POTENTIAL HYDROLOGIC IMPACTS OF A TAR-SAND INDUSTRY IN 11 SPECIAL TAR SAND AREAS IN EASTERN UTAH

By K. L. Lindskov and others

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CONVERSION FACTORS

For use of readers who prefer to use metric units, conversion factors for inch-pound units used in this report are listed below:

Multiply inch-pound units	By	To obtain metric units
acre	0.4047	square hectometer
acre-foot	0.001233	cubic hectometer
acre-foot per square mile	476.1	cubic meter per square kilometer
acre-feet per year	0.001233	cubic hectometer per year
barrel (42 gallons)	0.1590	cubic meter
barrel per day	159	liter per day
cubic foot per second	0.02832	cubic meter per second
foot	0.3048	meter
foot per mile	0.1894	meter per kilometer
gallon	3.785	liter
gallon per minute	0.06309	liter per second
inch	25.40	millimeter
	2.540	centimeter
inch per hour	25.40	millimeter per hour
mile	1.609	kilometer
square mile	2.590	square kilometer
ton, short	0.9072	megagram
ton per acre per hour	2.242	metric ton per square hectometer per hour

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

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 Sates and Canada, formerly called "Mean Sea Level." NGVD of 1929 is referred to as sea level in this report.

POTENTIAL HYDROLOGIC IMPACTS OF A TAR-SAND INDUSTRY

IN 11 SPECIAL TAR SAND AREAS IN EASTERN UTAH

By K. L. Lindskov and others

ABSTRACT

About 93 percent of the Nation's estimated 30 billion barrels of crude oil in tar-sand deposits is in 11 areas in eastern Utah that were chosen for leasing by the U.S. Bureau of Land Management. The largest deposit, which is in the Tar Sand Triangle area, contains about 15 billion barrels of oil. This area and the Sunnyside and P R Spring areas contain more than three-fourths of the Utah reserves.

About 88,000 acre-feet per year of water would be required for a commercial tar-sand industry producing about 365,000 barrels per day; at this rate, most of the recoverable oil would be mined within 30 years. About 22,000 acre-feet of water per year would be required for a commercial tar-sand industry producing about 83,000 barrels per day and about 5,500 acre-feet of water per year would be required for a pilot-size industry producing about 22,000 barrels per day.

Impacts on local hydrology would be greatest in the Tar Sand Triangle, Sunnyside, and P R Spring areas. These impacts could be minimized, however, with proper construction of surface facilities to reduce erosion and sediment transport and to impound mining and retort waters. A commercial tar-sand industry producing 365,000 barrels per day could result in an average salinity increase of about 3 milligrams per liter with a peak of about 9 milligrams per liter in the Colorado River at Imperial Dam, Ariz.-Calif., whereas a commercial tar-sand industry producing 83,000 barrels per day could increase the average salinity by less than 1 milligram per liter with a peak of 2 milligrams per liter.

INTRODUCTION

Purpose and Scope

The dependence of the United States on petroleum supplies has focused attention on the tar-sand deposits in the Upper Colorado Region (fig. 1). Of the Nation's estimated 30 billion barrels of crude oil in tar-sand deposits, about 93 percent is in Utah (Baughman, 1978, p. 268 and Campbell and Ritzma, 1979, p. 1). Large-scale mining and processing of the tar sands, combined with mining and processing of oil shale and coal within the region, could cause a deterioration of local water resources and possibly an increase in the salinity of the Colorado River. Thus, the U.S. Bureau of Land Management is preparing an environmental assessment as a prerequisite to leasing of Federal lands within 11 of the most commercially attractive tar-sand areas in Utah.

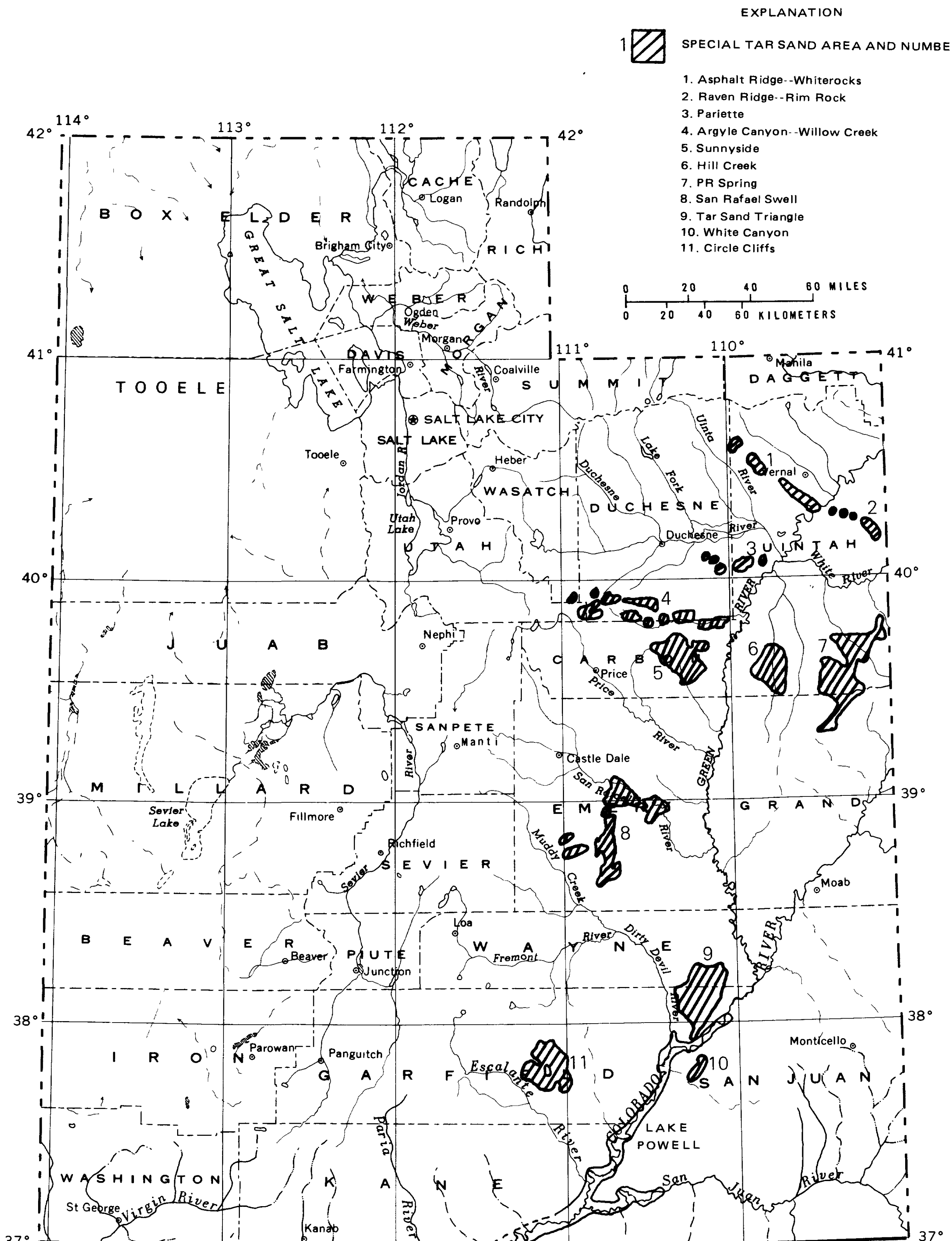

Figure 1.—Location and areal extent of 11 Special Tar Sand Areas in Utah.

This report summarizes the hydrology in and near the 11 Special Tar Sand Areas (fig. 1) which were designated by the U.S. Bureau of Land Management (1982, p. 25720). The 11 areas are in eastern Utah where normal annual precipitation generally ranges from less than 6 to about 20 inches and runoff is minimal. About 2 to 10 barrels of water may be required to extract each barrel of oil from the tar sands (Keefer and McQuivey, 1979, p. 23). "High" commercial production with 10-percent recovery could attain about 365,000 barrels per day of oil during a 30-year mining period, with about 125,000 barrels per day in the Sunnyside area alone (Earl Hindley, U.S. Bureau of Land Management, written commun., 1982). Thus, water requirements for a 365,000 barrel-per-day industry could be about 88,000 acre-feet per year (represents about 5 barrels of water per barrel of oil). Even for a "low" commercial industry producing about 83,000 barrels per day, about 22,000 acre-feet per year of water may be required.

The Utah State Engineer is responsible for the administration of water rights within the State and for determining whether or not proposed water-right applications can be approved on the basis of existing State statutes and laws, interstate compacts, and a treaty between the United States and Mexico. Existing approved rights plus unapproved applications for Utah's unused share of water from the Upper Colorado River Basin exceeds the share allocated to Utah by the Upper Colorado River Compact. Thus, permits for all Utah waters within the Upper Colorado River Basin are on administrative hold, unless deemed by the State Engineer's Office to have a minimal net impact on the water resources (Dorothy Boulton, Utah Division of Water Rights, oral commun., 1982). A tar-sand industry in Utah will have to compete with other users such as oil-shale and coal industries, irrigation, public supply, and other industrial uses.

Only data available from previous studies were used in this report, which was prepared at the request of the U.S. Bureau of Land Management. The main objective of the report is to define the local hydrology of each of the 11 Special Tar Sand Areas in Utah and to estimate potential hydrologic impacts of a tar-sand industry.

Geographic, Geologic, and Hydrologic Settings

The 11 Special Tar Sand Areas include about 1,500 square miles (about 300 of which are unleased) in eastern Utah. Included are parts of Carbon, Duchesne, Emery, Garfield, Grand, San Juan, Uintah, Wasatch, and Wayne Counties. The 11 areas (fig. 1) as designated by the Secretary of the Interior's Orders of November 20, 1980, are: (1) Asphalt Ridge--Whiterocks, (2) Raven Ridge--Rim Rock, (3) Pariette, (4) Argyle Canyon--Willow Creek, (5) Sunnyside, (6) Hill Creek, (7) P R Spring, (8) San Rafael Swell, (9) Tar Sand Triangle, (10) White Canyon, and (11) Circle Cliffs.

About 70 percent of the land in the 11 areas is owned by the Federal Government (a large part of the Hill Creek area is in Indian Trust), about 20 percent is owned by private interests, and about 10 percent is owned by the State. The Combined Hydrocarbon Lease Act of 1981 combines the rights to all hydrocarbons within each Federal lease except coal, oil shale, and gilsonite. Thus, areas within each of the 11 areas are grouped according to prior leasing, potential leasing, those not available for leasing due to their vicinity to National Parks, and to the Operating Regulations for Exploration, Development, and Production of the U.S. Minerals Management Service.

The tar-sand deposits occur in a variety of stratigraphic and structural circumstances and are of variable thickness and petroleum content. Campbell and Ritzma (1979) separate the deposits in Utah into two groups: (1) The Uinta Basin group, which contains petroleum that probably originated in lacustrine source rocks of the Green River Formation of Paleocene (in some areas) and Eocene age, although some of the deposits are in strata of Permian-Pennsylvanian, Triassic-Jurassic, and Cretaceous age; and (2) the central-southeast group, which are now in and probably originated in marine source rocks of Permian and Triassic age. Some of the deposits are found in large stratigraphic traps containing oil which was formed in adjacent stratigraphic units. Apparently, others are derived from leaks from older petroleum-bearing strata. The Uinta Basin group includes the Asphalt Ridge--Whiterocks, Raven Ridge--Rim Rock, Pariette, Argyle Canyon--Willow Creek, Sunnyside, Hill Creek, and P R Spring deposits. The central-southeast group includes the San Rafael Swell, Tar Sand Triangle, White Canyon, and Circle Cliffs deposits.

The chemical quality of the local streamflow and of ground water is strongly influenced by the nature of the rocks through and over which the water passes. Water in shallower formations generally is less mineralized than that at greater depth. Important aquifers in and near the 11 areas are discussed under each area.

The 11 areas are in the Colorado Plateau's physiographic province (Fenneman, 1946). Most streamflow originates at altitudes above 8,000 feet and flow is typically perennial in the higher altitudes where normal annual precipitation exceeds 20 inches. As the smaller streams flow through areas receiving less than 10 inches of precipitation annually, they become intermittent and ultimately ephemeral. Normal annual precipitation in much of the area below 5,000 feet is less than 8 inches and less than 6 inches near the San Rafael Swell area.

Major tributaries to the Colorado and Green Rivers in and near the 11 areas are the Dirty Devil, Duchesne, Escalante, Price, San Rafael, and White Rivers. Most of these rivers drain to the Green River and ultimately all drain to the Colorado River and to Lake Powell (fig. 1). Much of the variation in annual precipitation and resulting runoff in and near the 11 areas reflects differences in altitude.

Previous Investigations

Considerable hydrologic information for the 11 Special Tar Sand Areas is available in comprehensive studies of the Upper Colorado River Basin by Iorns and others (1964 and 1965) and Price and Arnow (1974) and for the Colorado Plateau of Utah by Feltis (1966). Several studies provide information for defining the hydrology of the 11 areas. Campbell and Ritzma (1979), Cashion (1967), Cashion and Donnell (1974), Holmes (1979, 1980), Holmes and Kimball (1983), Hood (1976, 1977), Hood and Danielson (1981), Hood and Fields (1978), Hood and Patterson (1982), Osterwald and others (1981), and Price and Miller (1975) contain information on geology and ground-water characteristics. Fields (1975), Jurado and Fields (1978), Lindskov and Kimball (1982), Lines and others (1983), Mundorff (1972, 1977, 1979), Mundorff and Thompson (1982), Waddell (1976), and Waddell and others (1981) contain hydrologic information on the Colorado, Dirty Devil, Duchesne, Green, Price, San Rafael, Uinta, and White Rivers and other smaller streams.

Data reports by Austin and Skogerboe (1970), Conroy (1979, 1980), Conroy and Fields (1977), Hood and others (1976), Sumsion (1979), Utah Department of Natural Resources (1975a, b, and 1977), and Waddell and others (1978) contain surface-water, ground-water, and water-quality data for eastern Utah. These and other papers listed in the References Cited, in addition to regular network data for streams and ground water, contain precipitation, evaporation, and air-temperature data; landsat photographs; semicontrolled photomosaics of the Uinta Basin; channel morphology of the White River; and sediment-concentration and particle-size data.

DATA-SITE NUMBERING SYSTEMS

Locations of the data sites mentioned in this report can be determined by using the numbering systems described herein. Also, the sites are located on illustrations in many of the reports listed in the References Cited.

Well- and Spring-Numbering System

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake base line and meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, indicating the northeast, northwest, southwest, and southeast quadrants, respectively. Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and it is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section--generally 10 acres.[1] The letters a, b, c, and d indicate, respectively, the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre tract; the letter S preceding the serial number denotes a spring. If a well or spring cannot be located within a 10-acre tract, one or two location letters are used and the serial number is omitted. Thus, (D-4-21)2bad-1 designates the first well constructed or visited in the SE¼NE¼NW¼ sec.2, T.4 S., R.21 E., and (A-1-21)33bdd-S1 designates a spring in the SE¼SE¼NW¼ sec.33, T.1 N., R.21 E. The numbering system is illustrated in figure 2.

Part of northeastern Utah has been subdivided by the Uintah base line and meridian, as shown in figure 2. Wells and springs in this area are numbered in the same manner described above, but the numbers are preceded by the letter U. Thus, well U(C-1-2)4add-1 is in the SE¼SE¼NE¼ sec.4, T.1 S., R.2 W., Uintah meridian.

In Colorado, the well- and spring-numbering system also is based on the cadastral land-survey system, and in most of the State the system is referenced to the base line and the Sixth principal meridian and identified by the prefix letter S. Thus, well S(B-2-103)7bbb-1 is in the NW¼NW¼NW¼ sec.7, T.2 N., R.103 W., Sixth principal meridian (fig. 2). In Colorado records, springs are not identified by the letter S preceding the serial number, but in this report, springs are so designated in order to clearly identify the nature of the water source.

Gaging-Station Numbering System

The U.S. Geological Survey uses a nationwide system of numbering gaging stations by referring to the position of the station in a major river basin. Gaging-station numbers are assigned in a downstream order along the main stems of the major streams, and all stations on a tributary stream that enters upstream from a main-stem station are assigned numbers smaller than that main-stem station. A similar order is followed in listing stations on first rank, second rank, and other ranks of tributaries. The numbering system consists of an 8-digit number for each station, for example 09261000. The first two digits (09) represent the "part" number identifying the hydrologic region used by the Geological Survey for reporting surface-water data. The 11 Special Tar Sand Areas are in Part 9, the Colorado River Basin. The next six digits represent the location in a downstream order.

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[1] Although the basic land unit, the section, is theoretically 1-square mile, many sections are irregular. Such sections are subdivided into 10-acre tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section.

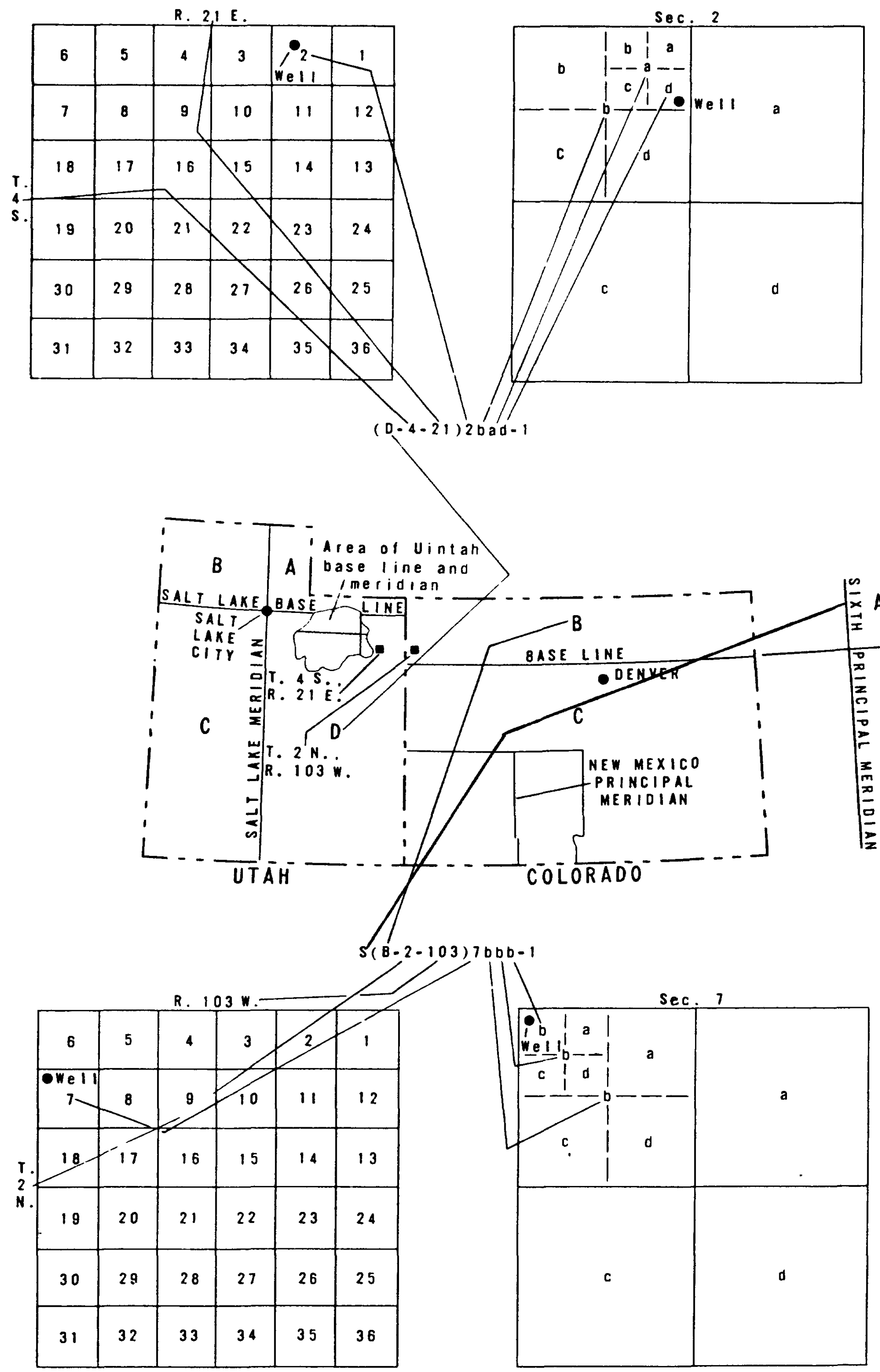

Figure 2.—Well - and spring-numbering systems used in Utah and Colorado.

ASPHALT RIDGE--WHITEROCKS SPECIAL TAR SAND AREA

By H. F. McCormack, Willis Dorman-Ligh, and G. E. Pyper

Location

The Asphalt Ridge--Whiterocks Special Tar Sand Area covers about 62 square miles in Uintah County (fig. 3). The Asphalt Ridge part is 2 miles southwest of Vernal, along the west boundary of Ashley Creek drainage. The Whiterocks part is in the Whiterocks River drainage basin, about 4 miles northeast of Whiterocks. Land-surface altitudes decrease southward from about 8,000 feet in the northwest Whiterocks part to less than 5,000 feet near the Green River. The proven or inferred tar-sand deposits in the Asphalt Ridge part underlie parts of townships 4 to 6 south and ranges 20 to 22 east, Salt Lake base line and meridian, and the deposits are in the Duchesne River Formation and the Mesaverde Group. About 3 of the approximately 43 square miles of area are available for lease. The proven or inferred tar-sand deposits in the Whiterocks part underlie parts of townships 1 and 2 north and ranges 1 and 2 east and 1 west, Uintah base line and meridian and the deposits are in the Nugget (or Navajo of former usage) Sandstone (Ritzma, 1979, sheet 2). None of the 19 square miles in the Whiterocks part is available for lease. The Federal and State Governments are the major landowners and the Whiterocks part is under Indian Trust. The estimated oil in place in the Asphalt Ridge--Whiterocks Special Tar Sand Area is 1.2 to 1.3 billion barrels (table 1).

Climate

The climate of the area is influenced by local topographic features; and it generally is semiarid, with low relative humidity, abundant sunshine, low to moderate precipitation, warm summers, and cold winters. Seasonal and daily variations in air temperature are large. Climate at high altitudes is cool and semihumid, whereas at low altitudes it is warm and drier. The Roan Cliffs, which are about 80 miles south of Vernal, is an orographic barrier for much of the summer moisture moving north from the Gulf of Mexico. The Wasatch Range, which is about 110 miles west of Vernal, is an orographic barrier for winter and spring moisture moving east from the Pacific Ocean.

Normal annual precipitation varies with altitude from more than 16 inches in the northwestern tract to less than 8 inches in the southeastern tract near the Green River (see fig. 3). Normal annual air temperature ranges from about 39°F at the higher altitudes to about 45°F for altitudes of 5,000 feet along the Green River. Normal annual free-water surface evaporation ranges from 40 to 45 inches (Farnsworth and others, 1982, map 3).

Water Resources

The major water resources of the Asphalt Ridge--Whiterocks Special Tar Sand Area are the 50,000 to 75,000 acre-feet of recoverable ground water in the shallow aquifer of Ashley Valley (Hood, 1977, p. 9); about 250,000 acre-feet of average annual flow of the Uinta River, Whiterocks River, and Ashley and Dry Fork Creeks; and the average annual flow of 3.2 million acre-feet in the Green River (table 2).

Surface Water

Considerable long-term streamflow data are available for selected sites in and near the Asphalt Ridge--Whiterocks Special Tar Sand Area (see table 2). Short-term data were collected during 1971-74 and all data were summarized by Hood and others (1976). Fields (1975) reported statistical summaries of selected streamflow records with low flow, high flow, and flow duration for the period of record through 1971.

Major perennial streams in and near the area are Dry Fork, Ashley Creek, and Uinta, Whiterocks, and Green Rivers. Most of the smaller streams have at one time or another ceased to flow for short periods. The average flow of the streams varies from one location to another and also varies seasonally and yearly at each location (figs. 4 and 5 and table 2). A large part of the flow occurs from April to July as snowmelt (fig. 5).

There is little variation in the concentration of dissolved solids from one location to another in Dry Fork and the Uinta, Whiterocks, and Green Rivers near the area. The dissolved-solids concentrations in Ashley Creek, however, change markedly between its upper reaches and its mouth--from 40 to 4,440 milligrams per liter (table 3). According to Hood (1977, p. 15), the base flow at station 09271000 had a dissolved-solids concentration about three times as great as the snowmelt runoff in 1974; whereas the dissolved-solids concentration in the outflow from Ashley Valley at station 09271500 was seven times greater than the dissolved-solids concentration of water released from Steinaker Reservoir during the same period. Changes in irrigation practices owing to the availability of reservoir water apparently have contributed to the degradation of the chemical quality of the water that leaves Ashley Valley (Hood, 1977, p. 16).

Ground Water

The most important known sources of ground water in the Asphalt Ridge--Whiterocks Tar Sand Area are the unconsolidated glacial outwash and related coarse-grained deposits of Quaternary age (table 4), which comprise the most prolific aquifer system in the northern Uinta Basin (Hood, 1976, p. 23), the Duchesne River Formation (Eocene and Oligocene), Dakota Sandstone (Cretaceous), Morrison Formation (Jurassic), Nugget Sandstone (Jurassic and Triassic), Chinle Formation (Triassic) and the Weber Sandstone (Pennsylvanian and Permian). Rocks of Mississippian age are potential sources of water, but no well data are available for these rocks. The data in table 4 comprise a generalized stratigraphic section for the area.

The consolidated rocks immediately north and northeast of the area are intricately faulted, and a thrust fault beneath Asphalt Ridge has been detected in seismic work done by the Utah Geological and Mineral Survey (Utah Geological Association, 1974, p. 60) (fig. 6). A well on the southwest end of the ridge penetrated the thrust fault at a depth of approximately 9,000 feet, passing from Triassic rocks into the Mesaverde Group. About 7,000 feet of vertical displacement is indicated.

Water in shallow, unconsolidated deposits of Quaternary age moves toward stream channels or downslope on top of consolidated rocks (Hood and Fields, 1978, p. 34). According to Hood (1977, p. 8), the water-table slope in most of Ashley Valley was almost directly eastward from the high western part of the alluvial plain along the foot of Asphalt Ridge toward the Ashley Creek bottoms east of Vernal.

Movement in the deep bedrock aquifers generally is confined and is downdip to the south and southeast in the Dry Fork and Brush Creek area northeast of Vernal, and to the south in Pole Creek (about 10 miles west of Ice Cave Peak) and Little Brush Creek areas (Maxwell and others, 1971, p. 10). Water in Mississippian and Pennsylvanian rocks, which rises along fractures in and near the Dry Fork Springs and between Dry Fork and Ashley Creek, saturates the overlying Weber Sandstone of Pennsylvanian and Permian age. Most of the water in the Weber Sandstone discharges through joints and fissures to Dry Fork and Ashley Springs (Maxwell and others, 1971, p. 10).

Ground-water recharge in the area is from precipitation, streamflow, and subsurface inflow. The recharge is small during periods of low streamflow in Ashley Valley, and the converse is true during periods of high streamflow (Hood, 1977, p. 7). Recharge to the valley fill from precipitation is sporadic and infrequent, depending upon the intensity of precipitation and rate of melting and thickness of snow cover (Hood, 1977, p. 8). According to Hood, two intense thunderstorms in October 1949 resulted in a water-level rise of almost 0.5 foot. Recharge from subsurface flow beneath Ashley Creek where it enters the valley is relatively constant but small. A smaller quantity of inflow comes from the unconsolidated rocks that abut the valley fill (Hood, 1977, p. 8).

Limestone of Mississippian age is an important part of the recharge system in the area (Hood, 1976, p. 36). They crop out in areas of considerable precipitation, and they contain cavernous zones, which are capable of absorbing and transmitting a large quantity of water rapidly to nearby discharge points or downdip. The water that moves downdip eventually moves upward through fractures to overlying formations. In and near the study area, sinks exist in Pole Creek and the three forks of Dry Creek; and large caves occur in the Brush Creek drainage (Maxwell and others, 1971, p. 11).

Data for selected wells and springs in and near the Asphalt Ridge--Whiterocks Special Tar Sand Area are shown in table 5. There are large quantities of ground water in nearby valleys. For example, Hood (1977, p. 9) reported 50,000 to 75,000 acre-feet of recoverable ground water in the shallow aquifer of Ashley Valley. Data in table 5 show wells completed in the unconsolidated glacial outwash in Ashley Valley to the east and the Uinta-Whiterocks area to the west yield from 0.1 to 503 gallons per minute with dissolved-solids concentrations that range from 149 to 2,420 milligrams per liter. The principal dissolved constituents are sulfate and bicarbonate or calcium and bicarbonate. Springs north of the study area that discharge from the outwash yield from 36 to 83,250 gallons per minute. The largest value represents discharge from the Weber Sandstone through the outwash. Including all springs, dissolved-solids concentrations range from 69 to 742 milligrams per liter.

Wells completed in the Duchesne River Formation yield from 0.1 to 40 gallons per minute, and dissolved-solids concentrations range from 505 to 1,400 milligrams per liter. The major dissolved constituents are sulfate and bicarbonate. Two springs discharge about 2 gallons per minute from the Duchesne River Formation with dissolved-solids concentrations of less than 400 milligrams per liter. The principal dissolved constituents are calcium, sulfate, and bicarbonate.

Wells completed in the Dakota Sandstone and the Morrison Formation yield from 3 to 20 gallons per minute, but there are no data for dissolved-solids concentrations. Shallow wells completed in the Nugget Sandstone yield from 1 to 100 gallons per minute with dissolved-solids concentrations ranging from 336 to 721 milligrams per liter. The major dissolved constituents are calcium, sulfate, and bicarbonate. A deep well, (D-4-21)16ccc-1, obtained water from the Nugget Sandstone at a depth of approximately 6,000 feet. The dissolved-solids concentration was 1,870 milligrams per liter, and the major dissolved constituents were sodium, potassium, and sulfate.

A well completed in the Gartra Grit Member of the Chinle Formation yielded 2 gallons per minute. North of the area, spring (D-3-20)23adb-S1 discharges 45 gallons per minute from the Chinle Formation. The spring water has a dissolved-solids concentration of 742 milligrams per liter and is of the calcium magnesium sulfate bicarbonate type.

The Weber Sandstone is a source of water to wells and springs, particularly in the Ashley Valley oil field. Petroleum tests in this area have indicated fresh to slightly saline[1] water under artesian pressure, at depths of about 4,000 feet, from a zone that includes the upper part of the Weber Sandstone and the lower part of the Park City Formation (Hood, 1976, p. 36). The source of this water is thought to be at least in part from underlying limestone of Mississippian age (Hood and Fields, 1978, p. 37). Data in table 5 show dissolved-solids concentrations ranging from 380 to 2,020 milligrams per liter and calcium or sodium and sulfate and bicarbonate are the principal dissolved constituents. Individual well-yield data are not available, but 1981 water production from the Ashley Valley oil field was about 3,360 acre-feet (Utah Division of Oil, Gas, and Mining, December 1981, p. 52). North of the area, spring (D-3-20)1dcc-S1 discharges 19,800 gallons per minute from the Weber Sandstone, and during 1955-68 the dissolved-solids concentration of the water ranged from 57 to 84 milligrams per liter. The major dissolved constituents are calcium and bicarbonate. As water moves downdip in the aquifers in the Asphalt Ridge--Whiterocks Special Tar Sand Area, the concentrations of dissolved solids generally increase (Hood and Fields, 1978, p. 2).

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[1]The terms used in this report to classify water according to the concentration of dissolved solids, in milligrams per liter, are as follows:

Fresh		Less than 1,000
Saline	Slightly saline	1,000-3,000
	Moderately saline	3,000-10,000
	Very saline	10,000-35,000
Briny		More than 35,000

Existing Water Use

The Asphalt Ridge--Whiterocks Tar Sand Area is in Water Rights Area 45 (Utah Division of Water Rights, 1974). All water in Ashley Creek and Whiterocks River is fully appropriated by existing rights, thus, water rights for a tar-sand industry would have to be purchased or leased.

Water in the area is used primarily for irrigation and domestic, municipal, and industrial supplies. The irrigated crops are used mainly as food for livestock. In the Ashley Creek--Dry Fork drainage, approximately 29,000 acres are irrigated with water consumption of about 71,000 acre-feet per year (Hood and Fields, 1978, p. 12). Northeast of Ashley Creek, in the Brush Creek drainage, approximately 4,700 acres are irrigated with consumption of about 10,700 acre-feet per year. Most of the irrigation water is obtained from streams. In 1974, about 4,500 acre-feet of irrigation water was obtained from wells in the Ashley Valley oil field (Hood and Fields, 1978, p. 13). Water for domestic and industrial uses is obtained primarily from wells and springs. Diversions, mainly from springs, by the towns of Vernal, Ashley, Naples, and Maeser totaled about 1.8 million gallons in 1979, or about 275 gallons per capita per day (Hooper, 1981, p. 47).

According to Hood (1977, p. 10), the use of ground water is increasing because of the rapid population increase in Ashley Valley coupled with the great costs of piping surface water long distances. The withdrawal of ground water, however, is estimated to be only about 1 percent of the total quantity of water moving through the valley.

Hydrologic Impacts Unique to This Area

A "high" commercial tar-sand industry producing 10,000 barrels per day in the Asphalt Ridge--Whiterocks Special Tar Sand Area would require 5,770 acre-feet of water per year (table 1). Those needs could be supplied from the area without any unique hydrologic impacts other than rearrangement of water rights. Potential impacts that generally apply to all areas are discussed in the section "Hydrologic impacts of a tar-sand industry," near the end of this report.

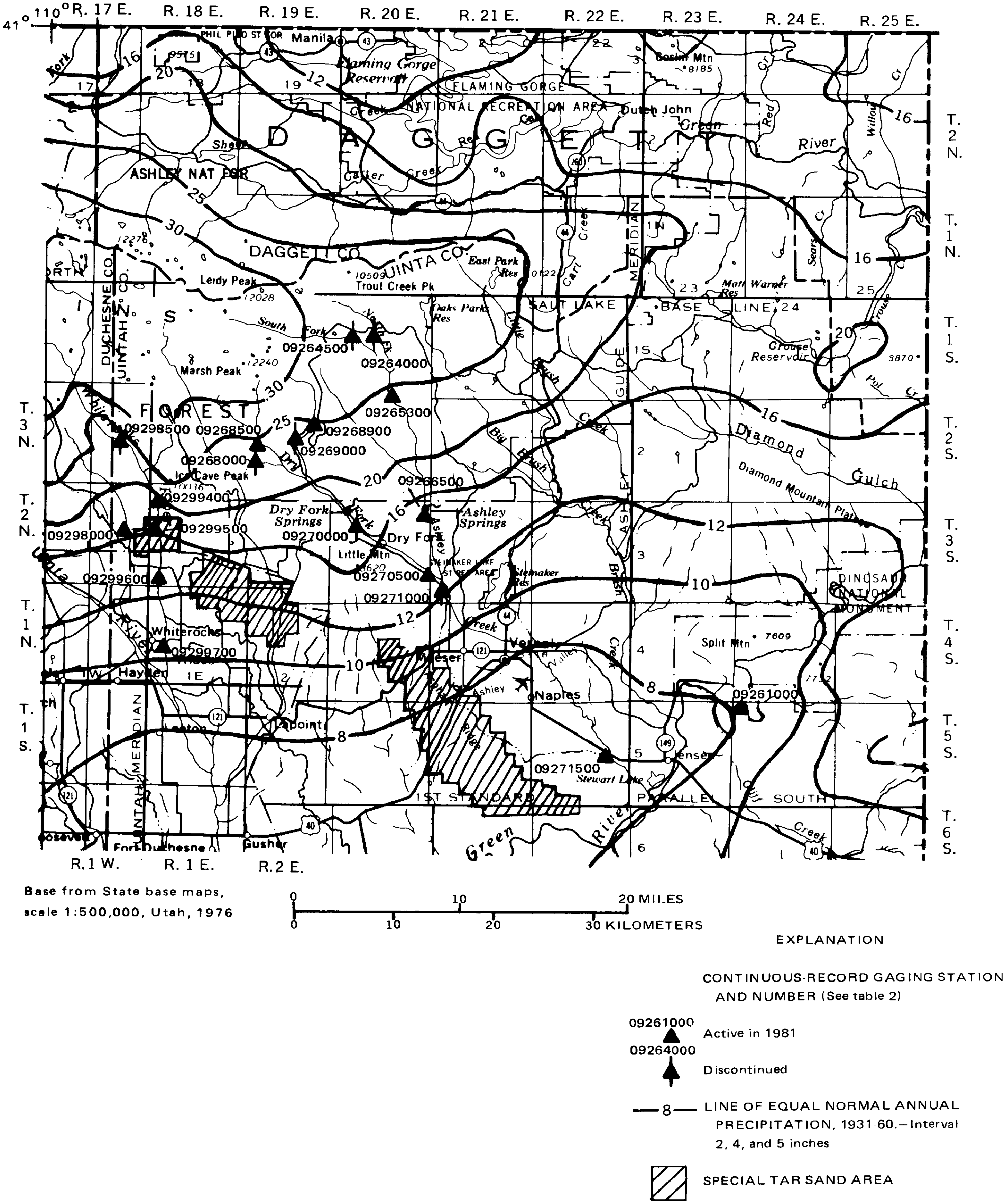

Figure 3.—Normal annual precipitation and location of stream-gaging stations in and near the Asphalt Ridge--Whiterocks Special Tar Sand Area. Precipitation from U. S. Weather Bureau, 1963.

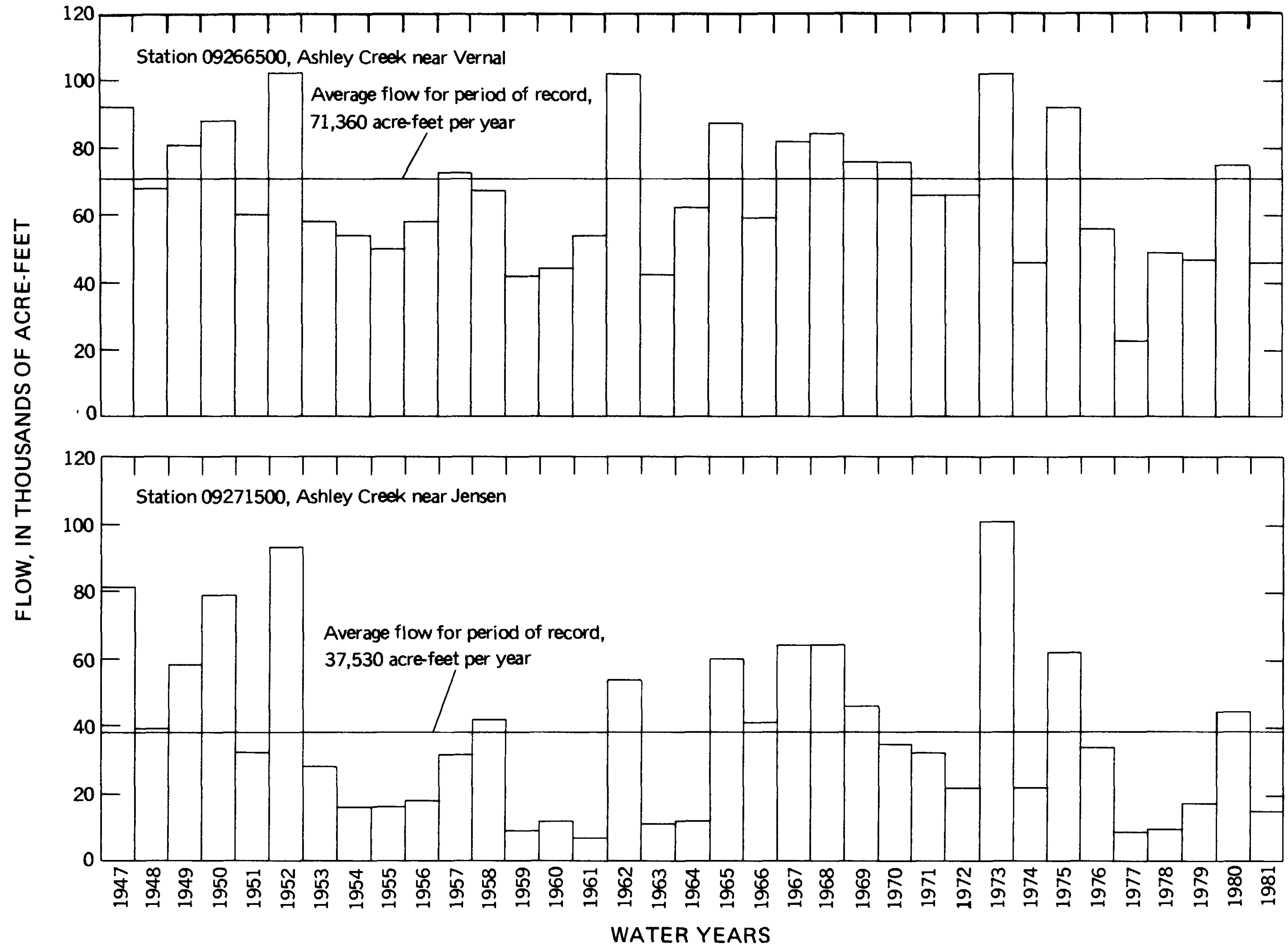

Figure 4. —Annual flow at two gaging stations in and near the Asphalt Ridge - - Whiterocks Special Tar Sand Area.

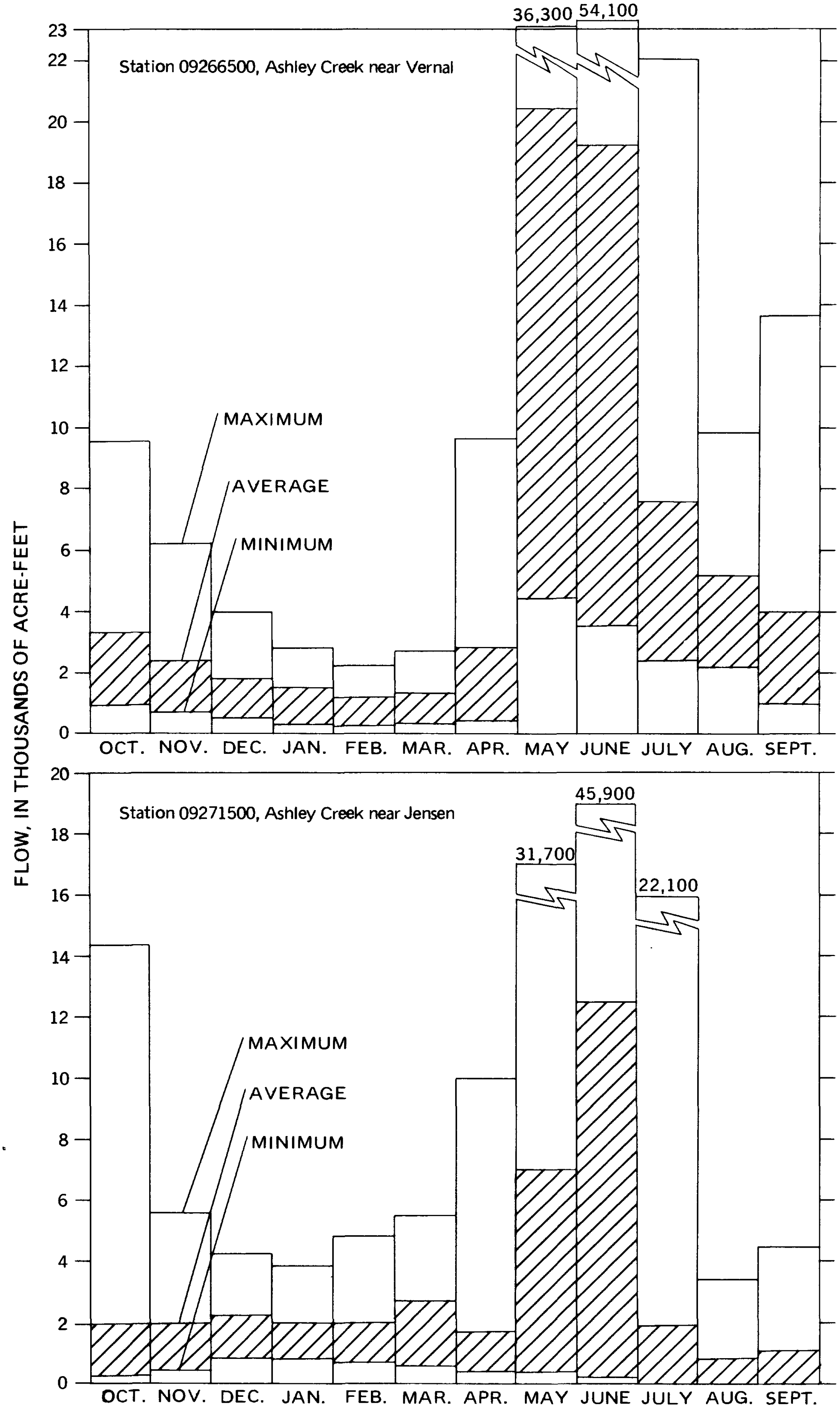

Figure 5.—Average, maximum, and minimum monthly mean flow at two gaging stations in and near the Asphalt Ridge - - Whiterocks Special Tar Sand Area.

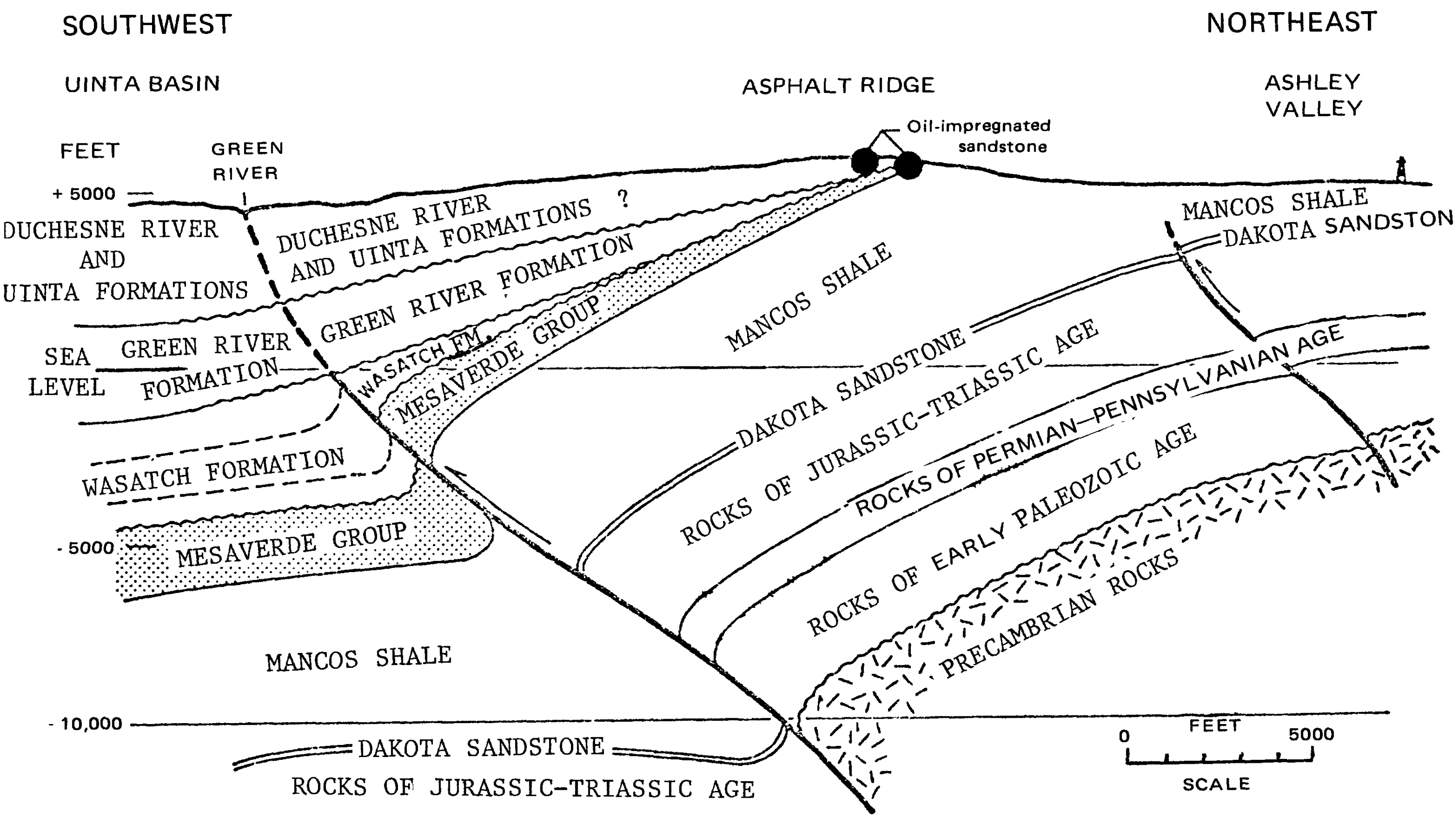

Figure 6.—Geologic section through Asphalt Ridge. Modified from Utah Geological Association (1974, p. 60).

Table 1.--Estimated oil reserves, production levels, and water requirements for the 11 Special Tar Sand Areas

[From information furnished by Earl Hindley, U.S. Bureau of Land Management, Salt Lake City, Utah, 1983.]

Special Tar Sand Area	Total inplace reserve (barrels)	Mining method	Production (barrels per day)			Water requirements (acre-feet per year)		
			Commercial			Commercial		
			"High"	"Low"	Pilot	"High"	"Low"	Pilot
Asphalt Ridge-Whiterocks	1.2-1.3 billion	Surface	10,000	5,000	0	5,770	4,520	0
Raven Ridge-Rim Rock	100-130 million	Surface	5,000	0	0	1,250	0	0
Pariette	12-15 million	—	None projected	—	—	—	—	—
Argyle Canyon-Willow Creek	60-90 million	Surface	5,000	0	0	1,250	0	0
Sunnyside	3.5-4.0 billion	Surface and in situ	125,000	30,000	10,000	36,140	3,840	2,500
Hill Creek	1.2 billion	In situ	10,000	0	0	2,300	0	0
P R Spring	4-4.5 billion	Surface and in situ	100,000	25,000	10,000	21,300	5,250	2,500
San Rafael Swell	440-540 million	In situ	20,000	1,000	0	4,600	230	0
Tar Sand Triangle	12.5-16 billion	Surface and in situ	70,000	20,000	2,000	11,100	2,900	460
White Canyon	12-15 million	—	None projected	—	—	—	—	—
Circle Cliffs	1.3 billion	In situ	20,000	2,000	0	4,600	460	0
Total	24.3-29.1 billion	—	365,000	83,000	22,000	88,310	22,200	5,460

Table 2.—Streamflow at selected gaging stations in and near the Asphalt Ridge—Whiterocks Special Tar Sand Area

Station number	Station name	Period of record used (water years)	Drainage area (square miles)	Average flow: Cubic feet per second	Average flow: Acre-feet per year	Flow (cubic feet per second): Minimum	Flow (cubic feet per second): Maximum
09261000	Green River near Jensen	1965-82	29,660	4,354	3,154,000	663	27,000
09264000	Ashley Creek below Trout Creek, near Vernal	1944-54	27	24.1	17,450	1.2	630
09264500	South Fork Ashley Creek near Vernal	1944-55	20	19.9	14,410	.8	460
09265300	Ashley Creek above Red Pine Creek, near Vernal	1965-75	55.8	67.1	48,610	.8	7,400
09266500	Ashley Creek near Vernal	1914-81	101	98.5	71,360	3.2	3,500
09268000	Dry Fork above sinks, near Dry Fork	1940-75	44.4	36.0	26,080	0	1,010
09268500	North Fork of Dry Fork near Dry Fork	1947-81	8.62	6.57	4,760	0	169
09268900	Brownie Canyon above sinks, near Dry Fork	1961-81	8.24	12.7	9,200	0	395
09269000	East Fork of Dry Fork near Dry Fork	1947-63	12	7.97	5,770	0	240
09270000	Dry Fork below springs, near Dry Fork	1942-45, 1954-69	97.4	31.8	23,040	0	974
09270500	Dry Fork at mouth, near Dry Fork	1955-81	115	25.1	18,180	0	1,210
09271000	Ashley Creek at Sign of the Maine, near Vernal	1901-04, 1940-65	241	124	89,770	10	4,110
09271500	Ashley Creek near Jensen	1947-81	383	51.8	37,530	0	2,790
09297000[1]	Uinta River near Neola	1925-26, 1930-81	163	177	128,200	14	5,000
09298000	Farm Creek near Whiterocks	1950-81	14.9	6.09	4,410	1.2	350
09298500	Whiterocks River above Paradise Creek, near Whiterocks	1946-55	90	98.3	71,170	—	1,780
09299400	Whiterocks River below dam site, near Whiterocks	1977-81	110	90.6	65,640	8.1	1,660
09299500	Whiterocks River near Whiterocks	1900-03, 1909-10, 1914-81	113	122	88,390	9.2	2,750
09299600	Whiterocks River below Farm Creek Canal, near Whiterocks	1977-81	120	68.5	49,630	5.8	1,260
09299700	Whiterocks River at Whiterocks	1977-81	124	35.3	25,570	0	1,660
09315000[1]	Green River at Green River	1965-81	44,850	5,735	4,152,000	834	30,500

[1] Not located in figure 3.

Table 3.—Concentrations of major dissolved constituents and suspended sediment of streamflow for sites in and near the Asphalt Ridge—Whiterocks Special Tar Sand Area

Station number and name	Period of record used (water years)		Concentration (milligrams per liter): Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)	Suspended sediment
09261000 Green River near Jensen	1965–82	Maximum	1,220	80	36	202	4.0	70	649	238	18,200
		Minimum	90	17	5.3	11	1.1	3.3	30	44	20
		Number of samples	161	161	161	237	161	274	275	231	108
09266500 Ashley Creek near Vernal	1955–58	Maximum	86	23	4.9	2.3	—	2.8	7.0	91	—
		Minimum	40	9.6	1.2	1.4	—	.5	2.7	32	—
		Number of samples	3	4	4	4	—	3	4	4	—
09271000 Ashley Creek at Sign of the Maine, near Vernal	1947–58, 1973–74	Maximum	264	57	19	7.8	2.0	3.8	88	172	—
		Minimum	—	11	1.3	.5	.4	0	0	40	—
		Number of samples	1	46	46	43	42	45	46	46	—
09271500 Ashley Creek near Jensen	1947–58, 1973–74	Maximum	4,440	451	376	641	15	999	3,190	525	—
		Minimum	1,740	32	12	9.0	1.4	2.7	72	0	—
		Number of samples	3	55	55	43	40	57	57	57	—
09297000[1] Uinta River near Neola	1941, 1957–82	Maximum	279	66	33	6.4	1.6	2.5	43	254	—
		Minimum	15	3.2	0	.5	0	0	.5	11	—
		Number of samples	73	73	73	79	79	81	81	82	—
09298000 Farm Creek near Whiterocks	1956–64, 1973	Maximum	138	61	23	17	1.6	10	77	227	—
		Minimum	18	3.1	.7	.7	.4	0	3.8	10	—
		Number of samples	3	11	11	10	10	11	11	12	—
09299500 Whiterocks River near Whiterocks	1941, 1963–74	Maximum	67	16	4.1	4.8	2.4	6.5	21	50	—
		Minimum	18	3.4	0	.2	0	0	0	9.8	—
		Number of samples	7	70	70	78	78	78	78	78	—
09299700 Whiterocks River at Whiterocks	1973	Maximum	38	7.2	1.9	1.1	1.4	.9	7.1	30	—
		Minimum	29	5.7	1.5	1.0	.4	.8	4.5	23	—
		Number of samples	2	2	2	2	2	2	2	2	—
09315000[1] Green River at Green River	1965–82	Maximum	3,160	507	150	135	7.0	70	2,000	382	39,900
		Minimum	196	29	10	19	.6	6.2	60	107	17
		Number of samples	247	360	358	291	196	359	358	328	207
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 206)			500	—	—	—	—	250	250	—	—

[1] Not located in figure 3.

Table 4.—Generalized stratigraphic section of lithologic units discussed in the text for the Asphalt Ridge—Whiterocks Special Tar Sand Area

[Data from Hood (1976, table 1).]

System	Series	Geologic unit	Thickness (feet)	Symbol	Description
Quaternary	Holocene	Unconsolidated deposits	—	Qay	Relatively young alluvial deposits, chiefly along and on flood plains of active streams.
	Pleistocene	Unconsolidated deposits	—	Qgo	Glacial outwash, fine and coarse material deposited by stream beyond margins of glaciers.
Tertiary	Eocene and Oligocene	Duchesne River Formation	0-3,000	Tdr	Shale, mainly red, but including green and other pale colors, siltstone, sandstone, and conglomerate. Contains tar-sand deposits at Asphalt Ridge.
	Eocene	Uinta Formation	0-4,000	Tu	Calcareous shale, some limestone, claystone, siltstone, and sandstone. Interfingers with rocks similar in appearance to that of Duchesne River Formation.
	Paleocene and Eocene	Green River Formation	0-5,000	Tg	Mainly lacustrine shale with some limestone, siltstone, and sandstone. Includes beds of oil shale and carbonate evaporites.
		Wasatch Formation	0-10,000	Tw	Mainly lacustrine shale, sandstone, and conglomerate.
Cretaceous	Lower and Upper Cretaceous	Mesaverde Group	400-1,160	Kmv	Shale, sandstone, and coal beds. Interfingers with upper part of Mancos Shale. Contains tar-sand deposits at Asphalt Ridge.
		Mancos Shale	0-4,900	Kms	Gray soft shale. Includes an unnamed upper shale member, the Frontier Sandstone Member, and a lower member-the Mowry Shale Member.
		Frontier Sandstone Member		Kmf	
		Dakota Sandstone	50-90	Kd	Basal sandstone, variegated soft shale, and fine-grained sandstone and siltstone, which locally is conglomeratic and crossbedded.
Jurassic	Upper Jurassic	Morrison Formation	830-890	Jm	Thins eastward and consists of variegated shale and siltstone, red and gray fine-grained silty sandstone, medium- to coarse-grained pebbly sandstone, and thin beds of gypsum. Probably fractured in most areas.
	Middle Jurassic	San Rafael Group: Entrada Sandstone	100-160	Je	Massive crossbedded, fine- to medium-grained friable sandstone. Probably fractured extensively in areas of faulting and a sharp folding.
Triassic and Jurassic	Upper Triassic and Lower Jurassic	Glen Canyon Sandstone (Formerly called Navajo Sandstone in area) or Nugget Sandstone	700-900	JTRg (JTRna) JTRn	Thins eastward and consists of white to gray, massive, crossbedded sandstone, generally friable at the outcrop. Some cliff outcrops have near-surface "case-hardening" and a desert varnish on surface. Extensively jointed at places, fractured where flexed and on basis of a well in Dry Fork Canyon, probably fractured extensively. The Whiterocks tar-sand deposit is in this formation.
Triassic	Upper Triassic	Chinle Formation	260	TRc	Variegated shale with the upper one-third red ripple-marked sandstone and thin beds of red shale. Contains a basal conglomerate member.
		Gartra Grit Member of Chinle Formation (Formerly called Shinarump Conglomerate)	1-60	TRcg	Crossbedded, medium- to coarse-grained sandstone with streaks of quartzite pebbles. Locally, occupies channels cut 20-25 feet into the underlying formation.

Table 4.--Generalized stratigraphic section of lithologic units discussed in the text for the Asphalt Ridge--Whiterocks Special Tar Sand Area--Continued

System	Series	Geologic unit	Thickness (feet)	Symbol	Description
Permian	Lower Permian	Park City Formation	120-340	Ppc	Thins eastward and consists of 24-28 feet of phosphatic shale and phospate rock overlain by about 100 feet of thin-bedded cherty and sandy dolomite limestone interbedded with shale and fine-grained sandstone.
Permian / Pennsylvanian	Lower Permian	Weber Sandstone	1,200	PIPw	Massive, fine- to coarse-grained sandstone with well-developed cross-bedding locally, especially in the upper part.
Mississippian	Lower and Upper Mississippian	Mississippian rocks, undivided	1,200-1,300	Mru	Massive limestone and dolomitic limestone. Thins eastward. Upper surface has karst topography and some zones are locally cavernous.

Location: See explanation in text for numbering system for wells and springs.
Geologic unit: Principal water-bearing unit; see table 4 for explanation of symbols.
Altitude of land surface: Altitudes from most detailed topographic maps; National Geodetic Vertical Datum of 1929.
Depth to water: Above (+) or below land-surface datum.

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			WELLS				
(D-3-19) 13bab-1	JTRn	7,025	200	12- -65	12	2	—
19dba-1	Kd	7,000	240	8- -59	5	3	—
19dbb-1	Kd	7,020	200	6- -73	45	20	—
21aac-1	JTRn	6,850	304	9- -64	+20	2	—
21aba-1	JTRn	6,890	415	4- -67	12	30	—
21aca-1	JTRn	6,790	100	12- -60	+1	2	—
21adc-1	JTRn	6,760	85	5- -70	0	6	—
21add-1	JTRn	6,650	302	5- -62	+2	7	—
21dca-1	Jm	6,750	305	10- -61	6	20	—
22cac-1	JTRn	6,700	100	9- -59	0	5	—
22cda-1	JTRn	6,670	40	5-21-73	+4	5	—
22dcb-1	JTRn	6,645	60	5- -69	0	1	—
23bbb-1	JTRn	6,820	226	5-21-73	4	10	—
(D-3-20) 5ccb-1	Qgo	6,860	93	7-28-54	23	—	At 30
15bca-1	Qgo	6,460	52	7-28-54	7	200	At 52
				8-12-55	—	—	—
16acd-1	Qgo	6,520	80	5- -73	62	5	—
22aab-1	Qgo	6,375	67	7- -73	25	100	—
22aad-1	TRcg	6,460	200	—	—	2	—
25abc-1	Qgo	5,997	65	3- 9-71	4.57	30	—
				8-19-74	6.86	—	—
25abc-2	Qgo	5,992	43	3-29-72	4	—	At 43
				8-15-74	7.01	—	—
(D-4-20) 1dca-1	JTRn	5,925	740	1- -54	40	100	—
12abb-1	JTRn	5,883	1,200	1-11-65	0	—	—
				5-10-72	—	20	0-1,200
(D-4-21) 2bad-1	Qay	5,385	50	4- -60	21	18	—
2cca-1	Qgo	5,355	16	7-24-64	—	—	—
3bbd-1	Jm	5,550	50	7- -70	13	10	—
4cdd-1	Kd	5,575	40	6- -72	6	30	—
7aad-1	Qgo	5,680	50	5- -64	21	15	—
7bcb-1	JTRn	5,810	882	5- 1-73	0	30	—
8ccc-1	Qgo	5,655	46	5- -57	17	14	—
9bcc-1	Qgo	5,545	26	5- 1-73	8	25	—
9cdd-1	Qgo	5,510	30	8- -70	5	100	—
10bbb-1	Qgo	5,464	34	7-10-58	21	14	At 34
10bcc-1	Qgo	5,465	20	5- 2-73	—	—	—
11cbc-1	Qgo	5,380	15	5- 2-73	—	—	—
11dbb-2	Qay	5,339	30	6-10-53	—	—	At 30
11dcb-1	Qgo	5,335	35	12- -66	3	20	—
12bcb-1	Qgo	5,300	16	3- -47	4	20	—
12bcc-3	Qay	5,293	10	7- -48	3	8	—
13bbb-1	Qgo	5,290	26	5- 2-73	12	10	—
14cdc-1	Qgo	5,330	24	12- -72	10	30	—
14cdd-1	Qgo	5,319	100	3- 9-71	9	8	—
15dab-1	Qgo	5,378	30	11- -56	3	25	—
16bba-2	Qgo	5,521	37	12- -60	24	30	—
16ccb-2	Qgo	5,530	26	5- -63	8	100	—
16ccc-1	PIPw	5,323	7,960	2-27-53	—	—	7,867-7,960
	JTRn			3- 3-53	—	—	5,852-6,600
17aaa-2	Qgo	5,545	26	3- -73	10	60	—
17aab-1	Qgo	5,555	30	5- -72	8	30	—
17abb-1	Qgo	5,580	52	7- -64	5	30	—
20aaa-2	Qgo	5,435	28	5- 1-73	9	40	—

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			WELLS				
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
336	83	22	3.2	1.3	2.2	74	276
—	—	—	—	—	—	—	162
—	—	—	—	—	—	17	376
—	45	33	5.1	1.9	3.0	13	368
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
362	82	31	6.7	.9	2.7	68	318
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
704	145	45	15	5.0	10	377	215
721	140	45	18	4.7	6.9	390	210
—	—	—	—	—	—	—	—
470	118	29	(1) 18	—	10	86	423
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
586	120	36	13	4.3	4.1	300	196
—	—	—	—	—	—	—	—
149	32	9.5	5.2	.7	2.3	33	119
—	—	—	—	—	—	—	—
228	62	11	(1) 6.8	—	1.0	30	217
339	88	19	4.9	2.3	11	54	297
469	110	37	9.8	3.0	9.1	59	464
—	101	33	(1) 3.9	—	3.4	55	403
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
381	78	35	11	1.2	3.4	57	376
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
714	28	—	(1) 120	—	28	213	183
1,870	35	—	(1) 675	—	71	705	0
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
651	110	61	25	.8	4.0	220	385

Table 5.--Selected well and spring data for sites in and near

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			WELLS				
(D-4-21) 20aba-1	Qgo	5,560	54	5- -60	22	16	—
20dad-1	Qgo	5,518	55	4- -69	12	60	—
21bab-1	Qgo	5,504	30	3- -60	10	45	—
22ada-1	Qgo	5,365	23	5- 2-73	8	30	—
22daa-1	Qgo	5,355	27	3- -74	14	7	—
23bcc-1	Qgo	5,357	23	3- -72	6	20	—
23cba-1	Qgo	5,339	26	1- -72	10	30	—
23cdb-1	Qgo	5,330	25	5- -71	11	60	—
23dbb-2	Qgo	5,319	18	3- 9-71	9	5	—
23dca-1	Qgo	5,308	40	9- -65	12	16	—
23ddd-1	Qgo	5,290	20	9- -61	8	20	—
24ada-2	Qgo	5,205	20	5- 3-73	0	15	—
24ddd-1	Qgo	5,233	25	2- 2-48	3.42	30	—
25ada-1	Qgo	5,230	100	3- -60	8	20	—
26acb-1	Qgo	5,310	20	5- 3-73	7	30	—
26dbc-1	Qgo	5,315	58	4- -64	12	30	—
27bbb-1	Qgo	5,415	46	8- -66	8	40	—
28abd-1	Qgo	5,460	67	7- -60	22	15	—
29bbb-1	Qgo	5,700	60	5- 1-73	27	6	—
34ddc-1	Qgo	5,460	55	3- -74	30	3	—
34ddd-1	Qgo	5,419	94	2- 2-48	13.17	10	—
35cad-1	Qgo	5,340	35	5- 3-73	--	—	—
36bdb-1	Qgo	5,270	50	9- -65	10	10	—
(D-5-20) 5cab-1	Tg	5,725	6,915	3- 8-51	—	—	6,475-6,495
	Tg			3-19-51	—	—	6,894-6,915
5cab-2	Tdr	5,725	610	2- -51	300	5	—
(D-5-21) 2dcb-1	Qgo	5,410	50	3- 9-71	13.03	4	—
33cdc-1	Tg	5,320	7,884	11- 2-48	—	—	4,290-4,311
	Tg			11- 3-48	—	—	4,397-4,411
	Tw			11- 4-48	—	—	6,717-6,731
	Tw			11- 5-48	—	—	7,072-7,078
(D-5-22) 6daa-1	Qgo	5,185	50	4- -74	35	4	—
8dab-1	Qgo	5,140	42	4- -63	26	7	—
17acb-1	Qgo	5,150	30	3- -57	14	12	—
22acd-1	PIPw	4,935	4,301	11- 4-60	—	—	4,266-4,301
22add-1	Ppc	4,910	4,293	10- 1-59	—	—	4,150-4,160
22dba-1	PIPw	4,938	4,306	10- 1-59	—	—	4,282-4,306
22dca-1	PIPw	4,950	4,330	11- 3-59	—	—	4,323-4,330
23bdc-1	PIPw	4,888	4,230	11- 1-59	—	—	4,152-4,230
				11- 3-59	—	—	4,152-4,230
23cba-1	PIPw	4,898	4,152	11- 3-59	—	—	4,134-4,152
23cca-1	PIPw	4,898	4,278	11 -1-59	—	—	4,097-4,278
				11- 3-59	—	—	4,097-4,278
23dac-1	PIPw	4,844	4,235	7- 1-49	—	—	4,207-4,235
23dcb-1	PIPw	4,882	4,130	11- 3-59	—	—	4,050-4,130
23dcc-1	Je	4,883	2,069	6-22-65	—	—	2,063-2,069
23ddb-1	PIPw	4,858	4,208	6-22-65	—	—	4,135-4,208
24ccc-1	PIPw	4,842	4,230	11- 3-59	—	—	4,134-4,230
				2-24-67	—	—	
25bbb-1	Ppc	4,845	(2)4,166	10- 1-59	—	—	4,141-4,145
26aab-1	PIPw	4,855	4,243	10- 1-59	—	—	4,085-4,243
26abb-1	PIPw	4,880	4,251	5-22-49	—	—	4,290-4,310
				11- 3-59	—	—	4,096-4,251

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			WELLS				
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
704	120	66	26	1.1	11	220	460
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
528	91	47	21	2.5	23	94	416
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
672	120	59	19	.9	6.5	250	381
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
1,950	470	66	16	2.2	2.7	1,300	144
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
2,420	570	79	32	1.2	15	1,500	381
—	—	—	—	—	—	—	
2,380	21	<1.0	(1) 975	—	470	21	1,450
1,690	—	—	(1) 697		180	140	1,075
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
8,260	11	2.6	(1) 2,720	—	1,750	18	3,322
11,000	13	6.8	(1) 3,330	—	1,080	48	6,160
5,340	11	14	(1) 1,660	—	832	278	2,380
18,000	123	49	(1) 6,720	—	10,100	238	793
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
731	103	28	38	20	104	244	386
2,020	129	28	(1) 552	—	410	700	403
692	102	33	(1) 103	—	60	204	386
532	85	27	(1) 52	—	4.0	227	238
762	122	30	(1) 97	—	64	319	264
925	112	30	(1) 158	—	76	379	260
1,090	93	27	(1) 253	—	170	362	291
1,050	132	42	(1) 163	—	104	499	232
1,210	155	38	(1) 198	—	108	519	340
1,500	244	78	(1) 157	—	100	653	500
1,960	109	31	(1) 547	—	372	615	518
936	9.0	3.0	410	5.0	17	93	754
1,400	245	46	125	27	84	750	191
1,930	338	74	(1) 163	—	77	1,120	280
1,240	371	76	90	17	78	1,275	121
1,690	395	79	(1) 13	—	60	1,030	220
1,700	289	60	(1) 174	—	110	924	281
940	107	34	(1) 94	—	46	37	622
1,780	242	56	(1) 261	—	162	874	317

Table 5.—Selected well and spring data for sites in and near

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			WELLS				
(D-5-22) 26adb-1	Je	4,871	(2) 2,300	8-26-65	—	—	2,180-2,195
26bab-1	PIPw	4,905	4,287	11- 4-60	—	—	4,148-4,287
26bca-1	Ppc	4,945	4,393	5-23-49	—	—	4,372-4,393
27aaa-1	PIPw	4,913	4,290	10- 1-59	—	—	4,268-4,290
(D-6-20) 10aac-1	Tg	5,040	(2) 8,041	9-10-57	—	—	7,748-7,985
(D-6-22) 1dad-1	Qgo	4,720	43	1-28-64	6	503	23-43
1dda-1	Qgo	4,720	40	1-28-64	6	457	20-40
1ddc-1	Qgo	4,720	40	5-11-73	—	—	—
U(A-1-1) 5aba-1	Qgo	6,580	—	4- 7-72	—	5	—
5dca-1	Qgo	6,465	96	—	—	.1	—
6aca-1	Tw	6,510	7,250	5- 1-56	—	—	4,658-4,690
				5- 2-56	—	—	4,957-4,976
18cdb-1	Tdr	6,143	750	10- -36	+1	.1	—
20acc-1	Qgo	6,050	52	5- -73	21	20	—
20add-1	Qgo	6,050	43	5- -73	16	11	—
21bbb-1	Tdr	6,135	111	4- -72	55	2	—
21cbb-1	Tdr	6,045	—	4- 7-72	—	5	—
23ccc-1	Tdr	5,686	190	4- -46	40	5	—
23ccc-2	Tdr	5,686	327	—	—	9	—
26dbb-1	Tdr	5,635	512	6- -34	80	10	—
27ddd-1	Tdr	5,620	312	1-24-47	95	5	—
28abb-2	Qgo	5,965	27	2- -54	20	10	—
28cbb-1	Qgo	5,900	45	11- -71	25	15	—
33bba-1	Qgo	5,845	74	5- -69	47	20	—
36dbc-1	Tdr	5,570	263	2- -46	45	5	—
U(A-1-2) 31dcc-1	Tdr	5,610	94	9- -67	17	11	—
			(3) 200	6- 2-72	64	9	64-200
32aca-1	Tdr	5,935	200	7-19-73	114	40	—
U(A-2-1) 36bbd-1	Qgo	6,835	33	8- -53	6	20	—
U(A-2-2) 32aca-1	Kmf	6,690	44	5- 4-73	+12	4	—
24ccc-1	Qgo	6,810	45	5-10-73	17	15	—
26dad-1	Tdr	6,690	85	6- -52	15	10	—
			SPRINGS				
(D-3-19) 11cbc-S1	Mru	7,155	—	7-29-54	—	—	—
				7-26-55	—	—	—
				8- 9-55	—	—	—
				5-15-67	—	—	—
				7-30-68	—	2,020	—
(D-3-20) 1dcc-S1	PIPw	6,260	—	8-12-55	—	—	—
				10-22-57	—	—	—
				5- 9-58	—	—	—
				7-10-58	—	—	—
				5-17-67	—	—	—
				7-29-68	—	19,800	—
5ccc-S1	Qgo, PIPw	6,860	—	7-11-58	—	83,250	—
15bca-S1	Qgo	6,460	—	7-28-54	—	36	—
				8-11-55	—	—	—
23adb-S1	TRc	6,160	—	7-28-54	—	45	—
				8-11-55	—	—	—
(D-4-20) 16cdd-S1	Tdr	6,465	—	5-10-72	—	2	—
U(B-2-1) 15dcb-S1	Tdr	7,630	—	8- 9-73	—	2	—

1 Sodium plus potassium
2 Well originally drilled deeper, then plugged back to depth indicated.
3 Well deepened in 1968.

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			WELLS				
479	18	2.2	[1] 165	—	42	66	348
1,380	192	43	171	27	116	681	270
564	56	23	[1] 78	—	21	33	293
380	84	31	[1] 8.0	—	16	111	264
15,900	104	68	[1] 6,080	—	8,990	151	1,120
—	176	114	[1] 514	—	220	1,360	—
—	124	46	[1] 133	—	106	420	—
1,060	110	52	170	3.4	77	510	252
—	—	—	—	—	4.4	12	109
—	—	—	—	—	—	—	—
—	18	18	[1] 1,740	—	1,530	18	1,430
1,300	9.0	15	[1] 511	—	200	43	720
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	4.9	20	335
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	59	31	[1] 670	—	40	1,470	177
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
505	6.7	3.2	180	3.3	15	97	381
1,400	130	120	150	3.2	110	520	375
—	—	—	—	—	—	—	—
495	71	21	66	1.8	11	200	228
331	70	16	24	3.3	5.3	57	292
—	—	—	—	—	—	—	—
			SPRINGS				
—	—	—	—	—	—	9.1	84
105	23	6.0	1.7	0.5	4.0	10	90
97	25	5.7	1.4	.5	2.6	7.0	98
84	21	6.3	.9	1.6	.7	14	82
85	18	8.0	.9	.5	1.1	7.8	87
84	22	4.8	1.4	.3	1.2	3.0	88
84	22	5.6	[1] .9	—	.5	3.1	92
57	14	3.6	[1] .9	—	.2	4.3	56
77	18	4.1	[1] 4.3	—	1.0	8.6	72
66	17	4.9	.7	1.2	2.5	9.1	63
70	14	7.8	.9	.4	1.0	3.8	76
69	18	3.6	[1] 2.0	—	1.0	3.3	72
—	—	—	—	—	—	17	423
—	98	34	2.9	3.8	1.0	16	443
—	—	—	—	—	—	251	474
742	148	57	13	5.8	4.0	268	424
381	78	33	12	1.4	8.8	69	335
84	6.8	1.4	1.6	4.3	3.1	44	0

RAVEN RIDGE--RIM ROCK SPECIAL TAR SAND AREA

By H. F. McCormack and G. E. Pyper

Location

The Raven Ridge--Rim Rock Special Tar Sand Area covers about 24 square miles in Uintah County. The area is about 10 miles north of Bonanza (fig. 7) and 21 miles southeast of Vernal in the Uinta Basin physiographic subdivision of the Colorado Plateaus (Fenneman, 1946). Land-surface altitudes range from about 6,000 feet in the southeast corner to about 5,000 feet in the northwest corner. The proven or inferred tar-sand deposits underlie parts of townships 6 and 7 south and ranges 23 to 25 east, Salt Lake base line and meridian. The tar-sand deposits in the Raven Ridge part are in the Green River Formation, whereas in the Rim Rock part the deposits are in the Wasatch Formation and the basal part of the Green River Formation (Ritzma, 1979, sheet 2). About 2.5 of the 24 square miles are available for lease. The Federal Government is the major landowner; however, ownership of the minerals commonly is different from ownership of the surface rights. The estimated oil in place is 100 to 130 million barrels (table 1).

Climate

The climate of the area is influenced by local and regional topographic features; and it generally is semiarid, with low relative humidity, abundant sunshine, low to moderate precipitation, warm summers, and cold winters. Seasonal and daily variations in air temperature are large. The Wasatch Range, about 140 miles to the west, acts as an orographic barrier for moisture moving east from the Pacific Ocean. The Roan Cliffs (fig. 7) to the south acts as an orographic barrier for much of the summer moisture moving north from the Gulf of California or the Gulf of Mexico. Thunderstorms result in precipitation during the summer and fall when moist tropical air masses occasionally move into the region.

Selected climatic characteristics were reported for the southeastern Uinta Basin by Waltemeyer (1982). In addition, precipitation for the basin is reported by the U.S. Weather Bureau (1963), air temperature by the National Oceanic and Atmospheric Administration (1973), and evaporation by Farnsworth and others (1982, map 3), and the U.S. Weather Bureau (1957).

Normal annual precipitation for the area is about 10 inches (fig. 7), and the average annual air temperature is about 45°F. Large variations in daily air temperature are caused by relatively strong daytime warming and rapid nighttime cooling. Normal annual free-water surface evaporation ranges from 40 to 45 inches (Farnsworth and others, 1982, map 3).

Water Resources

The major water resources in and near the Raven Ridge--Rim Rock Special Tar Sand Area consists of flows in the Green and White Rivers and some of their tributaries and the recoverable ground water in alluvial deposits and in the Duchesne River, Uinta, Green River, Wasatch, and Park City Formations.

Surface Water

The surface drainage within the Raven Ridge--Rim Rock Special Tar Sand Area is north from the Deadman Bench divide to Cliff Creek (a tributary of the Green River) and south from the same divide to the White River. Streamflow data are available for only six sites in or near the area (table 6), and for two of the sites, only annual peak-flow data are available. No perennial streams originate in the area, although small streams flow intermittently from snowmelt. The combined flow of about 3.6 million acre-feet for the Green and White Rivers is about 1,000 times larger than the combined flows in small ephemeral washes in and near the area. These small washes include Cliff Creek (tributary to the Green River); Kennedy and Red, which are tributary to Coyote Wash (which is tributary to the White River); and several small tributaries to the Green River. There are numerous stock ponds on these small washes.

Flows representative of those in the ephemeral washes in and near the area are gaged at station 09306878, Coyote Wash near mouth, near Ouray, about 20 miles southwest of the area. Flow varies daily, seasonally, and annually and in wet years has been as much as eight times greater than during dry years (see figs. 8 and 9). The peak flow for the 5 years of record (water years 1977-81) is 829 cubic feet per second, and there was no flow for an average of 326 days per year. The average flow was 3.6 cubic feet per second (table 6 and Lindskov and Kimball, 1982, table 2).

The flow of the Green or White Rivers could support a "high" commercial tar-sand industry producing 5,000 barrels per day with a water requirement of 1,250 acre-feet per year (table 1). With storage, the total flow of the small streams in the area could possibly support a "high" commercial tar-sand industry.

The range in concentration of dissolved solids in the streamflow in and near the area is from 73 to 1,400 milligrams per liter (table 7). The concentration of dissolved solids generally is inversely proportional to the flow, thus, the chemical quality improves as the flow increases. If flow decreases due to seepage or evapotranspiration, however, the concentration of dissolved solids can increase downstream.

The measured range of suspended-sediment concentration in Coyote Wash is shown in table 7. The maximum value is 96,900 milligrams per liter, which could be representative of the ephemeral washes in the area.

Ground Water

The unconsolidated deposits in the Raven Ridge--Rim Rock Tar Sand Area are thin and mostly unsaturated; thus, the most important aquifers in the area are in consolidated rocks. According to the data in tables 8 and 9, the following consolidated formations have yielded water to wells or springs in or near the area: Uinta, Green River, and Wasatch Formations, Mesaverde Group, Entrada and Nugget Sandstones, Park City Formation, and the Weber Sandstone. Although all these formations have been reported by Feltis (1966) to contain fresh water in other areas, in the Raven Ridge--Rim Rock Tar Sand Area, according to table 9, only the Uinta and Green River Formations and the Nugget and Weber Sandstones have yielded fresh water.

The largest yield recorded from a well in or near the area was 200 gallons per minute from the Weber Sandstone at a depth of 2,650 feet. The water from that well is saline, however, as is the water produced from the Green River Formation in the Red Wash oil field southwest of the area. In 1981, about 1,300 acre-feet of water was produced from the Red Wash oil field (Utah Division of Oil, Gas, and Mining, December 1981, p. 61); but the water is of the sodium chloride type, with dissolved-solids concentrations ranging from 4,500 to more than 100,000 milligrams per liter. Thus, the water generally is unfit for any use (Austin and Skogerboe, 1970, p. 99).

The exposed formations at Raven Ridge dip about 35° toward the southwest (Cashion, 1967, p. 22) thus indicating that the general direction of ground-water movement is to the southwest. However, locally ground-water movement is from outcrop areas to the nearest lowest incised drainage, which generally is the same direction as the surface drainage.

Existing Water Use

This tar-sand area is within Water Rights Area 49, southeast Uinta Basin, Uintah and Grand Counties. All water in and near the area is fully appropriated by existing rights (Jensen, 1975, p. 179), therefore, water rights for a tar-sand industry would have to be purchased or leased.

Presently (1983), water use in and near the area is minimal and is primarily for livestock. Some water is used for the oil fields, particularly the Red Wash oil field southwest of the area. The major local water use is for a gilsonite mine at Bonanza. This mine obtains about 1,000 acre-feet per year from wells completed in the alluvium of the White River south of Bonanza (Ronald Jibson, Utah Division of Water Rights, written commun., February 19, 1980).

The Ute Indian Tribe, of Fort Duchesne, Utah, has prime rights on the White River under the Winters Doctrine (Winter v. United States, 207 U.S. 564, 52 L.Ed. 340, 28 S. Ct. 207, 1908) with a potential to irrigate 12,833 acres of land near Ouray, Utah. This entitlement has been estimated to be about 62,000 acre-feet of water per year. A bill was passed endorsing a Ute Indian Water Compact during the 1980 session of the Utah Legislature, however, it has not been ratified by the Tribe. In addition, Colorado and Utah have no interstate compact to regulate the flow of the White River. Thus, water use in Colorado could deplete the flow in the White River in Utah.

The Utah State Division of Water Resources has a filing to appropriate 250,000 acre-feet of water per year from the White River and tributaries for mining, drilling, and retorting oil shale and other energy-related projects including a powerplant which is under construction west of Bonanza.

Hydrologic Impacts Unique to This Area

Little hydrologic impact would be expected from a tar-sand industry where the inplace reserves are only 100 to 130 million barrels. A "high" commercial tar-sand industry producing 5,000 barrels per day in the Raven Ridge--Rim Rock Tar Sand Area would require about 1,250 acre-feet of water annually (table 1). These needs could be supplied from the available water resources in the area without any unique hydrologic impacts other than rearrangement of water rights. Potential impacts that generally apply to all areas are discussed in the section "Hydrologic impacts of a tar-sand industry," near the end of this report.

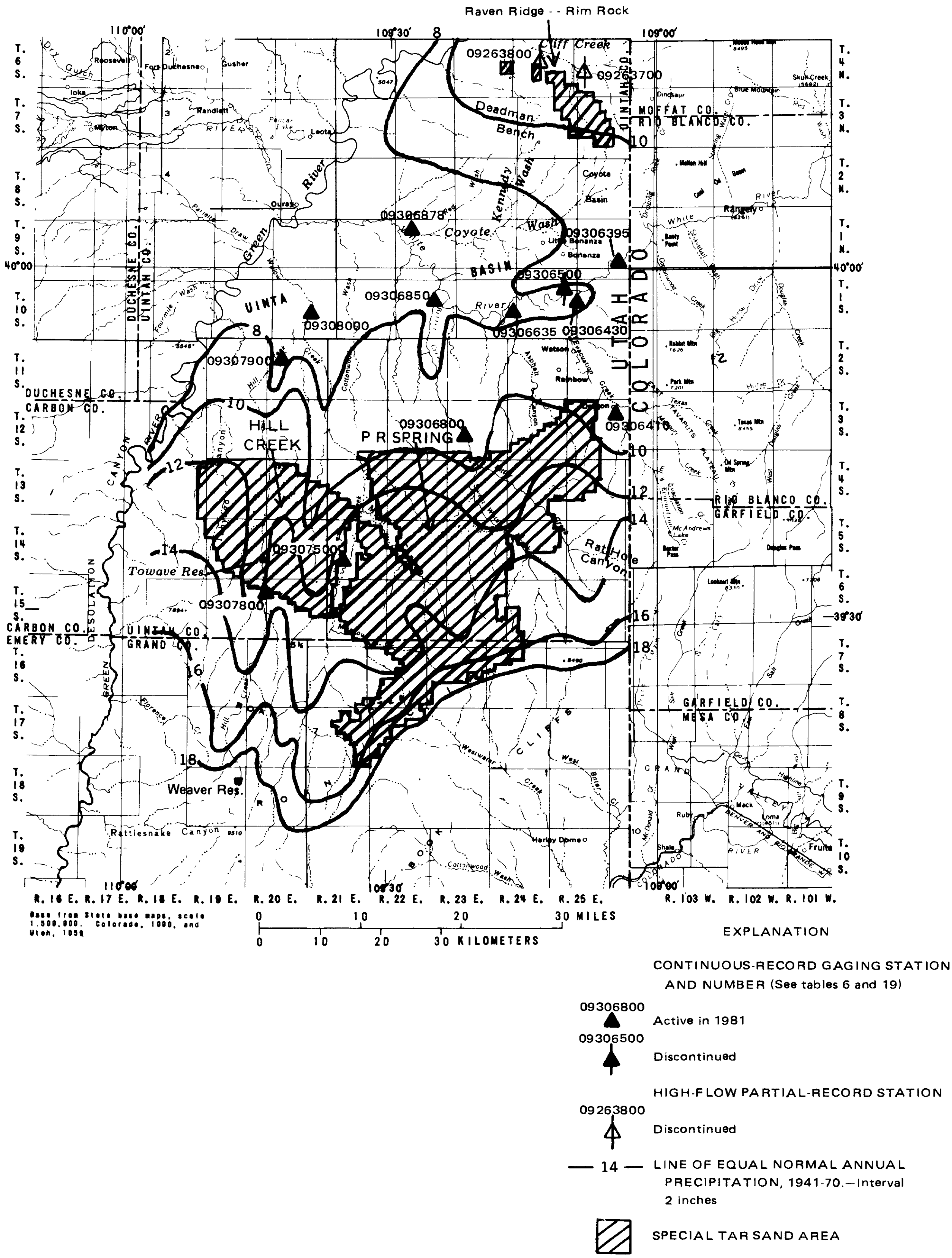

Figure 7.—Normal annual precipitation and location of stream-gaging stations in and near the Raven Ridge - - Rim Rock, Hill Creek, and P R Spring Special Tar Sand Areas. Precipitation from Waltemeyer, 1982, pl. 1.

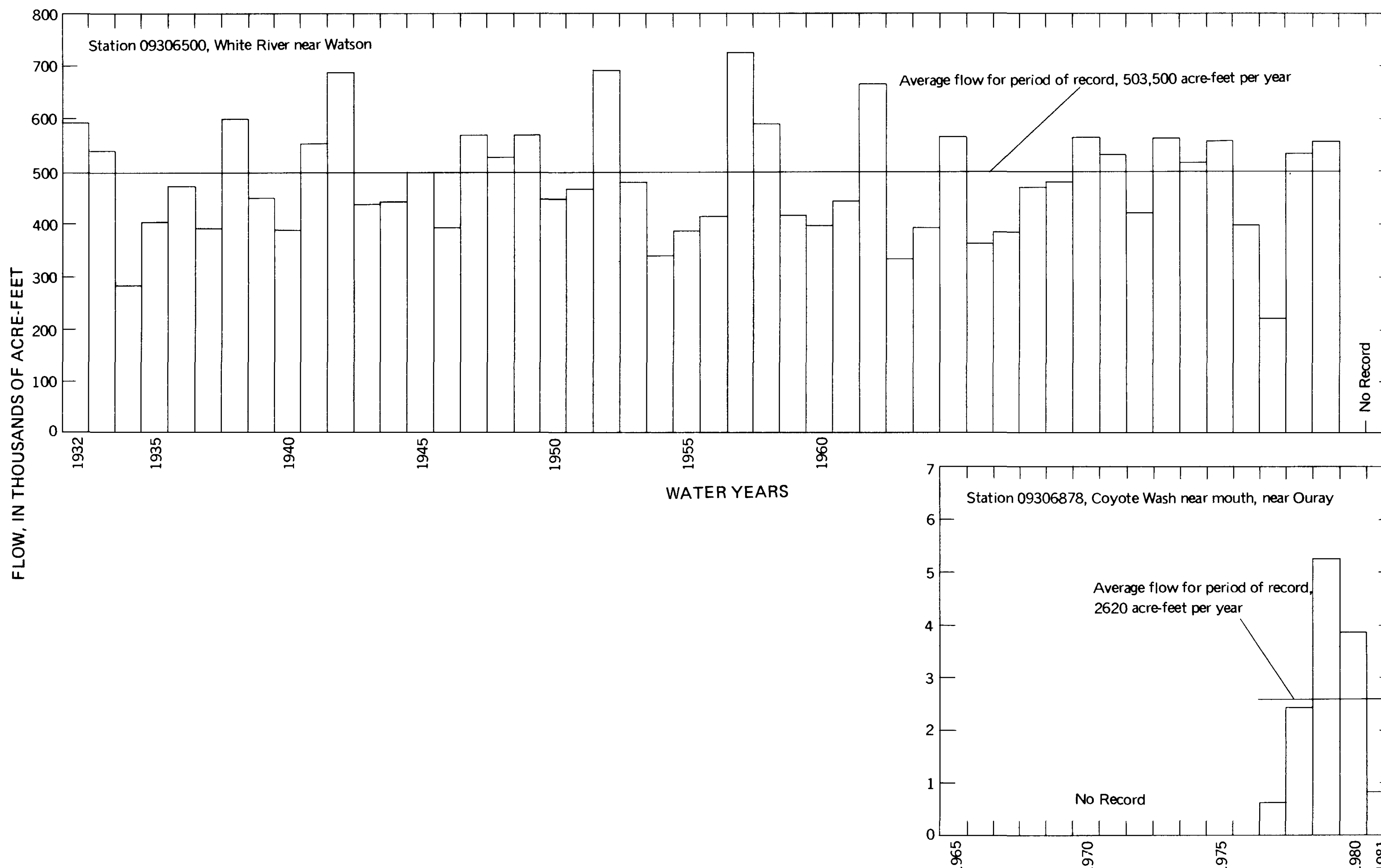

Figure 8.—Annual flow at two gaging stations in and near the Raven Ridge - - Rim Rock Special Tar Sand Area.

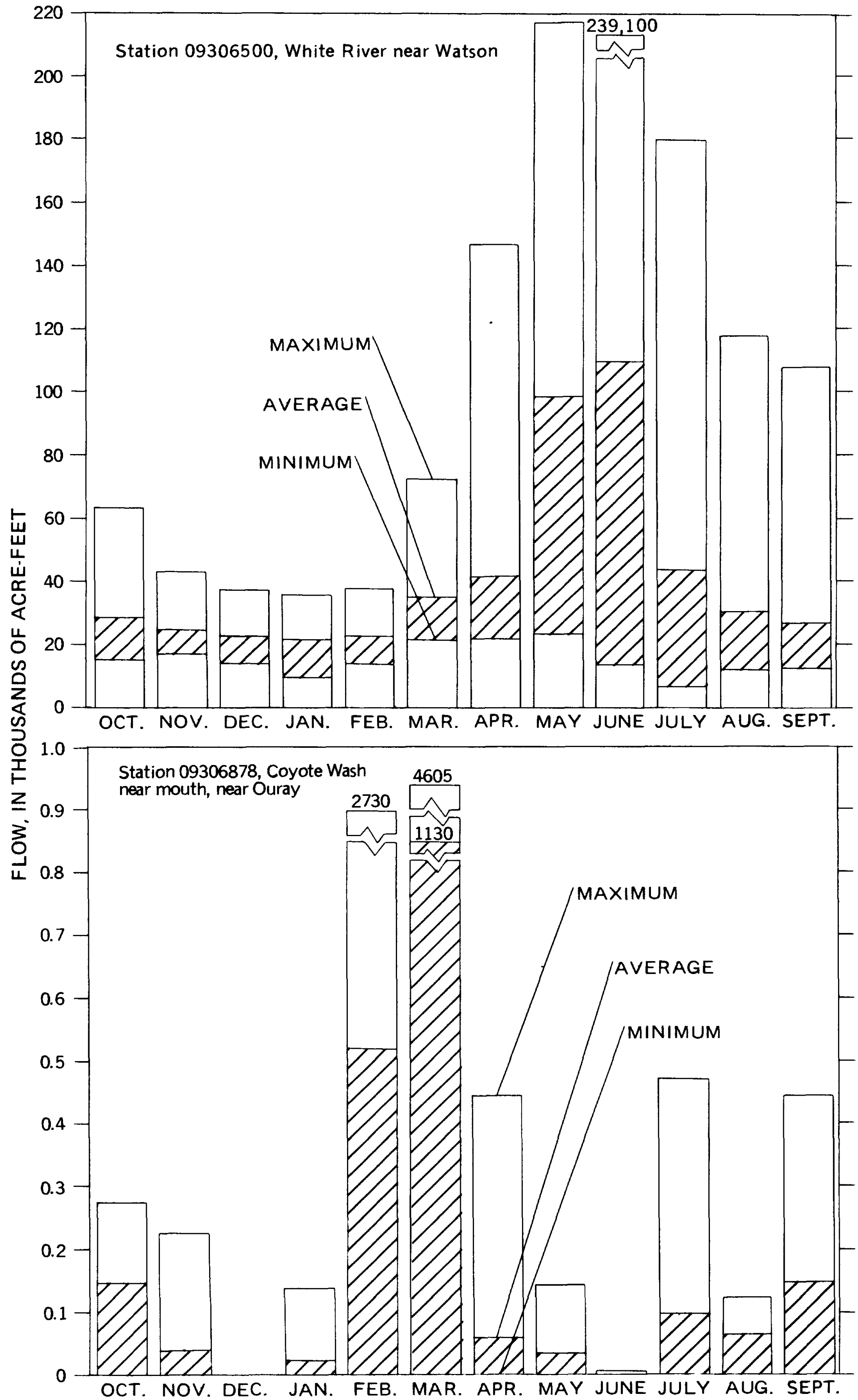

Figure 9.—Average, maximum, and minimum monthly mean flow at two gaging stations in and near the Raven Ridge - - Rim Rock Special Tar Sand Area.

Table 6.--Streamflow at selected gaging stations in and near the Raven Ridge--Rim Rock Special Tar Sand Area

Station number and name		Period of record used (water years)	Drainage area (square miles)	Average flow		Flow (cubic feet per second)	
				Cubic feet per second	Acre-feet per year	Minimum	Maximum
09261000[1]	Green River near Jensen	1965-82	29,660	4,354	3,154,000	663	27,000
09263700	Cliff Creek near Jensen	1960-74[2]	64	—	—	0	1,360
09263800	Cow Wash near Jensen	1960-74[2]	3.9	—	—	0	2,950
09306395	White River near Colorado-Utah State line	1977-81	3,680	602	436,100	10	4,470
09306500	White River near Watson	1924-79	4,020	695	503,500	11	8,160
09306878	Coyote Wash near mouth, near Ouray	1977-81	228	3.62	2,620	0	829

[1] Not located in figure 7.
[2] Annual maximum only.

Table 7.--Concentrations of major dissolved constituents and suspended sediment of streamflow for sites in and near the Raven Ridge--Rim Rock Special Tar Sand Area

Station number and name	Period of record used (water years)		Concentration (milligrams per liter)								
			Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)	Suspended sediment
09261000[1] Green River near Jensen	1965-82	Maximum	1,220	80	36	202	4.0	70	649	238	18,200
		Minimum	90	17	5.3	11	1.1	3.3	30	44	20
		Number of samples	161	161	161	237	161	274	275	231	108
09306395 White River near Colorado-Utah State line	1977-82	Maximum	924	95	50	150	4.9	88	360	320	23,200
		Minimum	213	38	12	13	1.2	5.5	53	170	36
		Number of samples	46	46	46	46	46	46	46	9	61
09306500 White River near Watson	1950-79	Maximum	1,400	283	170	566	12	420	2,160	736	51,700
		Minimum	203	26	9.7	14	1.0	4.5	43	94	3
		Number of samples	195	366	366	544	314	633	636	622	111
09306878 Coyote Wash near mouth, near Ouray	1977-82	Maximum	645	17	2.6	190	3.7	18	150	500	96,900
		Minimum	73	1.3	.5	29	.7	2.2	9.7	232	5,080
		Number of samples	11	11	11	11	11	11	11	5	32
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 206)			500	—	—	—	—	250	250	—	—

[1] Not located in figure 7.

Table 8.--Generalized stratigraphic section of lithologic units discussed in the text for the Raven Ridge—Rim Rock Special Tar Sand Area

[Data from Hood (1976, table 1).]

System	Series	Geologic unit	Thickness (feet)	Symbol	Description
Tertiary	Eocene and Oligocene	Duchesne River Formation	0-3,000	Tdr	Shale, mainly red, but including green and other pale colors, siltstone and conglomerate, unconformably underlying younger rocks.
		Uinta Formation	0-4,000	Tu	Calcareous shale, some limestone, claystone, siltstone and sandstone. Interfingers with rocks similar in appearance to that of Duchesne River Formation.
	Paleocene and Eocene	Green River Formation	0-5,000	Tg	Mainly lacustrine shale with some limestone, siltstone, and sandstone. Includes beds of oil shale and carbonate evaporites. Tar-sand deposits in the Raven Ridge—Rim Rock area are in this formation.
		Wasatch Formation	1,000-4,000	Tw	Mainly lacustrine shale, sandstone and conglomerate.
Cretaceous	Upper Cretaceous	Mesaverde Group	400-1,160	Kmv	Shale, sandstone, and coal beds. Interfingers with upper part of Mancos Shale.
Jurassic	Middle Jurassic	San Rafael Group: Entrada Sandstone	100-160	Je	Massive crossbedded, fine- to medium-grained friable sandstone. Probably fractured extensively in areas of faulting and sharp folding.
Triassic and Jurassic	Upper Triassic and Lower Jurassic	Glen Canyon Sandstone (Formerly called Navajo Sandstone in area) or Nugget Sandstone	700-900	JRg (JRna) JRn	Thins eastward and consists of white to gray, massive, crossbedded sandstone, generally friable at the outcrop. Some cliff outcrops have near-surface "case-hardening" and a desert varnish on surface. Extensively jointed at places and fractured where flexed.
Permian		Park City Formation, equivalent to Phosphoria Formation	120-340	Ppc	Phosphatic shale and phospate rock overlain by thin-bedded cherty and sandy dolomitic limestone interbedded with shale and fine-grained sandstone.
	Lower Permian	Weber Sandstone	1,200	PPw	Massive, fine- to coarse-grained sandstone with well-developed crossbedding locally, especially in upper part.
Pennsylvanian					

Table 9.—Selected well and spring data for sites in and

Location: See explanation in text for numbering system for wells and springs.
Geologic unit: Principal water-bearing unit; see table 8 for explanation of symbols.
Altitude of land surface: Altitudes from most detailed topographic maps; National Geodetic Vertical Datum of 1929.
Depth to water: Above (+) or below land-surface datum.

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
				WELLS			
(D-6-23)1acc-1	PIPw	5,150	2,252	—	—	—	—
1bad-1	PIPw	5,170	2,650	6-25-57	—	200	At 2,650
				9-10-57	—	—	At 2,650
				7-13-58	—	—	At 2,650
				9- 6-64	—	—	At 2,650
				11-27-65	—	—	At 2,650
(D-6-25)21bba 1	Qa[2]	5,370	—	—	40	—	—
34	Tw	5,500	447	—	400	—	—
36cab-1	Ku[3]	5,695	1,420	9-26-56	+	.5	—
(D-7-24) 8aca-1	Tg	5,621	5,640	9-10-57	—	—	5,447-5,486
11ccb-1	Tg	5,695	—	11- 8-65	—	—	5,000-5,035
14ccd-1	Tg	5,782	—	4- 9-61	—	—	4,991-5,121
				4-11-61	—	—	5,155-5,216
15ccd-1	Tg	5,747	5,625	9-10-57	—	—	5,308-5,319
21cad-1	Tg	5,646	5,261	8- 5-65	—	—	4,096-4,125
				8- 6-65	—	—	3,993-4,022
21dad-1	Tg/Tw	5,708	5,373	1-13-65	—	—	4,230-4,250
				1-14-65	—	—	4,275-4,295
				1-15-65	—	—	5,238-5,258
21dda-1	PIPw	5,270	18,607	5-14-74	—	—	18,320-18,520
				5-16-74	—	—	18,060-18,190
26acd-1	Tu	5,683	5,100	5- 6-65	—	—	1,675-2,310
27ccd-1	Kmv	5,673	—	12-14-66	—	—	9,639-9,640
				12-19-66	—	—	9,633-9,637
28acd-1	Tg	5,655	5,100	1- 6-66	—	—	3,571-3,586
31acb-1	Tg	5,328	—	4-17-63	—	—	3,788-3,805
				4-17-63	—	—	4,990-5,007
35acc-1	Tg	5,555	—	10-29-65	—	—	2,145-2,185
				10-29-65	—	—	3,390-3,408
				10-29-65	—	—	4,793-4,823
36aaa-1	Tg	5,744	—	3- 2-65	—	—	3,362-3,382
				3- 2-65	—	—	4,900-4,920
				3- 2-65	—	—	5,052-5,072
S(B-3-104)1dca-1	Je	5,860	200	—	—	10	—
1dca-2	JTRna	5,860	700	7-14-58	—	35	—
				10- 3-58	—	—	—
S(B-4-104)23aca-1	PIPw	5,670	—	5- 4-73	+	50	—
36ddd-1	PIPw	6,288	1,451	—	—	15	—
				SPRING			
(D-6-24)5acd-S1	Ppc	5,175	—	5-11-73	—	.1	—

1 Sodium plus potassium.
2 Alluvial deposits of Quaternary age.
3 Undivided rocks of Cretaceous age.

near the Raven Ridge—Rim Rock Special Tar Sand Area

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
				WELLS			
—	—	—	—	—	—	—	—
1,870	367	69	91	23	78	1,150	139
1,720	321	31	(1) 140	—	81	1,090	81
1,850	357	75	(1) 104	—	80	1,150	141
—	—	—	—	—	80	1,060	—
1,880	372	67	106	20	77	1,145	147
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
1,900	491	26	37	7.4	12	1,240	135
6,180	3	2	(1) 2,660	—	704	2	5,710
3,950	55	15	1,500	30	1,230	150	1,540
2,330	9.2	16	(1) 949	—	78	120	2,340
3,630	18	12	(1) 1,520	—	51	52	4,000
6,944	2	2	(1) 2,981	—	380	9	5,693
1,460	8.0	2.0	612	5.0	20	27	866
881	2.0	0	376	5.0	0	0	500
4,100	8.0	0	1,800	10	300	0	3,280
4,590	8.0	2.0	1,950	10	300	0	3,950
4,500	11	5.0	1,810	12	1,620	0	2,040
—	4,300	770	41,000	2,700	80,000	840	418
118,000	5,400	1,100	36,000	2,200	72,000	840	700
898	12	3.0	240	0	28	90	525
73,530	590	153	27,900	300	44,000	28	1,150
70,500	1,740	357	24,700	550	44,000	1,820	647
14,800	75	21	5,770	45	7,600	10	2,640
3,430	<1.0	0	1,000	2.0	124	12	2,160
7,530	17	3.0	2,670	8.0	3,100	74	1,590
1,380	9.0	1.0	547	<1.0	148	200	732
669	6.0	3.0	274	<1.0	16	50	549
3,008	36	7.0	1,132	10	680	428	1,403
1,900	9.0	3.0	762	5.0	40	238	1,560
3,400	11	9.0	1,330	8.0	590	405	1,920
5,600	14	3.0	2,210	2.0	2,560	148	1,340
—	—	—	—	—	—	—	—
300	46	28	(1) 25	—	13	35	282
313	45	30	(1) 27	—	14	40	284
221	28	14	30	3.0	2.4	26	208
—	—	—	—	—	—	—	—
				SPRING			
1,420	240	64	88	27	19	910	108

PARIETTE SPECIAL TAR SAND AREA

By G. E. Pyper

Location

The Pariette Special Tar Sand Area covers about 35 square miles in Duchesne and Uintah Counties in the southern Uinta Basin, about 10 miles south of Myton (fig. 10). Land-surface altitudes decrease northeastward across the area from about 8,000 feet to less than 4,600 feet at the mouth of Pariette Draw. The proven or inferred tar-sand deposits underlie parts of townships 8 to 9 south and ranges 16 to 19 east, Salt Lake base line and meridian, and part of townships 4 to 5 south and ranges 2 west to 2 east, Uintah meridian. About 7 of the approximately 35 square miles of area are available for lease, and all unleased tracts are owned by the Federal Government. The tar-sand deposits in the Pariette area contain an estimated reserve of 12 to 15 million barrels of oil in place (table 1) in the Uinta Formation, with 0 to 300 feet of overburden (Ritzma, 1979, sheet 2).

Climate

The climate in and near the area is influenced by regional and local topographic features and generally is arid to semiarid, with low relative humidity, abundant sunshine, low to moderate precipitation, hot summers, and cold winters. The high altitudes to the southwest of the area are cool and semihumid, with annual precipitation of 18 to 20 inches (fig. 10). The low altitudes in the northeast are warmer, with annual precipitation averaging 6 inches or less. During the summer, the Roan Cliffs about 65 miles south, and the Wasatch Plateau, about 80 miles southwest, are orographic barriers for moisture moving north from the Gulf of Mexico or the Gulf of California. The Wasatch Range, about 90 miles to the west, is the orographic barrier for winter moisture moving east from the Pacific Ocean. Normal annual air temperature ranges from 39°F at the higher altitudes to 46°F at Duchesne and 48°F at Ouray, at altitudes of 5,510 and 4,860 feet above sea level, respectively. Normal annual pan evaporation at Fort Duchesne (5 miles northwest of Randlett), about 16 miles northeast of the area at an altitude of 4,990 feet, is 51 inches. The corresponding value, 50 miles southeast in the P R Spring Area at an altitude of 7,900 feet, is 50 inches. Although evaporation shows little variance, other climatic characteristics vary considerably. Selected climatic characteristics were reported for precipitation by the U.S. Weather Bureau (1963), air temperature by the National Oceanic and Atmospheric Administration (1973), and pan evaporation by Cruff and Thompson (1967, p. 19) and the U.S. Weather Bureau (1957).

Water Resources

The area lies within the Pariette Draw drainage; Pariette Draw is a tributary to the Green River. The surface drainage at the higher altitudes of the basin is north-northeast, but most of the basin drains to the east. Water is imported into the Pariette Draw drainage from the Duchesne River basin via the Grey Mountain and Pleasant Valley Canal system. Ground water generally moves north to the Duchesne River, east toward the Green River (Price and Miller, 1975, p. 29), and southeast in the bottoms of stream drainages.

Surface Water

Streamflow data available for sites within the Pariette Special Tar Sand Area were collected at two continuous-record stations and one peak-flow station. A summary of these data and other streamflow records for selected sites in and near the area is shown in table 10. A major source of water to the area is from the Duchesne River via the Grey Mountain and Pleasant Valley Canal system. According to annual reports of the Duchesne River Commissioner, Pleasant Valley Wash and Pariette Draw, both perennial streams in their lower reaches, import an estimated 44,000 acre-feet annually of water from the Duchesne River through the Upper and Lower Pleasant Valley Canals. On Pariette Draw and its tributaries, there is considerable storage in small reservoirs, water-fowl management areas, and facilities for storing imported water. The largest impoundment is Lamb Reservoir, with a surface area of about 150 acres. Streamflow leaving the area, measured at station 09307300, Pariette Draw at mouth, near Ouray, averages 14,780 acre-feet annually (table 10, figs. 11 and 12) and shows typical year-to-year and monthly variations in flow. Price and Miller (1975, p. 27), however, reported that return flow from irrigation could average as much as 30 percent of the imported water.

There are numerous small ephemeral or intermittent streams in and near the area. A typical example of peak flow is the 2,590 cubic feet per second (table 10), which was recorded at station 09308200, Pleasant Valley Wash tributary near Myton. The flow of 2,590 cubic feet per second has a recurrence interval of 5 years (Price and Miller, 1975, p. 19).

Water imported from the Duchesne River generally is degraded in chemical quality by the time it returns to the Green River by way of Pariette Draw. At station 09295000, Duchesne River at Myton, the maximum concentration of dissolved solids was 1,810 milligrams per liter, and the principal dissolved constituents were sulfate, sodium, and bicarbonate (table 11). The water entering Pariette Draw is of similar quality. Water in the lower reaches of Pariette Draw, however, contained the same major dissolved constituents but had a maximum concentration of dissolved solids of 4,190 milligrams per liter. The increase in concentration of dissolved solids is attributed to return flow from irrigation and concentration by evapotranspiration.

Ground Water

Shallow unconfined aquifers in the unconsolidated deposits underlying Pleasant Valley receive a considerable amount of recharge from imported irrigation water (Price and Miller, 1975, p. 28). Cruff and Hood (1976, p. 28-29) found a net loss of water in the Grey Mountain--Pleasant Valley Canal system which averaged 8 percent during seepage studies made during 1972-73. According to Price and Miller (1975, p. 28), some of this water is lost to evapotranspiration and some percolates to the water table.

Wells completed in the upper 150 feet of unconsolidated deposits and in the Uinta Formation (table 12) have yields ranging from 3 to 60 gallons per minute, with concentrations of dissolved solids ranging from 116 to 4,480 milligrams per liter (table 13) and chloride concentrations ranging from 1 to 91 milligrams per liter.

Water with a dissolved-solids concentration of 29,900 milligrams per liter was withdrawn from unconsolidated deposits at well U(C-4-2)15bcd-1. This suggests interformational leakage, however, because the chloride concentration was 573 milligrams per liter, which compares with a range of about 7,000 to 49,000 milligrams per liter of chloride from deep wells in the Green River Formation. According to Price and Miller (1975, p. 29), low permeability, which leads to slow movement of ground water and consequently lengthy duration of contact with rocks, contributes to large concentrations of dissolved solids. They also report (p. 39), however, that there is no clear correlation between the chemical type of ground water and the geologic source of the water in the southern Uinta Basin.

Existing Water Use

All water in the Pariette Special Tar Sand Area is fully appropriated by existing rights; thus, water rights for a tar-sand industry would have to be purchased or leased. There are a number of applications for water rights for proposed energy development in nearby areas.

Little water is used for domestic or public supply within the Pariette Special Tar Sand Area. Outside the area, however, water use by nearby communities totals about 300 million gallons per year. Myton, about 10 miles north, uses 72.5 million gallons; Ouray, about 11 miles east, uses 19.5 million gallons; and Duchesne, about 25 miles northwest, uses 207.3 million gallons (Hooper, 1981). Water imported from the Duchesne River for irrigation brings an estimated 44,000 acre-feet per year into the area. It is not known how many of the 11,000 acres of land classified as arable in and near the area are irrigated.

Hydrologic Impacts Unique to This Area

A tar-sand industry is not projected for the Pariette Special Tar Sand Area where the inplace reserves of oil are only 12 to 15 million barrels (table 1). If a commercial production level of 5,000 barrels per day of oil were developed, however, the annual water requirement would be about 1,200 acre-feet, which is a minimal amount of the surface- and ground-water resources of the area. A potential hydrologic impact, if the 1,200 acre-feet were diverted from Pariette Draw, might be an increase in the concentration of dissolved solids of the flow at station 09307300. Other potential impacts that generally apply to all areas are discussed in the section "Hydrologic impacts of a tar-sand industry," near the end of this report.

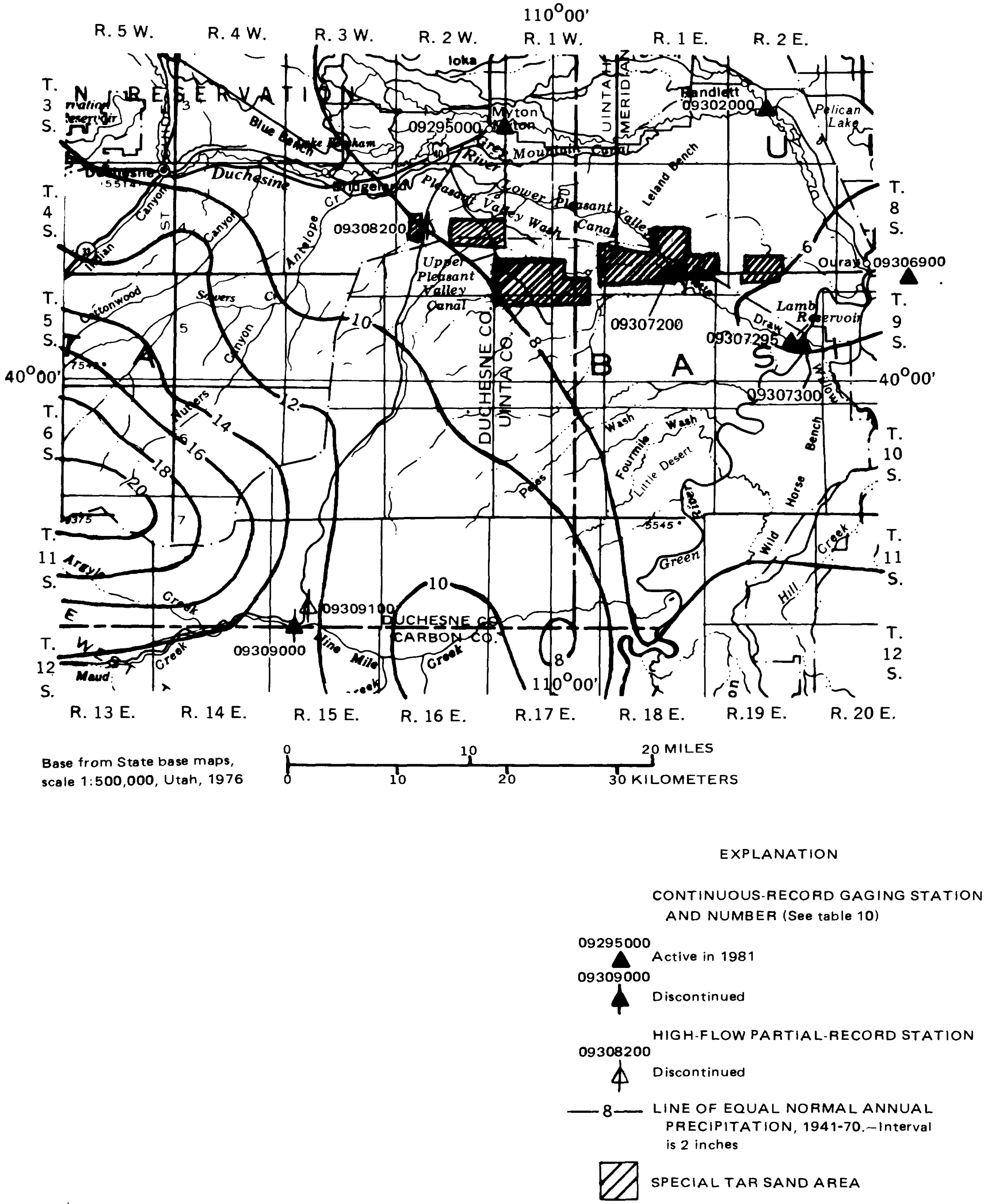

Figure 10.—Normal annual precipitation and location of stream-gaging stations in and near the Pariette Special Tar Sand Area. Precipitation from Price and Miller, 1975, pl. 1.

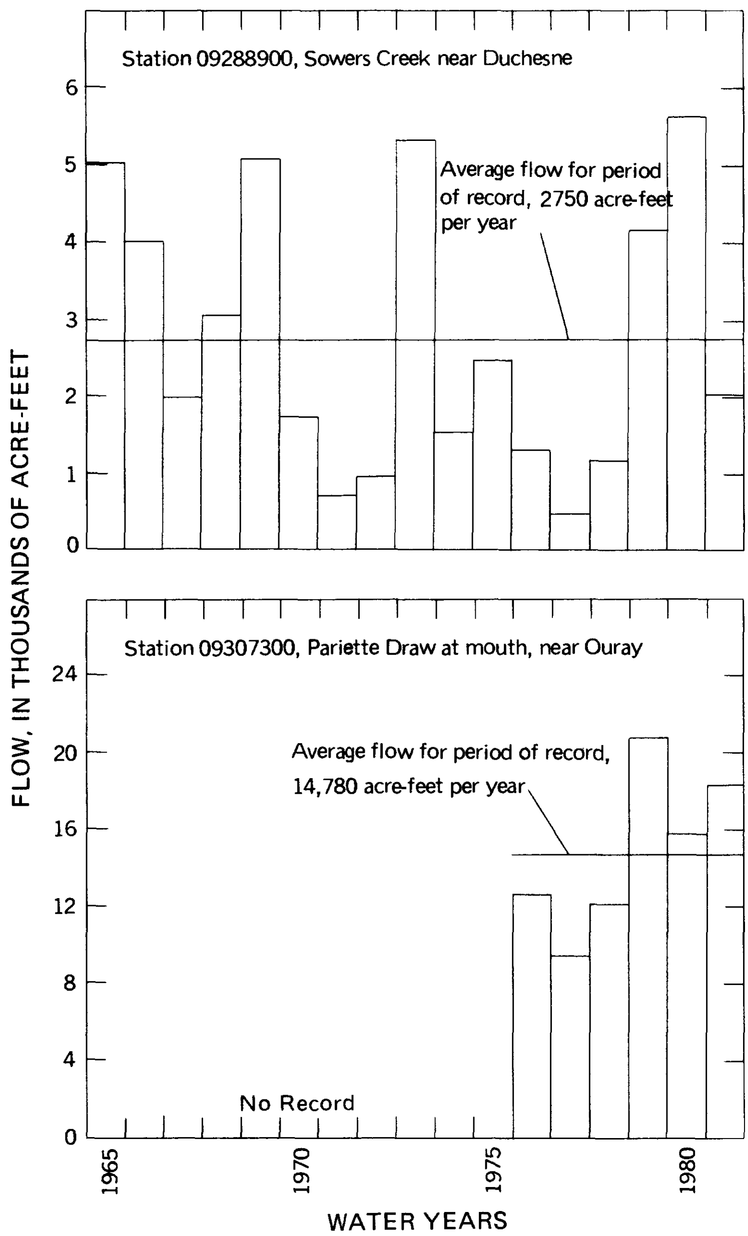

Figure 11.—Annual flow at two gaging stations in and near the Pariette Special Tar Sand Area.

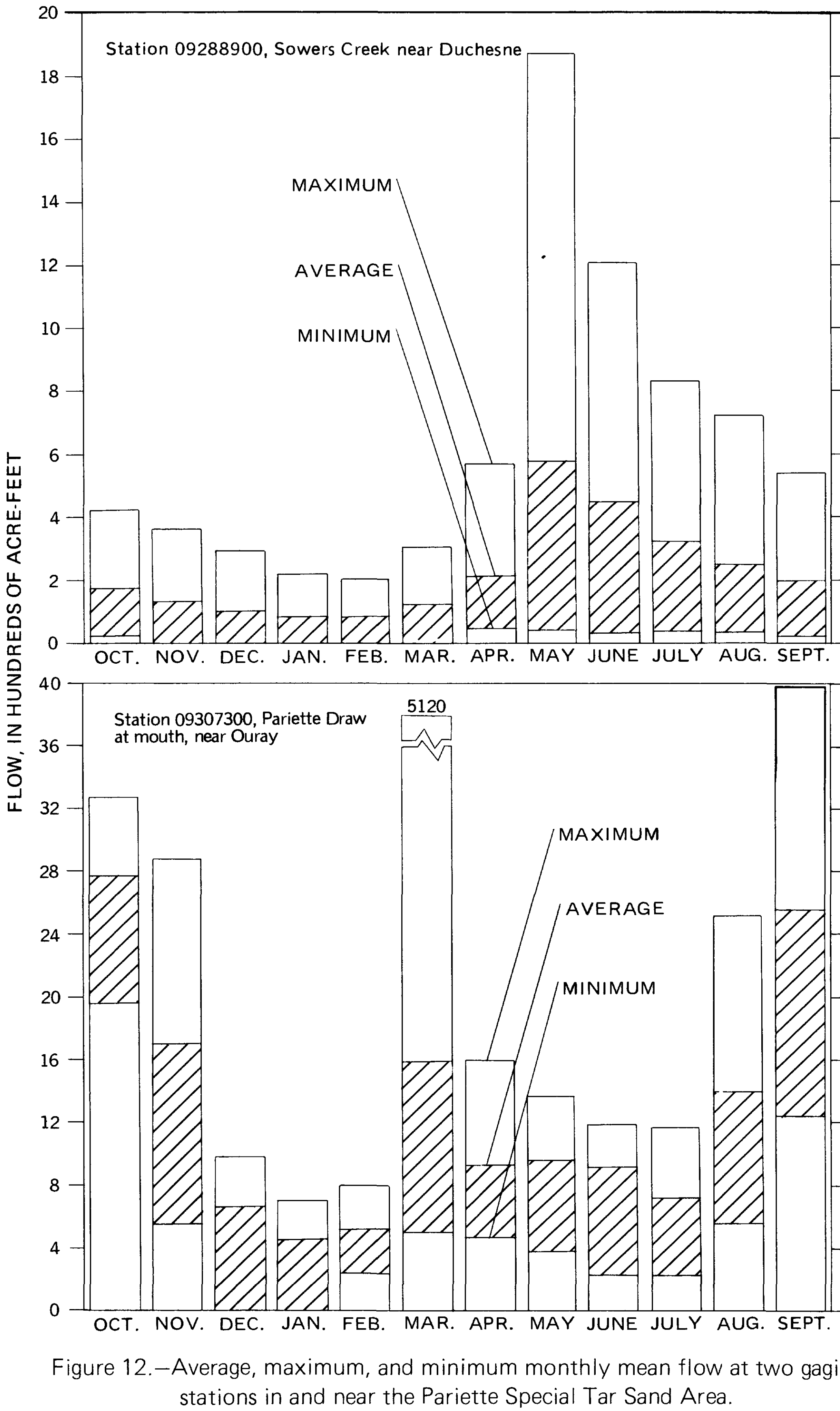

Figure 12.—Average, maximum, and minimum monthly mean flow at two gaging stations in and near the Pariette Special Tar Sand Area.

Table 10.—Streamflow at selected gaging stations in and near the Pariette Special Tar Sand Area

Station number and name		Period of record used (water years)	Drainage area (square miles)	Average flow		Flow (cubic feet per second)	
				Cubic feet per second	Acre-feet per year	Minimum	Maximum
09288180[1]	Strawberry River near Duchesne	1969-81	917	125	90,560	17	1,310
09288500[1]	Strawberry River at Duchesne	1915-68	950	151	109,300	1.0	3,490
09288900[1]	Sowers Creek near Duchesne	1965-81	40.6	3.80	2,750	0	350
09295000	Duchesne River at Myton	1900-02, 1912-81	2,643	503	364,400	<1	12,800
09302000	Duchesne River near Randlett	1943-81	4,247	550	398,500	2.2	10,300
09306900	White River at mouth, near Ouray	1975-81	5,120	632	457,900	1.6	4,260
09307200	Pariette Draw near Ouray	1976-81	153	24.9	18,040	30	626
09307295	Lambs Diversion from Pariette Draw, near Ouray	1979-81	—	1.6	1,180	0	18
09307300	Pariette Draw at mouth, near Ouray	1976-81	298	20.4	14,780	0	450
09308200	Pleasant Valley Wash tributary near Myton	1960-73[2]	15	—	—	0	2,590
09308500[1]	Minnie Maud Creek near Myton	1951-55, 1958-81	32.0	5.03	3,640	0	>1,370
09309000	Minnie Maud Creek at Nutter Ranch, near Myton	1948-55, 1960-73[2]	231	20.4	14,770	0	1,380
09309100	Gate Canyon near Myton	1960-72[2]	5.4	—	—	0	1,000
09314500[1]	Price River at Woodside	1910, 1946-81	1,540	103	74,620	0	9,720
09315000[1]	Green River at Green River	1965-81	44,850	5,735	4,152,000	834	30,500

[1] Not located in figure 10.
[2] Annual maximum only.

Table 11.—Concentrations of major dissolved constituents and suspended sediment of streamflow for sites in and near the Pariette Special Tar Sand Area

Station number and name	Period of record used (water years)		Concentration (milligrams per liter)								
			Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)	Suspended sediment
09288180[1] Strawberry River near Duchesne	1973-82	Maximum	548	57	38	99	4.3	34	110	458	—
		Minimum	442	19	35	75	2.0	25	93	257	—
		Number of samples	5	5	5	5	5	5	5	5	—
09288500[1] Strawberry River at Duchesne	1942-74	Maximum	629	66	43	131	5.9	63	183	430	—
		Minimum	265	19	19	16	0	5.8	33	176	—
		Number of samples	68	92	92	75	69	105	103	106	—
09288900[1] Sowers Creek near Duchesne	1972-82	Maximum	879	88	79	100	7.3	13	350	458	—
		Minimum	635	75	56	63	4.7	9.1	190	403	—
		Number of samples	5	5	5	5	5	5	5	5	—
09295000 Duchesne River at Myton	1942-82	Maximum	1,810	139	81	322	12	112	1,130	354	—
		Minimum	18	3.4	1.3	.2	0	0	4.8	13	—
		Number of samples	77	71	71	63	60	79	79	81	—
09302000 Duchesne River near Randlett	1951-82	Maximum	3,330	228	196	709	13	545	1,670	920	2,190
		Minimum	42	27	0	0	1.1	7.5	15	99	11
		Number of samples	558	387	387	619	352	712	712	673	75
09306900 White River at mouth, near Ouray	1975-82	Maximum	1,180	94	47	230	6.7	86	570	400	51,700
		Minimum	197	31	4.8	18	1.2	6.9	51	132	3.0
		Number of samples	113	120	120	120	120	120	120	97	149
09307200 Pariette Draw near Ouray	1976-82	Maximum	4,220	260	140	1,000	5.5	270	2,500	454	7,400
		Minimum	1,210	86	19	230	.3	22	610	250	38
		Number of samples	72	72	72	73	72	73	73	30	67
09307300 Pariette Draw at mouth, near Ouray	1976-82	Maximum	4,190	240	130	940	9.7	210	2,500	556	953
		Minimum	1,240	83	49	240	1.6	46	680	250	18
		Number of samples	74	73	73	74	73	74	74	39	58
09314500[1] Price River at Woodside	1949, 1951-82	Maximum	7,060	550	421	1,430	124	274	4,700	1,450	69,600
		Minimum	592	50	0	65	1.4	0	0	40	8
		Number of samples	772	515	515	815	487	920	921	898	76
09315000[1] Green River at Green River	1965-82	Maximum	3,160	507	150	135	7.0	70	2,000	382	39,900
		Minimum	196	29	10	19	.6	6.2	60	107	17
		Number of samples	247	360	358	291	196	359	358	328	207
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 206)			500	—	—	—	—	250	250	—	—

[1] Not located in figure 10.

Table 12.—Generalized stratigraphic section of lithologic units discussed in the text for the Pariette Special Tar Sand Area

[Data from Price and Miller (1975, table 1).]

System	Series	Geologic unit	Thickness (feet)	Symbol	Description
Quaternary	Pleistocene and Holocene	Unconsolidated deposits	0-50 Locally, may be more than 150 feet	Qa	Alluvium, glacio-fluvial deposits, terrace gravels, and dune sand. Clay, sand, gravel, and cobbles beneath the alluvial plains of the larger streams and adjacent terraces and in the Pleasant Valley Wash area.
Tertiary	Eocene	Uinta Formation	1,200-1,500 ([1])	Tu	Mostly thinly bedded shale, siltstone, and fine-grained sandstone with interbedded claystone and limestone. Tar-sand deposits in the Pariette area are in this formation.
	Paleocene and Eocene	Green River Formation	4,500-6,500 ([1])	Tg	Thinly bedded strata of shale, siltstone, mudstone, and fine-grained sandstone; some limestone and tuff. Formation is noted as source of oil and gas. Parachute Creek Member contains extensive deposits of oil shale.

[1] Thickness from Campbell and Bacon, 1976, pl. 1.

Location: See explanation in text for numbering system for wells and springs.
Geologic unit: Principal water-bearing unit; see table 12 for explanation of symbols.
Altitude of land surface: Altitudes from most detailed topographic maps; National Geodetic Vertical Datum of 1929.
Depth to water: Above (+) or below land-surface datum.

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			WELLS				
(D-9-16) 5ddb-1	Tg	5,810	5,815	3-20-68	—	—	4,602-5,747
15cbb-1	Tg	5,835	5,560	3-20-68	—	—	4,440-5,180
(D-9-17) 21dca-1	Tu	5,295	22	9- 3-71	—	3	—
U(C-4-1) 7ccb-1	Qa	5,182	36	4- -49	16	12	—
13dad-1	Tg	4,942	5,400	4-10-69	—	—	5,140-5,306
	Tg			4-10-69	—	—	4,020-4,080
17ccc-1	Tu	5,188	25	3- -51	10	30	—
18dcc-1	Qa	5,185	80	4- -45	15	60	—
28aba-1	Tu	5,155	150	10- -48	20	15	—
U(C-4-2) 2cda-1	Tu	5,295	700	8- -52	25	25	—
5abb-1	Qa	5,180	23	4- -45	8	20	—
5bba-2	Qa	5,185	40	5-22-72	1.8	—	—
13daa-2	Tu	5,195	28	5- 7-72	16.7	20	—
14bbb-1	Tu	5,237	65	12- -54	24	8	—
14bbc-1	Qa	5,245	80	11- -57	10	10	—
15bcd-1	Qa	5,270	—	6-14-62	—	—	—

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
WELLS							
—	—	—	—	—	49,128	—	—
—	—	—	—	—	6,941	—	—
1,600	20	16	510	2.2	91	720	467
—	—	—	—	—	—	—	—
44,300	22	20	17,260	174	25,000	584	2,086
60,530	17	<1.0	23,840	151	34,000	102	4,355
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
116	23	5.0	8.0	2.0	1.0	29	79
—	—	—	—	—	—	—	—
4,480	400	230	620	3.9	84	2,900	414
769	95	34	110	3.7	21	280	411
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
29,900	801	973	7,540	21	573	20,460	375

ARGYLE CANYON--WILLOW CREEK AND SUNNYSIDE SPECIAL TAR SAND AREAS

By Willis Dorman-Ligh

Location

The Argyle Canyon--Willow Creek and Sunnyside Special Tar Sand Areas cover about 280 square miles in five counties and three physiographic areas (fig. 13): (1) Utah, Wasatch, and Duchesne Counties, on the Argyle Ridge in the west part of the southern Uinta Basin; (2) Duchesne and Carbon Counties, on the West Tavaputs Plateau in the southwest part of the southern Uinta Basin; and (3) Carbon County in the Price River basin. The surface of the southern Uinta Basin ascends rather uniformly from an altitude of about 4,700 feet above sea level near the confluence of the Green, White, and Duchesne Rivers to more than 9,000 feet along the Argyle Ridge and Roan Cliffs. Thence to the southeast, altitudes decrease to about 4,200 feet at the confluence of the Price and Green Rivers. Altitudes in the Price River basin range from more than 9,000 feet in the headwaters about 25 miles west of Price between Pleasant and Huntington Creeks and on the Roan Cliffs in the northeast part of the basin to about 4,200 feet at the mouth.

Proven or inferred tar-sand deposits underlie all or parts of townships 11 to 15 south and ranges 9 to 17 east, Salt Lake base line and meridian, and townships 6 to 7 south, ranges 5 to 9 west, Uintah meridian.

The tar sands in the Argyle Canyon--Willow Creek Special Tar Sand Area are in the Green River Formation, but in the Sunnyside Special Tar Sand Area they are in the Wasatch and Green River Formations (Ritzma, 1979, sheet 2). At Sunnyside, the tar-sand deposit is more than 1,000 feet thick, but it thins to the south (Banks, 1981, p. 8). Campbell and Ritzma (1979, p. 15) estimate a 75-percent reduction in the thickness of the tar-sand deposit in as little as 1.5 miles east of the main outcrop. About 46 square miles of the approximately 280 square miles of area are available for lease. The estimated oil in place for the Argyle Canyon--Willow Creek and Sunnyside Special Tar Sand Areas totals about 4 billion barrels.

Climate

Topography and geographic location relative to the prevailing west-to-east storm track are the major factors that affect the climate of the area. The Wasatch Range, Wasatch Plateau (about 30 miles west of Price), and Argyle Ridge are orographic barriers for winter moisture moving east from the Pacific Ocean. In the summer, however, the Wasatch Plateau and Roan Cliffs are orographic barriers for moisture moving north from either the Gulf of Mexico or the Gulf of California.

The climate and precipitation vary with altitude. Above 8,000 feet, the climate is subhumid to humid, and the precipitation is greater than at lower altitudes where the climate is arid to semiarid. Normal annual precipitation ranges from about 10 inches in the eastern part of the area to more than 20 inches in the extreme west part (fig. 13). In the Price River basin, normal annual precipitation ranges from 8 inches in the southeast part to more than

30 inches in the extreme northwest part (Mundorff, 1972, pl. 2), with more than 20 inches at high altitudes along the northeast side. Precipitation generally is less above 7,000 feet along the northeast side of the Price River basin than it is at similar altitudes in the west or headwaters part of the basin (Mundorff, 1972, p. 6). Most of the precipitation in the lower altitudes of both basins comes from thunderstorms during the late summer months. During the period October-April, however, most of the precipitation comes from snowfall at altitudes greater than 6,000 feet (Mundorff, 1972, p. 6). Seasonal and daily variation in temperature is large throughout both the southern Uinta and Price River Basins, which have hot summers and cold winters. Mean annual air temperatures range from $35^{\circ}F$ at the higher altitudes to about $50^{\circ}F$ at altitudes below 6,000 feet. Normal annual free-water surface evaporation is between 35 and 40 inches per year in both basins (Farnsworth and others, 1982, map 3).

Water Resources

The southern Uinta Basin and the Price River basin drain to the Green River, either directly or through major tributaries such as the Strawberry and Duchesne Rivers. All the rivers receive runoff from smaller perennial tributaries and numerous intermittent and ephemeral tributaries.

In the southern Uinta Basin, ground water generally moves north to the Strawberry and Duchesne Rivers and east toward the Green River, with local components of movement toward the larger tributary streams (Price and Miller, 1975, p. 29). In the Price River basin, ground-water flow is generally east.

Surface Water

Major streams in and near the area are the Green, Strawberry, and Duchesne Rivers, and West Fork of Avintaquin, Nine Mile, Minnie Maud, Argyle, and Range Creeks in the southern Uinta Basin; and the Price River and Willow, Grassy Trail, and Icelander Creeks in the Price River basin. Records for streamflow in the area are given in table 14.

Many of the streams are intermittent or ephemeral, and even the Price River has been dry in its lower reaches sometime during the period of record. Many of the perennial tributaries to the Strawberry, Green, and Price Rivers become intermittent as they flow across areas receiving 14 inches or less of annual precipitation. Diversion for irrigation and evapotranspiration depletes the flow, and there is no net gain in average flow in the lower reaches of these streams.

The average flow in streams tributary to the Price, Strawberry, and Green Rivers is highly variable, in wet years being three or more times greater than during dry years. This is shown in figure 14 for two representative streams. Most of the flow comes from snowmelt during spring and early summer (fig. 15). During late summer, however, cloudbursts account for a large percentage of the total flow.

The flow in the lower reaches of the Strawberry, Duchesne, and Price Rivers is controlled by regulation. The daily flow of the Green River from Ouray to the Price River does not vary much from one location to another. The flows of these larger rivers, however, do vary appreciably monthly and annually.

Scofield Reservoir (about 20 miles northwest of Price), with a capacity of 74,000 acre-feet (Utah Department of Natural Resources, 1975a, p. 9), on the upper Price River is the only large source of surface-water storage within 20 miles of the area. Whitmore Canyon Reservoir (shown as Grassy Trail Reservoir on the Sunnyside 7.5-minute quadrangle), at the confluence of the Right and Left Forks of Whitmore Creek (about 4 miles north of Sunnyside), has a capacity of about 700 acre-feet and supplies water to the town of Sunnyside and the mines.

Water-quality data for the major streams in and near the area are shown in table 15. The chemical quality of the tributary streams generally deteriorates downstream, except during periods of high runoff (Price and Miller, 1975, p. 37). The average concentration of dissolved solids ranges from about 200 to 500 milligrams per liter in the upper reaches of some streams to about 200 to 10,000 milligrams per liter in the lower reaches. The higher concentrations are attributed to inflow of saline ground water, to return flows from irrigation, to domestic and livestock waste, to industrial operations, and to concentration by evapotranspiration. In general, the principal dissolved constituents in water in the upper reaches are bicarbonate and calcium; whereas in the lower reaches they are bicarbonate, sodium, and sulfate.

In the upper Price River basin, water samples obtained at station 09312800, Willow Creek near Castle Gate (about 5 miles upstream from the mouth), and at station 09312900, Willow Creek at Castle Gate, showed no change in water quality or water type. According to Mundorff (1972, p. 13), these data indicate that the chemical characteristics of the water in Willow Creek are determined by the characteristics of the upper part of the basin. In the lower Price River basin, the range of dissolved solids is markedly greater in the upper reaches of the streams than it is in the lower reaches. As streams cross the Mesaverde Group and Mancos Shale, they dissolve greater concentrations of sulfates and alkali salts (sodium) (Osterwald and others, 1981, p. 60). Some increases also result from return flow of water used for irrigation. In addition, discharge from mines can affect the water quality. During 1976, dissolved-solids concentrations in Grassy Trail Creek upstream and downstream from the Sunnyside Mine ranged from 250 to 451 milligrams per liter at the upper site and from 1,250 to 2,000 milligrams per liter at the lower site (Waddell and others, 1981, p. 27).

Dissolved-solids concentrations in the Price River increase downstream but remain essentially constant in the central and lower reaches (table 15). This suggests that the chemical quality in the lower basin results mainly from the central-basin environment (Mundorff, 1972, p. 32).

The chemical quality of the water that enters the Green River between Ouray and Green River, Utah generally is relatively poor. The inflow, however, is small compared to the large quantity of flow in the Green River; thus, the inflow causes only a slight increase in the concentration of dissolved solids (Austin and Skogerboe, 1970, p. 100) recorded at Green River, Utah (table 15).

Little suspended-sediment data are available for the smaller tributary streams in the area. However, about 25 percent of the capacity of Whitmore Canyon Reservoir has been depleted by sedimentation. Large variations in suspended-sediment concentration occur during short periods on tributaries and along the main stem of the Price River, and concentrations at a particular location can range from a few hundred to more than 100,000 milligrams per liter (Mundorff, 1972, p. 37-38). Most of the sediment that is discharged by the Price River into the Green River comes from the central and lower parts of the Price River basin (Mundorff, 1972, p. 38). Suspended-sediment concentrations measured for the Duchesne River near Randlett during 1951-82 ranged from 11 to 2,190 milligrams per liter, and for the Green River at Green River during 1965-82 the range was from 17 to 39,900 milligrams per liter.

Concentrations of dissolved trace elements in and near the area (table 16) are mostly less than the maximum concentrations recommended by the U.S. Environmental Protection Agency (1977, p. 96) for public-water supply. In the southeastern Uinta Basin, concentrations increase in a downstream direction with some temporal variance (Lindskov and Kimball, 1982, p. 138). The concentrations of boron in streamflow in the southern Uinta Basin range from 0.1 to 10 milligrams per liter, with the boron content becoming more concentrated as the flow is depleted by evapotranspiration (Price and Miller, 1975, p. 41). In the Price River basin, the concentrations of boron, lithium, and strontium generally increase downstream in quantities proportional to the increase of dissolved solids in the streams (Waddell and others, 1981, p. 28). Dissolved trace elements in the Green River are relatively constant (Lindskov and Kimball, 1982, p. 135).

Ground Water

The rocks exposed in and near the area range in age from Cretaceous to Holocene (table 17). This sequence is about 10,000 feet thick, it generally dips 5° northward (Feltis, 1966, p. 9), and it represents deposition in continental (fluvial and lacustrine) and marine environments. Unconsolidated sediments of Quaternary age cover large areas, but they are not areally continuous, and some are thin and dry (Osterwald and others, 1981, p. 7).

Selected well and spring data for the area are given in table 18. Yields of wells generally are small, and the water from many of the wells is saline. Price and Miller (1975, p. 29) state that the rate of ground-water movement is slow in most places because of the generally poor permeability of the rocks. This slow rate of movement, which allows longer periods of contact between the water and soluble rock minerals, contributes to the low yields of wells and the highly mineralized water.

The alluvium in the larger streams in the southern Uinta Basin may yield more than 100 gallons per minute to wells, but these deposits are thin and of small extent (Price and Miller, 1975, p. 10). In the Price River basin, Whitmore Spring, the source of Icelander Creek, yields more than 200 gallons per minute from fan deposits at the mouth of Whitmore Canyon. According to Waddell and others (1981, p. 27), the discharge from Whitmore Spring, (D-15-13)1ddc-S1, probably reflects seepage from Grassy Trail Creek into the alluvium near the canyon mouth. A few wells in surficial material contain fresh water, mostly at the crest of the Roan Cliffs. The dissolved-solids concentration in the ground water increases with depth. Thus even at higher altitudes, where fresh water may be obtained from springs and shallow wells, deep aquifers are likely to contain saline water (Price and Miller, 1975, p. 38).

Data from table 18 and Keefer and McQuivey (1979, p. 164) indicate well yields of 40 gallons per minute from the Green River Formation and 55 gallons per minute from the Wasatch Formation in the area. Water from springs and water wells that discharge from the Green River Formation have dissolved-solids concentrations ranging from 190 to 3,580 milligrams per liter, and the principal dissolved constituents are calcium or sodium and sulfate and bicarbonate. Samples from oil and gas wells had dissolved-solids concentrations ranging from 619 to 31,400 milligrams per liter. In a well that penetrated intertonguing Green River and Wasatch Formations below 4,150 feet, a drill-stem test produced water with dissolved-solids concentrations in the range of 35,600 milligrams per liter. The principal dissolved constituents were sodium, chloride, and sulfate.

Outside the area, two wells drilled in the Colton area (about 20 miles northwest of Price) have been pumped at rates exceeding 1,000 gallons per minute from the Flagstaff Limestone and North Horn Formation (Cordova, 1964, p. 13, 15). The water is fresh. According to Keefer and McQuivey (1979, p. 164), an oil and gas test in the area produced 4 to 8 gallons per minute of fresh water from the North Horn Formation and 25 to 30 gallons per minute from the Price River Formation.

Spring water from the Flagstaff Limestone (table 18) and the North Horn, Price River, and Blackhawk Formations contains dissolved-solids concentrations averaging about 500 milligrams per liter, and the principal dissolved constituents are calcium, magnesium, and bicarbonate. Water discharging in the Sunnyside Mine from the Blackhawk Formation has a dissolved-solids concentration of about 1,600 milligrams per liter. In this area of the Book Cliffs, the Mancos Shale commonly intertongues with the Blackhawk, and water in the Mancos is highly mineralized. This probably accounts for the poor quality of the water discharging from the mine (Waddell and others, 1981, p. 41).

In wells outside the area, samples believed to be representative of water in the Ferron Sandstone Member of the Mancos Shale had dissolved-solids concentrations ranging from 652 to 1,230 milligrams per liter. The principal constituents were sodium, sulfate, and bicarbonate (Waddell and others, 1981, p. 41, 42). The largest source of recharge for the Ferron Sandstone Member is subsurface flow from the Wasatch Plateau, most of which is transmitted through a permeable fracture zone near the eastern edge of southern Castle Valley (about 20 miles southeast of Price) (Lines and Plantz, 1981, p. 5).

Existing Water Use

The Argyle Canyon--Willow Creek and Sunnyside Special Tar Sand Areas are within Water Rights Areas 47 and 91 (Utah Division of Water Rights, 1974). All water within the areas is fully appropriated by existing rights (Dorothy Boulton and LaMond Gardner, Utah Division of Water Rights, oral commun., 1982), therefore, water rights would have to be purchased or leased for a tar-sand industry. Water in the area is used primarily for irrigation and livestock. Nearby, domestic and boiler water for the town of Sunnyside and for electric power in the nearby mines is obtained from a dam and reservoir (Whitmore Canyon Reservoir), built in 1952, in the upper part of Whitmore Canyon, on Grassy Trail Creek (Osterwald and others, 1981, p. 60). Outside the area, in the headwaters of the Price River, 6,000 acre-feet of ground water are obtained mostly from springs and seeps for culinary use for the towns of Price and Helper and for livestock (Utah Department of Natural Resources, 1975a, p. 12). Scofield Reservoir to the northwest is a source of surface water used mainly for irrigation in the vicinity of Price.

Hydrologic Impacts Unique to This Area

A shift in the allocation of water rights would be required to meet the water needs for anything from a pilot to a "high" commercial tar-sand industry in the Argyle Canyon--Willow Creek and Sunnyside Tar Sand Areas. The water requirement of 2,500 acre-feet per year for a 10-thousand barrel pilot tar-sand industry (table 1) could be met by the storage of water from major streams that head or flow through the area. The water requirement of 37,390 acre-feet per year for a "high" commercial tar-sand industry would require that additional water would have to be pumped from the Price River, at a considerable distance from the tar-sand deposits and from a much lower altitude. According to Keefer and McQuivey (1979, p. 158), however, during dry years the flow in the Price River would be insufficient to meet the water requirements. For example, the flow at station 09314250 near Wellington in 1976 was only 30,250 acre-feet, considerably less than the 37,390 acre-feet required to meet the needs of a "high" commercial tar-sand industry. Flow in the Strawberry and Green Rivers would be sufficient to meet these needs, however, both are still farther from the deposits than is the Price River.

Supplemental water requirements for any type of tar-sand industry might be met by using ground water. If additional quantities are pumped from wells, however, it is possible that water may be diverted from existing spring discharge or streamflow. Other potential impacts that generally apply to all areas are discussed in the section "Hydrologic impacts of a tar-sand industry," near the end of this report.

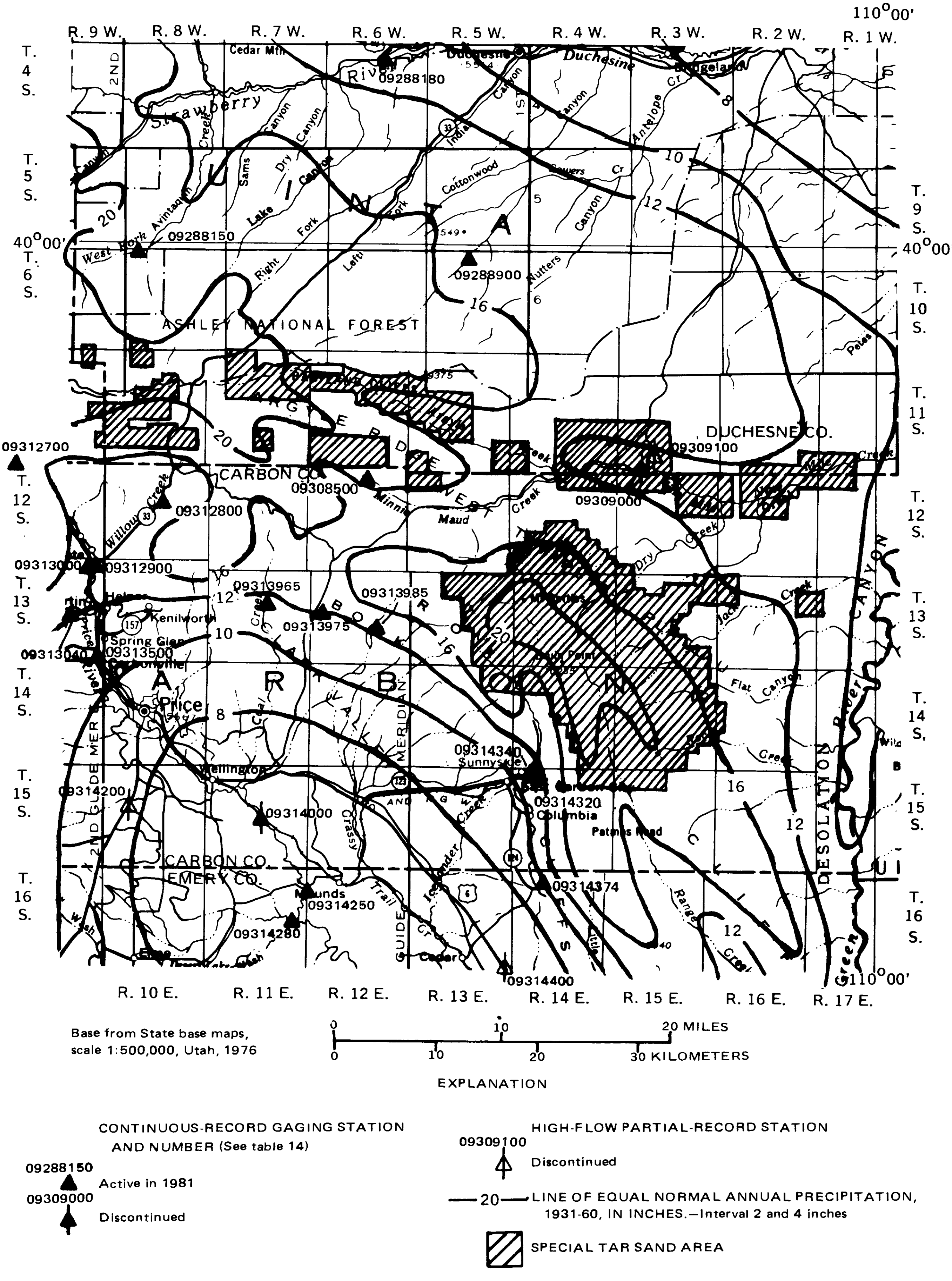

Figure 13.—Normal annual precipitation and location of stream-gaging stations in and near the Argyle Canyon - - Willow Creek and Sunnyside Special Tar Sand Areas. Precipitation from U. S. Weather Bureau, 1963.

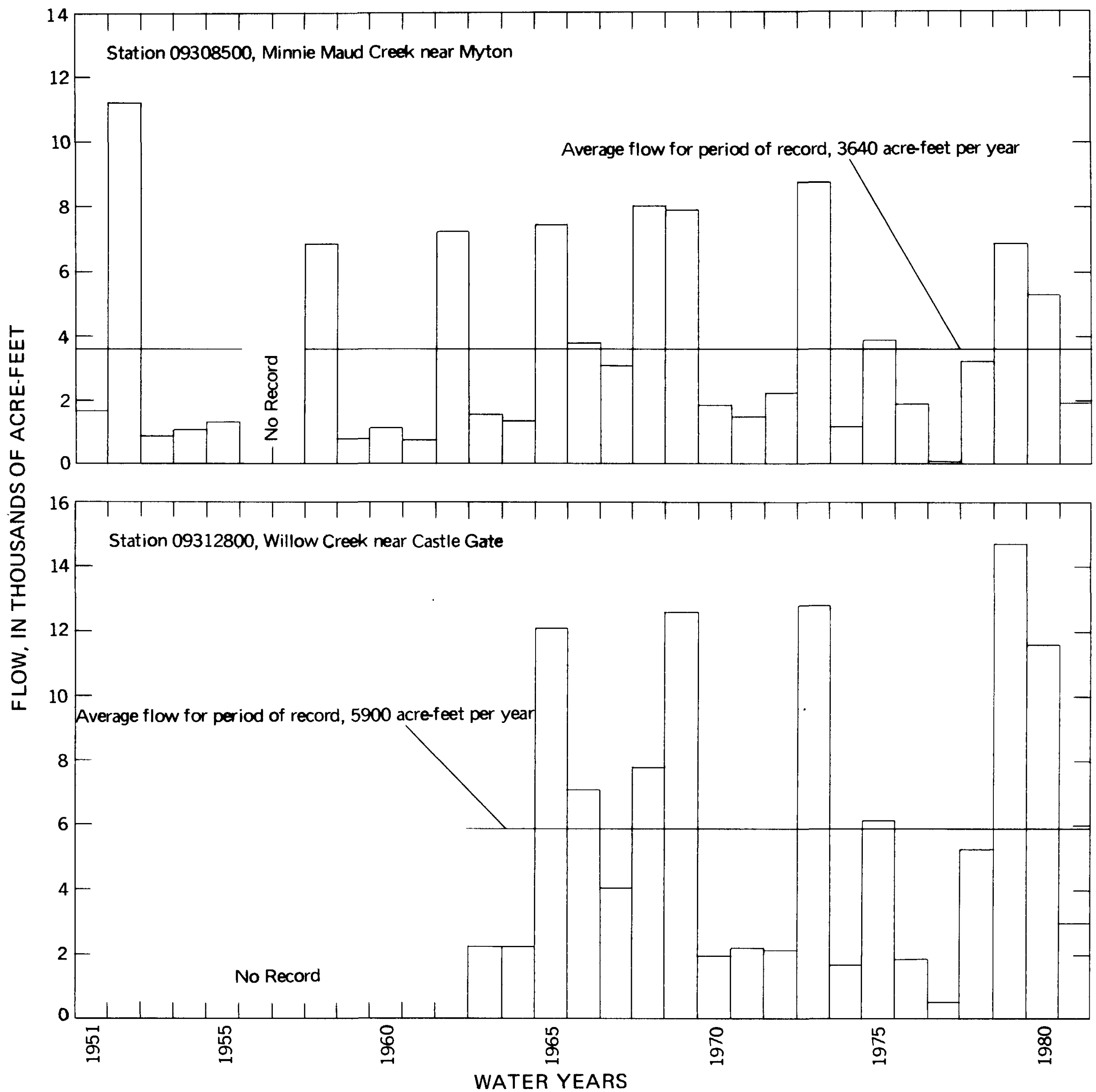

Figure 14.—Annual flow at two gaging stations in and near the Argyle Canyon - - Willow Creek and Sunnyside Special Tar Sand Areas.

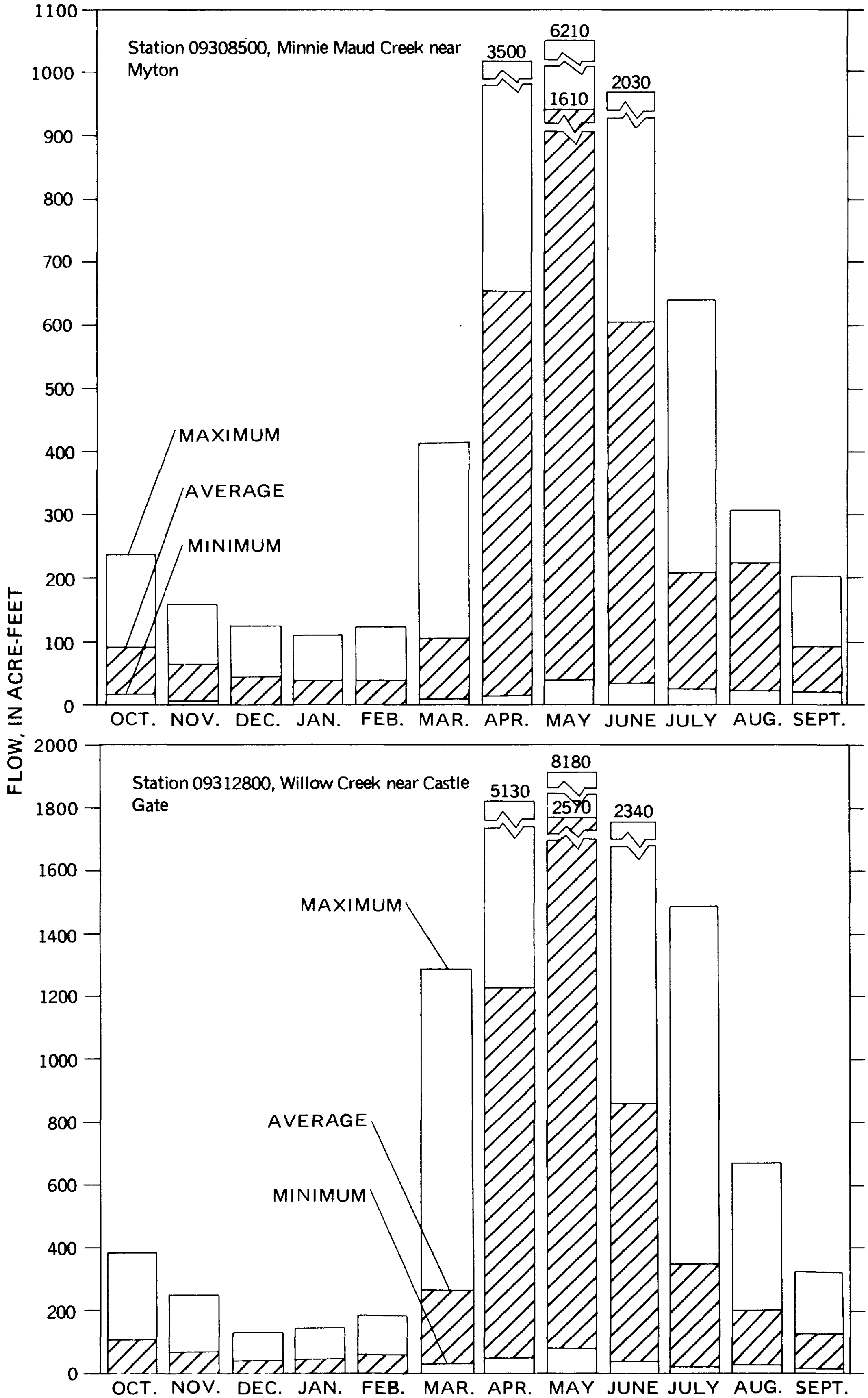

Figure 15.—Average, maximum, and minimum monthly mean flow at two gaging stations in and near the Argyle Canyon - - Willow Creek and Sunnyside Special Tar Sand Areas.

Table 14.—Streamflow at selected gaging stations in and near the Argyle Canyon—Willow Creek and Sunnyside Special Tar Sand Areas

Station number	Station name	Period of record used (water years)	Drainage area (square miles)	Average flow: Cubic feet per second	Average flow: Acre-feet per year	Flow (cubic feet per second): Minimum	Flow (cubic feet per second): Maximum
09288150	West Fork Avintaquin Creek near Fruitland	1965-81	56.1	14.4	10,430	0.2	1,830
09288180	Strawberry River near Duchesne	1969-81	917	125	90,560	17	1,310
09288900	Sowers Creek near Duchesne	1965-81	40.6	3.80	2,750	0	350
09302000[1]	Duchesne River near Randlett	1943-81	4,247	550	398,500	2.2	10,300
09308500	Minnie Maud Creek near Myton	1951-55, 1958-81	32.0	5.03	3,640	0	>1,370
09309000	Minnie Maud Creek at Nutter Ranch, near Myton	1948-55, 1960-73[2]	231	20.4	14,770	0	1,380
09309100	Gate Canyon near Myton	1960-72[2]	5.4	—	—	0	1,000
09311500[1]	Price River near Scofield	1926-31, 1938-68	155	59.7	43,220	0	1,060
09312500[1]	White River near Soldier Summit	1939-68	53	19.4	14,050	0	1,120
09312600[1]	White River below Tabbyune Creek, near Soldier Summit	1968-81	75.6	27.3	19,780	0	458
09312700	Beaver Creek near Soldier Summit	1961-81	26.1	3.88	2,810	0	135
09312800	Willow Creek near Castle Gate	1963-81	62.8	8.15	5,900	0	836
09312900	Willow Creek at Castle Gate	1980-81	77.4	—	—	.6	210
09313000[1]	Price River near Heiner	1935-69, 1980-81	415	112	81,140	.4	9,340
09313040	Spring Canyon below Sowbelly Gulch, at Helper	1979-81	23.0	.3	220	.02	271
09313500	Price River near Helper	1905-34	530	143	103,500	2.0	12,000
09313965	Coal Creek near Helper	1979-81[3]	25.3	(4)2.6	1,880	0	458
09313975	Soldier Creek below mine, near Wellington	1979-81[3]	17.7	(4)2.0	1,450	.08	472
09313985	Dugout Creek near Sunnyside	1980-81[3]	5.8	(4)1.0	720	0	127
09314000	Price River near Wellington	1950-58	850	75.4	54,590	2.4	4,190
09314200	Miller Creek near Price	1960-74[2]	62	(4)2.8	2,030	0	4,000
09314250	Price River below Miller Creek, near Wellington	1973-81	956	84.0	60,860	.68	2,880
09314280	Desert Seep Wash near Wellington	1973-81	191	22.6	16,370	0	2,060
09314320	Grassy Trail Creek in Whitmore Canyon, above Sunnyside	1975-76	39.9	3.5	2,500	—	—

Table 14.--Streamflow at selected gaging stations in and near the Argyle Canyon—Willow Creek and Sunnyside Special Tar Sand Areas—Continued

Station number and name	Period of record used (water years)	Drainage area (square miles)	Average flow: Cubic feet per second	Average flow: Acre-feet per year	Flow (cubic feet per second): Minimum	Flow (cubic feet per second): Maximum
09314340 Grassy Trail Creek at Sunnyside	1979-81	40.1	6.9	5,000	0	138
09314374 Horse Canyon near Sunnyside	1979-81	12.5	.4	290	0	93
09314400 Coleman Wash tributary near Woodside	1959-68[2]	3.6	(4) .1	70	0	1,040
09314500[1] Price River at Woodside	1910, 1946-81	1,540	103	74,620	0	9,720
09315000[1] Green River at Green River	1965-81	44,850	5,735	4,152,000	834	30,500

[1] Not located in figure 13.
[2] Annual maximum only.
[3] Seasonal record.
[4] Computed by the following equation: $Q = 0.000054 A^{0.81} p^{3.02}$
Q is the average flow, in cubic feet per second;
A is the drainage area, in square miles;
p is the normal annual precipitation for the drainage area, in inches.

Table 15.—Concentrations of major dissolved constituents and suspended sediment of streamflow for sites in and near the Argyle Canyon—Willow Creek and Sunnyside Special Tar Sand Areas

Station number and name	Period of record used (water years)		Concentration (milligrams per liter): Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)	Suspended sediment
09288150 West Fork Avintaquin Creek near Fruitland	1971-82	Maximum	413	52	32	66	2.1	10	65	360	—
		Minimum	316	46	26	27	1.4	5.9	28	317	—
		Number of samples	3	3	3	3	3	3	3	3	—
09288180 Strawberry River near Duchesne	1973-82	Maximum	548	57	38	99	4.3	34	110	458	—
		Minimum	442	19	35	75	2.0	25	93	257	—
		Number of samples	5	5	5	5	5	5	5	5	—
09288900 Sowers Creek near Duchesne	1972-82	Maximum	879	88	79	100	7.3	13	350	458	—
		Minimum	635	75	56	63	4.7	9.1	190	403	—
		Number of samples	5	5	5	5	5	5	5	5	—
09302000[1] Duchesne River near Randlett	1951-82	Maximum	3,330	228	196	709	13	545	1,670	920	2,190
		Minimum	42	27	0	0	1.1	7.5	15	99	11
		Number of samples	558	387	387	619	352	712	712	673	75
09308500 Minnie Maud Creek near Myton	1958, 1971	Maximum	511	59	44	61	1.8	7.8	150	350	—
		Minimum	343	51	27	29	—	3.5	69	294	—
		Number of samples	3	3	3	3	1	3	3	3	—
09309000 Nine Mile Creek at Nutter Ranch, near Myton[2]	1958	Maximum	1,000	60	94	168	—	15	361	606	—
		Minimum	296	58	32	42	—	5.0	84	338	—
		Number of samples	2	2	2	2	—	2	2	2	—
09311500[1] Price River near Scofield	1962-80	Maximum	200	56	14	5.2	1.8	5.1	18	219	—
		Minimum	160	38	11	1.9	.8	2.6	9.8	191	—
		Number of samples	10	10	10	11	9	11	11	6	—
09312500[1] White River near Soldier Summit	1947-80	Maximum	907	140	40	100	3.8	53	430	374	—
		Minimum	320	51	21	16	—	3	21	260	—
		Number of samples	3	5	5	5	1	5	6	4	—
09312600[1] White River below Tabbyune Creek, near Soldier Summit	1962-82	Maximum	370	63	34	52	341	11	54	375	—
		Minimum	293	49	23	18	1.3	5.0	24	246	—
		Number of samples	8	8	8	9	6	9	9	9	—
09312700 Beaver Creek near Soldier Summit	1969-82	Maximum	256	60	18	18	1.9	10	33	255	—
		Minimum	177	42	11	3.4	1.4	3.0	18	169	—
		Number of samples	6	6	6	7	4	7	7	7	—
09312800 Willow Creek near Castle Gate	1969-82	Maximum	536	55	61	72	2.3	27	170	326	—
		Minimum	421	21	42	49	1.4	12	98	296	—
		Number of samples	3	3	3	3	2	3	3	3	—
09312900 Willow Creek at Castle Gate	1980-81	Maximum	814	82	72	100	3.6	45	300	420	4,820
		Minimum	274	32	20	30	1.7	9.8	70	230	2
		Number of samples	24	25	25	25	25	25	25	24	20
09313000 Price River near Heiner	1948-81	Maximum	648	130	50	64	3.9	41	250	380	4,170
		Minimum	163	20	0	4.8	.9	2.0	15	116	20
		Number of samples	69	71	71	72	61	73	73	71	21
09313040 Spring Canyon below Sowbelly Gulch, at Helper	1981	Maximum	2,420	230	290	150	20	100	1,400	480	99,800
		Minimum	481	79	42	15	1.7	61	200	120	3
		Number of samples	12	13	13	13	13	13	13	12	14
09313500 Price River near Helper	1970	Maximum	340	57	28	26	3.2	12	93	282	—
		Minimum	306	54	24	18	1.8	7	46	225	—
		Number of samples	2	2	2	2	2	2	2	2	—
09313965 Coal Creek near Helper	1976-81	Maximum	798	78	78	110	12	52	270	470	2,710
		Minimum	469	29	28	22	2.4	11	110	310	2
		Number of samples	23	24	24	24	24	24	24	22	15

Table 15.--Concentrations of major dissolved constituents and suspended sediment of streamflow for sites in and near the Argyle Canyon--Willow Creek and Sunnyside Special Tar Sand Areas--Continued

Station number	Station name	Period of record used (water years)		Concentration (milligrams per liter): Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)	Suspended sediment
09313975	Soldier Creek below mine, near Wellington	1969-82	Maximum	696	65	58	150	8.6	30	230	500	406
			Minimum	277	23	18	21	1.6	5.2	44	240	6
			Number of samples	25	29	29	29	28	29	29	23	15
09313985	Dugout Creek near Sunnyside	1980-81	Maximum	485	68	52	27	4.1	6.8	110	420	1,000
			Minimum	348	50	36	15	1.7	4.9	51	320	5
			Number of samples	15	16	16	16	16	16	16	14	11
09314200	Miller Creek near Price	1969-70	Maximum	4,720	397	319	649	12	161	3,010	341	—
			Minimum	1,970	208	140	219	9.1	64	1,180	216	—
			Number of samples	4	4	4	4	3	4	4	4	—
09314250	Price River below Miller Creek, near Wellington	1969-82	Maximum	3,930	320	220	620	14	82	2,500	470	—
			Minimum	482	68	32	46	2.3	9.9	190	180	—
			Number of samples	100	100	100	100	100	100	100	100	—
09314280	Desert Seep Wash near Wellington	1969-82	Maximum	10,060	420	520	2,100	27	150	6,600	550	—
			Minimum	1,390	100	74	250	5.5	13	790	210	—
			Number of samples	91	91	91	91	90	91	91	91	—
09314340	Grassy Trail Creek at Sunnyside	1975-82	Maximum	1,810	76	67	530	15	77	730	770	1,640
			Minimum	331	24	33	23	1.4	2.6	69	210	4
			Number of samples	41	47	47	47	47	46	47	43	27
09314374	Horse Canyon near Sunnyside	1975-81	Maximum	4,220	210	260	1,000	26	1,500	1,300	570	2,270
			Minimum	953	51	65	130	4.6	18	440	338	2
			Number of samples	33	33	33	33	33	33	33	33	23
09314378	Icelander Creek at Highway 6 and 50, near Dragerton	1947, 1969-70	Maximum	6,080	697	413	877	23	150	4,000	362	—
			Minimum	3,200	244	224	378	20	105	2,020	234	—
			Number of samples	6	6	6	6	4	6	6	6	—
09314500[1]	Price River at Woodside	1949, 1951-82	Maximum	7,060	550	421	1,430	124	274	4,700	1,450	69,600
			Minimum	592	50	0	65	1.4	0	0	40	8
			Number of samples	772	515	515	815	487	920	921	898	76
09315000[1]	Green River at Green River	1965-82	Maximum	3,160	507	150	135	7.0	70	2,000	382	39,000
			Minimum	196	29	10	19	.6	6.2	60	107	17
			Number of samples	247	360	358	291	196	359	358	328	207
([3])	Whitmore Canyon near Sunnyside	1969	Maximum	658	48	46	124	3.1	12	239	366	—
			Minimum	633	35	43	123	—	1	206	332	—
			Number of samples	2	2	2	2	1	2	2	2	—
([3])	Rock Creek at Desolation Canyon	1947	Maximum	440	53	35	72	—	80	81	301	—
			Minimum	354	47	28	30	—	6.0	53	270	—
			Number of samples	2	2	2	2	—	2	2	2	—
([3])	Grassy Trail Creek above junction with Dugout and Rock Creeks near Dragerton; Grassy Trail Creek below junction with Dugout and Rock Creeks, near Dragerton; and Grassy Trail Creek near Mounds[4]	1969-70	Maximum	2,510	164	233	315	4.2	78	1,560	364	—
			Minimum	872	68	48	97	2.7	18	423	257	—
			Number of samples	8	8	8	8	8	8	8	8	—
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 206)				500	—	—	—	—	250	250	—	—

[1] Not located in figure 13.
[2] Published as Minnie Maud.
[3] Miscellaneous site--no station number assigned and site not located in figure 13.
[4] Includes data for the three sites.

Table 16.—Concentrations of dissolved trace elements in streamflow for sites in and near the Argyle Canyon—Willow Creek and Sunnyside Special Tar Sand Areas

[ND, not detected]

Station number and name	Period of record used (water years)		Concentration (micrograms per liter)												
			Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Zinc (Zn)
09302000[1] Duchesne River near Randlett	1971-80	Maximum	7	3	<20	—	6	150	22	200	<0.5	7	1	—	50
		Minimum	<1	ND	0	—	0	<10	0	0	0	ND	0	—	ND
		Number of samples	15	14	14	—	14	58	15	17	15	14	15	—	15
09311500[1] Price River near Scofield	1980	Maximum	11	8	10	—	<10	20	19	—	0	—	0	—	20
		Minimum	0	<1	0	—	0	<10	0	—	0	—	0	—	<3
		Number of samples	6	6	6	—	6	5	6	—	4	—	6	—	6
09312900 Willow Creek at Castle Gate	1980-81	Maximum	3	<1	10	—	3	80	2	30	0	0	3	—	7
		Minimum	2	<1	0	—	2	<10	0	2	0	0	1	—	<3
		Number of samples	6	2	6	—	2	17	6	17	2	2	6	—	6
09313000 Price River near Heiner	1980-81	Maximum	3	2	20	—	4	30	5	30	0	14	3	—	20
		Minimum	<1	1	0	—	2	<10	0	3	0	2	0	—	<3
		Number of samples	6	2	6	—	2	17	6	17	2	2	6	—	6
09313040 Spring Canyon below Sowbelly Gulch, at Helper	1981	Maximum	3	1	30	—	10	60	2	50	.1	6	20	—	40
		Minimum	0	0	10	—	2	20	1	10	0	1	3	—	10
		Number of samples	3	3	3	—	3	13	3	13	3	3	3	—	3
09313965 Coal Creek near Helper	1976-81	Maximum	4	<1	<20	—	3	86	19	80	.5	2	4	—	70
		Minimum	1	<1	0	—	1	<10	0	2	0	0	0	—	ND
		Number of samples	10	3	10	—	3	15	10	14	4	3	10	—	10
09313975 Soldier Creek below mine, near Wellington	1976-82	Maximum	3	<1	<10	—	3	140	18	70	<.5	3	3	—	25
		Minimum	0	<1	0	—	1	7	0	8	0	0	0	—	ND
		Number of samples	13	6	13	—	6	19	13	17	7	5	13	—	13
09313985 Dugout Creek near Sunnyside	1980-81	Maximum	2	<1	0	—	1	20	4	25	.2	2	1	—	4
		Minimum	1	<1	0	—	1	<10	0	<1	0	0	0	—	<3
		Number of samples	6	3	6	—	3	11	6	11	3	3	6	—	6
09314250 Price River below Miller Creek, near Wellington	1976	Maximum	1	ND	<50	<100	<20	100	<50	180	—	<50	7	<6	<20
		Minimum	1	ND	<40	<40	<20	70	<40	80	—	<40	4	<5 .	ND
		Number of samples	2	2	2	2	2	2	2	2	—	2	2	2	2
09314340 Grassy Trail Creek at Sunnyside	1975-82	Maximum	3	<1	40	<30	<7	60	55	30	<.1	<30	1	<5	24
		Minimum	1	ND	0	<10	1	<3	0	<1	0	0	0	<3	0
		Number of samples	18	7	17	3	7	29	18	29	4	7	18	3	18
09314374 Horse Canyon near Sunnyside	1978-81	Maximum	2	—	<20	—	—	110	47	540	—	—	5	—	43
		Minimum	0	—	0	—	—	0	0	0	—	—	0	—	<3
		Number of samples	8	—	8	—	—	16	8	16	—	—	8	—	9
09314500[1] Price River at Woodside	1975-81	Maximum	6	8	20	589	13	260	150	110	<.5	8	12	—	240
		Minimum	<1	0	0	341	ND	0	ND	8	0	1	<1	—	<20
		Number of samples	15	15	15	4	15	47	15	15	16	15	15	—	15
09315000[1] Green River at Green River	1971-82	Maximum	5	4	<20	<3	19	190	70	20	<.5	—	5	ND	120
		Minimum	<1	ND	ND	ND	ND	<2	<1	<10	<.5	—	<1	ND	ND
		Number of samples	24	24	24	24	24	26	24	26	24	—	24	—	24
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 14-106, 200-204, 245)			50	10	50	—	1,000	300	50	50	2	—	10	50	5,000

[1] Not located in figure 13.

Table 17.—Generalized stratigraphic section of lithologic units discussed in the text for the Argyle Canyon—Willow Creek and Sunnyside Special Tar Sand Areas

[Data from Osterwald and others, 1981; Waddell and others, 1981; Banks, 1981; and Ryder and others, 1976.]

System	Series	Geologic unit		Thickness (feet)	Symbol	Description
Quaternary	Pleistocene and Holocene	Unconsolidated deposits		—	Qa	Alluvial deposits of clay, sand, silt, and gravel in talus, stream channel, and fan deposits.
Tertiary	Eocene	Uinta Formation		0-4,000	Tu	Calcareous shale, some limestone, claystone, siltstone, sandstone.
	Paleocene and Eocene	Green River Formation		0-5,000	Tg	Marl, limestone, siltstone, sandstone, shale, and oil shale, mostly of lacustrine origin. Most of the tar-sand deposits in the Argyle Canyon—Willow Creek and Sunnyside areas are in this formation.
		Wasatch and Colton Formations		900-3,400	Tw Tc	Interbedded fluvial and flood-plain deposits; a series of variegated sandstone and mudstone. Thickens to the southeast reaching 3,400 feet thick in the cliffs north of the town of Green River, Utah. In the Sunnyside area, the Colton Formation forms the Roan Cliffs. The Wasatch Formation is mostly fluvial channel sandstone and contains beds of oil-impregnated sandstone ("tar sands").
	Paleocene	Flagstaff Limestone		0-100	Tf	Lacustrine deposits of marl, limestone, and shale. In the Sunnyside area, forms ledges of varying thicknesses and dip slopes.
Tertiary / Cretaceous	Paleocene / Upper Cretaceous	North Horn Formation		400-500	TKn	Alternating beds of lacustrine and fluvial origin, consisting of interbedded claystone, mudstone, limestone, siltstone, and sandstone, with fossil algae near the town of Sunnyside. Interfingers with and is transitional with the Flagstaff Limestone.
Cretaceous	Upper Cretaceous	Mesa-verde Group	Price River Formation	600-1,200	Kp	Interbedded mudstone, claystone, and siltstone thinning eastward across the area. Upper part consists of fine-grained to medium-grained sandstone, thickest and most coarse-grained in the northwest part of the Book Cliffs.
			Blackhawk Formation	500-600	Kb	Thick cliff-forming sandstone beds and slope-forming mudstone beds between the sandstone. Forms the main scarp of the Book Cliffs in the Sunnyside area.
		Mancos Shale	Ferron Sandstone Member	20-50	Kfe	Thin beds of interbedded siltstone and fine-grained sandstone.

Table 18.--Selected well and spring data for sites in and near the

Location: See explanation in text for numbering system for wells and springs.
Geologic unit: Principal water-bearing unit; see table 17 for explanation of symbols.
Altitude of land surface: Altitudes from most detailed topographic maps; National Geodetic Vertical Datum of 1929.
Depth to water: Above (+) or below land-surface datum.

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			WELLS				
U(C-6-6)35bdd-1	Tg	7,490	5,500	11- -61	—	—	3,190-3,260
U(C-7-4)7aaa-1	Tg	—	4,679	11- -59	—	—	4,223-4,345
(D-11-9)30dca-1	Tf	7,119	2,362	5- 3-77	—	<1	225-326
(D-11-12)14baa-1	Tg	7,310	2,240	7-22-65	—	.5	635-650
				7-22-65	—	—	1,883-1,910
(D-11-15)2ccc-1	Tg-Tw	7,124	4,860	10- 3-67	—	—	4,148-4,163
32dcd-1	Tg	5,780	—	4-11-72	42.9	—	—
(D-11-16)3bbc-1	Tg	6,910	5,296	9-11-67	—	—	4,119-4,170
(D-12-12)28ccb-1	TKn	7,240	3,520	4-25-78	11.37	—	—
				8-23-67	—	7	760-775
	TKn			8-23-67	—	3.5	1,000-1,040
	Kp			8-23-67	—	24.5	1,805-1,830
	Kp			8-23-67	—	28	1,980-2,000
(D-12-14)13acb-1	Kmv[2]	7,591	(3)5,515	6-27-52	—	—	8,505-8,617
(D-13-12)2cbb-1	Tf	7,850	2,800	7- -77	—	25	250-350
9cdc-1	TKn	8,330	2,040	11- -77	283	1	At 295
	Tf			11- -77	—	6	At 465
	Tf			11- -77	—	15	520-680
	Tf			11- -77	—	25	700-880
16dcb-1	Kb	7,260	440	9- -77	—	5	46-50
22baa-1	Kb	8,230	1,220	11- -77	1,150		—
(D-13-14)24dba-1	Tg	8,225	—	7-15-66	150	—	—
(D-14-12)30caa-1	Kfe	5,705	340	11-30-62	—	70	116-130
(D-15-12)7ccc-1	M[4]	—	8,154	4- -63	—	—	7,433-7,986
8ccd-1	M-D[5]	—	—	8-18-59	—	—	8,323-9,174
15acc-1	Kms[6]	5,750	61	6-17-49	35	.5	At 56
27bad-1	Qa	5,435	53	5-27-49	18	30	21-32
(D-15-13)2dad-1	Qa	6,240	65	7-11-48	26	33	—
				9-17-75	—	—	—
2dad-2	Qa	6,240	76	12-30-75	24.56	—	—
				9- 2-76	29.27	—	—
3dac-1	Qa	6,100	90	8-16-48	52	25	68-69
6bbc-1	Kms[6]	5,750	150	6- 2-49	35	—	At 139
11baa-1	Qa	6,195	102	12-30-75	59.11	36	—
(D-15-14)6cbd-1	Qa	6,400	42	9-12-75	14.12	—	—
				12-30-75	19.37	—	—
				9- 6-77	25.56	—	—
			SPRINGS				
U(C-5-6)1caa-S1	Tu	6,240	—	5-15-60	—	200	—
U(C-5-7)12cab-S1	Tu	6,880	—	5-15-60	—	225	—
U(C-7-8)1acd-S1	Tg	8,290	—	8- 9-71	—	5	—
U(C-7-9)9dcd-S1	Tg	9,770	—	7-18-60	—	—	—
(D-11-15)5dbb-S1	Tg	6,660	—	3-16-72	—	.9	—
(D-11-17)20aca-S1	Tg	5,600	—	3-16-72	—	<.5	—
(D-12-9)1ccc-S1	Tf	7,310	—	8- 6-76	—	2.3	—

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			WELLS				
9,670	32	8	(1) 3,979	—	2,400	58	5,120
31,400	827	242	(1) 10,683	—	15,100	4,336	586
—	—	—	—	—	—	—	—
619	6.4	4.4	(1) 221	—	5.1	179	392
818	—	—	—	—	—	—	—
35,600	559	426	11,700	30	10,900	10,580	2,769
1,100	75	100	170	2.8	15	360	726
6,616	27	10	2,419	16	380	2,262	2,440
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
26,630	350	64	(1) 8,198	—	11,000	2,523	1,015
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
327	59	29	30	1.0	8.0	20	366
—	—	—	—	—	—	—	—
35,800	1,144	311	(1) 10,960	—	13,100	8,400	2,270
67,800	3,500	716	(1) 21,600	—	38,600	2,350	2,150
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
1,790	130	120	280	4.4	44	920	532
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
			SPRINGS				
1,840	61	125	(1) 420	—	41	682	988
2,710	37	131	(1) 779	—	124	887	1,200
525	57	45	62	3.6	35	33	475
190	42	17	3.8	—	2.8	7.8	211
2,440	32	29	810	5.6	48	980	983
3,580	75	63	1,000	—	—	—	690
338	69	25	21	1.4	20	57	280

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			SPRINGS—Continued				
(D-12-10) 34aad-S1	TKn	8,120	—	8- 4-76	—	4.5	—
35dbc-S1	TKn	8,070	—	8- 4-76	—	4.5	—
(D-12-11) 20aaa-S1	Tf	7,710	—	8- 4-76	—	2.3	—
20aaa-S2	Tf	7,720	—	8- 4-76	—	3.0	—
21aca-S1	Tf	7,720	—	8- 5-76	—	2.8	—
21bab-S1	Tf	7,710	—	8- 5-76	—	.8	—
36aad-S1	Tf	7,890	—	7-28-76	—	.3	—
(D-12-12) 30dcc-S1	Tf	7,560	—	7-28-76	—	5.4	—
(D-13-12) 5cbc-S1	Kp	6,930	—	8-18-77	—	2.6	—
(D-13-12) 9ddc-S1	Tf	8,090	—	7-15-76	—	4.3	—
10abb-S1	Tf	7,740	—	7-14-76	—	11	—
10adb-S1	Tf	7,870	—	7-14-76	—	3.0	—
11acd-S1	Tf	7,990	—	7-15-76	—	12	—
12adb-S1	Tc	8,360	—	7-14-76	—	11	—
12cbb-S1	Tf	7,930	—	7-14-76	—	2.0	—
13aaa-S1	Tf	8,000	—	7-20-76	—	3.5	—
(D-131/2-12) 4bdc-S1	TKn	7,410	—	7-14-76	—	2.4	—
5cbc-S1	Kp	6,990	—	7-14-76	—	2.1	—
(D-13-13) 18bac-S1	TKn	8,200	—	7-20-76	—	38	—
(D-13-14) 24adb-S1	Tg	8,275	—	7-15-66	—	—	—
(D-14-14) 4abd-S1	Tg	9,500	—	7-15-66	—	—	—
(D-15-13) 1ddc-S1	Qa	6,240	—	9-12-75	—	206	—
				8-18-77	—	28.2	—
18caa-S1	Qa	5,700	—	9-17-75	—	168	—
(D-14-14) 20dcc-1 (7)	Kb	6,800	—	7- 1-76	—	350	—
32dbb-1 (7)	Kb	6,760	—	3-18-53	—	—	—

1 Sodium plus potassium.
2 Rocks of Mesaverde Group.
3 Plugged back at this depth.
4 Rocks of Mississippian age.
5 Rocks of Mississippian and Devonian age.
6 Rocks of Mancos Shale.
7 A mine sump.

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			SPRINGS—Continued				
311	75	30	13	1.4	4.7	37	292
326	78	29	6.9	.8	4.9	32	336
420	110	26	17	2.4	21	23	426
—	—	—	—	—	—	—	—
386	86	28	21	1.1	12	30	399
374	91	26	17	2.6	6.2	25	396
325	66	24	24	.9	9.0	23	341
323	86	27	21	1.2	6.5	23	300
—	—	—	—	—	—	—	—
—	72	28	12	1.8	4.4	24	315
—	69	28	17	.9	4.4	22	203
371	110	27	11	1.4	4.6	25	276
—	66	35	29	1.2	6.2	37	359
—	44	42	24	1.1	4.5	36	338
—	76	35	21	.9	9.1	35	401
282	67	25	10	.8	2.5	21	302
—	48	32	35	1.0	4.5	26	306
—	36	32	140	2.6	12	110	472
350	63	34	29	1.6	3.7	54	310
356	73	31	25	1.0	6.0	15	415
445	36	60	37	1.0	14	153	293
1,380	130	120	160	4.0	29	680	470
—	—	—	—	—	—	—	—
1,080	77	110	120	2.6	47	480	395
1,600	—	—	—	—	—	—	—
601	61	67	(1) 47	—	15	186	384

HILL CREEK AND P R SPRING SPECIAL TAR SAND AREAS

By H. F. McCormack and G. E. Pyper

Location

The Hill Creek and P R Spring Special Tar Sand Areas cover about 590 square miles in Uintah and Grand Counties on the Roan Plateau of the southeastern Uinta Basin (fig. 7). Land-surface altitudes decrease northward from about 9,000 feet to less than 5,800 feet along Willow and Hill Creeks. The proven or inferred tar-sand deposits underlie all or parts of townships 12 to 17 south and ranges 18 to 25 east, Salt Lake base line and meridian and the deposits are in the Douglas Creek and Parachute Creek Members of the Green River Formation (Ritzma, 1979, sheet 2). About 106 of the approximately 590 square miles of area are available for lease. The Federal Government is the major landowner, a large part is under Indian Trust, and small tracts are private land. However, ownership of the minerals commonly is different from ownership of the surface rights. The estimated oil in place for these two tar-sand areas is 5.2 to 5.7 billion barrels (table 1).

Climate

The climate of the area is influenced by regional and local topographic features; and it generally is semiarid, with low relative humidity, abundant sunshine, low to moderate precipitation, warm summers, and cold winters. Seasonal and daily variations in temperatures are large. The climate at high altitudes is cool and semihumid, whereas at low altitudes it is warmer with annual precipitation averaging 10 inches or less. The Roan Cliffs to the south and the Wasatch Plateau, about 80 miles to the southwest, are orographic barriers for much of the summer moisture moving north from the Gulf of Mexico and the Gulf of California. The Wasatch Range, about 100 miles to the west, is an orographic barrier for winter moisture moving east from the Pacific Ocean.

Selected climatic characteristics were reported for the southeastern Uinta Basin by Waltemeyer (1982). In addition, precipitation values were summarized by the U.S. Weather Bureau (1963), air temperatures by the National Oceanic and Atmospheric Administration (1973), and pan evaporation by Cruff and Thompson (1967, p. 19) and the U.S. Weather Bureau (1957).

Normal annual precipitation varies with altitude from about 10 inches in the northern part of the area to about 18 inches in the southern part (fig. 7). Normal annual air temperature ranges from 39°F at the higher altitudes to about 45°F at an altitude of 5,800 feet. Normal annual pan evaporation ranges from less than 48 to more than 56 inches. In addition to the areal variance, there are considerable temporal variations in these climatic characteristics.

Water Resources

A large part of the area drains to Bitter Creek, a tributary to the White River, which in turn joins the Green River near Ouray. A part of the P R Spring area drains to Evacuation Creek, also a tributary to the White River. The remainder including the Hill Creek area drains to Willow Creek and Tabyago Canyon Creek, which are tributaries to the Green River in Desolation Canyon. The surface drainage is primarily to the north-northwest and ground water generally flows in the same direction. Major aquifers in the northern part of the area are the bird's-nest and the Douglas Creek aquifers of the Green River Formation of Tertiary age.

Surface Water

Streamflow data for specific sites in and near the Hill Creek and P R Spring Special Tar Sand Areas are summarized in table 19. Most of the short-term data were collected during 1975-79 for a comprehensive hydrologic study of the southeastern Uinta Basin to define baseline conditions prior to oil-shale development (Conroy and Fields, 1977; Conroy, 1979, 1980; Lindskov and Kimball, 1982). Long-term data are available for sites on Willow and Bitter Creeks and the White and Green Rivers.

Bitter, Hill, and Willow Creeks originate in areas where mean annual runoff exceeds 1 inch (Lindskov and Kimball, 1982, fig. 13). As these perennial streams flow north across areas receiving 10 or less inches of precipitation annually, they become intermittent. According to Lindskov and Kimball (1982, figs. 15-17) and table 19, the largest long-term mean annual flows at any location for these streams are about 3,000 acre-feet for Bitter Creek at Rat Hole Canyon; about 6,000 acre-feet for Hill Creek; and about 15,000 acre-feet for Willow Creek from bottom of township 14 south to where it joins Hill Creek. These compare to mean annual flows of about 500,000 acre-feet for the White River and about 4.1 million acre-feet for the Green River through Desolation Canyon (Lindskov and Kimball, 1982, table 2 and table 19 of this report).

The yearly flow from the streams tributary to the White and Green Rivers varies from one location to another and also varies seasonally and yearly at each location. As shown in figure 16 for two representative gaging stations, the annual flow in wet years can be five or more times greater than during dry years. Figure 17 shows the variation of monthly mean flows for these two sites. A large part of the flow comes from March to June as snowmelt. The flows of the White River in Utah and the Green River downstream from its confluence with the White River do not vary appreciably from one location to another. However, the flows of these larger rivers do vary appreciably from month to month and year to year.

Towave and Weaver Reservoirs on upper Hill Creek are the only large surface-storage sites in the area. Their combined storage of about 2,000 acre-feet, however, is not large enough to meet the needs of a tar-sand industry.

The quality of the water in the tributary streams in the area changes markedly as they flow across areas receiving less than 10 inches of precipitation annually. The dissolved-solids concentrations increase because of (1) inflow from springs that discharge poor-quality water (Kimball, 1981), (2) solution of soluble minerals in the stream channels, and (3) concentration by evapotranspiration as streamflow diminishes to the north.

Concentrations of dissolved solids in tributary streams range from 196 to 15,500 milligrams per liter (table 20) and generally increase toward the north. For example, the mean dissolved-solids concentrations for Bitter Creek range from 412 to 13,100 milligrams per liter (Lindskov and Kimball, 1982, p. 128) between the upper (southern) and lower (northern) stations. The concentrations of dissolved solids generally are inversely proportional to flow; thus, the chemical quality improves as flow increases.

Data in table 20 show that suspended-sediment concentrations for some tributary streams ranged with time from 2 to 183,000 milligrams per liter, while values for the White River ranged with time from 3 to 51,700, and values for the Green River ranged with time from 17 to 39,900 milligrams per liter. The presence of alluvial fans in channels and the measurement of aggradation in stream channels (Seiler and Tooley, 1982, p. 21) indicate that deposition of eroded material is occurring in the area. Average source-area sediment yields (the amount of sediment moved from a source area through the tributary channels to the main transport channel) range from less than 0.2 acre-foot per square mile per year on grass- and brush-covered plateaus to more than 2 acre-feet per square mile per year on extremely dissected hills and valleys (Seiler and Tooley, 1982, p. 37).

Concentrations of dissolved trace elements in tributary streams in the area are mostly less than the maximum concentrations recommended by the U.S. Environmental Protection Agency (1977) for public-water supply (table 21). The dissolved trace elements in the tributary streams generally increase in a downstream direction with some variance with time (Lindskov and Kimball, 1982, p. 138). In contrast, concentrations of dissolved trace elements in the White and Green Rivers, for the most part, are constant from one location to another and from season to season.

Ground Water

The Green River Formation, which was deposited in Lake Uinta during the Tertiary Period (Bradley, 1930, p. 88), crops out in most of the area. The formation dips to the north (fig. 18) at a slightly greater rate than does the gently descending plateau surface, so the entire section of the formation is exposed from north to south. The Douglas Creek Member of the Green River Formation (table 22) is the principal unit cropping out in the Roan Cliffs in the eastern half of the area, and the Parachute Creek Member is exposed to the west. Chemical analyses for water from wells and springs in the area are given in table 23.

Three aquifers could supply water to wells for a tar-sand industry: Quaternary alluvium, the bird's-nest aquifer in the Parachute Creek Member, and the Douglas Creek aquifer in the Douglas Creek Member. The alluvial aquifer is present only along the major streams. The bird's-nest aquifer is limited to the area along the White River, mostly west of Evacuation Creek. The Douglas Creek aquifer underlies most of the study area and thickens to the north. The recoverable water in storage is 0.2 million acre-feet in alluvium, 1.9 million acre-feet in the bird's-nest aquifer, and 16 million acre-feet in the Douglas Creek aquifer (Holmes and Kimball, p. 14-15).

Holmes and Kimball (1983, p. 15) reported that the maximum annual yields for 20 years of pumping would be 10,000 acre-feet from that part of the bird's-nest aquifer south of the White River and 1,400 acre-feet from the entire Douglas Creek aquifer. Thus, it appears that ground water could supply the needs of a tar-sand industry only at the "low" commercial level (table 1).

Data for selected wells and springs in and near the Hill Creek and P R Spring Special Tar Sand Areas are shown in table 23. Springs in the southeastern Uinta Basin generally are above an altitude of 6,000 feet, and they discharge from the Horse Bench Sandstone Bed of the Parachute Creek Member, the upper part of the Douglas Creek Member and the Renegade Tongue of the Wasatch Formation (Kimball, 1981, p. 4-5). In each of these horizons, springs discharge where channel-form sandstone bodies are cut by drainages (fig. 18).

The chemical character, temperature, and discharge of spring water from the Horse Bench Sandstone Bed vary seasonally. This suggests that the springs represent only local flow of ground water. In contrast, the characteristics of spring water from the Renegade Tongue of the Wasatch Formation remain constant throughout the year. That consistency suggests that the springs are discharging from a larger or even regional flow system. Flow in the Douglas Creek Member has intermediate characteristics. Springs from the Horse Bench Sandstone Bed discharge water of the calcium bicarbonate type, springs from the Douglas Creek discharge water of the calcium magnesium bicarbonate type, and springs from the Renegade Tongue discharge water of the calcium magnesium sodium bicarbonate sulfate type. All springs discharge less than 50 gallons per minute and most discharge less than 10 gallons per minute. Dissolved-solids concentrations range from 297 to 6,110 milligrams per liter.

Existing Water Use

All water within the areas is fully appropriated, therefore, rights would have to be purchased or leased for a tar-sand industry. The Ute Indian Tribe, of Fort Duchesne, Utah, has prime rights on the White River under the Winters Doctrine (Winters v. United States, 207 U.S. 564, 52 L.Ed. 340, 28 S. Ct. 207, 1908) with a potential to irrigate 12,833 acres of land near Ouray, Utah. This entitlement has been estimated to be about 62,000 acre-feet of water per year. A bill was passed endorsing a Ute Indian Water Compact during the 1980 session of the Utah Legislature, however, it has not been ratified by the Tribe. In addition, no interstate compact between Colorado and Utah regulates the flow of the White River. Thus, water use in Colorado could deplete the flow in the White River in Utah.

The Utah State Division of Water Resources has a filing to appropriate 250,000 acre-feet of water per year from the White River and tributaries for mining, drilling, and retorting oil shale and other energy-related projects including a powerplant which is under construction west of Bonanza. Presently (1983), water use in and near the area is small. Some water is used for livestock and in the oil fields. A major local water use is for irrigation of alfalfa along Hill and Willow Creeks, which totals less than 3,000 acre-feet per year. Another large use is for a gilsonite mine at Bonanza. This mine obtains about 1,000 acre-feet of water per year from wells completed in the alluvium of the White River south of Bonanza (Ronald Jibson, Utah Division of Water Rights, written commun., February 19, 1980).

Hydrologic Impacts Unique to This Area

A "high" commercial tar-sand industry producing 110,000 barrels of oil per day in the Hill Creek and P R Spring Special Tar Sand Areas would require about 23,600 acre-feet of water per year (table 1). These needs could be supplied from the area without any unique hydrologic impacts other than the rearrangement of water rights. Other potential impacts that generally apply to all areas are discussed in the section "Hydrologic impacts of a tar-sand industry," near the end of this report.

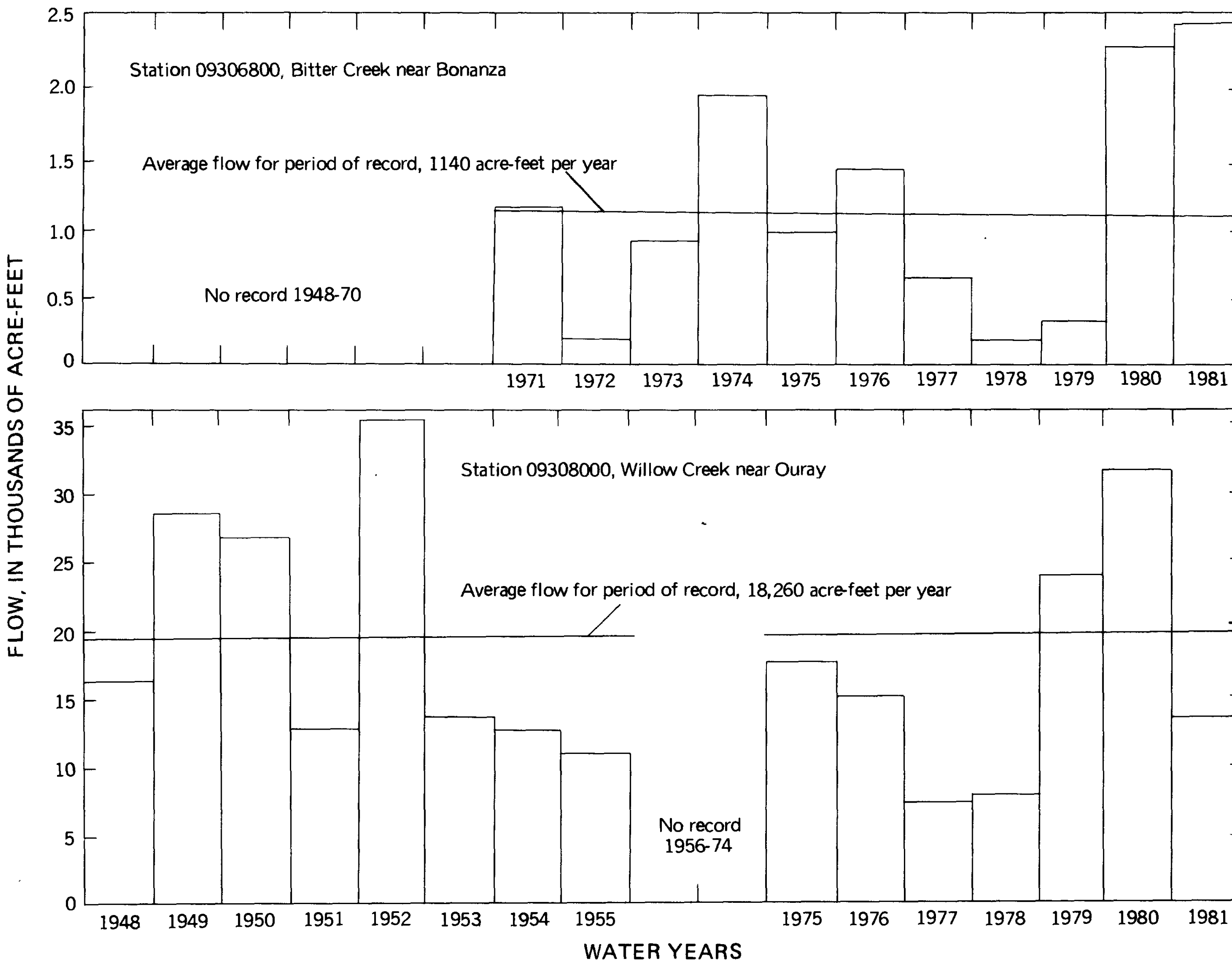

Figure 16.—Annual flow at two gaging stations in and near the Hill Creek and P R Spring Special Tar Sand Areas.

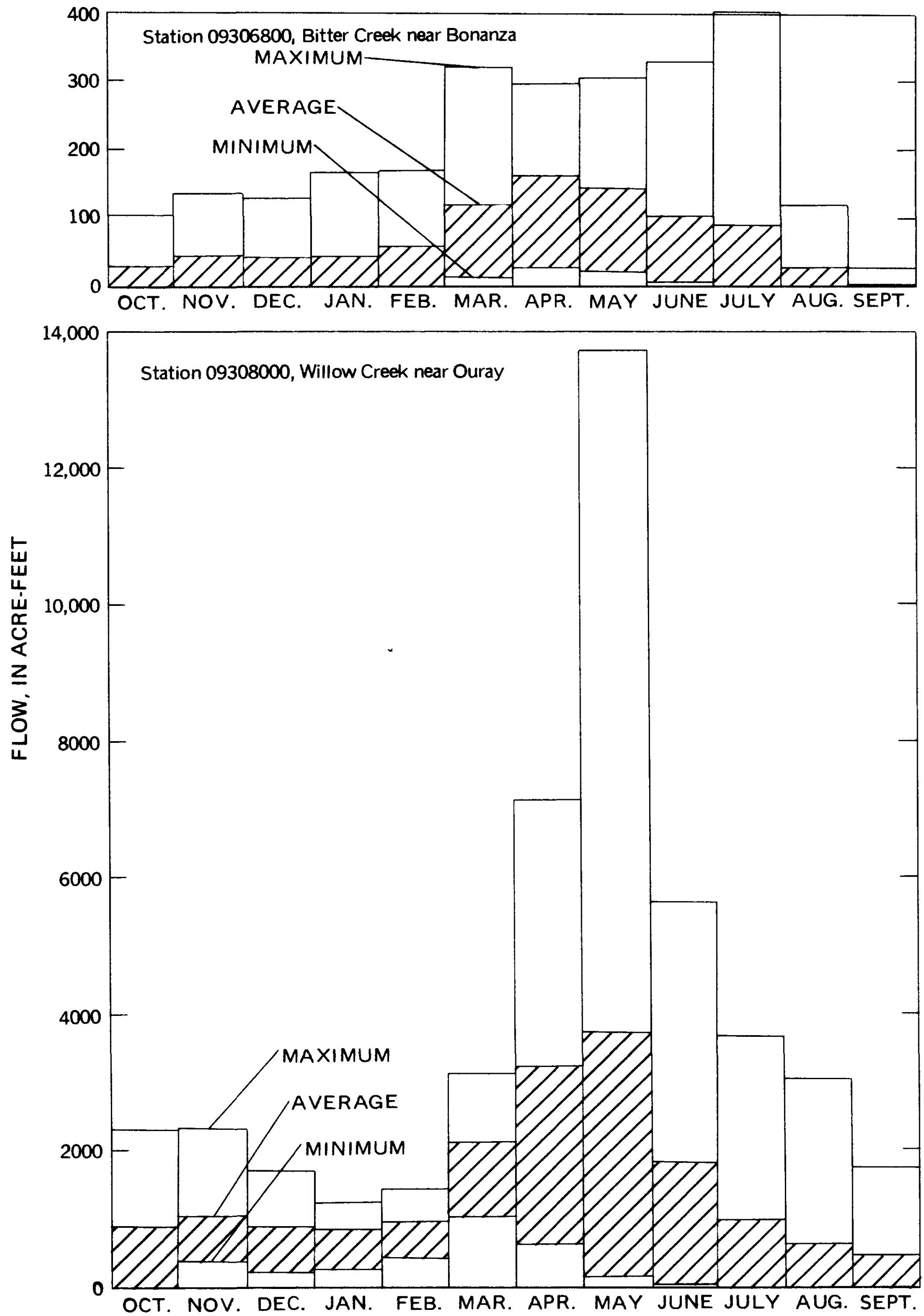

Figure 17.—Average, maximum, and minimum monthly mean flow at two gaging stations in and near the Hill Creek and P R Spring Special Tar Sand Areas.

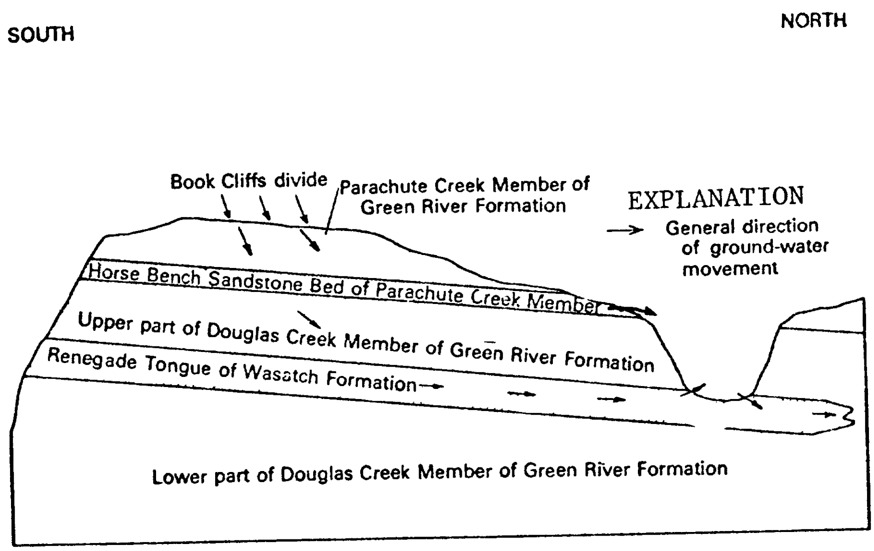

Figure 18.—Schematic representation of ground-water flow to springs in and near the Hill Creek and P R Spring Special Tar Sand Areas. From Kimball (1981, fig. 2).

Table 19.--Streamflow at selected gaging stations in and near the Hill Creek and P R Spring Special Tar Sand Areas

Station number and name		Period of record used (water years)	Drainage area (square miles)	Average flow		Flow (cubic feet per second)	
				Cubic feet per second	Acre-feet per year	Minimum	Maximum
09306395	White River near Colorado-Utah State line	1977-81	3,680	602	436,100	10	4,470
09306410	Evacuation Creek above Missouri Creek, near Dragon	1975-81	100	1.34	971	.04	835
09306430	Evacuation Creek near Watson	1975-81	284	1.55	1,120	0	1,980
09306500	White River near Watson	1924-79	4,020	695	503,500	11	8,160
09306625	Asphalt Wash near mouth, near Watson	1975-81	97.5	.18	130	0	3,200
09306800	Bitter Creek near Bonanza	1971-81	324	1.57	1,140	0	1,660
09306850	Bitter Creek at mouth, near Bonanza	1975-81	398	1.08	782	.10	188
09307500	Willow Creek above diversions, near Ouray	1951-55, 1958-70, 1975-81	297	20.6	14,920	.3	2,240
09307800	Hill Creek above Towave Reservoir, near Ouray	1975-81	89.7	9.39	6,800	0	106
09307900	Hill Creek near mouth, near Ouray	1975-81	288	5.09	3,690	0	201
09308000	Willow Creek near Ouray	1948-55, 1975-81	897	25.2	18,260	0	11,000
09315000[1]	Green River at Green River	1965-81	44,850	5,735	4,152,000	834	30,500

[1] Not located in figure 7.

Table 20.--Concentrations of major dissolved constituents and suspended sediment of streamflow for sites in and near the Hill Creek and P R Spring Special Tar Sand Areas

[Modified from Lindskov and Kimball, 1982, tables 9-10.]

Station number and name	Period of record used (water years)		Concentration (milligrams per liter) Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)	Suspended sediment
09306410 Evacuation Creek[2]	1975-81	Maximum	5,310	240	250	1,100	12	100	3,300	642	183,000
09306415[1]		Minimum	283	49	14	29	1.4	3.4	83	120	2
09306420[1]											
09306430		Number of samples	154	156	156	155	155	157	157	136	142
09306500 White River near Watson	1950-79	Maximum	1,400	283	170	566	12	420	2,160	736	51,700
		Minimum	203	26	9.7	14	1.0	7.5	43	94	3
		Number of samples	195	366	366	544	314	633	636	622	294
09306740[1] Bitter Creek[2]	1975-81	Maximum	15,500	490	750	4,000	19	510	10,000	842	31,800
09306760[1]		Minimum	196	31	14	15	.9	1.0	63	125	6
09306780[1]											
09306800		Number of samples	105	107	106	107	107	106	106	81	129
09306850											
09307500 Willow Creek[2]	1975-81	Maximum	3,650	91	180	890	8.5	84	2,000	805	112,000
09307800		Minimum	309	52	24	15	1.1	1.8	54	244	13
09307900											
09308000		Number of samples	90	96	96	93	93	98	97	90	140
09315000[1] Green River at Green River	1965-82	Maximum	3,160	507	150	135	7.0	70	2,000	382	39,900
		Minimum	196	29	10	19	.6	6.2	60	107	17
		Number of samples	247	360	358	291	196	359	358	328	207
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 206)			500	--	--	--	--	250	250	--	--

[1] Not located in figure 7.
[2] Includes data for number of stations listed.

Table 21.--Concentrations of dissolved trace elements in streamflow for sites in and near the Hill Creek and P R Spring Special Tar Sand Areas

[From Lindskov and Kimball, 1982, table 12; ND, not detected]

Station number and name	Period of record used (water years)		Concentration (micrograms per liter)												
			Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Zinc (Zn)
09315000[1] Green River at Green River	1971-82	Maximum	5	4	<20	<3	19	190	70	20	<0.5	---	5	ND	120
		Minimum	<1	ND	ND	ND	ND	<2	<1	<10	<.5	---	<1	ND	ND
		Number of samples	24	24	24	24	24	26	24	26	24	---	24	---	24
09306500 White River near Watson	1950-79	Maximum	4	<2	<20	<11	8	270	5	30	<.5	12	3	<2	110
		Minimum	<1	ND	ND	ND	ND	<10	<1	<10	<.1	ND	<1	ND	ND
		Number of samples	28	24	24	19	25	37	24	37	24	19	23	10	24
09307500 Willow Creek 09307800 09307900 09308000	1975-79	Maximum	58	3	<20	<12	670	650	34	170	1.7	<12	5	<2	870
		Minimum	1	ND	ND	<2	ND	<10	<1	<10	<.1	<2	<1	ND	ND
		Number of samples	76	32	32	7	75	91	32	46	75	8	76	7	76
09306740[1] Bitter Creek 09306760[1] 09306780[1] 09306800 09306850	1975-79	Maximum	19	<2	25	<40	210	90	19	170	7	---	10	<9	1,400
		Minimum	<1	ND	ND	<2	ND	<10	<1	<10	<.1	<2	<1	ND	ND
		Number of samples	76	28	28	5	75	103	27	55	75	5	76	5	75
09306410 Evacuation Creek 09306415[1] 09306420[1] 09306430	1975-79	Maximum	6	<2	30	<75	600	470	5	410	<.5	18	20	<8	110
		Minimum	<1	ND	ND	ND	ND	<10	<1	<10	<.1	ND	<1	ND	ND
		Number of samples	87	67	67	54	80	102	67	89	79	54	79	23	79
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 14-106, 200-204, 245)			50	10	50	---	1,000	300	50	50	2	---	10	50	5,000

[1] Not located in figure 7.

Table 22.--Generalized stratigraphic section of lithologic units discussed in the text for the Hill Creek and P R Spring Special Tar Sand Areas

System	Series	Geologic unit		Thickness (feet)	Symbol	Description
Quaternary	Holocene	Unconsolidated deposits		10-20	Qay	Surficial deposits of clay, silt, sand, gravel, and large angular blocks. Gravel surfaces are the upper parts of terrace deposits and appear in many places to be separated from deeper older gravels by a layer of clay or material of low permeability.
Tertiary	Eocene	Green River Formation	Parachute Creek Member	490-1,200	Tgp (Tg)	Thin beds of tan to light brown calcareous siltstone and sandstone, and tar sands. Nearshore to open lacustrine deposits. Some saline beds near top. Includes Horse Bench Sandstone bed. Principal oil-shale and tar-sand members. Mud-supported carbonate and calcareous claystone. Colors are medium to dark brown. Open lacustrine deposits. Beds laterally continuous.
Tertiary	Eocene	Green River Formation	Douglas Creek Member	200-1,310	Tgd (Tg)	Marginal lacustrine deposits of white sandstone and siltstone, light to medium gray to green claystone, and tar sand. Channel-form sandstone is common to all tongues.
Tertiary	Eocene		Renegade Tongue of Wasatch Formation	0-1,030	Twr	Red, purple, and green claystone, and green and red clayey sandstone and siltstone beds. Massive channel-form sandstone common. Fluvial deposits.
Tertiary	Eocene / Paleocene	Wasatch and/or Colton Formation		980-3,940	Tw Tc	Similar to Renegade Tongue.
Cretaceous	Upper Cretaceous	Mesaverde Group		400-1,160	Kmv	Shale, sandstone, and coal beds.

Table 23.—Selected well and spring data for sites

Location: See explanation in text for numbering system for wells and springs.
Geologic unit: Principal water-bearing unit; see table 22 for explanation of symbols.
Altitude of land surface: Altitudes from most detailed topographic maps; National Geodetic Vertical Datum of 1929.
Depth to water: Above (+) or below land-surface datum.

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			WELLS				
(D-13-19) 13aad-1	Qay	5,810	129	4- 5-77	18.6	—	—
13aad-2	Qay	5,810	37	4- 5-77	20.8	—	—
				7- 3-78	23.4	—	—
(D-13-23) 9aac-1	Qay	5,730	119	5-10-77	14.8	—	—
9aac-2	Qay	5,730	40	5-10-77	15.9	—	—
26bdc-1	Tg	6,340	1,290	6-29-77	—	—	—
				7- 7-78	380.5	11	—
(D-13-24) 18bbb-1	Qay	5,876	82	1-28-76	32.2	—	—
				4- 7-76	26.5	—	—
				7-21-76	30.1	—	—
				10- 8-76	28.7	—	—
				5- 9-77	24.6	—	—
				6- 1-78	35.9	—	—
18bbb-2	Qay	5,876	42	1-28-76	31.6	—	—
				4- 7-76	25.6	—	—
				7-21-76	29.2	—	—
				10- 8-76	27.9	—	—
				5- 9-77	23.7	—	—
(D-14-18) 1bbd-1	Tg	7,045	150	8- 8-72	68	7	—
(D-14-19) 3cdb-1	Tg	6,880	96	12- -60	80	5	—
(D-14-20) 7adb-1	Kmv	7,015	7,300	9-17-62	—	—	—
30bab-1	Tg	7,210	4,450	7-22-63	700	11	—
(D-14-22) 2aaa-1	Tgd	6,700	1,312	4-19-78	—	—	—
(D-15-20) 3bab-1	Tg	7,440	108	12- -60	52	15	—
12cca-1	Tg	7,425	120	6- -64	60	4	—
(D-15-21) 22dcc-1	Tw	7,420	5,700	9-26-63	—	—	At 3,134
	Tw			9-28-63	—	—	At 3,466
	Kmv			10-12-63	—	—	At 5,518
			SPRINGS				
(D-13-19) 8aa-S1	Tgp	6,150	—	8- 8-72	—	.25	—
(D-13-23) 3cbb-S1	Tgp	5,720	—	5-21-77	—	50	—
				9-15-77	—	4	—
27acd-S1	Tgp	6,180	—	4-12-72	—	<.5	—
(D-13-25) 29bab-S1	Tgp	7,050	—	9- 1-71	—	2	—
(D-14-19) 33aad-S1	Tgp	7,120	—	9- 2-71	—	<.5	—
(D-14-22) 25cac-S1	Tgp	7,060	—	4-12-72	—	4.5	—
				8-21-74	—	2.0	—
(D-14-24) 21ccc-S1	Tgp	6,580	—	9-13-72	—	10	—
(D-15-20) 15bbd-S1	Tgp	7,240	—	8-31-71	—	2.2	—
				9- 8-77	—	.13	—
(D-15-23) 32bcc-S1	—	7,000	—	9-10-74	—	20	—
				9- 7-77	—	17	—
(D-15-23) 36ddd-S1	Tgp	8,040	—	9-17-64	—	5.6	—
				9-15-77	—	1.1	—
(D-15-24) 18cdd-S1	—	7,480	—	9-10-74	—	3	—
				9-14-77	—	2	—
(D-16-22) 23dad-S1	Tgp	7,640	—	8-22-74	—	.30	—
				9- 7-77	—	.10	—
(D-16-23) 16bbd-S1	Tgp	7,680	—	8-22-74	—	3.0	—
(D-17-21) 10bdd-S1	Tgp	8,000	—	6-19-75	—	10	—
				9- 8-77	—	—	—
(D-17-22) 19bbd-S1	Tgp	8,160	—	8-22-74	—	20	—
				9- 8-77	—	—	—

[1] Sodium plus potassium.

in and near the Hill Creek and P R Spring Special Tar Sand Areas

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			WELLS				
1,460	130	130	180	3.6	45	690	510
657	71	57	82	3.4	11	180	480
793	95	68	81	2.6	18	250	500
6,030	410	590	800	4.1	120	3,800	560
27,800	500	2,700	4,400	19	460	19,000	1,410
4,920	3.4	4.5	2,300	3.8	980	39	2,430
960	54	44	190	.7	12	470	240
4,680	360	400	490	12	52	3,100	509
3,430	260	300	360	11	31	2,200	527
3,660	270	320	370	10	36	2,400	492
3,530	270	300	390	14	56	2,200	588
3,520	310	340	360	14	38	2,200	480
6,670	240	560	890	14	81	4,600	550
3,180	280	270	300	15	50	2,100	291
3,050	260	260	310	13	27	1,900	549
3,450	300	300	320	13	29	2,200	554
3,250	240	300	340	14	32	2,100	437
3,540	380	330	360	15	31	2,000	840
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
4,711	8.0	2.0	(1) 1,672	—	140	2,150	964
818	10	7.0	274	13	32	290	366
661	13	20	180	.6	8.2	320	170
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
1,966	20	36	(1) 644	—	1,065	2.0	149
11,986	80	36	(1) 3,766	—	355	7,579	156
33,253	600	109	(1) 11,643	—	14,981	5,813	107
			SPRINGS				
—	—	—	—	—	—	—	—
6,110	360	510	860	10	4,000	74	608
5,680	360	500	770	5.7	3,700	62	577
2,720	160	200	410	7.3	1,500	140	576
1,460	150	110	140	.7	850	33	308
802	84	61	93	1.3	300	18	438
783	63	86	92	1.9	240	29	506
934	75	100	110	2.1	310	33	563
976	130	72	74	1.2	500	13	319
322	65	17	25	.8	64	14	254
297	56	15	23	.4	57	7.9	220
796	120	63	61	1.6	350	8.6	376
755	110	57	57	1.1	310	8.0	346
381	65	36	17	.9	94	4.1	317
349	54	32	15	.7	72	2.8	282
768	120	54	54	1.1	340	9.9	326
749	97	57	52	1.0	350	7.9	332
448	76	39	29	.8	58	3.8	434
422	63	39	30	.7	55	3.4	419
474	78	55	16	1.1	70	6.7	470
302	48	20	33	.9	44	3.5	268
358	60	25	35	.9	63	3.3	306
407	77	26	27	.8	100	2.2	303
407	77	26	27	.8	110	2.5	287

SAN RAFAEL SWELL SPECIAL TAR SAND AREA

By H. F. McCormack

Location

The San Rafael Swell Special Tar Sand Area covers about 215 square miles in Emery County about 20 miles southeast of Castle Dale and about 25 miles east of Emery in the San Rafael Swell area of Canyon Lands physiographic subdivision of the Colorado Plateaus (Fenneman, 1946) (fig. 19). Land-surface altitudes range from about 8,000 feet at the San Rafael Knob on the west side of the area to less than 4,500 feet in the San Rafael Desert on the east. The proven or inferred tar-sand deposits underlie parts of townships 20 to 25 south and ranges 9 to 14 east, Salt Lake base line and meridian. About 69 of the approximate 215 square miles are available for lease. The Federal Government is the major landowner. The estimated oil in place is 440 to 540 million barrels (table 1). The tar-sand deposits are primarily in the Moenkopi Formation (Triassic) with small deposits in the Mossback Member of the Chinle Formation (Triassic) and in the Kaibab Limestone (Permian) (Ritzma, 1979, sheet 2).

Climate

The climate of the area is influenced by local topographic features; and it generally is arid to semiarid, with low relative humidity, abundant sunshine, low precipitation, hot summers, and cold winters. Seasonal and daily variations in air temperatures are large. The Wasatch Plateau, about 40 miles to the west, acts as an orographic barrier to winter and spring moisture moving from the Pacific Ocean. Summer and fall precipitation comes from moist tropical air masses that occasionally move into the region from the Gulf of Mexico and the Gulf of California, resulting in thunderstorms.

Normal annual precipitation varies with altitude from more than 12 inches at San Rafael Knob on the west to less than 6 inches in the San Rafael Desert on the east (fig. 19). The average annual air temperature is 46°F, with large variations in daily air temperature caused by relatively strong daytime warming and rapid nighttime cooling. Seasonal variation in daily mean temperature is greater in the valleys, where the air is more confined, than in the higher areas. Normal annual free-water surface evaporation ranges from 40 to 50 inches (Farnsworth and others, 1982, map 3).

Water Resources

The San Rafael Swell Special Tar Sand Area is in the San Rafael River and Muddy Creek drainage basins. The San Rafael River is tributary to the Green River, whereas Muddy Creek joins with the Fremont River to form the Dirty Devil River, which is tributary to the Colorado River. The surface drainage is primarily to the southeast. Ground-water movement locally is complex, but generally the ground water ultimately discharges to the Green River basin or to the Dirty Devil River basin.

Surface Water

Major perennial streams in and near the area are the San Rafael River and the upper reaches of Muddy Creek. None of the tributaries to the San Rafael River or Muddy Creek in the area are perennial, and many of the smaller streams are ephemeral. The San Rafael River is the only major stream that crosses the study area. Streamflow data for selected sites in and near the area are summarized in table 24. The average annual flow for two locations about 35 miles apart on the San Rafael River shows no appreciable variation (fig. 20). Monthly mean flow, however, varies at the same locations (fig. 21).

In the San Rafael River basin, west of the study area, there are eight reservoirs with a total usable capacity of 115,000 acre-feet. Seven of the reservoirs supply water mainly for irrigation; and the other, which has a usable capacity of 30,530 acre-feet, supplies water for the Huntington Plant of Utah Power & Light Co.

From April to November, major diversions in the upper part of the San Rafael and Muddy Creek basins nearly deplete the flow in those streams. During such periods, the streamflow that enters the study area is mainly return flow from irrigation with some additional flow from infrequent thunderstorms.

Dissolved-solids concentrations and suspended-sediment data for selected gaging stations in and near the area are listed in table 25. The major changes in chemical quality are increases in the dissolved-solids concentrations which occur northwest of the area where streams cross the Mancos Shale, where it crops out in a belt about 10 to 15 miles wide, about 15 miles from the area. See Mundorff (1979, p. 12) and Mundorff and Thompson (1982, p. 13). Most of the suspended-sediment discharge of streams probably occurs during a few days each year, resulting mainly from cloudburst runoff (Mundorff and Thompson, 1982, p. 46). Concentrations of dissolved trace elements were relatively small.

Ground Water

The Entrada, Navajo, Wingate, and Coconino Sandstones, the Moenkopi Formation, and rocks of Mississippian age are considered to be major water-bearing formations in the area because of their large areal extent or thickness (table 26). Their water-yielding ability is affected mainly by depth of burial and by faulting and folding, which locally enhance ground-water circulation by fracturing or they impede circulation by offsetting permeable beds. Water yield in the area ranges from less than 1 to 200 gallons per minute for springs and from 2.8 to 200 gallons per minute for wells (table 27). The higher recorded yields are from the Navajo Sandstone and the Moenkopi Formation.

The dissolved-solids concentration of ground water shown in table 27 for samples from selected wells and springs ranges from 355 to 4,080 milligrams per liter.

Existing Water Use

The San Rafael Swell Special Tar Sand Area is within Utah State Water Rights Areas 93 and 95, in Emery County (Utah Division of Water Rights, 1974). According to Jensen (1975) there is no unappropriated water; thus, water rights would have to be purchased or leased for a tar-sand industry.

There are no major diversions from the San Rafael River or Muddy Creek within the study area. Water in the upper reaches of the tributary streams, however, is impounded by small earthfill dams for livestock. Ground water from both wells and springs is used for livestock watering. Outside the study area, in the upper San Rafael River basin, the amount of surface water diverted annually for irrigation is about 150,000 acre-feet. Coal-fired electric powerplants will use about 62,000 acre-feet of water annually (Mundorff and Thompson, 1982, p. 8). About 10,000 acre-feet per year of ground water is used for irrigation, livestock, and domestic use (Hood and Patterson, 1982, p. 25).

Hydrologic Impacts Unique to This Area

A "high" commercial tar-sand industry in the San Rafael Swell Special Tar Sand Area could require about 4,600 acre-feet of water per year for a production level of 20,000 barrels per day (table 1). These needs could be supplied from surface and supplemental ground-water sources in the area, without any unique hydrologic impacts other than rearrangement of water rights. The salinity of the Colorado River System probably would not be increased by a tar-sand industry in the area. Potential impacts that generally apply to all areas are discussed in the section "Hydrologic impacts of a tar-sand industry," near the end of this report.

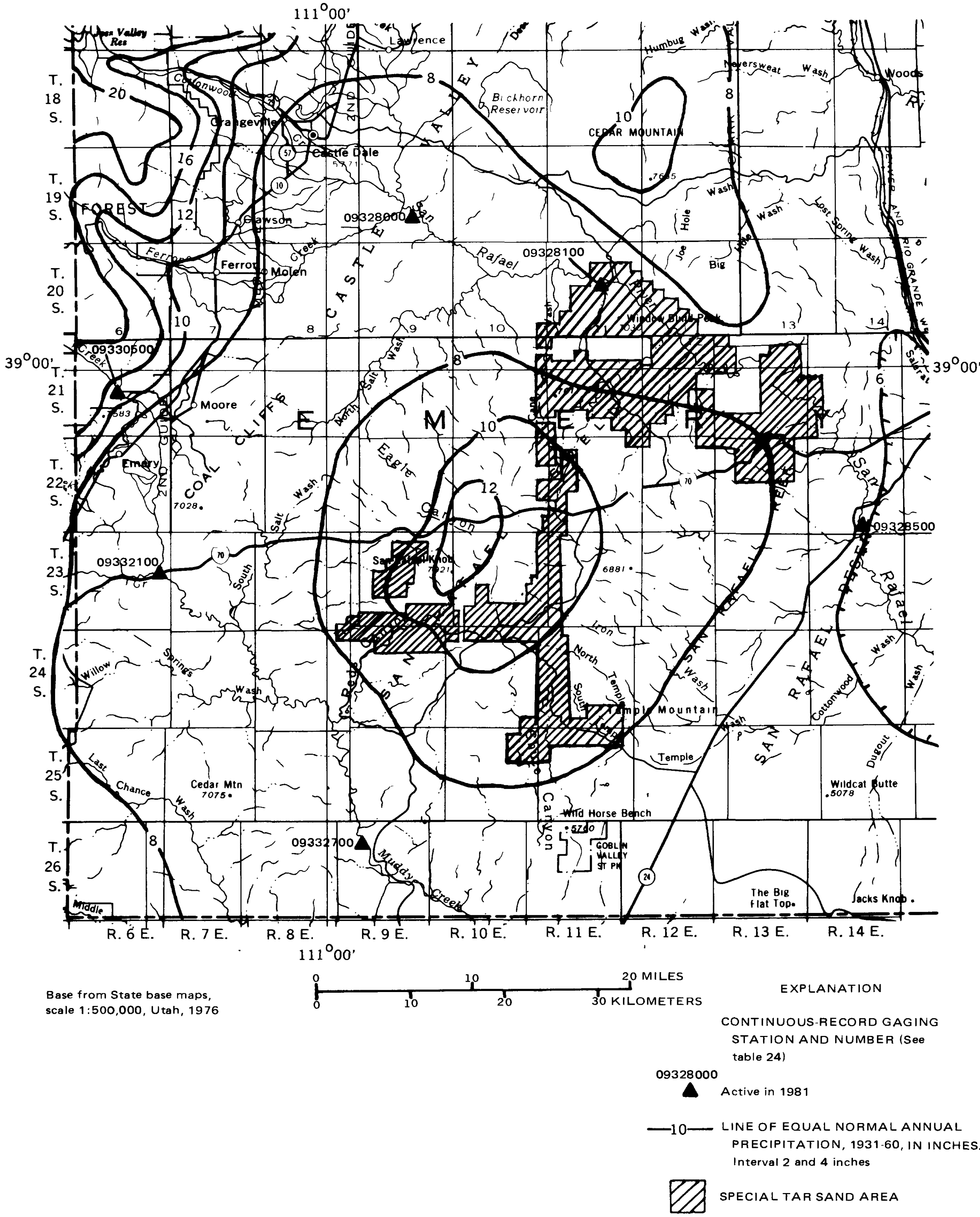

Figure 19.—Normal annual precipitation and location of stream-gaging stations in and near the San Rafael Swell Special Tar Sand Area. Precipitation from U. S. Weather Bureau, 1963.

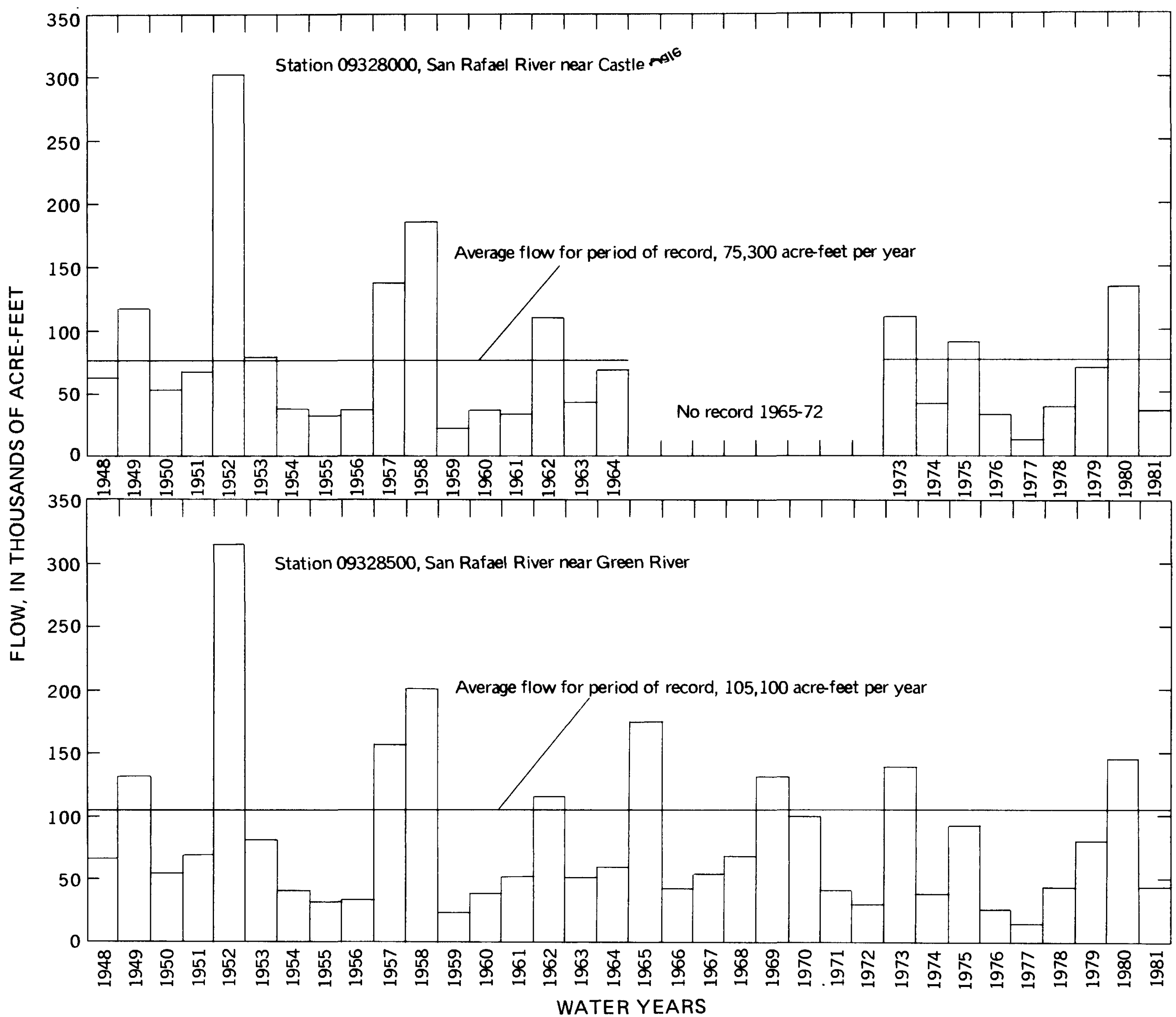

Figure 20.—Annual flow at two gaging stations in and near the San Rafael Swell Special Tar Sand Area.

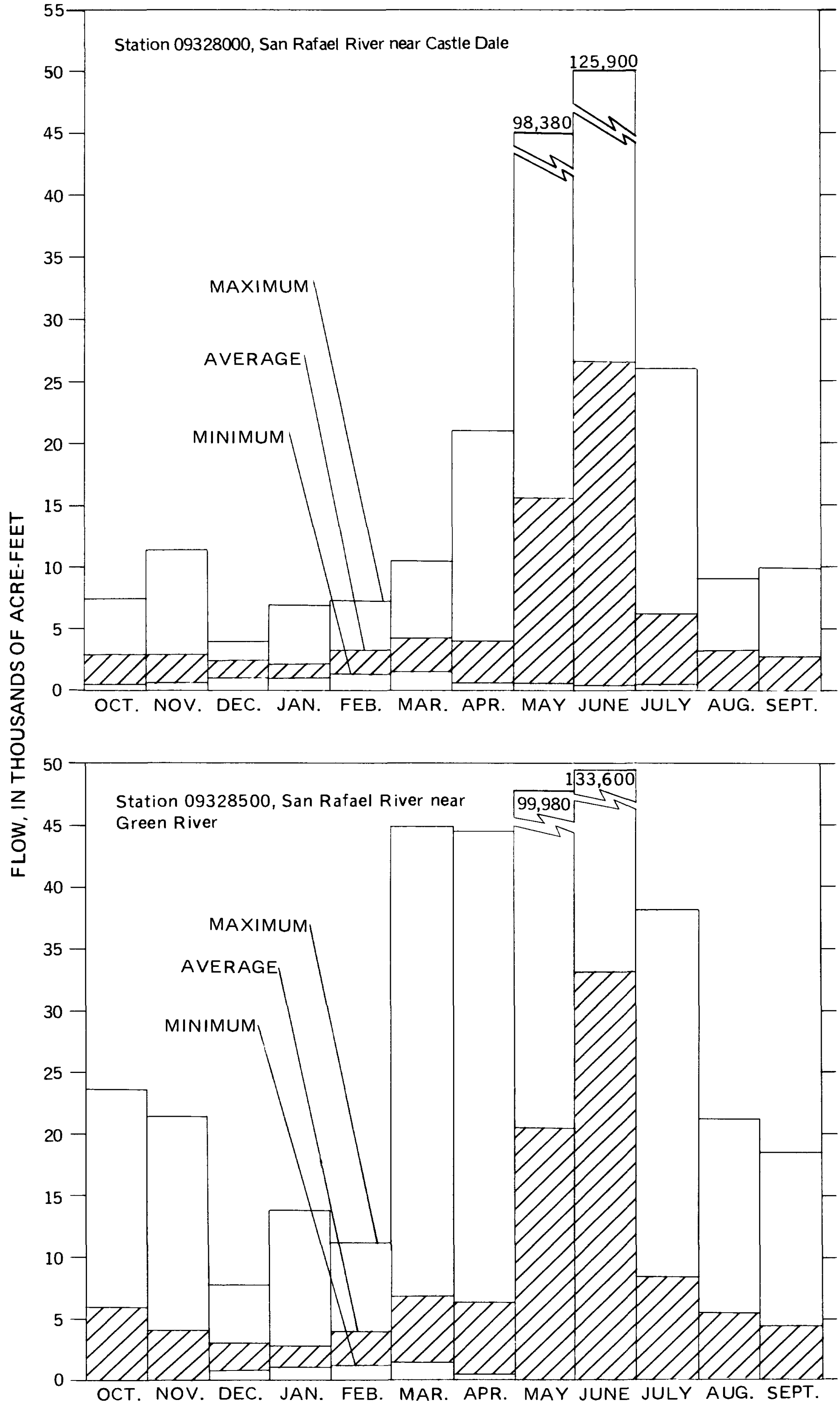

Figure 21.—Average, maximum, and minimum monthly mean flow at two gaging stations in and near the San Rafael Swell Special Tar Sand Area.

Table 24.--Streamflow at selected gaging stations in and near the San Rafael Swell Special Tar Sand Area

Station number and name		Period of record used (water years)	Drainage area (square miles)	Average flow		Flow (cubic feet per second)	
				Cubic feet per second	Acre-feet per year	Minimum	Maximum
09328000	San Rafael River near Castle Dale	1948-64, 1973-81	930	104	75,300	0	4,510
09328100	San Rafael River at San Rafael Bridge Campground, near Castle Dale	1976-81	1,284	76.8	55,640	0	4,630
09328500	San Rafael River near Green River	1910-18, 1946-81	1,628	145	105,100	0	12,000
09330500	Muddy Creek near Emery	1911-13, 1950-81	105	37.3	27,020	0	3,340
09332100	Muddy Creek below Interstate Highway I-70, near Emery	1951-61, 1974-81	418	16.4	11,900	0	9,400
09332700	Muddy Creek at Delta Mine, near Hanksville	1976-81	841	21.9	15,870	0	6,840
09333500[1]	Dirty Devil River above Poison Spring Wash, near Hanksville	1949-81	4,159	96.3	69,770	0	35,000

[1] Not located in figure 19.

Table 25.—Concentrations of major dissolved constituents and suspended sediment of streamflow for sites in and near the San Rafael Swell Special Tar Sand Area

Station number and name		Period of record used (water years)		Concentration (milligrams per liter)								
				Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)	Suspended sediment
09328100	San Rafael River at San Rafael Bridge Campground, near Castle Dale	1976-81	Maximum	6,030	590	320	1,100	29	150	4,000	463	4,230
			Minimum	453	63	32	23	2.1	6.0	180	140	15
			Number of samples	82	83	83	83	83	83	83	43	54
09328500	San Rafael River near Green River	1947-49, 1951-81	Maximum	6,530	560	380	1,100	31	200	4,300	600	96,700
			Minimum	487	14	24	43	2.1	7.2	200	60	18
			Number of samples	853	1,139	1,139	1,074	800	1,269	1,267	1,241	215
09332700	Muddy Creek at Delta Mine, near Hanksville	1976-81	Maximum	4,860	520	190	820	16	880	2,600	273	23,700
			Minimum	694	80	28	79	2.1	39	250	150	12
			Number of samples	55	56	56	56	56	56	56	26	34
09333500[1]	Dirty Devil River above Poison Spring Wash, near Hanksville	1975-76	Maximum	3,460	587	101	440	26	370	2,030	257	—
			Minimum	963	140	34	110	5.8	90	420	129	—
			Number of samples	18	18	18	19	19	19	19	18	—
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 206)				500	—	—	—	—	250	250	—	—

[1] Not located in figure 19.

Table 26.—Generalized stratigraphic section of lithologic units discussed in the text for the San Rafael Swell Special Tar Sand Area

[Data from Hood and Danielson (1981, table 1).]

System	Series	Geologic unit		Thickness (feet)	Symbol	Description
Quaternary	Holocene	Younger alluvium		0-20	Qay	Surficial deposits of clay, silt, sand, gravel, and angular blocks. Along stream valley, young alluvium is often well-sorted, but generally is fine grained.
Jurassic	Middle Jurassic	San Rafael Group	Curtis Formation	0-240	Jcu	Greenish-gray and brown fine- to coarse-grained thin- to thick-bedded glauconitic marine sandstone and siltstone with minor greenish-gray to red shale and local thin lenses of conglomerate.
			Entrada Sandstone	300-800	Je	In the northeastern part of area, light-reddish-brown to tan massive crossbedded eolian sandstone dominates; changes westward to an earthy reddish-brown thin- to thick-bedded fine-grained sandstone with substantial amount of clay.
			Carmel Formation		Jca	Removal of limestone and gypsum has lead to considerable distortion of the formation and overlying rocks. Consists of a basal red shale and a siltstone bed, overlain by a lower part of limestone and an upper part of shale with some sandstone and beds of gypsum.
Triassic(?) and Jurassic	Triassic(?) and Lower Jurassic	Glen Canyon Group	Navajo Sandstone	450-1,100	JTRna	White, tan, and buff thickly and intricately crossbedded very fine to fine-grained eolian sandstone.
Triassic	Upper Triassic		Wingate Sandstone	270-400	TRwi	Reddish-brown, buff, and grayish-orange very fine-grained thickly crossbedded calcareous eolian sandstone.
		Chinle Formation		215-550	TRc	Seven members or lithologic equivalents mostly of fluvial and lacustrine origin; not all present in any given locality. Mudstone, siltstone, sandstone, and some conglomerate in various shades of purple, red, and brown.
	Lower and Middle(?) Triassic	Moenkopi Formation		360-1,000	TRm	Upper part of formation consists of reddish-brown even-bedded fissile mudstone and siltstone and fine-grained sandstone with thin layers and veins of gypsum and anhydrite. The Sinbad Limestone Member is yellowish-gray and tan thin- to medium-bedded oolitic dolomite and limestone with minor amounts of siltstone and sandstone. Lower part of formation is light-reddish-brown, yellow, and green even-bedded siltstone and sandstone containing gypsum veinlets; a chert pebble conglomerate at base. Tar-sand deposits in the San Rafael Swell area are in this formation.
Permian	Lower Permian	Coconino Sandstone		700-1,200	Pco	Light-gray to buff friable to hard fine-grained thickly crossbedded eolian sandstone; grit and considerable limestone in lower 40 feet.

Location: See explanation in text for numbering system for wells and springs.
Geologic unit: Principal water-bearing unit; see table 26 for explanation of symbols.
Altitude of land surface: Altitudes from most detailed topographic maps; National Geodetic Vertical Datum of 1929.
Depth to water: Above (+) or below land-surface datum.

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			WELLS				
(D-20-10)6bdd-11	JTRna	5,260	475	7-14-80	+16	2.8	152-475
				8-14-80	—	10	147-475
(D-21-9)2bbb-1	JTRna	5,770	1,772	5- 9-79	—	100	350-520
	JTRna			5-10-79	—	100	350-640
	JTRna			5-10-79	—	—	350-860
	TRwi			5-12-79	—	200	350-1,450
(D-22-10)23cbc-1	TRwi	7,035	84	12-27-71	33.1	—	At 83
30aca-1	TRm	6,550	1,200	6-15-66	—	—	At 704
				6-17-66	—	—	At 1,080
				6-27-66	—	—	At 1,200
(D-22-13)35bcd-2	JTRna	4,510	310	7-17-80	138	20	At 310
(D-22-14)28dba-1	Je	4,235	515	5-21-80	16.7	5	At 515
28ddd-1	Jcu	4,200	265	10-28-58	6	—	At 265
31ddb-1	Jca	4,290	350	1- 9-36	40	10	At 350
(D-23-9)2ccb-1	Pco	7,030	690	8-12-71	576	—	At 690
(D-23-10)12ddd-1		6,850	217	10-31-58	160	4	At 217
				7-19-79	25.6	7.2	—
28dbb-1	Mu[2]	6,817	3,144	6- -61	—	—	At 2,197
				7- -61	—	—	At 2,265
(D-24-9)5bcb-1	TRc	5,900	—	7-21-79	19.8	10	—
(D-25-11)33dbd-1	JTRna	4,900	2,090	3- 7-75	—	60	380-400
			SPRINGS				
(D-20-11)3cab-S1	Qay	5,260	—	5- 3-78	—	—	—
				6- 8-78	—	—	—
4aab-S1		5,310	—	10-31-58	—	20	—
				5- 3-78	—	—	—
				6- 8-78	—	—	—
11bcc-S1	Qay	5,155	—	5- 3-78	—	—	—
				6- 8-78	—	—	—
(D-21-13)24cbb-S1		4,320	—	9-19-31	—	200	—
(D-21-14)5aab-S1	Jca	4,565	—	8- 6-79	—	<5	—
(D-22-9)8aca-S1	Jca	6,040	—	10-25-79	—	10	—
(D-22-13)35bcd-S1	Qay	4,500	—	7- 6-79	—	<5	—
(D-22-14)6bbc-S1	JTRna	4,500	—	10-28-58	—	5	—
				2- 1-68	—	—	—
(D-23-10)9bbd-S1	TRwi	7,120	—	10-31-58	—	<1	—
(D-24-9)5bcb-S1	TRc	5,840	—	7-19-79	—	10	—
(D-24-10)3bba-S1	TRm	6,700	—	10-27-44	—	5	—

[1] Sodium plus potassium.
[2] Undivided rocks of Mississippian age.

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			WELLS				
631	100	40	43	15	13	260	—
552	100	41	42	16	16	260	—
850	180	60	17	6.9	16	380	—
766	160	50	7.5	6.5	9.1	380	—
702	160	49	10	8.1	9.2	290	—
692	130	50	22	16	14	290	—
360	68	31	11	18	8.0	73	295
1,930	40	215	(1)292	—	45	1,040	572
1,270	12	137	(1)247	—	45	472	700
1,820	112	126	(1)316	—	70	934	506
933	160	74	23	10	35	450	—
4,080	800	220	390	1.9	110	1,200	—
3,370	321	246	(1)551	—	132	1,120	2,020
—	—	—	—	—	86	2,380	—
1,214	216	112	10	8.0	14	412	700
3,260	238	400	(1)204	—	81	2,100	465
3,060	270	350	170	53	93	1,8u0	—
—	400	340	416	—	1,350	900	573
2,260	160	196	(1)331	—	284	1,000	586
1,890	230	130	150	100	93	990	—
879	150	66	46	8.2	6.0	400	450
			SPRINGS				
—	259	37	198	—	38	970	212
—	296	101	210	—	30	1,300	256
2,250	329	124	(1)194	—	36	1,430	232
—	263	85	180	85	32	1,060	2,830
—	444	218	576	—	60	2,870	207
—	280	149	280	—	80	1,520	256
—	344	161	488	—	30	2,140	402
3,080	681	133	(1)171	—	208	1,310	1;170
642	120	48	24	12	12	240	—
3,380	520	230	170	11	120	2,200	—
1,700	260	120	100	15	59	980	—
390	76	33	(1)16	—	8	112	267
355	60	32	5.0	3.0	11	86	248
914	127	112	(1)39	—	24	285	648
1,890	230	130	150	100	93	990	—
1,990	232	216	(1)70	—	28	1,310	262

TAR SAND TRIANGLE AND WHITE CANYON SPECIAL TAR SAND AREAS

By G. E. Pyper

Location

The Tar Sand Triangle and White Canyon Special Tar Sand Areas cover about 270 square miles in Garfield, Wayne, and San Juan Counties in the Canyon Lands, a physiographic subdivision of the Colorado Plateaus (Fenneman, 1946) (fig. 22).

The Tar Sand Triangle deposits lie north of the Colorado River within the area bounded on the west by the Dirty Devil River and on the east by the Green River. Land-surface altitudes generally decrease east and west of the Orange Cliffs from about 7,000 feet to about 3,700 feet at the Green and Dirty Devil Rivers. The topography is block-type ledges, ridges, and buttes cut by canyons that form benches and flats. Numerous canyons drain to the Dirty Devil, Green, and Colorado Rivers. The proven or inferred tar-sand deposits underlie all or parts of townships 29 to 33 south and ranges 14 to 17 east, Salt Lake base line and meridian. The deposits are in the White Rim Sandstone Member with about 1 percent in the Cedar Mesa Sandstone Member, both of the Cutler Formation (Ritzma, 1979, sheet 2). In addition to present mineral leases, about 40 percent of the deposits are in the Glen Canyon National Recreation area, a few hundred acres are in Canyonlands National Park (extreme northeastern edge of deposits), and a large part of the area to the west is under review for wilderness classification by the U.S. Bureau of Land Management (Campbell and Ritzma, 1979, p. 15). Therefore, only about 35 of the approximately 250 square miles of area are available for lease. The Tar Sand Triangle is the largest tar-sand deposit in Utah, with an estimated inplace reserve of 12.5 to 16 billion barrels of oil (table 1).

The White Canyon deposit lies south of the Colorado River and about 15 miles south of the Tar Sand Triangle Area, in and near White Canyon. The land-surface altitude decreases generally to the southwest from about 6,500 feet in the northeast part of the area to 4,600 feet at White Canyon. The proven or inferred tar-sand deposits underlie parts of townships 34 and 35 south and ranges 15 and 16 east, Salt Lake base line and meridian, and the deposits are in the Hoskinnini Tongue of the Moenkopi Formation (Ritzma, 1979, sheet 2). About 12 of the approximately 17 square miles of the area are available for lease. The estimated inplace reserve is 12 to 15 million barrels of oil (table 1).

Climate

The climate of both areas generally is arid, with low relative humidity, abundant sunshine, small amounts of precipitation, hot summers, and cold winters. The normal annual precipitation ranges from about 14 inches at the head of White Canyon to less than 8 inches along the Dirty Devil and Colorado Rivers (fig. 22). About 40 miles northwest at Hanksville, the average annual air temperature is 52°F and the normal annual precipitation is less than 6 inches, with the greatest quantity of precipitation falling during July through October. The Wasatch and Aquarius Plateaus about 40 miles to the west and mountains in Arizona to the south act as orographic barriers to air masses moving from the Pacific Ocean in the winter and from the Gulf of Mexico in the summer.

Selected climatic characteristics are published monthly by the National Oceanic and Atmospheric Administration for Hanksville about 40 miles to the west, Canyonlands--The Neck and The Needle to the east, and Hite Ranger Station to the southwest, which are near the area. These climatic characteristics vary considerably from day to day, month to month, and year to year except for the normal annual free-water surface evaporation which is fairly constant at 55 inches (Farnsworth and others, 1982, map 3).

Water Resources

Water in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas consists of approximately 9.8 million acre-feet annually in the Dirty Devil, Green, and Colorado Rivers and their tributaries; about 210 million acre-feet of recoverable fresh to moderately saline ground water in the Navajo, Wingate, and Coconino Sandstones in the lower Dirty Devil River basin, which includes an area 60 miles to the west (Hood and Danielson, 1981, p. 36); and 25 million acre-feet of water in storage in Lake Powell. The surface drainage in the Tar Sand Triangle is primarily west from the Orange Cliffs drainage divide to the Dirty Devil River; northeast to the Green River from this same divide; and south to the Colorado River from the south flank of the area. The White Canyon part drains primarily southwest to White Canyon, which flows northwestward to Lake Powell. In both parts, flow in tributaries is ephemeral or intermittent and is minimal.

Data are insufficient to determine the direction of ground-water movement but most of the water probably moves from recharge areas at local rock outcrops to discharge areas in the nearest lower surface-drainage channel. Locally water probably also moves downdip in the aquifers.

Surface Water

Streamflow data for selected sites near the Tar Sand Triangle and White Canyon Special Tar Sand Areas are summarized in table 28. The runoff in the area is considered to be less than 1 inch per year (Utah Department of Natural Resources, 1977, p. 62), and the only possible perennial stream that originates in the area is Horseshoe Canyon. Keefer and McQuivey (1979, p. 222) computed annual runoff from Happy and Millard Canyons as 1,920 and 960 acre-feet, respectively, but the average flow per square mile for these canyons as computed by Keefer and McQuivey appear high when compared to the values for North Wash and White Canyon in table 28.

The mean annual flows for North Wash and White Canyon varied greatly during the 20 years of record (fig. 23). Values for station 09334000, North Wash near Hanksville, ranged from 80 to 2,690 acre-feet per year, and those for station 09334500, White Canyon near Hanksville, ranged from 413 to 8,480 acre-feet per year. Computations indicate there is a 60-percent chance that in any year the annual flow will be less than the average annual flow. As shown in figure 23, for four representative gaging stations, the flow during wet years can be 15 or more times greater than during dry years. The variation of monthly mean and daily mean flows for these four sites is even greater (fig. 24) and the flow varies considerably from one location to another and from month to month and year to year. In contrast, the flows at station 09315000, Green River at Green River, and at station 09180500, Colorado River near Cisco, although varying considerably from month to month and year to year do not vary much from one location to another (see table 28).

The dissolved-solids concentrations and suspended-sediment data for selected gaging stations near the area are listed in table 29. The range in concentration of dissolved solids, which is from 71 to 6,530 milligrams per liter, indicates considerable variation; however, except for the San Rafael River, the ranges are similar.

In the headwater areas of Muddy Creek and the Fremont River, which are tributaries of the Dirty Devil River, the dissolved-solids concentrations generally are less than 300 milligrams per liter (Mundorff, 1979, p. 12). The concentration of dissolved solids generally is inversely proportional to the flow, and the concentrations increase in a downstream direction owing to evapotranspiration and return flow from irrigation. Downstream at station 09333500, Dirty Devil River above Poison Spring Wash, near Hanksville, the dissolved-solids concentration ranged from 963 to 3,460 milligrams per liter.

The measured range of suspended-sediment concentration in perennial streams near the area is shown in table 29. A maximum value of 232,000 milligrams per liter was obtained for station 09330230, Fremont River near Caineville. Mundorff (1979, p. 23) reported the average annual suspended-sediment discharge of the Dirty Devil River near Hite to be about 5.6 million tons. About 20 percent of the sediment discharge during 1948-51 probably occurred during a single 3-day flood in August 1951. Mundorff also states that about 1,500 of the 4,360 square miles in the lower Dirty Devil River basin probably contribute most of the sediment discharged by the Dirty Devil River. The Tar Sand Triangle and White Canyon Special Tar Sand Areas are in this area of high sediment yield.

The only dissolved trace elements found that exceeded the U.S. Environmental Protection Agency (1977) recommended maximum concentrations were iron, lead, and manganese for station 09328500, San Rafael River near Green River, and lead, manganese, and selenium for station 09180500, Colorado River near Cisco (table 30). Additional data are needed for suspended-sediment characteristics and dissolved trace-element concentrations for the ephemeral streams within the area.

Ground Water

The withdrawal of water by wells in the area is small. Hood and Danielson (1981, p. 36) estimated that the Navajo, Wingate, and Coconino Sandstones (table 31) in the lower Dirty Devil River basin contain about 210 million acre-feet of water that could be recovered if the aquifers were completely drained. Yields of individual wells, interference between wells, and migration of saline water undoubtedly would limit the amount that could be withdrawn during the life of a tar-sand industry. Data for wells and springs in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas indicate fairly large variations in yield and quality of water (table 32). Although there are numerous springs in the area, only 12 are listed in table 32. Yields of these springs generally are less than 50 gallons per minute, however, two springs are reported with yields of 360 and 450 gallons per minute. In most cases, the flow of springs seeps into the ground within a short distance from the point of discharge. The concentrations of dissolved solids for the springs range from 179 to 6,530 milligrams per liter, but they generally are less than 2,400 milligrams per liter.

Data from a few wells in the area showed a maximum yield of 40 gallons per minute from a well in the Wingate Sandstone. Concentrations of dissolved solids for these wells range from 318 to 85,500 milligrams per liter.

Existing Water Use

The Tar Sand Triangle and White Canyon Tar Sand Areas are in Water Rights Areas 95, 97, and 99 (Utah Division of Water Rights, 1974). All water in the area is fully appropriated by existing rights; thus water rights for a tar-sand industry would have to be purchased or leased. Water is used in the area for stock, mining, and public supply for tourists. In addition, about 510 acres are irrigated near Hanksville, which is about 40 miles northwest of the area.

Hydrologic Impacts Unique to This Area

A "high" commercial tar-sand industry in the Tar Sand Triangle Special Tar Sand Area would require about 11,100 acre-feet of water per year for a production level of 70,000 barrels of oil per day. The flow from the Green, Colorado, or Dirty Devil Rivers could support such an industry. Without proper safeguards, a "high" commercial tar-sand industry in this area could result in a slight increase in the salinity of the Colorado River.

Some water to support a tar-sand industry could be obtained from bedrock aquifers in the lower Dirty Devil River basin in and near the area, however, it would require operation under constraints of low permeability and the probability of the degradation of the chemical quality of the water (Hood and Danielson, 1981, p. 52-53). The withdrawal of large amounts of water from wells, however, could result in the lessening of streamflow in the lower Dirty Devil River and reduction of some flow of springs. Other potential impacts that generally apply to all areas are discussed in the section "Hydrologic impacts of a tar-sand industry," near the end of this report.

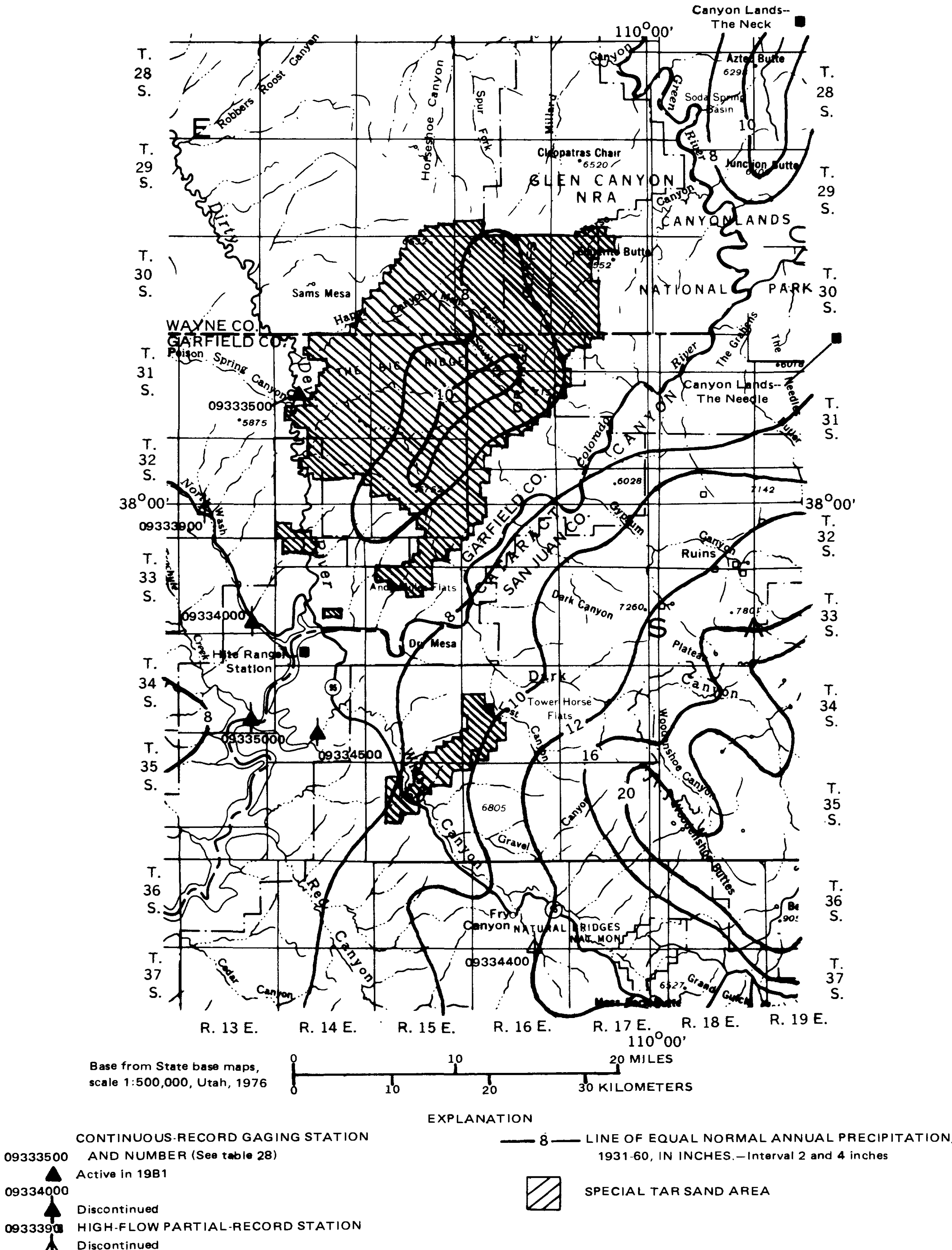

Figure 22.—Normal annual precipitation and location of stream-gaging stations in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas. Precipitation from U. S. Weather Bureau, 1963.

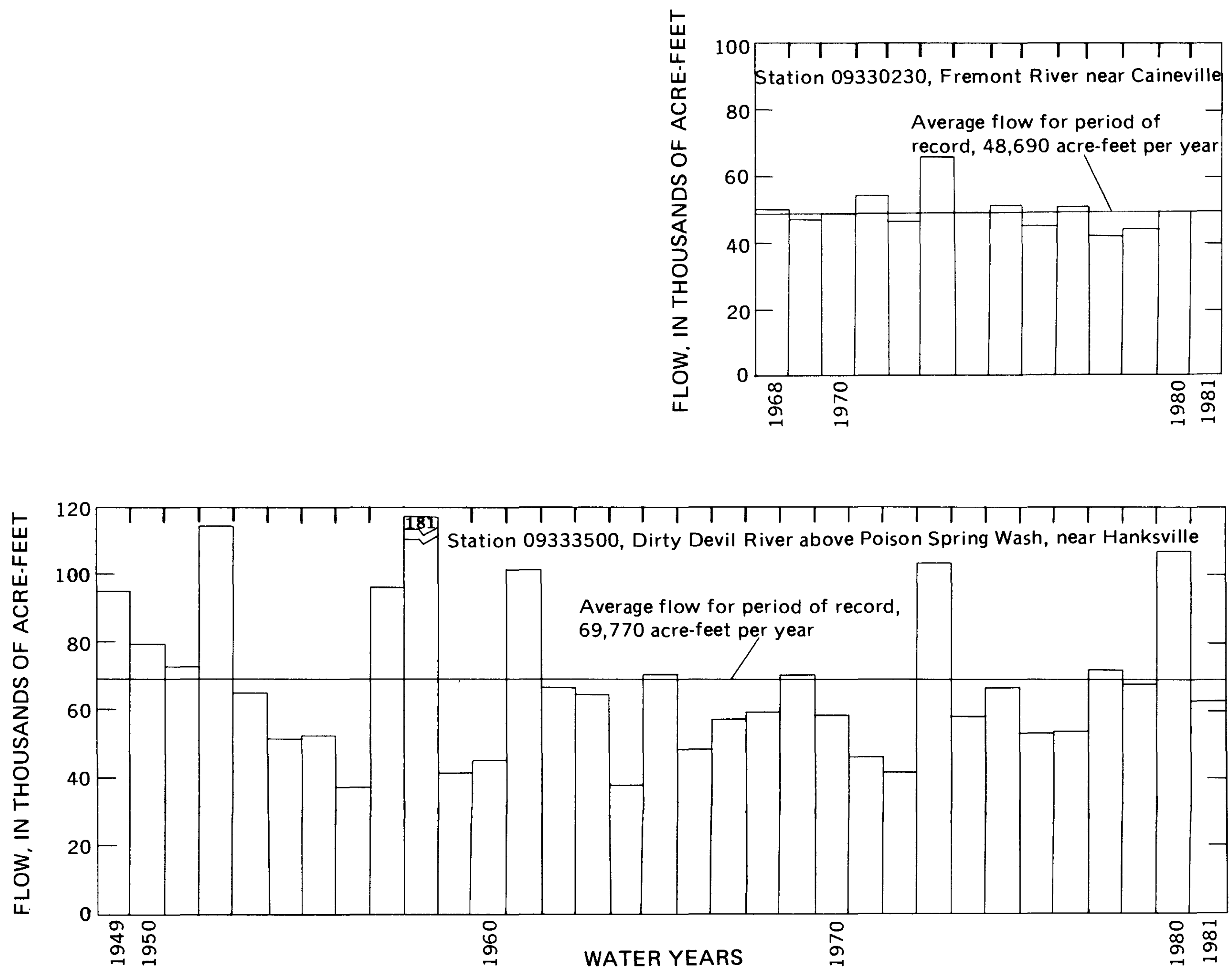

Figure 23.—Annual flow at four gaging stations in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas.

Figure 23--Continued

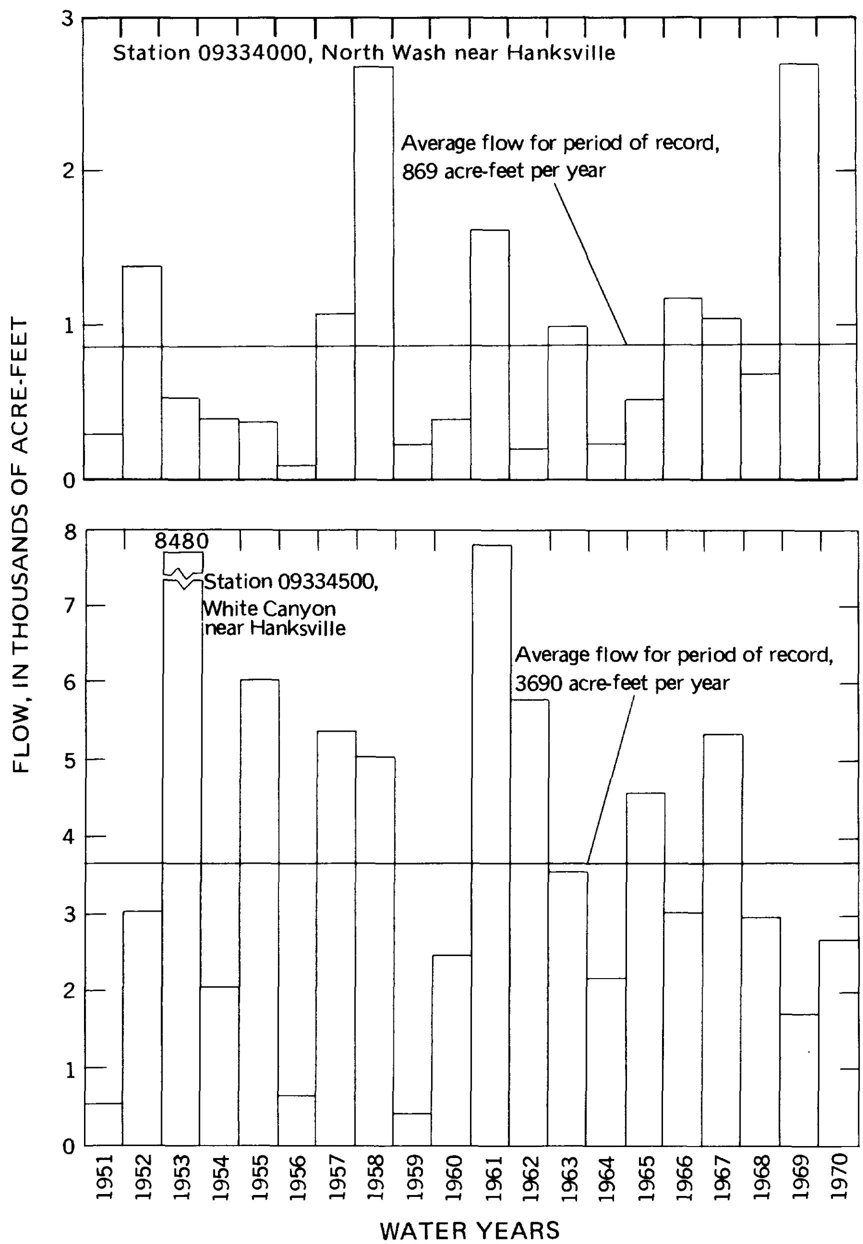

Figure 23.—Annual flow at four gaging stations in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas--Continued.

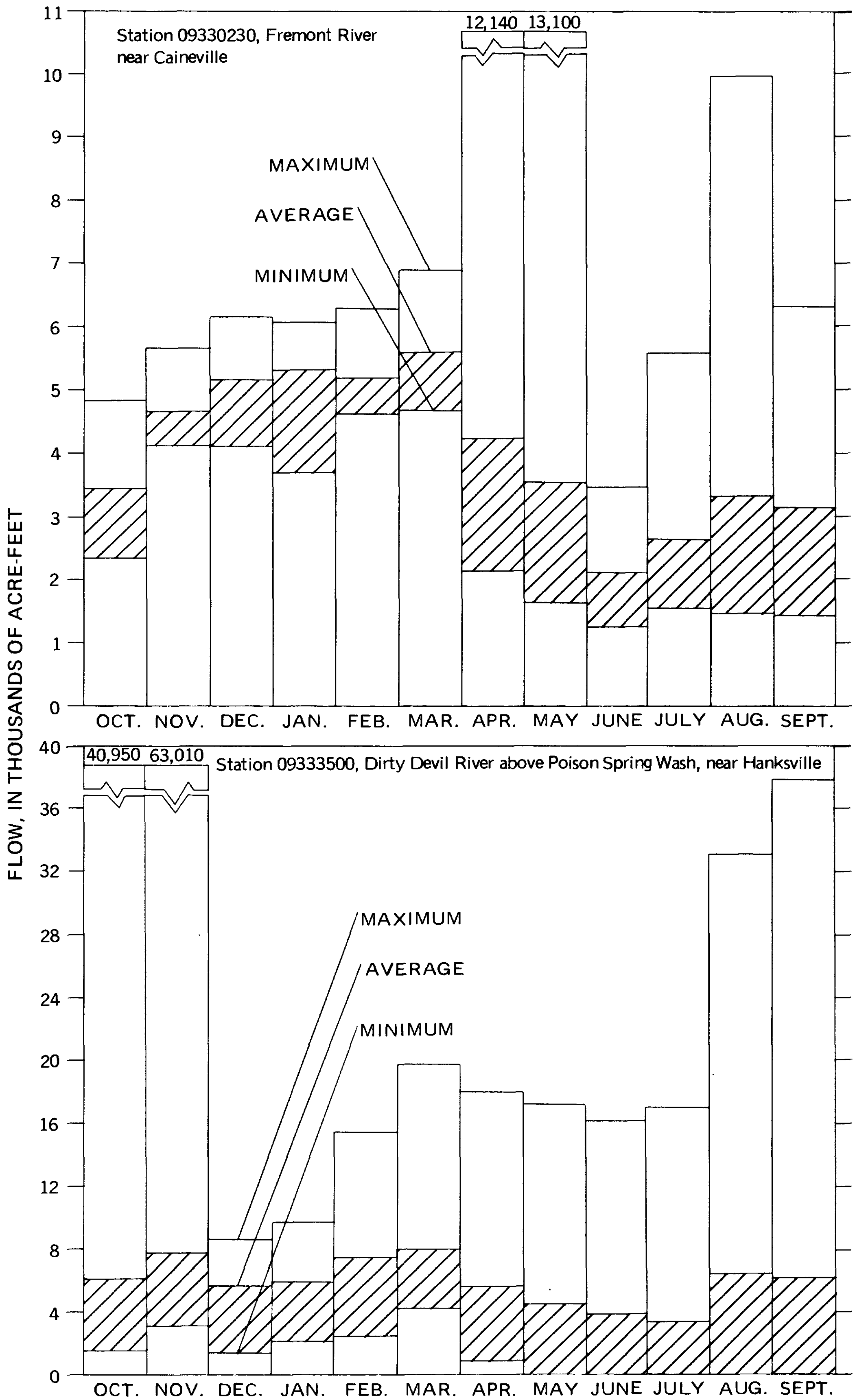

Figure 24.—Average, maximum, and minimum monthly mean flow at four gaging stations in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas.

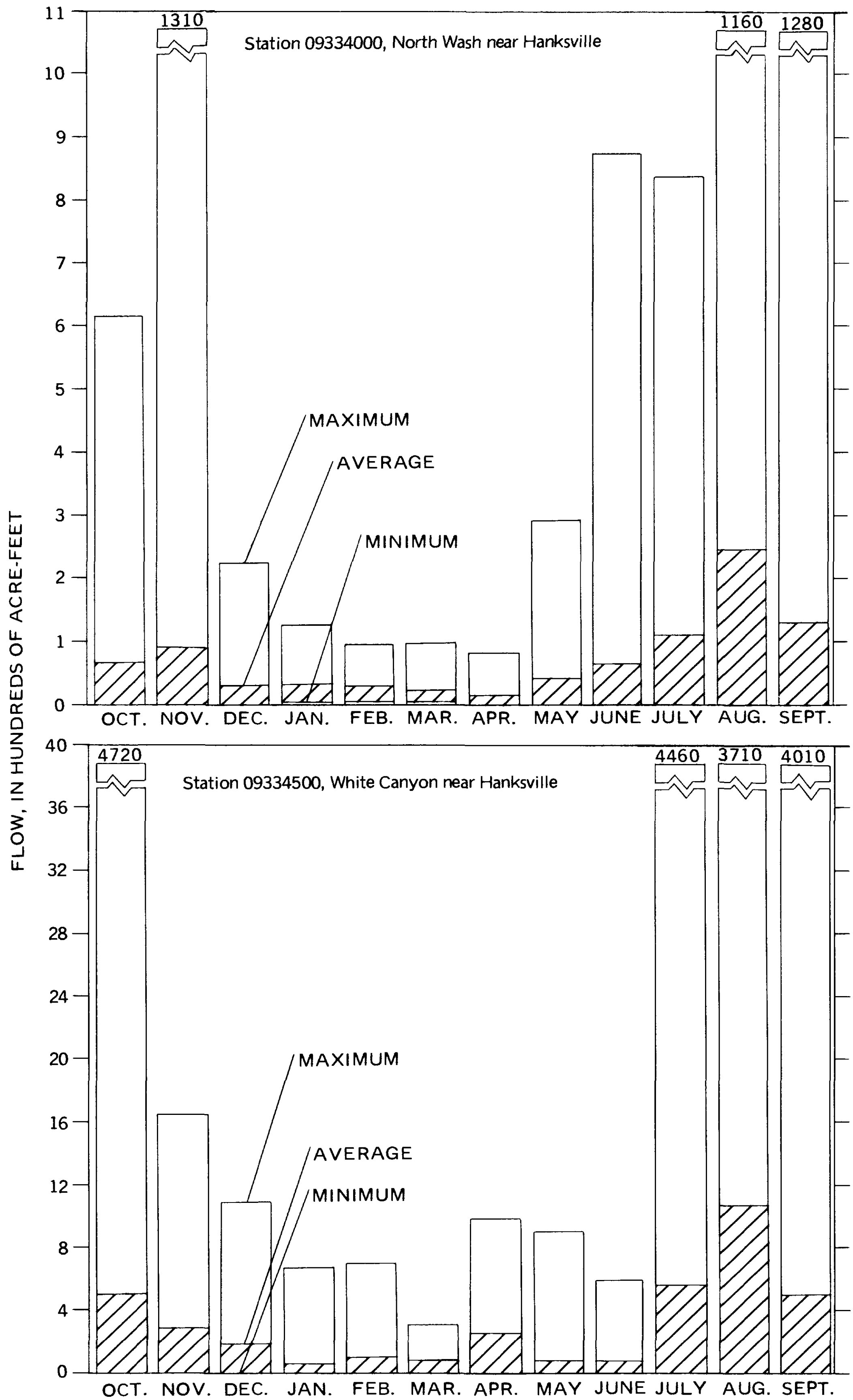

Figure 24.—Average, maximum, and minimum monthly mean flow at four gaging stations in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas--Continued.

Table 28.--Streamflow at selected gaging stations in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas

Station number and name		Period of record used (water years)	Drainage area (square miles)	Average flow		Flow (cubic feet per second)	
				Cubic feet per second	Acre-feet per year	Minimum	Maximum
09180500[1]	Colorado River near Cisco	1911-81	24,100	7,500	5,434,000	558	76,800
09315000[1]	Green River at Green River	1965-81	44,850	5,735	4,152,000	834	30,500
09328500[1]	San Rafael River near Green River	1910-18, 1946-81	1,628	145	105,100	0	12,000
09330230[1]	Fremont River near Caineville	1968-81	1,208	67.2	48,690	10	4,000
09333500	Dirty Devil River above Poison Spring Wash, near Hanksville	1949-81	4,159	96.3	69,770	0	35,000
09333900	Butler Canyon near Hite	1959-74[2]	14.7	—	—	0	1,950
09334000	North Wash near Hanksville	1951-70	136	1.20	869	0	8,900
09334400	Fry Canyon near Hite	1959-73[2]	20.9	—	—	0	3,500
09334500	White Canyon near Hanksville	1951-70	276	5.10	3,690	0	7,390
09335000	Colorado River at Hite	1948-58	76,600	13,500	9,775,000	2,400	105,600

1 Not located in figure 22.
2 Annual maximum only.

Table 29.—Concentrations of major dissolved constituents and suspended sediment of streamflow for sites in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas

Station number and name	Period of record used (water years)		Concentration (milligrams per liter): Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)	Suspended sediment
09180500[1] Colorado River near Cisco	1929–82	Maximum	2,500	265	131	495	16	1,838	1,320	270	68,100
		Minimum	198	36	.1	0	1.5	0	52	84	6.0
		Number of samples	817	1,394	1,394	1,236	1,006	1,465	1,461	1,443	468
09183210[1] Colorado River above Mill Creek, near Moab	1974–81	Maximum	2,000	200	79	250	9.1	310	820	260	—
		Minimum	230	37	11	.2	.8	14	70	14	—
		Number of samples	134	88	88	88	88	88	88	73	—
09315000[1] Green River at Green River	1965–82	Maximum	3,160	507	150	135	7.0	70	2,000	382	47,500
		Minimum	196	29	10	19	.6	6.2	60	107	17
		Number of samples	247	360	358	291	196	359	358	328	207
09328500[1] San Rafael River near Green River	1947–49, 1951–81	Maximum	6,530	560	380	1,100	31	200	4,300	600	96,700
		Minimum	487	14	24	43	2.1	7.2	200	60	18
		Number of samples	853	1,139	1,139	1,074	800	1,269	1,267	1,241	215
09330230[1] Fremont River near Caineville	1967–82	Maximum	3,010	577	68	185	28	268	1,780	278	232,000
		Minimum	71	10	5.8	10	2.0	3.5	2.5	64	34
		Number of samples	26	32	31	30	30	32	32	32	77
09333500 Dirty Devil River above Poison Spring Wash, near Hanksville	1975–76	Maximum	3,460	587	101	440	26	370	2,030	257	—
		Minimum	963	140	34	110	5.8	90	420	129	—
		Number of samples	18	18	18	19	19	19	19	18	—
09335000 Colorado River at Hite	1951–56	Maximum	1,530	219	74	212	8.4	184	834	285	18,200
		Minimum	250	38	11	20	1.0	11	63	22	288
		Number of samples	206	206	206	206	206	207	207	207	32
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 206)			500	—	—	—	—	250	250	—	—

[1] Not located in figure 22.

Table 30.--Concentrations of dissolved trace elements in streamflow for sites in and near the Tar Sand Triangle and White Canyon Special Tar Sand Areas

[ND, not detected]

Station number and name	Period of record used (water years)		Concentration (micrograms per liter) Arsenic (As)	Cadmium (Cd)	Chromium (Cr)	Cobalt (Co)	Copper (Cu)	Iron (Fe)	Lead (Pb)	Manganese (Mn)	Mercury (Hg)	Nickel (Ni)	Selenium (Se)	Silver (Ag)	Zinc (Zn)
09180500[1] Colorado River near Cisco	1971-82	Maximum	4	6	10	<3	10	180	51	70	1	14	23	<1	250
		Minimum	<1	ND	0	ND	0	8	0	0	0	0	<1	0	ND
		Number of samples	33	33	33	33	33	35	33	36	33	12	33	20	33
09183210[1] Colorado River above Mill Creek, near Moab	1976-81	Maximum	—	—	—	259	—	—	—	—	—	—	—	—	—
		Minimum	—	—	—	114	—	—	—	—	—	—	—	—	—
		Number of samples	—	—	—	7	—	—	—	—	—	—	—	—	—
09315000[1] Green River at Green River	1971-82	Maximum	5	4	<20	<3	19	190	70	20	<.5	—	5	ND	120
		Minimum	<1	ND	ND	ND	ND	<2	<1	<10	<.5	—	<1	ND	ND
		Number of samples	24	24	24	24	24	26	24	26	24	—	24	—	24
09328500 San Rafael River near Green River	1975-80	Maximum	4	6	20	282	8	1,700	74	180	<.5	8	5	—	200
		Minimum	<1	0	0	ND	ND	<10	2	10	0	0	<1	—	10
		Number of samples	16	15	15	2	15	54	16	15	17	15	16	—	16
09330230 Fremont River near Caineville	1971-76	Maximum	—	—	—	—	—	130	—	20	—	—	—	—	—
		Minimum	—	—	—	—	—	30	—	0	—	—	—	—	—
		Number of samples	—	—	—	—	—	3	—	3	—	—	—	—	—
Fremont River 1 mile above mouth, near Hanksville	1975-76	Maximum	3	—	—	0	—	30	3	40	1	—	2	—	250
		Minimum	2	—	—	0	—	20	0	0	0	—	0	—	20
		Number of samples	3	—	—	3	—	5	3	5	3	—	4	—	3
09333500 Dirty Devil River above Poison Spring Wash, near Hanksville	1971-76	Maximum	—	—	—	—	—	100	—	20	—	—	—	—	—
		Minimum	—	—	—	—	—	20	—	0	—	—	—	—	—
		Number of samples	—	—	—	—	—	3	—	3	—	—	—	—	—
Recommended maximum concentration for public-water supply (U.S. Environmental Protection Agency, 1977, p. 14-106, 200-204, 245)			50	10	50	—	1,000	300	50	50	2	—	10	50	5,000

[1] Not located in figure 22.

Table 31.—Generalized stratigraphic section of lithologic units discussed in the text for the Tar Sand Triangle and White Canyon Special Tar Sand Areas

[Data from Hood and Danielson (1981, table 1).]

System	Series	Geologic unit		Thickness (feet)	Symbol	Description
Quaternary	Holocene	Younger alluvium		0-20	Qay	Surficial deposits of clay, silt, sand, gravel, and angular blocks. Along stream valley, young alluvium is often well-sorted, but generally is fine grained.
Triassic(?) and Jurassic	Triassic(?) and Lower Jurassic	Glen Canyon Group	Navajo Sandstone	450-1,100	JTRna	White, tan, and buff thickly and intricately crossbedded very fine to fine-grained eolian sandstone.
			Kayenta Formation	180-350	JTRk	Irregularly interbedded red, reddish-brown, buff, gray, and lavender shale, siltstone, and fine- to coarse-grained sandstone.
Triassic	Upper Triassic		Wingate Sandstone	270-400	TRwi	Reddish-brown, buff, and grayish-orange very fine to fine-grained thickly crossbedded calcareous eolian sandstone.
		Chinle Formation	Shinarump Member	0-90	TRcs	One of the basal members of the seven members of the Chinle Formation; not all members present in any given locality. Light-gray to yellow fine- to coarse-grained sandstone and conglomerate sandstone with minor mudstone lenses and plant remains.
	Lower Triassic	Moenkopi Formation		360-1,000	TRm	Upper part of formation consists of reddish-brown even-bedded fissile mudstone and siltstone and fine-grained sandstone with thin layers and veins of gypsum and anhydrite. The Sinbad Limestone Member is yellowish-gray and tan thin- to medium-bedded oolitic dolomite and limestone with minor amounts of siltstone and sandstone. Lower part of formation is light-reddish-brown, yellow, and green even-bedded siltstone and sandstone containing gypsum veinlets; a chert pebble conglomerate at base.
			Hoskinnini Tongue	0-50		Red sandstone and shale. Tar-sand deposits in White Canyon area are in this unit.
Permian	Lower Permian	Coconino Sandstone and Cutler Formation	Culter Formation	—	Pc	The Coconino Sandstone, interfingers with members of the Cutler Formation.
			White Rim Sandstone Member	0-230	Pcw	White, gray, and buff fine- to medium-grained eolian sandstone. Tar-sand deposits in the Tar Sand Triangle area are in this unit.
			Cedar Mesa Sandstone Member	750	Pcm	Yellowish-gray, reddish-orange, and reddish-brown friable fine- to coarse-grained thickly crossbedded eolian sandstone.
			Halgaito Member	295	Pch	Thin-bedded mudstone and siltstone.
Pennsylvanian and Permian		Rico Formation		0-600	PIPr	Reddish-brown and greenish-gray fine- to coarse-grained crossbedded sandstone; gray and grayish-green thin- to thick-bedded cherty limestone, red and purple shale, and siltstone.
Pennsylvanian	Middle Pennsylvania	Hermosa Formation	Hermosa Formation	200-1,300	IPh	Upper member: gray thin- to thick-bedded dense to coarsely crystalline cherty limestone, interbedded with gray and brown massive to thin-bedded sandstone, siltstone, and sparse beds of gray and red shale.
			Paradox Member	0-2,500	IPhp	Salt, gypsum, anhydrite, black shale and gray sandstone and limestone.

Location: See explanation in text for numbering system for wells and springs.
Geologic unit: Principal water-bearing unit; see table 31 for explanation of symbols.
Altitude of land surface: Altitudes from most detailed topographic maps; National Geodetic Vertical Datum of 1929.
Depth to water: Above (+) or below land-surface datum.

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
				WELLS			
(D-29-15)20add-1	Mu[1]	6,235	6,886	10- 4-58	—	—	6,685-6,846
(D-29-16)28cbc-1	Pc	6,570	2,750	11- 5-73	2,492	5	—
(D-30-14)23bbb-1	╤wi	5,440	860	2- -73	600	40	—
(D-30-15)13cbd-1	Pcw	4,949	760	6-29-66	720	—	720-760
23dbc-1	Pcw	4,821	1,618	6-29-66	750	—	750-1,615
(D-31-15)19bdb-1	IPhp	—	—	12- -58	—	—	2,839-2,864
(D-35-15)4ccc-1	Pcw	4,715	4,535	6- 9-63	1,000	10	—
				SPRINGS			
(D-29-15)14dbb-S1	J╤na	5,760	—	5-22-57	—	.5	—
(D-30-16)3aab-S1	Qay	6,520	—	5-22-57	—	1.0	—
(D-31-14)23da-S1	╤m	—	—	12- -58	—	—	—
36bc-S1	╤cs	—	—	8- 4-58	—	—	—
(D-31-15)9bbc-S1	J╤k	—	—	9- -56	—	.5	—
(D-33-15)19-S1	Pch	—	—	4-23-59	—	20	—
28-S1	PIPr	—	—	4-23-59	—	2	—
29-S1	PIPr	—	—	4-23-59	—	15	—
32-S1	PIPr	—	—	4-23-59	—	25	—
(D-33-16)19-S1	Pc	—	—	6-25-47	—	360	—
19-S2	IPh	—	—	10- 3-48	—	450	—
(D-35-14)30-S1	╤m	—	—	6- 9-63	—	50	—

[1] Undivided rocks of Mississippian age.
[2] Sodium plus potassium.

the Tar Sand Triangle and White Canyon Special Tar Sand Areas

Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			Concentration (milligrams per liter)				
				WELLS			
85,500	2,100	471	30,000	218	46,500	5,900	586
1,720	270	53	180	52	45	960	304
—	—	—	—	—	—	—	—
916	40	35	(2) 272	—	90	119	714
933	80	88	(2) 190	—	60	432	320
43,770	1,076	477	(2) 14,810	—	23,000	3,980	323
318	38	46	(2) 19	—	9.0	26	348
				SPRINGS			
179	28	22	4.8	2.1	10	15	174
205	43	13	11	1.5	18	22	165
2,355	26	66	(2) 642	—	507	592	489
1,613	36	52	(2) 378	—	64	650	434
220	36	15	26	4.0	21	25	171
6,530	838	202	(2) 1,180	—	1,800	1,920	1,160
1,220	220	65	(2) 79	—	98	616	252
3,920	517	137	(2) 659	—	970	1,250	752
4,770	640	161	768	56	1,270	1,430	847
770	135	64	(2) 16	—	20	456	167
414	84	28	(2) 12	—	8.0	183	181
1,860	150	97	(2) 342	—	356	770	259

CIRCLE CLIFFS SPECIAL TAR SAND AREA

By H. F. McCormack

Location

The Circle Cliffs Special Tar Sand Area covers about 150 square miles in Garfield County (fig. 25). The area is about 13 miles southeast of Boulder, in the Circle Cliffs upwarp of the Canyon Lands physiographic subdivision of the Colorado Plateaus (Fenneman, 1946). The Henry Mountains rise to the east, and to the northwest is the flat-topped Boulder Mountain. Land-surface altitudes range from about 7,000 feet along the summit of Circle Cliffs to about 4,000 feet along Halls Creek in the southeast. The proven or inferred tar-sand deposits underlie parts of townships 33 to 36 south and ranges 6 to 9 east, Salt Lake base line and meridian. The Federal Government is the major landowner, and about 4 of the approximate 150 square miles are available for lease.

The tar-sand deposits in the area are in the Moenkopi Formation (Triassic) and are in two units called the East and West Flanks (fig. 26). The East Flank deposit, which is in the Capitol Reef National Park, is about 50 square miles in area and is not considered for leasing. Four square miles of the West Flank deposit is in the Glen Canyon National Recreation Area. The entire West Flank deposit contains about 0.4 billion of the total of 1.3 billion barrels of oil in the area (table 1).

Climate

The climate of the area is influenced partly by local topographic features; and it generally is arid to semiarid, with low relative humidity, abundant sunshine, low to moderate precipitation, hot summers, and cold winters. Seasonal and daily variations in air temperatures are large. The High Plateaus (Fenneman, 1946) deplete the winter and spring moisture before it reaches the lower altitudes east of the plateaus. Precipitation in the area is greater in summer and fall when moist tropical air masses from the Gulf of Mexico and the Gulf of California occasionally move into the region, resulting in thunderstorms. At that time, however, warm temperatures result in high rates of evapotranspiration; thus most of the summer rain evaporates before there is any runoff. The precipitation in the winter is usually light snow, which melts quickly, and rain.

Normal annual precipitation ranges from more than 10 inches in the north part of the tar-sand area to less than 8 inches in the southeast part (fig. 25). The average annual air temperature is 49°F. Large variations in daily air temperature are caused by relatively strong daytime warming and rapid nighttime cooling. Seasonal variation in daily mean air temperature is greater in valleys where there is less movement of air than in the higher areas. The normal annual evaporation from a free-water surface, which is about 40 to 45 inches (Farnsworth and others, 1982, map 3), shows little variation. Such evaporation, however does vary considerably from day to day and month to month. Selected climatic characteristics are published monthly by the National Oceanic and Atmospheric Administration for Boulder to the northwest, Capitol Reef National Park Headquarters, Escalante, 25 miles to the southwest, and Bullfrog Basin in Utah and for Page, Arizona, 60 miles to the south.

Water Resources

The Circle Cliffs Special Tar Sand Area is in the Escalante River and Halls Creek drainage basins, which are tributary to Lake Powell. The surface drainage is primarily to the southeast towards the Colorado River, and the ground water generally moves in the same direction.

Surface Water

The major perennial streams in or near the tar-sand area are the Escalante River and possibly part of Halls Creek, which is the only stream that flows through the area. There are no perennial tributaries to these streams in the area. No records for streamflow or water-quality sites in or near the area are available, but Davidson (1967, p. 4) reported that there was flow all year in the lower reaches of Halls Creek and the Escalante River during 1954-57. The average flow at station 09339500, Escalante River at mouth, near Escalante, about 30 miles south is about 62,000 acre-feet. Flash floods are common after thunderstorms. The chemical quality of the streamflow would be expected to change markedly as streams cross the outcrop of the Shinarump Member of the Chinle Formation or the Moenkopi Formation (table 33), both of which contain readily dissolved minerals.

Ground Water

Recharge to bedrock aquifers in the Canyon Lands occurs where permeable formations crop out along the flanks of folds, such as Waterpocket Fold (fig. 25), or on the wide expanse of flat-lying aquifers that are exposed between major structural elements (Feltis, 1966, p. 21). The amount of recharge, however, generally is small because of the small annual precipitation.

Little ground-water data are available for sites in and near the area, mainly because few water wells have been drilled and because such data were not collected during oil and gas exploration. A summary of selected well and spring data for sites in and near the area is given in table 34. Outside the area and about 15 miles to the northeast, a drill-stem test at well (D-34-9)2ccd-1 in the White Rim Sandstone Member of the Cutler Formation (table 33) produced water with a dissolved-solids concentration of 4,627 milligrams per liter (table 34). Other drill-stem test information is available for areas to the southeast. Water from a mine sump, (D-35-7)26dda, in the southern part of the area in the Shinarump Member of the Chinle Formation had a dissolved-solids concentration of 8,510 milligrams per liter. The major constituent of the water in the well and mine sump is sulfate. According to Davidson (1967, p. 4), springs in the area that issue at the base of the Wingate Sandstone flow as much as 40 gallons per minute and those at the base of the Shinarump Member of the Chinle Formation discharge 1 to 2 gallons per minute (fig. 26).

Existing Water Use

The Circle Cliffs Tar Sand Area is in Water Right Area 97, Garfield County (Utah Division of Water Rights, 1974). There is no unappropriated water (Jensen, 1975, p. 179); thus, water rights would have to be purchased or leased for a tar-sand industry.

About 15,000 acre-feet of surface water is diverted annually for irrigation in the upper Escalante River basin. However, there is no known irrigated land in the Circle Cliffs Tar Sand Area. Flow of springs in the area is used for watering livestock.

Hydrologic Impacts Unique to This Area

A "high" commercial tar-sand industry producing 20,000 barrels of oil per day would require about 4,600 acre-feet per year of water (table 1). The withdrawal of large amounts of water from wells, however, could decrease streamflow in nearby streams. A "high" commercial tar-sand industry in the area is not expected to impact the salinity of the Colorado River. Other potential impacts that generally apply to all areas are discussed in the section "Hydrologic impacts of a tar-sand industry," which follows.

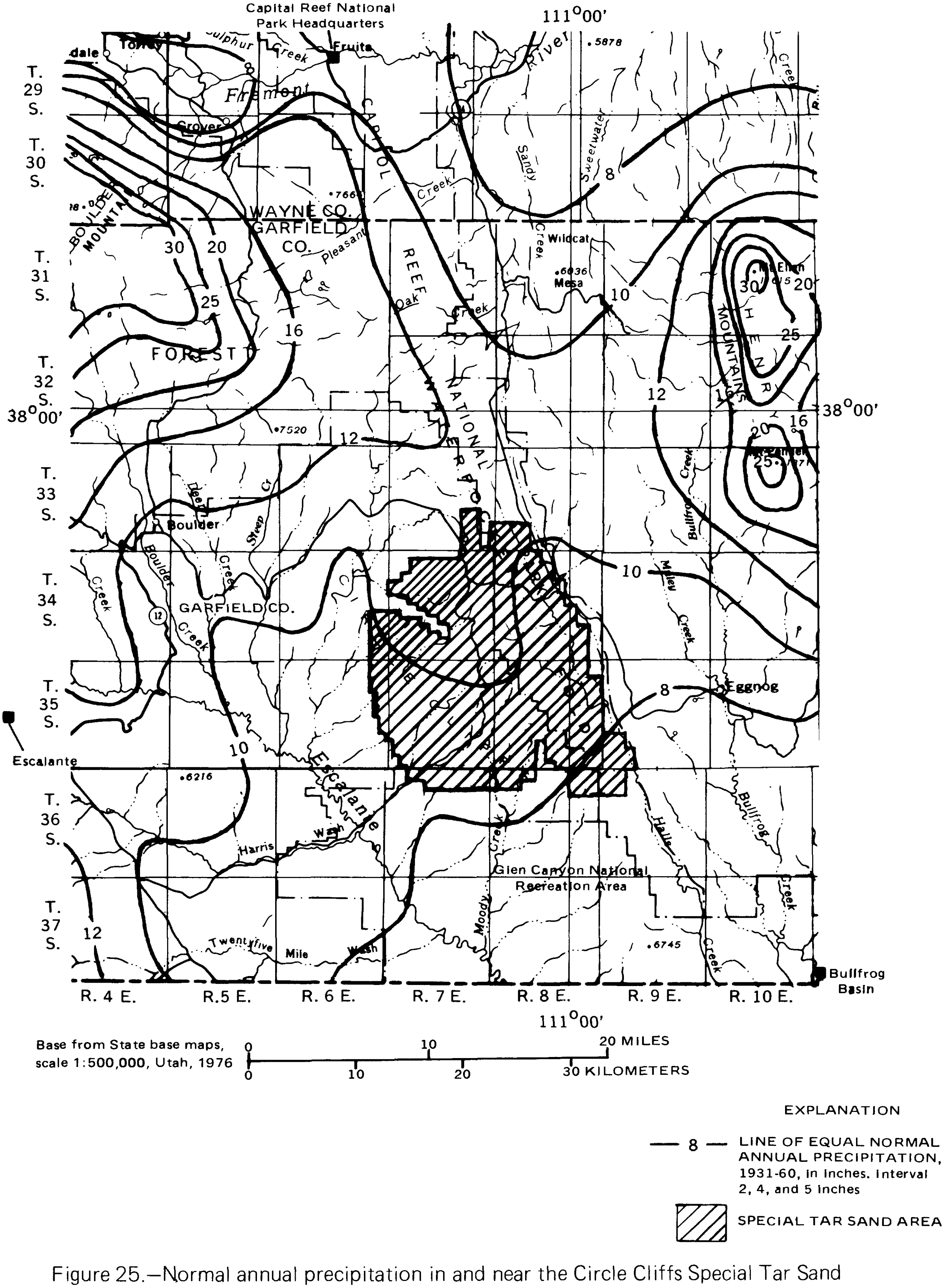

Figure 25.—Normal annual precipitation in and near the Circle Cliffs Special Tar Sand Area. From U. S. Weather Bureau, 1963.

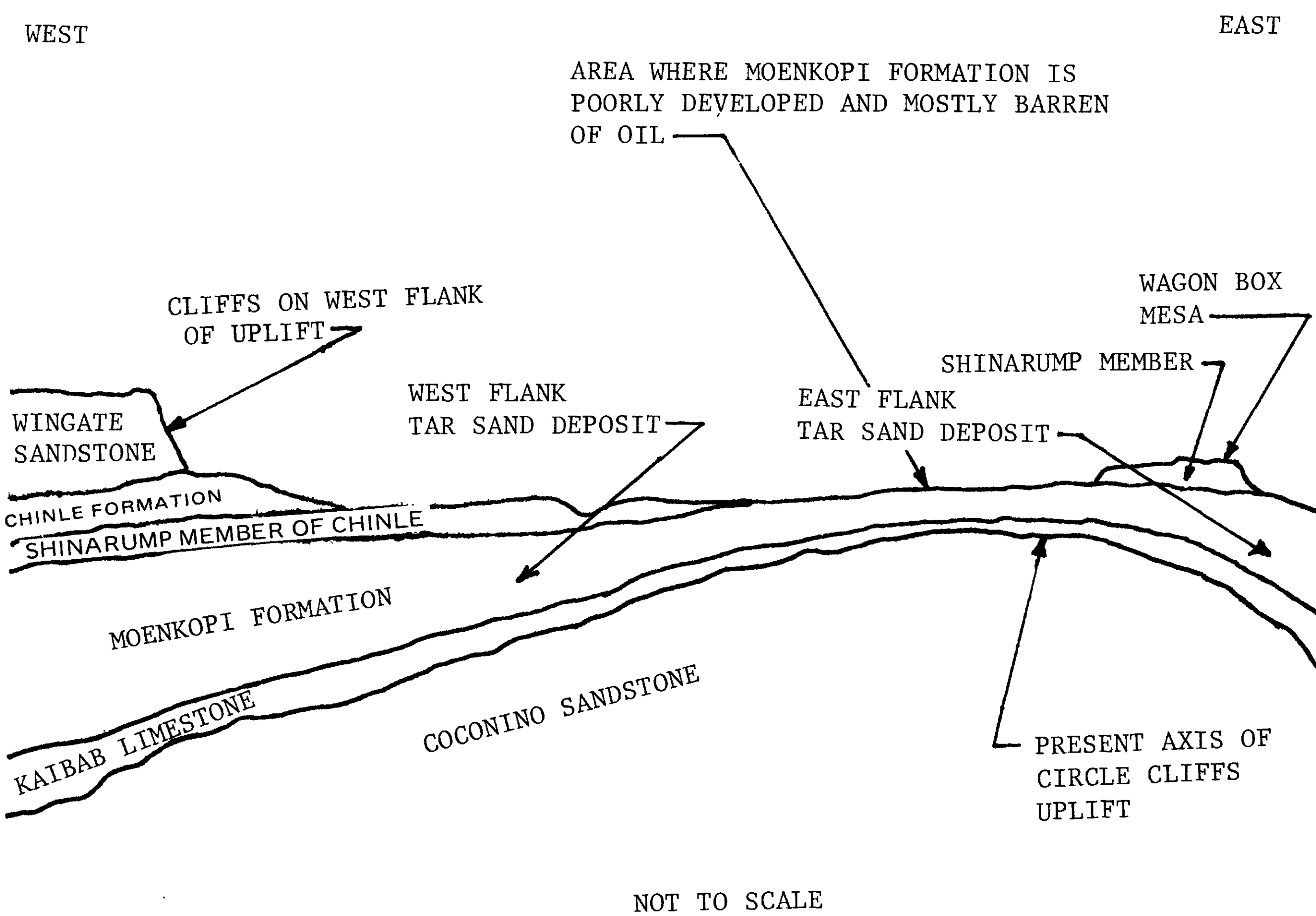

Figure 26.—Diagrammatic geologic section of Circle Cliffs uplift showing relative position of the tar-sand deposits to other geologic units. Modified from Campbell and Ritzma (1979).

Table 33.—Generalized stratigraphic section of lithologic units discussed in the text for the Circle Cliffs Special Tar Sand Area

[Data from Hood and Danielson (1981, table 1).]

System	Series	Geologic unit	Thickness (feet)	Symbol	Description
Quaternary	Holocene	Younger alluvium	0-20	Qay	Surficial deposits of clay, silt, sand, gravel, and angular blocks. Along stream valley, young alluvium is often well-sorted, but generally is fine grained.
Cretaceous	Upper Cretaceous	Mesaverde Formation	300	Kmv	Pale-yellow thick-bedded sandstone and thin interbedded dark-gray shale.
		Mancos Shale	3,200-4,900	Kms	Five members: Dark-gray to black carbonaceous and sandy shale interbedded with pale-yellow sandstone and shaly sandstone.
		Emery Sandstone Member	250-800	Ke	Pale-yellow thin- to thick-bedded lenticular sandstone and minor interbedded carbonaceous shale and impure coal.
		Dakota Sandstone	0-125	Kd	Light-yellow and yellowish-brown friable to quartzitic coarse-grained crossbedded fluvial sandstone, conglomeratic sandstone, and conglomerate, with minor interbedded carbonaceous shale and impure coal.
Jurassic	Upper Jurassic	Morrison Formation	0-750	Jm	Brushy Basin Shale Member: Light-red, purple, and grayish-green bentonitic lacustrine mudstone; minor limestone lenses; minor white, gray, and buff crossbedded sandstone lenses; minor conglomerate lenses. Salt Wash Sandstone Member: Light-gray, tan, and white thickly crossbedded fine- to coarse-grained lenticular fluvial sandstone with thin beds of conglomerate; contains interbeds of variegated sandy mudstone.
Jurassic / Triassic(?)	Lower Jurassic	Glen Canyon Group: Navajo Sandstone	450-1,100	JŦna	White, tan, and buff thickly and intricately crossbedded very fine to fine-grained eolian sandstone.
Triassic	Upper Triassic	Glen Canyon Group: Wingate Sandstone	270-400	Ŧwi	Reddish-brown, buff, and grayish-orange very fine- to fine-grained thickly crossbedded calcareous eolian sandstone.
		Chinle Formation	215-550	Ŧc	Seven members or lithologic equivalents mostly of fluvial and lacustrine origin; not all present in any given locality. Mudstone, siltstone, sandstone, and some conglomerate in various shades of purple, red, and brown.
		Shinarump Member	0-90	Ŧs	Light-gray to yellow fine- to coarse-grained sandstone and conglomerate sandstone with minor mudstone lenses and plant remains.
	Lower and Middle(?) Triassic	Moenkopi Formation	360-1,000	Ŧm	Upper part of formation consists of reddish-brown even-bedded fissile mudstone and siltstone and fine-grained sandstone with thin layers and veins of gypsum and anhydrite. The Sinbad Limestone Member is yellowish-gray and tan thin- to medium-bedded oolitic dolomite and limestone with minor amounts of siltstone and sandstone. Lower part of formation is light-reddish-brown, yellow, and green even-bedded siltstone and sandstone containing gypsum veinlets; a chert pebble conglomerate at base. Tar-sand deposits in the Circle Cliffs area are in this formation.
Permian	Lower Permian	Kaibab Limestone	0-350	Pka	Light-gray to brown cherty silty limestone, white calcareous siltstone, white thin beds of crossbedded fine-grained sandstone, and some dolomite.
		Cutler Formation: White Rim Sandstone Member	0-230	Pwr	White, gray, and buff fine- to medium-grained eolian sandstone.

Location: See explanation in text for numbering system for wells and springs.
Geologic unit: Principal water-bearing unit; see table 33 for explanation of symbols.
Altitude of land surface: Altitudes from most detailed topographic maps; National Geodetic Vertical Datum of 1929.
Depth to water: Above (+) or below land-surface datum.

Location	Geologic unit	Altitude of land surface (feet)	Depth of well (feet)	Date	Depth to water (feet)	Yield (gallons per minute)	Sample depth (feet)
			WELLS				
(D-31-7)36dad-1	Ka[1]	5,361	6,648	12-23-68	—	243	600-2.446
	Pka			1-31-69	—	—	3,414-3.417
	JTRna		[2]2,305	7- -70	305	55	—
	JTRna			11-13-70	—	161	—
	JTRna			8-29-75	—	—	580-1,140
(D-31-8)9aad-1	Qay	5,275	—	2- -69	—	—	—
(D-31-9)32ddd-1	Ke	5,925	404	6-14-49	305	15	—
(D-34-9)2ccd-1	Pwr	5,390	9,682	5- -61	—	—	5,858-5,991
	Mu[4]			5- -61	—	—	9,555-9,682
(D-35-7)26dda[5]	TRs	5,760	—	4-26-59	—	—	—
(D-36-10)18ddd-1	Mu[4]	5,100	8,362	3- -52	—	—	7,316-7,349
	Du[6]			3-27-52	—	—	8,279-8,314
	Pwr			4- 6-52	—	—	3,924-3,946
				4- 7-52	—	—	3,964-3,982
			SPRINGS				
(D-31-8)7ada-S1	Qay	5,120	—	8-23-75	—	5	—
24caa-S1	Ke	5,030	—	8-22-75	—	5	—
27dab-S1	Ke	5,450	—	7-22-75	—	.1	—
				8-22-75	—	<.1	—
(D-31-9)18adc-S1	Kms	5,700	—	7-31-75	—	10	—
(D-32-8)21dba-S1	Ke	5,500	—	9- 1-76	—	2	—
(D-33-8)2ccd-S1	Kmv	6,100	—	8-13-75	—	10	—
25dcd-S1	Ke	5,360	—	8-20-75	—	13	—
27bbb-S1	Ke	5,280	—	8-21-75	—	10	—
36dab-S1	Ke	5,300	—	8-20-75	—	5	—
(D-35-9)13cbc-S1	Kd	4,920	—	8-21-81	—	<1	—
26bbb-S1	Jm	4,990	—	4-26-59	—	1	—
				8-21-81	—	<.1	—
(D-36-9)10acc-S1	Kd	4,960	—	8-19-75	—	1	—
10dcb-S1	Kd	4,930	—	4-26-59	—	.5	—

1 Rocks of Cretaceous age.
2 Plugged back to this depth.
3 Sodium plus potassium.
4 Undivided rocks of Mississippian age.
5 A mine sump.
6 Undivided rocks of Devonian age.

in and near the Circle Cliffs Special Tar Sand Area

Concentration (milligrams per liter)							
Dissolved solids (sum of constituents)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Chloride (Cl)	Sulfate (SO_4)	Bicarbonate (HCO_3)
			WELLS				
744	144	30	62	4	10	344	305
505	93	20	46	7	8	223	220
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
188	32	20	6.5	2.0	2.8	27	175
760	145	31	15	4	14	330	198
—	—	—	—	—	—	—	—
4,627	680	316	(3) 48	—	40	2,900	635
7,259	497	170	(3) 1,485	—	525	3,200	1,366
8,510	70	48	(3) 2,850	—	1,040	3,800	1,370
4,669	852	192	(3) 456	—	320	2,061	1,600
6,891	632	160	(3) 1,476	—	500	3,399	1,470
2,236	146	67	(3) 593	—	86	972	755
2,045	163	87	(3) 492	—	58	831	840
			SPRINGS				
—	—	—	—	—	—	—	—
1,170	140	120	74	4.3	11	630	364
1,990	200	140	230	7.1	20	1,200	368
1,900	160	160	240	6.6	19	1,200	383
971	150	67	62	.8	29	520	0
2,320	220	150	270	8.5	22	1,400	479
1,080	200	80	28	4.3	15	620	256
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
383	26	10	(3) 103	—	11	72	293
—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—
601	79	41	(3) 66	—	22	246	269

HYDROLOGIC IMPACTS OF A TAR-SAND INDUSTRY

The hydrologic impacts of a tar-sand industry will depend on the size of the industry, the methods of recovery (steam drive, in situ combustion, or surface mining), and most importantly the care taken in construction of the surface facilities and the disposal of wastes. Detailed mining plans are not available; thus, only the general types of hydrologic problems that might result from a tar-sands industry are discussed here.

Only the hydrologic impacts that generally apply to all tar-sand areas are discussed in this section. Impacts unique to individual areas are discussed above in the sections that apply to those areas.

General Local Impacts and Possible Mitigating Actions

The consumptive use of water in all tar-sand areas could locally deplete flow of springs, decrease yields of existing wells, and effect water quality directly or indirectly. Direct effects would be caused by accidental release of process or leachate waters or the failure of holding ponds for wastes. Indirect effects would result from construction, mining, processing, or disposal activities.

The mining of tar sand will seldom impact a principal aquifer. However, pre-mining planning will be desirable for areas where tar-sand mining has the potential to decrease discharge to springs that supply water for livestock or domestic and irrigation use. Such impacts could be mitigated by drilling of deep wells or providing other supplies where impacts cannot be avoided.

The residues from processing tar sand may contain leachable organic and inorganic substances that could degrade local water quality. Some of the leachable substances may be toxic to stream organisms if present in large concentrations, and some substances may be carcinogenic.

The leachable substances in water that has seeped through tar-sand wastes may be decreased in concentration naturally by biological degradation, attachment to mineral surfaces, or dispersion. Ground-water movement is slow, however, and a long time may pass before contaminants are decreased to undetectable limits. Other mitigating actions that could be taken are:

(1) Disposal of wastes in areas of ground-water discharge rather than in areas of recharge. In particular, avoid recharge areas of extensive freshwater aquifers.

(2) Line bottoms of spoils and holding ponds with impervious material.

Erosion resulting from surface construction and loading of streams with sediment could be the most serious water-quality problem resulting from a tar-sand industry. For example, erosion rates resulting from surface mining of coal have been estimated to be 10 times greater than that expected under natural conditions (U.S. Department of Interior, 1979, p. 34).

Sheet-erosion rates are great for many areas in eastern Utah (Seiler and Tooley, 1982, p. 37 and Mundorff, 1979, p. 22); but because of the small flow in most tributaries, sediment yield to larger streams is less than might be expected. If water used for mining, processing of oil, or construction of surface facilities is discharged into a normally dry streambed, increased channel erosion and sediment transport would result. This problem could be minimized if construction is completed at times other than during the thunderstorm season.

Other sediment-related problems could result from disposal of wastes in spoil piles. According to a report by the Colorado State University (1971, table 11), during a simulated rain of 0.54 inch per hour, an uncompacted pile of retorted oil shale on a grade of 0.75 percent (40 feet per mile) had a sediment yield exceeding 0.3 ton per acre per hour, or 0.1 acre-foot per square mile per hour. Even after compaction, the yield from the same pile was about 0.1 ton per acre per hour. Sediment-yield rates from actual disposal piles could be greater because the grades of the piles may be steeper than 0.75 percent. The maximum 2-year rain intensity in and near the 11 Special Tar Sand Areas in eastern Utah averages about 0.5 inch per hour (Miller and others, 1973), so rain intensities similar to those used in the study by Colorado State University are common.

Holding ponds for disposal of wastes need to have a capacity to retain at least 100 percent of the maximum flow expected once every 100 years, on the average. Because of the potential for rapid filling with sediment, periodic inspection and cleaning would be necessary.

Cumulative Impacts on the Upper Colorado River

A commercial tar-sand industry in eastern Utah producing 365,000 barrels of oil per day (table 1) could increase the annual consumptive water use in the Upper Colorado River Basin by about 88,000 acre-feet (table 1). Such an industry also could increase the salinity of the Colorado River.

A proposed "high" commercial production level action plan for a Federal oil-shale program is reported by the U.S. Bureau of Land Management (1983, p. A-2-19). For this level, the Bureau reports cumulative impacts as a 368,000 acre-feet per year increase in water use, a 4-percent decrease in flow of the Colorado River at Lake Powell, and an increase in salinity of 12 milligrams per liter at Imperial Dam, Ariz.-Calif., with salinity increases ranging from 1 to 36 milligrams per liter during a 25-year period.

Assuming that the wastes and impacts from the mining of tar sand are similar to those from the mining of oil shale, a commercial tar-sand industry producing 365,000 barrels of oil per day in eastern Utah that required about 88,000 acre-feet of water annually could result in an average salinity increase of about 3 milligrams per liter and a peak of 9 milligrams per liter in the Colorado River at Imperial Dam. In contrast, a commercial tar-sand industry producing 83,000 barrels of oil per day could increase the average salinity by less than 1 milligram per liter, with a peak of 2 milligrams per liter. A pilot industry would have little impact on the salinity of the Colorado River.

SUMMARY

About 93 percent of the Nation's estimated 30 billion barrels of crude oil in tar-sand deposits is in 11 areas in eastern Utah chosen for leasing by the U.S. Bureau of Land Management. The largest deposit is the Tar Sand Triangle Area, which contains about 15 billion barrels of oil. More than three-fourths of the Utah reserves are in the Tar Sand Triangle, Sunnyside, and P R Spring areas.

A tar-sand industry in Utah could have an impact on local water resources and the Upper Colorado River. A "high" commercial tar-sand industry producing 365,000 barrels of oil per day would consume most of the recoverable oil in about 30 years and would require about 88,000 acre-feet of water annually. A "low" commercial tar-sand industry producing about 83,000 barrels of oil per day could require about 22,000 acre-feet of water annually. Because most water in the tar-sand areas is fully appropriated, water rights for a tar-sand industry will have to be purchased or leased.

Impacts on local hydrology would be greatest in the Tar Sand Triangle, Sunnyside, and P R Springs areas. However, these impacts could be minimized with proper construction of surface facilities to reduce erosion and sediment transport and to impound mining and retort waters. A "high" commercial tar-sand industry producing 365,000 barrels per day could result in an average salinity increase of about 3 milligrams per liter with a peak of 9 milligrams per liter in the Colorado River at Imperial Dam, Ariz.-Calif., whereas a "low" commercial tar-sand industry producing 83,000 barrels per day could increase the average salinity by less than 1 milligram per liter with a peak of 2 milligrams per liter.

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