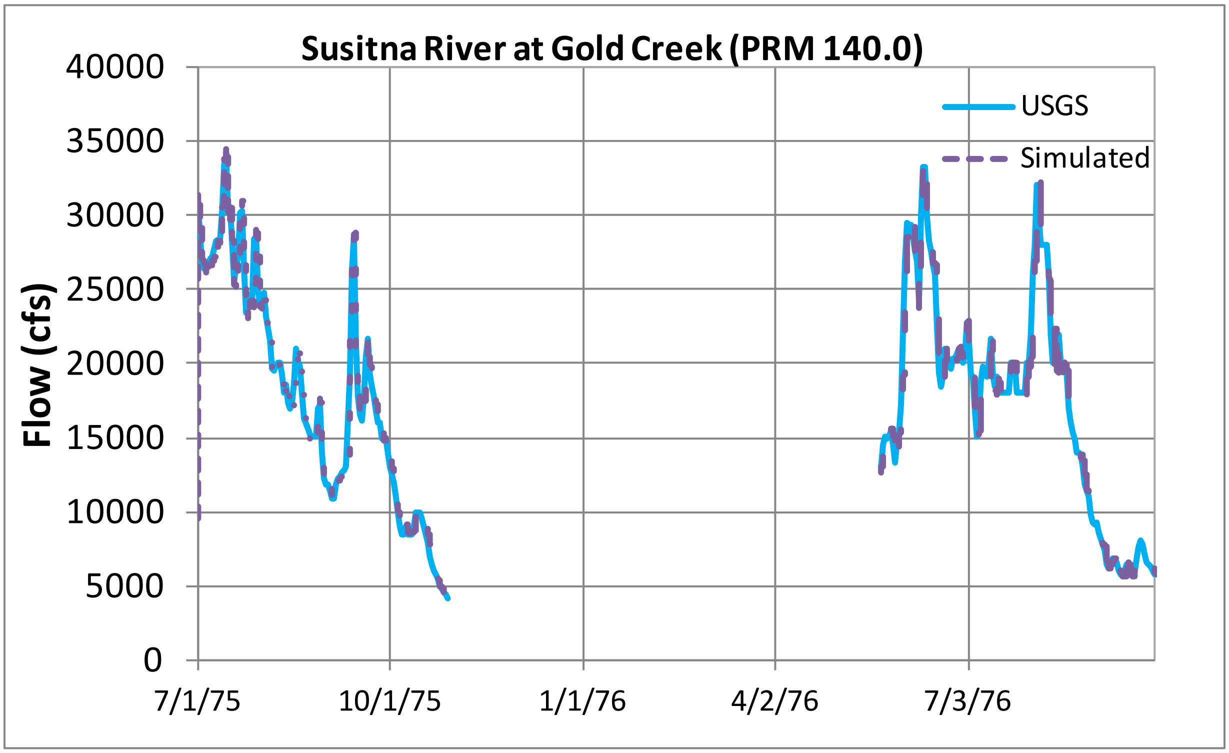


Figure 6.4-4. Comparison of measured versus simulated flow hydrographs in the Susitna River at Susitna Station (USGS 15294345) during the period from July 28 to August 3, 2013.



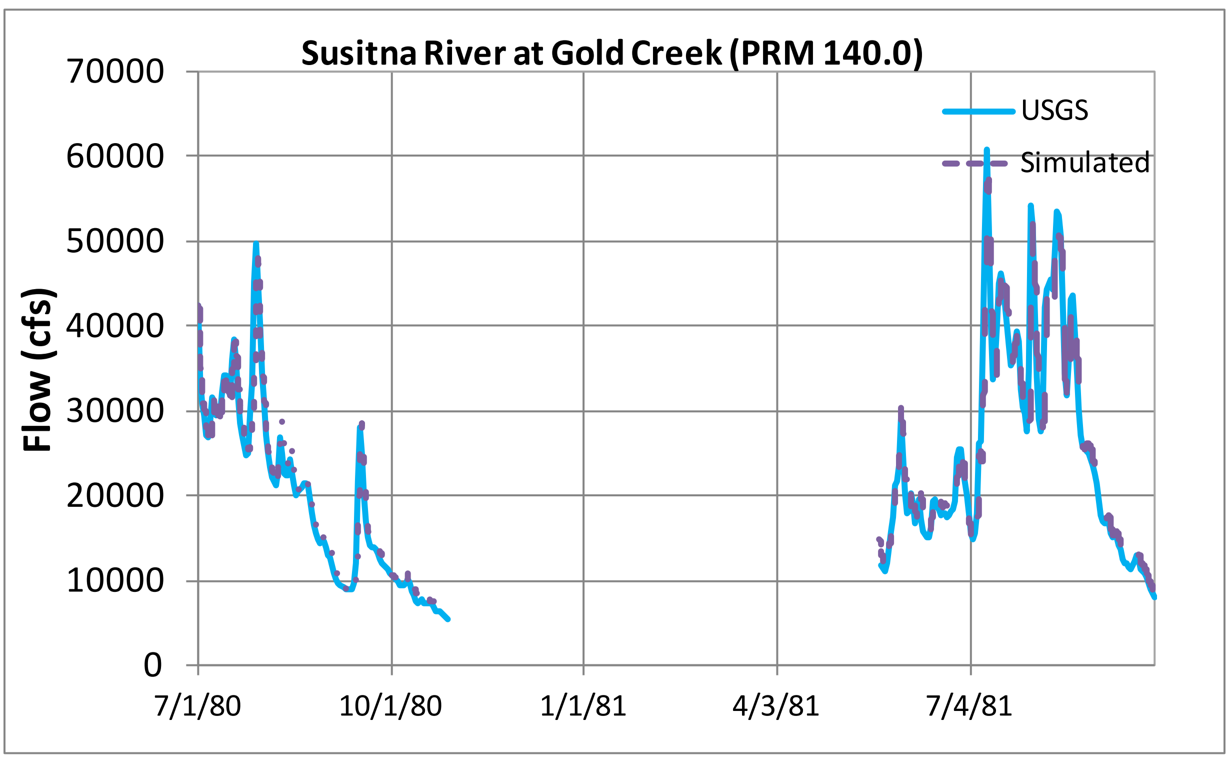


Figure 6.4-5. Comparison of measured versus simulated flow hydrographs in the Susitna River at Gold Creek (USGS 15292000) during the 1976 (top) and 1981 (bottom) simulation periods.

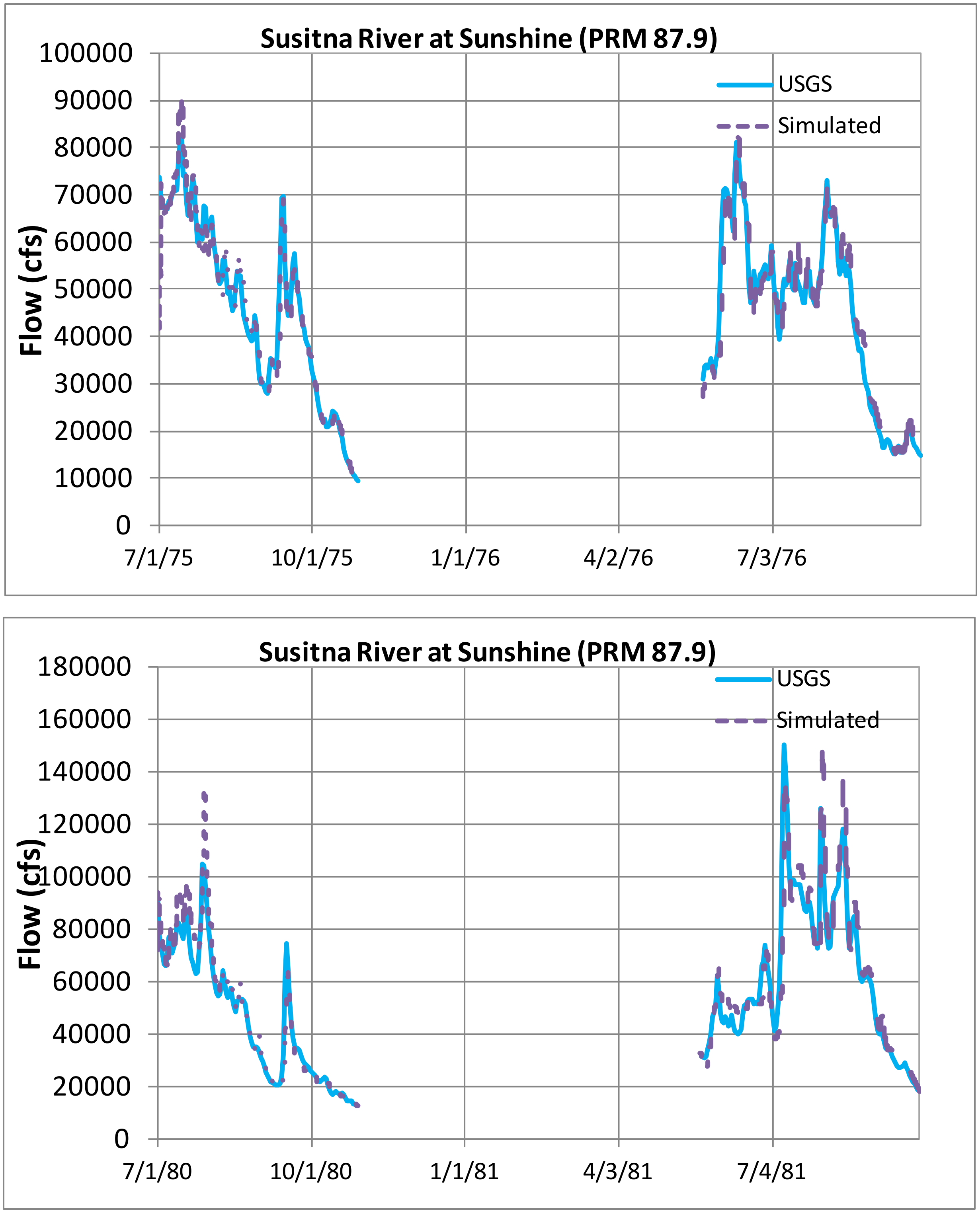


Figure 6.4-6. Comparison of measured versus simulated flow hydrographs in the Susitna River at Sunshine (USGS 15292780) during the 1976 (top) and 1981 (bottom) simulation periods.

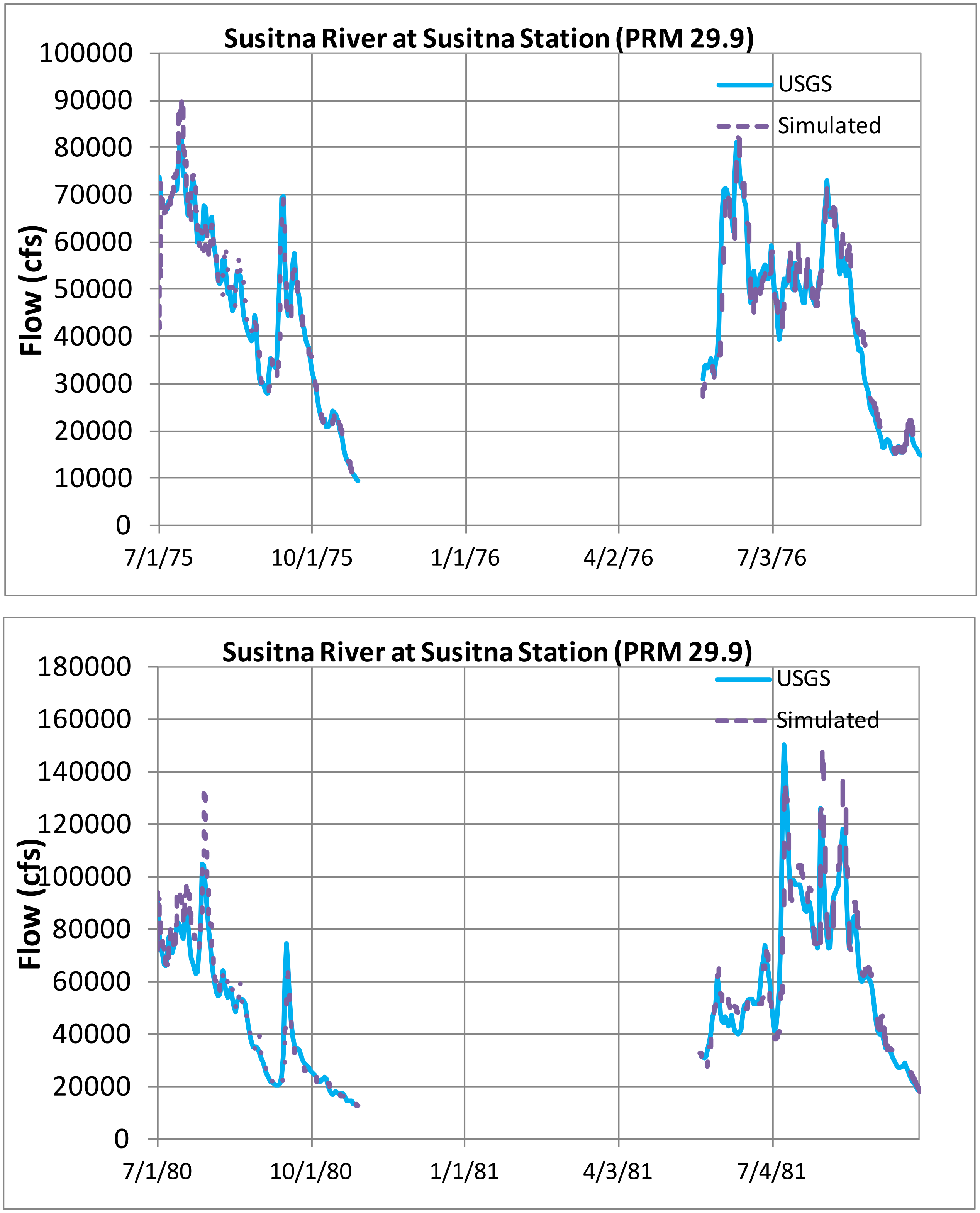
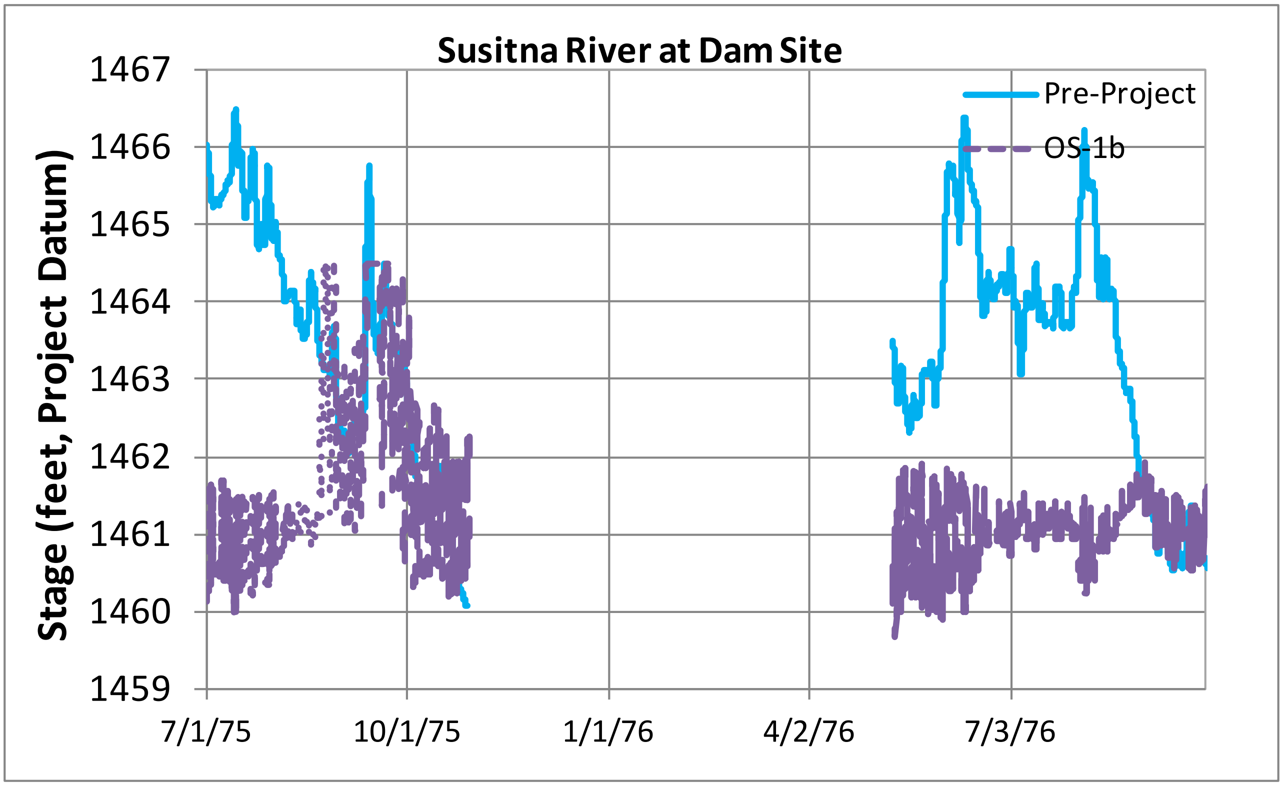


Figure 6.4-7. Comparison of measured versus simulated flow hydrographs in the Susitna River at Susitna Station (USGS 15294350) during the 1976 (top) and 1981 (bottom) simulation periods.



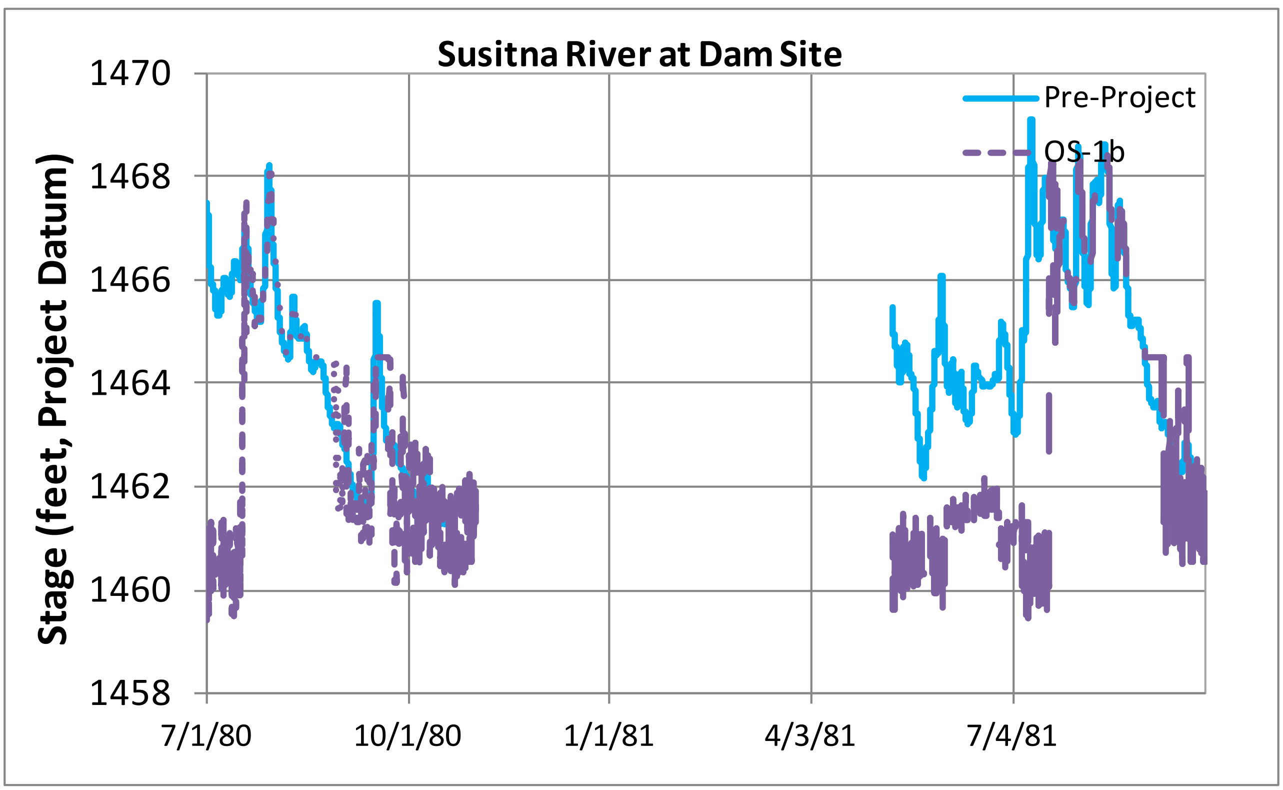
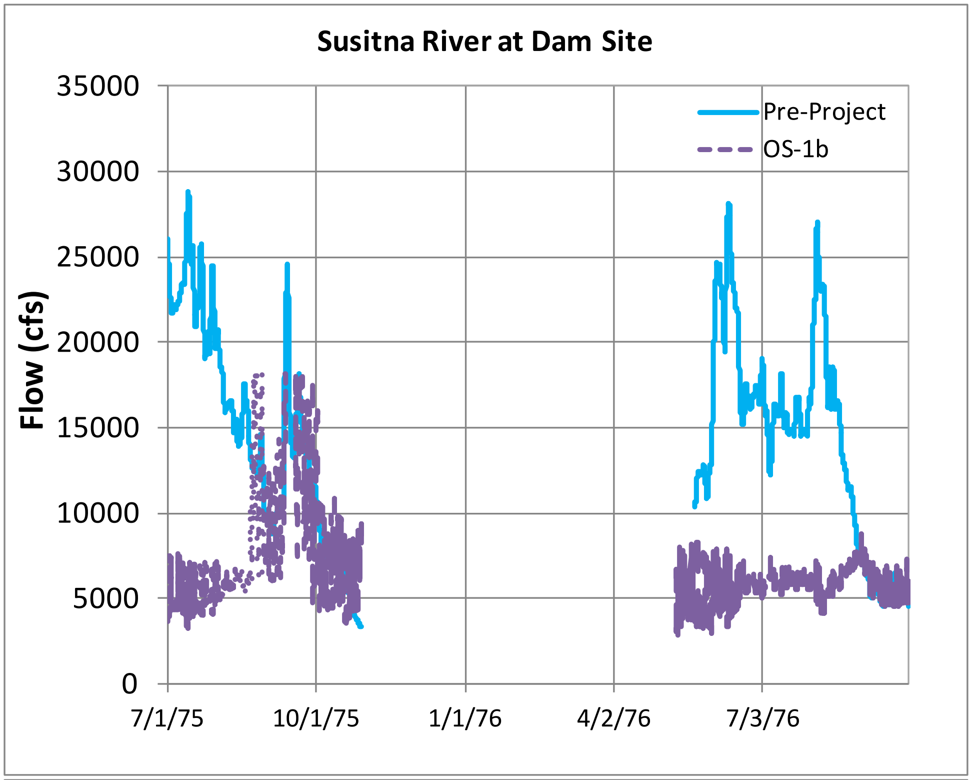


Figure 6.4-8. Predicted stage hydrographs in the Susitna River below Watana Dam Site under Pre-Project and Maximum Load Following OS-1b conditions for the 1976 (top) and 1981 (bottom) simulation periods.



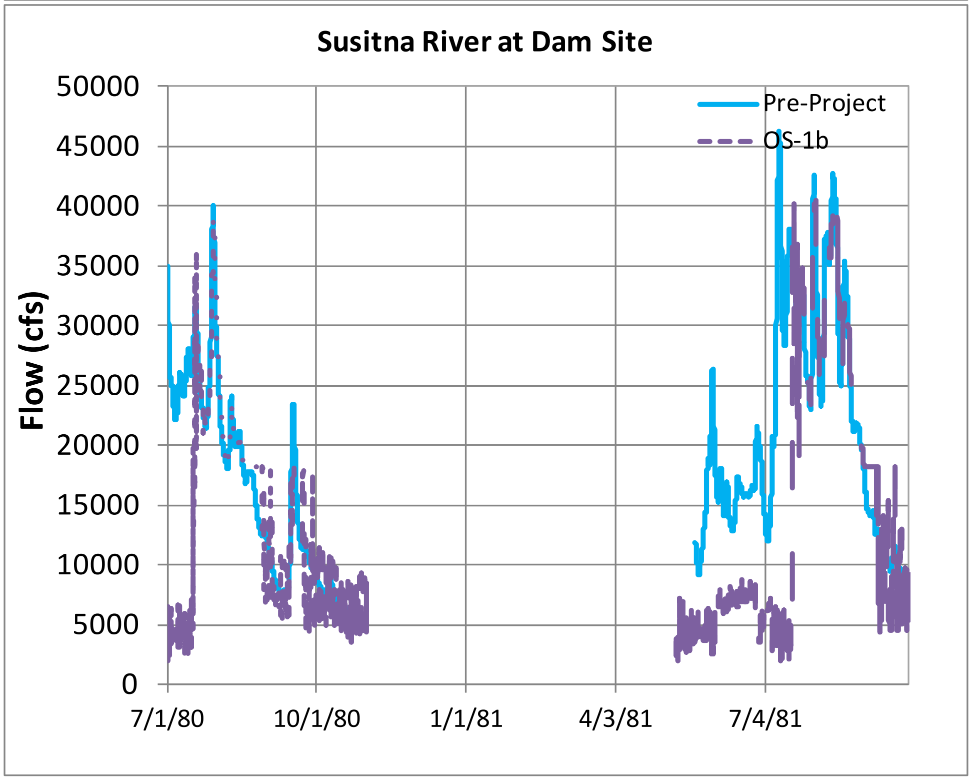


Figure 6.4-9. Predicted flow hydrographs in the Susitna River below Watana Dam Site under Pre-Project and Maximum Load Following OS-1b conditions for the 1976 (top) and 1981 (bottom) simulation periods.

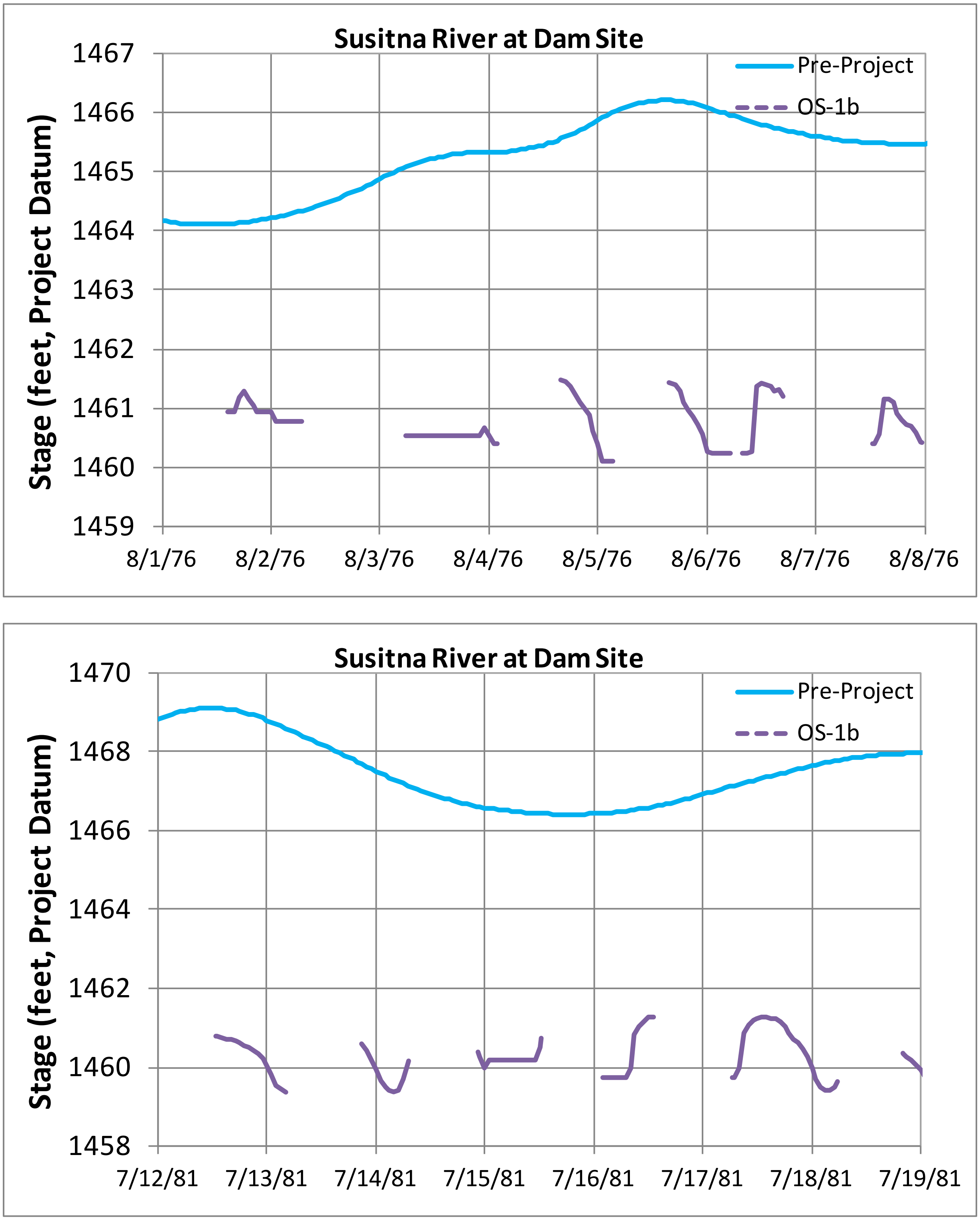
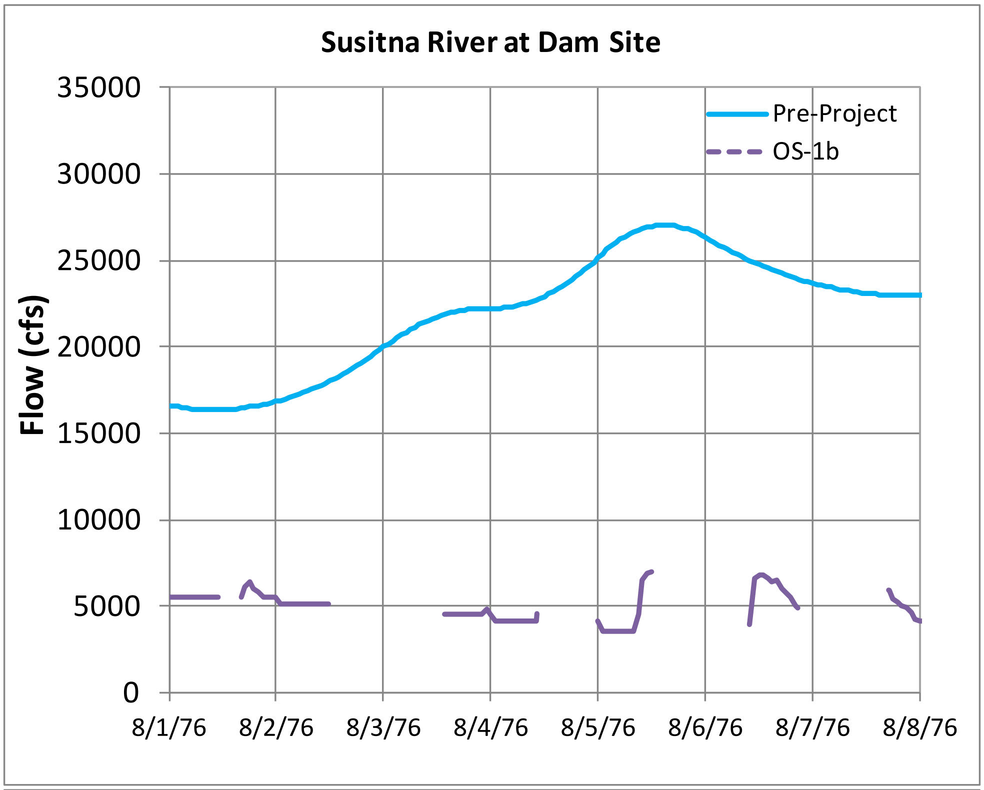


Figure 6.4-10. Predicted stage hydrographs in the Susitna River below Watana Dam Site under Pre-Project and Maximum Load Following OS-1b conditions during the week of August 1-8, 1976 (top) and July 12-19, 1981 (bottom). Pre-Project conditions do not account for potential diurnal fluctuations associated with glacial melt.



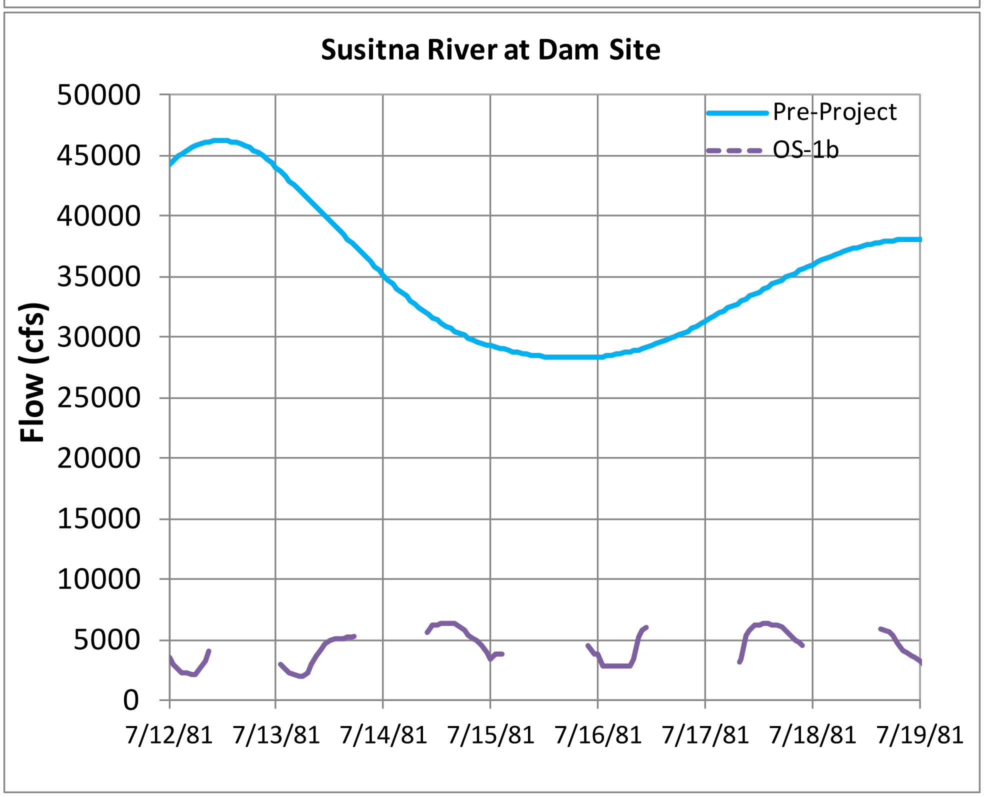
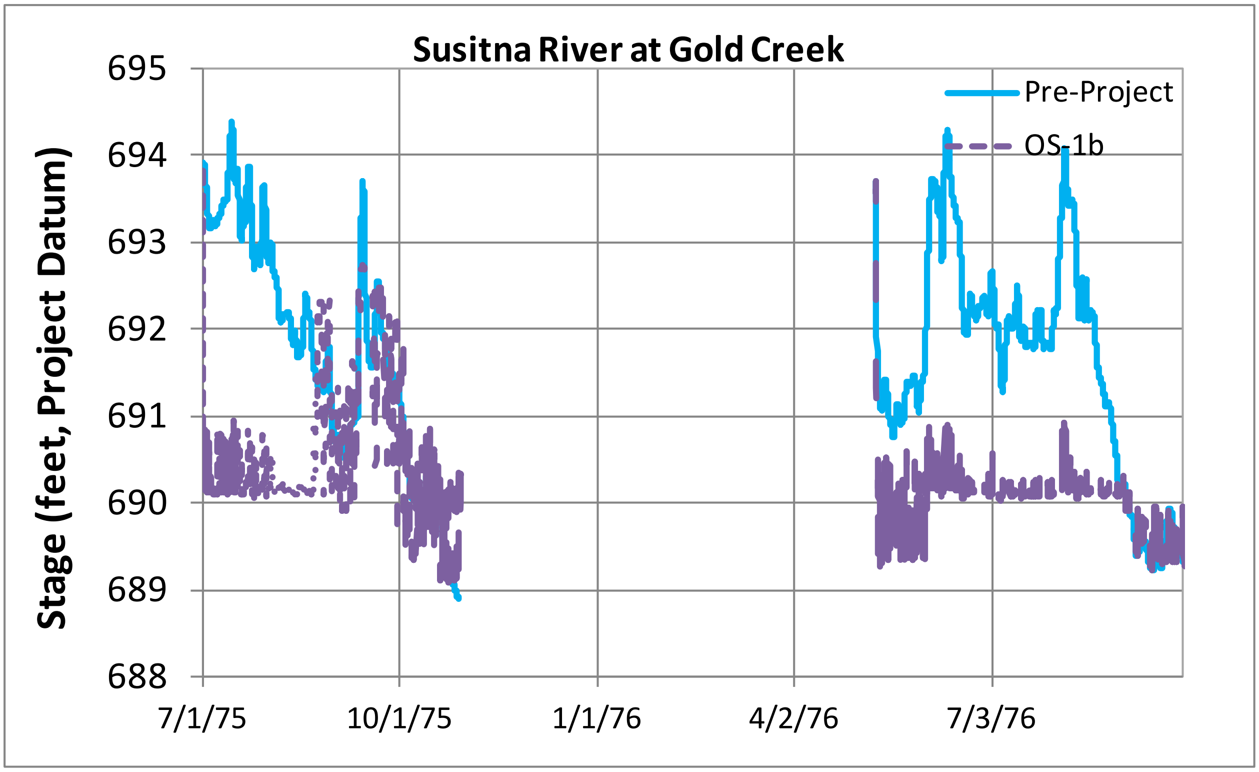


Figure 6.4-11. Flow releases from Watana Dam site, input to the flow routing model for the Pre-Project and Maximum Load Following OS-1b scenarios during the week of August 1-8, 1976 (top) and July 12-19, 1981 (bottom). Pre-Project conditions do not account for potential diurnal fluctuations associated with glacial melt.



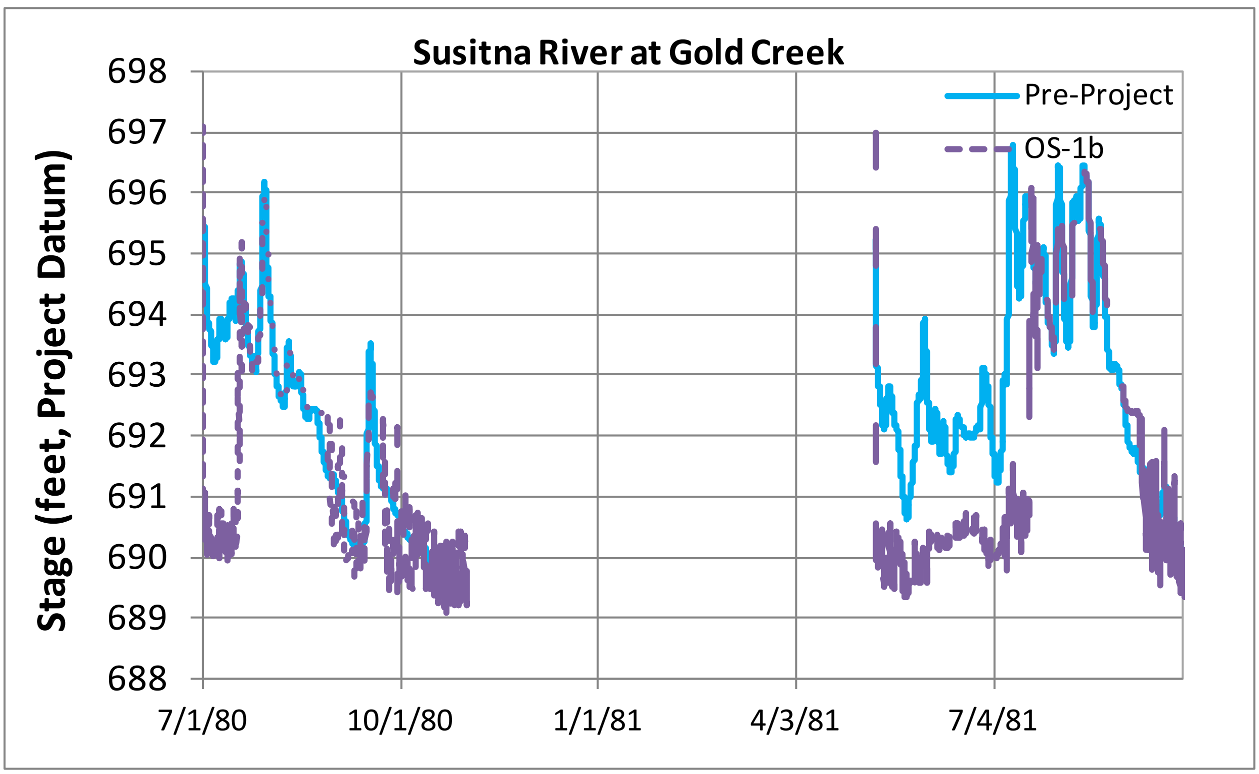


Figure 6.4-12. Predicted stage hydrographs in the Susitna River at Gold Creek (USGS 15292000) under Pre-Project and Maximum Load Following OS-1b conditions for 1976 (top, dry) and 1981 (bottom, wet).

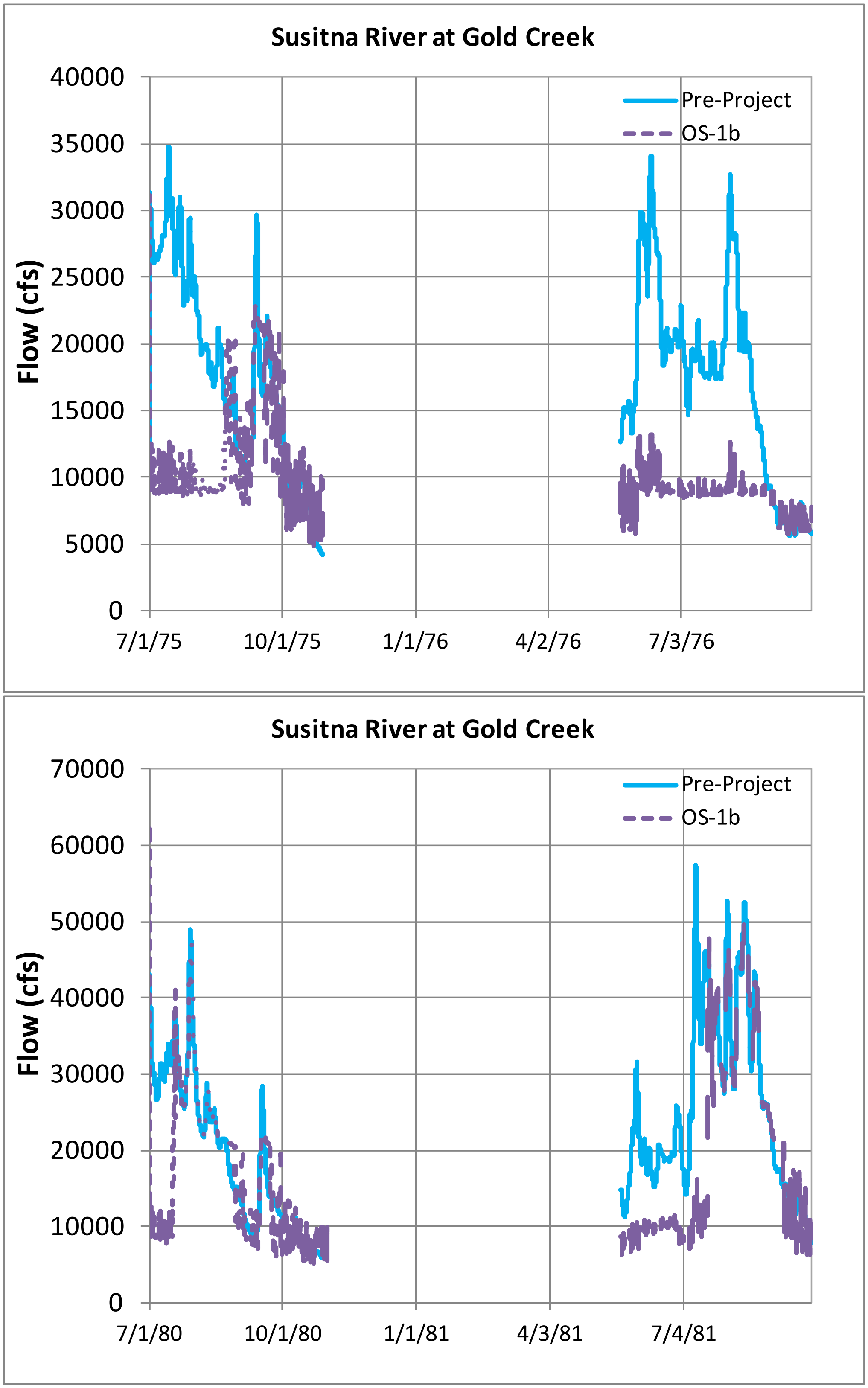
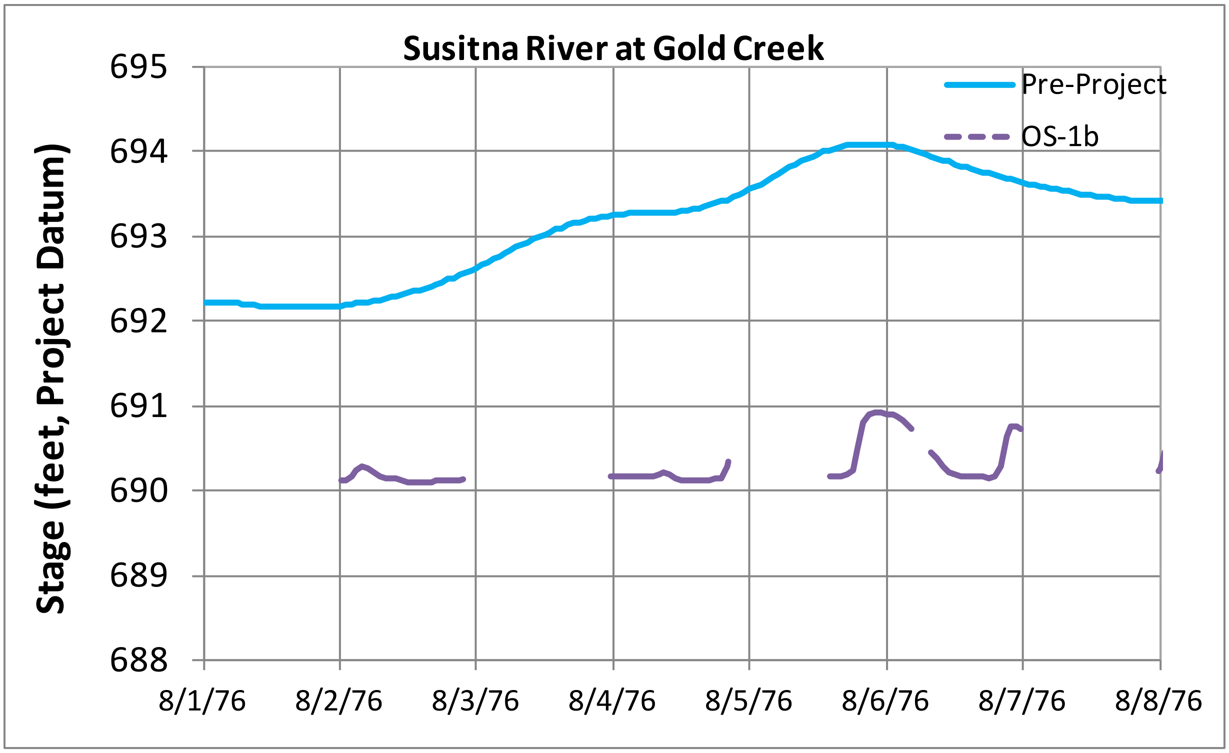


Figure 6.4-13. Predicted flow hydrographs in the Susitna River at Gold Creek (USGS 15292000) under Pre-Project and Maximum Load Following OS-1b conditions for 1976 (top, dry) and 1981 (bottom, wet).



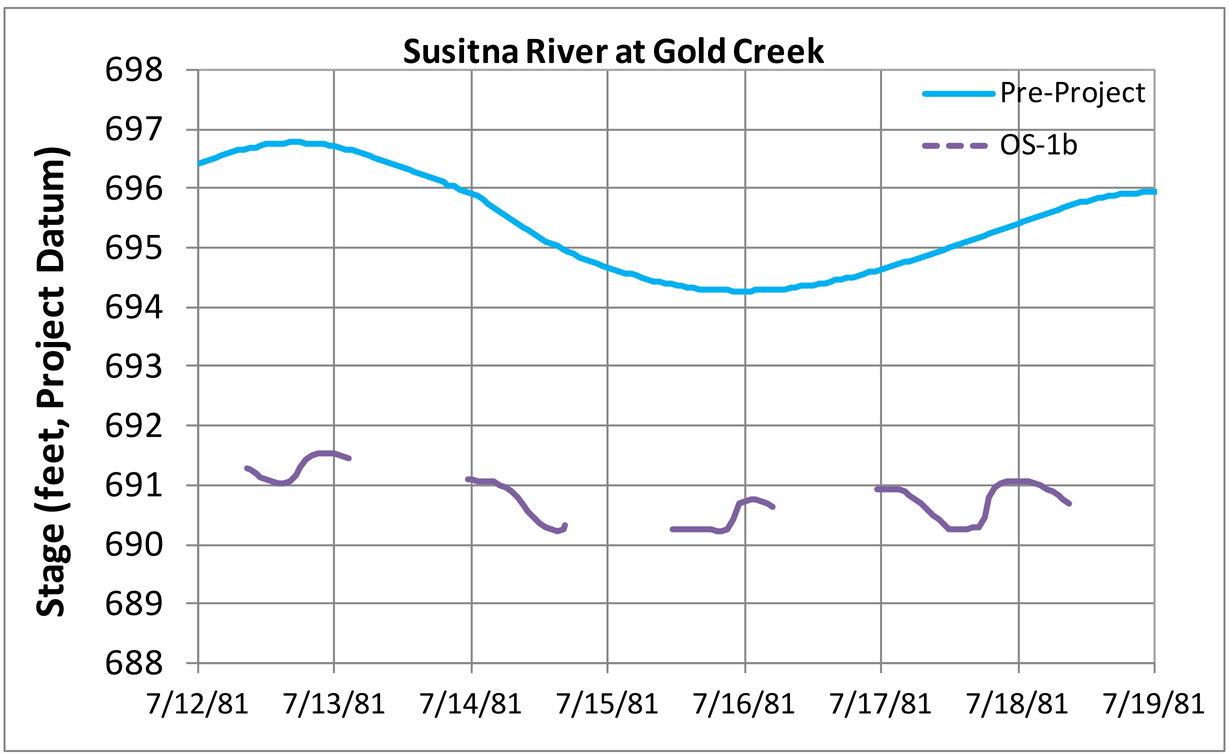


Figure 6.4-14. Predicted stage hydrographs in the Susitna River at Gold Creek (USGS 15292000) under Pre-Project and Maximum Load Following OS-1b conditions during the week of August 1-8, 1976 (top) and July 12-19, 1981 (bottom). Pre-Project conditions do not account for potential diurnal fluctuations associated with glacial melt.

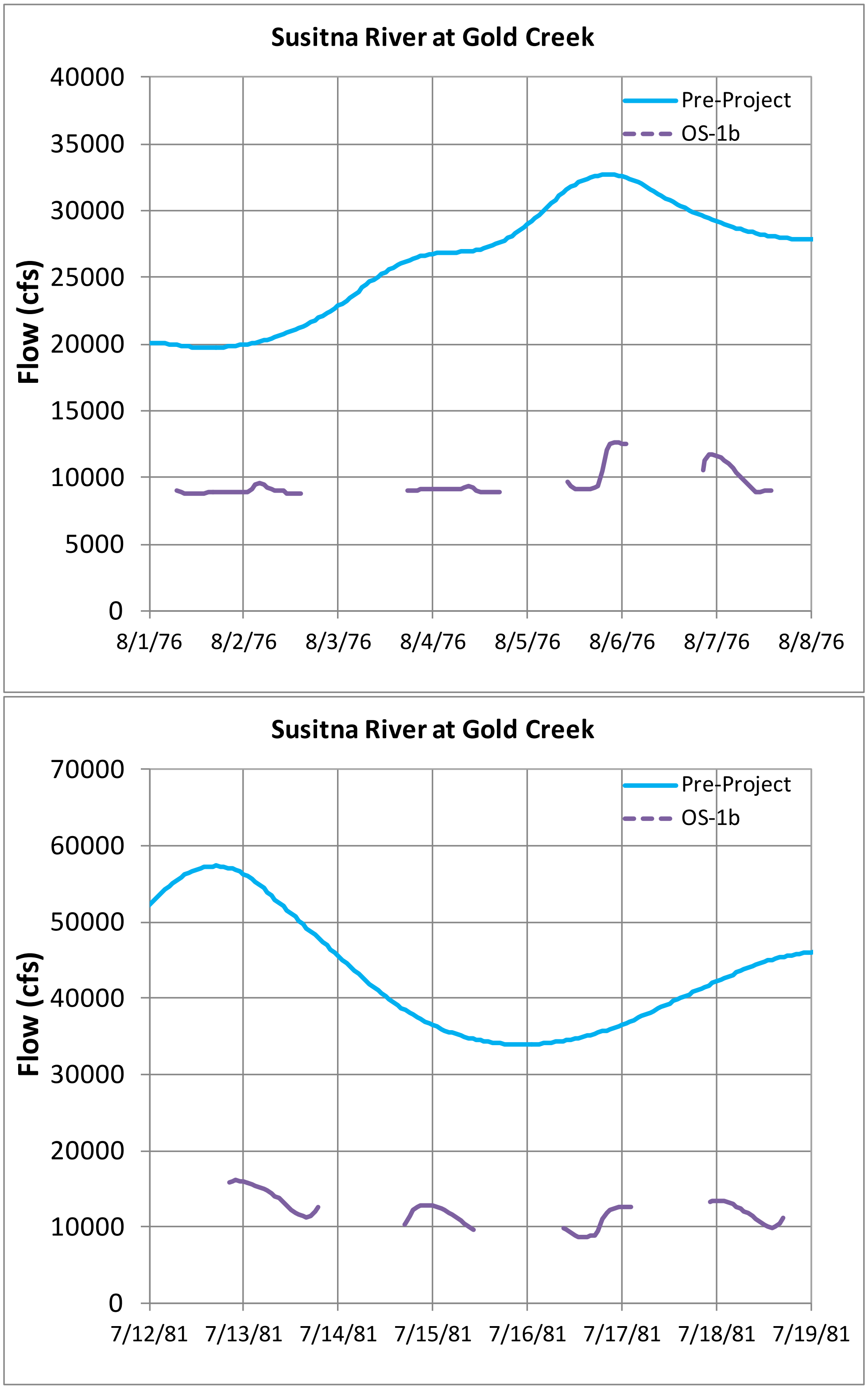


Figure 6.4-15. Predicted flow hydrographs in the Susitna River at Gold Creek (USGS 15292000) under Pre-Project and Maximum Load Following OS-1b conditions during the week August 1-8, 1976 (top) and July 12-19, 1981 (bottom). Pre-Project conditions do not account for potential diurnal fluctuations associated with glacial melt.

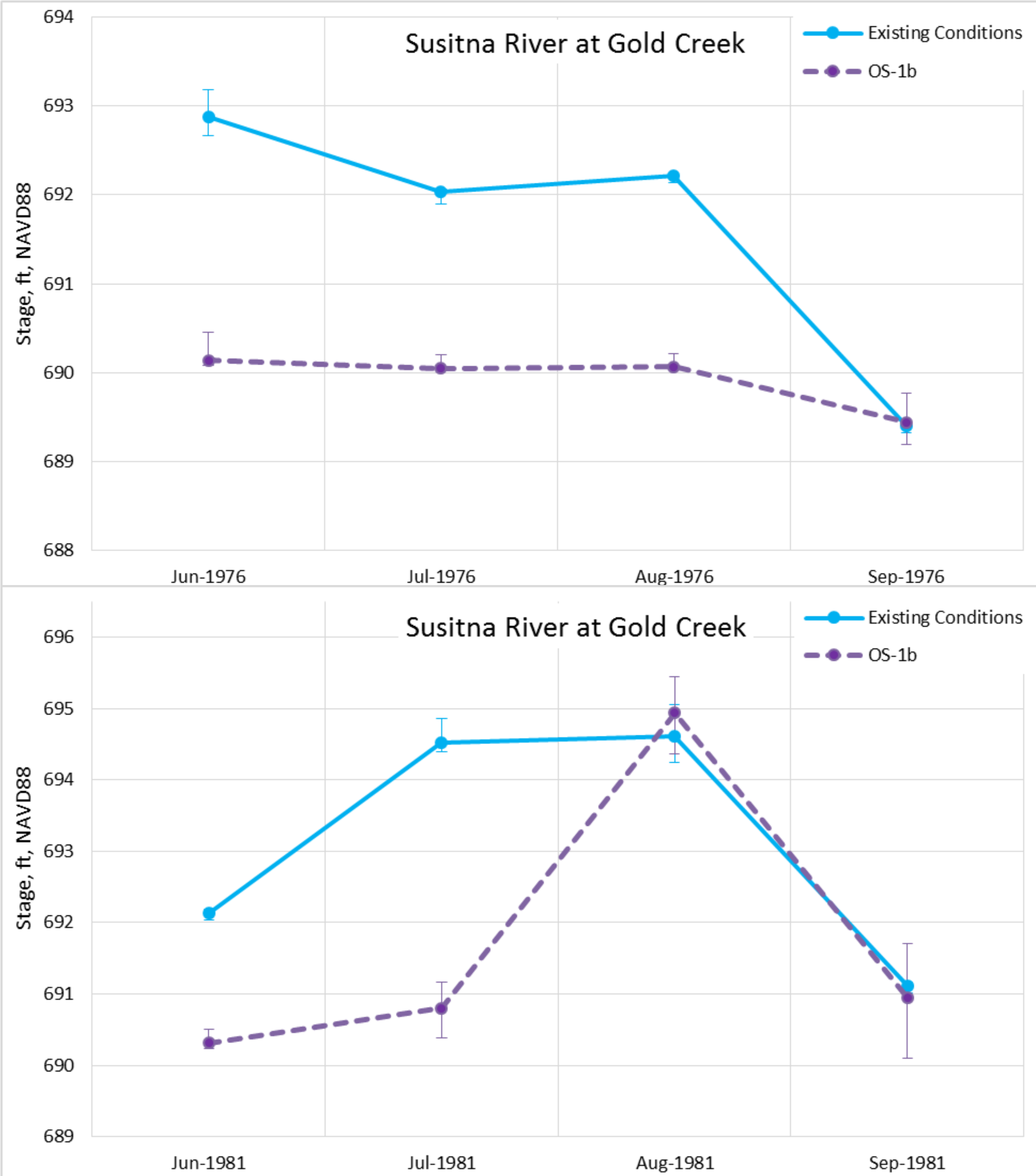


Figure 6.4-16. Monthly medians of predicted daily average stage in the Susitna River at Gold Creek (USGS 15292000) under Pre-Project and Maximum Load Following OS-1b conditions for 1976 (top, dry) and 1981 (bottom, wet). Error bars denote the monthly medians of daily maximums and daily minimums.

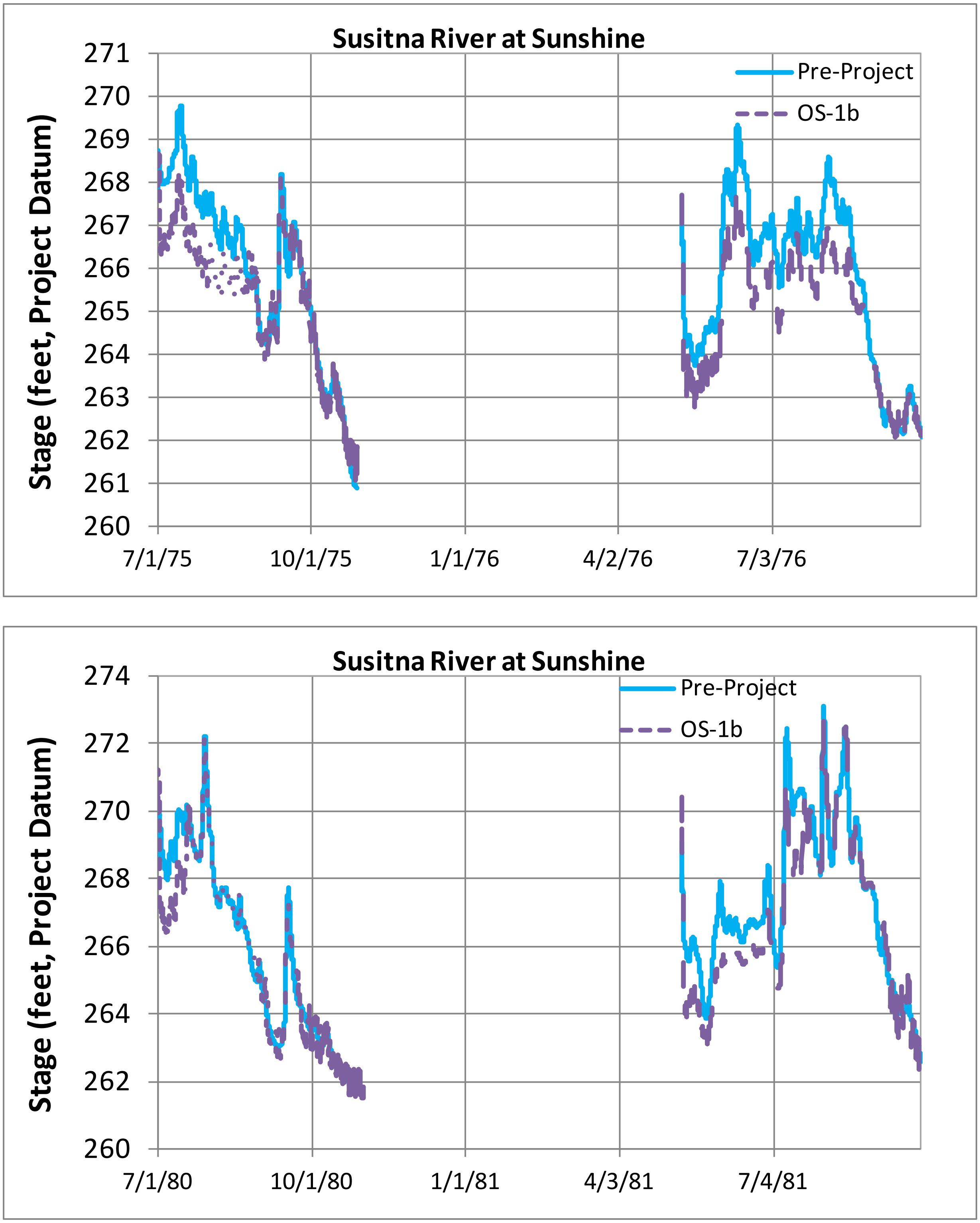
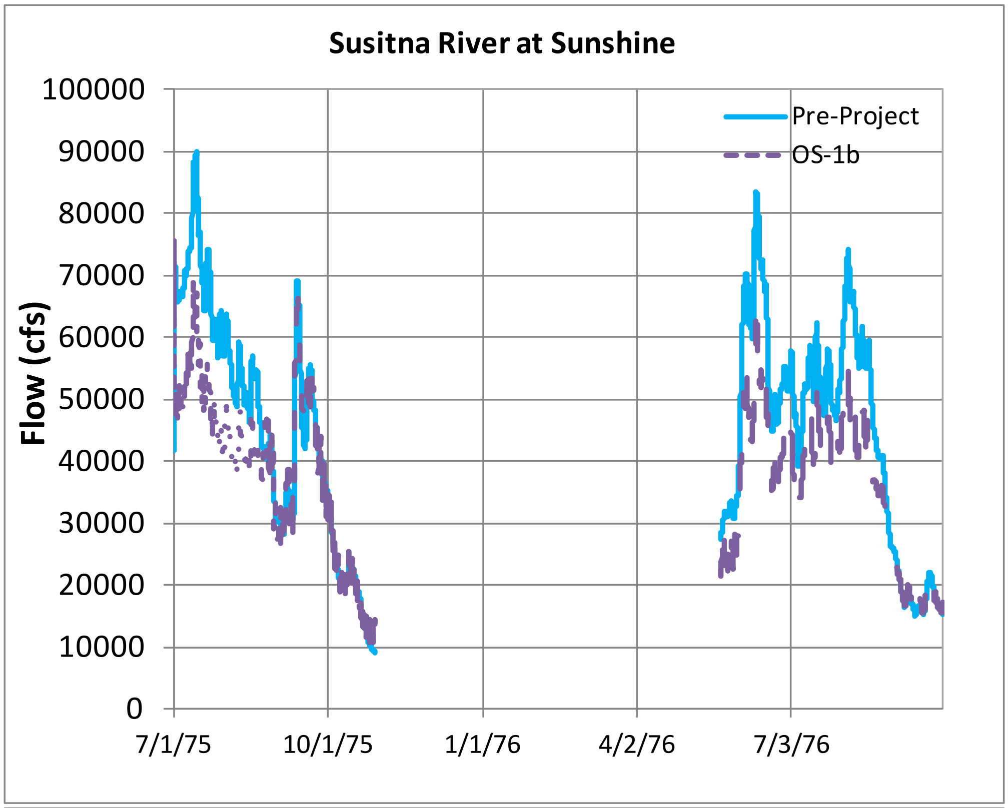


Figure 6.4-17. Predicted stage hydrographs in the Susitna River at Sunshine (USGS 15292780) under Pre-Project and Maximum Load Following OS-1b conditions 1976 (top, dry) and 1981 (bottom, wet).



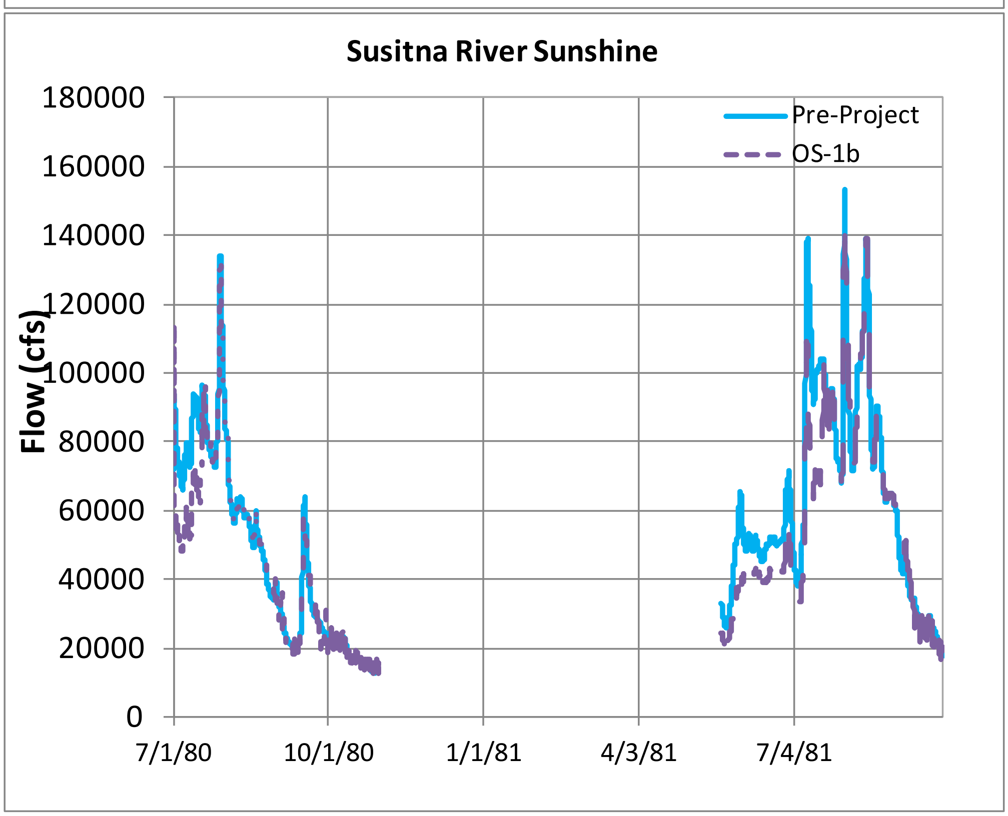
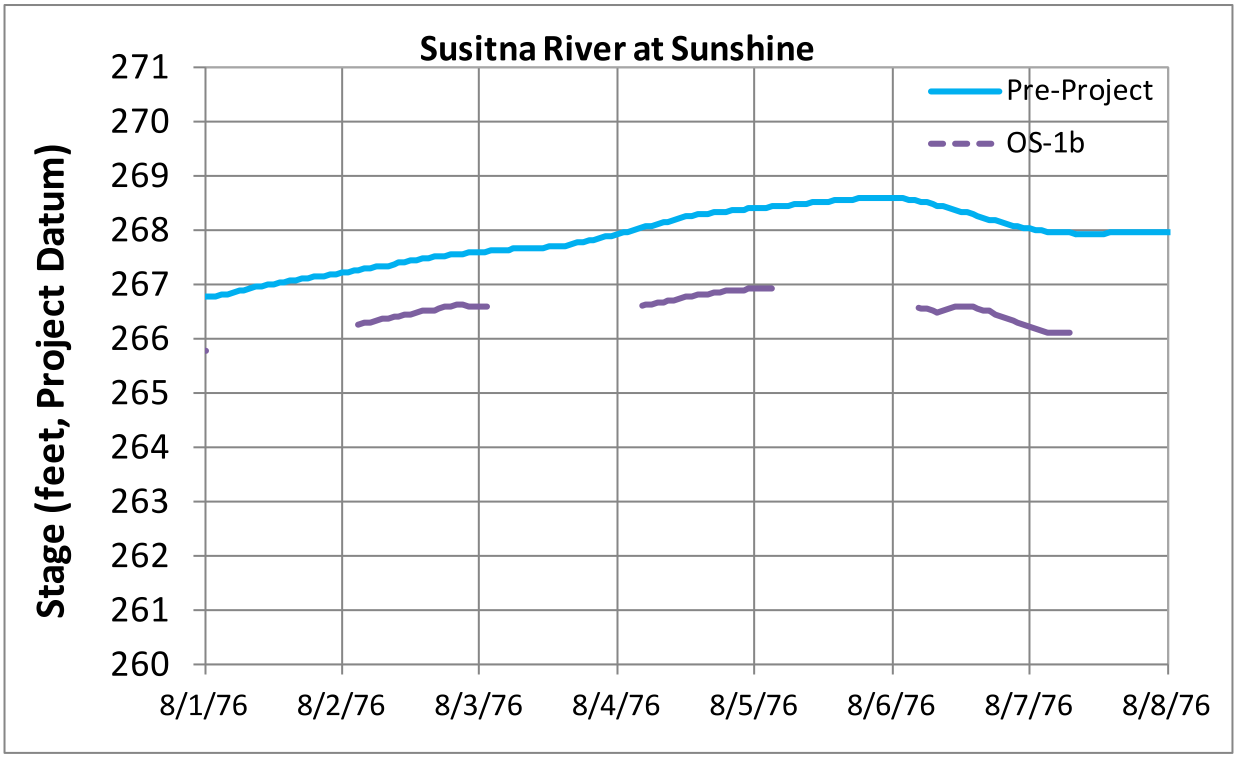


Figure 6.4-18. Predicted flow hydrographs in the Susitna River at Sunshine (USGS 15292780) under Pre-Project and Maximum Load Following OS-1b conditions for 1976 (top, dry) and 1981 (bottom, wet).



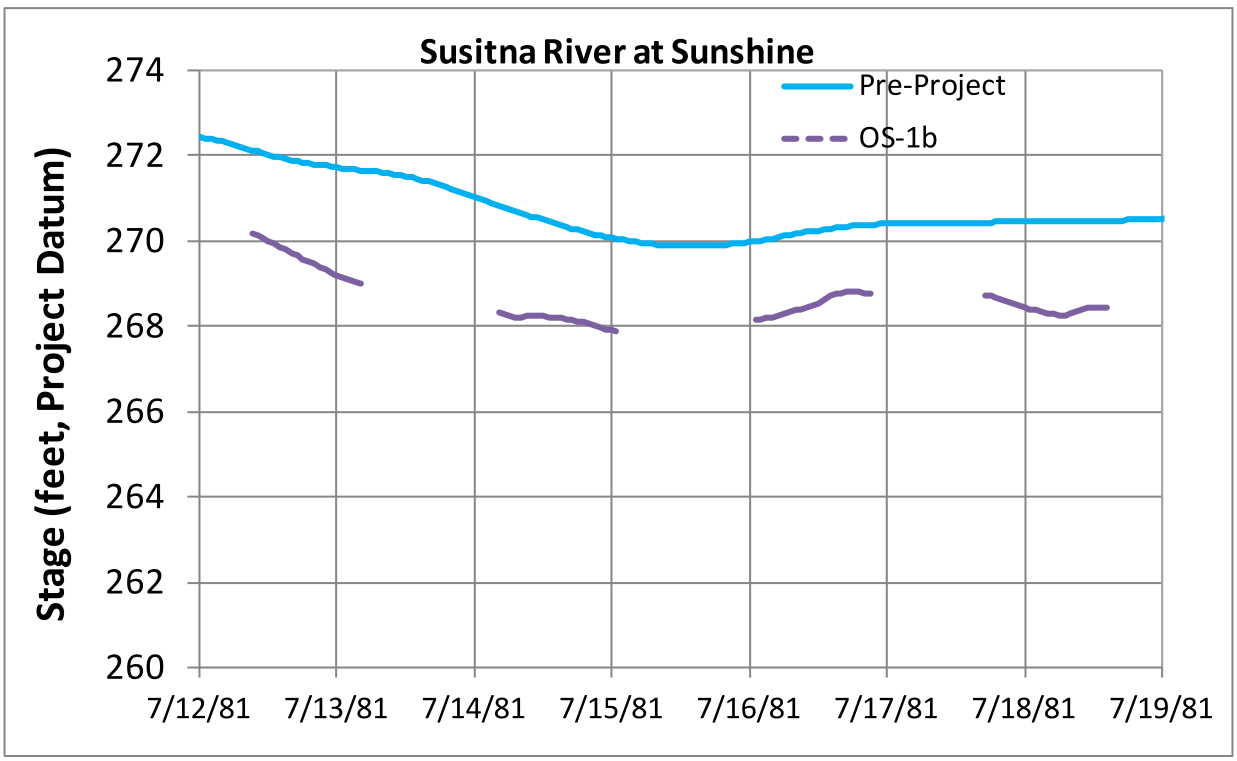
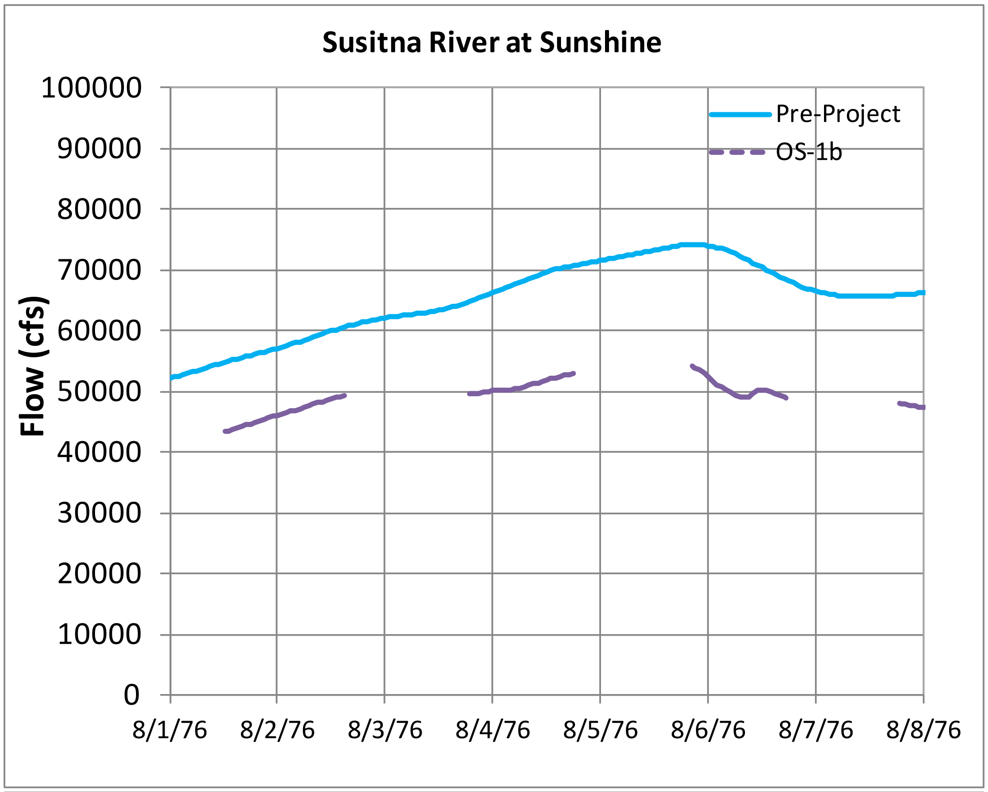


Figure 6.4-19. Predicted stage hydrographs in the Susitna River at Sunshine (USGS 15292780) under Pre-Project and Maximum Load Following OS-1b conditions during the week of August 1-8, 1976 (top) and July 12-19, 1981 (bottom). Pre-Project conditions do not account for potential diurnal fluctuations associated with glacial melt.



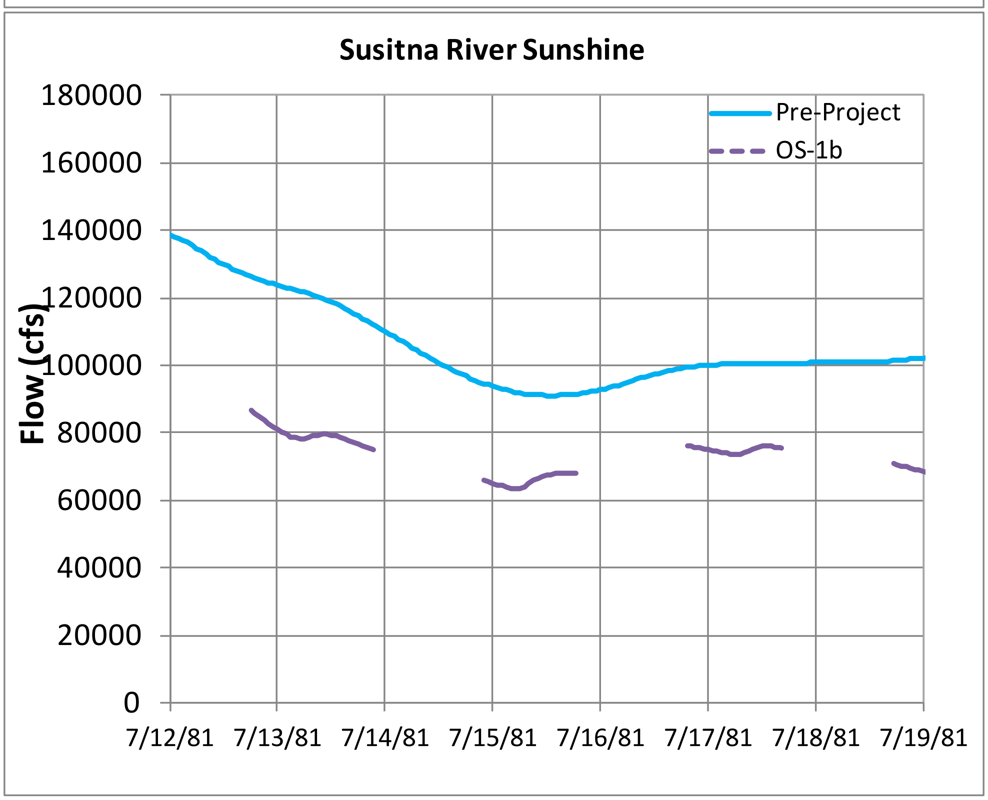


Figure 6.4-20. Predicted flow hydrographs in the Susitna River at Sunshine (USGS 15292780) under Pre-Project and Maximum Load Following OS-1b conditions during the week of August 1-8, 1976 (top) and July 12-19, 1981 (bottom). Pre-Project conditions do not account for potential diurnal fluctuations associated with glacial melt.

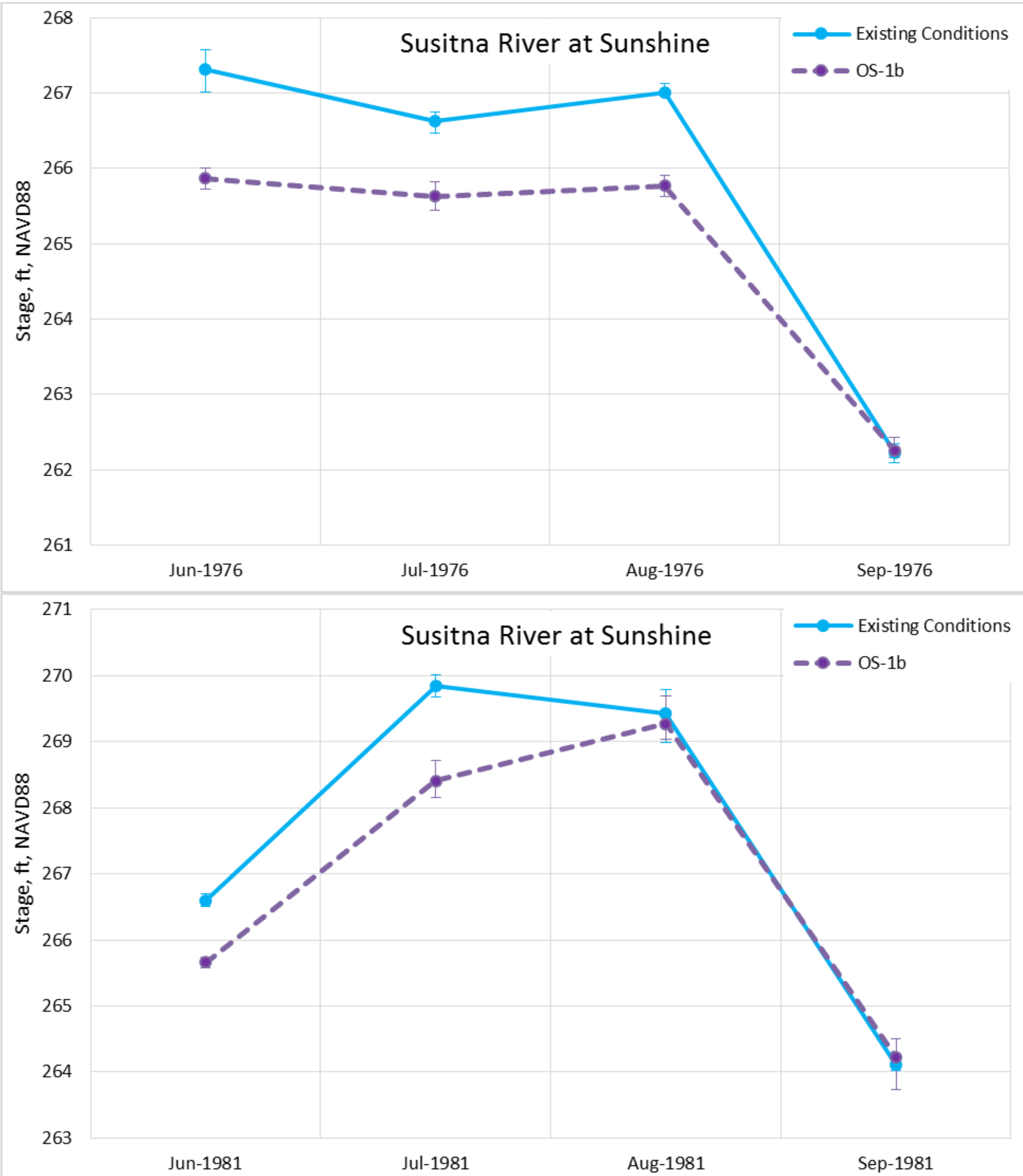
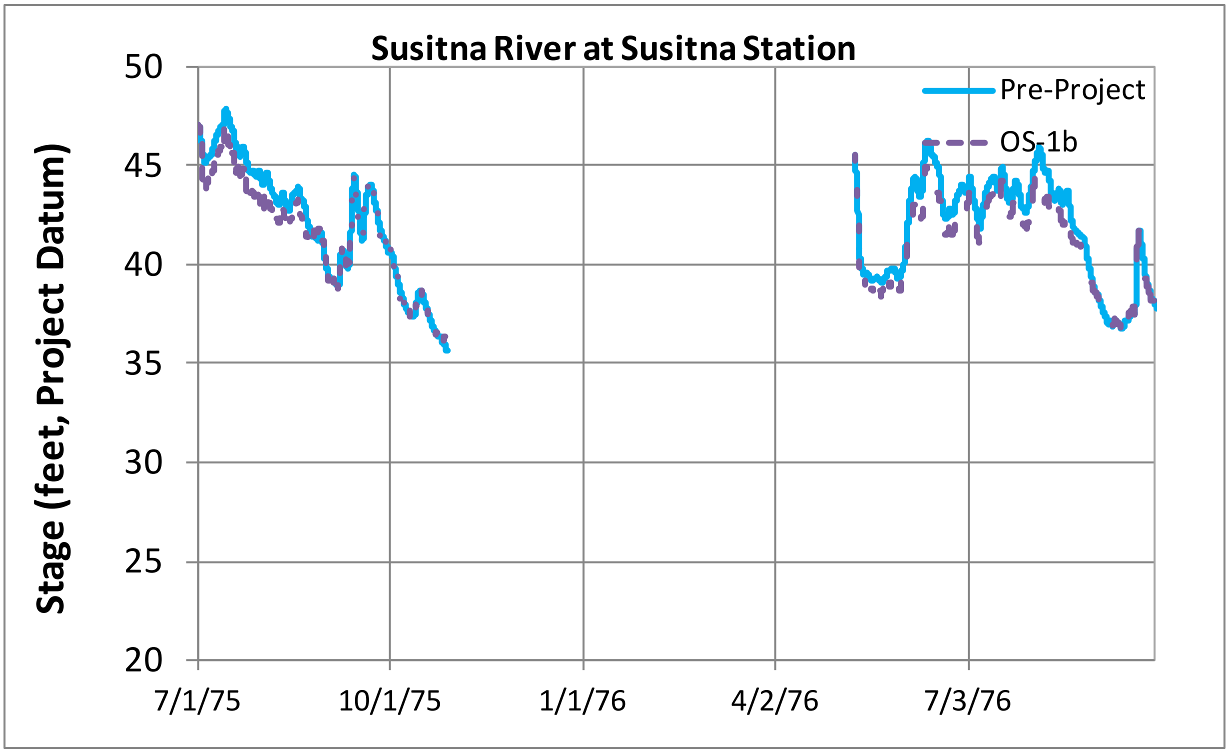


Figure 6.4-21. Monthly medians of predicted daily average stage in the Susitna River at Sunshine (USGS 15292780) under Pre-Project and Maximum Load Following OS-1b conditions for 1976 (top, dry) and 1981 (bottom, wet). Error bars denote the monthly medians of daily maximums and daily minimums.



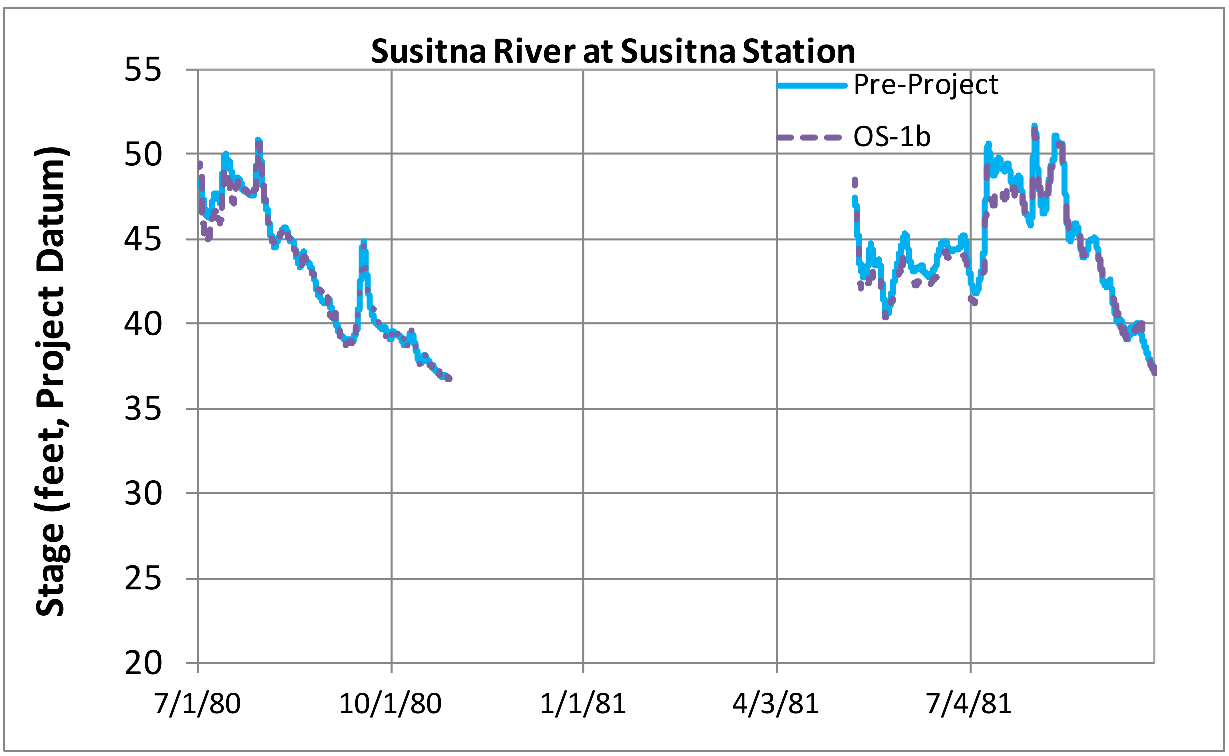


Figure 6.4-22. Predicted stage hydrographs in the Susitna River at Susitna Station (USGS 15294350) under Pre-Project and Maximum Load Following OS-1b conditions 1976 (top, dry) and 1981 (bottom, wet).

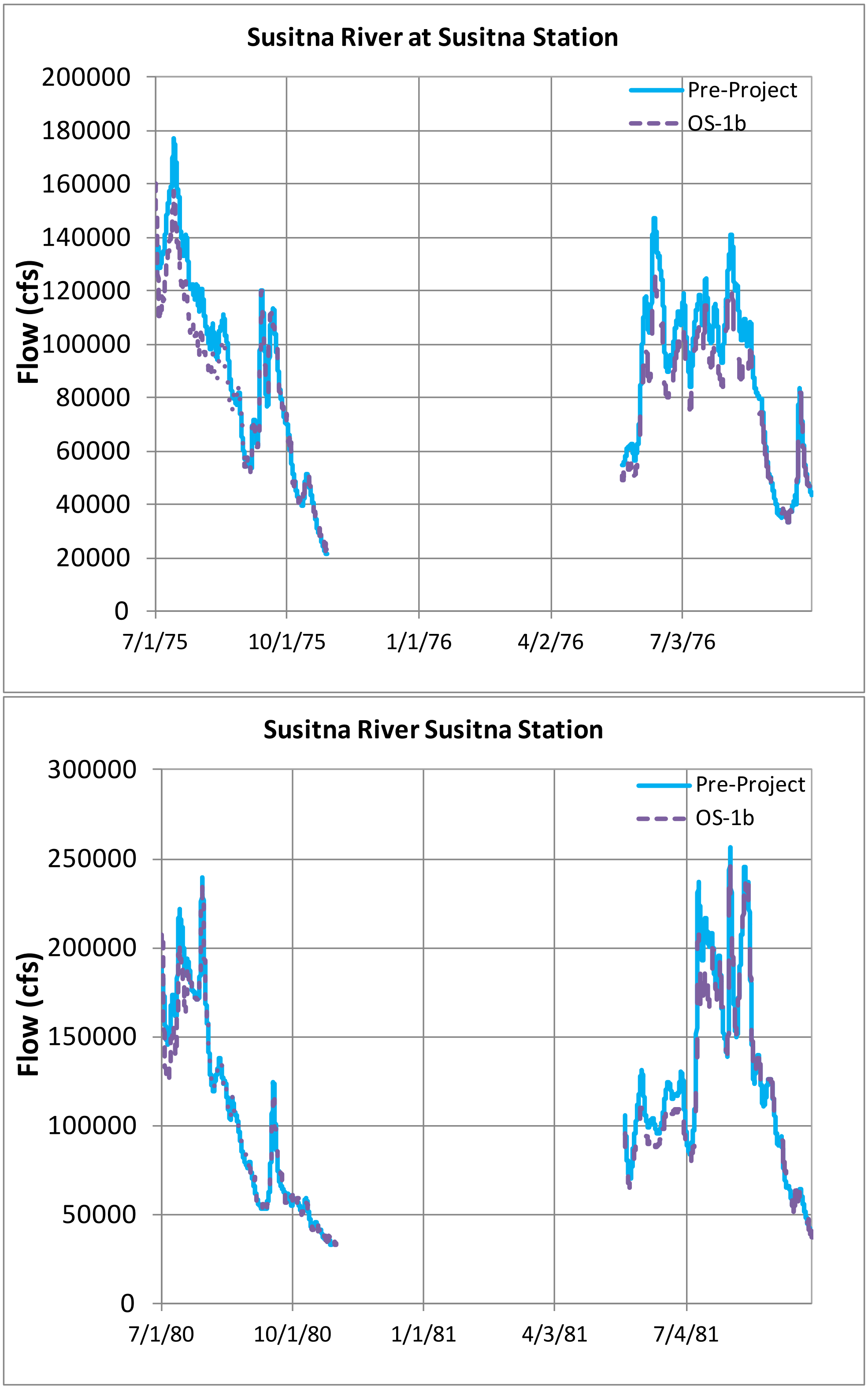
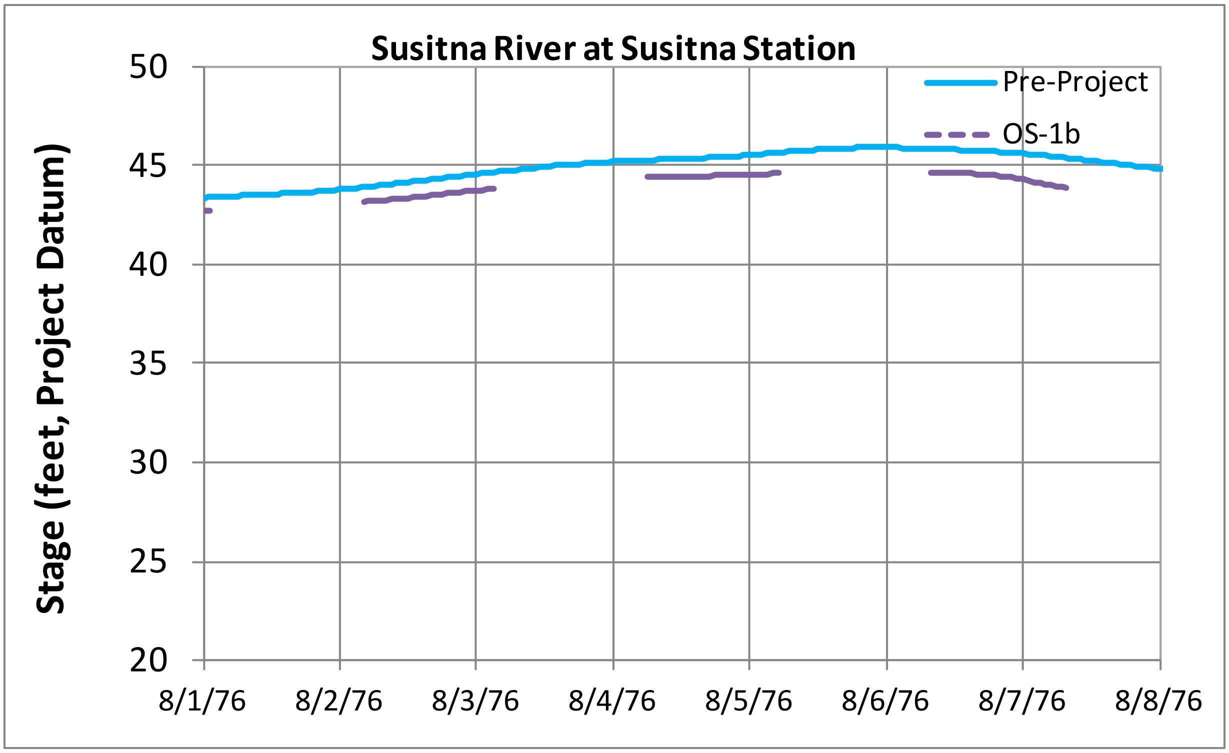


Figure 6.4-23. Predicted flow hydrographs in the Susitna River at Susitna Station (USGS 15294350) under Pre-Project and Maximum Load Following OS-1b conditions for 1976 (top, dry) and 1981 (bottom, wet).



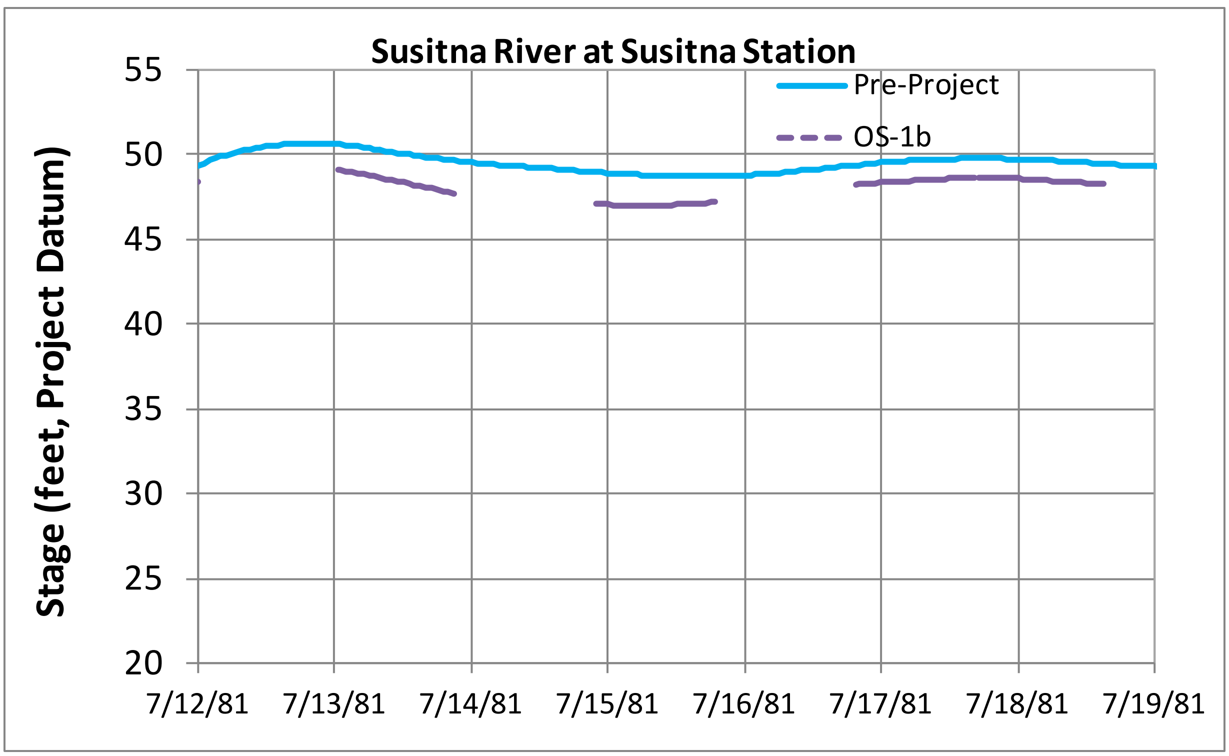
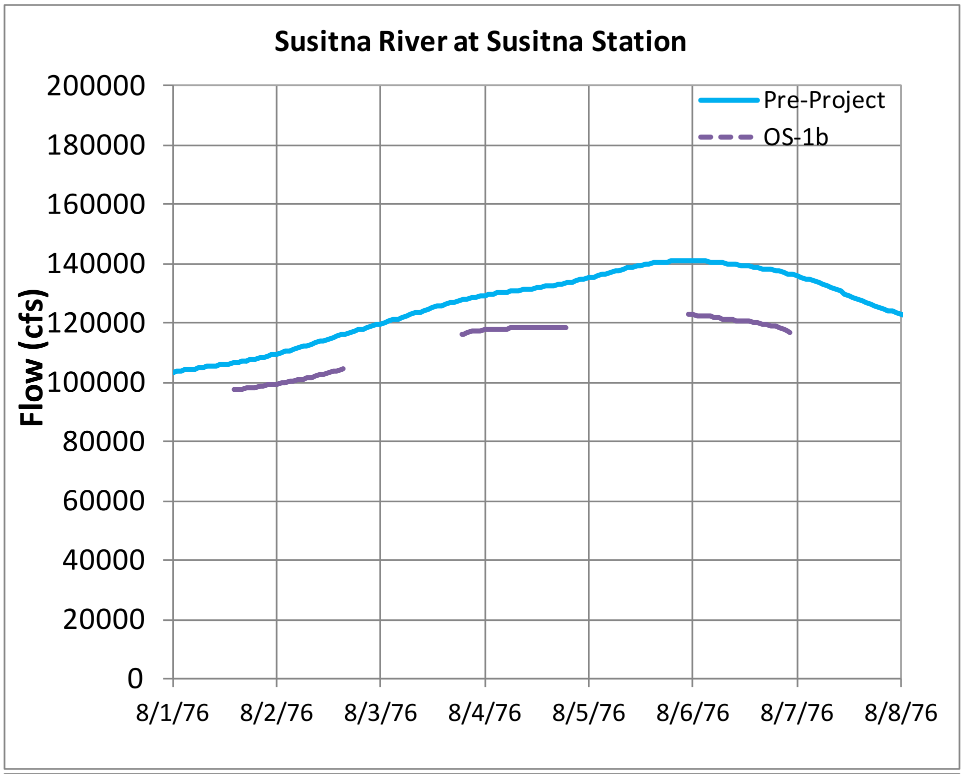


Figure 6.4-24. Predicted stage hydrographs in the Susitna River at Susitna Station (USGS 15294350) under Pre-Project and Maximum Load Following OS-1b conditions during the week of August 1-8, 1976 (top) and July 12-19, 1981 (bottom). Pre-Project conditions do not account for potential diurnal fluctuations associated with glacial melt.



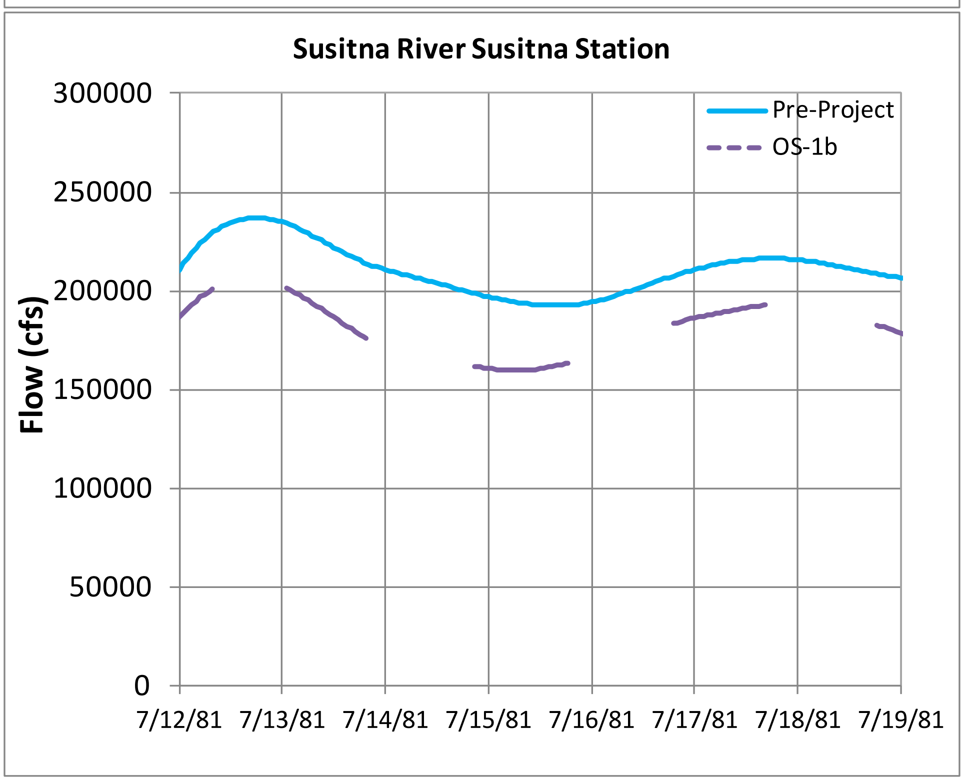


Figure 6.4-25. Predicted flow hydrographs in the Susitna River at Susitna Station (USGS 15294350) under Pre-Project and Maximum Load Following OS-1b conditions during the week of August 1-8, 1976 (top) and July 12-17, 1981 (bottom). Pre-Project conditions do not account for potential diurnal fluctuations associated with glacial melt.

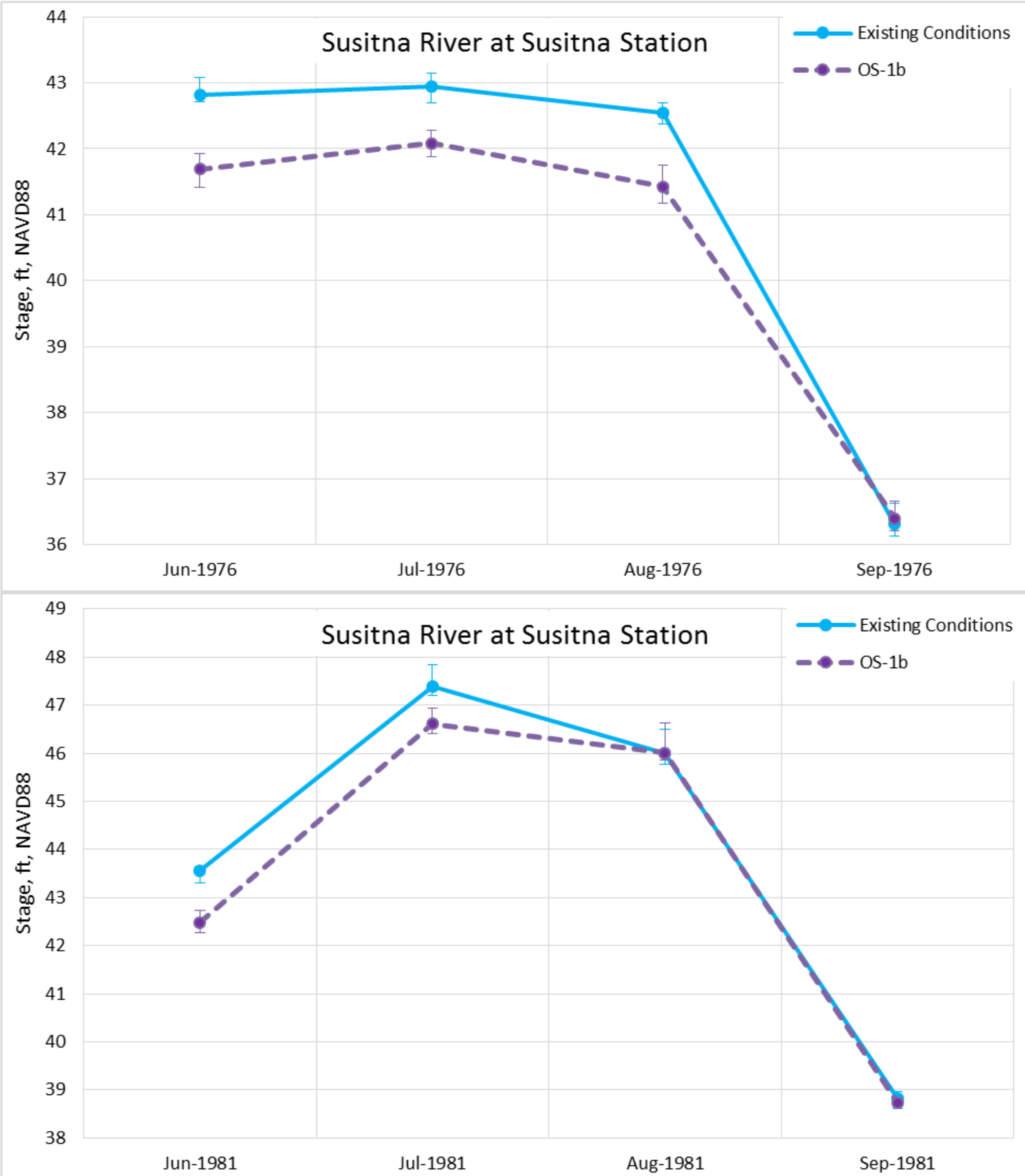
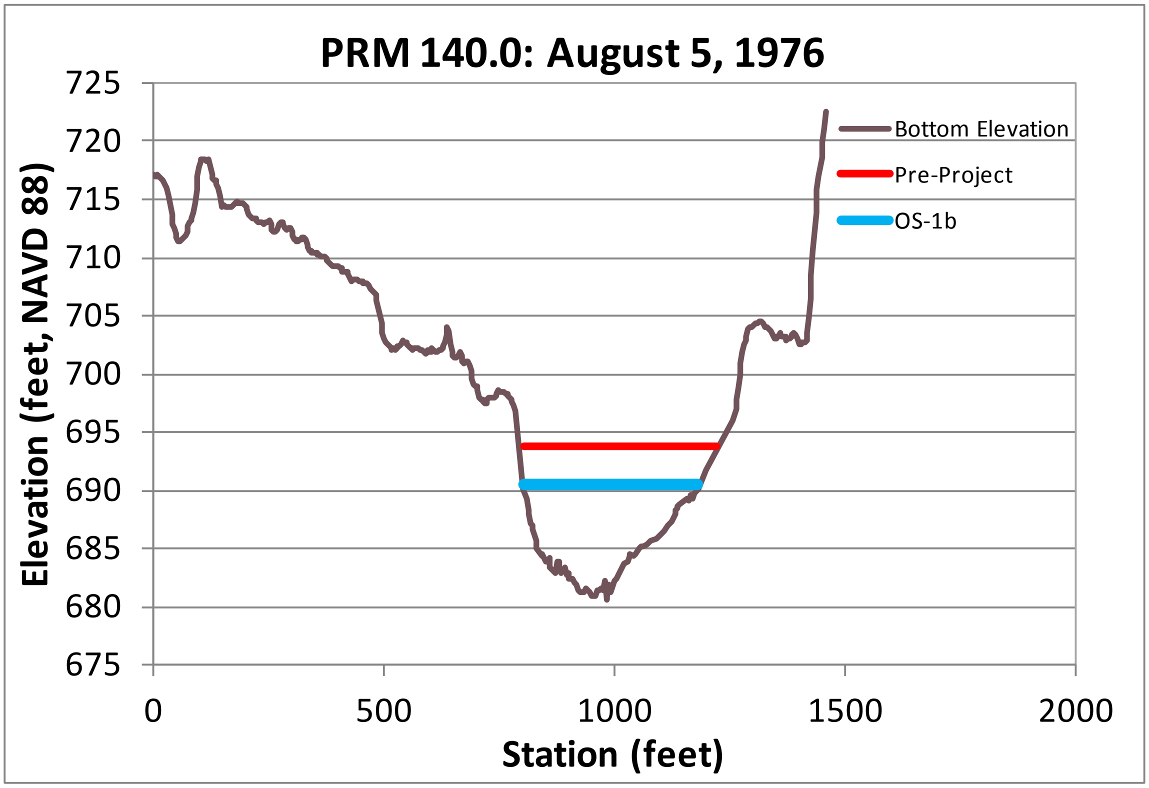


Figure 6.4-26. Monthly medians of predicted daily average stage in the Susitna River at Susitna Station (USGS 15293450) under Pre-Project and Maximum Load Following OS-1b conditions for 1976 (top, dry) and 1981 (bottom, wet). Error bars denote the monthly medians of daily maximums and daily minimums.



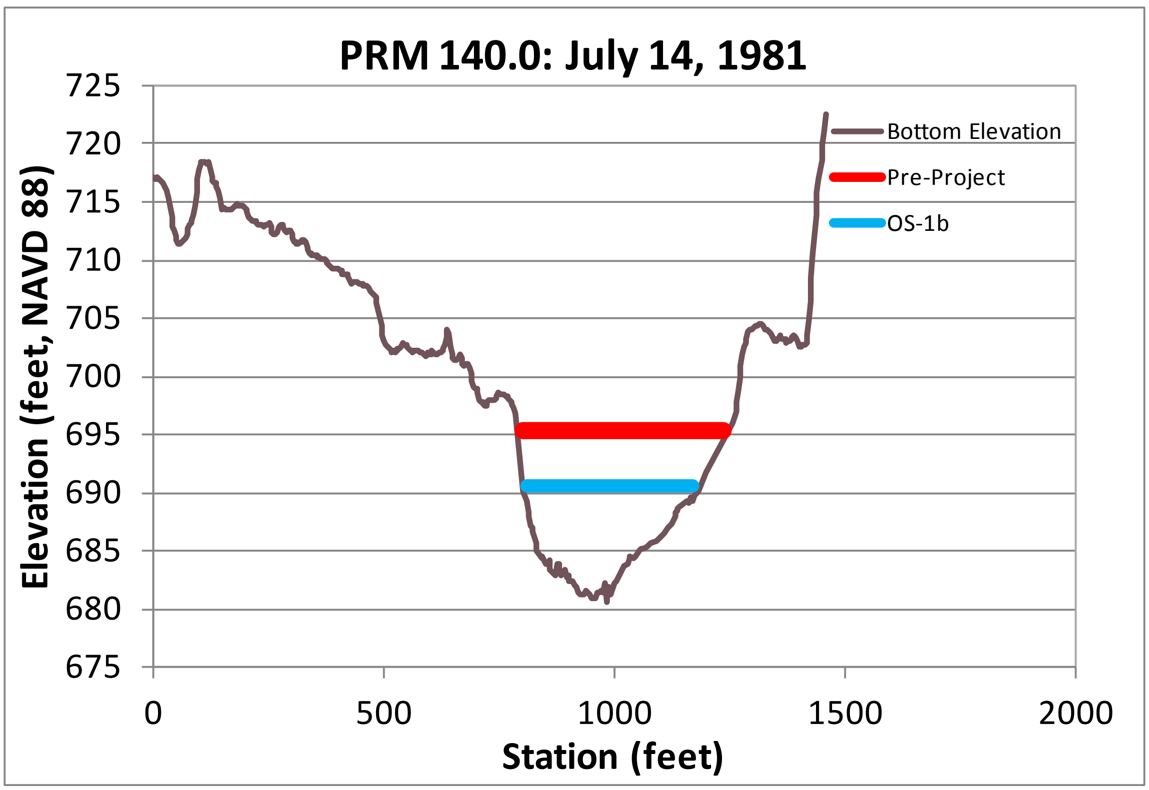
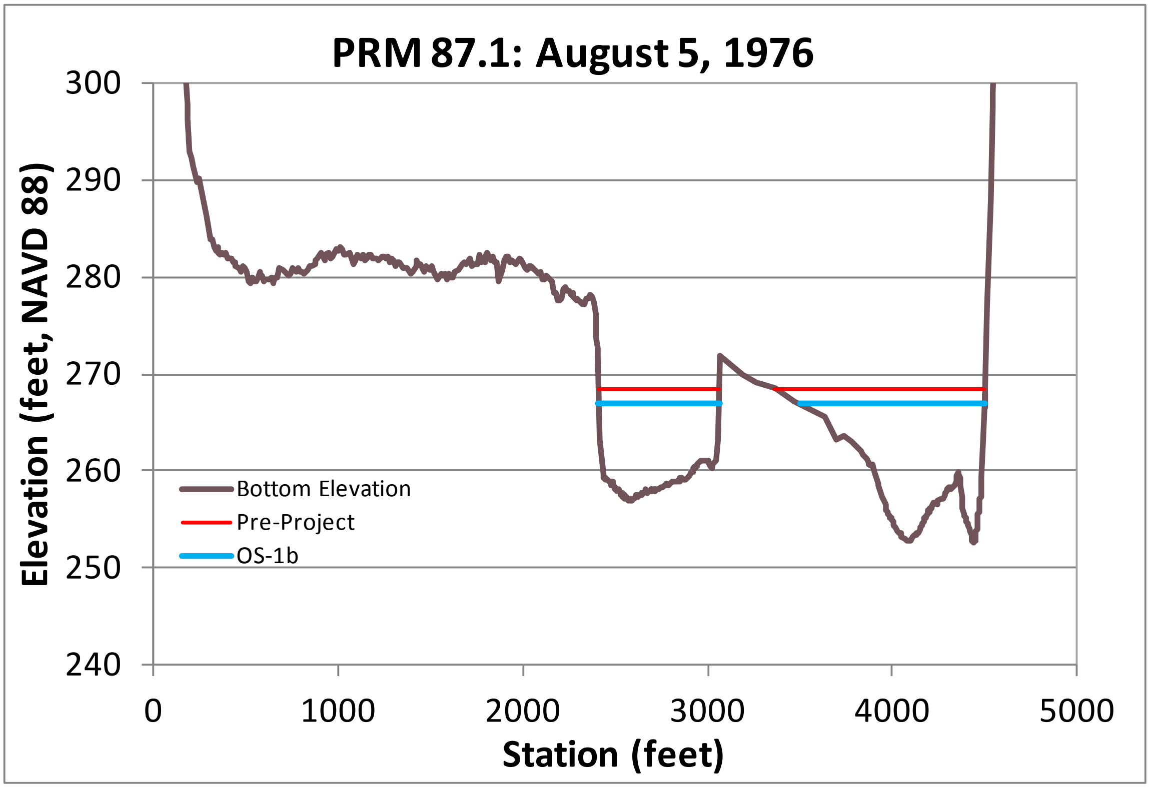


Figure 6.4-27. Range of daily stage fluctuations in the Susitna River cross-section at PRM 140.0 under Pre-Project and Maximum Load Following OS-1b conditions on July 14, 1976 and August 5, 1981. The thickness of each water surface elevation line was scaled to represent the range between minimum and maximum water surface elevation each day.



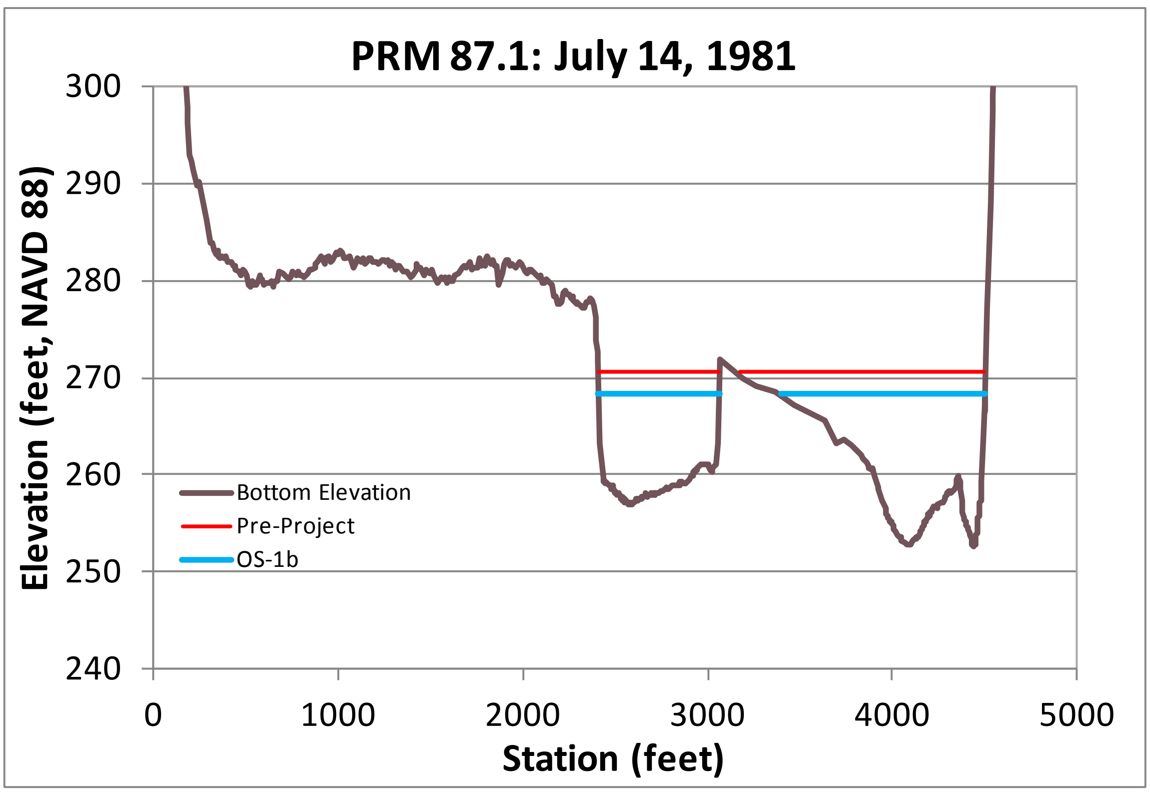


Figure 6.4-28. Range of daily stage fluctuations in the Susitna River cross-section at PRM 87.1 under Pre-Project and Maximum Load Following OS-1b conditions on August 5, 1976 and July 14, 1981. The thickness of each water surface elevation line was scaled to represent the range between minimum and maximum water surface elevation each day.

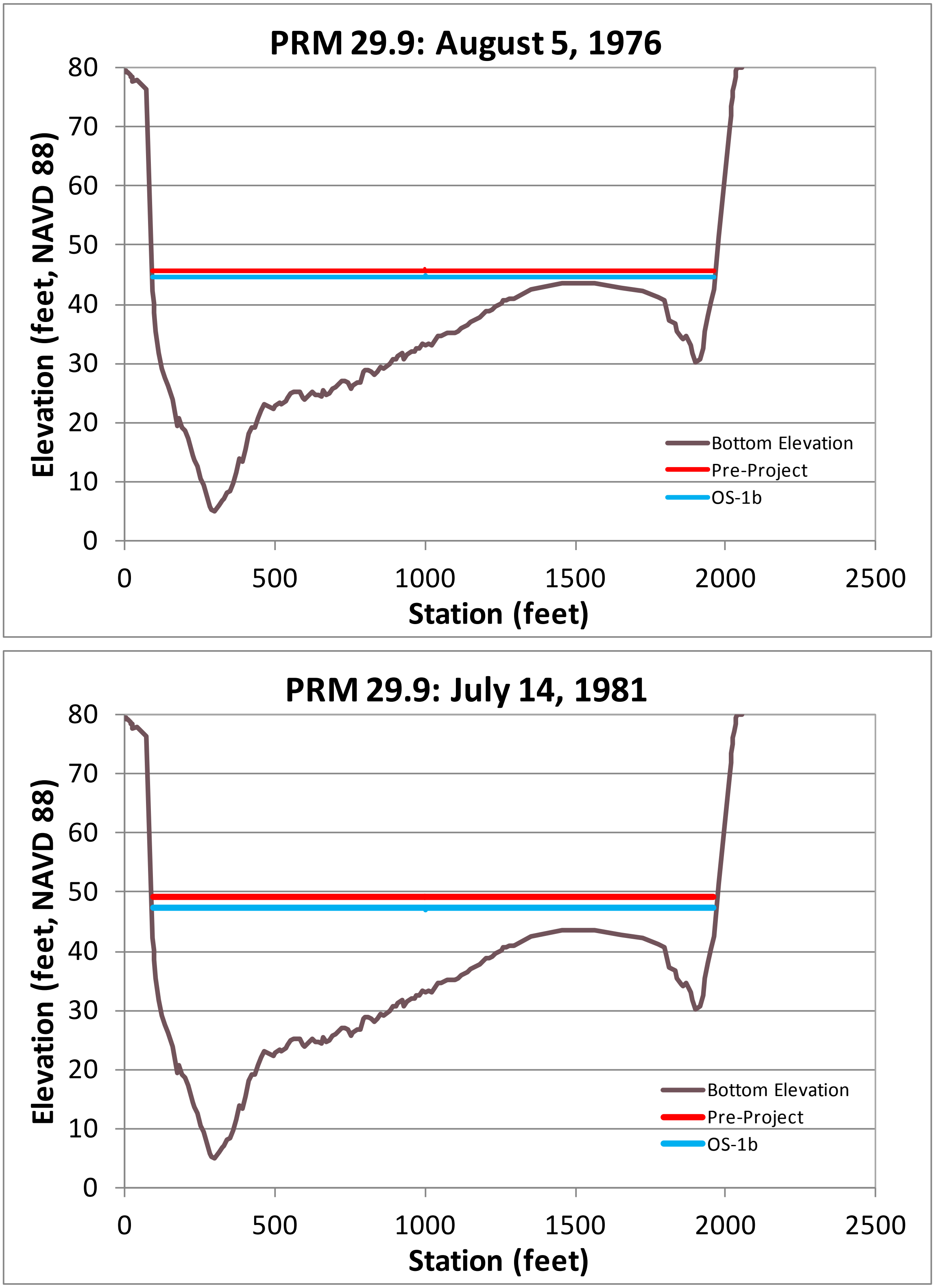


Figure 6.4-29. Range of daily stage fluctuations in the Susitna River cross-section at PRM 29.9 under Pre-Project and Maximum Load Following OS-1b conditions on August 5, 1976 and July 14, 1981. The thickness of each water surface elevation line was scaled to represent the range between minimum and maximum water surface elevation each day.

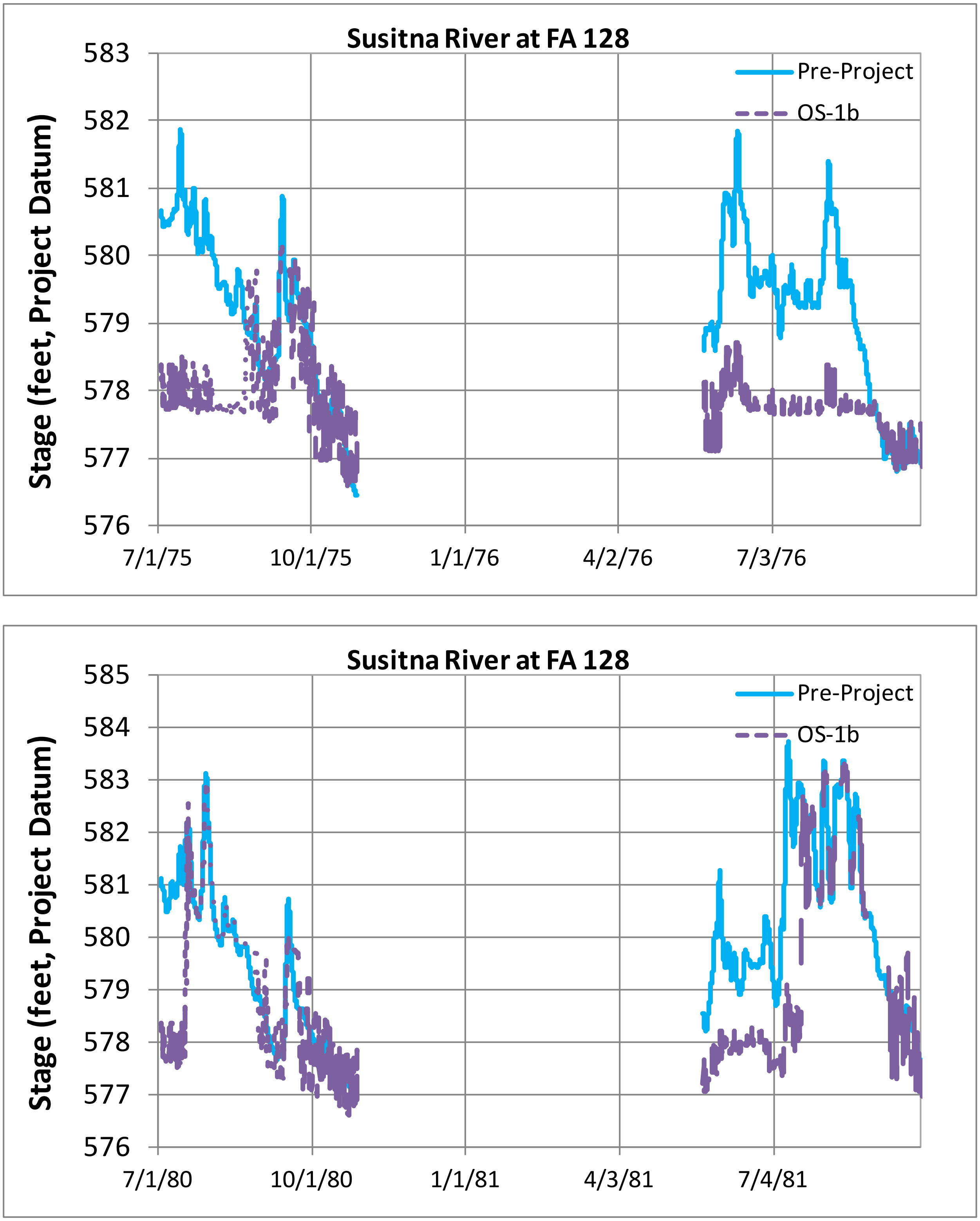


Figure 6.4-30. Predicted stage hydrographs in the Susitna River at FA 128 under Pre-Project and Maximum Load Following OS-1b conditions in 1976 (top, dry) and 1981 (bottom, wet).

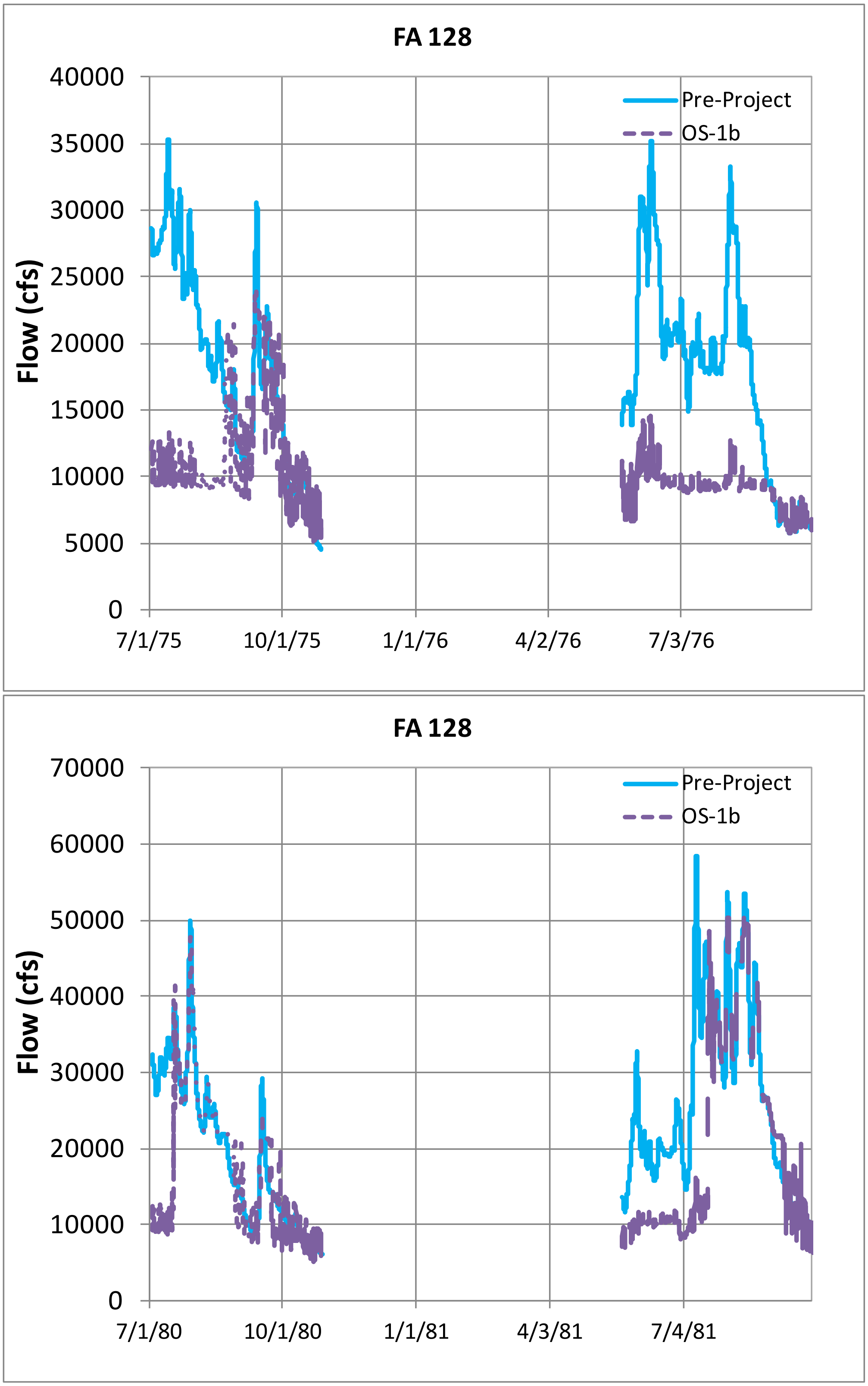
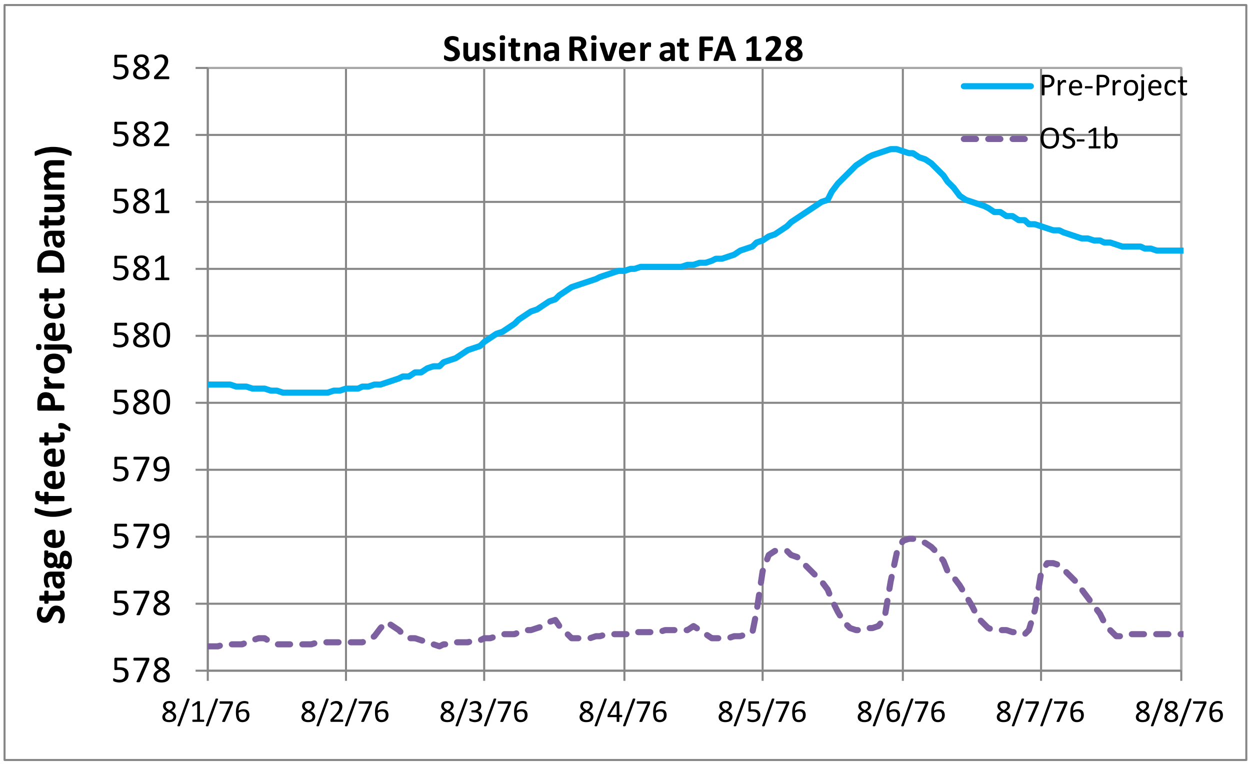


Figure 6.4-31. Predicted flow hydrographs in the Susitna River at FA 128 under Pre-Project and Maximum Load Following OS-1b conditions in 1976 (top, dry) and 1981 (bottom, wet).



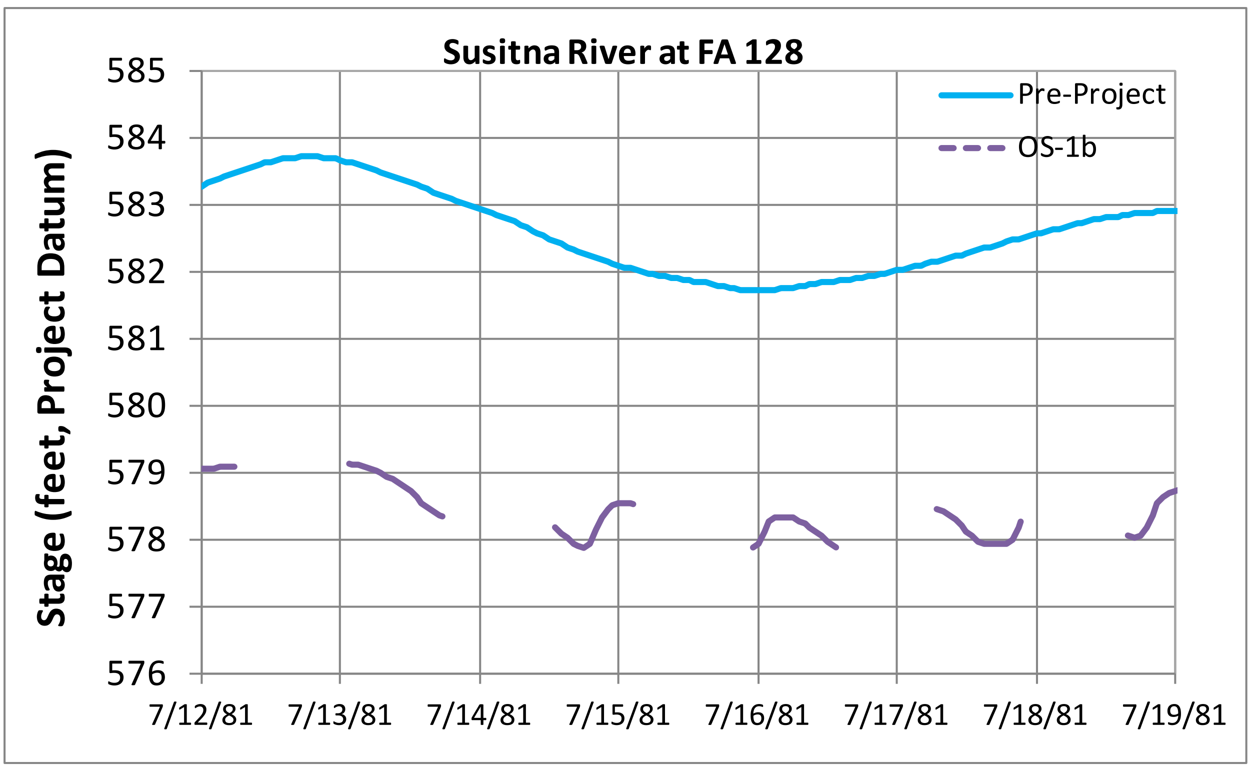


Figure 6.4-32. Predicted stage hydrographs in the Susitna River at FA 128 under Pre-Project and Maximum Load Following OS-1b conditions during the week of August 1-8, 1976 (top) and July 12-19, 1981 (bottom).

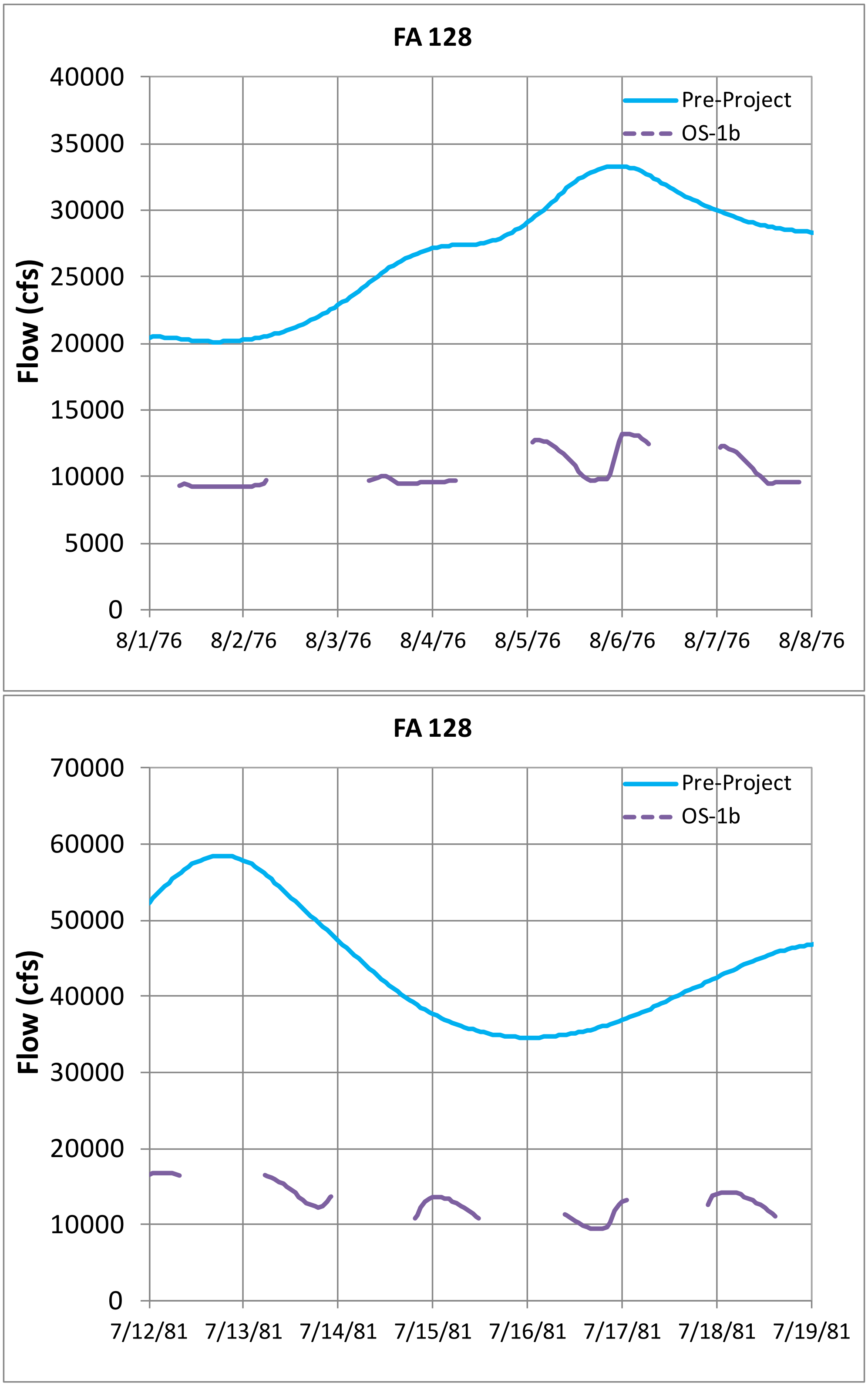
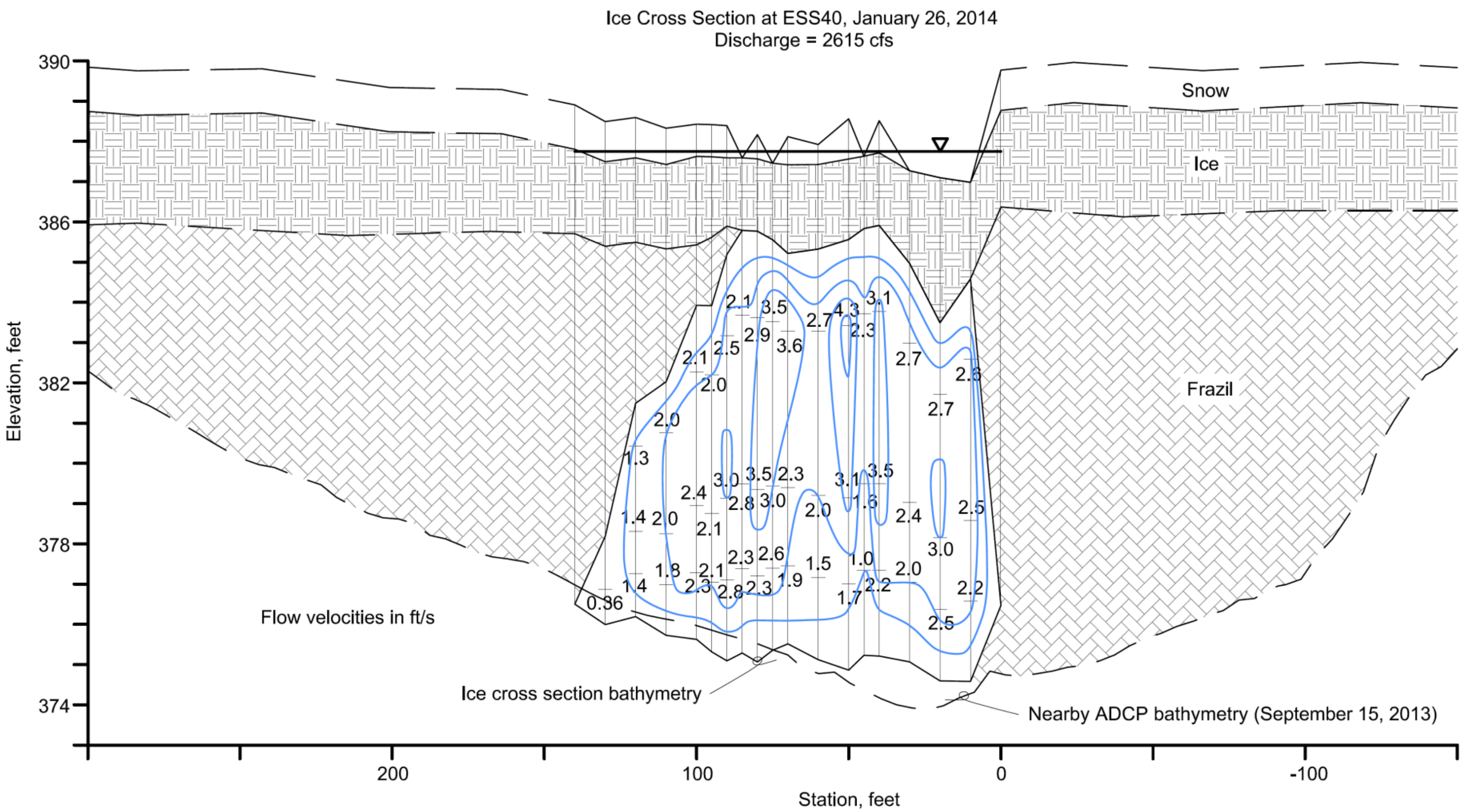
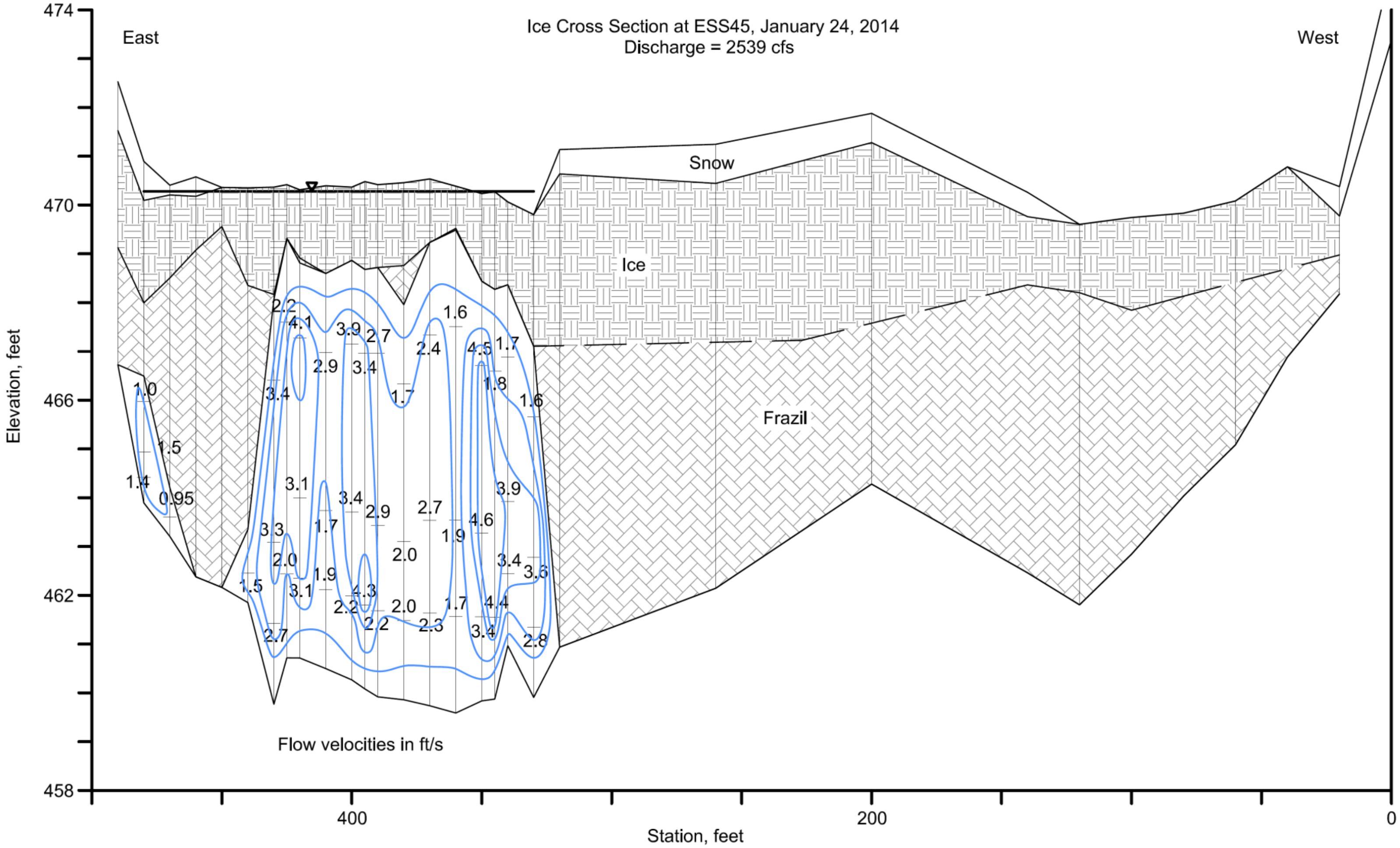


Figure 6.4-33. Predicted flow hydrographs in the Susitna River at FA 128 under Pre-Project and Maximum Load Following OS-1b conditions during the week of August 1-8, 1976 (top) and July 12-19, 1981 (bottom).

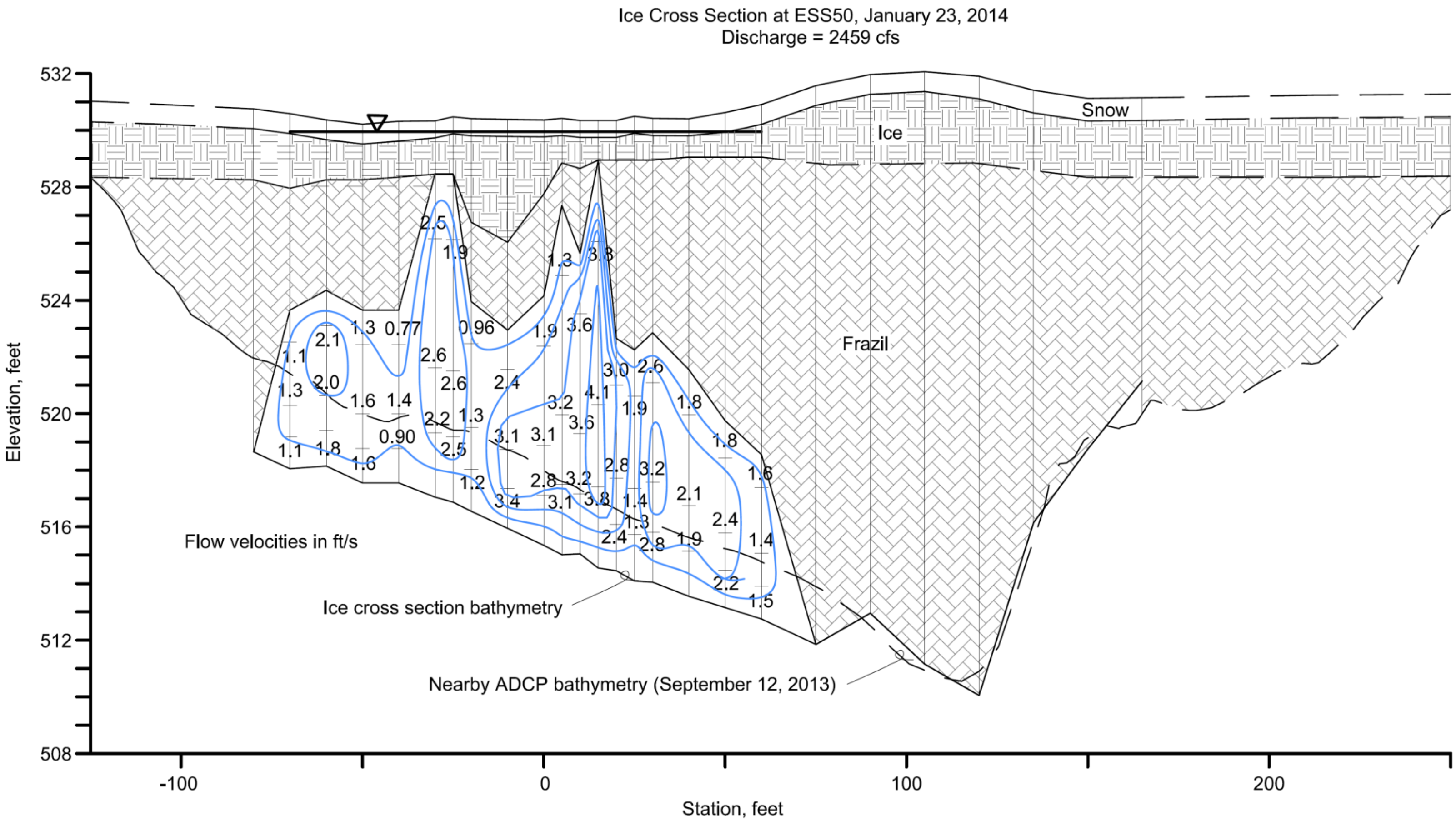
ATTACHMENT 1 – WINTER GAGING MAINSTEM CROSS SECTION DIAGRAMS

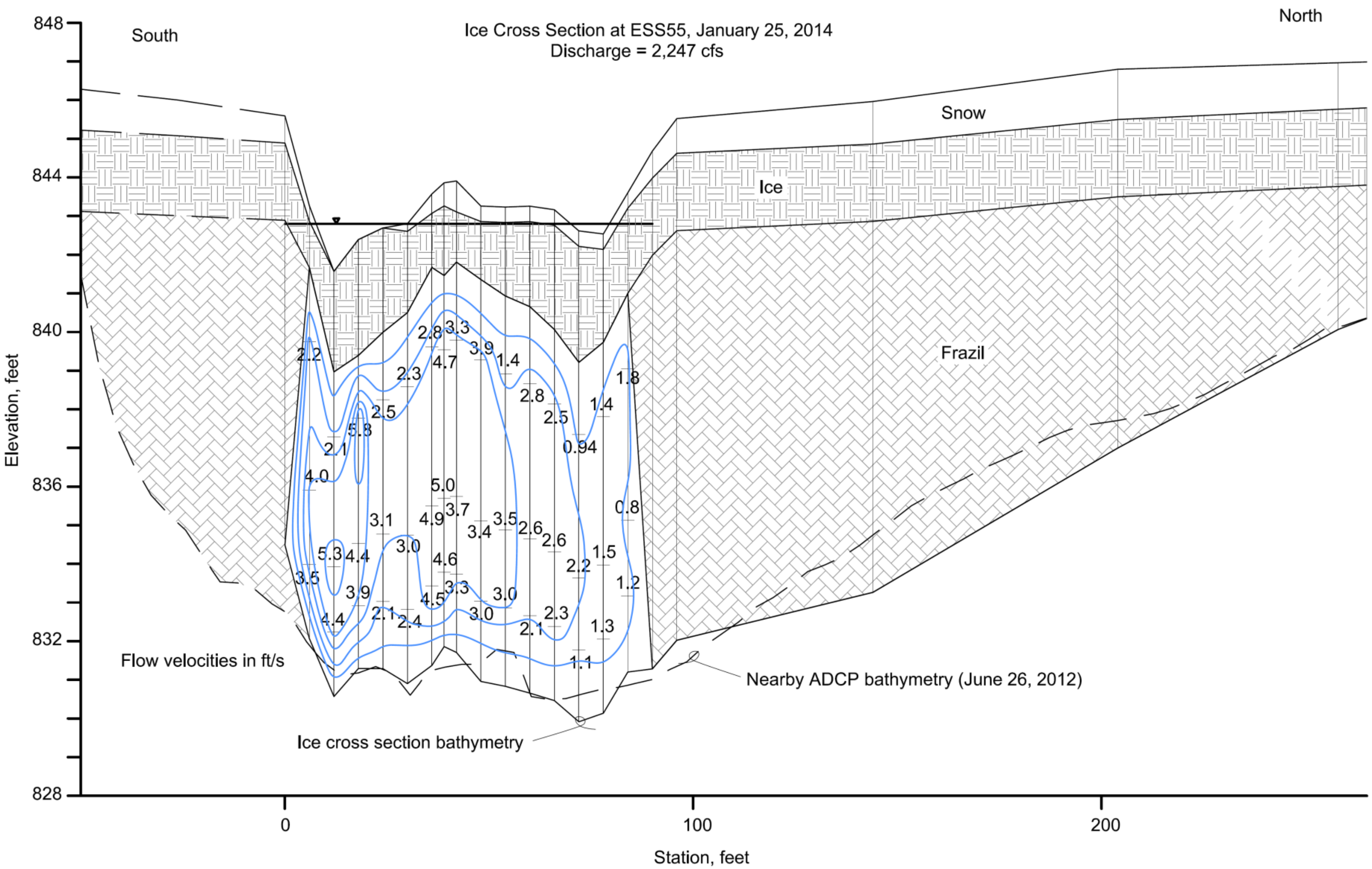


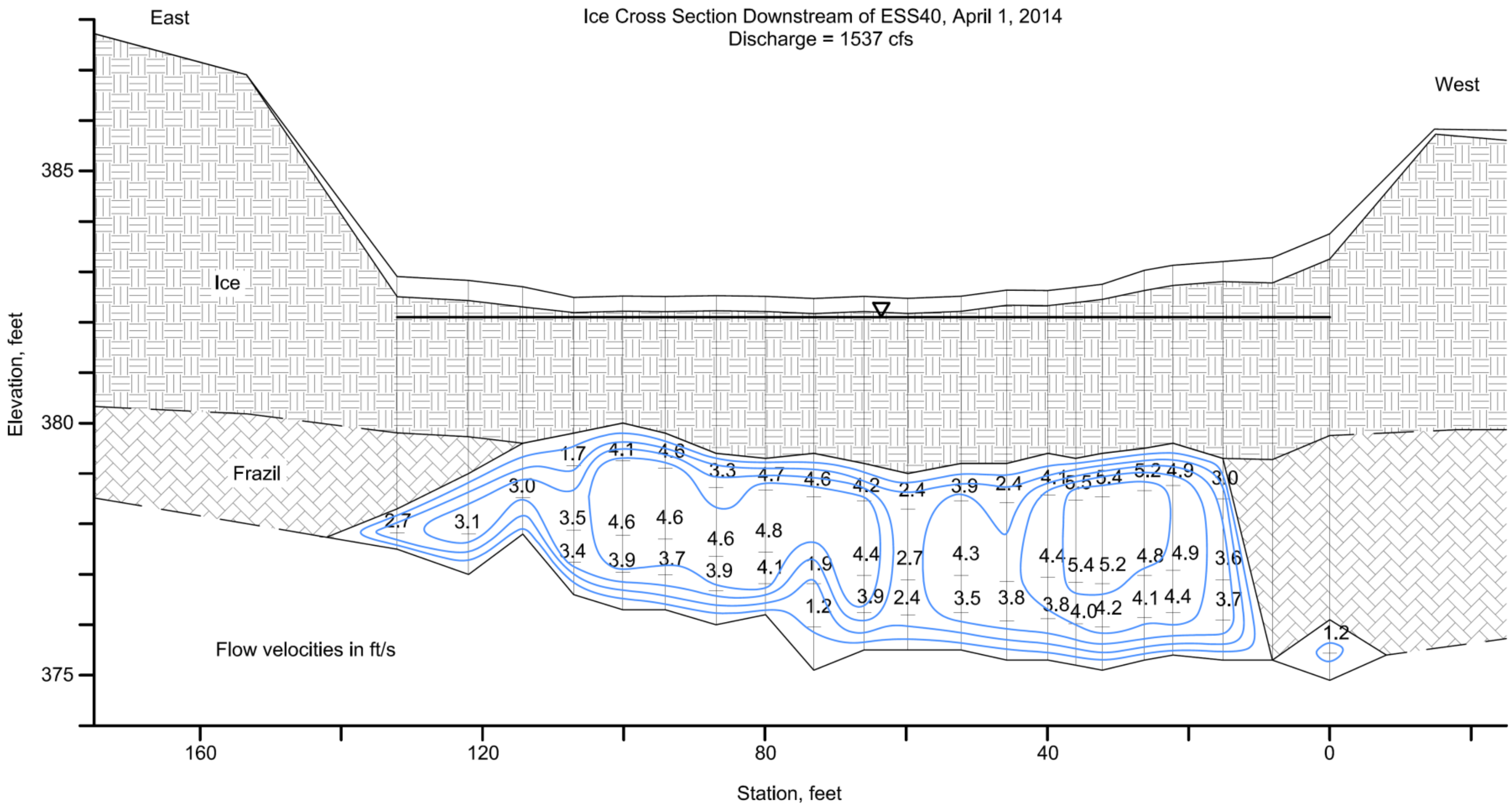
Ice Cross Section at ESS40, January 26, 2014
Discharge = 2615 cfs
Snow
Ice
Frazil
Flow velocities in ft/s
Ice cross section bathymetry
Nearby ADCP bathymetry (September 15, 2013)
Elevation, feet
Station, feet

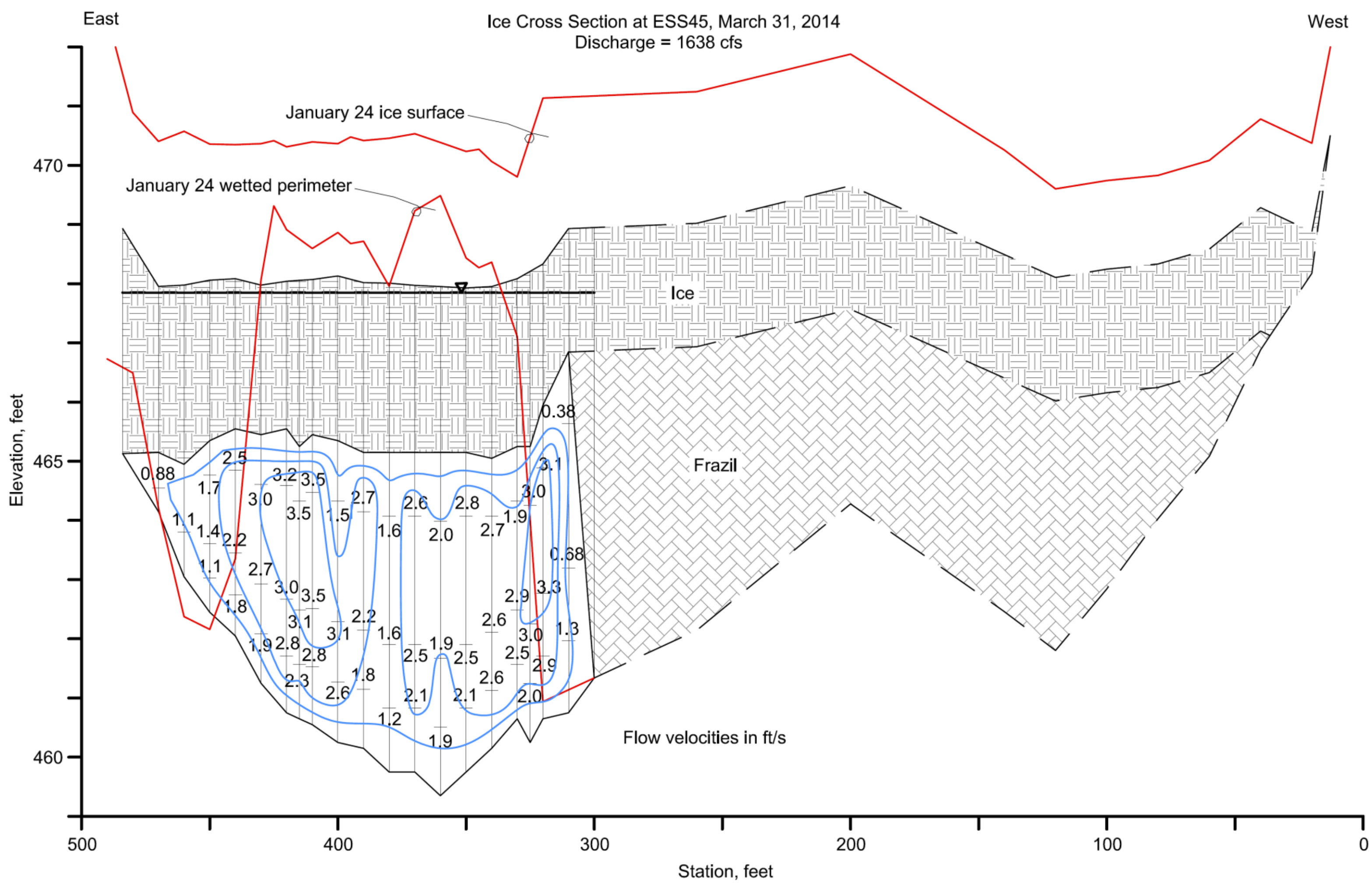


Ice Cross Section at ESS45, January 24, 2014
Discharge = 2539 cfs
East
West
Snow
Ice
Frazil
Flow velocities in ft/s
Elevation, feet
Station, feet
474
470
466
462
458
400
200
0


Ice Cross Section at ESS50, January 23, 2014
Discharge = 2459 cfs
Snow
Ice
Frazil
Flow velocities in ft/s
Ice cross section bathymetry
Nearby ADCP bathymetry (September 12, 2013)
Elevation, feet
Station, feet
532
528
524
520
516
512
508
-100
0
100
200


Ice Cross Section at ESS55, January 25, 2014
Discharge = 2,247 cfs
South
North
Snow
Ice
Frazil
Flow velocities in ft/s
Nearby ADCP bathymetry (June 26, 2012)
Ice cross section bathymetry
Elevation, feet
Station, feet
848
844
840
836
832
828
0
100
200


Ice Cross Section Downstream of ESS40, April 1, 2014
Discharge = 1537 cfs
East
West
Ice
Frazil
Flow velocities in ft/s
Elevation, feet
Station, feet
385
380
375
160
120
80
40
0


East
Ice Cross Section at ESS45, March 31, 2014
Discharge = 1638 cfs
West
January 24 ice surface
January 24 wetted perimeter
Ice
Frazil
Flow velocities in ft/s
Elevation, feet
470
465
460
500
400
300
200
100
0
Station, feet
0.88
2.5
1.7
3.2
3.5
3.0
3.5
1.5
2.7
2.6
2.8
1.6
2.0
2.7
1.9
0.38
3.1
3.0
1.1
1.4
2.2
1.1
2.7
0.68
3.0
3.5
2.9
3.3
1.8
3.1
2.2
2.6
1.9
2.8
3.1
1.6
3.0
1.3
2.8
1.9
2.5
2.5
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1.8
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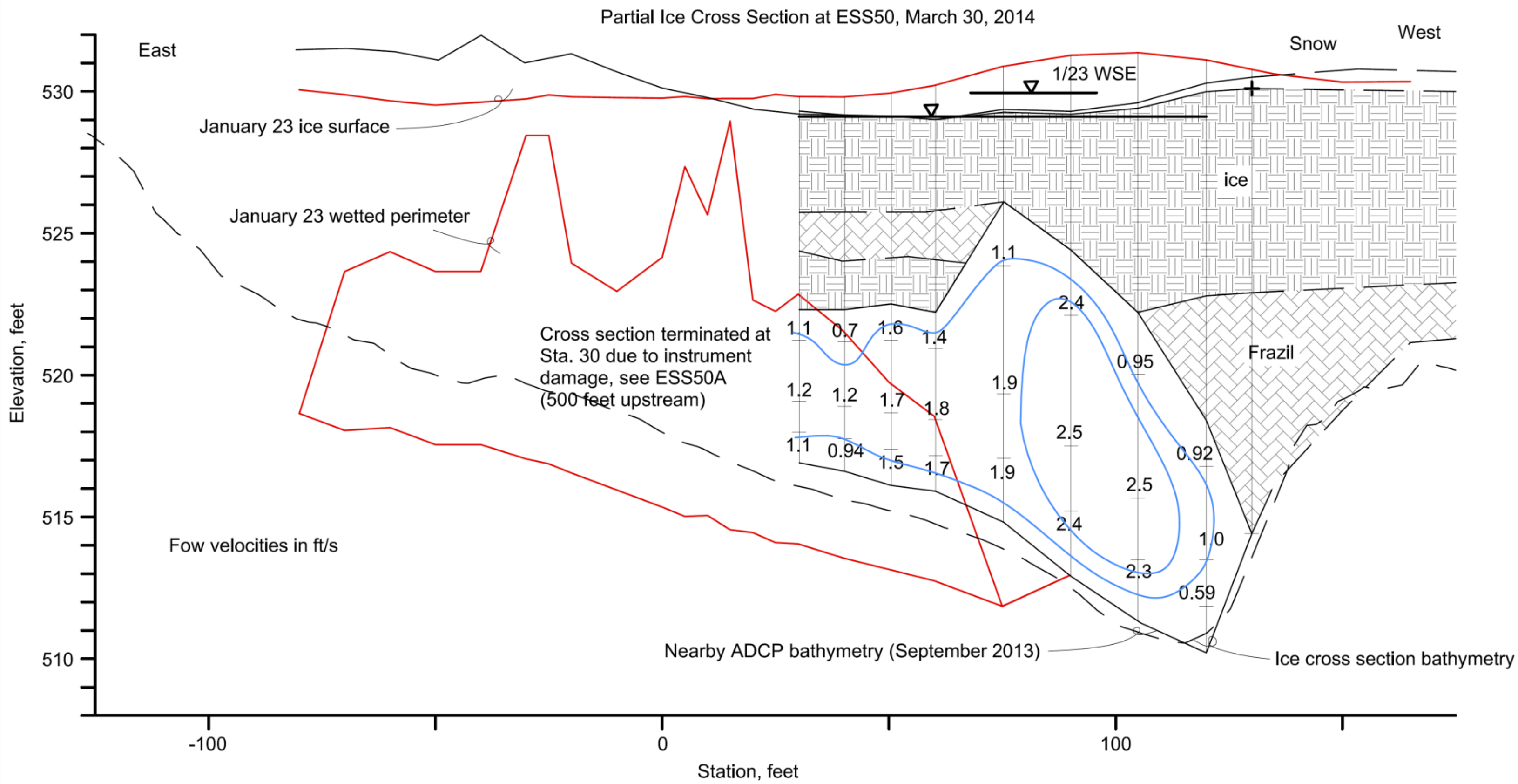
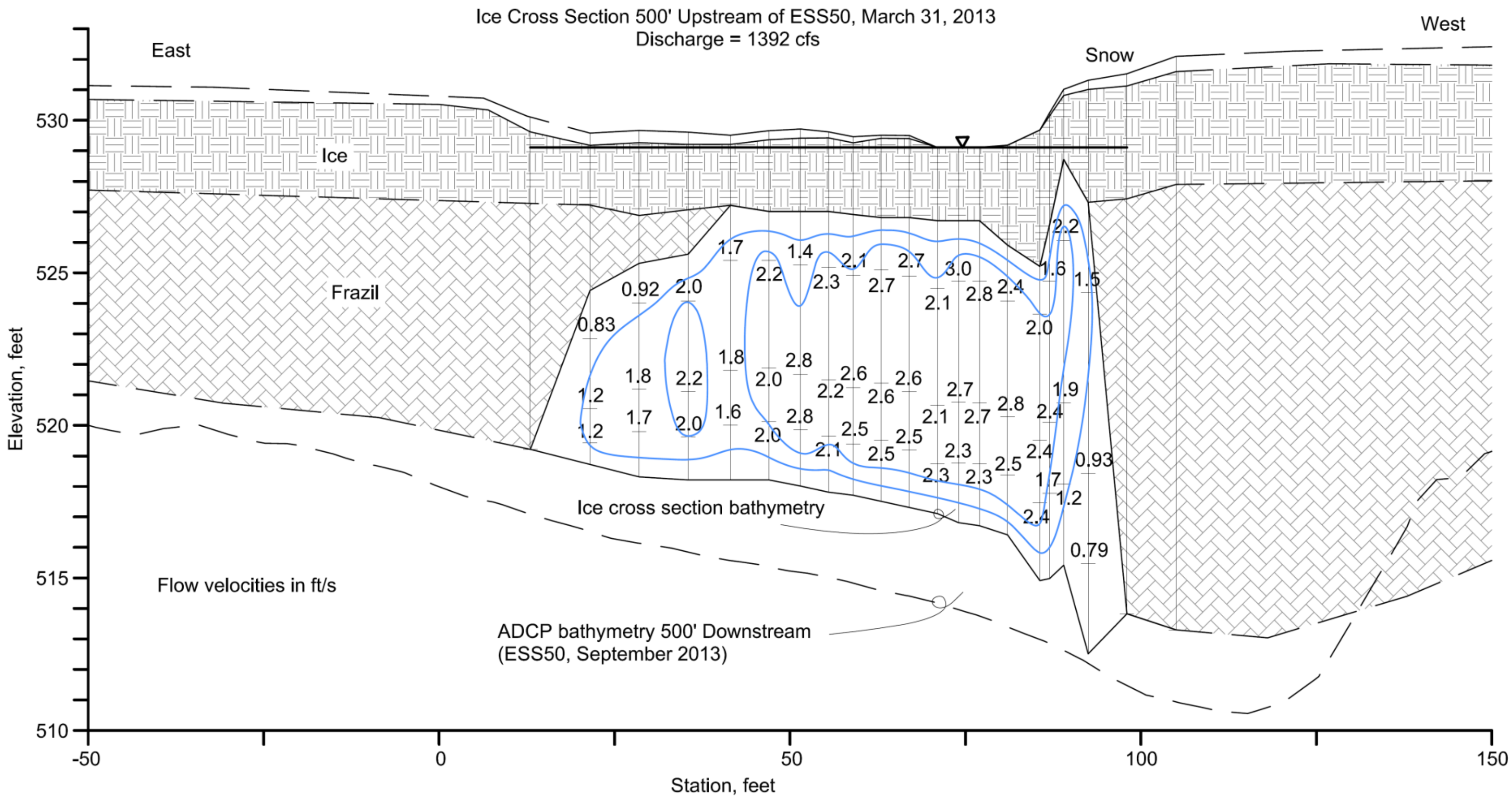
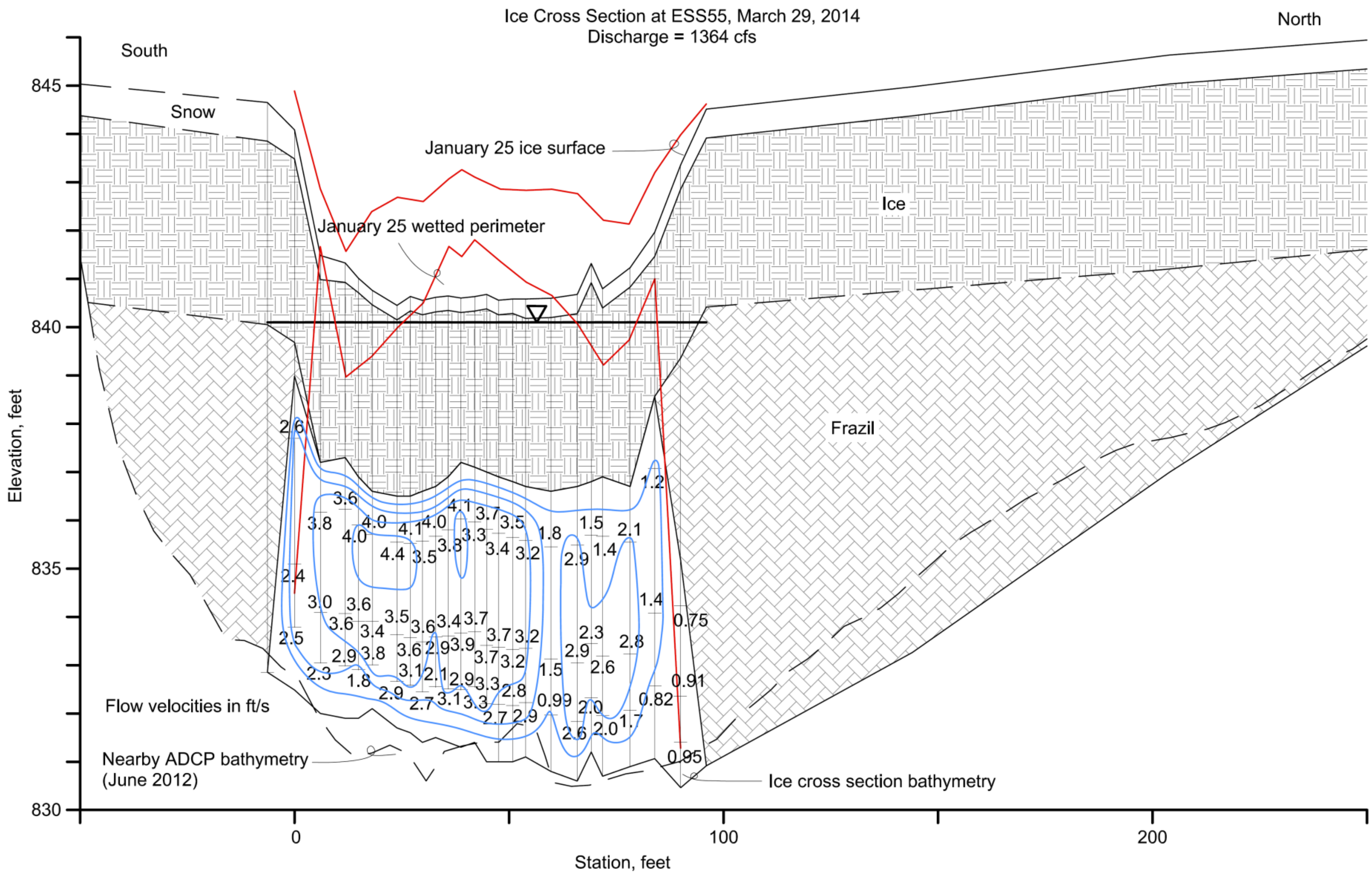
2.1
2.0
1.2
1.9

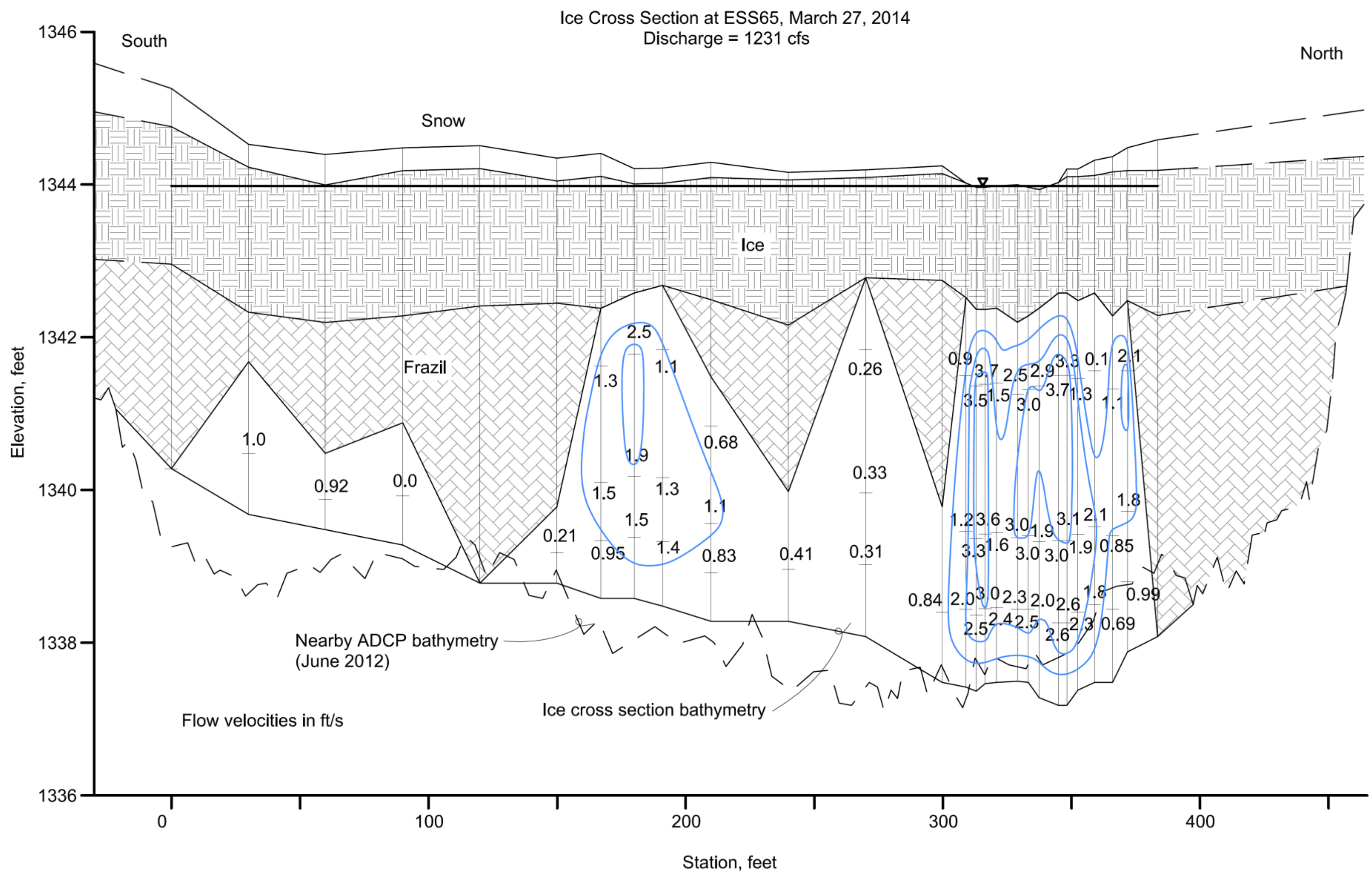


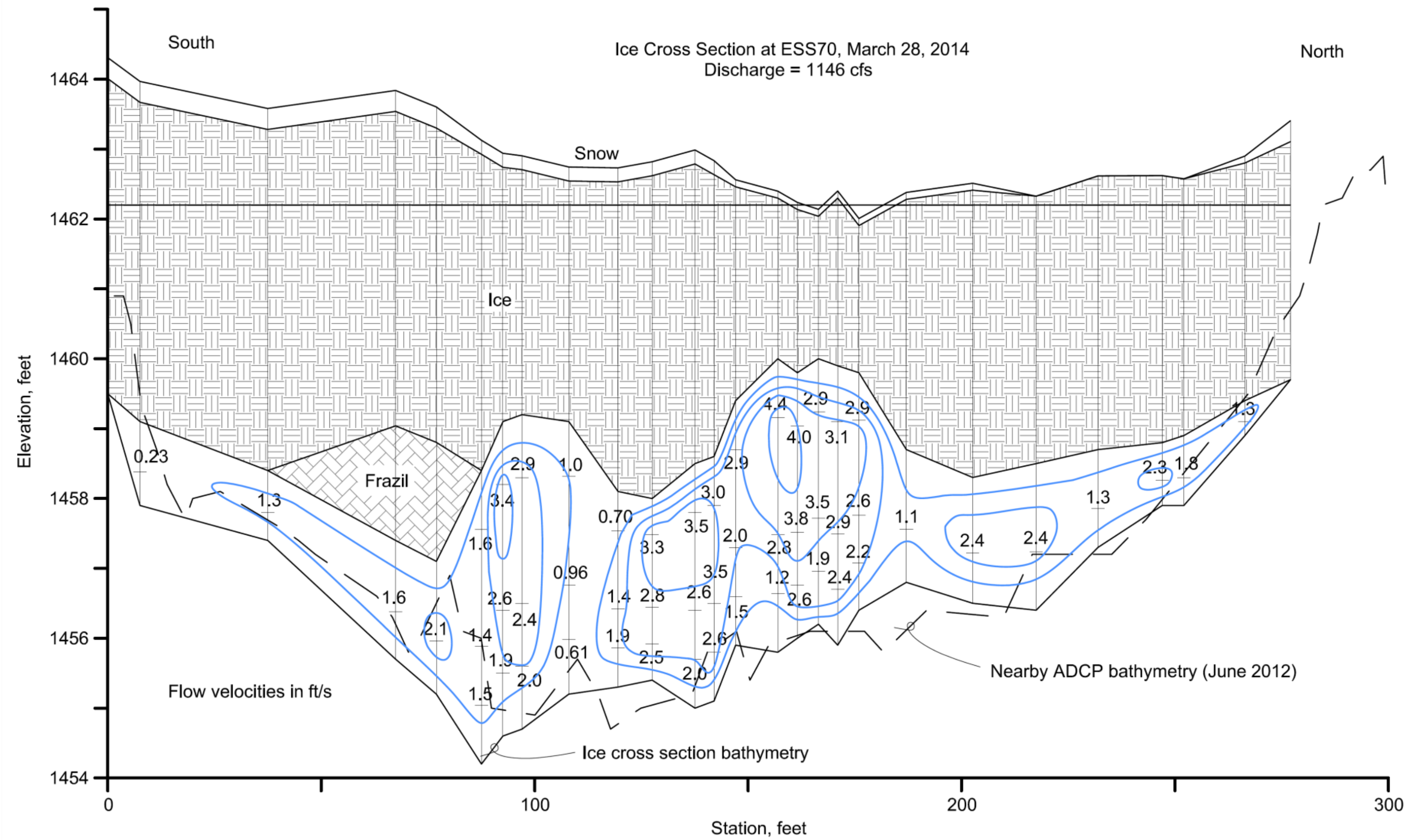
Partial Ice Cross Section at ESS50, March 30, 2014
East
West
Snow
1/23 WSE
ice
Frazil
January 23 ice surface
January 23 wetted perimeter
Cross section terminated at Sta. 30 due to instrument damage, see ESS50A (500 feet upstream)
Fow velocities in ft/s
Nearby ADCP bathymetry (September 2013)
Ice cross section bathymetry
1.1
0.7
1.6
1.4
1.1
2.4
0.95
1.2
1.2
1.7
1.8
1.9
2.5
0.92
1.1
0.94
1.5
1.7
1.9
2.5
2.4
1.0
2.3
0.59
Elevation, feet
530
525
520
515
510
-100
0
100
Station, feet



Ice Cross Section 500' Upstream of ESS50, March 31, 2013
Discharge = 1392 cfs
East
West
Snow
Ice
Frazil
Ice cross section bathymetry
Flow velocities in ft/s
ADCP bathymetry 500' Downstream
(ESS50, September 2013)
Elevation, feet
Station, feet


Ice Cross Section at ESS55, March 29, 2014
Discharge = 1364 cfs
South
North
Snow
January 25 ice surface
Ice
January 25 wetted perimeter
Frazil
Flow velocities in ft/s
Nearby ADCP bathymetry
(June 2012)
Ice cross section bathymetry
Elevation, feet
Station, feet
845
840
835
830
0
100
200


Ice Cross Section at ESS65, March 27, 2014
Discharge = 1231 cfs
South
North
Snow
Ice
Frazil
Elevation, feet
Station, feet
Nearby ADCP bathymetry
(June 2012)
Ice cross section bathymetry
Flow velocities in ft/s
1346
1344
1342
1340
1338
1336
0
100
200
300
400


Ice Cross Section at ESS70, March 28, 2014
Discharge = 1146 cfs
South
North
Snow
Ice
Frazil
Flow velocities in ft/s
Nearby ADCP bathymetry (June 2012)
Ice cross section bathymetry
Elevation, feet
Station, feet
1464
1462
1460
1458
1456
1454
0
100
200
300

PART C - APPENDIX L: 2012-2013 INSTREAM FLOW WINTER PILOT STUDIES

[See separate file for Appendix.]

PART C - APPENDIX M: HABITAT SUITABILITY CURVE DEVELOPMENT

[See separate file for Appendix.]

PART C - APPENDIX N: MIDDLE RIVER FISH HABITAT AND RIVERINE MODELING: PROOF OF CONCEPT

[See separate file for Appendix.]

PART C - APPENDIX O: FISH HABTAT MODELING IN LOWER RIVER

[See separate file for Appendix.]