[Wyoming:

HYDROLOGY OF SALT WELLS CREEK --A PLAINS STREAM IN SOUTHWESTERN WYOMING]

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This report summarizes results of a hydrologic study made during 1975-78 on the basin of Salt Wells Creek, a drainage area of about 500 square miles located southeast of Rock Springs, Wyoming. The area is typical of arid and semiarid plains areas in southwestern Wyoming where mineral development is occurring.

Salt Wells Creek is predominately an intermittent stream. Numerous springs in the headwaters cause small perennial flows in some upstream tributaries, but evaporation, freezeup, and seepage deplete these flows so that the middle and lower reaches of the main channel have only intermittent flows. The intermittent nature of streamflow affects water quality. Dissolved solids and suspended sediment are flushed during the first flows of runoff following rainfall or snowmelt.

A striking feature of the stream is its deeply incised channel. The downcutting is attributed to the cumulative effects of: (1) Change in climate, (2) change in base level due to downstream channelization, and (3) changes in land use. Because of the incision, erosion is now expanding to include intervening tributaries.

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UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

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CONVERSION FACTORS AND VERTICAL DATUM

The following factors may be used to convert the inch-pound units used in this report to metric (SI) units:

Multiply	By	To obtain
inch	25.40	millimeter
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.590	square kilometer
acre-foot	1,233	cubic meter
acre-foot per square mile	476.1	cubic meter per square kilometer
cubic foot per second	28.32	liter per second
	0.02832	cubic meter per second
short ton	0.9072	metric ton

National Geodetic Vertical Datum of 1929 (NGVD of 1929) is 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.

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By H. W. Lowham, Lewis L. DeLong,
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ABSTRACT

Development of energy minerals in plains areas of Wyoming is increasing rapidly. Such developments may affect water resources and hydrologic relations of the plains; however, little information exists concerning hydrologic processes of these areas. This report summarizes results of a hydrologic study made during 1975-78 of Salt Wells Creek, a stream typical of those in arid and semiarid plains areas in southwestern Wyoming where mineral development is occurring.

Salt Wells Creek has a drainage area of about 500 square miles and is located southeast of Rock Springs, Wyoming. The creek drains into Bitter Creek, which is a tributary of the Green River. Numerous springs in the headwaters cause small perennial flows in some upstream tributaries. Evaporation, freezeup, and seepage deplete these flows so that the middle and lower reaches of the main channel have only intermittent flows as a result of snowmelt and rainfall runoff. The average annual runoff of the stream is estimated to be about 2,000 to 3,000 acre-feet, which is not a large amount in comparison to flows of major perennial streams of southwestern Wyoming.

The intermittent nature of the streamflow has a significant effect on water quality. "Flushing" of accumulated salts and sediment occurs during the first flows following rainfall or snowmelt. This flushing follows dry periods when salts and loose sediment accumulate on the basin surface and in the stream channels. The first flows during runoff transport these materials as dissolved and suspended loads. After this initial flushing of the basin surface and channels, concentrations decrease.

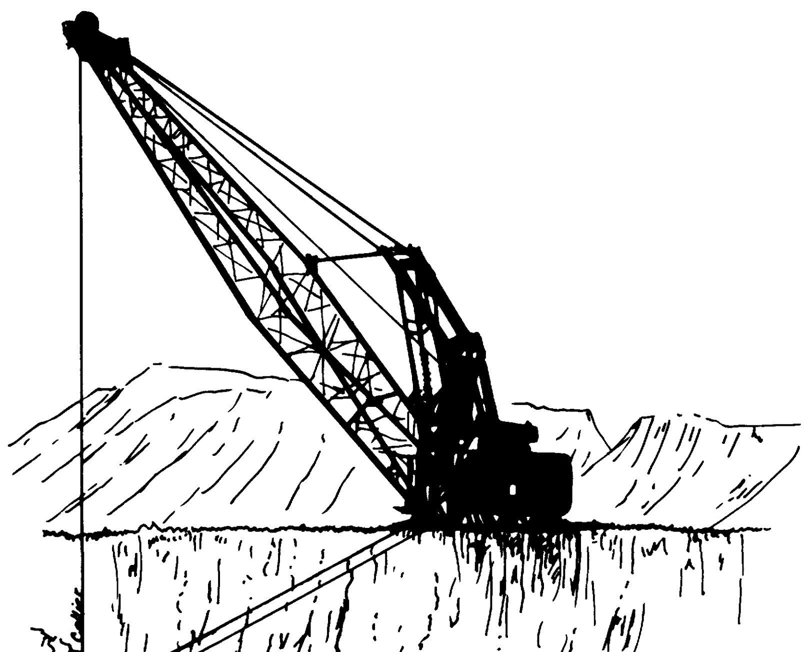
Ground water is significant to the area because numerous springs in the headwaters are used for stock and wildlife watering. Ground-water quality depends greatly upon the source aquifer. Dissolved-solids concentrations ranged from 70 to 2,400 milligrams per liter. At 12 of the 14 ground-water sites where samples were collected, dissolved-solids concentrations were less than 1,000 milligrams per liter. Calcium and magnesium generally are the dominant cations and sulfate and bicarbonate, the dominate anions.

A striking feature of Salt Wells Creek and its major tributaries is their deeply incised channels. The incision is attributed to the cumulative effects of: (1) A change in the relative amounts of annual precipitation occurring as rain and snow, (2) a change in the base level of the streambed due to downstream channelization, and (3) changes in land use. Gullies are now expanding to include intervening tributaries, and an erosion problem exists.

INTRODUCTION

Located just southeast of Rock Springs, Wyo., Salt Wells Creek is an intermittent stream that drains a 500 square-mile area comprised mainly of arid or semiarid plains; the drainage pattern is shown in figure 1. The stream heads in low-lying mountains near the Colorado-Wyoming State line and flows in a northerly direction into Bitter Creek, a stream that flows westerly through Rock Springs and eventually into the Green River. The hydrology of Salt Wells Creek is typical of that for other basins in the desolate, mineral-rich plains of southwestern Wyoming.

An increasing amount of attention is being directed toward these areas due to their extensive coal, oil, gas, uranium, trona, and oil-shale deposits. Large-scale developments of these deposits will require an understanding of the plains environment, including its hydrology. Prior to this study, few comprehensive investigations had been made and little knowledge existed about hydrology of plains areas in southwestern Wyoming (Lowham and others, 1976).



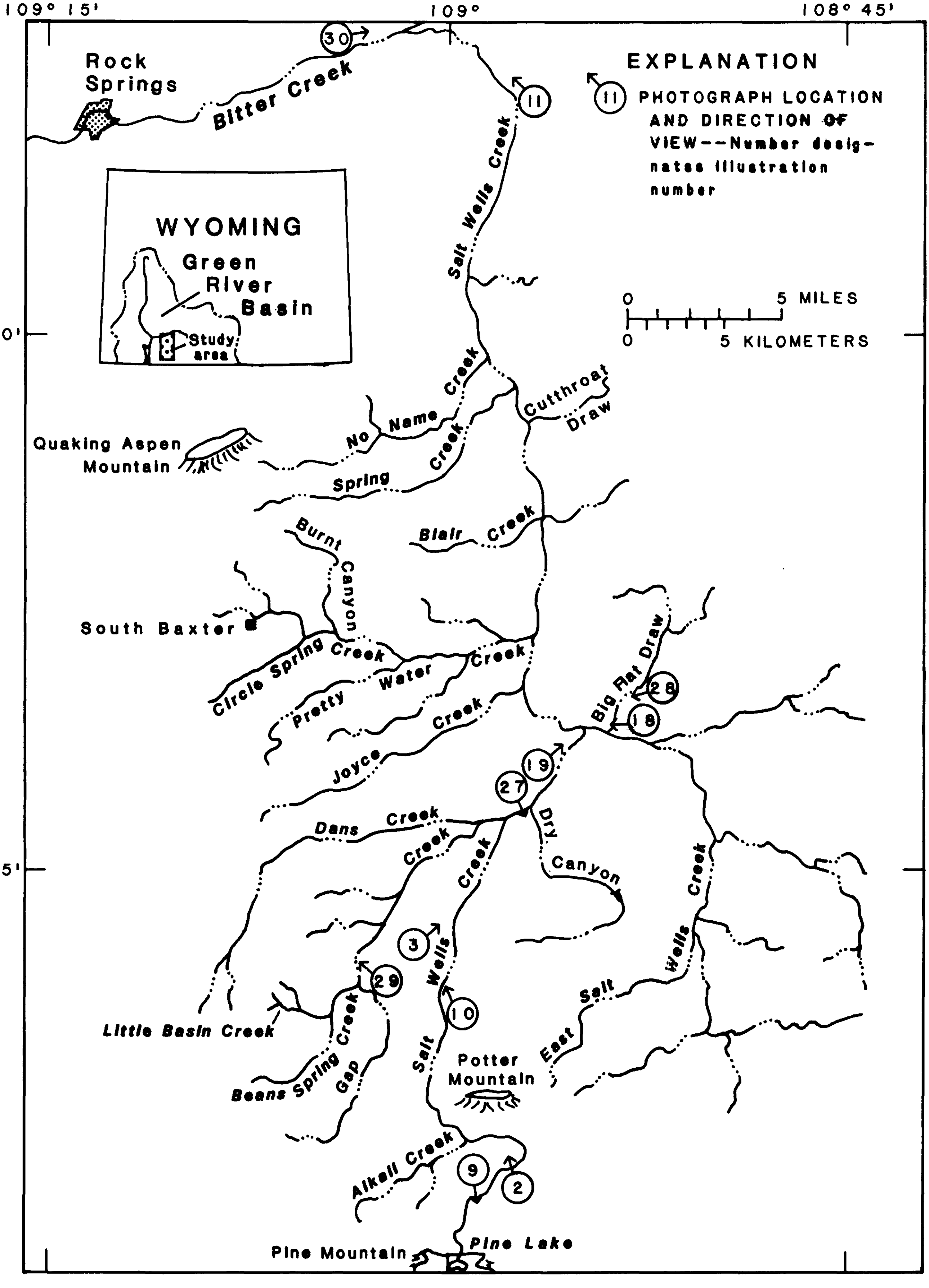


Figure 1.--Salt Wells Creek study area in Green River Basin of Wyoming.

One of the first written descriptions of a plains stream in southwestern Wyoming was made by D. G. Thomas (1912, p. 83, 84), whose outlook of Bitter Creek follows:

> Here's Bitter Creek; an empty thing
> Save when the melting snow in spring
> Rolls madly down the mountain's side
> And fills its channel deep and wide.
> At times it nearly overflows
> With dirty water, as it goes
> Beyond the home of Noah Walters
> Where it for a moment falters
> To proudly view Jock Noble's castle
> Before it starts to fight and wrestle
> With old bottles, cans, and sundries
> Certain men throw in on Sundays,
> Mondays, Tuesdays and on all days
> When they're drinking--which is always;
> On it goes--its filthy charges
> Dash against old Uncle George's
> House on stilts, from which it dodges
> Past the stable of Frank Hodges',
> By Woll Dickson's humble dwelling;
> Chopping, grinding, booming, swelling,
> Curling, whirling, onward ever
> Till it flows into Green River.
>
> O, Classic Creek! rich in tradition
> Of tragedy and superstition;
> Your yearly, reckless inundation
> Provides the means of sanitation;
> Besides, the Lord knows very well
> When you have purged yourself of smell
> And other things that much displease
> You've freed the town of foul disease.

[Excerpt from the poem ROCK SPRINGS reprinted from "Overland and Underground," published with permission.]

Although light and humorous, the preceding description accurately portrays the characteristic flashy and turbid flow of Bitter Creek, as well as of Salt Wells Creek and other plains streams of the area.

Purpose and Scope

The study on which this report is based began during 1975 in cooperation with the U.S. Bureau of Land Management as part of their Energy Mineral Rehabilitation Inventory and Analysis program. The study was directed toward determining hydrologic processes and their relation to other aspects of the environment in the Salt Wells Creek basin, and how this knowledge might be used in planning for the strip mining of coal. Two strip mines are currently (1982) in operation in separate nearby basins, and the possibility of future mining exists in the upstream part of Salt Wells Creek basin. Information in this report will therefore benefit mining companies, government and resource-planning agencies, environmental groups, and others interested in developments in Salt Wells Creek and similar drainage basins. The effects that strip mines might have on surface and ground waters are sometimes predicted with the aid of mathematical models. In Wyoming, most of the current and proposed mining is in plains areas. Before predictive models are formulated, hydrologic processes unique to such areas must be understood. Thus, results of this report will aid modeling efforts.

Water quality was described in detail because it is important to local and downstream environments. Flows from Salt Wells Creek eventually reach and affect the Green River and Flaming Gorge Reservoir, which are important as water supplies and recreation sources.

Acknowledgements

The cooperation received from local ranchers in granting access to private land is gratefully acknowledged. Mrs. John Bunning, Jr., granted permission to reproduce the excerpt from the poem ROCK SPRINGS which was written by her grandfather, D. G. Thomas.

PHYSICAL SETTING

Topography

The study area is situated on the eastern flank of an extensively dissected, asymmetrical, doubly plunging anticline that has a north-trending axis. This major structural feature, known as the Rock Springs Uplift, interrupts the nearly horizontal Tertiary beds more characteristic of the Green River Basin. The older rock units exposed within the uplift area form surface features determined by their altitude and relative resistance to erosion.

The crest of the uplift has an average elevation of about 6,500 feet above NGVD of 1929 and is occupied by the Baxter Basin, a relatively flat topographic basin eroded into soft shale. Resistant sandstone beds form a series of inward-facing escarpments that surround the basin and attain elevations from about 7,000 to 7,900 feet above NGVD of 1929. The escarpments are separated by strike valleys eroded into softer beds of coal, shale, and siltstone. Several small intermittent tributaries have incised, steep-walled canyons as much as 500 feet deep in the more resistant escarpments.

The three most prominent topographic features of the study area are: Quaking Aspen Mountain, 8,680 feet above NGVD of 1929; Potter Mountain, 8,150 feet above NGVD of 1929; and Pine Mountain, 9,720 feet above NGVD of 1929 (fig. 1). These three "mountains" are actually the mesas left standing as eroded remnants of a single, once-continuous sedimentary-rock unit that extended over much of the southwestern corner of the State. General views of the area are shown in figures 2 and 3.

Figure 2.--Salt Wells Creek, looking downstream (northwest), April 9, 1976. Potter Mountain is the highest point in the background, center left.

Figure 3.--Salt Wells Creek looking downstream (northeast), April 9, 1976.

Geology

Exposed bedrock in the study area is of sedimentary origin deposited during Late Cretaceous and Tertiary time. Cretaceous strata that crop out are shallow marine shale, near-shore fluvial sandstone and siltstone, and lagoonal shale, mudstone, and coal. The Tertiary strata that crop out are mostly stream- and lake-deposited sandstone and shale, and swamp-deposited carbonaceous shale and coal.

Eleven geologic units that crop out in the Salt Wells Creek drainage basin are significant to water quality and quantity. These units are described in table 1 according to their lithologies, water-bearing characteristics, and relative salinity of water in the units. The geologic map (fig. 4) shows the areal distribution of these formations (excluding Quaternary alluvium, which was not mapped due to its small areal extent).

Soils

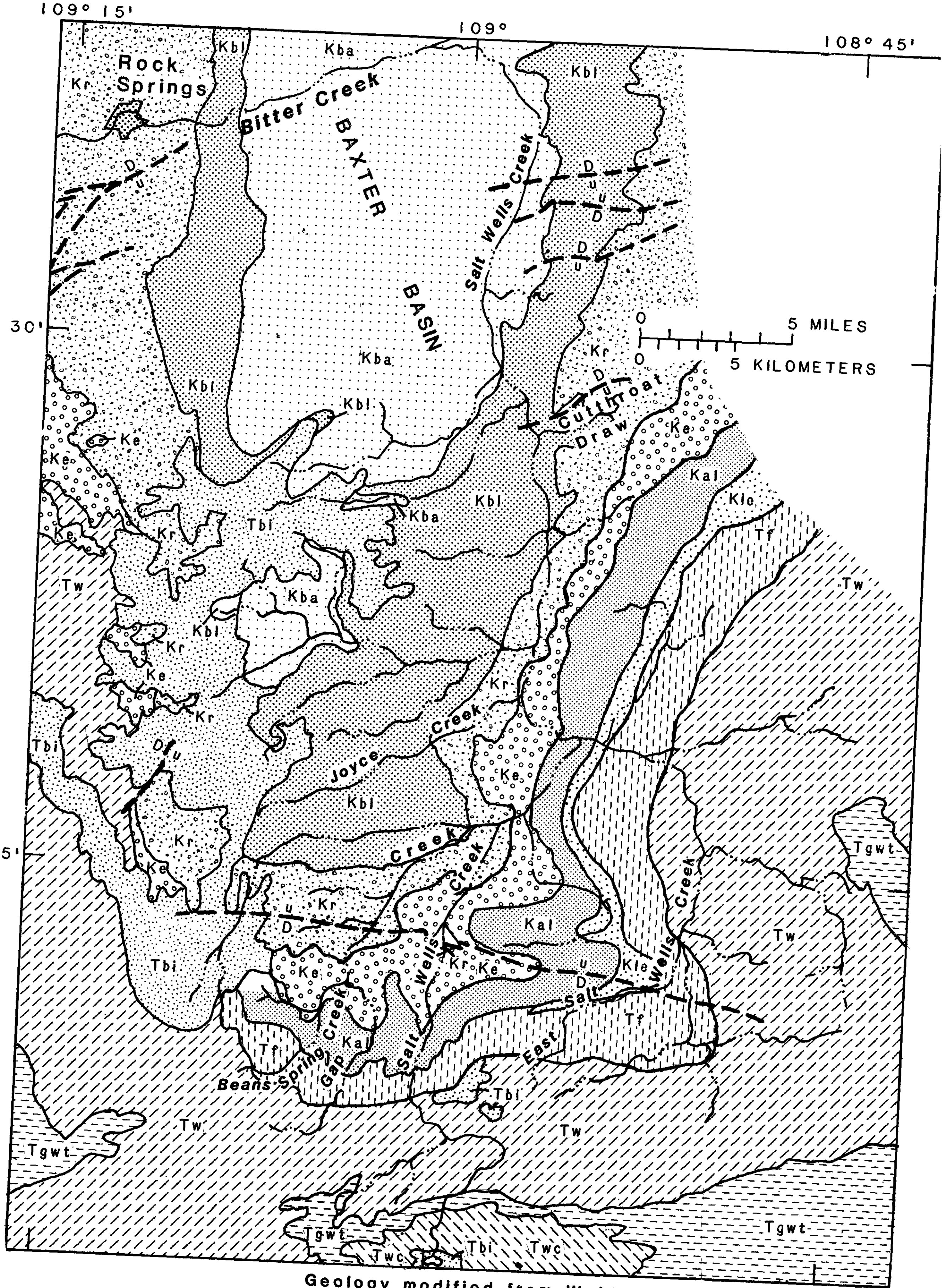
Soils occurring in the study area are either of alluvial or residual origin. The alluvium was deposited by flowing water and occurs mainly along stream channels. Alluvial soils reflect a heterogeneous mixture of parent materials, being derived from a variety of bedrock sources. The residual soils are formed in situ upon parent bedrock; consequently, they resemble the parent bedrock both in physical and chemical nature. Steep slopes and slow weathering of parent rocks have allowed only thin, poorly developed soils to form, although small isolated areas of deep soils occur where eroded soil particles have accumulated. Soil depths range from no soil on rock outcrops to nearly 5 feet along stream channels. Soil types range from sandy to clayey loam and contain varying amounts of soluble salts and small amounts of organic matter.

Climate

The Salt Wells Creek drainage basin has an arid to semiarid climate that is characterized by an extreme range of temperatures, minimal relative humidity, abundant sunshine, and strong winds. Data from the weather station at the Rock Springs airport show that at lower elevations precipitation occurs mainly as rainfall during May and June. Snowfall accounts for a significant part of the annual precipitation at higher elevations. Based on a precipitation-distribution map prepared by the Wyoming Water Planning Program (1965), average annual precipitation in the basin ranges from 7 inches at the lower elevations to more than 9.5 inches in the higher mountainous areas.

Vegetation

At elevations above about 8,000 feet on Pine and Quaking Aspen Mountains, pine and aspen trees are predominant. Juniper-pinyon woodland communities occupy the steep escarpments and foothills between 7,000 and 8,000 feet in elevation. Sagebrush and grasses grow at elevations between 6,500 and 7,500 feet. Around the 6,500-foot elevation saltbush is found growing on soils derived from saline marine shale. Greasewood grows along downstream reaches of Salt Wells Creek (Bentley, and others, 1978, p. 47-59).



Geology modified from Welder and McGreevy, 1966.

Figure 4.--Surface geology.

EXPLANATION

Oligocene		Tbi	Bishop Conglomerate	TERTIARY
Middle and lower Eocene		Twc	Cathedral Bluffs Tongue of the Wasatch Formation	TERTIARY
Middle and lower Eocene		Tgwt	Wilkins Peak and Tipton Shale Members of Green River Formation	TERTIARY
Middle and lower Eocene		Tw	Main body of Wasatch Formation including Niland Tongue	TERTIARY
Paleocene		Tf	Fort Union Formation	TERTIARY
Upper Cretaceous		Kle	Lewis Shale	CRETACEOUS
Upper Cretaceous	Mesaverde Group	Kal	Almond Formation	CRETACEOUS
Upper Cretaceous	Mesaverde Group	Ke	Ericson Formation	CRETACEOUS
Upper Cretaceous	Mesaverde Group	Kr	Rock Springs Formation	CRETACEOUS
Upper Cretaceous	Mesaverde Group	Kbl	Blair Formation	CRETACEOUS
Upper Cretaceous		Kba	Baxter Shale	CRETACEOUS

CONTACT

u
D

FAULT--u, upthrown side; D, downthrown side

Table 1.--Generalized stratigraphy

[Compiled from various sources, principally: Roehler, 1972, 1973a, 1973b; 1973; Smith, 1965; Hale, 1950; Schultz, 1920; Bentley and others, 1978.]

System	Series	Geologic units	Thickness (feet)	Lithology	Water-bearing characteristics	Relative salinity of water[1/] (Bentley and others, 1978).
QUATERNARY	Holocene	Alluvial deposits	0-10	Unconsolidated gravel, sand, silt, and clay.	Too thin to constitute aquifer although some streamflow may be lost to it during periods of high flow.	Yields fresh to highly saline water. Leached salts accumulate during dry period and are then "flushed" at first stage of runoff.
TERTIARY	Oligocene	Bishop Conglomerate	0-200	Poorly sorted cobbles, gravel, and coarse-grained sandstone.	Moderate to large permeability. Supplies water to springs at lower contact throughout the year.	Yields fresh water.
TERTIARY	middle and lower Eocene	Green River Formation --- Wilkins Peak and Tipton Shale Members, and Luman Tongue	300-1,000	Thin-bedded, gray-green, calcareous or dolomitic clay, mudstone and siltstone. Soft, brown, papery oil shale. Occasional thin limestone, fine sandstone, and coal.	Most of formation has minimal permeability. Thin sandstone beds are permeable and will yield small amounts of water. Springs likely to occur where sandstones crop out.	Yields slightly saline water.
TERTIARY	middle and lower Eocene	Wasatch Formation --- Cathedral Bluffs Tongue, main body, and Niland Tongue	0-4,000	Thick, light-tan to rust-colored, fine- to coarse-grained sandstone. Thin coal, carbonaceous shale, and variegated mudstone. Small amount of limestone and oil shale. Sandstone commonly micaceous and calcareous. Iron stained.	Moderate to large permeability. Major shallow aquifer for area surrounding Rock Springs Uplift.	Yields slightly to moderately saline water.
TERTIARY	Paleocene	Fort Union Formation	1,000-1,700	Interbedded gray, carbonaceous shale; coal; fine-grained, light-colored, calcareous, sandstone and siltstone. Sparse iron concretions. Organic matter abundant.	Sandstones are permeable.	Yields slightly to highly saline water.
CRETACEOUS	Upper Cretaceous	Lewis Shale	300-1,400	Highly gypsiferous bluish-gray to black marine shale. Occasional thin bed of soft shaly sandstone. Easily eroded.	Poor permeability. Little or no ground water expected. Springs may appear along faults.	Yields moderately to highly saline water.
CRETACEOUS	Upper Cretaceous	Mesaverde Group: Almond Formation	700-1,000	Light-gray, silty or limy shale, dark-gray, carbonaceous shale; gray to brown, fine-grained, calcareous sandstone; gray limonitic siltstone; and coal beds of variable thicknesses.	Permeability of sandstone good but most beds are too thin and small in areal extent to yield a good supply of ground water.	Yields slightly saline water.
CRETACEOUS	Upper Cretaceous	Mesaverde Group: Ericson Formation	800-1,000	Two massive, fine- to medium-grained, light-gray sandstone units separated by a "Rusty Zone" of pyritic, limonitic, calcareous sandstone. Local lenses of carbonaceous shale and coal.	Permeability very good. Major deep aquifer for area surrounding Rock Springs uplift. Locally under artesian pressure.	Yields fresh to slightly saline water.
CRETACEOUS	Upper Cretaceous	Mesaverde Group: Rock Springs Formation	600-1,400	Drab-gray, marine shale; sandy, carbonaceous shale. A few thin to thick, brown to gray, very fine grained sandstone beds relatively free of carbonaceous matter and containing an abundance of hematite or limonite.	Permeability of sandstone good but most beds are too thin and small in areal extent to provide a good supply of ground water.	Yields moderately to highly saline water.
CRETACEOUS	Upper Cretaceous	Mesaverde Group: Blair Formation	1,000-1,200	Fine- to very fine grained, yellowish-brown sandstone predominates. Thin, interbedded, brownish-gray, silty to sandy shale. Contains little or no carbonaceous matter.	Permeability of sandstone good. Ground water likely to be under artesian pressure outside Rock Springs Uplift.	Yields slightly to moderately saline water.
CRETACEOUS	Upper Cretaceous	Baxter Shale	1,000+	Homogeneous, dark-gray, marine shale with a few thin, silty shale and very fine grained sandstone beds. Contains abundant clay, gypsum, and calcareous concretions. Easily eroded.	Poor permeability due to high swelling-clay content. Little to no ground water expected. Springs may occur along fault or fracture lines.	Yields moderately to highly saline water.

1/ Fresh water (less than 250 milligrams per liter of dissolved solids).
Slightly saline water (251 to 1,000 milligrams per liter of dissolved solids).
Moderately saline water (1,001 to 2,000 milligrams per liter of dissolved solids).
Highly saline water (more than 2,000 milligrams per liter of dissolved solids).

Soil-Water-Vegetation Relationships

Water relationships in soils associated with native vegetation types that grow along Gap Creek were studied by Reuben F. Miller (Shown and others, 1977, p. 50). Miller reported, "Most of the effective soil moisture in the area is derived from snowmelt because most of the soil moisture from rains during the growing season is lost by evaporation. Wettest sites occur in low places where deep snowdrifts form. Vasey rabbitbrush occurs with big sagebrush in upland depressions where snow accumulates. Vigorous big sagebrush occurs with greasewood on lowland terraces where snow accumulates, but this type also utilizes ground water from the alluvium.

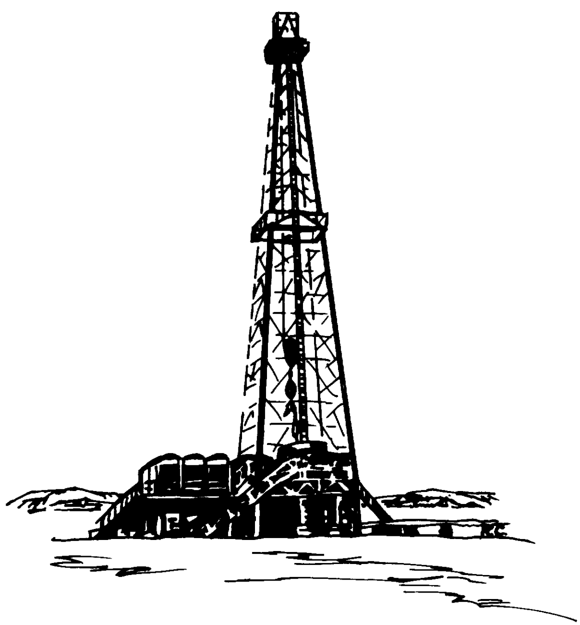
Drier areas on uplands where snow accumulation is minimal are occupied by the black sagebrush-bluebunch-wheatgrass type, by the big sagebrush-shadscale type, and by the big sagebrush-bottlebrush-squirreltail type in steep, broken areas. The black sagebrush occurs on a coarse soil where runoff is low and the bluebunch wheatgrass understory provides appreciable herbaceaus forage and protects the soil from erosion.

Some greasewood occurs in the big sagebrush-bottlebrush-squirreltail type indicating, as do the moisture relationships for the soil, that soil moisture is perched above the 50-centimeter (20-inch) depth. Moisture perching in the upper soil zone is also indicated in the Utah juniper type."

Land Use

The Union Pacific Railroad was built along Bitter Creek during 1868, and the first sheep and cattle were brought into the area around 1890. Oil and natural gas exploration began during 1900. Present day land use in the study area includes livestock grazing, natural gas production, mineral exploration (mainly coal, uranium, oil, and gas), hunting, and more recently, off-road vehicle recreation.

More than 50 coal beds are included in the geologic formations, most of them in the Fort Union or Almond Formations underlying the Salt Wells Creek basin (Roehler, 1972, 1973a, and 1973b). Minable reserves probably exceed 1 billion short tons under less than 3,000 feet of overburden. Some of the coal beds are now (1982) being mined in adjacent areas. Extensive exploration has been done in Salt Wells Creek basin although no commercial development is yet (1982) underway. Exploration for uranium in the basin has resulted in staking of many claims but there has been no commercial development as yet (1982).



LOCATION-NUMBERING SYSTEM

Locations where streams are measured or sampled on a regular basis are assigned eight-digit numbers, such as 09216565. The first two digits (09) identify the site as being located in the Colorado River basin. The remaining six digits identify the relative location of the site, with numbers increasing progressively in the downstream direction.

Wells and miscellaneous sites where only a few measurements or samples have been obtained are not assigned regular downstream station numbers. Instead, these sites are identified by a 15-digit number, such as 410343108592901. The first six digits designate latitude of the site, the next seven digits designate longitude, and the last two digits are sequence numbers to distinguish between several sites that may be in close proximity of one another.

Surface- or ground-water data were obtained at 50 sites for this study. For simplification purposes, a site number ranging from 1 through 50 was assigned to each site in addition to its regular or miscellaneous station number. The site numbers were assigned in downstream order.

DATA COLLECTION

Locations where hydrologic data were collected as part of this study are shown in figure 5. Site and station numbers, station names, and the type of data available are listed in table 2. Since 1975, continuous-record streamflow gages have been operated for one or more water years at sites 10, 21, 25, and 50. Water-quality monitors that automatically measure or sample stream temperature, specific conductance, and suspended sediment were operated at sites 10 and 21. A monitor at site 25 measured stream temperature and specific conductance. The remaining sites were measured and sampled monthly or intermittently when water was flowing.

The continuous-record stations at sites 10 and 21 were installed on major tributaries draining areas of significant coal deposits. Preliminary reconnaissance of the area indicated Gap Creek (site 21) to be perennial; whereas, the reach of Salt Wells Creek near site 10 appeared to be intermittent. The station and monitor at site 25 on Dry Canyon were installed to obtain data representative of an ephemeral-type stream. Site 50, located near the mouth of Salt Wells Creek, records virtually all runoff from the basin. Sites 33, 47, and 48 had been operated previously as partial-record sites for the purpose of determining peak flows that occur during floods.

The main objective of installing the gages and monitors was to obtain a continuous record of streamflow and water quality through the seasons. In contrast, the main objective of sampling at other stream sites was to determine the downstream changes in water quality for different seasons of the year. The springs and wells were sampled to obtain information regarding the source aquifer. Only a few wells are present in the area, and the ground-water data were obtained mainly from springs. Hydrologic data collected as part of the study are published in Water-Resources Data for Wyoming (U.S. Geological Survey, 1978a; 1978b; 1980) for water years 1976-78.

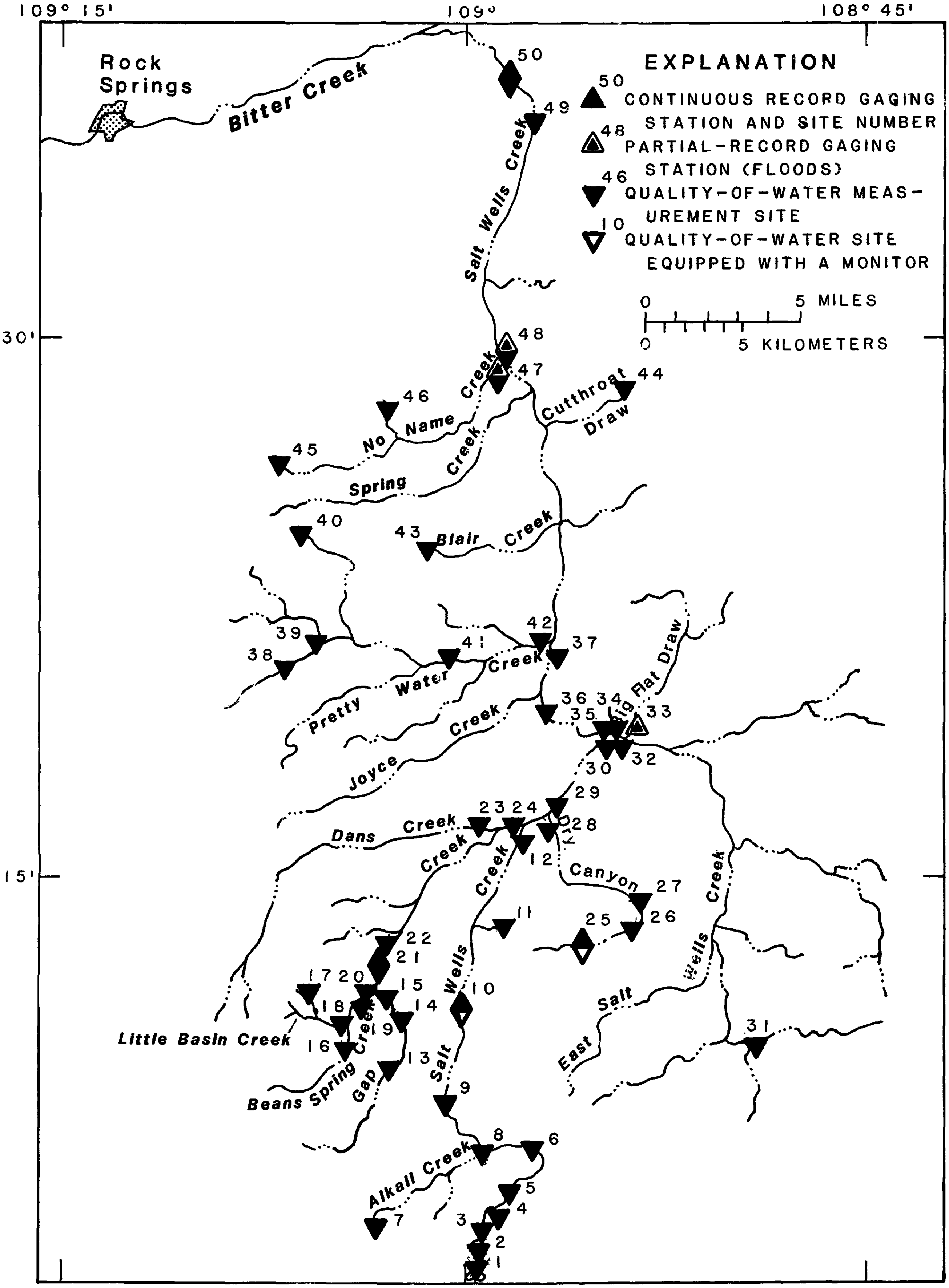


Figure 5.--Location of hydrologic-data-collection sites.

TABLE 2. DESCRIPTION OF HYDROLOGIC-DATA-COLLECTION SITES
SAMPLING FREQUENCY: D=DAILY; M=MONTHLY; Q=QUARTERLY; I=INTERMITTENTLY
ANALYSIS SCHEDULE: 1=INSTANTANEOUS DISCHARGE; 2=ONSITE DETERMINATIONS OF PH,SPECIFIC CONDUCTANCE,TEMPERATURE,DISSOLVED OXYGEN,AND (OR) TURBIDITY; 3=SALINITY; 4=SUSPENDED SEDIMENT; 5=NUTRIENTS; 6=TRACE METALS; 7=RADIOCHEMICALS; 8=PEAK FLOWS

SITE	STATION NUMBER	STATION NAME	SAMPLING FREQUENCY	ANALYSIS SCHEDULE
1	410343108592901	PINE LAKE ON PINE MOUNTAIN	I, 1977	1,2,3,5
2	410417108585301	SALT WELLS C BL PINE LAKE NR S BAXTER	I, 1976	1,2,3,4,5
3	410510108591401	SALT WELLS C AT SITE SW-2.4	I, 1977	1,2,3,5
4	410520108583201	SALT WELLS C TRIB SPRING NR S BAXTER	I, 1976	1,2,3,4, 5,6
5	410547108582301	SALT WELLS C 6.0 MI AB ALKALI C NR S BAXTER	I,1976-77	1,2,3,4, 5,6,7
6	410730108571001	SALT WELLS C 2.2 MI AB ALKALI C NR S BAXTER	I,1976-77	1,2,3,4,5
7	410511109024701	ALKALI SPRINGS NR S BAXTER	I, 1976	2,3,5
8	410722108592001	ALKALI C AT MOUTH, NR S BAXTER	I, 1976	1,2,3,4,5
9	410847109002301	SALT WELLS C BL ALKALI C, NR S BAXTER	I,1976-77	1,2,3,4,5
10	09216565	SALT WELLS C NR S BAXTER	I, 1974	1,2,3,4
			M, 1975-	1,2,3,4,5
			Q, 1975-	6
			D, 1976-	1
11	411335108581501	JIM WASHUM SPRING NR S BAXTER	I, 1976	2,3,5,6,7
12	411618108574001	SALT WELLS C AB GAP C, NR S BAXTER	I, 1976	1,2,4
			M, 1976	3,5,6,7
13	411003109015601	GAP C NR RED C RANCH	I, 1976	1,2,4
14	411106109021701	IRON SPRINGS NR S BAXTER	I, 1976	2
15	09216570	GAP C AB BEANS SPRING C, NR S BAXTER	M, 1975-	1,2,3,4,5
16	09216572	BEANS SPRING C NR S BAXTER	I, 1974	1,2
			M, 1975-	1,2,4
17	411055109060201	LITTLE BASIN C TRIB NR S BAXTER	I, 1976	1,2,3,4,5
18	411038109042101	LITTLE BASIN C AT MOUTH, NR S BAXTER	I, 1976	1,2,3,4 5,7
19	411153109030201	GAP SPRING NR MOUTH BEANS SPRING C NR S BAXTER	I, 1976	1,2,3,5
20	09216574	BEANS SPRING C AT MOUTH, NR S BAXTER	I, 1974	1,2
			I, 1975	3,5,7
			M, 1975-	1,2,4
21	09216576	GAP C BL BEANS SPRING C, NR S BAXTER	I, 1974	1,2,3,4
			I, 1975	3,6
			M, 1975-	2,4
			D,1975-76	1
22	411249109025601	TITSWORTH SPRING NR S BAXTER	I, 1976	1,2,3,5
23	411622108583501	DANS C NR S BAXTER	I, 1976	1,2,4
24	411630108574801	GAP C AT MOUTH, NR S BAXTER	M, 1976	1,2,4
			I, 1976	3,5,6
			I, 1977	1,2,3,5

TABLE 2. DESCRIPTION OF HYDROLOGIC-DATA-COLLECTION SITES--CONTINUED

SITE	STATION NUMBER	STATION NAME	SAMPLING FREQUENCY	ANALYSIS SCHEDULE
25	09216578	DRY CANYON NR S BAXTER	M, 1976- D, 1976-	2 1
26	411352108533001	DRY CANYON AB PIO RE, NR S BAXTER	I, 1976	1,2,3,4,5
27	411417108532901	PIO RE NR SALT WELLS	I, 1976	1,2,3,5, 6,7
28	411639108564401	DRY CANYON AT MOUTH, NR S BAXTER	I, 1976	1,2,3,4, 5,6,7
29	411652108564701	SALT WELLS C BL DRY CANYON, NR S BAXTER	I, 1976	1,2,3,4, 5,7
30	411858108545501	SALT WELLS C AB E SALT WELLS C, NR S BAXTER	I, 1976	1,2,3,4,5
31	411016108490001	PUMPING WELL NR E DRAW-E SALT WELLS C CONFLUENCE	I, 1963	2,3,4
32	411845108541501	PUMPING WELL NR E SALT WELLS C-SALT WELLS C CONFLUENCE	I, 1963	2,3,4
33	09216580	BIG FLAT DRAW NR ROCK SPRINGS	M, 1975- M, 1973-	1,2,3,4,5 8
34	411855108542401	E SALT WELLS C AT HWY 436 BRIDGE, NR S BAXTER	I, 1976	1,2,4
35	411900108545601	E SALT WELLS C AT MOUTH, NR S BAXTER	I, 1976	1,2
36	412000108565701	SALT WELLS C AB JOYCE C, NR S BAXTER	I, 1976	1,2
37	412125108562501	SALT WELLS C AB PRETTY WATER C, NR S BAXTER	I, 1976	1,2,4
38	412031109064501	CIRCLE SPRINGS NR SALT WELLS	I, 1976	2,3,5
39	412128109053001	SPRING ON CIRCLE SPRINGS DRAW, NR SALT WELLS	I, 1976	2,3,5
40	412409109053001	SPRING ON BURNT CANYON C, NR SALT WELLS	I, 1976	2,3,5
41	412130109025001	CIRCLE C NR SALT WELLS	I, 1976	1,2,3,4,5
42	412126108562701	PRETTY WATER C AT MOUTH, NR S BAXTER	I, 1976	1,2,3,4,5
43	412324109005101	SPRING ON BLAIR C, NR S BAXTER	I, 1976	2,3,5
44	412827108550201	CUTTHROAT DRAW TRIB SPRING NR ROCK SPRINGS	I, 1976	2,3,5
45	412604109060001	SPRING ON PINE C AB NO NAME C, NR SALT WELLS	I, 1976	2,3,5
46	412813109032501	SPRING AT DORRENCE RECREATION PARK, NR SALT WELLS	I, 1976	2,3,5
47	09216695	NO NAME C NR ROCK SPRINGS	M, 1975- M, 1973-	1,2,3,5 8
48	09216700	SALT WELLS C NR ROCK SPRINGS	I, 1967 I, 1974 I, 1975 M,1959-76	1,5 1,2,5 1,2,5 8
49	413530108571501	SALT WELLS C AT IRON CULVERT, NR ROCK SPRINGS	I, 1976	1,2
50	09216750	SALT WELLS C NR SALT WELLS	M, 1975- I, 1975- Q, 1975- D, 1976-	1,2,4 3,5,6 7 1

DESCRIPTION OF THE HYDROLOGIC SYSTEM

The drainage of Salt Wells Creek has been affected by the Rock Springs Uplift. The main-stem stream originates on Pine Mountain and flows northward along strike valleys formed by the softer shale beds of the Mesaverde Group (figs. 1 and 4). The stream flows into Bitter Creek approximately 54.5 river miles downstream of Pine Mountain. Several of the tributaries to Salt Wells Creek, such as Beans Spring Creek, Gap Creek, Dry Canyon, and East Salt Wells Creek, have formed superposed valleys that cut across pronounced hogback ridges of the Mesaverde Group instead of following the strike of softer shale beds.

Water Use

The main use of water in the study area is for consumption by livestock and wildlife. About 15 springs and 12 wells provide the bulk of this supply; several stockponds have been constructed on small headwater tributaries.

Natural gas wells are scattered throughout the study area. Sporadic exploration for additional oil and gas reserves continues (1982). The exploratory drilling requires a dependable source of water, which is commonly obtained from either surface-water impoundments or water wells drilled at the sites.

Streamflow

Streamflow in Salt Wells Creek and its tributaries varies with the position along the drainage. An appreciable amount of snow accumulates during winter months on areas above about 7,000 feet. Therefore, snowmelt during the spring months accounts for a significant part of annual runoff for headwater tributaries draining these areas. Rainstorms also contribute to runoff. Hydrographs of daily discharges recorded at sites 10 and 21 for different water years are shown in figures 6 and 7. Numerous springs contribute perennial low flows to the headwater tributaries; however, evapotranspiration, freezeup, and seepage deplete these flows so that the downstream reach of Salt Wells Creek has only intermittent flows. For example, daily discharges recorded for the 1977 water year at site 50, which is located 3.0 river miles upstream from the mouth, are shown in figure 8. A comparison of the daily discharges shown in figures 6 and 8 shows many more days of no flow occur at site 50 than at site 10.

Photographs show the downstream change in stream conditions (figs. 9-11). The photographs exemplify the changes that take place in the channels and their flows from the headwater to downstream reaches.

Based on the available streamflow records and on observations of the area during 1975-78, snowmelt seems to yield the major part of runoff from the higher elevations of Salt Wells Creek basin. The relative yield from rainstorms becomes more significant in the lower elevations of the basin. Because precipitation varies significantly from year to year, runoff varies significantly as well. Rainstorm runoff sometimes causes large peak flows. (See figs. 6-8.) However, the duration of flow from rainstorm runoff is relatively short in comparison to snowmelt runoff.

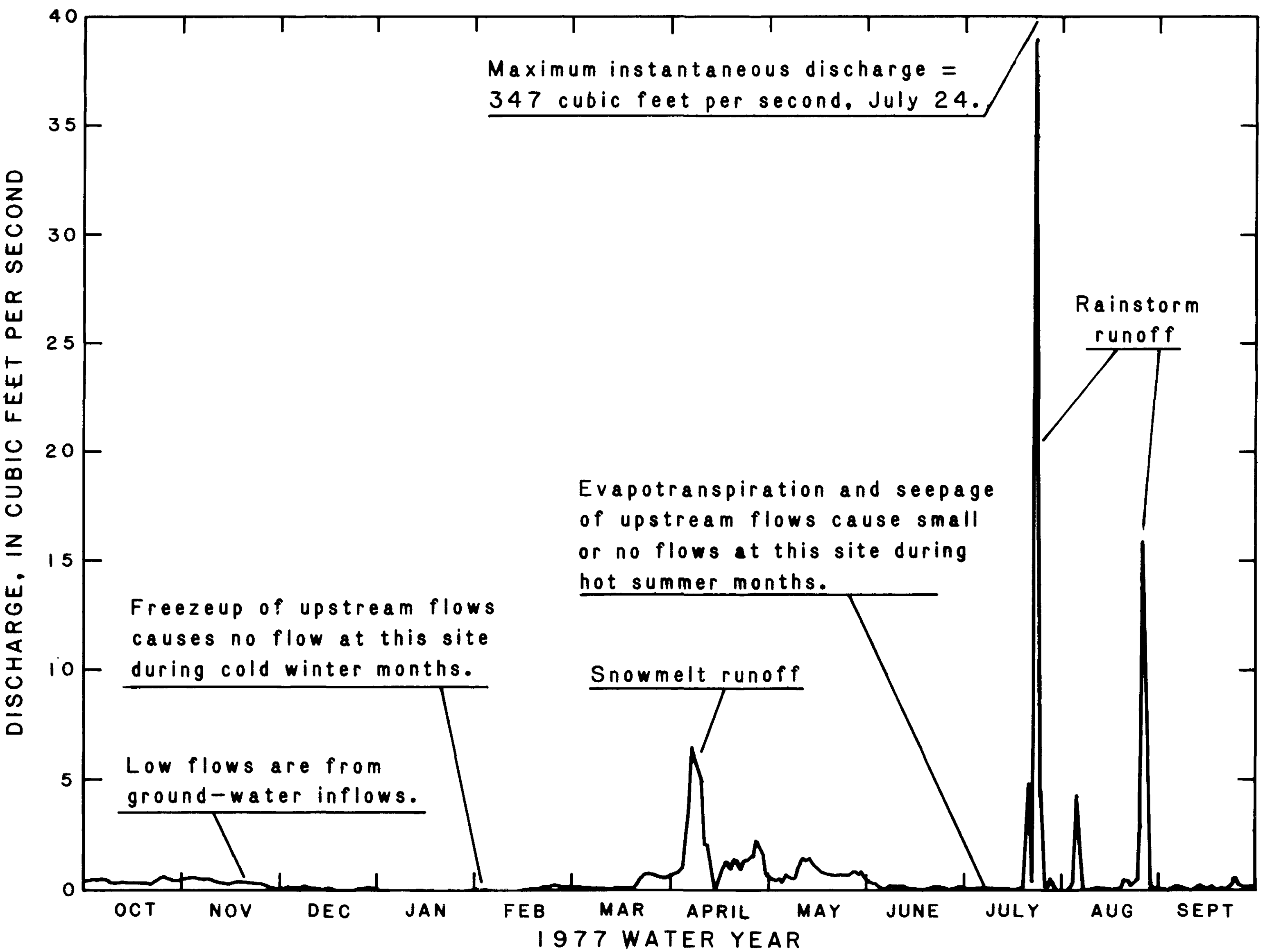


Figure 6.--Daily discharge at site 10 on Salt Wells Creek near South Baxter, Wyoming (1977 water year).

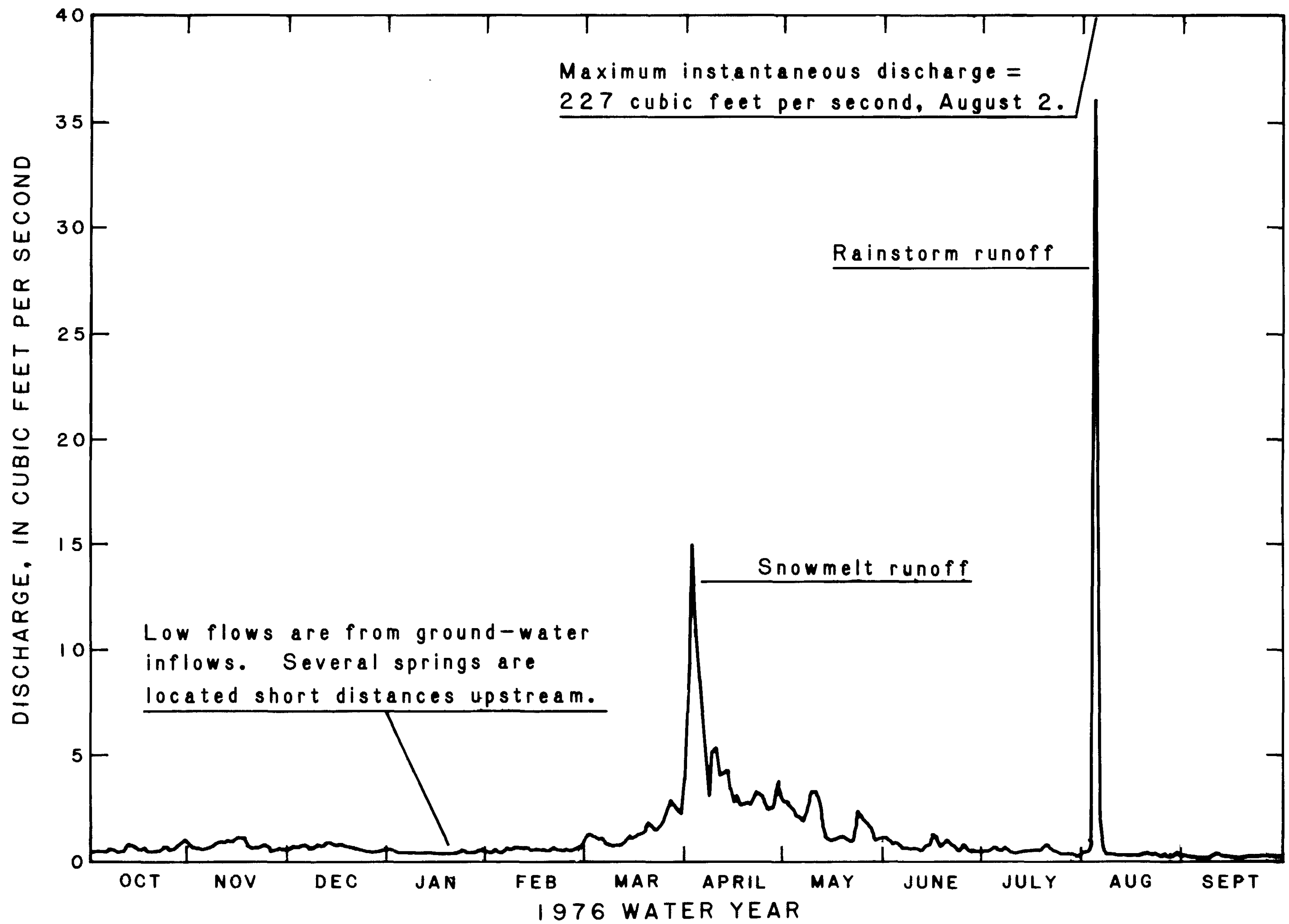


Figure 7.--Daily discharge at site 21 on Gap Creek below Beans Spring Creek, near South Baxter, Wyoming (1976 water year).

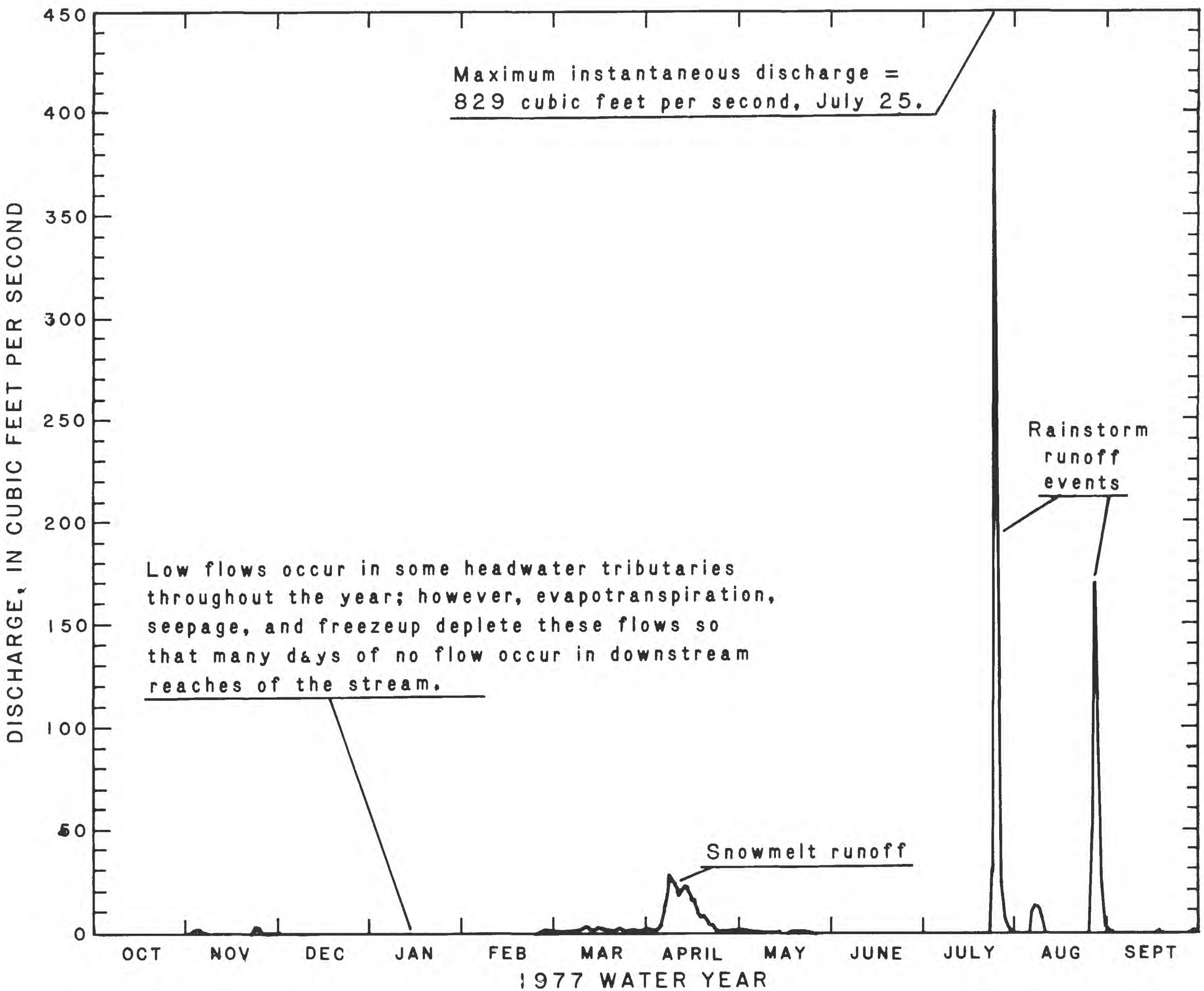


Figure 8.--Daily discharge at site 50 on Salt Wells Creek near Salt Wells, Wyoming (1977 water year).

Figure 9.--Spring at site 4 on Salt Wells Creek tributary, March 31, 1976. Looking upstream (south). Elevation of this site is 7,960 feet. Significant accumulation of snow occurs in the headwater areas above 7,000 feet.

Figure 10.--Salt Wells Creek at site 10, March 31, 1976. Looking downstream (north).

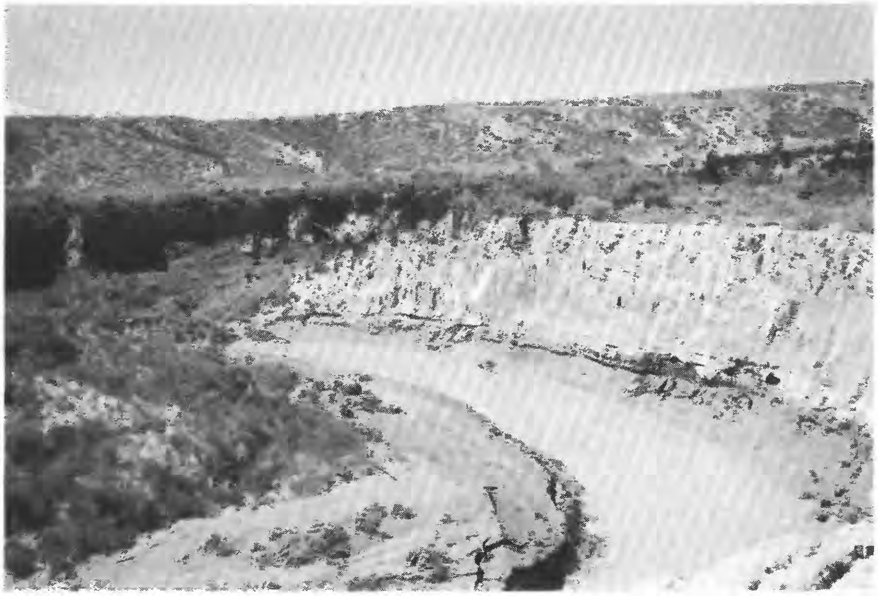


Figure 11.--Salt Wells Creek near site 50, August 5, 1976. Looking downstream (northwest). Right terrace wall is about 20-feet high.

Only a few years of record are available for most gaged sites in the basin. At least 10 years of record at a site generally are necessary before its peak-flow characteristics can be reliably determined, and 5 years of record are desired before average runoff is computed. The length of record necessary depends on the yearly variability of flows at the site.

The partial-record gaging station at site 48 was operated during the 1959-76 water years (18 years) for the purpose of determining peak flows. An analysis of these data shows peak flows expected for various frequencies to be as follows:

Recurrence interval of peak flow, in years	Peak flow, in cubic feet per second
2	1,150
5	2,190
10	2,960
25	4,000

The maximum flow recorded at the site was 3,750 cubic feet per second on February 11, 1962. A review of weather records for the area indicates this flood was the result of rain on snow.

A continuous-record gaging station was installed at site 50 during 1976. The partial-record station at site 48 was discontinued during 1977. Peak flows at these two sites generally should be about equivalent as the drainage area for site 50 (526 square miles) is only slightly larger than that for site 48 (515 square miles). Yearly totals of runoff for the gage at site 50, which records virtually all runoff from the basin, are as follows:

Water year	Annual runoff, in acre-feet
1976 (June 1 to Sept 30 only)	3,069
1977	2,800
1978	1,450
1979	2,210
1980	2,790

Several more years of record are necessary before an accurate determination can be made of the long-term average runoff; however, based on the records obtained so far it appears that average runoff for the stream is about 2,000 to 3,000 acre-feet per year.

The gage on Dry Canyon at site 25 was installed during October 1976. Dry Canyon is a befitting name as only three occurrences of runoff were recorded during 3 years of record. No flow occurred throughout the 1978 water year. The stream drains the east side of a relatively flat mesa where no springs occur. The stream is ephemeral and flows only for brief periods following rainstorms or snowmelt. Relief in the basin upstream from the gage is relatively less than for tributaries of Salt Wells and Gap Creeks to the west. Although elevations range from 7,200 to almost 8,000 feet, snow accumulation is less on the flat mesa than for areas of similar elevation that have more pronounced gullies and canyons.

Surface-Water Quality

Surface-water quality within the study area, like streamflow, is variable both areally and temporally. Dissolved-solids concentrations in the headwaters were typically less than 100 milligrams per liter, whereas dissolved-solids concentrations downstream near site 50 commonly exceeded 3,000 milligrams per liter. An example of temporal variation showing water temperature, specific conductance, and streamflow during April-July, 1977 at site 10 on Salt Wells Creek is shown in figure 12. The data shown are daily means of hourly data recorded by automatic monitors. Specific conductance is directly related to the dissolved-solids concentration. Although daily mean water temperatures recorded at site 10 during the study ranged from 0°C to about 19°C seasonally, variation of more than 15°C in a single day commonly were recorded.

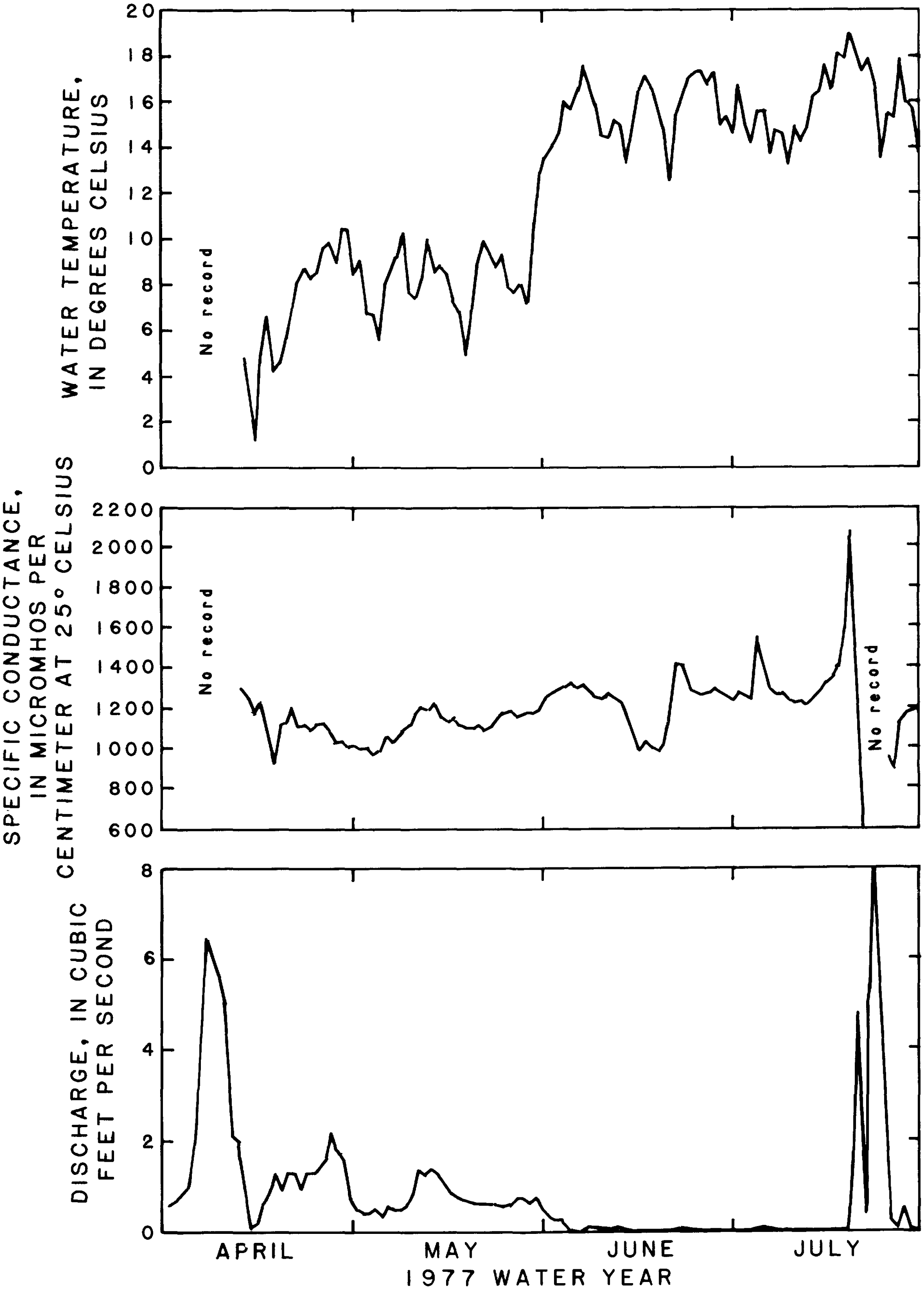


Figure 12.--Water temperature, specific conductance, and daily discharge at site 10 on Salt Wells Creek near South Baxter, Wyoming.

Dissolved Inorganic Constituents

Concentrations of the major dissolved inorganic constituents in Salt Wells Creek, with the exception of bicarbonate (HCO_3) and carbonate (CO_3), increase in the downstream direction. Data collected March 31, 1976, during early spring runoff are shown in figure 13. As shown in figure 14, increases in dissolved-solids concentrations in the downstream direction are typical of Salt Wells Creek during other seasons and under different streamflow conditions as well. On August 13, 1977, (fig. 14) Salt Wells Creek was dry just downstream from site 10. On March 31, 1976, streamflow was continuous throughout the study reach.

The concentration of an individual ion (fig. 13) relative to the concentrations of other ions may vary along the stream length. Downstream changes in composition of the water in Salt Wells Creek can be seen on trilinear diagrams such as figures 15-17. Chemical analyses are represented on the trilinear diagrams in milliequivalents per liter to facilitate comparison of relative combining masses. (If two constituents were to combine, the milliequivalents of one constituent would combine with an equal number of milliequivalents of the other constituent). Each chemical analysis is represented by three points on the diagrams. Based on ratios among cations and anions, a point is positioned in each of the equilateral triangles. The location of the third point is at the intersection of projection from the first two points into the rhombus. Analyses with identical individual ion ratios plot identically on the diagram. Conversely, different locations on the diagram represent different ion ratios. A more complete discussion of the development and use of trilinear diagrams is contained in Hem (1970, p. 264-270).

The downstream trend, moving sequentially from site 5 to site 30, is toward increasing concentrations of sulfate (SO_4) and chloride (Cl) relative to bicarbonate and carbonate throughout the year (figs. 15-17). Equilibrium calculations, similar to those demonstrated in Hem (1966, p. 64-77; 1970, p. 252-255), indicate that samples collected from Salt Wells Creek are supersaturated with respect to calcium carbonate minerals, such as calcite and aragonite, but undersaturated with respect to calcium sulfate minerals, such as gypsum and anhydrite. The relative increase in sulfate concentration in the downstream direction could be explained by preferential dissolution of sulfate minerals and subsequent precipitation of calcium carbonate minerals.

There are numerous small springs in the headwaters of Salt Wells Creek. Water flowing from these springs as well as discharge from the unsaturated zone leach salts from surficial material. During periods between precipitation, salts accumulate and are concentrated by evapotranspiration in channels as shown in figures 18 and 19. Runoff from snowmelt or rainfall may readily dissolve the salts and, if sufficient in magnitude, will flush salts from stream channels and other inundated surfaces.

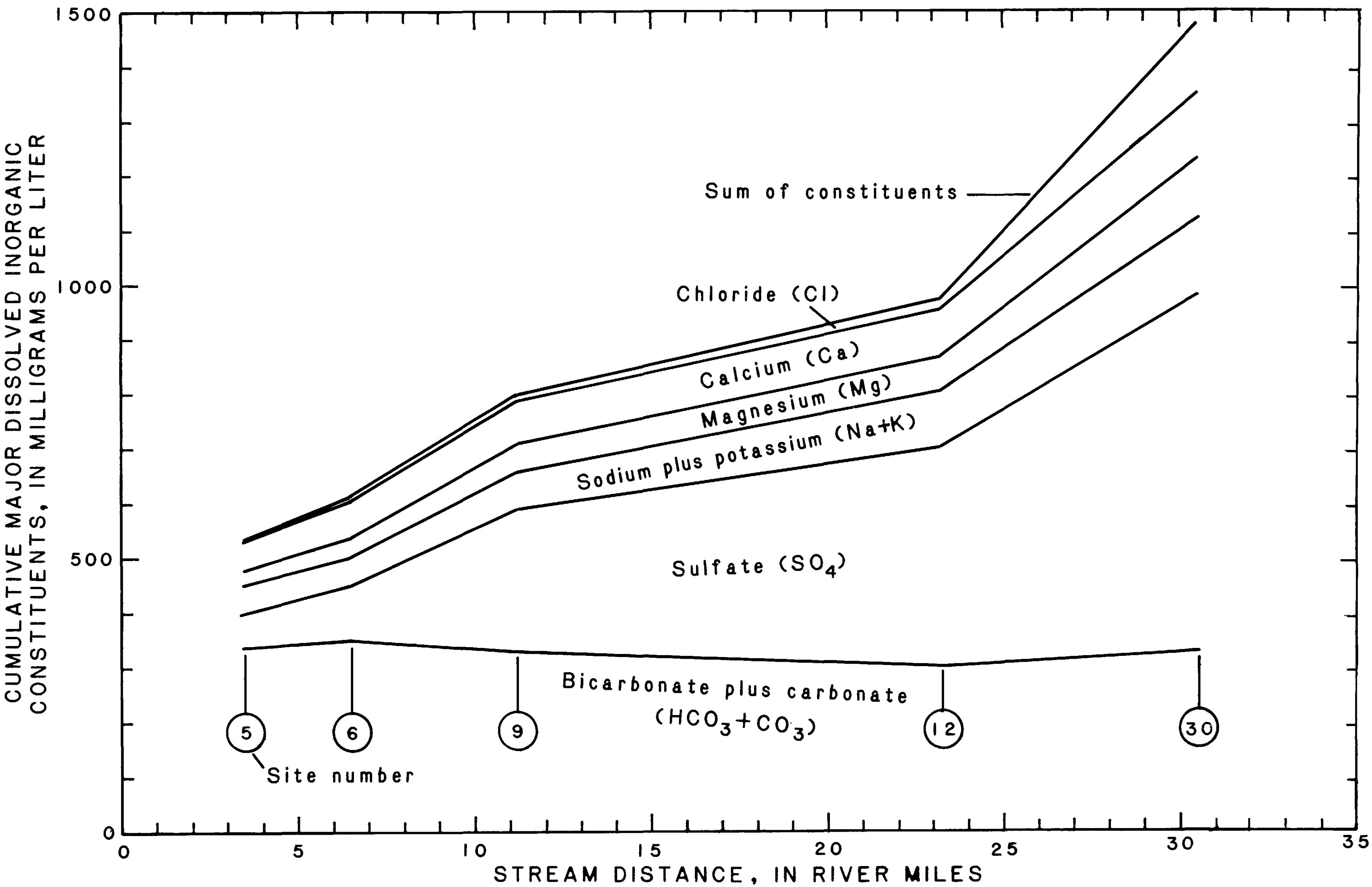


Figure 13.--Downstream change in major dissolved inorganic constituents, March 31, 1976.

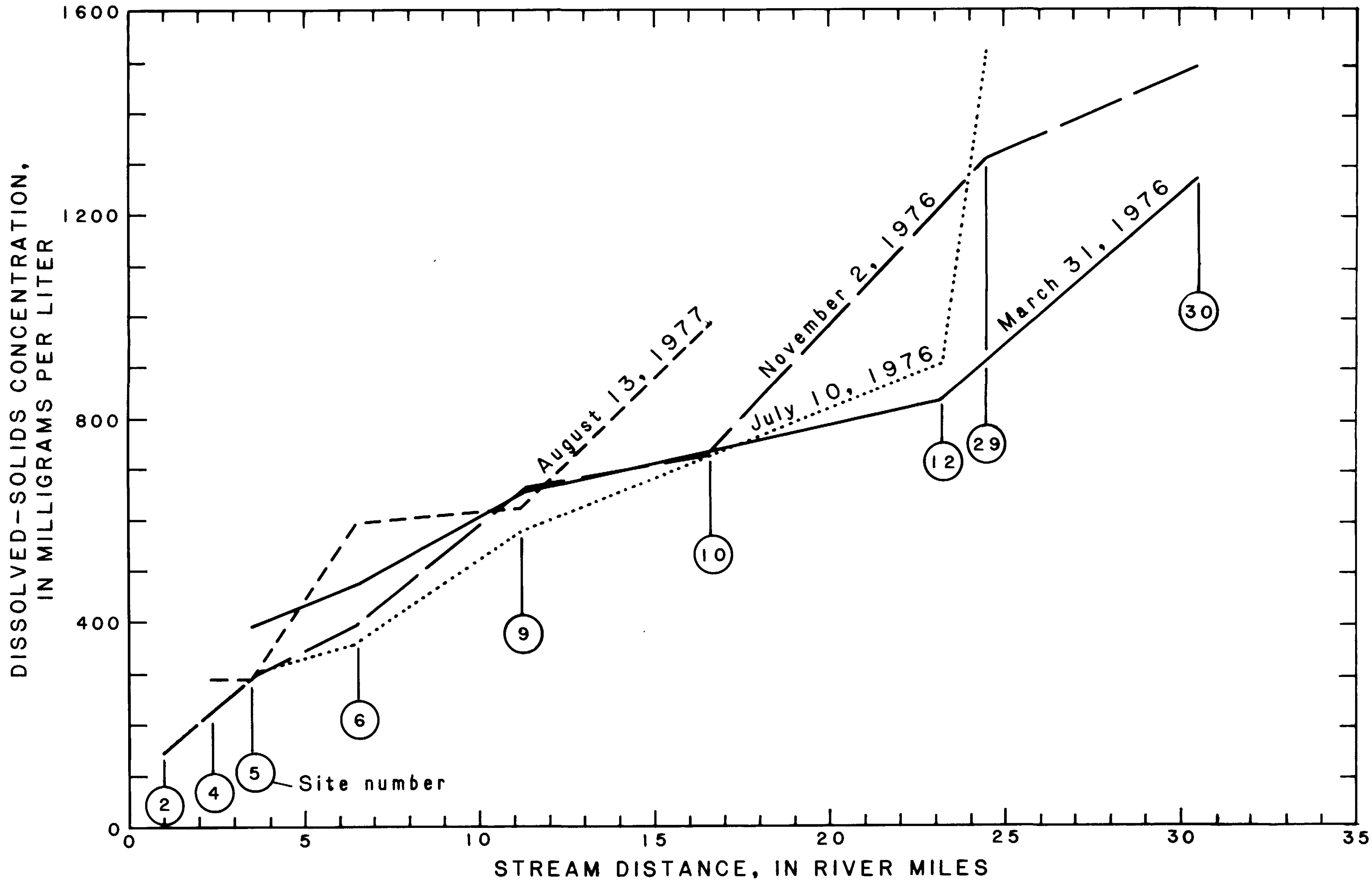


Figure 14.--Downstream change in dissolved-solids concentration at different times of the year under various flow conditions.

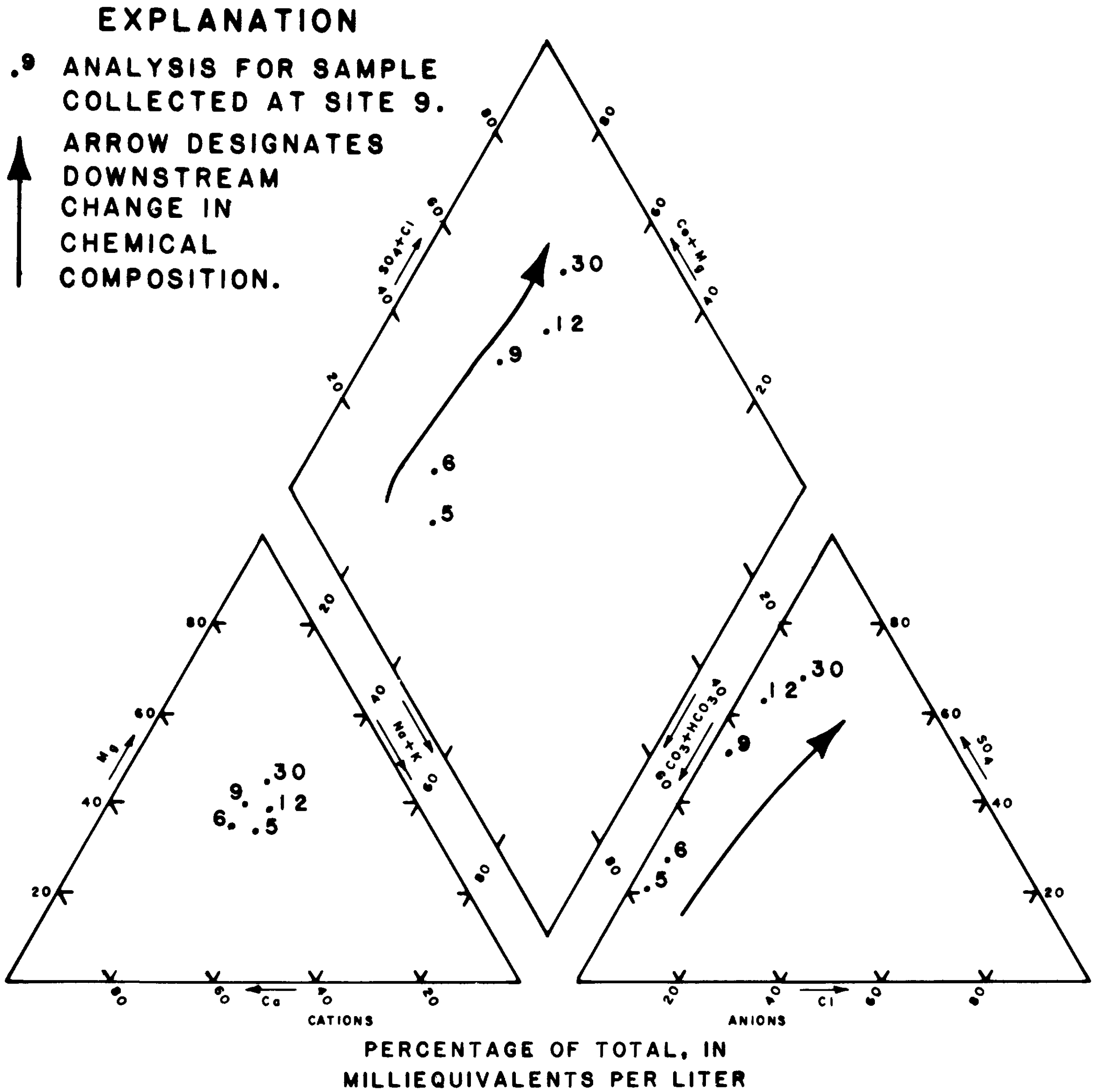


Figure 15.--Chemical analyses of water samples collected at sites 5, 6, 9, 12, and 30, March 31, 1976.

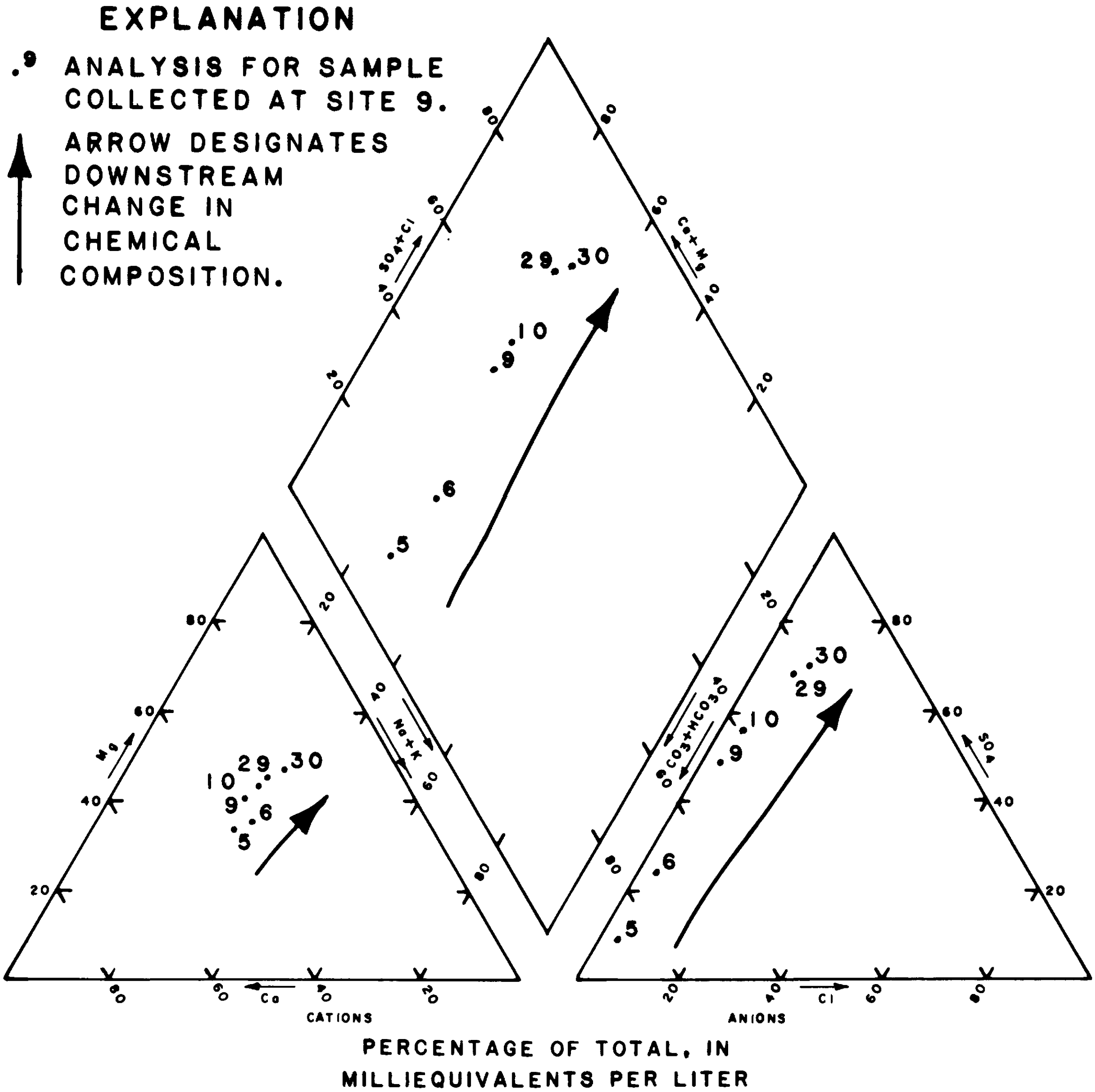


Figure 16.--Chemical analyses of water samples collected at sites 5, 6, 9, 10, 29, and 30, November 2, 1976.

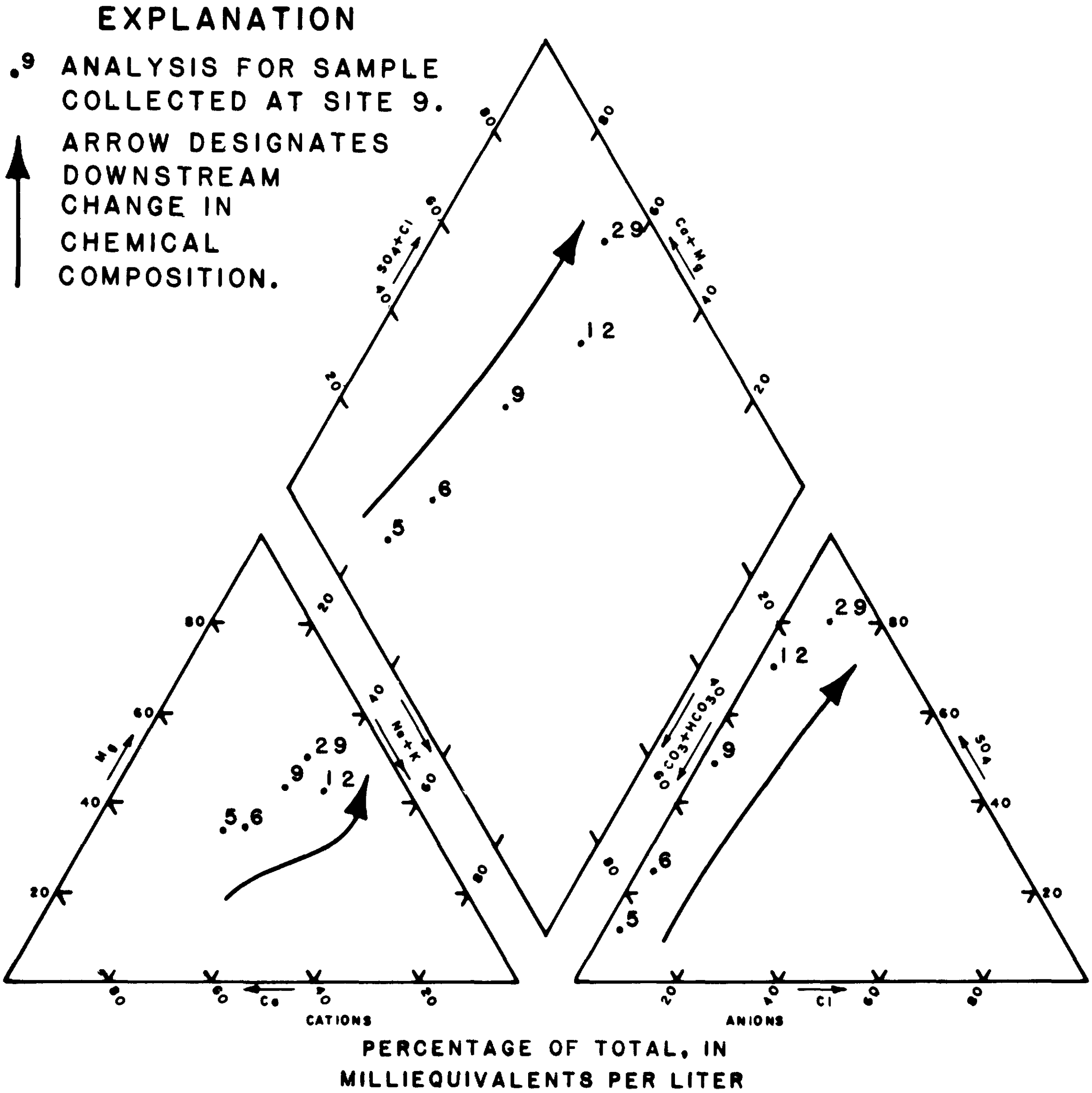


Figure 17.--Chemical analyses of water samples collected at sites 5, 6, 9, 12, and 29, July 10, 1976.

Figure 18.--Accumulation of salts in gully of East Salt Wells Creek at site 34, May 18, 1979. View is downstream (northwest). Gully is about 15-feet deep.

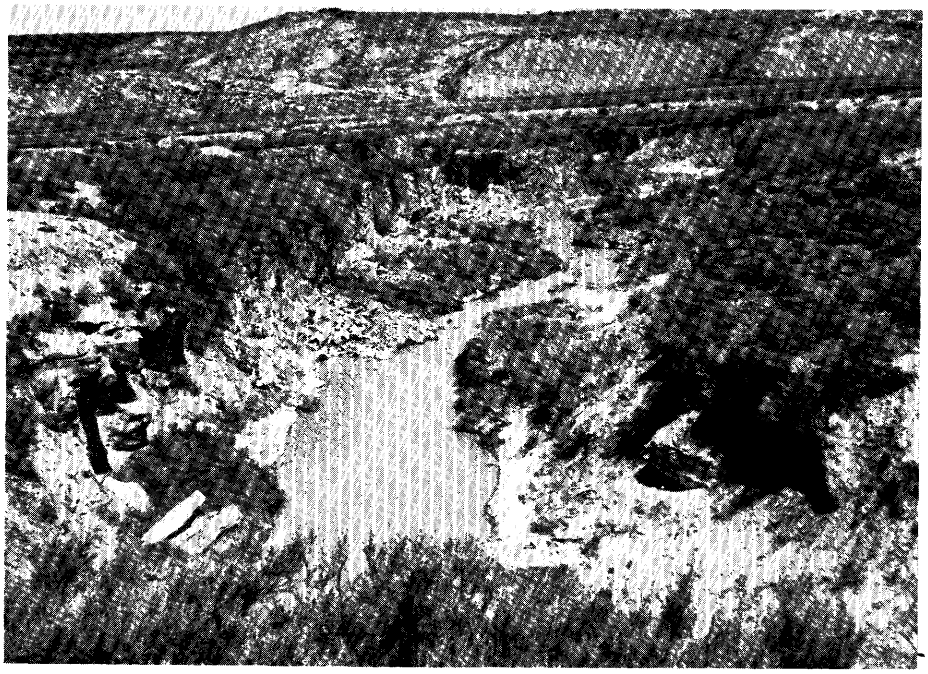


Figure 19.--Snowmelt runoff in Salt Wells Creek at site 30, May 18, 1979. During periods of streamflow, the salt deposits are dissolved and flushed downstream. View is downstream (northeast). Depth of gully is about 15 feet.

An example of the flushing action is shown in data collected at site 10. Dissolved-solids concentration there is related to specific conductance as shown in figure 20. Specific conductance and discharge recorded at site 10 during runoff are given in figure 21. As indicated by specific conductance, dissolved-solids concentration increased and peaked as the first of the runoff reached the site, then began to decrease before the maximum streamflow at the site occurred.

The variation of dissolved-solids concentration with discharge is shown schematically in figure 22. As streamflow begins, runoff originating furthermost upstream from the measurement site has the greatest potential for dissolving salt by virtue of greater surface area contacted en route to the site. Dissolved-solids concentration would be expected to increase through the early period of runoff as water traveling greater distances, transporting a greater concentration of salt, begins to arrive at the measurement site. However, there is a finite amount of readily soluble salt available to the water, and as it is depleted, dissolved-solids concentration at the measurement site reaches a maximum and begins to decrease. Streamflow may continue to increase, but by then the effect of dilute water flowing over previously flushed surfaces is greater than the effect of water flowing over newly contacted surfaces, and the dissolved-solids concentration at the site continues to decrease.

The records of specific conductance and discharge shown in figure 21 are plotted in figure 23 showing a relation similar to that postulated in the schematic diagram (fig. 22). In those stream reaches where base flows are responsible for a very small part of overall streamflow, flushing of salts by floods appears to be the major mechanism by which dissolved solids are transported from the basin.

Flushing by runoff also appears to be a dominant mechanism in the transport of phosphorus. The direct relation between total-phosphorus concentrations and suspended-sediment concentrations in samples collected from surface water (fig. 24) indicates that phosphorus is transported largely by suspended sediment. Sediment transport, described later in this report, is affected by the flushing action of first flows.

The flushing action shown to occur during runoff of Salt Wells Creek is a process that affects the quality of runoff from similar streams in the plains of southwestern Wyoming. Although the amount of runoff from intermittent or ephemeral streams (such as Salt Wells and Bitter Creeks) may be small in relation to that of receiving streams (such as the Green River) the flushing process results in relatively large concentrations of material that may constitute a shock load to receiving streams, particularly during the low flow summer months. Runoff from arid and semiarid plains areas is therefore significant to the water quality of the perennial streams receiving such runoff.

The quality of runoff from plains areas is greatly dependent upon the rates of accumulation of salt, sediment, and organic materials. The principal factors governing the rate of material buildup between periods of runoff are basin and channel characteristics, season of the year, and land use (Overton and Meadows, 1976, p. 304-311). Subsequent removal of these materials by runoff is dependent upon their composition, the amount

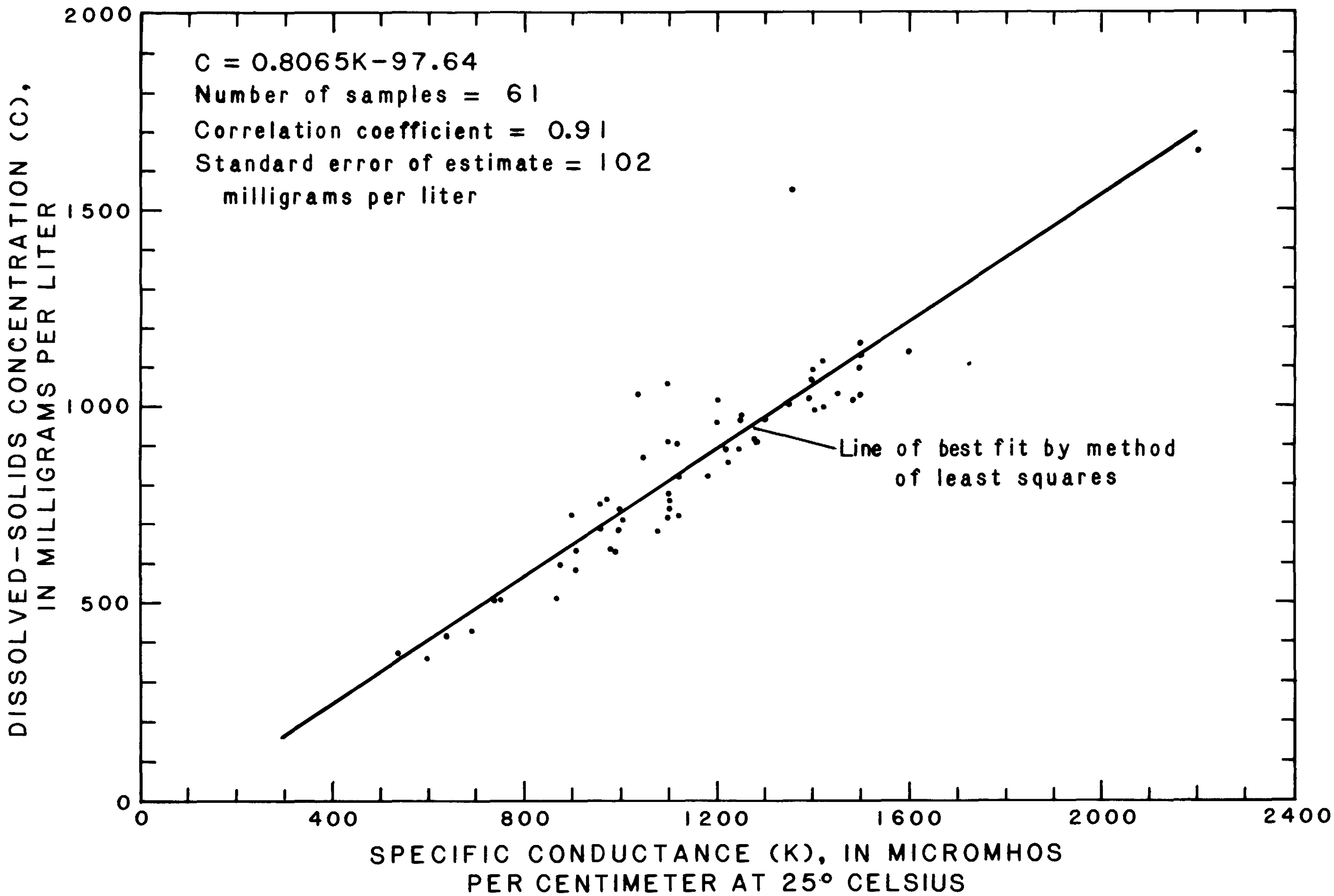


Figure 20.--Relation of dissolved-solids concentration to specific conductance at site 10.

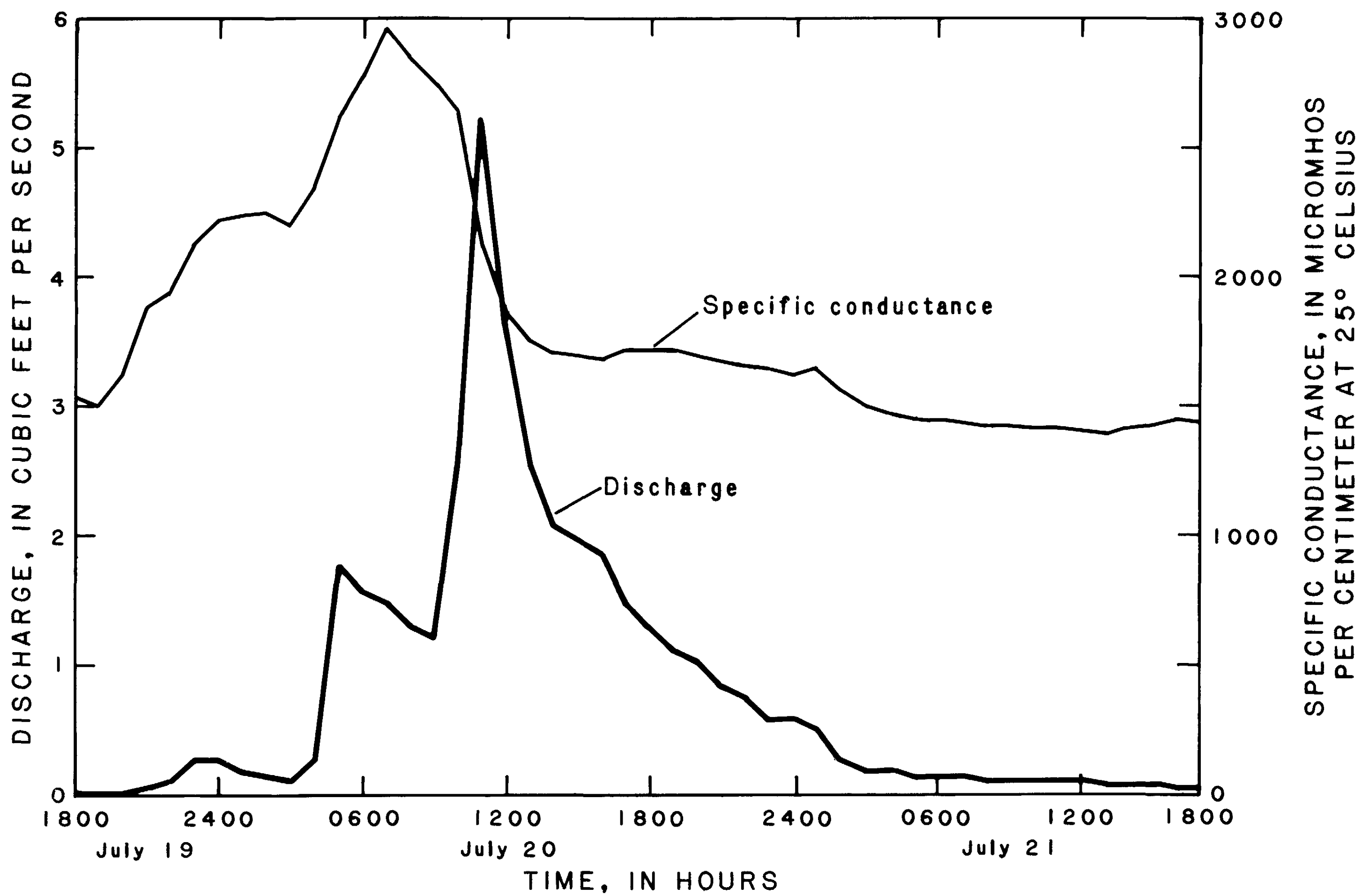


Figure 21.--Discharge and specific conductance at site 10, July 19-21, 1977.

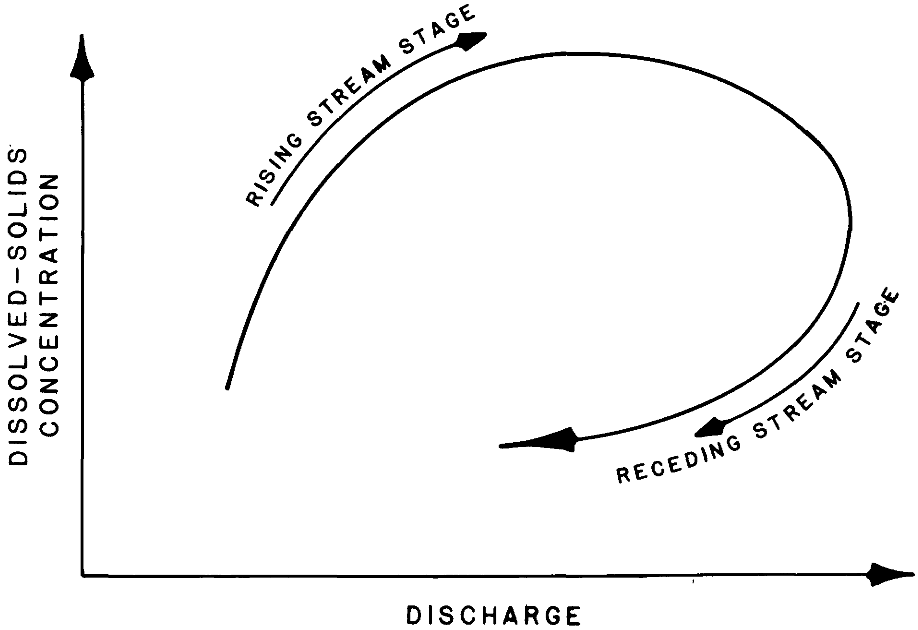


Figure 22.--Flushing of salts during runoff. (Typical of a plains stream in southwestern Wyoming).

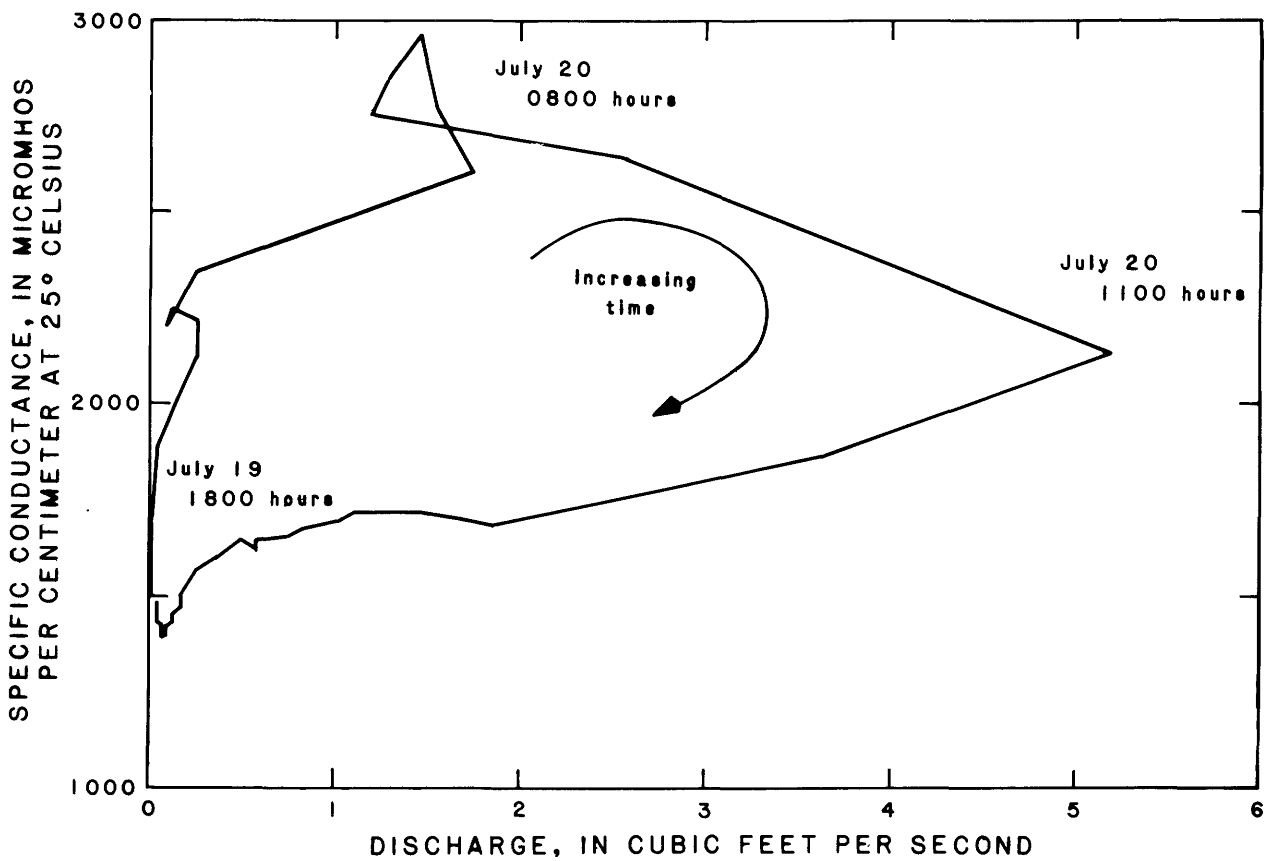


Figure 23.--Flushing of salts from channel as shown by variation of specific conductance with discharge at site 10, July 19-21, 1977.

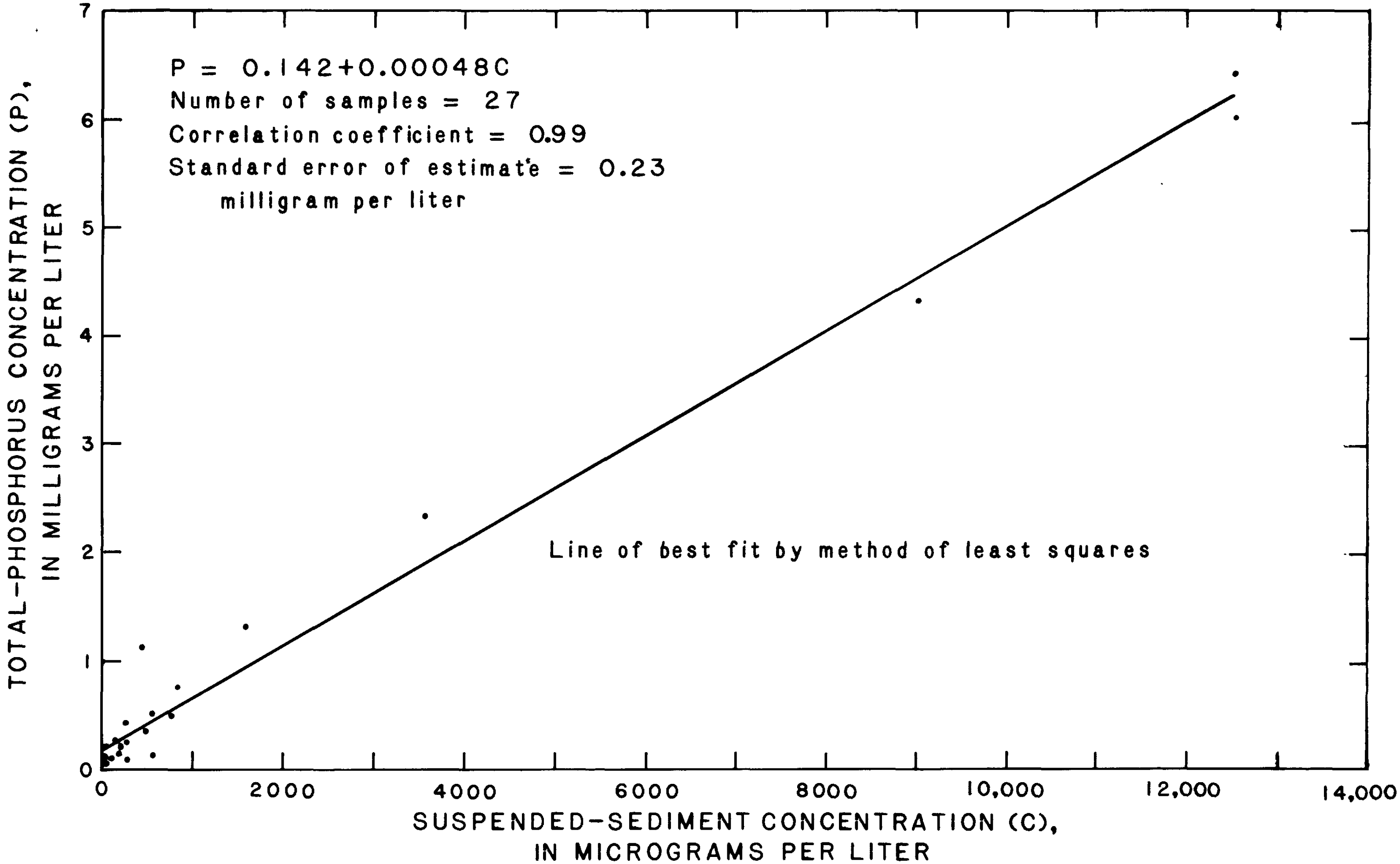


Figure 24.--Relation of total-phosphorus concentration to suspended-sediment concentration.

and form of precipitation, and especially the rate and duration of flow. In a study of mechanisms affecting salt pickup and transport in surface runoff, and possible means of reducing salinity in runoff from rangelands, Bentley and others (1978, p. 111-139) determined that properly implemented control measures can reduce erosion and salinity.

Trace Elements

Twenty-nine water samples from the basin have been analyzed for selected trace elements. Twenty-three of the samples were collected at stream sites 10, 21, and 50; two are from springs at sites 4 and 11; and the remainder are from stream sites 5, 12, and 28. Concentration ranges of the trace elements commonly detected in samples from the basin (fig. 25) are "total" concentrations. "Total" in this instance refers to the part of a particular element concentration in a sample that passes through a 0.45-micrometer filter plus that which is extracted from particulate matter in the sample by partial digestion (Skougstad and others, 1979, p. 21-22, 35). The 29 analyses do not provide a complete description of distribution and occurrence of trace elements in the basin but rather are a reconnaissance of trace elements potentially available to surface-water runoff from the basin.

Radiochemicals

The occurrence of uranium has been noted in the study area (Hausel and others, 1979) and it is expected that water and fluvial sediment should reflect this occurrence. Samples for general radiochemical analysis were obtained from streams at sites 5, 12, 18, 20, 26, 28, and 29, and from Jim Washum Spring at site 11. Gross alpha results for the suspended sediment in the samples ranged from 16 to 163 micrograms uranium equivalent per gram of sediment. The results indicate the probable presence of uranium or thorium. Ordinary organic shales contain from 10 to 40 micrograms uranium equivalent per gram of shale (Beers and Goodman, 1944, p. 1248), and the values reported for the study area would not be considered unusual even if uraniferous rocks were not reported to be present.

Aquatic Biology

A detailed description of biological communities in Salt Wells Creek was presented by Engelke (1978). The description included population distribution patterns, community edge effects, the food pyramid, and nutrition (trophic) levels between various types of plants and animals. Salt Wells Creek has a small nutrient level, a large number of diatom taxa, a fairly large assortment of insect taxa, and several other invertebrate taxa such as snails, worms, and scuds. Two species of fish--the mountain sucker, Catostoma platyrhynchus (Cope) and the speckled dace, Rhinichthys osculus (Girard)--were found in perennial reaches of the stream.

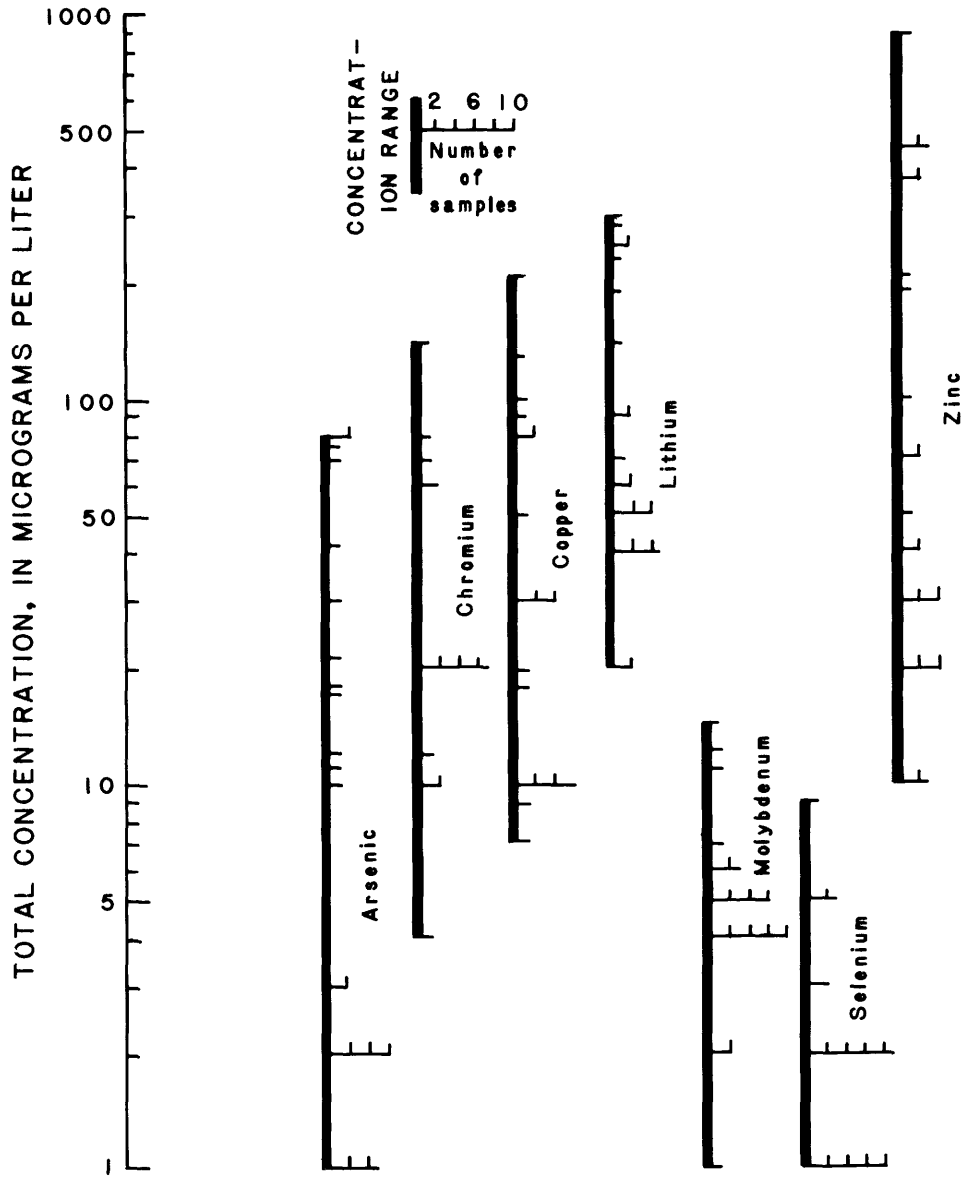


Figure 25.--Trace-element concentrations in streamflow and spring discharge.

Sediment

Medium and high flows of Salt Wells Creek and its tributaries generally are turbid and have relatively large concentrations of suspended sediment. The general sediment-transport characteristics of the stream are shown in figure 26, which presents analytical results of three separate downstream samplings of Salt Wells Creek and its tributaries. The samplings were made under three different runoff conditions: High, medium, and low flows. Also shown on the figure are analytical results of samples collected from the first flows of six floodwaves. These samples were collected by automatic sampling devices located at sites 33, 47, and 48.

Results of the analyses indicate that during the first flows of a floodwave, sediment concentrations sometimes exceed 100,000 milligrams per liter. The relatively large concentrations are apparently the result of a flushing action similar to the flushing of salts. Ephemeral streams in the area commonly have periods of several months or more without flow, during which the basin surface and channels accumulate loose material due to weathering, bank caving, livestock and wildlife movement, and wind deposits. This material is picked up readily and transported (flushed) by the turbulent first flows of a floodwave. Once the basin surface and channels have been flushed, the amount of sediment transported is dependent upon supply (erosion of the upstream basin surface and streambanks) and stream power (magnitude of discharge). The general sediment transport capability of Salt Wells Creek and its major tributaries then reverts approximately to the relation shown in figure 26.

The flushing of sediment from the basin surface and small hills also has been observed by Gregg C. Lusby (Shown and others, 1977, p. 28-49) during rainfall simulation experiments that were made on several selected areas along Gap Creek during June 1976. The simulation experiments were made by measuring runoff and sediment yield following application of simulated rainfall with a sprinkler system. The resulting data provide a base for comparison with future changes in land use or land management that might occur.

Sediment yields for source areas along Gap Creek were estimated by Shown and others (1977, p. 51) using the qualitative Pacific Southwest Inter-Agency Committee (1968) method. Shown reported that "Source-area sediment yields for much of the study area are low to moderate with the rates ranging from 0 to 0.9 acre-foot per square mile. Some of the steeper, more barren areas have high sediment rates, which range from 0.9 to 1.6 acre-feet per square mile. Most of the sediment appears to be coming off hillslopes with minor amounts from a few slowly-advancing headcuts."

Turbidity

Turbidity is an expression of the optical property of water that causes light rays to be scattered and absorbed. Turbidity is caused by a variety of suspended particulate matter such as organic material and sediment.

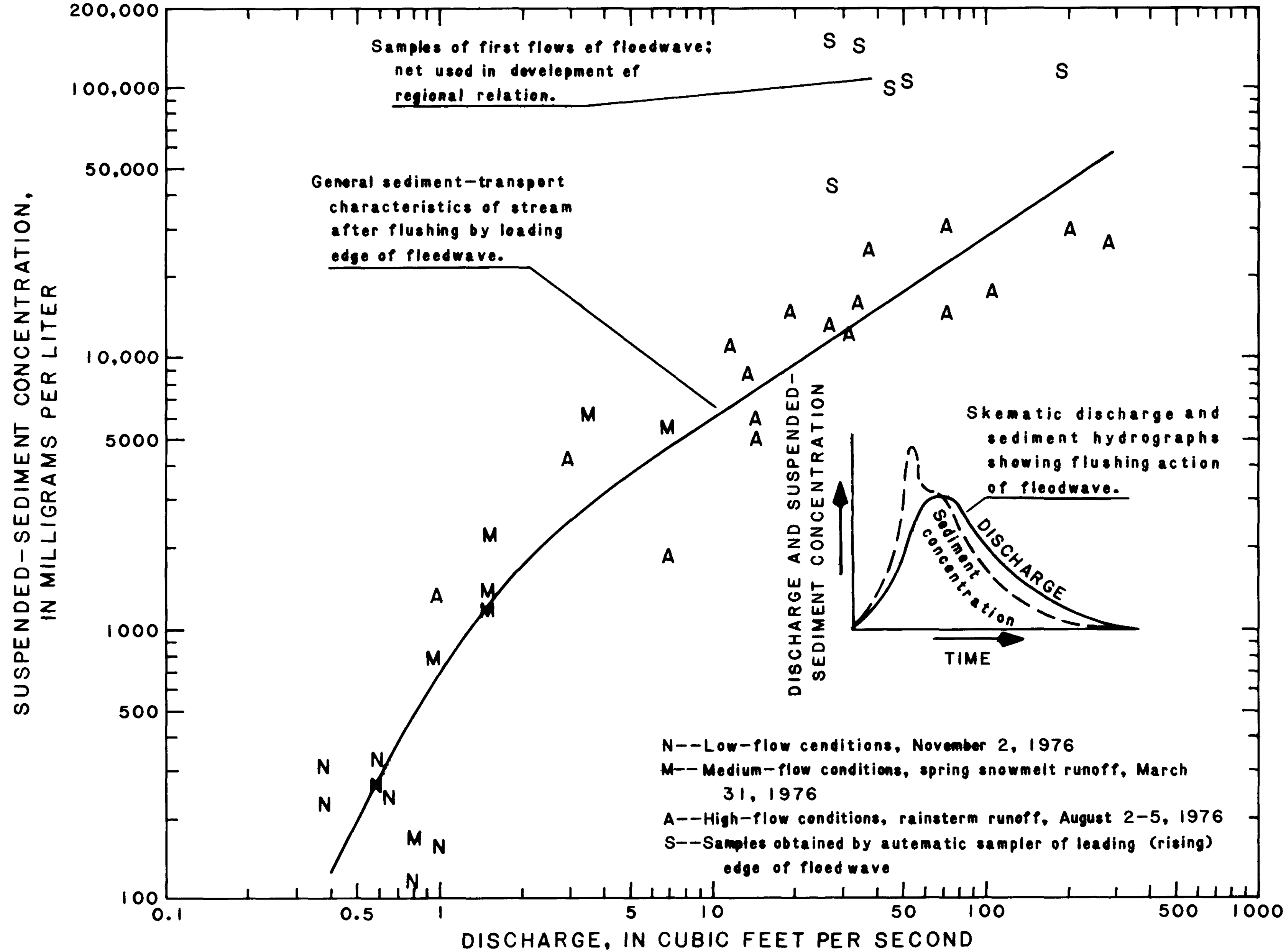


Figure 26.--Variation of suspended-sediment concentration with water discharge--Salt Wells Creek and tributaries.

The turbidity of Salt Wells Creek and its tributaries is caused mainly by clay particles that are eroded from the basin surface following snowmelt or rainfall. Low flows are relatively clear and generally had turbidities of less than 200 Jackson turbidity units; medium and high flows resulting from overland runoff yielded turbidities of up to 9,000 Jackson turbidity units. Turbid flood runoffs (results of rainstorms) in two tributaries of Salt Wells Creek are shown in figures 27 and 28.

Channel Morphology

A striking feature of Salt Wells Creek and many of its tributaries is their deeply incised channels. For example, a 22-foot incision (vertical distance, terrace to flood plain) on Gap Creek near site 21 is shown in figure 29. The deepest incision observed along the stream is 26 feet at the mouth of Salt Wells Creek (fig. 30). From sites 34 to 50, the main channel is incised an average of about 16 feet. Most of the major tributaries are incised in their downstream reaches, but erosion-resistant outcrops have prevented the incision from extending uniformly throughout the upstream reaches. Long-time residents of the area say that substantial development of gullies began between 1890 and 1916.

Incision of the stream is attributed to the cumulative effects of: (1) Change in climate, (2) change in base level due to downstream channelization, and (3) changes in land use. A description of these changes follows:

1. Change in climate. An evaluation of tree-ring data by Schulman (1945) indicates that in the Upper Colorado River basin a period of minimum growth (indicating minimal soil moisture due to minimal winter precipitation) occurred from 1870-1905. During 1906-30 maximum growth (indicating significant winter precipitation) occurred.

   The tree-ring analysis offers no assurance that grass cover was lush or that erosion of the basin surface was different during the period of maximum tree growth. But a change in the relative amounts of runoffs from snowmelt and rainfall could induce channel erosion because of the different sediment yields associated with overland flows from the two sources.

Figure 27.--Turbid rainstorm runoff in Dry Canyon at site 28, August 1, 1976. Looking upstream. Flow is 32 cubic feet per second.

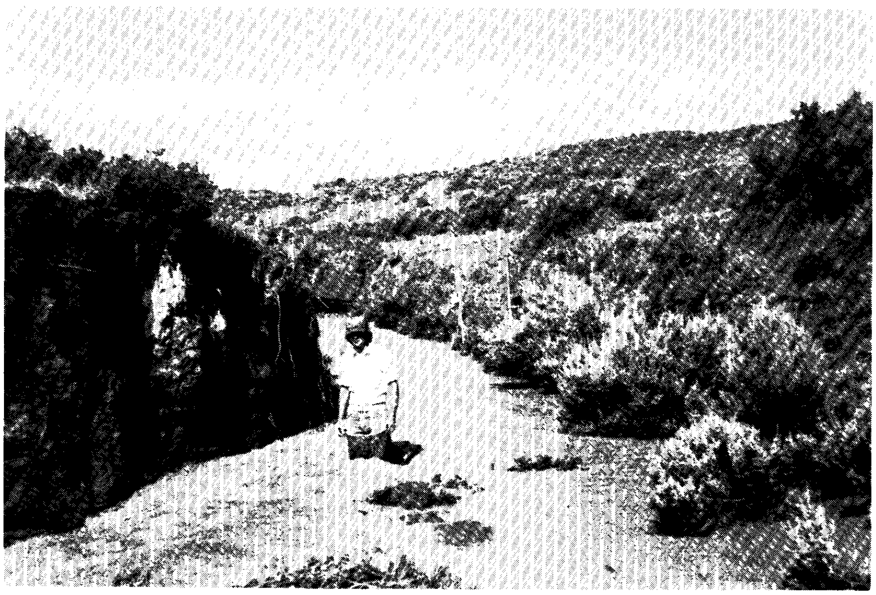


Figure 28.--Turbid rainstorm runoff in Big Flat Draw at site 33, August 3, 1976. View is downstream. Flow is 36 cubic feet per second.

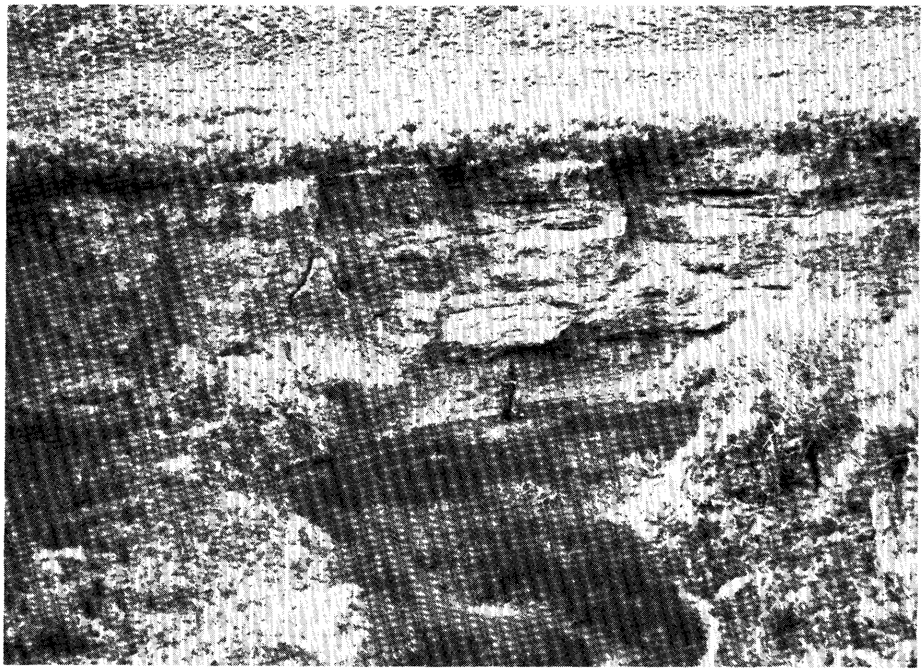


Figure 29.--Incised channel of Gap Creek near site 21, looking downstream (northwest), July 22, 1976.

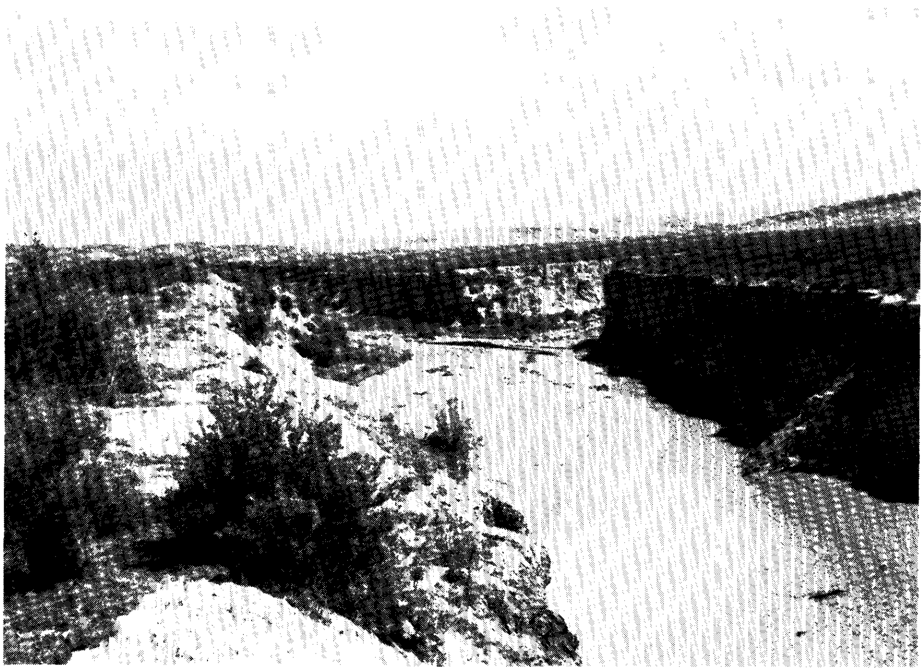


Figure 30.--Incised channels of Bitter Creek and Salt Wells Creek, looking upstream, August 12, 1979. Mouth of Salt Wells Creek is at right center of photograph. Bitter Creek has been extensively channelized in this reach. Depth of the gullies is about 26 feet.

Snowfall is greatest in the higher elevations of the headwater areas. During years when deep snowpacks accumulate in these areas, significant runoffs occur during spring months. In contrast, rainfall is more uniformly distributed throughout the basin. The lower the elevation, the greater the percentage of annual precipitation that occurs as rainfall.

The yield of sediment for overland flows generally is less for snowmelt than for rainstorm runoff. This is because:

1. Smaller rates of runoff occur from snowmelt; hence, sediment-transport capabilities are less than for rainstorm runoff,

2. Overland flow during snowmelt commonly is over ice or frozen ground,

3. A more erosion-resistant vegetative cover exists in valleys of the headwater areas where snow tends to accumulate, and

4. Erosion-resistant outcrops occur in the headwater areas.

During 1870-1905 when snowmelt runoff was small, the channel may have been receiving a relatively large part of its water and sediment contribution from rainstorms in the downstream part of the basin. The main channel would adjust its slope and size to convey this runoff and load. After 1906 when snowfall became more significant, snowmelt would then constitute a relatively larger part of total runoff for the stream. The overland flows originating from snowmelt in the headwaters would contribute a relatively small sediment washload. But, when the snowmelt runoff accumulated in the channels, it would have an affinity for sediment. Erosion of the channels and subsequent downcutting may have been the result.

2. Change in base level of Bitter Creek. The channel of Bitter Creek has incised 26 feet near the mouth of Salt Wells Creek. This erosion has been caused in part by: (1) Extensive channelization of Bitter Creek, and (2) dewatering of upstream coal mines.

   Channelization of Bitter Creek was done to accommodate construction of the highway and railroad. The channelization involved straightening and shortening the channel of Bitter Creek near the mouth of Salt Wells Creek. The slope of the streambed was increased by channelization; this increased stream velocities and accelerated channel erosion.

   Dewatering of underground coal mines at Superior, Wyo., about 18 miles northeast of Rock Springs, involved pumping water into Horsethief Canyon, an ephemeral tributary that enters Bitter Creek about 9 river miles upstream from Salt Wells Creek. The introduction of perennial flow to formerly ephemeral streams will accelerate channel erosion when, as is the case with these streams, the streambeds are composed largely of sand and smaller-sized material. Because the flow was added without a sediment load, there was no replacement of eroded bed material and consequently the channel downcut. Significant underground mining began about 1900 and continued until 1954.

The combination of channelization and dewatering appears to have induced extensive channel erosion and deep incision of Bitter Creek at the mouth of Salt Wells Creek. The channel of Salt Wells Creek has subsequently adjusted to the lower base level. When a situation such as this occurs, headcutting and erosion of the affected basin spreads upstream, until the entire watershed has reached equilibrium with the new base level.

3. Changes in land use. The Union Pacific Railroad was built through the Bitter Creek Valley during 1868. This aided the marketing of livestock. According to Albert Angelovich, longtime resident and former rancher of the area, cattle and sheep were brought into the area about 1890. Depletion of vegetative cover by overgrazing results in less retardation of overland flows, causing higher peak flows with more potential for channel erosion. Overgrazing may have initiated some gullying, especially if it were coupled with several large floods.

The above changes were all about concurrent with the development of gullies; thus, none of them can be proven to be its sole or principal cause. However, because the incision has occurred, several undesirable side effects are now present:

1. Erosion is expanding to include the smaller tributaries and basin surface as the drainage adjusts to the lower base level of the main stem. This results in increased sediment loads, which eventually reach and deposit in Flaming Gorge Reservoir.

2. Deep gullies form dangerous and formidable barriers to crossing by people and animals.

3. Ground-water levels in alluvium bordering deeply incised streams are lowered in accordance with elevations of the streambeds. This commonly affects plant growth along the streams.

4. When shallow ground-water tables exist along an incised channel, ground-water inflows to the stream may increase. These inflows generally are insufficient to cause perennial flow in the stream; however, they can cause large amounts of dissolved solids to be introduced to the stream. In addition to receiving greater quantities of ground-water inflow, an incised stream exposes deeper soil materials that have not been exposed to leaching as much as surface soils.

   The gully and banks of an incised stream accumulate deposits of dissolved solids, as shown in figures 18 and 19. Subsequent streamflows periodically flush the salts downstream. (See figs. 21-23.)

Land-management practices that would lessen incision and accelerated erosion on Salt Wells Creek, could provide benefits within the basin as well as reduce sediment and dissolved-solids loads to the Green River and Flaming Gorge Reservoir.

Ground-Water Quality

Ground-water quality in the study area is variable. Dissolved-solids concentrations in samples collected ranged from 70 to 2,400 milligrams per liter. Samples were collected from 12 springs and 2 wells. Seven of these samples had dissolved-solids concentrations of less than 500 milligrams per liter, and only two samples had concentrations greater than 1,000 milligrams per liter.

The chemical composition of water samples collected from different geologic units underlying Salt Wells Creek basin is illustrated in figure 31. The heights of the bars in figure 31 are proportional to the concentrations of ions expressed as milliequivalents per liter.

Samples of springs flowing from the Bishop Conglomerate (sites 40 and 45) had the smallest dissolved-solids concentrations (70 milligrams per liter) of any ground-water sites sampled. This formation caps the high hills and lies fairly flat, a favorable position to receive direct recharge from rain and melting snow. The water would have been in contact only with this formation and for a relatively short time. Calcium and bicarbonate were dominant ions (see figure 31).

Site 4 is a spring flowing into a gully that is incised through the Cathedral Bluffs Tongue of the Wasatch Formation. The Cathedral Bluffs Tongue of the Wasatch Formation is therefore considered to be the source aquifer for the spring though it appears at the surface a short distance downstream from the contact with the underlying Wilkins Peak Member of the Green River Formation. The water sample from this site had a dissolved-solids concentration of 270 milligrams per liter. Calcium and magnesium were the dominant cations, and bicarbonate the dominant anion.

Alkali Spring (site 7) discharges water from the Tipton Member of the Green River Formation. The dissolved-solids concentration was 760 milligrams per liter in the sample from the spring. Magnesium was the dominant cation although sodium was of almost equal concentration. Bicarbonate was the dominant anion.

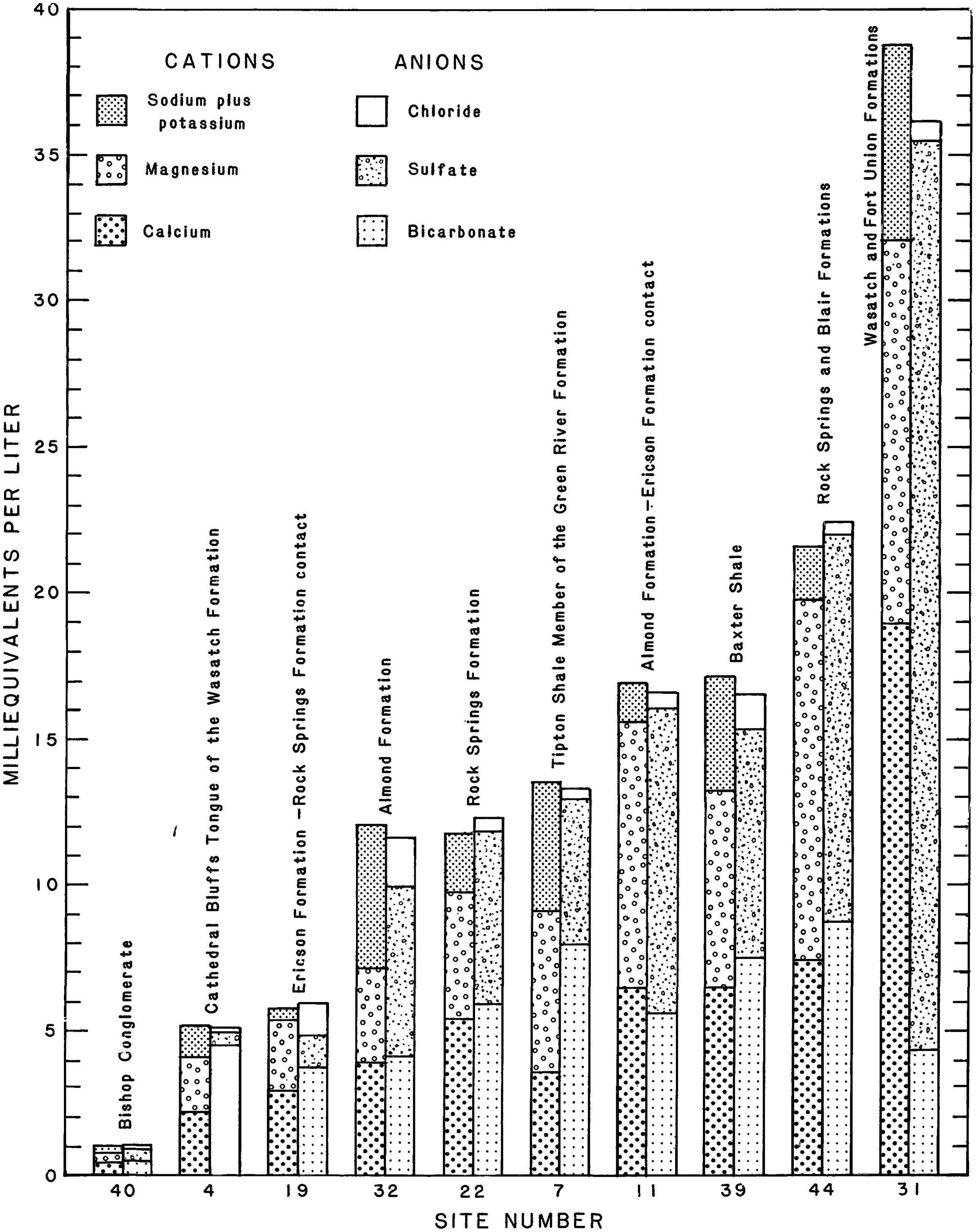


Figure 31.--Chemical composition of ground water by stratigraphic units.

Site 31 is a 145-foot well screened in the basal part of the Wasatch Formation and, possibly, the uppermost part of the Fort Union Formation. The dissolved-solids concentration of the sample from this well was 2,400 milligrams per liter--the largest concentration of any ground water sampled in the study area. Calcium and bicarbonate were the dominant ions.

The Almond Formation is the source of the water for the spring at site 11 and the well at site 32. This formation is one of the principal coal-bearing formations and is thus likely to be mined. The samples from sites 11 and 32 had dissolved-solids concentrations of 973 and 711 milligrams per liter. Site 11, Jim Washum Spring, is at the contact between the Almond Formation and the underlying Ericson Formation. Magnesium was the dominant cation and sulfate the dominant anion in the sample. Site 32 is a 60-foot well drilled through alluvium into the Almond. The water may be a blend of that from the alluvium and from the Almond. Sodium dominated the cations and sulfate dominated the anions in the sample.

The Ericson Formation yields water to Gap Spring at site 19. The sample had a dissolved-solids concentration of 320 milligrams per liter. Calcium and bicarbonate were the dominant ions. The water from Gap Spring is conspicuously rusty in appearance; the sample contained 2,500 micrograms per liter of dissolved iron.

Site 22, Titsworth Spring, is on a fault that cuts the Rock Springs Formation. The sample had a dissolved-solids concentration of 700 milligrams per liter. Calcium was the dominant cation and bicarbonate, nearly equaled by sulfate, dominated the anions.

Site 44 also is a spring along a fault. The fault cuts the Blair Formation along Cutthroat Draw just downstream from the contact with the Rock Springs Formation. The fault, upthrown on the downstream side, forms a ground-water dam. This dam causes water from sandstone beds in the Rock Springs Formation, percolating down the draw through weathered Blair Formation, to rise to the surface. The dissolved-solids concentration in the sample was 1,290 milligrams per liter. Magnesium and sulfate were the dominant ions.

The Blair Formation yields water to a spring at site 43. The dissolved-solids concentration of the sample from this spring was 420 milligrams per liter. The dominant ions were calcium and bicarbonate.

Springs at sites 38, 39, and 46 produce water from the Baxter Shale. Because the permeability of the Baxter generally is small and the rocks gypsiferous, the springs sampled probably represent only superficial circulation in weathered parts of the formation. Sites 38 and 46 produced samples with dissolved-solids concentrations of 470 and 420 milligrams per liter, dominated by calcium and bicarbonate. The water from site 39 may represent a somewhat deeper circulation system. The sample had 960 milligrams per liter of dissolved solids. Magnesium slightly exceeded calcium, and sulfate slightly exceeded bicarbonate.

A trilinear diagram illustrating the ionic composition of water from the ground-water sites sampled is shown in figure 32. Calcium is the only cation that exceeded 60 percent of the total cations. Chloride was less than 20 percent in all the samples. Sodium plus potassium exceeded 40 percent only in the sample from site 32.

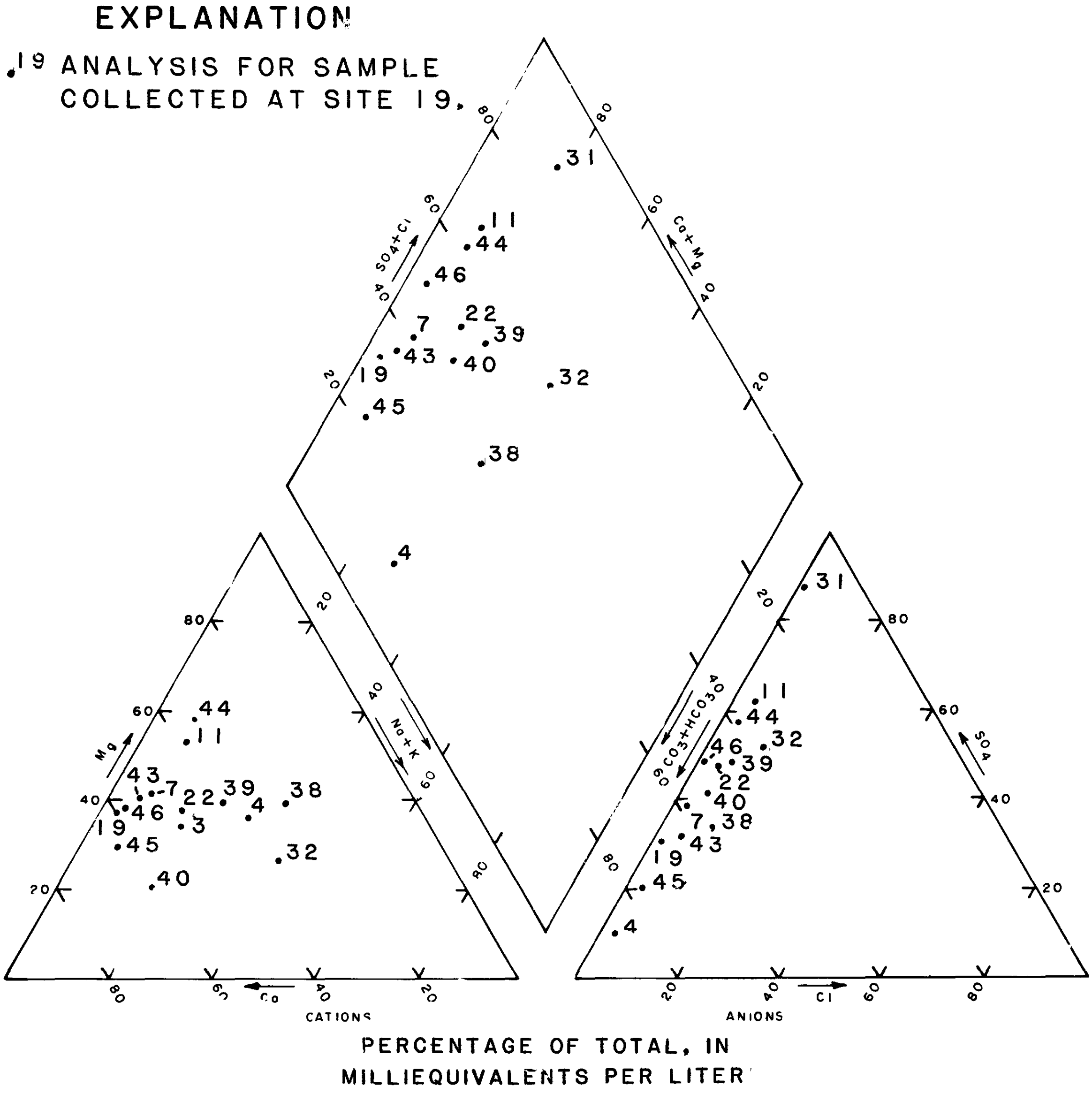


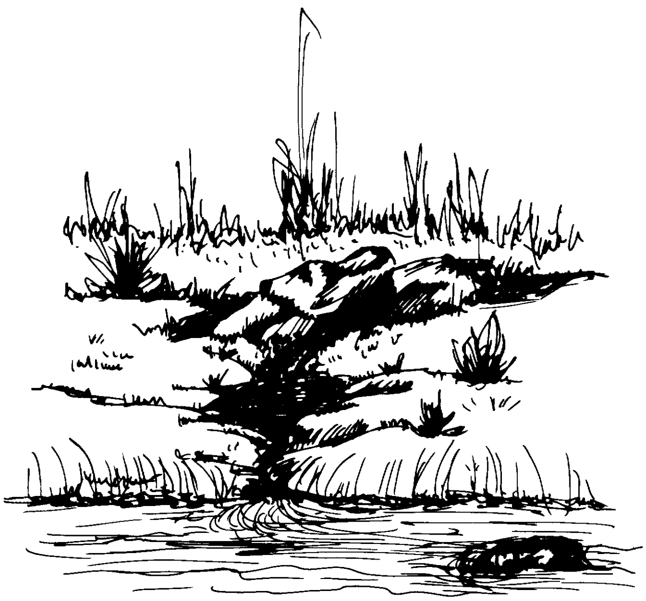
Figure 32.--Chemical analyses of ground-water samples.

The quality of the ground water is a function of the present, premining, flow regime. If this flow regime is altered by mining activity, as by disruption of aquifers by excavation, the ground-water quality could be altered.

SUMMARY AND CONCLUSIONS

A variety of minerals, including coal, oil and gas, oil shale, uranium, and trona, are located in the plains of southwestern Wyoming. Expected large-scale development of these minerals will require an understanding of the hydrologic environment of these plains. Salt Wells Creek basin was selected for study as being representative of such areas.

Salt Wells Creek is predominantly an intermittent stream. Although numerous springs cause perennial flows in several upstream tributaries, evaporation, freezeup, and seepage deplete these flows so that the downstream reach has only intermittent flows. Direct runoff occurs from both snowmelt and rainstorms. Rainstorm runoffs commonly have high peak flows; however, the duration of flow from rainfall is relatively short in comparison to snowmelt. The occurrence and amount of runoff is variable from year to year. Average annual runoff of the stream is estimated to be about 2,000 to 3,000 acre-feet. This is not a significant amount in comparison to flows of major perennial streams of southwestern Wyoming. For example, average annual runoff of the Green River into Flaming Gorge Reservoir is more than 1,200,000 acre-feet. However, the streamflows of Salt Wells Creek and its tributaries are important to the local environment; the small springs are especially important as water supplies for wildlife and livestock.



The quality of the intermittent flows of Salt Wells Creek, as well as similar plains streams, may temporarily degrade receiving waters. The intermittent flows cause water quality to be affected by a process known as "first flush." During dry periods, salts, sediments, and organic material accumulate on the basin surface and in the channels. Subsequent rainfall or snowmelt dissolves or suspends these materials and flushes them from the basin. Large concentrations of dissolved and suspended materials were observed to occur during the first flows of floods. As this pulse of inferior-quality water enters the Green River and Flaming Gorge Reservoir, concentrations of dissolved and suspended materials in their waters are increased temporarily. After the initial flushing of the basin and channel, concentrations of these natural contaminants decrease and become dependent upon the magnitude of discharge. Dissolved-solids concentrations then generally decrease and suspended-sediment concentrations increase with the magnitude of discharge.

The rate of salt, sediment, and organic material accumulation between periods of runoff is dependent upon basin characteristics, season of the year, and land use (Overton and Meadows, 1976, p. 304-311). Subsequent removal of these materials and the resulting water quality is dependent upon the composition of the materials, the amount and form of precipitation, and especially the rate and duration of flow. Control measures can decrease the washoff of salts and sediment (Bentley and others, 1978, p. 111-139).

Water from springs supports a fairly large assortment of insects and other invertebrate taxa. In addition, two species of fish, mountain sucker and speckled dace, were found in perennial tributaries. Many plains streams of southwestern Wyoming may not have sufficient spring inflows to support the same abundance of aquatic life found in Salt Wells Creek.

A striking feature of Salt Wells Creek and its major tributaries is their deeply incised channels. The gullying is attributed to: (1) A historical change in the relative amounts of annual precipitation occurring as rain or snow, (2) a change in the base level of Bitter Creek, and (3) changes in land use. Because of the incision of the main channel, erosion is now expanding to include smaller intervening tributaries. Unless remedial action is taken, the erosion problem will become progressively more serious resulting in further gullying, loss of topsoil, and impaired water quality.

The most promising aquifer of the area for water-well development is the Ericson Formation that is composed of thick, relatively permeable sandstones, which yield fresh to slightly saline water. The largest springs generally are supplied by water from the Bishop Conglomerate, which is composed of poorly sorted cobbles, gravel, and coarse-grained sandstone and yields fresh water. In 12 of the 14 ground-water samples collected for the study, dissolved-solids concentrations were less than 1,000 milligrams per liter. In most of the samples magnesium and calcium were the dominant cations and sulfate and bicarbonate were the dominant anions.

The identification of hydrologic processes unique to Salt Wells Creek and similar plains streams can aid in the design of land-management plans, including those related to mining and reclamation, for such areas. Strip mining of coal is expanding rapidly and can significantly affect the hydrology and related environment of plains areas. In the study area, the Fort Union and Almond Formations contain many extensive coal beds and are thus the most likely to be mined. Depending on the location, mining could alter the flow of ground water by creating new discharge points, destroying parts of some aquifers, or changing the recharge pattern.

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