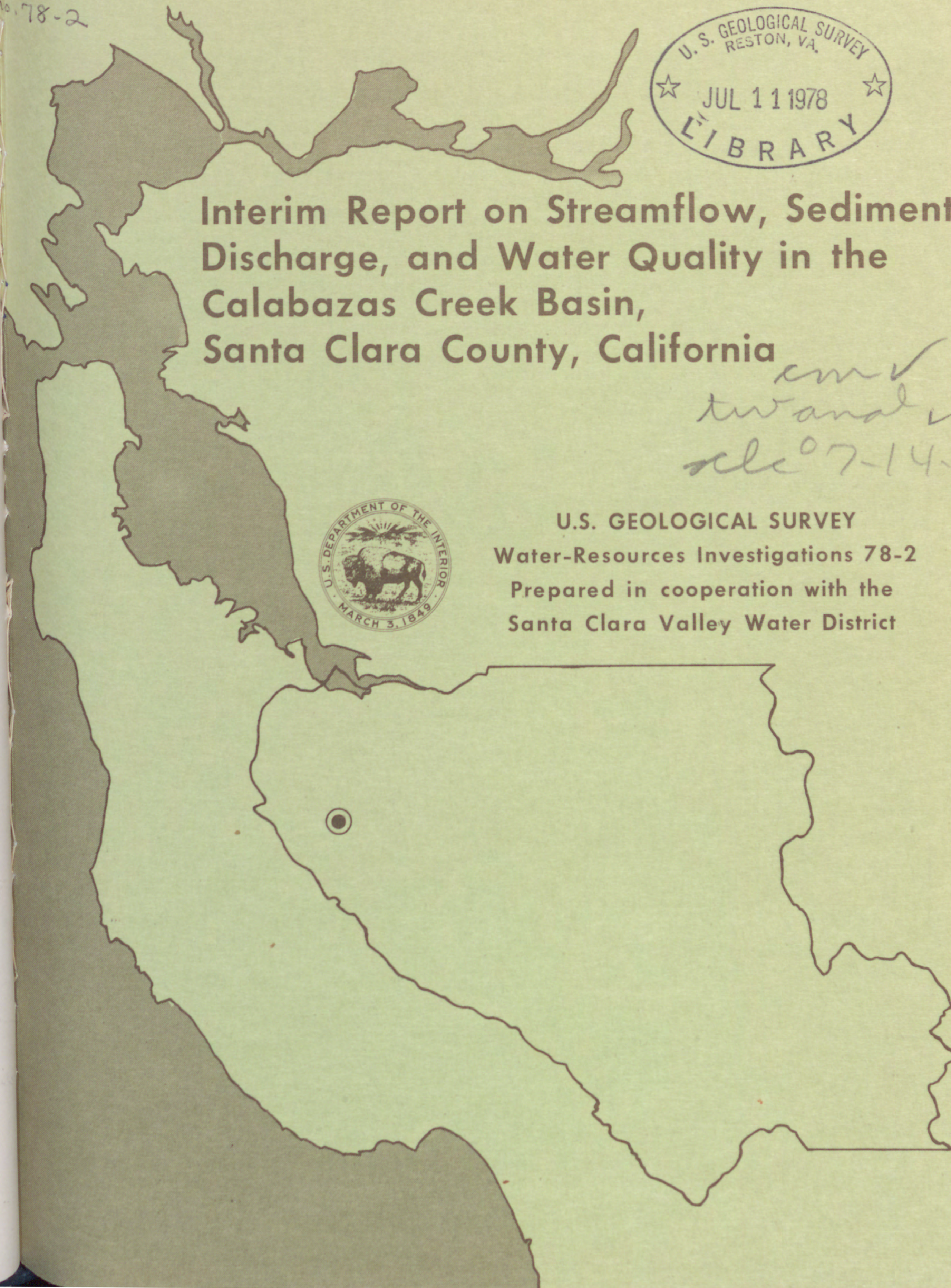
Interim Report on Streamflow, Sediment Discharge, and Water Quality in the Calabazas Creek Basin, Santa Clara County, California



U.S. GEOLOGICAL SURVEY

Water-Resources Investigations 78-2

Prepared in cooperation with the Santa Clara Valley Water District

BIBLIOGRAPHIC DATA SHEET	1. Report No.	2.	3. Recipient's Accession No.
4. Title and Subtitle INTERIM REPORT ON STREAMFLOW, SEDIMENT DISCHARGE, AND WATER QUALITY IN THE CALABAZAS CREEK BASIN, SANTA CLARA COUNTY, CALIFORNIA			5. Report Date April 1978 6.
7. Author(s) J. M. Knott, G. L. Pederson, and R. F. Middelburg			8. Performing Organization Rept. No. USGS/WRI 78-2
9. Performing Organization Name and Address U.S. Geological Survey, Water Resources Division California District 345 Middlefield Road Menlo Park, California 94025			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address U.S. Geological Survey, Water Resources Division California District 345 Middlefield Road Menlo Park, California 94025			13. Type of Report & Period Covered Interim 14.

15. Supplementary Notes

Prepared in cooperation with the Santa Clara Valley Water District

16. Abstracts

Streamflow, sediment-discharge, and water-quality data were collected in an area of Santa Clara County, Calif., to determine base-line conditions prior to possible urbanization. Most of the study area is nonurban (93 percent). Precipitation was representative of a very wet year (1973) and 2 years of above average rainfall (1974 and 1975). Most of the total annual sediment was transported during a few days each year. Maximum daily sediment discharge in a given year ranged from 23 to 62 percent of the annual total. Analyses of water quality indicated significant concentrations of certain heavy metals and pesticides during high flows. A parametric rainfall-runoff model was used to simulate discharge hydrographs at stations in the study area. Simulated values of runoff volume and peak discharge during observed storms were generally within 35 percent of values observed during large storms; simulation of small storms produced less satisfactory results.

17. Key Words and Document Analysis. 17a. Descriptors

*Model Studies, *Rainfall-Runoff Relationships, *Sediment Discharge, *Urbanization, California, Heavy Metals, Pesticides, Sediment Transport, Suspended Sediment, Water Quality

17b. Identifiers/Open-Ended Terms

Santa Clara County

17c. COSATI Field/Group

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
No restriction on distribution	UNCLASSIFIED	47
	20. Security Class (This Page) UNCLASSIFIED	22. Price

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Santa Clara Valley Water District

April 1978

UNITED STATES DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

Metric units are used in this report, except for the contours of figure 1. For those readers who may prefer to use English units rather than metric units, the conversion factors for the units used in this report are listed below.

Metric	*Multiply by*	*English*
g/m^3 (grams per cubic meter)	6.242×10^{-5}	lb/ft^3 (pounds per cubic foot)
km (kilometers)	6.215×10^{-1}	mi (miles)
km^2 (square kilometers)	3.861×10^{-1}	mi^2 (square miles)
m (meters)	3.281	ft (feet)
m^2 (square meters)	1.076×10^1	ft^2 (square feet)
m^3 (cubic meters)	3.531×10^1	ft^3 (cubic feet)
m^3/s (cubic meters per second)	3.531×10^1	ft^3/s (cubic feet per second)
mm (millimeters)	3.937×10^{-2}	in (inches)
t (tonnes)	1.102	tons (short)
t/km^2 (tonnes per square kilometer)	2.855	ton/mi^2 (tons per square mile)

INTERIM REPORT ON STREAMFLOW, SEDIMENT DISCHARGE, AND WATER QUALITY

IN THE CALABAZAS CREEK BASIN, SANTA CLARA COUNTY, CALIFORNIA

By J. M. Knott, G. L. Pederson, and R. F. Middelburg

SUMMARY AND RECOMMENDATIONS FOR FURTHER STUDY

Streamflow, sediment-discharge, and water-quality data are being collected in the Calabazas Creek basin, Santa Clara County, Calif., to determine annual water and sediment discharge at base-line conditions that are representative of a basin prior to urbanization. Results of the first 3 years of the study (1973-75) are given in this report.

Climatic conditions during this period were representative of a very wet year (1973) and 2 years of above-average rainfall (1974 and 1975).

Daily water and sediment discharge were monitored at three primary stations in the basin, and periodic measurements were made at five secondary stations during selected storms. Most of the total annual sediment discharge at each station was transported during a few days each year. Maximum daily sediment discharge in a given year ranged from 23 to 62 percent of the annual total. Daily water discharge at the gaging station Calabazas Creek at Rainbow Drive, near Cupertino (11169616), ranged from no flow to 3.31 m^3/s. Streamflow at this location was significantly augmented during low flow by diversion of water from the South Bay Aqueduct.

Annual sediment discharge at Calabazas Creek at Rainbow Drive (11169616) was 4,900 t in 1974 and 9,570 t in 1975. A large quantity of sediment was trapped in a debris basin at Comer Drive upstream from this station during both years. If this sediment had not been trapped, sediment discharge at the station would have been about 35 percent greater in 1974 and 30 percent greater in 1975. Most of the trapped sediment consists of sand and gravel that would probably have been deposited in the Calabazas Creek channel downstream from the station.

Monitoring of sediment transported by tributaries upstream from the debris basin at Comer Drive showed that Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga (11169588) probably transports eight or nine times as much sediment per square kilometer as other upstream tributaries. This tributary is apparently contributing 50 percent of the sediment trapped in the debris basin.

Analyses of water quality at primary stations suggested a classification of the streams as having magnesium-calcium bicarbonate or mixed-cation bicarbonate water. The water at all stations varied from moderately hard at medium to high flows to very hard at low flows.

Significant concentrations of chromium, mercury, and lead were detected during some high flows. Pesticides were found in insignificant concentrations at two upstream stations (11169580 and 11169600). Significant concentrations of pesticides were found during high flows at Calabazas Creek at Rainbow Drive (11169616).

Annual surveys of stream-channel geometry at 14 sites showed that changes in relative depth and bed elevation in rural areas were of the same general magnitude as those in urban areas. Large changes in the channel were observed at two sites (C5 and C6) upstream from the debris basin at Comer Drive.

Hydrologic data collected at one precipitation station (11169575) and two water discharge stations (11169580 and 11169600) were used to simulate rainfall-runoff characteristics. Two existing simulation models were combined and modified to define hydrologic conditions in the Calabazas Creek basin. The resulting model is based largely on antecedent-moisture accounting, infiltration, and the physical characteristics of the basin. Simulated values of runoff volume and peak discharge during observed storms were generally within 35 percent of observed values during large storms. Simulation of small storms produced less satisfactory results.

Because urban development in the basin during the period 1973-75 was less than that anticipated at the beginning of the study, few changes in the hydrology of the basin were observed. The scope of the study could, therefore, be reduced substantially.

Early emphasis should be placed on collecting data needed to complete an adequate definition of base-line conditions in the Calabazas Creek basin. Work suggested through the 1978 fiscal year would include:

1. Operation of the rainfall and streamflow stations.
2. Monitoring of sediment discharge at primary and secondary stations during selected storm periods.
3. Water-quality monitoring at primary stations.

After the 1978 fiscal year, the study should be oriented toward using information already obtained to estimate probable effects of urbanization in other areas in Santa Clara County. In the event that urbanization in the Calabazas Creek basin increases significantly in the future, consideration should be given to documenting any changes in the hydrology of the basin.

INTRODUCTION

Since the end of World War II, urbanization has proceeded at a rapid pace throughout much of Santa Clara County, Calif. In recent years urban development has spread from the flat valley areas into the foothills, where erosion problems are likely to be more severe. Future development in the foothills, associated with an increase in impervious area, could result in increased flooding in downstream urban areas. Excavation at development sites could result in accelerated erosion in foothill areas and subsequent sediment deposition in storm drains and at sites where gradients are reduced. In addition, the water quality in existing urban areas may change with increased urbanization.

The objectives of this study are to:

1. Document changes in water and sediment discharge and water-quality characteristics that are associated with urban development in the Calabazas Creek basin (fig. 1).
2. Estimate the probable effects of urbanization on the hydrology of other areas in Santa Clara County.
3. Provide regional planners with reliable criteria for designing future developments in foothill areas.

This report, prepared in cooperation with the Santa Clara Valley Water District, is a summary of hydrologic data obtained during the initial 3 years of the study (1973-75). All years referred to in this report are water years, unless otherwise noted. A water year is the 12-month period October 1 through September 30 and is designated by the calendar year in which it ends.

DESCRIPTION OF THE AREA

General Features

The Calabazas Creek basin, as referred to in this report, includes the 10.31-km^2 drainage area upstream from the gaging station Calabazas Creek at Rainbow Drive, near Cupertino (station 11169616, fig. 1). The basin lies in the western foothills of the Santa Clara Valley near Cupertino, Saratoga, and western San Jose. The terrain is moderately steep, with elevations ranging from about 80 m at Rainbow Drive to about 600 m at Table Mountain.

The major tributary of Calabazas Creek is Prospect Creek, which is in the northern part of the basin. All other tributaries in the basin are unnamed. Calabazas Creek and its tributaries are intermittent streams.

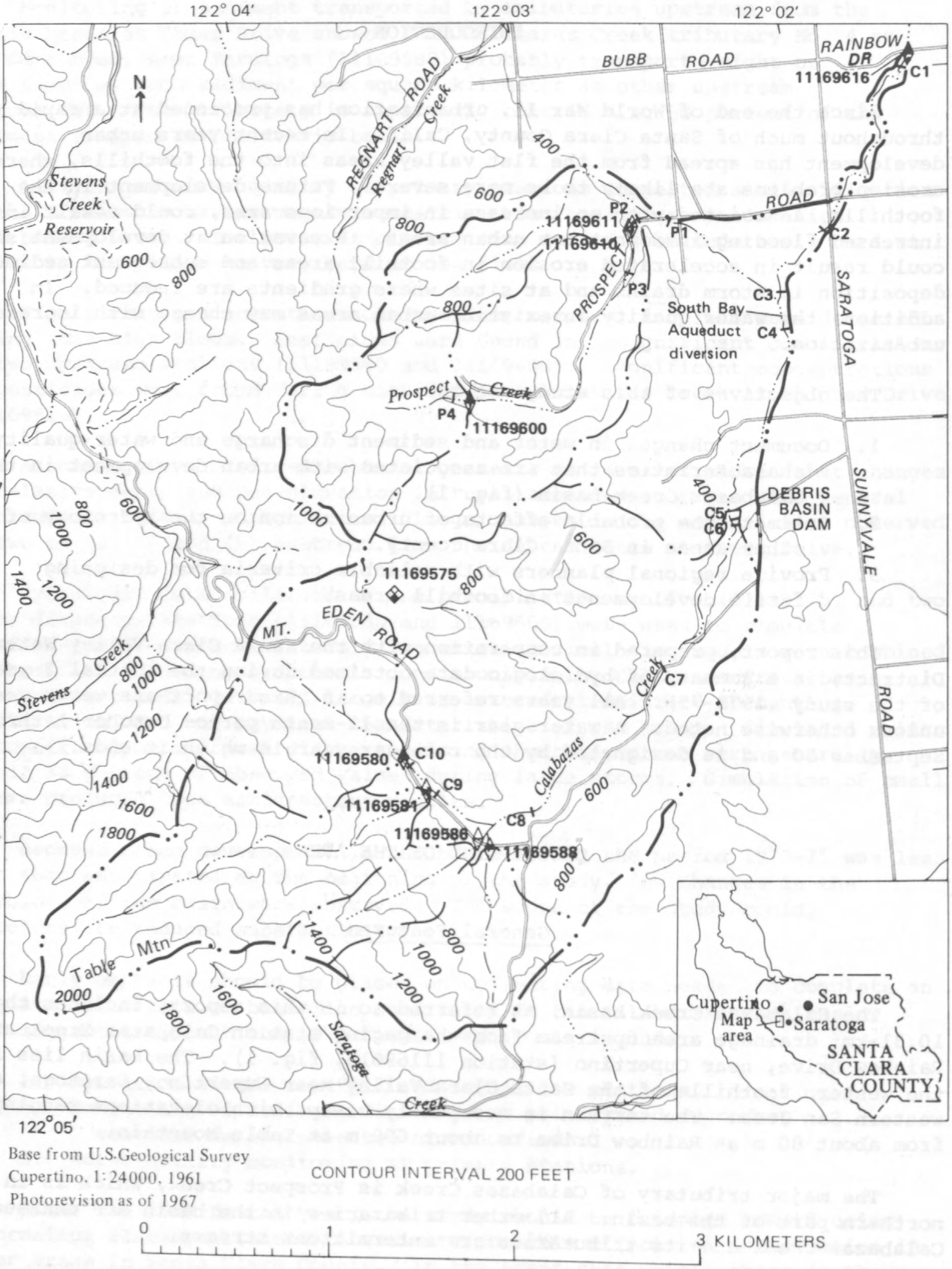


FIGURE 1.--Hydrologic-data monitoring stations and channel-geometry survey sites in the Calabazas Creek basin.

EXPLANATION

U.S. GEOLOGICAL SURVEY SURFACE WATER AND SEDIMENT STATION LOCATION AND NUMBER

11169600 ▲ Continuous-record gaging station

11169581 △ Measurement station without a gage

11169586 ▽ Sediment-measurement station

11169575 ◈ PRECIPITATION STATION AND NUMBER

C8 ⌐ SURVEYED CHANNEL CROSS-SECTION SITE AND LETTER AND NUMBER– P, Prospect Creek subbasin; C, Calabazas Creek basin

—— •• —— BASIN BOUNDARY

—— • • —— SUBBASIN BOUNDARY

At the outset of this study (1973) most of the basin was rural in character (fig. 2), with the area covered by rangeland and forest land (47 percent), orchards and vineyards (35 percent), and cropland or pasture (10 percent). About 6 percent of the area was urbanized. About 200 homes are scattered throughout the foothills. The rest of the basin (2 percent) consists of a golf course, some small ponds, and several gravel pits. Between 1973 and 1975 a small additional part of the basin became urbanized (less than 1 percent).

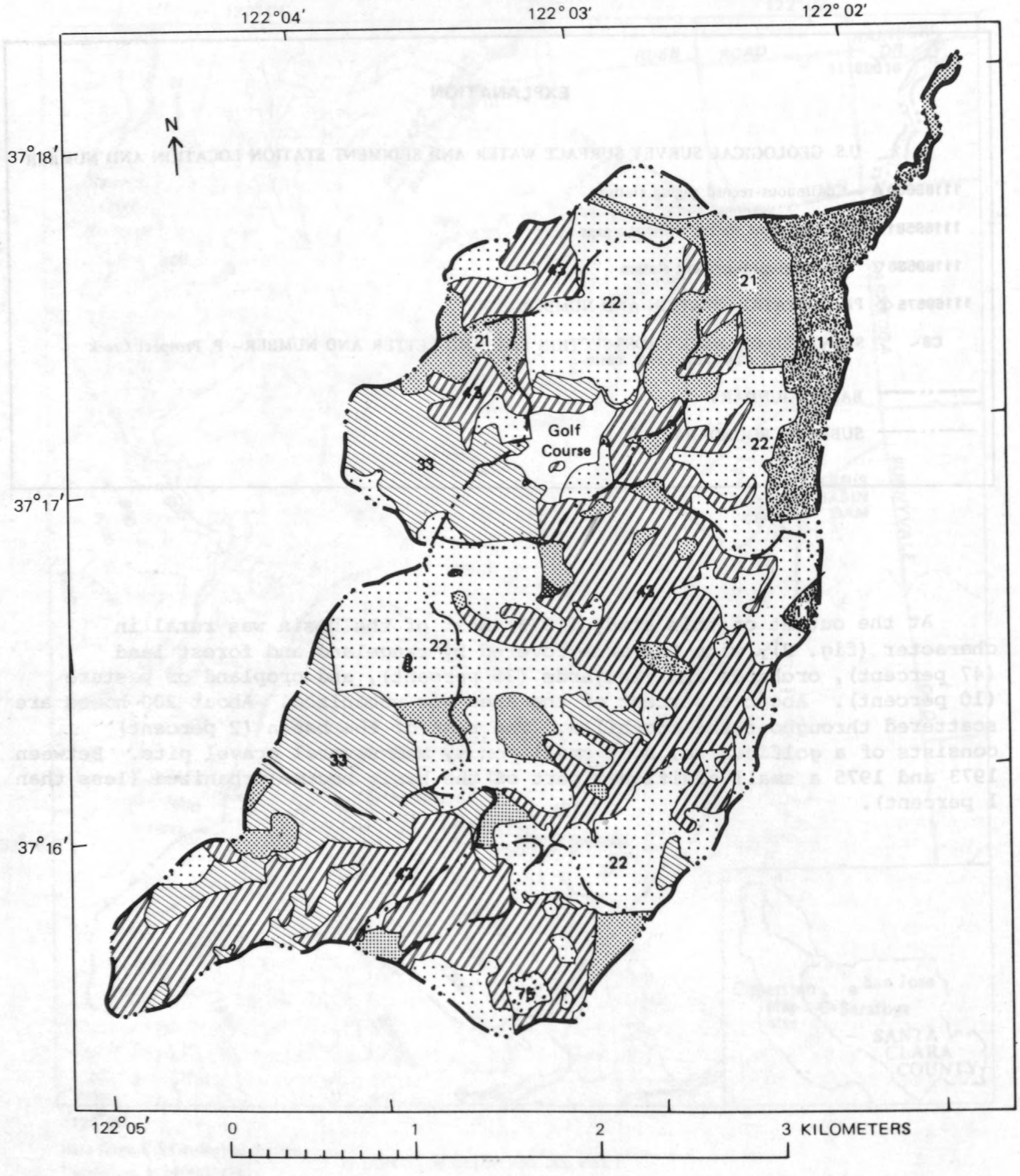
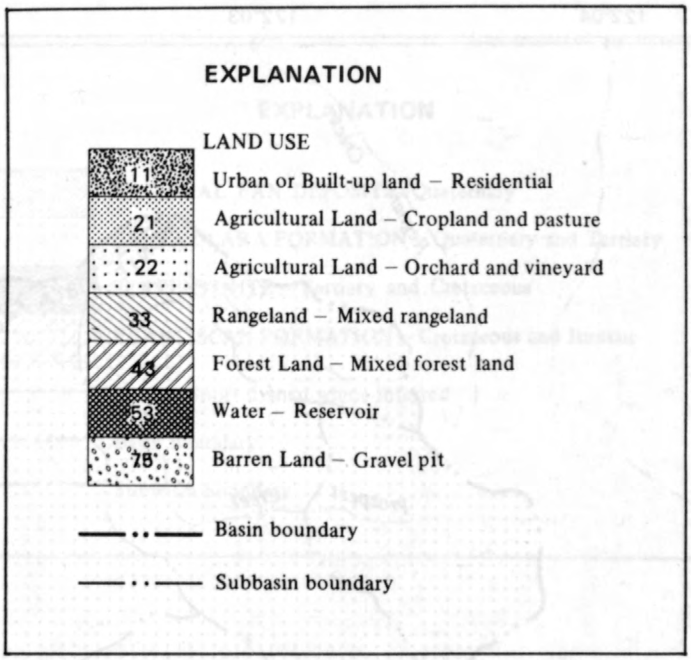


FIGURE 2.--Generalized land use, 1973.
[Land-use classifications and numbers from Anderson and others, 1976]



Geology

Geologic maps by Sorg and McLaughlin (1975) indicate that the Calabazas Creek basin upstream from Rainbow Drive is underlain primarily by the Franciscan and Santa Clara Formations, separated by the Berrocal fault (fig. 3).

The Franciscan Formation ranges in age from Late Jurassic to Late Cretaceous and includes rock units of metashale, metagraywacke, and greenstone. Soils are generally shallow, and rock outcrops are prominent at many locations. Landslide areas within the Franciscan Formation are locally significant in shear zones and near faults. Serpentinized rocks occur as pervasively sheared lenticular bodies within fault and shear zones cutting the Franciscan Formation.

The Santa Clara Formation is late Pliocene to early Pleistocene in age and consists of semiconsolidated to moderately lithified conglomerate, sandstone, siltstone, and mudstone. Landslide deposits are abundant in areas underlain by the Santa Clara Formation, especially where soils are underlain by poorly consolidated siltstone and mudstone. Soils are generally deep and well drained.

Alluvial fan deposits occur in the lower part of the basin. These deposits generally consist of poorly sorted gravel, sand, silt, and clay.

A generalized distribution of the Franciscan and Santa Clara Formations and the downstream alluvium is shown in figure 3. The many landslides and minor alluvial deposits are not shown. Only the major outcrop of serpentinite is shown.

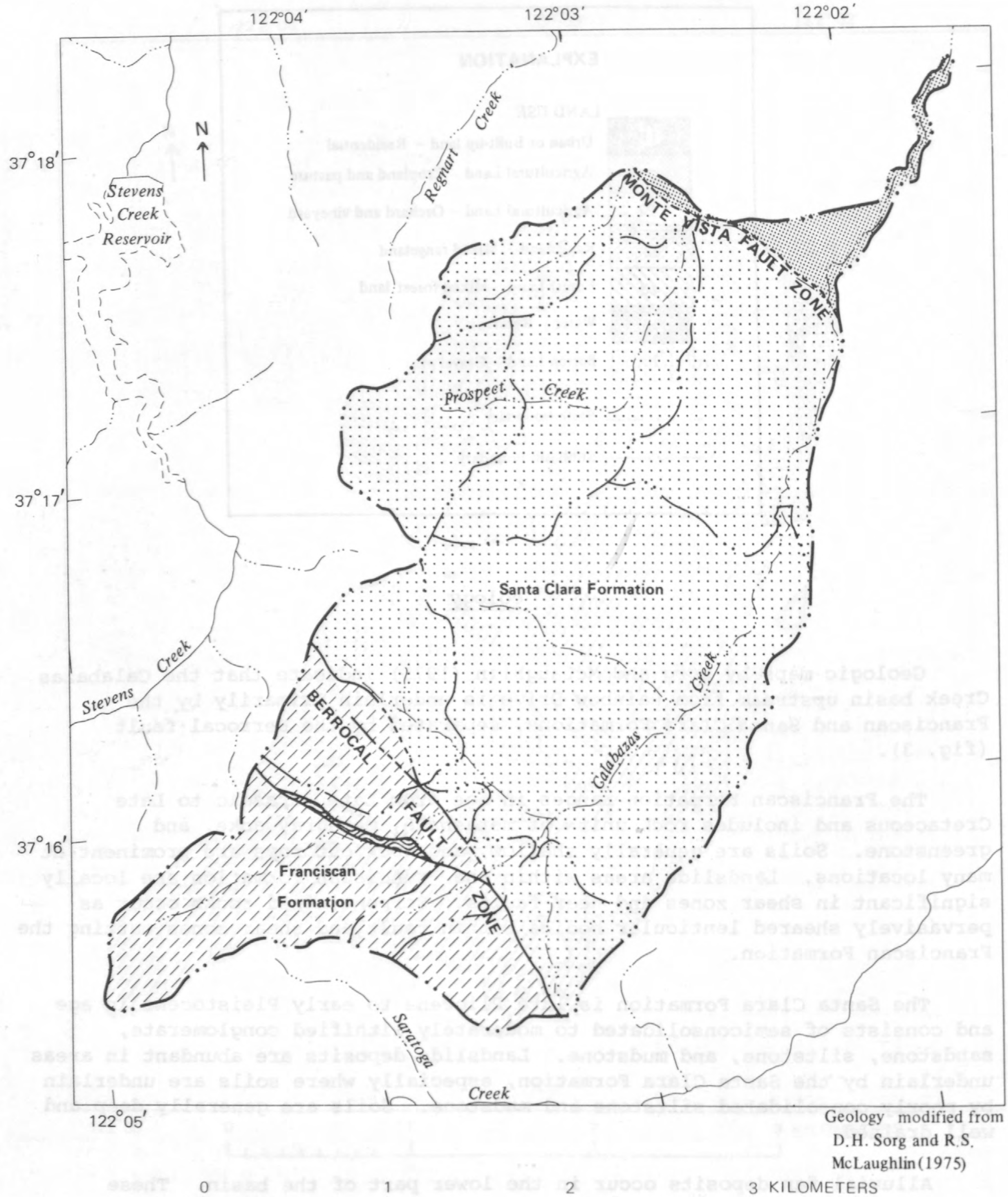
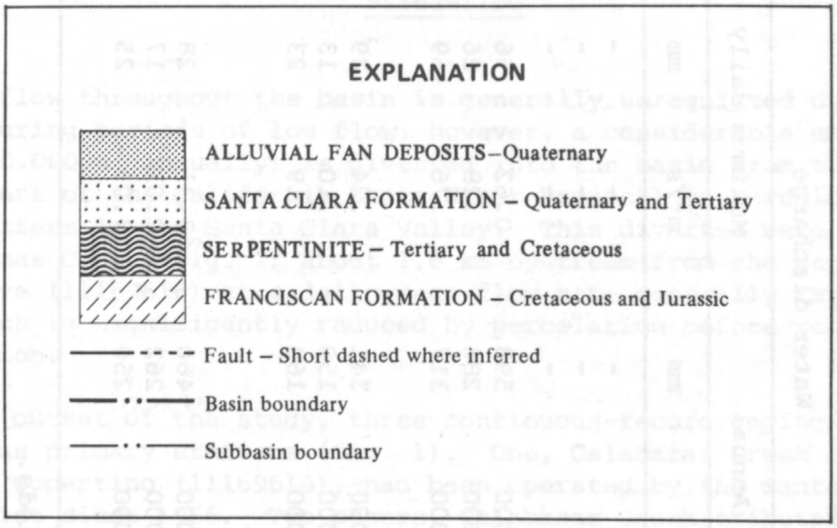


FIGURE 3.--Generalized geology.



HYDROLOGY

Precipitation

Precipitation in the Calabazas Creek basin is generally moderate to heavy during the winter storm season (November through March) and is light to nonexistent during the rest of the year. Precipitation is almost entirely in the form of rainfall, although snow occasionally falls at the highest elevations. Average annual rainfall is less than 460 mm in the lower part of the basin and more than 890 mm on Table Mountain (Santa Clara Valley Water District, written commun., 1976).

A nonrecording precipitation station has been operated at Garrod Ranch (11169575, fig. 1) since 1935. A recording gage was installed in October 1972. Rainfall is recorded in 5-minute time increments during the storm season and in 15-minute time increments during the rest of the year. Rainfall data at this station are used as an input component for rainfall-runoff simulation of stormflows in the basin. The station is at an elevation of about 274 m and intercepts an average annual rainfall of 660 mm.

Annual rainfall at the Garrod Ranch station was about 40 percent above average in 1973 and about 10 percent above average in 1974 and 1975 (table 1).

TABLE 1.--*Precipitation and water discharge at hydrologic stations*

Station number and name	Drainage area (km^2)	Water year	Precipitation		Water discharge			
			Annual (mm)	Maximum daily (mm)	Annual		Maximum daily	
					m^3	mm	m^3/s	mm
11169575 Garrod Ranch near Saratoga	-	1973	[1]943	75	-	-	-	-
		1974	[1]631	84	-	-	-	-
		1975	723	91	-	-	-	-
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	0.96	1973	-	-	572,000	598	0.62	56
		1974	-	-	275,000	288	.28	26
		1975	-	-	303,000	317	.76	69
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga	.70	1973	-	-	238,000	341	.24	29
		1974	-	-	105,000	150	.10	13
		1975	-	-	117,000	168	.19	23
11169616 Calabazas Creek at Rainbow Drive, near Cupertino	10.31	1973	-	-	[2]4,750,000	[2]460	[2]3.31	28
		1974	-	-	[2]2,700,000	[2]262	[2]2.01	17
		1975	-	-	[2]2,580,000	[2]250	[2]3.03	25

[1]Minimum precipitation, recorder malfunction during some periods.
[2]Includes diversion flows from South Bay Aqueduct.

Streamflow

Streamflow throughout the basin is generally unregulated during storm periods. During periods of low flow, however, a considerable amount of water (about 2,500,000 m^3 annually) is diverted into the basin from the South Bay Aqueduct (part of the California State Water Project) to percolate water into various aquifers in the Santa Clara Valley. This diverted water is discharged into Calabazas Creek (fig. 1) about 1.6 km upstream from the gaging station at Rainbow Drive (11169616) at a daily mean flow rate generally ranging from 1 to 2 m^3/s, which is significantly reduced by percolation before reaching the gaging station.

At the outset of the study, three continuous-record gaging stations were designated as primary stations (fig. 1). One, Calabazas Creek at Rainbow Drive, near Cupertino (11169616), had been operated by the Santa Clara Valley Water District since 1966. Two others, Calabazas Creek tributary at Mt. Eden Road, near Saratoga (11169580), and Prospect Creek at Saratoga Golf Course, near Saratoga (11169600), were established in October 1972 for this study. In addition, periodic measurements of water discharge were made at various secondary stations (fig. 1). Stream discharge measurements are published annually (U.S. Geological Survey, 1973a, 1974a, and 1975).

An examination of runoff data in table 1 indicates that the subbasin above the Calabazas Creek tributary station (11169580) contributes about 80 percent more runoff than the subbasin above the Prospect Creek station (11169600). Average annual rainfall over the former subbasin, however, is only 14 percent larger than that of the Prospect Creek subbasin. This comparison suggests that infiltration characteristics of the two subbasins are different, with a much smaller part of total rainfall in the Prospect Creek subbasin being discharged as surface runoff. Maximum daily water discharge for the Prospect Creek station (11169600) is also much smaller than that for the Calabazas Creek tributary station (11169580).

Infiltration of rainfall in the area between the upstream stations and the Rainbow Drive station is also large. Variability of infiltration in the subbasins and streamflow characteristics will be discussed in the section on rainfall-runoff simulation.

SEDIMENT DISCHARGE

Sediment Transport in the Basin

More than half the sediment transported in the basin is derived from sheet erosion of hillsides and channel erosion during winter rainstorms. Cultivated areas, construction sites, landslides, and rock slides are major local sources of sediment in areas where bare soil is exposed and where hillslopes are steep.

The quantity of sediment transported depends largely on the particle size of sediment, streamflow characteristics, and the available supply of sediment. Transported sediment includes particles moved in suspension by the flowing water (suspended-sediment discharge) and the coarser particles that move along or near the bed of the stream (bedload discharge). Silt and clay are carried in suspension; pebbles and coarser particles are generally transported as bedload. Sand may be transported either in suspension or as bedload. Coarse sediment (sand and gravel) is commonly transported with ease by the foothill streams where gradients are large but tends to be deposited in the stream channels in valley areas where gradients are smaller. Because urbanized areas are located predominantly in the valley part of the Calabazas Creek basin, where stream gradients are smaller than in foothill areas, accelerated erosion in the foothills would be expected to result in an increase of coarse sediment deposits in urban stream channels and a reduction in channel capacity.

Data Collection

Sediment discharge data were collected at eight stations in the basin (fig. 1) during the 1973-75 water years. These data consisted of daily records of total sediment discharge at three primary stations, where water discharge data were being collected, and periodic samples of suspended-sediment and total sediment discharge at five secondary stations. Two of the primary gaging stations, Calabazas Creek tributary at Mt. Eden Road, near Saratoga (11169580) and Prospect Creek at Saratoga Golf Course, near Saratoga (11169600), were used to define annual sediment yields (sediment quantity per square kilometer of basin) that were representative of foothill areas prior to urbanization. A primary sediment station was established at the gaging station Calabazas Creek at Rainbow Drive, near Cupertino (11169616), in 1974 to determine the sediment yields for an area containing urban development and to evaluate the effect of a debris basin which was constructed at Comer Drive during the summer 1973.

Periodic samples were collected at various secondary stations (fig. 1) to determine if sediment yields throughout the basin were uniform or if any tributaries were transporting unusually large or small quantities of sediment relative to the primary stations. Samples were collected during one or two storms per year. The secondary stations include: Calabazas Creek at Mt. Eden Road, near Saratoga (11169581); Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga (11169586); Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga (11169588); Prospect Creek at Maria Lane, near Saratoga (11169610); and Prospect Creek tributary near Saratoga (11169611).

Sediment samples at all stations were collected with standard depth-integrating suspended-sediment samplers (U.S. Inter-Agency Committee on Water Resources, 1963). Samples were collected at selected verticals in the stream cross section to determine the average sediment concentration and particle-size distribution of sediment in the water-sediment mixture.

Sediment transported throughout the depth of the stream (total sediment) was sampled using suspended-sediment samplers and bedload samplers (Helley and Smith, 1971, p. 1-18). Two techniques were used to sample total sediment discharge (fig. 4).

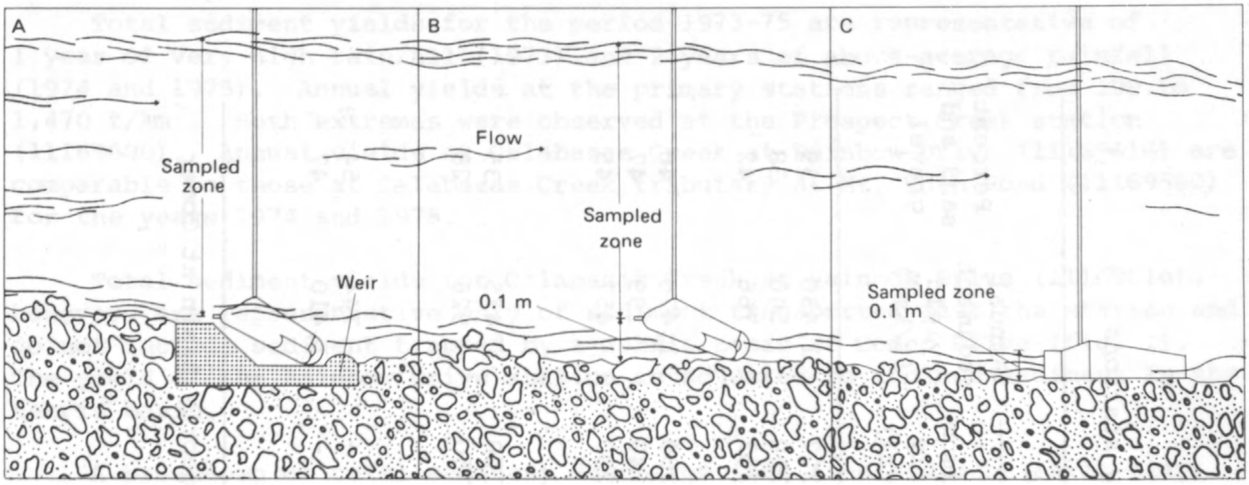


FIGURE 4.--Sampling zones of various sediment samplers.

The first technique (fig. 4*A*), which was used at culverts and at sites where a concrete weir had been installed in the stream, employed a suspended-sediment sampler and was used during low to intermediate flows when the stream was transporting sediment particles finer than 4.0 mm, two-thirds the diameter of the sampler nozzle. Samples were integrated through the total depth of the stream between the water surface and the weir using only the suspended-sediment sampler.

A second technique was used during high flows when the weir was inaccessible because of high stream velocities and excessive water depths. Sediment in the sampled zone (fig. 4*B*) was obtained with a suspended-sediment sampler, and sediment in the bottom 0.1 m was obtained with a bedload sampler (fig. 4*C*). In this report, bedload is considered to consist of particles in transit within 0.1 m of the streambed. Total sediment discharge was obtained as the sum of bedload discharge and suspended-sediment discharge. A trap efficiency coefficient of 1.0 was assumed for the bedload sampler, which has not yet been calibrated.

Sediment Records at Primary Stations

Sediment data obtained during the initial 3 years of the study (1973-75) indicate that the annual quantity of sediment transported at each primary station is extremely variable and depends largely on the length and intensity of individual storms. Runoff during a few large storms each year generally transports a major part of the annual sediment discharge. A comparison of data in table 2 shows that the maximum daily total sediment discharge in a given year ranges from 23 to 62 percent of the annual total. Also, the quantity of sediment transported during 1 day in a wet year may be as large or larger than the sediment transported during 1 or more dry years.

TABLE 2.--*Total sediment discharge and yield at primary stations*

Station number and name	Drainage area (km^2)	Water year	Sediment discharge, in tonnes: Annual: Silt-clay	Sediment discharge, in tonnes: Annual: Sand-gravel	Sediment discharge, in tonnes: Annual: Total	Sediment discharge, in tonnes: Maximum daily (total)	Annual sediment yield (t/km^2)	Percent sand and gravel
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	0.96	1973	833	533	1,370	327	1,430	39
		1974	324	200	524	190	546	38
		1975	425	310	735	363	766	42
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga	.70	1973	548	477	1,030	289	1,470	46
		1974	73	66	139	49	199	47
		1975	176	144	320	200	457	45
11169616 Calabazas Creek at Rainbow Drive, near Cupertino	10.31	1974	3,200	1,700	4,900	1,120	475	35
		1975	6,850	2,720	9,570	3,750	928	28
11169616 Calabazas Creek at Rainbow Drive, near Cupertino[1]	10.31	1974	3,500	4,170	7,670	-	744	54
		1975	6,880	7,650	14,500	-	1,410	47

[1]Sediment discharge and yield including sediment deposited in debris basin at Comer Drive.

Total sediment yields for the period 1973-75 are representative of 1 year of very high rainfall (1973) and 2 years of above-average rainfall (1974 and 1975). Annual yields at the primary stations ranged from 199 to 1,470 t/km^2. Both extremes were observed at the Prospect Creek station (11169600). Annual yields at Calabazas Creek at Rainbow Drive (11169616) are comparable to those at Calabazas Creek tributary at Mt. Eden Road (11169580) for the years 1974 and 1975.

Total sediment yields for Calabazas Creek at Rainbow Drive (11169616), however, are representative only of sediment transported past the station and do not include sediment trapped by a debris basin at Comer Drive (fig. 1). The yield of the Rainbow Drive station is adjusted to include sediment in the debris basin.

A breakdown of total sediment discharge into fine sediment (silt-clay) and coarse sediment (sand-gravel) indicates that coarse sediment accounts for a large percentage (38 to 47 percent) of the annual total sediment discharge at Calabazas Creek tributary at Mt. Eden Road (11169580) and Prospect Creek at Saratoga Golf Course (11169600). Coarse sediment at Calabazas Creek at Rainbow Drive (11169616) was significantly less (28 to 35 percent) (table 2).

If sediment deposited in the debris basin is included with sediment passing the Rainbow Drive station, the total sediment yield of Calabazas Creek at Rainbow Drive (11169616) would be considerably larger than that of stations in the foothills. The percentage of coarse sediment would also be increased (from 28-35 percent to 47-54 percent).

Relation Between Total Sediment Discharge and Water Discharge

A common method for studying sediment-transport characteristics at individual stations is to construct a graph of sediment discharge versus water discharge. This relation is generally expressed as a plot on logarithmic paper and is referred to as a sediment-transport curve. Sediment-transport curves for primary stations in the Calabazas Creek basin were obtained by averaging values of daily total sediment discharge within a narrow range of daily mean water discharge. For example, all values of daily mean water discharge ranging from 0.5 to 0.6 m^3/s were averaged and, together with the average sediment discharge for concurrent days, resulted in one plotted point. Each plotted point shown in figures 5-7 may represent 1 day or the average of a group of days of sediment and water discharge during a given year.

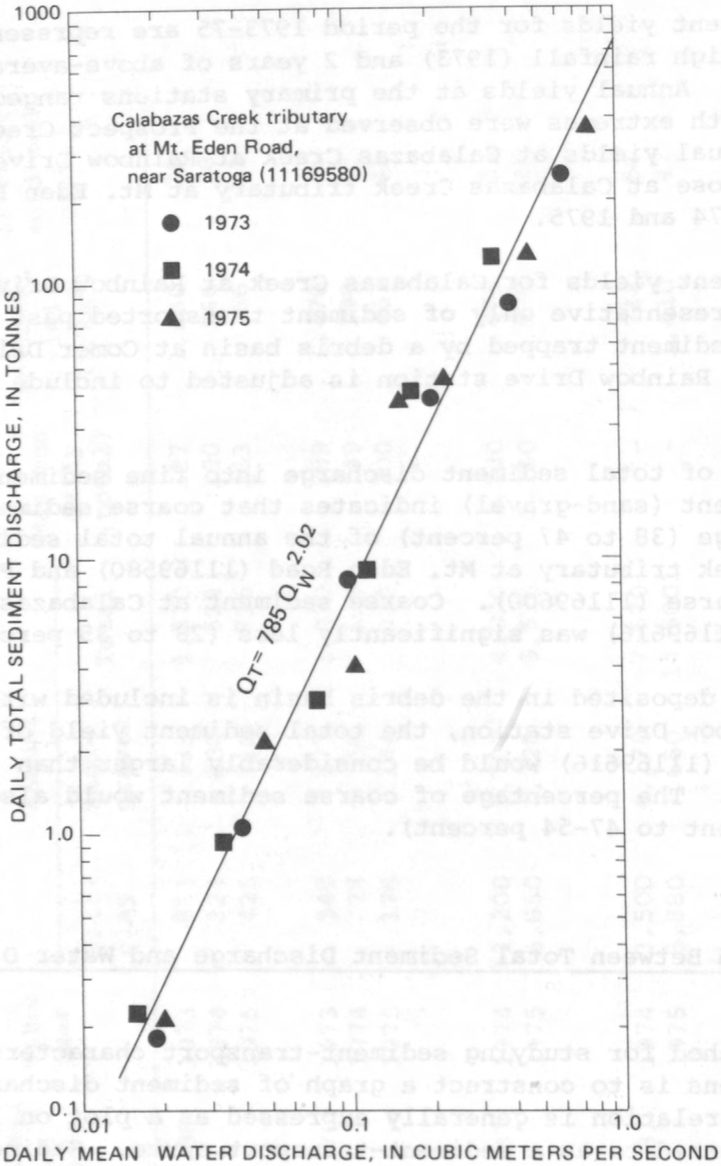


FIGURE 5.--Relation of total sediment discharge to water discharge at Calabazas Creek tributary at Mt. Eden Road, near Saratoga, 1973-75.

Sediment-transport curves for each of the primary stations can be expressed by the following empirical equations for given ranges of water discharge:

1. Calabazas Creek tributary at Mt. Eden Road (11169580)

$$Q_T = 785\ Q_W^{2.02},\ 0.01<Q_W<1.0 \qquad (1)$$

2. Prospect Creek at Saratoga Golf Course (11169600)

$$Q_T = 6410\ Q_W^{2.34},\ 0.01<Q_W<0.40 \qquad (2)$$

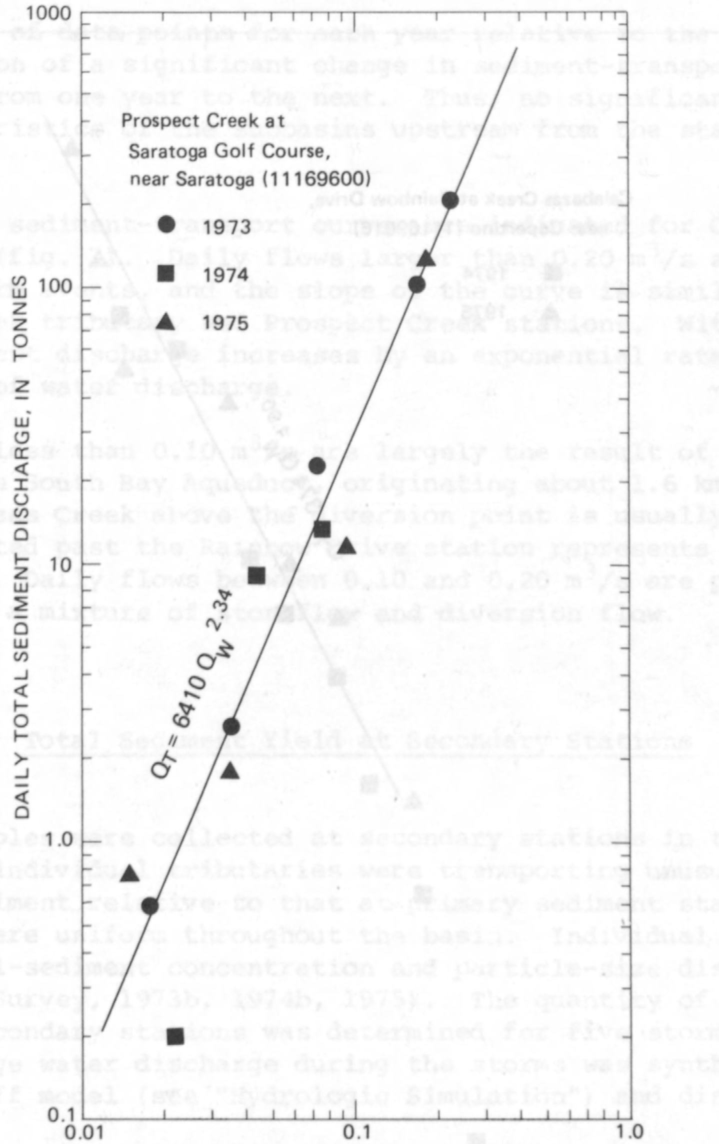


FIGURE 6.--Relation of total sediment discharge to water discharge at Prospect Creek at Saratoga Golf Course, near Saratoga, 1973-75.

3. Calabazas Creek at Rainbow Drive (11169616)

$$Q_T = 10.6\ Q_W^{1.13},\ 0.01<Q_W<0.10 \qquad (3)$$

$$Q_T = 374\ Q_W^{1.90},\ 0.20<Q_W<4.0 \qquad (4)$$

where Q_T = daily total sediment discharge, in tonnes, and

Q_W = daily mean water discharge, in cubic meters per second.

Table 2.--Discharge at station 01508962, Otter Creek at mouth, January 5 to September 30, 1976

[Discharges in cubic feet per second; dashes indicate no measurement taken]

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	--	9.1	51	26	20	32	38	19	0.37
2	--	8.4	48	23	21	26	26	14	.26
3	--	12	82	21	24	21	26	11	.04
4	--	8.4	74	20	17	18	22	10	.03
5	5.6	8.4	57	13	15	16	24	9.1	0
6	5.0	9.1	56	15	15	20	20	8.6	0
7	1.5	7.8	45	14	14	22	17	10	0
8	1.1	7.8	42	14	13	18	16	13	0
9	2.3	7.2	39	13	13	17	18	18	0
10	1.3	6.2	36	12	12	18	14	10	.80
11	1.2	6.5	33	12	17	14	15	9.6	.06
12	2.3	6.5	30	11	22	13	54	86	.03
13	2.5	6.5	30	10	20	13	51	9.1	0
14	2.3	7.2	28	9.1	26	13	42	8.6	0
15	1.5	7.8	26	10	28	11	33	8.6	0
16	1.5	16	24	24	29	10	30	8.2	.03
17	1.5	53	22	18	30	13	28	6.3	.21
18	2.1	57	22	12	31	10	26	5.2	.03
19	2.1	117	21	11	36	10	22	4.6	0
20	2.5	63	22	13	63	18	21	3.5	0
21	3.1	53	25	13	43	18	22	2.9	0
22	2.5	140	24	15	35	16	21	2.6	0
23	.64	75	20	15	34	17	20	2.1	0
24	.90	62	18	15	32	16	19	1.3	0
25	.65	56	18	40	31	16	19	1.0	0
26	3.6	46	16	43	29	15	18	.58	.04
27	24	46	16	24	27	17	18	.37	.05
28	24	40	18	26	26	18	14	.06	.04
29	16	39	16	24	25	19	15	.94	.03
30	12	--	14	21	26	26	15	.53	.03
31	9.8	--	15	--	28	--	13	.16	--

The location of data points for each year relative to the average curve shows no indication of a significant change in sediment-transport characteristics from one year to the next. Thus, no significant change in the physical characteristics of the subbasins upstream from the stations is assumed.

Two distinct sediment-transport curves are indicated for Calabazas Creek at Rainbow Drive (fig. 7). Daily flows larger than 0.20 m^3/s are generally the result of storm events, and the slope of the curve is similar to that for the Calabazas Creek tributary and Prospect Creek stations. With increasing flow, total sediment discharge increases by an exponential rate of about 2 relative to that of water discharge.

Daily flows less than 0.10 m^3/s are largely the result of low-flow diversion from the South Bay Aqueduct, originating about 1.6 km upstream. The channel of Calabazas Creek above the diversion point is usually dry, and sediment transported past the Rainbow Drive station represents material eroded from the channel. Daily flows between 0.10 and 0.20 m^3/s are probably representative of a mixture of stormflow and diversion flow.

Total Sediment Yield at Secondary Stations

Sediment samples were collected at secondary stations in the basin to determine if any individual tributaries were transporting unusually large quantities of sediment relative to that at primary sediment stations or if sediment yields were uniform throughout the basin. Individual samples were analyzed for total-sediment concentration and particle-size distribution (U.S. Geological Survey, 1973b, 1974b, 1975). The quantity of sediment transported at secondary stations was determined for five storm periods (table 3). Average water discharge during the storms was synthesized using the rainfall-runoff model (see "Hydrologic Simulation") and discharge measurements.

To facilitate a comparison of the relative quantity of sediment transported at various stations throughout the basin, the data in table 3 were summarized in terms of total sediment yield and as a ratio between the total sediment yield at a given station and that of a primary station (table 4). Calabazas Creek tributary at Mt. Eden Road (11169580) was chosen as an index station because its drainage area contained no urban development and was underlain by both of the principal geologic formations in the Calabazas Creek basin--the Franciscan and the Santa Clara.

Sediment data in tables 3 and 4 represent two large storms (rainfall greater than 50 mm) and three small storms (rainfall less than 20 mm) that occurred during 1973-75. Although the number of storms sampled is small, some general sediment yield characteristics typical of each storm are apparent.

TABLE 3.--*Average water discharge and total sediment discharge at storm-sampling stations, 1973-75*

Station number and name	Storm date and size	Drainage area (km^2)	Average water discharge (m^3/s)	Sediment discharge, in tonnes: Silt-clay	Sand-gravel	Total
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	January 16, 1973 (large)	0.96	0.85	182	133	315
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		.70	.31	170	165	335
11169610 Prospect Creek at Maria Lane, near Saratoga		1.97	.62	244	120	364
11169611 Prospect Creek tributary near Saratoga		.04	.008	.15	.04	.19
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	March 6, 1973 (small)	.96	.16	9.1	3.6	13
11169581 Calabazas Creek at Mt. Eden Road, near Saratoga		1.27	.043	.38	.10	.48
11169586 Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga		.28	.018	.05	.05	.10
11169588 Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga		.67	.059	3.6	7.3	11
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		.70	.024	1.1	.34	1.4
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	January 16, 1974 (small)	.96	.040	.24	.01	.25
11169581 Calabazas Creek at Mt. Eden Road, near Saratoga		1.27	.018	.15	.01	.16
11169586 Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga		.28	.010	.07	0	.07

11169588 Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga		.67	.042	11	24	35
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		.70	.005	.03	0	.03
11169616 Calabazas Creek at Rainbow Drive, near Cupertino		10.31	.21	15	5.1	20
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	February 13, 1975 (small)	.96	.10	.54	.36	.90
11169581 Calabazas Creek at Mt. Eden Road, near Saratoga		1.27	.062	.21	.04	.25
11169586 Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga		.28	.025	.32	.03	.35
11169588 Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga		.67	.091	12	51	63
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		.70	.022	.05	0	.05
11169616 Calabazas Creek at Rainbow Drive, near Cupertino		10.31	.42	15	2.2	17
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	March 7, 1975 (large)	.96	.79	42	40	82
11169581 Calabazas Creek at Mt. Eden Road, near Saratoga		1.27	.51	43	55	98
11169586 Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga		.28	.16	12	15	27
11169588 Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga		.67	.45	108	142	250
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		.70	.21	15	13	28
11169616 Calabazas Creek at Rainbow Drive, near Cupertino		10.31	3.65	504	230	734

TABLE 4.--*Comparison of total sediment yield at storm-sampling stations, 1973-75*

Station number and name	Storm date and size	Sediment yield: Silt-clay: Tonnes per square kilometer	Silt-clay: Ratio[1]	Sand-gravel: Tonnes per square kilometer	Sand-gravel: Ratio[1]	Total: Tonnes per square kilometer	Total: Ratio[1]	Percent sand and gravel
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	January 16, 1973 (large)	190	1.0	139	1.0	329	1.0	42
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		243	1.3	236	1.7	479	1.5	49
11169610 Prospect Creek at Maria Lane, near Saratoga		124	.7	61	.4	185	.6	33
11169611 Prospect Creek tributary near Saratoga		3.8	.02	1.0	.01	4.8	.01	21
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	March 6, 1973 (small)	9.5	1.0	3.8	1.0	13	1.0	28
11169581 Calabazas Creek at Mt. Eden Road, near Saratoga		.30	.03	.08	.02	.38	.03	21
11169586 Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga		.18	.02	.18	.05	.36	.03	50
11169588 Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga		5.4	.6	11	2.9	16	1.2	66
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		1.6	.2	.49	.1	2.1	.2	24
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	January 16, 1974 (small)	.25	1.0	.01	1.0	.26	1.0	4
11169581 Calabazas Creek at Mt. Eden Road, near Saratoga		.12	.5	.01	1.0	.13	.5	6
11169586 Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga		.25	1.0	0	-	.25	1.0	0

11169588 Calabazas Creek tributary No. 4, at Mt. Eden Road, near Saratoga		16	64	36	3,600	52	200	69
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		.04	.2	0	-	.04	.2	0
11169616 Calabazas Creek at Rainbow Drive, near Cupertino		1.5	6.0	.49	49	2.0	7.7	26
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	February 13, 1975 (small)	.56	1.0	.38	1.0	.94	1.0	40
11169581 Calabazas Creek at Mt. Eden Road, near Saratoga		.17	.3	.03	.08	.20	.2	16
11169586 Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga		1.1	2.0	.11	.3	1.2	1.3	9
11169588 Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga		18	32	76	200	94	100	81
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		.07	.1	0	-	.07	.07	0
11169616 Calabazas Creek at Rainbow Drive, near Cupertino		1.5	2.7	.21	.6	1.7	1.8	13
11169580 Calabazas Creek tributary at Mt. Eden Road, near Saratoga	March 7, 1975 (large)	44	1.0	42	1.0	86	1.0	49
11169581 Calabazas Creek at Mt. Eden Road, near Saratoga		34	.8	43	1.0	77	.9	56
11169586 Calabazas Creek tributary No. 3 at Mt. Eden Road, near Saratoga		43	1.0	54	1.3	97	1.1	56
11169588 Calabazas Creek tributary No. 4 at Mt. Eden Road, near Saratoga		161	3.7	212	5.0	373	4.3	57
11169600 Prospect Creek at Saratoga Golf Course, near Saratoga		21	.5	19	.5	40	.5	46
11169616 Calabazas Creek at Rainbow Drive, near Cupertino		49	1.1	22	.5	71	.8	31

[1]Ratio of sediment yield at indicated station to that of Calabazas Creek tributary at Mt. Eden Road, near Saratoga (11169580).

During small storms:

1. Total sediment yield is extremely variable from station to station. This is probably due to a nonuniformity of rainfall intensity and magnitude throughout the basin.
2. Total sediment yield at the index station (Calabazas Creek tributary at Mt. Eden Road) is less than the yield of the Calabazas Creek basin above Rainbow Drive.
3. Total sediment yield at Calabazas Creek tributary No. 4 (11169588) is generally many times larger than that for any other station in the basin. Fine-sediment yield ranges from 0.6 to 64 times larger than the index station. Coarse-sediment yield ranges from 2.9 to 3,600 times larger than the index station. The Calabazas Creek tributary No. 4 station is downstream from a large gravel pit, which is adjacent to the stream, and near a vineyard.
4. Total sediment yield from Prospect Creek at Saratoga Golf Course (11169600) is consistently lower than that of the index station. Prospect Creek is underlain entirely by the Santa Clara Formation, which allows larger infiltration of rainfall into the soil and less runoff than the Franciscan Formation.

During large storms:

1. Total sediment yields are relatively uniform at most stations because rainfall is more uniform throughout the basin during large storms.
2. Coarse sediment constitutes a large percentage of the total sediment yield because stream velocities are sufficiently large to transport most of the coarse particles found in the streambed.
3. The percentage of coarse sediment transported during large storms is about the same as the percentage of coarse sediment transported annually at primary stations.
4. Total sediment yield at Calabazas Creek tributary No. 4 (11169588) is four to nine times larger than that for other stations in the basin. Considering sediment transported during large and small storms (see item 4 for small storms), the annual total sediment yield of Calabazas Creek tributary No. 4 would, by rough estimate, be about 10 times that of the index station.
5. Total sediment yield at Prospect Creek tributary near Saratoga (11169611), which drains a single-family residential area, is very small. During the one large storm that was monitored, the yield was about 1 percent of that for the index station.

Sediment Trapped in Comer Drive Debris Basin

A significant part of the sediment eroded from the area upstream from the Calabazas Creek at Rainbow Drive station (11169616) is trapped in a debris basin at Comer Drive (fig. 1). The volume of sediment trapped in the debris basin during the 1974 and 1975 storm seasons was determined by annual surveys. Additional surveys were made after sediment was removed by personnel of the Santa Clara Valley Water District.

Surveys of the debris basin (table 5) indicate that 1,750 and 2,790 m^3 of sediment were trapped during the 1974 and 1975 storm seasons. After each storm season a volume of sediment approximately equal to that trapped was removed to restore the capacity of the debris basin.

Samples of deposited sediment were obtained during each survey and analyzed for average specific weight and particle-size distribution. These analyses were used to convert sediment volume to weight units for a comparison of the amount of sediment trapped in the debris basin with concurrent total sediment-discharge data for primary sediment stations.

The relative quantity of particles of various sizes deposited during each storm season suggests that the trap efficiency of the debris basin is variable and depends on the total quantity of sediment contributed to the basin. An increase in coarse sediment and a decrease in fine sediment during 1975 indicates sorting of particles within the debris basin. Stormflows passing through the basin, after it is filled, pick up fine sediment which was previously deposited and transport the fine sediment downstream. This sorting process results in a coarser mix of sediment particles at the end of large storm seasons. The storage capacity of the debris basin differs each year, depending upon maintenance precedures, but is small relative to the annual sediment inflow. The basin was filled to near capacity at the end of the 1975 storm season, with about 150 m^3 storage below spillway elevation. Aggradation of the streambed relative to the dam is shown in figure 8.

TABLE 5.--*Summary of sediment deposition and removal at Comer Drive debris basin*

[Sediment data in parentheses indicate quantity of deposited sediment per square kilometer of drainage area]

Storm season	Drainage area (km^2)	Sediment deposited: Cubic meters	Tonnes: Silt-clay	Sand	Gravel	Total	Specific weight (g/m^3)	Sediment removed: Cubic meters
1974	6.32	1,750	300	1,420 (225)	1,050 (166)	2,770	$1.58x10^6$	1,740
1975	6.32	2,790	30	1,840 (291)	3,090 (489)	4,960	$1.78x10^6$	2,490

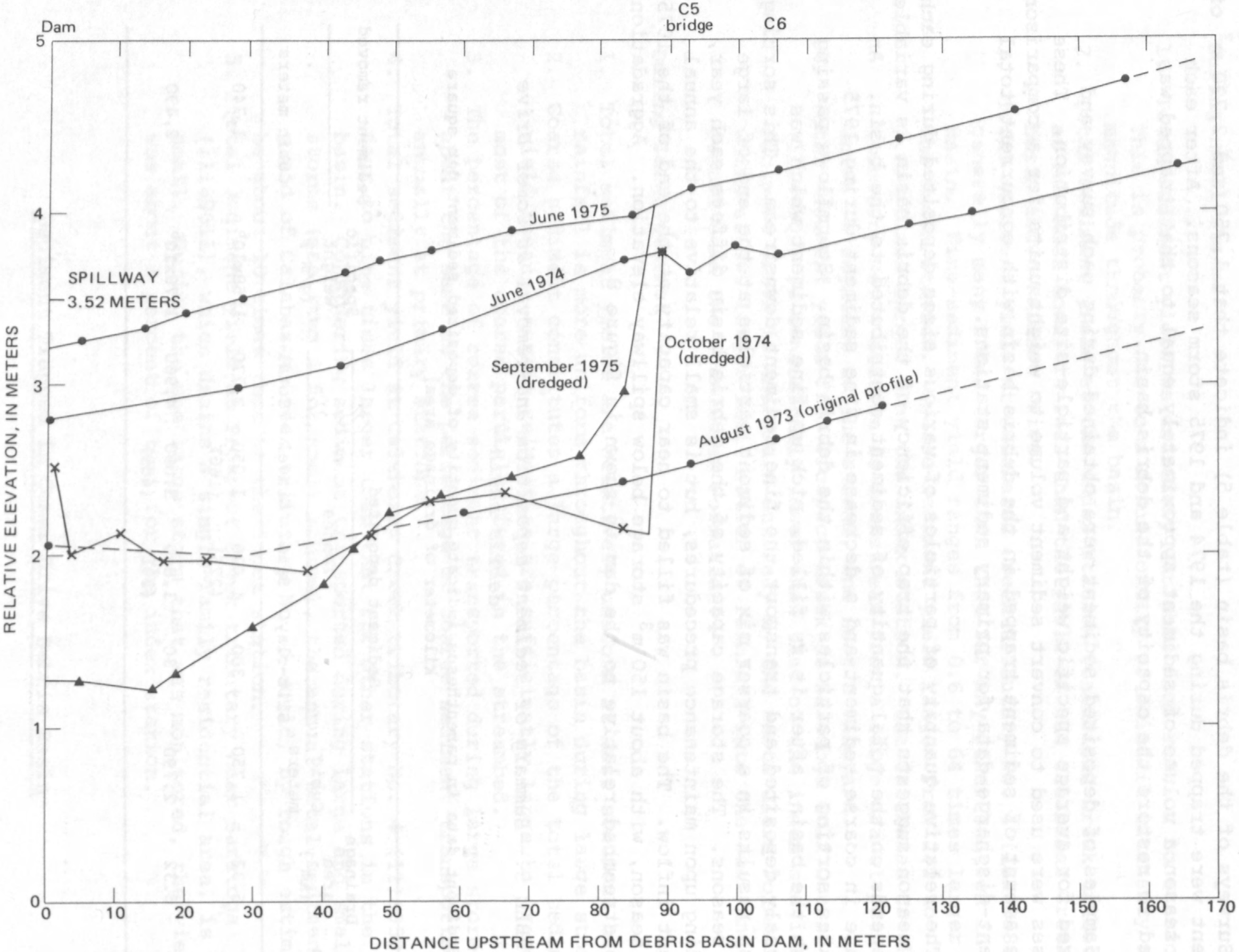


FIGURE 8.--Longitudinal thalweg profile of debris basin at Comer Drive.

Sediment inflow to the debris basin is eroded from a 6.32-km^2 area including a primary sediment station (Calabazas Creek tributary at Mt. Eden Road, 11169580) and three secondary stations (Calabazas Creek, 11169581; Calabazas Creek tributary No. 3, 11169586; and Calabazas Creek tributary No. 4, 11169588). A comparison of coarse sediment deposited in the debris basin (391 t/km^2, 1974; 780 t/km^2, 1975) with total sediment yield for the primary station (208 t/km^2, 1974; 323 t/km^2, 1975) indicates that the intervening drainage area contributes about twice as much coarse sediment per square kilometer as the area upstream from the primary station.

Sediment-yield ratios in table 4 suggest that much of the sediment in the drainage area between the primary station and the debris basin is contributed from Calabazas Creek tributary No. 4 (11169588). If the coarse-sediment yield from the intervening drainage area is assumed to be similar to that of the primary station, the coarse-sediment yield of Calabazas Creek tributary No. 4 would have been eight times that of the upstream drainage in 1974 and 13 times greater in 1975. At least 50 percent of the sediment trapped in the debris basin annually probably originates from Calabazas Creek tributary No. 4.

The quantity of sediment trapped in the debris basin is a significant part of that transported in the Calabazas Creek basin. If this sediment were not intercepted, the quantity of sediment passing the Rainbow Drive station would probably have been about 30 percent larger in 1974 and 1975. Additionally, the sediment trapped by the debris basin is virtually all coarse material, which would be expected to deposit in the lower reaches of Calabazas Creek where stream gradients are small.

WATER QUALITY

Water samples were analyzed during the study period for various constituents to determine a baseline of water-quality characteristics and to determine if the trace elements and pesticides detected in streambed sediment in calendar year 1972 (U.S. Geological Survey, 1973b) were transported by the streams. Three water samples per year (1974 and 1975) were collected at Calabazas Creek tributary at Mt. Eden Road (11169580), Prospect Creek at Saratoga Golf Course (11169600), and Calabazas Creek at Rainbow Drive (11169616). Analyses of the samples indicate that the water at Prospect and Calabazas Creeks can be classified as magnesium-calcium bicarbonate. The water from the Calabazas Creek tributary is best classified as mixed-cation bicarbonate. Figure 9 shows the Stiff diagrams for the three stations. These diagrams show that water type remains the same at low and high flow, but ion concentrations are greater at low flow.

The water at all stations varies from moderately hard at medium to high flows to very hard at low flows. Nutrient concentrations (nitrogen and phosphorus) are not high if compared with other streams in the San Francisco Bay area. The nutrient concentrations are higher during high flows. A similar relation was observed at Castro Valley Creek, Calif. (Sylvester and Brown, 1978). Nutrient concentrations for the three stations sampled were within these ranges: total nitrogen, 0.66 to 10 mg/L (milligrams per liter), and total phosphorus, 0.04 to 3.5 mg/L.

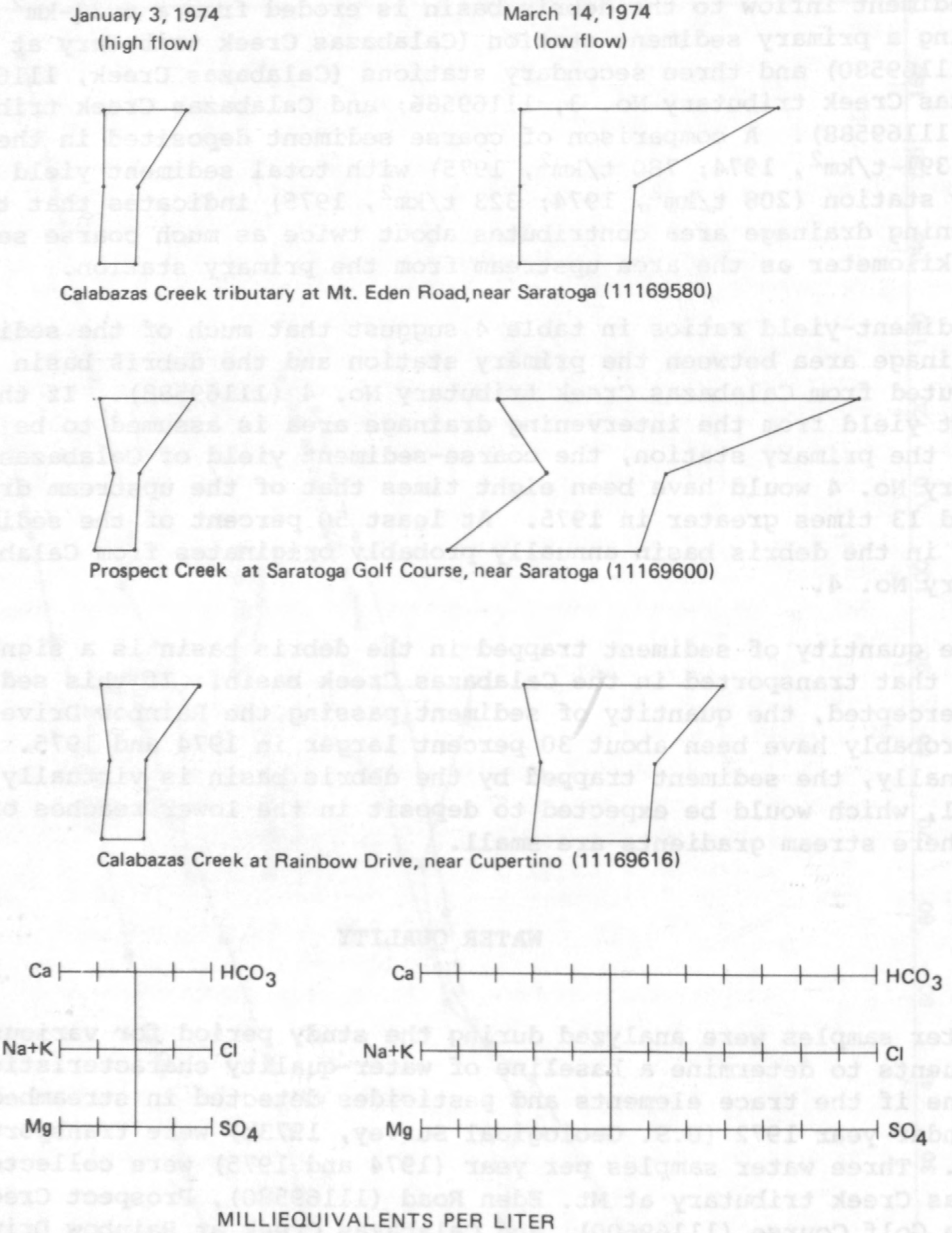


FIGURE 9.--Major-ion characteristics at the primary stations.

Three trace elements--chromium, mercury, and lead--were detected in significant concentrations only during high flows, when the streams were turbid. Significant concentrations for this study are defined as those that exceed the limits for public water supplies recommended by the U.S. Environmental Protection Agency (1973). The relation of significant concentrations of trace elements to high flow suggests that these elements are probably adsorbed or transported on sediment particles. Arsenic and cadmium were not detected in significant concentrations.

Pesticides were absent or found in insignificant concentrations in water samples collected from Calabazas Creek tributary at Mt. Eden Road (11169580) and Prospect Creek at Saratoga Golf Course (11169600). However, DDT, DDE, diazinon, 2,4-D, and silvex were detected in significant concentrations at Calabazas Creek at Rainbow Drive (11169616) during high flows. Pesticides, like trace elements, are probably closely associated with the sediment particles.

Six water samples, two at each of the three primary stations, were analyzed for fecal-coliform and fecal-streptococcal bacteria during 1974 and 1975. Results showed low to moderate concentrations of bacteria--a range of 50-100 col/100 mL (colonies per 100 milliliters of water) for fecal-coliform and 43-880 col/100 mL for fecal streptococci. The Environmental Protection Agency (EPA) has not established acceptable limits for fecal-coliform or fecal-streptococcal bacteria in recreational water. They have suggested that if an arbitary limiting value for fecal-coliform bacteria is desired for bathing and swimming water, then a geometric mean of a series of samples should not exceed 1,000 col/100 mL (U.S. Environmental Protection Agency, 1973, p. 32). No suggested standards for fecal-streptococcal bacteria are given by the EPA.

In summary, water-quality conditions during low-flow periods have been well-defined by the chemical and bacteriological analyses to date. The high-flow samples indicate that significant amounts of various trace elements and pesticides adsorbed on sediment can be transported by streams in the basin. The few samples analyzed, however, are insufficient to make an estimate of sources or of quantities transported. Intensive sampling throughout several storms would be needed to define concentrations of constituents during storms.

CHANGES IN STREAM-CHANNEL GEOMETRY

Stream channels are influenced by climatic factors and the physical characteristics of the basin. If an external impact is imposed on the basin that significantly changes the character of the basin, the shape and dimensions of stream channels may undergo large changes.

Repetitive surveys of stream-channel geometry were made at 14 sites in the basin (fig. 1) to document normal changes resulting from climatic events and unusual changes that may be related to present urban development. These sites were established in the summer 1973 in rural and urban areas. Permanent reference points were established on each bank of the channel for use in future surveys.

To facilitate a comparison of large changes in channel geometry, an arbitrary elevation was selected to represent the upper limit of the channel at a given site (fig. 10). This elevation was generally located about half a meter above estimated flood stage at sites where all probable flows would be confined to the channel.

Initial dimensions and thalweg characteristics of the stream channels and net changes between storm seasons are summarized in table 6. Annual changes in channel dimensions (depth and width) were small at most of the sites.

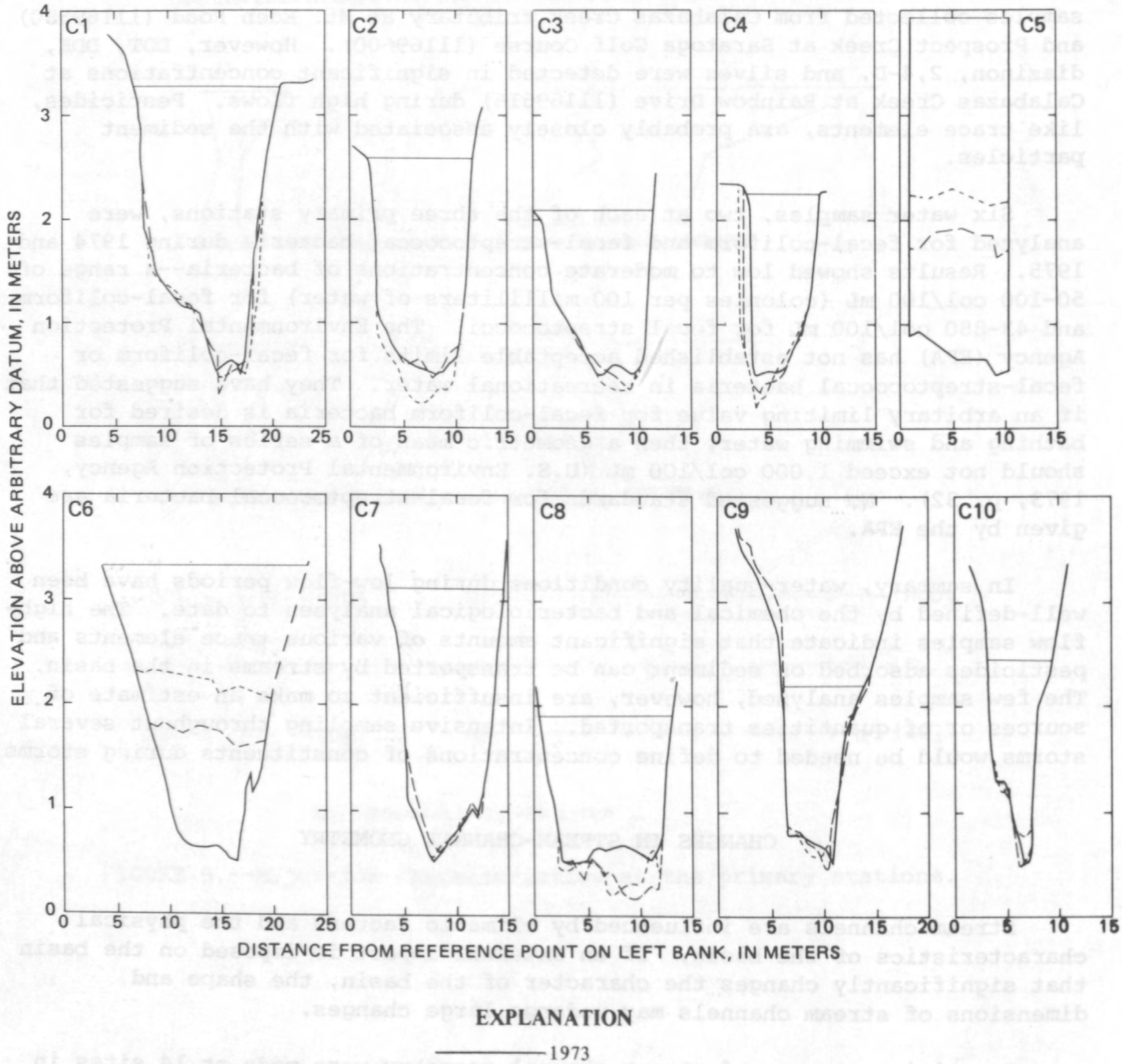


FIGURE 10.--Changes in stream channel at channel-geometry survey sites, 1973-75.

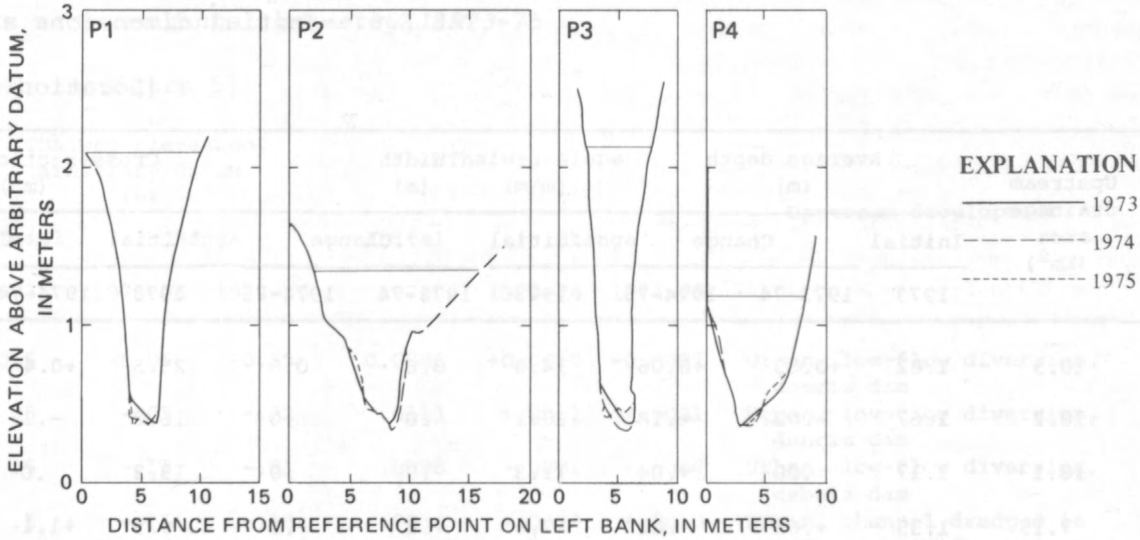


FIGURE 10.--Changes in stream channel at channel-geometry survey sites, 1973-75--Continued.

Changes in average depth were generally less than 0.1 m, and an increase in depth for one year was often compensated for by a decrease in depth for the other year. There were no appreciable differences in depth changes in urban areas relative to rural areas. Large decreases in depth were observed at sites C5 and C6 between both storm seasons. These decreases are due to sediment deposited upstream from the debris dam.

A significant change in width was observed only at site C4. This increase in width was caused by dredging of the channel between the 1973 and 1974 surveys, according to a nearby resident. Continued widening between 1974 and 1975 may be due to channel adjustment to subsequent dredging.

Changes in the thalweg (lowest point in the streambed) are often indicative of the stability of the streambed. The thalweg generally moves back and forth across the streambed, defining the most active part of the channel. Over a long period of time, a raising or lowering of the thalweg elevation may indicate an increase or decrease in the transport rate of coarse sediment.

Changes in thalweg elevation (table 6) follow trends similar to those for average depth, indicating that channel changes at all survey sites are mostly confined to the streambed and that the banks of the channels are stable. Although no conclusive trends can be drawn from the survey data obtained thus far, a slight lowering of the streambed may be occurring at sites C1, C2, C3, and C4. This result would be expected downstream from the debris basin at Comer Drive as coarse sediment is trapped and removed from the stream.

TABLE 6.--*Initial dimensions and annual*

[Location of survey

Survey site	Upstream drainage area (km^2)	Average depth (m) Initial	Average depth (m) Change		Width (m) Initial	Width (m) Change		Cross-sectional area (m^2) Initial	Cross-sectional area (m^2) Change	
		1973	1973-74	1974-75	1973	1973-74	1974-75	1973	1973-74	1974-75
C 1	10.3	1.82	+0.03	+0.06	14.0	0.0	0.0	25.5	+0.4	+0.8
C 2	10.2	1.67	-.02	+.18	10.1	.0	.0	16.8	-.1	+1.8
C 3	10.1	1.17	.00	+.04	11.3	.0	.0	13.2	.0	+.5
C 4	7.15	1.35	+.08	-.01	7.0	+.4	+.3	9.5	+1.1	+.3
C 5	6.35	3.20	-1.10	-.37	9.5	.0	.0	30.4	-10.5	-3.5
C 6	6.35	1.66	-.44	-.30	19.9	.0	.0	>33.0	-8.7	-6.0
C 7	5.41	1.80	-.05	+.02	11.3	.0	.0	>20.3	-.5	+.2
C 8	3.50	1.14	+.17	-.03	12.8	.0	.0	>14.6	+2.2	-.4
C 9	2.36	1.09	-.02	-.02	7.9	.0	.0	> 8.6	-.1	-.2
C10	1.06	1.09	.00	-.06	6.1	.0	.0	> 6.6	.0	-.3
P 1	2.51	1.11	-.04	+.01	10.0	.0	.0	11.1	-.4	+.1
P 2	1.99	.58	+.01	-.01	14.6	.0	.0	> 8.5	+.1	-.1
P 3	1.92	1.50	+.02	-.03	5.5	.0	.0	> 8.2	+.2	-.2
P 4	.70	.67	+.02	-.02	8.6	.0	.0	> 5.8	+.1	-.1

HYDROLOGIC SIMULATION

Hydrologic simulation is a potentially important tool for estimating the magnitude and future frequency of floods, water-quality loading of streams, and the effects of urbanization on the hydrology of an area. In recent years, increased availability of computers has led to the development of numerous mathematical models that are capable of simulating hydrologic processes quickly and economically.

During this study, a parametric rainfall-runoff model, developed by D. R. Dawdy, was used to simulate discharge hydrographs at secondary stations where sediment samples were taken. The probable accuracy of simulation of the model was tested by comparing simulated water discharges at primary stations with observed data.

changes in stream-channel geometry, 1973-75

sites shown in figure 5]

Survey site	Thalweg elevation, arbitrary datum (m) Initial 1973	Change 1973-74	Change 1974-75	Thalweg slope (m/m) Inital 1973	Change 1973-74	Change 1974-75	Upstream development
C 1	0.5	-0.06	+0.13	0.0086	+0.0010	-0.0007	Urban, low-flow diversion, debris dam
C 2	.5	-.02	-.22	.0113	+.0001	+.0001	Urban, low-flow diversion, debris dam
C 3	.5	-.13	-.01	.0098	-.0001	+.0048	Urban, low-flow diversion, debris dam
C 4	.5	-.15	-.18	.0084	+.0023	+.0010	Urban, channel dredged in 1973, debris dam
C 5	.5	+1.13	+.50	.0101	-.0009	+.0006	Rural, 92 m upstream from debris dam
C 6	.5	+1.05	+.51	.0101	-.0009	+.0006	Rural, 105 m upstream from debris dam
C 7	.5	+.08	-.03	.0158	+.0005	-.0073	Rural, gravel pit
C 8	.5	-.34	+.03	.0142	+.0035	+.0001	Rural, gravel pit
C 9	.5	-.04	+.11	.0187	-.0052	+.0061	Rural
C10	.5	-.02	+.27	.0256	+.0016	-.0015	Rural
P 1	.5	+.05	+.04	.0125	-.0007	+.0008	Rural subdivision, golf course
P 2	.5	-.03	+.07	.0414	-.0044	+.0180	Rural subdivision, golf course
P 3	.5	-.07	+.12	.0174	+.0018	-.0012	Rural, golf course
P 4	.5	+.01	-.00	.0149	+.0020	-.0049	Rural

Description of Rainfall-Runoff Model

The basic model is divided into three principal components taken from other models. The antecedent-moisture accounting and infiltration components are similar to those described by Dawdy, Lichty, and Bergmann (1972). The routing component was developed by Schaake (1971) and is based on the theoretical motion of kinematic waves in uniform channels. The resulting model attempts to simulate events by approximating physical laws which apply to the hydrologic cycle and includes various parameters and input data which are representative of the physical characteristics of the basin. Model inputs and parameters were in English units. Results were converted to metric units for ease of comparison with previous sections of this report.

The antecedent-moisture accounting component contains four parameters which are used to simulate moisture redistribution in the soil column and evapotranspiration from the soil:

EVC is a pan coefficient for converting measured pan evaporation data at a given site to potential evapotranspiration in the basin.

RR represents the proportion of daily rainfall that infiltrates into the soil during periods that are not simulated by the model. This parameter enables the model to continue soil moisture accounting during periods when rainfall is too small for simulation or during periods when hydrologic data are missing or doubtful.

BMSM is the maximum amount of base moisture storage (inches) at field capacity or when the soil is near saturation.

DRN is a constant drainage rate for redistributing soil moisture at the end of a simulated storm event, in inches per hour.

Input data required for this component include daily rainfall, daily pan evaporation, and the initial condition of the soil column. The model assumes that this initial condition is at the wilting point, or the moisture content of the soil which is insufficient for plant growth.

Output from this component consists of the moisture content of the soil prior to a storm (BMS) and the volume of moisture which infiltrates into the soil during a storm (SMS). Output from the antecendent-moisture component (BMS and SMS) and unit rainfall data are provided as input to the infiltration component of the model.

The infiltration component contains three parameters which are used to determine infiltration rates and rainfall excess during a storm:

SWF is the suction at the wetted front for soil moisture at field capacity, in inches of pressure.

KSAT is the minimum value of hydraulic conductivity used to determine infiltration rates (minimum infiltration rate, in inches per hour).

RGF is the ratio of suction at the wetted front for soil moisture at wilting point to that at field capacity.

The model simulates infiltration into the soil using the Philips concept (Dawdy, Lichty, and Bergman, 1972) of a two-part soil-moisture distribution. Prior to a storm the soil column contains an amount of soil moisture stored at a uniform soil moisture content which can vary from wilting point to field capacity. During the storm, moisture is added to the soil column. The wetted front moves from the soil surface downward. At the end of the storm the wetted front moves back toward the soil surface. Moisture accumulated during the storm is redistributed to base moisture storage and is dissipated by evapotranspiration. This process continues until the next storm.

The routing component distributes the rainfall excess derived from the infiltration component through a series of overland flow and channel segments in the basin. All required parameters and input data are expressed as functions of time or are related to the physical characteristics of the basin. The routing component contains three parameters:

FRN is a roughness parameter similar to the Manning *n*.

PARAM (1) is a parameter generally representative of a dimension of a given type of segment, such as width for overland flow and channel segments, or diameter for a pipe segment.

PARAM (2) is a parameter representative of depth in the special case of a rectangular channel or the proportion of impervious area for an overland flow segment. Other types of channels (triangular or pipe) are defined completely by PARAM (1).

Input data required for the routing component include physical characteristics of the basin obtained from a contour map (segment length and slope), Thiessen coefficients obtained from an annual isohyetal map of the area, and optional items which control the desired accuracy or detail of the routing (number of segments, identity of segment, subdivision of channel length, time intervals). Output data consist of water discharge hydrographs. These hydrographs can be determined at the downstream end of any segment in the basin.

The division of a given basin into individual segments is illustrated in figure 11, which is the model's conception of the basin upstream from the gaging station Calabazas Creek tributary at Mt. Eden Road (11169580). The upper part of figure 11 shows a sketch of the drainage boundaries, variation of annual rainfall, and an arbitrary division of the stream channel network of the basin into various channels. If two or more channels have similar length, slope, roughness, rainfall, imperviousness, and upstream tributaries, the channels can be given the same numerical designation. The combining of similar channels and overland flow segments is advantageous because less computer time is needed for the simulation.

The lower part of figure 11 shows the division of the basin into overland flow and channel segments as conceptualized by the model. Overland-flow segments with similar physical characteristics can also be given the same number. Thus it is possible for this basin to model 54 actual physical segments by the use of only 20 different model segments (7 overland-flow segments and 13 channel segments).

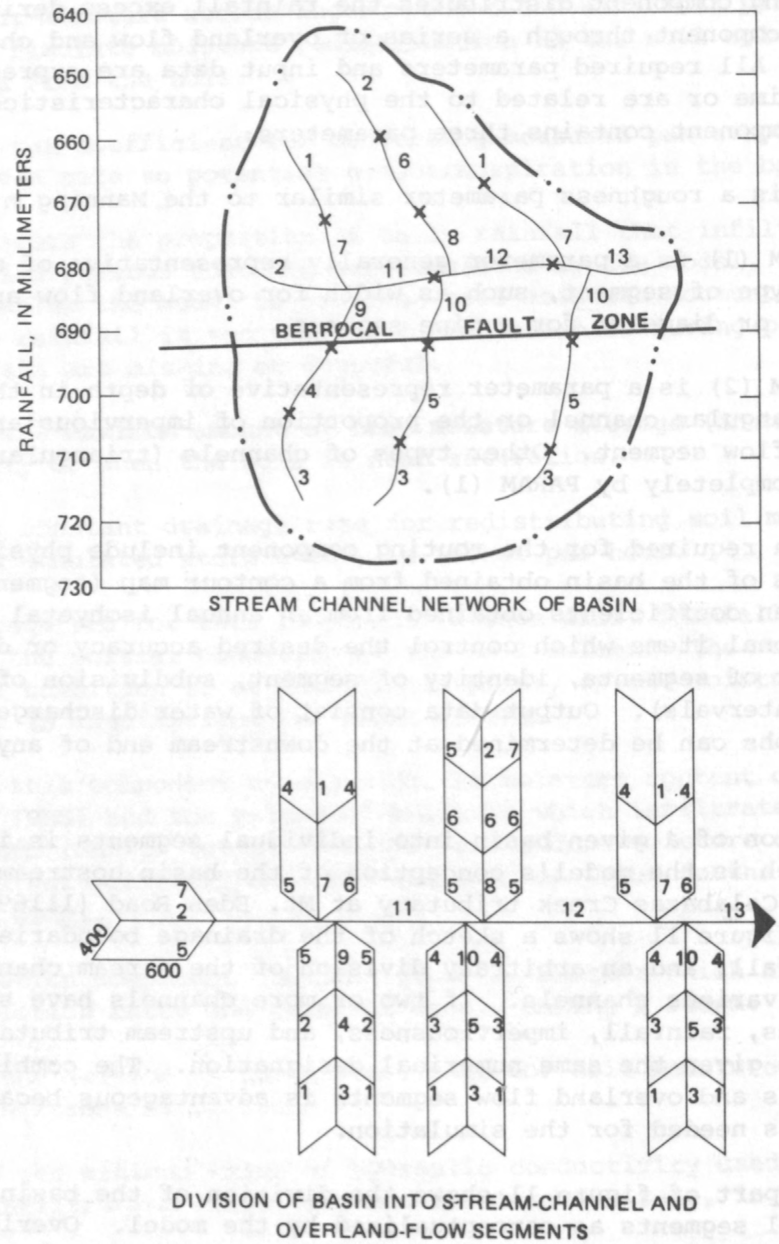


FIGURE 11.--Stream-channel network and division of the basin into stream-channel and overland-flow segments.

Preliminary Simulation Results

Simulation runs with the rainfall-runoff model were made for two subbasins--Prospect Creek at Saratoga Golf Course (11169600) and Calabazas Creek tributary above Mt. Eden Road (11169580). The 1973 storm season (October 1972 through March 1973) was arbitrarily chosen as the calibration period for the model. This period was chosen because hydrologic data had been obtained for a large number of storms and because a debris basin had been constructed during the following summer which could significantly affect later stormflows in the Calabazas Creek basin.

Hydrologic data used in the calibration of the model include:

1. Daily and unit rainfall (compiled for 15-minute time increments) at Garrod Ranch (11169575).
2. Daily pan evaporation at Alamitos percolation pond, San Jose (about 17 km east of study basin).
3. Daily and unit water discharge (15-minute) at Prospect Creek at Saratoga Golf Course, near Saratoga (11169600).
4. Daily and unit water discharge (15-minute) at Calabazas Creek tributary at Mt. Eden Road (11169580).
5. Mean annual isohyetal map for Cupertino 7 1/2-minute quadrangle (Santa Clara Valley Water District, written commun., 1973).
6. Data related to the physical characteristics of the basin (segment length, slope, and channel dimensions), estimated from contours on the Cupertino 7 1/2-minute quadrangle map.
7. Initial parameter values, obtained from suggested values given in the documentation of the model (D. R. Dawdy, written commun., 1976), or, in the case of EVC, RR, and DRN, estimated or computed from rainfall and water discharge records. Initial parameter values are given in table 7.

Optimization runs were made to determine a combination of parameters SWF, KSAT, RFG, and BMSM which best fit the storm runoff of storms selected for calibrating the model. Optimization was based on an objective function equal to the sum of the squared deviations of the logarithms of storm volumes (Dawdy, Lichty, and Bergman, 1972). After several optimization runs were made, individual storms were analyzed to determine if the observed runoff at gaging stations was related to observed rainfall. Several storms in the early part of the storm season (October and November) were rejected for simulation because insignificant runoff was observed or runoff was low relative to most of the other storms. Of the 14 storms selected for simulation, 3 were not used in optimization of storm volume, but data were retained for possible further analysis. The storms not used include the large storm of November 13-16, 1972, and the two small storms of January 29-30, 1973, and March 6, 1973.

TABLE 7.--*Initial and optimum parameters used to fit hydrologic data for Calabazas Creek tributary at Mt. Eden Road, near Saratoga, and Prospect Creek at Saratoga Golf Course, near Saratoga*

Parameter	Calabazas Creek tributary at Mt. Eden Road, near Saratoga (11169580)		Prospect Creek at Saratoga Golf Course, near Saratoga (11169600)	
	Initial	Optimum	Initial	Optimum
SWF	5.0	3.4	5.0	5.9
KSAT	.1	.029	.1	.045
RGF	10	6.7	10	10.9
BMSM	3.0	3.2	3.0	3.5
EVC	.7	.7	.7	.7
RR	.41	.41	.82	.82
DRN	.5	.5	.5	.5

After storm volumes had been optimized to determine the lowest value of the objective function, peak flows were computed. Initial values of simulated peak flow were close to those obtained from flow records. Only minor adjustments in overland flow and channel roughness were needed to obtain adequate agreement between observed and simulated peak flows. Other data pertaining to the physical characteristics of the individual basins were not altered.

A comparison of observed runoff and peak flow data thus far analyzed is shown in table 8. Actual and simulated hydrographs for the two stations modeled are shown in figure 12. These data, although preliminary, indicate that simulated storm runoff and peak flow values are in reasonable agreement with observed values for the larger storms. Small storms show poor agreement.

TABLE 8.--*Comparison of simulated and observed rainfall and runoff data*

Storm date	Observed rainfall at Garrod Ranch (mm)	Calabazas Creek tributary at Mt. Eden Road, near Saratoga (11169580)						Prospect Creek at Saratoga Golf Course, near Saratoga (11169600)					
		Runoff volume (mm)		Percent deviation	Peak flow (m^3/s)		Percent deviation	Runoff volume (mm)		Percent deviation	Peak flow (m^3/s)		Percent deviation
		Observed	Simulated		Observed	Simulated		Observed	Simulated		Observed	Simulated	
1972													
November 13-16	115	53.1	55.6	+5	1.42	1.28	-10	13.8	26.6	+93	0.51	0.60	+18
1973													
January 8-10	70.9	33.8	26.9	-20	1.16	.91	-22	13.8	10.9	-21	.19	.28	+47
January 15-16	69.3	48.5	42.7	-12	2.58	2.20	-15	24.6	21.6	-12	1.10	.83	-25
January 16-18	87.9	75.4	69.6	-8	1.76	1.23	-30	40.3	53.3	+32	.96	.67	-30
January 29-30	24.6	3.7	5.0	+35	.051	.055	+8	3.8	1.4	-63	.057	.007	-88
February 3- 5	49.5	15.6	21.1	+35	.25	.35	+40	13.3	8.3	-38	.093	.092	-1
February 5- 7	61.7	48.8	46.7	-4	1.13	1.23	+9	26.8	31.3	+17	.48	.65	+35
February 9-12	65.5	66.8	57.7	-14	1.59	1.16	-27	45.7	33.8	-26	.76	.48	-37
February 12-13	24.9	18.1	19.2	+6	.42	.48	+14	14.6	14.1	-3	.21	.19	-10
February 24	27.2	8.4	9.2	+10	.65	.27	-58	3.8	4.0	+5	.068	.043	-37
February 26-27	41.9	21.3	23.1	+8	1.36	.88	-35	10.7	12.1	+13	.42	.31	-26
February 27-28	51.6	70.9	45.0	-37	2.46	1.01	-59	24.1	29.2	+21	.62	.46	-26
March 6	12.4	6.5	3.4	-48	.51	.047	-91	1.9	1.3	-31	.040	.010	-75
March 19-20	31.0	10.5	13.2	+26	.51	.54	+6	5.0	5.3	+6	.068	.094	+38

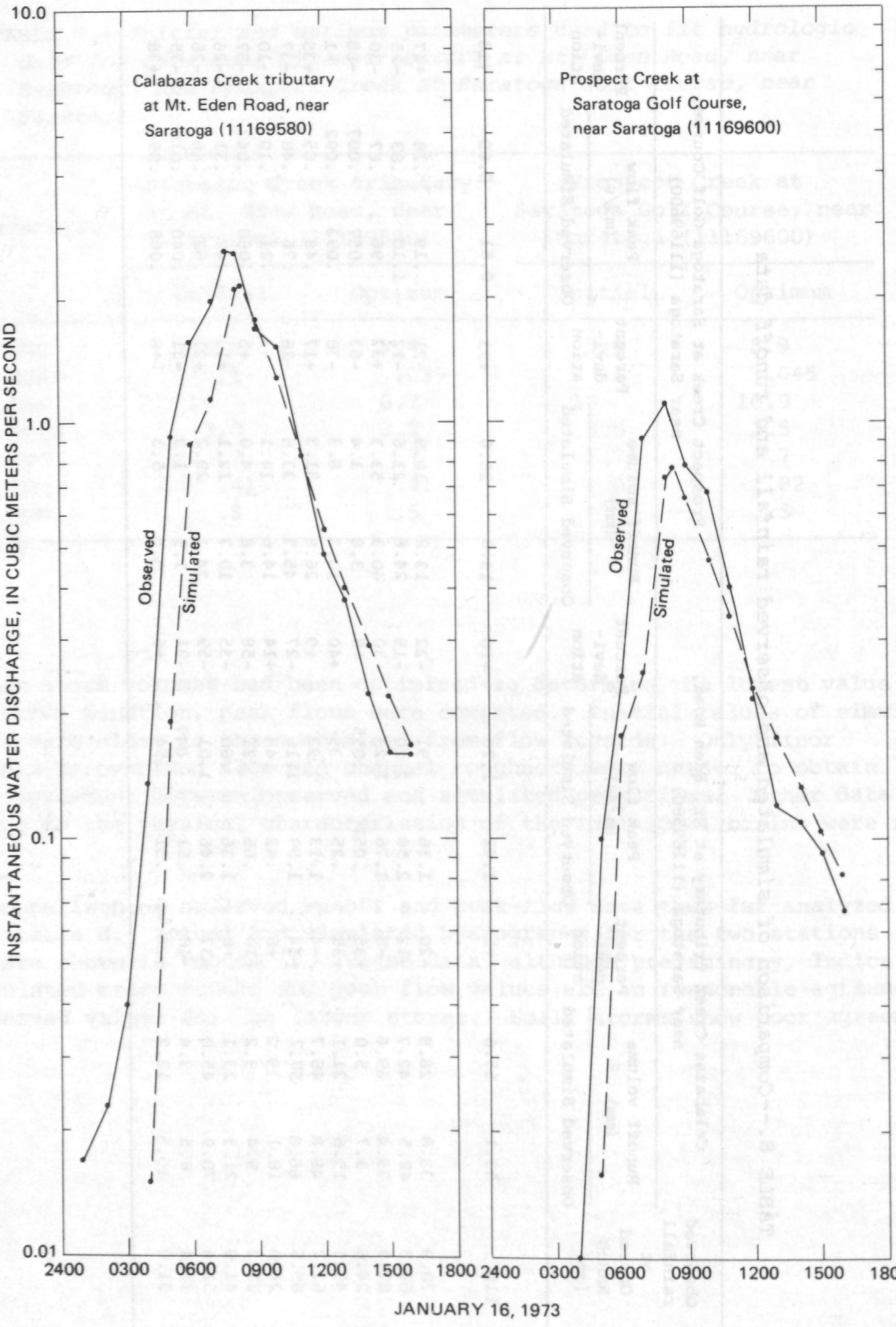


FIGURE 12.--Typical comparison of simulated and observed streamflow at Calabazas Creek tributary at Mt. Eden Road, near Saratoga, and Prospect Creek at Saratoga Golf Course, near Saratoga.

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