SEDIMENT DATA: COLLECTION, ANALYSIS, AND USE

Sheet 1 of this report deals primarily with the erosion and deposition of sediment--where sediment comes from and where it goes. This sheet (sheet 2) describes what sediment is, how its movement is measured, and what sediment data mean in terms of land-surface change. The sediment data shown on this sheet were collected at 10 sites in Marin and Sonoma Counties and at one site (11-4630.00) north of the study area near where the Russian River flows into Sonoma County. Most of the data were collected for special-purpose studies (Ritter, 1973; Ritter and Brown, 1972; Brown, 1971). However, the data are generally applicable to a variety of situations. The data for stations 11-4608.00 and 11-4609.20 were collected expressly for this report.

WHAT IS SEDIMENT?

The term sediment, as used in this report, refers to particles of material in and on the earth's crust that are moved about, suspended, or deposited by water, air, ice, gravity, organisms, or combinations thereof. These particles originate from the mechanical and chemical breakdown of rocks and from biologic activity; therefore, sediment includes both inorganic and organic particles. The following table lists the types and sizes of material generally reported as sediment by the U.S. Geological Survey.

Type of material	Size of material in average dimension (mm, millimetre; μm, micrometre)	Means of transport
Boulders	>256 mm	Generally transported as bedload
Cobbles	64-256 mm	
Gravel	2.0-64 mm	
Sand	62-2,000 μm	May be transported either as bedload or in suspension
Silt	4-62 μm	Transported in suspension
Clay	0.24-4 μm	
Colloids	0.05-0.24 μm	
Biota	Phytoplankton, zooplankton--living organisms	
Organic remains	Nonliving particles of organic matter	

SEDIMENT DISCHARGE

The material eroded from the land surface and transported in suspension by flowing water is called suspended sediment[1]. The quantity of suspended sediment that passes a given section of a stream in a given time is termed suspended-sediment discharge and is expressed as tons per day or acre-feet per year. Suspended-sediment discharge is measured in the study area almost exclusively by the Geological Survey at the 11 gaging stations shown on sheets 1 and 2. Suspended-sediment discharge is measured usually by collecting and analyzing samples of the water-sediment mixture passing the stream section at the gaging station and then extrapolating the sample data to the total water-sediment mixture flowing past the section when the samples were taken. Detailed information on sediment-discharge, including the practical aspects of selecting sampling points and determining the frequency of sampling, are discussed in several reports. Suitable references on methods of measurement and analysis of sediment discharge are Porterfield (1972), and Report 14 of the U.S. Interagency Committee on Water Resources (1963). The procedure for measuring water discharge is described in detail by Carter and Davidian (1968).

EROSION RATES AND SUSPENDED-SEDIMENT YIELD

The rate of erosion of a drainage basin, often called a landscape denudation rate, is a measure of the removal of material from the land surface by all the erosional forces acting within that basin. This denudation rate is very difficult to measure, and it is usually estimated from geologic interpretations or extrapolated from sediment-discharge figures. The denudation rate is characteristically associated with the long term and is commonly expressed in inches or feet per 1,000 years.

The suspended-sediment discharge at a gaging station reflects only a part of the rate of erosion of the drainage basin upstream from that station. For example, a suspended-sediment discharge of 300,000 tons per year past a gaging station means that at least 300,000 tons of fragmental rock material and other detritus were eroded from the basin upstream from the station and carried downstream by running water during that year. The 300,000 tons of sediment was not derived evenly from all parts of the basin; it came from isolated gullies, landslides, streambanks, and other sediment source areas such as those shown on sheet 1. However, for comparative purposes and standardization of information, the 300,000 tons per year of eroded material is expressed as an average rate for the entire basin by dividing it by the drainage area of the basin. Thus, if the drainage area was 100 square miles, the suspended-sediment yield for the basin would be 3,000 tons per square mile per year.

In the accompanying tables, values for suspended-sediment yield are given to show the characteristic variability of the sediment system in the study area and to be used for comparison with other areas. The suspended-sediment yield was converted to a landscape denudation rate based on the assumption that the eroded material, later transported as suspended sediment, had a unit weight of 100 pounds per cubic foot in its source area. The conversion should be adjusted where data on the unit weight of eroded material are known. Again, erosion rates and suspended-sediment yields shown in the accompanying tables are based only on suspended-sediment discharge figures and are conservative measures of the sediment system in the study area.

SEDIMENT-TRANSPORT RELATIONS

Commonly used tools for determining erosion rates and sediment yield are the relations between the flow of water (water discharge) and the quantity of sediment that the water carries (sediment discharge). The relations between water discharge and sediment discharge[2] are shown on the accompanying graphs for the 11 Geological Survey gaging-station sites shown on the map. The graphs show points representing nearly all of the samples collected during the period of record for each station.[3] A curve fitted to the points is called a sediment-transport curve, and it is commonly used to estimate periods of missing data or to extend records (Porterfield, 1972, p. 21). Many types of sediment-transport curves may be developed from sediment-discharge data. The two types of sediment-transport curves shown on this sheet are basic and practical for evaluating erosion rates and sediment yield.

The simplest relation between sediment discharge and water discharge is called an instantaneous sediment-transport curve. The curve is defined by measurements of water discharge and sediment discharge taken concurrently during a short period of time. Ideally, the measurements reflect an instantaneous condition of the stream rather than the constantly fluctuating conditions characteristic of longer periods of streamflow. The instantaneous conditions of the stream, measured at many different values of streamflow, act as an index of the factors that affect sediment transport upstream from the measuring site. Each drainage basin has a unique instantaneous sediment-transport curve reflecting basin conditions for a given period of time. Given such a curve, departures from the curve due to changes in factors affecting sediment transport may be noted and explained.

The daily sediment-transport curve is defined by average values of water discharge and sediment discharge during a 24-hour period. The daily curve takes into account the many fluctuations in streamflow and sediment discharge that commonly occur during a single day. Typically, monthly and annual sediment discharge are computed by the summation of daily sediment-transport values. The daily curve may also reflect changing conditions of a drainage basin, albeit with less sensitivity than the instantaneous curve.

For most practical purposes, instantaneous curves may be used for computing daily, monthly, and annual sediment discharge when data for daily curves are not available. In practice, an instantaneous curve may agree with a daily curve within the limits of accuracy of their definition (Porterfield, 1972, p. 24).

In general, a curve along the right side of an envelope of data points for a drainage basin is the index curve for that basin. Modifications of the drainage basin that accelerate erosion rates cause variations upward and to the left of the index curve. The modifications that decelerate erosion rates cause variations downward and to the right of the index curve. It is noteworthy that no indications of deceleration of erosion rates in the long term have been observed at stations for which long-term data exist.

The envelopes of data points on this sheet, therefore, are background data to be used for comparative purposes as the new data are collected. For example, a decrease in sediment transported by Dry Creek due to the sediment-trapping effects of a proposed reservoir would be readily noted using the data for Dry Creek near Geyserville (station 11-4652.00). An increase in the sediment yield of the Walker Creek basin because of intensified grazing or a rare storm could be observed even on the basis of the limited data for Walker Creek near Tomales (station 11-4608.00). Also, many of the past characteristics of the drainage basins could be interpreted from the existing data by selectively analyzing the data for any period within the period of record. Selective analyses for the variety of needs of users of this report are beyond the scope of this report. However, users of this report are encouraged to inquire as to the possibilities for the uses of the data in the detection of local land-surface changes.

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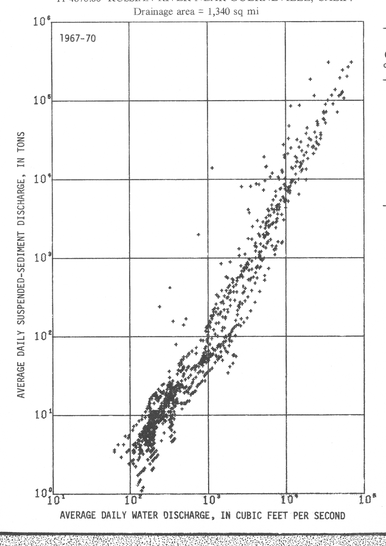
[1]Additional material, termed bedload, moves along in continuous contact with the streambed or bounces along the streambed in short skips or leaps. This material is considerably coarser than the suspended sediment, and bedload discharge may be appreciable. Analyzing bedload discharge is exceedingly complex and has been attempted so infrequently in the study area that representative data are not readily available. Therefore, the erosion rates tabulated on this sheet and based on suspended-sediment discharge are conservative figures lacking a bedload component.

[2]The graphs show only the relations for sediment carried in suspension. Similar graphs can be developed for sediment carried as bedload, given an appropriate sampling program.

[3]A very few points have been left off the lower part of the graphs where the difference between the highest and lowest values of sediment discharge exceeded the six log cycles of the standardized plot. The indices for all the graphs are not the same because of wide differences in drainage-basin area and water and sediment discharge for the basins.

11-4670.00 RUSSIAN RIVER NEAR GUERNEVILLE, CALIF.[1]

Drainage area = 1,340 sq mi



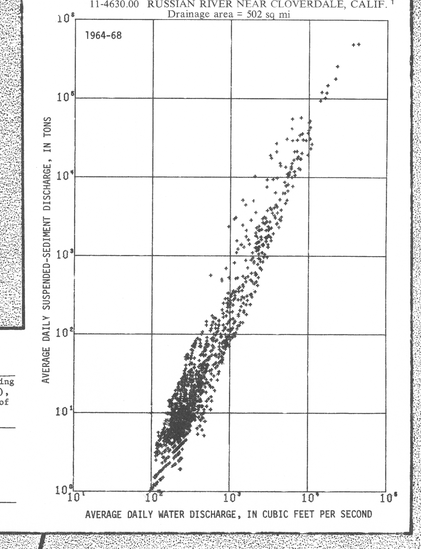
Summary of annual suspended-sediment and water discharge, and average lowering of land surface

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1965	2,164,000	[1]1,400,000	8,510	0.073
1966	1,564,000	[1]4,600,000	3,430	.030
1967	2,242,000	[1]3,900,000	2,910	.025
1968	1,175,000	1,147,000	860	.007
1969	2,753,000	1,746,000	1,300	.011
1970	2,700,000	2,643,000	1,970	.017
1971	904,300	1,102,000	820	.007

[1]Computed on the basis of periodic measurements (Ritter and Brown, 1971, p. 24).

11-4630.00 RUSSIAN RIVER NEAR CLOVERDALE, CALIF.[1]

Drainage area = 502 sq mi



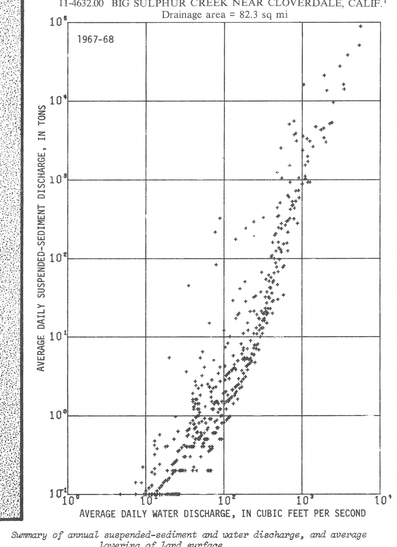
Summary of annual suspended-sediment and water discharge, and average lowering of land surface

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1965	950,400	2,110,000	4,210	0.036
1966	630,100	623,000	1,240	.011
1967	838,200	[1]537,000	1,070	.009
1968	491,800	345,000	690	.006

[1]Estimated (Ritter and Brown, 1971, p. 24).

11-4632.00 BIG SULPHUR CREEK NEAR CLOVERDALE, CALIF.[1]

Drainage area = 82.3 sq mi



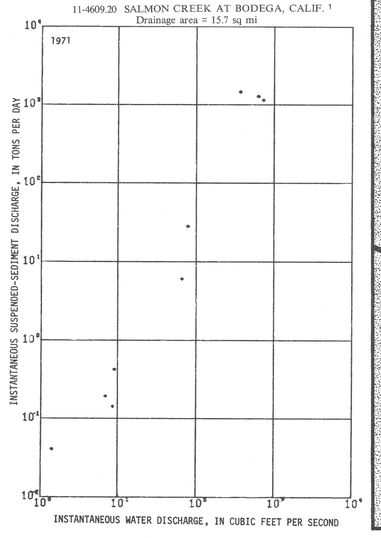
Summary of annual suspended-sediment and water discharge, and average lowering of land surface

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1965	194,200	[1]856,000	10,400	0.090
1966	118,500	[1]260,000	3,160	.027
1967	188,600	295,000	3,580	.031
1968	97,600	103,000	1,260	.011

[1]Computed on the basis of periodic measurements (Ritter and Brown, 1971, p. 24).

11-4609.20 SALMON CREEK AT BODEGA, CALIF.[1]

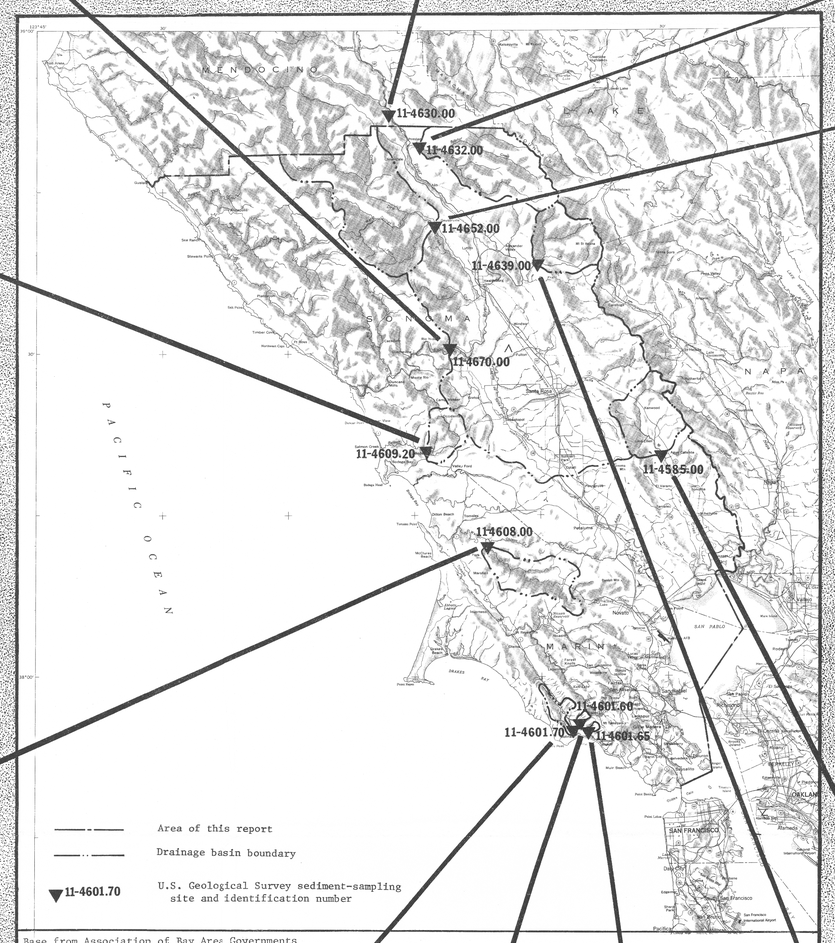
Drainage area = 15.7 sq mi



Summary of annual suspended-sediment and water discharge, and average lowering of land surface

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1971	17,790	[1]8,600	[1]550	0.005

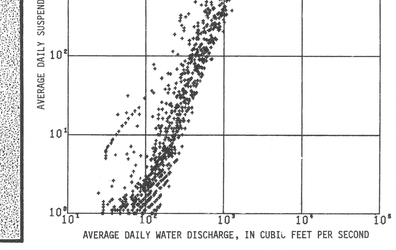
[1]Computed on the basis of periodic measurements.



SEDIMENT-SAMPLING SITES IN MARIN AND SONOMA COUNTIES

11-4652.00 DRY CREEK NEAR GEYSERVILLE, CALIF.

Drainage area = 162 sq mi

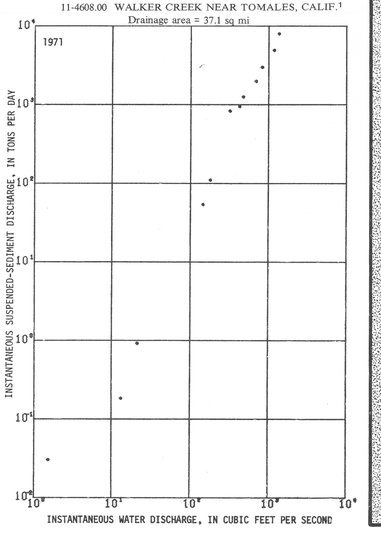


Summary of annual suspended-sediment and water discharge, and average lowering of land surface

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1965	316,000	2,283,000	14,100	0.121
1966	212,100	717,000	4,430	.038
1967	294,200	554,700	3,420	.029
1968	159,000	186,700	1,150	.010
1969	393,300	694,500	4,290	.037
1970	386,900	1,216,000	7,500	.065
1971	111,300	302,200	1,870	.016

11-4608.00 WALKER CREEK NEAR TOMALES, CALIF.[1]

Drainage area = 37.1 sq mi



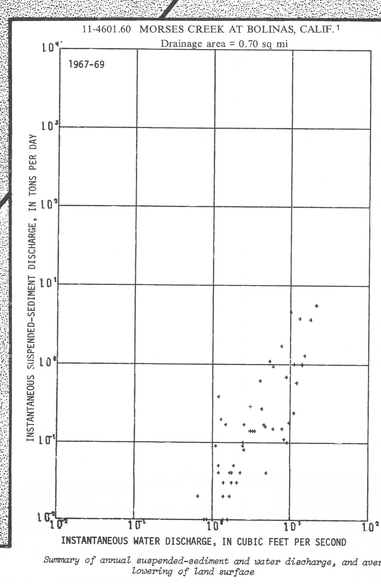
Summary of annual suspended-sediment and water discharge, and average lowering of land surface

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1971	33,620	[1]41,500	[1]1,120	[1]0.010

[1]Computed on the basis of periodic measurements.

11-4601.60 MORSES CREEK AT BOLINAS, CALIF.[1]

Drainage area = 0.70 sq mi



Summary of annual suspended-sediment and water discharge, and average lowering of land surface

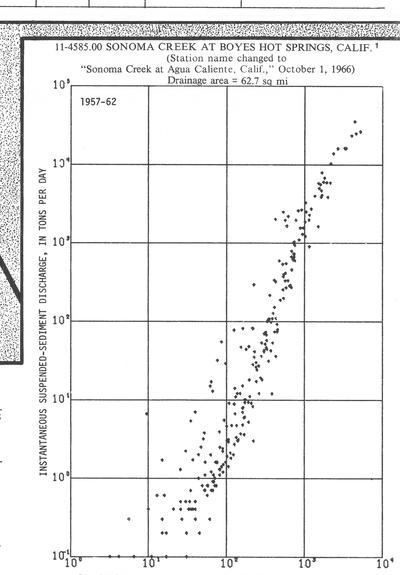
Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1968	159	[1]34	[1]49	--
1969	813			

[1]Computed average for the 2-year period (1968-69) on the basis of periodic measurements.

11-4585.00 SONOMA CREEK AT BOYES HOT SPRINGS, CALIF.[1]

(Station name changed to "Sonoma Creek at Agua Caliente, Calif.," October 1, 1966)

Drainage area = 62.7 sq mi



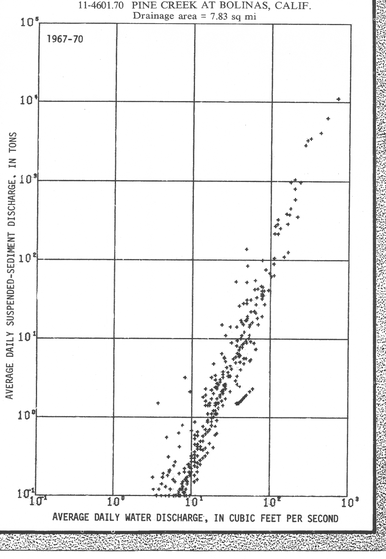
Summary of annual suspended-sediment and water discharge, and average lowering of land surface

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1956	113,800	[2]174,000	[2]2,800	[2]0.024
1957	19,450	4,200	67	.001
1958	105,300	93,000	1,480	.013
1959	19,170	10,500	170	.001
1960	32,540	22,700	360	.003
1961	18,890	2,900	46	.000
1962	41,550	36,200	580	.005

[1]All sediment data in this table, except as noted for the 1956 water year, were computed on the basis of 1957-62 periodic measurements.
[2]Estimated using the 1957-62 sediment-transport curve, and 1956 daily streamflow.

11-4601.70 PINE CREEK AT BOLINAS, CALIF.

Drainage area = 7.83 sq mi

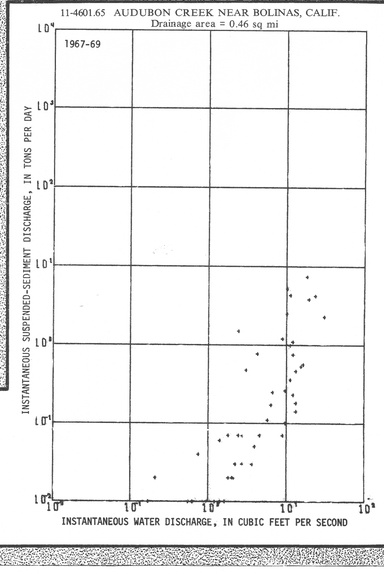


Summary of annual suspended-sediment and water discharge, and average lowering of land surface

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1968	3,640	380	50	--
1969	12,100	7,580	970	0.008
1970	14,100	33,400	4,260	.037

11-4601.65 AUDUBON CREEK NEAR BOLINAS, CALIF.

Drainage area = 0.46 sq mi

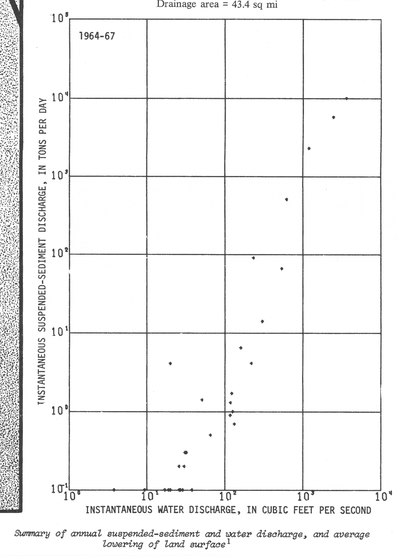


Summary of annual suspended-sediment and water discharge, and average lowering of land surfaces

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1968	Water and suspended-sediment discharge data are insufficient for computation of annual figures.			
1969				

11-4639.00 MAACAMA CREEK NEAR KELLOGG, CALIF.[1]

Drainage area = 43.4 sq mi



Summary of annual suspended-sediment and water discharge, and average lowering of land surface[1]

Water year (ending Sept.30 of year listed)	Water discharge (acre-ft)	Suspended-sediment discharge (tons)	Suspended-sediment yield (tons/sq mi of drainage area)	Average basin-wide lowering of land surface (inches), assuming a unit weight of in-place material at 100 lbs/ft³
1964	23,520	4,700	110	0.001
1965	85,080	60,000	1,400	.012
1966	50,450	23,000	530	.005
1967	91,110	51,000	1,200	.010

[1]All sediment data in this table were computed on the basis of 1964-67 periodic measurements.

Graphs showing sediment-transport data to accompany preliminary map of sediment source and deposition sites and erosional and depositional provinces

SEDIMENT SOURCE AND DEPOSITION SITES AND EROSIONAL AND DEPOSITIONAL PROVINCES, MARIN AND SONOMA COUNTIES, CALIFORNIA

By
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1974

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