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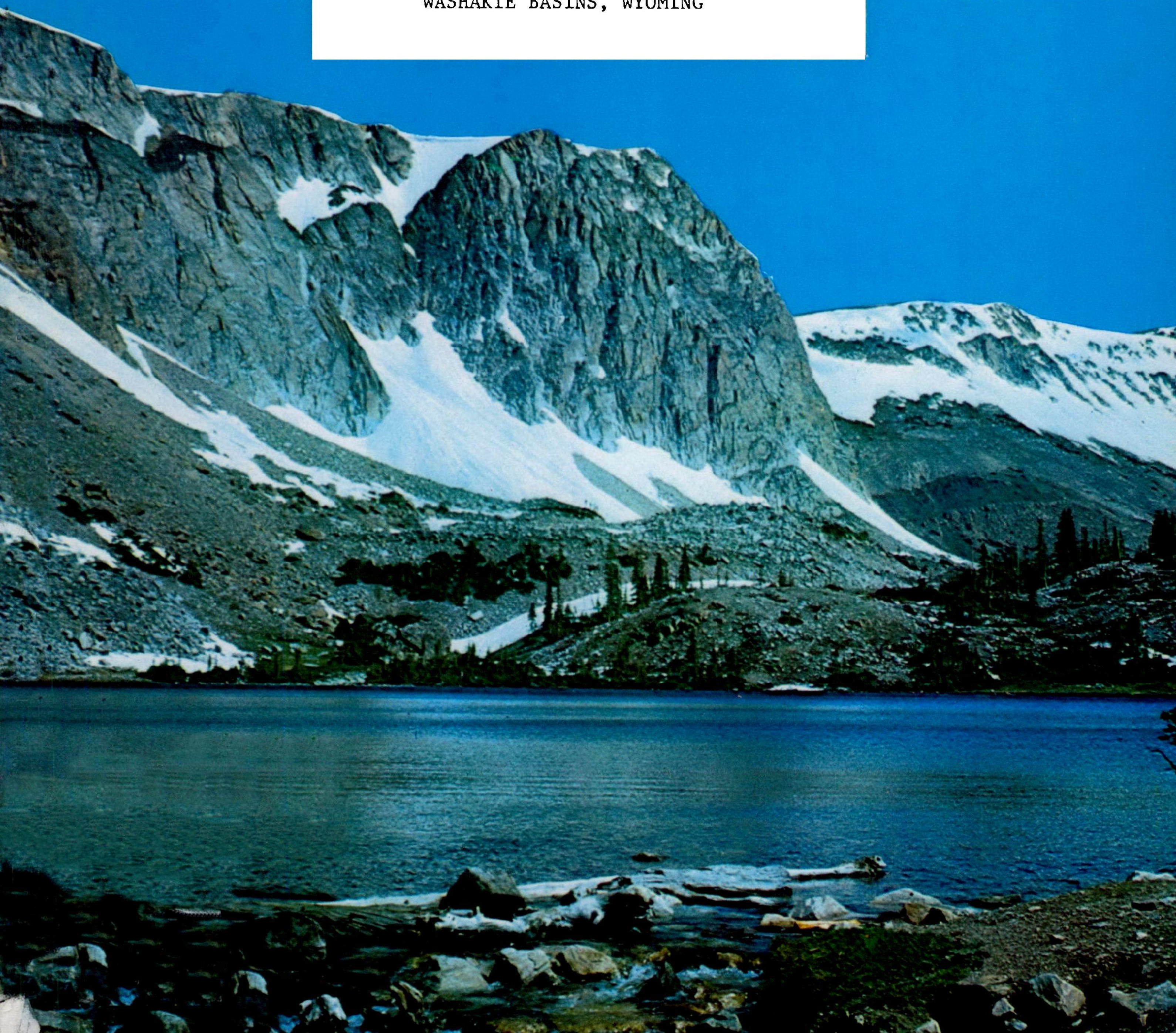
OCCURRENCE AND CHARACTERISTICS OF GROUND WATER IN THE GREAT DIVIDE AND WASHAKIE BASINS, WYOMING



Volume VI-A

OCCURRENCE AND CHARACTERISTICS OF GROUND WATER IN THE GREAT DIVIDE AND WASHAKIE BASINS, WYOMING

by

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Introduction

This report presents the findings of a ground-water study of the Great Divide and Washakie basins in south-central Wyoming. The study was funded by the U.S. Environmental Protection Agency (EPA) for the Underground Injection Control (UIC) program, which is designed to protect sources of usable ground water from possible contamination caused by underground injection of liquid wastes and other fluids. This ground-water report is one of seven prepared by the Wyoming Water Resources Research Institute for the EPA. The reports cover all of the state of Wyoming except for the Yellowstone National Park area in the northwestern part of the state. The results of the study are primarily intended for use by the EPA and Wyoming state agencies concerned with development and preservation of the ground-water resources of the area.

The purpose of this report is to delineate, characterize, and document ground-water occurrence, flow, quality, and use in the Great Divide and Washakie basins, using available information; no site-specific ground-water investigations were conducted during the course of this study by the Wyoming Water Resources Research Institute (WRRI). Specific work by WRRI included (a) field geologic reconnaissance of parts of the study area and adjacent areas; (b) collection, screening, and analyses of existing water well and oil test well data; and (c) review of previous reports.

Water well and oil test well data were obtained from well records at the Wyoming State Engineer's Office, Wyoming Geological Survey, Wyoming Oil and Gas Conservation Commission, and from tabulated data in previous reports. Published reports of previous studies with pertinent information on the geology and ground-water conditions in the study area include (a) a detailed U.S. Geological Survey report on ground-water conditions in a 634-square mile tract located in the vicinity of Rawlins in the eastern part of the study area (Berry, 1960); (b) a reconnaissance-level U.S. Geological Survey report on ground-water conditions in the study area (Welder and McGreevy, 1966); and (c) a reconnaissance-level ground-water report of the study area prepared for the Wyoming Natural Resources Board by a private consultant (Dana, 1962). Some of the information provided in these reports is used herein.

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I. SUMMARY OF FINDINGS

I. SUMMARY OF FINDINGS

1. Eight major water-bearing zones, each consisting of one or more aquifers, have been identified in the Great Divide and Washakie basins. They are: (1) Quaternary aquifers, (2) Upper Tertiary aquifers, (3) the Tertiary aquifer system, (4) Mesaverde aquifer (Upper Cretaceous), (5) Frontier aquifer (Upper Cretaceous), (6) Cloverly aquifer (Lower Cretaceous), (7) Sundance-Nugget aquifer (Jurassic), and (8) the Paleozoic aquifer system. These zones are separated by either stratigraphic unconformities or thick and extensive geologic units of very low permeability (primarily shale). Many of the aquifers are under confined conditions over large area. Yields are generally low, and water quality is poor, relative to other basins of the state.

2. The following aquifers are considered to be the most important ground-water sources in the study area based on estimates of well yield, water quality, and accessibility.

   a. The Tertiary aquifer system is the most important and most extensively distributed and accessible ground-water source in the study area. Permeable sandstones of the Wasatch Formation are present throughout most of the Great Divide and Washakie basins. Sandstones and conglomerates of the Battle Spring Formation are at the surface in the eastern part of the Great Divide basin. The upper Laney Member of the Green River Formation is an important aquifer in the western part of the Washakie basin, where permeable sand lenses intertongue with silts and shales. Sandstones of the Fort Union Formation are considered a major aquifer around the periphery of the basins. Tertiary aquifer system transmissivities range from less than 300 in the Laney Member to more than 1,000 gpd/ft in the Wasatch, Battle Spring, and Fort Union formations.

Shallow (<1,500 feet) Tertiary ground waters from all member aquifers generally contain less than 3,000 mg/l TDS. The Battle Spring and Wasatch aquifers in the Great Divide basin typically yield water with less than 1,000 mg/l TDS, with sodium, calcium, sulfate, and bicarbonate predominating.

b. The permeable unconsolidated sand and gravel aquifers of Quaternary age constitute important water sources in the valleys of the Little Snake River and its major tributaries in the southeastern Washakie basin, and in the area south of the Ferris Mountains in the northeastern Great Divide basin.

Low TDS (<1,000 mg/l) waters are generally available in these areas. Calcium, sodium, and bicarbonate are the principal dissolved constituents. Transmissivity estimates from alluvial aquifers east of the Rock Springs uplift range from 168 to 560 gpd/ft, though water quality in this area is very poor.

c. The Upper Tertiary aquifers are important sources of water in the eastern and western parts of the study area. These aquifers include saturated parts of the Browns Park Formation on the western side of the Sierra Madre uplift, North Park Formation in the vicinity of Rawlins, and South Pass Formation and Bishop Conglomerate in the Rock Springs uplift area. These aquifers are characterized by good interstitial permeability, particularly in conglomerate zones. Transmissivities are generally 1,000 gpd/ft or less, with specific capacities ranging from less than 1 to 1.5 gpm/ft.

Chemical data for the eastern part of the area indicate TDS levels generally below 500 mg/l, primarily as calcium bicarbonate. No data are available for the western part of the area.

d. The Mesaverde aquifer is a major aquifer throughout the study area, but, due to water quality variability, it is considered an important water source only near outcrop areas on the structural uplifts in the eastern and western parts of the study area. Major producing members within the aquifer include the Ericson Formation, and to a lesser degree, the Almond and Rock Springs formations. Transmissivity estimates for the Mesaverde aquifer are generally less than 3,000 gpd/ft, though much lower in the uppermost part of the aquifer (Almond Formation).

Mesaverde outcrop waters generally contain less than 1,000 mg/l TDS, principally as sodium-bicarbonate. Water quality degrades rapidly away from outcrop, with TDS levels exceeding 10,000 mg/l in mid-basin areas where the aquifer is deeply buried.

3. All of the water-bearing units below the Baxter Shale (Frontier, Cloverly, and Sundance-Nugget aquifers and the Paleozoic aquifer system) are considered important sources of water only in the vicinity of their outcrops, where drilling depths are shallow, and these aquifers produce low TDS (<1,000 mg/l) waters. The major ion composition of near-outcrop waters varies from calcium-magnesium-bicarbonate to sodium sulfate. Salinity increases rapidly away from outcrop, generally exceeding 10,000 mg/l in all pre-Baxter aquifers.

4. Ground-water movement within the Great Divide and Washakie basins is generally from topographically high areas along the basin peripheries toward discharge areas in the basin centers. However, available data also indicate some discharge across the western basin boundaries into the Green River basin, and from the Washakie basin into the Sand Wash basin in Colorado. Interaquifer flow across the Baxter Shale is highly restricted, as indicated by segregation of ground-water chemistries.

5. Total estimated water use in the Great Divide and Washakie basins is 80,000 to 89,000 acre-feet/year. Industry uses about 46,000 acre-feet/year. Half the industrial use (25,000 acre-feet/year) is surface water diverted from the Green River for power plant cooling. The remainder (21,000 acre-feet/year) is ground-water use, which is evenly used by the petroleum, coal and uranium industries. Agriculture uses 31,000 to 39,000 acre-feet/year, 95 percent of which is surface water used for irrigation. The remainder (1,800 acre-feet/year) is ground water used for either irrigation or stock watering. Estimated public and private domestic water use is 3,000 to 3,600 acre-feet/year, of which 2,400 acre-feet/year is surface water.

The majority of ground water withdrawn in the Great Divide and Washakie basins is derived from the Tertiary aquifer system and, where drilling depths permit, the Mesaverde aquifer. Petroleum industry ground-water withdrawals are principally oil well by-product water derived from Paleozoic rocks.

II. GENERAL DESCRIPTION OF STUDY AREA

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POPULATION AND LAND USE

The study area encompasses approximately 10,500 square miles located in parts of Sweetwater, Carbon, and Fremont counties in south-central Wyoming (Figure II-1). It extends from T. 12 N. to T. 26 N., inclusive, and from R. 86 W. to R. 103 W., inclusive.

According to the 1980 preliminary census data, the total population of the area is 15,000, or about 1.4 people per square mile (Table II-1). Most of the population is centered about the city of Rawlins (1980 population: 11,547), which is the county seat for Carbon County. Practically all of the residents of Sweetwater County live in towns, oil company camps, or residences near the highways. Vast areas of this region are uninhabited.

More than 50 percent of the land in the area is public domain, administered by the Bureau of Land Management. Most of the remaining land is owned by the Union Pacific Railroad, controlling nearly all odd-numbered sections for 20 miles north and south of the railroad, which roughly bisects the area.

The principal mineral resources of the region are natural gas, oil, coal, oil shale, uranium, and sodium sulfate salts. Gas and oil development is one of the most important stimulations to the local economy. There are also large reserves of high-grade coal. Oil shale occurs in the Green River Formation, especially in the Washakie basin. Uranium-bearing ores have been found in the Great Divide (Pipiringos,

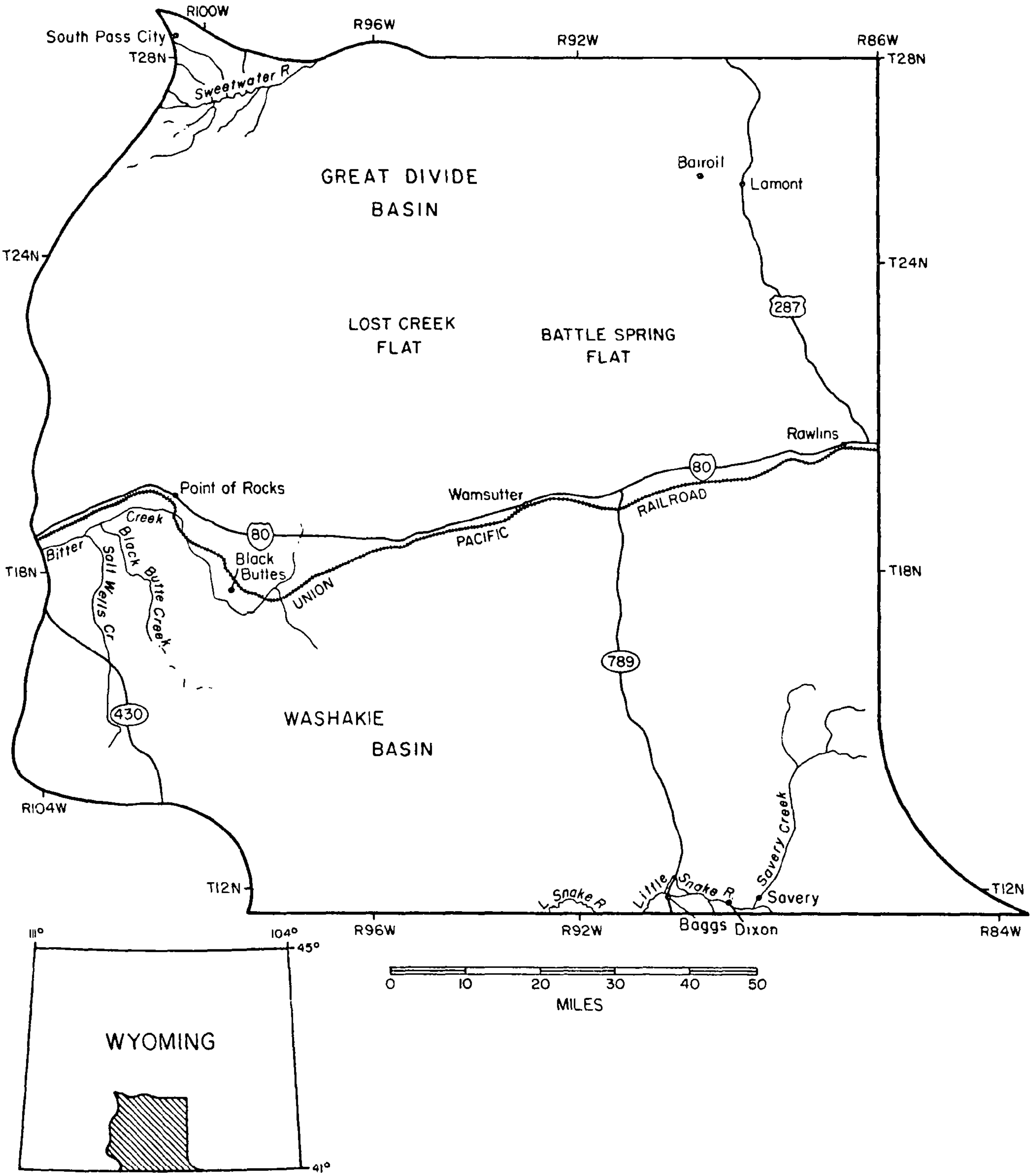

Figure II-1. Great Divide and Washakie basins study area.

Table II-1. Population of the Great Divide and Washakie basins.

County	Locality	1980 Population[a]
Carbon	Baggs	433
	Dixon	82
	Rawlins	11,547
	Rural areas	1,037
Sweetwater	South Superior	586
	Wamsutter	681
	Rural areas	634
TOTAL		15,000

[a]U.S. Department of Commerce, Bureau of the Census, 1980 Census of Population and Housing Preliminary Reports, Wyoming.

1961) and Washakie (Vine and Prichard, 1954) basins and on Miller Hill south of Rawlins (Vine and Prichard, 1959), but the only commercial production in the area is in the southeastern Washakie basin, west of the town of Baggs. Sodium sulfate salts were being mined in 1964 from Bull Lake, 25 miles north of Rawlins in T. 25 N., R. 89 W. (Young, 1951); other commercial deposits may be present in the playa lakes in the Great Divide basin.

In addition to mining, transportation, tourist trade, and agriculture are the basic industries in the region. Agricultural activities include sheep and cattle raising throughout much of the area and farming in the Little Snake River valley, where approximately 20,000 acres are cultivated.

With the exception of several species of sagebrush (Artemesia), more than 90 percent of the region supports little vegetation, although pine, spruce, and aspen grow at the higher altitudes (Welder and McGreevy, 1966).

TOPOGRAPHY AND DRAINAGE

The greater part of the study area is occupied by two large, centrally located basins: the Great Divide basin, also known as the Red Desert basin in the north, and the Washakie basin in the south. In general, the topography of both basins is controlled by and coincides with the major basin and uplift structural features.

The basins are characterized by low-lying plains that grade upward into relatively rugged uplifts, including the Sierra Madre uplift and Rawlins uplift in the east; the Wind River Mountains and Granite Mountains uplift in the north; the Rock Springs uplift in the west; and the Cherokee Ridge along the Wyoming-Colorado state line in the south

(Figure II-1). The Wamsutter arch, a broad subsurface structural feature, structurally separates the basins.

The Great Divide basin is a large structural and topographic basin having an area of about 3,500 square miles. Altitudes range from 6,467 feet in T. 24 N., R. 94 W., section 32, near the center to more than 8,000 feet in some of the adjacent highlands. The rounded ridge and valley topography along the margins has a maximum relief of as much as 400 feet, but toward the middle of the basin vast stretches of sand dunes and playa lakes generally have less than 100 feet of relief. Some parts of the basin are topographically closed and almost no precipitation leaves as surface runoff. Precipitation to the basin seeps into the ground, evaporates, or flows into large playa lakes where additional evaporation and seepage take place. A few of the lakes, such as Hansen Lake in T. 23 N., R. 93 W., section 16, are also fed by springs and contain water during most of the year.

The Washakie basin is about 2,600 square miles in area. Topography in the basin is characterized by high rock rims on the north and southwest, and by isolated, irregularly shaped highlands and lowlands elsewhere. Altitudes range from 6,100 feet near the Little Snake River in the southeast to 8,700 feet at Pine Butte on the west margin. Most of the streams in the basin, except for those such as the Little Snake River and Bitter Creek, flow only for short periods in response to precipitation. Drainage is westward to the Green River and southward to the Little Snake River, and is part of the Colorado River system.

The topography of the Rock Springs uplift, an area of about 1,400 square miles, consists of a central basin and surrounding ridges and mountains. Altitudes average about 6,400 feet in the Baxter basin and over 7,000 feet in the highlands. The lowest point (6,200 feet) is in Bitter Creek at the west side of the uplift, and the highest point (8,680 feet) is on Aspen Mountain in the south half of the uplift. Several igneous extrusive rocks in the north part of the uplift, known as the Leucite Hills, have altitudes in excess of 7,500 feet. Stream drainage is toward Bitter Creek, which flows westward across the middle of the structure to the Green River. Little Bitter, Salt Wells, and Killpecker creeks flow intermittently for much of the year in response to runoff from precipitation and discharge from springs.

The Sierra Madre uplift is topographically higher than other major structures in the study area; altitudes average more than 7,000 feet and range from 6,330 feet in the bed of the Little Snake River near Dixon to 11,007 feet on Bridger Peak.

The Rawlins uplift, an area of about 350 square miles, has rugged topography and altitudes that range from 6,400 to 7,800 feet. The Continental Divide, which separates drainages of the Colorado and Missouri rivers, crosses the uplift 4 miles north of Rawlins, and encircles the northeastern half of the Great Divide basin.

CLIMATE

The climate of the study area is characterized by low precipitation, rapid evaporation, and a wide temperature range. The summers are usually dry and mild and the winters are very cold. Summer days are occasionally hot, but wind and low humidity make the nights relatively cool.

The average annual precipitation at Rawlins in the eastern part of the study area is 11.3 inches; the highest recorded precipitation is 17.0 inches (1912) and the lowest is 3.8 inches (1907) (Berry, 1960).

At Wamsutter, near the center of the study area, and Rock Springs, just west of the study area, precipitation averages 6.3 and 7.0 inches per year, respectively (Welder and McGreevy, 1966). Welder and McGreevy (1966) also indicate that some of the highlands surrounding the basins probably receive 12 to 15 inches of precipitation per year, and part of the Sierra Madre uplift may receive as much as 35 inches in some years. Precipitation is greatest in the spring and summer months, particularly in May and August.

The mean annual temperature is 43.5°F at Rawlins and the length of the growing season generally is about 4 months. In 1953, however, the last day in the spring having a temperature below 32°F was June 25, and the earliest day in the fall having a temperature below 32°F was September 3 (Berry, 1960). The temperature extremes for 18 years of record at Wamsutter are -37°F and +104°F, and the average annual temperature is reportedly 42°F (Welder and McGreevy, 1966).

III. GEOLOGY AND HYDROSTRATIGRAPHY

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GEOLOGIC OUTCROPS AND STRATIGRAPHIC SEQUENCE

The geologic formations that underlie the study area range in age from Precambrian to Recent. Figure III-1 is a general surficial geology map for the area. About 75 percent of the rocks exposed at the surface are post-Cretaceous in age and about 22 percent are of Cretaceous age; the remaining outcrops are Jurassic through Precambrian in age.

A generalized geologic column for the area indicating formation types and stratigraphic sequence is given in Figure III-2. Descriptions of individual formations are provided in Table V-1 (Chapter V).

Figure III-3 shows two east-west and one north-south geologic sections through the study area; locations of the cross-sections are shown in Figure III-4. The Precambrian basement consists of igneous and metamorphic rocks with outcrops that are found mostly in the Sierra Madre uplift in the southeastern part of the area and in some smaller uplift areas in the north and northeast. In the remaining part of the area, the Precambrian is overlain by variable but generally large thicknesses of sedimenary rocks. The greatest thicknesses of sedimentary formations in the area are found in the eastern part of the Great Divide basin and the central Washakie basin. Sedimentary rocks in the Washakie basin may have a thickness in excess of 25,000 feet (Welder and McGreevy, 1966).

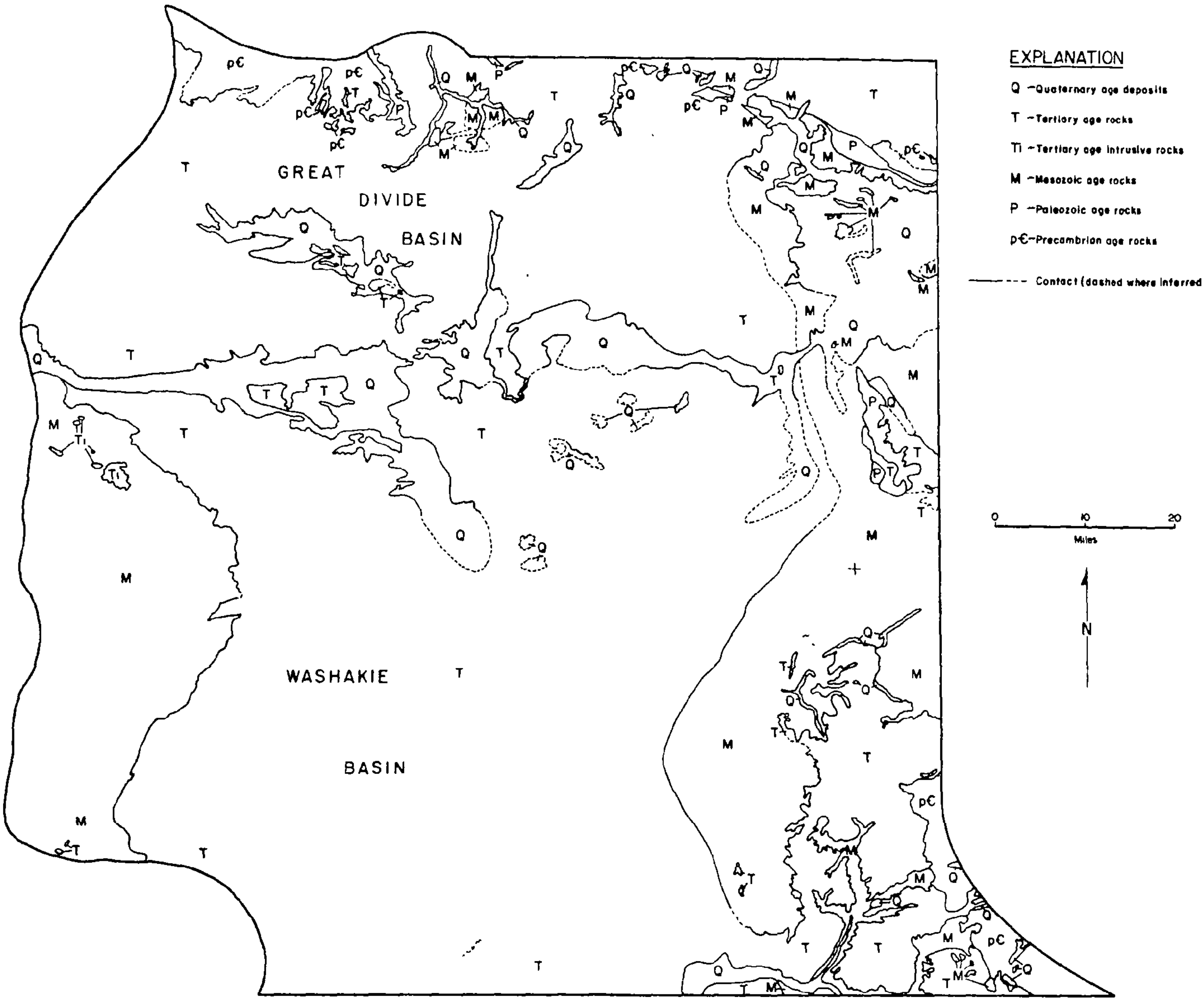


Figure III-1. General surficial geology, Great Divide and Washakie basins.

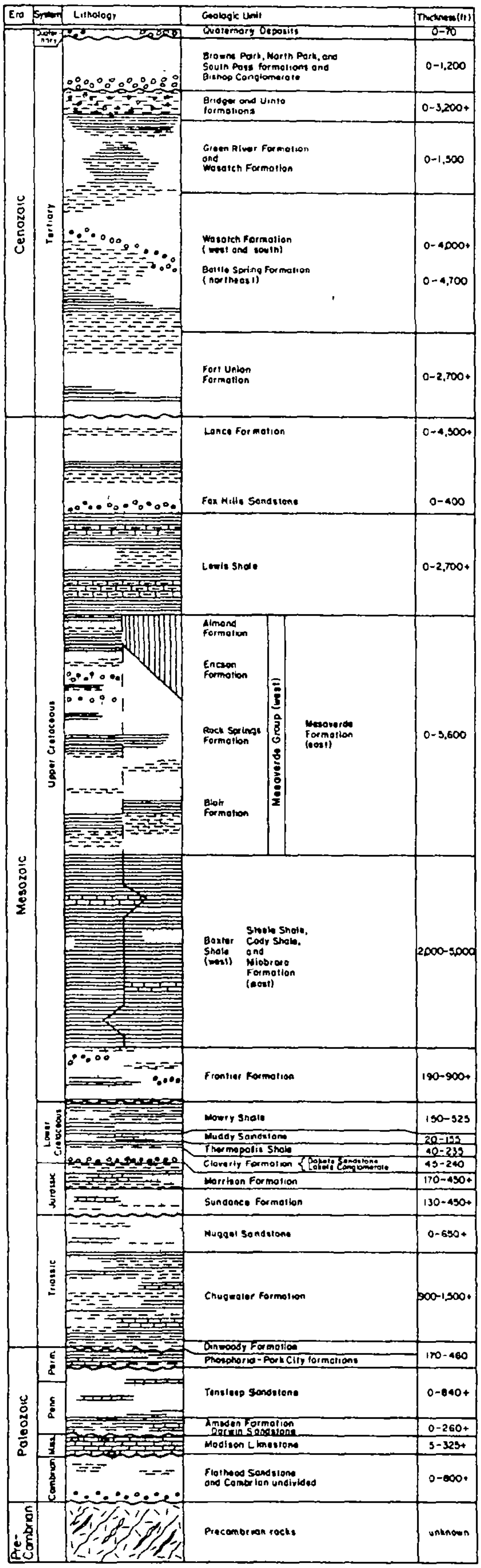


Figure III-2. Generalized geologic column, Great Divide and Washakie basins.

Paleozoic rocks are characterized by an undifferentiated Cambrian sandstone base overlain by the Mississippian Madison Limestone, and the Pennsylvanian Amsden Formation and Tensleep Sandstone. The uppermost Permian Phosphoria Formation is composed of dolomite and shale beds. There are no rocks of Ordovician, Silurian, or Devonian age within the report area. The Paleozoic formations in the area are primarily marine shelf deposits with a maximum reported thickness of about 2,600 feet in the deepest part of the Great Divide basin, though some units thin out or are even absent toward the southeast (Keller and Thomaidis, 1971).

The Triassic and Jurassic rocks of the Mesozoic are essentially shelf or shelf-marginal marine sediments about 3,000 feet thick. Lower units are composed of siltstone, sandstone, and shale in the Dinwoody and Chugwater formations. They are overlain by the Nugget Sandstone and limestones and shales of the Sundance Formation.

Cretaceous deposits consist of alternating and intertonguing sandstone and shale formations. Thick sandstones are found in the Cloverly, Frontier, Mesaverde, and Lance formations. Shales of the Thermopolis, Mowry, Frontier, Niobrara, Baxter, and Lewis formations comprise several thousand feet of cumulative thickness.

Tertiary deposits are composed of intertonguing sandstones, siltstones, and shales. Sandstones are found in the Wasatch, Battle Spring, Fort Union, Browns Park, and North Park formations. Conglomerate and sandstone comprise the South Pass Formation and Bishop Conglomerate. The Bridger and Uinta formations are primarily claystones and siltstones. The Green River Formation consists of fine-

EXPLANATION

○ Water Well
⊛ Oil Well
▲ Spring
⊘ unidentified well

Tma – Moonstone–Arikaree formations
Tnp – North Park Formation
Tbp – Browns Park Formation
Tgr – Green River Formation
Tgl – Laney Member (Green River Formation)
Tbs – Battle Spring Formation
Tw – Wasatch Formation
Twc – Cathedral Bluffs Member (Wasatch Formation)
Tfu – Fort Union Formation
Tu – Tertiary undivided
Kl – Lance Formation
Kfh – Fox Hills Sandstone
Kle – Lewis Shale
Kal – Almond Formation
Ke – Ericson Formation
Kr – Rock Springs Formation
Kbl – Blair Formation
Kmv – Mesaverde Formation
Kb–Kst – Baxter–Steele Shale
Kc – Cody Shale
Kn – Niobrara Formation
Kf – Frontier Formation
Kmd – Muddy Sandstone
Kcv – Cloverly Formation
Kd – Dakota Sandstone
Kla – Lakota Sandstone
Jm – Morrison Formation
Js – Sundance Formation
Jn – Nugget Sandstone
TRc – Chugwater Group
Pp – Phosphoria Formation
IPt – Tensleep Sandstone
IPa – Amsden Formation
Mm – Madison Limestone
Єf – Flathead Sandstone
Є – Cambrian undivided
pЄ – Precambrian

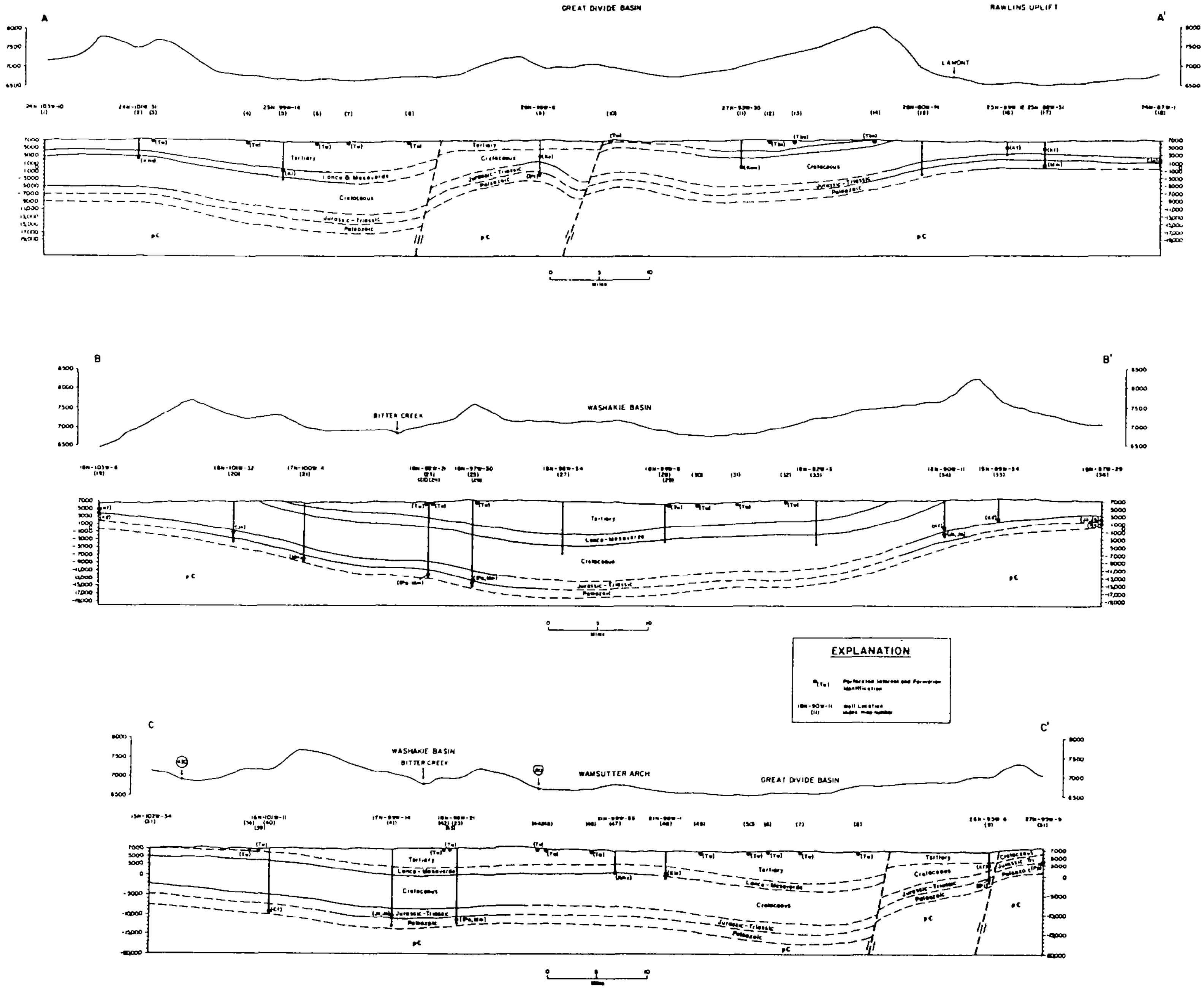


Figure III-3. Structural cross-sections, Great Divide and Washakie basins (locations shown on Figure III-4).

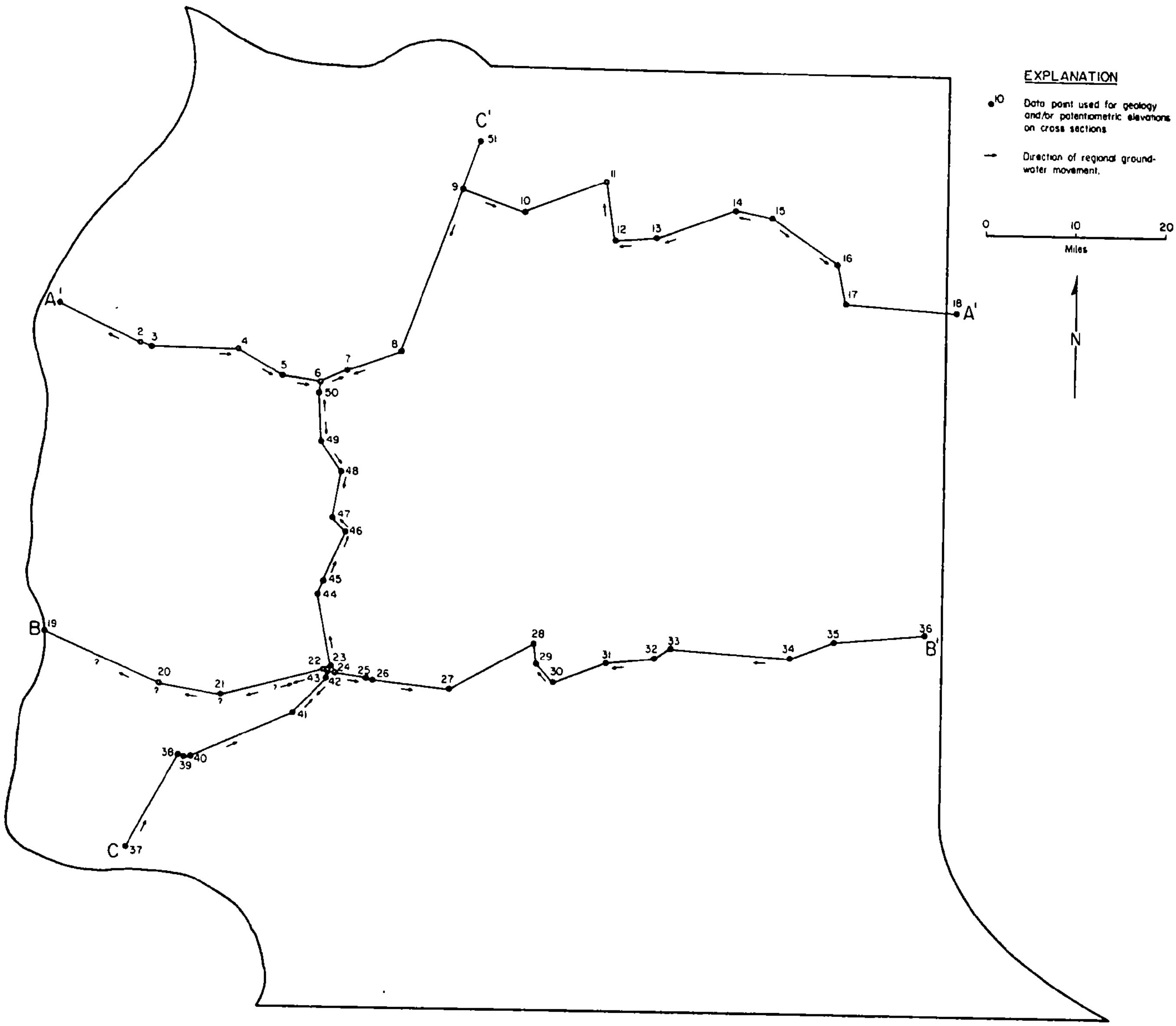


Figure III-4. Index map for structural and potentiometric cross-sections.

grained lacustrine shales with several discontinuous sandstones. The maximum thickness of the Tertiary deposits is estimated at about 14,000 feet (Welder and McGreevy, 1966).

The Quaternary deposits in the study area include Pleistocene to Recent sand, silt, and gravel deposits of glacial, lacustrine, aeolian, and alluvial origin. The maximum thickness of these deposits is approximately 70 feet (Welder and McGreevy, 1966).

STRUCTURAL GEOLOGY

The general structural setting of the Great Divide and Washakie basins is depicted in Figure III-5 and Plate 1.

The Great Divide basin is a broad synclinal depression containing up to 18,000 feet of Paleozoic through Recent sediments which unconformably overlie the Precambrian basement rocks. The axis of the syncline generally trends northwest to southeast and is located northeast of the basin center (Figure II-5). Maximum structural relief in the basin is on the order of 20,000 feet (Keller and Thomaidis, 1971). North-south trending anticlines, the Rock Springs uplift and the Rawlins uplift, bound the basin on the west and east, respectively.

Separating the Great Divide basin from the Wind River basin to the north are a series of major structural features characterized by a major thrust zone on the west side and complicated thrust and normal faulting along the South Granite Mountains fault system to the east (Figure III-5). For a descriptive summary of the structural and tectonic history of the Granite Mountain uplift area, the reader is referred to Heisey (1951), Berg (1961), Love (1970), and Sales (1971).

The Great Divide and Washakie basins are structurally separated by the Wamsutter arch (Figure III-5). The Wamsutter arch is a broad,

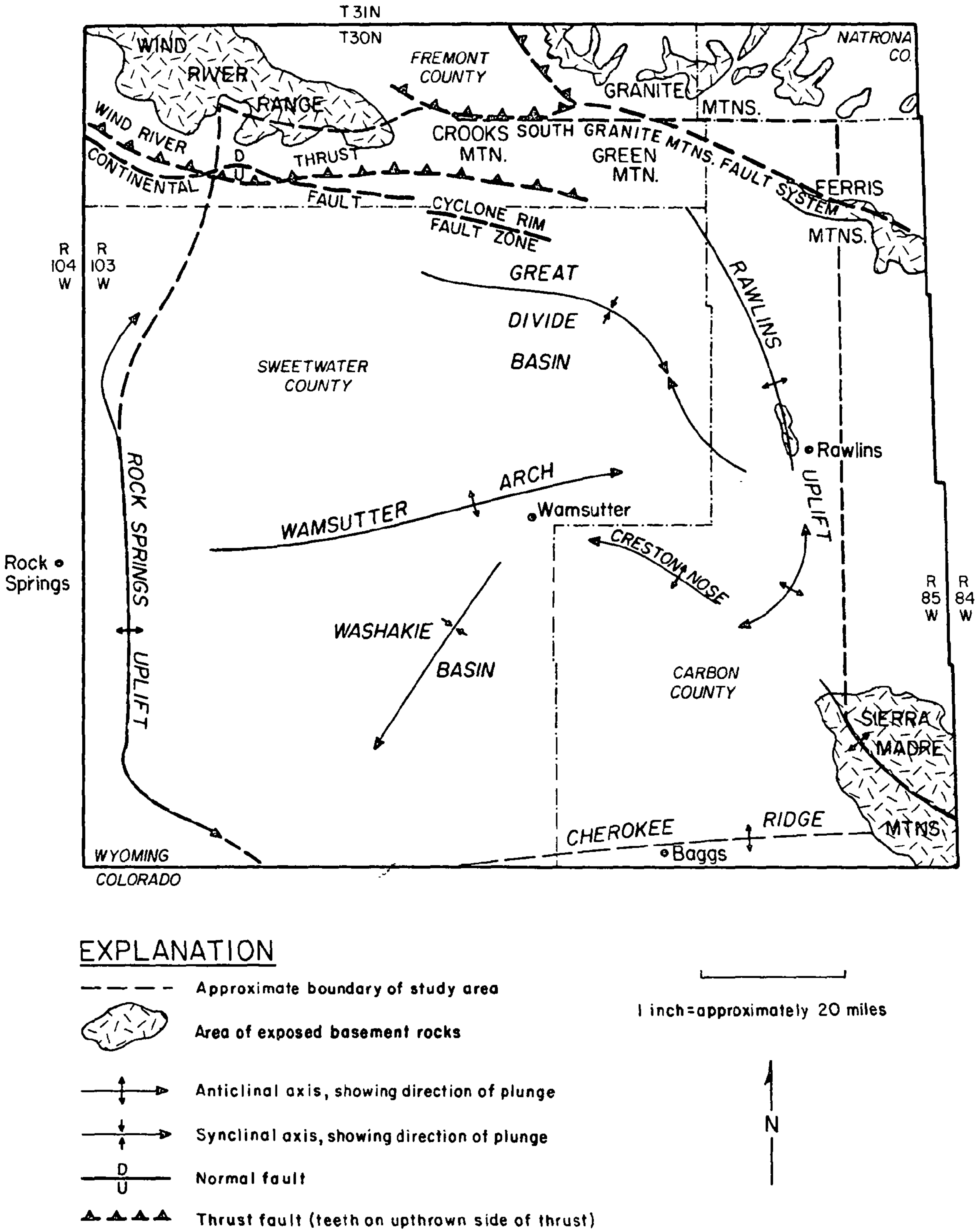


Figure III-5. Major structural features of the Great Divide and Washakie basins (modified from Dana, 1962, and POMCO Geologic Structure map (Plate 1)).

east-west trending anticline with no surface expression (Berry, 1960; Dana, 1962; and Welder and McGreevy, 1966); however, Precambrian rocks along the arch are elevated as much as 9,000 feet above basement rocks of the Washakie basin and 3,000 feet above the Precambrian underlying the western platform of the Great Divide basin (Love, 1961).

The Washakie basin is a deep structural depression, smaller in area and more symmetrical than the Great Divide basin. The axis of the syncline plunges to the southwest and is located close to the center of the basin (Figure III-5). Paleozoic through Recent sedimentary rocks may have a thickness exceeding 25,000 feet in the central Washakie basin (Welder and McGreevy, 1966). On the east and west sides, the Washakie basin is bounded by anticlinal uplifts. Separating the basin from the Sand Wash basin south of the Wyoming-Colorado border is a complex series of east-west trending anticlines and normal faults (Keller and Thomaidis, 1971). Undeformed Tertiary strata extend across these structures (McDonald, 1975).

The major structural features between the study area and basins to the west and east are the Rock Springs uplift, and the Sierra Madre and Rawlins uplifts, respectively.

The north-south trending Rock Springs uplift (Figure III-5) is cut by numerous normal faults with throws commonly less than 100 feet and lengths exceeding 15 miles in some instances (Schultz, 1920). Maximum structural relief at the crest of the uplift is estimated at about 17,000 feet (Love, 1961).

The Sierra Madre uplift (Figure III-5) is a westward thrust block of Precambrian through Early Cenozoic rocks which extends southeastward into the Park Range of Colorado. Anticlinal structures on the west flank of the uplift are genetically related to the westward thrusting of the Sierra Madre fault block (Ritzma, 1949). Vertical and horizontal displacements along faults associated with the Sierra Madre uplift are not known.

The Rawlins uplift (Figure III-5) is a north trending asymmetric anticline with steeply dipping strata on the west flank. Maximum structural relief is estimated at 30,000 feet. A large reverse fault on the west side of the uplift has a reported maximum displacement of about 5,000 feet (Barlow, 1955).

HYDROSTRATIGRAPHY

Various data sources were utilized to identify water-bearing units within the Great Divide and Washakie basin. Spring occurrence and flow is an indicator of saturated, permeable zones within sedimentary strata. Records of water well pump tests and completion intervals provide quantitative data on the hydrologic properties and thicknesses of producing zones. Petroleum test data can provide similar information. Qualitative information on water-bearing capabilities is determined by the lithologic, structural, and secondary features of the rock units.

The hydrologic divisions to which the rock units within the study area have been assigned are identified solely by their water-bearing properties.

The term "aquifer system" is used in this report to identify a group of water-bearing units with (1) relatively similar hydrologic properties, and (2) the absence of extensive regional zones of low vertical permeability that will greatly restrict vertical hydraulic communication within the system. Therefore, an aquifer system typically contains a thick series of permeable zones with interbedded low-permeability intervals, none of which are considered to effectively isolate any specific water-bearing unit.

The term "aquifer" identifies a distinct water-bearing unit that has regional extent and favorable water-bearing potential for exploitation. Aquifers are positioned either within aquifer systems or hydrologically isolated by regionally extensive low-permeability confining beds (aquitards). Aquifers are categorized herein as "major" or "minor" based on their relative regional water-bearing potential.

A total of eight water-producing zones, each consisting of a single aquifer or a number of aquifers, have been identified using the above criteria (Figure III-5). These are: (1) Quaternary aquifers, (2) Upper Tertiary aquifers, (3) the Tertiary aquifer system, (4) Mesaverde aquifer, (5) Frontier aquifer, (6) Cloverly aquifer, (7) Sundance-Nugget aquifer, and (8) the Paleozoic aquifer system. Ground-water occurrence and flow and ground-water quality in each zone are discussed subsequently.

These aquifers and aquifer systems are separated by a number of thick regional confining layers (aquitards) (Figure III-6). Although the aquitards are often capable of transmitting small amounts of water to wells and over large areas and time periods can provide significant interformational flow, they serve principally to hydraulically isolate the more highly permeable zones. The two thickest regionally extensive aquitards are the Upper Cretaceous Lewis and Baxter shales, both more than 2,000 feet thick over much of the area.

Geologic Age	Lithology	Formation	Hydrologic Role	Hydrologic Unit
Quaternary		Alluvial, dune, lake, and glacial deposits	Discontinuous Major Aquifer	Quaternary Aquifers
Tertiary		North Park, Browns Park and South Pass formations and Bishop Conglomerate	Discontinuous Minor Aquifers	Upper Tertiary Aquifers
		Bridger and Uinta formations	Aquitard	
		Green River Formation	Confining Unit with Discontinuous Aquifers	Tertiary Aquifer System
		Wasatch and Battle Spring formations	Major Aquifers	
		Fort Union Formation	Major Aquifer	
Upper Cretaceous		Lance Formation	Minor Aquifer	
		Fox Hills Sandstone		
		Lewis Shale	Major Aquitard	
		Mesaverde Formation	Major Aquifer	Mesaverde Aquifer
		Baxter Shale and equivalents	Major Aquitard	
		Frontier Formation	Minor Aquifer	Frontier Aquifer
Lower Cretaceous		Mowry Shale	Aquitard	
		Thermopolis Shale		
		Cloverly Formation	Minor Aquifer	Cloverly Aquifer
Jurassic		Morrison Formation	Aquitard	
		Sundance Formation	Minor Aquifer	Sundance-Nugget Aquifer
		Nugget Sandstone		
Triassic		Chugwater Formation	Aquitard	
Permian		Phosphoria Formation		
Pennsylvanian		Tensleep Formation	Major Aquifer	Paleozoic Aquifer System
		Amsden Formation	Aquitard	
Mississippian		Madison Limestone	Major Aquifer	
Cambrian		Undifferentiated Cambrian Rocks	Major Aquifer	
Precambrian		Precambrian Rocks	Minor Aquifer	

Figure III-6. Hydrostratigraphic column, Great Divide and Washakie basins.

IV. W A T E R U S E

IV. W A T E R U S E

Water use within the Great Divide and Washakie basins is estimated to be 80,000 to 89,000 acre-feet/year (Table IV-1, Figure IV-1). Industrial water demands, related to energy resource development and power generation, are met by roughly equal volumes of surface and ground water, and require about 46,000 acre-feet/year. Agricultural water use, mainly surface water for irrigation, is estimated to be 31,000 to 39,000 acre-feet/year. Public and private domestic water use is between 3,000 and 3,600 acre-feet/year, and is met primarily by surface-water supplies. Estimates of total surface-water use vary from 56,400 to 64,400 acre-feet/year, with 25,000 acre-feet/year imported from outside the basin. Annual ground-water use is estimated to be between 23,000 and 24,500 acre-feet.

Appendix A details ground-water use for industry, irrigation, and public drinking water supply. Figure IV-2 shows the areal distribution of principal industrial users, all inventoried public drinking water supplies, and irrigation wells. The areal and stratigraphic distribution of permitted domestic use wells is shown on Plate 2.

INDUSTRIAL WATER USE

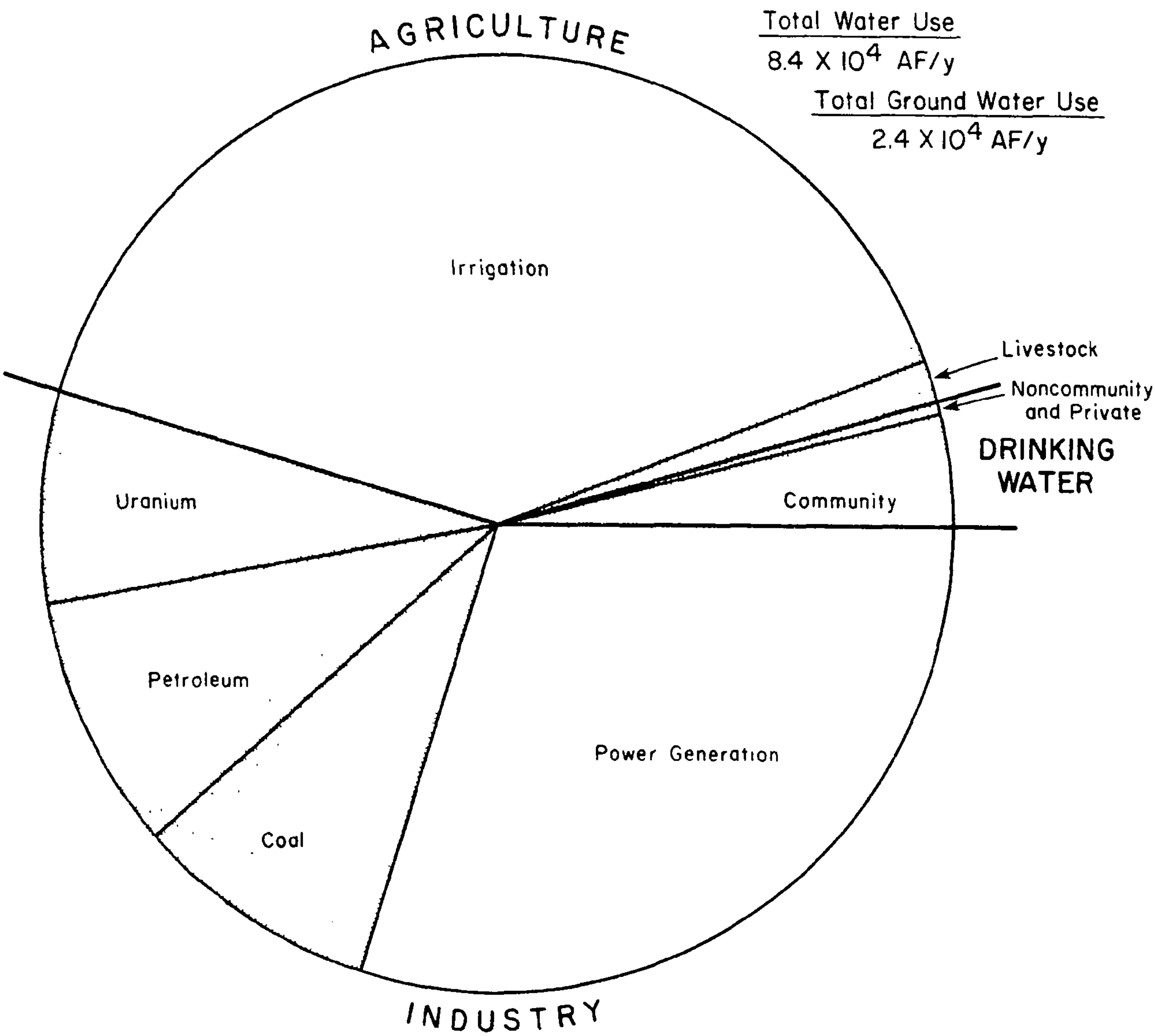
Total industrial water use is about 46,000 acre-feet/year in the Great Divide and Washakie basins. Over half is surface water, diverted from the Green River for power plant cooling use, and the remainder is ground water. Ground-water use is evenly divided between petroleum, coal, and uranium industry users, and all principal aquifers are utilized.

Table IV-1. Estimated water use in the Great Divide and Washakie basins (see text and Appendix A for detailed information).

Economic Sector	Ground-Water Use (acre-feet/yr)	Surface Water Use (acre-feet/yr)	Total Use (acre-feet/yr)
Industry	<20,562-21,550	∿25,000[a]	<45,562-46,550
Petroleum	7,492-7,550	0	7,492-7,550
By-product water	6,510	0	6,510
Fresh water	982-1,040	0	982-1,040
Coal mining	<7,344	0	<7,344
Power production	0	∿25,000[a]	∿25,000
Uranium mining	5,726-6,656	0	5,726-6,656
Agriculture	1,929	29,000-37,000	30,929-38,929
Irrigation	829	29,000-37,000	29,829-37,829
Stock watering	∿1,100	0	1,100
Public and Private Domestic Use	1,158	2,437	3,027[b]-3,595
Community supplies	767	2,409	3,176
Non-community supplies	54	28	82
Private domestic supply	337	0	337
TOTAL	<23,649-24,637+	56,437-64,437	<79,518-89,074

[a]Diverted from the Green River.

[b]Estimate based on total population, undivided by use class or water source.



Economic Sector	Percent total water use	Percent total ground water use	Percent total surface water use
INDUSTRY	55	87	41
AGRICULTURE	41	8	55
DRINKING WATER	4	5	4

Figure IV-1. Percent total water use arranged by economic sector. Shaded areas designate percent ground-water use, unshaded areas designate surface-water use.

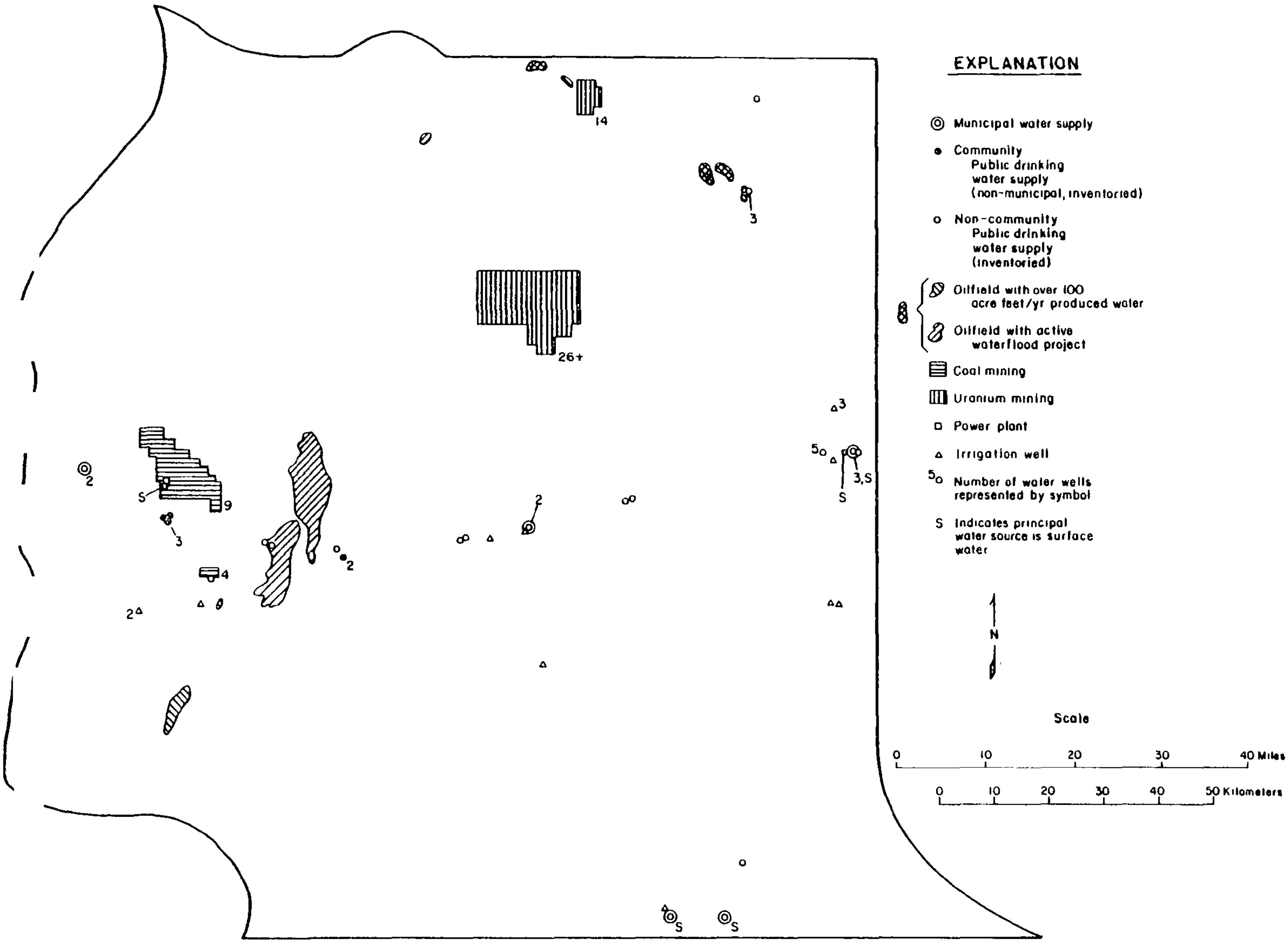


Figure IV-2. Areal distribution of water users.

Petroleum Industry

The petroleum industry uses about 7,500 acre-feet of ground water annually in the Great Divide and Washakie basin. Although most water used is a by-product of petroleum production, about 13 percent is fresh water used to enhance oil recovery through waterflooding.

In 1979, a total of 6,510 acre-feet of water were produced as a by-product of oil and gas production at 61 active fields through 743 wells (Appendix A, Table A-1). An additional 45 fields with 133 wells produced no water, according to operator reports. There are another 53 fields in the basins with no reported 1979 production; 20 of these fields are classed as abandoned. Paleozoic and Lower Cretaceous strata yield most of the produced water in the basins. The overlying Frontier and Mesaverde formations produce significant amounts of gas, but little associated water. Roughly 60 percent of the total produced water is from Paleozoic strata at the Lost Soldier Field (T. 26 N., R. 90 W.).

A total of 3,676 acre-feet of water was injected during 1979 to enhance petroleum recovery through waterflooding at 10 units in six fields (Appendix A, Table A-2). Sixty percent of this water was injected into the Tensleep Sandstone at the Lost Soldier and Wertz fields.

Most secondary oil recovery projects in the study area inject solely produced water. Those projects which use "fresh" (make-up) water from other ground-water sources withdrew about 1,000 acre-feet in 1979. About 70 percent of the fresh water used for waterflooding in the basins is derived from the Fox Hills Sandstone of the Tertiary aquifer system and injected into the Mesaverde Formation at the Patrick Draw Field (T. 18 N., R. 99 and 100 W.). More detailed information on water injection projects in Wyoming can be found in Collentine and others (1981).

Coal Industry

The two active coal mines within the Great Divide and Washakie basins produced an estimated 6,900,000 tons of coal from the Fort Union Formation in 1979 (Glass, 1980). Production levels should double in the next few years as the Black Butte Mine becomes fully developed. Currently most coal production in the basin is utilized in the Jim Bridger Power Plant, with expected production increases contracted to out-of-state users.

The active coal mines in the basin hold 13 water well permits with permitted yields totaling 4,500 gpm (Appendix A, Table A-3). If fully utilized, the maximum permitted ground-water use is 7,344 acre-feet/year, but intermittent production by these wells is expected. Exact water use data are unavailable. The primary coal mine water use is for dust control; other uses include equipment washdown and irrigation.

The Bridger Coal Company obtains its water from pit dewatering wells completed in the Fort Union Formation of the Tertiary aquifer system, while the Black Butte Coal Company taps the Ericson Formation of the Mesaverde aquifer.

The Jim Bridger Power Plant is a 4-unit, 2,000-megawatt, coal-fired steam-generated electric power plant operated by Pacific Power and Light. Approximately 25,000 acre-feet of cooling water, diverted from the Green River, are used annually. Most waste water is discharged to evaporation ponds but up to 750 acre-feet/year are used for irrigation at the Jim Bridger Mine.

Uranium Industry

The Crooks Gap-Green Mountain uranium district is located in the northeastern part of the Great Divide basin and produces uranium from the Tertiary Battle Spring Formation. Annual water use at the two active mines is about 5,700-6,700 acre-feet (see Appendix A, Table A-4), and is entirely derived from the Tertiary aquifer system. A commercial scale in-situ mine, approved by the Wyoming Department of Environmental Quality, has a planned plant capacity of 1,200 gpm; little water will be used because fluids are to be recirculated in closed cycle during both mining and restoration. Numerous uranium test holes have also been drilled within the basins, but no water is produced from these wells.

AGRICULTURAL WATER USE

Agriculture uses minimal amounts of water in the Great Divide and Washakie basins, in comparison to the rest of the state. Total annual water use is about 31,000 to 39,000 acre-feet, most of which is surface water used for irrigation.

Irrigation

Little irrigation is conducted within the Great Divide and Washakie basins, and most irrigated acreage is supplied by surface-water rights along the Little Snake River. Permitted irrigation using ground water represents only one to two percent of total irrigation.

Inventories of acreage with valid surface-water rights have been conducted at various times (Smith and Associates, 1965; Worthington and others, 1965; Wyoming Water Planning Program, 1971). Within the drainages of the Little Snake and Sweetwater rivers, Bitter Creek, and the Great Divide basin, there are valid surface-water irrigation rights for about 53,000 acres of land; over half are in the Little Snake River drainage area and most of the remainder lie outside the basin boundaries. Inventories of the amount of land irrigated in the same area during 1968 and 1969 (Wyoming Water Planning Program, 1970 and 1971) determined that only approximately 22,000 acres of land were actually irrigated, and almost two-thirds were in the Little Snake River drainage.

Ground water is permitted as a source of irrigation water for 492.5 acres. It is obtained from 13 wells with a total permitted yield of 7,766 gpm (Appendix A, Table A-5). The majority of water is derived from the Mesaverde and Upper Tertiary aquifers.

Trelease and others (1970) determined irrigation water requirements of grass at four climate stations in the basins, using the Blaney-Criddle method. They found water needs were 20.08, 21.90, 18.55, and 12.83 inches per acre per year at Rawlins, Wamsutter, Dixon, and South Pass City, respectively. The first three stations, located in more arid central basin areas, average 20.2 inches per year. On the basis of acreage for which ground water is permitted as a water source and this average water requirement, irrigation in the basins uses about 800 acre-feet of ground water annually. Assumptions incorporated into this estimate include: (1) irrigation of 100 percent of permitted acreage, (2) all irrigated acreage is grass or crops with similar water needs, (3) 100 percent of calculated water needs are met, and (4) no excess water is applied and lost as waste. Surface water use for irrigation totals about 37,000 acre-feet/year using the same estimating technique. The actual amount of surface water used for irrigation may be only 16 inches/acre/year (Wyoming Water Planning Program, 1970), giving a lower water use estimate of 29,000 acre-feet/year.

Little increase in irrigated acreage in the Great Divide and Washakie basins is anticipated (Wyoming Water Planning Program, 1970 and 1971) with the exception of the Savery-Pot Hook Project, which will use surface water from the Little Snake River to irrigate an additional 7,000 acres of cropland.

Stock Watering

Sparseness of vegetation limits the numbers of cattle and sheep within the Great Divide and Washakie basins; estimated populations are 53,800 cattle and 73,900 sheep. These estimates are derived from 1979 county stock population reports (Wyoming Crop and Livestock Reporting Service, 1979), proportionally divided on the basis of county area within the study area boundaries.

Total stock use of water is about 1,100 acre-feet/year based on estimated populations and consumption rates of 15 and 3 gpd per capita for cattle and sheep, respectively. The proportion of stock water supplied by surface sources is presumed small due to the scarcity of dependable surface flow. Because stock water from underground sources is typically supplied by shallow, low-yield, intermittently producing wells at the point of use, the major ground-water source for stock water is the areally extensive Tertiary aquifer system.

PUBLIC AND PRIVATE DOMESTIC WATER USE

Drinking water supplies can be divided into public and private systems. Public systems include community systems, serving more than

25 permanent residents, and noncommunity systems, serving less than 25 permanent residents but a transient population greater than 25. Within the Great Divide and Washakie basins there are 12 community systems and 15 noncommunity systems listed in the U.S. Environmental Protection Agency Public Water System Inventory (1979) (see Appendix A, Tables A-6 and A-7).

The total number of completed wells permitted by the Wyoming State Engineer for domestic use within the basin boundaries was 202 as of February, 1980. The locations of these wells are shown on Plate 2, which also identifies source aquifers.

Estimated total public and private domestic water use in the Great Divide and Washakie basins is 3,027 acre-feet/year, based on a population of 15,000 and per capita use of 180 gpd. Estimated use by individual supply class (U.S. Environmental Protection Agency, 1979) totals 3,595 acre-feet/year, which is somewhat higher than the above estimate. Community systems account for 88 percent of this higher total (3,176 acre-feet/year) and noncommunity systems account for only 82 acre-feet/year. Private domestic use is estimated at 337 acre-feet/year, based on a rural population of 1,671 and daily consumption of 180 gallons per capita.

Over two-thirds (2,437 acre-feet/year) of the total estimated domestic water use is surface water, diverted from the North Platte drainage basin to supply Rawlins, the Little Snake River to supply Baggs and Dixon, and the Green River to supply the Jim Bridger Power Plant. Ground-water sources supply most of the remaining 590 to 1,158 acre-feet/year of water used for domestic purposes, generally through intermittently pumped, relatively shallow wells at the point of use.

The principal aquifers utilized are the Tertiary aquifer system in much of the area, Upper Tertiary aquifers (where present in the eastern uplift areas), the Mesaverde aquifer near outcrops, and the Paleozoic aquifer system near Rawlins.

V. GROUND-WATER OCCURRENCE AND FLOW PATTERNS

V. GROUND-WATER OCCURRENCE AND FLOW PATTERNS

This chapter presents a thorough description of individual water-bearing zones, and discusses ground-water flow patterns within the study area.

MAJOR WATER-PRODUCING ZONES

The water-producing zones discussed below range in age from Quaternary to Precambrian, and will be considered in descending stratigraphic order. The stratigraphic sequence of these zones and the confining beds separating them can be seen in Figures III-2 and III-6. Information on formation type, thickness, and water-bearing characteristics are summarized in Table V-1. The results of aquifer tests and yields of all wells and springs on record are tabulated by formation in Appendix C. Transmissivity data based on estimated calculations from drill stem tests and specific capacities are, at best, accurate only to an order of magnitude. The methodology used to determine transmissivity is described in Appendix D.

Quaternary Aquifers

The Quaternary aquifers consist of unconsolidated sand and gravel formations, mainly of alluvial origin, interbedded with lake and wind-blown sediments. The Quaternary sediments occur in several localities throughout the Great Divide basin; in the Washakie basin, they occupy the flood plains of the Little Snake River and its major tributaries, Bitter Creek, Shell Creek, Vermillion Creek, and Alkali Creek (see

Table V-1. Generalized stratigraphy, lithology and water-bearing characteristics of geologic formations in the Great Divide and Washakie basins.[a]

Era	Period	Geologic Unit	Thickness (ft.)	Lithologic Description	Hydrologic Properties
Cenozoic	Quaternary		0-70	Unconsolidated alluvial clay, silt sand and gravel along Little Snake River valley, playa lake deposits of clay, silt, and sand present in Great Divide basin, and sand dunes of northern Rock Springs uplift, west-central Great Divide basin and north of the Rawlins uplift. Also glacial clay, silt, sand, and gravel on the flanks of the Sierra Madre Mountains.	Sand and gravel deposits capable of supplying stock and domestic water supplies. Utilized extensively in Little Snake River valley and area north of Rawlins uplift. Well yields are generally less than 30 gpm. Springs south of Ferris Mountains flow up to 20 gpm. Transmissivity estimates from area east of Rock Springs uplift are 168 to 560 gpd/ft. Calculated permeabilities in same areas range from 21 to 62 gpd/ft^2. Fine-grained lake deposits will produce poor yields.
	Tertiary	North Park Formation	0-800	Fine- to medium-grained sandstone, tuff and limestone with a basal conglomerate member up to 100 feet thick. Present in the northwest Sierra Madre uplift.	Minor aquifer that supplies excellent quality spring water to City of Rawlins. Three wells yield 4 to 20 gpm. Transmissivity estimates from two pump tests are 150 and 1,000 gpd/ft. Specific capacity values from same tests are .06 and 1.43 gpm/ft.
		Browns Park Formation	0-1,200	Sandstone, tuffaceous, sandy claystone, and conglomerate. Present on the Rock Springs uplift, southern Washakie basin, western Sierra Madre uplift and possibly along the northern edge of the Great Divide basin. Basal conglomerate up to 100 feet thick with quartz and quartzite boulders, cobbles, and pebbles in sandstone and volcanic ash. Uranium occurrences near Baggs, Wyoming.	Unit is considered an excellent aquifer with good interstitial permeability, particularly in the basal conglomerate zone. Well yields range from 3 to 30 gpm with specific capacities generally between 0.03 and 1.0 gpm/ft (10 wells). Transmissivity estimates are 100 to 10,000 gpd/ft. Numerous springs maintain base flow of streams south of the Rawlins area. One spring flows 343 gpm. Possible saturated zone 870 feet thick, based on water depths in wells.
		Bishop Conglomerate	0-200+	Conglomerate with well rounded boulders and cobbles of quartzite limestone and schist. Present in southern Rock Springs uplift area.	Major aquifer in Rock Springs uplift area, though absence of thick, saturated zones limits well yields. One well yields 42 gpm. Good interstitial permeability.
		Uinta Formation Bridger Formation (Washakie Formation in Washakie Basin)	0-3,200+	Tuffaceous claystone with tuffaceous, fine-grained, lenticular sandstone and minor amounts of shale, limestone, and dolomite. Present mainly in central Washakie basin. Tuffaceous clastic sediments present in NW Great Divide basin.	Relatively impermeable unit with only one questionably identified well and no spring data reported. Very low yields are expected.
		Green River Formation (includes Tipton, Wilkins Peak, and Laney members)	0-1,500	Generally, a thick lens of fine-grained, calcareous lake sediments-oil shale, mudstone, shale and sandy mudstone, with few, relatively thick sandstone lenses, particularly in the upper part of the unit (Sand Butte Bed of Laney Member), and some evaporite deposits in the middle part (Wilkins Peak Member).	Laney Member of the Green River Formation includes sandstone lenses which yield up to 200 gpm to wells, particularly in the western Washakie basin. Other members are relatively impermeable and would produce very low yields to wells. Laney transmissivities range from 110 to 300 gpd/ft. Permeability in the Laney averages around 10 gpd/ft^2 and the storage coefficient is between 3.4×10^{-5} and 5.9×10^{-4}.

Table V-1. (continued)

Era	Period	Geologic Unit	Thickness (ft.)	Lithologic Description	Hydrologic Properties
Cenozoic	Tertiary	Wasatch Formation	0-4,000+	Claystone, siltstone, fine-to medium-grained, calcareous sandstone, carbonaceous shale, oil shale, and coal. Grades eastward into Battle Spring Formation in eastern Great Divide basin.	Major aquifer of Tertiary aquifer system. Numerous water-bearing sandstone lenses yield 5 to 250 gpm (~90 wells) though most yields are 30 to 50 gpm. Wells tapping the lower sands are artesian in some areas. Transmissivity estimates from 9 pump tests are 150 to 10,000 gpd/ft. Specific capacities for same wells range from 0.17 to more than 10 gpm/ft. Porosity and permeability from 6 oil field reports are 16 to 38 percent and 0.04 to 18.2 gpd/ft^2, respectively. Yield-drawdown relationships from 5 wells indicate possible yields of 500 gpm from thick, saturated sequences.
		Battle Spring Formation	0-4,700	Arkosic, fine-to coarse-grained sandstone and claystone with boulder conglomerate near the Green Mountains. Intertongues with Wasatch and Green River formations to the west. Uranium deposits in Crooks Gap area.	Major aquifer of eastern Great Divide basin. Well yields range from 1 to 157 gpm. Estimates of transmissivity are 29 to 3,157 gpd/ft from 26 test wells. Specific capacity is typically less than 1 gpm/ft. Pay zone porosity at one oil field is 15 to 25 percent. Estimated coefficient of storage is 1 x 10^{-3}.
		Fort Union Formation	0-2,700+	Fine-to coarse-grained sandstone, carbonaceous shale, and coal with minor siltstone and claystone in the upper part.	Major aquifer, particularly around the periphery of the basins. Water-bearing sandstones are lenticular causing discontinuous, isolated water-bearing zones. Well yields range from 3 to 300 gpm Transmissivity estimates are generally less than 2,500 gpd/ft. Porosity and permeability are 15 to 39 percent and less than 1 gpd/ft^2, respectively, based on oil field and coal mine reports. Specific capacity ranges from less than 0.001 to 75 gpm/ft (6 pump tests). Permeability is largely fault-related on east side of Rock Springs uplift.
Mesozoic	Upper Cretaceous	Lance Formation	0-4,500+	Very fine- to fine-grained, clayey, calcareous sandstone with shale, coal and lignite. Sandstone lenses up to 20 feet thick at intervals within the formation near Rawlins.	Minor aquifer of Tertiary system with well yields typically less than 25 gpm. Transmissivity estimates are generally less than 20 gpd/ft with two estimates of 150 and 200 gpd/ft. Oil field porosity and permeability are 12 to 26 percent and 0.007 to 8.2 gpd/ft^2, respectively.
		Fox Hills Sandstone	0-400	Fine-to medium-grained, cross-stratified, calcareous sandstone.	Minor aquifer at base of Lance Formation. Well and spring yields not available. Oil field reports indicate pay zone porosity, permeability, and transmissivity of 20 percent, 0.9 gpd/ft^2, and 10 to 20 gpd/ft, respectively.

Table V-1. (continued)

Era	Period	Geologic Unit	Thickness (ft.)	Lithologic Description	Hydrologic Properties
Mesozoic	Upper Cretaceous	Lewis Shale	0-2,700+	Calcareous to non-calcareous, carbonaceous shale, with numerous beds of siltstone and very fine-grained sandstone.	Aquitard between underlying Mesaverde aquifer and overlying Tertiary aquifer system. Mostly impermeable shale, but scattered sandstone lenses may be capable of yielding stock supplies. Porosity ranges from 6 to 24 percent, permeability from 0.002 to 0.9 gpd/ft^2, and transmissivity from 0.03 to 50 gpd/ft, based on oil field data.
		Mesaverde Formation (Mesaverde Group near Rock Spring Uplift includes Blair, Rock Springs, Ericson, and Almond formations)	0-2,800 (2,200-5,600 on west side of study area)	Massive, very fine- to medium-grained sandstone with carbonaceous shale, lignite and coal.	Major aquifer throughout study area. Maximum well yield is 470 gpm from Rock Springs Formation. Most reported yields are less than 100 gpm. Transmissivity estimates are generally less than 3,000 gpd/ft and much lower in the uppermost part of the aquifer (Almond Fm). Porosity ranges from 8 to 26 percent. Ericson Formation is best water source near Rock Springs uplift.
		Baxter Shale (includes Cody and Steele shales, and Niobrara Formation)	2,000-5,000+	Shale with minor, interbedded sandstone, siltstone, and limestone.	Major regional aquitard between Mesaverde and Frontier aquifers throughout area west of Rawlins uplift. Thin sandstone beds may yield small quantities of water; however, high TDS concentrations are likely.
		Frontier Formation	190-900+	Sandstone and shale with bentonite beds and lenses of chert-pebble conglomerate.	Productive aquifer, particularly in the eastern part of the study area near outcrop. Yields range from 1 to more than 100 gpm with specified capacities between 0.29 and 30 gpm/ft. Transmissivity estimates from water well pump tests were 15,000 to 20,000 gpd/ft; however, drill stem test transmissivities were generally less than 100 gpd/ft with a maximum of 6,500 gpd/ft. Variability probably due to varying percentage of bentonite and shale within the tested interval.
	Lower Cretaceous	Mowry Shale	150-525	Siliceous shale with siltstone and bentonite.	Unit is considered a regional aquitard. Well and spring data are not available.
		Thermopolis Shale (includes Muddy Sandstone Member)	40-235 (20-155)	Fissile shale containing a few thin beds of sandstone, siltstone, and bentonite. The Muddy Sandstone Member consists of fine-grained, shaly sandstone and interbedded siltstone and shale.	Unit is considered a leaky confining unit; however, water is produced from the Muddy Sandstone Member at oilfields in the northeast Great Divide basin. Well and spring data are not available.
		Cloverly Formation	45-240	Sandstone, shale, conglomerate, and a lesser amount of siltstone.	Major Mesozoic aquifer which crops out on Rawlins uplift. Deeply buried over most of the study area. Water well yields range from 25 to more than 120 gpm with specific capacities between 0.26 to 1.36 gpm/ft. Water well and drill stem test transmissivities are 340 to 1,700 and 1 to 177 gpd/ft, respectively.

Table V-1. (continued)

Era	Period	Geologic Unit	Thickness (ft.)	Lithologic Description	Hydrologic Properties
Mesozoic	Upper Jurassic	Morrison Formation	170-450+	Variegated claystone, shale, lenticular sandstone, and minor conglomerate and limestone.	Confining unit between the Cloverly and Sundance-Nugget aquifers. Well and spring data unavailable.
		Sundance Formation	130-450+	Sandstone, shale, siltstone, and limestone; upper part is glauconitic.	Upper unit of the Sundance-Nugget aquifer. Artesian flow to several wells in Rawlins area. Well yields between 27 and 35 gpm (3 wells). Specific capacity at one well is 0.17 gpd/ft. Transmissivity ranges from 12 to 3,500 gpd/ft.
	Lower Jurassic-Upper Triassic	Nugget Sandstone	0-650+	Fine- to medium-grained sandstone with minor, interbedded shale and siltstone.	Lower unit of the Sundance-Nugget aquifer. Two well yields reported, 35 and 200 gpm. Maximum transmissivity from drill stem tests was 2,166 gpd/ft.
	Triassic	Chugwater Formation	900-1,500+	Shale, siltstone and interbedded, fine-grained sandstone.	Generally considered a confining unit between Sundance-Nugget aquifer and Paleozoic aquifer system. Hydrologic data not available for Chugwater.
Mesozoic-Paleozoic	Lower Triassic-Permian	Phosphoria Formation (includes Phosphoria Formation and intertonguing Permian Park City, Goose Egg and Lower Triassic Dinwoody formations)	170-460	Interbedded shale, siltstone, sandstone, and limestone.	Water-bearing capabilities for these formations are unknown in the study area, but are probably poor, due to low permeability of the rock units.
Paleozoic	Permian-Pennsylvanian	Tensleep Formation	0-840+	Fine- to medium-grained, quartzitic sandstone and lesser amounts of thin, interbedded limestone and dolomite. Absent in the southeast part of the area. Crops out on Rawlins uplift.	Important water-bearing zone of Paleozoic aquifer system. Well yields range from 24 to 400 gpm. One spring flows 200 gpm in Rawlins area. Transmissivity is generally low, ranging from 1 to 374 gpd/ft.
	Lower and Middle Pennsylvanian	Amsden Formation	0-260+	Sandstone, shale, and siltstone with cherty limestone. Approximately 60 feet of basal, fine-grained sandstone (Darwin Sandstone Member). Amsden is absent in the southeast part of the area.	Hydrologic data are not available; unit probably has poor water-bearing potential due to predominance of fine-grained sediments.
	Mississippian	Madison Limestone	5-325+	Limestone, dolomite, and lesser amounts of thin-bedded sandstone and chert.	Major aquifer of Paleozoic system. Excellent secondary permeability development due to solution channeling, caverns, and fractures. Well yields up to 400 gpm are reported with specific capacities of 100 gpm/ft at two wells. Reported transmissivities are highly variable.

Table V-1. (continued)

Era	Period	Geologic Unit	Thickness (ft.)	Lithologic Description	Hydrologic Properties
Paleozoic	Cambrian	Undifferentiated Cambrian rocks	0-800+	Quartzitic, conglomeratic sandstone in the lower part; upper part consists of glauconitic sandstone and inter-bedded siltstone, shale, and limestone.	Major water-bearing zone, especially near Rawlins, where 13 wells are completed in Cambrian units. Wells yield between 4 and 250 gpm. Specific capacities at two wells were 0.67 and 150 gpm/ft. Transmissivity data are suspect.
Precambrian	-	-	unknown	Granite, gneiss, and schist exposed in Sierra Madre and Rawlins uplifts, and along northern edge of Great Divide basin.	Frequently utilized aquifer in the north-western corner of the Great Divide basin, near South Pass City. Well yields typically range from 10 to 20 gpm with specific capacities between 0.5 and 2 gpm/ft. Most reported transmissivity values are less than 1,000 gpd/ft. Generally high permeability in fractured and weathered zone in upper 200 feet of the unit.

[a]Data Sources: Berry, 1960; Black Butte Coal Mine Report; Bradley, 1945; Dana, 1962; Pipiringos, 1955; Randall, 1960; Roehler, personal communication, 1981; Roehler, 1973; Stephens, 1964; Sullivan, 1980; Welder and McGreevy, 1966; Wyoming Geological Association, 1979; Woodward Clyde Consultants, 1980.

Figure III-1). Maximum total thickness for the Quaternary sediments is estimated at 70 feet.

Hundreds of water wells are completed in the coarse sand and gravel of the Little Snake River Valley where yields of 25 to 50 gallons per minute (gpm) are common. One well in that area yields 300 gpm (T. 12 N., R. 91 W., section 5 ad). South of the Ferris and Green mountains, wind-blown sand is typically 50 to 70 feet thick, and reported well and spring yields range from 1 to 20 gpm. East of the Rock Springs uplift, monitoring wells at the Black Butte Coal Mine produced 5 to 30 gpm from the alluvium of Bitter Creek (Black Butte Coal Co., 1981), though these waters are of generally poor quality (Chapter VI).

Transmissivities in the alluvial aquifer near the Jim Bridger Coal Mine (T. 19 and 20 N., R. 99 W.) are 168 to 500 gallons per day per foot (gpd/ft) with calculated permeabilities of 21 to 62 gallons per day per square foot (gpd/ft^2) (Woodward-Clyde Consultants, 1980).

The Quaternary deposits are not productive everywhere they occur. In the Rawlins area, Quaternary deposits generally lie above the water table. The deposits are highly permeable, absorb rainfall and ephemeral streamflow, and transmit it downward into the underlying formations (Berry, 1960). The Quaternary lake deposits in the interior of the Great Divide basin consist of predominantly fine-grained sediments and are poor aquifers (Welder and McGreevy, 1966).

Upper Tertiary Aquifers

These aquifers consist of conglomerates and sandstones of the Bishop Conglomerate, Browns Park Formation, South Pass Formation, and North Park Formation. They vary in thickness depending on location, but generally are several hundred feet thick. These formations do not overlie one another; they have been identified at different localities and are considered as equivalents. Major outcrop areas include the Bishop Conglomerate in the southern part of the Rock Springs uplift; the Browns Park Formation along the west side of the Sierra Madre uplift; and the North Park Formation in the Rawlins area (Berry, 1960; Welder and McGreevy, 1966).

The Upper Tertiary aquifers are either exposed at the land surface or blanketed by a thin cover of Quaternary sediments. Locally, Upper Tertiary deposits are separated from Quaternary deposits by intrusive and extrusive rocks north of Rock Springs and east of Baggs (Love and others, 1955).

Quantitative data from 43 water wells were used to evaluate the hydrologic properties of the Upper Tertiary aquifers. Sources for the well data are Dana (1962), Welder and McGreevy (1966), U.S. Geological Survey well records, well permit records from the Wyoming State Engineer's Office, and one preliminary coal mine report.

Well data indicate that the Browns Park Formation is the most productive unit of the Upper Tertiary. This formation consists of about 100 feet of basal conglomerate and up to 1,000 feet of fine- to medium-grained sandstone. Water well yields of up to 30 gpm are common. Berry (1960) reports that several Browns Park wells south of Rawlins have reached water at only 5 to 128 feet, indicating a possible zone of saturation at least 870 feet thick. One spring in that area flows 343 gpm (Welder and McGreevy, 1966). It is also reported that springs issuing along the contact of the basal Browns Park and the underlying less permeable units maintain the base flow of the perennial streams in the southeastern part of the Washakie basin (Berry, 1960).

The yields of three wells completed in the North Park Formation, located on the northwest side of the Sierra Madre uplift, range from 4 to 20 gpm. There is only one well on record that is completed in the Bishop Conglomerate. This well, located in T. 16 N., R. 104 W., section 8, has a yield of 42 gpm. There are no wells on record that are completed in the South Pass Formation.

Based on the results of pumping tests of ten Browns Park wells, the aquifer transmissivity generally ranges from 100 to 1,500 gpd/ft. One test result gives an estimate of 10,000 gpd/ft (T. 12 N., R. 91 W., section 9 ad). The results of tests of two North Park wells indicate an aquifer transmissivity between 150 and 1,000 gpd/ft. Well specific capacities from both formations were found to be on the order of 1 gallon per minute per foot of drawdown (gpm/ft).

The potentiometric gradients in the Upper Tertiary aquifers generally conform with topography. Ground-water movement is from topographically high areas along the flanks of the Sierra Madre uplift toward topographically low areas in the valleys of the Snake River and its tributaries, where the aquifers are partially or completely dissected (Figure V-1).

Tertiary Aquifer System

The Tertiary aquifer system includes all formations between the Laney Member of the Green River Formation and the Fox Hills Sandstone, inclusive (Figure III-6). This zone is separated from the overlying Upper Tertiary aquifers by a large thickness of low-permeability claystone and shale (Uinta and Bridger formations). The Lewis Shale

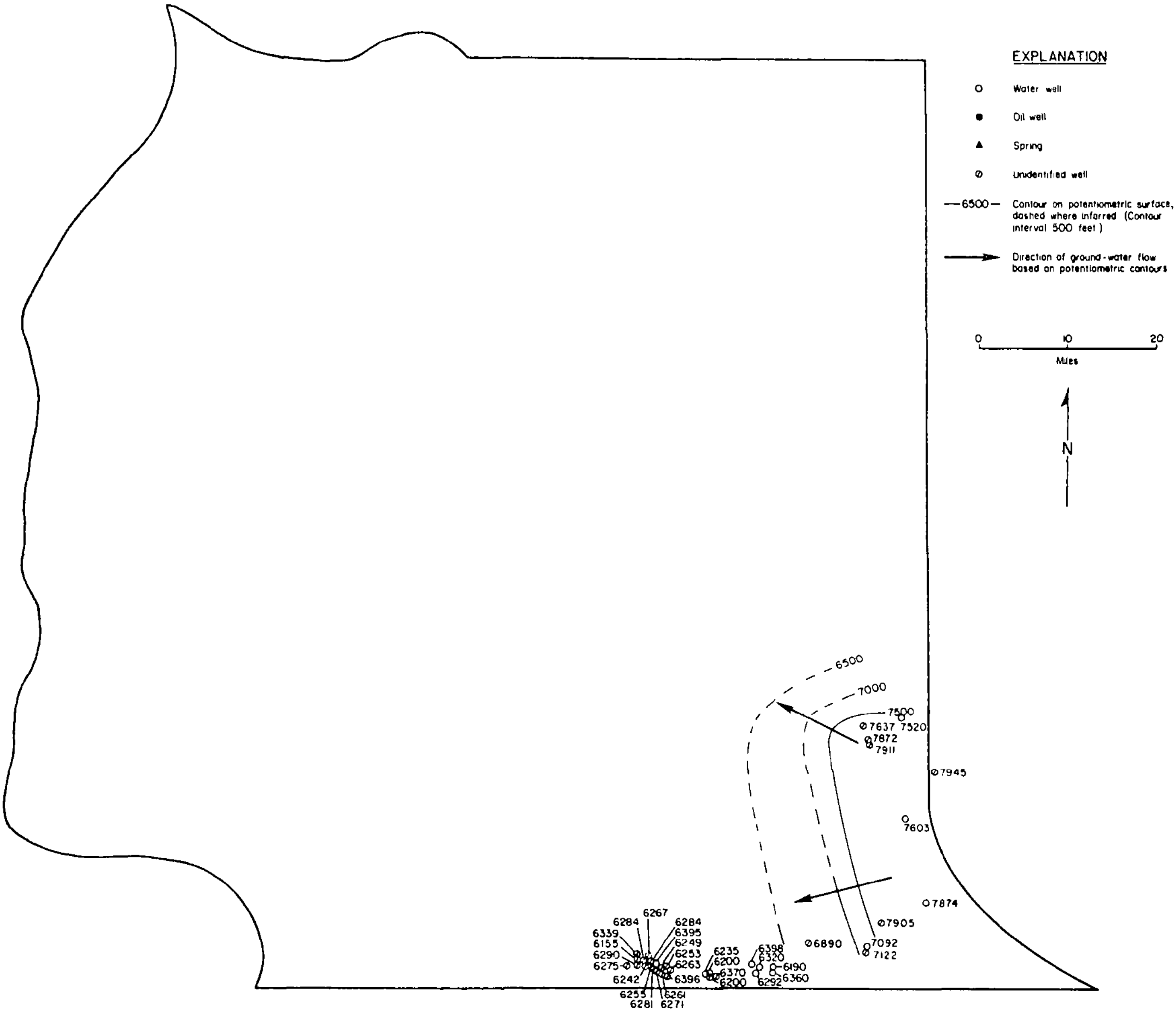


Figure V-1. Potentiometric surface map, Upper Tertiary aquifers.

constitutes the basal boundary for the Tertiary aquifer system and separates it from the underlying Mesaverde aquifer.

Over the greater part of the study area, the formations of the Tertiary system are exposed at the land surface or underlie Quaternary and Upper Tertiary deposits. The Tertiary formations are missing in those areas adjacent to the Rock Springs, Rawlins, and Sierra Madre uplifts, where older rocks are exposed. The maximum thickness of the Tertiary aquifer system is estimated between 11,000 and 12,000 feet in the central Washakie basin (McDonald, 1975).

Hydrologic data for the Tertiary aquifer system are derived from the records of 193 water wells and springs, and 13 oil field drill stem tests. Other sources of information include Wyoming Geological Association (1979). The sources for well and spring data are the State Engineer's Office, the Wyoming Geological Survey, Welder and McGreevy (1966), Dana (1962), Berry (1960), and numerous coal mine reports.

Each geologic unit within the Tertiary aquifer system is water-bearing to some degree. The major aquifers, in order of importance, are the sandstones and conglomerates in the Battle Spring, Wasatch, and Fort Union formations, and the Laney Member of the Green River Formation.

The Battle Spring Formation crops out over most of the eastern Great Divide basin west of the Rawlins uplift. It is a stream and deltaic facies of the Wasatch Formation composed of fine- to coarse-grained, highly permeable, arkosic sandstone and conglomerate. The Battle Spring is capable of yielding at least 150 gpm to water wells, though most yields generally range from 30 to 40 gpm. Welder and McGreevy (1966) state that wells tapping the greatest thicknesses of the Battle Spring can have yields of over 1,000 gpm; however, specific capacities for 23 of 26 tested wells were less than 1 gpm/ft. Data obtained from pump tests for 26 water wells indicate a transmissivity range between 29 and 3,157 gpd/ft, though most values are less than 500 gpd/ft. Transmissivity values from 11 aquifer tests in the area of Minerals Exploration Company's proposed uranium mine (T. 22-26 N., R. 90-95 W.) averaged 40,000 gpd/ft, with a calculated average storage coefficient ranging from 10^{-3} to 10^{-5} (Minerals Exploration Company, 1978).

The Wasatch Formation is an excellent source of water, particularly in the western Great Divide basin and along the axis of the Wamsutter arch. In these areas it crops out or underlies younger, permeable formations and has its highest percentage of sandstone (Welder and McGreevy, 1966). In the Washakie basin, the Wasatch intertongues with or underlies relatively impermeable claystone and shale beds of the Green River, Bridger, and Uinta formations.

In the Great Divide basin, the discontinuous sandstones of the Wasatch are generally fine- to medium-grained, coarsening toward the southern end of the Wind River Mountains, where highly permeable boulder conglomerates are present. Artesian conditions exist in many of the sandstone lenses of the lower Wasatch Formation, especially in the northwestern Great Divide basin (Dana, 1962; Welder and McGreevy, 1966).

Water well yields from the Wasatch Formation are typically between 5 and 50 gpm, though several wells completed in thick saturated sequences produce between 200 and 325 gpm. Well specific capacities less than 1 gpm/ft are characteristic of the Wasatch aquifer.

Transmissivity estimates from water well and oil field aquifer tests range from 1 to 100,000 gpd/ft, with the majority between 150 and 6,000 gpd/ft. Porosity and permeability estimates from Wasatch tests at oil fields across the southern Washakie basin are 16 to 38 percent and <1 to 18.2 gpd/ft^2, respectively (Wyoming Geological Association, 1979).

The Fort Union Formation underlies the Great Divide and Washakie basins between outcrop areas on the east flank of the Rock Springs uplift and the west flank of the Rawlins uplift. The thickness of the Fort Union varies from less than 1,000 feet in the northern Great Divide basin to approximately 2,500 feet immediately west of the Rawlins uplift (Pipiringos, 1955; Berry, 1960; Weimer and Guyton, 1961; Stephens, 1964; Welder and McGreevy, 1966). According to Woodward-Clyde Consultants (1980) and Haun (1961), discontinuous lenticular sandstone and conglomerate beds in the lower 200 to 500 feet of the formation are integrated into one aquifer through possible fracture zones.

Fort Union well yields are generally less than 100 gpm, although yields of up to 300 gpm have been reported. Welder and McGreevy (1966) suggest that yields as high as 500 gpm could be expected from a well penetrating the thickest sections of the Fort Union. Oil field data indicate a porosity range in Fort Union pay zones of 15 to 39 percent, and permeabilities typically less than 1 gpd/ft^2 (Wyoming Geological Association, 1979). Transmissivities are characteristically less than 2,500 gpd/ft.

The Laney Member of the Green River Formation is present throughout the Washakie basin. A band of Laney outcrop 3 to 10 miles wide encircles the central basin area. Within the central basin, the Laney is buried by younger Tertiary age silts and shales. The Laney Member is composed of fine-grained, calcareous mudstone and shale with several relatively thick sandstone lenses. The thickness of the Laney Member ranges from 900 to 1,200 feet in the western part of the basin and from 500 to 900 feet in the east, with a maximum reported thickness of 1,800 feet (T. 14 N., R. 97 W.) in the south-central area (Roehler, 1973a).

Wells completed in the Laney Member in the western Washakie basin (Kinney Rim area) have reported yields of up to 200 gpm. Transmissivities between 110 and 300 gpd/ft were estimated from Laney aquifer tests at Ogle Petroleum's Bison Basin uranium mine site in the northwestern Great Divide basin. Permeability reportedly ranges from 7.4 to 13.0 gpd/ft^2; the storage coefficient varies from 3.4×10^{-5} to 5.9×10^{-4}.

Ground-water producing capabilities from minor water-bearing units of the Tertiary aquifer system--the Fox Hills, Lance, and Green River (except the Laney Member)--are adequate for stock and domestic supplies over most of the Great Divide and Washakie basin.

Oil field pay zone data indicate porosity, permeability, and transmissivity values of approximately 20 percent, 0.9 gpd/ft^2, and 10 to 20 gpd/ft, respectively, for the Fox Hills Sandstone (Wyoming Geological Association, 1979). Yields from stock wells in the Lance Formation near outcrop areas on the west flank of the Rawlins uplift are estimated between 5 and 30 gpm (Welder and McGreevy, 1966). Twenty of 22 transmissivity estimates from the Lance Formation pump tests and drill stem tests were less than 22 gpd/ft.

No well data exist for specific members of the Green River Formation, with the exception of the Laney Member. Welder and McGreevy (1966) characterize ground-water possibilities from the Tipton and Wilkins Peak members of the Green River Formation as very poor, due to the low permeability of the marlstone, oil shale, and infrequent, thinly bedded, fine-grained sandstones particularly in the central Washakie basin. Eight water wells, identified as "Green River Formation Undivided," yield 15 to 250 gpm; however, these wells may be completed in the Laney Member and may not be indicative of well yields from other members of the Green River Formation.

Potentiometric data for the Tertiary aquifer system (Figure V-2) indicate that ground-water flow is from the high peripheral areas of the Great Divide and Washakie basins toward the basin centers. Although it has no surface expression, the Wamsutter arch is a ground-water divide for flow within the Washakie and Great Divide basins. The Tertiary aquifer system is recharged primarily by outcrop-related infiltration of snowmelt and streamflow, and by downward seepage from overlying, permeable Miocene, Pliocene, and Quaternary sediments (Welder and McGreevy, 1966). The areas of ground-water discharge include the valleys and playas in the central part of the Great Divide basin, particularly Chain Lakes flat and Battle Spring flat (Minerals Exploration Company, 1978). Discharge areas in the Washakie basin include springs along the Little Snake River and its tributary valleys, and underflow to the Tertiary formations of the Sand Wash basin in northwestern Colorado (Welder and McGreevy, 1966).

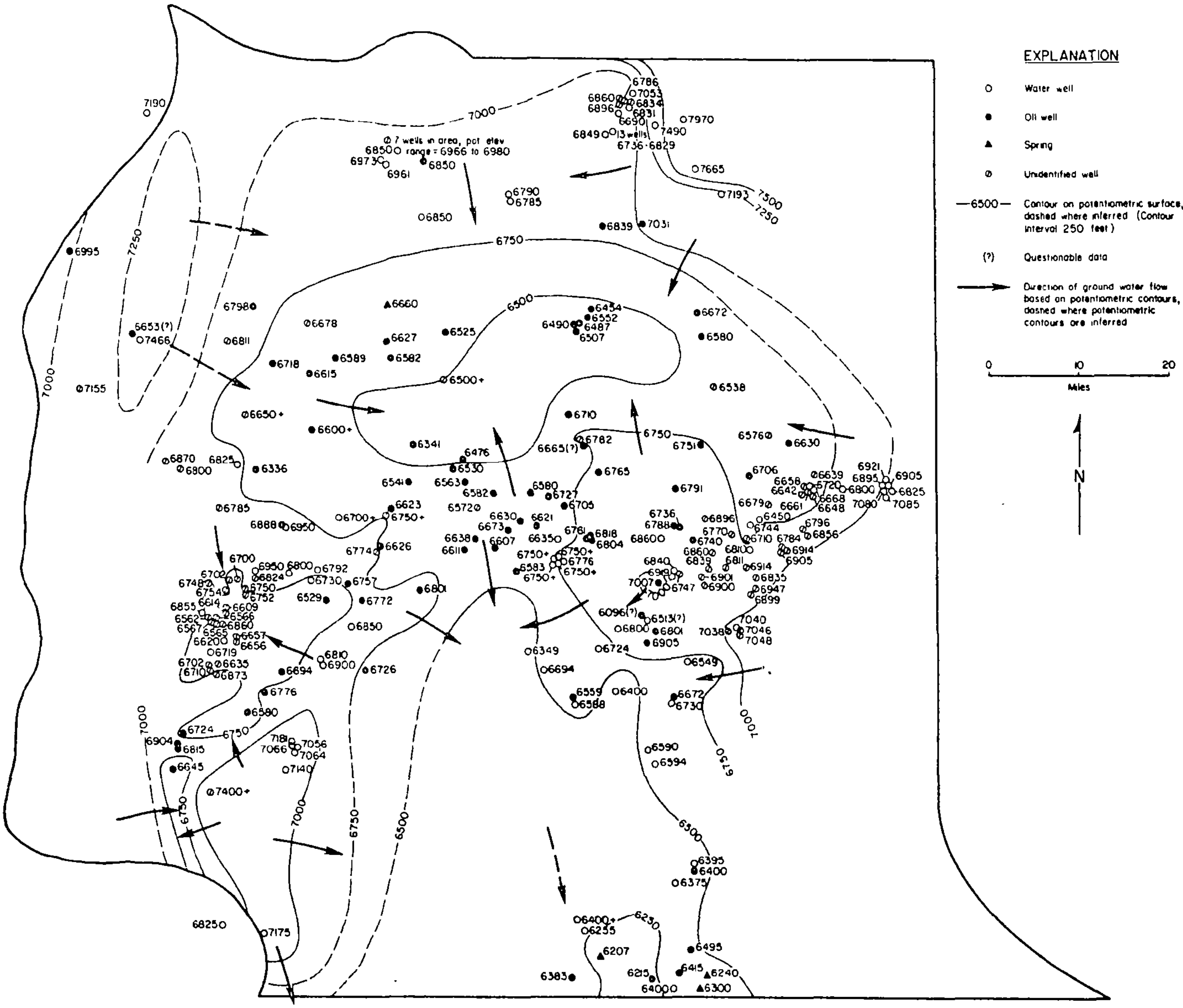


Figure V-2. Potentiometric surface map, Tertiary aquifer system.

Mesaverde Aquifer

The Mesaverde aquifer consists predominantly of fine- to medium-grained sandstone interbedded with some shale and coal beds (Welder and McGreevy, 1966; Hale, 1950). It is situated stratigraphically between the major confining units of the Lewis Shale above and the Baxter Shale and equivalents below. On the western side of the study area along the Rock Springs uplift, this aquifer consists of, in ascending order, the Blair, Rock Springs, Ericson, and Almond formations of the Mesaverde Group. In this area, the maximum thickness of the aquifer ranges from 2,200 to 5,600 feet (Welder and McGreevy, 1966). To the east, the Mesaverde is not subdivided, and has a maximum thickness of about 2,800 feet (Berry, 1960; Welder and McGreevy, 1966). Along the axes of the Rawlins and Rock Springs uplifts, the Mesaverde has been eroded, exposing older Mesozoic and Paleozoic geologic units. On the east flanks of the Rock Springs uplift, the continuity of the Mesaverde is disrupted by a series of east-west trending faults.

Quantitative data for the Mesaverde aquifer were obtained from a number of sources, including well and spring permit records from the Wyoming State Engineer's Office, the Wyoming Geological Survey, and previous publications (Welder and McGreevy, 1966; Dana, 1962; Berry, 1960; and several coal mine reports).

Records of existing wells completed in the Mesaverde aquifer indicate that in the western part of the study area, water is obtained from all units within the Mesaverde Group, including the Blair, Rock Springs, Ericson, and Almond formations.

The Ericson is the primary water-bearing unit with well yields between 10 and 200 gpm (Dana, 1962; Welder and McGreevy, 1966). One well (T. 21 N., R. 101 W., section 21 ada) has a reported yield of 250 gpm from two Ericson intervals. Transmissivity values for the Ericson Formation, estimated from two oil field drill stem tests, were 43 and 2,883 gpd/ft (see Appendix C).

The Rock Springs Formation constitutes a unit of permeable fine- to medium-grained sandstone with good water-bearing capability (Hale, 1950). The records of nine wells completed in this unit indicate that well yields vary between 2 and 470 gpm, though most wells produce between 100 and 250 gpm. Reported porosity of one oil-producing zone in the Rock Springs Formation is 10 percent (Wyoming Geological Association, 1979).

The yields of four wells completed in the Blair Formation are 30 to 60 gpm from fine- to medium-grained sandstones in the upper part of the formation. The lower part of the Blair is composed of relatively impermeable interbedded shales and siltstones. Blair pay zone porosities from two oil fields on the east flank of the Rock Springs uplift are 16 and 19 percent (Wyoming Geological Association, 1979). There are no available data to compute the permeability or transmissivity for the Rock Springs and Blair formations.

The upper part of the Almond Formation consists of permeable massive beds of fossiliferous sandstone which overlie low-permeability carbonaceous shale, siltstone, mudstone, and coal beds of variable thickness and quality. The upper sandstone has a reported porosity of 16 to 23 percent and permeability of <1 gpd/ft^2 (Wyoming Geological Association, 1979). One water well yield of 250 gpm was reported by Dana (1962), and is the only available yield data for the Almond Formation. Transmissivity values determined from two coal mine pump tests and 11 oil field drill stem tests were low, between 0.7 and 15.8 gpd/ft.

On the east side of the study area the Mesaverde Formation consists mainly of fine- to medium-grained sandstone with localized lenses of carbonaceous shale, lignite, and coal. Yields from five wells completed in the Mesaverde in this area are between 15 and 40 gpm. Specific capacities determined from pump tests on these wells varied from less than 2 to greater than 20 gpm/ft. Transmissivity values from two of the wells were less than 3,000 gpd/ft. Transmissivities estimated from five Mesaverde drill stem tests range from 4 to 67 gpd/ft. Reported data from 50 oil field test wells, the majority of which are located in the Washakie basin, indicate a porosity range from 8 to 26 percent, and hydraulic conductivity between <1 and 1.8 gpd/ft^2 (Wyoming Geological Association, 1979).

Based on potentiometric data (Figure V-3), the general direction of ground-water flow in the Mesaverde aquifer is from the recharge areas toward the basin centers. Outcrop-related recharge to the Mesaverde aquifer occurs along the Rock Springs, Rawlins, and Sierra Madre uplifts. Recharge is mainly from infiltration of snowmelt and streamflow (Welder and McGreevy, 1966). Little flow contribution is supplied by the Tertiary aquifers due to the presence of the intervening Lewis Shale.

Frontier Aquifer

The Frontier aquifer consists of sandstone and shale with a few bentonite beds and lenses of pebble conglomerate (Welder and McGreevy, 1966). It underlies most of the study area and has a thickness of 190 to 900 feet. It crops out along the Rawlins uplift in the east and the

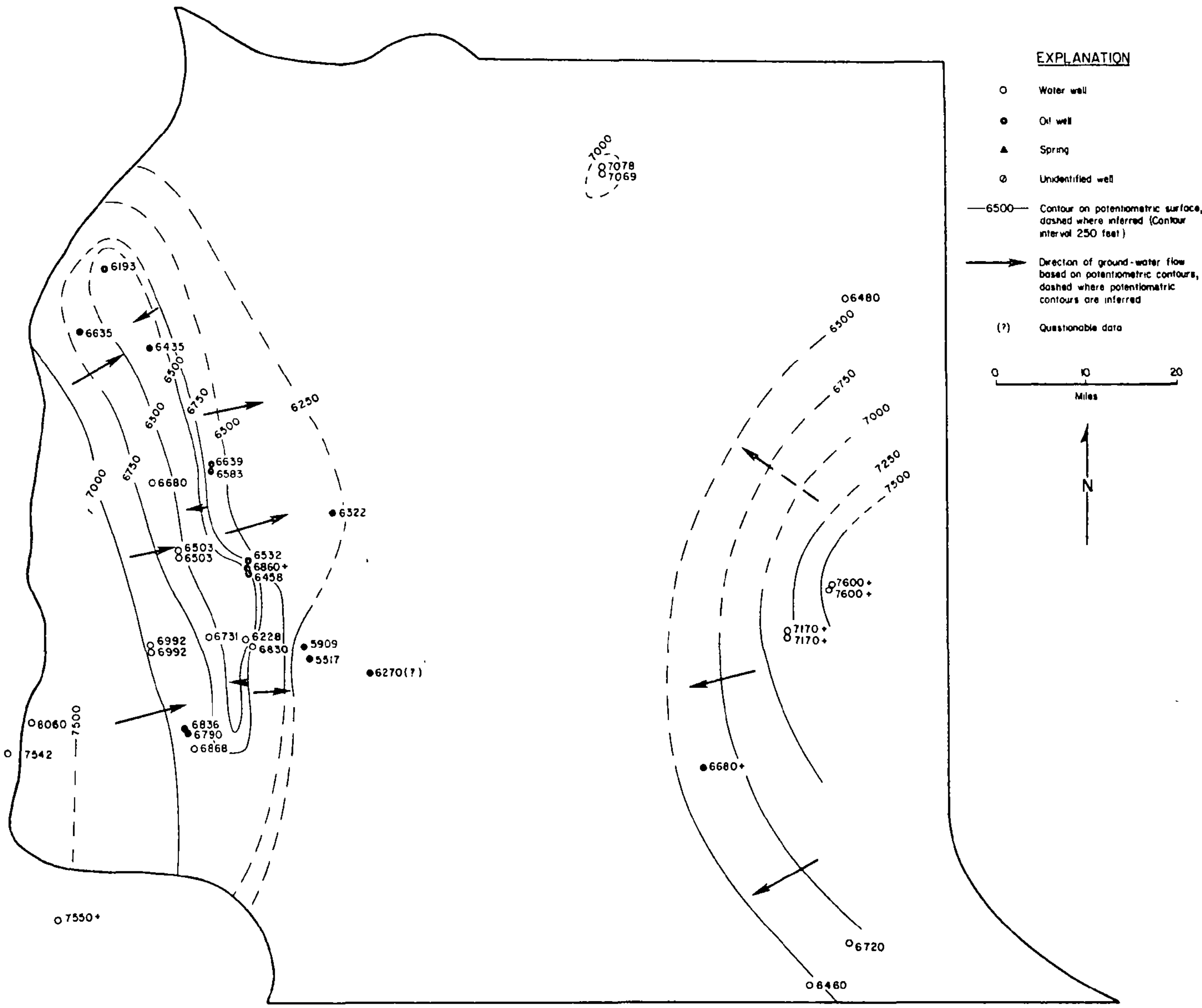


Figure V-3. Potentiometric surface map, Mesaverde aquifer.

Rock Springs uplift in the west. The formation dips from the east and west toward the central part of the area; depth to the top of this formation in the central parts of the Great Divide and Washakie basins is estimated at over 8,000 feet.

Information on ground-water occurrence and water-bearing characteristics for the Frontier is available from the records of 24 oil test wells, 21 water wells, and 2 springs. The great majority of the water wells and all springs are located in the eastern outcrop areas. The remainder of the wells are located in the western part of the area in the vicinity of the Rock Springs uplift. About one-third of the wells are flowing.

Based on the results of two short-term pump tests, the estimated aquifer transmissivity is between 15,000 and 20,000 gpd/ft. Other computations from results of drill stem tests indicate values usually less than 100 gpd/ft, with a maximum of about 6,500 gpd/ft. Aquifer transmissivity probably varies over a wide range depending on the percentage of bentonite and shale beds within the sandstone; however, it is believed that the values computed from the drill stem tests are underestimates because of inherent test and calculation errors (see Appendix D).

Frontier well yields for five wells reportedly vary over a wide range, from 1 gpm to over 100 gpm, and well specific capacities vary from 0.3 gpm/ft to as much as 30 gpm/ft.

Potentiometric data for the Frontier aquifer are sparse. Available data indicate that the regional flow in this aquifer is toward the center of the Great Divide and Washakie basins (Figure V-4). Recharge occurs in the uplift areas in the east, north, and west parts

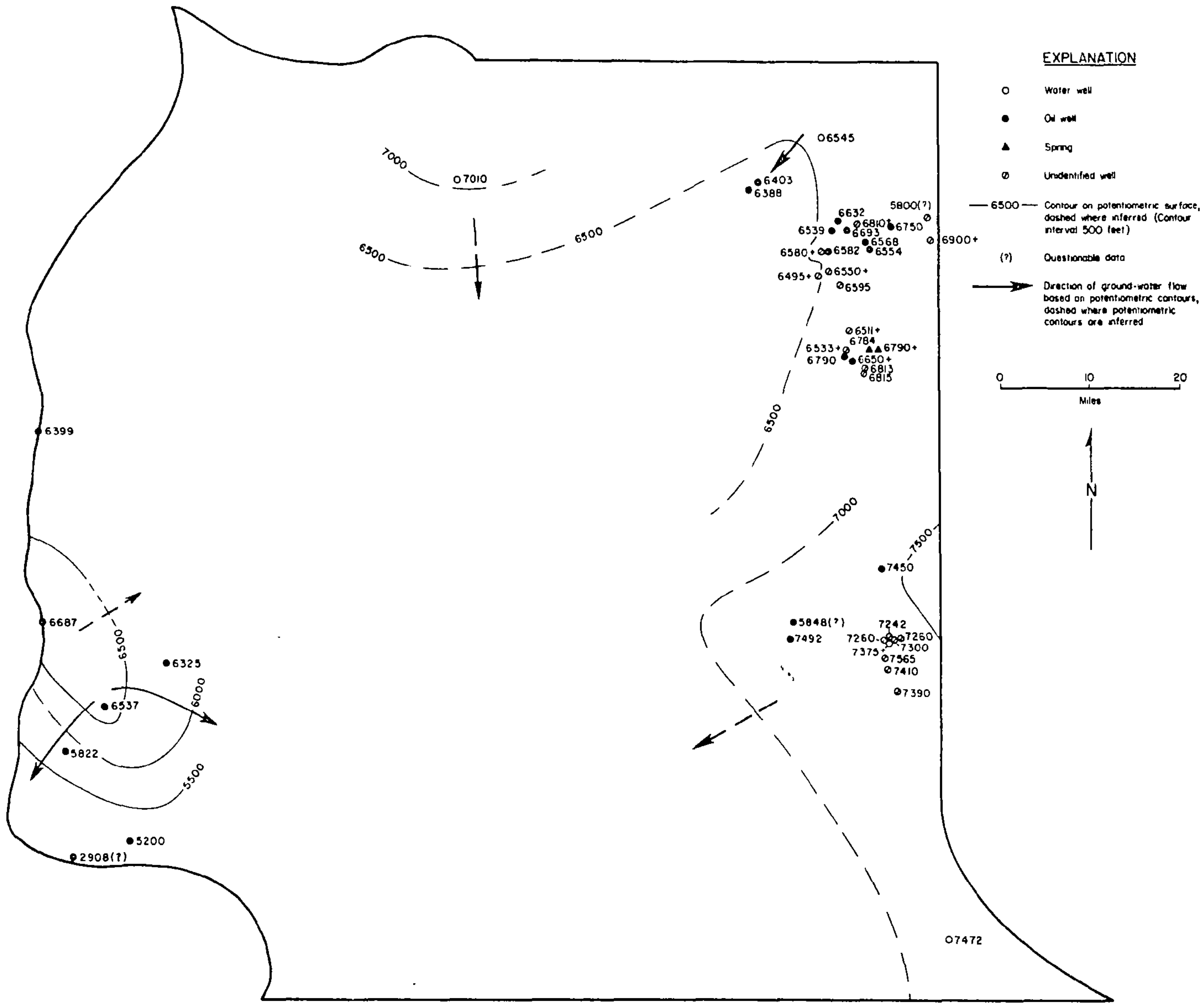


Figure V-4. Potentiometric surface map, Frontier aquifer.

of the study area. Discharge from the Frontier aquifer to overlying formations is assumed to occur in the central basin areas.

Cloverly Aquifer

The Cloverly aquifer consists of two parts: an upper sandstone unit and a lower unit, known elsewhere as the Dakota Sandstone and the Lakota Conglomerate, respectively. It is between 45 and 240 feet thick and is separated from the Frontier aquifer by several hundred feet of low-permeability sediments in the Mowry and Thermopolis shales. This aquifer crops out at the Rawlins uplift in the eastern part of the area. It dips basinward to the west and occurs at a depth of over 13,000 feet in the vicinity of Baggs, near the central part of the Washakie basin.

Information on ground-water occurrence and hydrologic characteristics of the Cloverly aquifer is available from 39 oil test wells and 7 water wells. The water wells are located south of Rawlins, and the majority of the oil wells are located to the south of the Rock Springs uplift.

Based on available potentiometric data (Figure V-5), recharge to the aquifer from overlying formations occurs along the Sierra Madre and Rawlins uplifts in the east, Crooks Mountain in the north, and the Rock Springs uplift in the west. There are no potentiometric data to delineate flow in the central part of the Great Divide and Washakie basins.

The aquifer transmissivity estimates computed from drill stem test data are generally low, between 1 and 177 gpd/ft. Available information from other sources (Berry, 1960; Dana, 1962; Welder and McGreevy, 1966) suggests that aquifer transmissivity is higher than

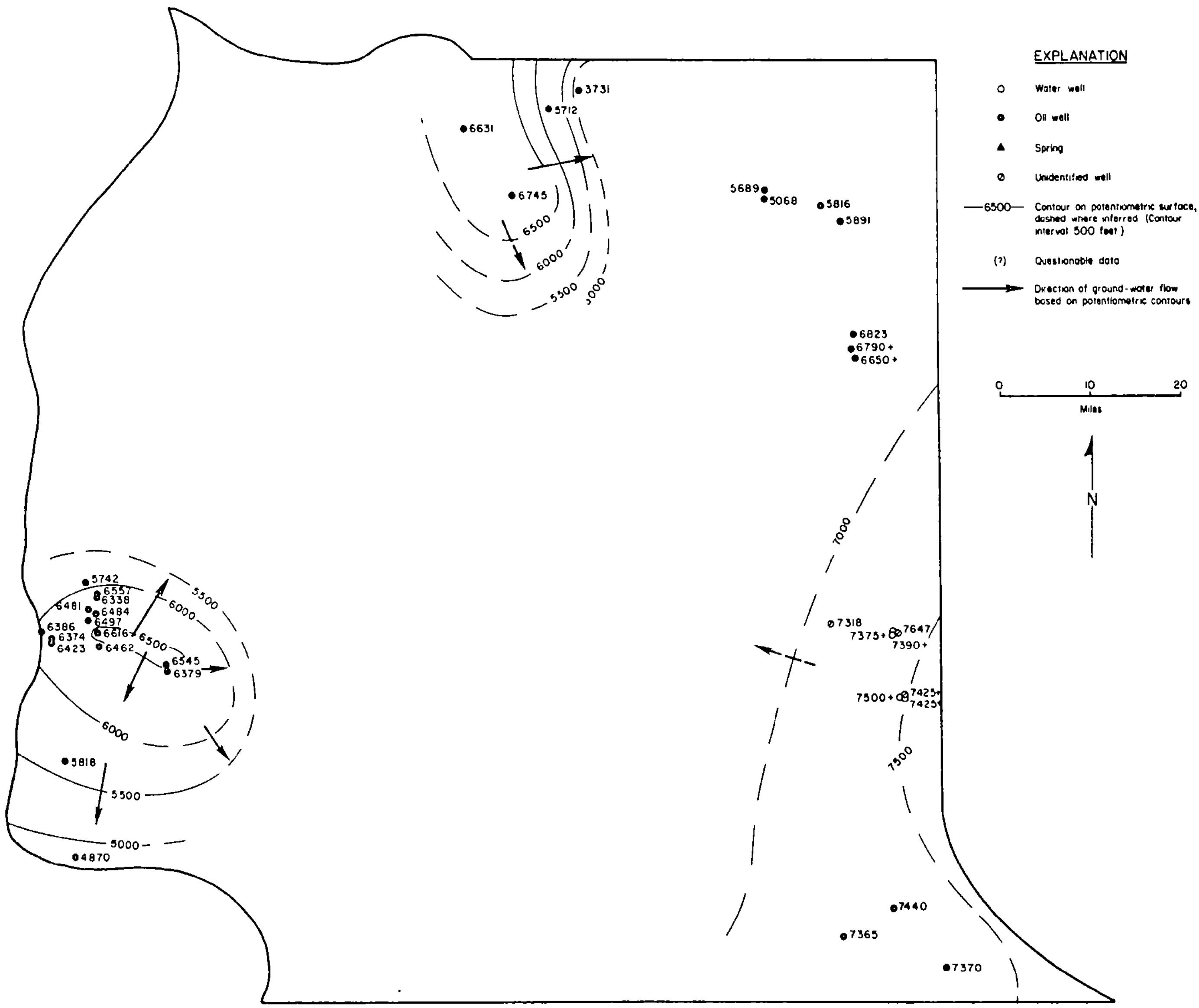


Figure V-5. Potentiometric surface map, Cloverly aquifer.

that computed from the drill stem tests, ranging between 340 and 1,700 gpd/ft.

Based on reported tests for 13 wells, well yields range from 25 gpm to over 120 gpm, and specific capacities range from about 0.3 to 1.4 gpm/ft.

Sundance-Nugget Aquifer

The Sundance-Nugget aquifer is comprised of permeable sandstone beds, separated from the Cloverly aquifer by 200 to 300 feet of Morrison shale. The lower part of the Sundance reportedly contains some shale, siltstone, and limestone beds, while the Nugget contains minor interbedded shale and siltstone. Both formations either crop out or are thinly covered with Tertiary deposits in the uplift areas. Maximum combined thickness of the Sundance Formation and Nugget Sandstone is between 170 and 1,100 feet. These formations may be as deep as 14,000 feet below ground surface near the center of Washakie basin.

Information about ground-water occurrence and hydrologic characteristics of the Sundance-Nugget aquifer is available from 30 oil test wells and 7 water wells. One water well and five oil test wells are reportedly flowing. Most wells are located in the northern and western parts of the study area.

The available potentiometric data are sporadic and cannot be used to delineate flow patterns in the Sundance-Nugget aquifer. Potentiometric heads are highest in the uplift areas of the east, west, north, and northeast (Figure V-6).

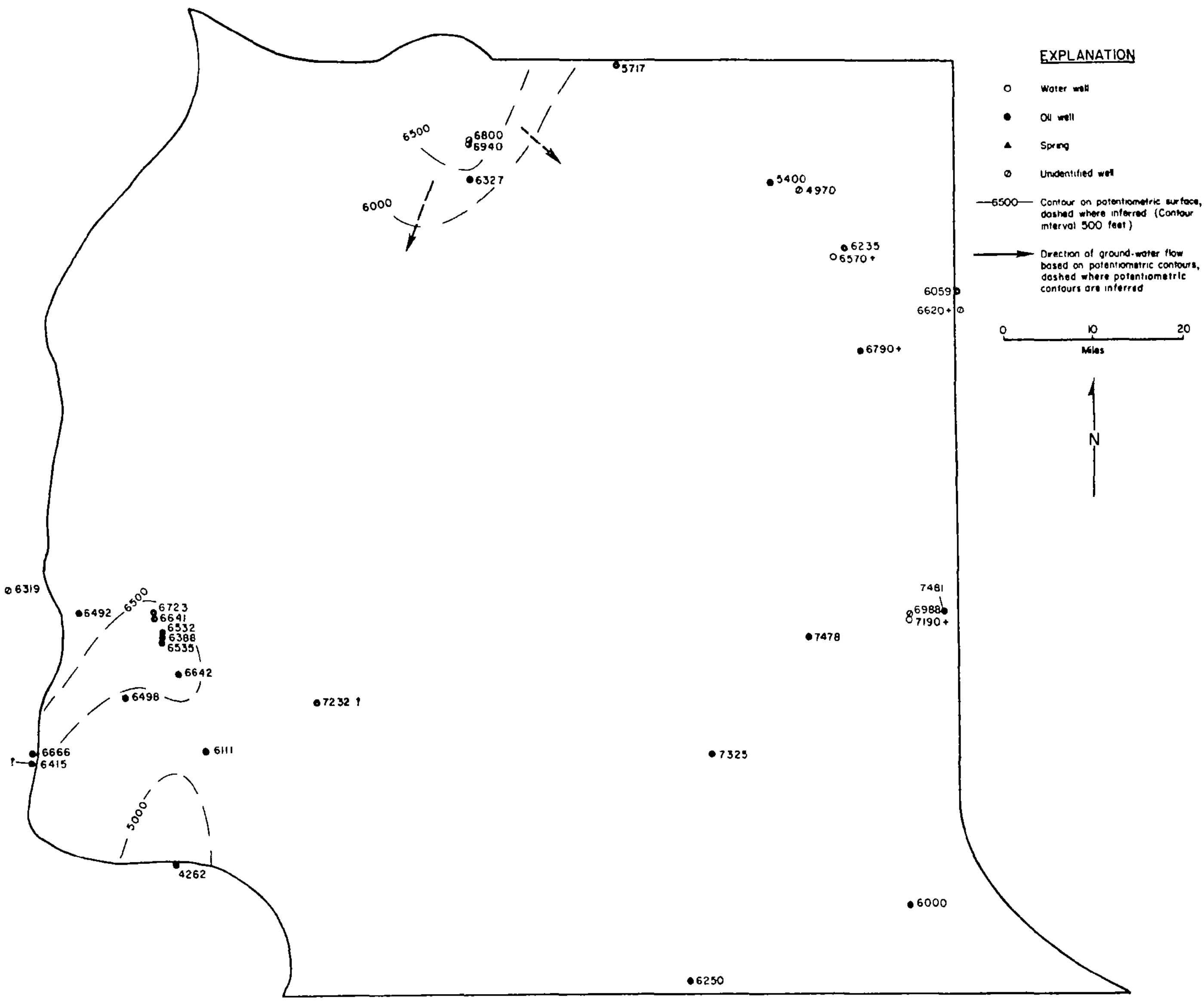


Figure V-6. Potentiometric surface map, Sundance-Nugget aquifer.

Paleozoic Aquifer System

The Paleozoic aquifer system consists of all the formations below the shales and other fine-grained sediments of the Chugwater and Phosphoria formations. It includes three important water-bearing intervals: the Tensleep Sandstone, the Madison Limestone, and undifferentiated Cambrian and weathered Precambrian rocks. The Amsden Formation, which is of low permeability, partially separates the Tensleep and Madison aquifers. There is no apparent confining bed separating the Madison Limestone and the underlying Cambrian and Precambrian undifferentiated rocks.

Although the carbonate units of the Paleozoic aquifer system have very low intergranular permeability, they are highly permeable where secondary porosity features exist. These features occur where solution zones and fractures are prominent. Permeabilities in the Tensleep and Cambrian sandstone aquifers are primarily intergranular.

The Tensleep consists of fine- to medium-grained sandstone, locally quartzitic, with lesser amount of thin interbedded layers of limestone and dolomite. It has a maximum thickness of about 800 feet (Welder and McGreevy, 1966) and, reportedly, it is completely missing in the southeastern part of the study area (Gudim, 1956; Ritzma, 1951; Lawson, 1949; Weimer, 1949).

Information about the water-bearing capabilities and ground-water occurrence in the Tensleep aquifer is available from the records of 28 wells, of which the great majority are oil test wells. At least three of the wells are flowing. Tensleep well yields are reported at between 24 and 400 gpm. Aquifer transmissivity is low, ranging from less than 1 to 374 gpd/ft.

Potentiometric data for the Tensleep aquifer are shown in Figure V-7; the resultant potentiometric contours are considered representative of the entire aquifer system. Figure V-7 shows recharge occurring along the northern and eastern flanks of the Great Divide basin. Additional recharge into the Washakie basin may occur to the south and east of the Rock Springs uplift. Ground-water flow from the recharge areas is toward the basin centers.

The Madison aquifer is comprised of predominantly limestone and dolomite, with thin sandstone and chert beds (Gudim, 1956; Ritzma, 1951; Lawson, 1949; and Weimer, 1949). Aquifer thickness reportedly ranges from about 5 feet to 325 feet (Welder and McGreevy, 1966). Information about the water-bearing characteristics and ground-water occurrence in the Madison Limestone is available from the records of 15 wells and 1 spring. Four water wells are located near the city of Rawlins. The other wells are oil wells located near the uplifts in the east, west, and north parts of the study area. The spring is located to the north of the study area. Based on outcrops outside the study area, much of the Madison Limestone permeability is secondary due to development of caverns and solution channels (karst conditions).

Well yields on record range from 4 to 400 gpm. Well specific capacity for two of the wells is reported at 100 gpm/ft. There are no other well specific capacity data available.

Madison aquifer transmissivity, based on DST results, is low, on the order of 10 to 20 gpd/ft; however, the results of pump testing at a water well (T. 21 N., R. 87 W., section 9 bd) is reportedly 200,000 gpd/ft (see Appendix C). Where Madison transmissivities are high, secondary permeability is typically well developed.

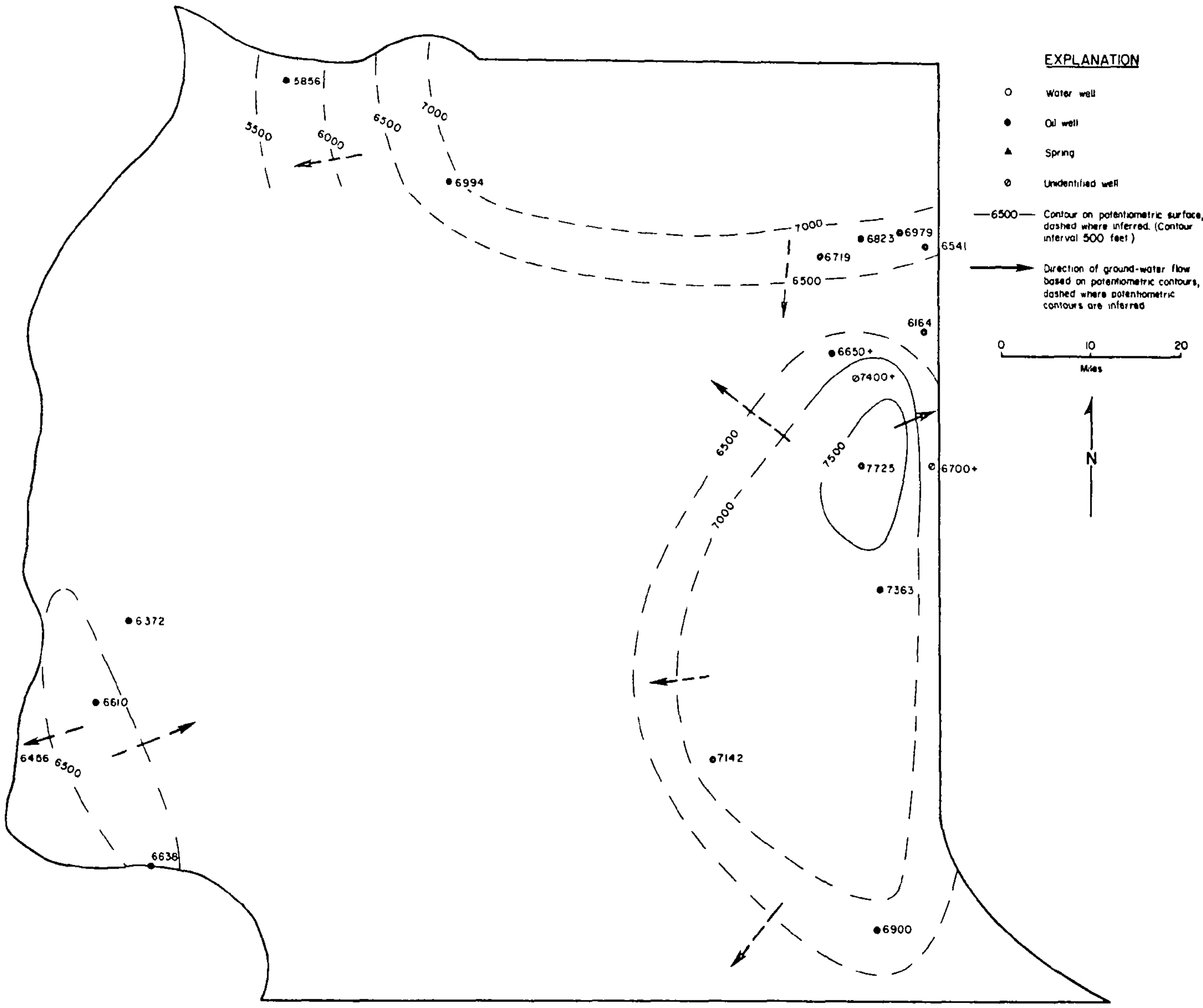


Figure V-7. Potentiometric surface map, Tensleep aquifer.

The Cambrian rocks consist of sandstones with interbedded siltstone, shale, and limestone (Berry, 1960; Gudim, 1956; Lawson, 1949; Weimer, 1949). Parts of the underlying Precambrian include weathered granite, gneiss, and schist (Love and others, 1955). Information about the water-bearing capability and ground-water occurrence in these formations is available from water wells and springs located at or near these formation outcrops and from a limited number of deep oil wells.

Well records indicate that 13 water wells and one spring, all located near the city of Rawlins, derive their supply from the Cambrian formations at less than 400-foot depth (most wells are less than 250 feet deep). Two oil wells, located in the Bison basin area (T. 27 N., R. 97 W.), reportedly encountered water in the Cambrian at about 1,650 feet and 1,300 feet. Water well yields reportedly range from 4 to 250 gpm; specific capacities for two of the water wells are reported at about 1 and 150 gpm/ft. Aquifer transmissivity is reported at <1 and 27 gpd/ft based on drill stem tests of the oil wells, and 100 and 300,000 gpd/ft (T. 21 N., R. 87 W., section 17 aa) based on testing of two of the water wells (see Appendix C). This wide range in aquifer transmissivity may result from increased permeability due to fracture enhancement in structurally disturbed areas in the north and east Great Divide basin.

Available records indicate that 11 springs and about 70 water wells derive their supply from the Precambrian. The springs and wells are generally located at or near the weathered Precambrian outcrops in the vicinity of South Pass City in the extreme northwest part of the study area. One spring is located in the southeast flank of the Sierra Madre uplift in the eastern Washakie basin.

Well yields in the Precambrian range from 2 to 150 gpm, with the majority yielding 10 to 20 gpm. Specific capacities range from 0.1 to 150 gpm/ft, with most between 0.5 and 2 gpm/ft. Aquifer transmissivities range from 6 to 4,000 gpd/ft, but the majority are less than 1,000 gpd/ft.

SUMMARY OF REGIONAL GROUND-WATER CIRCULATION

Figure V-8 depicts regional ground-water circulation for two east-west cross-sections and one north-south cross-section through the study area. Potentiometric data from 50 wells were used in the construction of Figure V-8; the geographic locations of these data are shown in Figure III-4 (p. 22).

The potentiometric contours and flow lines shown in Figure V-8 are in agreement with individual aquifer potentiometric maps (Figures V-1 through V-7). In general, regional flow patterns are consistent with topographic features of the area: the recharge regions are located in the topographically high areas along the periphery of the basins, and the discharge areas are located in the nearly flat depressions in the central Great Divide and Washakie basins.

The Rawlins uplift is the location of the regional ground-water divide along the eastern boundary of the study area. The Wamsutter arch is also a ground-water divide between the two basins for aquifers above the Baxter Shale; ground-water flow paths for underlying aquifer cannot be determined from available data.

Along parts of the western boundary of the study area available data indicate that ground-water flow is across the Rock Springs uplift into the Green River basin to the west. In the southwest part of the study area, potentiometric data for the pre-Baxter aquifers indicate

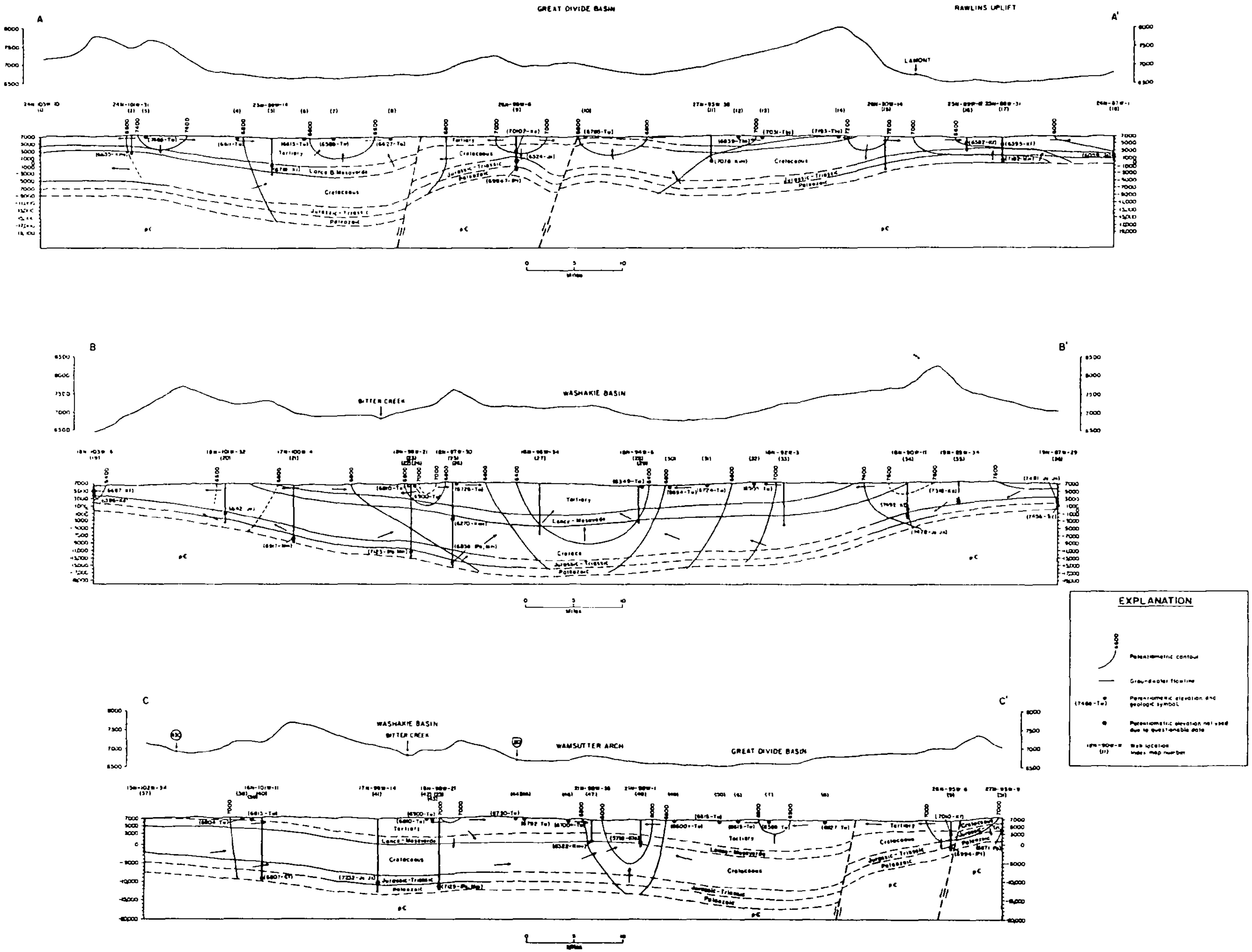


Figure V-8. Potentiometric cross-sections, Great Divide and Washakie basins (locations shown on Figure III-4).

that the regional ground-water divide is east of the uplift, with a component of flow toward the Green River basin. Recharge from the UInta Mountains to the south may provide the flow for this divide. In the northwest part of the Great Divide basin, data also indicate a Tertiary aquifer ground-water divide east of the Rock Springs uplift, and a western component of flow into the northeastern Green River basin. Certainly, more potentiometric elevations are needed to accurately determine ground-water circulation in this area.

VI. WATER QUALITY

VI. W A T E R   Q U A L I T Y

Water quality data for about 300 water samples were used to delineate ground-water quality in the Great Divide and Washakie basins. These data were obtained from several sources, including the records of the U.S. Geological Survey WATSTOR data system, the Wyoming Water Resources Research Institute (WRRI) WRDS data system, compilations of oil field water quality data by Crawford (1940) and Crawford and Davis (1962), and the Wyoming Oil and Gas Commission files. Additionally, water samples were collected by the WRRI staff from 10 wells, and analyzed by a private laboratory.

Water quality data on record generally include the results of chemical analyses of water samples, although much of the data obtained from the Wyoming Oil and Gas Commission files include only TDS estimates based on results of resistivity measurements of formation water samples. Water resistivity data were used herein to supplement other data in these areas where chemical analyses are lacking.

As virtually all data are available elsewhere, tabulated analyses are not produced in this report, except for determinations of samples collected by WRRI staff specifically for this report (see Appendix E).

It is difficult to assess the quality and accuracy of the available water quality data used in this report due to the variety of data sources and the long time period (more than 40 years) over which the measurements were made. Sampling techniques and analytical methods are not specified for some of the data sets, and older data and oil test well data may be suspect. The water samples collected through drill stem tests in oil test wells may not be representative of the formation sampled due to possible contamination by the drilling fluids or water from other formations. The Wyoming Oil and Gas Commission files do not provide any information with respect to the accuracy of data on record.

The spatial distribution of data is poor for the aquifers lying below the Baxter Shale, with essentially no data from the central part of the study area. Most of the available data are for the aquifers above the Baxter Shale due to larger surficial exposures and shallower drilling depths.

The following two sections summarize (1) general ground-water quality, and (2) ground-water quality in terms of U.S. Environmental Protection Agency standards.

GENERAL WATER QUALITY

This section presents a summary of regional water quality, and specific discussions of water quality by aquifer in terms of total dissolved solids (TDS) concentrations and major ion compositions. Relationships between these constituents are identified and where possible, geochemical controls on the observed trends are identified. Where data are sufficient, inferences into ground-water flow paths and interaquifer communication are suggested.

Summary of Regional Water Quality

Regional analysis of water quality data for the Great Divide and Washakie basins identifies several areas and aquifers where ground waters contain less than 1,000 mg/l total dissolved solids. These include: (1) Quaternary aquifers in most drainages other than Bitter Creek, (2) Upper Tertiary aquifers along the Sierra Madre and Rawlins uplifts, (3) shallow parts of the Battle Spring member aquifer, and, locally, other members of the Tertiary aquifer system, (4) the Mesaverde aquifer, in outcrop areas along both the Sierra Madre and Rock Springs uplifts, and (5) Cretaceous and older aquifers in limited outcrop exposures along the Sierra Madre and Rawlins uplifts. Major ion composition of these low-TDS waters is generally dominated by dissolved calcium, sodium, and bicarbonate and/or sulfate.

Ground-water supplies with less than 3,000 mg/l TDS may generally be obtained, in addition to the sources mentioned above, from shallow (<1,500 feet) wells completed in all members of the Tertiary aquifer system, with local exceptions. Limited data from the deeper parts of this system indicate waters with greater than 10,000 mg/l TDS. Available data for older aquifers indicate that salinity increases rapidly away from outcrop, and that ground water containing less than 3,000 mg/l TDS exists in limited near-outcrop areas only. Dissolved solids concentrations exceed 10,000 mg/l in these aquifers over most of their subsurface extent, with dissolved sodium and chloride ions predominating.

Quaternary Aquifers

Water quality data for the Quaternary aquifers are available from water samples from 21 wells. These wells are located in the alluvial deposits along a number of streams, including the Little Snake River, Bitter Creek, and Muddy Creek (Plate 3).

Total dissolved solids concentrations in Quaternary aquifers vary widely from about 200 to over 60,000 mg/l (Plate 3). Major ions in solution are calcium, sodium, and bicarbonate at TDS levels below 1,000 mg/l, while the more highly saline (TDS greater than 10,000 mg/l)

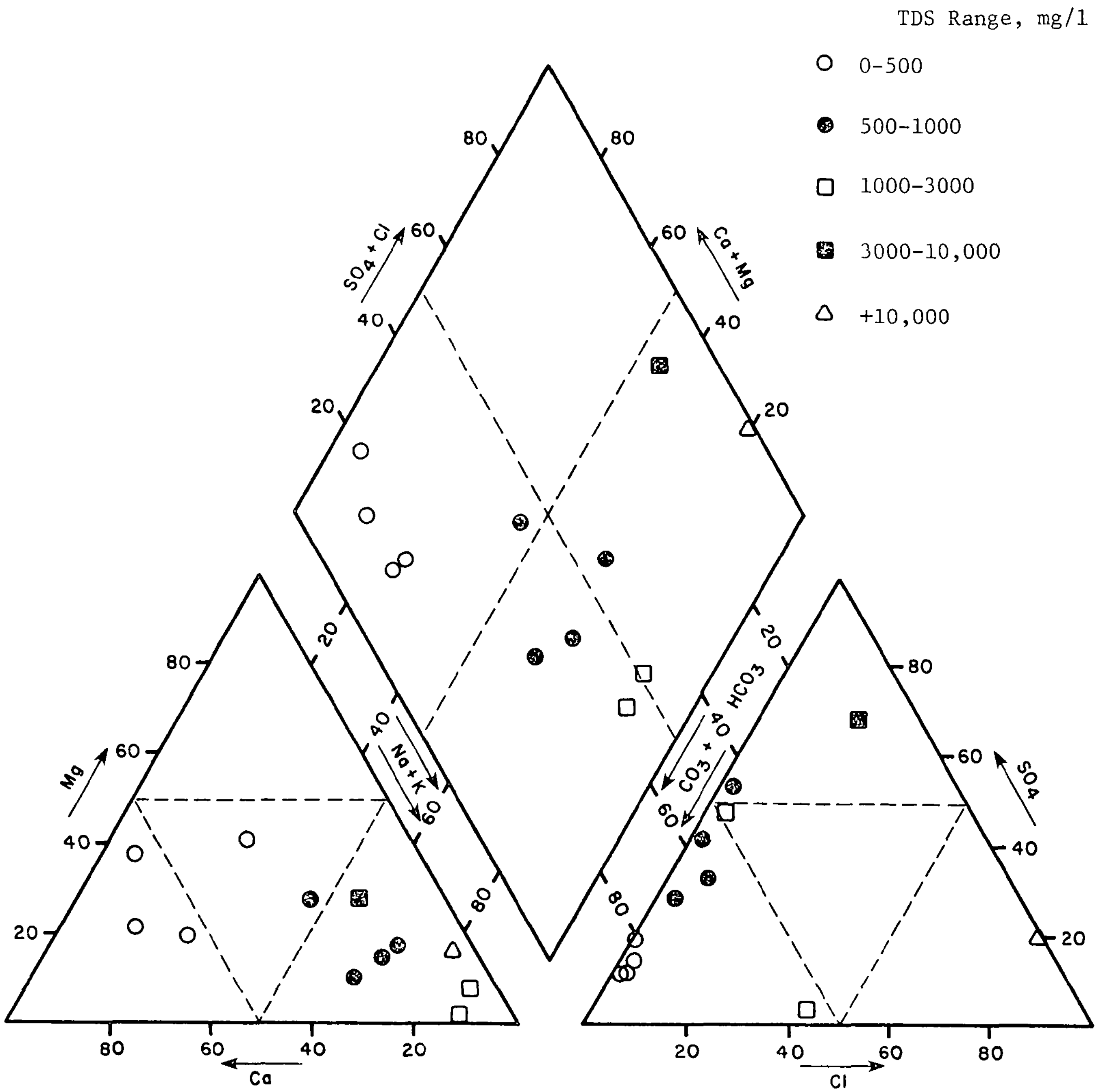


Figure VI-1. Major ion composition of waters from the Quaternary aquifers, Great Divide and Washakie basins.

Quaternary waters contain mainly sodium and chloride (Figure VI-1). Intermediate salinity corresponds to sodium and sulfate enrichment.

Data are insufficient to identify any spatial distribution of TDS and major ion composition within individual drainages. However, Quaternary waters with the highest TDS concentrations and sodium-chloride enrichment are located in the Bitter Creek drainage (Plate 3) in the western part of the area. High TDS levels are likely due to evapotranspiration. Additionally, the presence of faults in the underlying bedrock and the relatively high chloride enrichment in the alluvial waters suggests discharge from deeper aquifers into Quaternary aquifers in this vicinity. Combined with evaporation, these factors may generate the highly saline alluvial waters.

Upper Tertiary Aquifers

Chemical data from 19 shallow wells and springs in the eastern Washakie basin are available for the Upper Tertiary aquifers. Most data are for Browns Park/North Park waters. Total dissolved solids concentrations in waters from these aquifers vary from 84 to 860 mg/l, and are generally below 500 mg/l. Available data indicate that some spatial distribution of dissolved solids exists (Plate 4), with increased mineralization occurring away from the Sierra Madre uplift. Dissolved calcium and bicarbonate are the principal constituents of North Park/Browns Park waters (Figure VI-2), with sulfate enrichment coinciding with increased salinity.

Many of the existing ground-water analyses are from springs and seeps, and may represent the hydrochemical conditions of local flow systems. Therefore, increases in TDS and the accompanying changes in major ion composition may result from localized variations in

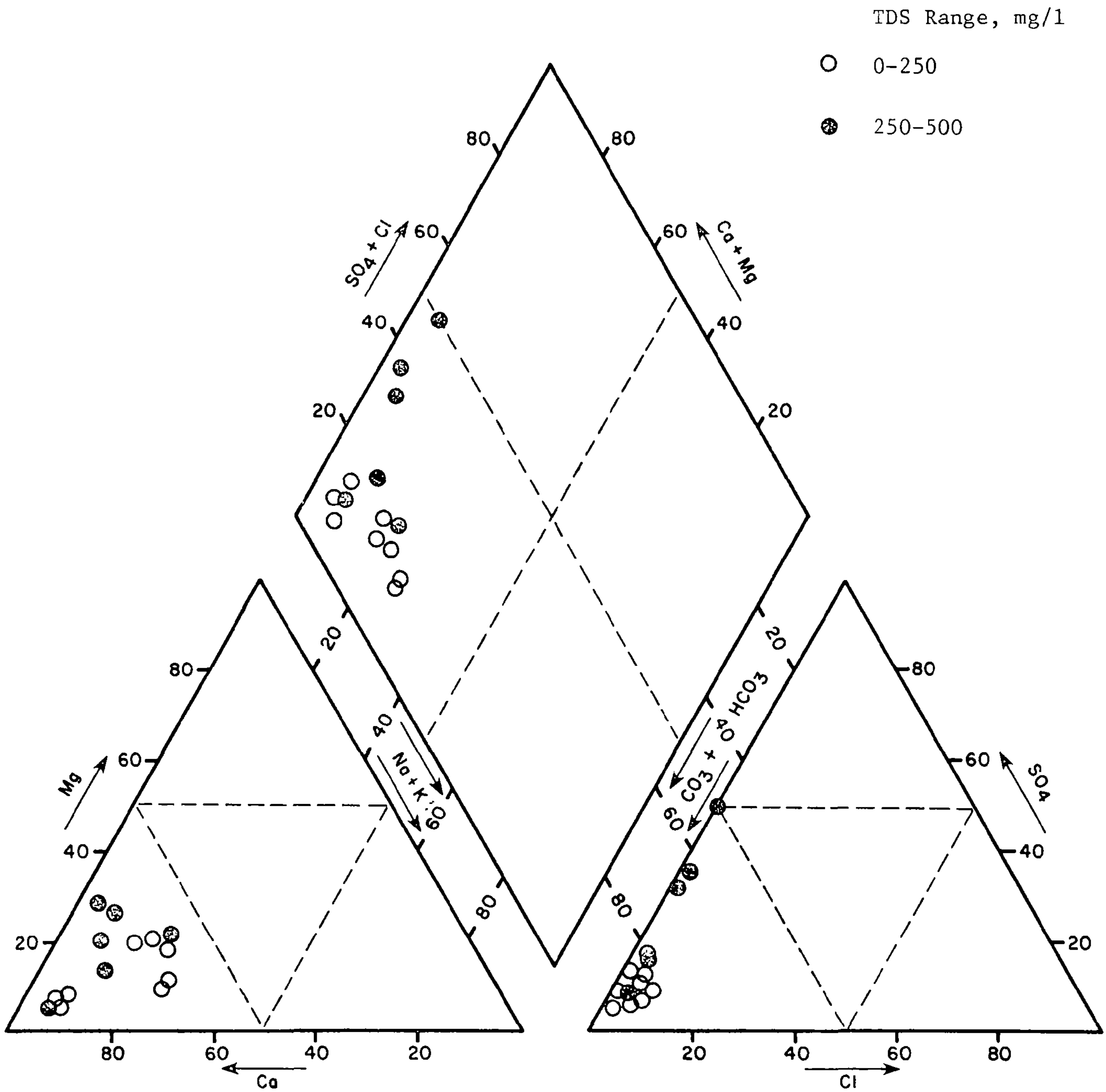


Figure VI-2. Major ion composition of waters from the Upper Tertiary aquifers, Great Divide and Washakie basins.

permeability and/or soluble mineral content, as opposed to regional downgradient geochemical evolution of the ground water.

Tertiary Aquifer System

Member aquifers of the Tertiary aquifer system are the shallowest present over much of the Great Divide and Washakie basins, and over 100 chemical analyses of ground waters from these units exist. Most analyses are for Laney Member (Green River Formation), Wasatch, and Battle Spring waters, and essentially all available data are from relatively shallow (maximum depth of about 1,500 feet and generally less than 500 feet) outcrop and near-outcrop wells. Therefore, this discussion is primarily concerned with the chemical character of shallow Tertiary waters; a discussion of available data on deep Tertiary ground waters is at the end of this section.

Total dissolved solids in shallow Tertiary aquifer system waters vary from 150 to 7,200 mg/l. A geographic distribution of dissolved solids exists which in part reflects differences in the soluble mineral content and/or permeability of the member aquifers. TDS levels below 500 mg/l are limited to Battle Spring and Wasatch aquifer waters along the northern Great Divide basin flank (Plate 5). The areas of high salinity (>3,000 mg/l TDS) are found within the Wasatch and Laney aquifers along the east rim of the Washakie basin and within the Fort Union and Lance aquifers along the east flank of the Rock Springs uplift. Over much of the remainder of the area, dissolved solids range from 1,000 to 3,000 mg/l.

Available data indicate interformational differences in major ion composition between Tertiary aquifer system member waters. Analyses of ground waters from the Battle Spring and Green River aquifers indicate changes in major ion composition occur with increasing salinity, while in waters from the other member aquifers the relationship between these parameters is sporadic and vague.

Low-TDS Battle Spring ground water contains primarily dissolved sodium-bicarbonate, with increasing calcium-sulfate as TDS levels approach 1,000 mg/l (Figure VI-3). Low TDS (<250 mg/l) water containing sodium enrichment, often exceeding 80 percent of the dissolved cations on a milliequivalent basis, and the common presence of calcium-magnesium carbonate soil horizons in arid region soils suggests that fairly complete reactions between exchangeable sodium and dissolved calcium and magnesium are taking place. Enrichment of calcium and sulfate with increased salinity is probably due to gypsum/anhydrite dissolution.

Analyses of Laney Member aquifer water indicate an increase of dissolved sodium with higher salinities, though this change is not always seen (Figure VI-4). Anionic composition varies from roughly equal amounts of dissolved sulfate and bicarbonate to primarily sulfate as TDS increases. The variable rate of sodium enrichment with increased TDS may result from differences in the amounts and types of ion exchange materials present within individual water-bearing zones.

Major ion composition of shallow waters from the Washakie, Fort Union, and Lance aquifers is shown in Figures VI-5 and VI-6. Little correlation between major ions and dissolved solids is apparent within these ground waters. Available data indicate Lance and Wasatch aquifer waters are generally sodium-sulfate in character, although exceptions exist; some Lance water shows chloride enrichment, for example. Fort

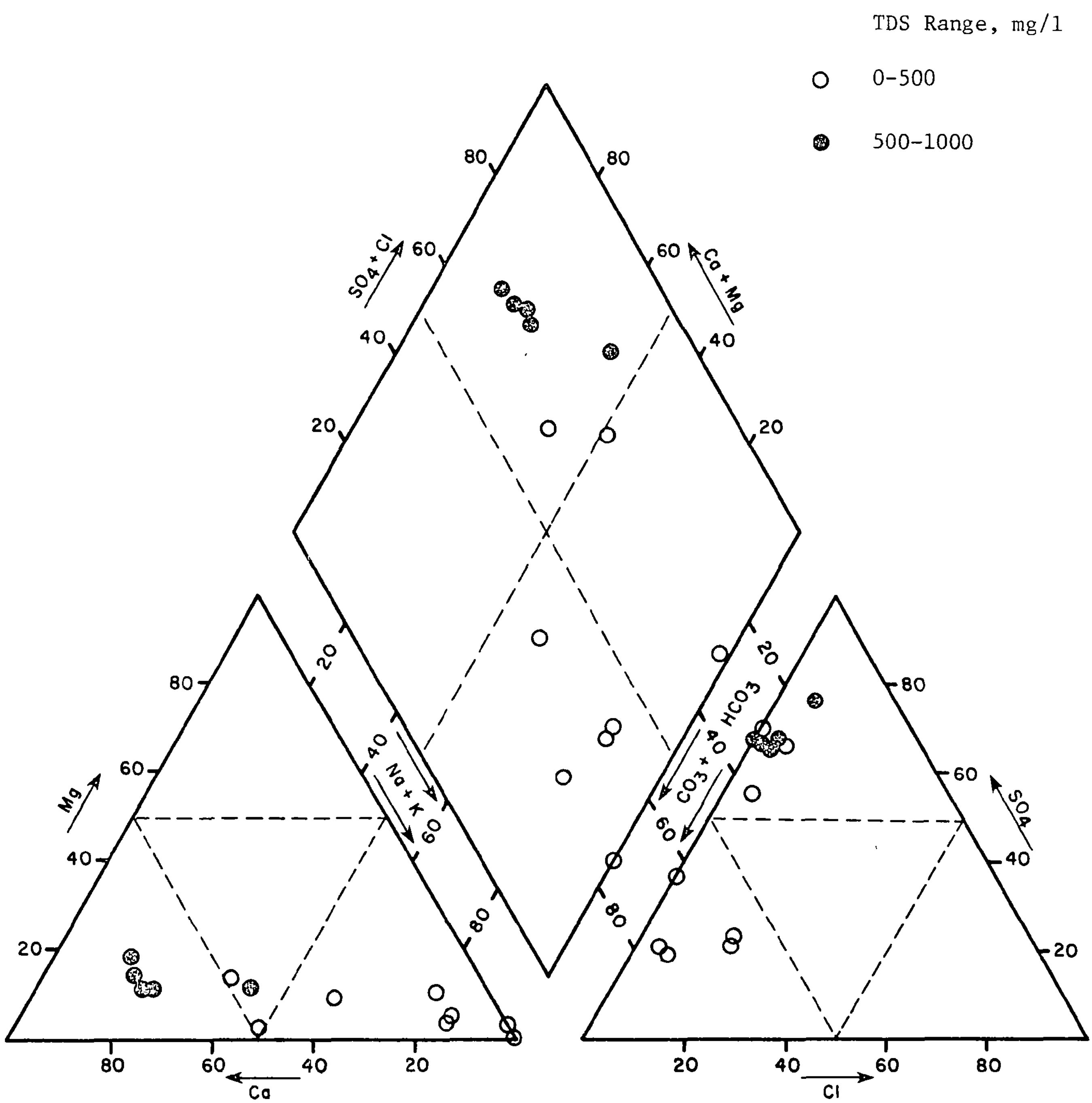


Figure VI-3. Major ion composition of waters from the Battle Spring aquifer, Great Divide and Washakie basins.

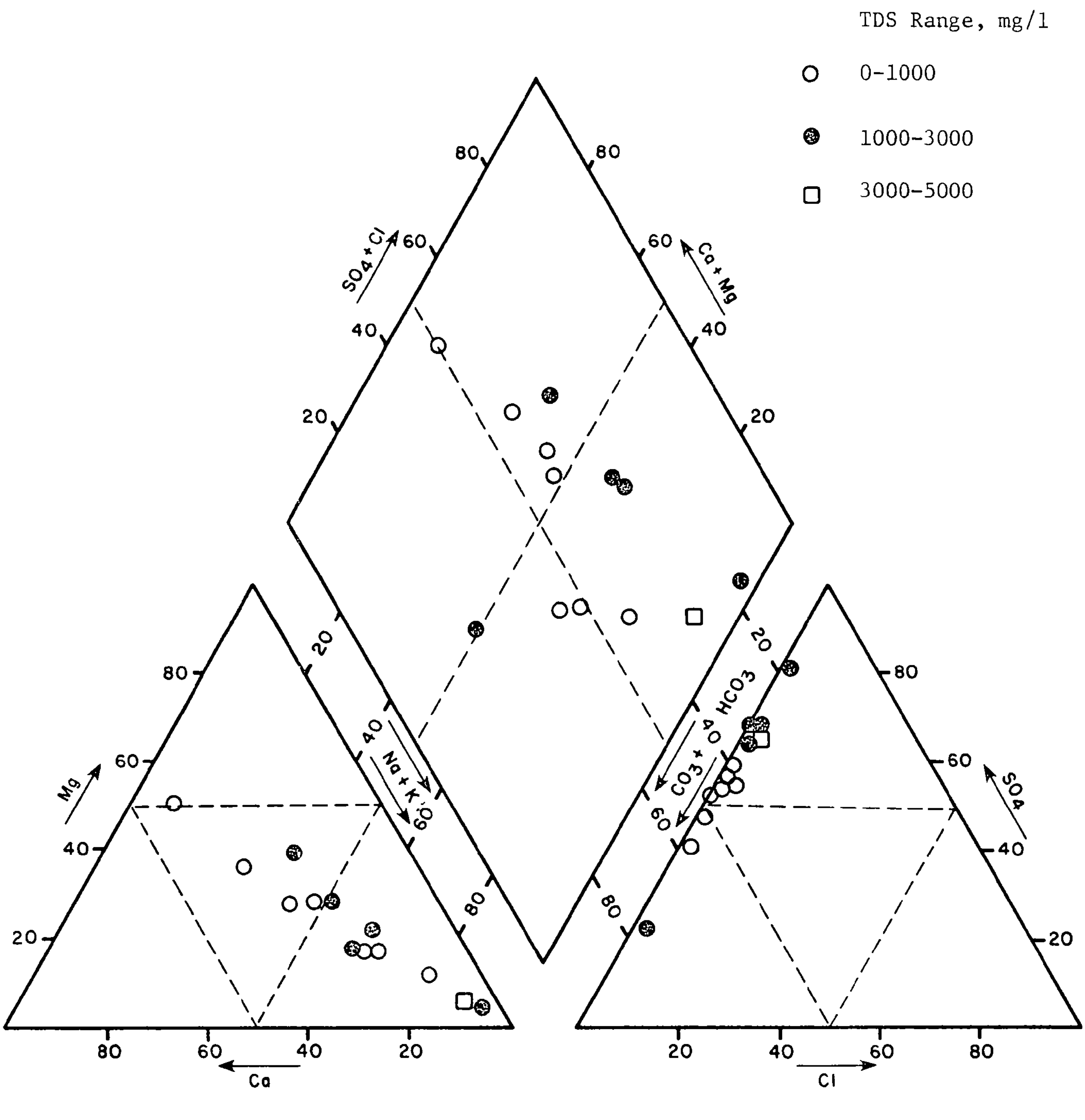


Figure VI-4. Major ion composition of waters from the Laney aquifer, Great Divide and Washakie basins.

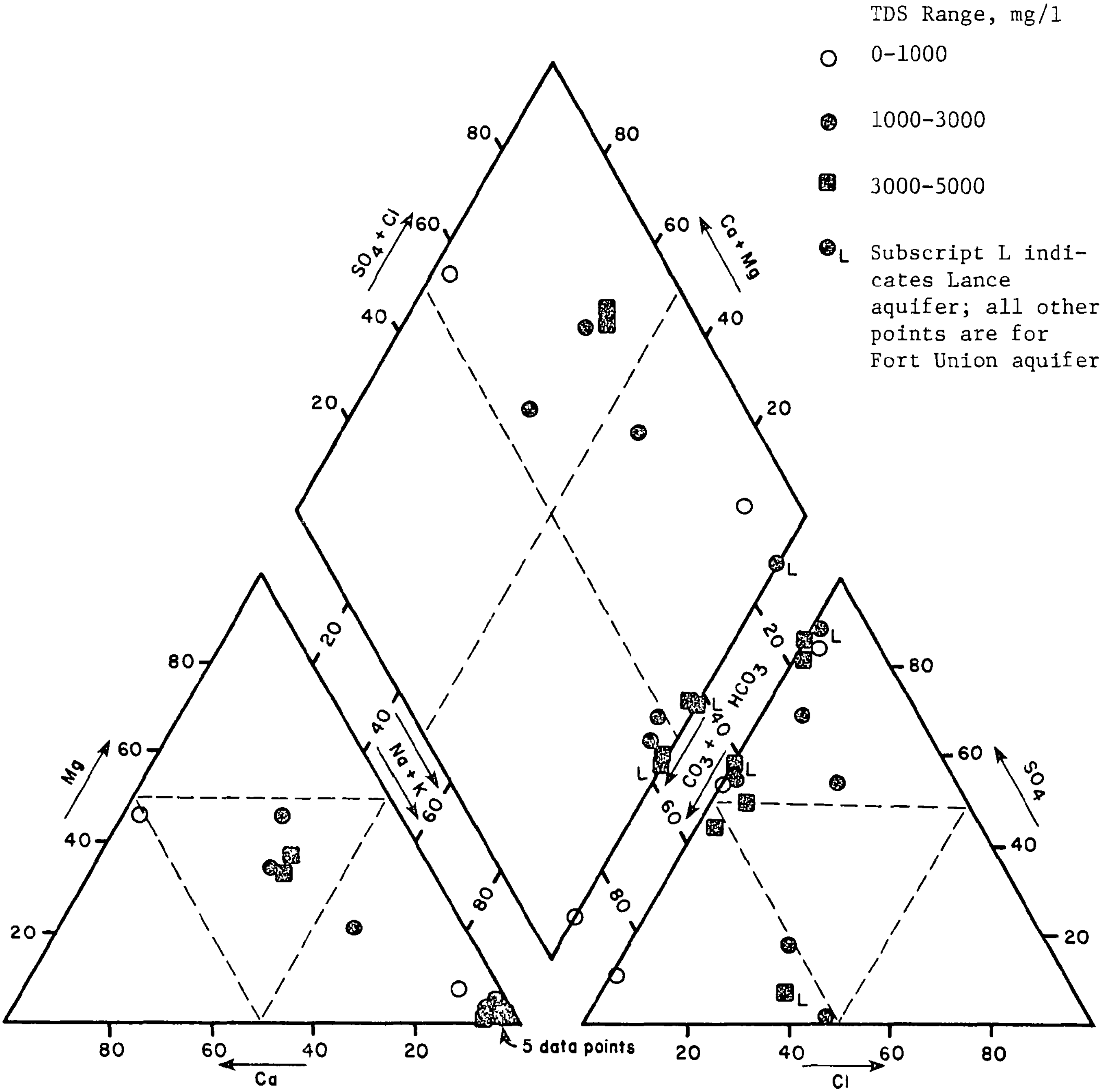


Figure VI-5. Major ion composition of waters from the Lance-Fort Union aquifers, Great Divide and Washakie basins.

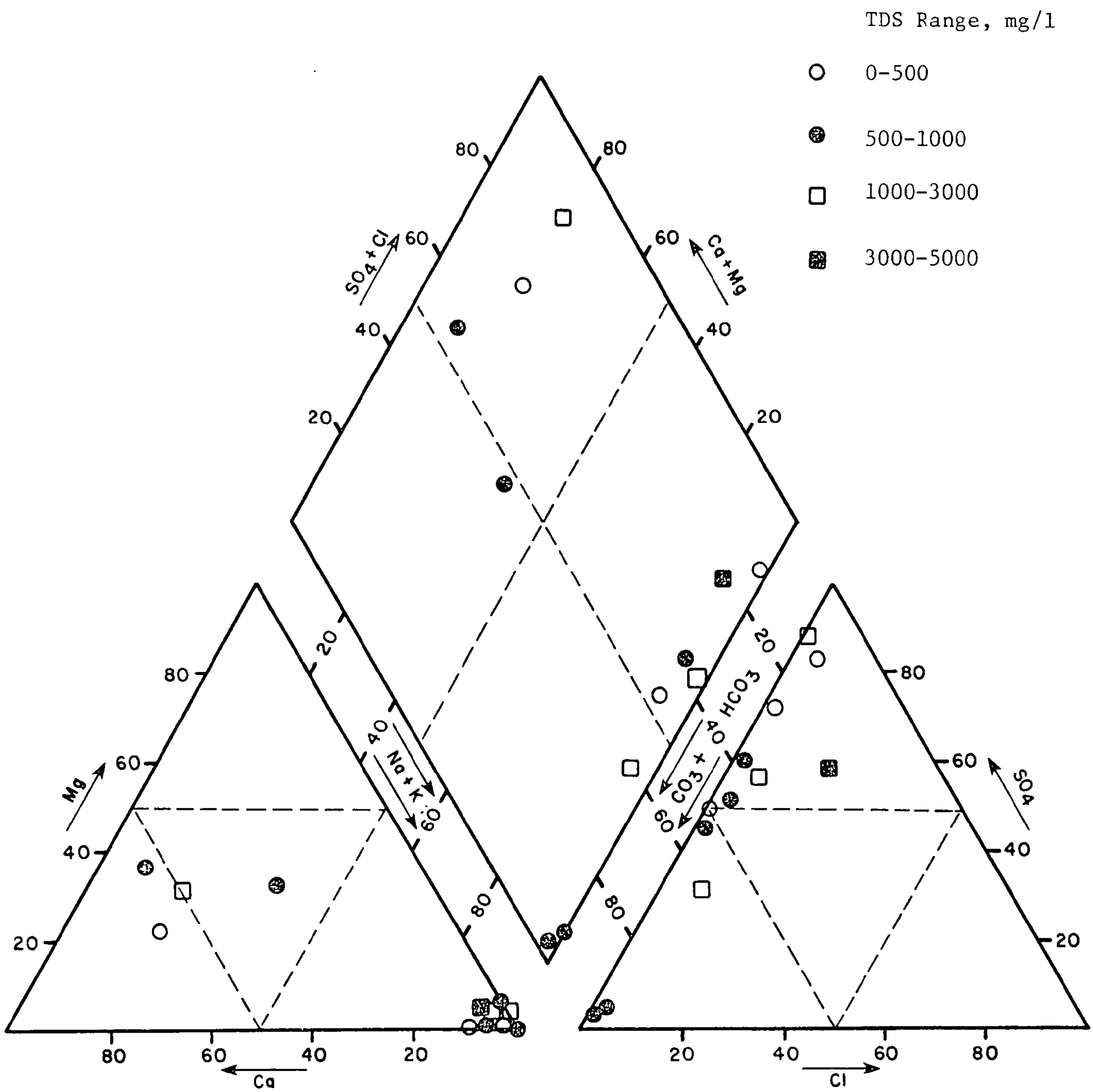


Figure VI-6. Major ion composition of waters from the Wasatch aquifer, Great Divide and Washakie basins.

Union ground water is extremely variable in composition, suggesting widely differing hydrochemical environments between individual water-bearing units.

Sparse water quality data are available for Tertiary aquifer system waters away from outcrop areas. Existing data are largely derived from formation water resistivities obtained during drill stem tests. Dissolved solids (as NaCl) exceed 35,000 mg/l in one Lance aquifer test (T. 23 N., R. 99 W., section 14). Along the southern edge of the area (T. 12 N.), TDS (as NaCl) increases westward from less than 2,000 mg/l near outcrop in R. 92 W., to over 35,000 mg/l in R. 99 W. One Fort Union test (T. 13 N., R. 95 W., section 25) indicated dissolved solids concentrations in excess of 60,000 mg/l. These extremely saline waters suggest highly restricted ground-water flow at depth within the Fort Union and Lance, or upward migration of saline waters from underlying units.

Mesaverde Aquifer

Hydrochemical data for the Mesaverde aquifer are fairly numerous, and include about 50 analyses and 10 resistivity measurements. Most data are for waters in the Washakie basin and its bounding uplifts. Available data indicate a wide, yet systematic, variability in dissolved solids concentrations and major ion compositions in Mesaverde ground water.

Dissolved solids concentrations in Mesaverde aquifer water vary from less than 500 to over 50,000 mg/l. TDS levels below 1,000 mg/l are limited to outcrop and near-outcrop zones along the southeast flank of the Washakie basin and on the northern and southern ends of the Rock Springs uplift (Plate 6). Increasingly saline water is found toward the central part of the Washakie basin, where TDS concentrations are generally in excess of 10,000 mg/l. The rate of increase in TDS away from outcrop is variable, with the most saline Mesaverde waters found along the east flank of the Rock Springs uplift at a relatively short distance from outcrop. Numerous faults cut the Mesaverde and associated rocks in that area. The high TDS levels that exist basinward may result from a fault-related restriction of ground-water circulation, or alternatively, through a fracture-controlled influx of saline waters from stratigraphically adjacent shales. The existence of stratigraphic gas traps and the generally low permeability (<1 gpd/ft^2) of Mesaverde gas reservoir rocks in this area (Higgins and Antelope fields, T. 16 N., R. 98-100 W.) indicate that zones of highly restricted flow also contribute to the high salinity levels (Wyoming Geological Association, 1979).

Major ion composition of Mesaverde aquifer water varies with salinity, and therefore with location within the basin. Low-TDS (<1,000 mg/l) outcrop water contains primarily dissolved sodium and bicarbonate (Figure VI-7). Water containing 1,000 to 3,000 mg/l is enriched in calcium sulfate, probably from gypsum/anhydrite dissolution. Increasingly saline water is characterized by dissolved sodium, chloride, and bicarbonate, and is essentially free of sulfate. The chemical character of this highly mineralized Mesaverde ground water likely results from (1) exchange of dissolved calcium for sodium; (2) sulfate reduction and the resulting bicarbonate generation; and/or (3) intermixing with saline, sodium-chloride rich water, from low permeability zones within either the Mesaverde or adjacent shale units.

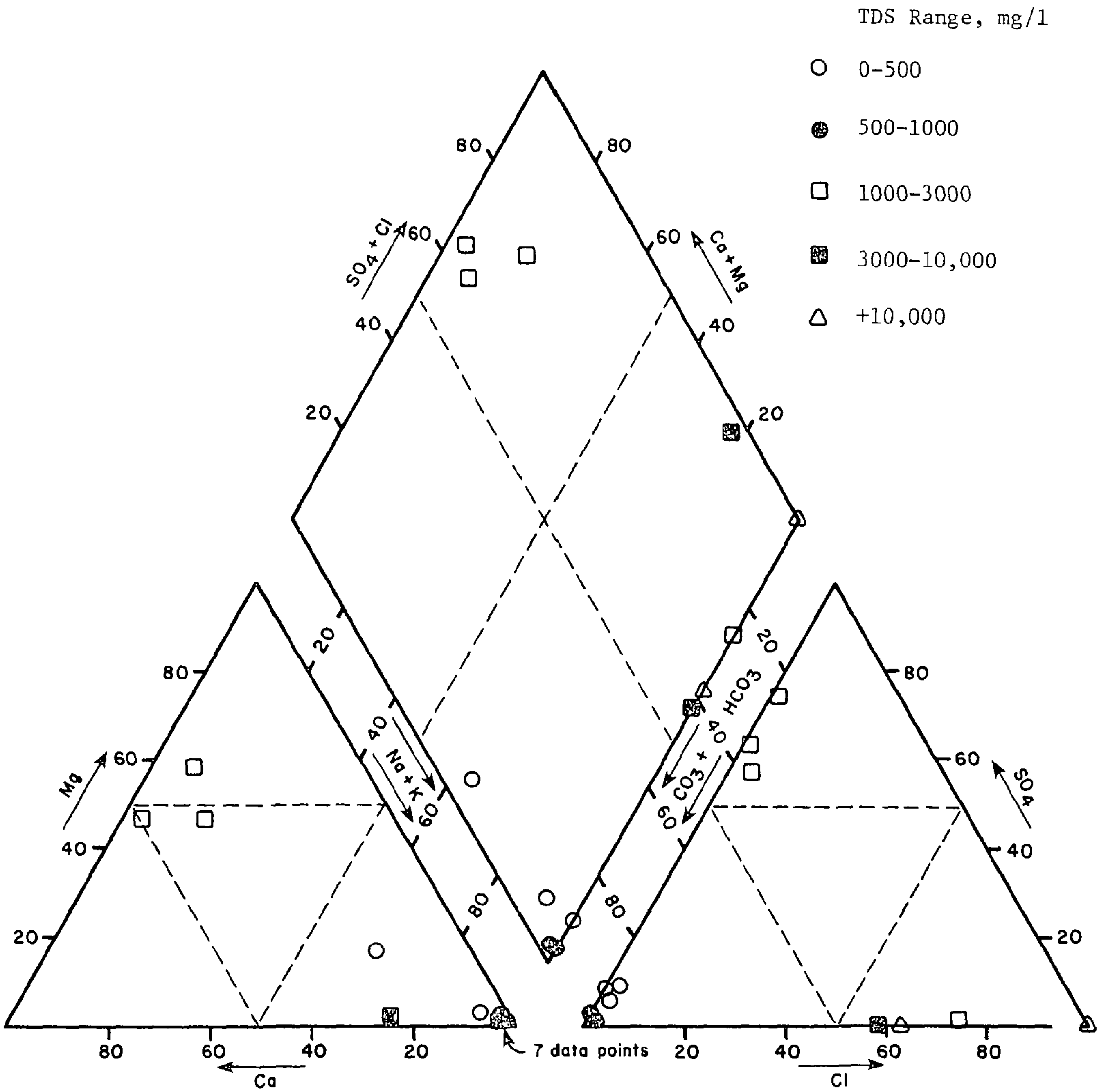


Figure VI-7. Major ion composition of waters from the Mesaverde aquifer, Great Divide and Washakie basins.

Frontier, Cloverly, and Sundance-Nugget Aquifers

Chemical data for the Frontier, Cloverly, and Sundance-Nugget aquifers are sparse and limited to three general areas: (1) outcrop and near-outcrop areas adjacent the Sierra Madre uplift, (2) scattered oil-producing areas in the northeast Great Divide basin, and (3) along the Rock Springs uplift. Available data indicate both similarities and differences in the general chemical character of waters from these aquifers.

Total dissolved solids range from 500 to 60,000 mg/1 in the Frontier, 200 to 60,000 mg/1 in the Cloverly, and 1,100 to 40,000 mg/1 in the Sundance-Nugget. Low TDS concentrations (less than 1,500 mg/1) for these aquifers are limited to near-outcrop areas along the Sierra Madre uplift (Plates 7, 8, and 9), indicating zones of recharge. These outcrop exposures are small, with much of the area along the Sierra Madre covered by Upper Tertiary aquifers, suggesting that part of the recharge to Cretaceous aquifers is through downward leakage from overlying units.

In the northeast Great Divide basin Sundance-Nugget and Cloverly aquifer waters generally contain 3,000 to 5,000 mg/1 dissolved solids, while Frontier waters vary between 1,000 and 15,000 mg/1 TDS.

The most saline water in all these aquifers occurs along the Rock Springs uplift. Data from this area indicate a distinct stratigraphic control on ground-water chemistry and circulation (Figure VI-8). Nugget water characteristically contains less than 10,000 mg/1 dissolved solids, as does most Sundance water, with several waters having TDS levels below 5,000 mg/1. Waters in overlying and underlying units are notably more saline in most cases, generally contain

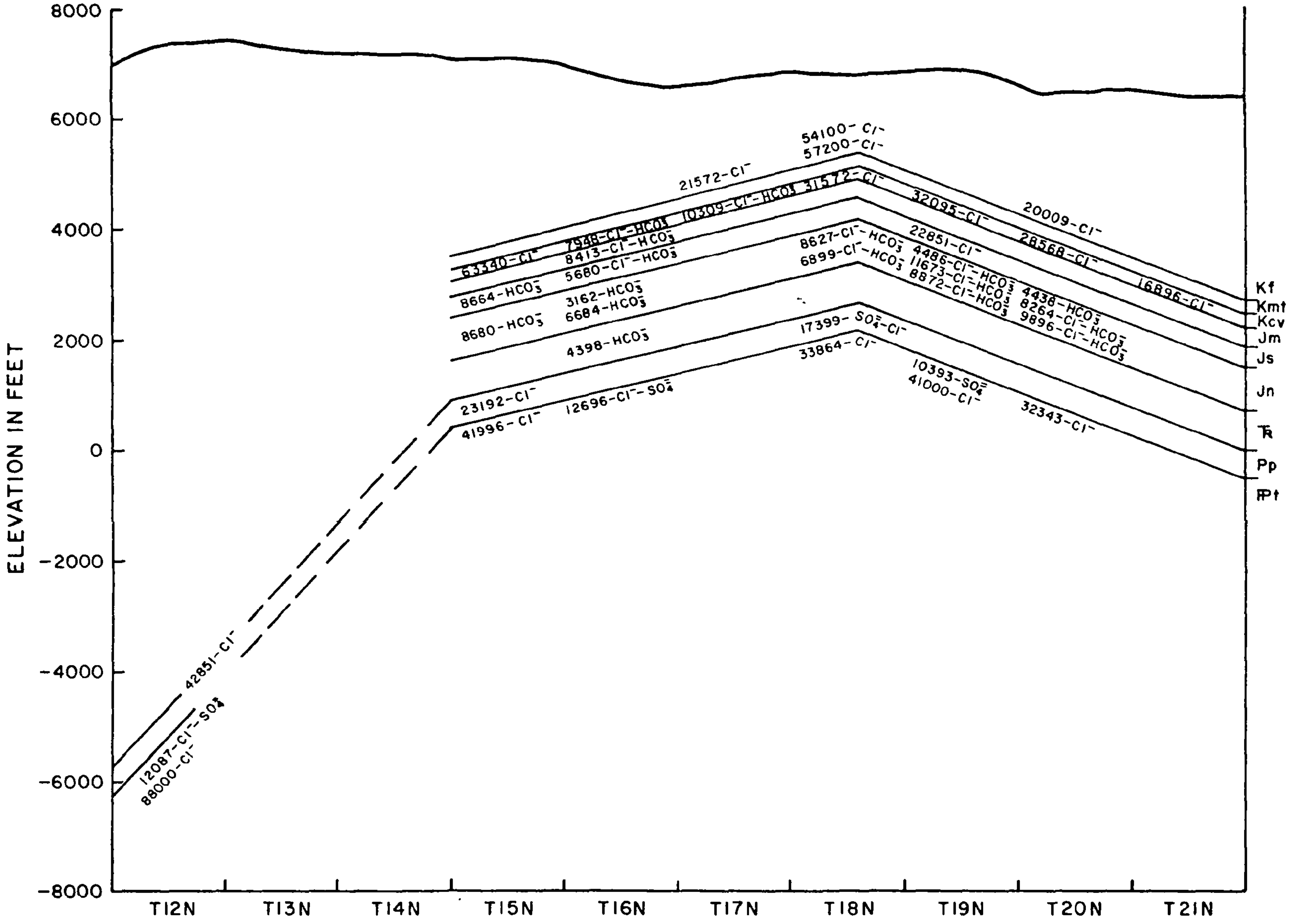


Figure VI-8. General stratigraphic distribution of total dissolved solids and major ion compositions within Mesozoic and Paleozoic aquifers, Rock Springs uplift area (for abbreviations, see p. 20).

significantly lower relative bicarbonate concentrations, and are chloride rich. This hydrochemical zonation indicates a lack of interformational flow through the Sundance-Nugget aquifer. However, one well (T. 16 N., R. 104 W., section 21), reportedly drilled in a fracture zone (U.S. Geological Survey Oil and Gas Division, Casper, information files, 1981), produced waters from the Triassic Chugwater through Cloverly sequence with less than 10,000 mg/l TDS and significantly higher relative bicarbonate concentrations. This suggests that although there is little interformational flow, vertical movement may take place in zones of faulting and fracturing.

These aquifer waters show similar trends in major composition as related to changes in salinity (Figures VI-9, VI-10, and VI-11). All vary from predominantly sodium-bicarbonate to sodium-chloride waters as TDS increases, with little calcium, magnesium, or sulfate present at TDS levels above 1,000 mg/l.

Paleozoic Aquifer System

Development of the Paleozoic aquifer system is currently limited to outcrop and near-outcrop areas along the eastern edge of the Great Divide and Washakie basins. Chemical data for these aquifers consist of water well samples from the east basin outcrop area, as well as oil field water analyses and resistivity measurements from scattered areas along the basin margins. Existing data, though sparse, show generally similar trends in the regional distribution of dissolved solids concentrations and associated major ion compositions in ground waters from these aquifers.

TDS concentrations in Paleozoic aquifer system waters vary from about 200 to over 100,000 mg/l. TDS levels below 1,000 mg/l (Plate 10)

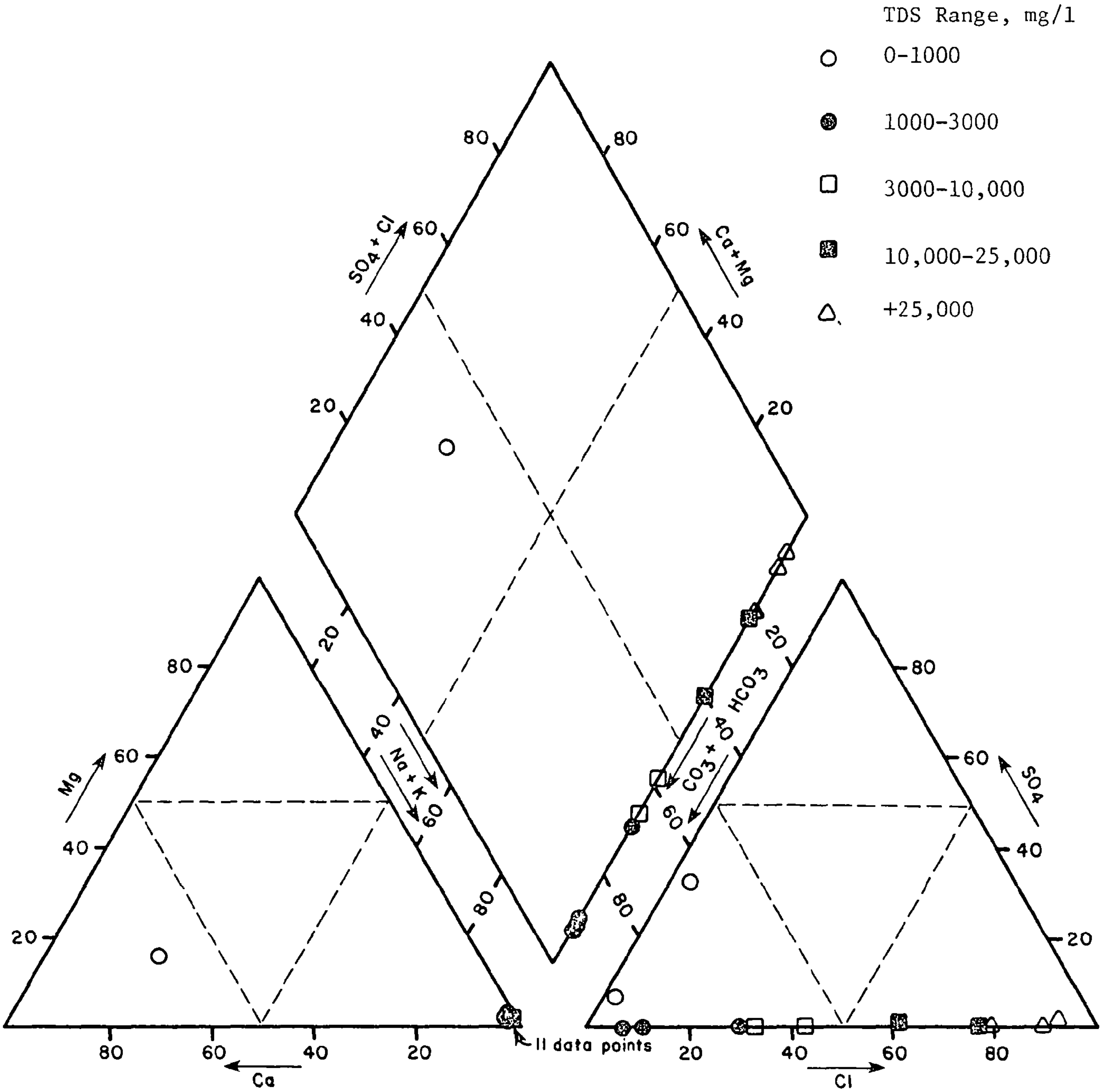


Figure VI-9. Major ion composition of waters from the Frontier aquifer, Great Divide and Washakie basins.

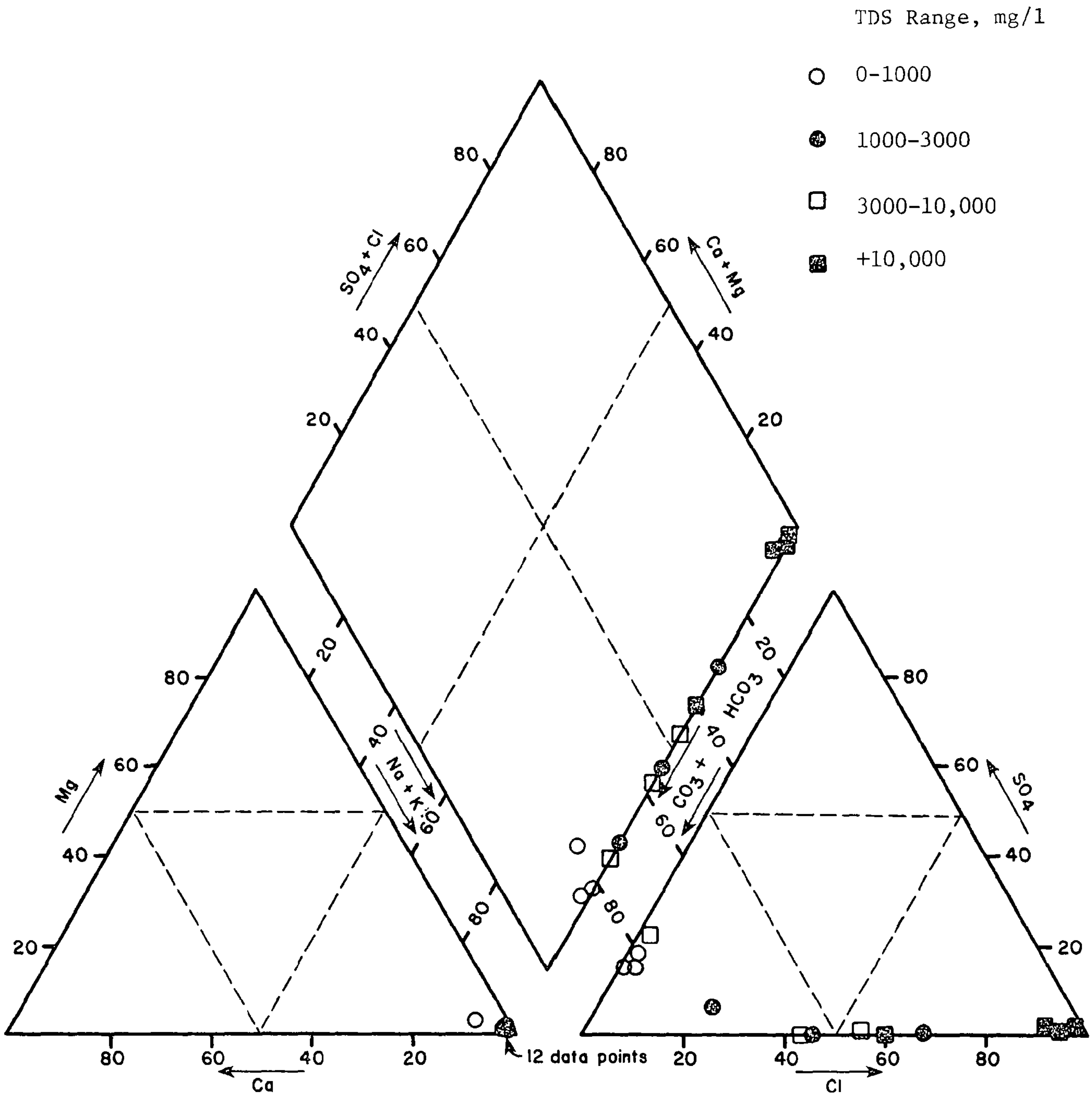


Figure VI-10. Major ion composition of waters from the Cloverly aquifer, Great Divide and Washakie basins.

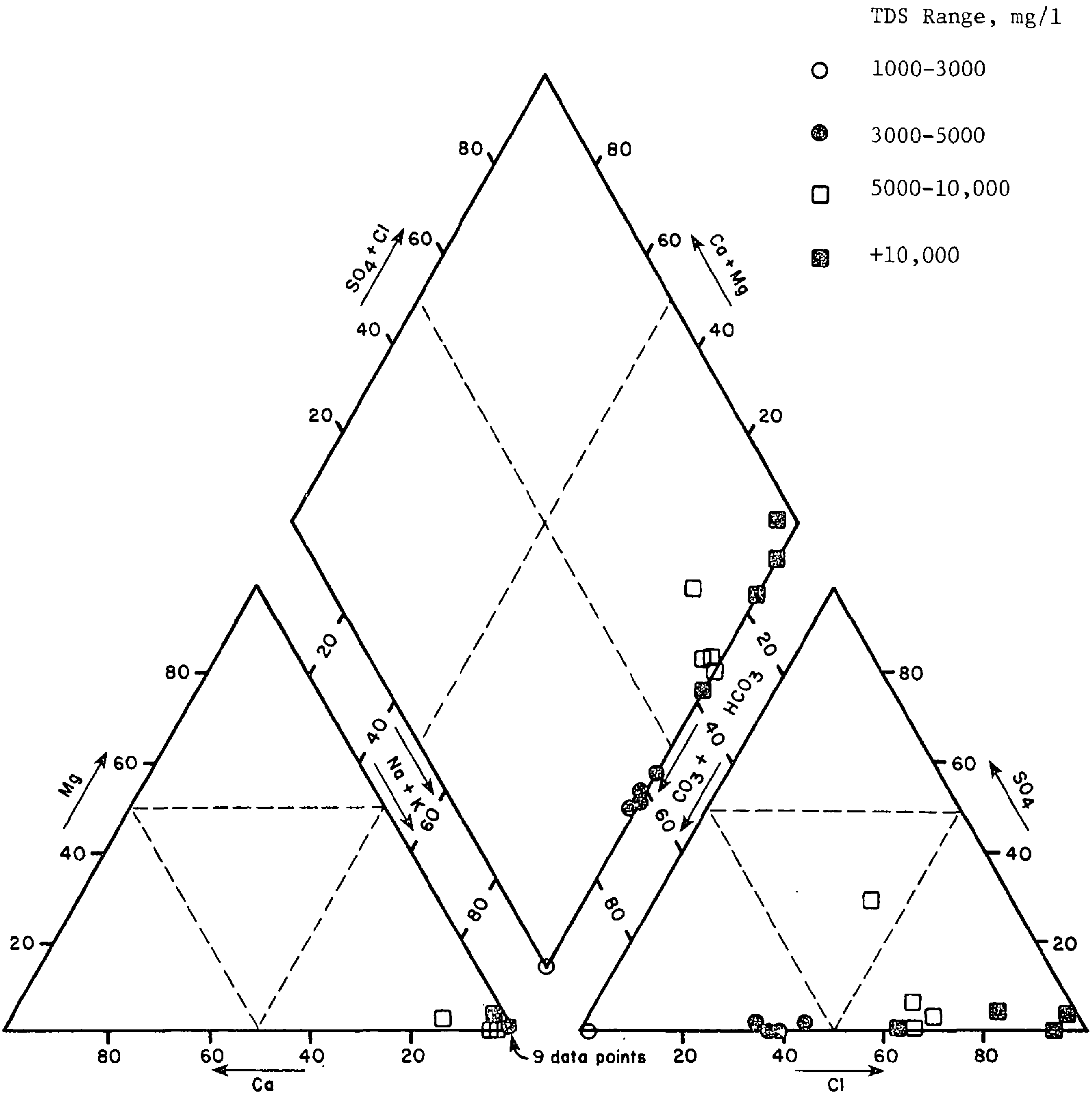


Figure VI-11. Major ion composition of waters from the Sundance-Nugget aquifer, Great Divide and Washakie basins.

are limited to outcrop and near-outcrop Tensleep and Cambrian aquifer waters along the eastern edge of the area. Dissolved solids concentrations increase downgradient from these areas, exceeding 100,000 mg/l along the east flank of the Rock Springs uplift. These highly saline waters are the result of lengthy subsurface residence time, due to: (1) the long distances from potential outcrop recharge zones, and (2) highly restricted flow as suggested by the existence of stratigraphic traps within some Paleozoic oil fields in the area (Brady South Unit, T. 16 N., R. 101 W.) (Wyoming Geological Association, 1979).

Dissolved solids concentrations are related to major ion composition in ground waters from Paleozoic aquifers (Figure VI-12). Low-TDS (<1,000 mg/l) near-outcrop waters are predominantly calcium-bicarbonate. Waters of intermediate salinity (3,000 to 10,000 mg/l TDS) contain mainly dissolved sodium and sulfate, while more highly mineralized waters, such as those along the Rock Springs uplift, are predominantly sodium and chloride.

DRINKING WATER STANDARDS

Primary Standards

Existing data on ground-water concentrations of species for which primary drinking water standards have been established are sparse in the Great Divide and Washakie basins. Most existing analyses originate from (1) U.S. Geological Survey investigations, (2) baseline monitoring adjacent to coal and uranium mines, and (3) samples collected by WRRI for this project. There are little data available for Cretaceous and older aquifers. Identified species with concentrations above primary

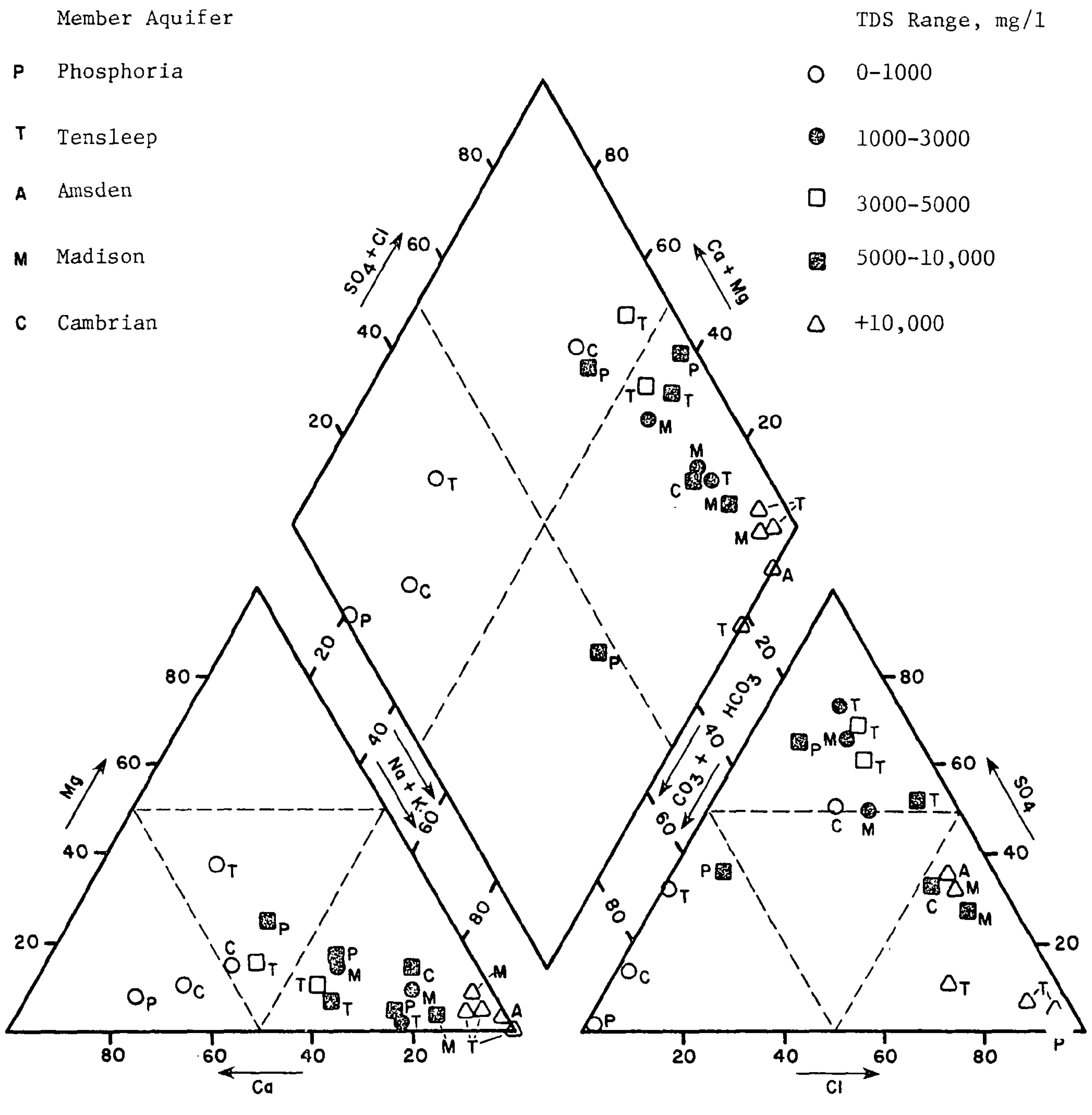


Figure VI-12. Major ion composition of waters from the Paleozoic aquifer system, Great Divide and Washakie basins.

standards include fluoride, lead, cadmium, selenium, silver, and chromium.

Fluoride

Existing data indicate 26 fluoride concentrations in excess of 2.0 mg/l F, all from aquifers lying stratigraphically above the Baxter Shale. The majority of these exceedences are from Mesaverde, Wasatch, Laney, and Fort Union waters. Nine analyses indicate fluoride levels of 5.0 mg/l F or more, four of which originated from the Mesaverde aquifer. Stratigraphic and areal distribution of fluoride exceedences are given in Figure VI-13. Whether this distribution of high fluoride levels is due to hydrogeologic conditions or a result of the small number of data points cannot be confidently determined.

Lead

Available data indicate 12 historic exceedences of the primary standard established for lead, 0.05 mg/l. All but one of these exceedences are from coal development areas (T. 18-20 N., R. 100-101 W., and T. 21 N., R. 89 W.), where analyses for trace elements are routinely performed. Therefore, distribution of data is biased toward such areas. Aquifers showing exceedences in these areas include the Mesaverde, Lance, Fort Union, and Quaternary alluvium. The single exceedence noted away from coal mine areas is from a Frontier outcrop well (T. 13 N., R. 87 W., section 15) with a lead concentration of 0.07 mg/l. Locations and source aquifers of lead exceedences are given in Table VI-1.

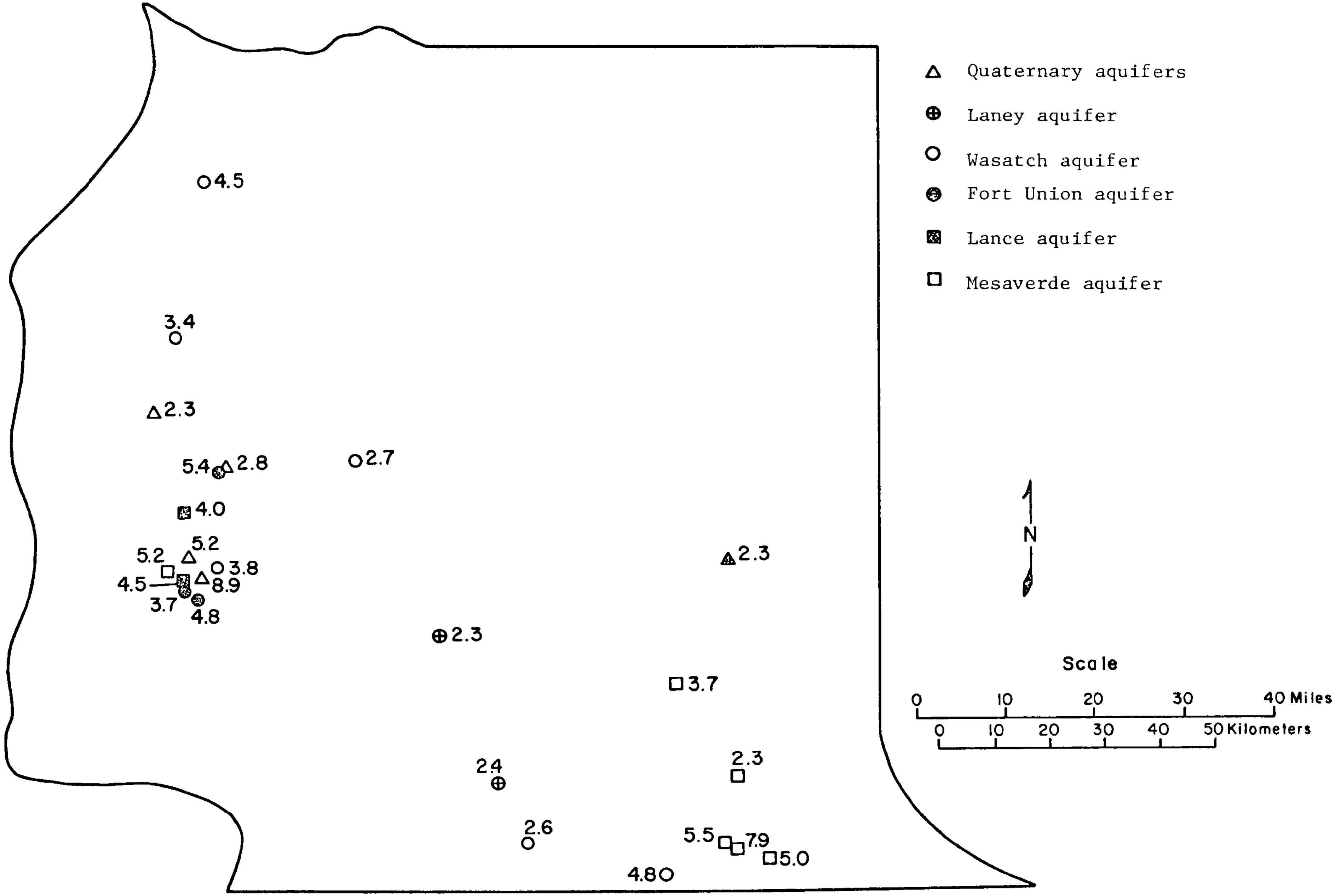


Figure VI-13. Fluoride concentrations exceeding the primary drinking water standard in Mesaverde through Quaternary aquifers, Great Divide and Washakie basins.

Table VI-1. Exceedences of primary drinking water standards for species other than fluoride in ground waters of the Great Divide and Washakie basins.

Location	Aquifer	NO_3-N	As	Pb	Ag	Ba	Cd	Cr	Se	Hg	Remarks
18/100-5 da	Alluvium			0.300							
18/100-22 ad	Alluvium			0.300							
23/96-25 bba	Wasatch							0.01			
18/100-29 dd	Ft. Union			0.400							
19/105-33 bc	Ft. Union			0.130							
21/89-11 d1	Ft. Union			0.050							Well completed in coal
21/89-11 d2	Ft. Union			0.110							Well completed in coal
21/89-11 d3	Ft. Union			0.228			0.073	0.091			Well completed in coal
18/100-10 cb	Lance			0.190			0.020				
18/100-20 db	Lance			0.300							
13/90-27 cca	Almond						0.010				
18/101-13 da	Almond			0.400			0.010				
20/101-27 ca	Mesaverde			0.160	0.020		0.010				
13/87-15 da	Frontier			0.070				0.01			
21/87-10 bb	Cambrian							0.01			

Other Primary Standards

Five cadmium, three selenium, one silver, and one chromium exceedence were found in existing data. As before, most are from coal mine areas. Locations and source aquifers are given in Table VI-1.

Secondary Standards

Species for which secondary drinking water standards have been established, and for which data exist within the Great Divide and Washakie basins, include sulfate, chloride, and total dissolved solids. The standards for sulfate and chloride are 250 mg/l; for TDS, 500 mg/l. Few aquifers within the basins meet these three criteria. As shown on TDS contour maps (Plates 3 through 10), TDS values below 500 mg/l are rare, consistently occurring only in upper Tertiary aquifers, the Battle Spring aquifer, and in outcrop zones of the Mesaverde aquifer. Where dissolved solids are greater than 1,000 mg/l, sulfate concentrations in most waters approach the 250 mg/l standard. Chloride, however, is generally below 250 mg/l in areas where dissolved solids are below 3,000 mg/l.

Table VI-2 summarizes ranges of concentrations of sulfate, chloride, and TDS by aquifer and geographic area for the two areas where data are available.

Radionuclide Species

Existing analyses of radionuclide species in the Great Divide and Washakie basins ground water generally include determinations for gross alpha and gross beta radiation, dissolved uranium, and radium-226 (Ra-226), a decay product of uranium-238. Primary drinking water

Table VI-2. Concentration ranges of TDS, chloride, and sulfate in ground waters of the Great Divide and Washakie basins.

Aquifer	Geographic Area	TDS[a]	Chloride[a]	Sulfate
Quaternary	Great Divide basin	200-2,050	4-114	25-914
	Washakie basin	200-60,700	9-31,000	15-1,450
Upper Tertiary aquifers	Sierra Madre uplift	84-860	1-41	6-175
Battle Spring	Great Divide basin	150-750	2-35	10-375
Wasatch	Great Divide basin	165-1,750	6-110	5-630
	Washakie basin	450-3,590	5-345	7-1,620
Green River	Great Divide basin	560-1,810	2-105	10-600
	Washakie basin	570-7,210	14-1,460	26-3,150
Ft. Union/Lance	Great Divide basin	84-4,950	3-945	10-2,010
Mesaverde	Great Divide-Washakie basins	250-64,000	15-35,400	12-2,240
Frontier	Northeast Great Divide-Sierra Madre	550-13,200	50-5,100	1-300
	Rock Springs uplift	21,600-57,300	5,150-30,000	40-90
Cloverly	Northeast Great Divide-Sierra Madre	200-5,500	2-1,100	30-740
	Rock Springs uplift	8,200-63,000	4,100-34,500	20-300
Sundance-Nugget	Northeast Great Divide-Sierra Madre	165-4,500	1-2,400	25-75
	Rock Springs uplift	4,400-49,950	1,560-26,970	160-3,407
Paleozoic (all)	Northeast Great Divide-Sierra Madre	215-14,960	3-6,140	25-5,225
	Rock Springs uplift	5,500-100,000	140-52,300	1,800-3,200

[a]All constituents in milligrams per liter.

standards have been established for radium-226 (5.0 pCi/l) and gross alpha (15.0 pCi/l).

Analyses for radium-226, gross alpha, and gross beta often contain an error limit that generally indicates the 95 percent confidence interval of the analysis. Large error limits are usually due to either (1) a lack of instrument sensitivity at low concentrations, or (2) particle absorption in samples containing high dissolved solids. Where the confidence interval is large relative to the given absolute value, interpretation of results is difficult.

Available data indicate two exceedences of the Ra-226 and gross alpha standards. These exceedences originated from two Battle Spring wells (T. 24 N., R. 93 W., section 9 ad, and T. 24 N., R. 94 W., section 25 db) (Table VI-3) drilled in uranium mine areas. All other analyses of Battle Spring water show relatively low levels of radiation.

There is currently no drinking water standard for uranium. Hem (1970) states that uranium concentrations in ground waters are generally less than 10 μg/l. Three analyses of ground waters in the Great Divide and Washakie basins from the Battle Spring, Mesaverde, and Madison aquifers indicated uranium levels of 12.2, 34, and 27 μg/l, respectively. All other tests indicate generally lower uranium content. Table VI-3 summarizes concentrations of radionuclide species in area ground waters.

Table VI-3. Concentrations of radionuclide species in ground waters of the Great Divide and Washakie basins.

Aquifer	Location	Ra-226 (pci/l)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Uranium (μg/l)
Bishop Conglomerate	12/90-11 ad	0.09±0.12	1±1	5±3	5.0
North Park/Browns Park	15/89-33 cc	0.3±0.2	1±1	6±2	5.0
	16/88-22 db	0.1	3.0	3.7	3.4
	18/88-22 dd	0.35	4.4	2.9	3.6
	88/89-15 cd	0.19	6.2	4.1	5.2
Battle Spring	24/93-9 ad	14.7±17	4.5±9	21±4	-
	24/93-10 dc	1.15±0.1	-	-	12.2
	24/93-14 cd	0.5±0.01	-	-	0.9
	24/93-15 ca	1.3±0.1	-	-	7.1
	24/93-15 dd	0.07	-	-	6.7
	24/93-25 ad	0.65±0.1	-	-	4.6
	24/94-22 c	-	0.6	0.4	0.5
	24/94-25 db	33.5	156±34	90±9	-
	25/90-17 ca	0.06	1.95	6.4	1.8
	26/91-11 bba	0.04	2.1	6.2	1.2
Wasatch	23/96-25 ba	1.3±0.3	0±4	5±6	2.0
	24/103-32	-	-	-	15
	26/97-3 ddc	0.71	4.5	2.1	2.7
Green River	15/99-12 bc	0±0.1	3±1	4±2	4.0
Ft. Union	20/100-13 bb	4	3.4	11.7	1.0
Mesaverde	12/90-14 ad	0.46±0.2	0±2	3±3	0
	13/90-22 aa	0.17	<5.0	4.7	-
	14/90-3 ad	0.88	2.3	4.9	0.5
	14/90-5 da	0.05	3	<1.7	0.07
	14/90-10 cb	0.12	8.3	7	0.18
	19/101-33 cd	0.86	<6.7	15	<0.01
	20/101-27 ca	0.38±0.16	0±16	16±7	34.0

Table VI-3. (continued)

Aquifer	Location	Ra-226 (pCi/l)	Gross Alpha (pCi/l)	Gross Beta (pCi/l)	Uranium (μg/l)
Frontier	13/87-15 da	0.23±0.16	0±1	4±3	5.0
	23/88-16 db	0.1±0.2	10±4	2±3	6.0
Madison	21/87-10 bb	1.5±0.3	13±5	36±8	27.0
Cambrian	21/87-9 bd	0.32±0.18	11±2	14±3	9.0

VII. R E F E R E N C E S

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APPENDIX A

GROUND-WATER USE BY INDUSTRY AND FOR IRRIGATION AND DRINKING WATER IN THE GREAT DIVIDE AND WASHAKIE BASINS, WYOMING

Table A-1. Water produced as a by-product of petroleum production in the Great Divide and Washakie basins, 1979, by field (data from Wyoming Oil and Gas Conservation Commission Files and Wyoming Oil and Gas Conservation Commission (1980)).

Field	Location (T/R)	No. of Wells	1979 Produced Water (bbl)	Producing Formation(s)	Remarks
Airport	19/103	2	30	Frontier	
Alkaline Creek	16/98	1	0	Lewis	Shut in 9 mos.
Antelope	17/99	10	0	Almond	
Antelope Springs, E.	27/93	0	0	UNK	No 1979 production; abd. 1964
Arch	19/98	23	38,758	Almond	
Baggs, S.	12/92	14	3,734	Lewis, Mesaverde	
Baggs, S. Extension	12/92	2	0	Lewis	
Baggs, W.	12/93	0	0	UNK	No 1979 production; shut down
Bailey Dome	26/89	2	1,390,492	Tensleep	
Barrel Springs	19/93	12	0	Almond	
Bartlett	19/102	1	0	UNK	Shut in 7 mos.
Bastard Butte	25/97	2	0	Lewis	No 1979 production; Discov. 1978
Battle Springs	23/94	1	0	Lewis	Shut in 9 mos.
Baxter Basin, Middle	18/103	5	0	Dakota, Frontier	
Baxter Basin, N.	19-20/103-104	18	0	Dakota, Nugget, Morrison, Frontier	
Baxter Basin, S.	16/104	17	2,277	Dakota, Frontier	
Bell Springs	23/88	0	0	UNK	No 1979 production; abd.
Bison Basin	27/95	13	182,930	Frontier	
Bitter Creek	16/99	1	0	Weber	
Black Butte Creek	19/102	1	0	Dakota, Morrison	No 1979 production
Blue Gap	15/92	18	81,884	Mesaverde	
Brady	16/101	19	1,397,682	Nugget	
Browning	14/91	2	0	Tensleep	
Browns Hill	14-16/89-91	1	0	UNK	No 1979 production; discov. 1976
Bunker Hill	27/89	1	0	Steele, Frontier	No 1979 production; shut-in
Bush Lake	24/96	4	0	Mesaverde	
Camel Rock	18/102	1	1,841	Dakota	Production started 4/79
Canyon Creek	12-13/100-101	35	17,128	Wasatch, Mesaverde	
Cherokee Creek	15/91	2	310	Frontier, Deep Creek	
Cherokee Ridge	12/96	0	0	UNK	No 1979 production; abd. 1962
Chimney Rock	18/102	0	0	UNK	No 1979 production; abd. 1964

Table A-1. (continued)

Field	Location (T/R)	No. of Wells	1979 Produced Water (bbl)	Producing Formation(s)	Remarks
Coal Gulch	17/93	1	0	Almond	Production started 10/79
Cole Springs Draw	23/88	0	0	UNK	No 1979 production; abd.
Continental Divide	22/93	0	0	UNK	No 1979 production; Temp. abd.
Cow Creek	16/92	2	914	Frontier, Dakota	
Creston	19/92	2	0	Ericson	
Creston, S.E.	19/90	1	18	Almond	
Crooked Canyon	21/103	11	2,931	Dakota	
Crooks Gap	28/92-93	9	3,555,014	Frontier, Lakota, Muddy, Nugget	
Deadman Wash	20/101	3	0	Dakota, Frontier	
Deep Creek	16/90	2	0	Deep Creek, Muddy	
Deep Gulch	16/91	3	15,486	Frontier, Deep Creek, Nugget	
Delaney Rim	18/97-98	10	24,965	Almond, Lewis	
Desert Flats	19/95	2	0	UNK	No 1979 production; shut-in
Desert Springs	20-21/97-98	9	2,304	Almond, Lewis	
Desert Springs, E.	21/97	1	402	Almond, Lewis	
Desert Springs, W.	19-20/99	44	5,237	Almond	
Divide	22/87	1	0	Steele	Temp. abd. 4/79
Dixon	13/90	1	0	UNK	No 1979 production; discov. 1979
Echo Springs	19/93	15	5,486	Mesaverde, Lewis	
Espy	19/89	9	48,215	Tensleep, Niobrara	Shut-in 5 mos.
Ferris, E.	26/86-87	0	0	UNK	No 1979 production; abd. 1945
Ferris, W.	26/87	0	0	UNK	No 1979 production; abd. 1954
Fillmore	20/92	2	239	Mesaverde, Lewis	
Fireplace Rock	12/95	1	0	UNK	No 1979 production; shut-in
Five Mile Gulch	21/93	2	0	Mesaverde	
Forbes	25/97	1	0	Ericson	No 1979 production; discov. 1979
Gale	23/96	1	138	Ericson	
Girrard	27/95	1	0	Dakota	Shut-in 2 mos.
Golden Goose	28/92	2	1,576	Dakota	
Golden Wall	18/101	1	0	Dakota	No 1979 production; shut-in
GP Dome	25/86	1	0	"Cretaceous"	Shut-in 5 mos.

Table A-1. (continued)

Field	Location (T/R)	No. of Wells	1979 Produced Water (bbl)	Producing Formation(s)	Remarks
Great Divide	22-23/95-96	4	15	Lewis	
Hallville	19/100	1	0	Almond	Shut-in 2 mos.
Hansen Draw	17/96	1	0	Rock Springs	Shut-in 10 mos.
Happy Springs	28/93	8	1,974,954	Frontier, Muddy, Dakota	
Hatfield	19-20/88	0	0	UNK	No 1979 production; abd. 1965
Hay Reservoir	24/97	29	3,986	Lewis	
Haystack	14/96	1	0	Mesaverde	No 1979 production; shut-in
Hiawatha	12/99	18	1,611	Wasatch	
Higgins	17/99	11	0	Lewis	
Horn Canyon Unit	24/100	1	0	Frontier	No 1979 production; shut-in
Hugus	19/87	0	0	UNK	No 1979 production; abd.
Iron Pipe	16/98	1	0	Mesaverde	No 1979 production; shut-in
Jade Ridge	28/93	2	0	Dakota	1 mo. data missing
Joyce Creek	15/103	9	34,320	Frontier, Dakota	
Kinney	13/99	7	12,805	Mesaverde, Dakota, Frontier, Nugget	
Kirk	28/92	0	0	UNK	No 1979 production; temp. abd.'72
Lamont	25/89	0	0	UNK	No 1979 production; shut-in
Laney Wash	17/97	1	0	Lance	No 1979 production; shut-in
Leucite Hills	22/103	3	40	Dakota	
Little Snake	12/94-96	0	0	UNK	No 1979 production; abd. 1969
Little Worm Creek	15/104	0	0	Lakota	No 1979 production; shut-in
Lost Creek	23/97	2	0	UNK	No 1979 production; abd. 1978
Lost Soldier	26/90	52	30,385,995	Frontier, Tensleep, Madison, Cambrian	
Mahony, S.	25/88	3	80,475	UNK	
Mahony Dome	26/88	7	421,445	Tensleep	
Mahony Dome, E.	26/87-88	0	0	UNK	No 1979 production; abd. 1953
Mahony Draw	21/90	1	68	Mesaverde	
Marianne	20/103	1	0	Lakota	No 1979 production; discov. 1979
Masterson	20/102	2	0	Dakota, Blair, Muddy	

Table A-1. (continued)

Field	Location (T/R)	No. of Wells	1979 Produced Water (bbl)	Producing Formation(s)	Remarks
McPherson Springs	13/94	1	0	UNK	No 1979 production; discov. 1979
Melton	22/86	0	0	UNK	No 1979 production; abd. 1966
Middle Mountain	12/103	1	0	UNK	No 1979 production; abd. 1977
Monell	18-19/99	49	1,657,300	Almond	
Monument Lake	21/92	1	0	Mesaverde	Production started 11/79
Mud Lake	23/98	0	0	UNK	No 1979 production; abd. 1960
Neff	18/98	0	0	UNK	No 1979 production; shut-in
Nickey	24/96	1	0	Almond	No 1979 production; discov. 1979
Nitchie Gulch	23/103	20	690	Frontier, Dakota	
O'Brien Springs	25/86	1	0	Tensleep, Muddy	
Osborne Draw	26/93	0	0	UNK	No 1979 production
Patrick Draw	18/99-100	36	4,270	Almond	
Picket Lake	26/97	2	0	Lewis	Shut-in 7 mos.
Pine Canyon	23/103	7	0	Frontier	
Platte River Bend	24/85	0	0	UNK	No 1979 production; abd. 1966
Playa	20-21/98-99	17	3,743	Almond, Lewis	Shut-in 7 mos.
Point of Rocks	20/101	1	56	Blair	
Potter Mountain	14/103	2	0	Frontier	
Powder Springs	12/97	1	93	UNK	
Pretty Water Creek	15/104	1	4	UNK	
Red	16/94	1	0	UNK	No 1979 production; discov. 1979
Red Desert	22/97	1	0	Mesaverde, Lewis	Shut-in 5 mos.
Red Hill	19/100	0	0	UNK	No 1979 production; shut-in
Red Lakes	18/94	5	4,649	Mesaverde	
Rim	19/88	1	0	UNK	No 1979 production; temp. abd.
Robbers Gulch	14/91	2	660	Mesaverde	Shut-in 4 mos.
Robin	19/97	3	963	Almond	
Roser	21/101	0	0	UNK	No 1979 production; shut-in
Round Table	12/96	0	0	UNK	No 1979 production; abd. 1971
Salazar	16/95	2	232	Mesaverde	
Salt Wells	14/103	2	1402	Frontier, Dakota	

Table A-1. (continued)

Field	Location (T/R)	No. of Wells	1979 Produced Water (bbl)	Producing Formation(s)	Remarks
Sand Butte	17/99	1	0	Almond	
Savery	13/89	2	0	Deep Creek	
Sentinel Ridge	23/94	2	0	Mesaverde	
Separation Flats	24/87	1	0	Muddy	
Sheep Camp	22/97	4	281	Almond	
Sheep Creek	28/92	4	7,100	Phosphoria	Shut-in 4 mos.
Shell Creek	19/96	1	0	Mesaverde	
Sherard	25/88	5	145,999	Tensleep, Mowry, Frontier, Muddy	
Shiprock	20/101	2	0	Frontier	Production started 5/79
Siberia Ridge	21/94	7	6,294	Mesaverde	
Six Mile Springs	18/104	2	0	Frontier	
Smith Ranch	12/93	4	0	Lewis, Lance	
Smokey	15/99	1	0	UNK	No 1979 production; discov. 1979
Stage Stop	18/99	11	5,141	Lewis, Lance, Almond	
Standard Draw	18/93	3	0	Mesaverde	Shut-in 3 mos.
State Line	12/94-95	0	0	UNK	No 1979 production; abd. 1970
Stock Pond	22/95	2	0	Mesaverde	
Sugar Creek	19/90	1	5,219	Frontier, Tensleep	Shut-in 7 mos.
Table Rock	18-19/97-98	35	59,336	Almond, Lewis	
Table Rock, S.	18/98	2	906	Almond	
Table Rock, S.W.	18/98	1	0	Mesaverde	
Ten Mile Draw	21/98-99	5	0	Lewis, Almond	Shut-in 2 mos.
Tierney	19/94	5	0	Mesaverde	
Tierney, N.	20/94	0	0	UNK	No 1979 production
Tipton	19/97	1	53	Almond	
Trail	13-14/100	5	5,869	Mesaverde	
Trail Ridge	27/95	0	0	UNK	No 1979 production; abd. 1966
Triton	13/94	1	0	UNK	No 1979 production; discov. 1979
Twin Buttes	26/90	0	0	UNK	No 1979 production; temp. abd.
Twin Rocks	21/103	0	0	UNK	No 1979 production; temp. abd.
Vermillion	13/100-101	0	0	UNK	No 1979 production; abd. 1963

Table A-1. (continued)

Field	Location (T/R)	No. of Wells	1979 Produced Water (bbl)	Producing Formation(s)	Remarks
Wamsutter	20-21/94-95	27	2,273	Mesaverde	
Wells Bluff	18/96	1	0	Mesaverde	Shut-in 10 mos.
Wertz	26/89-90	39	8,878,418	Tensleep, Mesaverde, Amsden	
Westside Canal	12/91	28	1,245	Fort Union, Lance, Lewis	
Wild Rose	17-18/94	29	14,552	Mesaverde	
Windmill Draw	15/94	0	0	UNK	No 1979 production; discov. 1979
TOTALS: 159 fields:		901	50,501,191		

Table A-2. Water use for secondary recovery of oil in the Great Divide and Washakie basins, Wyoming, 1979, by field.[a]

Field	Approximate Location	Unit	Injected Formation	No. Injectors Active	No. Injectors Inactive	Injected Water (1979, bbl) -	Produced Water (1979, bbl) =	Calculated Makeup Water[b] (bbl)	Makeup Water Source	Remarks
Arch	19N-98W	Arch	Almond (Mesaverde)	45	(5)	2,245,832	38,758	2,207,074	UNK	"Purchased water."
Bison Basin	27N-95W	Frontier	Frontier	1	(6)	182,930	182,930	0	None	Solely produced water
Happy Springs	28N-93W	Dakota	Dakota	0	(1)	56,597			None	Solely produced water from Dakota and Tensleep; no injection July-Dec., 1979.
		Frontier	Frontier	0	(1)	0			Surface	Shut-in during 1979.
		TOTAL		0	(2)	56,597	1,974,954	0	-	
Lost Soldier	26N-90W	Tensleep	Tensleep	40	(2)	9,574,778			-	Lost Soldier field uses solely produced water from Sundance, Tensleep, Madison, and Cambrian.
		Cambrian	Cambrian	3	(1)	1,797,240			-	
		Madison	Madison	4	(0)	1,463,164			-	
		TOTAL		47	(3)	12,835,182	30,385,995	0	None	
Patrick Draw	18N-99,100W	Monell	Almond (Mesaverde)	77	(1)	5,412,601	4,270	5,408,331	Fox Hills	
Wertz	26N-89,90W	Wertz	Tensleep	8?	(1)	6,739,459			None	Solely produced water from Paleozoic rocks
		Wertz "D"	Tensleep	1	(0)	412,789			Battle Spring	Also uses Madison produced water.
		West Wertz	Tensleep	1?	(0)	630,202			None	Solely Madison produced water
		TOTAL		10?	(1)	7,782,450	8,878,418	0		
TOTAL				180	(18)	28,515,592 (3,676 ac-ft)	-	7,615,405 (982 ac-ft)		

[a]Data from files of the Wyoming Oil and Gas Conservation Commission and Wyoming Oil and Gas Conservation Commission (1980).

[b]Amount of makeup water calculated by subtracting reported amount of produced water from reported amount of injected water.

Table A-3. Water use for coal mining in the Great Divide and Washakie basins, Wyoming (data from Wyoming Department of Environmental Quality (DEQ) files, Wyoming State Engineer's Office (SEO) files, and Glass, 1980).

Company	Mine	DEQ Permit #	Location (T/R)	1979 Production (tons)	Water Use
Black Butte Coal Co.	Black Butte Strip Mine	467	18/100	500,000	4 wells in Ericson Formation (Mesaverde aquifer) supply water for dust abatement, equipment washdown, irrigation, fire protection, and domestic use. Maximum permitted yields total 1,950 gpm (3,148 ac-ft/yr) but actual use may be less because water is recirculated and reused where possible, and intermittent pumpage is expected. Permits for up to 4,000 gpm of pit discharge (SEO permit #'s 40333-40335, 54328; Fort Union Formation; 1,000 gpm each) are pending completion. Water is to be used for dust abatement.
Bridger Coal Co.	Jim Bridger Mine	338	21/100	6,400,000	Water from 8 dewatering wells (maximum yield 250 gpm each, Fort Union Formation. SEO permits #36895, 54279-54285) is pumped to storage and evaporation ponds, then used for dust suppression or discharged to Deadman Draw, a tributary of Bitter Creek. One additional well permitted for construction, plant, and domestic uses (maximum yield 600 gpm, SEO permit #6437, see Appendix A-8). Maximum total ground-water use, based on permitted yield, is 2,600 gpm (4,197 ac-ft/yr) but actual use may be less, because intermittent or reduced pumpage is expected. Up to 750 ac-ft/yr of waste water from Jim Bridger power plant is also used for irrigation, source is diversion from the Green River.

Black Butte Strip Mine wells:

SEO Permit #	Well Name	Location	Yield (gpm)	Total Depth (ft)	Use	Remarks
28456	Bluebell #13	19/100-13	350?	1,219	Washdown, fire protection, domestic	SEO permitted yield is 50? gpm.
30220	Chandler-Simpson #1	18/100-8	500?	4,932	Dust abatement	SEO permitted yield is 250 gpm.
45085	Darter #1	19/100-29	500	2,077	Dust abatement	SEO permitted yield is 300 gpm.
51015	Darter #2	18/100-20	600	2,000	Washdown, dust abatement, irrigation	SEO permit #56050 enlarged yield to 600 gpm.
51016	Darter #3	19/100-35	(350)	(2,310)	Dust abatement	Permit pending completion at SEO.

Table A-4. Water use for uranium mining in the Great Divide and Washakie basins, Wyoming (data from Wyoming Department of Environmental Quality (DEQ) and Wyoming State Engineer's Office (SEO) files).

Company	Mine	DEQ Permit #	Location (T/R)	Ore Production	Water Use
Minerals Exploration Co.	Sweetwater Uranium Mine	481	23/93	720,000 yd^3/yr (projected 1980-1981)	26 dewatering wells removed 1,865.75 x 10^6 gal in 1979-80: 130 x 10^6 gal used on site 332.3 x 10^6 gal lost from settling ponds by infiltration and evaporation 1,403.21 x 10^6 gal discharged to Battle Spring Draw, a tributary to a playa on Battle Spring flat, from which it evaporated. SEO permit numbers for dewatering wells are 41699-41716, 53849, 54883-54894, 54896-54903; several of these wells are not yet completed (as of 7/81). Potable water and water for fire, offices, and trailers is supplied by 3 wells:

SEO Permit #	Well Name	Location	Total Depth (ft)	Yield (gpm)
34388	RDW-1	24/93-10	340	300
43125	P-1	24/93-15	400	60
43126	P-2	24/93-15	400	60

Company	Mine	DEQ Permit #	Location (T/R)	Ore Production	Water Use
Western Nuclear Inc.	Crooks Gap Mines (8 facilities)	381	28/92	652,000 T/yr (reported 1978-1979)	14 wells with maximum permitted yield 583 gpm, actual water use may be less because plant water is recycled and intermittent or reduced pumpage is expected. ∿35 gpm discharged to Crooks Creek drainage, remaining water used in mill.

SEO Permit #	Well Name	Location	Yield (gpm)	Total Depth (ft)	Use
1490	Golden Goose W.W.#1	28/92-21	800	5	Domestic, drilling water.
1458	Yellow Sands #1	28/92-20	500	12	Domestic, drilling fluid, dust abatement.
28674	Sheep Mountain #1	28/92-21	1,360	10	Shaft dewatering.
28675	Golden Goose II W.W.#1	28/92-20	500	18	Drinking, sanitation, equipment cleaning.
28676	Green Mountain WW#3	28/92-16	447	8	"Domestic, industrial."
32934	McIntosh #1	28/92-29	500	250	Pit dewatering
33910	McIntosh #2	28/92-29	250	5	Drinking and sanitation, at maintenance bldg.
41188	Golden Goose I #1	28/92-21	810	125	Shaft dewaterting.
41189	Reserve #1	28/92-21	462	15	Pit dewatering.
41190	Seismic #1	28/92-21	485	30	Pit dewatering.
43954	McIntosh #3	28/92-29	300	25	Sanitation, at pit office.
44469	SD 18-16	28/92-28	1,410	20	Offices, shops, drilling fluid.
44886	PL-21A	28/92-22	1,410	35	Offices, drilling fluid.
56266	Congo pit #1	28/92-16	225	25	Pit dewatering.
TOTAL				583	

Table A-5. Permitted irrigation wells in the Great Divide and Washakie basins, Wyoming (data from Wyoming State Engineer files, as of July (?), 1980).

						Acreage Irrigated		
County	Location	State Engineer's Permit Number	Total Depth (ft)	Aquifer(s)	Reported Yield (gpm)	Original Supply	Supplemental Supply	Total
Carbon	13/91-32	8616	31	Alluvium	30	20	0	20
	18/88-10	339G	210	Frontier?	50	10	0	10
	18/88-11	156	UNK	UNK	20	60	0	60
	21/88-24	1116	32	Alluvium	6	2.5	0	2.5
	22/88-24	325G	47	Upper Tertiary	3,000	30	0	30
	22/88-24	41	70	Upper Tertiary	350	100	0	100
	22/88-24	326G	49	Upper Tertiary	3,000	30	0	30
Sweetwater	17/94-13	43626	180		50	40	0	40
	18/100-8	6790	1,200	Mesaverde	500	61	39	100
	18/101-18	499C	400	Mesaverde	250	16	5	21
	18/101-18	500C	400	Mesaverde	250	17	47	64
	19/95-1	26024	300	Wasatch (Tertiary aquifer system)	10	UNK	0	UNK
	20/94-34	695	1,250	Wasatch (Tertiary aquifer system)	250	15	0	15
TOTALS:					7,766	401.5	91	492.5

Table A-6. Community water supplies in the Great Divide and Washakie basins. Facilities are those previously identified by the U.S. Environmental Protection Agency.

Facility	EPA PWS ID #[a]	Population Served[a]	Reported Production Rate[a] (gpd)	Water Source	Location[b]	SEO Well Permit #[b]	Total Depth[b] (ft)	Aquifer	Reported Yield[b] (gpm)	Completion Date[b]	Remarks
CARBON COUNTY											
Baggs (municipal)	5600058	350	100,000	Little Snake R.	-	-	-	-	-	-	Surface water; primary source, obtained by infiltration gallery?
				Baggs #1	12/91-5	15173	22	Alluvium	50	UNK	
				Baggs #1 Enl.	-	31718	-	-	300	N.A.	Increased permitted yield of Baggs #1.
				Baggs #2	12/91-5	13673	(50)	Alluvium	(350)	N.A.	Permit #13673 cancelled.
				Baggs well and infiltration Pipe #1	12/91-5	31	18	Alluvium	UNK	UNK	Replaced by Baggs #1.
Dixon (municipal)	5600059	80	21,000	Little Snake R.							Surface water; primary source.
				Dixon #1	12/90-5	40628	45	Alluvium	20	UNK	Long-term yield too small, pump may be installed in future.
				Dixon #2	13/90-33	40629	(500)	Upper Tertiary?	UNK	N.A.	Permit 40629 cancelled.
Lamont Village	5600227	25	3,000	Well	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well, no identifiable record at SEO.
Rawlins (municipal)	5600045	14,500	2,000,000	North Platte R.	-	-	-	-	-	-	Surface water.
				Sage Creek Drainage	-	-	-	-	-	-	Surface water and springs, primary source.
				Old City #1	21/87-16	2677	650?	Madison	300?	8/7/1891	
				New City #1A	21/87-16	26777	305?	Tensleep	400?	5/61	
				City of Rawlins #2	18/88-10	306G	1,000	Frontier & Morrison	120	8/27/54	
				Pine Grove Well	UNK	UNK	UNK	UNK	UNK	UNK	Well identified by EPA data base, no record at SEO.
Western Hills Trailer Court, Rawlins	5600066	150	28,000	Purchase	-	-	-	-	-	-	Purchased water from City of Rawlins.
				Well	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base also lists one well, no identifiable record at SEO.
SWEETWATER COUNTY											
AMOCO Production Company, Baroil (company town)	5600003	250	37,500	Baroil Well #1	26/90-16	1608	301	Mesaverde	10	3/28/66	EPA data base also lists a second well and springs, no identifiable records at SEO.
				Well	UNK	UNK	UNK	UNK	UNK	UNK	
				Springs	UNK	UNK	UNK	UNK	UNK	UNK	
Colorado Interstate Gas, Table Rock Village (company town)	5600100	120	9,000	Village well #1	19/98-11	42166	500	Wasatch	75	3/13/77	Well #2 is stand-by well.
				Village Well #2	19/98-11	42167	500	Wasatch	100	12/1/77	

Table A-6. (continued)

Facility	EPA PWS ID #[a]	Population Served[a]	Reported Production Rate[a] (gpd)	Water Source	Location[b]	SEO Well Permit #[b]	Total Depth[b] (ft)	Aquifer	Reported Yield[b] (gpm)	Completion Date[b]	Remarks
SWEETWATER COUNTY (continued)											
Point of Rocks Mercantile, Point of Rocks (trailer court, etc.)	5600093	120	15,000	Old Iron #1	20/101-27	12415	90	Ericson	11	-/-/50?	
				Soda #2	20/101-27	12416	90	Ericson	13	5/68	
				Deep Well #3	20/101-27	12508	340	Almond?	48	4/15/72	
South Superior (municipal)	5600092	647	52,000	Superior #14	21/101-21	459C	1,200	Ericson	250	6/30/43	
				Superior #15	21/101-21	460C	1,235	Ericson	250	9/23/43	
Stage Stop Texaco, Point of Rocks (trailer court, etc.)	5600094	90	8,500	Well	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well, no identifiable record at SEO.
Union Pacific Railroad, Point of Rocks (company town)	5600368	27	259,200	Well	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well, no identifiable record at SEO.
Wamsutter (municipal)	5600105	700	300,000	Well #6	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists two wells, no record at SEO.
				Well #7	UNK	UNK	UNK	UNK	UNK	UNK	

[a]Data from U.S. Environmental Protection Agency (EPA) Public Water Supply Inventory (1979).

[b]Data from Wyoming State Engineer's Office (SEO) well permit files.

Table A-7. Non-community public water supplies in the Great Divide and Washakie basins, Wyoming. Facilities are those previously identified by the U.S. Environmental Protection Agency.

Facility	EPA PWS ID #[a]	Population Served[a]	Reported Production Rate[a] (gpd)	Water Source	Location[b]	SEO Well Permit #[b]	Total Depth[b] (ft)	Aquifer	Reported Yield[b] (gpm)	Completion Date[b]	Remarks
CARBON COUNTY											
Boyer YL Ranch, 8 mi. NE of Savery	5600337	25	1,250	Well #1	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well, no identifiable record at SEO.
Dick's Service, Lamont	5600172	600	12,000	Well #1	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists 3 wells, no identifiable record at SEO.
				Well #2	UNK	UNK	UNK	UNK	UNK	UNK	
				Well #3	UNK	UNK	UNK	UNK	UNK	UNK	
Gay Johnsons, W of Rawlins	5600102	750	7,500	Gay Johnsons Well #1	21/88-14	1488	100	Upper Tertiary	(80)	11/19/64	EPA data base lists 5 wells, only 4 have records at SEO.
				Gay Johnsons Well #2	21/88-14	1489	100	Upper Tertiary	(80)	11/18/64	
				Well #3	UNK	UNK	UNK	UNK	UNK	UNK	
				Gay Johnsons Inc. #4	21/88-14	26400	200	Upper Tertiary	15	3/21/75	
				Gay Johnsons Inc. #5	21/88-14	26401	200	Upper Tertiary	15	4/3/75	
Red Hills Service, Rawlins	5600339	25	500	Spring	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one spring, no identifiable record at SEO.
Three Forks - Muddy Gap Service	5600350	35	1,750	Erickson #1	28/89-27	27507	223	Upper Tertiary	10	9/17/77	Well originally permitted for domestic use only
				1st ENL Erickson #1	28/89-27	50290	223	Upper Tertiary	12.7	N.A.	Enlarged for expanded yield and use.
FREMONT COUNTY											
Cove Bar & Grocery, South Pass City	5600712	25	250	Well #1	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well. no identifiable record at SEO.
SWEETWATER COUNTY											
Bitter Creek Rest Area - West, 13 mi. E of Point of Rocks	5600470	1,000	5,000	Bitter Creek #1	19/99-10	1642	472	Wasatch	30	10/66	
Bitter Creek Rest Area - East, 13 mi. E of Point of Rocks	5600469	1,000	5,000	Bitter Creek #2	19/99-11	1643	720	Wasatch	30	10/66	
Black Butte Coal Co., 9 mi. SE of Point of Rocks	5600638	400	8,000	Bluebell 13	19/100-33	28456	1,219	Mesaverde	50	3/18/75	Flowing well
Creston Junction Standard Station, Creston Junction	5600331	100	500	Well #1	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well, no identifiable record at SEO.
Divide Cafe & Truck Stop, W of Rawlins	5600327	200	1,500	Well #1	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well, no identifiable record at SEO.
Jim Bridger Power Plant, 3 mi. N of Point of Rocks	5600639	500	25,000	Green River	--	--	--	--	--	--	Surface water is only source listed by EPA.
				Jim Bridger #1	20/101-3	6437	1,451	Mesaverde	600	4/15/71	Well permitted for construction, plant, and domestic use.

Table A-7. (continued)

Facility	EPA PWS ID #[a]	Population Served[a]	Reported Production Rate[a] (gpd)	Water Source	Location[b]	SEO Well Permit #[b]	Total Depth[b] (ft)	Aquifer	Reported Yield[b] (gpm)	Completion Date[b]	Remarks
SWEETWATER COUNTY (continued)											
Moyers Service, Red Desert	5600101	100	1,650	Moyer #1	19/95-4	14942	210	Wasatch	10	8/30/73	EPA data base also indicates Wamsutter as a source.
Red Desert Standard, Red Desert	5600542	100	500	Well #1	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well, no identifiable record at SEO.
Table Rock Service, Table Rock	5600099	250	3,200	Well	UNK	UNK	UNK	UNK	UNK	UNK	EPA data base lists one well, no identifiable record at SEO.

[a]Data from U.S. Environmental Protection Agency (EPA) Public Water Supply Inventory (1979).

[b]Data from Wyoming State Engineer (SEO) well permit files.

APPENDIX B

SUMMARY OF HYDROLOGIC PROPERTIES OF MAJOR WATER-BEARING ZONES GREAT DIVIDE AND WASHAKIE BASINS

APPENDIX B

SUMMARY OF HYDROLOGIC PROPERTIES OF MAJOR WATER-BEARING ZONES, GREAT DIVIDE AND WASHAKIE BASINS

Major Water-bearing Zones	Data Type[a]	Number of Data Points Summarized	Yield Range (gpm)[b]	Specific Capacity Range (gpm/ft)[c]	Porosity Range (%)[d]	Permeability Range (gpd/ft^2)[e]	Transmissivity Range (gpd/ft)[f]	Remarks
Quaternary Aquifers	WW PUB	49	<1-200	-	-	-	-	
	SEO	50	<1-300	-	-	-	-	
Upper Tertiary Aquifers	WW PT	12	3-25	<1-6.3	-	-	100-10,000	10 specific capacities <1 gpm/ft.
	WW PUB	1	42	-	-	-	-	
	WW PO	5	6, 16.7	-	-	-	-	Only two with yield data
Tertiary Aquifer System	WW PT	52	<1-325	<1->85	-	-	20-150,000	Most yields <100 gpm 17 specific capacities <1 gpm/ft. Most transmissivities <2,500 gpd/ft.
	WW PUB	54	1-220	-	-	-	-	
	WW PO	16	15-250	-	-	-	-	
	CMTW	45	10.6-30	<1-2.9	-	-	<1-3,157	
	OW DST	14	-	-	-	-	<1-19	
	OF PUB	25	-	-	12-39	<1-18.2	<1-546	Most permeabilities <1 gpd/ft.^{2}
Mesaverde Aquifer	WW PT	3	15-<25	<1.67->20	-	-	25-35,000	Two transmissivities <3,000 gpd/ft.
	WW PUB	8	30-250	-	-	-	-	
	WW PO	7	-	-	-	-	-	
	CMTW	4	60	-	-	-	8, 10	Two wells yield 60 gpm each
	OW DST	18	-	-	-	-	<1-2,883	
	OF PUB	56	-	-	8-26	<1-1.8	<1-54	Most transmissivities <5 gpd/ft.
Frontier Aquifer	WW PT	4	10-106	<1-30	-	-	600-30,000	
	WW PUB	17	1-100	<1	-	-	-	
	WW PO	3	20	-	-	-	-	
	SP PO	2	-	-	-	-	-	
	OW DST	21	-	-	-	-	<1-6,552	
	OF PUB	31	-	-	7-25	<1-4.5	<1-164	Most transmissivities <10 gpd/ft.
	OW PO	4	-	-	-	-		
Cloverly Aquifer	WW PUB	10	25-85	<1-1.3	-	-	340-1,700	
	OW DST	29	-	-	-	-	1-175	Most transmissivities <20 gpd/ft.
	OF PUB	34	-	-	8-25	<1-18	<1-260	
Sundance-Nugget Aquifer	WW PUB	4	27, 28	<1	-	-	240	
	WW PO	2	-	-	-	-	-	
	OW DST	24	-	-	-	-	1-3,500	Most transmissivities <100 gpd/ft., several estimates from Entrada Sandstone.
	OF PUB	14	-	-	3-21	<1-4.8	<1-493	
	OW PUB	6	35	-	-	-	-	One reported yield.
Paleozoic Aquifer System								
Tensleep Aquifer	WW PUB	1	-	-	-	-	-	
	OW DST	17	-	-	-	-	<1-374	
	OF PUB	14	-	-	<1-15	<1-8.2	<1-318	
	OW PUB	10	24-400	-	-	-	-	
	OW PO	1	-	-	-	-	-	

APPENDIX B

(continued)

Major Water-bearing Zones	Data Type[a]	Number of Data Points Summarized	Yield Range (gpm)[b]	Specific Capacity Range (gpm/ft)[c]	Porosity Range (%)[d]	Permeability Range (gpd/ft^2)[e]	Transmissivity Range (gpd/ft)[f]	Remarks
Madison Aquifer	WW PT	1	100	100	-	-	150,000	
	WW PUB	8	5-400	100	-	-	200,000	
	SP PUB	1	-	-	-	-	-	
	OW DST	7	-	-	-	-	9-22	
	OF PUB	3	-	-	12-13	<1	5-68	
	OW PUB	2	-	-	-	-	-	
Cambrian and Precambrian Aquifers	WW PT	13	2-150	<1-150	-	-	6-300,000	Most transmissivities <1,000 gpd/ft. Only one specific capacity >10 gpm/ft.
	WW PUB	8	100-150	-	-	-	-	
	WW PO	73	4-250	-	-	-	-	
	SP PUB	1	-	-	-	-	-	
	OW DST	2	-	-	-	-	<1, 27	
	OF PUB	2	-	-	12, 12.3	<1	33-37	

[a]Data Type

WW PT - Water well pump test
WW PUB - Published water well data
WW PO - Water well potentiometric data only
SP PO - Spring potentiometric data only
SP PUB - Published spring data
OF PUB - Published oil field data
OW DST - Oil well drill stem test
OW PO - Oil well potentiometric data only
OW PUB - Published oil well data
SEO - State Engineer's Office
CMTW - Coal mine test well

[b]Yield Range
gpm - gallons per minute

[c]Specific Capacity Range
gpm/ft - gallons per minute per foot of drawdown

[d]Porosity Range
% - percent

[e]Permeability Range
gpd/ft^2 - gallons per day per square foot

[f]Transmissivity Range
gpd/ft - gallons per day per foot

APPENDIX C

RECORDS OF WELLS AND SPRINGS IN THE GREAT DIVIDE AND WASHAKIE BASINS

APPENDIX C

RECORDS OF EXISTING WELLS AND SPRINGS IN THE GREAT DIVIDE AND WASHAKIE BASINS

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentio-metric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmis-sivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
ALLUVIUM - QUATERNARY													
12-89-7 ac	18		Qal	1914	D		10		25			SEO	
12-89-7 c	20		Qal	1958								GD/W	
12-89-9 cc			Qal	1912	WS,D		Flowing		25			SEO	
12-89-18 ba	20		Qal	1920	WS,D		10		15			SEO	
12-90-4 cc	15		Qal	1920	D		1		25			SEO	
12-90-4 dd	25		Qal	1900	WS,D		20		20			SEO	
12-90-5 dc	30		Qal	1900	WS,D	15		20				SEO	
12-90-5 dd	12		Qal	1959	D	6		33				SEO	
12-90-6 dbc	5		Qal				1					GD/W	
12-90-7 db	35		Qal	1927	D	25		3				SEO	
12-90-8 aa	80		Qal	1958								GD/W	
12-90-8 ab	15		Qal		D	3		25				SEO	
12-91-2 ca	6		Qal	1920	WS,D	2		12.5				SEO	
12-91-3 ba	30		Qal	1945	WS,D	6		15				SEO	
12-91-3 ba	26		Qal	1973	D	9		25				SEO	
12-91-3 dc	25		Qal	1900	WS,D	15		25				SEO	
12-91-3 dd	10		Qal	1979	D	5		0?				SEO	
12-91-4 ac	30		Qal	1976	D	15		25				SEO	
12-91-4 cc	28		Qal	1978	D	7						SEO	
12-91-4 dc	25		Qal	1934	D	-0.1?		5				SEO	
12-91-5 ac	18		Qal	1979	M	18		0				SEO	
12-91-5 ac	10		Qal	1979	D	8		20				SEO	
12-91-5 ac	15		Qal	1900	D	13		15				SEO	
12-91-5 ac			Qal	1980	D							SEO	
12-91-5 ac			Qal	1980	D							SEO	
12-91-5 ad	22		Qal		D	10		50				SEO	
12-91-5 ad	22		Qal		P	10		300				SEO	
12-91-5 bd	15		Qal	1977	D	3		15				SEO	
12-91-5 bd			Qal	1979								SEO	
12-91-5 ca	14		Qal	1931	WS,D	10		25				SEO	
12-91-5 ca	20		Qal	1965	WS,D	10		2				SEO	
12-91-5 ca	15		Qal	1980	WS,D	5		0				SEO	
12-91-5 d	15		Qal									GD/W	
12-91-5 dab	18		Qal									GD/W	
12-91-5 dcb	50		Qal	1958								GD/W	
12-91-5 dd	14		Qal	1960	M	13		40				SEO	
12-91-5 dd	14		Qal	1961	M	13		40				SEO	
12-91-5 dd			Qal	1979								SEO	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentio-metric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmis-sivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
ALLUVIUM - QUATERNARY (continued)													
12-91-5 dd	14.5		Qal	1978	D	6		25				SEO	
12-91-5 dd			Qal	1980								SEO	
12-91-7 dc	16		Qal	1910	D	8		25				SEO	
12-91-9 ca	36		Qal	1975	WS,D	19		10				SEO	
12-91-9 ca	13		Qal	1977	WS,D	5		2.5				SEO	
12-91-9 ca	13		Qal	1977	D	6		25				SEO	
12-91-9 db	30		Qal	1978	D	6		15				SEO	
12-91-10 ca	5.5		Qal	1940	WS,D	4		25				SEO	
12-91-10 cc	4		Qal	1924	WS,D			25				SEO	
12-91-11 aa	12		Qal	1973	WS,D	4		20				SEO	
12-91-11 aa	12		Qal	1958								GD/W	
12-91-12 ab	25		Qal	1948	WS,D	8		10				SEO	
12-91-12 ab	20		Qal	1900	WS,D	5		10				SEO	
12-92-1 abb	136		Qal				37					GD/W	
12-92-12 bba	15		Qal				13					GD/W	
12-100-22 ab			Qal									GD/W	
12-102-24 ba			Qal	1963	S			F-15				GD/W	
13-89-22 aa	22		Qal	1941	D			25				SEO	
13-89-28 dad	18		Qal				6					GD/W	
13-91-32 ad	31		Qal	1973	WS,I,D	17		30				SEO	
14-90-8 dda	50		Qal				32					GD/W	
14-104-31 bd			Qal									GD/W	
15-94-4 d	50		Qal				22					GD/W	
15-102-34 cb	22		Qal				10					GD/W	
15-104-14 c	39		Qal				5					GD/W	
16-88-26 dd			Qal									GD/W	
16-91-27 bbb			Qs									GD/W	
16-92-29 dad			Qal	1958	S							GD/W	
16-93-19 cc	40		Qal				dry					GD/W	
17-90-17 bb			Qs	1958					200			GD/W	
17-90-32 ac	20		Qs	1945	WS,D	5		5				SEO	
17-92-12 b			Qal	1958	S			F-10				GD/W	
19-93-15 a			Qal									GD/W	
19-102-6 cd	30		Qal				22					GD/W	
22-101-22 bab			Qal		S				3			GD/W	
23-88-16 cb	9		Qal				5					GD/W	
23-88-24 dab			Qal									GD/W	
23-104-26 bdd	32		Qal				11					GD/W	
23-104-33 bdd	30		Qal				8					GD/W	
24-87-6 ad	21		Qs				4					GD/W	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentio-metric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmis-sivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
ALLUVIUM-QUATERNARY (continued)													
24-87-13 bab	115		Qal,Qs	1964		35		3				GD/W	
24-88-30 baa	2220	26-45	Qal	<1935					.3			D	
24-88-30 baa	2220	43-45	Qal?	<1935								D	
24-88-31 bb	2300	45-70	Qal?	<1935			art.					D	
24-88-31 dbc	1460	70-72	Qal?	<1935			100					D	
[illegible]	[illegible]		Qal				6					GD/W	
[illegible]	[illegible]		Qal				7					GD/W	
25-86-5 bca	3080	0-97	Qd?	1920								D	
25-86-9 ccc	3790	0-91	Qd?	<1935								D	
25-86-17 abb	4920	115-120	Qd?	<1920								D	
25-87-17 cd			Qs									GD/W	
25-87-22 bcd	70		Qs				34					GD/W	
26-88-32 abb			Qs	1964	S	1			20			GD/W	
26-88-35 bdc	5.5	?-5.5	Qd?	1922			2		5			D	
26-88-36 bdc			Qs		S				1			GD/W	
26-88-36 da		0-85	Qd?	<1935								D	
26-88-36 db	5.5		Qal	1922	C,D	2		5				SEO	
26-89-16 cdb	28		Qal,Qs			22		2				GD/W	
26-89-21 ba	40	20-30	Qal	1976	D	15		2	5			SEO	
27-97-32 cda			Qal									GD/W	
29-100-12 ac	10		Qal	1978	D	7		5				SEO	
NORTH PARK													
15-87-18 cc	60	26-60	Tnp			7610	7	7603	20	1.43	1000	SEO	
19-87-30 ba	160	80-160	Tnp		D,WS	7600	80	7520	4	.06	150	SEO	
17-88-33 bda	205		Tnp	8/64		7700	13	7687	6			GD/W	
17-88-33 to 36			Tnp	10/51	S(19)							GD/W	
BISHOP CONGLOMERATE													
16-104-8 ddd	120		Tbi	8/63		7600	78	7522	42			GD/W	
BROWNS PARK													
12-90-3 cd	100	80-100	Tbp		D,WS	6210	20	6190	7.5	.25	500	SEO	
12-90-5 da	45	21-41	Tbp		P	6365	.2	6320	20	.63	1000	SEO	
12-90-6 aa	160	120-140	Tbp		D	6488	90	6398	5	.08	200	SEO	
12-90-8 bc	125	95-125	Tbp		D	6300	8	6292	20	.33	700	SEO	
12-90-10 bb	95	70-95	Tbp		D,WS	6390	30	6360	15?	.75	1500	SEO	
12-91-9 ad	90	65-90	Tbp		D	6275	75	6200	25	.29	600	SEO	
12-91-9 ad	60		Tbp		D,WS	6275	40	6235	25	6.25	10000	SEO	
12-91-10 cb			Tbp			6390	20	6370				USGS	
12-92-3 bdc			Tbp			6390	37	6353				USGS	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentio-metric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmis-sivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
BROWNS PARK (continued)													
12-92-3 cdb			Tbp			6370	107	6263				USGS	
12-92-4 bcb			Tbp			6305	56	6249				USGS	
12-92-4 bcc			Tbp			6310	38.25	6271				USGS	
12-92-4 bcc			Tbp			6290	28.6	6261				USGS	
12-92-4 cac			Tbp			6340	59	6281				USGS	
12-92-4 dab			Tbp			6310	25.7	6284				USGS	
12-92-4 db	450		Tbp		M	6420	25	6395	3	.04	100	SEO	
12-92-5 db	210	170-200	Tbp		M	6285	30	6255	2.5	.03	100	SEO	
12-92-5 dcb			Tbp			6340	97.2	6242				USGS	
12-92-6 bcb			Tbp			6385	94.4	6290				USGS	
12-92-10 cba			Tbp			6520	124	6396				USGS	
12-93-1 baa			Tbp			6320	44.44	6276				USGS	
12-96-14 b			Tbp				104					USGS	
13-88-10 bc			Tbp			7910	5	7905				USGS	
13-88-29 ada			Tbp			7130	8	7122				USGS	
13-88-29 ada	15		Tbp	10/63		7100	8	7092				GD/W	
13-89-20 ca			Tbp			6930	40	6890				USGS	
13-92-31 cca			Tbp			6440	100.8	6339				USGS	
13-92-31 dac			Tbp			6340	184.6	6155				USGS	
13-92-32 dbc			Tbp			6422	137.6	6284				USGS	
13-92-33 ccc			Tbp			6365	97.2	6267				USGS	
14-87-33 ca	55	39-55	Tbp		P	7914	40	7874	5	.63	1000	SEO	
15-85-1 ca	106	4-18 36-48 100-106	Tbp	5/60	D	7400	6	7394	16.7			D	
16-87-22 cbb	60		Tbp			7950	5	7945				D	
16-88-4 bcc	600		Tbp	11/54		8000	128	7872				D	
16-88-4 bcc			Tbp			8040	129	7911				USGS	
17-85-31 bca			Tbp			7220	18	7202				USGS	
17-104-26 add			Tbp						30			CM	
BATTLE SPRING													
22-90-23 da	172		Tbs	5/63		6600	24	6576	3			GD/W	
22-91-8 cbc			Tbs	10/63	S				2			GD/W	
23-91-26 aaa	192		Tbs	6/64		6600	62	6538	5			GD/W	
24-90-2 ddd			Tbs	10/63	S				20			GD/W	
24-92-16	504		Tbs						300			CM	
24-93-20 ca	250		Tbs			6540	53.5	6487	15	1.15	1880	CM	
24-93-20 dd	365		Tbs			6540	50.9	6489	30	.33	395	CM	
24-93-29	424		Tbs			6540	33.5	6507	15	.54	1230	CM	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentio-metric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmis-sivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
BATTLE SPRING (continued)													
25-96-23 cba			Tbs	10/63	S							GD/W	
26-90-7 cc	367	102-367	Tbs		M	7275	82	7193	85	.52	1000	SEO	
26-94-30 ccd			Tbs	10/63	S							GD/W	
27-90-28			Tbs		S							CM	
27-91-4 ba	3441	1826-3360	Tbs		M	9020	1050	7970	37	.17	300	SEO	
27-91-34 ad	365	80-365	Tbs		M	7775	110	7665	96	.59	1300	SEO	
27-92-1 cc	850	440-850	Tbs		M	7700	210	7490	150	1.5	2500	SEO	
27-92-7 bb	420	300-340 360-420	Tbs		M	6843	57	6786	108	.35	900	SEO	
27-92-7 cc	154	134-144	Tbs		M	6832	8	6824	17.5	.44	600	SEO	
27-92-7 cc	145.6	8-145	Tbs		M	6832	8	6824	20.1	.29	300	SEO	
27-92-7 cc	162.8	8-20	Tbs		M	6835	8	6827	21	.31	300	SEO	
27-92-7 cc	152.6	8-25	Tbs		M	6832	8	6824	10	.15	150	SEO	
27-92-7 cd	157.1	143-155	Tbs		M	6832	11	6821	15.1	.23	2000	SEO	
27-92-7 cd	174	11-174	Tbs		M	6830	11	6819	24	.38	250	SEO	
27-92-7 cd	163	11-163	Tbs		M	6833	11	6822	24	.38	250	SEO	
27-92-7 cd	171	7.1-20	Tbs		M	6828	11	6817	19.6	.29	150	SEO	
27-92-7 dc	155	138-148	Tbs		M	6848	26.4	6821	5.1	.12	200	SEO	
27-92-7 dc	155.3	27-155	Tbs		M	6848	27	6821	19.2	.26	150	SEO	
27-92-7 dc	155	27.4-155	Tbs		M	6848	27.4	6820	19.6	.27	150	SEO	
27-92-7 dd	157.8	26.4-157	Tbs		M	6851	26.4	6825	20.6	.60	500	SEO	
[illegible]	325	155-235 255-295	Tbs		M	6860	11	6849	157	.79	150	SEO	
28-92-28	760	649-729	Tbs			7220	236	6984	15.1	.06	29	CM	
28-92-29	440	357-437	Tbs			7031	135	6896	20.2	.26	198	CM	
28-92-29	200	118-198	Tbs			6887	101	6786	11	2.89	3157	CM	
28-92-29	280	194-279	Tbs			6989	129	6860	11.8	.14	80	CM	
28-92-33	220	133-218	Tbs			6999	168	6831	10.6	.33	294	CM	
LANEY													
13-96-15 ac	710		Tgl	7/63					17			GD/W	
14-99-15 b	104		Tgl	8/63					10			GD/W	
15-98-18 a			Tgl	7/58	S							GD/W	
16-99-2 bd			Tgl	7/58	S				200			GD/W	
18-95-9 b			Tgl	7/58	S				1			GD/W	
27-96,97W		360-380	Tgl			7127	149	6978			190	CM	
		360-380	Tgl			7129	150	6979			180	CM	
		360-380	Tgl			7123	143	6980			300	CM	
		380-400	Tgl			7075	108	6967			135	CM	
		389-415	Tgl			7076	107	6969			120	CM	
		380-400	Tgl			7072	105	6967			165	CM	
		380-400	Tgl			7072	105	6967			117	CM	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentiometric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmissivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
LANEY (continued)													
			Tgl								110	CM	
			Tgl								130	CM	
			Tgl								110	CM	
			Tgl								110	CM	
			Tgl								120	CM	
			Tgl								120	CM	
			Tgl								120	CM	
			Tgl								120	CM	
			Tgl								110	CM	
			Tgl								110	CM	
			Tgl								120	CM	
			Tgl								120	CM	
			Tgl								120	CM	
			Tgl								120	CM	
GREEN RIVER (UNDIVIDED)													
13-99-16 cc	80	40-80	Tg	60	C							D	
13-99-18 bdc	80	55-80	Tg	60	C							D	
13-99-18 db	690	325-345 575-595 630-690	Tg	43	C	7300	125	7175	67			D	
13-99-19 acb	82	72-82	Tg	60	C							D	
13-99-21 bdc	82	45-82	Tg	60	C							D	
13-99-21 dbd	80	55-80	Tg	60	C							D	
13-99-21 dcd	81	45-81	Tg	60	C							D	
13-100-9 caa	377	368-377	Tg	52	D,C	7175	350	6825				D	
14-99-21 b	12180	200+	Tg	1/61								D	
14-100-36 abc	82		Tg	60								D	
16-99-3 dda	140	90-104	Tg	42	C	7200	19	7181	100			D	
16-99-11 b	235	40-150	Tg	42	C	7100	34	7066	200			D	
16-99-11 b	308	130-165	Tg	42	C	7100	44	7056	250			D	
16-99-11 bba	255		Tg	42	C	7100	36	7064	200			D	
16-99-18 cad	80	50-80	Tg	60	C							D	
16-99-22 cbd	309	195-200 230-309	Tg	56	C	7300	160	7140	15			D	
24-97-11 dd	255	175-180	Tg		WS	6700	40	6660	17			D	
WASATCH													
12-91-8 ac	420	390-420	Tw		D,WS	6300			15	.39	700	SEO	
12-91-8 baa	415		Tw	10/63					2			GD/W	
12-95-4 ddd	325	120-127	Tw	37	D,C				42			D	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentiometric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmissivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
WASATCH (continued)													
12-100-24 ab	2240	875-890	Tw	6/28								D	
12-101-3 cab	881	860-881	Tw	55	D,C	7050	art.	7050+	36			D	
12-101-10 dca	740	495-505 665-675	Tw	29	D,C	7050	540	6510	15			D	
13-94-12 ba	110	58-110	Tw	12/41	C,WS	6400	art.	6400+	110			D	
13-94-13 ac	200	180-200	Tw		D,WS	6405	150	6255	15	.6	1000	SEO	
13-97-28 da	150	90-140	Tw	12/41	C,WS				6			D	
13-99-22 ccc	82	60-80	Tw	60	C							D	
13-99-27 bbc	80	50-80	Tw	60	C							D	
14-92-12 ac	110	93-110	Tw	12/61	WS	6420	25	6395	30			D	
14-92-22 ab	145	57-145	Tw	12/41	C,WS	6410	35	6375	200			D	
14-93-32 bb	143	90-143	Tw	12/49	C,WS				109			D	
14-101-30 ba	145		Tw	9/63		7130	35	7095				GD/W	
16-92-7 ad	440	80-160	Tw		D,WS	6660	10	6590	10	.22	150	SEO	
16-92-17 dbb	330	40-65 105-115	Tw	59	C	6600	6	6594	11.5			D	
16-101-8 acc	115		Tw	60	C							D	
16-101-10 dac	335	285-320	Tw	51	C	7100	285	6815	67			D	
16-102-14 aa	115		Tw	60	C							D	
17-93-11 bb	600	560-600	Tw		M	6750	350	6400	50	.17	450	SEO	
18-93-2	265	180-210 230-258	Tw		M	6805	5	6800	90	1.91		SEO	
18-93-16 ca	300	180-280	Tw		M	6736	12	6724	48	4.0	6000	SEO	
18-98-1 bbd	572	354-358 498-517	Tw	45	C	7100	250	6850	14			D	
18-98-28 bdb	240	200-226	Tw	48	C	7000	100	6900	14			D	
18-99-10 da	900		Tw	7/58					5			GD/W	
19-92-2 db	3755	1300-1340 3000-3350	Tw		M	7120	280	6840	325	1.9	4000	SEO	
19-92-32 da	100		Tw	8/56	C				28			D	
19-96-18 a	1060		Tw	7/58								GD/W	
19-98-7 da	697	278-697	Tw		D	6775	45	6730	45	.47	800	SEO	
19-98-12 cdc	300		Tw	7/58								GD/W	
20-91-5 da	300		Tw	5/63		6990	94	6896				GD/W	
20-92-15 cc	265	245-265	Tw		M	7105	245	6860	10	>10	10000	SEO	
20-93-20 ba	1200		Tw	9/63					8			GD/W	
20-94-15 ddb	810	178-180 600-655	Tw	59	C	6810	175	6635	28			D	
20-94-34 aac	1590	795-920 1165-? 1260-?	Tw	1898	C	6750	art.	6750+	20			D	
20-94-34 abd	1905		Tw	12	C	6750	art.	6750+	15			D	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentio-metric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmis-sivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
WASATCH (continued)													
20-94-34 abd	1801		Tw	7/58		6800	24	6776				GD/W	
20-94-34 abc	1801		Tw	21	C	6750	art.	6750+	67			D	
20-94-34 aca	1365		Tw	1902	C	6750	art.	6750+	10			D	
20-94-34 bbd			Tw						250			CM	
20-97-3 aa	1910		Tw	8/64		6750	51+	6750+	32			GD/W	
20-97-28 bba	500		Tw	7/58		6850	76	6774				GD/W	
20-98-3 db	6460	1040-1300	Tw	5/58		6700	art.	6700+				D	
20-99-10 dcb	305	60-65 225-265	Tw		WS	6990	40	6950	30			D	
21-95-34 bcd	93		Tw	10/63		6620	48	6572	30			GD/W	
21-97-34 bba	7457		Tw						10			GD/W	
22-93-28 bb	105		Tw	5/63		6850	68	6782				GD/W	
22-98-22 bb	7642	1612 2000-3000	Tw	4/60	OA	6600	art.	6600+				D	
22-99-8 dbd	6100		Tw	9/63					110			GD/W	
22-99-28 aaa	195		Tw	7/58					11			GD/W	
23-96-24 cc	2250		Tw	31		6500	art.	6500+	30			D	
23-96-25 bba	2250		Tw	10/63					50			GD/W	
23-102-32 bb	108		Tw	9/63		7200	78	7122	3			GD/W	
24-98-2 cd	180		Tw	6/64		6700	22	6678	30			GD/W	
24-101-32 cd	125	55-84	Tw	60	WS	7500	34	7466	25			D	
26-94-17 bba	260	65-85 145-245	Tw		C	6850	65	6785	34			D	
26-94-17 bbc	285	265-280	Tw	56	C	6850	60	6790	50			D	
26-96-27 da	300	285-300	Tw	48	WS	6900	48	6850	17			D	
CATHEDRAL BLUFFS													
17-94-12 cc	300	100-120 180-220 240-260	Twc		M	6700	60		15	.25	600	SEO	
17-94-13 ad	180	140-180	Twc		D,WS,I	6618	30	6588	50	50	100000	SEO	
18-94-18 cc	580	415-580	Twc		M	6764	415	6349	125	.63	900	SEO	
18-94-28 cd	350	220-240 280-320	Twc		M	6764	70	6649	53	.59	800	SEO	
FORT UNION													
12-92-15 abc	4029	1600-3288	Tfu	7/49		6400	art.	6400+				D	
12-93-11 bb	5506	3345-3357 3370-3785	Tfu	2/62	OA		art.		11			D	
14-103-35 bdd			Tfu			7498						USGS	
16-92-17 dbb			Tfu				11.1					USGS	
17-92-12 bdd			Tfu			6800						USGS	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentio-metric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmis-sivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
FORT UNION (continued)													
17-92-14 bb	250	190-210, 230-250	Tfu		WS,D	6750	20	6730	4	.03	500	SEO	
18-91-1 acc			Tfu			7103	56	7047				USGS	
18-91-1 acc			Tfu			7103	54	7049				USGS	
18-91-2 bbd			Tfu			7110	72	7038				USGS	
18-91-29 cdd			Tfu			7005						USGS	
18-91-29 cdd			Tfu			7005						USGS	
18-92-24 db	460	360-400	Tfu		M	6929	380	6549	50	1.0	1500	SEO	
18-100-11 acb		236-248	Tfu			6797	140.73	6656				CM	
18-100-11 acb		236-248	Tfu			6796	140	6656				USGS	
18-100-22			Tfu			6718				.09		CM	
18-100-28	125	110-125	Tfu			6718	82.7	6635			448	CM	
18-100-29	176	156-176	Tfu			6874	172	6702			5.6	CM	
18-100-29 dad			Tfu			6874	164	6710				USGS	
18-100-33 cda			Tfu			7014	140	6874				USGS	
19-90-5 ccc			Tfu			6860	25	6835				USGS	
19-90-8 cdb			Tfu			6960	12	6948				USGS	
19-90-18 aaa			Tfu			6925	26	6899				USGS	
19-91-5 ccd			Tfu			7021	120	6901				USGS	
19-91-8 dc	550	390-470, 510-530	Tfu		M	7210	310	6900	60	.6	800	SEO	
19-92-1 bd			Tfu			7040	293	6747				USGS	
19-92-2 ca	3700		Tfu	2/62	C	7200	281	6919	220			D	
19-92-25 bca			Tfu			7050						USGS	
19-99-2 cbc	525	80-90	Tfu	53	WS	7000	200	6800	17			D	
19-99-6 (4 wells)	55-100		Tfu		WS	7000	50-65	6950	40-90			D	
19-99-6 b			Tfu				65					USGS	
19-99-7 aa			Tfu			6900	75	6825				USGS	
19-99-7 aa	161		Tfu	10/63		6900	75	6825				GD/W	
19-100-10 aad			Tfu			6850	148	6702				USGS	
19-100-11			Tfu			6850	148	6702				CM	
19-100-13	205	186-205	Tfu			6886	136	6750			15.5	CM	
19-100-13 bca			Tfu			6885	133	6752				USGS	
19-100-27	271	240-270	Tfu			6735	125	6610			1.4	CM	
19-100-27 abd			Tfu			6735	120	6615				USGS	
19-100-32	180		Tfu			6598	36	6562			17 5	CM	
19-100-33	225	205-225	Tfu			6636	70	6566			2	CM	
19-100-33 bac			Tfu			6636	69	6567				USGS	
19-100-33 bcc			Tfu			6598	33	6565				USGS	
19-100-33 ddb			Tfu			6955	95	6860				USGS	

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FORT UNION (continued)													
20-89-7 abc			Tfu			6862	66	6796				USGS	
20-89-8 ccc			Tfu			7024	168	6856				USGS	
20-90-5 dab	1740		Tfu	1900	C	6750	300	6450	20			D	
20-90-7 aa	155	132-152	Tfu		M	6860	116	6744	.07	.001	200	SEO	
20-90-12 cba			Tfu			6750						USGS	
20-90-18 bcd			Tfu			6860	150	6710				USGS	
20-90-19 da	70	50-69	Tfu		M	6830	20	6810	30	3.0	2500	SEO	
20-90-23 bbc			Tfu			6855	80	6775				USGS	
20-90-23 bbc			Tfu			6855	70	6785				USGS	
20-90-23 ddb			Tfu			6980	74	6906				USGS	
20-90-23 ddb			Tfu			6980	66	6914				USGS	
20-90-31 cbb	150		Tfu	7/63		7000	86	6914				GD/W	
20-90-31 cbb			Tfu				37					USGS	
20-90-34 acc			Tfu			7026						USGS	
20-91-11 dcc			Tfu			6930	160	6770				USGS	
20-91-15 bbb			Tfu			6866						USGS	
20-91-21 db			Tfu			6990	130	6860				USGS	
20-91-33 caa			Tfu			6914	75	6839				USGS	
20-91-35 cda			Tfu			7031	220	6811				USGS	
20-93-17 cb		3318-3411	Tfu		OA	6822K		6818			2496	DST	Transmissivity may be overestimated
20-93-17 cb		3549-3624	Tfu		OA	6822K		6804			33.9	DST	
20-95-12 d	10478		Tfu	6/58	OA							D	
20-95-14 d	10345		Tfu	1/59	OA							D	
21-89-10 dda			Tfu			6710	71	6639				USGS	
21-89-21 ccc			Tfu			6662	20	6642				USGS	
21-89-22 aaa			Tfu			6700	41	6659				USGS	
21-89-22 aaa	340		Tfu	6/64		6750	30	6720				GD/W	
21-89-22 ad	180	60-180	Tfu		M	6705	37	6668	75	75	150000	SEO	
21-89-22 ada			Tfu			6705	44	6661				USGS	
21-89-22 cb			Tfu			6678	30	6648				USGS	
21-90-26 db			Tfu			6723	44	6679				USGS	
21-100-7 cb			Tfu					6800				CM	
21-100-35 da			Tfu					6785				CM	
21-101-2 db			Tfu					6870				CM	
22-99-8 dbd	6100	370-? 573-618 653-710	Tfu	10/58		6650	art.	6650+				D	

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TERTIARY (UNDIVIDED)													
21-87-19 bb	165	140-160	Tu		D,C	6840	15	6825	20	.67	1000	SEO	
21-88-13 bb	140	20-140	Tu		D	6950	29	6921	9.5	.11	100	SEO	
21-88-13 cd	215	190-195	Tu		D,WS	6930	25	6905	12	.13	200	SEO	
21-88-13 db	200	100-200	Tu		D	6930	35	6895	5	2.5	4000	SEO	
21-88-14 cc	100	30-100	Tu		D	7090	10	7080	85	>85	1000000	SEO	
21-88-14 cc	200	20-40, 140-180	Tu		M,C	7090	15	7075	15	.5	800	SEO	
22-88-24 ac	47		Tu	12/54		7000	4	6996				GD/W	
27-96-20 bd	350	150-210 240-270 290-350	Tu		M	7000	150	6850	40	>40	70000	SEO	
27-97-25 bd	385	357-373	Tu		M	7126	153	6973	10.2	.17	300	SEO	
27-97-25 db	408	388-403	Tu		M	7073	112	6961	8.4	.05	100	SEO	
28-92-21 ac	800	600-640	Tu		D,C	7400	347	7053	5	.02	40	SEO	
28-92-28 cc	220	133-218	Tu		M	6999	168	6831	10.6	.34	700	SEO	
28-92-32 ad	440	357-437	Tu		M	6825	135	6690	20.2	.26	500	SEO	
28-101-34 db	70	45-70	Tu		D	7230	40	7190	8	.8	300	SEO	
LANCE													
15-100-6 ab	6230	6105+	Kl			7400	art.	7400+				D	
16-101-11 bc		1700-1805	Kl		OP	7121K		6724				DST	
17-99-8 db		3365-3658	Kl		OA	7060K		6776			.3	DST	
17-100-24 db		4474-4514	Kl		OP	7381K		5801			.7	DST	
18-91-1 bd	200	155-175	Kl		M	7103	63	7040	.015	<.001	20	SEO	
18-99-34 aa		3650-3693	Kl		OP	6818K		6694			4	DST	
18-100-10	65	54-65	Kl			6668	48	6620			13.24	CM	
18-100-20	150		Kl			6807	88	6719			21.7	CM	
19-92-32 da		5684-5718	Kl		OA	7277		6091			1.8	DST	
19-92-32 da		6184-6233	Kl		OA	7277		6513			3.5	DST	
19-98-21 db		3931-3957	Kl		OP	6744K		6529			8.7	DST	
19-100-8	198	178-198	Kl			6927	179	6748			9.28	CM	
19-100-15	164	144-164	Kl			6898	144	6758			.82	CM	
19-100-31	150	130-150	Kl			6883	28	6855			6.36	CM	
21-88-19 ac	305	245-305	Kl		D	6840	40	6800	7	.13	150	SEO	
21-99-10 cc		3030-3102	Kl		OA	7150K		6336			5.3	DST	
22-96-28 ca		6030-6050	Kl		OA	6591K		6341			1.6	DST	
23-99-14 ac		5239-5261	Kl		OP	6724K		6718			1.5	DST	
24-101-31 bd		3643-3680	Kl		OA	7473		6653			4	DST	

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FOX HILLS													
25-102-17 bc		5792-5892	Kfh		OA	7501K		6995			19.1	DST	
LEWIS													
12-98-14 db	11210	9878-9897 10574-10745	Kle	10/60	OA							D	
16-91-27 dcb	71		Kle	10/63								GD/W	
18-97-6 da		6790-6850	Kle		OP	7180K		6350			.5	DST	
18-97-6 da		6743-6800	Kle		OP	7180K		5991			.5	DST	
18-99-26 ab		5040-5107	Kle		OP	6747K		5776			2.9	DST	
21-97-6 db		5888-5928	Kle		OA	6693K		6073			2.9	DST	
21-97-19 ab		5864-5951	Kle		OA	6849K		6013			1.1	DST	
21-98-1 d		5787-5845	Kle		OS	6680K		5718			1.2	DST	
21-99-22 aa		3782-3785	Kle		OA	7168K		6606			6.5	DST	
ALMOND													
16-100-17 aa	6080	5555-5585	Kal									D	
17-101-35 bb		2291-2336	Kal		OA	7075K		6836			8.8	DST	
17-101-35 bb		2372-2478	Kal		OA	7075K		6790			5.7	DST	
18-99-13 bb		5440-5493	Kal		OA	6773		5909			.8	DST	
18-99-24 dd		6304-6621	Kal		OA	6954K		5517			.7	DST	
18-100-7	137	117-137	Kal			6745	14	6731			9.65	CM	
18-100-11 db		2650-2700	Kal		OA	6830K		6228			2.2	DST	
18-100-13	87		Kal			6901	71	6830			8.3	CM	
19-100-2 ad		2665-2685	Kal		OA	7030K		6560			5.3	DST	
19-100-2 ad		2851-2862	Kal		OA	7030K		6458			15.8	DST	
21-100-10 cc		3131-3197	Kal		OA	7104K		6639			11.5	DST	
21-100-10 cc		3132-3142	Kal		OA	7104K		6583			2.9	DST	
21-101-21 ada	1200	215-450 789-1200	Kal		P,D,C	6800	120	6680	250			D	
22-104-15 ccd				8/64								GD/W	
23-101-4 cb		4963-5018	Kal		OA	7189		6435			4.2	DST	
24-101-31 bd		4722-4866	Kal		OA	7473		6635			4.3	DST	
ERICSON													
15-102-4 bb	60		Ke	9/63								GD/W	
16-102-20 bca	115		Ke		C		60					D	
18-100-22 bb	5850	1925-1943 2190-2275	Ke	12/60								D	
19-99-29 bd		3930-3950	Ke		OA	7089K					2883	DST	

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ERICSON (continued)													
20-100-22 bbc	6052	2253-2292 5186-5237	Ke	7/60								D	
20-100-30 cc	1400?		Ke,Kal				17					GD/W	
20-100-36 cb		2578-2604	Ke		OA	6977K		6532			43.4	DST	
20-101-27 caa	90?		Ke,Kr?									GD/W	
20-101-27 cbd	480		Ke		C	6520	17	6503	100			D	
21-101-21 ada	1200	215-450 789-1200	Ke		P,D,C	6800	120	6680	250			D	
ROCK SPRINGS													
15-103-26 aaa	120		Kr	60	C							D	
18-100-8 cc	1000		Kr	9/63								GD/W	
18-101-18 bbb	400		Kr	16	D,WS,I	7000	8	6992	250			D	
18-101-18 bda	400		Kr	16	D,WS,I	7000	8	6992	250			D	
18-101-18 dc	110	48-110	Kr	60	C							D	
20-101-27 caa	90		Kr	7/58		6520	17	6503				D	
20-101-27 cbc	1112		Kr	05	C	6520	17	6503	100			D	
BLAIR													
15-103-22 bad	60	5-60	Kbl	60	C							D	
16-104-8 ddd	120	100-120	Kbl	36	D,C	7620	78	7542	42			D	
17-104-26 add	250	148-178	Kbl	36	D,C	8200	140	8060	30			D	
18-105-14 dc			Kbl						60			CM	
20-102-28 db			Kbl						60			CM	
MESAVERDE (UNDIVIDED)													
12-90-12 bb	160	100-160	Kmv		D,WS	6560	100	6460	20	20	35000	SEO	
13-89-15 dd	85	85	Kmv		D,WS	6720	0?	6720?	<25	<1.67	2500	SEO	
13-89-32 d			Kmv	7/59	S							GD/W	
13-103-8 da	4869	3450-3800	Kmv			7550	art.	7570+				D	
14-91-11 dd	10040		Kmv		OA							D	
14-102-36 abc	4092	1900-2455	Kmv									D	
16-91-21 aac	2933		Kmv	10/63								GD/W	
16-92-13 ac	4297		Kmv			6680	art.	6680+				D	
16-92-17 db	10415	9296-9422 9690-9781	Kmv		OA							D	
16-101-11 bc		2548-2600	Kmv		OP	7121K		6868			.3	DST	Transmissivity may be overestimated
18-90-3 a	250		Kmv		C	7170	art.	7170+				D	
18-90-3 add	605	138-200	Kmv		C	7170	art.	7170+				D	
19-89-9 aa	250		Kmv		C	7600	art.	7600+				D	

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MESAVERDE (UNDIVIDED) (continued)													
19-89-9 cc	2681	500-2681	Kmv		C	7600	art.	7600+				D	
21-98-35 da		6100-6115	Kmv		OP	6771		6322			2.7	DST	
24-89-1 dd	180	50-180	Kmv		D,WS	6540	60	6480	15	3.0	3000	SEO	
25-102-26 bd		6410-6546	Kmv		OA	7229		6193			5.1	DST	
27-93-35 ca		4257-4330	Kmv		OA	7107K		7078			66.7	DST	
27-93-35 ca		4969-5027	Kmv		OA	7107K		7069			2.4	DST	
BAXTER, STEELE, NIOBRARA, CODY													
14-87-33 ca	117	97-117	Kn-?		WM	7914	7	7907	3	0.03	10	SEO	Possibly Ks
14-89-1 bdd			Kb-Kst			7310						USGS	
15-88-30 bb			Kst		S	(7100)	F	7100+				SEO	
17-103-8 bbd			Kb			7310						USGS	
17-104-10 bad	16-?	0-76	Kb-?		W,D,C,WS	(7000)	F	7000+				D	Sandstone & shale
18-89-17 bcd			Kb-Kst			7380						USGS	
19-86-36 baa			Kb-Kst			6720	26	6694				USGS	
19-88-22 dd			Kb-Kst			7083						USGS	
19-104-23 ad			Kb			6307	180	6127				USGS	
21-88-5 dda	335		Kc-?			7155	30,31	7124	8-?			GD/W	Cretaceous undivided-?
22-89-17 cbb			Kb-Kst			6655						USGS	
26-89-17 cb-1	162		Kc			(6700)	F-?	6700+				SEO	
26-89-17 cb-2	208		Kc-?			(6700)	F-?	6700+				SEO	
26-89-17 cbd	208-?		Kc-?,Qal			(6650)	140	6510				GD/W	Same as well cb-2 (?)
26-89-18 cb	208	195-208-?	Kst-?			(6760)	195-?	6565	22			D	Same as well cb-2 (?)
26-89-18 da	126		Kc			(6700)	F-?	6700+				SEO	
26-89-18 dab	126	100-126-?	Kst-?			(6720)	100-?	6620	10			D	Same as well da (?)
26-90-3 ccd	860	770-790	Kc-?						"little"			D	
27-89-15 ac	120		Kc			--	7	6370				WR	Sp. Cond. = 7000
27-89-34 bd	105		Kc			--	42	6525				WR	
27-90-33 ad	35		Kc			(7350)	20	7330				SEO	
28-90-26 bc-1	100		Kc			(6720)	35	6685				SEO	
28-90-26 bc-2	180		Kc			(6720)	60	6660				SEO	
28-92-8 ca	730	649-729	Kc-?		WM	(6590)	236	6354	15	0.06	1500	SEO	
28-92-18 aa	215		Kc			--	10	6550				WR	
28-92-18 bc	8		Kc		S-?	(6660)	4	6656				SEO	
28-92-28 ab	1500	500-1500	Kc-?		WM	7516	500	7016	40-50	0.10-0.12	80	SEO	
28-92-28 ac	1410	530-1410	Kc-?		WM	7449	757	6692	42	0.07	200	SEO	
28-95-26 db	180		Kc			(6900)	100	6800				SEO	

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FRONTIER													
13-87-15 da	45		Kf-?		WD	(7500)	28	7472	10	0.83	90	SEO	
14-103-10 ab	9379	5735-5791	Kf	73	OA	7081		2908			2	DST	
15-102-34 d	9012	8880-9002	Kf-Kd	77	OA	7128		5200			3	DST	
16-103-16 bb	4822	3810-3849	Kf	60	OA	7257		5822			1	DST	
17-88-2 cd	1000		Kf			(7390)	F	7390+	20			SEO	
17-102-17 dc	8720	4370-4511	Kf	74	OA	6647		6537			9	DST	Probable water cushion in DST recovery
18-88-3 dca	1026		Kf,Kcv			7242	F	7242+	F-15			GD/W	Sp. Cond. = 1150
18-88-3 da						(7225)			38	0.29	340	R	Dual completion with Kcv (test in both aquifers) Field coef. of perm. = 17 gpd/ft^2; saturated thickness = 20'
18-88-10 ac			Kf						50-100?			R	Produces 50 gpm; possibly could produce 100 gpm
18-88-10 ac	210		Kf			(7380)	80	7300	50			D	
18-88-10 bda	1000	460-486	Kf		WD,P,C	(7375)	F	7375+	30			D	Triple completion with Kd,Jm
18-88-10 db	210		Kf			7340	15,80-?	7260	F-50-?			GD/W	
18-88-11 bb	165-?		Kf			7260	F	7260+	F-20-?			GD/W	
18-88-22 bb	90-?		Kf			7560	+5-?	7565	F-5-?			GD/W	
18-88-27 baa	860		Kf			(7420)	10	7410	50-?			GD/W	
18-90-11 ba	10330	7525-7575	Kf	71	OA	7551		7492			3	DST	Poor DST
18-101-28 bc	7910	6843-6867	Kf	63	OA	7233		6325			10	DST	Salt water; probable water cushion in DST recovery
18-103-6 bb	3250	2301-2318	Kf	73	OA	6403		6687				DST	
18-103-16 ccc	2654	2590-2625	Kf		oil		F-?		0.3			D	
19-90-36 bc	10795	7840-7896	Kf	71	OA	7689		5848			18	DST	Salt water; poor DST
20-88-34 bb	3460	2960-3065	Kf		oil	(7430)		7430				D	
22-103-20 bd	7585	6482-6532	Kf	75	OP	6866		6399			1	DST	
23-88-3 cb-1	7		Kf-?		WS	(6790)	6	6784				SEO	
23-88-3 cb-2	7		Kf-?		WS	(6790)	F	6790+				SEO	
23-88-6 cbc			Kf			6533	F	6533+	F-1-?			GD/W	Sp. Cond. = 4800
23-88-6 dbd	2561	1020-1125	Kf		oil	(6790)	F-?	6790+				D	Triple completion with Kd,Jsd "Salt water"
23-88-8 ccc	2445	1190-1225	Kf		oil	(6650)	F-?	6650+	1			D	Dual completion with Kd
23-88-16 cb-1	100	24-28-?	Kf			6837	24	6813	20	20*	15000	SEO	
23-88-16 cb-2	100	17-22-?	Kf			6837	22	6815	30	30*	20000	SEO	
24-88-30 bdc	2200-?		Kf			6511	F	6511+	F-1-?			GD/W	Sp. Cond. = 6000
25-87-2 dab	2600	1770-1780	Kf			(6900)	F	6900+				D	
25-88-3 cc	4908	1692-1715	Kf	61	OA	6784		6568			54	DST	Salt water
25-88-11 bb	2863	1730-1770	Kf	62	OA	6764		6554			10	DST	Muddy water
25-88-31 ac	6715	2103-2163	Kf	66	OA	6486		6595			6552	DST	Very poor DST
25-89-11 dbb	1845	1840-1845	Kf			(6580)	F	6580+	4			D	Water "brackish"

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentiometric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmissivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
FRONTIER (continued)													
25-89-12 ab	3541	1995-2002	Kf	60	OA	6548		6582			24	DST	Gas cut water
25-89-24 ccc	2010	?-2010	Kf			(6550)	F	6550+				D	
25-89-26 bca	3439-?		Kf			6495	F	6495+	F-10-?			GD/W	Sp. Cond. = 3500
26-87-26 bca	4623	1095-1305	Kf			(7000)	1200-?	5800				D	
26-87-30 dd	4557	4414-4474	Kf	59	OA	7033		6750			3.5	DST	Sulfur water
26-88-28 ddd	2511	1595-1605 1220-1650	Kf Kf			(6810)	F	6810+				D	
26-88-30 cc	3264	2045-2087	Kf	54		6602		6632			7	DST	
26-88-32 bb	2971	1882-1912	Kf	54	OA	6693		6598			13	DST	Fresh water
26-88-33 ad	5000	1199-1290	Kf	78	OP	6801		5936			6	DST	
26-89-25 ac	2373	2300-2360	Kf	59	OA	6600		6539			1	DST	Muddy fresh water
26-90-3 ad	5380	1814-1898	Kf	74	OP	7129		6403			28	DST	Salt water; poor DST
26-90-9 ba	6400	5129-5169	Kf	67	OA	6574		6388			3	DST	
26-95-6 a	7955	3960-4536	Kf	77	OA	6987		7010			23	DST	Poor DST
27-89-14 ba	220	130-140	Kf		WD	6580	35	6545	106	0.53	900	SEO	
MUDDY													
25-89-14 dc	6544	2826-2900	Kmd	64	OA	6496		6350			8	DST	
26-88-30 cc	3264	3089-3106	Kmd	54		6602		6604			3	DST	
26-90-3 ad	5380	2617-2680	Kmd	74	OP	7129		5169			17	DST	
26-90-14 cb	7010	4779-4796	Kmd	57	OA	6881		4316			3	DST	
27-95-5 cb	1852	1005-1050	Kmd & Kmr	74	OA	6959		6676			12	DST	
CLOVERLY (LAKOTA-DAKOTA)													
12-92-10 cc	16248	13443-13779	Kcv & Kmd	60	OA	6563		950?			1.1	DST	
13-87-33 dc	6475	5585-5600	Kd	75	OA	7760G		7370			36	DST	Probable water cushion in recovery
13-89-15 db	7958	6053-6066	Kd	66	OA	6978		7365			2	DST	
14-88-34 cb	7192	5247-5305	Kd	67	OA	7976		7440			16	DST	
14-103-10 ab	9379	6225-6330	Kd,Jm	73	OA	7081		4870			4	DST	
16-103-16 bb	4822	4216-4252	Kd	60	OA	7257		5818			10	DST	Oil & water cut mud; gas cut salt water
17-88-11 aa	580 -- 580		Kcv-? Kcv Kd		 WP	 (7425) (7425)	F ? F	 7425+ 7425+	F-85 85 85	 0.86 	 1600 	GD/W R D	Sp. Cond. = 913 4 other Kcv wells flow 25-65 gpm City of Rawlins
17-88-11 ba	620		Kd		WS	(7500)	F	7500+	25			D	
18-88-3 da	--		Kcv,Kf			(7225)			38	0.29	340	R	Field coef. of perm. = 17 gpd/ft^2; saturated thickness = 20'
18-88-10 bda	1000	928-955	Kd,Kf,Km		W,P,D,C	(7375)	F	7375+	70			D	Water quality "good" Triple completion with Kf,Jm
18-88-10 bda	--		Kcv			(7390)	–		65	0.26	450	R	
18-88-10 bda	1000		Kcv			(7360)	+287	7647	65			GD/W	Sp. Cond. = 346

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentiometric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmissivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
CLOVERLY (LAKOTA-DAKOTA) (continued)													
18-88-10 bdd	960		Kd		WP	(7390)	F	7390+	42			D	
	--		Kcv						43	1.36	1700	R	Field coef. of perm. = 25 gpd/ft^2; saturated thickness = 69'
18-101-28 bc	7910	7315-7385	Kd	63	OA	7233		6545			175	DST	Salt water; poor DST
18-101-28 bc	7910	7386-7512	Kd & Jm	63	OA	7233		6379			19	DST	Salt water
18-102-6 cd	4420	3740-3793	Kd	73	OA	6481		6616			45	DST	Gas cut black water; poor DST
18-102-18 ab	4715	4022-4033	Kd	72	OA	6593		6462			14	DST	Probable water cushion in DST recovery
18-103-6 bb	3250	2948-2978	Kd	73	OA	6403		6386			5		Poor DST
18-103-8 db	3133	2594-2623	Kd	71	OA	6558		6374			48	DST	Salt water; poor DST
18-103-8 db	3133	2653-2716	Kd	71	OA	6558		6423			47	DST	Gas cut salt water; poor DST
18-104-25 dc	2478	2368-2388	Kd		oil							D	
19-89-34 ab	13356	5702-5820	Kd	74	OP	7554		7318			17	DST	
19-102-19 a	4857	4281-4345	Kd	60	OA	6477		6557			14	DST	
19-102-19 a	4857	4355-4420	Kd	60	OA	6477		6338			5	DST	Gas cut salt water
19-102-30 cc	4216	3812-3850	Kd	65	P	6500		6484			11	DST	Sulfur water
19-103-12 cb	4455	3930-3978	Kd	77	OA	6369		5742			2	DST	Salt water
19-103-25 dd	4216	3812-3850	Kd	65	P	6499		6481			12	DST	Transmissivity may be overestimated; salty sulfur water
19-103-36 ca	4100	3886-3910	Kd & Jm	70	OA	6527		6497			4	DST	
23-88-6 dbd	2561	1928-2031	Kd		oil	(6790)	F	6790+				D	Triple completion with Jsd and Kf
23-88-8 ccc	2445	2431-2440	Kd		oil	(6650)	F	6650+				D	Dual completion with Kf
24-88-29 dd	3805	1810-1835	Kd & Jm	80	OP	6516		6823			2	DST	Gas cut water
26-88-30 cc	3264	3202-3221	Kc	54	OA	6602		5891			9	DST	
26-89-23 ba	4554	4503-4554	Kd?	73	OA	6670		5816			1	DST	
26-90-11 ac	5641	3830-3880	Kd	68	OA	6837		5689			35	DST	Mud and gas cut water; poor DST
26-90-14 cb	7010	5065-5095	Kd	57	OA	6881		5068			6	DST	
26-94-17 bb	9728	9506-9513	Kd	56	OA	6817		6745			1	DST	
27-95-8 aa	1600	1441-1500	Kd	62	OA	7092		6631			3	DST	Fresh water
28-93-4 dd	4470	4440-4465	Kd		oil-PB	(7000)	4450-?	2550-?	90				Dissolved solids = 7000 ppm
28-93-21 ab	7034	6900-6912	Kd	69	OA	8147		3731			7	DST	
28-94-36 bb	10720	10615-10637	Kd	74	OA	7500		5712			1	DST	Gas cut salt water; poor DST
30-93-32 bd	6592	4243-4278	Kla		oil	(6420)	F-?	6420+					3 DST recovered 2350-5925' "fresh water"; triple completion with Jsd, Pt
MORRISON													
13-89-17 ad	8055	6444-6457	Jm	54	OP	7030		--				DST	Incomplete data
17-103-33 ba	4665	4225-4296	Jm-Js?	62	OA	7699		6495			177	DST	Black mud cut sulfur water; poor DST with probable water cushion in recovery
18-88-10 bd	1000		Jm			(7380)	16	7364	120+			SEO	Probably same as 10 bda
18-88-10 bda	1000	968-983	Jm		W,P,D,C	(7375)	F	7375+	50			D	Water - "soft"
19-102-19 a	4857	4566-4619	Jm		OA	6477		5924			1	DST	Gas cut salt water

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MORRISON (continued)													
19-103-2 dc	4375	3805-3923	Jm & Kd	77	OP	6375		6397			3	DST	
20-103-18 bc	4973	4046-4167	Jm	72	OA	6513		7103			44	DST	Salt water; poor DST
20-103-24 da	5465	5307-5465	Jm & Kd	57	OA	6697		5818			2	DST	Gas cut sulfur water
23-103-29 dc	8600	8551-8576	Jm	67	OP	7203		4940			1	DST	Muddy water
27-95-29 bc	4558	4155-4182	Jm	57	OA	7409		6679			6	DST	Gas cut water
SUNDANCE AND ENTRADA													
13-89-17 ad	8055	6655-6700	Je	54	OP	7030		--			--	DST	Incomplete data
16-104-16 dd	7126	3340-3346	Je	73	OP	7299		6415			12	DST	Transmissivity may be under-estimated
18-87-27 ccd	2523	2515-2523	Jsd		oil							D	
18-102-12 cd	6746	6490-6630	Je & Jca	55	OP	7005		6535			3500	DST	Sulfur water; poor DST
19-88-34 da			Js			(7200)			28	0.17	240	R	Field coef. of perm. = 4 gpd/ft^2; saturated thickness = 60'
19-88-34 daa	1890	1750-1770	Js		WS	(7190)	F	7190+	27			D	
19-88-34 dac			Js			(7155)	167	6988				USGS	
19-102-35 aa	8644	6391-6426	Js	52	OA	7117		6723			22	DST	Sulfur water
19-103-28 cd	4250	4203-4211	Je	74	OA	6772		6492			374	DST	Gas cut sulfur water; poor DST
23-88-6 dbd	2561	2415-2505	Js		oil	(6790)	F-?	6790+?				D	"Salt water" Triple completion with Kf and Kd
24-87-13 aad	3300+	3300-?	Js		oil	(6620)	F	6620+				D	
25-89-14 bac	3477	3472-3477	Js		oil	(6570)	F	6570+				D	
26-89-7 bdc	5886	4065-4073	Js		oil	(6770)	1800	4970	35			D	
30-93-1[illegible] bd	6[illegible]92	4646-4692	Js		oil	(6420)	F-?	6420+				D	3 DSTs record 2350-5925' "fresh" water; triple completion with Kla, Pt
NUGGET													
12-92-10 cc	16248	14140-14273	Je & Jn	60	OP	6563		6250			38	DST	
14-88-34 bc	7192	5840-5860	Jn	67	OA	7976		6000			4	DST	Muddy water
14-101-18bb	12900	10711-10770	Jn	75	OA	7094		4262			9	DST	Gas cut water; probable water cushion with DST recovery
15-91-23 bd	11248	8776-8800	Jn	64	OA	6779K					47	DST	Gas cut water; probable water cushion with DST recovery
16-92-12 dc	12533	9686-9726	Jn	78	OA	6661		7325			12	DST	Gas cut water; poor DST; probable water cushion with DST recovery
16-101-15aa	14482	11820-11845	Jn	72	OP	7090		6111			3	DST	Sulfur water
16-104-16 dd	7126	3550-3571	Jn	73	OP	7299		6666			15	DST	Transmissivity may be underestimated
17-99-14 db	20000	16222-16506	Jm?, Js-Jn	78	OP	7070		7232			2	DST	Gas cut salt water
17-102-17 dc	8720	5788-5838	Jn	74	OA	6647		6498			60	DST	Sulfur water; poor DST; probable water cushion with DST recovery
18-90-11 ba	10330	8755-8785	Jn-Js	71	OP	7551		7478			14	DST	
18-101-32 bd	8121	8057-8071	Jn	74	OP	7032		6642			1329	DST	Black sulfur water; very poor DST
18-102-12 dc	6746	6683-6746	Jn	55	OP	7005		6388			1054	DST	Gas cut sulfur water; very poor DST

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NUGGET (continued)													
18-102-12 dc	6746	6701-6714	Jn?	55	OP	7005		6532			663	DST	Poor DST
19-87-29 ad	5811	3740-4107	Jn & Trc	71	OA	6993		7481			370	DST	Poor DST
19-102-35 aa	8644	6588-6631	Jn	52	OA	7117		6641			2166	DST	Sulfur water; poor DST
19-103-18 cc	4120-?		Jn				F	( )	F-200?			GD/W	Spec. Cond. = 13000-?
19-104-18 ccb			Jn					6319				USGS	
24-87-1 cb	6454	4776-4816	Jn	59	OA	6776		6059			1	DST	
25-89-12 ba	3541	3473-3481	Jn	60	OA	6548		6235			30	DST	
26-90-3 bb	7878	4100-4175	Jn	64	OS	7145		5400			114	DST	Gas & mud cut water; poor DST
26-95-6 a	7955	5942-5954	Jn	77	OA	6987		6327			8	DST	
27-95-18 bdd	4787	1690-1740	Jn			(7150)	200-500	6800	35			D	Total dissolved solids = 10436 mg/l
27-95-18 bd			Jn			7140	200	6940				USGS	
28-93-2 ad	5340	5092-5135	Jn	76	OP	6759		5717			10	DST	
CHUGWATER													
13-89-15 db	7958	6548-6574	Trc	66	OA	6978		--			2	DST	
16-104-16 dd	7126	4532-4570	Trc	73	P	7299		6388			.5	DST	
18-90-11 ba	10330	8755-8785	Trc?	71	OA	7551		7478			14	DST	
19-87-29 da	5811	4090-4200	Trc	71	OA	6993		7456			2	DST	
28-89-33 bc	60		Trc			--	F	6620				WR	
PHOSPHORIA - PARK CITY													
16-104-16 dd	7126	5459-5489	Pp	73	OP	7299		6522			12	DST	Transmissivity may be under-estimated Black salt water
16-104-16 dd	7126	5511-5672	Pp	73	OP	7299		6318			7	DST	Brackish salt water
17-102-17 cd	8720	7580-7607	Pp?	74	OA	6647		6600			7	DST	Black salt water; poor DST; probable water cushion with DST recovery
27-95-9 bc	3990	3535-3580	Pp	57	OP	7154		6871			1	DST	
27-97-25 ad	3700	2800-2878	Pp	59	OA	7040		6855			3	DST	
28-91-20 aa	8130	7665-7780	Pp & Trd	73	OA	7178		6848			20	DST	
28-93-4 ba	6292	6158-6190 6210-6224 6234-6284	Pp		Oil-PB				30			D	Dissolved solids = 4600 mg/l Yield applies to 3 intervals combined
28-94-2 bd	3095	2184-2226	Pp	54	OA	6726		--			--	DST	
29-96-20 ab	2578	1531-1561	Pp			(6675)	F	6675+				D	Dual completion with Mm DST record 320' sulfurous water
30-96-7 bcb	269	229-269	Pp			(5890)	F-?	5890+	700-?			D	Located north of study area Sp. Cond. = 1800
30-97-11 b	408		Pp				50	5810				WR	Sp. Cond. = 1400

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TENSLEEP AND WEBER													
13-88-8 d	8163	8010-8089	₽t		Oil			6900				D	Rec. 1893' "fresh" water Dissolved solids = 1363 ppm
14-101-18	12900	12771-12800	₽w	75	OA	7094		6638			.1	DST	
15-91-11 ba		10329	₽t		OA	6665G						DST	
16-91-8 dd	10913	10865-10913	₽t	75	OA	6608G		7142			.5	DST	
16-104-16 dd	7126	5700-5756	₽w	73	OP	7299		6456			.7	DST	
17-89-2 bba	1607	1050-1392	₽t or Mm		W-?							D	
17-102-17 dc	8720	7810-7850	₽t	74	OA	6647		6610			23	D	
18-88-20 aaa	2603	2432-?	₽t									D	DST rec. 440' sl. muddy water
18-101-32 ad	10100	10048-10066	₽w	75	OA	7129		--			--	DST	Gas cut sulfur water
19-88-10 cb	6305	6167-6220	₽t	74	OA	7224		7363			[illegible]	DST	Muddy sulfur water; probable water cushion with [illegible] recovery
19-101-35 aa	8644	8587-8637	₽t	52	OA	7117		6372			5	DST	Sulfur water
21-87-2 baa	980	600-800-?	₽t-?			(6900)	600	6300				D	
21-87-16 ccc	650		Mm, ₽t Mm, ₽t			( )	F		400 195			D R	Dual completion with Mm Water "rather" highly mineralized
21-87-16 cc	305		₽t			(6700)	F	6700+				SEO	
21-88-4 ac	1520	1481-1520	₽t	58	OA	7915		7725			374	DST	
22-88-28 bdd	2255	2161-2217	₽t									D	DST rec. 350' water
23-88-20 aaa			₽t-?			(7400)	F	7400+	200-?			GD/W	Sp. Cond. = 581
23-89-1 cbb	4818	4770-4811	₽t		oil	(6650)	F-?	6650+	24			D	Water quality "good"
24-87-27 dc	6313	6157-6175	₽t	70	OA	6580		6164			1	DST	
25-87-11 ba	6442	6360-6400	₽t	75	OA	6860		6541			5	DST	Brackish water
25-88-3 cc	4908	4805-4871	₽t	61	OA	6784		6823			156	DST	Black sulfur water; poor DST
25-89-14 dc	6544	5260-5310	₽t	64	OA	6496		6719			8	DST	
26-87-32 bb	4675	4420-	₽t-TrPc	58	OA	6998		6979			.4	DST	
26-89-6 cd	7818	6340-6402	₽t	78	OP	6978					4	DST	
26-95-6 a	7955	7791-7859	₽t	77	OA	6987		6994			45	DST	Poor DST
28-98-18 bb	8380	8340-8380	₽t	51	OA	5662		5856			60	DST	Sulfur water; poor DST
29-93-9 aa	6552	6301-6343	₽t		oil							D	DST records 5610 feet of "fresh" water
30-93-32 bd	6592	6525-6582	₽t		oil		F-?					D	3 DST rec. 2350-5925' "fresh" water; triple completion with Kla, Jsd
AMSDEN													
16-104-16 dd	7126	6150-6173	₽a	73	OP	7299		6358			5	DST	
18-97-30 dc	22290	21686-22293	₽m	74	OP	7547		6370			.3	DST	Gas and mud cut water

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentiometric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmissivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
MADISON													
16-92-12 cd	12533	12150-12310	Mm	78	OA	6661		7260			10	DST	Poor DST; probable water cushion with DST recovery
16-101-11 ba	16497	15013-15035	Mm	72	OP	7135		6317			9	DST	Sulfur water; mud cut sulfur water; probable water cushion with DST recovery
16-104-16 dd	7126	7074-7130	Mm	73	OP	7299		6496			12	DST	Water cut mud & brackish water
17-89-2 bba	1607	1050-1392	Pt or Mm		W-?							D	
17-100-4 db	15211	15145-15211	Mm	74	OP	6884		6917			15	DST	Salt water
18-97-30 dc	22290	21686-22290	Pa & Mm	74	OP	7547		6838			77	DST	Transmissivity may be overestimated; poor DST
19-98-21 db	19171	18652-19171	Pm & Mm	76	OP	6994		7125			11	DST	Salt water; probable water cushion with DST recovery
19-87-27 d[illegible]	5811	5711-5811	Mm	71	OA	6993		7297			--	DST	
21-87-9 bd-3	146		Mm		D	(6890)	80	6810	100	100*	200000	GD/W,SEO	
21-87-9 bda-2	146	94-140	Mm		WI,D				25			D	Dual completion with 6
21-87-9 bda-3	110	104-110	Mm		D	(6790)	72	6718	4-5			D	Water quality - "good"
21-87-16 cc-1	650	630-650	Mm		P	(6750)	F	6750+	100	100*	150000	SEO	
(ccc)	650		Mm				F		193-?			GD/W	Sp. Cond. = 2480
	650		Mm,Pt				F		400			D	
			Mm,Pt				F		195			R	Water "rather" highly mineralized
25-88-31 ac	6715	5935-6015	Mm	66	OA	6486		7182			22	DST	Poor DST*
29-96-20 ab	2578	2531-2578	Mm		oil	(6675)	F	6675+				D	DST rec. 2530' fresh muddy water
29-97-20 a	2578+?	2490-2578	Mm		oil	(7000)	F	7000+				D	Water "fresh" (DST)
30-99-13 ba	1627		Mm		W-?	--	446	6600				WR	Sp. Cond. = 570 Located north of study area
30-9[illegible] d	--	[illegible]	Mm		S	--	S	7700				WR	Sp. Cond. = 280
CAMBRIAN (UNDIVIDED)													
16-101-11 ba	16497	16350-16497	6f	72	OP	7135		6807			.3	DST	Muddy water, Prod -Weber 13762-14184 (gas & oil)
21-87-9 bd-1	110		6		WD	(6900)	72	6828	4	0.67	100	SEO	
21-87-9 bd-2	110		6			(6900)	110-	6790-	dry			SEO	
21-87-9 bda-1			6			6823	71	6752				USGS	Possibly same as bda-3 (Mm)
21-87-9 bda-2	146	144-146	6sst		WI,D				100			D	"Good clear water" Dual completion with Mm
21-87-10 bb	190		6-?			(6800)	17	6783	5			SEO	
21-87-16 ba	190		6f			(6780)	F	6780+	25			SEO	
21-87-17 aa	320	200-260	6f		M	(6900)	75	6825	150	150*	300000	SEO	
21-87-17 ac-1	384		6f			(6900)	65	6835	250			SEO	TD in Precambrian
21-87-17 ac-2	416		6			( )	63		150-?			GD/W,R	Sp. Cond. = 1060 Dual completion with Tu, but most production from 6
21-87-17 acb-2			6			6700	64	6636				USGS	State Penitentiary well
21-87-21 bb	348-?		6		M	(6800)	F	6800+				GD/W,D	Water quality "good"
21-87-32 cc	200		6f			(7080)	20	7060				SEO	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentiometric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmissivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
CAMBRIAN (UNDIVIDED) *(continued)*													
21-87-33 cc	206		Єf			(6990)	75	6915				SEO	
21-88-11 cd	--	S	Є		S	(7300)	100-?	7300+				GD/W	Sp. Cond. = 353
7-97-2? bc	1580	1280-1321	Єl	60	OA	7026		6945			27	DST	Brackish salt water
PRECAMBRIAN (UNDIVIDED)													
14-87-1 bd	S		pЄ		S		F					SEO	
14-87-1 ca-1	S		pЄ-?		S		F					SEO	
14-87-1 ca-2	S		pЄ-?		S		F					SEO	
15-87-8 bc	8		pЄ				F		10			SEO	
15-87-12 da	142		pЄ		W-M	(8380)	10	8370	2	0.03	6	SEO	
15-87-32 cd	S		pЄ		S		F		7-10			SEO	
29-87-28 aa	70		pЄ-?				20					SEO	
29-93-1 cd	30		pЄ				11					SEO	Granite
29-93-35 b	S		pЄ		S	--	F	7360				WR	Sp. Cond. = 130; out of study area
29-100-11 cc	60		pЄ			--	20					SEO	
29-100-11 da	60		pЄ				15					SEO	
29-100-12(1)	39		pЄ				9					SEO	
29-100-12(2)	61		pЄ				30					SEO	
29-100-12(3)	56		pЄ		W-D		17		3	0.09	10	SEO	
29-100-12 aa	80		pЄ				50					SEO	
29-100-12 ab	34		pЄ		W-D	7665	16	7649	5	0.56	50	SEO	
29-100-12 ca-1	63	46-61	pЄ		W-D		40		20	1.67	400	SEO	
29-100-12 ca-2	68		pЄ		W-D	7710	45	7665	8.3	0.83	300	SEO	
29-100-12 ca-3	39		pЄ				25					SEO	
29-100-12 ca-4	65		pЄ				25					SEO	
29-100-12 ca-5	41		pЄ		W-D		10		5	0.56	50	SEO	
29-100-12 ca-6	60		pЄ				40					SEO	
29-100-12 ca-7	31		pЄ		W-D		19		10-12	1.7-2.0	300	SEO	
29-100-12 ca-8	60		pЄ				30					SEO	
29-100-12 ca-9	37		pЄ		W-D		28		20	2.2	500	SEO	
29-100-12 ca-10	60		pЄ				F-?					SEO	
29-100-12 ca-11	5		pЄ		S		F					SEO	
29-100-12-cb-1	56						23						Water-bearing fault
29-100-12-cb-2	77		pЄ				32		10			SEO	
29-100-12-cb-3	40		pЄ				10					SEO	
29-100-12-cb-4	50		pЄ				20					SEO	
29-100-12-cc-1	50		pЄ				12					SEO	
29-100-12 cc-2	60		pЄ		W-D		36		150-?	150*	120000	SEO	
29-100-12 cc-3	40		pЄ				7.5					SEO	
29-100-12 cc-4	31		pЄ				15					SEO	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentiometric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmissivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
PRECAMBRIAN (UNDIVIDED) (continued)													
29-100-12 cc-5	50		pЄ				5					SEO	
29-100-12 cc-6	27		pЄ				15					SEO	
29-100-12 cc-7	12		pЄ				5					SEO	
29-100-12 cc-8	40		pЄ				12					SEO	
29-100-12 cc-9	103		pЄ			(7000)	34	6966				SEO	
29-100-12 cc-10	50		pЄ				39					SEO	
29-100-12 cc-11	100		pЄ				45					SEO	
29-100-12 cc-12	90		pЄ			(7000)	30	6970				SEO	
29-100-12 cc-13	60		pЄ				15					SEO	
29-100-12 cc-14	46		pЄ				10					SEO	
29-100-12 cd-1	92		pЄ				62					SEO	
29-100-12 cd-2	62		pЄ				40					SEO	
29-100-12 cd-3	42		pЄ				8					SEO	
29-100-12 cd-4	13	7-13	pЄ		W-D		8		10	10*	4000	SEO	
29-100-12 cd-5	47		pЄ				42					SEO	
29-100-12 cd-6	100		pЄ			(7175)	55	7120				SEO	
29-100-12 cd-7	50		pЄ				48					SEO	
29-100-12 cd-8	40		pЄ				27					SEO	
29-100-12 cd-9	13		pЄ				6					SEO	
29-100-12 cd-10	55		pЄ				45					SEO	
29-100-12 cd-11	100		pЄ			(7175)	12	7163				SEO	
29-100-12 cd-12	146	83-146	pЄ			(7175)	35	7140	14	2.3	1000	SEO	Open hole
29-100-12 cd-13	60		pЄ				20					SEO	
29-100-12 cd-14	80		pЄ				56					SEO	
29-100-12 cd-15	60		pЄ				30					SEO	
29-100-12 cd-16	38		pЄ				9					SEO	
29-100-12 cd-17	90		pЄ				50					SEO	
29-100-12 dd	40		pЄ				23					SEO	
29-100-13 aa	38		pЄ				10					SEO	
29-100-13 ab-1	88	27-88	pЄ				59		70	3.5		SEO	Open hole
29-100-13 ab-2	60		pЄ				15					SEO	
29-100-13 ad	90		pЄ				85					SEO	
29-100-13 ba	140		pЄ			(7800)	96	7704				SEO	
29-100-20 da-1	25		pЄ				12					SEO	
29-100-20 da-2	30		pЄ				18					SEO	
29-100-20 da-3	60		pЄ				15					SEO	
29-100-20 db-1	120		pЄ			(7900)	75	7825				SEO	
29-100-20 db-2	80		pЄ				12					SEO	
29-100-20 db-3	60		pЄ				45					SEO	
29-100-20 db-4	75		pЄ				22					SEO	

Location[a]	Total Depth (ft)	Tested or Perforated Interval (ft)	Geologic Formation[b]	Date of Test	Well Description[c]	Reference Elevation[d]	Water Level (ft bel. surface)	Potentio-metric Surface Elevation (ft abv msl)	Yield[e] (gpm)	Specific Capacity (gpm/ft of drawdown)	Transmis-sivity[f] (gpd/ft)	Data Source[g]	Remarks[h]
PRECAMBRIAN (UNDIVIDED) (continued)													
29-100-24 db	6-S		p6		S-?		2					SEO	
29-101-13 ac	40		p6				15					SEO	
30-87-29 db	S		p6			--	F	6400				R	Out of study area Sp. cap. = 100
30-88-34 bb	S		p6			--	F	6480				R	Out of study area Sp. cap. = 90
30-89-31 bc	S		p6			--	F	6495				R	Out of study area
30-90-15 bc	S		p6			--	F	6330				R	Out of study area Sp. cap. = 750

[a]Location (T-R-Sec,1/4,1/16,1/64)

[b]For abbreviations, see Figure III-4.

[c]Data type and status or use:
- OA - abandoned oil test
- OP - producing oil well (generally producing from a different formation)
- OS - suspended oil well
- S - spring
- W - water well
- WS - stock well
- D - domestic
- U - unused
- M - miscellaneous
- P - public supply
- C - commerical, industrial
- I - irrigation
- PB - plugged back well
- ( ) - number of wells or springs
- K - Kelly Bushing elevation

[d]Feet above mean sea level; elevations in parentheses from 1:250,000 AMS topographic maps.

[e]Well yield or flow; spring flow

[f]See Appendix C for methology. Number in parentheses indicates value calculated for specific capacity. Assumed one foot of drawdown.

[g]GD/W - USGS Hydrologic Atlas 219 (Welder and McGreevy, 1966)
USGS - Unpublished data from U.S. Geological Survey
SEO - Wyoming State Engineer's Office file of permitted domestic wells
D - Dana, 1962
R - USGS Water Supply Paper 1458 (Berry, 1960)
DST - Petroleum Information card drill stem test synopsis
WR - USGS Hydrologic Atlas 270 (Whitcomb and Lowry, 1968)
CM - Coal mine tests

[h]Sp. Cond. - Specific conductivity
Field Coef. of Perm. - Field coefficient of permeability
DST - Drill stem test

Miscellaneous abbreviations

- S - Spring
- F - Flowing well
- * - zero drawdown reported
- art. - artesian well
- ? - questionable data

APPENDIX D

DETERMINATION OF AQUIFER PROPERTIES

APPENDIX D

DETERMINATION OF AQUIFER PROPERTIES

Determination of Transmissivity from Specific Capacity

For many water wells in Wyoming the only pump test information available is yield-drawdown-duration data from constant yield well performance tests. Specific capacity (the yield per unit drawdown) and an estimation of transmissivity can be determined from these data.

Walton (1962) rearranged the Cooper-Jacob simplification of the Theis equation to express the theoretical relationship between specific capacity and aquifer properties as

$$\frac{Q}{s} = \frac{T}{[264 \log (\frac{Tt}{2693 r^2 S}) - 65.5]} \qquad (1)$$

where: $\frac{Q}{s}$ = specific capacity (gpm/ft),

Q = discharge (gpm),

s = drawdown (ft),

T = transmissivity (gpd/ft),

S = coefficient of storage,

r = nominal well radius (ft), and

t = time after pumping started (min).

Walton assumes an infinite, homogeneous, isotropic, non-leaky, artesian aquifer and a fully penetrating well with no well losses. He also assumes that the effective radius of the well is equal to the nominal radius. If drawdown is small compared to saturated thickness, the same equation can be applied to unconfined aquifers (Brouwer, 1978, p. 76).

Equation (1) cannot be rearranged to easily express transmissivity as a function of specific capacity; Walton (1962) constructed a series of graphs relating transmissivity and specific capacity. The individual graphs are each for a specific pumping time, assume a well radius of 6 inches, and require an estimate of the aquifer's coefficient of storage. According to Walton (1962, p. 12) "Because specific capacity varies with the logarithm of 1/S, large errors in estimated coefficients of storage result in comparatively small errors in coefficients of transmissibility estimated with specific capacity data." The transmissivity estimate is insensitive to variations in well radius for the same reason.

For the transmissivity estimates in this report all wells were presumed to have effective radius of six inches, in order to use Walton's (1962) graphs. Confined conditions (artesian, S = 0.0001) were assumed for wells over 200 feet deep and shallower wells were assumed to be unconfined (water table, S = 0.2).

Walton (1962) recognizes that partial penetration, well losses, and geohydrologic boundaries often adversely affect specific capacity, resulting in underestimation of transmissivity. Delayed drainage and vertical flow near wells affect specific capacity of water table (unconfined) wells and also violate some assumptions incorporated in equation (1). As a result transmissivity estimates based on specific capacity must be considered as indicative only of the general order of magnitude of true aquifer transmissivity.

Quantitative Determination of Aquifer Properties from Drill Stem Tests

If detailed drill stem test data are available, determination of aquifer hydraulic properties is relatively simple using the methods described in Bredehoeft (1965) and Miller (1976) (summarized below). The concepts involved resemble the recovery analysis of Theis (see Brouwer, 1978, p. 96) and are based on the non-steady state pressure buildup following a flow period. Basic assumptions include Darcian flow, a single fluid phase, a homogeneous and isotrophic reservoir, and uniform flow rates.

Horner (1951, in Miller, 1976) described the pressure buildup in the transient state as

$$p_w = p_o - \frac{2.3q\mu}{4\pi kh} \log \frac{t_o + \Delta t}{\Delta t} \qquad (2)$$

where t_o = preceding period of flow,

Δt = time elapsed since flow period,

q = production rate during test,

μ = viscosity of fluid,

k = intrinsic permeability,

h = thickness of producing zone,

p_w = pressure in the well at time Δt, and

p_o = undisturbed formation pressure.

Bredehoeft (1965) simplified this to

$$\frac{kh}{\mu} = \frac{2.30q_a}{4\pi\Delta p} \qquad (3)$$

where q_a = the average production rate during the test, and

Δp = the pressure change per one log cycle of time $(\ln \frac{t_o - \Delta t}{\Delta t})$ as axis).

Miller (1976) noted that Todd (1959) says

$$k = \frac{\mu K}{\gamma}, \qquad (4)$$

where K = hydraulic conductivity, and

γ = specific weight of water

and then simplified equation (3) to

$$T = 114 \frac{q_a}{\Delta p}, \qquad (5)$$

where q_a = average production rate (gal/min),

Δp = pressure change (psi/log cycle of time), and

T = transmissivity (gal/day/ft).

Miller's (1976) simplification requires water with temperatures less than 45°C and dissolved solids concentrations below 10,000 mg/l in order to limit errors to 1 percent because it assumes unity for the specific weight of water. Bredehoeft (1965) did not further simplify his equation because, where it was applied in the Bighorn basin, water temperatures exceeded 300°F and viscosity and specific weight were therefore important variables to consider.

The transient state solution procedure is to plot pressure versus the logarithm of $(t_o + \Delta t)/\Delta t$, with Δp determined from a straight line fitted to later time data. Undisturbed formation pressure is determined by linear extrapolation to the point where $\log((t_o + \Delta t)/\Delta t) = 0$.

For many drill stem tests the time versus pressure data required for the rigorous solution presented above are not available in the public sector. A less rigorous solution which can utilize the publicly available data is desirable. Presumption of steady state flow is a gross simplification which eliminates the need for time data.

Gatlin (1960) presents a steady-state equation for radial Darcian flow to a well of an incompressible fluid, which is essentially the Theis equation (see Brouwer, 1978, p. 67). This equation, simplified somewhat and rearranged, is

$$Q = \frac{2\pi\bar{k}h(p_e - p_w)}{\mu \ln(r_e/r_w)} , \tag{6}$$

where Q = productivity,

$\bar{k}$ = effective permeability,

h = net producing thickness,

μ = fluid viscosity at reservoir conditions,

r_e, r_w = drainage and well bore radii, and

p_e, p_w = undisturbed formation and well bore pressures.

The effective permeability $(\bar{k})$ incorporates formation damage due to drilling fluids, which results in reduced permeability of the near-well altered zone. The transient method avoids this complication through its biased use of late time data, which better reflect undisturbed formation permeability. The quantity $(p_e - p_w)$ can be viewed as the steady-state pressure difference which induces the observed flow. Gatlin (1960) notes that it is commonly assumed that $\ln(r_e/r_w) \cong 2\pi$ for drill stem tests. Equation (6) thus simplifies to

$$Q = \frac{\bar{k}h}{\mu} (p_e - p_w) \quad . \tag{7}$$

By rearranging, substituting equation (4), and following Miller's (1976) assumptions about the fluid, equation (7) is changed to

$$\bar{T} = 624 \frac{Q}{\Delta P}, \quad (8)$$

where ΔP = effective driving pressure differential (psi),

Q = productivity (gpm), and

$\bar{T}$ = effective transmissivity (gal/day/ft).

The term $Q/\Delta P$ in equation (8) is essentially the productivity index of the oil well (Gatlin, 1960, p. 246) and is comparable to the specific capacity of water wells (yield per unit drawdown). Estimation of transmissivity from this value incurs limitations equivalent to those for the water well case (see previous section).

The effective transmissivity ($\bar{T}$) determined using equation (8) is an underestimate of the formation transmissivity because it incorporates the reduced transmissivity of the damage zone near the well. Formation damage results from both interaction of formation clay with drilling fluid and invasion of drilling mud solids into the formation. The Damage Ratio (D.R.) expresses the relationships between true and effective transmissivity:

$$T = D.R.(\bar{T}) \quad (9)$$

Damage ratios of clay-poor formations such as clean sandstones and fractured carbonates are typically low, ranging from 2 to 3 according to John Evers, Associate Professor of Petroleum Engineering, University of Wyoming (personal communication, February, 1981), while damage ratios of clay-rich formations can exceed 30. Thus the effective transmissivity estimates true aquifer properties fairly closely for some formations but may be more than one order of magnitude too low for clay-rich formations.

Methodology and Limitations in Interpretation

Both Bredehoeft (1965) and Miller (1976) discuss the limitations of the drill stem test. By simplyifing the analysis to the steady-state the method described above introduces additional error if steady-state flow was not obtained. Uncertainty is also introduced by the necessity of estimating average productivity and driving pressure from drill stem test synopses, often the only data available.

The average productivity rate is determined by dividing total volume of fluid recovered by total flow duration. Typically fluid recovery data are reported as feet of drill pipe filled, but drill pipe diameter is not reported. Evers (personal communication) suggests assuming 4½ inch drill pipe (about 0.6 gal/ft) for "shallow" wells (<15,000 ft total depth) and 5½ inch drill pipe (about 0.9 gal/ft) for "deep" wells (>15,000 ft). If smaller drill pipe were actually used the flow rate and transmissivity would be overestimated, by a maximum one order of magnitude for the smallest (1.9 inch) pipe. Conversely, if larger drill pipe were used, the maximum underestimate would be by a factor of 3 (with 8-5/8 inch pipe).

Average driving pressure can be estimated as

$$\Delta P = FSIP - \frac{IFP + FFP}{2}, \qquad (10)$$

where FSIP = final shut-in pressure,

IFP = initial flow pressure, and

FFP = final flow pressure.

Due to short shut-in durations the final shut-in pressure may not be identical to undisturbed formation pressure, resulting in underestimation of the average driving pressure and overestimation of transmissivity.

Reported flow pressures and recovery often do not agree. In many instances the discrepency can be attributed to an unreported "water cushion" within the drill pipe, used to reduce pressure differentials between the drill pipe and both the hole and formation. As a result the reported recovery, calculated flow rate, and transmissivity are too high. For wells with large reported recoveries, verifiable by flow pressures, the error due to unreported water cushions is estimated as less than a one-half order of magnitude.

Madison Group (carbonate) transmissivities determined using equations (8) and (10), and reported flow rates were within one-half order of magnitude of transmissivities determined by Miller (1976), using equation (5), for 80 percent of the 16 tested data sets. The remaining 3 data sets underestimated transmissivity by one order of magnitude when steady state equations were used, as did a data set for the Tensleep Sandstone (from Bredehoeft, 1965). This demonstrates steady-state techniques will provide adequate estimates of transmissivity in the absence of better data.

It should be noted that transmissivities estimated using equations (5) or (8) are for water at formation temperatures and pressures, thus incorporating the decrease of viscosity associated with temperature increases.

Drill stem tests often are conducted only on selected, thin, porous and permeable intervals within a formation. Derived estimates of hydraulic conductivity thus represent a maximum for the formation but transmissivities underestimate total formation transmissivity due to the thickness differences.

Potentiometric Surface Elevation from Drill Stem Tests

The elevation of the potentiometric surface is determined from the following equation, modified from Miller (1976):

$$h = (Po \times C) - PRD + RP, \qquad (11)$$

where h = potentiometric elevation (feet above msl),

Po = undisturbed formation pressure (psi),

C = conversion factor from psi to feet of water,

PRD = pressure recorder depth (ft below reference point), and

RP = altitude of reference point (feet above msl).

The reference point utilized for most drill stem test data is the Kelly bushing.

If complete drill stem test data are available the undisturbed formation pressure can be determined by extrapolating pressure buildup during shut-in periods (see p. C-4), and the pressure recorder depth is also known.

If only drill stem test synopses are available the pressure recorder depth is unknown and reported shut-in pressure must be utilized as an estimate of undisturbed formation pressure. Initial shut-in pressures are often higher than undisturbed formation pressure due to "supercharging" (Murphy, 1965), which is formation overpressurization due to high drilling mud pressures. The reported final shut-in pressure may be less than undisturbed formation pressure due to incomplete recovery following the flow period. For this report the final shut-in pressure was used as an estimate of undisturbed formation pressure, resulting in possible underestimate of potentiometric elevation. The pressure recorder was presumed to be located at the top of the tested interval, following a suggestion by Evers (personal communication).

The conversion factor used in this report is 2.3067 feet of water per psi. It assumes water with a density of 1.0 gm/cm^3 (i.e., if pure, a temperature of 39.2°F or 4°C). Miller (1976) discusses temperature and dissolved solids corrections which may be made if data are available. Higher temperatures increase the conversion factor by up to five percent, because the density of water is less at elevated temperatures. Dissolved solids increase the density of water, resulting in a decrease in the conversion factor of up to ten percent for water with mg/l TDS.

APPENDIX E

CHEMICAL ANALYSIS OF GROUND WATERS SAMPLED BY WRRI IN THE GREAT DIVIDE AND WASHAKIE BASINS

APPENDIX E

CHEMICAL ANALYSES OF WATER SAMPLES COLLECTED BY WRRI STAFF,
GREAT DIVIDE AND WASHAKIE BASINS, WYOMING

Location	Aquifer	Ca^{++}[a]	Mg^{++}	Na^{+}	K^{+}	$SO_4^{=}$	HCO_3^{-}	$CO_3^{=}$	Cl^{-}	pH[b]	As	Ba	Cd
15/89-33 cc	North Park	54	17	8	2	9	241	0	72	8.1	ND[c]	0.09	ND
23/96-25 bba	Wasatch(?)	3	1	463	3	0	989	84	55	8.6	ND	0.64	ND
15/99-12 bc	Laney	42	19	103	1	174	273	0	8	8.0	ND	ND	ND
12/90-11 ad	Mesaverde	97	32	48	6	108	371	19	26	8.3	ND	ND	ND
20/101-27 ca	Mesaverde	726	542	293	25	4000	449	0	180	8.2	ND	ND	0.01
13/87-15 da	Frontier	126	17	47	2	157	293	48	10	8.6	ND	0.10	ND
21/87-9 bd	Madison	46	18	78	4	161	150	0	50	8.0	ND	ND	ND
21/87-10 bb	Cambrian	74	35	375	24	655	329	0	86	8.1	ND	ND	ND

APPENDIX E

(continued)

Location	Aquifer	Cr	F	Pb	Hg	NO_3-N	Se	Ag	U	Ra-226[d]	Gross Alpha[d]	Gross Beta[d]	TDS
15/89-33 cc	North Park	ND	0.18	ND	ND	0.09	ND	ND	0.005	0.32±0.16	1±1	6±2	246
23/96-25 bba	Wasatch(?)	ND	5.2	ND	ND	ND	0.01	ND	0.002	1.33±0.3	0±4	5±6	1088
15/99-12 bc	Laney	ND	0.15	ND	ND	0.14	ND	ND	0.004	0±0.1	3±1	4±2	496
12/90-11 ad	Mesaverde	ND	0.68	ND	ND	0.09	ND	ND	0.005	0.09±0.12	1±1	5±3	602
20/101-27 ca	Mesaverde	ND	0.54	0.16	ND	1.97	0.01	0.02	0.034	0.38±0.16	0±16	16±7	6378
13/87-15 da	Frontier	ND	0.16	0.07	ND	ND	ND	ND	0.005	0.23±0.16	0±1	4±3	534
21/87-9 bd	Madison	ND	0.34	ND	ND	0.79	ND	ND	0.009	0.32±0.18	11±2	14±3	514
21/87-10 bb	Cambrian	ND	0.73	ND	ND	ND	0.01	ND	0.027	1.5±0.3	13±5	36±8	1522

[a]All constituents in milligrams per liter, except as noted.

[b]pH given in standard units.

[c]ND indicates not detected. Pertinent detection limits are: As, 0.01; Ba, 0.05; Cd, 0.01; Cr, 0.05; Pb, 0.05; Hg, 0.001; NO_3-N, 0.01; Se, 0.01.

[d]Analyses of radioactive species in picocuries per liter.