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EROSION AND SEDIMENT CHARACTERISTICS OF THE SOUTHEASTERN UINTA BASIN, UTAH AND COLORADO

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[Plate is in pocket]

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CONVERSION FACTORS

Values in this report are given in inch-pound units. For those readers who may prefer to use metric units rather than inch-pound units the conversion factors for the terms used in this report are listed below. Multiply inch-pound units by the conversion factors given below to obtain their metric equivalents.

Inch-pound Unit	Inch-pound Abbreviation	Conversion factor	Metric Unit	Metric Abbreviation
Acre	--	4046.8	Square meter	m^2
		0.00405	Square kilometer	km^2
Acre-foot	acre-ft	1233	Cubic meter	m^3
Acre-foot per square mile	acre-ft/mi^2	476.2	Cubic meters per square kilometer	m^3/km^2
Cubic foot per second	ft^3/s	0.0283	Cubic meter per second	m^3/s
Cubic foot per second per square mile	$ft^3/s/mi^2$	0.0109	Cubic meter per second per square kilometer	$m^3/s/km^2$
Foot	ft	0.3048	Meter	m
Foot per mile	ft/mi	0.1894	Meter per kilometer	m/km
Foot per second	ft/s	0.3048	Meter per second	m/s
Inch	in.	2.540	Centimeter	cm
		0.0254	Meter	m
Mile	mi	1.609	Kilometer	km
Pound	lb	0.4536	Kilogram	kg
Pound per cubic foot	lb/ft^3	16.03	Kilogram per cubic meter	kg/m^3
Square foot	ft^2	0.0929	Square meter	m^2
Square mile	mi^2	2.590	Square kilometer	km^2
Ton (short, 2,000 lb)		0.9072	Metric ton	t
Ton per acre-foot		0.0007	Metric ton per cubic meter	t/m^3

Chemical concentration and sediment-particle fall diameter are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L). Milligrams per liter is a unit expressing the concentration of chemical constituent in solution as weight (milligrams) of solute per unit volume (liter) of water.

Sediment-particle fall diameters are given in micrometers (µm). One micrometer is equal to 0.0001 centimeters or 3.937×10^{-5} inches.

Air temperature is given in degrees Fahrenheit (°F), which can be converted to degrees Celsius (°C) by the following equation: $°C=(°F-32)/1.8$.

INTRODUCTION

Purpose and scope

The southeastern Uinta Basin of Utah and Colorado contains vast energy resources, the most extensive of which is oil shale. It is probable that mining and processing of the oil shale will have a large impact on the water resources of the basin. Therefore, in October 1974, the U.S. Geological Survey began a comprehensive investigation to determine hydrologic conditions prior to extensive mining. This report presents the results of the investigation pertaining to erosion and sediment. The data obtained during this investigation are reported by Conroy and Fields (1977) and Conroy (1979 and 1980), and numerous interpretive reports on other aspects of the investigation have been prepared.

The major objectives of this investigation were to: (1) Define the erosion and sediment characteristics prior to extensive mining and processing, and (2) determine impacts that the mining and processing might have on these characteristics. Most of the investigation was directed at the first objective.

The location of the study area, channel-erosion sites, and sediment stations are shown in figure 1. Beginning in the 1975 water year, the Geological Survey operated a hydrologic-monitoring network in the study area. The data network included 6 channel-erosion sites to measure streambed aggradation and degradation and 32 hillslope-transect sites to estimate sheet erosion. The channel-erosion and hillslope-transect sites were established during the summer and fall of 1975. Data obtained after the 1979 water year were not used in this report.

At the peak of data collection, 23 partial-record and 5 daily-record sediment stations were included in the network. The 28 sediment stations were at continous-record, streamflow-gaging stations. Samples generally were obtained monthly for the perennial streams and at times of flow for the ephemeral streams. Daily suspended-sediment discharges were determined for the five daily-sediment stations. On days when suspended-sediment samples were not obtained, suspended-sediment discharge was estimated using sediment-rating curves. Although monitoring is presently (1981) continuing at decreased levels, not all stations were maintained during the entire period.

Other investigations

The southeastern Uinta Basin has been the subject of many previous investigations, most of which focused on the economic geology of the area. Prior to 1974, the Geological Survey conducted three hydrologic investigations on surface- and ground-water supply (Price and Miller, 1975; Fields and Adams, 1975; Hood and Fields, 1978).

The White River Shale Project conducted an environmental-baseline investigation of part of the study area near Federal oil-shale lease tracts Ua and Ub (VTN Colorado, Inc., 1976, 1977). Grenney and Kraszewski (1980) evaluated the sediment discharge of the White River for the 1975-76 water years.

EROSION AND SEDIMENT CHARACTERISTICS OF THE SOUTHEASTERN UINTA BASIN, UTAH AND COLORADO

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ABSTRACT

The southeastern Uinta Basin contains extensive deposits of oil shale, and future oil-shale development probably will have a large impact on water resources in the basin. The U.S. Geological Survey has been determining baseline hydrologic characteristics. This report presents the results of the investigation pertaining to erosion and sediment.

The 1975-79 mean annual suspended-sediment discharge for the White River at its mouth was 1,759,000 tons and the 1977-79 mean for the White River near the Colorado-Utah State line was 1,031,000 tons. Suspended-sediment load of the White River at its mouth was between 69 and 77 percent of the total-sediment load. The sediment yield for the drainage area between the State line gage and the river's mouth for 1977-79 was about 900 tons per square mile per year. These values may be much less than the long-term values because there were no extreme peak flows in the White River during 1975-79.

During spring runoff (March-June), large amounts of sediment are scoured from the sandy bottom of the downstream reaches of the White River and during flow recession an almost equivalent amount of sediment is deposited, so that the mean streambed altitude changes only slightly. During the late summer, sediment discharge in the White River can increase significantly in response to thunderstorm runoff from normally dry tributaries.

The presence of alluvial fans in channels and the measurement of aggradation at several tributary streams indicates that upland deposition of eroded material is occurring in the basin. Estimated average source-area sediment yields ranged from less than 0.2 acre-foot per square mile per year on grass and brush-covered plateaus to 2.2 acre-feet per square mile per year on extensively dissected hills and valleys. The estimated annual source-area sediment yield for the entire basin is about 0.8 acre-foot per square mile.

Both in situ- and surface-retorting of oil shale will result in increased erosion during construction of surface facilities. Erosion of spent shale may be great during the operational phase, but impoundment ponds would prevent runoff from transporting large amounts of sediment to the White River. A reservoir on the White River has been proposed to supply water for oil-shale processing. Decreased peak flows and release of clear water from the reservoir could result in channel degradation and accelerated channel migration in downstream reaches of the White River. However, it is possible instead that vegetation encroachment could result in channel clogging and bank stabilization.

Definition of terms

Terms related to streamflow, erosion, sediment, and other hydrologic data as used in this report are defined below. A more complete list of terms is given by the U.S. Geological Survey (1977), and most of the following are taken wholly or partly from that report.

Aggradation. The geologic process by which streambeds, flood plains, and the bottoms of other water bodies are raised in altitude by the deposition of material eroded and transported from other areas. It is the opposite of degradation.

Alluvial. Pertains to material deposited by a stream or flowing water.

Armoring. The formation of a resistant layer of relatively large particles resulting from removal of finer particles by erosion.

Channel. A natural or artificial waterway which periodically or continuously contains moving water.

Concentration of sediment (by mass). The ratio of the mass of dry sediment in a water-sediment mixture to the mass of the mixture.

Degradation. The geologic process by which streambeds, flood plains, and the bottoms of other water bodies are lowered in altitude by the removal of material from the boundary. It is the opposite of aggradation.

Deposition. The mechanical or chemical processes through which sediments accumulate.

Discharge. See stream discharge and sediment discharge.

Drainage basin. The area tributary to or draining to a lake, stream, or measuring site.

Erosion. The wearing away of the land surface by detachment and movement of soil and rock fragments through the action of moving water and other geological agents.

Gaging station. A selected cross section of a stream channel where one or more variables are measured continuously or periodically to index discharge and other parameters.

Median diameter. The size of sediment such that one-half of the mass of the material is composed of particles larger, and the other one-half is composed of particles smaller.

Particle-size distribution. The frequency distribution of the relative amounts of particles in a sample that are within specified size ranges, or a cumulative frequency distribution of the relative amounts of particles coarser or finer than specified sizes. Relative amounts are usually expressed as percentages by mass.

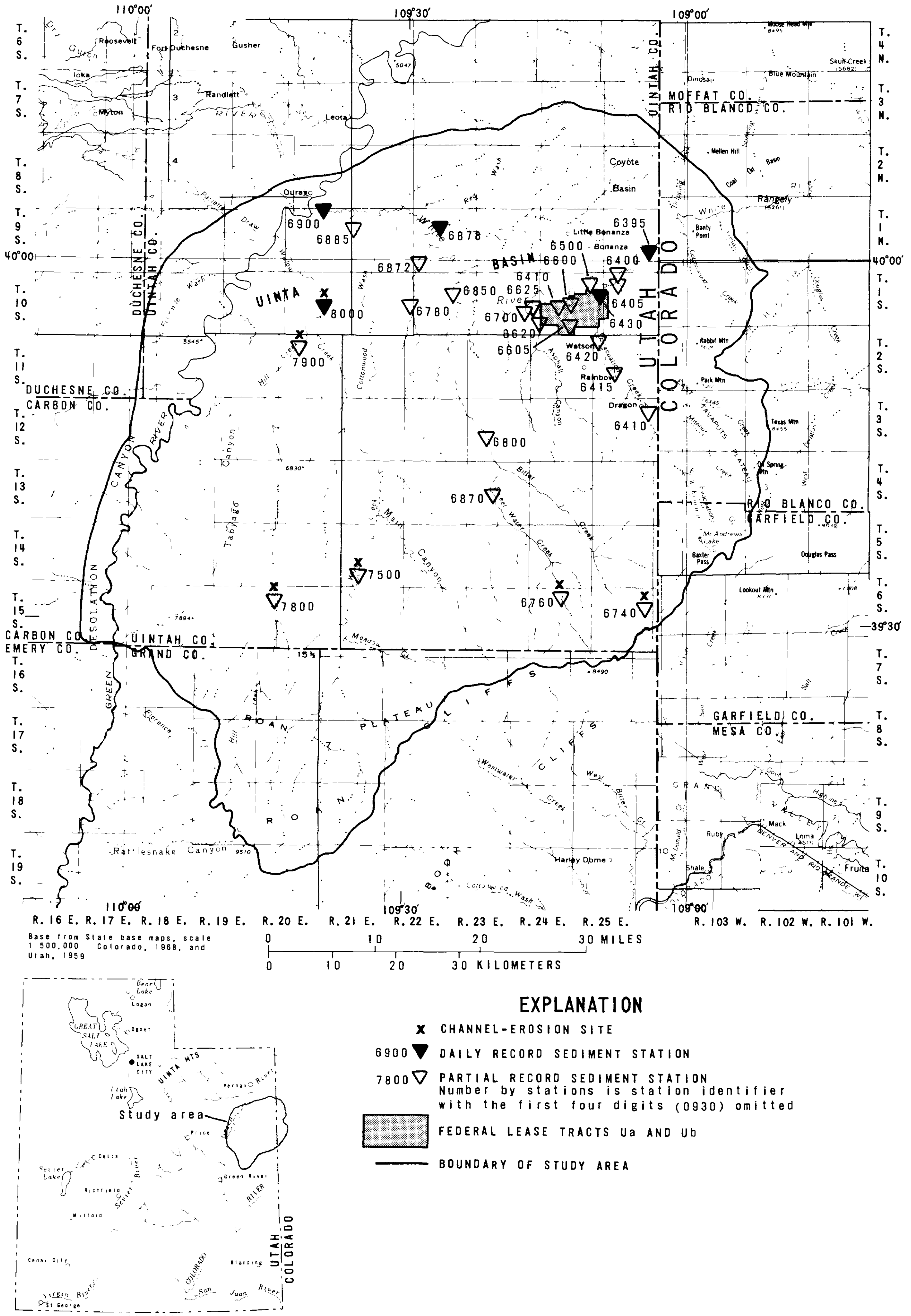

Figure 1.—Location of study area, channel-erosion sites, sediment stations, and Federal lease tracts Ua and Ub.

Recurrence interval (return period). The average interval of time within which the given flood will be equaled or exceeded once. The recurrence interval is the reciprocal of the probability of the given flood magnitude being equaled or exceeded in any 1 year.

Rill erosion. Land erosion forming small, well-defined incisions in the land surface less than 1 foot in depth. A subclass of sheet erosion.

Runoff. Flow that is discharged from the area by stream channels--sometimes subdivided into surface runoff, ground-water runoff, and seepage.

Scour. The enlargement of a flow section by the removal of boundary material through the action of the fluid in motion.

Sediment. (1) Particles derived from rocks or biological materials that have been transported by a fluid. (2) Solid material (sludges) suspended in or settled from water.

Sedimentation. A broad term that pertains to the five fundamental processes responsible for the formation of sedimentary rocks: (1) weathering, (2) detachment, (3) transportation, (4) deposition (sedimentation), and (5) diagenesis; and to the gravitational settling of suspended particles that are heavier than water.

Sediment discharge. The mass or volume of sediment (usually mass) passing a stream transect in a unit of time. The term may be qualified, for example, as suspended-sediment discharge, bedload discharge, or total-sediment discharge.

Sediment particle. Fragments of mineral or organic material in either a singular or aggregate state.

Sediment yield. Sometimes called basin sediment yield. The total sediment outflow from a drainage basin in a specific period of time. It includes bedload as well as suspended load, and usually is expressed in terms of mass, or volume per unit of time.

Sheet erosion. The more or less uniform removal of soil from an area by raindrop splash and overland flow without the development of water channels. Included with sheet erosion, however, are the numerous, conspicuous small rills that are caused by minor concentrations of runoff.

Source-area sediment yield. The amount of sediment moved from a source area through the tributary channels to the main transport channel.

Standard fall diameter. Sometimes simply fall diameter. The diameter of a sphere that has a specific gravity of 2.65 and has the same standard fall velocity as the particle.

Stream discharge. Often simply discharge. The quantity of flow passing a stream transect in a unit of time.

DESCRIPTION OF THE STUDY AREA

Topography and land use

The southeastern Uinta Basin has an area of about 3,000 square miles. A Landsat photograph (fig. 2) shows the north-trending stream valleys that dissect the area. The major topographic feature of the basin is the north sloping, greatly dissected Roan Plateau, where numerous stream valleys intersect to form benchlike mesas. Valley walls in the southern part of the plateau are nearly vertical. The maximum altitude in the basin, about 9,500 feet above sea level[1], is in the southern part of the basin near the Roan Cliffs. The minimum altitude, about 4,310 feet, is along the Green River.

About 56 percent of the land in the study area is owned by the Federal Government, 24 percent is in Indian Trust, 10 percent is State owned, and the rest is privately owned. The area is sparsely populated--only one person per 75 square miles. The main industries are cattle and sheep ranching, gilsonite mining, and oil and gas production. Several oil-shale mining and retort facilities are in various stages of planning and construction by the White River Shale Project, Paraho Development Corp., TOSCO Corp., and Geokinetics, Inc.

Geology and soils

The nature of the soils and the surface geology dictate, in part, the erosion characteristics of the area. The geology has been mapped by Cashion (1967) and Rowley, Tweeto, and Hansen (1978). In ascending order, the major exposed formations are the Wasatch, Green River, Uinta, and Duchesne River Formations, all of Tertiary age.

The Wasatch Formation is exposed in the upper reaches of the deep canyons and near the drainage divides of the north-trending streams. The Green River Formation is exposed throughout the study area, primarily on the high plateaus and lower canyon walls. The Uinta Formation is exposed on the low plateaus along the White River, and the Duchesne River Formation is exposed north of the White River.

Soil maps of Utah (Wilson and others, 1975) and of Rio Blanco County Colo. (U.S. Soil Conservation Service, 1972) were used to classify soil associations in the study area (fig. 3). A soil map of Garfield County, Colo. was not available. The extensions of the soil associations across the State line are not exact because the classification used by Wilson and others (1975) is not identical to that used by the U.S. Soil Conservation Service (1972). The hydrologic characteristics of the soils are presented in table 1.

Marlstone and shale fragments densely cover the soil in large parts of the southeastern Uinta Basin where the Parachute Creek Member of the Green River Formation is exposed. These fragments, shown in figure 4, protect the soil from the impact of raindrops and decrease sheet erosion.

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[1]National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

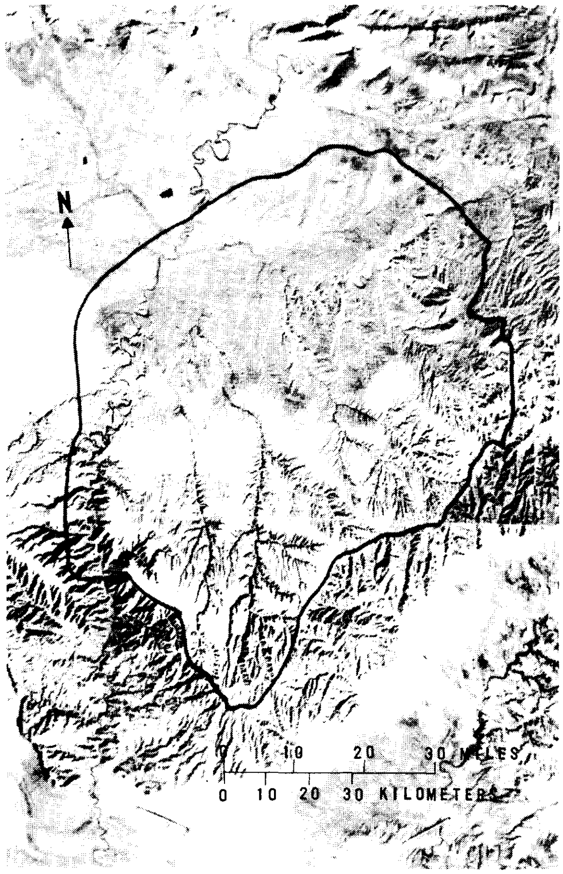

Figure 2.—Landsat photograph showing the north-trending stream valleys that dissect the southeastern Uinta Basin.

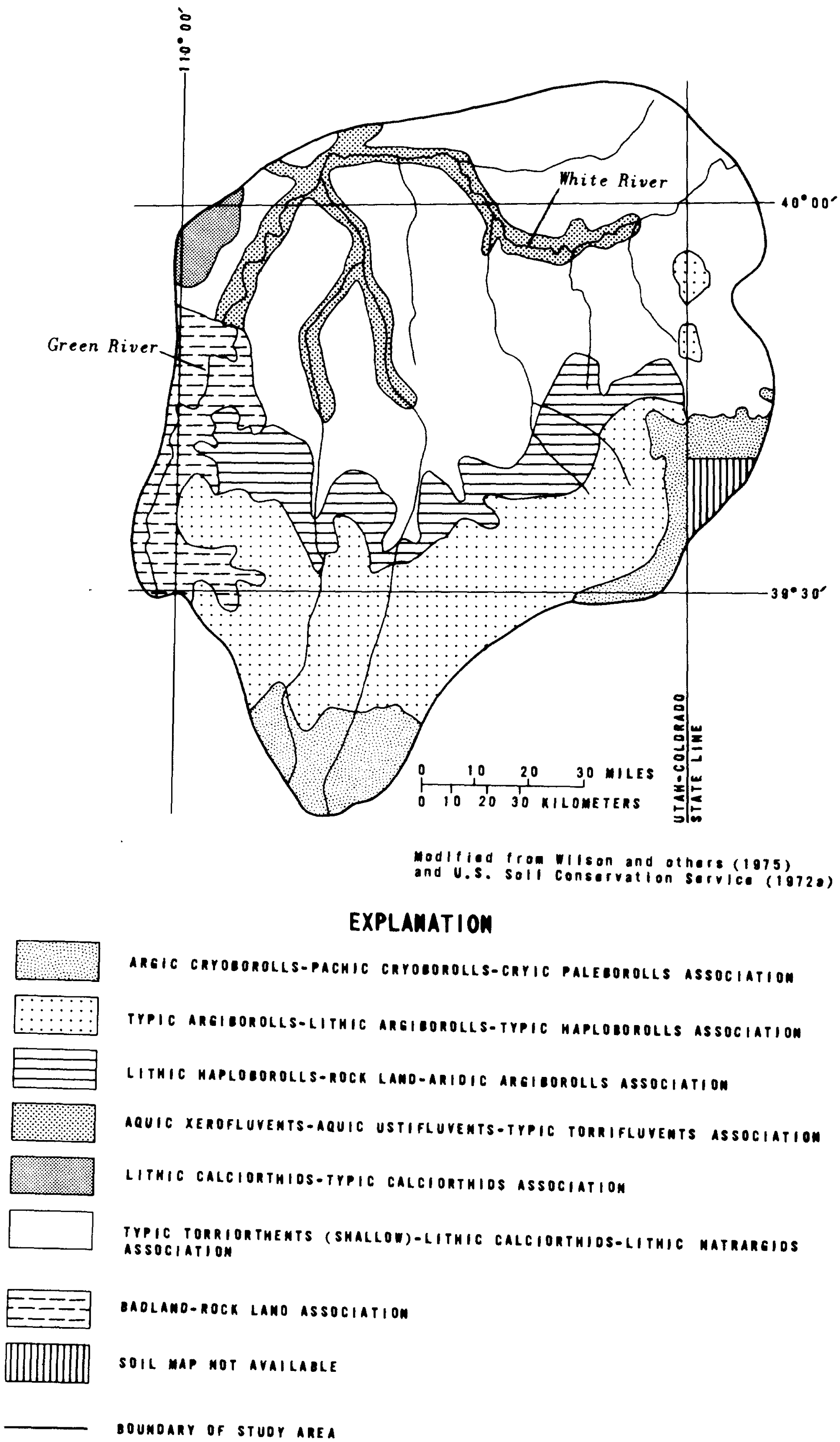

Figure 3.—Soil associations of the southeastern Uinta Basin.

Table 1.--Hydrologic characteristics of soils in the southeastern Uinta Basin of Utah and Colorado (Wilson and others, 1975)

Argic Cryoborolls-Pachic Cryoborolls-Cryic Paleborolls Association

Moderately well to somewhat excessively drained. Permeability slow to rapid. Runoff medium to slow and sediment yield moderately low.

Typic Argiborolls-Lithic Argiborolls-Typic Haploborolls Association

Well drained. Permeability slow to moderate. Runoff medium to rapid and sediment yield low.

Lithic Haploborolls-Rock Land-Aridic Argiborolls Association

Well drained. Permeability moderate to very slow. Runoff slow to medium and sediment yield moderate.

Aquic Xerofluvents-Aquic Ustifluvents-Typic Torrifluvents Association

Well to somewhat poorly drained. Permeability slow to moderately rapid. Runoff slow to rapid and sediment yield high mainly because of bank cutting.

Lithic Calciorthids-Typic Calciorthids Association

Well to somewhat excessively drained. Permeability slow to rapid. Runoff very slow to rapid and sediment yield moderate to low.

Typic Torriorthents (Shallow)-Lithic Calciorthids-Lithic Natrargids Association

Well drained. Permeability moderate to slow. Runoff rapid and sediment yield high.

Badland-Rock Land Association

Runoff rapid to very rapid and sediment yield very high. Control of soil loss and the resultant heavy sediment yield a major problem in these areas.

Figure 4.—Marlstone and shale fragments that cover large parts of the southeastern Uinta Basin.

Climate

The climatological characteristics of the southeastern Uinta Basin have been described in detail by Waltemeyer (1982). The study area is arid to subhumid; mean annual precipitation varies from less than 8 inches at lower altitudes to more than 20 inches in a part of the Roan Plateau. During late summer and early fall, intense thunderstorms cause flashfloods. The intensity of a 1-hour storm with a recurrence interval of 2 years is about 0.6 inch per hour, and for a 100-year recurrence interval it is about 1.5 inches per hour (Miller and others, 1973, table 11 and figs. 19, 24, 25, and 30).

The mean monthly air temperatures (1956-79) at the Ouray 4NE weather station are presented in figure 5 (U.S. Weather Bureau, 1956-66; U.S. Environmental Sciences Services Administration, Environmental Data Service, 1967-70; National Oceanic and Atmospheric Administration, Environmental Data Service, 1971-80). For December-February, the mean monthly temperature is below freezing.

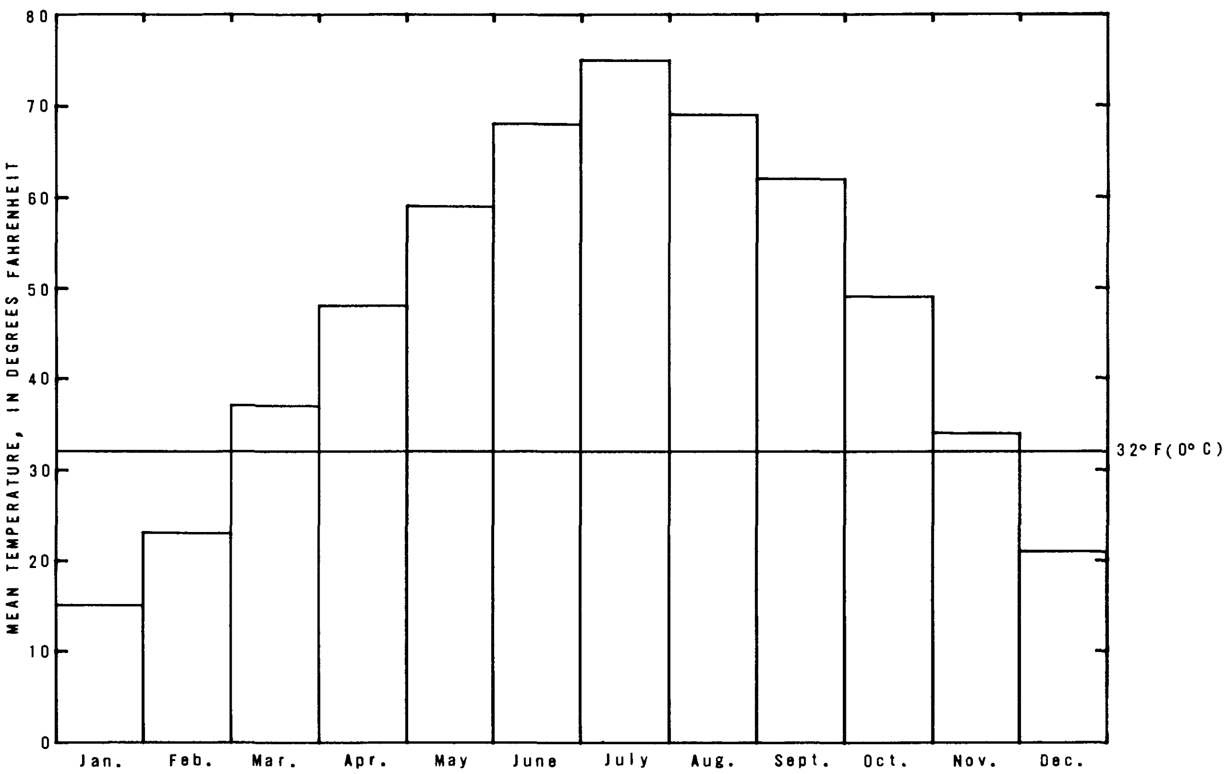

Figure 5.—Seasonal variation in mean monthly temperature at Ouray 4NE weather station, 1956-79.

Vegetation

The vegetation of the southeastern Uinta Basin has been mapped by Butler and England (1979). The northern one-half of the study area is sparsely vegetated and is dominated by salt-desert shrubs such as shadscale (*Atriplex confertifolia*), mat saltbrush (*A. corrugata*), little rabbitbrush (*Chrysothamnus viscidiflorus*), and bud sagebrush (*Artemesia spinescens*). In the southern one-half of the study area where the precipitation is greater, the vegetation is denser, and herbaceous ground cover is much more common. The dominant trees and shrubs in this area are Utah juniper (*Juniperus osteosperma*), Douglas fir (*Pseudotsuga menziesii*), pinyon (*Pinus edulis*), little rabbitbrush, and Utah serviceberry (*Amelanchier utahensis*). Along intermittent streams and on terraces near perennial streams, phreatophytes such as Fremont cottonwood (*Populus fremontii*), and greasewood (*Sarcobatus vermiculatus*) are common.

Runoff

Long-term average runoff of the Green and White Rivers in this vicinity is about 0.17 cubic foot per second per square mile and does not vary across the study area (K. L. Lindskov, U.S. Geological Survey, written commun., 1981). The average flows of the tributary streams vary from less than 0.001 to more than 0.10 cubic foot per second per square mile. The mean flow within the study area of all the tributaries to the White River was about 6 cubic feet per second (0.005 cubic foot per second per square mile) during 1975-79 water years and was primarily from Evacuation and Bitter Creeks and Coyote Wash. Willow Creek, a tributary to the Green River, drains about one-third of the study area and contributed an average annual discharge of 24 cubic feet per second (0.027 cubic foot per second per square mile) during the 1948-55 and 1975-79 water years.

Most of the inflow to the White River within the study area is from low-altitude snowmelt during February or March and from thunderstorms during late summer. In contrast to the White River tributaries, snowmelt runoff in Willow Creek peaks during April or May because Willow Creek drains the higher parts of the Roan Plateau where the water content of the snowpack reaches a maximum near April 1 (Waltemeyer, 1982, table 2). About two-thirds of the inflow to the White River from the study area is from the normally dry Coyote Wash which, after the spring snowmelt, only flows in response to thunderstorms. Except for the perennial flow in Bitter Creek, the pattern of runoff from the other tributaries to the White River is similar to that in Coyote Wash.

The 2-year peak flow for the White River near Watson (station 6500 in fig. 1) is about 4,100 cubic feet per second, and the mean daily flow for 56 years of record is 695 cubic feet per second. These flows are representative of the entire reach of the White River within the study area. The maximum flow occurs between March and October and results either from snowmelt or thunderstorm runoff. The Green River within the study area has been regulated since 1962 by the Flaming Gorge Reservoir on the Utah-Wyoming border, and the maximum flows usually are during late May or June. The 2-year peak flow for the Green River downstream from its confluence with the White River is about 23,000 cubic feet per second, and the mean daily flow since completion of the Flaming Gorge Reservoir is about 5,500 cubic feet per second. Low flows for both the White and Green Rivers generally occur during the winter.

Willow Creek is the only tributary with enough systematic record to define flood-frequency curves. The 2-year peak flow for Willow Creek near Ouray (station 8000 in fig. 1) is about 630 cubic feet per second. The maximum flows for the period 1975-79 for other study area streams are 687 cubic feet per second at Coyote Wash (station 6878); 1,980 cubic feet per second at Evacuation Creek near Watson (station 6430); and 1,660 cubic feet per second at Bitter Creek near Bonanza (station 6800). An indeterminate amount of flow (probably 10 to 15 percent) bypassed the gage during the flood in Coyote Wash.

EROSION AND SEDIMENT

Erosion

Erosion is the wearing away of the land by water, wind, or ice. Wind and water are the most active agents of erosion in the southeastern Uinta Basin, but ice causes erosion by freeze-thaw fracturing of hillslopes and streambanks. Channel-ice breakup during rapid spring thaws at times gouges the streambanks and channels, facilitating later erosion.

Erosion may be classified as sheet or channel erosion. Sheet erosion begins when rainfall loosens surface material that is transported overland in sheet flow, that is, not in discernible channels. The rate of sheet erosion is greatly increased with the formation of rills, small channels that concentrate the sheet flow. The transport capacity of the flow increases in rills, and additional material can be eroded from the bed and banks of the rills as they widen and deepen.

Channel erosion is similar to sheet erosion in rills, except that it occurs on a larger scale and may even result in the formation of gullies or major stream channels. Rills usually disappear seasonally in response to frost action, whereas channels and gullies generally are perennial features. As with rills, material is eroded from the beds and banks of channels and gullies. However, there is more opportunity for erosion to occur in channels and gullies because the duration of flow is much longer than in rills.

Mass wasting is the downslope movement by gravity of large quantities of soil, rock, and debris. In the study area, this occurs mostly on the steep-walled canyons. No quantitative data are available for the movement caused by mass wasting in the southeastern Uinta Basin.

Sheet erosion

Sheet erosion could not be measured accurately. Because of the diverse morphology of the area, it was not practical to use empirical erosion equations such as the Universal Soil Loss Equation (Musgrave, 1947). Thirty-two hillslope transects were established within the study area, but only a few could be located and remeasured. The erosion that was measured over a 5-year period at those sites that were found was less than the measurement error. Therefore, the only estimates of sheet-erosion rates are those included in the upland erosion factor of the method used to determine source-area sediment yield, which is discussed in a following section.

Channel erosion

The major types of channel erosion are headcutting in gullies, streambed degradation, and channel migration.

Gully-headcut advancement

Vertical or near vertical scarps in channels are called headcuts. Headcuts can advance upstream by erosion.

The movement of headcuts can be determined by locating the headcuts on successive aerial photographs. Aerial photographs for August 1965 and July-August 1974 were available for this study. The first set was stereographic black and white at a scale of 1:32,000, and the second set was false-color infrared at a scale of 1:31,688. Seventy-nine headcuts were located for first-, second-, and third-order streams (Chow, 1964, p. 4-43) on the two sets of photographs, and the locations are shown on plate 1. The distance from a headcut to a permanent feature, such as a stream confluence, was determined for each set of photographs, and a comparison of these lengths determined headcut advancement.

None of the 79 headcuts (pl. 1) show any signs of advancement during the 9 years between photography flights. However, only large movements could be observed at the scale of 1:32,000 (100 feet on ground equals 0.04 inch on photograph).

Streambed degradation and aggradation

Tributary channels.--Measurements were made at six channel-erosion sites near gaging stations on tributaries to the White and Green Rivers to monitor streambed degradation. Between 1 and 3 cross sections, usually separated by less than 300 feet, were monumented with steel pins at each site and changes in the mean altitude of the streambed were used as an indicator of erosion.

The results of the channel surveys (table 2) indicated a slight aggradation rather than degradation at the four cross sections on Bitter and Sweetwater Canyon Creeks. Sediment generally was accumulating on the sides of the banks between the bed and the flood plain, thus, indicating deposition during flow recession. The channel surveys indicate slight degradation at three of the four cross sections on Hill Creek. However, this probably resulted from channel migration.

It is possible that the small observed altitudinal changes in the streambeds represent changes caused only by annual scour and fill, despite the fact that some of the surveys were 5 years apart. Observations over a longer period would be needed to distinguish small amounts of aggradation and degradation from the effects of annual scour and fill.

Table 2.--Summary of streambed changes at tributaries to the White and Green Rivers

Stream type: P, perennial; E, ephemeral; I, intermittent.
Cross-section number: Increases in a downstream direction.
Average change in streambed altitude: Positive values indicate aggradation, negative values degradation.

Station number and name	Stream type	Period of record	Number of surveys	Number of cross sections	Cross-section number	Average change in streambed altitude (feet per year)
09306740, Bitter Creek above Dick Canyon, near Watson	P	6-12-75 to 10-13-77	3	2	1	+0.02
					2	+ .04
09306760, Sweetwater Canyon Creek below South Canyon, near Watson	P	6-26-75 to 5-21-80	4	2	1	+ .02
					2	+ .05
09307800, Hill Creek above Towave Reservoir, near Ouray	P	6-26-75 to 5-21-80	3	3	1	– .09
					2	+ .08
					3	– .05
09307900, Hill Creek near mouth, near Ouray	E	7- 2-75 to 5-20-80	2	1	1	– .09
09307500, Willow Creek[1] above diversions, near Ouray	P	6-11-75 to 11- 9-76	2	2	1	Degradation
					2	Do.
09308000, Willow Creek[1] near Ouray	I	7- 7-75 to 5-20-80	2	1	1	Channel migration

[1] Reference pins not recovered at final observation.

The observed changes in streambeds shown in table 2 probably are insignificant when compared to great changes caused by major floods. As an example, the channel at Willow Creek above diversions, near Ouray (09307500), showed some degradation between June 1975 and November 1976. By contrast, a July 1977 flood deposited between 6 and 12 inches of sand on the streambanks and flood plain and covered the reference pins, which could not be relocated. However, the channel near the gaging station was scoured.

The erosion at the channel at Willow Creek near Ouray (09308000) was primarily by channel migration between 1975 and 1980 (table 2). In fact, the reference pin installed at the left edge of the channel on July 1975 was removed by this migration, and the main channel during 1980 occupied the former site of the pin.

White River channel.--The mean channel altitude (gage datum) was determined for the White River at mouth, near Ouray (station 6900 in fig. 1), from 69 discharge measurements made during 5 years. The data in figure 6, which illustrate the seasonal variation in the streambed altitude caused by scour and fill, indicates that since 1975 the mean altitude of the streambed has remained relatively constant.

The data in figure 7 show the relation between mean altitude of the streambed and discharge for the 69 measurements, which indicates the effects of scour and fill. The equation for this relation follows:

$$E = 2.33 - 0.0009\ Q \qquad (2)$$

where

E = the mean altitude of the streambed, in feet (gage datum); and

Q = the measured discharge, in cubic feet per second.

This relationship indicates that the mean streambed altitude is about 3.3 feet lower for a discharge equal to the 2-year peak flow (4,100 ft^3/s) than it is at the median discharge (450 ft^3/s) (K. L. Lindskov, U.S. Geological Survey, written commun., 1981). The river channel is about 130 feet wide when the discharge is 4,100 cubic feet per second; therefore, about 430 square feet of area is scoured from the cross section.

Although the width varies, the section at White River at mouth, near Ouray (09306900) is assumed to be fairly representative of the 20-mile reach of the White River between the station and the confluence with Sand Wash. On the basis of that assumption, about 1,040 acre-feet of sediment would be scoured and filled in this reach by the 2-year peak flow. Assuming the specific weight of the sediment to be about 1,525 tons per acre-foot (Utah Division of Water Resources, 1979, p. 41), this would be equal to about 1.58 million tons of sediment.

Channel migration

Channel erosion can result from channel migration. Material from a cut bank may be deposited a short distance downstream or it can be transported long distances before deposition. Sediment from upstream sources is deposited when the stream power decreases to a point where sediment particles are no longer propelled downstream. In streams that are in equilibrium, eroded

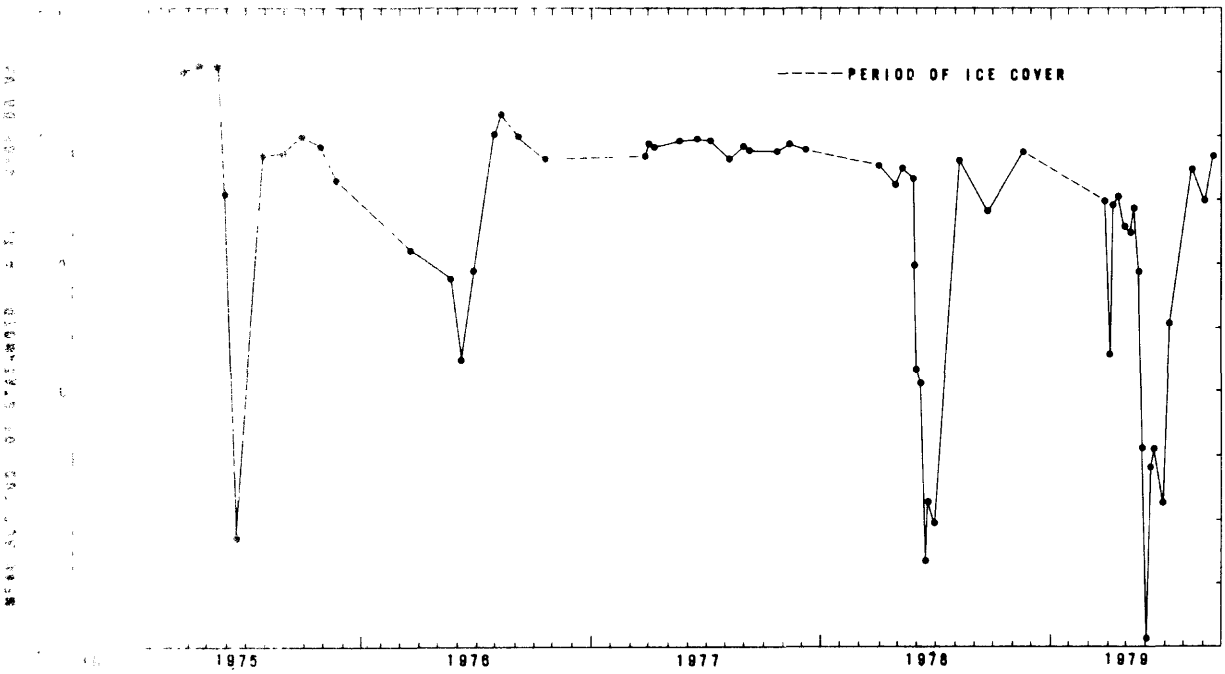

Figure 6.—Seasonal change in mean altitude of the streambed at White River at mouth, near Ouray (09306900).

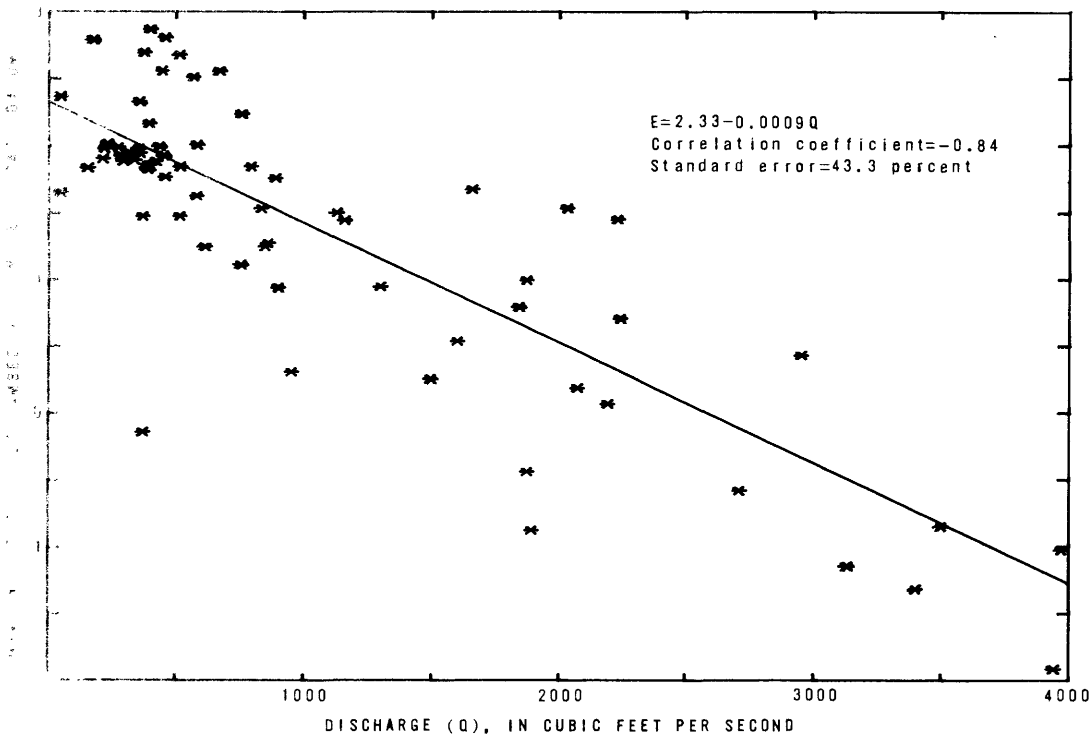

Figure 7.—Relation between mean altitude of the streambed and discharge at White River at mouth, near Ouray (09306900).

material is replaced by deposition of material from upstream sources [illegible] channel migration of the White River between 1936 and 1974 was m[illegible] Jurado and Fields (1978) who determined the locations of the chann[illegible] 1936, 1953, 1965, and 1974 aerial photographs. For this study, the [illegible] the channel from the Colorado-Utah State line to the confluence with [illegible] River for each of the 4 years was measured using the map by Jurado and [illegible] (1978). (See table 3.)

Although the length of the White River did not change between [illegible] 1953, the channel did migrate extensively within the flood plain. [illegible] 1953 and 1965, migration increased the channel length by 2.4 miles. [illegible] channel width was assumed to remain constant; however, the [illegible] volumetric calculations of sediment contribution caused by channel migration do not depend on this assumption. The volume of water in the extra 2.4 miles of channel must be approximately equal to the volume of material that was removed from the channel. The mean discharge of the White River is about 700 cubic feet per second and assuming a mean velocity of 1.5 feet per second at this discharge, an estimated 80 acre-feet [(700 ft^3/s / 1.5 ft/s) x 2.4 mi x 5,280 ft/mi x acre-ft / 43,560 ft^3] of material (120,000 tons) was eroded from the channel between 1953 and 1965, or about 6.7 acre-feet (10,000 tons) per year. Conversely, between 1965 and 1974, the channel shortened by 1.1 miles, which represents about 4 acre-feet (6,100 tons) per year of deposition in abandoned parts of the channel. About 60 percent of the channel migration occurred in the western reaches of the White River downstream from Sand Wash.

Sediment

Eroded material eventually leaves the southeastern Uinta Basin as sediment in the Green River. The total amount of sediment entering or leaving the basin (total-sediment discharge) is not easily determined, however, because the amount of sediment carried in, or on, the streambed (bed-load discharge) cannot be directly measured in natural streams. The am[illegible] sediment carried in suspension (suspended-sediment discharge) can be measured using standardized methods. Total-sediment discharge can be estimated using complex equations (Colby and Hubbell, 1961) which were developed for [illegible] Nebraska. However, the applicability of these equations to rivers in the southeastern Uinta Basin has not been proven.

Table 3.—Length of the White River from the Colorado-Utah State line to mouth

Date	Channel length (miles)
1936	69.8
1953	69.7
1965	72.1
1974	71.0

Description of the sediments

The mineralogy of the sediments has been studied by Kimball (1981) who found that the clays are illite, smectite, and mixed-layer illite-smectite clays. The silt-size particles include quartz, feldspar, and carbonates. Kaolinite is more abundant in the sediments of the White River than in the sediments of the smaller streams in the study area. The coarse sediments of the White River generally are nonspherical; therefore, fall diameters rather than sieve diameters are used to describe the particle-size distributions. Photomicrographs were taken of bed-material samples collected during the 1975-76 water years. These slides are in the National Archives and Records Center of the Geological Survey in Denver, Colo.

Particle-size distribution analyses for the suspended sediments and bed material from White River at mouth, near Ouray (09306900) are shown in figures 8 and 9, and particle-size distribution analyses for suspended sediments from Willow Creek near Ouray (09308000) are shown in figure 10, Evacuation Creek near Watson (09306430) in figure 11, and Coyote Wash near mouth, near Ouray (09306878) in figure 12. Suspended-sediment samples obtained when the stream discharge was minimal in the tributaries were collected by nondepth-integrated methods. The particle-size distributions are extremely variable and may vary with source of the runoff (snowmelt or thunderstorm), the amount of runoff, and whether the sample was obtained when flood discharge was increasing or decreasing.

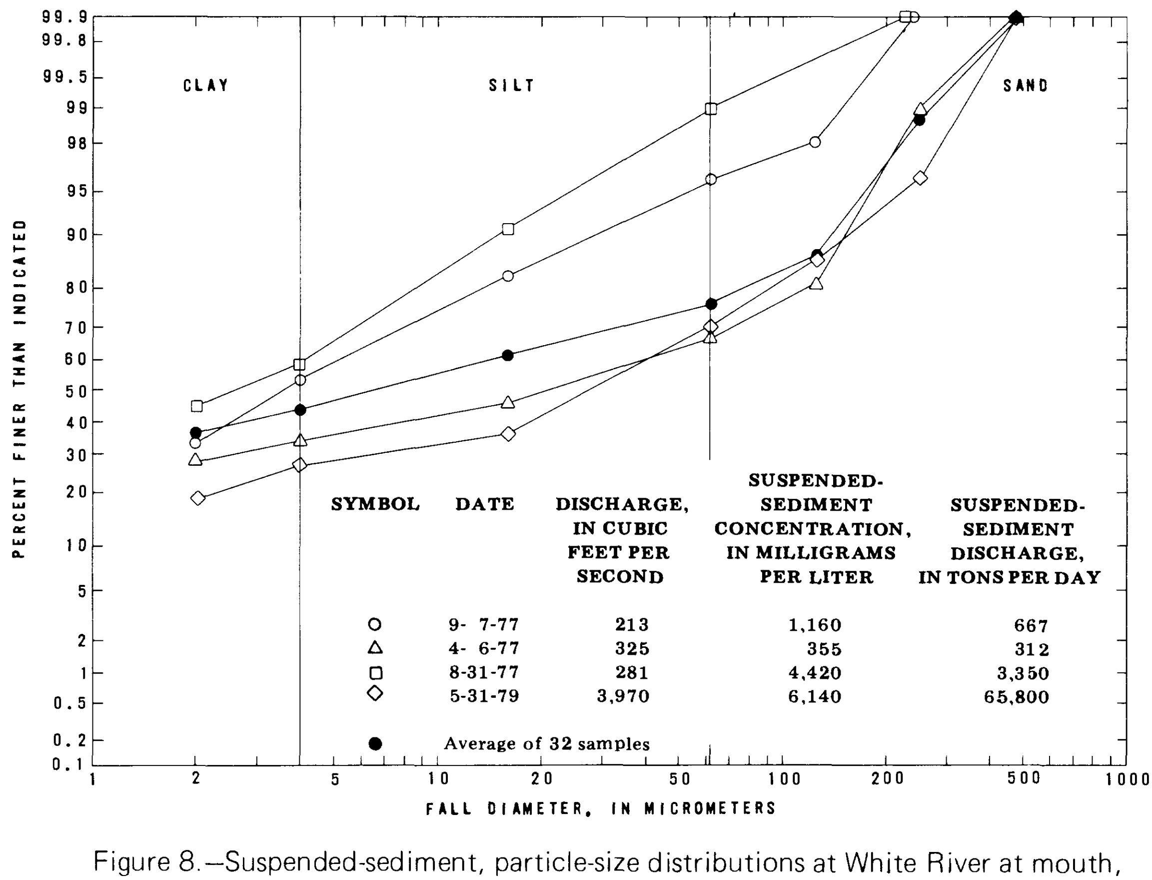

Figure 8.—Suspended-sediment, particle-size distributions at White River at mouth, near Ouray (09306900).

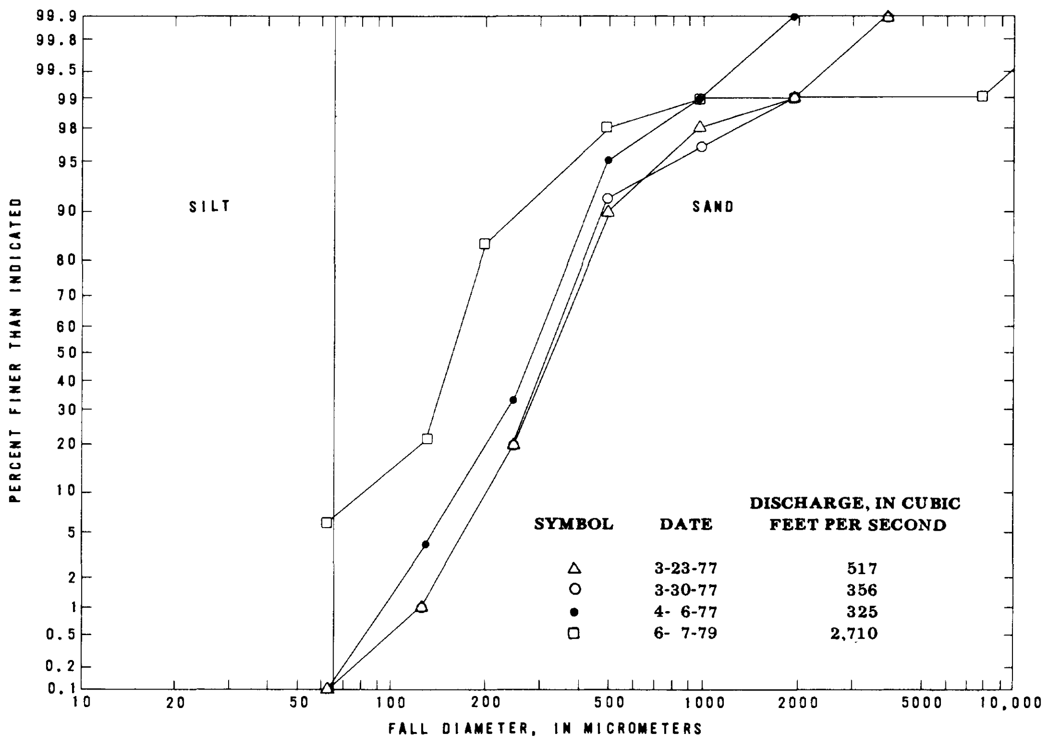

Figure 9.—Bed-material, particle-size distributions at White River at mouth, near Ouray (09306900).

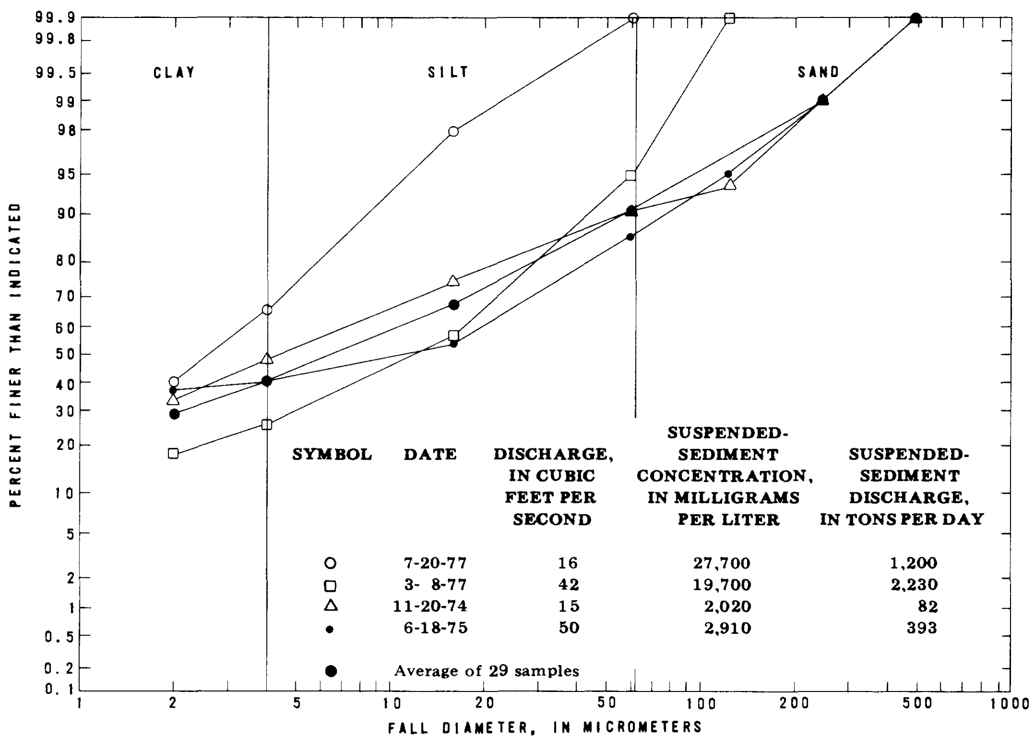

Figure 10.—Suspended-sediment, particle-size distributions at Willow Creek near Ouray (09308000).

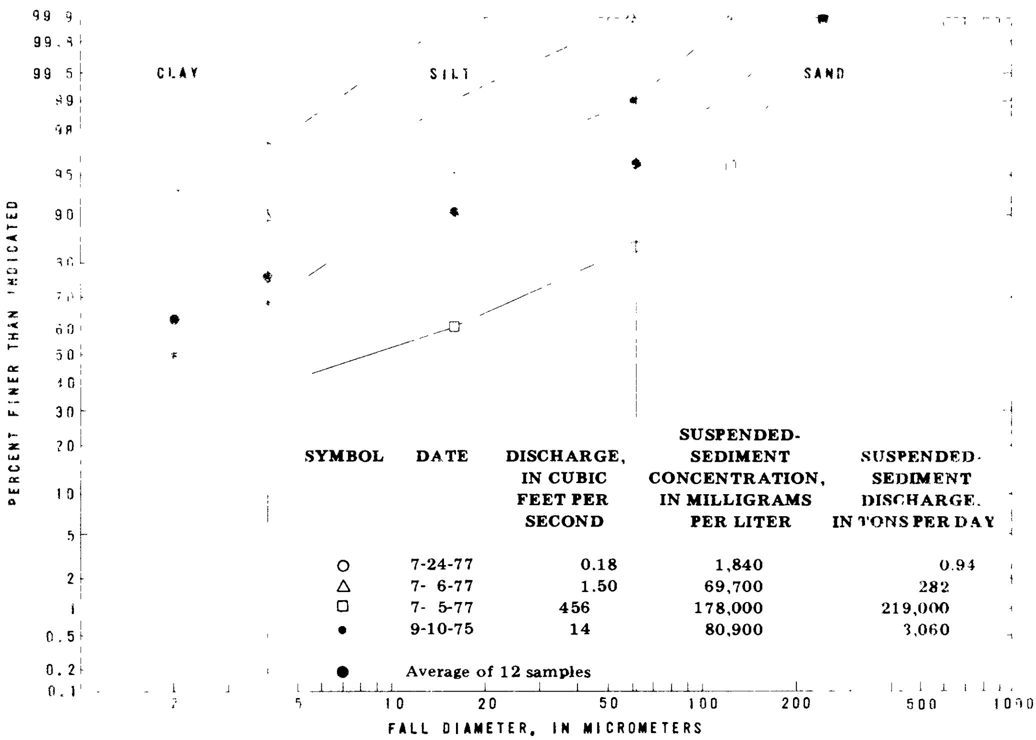

Figure 11. Suspended-sediment, particle-size distributions at Evacuation Creek near Watson (09306430).

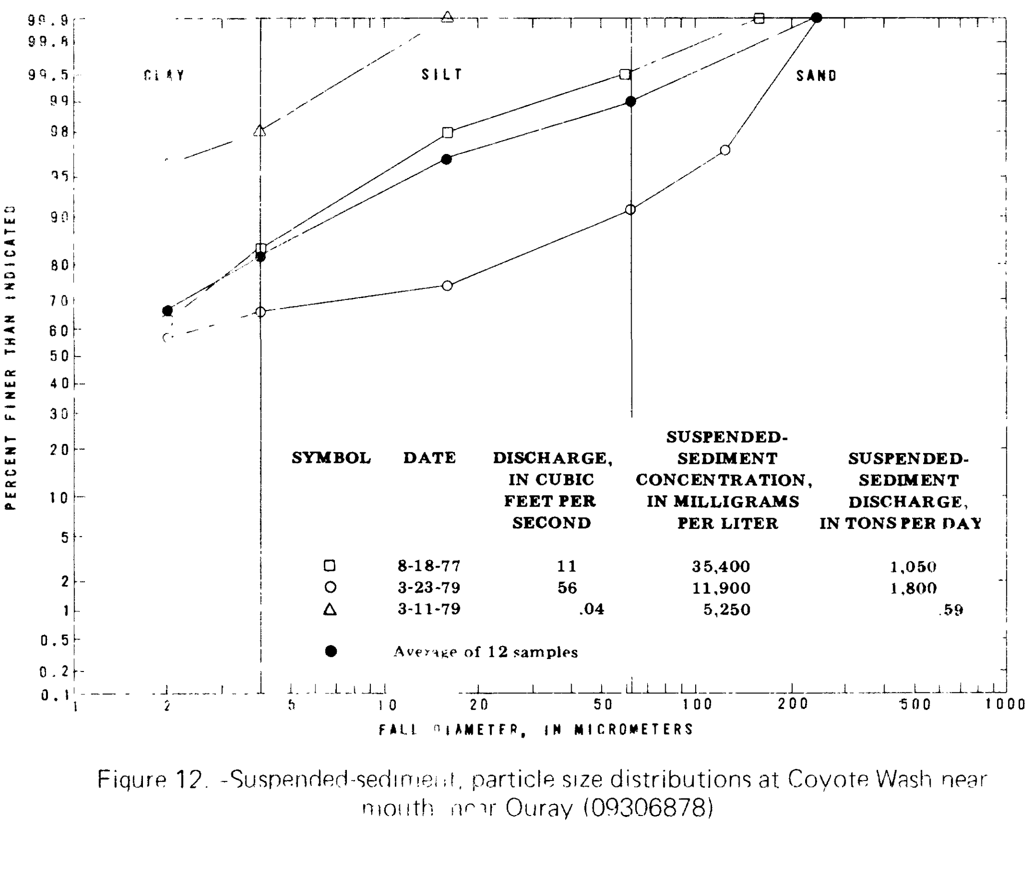

Figure 12. -Suspended-sediment, particle size distributions at Coyote Wash near mouth near Ouray (09306878)

Sediment transport

Alluvial fans

Small, unbreached alluvial fans occur in most small channels that are tributary to the major tributaries in the study area (pl. 1). These fans consist of sediment that was eroded from the uplands and is being stored in the channels. Nineteen unbreached fans were located on the two sets of aerial photographs that were used for studying gully-headcut advancement. None of the fans showed the formation of a breaching channel or a change in length during the 9 years between the sets of photographs. The 19 fans and 4 additional fans that did not appear on the 1965 photographs are plotted on plate 1.

The presence of these alluvial fans indicates that much sediment from the source areas is not transported to the mouth of these small drainages, probably because of the minimal runoff.

Tributary streams

Suspended-sediment characteristics of the streams tributary to the White and Green Rivers are summarized in table 4. Suspended-sediment concentrations in these streams ranged from 2 to 277,000 milligrams per liter and instantaneous suspended-sediment discharges from less than 0.01 to 219,000 tons per day. However, greater daily mean sediment discharges have been computed from extended discharge-concentration curves. The median fall diameters varied from less than 2 to 26 micrometers. Sediment-rating curves for Coyote Wash (fig. 13), Evacuation Creek (fig. 14), and Willow Creek (fig. 15) contain equations representing least-squares fits of the data.

As shown in table 5, the Coyote Wash drainage basin has a much greater sediment yield per square mile of drainage than do the Evacuation or Willow Creek drainage basins. Most of the Evacuation Creek drainage basin consists of greatly dissected hills and valleys which have a greater potential erosion rate than the badlands that form the Coyote Wash drainage basin. The annual sediment yield is not as great from the Evacuation Creek drainage, however, because annual runoff is much less.

Sediment discharge per square mile for the Willow Creek drainage basin is less than in the Coyote Wash drainage basin even though the amount of runoff per square mile in the two drainage basins is similar. Most of the runoff in Willow Creek originates as snowmelt on the vegetation-covered Roan Plateau; thus, it has a smaller potential erosion rate than the badlands of Coyote Wash, which receives much of its runoff from thunderstorms. The seasonal variation of monthly suspended-sediment discharge at Willow Creek near Ouray (09308000) for the 1975-79 water years is shown in figure 16. The sediment is assumed to have a density of 1,525 tons per acre-foot (Utah Division of Water Resources, 1979, p. 41). During the late summer, Willow Creek generally is dry and sediment discharge is zero. Brief periods of great sediment discharge are caused by runoff from intense thunderstorms during the summer. During the base-flow period from October to February, discharges range from 5 to 100 tons per day. The greatest maximum and mean monthly sediment discharges usually are during May when snowmelt runoff from the Roan Plateau causes the greatest sustained stream discharge of the year. During extremely dry years when the spring runoff is minimal (such as the 1977 water year), the greatest sediment discharge may occur during thunderstorm runoff during the summer.

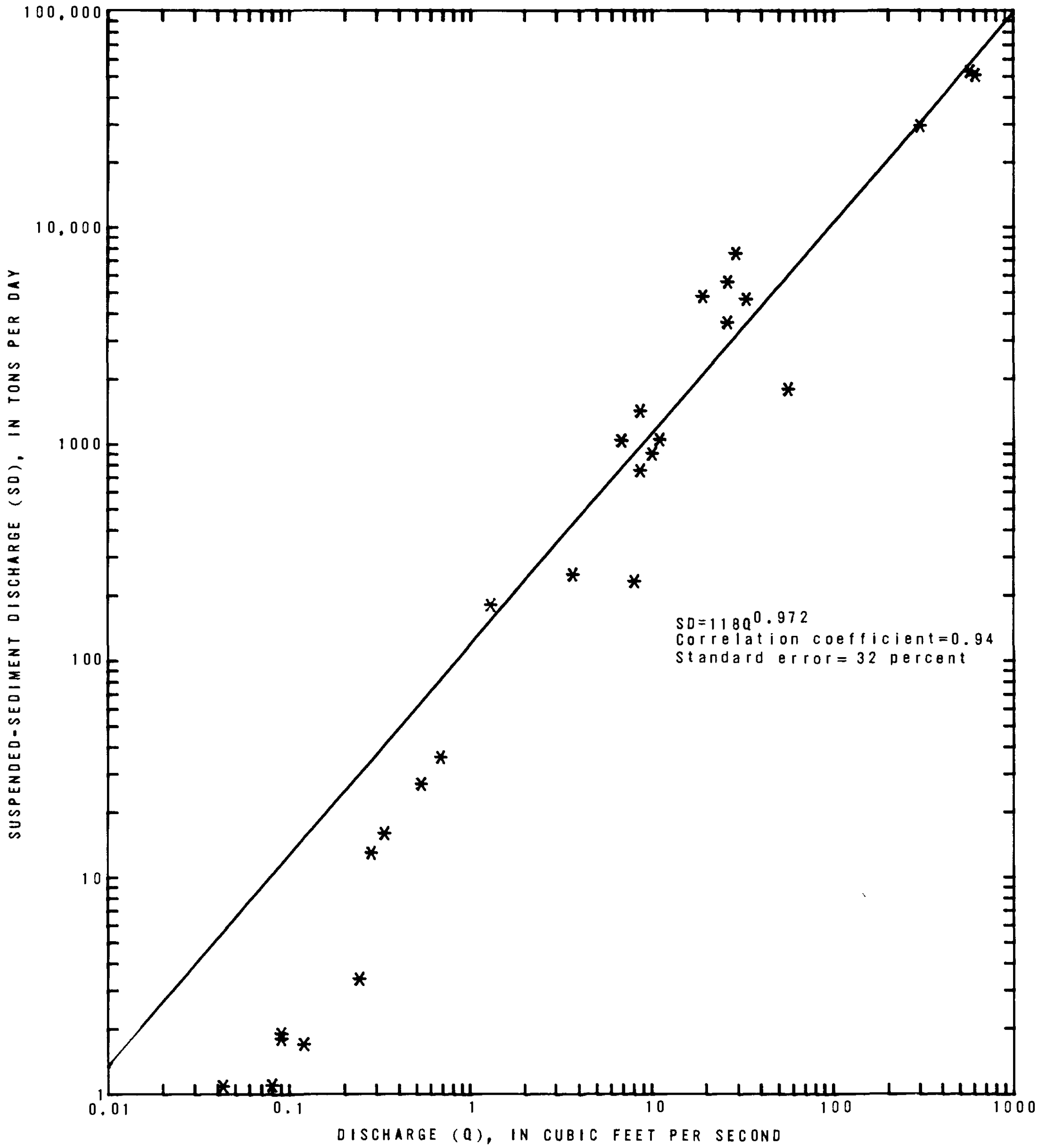

Figure 13.—Sediment-rating curve for Coyote Wash near mouth, near Ouray (09306878). Observations when the stream discharge was less than 1 cubic foot per second have been omitted from the statistical analysis.

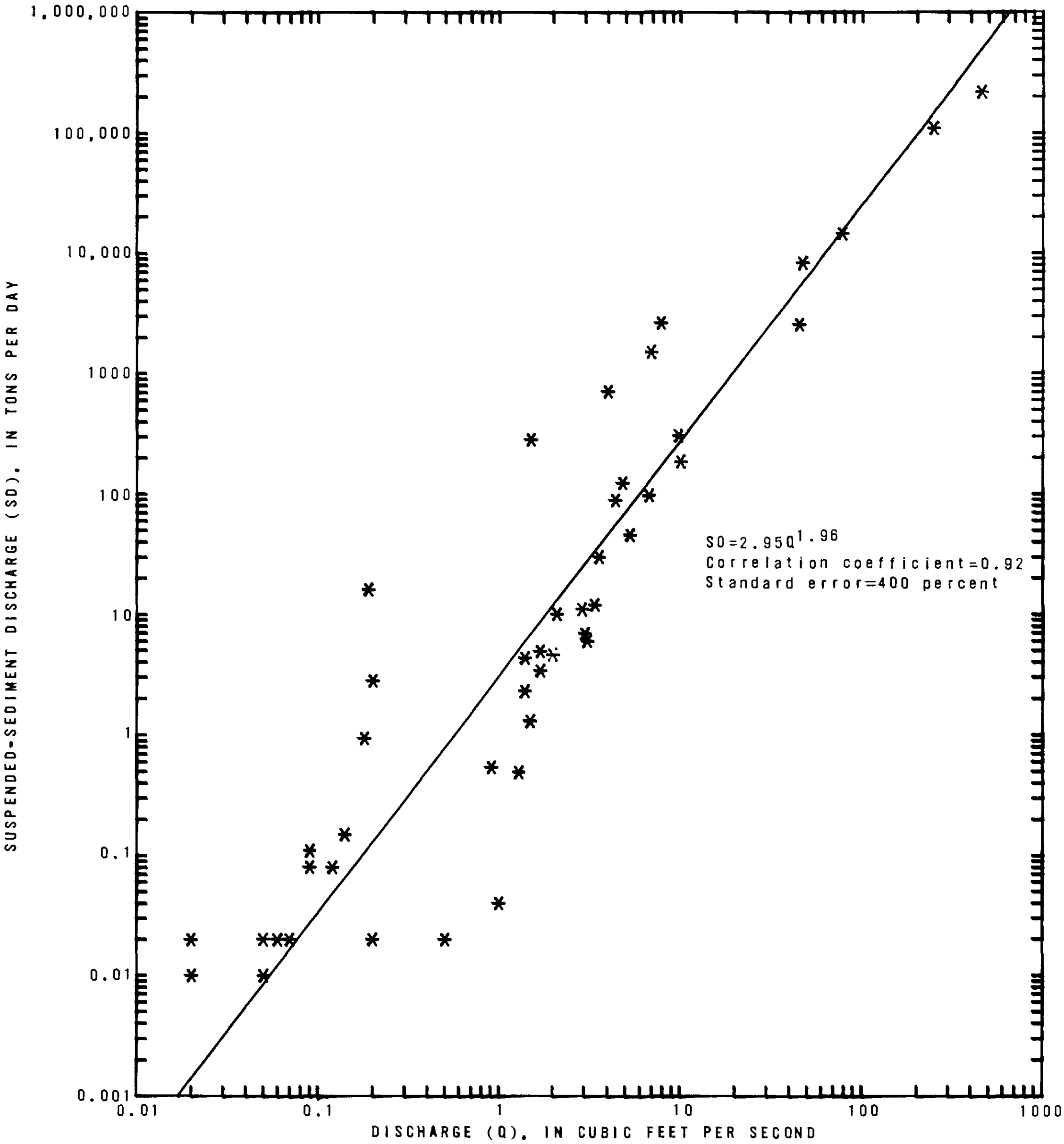

Figure 14.—Sediment-rating curve for Evacuation Creek near Watson (09306430). Observations when the stream discharge was less than 1 cubic foot per second have been omitted from the statistical analysis.

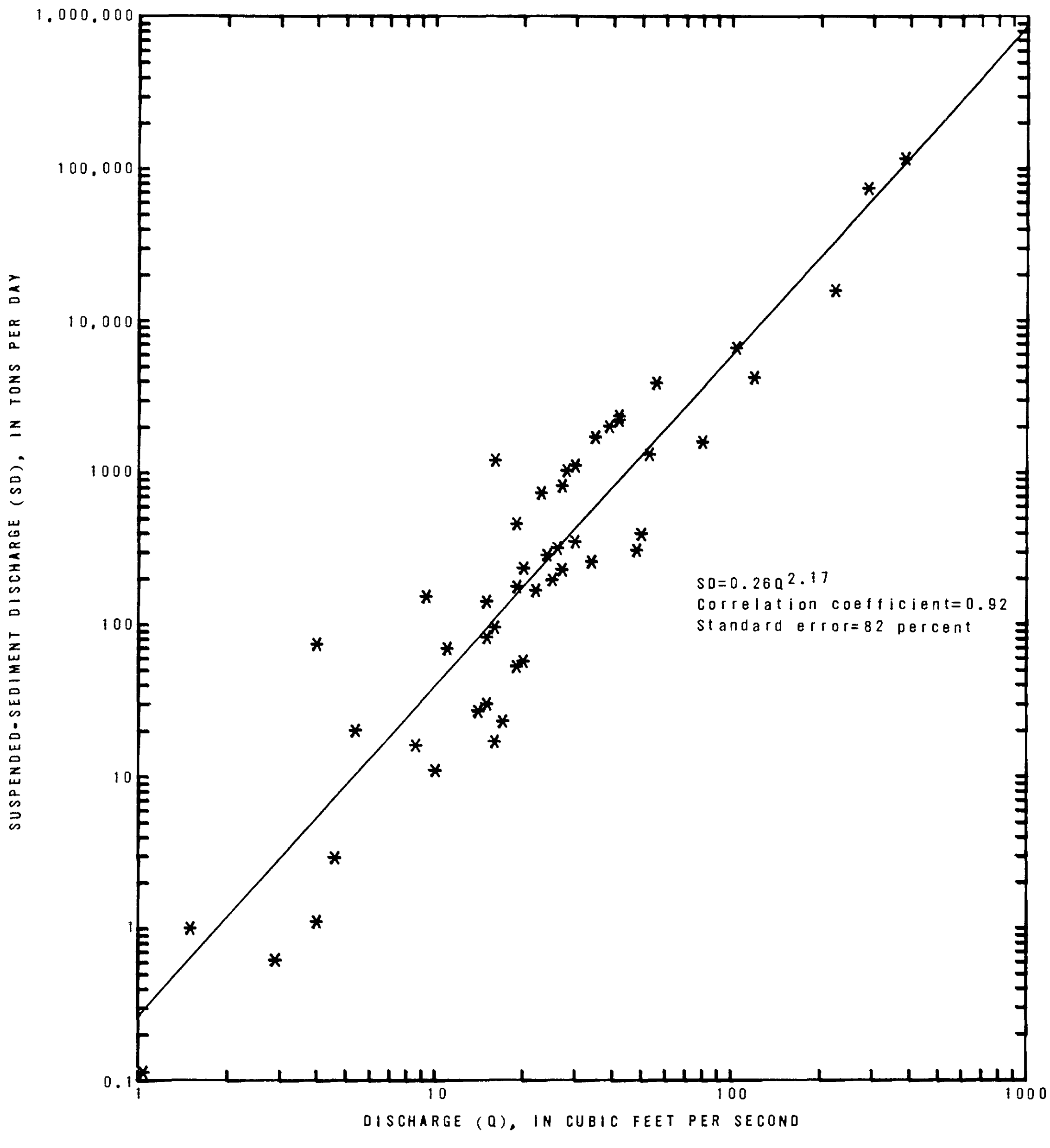

Figure 15.—Sediment-rating curve for Willow Creek near Ouray (09308000).

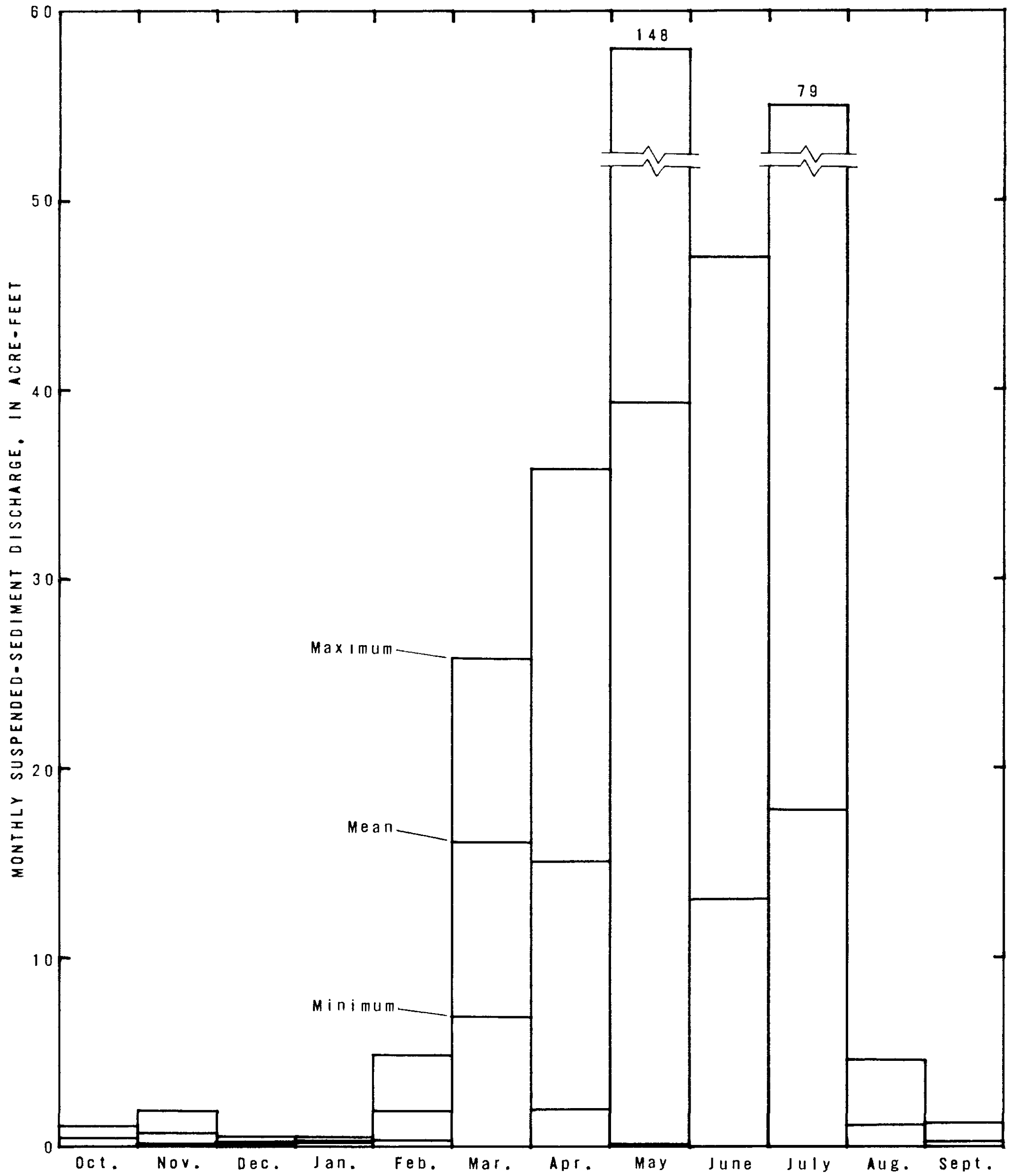

Figure 16.—Maximum, mean, and minimum monthly suspended-sediment discharge at Willow Creek near Ouray (09308000), 1975-79 water years. The minimum value for some months is zero.

Table 4.--Summary of suspended-sediment characteristics of streams tributary to the White and Green Rivers

Suspended-sediment concentration: Mean, discharge-weighted.
Suspended-sediment discharge: Mean, arithmetic.
Median-fall diameter: Number of analyses in parentheses.

Station number and name	Number of analyses	Suspended-sediment concentration (milligrams per liter)			Suspended-sediment discharge (tons per day)			Median-fall diameter (micrometers)
		Mean	Minimum	Maximum	Mean	Minimum	Maximum	
09306405, Hells Hole Canyon Creek at mouth, near Watson	7	197,000	3,540	277,000	11,600	23	44,000	2(3)
09306410, Evacuation Creek above Missouri Creek, near Dragon	32	3,720	2	7,800	10.2	<.01	133	<2(5)
09306415, Evacuation Creek below Park Canyon, near Watson	22	36,600	8	77,700	479	<.01	6,920	<2(6)
09306420, Evacuation Creek at Watson	31	55,100	16	183,000	936	<.01	11,700	2(6)
09306430, Evacuation Creek near Watson	57	13,800	3	178,000	6,300	<.01	219,000	2(12)
09306605, Southam Canyon Wash near Watson	2	1,380	739	2,020	.035	.02	.05	–
09306610, Southam Canyon Wash at mouth, near Watson	2	10,500	9,080	10,600	70	4.9	135	–
09306620, Asphalt Wash below Center Fork, near Watson	4	15,300	756	18,600	112	.31	442	–
09306625, Asphalt Wash near mouth, near Watson	4	9,800	1,960	10,800	168	4.2	254	14(1)
09306740, Bitter Creek above Dick Canyon, near Watson	27	192	14	995	.98	<.01	7.2	4(3)
09306760, Sweetwater Canyon Creek below South Canyon, near Watson	31	1,620	18	31,800	1.66	.01	37	5(6)
09306780, Sweetwater Canyon Creek near mouth, near Watson	11	5,250	202	8,660	10.1	.06	54	3(3)

Table 4.--Summary of suspended-sediment characteristics of streams tributary to the White and Green Rivers—Continued

Station number and name	Number of analyses	Suspended-sediment concentration (milligrams per liter)			Suspended-sediment discharge (tons per day)			Median-fall diameter (micrometers)
		Mean	Minimum	Maximum	Mean	Minimum	Maximum	
09306800, Bitter Creek near Bonanza	27	317	7	1,080	1.32	<0.01	10	6(2)
09306850, Bitter Creek at mouth, near Bonanza	33	1,820	6	5,770	6.25	<.01	112	5(1)
09306872, Sand Wash near mouth, near Ouray	3	8,200	6,730	14,400	230	191	280	4(2)
09306878, Coyote Wash near mouth, near Ouray	27	35,800	5,080	96,900	6,200	.57	52,700	<2(12)
09307500, Willow Creek above diversions, near Ouray	37	4,680	41	14,700	348	1.5	6,630	26(9)
09307800, Hill Creek above Towave Reservoir, near Ouray	28	176	13	661	4.27	.11	34	20(5)
09307900, Hill Creek near mouth, near Ouray	25	3,410	29	25,000	60.1	.01	335	5(10)
09308000, Willow Creek near Ouray	50	40,900	36	112,000	4,830	.01	116,000	6(29)

Table 5.--Annual discharge of suspended sediment for Evacuation Creek, Coyote Wash, and Willow Creek

Station number and name	Period of record (water years)	Drainage area (square miles)	Mean annual suspended-sediment discharge	
			(tons per year)	(tons per square mile per year)
09306430, Evacuation Creek near Watson	1977-79	284	66,900	236
09306878, Coyote Wash near mouth, near Ouray	1977-79	228	184,000	807
09308000, Willow Creek near Ouray	1975-79	897	162,000	181

White River

Velocity and slope affect the transport of sediment particles; thus, it is important to know how they change in a downstream direction. Mean velocity and discharge values for three gaging stations on the White River were obtained from lists of discharge measurements made at the stations. Mean velocity is a power function of discharge (fig. 17).

The relations were used to estimate the velocities at each of the stations during the mean annual peak flow, which has a recurrence interval of 2 years. The mean annual peak flow for the White River near Watson is about 4,100 cubic feet per second (K. L. Lindskov, U.S. Geological Survey, written commun., 1981). Because there is little tributary inflow in the study area during spring runoff, the value of 4,100 cubic feet per second can be considered as applying to the mean annual peak flow for the entire reach of the White River within the study area. The slope and velocity during discharges of 4,100 cubic feet per second for each of the three White River stations are presented in table 6. The velocity and slope increase in a downstream direction between the first two stations but decrease between the second and third stations. The decrease in velocity and slope causes sediment to be deposited in the lower reach of the river during the recession of the upper-basin runoff. This sediment is scoured and transported to the Green River during ensuing floods.

The suspended-sediment characteristics of the White River within the study area are summarized in table 7. Suspended-sediment concentrations ranged from 3 to 51,700 milligrams per liter and instantaneous suspended-sediment discharges from 2.8 to 89,400 tons per day. However, greater daily mean discharges have been calculated from an extended discharge-concentration curve. Median fall diameters ranged from 6 to 15 micrometers.

Total-sediment discharges at the White River at mouth, near Ouray (09306900), were computed using the modified Einstein procedure (Colby and Hubbell, 1961). These data indicate that suspended-sediment discharge may be between 69 and 77 percent of the total-sediment discharge (table 8). These data need to be used with caution because of the nonideal sampling location, the nature of the sediment, and because no data for total-sediment discharge were collected during large stream discharges.

The effect of runoff from thunderstorms on the suspended-sediment discharge of the White River at mouth, near Ouray (09306900) is shown in figure 18. Thunderstorm runoff is reflected by sharp increases in the suspended-sediment discharge of the White River. Records for the 1978 water year indicate that about 7 percent of the suspended sediment measured at White River at mouth, near Ouray (09306900), was from Coyote Wash while the flow was less than 0.5 percent.

The relation between suspended-sediment discharge and stream discharge for White River at mouth, near Ouray (09306900) is shown in figure 19. Many of the discharge measurements for suspended sediment were made from a bridge about 3.5 miles downstream from the gaging station. During high flow in the Green River there is backwater at the bridge, and samples gathered there are not representative of conditions at the gaging station. Therefore, measurements made from the bridge have been deleted from the regression analysis. The large scatter of points plotted in figure 19 for discharges between 300 and 800 cubic feet per second is due partly to sediment runoff

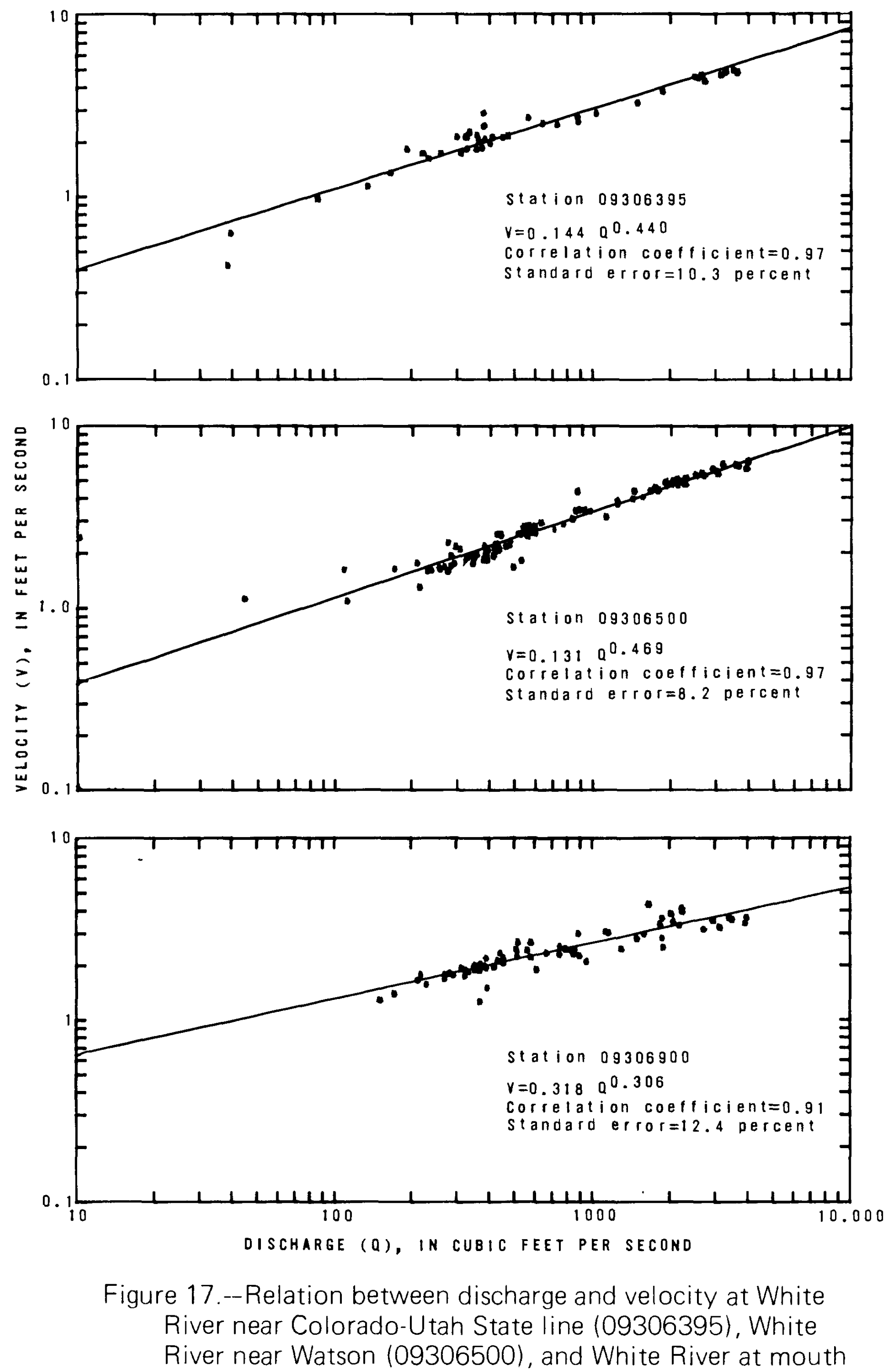

Figure 17.--Relation between discharge and velocity at White River near Colorado-Utah State line (09306395), White River near Watson (09306500), and White River at mouth near Ouray (09306900).

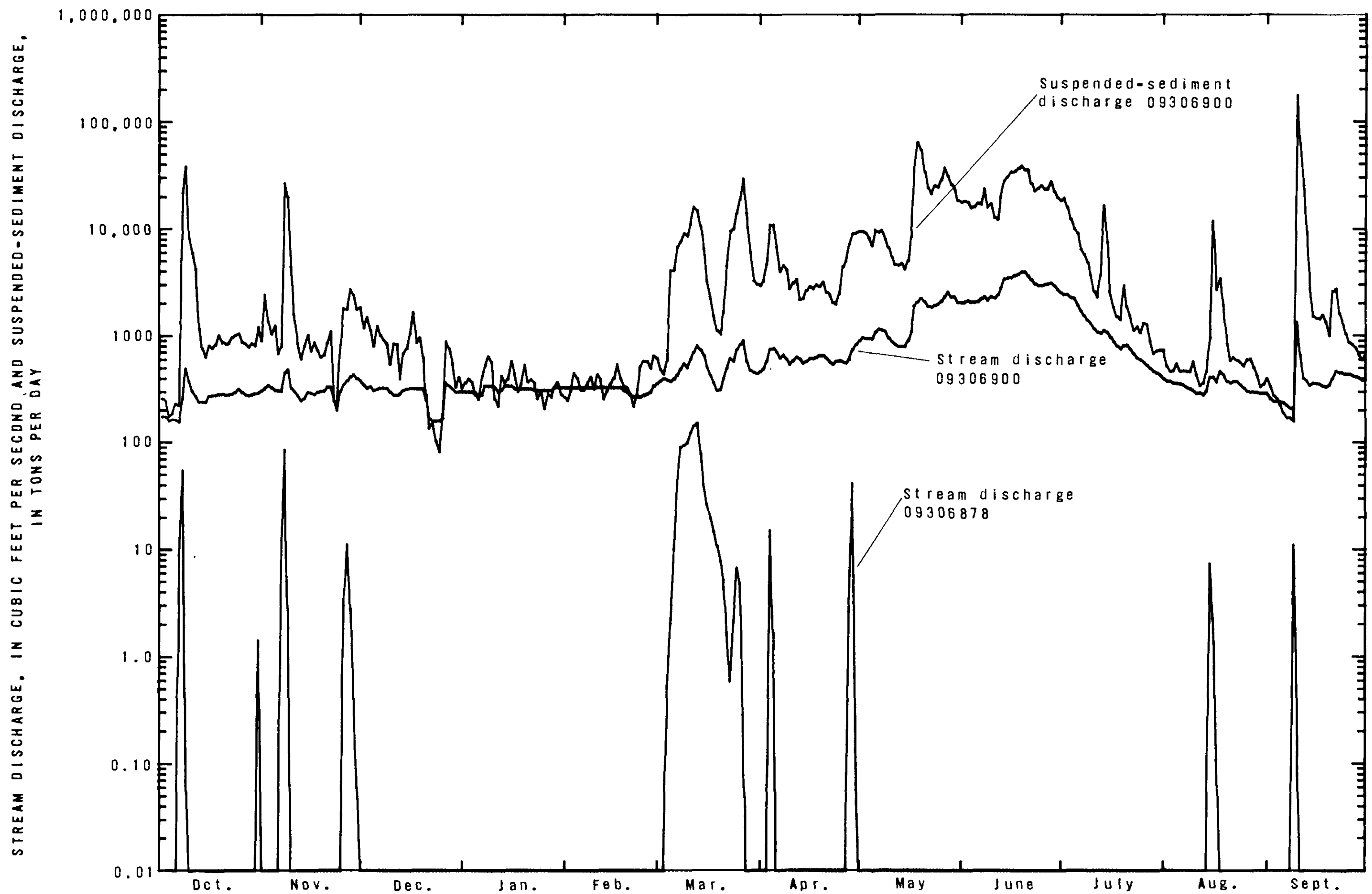

Figure 18.—Discharge and sediment at White River at mouth, near Ouray (09306900) [including discharge at Coyote Wash near mouth, near Ouray (09306878)] during the 1978 water year.

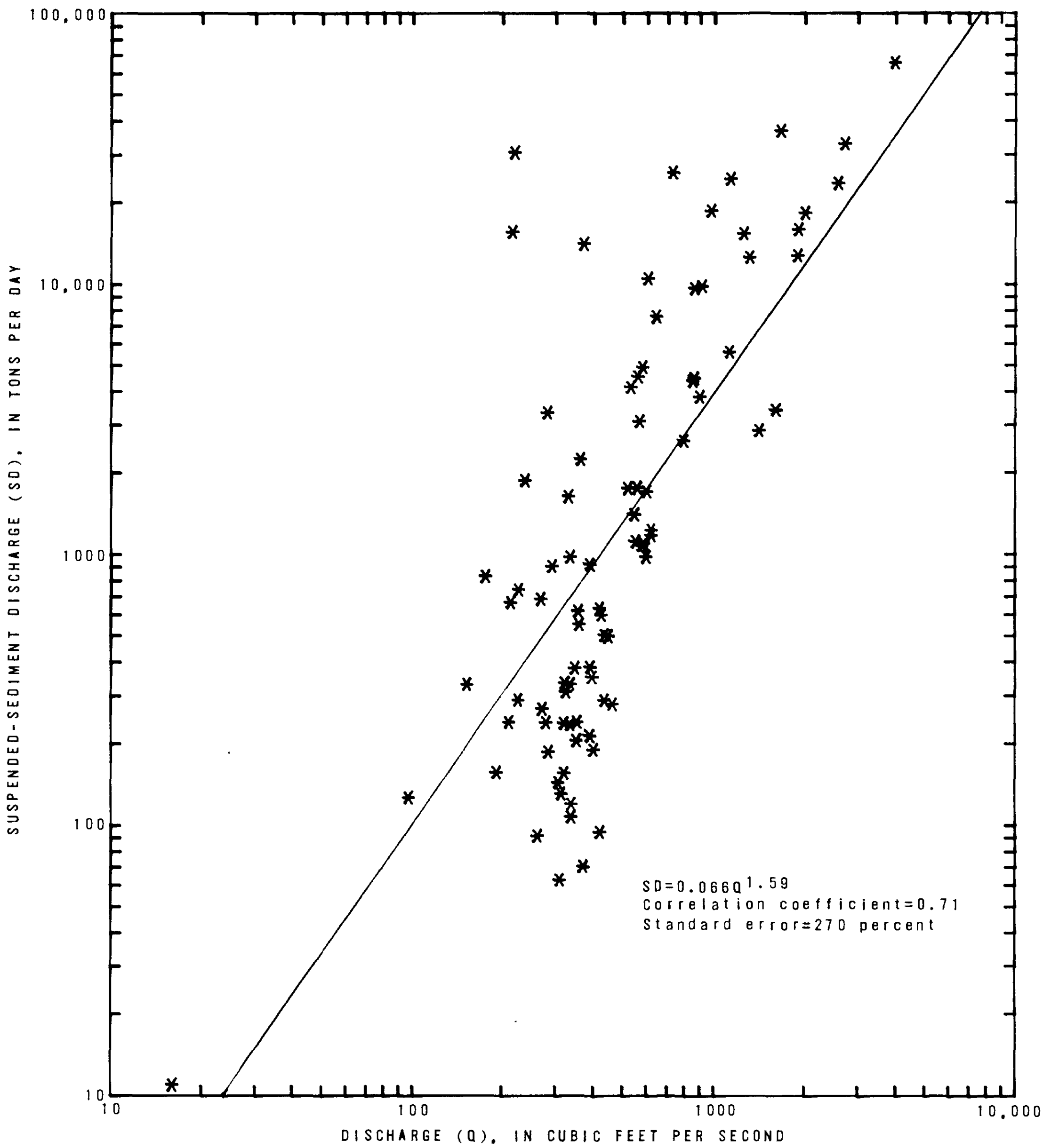

Figure 19.—Sediment-rating curve for White River at mouth, near Ouray (09306900). Measurements made from the downstream bridge have been deleted.

Table 6.--Velocity of mean annual peak flow and slope at three White River stations

Station number and name	Velocity, in feet per second, at mean annual peak flow (4,100 cubic feet per second)	Slope
09306395, White River near Colorado-Utah State line	5.60	0.0008
09306500, White River near Watson	6.48	.0021
09306900, White River at mouth, near Ouray	4.05	.0004

Table 7.--Summary of suspended-sediment characteristics of the White River

Suspended-sediment concentration: Mean, discharge-weighted.
Suspended-sediment discharge: Mean, arithmetic.
Median-fall diameter: Number of analyses in parentheses.

Station number and name	Number of analyses	Suspended-sediment concentration (milligrams per liter)			Suspended-sediment discharge (tons per day)			Median-fall diameter (micro-meters)
		Mean	Minimum	Maximum	Mean	Minimum	Maximum	
09306395, White River near Colorado-Utah State line	45	2,620	36	23,200	7,280	21	40,300	8(9)
09306400, White River above Hells Hole Canyon, near Watson	26	2,710	24	8,060	9,230	21	42,100	9(5)
09306500, White River near Watson	50	2,373	25	8,320	4,730	18	89,400	12(18)
09306600, White River above Southam Canyon, near Watson	6	4,320	689	11,700	14,800	1,100	32,100	6(6)
09306700, White River below Asphalt Wash, near Watson	63	2,620	46	8,700	6,280	39	54,000	15(9)
09306900, White River at mouth, near Ouray	103	3,320	3	51,700	5,580	11	65,800	6(32)

Table 8.--Comparison of total-sediment and suspended-sediment discharge at White River at mouth, near Ouray (09306900)

Date	Stream discharge (cubic feet per second)	Suspended-sediment discharge (tons per day)	Total-sediment discharge (tons per day)	Ratio of suspended-sediment discharge to total-sediment discharge
March 23, 1977	517	1,760	2,290	0.77
March 30, 1977	356	620	893	.69
April 6, 1977	325	312	448	.70

from lower-basin tributaries, such as Coyote Wash. Small flows from Coyote Wash can carry large amounts of sediment into the White River without much effect on the discharge of the White River. Also contributing to the variance is the fact that the sediment discharge for a given stream discharge can be much greater when the stream is rising than when it is ebbing.

Many attempts were made to improve the regression equation for sediment discharge so that long-term sediment discharges could be generated using the 56 years of streamflow record available for White River near Watson (09306500). These included regressions of clay, silt plus clay, and sand loads; clustered regressions of lower-basin runoff, upper-basin runoff, and base flow; clustered temporal regressions based on months and seasons; and multiple regressions including precipitation over the lower basin and runoff from the gaged tributary streams. None of these regressions had standard errors much better than the relation of sediment discharge as a function of instantaneous discharge at White River at mouth, near Ouray (09306900) (fig. 19). One equation, however, did have a somewhat smaller standard error. This equation relates suspended-sediment discharge to instantaneous discharge and turbidity. The equation is:

$$SD = 0.0225Q^{1.175}T^{0.657} \qquad (3)$$

where

SD = instantaneous suspended-sediment discharge, in tons;

Q = instantaneous stream discharge, in cubic feet per second;

T = instantaneous turbidity, in nephelometric turbidity units.

The correlation coefficient, r, is 0.92. Although the equation has a smaller standard error (78 percent), it cannot be used to generate a long-term suspended-sediment record because turbidity data are available for only a small part of the 56 years of streamflow records.

The monthly variation of suspended-sediment discharge at the White River at mouth, near Ouray (09306900) for the 1975-79 water years is shown in figure 20. The sediment density is assumed to be about 1,525 tons per acre-foot, or 70 pounds per cubic foot (Utah Division of Water Resources, 1979, p. 41). During the winter, the sediment discharge is small, generally less than 10 acre-feet per month. There is a high peak associated with the lower-basin runoff in March, and another, usually higher peak occurs in May and June associated with snowmelt runoff from the upper basin. The relatively large mean sediment discharge during late summer is due to runoff from thunderstorms over the lower basin which cause brief periods of great sediment discharge.

Sediment yield

Source-area sediment yield

The Pacific Southwest Inter-Agency Committee (PSIAC, 1968) method as modified by Frickel, Shown, and Patton (1975, p. 17), was used to estimate sediment yields of particular land-form or vegetative areas within the southeastern Uinta Basin. The sediment yield from these source areas may be more but usually is less than the rate of sheet erosion depending on whether net erosion or deposition is occurring in the small channels. It is differentiated from basin-sediment yield because a source area usually encompasses only part of a basin, and because the sediment transport in the major channels of the basin is not considered.

The PSIAC method estimates source-area sediment yield by rating nine factors: surface geology, soils, climate, runoff, topography, ground cover, land use, upland erosion, and channel erosion. Sheet, rill, and gully erosion constitute upland erosion. Each factor is assigned a numerical value according to the extent it contributes to sediment yield. Source-area sediment yield for eight areas in the southeastern Uinta Basin (pl. 1) was determined by summing the numerical values assigned to the contributing factors and applying this value to the rating curve presented by Shown (1970). Each source area was rated for the mean, minimum, and maximum conditions that exist. The rating of the factors affecting sediment yield, the estimated annual yield, and ranges in yields for the source areas are presented in table 9. Although the PSIAC method gives only estimated sediment yields, it does show the areas with large potential yields and the important factors contributing most to sediment yield. No data were obtained within the study area to verify the estimated source-area sediment yields.

The study area was divided into two subareas, one where streams drain to the White River and the other where streams drain to the Green River. The size of each source area within each of these two subareas was calculated from plate 1 and the results are shown in table 9. The estimated annual source-area sediment yield for the White River drainage is about 1,140 acre-feet, which is an average of about 0.7 acre-foot per square mile. The estimated annual source-area sediment yield for the Green River drainage is about 1,370 acre-feet, or about 0.9 acre-foot per square mile. The estimated annual source-area sediment yield for the entire southeastern Uinta Basin is about 0.8 acre-foot per square mile.

The smallest mean annual sediment yields (less than 0.2 acre-ft/mi^2) are from the grass and brush-covered plateaus and the low-altitude hills and valleys. The soils in the low-altitude hills and valleys are armored with rock fragments that protect the soils. The forest and mountain shrub and

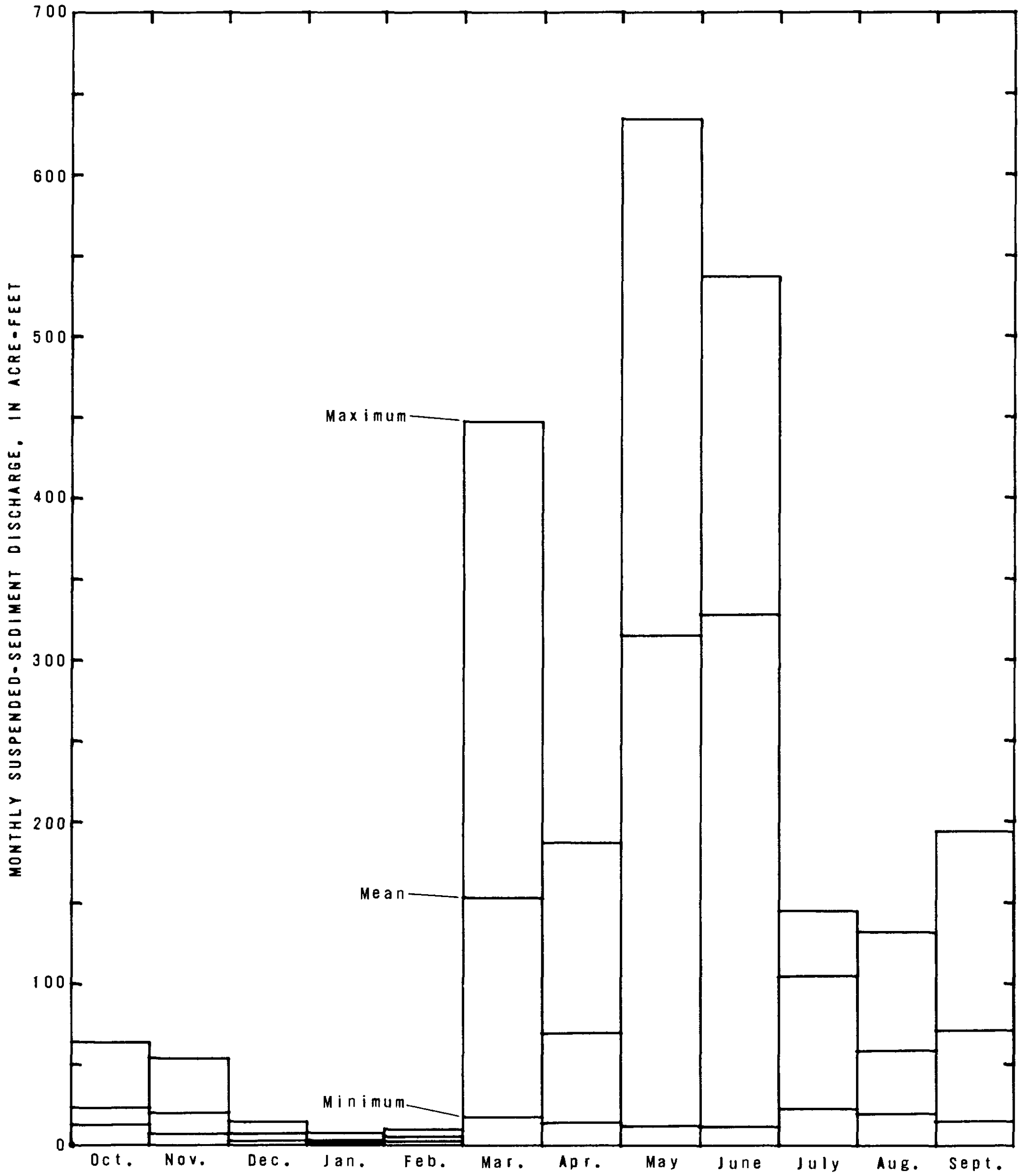

Figure 20.—Maximum, mean, and minimum monthly suspended-sediment discharge at White River at mouth, near Ouray (09306900), 1975-79 water years.

Table 9.—Estimated annual source-area sediment yield and factors affecting sediment yield

Factors affecting erosion in each source area: L, large contribution to erosion rate; S, small contribution to erosion rate; M, moderate contribution to erosion rate.
Size of source area: The area that contributes to the White and Green Rivers within the study area.

Source area	Size of source area (square miles)		Estimated annual sediment yield (acre-feet per square mile)			Factors affecting erosion in each source area								
	White River	Green River	Mean	Minimum	Maximum	Surface geology	Soils	Climate	Runoff	Topography	Ground cover	Land use	Upland erosion	Channel erosion
Forest and mountain shrubs	102	138	0.2	<0.2	0.5	S	S	M	M	S-L	S	S	M	S-M
Valley bottomlands	161	171	.2	<.2	.7	M	M	M-L	M	S	S-M	M-L	S-M	S-L
Grass and brush-covered plateaus	55	218	<.2	<.2	<.2	S	S	S	S	S	S	S	S	S
Low-altitude hills and valleys	611	235	<.2	<.2	.6	S	M	S-M	S-M	S-M	S-M	S-M	S	S-M
Moderately dissected hills and valleys	157	275	.4	.2	1.5	M	M-L	M	S-L	S-L	M	M	M	M-L
Extensively dissected hills and valleys	295	513	2.2	.7	>3.0	L	L	M	L	M-L	M-L	M	L	L
Badlands	126	0	1.8	1.0	2.6	L	L	M	M-L	S	L	M-L	L	M-L
Alluvial-colluvial deposits	66	0	.8	.4	1.1	M-L	L	M	M	S	L	M-L	L	L

valley bottomland source areas have sediment yields of about 0.2 acre-foot per square mile. Land use is an important factor in the valley bottomlands because of activities associated with the exploration for oil and gas that often cause much disturbance of areas as large as 2 acres. The mean annual sediment yield of the moderately dissected hills and valleys (0.4 acre-ft/mi^2) would be much greater if the relief were steeper. Relief, however, is of little importance to the sediment yield of the alluvial-colluvial deposits, which are most affected by sheet and gully erosion. The largest mean annual sediment yields are from the badlands (1.8 acre-ft/mi^2) and the greatly dissected hills and valleys (2.2 acre-ft/mi^2). Intense thunderstorm runoff is an important factor in both these areas, whereas relief is of major importance only for the extensively dissected hills and valleys.

The U.S. Soil Conservation Service (1975) has used the PSIAC method to estimate sediment-yield rates for the entire western United States. They estimated that the sediment yield for the entire southeastern Uinta Basin was between 0.5 and 1.0 acre-foot per square mile per year, of which about 40 percent is from sheet and rill erosion and 60 percent from channel and gully erosion.

Basin-sediment yield

The amount of sediment contributed to the White River within the study area can be computed from the records of daily suspended sediment for the river. A summary of these records is given in table 10. Sediment yield from the White River basin within the study area can be computed by dividing the difference in suspended-sediment discharge by the difference in drainage area. This calculation [(2,000,000-1,031,000)/(5,120-3,680)] shows an average annual suspended-sediment yield of 673 tons per square mile for the period of concurrent record, 1977-79. If the suspended-sediment discharge is about 75 percent of the total-sediment discharge, then the estimated annual sediment yield is about 900 tons (or 0.59 acre-foot) per square mile during this period. This value needs to be used with caution because it is based on the assumption that the ratio of suspended-sediment discharge to total-sediment discharge is the same at both White River stations. In some streams, however, the ratio varies from place to place because of different hydraulic conditions. Neff (1967, p. 236) reports that more than 60 percent of the long-term sediment yield in arid regions is associated with runoff having recurrence intervals exceeding 10 years. Within the study area, the 10-year, 24-hour storm intensity is about 1.6 inches (Miller and others, 1973, fig. 27). During this study, only one storm was reported to have a greater intensity--1.93 inches on July 23, 1977 (Conroy, 1979, p. 18). This occurred over the upper Willow Creek drainage basin and caused a flood at Willow Creek above diversions, near Ouray (09307500). No storms or peak flows with long recurrence intervals affected the White River. The peak flow for the White River at mouth near Ouray (09306900), during the study was 4,260 cubic feet per second with a recurrence interval of about 2.3 years (K. L. Lindskov, U.S. Geological Survey, written commun., 1981). These data indicate that the estimated sediment yield of 0.59 acre-foot per square mile per year for the White River drainage within the study area may be much less than the long-term sediment yield because the period of record contains no peak flows with long recurrence intervals.

Table 10.--Annual suspended-sediment discharge at two White River stations

Station number and name	Period of record (water years)	Drainage area (square miles)	Mean annual suspended-sediment discharge (tons per year)	(tons per square mile per year)
09306395, White River near Colorado-Utah State line	1977-79	3,680	1,031,000	280
09306900, White River at mouth, near Ouray	1977-79	5,120	2,000,000	391
	1975-79		1,759,000	344

Mass curves of combined monthly runoff from streams tributary to the White River (gaged at stations 09306405, 09306430, 09306625, 09306850, and 09306878) and the net suspended-sediment discharge from the White River within the study area are shown in figure 21. Net suspended-sediment discharge is the monthly sediment discharge at White River at mouth, near Ouray (09306900) minus that at White River near Colorado-Utah State line (09306395). These curves show that much of the increase in sediment discharge between the two stations is associated with tributary inflow. The record for May-July 1978 shows, however, that while the tributary streams were contributing only base flow (or no flow), 565,000 more tons of sediment were leaving the area than were entering it. This sediment probably came from bank cutting and the scour and transport of sediment deposited in the channel during the previous period of snowmelt runoff from the upper basin.

During only 1 month did more suspended sediment enter the study area than left it. On September 7, 1978, intense rains upstream in the Piceance Creek basin of Colorado caused floods which carried much larger amounts of sediment into the study area than left it. This is indicated in figure 21 by the downward dip in the sediment curve. This excess sediment was temporarily stored in the White River channel.

POTENTIAL EFFECTS OF ENERGY-RESOURCES DEVELOPMENT

Although there are extensive deposits of crude oil, natural gas, gilsonite, and bituminous sand in the study area, this section addresses itself primarily to the potential effects of oil-shale mining and processing. Two major elements are considered, together with their effects on erosion and sediment yield: (1) A proposed reservoir on the White River to supply water needs of the oil-shale industry, and (2) the mining and processing of oil shale either by the in situ-retort method or by the surface-retort method.

Proposed White River reservoir

A reservoir on the White River has been proposed to deliver water required for future oil-shale processing. The reservoir would have a capacity of 105,000 acre-feet, a usable storage capacity of 67,500 acre-feet, and a sediment-reserve capacity of 37,500 acre-feet (U.S. Bureau of Reclamation, 1980, p. 11). The location of the proposed dam is shown on plate 1. About 90 percent of the sediment entering the reservoir would be trapped therein, thus, limiting the sediment available to the river downstream from the dam (Utah

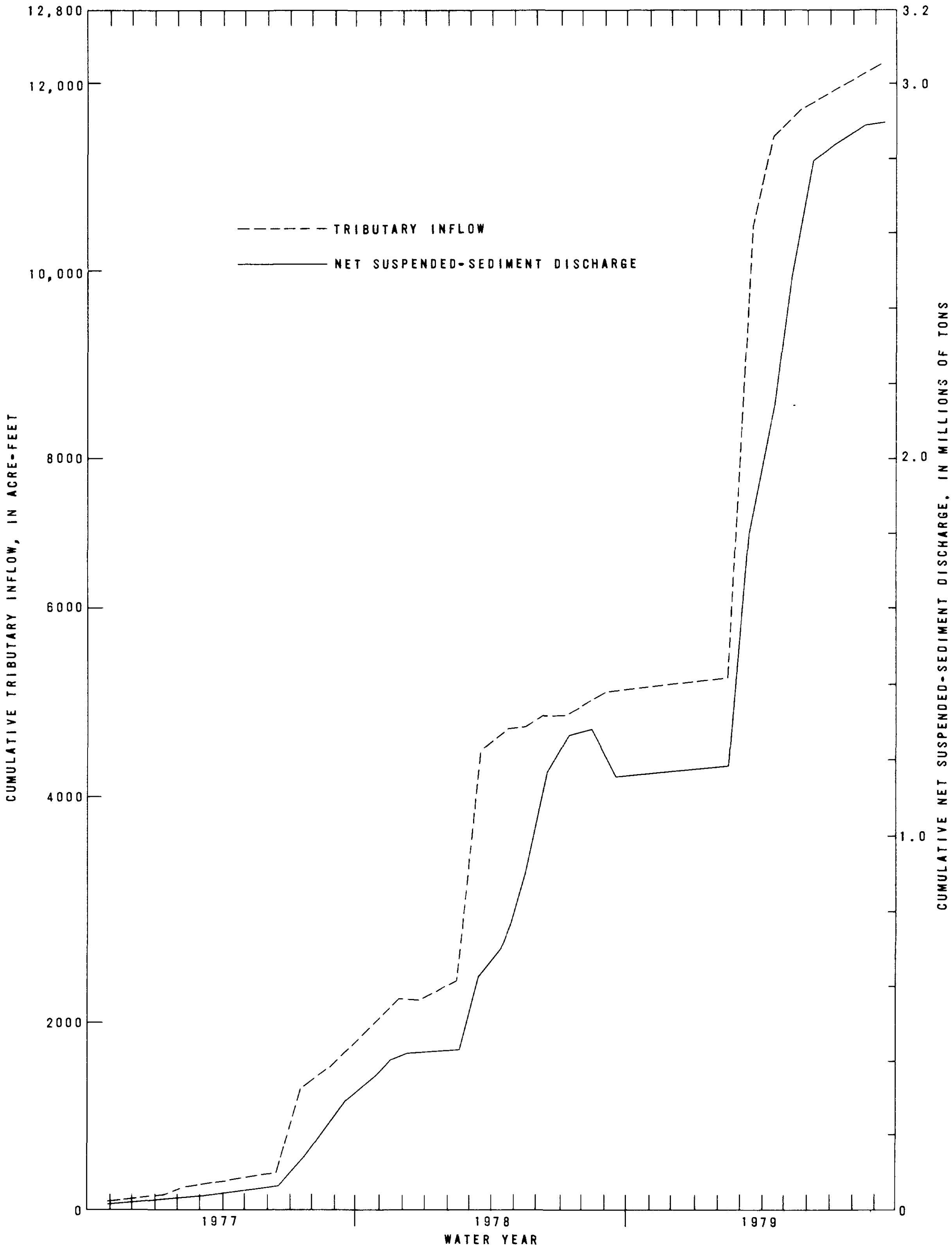

Figure 21.—Mass curves of tributary inflow and net suspended-sediment discharge from the White River drainage basin within the study area.

Division of Water Resources, 1979, p. 42). Minimum releases to the White River downstream from the dam would be 250 cubic feet per second, and maximum releases would be as much as 2,300 cubic feet per second during May and June of each year (Utah Division of Water Resources, 1979, p. 13 and 35).

The drastically changed flow regime and the clear-water releases that would result from the construction of the dam would cause changes in the White River as it adjusts to the new conditions. For about 18 miles downstream from the proposed dam site downcutting in the channel of the river would be controlled by bedrock outcrops. Chow (1964, p. 17-5) states that where materials in channel beds are more resistant to erosion than those in the channel banks, bank erosion and stream meandering may proceed at a greater pace than degradation; thus, channel migration may increase in this reach of the river. Channel degradation may occur in the downstream reaches of the river where bedrock controls are not present because the normal channel filling that occurs during peak flow recession will be decreased because of the decreased availability of sediment. Borland and Miller (1960, p. 71) reported about 1 foot of degradation per year about 12 miles downstream from Hoover Dam at Willow Beach from 1935 to 1949. If major degradation does occur in the downstream reaches, the lowered main channel also may result in headward erosion in the tributary streams.

It is possible that decrease of peak flows would allow vegetation to encroach on the channel; thus, resulting in bank stabilization and channel clogging instead of channel degradation. Osterkamp and Hedman (1981) compared the channel geometry of natural channels with channels downstream from reservoirs in Kansas. They concluded that impoundment and subsequent clear-water releases from reservoirs could result in any combination of the changes described above.

Oil-shale mining and processing

The in situ-retort method removes the kerogen (oil) from the shale without removing the shale from the ground. Wells are drilled at the ends of the shale deposit and explosions are set off to create fractures which will allow air to flow through the deposit. A fire is started underground near one of the wells, and as the fire moves through the deposit it vaporizes the kerogen, driving it from the shale. The kerogen then condenses and is pumped out through the other well. Because all shale processing is underground, this process would have little effect on the erosion and sediment regime. A potential effect would be increased sheet erosion in the cleared construction areas.

The surface-retort method requires that the shale be brought to the surface for processing. At the surface, the shale is sorted, crushed, and then placed in a retort where the kerogen is distilled. The spent shale is removed, cooled, and disposed of. Several disposal plans have been proposed, but all are similar in that the processed shale is deposited in terraced piles, compacted, and revegetated. Sheet erosion is expected to be great during the operational phase. A study by Colorado State University (1971) involved measuring the sediment yield from a pile of spent oil shale (processed by the TOSCO Corp. method) that had a slope of 0.75 percent. Before the pile was compacted, the measured sediment yield was about 0.3 ton per acre per hour during rains with intensities of 0.54 inch per hour. After compacting, the yield was about 0.1 ton per acre per hour during rains with intensities of 0.40 inch per hour.

The relatively small amount of sediment delivered to the White River from the tributary streams is due to the minimal runoff. Increased runoff, such as would result from process water being discharged into normally dry streambeds, would increase erosion and sediment transport. A pond of sufficient capacity to impound 100 percent of the 100-year, 24-hour storm runoff from the processing and disposal areas would prevent spilling of spent oil-shale residues into the White River. Periodic cleaning of such ponds would be needed so that accumulated sediment did not decrease their capacity to retain large amounts of runoff.

SUMMARY AND CONCLUSIONS

Premining characteristics

Average annual sediment yields from various source areas as estimated by the Pacific Southwest Inter-Agency Committee method ranged from less than 0.2 acre-foot per square mile on several areas to 2.2 acre-feet per square mile on the extensively dissected hills and valleys. The average annual sediment yield for that part of the study area that contributes to the White River is 0.7 acre-foot per square mile per year. The presence of unbreached alluvial fans in the channels of minor tributaries and the slight aggradation that was measured at major tributaries indicate that eroded material is being deposited in upland areas before it reaches the White River channel.

Peak flows scour the White River channel bottom, and on recession the channel fills to about its original altitude. Two peaks of sediment discharge occur during the year in the White River, one in March during snowmelt runoff from the lower basin and the other in late May or early June during snowmelt runoff from the upper basin. During late summer, sediment discharge generally is small, but thunderstorm runoff can cause brief periods of great sediment discharge. The mean suspended-sediment discharge for White River at mouth, near Ouray (09306900), is about 1,150 acre-feet (1,759,000 tons) per year. In arid regions, more than 60 percent of the long-term sediment discharge occurs during runoff that has recurrence intervals exceeding 10 years. No runoff peaks of this magnitude occurred on the White River during the study, so the annual suspended-sediment discharge of 1,150 acre-feet that was measured may be much less than the long-term rate.

Less sediment is delivered to the White River by its major tributaries within the study area than might be expected in such a barren area. For example, although most of the Evacuation Creek drainage area consists of extensively dissected hills and valleys, which have great potential erosion rates, sediment discharge from the creek is not great because of minimal runoff. Most of the sediment delivered to the White River from the major tributaries comes from Coyote Wash, and sediment discharge at the White River at mouth, near Ouray (09306900), is strongly influenced by runoff from Coyote Wash.

Sediment discharge in Willow Creek is strongly influenced by summer thunderstorms, but the greatest sediment discharge occurs during snowmelt runoff in late April or May. The mean annual suspended-sediment discharge from Willow Creek near Ouray (09308000), is about 106 acre-feet (162,000 tons).

Potential effects of oil-shale mining and processing

In situ-retort operations would have minor effects on the erosion and sediment regime, but erosion of disposal piles of spent shale from surface-retort operations would result in an increased sediment yield. An impounding pond of sufficient capacity to retain 100 percent of the 100-year, 24-hour storm runoff from processing and disposal areas would prevent spilling of spent oil-shale residues into the White River.

The proposed White River reservoir would trap approximately 90 percent of the sediment entering it. Clear-water releases from the reservoir may cause increased channel migration and degradation in downstream reaches of the White River. It is possible, however, that channel clogging caused by vegetation encroachment may occur instead because of the reduced peak flows.

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