

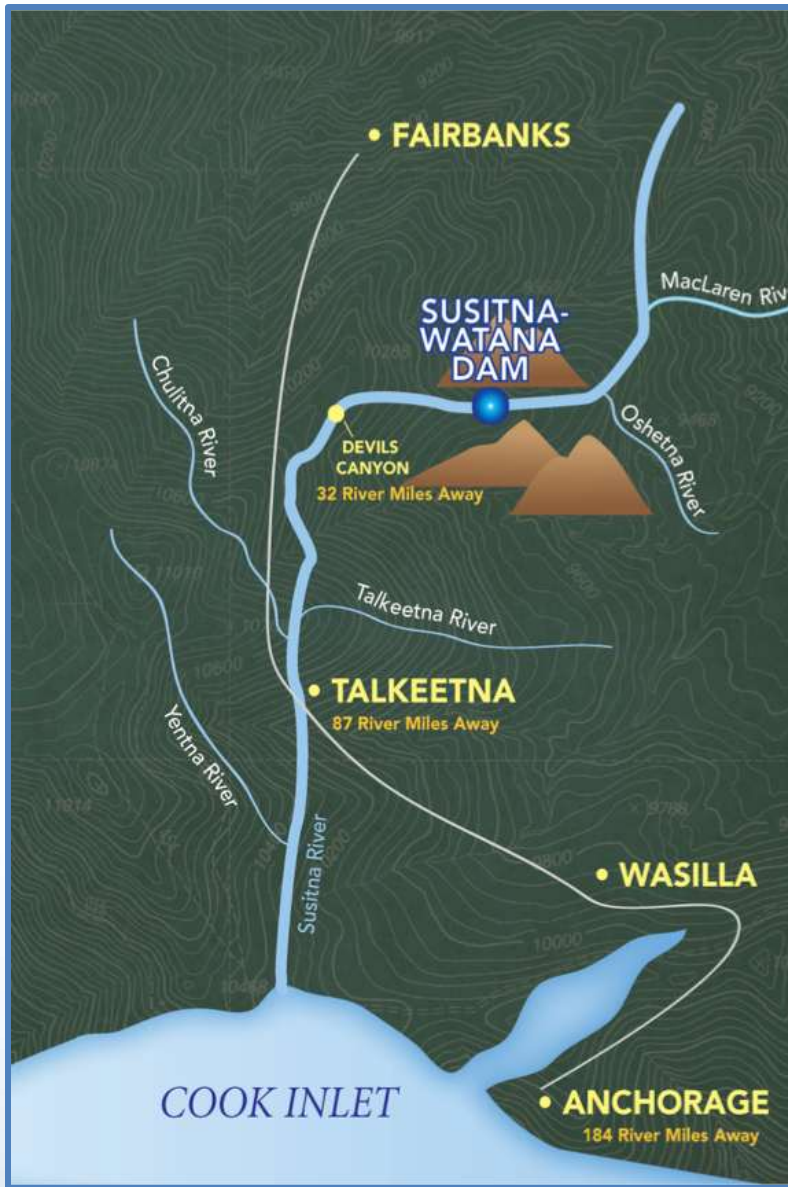
Response to FERC Order

Susitna River Pre-Project and Maximum Load Following Operational Scenario 1 Stages

Open Water HEC-RAS Flow Routing Model *Version 1*

1 February 2013

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and Geovera



Background

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- A hydrologic routing model (HEC-ResSim) was previously developed to analyze stages in the Susitna River between Devils Canyon and Sunshine Gage .
- The HEC-ResSim model was used to analyze Pre-Project and Maximum Load Following Operational Scenario 1 (OS-1) conditions during calendar year 1984.
- Input to the HEC-ResSim model included hourly flow releases from the proposed Watana Dam site (Project River Mile (PRM) 187.2.
- Results were presented at the October 23-25, 2012 Technical Workgroup meetings.



Maximum Load Following OS-1

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- Based on the assumption that the 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 stage changes.



Current Update

- A hydraulic flow routing model (HEC-RAS) was developed of the Susitna River from the proposed Watana Dam site downstream to PRM 80.0 (7 miles downstream from Sunshine Gage).
- Version 1 of the HEC-RAS model was developed and calibrated using data collected in 2012.
- Results of the HEC-RAS model are shown using same 1984 Pre- and Post-Project dam release hydrographs that were used in the previous HEC-ResSim study.



Hydrologic Versus Hydraulic Flow Routing

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- Hydrologic flow routing (as is used in HEC-ResSim) is used to route flows through a river and predict downstream flow hydrographs. A corresponding stage hydrograph can be developed at a particular location if a stage/discharge rating curve is available.
- Hydraulic flow routing (as is used in HEC-RAS) uses the momentum equation to route flows through a river and directly predict both flow and stage hydrographs at downstream locations of interest.



Limitations

- The HEC-RAS flow routing model is appropriate for analyzing stage and flow fluctuations under ice-free conditions.
- An ice processes flow routing model is currently being developed to analyze stage and flow fluctuations under ice-affected conditions.
- Actual results during the winter may differ from those presented herein as a result of ice formation on the river.

Downstream Stages with 15-Minute Flow Routing Basis and Assumptions

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- HEC-RAS model developed from 88 cross-sections surveyed on the Susitna River in 2012 from PRM 187.2 to PRM 80.0.
- Steady-state calibration focused on matching 170 pairs of flows and water surface elevations measured in 2012.
- Unsteady-state calibration focused on matching flow hydrographs during the week of August 11 to 17, 2012.
- Unsteady-state validation performed during the period from June 4 to October 14, 2012.

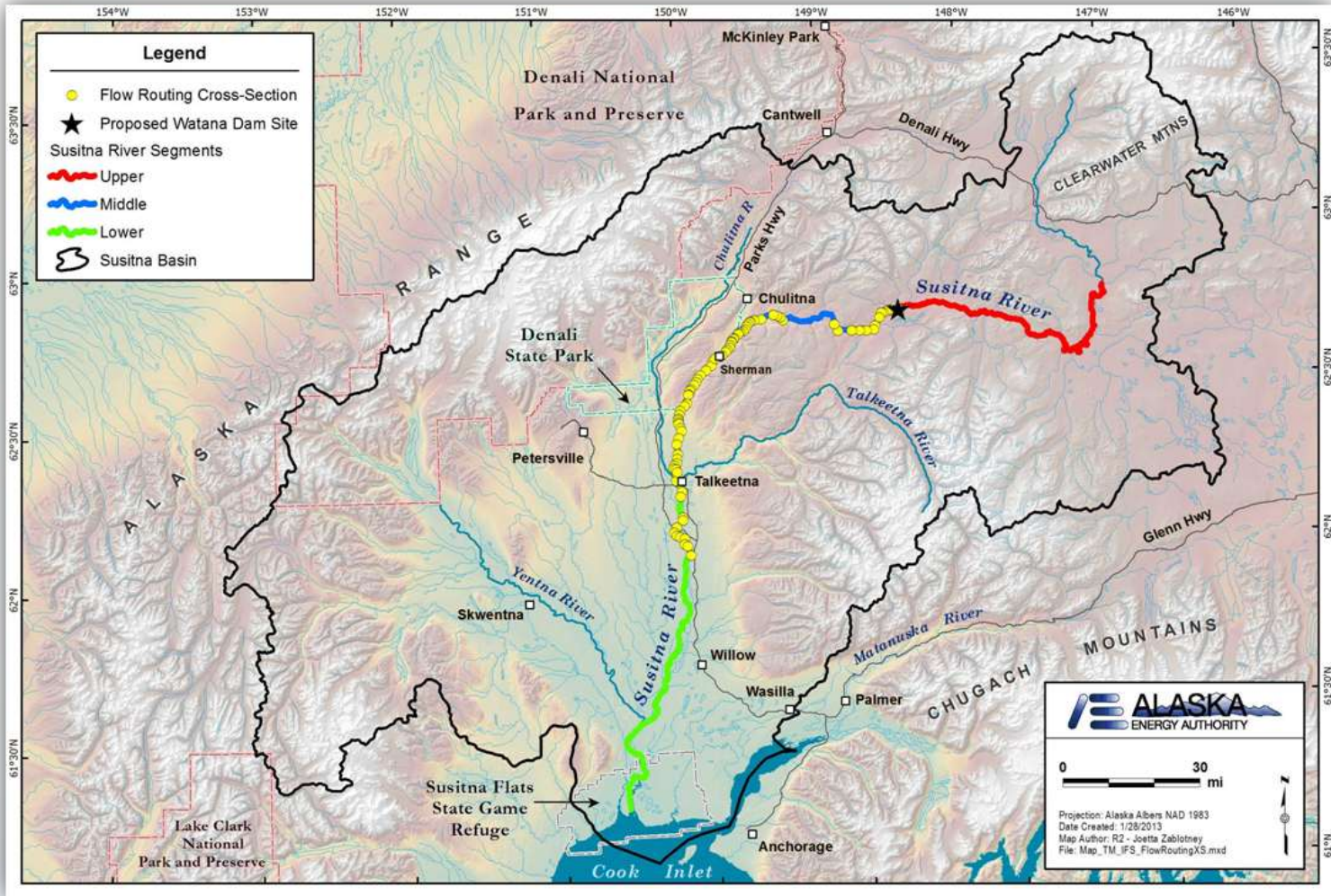


Open Water Flow Routing Model

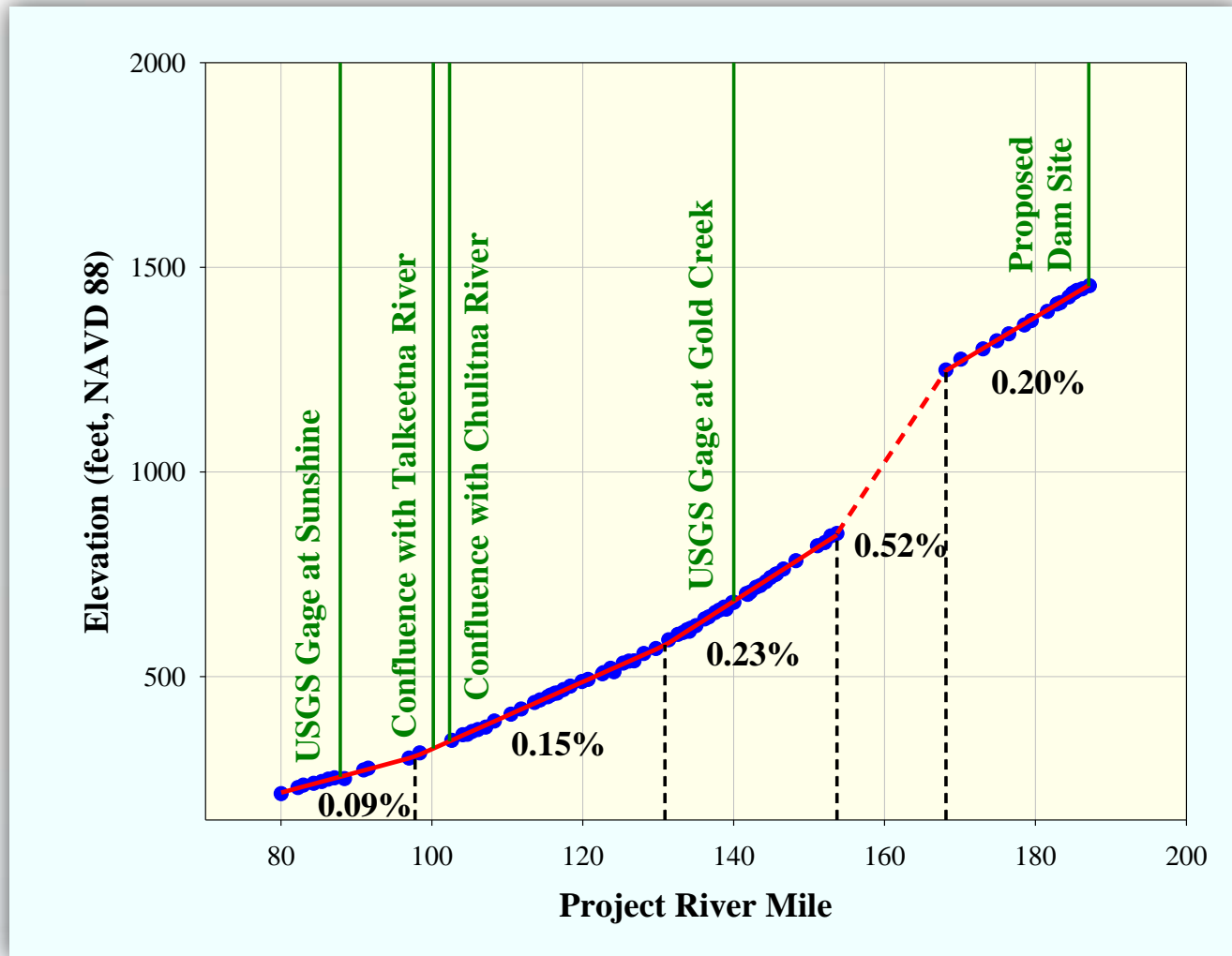
- HEC-RAS model developed from 88 cross-sections surveyed on the Susitna River in 2012 from PRM 187.2 to PRM 80.0.
- Additional river cross-sections were interpolated for reasons of numerical stability under unsteady flows conditions (especially through Devils Canyon).



Cross-Sections Surveyed in 2012



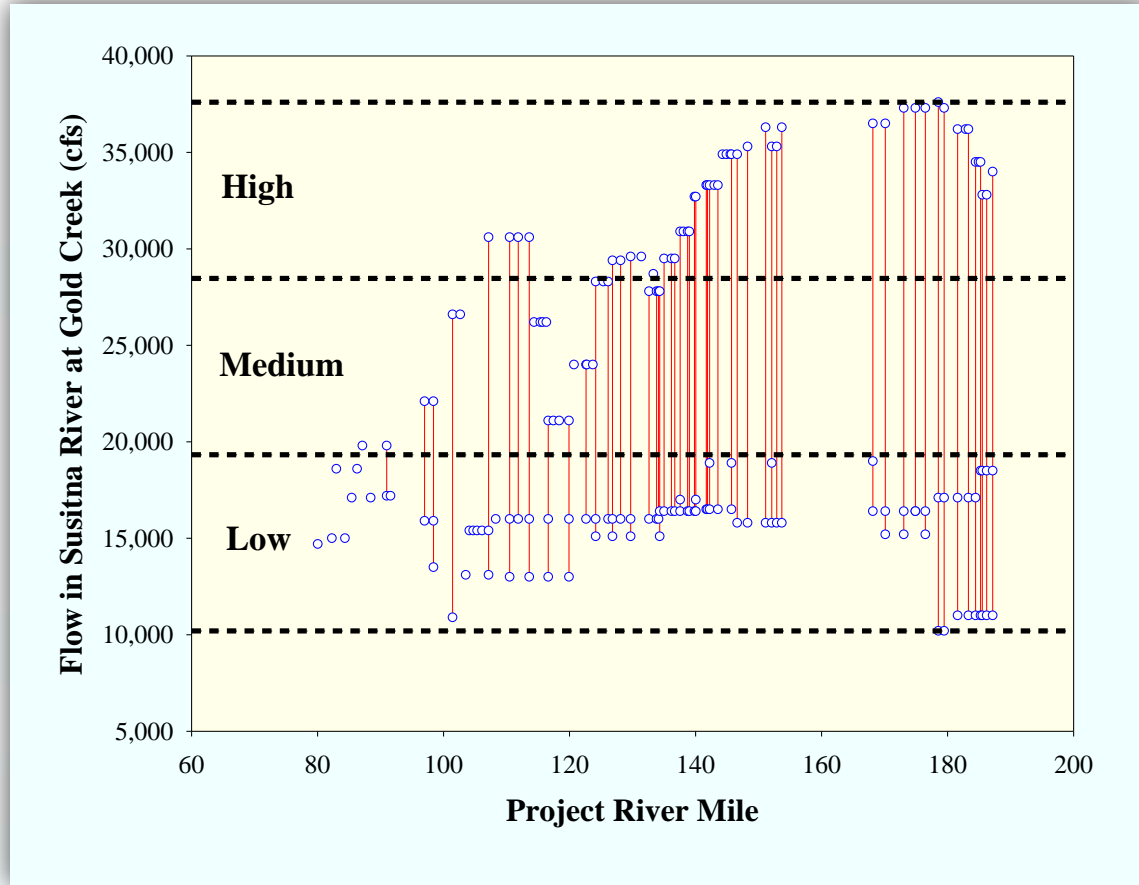
Longitudinal Thalweg Profile



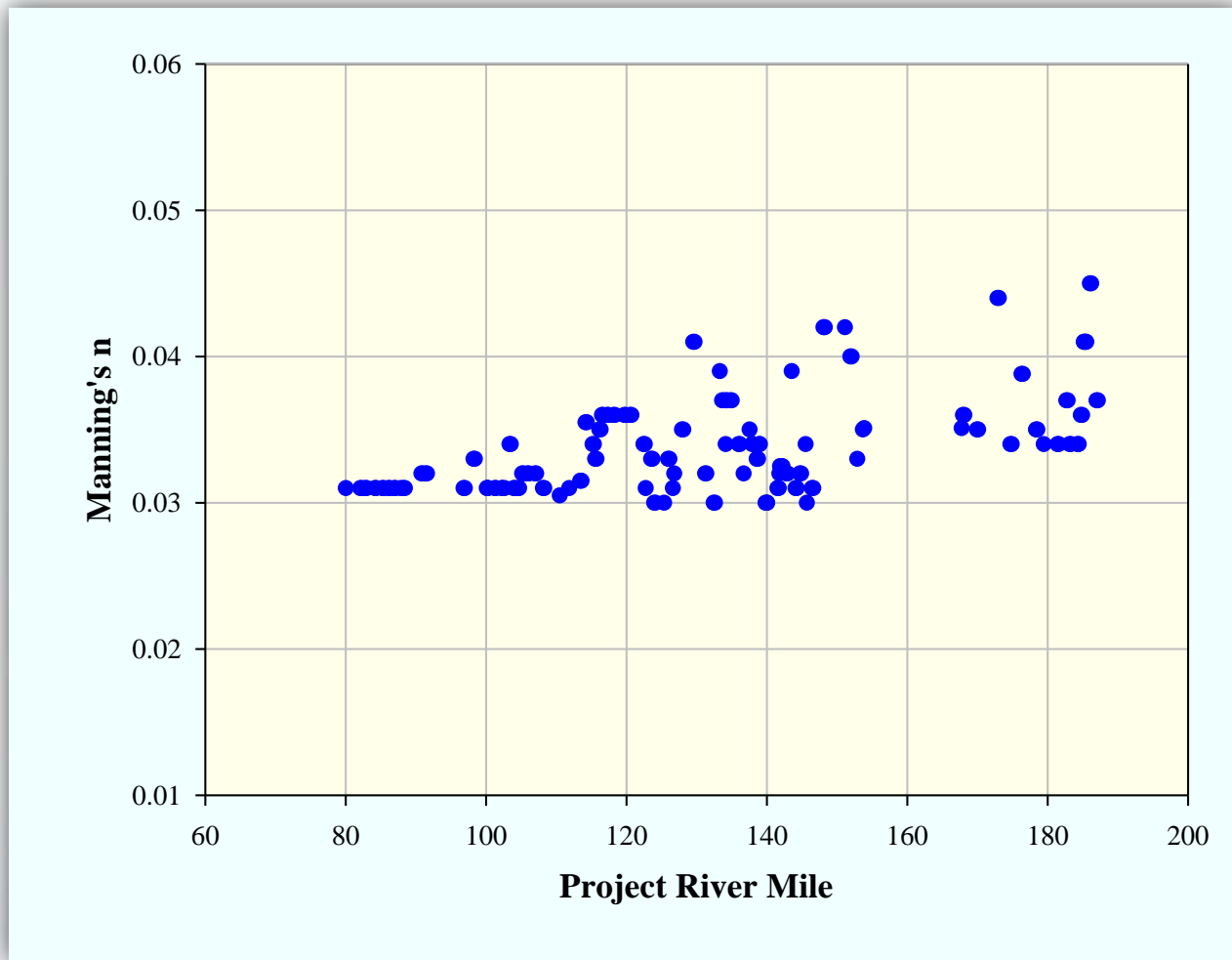
- Steady-state calibration focused on matching 170 pairs of flows and water surface elevations measured in 2012.
- Calibration was performed by selecting reasonable values of Manning's "n" and by adjusting the morphology of interpolated cross-sections.
- Predicted water surface elevations matched observed water surface elevations to within plus or minus 0.2 feet.



Flows Measured in 2012 Classified as Low, Medium, or High Based on Concurrent Flows at Gold Creek



Steady State Calibration Hydraulic Roughness



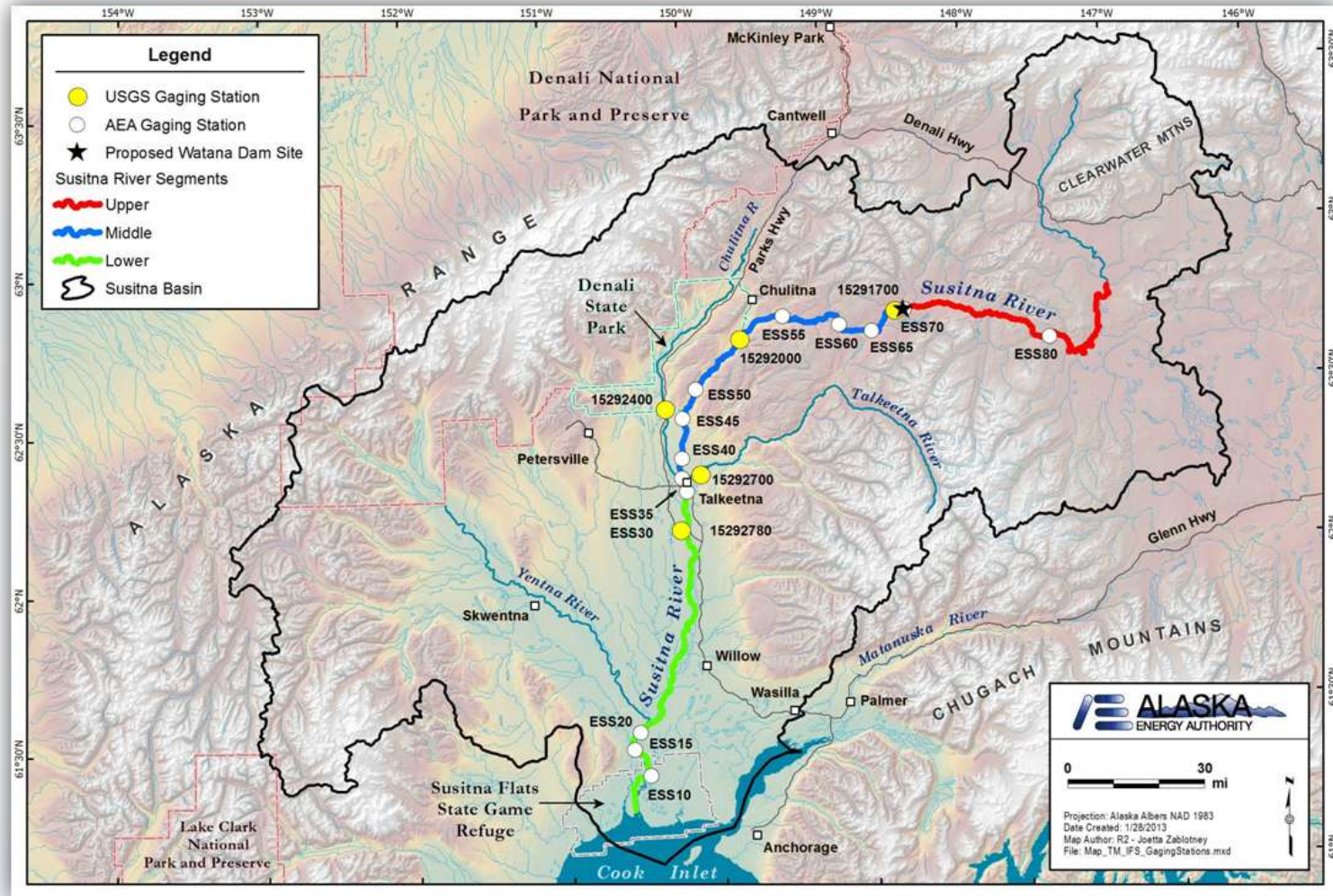
Unsteady-State Calibration

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- Focused on week of August 11 to 17, 2012 when diurnal pulses occurred as a result of glacial melt
- Calibration relied on flows measured by the US Geological Survey
- Calibration was focused on matching the arrival time of pulses at Gold Creek and Sunshine
- To accelerate the arrival of pulses, upstream interpolated cross-sections were made narrower.
- To decelerate the arrival of pulses, upstream interpolated cross-sections were made wider.

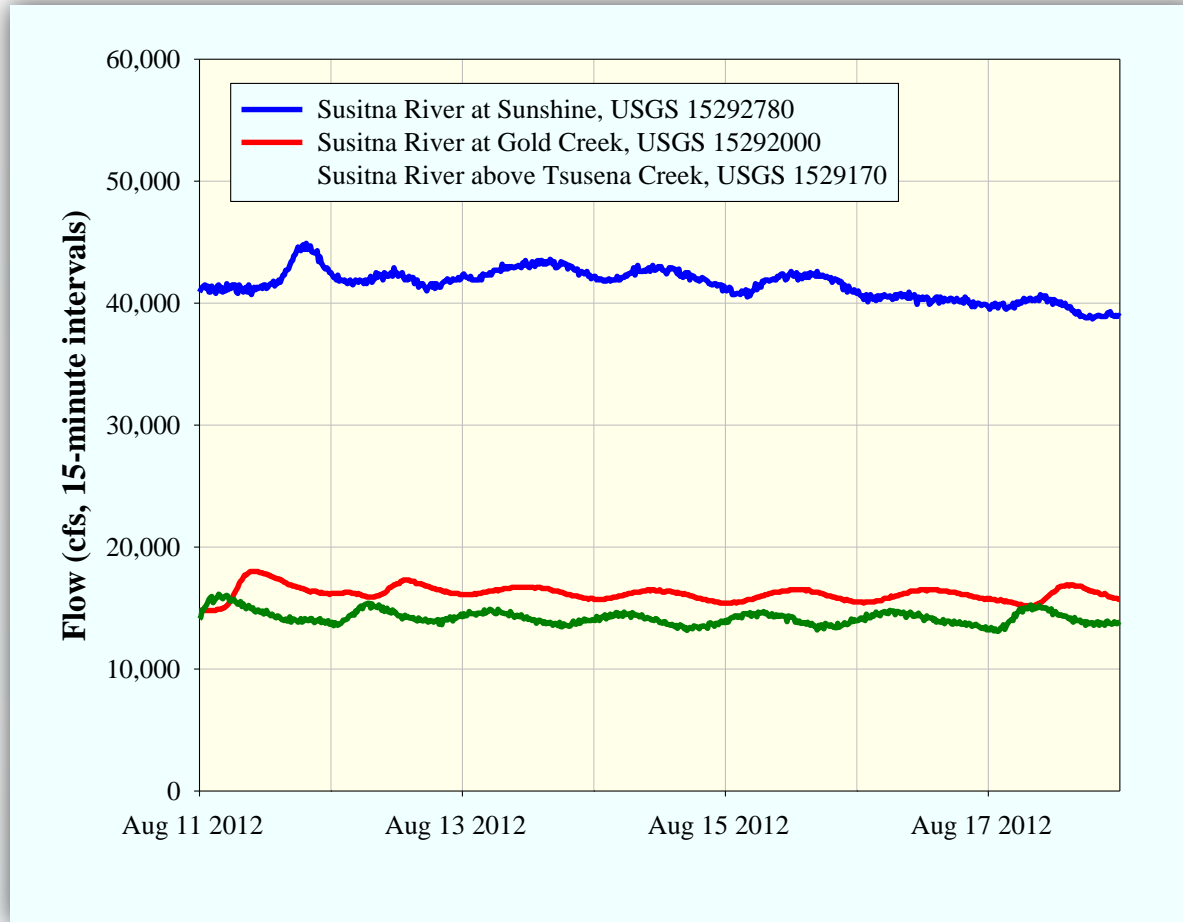


Gaging Station Locations

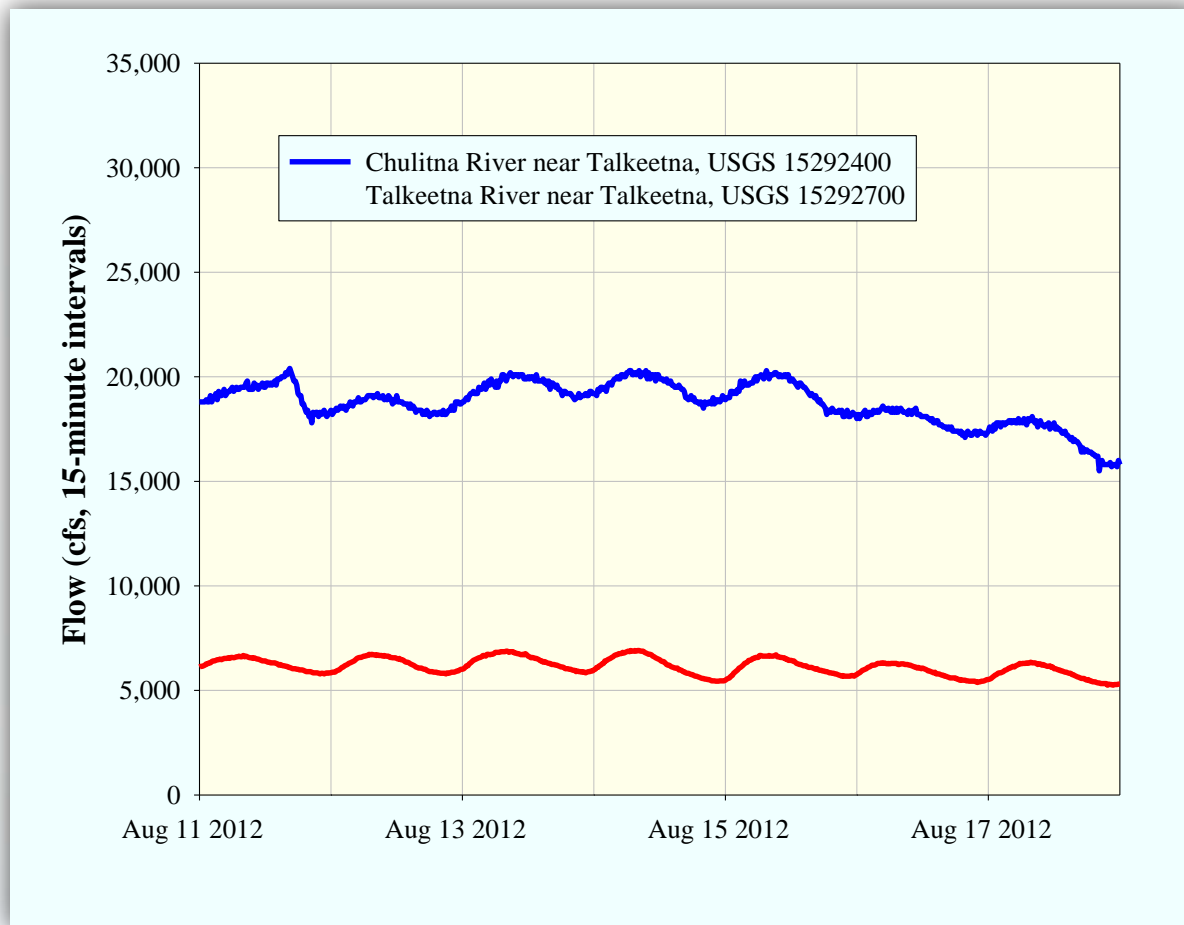


Unsteady-State Calibration 15-Minute Flows in Susitna River August 11 to 17, 2012

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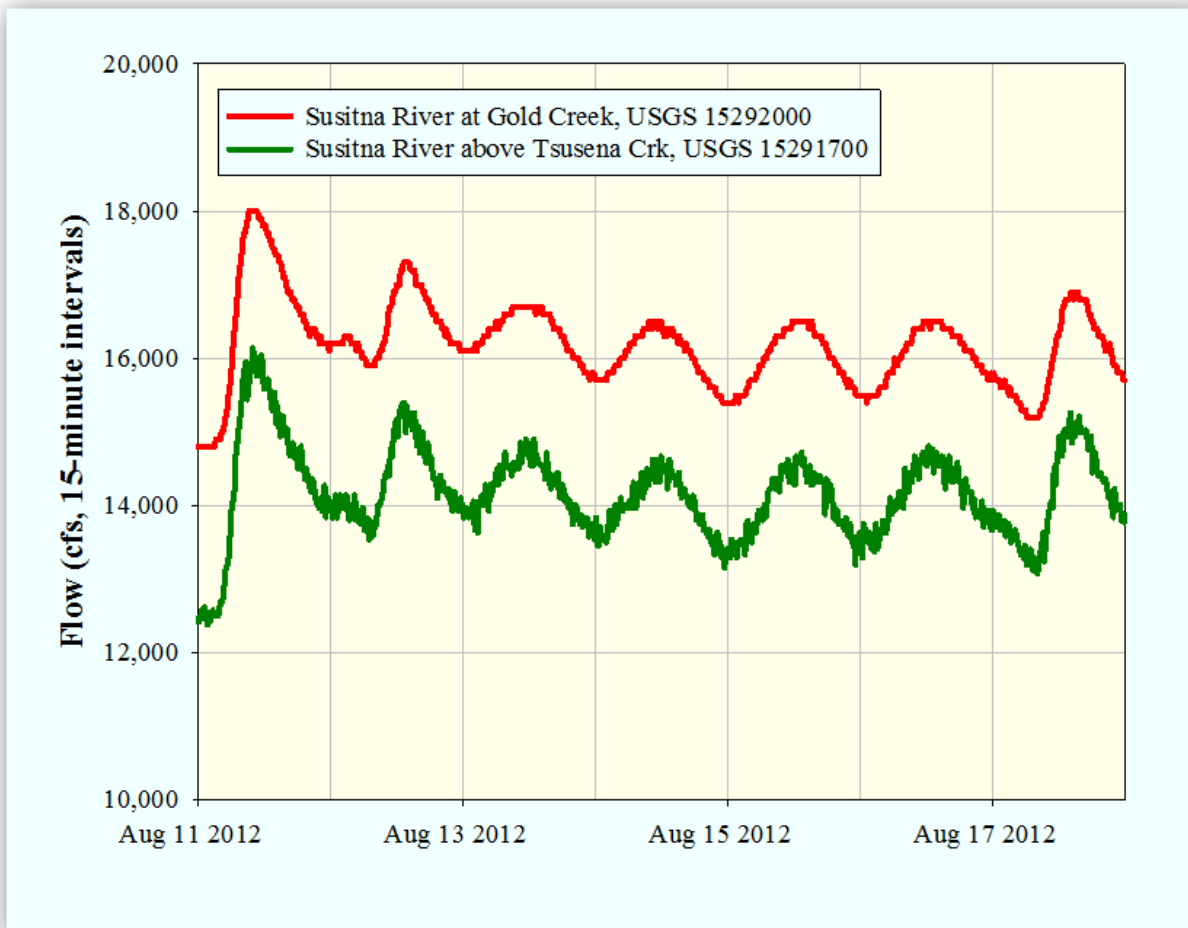


Unsteady-State Calibration 15-Minute Flows in Tributaries of the Susitna River – August 11 to 17, 2012



Unsteady-State Calibration Flows above Tsusena Creek Shifted Forward by 6.4 Hours

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Propagation of Diurnal Pulses Between Tsusena Creek and Gold Creek

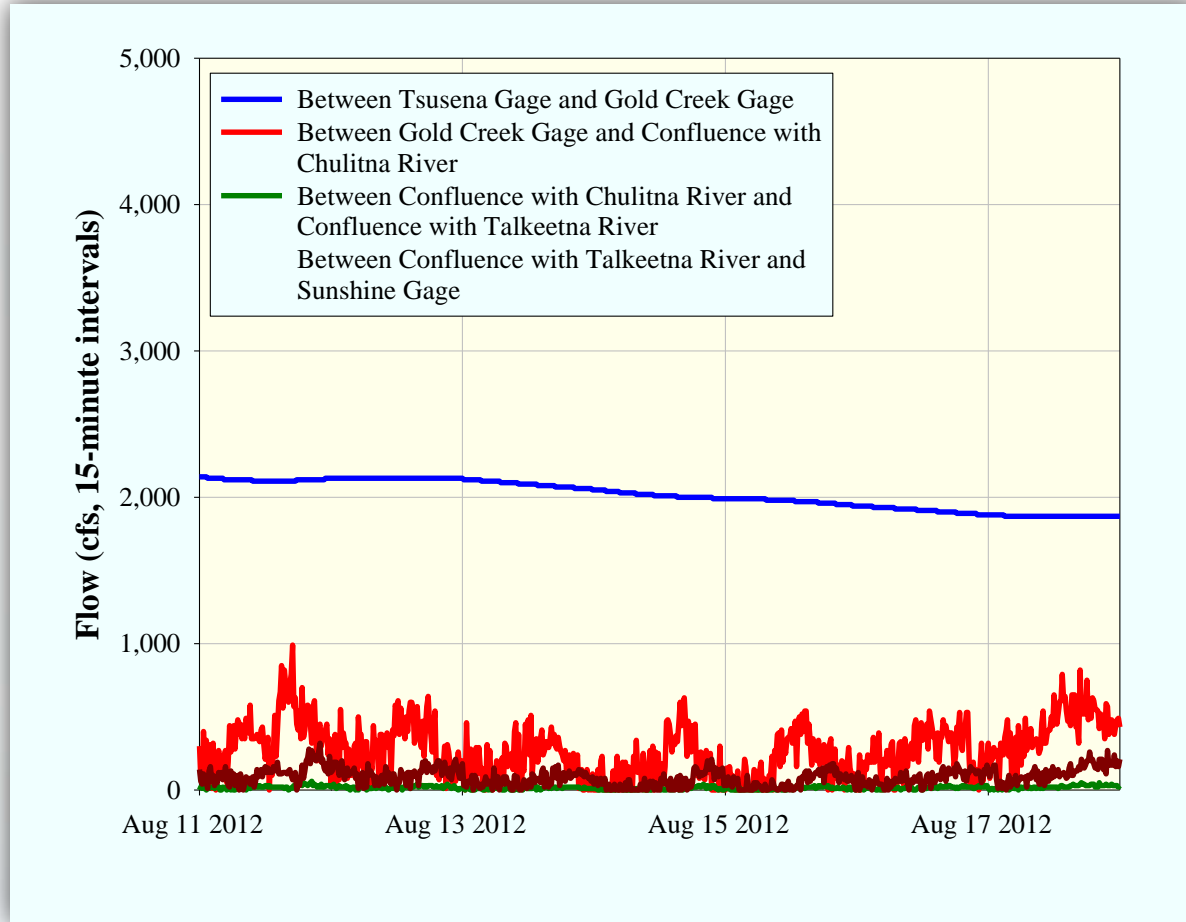
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- Pulses traveled 47.2 miles in 6.4 hours
- Speed of propagation, or celerity, was 7.4 miles per hour or 10.8 feet per second
- Celerity should be 1.25 to 1.50 times the channel flow velocity (Linsley 1975)
- Equivalent to average flow velocity of 7 to 9 feet per second, consistent with what was measured in 2012



Unsteady-State Calibration

15-Minute Ungaged Accretion Flows to the Susitna River – August 11 to 17, 2012

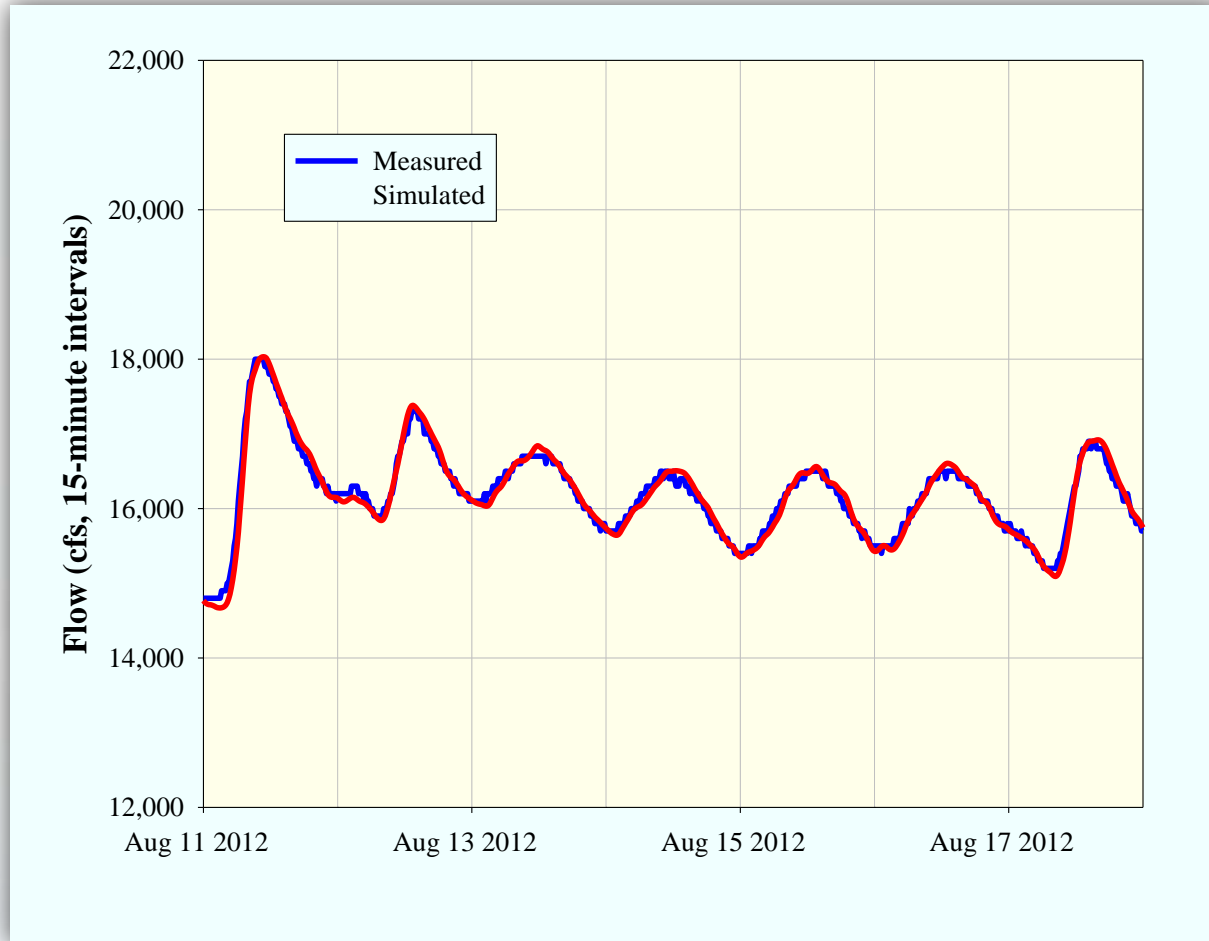


Selection of Computational Time Step

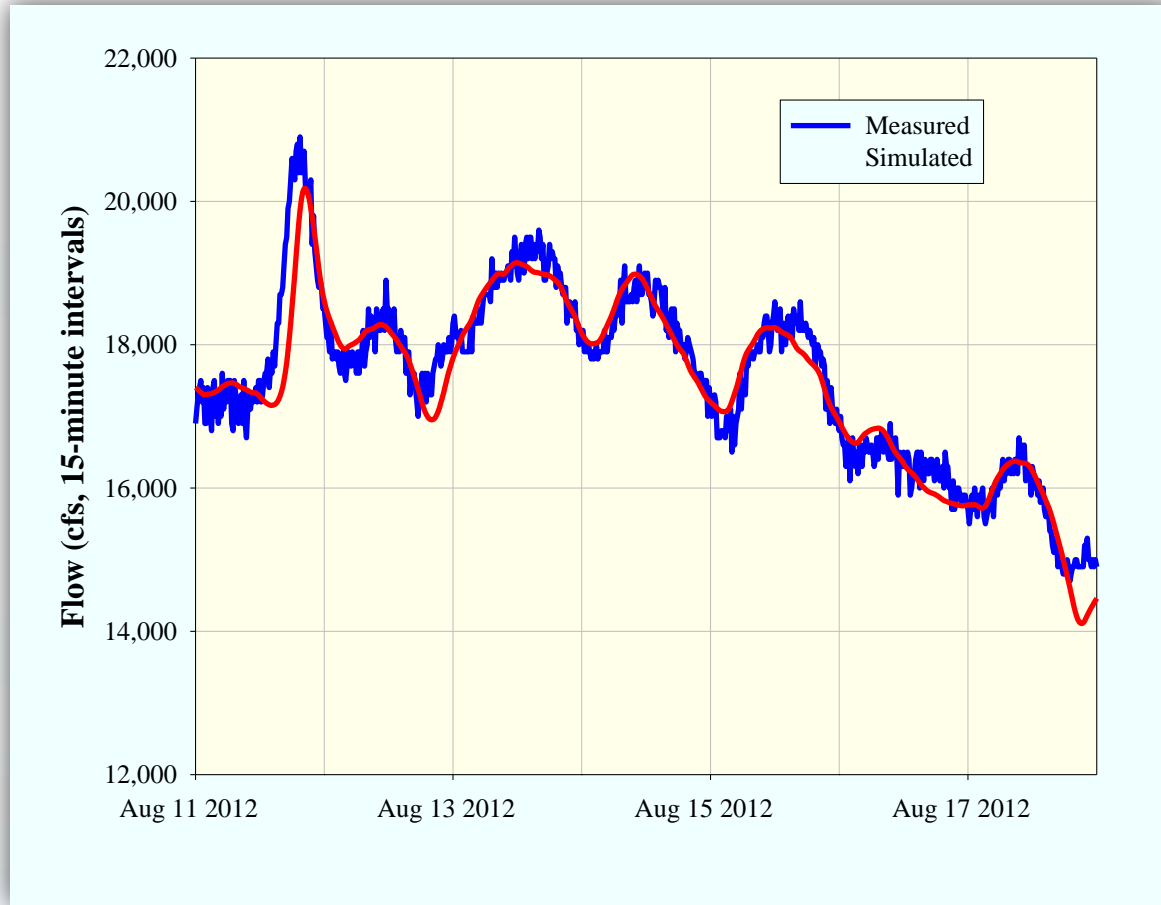
- For numerical stability and accurate results the computational time step should be less than the distance between cross-sections divided by the celerity
- Distance between cross-sections = 1,000 feet
- Celerity = 10.8 feet per second
- Time step should be less than 93 seconds
- Time step of one minute (60 seconds) was selected



Unsteady Flow Calibration Results Susitna River at Gold Creek August 11 to 17, 2012



Unsteady Flow Calibration Results Susitna River at Sunshine August 11 to 17, 2012



- The calibrated HEC-RAS model was then run for the period from June 4 to October 14, 2012.
- Good agreement between measured and simulated flow hydrographs was found for the Susitna River at Gold Creek Gage and Sunshine Gage over a wide range of flows (up to 200,000 cfs at Sunshine).

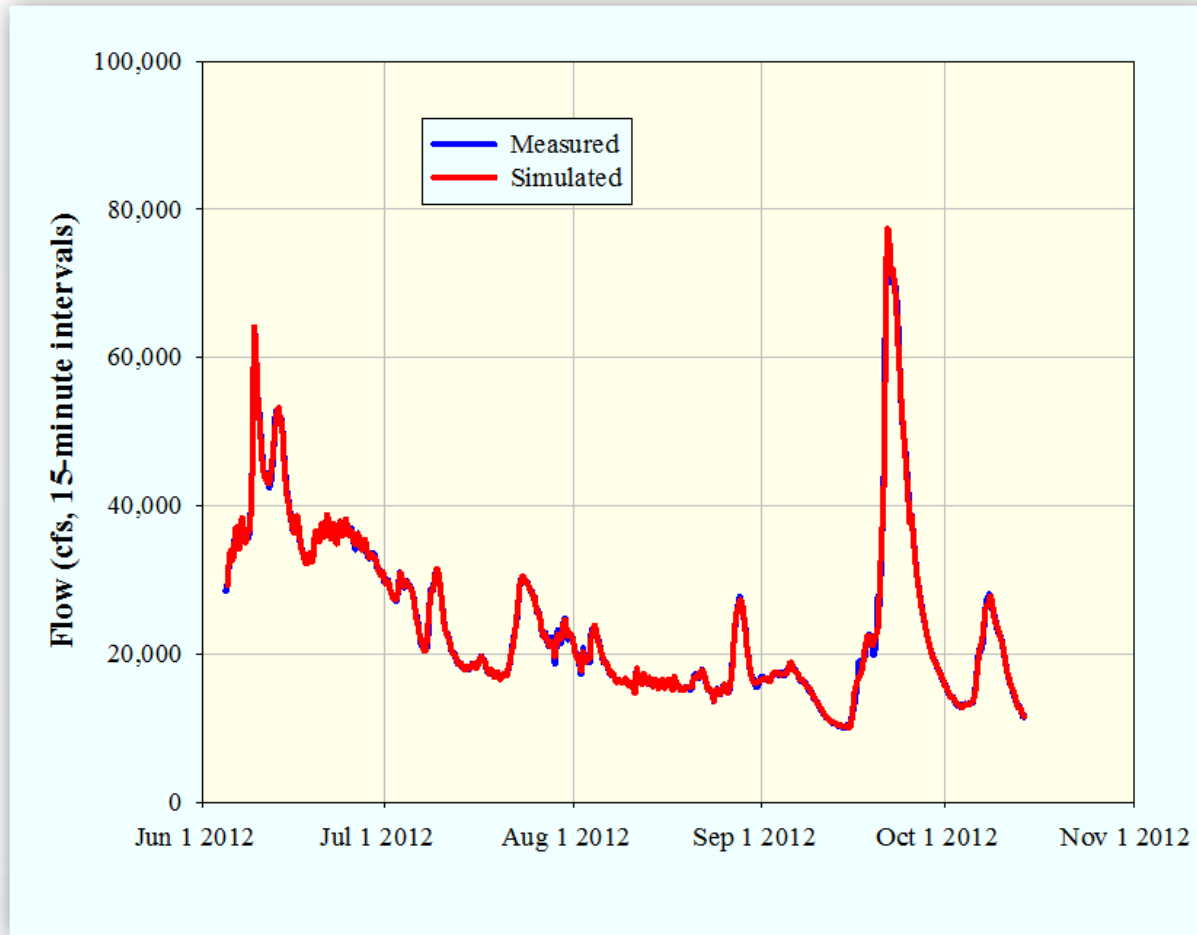


Model Validation

Susitna River at Gold Creek

June 4 to October 14, 2012

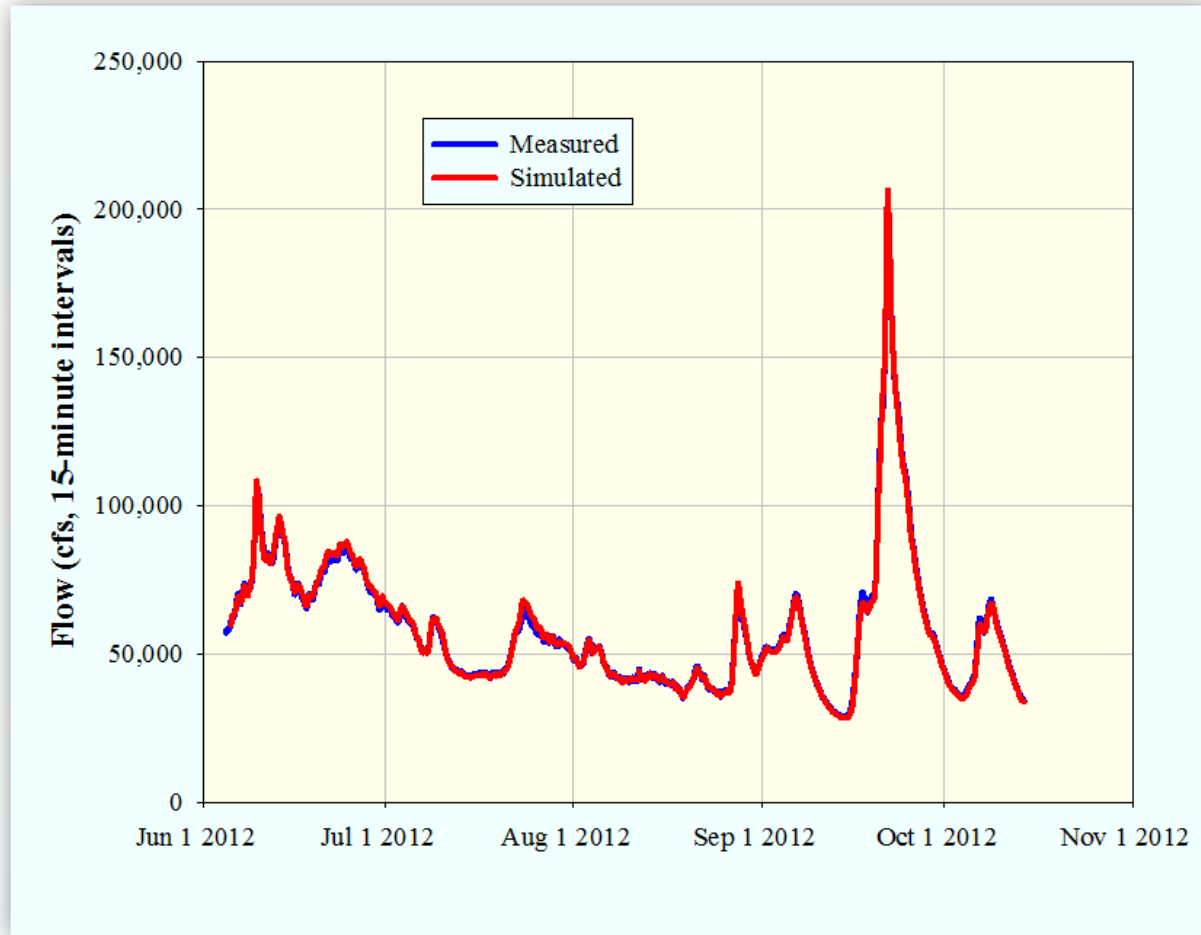
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Model Validation

Susitna River at Sunshine

June 4 to October 14, 2012

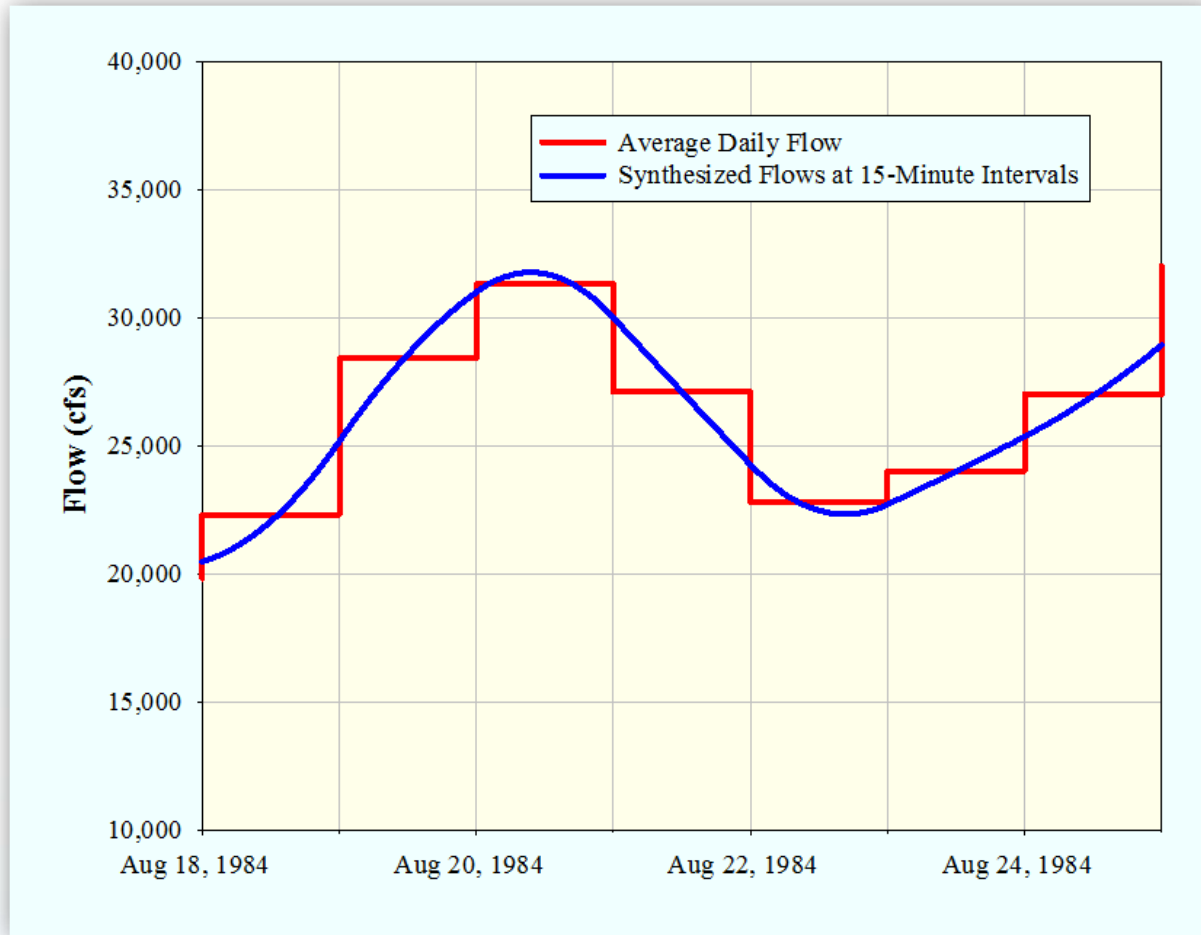


Effects of Proposed Project Operations

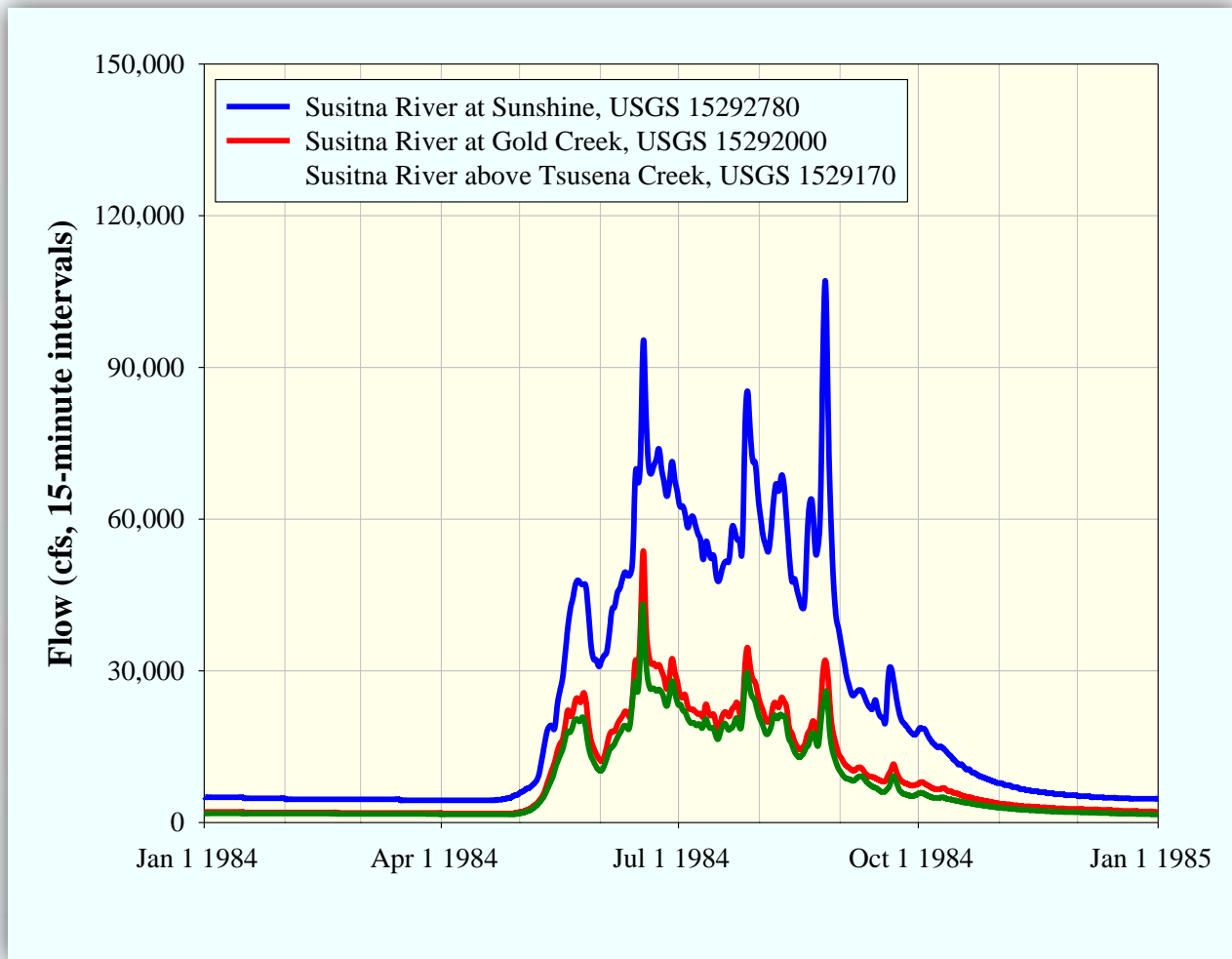
- The calibrated HEC-RAS model was then used to analyze Pre-Project and Maximum Load Following OS-1 conditions for calendar year 1984.
- Accretion flows downstream from the proposed dam site were derived from daily flows reported by the USGS.
- The daily flow hydrographs were converted to 15-minute flow hydrographs.
- The 15-minute flow hydrographs did not account for diurnal glacial melt fluctuations.
- During the winter, actual results may differ from those reported herein as a result of ice formation on the river



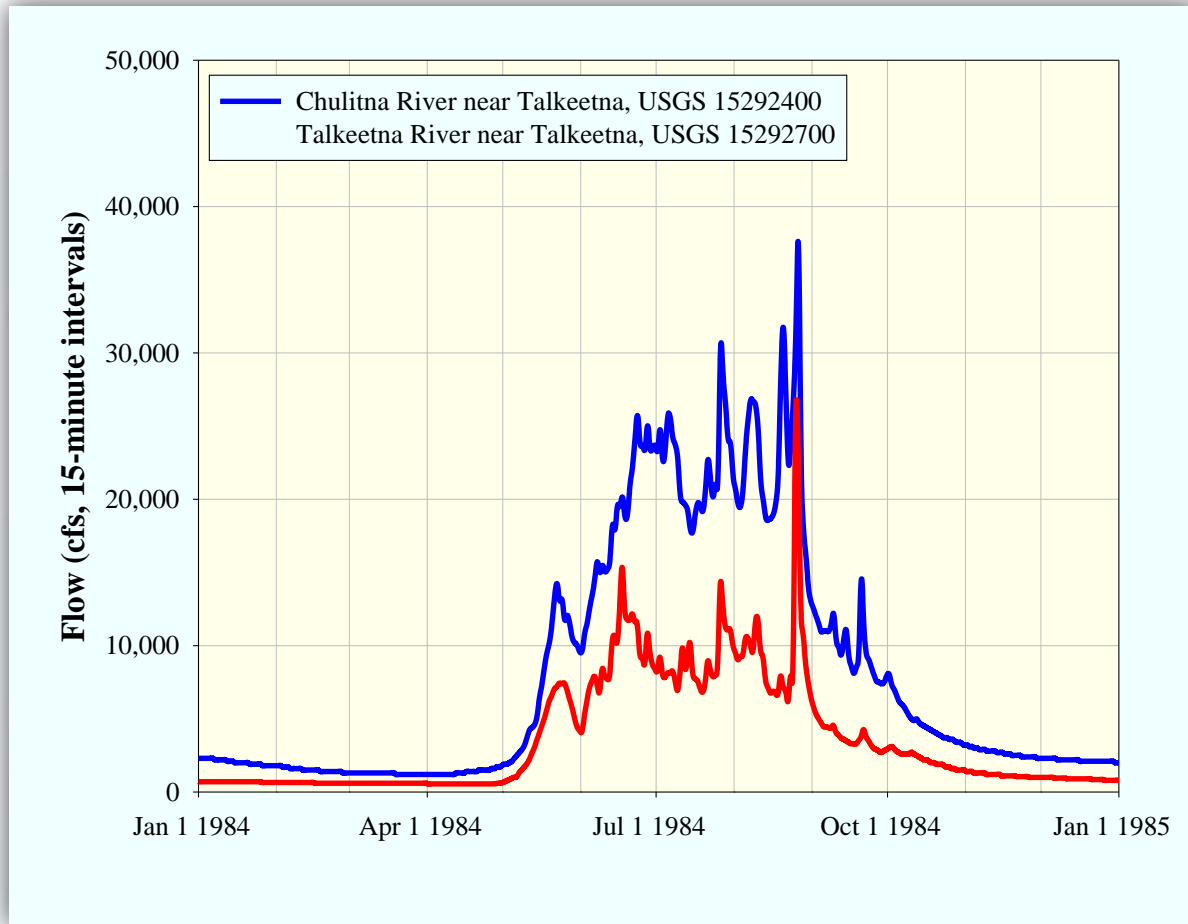
Derivation of 15-Minute Hydrograph from Daily Flows Reported for Chulitna River



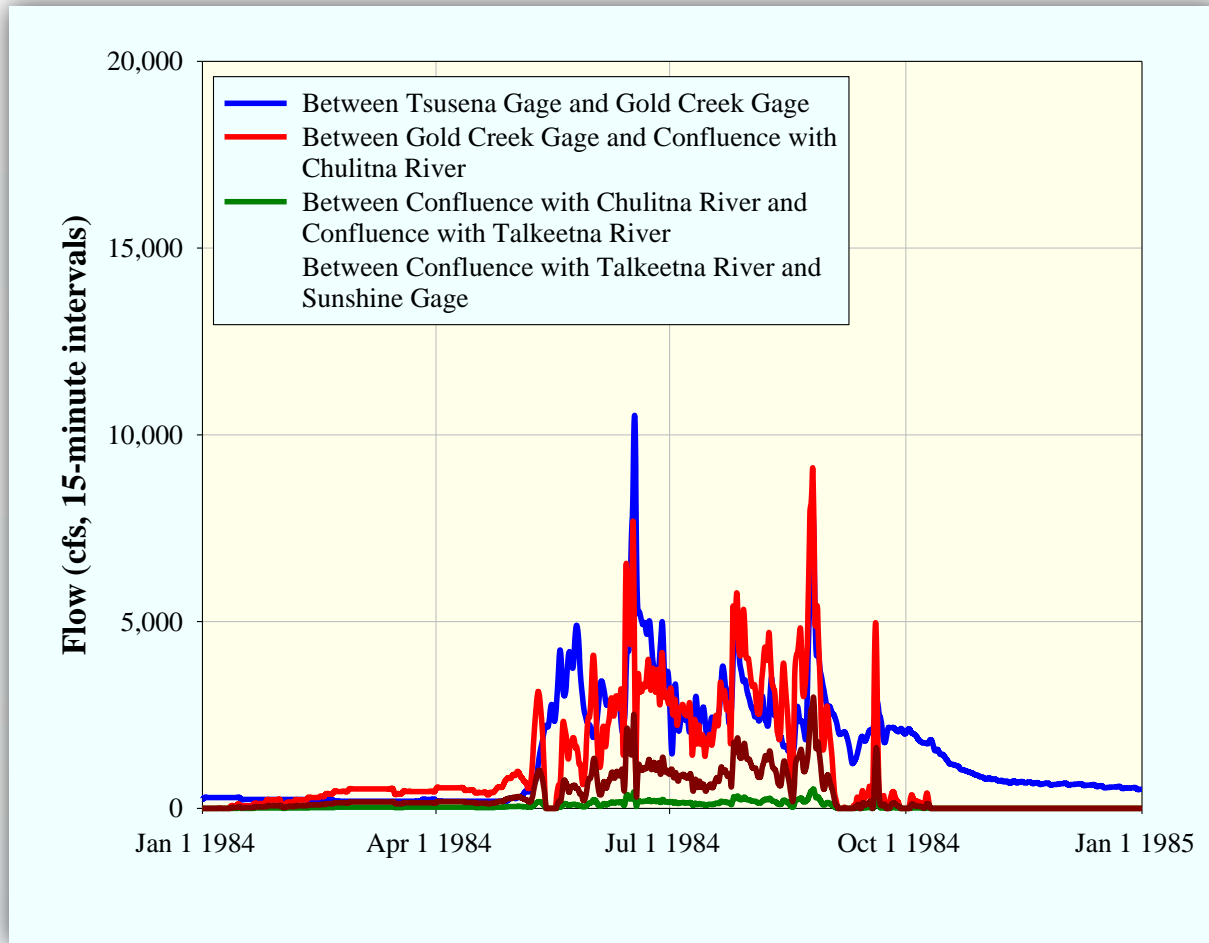
15-Minute Flows in Susitna River - 1984



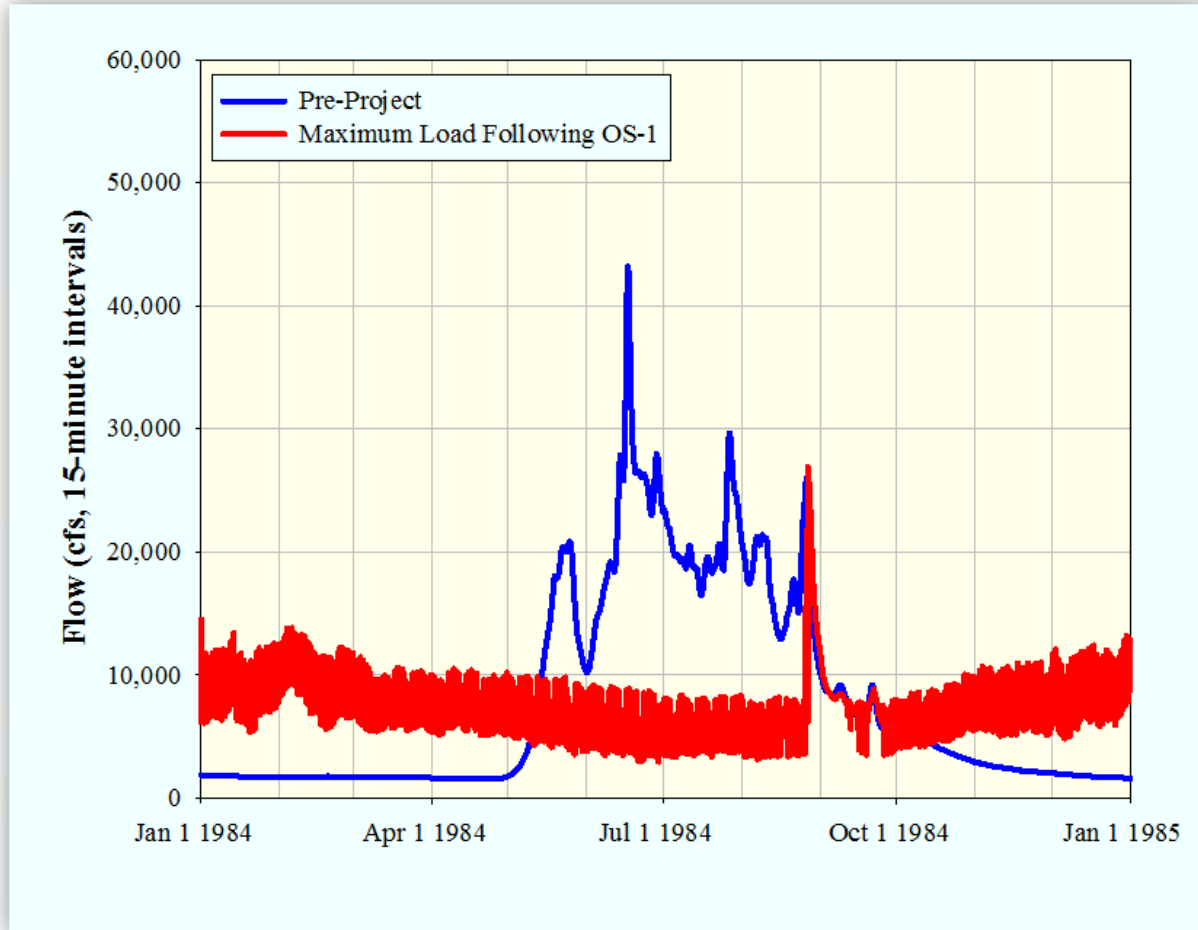
15-Minute Flows in Tributaries of the Susitna River - 1984



15-Minute Ungaged Accretion Flows to the Susitna River - 1984

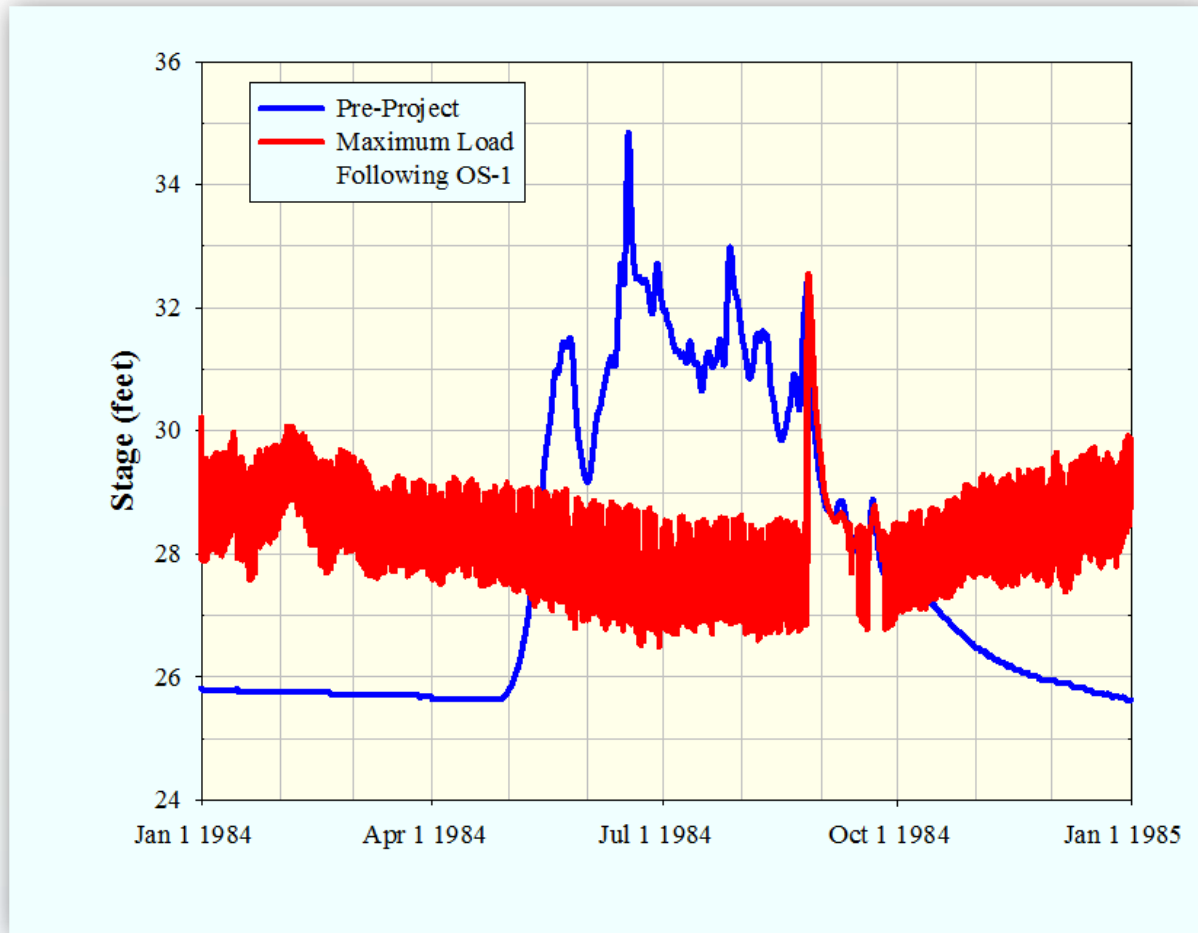


Effects of Proposed Project 15-Minute Flows in Susitna River Below Proposed Dam Site - 1984

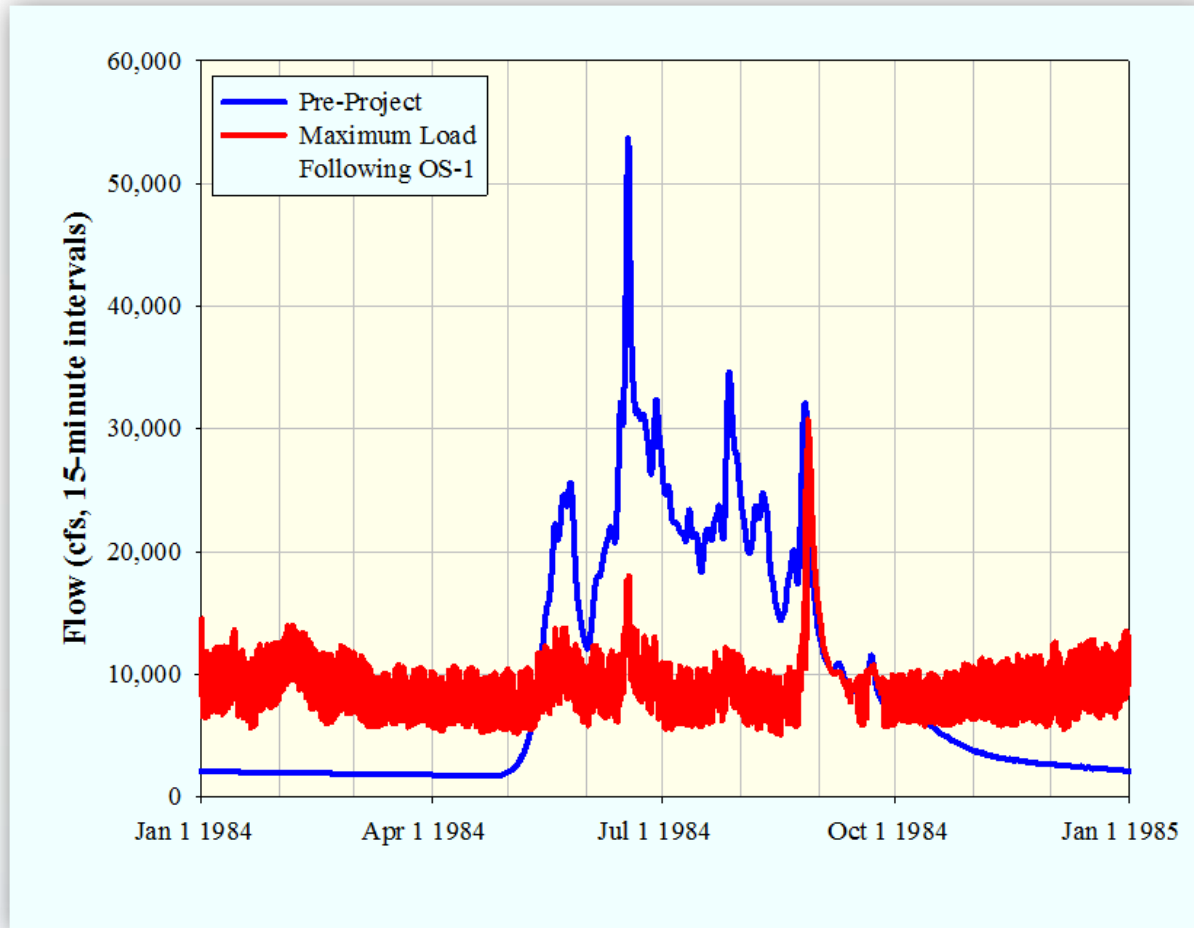


Effects of Proposed Project 15-Minute Stages in Susitna River Below Proposed Dam Site - 1984

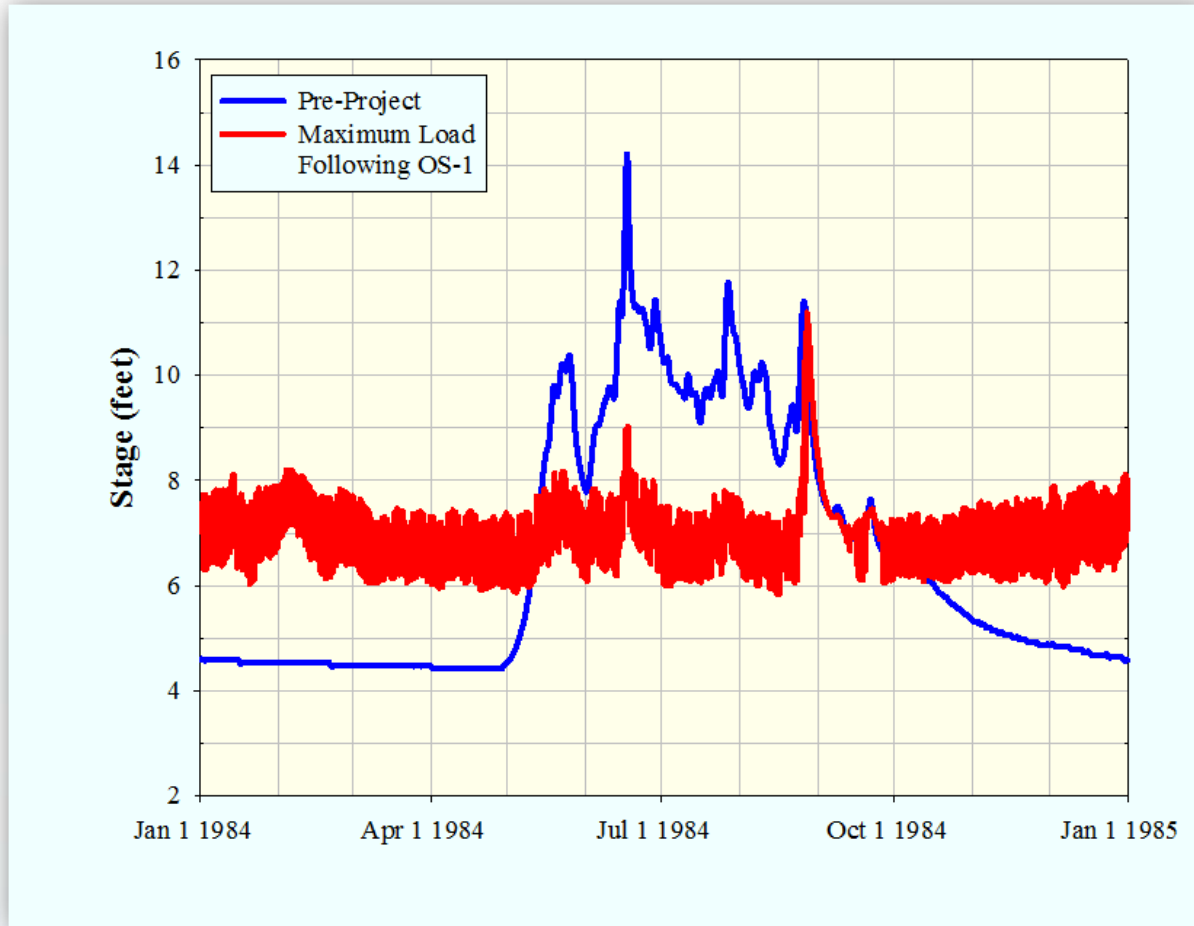
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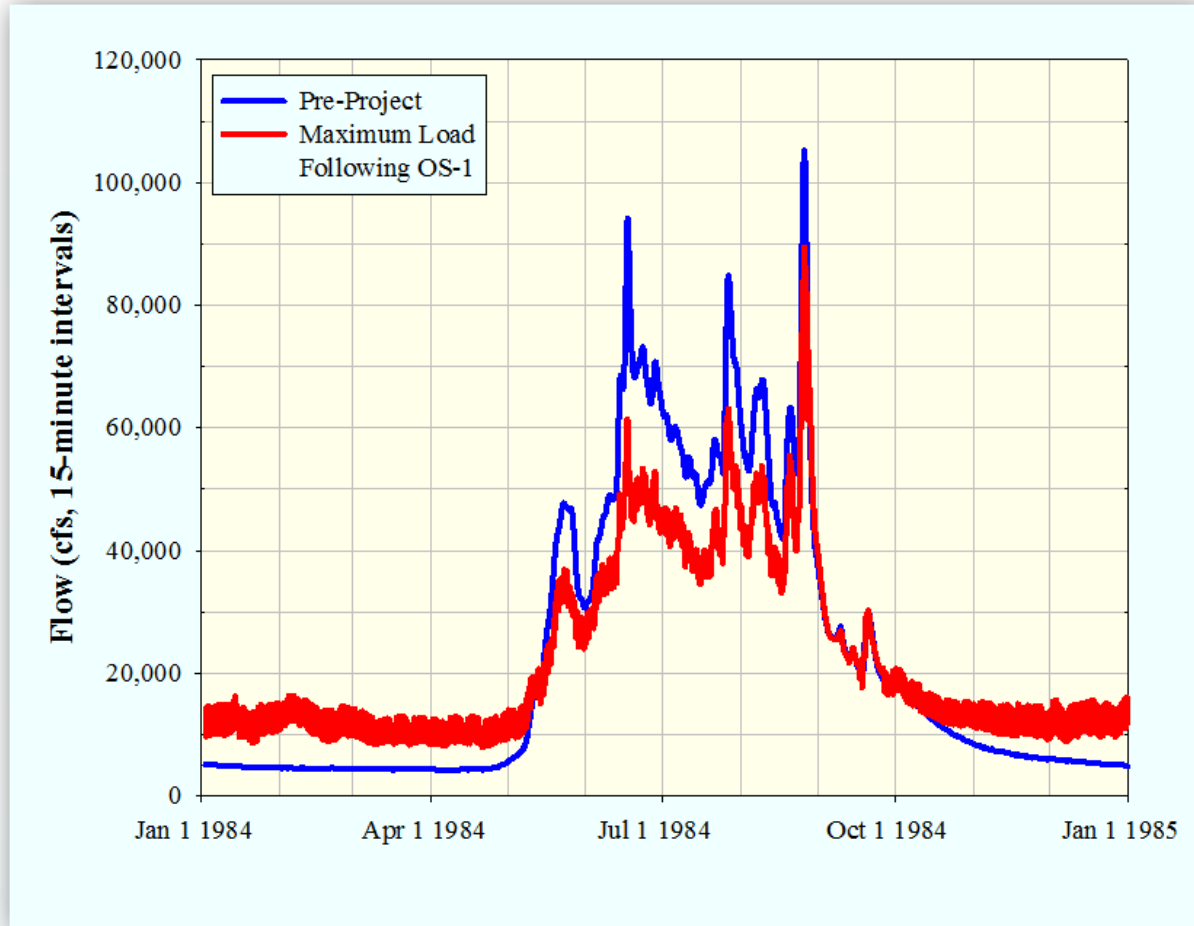
Effects of Proposed Project (HEC-RAS results) 15-Minute Flows in Susitna River at Gold Creek Gage - 1984



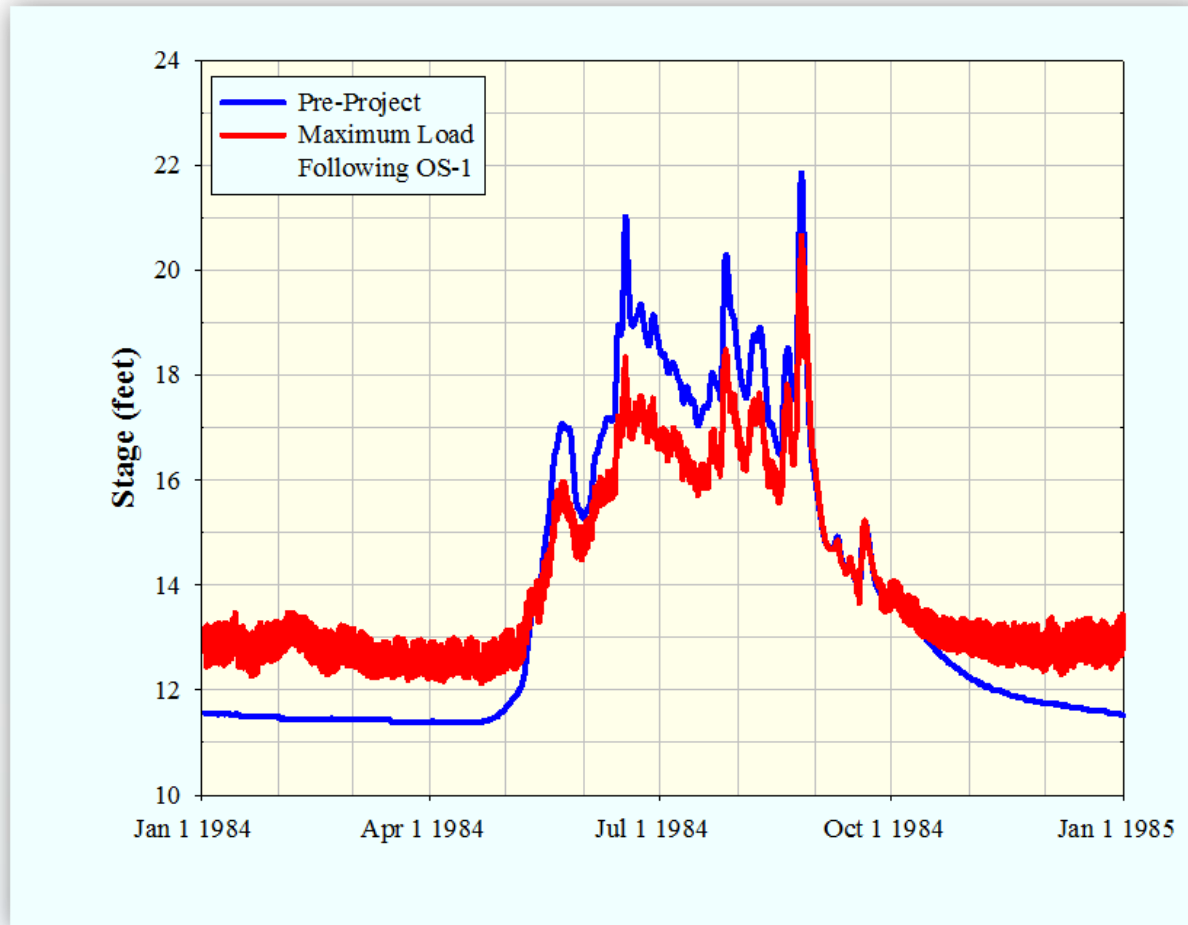
Effects of Proposed Project (HEC-RAS results) 15-Minute Stages in Susitna River at Gold Creek Gage - 1984



Effects of Proposed Project (HEC-RAS results) 15-Minute Flows in Susitna River at Sunshine Gage - 1984



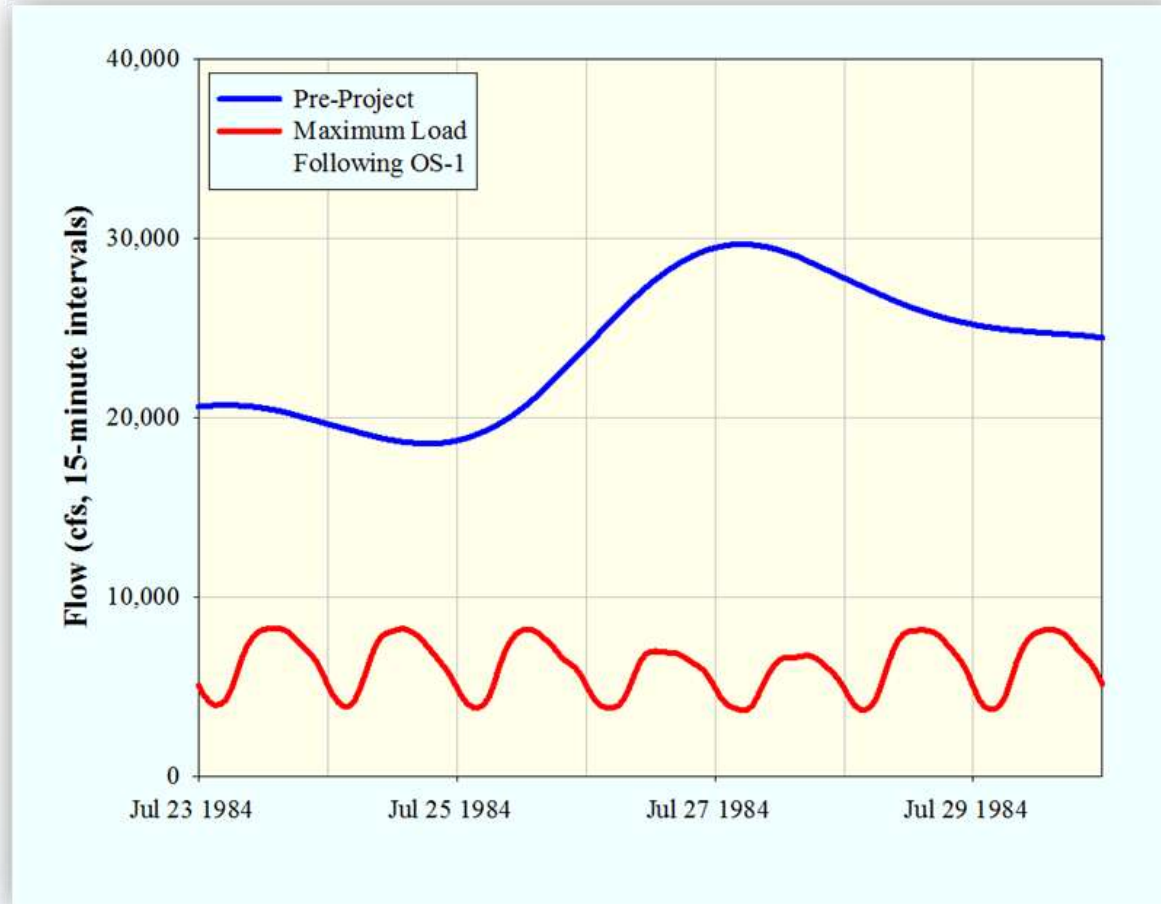
Effects of Proposed Project (HEC-RAS results) 15-Minute Stages in Susitna River at Sunshine Gage - 1984



Effects of Proposed Project

15-Minute Flows in Susitna River Below Proposed Dam Site – July, 1984

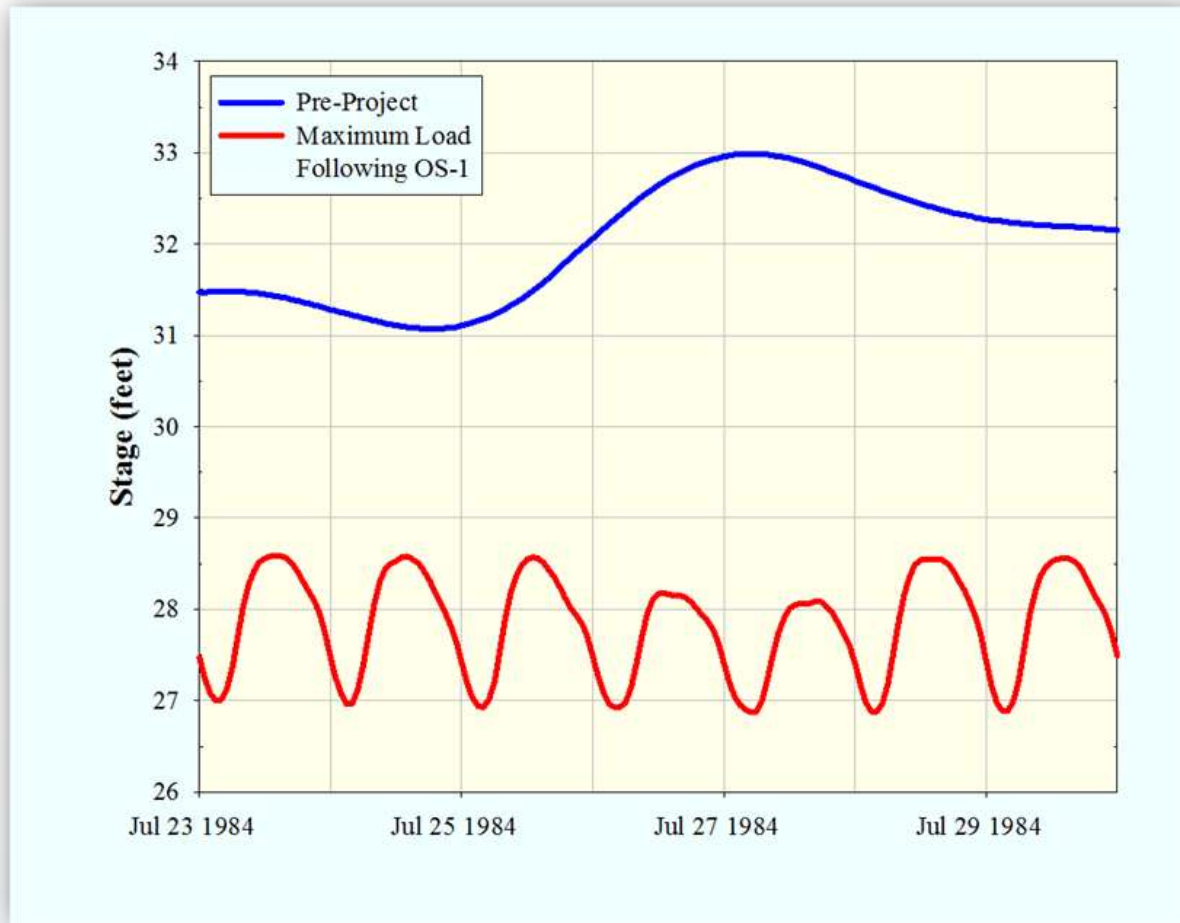
(Pre-Project conditions do not account for diurnal glacial melt fluctuations)



Effects of Proposed Project 15-Minute Stages in Susitna River Below Proposed Dam Site – July, 1984

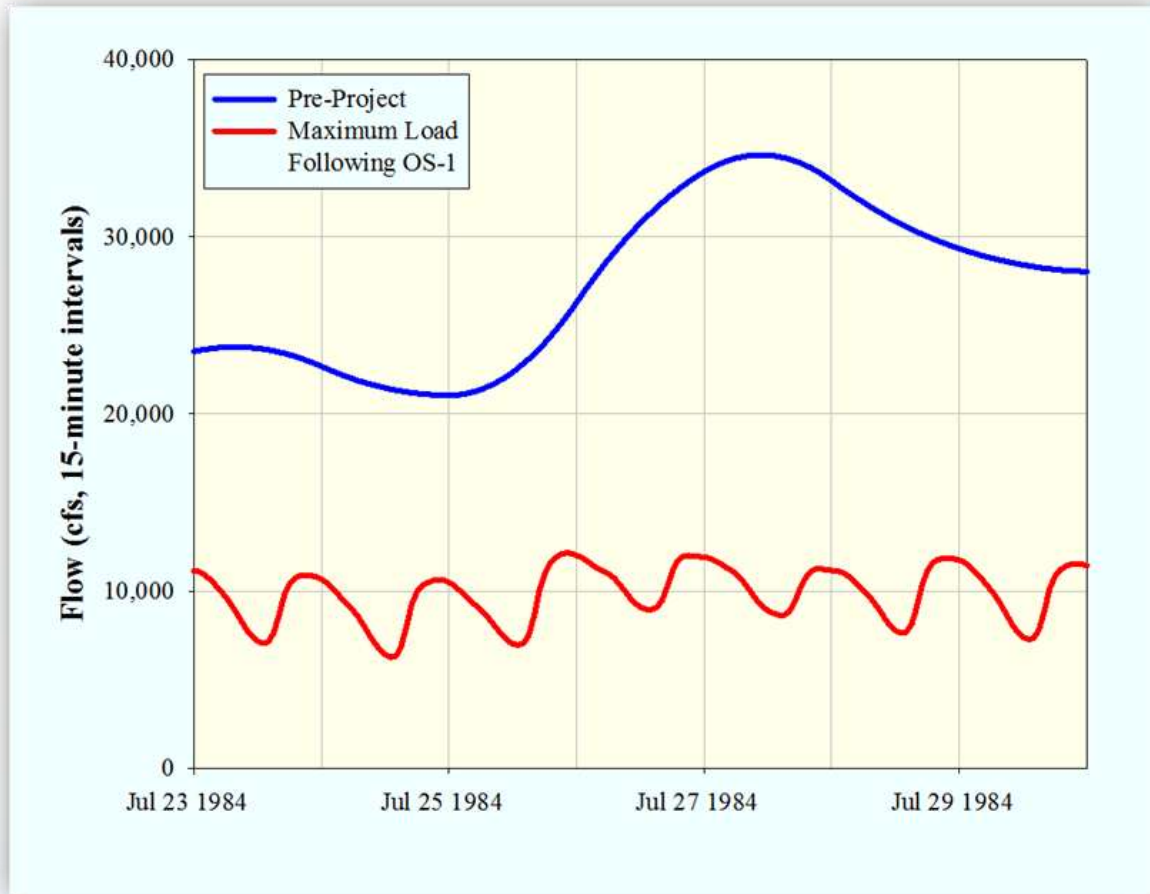
39

(Pre-Project conditions do not account for diurnal glacial melt fluctuations)



Effects of Proposed Project (HEC-RAS results) 15-Minute Flows in Susitna River at Gold Creek Gage – July, 1984

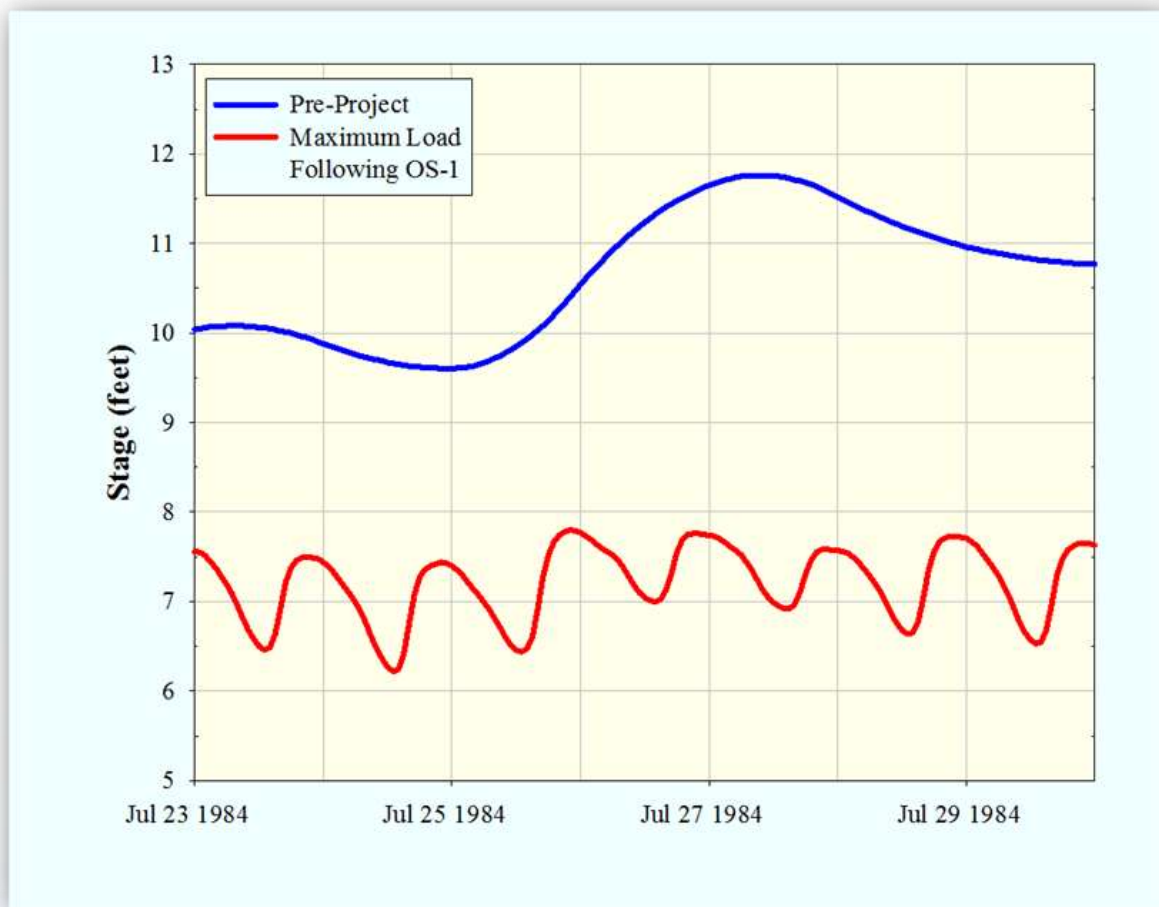
(Pre-Project conditions do not account for diurnal glacial melt fluctuations)



Effects of Proposed Project (HEC-RAS results) 15-Minute Stages in Susitna River at Gold Creek Gage – July, 1984

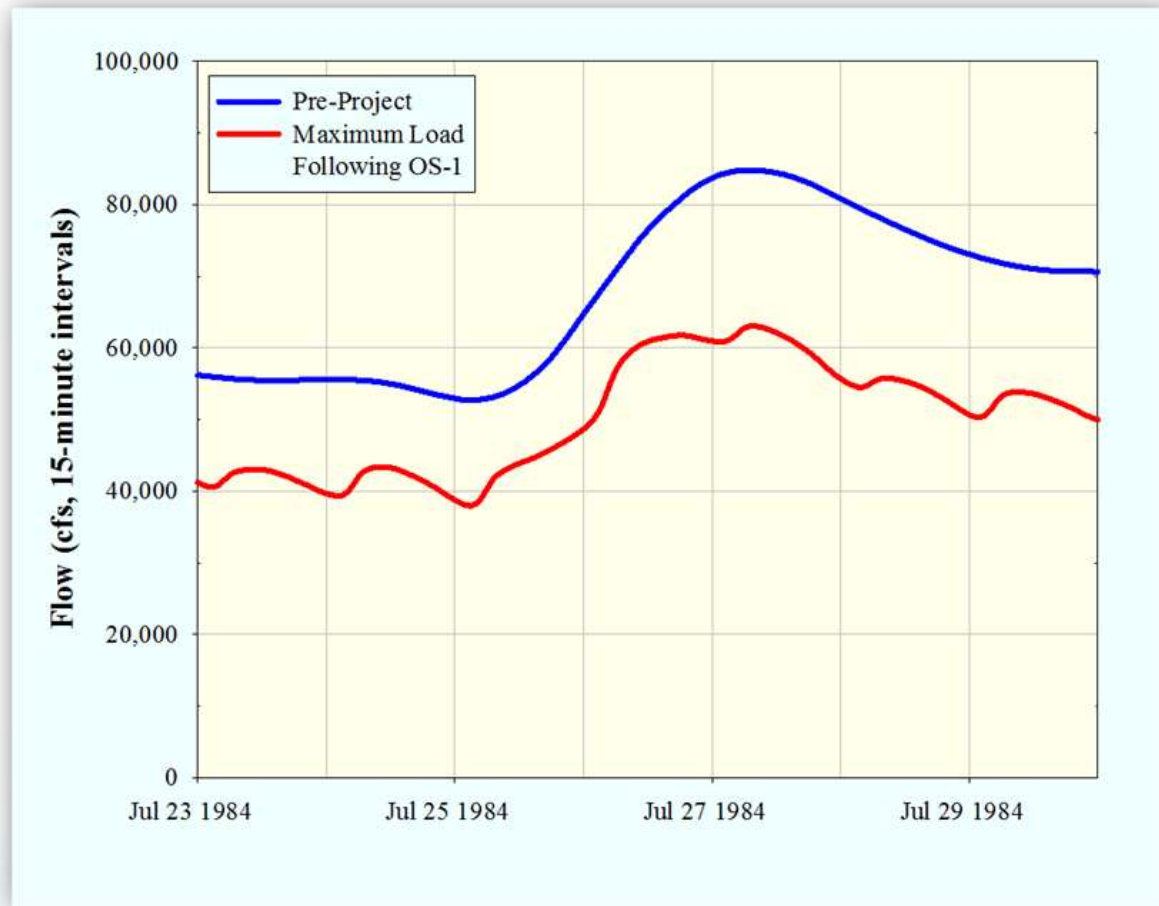
41

(Pre-Project conditions do not account for diurnal glacial melt fluctuations)



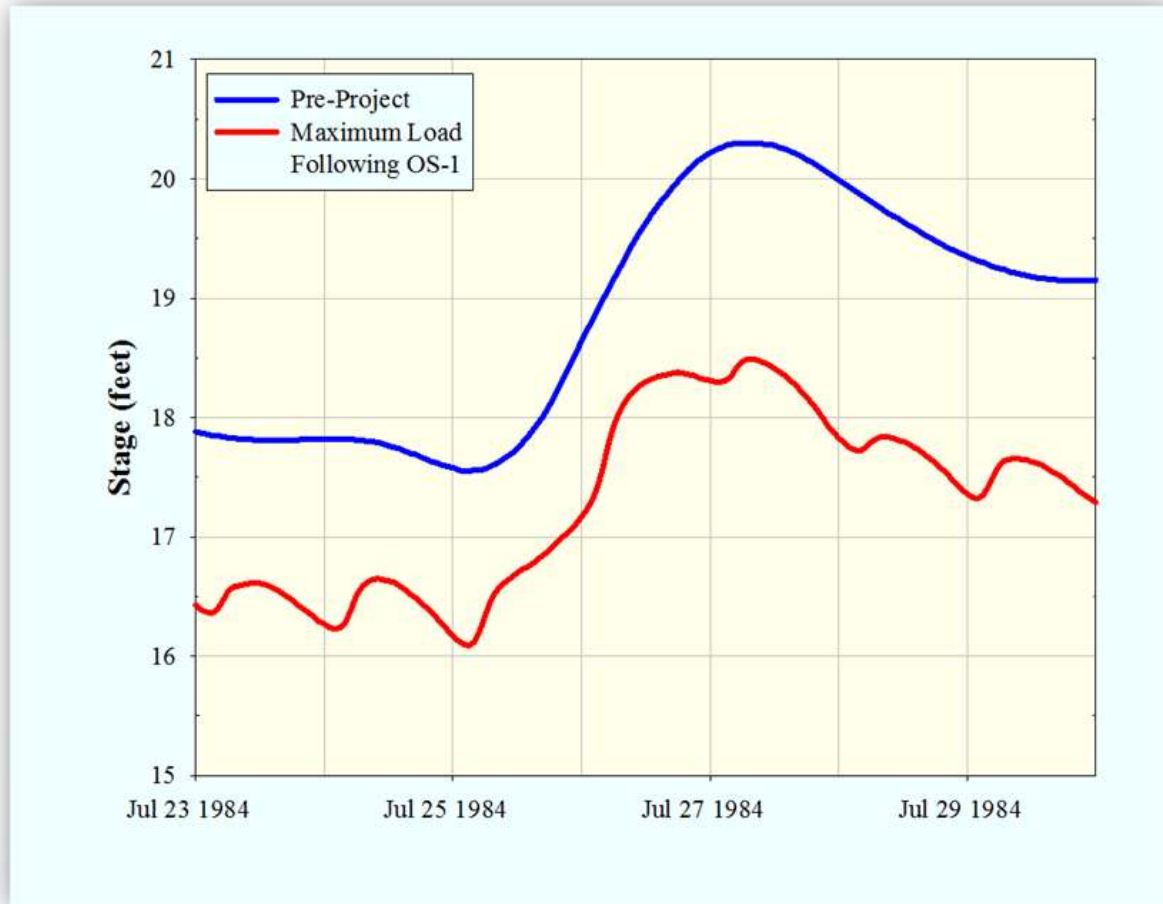
Effects of Proposed Project (HEC-RAS results) 15-Minute Flows in Susitna River at Sunshine Gage – July, 1984

(Pre-Project conditions do not account for diurnal glacial melt fluctuations)

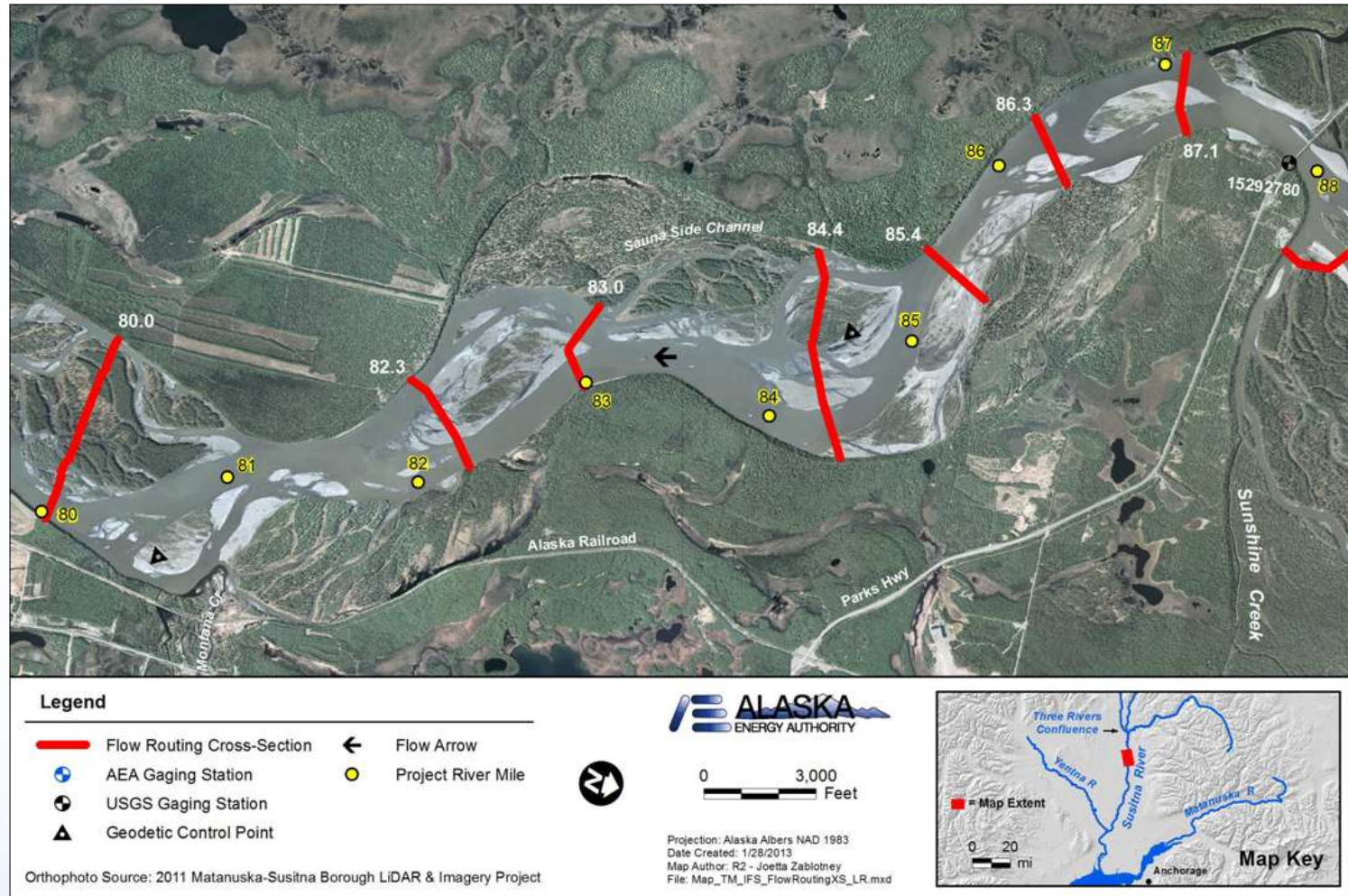


Effects of Proposed Project (HEC-RAS results) 15-Minute Stages in Susitna River at Sunshine Gage – July, 1984

(Pre-Project conditions do not account for diurnal glacial melt fluctuations)



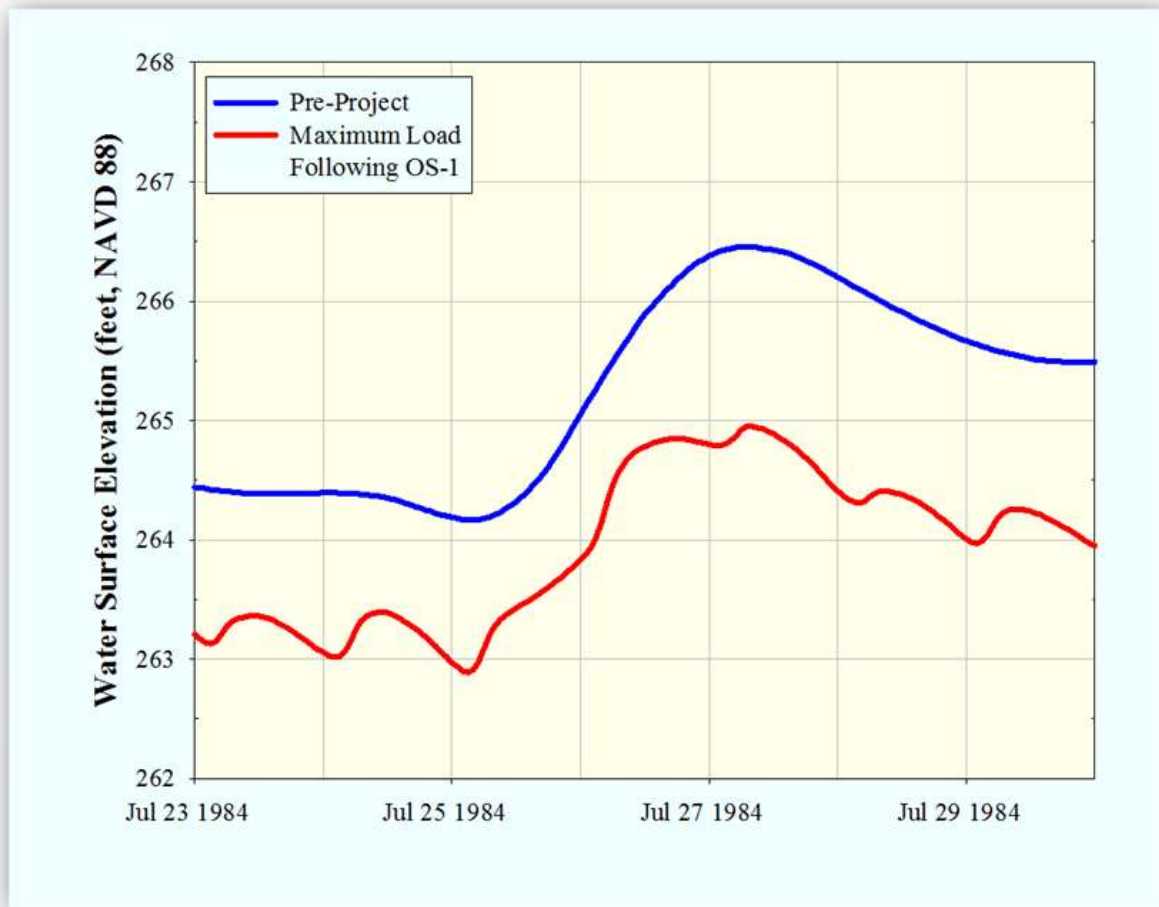
Sunshine Gage is Located at a Confined Single Channel - Not Representative of Local Conditions



Effects of Proposed Project (HEC-RAS results) 15-Minute Stages in Susitna River at PRM 87.1 (below Sunshine gage) – July, 1984

45

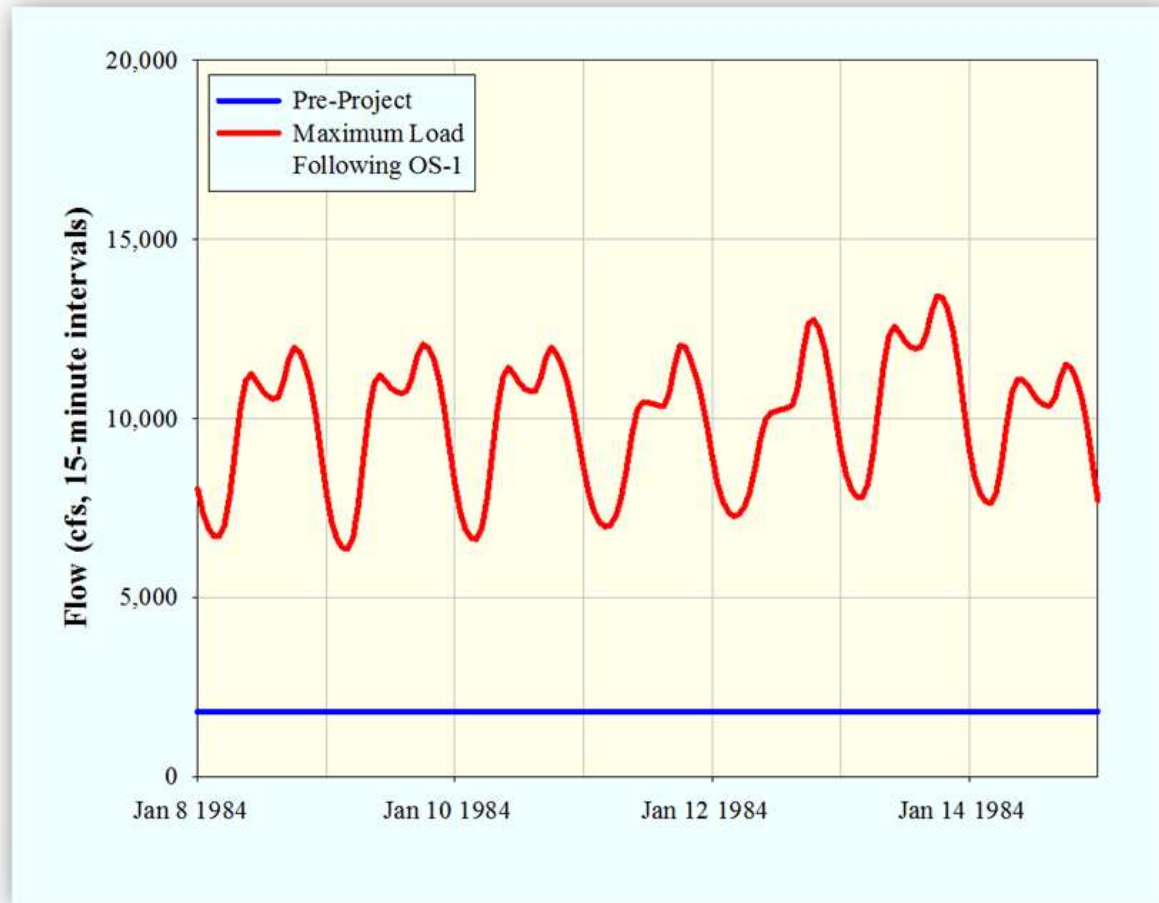
(Pre-Project conditions do not account for diurnal glacial melt fluctuations)



Effects of Proposed Project

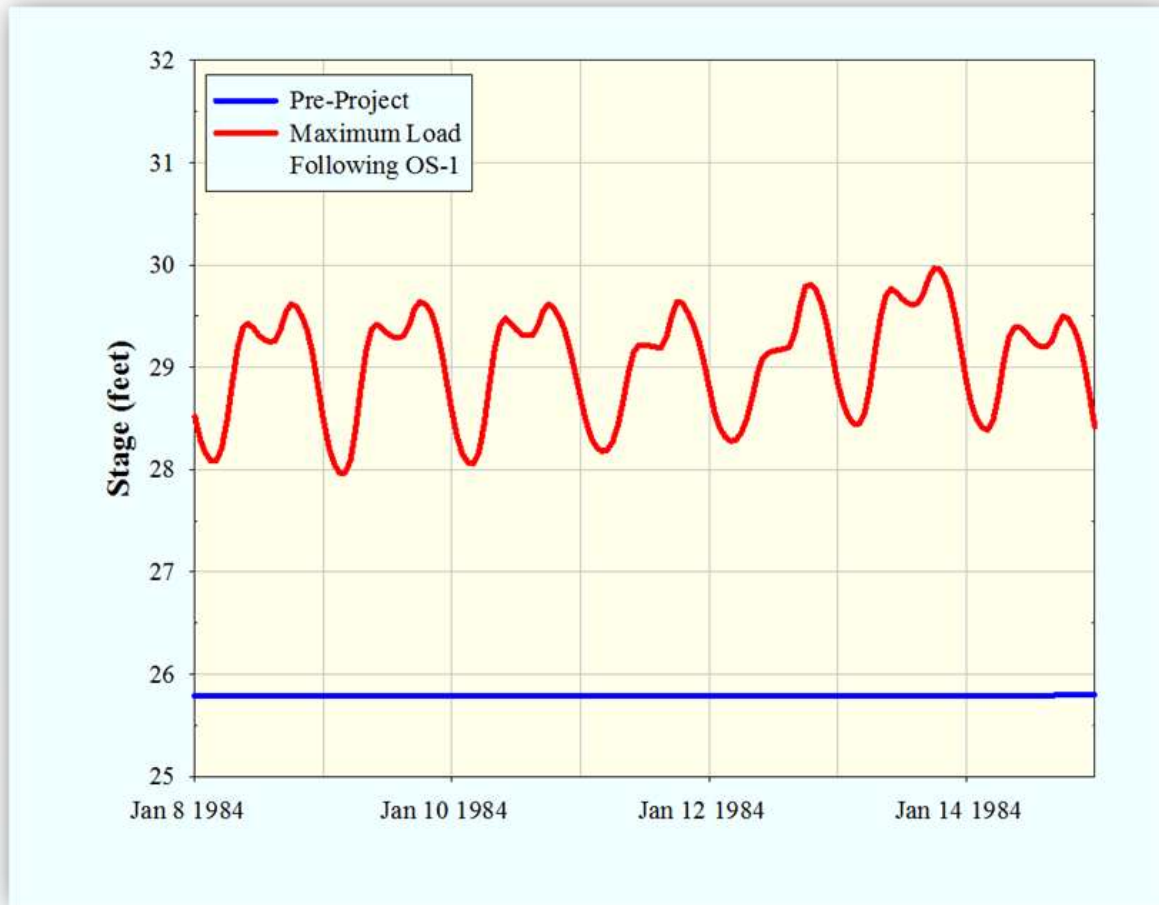
15-Minute Flows in Susitna River Below Proposed Dam Site – January, 1984

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Effects of Proposed Project 15-Minute Stages in Susitna River Below Proposed Dam Site – January, 1984

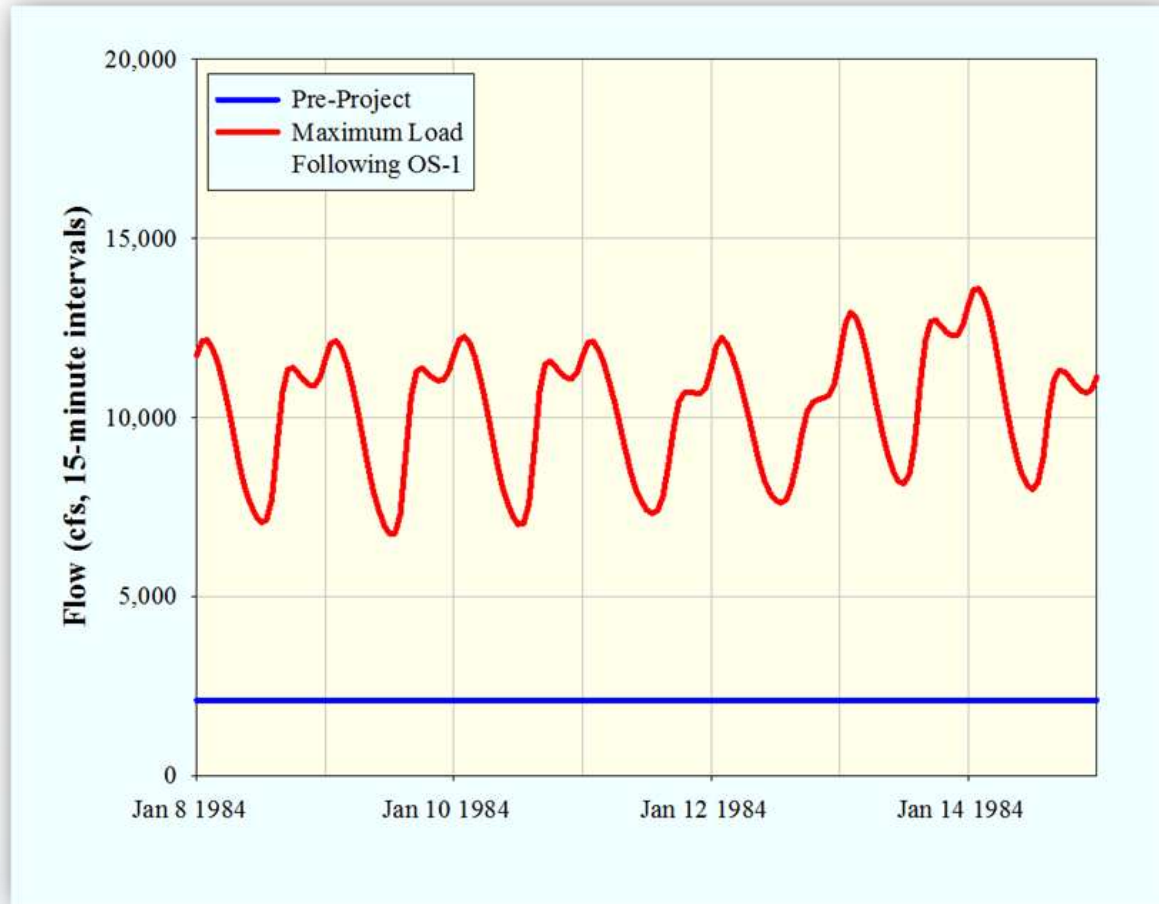
47



Effects of Proposed Project (HEC-RAS results) 15-Minute Flows in Susitna River at Gold Creek Gage – January, 1984

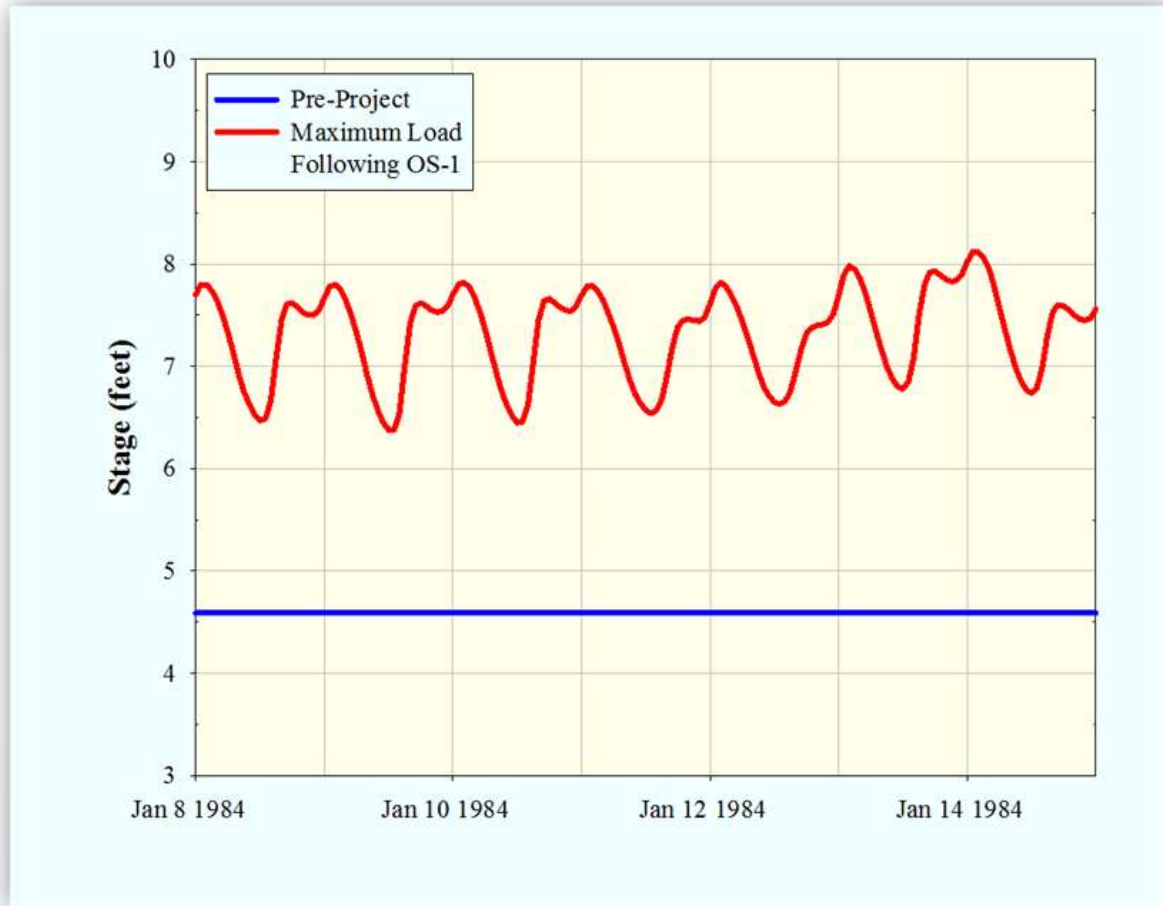
48

(Actual results may differ as a result of ice formation on the river)



Effects of Proposed Project (HEC-RAS results) 15-Minute Stages in Susitna River at Gold Creek Gage – January, 1984

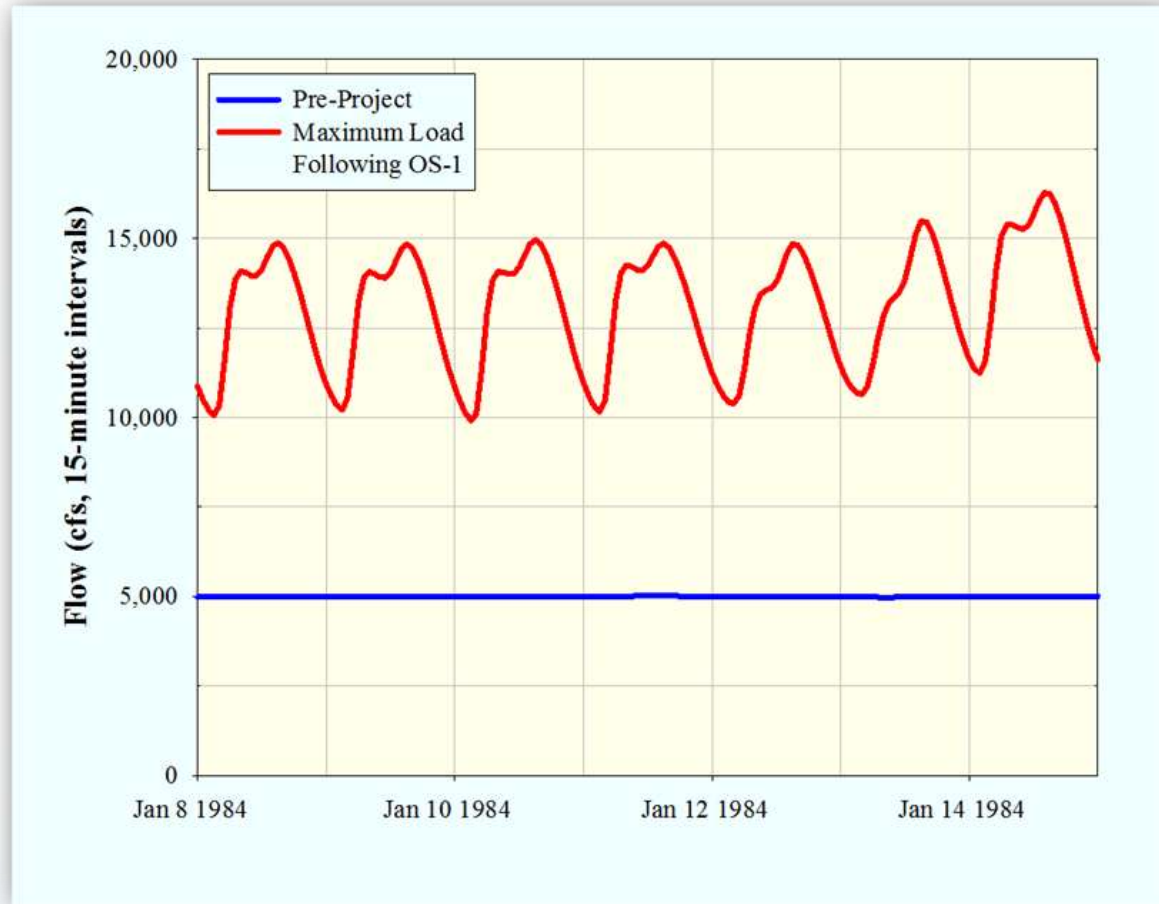
(Actual results may differ as a result of ice formation on the river)



Effects of Proposed Project (HEC-RAS results) 15-Minute Flows in Susitna River at Sunshine Gage – January, 1984

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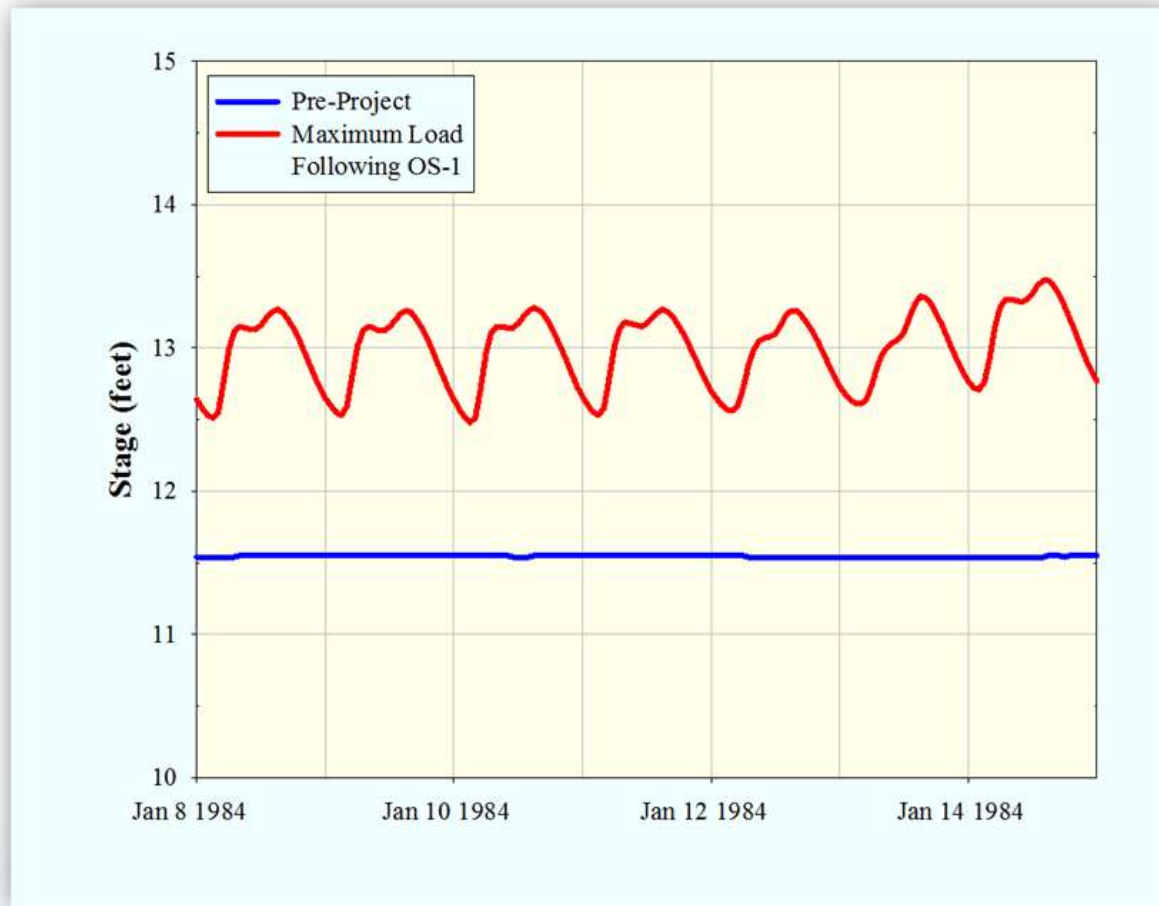
(Actual results may differ as a result of ice formation on the river)



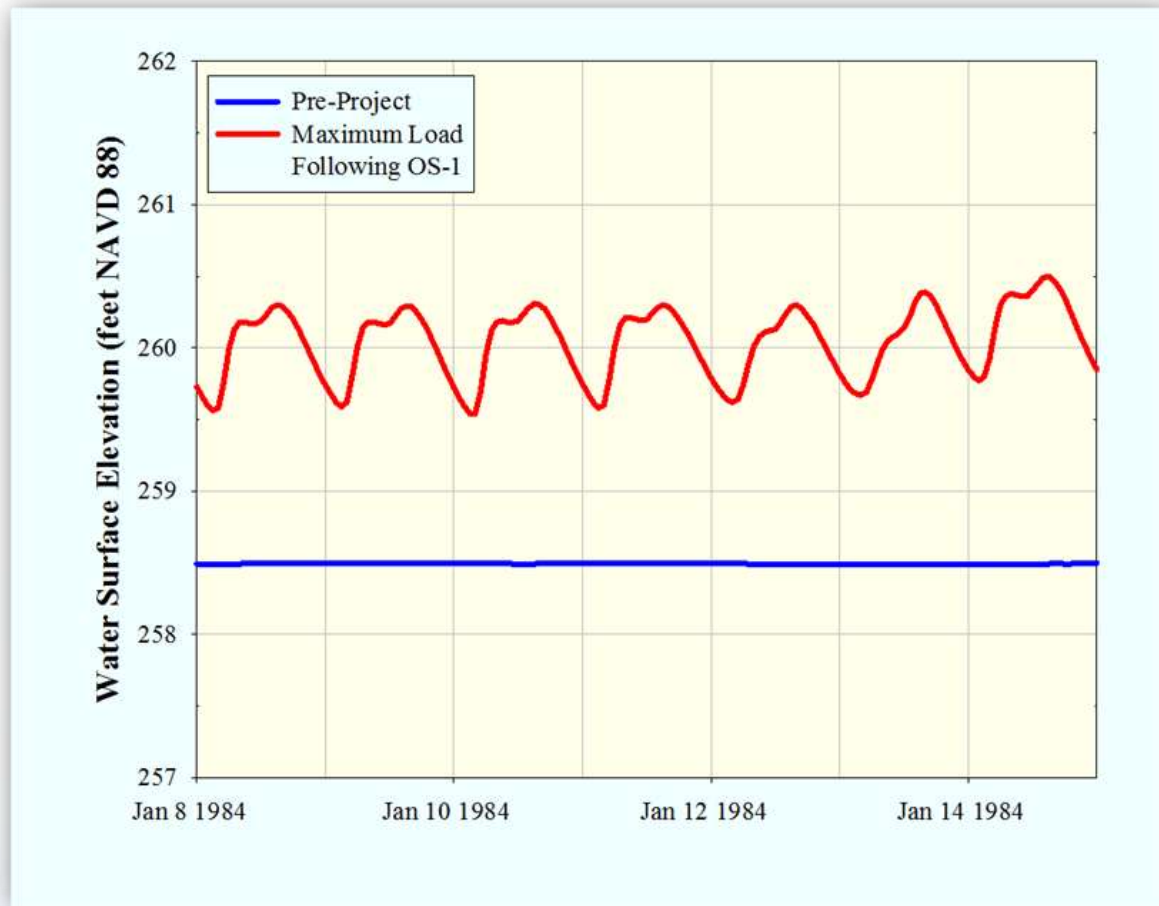
Effects of Proposed Project (HEC-RAS results) 15-Minute Stages in Susitna River at Sunshine Gage – January, 1984

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(Actual results may differ as a result of ice formation on the river)

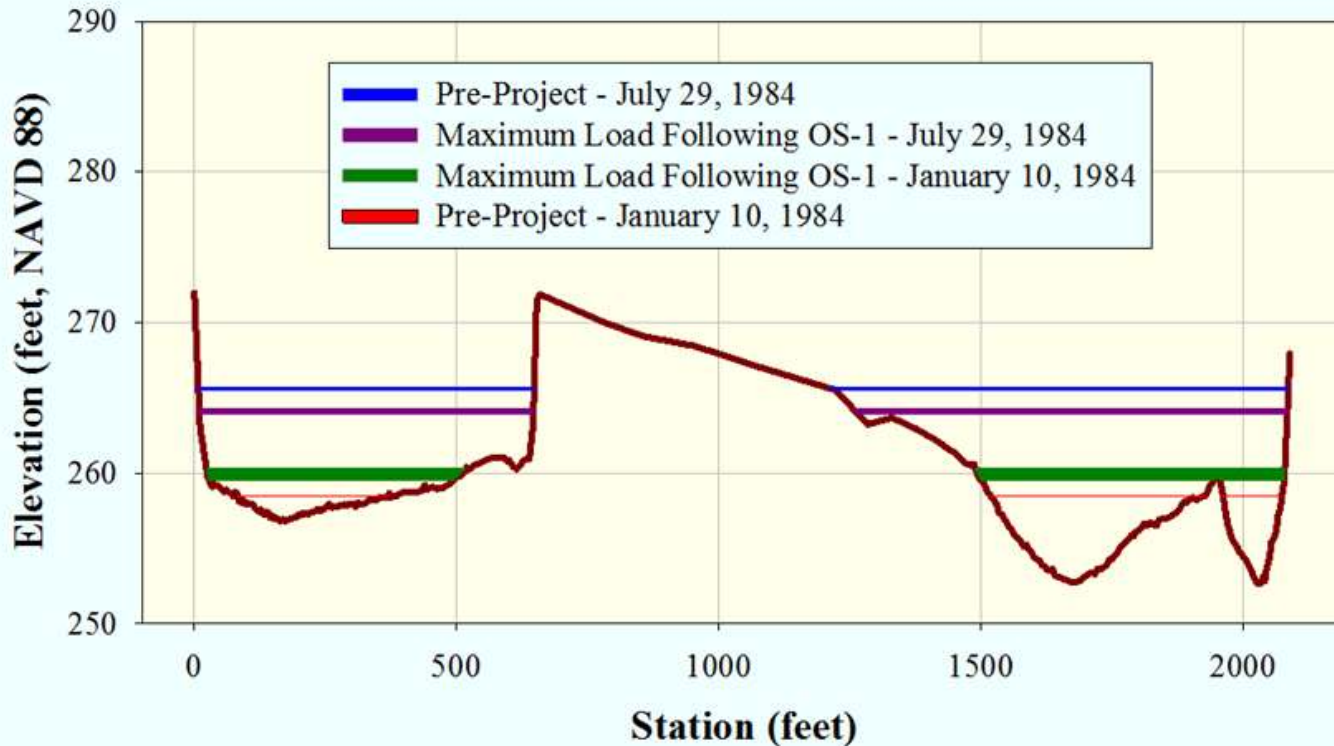


Effects of Proposed Project (HEC-RAS results) 15-Minute Stages in Susitna River at PRM 87.1 (below Sunshine Gage) – January, 1984 (Actual results may differ as a result of ice formation on the river)



Effects of Proposed Project (HEC-RAS results) Surveyed Cross-Section of Susitna River at PRM 87.1

(Actual results may differ as a result of ice formation on the river)



Planned Improvements to Open-Water Flow Routing Model

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- HEC-RAS: Version 2 will extend cross-section profiles to higher elevations using LiDAR, and ground-based RTK GPS surveys.
- Additional pairs of flow/water surface elevations will be measured and used in the model.
- Measured flows in tributaries will improve estimates of accretion flows.
- The model will include additional cross-sections surveyed in geomorphology study.
- Diurnal glacial melt fluctuations will be incorporated into summer hydrographs.

