DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Miscellaneous Field Studies
Map MF-515 (Sheet 2 of 3)

URBANIZATION AND CHANGES IN SEDIMENT YIELD

Almost any activity by man which displaces soil and vegetal covering on the landscape cannot avoid causing at least a temporary and local increase in the erosion potential of the disturbed area. In a region of intensive urban development where gross alterations of the landscape occur, the increase in erosion potential is especially pronounced.

Urban development and its effects on erosion and sediment yield has been studied for the Colma Creek basin, a 16.3-square-mile urban industrial area on the east side of the San Francisco peninsula (Knott, 1973, p. 6). The following observations partly describe the nature of sedimentation in the basin:

(1) An erosion cycle exists wherein erosion rates during construction periods increase dramatically above quasi-equilibrium rates characteristic of the previous landscape. Excessive erosion persists throughout the construction period until a new, almost impervious landscape dominated by streets, roof tops, gutters, and sewers is established. Erosion rates then may decline to values as low or lower than those experienced prior to construction. The interval of excessive erosion is short for an isolated unit of land and stream channel, but progressive development of a large drainage area will affect downstream reaches of channel for a longer period (Wolman, 1967, p. 385-386).

(2) Sediment yields from specific land-use types within the basin indicate the influence of progressive development. These yields vary considerably, however, with the amount and intensity of rainfall and other active factors. The following table summarizes land use and sediment yield for the Colma Creek basin for the period October 1, 1968, to September 30, 1970.

ANNUAL SEDIMENT YIELDS FROM DIFFERENT LAND-USE AREAS UPSTREAM FROM THE COLMA CREEK GAGING STATION
(Drainage area = 10.8 sq mi)
[Adapted from Knott, 1973, p. 46]

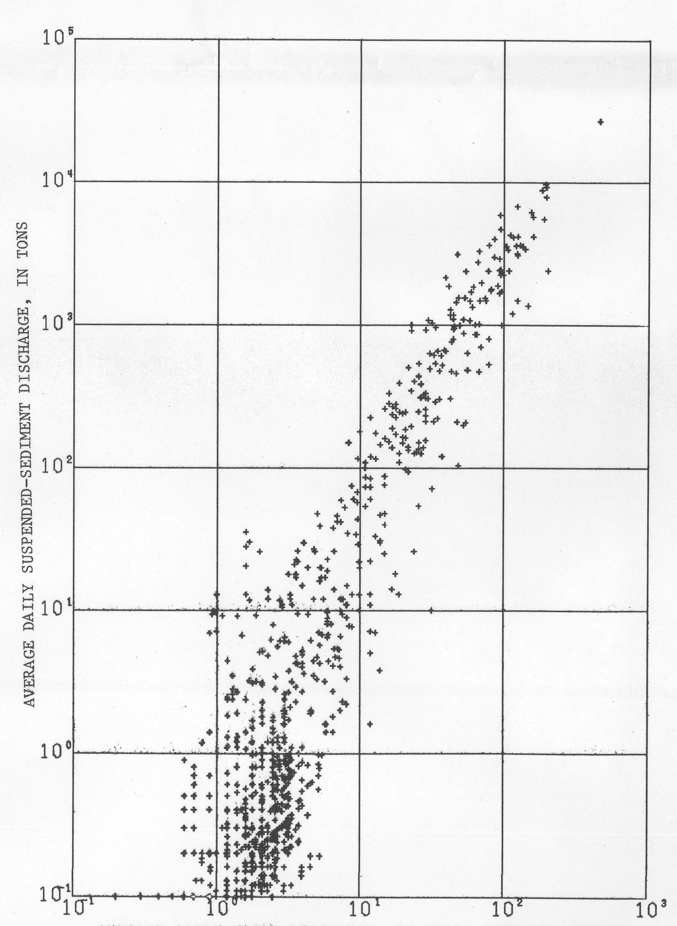
Year	Land use	Sediment yield (tons)	Percent of total sediment yield	Land-use percent of total area
1969	Vegetated	2,000	2.4	41
	Urban	4,820	5.8	40
	Exposed soil (>5 years of exposure)	16,190	19.6	5
	Exposed soil (<5 years of exposure)	59,470	72.0	14
1970	Vegetated	1,410	3.8	42
	Urban	3,750	10.2	46
	Exposed soil (>5 years of exposure)	8,990	24.4	4
	Exposed soil (<5 years of exposure)	22,660	61.6	8

(3) A significant part of the sediment eroded from areas under development is trapped in debris basins. During construction, the basins periodically fill with sediment that is subsequently dredged and used for fill on adjacent lands or transported out of the drainage system. Eventually, the debris basins are allowed to fill and become a foundation for further development as the upstream drainage becomes stabilized.

(4) As the basin is altered and natural stream channels become obliterated, runoff seeks the system of gutters, pipes, and channels newly implanted in the developed area. The runoff therefore is not attenuated by infiltration into soil and other temporary basin storage and a given runoff thus will occur in a shorter period of time. The reduced infiltration capacity resulting from development of impervious surfaces leads not only to a quicker response of runoff to precipitation, but also to the more frequent production of minor flood peaks and an accentuation of major flood peaks (Crippen, 1969, p. 65-98). These flows are then capable of more efficient transport of sediment downstream from developed areas and cause increased erosion of unprotected streambanks and streambeds. Lined channels resist this erosion, but must accommodate higher flood peaks than would be expected for the natural drainage system.

(5) Many fragmentary products of urban development enter the stream system and move in the streams in suspension or by adherence to sediment particles. These materials include various types of debris such as asphalt, glass, metals, rubber, oils, plastics, paper products, and other cultural byproducts. These materials are transported from urbanized areas and accumulate with natural sediment in depositional areas downstream.

(6) The following table shows several relations among water and sediment discharge in the Colma Creek basin. The sediment yields, in tons per square mile, are among the highest in the study area and reflect the excessive erosion associated with this urban construction.



RELATION OF WATER DISCHARGE TO SUSPENDED-SEDIMENT DISCHARGE, COLMA CREEK AT SOUTH SAN FRANCISCO, CALIFORNIA

SUMMARY OF ANNUAL SUSPENDED-SEDIMENT AND WATER DISCHARGE, AND AVERAGE LOWERING OF LAND SURFACE
Colma Creek at South San Francisco, California
USGS station 11-1627.20 — Drainage area = 10.9 sq mi

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/ft^3
1966	3,360	32,230	2,960	0.025
1967	7,220	122,200	11,200	.096
1968	3,800	35,740	3,280	.028
1969	7,710	65,120	5,970	.051
1970	5,750	24,880	2,280	.020
Totals	27,840	280,200		.220

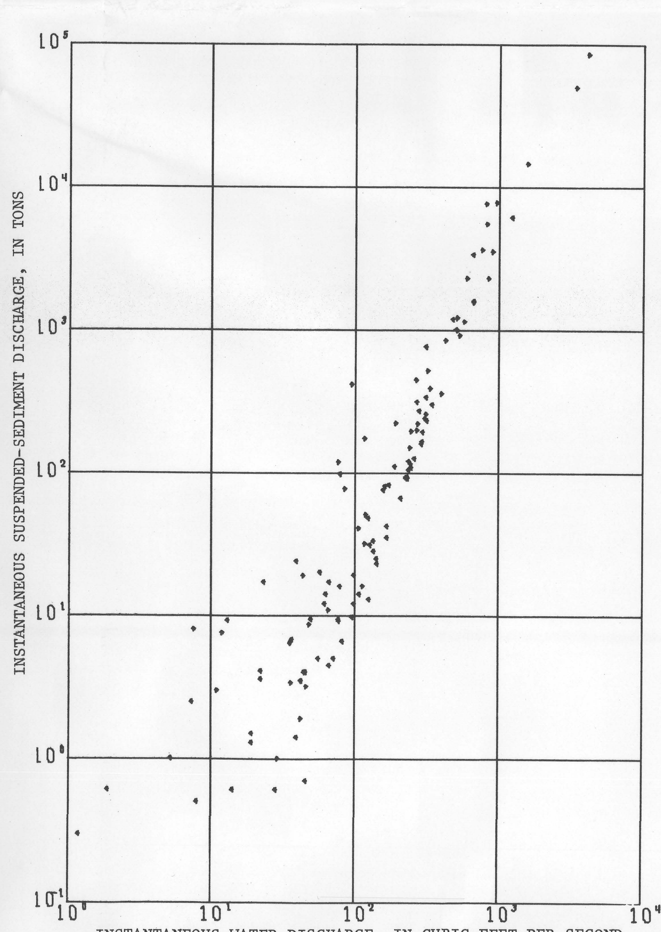
SEDIMENT YIELD TO UPPER CRYSTAL SPRINGS RESERVOIR, 1878-1935[1]

Drainage area in square miles: Total	Net[4]	Period (years)	Sediment yield based on sediment accumulation in reservoir: Ac-ft/sq mi/yr	Tons/sq mi/yr[2,3]
13.3	12.0	57.8	1.41	2,300

[1]Data from U.S. Department of Agriculture (1960, p. 50).
[2]Based upon a dry specific weight of 75 pounds per cubic foot. Specific weight is assumed, and not given by U.S. Department of Agriculture (1960).
[3]Additional sediment, principally fine material, may be carried downstream from reservoirs by release flows and overflows at spillways during storm periods, and thus is unmeasured.
[4]Total drainage area upstream from dam minus surface area of reservoir at spillway elevation.

SUMMARY OF ANNUAL SUSPENDED-SEDIMENT AND WATER DISCHARGE, AND AVERAGE LOWERING OF LAND SURFACE
San Francisquito Creek at Stanford, California
USGS station 11-1645.00 — Drainage area = 23.0 sq mi

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/ft^3
1962	4,630	1,880	81.7	0.001
1963	16,600	18,700	813	.007
1964	1,880	1,100	47.8	---
1965	15,960	10,500	457	.004
1966	4,470	1,100	47.8	---
1967	28,970	50,600	2200	.019
1968	4,200	2,700	117	.001
1969	31,380	34,200	1490	.013
Totals	108,100	120,800		.045



RELATION OF WATER DISCHARGE TO SUSPENDED-SEDIMENT DISCHARGE, SAN FRANCISQUITO CREEK AT STANFORD, CALIFORNIA

SCALE 1:125 000
CONTOUR INTERVAL 200 FEET
DOTTED LINES REPRESENT 40-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL
DEPTH CURVES AND SOUNDINGS IN FEET—DATUM IS MEAN LOWER LOW WATER

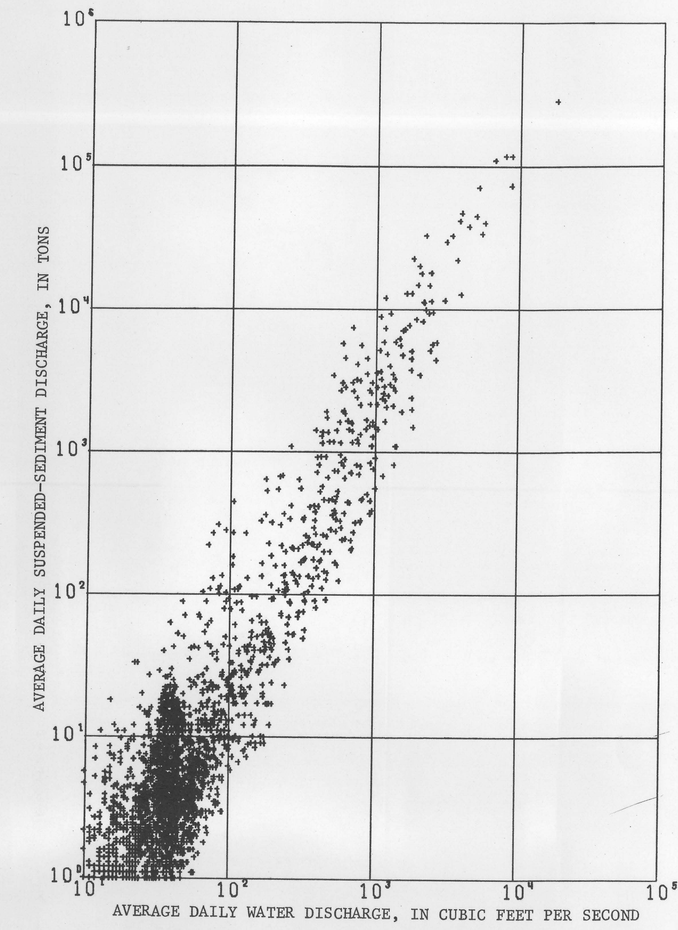
SEDIMENT DEPOSITION BY ALAMEDA CREEK

Alameda Creek drains an area of 633 square miles, much of which is outside the study area to the east. However, the sediment derived from the Alameda Creek basin passes through Niles Canyon and is deposited on the bay plains and in San Francisco Bay. During at least the past 5,000 years, or since the San Francisco Bay reached its present level, sediment deposits of Alameda Creek have built an extensive, gently-sloping alluvial fan upon which the cities of Fremont, Union City, and Newark are built. In past centuries, Alameda Creek has shifted constantly, sweeping back and forth across the alluvial fan from a fixed apex at the mouth of Niles Canyon and spreading its sediment across the plain during periods of flooding. Currently, Alameda Creek is routed through flood-control channels both north of Union City and, farther south, into Coyote Hills Slough. In order that these channels perform their intended function of carrying floodwaters away from urbanized areas, they must also allow a long-term net transport of sediment to the bay without deposition. Otherwise, frequent dredging operations are required to maintain the design capacities of the channels.

Alameda Creek discharged more than 1,770,000 tons of sediment to its flood-plain channels and the San Francisco Bay from October 1957 to September 1970. Apparently, much of this sediment has been retained in the flood-plain channels or was redistributed by dredging or channel construction operations. Aerial photography in March 1971 and subsequent field observations showed little noticeable deposition at the channel mouths, considerable growth of vegetation in the channels, and low-flow stream patterns within the channels characteristic of local redistribution of deposited sediment. Water stage-discharge relations at lower flows indicate a definite aggradation of the channels, although the high flows which might affect or might be affected by these aggradations have not been observed since flooding in 1958.

It is improbable that there is any unique or determinate relation among sediment transport and deposition, and water discharge for the existing (and progressively changing) Alameda Creek stream, canal, and reservoir system. Maddock (1969, p. A69) states the following:

> "Clearly, there is a great range of possible adjustments a stream may make yet remain in equilibrium as far as slope is concerned. These are all associated with changes in the size distribution of the sediment discharge or changes in the bed form. The easily observed behavior factors of an alluvial channel--scour, fill, bank erosion, overbank flow or anastomosis--are all related to these two complex phenomena. In view of this complexity, it will never be possible for an alluvial channel to remain stable and still pass a wide range of discharges of sediment and water. It appears, however, that given a good appraisal of local behavior, much can be done to mitigate the ill effects of any specific set of conditions."



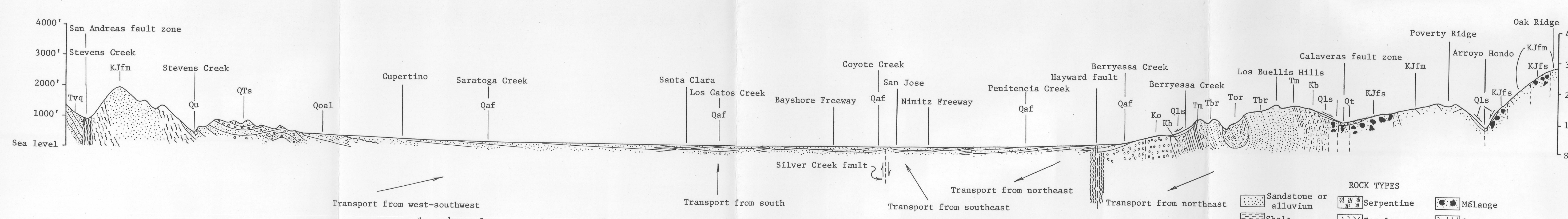
RELATION OF WATER DISCHARGE TO SUSPENDED-SEDIMENT DISCHARGE, ALAMEDA CREEK NEAR NILES, CALIFORNIA

SUMMARY OF ANNUAL SUSPENDED-SEDIMENT AND WATER DISCHARGE, AND AVERAGE LOWERING OF LAND SURFACE
Alameda Creek near Niles, California
USGS station 11-1790.00 — Drainage area = 633 sq mi

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/ft^3
1957	7,880	2,340	3.7	---
1958	245,700	844,900	1330	0.011
1959	14,660	20,860	3.3	---
1960	11,940	16,180	25.6	---
1961	649	13.9	.02	---
1962	34,740	40,550	64.0	.001
1963	66,670	180,100	285	.002
1964	22,940	7,090	11.2	---
1965	85,620	109,800	173	.002
1966	26,320	6,330	10.0	---
1967	140,000	287,500	454	.004
1968	41,510	9,200	14.5	---
1969	110,100	161,800	256	.002
1970	58,120	87,540	138	.001
Totals	866,800	1774,000		.023

SEDIMENT DISCHARGE AND SEDIMENT YIELD

Quantitative information on the sediment system is derived primarily from sediment-discharge data collected at U.S. Geological Survey gaging stations and from reservoir sedimentation surveys. The relation between water discharge and sediment discharge at the Survey stations is shown in conjunction with a tabulation of annual water and sediment discharges. Sediment yield is converted into a landscape-denudation rate expressed as a uniform lowering of the land surface of the basin in inches. Obviously, no surface is lowered uniformly, but the denudation rate serves as a basis for comparing the general magnitudes of geologic change among subunits of the study area. The assumed unit weight of 100 pounds per cubic foot for in-place material is arbitrary and should be adjusted where precise data are available.



Soils	West bay uplands	Alluvial fans and flood plains	Basin soils	Alluvial fans and flood plains	Diablo Range upland soils			
Vegetation communities	Fog belt evergreen forest; Broad leaf forest	Grasslands	Unclassified (urban area)	Agriculture	Grasslands			
Land use	Multiuse forest	Rural-residential	Urban	Urban-agriculture	Agriculture-grazing			
Mean annual rainfall, in inches	>40	35-40	30-35	25-30	20-25	15-20	<15	15-20 / 20-25 / 25-30
Erodibility	High, Low	High	Moderate	Low	Moderate, Extreme, Moderate	Extreme, Moderate	High, Extreme, High	

Geology by L. E. Jackson, Jr., modified after Cotton (1972), Crittenden (1951), and unpublished mapping by E. E. Brabb and Gertrude Edmonston.

SCHEMATIC CROSS SECTION FROM STEVENS CREEK NORTHEASTWARD TO OAK RIDGE SHOWING INTERRELATIONS AMONG GEOLOGY AND TOPOGRAPHY, SOILS, VEGETATION COMMUNITIES, LAND USE, RAINFALL, AND ERODIBILITY. THE VARIOUS FACTORS ARE DISCUSSED IN THE EXPLANATORY PAMPHLET, PAGES 3-14, AND THE GEOLOGIC SYMBOLS ARE EXPLAINED IN TABLE 2, PAGE 6.

PRELIMINARY MAP OF EROSIONAL AND DEPOSITIONAL PROVINCES AND DESCRIPTIONS OF SEDIMENT-TRANSPORT PROCESSES IN THE SOUTH AND CENTRAL SAN FRANCISCO BAY REGION, CALIFORNIA

BY
WILLIAM M. BROWN III AND LIONEL E. JACKSON, JR.
1973

Explanatory pamphlet accompanies map sheet