# Analysis of Monthly Suspended Sediment Load in Rivers and Streams Using Linear Regression and Similar Precipitation Data

by

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# ABSTRACT

Suspended sediment impacts the water quality of streams and rivers by retaining and acting as a carrier for other contaminants, increasing turbidity, which can block light from getting to submerged vegetation and clog fish gills, amongst other environmental effects. Therefore, understanding its dynamics and prediction is crucial to environmental protection and water management. The objective of this study is to improve the prediction accuracy of suspended sediment load in rivers and streams by grouping monthly data of suspended sediment and water discharge into groups of similar precipitation values. Linear regression was used to predict the suspended sediment load, a dependent variable, as a function of the stream water discharge, an independent variable on four U.S. rivers and streams. This study used ten years of data for the suspended sediment load, stream water discharge, and precipitation for each river. Results from the traditional approach, which does not have precipitation data and is therefore ungrouped, were compared with results from the precipitation approach using the correlation coefficient (*r*) and the percent deviation. Out of the 21 groups investigated, 19 groups showed a lower percent deviation from the traditional approach. For the correlation coefficient values, 12 groups were higher than the traditional approach, while two groups had the same values as the traditional approach. Ten groups had correlation coefficient values between 0.90 to 0.97. Overall, the precipitation approach has improved the prediction accuracy of the suspended sediment load compared to the traditional approach.

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# Chapter 1- Introduction

Water pollution can be caused by many pollutants including pathogens (infectious agents), inorganic chemicals, synthetic organic chemicals, and sediment. Pollutants get into water bodies either from point sources or non-point sources. Pollution from non-point sources including nutrient loading, soil erosion and associated pollutants is detrimental to the environment. Numerous water quality issues including suspended sediment in rivers and streams linger due to overflow from non-point sources (Melesse et al 2010). Sediment may move in rivers and streams either as bedload or suspended load (Garg, 2011).

The suspended load is made up of adequate materials with upward fluid stress which prevents the particles from sinking to the bed. The wash load which is the finest portion of suspended sediment load generally accounts for less than 10% of the bed material and is conveyed in near-continuous suspension (Gitto et al 2017). In addition, the suspended load flows in suspension within the water body, which would consist of bed or bank materials and materials washed from the watershed, usually silt and clay, as silt and clay have very low fall velocity. While the bed load is made up of the materials that travel close to the bed either with a rolling or sliding motion or in suspension. The composition of suspended sediment load transport is determined by factors such as river flow, transport capacity, sediment availability, and season (Iven et al 1981).

In rivers, streams, lakes, and reservoirs sediment is the most prevalent pollutant, which makes it a burden to be borne by the flowing water and is, consequently, designated as sediment load. However, when excessive, it poses serious environmental and health risks. Rhea (2019) posited that sediment alters water quality as it retains and carries other contaminants often, like pathogens, organic chemicals, nutrients, heavy metals, and bacteria along. Nutrients like phosphorus typically attach to fine sediment particles, which can lead to eutrophication downstream of a water body (Vaughan, 2016). The sources of these pollutants are mostly from urban contaminants, agriculture, mine spoils, and industrial waste which may have temporary and extended effects (Bartram and Balance, 1996).

One of the main sources of suspended sediment is soil erosion. Erosion occurs when soil materials are detached and transported by an erosive agent, this takes place in two stages. The first stage involves the detachment of small soil particles through runoff, rainfall impact, and the various weathering processes. The second stage is the transportation of the detached soil particles by wind or runoff away from their source (Aksoy et al, 2019; Vercruysse et al, 2017).

Precipitation is also an important element for surface erosion which brings about suspended transport across channels of a specific river basin. The combination of rainfall and changes in land use and land cover intensifies surface erosion in a watershed (Ampomah et al, 2020). In addition, an increase in the severity and amount of rainfall (different rain patterns) also increases surface erosion producing suspended sediment transport (Krajewski et al, 2017). Hence, different variables including the total length of a precipitation event, average rainfall intensity, preceding rainfall, peak discharge, and total discharge are mostly incorporated in models to analyze sediment concentration (Vercruysse et al, 2017). However, the correlation between different rain patterns and suspended sediment load can be non-linear and may vary as sediment load does not completely depend on precipitation (Ampomah et al, 2020).

Some of the factors that affect sediment transport characteristics include the nature of sediments or rocks through which the river flows and the amount of water moving through a river. Sediment load in rivers and streams can be curbed by either employing preventative measures or taking remedial measures. Some preventive measures that can be considered include repairing and maintaining drainage ditches and levees and ensuring there is a minimal disturbance of the banks. Remedial measures that can be taken include the construction of sedimentation ponds, detention reservoirs, settling basins, and using dredging to remove deposited sediment.

The United States is facing an immense challenge because of sediment pollution. Approximately 30 percent of the overall sediment in the United States is attributed to natural erosion while anthropogenic activities such as agricultural activities and construction in urban areas are responsible for 70 percent of the sediments (United States Environmental Protection Agency, 2006). It was estimated that the environmental damage caused by sediment in the United States is not less than $16 billion annually (Mid-America Regional Council (MARC), 2010). Among the environmental damages associated with sediments in rivers and streams are loss of sensitive aquatic habitat, abrasion of turbines and delicate plant and animal tissues, reduction in fishery resources, coastline alteration, eradication of wetlands, nutrient balance changes, increase in turbidity which can clog fish gills and block light from getting to submerged vegetation, loss of submerged vegetation, and replacement of coral reef communities (Orlando and Yee, 2017). Excessive sedimentation can change how the river flows and diminish water depth, which causes recreational use and navigation more challenging, thereby depleting the usable water volume. Therefore, sediment control and prediction of the suspended sediment load is crucial in reducing the environmental impacts of excessive sediment in surface waters (Amin and Jacobs 2007).

Given the risk associated with sediments, effective management of sediments is paramount. Effective management of sediments in water bodies requires understanding its dynamics and the factors responsible for it. Bong, Son, and Kim (2019) were of the view that insight on how sediment moves as suspended solids is crucial for predicting sediment transport in surface water bodies and can give understanding into the fate of pollutants transported by sediment. Information on suspended load is effective for countering or mitigating problems in reservoirs and dams design, sediment and pollutants transport in streams, estuaries, and lakes, and design of stable channels and dams. This can enhance the safety of wildlife habitats and fish (Melesse et al 2010).

The most evaluated constituent of the sediment load is the suspended material. Thus, many of the experiments and studies have focused on this and the functional correlation between suspended sediment and streamflow has been determined (Mimikou 2009). Nevertheless, drivers in the sediment delivery process are numerous than what most studies accounted for. Sediment transport and level of delivery from affected areas can vary with respect to prevailing vegetation type, land use, and connectivity to hillslopes. Also, the duration and intensity of rainfall occurrence can raise the amount of sediment carried to the channel from highland sources (Stout, 2012). Other factors that contribute to the amount of sediment in surface-water bodies include the following aspects of rivers and streams: source, length, flow path, flow rate, size of the drainage basin, amount of precipitation, and nature of flow (perennial or ephemeral). Therefore, the prediction of suspended sediment in rivers and streams can be particularly challenging.

## 1.1 Objectives

The objective of this research is to use monthly precipitation values to improve the accuracy of predicting suspended sediment loads in rivers and streams using linear regression. The dependent variable will be the suspended sediment load and the independent variable will be the river water discharge. In this study, linear regression will be employed to calculate (predict) the suspended sediment load, in response to river water discharge. The amount of precipitation received by a river, or a stream directly affects the flow rate (water discharge) of the river or stream and the suspended sediment resulting from that flow rate. Therefore, linear regression will be applied to flow rates and suspended sediment loads resulting from equal or comparable values of precipitation (monthly values). This approach is expected to yield high values of correlation coefficient between water discharge (flow rate) and suspended sediment load.

Linear regression will also be applied to water discharge data and sediment load data without using precipitation as a factor. This is the traditional approach usually used by researchers. Results of the proposed approach using precipitation and the traditional approach will be compared.

## 1.2 Scope

This study will focus on the San Joaquin River, Rio Puerco, Powder River, and Little Colorado River. The rivers are selected based on their distribution under different climatic conditions. For each river, suspended sediment load will be predicted utilizing linear regression analysis using the proposed precipitation approach and the traditional approach, as explained above. In this study, all the rivers will be considered in-depth with respect to their source, length, flow path, drainage basin, precipitation, nature of flow (perennial or ephemeral), suspended sediment data, and flow rate during the measurement period. Data for the study will be sourced from the United States Geological Survey National Water Information System: Web Interface (USGS, 2021).

## 1.3 Approach

SPSS and Microsoft Excel will be used to run the linear regression analysis. Linear regression will be applied to monthly water discharge and suspended sediment load values. Results of the proposed and traditional approaches will be compared, as explained in section 1.2 “Objectives.”

# Chapter 2 - Literature Review

## 2.1 Introduction

Soil erosion introduces significant quantities of sediment into rivers and streams. The classification of the erosion process that leads to the accumulation of sediments in rivers and streams includes gully, sheet, rill, and in-stream erosion. In most cases, these erosions occur due to heavy rainfall leading to an overland flow of rainwater that sweeps the sediments in various lands such as agricultural lands. The rainwater then transports and deposits these sediments in rivers and streams (Merrit et al., 2003). In-stream erosion refers to the removal of sediment located in the stream banks and bed of the stream. Some of the effects of the erosion of stream banks include deepening and widening rivers and streams. Excessive erosion in a stream collapses the stream's bank, which increases the stream's sediments. Deepening of the channel occurs since the increased weight of the materials forming the banks due to the new added sediments and materials becomes too much for the banks to handle leading to their collapse. In most cases, the stream bank's erosion stops when a stable channel is achieved when the deposition of sediments and the erosion process have reached equilibrium (Piest and Bowie, 1974).

The majority of a stream's sediment load is transported in solvated load (dissolved load) or suspension. The rest is referred to as the bed load. The dissolved load is materials from the Earth that have been broken down and incorporated into ions and are borne in the solution. This is often contributed by groundwater. Ions like potassium, chloride, calcium, sulfate, and bicarbonate are common. With the appropriate chemical conditions during flow, these ions can proceed to create new minerals. Minerals may also precipitate through evaporation. Fine-grained sediment such as clay and silt make up the suspended load and is carried in suspension attributed to turbulence. Coarser-grained sediment such as sand and gravel make up the bedload, and these heavier sediments are transported by rolling and sliding on the bottom of the stream bed.

Regression-based models have continued to be applied in studying, calculating, and predicting the suspended sediment load in streams and rivers, mostly since these models remain some of the most convenient, simple, and easily applicable in the analysis process (Jain 2001; Walling 1977). Furthermore, numerous researchers have shown that the correlation between the suspended sediment load in rivers and streams and water discharge is affected by different variables. Variables such as density, temperature, viscosity, compactness, the concentration of moving particles, and energy can also influence the level of sediment load in rivers and streams (Gunawan et al., 2018). For instance, different natural processes, e.g., sediment sources and sediment sinks, can change the quantity of suspended sediments since this factor can lead to the addition or removal of the suspended sediment load in rivers and streams (Araujo et al., 2012).

## 2.2 Previous Studies

Sediment transport equations can be grouped into three categories: physically based equations, regression-based, and empirical models. Substantial data and numerous parameter estimates are required for the physically based model (Tayfur 2003). Regression-based models do not require a huge amount of data like the physically based model. The empirical model is limited to cases and locations for which they have been developed but cannot be employed at other locations (Yang 1996; Tayfur 2003).

A known methodology in the study of sediment discharge is using linear regression analysis to correlate suspended sediment load or concentration with water discharge in rivers or streams (sediment rating curves). Prolonged irregularities of the suspended sediment load at a specific gauge station can be examined using the linear regression approach. Good outcomes can be produced for predicting monthly or annual sediment load in streams with large drainage basins using the linear regression approach. The approach could also provide reliable results for predicting the daily sediment load in streams of homogeneous and small drainage basins. Some investigators (Linsley et al., 1981) recommended employing linear regression for drainage basins not having sediment records to derive an order-of-magnitude estimate of the sediment yield.

Many researchers have utilized the linear regression approach to analyze and predict suspended sediment load in rivers and streams (sediment rating curves). Examples include Leopold and Maddock (1953), Leopold and Miller (1956), Brown and Ritter (1971), Bhowmik et al., (1980), Linsley et al., (1981), Asselman (2000), Rankl (2004), Amin and Jacobs (2007), and Amin and Jacobs (2020). Prediction of the suspended sediment load uses stream water discharge and suspended sediment load data collected daily, monthly, or annually. Amin and Jacobs (2007) stated that the monthly regression relationship gives the highest correlation when compared to the daily and annual relationships. They determined that when daily sediment load is added up to give monthly sediment load, the variations in the daily sediment load are evened out, and the monthly relationship is not prone to wide hydrologic changes. In contrast, the annual relationship is exposed to wide hydrologic alterations that occur all through the year.

To attain substantial model results from the regression analysis, it was proposed that water discharge and sediment data needs to be obtained daily or weekly over a period from 10 to 20 years (Bhowmik et al., 1980). Amin and Jacobs (2020), however, indicated that working with data collected over 5 to 10 years is as good as working with data that extends to over 20 years.

Brown and Ritter (1971) collected sediment-water discharge data at 22 locations within the Eel River Basin in California for a period of 12 years. They used the data to determine the quantity of sediment transported by streams in several areas of the Eel River Basin and to determine the relationship between sediment concentrations and stream water discharge using linear regression. Brown and Ritter used linear equations to evaluate the suspended sediment load in response to the water discharged in the analyzing process.

Rankl (2004) applied linear regression to predict the suspended sediment load in different rivers and streams in the State of Wyoming. In his study, he collected data from seven rivers for a period of 10 years. Rankl found that the correlation coefficient values between suspended sediment load and water discharge varied between 0.94 and 0.98, which indicates an excellent correlation between the two variables. He also found that the slope values of the regression lines ranged from 1.29 to 1.70. This range of values is close to that obtained by Leopold and Miller (1956) (1.09 to 1.58, with a median of 1.29) for intermittent streams in the western United States. His study concluded that "rainstorm energy, estimated by the rainfall intensity, is the primary mechanism for soil-particle detachment" (Rankl, 2004). Similarly, a study conducted by Jie and Yu (2011) found that the magnitude of rainfall and the velocity of the stream are the main factors leading to suspended load. These findings portray that fast-moving water has a high velocity which increases the ability to easily pick and move large sediment depicting that the faster the flow, the higher the energy for transporting the larger pieces of sediment.

Amin and Jacobs (2007) also applied the linear regression approach to address the effects of sediment sources and sinks on suspended sediment load in The Rio Puerco in central New Mexico. In this study, sources and sinks effects were considered compared to the traditional approach that in no way examines sources and sinks. Regression equations were used to predict daily, monthly, and annual suspended load, but the highest correlation coefficient was produced from the monthly regression relationship, which was chosen for the analysis. The results of sources and sinks were established by fitting three regression lines through the data. The regression equations were applied to determine the amount of sediment lost to sinks and those added from sources. Before adding the effects of sources and sinks to the simulation, the monthly suspended sediment and water discharge correlation coefficient was 0.93. After adding the effects of sources and sinks, the correlation coefficient raised to 0.98, consequently leading to a notable increase in not just the correlation coefficient but also in the suspended sediment load prediction accuracy when using linear regression.

As described earlier, different natural processes can change the quantity of suspended sediments in the channels of rivers or streams by adding or removing sediments (Amin and Jacobs, 2007). In the case of sediment addition, the sediments come from sources such as the surrounding watershed; in sediment removal, the sediments leave the channel and occupy locations outside the channel.

Bhowmik et al. (1980) examined sediment load and water discharge in the Kankakee River in Illinois in a two-year study 1967-1968 and 1977-1978. Daily suspended-sediment data were evaluated to establish rating curves at examined gauging stations and approximate the suspended sediment load conveyed by the river at each station. Regression equations were used to establish the relationship between the sediment loads in tons per day with discharge in cubic feet per second. The comparison from the daily water discharge and sediment load data show that the sediment discharge peaks do not always correlate with the water discharge peaks, making the development of a direct correlation between water discharge and sediment load at examined gauging station challenging.

Leopold and Miller (1956) investigated various ephemeral and perennial streams in the western United States to study the effect of discharge on suspended sediment load. The linear regression model was also applied to show the relationship between the suspended sediment load and water discharge. Their study illustrated that the suspended sediment load of the arroyos (dry ephemeral streams that flow only a few days or weeks during the entire year) increased downstream more rapidly than water discharge, which arises from the loss of water by infiltration to the channel bed, subsequently yielding increased levels of suspended sediment downstream. On the contrary, for the perennial streams (streams that flow year-round), the suspended sediment load declined downriver.

Ampomah et al., (2020) study assessed the impact of both intensified precipitation and urban development on suspended sediment yield in the Cuyahoga River utilizing numerical modeling. Historical Satellite-based land-cover data were used on the suspended sediment yield and precipitation data to produce a Multiple Linear Regression (MLR) model for the Cuyahoga River basin. The study model showed that an increment of 1 $km^2$ in urban areas could raise the mean annual suspended sediment yield by 0.9 tons/day, while every 1 mm increase in the mean annual precipitation can raise the mean annual suspended sediment yield by 860 tons/day. The findings from the above studies indicated that statistical analysis could produce improved predictability of sediment. Ampomah et al., (2020) also posited that the prediction of sediment could provide decision-makers with a benchmark for evaluating the possible effects of subsequent development on water quality in the river basin.

# Chapter 3- Study Sites and Method

## 3.1 Overview of Study Sites

In this study, four American rivers will be investigated for the prediction of the suspended sediment load. The rivers are:

1. San Joaquin River, California
2. The Rio Puerco, New Mexico
3. Powder River, Wyoming, and Montana
4. Little Colorado River, Arizona

### 3.1.1 San Joaquin River, California

The San Joaquin River is in central California. It is 350 miles long. The river rises from Mount Goddard in the Sierra Nevada Mountain range, flowing through the northern region of San Joaquin Valley and draining in the Suisun Bay in San Francisco and the Pacific Ocean.

San Joaquin River remains one of the rivers with the highest number of dams used to produce hydroelectric power. Its drainage basin is approximately 15,600 square miles with an annual average of 1.6 million-acre feet of surface runoff (California Water Boards, 2021). The river also provides a rich agricultural landmass, sources of irrigation, and wildlife. The river discharges an estimated 144.7 $m^3/s$ (United States Geological Survey, 2021). The watershed's land cover comprises forested and agricultural areas.

San Joaquin River (figure 3.1) has three main tributaries that directly flow into the river. The upper tributaries have led to the erosion of soil, rock, and sediment from the mountains. The river comprises high, flat, and low trajectories. The flat trajectory comprises the Central Valley which has created a rich agricultural, aquatic, and wildlife habitat.

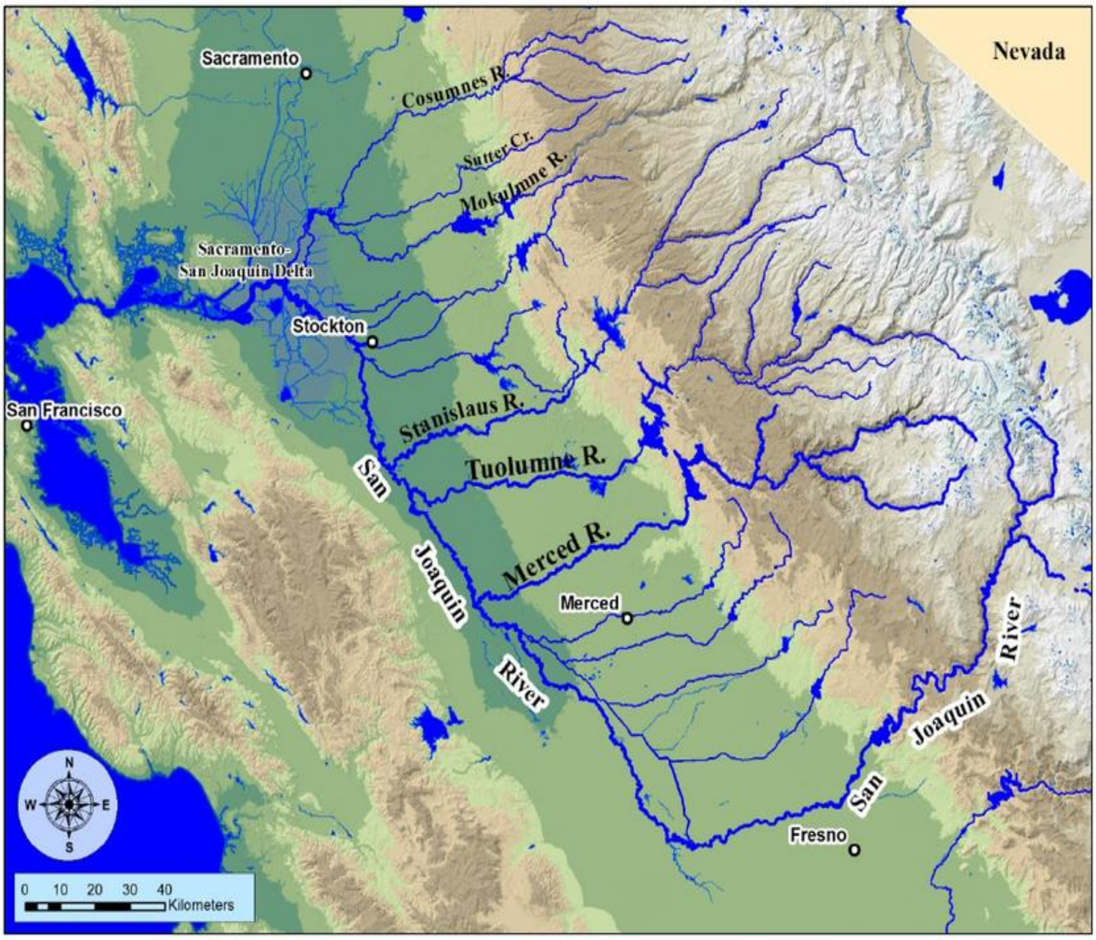

Figure 3. 1 Map of San Joaquin River Watershed and Associated Tributaries (Stringfellow and Camarillo, 2014)

The monthly precipitation data from 1980 to 1989 was derived from the National Oceanic and Atmospheric Administration (NOAA). The average monthly precipitation data for the San Joaquin River at Acampo 5 NE, California between 1980 to 1989 was about 1.745 inches, with the highest amount of precipitation in January (3.58 inches) and March (3.97 inches). The lowest amount of precipitation is in July and August.

The river discharge and the suspended sediment load data was obtained from the USGS gauging station 11303500 at Vernalis California. The water discharge, suspended sediment, and Precipitation data between 1980 to 1989 will be used in the linear regression analysis conducted in this study.

### 3.1.2 The Rio Puerco, New Mexico

The Rio Puerco (figure 3.2) is the largest tributary to the Rio Grande in New Mexico and drains approximately 6,200 square miles in central New Mexico. The drainage basin is bordered on the east by the Rio Grande drainage basin, on the west by the Continental Divide, on the north by the Jemez mountains, and on the South by the Ladrone mountain. The Rio Puerco drains more than 20% of its area at San Marcial which is only 4% of Rio Grande's annual runoff at San Marcial. The river also contributes about 70% of Rio Grande's average annual suspended sediment load (Gellis et al., 2001). Vegetation is sparse over most of the watershed which consists mostly of pinyon-juniper woodland and grassland, copious amount of readily erodible sediment is also available in the watershed (Nordin, 1963; Molnar and Ramirez, 2001).

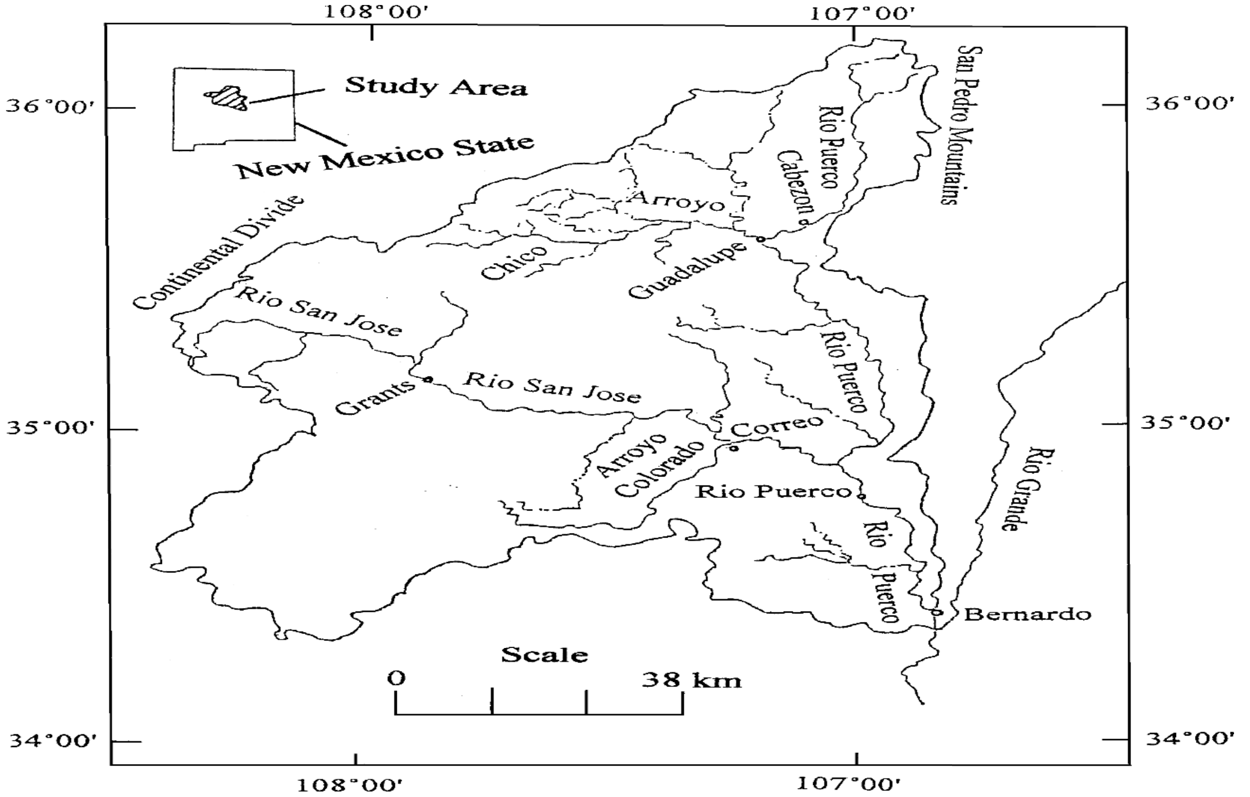

Figure 3. 2 Map of Rio Puerco Drainage Basin (Amin and Jacobs, 2007)

A huge section of the Rio Puerco basin is made up of siltstones and shales which readily erode, producing areas of high sediment yield that supply substantial amounts of easily eroded, fine-grained, and valley-filled materials. The high terrain of the Rio Puerco basin will help create precipitation and the steep slopes provide sediment-moving power to the resulting runoff (Watts et al., 1997).

The suspended sediment data and water discharge data examined in this study are computed at the Bernardo gauging station 0835300 from 1982 – 1991. The Rio Puerco is an ephemeral river that loses water through its bed but gets most of its runoff from rainfall influenced by thunderstorms; the type of intense rain that can easily move materials and cut channels (Amin and Jacobs, 2007; Molnar and Ramirez, 2001). The average monthly precipitation for Rio Puerco at Bernardo between 1982 – 1991 is 0.76 inches with the highest precipitation in August (1.69 inches), July (1.3 inches), and September (1.135 inches). The lowest precipitation occurs in February with 0.24 inches. The precipitation data was obtained from the NOAA website at the Bernardo station.

### 3.1.3 The Powder River, Wyoming, and Montana

The Powder River (figure 3.3) is a tributary of the Yellowstone River. The river is about 375 miles long in northeastern Wyoming and southeastern Montana in the United States. The powder River is produced by the junction of its middle forks and south forks. The river covers approximately 19,500 square miles that include the river and its tributaries. The larger part of the drainage basin is in Wyoming. (Hembree et al., 1952). The Powder River Basin (PRB) has the highest aggregation of low-sulfur sub-bituminous coal in the world (Luppens et al., 2013). Most of the sediment transported by the Powder River originates from regions of lower elevations bolstered by sedimentary rocks (Pizzuto, 1994).

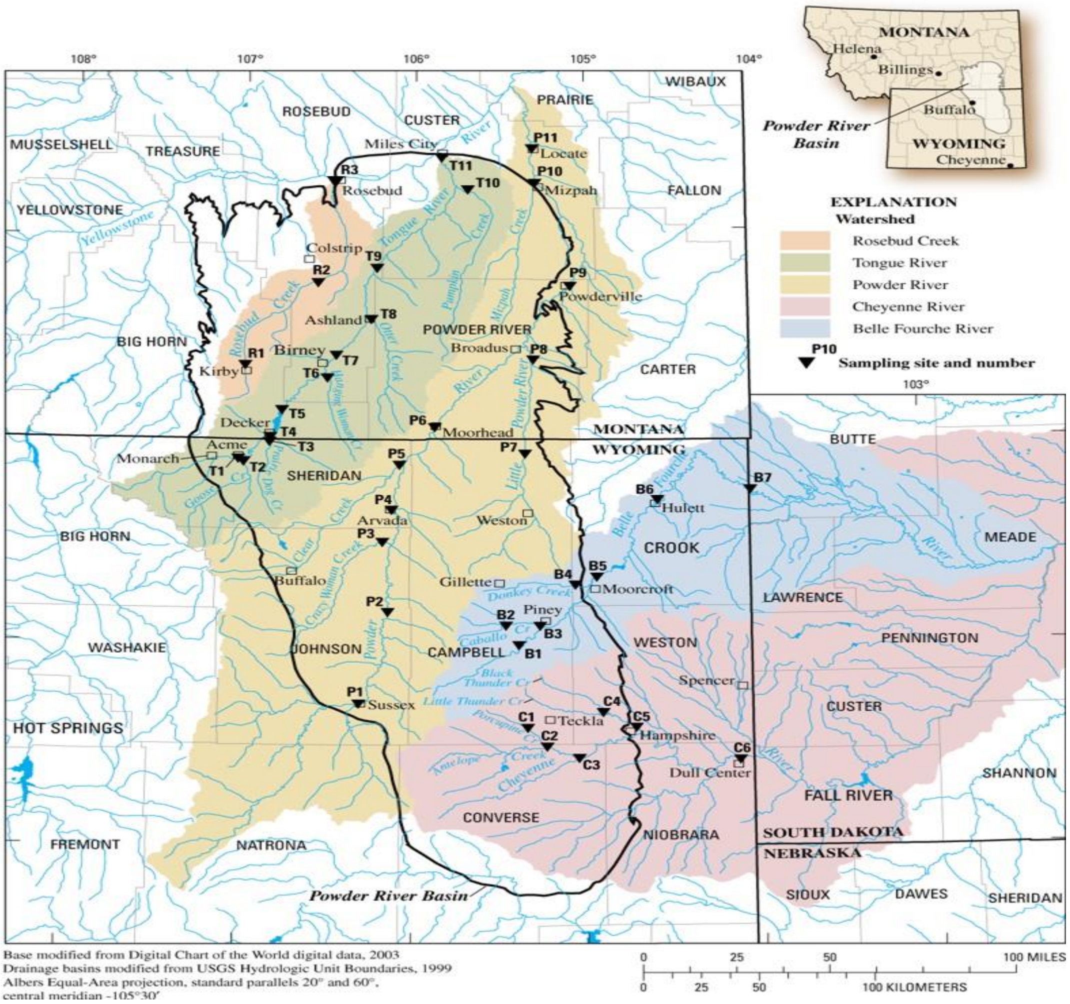

Figure 3. 3 Map of the Powder River Basin (Clark et al., 2005).

The Powder River Basin is bounded by the Cesar Ridge anticline to the north, the Casper Arch, Laramie Mountains, and the Hartville uplift to the south, the Bighorn Mountains to the west, and the Black Hills to the east. The two major geologic formations that define the Powder River Basin structure are the Wasatch and Fort Union, but the geologic formation of that of the Wyoming basin is the Wasatch and Fort Union alluvium veins (Ogden and Puckett, 2008).

The average monthly precipitation for the Powder River at Casper Natrona Co Airport, Wyoming between 1948 to 1957 (the period of data used in this study) is 0.90 inches which was also obtained from the NOAA website. The highest precipitation occurred in the month of

May with 2.084 inches and June with 1.19 inches. The lowest precipitation was in January and February.

### 3.1.4 Little Colorado River, Arizona

Little Colorado River (figure 3.4) is in eastern Arizona and western New Mexico. The river originates from two tributaries that arise from the White Mountains and Mount Baldy that meet at a canyon forming the Little Colorado River. The river stretches for 338 miles from the canyons and flows through the Richville Valley and eventually empties into Lyman Lake. The river then leaves the lake and flows northwards meeting with its main tributaries and eventually drains into the Colorado River in the Grand Canyon. The Little Colorado River is an ephemeral river with an arid climate in the lower basin and semi-arid in the upper basin. The daily average temperature in the basin ranges between -3 to 27°C (Gray and Fisk, 1992).

The monthly precipitation data from 1957 to 1966 was obtained from the National Oceanic and Atmospheric Administration (NOAA). The average monthly precipitation data for the Little Colorado River at Fort Valley Arizona from 1957 to 1966 was about 1.93 inches, with the highest amount of precipitation in August and July (3.51 and 2.71 inches), respectively. The lowest amount of precipitation was in June with 0.69 inches. The river discharge and the suspended sediment load data was obtained from the USGS gauging station 09402000 at Little Colorado River near Cameron, AZ.

Little Colorado River’s average annual discharge is estimated at 370 cubic feet per second and rises to about a thousand cubic feet per second during summer due to cloudbursts (Arizona Geological Survey, 2020). The sediments carried from the upper trajectories settle in the lower valleys, creating aquamarine waters and vegetation. However, in some cases, during the period of snowmelt in summer and spring, the increase of water velocity and volume erodes the lower parts below Cameron leading to various environmental detriments.

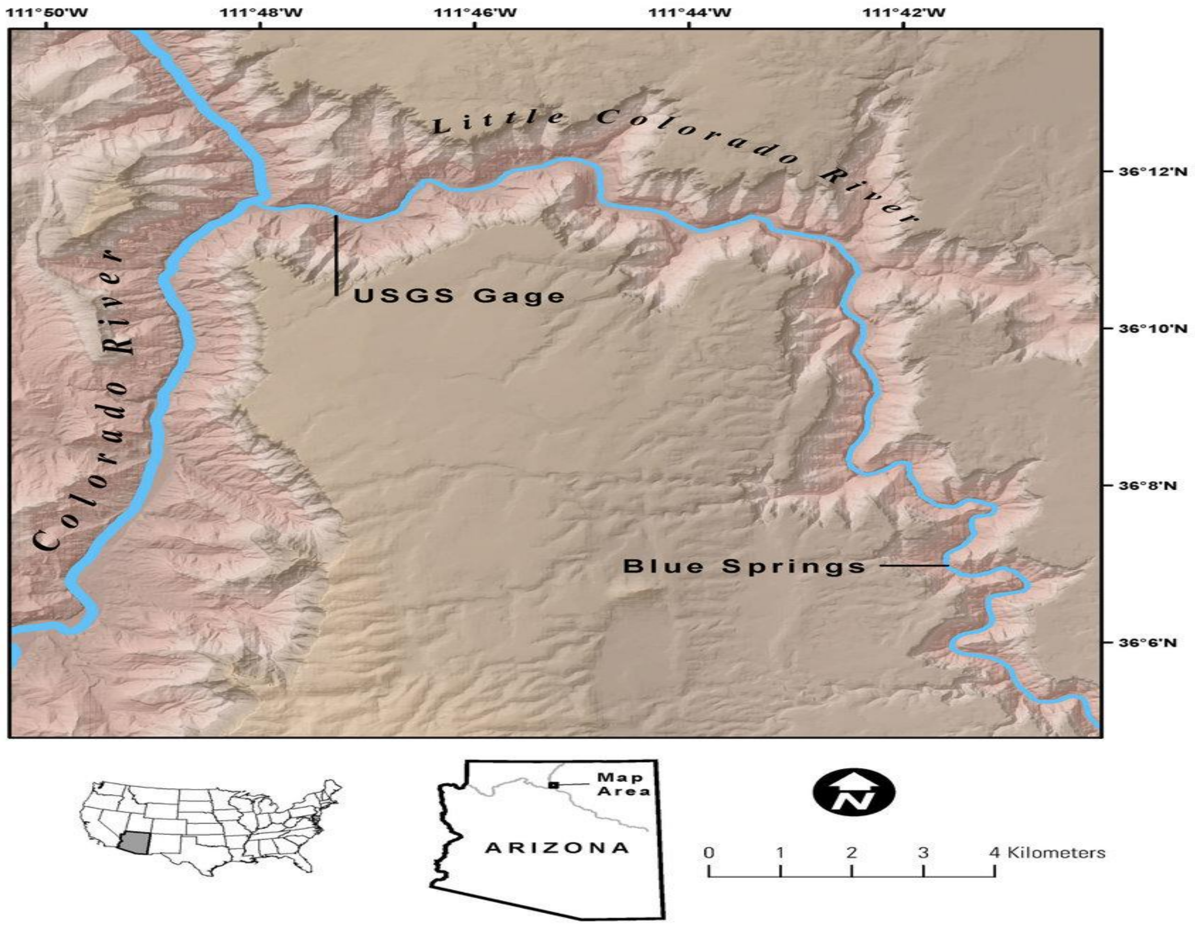

Figure 3. 4 Map of the Little Colorado River (Limburg et al, 2013).

### 3.2 Linear Regression Analysis

Different approaches have been used to determine suspended sediment load in rivers or streams. These include the direct measurements at sediment gauging stations, the regression method (sediment rating curve), empirical methods, wavelet-based artificial intelligence models, the artificial intelligence method such as artificial neural network, gene expressions and genetic programming models, and finally the support vector machine models (Ulke et al., 2016). One of the most used techniques in investigating the relationship between water discharge and suspended sediment in streams and rivers is linear regression which expresses the relationship in the form of a linear or power equation. There are several types of linear regression: Simple linear regression, multiple linear regression, ordinal regression, logistic regression, discriminant analysis and multinominal regression (Bewick et al., 2003; Kisi and Ozkan, 2016).

Linear regression connects one or more explanatory variables to a response variable using linear coefficients, as the coefficient of determination $R^2$ tells us how much variance is being explained by the model (Helsel and Hirsch, 2002). In this model, the correlation coefficient R is reported for the data analysis.

In this study, the linear regression model was applied to determine the power relationship between the response variable (suspended sediment) and the regressor variable (water discharge). The data used was categorized into groups of similar precipitation values for all the rivers studied.

The equation for regression takes the form:

$$Y = aX^m \quad \text{.............................................(equation 1)}$$

Where Y = suspended sediment load

X = water discharge

a = constant

m = slope of the regression line

Equation (1) logarithmic form:

$$\log Y = m \log X + \log a \quad \text{......................(equation 2)}$$

Equation (2) is in the form $y = mx + b$

Where m = slope of regression line

b = log a = intercept

Equation (1) was used for the prediction of monthly suspended sediment load at the four investigated rivers.

One of the several methods used to transform data sets to attain linearity, simplify the analysis, satisfy linear regression assumptions, improve regression model, and eliminate curvature is the logarithmic transformation (Helsel and Hirsch, 2002; Ott, 1993). This was employed in this research to transform equation 1 (originally in engineering units) to logarithmic function (equation 2) and was retransformed back to the original engineering unit. Retransformation leads to a bias that is usually negative except the data is positively and flawlessly correlated. The bias ensues because regression predicts the mean of a normal distribution in log units, but the retransformed values produce values closer to the mean (Miller, 1951; Koch and Smillie, 1986). Bias can be corrected by using the Minimum Variance Unbiased Estimator (MVUE) approach specifically with errors assumed to be normally distributed and the Smearing Estimator with non-normal error distribution (Cohn and Gilroy, 1991).

The smearing estimator is a nonparametric method developed by Duan (1983) and recommended by Cohn and Gilroy (1991) in handling the bias correction problem. This method is applied in this study because it assumes the residuals are independent and can support any distribution (Amin and Jacobs 2007). The equation for the smearing estimate is:

$$Y_{SE} = Y\,[\Sigma\ 10^{res}/n]$$

Where $Y_{SE}$ = the corrected predicted sediment load using the smearing factor

Y = the predicted sediment load

n = number of the predicted sediment loads

res = residuals

Residuals (res) are obtained by subtracting the logarithm of the predicted sediment load from the logarithm of the observed sediment load:

res = [(log observed sediment load) – (log predicted sediment load)].

# Chapter 4- Results and Discussion

## 4.1 Results of Linear Regression

The regression equations were used to establish the relationship between the stream water discharge and the suspended sediment load for the four rivers investigated in this study. The suspended sediment and water discharge data covered a period of 10 years as follows:

1. San Joaquin River, California (1980-1989)
2. The Rio Puerco, New Mexico (1982-1991)
3. Powder River, Wyoming, and Montana (1948-1957)
4. Little Colorado River, Arizona (1957-1966)

The data for water discharge is measured in cubic feet per second ($ft^3/s$) while the suspended sediment load is expressed in short tons per month (sh.t/month). Both the suspended sediment load and the river water discharge data were grouped based on similar precipitation values.

### 4.1.1 San Joaquin River Results and Discussion

The data between 1980 -1989 for the San Joaquin River was divided into six (6) groups of similar precipitation values. The record for suspended sediment and water discharge was complete. The correlation coefficient value for the ungrouped data (traditional linear regression analysis) was 0.90, and for the six grouped data: 0.82, 0.90, 0.92, 0.96, 0.93, and 0.92, respectively. Therefore, the correlation coefficient values for both the ungrouped and the grouped data sets for San Joaquin River show a strong correlation between the monthly suspended sediment load and the monthly river water discharge.

Figure 4.1 shows the regression relationship of the ungrouped data set.

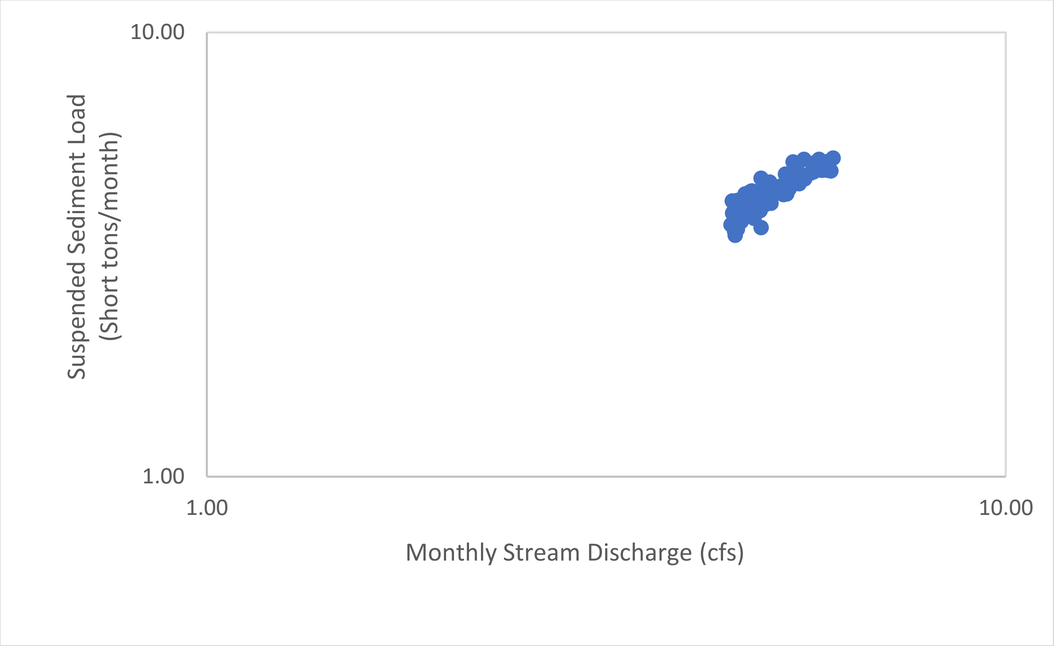

Figure 4. 1 San Joaquin River- Ungrouped: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 0.8273X^{1.0214}$

Figure 4.2 compares the annual observed and the predicted suspended sediment load (SSL).

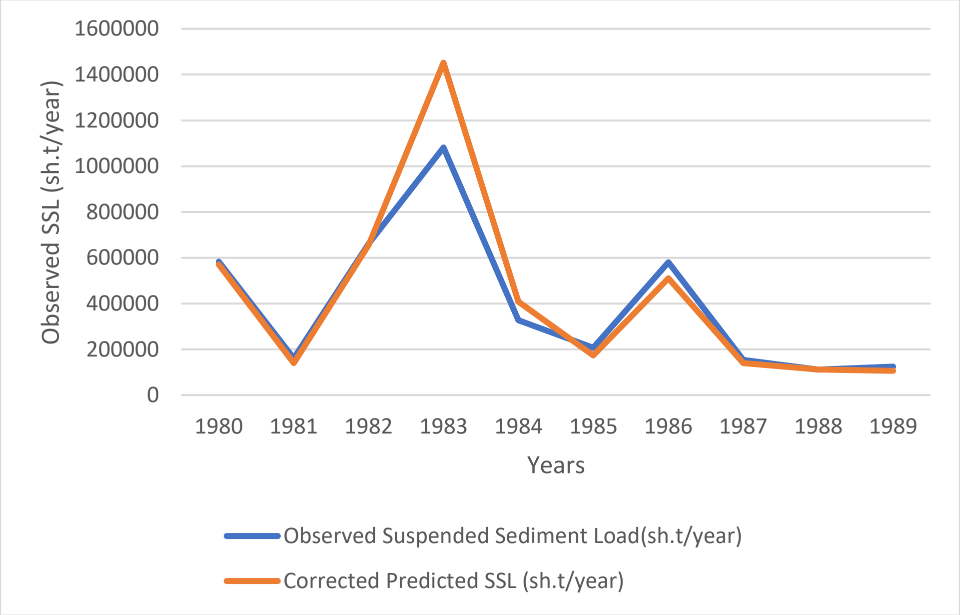

Figure 4. 2 San Joaquin River- Ungrouped Data set: Observed vs. Corrected Predicted Suspended Sediment Load

The corrected predicted suspended sediment load refers to the suspended sediment load that was corrected for the bias resulting from using logarithmic functions (see chapter 3).

The linear regression correlation coefficient for the San Joaquin River ungrouped data set was 0.90 with a percent deviation ranging from 0.05% to 3.26% and an average of 0.43%. From the graph of Figure 4.2, the corrected predicted suspended sediment line is reasonably close to the observed suspended sediment load.

Figures 4.3 through to 4.8 show the regression relationships of San Joaquin River six (6) groups.

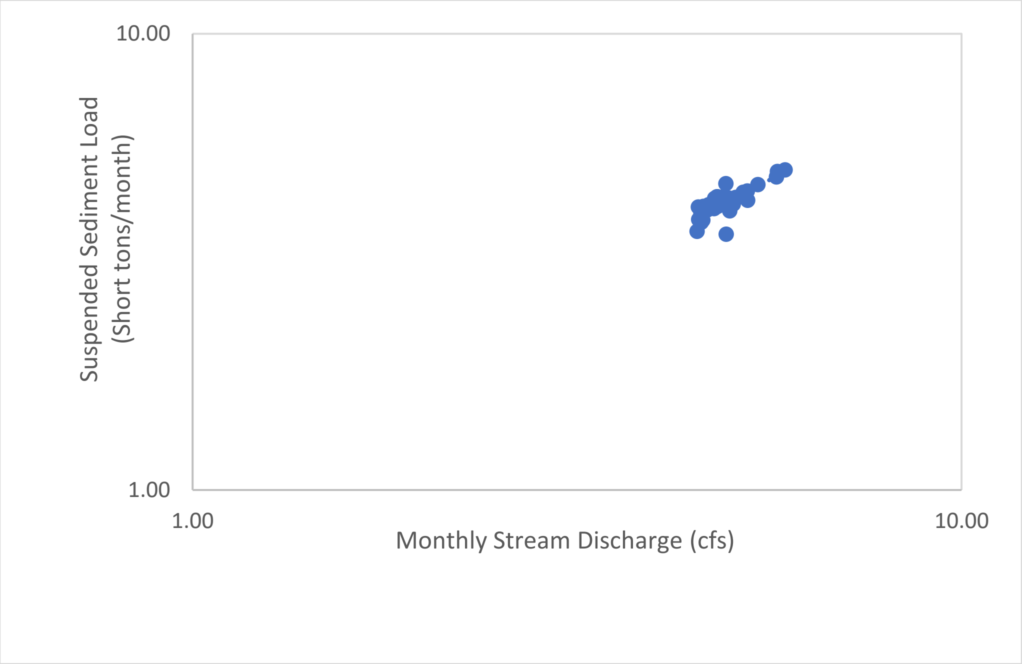

Figure 4. 3 San Joaquin River- Group 1: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.1673X^{0.816}$

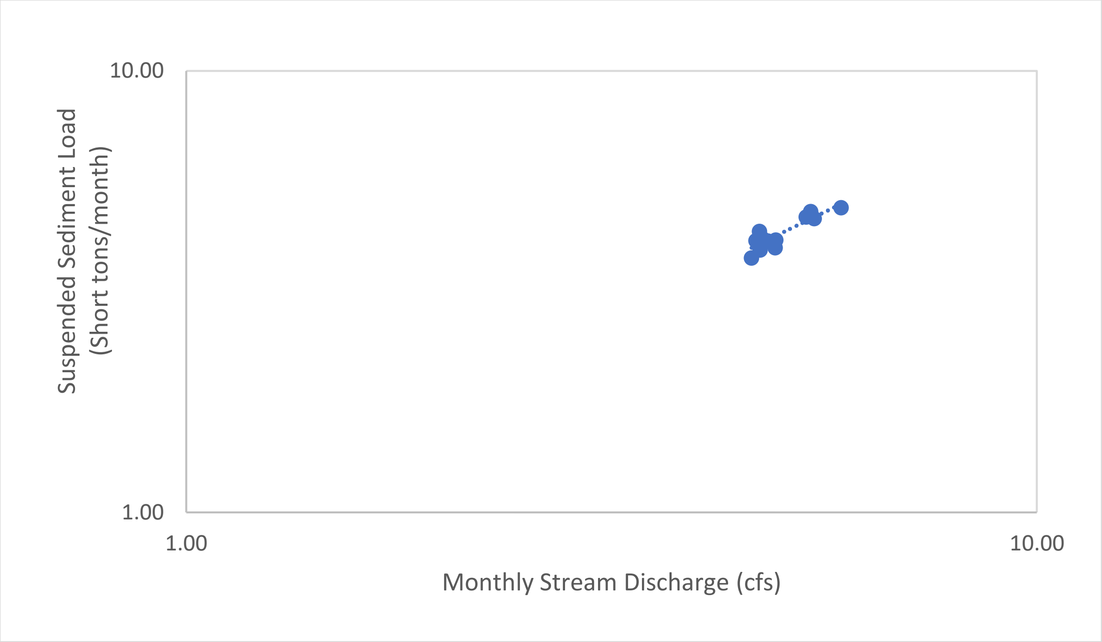

Figure 4. 4 San Joaquin River- Group 2: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 0.9412X^{0.9414}$

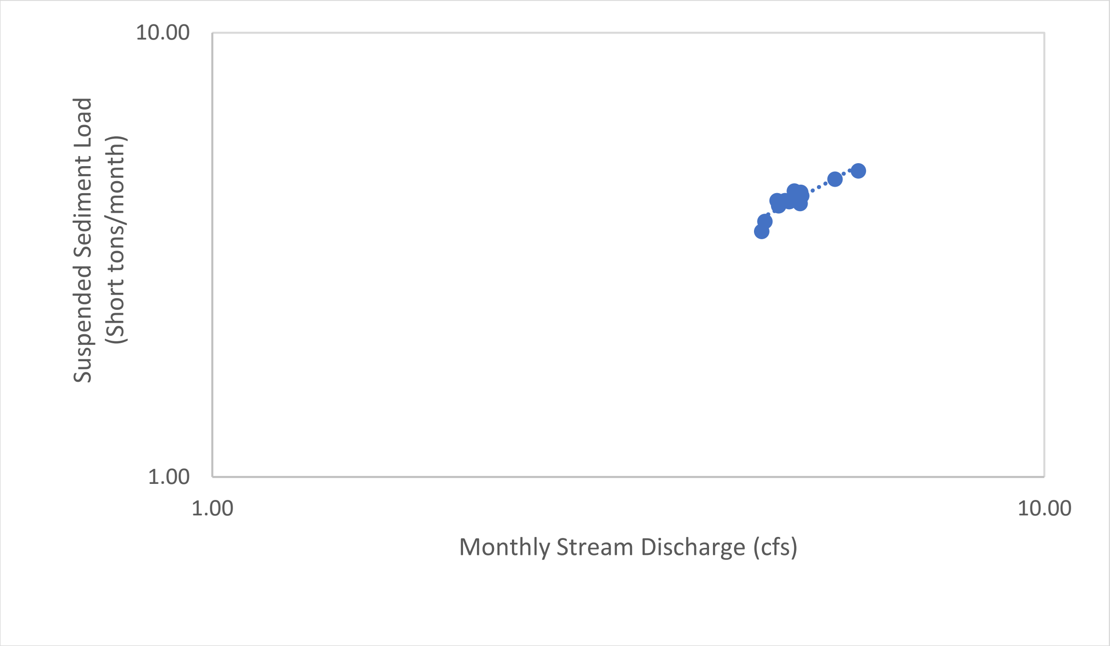

Figure 4. 5 San Joaquin River- Group 3: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 0.8293X^{1.0066}$

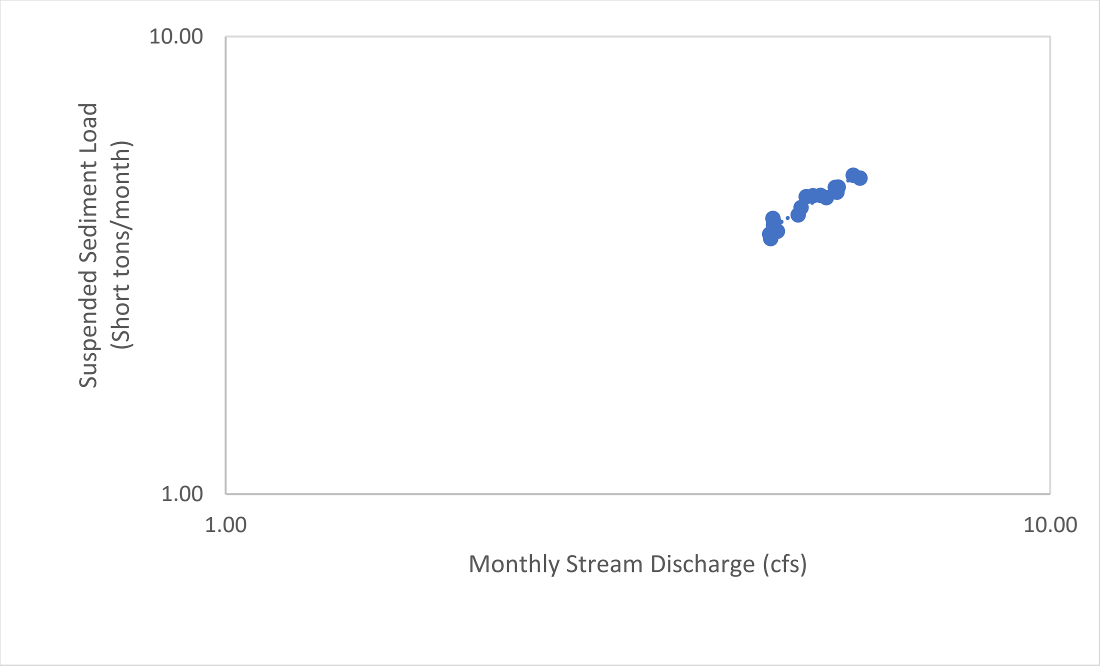

Figure 4. 6 San Joaquin River- Group 4: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 0.6955X^{1.1164}$

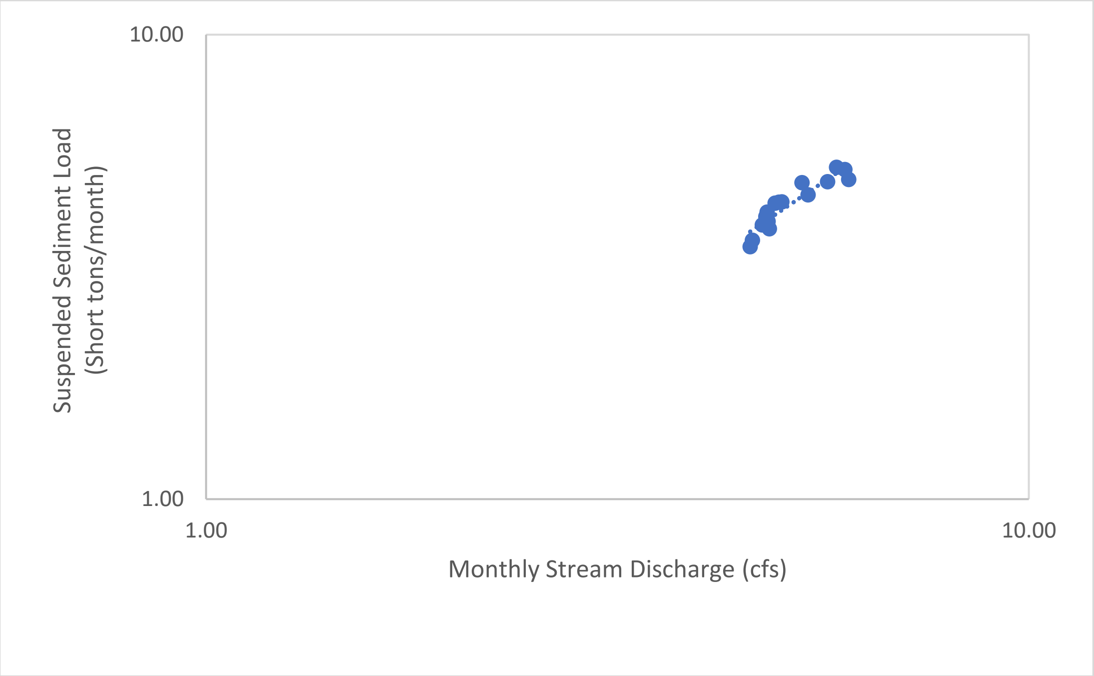

Figure 4. 7 San Joaquin River- Group 5: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 0.6068X^{1.1991}$

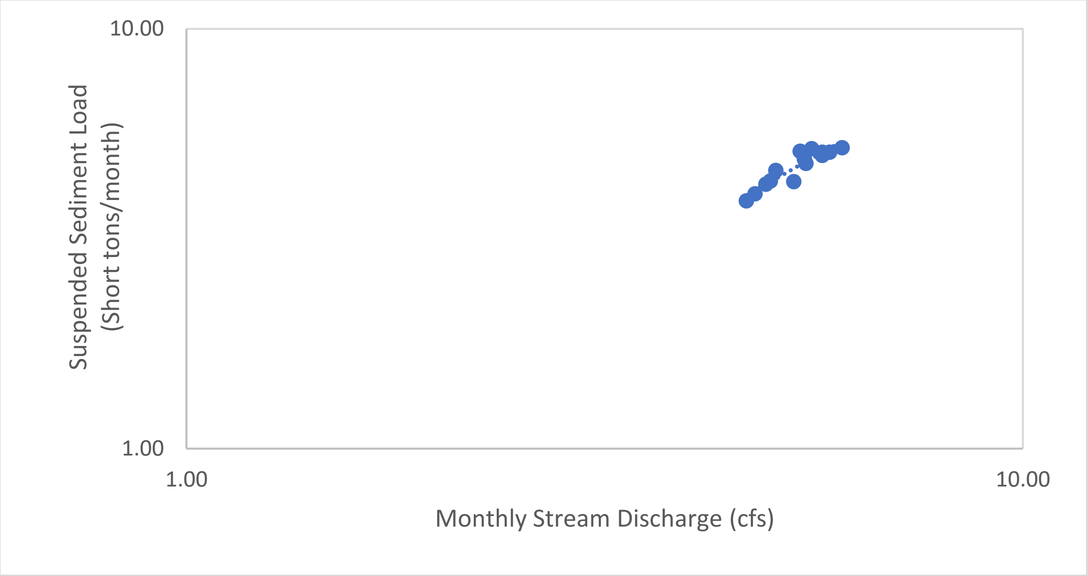

Figure 4. 8 San Joaquin River- Group 6: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 0.7118X^{1.1222}$

Figure 4.9 to 4.14 shows the comparison between the annual observed suspended sediment load and the corrected predicted suspended sediment load for groups 1-5. For all the groups, the observed and corrected predicted sediment load was reasonably close. The closer the lines, the better (accurate) the linear regression relationship.

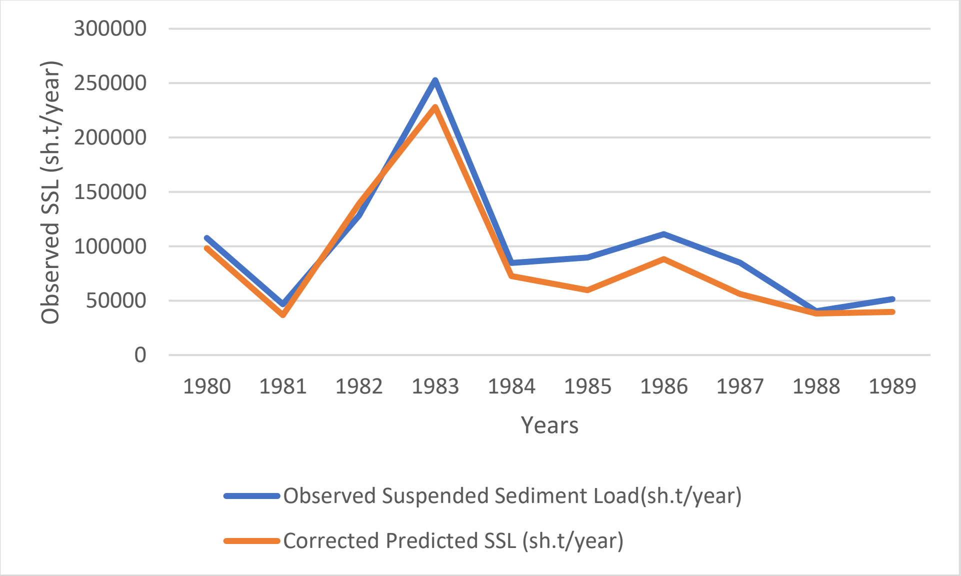

Figure 4. 9 San Joaquin River- Group 1: Observed vs. Corrected Predicted Suspended Sediment Load

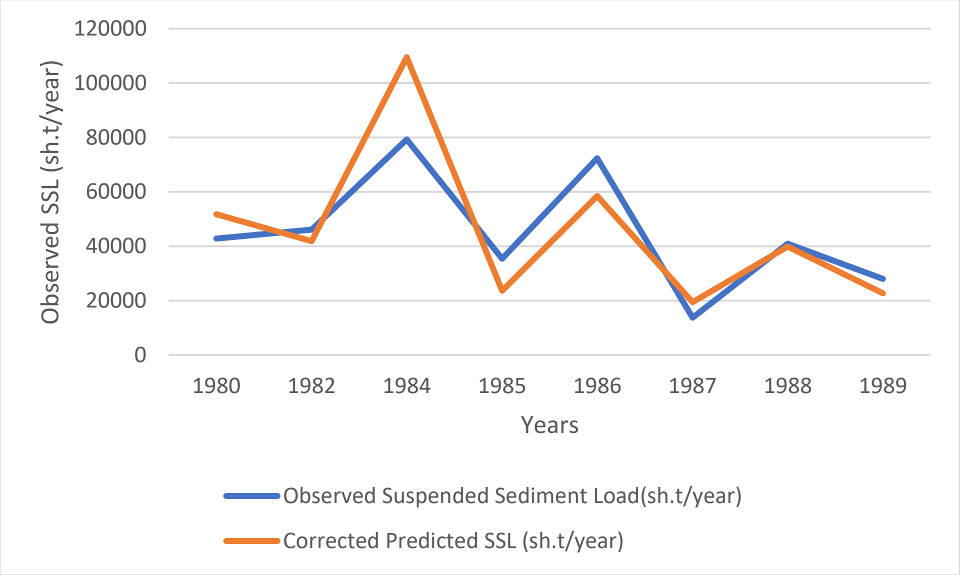

Figure 4. 10 San Joaquin River- Group 2: Observed vs. Corrected Predicted Suspended Sediment Load

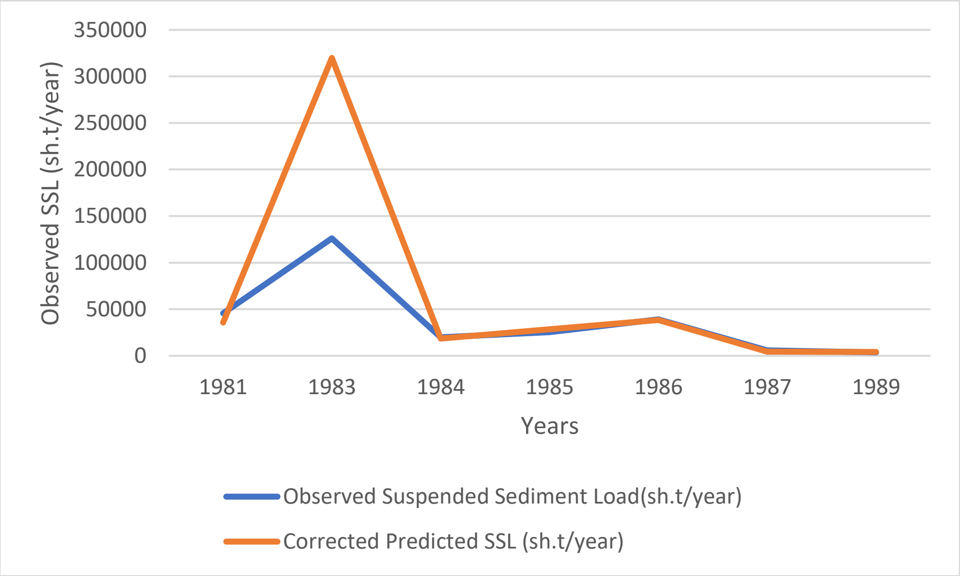

Figure 4. 11 San Joaquin River- Group 3: Observed vs. Corrected Predicted Suspended Sediment Load

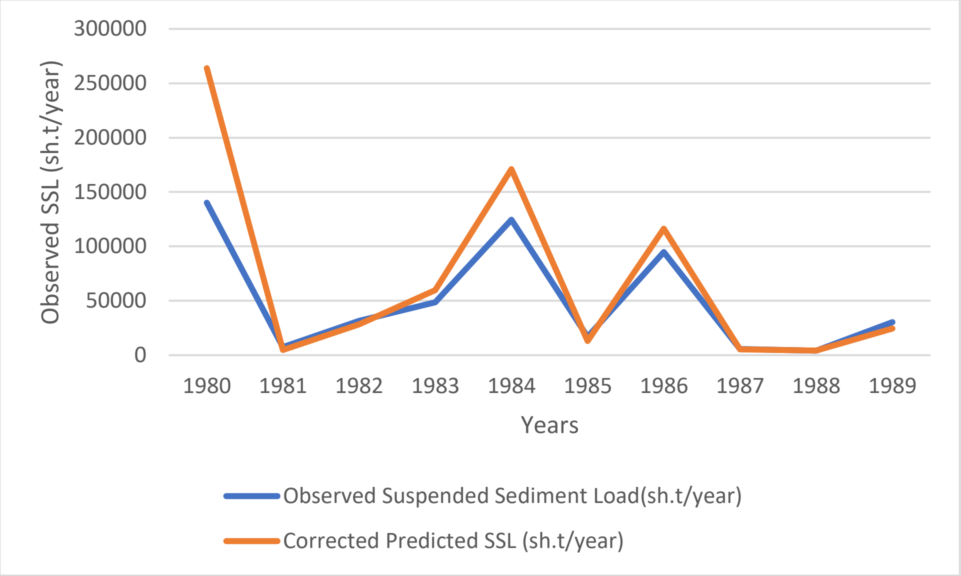

Figure 4. 12 San Joaquin River- Group 4: Observed vs. Corrected Predicted Suspended Sediment Load

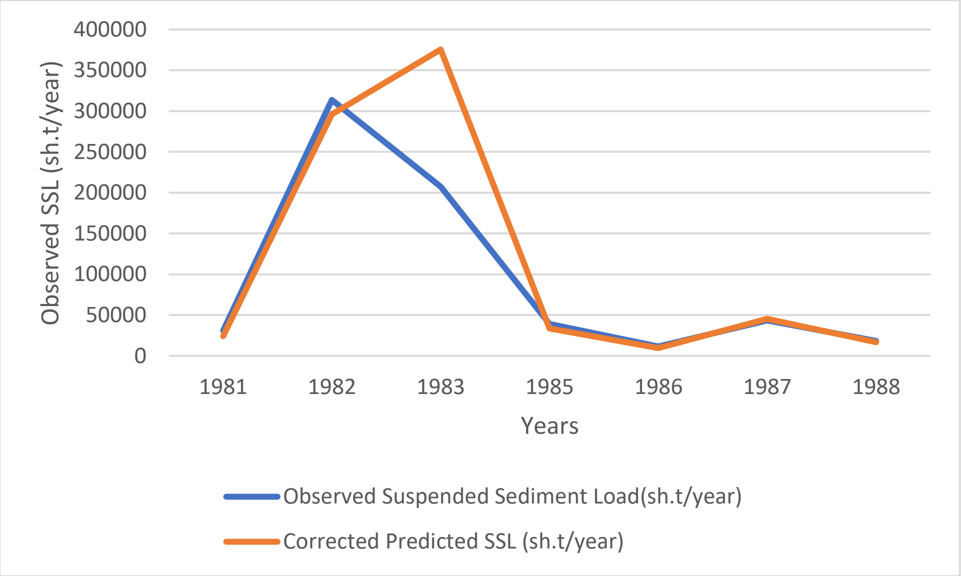

Figure 4. 13 San Joaquin River- Group 5: Observed vs. Corrected Predicted Suspended Sediment Load

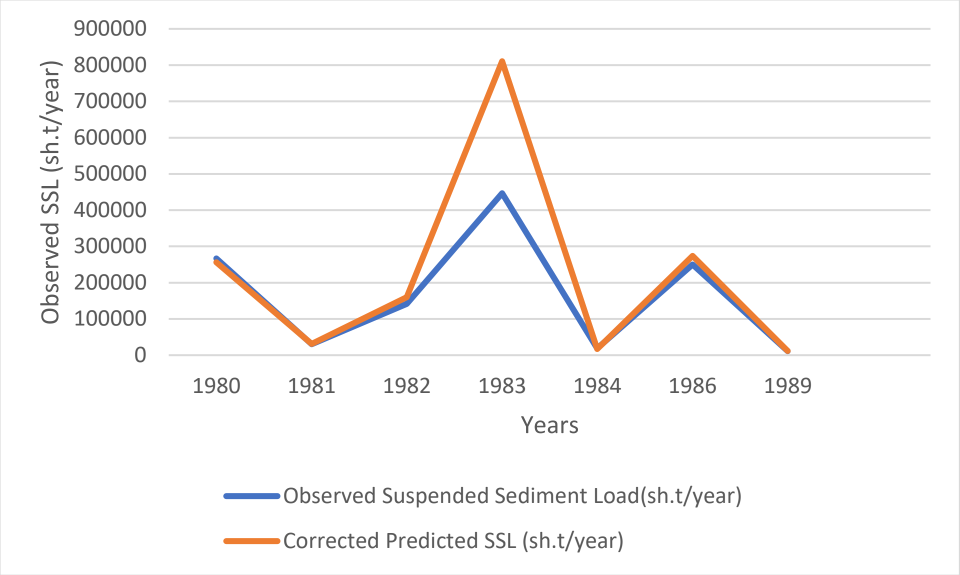

Figure 4. 14 San Joaquin River- Group 6: Observed vs. Corrected Predicted Suspended Sediment Load

Comparison between the observed suspended sediment and the corrected predicted sediment for all groups, except group 2, shows close agreement. The accuracy of the suspended sediment load is demonstrated by the absolute percent deviation (see chapter 3) using the smearing estimator (Appendix A). The smaller the percent deviation, the higher the accuracy of the prediction.

Group 1: Precipitation Range (1.0 – 0.19 inches)

The percent deviation for group 1 ranges from 0.01% to 3.97% with an average of 0.34%. The average percent deviation of group 1 is less than that of the (ungrouped) traditional data set which is 0.43%. Though the correlation coefficient of group 1 is lower than that of the ungrouped data set (0.82 to 0.90), the prediction accuracy is higher in group 1 than in the traditional data set.

### Group 2: Precipitation Range (0.2 – 0.69 inches)

The percent deviation for group 2 is between 0.03% and 0.86% with an average of 0.33% which is lower than both the ungrouped data set and group 1. The correlation coefficient of group 2 is the same as that of the ungrouped data set, which is 0.90, but group 2 has a higher prediction accuracy than the ungrouped data set.

### Group 3: Precipitation Range (0.7 – 1.3 inches)

Group 3 has a percent deviation ranging from 0.05% to 0.99% with an average of 0.32%. The percent deviation average of group 3 is smaller than the ungrouped data set (0.43%), but the ungrouped data set has a higher correlation coefficient of 0.92 t(compared to 0.90 for the ungrouped data set). This shows that group 3 also has a higher prediction accuracy than the ungrouped (traditional) data set.

### Group 4: Precipitation Range (1.4 – 2.5 inches)

The percent deviation for group 4 is between 0 to 0.90% with an average of 0.09% which is lower than the ungrouped data set. The high prediction accuracy of group 4 is supported by the high correlation coefficient of 0.96.

### Group 5: Precipitation Range (2.6 - 4.5 inches)

Group 5 has a percent deviation ranging from 0.11% to 3.21%., leading to an average of 0.56%. The average percent deviation for group 5 is higher than that of the ungrouped (traditional data set). This indicates a lower prediction accuracy than the ungrouped data set which has a percent deviation of 0.43%. However, the correlation coefficient value for group 5 is higher than that of the ungrouped with 0.93 and 0.90 respectively.

### Group 6: Precipitation Range (4.7 – 8.7 inches)

The percent deviation for group 6 is between 0.05% to 0.61% with 0.38% average. This demonstrates a higher prediction accuracy than the ungrouped data set with 0.43%. The correlation coefficient value for group 6 is 0.92 which is higher than the ungrouped data set.

For the San Joaquin River, 5 out of the 6 groups show a higher correlation coefficient value and higher prediction accuracy than the ungrouped (traditional data set).

Table 4. 1 San Joaquin River: Percent Deviation and Correlation Coefficient of the Groups

|  | **Groups** | **Percent Deviation (%)** | **Correlation Coefficient (*r*)** |
|---|---|---|---|
| **San Joaquin River** | Ungrouped (Traditional) | 0.43 | 0.90 |
|  | Group 1 | 0.34 | 0.82 |
|  | Group 2 | 0.33 | 0.90 |
|  | Group 3 | 0.32 | 0.92 |
|  | Group 4 | 0.09 | 0.96 |
|  | Group 5 | 0.56 | 0.93 |
|  | Group 6 | 0.38 | 0.92 |

### 4.1.2 The Rio Puerco Results and Discussion

The ten years data for Rio Puerco was divided into five groups based on similar precipitation values as shown in Appendix B. Linear regression analysis was applied to the ungrouped and grouped data. The ungrouped (Traditional) correlation coefficient is $r = 0.90$, and the values for the grouped are 0.88, 0.91, 0.94, 0.97 and 0.85, respectively. The correlation coefficient values for both the ungrouped (traditional) and the grouped data set for Rio Puerco show a strong correlation between the monthly suspended sediment load and the monthly stream discharge.

Figure 4.15 show the regression relationship of the ungrouped (traditional) data set.

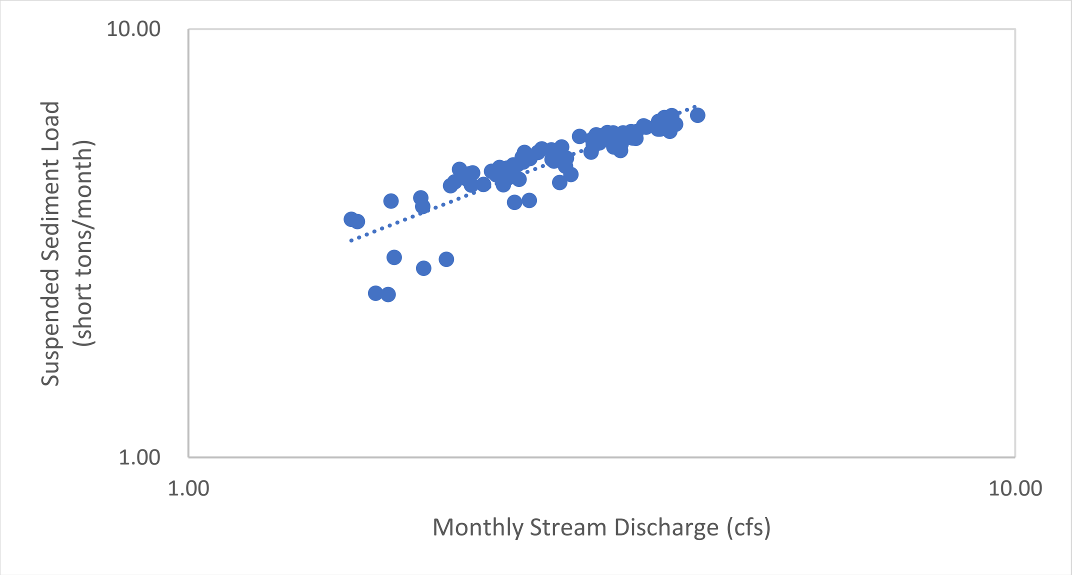

Figure 4. 15 Rio Puerco River- Ungrouped (Traditional): Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs)

The regression equation for this relationship is $Y = 2.2822X^{0.7512}$

Figure 4.16 shows the comparison between the annual observed and the predicted sediment load for the Rio Puerco River.

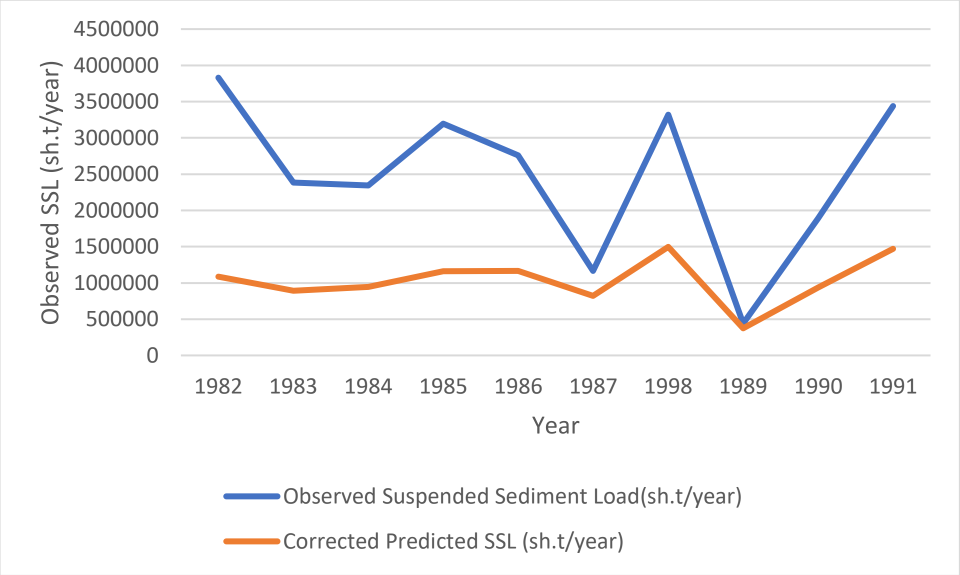

Figure 4. 16 Rio Puerco- Ungrouped Data Set: Observed vs. Corrected Predicted Suspended Sediment Load

The linear regression correlation coefficient for the ungrouped (traditional) data set for Rio Puerco was 0.90 with a percent deviation ranging from 0.04% to 79.29% and an average of 3.78%. From the comparison graph, the corrected predicted suspended sediment load line is reasonably close to the observed suspended sediment load.

Figures 4.17 through to 4.21 show the regression relationships for the (5) groups of the Rio Puerco.

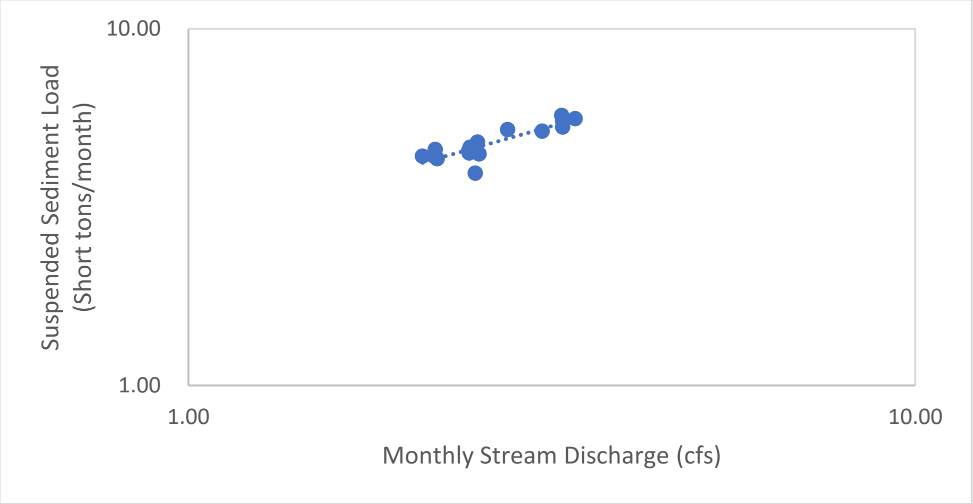

Figure 4. 17 Rio Puerco River- Group 1: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 2.7434X^{0.5784}$

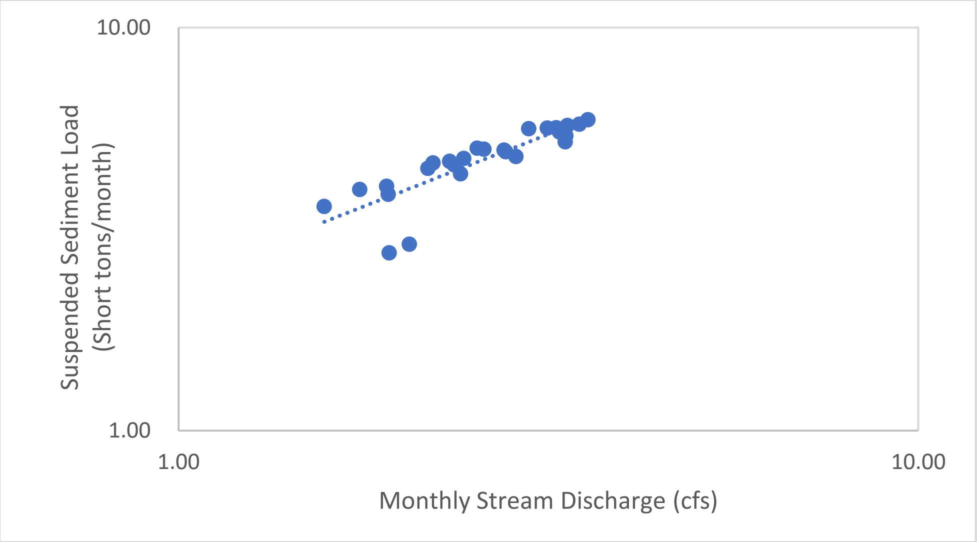

Figure 4. 18 Rio Puerco River- Group 2: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 2.5877X^{0.643}$

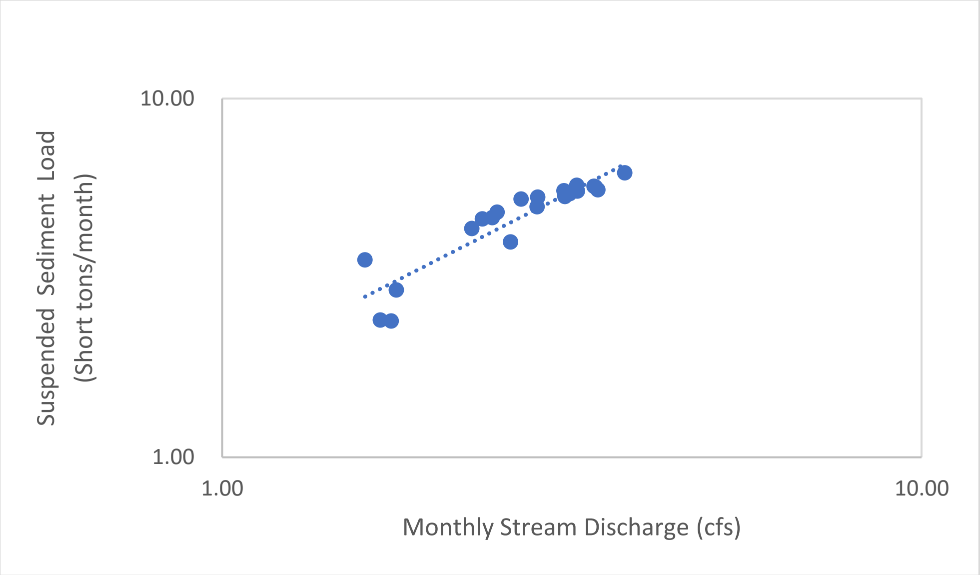

Figure 4. 19 Rio Puerco River- Group 3: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.9444X^{0.9037}$

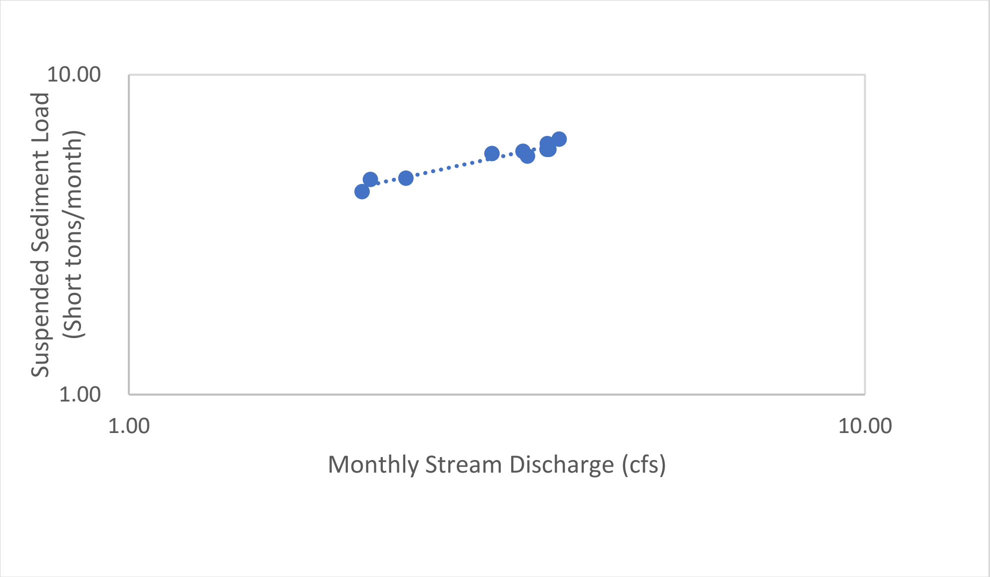

Figure 4. 20 Rio Puerco River- Group 4: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 3.1028X^{0.4998}$

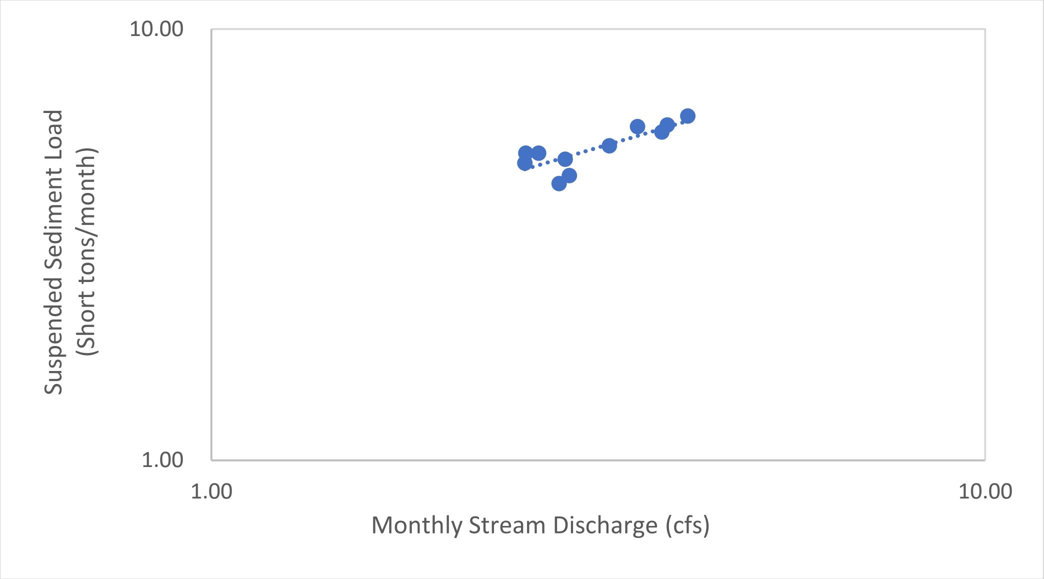

Figure 4. 21 Rio Puerco River- Group 5: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 2.8822X^{0.5313}$

Figure 4.22 to 4.26 shows the comparison between the observed suspended sediment load and the corrected predicted suspended sediment load for the 5 groups of the Rio Puerco River. The correction of bias and accuracy of the suspended sediment load for Rio Puerco is shown by the absolute percent deviation using the smearing estimator (see Appendix B).

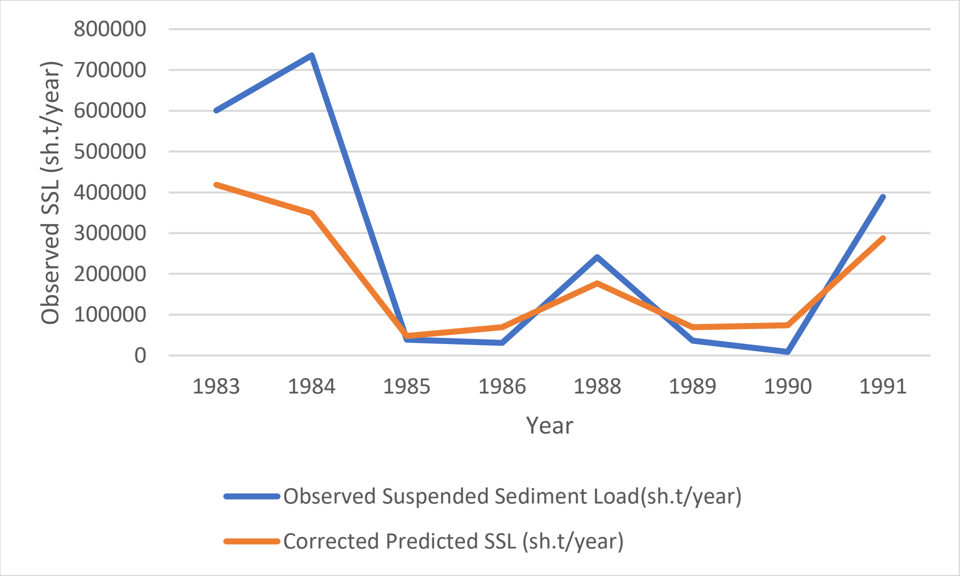

Figure 4. 22 Rio Puerco- Group 1: Observed vs. Corrected Predicted Suspended Sediment Load

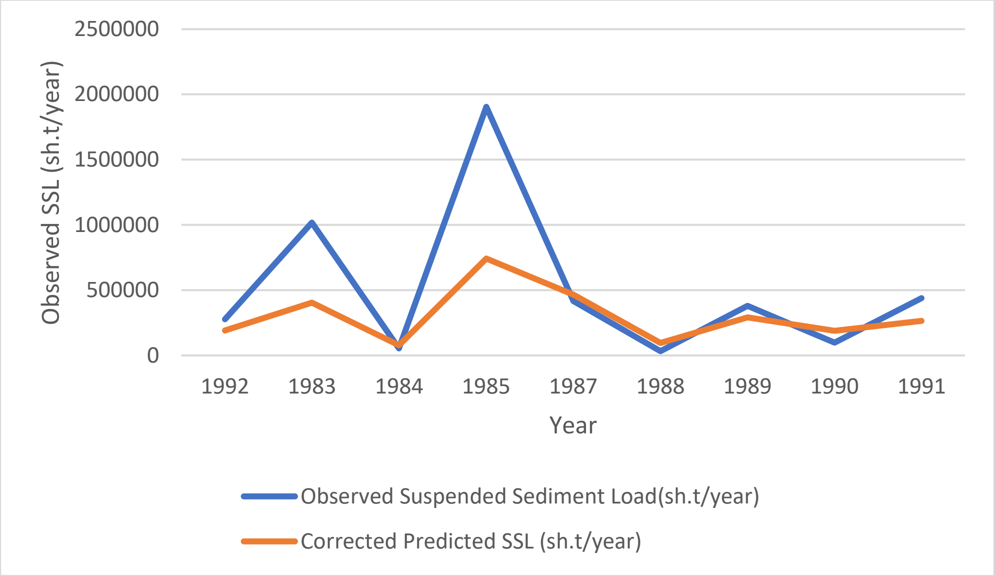

Figure 4. 23 Rio Puerco- Group 2: Observed vs. Corrected Predicted Suspended Sediment Load

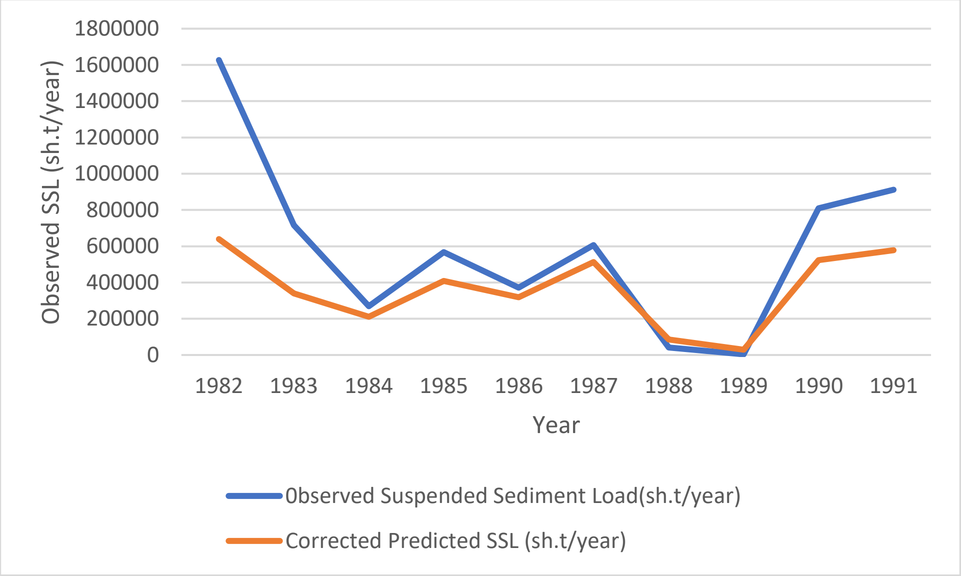

Figure 4. 24 Rio Puerco- Group 3: Observed vs. Corrected Predicted Suspended Sediment Load

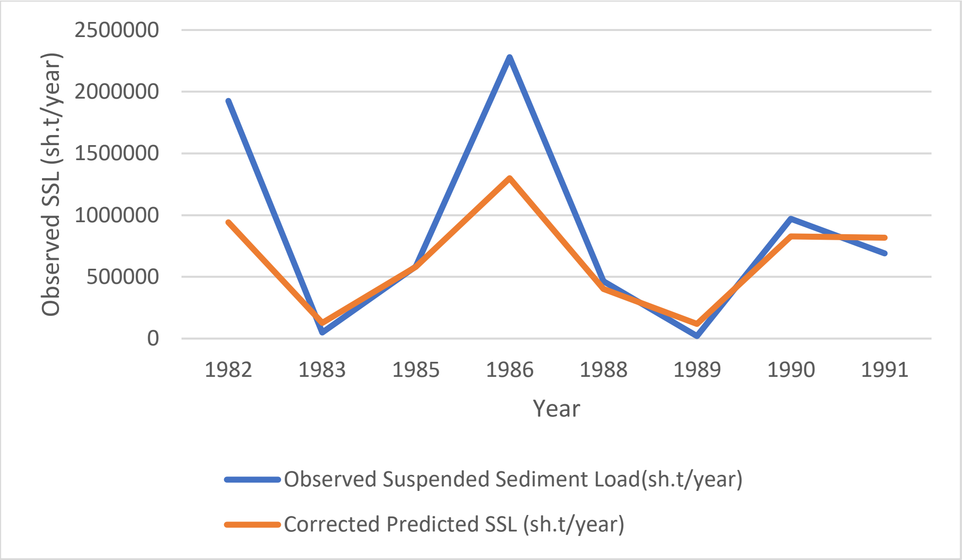

Figure 4. 25 Rio Puerco- Group 4: Observed vs. Corrected Predicted Suspended Sediment Load

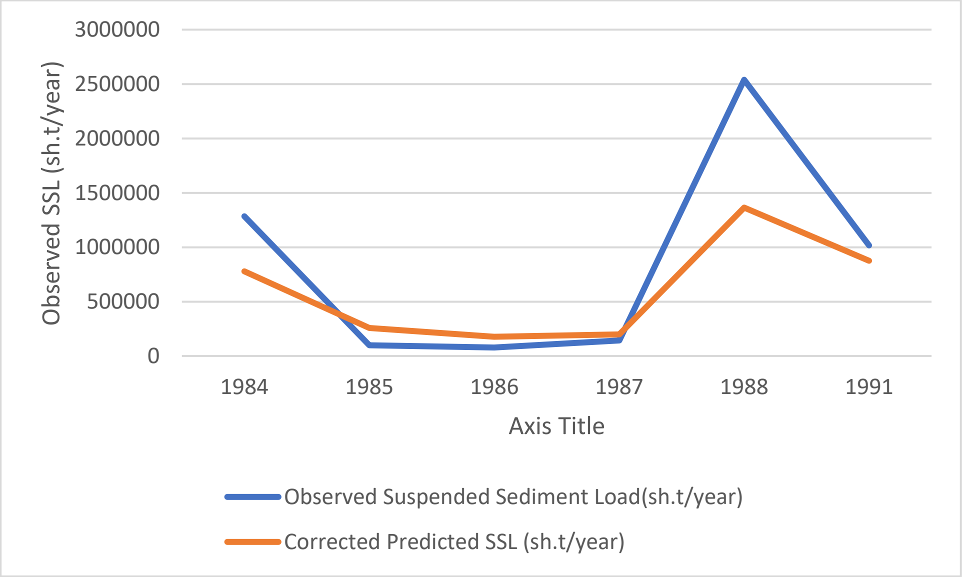

Figure 4. 26 Rio Puerco- Group 5: Observed vs. Corrected Predicted Suspended Sediment Load

### Group 1: Precipitation Range (0 – 0.19 inches)

The percent deviation for Rio Puerco group 1 ranges from 0.02% to 6.81% with an average of 0.97%. The average percent deviation of group 1 is much lower than that of the (ungrouped) traditional data set, which is 3.78%. The correlation coefficient of group 1 is lower than the traditional data set 0.88 and 0.90, respectively but the prediction accuracy is higher in group 1 than the traditional data set.

### Group 2: Precipitation Range (0.2 – 0.52 inches)

The percent deviation for group 2 is between 0.02% to 39.92% with an average of 2.37% which is lower than that of the ungrouped data set. The correlation coefficient for Rio Puerco group 2 is higher than the ungrouped data set and group 1 with a value of 0.91. With an average of 2.37 percent deviation, the prediction accuracy is higher than the ungrouped data set.

### Group 3: Precipitation Range (0.55 – 1.28 inches)

Group 3 has a percent deviation ranging from 0 to 33.56% with an average of 2.59%. The percent deviation average of group 3 is smaller than that of the ungrouped data set (3.78 percent deviation), but the ungrouped data set has a higher correlation coefficient (0.94 to 0.90). This shows that group 3 has a higher prediction accuracy than the ungrouped (traditional) data set.

### Group 4: Precipitation Range (1.3 – 1.98 inches)

The percent deviation for group 4 is between 0.09 to 4.48% with an average of 0.89% which is also lower than the ungrouped data set. The high prediction accuracy of group 4 is supported by the high correlation coefficient of 0.97.

Group 5: Precipitation Range (2.0 – 3.4 inches)

Group 5 has a percent deviation ranging from 0.01% to 6.36%., leading to an average of 1.27%. The average percent deviation for group 5 is lower than that of the ungrouped (traditional data set). This indicates a higher prediction accuracy than the ungrouped data set with a percent deviation of 3.78%. although, the correlation coefficient value for group 5 is lower than the ungrouped with 0.85 against 0.90, respectively.

The precipitation range for grouping the Rio Puerco River is less than that of the San Joaquin River as Rio Puerco is an ephemeral stream with large thunderstorms during the summer monsoon season and snowmelt during Spring only. All five (5) groups show a higher prediction accuracy than the ungrouped (traditional data set). Two groups from the five groups have a lower correlation coefficient than the ungrouped (traditional).

Table 4. 2 The Rio Puerco: Percent Deviation and Correlation Coefficient of the Groups

| | **Groups** | **Percent Deviation (%)** | **Correlation Coefficient (*r*)** |
|---|---|---|---|
| **Rio Puerco River** | Ungrouped (Traditional) | 3.78 | 0.90 |
| | Group 1 | 0.97 | 0.88 |
| | Group 2 | 2.37 | 0.91 |
| | Group 3 | 2.59 | 0.94 |
| | Group 4 | 0.89 | 0.97 |
| | Group 5 | 1.27 | 0.85 |

### 4.1.3 Powder River Results and Discussion

The data between 1948 -1957 for the Powder River was divided into five (5) groups of similar precipitation values. The correlation coefficient values for both the Ungrouped (traditional) and the grouped data set for Powder River show a good correlation between the monthly suspended sediment load and the monthly stream discharge.

The correlation coefficient value for the ungrouped data (traditional) was $r = 0.80$, and for the grouped data was 0.81, 0.80, 0.78, 0.78, and 0.90, respectively.

Figure 4.27 shows the regression relationship of the ungrouped (traditional) data set.

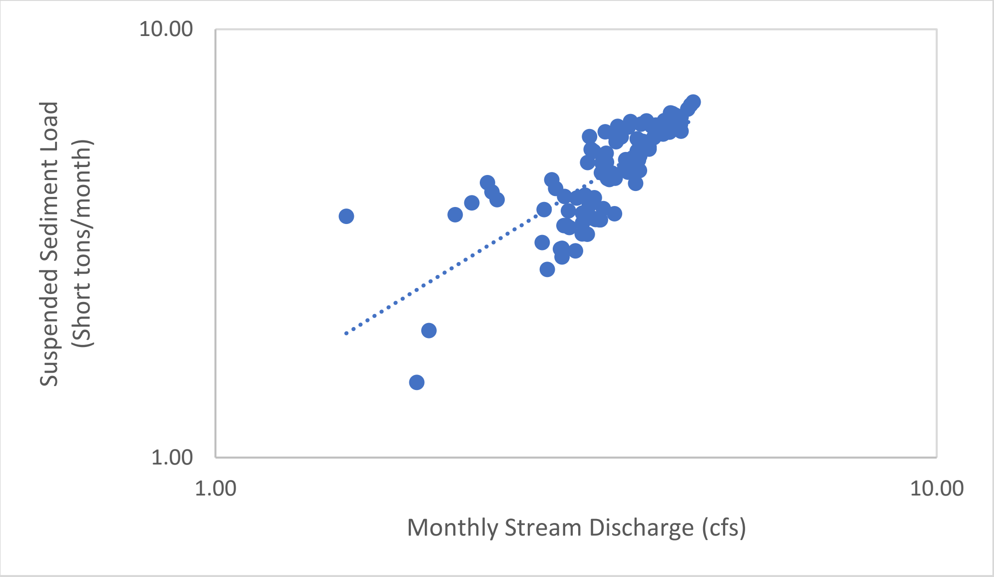

Figure 4. 27 Powder River- Ungrouped (Traditional): Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.2634X^{1.0395}$

Figure 4.28 shows the comparison of the annual observed vs. corrected predicted suspended sediment load.

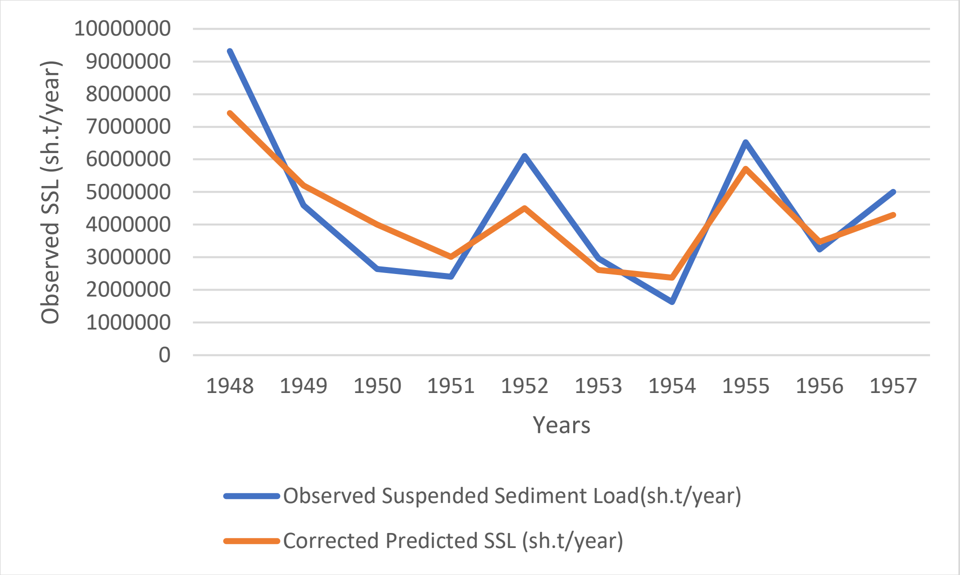

Figure 4. 28 Powder River- Ungrouped (Tradition): Observed vs. Corrected Predicted Suspended Sediment Load

The linear regression correlation coefficient for the ungrouped (traditional) data set for Powder River was 0.80 with a percent deviation ranging from 0.02% to 52.95% with an average of 8.03%. From the comparison graph, the corrected predicted suspended sediment line is considerately close to the observed suspended sediment load.

Figure 4.29 through 4.33 shows the regression relationships of the grouped data set.

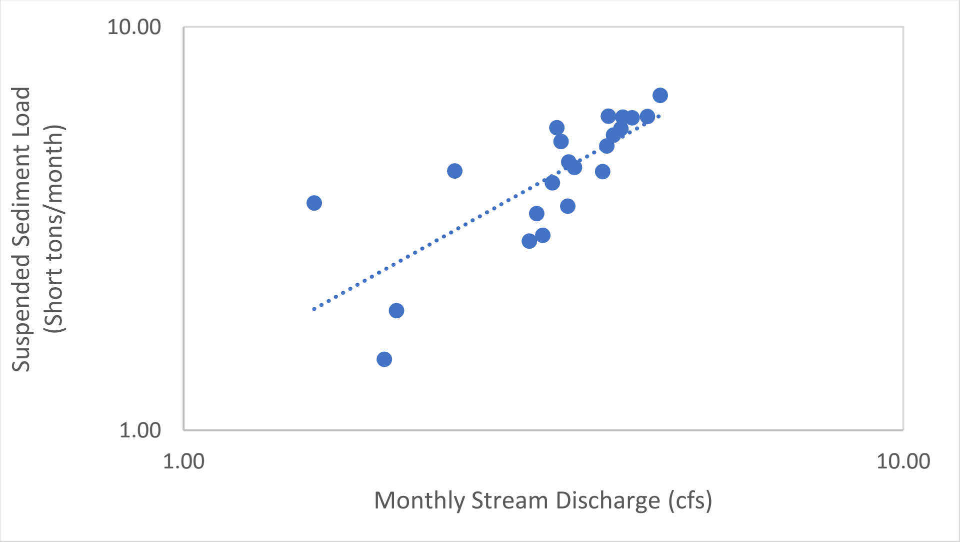

Figure 4. 29 Powder River- Group 1: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.3173X^{0.9974}$

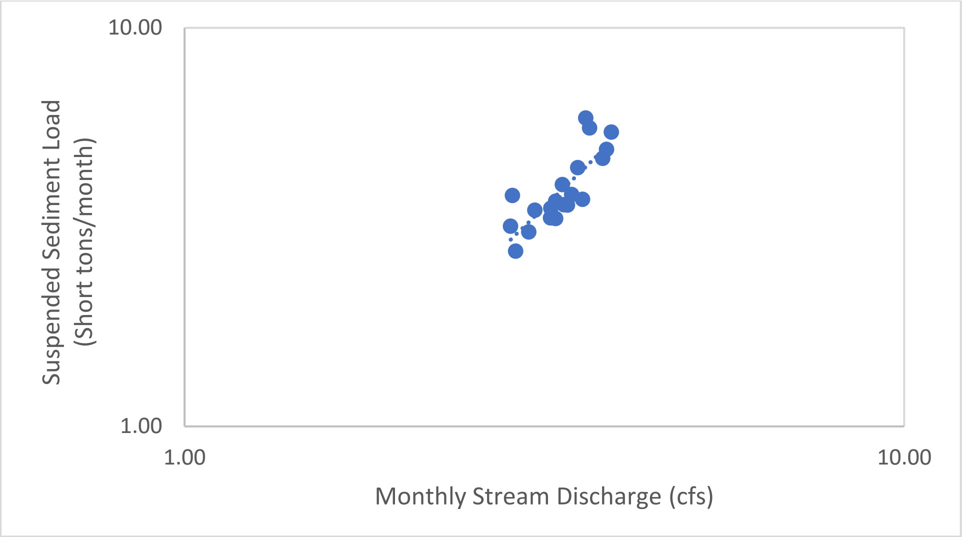

Figure 4. 30 Powder River- Group 2: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 0.4736X^{1.7502}$

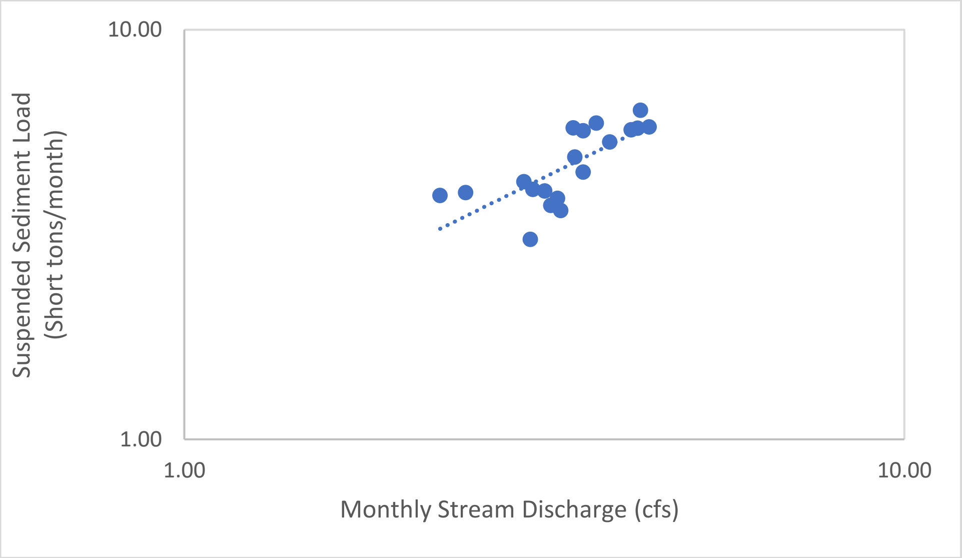

Figure 4. 31 Powder River- Group 3: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.6059X^{0.8679}$

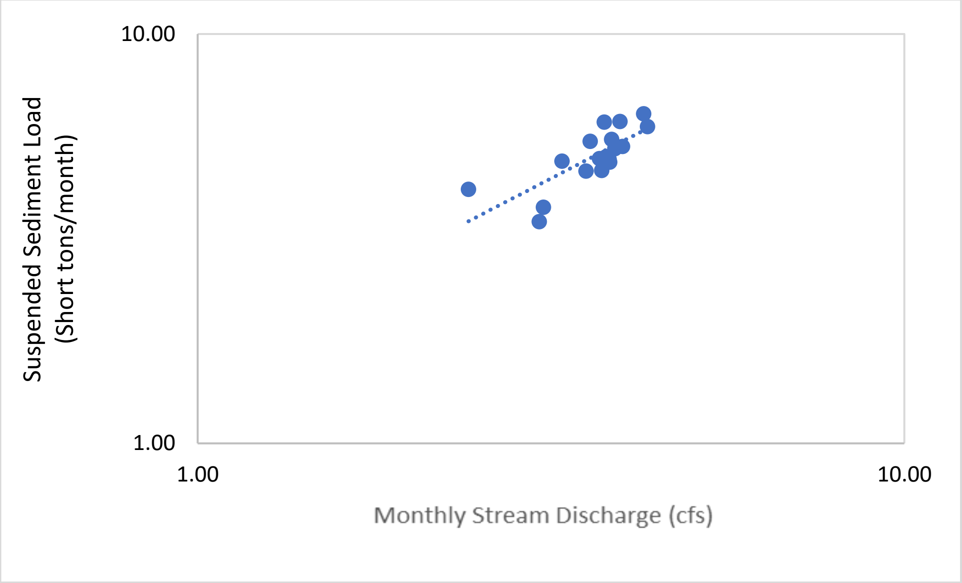

Figure 4. 32  Powder River- Group 4: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.5831X^{0.8952}$

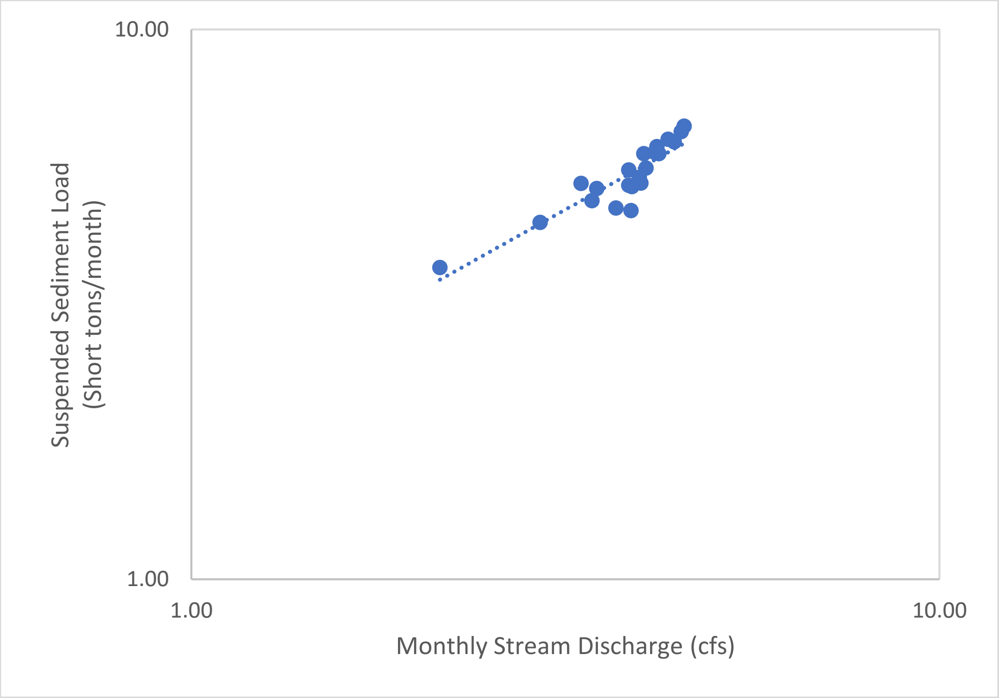

Figure 4. 33  Powder River- Group 5: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.9603X^{0.7599}$

Figure 4.34 to 4.38 shows the comparison between the observed suspended sediment load and the corrected predicted suspended sediment load for the Powder River. The correction of bias and accuracy of the suspended sediment load for Powder River is shown by the absolute percent deviation using the smearing estimator (see Appendix C).

Figure 4. 34 Powder River- Group 1: Observed vs. Corrected Predicted Suspended Sediment Load

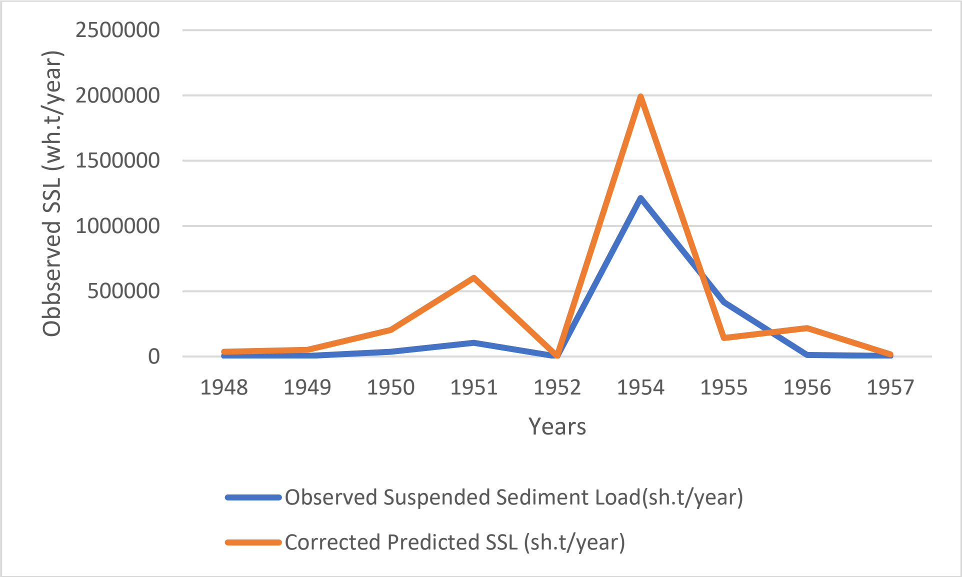

Figure 4. 35 Powder River- Group 2: Observed vs. Corrected Predicted Suspended Sediment Load

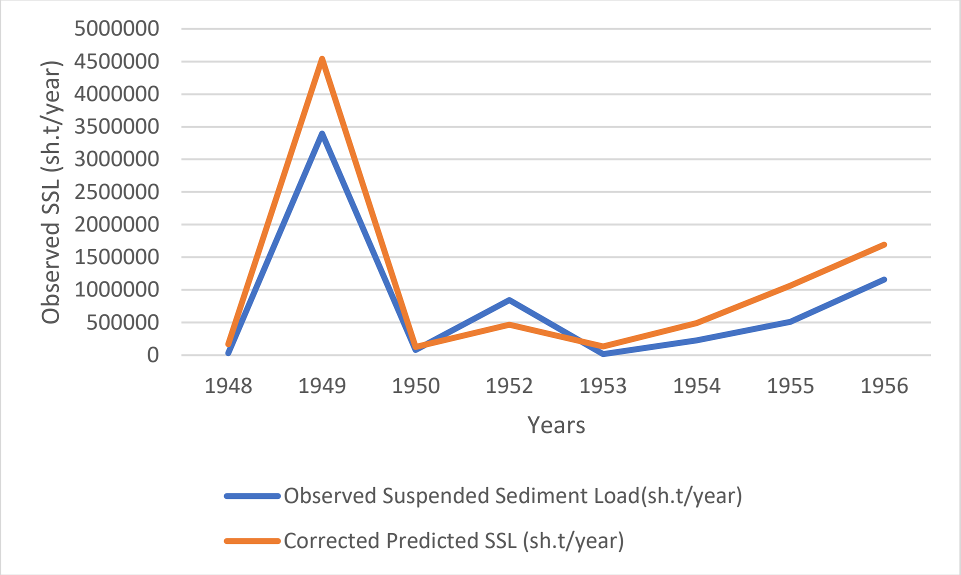

Figure 4. 36 Powder River- Group 3: Observed vs. Corrected Predicted Suspended Sediment Load

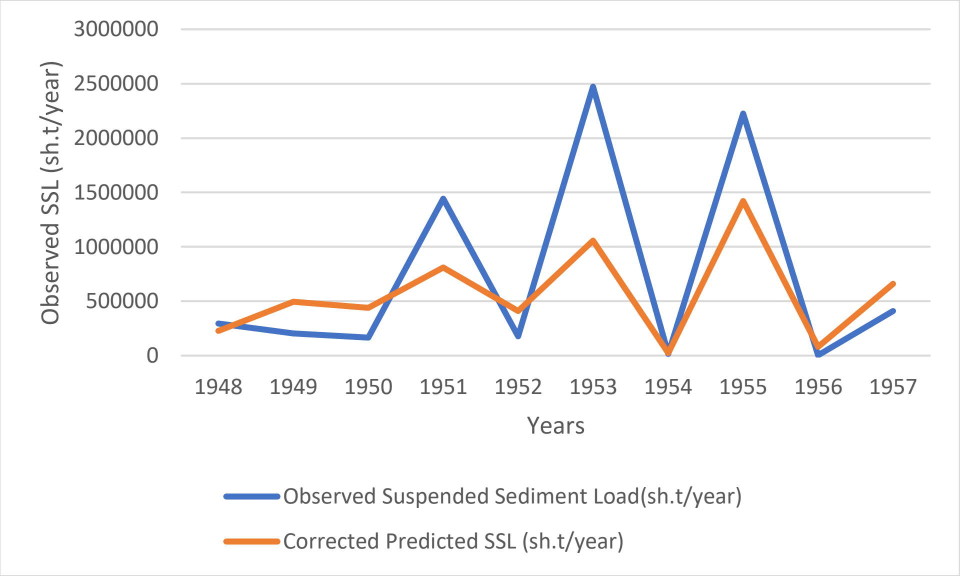

Figure 4. 37 Powder River- Group 4: Observed vs. Corrected Predicted Suspended Sediment Load

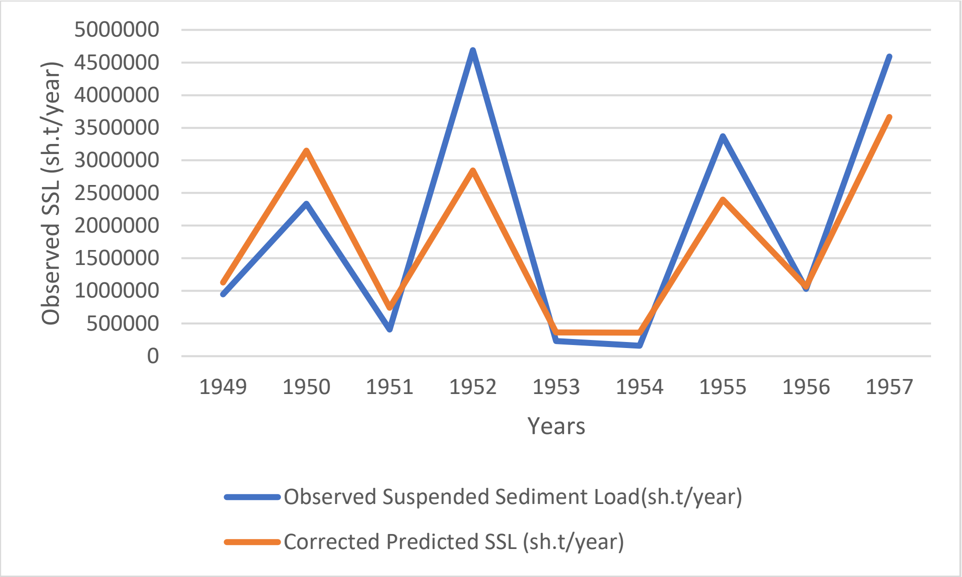

Figure 4. 38 Powder River- Group 5: Observed vs. Corrected Predicted Suspended Sediment Load

Group 1: Precipitation Range (0 – 0.25 inches)

The percent deviation for group 1 ranges from 0.012% to 64.12% with an average of 17.48%. The average percent deviation of group 1 is higher than that of the (ungrouped) traditional data set, which is 8.03%. The correlation coefficient of group 1 is slightly higher than that of the traditional data set, 0.81 and 0.80, respectively, but the prediction accuracy in group 1 is lower than the traditional data set.

Group 2: Precipitation Range (0.26 – 0.46 inches)

The percent deviation for group 2 is between 0.03% to 13.80% with an average of 4.44% which is lower than both the ungrouped data set and that of group 1. The correlation coefficient of group 2 is the same as that of the ungrouped data set, 0.80, but group 2 has a higher prediction accuracy than the ungrouped data set.

Group 3: Precipitation Range (0.55 – 0.78 inches)

Group 3 has a percent deviation ranging from 0.17% to 47.42% with an average of 6.49%. The percent deviation average of group 3 is smaller than that of the ungrouped data set which has an 8.03% deviation. The correlation coefficient for group 3 is lower than the traditional data set 0.78 against 0.80, but the prediction for group 3 is more accurate than the ungrouped (traditional) data set.

Group 4: Precipitation Range (0.80 – 1.36 inches)

The percent deviation for group 4 is between 0.03 to 20.23% with an average of 3.04% which is lower than that of the ungrouped data set. The correlation coefficient for group 4 is less than the ungrouped (traditional) data set but has the same value as group 3 and the prediction accuracy is higher than that of the ungrouped (traditional).

Group 5: Precipitation Range (1.40 – 3.95 inches)

Group 5 has a percent deviation ranging from 0.07% to 7.94%., leading to an average of 1.48%. The average percent deviation for group 5 is lower than that of the ungrouped (traditional data set). This indicates a higher prediction accuracy than the ungrouped data set, which has a percent deviation of 8.03%. The correlation coefficient value for group 5 is higher than the ungrouped with 0.90 and 0.80, respectively.

The statistical analysis of the Powder River shows 2 groups out of the 5 groups with a lower correlation coefficient value than the ungrouped data (traditional), though both groups produced a higher prediction accuracy. Group 2 regression analysis produced the same correlation coefficient value as that of the ungrouped and two other groups produced higher correlation coefficient value. Only group 1 percent deviation is higher than the traditional data set.

Table 4. 3 Powder River: Percent Deviation and Correlation Coefficient of the Groups

| | **Groups** | **Percent Deviation (%)** | **Correlation Coefficient (*r*)** |
|---|---|---|---|
| **Powder River** | Ungrouped (Traditional) | 8.03 | 0.80 |
| | Group 1 | 17.48 | 0.81 |
| | Group 2 | 4.44 | 0.80 |
| | Group 3 | 6.49 | 0.78 |
| | Group 4 | 3.04 | 0.78 |
| | Group 5 | 1.48 | 0.90 |

### 4.1.4 Little Colorado River Results and Discussion

The ten years data for the Little Colorado River between 1957 - 1966 was broken down into five groups based on similar precipitation values. Linear regression analysis was applied to the ungrouped and grouped data. The ungrouped (traditional) correlation coefficient $r$ =0.87, and the values for the grouped are 0.89, 0.87, 0.81, 0.82 and 0.90, respectively. The correlation coefficient values for both the ungrouped (traditional) and the grouped data for Little Colorado River show a good correlation between the monthly suspended sediment load and the monthly stream discharge.

Figure 4.39 shows the regression relationship between the suspended sediment load and stream discharge for the ungrouped (traditional) data set.

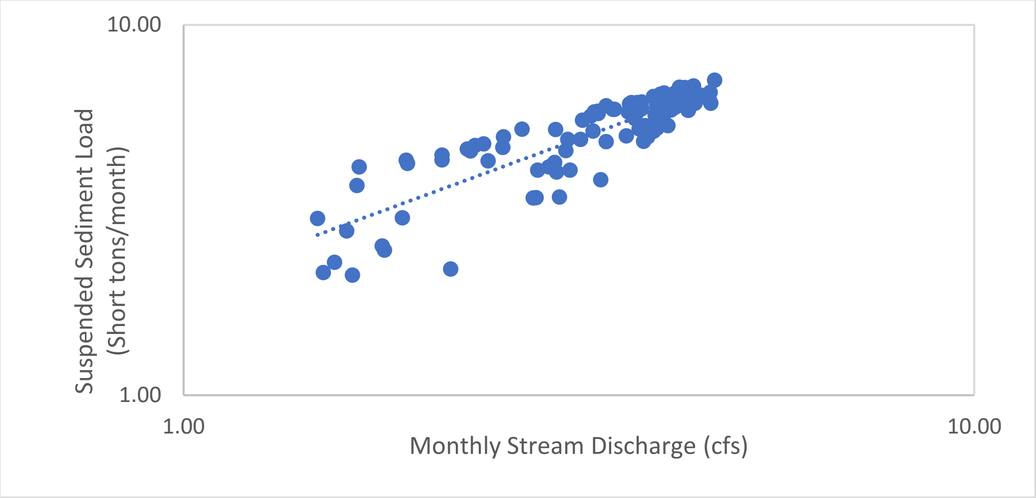

Figure 4. 39 Little Colorado River- Ungrouped (Traditional): Regression relationship between monthly sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.9942X^{0.786}$

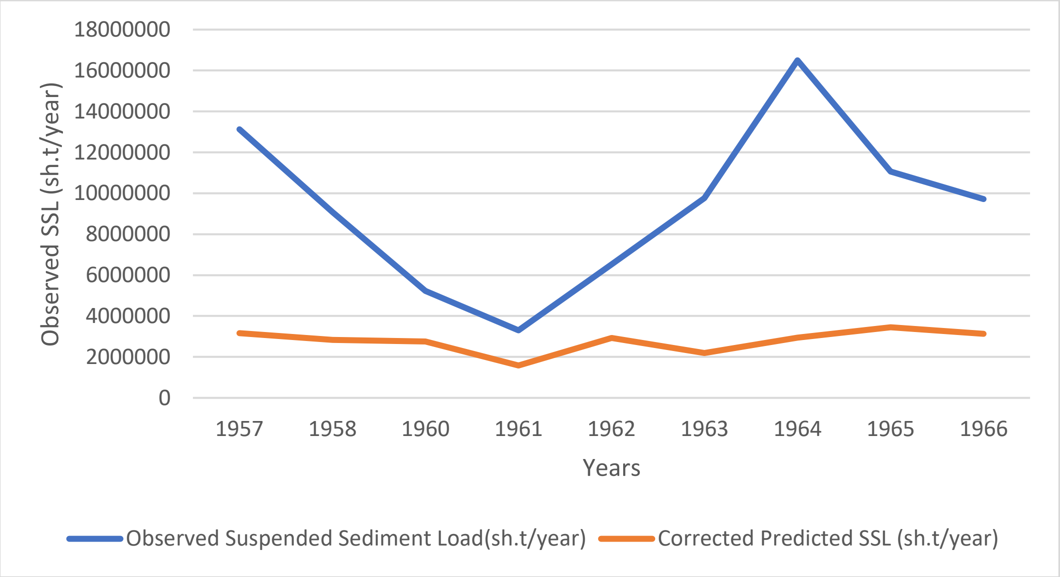

Figure 4. 40 Little Colorado River- Ungrouped: Observed vs. Corrected Predicted Suspended Sediment Load

Figure 4.40 shows the observed vs. corrected predicted suspended sediment load.

The linear regression correlation coefficient for the ungrouped (traditional) data set for Little Colorado River was 0.87 with a percent deviation ranging from 0.04% to 80.35% and an average of 11.02%. From the comparison graph, the deviation between the observed suspended sediment load and the corrected predicted sediment load is due to the enormous hydrologic changes that took place during the ten years of the study.

Figure 4.41 through 4.45 shows the regression relationships of the grouped data set.

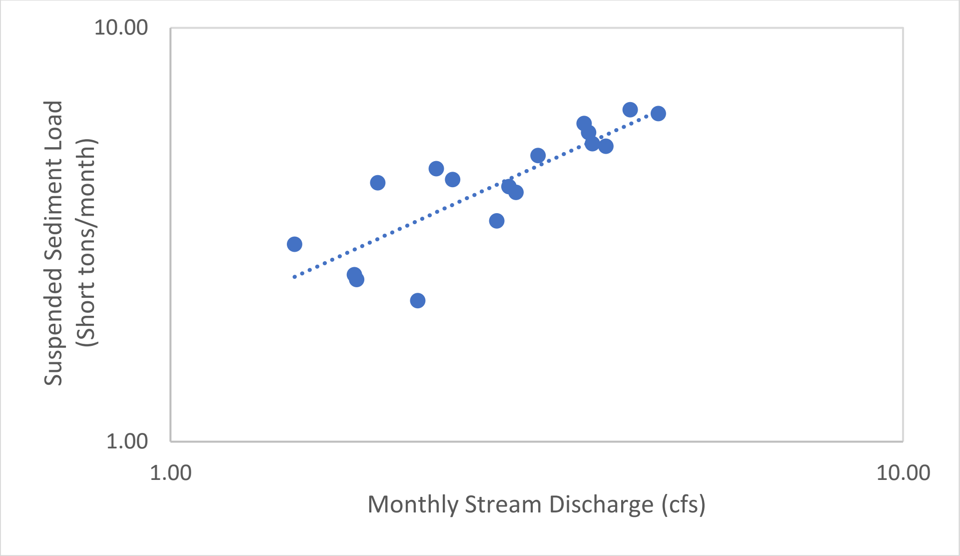

Figure 4. 41 Little Colorado River- Group 1: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 2.0037X^{0.7442}$

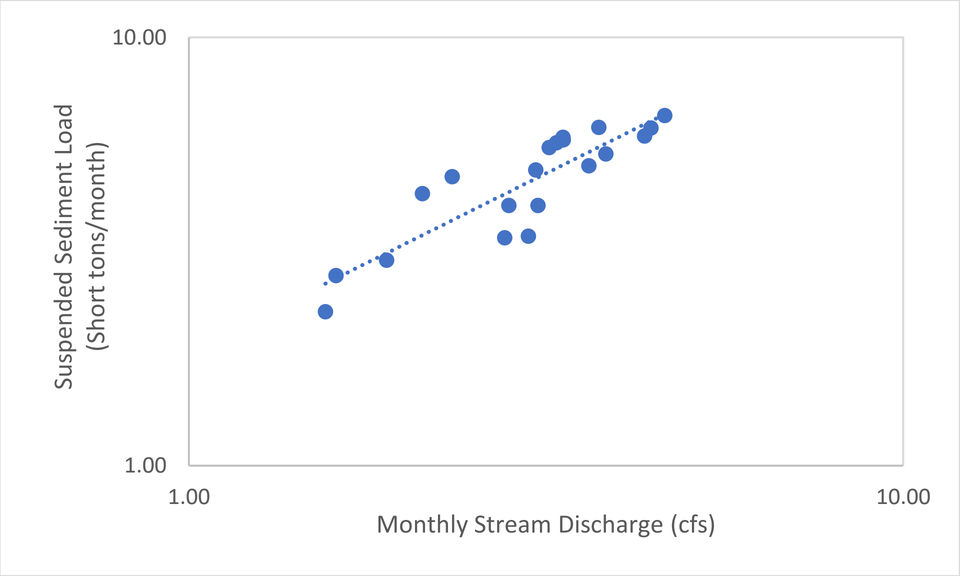

Figure 4. 42 Little Colorado River- Group 2: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 1.8442X^{0.833}$

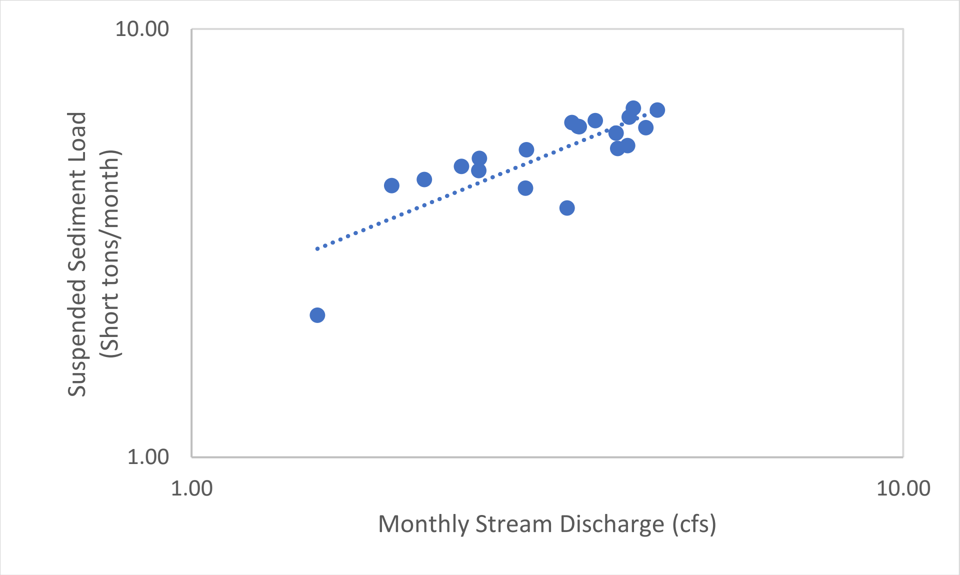

Figure 4. 43 Little Colorado River- Group 3: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 2.3271X^{0.6782}$

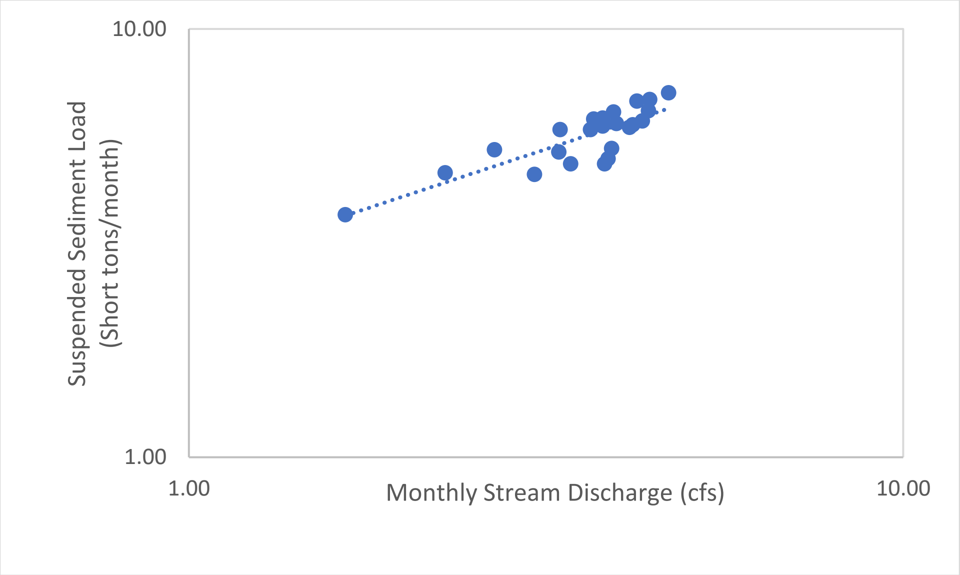

Figure 4. 44 Little Colorado River- Group 4: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 2.7724X^{0.5532}$

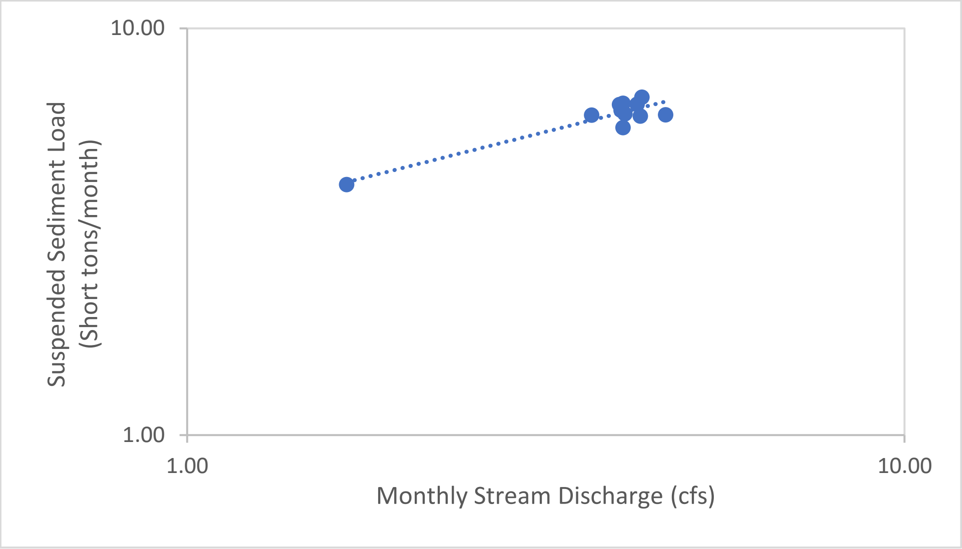

Figure 4. 45 Little Colorado River- Group 5: Regression relationship between monthly suspended sediment load (sh.t/month) and monthly stream discharge (cfs).

The regression equation for this relationship is $Y = 3.3336X^{0.4458}$

Figure 4.46 to 4.50 shows the comparison between the annual observed suspended sediment load and the corrected predicted suspended sediment load for Little Colorado River. The deviation between the observed and corrected predicted load in groups 2 and 3 is due to the vast hydrologic variations that took place during the ten years of study.

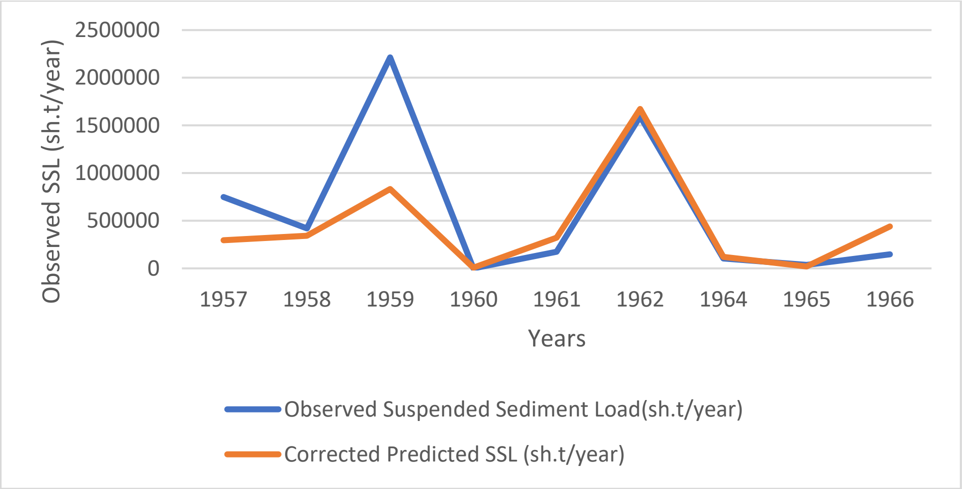

Figure 4. 46 Little Colorado River- Group 1: Observed vs. Corrected Predicted Suspended Sediment Load

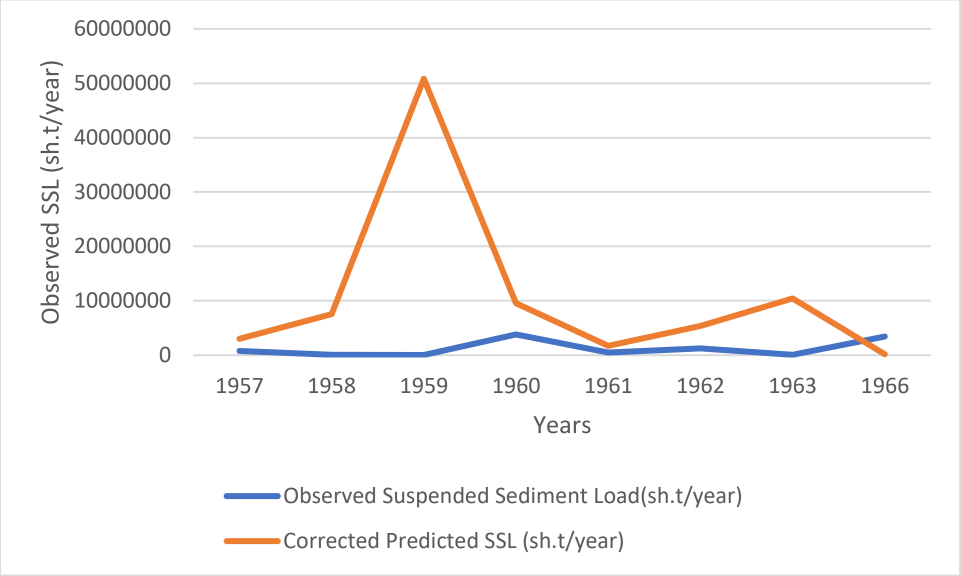

Figure 4. 47 Little Colorado River- Group 2: Observed vs. Corrected Predicted Suspended Sediment Load

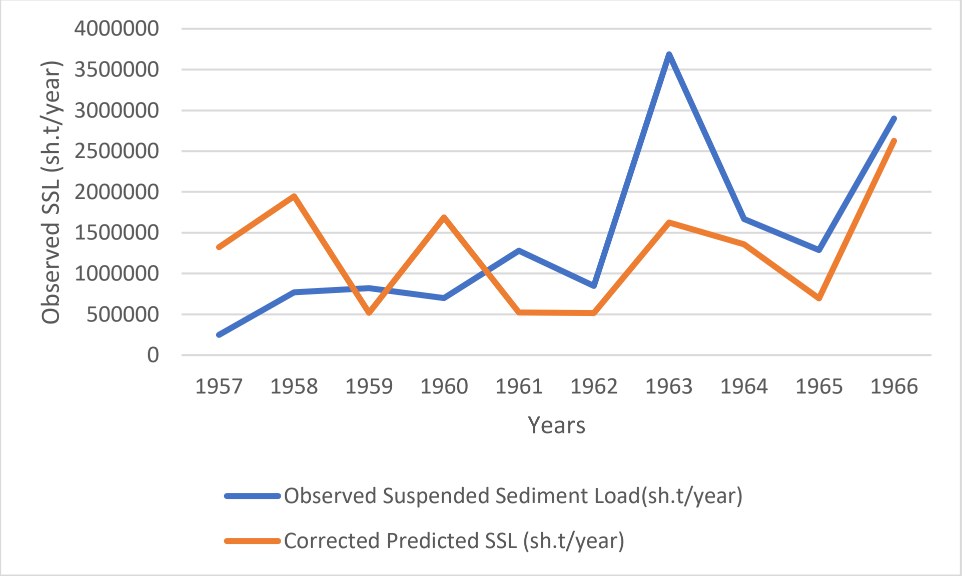

Figure 4. 48 Little Colorado River- Group 3: Observed vs. Corrected Predicted Suspended Sediment Load

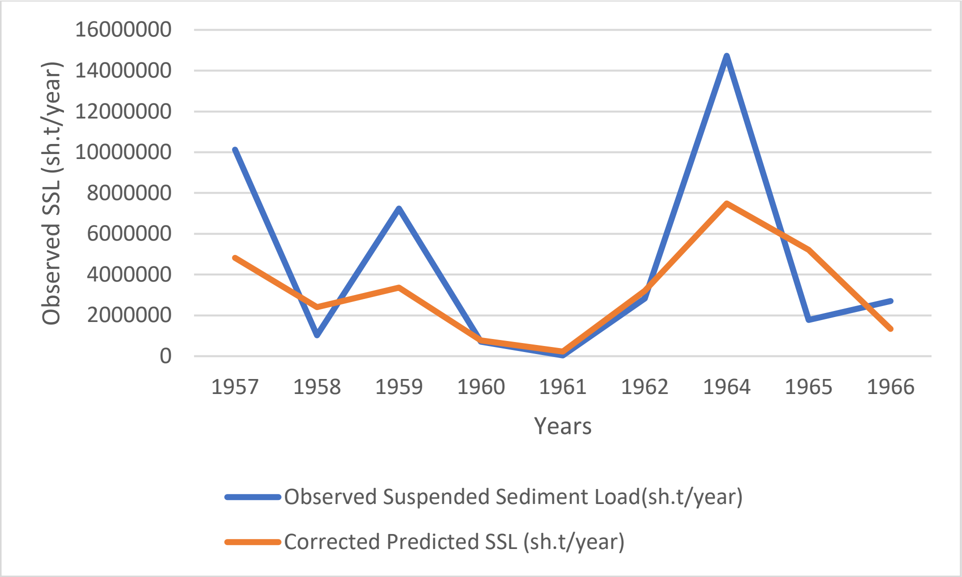

Figure 4. 49 Little Colorado River- Group 4: Observed vs. Corrected Predicted Suspended Sediment Load

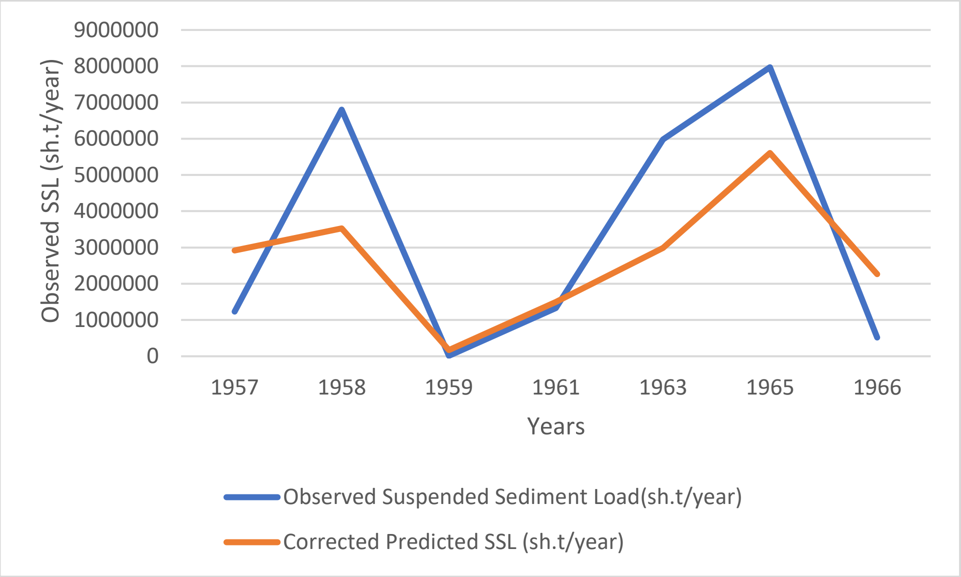

Figure 4. 50 Little Colorado River- Group 5: Observed vs. Corrected Predicted Suspended Sediment Load

### Group 1: Precipitation Range (0 – 0.85 inches)

The percent deviation for Little Colorado River group 1 ranges from 0.11% to 24.42% with an average of 4.92%. The average percent deviation of group 1 is much lower than that of the (ungrouped) traditional data set, which is 11.12%. The correlation coefficient of group 1 is higher than the traditional data set, 0.89 and 0.0.87, respectively. The prediction accuracy, however, is higher in group 1 than that of the traditional data set.

### Group 2: Precipitation Range (0.86 – 1.30 inches)

The percent deviation for group 2 is between 0.05% to 41.28% with an average of 7.93%, which is lower than that of the ungrouped data set. The correlation coefficient of Little Colorado River group 2 is the same as the ungrouped data set with a value of 0.87, but the prediction accuracy is higher than the ungrouped data set.

### Group 3: Precipitation Range (1.31 – 2.05 inches)

Group 3 has a percent deviation ranging from 0.02 to 53.70% with an average of 4.43%. The percent deviation average of group 3 is smaller than the ungrouped data set (which has a 11.12 percent deviation) but has a lower correlation coefficient of 0.81 compared to 0.87 for the traditional data set. This shows that group 3 has a higher prediction accuracy than the ungrouped (traditional) data set.

### Group 4: Precipitation Range (2.12 – 4.09 inches)

The percent deviation for group 4 is between 0.13 to 14.75% with an average of 3.35%, which is also lower than the ungrouped data set, but the correlation coefficient is lower than the ungrouped, 0.82 to 0.87, respectively. However, the prediction accuracy of group 4 is higher than that of the ungrouped data set.

### Group 5: Precipitation Range (4.1 – 8.35 inches)

Group 5 has a percent deviation ranging from 0.01% to 11.72%., leading to an average of 1.76%. The average percent deviation for group 5 is lower than that of the ungrouped (traditional data set). This indicates a higher prediction accuracy than the ungrouped data set with a percent deviation of 11.12%. The low percent deviation of group 5 is reflected in the high correlation coefficient of 0.90.

All five (5) groups show a higher prediction accuracy than the ungrouped (traditional data set). Two groups from the five groups have a lower correlation coefficient than the ungrouped (traditional).

Table 4. 4 Little Colorado River: Percent Deviation and Correlation Coefficient of the Groups

| | **Groups** | **Percent Deviation (%)** | **Correlation Coefficient (*r*)** |
|---|---|---|---|
| **Little Colorado River** | Ungrouped (Traditional) | 11.12 | 0.87 |
| | Group 1 | 4.92 | 0.89 |
| | Group 2 | 7.93 | 0.87 |
| | Group 3 | 4.43 | 0.81 |
| | Group 4 | 3.35 | 0.82 |
| | Group 5 | 1.76 | 0.90 |

# Chapter 5- Conclusions and Recommendations

## 5.1 Conclusions

This study focused on improving the prediction accuracy of suspended sediment load in rivers and streams in response to stream or river water discharge utilizing the linear regression approach. To accomplish the goal of the study, both the monthly suspended sediment load data and the monthly stream discharge data were grouped in reference to similar precipitation values. Furthermore, monthly suspended sediment load (in short tons per month) was regressed against monthly stream water discharge (in cubic feet per second) for each group to establish equations for calculating suspended sediment loads in four (4) American rivers. The correlation coefficients resulting from the regression of all groups were compared with that of the traditional approach, in which linear regression was applied without the precipitation data. In addition to the correlation coefficient, the percent deviation from the groups was also compared with that of the traditional approach.

The high correlation coefficient values (between the suspended sediment load and the stream water discharge) obtained from the groups have considerably improved the prediction accuracy compared to the traditional approach. The percent deviations for most of the groups were relatively low, ranging from 0.09% to 17.48%, which implies that the prediction has a high level of precision. This is shown by the graphs of the observed and corrected predicted suspended sediment load. The percent deviations were calculated using the smearing estimator, which is a statistical method used to remove the bias resulting from using logarithmic functions and retransforming back to engineering units.

## 5.2 Future Recommendation

Future studies may improve the prediction accuracy of the suspended sediment load by grouping the suspended sediment load and water discharge data using different precipitation intensities. Precipitation intensity is the rate of precipitation per unit time (e.g., precipitation in inches per hour). Further studies may include the correlation between suspended sediment load and precipitation values or intensities.

In this study, suspended sediment load was predicted using monthly sediment and water discharge data. Future studies can predict suspended sediment using daily sediment and water data.

The accuracy of predicting suspended sediment load can be increased by removing the effects of sediment sources and sinks. Sediment sources add sediment eroded outside the river channel (e.g., sediment eroded in the watershed surrounding the river) to the sediment eroded in the river channel. Sediment sinks remove sediment eroded from the river channel and transport it to locations outside the river channel.

Finally, non-linear regression or weighted non-linear least square method could be used to improve prediction accuracy for suspended sediment load as this method eliminate the need for logarithmic transformation and the resulting bias correction.

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| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/day) | Percent Deviation | Absolute Percent Deviation |
| Group 1 | 1980 | 6 | 0 - 0.19 | 159150 | 31560 | 5.20 | 4.50 | 4.31 | 20504.86 | 0.19 | 1.54 | 35063.30 | -0.11 | 0.11 |
|  | 1980 | 8 |  | 59070 | 16578 | 4.77 | 4.22 | 3.96 | 9133.09 | 0.26 | 1.82 | 15617.59 | 0.06 | 0.06 |
|  | 1980 | 9 |  | 114060 | 23079 | 5.06 | 4.36 | 4.19 | 15624.40 | 0.17 | 1.48 | 26717.72 | -0.16 | 0.16 |
|  | 1981 | 6 |  | 44970 | 13278 | 4.65 | 4.12 | 3.86 | 7310.84 | 0.26 | 1.82 | 12501.54 | 0.06 | 0.06 |
|  | 1981 | 7 |  | 37950 | 14073 | 4.58 | 4.15 | 3.80 | 6365.31 | 0.34 | 2.21 | 10884.67 | 0.23 | 0.23 |
|  | 1981 | 8 |  | 38070 | 11157 | 4.58 | 4.05 | 3.80 | 6381.73 | 0.24 | 1.75 | 10912.75 | 0.02 | 0.02 |
|  | 1982 | 5 |  | 559500 | 72150 | 5.75 | 4.86 | 4.76 | 57198.86 | 0.10 | 1.26 | 97810.05 | -0.36 | 0.36 |
|  | 1982 | 7 |  | 184890 | 33510 | 5.27 | 4.53 | 4.36 | 23173.08 | 0.16 | 1.45 | 39625.97 | -0.18 | 0.18 |
|  | 1982 | 8 |  | 120510 | 22665 | 5.08 | 4.36 | 4.21 | 16341.70 | 0.14 | 1.39 | 27944.31 | -0.23 | 0.23 |
|  | 1983 | 7 |  | 576900 | 98220 | 5.76 | 4.99 | 4.77 | 58646.29 | 0.22 | 1.67 | 100285.15 | -0.02 | 0.02 |
|  | 1984 | 8 |  | 65370 | 24750 | 4.82 | 4.39 | 4.00 | 9920.45 | 0.40 | 2.49 | 16963.97 | 0.31 | 0.31 |
|  | 1985 | 5 |  | 63960 | 24783 | 4.81 | 4.39 | 3.99 | 9745.49 | 0.41 | 2.54 | 16664.79 | 0.33 | 0.33 |
|  | 1985 | 7 |  | 76710 | 19083 | 4.88 | 4.28 | 4.05 | 11303.73 | 0.23 | 1.69 | 19329.38 | -0.01 | 0.01 |
|  | 1985 | 8 |  | 78030 | 24525 | 4.89 | 4.39 | 4.06 | 11462.20 | 0.33 | 2.14 | 19600.36 | 0.20 | 0.20 |
|  | 1986 | 6 |  | 186990 | 20796 | 5.27 | 4.32 | 4.37 | 23387.63 | -0.05 | 0.89 | 39992.85 | -0.92 | 0.92 |
|  | 1986 | 7 |  | 86820 | 49680 | 4.94 | 4.70 | 4.10 | 12505.36 | 0.60 | 3.97 | 21384.17 | 0.57 | 0.57 |
|  | 1986 | 8 |  | 95490 | 23418 | 4.98 | 4.37 | 4.13 | 13515.38 | 0.24 | 1.73 | 23111.29 | 0.01 | 0.01 |
|  | 1987 | 6 |  | 59700 | 23100 | 4.78 | 4.36 | 3.96 | 9212.50 | 0.40 | 2.51 | 15753.38 | 0.32 | 0.32 |
|  | 1987 | 7 |  | 48960 | 16578 | 4.69 | 4.22 | 3.89 | 7835.98 | 0.33 | 2.12 | 13399.52 | 0.19 | 0.19 |
|  | 1987 | 8 |  | 48810 | 16149 | 4.69 | 4.21 | 3.89 | 7816.38 | 0.32 | 2.07 | 13366.01 | 0.17 | 0.17 |
|  | 1987 | 9 |  | 47910 | 13707 | 4.68 | 4.14 | 3.89 | 7698.57 | 0.25 | 1.78 | 13164.56 | 0.04 | 0.04 |
|  | 1988 | 7 |  | 40710 | 8046 | 4.61 | 3.91 | 3.83 | 6740.60 | 0.08 | 1.19 | 11526.43 | -0.43 | 0.43 |
|  | 1988 | 8 |  | 46710 | 13056 | 4.67 | 4.12 | 3.88 | 7540.86 | 0.24 | 1.73 | 12894.87 | 0.01 | 0.01 |
|  | 1988 | 9 |  | 43560 | 14292 | 4.64 | 4.16 | 3.85 | 7123.25 | 0.30 | 2.01 | 12180.76 | 0.15 | 0.15 |
|  | 1989 | 7 |  | 38520 | 7314 | 4.59 | 3.86 | 3.81 | 6443.21 | 0.06 | 1.14 | 11017.89 | -0.51 | 0.51 |
|  | 1989 | 12 |  | 41430 | 15345 | 4.62 | 4.19 | 3.83 | 6837.72 | 0.35 | 2.24 | 11692.51 | 0.24 | 0.24 |
|  | 1984 | 9 |  | 87510 | 4332 | 4.94 | 3.64 | 4.10 | 12586.40 | -0.46 | 0.34 | 21522.75 | -3.97 | 3.97 |
|  | 1983 | 8 |  | 271050 | 47070 | 5.43 | 4.67 | 4.50 | 31662.91 | 0.17 | 1.49 | 54143.57 | -0.15 | 0.15 |
|  | 1987 | 5 |  | 65340 | 15297 | 4.82 | 4.18 | 4.00 | 9916.73 | 0.19 | 1.54 | 16957.61 | -0.11 | 0.11 |
|  | 1986 | 10 |  | 112230 | 17175 | 5.05 | 4.23 | 4.19 | 15419.54 | 0.05 | 1.11 | 26367.41 | -0.54 | 0.54 |
|  | 1984 | 7 |  | 57120 | 15882 | 4.76 | 4.20 | 3.95 | 8886.31 | 0.25 | 1.79 | 15195.60 | 0.04 | 0.04 |
|  | 1989 | 8 |  | 35070 | 15003 | 4.54 | 4.18 | 3.78 | 5968.29 | 0.40 | 2.51 | 10205.78 | 0.32 | 0.32 |
|  | 1981 | 9 |  | 35430 | 8310 | 4.55 | 3.92 | 3.78 | 6018.24 | 0.14 | 1.38 | 10291.19 | -0.24 | 0.24 |
|  | 1989 | 5 |  | 58470 | 13743 | 4.77 | 4.14 | 3.96 | 9057.32 | 0.18 | 1.52 | 15488.02 | -0.13 | 0.13 |
|  | 1984 | 5 |  | 97200 | 19104 | 4.99 | 4.28 | 4.14 | 13712.55 | 0.14 | 1.39 | 23448.46 | -0.23 | 0.23 |
|  | 1988 | 10 |  | 33810 | 4941 | 4.53 | 3.69 | 3.76 | 5792.73 | -0.07 | 0.85 | 9905.57 | -1.00 | 1.00 |
|  | 1983 | 6 |  | 782400 | 107430 | 5.89 | 5.03 | 4.88 | 75200.45 | 0.15 | 1.43 | 128592.76 | -0.20 | 0.20 |
|  | 1980 | 10 |  | 122160 | 24030 | 5.09 | 4.38 | 4.22 | 16524.05 | 0.16 | 1.45 | 28256.13 | -0.18 | 0.18 |
|  | 1980 | 11 |  | 98340 | 12438 | 4.99 | 4.09 | 4.14 | 13843.64 | -0.05 | 0.90 | 23672.63 | -0.90 | 0.90 |
|  | 1985 | 4 |  | 73980 | 21396 | 4.87 | 4.33 | 4.04 | 10974.37 | 0.29 | 1.95 | 18766.18 | 0.12 | 0.12 |
|  | 1984 | 6 |  | 68910 | 20748 | 4.84 | 4.32 | 4.02 | 10356.69 | 0.30 | 2.00 | 17709.93 | 0.15 | 0.15 |
|  | 1987 | 4 |  | 86010 | 13722 | 4.93 | 4.14 | 4.62 | 41597.41 | -0.48 | 0.33 | 17886.89 | -0.30 | 0.30 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/day) | Percent Deviation | Absolute Percent Deviation |
| Group 2 | 1986 | 11 | 0.2 - 0.69 | 84240 | 9411 | 4.93 | 3.97 | 4.61 | 40791.05 | -0.64 | 0.23 | 17540.15 | -0.86 | 0.86 |
| | 1988 | 3 | | 67230 | 13104 | 4.83 | 4.12 | 4.52 | 32987.53 | -0.40 | 0.40 | 14184.64 | -0.08 | 0.08 |
| | 1988 | 6 | | 51330 | 13500 | 4.71 | 4.13 | 4.41 | 25587.36 | -0.28 | 0.53 | 11002.56 | 0.18 | 0.18 |
| | 1985 | 6 | | 52440 | 21264 | 4.72 | 4.33 | 4.42 | 26107.93 | -0.09 | 0.81 | 11226.41 | 0.47 | 0.47 |
| | 1986 | 5 | | 262920 | 63000 | 5.42 | 4.80 | 5.08 | 119097.84 | -0.28 | 0.53 | 51212.07 | 0.19 | 0.19 |
| | 1988 | 2 | | 41670 | 5862 | 4.62 | 3.77 | 4.32 | 21027.31 | -0.55 | 0.28 | 9041.74 | -0.54 | 0.54 |
| | 1989 | 4 | | 57450 | 14634 | 4.76 | 4.17 | 4.45 | 28449.69 | -0.29 | 0.51 | 12233.37 | 0.16 | 0.16 |
| | 1982 | 6 | | 227520 | 46140 | 5.36 | 4.66 | 5.02 | 103939.39 | -0.35 | 0.44 | 44693.94 | 0.03 | 0.03 |
| | 1989 | 6 | | 47490 | 13353 | 4.68 | 4.13 | 4.38 | 23781.28 | -0.25 | 0.56 | 10225.95 | 0.23 | 0.23 |
| | 1984 | 1 | | 768900 | 79290 | 5.89 | 4.90 | 5.51 | 327069.32 | -0.62 | 0.24 | 140639.81 | -0.77 | 0.77 |
| | 1980 | 5 | | 297360 | 42870 | 5.47 | 4.63 | 5.13 | 133730.39 | -0.49 | 0.32 | 57504.07 | -0.34 | 0.34 |
| | 1988 | 5 | | 53430 | 8526 | 4.73 | 3.93 | 4.42 | 26571.67 | -0.49 | 0.32 | 11425.82 | -0.34 | 0.34 |
| | 1985 | 9 | | 57750 | 14112 | 4.76 | 4.15 | 4.46 | 28589.53 | -0.31 | 0.49 | 12293.50 | 0.13 | 0.13 |
| Group 3 | 1980 | 7 | 0.7 - 1.3 | 101520 | 25392 | 5.01 | 4.40 | 4.96 | 90846.15 | -0.55 | 0.28 | 16352.31 | 0.36 | 0.36 |
| | 1987 | 10 | | 41100 | 5757 | 4.61 | 3.76 | 4.56 | 36559.89 | -0.80 | 0.16 | 6580.78 | -0.14 | 0.14 |
| | 1984 | 4 | | 128550 | 19785 | 5.11 | 4.30 | 5.06 | 115213.57 | -0.77 | 0.17 | 20738.44 | -0.05 | 0.05 |
| | 1983 | 10 | | 399600 | 47940 | 5.60 | 4.68 | 5.56 | 360834.35 | -0.88 | 0.13 | 64950.18 | -0.35 | 0.35 |
| | 1989 | 1 | | 37650 | 3717 | 4.58 | 3.57 | 4.52 | 33471.62 | -0.95 | 0.11 | 6024.89 | -0.62 | 0.62 |
| | 1981 | 5 | | 59010 | 15411 | 4.77 | 4.19 | 4.72 | 52616.92 | -0.53 | 0.29 | 9471.04 | 0.39 | 0.39 |
| | 1986 | 12 | | 111180 | 15477 | 5.05 | 4.19 | 5.00 | 99550.19 | -0.81 | 0.16 | 17919.03 | -0.16 | 0.16 |
| | 1985 | 1 | | 121950 | 13446 | 5.09 | 4.13 | 5.04 | 109260.27 | -0.91 | 0.12 | 19666.85 | -0.46 | 0.46 |
| | 1985 | 10 | | 62160 | 12102 | 4.79 | 4.08 | 4.74 | 55444.68 | -0.66 | 0.22 | 9980.04 | 0.18 | 0.18 |
| | 1981 | 2 | | 86370 | 14724 | 4.94 | 4.17 | 4.89 | 77206.63 | -0.72 | 0.19 | 13897.19 | 0.06 | 0.06 |
| | 1983 | 5 | | 953100 | 78180 | 5.98 | 4.89 | 5.94 | 865590.44 | -1.04 | 0.09 | 155806.28 | -0.99 | 0.99 |
| | 1986 | 9 | | 125430 | 23838 | 5.10 | 4.38 | 5.05 | 112399.02 | -0.67 | 0.21 | 20231.82 | 0.15 | 0.15 |
| | 1981 | 4 | | 75960 | 15453 | 4.88 | 4.19 | 4.83 | 67843.54 | -0.64 | 0.23 | 12211.84 | 0.21 | 0.21 |
| Group 4 | 1980 | 4 | 1.4 - 2.5 | 307500 | 47700 | 5.49 | 4.68 | 5.97 | 930952.29 | -1.29 | 0.05 | 55857.14 | -0.17 | 0.17 |
| | 1983 | 9 | | 339300 | 48480 | 5.53 | 4.69 | 6.02 | 1039060.79 | -1.33 | 0.05 | 62343.65 | -0.29 | 0.29 |
| | 1985 | 2 | | 97230 | 16899 | 4.99 | 4.23 | 5.41 | 257440.80 | -1.18 | 0.07 | 15446.45 | 0.09 | 0.09 |
| | 1989 | 2 | | 37020 | 5022 | 4.57 | 3.70 | 4.94 | 87599.08 | -1.24 | 0.06 | 5255.94 | -0.05 | 0.05 |
| | 1981 | 10 | | 41580 | 7539 | 4.62 | 3.88 | 5.00 | 99728.61 | -1.12 | 0.08 | 5983.72 | 0.21 | 0.21 |
| | 1980 | 3 | | 759000 | 80610 | 5.88 | 4.91 | 6.41 | 2552695.74 | -1.50 | 0.03 | 153161.74 | -0.90 | 0.90 |
| | 1984 | 3 | | 225060 | 27693 | 5.35 | 4.44 | 5.82 | 657056.89 | -1.38 | 0.04 | 39423.41 | -0.42 | 0.42 |
| | 1980 | 12 | | 88470 | 11877 | 4.95 | 4.07 | 5.36 | 231686.23 | -1.29 | 0.05 | 13901.17 | -0.17 | 0.17 |
| | 1989 | 11 | | 42120 | 6735 | 4.62 | 3.83 | 5.01 | 101175.64 | -1.18 | 0.07 | 6070.54 | 0.10 | 0.10 |
| | 1989 | 10 | | 42030 | 8499 | 4.62 | 3.93 | 5.00 | 100934.31 | -1.07 | 0.08 | 6056.06 | 0.29 | 0.29 |
| | 1986 | 4 | | 587700 | 94830 | 5.77 | 4.98 | 6.28 | 1918591.64 | -1.31 | 0.05 | 115115.50 | -0.21 | 0.21 |
| | 1984 | 2 | | 324900 | 36930 | 5.51 | 4.57 | 6.00 | 989952.85 | -1.43 | 0.04 | 59397.17 | -0.61 | 0.61 |
| | 1989 | 9 | | 40590 | 10035 | 4.61 | 4.00 | 4.99 | 97081.43 | -0.99 | 0.10 | 5824.89 | 0.42 | 0.42 |
| | 1987 | 11 | | 46440 | 5688 | 4.67 | 3.75 | 5.05 | 112827.66 | -1.30 | 0.05 | 6769.66 | -0.19 | 0.19 |
| | 1984 | 12 | | 143130 | 30720 | 5.16 | 4.49 | 5.60 | 396419.36 | -1.11 | 0.08 | 23785.16 | 0.23 | 0.23 |
| | 1982 | 9 | | 183870 | 31440 | 5.26 | 4.50 | 5.72 | 524320.79 | -1.22 | 0.06 | 31459.25 | 0.00 | 0.00 |

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/day) | Percent Deviation | Absolute Percent Deviation |
|  | 1988 | 11 |  | 38220 | 4134 | 4.58 | 3.62 | 4.96 | 90775.04 | -1.34 | 0.05 | 5446.50 | -0.32 | 0.32 |
|  | 1984 | 10 |  | 114420 | 29250 | 5.06 | 4.47 | 5.49 | 308751.24 | -1.02 | 0.09 | 18525.07 | 0.37 | 0.37 |
| Group 5 | 1982 | 10 | 2.6 - 4.5 | 245370 | 33150 | 5.39 | 4.52 | 6.25 | 1761896.89 | -1.73 | 0.02 | 52856.91 | -0.59 | 0.59 |
|  | 1986 | 1 |  | 61800 | 11424 | 4.79 | 4.06 | 5.53 | 337225.07 | -1.47 | 0.03 | 10116.75 | 0.11 | 0.11 |
|  | 1988 | 12 |  | 41160 | 4056 | 4.61 | 3.61 | 5.32 | 207139.53 | -1.71 | 0.02 | 6214.19 | -0.53 | 0.53 |
|  | 1987 | 1 |  | 69150 | 6564 | 4.84 | 3.82 | 5.59 | 385869.44 | -1.77 | 0.02 | 11576.08 | -0.76 | 0.76 |
|  | 1985 | 3 |  | 82080 | 21753 | 4.91 | 4.34 | 5.68 | 473922.77 | -1.34 | 0.05 | 14217.68 | 0.35 | 0.35 |
|  | 1981 | 12 |  | 55560 | 7803 | 4.74 | 3.89 | 5.47 | 296817.82 | -1.58 | 0.03 | 8904.53 | -0.14 | 0.14 |
|  | 1985 | 12 |  | 66150 | 9141 | 4.82 | 3.96 | 5.56 | 365883.57 | -1.60 | 0.02 | 10976.51 | -0.20 | 0.20 |
|  | 1987 | 12 |  | 38340 | 3126 | 4.58 | 3.49 | 5.28 | 190240.43 | -1.78 | 0.02 | 5707.21 | -0.83 | 0.83 |
|  | 1983 | 4 |  | 1093500 | 75330 | 6.04 | 4.88 | 7.02 | 10572877.00 | -2.15 | 0.01 | 317186.31 | -3.21 | 3.21 |
|  | 1988 | 4 |  | 64380 | 13971 | 4.81 | 4.15 | 5.55 | 354175.78 | -1.40 | 0.04 | 10625.27 | 0.24 | 0.24 |
|  | 1982 | 2 |  | 199350 | 63510 | 5.30 | 4.80 | 6.14 | 1373458.07 | -1.33 | 0.05 | 41203.74 | 0.35 | 0.35 |
|  | 1982 | 4 |  | 688800 | 150810 | 5.84 | 5.18 | 6.78 | 6074395.35 | -1.61 | 0.02 | 182231.86 | -0.21 | 0.21 |
|  | 1985 | 11 |  | 57870 | 7971 | 4.76 | 3.90 | 5.49 | 311676.13 | -1.59 | 0.03 | 9350.28 | -0.17 | 0.17 |
|  | 1981 | 3 |  | 93660 | 22794 | 4.97 | 4.36 | 5.74 | 555183.00 | -1.39 | 0.04 | 16655.49 | 0.27 | 0.27 |
|  | 1982 | 12 |  | 494700 | 66240 | 5.69 | 4.82 | 6.61 | 4084425.29 | -1.79 | 0.02 | 122532.76 | -0.85 | 0.85 |
|  | 1983 | 2 |  | 948000 | 132180 | 5.98 | 5.12 | 6.95 | 8909153.66 | -1.83 | 0.01 | 267274.61 | -1.02 | 1.02 |
|  | 1987 | 3 |  | 102450 | 23199 | 5.01 | 4.37 | 5.79 | 618230.56 | -1.43 | 0.04 | 18546.92 | 0.20 | 0.20 |
|  | 1987 | 2 |  | 64080 | 10383 | 4.81 | 4.02 | 5.55 | 352197.71 | -1.53 | 0.03 | 10565.93 | -0.02 | 0.02 |
| Group 6 | 1986 | 3 | 4.7 - 8.7 | 751200 | 121740 | 5.88 | 5.09 | 6.45 | 2793385.63 | -1.36 | 0.04 | 195536.99 | -0.61 | 0.61 |
|  | 1980 | 2 |  | 563400 | 115860 | 5.75 | 5.06 | 6.31 | 2022668.19 | -1.24 | 0.06 | 141586.77 | -0.22 | 0.22 |
|  | 1989 | 3 |  | 60690 | 11094 | 4.78 | 4.05 | 5.22 | 165948.00 | -1.17 | 0.07 | 11616.36 | -0.05 | 0.05 |
|  | 1981 | 11 |  | 46920 | 7788 | 4.67 | 3.89 | 5.09 | 124324.27 | -1.20 | 0.06 | 8702.70 | -0.12 | 0.12 |
|  | 1981 | 1 |  | 97530 | 22062 | 4.99 | 4.34 | 5.45 | 282597.88 | -1.11 | 0.08 | 19781.85 | 0.10 | 0.10 |
|  | 1982 | 1 |  | 116670 | 39990 | 5.07 | 4.60 | 5.54 | 345541.01 | -0.94 | 0.12 | 24187.87 | 0.40 | 0.40 |
|  | 1983 | 12 |  | 573900 | 99960 | 5.76 | 5.00 | 6.31 | 2065018.73 | -1.32 | 0.05 | 144551.31 | -0.45 | 0.45 |
|  | 1980 | 1 |  | 392100 | 151020 | 5.59 | 5.18 | 6.13 | 1346690.88 | -0.95 | 0.11 | 94268.36 | 0.38 | 0.38 |
|  | 1984 | 11 |  | 84660 | 18447 | 4.93 | 4.27 | 5.38 | 241100.73 | -1.12 | 0.08 | 16877.05 | 0.09 | 0.09 |
|  | 1983 | 11 |  | 320400 | 60480 | 5.51 | 4.78 | 6.03 | 1073608.93 | -1.25 | 0.06 | 75152.63 | -0.24 | 0.24 |
|  | 1982 | 3 |  | 301800 | 79830 | 5.48 | 4.90 | 6.00 | 1003919.55 | -1.10 | 0.08 | 70274.37 | 0.12 | 0.12 |
|  | 1982 | 11 |  | 209220 | 21351 | 5.32 | 4.33 | 5.82 | 665485.95 | -1.49 | 0.03 | 46584.02 | -1.18 | 1.18 |
|  | 1983 | 1 |  | 572100 | 122550 | 5.76 | 5.09 | 6.31 | 2057751.86 | -1.23 | 0.06 | 144042.63 | -0.18 | 0.18 |
|  | 1983 | 3 |  | 1201200 | 163650 | 6.08 | 5.21 | 6.67 | 4730448.29 | -1.46 | 0.03 | 331131.38 | -1.02 | 1.02 |
|  | 1986 | 2 |  | 262320 | 128610 | 5.42 | 5.11 | 5.93 | 857769.47 | -0.82 | 0.15 | 60043.86 | 0.53 | 0.53 |

(Column 11) Residual = [log observed suspended sediment load (column 8)] - [log predicted suspended sediment load (column 9)]
(Column 12) Power Residual = 10^Residual
(Column 13) Corrected Predicted Suspended Sediment Load using the Smearing estimator method (Mean of column 12 for each group multiplied by (Column 10)
(Column 14) Percent Deviation = [(observed sediment - corrected sediment )]/(observed sediment) * 100%

Appendix A

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/day) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/day) | Percent Deviation | Absolute Percent Deviation |
| Group 1 | 1984 | 2 | 0 - 0.19 | 1170 | 145860 | 3.07 | 5.16 | 2.21 | 163.28 | 2.95 | 893.32 | 148958.58 | -0.02 | 0.02 |
| | 1988 | 3 | | 324 | 28947 | 2.51 | 4.46 | 1.89 | 77.69 | 2.57 | 372.58 | 70880.38 | -1.45 | 1.45 |
| | 1991 | 4 | | 125.7 | 24981 | 2.10 | 4.40 | 1.65 | 44.93 | 2.75 | 555.99 | 40990.42 | -0.64 | 0.64 |
| | 1991 | 2 | | 1872 | 333900 | 3.27 | 5.52 | 2.33 | 214.28 | 3.19 | 1558.21 | 195491.78 | 0.41 | 0.41 |
| | 1984 | 5 | | 1833 | 524400 | 3.26 | 5.72 | 2.33 | 211.69 | 3.39 | 2477.20 | 193125.66 | 0.63 | 0.63 |
| | 1988 | 10 | | 561 | 167160 | 2.75 | 5.22 | 2.03 | 106.73 | 3.19 | 1566.19 | 97370.39 | 0.42 | 0.42 |
| | 1989 | 2 | | 270.6 | 36690 | 2.43 | 4.56 | 1.85 | 70.01 | 2.72 | 524.08 | 63868.28 | -0.74 | 0.74 |
| | 1991 | 3 | | 158.4 | 20934 | 2.20 | 4.32 | 1.71 | 51.36 | 2.61 | 407.59 | 46856.00 | -1.24 | 1.24 |
| | 1983 | 4 | | 1866 | 202350 | 3.27 | 5.31 | 2.33 | 213.89 | 2.98 | 946.06 | 195129.13 | 0.04 | 0.04 |
| | 1990 | 2 | | 303 | 8727 | 2.48 | 3.94 | 1.87 | 74.74 | 2.07 | 116.76 | 68185.69 | -6.81 | 6.81 |
| | 1983 | 5 | | 2532 | 397800 | 3.40 | 5.60 | 2.41 | 255.18 | 3.19 | 1558.88 | 232803.88 | 0.41 | 0.41 |
| | 1988 | 5 | | 275.7 | 45300 | 2.44 | 4.66 | 1.85 | 70.77 | 2.81 | 640.12 | 64561.77 | -0.43 | 0.43 |
| | 1986 | 4 | | 271.5 | 30960 | 2.43 | 4.49 | 1.85 | 70.14 | 2.64 | 441.39 | 63991.06 | -1.07 | 1.07 |
| | 1984 | 3 | | 315 | 65370 | 2.50 | 4.82 | 1.88 | 76.44 | 2.93 | 855.20 | 69734.81 | -0.07 | 0.07 |
| | 1985 | 6 | | 153.3 | 38850 | 2.19 | 4.59 | 1.70 | 50.40 | 2.89 | 770.88 | 45977.40 | -0.18 | 0.18 |
| Group 2 | 1984 | 4 | 0.2 - 0.52 | 268.8 | 54750 | 2.43 | 4.74 | 2.12 | 131.17 | 2.62 | 417.40 | 63341.96 | -0.16 | 0.16 |
| | 1985 | 5 | | 3780 | 802200 | 3.58 | 5.90 | 2.94 | 872.04 | 2.96 | 919.91 | 421107.64 | 0.48 | 0.48 |
| | 1982 | 2 | | 148.8 | 29535 | 2.17 | 4.47 | 1.93 | 85.86 | 2.54 | 343.99 | 41461.95 | -0.40 | 0.40 |
| | 1983 | 3 | | 585 | 83310 | 2.77 | 4.92 | 2.36 | 229.01 | 2.56 | 363.79 | 110587.59 | -0.33 | 0.33 |
| | 1985 | 2 | | 2265 | 523500 | 3.36 | 5.72 | 2.78 | 604.15 | 2.94 | 866.50 | 291745.64 | 0.44 | 0.44 |
| | 1990 | 10 | | 723 | 60690 | 2.86 | 4.78 | 2.43 | 266.54 | 2.36 | 227.69 | 128712.58 | -1.12 | 1.12 |
| | 1991 | 6 | | 1737 | 439500 | 3.24 | 5.64 | 2.70 | 499.51 | 2.94 | 879.86 | 241214.30 | 0.45 | 0.45 |
| | 1989 | 9 | | 161.1 | 41370 | 2.21 | 4.62 | 1.96 | 90.89 | 2.66 | 455.17 | 43890.16 | -0.06 | 0.06 |
| | 1982 | 5 | | 387 | 97920 | 2.59 | 4.99 | 2.23 | 170.32 | 2.76 | 574.93 | 82246.26 | 0.16 | 0.16 |
| | 1988 | 12 | | 83.1 | 7170 | 1.92 | 3.86 | 1.75 | 56.56 | 2.10 | 126.77 | 27311.69 | -2.81 | 2.81 |
| | 1987 | 3 | | 2178 | 248760 | 3.34 | 5.40 | 2.77 | 587.43 | 2.63 | 423.47 | 283670.89 | -0.14 | 0.14 |
| | 1990 | 3 | | 112.5 | 798 | 2.05 | 2.90 | 1.85 | 70.27 | 1.06 | 11.36 | 33932.70 | -41.52 | 41.52 |
| | 1990 | 5 | | 228 | 36690 | 2.36 | 4.56 | 2.07 | 116.57 | 2.50 | 314.74 | 56293.55 | -0.53 | 0.53 |
| | 1983 | 8 | | 939 | 411600 | 2.97 | 5.61 | 2.51 | 321.45 | 3.11 | 1280.44 | 155229.64 | 0.62 | 0.62 |
| | 1988 | 2 | | 254.1 | 21552 | 2.41 | 4.33 | 2.10 | 125.99 | 2.23 | 171.06 | 60839.95 | -1.82 | 1.82 |
| | 1982 | 3 | | 211.8 | 45180 | 2.33 | 4.65 | 2.04 | 110.58 | 2.61 | 408.58 | 53397.51 | -0.18 | 0.18 |
| | 1983 | 6 | | 1416 | 431400 | 3.15 | 5.63 | 2.63 | 431.48 | 3.00 | 999.82 | 208360.04 | 0.52 | 0.52 |
| | 1987 | 2 | | 2148 | 159390 | 3.33 | 5.20 | 2.76 | 581.62 | 2.44 | 274.04 | 280865.41 | -0.76 | 0.76 |
| | 1983 | 2 | | 567 | 91950 | 2.75 | 4.96 | 2.35 | 223.94 | 2.61 | 410.61 | 108138.44 | -0.18 | 0.18 |
| | 1987 | 11 | | 57.3 | 9255 | 1.76 | 3.97 | 1.64 | 43.33 | 2.33 | 213.59 | 20924.55 | -1.26 | 1.26 |
| | 1985 | 3 | | 3036 | 579300 | 3.48 | 5.76 | 2.87 | 745.29 | 2.89 | 777.29 | 359898.42 | 0.38 | 0.38 |
| | 1989 | 3 | | 81.3 | 10917 | 1.91 | 4.04 | 1.75 | 55.68 | 2.29 | 196.08 | 26886.44 | -1.46 | 1.46 |
| | 1989 | 8 | | 1872 | 327300 | 3.27 | 5.51 | 2.72 | 527.04 | 2.79 | 621.02 | 254505.32 | 0.22 | 0.22 |
| | 1982 | 7 | | 342 | 104550 | 2.53 | 5.02 | 2.19 | 155.88 | 2.83 | 670.71 | 75274.11 | 0.28 | 0.28 |
| | 1988 | 6 | | 37.5 | 3954 | 1.57 | 3.60 | 1.50 | 31.98 | 2.09 | 123.65 | 15442.35 | -2.91 | 2.91 |
| | 1983 | 7 | | 474 | 177510 | 2.68 | 5.25 | 2.91 | 803.57 | 2.34 | 220.90 | 87083.38 | 0.51 | 0.51 |
| | 1987 | 4 | | 2796 | 368400 | 3.45 | 5.57 | 3.67 | 4692.36 | 1.89 | 78.51 | 508511.47 | -0.38 | 0.38 |
| | 1989 | 1 | | 39.9 | 3579 | 1.60 | 3.55 | 1.84 | 68.60 | 1.72 | 52.17 | 7434.58 | -1.08 | 1.08 |
| | 1986 | 12 | | 59.4 | 852 | 1.77 | 2.93 | 2.01 | 101.90 | 0.92 | 8.36 | 11042.94 | -11.96 | 11.96 |
| | 1984 | 6 | | 296.7 | 65970 | 2.47 | 4.82 | 2.70 | 504.34 | 2.12 | 130.80 | 54655.54 | 0.17 | 0.17 |

Appendix B

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/ day) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/day) | Percent Deviation | Absolute Percent Deviation |
| Group 3 | 1985 | 8 | 0.55 -1.28 | 1206 | 340200 | 3.08 | 5.53 | 3.31 | 2033.68 | 2.22 | 167.28 | 220390.30 | 0.35 | 0.35 |
| | 1990 | 12 | | 48.3 | 260.1 | 1.68 | 2.42 | 1.92 | 82.96 | 0.50 | 3.14 | 8989.95 | -33.56 | 33.56 |
| | 1991 | 5 | | 1665 | 338100 | 3.22 | 5.53 | 3.45 | 2802.54 | 2.08 | 120.64 | 303711.35 | 0.10 | 0.10 |
| | 1986 | 9 | | 1650 | 348600 | 3.22 | 5.54 | 3.44 | 2777.44 | 2.10 | 125.51 | 300990.74 | 0.14 | 0.14 |
| | 1985 | 1 | | 384 | 9603 | 2.58 | 3.98 | 2.81 | 651.78 | 1.17 | 14.73 | 70633.28 | -6.36 | 6.36 |
| | 1990 | 11 | | 271.2 | 45060 | 2.43 | 4.65 | 2.66 | 461.23 | 1.99 | 97.69 | 49983.74 | -0.11 | 0.11 |
| | 1984 | 9 | | 672 | 202680 | 2.83 | 5.31 | 3.06 | 1136.98 | 2.25 | 178.26 | 123214.59 | 0.39 | 0.39 |
| | 1982 | 9 | | 5829 | 1626900 | 3.77 | 6.21 | 3.99 | 9741.59 | 2.22 | 167.01 | 1055696.35 | 0.35 | 0.35 |
| | 1987 | 5 | | 1230 | 238410 | 3.09 | 5.38 | 3.32 | 2073.92 | 2.06 | 114.96 | 224750.93 | 0.06 | 0.06 |
| | 1991 | 11 | | 663 | 99390 | 2.82 | 5.00 | 3.05 | 1121.84 | 1.95 | 88.60 | 121573.73 | -0.22 | 0.22 |
| | 1988 | 4 | | 227.1 | 41400 | 2.36 | 4.62 | 2.59 | 386.62 | 2.03 | 107.08 | 41898.22 | -0.01 | 0.01 |
| | 1986 | 5 | | 188.4 | 21972 | 2.28 | 4.34 | 2.51 | 321.08 | 1.84 | 68.43 | 34795.40 | -0.58 | 0.58 |
| | 1990 | 7 | | 1383 | 268950 | 3.14 | 5.43 | 3.37 | 2330.34 | 2.06 | 115.41 | 252538.94 | 0.06 | 0.06 |
| | 1983 | 10 | | 1635 | 537300 | 3.21 | 5.73 | 3.44 | 2752.33 | 2.29 | 195.22 | 298269.99 | 0.44 | 0.44 |
| | 1985 | 9 | | 1233 | 218160 | 3.09 | 5.34 | 3.32 | 2078.95 | 2.02 | 104.94 | 225295.98 | -0.03 | 0.03 |
| | 1991 | 9 | | 2616 | 474300 | 3.42 | 5.68 | 3.64 | 4391.95 | 2.03 | 107.99 | 475955.18 | 0.00 | 0.00 |
| | 1990 | 8 | | 2517 | 494700 | 3.40 | 5.69 | 3.63 | 4226.67 | 2.07 | 117.04 | 458043.83 | 0.07 | 0.07 |
| Group 4 | 1985 | 4 | 1.3 - 1.98 | 2691 | 583800 | 3.43 | 5.77 | 2.21 | 160.70 | 3.56 | 3632.78 | 533578.17 | 0.09 | 0.09 |
| | 1983 | 9 | | 134.4 | 50400 | 2.13 | 4.70 | 1.56 | 35.94 | 3.15 | 1402.50 | 119316.67 | -1.37 | 1.37 |
| | 1989 | 10 | | 118.8 | 20460 | 2.07 | 4.31 | 1.53 | 33.79 | 2.78 | 605.56 | 112181.29 | -4.48 | 4.48 |
| | 1986 | 11 | | 3006 | 363900 | 3.48 | 5.56 | 2.23 | 169.84 | 3.33 | 2142.54 | 563931.14 | -0.55 | 0.55 |
| | 1988 | 7 | | 1302 | 465600 | 3.11 | 5.67 | 2.05 | 111.80 | 3.62 | 4164.63 | 371201.53 | 0.20 | 0.20 |
| | 1991 | 8 | | 5247 | 690300 | 3.72 | 5.84 | 2.35 | 224.37 | 3.49 | 3076.61 | 744969.91 | -0.08 | 0.08 |
| | 1990 | 4 | | 239.1 | 56400 | 2.38 | 4.75 | 1.68 | 47.93 | 3.07 | 1176.82 | 159126.04 | -1.82 | 1.82 |
| | 1986 | 10 | | 4977 | 692100 | 3.70 | 5.84 | 2.34 | 218.52 | 3.50 | 3167.16 | 725557.12 | -0.05 | 0.05 |
| | 1990 | 9 | | 5124 | 915000 | 3.71 | 5.96 | 2.35 | 221.73 | 3.62 | 4126.72 | 736189.85 | 0.20 | 0.20 |
| | 1986 | 7 | | 5046 | 1224000 | 3.70 | 6.09 | 2.34 | 220.03 | 3.75 | 5562.81 | 730567.28 | 0.40 | 0.40 |
| | 1982 | 8 | | 6939 | 1926000 | 3.84 | 6.28 | 2.41 | 258.01 | 3.87 | 7464.87 | 856657.79 | 0.56 | 0.56 |
| Group 5 | 1991 | 7 | 2.0 - 3.4 | 7674 | 993300 | 3.89 | 6.00 | 2.52 | 334.07 | 3.47 | 2973.34 | 656552.51 | 0.34 | 0.34 |
| | 1984 | 10 | | 1860 | 232080 | 3.27 | 5.37 | 2.20 | 157.33 | 3.17 | 1475.10 | 309207.21 | -0.33 | 0.33 |
| | 1984 | 12 | | 798 | 37890 | 2.90 | 4.58 | 2.00 | 100.36 | 2.58 | 377.54 | 197238.42 | -4.21 | 4.21 |
| | 1986 | 6 | | 348 | 77850 | 2.54 | 4.89 | 1.81 | 64.58 | 3.08 | 1205.57 | 126910.76 | -0.63 | 0.63 |
| | 1984 | 7 | | 354 | 143040 | 2.55 | 5.16 | 1.81 | 65.16 | 3.34 | 2195.07 | 128068.65 | 0.10 | 0.10 |
| | 1991 | 12 | | 651 | 24042 | 2.81 | 4.38 | 1.95 | 90.07 | 2.43 | 266.93 | 177016.18 | -6.36 | 6.36 |
| | 1987 | 8 | | 444 | 142890 | 2.65 | 5.16 | 1.87 | 73.50 | 3.29 | 1944.12 | 144448.14 | -0.01 | 0.01 |
| | 1988 | 9 | | 6633 | 593700 | 3.82 | 5.77 | 2.49 | 309.17 | 3.28 | 1920.30 | 607619.79 | -0.02 | 0.02 |
| | 1985 | 10 | | 735 | 98640 | 2.87 | 4.99 | 1.98 | 96.07 | 3.01 | 1026.76 | 188806.03 | -0.91 | 0.91 |
| | 1984 | 8 | | 3582 | 872100 | 3.55 | 5.94 | 2.35 | 222.86 | 3.59 | 3913.23 | 437990.12 | 0.50 | 0.50 |
| | 1988 | 8 | | 13464 | 1945800 | 4.13 | 6.29 | 2.65 | 450.35 | 3.64 | 4320.60 | 885090.31 | 0.55 | 0.55 |

(Column 11) Residual = [log observed suspended sediment load (column 8)] - [log predicted suspended sediment load (column 9)]

(Column 12) Power Residual = 10^Residual

(Column 13) Corrected Predicted Suspended Sediment Load using the Smearing estimator method (Mean of column 12 for each group multiplied by (Column 10)

(Column 14) Percent Deviation = [(observed sediment - corrected sediment )]/(observed sediment) * 100%

Appendix B

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/day) | Percent Deviation | Absolute Percent Deviation |
| Group 1 | 1948 | 2 | 0 - 0.25 | 6660 | 23724 | 3.82 | 4.38 | 3.93 | 8574.68 | 0.44 | 2.77 | 330982.62 | -12.95 | 12.95 |
| | 1948 | 3 | | 25866 | 992400 | 4.41 | 6.00 | 4.52 | 33184.93 | 1.48 | 29.91 | 1280938.19 | -0.29 | 0.29 |
| | 1948 | 4 | | 7497 | 116340 | 3.87 | 5.07 | 3.98 | 9649.34 | 1.08 | 12.06 | 372464.43 | -2.20 | 2.20 |
| | 1948 | 5 | | 15906 | 893100 | 4.20 | 5.95 | 4.31 | 20432.50 | 1.64 | 43.71 | 788694.69 | 0.12 | 0.12 |
| | 1948 | 6 | | 39300 | 5859000 | 4.59 | 6.77 | 4.70 | 50365.35 | 2.07 | 116.33 | 1944102.35 | 0.67 | 0.67 |
| | 1948 | 7 | | 11973 | 948000 | 4.08 | 5.98 | 4.19 | 15391.62 | 1.79 | 61.59 | 594116.55 | 0.37 | 0.37 |
| | 1952 | 1 | | 1053 | 876 | 3.02 | 2.94 | 3.13 | 1362.24 | -0.19 | 0.64 | 52582.60 | -59.03 | 59.03 |
| | 1950 | 8 | | 241.2 | 24549 | 2.38 | 4.39 | 2.50 | 313.23 | 1.89 | 78.37 | 12090.80 | 0.51 | 0.51 |
| | 1952 | 12 | | 1437 | 1101 | 3.16 | 3.04 | 3.27 | 1857.51 | -0.23 | 0.59 | 71700.04 | -64.12 | 64.12 |
| | 1956 | 6 | | 7800 | 1027200 | 3.89 | 6.01 | 4.00 | 10038.29 | 2.01 | 102.33 | 387478.09 | 0.62 | 0.62 |
| | 1949 | 11 | | 2679 | 42270 | 3.43 | 4.63 | 3.54 | 3457.36 | 1.09 | 12.23 | 133454.12 | -2.16 | 2.16 |
| | 1956 | 9 | | 33 | 4596 | 1.52 | 3.66 | 1.63 | 43.08 | 2.03 | 106.69 | 1662.79 | 0.64 | 0.64 |
| | 1951 | 8 | | 2004 | 419100 | 3.30 | 5.62 | 3.41 | 2588.20 | 2.21 | 161.93 | 99904.44 | 0.76 | 0.76 |
| | 1957 | 2 | | 1248 | 2796 | 3.10 | 3.45 | 3.21 | 1613.80 | 0.24 | 1.73 | 62292.60 | -21.28 | 21.28 |
| | 1951 | 2 | | 2619 | 3942 | 3.42 | 3.60 | 3.53 | 3380.13 | 0.07 | 1.17 | 130472.91 | -32.10 | 32.10 |
| | 1953 | 10 | | 94.8 | 95.7 | 1.98 | 1.98 | 2.09 | 123.41 | -0.11 | 0.78 | 4763.66 | -48.78 | 48.78 |
| | 1951 | 11 | | 3120 | 30510 | 3.49 | 4.48 | 3.60 | 4024.89 | 0.88 | 7.58 | 155360.92 | -4.09 | 4.09 |
| | 1952 | 4 | | 11322 | 390300 | 4.05 | 5.59 | 4.16 | 14556.86 | 1.43 | 26.81 | 561894.71 | -0.44 | 0.44 |
| | 1948 | 8 | | 2214 | 157230 | 3.35 | 5.20 | 3.46 | 2858.68 | 1.74 | 55.00 | 110344.87 | 0.30 | 0.30 |
| | 1952 | 9 | | 79.8 | 31.5 | 1.90 | 1.50 | 2.02 | 103.93 | -0.52 | 0.30 | 4011.71 | -126.36 | 126.36 |
| | 1953 | 3 | | 9048 | 248040 | 3.96 | 5.39 | 4.07 | 11639.93 | 1.33 | 21.31 | 449301.17 | -0.81 | 0.81 |
| | 1954 | 11 | | 1800 | 12735 | 3.26 | 4.10 | 3.37 | 2325.38 | 0.74 | 5.48 | 89759.58 | -6.05 | 6.05 |
| Group 2 | 1950 | 12 | 0.26 - 0.46 | 1164 | 3060 | 3.07 | 3.49 | 5.04 | 110012.64 | -1.56 | 0.03 | 9901.14 | -2.24 | 2.24 |
| | 1951 | 1 | | 1893 | 2106 | 3.28 | 3.32 | 5.41 | 257679.99 | -2.09 | 0.01 | 23191.20 | -10.01 | 10.01 |
| | 1955 | 7 | | 4503 | 410700 | 3.65 | 5.61 | 6.07 | 1174277.67 | -0.46 | 0.35 | 105684.99 | 0.74 | 0.74 |
| | 1954 | 8 | | 4074 | 863100 | 3.61 | 5.94 | 5.99 | 985531.46 | -0.06 | 0.88 | 88697.83 | 0.90 | 0.90 |
| | 1949 | 2 | | 2319 | 3993 | 3.37 | 3.60 | 5.57 | 367587.78 | -1.96 | 0.01 | 33082.90 | -7.29 | 7.29 |
| | 1950 | 2 | | 1896 | 4689 | 3.28 | 3.67 | 5.41 | 258395.14 | -1.74 | 0.02 | 23255.56 | -3.96 | 3.96 |
| | 1954 | 4 | | 8256 | 297270 | 3.92 | 5.47 | 6.53 | 3392672.94 | -1.06 | 0.09 | 305340.56 | -0.03 | 0.03 |
| | 1954 | 12 | | 1017 | 1185 | 3.01 | 3.07 | 4.94 | 86861.00 | -1.87 | 0.01 | 7817.49 | -5.60 | 5.60 |
| | 1950 | 11 | | 3285 | 28881 | 3.52 | 4.46 | 5.83 | 676163.78 | -1.37 | 0.04 | 60854.74 | -1.11 | 1.11 |
| | 1954 | 2 | | 6447 | 50700 | 3.81 | 4.71 | 6.34 | 2200642.46 | -1.64 | 0.02 | 198057.82 | -2.91 | 2.91 |
| | 1948 | 12 | | 2547 | 3936 | 3.41 | 3.60 | 5.64 | 433155.22 | -2.04 | 0.01 | 38983.97 | -8.90 | 8.90 |
| | 1957 | 1 | | 1686 | 3387 | 3.23 | 3.53 | 5.32 | 210405.85 | -1.79 | 0.02 | 18936.53 | -4.59 | 4.59 |
| | 1951 | 12 | | 2241 | 11046 | 3.35 | 4.04 | 5.54 | 346222.30 | -1.50 | 0.03 | 31160.01 | -1.82 | 1.82 |
| | 1951 | 3 | | 7206 | 90990 | 3.86 | 4.96 | 6.43 | 2673918.61 | -1.47 | 0.03 | 240652.67 | -1.64 | 1.64 |
| | 1954 | 1 | | 1674 | 2157 | 3.22 | 3.33 | 5.32 | 207791.84 | -1.98 | 0.01 | 18701.27 | -7.67 | 7.67 |
| | 1956 | 1 | | 2823 | 6543 | 3.45 | 3.82 | 5.71 | 518615.95 | -1.90 | 0.01 | 46675.44 | -6.13 | 6.13 |
| | 1956 | 2 | | 3753 | 5190 | 3.57 | 3.72 | 5.93 | 853668.11 | -2.22 | 0.01 | 76830.13 | -13.80 | 13.80 |
| | 1952 | 10 | | 765 | 564 | 2.88 | 2.75 | 4.72 | 52771.07 | -1.97 | 0.01 | 4749.40 | -7.42 | 7.42 |
| | 1955 | 10 | | 717 | 6303 | 2.86 | 3.80 | 4.67 | 47113.06 | -0.87 | 0.13 | 4240.18 | 0.33 | 0.33 |
| | 1949 | 12 | | 690 | 1515 | 2.84 | 3.18 | 4.64 | 44051.97 | -1.46 | 0.03 | 3964.68 | -1.62 | 1.62 |
| | 1952 | 11 | | 1989 | 7581 | 3.30 | 3.88 | 3.07 | 1171.13 | 0.81 | 6.47 | 100904.22 | -12.31 | 12.31 |

Appendix C

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/day) | Percent Deviation | Absolute Percent Deviation |
| Group 3 | 1952 | 7 | 0.55 - 0.78 | 5418 | 824100 | 3.73 | 5.92 | 3.45 | 2794.59 | 2.47 | 294.89 | 240781.47 | 0.71 | 0.71 |
| | 1956 | 12 | | 2160 | 4200 | 3.33 | 3.62 | 3.10 | 1258.03 | 0.52 | 3.34 | 108391.84 | -24.81 | 24.81 |
| | 1955 | 1 | | 1059 | 1206 | 3.02 | 3.08 | 2.83 | 677.68 | 0.25 | 1.78 | 58389.05 | -47.42 | 47.42 |
| | 1952 | 8 | | 1116 | 11925 | 3.05 | 4.08 | 2.85 | 709.23 | 1.23 | 16.81 | 61107.14 | -4.12 | 4.12 |
| | 1954 | 6 | | 918 | 18009 | 2.96 | 4.26 | 2.78 | 598.65 | 1.48 | 30.08 | 51579.29 | -1.86 | 1.86 |
| | 1955 | 9 | | 287.4 | 10101 | 2.46 | 4.00 | 2.34 | 218.49 | 1.66 | 46.23 | 18825.43 | -0.86 | 0.86 |
| | 1949 | 9 | | 184.5 | 8685 | 2.27 | 3.94 | 2.17 | 148.72 | 1.77 | 58.40 | 12813.93 | -0.48 | 0.48 |
| | 1949 | 3 | | 26415 | 619800 | 4.42 | 5.79 | 4.04 | 11052.05 | 1.75 | 56.08 | 952244.20 | -0.54 | 0.54 |
| | 1954 | 5 | | 7950 | 208740 | 3.90 | 5.32 | 3.59 | 3898.05 | 1.73 | 53.55 | 335855.77 | -0.61 | 0.61 |
| | 1948 | 11 | | 3810 | 31230 | 3.58 | 4.49 | 3.31 | 2058.75 | 1.18 | 15.17 | 177381.77 | -4.68 | 4.68 |
| | 1953 | 11 | | 1470 | 10926 | 3.17 | 4.04 | 2.95 | 900.81 | 1.08 | 12.13 | 77613.79 | -6.10 | 6.10 |
| | 1956 | 3 | | 18219 | 570000 | 4.26 | 5.76 | 3.90 | 8006.22 | 1.85 | 71.19 | 689816.27 | -0.21 | 0.21 |
| | 1950 | 10 | | 3054 | 78390 | 3.48 | 4.89 | 3.23 | 1699.17 | 1.66 | 46.13 | 146400.32 | -0.87 | 0.87 |
| | 1953 | 12 | | 1689 | 5307 | 3.23 | 3.72 | 3.01 | 1016.20 | 0.72 | 5.22 | 87555.61 | -15.50 | 15.50 |
| | 1955 | 5 | | 14904 | 497400 | 4.17 | 5.70 | 3.83 | 6725.55 | 1.87 | 73.96 | 579473.69 | -0.17 | 0.17 |
| | 1949 | 6 | | 19995 | 2303400 | 4.30 | 6.36 | 3.94 | 8679.37 | 2.42 | 265.39 | 747814.49 | 0.68 | 0.68 |
| | 1956 | 7 | | 2946 | 583500 | 3.47 | 5.77 | 3.22 | 1646.89 | 2.55 | 354.30 | 141896.37 | 0.76 | 0.76 |
| | 1949 | 7 | | 3795 | 463500 | 3.58 | 5.67 | 3.31 | 2051.71 | 2.35 | 225.91 | 176775.51 | 0.62 | 0.62 |
| Group 4 | 1955 | 8 | 0.80 - 1.36 | 5772 | 1237500 | 3.76 | 6.09 | 3.57 | 3686.78 | 2.53 | 335.66 | 284251.03 | 0.77 | 0.77 |
| | 1950 | 7 | | 1905 | 77970 | 3.28 | 4.89 | 3.14 | 1366.69 | 1.76 | 57.05 | 105371.88 | -0.35 | 0.35 |
| | 1949 | 4 | | 9837 | 203790 | 3.99 | 5.31 | 3.77 | 5941.81 | 1.54 | 34.30 | 458113.82 | -1.25 | 1.25 |
| | 1951 | 10 | | 3510 | 41970 | 3.55 | 4.62 | 3.37 | 2361.93 | 1.25 | 17.77 | 182104.91 | -3.34 | 3.34 |
| | 1950 | 3 | | 6639 | 88770 | 3.82 | 4.95 | 3.62 | 4178.83 | 1.33 | 21.24 | 322187.76 | -2.63 | 2.63 |
| | 1957 | 3 | | 6726 | 73110 | 3.83 | 4.86 | 3.63 | 4227.82 | 1.24 | 17.29 | 325964.77 | -3.46 | 3.46 |
| | 1953 | 4 | | 5403 | 43740 | 3.73 | 4.64 | 3.54 | 3475.07 | 1.10 | 12.59 | 267927.66 | -5.13 | 5.13 |
| | 1955 | 3 | | 21462 | 879900 | 4.33 | 5.94 | 4.08 | 11945.92 | 1.87 | 73.66 | 921030.22 | -0.05 | 0.05 |
| | 1957 | 7 | | 7140 | 335400 | 3.85 | 5.53 | 3.65 | 4460.04 | 1.88 | 75.20 | 343869.27 | -0.03 | 0.03 |
| | 1955 | 12 | | 6093 | 102900 | 3.78 | 5.01 | 3.59 | 3869.81 | 1.42 | 26.59 | 298362.06 | -1.90 | 1.90 |
| | 1952 | 6 | | 7836 | 177990 | 3.89 | 5.25 | 3.69 | 4847.32 | 1.56 | 36.72 | 373728.36 | -1.10 | 1.10 |
| | 1953 | 6 | | 18864 | 2428500 | 4.28 | 6.39 | 4.03 | 10642.80 | 2.36 | 228.18 | 820559.53 | 0.66 | 0.66 |
| | 1951 | 9 | | 9087 | 1307100 | 3.96 | 6.12 | 3.74 | 5534.60 | 2.37 | 236.17 | 426717.82 | 0.67 | 0.67 |
| | 1948 | 10 | | 3912 | 294150 | 3.59 | 5.47 | 3.42 | 2602.70 | 2.05 | 113.02 | 200668.02 | 0.32 | 0.32 |
| | 1955 | 11 | | 1218 | 5919 | 3.09 | 3.77 | 2.96 | 915.76 | 0.81 | 6.46 | 70604.79 | -10.93 | 10.93 |
| | 1956 | 11 | | 1104 | 3045 | 3.04 | 3.48 | 2.92 | 838.64 | 0.56 | 3.63 | 64658.95 | -20.23 | 20.23 |
| | 1951 | 4 | | 5076 | 92040 | 3.71 | 4.96 | 3.52 | 3286.18 | 1.45 | 28.01 | 253364.45 | -1.75 | 1.75 |
| | 1954 | 10 | | 261.3 | 14853 | 2.42 | 4.17 | 2.36 | 230.85 | 1.81 | 64.34 | 17798.60 | -0.20 | 0.20 |
| | 1955 | 4 | | 15504 | 1322100 | 4.19 | 6.12 | 3.48 | 2996.68 | 2.64 | 441.19 | 757651.27 | 0.43 | 0.43 |
| | 1951 | 5 | | 9348 | 240480 | 3.97 | 5.38 | 3.31 | 2040.20 | 2.07 | 117.87 | 515822.51 | -1.14 | 1.14 |
| | 1950 | 6 | | 9807 | 179010 | 3.99 | 5.25 | 3.33 | 2115.88 | 1.93 | 84.60 | 534957.75 | -1.99 | 1.99 |
| | 1953 | 7 | | 2079 | 176910 | 3.32 | 5.25 | 2.81 | 650.97 | 2.43 | 271.76 | 164584.44 | 0.07 | 0.07 |
| | 1951 | 6 | | 3036 | 137370 | 3.48 | 5.14 | 2.94 | 868.01 | 2.20 | 158.26 | 219458.42 | -0.60 | 0.60 |
| | 1952 | 3 | | 7422 | 48420 | 3.87 | 4.69 | 3.23 | 1712.11 | 1.45 | 28.28 | 432872.52 | -7.94 | 7.94 |
| | 1956 | 4 | | 7650 | 151050 | 3.88 | 5.18 | 3.24 | 1751.93 | 1.94 | 86.22 | 442940.58 | -1.93 | 1.93 |

Appendix C

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/day) | Percent Deviation | Absolute Percent Deviation |
| Group 5 | 1953 | 5 | 1.40 - 3.95 | 4950 | 53970 | 3.69 | 4.73 | 3.10 | 1258.50 | 1.63 | 42.88 | 318186.42 | -4.90 | 4.90 |
| | 1957 | 6 | | 32820 | 3297000 | 4.52 | 6.52 | 3.72 | 5298.30 | 2.79 | 622.28 | 1339568.26 | 0.59 | 0.59 |
| | 1950 | 5 | | 26289 | 1754100 | 4.42 | 6.24 | 3.65 | 4476.19 | 2.59 | 391.87 | 1131716.00 | 0.35 | 0.35 |
| | 1956 | 5 | | 10584 | 881400 | 4.02 | 5.95 | 3.35 | 2242.09 | 2.59 | 393.11 | 566868.80 | 0.36 | 0.36 |
| | 1949 | 10 | | 2715 | 75780 | 3.43 | 4.88 | 2.90 | 797.34 | 1.98 | 95.04 | 201591.79 | -1.66 | 1.66 |
| | 1955 | 6 | | 21909 | 2047800 | 4.34 | 6.31 | 3.59 | 3897.28 | 2.72 | 525.44 | 985349.33 | 0.52 | 0.52 |
| | 1950 | 4 | | 11334 | 396000 | 4.05 | 5.60 | 3.37 | 2361.83 | 2.22 | 167.67 | 597141.07 | -0.51 | 0.51 |
| | 1954 | 3 | | 7002 | 160200 | 3.85 | 5.20 | 3.21 | 1637.97 | 1.99 | 97.80 | 414128.79 | -1.59 | 1.59 |
| | 1957 | 4 | | 7005 | 354600 | 3.85 | 5.55 | 3.21 | 1638.51 | 2.34 | 216.42 | 414263.61 | -0.17 | 0.17 |
| | 1949 | 5 | | 16491 | 874200 | 4.22 | 5.94 | 3.50 | 3140.57 | 2.44 | 278.36 | 794030.41 | 0.09 | 0.09 |
| | 1951 | 7 | | 846 | 28425 | 2.93 | 4.45 | 2.52 | 328.72 | 1.94 | 86.47 | 83111.26 | -1.92 | 1.92 |
| | 1950 | 9 | | 141 | 4908 | 2.15 | 3.69 | 1.93 | 84.24 | 1.77 | 58.26 | 21298.19 | -3.34 | 3.34 |
| | 1957 | 5 | | 14550 | 941400 | 4.16 | 5.97 | 3.46 | 2855.50 | 2.52 | 329.68 | 721956.01 | 0.23 | 0.23 |
| | 1952 | 5 | | 36030 | 4641000 | 4.56 | 6.67 | 3.75 | 5687.63 | 2.91 | 815.98 | 1438004.74 | 0.69 | 0.69 |

(Column 11) Residual = [log observed suspended sediment load (column 8)] - [log predicted suspended sediment load (column 9)]

(Column 12) Power Residual = 10^Residual

(Column 13) Corrected Predicted Suspended Sediment Load using the Smearing estimator method (Mean of column 12 for each group multiplied by (Column 10)

(Column 14) Percent Deviation = [(observed sediment - corrected sediment )]/(observed sediment) * 100%

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/ month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/month) | Percent Deviation | Absolute Percent Deviation |
| Group 1 | 1957 | 9 | 0 - 0.85 | 4671 | 744600 | 3.67 | 5.87 | 3.22 | 1671.40 | 2.65 | 445.49 | 240331.20 | 0.68 | 0.68 |
| | 1959 | 3 | | 921 | 10071 | 2.96 | 4.00 | 2.65 | 450.77 | 1.35 | 22.34 | 64816.18 | -5.44 | 5.44 |
| | 1964 | 10 | | 267.6 | 19785 | 2.43 | 4.30 | 2.22 | 166.24 | 2.08 | 119.02 | 23903.06 | -0.21 | 0.21 |
| | 1965 | 10 | | 202.8 | 37140 | 2.31 | 4.57 | 2.12 | 132.90 | 2.45 | 279.45 | 19110.15 | 0.49 | 0.49 |
| | 1962 | 4 | | 43170 | 1594500 | 4.64 | 6.20 | 4.00 | 10059.03 | 2.20 | 158.51 | 1446388.26 | 0.09 | 0.09 |
| | 1964 | 6 | | 30 | 999 | 1.48 | 3.00 | 1.45 | 28.42 | 1.55 | 35.15 | 4087.09 | -3.09 | 3.09 |
| | 1959 | 11 | | 17502 | 2203200 | 4.24 | 6.34 | 3.69 | 4853.97 | 2.66 | 453.90 | 697951.95 | 0.68 | 0.68 |
| | 1958 | 6 | | 83.1 | 16710 | 1.92 | 4.22 | 1.81 | 64.69 | 2.41 | 258.32 | 9301.21 | 0.44 | 0.44 |
| | 1966 | 4 | | 8547 | 147990 | 3.93 | 5.17 | 3.43 | 2721.87 | 1.74 | 54.37 | 391377.90 | -1.64 | 1.64 |
| | 1959 | 1 | | 62.4 | 290.4 | 1.80 | 2.46 | 1.71 | 51.33 | 0.75 | 5.66 | 7381.13 | -24.42 | 24.42 |
| | 1961 | 4 | | 5856 | 175350 | 3.77 | 5.24 | 3.30 | 2006.00 | 1.94 | 87.41 | 288443.18 | -0.64 | 0.64 |
| | 1964 | 5 | | 1503 | 81510 | 3.18 | 4.91 | 2.83 | 669.31 | 2.09 | 121.78 | 96239.43 | -0.18 | 0.18 |
| | 1960 | 12 | | 60.6 | 339 | 1.78 | 2.53 | 1.70 | 50.13 | 0.83 | 6.76 | 7208.80 | -20.26 | 20.26 |
| | 1958 | 10 | | 5274 | 387600 | 3.72 | 5.59 | 3.27 | 1843.49 | 2.32 | 210.25 | 265074.99 | 0.32 | 0.32 |
| | 1957 | 12 | | 618 | 2610 | 2.79 | 3.42 | 2.51 | 326.67 | 0.90 | 7.99 | 46971.70 | -17.00 | 17.00 |
| | 1958 | 5 | | 789 | 13590 | 2.90 | 4.13 | 2.60 | 397.86 | 1.53 | 34.16 | 57208.47 | -3.21 | 3.21 |
| Group 2 | 1966 | 10 | 0.86 - 1.30 | 2208 | 575700 | 3.34 | 5.76 | 3.05 | 1125.54 | 2.71 | 511.49 | 226367.72 | 0.61 | 0.61 |
| | 1962 | 12 | | 77.7 | 1038 | 1.89 | 3.02 | 1.84 | 69.27 | 1.18 | 14.99 | 13931.05 | -12.42 | 12.42 |
| | 1966 | 1 | | 27234 | 1403700 | 4.44 | 6.15 | 3.96 | 9125.48 | 2.19 | 153.82 | 1835317.06 | -0.31 | 0.31 |
| | 1963 | 3 | | 639 | 11265 | 2.81 | 4.05 | 2.60 | 400.67 | 1.45 | 28.12 | 80583.38 | -6.15 | 6.15 |
| | 1958 | 7 | | 216.9 | 53520 | 2.34 | 4.73 | 2.21 | 162.90 | 2.52 | 328.55 | 32761.78 | 0.39 | 0.39 |
| | 1961 | 11 | | 1872 | 477900 | 3.27 | 5.68 | 2.99 | 980.93 | 2.69 | 487.19 | 197284.99 | 0.59 | 0.59 |
| | 1957 | 4 | | 972 | 2703 | 2.99 | 3.43 | 2.75 | 568.24 | 0.68 | 4.76 | 114285.01 | -41.28 | 41.28 |
| | 1966 | 9 | | 5604 | 1464000 | 3.75 | 6.17 | 3.39 | 2445.16 | 2.78 | 598.73 | 491770.21 | 0.66 | 0.66 |
| | 1959 | 4 | | 1206 | 11304 | 3.08 | 4.05 | 2.83 | 680.10 | 1.22 | 16.62 | 136780.94 | -11.10 | 11.10 |
| | 1957 | 2 | | 22080 | 765900 | 4.34 | 5.88 | 3.88 | 7662.30 | 2.00 | 99.96 | 1541042.10 | -1.01 | 1.01 |
| | 1961 | 1 | | 35.7 | 193.5 | 1.55 | 2.29 | 1.56 | 36.24 | 0.73 | 5.34 | 7288.46 | -36.67 | 36.67 |
| | 1960 | 3 | | 43170 | 3711000 | 4.64 | 6.57 | 4.13 | 13394.13 | 2.44 | 277.06 | 2693828.38 | 0.27 | 0.27 |
| | 1962 | 11 | | 1569 | 342000 | 3.20 | 5.53 | 2.93 | 846.76 | 2.61 | 403.89 | 170301.00 | 0.50 | 0.50 |
| | 1962 | 5 | | 585 | 2547 | 2.77 | 3.41 | 2.57 | 372.26 | 0.84 | 6.84 | 74869.36 | -28.40 | 28.40 |
| | 1962 | 3 | | 6834 | 219060 | 3.83 | 5.34 | 3.46 | 2884.64 | 1.88 | 75.94 | 580159.67 | -1.65 | 1.65 |
| | 1959 | 9 | | 132.9 | 20778 | 2.12 | 4.32 | 2.03 | 108.32 | 2.28 | 191.82 | 21785.10 | -0.05 | 0.05 |
| | 1960 | 11 | | 40.5 | 600 | 1.61 | 2.78 | 1.60 | 40.25 | 1.17 | 14.91 | 8096.05 | -12.49 | 12.49 |
| | 1962 | 10 | | 2193 | 702000 | 3.34 | 5.85 | 3.05 | 1119.16 | 2.80 | 627.25 | 225085.99 | 0.68 | 0.68 |
| | 1963 | 2 | | 1149 | 80040 | 3.06 | 4.90 | 2.82 | 653.21 | 2.09 | 122.53 | 131374.13 | -0.64 | 0.64 |
| | 1960 | 2 | | 4284 | 103140 | 3.63 | 5.01 | 3.29 | 1954.96 | 1.72 | 52.76 | 393182.23 | -2.81 | 2.81 |
| | 1957 | 3 | | 12567 | 220290 | 4.10 | 5.34 | 3.15 | 1402.54 | 2.20 | 157.07 | 1185605.51 | -4.38 | 4.38 |
| | 1957 | 6 | | 132.9 | 28203 | 2.12 | 4.45 | 1.81 | 64.12 | 2.64 | 439.85 | 54202.08 | -0.92 | 0.92 |
| | 1966 | 2 | | 2340 | 6588 | 3.37 | 3.82 | 2.65 | 448.56 | 1.17 | 14.69 | 379178.34 | -56.56 | 56.56 |
| | 1966 | 3 | | 32640 | 2895300 | 4.51 | 6.46 | 3.43 | 2679.42 | 3.03 | 1080.57 | 2264992.04 | 0.22 | 0.22 |
| | 1962 | 8 | | 81.6 | 20322 | 1.91 | 4.31 | 1.66 | 46.06 | 2.64 | 441.21 | 38935.84 | -0.92 | 0.92 |
| | 1961 | 10 | | 249 | 59820 | 2.40 | 4.78 | 1.99 | 98.16 | 2.78 | 609.44 | 82974.32 | -0.39 | 0.39 |
| | 1962 | 9 | | 3090 | 829200 | 3.49 | 5.92 | 2.73 | 541.63 | 3.18 | 1530.93 | 457858.38 | 0.45 | 0.45 |

Appendix D

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/ month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/month) | Percent Deviation | Absolute Percent Deviation |
| Group 3 | 1963 | 4 | 1.31 - 2.05 | 885 | 17790 | 2.95 | 4.25 | 2.37 | 231.97 | 1.88 | 76.69 | 196091.27 | -10.02 | 10.02 |
|  | 1960 | 1 |  | 8877 | 515700 | 3.95 | 5.71 | 3.04 | 1107.97 | 2.67 | 465.44 | 936602.86 | -0.82 | 0.82 |
|  | 1963 | 10 |  | 903 | 166560 | 2.96 | 5.22 | 2.37 | 235.16 | 2.85 | 708.29 | 198787.36 | -0.19 | 0.19 |
|  | 1961 | 9 |  | 2655 | 1121400 | 3.42 | 6.05 | 2.69 | 488.67 | 3.36 | 2294.80 | 413087.34 | 0.63 | 0.63 |
|  | 1958 | 4 |  | 22455 | 770100 | 4.35 | 5.89 | 3.32 | 2079.10 | 2.57 | 370.40 | 1757526.35 | -1.28 | 1.28 |
|  | 1959 | 10 |  | 3210 | 821100 | 3.51 | 5.91 | 2.74 | 555.81 | 3.17 | 1477.30 | 469843.30 | 0.43 | 0.43 |
|  | 1964 | 9 |  | 13209 | 1667700 | 4.12 | 6.22 | 3.16 | 1450.74 | 3.06 | 1149.55 | 1226352.50 | 0.26 | 0.26 |
|  | 1963 | 11 |  | 342 | 47040 | 2.53 | 4.67 | 2.09 | 121.73 | 2.59 | 386.43 | 102900.58 | -1.19 | 1.19 |
|  | 1960 | 4 |  | 9357 | 182940 | 3.97 | 5.26 | 3.06 | 1148.26 | 2.20 | 159.32 | 970657.89 | -4.31 | 4.31 |
|  | 1961 | 7 |  | 345 | 96780 | 2.54 | 4.99 | 2.09 | 122.45 | 2.90 | 790.35 | 103511.89 | -0.07 | 0.07 |
|  | 1965 | 8 |  | 4932 | 1288500 | 3.69 | 6.11 | 2.87 | 743.74 | 3.24 | 1732.45 | 628708.85 | 0.51 | 0.51 |
|  | 1963 | 9 |  | 15090 | 3456000 | 4.18 | 6.54 | 3.20 | 1587.82 | 3.34 | 2176.57 | 1342234.42 | 0.61 | 0.61 |
| Group 4 | 1965 | 2 | 2.12 - 4.09 | 6597 | 70410 | 3.82 | 4.85 | 2.56 | 359.52 | 2.29 | 195.85 | 1108657.83 | -14.75 | 14.75 |
|  | 1957 | 8 |  | 26088 | 7014000 | 4.42 | 6.85 | 2.89 | 769.19 | 3.96 | 9118.74 | 2371974.93 | 0.66 | 0.66 |
|  | 1965 | 5 |  | 8085 | 184980 | 3.91 | 5.27 | 2.60 | 402.33 | 2.66 | 459.77 | 1240691.03 | -5.71 | 5.71 |
|  | 1965 | 1 |  | 20562 | 1274700 | 4.31 | 6.11 | 2.83 | 674.29 | 3.28 | 1890.45 | 2079327.07 | -0.63 | 0.63 |
|  | 1965 | 3 |  | 7305 | 96390 | 3.86 | 4.98 | 2.58 | 380.37 | 2.40 | 253.41 | 1172977.71 | -11.17 | 11.17 |
|  | 1958 | 2 |  | 2649 | 69720 | 3.42 | 4.84 | 2.34 | 217.02 | 2.51 | 321.26 | 669243.24 | -8.60 | 8.60 |
|  | 1966 | 8 |  | 8541 | 2535600 | 3.93 | 6.40 | 2.62 | 414.73 | 3.79 | 6113.84 | 1278926.77 | 0.50 | 0.50 |
|  | 1964 | 4 |  | 13707 | 785100 | 4.14 | 5.89 | 2.73 | 538.78 | 3.16 | 1457.18 | 1661466.52 | -1.12 | 1.12 |
|  | 1957 | 7 |  | 2034 | 665100 | 3.31 | 5.82 | 2.27 | 187.51 | 3.55 | 3546.92 | 578248.88 | 0.13 | 0.13 |
|  | 1962 | 1 |  | 45.3 | 4839 | 1.66 | 3.68 | 1.36 | 22.86 | 2.33 | 211.71 | 70483.68 | -13.57 | 13.57 |
|  | 1962 | 2 |  | 25008 | 2816700 | 4.40 | 6.45 | 2.88 | 751.40 | 3.57 | 3748.59 | 2317140.32 | 0.18 | 0.18 |
|  | 1960 | 9 |  | 192.6 | 41520 | 2.28 | 4.62 | 1.71 | 50.90 | 2.91 | 815.70 | 156966.48 | -2.78 | 2.78 |
|  | 1961 | 3 |  | 1110 | 37800 | 3.05 | 4.58 | 2.13 | 134.13 | 2.45 | 281.81 | 413625.90 | -9.94 | 9.94 |
|  | 1959 | 8 |  | 17364 | 6183000 | 4.24 | 6.79 | 2.79 | 614.09 | 4.00 | 10068.60 | 1893691.85 | 0.69 | 0.69 |
|  | 1966 | 7 |  | 477 | 168390 | 2.68 | 5.23 | 1.92 | 84.06 | 3.30 | 2003.11 | 259233.68 | -0.54 | 0.54 |
|  | 1960 | 10 |  | 4461 | 664200 | 3.65 | 5.82 | 2.46 | 289.55 | 3.36 | 2293.91 | 892896.17 | -0.34 | 0.34 |
|  | 1959 | 12 |  | 9273 | 1053900 | 3.97 | 6.02 | 2.64 | 434.03 | 3.39 | 2428.16 | 1338447.38 | -0.27 | 0.27 |
|  | 1964 | 7 |  | 4851 | 1481400 | 3.69 | 6.17 | 2.48 | 303.29 | 3.69 | 4884.44 | 935269.81 | 0.37 | 0.37 |
|  | 1957 | 11 |  | 6264 | 874200 | 3.80 | 5.94 | 2.54 | 349.36 | 3.40 | 2502.28 | 1077341.63 | -0.23 | 0.23 |
|  | 1964 | 8 |  | 49710 | 12462000 | 4.70 | 7.10 | 3.04 | 1098.83 | 4.05 | 11341.20 | 3388501.97 | 0.73 | 0.73 |
|  | 1965 | 11 |  | 1974 | 145440 | 3.30 | 5.16 | 2.27 | 184.43 | 2.90 | 788.57 | 568749.59 | -2.91 | 2.91 |
|  | 1957 | 10 |  | 6258 | 1579500 | 3.80 | 6.20 | 2.54 | 349.18 | 3.66 | 4523.51 | 1076770.64 | 0.32 | 0.32 |
|  | 1958 | 3 |  | 15249 | 958500 | 4.18 | 5.98 | 2.76 | 571.51 | 3.22 | 1677.13 | 1762398.75 | -0.84 | 0.84 |
| Group 5 | 1958 | 8 | 4.1 - 8.35 | 11265 | 3543000 | 4.05 | 6.55 | 2.33 | 213.39 | 4.22 | 16603.36 | 1998093.42 | 0.44 | 0.44 |
|  | 1965 | 9 |  | 10572 | 1957500 | 4.02 | 6.29 | 2.32 | 207.44 | 3.97 | 9436.68 | 1942331.18 | 0.01 | 0.01 |
|  | 1959 | 7 |  | 46.5 | 13590 | 1.67 | 4.13 | 1.27 | 18.46 | 2.87 | 736.13 | 172864.00 | -11.72 | 11.72 |
|  | 1965 | 7 |  | 10155 | 3165000 | 4.01 | 6.50 | 2.31 | 203.75 | 4.19 | 15533.96 | 1907796.00 | 0.40 | 0.40 |
|  | 1961 | 8 |  | 4614 | 1330500 | 3.66 | 6.12 | 2.16 | 143.34 | 3.97 | 9282.30 | 1342146.15 | -0.01 | 0.01 |
|  | 1965 | 4 |  | 44130 | 1383900 | 4.64 | 6.14 | 2.59 | 392.23 | 3.55 | 3528.33 | 3672623.48 | -1.65 | 1.65 |
|  | 1966 | 12 |  | 11229 | 514800 | 4.05 | 5.71 | 2.33 | 213.09 | 3.38 | 2415.92 | 1995244.29 | -2.88 | 2.88 |
|  | 1965 | 12 |  | 11952 | 1465500 | 4.08 | 6.17 | 2.34 | 219.10 | 3.83 | 6688.82 | 2051526.04 | -0.40 | 0.40 |

Appendix D

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Groups | Year | Months | Monthly Precipitation Values (in) | Monthly Stream Discharge (cfs) | Observed Suspended Sediment Load(sh.t/ month) | Monthly Stream Discharge (log X) | Suspended Sediment (log Y) | Log Y | Antilog Y | Residual | Power Residual | Corrected Predicted SSL (sh.t/month) | Percent Deviation | Absolute Percent Deviation |
|  | 1957 | 1 |  | 19113 | 1235400 | 4.28 | 6.09 | 2.43 | 270.10 | 3.66 | 4573.81 | 2529125.77 | -1.05 | 1.05 |
|  | 1963 | 8 |  | 20178 | 5982000 | 4.30 | 6.78 | 2.44 | 276.71 | 4.33 | 21618.14 | 2591007.60 | 0.57 | 0.57 |
|  | 1958 | 9 |  | 17352 | 3255000 | 4.24 | 6.51 | 2.41 | 258.71 | 4.10 | 12581.59 | 2422456.83 | 0.26 | 0.26 |

(Column 11) Residual = [log observed suspended sediment load (column 8)] - [log predicted suspended sediment load (column 9)]
(Column 12) Power Residual = 10^Residual
(Column 13) Corrected Predicted Suspended Sediment Load using the Smearing estimator method (Mean of column 12 for each group multiplied by (Column 10)
(Column 14) Percent Deviation = [(observed sediment - corrected sediment )]/(observed sediment) * 100%