Susitna-Watana Hydroelectric Project Document
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March 1, 2013

Ms. Kimberly D. Bose
Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Re: Susitna-Watana Hydroelectric Project, FERC Project No. 14241-000; Filing of 2012 Baseline Environmental and Resources Study Reports

Dear Secretary Bose:

As explained in its Pre-Application Document and Revised Study Plan (RSP) for the proposed Susitna-Watana Hydroelectric Project, FERC Project No. 14241 (Project), the Alaska Energy Authority (AEA) carried out numerous baseline environmental and resources studies related to the proposed Project during the 2012 field season. Because the 2012 studies occurred prior to the commencement of the study phase of the licensing effort under the Federal Energy Regulatory Commission's (Commission) Integrated Licensing Process, AEA was not required to complete these baseline studies. However, AEA voluntarily undertook these studies for purposes of taking advantage of the 2012 field season to gather environmental data related to the proposed Project, and to help inform the scope and methods of the licensing studies during 2013-14, as set forth in AEA's RSP.

As AEA has completed the study reports associated with these 2012 baseline environmental and resources studies, it has made the study reports publicly available by uploading them to the "Documents" page of its licensing website, http://www.susitna-watanahydro.org/type/documents/. The purpose of this filing is to submit these study reports to the Commission's record for the above-referenced Project.

In particular, the following study reports are attached, all of which are relevant to the Commission's study plan determination scheduled for April 1, 2013:

- Attachment A: *Adult Salmon Distribution and Habitat Utilization Study* (January 2013)
- Attachment B: *Synthesis of Existing Fish Population Data* (February 2013)
- Attachment C: *Mercury Assessment and Potential for Bioaccumulation* (February 2013)

- Attachment D: *Technical Memorandum, Susitna River Large Woody Debris Reconnaissance* (March 2013)

- Attachment E: *Riparian Vegetation Study Downstream of the Proposed Susitna-Watana Dam* (February 2013)

- Attachment F: *Technical Memorandum, Reconnaissance Level Assessment of Potential Channel Change in the Lower Susitna River Segment* (February 2013)

- Attachment G: *Stream Flow Assessment* (February 2013)

- Attachment H: *Development of Sediment-Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments* (February 2013)

- Attachment I: *Technical Memorandum, Initial Geomorphic Reach Delineation and Characterization, Middle and Lower Susitna River Segments* (February 2013)

As the remaining 2012 study reports are finalized, AEA will continue to update its website and submit them to the record.

If you have questions concerning this submission, please contact me at wdyok@aidea.org or (907) 771-3955.

Sincerely,

Wayne M Dyok

Wayne Dyok
Project Manager
Alaska Energy Authority

Attachments

cc: Distribution List (w/o Attachments)

Attachment H

Development of Sediment-Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments (February 2013)

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Development of Sediment-Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Tetra Tech

February 2013

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LIST OF ACRONYMS AND SCIENTIFIC LABELS

Abbreviation	Definition
AEA	Alaska Energy Authority
cfs	cubic feet per second
FERC	Federal Energy Regulatory Commission
ILP	Integrated Licensing Process
M	million
mm	millimeter
MVUE	Minimum Variance Unbiased Estimator
NEPA	National Environmental Policy Act
NGVD	National Geodetic Vertical Datum
NWIS	National Water Information System
OS	Operation Scenario
PRM	Project River Mile
RM	River Mile
RSP	Revised Study Plan
sq mi	square mile
USGS	U.S. Geological Survey
WY	Water Year

SUMMARY

The purpose of the study effort was to make preliminary estimates of the overall sediment balance in the Middle and Lower River segments under pre-Project conditions and the potential magnitude of the changes that will occur under Maximum Load Following Operating Scenario (OS)-1 hydrologic conditions. A sediment balance is the determination of the difference between the inflowing sediment (supply) to a reach and the outflowing sediment from the reach (transport). If the sediment inflow to the reach is greater than the outflow, then sediment is stored within the reach. If the sediment supply into the reach is less than the sediment outflow from the reach, then sediment is removed from the reach. In the former case, the reach is considered depositional and in the latter case it is considered aggradational. If the sediment inflow and outflow are nearly equal, the reach is considered in balance with its sediment supply and transport.

Sediment transport relationships were developed at three locations on the mainstem Susitna River, Gold Creek, Sunshine and Susitna Station, and on its three largest tributaries, the Chulitna, Talkeetna and Yentna Rivers. Since the ability of the river to transport sediment and its response to the sediment being supplied varies greatly with the size of the sediment, relationships were developed for three sizes of sediment, wash load (silts and clay), sand load and gravel load. The relationships were applied to the long term hydrologic conditions represented by the Pre-Project and Maximum Load Following OS-1 scenarios. The sediment balance was computed for both conditions for the portion of the Susitna River from the Watana dam site to the Susitna Station gage approximately 30 miles upstream of the river's mouth.

The sediment transport relationships developed in the 2012 effort will be used in the 2013 and 2014 Geomorphology Studies to support detailed 1-D and 2-D bed evolution modeling of the Susitna River below Watana Dam. The relationships supported the assessment of 2012 study Reconnaissance Level Assessment of Potential Channel Change in the Lower Susitna River Segment. The sediment transport relationships may be updated based on comparison with data collected by the U.S. Geological Survey (USGS) in 2012 and additional data to be collected in 2013.

For most of the Susitna River above Susitna Station, the gravel load plays the most significant role in determining the river's morphology. Under Maximum Load Following OS-1 conditions, the average annual gravel load at Sunshine will decrease to about 140,000 tons; thus, the total gravel supply above Susitna Station will decrease to about 370,000 tons/year. Based on integration of the gravel load rating curve over the Maximum Load Following OS-1 flow record, the average annual gravel load at Susitna Station would decrease to about 200,000 tons. This indicates that the reach between Sunshine and Susitna Station would remain aggradational, but the relative imbalance in gravel loads would decrease by about one-third from an excess of 250,000 tons under pre-Project conditions to about 170,000 tons under Maximum Load Following OS-1 conditions. Review of USGS data and the results of the sediment balance also indicated that at Susitna Station, the sand load may be the dominant factor in determining the morphology of the river. Sufficient information is not available at this time to identify the location of the transition zone from gravel to sand dominance, and specifically whether this occurs above or below the Yentna River confluence. This determination will be important in understanding potential Project effects. The 1-D sediment-transport modeling to be conducted in 2013 between Sunshine and Susitna Station will be a key tool in making these assessments.

1. INTRODUCTION

The Alaska Energy Authority (AEA) is preparing a License Application that will be submitted to the Federal Energy Regulatory Commission (FERC) for the Susitna-Watana Hydroelectric Project (Project) using the Integrated Licensing Process (ILP). The Project is located on the Susitna River, an approximately 300-mile-long river in the Southcentral Alaska. The Project's dam site would be located at Project River Mile (PRM) 187.1. The results of this study will provide information that will inform the 2013–2014 formal study program, and Exhibit E of a license application, and FERC's National Environmental Policy Act (NEPA) analysis for the Project license.

The G-S4: Reconnaissance-level Geomorphic and Aquatic Habitat Assessment of Project Effects on Lower River Channel study plan includes, among other objectives, a preliminary evaluation of the relative magnitude of changes in the sediment regime associated the Susitna-Watana Hydroelectric Project. This memorandum summarizes work performed under the *Sediment Load Comparison* section of the *Sediment Transport Assessment* task to meet this objective, including the development of sediment-transport relationships using the available sediment-transport data, and an initial sediment balance for the Middle and Lower Susitna River segments, based on the pre-Project hydrology and post-Project hydrology under an operations scenario referred to as Maximum Load Following Operation Scenario 1 (OS-1). These two hydrology scenarios were analyzed in detail in Tetra Tech (2013a). The pre-Project analysis was performed for six streamflow gages located in the Susitna Basin using 61 years of extended hydrologic records developed by the U.S. Geological Survey (USGS 2012) for the period from Water Year (WY) 1950 through WY2010. Three of the gages are located on the mainstem Susitna River and three of the gages are located on major tributaries (the Chulitna, Talkeetna and Yentna Rivers). The Maximum Load Following OS-1 hydrology is a simulated flow record developed with the Project-conditions flow-routing model (MWH 2012) for the same 61-year period as the pre-Project records. Maximum Load Following OS-1 is based on the assumption that the load fluctuation of the entire Railbelt would be provided by the Project, and all other sources of electrical power in the Railbelt would be running at base load. This assumed condition is not realistic for an entire year, and the results of this condition should be conservative with respect to assessing downstream impacts of load following.

The main components of the sediment-transport analysis include the following:

- A review of previously published relationships between discharge and (1) suspended sediment load, (2) bed load, and (3) total sediment load (Knott et al. 1987), and refinement of those relationships where additional data were available.
- Application of selected relationships to both the pre-Project and Maximum Load Following OS-1 flow records to estimate annual sediment loads for suspended silt/clay (i.e., wash load), total sand load based on independent estimates of the amount of sand being carried in suspension and as bed load, and the gravel component of the bed load.
- Comparison of the estimated annual sediment loads to provide an approximate sediment balance in the river reaches between the mainstem gages in the Middle and Lower Rivers.

2. STUDY OBJECTIVES

The overall objective of this memorandum is to make preliminary estimates of the overall sediment balance in the Middle and Lower River segments under pre-project conditions and the potential magnitude of the changes that will occur under Maximum Load Following OS-1 hydrologic conditions, including the specific assessments of the following, interrelated topics:

- Determination of the suitability of previously published sediment transport relationships between discharge and sediment load and update the relationships if necessary.
- Selection of the most appropriate sediment transport relationships for use in the preliminary sediment balance.
- Use the selected sediment transport relationships to estimate the pre-Project and Maximum Load Following OS-1 annual loads. The sediment loads will be divided into wash load (silt and clay), sand load and gravel load.
- Comparison of estimated annual sediment loads at the three mainstem Susitna River gages to characterize the overall sediment balance under pre-Project conditions and the potential changes under Maximum Load Following OS-1 conditions.

A sediment balance is the determination of the difference between the inflowing sediment (supply) to a reach and the outflowing sediment from the reach (transport). If the sediment inflow to the reach is greater than the outflow, then sediment is stored within the reach. If the sediment supply into the reach is less than the sediment outflow from the reach, then sediment is removed from the reach. In the former case, the reach is considered depositional and in the latter case it is considered aggradational. If the sediment inflow and outflow are nearly equal, then the reach is considered in balance or in equilibrium in terms of sediment supply and transport.

3. STUDY AREA AND AVAILABLE DATA

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

There are 14 USGS streamflow gages located in the Susitna River Basin plus one on the Little Susitna River that was used as an index station (Table 3.0-1 and Figure 3.0-1). The period of recorded data available for these gages ranges from 58 years at the Gold Creek gage to less than 10 years at gages such as the Yentna River at Susitna Station and the Susitna River at Sunshine gages. The data available from many of these gages may not adequately represent long-term streamflow conditions in the Susitna River Basin because of the short period of record and the distribution of years during which data were collected (USGS 2012). To provide a consistent long-term record, the USGS extended the record of 11 of these gages to 61 years (WY1950 – WY2010). WY1950 was selected for the start of the record because this was the first full water year of data collection for the primary index station at Gold Creek. The Montana Creek (Mont), Deception Creek (Decep), and the Deshka River (Desh) gages were not included in the extended record analysis because they could not be adequately correlated to any long-term index station for the entire study period (USGS 2012).

Three main stem gages and three primary tributary gages locations downstream of the Project site PRM 187.1 (Figure 3.0-1) were used to characterize the sediment-transport regime under the 61-year hydrology record for each portion of the reach, as follows:

- Main Steam Gages
  - Middle River Mainstem: Susitna River at Gold Creek Gage (15292000) and Susitna River near Talkeetna Gage (15292100)[1]
  - Lower River mainstem below Three Rivers Confluence: Susitna River at Sunshine Gage (15292780)
  - Lower River mainstem below Yentna River: Susitna River at Susitna Station Gage (15294350)
- Primary Tributary Gages
  - Tributary Supply to Three River Confluence (Chulitna River near Talkeetna Gage (15292400) and the Chulitna River below canyon near Talkeetna gage (15292410)[1])
  - Talkeetna River near Talkeetna Gage (15292700)
  - Tributary Supply to Lower River: Yentna River near Susitna Station Gage (15294345)

The number and types of sediment samples, and the dates of sampling vary among the gages, but generally include both the magnitude and gradation of the suspended sediment and bed load for samples collected between the late-1970s and the late-1980s (Table 3.0-2). The bulk of these data that were collected through WY1985 were previously analyzed by Knott et al. (1987). As part of the current analysis, the available data for each of the gages were downloaded from the USGS National Water Information System (NWIS) website (http://waterdata.usgs.gov), and relevant data collected after 1985 were added to the data sets.

The post-Project hydrologic conditions of the Chulitna, Talkeetna and Yentna Rivers would be unaffected by the Maximum Load Following OS-1 condition; thus, the post-Project sediment supply from tributaries were assumed to be equivalent to the pre-Project supply.

[1] Data from both these gages were combined into a single data set for the USGS (1987) analysis; this approach was adopted for this preliminary study, as well.

4. METHODS

This section describes the methods used to select or develop relationships between discharge and sediment load for each component of the sediment load at the six USGS gaging stations, and apply these relationships, with the minimum variance unbiased estimator (MVUE) bias-correction technique, to the pre-Project and Maximum Load Following OS-1 extended flow records to estimate the annual sediment loads for each size range.

4.1. Deviations from Study Plan

The Study Plan calls for comparison of the total sediment load at the Sunshine and Susitna Station gaging stations for an average, wet, and dry year between pre-Project and adjusted post-Project conditions using adjusted post-Project rating curves. Because the 61-year daily flow record was available for pre-Project and Maximum Load Following OS-1 conditions, the full record was used for this purpose in lieu of selecting specific years for the analysis, with sediment loads compared on an average annual basis over all years, and the variability assessed by considering the range of annual loads from the 61-year record. This more comprehensive approach to assessing sediment loads provides a better assessment of the long-term project influence on sediment transport than considering only the three "representative" years.

4.2. Sediment Load Rating Curves

Knott et al. (1987) used the data collected through WY1985 at the six gages to characterize sediment-transport conditions in the reach. This included development of relationships between discharge and sediment loads from data for four components of the total sediment load collected during the period between October 1984 and September 1985, data collected from WY1981 through WY1984, and historical records (USGS 1953 to 1980):

- Suspended silt/clay
- Suspended sand
- Sand bed load,
- Gravel bed load

The Knott et al. (1987) relationships were of the power-function form:

$$Q_s = a(Q)^b \qquad (4.2\text{-}1)$$

where:

Q_s	=	sediment load (tons/day)
a	=	coefficient
b	=	exponent
Q	=	discharge (cubic feet/second)

For consistency with Knott et al. (1987) and standard practice in developing sediment load rating curves (USGS, 1992), power function relationships were also used for the current study.

As an initial step in the analysis, the available data through WY1985 in each size-range at each of the gages was plotted and compared with the data plots in Knott et al. (1987). This comparison revealed a limited number of available data points from the NWIS database that were not used in the Knott et al. (1987) analysis. No explanation was provided in their report for why these data points were not used. In an attempt to ascertain the reason(s), Mr. Gary Solin at the USGS Alaska Science Center, where the original data collection and analysis were performed, was contacted. Mr. Solin indicated that the individuals who performed the analysis were either retired and out of contact; thus, he was not able to provide specific information about the issue. He did, however, suggest that the data points used in the analysis were probably limited to those directly collected by the study team and/or for which the study team had specific knowledge. Based on this information, the decision was made to limit the WY1985 and earlier data to those data points used by Knott et al. (1987), under the assumption that their study team had the best knowledge of the quality and relevance of the data at that time; thus, their dataset represents the best-available data through WY1985.

After identifying the data points used by Knott et al. (1987), the data sets were updated by adding relevant data collected since WY1985. Power-function regression lines were then fit to the extended data sets using the least-squares regression technique and compared to the Knott et al. (1987) line-of-best-fit. Through analysis and inspection of the data and knowledge of the range of typical exponents for the different components of the sediment load, either the USGS line-of-best fit or the new regression equations were selected for this preliminary study (Table 4.1-1 and Appendix A). With the exception of the silt/clay load for the Gold Creek/near Talkeetna data set, new regression equations were developed for all of the suspended sediment loads to incorporate the post-WY1985 data points. The USGS equation was used for the Gold Creek/near Talkeetna data set because the new regression line significantly over-predicts the loads at flows less than about 20,000 cfs. It appears that Knott et al. (1987) also recognized this issue and visually fit a line to the data that provided better fit to data over the full range of discharges. Because of the significant scatter in the data and the typically limited range of flows over which the data were collected, regression equations do not provide reasonable relationships for most of the bed-load data sets. For this reason, the USGS equations were adopted for all of the data sets except for those at Susitna Station. Partly because of the influence of five newer sand bed load and three newer gravel bed load data points that were collected in 2003, the regression equations for both appear to fit the data better than the USGS equations, and the regression equations were, thus, used for both components of the bed load at this site.

4.3. Bias Correction and Annual Load Estimates

The selected relationships between discharge and the various components of the sediment load were then used with the MVUE bias-correction technique to estimate daily sediment loads for the entire 61-year record of mean daily flows for both pre-Project and Maximum Load Following OS-1 conditions. The MVUE technique was used to correct for the statistical bias that occurs in basic power-function regression, based guidance from USGS (1992). Previous studies have demonstrated that the bias occurs in the process of linearizing the data set by transforming it into the logarithmic domain and then back-transforming the resulting relationship into the arithmetic domain (Walling 1977b; Thomas 1985; Ferguson 1986). Various procedures are available to address the bias, including accounting for seasonal differences in sediment transport and accounting for hysteresis related to rising and falling limbs of flood hydrographs (Guy 1964; Walling 1974). Koch and Smillie (1986) and Cohn and Gilroy (1991) described methods of numerically correcting for the bias that depend on the expected distribution of errors. USGS (1992) endorsed the recommendations in Cohn and Gilroy (1991) to use the MVUE bias correction for normally distributed errors, or the Smearing Estimator (Duan 1983) when a non-normal error distribution is identified. The MVUE method was selected in this analysis to remove the bias from the log-transformed sediment loads because the errors are generally normally-distributed.

Annual sediment loads for each year in the pre-Project and Maximum Load Following OS-1 records were developed by summing the bias-corrected daily sediment loads.

5. RESULTS

This section summarizes the annual sediment yields developed using the methods described in Section 4 for the pre-Project and Maximum Load Following OS-1 conditions at the three main stem gages and three primary tributary gages. As noted above, Knott et al. (1987) divided the total sediment load into four components, primarily because of the manner in which the data are collected. It is, however, more meaningful from a river-process perspective to re-group these components into three components, consisting of the wash load (i.e., silt/clay that is almost exclusively carried in suspension), the sand component of the bed material load that consists of the sand that is carried both in suspension and as bed load, and the gravel component of the bed load. The sand load is being treated separately in this analysis because it may be strongly supply-limited, and thus more correctly categorized as part of the wash load in the Middle River and tributaries; however, in the Lower River in the area of Susitna Station and further downstream, the sand load may be transport limited.

5.1. Pre-Project

Under pre-Project conditions, the estimated total annual sediment loads at the Gold Creek/near Talkeetna gage average about 3.3 million (M) tons, varying from about 550,000 tons to nearly 11M tons (Figure 5.1-1). Of these amounts, the silt/clay, wash load accounts for about 55 percent (1.8M tons) of the total, on average, while the sand accounts for about 43 percent (1.4M tons) and the gravel bed load accounts for only about 2 percent (66,000 tons) of the total.

At the Sunshine gage, the average, pre-Project total annual sediment load increases to about 16.4M tons, ranging from about 4.7M to 26.8M tons (Figure 5.1-2). The relative proportion of wash load increases to about 61 percent (10.0M tons) of the total, with the sand and gravel loads accounting for about 37 and 1.7 percent (6.1M and 280,000 tons) of the total, respectively.

The annual total load at the Susitna Station gage averages about 34.1M tons, and ranges from 18.3M to 53.1M tons (Figure 5.1-3). The silt/clay load accounts for about 57 percent (19.5M tons), and the sand and gravel loads account for about 42 percent (14.3M tons) and less than 1 percent (260,000 tons) of the total, respectively, at this location.

The three primary tributaries supply a significant amount of the sediment to the mainstem. The annual load from the Chulitna River, for example, averages about 9.9M tons, ranging from 4.8M tons to 24.7M tons (Figure 5.1-4), and the Talkeetna River supplies an average of about 1.9M tons/year, ranging from about 380,000 to 6.9M tons/year (Figure 5.1-5). The Yentna River carries the largest total load of the three, averaging about 15.5M tons/year and ranging from 6.7M to 31.5M tons/year (Figure 5.1-6). The Chulitna River delivers a much larger percentage of gravel than either the mainstem or the other two major tributaries (about 7.5 percent versus 3.1 and 1.2 percent for the Talkeetna and Yentna Rivers, respectively). The Yentna River delivers the smallest relative percentage of wash load of the three tributaries (48 percent versus 53 and 50 percent for the Chulitna and Talkeetna Rivers, respectively).

Based on these results, the Middle River supplies about 22 percent of the total sediment load to the Three Rivers Confluence, and the Chulitna and Talkeetna Rivers supply about 66 and 12 percent of the total load, respectively (Figure 5.1-7). On a by-size-fraction basis, the relative contributions of silt/clay and sand are about the same as the total load; however, the Chulitna River supplies the bulk of the gravel load that is key to the channel morphology (about 86 percent of the total, compared to about 8 percent from the Middle River and 7 percent from the Talkeetna River). The total sediment load from the Yentna River represents about 46 percent of the total load at Susitna Station, and about 65 percent of the gravel load.

A tabulation of the estimated annual loads under pre-Project conditions for each component of the load at each of the six gages is provided Appendix B.1.

5.2. Maximum Load Following Operation Scenario 1

Watana Dam and Reservoir will trap a significant percentage of the sediment supply to the Middle River. For purposes of this preliminary analysis, it is assumed that the trap efficiency for the silt/clay load will be on the order of 90 percent, and all of the sand and coarser sediment will be trapped. In addition to the effects on sediment supply, the dam will also modify the flow regime in the downstream river in a manner that will affect the transport capacity along the reach. Tetra Tech (2013a) evaluated the changes in flow regime in the Middle and Lower River associated with Maximum Load Following OS-1 conditions that are based on the very conservative assumption that the load fluctuation of the entire Railbelt would be provided by the Susitna-Watana Project, and all other sources of electrical power in the Railbelt would be running at base load. Under these conditions, the total volume of flow will be essentially the same as under pre-Project conditions on an annual basis, but the distribution throughout the year will change, with a general increase in the winter base flows and decrease in the summer high flows. The effects are most significant in the Middle River, where tributary inflows are relatively small compared to the mainstem flows. The effects diminish significantly downstream from the Three Rivers Confluence due to the relatively large inflows from the Chulitna and Talkeetna Rivers, and they continue to diminish in the downstream direction as the relative contribution from local tributaries increases. Because of the nonlinear relationship between discharge and sediment-transport rates, the changes in flow regime associated with the Project will result in a general decrease in the capacity of the river to transport sediment in each segment of the reach.

Based only on the changes in flow regime (i.e., not accounting for the effects of sediment trapping the reservoir), the total sediment load at the Gold Creek/near Talkeetna gage would decrease to about 502,000 tons on an average annual basis, about 285,000 tons of which would be suspended silt/clay, 213,000 tons would be sand, and only about 4,400 tons would be in the gravel size-range (Figure 5.2-1). The supply of gravel from the tributaries between Watana Dam and Gold Creek/near Talkeetna gage is 11,000 tons if it is assumed to be in proportion with the intervening drainage area. If this assumption is reasonable, then gravel materials would tend to accumulate as fans at the mouths of the tributaries and within this reach or river. This amount could be more or less and will be investigated further. Because the bulk of the suspended silt/clay load is derived from upstream of the Watana Dam site, the trap efficiency of the reservoir will directly impact this component of the load throughout the Middle River immediately upon closure of the dam. Based on the preliminary estimate of 90 percent trap efficiency, and considering the estimated 117,000 tons contributed by the tributaries between the dam site and the gage, the average annual suspended silt/clay load at Gold Creek would, therefore, likely decrease to about 285,000 tons/year, an approximately 84-percent reduction from pre-Project conditions.

The relative contribution of the river upstream from the dam site to the sand load, compared to the contributions from within the channel and the intervening tributaries is not known at this time, but it is likely that the upstream contribution represents a relatively significant percentage of the total. During the initial period of a few to several years after closure of the dam, the average annual sand load passing the Gold Creek/above Talkeetna gage will likely be on the order of the 320,000 tons estimated using the pre-Project sand transport rating curves with the Maximum Load Following OS-1 flows, an approximately 77-percent reduction from pre-Project conditions. Based on these estimates, the year-to-year variability would range from only about 88,000 tons to about 1.3M tons. As the supply of sand that is available from the Middle River channel is depleted, the sand load in the vicinity of the Gold Creek/near Talkeetna gage will diminish relatively rapidly to a value that is consistent with the sand load from the intervening tributaries, or about 213,000 tons/year, an approximately 85-percent reduction from pre-Project conditions.

The gravel load at Gold Creek/near Talkeetna will likely remain at about the estimated 4,400-tons/year value for a significant period of time because of the slower overall response of gravel-sized material between the dam site and the gage. If the annual supply from the intervening tributaries is less than 4,400 tons then the response will be slow because of the relatively large reservoir of gravel-sized material between the dam site and the gages. If the annual supply is greater than 4,400 tons (preliminary estimate is 11,000 tons), then gradually through time the gravel materials will accumulate and the supply of gravel from the Middle River will tend toward the higher supply rate. The 4,400 tons/year represents an approximately 93-percent reduction from pre-Project conditions. Based on integration of the pre-Project gravel transport curve over the Maximum Load Following OS-1 flow record, the annual gravel loads would vary from about 50 to 42,300 tons on a year-to-year basis.

The total sediment load at Sunshine would diminish to about 13.6M tons on an average annual basis under Maximum Load Following OS-1 conditions, of which about 8.5M tons would be suspended silt/clay, 5.0M tons would be sand and about 142,000 tons would gravel (Figure 5.2-2). This represents an approximately 17-percent reduction in the total sediment load and a 15-percent reduction in the silt/clay load compared to pre-Project conditions. The average annual gravel load would diminish to about 142,000 tons, varying from about 67,000 to 377,000 tons on a year-to-year basis. The average annual gravel load represents a 49-percent reduction from pre-Project conditions.

Accounting for the effects of silt/clay trapping in the reservoir that would be seen very rapidly throughout the Middle and Lower Rivers, the average annual total load at Susitna Station would decrease to about 31.3M tons, of which about 18.0M tons would be suspended silt/clay (Figure 5.2-3). This represents an 8-percent reduction in both the total and silt/clay load. The effects of sediment trapping in the upstream reservoir on the sand-and-gravel supply to this portion of the lower river would not be seen for a relatively long period of time (likely, the life of the Project); however, as with the upstream gages, the changes in flow regime associated with the Project would change the transport capacities. Based on integration of the pre-Project sand transport rating curves over the Maximum Load Following OS-1 flows, the total sand load at Susitna Station would decrease to about 13M tons, an approximately 9-percent reduction from pre-Project conditions. The sand loads would vary from about 8.4M to 18.7M tons on a year-to-year basis. Similarly, the gravel loads would decrease to about 207,000 tons, an approximately 20-percent reduction from pre-Project conditions. The gravel loads would vary from 110,000 to 364,000 tons on an average annual basis.

Based on these results, the Middle River would supply only about 4 percent of the total sediment load to the Three Rivers Confluence under Maximum Load Following OS-1 conditions, and the Chulitna and Talkeetna Rivers supply about 81 and 15 percent of the total load, respectively (Figure 5.2-4). On a by-size-fraction basis, the contributions of silt/clay from the Middle River would decrease 4 percent of the total. During the initial periods after closure of the dam, the Middle River would supply about 10 percent of the sand load and only about 0.5 percent of the gravel load to the Three Rivers Confluence. The total sediment load from the Yentna River would supply about 48 percent of both the total load and the gravel load to Susitna Station under Maximum Load Following OS-1 conditions.

A tabulation of the estimated annual loads under Maximum Load Following OS-1 conditions for each component of the load at each the three mainstem gages is provided Appendix B.2.

6. DISCUSSION

The sediment load analyses presented in the previous sections provide a basis for development of a preliminary sediment balance for the Middle and Lower Rivers. The effects of the dam on the sediment balance vary between the silt/clay, sand and gravel loads.

As discussed above, the dam would likely cut off at least 90 percent of the silt/clay supply and essentially all of the sand and gravel supply to the head of the Middle River. The effects on all components of the sediment load would diminish in the downstream direction due to contributions from the tributaries and entrainment of material that is currently stored in the channel. The silt/clay load is carried almost exclusively in suspension. As a result, the effects of sediment trapping in the reservoir on downstream silt/clay loads would be felt within a very short time-frame (i.e., on the order of the travel time of the water) throughout the Middle and Lower Rivers after closure of the dam. Considering the estimated contributions from the tributaries between the dam and the Three Rivers Confluence, the silt/clay load at the lower end of the Middle River would be only about 16 percent of the pre-Project loads (Figure 6.0-1). The effects of the dam on the silt/clay load below Three Rivers diminish significantly due to the large contributions from the Chulitna and Talkeetna Rivers. Based on the available information, the loads at Sunshine with the dam in-place would be about 82 percent of the pre-Project loads, and the contributions from the Yentna and other tributaries between Sunshine and Susitna Station cause the effect to diminish even further so that the post-Project silt/clay loads would be about 92 percent of the pre-Project loads at Susitna Station. Even the very large changes in the silt/clay load in the Middle River are not anticipated to have a significant effect on active channel morphology in Middle River, and the smaller downstream changes are even less likely to affect active channel morphology in the Lower River. The significant reduction in the silt/clay load in the Middle River, along with decreased frequency of floodplain inundation, will have an effect on floodplain sedimentation processes.

During the initial period after closure of the dam, Project effects on the sand load in the lower part of the Middle River and the Lower River would result primarily from the change in flow regime, because there is currently sand moving through the system and it moves at a much slower rate than the flow. Over time, much of the stored sand will be depleted from the Middle River, and the load just upstream from the Three Rivers Confluence area will be consistent with the supply from the local tributaries. After this occurs, the sand load above the Three Rivers Confluence will be only about 15 percent of the pre-Project load (Figure 6.0-2). Similar to the silt/clay load, sand inflows from the Chulitna and Talkeetna Rivers will decrease the relative impact of the Project, with Maximum Load Following OS-1 sand-load conditions of about 82 percent of the pre-Project loads. Contributions from the Yentna River and other tributaries downstream from Sunshine will increase the sand loads to about 91 percent of the pre-Project loads at Susitna Station.

Except for the upstream portion of the Middle River, Project effects on gravel loads will derive primarily from the changes in flow regime. There appears to be a relatively significant supply of gravel and coarser material between the dam site and the Three Rivers Confluence, the local tributaries likely supply a significant amount of gravel to the river, and the response rate of upstream changes in supply will progress downstream relatively slowly compared to the sand. Based strictly on integration of the pre-Project gravel transport curves over the Maximum Load Following OS-1 flows, the gravel loads in the lower part of the Middle River will be only about 7 percent of the pre-Project loads (Figure 6.0-3). Based on the same assumptions, the gravel loads at Sunshine in the upstream portion of the Lower River will be about 51 percent of the pre-Project loads, and this increases to about 80 percent at Susitna Station.

The above information was used to develop a preliminary sediment balance for the Lower and Middle Rivers under pre-Project and Maximum Load Following OS-1 conditions (Tables 6.0-1 and 6.0-2). Ungaged tributaries between the Watana Dam site and the Gold Creek gage account for about 16 percent of the total drainage at Gold Creek, and ungaged tributaries between Sunshine and Susitna Station account for about 11 percent of the total drainage area at Susitna Station. Because they may contribute sufficient sediment to the mainstem to affect this balance, estimates of the ungaged tributary sediment inflows were made based on the unit yields of the various size-ranges of sediment from the available data. Based on these very preliminary estimates, the silt/clay load from ungaged tributaries contribute about 120,000 tons/year of silt/clay to the Middle River on an average annual basis, and the ungaged tributaries between Sunshine and Susitna Station contribute about 2.4M tons/year of silt/clay to the Lower River.

Assuming that the unit sand yield is approximately the same at the Watana Dam site as it is at the Gold Creek/near Talkeetna gages (~220 tons/mi^2/year), the average annual total sand load at the dam site is about 1.2M tons/year. Further assuming that the Middle River is supply limited with respect to the sand loads, the total sand load passing Gold Creek/near Talkeetna is the same as the total upstream supply and the ungaged tributaries in the Middle River deliver about 210,000 tons of sand to the river on an average annual basis. Based on these estimates, the total sand supply to Sunshine from the Middle River and tributaries under pre-Project conditions is about 6.2M tons, which is remarkably similar to the estimated pre-Project sand load at Sunshine, discussed above, of about 6.1M tons (Figure 6.0-4). Assuming that the ungaged tributaries between Sunshine and Susitna Station have unit sand yields that are similar to the ungaged tributaries to the Middle River, these tributaries deliver about 530,000 tons/year of sand to the Lower River. Based on the sum of the Sunshine, Yentna River and ungaged tributary inflows, the total sand load above Susitna Station is about 14.8M tons/year, very close to the average annual sand load at Susitna Station of 14.3M tons, estimated by integrating the Susitna Station sand-load rating curves over the 61-year pre-Project flow record. Collectively, these results indicate that the Middle and Lower Rivers are in approximate balance with respect to sand loads under pre-Project conditions.

Under Maximum Load Following OS-1 conditions, the sand supply to the upstream end of the Middle River will be essentially eliminated. As noted above, the sand loads in the lower part of the Middle River will remain about the same as they are under pre-Project conditions during the early period of Project operations, with the downstream sand loads decreasing over time to a level that is consistent with the tributary inflows as the sand that is currently stored within the mainstem river channel is depleted. After this occurs, the sand supply to the Three Rivers Confluence will diminish to about 5M tons. Since the sand load is most likely supply-limited in this part of the reach, the sand load at Sunshine will decrease to a level consistent with the supply (i.e., ~5M tons/year, on average).

The sand supply from the Yentna River and other ungaged tributaries between Sunshine and Susitna Station is estimated to be about 8.7M tons. Considering the 5M ton sand load at Sunshine, the total sand supply above Susitna Station under Maximum Load Following OS-1 is about 13.7M tons. The degree to which the sand load between Sunshine and the Yenta River confluence is supply-limited is not apparent from the available information. Based on the available data, however, the bed material at Susitna Station is primarily sand; thus, the sand load at this location is probably not supply-limited. This means that the quantity of sand transported in this part of the Lower River is controlled primarily by the flows and not by the upstream supply, and the Project effects on the sand load can be estimated by directly integrating the sand-load rating curves over the Project conditions flow record. Based on this integration, the average annual sand load at Susitna Station will decrease to about 13M tons. Considering the uncertainty in the sand-load estimates, the cumulative sand supply above Susitna Station and the load at Susitna Station are essentially the same (13.7M tons versus 13M tons); thus, this part of the reach would likely remain in approximate balance with respect to the sand load under Maximum Load Following OS-1 conditions.

Based on the gravel transport curves, the unit gravel load at Gold Creek/near Talkeetna is about 11 tons/mi^2/year. Assuming that the unit yields are similar, the average annual gravel load at the dam site is about 56,000 tons under pre-Project conditions and the gravel supply from the ungaged tributaries is about 11,000 tons (Figure 6.0-5). Based on these estimates and the estimated gravel loads from the Chulitna and Talkeetna Rivers presented above, the total gravel supply upstream from Sunshine under pre-Project conditions is about 870,000 tons, compared to the estimated loads at Sunshine of about 280,000 tons. Even considering the uncertainty in the transport relationships, these results strongly indicate that the river is aggradational between the Three Rivers Confluence and Sunshine. This conclusion is supported by the highly braided character of the river in this part of the reach. The gravel loads at Sunshine and the Yentna River from the results in the previous section equate to unit yields of about 27 and 25 tons/ mi^2/year, respectively. Assuming that the ungaged tributaries between Sunshine and Susitna Station have similar unit yields, these tributaries deliver approximately 53,000 tons of gravel to the mainstem on an average annual basis. The approximate gravel supply to the lower river from Sunshine, the Yentna River and the ungaged tributaries, therefore, averages about 510,000 tons/year. The average annual gravel load at Susitna Station under pre-Project conditions is about 260,000 tons, indicating that the portion of the Lower River between Sunshine and Susitna Station is also net aggradational. Similar to the Three Rivers Confluence to Sunshine portion, this result is consistent with the highly braided character of this part of the river.

Under Maximum Load Following OS-1 conditions, the average annual gravel load at Sunshine will decrease to about 142,000 tons; thus, the total gravel supply above Susitna Station will decrease to about 375,000 tons/year. Based on integration of the gravel load rating curve over the Maximum Load Following OS-1 flow record, the average annual gravel load at Susitna Station would decrease to about 207,000 tons. This indicates that the reach between Sunshine and Susitna Station would remain aggradational, but the relative imbalance in gravel loads would decrease by about one-third from an excess of 252,000 tons under pre-Project conditions to about 168,000 tons under Maximum Load Following OS-1 conditions.

As described in RSP Sections 6.5.4.3 and 6.6, and based on the above results, the following actions will be implemented:

1. New sediment load data that have been collected over the past few years by the USGS will be incorporated into the analysis to improve the sediment-transport rating curves.
2. The USGS will extend their sediment data collection program to include bed load, suspended sediment load, bed material and discharge to include Susitna Station and the Yentna River near Susitna Station to support the recent decision (Tetra Tech 2013b) to extend the 1-D sediment- transport model downstream to Susitna Station (PRM 29). The data from this effort will facilitate comparison with the 1980s data at these locations to check the validity of the earlier data, and it will also expand the data base that is available for development of sediment- transport relationships.
3. The updated sediment-transport rating curves for the mainstem gages will be used to calibrate the sediment-transport rates in the reach-wide 1-D sediment-transport model.
4. In the current analysis, sediment loading from all ungaged sources was lumped into the “ungaged tributary” category. In reality, sediment is also supplied to the river from bank erosion and mass wasting from unstable hillslopes. Estimates of the sediment loading from all of these sources, including the ungaged tributaries, will be segregated and improved based on field observations, evaluation of lateral bankline shifting and bed material measurements and transport capacity calculations in the lower end of a selected number of the larger ungaged tributaries. As described in RSP Section 6.6.4.1.2.6 (AEA 2012), sediment-load rating curves for the ungaged tributaries will be developed by surveying cross sections and collecting bed material samples in an appropriate reach near the mouth, developing 1-D hydraulic conditions using either step-backwater or normal depth calculations, as appropriate, and applying an appropriate bed material transport equations with the measured bed material gradations. For those tributaries that enter the river within the Focus Areas, the hydraulic and sediment-transport analysis to assess the response of the Susitna River channel to Project conditions will be performed using the 2-D model(s). For the selected tributaries outside the focus areas, the analysis will be performed using 1-D hydraulic modeling with relatively closely spaced cross sections in the vicinity of the confluence.
5. The tributary-specific sediment loads estimated in the previous task will be used to assess the potential impact of changes in flow and sediment load in the mainstem on the sediment-transport behavior at the tributary mouths. A key question to be answered by this analysis is

the extent to which the coarse-grained sediment from the tributaries will be entrained and transported downstream away from the tributary mouth versus building of the delta in a manner that could potentially affect fish passage into the tributary and/or constrict the river causing other impacts to water-surface elevations and channel stability. Similar to the sediment loading analysis, the analysis for those tributaries that are located within a Focus Area will be conducted using the 2-D mobile-boundary model. At the selected tributaries outside the Focus Areas, additional mainstem cross sections (typically 5 to 7, in total) will be surveyed in the vicinity of the mouth, and 1-D hydraulic modeling and sediment-transport calculations will used to perform the assessment.

6. Section 6.6.4.1.2.6., Tributary Delta Modeling of the RSP (AEA 2012), indicates that modeling of the sediment-transport dynamics at the Three Rivers Confluence may be necessary to understand the potential effects of Project operations. Based on the initial sediment balance presented above, the total gravel bed-load supply that is key to the behavior of this area would decrease by only about 7 percent from about 871,000 ton/year, on average, to about 810,000 tons/year under Maximum Load Following OS-1 conditions because of the overwhelming contribution from the Chulitna River and the large (relative to Middle River) contribution from the Yentna River. The transport capacity for gravel bed load past the Sunshine gage would decrease by about 50 percent from about 279,000 tons/year to about 142,000 tons/year under Maximum Load Following OS-1 conditions. As a result, the pre-Project gravel excess in this area will increase by about 12 percent from 592,000 to 667,000 ton/year. Under pre-Project conditions, the excess in gravel load corresponds to a net aggradational tendency that averages about 0.05 feet/year over the approximately 5,600-acre active channel between the confluence and the Sunshine gage. The aggradational tendency would increase modestly to about 0.055 feet/year under Maximum Load Following OS-1 conditions. (Of course, the aggradation depths will vary spatially within this area, with some locations changing significantly more than the average and some locations significantly less.) Because of the relatively small net change, however, it is our opinion that the potential impacts to this area can be adequately described based on the refined reach-wide sediment balance that will be developed from the 1-D mobile sediment-transport modeling, field observations, and knowledge of how rivers typically respond to modest changes in sediment load. As a result, additional 2-D mobile boundary modeling in this large and complex area is not warranted.

7. In spite of the above opinion that 2-D modeling of the Three Rivers Confluence is not warranted, AEA will extend the 1-D sediment-transport model downstream to at least Susitna Station (PRM 29) (Tetra Tech 2013b). Based on the limited bed material data that is available from the previous studies, the bed is primarily gravel with median (D_{50}) size in the range of 50 to 100 millimeters (mm), and only a small amount of sand (typically <5 percent) at Sunshine. In contrast, the bed material at Susitna Station is primarily sand (D_{50}~0.4 mm and nearly 90 percent <2 mm based on one sample). Based on this information, alone, the sediment load at Sunshine is almost certainly supply-limited with respect to sand, but is capacity-controlled with respect to sand at Susitna Station. From the above rating curve analysis, the reach between Sunshine and Susitna Station, and possibly through Susitna Station, is aggradational under pre-Project conditions with respect to both the sand and gravel loads (excess of ~250,000 and 562,000 tons/year, respectively). Under Maximum Load Following OS-1 conditions, that reach will remain aggradational for both components of the sediment load, but the magnitude of the excess in gravel supply will decrease by about one-

third to 168,000 tons/year, while the excess in sand load will increase by about 24 percent to 694,000 tons/year, due primarily to the reduced transport capacity associated with the change in flow regime. The Yentna River supplies about 55 percent of the sand load and 35 percent of the gravel load; thus is probably a significant factor in the mainstem dynamics at and downstream from Susitna Station. Sufficient information is not available at this time to identify the location of the transition zone from supply-limited to capacity-controlled in the Lower River, and specifically whether this occurs above or below the Yentna River confluence. This determination will be important in understanding potential Project effects. The sediment-transport behavior of mainstem at the tributary mouths will also be an important factor in understanding Project effects in the Lower River, particularly in the reaches upstream from the gravel-sand transition zone. The 1-D sediment- transport modeling will be a key tool in making these assessments.

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8. TABLES

Table 3.0-1. List of streamflow gages.

Gage Number	Gage Name	Drainage Area (sq mi)	Gage Datum (NGVD 29, feet)	Latitude	Longitude	Available Record	Extended Record	Main Stem River Mile
15290000	Little Susitna River near Palmer	63	917	61º 42' 37"	149º 13' 47"	1948 - 2011		-
15291000	Susitna River near Denali	950	2,440	63º 06' 14"	147º 30' 57"	1957 - 1966; 1968 - 1986	Yes	291
15291200	Maclaren River near Paxson	280	2,866	63º 07' 10"	146º 31' 45"	1958 - 1986	Yes	-
15291500	Susitna River near Cantwell	4,140	1,900	62º 41' 55"	147º 32' 42"	1961 - 1972; 1980 - 1986	Yes	223
15292000	Susitna River at Gold Creek	6,160	677	62º 46' 04"	149º 41' 28"	1949 - 1996; 2001 - 2011	Yes	136
15292400	Chulitna River near Talkeetna	2,570	520	62º 33' 31"	150º 14' 02"	1958 - 1972; 1980 - 1986	Yes	-
15292700	Talkeetna River near Talkeetna	1,996	400	62º 20' 49"	150º 01' 01"	1964 - 2011	Yes	-
15292780	Susitna River at Sunshine	11,100	270	62º 10' 31.3"	150º 10' 13.5"	1981 - 1986	Yes	84
15292800	Montana Creek near Montana	164	250	62º 06' 19"	150º 03' 27"	2005 - 2006; 2008 - 2011		-
15294005	Willow Creek near Willow	166	350	61º 46' 51"	149º 53' 04"	1978 - 1993; 2001 - 2011	Yes	-
15294010	Deception Creek near Willow	48	250	61º 44' 52"	149º 56' 14"	1978 - 1985		-
15294100	Deshka River near Willow	591	80	61º 46' 05"	150 20' 13"	1978 - 1986; 1998 - 2001		-
15294300	Skwentna River near Skwentna	2,250	200	61º 52' 23"	151 22' 01"	1959 - 1982	Yes	-
15294345	Yentna River near Susitna Station	6,180	80	61º 41' 55"	150 39' 02	1980 - 1986	Yes	-
15294350	Susitna River at Susitna Station	19,400	40	61º 32' 41"	150 30' 45	1974 - 1993	Yes	28

Table 3.0-2. Sediment-transport data summary.

Gage Number	Gage Name	Number of Samples								Record
		Suspended Silt/Clay		Suspended Sand		Bed-load Sand		Bed-load Gravel		
		Pre-1985	Post-1985	Pre-1985	Post-1985	Pre-1985	Post-1985	Pre-1985	Post-1985	
15292000	Susitna River at Gold Creek	45	5	46	5	45	0	38	0	1962 - 1986
15292400	Chulitna River near Talkeetna	48	2	46	2	48	0	48	0	1973 - 1986
15292700	Talkeetna River near Talkeetna	53	23	56	22	45	0	40	0	1967 - 1995
15292780	Susitna River at Sunshine	52	2	53	2	50	0	50	0	1971 - 1986
15294345	Yentna River near Susitna Station	24	1	24	1	13	0	13	0	1981 - 1986
15294350	Susitna River at Susitna Station	37	9	35	9	13	5	13	3	1975 - 2003

Table 4.1-1. Summary of sediment load relationships used for the analysis.

Gage Number	Gage Name	Suspended Load		Bed Load	
		Silt/Clay	Sand	Sand	Gravel
15292000	Susitna River at Gold Creek	$6.97E-10\ Q^{3.00}$	$1.09E-11\ Q^{3.38}$	$4.49E-9\ Q^{2.46}$	$1.89E-20\ Q^{4.84}$
			n = 51 (46/5), R^2 = 0.89	$1.02E-11\ Q^{3.10}$	
15292400	Chulitna River near Talkeetna	$1.12E-7\ Q^{2.66}$	$1.01E-5\ Q^{2.14}$	$5.1E-6\ Q^{2.09}$	$2.6E-9\ Q^{2.80}$
		n = 50 (48/2), R^2 = 0.91	n = 48 (46/2), R^2 = 0.86	$3.51E-12\ Q^{3.63}$	$1.23E-14\ Q^{4.22}$
15292700	Talkeetna River near Talkeetna	$2.33E-8\ Q^{2.81}$	$2.58E-6\ Q^{2.32}$	$2.17E-5\ Q^{1.82}$	Parker Equation
		n = 76 (53/23), R^2 = 0.76	n = 78 (56/22), R^2 = 0.86	$1.43E-12\ Q^{3.99}$	
15292780	Susitna River at Sunshine	$2.29E-8\ Q^{2.61}$	$3.28E-6\ Q^{2.12}$	$8.16E-4\ Q^{1.29}$	$3.11E-17\ Q^{4.07}$
		n = 54 (52/2), R^2 = 0.82	n = 55 (53/2), R^2 = 0.83		$3.68E-2\ Q^{0.820}$
15294345	Yentna River near Susitna Station	$1.27E-7\ Q^{2.48}$	$4.10E-6\ Q^{2.14}$	$1.93E-4\ Q^{1.63}$	$1.99E-9\ Q^{2.49}$
		n = 25 (24/1), R^2 = 0.94	n = 25 (24/1), R^2 = 0.84		
15294350	Susitna River at Susitna Station	$4.49E-8\ Q^{2.46}$	$3.31E-3\ Q^{1.46}$	$4.45E-7\ Q^{2.04}$	$4.85E-10\ Q^{2.47}$
		n = 46 (37/9), R^2 = 0.87	n = 44 (35/9), R^2 = 0.87	n = 18 (13/5), R^2 = 0.92	n = 16 (13/3), R^2 = 0.92

from Knott et al (1987)

New Regression

Q = Water discharge in cfs
Sediment load in tons/day (tpd)
n = Total number of sample points (pre-1985 data/post-1985 data)

Table 6.0-1. Comparison of average annual sediment loads under pre-Project conditions.

Gage	Drainage Area (mi^2)	Water Discharge (acre-ft)	Average Annual Load (tons)				
			Wash Load	Bed Material			Total Load
			Silt/Clay	Sand	Gravel	Total	
Watana	5,180	5,803,000	1,684,000	1,197,000	56,000	1,252,000	2,936,000
Ungaged Tributaries	980	*1,242,000*	*117,000*	*213,000*	*11,000*	*223,000*	*340,000*
Supply above Gold Creek	6,160	7,045,000	1,800,000	1,409,000	66,000	1,475,000	3,276,000
Gold Creek/Susitna nr Talkeetna	6,160	7,045,000	1,800,000	1,409,000	66,000	1,475,000	3,276,000
Talkeetna	1,996	2,938,000	940,000	866,000	57,000	923,000	1,863,000
Chulitna	2,570	6,231,000	5,264,000	3,917,000	748,000	4,665,000	9,929,000
Supply above Sunshine	10,726	16,213,000	8,005,000	6,192,000	871,000	7,063,000	15,067,000
Sunshine	11,100	17,426,000	10,012,000	6,101,000	279,000	6,380,000	16,392,000
Ungaged Tributaries	2,120	*3,654,000*	*2,366,000*	*534,000*	*53,000*	*587,000*	*2,953,000*
Yentna	6,180	14,102,000	7,162,000	8,205,000	180,000	8,385,000	15,547,000
Supply above Susitna Station	19,400	35,182,000	19,540,000	14,840,000	512,000	15,352,000	34,892,000
Susitna Station	19,400	35,182,000	19,534,000	14,278,000	260,000	14,538,000	34,072,000

Table 6.0-2. Comparison of average annual sediment loads under Maximum Load Following OS-1 conditions.

Gage	Water Discharge (acre-ft)	Average Annual Load (tons)				
		Wash Load	Bed Material			Total Load
		Silt/Clay	Sand	Gravel	Total	
Watana Dam	5,785,000	168,000	0	0	0	168,000
Ungaged Tribs	*1,209,000*	*117,000*	*213,000*	*11,000*	*223,000*	*340,000*
Supply above Gold Creek	6,995,000	285,000	213,000	11,000	223,000	508,000
Gold Creek	6,995,000	285,000	213,000	4,000	217,000	502,000
Talkeetna	2,938,000	940,000	866,000	57,000	923,000	1,863,000
Chulitna	6,231,000	5,264,000	3,917,000	748,000	4,665,000	9,929,000
Supply above Sunshine	16,164,000	6,490,000	4,995,000	809,000	5,804,000	12,294,000
Sunshine	17,375,000	8,497,000	4,995,000	142,000	5,137,000	13,634,000
Ungaged Tributaries	*3,654,000*	*2,366,000*	*534,000*	*53,000*	*587,000*	*2,953,000*
Yentna	14,102,000	7,162,000	8,205,000	180,000	8,385,000	15,547,000
Supply above Susitna Station	35,131,000	18,025,000	13,734,000	375,000	14,109,000	32,134,000
Susitna Station	35,131,000	18,019,000	13,040,000	207,000	13,247,000	31,266,000

9. FIGURES

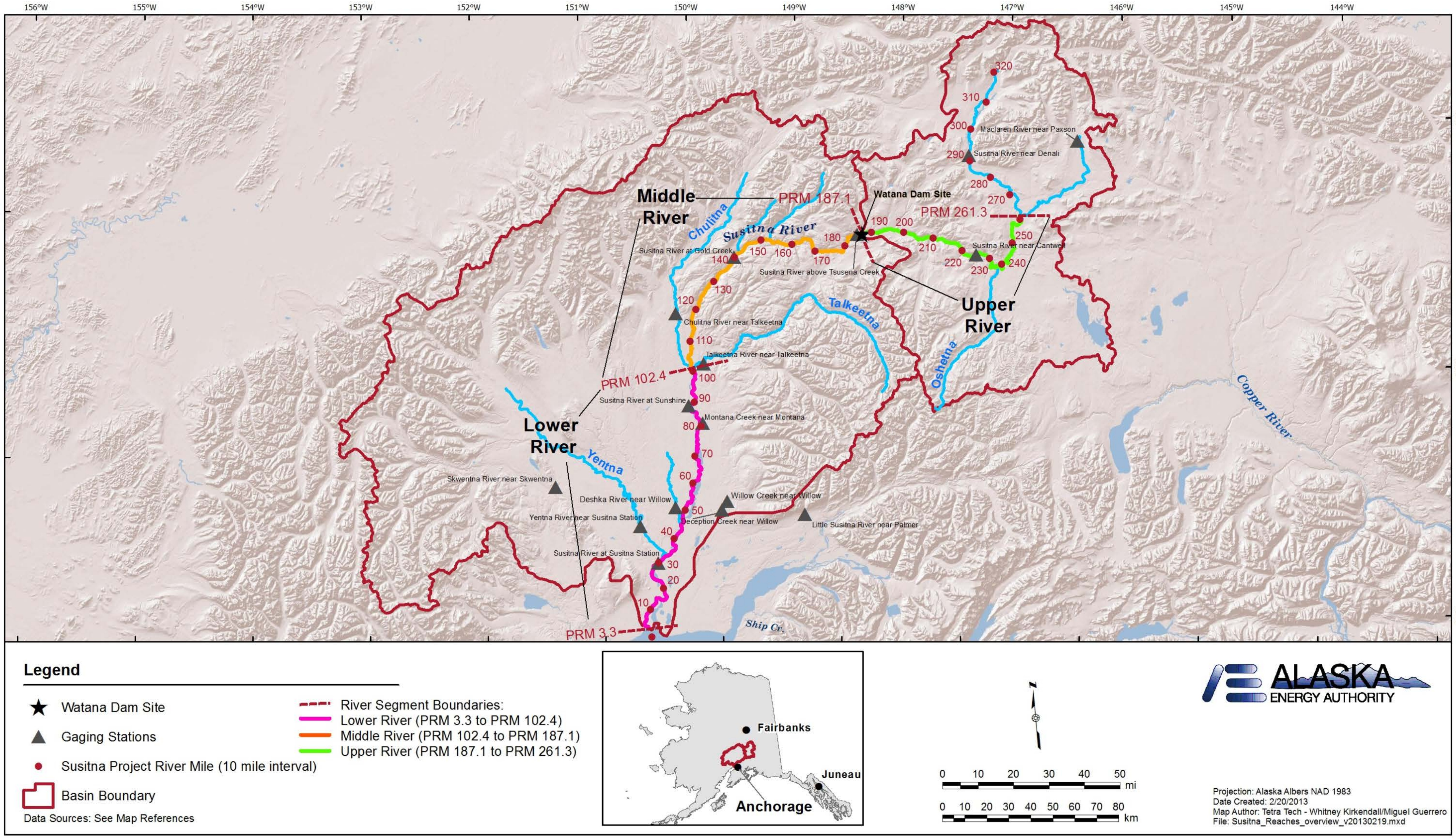

Figure 3.0-1. Susitna River study area and large-scale river segments.

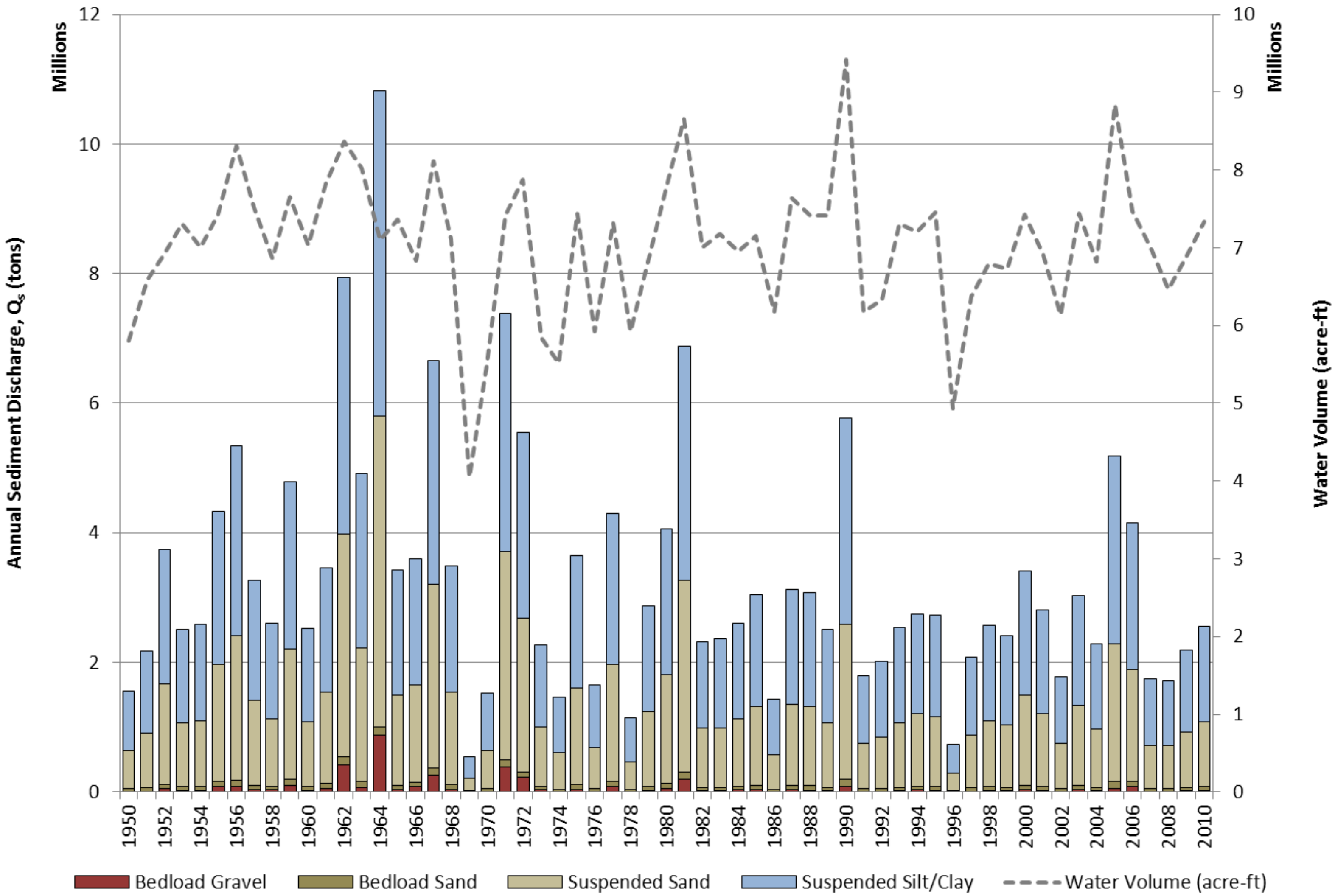

Figure 5.1-1. Estimated annual silt/clay, sand and gravel loads at the Gold Creek (Gage No. 15292000)/, Susitna River near Talkeetna (Gage No. 15292100) gage over the 61-year period of flows under pre-Project conditions. Also shown is the annual flow volume for each of the years.

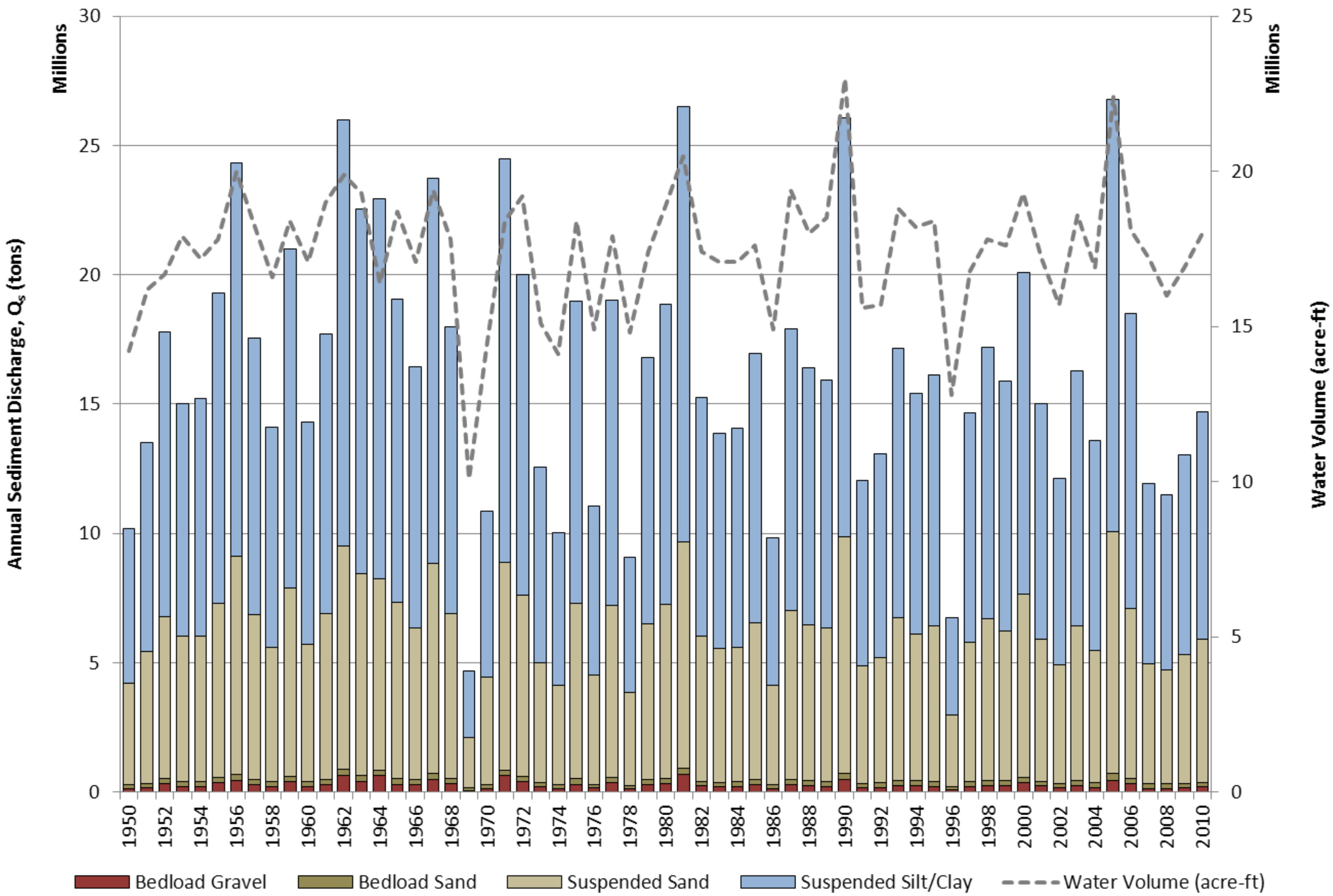

Figure 5.1-2. Estimated annual silt/clay, sand and gravel loads at the Susitna River at Sunshine (Gage No. 15292780) gage over the 61-year period of flows under pre-Project conditions. Also shown is the annual flow volume for each of the years.

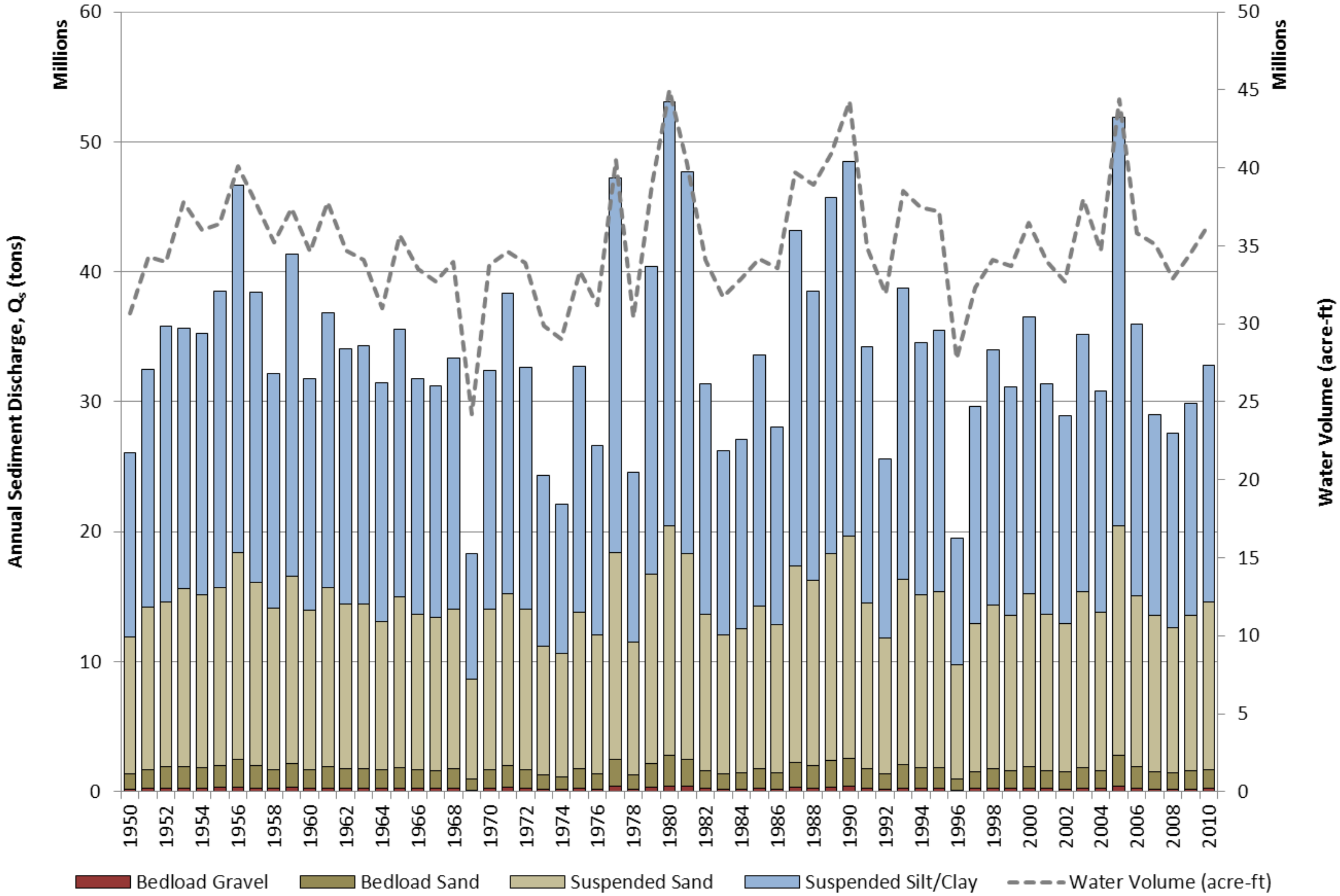

Figure 5.1-3. Estimated annual silt/clay, sand and gravel loads at the Susitna River at Susitna Station (Gage No. 15294350) gage over the 61-year period of flows under pre-Project conditions. Also shown is the annual flow volume for each of the years.

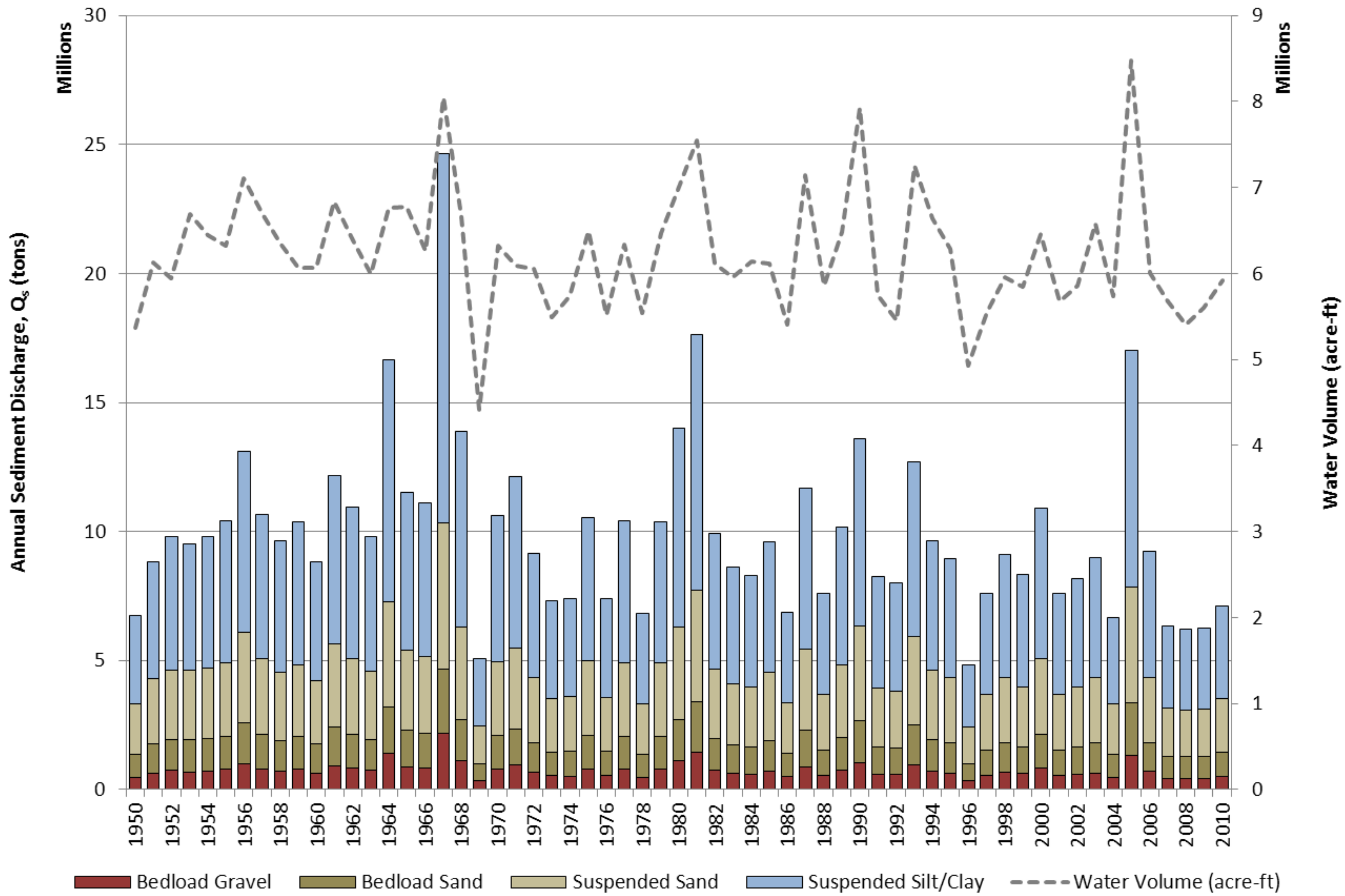

Figure 5.1-4. Estimated annual silt/clay, sand and gravel loads at the Chulitna River near Talkeetna (Gage No. 15292400), Chulitna River below Canyon near Talkeetna (Gage No. 15292410) gage over the 61-year period of flows under pre-Project conditions. Also shown is the annual flow volume for each of the years.

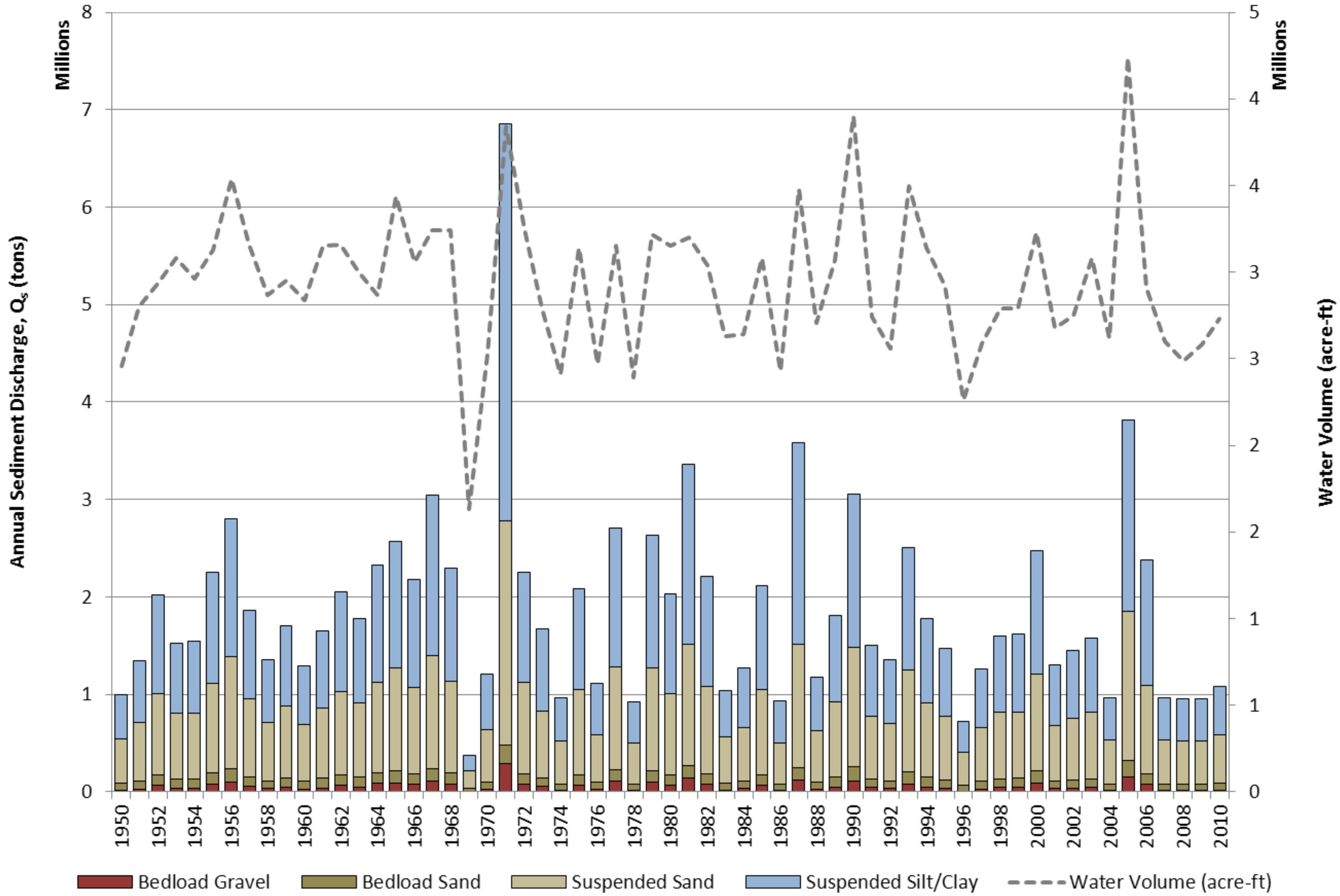

Figure 5.1-5. Estimated annual silt/clay, sand and gravel loads at the Talkeetna River near Talkeetna (Gage No. 15292700) gage over the 61-year period of flows under pre-Project conditions. Also shown is the annual flow volume for each of the years.

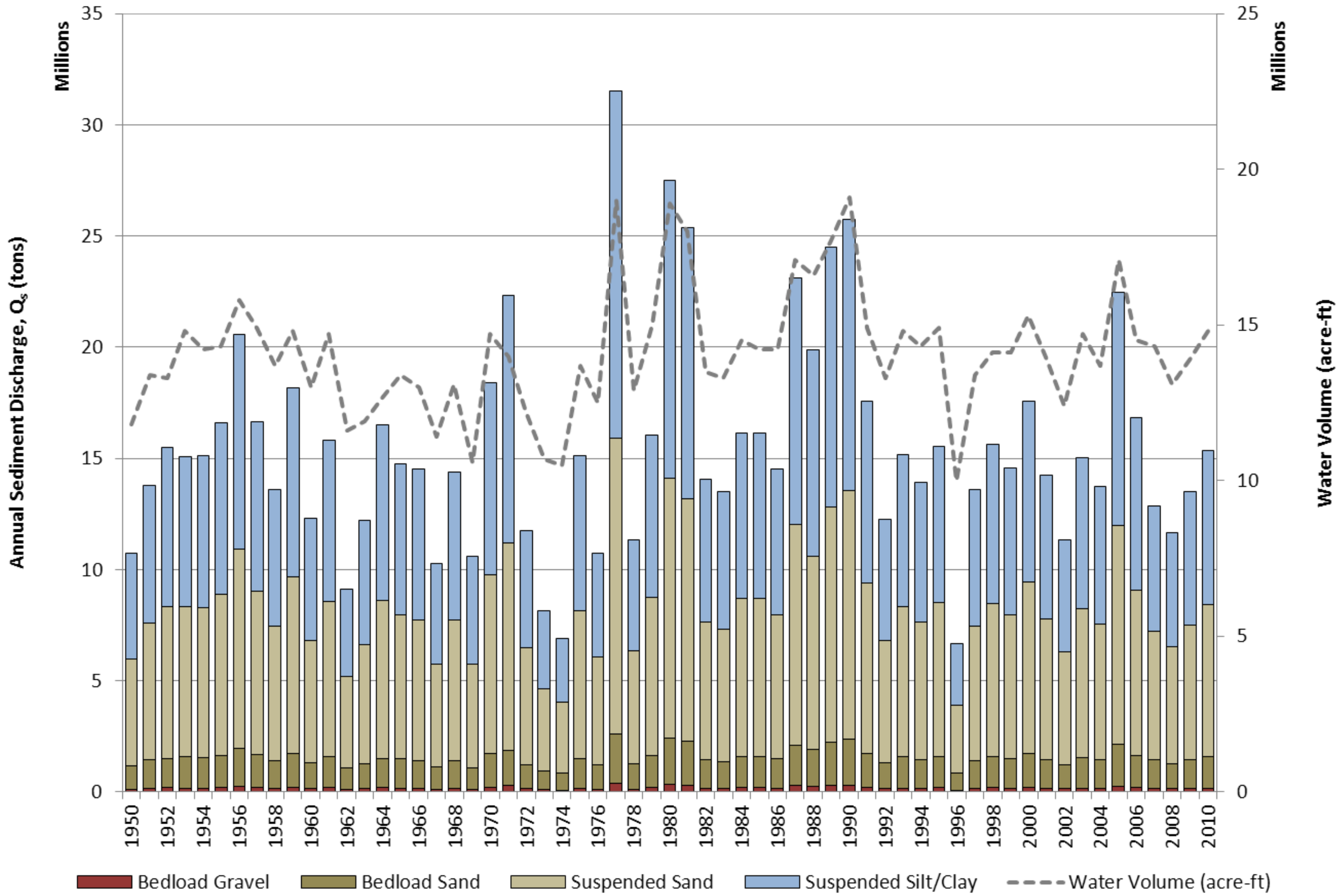

Figure 5.1-6. Estimated annual silt/clay, sand and gravel loads at the Yentna River near Susitna Station (Gage No. 15294345) gage over the 61-year period of flows under pre-Project conditions. Also shown is the annual flow volume for each of the years.

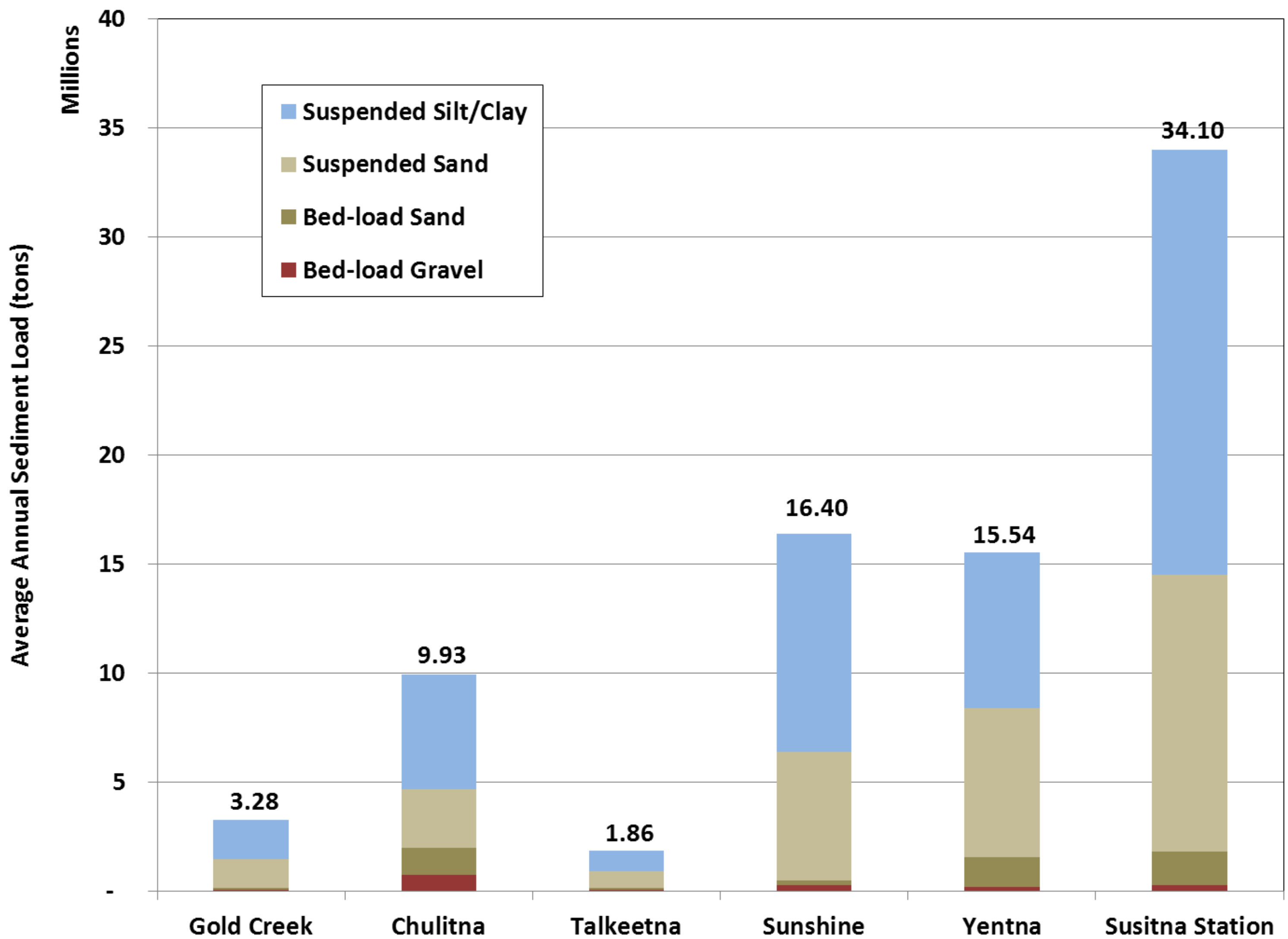

Figure 5.1.7. Average annual silt/clay, sand and gravel loads under pre-Project conditions for the three mainstem gages and three major tributary gages considered in the analysis.

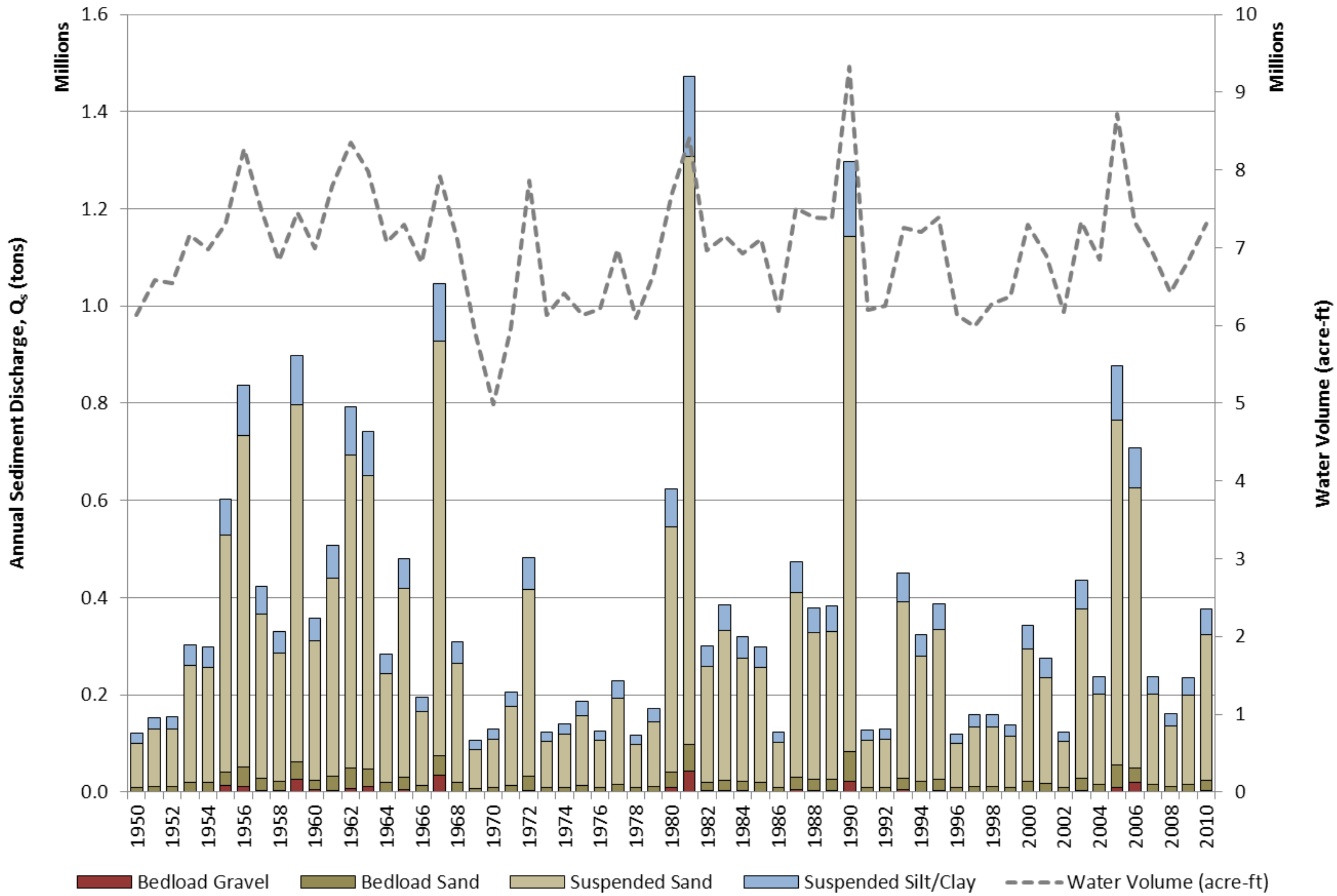

Figure 5.2-1. Estimated annual silt/clay, sand and gravel loads at the Gold Creek (Gage No. 15292000), Susitna River near Talkeetna (Gage No. 15292100) gage over the 61-year period of flows under Max LF OS-1conditions. Also shown is the annual flow volume for each of the years.

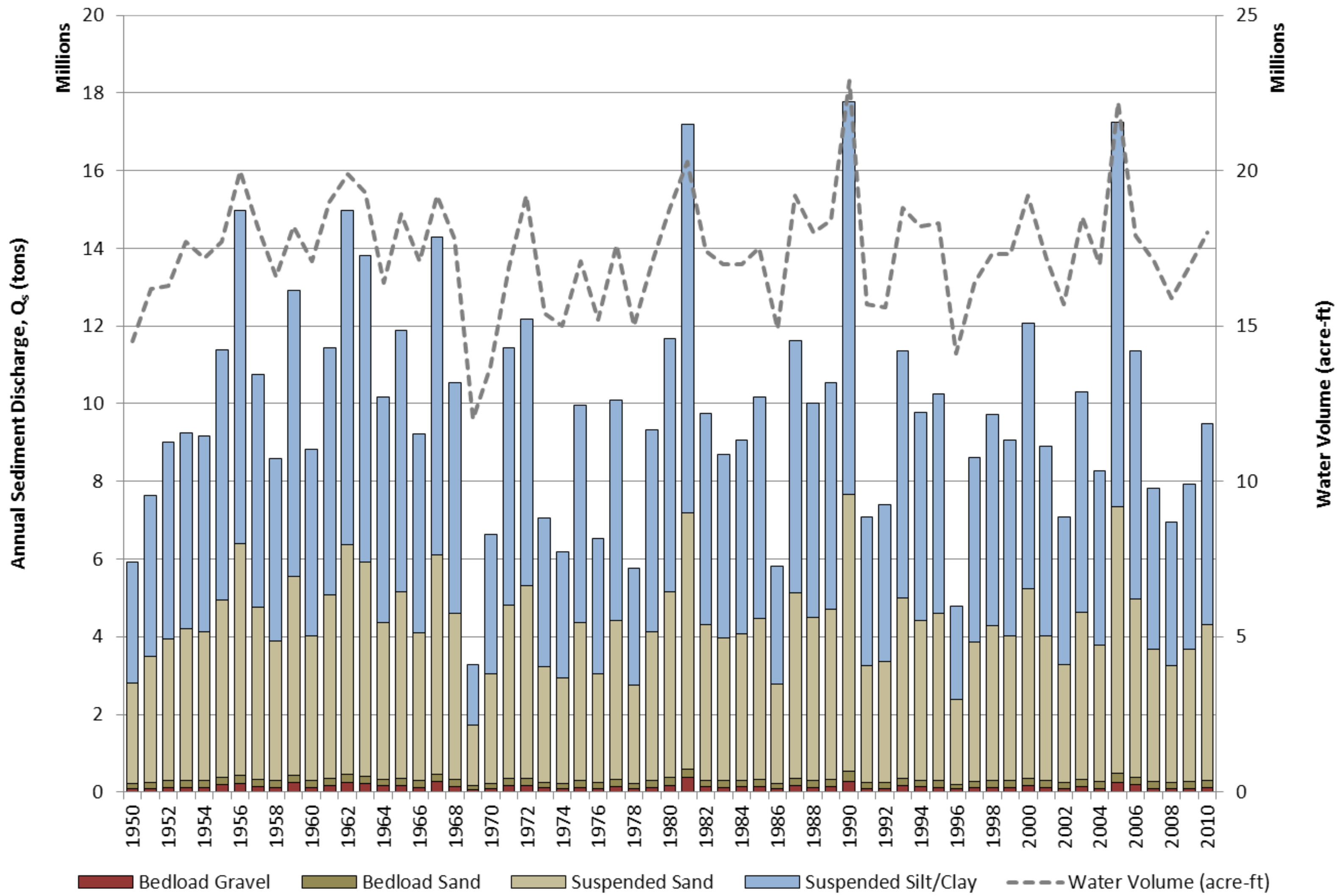

Figure 5.2-2. Estimated annual silt/clay, sand and gravel loads at the Susitna River at Sunshine (Gage No. 15292780) gage over the 61-year period of flows under Max LF OS-1conditions. Also shown is the annual flow volume for each of the years.

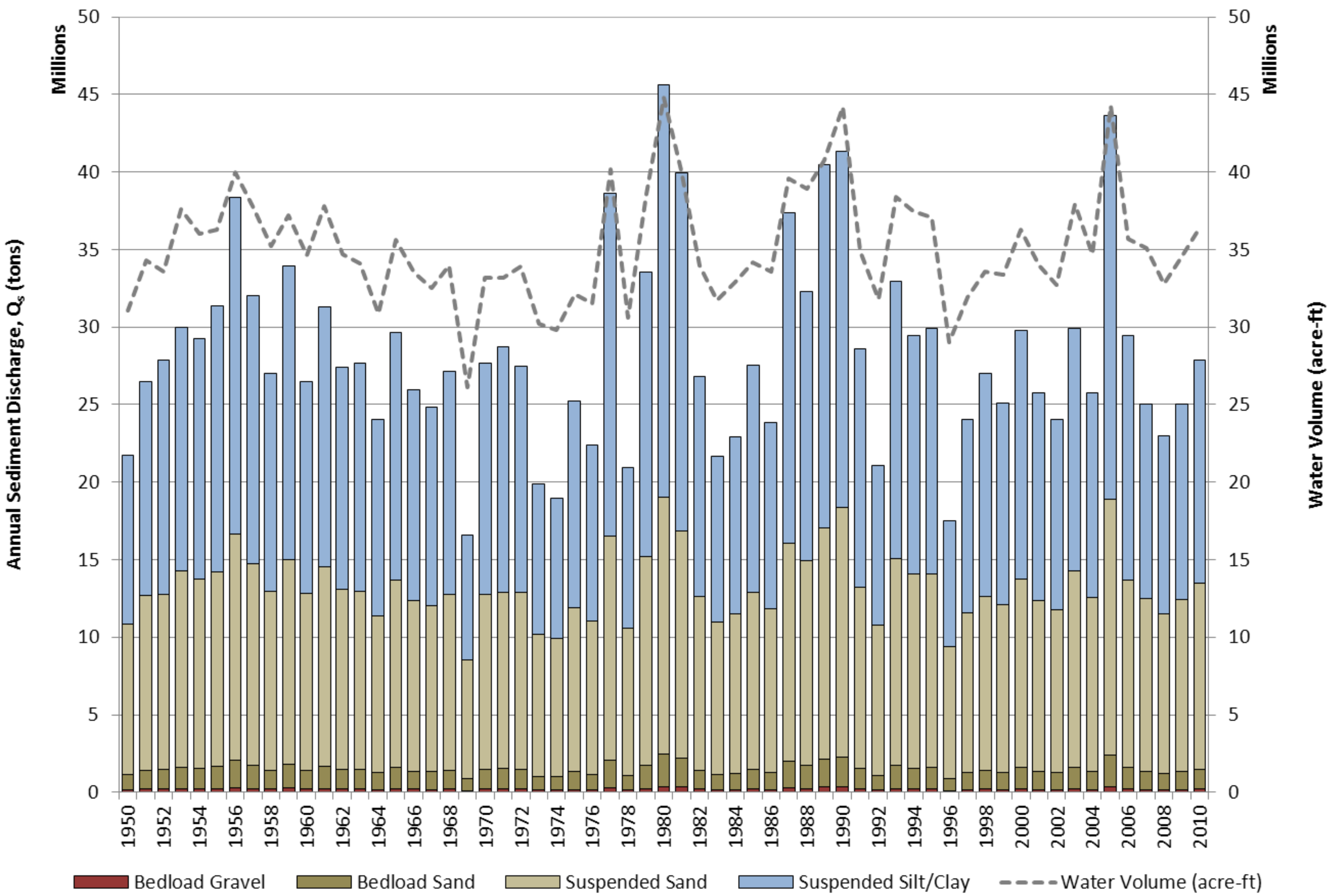

Figure 5.2-3. Estimated annual silt/clay, sand and gravel loads at the Susitna River at Susitna Station (Gage No. 15294350) gage over the 61-year period of flows under Max LF OS-1conditions. Also shown is the annual flow volume for each of the years.

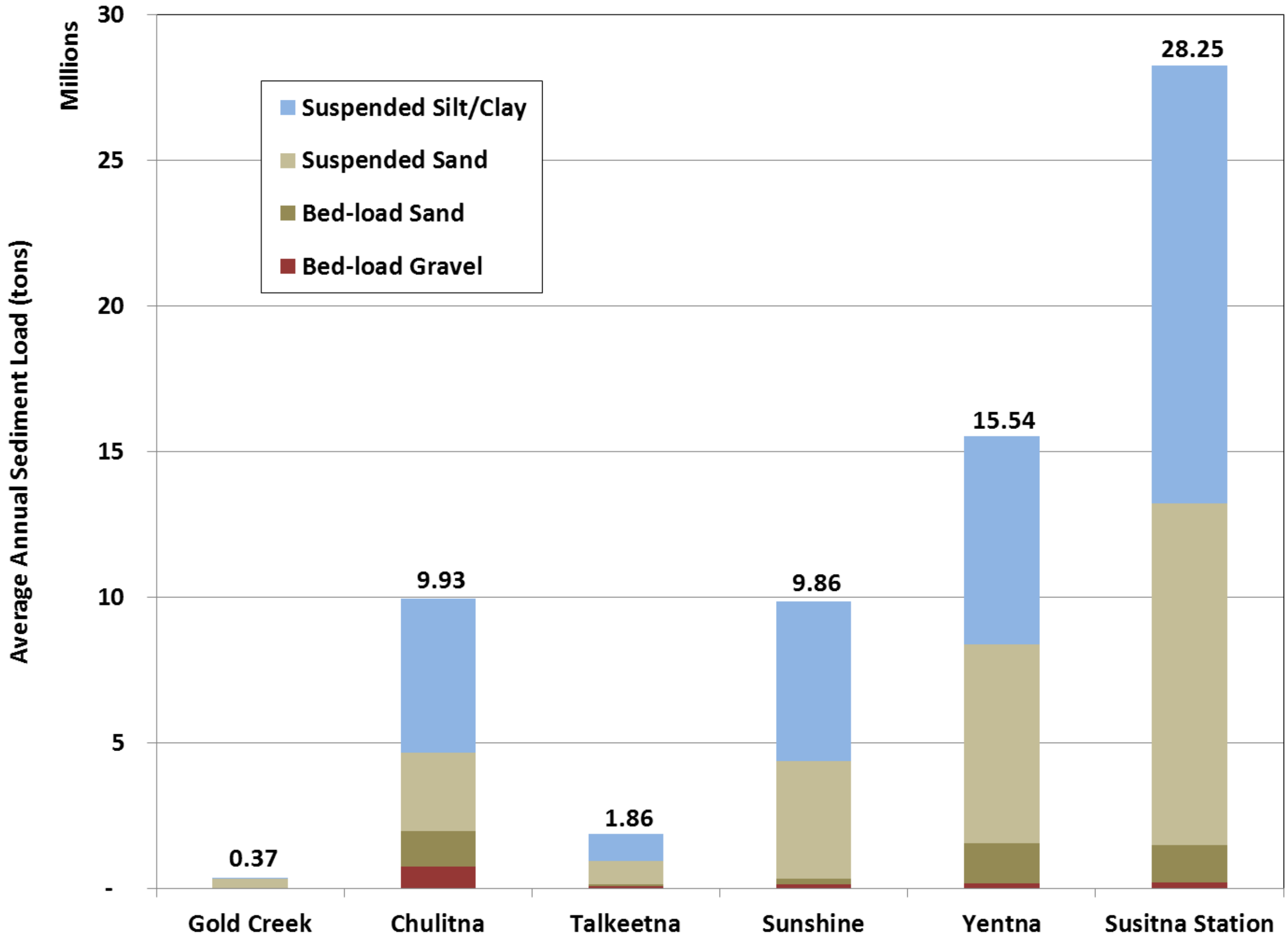

Figure 5.2.4. Average annual silt/clay, sand and gravel loads under Maximum Load Following OS-1 conditions for the three mainstem gages and three major tributary gages considered in the analysis. Note that the tributary loads are the same as pre-Project conditions.

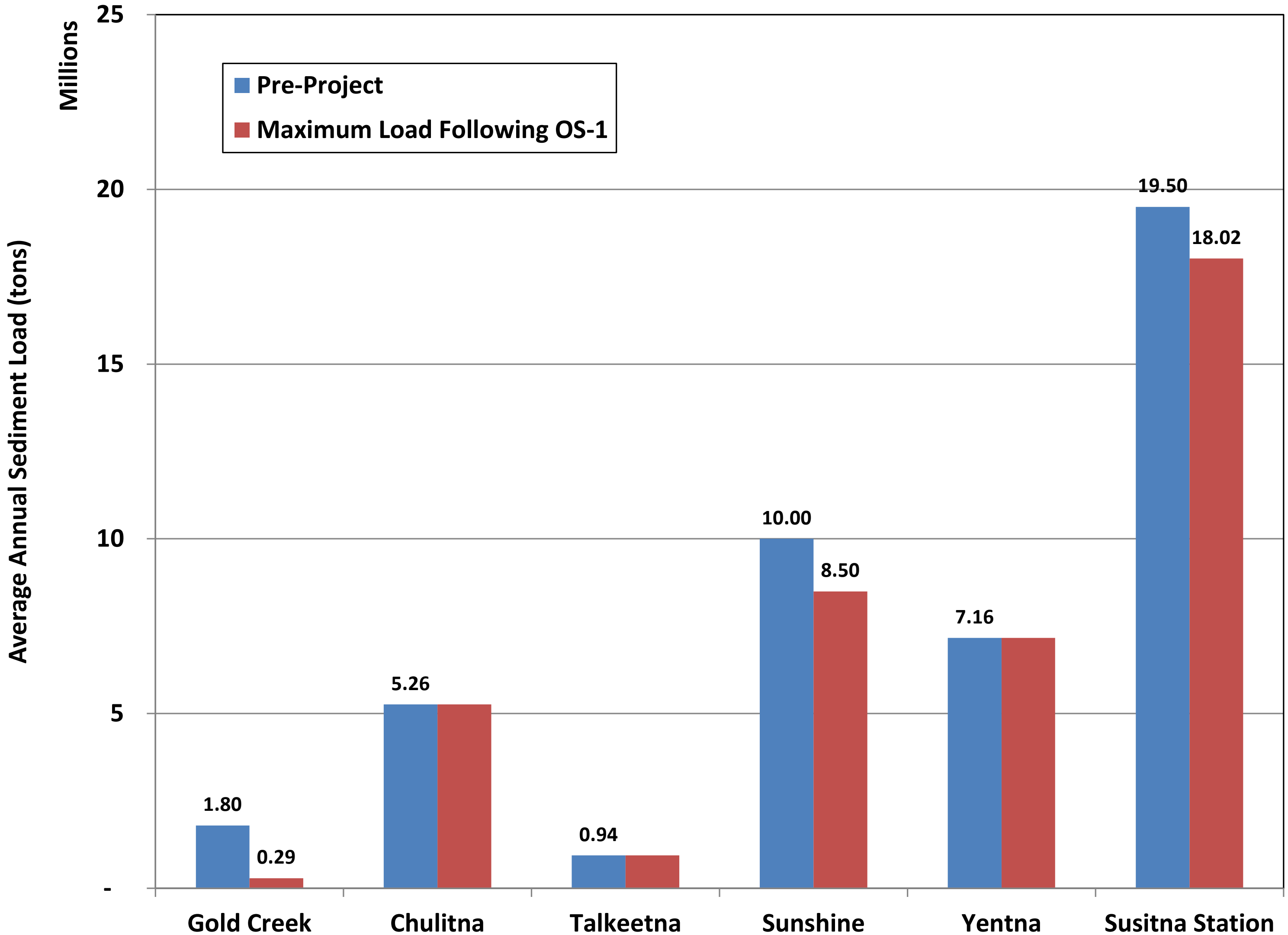

Figure 6.0-1. Average annual silt/clay loads at the three mainstem gages and the three primary tributary gages under pre-Project and Maximum Load Following OS-1 conditions.

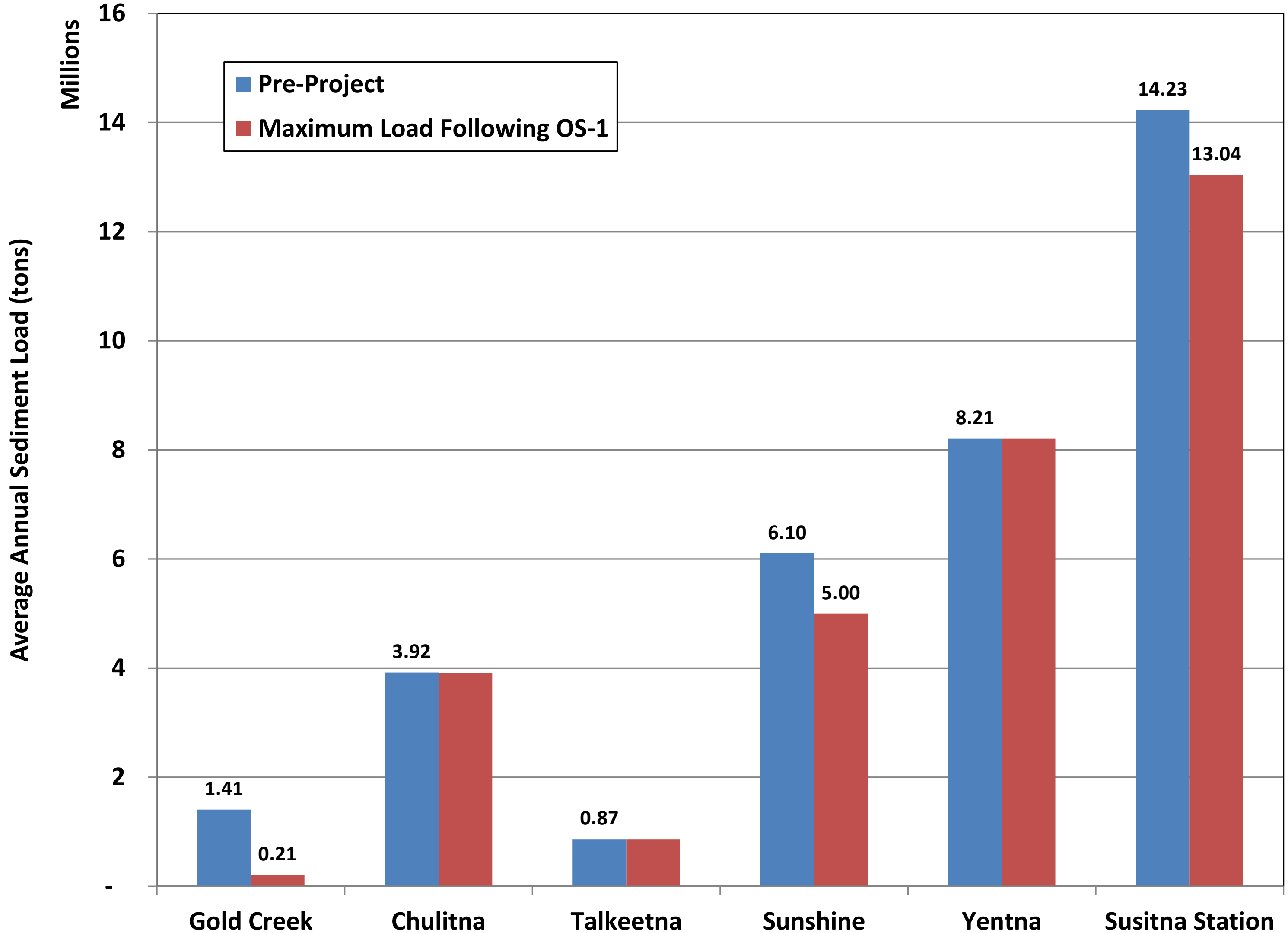

Figure 6.0-2. Average annual sand loads at the three mainstem gages and the three primary tributary gages under pre-Project and Maximum Load Following OS-1 conditions.

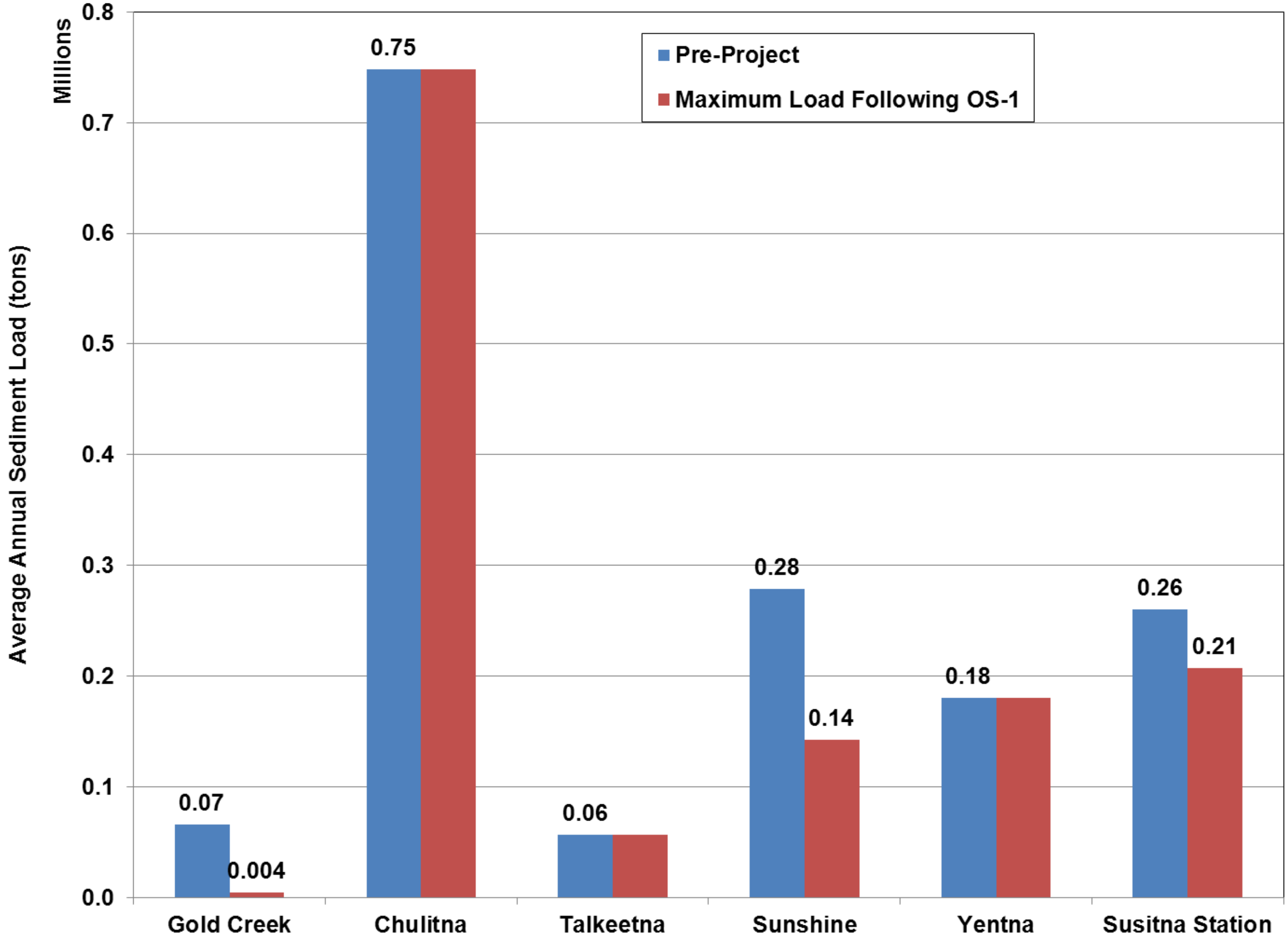

Figure 6.0-3. Average annual gravel loads at the three mainstem gages and the three primary tributary gages under pre-Project and Maximum Load Following OS-1 conditions.

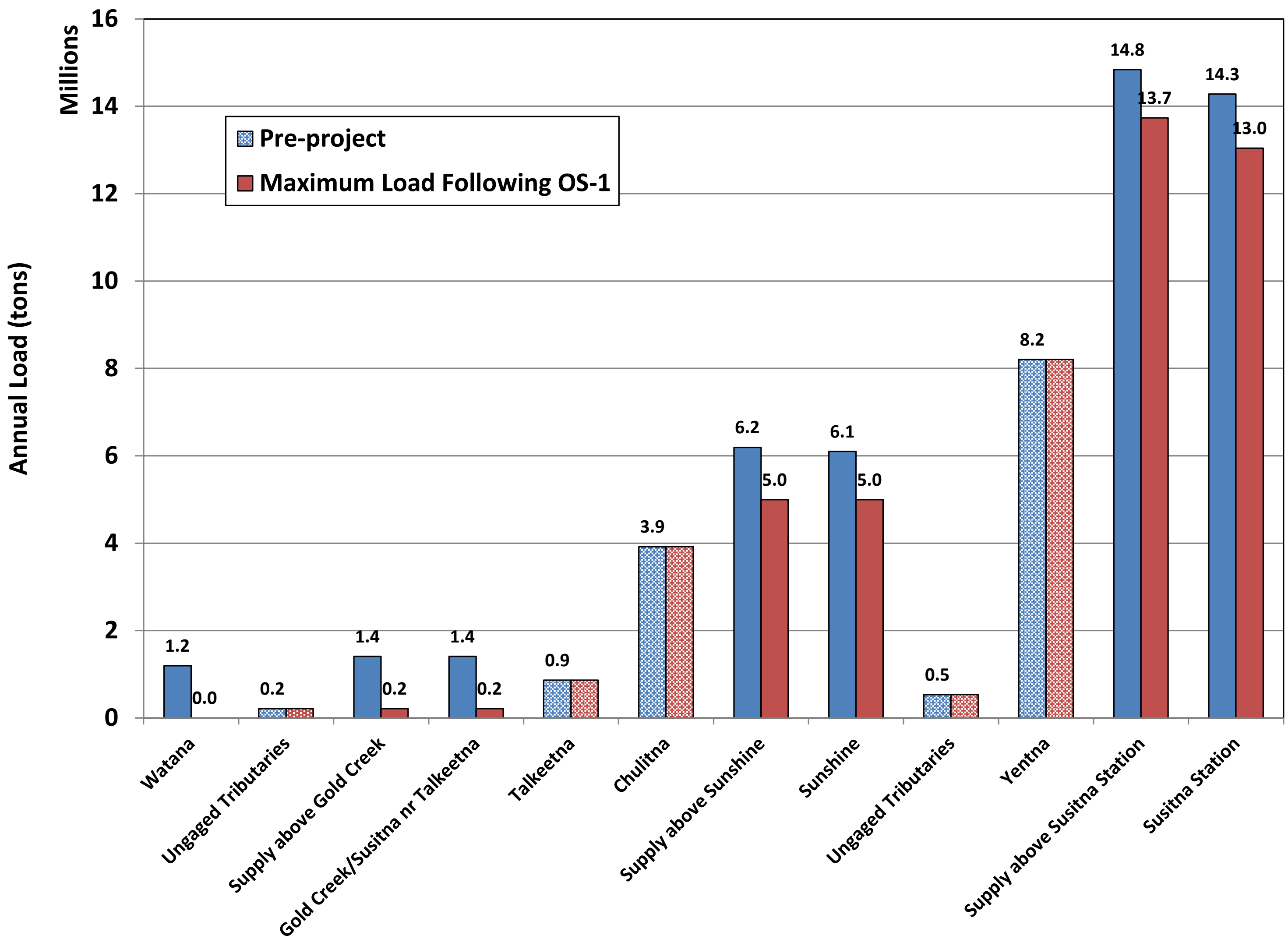

Figure 6.0-4. Average annual sand loads at the mainstem and tributary gages, along with the estimated annual sand load from ungaged tributaries, under pre-Project and Maximum Load Following OS-1 conditions. Also shown is the accumulated sediment supply to key points along the reach based on the gaged and ungaged sand loads.

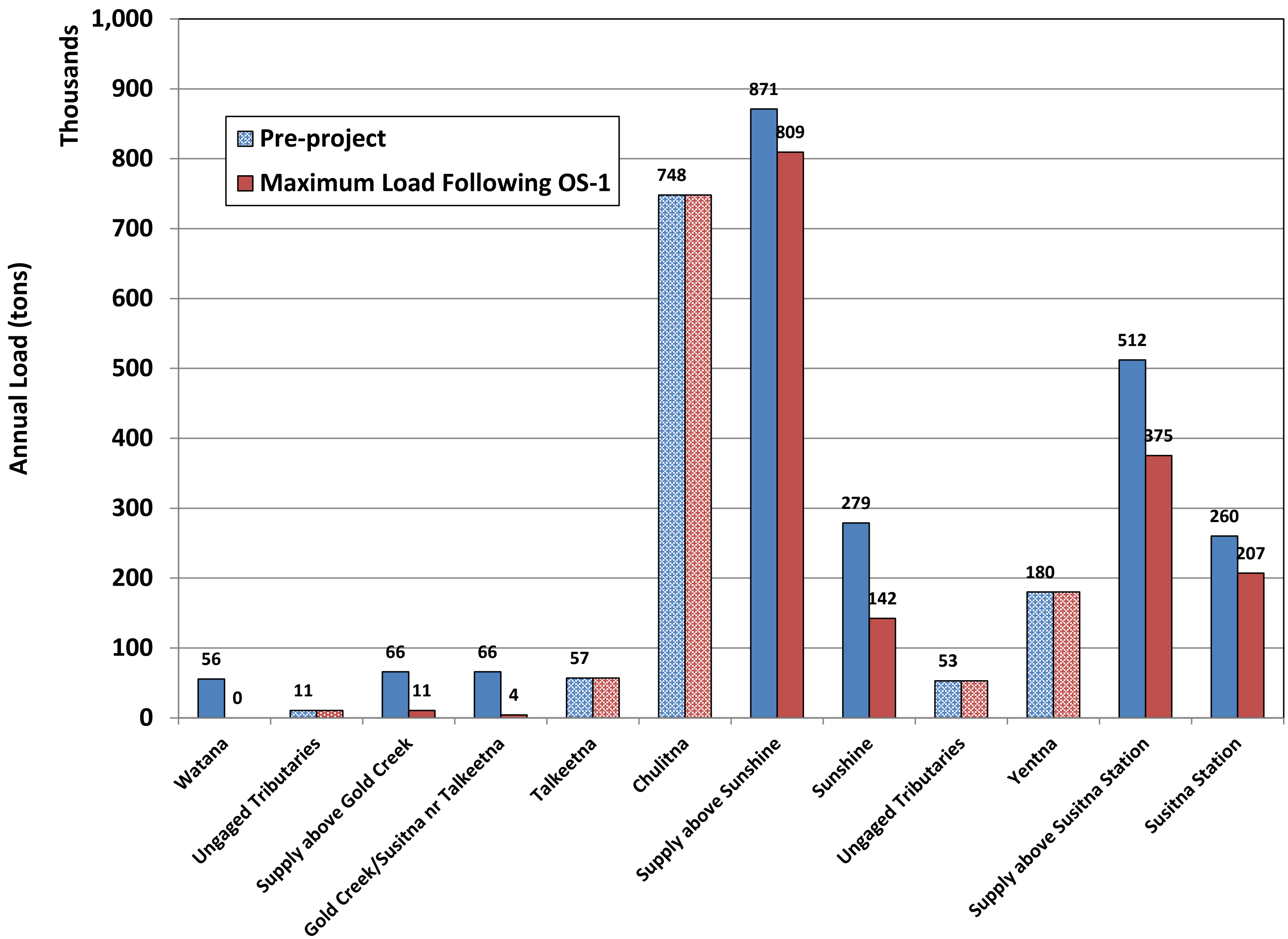

Figure 6.0-5. Average annual gravel loads at the mainstem and tributary gages, along with the estimated annual gravel load from ungaged tributaries, under pre-Project and Maximum Load Following OS-1 conditions. Also shown is the accumulated sediment supply to key points along the reach based on the gaged and ungaged gravel loads.

APPENDIX A.
SEDIMENT TRANSPORT DATA AND REGRESSION SUMMARY

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Development of Sediment Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Tetra Tech

February 2013

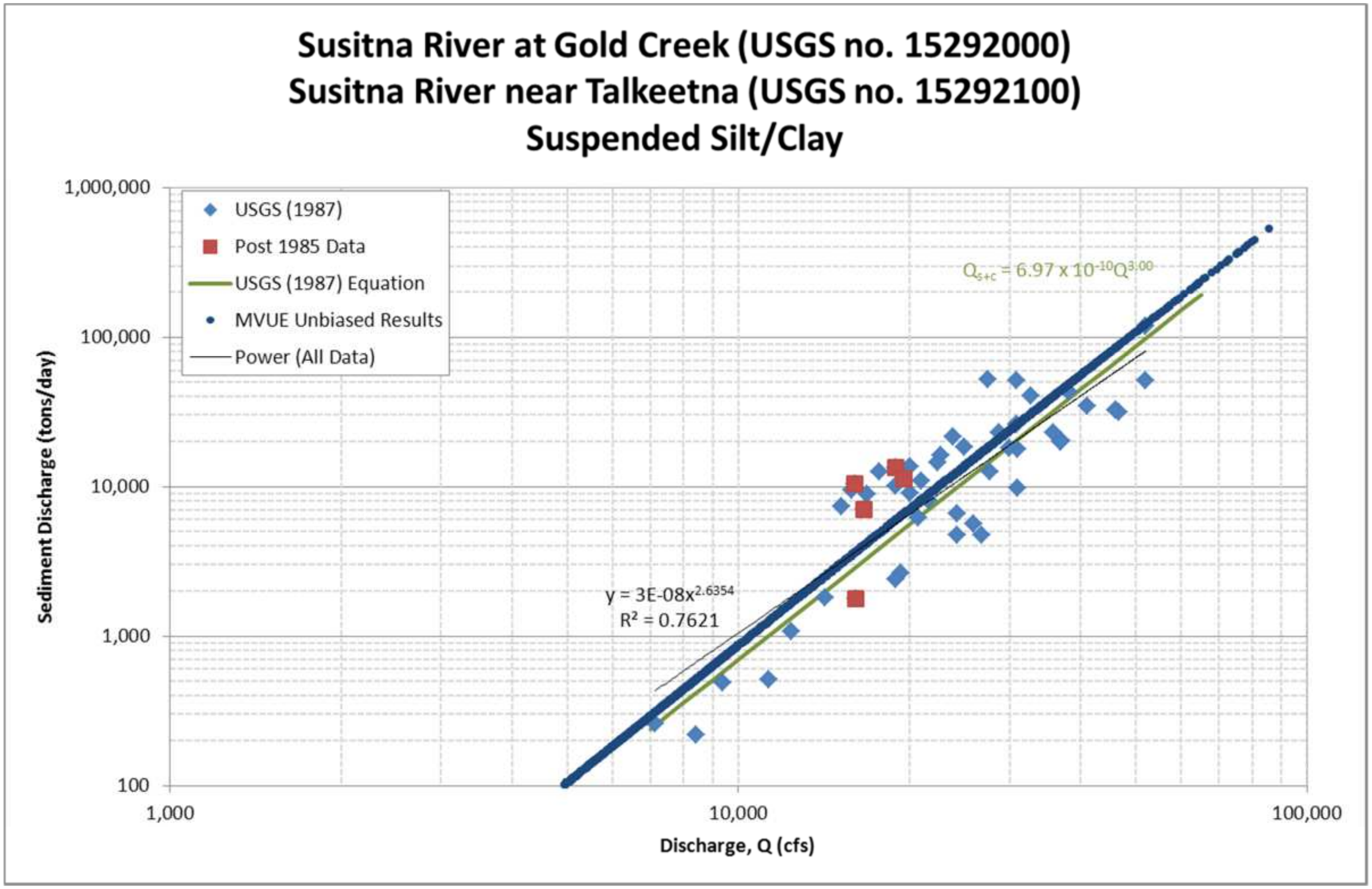

Figure A.1 – Suspended silt/clay sediment transport data and rating equations for Susitna River at Gold Creek and Susitna River near Talkeetna

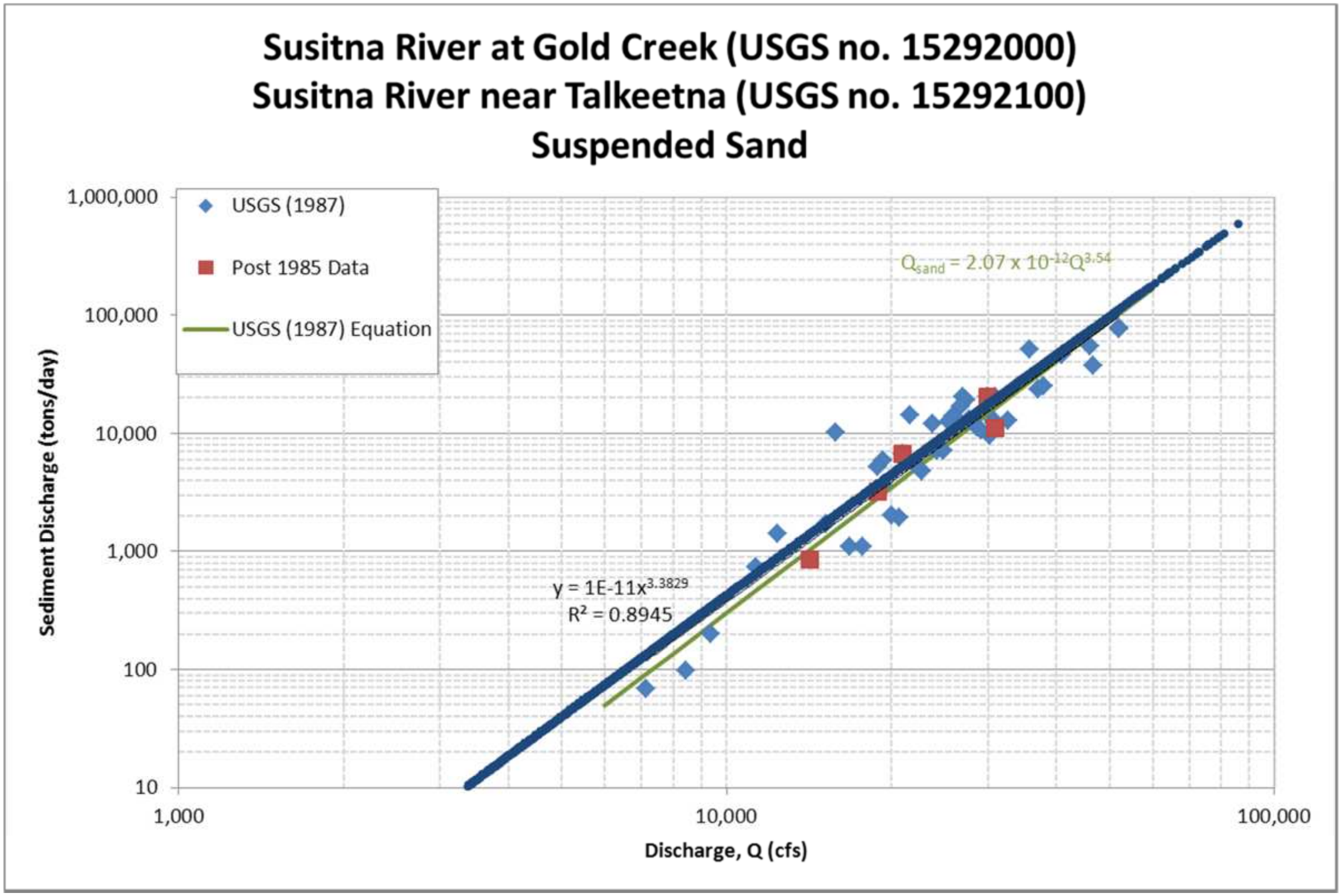

Figure A.2 – Suspended sand sediment transport data and rating equations for Susitna River at Gold Creek and Susitna River near Talkeetna

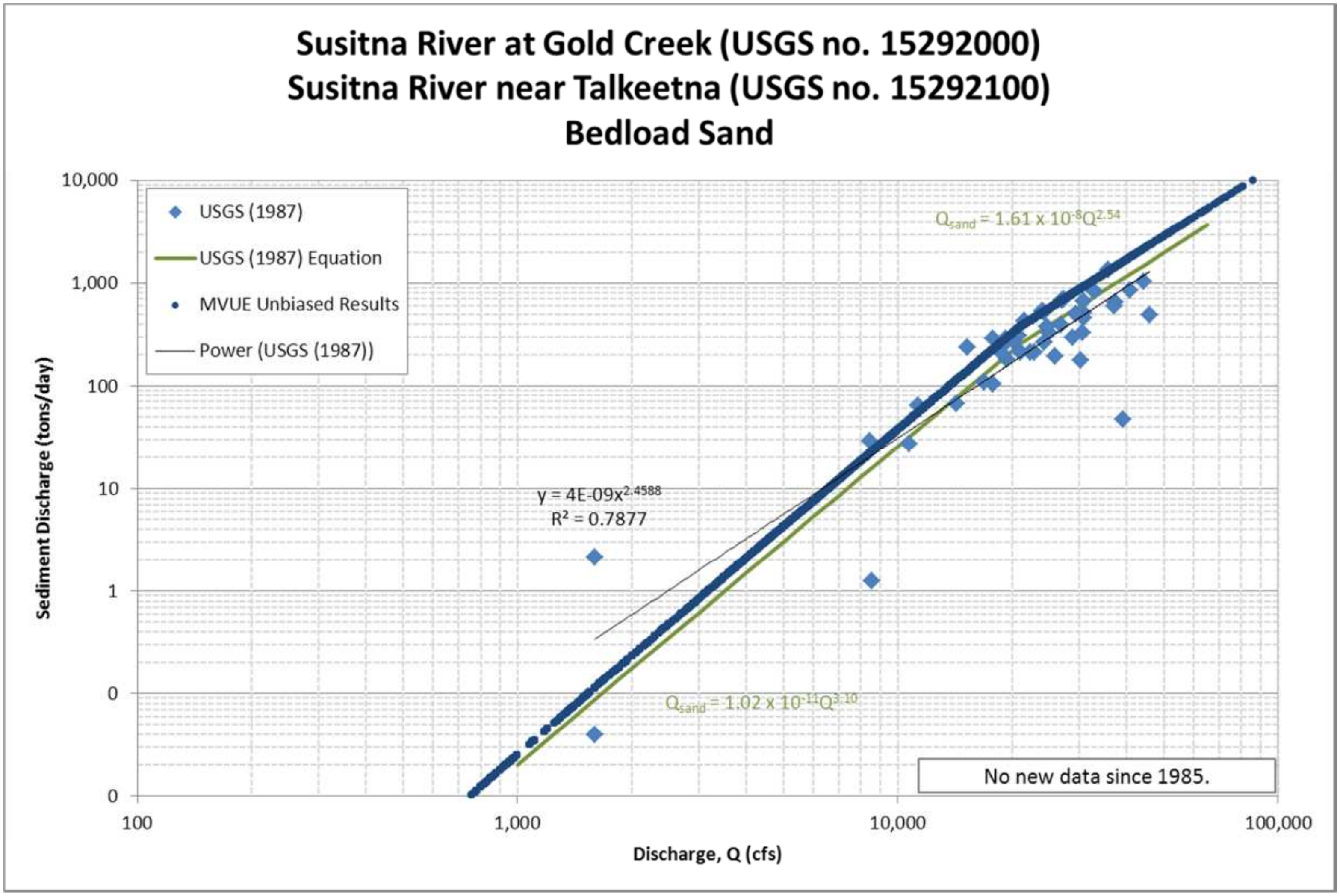

Figure A.3 – Bed-load Sand sediment transport data and rating equations for Susitna River at Gold Creek and Susitna River near Talkeetna

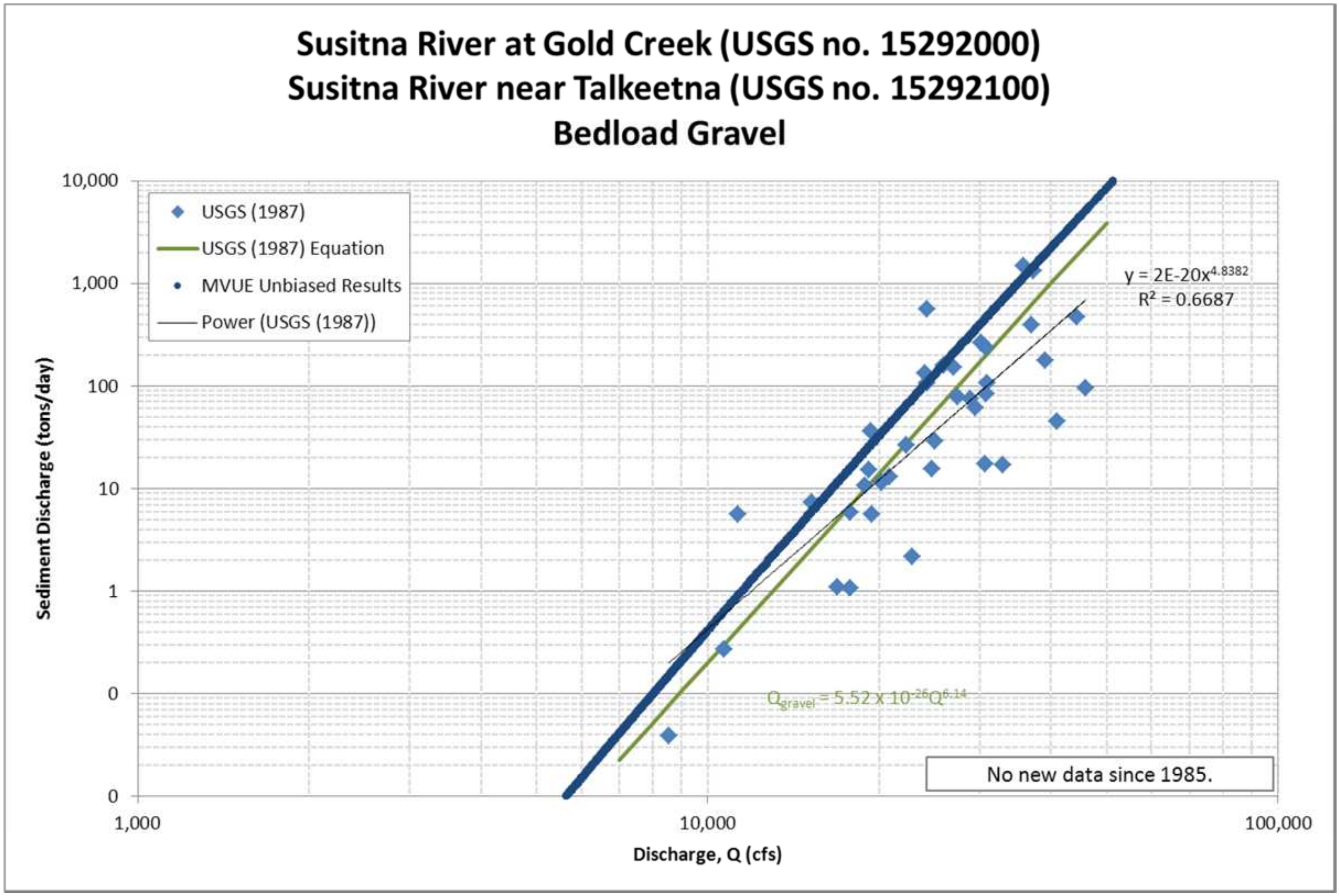

Figure A.4 – Bed-load gravel sediment transport data and rating equations for Susitna River at Gold Creek and Susitna River near Talkeetna

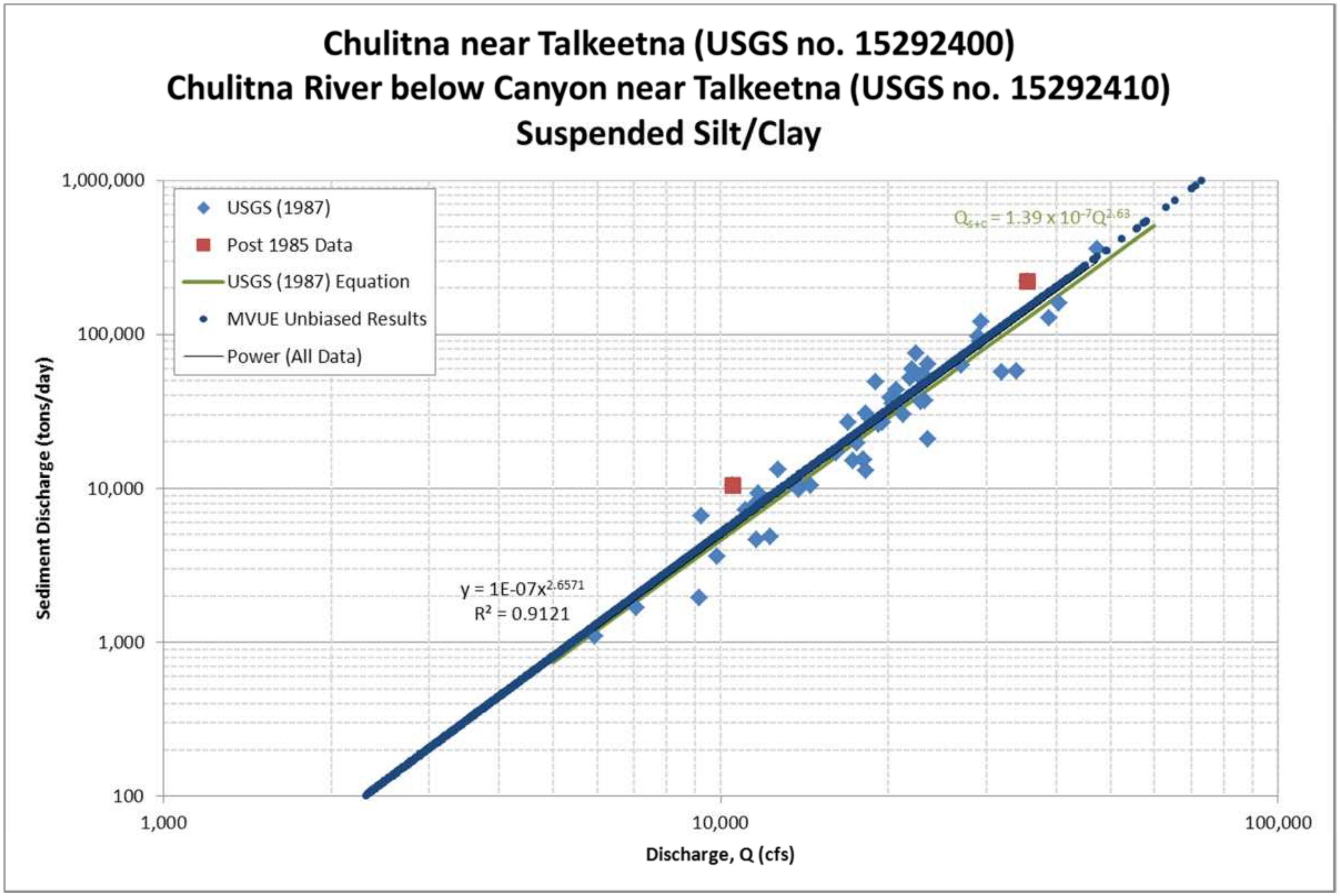

Figure A.5 – Suspended silt/clay sediment transport data and rating equations for Chulitna River near Talkeetna and Chulitna River below Canyon near Talkeetna

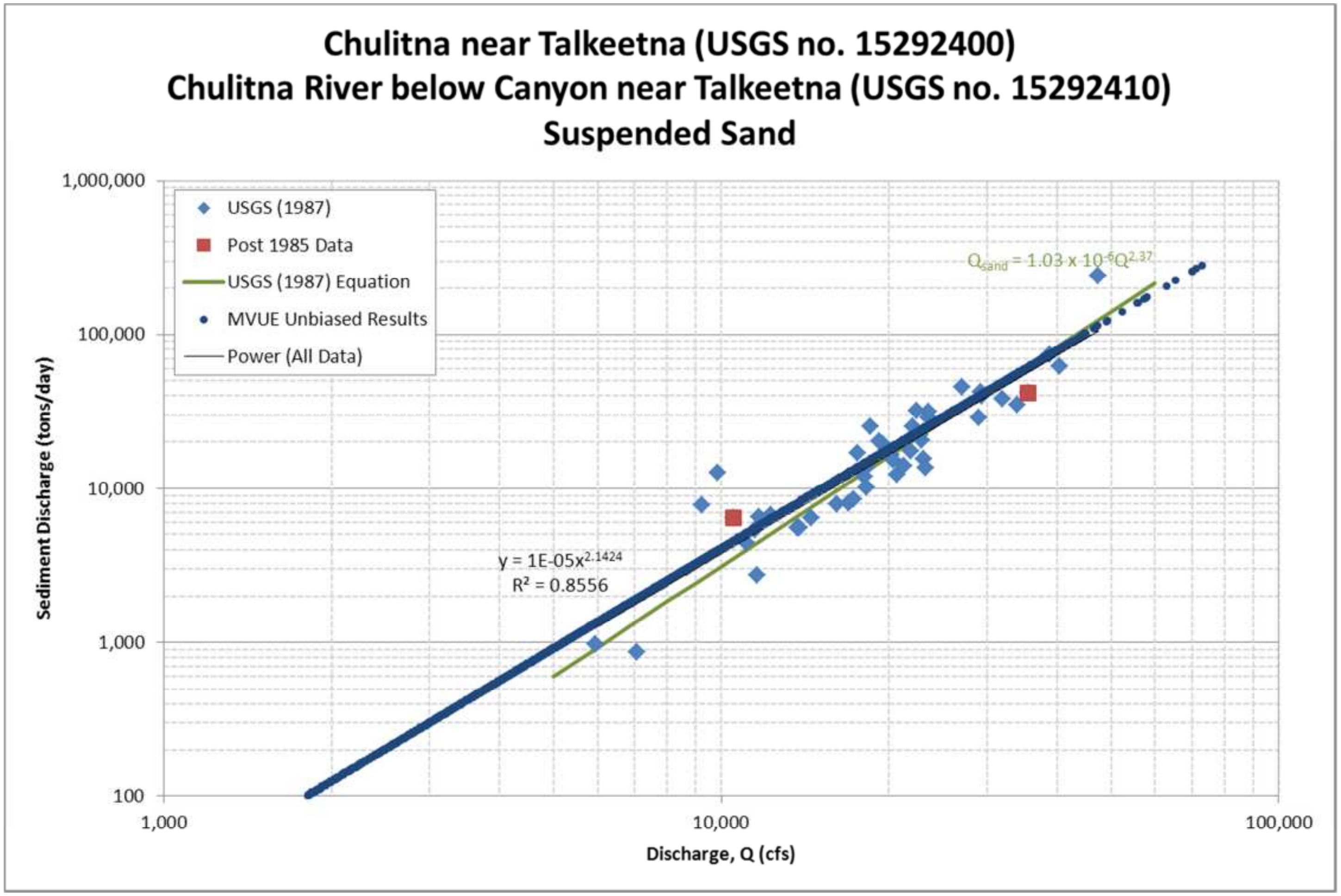

Figure A.6 – Suspended sand sediment transport data and rating equations for Chulitna River near Talkeetna and Chulitna River below Canyon near Talkeetna

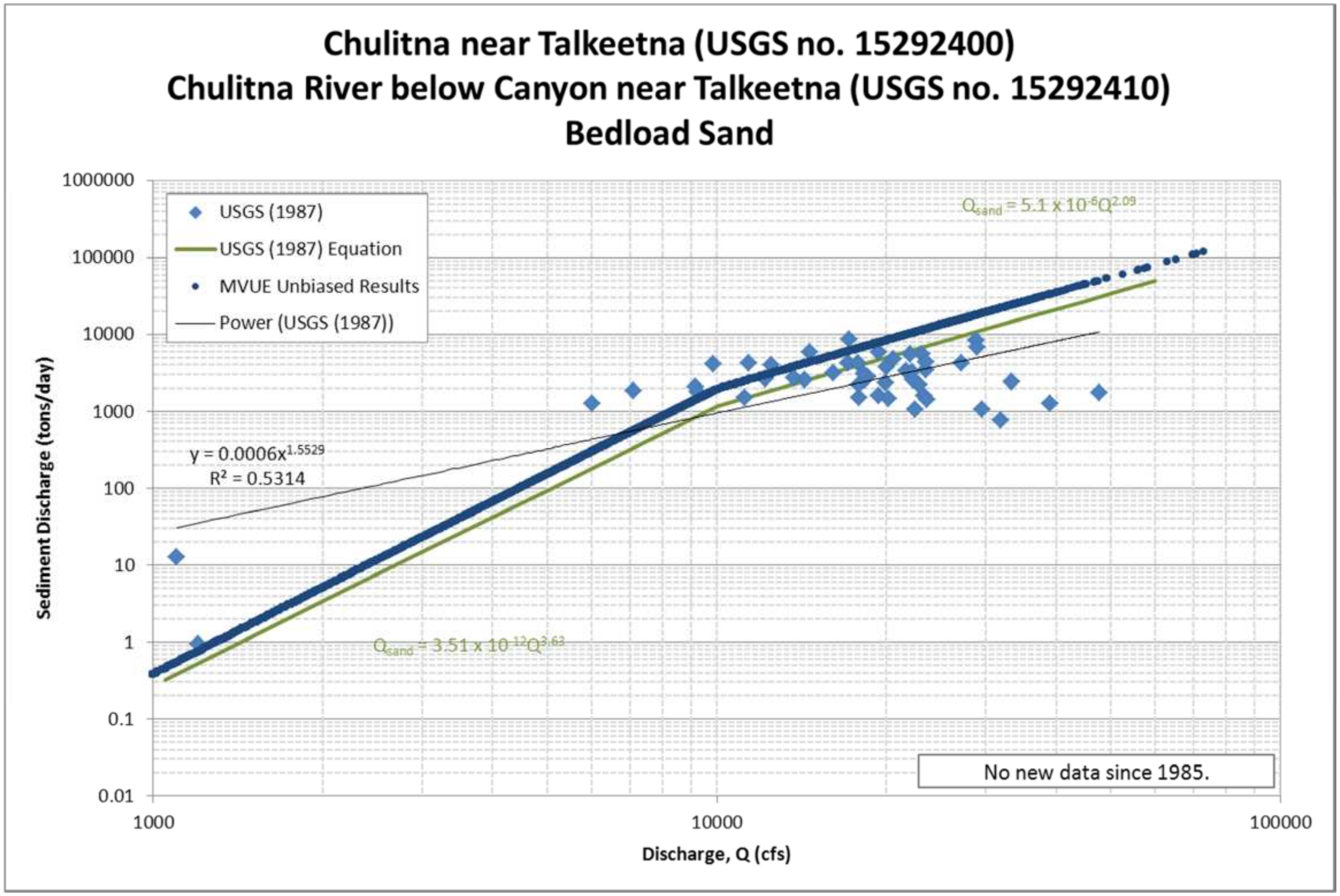

Figure A.7 – Bed-load sand sediment transport data and rating equations for Chulitna River near Talkeetna and Chulitna River below Canyon near Talkeetna

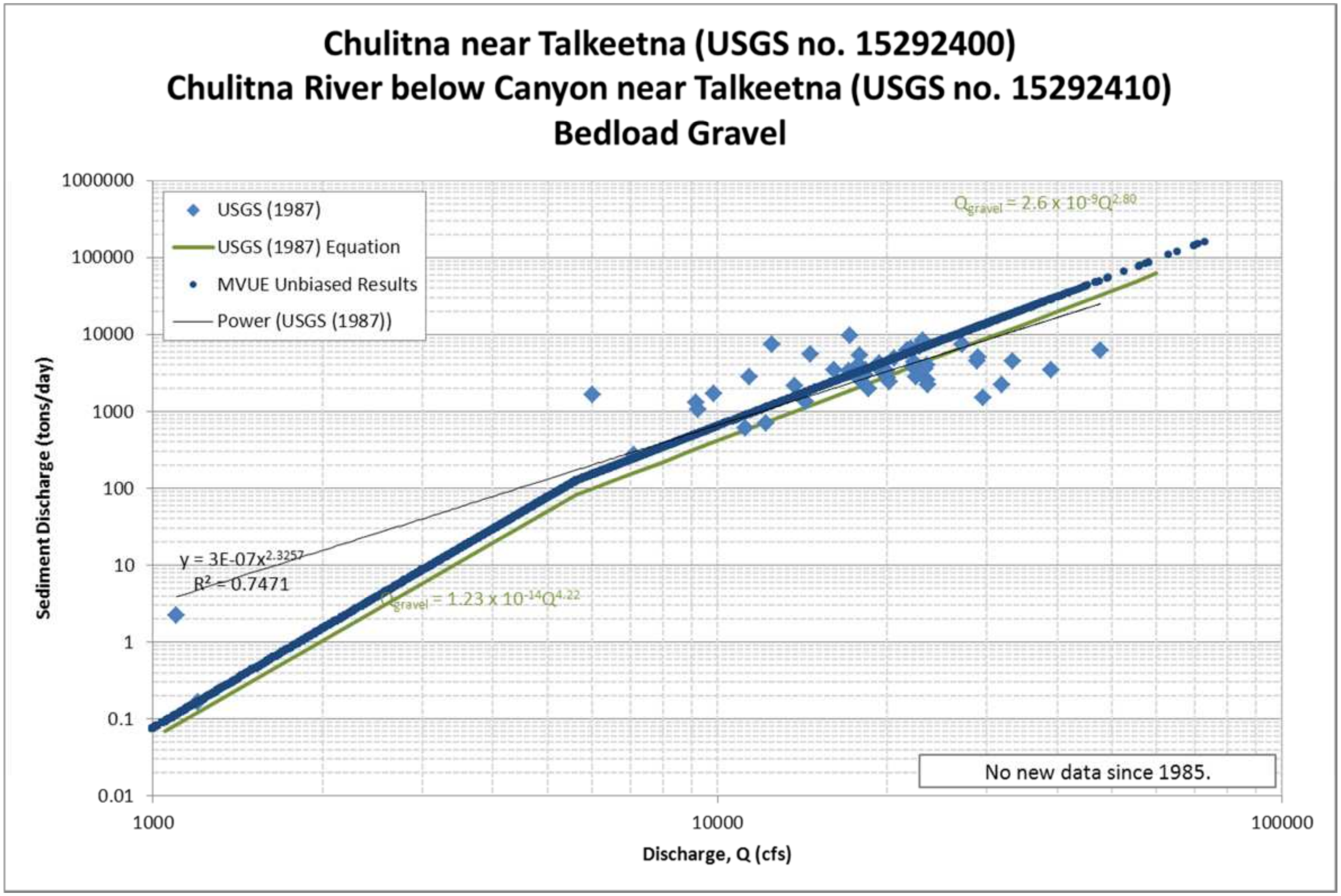

Figure A.8 – Bed-load Gravel sediment transport data and rating equations for Chulitna River near Talkeetna and Chulitna River below Canyon near Talkeetna

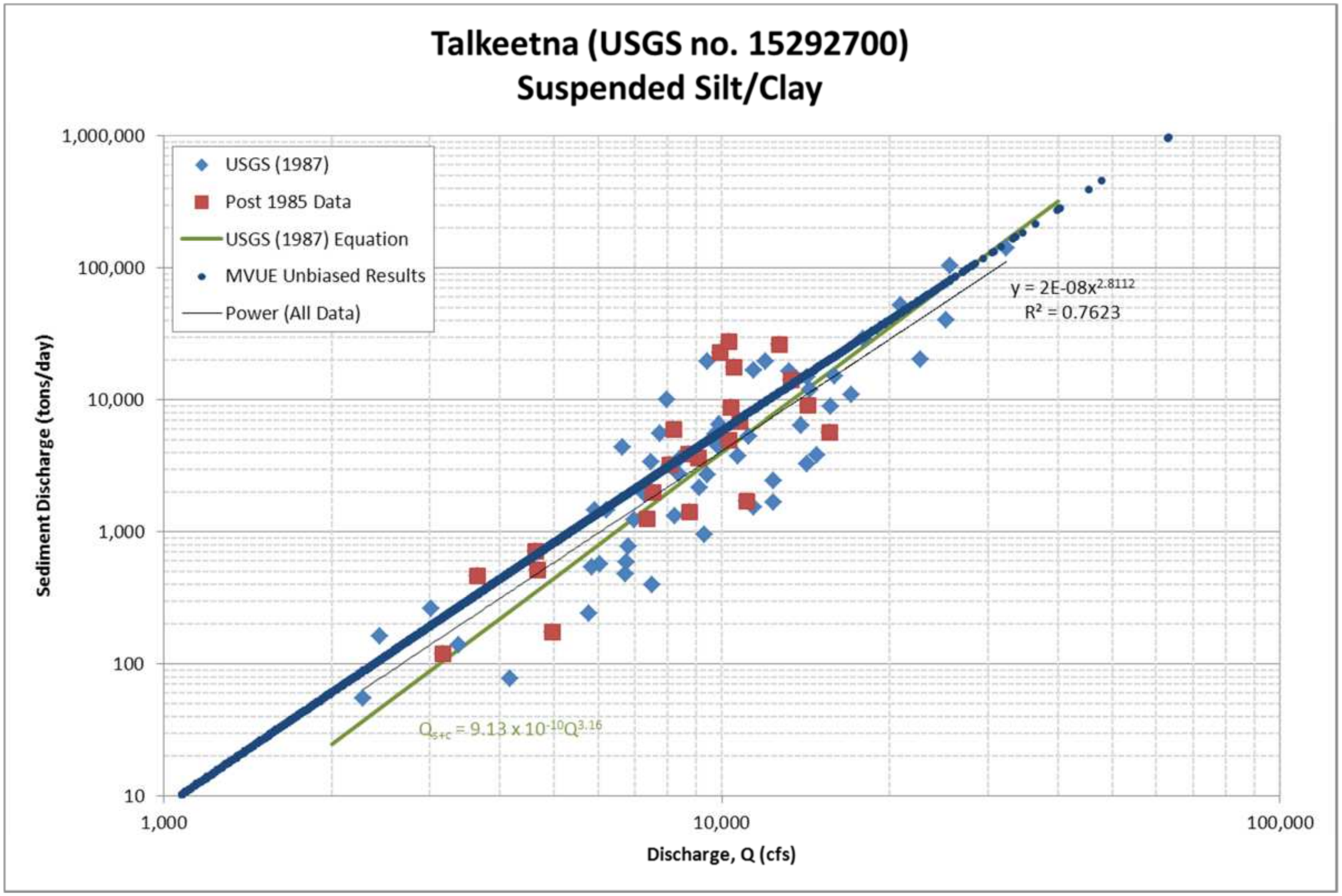

Figure A.9 – Suspended silt/clay sediment transport data and rating equations for Talkeetna River near Talkeetna

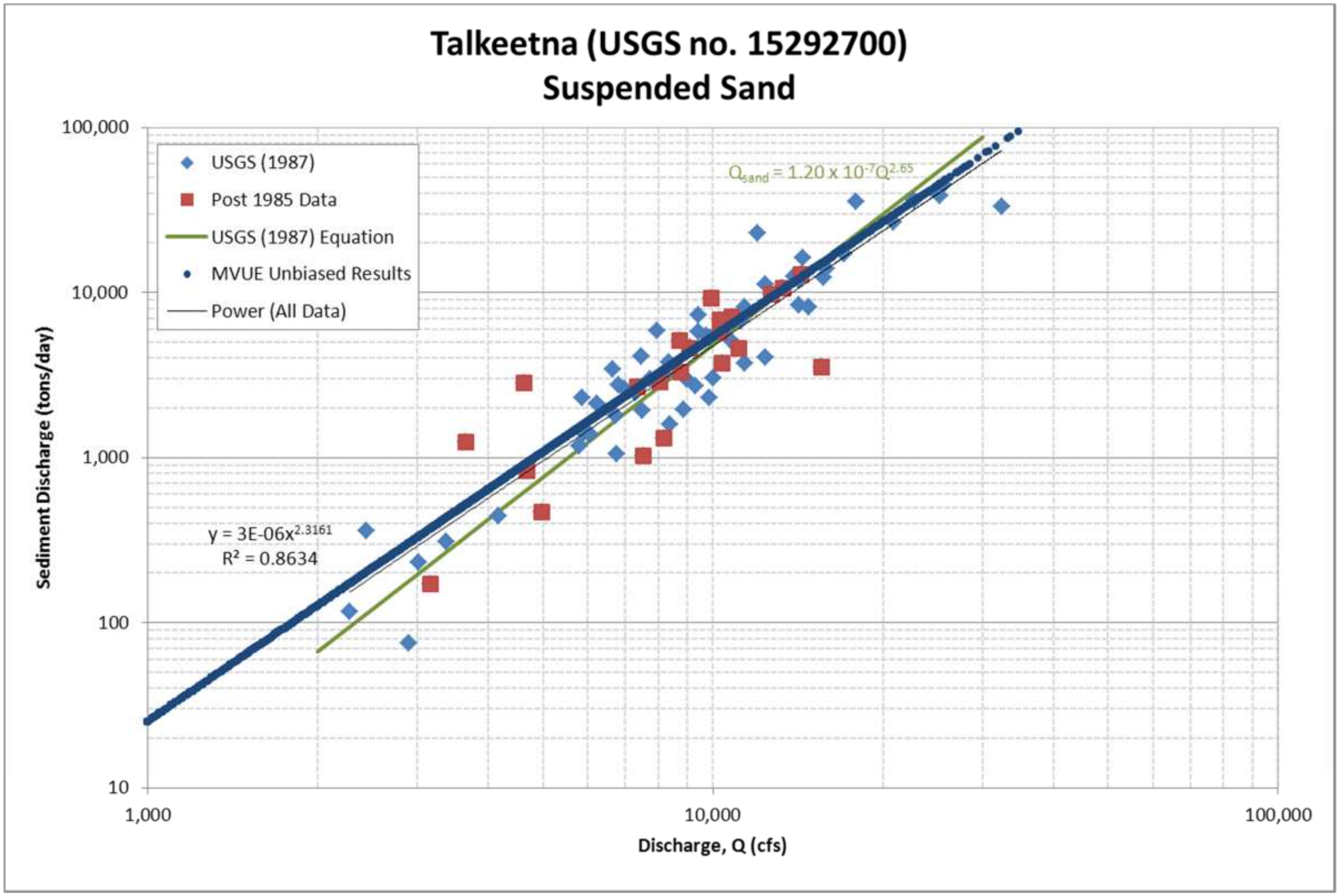

Figure A.10 – Suspended sand sediment transport data and rating equations for Talkeetna River near Talkeetna

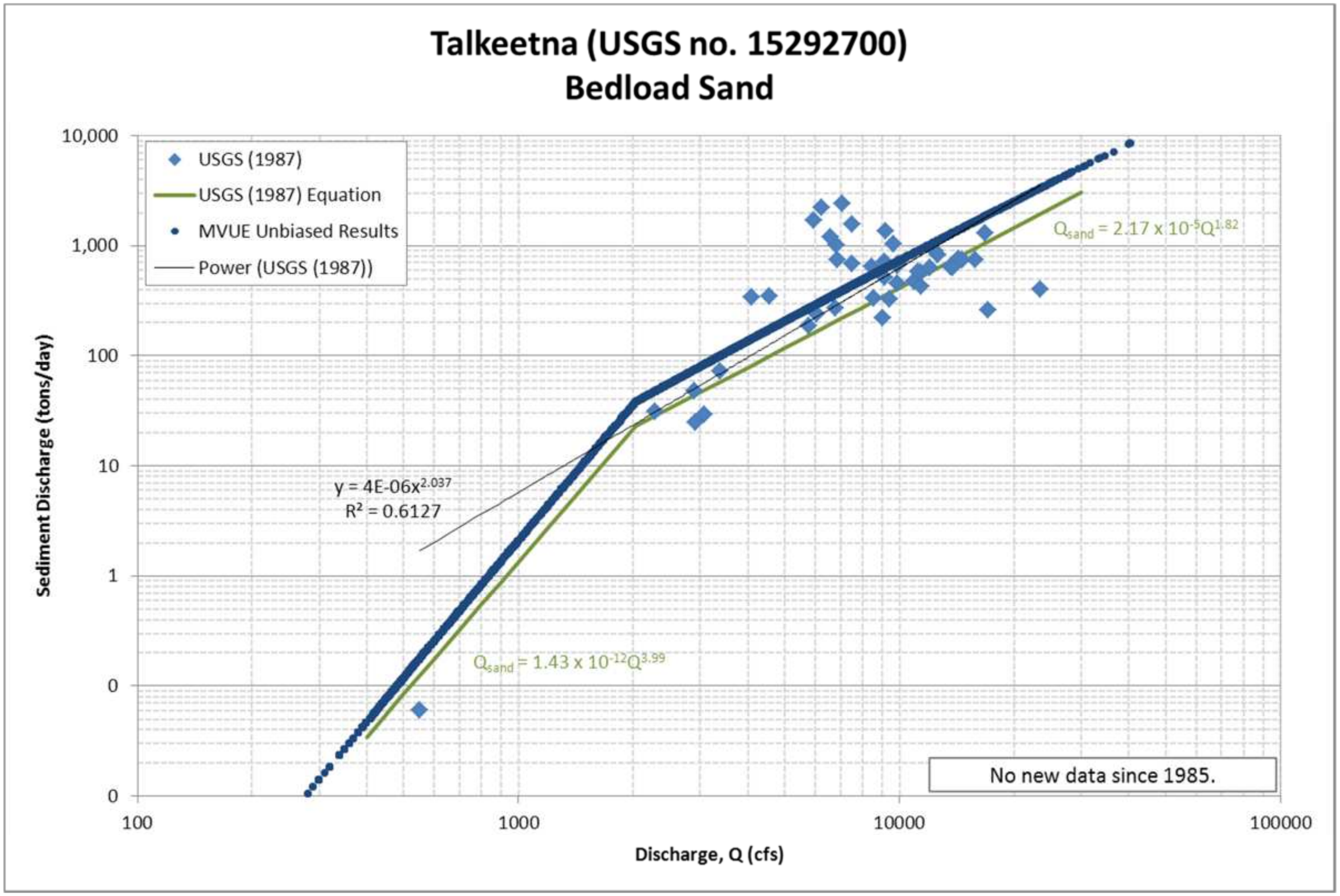

Figure A.11 – Bed-load sand sediment transport data and rating equations for Talkeetna River near Talkeetna

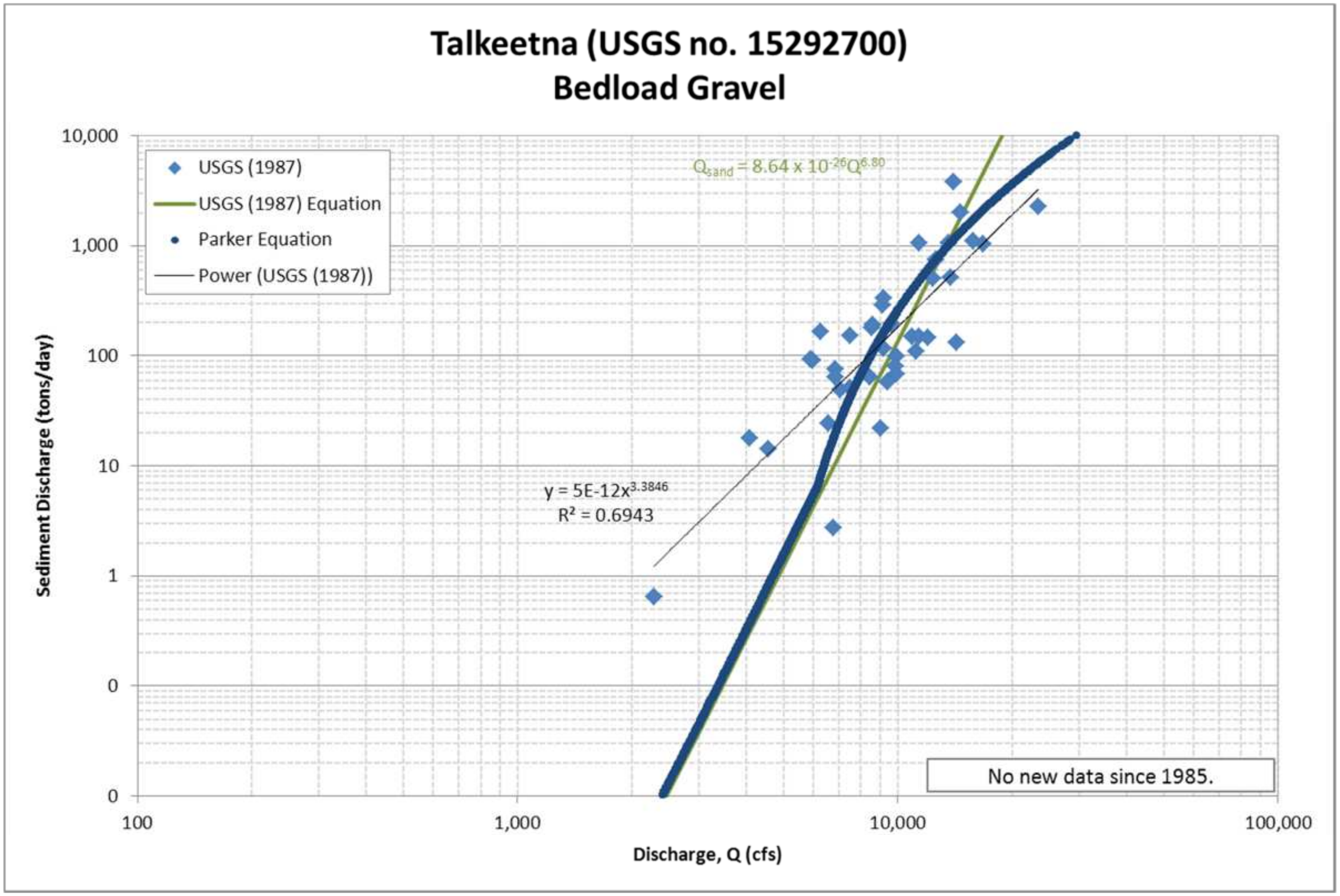

Figure A.12 – Bed-load gravel sediment transport data and rating equations for Talkeetna River near Talkeetna

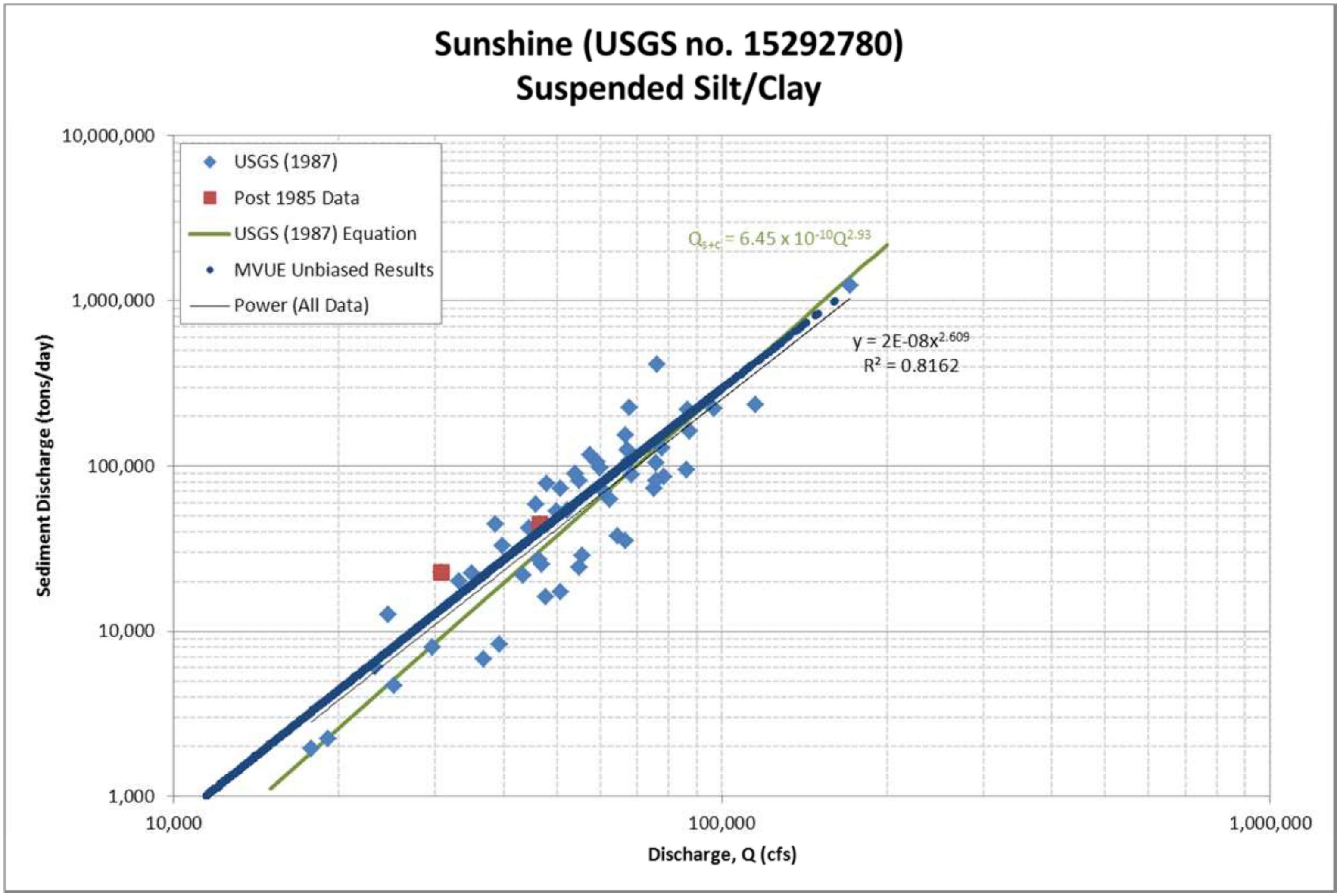

Figure A.13 – Suspended silt/clay sediment transport data and rating equations for Susitna River at Sunshine

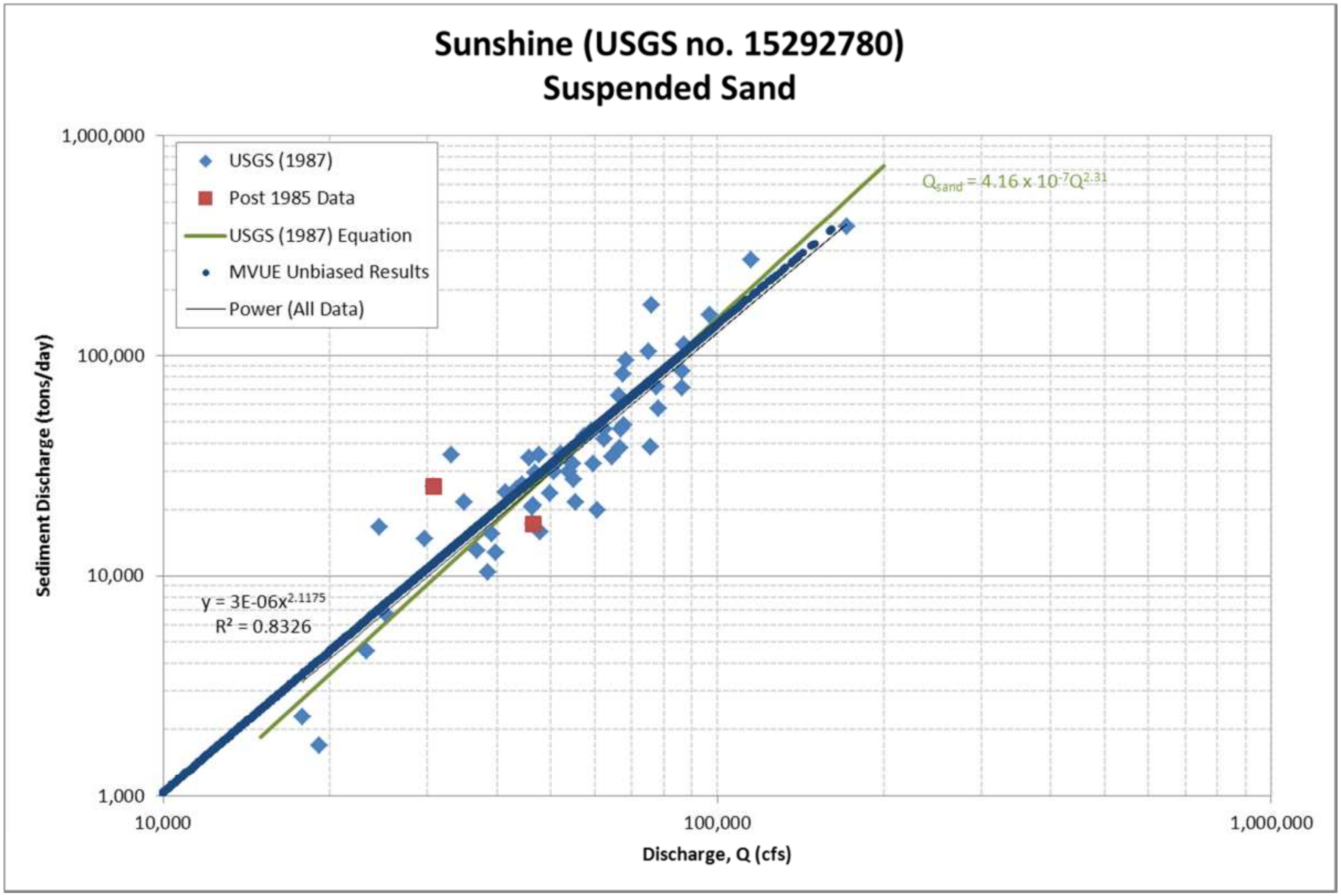

Figure A.14 – Suspended sand sediment transport data and rating equations for Susitna River at Sunshine

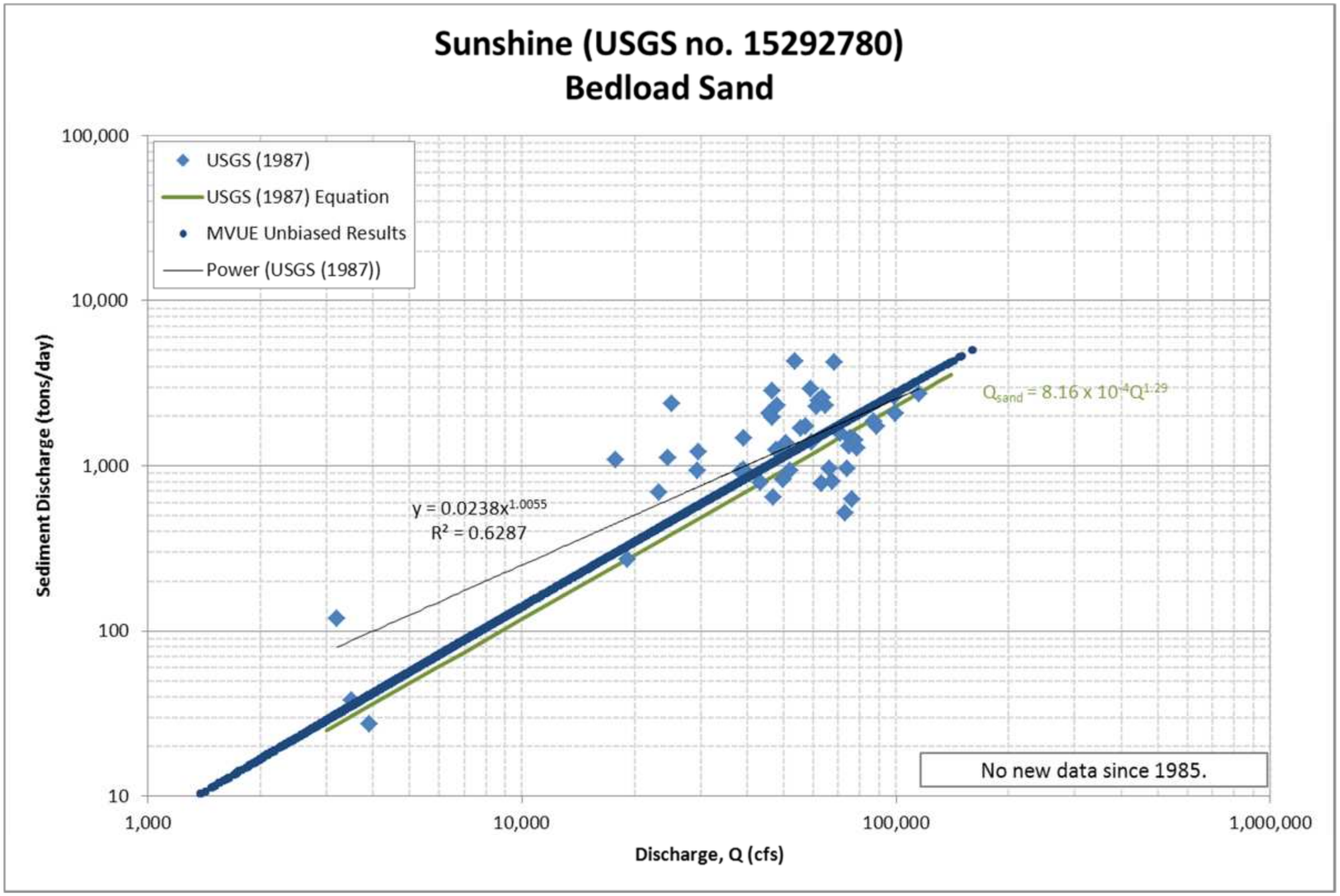

Figure A.15 – Bed-load sand sediment transport data and rating equations for Susitna River at Sunshine

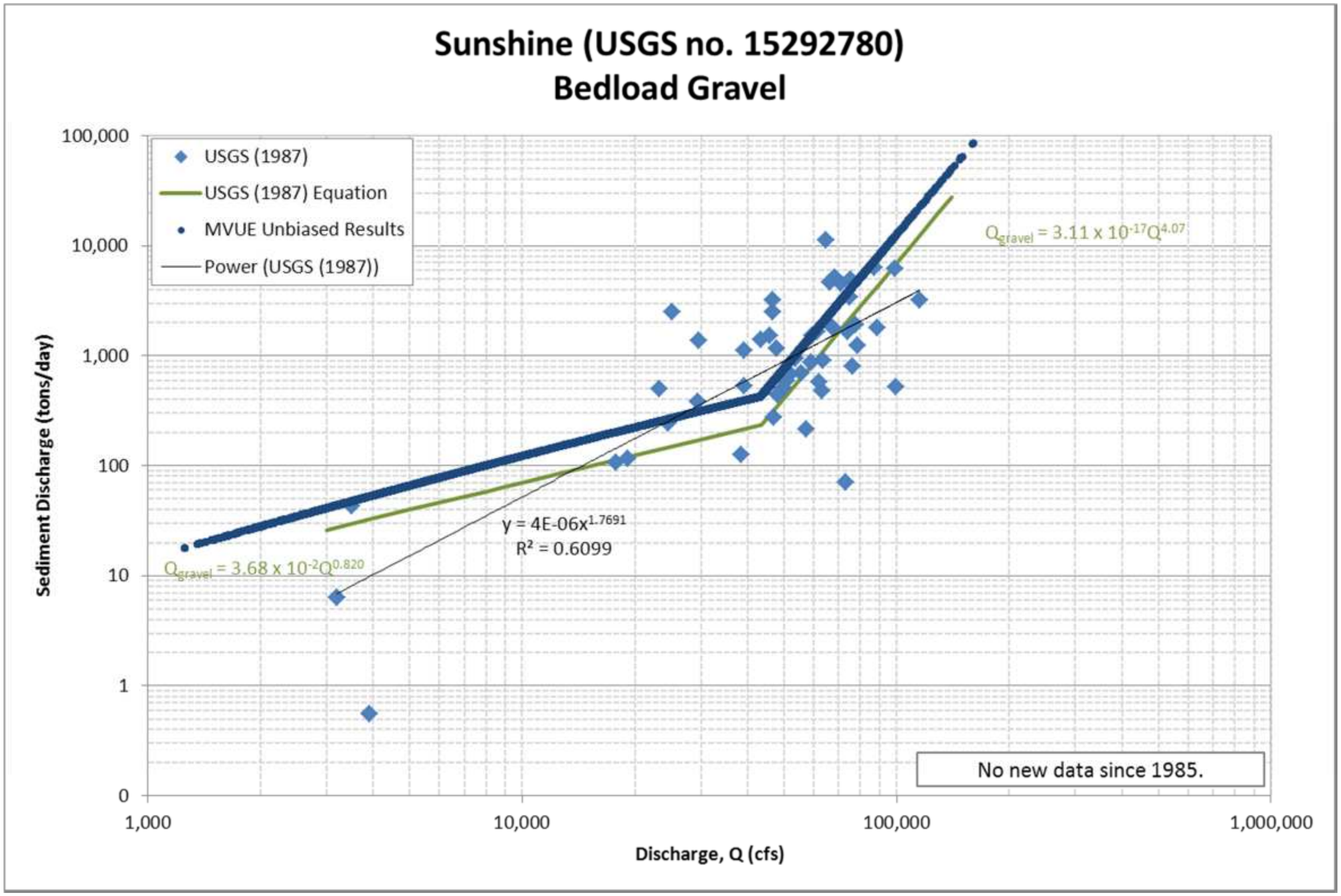

Figure A.16 – Bed-load gravel sediment transport data and rating equations for Susitna River at Sunshine

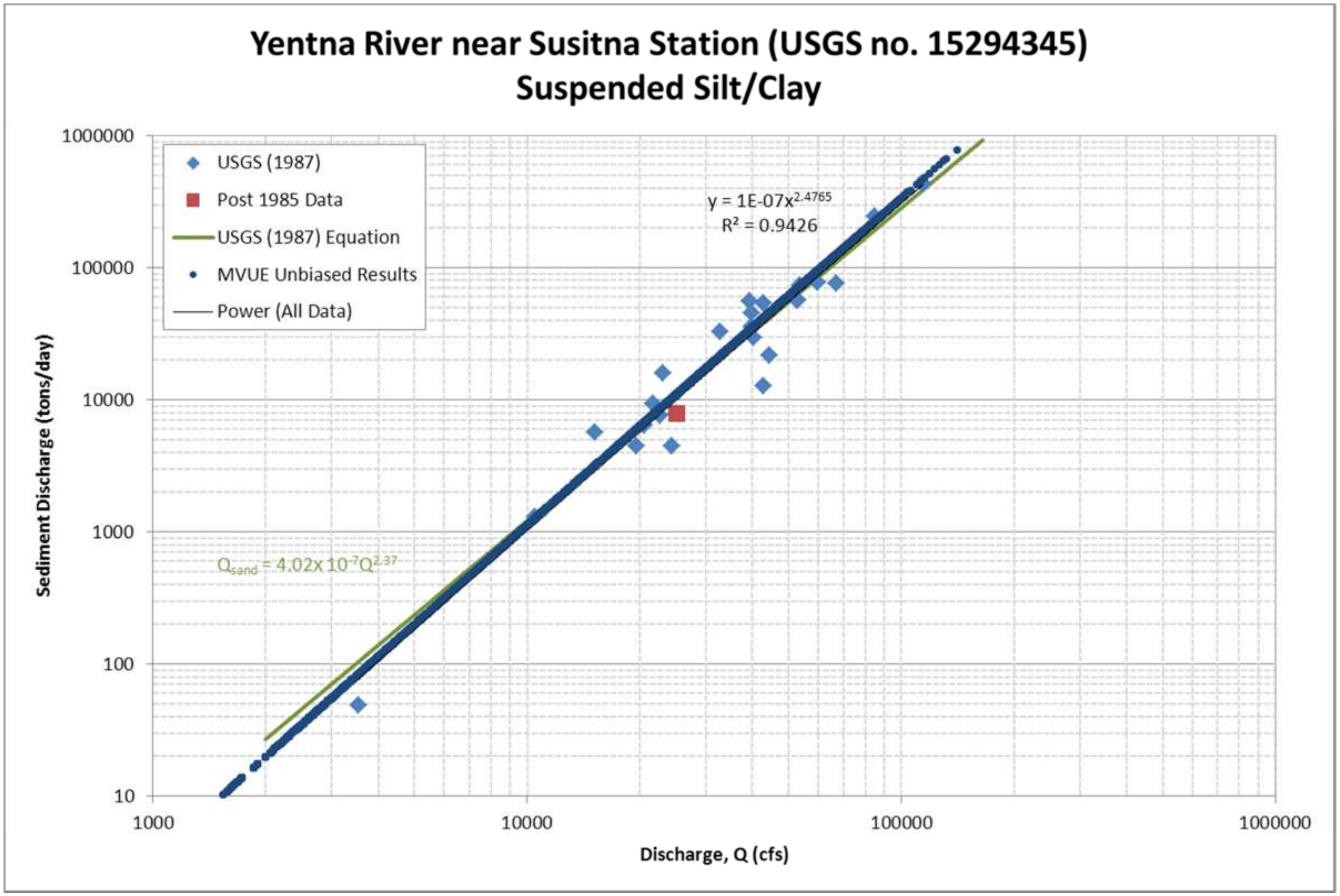

Figure A.17 – Suspended silt/clay sediment transport data and rating equations for Yentna River near Susitna Station

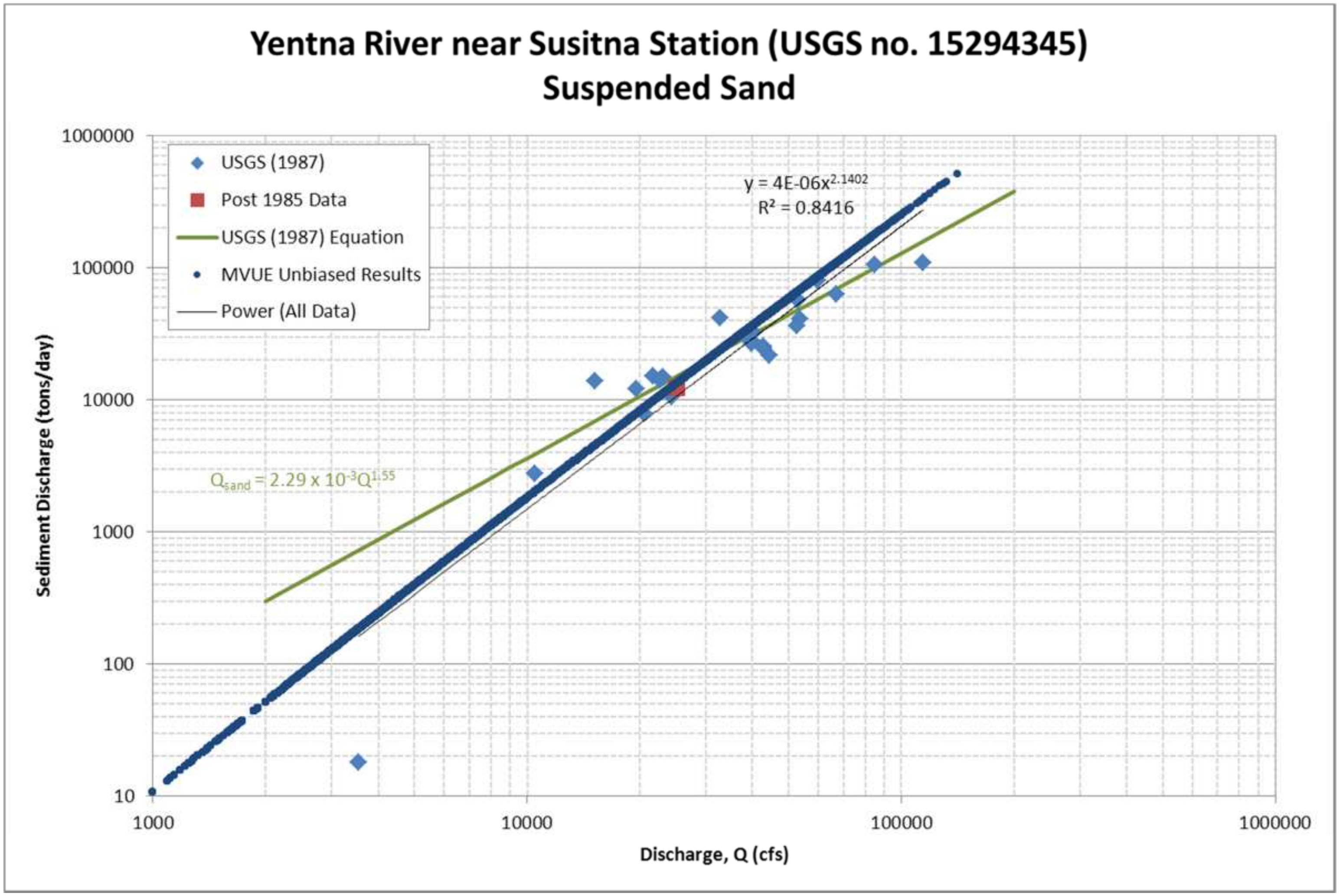

Figure A.18 – Suspended sand sediment transport data and rating equations for Yentna River near Susitna Station

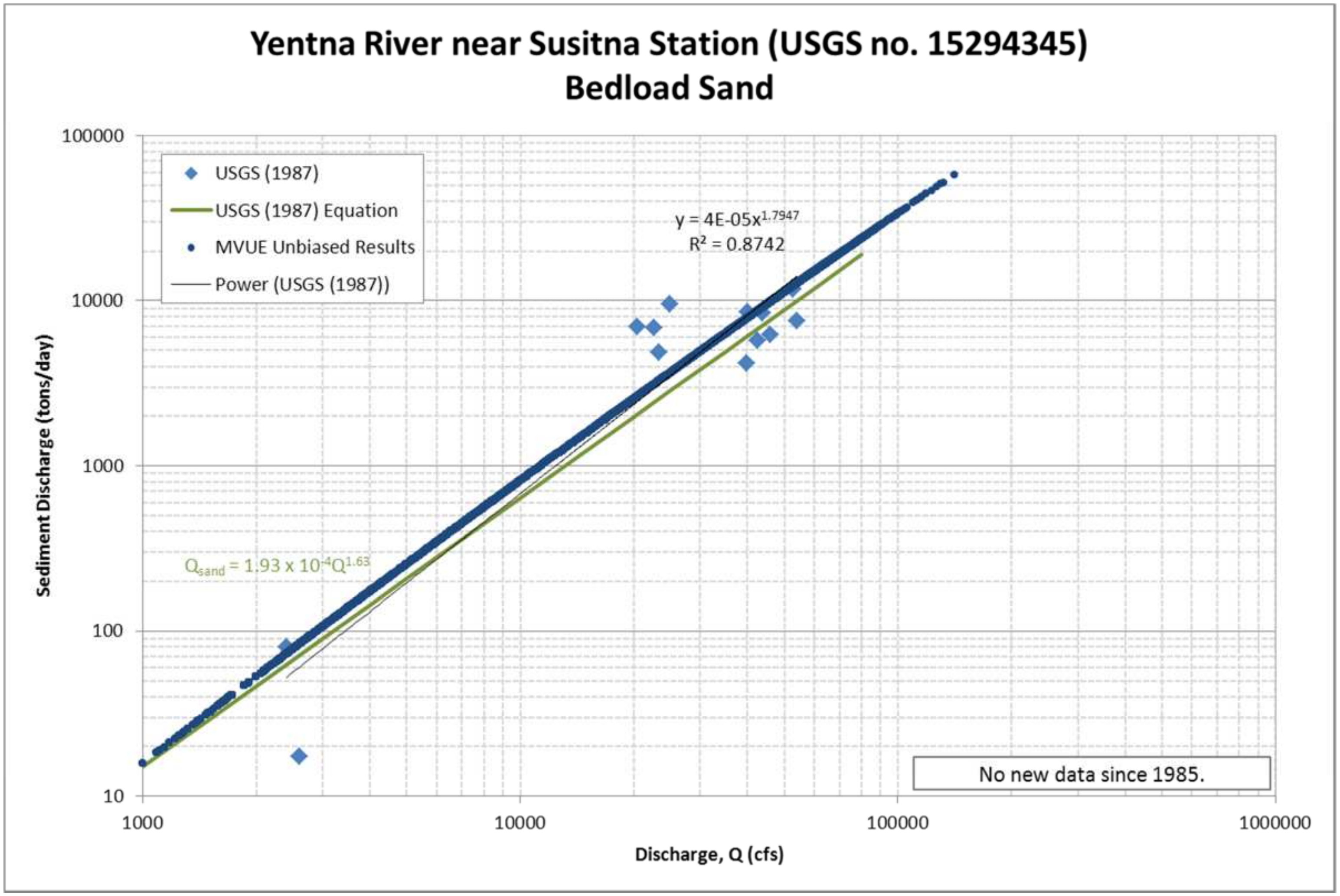

Figure A.19 – Bed-load sand sediment transport data and rating equations for Yentna River near Susitna Station

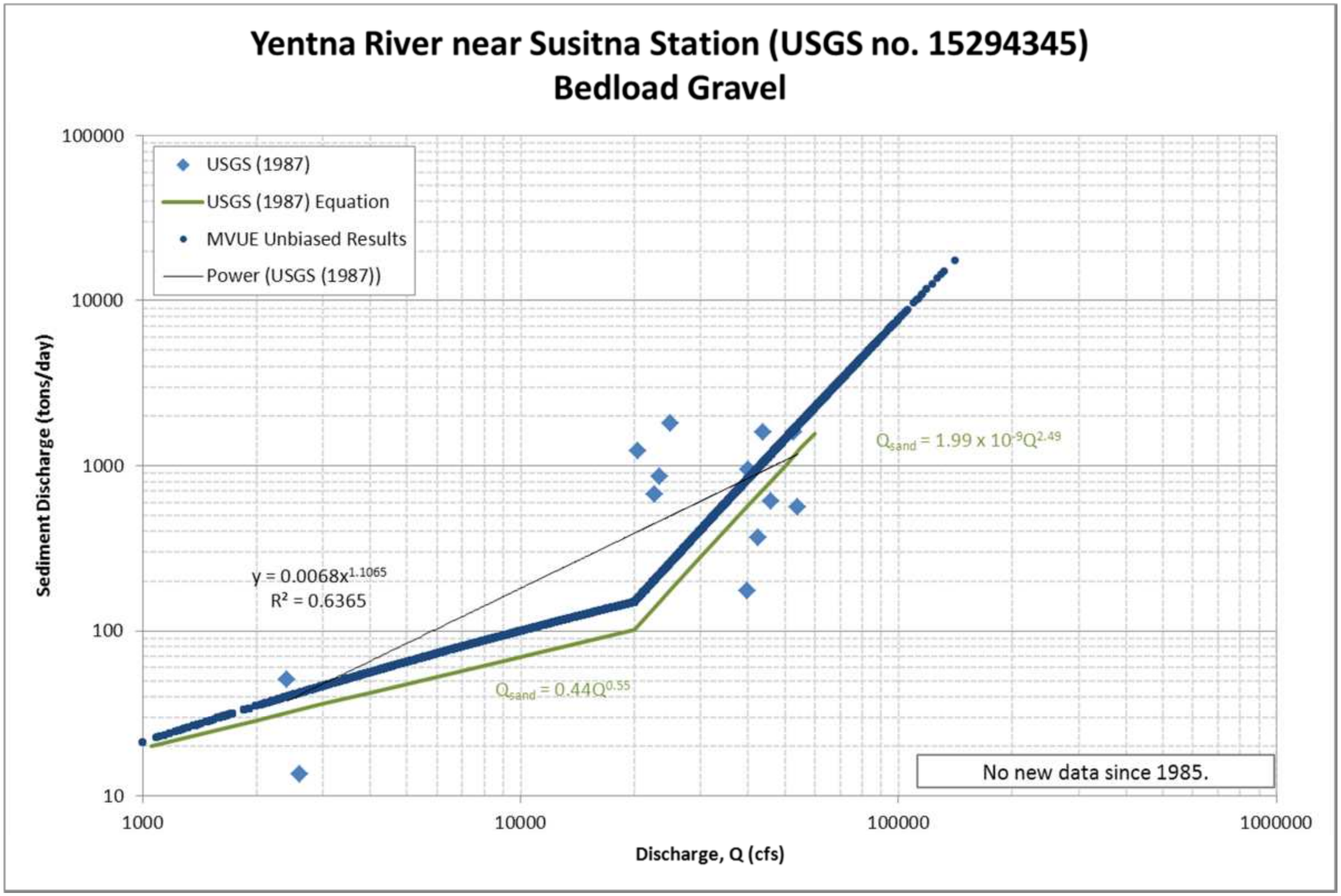

Figure A.20 – Bed-load gravel sediment transport data and rating equations for Yentna River near Susitna Station

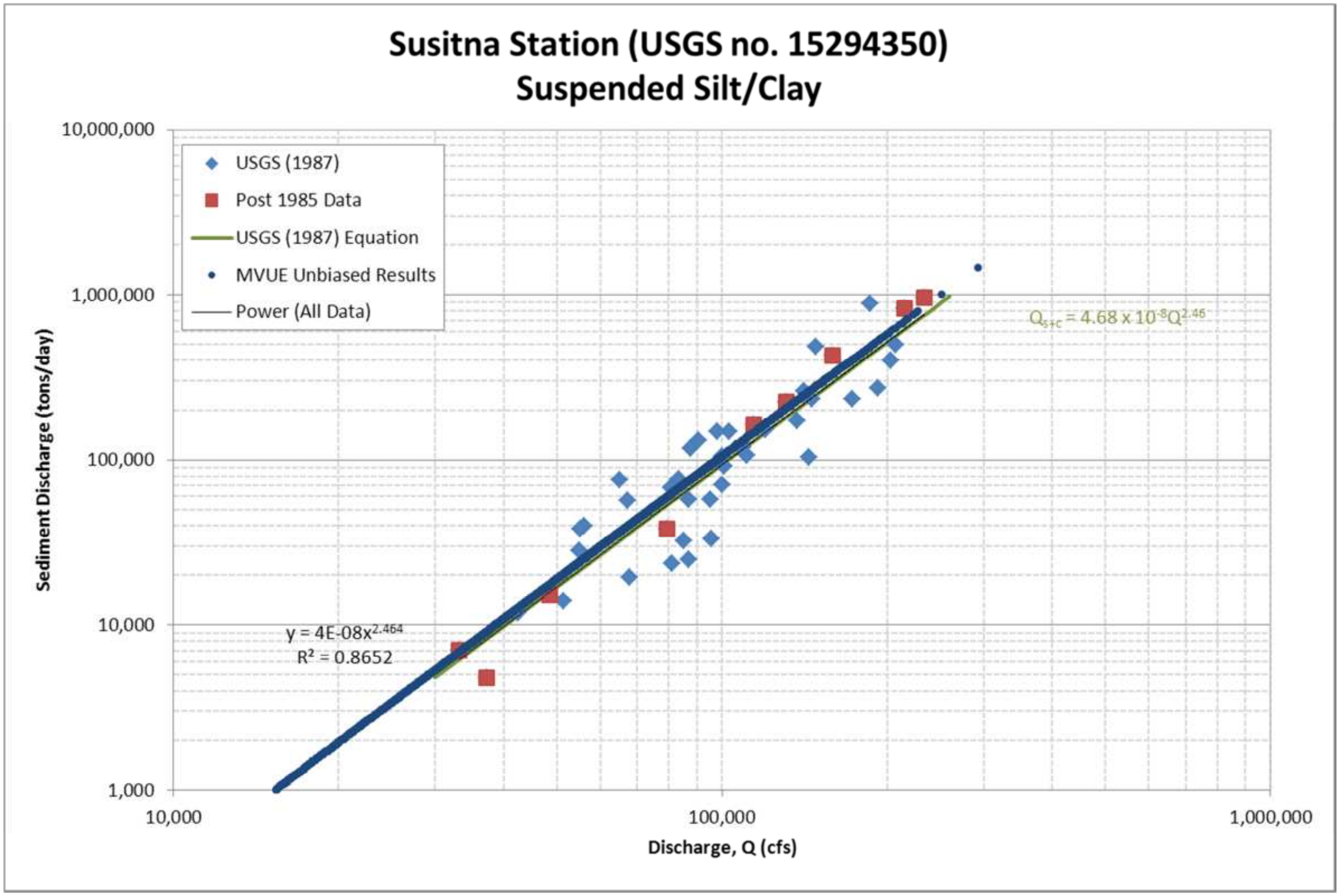

Figure A.21 – Suspended silt/clay sediment transport data and rating equations for Susitna River near Susitna Station

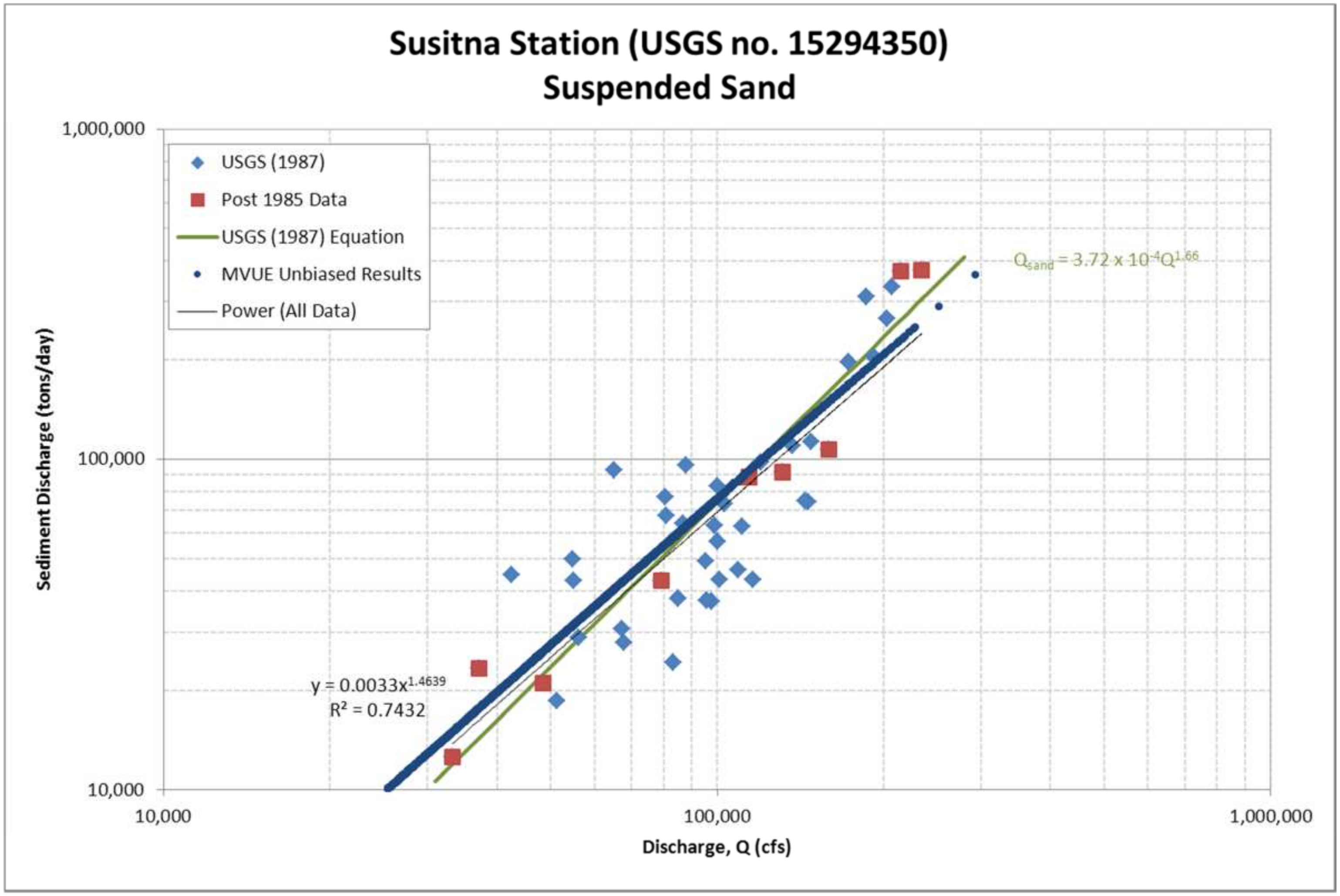

Figure A.22 – Suspended sand sediment transport data and rating equations for Susitna River near Susitna Station

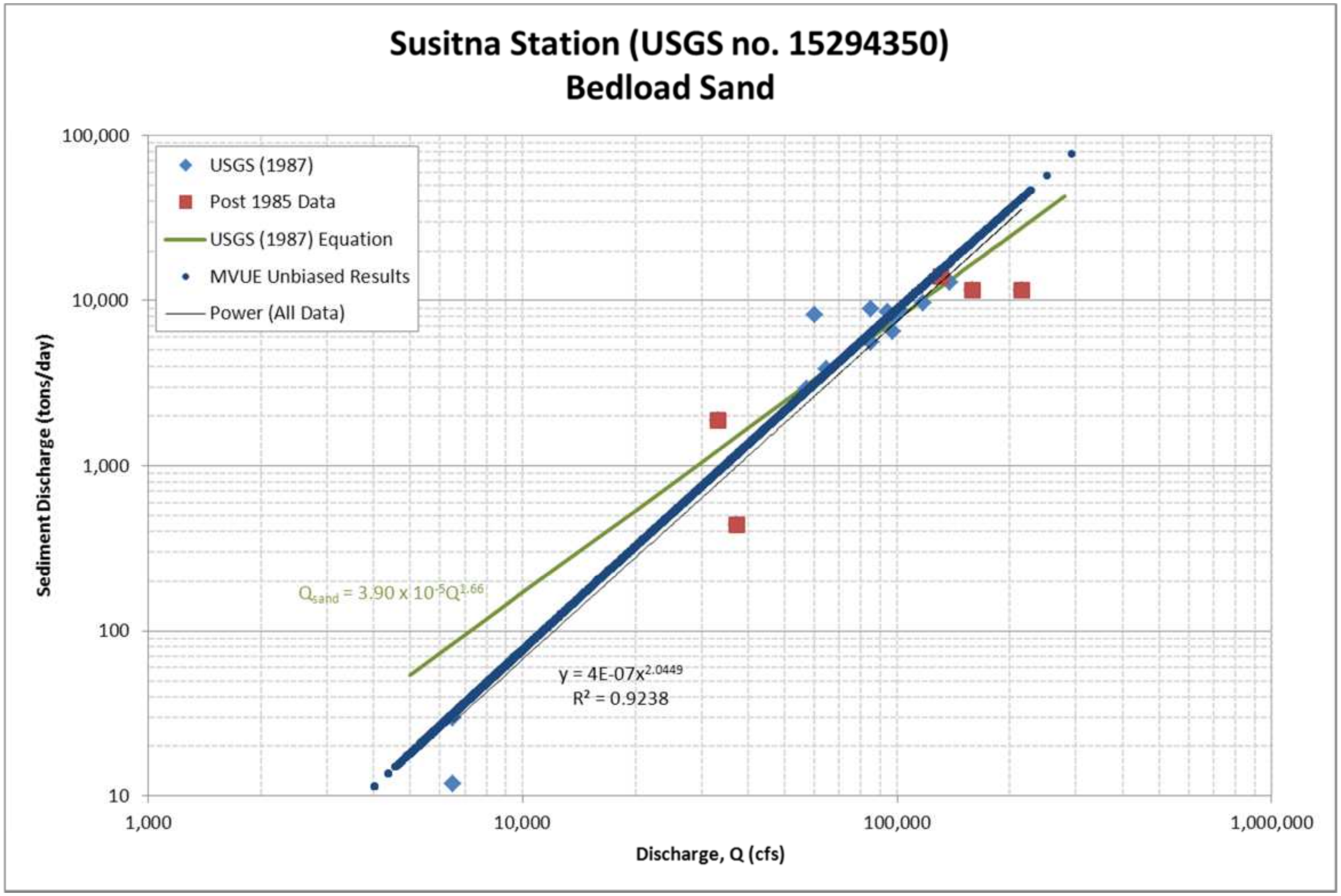

Figure A.23 – Bed-load sand sediment transport data and rating equations for Susitna River near Susitna Station

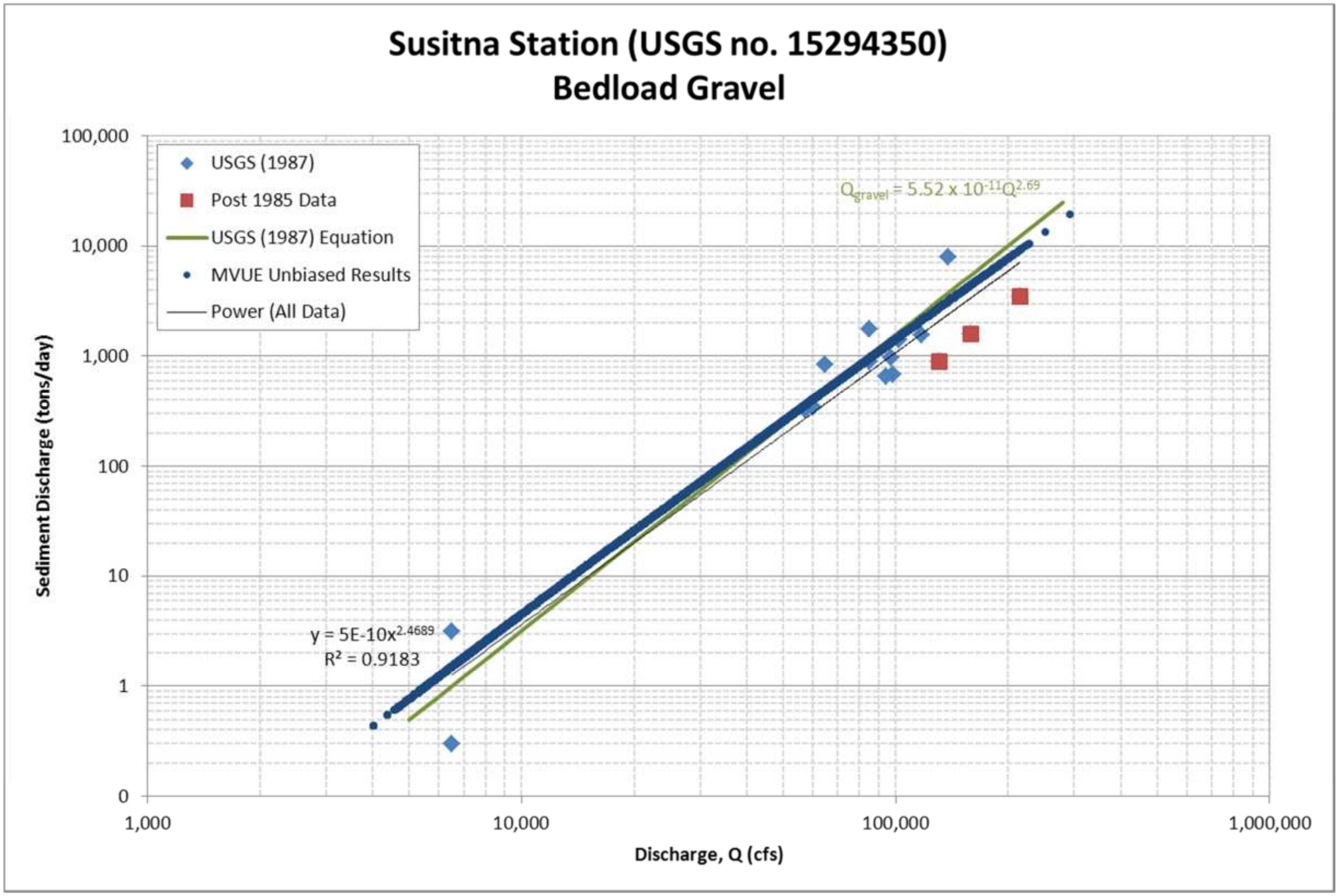

Figure A.24 – Bed-load gravel sediment transport data and rating equations for Susitna River near Susitna Station

APPENDIX B.1. ANNUAL SEDIMENT LOAD TABULAR SUMMARY FOR PRE-PROJECT CONDITIONS

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Development of Sediment Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Tetra Tech

February 2013

Table B.1-1 – Annual Sediment Load for Pre-Project Conditions for Susitna River at Gold Creek

Susitna River at Gold Creek - 15292000								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	5,810,000	914,000	598,000	1,512,000	38,900	7,520	46,420	1,558,420
1951	6,590,000	1,260,000	845,000	2,105,000	52,900	11,900	64,800	2,169,800
1952	6,920,000	2,070,000	1,550,000	3,620,000	74,200	48,900	123,100	3,743,100
1953	7,310,000	1,450,000	985,000	2,435,000	59,100	17,200	76,300	2,511,300
1954	7,010,000	1,480,000	1,020,000	2,500,000	60,200	19,300	79,500	2,579,500
1955	7,430,000	2,350,000	1,810,000	4,160,000	81,800	79,600	161,400	4,321,400
1956	8,310,000	2,930,000	2,230,000	5,160,000	103,000	81,800	184,800	5,344,800
1957	7,520,000	1,850,000	1,310,000	3,160,000	71,600	30,300	101,900	3,261,900
1958	6,860,000	1,470,000	1,050,000	2,520,000	56,600	29,100	85,700	2,605,700
1959	7,650,000	2,590,000	2,010,000	4,600,000	89,500	103,000	192,500	4,792,500
1960	7,030,000	1,440,000	999,000	2,439,000	56,900	21,600	78,500	2,517,500
1961	7,830,000	1,920,000	1,410,000	3,330,000	71,700	52,100	123,800	3,453,800
1962	8,370,000	3,960,000	3,440,000	7,400,000	118,000	423,000	541,000	7,941,000
1963	8,020,000	2,700,000	2,050,000	4,750,000	95,000	73,100	168,100	4,918,100
1964	7,100,000	5,030,000	4,800,000	9,830,000	127,000	872,000	999,000	10,829,000
1965	7,360,000	1,930,000	1,390,000	3,320,000	73,800	31,900	105,700	3,425,700
1966	6,830,000	1,940,000	1,500,000	3,440,000	67,100	85,400	152,500	3,592,500
1967	8,120,000	3,440,000	2,840,000	6,280,000	110,000	260,000	370,000	6,650,000
1968	7,110,000	1,950,000	1,430,000	3,380,000	71,500	39,100	110,600	3,490,600
1969	4,050,000	337,000	198,000	535,000	15,000	1,150	16,150	551,150
1970	5,500,000	896,000	587,000	1,483,000	37,900	7,230	45,130	1,528,130
1971	7,420,000	3,670,000	3,220,000	6,890,000	107,000	390,000	497,000	7,387,000
1972	7,880,000	2,860,000	2,370,000	5,230,000	91,300	219,000	310,300	5,540,300
1973	5,850,000	1,270,000	919,000	2,189,000	47,400	31,400	78,800	2,267,800
1974	5,520,000	858,000	565,000	1,423,000	35,700	8,170	43,870	1,466,870
1975	7,440,000	2,050,000	1,490,000	3,540,000	76,700	37,500	114,200	3,654,200
1976	5,930,000	967,000	642,000	1,609,000	40,200	9,120	49,320	1,658,320
1977	7,320,000	2,330,000	1,810,000	4,140,000	80,100	83,400	163,500	4,303,500
1978	5,930,000	687,000	425,000	1,112,000	30,900	3,240	34,140	1,146,140
1979	6,870,000	1,630,000	1,160,000	2,790,000	63,000	24,600	87,600	2,877,600

Susitna River at Gold Creek – 15292000 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	7,780,000	2,240,000	1,680,000	3,920,000	79,900	57,600	137,500	4,057,500
1981	8,660,000	3,610,000	2,960,000	6,570,000	113,000	188,000	301,000	6,871,000
1982	7,000,000	1,340,000	913,000	2,253,000	54,300	14,800	69,100	2,322,100
1983	7,180,000	1,370,000	924,000	2,294,000	56,200	14,200	70,400	2,364,400
1984	6,950,000	1,470,000	1,050,000	2,520,000	56,900	29,100	86,000	2,606,000
1985	7,150,000	1,720,000	1,230,000	2,950,000	65,800	29,300	95,100	3,045,100
1986	6,180,000	846,000	535,000	1,381,000	37,200	4,920	42,120	1,423,120
1987	7,640,000	1,770,000	1,260,000	3,030,000	68,000	29,300	97,300	3,127,300
1988	7,420,000	1,750,000	1,230,000	2,980,000	68,900	24,200	93,100	3,073,100
1989	7,420,000	1,450,000	986,000	2,436,000	59,300	15,900	75,200	2,511,200
1990	9,420,000	3,180,000	2,400,000	5,580,000	113,000	80,800	193,800	5,773,800
1991	6,180,000	1,040,000	694,000	1,734,000	43,100	10,100	53,200	1,787,200
1992	6,330,000	1,170,000	791,000	1,961,000	48,600	11,200	59,800	2,020,800
1993	7,310,000	1,470,000	998,000	2,468,000	60,200	15,800	76,000	2,544,000
1994	7,210,000	1,550,000	1,110,000	2,660,000	58,500	32,500	91,000	2,751,000
1995	7,450,000	1,570,000	1,080,000	2,650,000	63,000	18,900	81,900	2,731,900
1996	4,940,000	451,000	266,000	717,000	20,200	1,510	21,710	738,710
1997	6,370,000	1,210,000	815,000	2,025,000	50,100	11,700	61,800	2,086,800
1998	6,790,000	1,480,000	1,020,000	2,500,000	60,100	17,000	77,100	2,577,100
1999	6,730,000	1,380,000	962,000	2,342,000	54,500	20,200	74,700	2,416,700
2000	7,430,000	1,920,000	1,390,000	3,310,000	71,100	34,600	105,700	3,415,700
2001	6,910,000	1,590,000	1,130,000	2,720,000	60,800	25,700	86,500	2,806,500
2002	6,140,000	1,040,000	693,000	1,733,000	42,700	10,900	53,600	1,786,600
2003	7,440,000	1,700,000	1,230,000	2,930,000	64,500	35,500	100,000	3,030,000
2004	6,820,000	1,320,000	900,000	2,220,000	54,000	15,600	69,600	2,289,600
2005	8,840,000	2,890,000	2,130,000	5,020,000	107,000	56,400	163,400	5,183,400
2006	7,470,000	2,270,000	1,730,000	4,000,000	80,300	79,000	159,300	4,159,300
2007	6,990,000	1,040,000	662,000	1,702,000	45,300	6,460	51,760	1,753,760
2008	6,460,000	1,010,000	662,000	1,672,000	42,600	8,510	51,110	1,723,110
2009	6,880,000	1,270,000	856,000	2,126,000	51,900	14,600	66,500	2,192,500
2010	7,340,000	1,480,000	1,000,000	2,480,000	60,600	16,600	77,200	2,557,200

Table B.1-2. Annual Sediment Load for Pre-Project Conditions for Chulitna River near Talkeetna

Chulitna River near Talkeetna - 15292400								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	5,370,000	3,440,000	1,940,000	5,380,000	885,000	476,000	1,361,000	6,741,000
1951	6,130,000	4,550,000	2,500,000	7,050,000	1,150,000	634,000	1,784,000	8,834,000
1952	5,940,000	5,190,000	2,670,000	7,860,000	1,210,000	736,000	1,946,000	9,806,000
1953	6,690,000	4,910,000	2,700,000	7,610,000	1,240,000	684,000	1,924,000	9,534,000
1954	6,440,000	5,090,000	2,730,000	7,820,000	1,250,000	713,000	1,963,000	9,783,000
1955	6,320,000	5,510,000	2,830,000	8,340,000	1,290,000	781,000	2,071,000	10,411,000
1956	7,110,000	6,980,000	3,520,000	10,500,000	1,600,000	993,000	2,593,000	13,093,000
1957	6,690,000	5,580,000	2,940,000	8,520,000	1,340,000	785,000	2,125,000	10,645,000
1958	6,350,000	5,080,000	2,650,000	7,730,000	1,190,000	719,000	1,909,000	9,639,000
1959	6,060,000	5,540,000	2,780,000	8,320,000	1,260,000	791,000	2,051,000	10,371,000
1960	6,070,000	4,620,000	2,460,000	7,080,000	1,110,000	649,000	1,759,000	8,839,000
1961	6,840,000	6,530,000	3,240,000	9,770,000	1,470,000	935,000	2,405,000	12,175,000
1962	6,380,000	5,850,000	2,930,000	8,780,000	1,320,000	836,000	2,156,000	10,936,000
1963	5,990,000	5,220,000	2,650,000	7,870,000	1,210,000	743,000	1,953,000	9,823,000
1964	6,760,000	9,370,000	4,080,000	13,450,000	1,820,000	1,390,000	3,210,000	16,660,000
1965	6,780,000	6,140,000	3,100,000	9,240,000	1,410,000	876,000	2,286,000	11,526,000
1966	6,260,000	5,960,000	2,960,000	8,920,000	1,340,000	853,000	2,193,000	11,113,000
1967	8,050,000	14,300,000	5,670,000	19,970,000	2,510,000	2,170,000	4,680,000	24,650,000
1968	6,660,000	7,610,000	3,570,000	11,180,000	1,610,000	1,100,000	2,710,000	13,890,000
1969	4,420,000	2,610,000	1,470,000	4,080,000	652,000	361,000	1,013,000	5,093,000
1970	6,320,000	5,660,000	2,860,000	8,520,000	1,300,000	806,000	2,106,000	10,626,000
1971	6,090,000	6,670,000	3,110,000	9,780,000	1,390,000	971,000	2,361,000	12,141,000
1972	6,050,000	4,800,000	2,520,000	7,320,000	1,140,000	677,000	1,817,000	9,137,000
1973	5,490,000	3,780,000	2,060,000	5,840,000	930,000	528,000	1,458,000	7,298,000
1974	5,730,000	3,780,000	2,120,000	5,900,000	971,000	524,000	1,495,000	7,395,000
1975	6,490,000	5,550,000	2,880,000	8,430,000	1,310,000	785,000	2,095,000	10,525,000
1976	5,510,000	3,820,000	2,090,000	5,910,000	942,000	533,000	1,475,000	7,385,000
1977	6,330,000	5,510,000	2,830,000	8,340,000	1,290,000	781,000	2,071,000	10,411,000
1978	5,540,000	3,490,000	1,960,000	5,450,000	885,000	483,000	1,368,000	6,818,000
1979	6,470,000	5,470,000	2,840,000	8,310,000	1,290,000	773,000	2,063,000	10,373,000

Chulitna River near Talkeetna – 15292400 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	7,010,000	7,730,000	3,570,000	11,300,000	1,590,000	1,130,000	2,720,000	14,020,000
1981	7,540,000	9,890,000	4,340,000	14,230,000	1,930,000	1,460,000	3,390,000	17,620,000
1982	6,120,000	5,280,000	2,690,000	7,970,000	1,220,000	751,000	1,971,000	9,941,000
1983	5,950,000	4,530,000	2,380,000	6,910,000	1,080,000	639,000	1,719,000	8,629,000
1984	6,140,000	4,300,000	2,330,000	6,630,000	1,060,000	602,000	1,662,000	8,292,000
1985	6,120,000	5,080,000	2,620,000	7,700,000	1,190,000	720,000	1,910,000	9,610,000
1986	5,410,000	3,510,000	1,960,000	5,470,000	897,000	488,000	1,385,000	6,855,000
1987	7,140,000	6,240,000	3,130,000	9,370,000	1,420,000	894,000	2,314,000	11,684,000
1988	5,860,000	3,880,000	2,170,000	6,050,000	994,000	537,000	1,531,000	7,581,000
1989	6,480,000	5,330,000	2,800,000	8,130,000	1,280,000	750,000	2,030,000	10,160,000
1990	7,920,000	7,250,000	3,660,000	10,910,000	1,650,000	1,030,000	2,680,000	13,590,000
1991	5,750,000	4,300,000	2,300,000	6,600,000	1,040,000	605,000	1,645,000	8,245,000
1992	5,450,000	4,180,000	2,230,000	6,410,000	1,010,000	587,000	1,597,000	8,007,000
1993	7,250,000	6,750,000	3,430,000	10,180,000	1,560,000	959,000	2,519,000	12,699,000
1994	6,640,000	5,020,000	2,690,000	7,710,000	1,220,000	705,000	1,925,000	9,635,000
1995	6,290,000	4,620,000	2,520,000	7,140,000	1,160,000	645,000	1,805,000	8,945,000
1996	4,930,000	2,390,000	1,460,000	3,850,000	658,000	324,000	982,000	4,832,000
1997	5,550,000	3,940,000	2,150,000	6,090,000	977,000	551,000	1,528,000	7,618,000
1998	5,960,000	4,770,000	2,530,000	7,300,000	1,150,000	670,000	1,820,000	9,120,000
1999	5,850,000	4,360,000	2,320,000	6,680,000	1,050,000	613,000	1,663,000	8,343,000
2000	6,460,000	5,830,000	2,920,000	8,750,000	1,320,000	832,000	2,152,000	10,902,000
2001	5,680,000	3,930,000	2,150,000	6,080,000	972,000	549,000	1,521,000	7,601,000
2002	5,860,000	4,230,000	2,310,000	6,540,000	1,060,000	591,000	1,651,000	8,191,000
2003	6,580,000	4,640,000	2,540,000	7,180,000	1,150,000	648,000	1,798,000	8,978,000
2004	5,730,000	3,370,000	1,960,000	5,330,000	892,000	461,000	1,353,000	6,683,000
2005	8,470,000	9,190,000	4,480,000	13,670,000	2,030,000	1,320,000	3,350,000	17,020,000
2006	6,000,000	4,890,000	2,510,000	7,400,000	1,130,000	695,000	1,825,000	9,225,000
2007	5,670,000	3,180,000	1,880,000	5,060,000	861,000	434,000	1,295,000	6,355,000
2008	5,410,000	3,130,000	1,820,000	4,950,000	833,000	429,000	1,262,000	6,212,000
2009	5,600,000	3,140,000	1,850,000	4,990,000	848,000	429,000	1,277,000	6,267,000
2010	5,920,000	3,620,000	2,070,000	5,690,000	940,000	499,000	1,439,000	7,129,000

Table B.1-3. Annual Sediment Load for Pre-Project Conditions for Talkeetna River near Talkeetna

Talkeetna River near Talkeetna - 15292700								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	2,460,000	459,000	454,000	913,000	65,900	17,300	83,200	996,200
1951	2,800,000	631,000	601,000	1,232,000	84,000	26,800	110,800	1,342,800
1952	2,930,000	1,010,000	836,000	1,846,000	102,000	67,100	169,100	2,015,100
1953	3,080,000	720,000	676,000	1,396,000	93,400	33,100	126,500	1,522,500
1954	2,960,000	736,000	679,000	1,415,000	92,100	35,400	127,500	1,542,500
1955	3,130,000	1,140,000	923,000	2,063,000	111,000	77,300	188,300	2,251,300
1956	3,540,000	1,420,000	1,150,000	2,570,000	137,000	97,900	234,900	2,804,900
1957	3,160,000	908,000	801,000	1,709,000	104,000	51,100	155,100	1,864,100
1958	2,870,000	642,000	600,000	1,242,000	82,900	30,900	113,800	1,355,800
1959	2,950,000	826,000	735,000	1,561,000	95,900	45,600	141,500	1,702,500
1960	2,840,000	607,000	581,000	1,188,000	81,600	26,000	107,600	1,295,600
1961	3,150,000	789,000	724,000	1,513,000	97,300	40,000	137,300	1,650,300
1962	3,160,000	1,020,000	860,000	1,880,000	107,000	62,800	169,800	2,049,800
1963	3,000,000	867,000	764,000	1,631,000	98,700	49,200	147,900	1,778,900
1964	2,870,000	1,210,000	925,000	2,135,000	106,000	88,300	194,300	2,329,300
1965	3,440,000	1,300,000	1,050,000	2,350,000	126,000	89,700	215,700	2,565,700
1966	3,060,000	1,110,000	886,000	1,996,000	106,000	76,500	182,500	2,178,500
1967	3,240,000	1,640,000	1,160,000	2,800,000	126,000	114,000	240,000	3,040,000
1968	3,240,000	1,160,000	942,000	2,102,000	113,000	79,700	192,700	2,294,700
1969	1,630,000	161,000	183,000	344,000	30,600	3,070	33,670	377,670
1970	2,530,000	574,000	535,000	1,109,000	73,500	27,700	101,200	1,210,200
1971	3,840,000	4,070,000	2,300,000	6,370,000	196,000	285,000	481,000	6,851,000
1972	3,250,000	1,130,000	936,000	2,066,000	114,000	72,900	186,900	2,252,900
1973	2,790,000	842,000	691,000	1,533,000	86,100	53,900	140,000	1,673,000
1974	2,410,000	445,000	435,000	880,000	62,800	17,700	80,500	960,500
1975	3,140,000	1,030,000	876,000	1,906,000	109,000	64,500	173,500	2,079,500
1976	2,470,000	527,000	493,000	1,020,000	68,700	25,500	94,200	1,114,200
1977	3,150,000	1,420,000	1,060,000	2,480,000	118,000	105,000	223,000	2,703,000
1978	2,390,000	424,000	418,000	842,000	60,900	17,400	78,300	920,300
1979	3,220,000	1,360,000	1,050,000	2,410,000	119,000	100,000	219,000	2,629,000

Talkeetna River near Talkeetna – 15292700 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	3,150,000	1,020,000	840,000	1,860,000	104,000	66,600	170,600	2,030,600
1981	3,200,000	1,840,000	1,250,000	3,090,000	128,000	139,000	267,000	3,357,000
1982	3,040,000	1,130,000	897,000	2,027,000	107,000	77,000	184,000	2,211,000
1983	2,630,000	477,000	473,000	950,000	68,800	18,200	87,000	1,037,000
1984	2,640,000	610,000	551,000	1,161,000	74,800	30,900	105,700	1,266,700
1985	3,080,000	1,060,000	875,000	1,935,000	107,000	67,800	174,800	2,109,800
1986	2,430,000	425,000	426,000	851,000	62,800	15,200	78,000	929,000
1987	3,480,000	2,070,000	1,270,000	3,340,000	129,000	115,000	244,000	3,584,000
1988	2,710,000	546,000	530,000	1,076,000	75,000	21,900	96,900	1,172,900
1989	3,070,000	882,000	775,000	1,657,000	100,000	50,100	150,100	1,807,100
1990	3,900,000	1,570,000	1,230,000	2,800,000	143,000	111,000	254,000	3,054,000
1991	2,740,000	727,000	646,000	1,373,000	84,900	42,000	126,900	1,499,900
1992	2,560,000	653,000	591,000	1,244,000	78,500	34,700	113,200	1,357,200
1993	3,500,000	1,260,000	1,040,000	2,300,000	126,000	82,100	208,100	2,508,100
1994	3,140,000	869,000	758,000	1,627,000	98,500	50,200	148,700	1,775,700
1995	2,920,000	701,000	650,000	1,351,000	88,600	33,500	122,100	1,473,100
1996	2,260,000	317,000	338,000	655,000	53,100	8,410	61,510	716,510
1997	2,590,000	601,000	557,000	1,158,000	75,900	29,600	105,500	1,263,500
1998	2,790,000	776,000	687,000	1,463,000	89,600	42,800	132,400	1,595,400
1999	2,790,000	805,000	683,000	1,488,000	87,100	48,900	136,000	1,624,000
2000	3,230,000	1,260,000	1,000,000	2,260,000	117,000	92,700	209,700	2,469,700
2001	2,680,000	621,000	571,000	1,192,000	77,500	32,200	109,700	1,301,700
2002	2,750,000	700,000	630,000	1,330,000	84,100	37,000	121,100	1,451,100
2003	3,080,000	762,000	686,000	1,448,000	92,600	40,400	133,000	1,581,000
2004	2,620,000	438,000	450,000	888,000	67,700	12,700	80,400	968,400
2005	4,240,000	1,970,000	1,530,000	3,500,000	174,000	146,000	320,000	3,820,000
2006	2,910,000	1,290,000	906,000	2,196,000	101,000	81,300	182,300	2,378,300
2007	2,600,000	436,000	447,000	883,000	67,500	14,100	81,600	964,600
2008	2,490,000	433,000	437,000	870,000	65,000	15,000	80,000	950,000
2009	2,580,000	430,000	440,000	870,000	66,200	13,600	79,800	949,800
2010	2,730,000	497,000	495,000	992,000	72,600	18,100	90,700	1,082,700

Table B.1-4. Annual Sediment Load for Pre-Project Conditions for Susitna River at Sunshine

Susitna River at Sunshine - 15292780								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	14,200,000	6,000,000	3,920,000	9,920,000	148,000	130,000	278,000	10,198,000
1951	16,200,000	8,080,000	5,100,000	13,180,000	176,000	172,000	348,000	13,528,000
1952	16,700,000	11,000,000	6,260,000	17,260,000	187,000	324,000	511,000	17,771,000
1953	17,900,000	8,980,000	5,630,000	14,610,000	195,000	202,000	397,000	15,007,000
1954	17,200,000	9,160,000	5,640,000	14,800,000	189,000	212,000	401,000	15,201,000
1955	17,800,000	12,000,000	6,730,000	18,730,000	200,000	369,000	569,000	19,299,000
1956	20,000,000	15,200,000	8,440,000	23,640,000	235,000	454,000	689,000	24,329,000
1957	18,300,000	10,700,000	6,370,000	17,070,000	203,000	271,000	474,000	17,544,000
1958	16,600,000	8,520,000	5,170,000	13,690,000	178,000	228,000	406,000	14,096,000
1959	18,400,000	13,100,000	7,290,000	20,390,000	211,000	406,000	617,000	21,007,000
1960	17,100,000	8,590,000	5,320,000	13,910,000	184,000	208,000	392,000	14,302,000
1961	19,000,000	10,800,000	6,410,000	17,210,000	209,000	297,000	506,000	17,716,000
1962	19,900,000	16,500,000	8,610,000	25,110,000	232,000	664,000	896,000	26,006,000
1963	19,300,000	14,100,000	7,810,000	21,910,000	223,000	424,000	647,000	22,557,000
1964	16,400,000	14,700,000	7,380,000	22,080,000	190,000	663,000	853,000	22,933,000
1965	18,700,000	11,700,000	6,830,000	18,530,000	210,000	305,000	515,000	19,045,000
1966	17,100,000	10,100,000	5,860,000	15,960,000	188,000	297,000	485,000	16,445,000
1967	19,400,000	14,900,000	8,100,000	23,000,000	226,000	497,000	723,000	23,723,000
1968	17,800,000	11,100,000	6,390,000	17,490,000	197,000	314,000	511,000	18,001,000
1969	10,100,000	2,590,000	1,940,000	4,530,000	94,700	61,900	156,600	4,686,600
1970	14,300,000	6,420,000	4,140,000	10,560,000	151,000	139,000	290,000	10,850,000
1971	18,400,000	15,600,000	8,030,000	23,630,000	213,000	649,000	862,000	24,492,000
1972	19,200,000	12,400,000	7,010,000	19,410,000	214,000	391,000	605,000	20,015,000
1973	15,100,000	7,590,000	4,620,000	12,210,000	160,000	206,000	366,000	12,576,000
1974	14,100,000	5,890,000	3,870,000	9,760,000	147,000	127,000	274,000	10,034,000
1975	18,400,000	11,700,000	6,780,000	18,480,000	207,000	307,000	514,000	18,994,000
1976	14,900,000	6,550,000	4,210,000	10,760,000	156,000	151,000	307,000	11,067,000
1977	17,900,000	11,800,000	6,660,000	18,460,000	200,000	366,000	566,000	19,026,000
1978	14,800,000	5,240,000	3,590,000	8,830,000	149,000	115,000	264,000	9,094,000
1979	17,400,000	10,300,000	6,050,000	16,350,000	192,000	277,000	469,000	16,819,000

Susitna River at Sunshine – 15292780 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	18,900,000	11,600,000	6,700,000	18,300,000	210,000	334,000	544,000	18,844,000
1981	20,500,000	16,800,000	8,780,000	25,580,000	237,000	674,000	911,000	26,491,000
1982	17,400,000	9,220,000	5,620,000	14,840,000	189,000	231,000	420,000	15,260,000
1983	17,100,000	8,300,000	5,170,000	13,470,000	182,000	201,000	383,000	13,853,000
1984	17,100,000	8,460,000	5,190,000	13,650,000	181,000	219,000	400,000	14,050,000
1985	17,600,000	10,400,000	6,090,000	16,490,000	194,000	277,000	471,000	16,961,000
1986	14,900,000	5,710,000	3,860,000	9,570,000	153,000	117,000	270,000	9,840,000
1987	19,400,000	10,900,000	6,520,000	17,420,000	213,000	286,000	499,000	17,919,000
1988	18,000,000	9,940,000	6,030,000	15,970,000	198,000	236,000	434,000	16,404,000
1989	18,500,000	9,600,000	5,920,000	15,520,000	201,000	223,000	424,000	15,944,000
1990	23,000,000	16,200,000	9,140,000	25,340,000	265,000	469,000	734,000	26,074,000
1991	15,600,000	7,180,000	4,540,000	11,720,000	165,000	168,000	333,000	12,053,000
1992	15,700,000	7,870,000	4,850,000	12,720,000	167,000	186,000	353,000	13,073,000
1993	18,800,000	10,400,000	6,310,000	16,710,000	208,000	244,000	452,000	17,162,000
1994	18,200,000	9,290,000	5,670,000	14,960,000	195,000	242,000	437,000	15,397,000
1995	18,400,000	9,740,000	5,980,000	15,720,000	201,000	226,000	427,000	16,147,000
1996	12,800,000	3,780,000	2,760,000	6,540,000	126,000	79,800	205,800	6,745,800
1997	16,800,000	8,860,000	5,400,000	14,260,000	182,000	215,000	397,000	14,657,000
1998	17,800,000	10,500,000	6,250,000	16,750,000	198,000	260,000	458,000	17,208,000
1999	17,600,000	9,660,000	5,790,000	15,450,000	192,000	255,000	447,000	15,897,000
2000	19,300,000	12,400,000	7,090,000	19,490,000	216,000	366,000	582,000	20,072,000
2001	17,200,000	9,100,000	5,500,000	14,600,000	186,000	236,000	422,000	15,022,000
2002	15,700,000	7,210,000	4,600,000	11,810,000	166,000	161,000	327,000	12,137,000
2003	18,600,000	9,850,000	5,960,000	15,810,000	201,000	258,000	459,000	16,269,000
2004	16,900,000	8,110,000	5,130,000	13,240,000	181,000	179,000	360,000	13,600,000
2005	22,400,000	16,700,000	9,350,000	26,050,000	263,000	459,000	722,000	26,772,000
2006	18,100,000	11,400,000	6,550,000	17,950,000	202,000	339,000	541,000	18,491,000
2007	17,200,000	6,950,000	4,650,000	11,600,000	180,000	140,000	320,000	11,920,000
2008	16,000,000	6,770,000	4,420,000	11,190,000	167,000	147,000	314,000	11,504,000
2009	16,900,000	7,720,000	4,970,000	12,690,000	181,000	165,000	346,000	13,036,000
2010	18,000,000	8,790,000	5,540,000	14,330,000	194,000	194,000	388,000	14,718,000

Table B.1-5. Annual Sediment Load for Pre-Project Conditions for Yentna River near Susitna Station

Yentna River near Susitna Station - 15294345								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	11,800,000	4,730,000	4,820,000	9,550,000	1,050,000	122,000	1,172,000	10,722,000
1951	13,400,000	6,180,000	6,160,000	12,340,000	1,290,000	155,000	1,445,000	13,785,000
1952	13,300,000	7,180,000	6,810,000	13,990,000	1,330,000	180,000	1,510,000	15,500,000
1953	14,800,000	6,750,000	6,730,000	13,480,000	1,410,000	168,000	1,578,000	15,058,000
1954	14,200,000	6,830,000	6,720,000	13,550,000	1,380,000	171,000	1,551,000	15,101,000
1955	14,300,000	7,710,000	7,290,000	15,000,000	1,420,000	194,000	1,614,000	16,614,000
1956	15,800,000	9,650,000	9,000,000	18,650,000	1,700,000	236,000	1,936,000	20,586,000
1957	14,900,000	7,610,000	7,370,000	14,980,000	1,480,000	191,000	1,671,000	16,651,000
1958	13,700,000	6,140,000	6,030,000	12,170,000	1,260,000	158,000	1,418,000	13,588,000
1959	14,800,000	8,460,000	7,950,000	16,410,000	1,530,000	210,000	1,740,000	18,150,000
1960	13,000,000	5,490,000	5,480,000	10,970,000	1,170,000	142,000	1,312,000	12,282,000
1961	14,700,000	7,260,000	6,970,000	14,230,000	1,410,000	183,000	1,593,000	15,823,000
1962	11,600,000	3,940,000	4,120,000	8,060,000	948,000	106,000	1,054,000	9,114,000
1963	11,900,000	5,580,000	5,380,000	10,960,000	1,100,000	142,000	1,242,000	12,202,000
1964	12,700,000	7,900,000	7,090,000	14,990,000	1,310,000	197,000	1,507,000	16,497,000
1965	13,400,000	6,780,000	6,490,000	13,270,000	1,300,000	171,000	1,471,000	14,741,000
1966	13,000,000	6,800,000	6,320,000	13,120,000	1,240,000	172,000	1,412,000	14,532,000
1967	11,400,000	4,550,000	4,610,000	9,160,000	1,000,000	118,000	1,118,000	10,278,000
1968	13,100,000	6,640,000	6,310,000	12,950,000	1,250,000	170,000	1,420,000	14,370,000
1969	10,600,000	4,830,000	4,670,000	9,500,000	957,000	126,000	1,083,000	10,583,000
1970	14,700,000	8,640,000	8,020,000	16,660,000	1,520,000	213,000	1,733,000	18,393,000
1971	14,000,000	11,100,000	9,360,000	20,460,000	1,580,000	271,000	1,851,000	22,311,000
1972	12,200,000	5,280,000	5,230,000	10,510,000	1,100,000	136,000	1,236,000	11,746,000
1973	10,700,000	3,520,000	3,670,000	7,190,000	851,000	94,700	945,700	8,135,700
1974	10,500,000	2,860,000	3,170,000	6,030,000	789,000	79,800	868,800	6,898,800
1975	13,700,000	6,960,000	6,660,000	13,620,000	1,330,000	176,000	1,506,000	15,126,000
1976	12,500,000	4,710,000	4,840,000	9,550,000	1,080,000	123,000	1,203,000	10,753,000
1977	19,000,000	15,600,000	13,300,000	28,900,000	2,220,000	378,000	2,598,000	31,498,000
1978	12,900,000	4,990,000	5,080,000	10,070,000	1,120,000	129,000	1,249,000	11,319,000
1979	15,000,000	7,330,000	7,110,000	14,440,000	1,440,000	185,000	1,625,000	16,065,000

Yentna River near Susitna Station – 15294345 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	18,900,000	13,400,000	11,700,000	25,100,000	2,080,000	324,000	2,404,000	27,504,000
1981	18,000,000	12,200,000	10,900,000	23,100,000	1,960,000	297,000	2,257,000	25,357,000
1982	13,500,000	6,430,000	6,190,000	12,620,000	1,260,000	164,000	1,424,000	14,044,000
1983	13,300,000	6,190,000	5,930,000	12,120,000	1,210,000	158,000	1,368,000	13,488,000
1984	14,500,000	7,450,000	7,100,000	14,550,000	1,410,000	187,000	1,597,000	16,147,000
1985	14,200,000	7,430,000	7,110,000	14,540,000	1,410,000	186,000	1,596,000	16,136,000
1986	14,200,000	6,570,000	6,460,000	13,030,000	1,340,000	166,000	1,506,000	14,536,000
1987	17,100,000	11,100,000	9,940,000	21,040,000	1,820,000	271,000	2,091,000	23,131,000
1988	16,600,000	9,270,000	8,700,000	17,970,000	1,680,000	232,000	1,912,000	19,882,000
1989	17,700,000	11,700,000	10,600,000	22,300,000	1,930,000	284,000	2,214,000	24,514,000
1990	19,100,000	12,200,000	11,200,000	23,400,000	2,070,000	297,000	2,367,000	25,767,000
1991	14,900,000	8,160,000	7,690,000	15,850,000	1,500,000	204,000	1,704,000	17,554,000
1992	13,300,000	5,480,000	5,480,000	10,960,000	1,170,000	144,000	1,314,000	12,274,000
1993	14,800,000	6,830,000	6,750,000	13,580,000	1,400,000	174,000	1,574,000	15,154,000
1994	14,300,000	6,240,000	6,190,000	12,430,000	1,310,000	159,000	1,469,000	13,899,000
1995	14,900,000	7,020,000	6,910,000	13,930,000	1,420,000	178,000	1,598,000	15,528,000
1996	10,000,000	2,780,000	3,070,000	5,850,000	762,000	76,800	838,800	6,688,800
1997	13,400,000	6,130,000	6,050,000	12,180,000	1,250,000	157,000	1,407,000	13,587,000
1998	14,100,000	7,140,000	6,920,000	14,060,000	1,390,000	180,000	1,570,000	15,630,000
1999	14,100,000	6,620,000	6,470,000	13,090,000	1,330,000	167,000	1,497,000	14,587,000
2000	15,300,000	8,130,000	7,710,000	15,840,000	1,520,000	203,000	1,723,000	17,563,000
2001	13,900,000	6,460,000	6,310,000	12,770,000	1,300,000	165,000	1,465,000	14,235,000
2002	12,400,000	5,000,000	5,080,000	10,080,000	1,100,000	130,000	1,230,000	11,310,000
2003	14,700,000	6,820,000	6,670,000	13,490,000	1,380,000	173,000	1,553,000	15,043,000
2004	13,700,000	6,160,000	6,120,000	12,280,000	1,280,000	157,000	1,437,000	13,717,000
2005	17,100,000	10,500,000	9,840,000	20,340,000	1,860,000	257,000	2,117,000	22,457,000
2006	14,500,000	7,780,000	7,410,000	15,190,000	1,460,000	194,000	1,654,000	16,844,000
2007	14,300,000	5,650,000	5,800,000	11,450,000	1,280,000	145,000	1,425,000	12,875,000
2008	13,100,000	5,130,000	5,240,000	10,370,000	1,150,000	133,000	1,283,000	11,653,000
2009	13,900,000	6,020,000	6,050,000	12,070,000	1,290,000	152,000	1,442,000	13,512,000
2010	14,800,000	6,900,000	6,840,000	13,740,000	1,420,000	174,000	1,594,000	15,334,000

Table B.1-6. Annual Sediment Load for Pre-Project Conditions for Susitna River at Susitna Station

Susitna River at Susitna Station - 15294350								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	30,700,000	14,200,000	10,500,000	24,700,000	1,180,000	190,000	1,370,000	26,070,000
1951	34,300,000	18,300,000	12,500,000	30,800,000	1,470,000	244,000	1,714,000	32,514,000
1952	34,000,000	21,200,000	12,700,000	33,900,000	1,610,000	283,000	1,893,000	35,793,000
1953	37,800,000	20,100,000	13,700,000	33,800,000	1,620,000	268,000	1,888,000	35,688,000
1954	36,000,000	20,100,000	13,300,000	33,400,000	1,600,000	268,000	1,868,000	35,268,000
1955	36,400,000	22,800,000	13,700,000	36,500,000	1,730,000	304,000	2,034,000	38,534,000
1956	40,100,000	28,300,000	15,900,000	44,200,000	2,100,000	377,000	2,477,000	46,677,000
1957	37,800,000	22,300,000	14,100,000	36,400,000	1,740,000	297,000	2,037,000	38,437,000
1958	35,200,000	18,100,000	12,400,000	30,500,000	1,450,000	242,000	1,692,000	32,192,000
1959	37,400,000	24,800,000	14,400,000	39,200,000	1,860,000	330,000	2,190,000	41,390,000
1960	34,600,000	17,800,000	12,300,000	30,100,000	1,440,000	237,000	1,677,000	31,777,000
1961	37,800,000	21,100,000	13,800,000	34,900,000	1,660,000	281,000	1,941,000	36,841,000
1962	34,700,000	19,700,000	12,600,000	32,300,000	1,540,000	263,000	1,803,000	34,103,000
1963	34,100,000	19,900,000	12,600,000	32,500,000	1,540,000	265,000	1,805,000	34,305,000
1964	31,000,000	18,400,000	11,400,000	29,800,000	1,410,000	245,000	1,655,000	31,455,000
1965	35,700,000	20,600,000	13,100,000	33,700,000	1,610,000	275,000	1,885,000	35,585,000
1966	33,500,000	18,100,000	12,000,000	30,100,000	1,430,000	241,000	1,671,000	31,771,000
1967	32,700,000	17,800,000	11,800,000	29,600,000	1,410,000	237,000	1,647,000	31,247,000
1968	34,000,000	19,300,000	12,300,000	31,600,000	1,500,000	257,000	1,757,000	33,357,000
1969	24,200,000	9,610,000	7,720,000	17,330,000	821,000	128,000	949,000	18,279,000
1970	33,800,000	18,400,000	12,300,000	30,700,000	1,460,000	245,000	1,705,000	32,405,000
1971	34,600,000	23,100,000	13,200,000	36,300,000	1,710,000	307,000	2,017,000	38,317,000
1972	33,900,000	18,600,000	12,300,000	30,900,000	1,470,000	248,000	1,718,000	32,618,000
1973	29,900,000	13,100,000	9,950,000	23,050,000	1,090,000	174,000	1,264,000	24,314,000
1974	29,000,000	11,500,000	9,460,000	20,960,000	1,000,000	154,000	1,154,000	22,114,000
1975	33,400,000	18,900,000	12,100,000	31,000,000	1,480,000	252,000	1,732,000	32,732,000
1976	31,200,000	14,500,000	10,700,000	25,200,000	1,200,000	193,000	1,393,000	26,593,000
1977	40,500,000	28,800,000	15,900,000	44,700,000	2,110,000	383,000	2,493,000	47,193,000
1978	30,400,000	13,100,000	10,200,000	23,300,000	1,110,000	175,000	1,285,000	24,585,000
1979	38,900,000	23,700,000	14,600,000	38,300,000	1,820,000	316,000	2,136,000	40,436,000

Susitna River at Susitna Station – 15294350 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	45,000,000	32,600,000	17,700,000	50,300,000	2,360,000	434,000	2,794,000	53,094,000
1981	40,300,000	29,400,000	15,800,000	45,200,000	2,110,000	390,000	2,500,000	47,700,000
1982	34,100,000	17,700,000	12,000,000	29,700,000	1,410,000	236,000	1,646,000	31,346,000
1983	31,700,000	14,200,000	10,700,000	24,900,000	1,180,000	189,000	1,369,000	26,269,000
1984	32,900,000	14,600,000	11,100,000	25,700,000	1,220,000	196,000	1,416,000	27,116,000
1985	34,200,000	19,300,000	12,500,000	31,800,000	1,510,000	257,000	1,767,000	33,567,000
1986	33,600,000	15,200,000	11,400,000	26,600,000	1,270,000	203,000	1,473,000	28,073,000
1987	39,700,000	25,800,000	15,100,000	40,900,000	1,920,000	343,000	2,263,000	43,163,000
1988	38,900,000	22,300,000	14,200,000	36,500,000	1,740,000	297,000	2,037,000	38,537,000
1989	40,900,000	27,400,000	15,900,000	43,300,000	2,050,000	365,000	2,415,000	45,715,000
1990	44,300,000	28,800,000	17,100,000	45,900,000	2,180,000	384,000	2,564,000	48,464,000
1991	34,900,000	19,700,000	12,700,000	32,400,000	1,540,000	263,000	1,803,000	34,203,000
1992	31,900,000	13,800,000	10,500,000	24,300,000	1,150,000	184,000	1,334,000	25,634,000
1993	38,500,000	22,400,000	14,300,000	36,700,000	1,750,000	298,000	2,048,000	38,748,000
1994	37,500,000	19,400,000	13,300,000	32,700,000	1,560,000	259,000	1,819,000	34,519,000
1995	37,200,000	20,100,000	13,500,000	33,600,000	1,610,000	268,000	1,878,000	35,478,000
1996	27,800,000	9,770,000	8,720,000	18,490,000	878,000	131,000	1,009,000	19,499,000
1997	32,300,000	16,700,000	11,400,000	28,100,000	1,340,000	223,000	1,563,000	29,663,000
1998	34,100,000	19,600,000	12,600,000	32,200,000	1,530,000	261,000	1,791,000	33,991,000
1999	33,700,000	17,600,000	11,900,000	29,500,000	1,400,000	235,000	1,635,000	31,135,000
2000	36,500,000	21,300,000	13,300,000	34,600,000	1,640,000	284,000	1,924,000	36,524,000
2001	34,000,000	17,700,000	12,000,000	29,700,000	1,410,000	236,000	1,646,000	31,346,000
2002	32,700,000	16,000,000	11,400,000	27,400,000	1,310,000	214,000	1,524,000	28,924,000
2003	38,000,000	19,800,000	13,500,000	33,300,000	1,590,000	265,000	1,855,000	35,155,000
2004	34,700,000	17,000,000	12,200,000	29,200,000	1,400,000	227,000	1,627,000	30,827,000
2005	44,400,000	31,400,000	17,700,000	49,100,000	2,340,000	418,000	2,758,000	51,858,000
2006	35,800,000	20,900,000	13,200,000	34,100,000	1,620,000	278,000	1,898,000	35,998,000
2007	35,100,000	15,500,000	12,000,000	27,500,000	1,320,000	207,000	1,527,000	29,027,000
2008	32,900,000	14,900,000	11,200,000	26,100,000	1,250,000	199,000	1,449,000	27,549,000
2009	34,500,000	16,300,000	12,000,000	28,300,000	1,360,000	217,000	1,577,000	29,877,000
2010	36,400,000	18,200,000	12,900,000	31,100,000	1,480,000	242,000	1,722,000	32,822,000

APPENDIX B.2. ANNUAL SEDIMENT LOAD TABULAR SUMMARY FOR MAXIMUM LOAD FOLLOWING OPERATIONS SCENARIO 1

Susitna-Watana Hydroelectric Project
(FERC No. 14241)

Development of Sediment Transport Relationships and an Initial Sediment Balance for the Middle and Lower Susitna River Segments

Prepared for

Alaska Energy Authority

SUSITNA-WATANA HYDRO

Clean, reliable energy for the next 100 years.

Prepared by

Tetra Tech

February 2013

Table B.2-1. Annual Sediment Load for Max LF OS-1 Conditions for Susitna River at Gold Creek

Susitna River at Gold Creek - 15292000								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	6,130,000	19,900	92,100	112,000	8,480	67	8,547	120,547
1951	6,590,000	24,700	118,000	142,700	10,600	107	10,707	153,407
1952	6,540,000	24,700	119,000	143,700	10,600	122	10,722	154,422
1953	7,160,000	43,500	239,000	282,500	19,300	1,050	20,350	302,850
1954	6,980,000	42,200	237,000	279,200	18,100	1,520	19,620	298,820
1955	7,310,000	72,700	488,000	560,700	27,600	13,500	41,100	601,800
1956	8,270,000	103,000	681,000	784,000	41,100	11,100	52,200	836,200
1957	7,480,000	57,700	338,000	395,700	25,400	2,330	27,730	423,430
1958	6,840,000	44,600	264,000	308,600	18,500	2,980	21,480	330,080
1959	7,450,000	101,000	735,000	836,000	35,100	26,500	61,600	897,600
1960	6,990,000	47,700	287,000	334,700	19,400	4,170	23,570	358,270
1961	7,800,000	67,500	408,000	475,500	28,600	3,810	32,410	507,910
1962	8,350,000	100,000	643,000	743,000	42,000	7,740	49,740	792,740
1963	7,980,000	91,900	603,000	694,900	36,700	10,400	47,100	742,000
1964	7,070,000	41,300	224,000	265,300	18,300	857	19,157	284,457
1965	7,300,000	62,300	387,000	449,300	25,700	5,130	30,830	480,130
1966	6,810,000	30,400	152,000	182,400	13,200	276	13,476	195,876
1967	7,910,000	117,000	853,000	970,000	41,400	33,600	75,000	1,045,000
1968	7,100,000	43,900	245,000	288,900	19,200	1,410	20,610	309,510
1969	5,920,000	17,700	80,600	98,300	7,510	52	7,562	105,862
1970	4,980,000	20,500	100,000	120,500	8,880	115	8,995	129,495
1971	5,960,000	31,000	161,000	192,000	13,600	371	13,971	205,971
1972	7,870,000	65,600	386,000	451,600	28,900	2,650	31,550	483,150
1973	6,140,000	20,300	95,000	115,300	8,690	79	8,769	124,069
1974	6,410,000	22,800	108,000	130,800	9,790	93	9,883	140,683
1975	6,140,000	28,800	145,000	173,800	12,500	239	12,739	186,539
1976	6,210,000	20,600	96,300	116,900	8,820	76	8,896	125,796
1977	6,980,000	34,500	178,000	212,500	15,100	464	15,564	228,064
1978	6,100,000	19,400	89,400	108,800	8,260	63	8,323	117,123
1979	6,650,000	27,100	133,000	160,100	11,700	182	11,882	171,982

Susitna River at Gold Creek – 15292000 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	7,690,000	77,800	505,000	582,800	31,000	9,850	40,850	623,650
1981	8,410,000	163,000	1,210,000	1,373,000	56,400	42,300	98,700	1,471,700
1982	6,960,000	41,900	239,000	280,900	17,500	2,200	19,700	300,600
1983	7,150,000	51,700	308,000	359,700	21,800	3,040	24,840	384,540
1984	6,930,000	44,200	254,000	298,200	18,800	2,120	20,920	319,120
1985	7,110,000	42,800	236,000	278,800	18,700	1,190	19,890	298,690
1986	6,190,000	20,200	94,000	114,200	8,640	70	8,710	122,910
1987	7,510,000	62,500	380,000	442,500	26,400	4,000	30,400	472,900
1988	7,390,000	52,400	302,000	354,400	23,100	1,920	25,020	379,420
1989	7,380,000	52,900	305,000	357,900	23,100	2,010	25,110	383,010
1990	9,330,000	154,000	1,060,000	1,214,000	60,300	22,000	82,300	1,296,300
1991	6,200,000	20,900	97,700	118,600	8,930	81	9,011	127,611
1992	6,250,000	21,200	99,200	120,400	9,070	80	9,150	129,550
1993	7,260,000	58,500	362,000	420,500	23,900	5,260	29,160	449,660
1994	7,210,000	45,900	257,000	302,900	20,200	1,330	21,530	324,430
1995	7,390,000	53,200	308,000	361,200	23,200	2,130	25,330	386,530
1996	6,130,000	19,700	91,400	111,100	8,420	67	8,487	119,587
1997	5,990,000	25,100	123,000	148,100	10,800	146	10,946	159,046
1998	6,280,000	25,100	122,000	147,100	10,800	130	10,930	158,030
1999	6,370,000	22,400	105,000	127,400	9,600	89	9,689	137,089
2000	7,300,000	48,100	272,000	320,100	21,000	1,710	22,710	342,810
2001	6,900,000	39,200	217,000	256,200	16,800	1,340	18,140	274,340
2002	6,170,000	20,300	94,600	114,900	8,690	72	8,762	123,662
2003	7,330,000	57,900	349,000	406,900	24,300	3,670	27,970	434,870
2004	6,850,000	35,200	186,000	221,200	15,500	608	16,108	237,308
2005	8,720,000	110,000	711,000	821,000	46,300	8,740	55,040	876,040
2006	7,340,000	82,600	577,000	659,600	29,800	18,700	48,500	708,100
2007	6,930,000	35,300	185,000	220,300	15,500	575	16,075	236,375
2008	6,430,000	25,200	124,000	149,200	10,900	231	11,131	160,331
2009	6,850,000	34,700	184,000	218,700	15,100	727	15,827	234,527
2010	7,310,000	51,900	300,000	351,900	22,700	2,050	24,750	376,650

Table B.1-2. Annual Sediment Load for Max LF OS-1 Conditions for Susitna River at Sunshine

Susitna River at Sunshine - 15292780								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	14,500,000	3,130,000	2,580,000	5,710,000	136,000	83,300	219,300	5,929,300
1951	16,200,000	4,140,000	3,250,000	7,390,000	156,000	96,700	252,700	7,642,700
1952	16,300,000	5,070,000	3,660,000	8,730,000	160,000	127,000	287,000	9,017,000
1953	17,700,000	5,030,000	3,920,000	8,950,000	176,000	112,000	288,000	9,238,000
1954	17,200,000	5,030,000	3,840,000	8,870,000	170,000	116,000	286,000	9,156,000
1955	17,700,000	6,440,000	4,570,000	11,010,000	180,000	191,000	371,000	11,381,000
1956	20,000,000	8,590,000	5,950,000	14,540,000	212,000	228,000	440,000	14,980,000
1957	18,200,000	5,980,000	4,450,000	10,430,000	185,000	136,000	321,000	10,751,000
1958	16,600,000	4,710,000	3,600,000	8,310,000	163,000	124,000	287,000	8,597,000
1959	18,200,000	7,370,000	5,110,000	12,480,000	189,000	241,000	430,000	12,910,000
1960	17,100,000	4,820,000	3,720,000	8,540,000	168,000	125,000	293,000	8,833,000
1961	19,000,000	6,370,000	4,720,000	11,090,000	194,000	159,000	353,000	11,443,000
1962	19,900,000	8,620,000	5,910,000	14,530,000	211,000	243,000	454,000	14,984,000
1963	19,300,000	7,890,000	5,510,000	13,400,000	202,000	212,000	414,000	13,814,000
1964	16,400,000	5,800,000	4,050,000	9,850,000	164,000	156,000	320,000	10,170,000
1965	18,600,000	6,720,000	4,810,000	11,530,000	190,000	168,000	358,000	11,888,000
1966	17,100,000	5,130,000	3,800,000	8,930,000	169,000	126,000	295,000	9,225,000
1967	19,200,000	8,190,000	5,630,000	13,820,000	202,000	267,000	469,000	14,289,000
1968	17,800,000	5,920,000	4,290,000	10,210,000	179,000	143,000	322,000	10,532,000
1969	12,000,000	1,570,000	1,550,000	3,120,000	103,000	67,200	170,200	3,290,200
1970	13,700,000	3,600,000	2,820,000	6,420,000	133,000	82,700	215,700	6,635,700
1971	16,900,000	6,630,000	4,470,000	11,100,000	174,000	175,000	349,000	11,449,000
1972	19,200,000	6,850,000	4,950,000	11,800,000	197,000	167,000	364,000	12,164,000
1973	15,400,000	3,840,000	2,980,000	6,820,000	146,000	102,000	248,000	7,068,000
1974	15,000,000	3,260,000	2,700,000	5,960,000	141,000	87,700	228,700	6,188,700
1975	17,100,000	5,600,000	4,070,000	9,670,000	172,000	123,000	295,000	9,965,000
1976	15,200,000	3,480,000	2,810,000	6,290,000	143,000	89,800	232,800	6,522,800
1977	17,600,000	5,680,000	4,110,000	9,790,000	175,000	139,000	314,000	10,104,000
1978	15,000,000	2,990,000	2,540,000	5,530,000	139,000	82,100	221,100	5,751,100
1979	17,100,000	5,210,000	3,830,000	9,040,000	169,000	124,000	293,000	9,333,000

Susitna River at Sunshine – 15292780 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	18,800,000	6,530,000	4,780,000	11,310,000	192,000	179,000	371,000	11,681,000
1981	20,300,000	10,000,000	6,590,000	16,590,000	217,000	377,000	594,000	17,184,000
1982	17,400,000	5,440,000	4,010,000	9,450,000	173,000	138,000	311,000	9,761,000
1983	17,000,000	4,710,000	3,690,000	8,400,000	167,000	123,000	290,000	8,690,000
1984	17,000,000	5,000,000	3,760,000	8,760,000	167,000	138,000	305,000	9,065,000
1985	17,500,000	5,700,000	4,160,000	9,860,000	176,000	138,000	314,000	10,174,000
1986	14,900,000	3,020,000	2,570,000	5,590,000	139,000	82,600	221,600	5,811,600
1987	19,200,000	6,490,000	4,770,000	11,260,000	196,000	163,000	359,000	11,619,000
1988	18,000,000	5,510,000	4,190,000	9,700,000	180,000	124,000	304,000	10,004,000
1989	18,400,000	5,850,000	4,380,000	10,230,000	186,000	136,000	322,000	10,552,000
1990	22,900,000	10,100,000	7,130,000	17,230,000	248,000	282,000	530,000	17,760,000
1991	15,700,000	3,820,000	3,020,000	6,840,000	150,000	96,100	246,100	7,086,100
1992	15,600,000	4,030,000	3,110,000	7,140,000	150,000	96,200	246,200	7,386,200
1993	18,800,000	6,360,000	4,660,000	11,020,000	191,000	154,000	345,000	11,365,000
1994	18,200,000	5,370,000	4,100,000	9,470,000	181,000	128,000	309,000	9,779,000
1995	18,300,000	5,640,000	4,290,000	9,930,000	184,000	127,000	311,000	10,241,000
1996	14,100,000	2,400,000	2,170,000	4,570,000	127,000	77,100	204,100	4,774,100
1997	16,400,000	4,770,000	3,580,000	8,350,000	161,000	109,000	270,000	8,620,000
1998	17,300,000	5,460,000	3,980,000	9,440,000	172,000	122,000	294,000	9,734,000
1999	17,300,000	5,040,000	3,740,000	8,780,000	170,000	121,000	291,000	9,071,000
2000	19,200,000	6,850,000	4,870,000	11,720,000	196,000	168,000	364,000	12,084,000
2001	17,200,000	4,880,000	3,740,000	8,620,000	170,000	120,000	290,000	8,910,000
2002	15,700,000	3,820,000	3,030,000	6,850,000	150,000	94,500	244,500	7,094,500
2003	18,500,000	5,680,000	4,310,000	9,990,000	185,000	138,000	323,000	10,313,000
2004	17,000,000	4,470,000	3,530,000	8,000,000	166,000	99,700	265,700	8,265,700
2005	22,200,000	9,900,000	6,860,000	16,760,000	240,000	244,000	484,000	17,244,000
2006	17,900,000	6,390,000	4,590,000	10,980,000	182,000	199,000	381,000	11,361,000
2007	17,100,000	4,160,000	3,410,000	7,570,000	166,000	98,600	264,600	7,834,600
2008	15,900,000	3,690,000	3,010,000	6,700,000	152,000	92,100	244,100	6,944,100
2009	16,900,000	4,250,000	3,420,000	7,670,000	164,000	98,800	262,800	7,932,800
2010	18,000,000	5,160,000	4,020,000	9,180,000	179,000	120,000	299,000	9,479,000

Table B.2-3. Annual Sediment Load for Max LF OS-1 Conditions for Susitna River at Susitna Station

Susitna River at Susitna Station - 15294350								
WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1950	31,100,000	10,900,000	9,710,000	20,610,000	982,000	148,000	1,130,000	21,740,000
1951	34,300,000	13,800,000	11,300,000	25,100,000	1,210,000	187,000	1,397,000	26,497,000
1952	33,600,000	15,100,000	11,300,000	26,400,000	1,260,000	204,000	1,464,000	27,864,000
1953	37,600,000	15,700,000	12,700,000	28,400,000	1,380,000	215,000	1,595,000	29,995,000
1954	36,000,000	15,500,000	12,200,000	27,700,000	1,340,000	213,000	1,553,000	29,253,000
1955	36,300,000	17,200,000	12,500,000	29,700,000	1,440,000	238,000	1,678,000	31,378,000
1956	40,000,000	21,700,000	14,600,000	36,300,000	1,780,000	302,000	2,082,000	38,382,000
1957	37,800,000	17,300,000	13,000,000	30,300,000	1,470,000	238,000	1,708,000	32,008,000
1958	35,200,000	14,100,000	11,500,000	25,600,000	1,230,000	193,000	1,423,000	27,023,000
1959	37,200,000	18,900,000	13,200,000	32,100,000	1,560,000	263,000	1,823,000	33,923,000
1960	34,600,000	13,700,000	11,400,000	25,100,000	1,210,000	188,000	1,398,000	26,498,000
1961	37,800,000	16,700,000	12,900,000	29,600,000	1,440,000	231,000	1,671,000	31,271,000
1962	34,700,000	14,300,000	11,600,000	25,900,000	1,280,000	204,000	1,484,000	27,384,000
1963	34,100,000	14,700,000	11,500,000	26,200,000	1,280,000	207,000	1,487,000	27,687,000
1964	30,900,000	12,700,000	10,100,000	22,800,000	1,100,000	174,000	1,274,000	24,074,000
1965	35,600,000	16,000,000	12,100,000	28,100,000	1,360,000	221,000	1,581,000	29,681,000
1966	33,500,000	13,600,000	11,000,000	24,600,000	1,180,000	186,000	1,366,000	25,966,000
1967	32,500,000	12,800,000	10,700,000	23,500,000	1,170,000	185,000	1,355,000	24,855,000
1968	34,000,000	14,400,000	11,300,000	25,700,000	1,240,000	198,000	1,438,000	27,138,000
1969	26,100,000	8,050,000	7,660,000	15,710,000	742,000	110,000	852,000	16,562,000
1970	33,200,000	14,900,000	11,300,000	26,200,000	1,260,000	201,000	1,461,000	27,661,000
1971	33,200,000	15,800,000	11,400,000	27,200,000	1,300,000	215,000	1,515,000	28,715,000
1972	33,900,000	14,600,000	11,400,000	26,000,000	1,260,000	203,000	1,463,000	27,463,000
1973	30,200,000	9,720,000	9,160,000	18,880,000	896,000	132,000	1,028,000	19,908,000
1974	29,800,000	9,060,000	8,940,000	18,000,000	857,000	124,000	981,000	18,981,000
1975	32,100,000	13,300,000	10,600,000	23,900,000	1,140,000	181,000	1,321,000	25,221,000
1976	31,500,000	11,300,000	9,910,000	21,210,000	1,010,000	153,000	1,163,000	22,373,000
1977	40,200,000	22,100,000	14,500,000	36,600,000	1,750,000	299,000	2,049,000	38,649,000
1978	30,600,000	10,400,000	9,460,000	19,860,000	946,000	141,000	1,087,000	20,947,000
1979	38,600,000	18,400,000	13,400,000	31,800,000	1,520,000	248,000	1,768,000	33,568,000

Susitna River at Susitna Station – 15294350 cont.

WY	Water Volume (acre-ft)	Suspended Load			Bed Load			Total Load
		Silt/Clay	Sand	Total	Sand	Gravel	Total	
1980	44,800,000	26,600,000	16,600,000	43,200,000	2,070,000	364,000	2,434,000	45,634,000
1981	40,100,000	23,100,000	14,700,000	37,800,000	1,840,000	327,000	2,167,000	39,967,000
1982	34,000,000	14,200,000	11,200,000	25,400,000	1,220,000	195,000	1,415,000	26,815,000
1983	31,700,000	10,700,000	9,840,000	20,540,000	990,000	149,000	1,139,000	21,679,000
1984	32,900,000	11,400,000	10,300,000	21,700,000	1,040,000	158,000	1,198,000	22,898,000
1985	34,200,000	14,700,000	11,400,000	26,100,000	1,260,000	202,000	1,462,000	27,562,000
1986	33,600,000	12,000,000	10,600,000	22,600,000	1,080,000	163,000	1,243,000	23,843,000
1987	39,600,000	21,300,000	14,100,000	35,400,000	1,690,000	291,000	1,981,000	37,381,000
1988	38,900,000	17,400,000	13,200,000	30,600,000	1,480,000	238,000	1,718,000	32,318,000
1989	40,800,000	23,400,000	14,900,000	38,300,000	1,830,000	318,000	2,148,000	40,448,000
1990	44,200,000	23,000,000	16,100,000	39,100,000	1,930,000	325,000	2,255,000	41,355,000
1991	34,900,000	15,400,000	11,700,000	27,100,000	1,300,000	208,000	1,508,000	28,608,000
1992	31,800,000	10,300,000	9,680,000	19,980,000	948,000	140,000	1,088,000	21,068,000
1993	38,400,000	17,900,000	13,300,000	31,200,000	1,520,000	247,000	1,767,000	32,967,000
1994	37,500,000	15,400,000	12,500,000	27,900,000	1,350,000	211,000	1,561,000	29,461,000
1995	37,100,000	15,800,000	12,500,000	28,300,000	1,370,000	217,000	1,587,000	29,887,000
1996	29,000,000	8,100,000	8,490,000	16,590,000	786,000	111,000	897,000	17,487,000
1997	31,900,000	12,500,000	10,300,000	22,800,000	1,090,000	170,000	1,260,000	24,060,000
1998	33,600,000	14,400,000	11,200,000	25,600,000	1,230,000	195,000	1,425,000	27,025,000
1999	33,400,000	13,000,000	10,800,000	23,800,000	1,130,000	176,000	1,306,000	25,106,000
2000	36,300,000	16,000,000	12,200,000	28,200,000	1,360,000	219,000	1,579,000	29,779,000
2001	34,000,000	13,400,000	11,000,000	24,400,000	1,170,000	183,000	1,353,000	25,753,000
2002	32,700,000	12,300,000	10,500,000	22,800,000	1,090,000	166,000	1,256,000	24,056,000
2003	37,900,000	15,600,000	12,700,000	28,300,000	1,370,000	215,000	1,585,000	29,885,000
2004	34,700,000	13,200,000	11,200,000	24,400,000	1,180,000	180,000	1,360,000	25,760,000
2005	44,300,000	24,800,000	16,500,000	41,300,000	2,020,000	344,000	2,364,000	43,664,000
2006	35,700,000	15,800,000	12,100,000	27,900,000	1,360,000	221,000	1,581,000	29,481,000
2007	35,100,000	12,500,000	11,200,000	23,700,000	1,140,000	171,000	1,311,000	25,011,000
2008	32,800,000	11,500,000	10,300,000	21,800,000	1,040,000	156,000	1,196,000	22,996,000
2009	34,500,000	12,600,000	11,100,000	23,700,000	1,140,000	172,000	1,312,000	25,012,000
2010	36,400,000	14,400,000	12,000,000	26,400,000	1,280,000	198,000	1,478,000	27,878,000