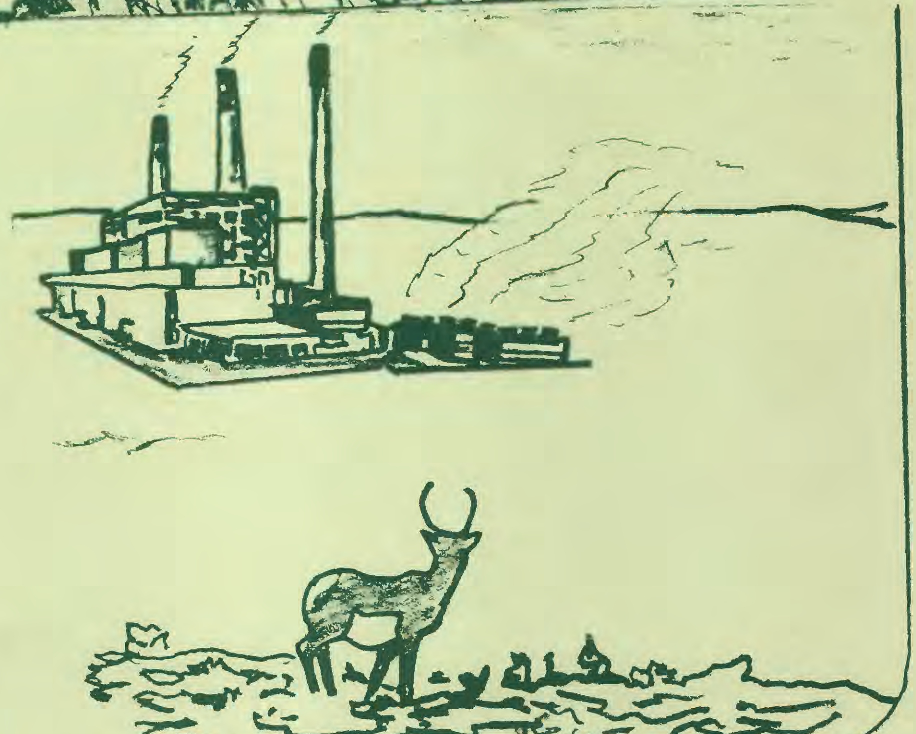
A PLAN FOR STUDY OF WATER AND ITS RELATION TO ECONOMIC DEVELOPMENT IN THE GREEN RIVER AND GREAT DIVIDE BASINS IN WYOMING

Open-File Report 76-349



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A PLAN FOR STUDY OF WATER AND ITS RELATION TO ECONOMIC DEVELOPMENT IN THE GREEN RIVER AND GREAT DIVIDE BASINS IN WYOMING

By H. W. Lowham, L. L. De Long, K. D. Peter, D. J. Wangsness, W. J. Head, and B. H. Ringen

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ABSTRACT

Development of extensive coal, oil, gas, trona, and oil-shale resources as well as other developments in the Green River and Great Divide Basins will require a projected increase in water consumption of 490,000 acre-ft (600 hm^3) per year by 2020. Developments of energy resources in other parts of Wyoming will also require large amounts of water; transbasin diversion of Green River water to other areas could total an additional 270,000 acre-ft (330 hm^3) per year. In anticipation of this increased demand, water planners and managers need much more information about available ground and surface waters, present quality of the waters, and hydrologic effects that would be caused by development of energy resources.

The U.S. Geological Survey is conducting an extensive hydrologic study of the basins. This report summarizes the study plan and discusses particular methods of approach that would be utilized in the study. The principal objectives of the study are: 1) To describe the water resources and hydrologic relations that presently exist; 2) to develop predictive methods that can be used to describe future conditions, including reactions to increased water development; and 3) to establish monitoring programs for detecting possible changes in water conditions.

The most up-to-date methods available are being utilized to collect and analyze the hydrologic data. Regarding water quality, particular attention is being given to trace metals, biological characteristics, and trend analyses of salinity. Channel-geometry techniques, detailed statistical analyses, and mathematical models are being applied to surface-water studies. An updated well inventory, aquifer tests, and borehole and surface geophysical surveys are being used in ground-water studies.

Efforts will be made by the U.S. Geological Survey to coordinate this study with the needs of the prospective users of the results, including industries and government agencies.

INTRODUCTION

Description of the Problem

Water demands in the Green River and Great Divide Basins of Wyoming are increasing rapidly due to development of extensive coal, oil, gas, uranium, and trona resources. The potential also exists for future development of extensive oil-shale resources. As these developments proceed, large supplies of water will be needed at widely separated parts of the basins for recovery and utilization of the resources, for municipal supplies, and for recreation. The importance of water to the economic and social development of the area requires that careful attention be given to planning for the optimum control, conservation, and use of this resource.

Water planners and managers need much more information than is now available concerning ground and surface waters, present quality of the waters, and hydrologic effects caused by development of mineral resources.

Scope of the Investigation

The U.S. Geological Survey is conducting a study of water resources in the Green River and Great Divide Basins. The study began in November 1974 and is scheduled to continue through 1979. The study is designed to provide interested persons with up-to-date information concerning water resources of the area. This information is especially needed by decisionmakers and planners who must make judicious decisions regarding development and use of this land and its natural resources. Results of the study would provide sound background information for rational, well-considered decisions among alternative or competing uses of water and related land resources.

This report presents: 1) Objectives of the study; 2) a general description of the study area, including its mineral and water resources; 3) a summary of existing data and knowledge of the water resources of the area; 4) a detailed description of the study plan; and 5) a schedule of reports to be prepared by the study group. This report was prepared so that decisionmakers, planners, and others interested in the subject area may be made aware of the study. Comments regarding the proposed methods of approach are invited from interested persons. Efforts will be made by the U.S. Geological Survey to coordinate this study with the needs of the prospective users, including industries and government agencies.

Objectives of the Study

Objectives

The principal objectives of the study are to: 1) Describe the existing water resources and hydrologic relations necessary to determine water supply and predict effects of proposed water development; and 2) design data-collection programs for the evaluation of the effects of water development.

Specific Objectives

Surface water.--1) Describe distribution and quality of streamflow areally and with time. Special emphasis would be directed toward ephemeral and intermittent streams. 2) Determine the relation of hydrology to other aspects of the environment, including erosion and sedimentation, the biologic community, and land use. 3) Define hydrologic relations necessary for estimating quantity and quality of surface water at sites not routinely gaged or sampled. 4) Develop methods to predict effects of proposed water development.

Ground water.--The present extent and distribution of ground-water withdrawals would be described. The extent and characteristics of the aquifers would be determined in order to predict potential water supplies available for new energy developments. Energy-development sites would be monitored to detect potential effects on ground water including:

1. Changes in permeability of confining beds due to mining.

2. Effects of heat from in-situ processing of oil shale on the hydrologic properties of aquifers and on water quality.

3. Changes in water quality resulting from shattering or pulverizing saline rocks in contact with ground waters; also, changes in the solvent action of ground water due to changes in temperature or changes in the content of dissolved gases.

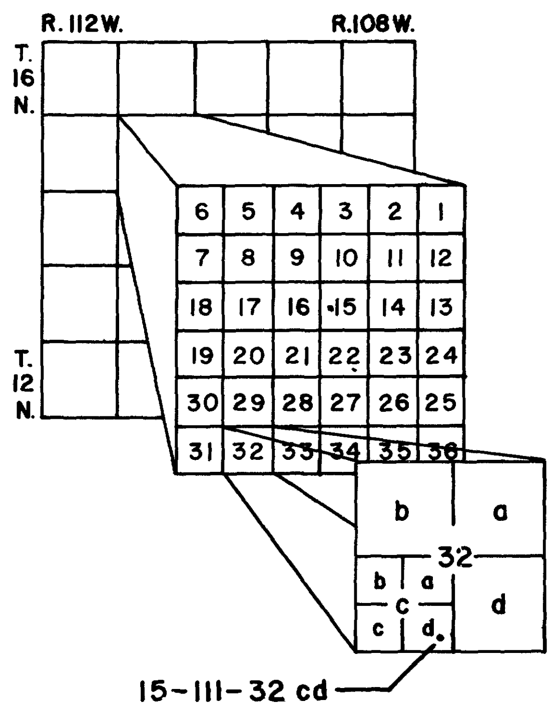
Units of Measurement

The analyses and compilations in this report were made with English units of measurement. The equivalent metric units are given in the text and illustrations, where appropriate. English units only are shown in tables where, because of space limitations, the dual system of English and metric units would not be practicable. For those readers who may prefer to use metric units rather than English units, conversion factors for terms used in this report are as follows:

Multiply English units	By	To obtain metric units
	Length	
inches (in)	25.4	millimetres (mm)
	.0254	metres (m)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
	Area	
acres	4047	square metres (m^2)
	.4047	hectares (ha)
	.4047	square hectometre (hm^2)
	.004047	square kilometres (km^2)
square miles (mi^2)	2.590	square kilometres (km^2)
	Volume	
gallons (gal)	3.785	litres (l)
	3.785	cubic decimetres (dm^3)
	3.785×10^{-3}	cubic metres (m^3)
gallons per ton (gal/ton)	4.172	litres per tonne (l/t)
cubic feet (ft^3)	28.32	cubic decimetres (dm^3)
	.02832	cubic metres (m^3)
acre-feet (acre-ft)	1233	cubic metres (m^3)
	1.233×10^{-3}	cubic hectometres (hm^3)
	1.233×10^{-6}	cubic kilometres (km^3)
barrels (bbls)	158.8	litres (l)
	Flow	
cubic feet per second (ft^3/s)	28.32	litres per second (l/s)
	28.32	cubic decimetres per second (dm^3/s)
	.02832	cubic metres per second (m^3/s)
gallons per minute (gal/min)	.06309	litres per second (l/s)
	.06309	cubic decimetres per second (dm^3/s)
	6.309×10^{-5}	cubic metres per second (dm^3/s)
million gallons per day (Mgal/d)	43.81	cubic decimetres per second (dm^3/s)
	.04381	cubic metres per second (m^3/s)
	Mass	
pound (lb)	453.6	grams (gm)
ton (short)	.9072	tonne (t)
	Heat value	
British thermal units per pound (BTU/lb)	.5556	calorie, gram per gram (cal, gm/gm)

Well and Surface-Water Station Numbering System

The location sites of wells, springs, and oil- and gas-test holes, referred to in this report, are designated by a numbering system based on the Federal system of land subdivision. The first number denotes the township, the second number denotes the range, and the third number denotes the section. One or more letters follow the section number and denote the location within the section. The section is divided into four quarters of 160 acres (64.8 hm^2) and lettered a, b, c, and d in a counterclockwise direction, beginning in the northeast quarter. Similarly, each quarter may be further divided into quarters of 40 acres (16.2 hm^2) and again into 10-acre (4.05 hm^2) tracts and lettered as before. The first letter following the section number denotes the quarter section; the second letter, if shown, denotes the quarter-quarter section; and the third letter denotes the quarter-quarter-quarter section, or 10-acre (4.05 hm^2) tract. For example, in the following illustration, the location-site number 15-111-32cd is in the SE¼ of the SW¼ of sec. 32, T. 15 N., R. 111 W.:



Each streamflow and water-quality station referred to in this report has a station number. The complete 8-digit number, such as 09188500, includes the part number "09" and a 6-digit station number. The first two digits designate the part number, which refers to the major drainage basin involved. The last six digits refer to individual station location with increasing numbers referring to locations progressively farther downstream.

GENERAL DESCRIPTION OF THE STUDY AREA

Location

The study area includes approximately 21,020 mi^2 (54,440 km^2) in southwestern Wyoming, bordering on the states of Utah and Colorado. Its location with reference to Wyoming is shown in figure 1. The study area is that part of southwestern Wyoming drained by the Green River and its tributaries, including the Little Snake River and other tributaries that join the Green River downstream from the State line, and the Great Divide Basin. The Green River Basin is about 17,100 mi^2 (44,290 km^2), and the Great Divide Basin is about 3,920 mi^2 (10,150 km^2).

The Great Divide Basin is topographically closed, so all surface drainage is internal. The Great Divide Basin is technically considered to be part of the North Platte River system; however, it is included in this study because the Green River and Great Divide Basins have similar geologic features, and both have large deposits of oil shale and coal.

Physiography

The study area is a high desert plateau flanked by higher mountain ranges. The Wind River Range to the northeast, the Gros Ventre Range to the north, the Wyoming Range to the west, the Uinta Mountains to the south, and the Sierra Madre to the southeast border the interior plains. Elevations range from 6,050 ft (1,840 m) in the Green River drainage near the State line to 13,785 ft (4,202 m) at Gannett Peak in the Wind River Range.

More than 1,000 glacial lakes are located in headwater areas of streams that originate along the west slope of the Wind River Range. Numerous perennial streams originate in the mountain ranges.

The interior plains of the Green River Basin are characterized by shallow river valleys and scattered buttes rising from the basin floor. Ephemeral and intermittent streams originate in this area of treeless plains, mesas, and picturesque badlands. Active sand dunes are present in the central part of the basin.

The Great Divide Basin is a relatively shallow depression with isolated buttes, pan-like depressions, and sparse vegetation. The Continental Divide is the hydrographic boundary separating the Great Divide and Green River Basins, but it is barely perceptible as a surface feature along much of its length.

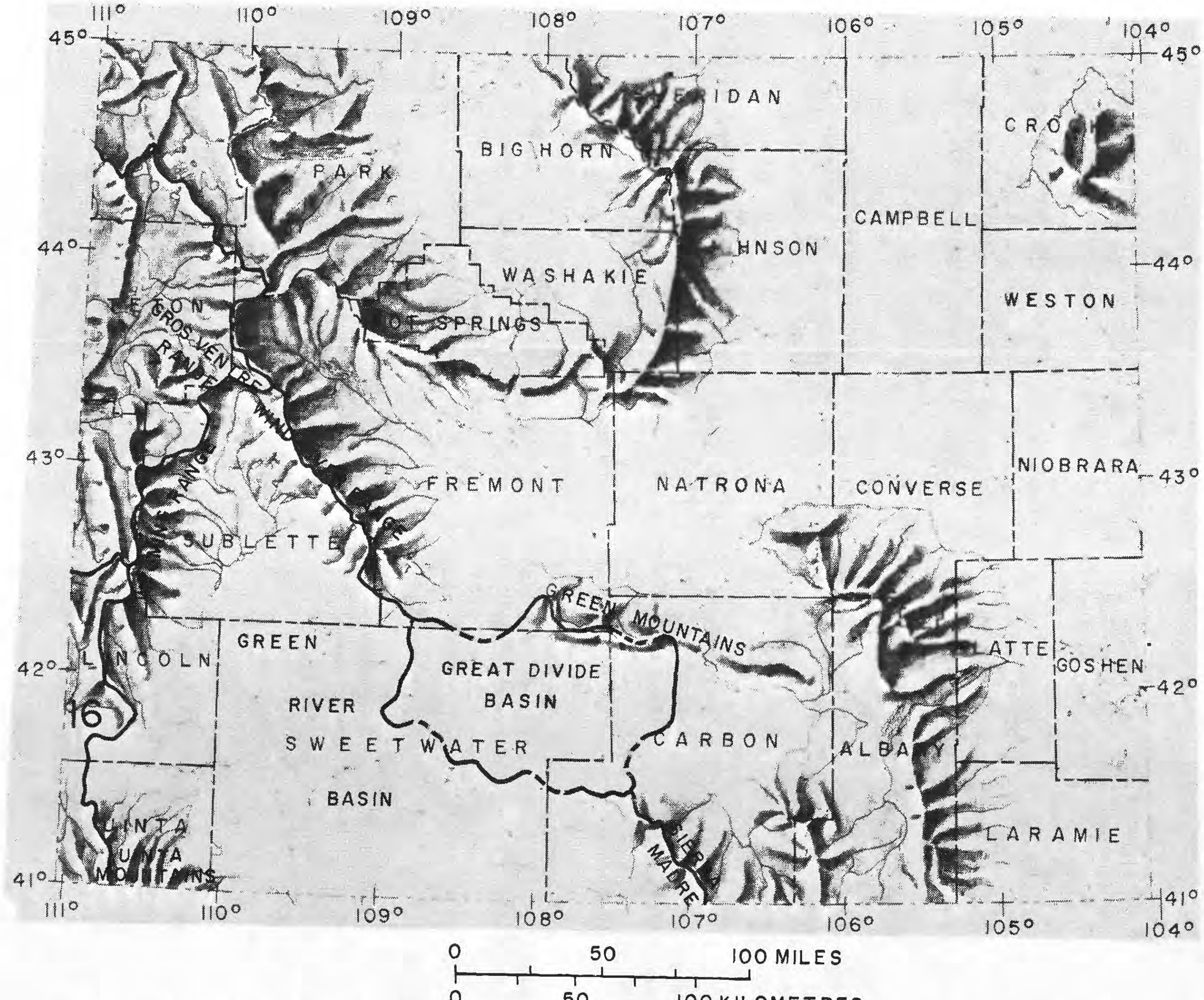


Figure 1.—Locations of Green River and Great Divide Basins in Wyoming

Geology

The study area contains four major structural units: The Green River, Washakie, and Great Divide Basins; and the Rock Springs Uplift. Their geographic locations are shown in figure 2.

The Green River structural basin is a large (approximately 600 mi^2 or 1,600 km^2) synclinal basin with a north trending axis. The beds of Tertiary rocks in most of the basin are nearly flat lying, with dips generally less than 1°. In a narrow margin around the perimeter of the basin dips are steeper, but less than 15° in most areas. The southern margin is an exception, where dips up to 35° occur and some beds are overturned as a result of a large thrust fault. The beds about 200 ft (60 m) north of this fault are dipping less than 15° (Bradley, 1964, p. A-9, A-10).

The Washakie Basin is an almost circular synclinal basin also with a north trending axis and very low-dipping beds. Dips of Tertiary rocks range from nearly 0° in most of the basin to 15° along the margins. In the southern part of the basin, approximately from Shell Creek east to Baggs, Wyo., there are gentle folds and many northwest trending faults (Bradley, 1964, p. A-10).

The Great Divide Basin is an asymmetrical synclinal basin. The axis of the basin trends northwest, and rocks have an average dip of about 3° on the southwest limb and more than 20° on the northeast limb (Welder and McGreevy, 1966, p. 4). The northern end of the basin is bounded by the Wind River Range and the Green Mountains and is highly faulted.

The Rock Springs Uplift separates the Green River and Washakie Basins. It is an asymmetrical, doubly plunging anticline. Cretaceous rocks dip 12° on the west flank and 5° or 6° on the east (Bradley, 1964, p. A-10). The axis of the uplift is north trending. The center of the uplift has been eroded, and rocks of the Mesaverde Group and the Baxter Shale of Cretaceous age are exposed.

Extensive work has been done by several researchers on the geology of the Green River structural basin. Most of this work has been in the study of rocks of Late Cretaceous and Tertiary ages. Approximately 80 percent of the rocks exposed at the surface are post-Cretaceous in age. Depths to the top of rocks of Early Cretaceous age generally exceed 8,000 ft (2,400 m) except near the Rock Springs Uplift.

A generalized column of the formations, groups, and some members in the study area is shown in table 1.

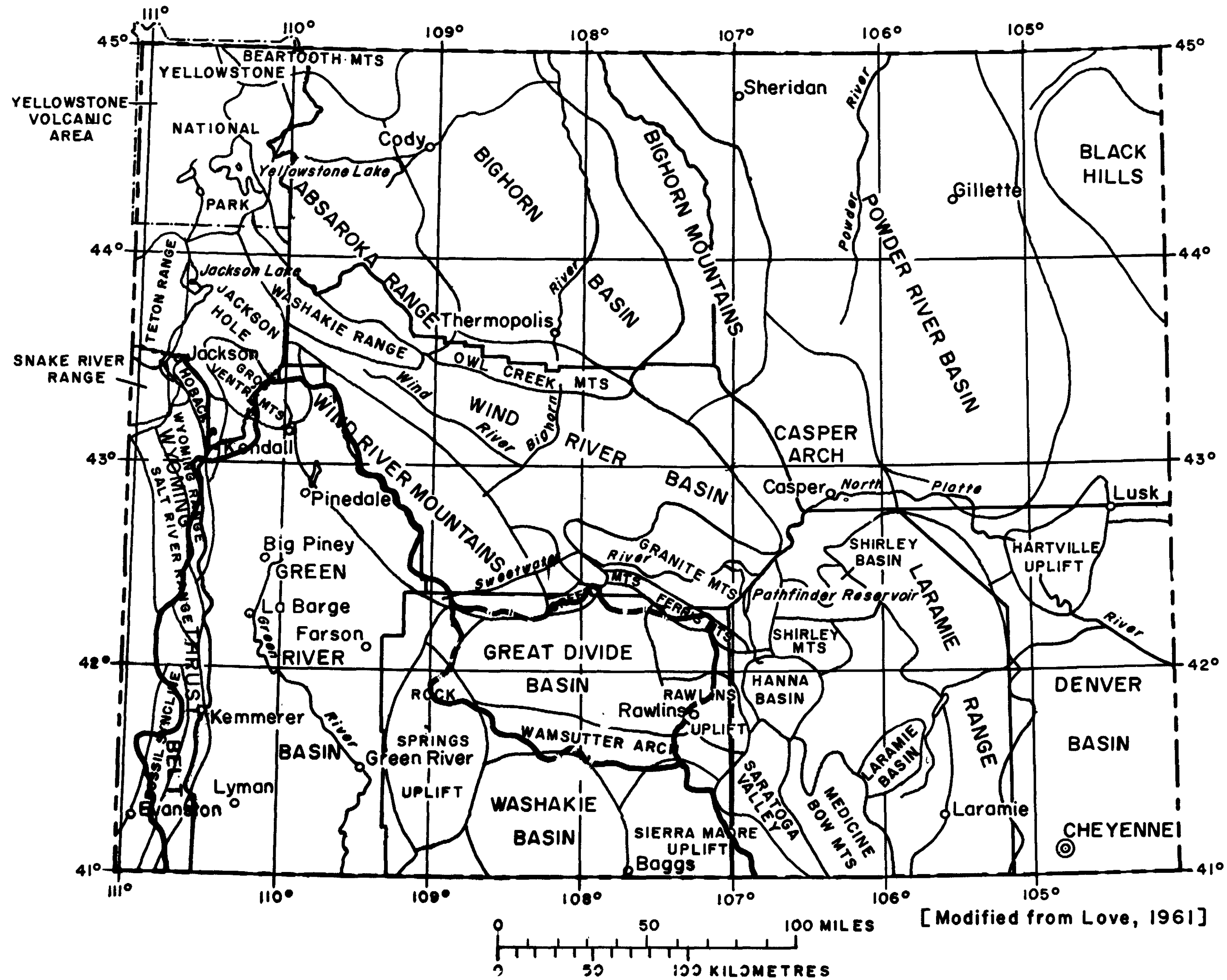


Figure 2.–Location of study area in relation to major structural features of Wyoming

Table 1.--Generalized column of geologic formations (from various sources, principally: Welder, 1968; Welder and McGreevy, 1966; Bradley, 1964; Bradley and Eugster, 1969; Oriel, 1969; Anderman, 1956; and Gudim, 1956).

Erathem	System	Series	Geologic Units: Green River Structural Basin	Geologic Units: Great Divide and Washakie Basins	Lithology and Distribution: Green River Structural Basin	Lithology and Distribution: Great Divide and Washakie Basins
CENOZOIC	QUATERNARY	Pleistocene and Holocene	Alluvial deposits		Clay, silt, sand, and gravel; some slopewash material. Coarser deposits in and near highlands and in Little Snake valley and Green River valley (Welder, 1968; Welder and McGreevy, 1966).	
			Windblown sand		Sand and silt, unconsolidated. Both active and inactive sand dunes widely scattered throughout area (Welder and McGreevy, 1966; Welder, 1968).	
			Glacial deposits	Lake deposits	Clay, silt, sand, gravel and boulders. Present in Sierra Madre uplift, Wind River Mountain front, and south of Lyman (Welder and McGreevy, 1966; Welder, 1968).	Clay, silt, and sand (Welder and McGreevy, 1966).
			Gravel deposits		Gravel, pebble to boulder size, sand, and silt. Scattered outcrops in Great Divide Basin, Rawlins uplift, southeastern area, and in some terraces above streams (Welder and McGreevy, 1966; Welder, 1968).	
	TERTIARY	Pliocene(?)	Igneous rocks	North Park(?) Formation	Alkalic intrusive and extrusive rocks north of Rock Springs, lava flows east of Baggs and at Pilot Butte (Welder and McGreevy, 1966, Welder, 1968).	Sandstone, tuff and limestone, basal conglomerate (Welder and McGreevy, 1966).
		Miocene to upper Pliocene	South Pass Formation		Pebble to boulder size conglomerate in a fine-grained ashy matrix. In northern and southeastern part of area (Welder and McGreevy, 1966; Welder, 1968).	
		Miocene(?)	Browns Park Formation		Tuffaceous sandstone, sandy claystone, and conglomerate. Present in Rock Springs uplift, southern Washakie Basin, Sierra Madre uplift, and possibly northern edge of Great Divide Basin (Welder, 1968; Welder and McGreevy, 1966).	
		Oligocene or Miocene	Bishop Conglomerate		Conglomerate containing well-rounded boulders and cobbles of quartzite, limestone, schist, and sandstone. Present in southwestern part of area (Welder, 1968; Welder and McGreevy, 1966).	
		Upper Eocene		Uinta Formation		Varicolored tuffaceous claystone, contains lenticular fine-grained sandstone. Restricted to Washakie Basin (Welder and McGreevy, 1966).

CENOZOIC	TERTIARY	Middle and Upper(?) Eocene	Bridger Formation		Sandy, tuffaceous mudstone, light neutral gray to dark greenish drab to gray chocolate brown. Interbedded medium-grained tuffaceous sandstone; minor amounts of shale, limestone, and dolomite. Up to 15 or 20 percent of formation is volcanic ash (Bradley, 1964; Welder and McGreevy, 1966; Welder, 1968).
		Middle Eocene	Pass Creek Conglomerate		Conglomerate, sandstone, and shale. Present in northwestern part of area (Welder, 1968).
		Upper Paleocene to upper(?) Eocene	Wasatch and Green River Formations	Upper tongue of Green River Formation	Algal limestone, calcareous sandstone, siltstone, marlstone, mudstone, fossiliferous limestone, and chert (Oriel, 1969; Welder, 1968).
				Laney Shale Member of Green River Formation	Buff, chippy marlstones, sandstone lenses, volcanic ash in upper part, oil shale, siltstone, fine- to medium-grained sandstone. Characteristically buff colored. Encircles Washakie Basin, east side of Green River Basin and west side of Great Divide Basin (Bradley, 1964; Welder, 1968, Welder and McGreevy, 1966).
				Upper tongue of Wasatch Formation	Green and gray mudstone and yellow to brown and gray locally conglomeratic fine- to medium-grained sandstone. Present along western margin (Oriel, 1969; Welder, 1968)
				Middle tongue of Green River Formation	Limestone, marlstone, calcareous mudstone, calcareous sandstone, ash beds, siltstone, abundant low-grade oil shale, some high grade (Oriel, 1969; Welder, 1968).
				New Fork Tongue of Wasatch Formation	Variegated sandy mudstone. Irregular beds and lenses of course-grained sandstone with well-rounded chert pebbles making up large part of unit (Bradley, 1964; Oriel, 1969).
				—?—?— Fontenelle Tongue of Green River Formation	Light-gray soft flakey marly shale, marlstone, hard sandy limestone, very fine-grained calcareous sandstone (Oriel, 1964; Bradlev, 1964; Welder, 1968).
				Wilkins Peak Member of Green River Formation	Gray to greenish-gray dolomitic and tuffaceous marlstone, limestone, mudstone, muddy sandstone lean to rich oil shale, volcanic ash beds, trona beds. Persistant mudstone siltstone, and sandstone in eastern part of area, grades north and west to claystone or clayey marlstone (Bradley, 1964; Culbertson, 1966; Welder, 1968; Welder and McGreevy, 1966).
				Cathederal Bluffs Tongue of Wasatch Formation	Gray mudstone with pink and red layers. Lenses of sandstone common near mountains Thin beds of limestone locally.More sandy and conglomcrate in Great Divide Basin. Fine grained sandstone beds in Washakie Basin. Mostly absent in Green River structural basin (Bradley, 1964; Welder, 1968; Welder and McGreevy, 1966)
				Tipton Tongue and Tipton Shale Member of Green River Formation	Soft brown papery organic shale and low-grade oil shale interbedded with harder beds of gray flakey marlstone and thin beds of brown limy sandstone; and fossiliferous limestone. Sandstone unit, discernible on electric logs over an area of about 4,000 square miles may merge with New Fork Tongue (Bradley, 1964; Welder, 1968; Welder and McGreevy, 1966)
			Battle Spring Formation		Very coarse-grained to pebbly arkosic sandstone with smaller amounts of bright-green claystone and some moderately calcareous quartz concretions. Only present in eastern Great Divide Basin (Bradley, 1964; Welder and McGreevy, 1966).

Table 1.--Generalized column of geologic formations (*from various sources, principally*: Welder, 1968; Welder and McGreevy, 1966; Bradley, 1964; Bradley and Eugster, 1969; Oriel, 1969; Anderman, 1956; and Gudim, 1956)--continued

Erathem	System	Series	Geologic Units: Green River Structural Basin	Geologic Units: Great Divide and Washakie Basins	Lithology and Distribution: Green River Structural Basin	Lithology and Distribution: Great Divide and Washakie Basins
CENOZOIC	TERTIARY	Upper Paleocene to upper(?) Eocene	Wasatch and Green River Formations	Main body of the Wasatch Formation	Sandy, variegated mudstone, fine- to medium-grained calcareous sandstone, carbonaceous shale, small amounts of oil-shale and coal, conglomeratic sandstone near periphery, small amount of limestone. Includes conglomerate member, LaBarge and Chappo Members in the western part of area (Oriel, 1969) and Niland Tongue in south central part of area and Luman Tongue of Green River Formation (Bradley, 1964; Welder, 1968; Welder and McGreevy, 1966).	
		Paleocene	Hoback(?) Formation	Ft. Union Formation	Mudstone, claystone sandstone, siltstone, coal, and limestone (Oriel, 1969).	Sandstone, carbonaceous shale, coal, siltstone, and claystone (Welder, 1968; Welder and McGreevy, 1966).
MESOZOIC	CRETACEOUS	Upper		Lance Formation		Sandstone, some clayey calcareous shale, and coal (Welder and McGreevy, 1966).
				Fox Hills Sandstone		Calcareous sandstone (Weimer, 1965).
				Lewis Shale		Sandstone, siltstone, limestone, and bentonite (Haun, 1961; Welder and McGreevy, 1966).
			Adaville(?) Formation	Mesaverde Formation / Mesaverde Group: Almond Formation	Sandstone, mudstone, some coal, conglomeratic sandstone, may be Mesaverde Group (Oriel, 1969).	Mesaverde Formation / Mesaverde Group: Sandstone, siltstone, coal and carbonaceous shale (Welder and McGreevy, 1966).
				Ericson Formation		Sandstone, cherty conglomerates, silt, shale and thin coals (Smith, 1965; Welder and McGreevy, 1966).
				Rock Springs Formation		Sandstone, shale, and coal. Shalier to the southeast (Smith, 1965; Welder and McGreevy, 1966).
				Blair Formation		Sandy shale, sandstone, and siltstone (Smith, 1965; Welder and McGreevy, 1966).
				Mesaverde Formation		Silty sandstone, shale, and coal (Welder and McGreevy, 1966).
				Steele Shale		Shale, and some sandstone (Welder and McGreevy, 1966).
			Hilliard Shale	Baxter Shale	Mudstone, some siltstone, and sandstone (Oriel, 1969).	Gypsiferous, silty shale, some sandstone and siltstone, limestone and sandstone unit near middle (Smith, 1965; Welder and McGreevy, 1966).
				Cody Shale		Shale, some sandstone, and bentonite (Welder and McGreevy, 1966).
				Niobrara Formation		Shale and some limestone (Welder and McGreevy, 1966).
			Frontier Formation	Frontier Formation	Shale, thin sandstone, siliceous shale, and coal (Anderman, 1956; Gudim, 1956).	

Era	System	Series	Western units		Eastern units	Lithology (western units)		Lithology (eastern units)
MESOZOIC	CRETACEOUS	Lower	Aspen Formation	Mowry Shale		Claystone, mudstone, sandstone, and porcellanite (Oriel, 1969).	Siliceous shale, bentonitic shale, some siltstone (Welder and McGreevy, 1966; Anderman, 1956; Burk, 1956).	
			Bear River Formation	Dakota(?), Cloverly, and Morrison Formations	Thermopolis Shale	Claystone, some sandstone, limestone, some ironstone, and bentonitic mudstone (Oriel, 1969).	Claystone, shale, lenticular sandstone and conglomerate, and chert pebbles (Anderman, 1956).	Shale, sandy shale, and bentonite. Includes Muddy Sandstone, a sandstone and silty shale unit (Gudim, 1956).
			Gannett Group, undivided		Cloverly Formation	Mudstone, siltstone, some sandstone, limestone, chert, and conglomerate (Oriel, 1969).		Conglomerate, shale, and sandstone (Gudim, 1956).
	JURASSIC	Upper			Morrison Formation			Sandstone, shale, some conglomerate, some calcareous conglomerate, and limestone (Gudim, 1956; Welder and McGreevy, 1966).
			Stump Sandstone	Curtis Formation	Sundance Formation	Sandstone, siltstone, mudstone and limestone (Oriel, 1969; Anderman, 1956).		Sandstone, shale, siltstone, and some limestone (Gudim, 1956; Pipringos, 1968; Burk, 1956).
			Preuss Sandstone	Entrada Standstone		Siltstone, mudstone, sandstone, and anhydrite (Oriel, 1969; Anderman, 1956).		
		Middle	Twin Creek Limestone	Carmel Formation		Limestone, some silty limestone, mudstone, and siltstone. Includes Gypsum Spring Member in northwest and eastern parts of area (Oriel, 1969; Burk, 1956; Anderman, 1956).		
		Lower	Nugget Sandstone			Quartzitic and calcareous sandstone, shale and dolomite beds near base (Oriel, 1969; Gudim, 1956; Burk, 1956; Anderman, 1956).		
	TRIASSIC	Upper	Ankareh Formation	Chugwater Group	Popo Agie Formation	Calcareous mudstone, siltstone, sandstone, and limestone (Oriel, 1969).		Sandstone, some shale, and siltstone (Burk, 1956; Gudim, 1956; Pipringos, 1968).
		Lower	Thaynes Limestone		Jelm Formation	Limestone, some calcareous siltstone, and mudstone (Oriel, 1969; Burk, 1956).		Sandstone, and siltstone (Pipringos, 1968).
					Alcova Limestone			Limestone, absent in southeastern part of area (Gudim, 1956).
			Woodside Formation		Red Peak Shale	Anhydritic and dolomitic siltstone, claystone, and some sandstone (Oriel, 1969).		Shale and siltstone; truncated in southeastern part of area (Gudim, 1956).
			Dinwoody Formation			Calcareous siltstone, mudstone, argillaceous and sandy dolomite, and anhydrite (Oriel, 1969; Gudim, 1956).		

Table 1.--Generalized column of geologic formations (from various sources, principally: Welder, 1968; Welder and McGreevy, 1966; Bradley, 1964; Bradley and Eugster, 1969; Oriel, 1969; Anderman, 1956; and Gudim, 1956)--continued

Erathem	System	Series	Geologic Units: Green River Structural Basin	Geologic Units: Great Divide and Washakie Basins	Lithology and Distribution: Green River Structural Basin	Lithology and Distribution: Great Divide and Washakie Basins
PALEOZOIC	PERMIAN		Phosphoria and Park City Formations, undivided		Mudstone, phosphatic mudstone, dolomite, chert, phosphorite, limestone, and shale (Oriel, 1969; Gudim, 1956; Burk, 1956)	
	PENNSYLVANIAN	Upper	Wells(?) Formation; Tensleep Sandstone; Weber Sandstone	Tensleep Sandstone	Calcareous and quartzitic sandstone, with some dolomite and limestone beds. Truncated in southeastern part of basin (Oriel, 1969; Gudim, 1956; Anderman, 1956; Burk, 1956).	
		Middle Lower	Amsden Formation; Morgan Formation and Round Valley Limestone	Amsden Formation	Heterogeneous mudstone, limestone, dolomite, sandstone, and anhydrite (Oriel, 1969). Argillaceous limestone, sandstone, and shale (Anderman, 1956).	Shale, siltstone, dolomite, limestone, and anhydrite. Absent in southeastern part of area (Gudim, 1956; Welder and McGreevy, 1966).
	MISSISSIPPIAN	Upper Lower	Madison Limestone		Limestone and dolomite with chert nodules and lenses. Thins southward on eastern margin (Burk, 1956; Gudim, 1956; Oriel, 1969).	
	DEVONIAN	Upper	Darby Formation		Dolomite, limestone, some detritus, and breccias (Oriel, 1969).	
	ORDOVICIAN	Middle Upper	Bighorn Dolomite		Dolomite and dolomitic limestone (Oriel, 1969).	
	CAMBRIAN	Upper	Gallatin Limestone		Limestone, dolomitic limestone, shale, and bioclastic and conglomeratic limestone (Oriel, 1969; Anderman, 1956).	Cambrian thins toward southeast and is absent in some areas.
		Middle	Gros Ventre Formation	Buck Spring Formation	Two shale units separated by a thick limestone unit, includes limestone breccias and conglomerates (Oriel, 1969).	Gros Ventre equivalent in eastern Great Divide Basin (Gudim, 1956).
			Flathead Sandstone		Arkosic sandstone (Anderman, 1956).	
PRECAMBRIAN			Igneous and metamorphic rocks		Granite, gneiss, and schist (Welder and McGreevy, 1966).	

Most of the exposed and near surface formations are of Tertiary age, and those of particular importance are the Wasatch, Green River, and Bridger Formations. The intertonguing relation of these three formations is shown in figure 3.

Climate

The climate within the study area varies widely according to location, elevation, and topography. The mountainous areas annually receive as much as 40 in (1,000 mm) of precipitation, while the interior plains area receives as little as 6 in (150 mm). The high elevation and northerly latitude of the area results in relatively low average temperatures and short growing seasons.

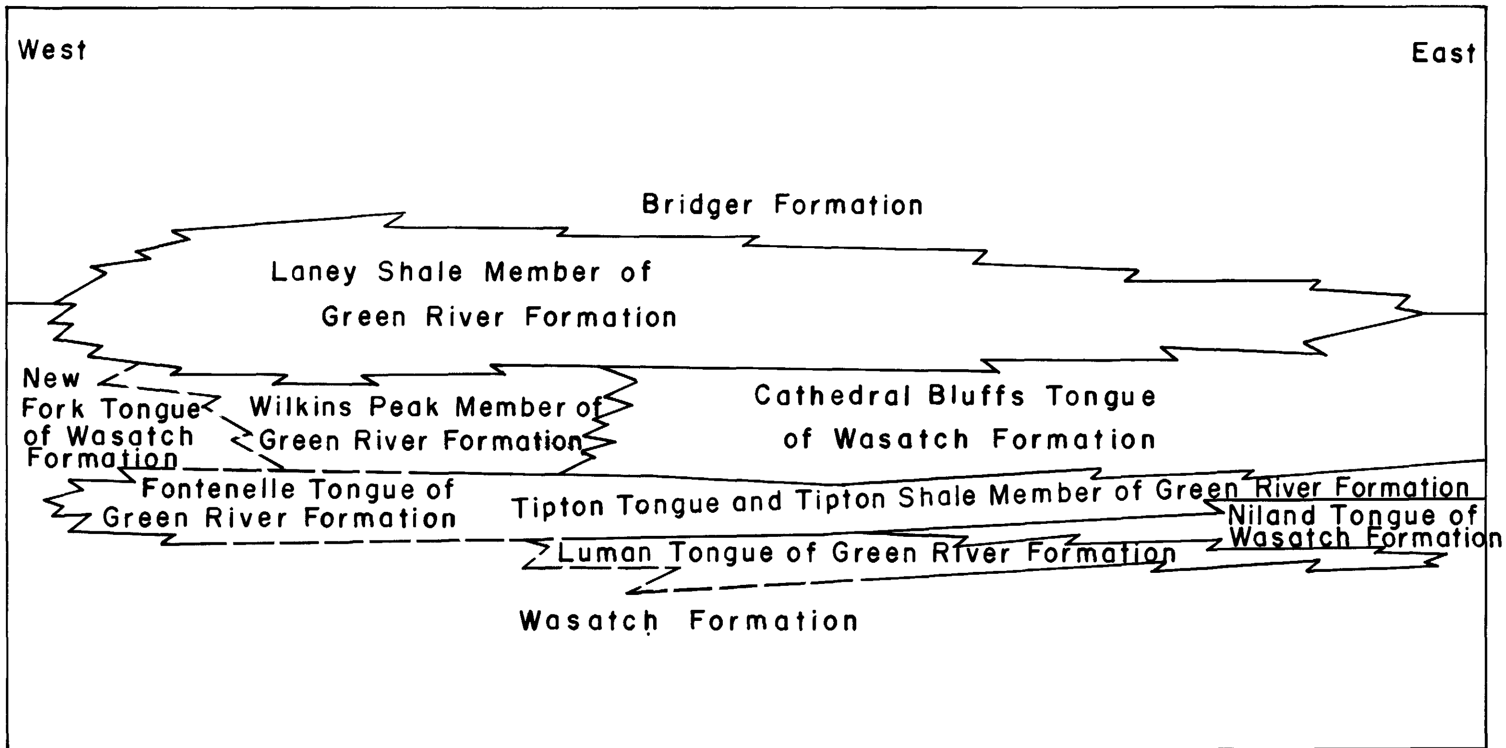
The main source of precipitation for the basins is maritime air masses from the Pacific Ocean. Canadian arctic air masses occasionally move into the area, but are usually blocked by the Wind River Range. The variation of mean annual precipitation in the basins is shown in figure 4.

The variation of precipitation throughout the year is shown in table 2, which shows monthly averages for representative weather stations.

Variations of temperature at different sites throughout the year are shown in table 3, which shows monthly and annual mean temperatures. The relatively high elevation along with the varying warm and cold air masses that move through the area cause large annual and daily temperature ranges. The maximum recorded summer temperature is 107°F (41.7°C), at the Green River Aviation station. The coldest recorded winter temperature is -55°F (-48.3°C), at Farson.

The average growing season of the basins is shown in figure 5. The growing season for the main crops of the study area, grass and alfalfa, is between the last killing frost in the spring and the first killing frost in the fall. A killing frost for these crops is considered to occur when the minimum temperature dips to 28°F (-2.2°C) or lower.

Winds are relatively strong, especially in the plains areas. Wind velocity averages about 15 mi/hr (24 km/hr) during winter and spring, and about 8 mi/hr (13 km/hr) during summer. Strong winds of 30 to 40 mi/hr (48 to 64 km/hr) with stronger gusts sometimes prevail for several days. Wind direction is predominantly from the west.



[From Bradley, 1964, p-A18]

Figure 3.— Schematic section showing stratigraphic relation of the Wasatch, Green River, and Bridger Formations and their members.

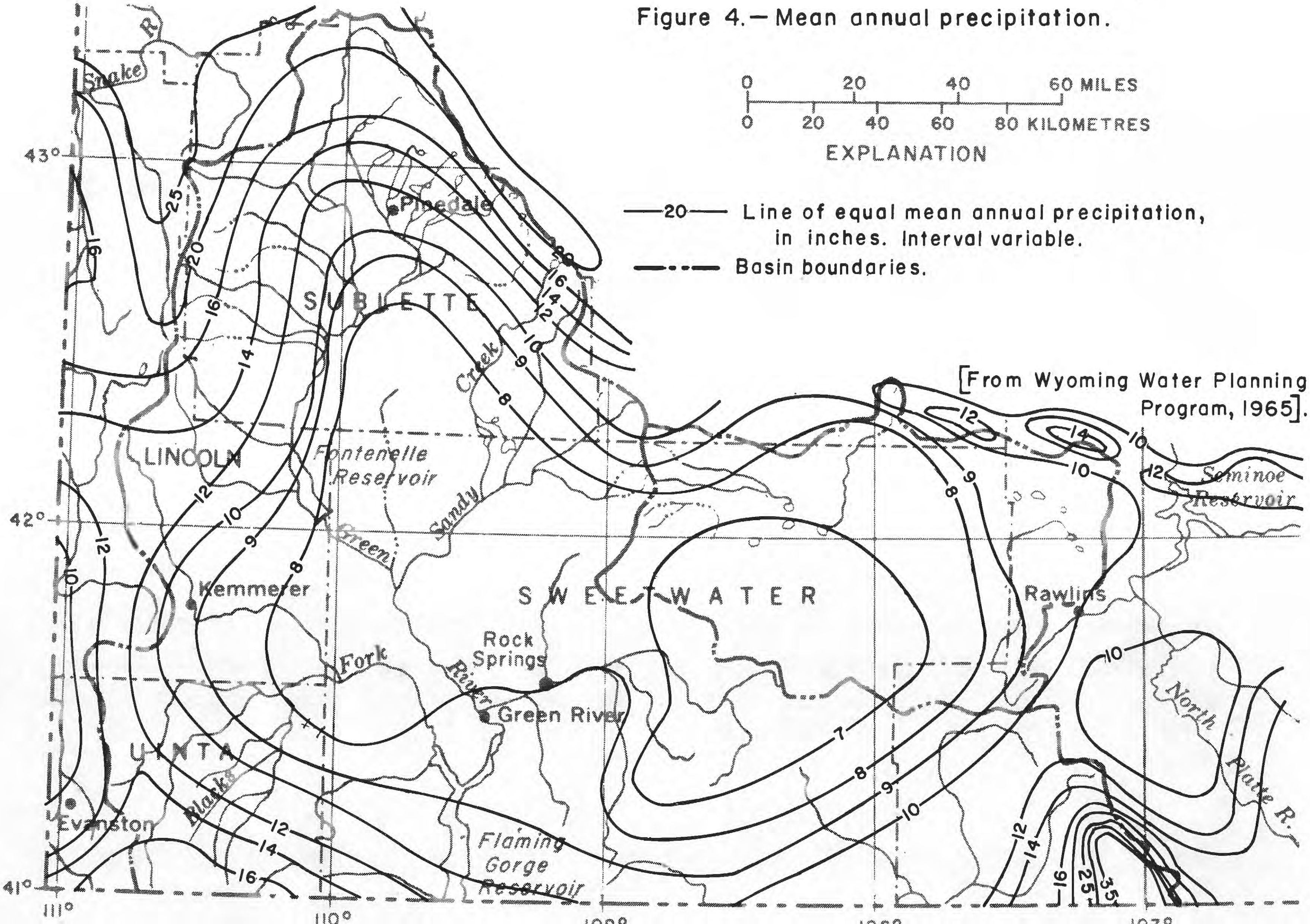


Figure 4.— Mean annual precipitation.

EXPLANATION

—20— Line of equal mean annual precipitation, in inches. Interval variable.

—·—·— Basin boundaries.

[From Wyoming Water Planning Program, 1965].

Table 2.--Monthly and annual precipitation normals, in inches, for the period 1941-70.

[From U.S. Dept. of Commerce, 1973, p. 2]

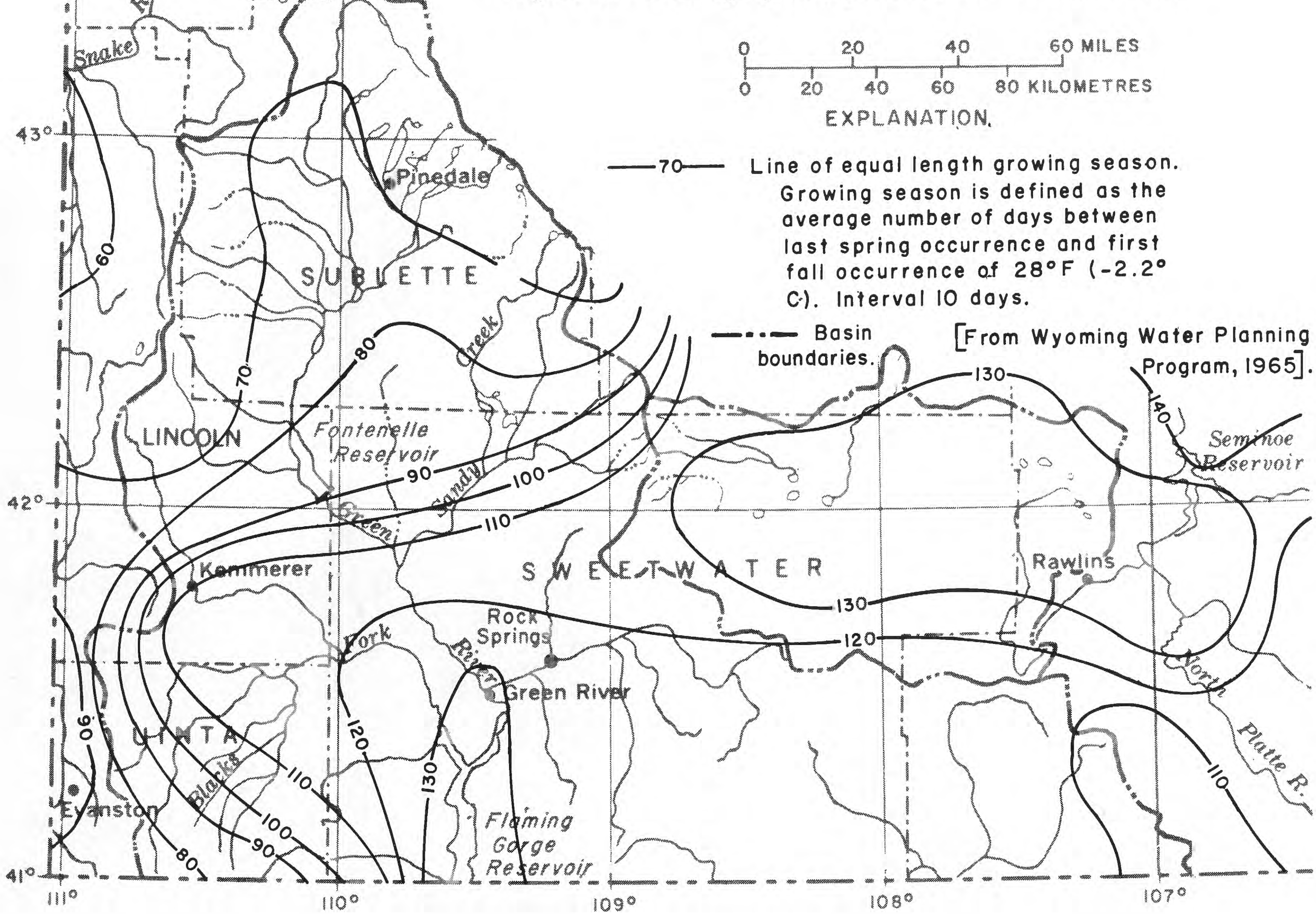
Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Afton----------------	1.51	1.38	1.31	1.60	2.05	2.41	0.92	1.18	1.37	1.44	1.65	1.65	18.47
Big Piney----------	.37	.33	.41	.84	1.31	1.23	.75	.91	.90	.65	.44	.46	8.60
Border 3 N---------	1.30	1.07	.97	1.17	1.30	1.72	.66	.94	1.05	1.06	1.20	1.34	13.78
Dixon--------------	.87	.67	.98	1.23	1.21	1.20	1.06	1.20	1.00	1.27	.76	1.01	12.46
Evanston 1 E-------	.72	.68	.94	1.16	1.23	1.30	.60	.90	.74	1.02	.91	.78	10.98
Farson-------------	.36	.31	.46	.61	1.16	1.29	.44	.77	.64	.73	.44	.40	7.61
Green River--------	.44	.41	.60	.92	1.28	1.18	.43	.83	.63	.94	.46	.42	8.54
Kemmerer 4 SW------	.66	.61	.67	.72	1.23	1.42	.51	.82	.73	.74	.71	.71	9.53
Kendall------------	1.65	.98	1.24	1.09	1.93	2.05	1.03	1.33	1.39	1.00	1.26	1.57	16.52
Pinedale-----------	.73	.59	.63	.92	1.57	1.60	.77	1.02	.94	.84	.71	.91	11.23
Rock Springs FAA AP	.46	.54	.68	1.02	1.11	1.14	.49	.74	.72	.87	.53	.49	8.79
Sage 4 NMW---------	.73	.62	.74	.89	1.26	1.37	.49	.84	.90	.89	.79	.64	10.16
South Pass City----	1.25	.84	1.22	1.57	1.48	1.70	.61	.84	.93	1.10	1.09	1.10	13.73

Table 3.--Monthly and annual mean temperatures, in degrees Fahrenheit, for the period 1941-70.

[From U.S. Dept. of Commerce, 1973, p. 1]

Station	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Afton--------------	14.3	19.1	24.8	37.1	47.6	53.4	60.8	59.3	51.9	42.3	28.1	17.6	38.0
Big Piney----------	9.1	13.6	22.0	35.2	45.3	52.7	59.3	56.4	47.6	37.2	23.5	12.4	34.5
Border 3 N---------	12.4	16.6	23.6	37.7	48.2	54.7	62.4	60.7	52.2	41.9	27.9	16.6	37.9
Dixon--------------	17.8	22.2	29.2	41.5	50.7	57.8	65.0	62.9	54.0	43.7	30.6	21.6	41.4
Evanston 1 E-------	17.9	21.0	26.1	37.5	47.4	54.5	62.7	61.0	52.5	42.4	28.9	21.1	39.4
Farson-------------	9.3	14.6	23.9	37.8	47.8	55.9	63.4	60.8	51.6	39.8	24.6	13.2	36.9
Green River--------	18.6	23.9	31.0	42.4	52.4	60.4	68.6	66.3	56.6	45.5	31.6	22.2	43.3
Kemmerer 4 SW------	17.0	20.0	25.7	38.1	48.1	55.1	62.7	60.8	52.3	41.8	28.5	20.1	39.2
Kendall------------	12.3	15.1	19.2	30.9	41.8	48.2	55.1	53.8	46.3	37.3	23.9	15.1	33.3
Pinedale-----------	11.5	15.3	20.9	34.4	44.5	52.6	60.2	57.5	49.2	39.1	25.0	15.4	35.5
Rock Springs FAA AP	19.2	23.4	28.9	40.1	50.4	58.9	68.2	66.1	56.4	44.7	30.7	22.6	42.5

Figure 5.—Average growing season for forage crops.



Vegetation

Figure 6 is a map showing general vegetal cover types in the study area. Vegetal cover types indicate regions having similar plants, soils, and climates.

Land Use

Population and Economic Base

According to the Bureau of Census (1970), approximately 37,000 people lived in the Green River Basin during 1970 with population concentrated in the cities of Rock Springs, Green River, and Kemmerer. However, significant commercial development with accompanying influx of people has occurred since 1970. An estimated increase of 11,000 people has occurred (S. Young, Sweetwater County Planner, written commun., 1975) in the cities of Rock Springs and Green River since 1970. Kemmerer and other areas have experienced a more limited expansion.

Mining, oil and gas production, power plants, and supporting industries and services account for most of the recent economic growth and population influx. Agriculture, timbering, and tourism are also important industries. Figure 7 shows locations of timber industries in the study area. Locations of mineral resources are shown later in the report.

Commerce

Portions of all raw materials are exported to other states by rail, pipeline, and road. Figure 8 shows the major transportation systems. Some products such as timber, beef, oil, gas, and coal are used in the Green River Basin and Statewide. Almost all finished or manufactured products available in the study area are imported from other parts of the State, other states, and other countries.

Recreation

The Green River Basin provides numerous and diverse recreational opportunities. These include the rugged mountains on the northern rim of the basin with their pristine streams and alpine lakes, the lower desert area that provides a habitat for antelope and mule deer, many miles of fishing streams, Fontenelle Reservoir, and the Flaming Gorge National Recreation Area. Hunting, fishing, boating, camping, hiking, skiing, and snowmobiling are some of the popular activities in the area.

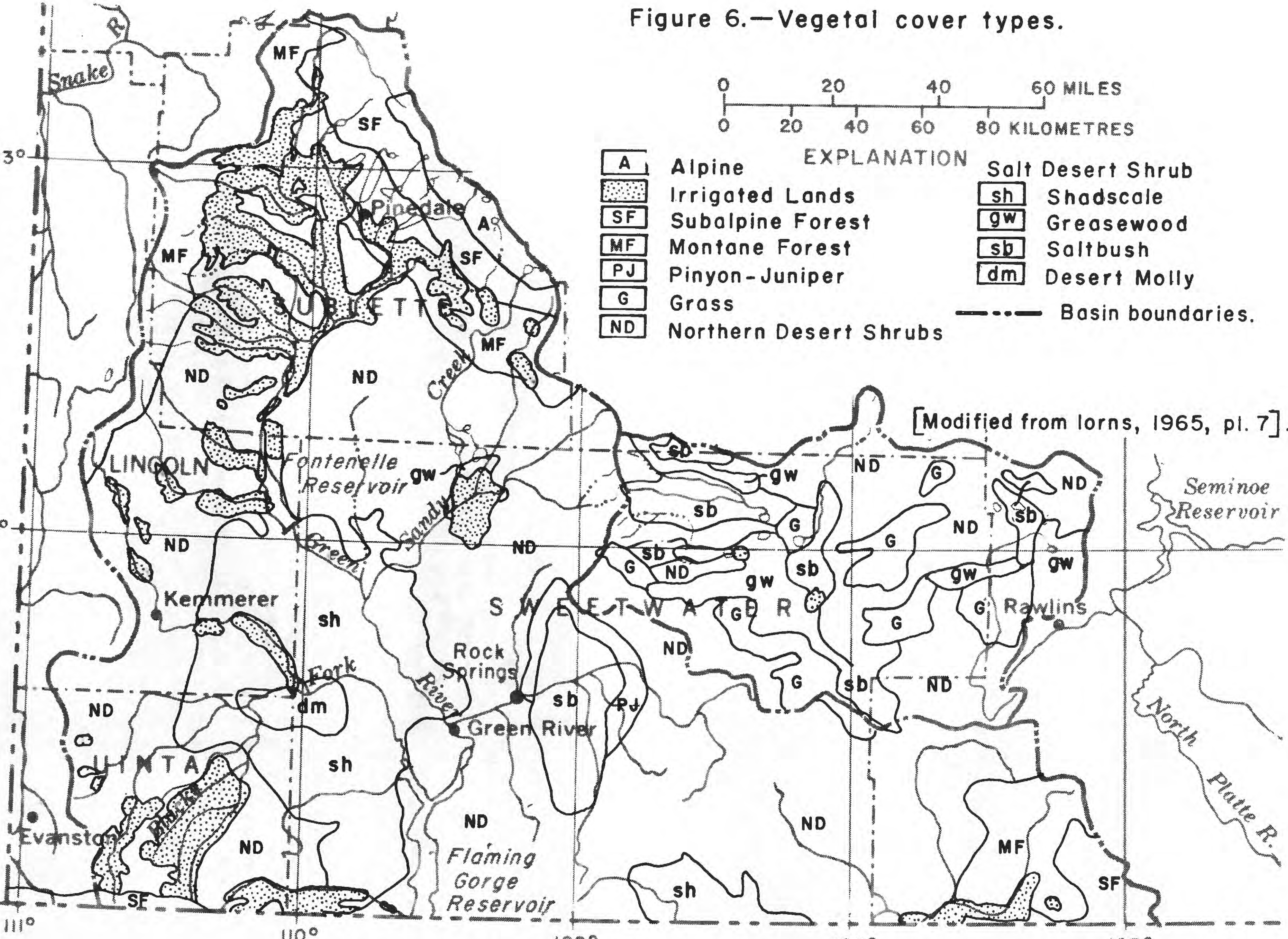


Figure 6.—Vegetal cover types.

[Modified from Iorns, 1965, pl. 7].

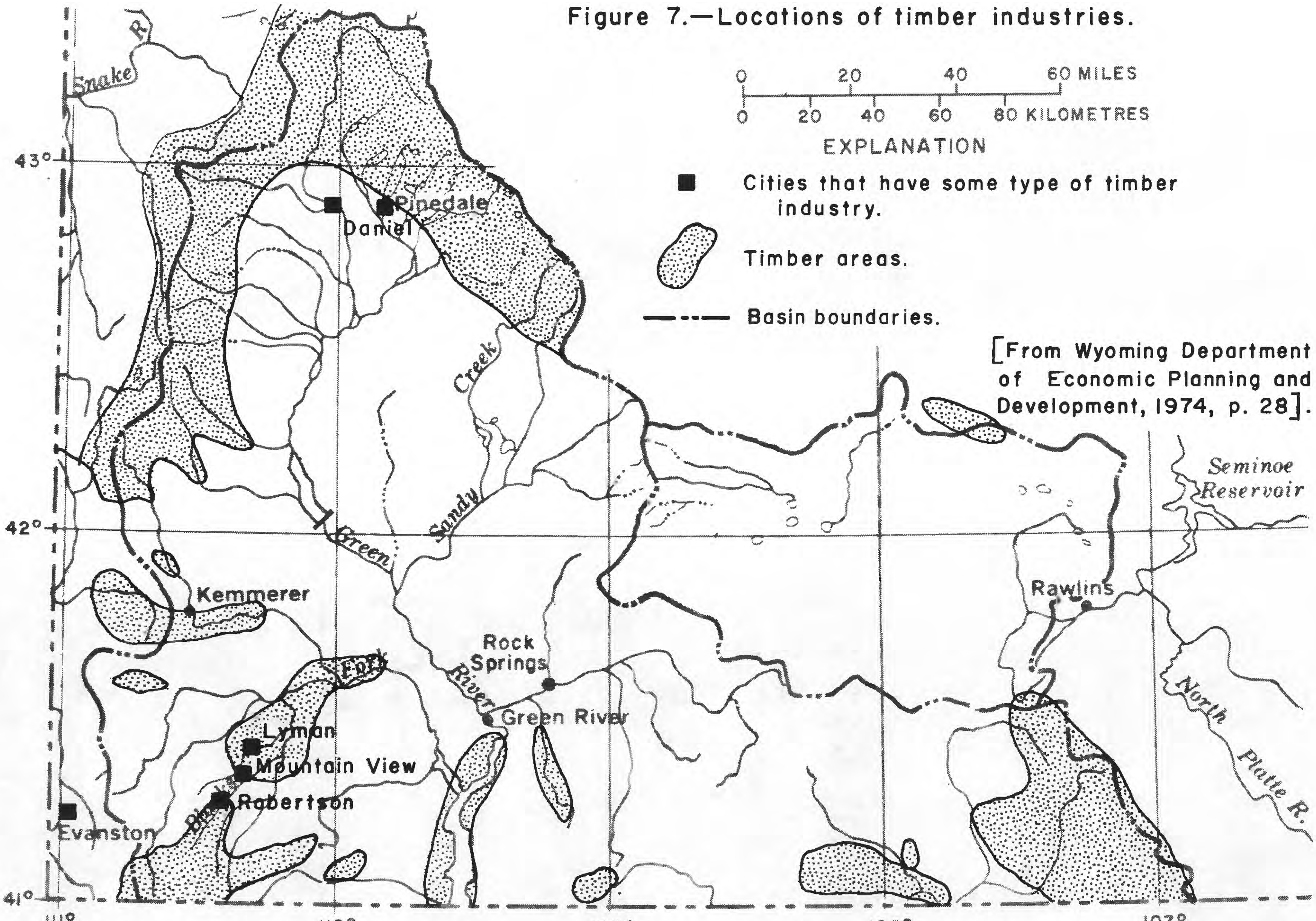


Figure 7.—Locations of timber industries.

[From Wyoming Department of Economic Planning and Development, 1974, p. 28].

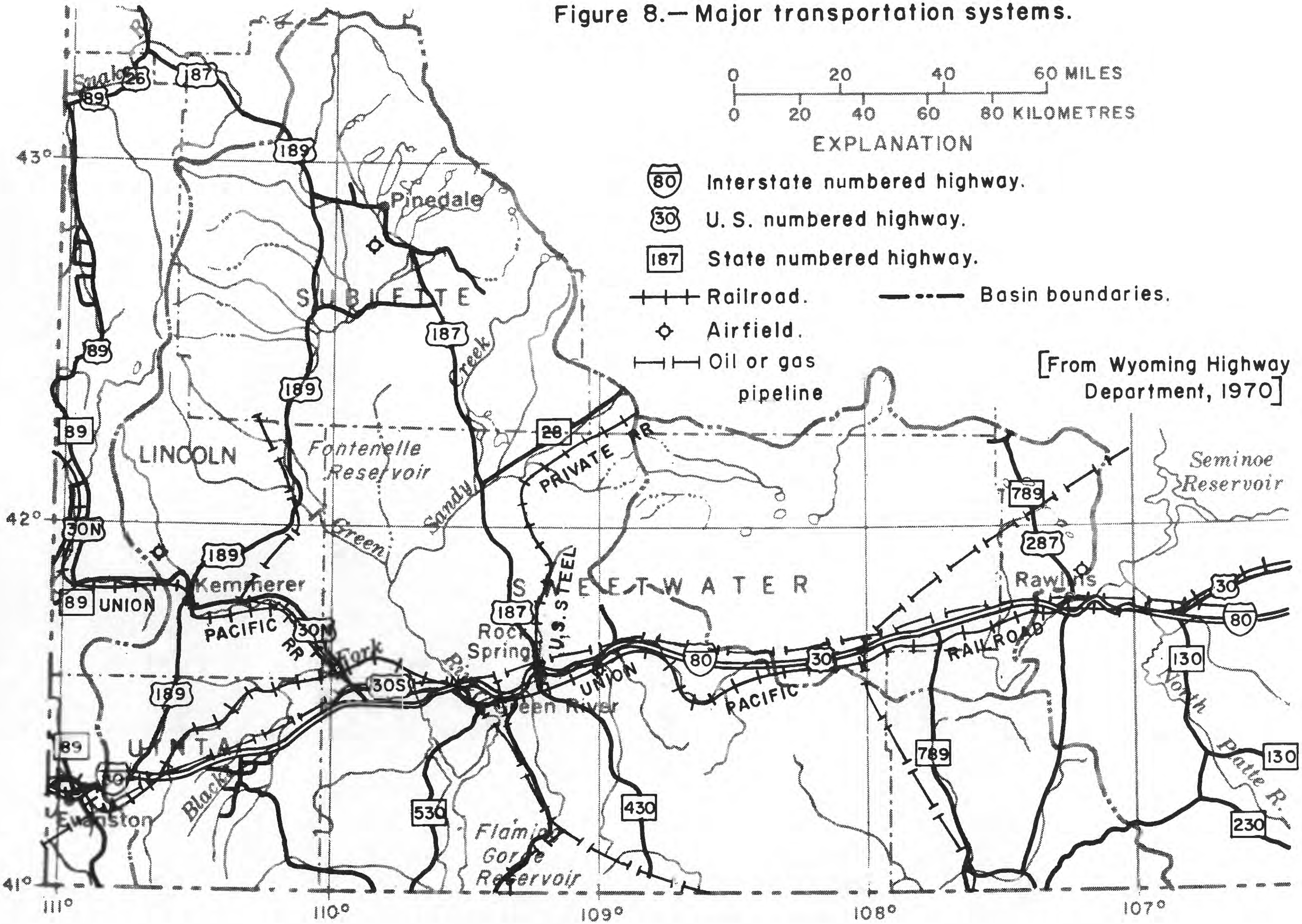


Figure 8.—Major transportation systems.

Agriculture

There are about 4,000 acres (16 km^2) of dry cropland and more than 300,000 acres (1,200 km^2) of irrigated land in the Green River and Great Divide Basins. Because of a combination of factors including a short growing season and the low water-holding capacity of the shallow soils, nearly two-thirds of the irrigated land is used for pasture and production of native hay. Agriculture is based on the production of livestock, and most of the harvested hay and limited amounts of grain are used locally.

Irrigated lands are located mostly along stream channels and along the terraces bordering the channels. Soil textures vary from sandy loam on the terraces to clay in some reaches of the river bottoms and are normally underlain with several feet of sand and gravel. Irrigated lands are shown in figure 6.

Energy Mineral Resources

Energy mineral resources include oil, natural gas, coal, uranium, and oil shale. Background information concerning reserves and production in this report are from the Wyoming Geological Survey, office of the Wyoming State Engineer, U.S. Bureau of Mines, and the U.S. Geological Survey.

Oil and Gas.--The oil and gas industry in the study area contributes significantly to United States production levels. Figure 9 shows oil and natural gas fields in the study area. The study area currently contributes about 9.1 percent of Wyoming crude-oil production and about 57 percent of Wyoming natural-gas production (Wyoming Water Planning Program, 1970, p. 82).

Coal.--Current estimates place recoverable reserves of coal in the study area at more than 19 billion tons (17 billion tonnes). Estimated recoverable, strippable subbituminous coal resources as of January 1, 1972 were over 900 million tons (800 million tonnes) (Glass, 1973, p. 118). The coal mining areas are shown in figure 10.

Coal is currently being mined from three strip mines and two underground mines. Several new strip mines are in the planning stage. (See fig. 10.) Two coal-fired power plants and two coke plants are currently in operation.

In addition to expanded mine facilities, more power, synthetic-coke, synthetic-liquid and gas-fuel plants may be built in the future. The large individual deposits of subbituminous coal are desirable for processes that convert coal to gaseous and liquid fuels. It is expected that the synthetic-coke industry will expand its facilities as demand increases.

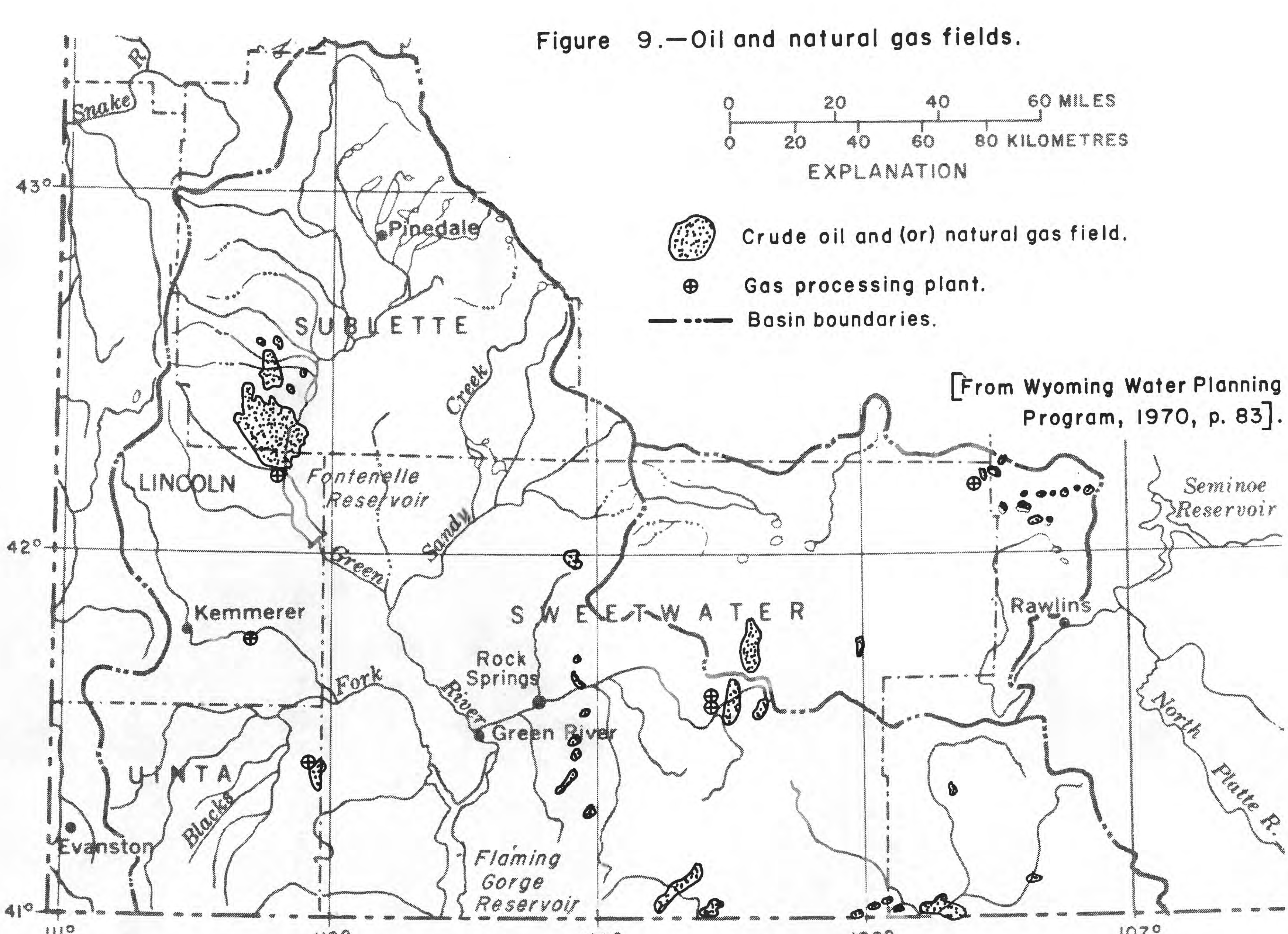
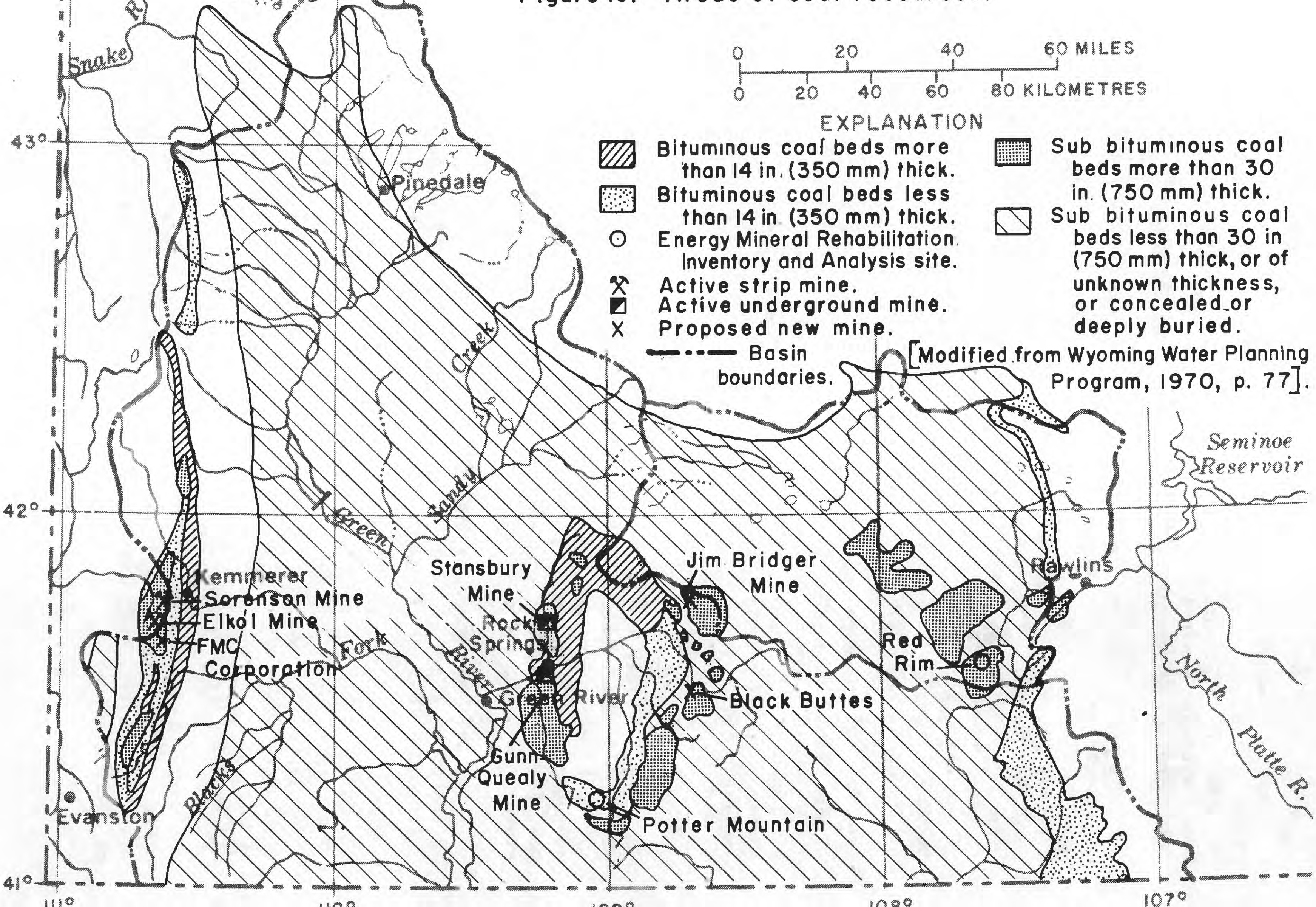


Figure 9.—Oil and natural gas fields.

Figure 10.—Areas of coal resources.



Uranium.--Two uranium mines are currently being operated in the Great Divide structural basin. Figure 11 shows locations of the mines and areas of major uranium exploration. Known deposits of uranium in the study area are generally low grade, but have economic potential because their shallow depths are suitable for surface mining.

Oil shale.--Recent demands for National independence in energy have accelerated the development of technology that would make it economically practical to use oil shale as a source of fuel. The principal oil-shale deposits are in the Green River Formation of Tertiary age in Colorado, Utah, and Wyoming. There are about 25,000 mi^2 (65,000 km^2) of land with underlying oil-shale deposits in Wyoming, Utah, and Colorado (U.S. Dept. of Int., 1973, v. I, p. I-2). About 17,000 mi^2 (44,000 km^2) are underlain by deposits of potential commercial value. There are about 30 billion barrels (over 1.3 trillion gal or 4.8 trillion l) of shale oil in rich oil-shale deposits in Wyoming.

West of the Rock Springs Uplift, the richest oil-shale deposits are in the Wilkins Peak and Tipton Shale Members; in the Washakie Basin, the richest are in the Tipton Shale and Laney Shale Members (Surdam and Wolfbauer, 1973, p. 207). The general locations of surface exposures of three oil-shale bearing members of the Green River Formation are shown in figure 12.

Non-Energy Minerals

The main non-energy mineral currently mined in the Green River Basin is trona. Trona is a basic material for production of soda ash, sodium bicarbonate, sal soda, and sodium tripolyphosphate. These products are used in many industries such as pulp and paper, glass, textiles, and foods. Soda ash (Na_2CO_3) is the primary product of the trona in Wyoming and most of this is used outside the State.

The only commercial deposits of trona are in the Green River Formation as shown in figure 13. The deposits are well described by Culbertson (1966, p. 158-164) and by Bradley and Eugster (1969).

Land Ownership

Figure 14 shows the approximate distribution of land ownership within the study area. Table 4 lists details concerning land ownership as determined by the Upper Colorado Region Comprehensive Framework Study (1971, App. VI, p. 15).

Sixty-eight percent of the land is Federally owned, 7 percent State owned, and 25 percent is in private, municipal, or county ownership. The Union Pacific Railroad owns a "checkerboard" of every other section of land in a strip 20 mi (32 km) wide on each side of the railroad.

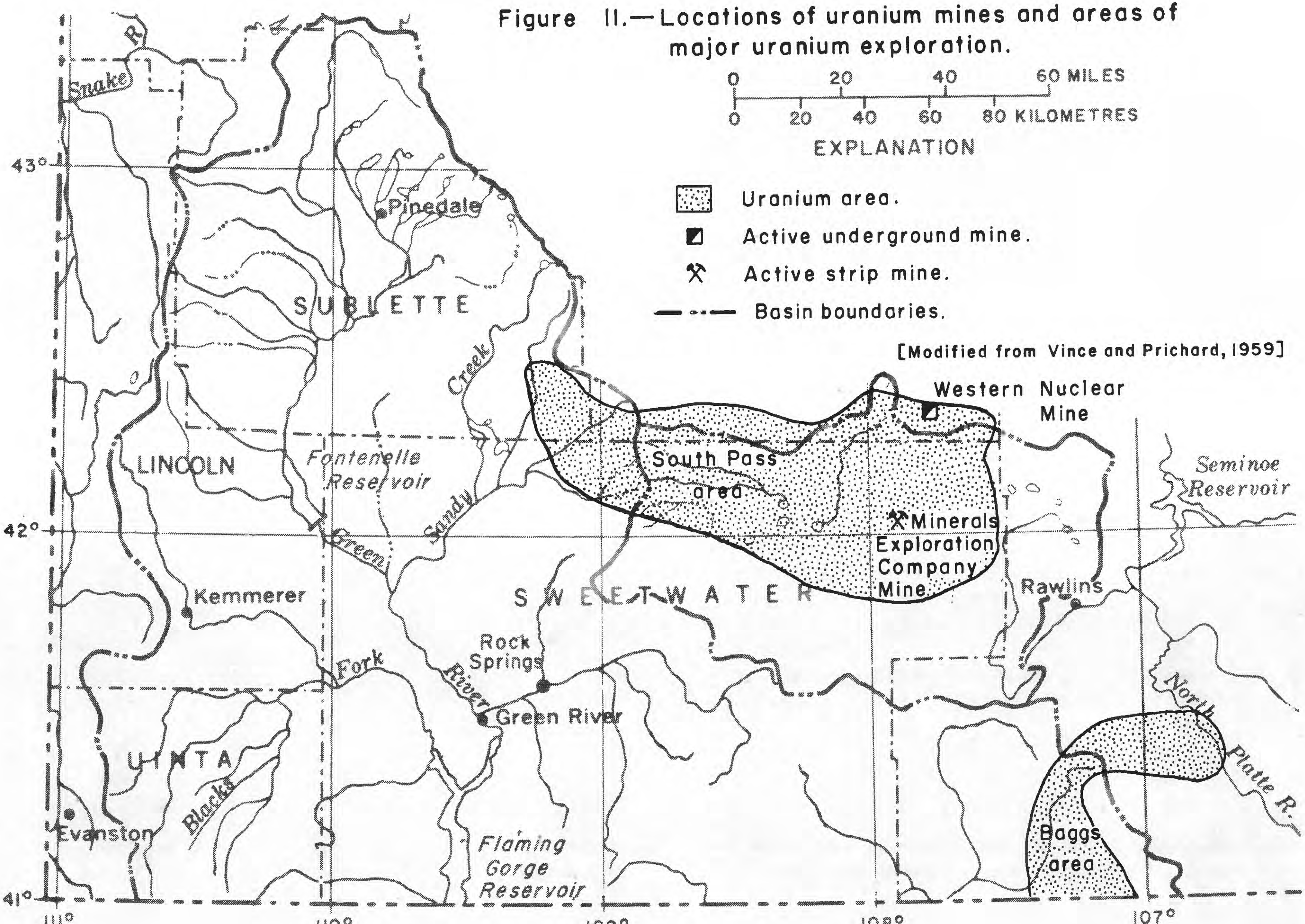


Figure 11.—Locations of uranium mines and areas of major uranium exploration.

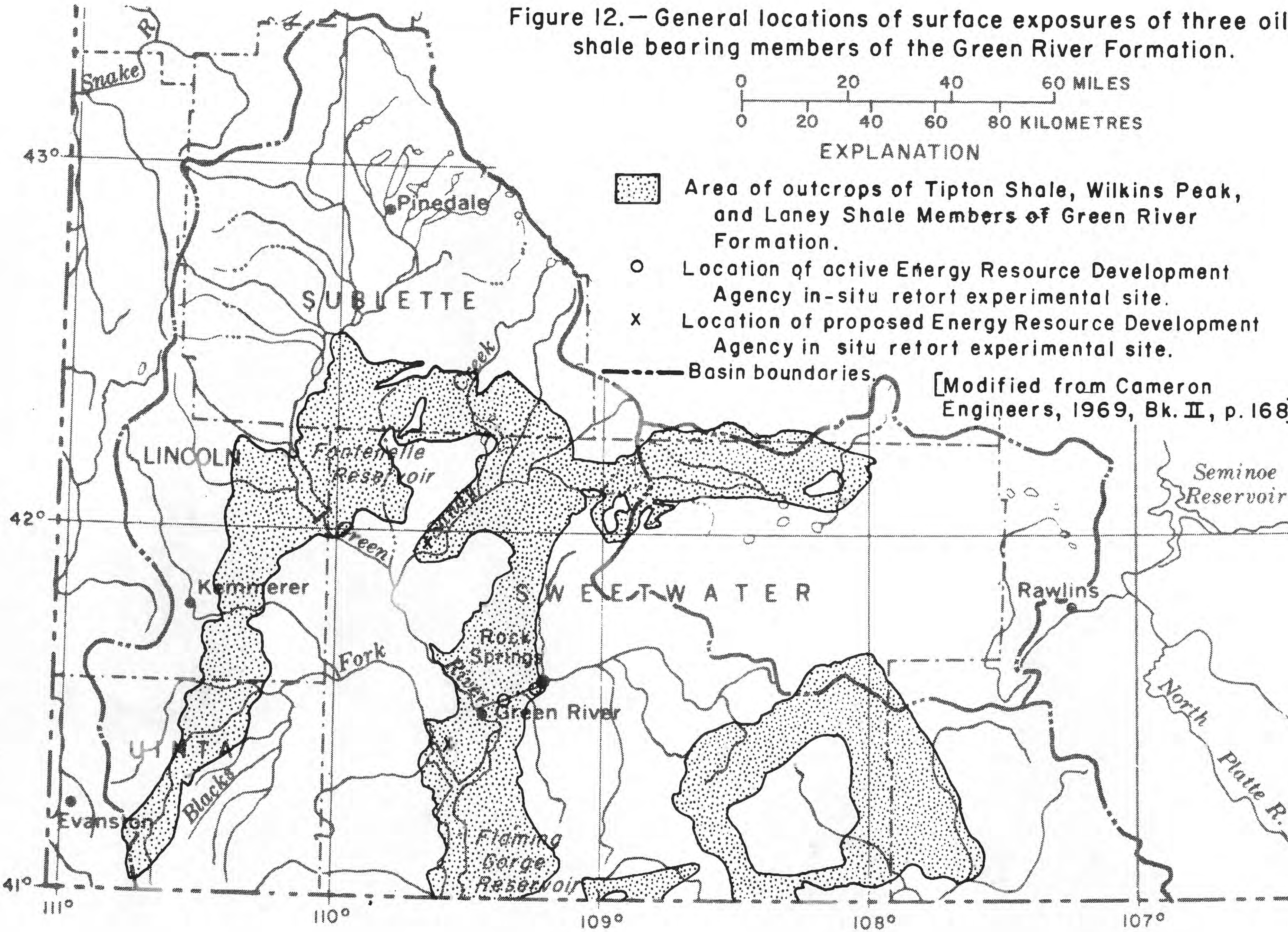


Figure 12.—General locations of surface exposures of three oil-shale bearing members of the Green River Formation.

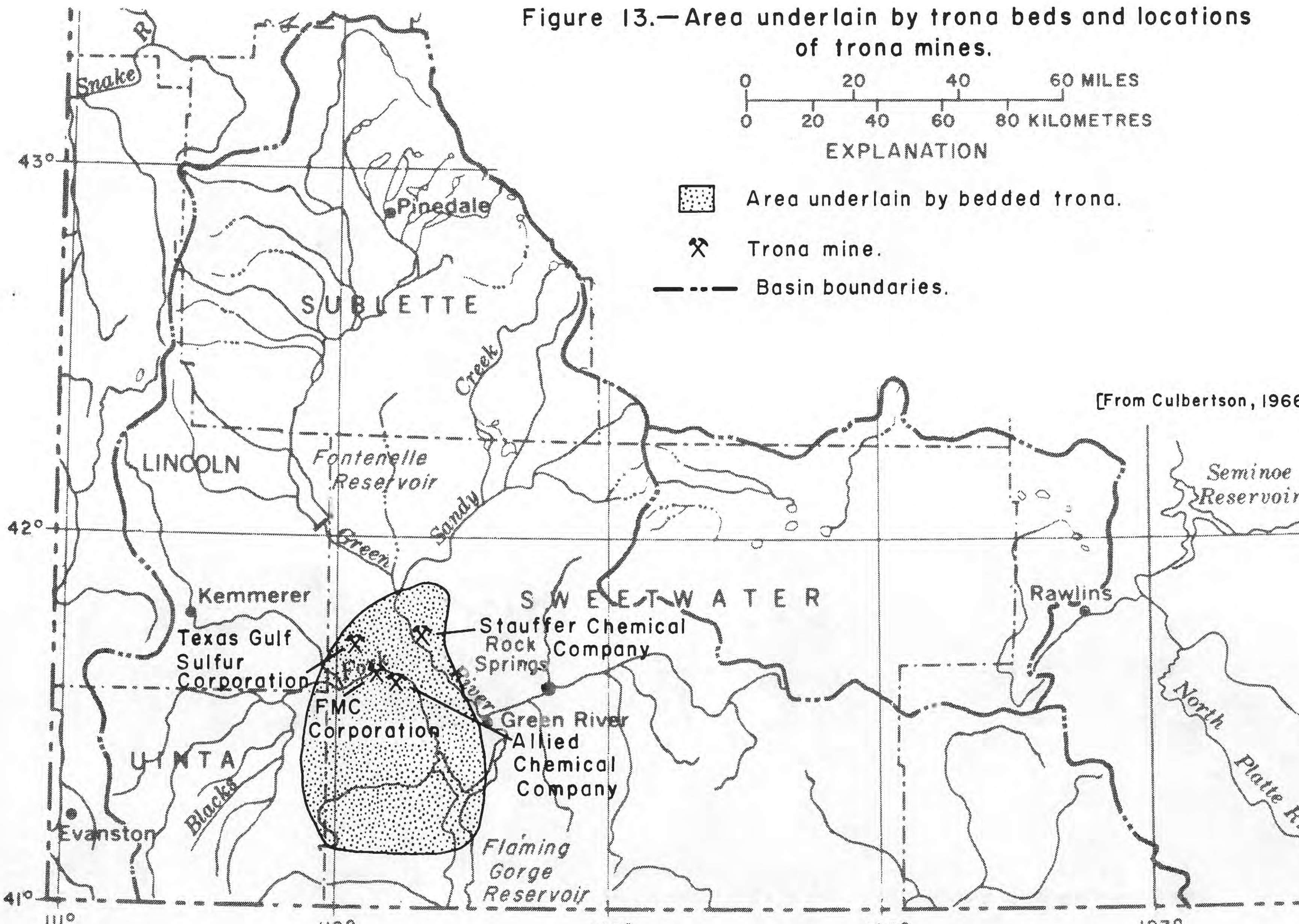


Figure 13.—Area underlain by trona beds and locations of trona mines.

[From Culbertson, 1966]

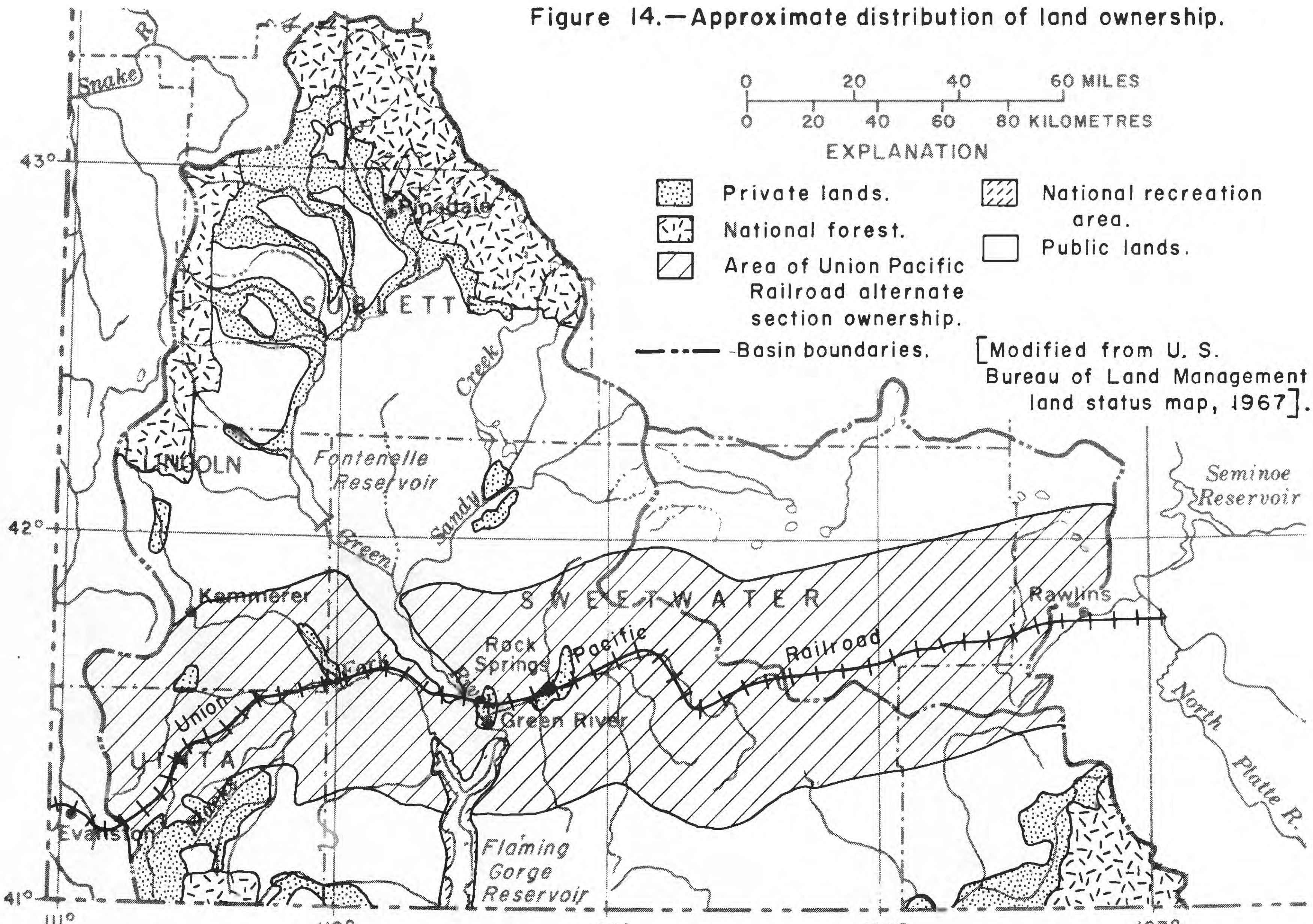


Figure 14.—Approximate distribution of land ownership.

Table 4.--Land ownership in the Green River and Great Divide Basins

	Area (acres)	Percentage of land area
Federal lands		
Forest Service	1,130,000	
Bureau of Land Management	7,861,000	
Fish and Wildlife Service	12,000	
Bureau of Reclamation	45,000	
Subtotal	9,048,000	68
State lands	951,000	7
Private, municipal, and county lands	3,366,000	25
Total land area	13,365,000	100
Water area	88,000	
Total land and water area	13,453,000	

Water Resources

General Description of the Hydrology

The Green River, the major tributary of the Colorado River, drains the Green River Basin. The Great Divide Basin is topographically closed, and no streams flow out of it.

Most of the perennial streams in the Green River Basin originate in the mountainous areas, where the greatest precipitation occurs and where ground-water inflows sustain base flows.

Streams originating at lower elevations in the Green River Basin and those in the Great Divide Basin are ephemeral or intermittent and flow mainly in response to direct runoff from rainstorms and snowmelt.

Streams in the Green River Basin that are important as water-supply sources contribute the major part of their annual runoff during spring and early summer as a result of snowmelt. Late summer, fall, and winter flows are mainly the result of ground-water inflow. A hydrograph of a typical perennial stream in the Green River Basin is shown in figure 15. Figure 16 shows a hydrograph of an intermittent stream in the plains area.

The quality of surface waters in the study area is generally good. Water in the headwaters of streams is normally clear and relatively low in dissolved-solids concentrations. Concentrations increase in lower reaches of the streams as a result of natural sources of dissolved solids and man-made influences. During spring runoff, dissolved-solids concentrations typically fall below 100 mg/l in headwaters near mountain divides, but later in the season may rise above 200 mg/l. Dissolved-solids concentration in the Green River near Green River, Wyoming, normally ranges from about 300 to 600 mg/l. During periods of low flow, dissolved-solids concentrations exceed 2,000 mg/l in water of a few streams that have mean discharges of less than 100 ft^3/s (3 m^3/s).

Ground-water conditions in the study area are the result of climate, topography, geology, and activities of man. Recharge to ground-water reservoirs is mainly by seepage from precipitation and streams. Discharge is mainly by evaporation, seepage to streams and lakes, transpiration, and pumpage from wells. Ground water down to a depth of as much as 300 ft (91 m) below land surface is generally unconfined over most of the study area. The Green River, Wasatch, Fort Union, and older formations generally contain water under artesian pressure due to impermeable layers above and below the aquifer. The depth to water in wells that tap artesian and unconfined aquifers is generally less than 200 ft (60 m), but the drilling depth to artesian aquifers exceeds 1,000 ft (300 m) in the deeper parts of structural basins (Welder, 1968). Ground-water occurrence in the alluvial aquifers along streams is closely related to streamflow.

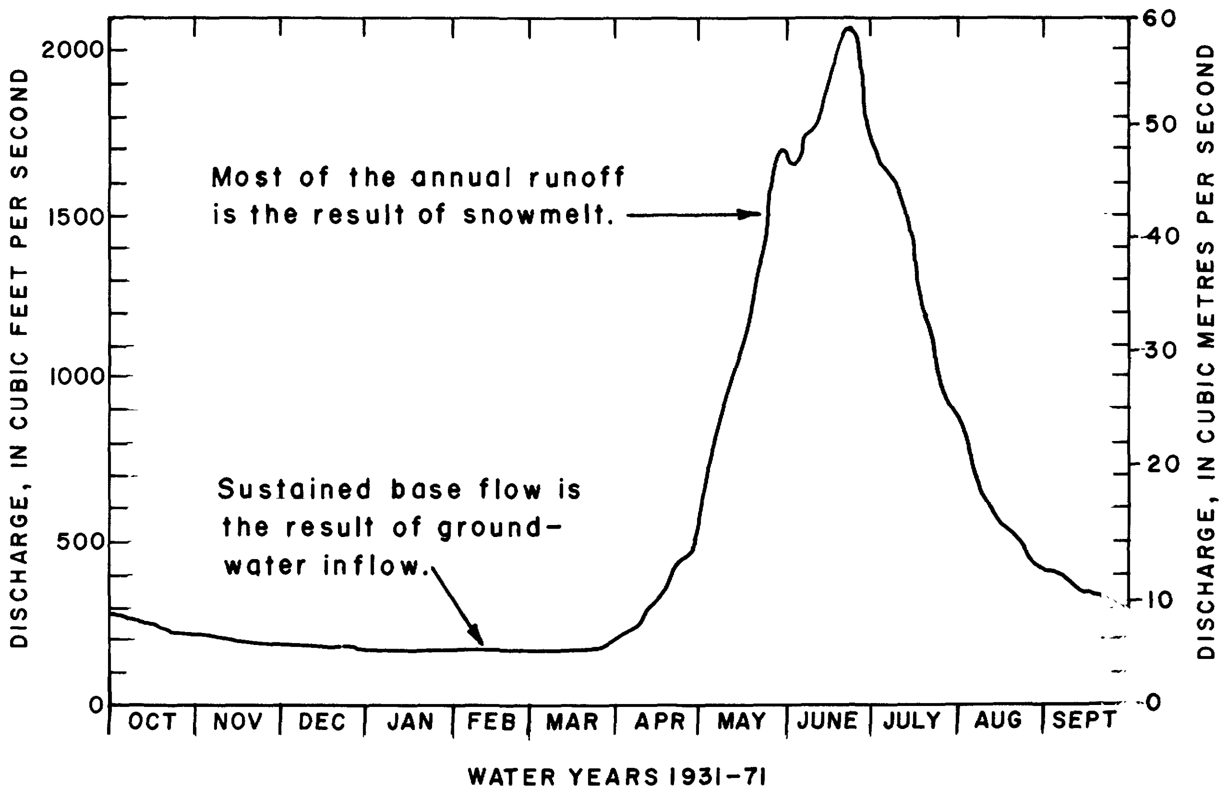


Figure 15.—Mean daily discharge at station 09188500 Green River at Warren Bridge, near Daniel, Wyoming (average of 1931-71 water years).

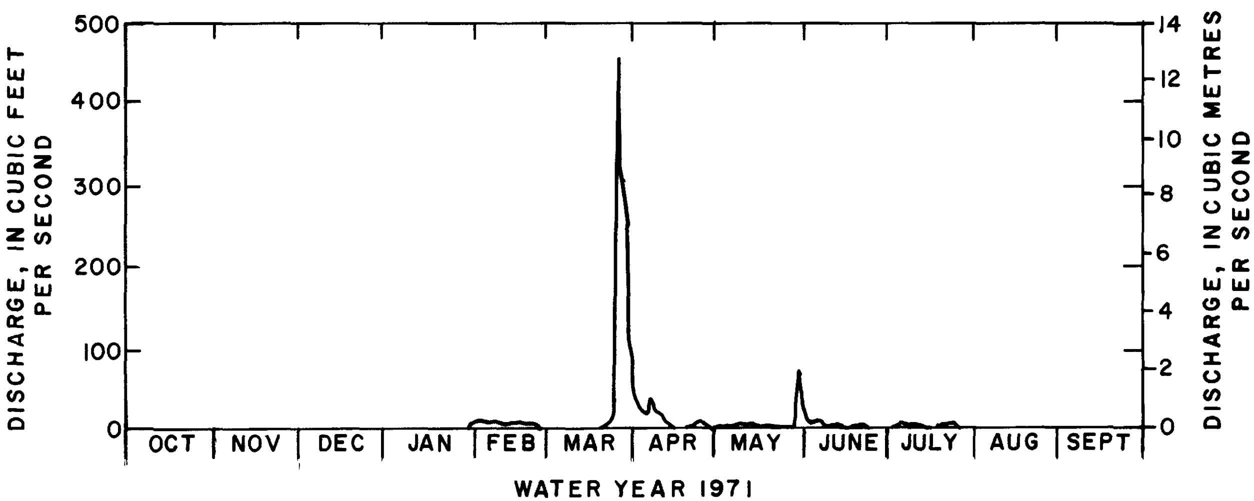


Figure 16.—Daily discharge at station 09215000 Pacific Creek near Farson, Wyoming (1971 water year).

Maximum yields of existing wells in the study area range from about 1 to 500 gal/min ($6x10^{-2}$ to 30 l/s), but yields of most wells range from about 10 to 100 gal/min (0.6 to 6 l/s). Yields greater than 500 gal/min (30 l/s) could probably be obtained from deep wells (2,000 to 5,000 ft or 600 to 1,500 m) penetrating thick sandstone sections in the Wasatch and Fort Union Formations, and from shallow wells tapping some of the well-sorted alluvial and gravel deposits near Pinedale.

Water in the alluvial and gravel deposits and in the more permeable sandstone of the Wasatch Formation near the surface in the northern two-thirds of Sublette County generally contains less than 500 mg/l dissolved solids. Ground water containing from 500 to 3,500 mg/l dissolved solids occurs in at least one aquifer in areas in southern Sublette County and southward. Water containing less than 1,000 mg/l dissolved solids may be found in about one-third of the area in the Great Divide Basin. In general, dissolved-solids concentrations increase with depth throughout the study area.

Summary of Existing Data

Water-resources programs of the U.S. Geological Survey consist of the collection of basic information at its hydrologic-data stations, areal hydrologic and interpretive studies, and research projects. The basic data collected, the results of the areal studies, and the research findings are presented mainly in publications of the U.S. Geological Survey and State agencies, but some appear also in technical journals and other publications.

Much of the data collection in the Green River and Great Divide Basins is a cooperative effort in which the planning and financial support are shared by State and local governments and other Federal agencies. Various programs are conducted in cooperation with the Wyoming State Engineer; Wyoming Department of Economic Planning and Development; Wyoming Department of Agriculture; Wyoming Highway Commission; Wyoming Game and Fish Commission; Wyoming Department of Environmental Quality; U.S. Bureau of Reclamation; U.S. Bureau of Land Management; U.S. Army Corps of Engineers; U.S. Environmental Protection Agency; Federal Insurance Administration; and U.S. Department of Housing and Urban Development.

Hydrologic data collected by the U.S. Geological Survey as part of its basic-data programs include:

a. Streamflow records.
b. Measurements of water levels in wells.
c. Chemical analyses of water from streams and wells.
d. Biologic and bacterial analyses of water from streams.
e. Sediment analyses of water from streams.

In addition, records of reservoir levels and contents of major reservoirs are collected by the U.S. Bureau of Reclamation and published by the U.S. Geological Survey.

Figures 17-22 show sites where hydrologic data have been collected in the study area. Tables 5-10 list pertinent information concerning the data sites.

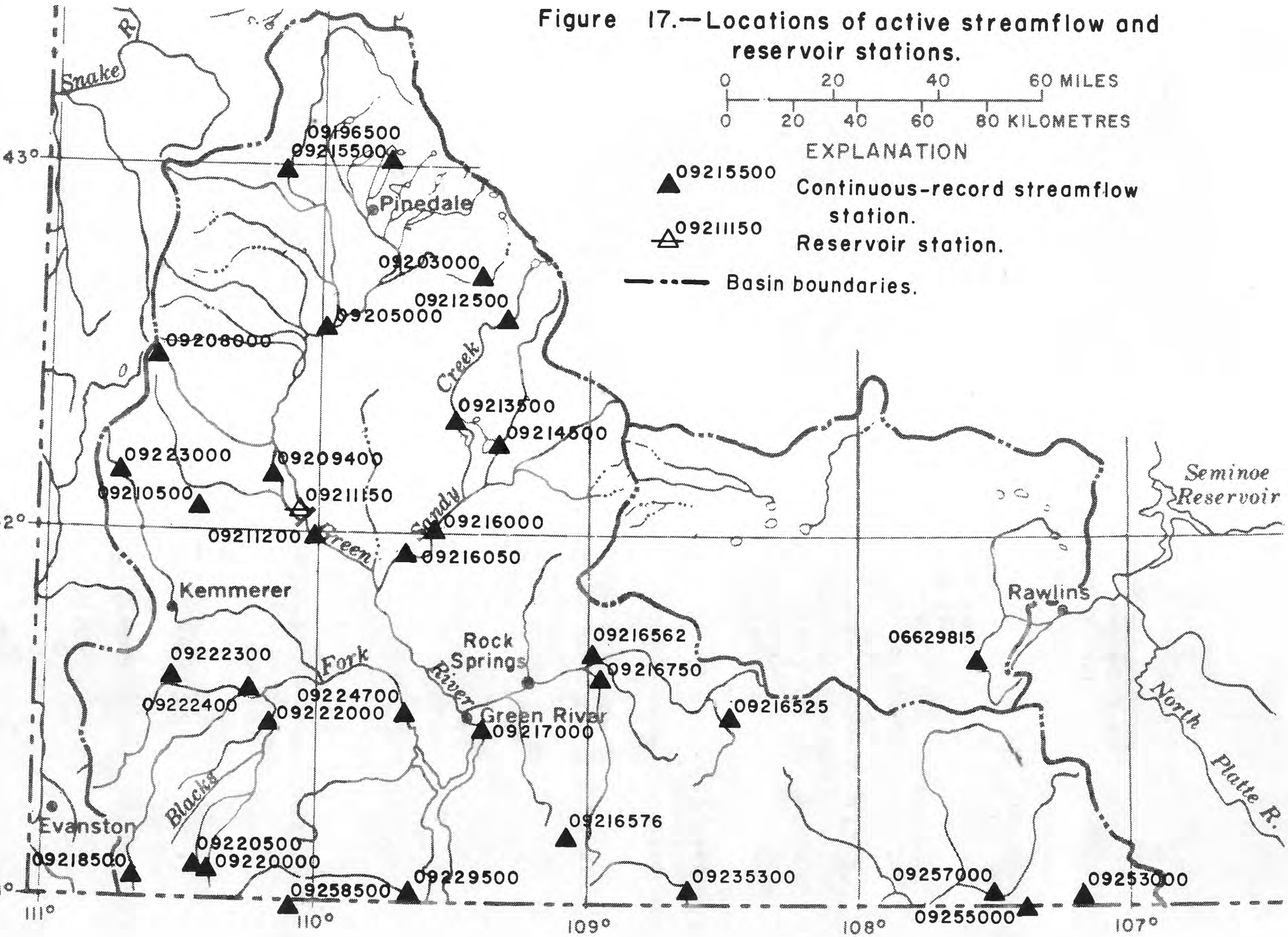


Figure 17.—Locations of active streamflow and reservoir stations.

Table 5.--Active streamflow and reservoir stations

Station no.	Station name	Cooperator a/	Period of record
06629815	Separation Creek near Riner	BLM	1975-
09188500	Green River at Warren Bridge, near Daniel	WSE	1931-
09196500	Pine Creek above Fremont Lake	USGS	1954-
09203000	East Fork River near Big Sandy	WSE	1954-
09205000	New Fork River near Big Piney	WSE	1954-
09208000	La Barge Creek near La Barge Meadows ranger station	USGS	1940-42, 1950-
09209400	Green River near La Barge	WSE	1963-
09210500	Fontenelle Creek near Herschler Ranch, near Fontenelle	USGS	1951-
09211150	Fontenelle Reservoir near Fontenelle		1964-
09211200	Green River below Fontenelle Reservoir	BRUC	1963-
09212500	Big Sandy River at Leckie Ranch, near Big Sandy	WSE	1910, 1911, 1939-
09213500	Big Sandy River near Farson	WSE	1914-17, 1920-24, 1926-34, 1953-
09214500	Little Sandy Creek above Eden	BLM	1954-
09216000	Big Sandy River below Eden	BRUC	1954-
09216050	Big Sandy River at Gasson Bridge, near Eden	BRUC	1972-
09216525	Bitter Creek near Bitter Creek	BLM	1975-
09216562	Bitter Creek above Salt Wells Creek, near Salt Wells	BLM	1975-
09216576	Gap Creek below Beans Spring Creek, near South Baxter	BLM	1975-
09216750	Salt Wells Creek near Salt Wells	BLM	1975-
09217000	Green River near Green River	USGS	1951-
09218500	Blacks Fork near Millburne	WSE	1939-
09220000	E F of Smith Fork near Robertson	WSE	1939-
09220500	W F of Smith Fork near Robertson	WSE	1939-
09222000	Blacks Fork near Lyman	BRUC	1937-57, 1962-
09222300	Little Muddy Creek near Glencoe	BLM	1975-
09222400	Muddy Creek near Hampton	BLM	1975-
09223000	Hams Fork below Pole Creek, nr Frontier	USGS	1952-
09224700	Blacks Fork near Little America	USGS	1962-
09228500	Burnt Fork near Burntfork	WSE	1943-
09229500	Henrys Fork near Manila, Utah	USGS	1928-
09235300	Vermillion Creek near Hiawatha, Colo.	BLM	1975-
09253000	Little Snake River near Slater, Colo.		1942-47, 1950-
09255000	Slater Fork near Slater, Colo.		1931-
09257000	Little Snake River near Dixon	WSE	1910-23, 1938-

a/ Cooperators:
- BLM Bureau of Land Management.
- BRUC Bureau of Reclamation, Upper Colorado Region, Salt Lake City, Utah.
- USGS U.S. Geological Survey.
- WSE Wyoming State Engineer.

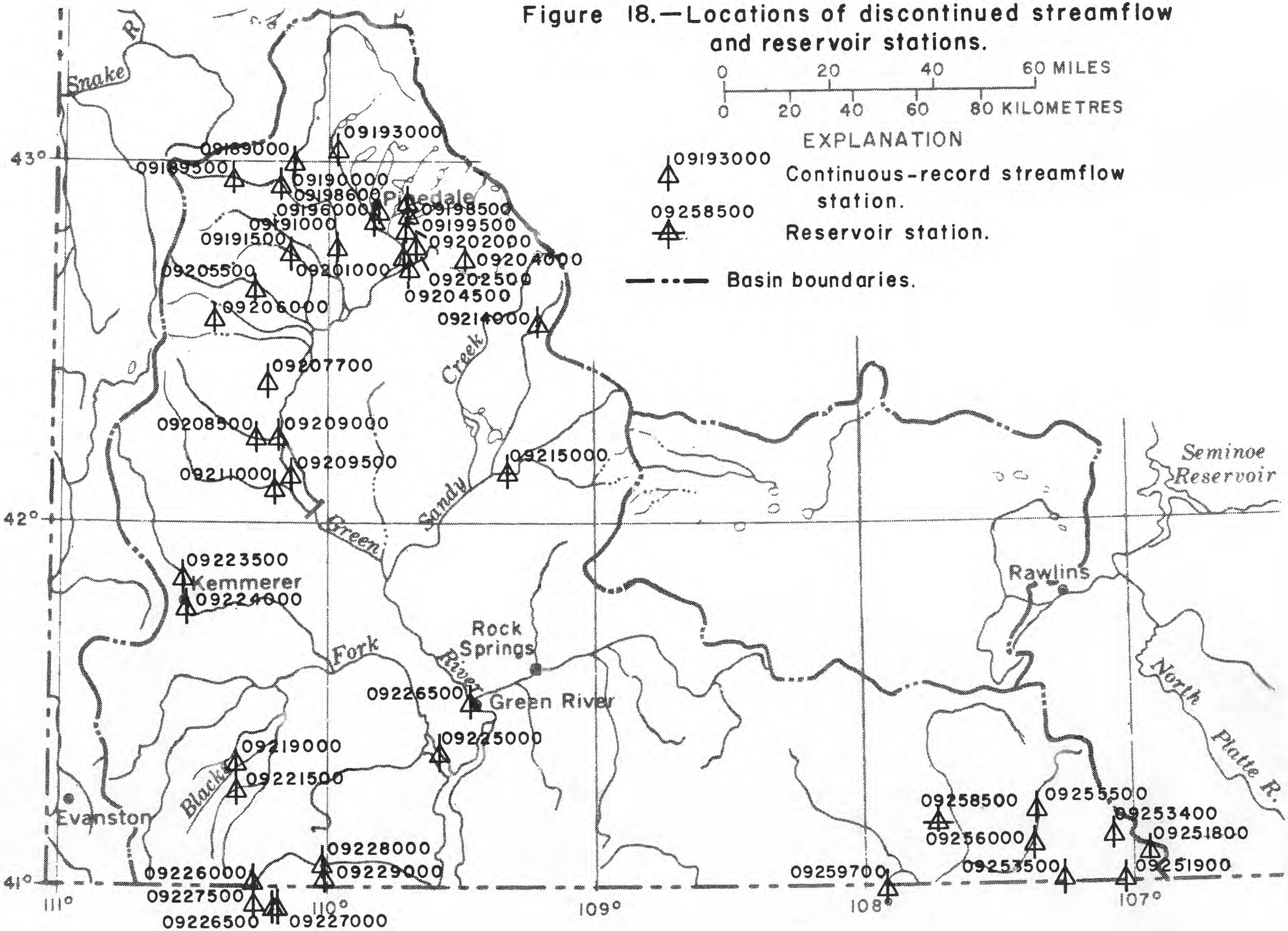


Figure 18.—Locations of discontinued streamflow and reservoir stations.

Table 6.--Discontinued streamflow and reservoir stations

(Stations with at least 5 years of record.)

Station	Station name	Period of record
09189000	Beaver Creek near Daniel	1938-54
09189500	Horse Creek at Sherman ranger station	1954-73
09190000	Horse Creek near Daniel	1931-54
09191000	Green River near Daniel	1912-32
09191500	Cottonwood Creek near Daniel	1938-54
09193000	New Fork River below New Fork Lake, near Cora	1938-72
09196000	New Fork River near Pinedale	1938-44
09198000	Pine Creek at Pinedale	1903-04, 1914-54
09198500	Pole Creek below Little Half Moon Lake, near Pinedale	1938-71
09199500	Fall Creek near Pinedale	1938-71
09201000	New Fork River near Boulder	1914-69
09202000	Boulder Creek below Boulder Lake, near Boulder	1938-73
09202500	Boulder Creek near Boulder	1903-06, 1914-24, 1930-32
09204000	Silver Creek near Big Sandy	1938-71
09204500	East Fork at New Fork	1904-06, 1914-24, 1930-32
09205500	North Piney Creek near Mason	1915-16, 1931-72
09206000	Middle Piney Creek below South Fork, near Big Piney	1939-54
09207700	Dry Piney Creek near Big Piney	1965-73
09208500	La Barge Creek near Viola	1913-16, 1940-49
09209000	La Barge Creek near La Barge	1931-39
09209500	Green River near Fontenelle	1946-65
09211000	Fontenelle Creek near Fontenelle	1931-53
09214000	Little Sandy Creek near Elkhorn	1939-71
09215000	Pacific Creek near Farson	1954-73
09216500	Green River at Green River	1891, 1894-1906, 1914-45
09219000	Blacks Fork near Urie	1913-24, 1937-55
09221500	Smith Fork at Mountain View	1941-57
09223500	Hams Fork near Frontier	1945-72
09224000	Hams Fork at Diamondville	1917-33, 1945-49
09225000	Blacks Fork near Green River	1947-62
09226000	Henrys Fork near Lonetree	1942-72
09226500	Middle Fork Beaver Creek near Lonetree	1948-70
09227000	East Fork Beaver Creek near Lonetree	1948-62
09227500	West Fork Beaver Creek near Lonetree	1948-62
09228000	Henrys Fork near Burntfork	1942-54
09229000	Burnt Fork at Burntfork	1929-43

Table 6.--Discontinued streamflow and reservoir stations--continued

Station	Station name	Period of record
09251800	North Fork Little Snake River near Encampment	1956-65
09251900	North Fork Little Snake River near Slater, Colo.	1956-63
09253400	Battle Creek near Encampment	1956-63
09253500	Battle Creek near Slater, Colo.	1942-51
09255500	Savery Creek at upper station, near Savery	1940-44, 1952-71
09256000	Savery Creek near Savery	1941-46, 1947-72
09258500	Little Robber Reservoir	1954-62
09259700	Little Snake River near Baggs	1961-68

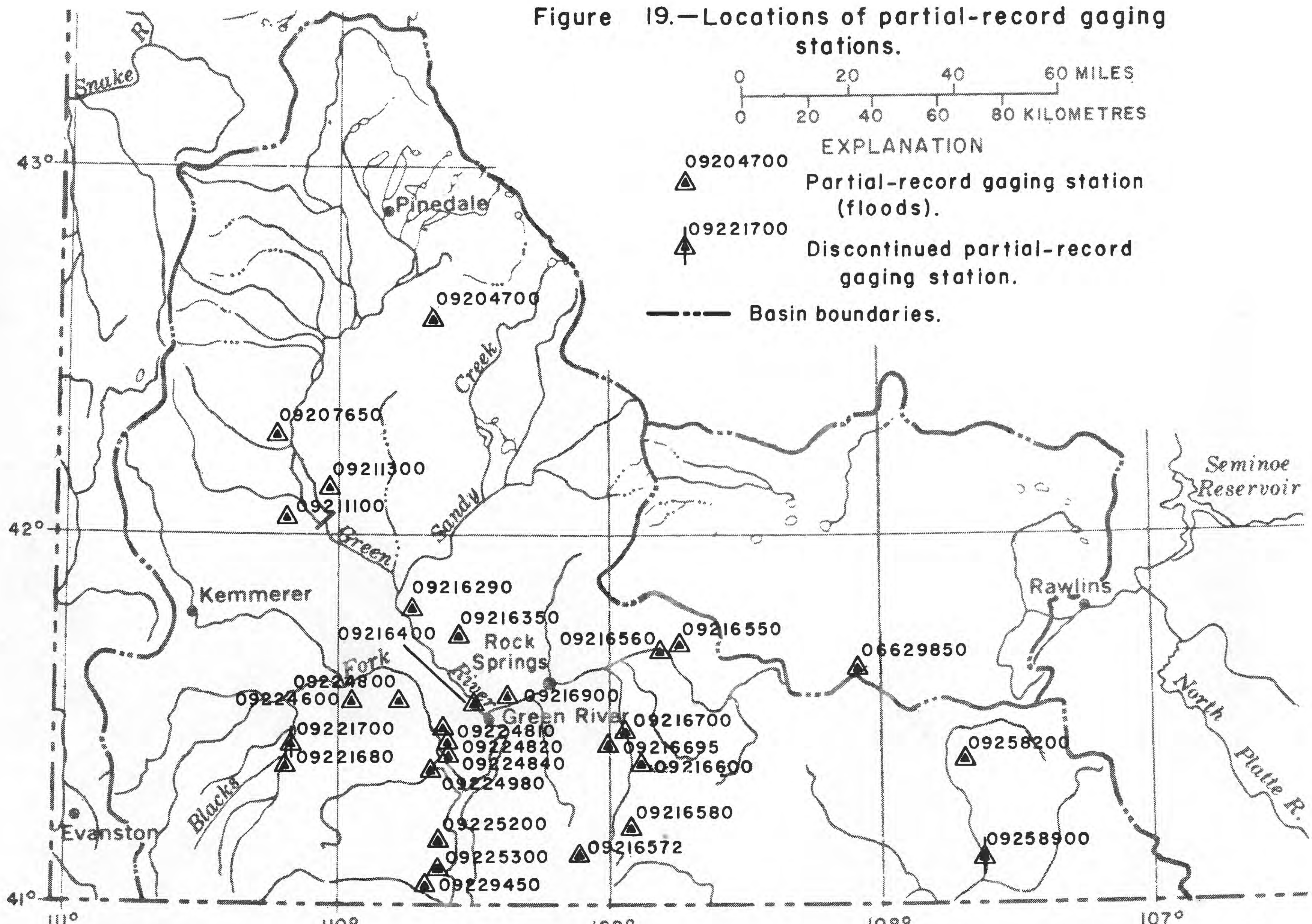


Figure 19.—Locations of partial-record gaging stations.

Table 7.--Partial-record gaging stations

Station no.	Station name	Period of record
	Great Divide Basin	
06629850	Delaney Draw near Red Desert	1961-
	Green River Basin	
09204700	Sand Springs Draw tributary near Boulder	1961-
09207650	Dry Basin Creek near Big Piney	1971-
09211100	Green River tributary near Fontenelle	1961-74
09211300	Fourmile Gulch tributary near Fontenelle	1971-
09216290	E Otterson Wash near Green River	1970-
09216350	Skunk Canyon Creek near Green River	1965, 1971-
09216400	Greasewood Canyon near Green River	1959-
09216550	Deadman Wash near Point of Rocks	1961-
09216560	Bitter Creek near Point of Rocks	1961-
09216572	Bean Spring Creek near South Baxter	1975-
09216580	Big Flat Draw near Rock Springs	1972-
09216600	Salt Wells Creek tributary near Rock Springs	1959-70, 1970-72, 1972-
09216695	No Name Creek near Rock Springs	1972-
09216700	Salt Wells Creek near Rock Springs	1959-
09216900	Bitter Creek tributary near Green River	1959-
09221680	Mud Spring Hollow near Church Butte, near Lyman	1965-73, 1973-
09221700	Mud Spring Hollow near Lyman	1959-71
09224600	Blacks Fork tributary near Granger	1959-
09224800	Meadow Springs Wash tributary near Green River	1962-65, 1968-
09224810	Blacks Fork tributary No. 2 near Green River	1965-
09224820	Blacks Fork tributary No. 3 near Green River	1965-
09224840	Blacks Fork tributary No. 4 near Green River	1965-
09224980	Summers Dry Creek near Green River	1965-
09225200	Squaw Hollow near Burntfork	1965-
09225300	Green River tributary No. 2 near Burntfork	1959, 1961-
09229450	Henrys Fork tributary near Manila, Utah	1965-74
09258200	Dry Cow Creek near Baggs	1970-
09258900	Muddy Creek above Baggs	1958-71

Cooperator for partial-record stations: Wyoming Highway Department.

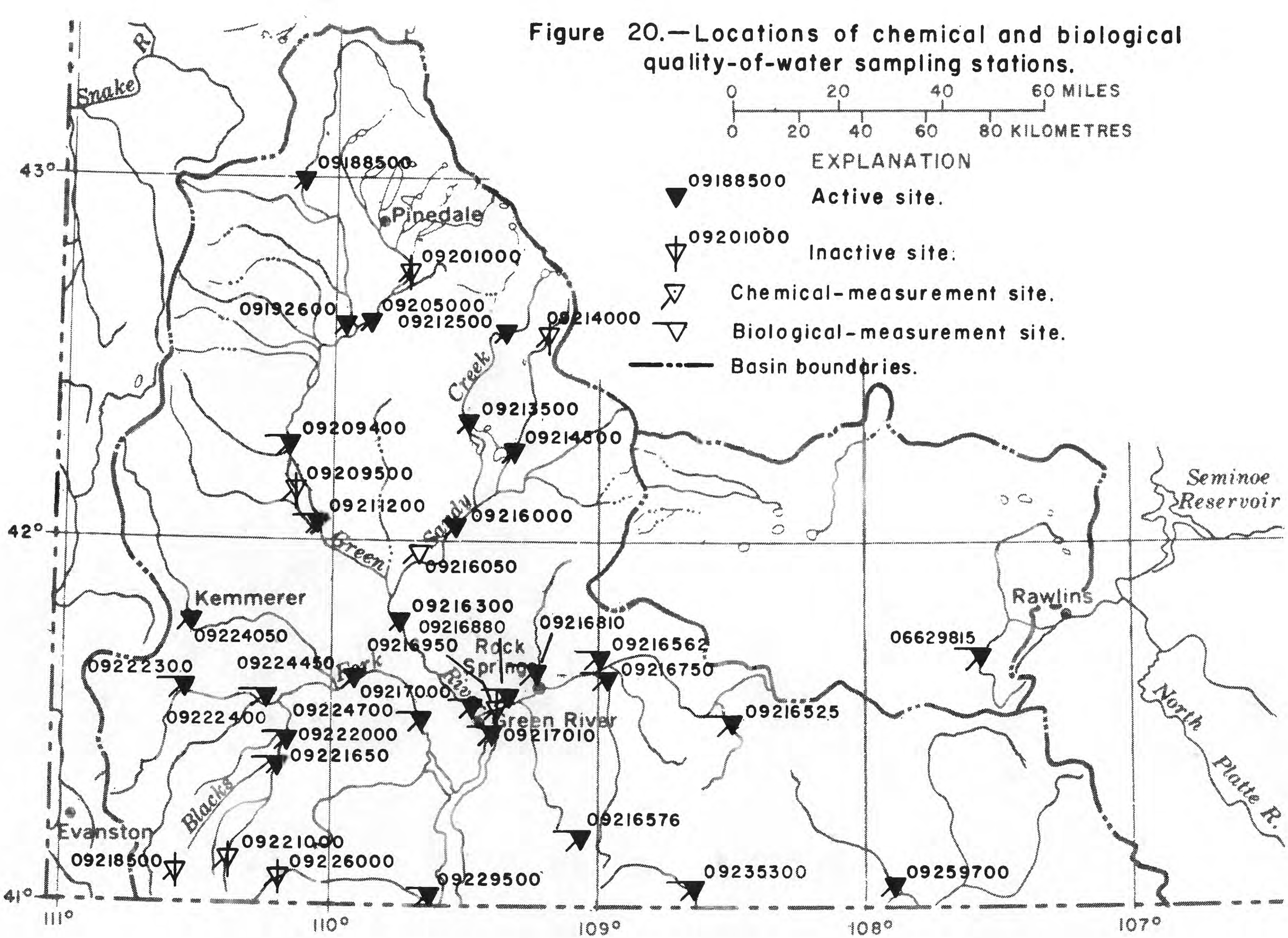


Figure 20.—Locations of chemical and biological quality-of-water sampling stations.

Table 8.--Chemical and biological quality-of-water sampling stations.

Station	Name	Cooperators [a/]	Parameters [b/]	Period of record
06629815	Separation Creek near Riner	BLM	1,4,5	1975-
09188500	Green River at Warren Bridge, nr Daniel	WDEQ	1,5,6	1962-64, 1967-73, 1974-
09192600	Green River nr Big Piney	WDA	1	1967-
09201000	New Fork River nr Boulder	--------	1	1967-71
09205000	New Fork River nr Big Piney	WDA	1	1965-
09209400	Green River nr La Barge	WDA,WDEQ	1,2,3,5,6	1963-
09209500	Green River nr Fontenelle	--------	1	1962-63
09211200	Green River bl Fontenelle Reservoir	WDA,	1,2,3,5,6	1967-
09212500	Big Sandy River at Leckie Ranch	--------	1	1961-62, 1975-
09213500	Big Sandy River nr Farson	--------	1	1962-64, 1975-
09214000	Little Sandy Creek nr Elkhorn	--------	1	1961-62, 1975-
09214500	Little Sandy Creek nr Eden	--------	1	1962-64
09216000	Big Sandy River bl Eden	WDA	1	1961-64, 1967-
09216050	Big Sandy River at Gasson Bridge, near Eden	USGS	1,5	1975-
09216300	Green River at Big Island, nr Green River	WDA,WDEQ	1,5,6	1966-
09216525	Bitter Creek nr Bitter Creek	BLM	1,4,5	1975-
09216562	Bitter Creek ab Salt Wells Creek, nr Salt Wells	BLM	1,4,5	1975-
09216576	Gap Creek bl Beans Spring Cr, nr South Baxter	BLM	1,4,5	1975-
09216750	Salt Wells Creek near Salt Wells	BLM	1,4,5	1975-
09216810	Killpecker Creek at Rock Springs	EPA	1,4,5	1975-
09216880	Bitter Creek bel Little Bitter Creek, nr Kanda	EPA	1,4,5	1975-
09216950	Bitter Creek nr Green River	--------	1,5	1966-72
09217000	Green River nr Green River	USGS,WDEQ	1,2,3,5,6	1951-
09217010	Green River bl Green River	WDEQ	1,5,6	1974-
09218500	Blacks Fork nr Millburne	--------	1,5	1969-70
09221000	Smith Fork nr Robertson	--------	1,5	1969-70
09221650	Smiths Fork nr Lyman	WDEQ	1,5,6	1974-
09222000	Blacks Fork nr Lyman	BRUC,WDEQ	1,2,3,5,6	1962-
09222300	Little Muddy Creek nr Glencoe	BLM	1,4,5	1975-
09222400	Muddy Creek nr Hampton	BLM	1,4,5	1975-
09224050	Hams Fork nr Diamondville	EPA	1,2,3,5,6	1975-
09224450	Hams Fork nr Granger	WDA	1	1965-
09224700	Blacks Fork nr Little America	USGS,WDEQ	1,2,3,5,6	1961-
09226000	Henrys Fork nr Lonetree	--------	1,5	1969-72

Table 8.--Chemical and biological quality-of-water sampling stations--continued

Station	Name	Cooperators a/	Parameters b/	Period of record
09228500	Burnt Fork nr Burnt Fork	--------	1,5	1969-70
09229500	Henrys Fork nr Manila, Utah	USGS	1,2,3	1951-
09235300	Vermillion Creek nr Hiawatha,	BLM	1,4,5	1975-
09259700	Little Snake River nr Baggs	WDA	1	1965-

a/ Cooperators:
- BLM U.S. Bureau of Land Management.
- WDEQ Wyoming Department of Environmental Quality.
- WDA Wyoming Department of Agriculture.
- USGS U.S. Geological Survey.
- BRUC U.S. Bureau of Reclamation - Upper Colorado Region.

b/ Parameters:
1. Salinity (major constituents).
2. Daily specific conductance.
3. Daily temperature (observed).
4. Bacteria or chemical oxygen demand.
5. Field determinations of: pH, specific conductance, dissolved oxygen, temperature, and (or) turbidity.
6. Fecal coliform and (or) fecal streptococcus and total coliform.

NOTE: As part of the Green River Basin project, specific conductance and turbidity will be measured monthly at all active continuous- and partial-record gaging stations.

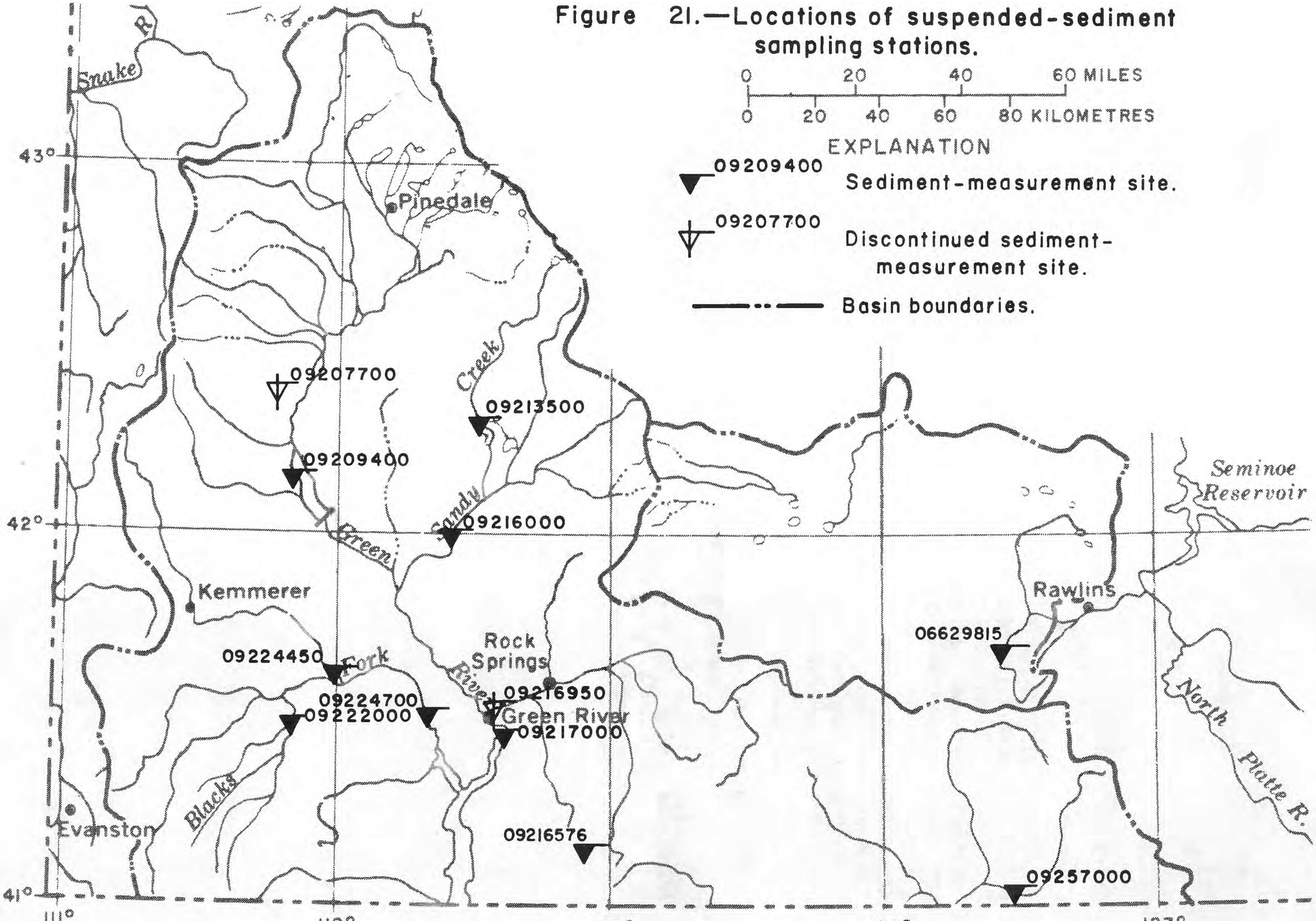


Figure 21.—Locations of suspended-sediment sampling stations.

Table 9.--Suspended-sediment sampling stations

Station no.	Station name	Cooperator [a]	Period of record
09207700	Dry Piney Creek near Big Piney		1966-71
09209400	Green River near La Barge	WSE	1974-
09213500	Big Sandy River near Farson	WSE	1971-
09216000	Big Sandy River below Eden	WSE	1971-
09216950	Bitter Creek near Green River		1966-72
09217000	Green River near Green River	USGS	1951-
09222000	Blacks Fork near Lyman	WSE	1971-
09224450	Hams Fork near Granger	WSE	1971-
09224700	Blacks Fork near Little America	WSE	1967-
09257000	Little Snake River near Dixon	WSE	1971-

[a] Cooperators: USGS U.S. Geological Survey.
WSE Wyoming State Engineer.

NOTE: As part of the Green River Basin project, suspended sediment and turbidity will be measured monthly at all active continuous- and partial-record gaging stations.

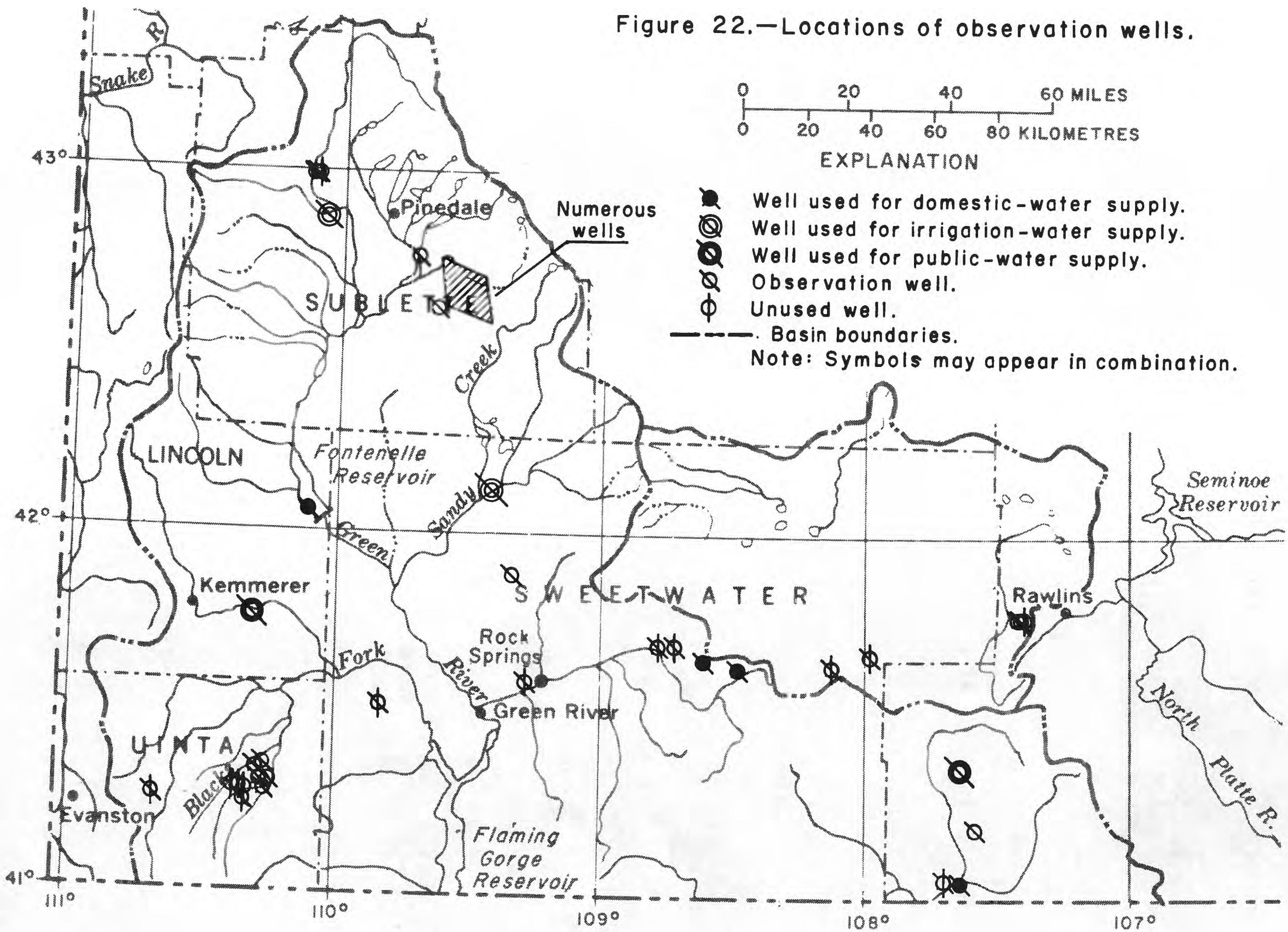


Figure 22.—Locations of observation wells.

Table 10.--Observation wells

Well no. and location	Well depth (ft)	Use of water a/	Geologic source b/	Cooper-ators c/	Records available
			CARBON COUNTY		
12- 91- 5dcb	50	H	111 ALVL		1965-69
12- 92- 1abb	136	U	111 ALVL		1963-64
14- 92-12ac	110	S	124 WSTC		1963-65
16- 92-17dbb	330	P	125 FRUN		1963-65
21- 89-22ada	156	U	125 FRUN	WSE	1963, 1965-
22bc	340	S	125 FRUN		1963-64
			LINCOLN COUNTY		
21-114-26bdb	180	P	124 LNEY	WSE	1965-
24-112- 8ccb	150	H,P	124 LNEY	WSE	1966-70, 1972-
			SUBLETTE COUNTY		
28-112-19ac	153	U	124 WSTC	WSE	1965-70, 1972-
30-106- 2ccc	67	U	111 ALVL		1966-67
3bbc	8	U	111 ALVL		1966-67
4ddd	50	U	111 ALVL		1965-68
10bcc	50	U	111 ALVL		1966-67
10ccc	27	U	111 ALVL		1965-68
12ad	102	S	124 WSTC		1966-67
13acc	62	U	111 ALVL		1966-67
22bd	101	S	124 WSTC		1966-67
30-107- 6dd	153	S	124 WSTC	WSE	1964-66, 1968-
30-108- 5bcd1	5,200	U	125 FRUN	USGS	1973-
5bcd2	2,300	U	124 WSTC	USGS	1973-
30-111-17aca	435	P	124 WSTC	WSE	1965-
31-106- 5cad	59	U	111 ALVL		1965-68
6aad	30	U	111 ALVL		1965-68
6cbb	47	U	111 ALVL		1966-68
8cdc	37	U	111 ALVL		1966-67
17cbc	72	U	111 ALVL		1966-67
17dad	25	U	111 ALVL		1965-68
19bab	42	U	111 ALVL		1966-67
20cbc	57	U	111 ALVL		1965-68
20ddc	61	U	111 ALVL		1965-68
28cdd	50	U	111 ALVL		1966-67
32aba	50	P	124 WSTC		1965-68
33bca	8	U	111 ALVL		1965-68
33daa	33	U	111 ALVL		1965-68

Table 10.--Observation wells--continued

Well no. and location	Well depth (ft)	Use of water a/	Geologic source b/	Cooper-ators c/	Records available
			SUBLETTE COUNTY--continued		
31-107- 1aaa	37	U	111 ALVL		1965-68
1bbb	60	U	111 ALVL		1965-68
1dcc	65	U	111 ALVL		1966-67
2dab	62	U	111 ALVL		1965-68
11acb	33	U	111 ALVL		1965-68
13baa	62	U	111 ALVL		1966-67
23dc	133	U	124 WSTC		1966-67
24bda	32	U	111 ALVL		1966-67
32-106-31aac	25	U	111 ALVL		1966-67
32dca	75	S	124 WSTC		1966-67
32-107-15dca	29	U	111 ALVL		1965-68
22dcc	57	U	111 ALVL		1966-67
23cda	30	U	111 ALVL		1966-67
25aad	85	U	124 WSTC		1966-68
25add	26	U	111 ALVL		1965-67
25ccc	27	U	111 ALVL		1965-68
26add	32	U	124 WSTC		1965-68
35ccb	37	U	111 ALVL		1966-67
32-108- 5ba	77	U	--------	WSE	1965-
34-111-35cb	117	P	124 WSTC		1966-69
35-111- 8adb	39	U	111 ALVL	USGS	1965-
8db	32	U	111 ALVL		1942-65
			SWEETWATER COUNTY		
18-110-21dba	40	U	111 ALVL	WSE	1964-
19- 95- 5dd	1,100	U	124 WSTC	WSE	1972-
19- 98- 8ca	697	H	124 WSTC		1964-70
19- 99- 6dcc	161	S	125 FRUN	WSE	1963-
19-105-32dab	152	U	124 WSTC		1965-69
20- 94-34bbd	1,046	U	124 WSTC		1964-71
20-100-30cc	166	U	211 ALMD	WSE	1963-
20-101-27cbc2	523	U	211 ERCS		1966-70
22-105- 7aad	99	S	124 LNEY	WSE	1964-
25-106-27ccd	60	I	124 LNEY	WSE	1965-

Table 10.--Observation wells--continued

Well no. and location	Well depth (ft)	Use of water a/	Geologic source b/	Cooper- ators c/	Records available
			UINTA COUNTY		
15-114- 3cbc	45	U	124 BRDG		1957-69
4daa2	25	U	111 TRRC		1957-62
10ccc	17	S	111 TRRC		1957-64
15-115-20cba	17	U	111 TRRC	WSE	1957-
21cbd2	103	S	111 TRRC		1957-64
23bdd	5	U	111 ALVL		1957-64
24bad	6	U	111 ALVL		1957-69
15-118-24bc	80	U	124 WSTC	WSE	1964-
16-114-27ddd2	13	S	111 TRRC		1957-69
32bcb	12	U	111 TRRC		1957-62, 1964

a/ Use of water: H, domestic; I, irrigation; P, public supply; S, stock; U, unused.

b/ Geologic source:

111 ALVL	alluvial deposits
111 TRRC	terrace deposits
124 BRDG	Bridger Formation
124 LNEY	Laney Shale Member of Green River Formation
124 WSTC	Wasatch Formation
125 FRUN	Fort Union Formation
211 ALMD	Almond Formation
211 ERCS	Ericson Sandstone or Formation

c/ Cooperators:

USGS	U. S. Geological Survey.
WSE	Wyoming State Engineer.

Summary of Previous Studies

Surface waters of the study area have been described previously in U.S. Bureau of Reclamation reports, Upper Colorado Region Framework reports, Wyoming State Planning reports, and U.S. Geological Survey publications. The more comprehensive reports are discussed below.

A comprehensive study of surface-water resources of the Upper Colorado River Basin, which included the Green River Basin in Wyoming, was made by Iorns, Hembree, and Oakland (1965). Their report discusses water quantity and quality and determines the effects of water use on streamflow.

The Wyoming Water Planning Program (1970) prepared a report on water and related land resources in the Green River and Great Divide Basins. The report presents an inventory of present water uses and future water needs. Several plans are presented in which alternative water-development facilities are proposed.

The U.S. Bureau of Reclamation (1972) prepared a special report on plans for development of water in the Green River Basin. A number of alternative plans are presented that could supply water needs for the next 50 years.

The Upper Colorado Region Comprehensive Framework Study (1970) and continuing studies on water quality by the U.S. Department of Interior (1975) include the Green River Basin in their discussions of water problems in the Colorado River Basin.

The ground-water supply has been described previously in Wyoming State Planning reports, and U.S. Geological Survey water-supply papers, hydrologic atlases, and a professional paper. These reports discuss ground water at a reconnaissance or descriptive level. Very little data have been gathered or analyzed about water supplies of deep aquifers.

Welder and McGreevy (1966), Welder (1968), and Lines and Glass (1973) describe results of water-resources investigations of large areas in Wyoming that include the study area. Their investigations were made with the purpose of locating potential water supplies for possible future development.

Data concerning ground-water and surface-water conditions in the East Fork River area were reported by O'Connell (1969), but no interpretation was made of the data.

A number of researchers have gathered and interpreted data from the Green River Basin to describe various hydrologic relations. Many of these studies are concerned with fluvial processes in geomorphology, as discussed by Leopold, Wolman, and Miller (1964).

An evaluation of the general quality of game and fish resources and effects of water development on these resources was made by Binns (1972) for the Upper Green and New Fork Rivers.

Water Demands and Uses

Reports by the Wyoming Water Planning Program (1970) and by the U.S. Bureau of Reclamation (1972) provided the background information for the following discussion of water demands and uses.

Existing demands and uses.--Most of the water presently used in the study area is for irrigation. About 303,200 acres (122,700 hm^2) of land are presently being irrigated, and consumptive use of irrigation water is estimated to be 241,600 acre-ft (297.9 hm^3) per year. Irrigation water is obtained mainly from direct diversion of streamflows. Streamflow is largely the result of runoff from snowmelt, and flows generally diminish by the end of July. Most parts of the study area have inadequate reservoir storage to provide for late-season irrigation demands. Evaporation from reservoirs and stockponds amounts to about 26,000 acre-ft (32 hm^3) per year.

Industries, including two coal-fueled power plants and four trona processing plants, consume an estimated 30,000 acre-ft (37 hm^3) of water per year. Municipal water systems, serving about 40,000 persons in 17 communities, consume about 4,000 acre-ft (4.9 hm^3) per year. Domestic requirements consume about 2,000 acre-ft (2.5 hm^3) per year, and stockwater depletions amount to about 5,000 acre-ft (6.2 hm^3) per year.

Surface waters provide most of the above supplies; however, ground water is widely used for domestic and livestock purposes, and locally for municipal and industrial purposes.

Recreational activities, including fishing, hunting, boating, and camping are important nonconsumptive uses of water resources in the area. About 2,520 mi (4,050 km) of streams and 70,000 surface acres (28,000 hm^2) of lakes and impoundments provide cold-water fishery habitat in the basin. The area also supports some of the most varied and unique wildlife habitat in the United States. Excellent environments exist for several big game species, including antelope, mule deer, elk, and moose.

Future needs.--A review of proposed developments for the study area indicates that water needs will significantly increase. Table 11 lists present and projected water requirements for the various developments.

Table 11.--Summary of present and projected consumptive water uses in the Green River and Great Divide Basins

[From Wyoming Water Planning Program, 1970, p. 110]

	(1,000 acre-ft per year)			
	1975	1980	2000	2020
Agricultural	268	339	408	415
Industrial	30	55	86	231
Municipal, domestic, and stock	6	6	7	9
Recreation, fish, and wildlife 1/	---	20	20	20
Transbasin diversion for city of Cheyenne	7	15	31	31
Colorado River storage project evaporation	---	92	92	92
Total	311	526	644	798
Potential additional consumption from irrigation in the Green River Basin 2/				0 to 164
Potential transbasin diversion 2/				39 to 272

1/ Recreational water use presently consumes less than 1,000 acre-ft (1.233 hm^3) per year. Future recreational water use was not estimated for this report. The 20,000 acre-ft (24.66 hm^3) per year given is the depletion on the Seedskadee Wildlife Refuge. Some reservoir evaporation could be assigned to recreation.

2/ The amount of these potential uses will depend upon the demands for water that develop in the future, the amount of water finally determined to be available under the Colorado River Compacts, and the amount of water imported from other sources.

Water Supplies for Future Demands

As economic development proceeds, large supplies of water will be needed at widely separated parts of the basins for recovery and utilization of the resources, for municipal supplies, and for recreation. Although surface-water resources are adequate for projected demands, the distribution of demands does not coincide with the distribution of supplies. Economic and environmental considerations may make ground-water supplies more attractive than surface-water supplies. Thus, water supplies may be developed from ground-water sources and from small watersheds near the coal and oil-shale deposits. Some supplies will likely be transferred from one part of the area to other areas within the basins and, possibly, to other water-short areas in the State.

Several methods of developing surface-water supplies in the study area have been proposed by the U.S. Bureau of Reclamation (1972, p. IV-1 to IV-29) and the Wyoming Water Planning Program (1970, p. 115-154). Figure 23 shows locations of these potential water-supply developments. Several reservoir sites exist that could provide water for the study area, as well as for transbasin diversion to the Platte and Powder River basins.

Very important to the development of surface waters in the Green River Basin are the compact agreements for the Colorado River system. The Colorado River Compact of 1922 and the Upper Colorado River Basin Compact of 1948 apportion the use of waters from the Colorado River system among the seven states involved. Due to differences of interpretation of certain Compact provisions, the amounts of water allocated to individual states are not clear. Depending on the interpretation of the Compact, allocation of water for Wyoming may be as little as 875,000 acre-ft (1,080 hm^3) per year, or as much as 1,043,000 acre-ft (1,286 hm^3) per year.

The development of ground waters has not been investigated as thoroughly as surface waters. There is concern that extensive ground-water development would decrease streamflows, and thereby affect surface-water rights from streams. Deep ground water might be developed in the sedimentary rocks in the northern part of the study area; however, additional data and study are needed to determine water resources of the deep aquifers.

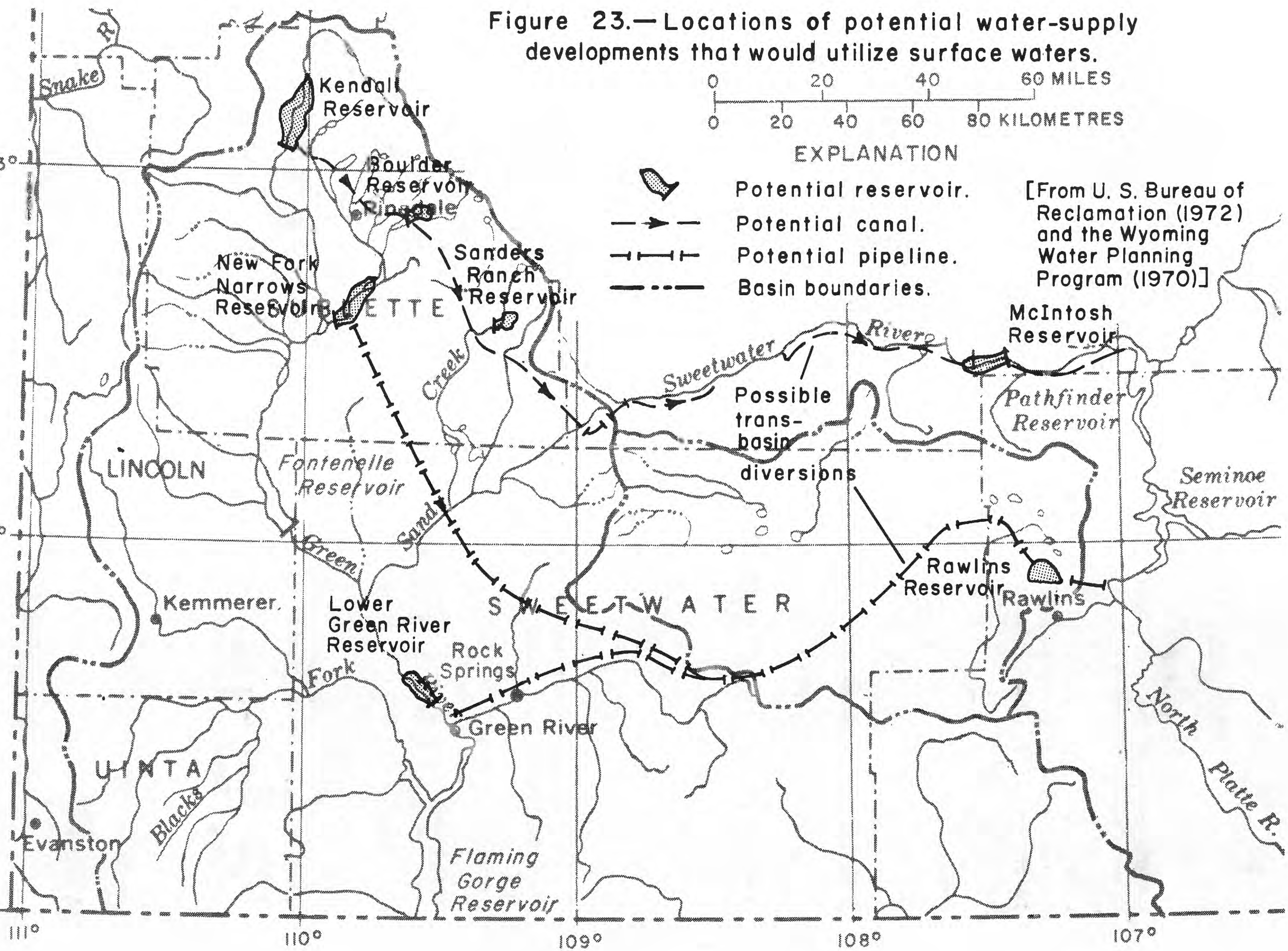


Figure 23.—Locations of potential water-supply developments that would utilize surface waters.

DESCRIPTION OF THE STUDY PLAN

This section of the report presents a description of the procedures, techniques, and methodologies to be used in fulfilling the project objectives. The overall plan of the study is to determine important hydrologic variables, and to define interrelations that exist between these and other variables. In general, the study would be directed towards providing an overall view of the water and water-related resources in the project area. However, intensive studies would be made at Energy Mineral Rehabilitation Inventory and Analysis (EMRIA) sites, and at a few areas where energy development is already taking place. These intensive studies would be made to determine hydrologic effects of energy development so that a better understanding of these effects will be available for planning of future developments. The EMRIA study sites are under the direction of the U.S. Bureau of Land Management and involve rehabilitation studies of oil shale and coal strip-mine areas.

The study plan would remain flexible so that it can be modified to fit the particular needs of other Federal, State, and local agencies. The study plan is tentative, and can be changed to fit budgetary, personnel, and travel restrictions, if they occur.

Surface Water

Streamflow

A review of surface-water data needs reveals that 35 new gaging stations should be installed on streams in the study area. Many of the new gages should be installed in the plains areas, as little data presently exist for runoff of ephemeral and intermittent streams. Figure 24 shows approximate locations of the proposed stations. Fifteen continuous-record stations and 20 partial-record stations are proposed for new operation. Selection of the gaged sites was made with both streamflow and quality-of-water data needs in mind.

The operation of the new partial-record stations would be provided for by project funds of the U.S. Geological Survey. The U.S. Bureau of Land Management is providing funds for operation of six of the continuous-record stations. The remaining nine continuous-record stations would require additional funding; it is hoped that this will be provided for by other Federal and State agencies.

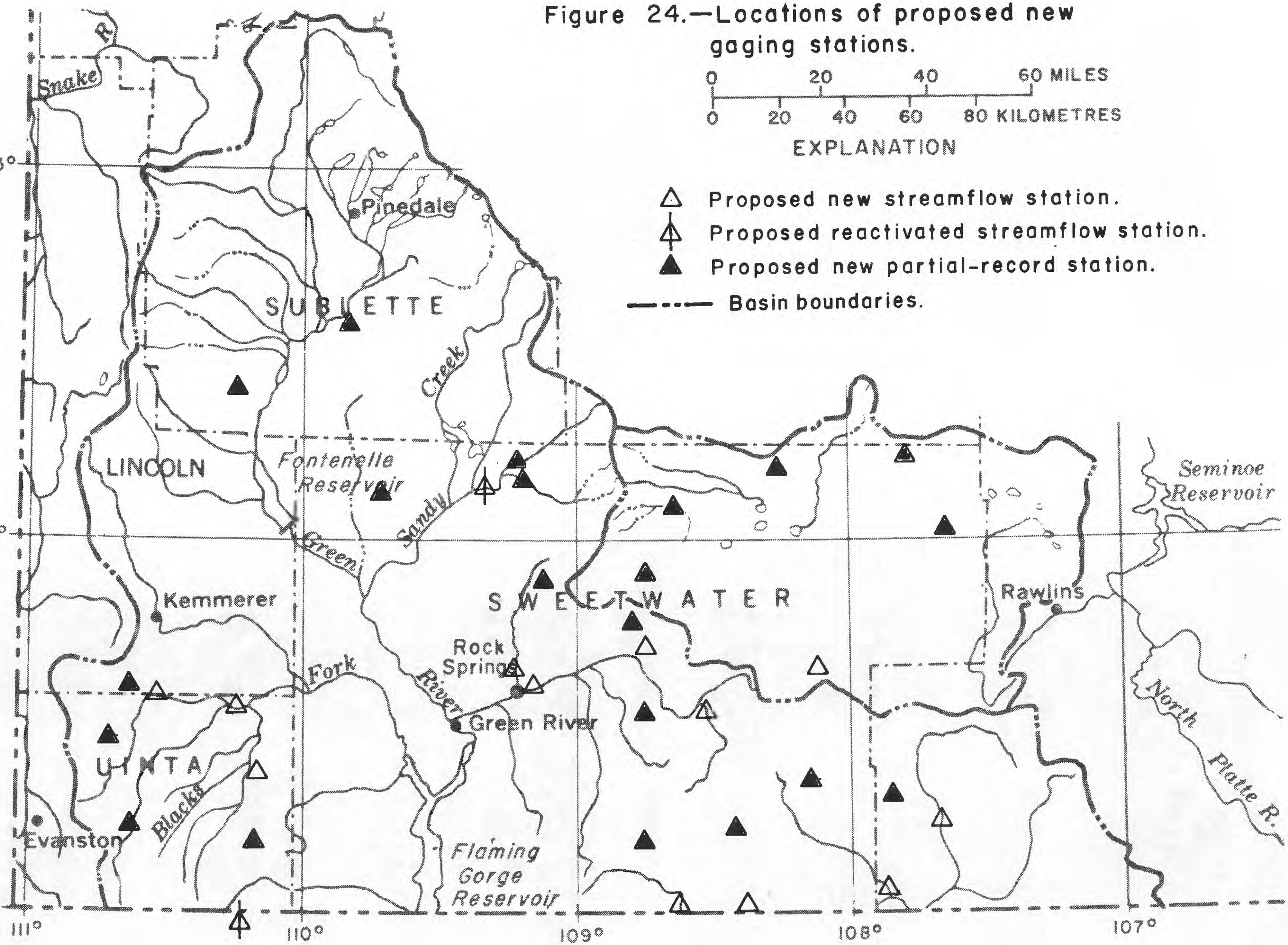


Figure 24.—Locations of proposed new gaging stations.

In addition to streamflow records, data would also be obtained from measurements of related variables, which will include:

1. Base-flow (seepage) measurements along selected streams. These measurements would help identify surface water-ground water relations.

2. Traveltime and dispersion measurements of main streams. These measurements would be used to identify hydraulic characteristics of the streams in the area, and also would be used to help develop a water-quality solute model (discussed more fully in a later section).

3. Measurements of basin characteristics from maps and field surveys to determine cause-effect relations that exist between basin and streamflow characteristics.

4. Field measurements of channel dimensions, and measurements of streambed material along selected streams to determine relations that exist between channels and their flows. The investigation of channel characteristics is discussed more fully in a later section of the report.

Existing and new surface-water data would be analyzed to determine streamflow characteristics at gaged sites, and to develop improved relations for estimating these characteristics at ungaged sites. Statistical analyses would be made to determine potential water supply, and to determine the relation of surface waters to other aspects of the hydrologic environment. The statistical methods will include trend analyses, probability studies, and correlation analyses.

A streamflow routing model would be tested by personnel of the U.S. Geological Survey on data gathered from a reach of the East Fork River during the spring of 1975. The model is a recent development of James P. Bennett (written commun., 1975) and is being tested as part of a research project in collaboration with William W. Emmett, Carl F. Nordin, and Robert H. Meade. Their plan is to test the usefulness and applicability of the model in routing streamflows, as well as for the determination of total sediment load. If the model proves to be applicable, it could provide the basis for streamflow and water-quality modeling of streams throughout the study area.

Chemical Quality

Specific conductance, salinity, and discharge data would be used to determine functional relations, which would be used to describe the chemical quality of surface waters. For example, figure 25 shows the seasonal variation of discharge, dissolved-solids concentration, and dissolved-solids load at station 09188500 Green River at Warren Bridge, near Daniel, Wyoming. The dissolved-solids concentrations and loads at this station were simulated through the use of a functional relation between total-dissolved solids concentration and discharge. Figure 26 shows the relation of daily specific conductance to daily discharge at station 09217000 Green River near Green River, Wyoming for the 1972 water year. This relation was developed through the use of a simple two-variable regression model (Steele, 1970). Refinement of such regression equations[1] to include seasonal effects, stage gradient, antecedent conditions, or areal variations would be investigated to improve sensitivity of these relations in detecting trends in water quality and their related causes. For example, the hysteresis apparent in figure 26 might be attributed to one or more of the variables mentioned before. Time dependence of this effect is shown in figure 27. Measurement of specific conductance with all discharge measurements would be initiated to increase areal coverage of salinity data with a minimal increase in the data-collection effort. Additional stations, shown necessary by analysis of the data, would be established to identify major sources of salinity and possible changes resulting from development. Special emphasis would be placed on ephemeral and intermittent streams.

Mathematical models would be investigated as an aid in predicting salinity in the Green River and its major tributaries. Stresses imposed on the model(s) would include construction and operation of new reservoirs, diversions, increased irrigation, discharge of wastes, and shallow groundwater development. Because it is necessary that the stresses be applied and effects simulated both above and below Fontenelle Reservoir, a mathematical model may also be required for the reservoir.

Chemical-quality data, other than salinity, are virtually nonexistent in the study area. Preliminary data concerning trace elements, radioactive elements, and organics would be collected at selected water-quality stations. Variables to be measured and frequency of sampling would be determined from this reconnaissance in order to efficiently allocate the data-collection effort.

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[1] $AQ^B = K$ or $A + BK = C$; where A and B are regression coefficients, Q = discharge, C = constituent concentration, and K = specific conductance at 25°C.

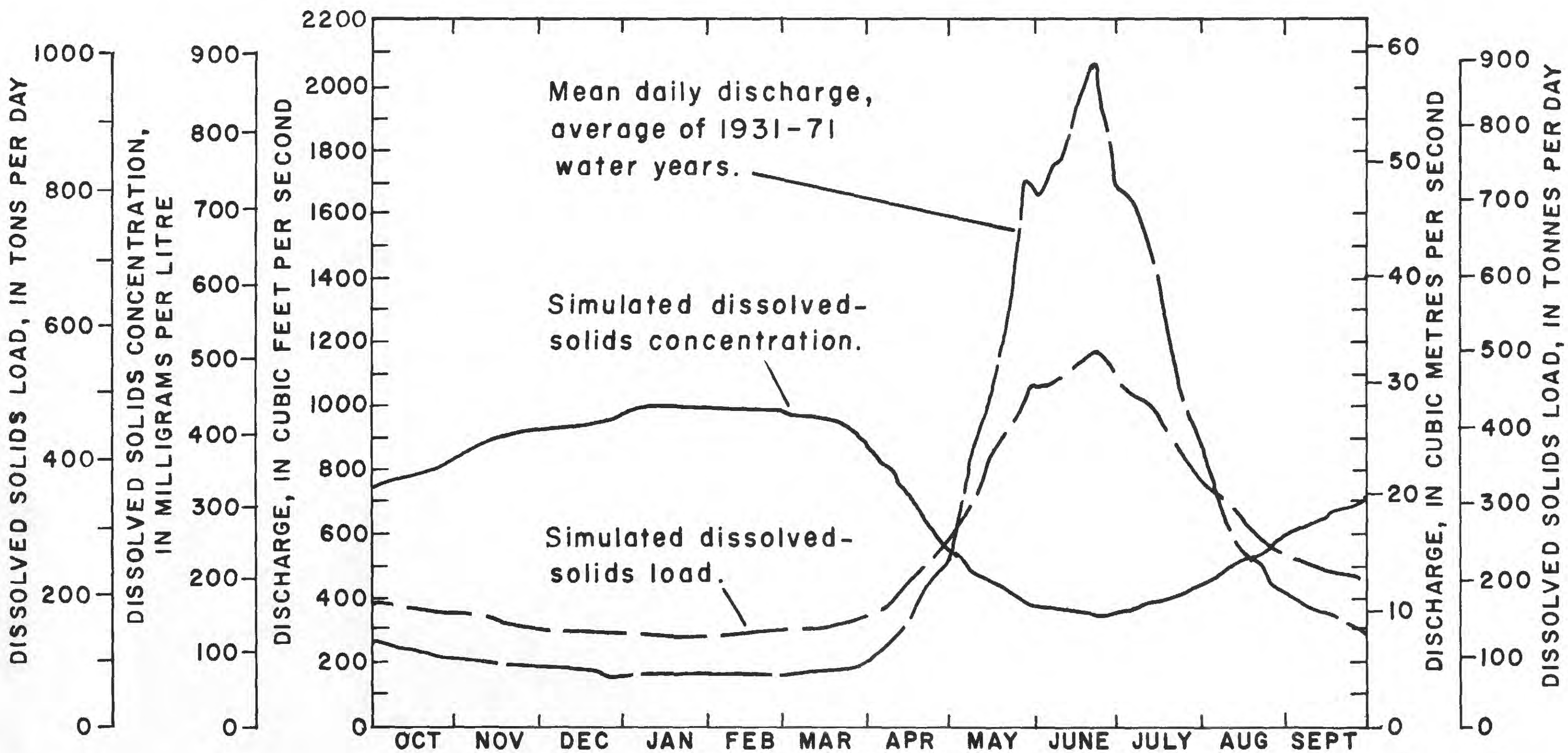


Figure 25.—Mean daily discharge, dissolved-solids concentration, and dissolved-solids load at station 09188500 Green River at Warren Bridge, near Daniel, Wyoming.

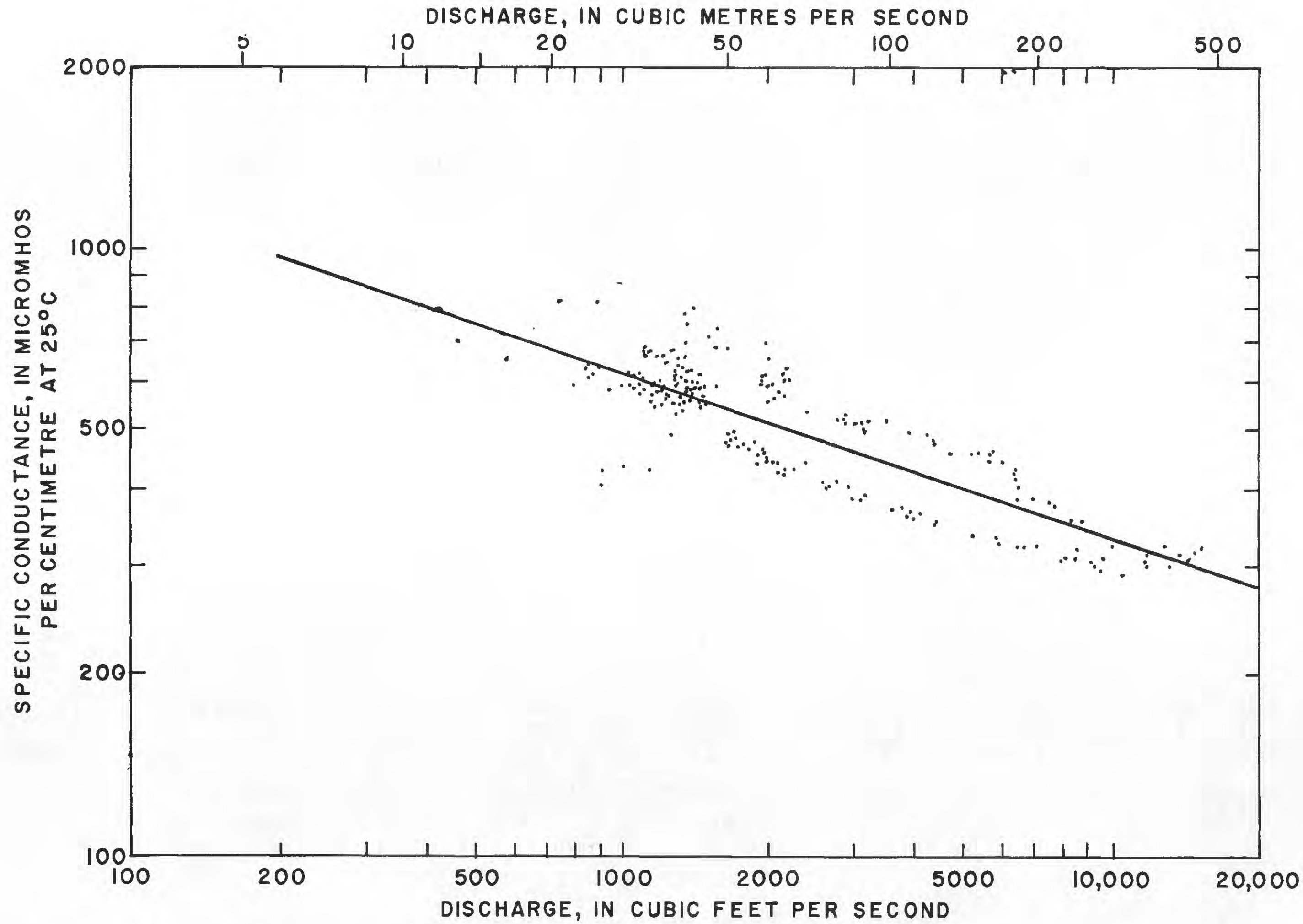


Figure 26.—Relation of daily specific conductance to daily discharge at station 09217000 Green River near Green River, Wyoming (1972 water year).

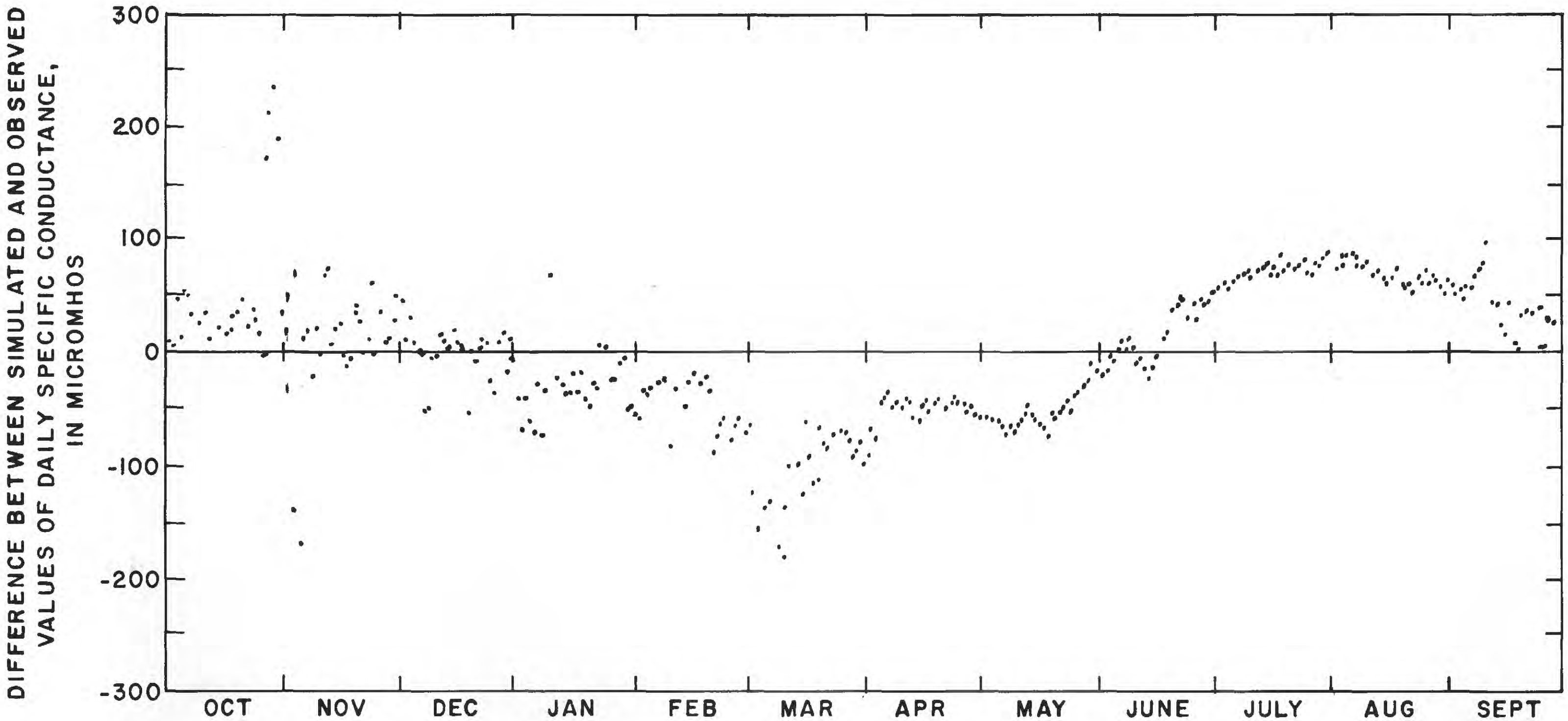


Figure 27.—Plot of differences between the simulated and observed values of daily specific conductance at station 09217000 Green River near Green River, Wyoming (1972 water year).

Biological Quality

Water users and planners are becoming increasingly aware of the relation between the biologic community and the qualitative and physical characteristics of surface water. Aquatic organisms respond continually to the environment, and reflect in their numbers and kinds the interactions of chemical, physical, and biological factors. Changing land use and industrial development can significantly affect aquatic biology. With proper understanding of these relations, water developments can often be planned in such a way as to improve, rather than degrade, the environment.

Existing information concerning the aquatic biology of the study area is limited. Previous studies have been concerned primarily with fish and only passing reference has been made to benthic organisms and plankton as a source of fish food.

Increased data-collection activity would be implemented during the first year of the study. Nine water-quality stations have been selected for biological assessment. (See fig. 28.) Samples at each station would be collected in such a way as to represent total populations of the stream reach. In addition, periodic samples would be obtained on major lakes and reservoirs of the area to determine baseline conditions. Random samples of other streams and lakes would be collected to supplement data obtained at the regular stations and to define areal variability.

All members of an aquatic community should be defined in a biological study. Limitations in time and money would generally restrict the study to a monthly sampling schedule that would include bacteria, fish, plankton, periphyton, macroinvertebrates, macrophytes, and algal growth potential.

A preliminary analysis of the data would be made after the first year of data collection. Biologic variables would be related to chemical and physical variables, and to each other. A species-diversity index would be determined at each sampling site.

Temperature

Water temperatures are important to many water users. They are important to the sportsman, as they are a vital factor affecting fish life. They are important to agricultural users, as temperature of irrigation water can affect crop production. Industrial water users often utilize water for cooling purposes, and must consider temperature in plant design and operation. The physical, chemical, and biological properties of water are closely related to temperature as it affects sediment transport, rates of chemical reactions, and biological processes. As part of the study, a compilation of periodic water-temperature data at streamflow stations has been made (Lowham, Kircher, and Boner, 1975).

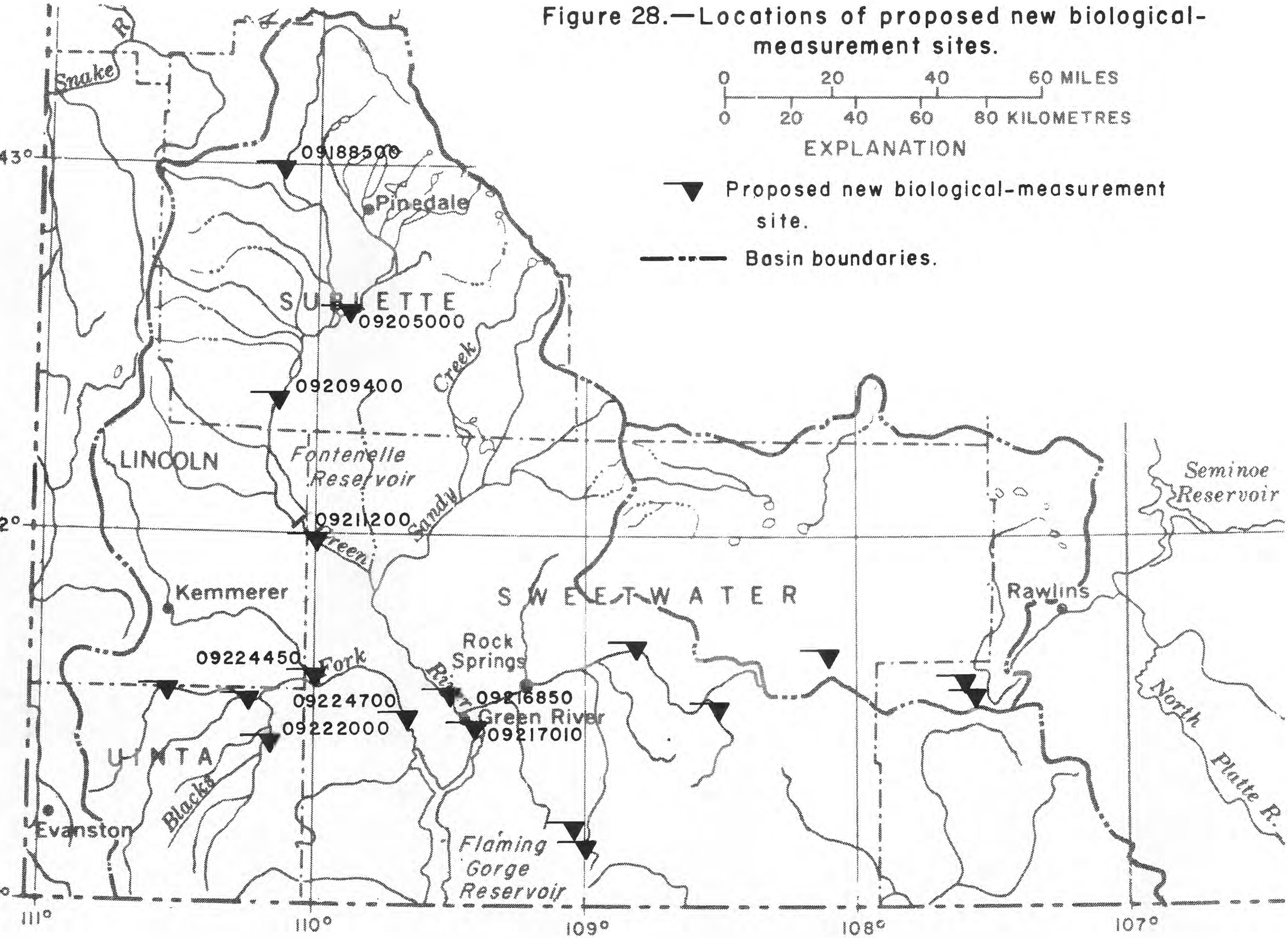


Figure 28.—Locations of proposed new biological-measurement sites.

An analysis would be made to determine stream-temperature characteristics on a regional basis. Continuous and periodic water-temperature data would be analyzed by using a simple harmonic curve-fitting procedure (Steele, 1974, p. 1-6). Regional values of the harmonic coefficients would then be analyzed by regression with basin and climatic variables. Results of the analyses would be published along with typical examples (case studies) so that the relations determined may be helpful to water managers in making their decisions and plans.

Sediment

Sediment is an important factor of water quality in the study area. Sediment concentration can affect the use of water and design of structures. Sediment also affects turbidity, which is important to aesthetic value and certain biological relations.

A study of available data concerning sediment reveals that much additional data is needed, particularly for the smaller streams. Data-collection activities have thus been expanded to include the collection of suspended-sediment samples at all continuous- and partial-record gaging stations whenever discharge measurements are made. In addition, single-stage samplers have been installed at all gage sites on ephemeral and intermittent streams.

Many variables affect sediment discharge, and no simple method exists for accurately describing sediment concentrations or yields for an area of diverse physiographic and hydrologic conditions; however, approximate relations can be developed that would serve the purposes of most users. For example, figure 29 shows the relation of suspended-sediment concentration versus discharge at station 09213500 Big Sandy River near Farson, Wyoming. Similar relations would be developed for all continuous-and partial-record gaged sites, and a sediment-yield map would be prepared with the aid of these relations.

Supply of sediment to a stream is largely dependent upon erosion of the drainage-basin surface. Rates of erosion would be determined by establishing reference marks and periodically surveying grid sections at several locations throughout the study area. These data would aid in defining sediment yields.

Research on bedload transport has been done on the East Fork River near Pinedale (Leopold, L. B., and Emmett, W. W., 1976) for about the past 10 years. Data collected for these research activities will provide useful information concerning bedload transport of the streams of the area.

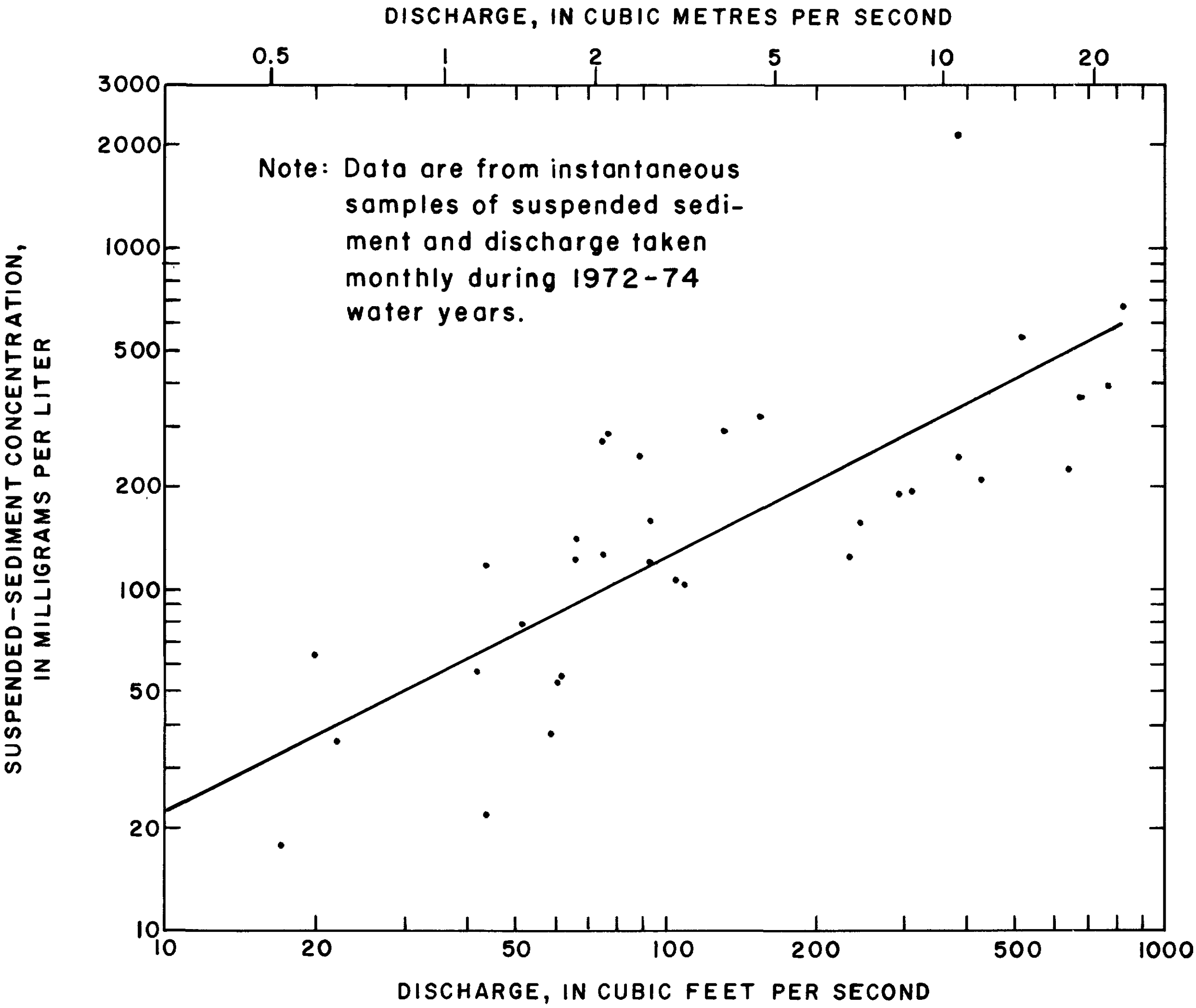


Figure 29.—Relation of suspended-sediment concentration to discharge at station 09213500 Big Sandy River near Farson, Wyoming.

Channel Characteristics

The physical characteristics of a stream channel are highly related to its flow and sediment discharge. Depending on the flow regime and available sediment load, a stream naturally strives toward a state of equilibrium by aggrading or degrading. Many aspects of the environment, such as aquatic biology, are in turn dependent upon the physical characteristics of the stream channel. Thus, a change in the flow regime or sediment discharge will result in changes to the physical characteristics of the channel, which can in turn affect certain aspects of plant and animal life.

Man's activities may produce major changes in a stream both locally and along a reach of channel. Proper planning of developments requires an understanding of the basic relations that exist between streamflow variables and other aspects of the environment.

The hydraulic properties of the streams of the area would be defined in a manner similar to studies conducted by Leopold and Maddock (1953), and Emmett (1972, 1975). Data obtained at gaging stations would be used to define the hydraulic characteristics at the gaged sites. These characteristics would then be used to develop regional relations so that hydraulic characteristics at ungaged sites may be inferred. Relations of width, mean depth, mean velocity, and flow area as functions of discharge have already been defined for 42 gaged sites in the study area. Figure 30 is a typical example of these relations, showing changes in width, mean depth, and mean velocity with discharge at station 09205500 North Piney Creek near Mason.

Regional relations, which utilize the hydraulic characteristics defined at the 42 gaged sites, have been developed to compare hydraulic characteristics of streams throughout the study area. It is planned to gather additional data to further refine these relations; however, preliminary examples of the regional relations are shown in figure 31.

The relations shown in figures 30 and 31 utilized data from current-meter discharge measurements made at the gaged sites. Discharge measurements are generally made at various sections of a stream reach near the gage. Prior to measuring, the hydrographer selects a good measuring section for the particular discharge and does not choose the same section each time. The hydraulic data thus contain some inconsistencies due to variabilities inherent to the measurement process. More consistent relations could be developed if the data were derived from a particular cross section of the stream. Data of this type would be obtained for this part of the study.

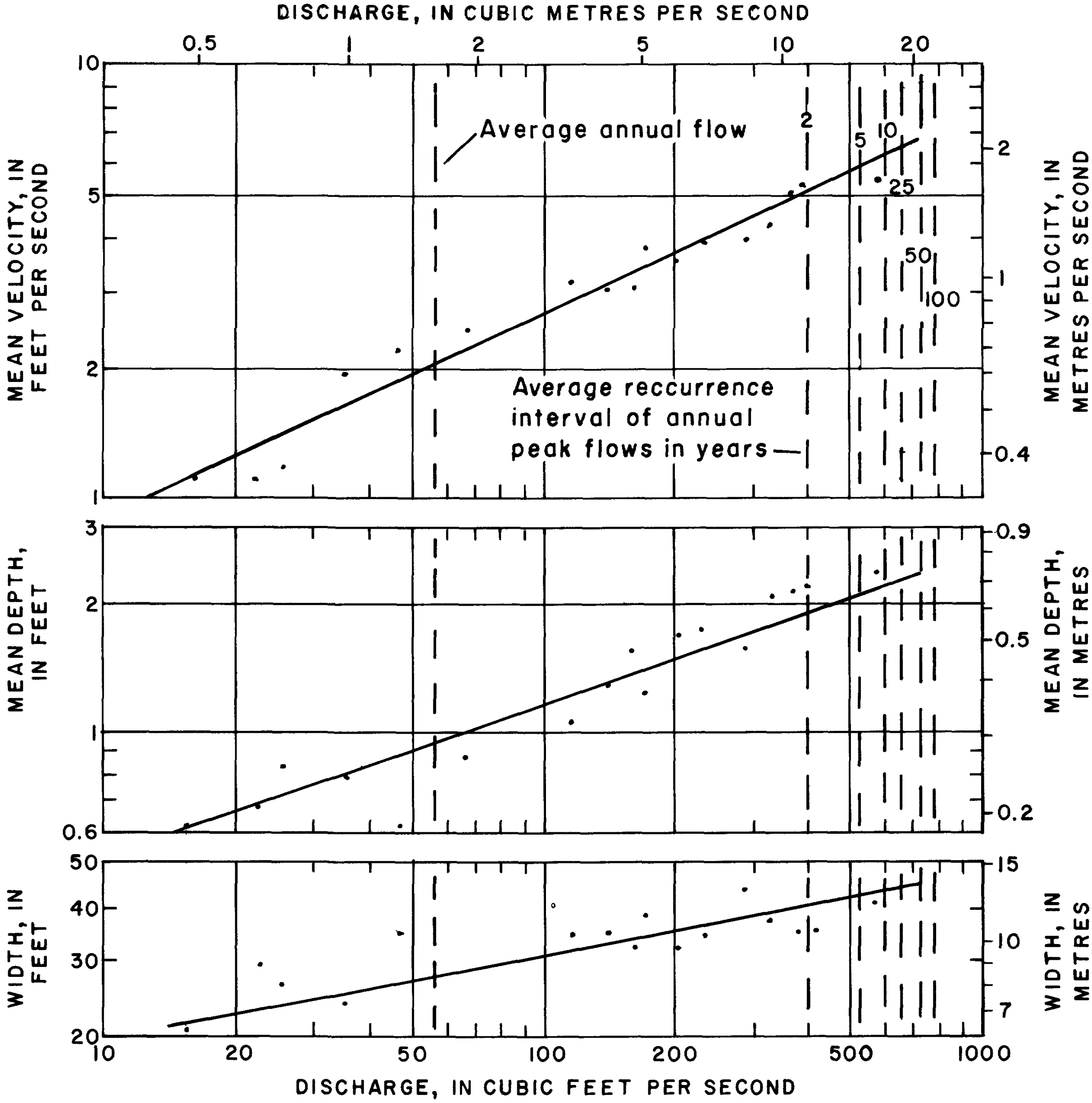


Figure 30.—Changes of width, mean depth, and mean velocity with discharge at a channel cross section, station 09205500 North Piney Creek near Mason, Wyoming.

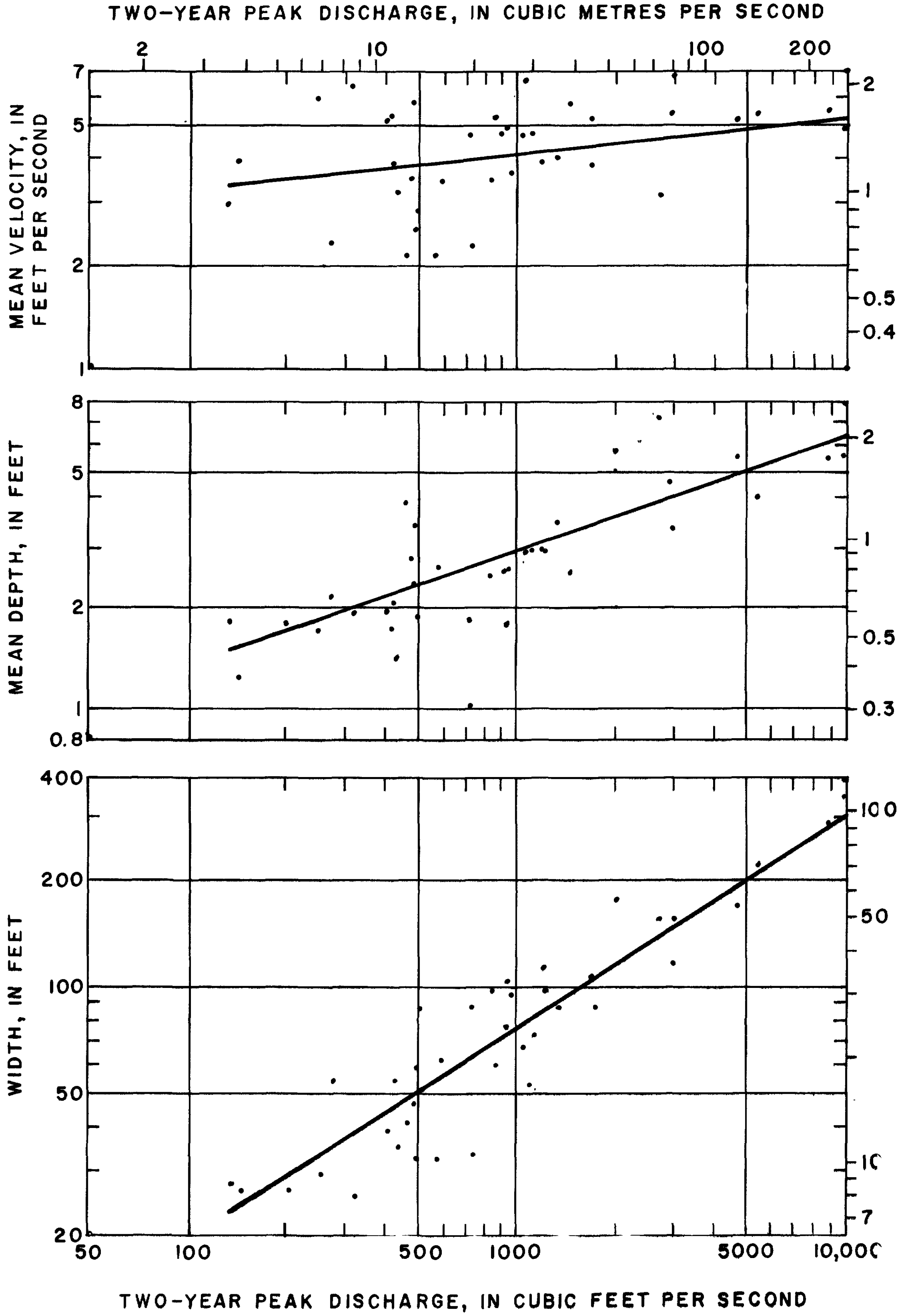


Figure 31.—Stream width, mean depth, and mean velocity in relation to 2-year peak discharge as discharge increases downstream, Green River and tributaries, Wyoming.

Because the physical properties of a channel are representative indices of the prevailing streamflow and sediment discharge, the establishment of a number of cross sections on stream channels throughout the study area is an excellent way to determine baseline conditions and to detect changes in these conditions. Several cross sections have already been surveyed, and reference marks were established so that subsequent surveys may be made to detect possible changes or trends in the hydrologic environment. Figure 32 shows the results of one such survey made on Delaney Draw near Red Desert. This is an ephemeral stream whose channel has recently downcut as a result of changes in its upstream drainage. Subsequent surveys of the cross section will help determine whether the stream has reached a new equilibrium profile, or whether some changes are still occurring.

Data concerning other channel characteristics such as slope, sinuosity, and bed material would also be collected and related to the hydrologic environment. It is planned to conduct a number of surveys along selected streams to determine relations in respect to increasing discharge in the downstream direction, and in particular to determine the effects of surface geology and land use on these relations.

Ground Water

Determination of Potential Supply

As developments proceed, large supplies of water will be needed at widely separated parts of the study area for recovery and utilization of the resources, for municipal supplies, and for recreation. Although present surface-water resources are adequate in quantity, distribution in space and time do not fit projected demands. Economic and environmental considerations may make ground-water supplies more attractive than surface-water supplies. Thus, as often happens in a developing area, attention is focused on the potential of ground water to supply the new water demands. Ground water in the study area is relatively undeveloped and very little quantitative information is available on this resource.

The evaluation of a potential ground-water supply requires data concerning both the chemical quality and yield of underlying aquifers. Particular uses of water have certain standards; for example, ground water from a particular aquifer could have fluoride concentrations that would prohibit its use for domestic purposes, but it could still be used for many industrial purposes. An aquifer may not have the capability to yield large supplies of water for a long period of time without the ground-water level being seriously lowered, but it may yield small supplies of good quality water for domestic use. Information on both chemical quality and water availability is thus very important in planning ground-water development, and the study would be directed towards determining these items.

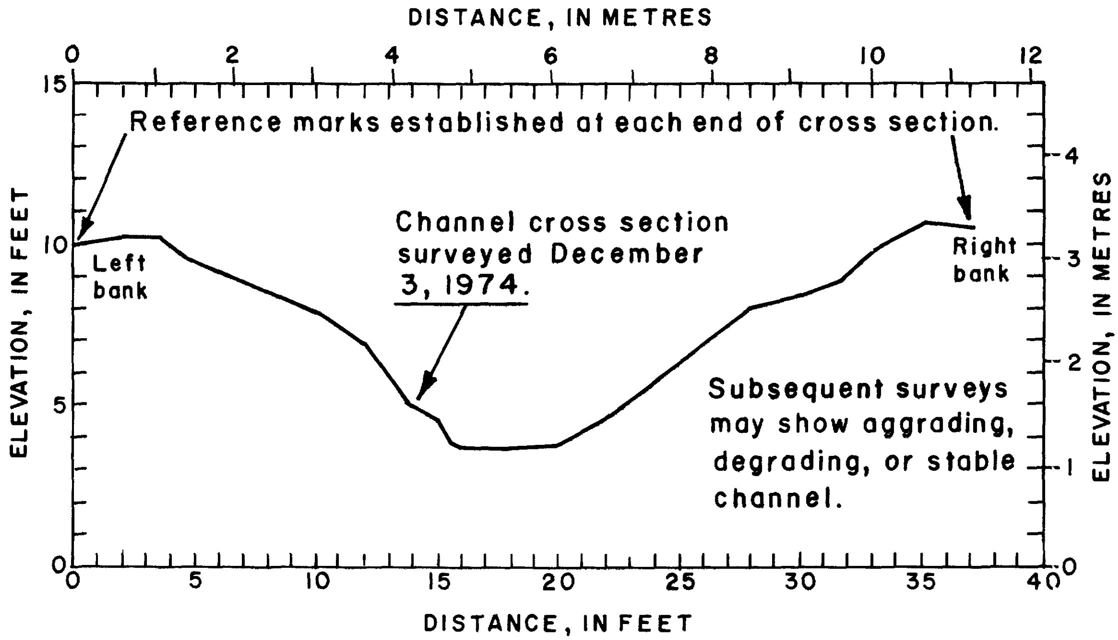


Figure 32.—Cross section of Delaney Draw near Red Desert, Wyoming.

Emphasis of study would be on aquifers of Holocene, Tertiary, and Late Cretaceous ages. (See fig. 3.) The formations with the greatest ground-water potential are gravel deposits near the Wind River Range, some alluvial deposits, the North Park(?) Formation, the South Pass Formation, the Browns Park Formation, the Pass Peak Conglomerate, the Battle Spring Formation, the Green River Formation, the Wasatch Formation, the Fort Union Formation, the Ericson Formation, and the Rock Springs Formation (Welder, 1968; and Welder and McGreevy, 1966). Some of these aquifers, such as the North Park(?) Formation along the eastern edge of the study area, are very limited in extent. Also, some of the formations have good ground-water potential in some, but not all, of their members. For example, the ground-water potential of the Laney and Tipton Shale Members of the Green River Formation is good, but the potential is poor for the Wilkins Peak Member.

First efforts of the study would be directed toward compiling and evaluating data that are already available. These data would be obtained from basic-data reports (Ringen, 1973, 1974) and from a well inventory conducted during the early part of the project. Records of chemical analyses of water and yields of wells would be compiled for each aquifer studied. Water samples would be analyzed for common chemical constituents, trace elements, and radiochemicals.

To quantitatively evaluate aquifer characteristics such as transmissivity and storage coefficient, aquifer tests would be conducted wherever practical. Numerous test methods may be used such as recovery, slug, bailer, constant discharge, constant drawdown, and specific capacity methods. The method used would depend on the condition of the well, the availability of observation wells, and knowledge of the geology and hydrology of the aquifer. Specific capacities would be used for estimating transmissivities if the wells are known to be properly constructed. Lithologic logs, the results of drill-stem tests performed by industry, and geophysical logs would provide supplementary data on aquifer characteristics.

Water levels would be measured in all available wells. Where more long-term information is needed, observation wells would be installed. Chemical analyses would be compiled and, if sufficient data exist, maps would be prepared that show how chemical quality varies areally and vertically in different aquifers. Water-level measurements would be used for drawing potentiometric maps. Potentiometric-surface maps, used with topographic and structure maps, would show direction of ground-water movement, depth to water, and saturated thicknesses. In areas of development, water-level measurements may be used to draw water-level change maps. Water-level hydrographs may also be drawn to illustrate normal variability or regional trends. Maps of transmissivity would be drawn where possible. Storage coefficients and transmissivities calculated from aquifer tests would be used with chemical analyses to describe the potential of the aquifers as sources of ground water.

Effects of Economic Development

As economic development accelerates in the study area, ground water may be affected in many complex ways. If ground-water withdrawals exceed recharge, water levels will decline. If leakage between saline and non-saline aquifers is increased, water quality will change. Mining activities, waterflooding in oil and gas fields, and oil-shale retorting could affect the ground-water system.

Because of the large size of the study area, this work would begin with a reconnaissance of areas of potential impact. This would include examination of development in mining areas and oil and gas fields. Both active and abandoned sites would be studied. In addition, the reconnaissance phase would evaluate areas most likely to have oil-shale development. A system for gathering background data and monitoring effects of future oil-shale development would be established.

Intensive study would take place at the EMRIA (Energy Mineral Rehabilitation Inventory and Analysis) sites and at other sites where development may take place.

In coal mining areas, the ground-water conditions would be examined at a reconnaissance level, with more intensive study as needed. Study would be oriented towards such activities as mine dewatering, spoil banks, flooding in abandoned mines, and current and planned reclamation.

Underground trona mines have had flooding problems with ground water from the Tipton Shale Member of the Green River Formation. The trona-bearing rocks in the Wilkins Peak Member of the Green River Formation overlie the Tipton Shale Member. The steps that industry has taken to relieve this problem would be studied. This information would be important because the oil shale that may be developed in this area is in the same formation members.

Waterflooding as part of oil and gas production may affect ground-water chemistry and supply. A reconnaissance study of available company records would be used to evaluate areas where more intensive study may be needed. Particular attention would be given to the aquifer characteristics, the chemical quality of water, and the potentiometric surfaces of both the source aquifer and the injected unit.

Currently (1976), there are no oil-shale leases in Wyoming. The study of the relation between ground water and oil-shale development would be at a reconnaissance level. An important part of the study would involve obtaining background data on current ground-water conditions in areas of potential oil-shale development. Data collection would be intensified in areas where development is planned.

Well and Spring Inventory

Except for a small part of the study area investigated by Lines and Glass (1973), there has been no inventory of the wells and springs in the area since those done by Welder (1968) and Welder and McGreevy (1966). Many wells have since been developed.

A well and spring inventory would be made during the first few years of the project. A record of all registered wells would be obtained from the Wyoming State Engineer's office. Requests would be made to industry and local landowners for information on additional wells that have been drilled recently.

Observation wells would be selected from the well inventory in areas where aquifer tests and water-quality samples are needed. Wells would also be selected along major streams for use in studying surface- and ground-water interrelations.

Borehole Geophysics

Techniques of borehole geophysics including geophysical well logs, temperature logs, and vertical seismic profiling, can provide valuable information about ground-water resources. Oil companies have used these techniques extensively in the study area; however, they have not been previously used for water-resource investigations.

Geophysical logs can provide information concerning primary and secondary porosities, rock density, rock velocity, thickness, and structure. For example, figure 33 shows results of geophysical logs cross correlated by computer analysis for porosity and lithology. Temperature data can be interpreted to show ground-water movement and anomalies reflecting aquifer characteristics. Vertical seismic profiles can be correlated with surface seismic data to extend borehole information on lithology, porosity, and fluid content. Geophysical logs would be obtained at all new test holes and observation wells drilled as part of the project study. Temperature data would be collected from commercial logging sources and through new logging.

Surface Geophysics

Surface geophysical methods, including resistivity, gravity, and seismic measurements, can provide efficient and inexpensive exploration of shallow aquifers.

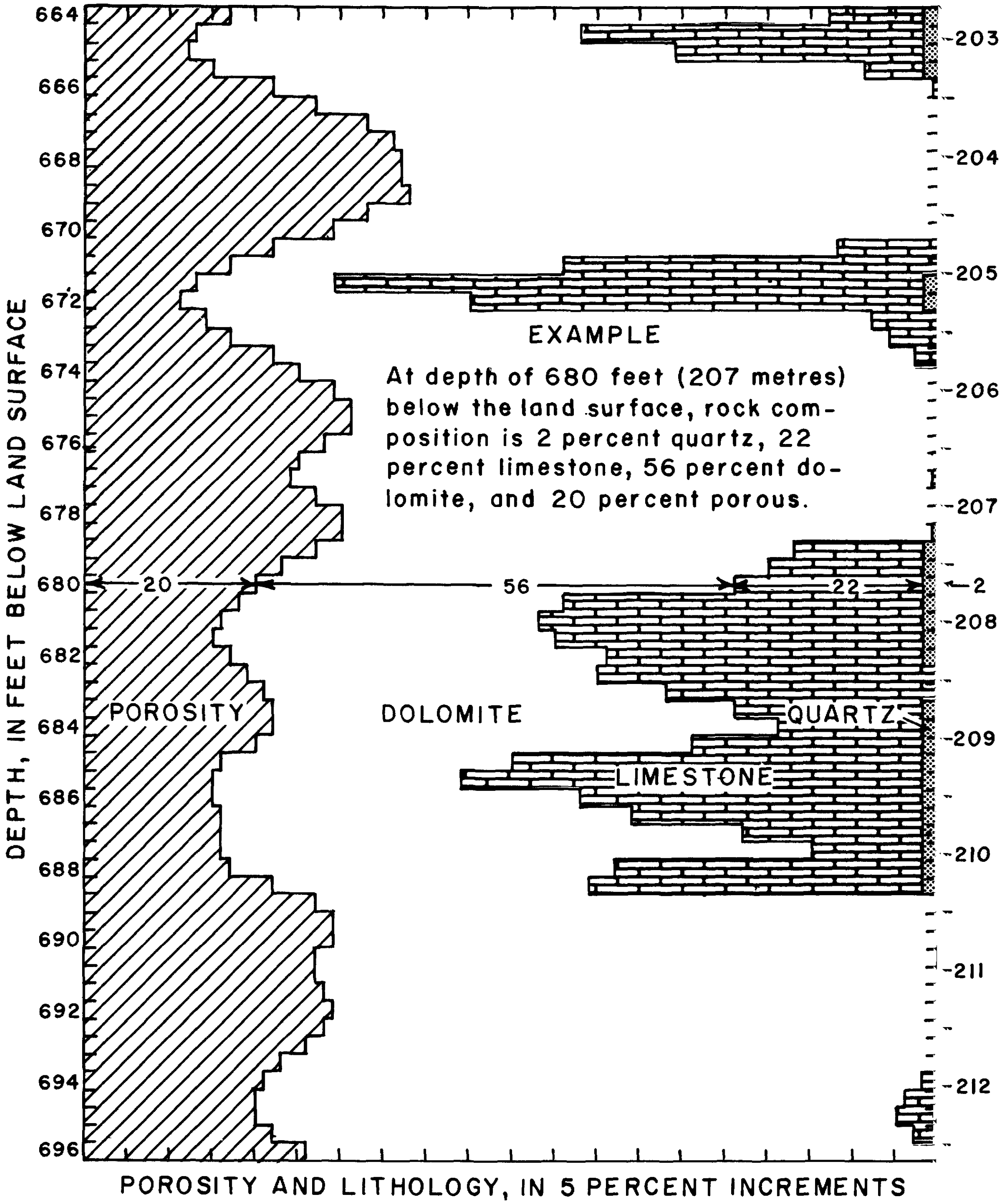


Figure 33.—Porosity and lithology as determined from an analysis of geophysical well logs.

Techniques of surface geophysics have not been widely used in the past for water-resource investigations due to the expensive equipment and special technical knowledge required. The Wyoming District of the U.S. Geological Survey has recently acquired the necessary equipment and expertise for conducting certain types of these studies, and these methods would be utilized for ground-water investigations in the study area.

Direct-current resistivity measurements can define the areal extent and vertical thickness of shallow aquifers, the porosity, water-level changes, and water-quality changes. Figure 34 is an example of interpreted resistivity measurements in alluvium. This figure shows the interpreted resistivity values of a depth sounding in comparison with a gamma log and with a geologic section made from drill-hole data. Figure 35 shows results of interpreted resistivity measurements in till where the extent, composition of the till, and a filled stream channel were defined (Frohlich and Head, 1972). Porosity can be estimated using resistivity of the formation and resistivity of the ground water (Schlumberger Limited, 1972).

Proposed sites for resistivity measurements are shown in figure 36. Sites in alluvial aquifers along major streams would be measured to aid in the determination of surface- and ground-water interrelations. Measurements at EMRIA study sites would aid in the definition of ground-water supply and effects of mining on ground-water resources. Measurements in glacial deposits along the south side of the Wind River Range would aid in determining potential supply as well as interrelations with surface water. Gravity measurements at coal gasification and oil-shale retort sites could be used in estimating specific yield and the extent of cones of depression by measuring the change in mass near a well resulting from the withdrawal of fluids. The method has been described by E. L. Montgomery (written commun., 1971).

Surface seismic methods would be used to study deep aquifers. Interpretations of velocity analyses, amplitude analyses, reflection-coefficient analyses and other routines can provide information concerning structure, thickness, and depth of geologic units. Figure 37 shows a typical velocity analysis of interpreted seismic data. Combining surface seismic data with borehole information allows for quantified interpolation between well control points where hydrologic and geologic parameters (porosity, lithology, etc.) are known. Seismic models would be defined in terms of hydrologic parameters and compared with borehole data. Seismic techniques would be used primarily between areas where well control exists or where well development is planned.

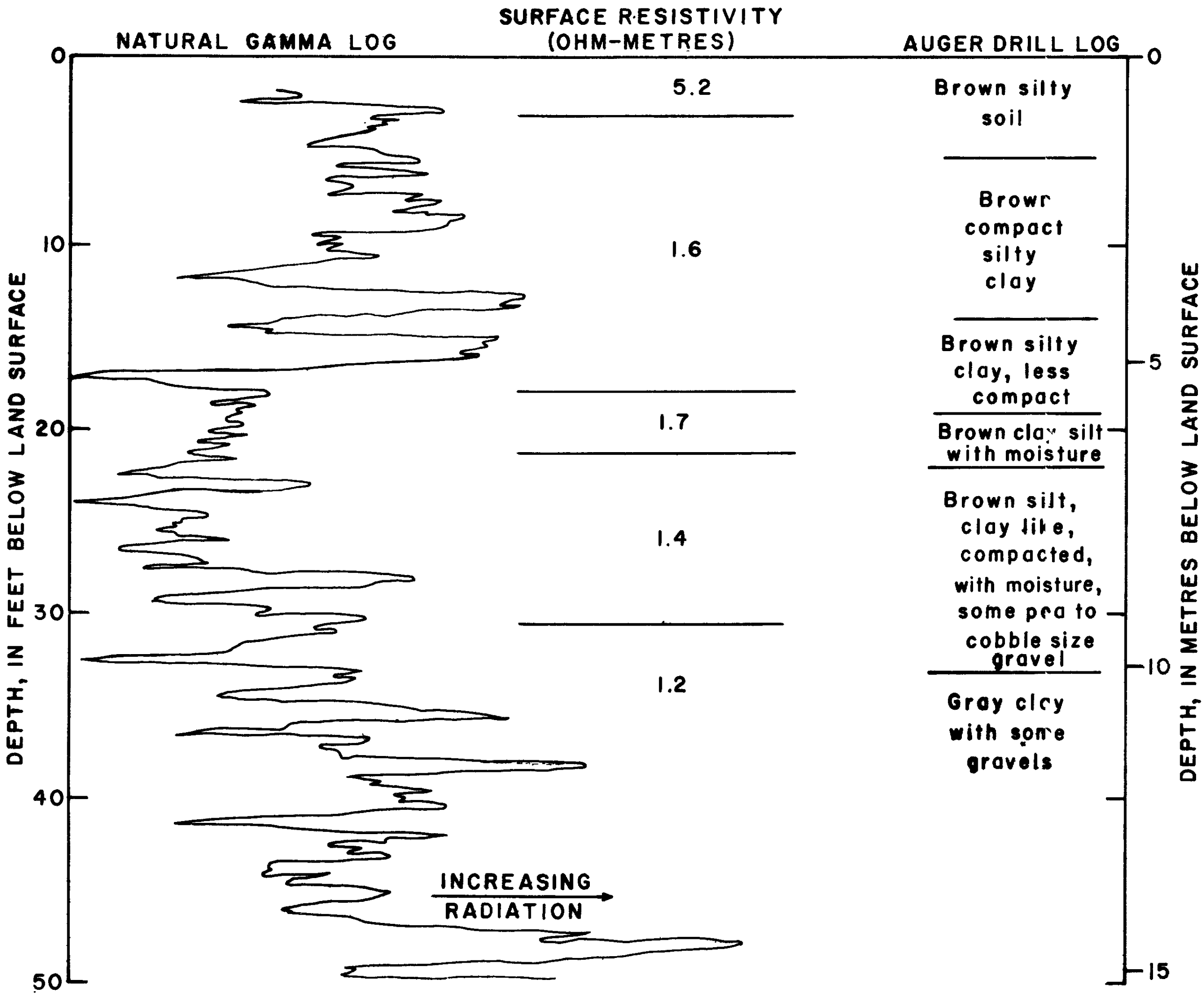


Figure 34.—Example of surface-resistivity measurements in alluvium compared to drill log and gamma log of a nearby hole.

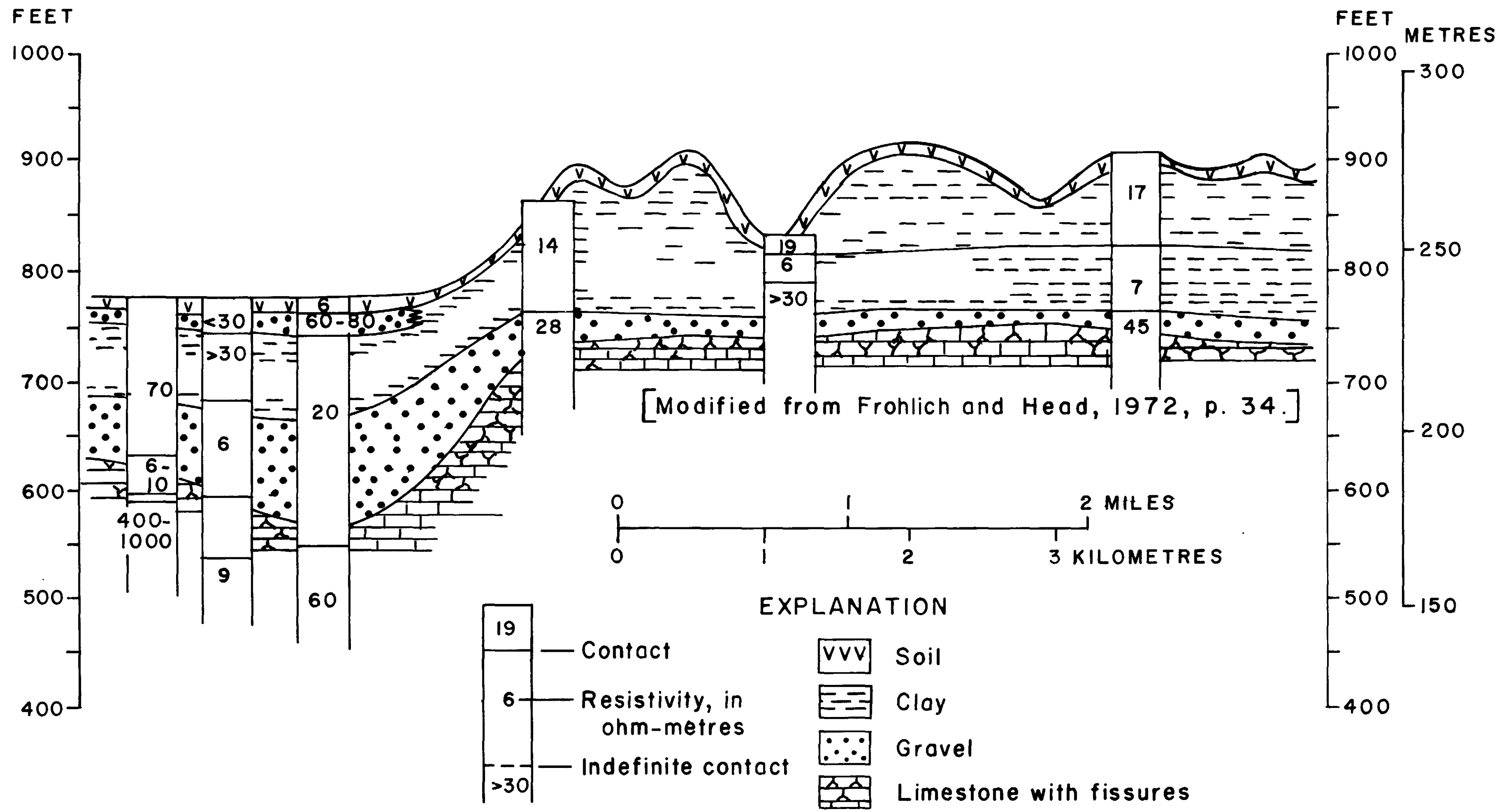


Figure 35.—Interpretations of resistivity measurements in till compared with lithologic log information.

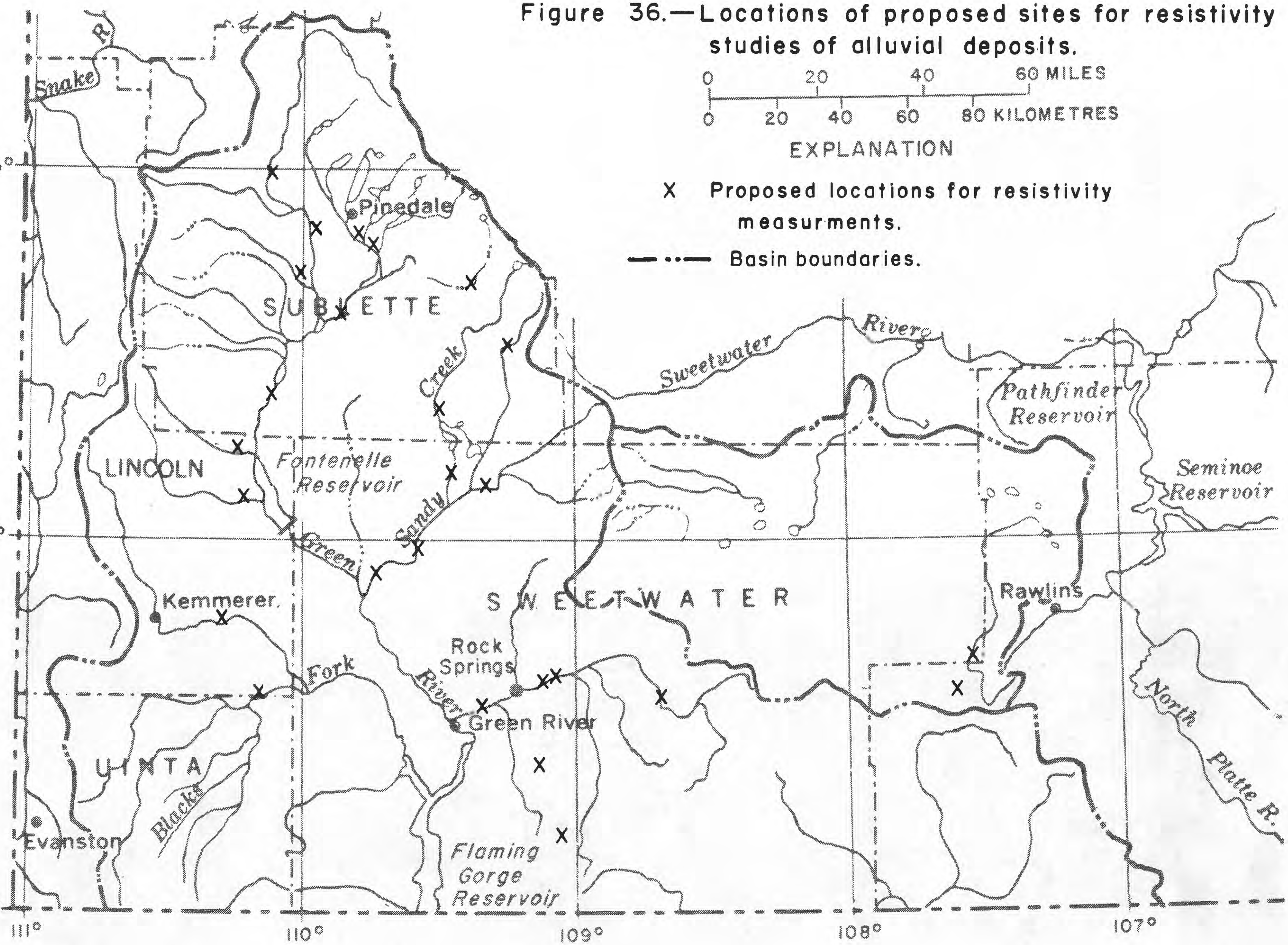
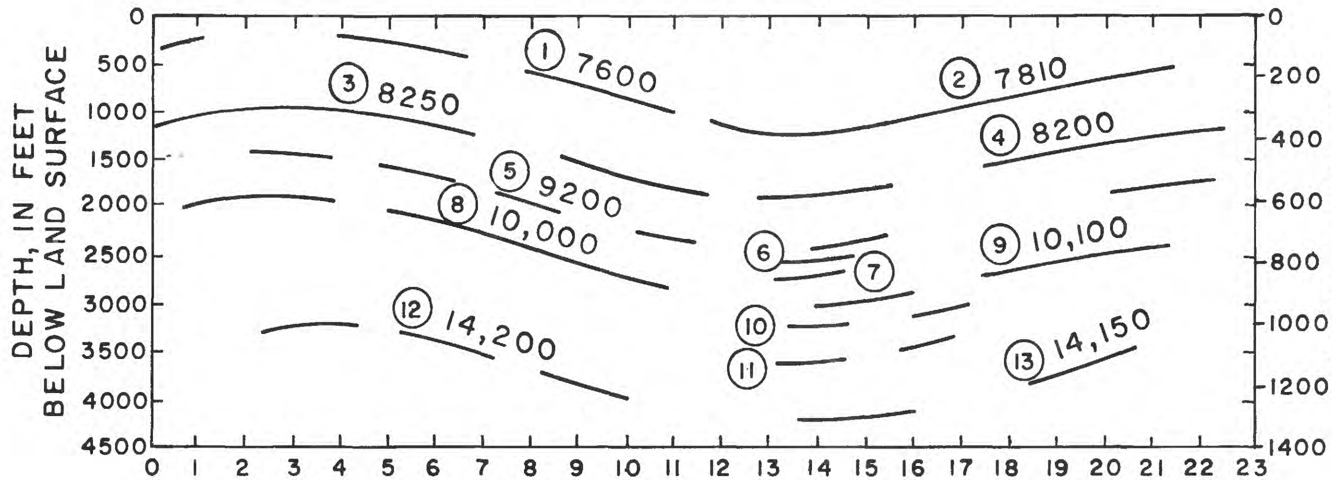


Figure 36.—Locations of proposed sites for resistivity studies of alluvial deposits.



EXPLANATION

	Velocity (ft/s)	Thickness of geologic unit (ft)		Velocity (ft/s)	Thickness of geologic unit (ft)
(1)	7600	200	(8)	10,000	350
(2)	7810	300	(9)	10,100	250
(3)	8250	200	(10)	10,300	300
(4)	8200	200	(11)	12,400	300
(5)	9200	200	(12)	14,200	400
(6)	9400	200	(13)	14,150	400
(7)	9700	300			

Figure 37.—Example seismic section interpreted to show velocity segment analysis, depth, unit thickness, and geologic structure.

Drilling and Well Development

When the well inventory has been completed, a review would be made of data deficiencies for the ground-water investigations. Hydrologic information would be obtained in data-deficient areas by geophysical and geochemical methods when possible. Where additional data are needed, existing drill holes would be developed for observation purposes. The oil and gas industries have abandoned many of their wells and test holes, some of which could be developed as observation wells.

The U.S. Geological Survey has an extensive drilling effort planned in connection with coal development in the Great Divide Basin. The study group would obtain borehole data and establish observation wells in connection with this exploration study.

The trona companies have drilling operations as part of their flood-control program, as well as for exploratory drilling. Some of these holes may be cased and used as observation wells.

A few shallow test holes would be drilled to provide control for the geophysical studies. The U.S. Geological Survey might occasionally participate in deepening an existing well or purchase rig time during a drilling operation to deepen a well.

WORK SCHEDULE AND REPORT PLANS

A final report would be prepared summarizing and drawing together information contained in the 11 scheduled reports listed below:

Subject	Report number and planned year of completion				
Years	1975	1976	1977	1978	1979
Streamflow		2			11
Chemical quality			7		
Biological quality				10	
Sediment				8	
Temperature	1				
Channel characteristics			5		
Well and spring inventory			6		
EMRIA site studies		3 4			
Ground-water supply				9	

Report no.	Tentative Report Subject
1.	Temperatures of Wyoming streams (published).
2.	Peak-flow data of Wyoming streams.
3.	Energy mineral rehabilitation inventory and analysis - Red Rim site.
4.	Energy mineral rehabilitation inventory and analysis - Potter Mountain site.
5.	Hydraulic characteristics of the Green River and its tributaries.
6.	Records of selected water wells, springs, oil- and gas-test holes in the Green River Basin.
7.	An evaluation of salinity in surface waters of the Green River Basin, Wyoming.
8.	Sediment yields of streams in the Green River and Great Divide Basins, Wyoming.
9.	Potential ground-water supply, northern Green River Basin.
10.	Identification of biological indicators and their relation to the quality of water in the Green River and Great Divide Basins.
11.	Potential surface-water supply of the Green River and its tributaries.

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