Appendix B

COMPUTER ANALYSIS OF GS_SED DATA

Work on the Delta Impacts Sediment and Scour Staff Paper included the analysis of a series of computer plots. The data used were the stream flow and suspended sediment measurements collected by the U. S. Geological Survey (USGS) from 1956 to 1980. In 1979, the surface water sampling station on the Sacramento River was moved from "I" Street Bridge in Sacramento to Freeport. The data were compiled and programmed onto a data file named GS_SED, which is accessed through the Department of Water Resources (DWR) computer files. GS_SED contains six variables:

1. Year
2. Month
3. Day of Observation
4. Daily Suspended Sediment Concentration in mg/L (SSCONC)
5. Daily Suspended Sediment Load in tons/day (SSLOAD)
6. Daily Flow in cfs (DAILYCFS)

All computer plots and the GS_SED data file were programmed in Job Control Language (JCL) using the Statistical Analysis Systems (SAS) programs.

Initially, three computer plots were made to determine:

1. How the data would appear graphically
2. What trends, if any could be seen
3. What additional plots needed to be made

From preliminary analysis of these plots additional plots were developed.

To date, 11 plots have been made. The individual plots can be grouped into 3 sets:

1. Suspended Sediment versus Time
2. Flow versus Time
3. Suspended Sediment versus Flow

The first group of plots, suspended sediment versus time include the following:

1. Monthly Average Suspended Sediment Load vs Month by Year (LOADMON)
2. Monthly Average Suspended Sediment Load vs Year by Month (LODYEAR)
3. Monthly Average Suspended Sediment Concentration vs Month by Year (SEDMON)
4. Monthly Average Suspended Sediment Concentration vs Year by Month (SEDYEAR)
5. Suspended Sediment Concentration vs Day (SSCODAY) for years 1958, 1961, 1964, 1965, 1975, 1977, and 1978

The second group of plots, flow vs time, include:

1. Monthly Average Flow vs Month by Year (FLOMON)
2. Monthly Average Flow vs Year by Month (FLOYEAR)
3. Daily Flow vs Day (FLODAY) for years 1958, 1961, 1964, 1965, 1975, 1977, and 1978

The last group of plots, suspended sediment vs flow contain the following:

1. Suspended Sediment Concentration vs Daily Flow (MUDFLOW)
2. Monthly Average Suspended Sediment Concentration vs Monthly Average Flow by Year (SSCONCFS)
3. Monthly Average Suspended Sediment Load vs Monthly Average Flow (REGRESS)

The last plot includes a regression analysis of the curve produced by the plot.

These computer plots were analyzed for overall trends, specific anomalies, and any other generalizations that could be made. Because it is helpful to analyze and discuss sediment vs time and flow vs time plots together, they will be presented first. Discussion of sediment vs flow graphs will follow.

Monthly Average Suspended Sediment Load (SSLOAD) and Flow vs Month by Year - SSLOAD in tons, flow in cfs.

High sediment loads generally correspond with the high flows of the winter months. The lower summer flows support much less suspended sediment. Rises or falls in flow were generally accompanied by corresponding changes in the sediment load. The peak flows generally occur in February and drop off rather sharply in later months. These first storms have low flow to sediment ratios, generally 1.5:1 to 2:1. Later storms have higher ratios typically 3:1. Low flows that occur during summer through fall and drought years have the highest ratios ranging from 6:1 to 11:1, but average around 9:1. After the 1977 drought year, the first winter storm of Januray 1978 had a very sharp increase in the suspended sediment load compared to the flow. The ratio of flow to sediment load was approximately .9:1, the lowest observed. See Table 1 for specific comments.

Monthly Average Suspended Sediment Load and Flow vs Year by Months - Comparing the graphs of monthly average suspended sediment load and flow by year shows a general correlation between the two - suspended sediment is higher, and vice versa (see Table 2).

TABLE 1

Monthly Average Suspended Sediment Load (SSLOAD) and Monthly Average Flow vs Month by Year

1958	April	Flow higher than Mar by ≈ 10,000 cfs		
		ssload lower than Mar by ≈ 3,000 tons		
	July-Dec	Flow average 15,000 cfs	≈ 7:1	
		ssload average 2,200 tons		
1959	Feb	Peak flow = 40,000 cfs	≈ 2:1	
		Peak ssload = 22,500 tons		
	April-Dec	Flow average 10,000 cfs	10:1	
		Ssload average 1,000 tons		
1960	Feb	Ssload rises sharply then drops in March		
		Flow rises less with little drop in March		
	June-Nov	Flow average 10,000 cfs	≈ 6.5:1	Graphs look very similar
	April-Nov	Ssload average 1,500 tons		
1961	May-Nov	Flow average 10,000 cfs	≈ 8:1	
		Ssload average 1,200 tons		
	Feb	Peak flow = 38,000 cfs	≈ 1.5:1	
		Peak ssload = 26,000 tons		
1962	June-Sept	Flow average 12,000 cfs	≈ 6:1	
	April-Sept	Ssload average 2,000 tons		
	Feb	Peak flow = 44,000 cfs	≈ 2:1	
		Peak ssload = 24,000 tons		Increase in flows from Oct-Nov on ↓
	Oct	Substantial rise in flow (28,000 cfs) & ssload (17,000 tons) drop in Nov and rise in Dec		

1963	Feb	Sharp peak in flow 56,000 cfs Sharp peak in ssload = 44,000 tons	≃1.2:1
		Drop in March	
	April	Sharp peak in flow = 61,000 cfs Peak in ssload = 21,000 cfs	≃3:1
	June-Oct	Flow average = 15,000 cfs Ssload average = 2,500 tons	6:1
1964	Low flow and ssload year		
	Mar-Nov	Flow average = 13,000 cfs	≃8.5:1
	Feb-Oct	Ssload average 1,500 tons	
1965	Jan	Peak flow = 72,000 cfs Peak ssload = 45,000 tons	1.6:1
	April	Second peak flow = 42,000 cfs Second peak ssload = 28,000 cfs	1.5:1
	June-Oct	Flow average = 15,000 cfs Ssload average = 1,700 cfs	≃9:1
1966	Dec	Peak flows - 46,000 cfs Peak ssload = 16,000 tons	≃3:1
	May-Oct	Flow average = 13,000 cfs Ssload average = 1,300 tons	10:1
1967	Steady high flows until June (average 46,000 cfs		
	July-Dec	Flows average = 16,000 cfs Ssload average = 2,000 tons	≃8:1
1968	Feb	Peak flow = 40,000 cfs Peak ssload - 21,000 tons	≃2.1
	April-Nov	Flow average - 13,000 cfs ssload average = 1,300 tons	10:1

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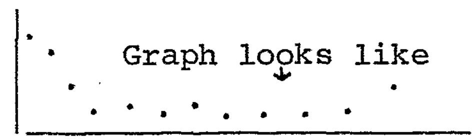
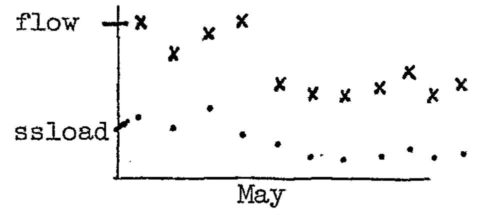
1969	Jan	Flow = 56,000 cfs Ssload = 31,000 tons	1.8:1
	Feb	Flow = 72,000 cfs Ssload - 26,000 tons	≈3:1
		Drop in flow and ss load until July (lowest values)	
	July-Nov	Flow average = 17,000 cfs Ssload average = 2,500-3000 tons	≈6:1
1970	Jan	Peak flow = 70,000 cfs Ssload - 29,000 tons	≈2.5:1



1971	Relative steady flows all year		
	Jan	Peak flow = 52,000 cfs Peak ssload = 26,000 tons	≈2:1

1972	Relatively lower flows all year and lower sediment loads		
	March	Small jump in ssload (2,500 tons Jan-Feb to 7,500 tons March)	
		Flow rose only 2,000 cfs (20,000-22,000)	
	April-Oct	Flow average = 15,000 cfs ssload average = 1,300 cfs	11:1
1973	Jan	Peak sed load = 22,500 (flow = 60,000)	≈2.5:1
	Feb	Peak flow - 66,000 (ssload - 18,000 tons)	≈3.5:1
	Nov-Dec	Jump in flow and ssload	
	April-Oct	Flow average = 15,000 cfs ssload average - 2,000 tons	7.5:1

1974		High flows and ssload until May	
	June-Dec	Flows average + 25,000 cfs Ssload average _ 3,000 cfs	≃ 8:1
1975	Mar	Peak flow = 50,000 cfs Peak ssload = 28,000 cfs	1.8:1
	June-Dec	Flow average = 21,000 cfs ssload average - 2,600 tons	8:1
1976		Low flow year	
	Jan-Dec	Flow average = 11,000 cfs Ssload average = 1,100 tons	10:1
1977		Low flow year	
	Jan-Nov	Flow average = 7,000 cfs Ssload average = 500 tons	14:1
	Dec	Peak flow = 12,000 cfs Peak ssload = 8,000 tons	1.5:1
1978	Jan	Sharp peak ssload = 49,000 tons (flow - 45,000 cfs)	1:1
	Mar	Peak flow - 55,000 cfs (ssload = 18,000 tons)	3:1
	June-Dec	Flow average = 14,000 cfs ssload average 1,400 tons	10:1
1979		Relatively steady flow year	
	April-Nov	Flow average - 15,000 cfs Ssload average = 1,500 tons	10:1
1980	Jan	Peak flow - 58,000 cfs Peak ssload - 36,000 tons	1.6:1



1980 (contd)			
March	Ssload drops to 21,000 tons		
	Flow drops in Feb and rises in March - 55,000 cfs		
April-Sept*	Flow average - 17,000 cfs	}	11:1
	Ssload average - 1,500 tons		

*Data ends in September

TABLE 2

Monthly Average Flow vs Year by Month

Approximate Ranges of Average Flow (cfs)

Month	Range	Month	Range
Jan	10,000 - 74,000	Jul	9,000 - 22,000
Feb	9,000 - 72,000	Aug	9,000 - 24,000
Mar	7,000 - 64,000	Sep	7,000 - 26,000
Apr	7,000 - 72,000	Oct	5,000 - 28,000
May	9,000 - 55,000	Nov	7,000 - 48,000 only 1 high value
June	7,000 - 45,000 (only 2 high values)	Dec	7,000 - 65,000

December through May has wide spread of cfs values. June through November has narrow spread of cfs values. The fluctuation of values in the wide spread occurs throughout the study period (1956-1980).

Monthly Average Suspended Sediment Load vs Year by Month

Approximate Ranges of Average Sediment Load (tons)

Month	Range	Month	Range
Jan	1,000 - 49,000	Jul	1,000 - 3,000
Feb	>0 - 44,000	Aug	2,000 - 4,000
Mar	>0 - 29,000	Sep	2,000 - 4,000
Apr	>0 - 29,000	Oct	>0 - 17,000 (only 1 high value)
May	1,000 - 17,000	Nov	>0 - 17,000 (only 1 high value)
Jun	>0 - 8,000	Dec	>0 - 22,000

December through May has wide spread of sediment load values. June through November has narrow spread of sediment load values.

Some small anomalies from the correlation include the following:

Jan	1957	Flow up - sediment load down
	1970	Flow up - sediment load dropping
	1974	Flow up - sediment load down
Feb	1960	Flow down - sediment load still up
	1958	Flow down - sediment load still up
	1975	Flow down - sediment load still up
Mar	1970	Flow dropping - sediment load even
	1975	Flow down - sediment load going up
Apr	--	Varies from year to year in that some higher flows give lower sediment loads
May	1962	Flow up - sediment load down
	1973	Flow up slightly - sediment load even
June	1959-1962	Flow up slightly - sediment load stays even
	1980	Flow up slightly - sediment load even
Jul	1977-1980	Flow up slightly - sediment load even
Aug	1963	Flow even - sediment load up slightly
	1965	Flow up slightly - sediment load even
	1971	Flow up slightly - sediment load even
Sep	1959	Flow down- sediment load even
	1971	Flow up - sediment load even
	1977	Flow down - sediment load even
Oct	1965	Flow up - sediment load even
Dec	1961	Flow down slightly - sediment load up
	1964	Flow up slightly - sediment load up considerably
	1978	Flow up slightly - sediment load down

A higher sediment rate is related to higher flow. In winter rivers have a higher carrying capacity and watershed runoff is feeding in more sediment. A lower sediment rate is related to lower flows. In summer, rivers have a lower carrying capacity, and water is released from reservoirs which should be clearer.

Decrease of river flow (cfs) decreases sediment transport because of decreased carrying capacity. The decreased water amount also carries less material (tons) by virtue of the smaller water quantity, even if the actual concentration were the same.

Monthly Average Suspended Sediment Concentration and Monthly Average Suspended Sediment Load vs. Month by Year and Year by Month

Suspended sediment load is a computed value from the sediment concentration total river discharge, and a conversion factor, rather than a direct measurement. As a result, the direct relationship between sediment load and discharge is obscured because the discharge value has already been included in the computation of sediment load. It was decided that it is more useful to compare sediment concentration values rather than sediment load values. Consequently, sediment load values will not be used for future plots.

Graphs of monthly average suspended sediment concentration vs time were compared with monthly average suspended sediment load vs time graphs. The concentration graphs exhibit the same trends and differ only slightly from the sediment load graphs. This is expected since sediment load is directly related to the sediment concentration. The observed differences are most likely a result of variances in discharges. These differences are listed in Table 3.

One distinguishable difference is the relative ratios of flow to sediment load and flow to sediment concentration. During the high flow (winter) months, the ratio of flow to sediment concentation is about the same or slightly higher than the ratio of flow to sediment load. But, in the low flow (summer) months, the ratio of flow to concentration is only half the ratio of flow to load (see Table 4 and Table 1). This represents twice as much sediment using the sediment concentration values.

Table 3

Monthly Average Suspended Sediment Concentration and Monthly Average Suspended Sediment Load vs Year by Month

Month	Year	Observation
January	1959	Concentration up load down
	1964	Concentration down load up
	1966	Concentration slightly up from 1964 load way down from 1964
	1968	Concentration the same load down
	1971	Concentration up load down
February	1966	Concentration up load down
	1969	Concentration down load up
	1974	Concentration up load down
March	1961	Concentration up load down
	1962	Concentration down load up
	1968	Concentration slightly up load down
	1974	Concentration down load up
April - No specific anomalies - seems to vary cyclicly by year		
May	1960	Concentration down load slightly up
	1961	Concentration up load the same
	1962	Concentration down load the same

Table 3 (continued)

Month	Year	Observation
June	1958	Concentration slightly down load up
	1967	Concentration the same load up
July	–	load fairly constant concentration fluctuates slightly (20-50 mg/L)
December	1970	Concentration the same load up
	1973	Concentration down load up

Table 4

Monthly Average Suspended Sediment Concentration (SSCONC)
and Monthly Average Flow vs. Month by Year

Year	Month(s)	Observation	
1958	July - Dec.	SSCONC avg. 20 mg/L	7.5:1
		flow avg. 15,000 cfs	
1959	Jan.	peak SSCONC 190 mg/L	3:1
	Feb.	peak flow 40,000 cfs	
	May-Dec	SSCONC avg. 30 mg/L	
	May-Aug & Oct.-Dec.	SSCONC avg. 20 mg/L	5:1
	April - Dec.	flow avg. 10,000 cfs	
1960	April - Oct.	SSCONC avg. 19 mg/L	5:1
	June - Nov.	flow avg. 10,000 cfs	
1961	May - Nov.	SSCONC avg. 26 mg/L	4:1
		flow avg. 1,000 cfs	
	Feb.	peak SSCONC 240 mg/L	1.5:1
		peak flow 38,000 cfs	
1962	April - Sept.	SSCONC avg. 43 mg/L	≈3:1
	June - Sept.	flow avg. 12,000 cfs	
	Feb.	peak SSCONC 168 mg/L	≈2.6:1
		peak flow 44,000 cfs	
1963	Feb.	peak SSCONC 250 mg/L	
		peak flow 56,000 cfs	
	June - Sept.	SSCONC avg. 45 mg/L	
	June - Oct.	flow avg. 15,000 cfs	
1964	Feb. - Oct.	SSCONC avg = 36 mg/L	3.5:1
	Mar. - Nov.	flow avg. = 13,000 cfs	
1965	Jan.	peak SSCONC = 225 mg/L	3.2:1
		peak flow = 72,000 cfs	
	June - Oct.	SSCONC avg. = 45 mg/L	3.3:1
		flow avg. = 15,000 cfs	
1966	Jan.	Peak SSCONC = 232 mg/L	≈2:1
	Dec.	Peak flow = 46,000 cfs	
	May - Oct.	SSCONC avg. = 45 mg/L	≈3:1
		flow avg. = 13,000 cfs	
1967	July - Dec.	SSCONC avg. = 38 mg/L	≈6:1
		flow avg. = 16,000 cfs	

Year	Month(s)	Observation	Ratio
1968	Feb.	Peak SSCONC = 166 mg/L	≈2.5:1
		peak flow = 40,000 cfs	
	April - Nov.	SSCONC avg. = 37 mg/L	3.5:1
		flow avg. = 13,000 cfs	
1969	July - Nov.	SSCONC avg. = 45 mg/L	3.7:1
		flow avg. = 17,000 cfs	
1970	Jan.	Peak SSCONC = 150 mg/L	4.5:1
		peak flow = 70,000 cfs	
1971	Jan.	Peak SSCONC = 166 mg/L	≈3:1
		peak flow = 52,000 cfs	
1972	April - Oct.	SSCONC avg. = 40 mg/L	≈4:1
		flow avg. = 15,000 cfs	
1973	April - Oct.	SSCONC avg. = 40 mg/L	≈4:1
		flow avg. = 15,000 cfs	
1974	June - Dec.	SSCONC avg. = 48 mg/L	≈5:1
		flow avg. = 25,000 cfs	
1975	Feb.	Peak SSCONC = 208 mg/L	≈2.5:1
	Mar.	peak flow = 50,000 cfs	
	June - Dec.	SSCONC avg. = 43 mg/L	≈5:1
		flow avg. = 21,000 cfs	
1976	Jan. - Dec.	SSCONC avg. = 34 mg/L	3.2:1
		flow avg. = 11,000 cfs	
1977	Dec.	Peak SSCONC = 185 mg/L	≈.6:1
		peak flow = 12,000 cfs	
		SSCONC avg. = 32 mg/L	≈2:1
		flow avg. = 7,000 cfs	
1978	June - Dec.	SSCONC avg. = 34 mg/L	≈4:1
		flow avg. = 14,000 cfs	
1979	May - Nov.	SSCONC avg. = 30 mg/L	5:1
	April - Nov.	flow avg. = 15,000 cfs	
1980	April - Sept.	SSCONC avg. = 28 mg/L	≈6:1
		flow avg. = 17,000 cfs	

Suspended Sediment Concentration and Flow vs. Day by Month and Year - The daily data proved to be the most useful and informative for analyses. Individual storms were shown as "sinusoidal-like" curves in the daily flow graphs. These curves have relatively high amplitudes and long "wavelengths" in winter months. The summer curves show only minor fluctuations in flow. The concentration graphs generally closely paralleled the flow graphs. The sediment concentration showed an immediate response to the flow rise during the initial storms of the season. After a period of several storms the concentration curves tended to lag behind the flow curves by a few days. Also, even if the flow remained high or increased, the sediment concentration tended to stay the same and even drop in some cases (see Table 5).

For this analysis the years 1958 and 1977 were used as examples of high and low flow years respectively. Representative trends are shown in Table 6. The data for 1961, 1964, 1965, and 1975 and 1977 were also analyzed. They exhibited the same trends as the data for 1958 and 1977.

Table 5

Relationship of Sediment Concentration and Flow for 1958 and 1977

1958	2/9-2/12 4/3-4/10	Flow constant - sediment concentration drops
1958	1/1-1/25 3/17-3/20	Flow rise - sediment concentration rise
1958	3/20-3/25	Flow rise - sediment concentration constant
1958	1/25-1/31	Flow rise - sediment concentration drops
1958	2/20-2/28 (lag = 5 days)	Exhibit same trend but concentration lags flow (>1 day lag time)
1977	1/1-1/8	

Table 6

Daily Suspended Sediment Concentration (SSCONC) and Daily Flow vs. Day by Month for 1958 and 1977

1958 January - peaks on the 5th, 15th, and 27th -- the trends were the same for the first two storms - during the last storm, flow increased and SSCONC dropped.

	SSCONC (mg/L)	Flow (cfs)
1/5	200	31,000
1/15	280	38,000
1/27	420	46,000
1/31	320	62,000

February - Flow remained high (>60,000 cfs) but SSCONC ranged from 150-300 mg/L

March - Flow dropped from 80,000 cfs to 44,000 cfs from 3/1 to 3/14, SSCONC fluctuated between 220 mg/L and 180 mg/L

3/20-3/25 flow rises from 40,000 to 78,000 cfs

3/20-3/25 SSCONC remains constant at 200 mg/L

April - Flow and SSCONC rise

4/4-4/10 Flow stays constant at 88,000 cfs

4/3-4/10 SSCONC drops from 260 - 120 mg/L

4/10-4/15 Flow drops

4/9-4/23 SSCONC constant

May - 5/21-5/26 flow increased to peak (66,000 cfs)

5/22-5/25 SSCONC increased to peak (200 mg/L)

June - Trend of overall decrease in flow SSCONC fluctuated on a daily basis between 0 and 100 mg/L on a daily basis.

July - December - SSCONC fluctuated between 0 and 100 mg/L on a daily basis. Flows remain essentially constant fluctuating only by about 2,000 cfs

July = 14 - 16K cfs	Oct = 12 - 14K
Aug = 12 - 14K cfs	Nov. = 12-14K
Sept. = 14 - 18K cfs	Dec. = 12 - 14K

1977 January - Flow peak on 1/5 (14,000 cfs) SSCONC peak on 1/7 (100 mg/L) after that both flow and SSCONC remained constant (10,000 cfs, 20 mg/L)

Table 6
(continued)

February	- Flow = 8,000 cfs (1 day flow = 10,000 cfs) SSCONC = 20 mg/L (2 days SSCONC = 40 mg/L)
March	- Flow = 6,000 cfs (5 days flow = 8,000 cfs) SSCONC = 20 mg/L (16 days SSCONC = 40 mg/L)
April	- Flow = 6,000 cfs SSCONC = 40 mg/L (9 days SSCONC = 20 mg/L)
May	- Flow = 8,000 cfs (12 days flow = 6,000 cfs) SSCONC = increase from 20-80 mg/L from 5/2 - 5/5, dropped to 40 mg/L from 5/11 - 5/30
June	= 6/1 - 6/16 flow = 6,000 cfs, 6/17 - 6/30 flow = 8,000 cfs 6/1 - 6/19 SSCONC = 20 mg/L, 6/20 - 6/30 = 40 mg/L
July	- Flow = 8,000 cfs (3 days flow = 10,000 cfs) SSCONC = 40 mg/L (2 days SSCONC = 60 mg/L)
August	- flow = 8,000 cfs (1 day flow = 6,000 cfs) SSCONC = 40 mg/L (2 days SSCONC = 60 mg/L)
September	- Flow fluctuated between 6,000 - 8,000 cfs SSCONC = 40 mg/L (3 days SSCONC = 60 mg/L)
October	- Flow = 4,000 cfs (10/1 - 10/3 flow = 6,000 cfs) SSCONC = 20 mg/L (10/1 - 10/3 SSCONC = 40 mg/L)
November	- Flow = 6,000 cfs from 11/1 - 11/21, 8,000 cfs from 11/22 - 11/30 SSCONC = 20 mg/L from 11/1 - 11/10 40 mg/L from 11/21 - 11/30.
December	- Flow = 6,000 cfs from 12/2 - 12/14 Flow rose to 22,000 cfs from 12/15 - 12/19 SSCONC = 20 mg/L from 12/2 - 12/15 SSCONC rose to 660 mg/L from 12/15 - 12/18

Suspended Sediment vs. Flow Graphs - The graphs of daily flow vs. daily suspended sediment concentration (MUDFLOW) by year showed the sediment-flow discharge relationship was not linear but was of the form $S=aQ^b$ (S = daily sediment load (tons/day); Q = mean daily discharge (cfs); a and b are constants) Kadir, et al 1983). A low, narrow range of sediment concentration (0-200 mg/L, mostly 0 - 100 mg/L) occurs below 25,000 cfs. Above 25,000 cfs a wider and higher range of concentration (0 - 1,100, mostly 0 - 500 mg/L) occurs. These trends cannot be tied to seasonal effects because each graph represents an entire year of data.

The Monthly Average Suspended Sediment Concentration vs. Monthly Average Flow (SSCOCFS) and Monthly Average Suspended Sediment Load vs. Monthly Average Flow (REGRESS) also show little because the actual daily relationship between sediment concentration and flow is obscured in the mean values. Curves similar to these have been used for regression analyses where the data were transformed into mathematical equations (see Kadir, 1983). Due to complicating factors, these equations did not seem to fit the data very well.

Conclusions

Analyses of these computer plots shows that the relationship between suspended sediment concentration and flow is determined by the time of year and sediment source. Generally, the initial storms of the rainy season produce a large sediment yield compared to the flow, and thus relative ratios of flow to sediment concentration are lower. Peaks in the sediment concentration graphs are invariably higher for the first storm of the season than for succeeding storms, assuming the same magnitude of flow. The storm intensity effects the erosion of sediment. As the frequency of storms increases the ground in the watershed becomes wet and easily eroded sediment has already been flushed down. This is often reflected downstream as an overall decrease in sediment concentration even with static or rising discharge. Additional surges in sediment concentration arise when the ground has become saturated. At this stage, water cannot infiltrate, so runoff becomes greater causing increased erosion. Also, at this time, gully and channel banks become unstable and are easily eroded. Other major sediment inputs such as landslides and slumps introduce large quantities of sediment which may or may not be accompanied by coincident storms. These events generally occur in the latter part of the rainy season after the ground has become well saturated.

Sediment inputs vary during the spring, but are generally lower. Runoff produced by spring snowmelt yields a fairly high discharge, but a relatively lower sediment concentration. The melting of the snowpack varies with the weather; higher runoff occurring during warmer days. Snowmelt does not have soil impact force as does rainfall, so may account for the lesser erosion, though the discharge may be comparable. Summer flows are regulated by upstream storage facility releases such as Oroville, Shasta, and Folsom Dams. Since most of the sediment has dropped out of suspension, dams tend to release clearer water.

These flows carry little sediment in proportion to the flow, and flow to sediment ratios are much higher. These clearer waters could potentially be erosive but at present the discharge are not high enough to provide velocities that cause noticeable channel erosion.

Another factor that influences the sediment-flow relationship is the amount of material available to be transported. Tremendous sediment loads were introduced to the system during the gold rush era from hydraulic mining debris. As the stockpile of this debris have diminshed, the sediment input to the system has continually decreased.

The change in sediment input to the system from season to season coupled with an overall decrease in sediment load complicate any efforts to determine a mathematical relationship between sediment discharge and flow discharge. Both Graves, 1977 (11) and Kadir, et al, 1983 (37) attempted to define this relationship by performing linear regressions on sediment load vs flow graphs. Mathematical equations were then developed from these data. A better correlation was obtained by developing 12 separate equations, one for each month rather than using an entire year's worth of

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data to develop an equation because the sediment-flow relationship varies seasonally. The best correlation was found by using mean monthly sediment loads and water discharge rather than daily values. By averaging the data the variability or spread of the data points is reduced.

Graves summarizes the difficulties in attempting to quantify this relationship as follows. "Equation 2 Smm = (2.1×10^{-8}) $(MAE)^{21}$, Smm = mean monthly sediment load, in tons - MAF = mean monthly runoff, in million acre-feet) should not be used to estimate sediment loads since the same runoff does not produce equal sediment loads during different times of the year. Since there were obviously seasonal effects to consider, the rate of upstream water projects upon any changes in the seasonal pattern of runoff and sediment load would also have to be considered."

RECOMMENDATIONS

From analyses of plots already made, it is concluded that the flow and SSCONC vs Day are the most informative. It would be useful to plot the logs of these values and reverse the axes for the sediment vs flow graphs. This would standarize our plots to published plots of sediment vs flow. In addition, monthly and yearly averages and totals in numerical form for both flow and suspended sediment load would be useful.

It is recommended that the following tasks be completed:

1. Put Vernalis data on NCC system.
2. Additional plots that need to be run include:

Sacramento River

a. Log=log plot of SSCONC vs Day by Month for selected years probably 2 to 10 years).

b. Log-log plot of Flow vs Day by Month for selected years (probably 2 to 10 years).

c. Log-log plot of SSCONC vs Flow by Month for selected years (probably 2 to 10 years).

San Joaquin River

a. Log-log plot of SSCONC vs Day by Month for selected years (probably 2 to 10 years).

b. Log-log plot of Flow vs Day by Month for selected years (probably 2 to 10 years).

c. Log-log plot of SSCONC vs Flow by Month for selected years (probably 2 to 10 years).

d. Monthly average SSCONC vs Month.

e. Monthly average Flow vs Month.

f. Monthly average SSCONC vs Monthly average flow.

3. Printouts of the following:

Sacramento River and San Joaquin River

a. Monthly average for flow and sediment load.

b. Monthly totals for flow and sediment load.

c. Yearly averages for flow and sediment load.

d. Yearly totals for flow and sediment load.

These graphs should then be examined and compared for trends and anomalies. Comparison with other analyses of graphs such as these help to explain sedimentation and/or erosion in the Sacramento and San Joaquin Rivers and the Delta.