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DEPARTMENT OF THE INTERIOR
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REGIONAL HYDROLOGY OF THE GREEN RIVER-MOAB AREA, NORTHWESTERN PARADOX BASIN, UTAH

By F. E. Rush, M. S. Whitfield, and I. M. Hart

Open-File Report 82-107

Prepared in cooperation with the

U.S. DEPARTMENT OF ENERGY

Denver, Colorado

December 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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[in pocket]

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METRIC CONVERSION FACTORS

Metric units in this report may be converted to inch-pound units by using the following conversion factors:

Multiply metric unit	By	To obtain inch-pound unit
millimeter (mm)	0.03937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square kilometer (km^2)	0.3861	square mile
cubic meter (m^3)	35.31	cubic foot
	264.2	gallon
	8.107×10^{-4}	acre-foot
liter per second (L/s)	15.86	gallon per minute
cubic meter per second (m^3/s)	35.31	cubic foot per second
	5,850	gallon per minute
meter per day (m/d)	3.281	foot per day
microgram per liter (μg/L)	[1] 1.0	part per billion
milligram per liter (mg/L)	[1] 1.0	part per million
degree Celsius (°C)	[°F = 1.8 temp °C+32]	degree Fahrenheit

[1] For concentrations less than 5,000 milligrams per liter.

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ABSTRACT

The Green River-Moab area encompasses about 7,800 square kilometers or about 25 percent of the Paradox basin. The entire Paradox basin is a part of the Colorado Plateaus that is underlain by a thick sequence of evaporite (salt) beds of Pennsylvanian age. The rock units that underlie the area have been grouped into hydrogeologic units based on their water-transmitting ability. Confining beds consist of evaporite beds of mostly salt, and overlying and underlying thick sequences of rocks with minimal permeability; above and below these confining beds are aquifers. The upper Mesozoic sandstone aquifer, probably is the most permeable hydrogeologic unit of the area and is the subject of this investigation. The principal component of ground-water outflow from this aquifer probably is subsurface flow to regional streams (the Green and Colorado Rivers) and is about 100 million cubic meters per year. All other components of outflow are relatively small. The average annual recharge to the aquifer is about 130 million cubic meters, of which about 20 million cubic meters is from local precipitation. For the lower aquifer, all recharge and discharge probably is by subsurface flow and was not estimated.

The aquifers are generally isolated from the evaporite beds by the bounding confining beds; as a result, most ground water has little if any contact with the evaporites. Brines are present in the confining beds, but solution of beds of salt probably is very slow in most parts of the area. No brine discharges have been identified.

INTRODUCTION

The U.S. Geological Survey, in cooperation with the U.S. Department of Energy, has been investigating potential areas for underground isolation of high-level radioactive wastes generated in the various processes comprising the nuclear cycle. The investigation includes geological, geophysical, and hydrological studies to locate suitable underground environments for waste storage, and to develop new techniques for site exploration and evaluation. This reconnaissance study was part of the investigation, and addressed general hydrology of the northwestern part of the Paradox basin of Utah and Colorado. The Paradox basin was chosen for exploration because the salt beds of the basin were believed to have favorable physical and chemical properties as a storage environment.

The purpose of this report is to describe hydrologic flow systems of the area. Interpretations are based principally on existing data; however, onsite inventories and measurements were made (during 1977 and 1978) where additional information readily could be obtained.

Location and Extent of the Area

The area described in this report, shown in figures 1 and 2, is about 140 km long in a northerly direction and encompasses about 7,800 km^2 or about 25 percent of the Paradox basin. The Paradox basin is nearly evenly divided into two parts by the boundary between southeastern Utah and southwestern Colorado; the area described in this report is entirely in Utah. The largest community, Green River (fig. 2), is in the northwestern part. Moab, just beyond the southeastern boundary of the study area, is the largest town in the northern part of the Paradox basin.

Previous Work

One of the earliest hydrologic studies that included the Green River-Moab area (pl. 1) was a hydrologic reconnaissance of the Green River by Thomas (1952). A few years later, a report describing the drilling and testing of a water well at Arches National Park was made by Price (1959). Water resources of the Upper Colorado River Basin, which includes the Green River-Moab area, is described in two reports (Iorns and others, 1965; Price and Arnow, 1974). Feltis (1966) presents hydrologic data for about 50 wells for the Green River-Moab area, with interpretations of bedrock hydrology. A report on the Paradox basin by Hanshaw and Hill (1969) includes potentiometric maps and hydrologic interpretations for five aquifers ranging in age from Mississippian to Permian; chemical analyses of water from Mississippian, Pennsylvanian, and Permian strata are also included. An inventory of springs of the area was made by Mundorff (1971) and Sumsion and Bolke (1972). An adjoining area, Spanish Valley, was the subject of a water-resources study by Sumsion (1971). The occurrence of ground water in the area was described by Huntoon (1979).

Reports published as part of the general program to provide geologic and hydrologic information for determining the suitability of salt deposits for waste storage include those by Hite and Lohman (1973), Gard (1976), Hite (1977), Rush and others (1980), Thackston and others (1981), and Wollitz and others (1982). The first three reports describe geology of salt anticlinal areas and contain references to most of the geologic interpretations published for the Paradox basin. A recently completed report by Hood and Danielson (1979) describes the hydrology of the Dirty Devil River basin (fig. 2), southwest of and adjoining the area described in this report.

Numbering System of Hydrologic Sites

Location numbers for hydrologic sites in this report are based on the rectangular subdivision of the public lands, referenced to the Salt Lake base

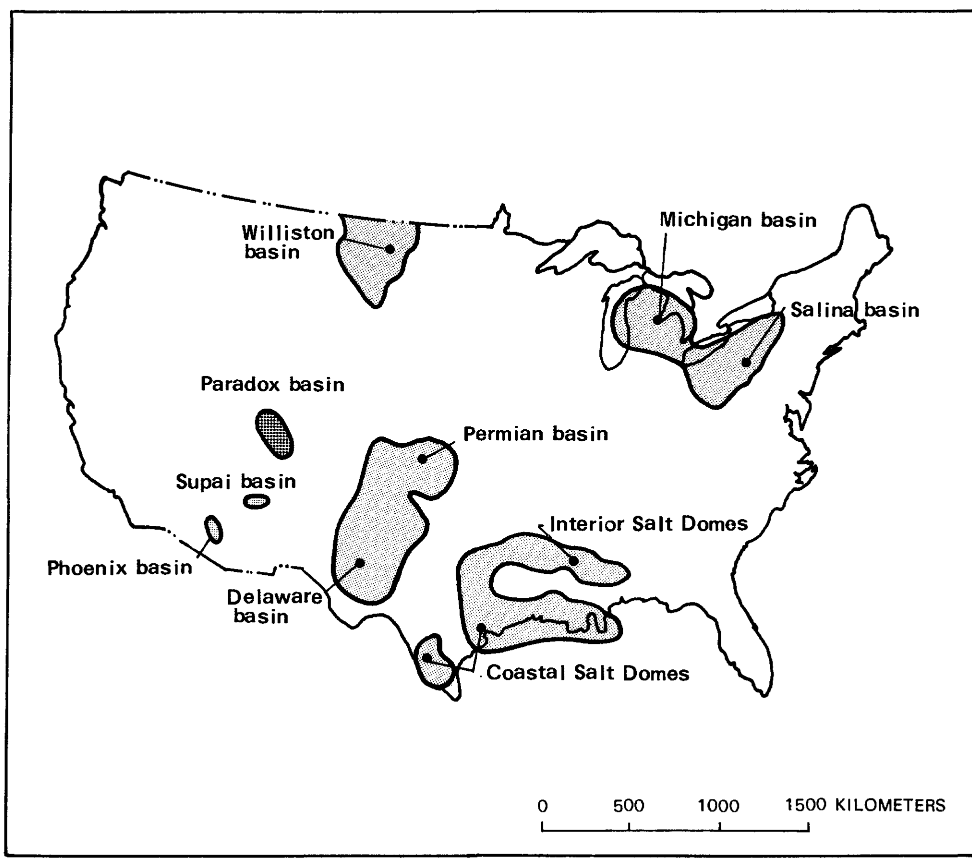


Figure 1.--Location of the Paradox basin and other areas underlain by rock salt in the conterminous United States.

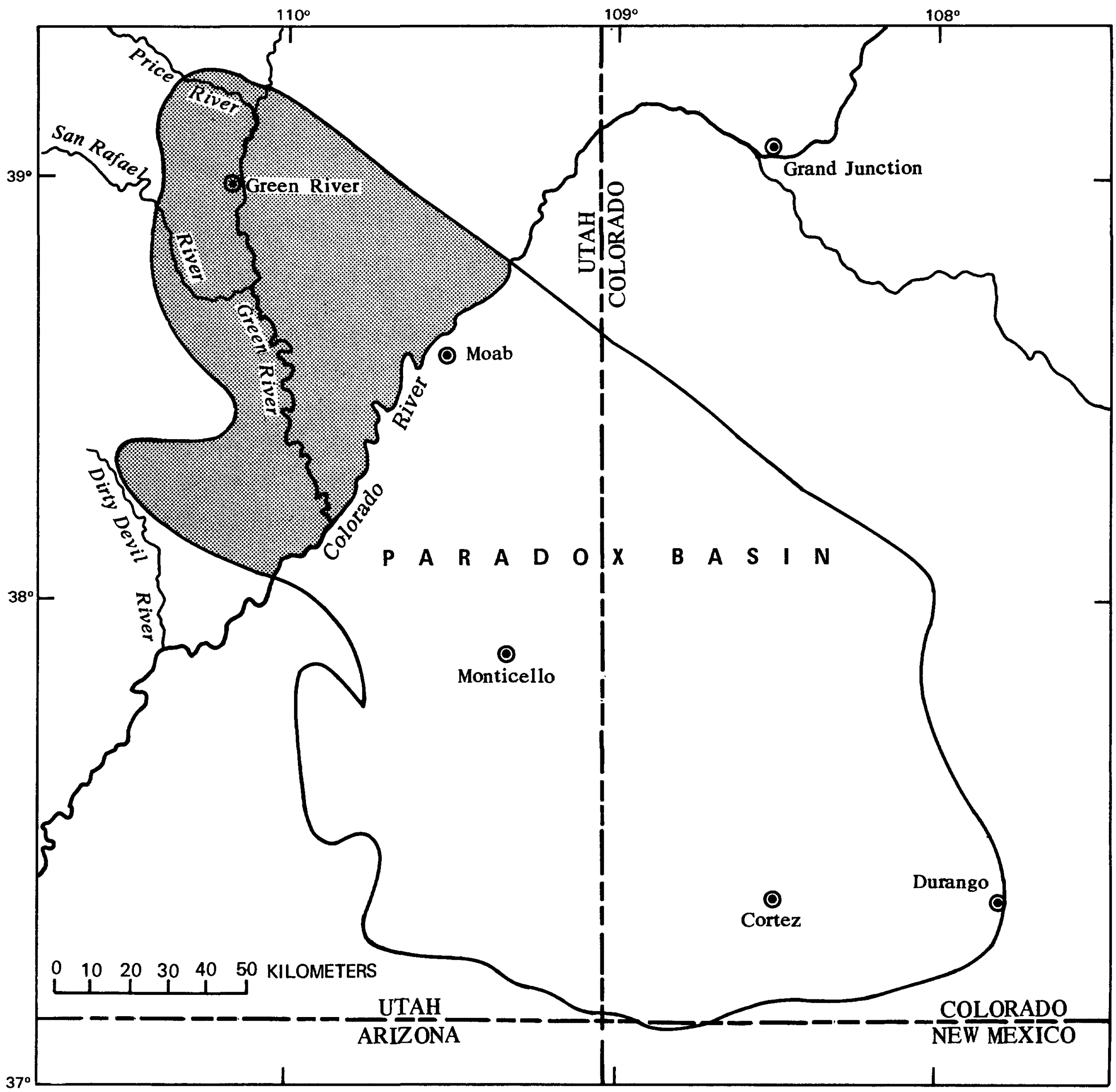


Figure 2.--Location of the Green River-Moab area in the Paradox basin of southeastern Utah and southwestern Colorado.

line and principal meridian. The location number consists of three units: The first is the township south of the base line; the second unit, separated from the first by a slant, is the range east of the principal meridian; the third unit, separated from the second by a dash, designates the section number. The section number is followed by as many as three letters that indicate successive quadrant divisions of the section to 160, 40, and 10 acres. The letters a, b, c, and d designate the northeast, northwest, southwest, and southeast quadrants, respectively. For example, the well with location number 21/23-10acd is in the SE¼ SW¼ NE¼ sec. 10, T. 21 S., R. 23 E., Salt Lake base line and principal meridian. If the location of a hydrologic site is not accurately known, only that part of the location number is given that represents the ability to determine the location of the site. Hydrologic sites shown on plate 2 are identified only by township, range, and section, unless the letters are needed to distinguish among sites.

HYDROLOGIC ENVIRONMENT

Physiography and Drainage

The Paradox basin is part of the Colorado Plateaus, as defined by Fenneman (1946). The basin is in the Canyonlands section, characterized by young-to-mature plateaus and large topographic relief. According to Hite and Lohman (1973, p. 4) the Paradox basin (fig. 1) is not a definable physiographic feature, but is defined as the area of the Colorado Plateaus that is underlain by a sequence of Pennsylvanian evaporites, mostly halite (salt) beds. Other areas underlain by salt in the conterminous United States are shown in figure 1.

Two large, regional streams, the Green and Colorado Rivers, originate beyond the boundaries of the report area to the north and northeast, traverse the area in a southerly direction (fig. 2), and flow from the area southwestward. The Green River has two generally perennial tributaries within the report area, the Price and San Rafael Rivers, that enter from the northwest (fig. 2). A few drainages have short segments with minor perennial flow. All other streamflow in the area is short-term response to snowmelt and infrequent storm runoff.

Rock units underlying the plateaus in the report area dip gently to the northwest. Near the town of Green River, land-surface altitude is about 1,300 m above sea level. Southeastward toward the Colorado River the plateau rises to an altitude of about 1,900 m. Another higher plateau is present north of the report area, the East Tavaputs Plateau. Its eroded south flank forms the Book and Roan Cliffs (pl. 1). These cliffs rise as high as 2,200 m at the north boundary of the report area, the maximum land-surface altitude in the report area, and to 2,900 m a few kilometers farther north. The Book and Roan Cliffs have a maximum topographic relief of about 1,400 m compared to the nearby areas to the south.

The Green River cuts increasingly deeper into the terrain and rock-unit sequence as it flows southward across the plateau of the report area. At the town of Green River (pl. 1) it flows virtually on the plateau top; farther south, however, 15 km northwest of its confluence with the Colorado River, maximum canyon depth reaches 700 m. Along the Colorado River throughout the report area, the topographic relief is as much as 600 m. The lowest point in the report area is along the Colorado River at the southwestern boundary of the area, an approximate altitude of 1,120 m.

Average annual discharge for streams in the area, based on U.S. Geological Survey measurements, is shown in figure 3. The Green and Colorado Rivers have 98 percent of the gaged flow in the report area. Hydrographs of the principal streams of the area are shown in figure 4; the data base also is from U.S. Geological Survey sources. May and June are the months of generally maximum flow, resulting from spring snow melt, mostly upstream from the report area. During most of the remainder of the year, the streams have much less flow; during these times the streams are maintained mostly by ground-water contributions throughout their drainage basins.

A summary of selected characteristics of the Green and Colorado Rivers is presented in table 1. These data support discussions later in the report.

Hydrogeologic Units and Structural Features

The rock units that underlie the Green River-Moab area are summarized in table 2 and have been grouped into hydrogeologic units and ground-water systems according to their approximate relative water-transmitting ability, and their general lithology. Usually, granite, siltstone, mudstone, and shale transmit little water. Sandstone, conglomerate, and carbonate rocks have a range in hydraulic conductivities; however, generally, they are more transmissive than the former group. Sandstone and conglomerate may have both primary and secondary permeability; carbonate rocks, have mostly secondary permeability. Salt is plastic, flows (Hite and Lohman, 1973, p. 28-33) and presumably self-seals. Based on information from Cater (1970, p. 63 and 64), as little as 150 m of overburden is sufficient to start plastic deformation of halite. As a result, it likely transmits little, if any, ground water. If these salt deposits are typical, then salt solution takes place only along the upper surface (Hite and Lohman, 1973, p. 38). The best water-transmitting and yielding materials in the study area are the saturated alluvial deposits; however, few alluvial deposits are saturated.

Within the rock sequence (table 2), two aquifers have been defined: (1) The lower Paleozoic aquifer and (2) the Mesozoic sandstone aquifer. The lower Paleozoic aquifer includes Mississippian dolomites that generally are porous and permeable (Hanshaw and Hill, 1969, p. 271; and Hood and Danielson, 1979, p. 14). According to Neff and Brown (1958, p. 108), some of the Devonian rocks also are porous.

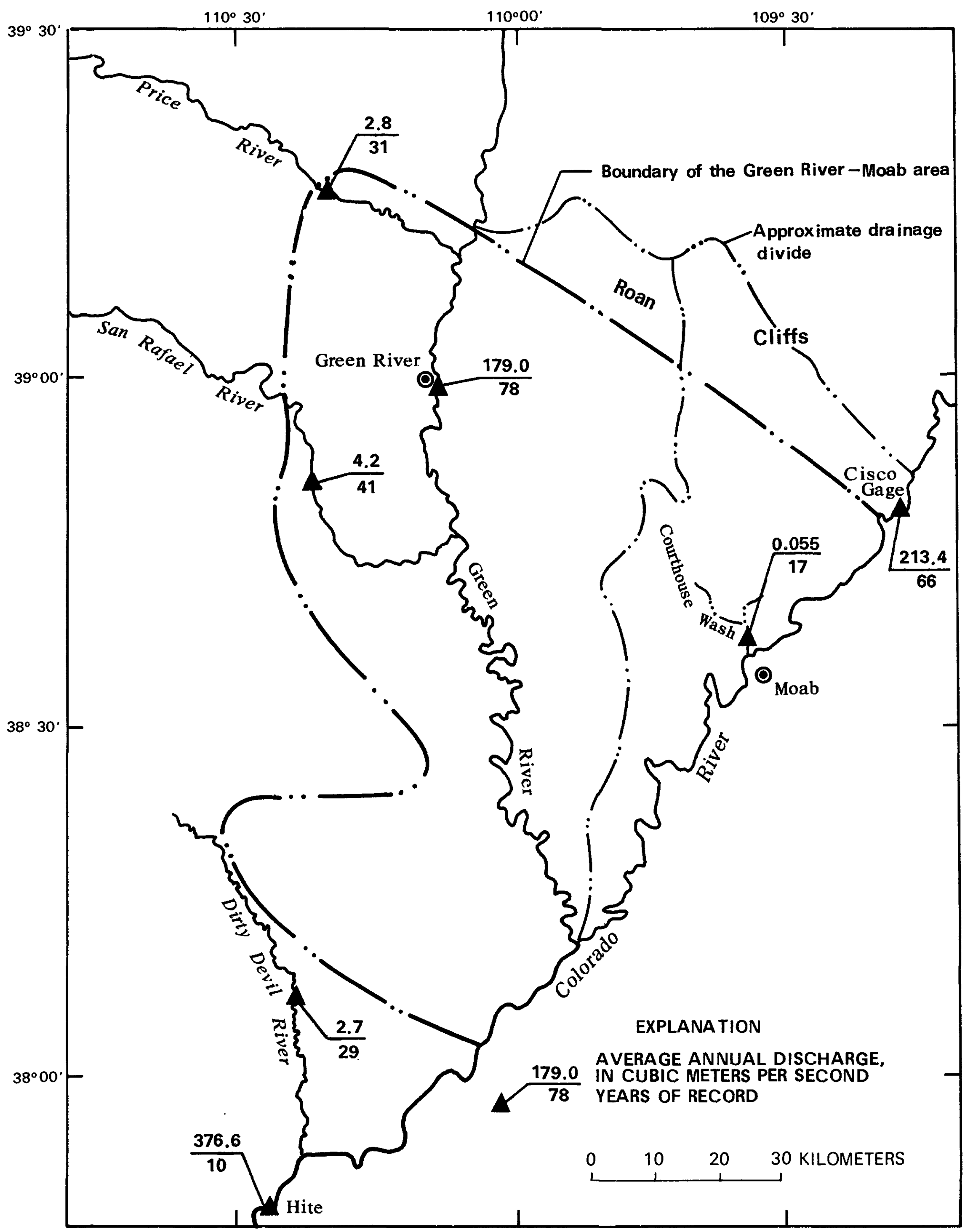


Figure 3.--Location and average annual discharges at U.S. Geological Survey streamflow-gaging stations.

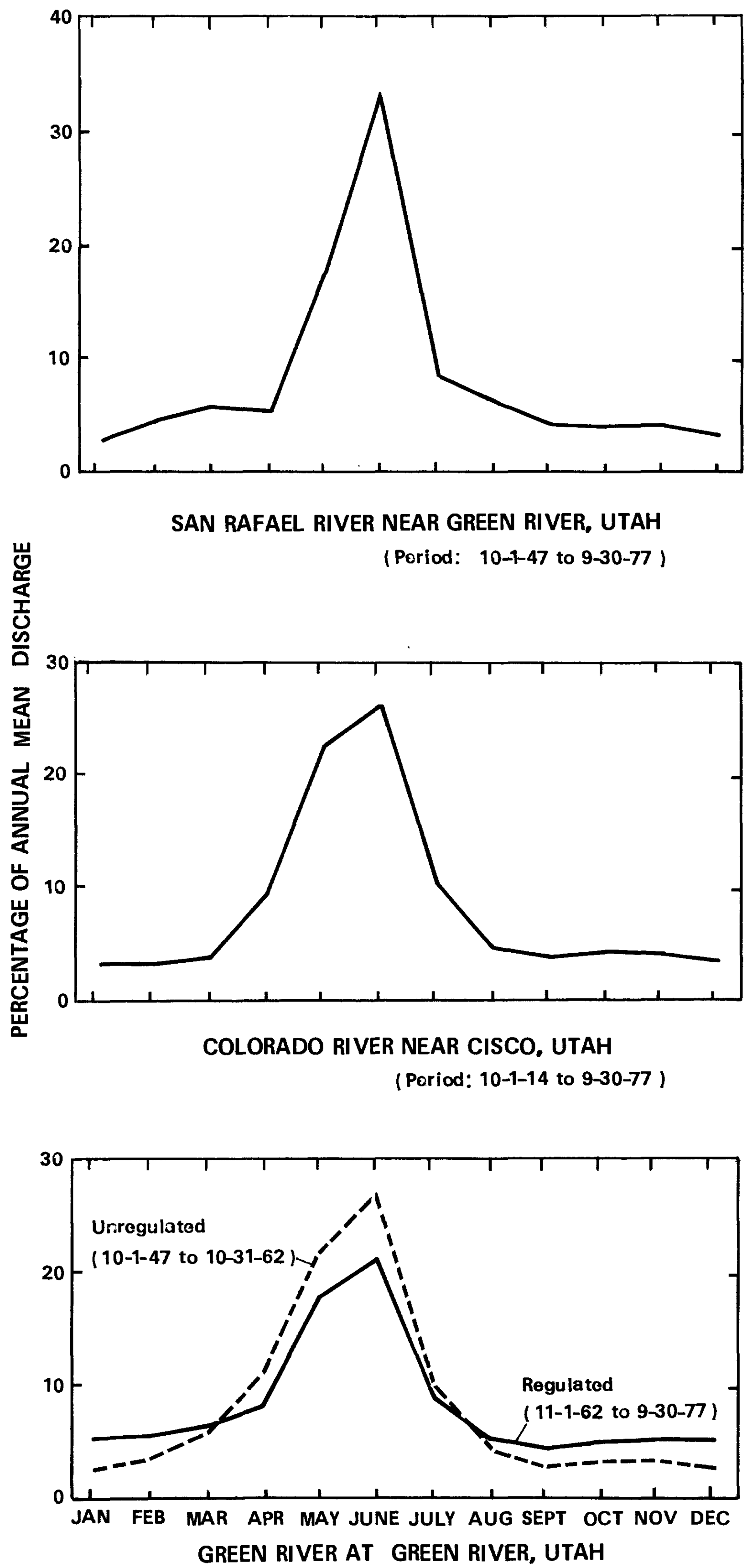


Figure 4.--Monthly distribution of average annual flow in the San Rafael, Colorado, and Green Rivers.

Table 1.--*Summary of some of the characteristics of the Green and Colorado Rivers in the vicinity of the Green River-Moab area*

[River mile--for Green River, distance upstream from mouth; for Colorado River, distance above Lees Ferry, Ariz.; altitude range--altitude of gaging station on river bank; channel--data computed from river-profile sheets of U.S. Geological Survey; estimated area of flood plain--determined mostly from topographic and river-profile maps; approximate aquifer distance--straight-line distance for river segment]

River segment between stream-flow gages[1]	River mile	Altitude range (meters)	Channel: Length (kilometers)	Channel: Average width (meters)	Channel: Water-surface area (square kilometers)	Estimated area of flood plain (square kilometers)	Approximate aquifer distance (kilometers)	Remarks
GREEN RIVER								
Rattlesnake Canyon - Green River, Utah---	139-117	1,268-1,231	[2] 36	[2] 150	[2] 5.4	[2] 24	27	Price River mouth at mile 136 on Green River. Green River enters Paradox basin at Rattlesnake Canyon.
Green River, Utah - river mouth---------	117-0	1,231-1,175	[2] 189	[2] 140	[2] 2.6	[2] 2.9	95	San Rafael River mouth at mile 95 on Green River.
COLORADO RIVER								
Cisco gage - Green River mouth---------	313-216	1,270-1,175	156	130±	20±	3.8±	90	Colorado River enters Paradox basin 3 kilometers southwest of Cisco gage.
Green River mouth - Hite[3]---------------	216-162	1,175-1,049	87	75	6.5	.7	[4] 70	Dirty Devil River mouth at mile 170 on Colorado River.
Hite - Lees Ferry[3]----	162-0	1,049- 947	261	150	39	6.2	150	Escalante and San Juan Rivers at miles 88 and 78, respectively, on Colorado River.

[1]No gage on the Green River at Rattlesnake Canyon.

[2]Based on data from Thomas (1952, p. 24-28).

[3]Data for pre-dam construction conditions.

[4]Boundary of Paradox basin is 22 kilometers southwest of the mouth of the Green River.

The Mesozoic sandstone aquifer consists of a thick sequence of 11 northwesterly-dipping rock units that are mostly sandstones (table 2). In most parts of the report area, much of the volume of this sequence is unsaturated; however, perched water bodies are common and yield small supplies to wells and springs. The most permeable units, in ascending order, are: Wingate and Navajo Sandstones; Slick Rock and Moab Members of the Entrada Sandstone; Salt Wash Member of the Morrison Formation; Burro Canyon Formation; and Dakota Sandstone (Hite and Lohman, 1973, p. 9; Huntoon, 1977, p. 5; and Hood and Danielson, 1979, p. 14). The springs in the Wingate and Navajo Sandstones commonly occur near their bases, which overlie the much less permeable Chinle and Kayenta Formations, respectively.

The White Rim Sandstone Member of the Cutler Formation, the most permeable rock unit in the Mesozoic and upper Paleozoic confining beds, crops out near the mouth of the Green River and has an almost continuous series of small springs and seeps near its lower contact, controlled by laminae bedding and jointing (Huntoon, 1977, p. 5-7). The general intergranular hydraulic conductivity of the White Rim Sandstone Member probably is quite small, based on its lithology and cementation.

Hydrogeologic units immediately above and below the evaporite-confining beds and the formations overlying the Dakota Sandstone generally transmit little water and are considered leaky confining beds. The evaporites and interbeds (table 2) probably have only minor interconnected pores and fractures and therefore are nearly impermeable, do not yield appreciable quantities of water to wells, and thus constitute a boundary between the ground-water flow systems. These general conclusions are based on data from 396 drill-stem tests presented in table 3 and hydraulic-testing results by Rush and others (1980) and Wollitz and others (1982). Throughout most of the area, the evaporites appear to have undergone only minor, if any, solution. This condition probably is due to the common presence of the almost impermeable units in the underlying and overlying confining beds. Exceptions occur along salt anticlines, such as beneath Salt and Cache Valleys (pl. 1), where the overlying confining beds were not deposited; as a result, extensive salt solution has occurred along the top surface of the salt (Hite and Lohman, 1973, p. 35).

Formation-fluid recovery rates observed during drill-stem and similar tests of petroleum-exploration wells are related in part to the permeability of tested zones. A summary of 396 tests is presented in table 3 and is based on data in table 15, which is in the Supplemental Data section in the back of the report. The mean fluid-recovery rates indicate that the Mesozoic sandstone aquifer generally has much greater permeability than evaporites of the Paradox Member of the Hermosa Formation and the overlying and underlying confining beds. The lower Paleozoic aquifer has a relatively large mean fluid recovery rate, but not as large as the Mesozoic sandstone aquifer. These mean fluid-recovery rates need to be considered only as general relative indexes of permeability, having little other quantitative relevance.

Outcrop distribution of the hydrogeologic units is shown on plate 1. Only the upper four units (of the seven units described in table 2) crop out. Near the southeastern boundary of the area, the Colorado River has almost

Table 3.--*Summary of formation-fluid recovery rate during drill-stem tests*

[Based on data in table 15; rock unit--only units having tests are listed; fluid recovery rate--meters of formation fluid recovered in drill stem per hour of test per meter of tested-zone thickness; m--minor recovery rate]

Rock unit (from table 2)	Number of tests	Fluid-recovery rate (meters per hour per meter) Range	Mean	Hydrogeologic unit (from table 2)	Number of tests	Fluid-recovery rate (meters per hour per meter) Range	Mean
Mancos Shale	2	-----	0	Tertiary and Cretaceous confining beds	2	-----	0
Dakota Sandstone	7	0-112	19				
Morrison Formation	8	0-911	224				
Summerville Formation	2	0-m	m	Mesozoic sandstone aquifer	26	0-911	77
Entrada Sandstone	4	0-41	18				
Navajo Sandstone	3	m-12	4				
Wingate Sandstone	2	m-2	1				
Chinle Formation	3	0-1	m				
Moenkopi Formation	41	0-27	2				
Cutler Formation	20	0-120	19	Mesozoic and upper Paleozoic confining beds	123	0-120	[1] 6
Rico Formation	6	0-46	11				
Hermosa Formation (undivided)[2]	53	0-116	6				
Paradox Member[2]	113	0-205	5	Evaporite confining beds	6	0-205	[3] 5
Lower Member (equivalent to "Pinkerton Trail Formation of local usage)	2	0-27	14				
Molas Formation	4	0-3	m	Upper Paleozoic confining beds	6	0-27	[4] 5
Leadville Limestone	114	0-243	28				
Ouray Limestone	2	0-26	13				
Elbert Formation (undivided)	6	0-134	28	Lower Paleozoic aquifer	126	0-243	27
McCracken Sandstone Member	4	0-14	7				

[1]Eighty-six tests had minor or no formation fluid recovery.

[2]Some tests included the "Pinkerton Trail Formation."

[3]Ninty-seven tests had minor or no formation fluid recovery.

[4]Four tests had minor or no formation recovery.

eroded through the full thickness of the Mesozoic and upper Paleozoic confining beds, leaving only a small thickness of confining beds between the river bed and the evaporites. The remaining units are present only in the subsurface, but they have been identified by deep-well drilling. Also shown on plate 1 are the principal mapped faults (Hintze and Stokes, 1964; Andrews and Hunt, 1956). Faults and fractures associated with faulting and folding locally may be routes of lateral and vertical flow within each ground-water system; they may control the direction and rates of flow; and they may compartmentalize parts of ground-water systems. For example, Huntoon (1977, p. 5-8) reports that pressurized artesian brines were penetrated by holes drilled in the upper member of the Hermosa Formation (table 2), where this member was cut by a series of localized faults that form a graben complex along the axis of the Cane (Creek) Springs Anticline near Potash, Utah (26/20 on pl. 1).

In most areas, the upper and lower ground-water systems are hydraulically isolated from each other by evaporite confining beds (table 2); as a result, the two systems generally function independently. A possible exception to this common condition may occur where salt evaporite beds are not continuous, due to faulting or removal by solution or plastic flow. Along some faults the lower ground-water system may be in contact with the upper ground-water system, due to stratigraphic offset. The result would be a potential for inter-system flow; the direction of vertical flow would be controlled by hydraulic-head differences between the upper and lower ground-water systems, as shown in figure 5. Generalized areas where the salt probably is absent due to plastic flow are shown on plate 1 (R. J. Hite, U.S. Geological Survey, Denver, written commun., 1979) and illustrated in figure 6; however, no data support interconnected flow in these areas and, possibly, it does not exist. However, if interconnected flow is occurring, direction of leakage would be upward to the upper system.

If there is no interconnected flow, then all ground-water recharge from and discharge to the biosphere within the study area is limited to the upper ground-water system. The lower system then would be in equilibrium, with subsurface inflow equal to subsurface outflow.

Salt anticlines in the study area functioning as barriers to ground-water flow in the upper ground-water system are illustrated in figure 6. At the Salt Valley and Cane Springs anticlines (24/21 (Salt Valley) and 25/20 (Cane Springs) on plate 2) flow probably is directed southeastward by the trends of the anticlines. Locally, in caprock and adjacent to anticlinal crests, flow directions may be modified by local conditions and may be complex (Wollitz and others, 1982, p. 60-62).

The values of transmissivity and hydraulic conductivity of hydrogeologic units generally are not known; however, their probable permeability ranking follows, based on lithologic interpretations and data in table 3:

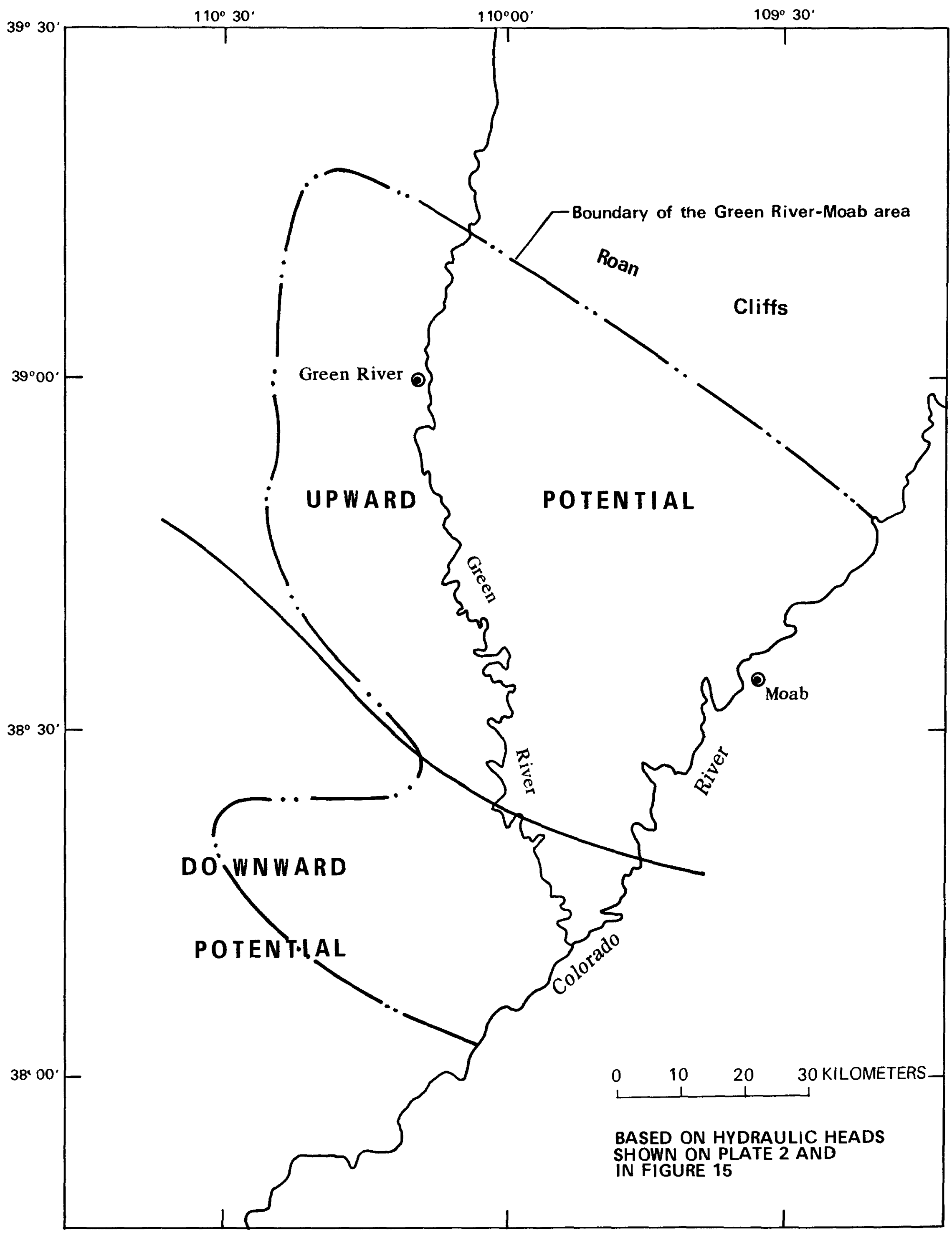


Figure 5.--Direction of potential leakage between the upper and lower ground-water systems.

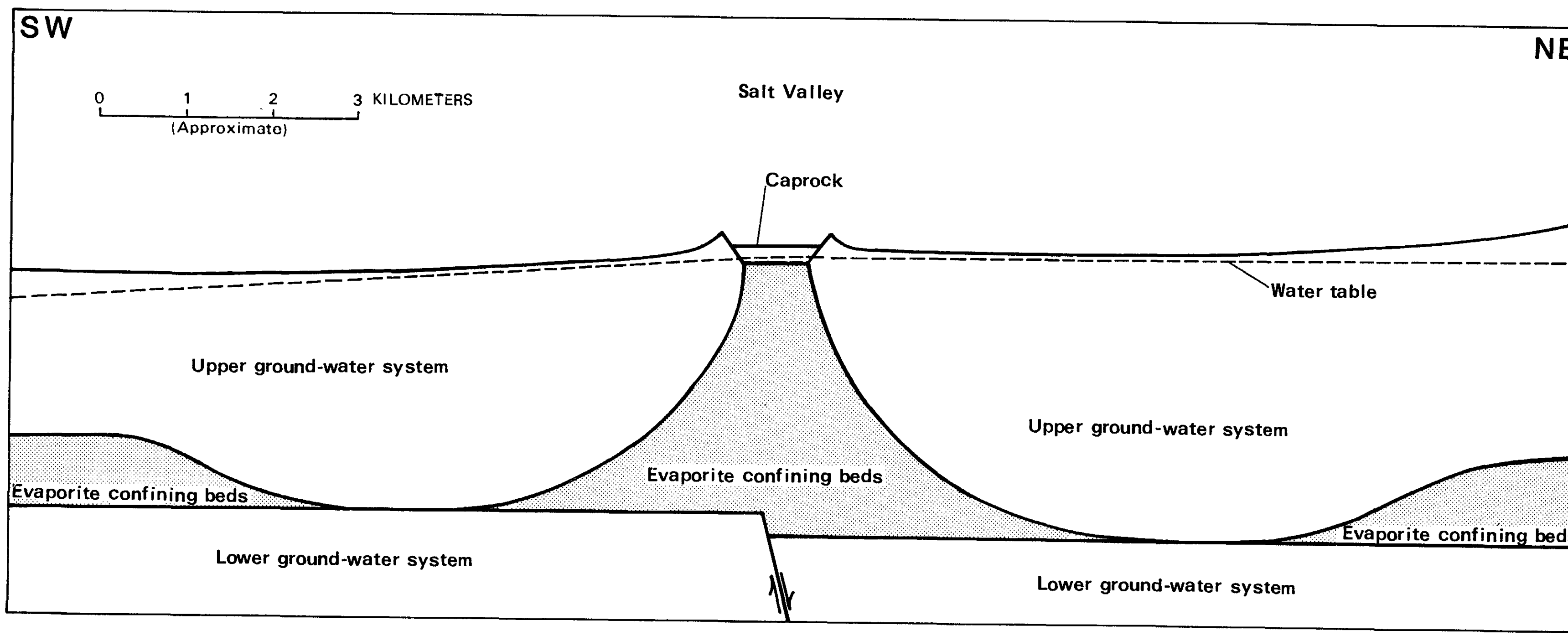


Figure 6.--Schematic cross-section of the Salt Valley area showing the relation of the ground-water systems to the evaporite confining beds. (Hydrogeologic units are not to scale; location of section is not specific.)

Rank	Unit
Most permeable ↑	Mesozoic sandstone aquifer. Lower Paleozoic aquifer.
	Tertiary and Cretaceous confining beds. Mesozoic and upper Paleozoic confining beds. Lower Paleozoic and Precambrian confining beds. Upper Paleozoic confining beds.
↓ Least permeable	Evaporite confining beds.

North of Moab, at 23/23-5 in Salt Valley (pl. 1), caprock overlies the evaporite deposits. This residual nonsalt interbed material that remains above the salt sequences of the Paradox Member upon solution of salt, has hydraulic conductivity values ranging from 9.3×10^{-5} to 2.06×10^{-1} m/d, based on a series of tests in nine wells (Rush and others, 1980; and Wollitz and others, 1982). This value is indicative of minimal ability to yield water to the well. Salt and interbeds tested had hydraulic conductivities less than 1×10^{-4} m/d (Rush and others, 1980, p. 32).

The data presented in figures 7 and 8 can be used as approximate indexes of relative permeability distribution in the lower (fig. 7) and upper (fig. 8) ground-water systems as defined in table 2. These maps show the generalized areal distribution of relative rates of fluid recovery during formation tests. The ratings shown have the following bases:

Rating	Meters of formation fluid recovered in drill stem per hour of test per meter of tested-zone thickness
Large------------	More than 50
Medium-----------	30-50
Small------------	Less than 30

The general northerly or northeasterly orientation of the distribution pattern shown in figure 7 may be related to solution zones of the dolomite phase that developed in the area following the deposition of Mississippian rocks (Neff and Brown, 1958). The pattern in figure 7 is based on 126 data values listed in table 15 (in the Supplemental Data section in the back of the report).

Areas of large relative permeability in the upper ground-water system (fig. 8) possibly are associated with fault zones shown on plate 1. More data are needed before a confident analysis of permeability distribution is possible. The pattern in figure 8 is based on 52 data values (table 15).

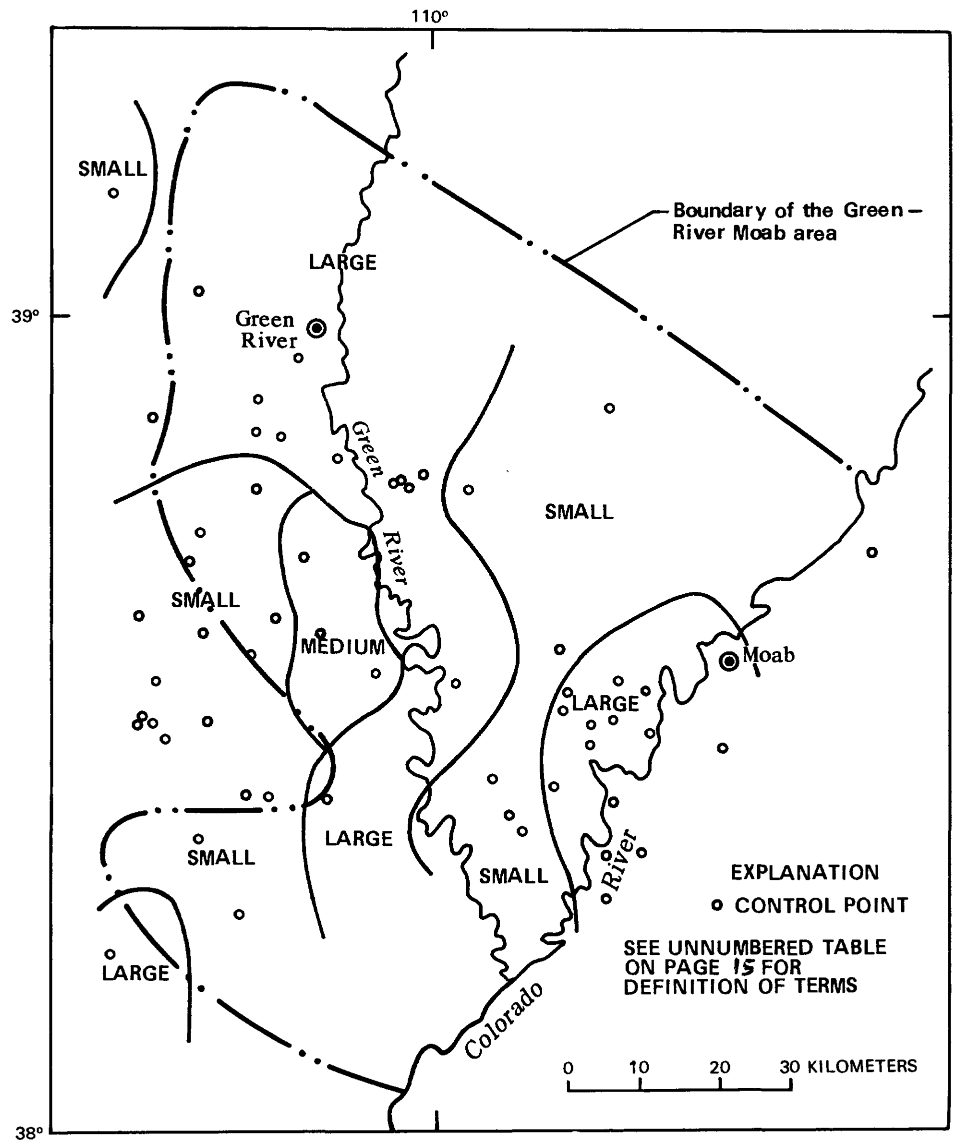


Figure 7.--Distribution of relative ability of the lower ground-water system to yield fluid during drill-stem tests.

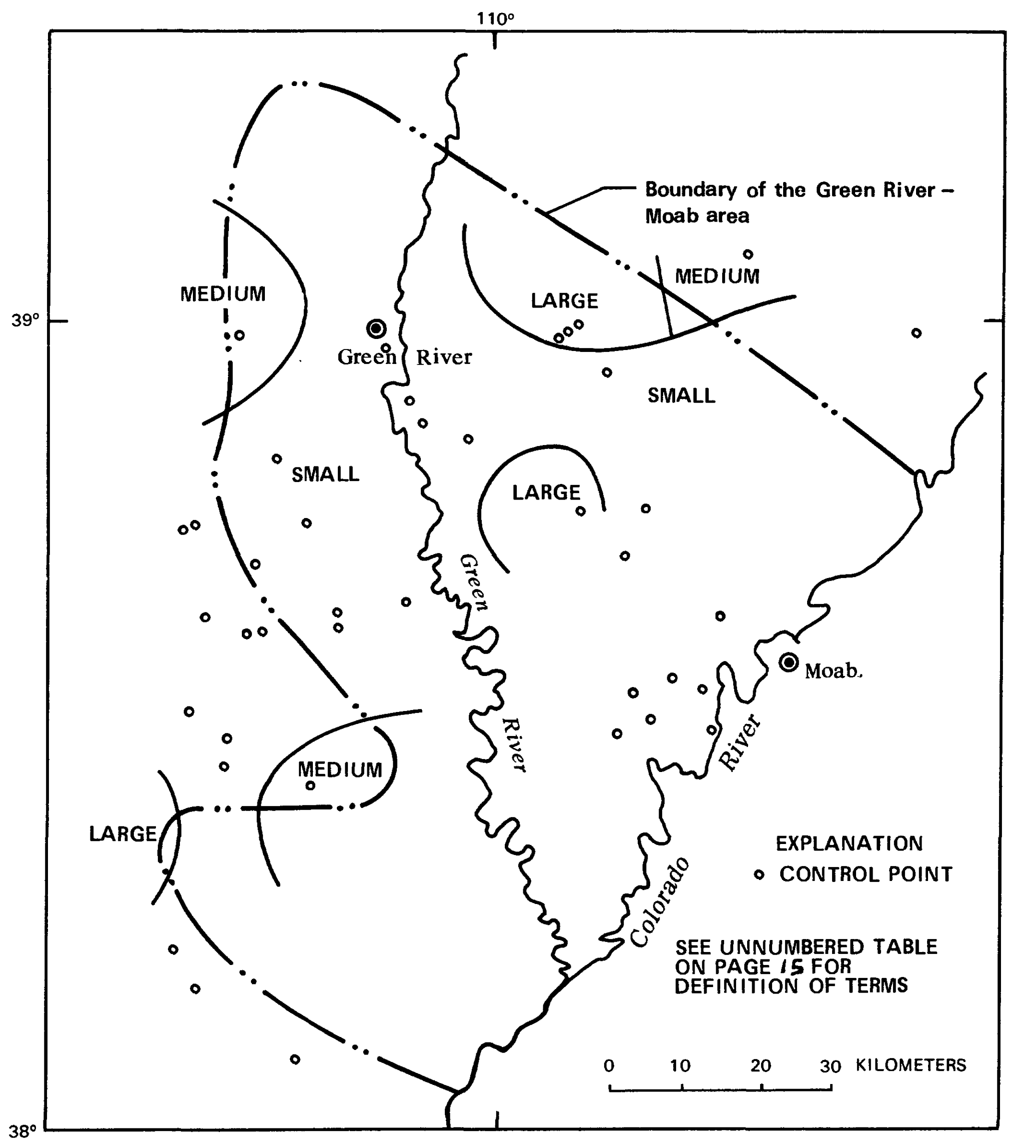


Figure 8.--Distribution of relative ability of the upper ground-water system to yield fluid during drill-stem tests.

The average specific yield (that is the approximate amount of water that a rock will yield by gravity) of sedimentary rocks and alluvium in the area has been estimated by Price and Arnow (1974, p. C10) to be about 0.2 to 0.7 percent. The evaporite confining beds, with almost no permeability and porosity, virtually have no specific yield. In general, the hydrogeologic units probably have the same relative ranking for specific yield as permeability (described earlier in this section).

Water Saturation

Water occurs in the rocks of the area under two conditions: (1) In the generally unsaturated part of the upper ground-water system that originates as recharge from local precipitation and is percolating downward toward the underlying zone of saturation; and (2) in the lower ground-water system and the saturated part of the upper ground-water system, whose principal component of flow is in a horizontal direction. The latter enters the saturated zones of the study area principally as subsurface inflow from beyond the boundaries of the area, and is part of large, regional flow systems.

Water in the unsaturated zone commonly percolates downward through several tens or hundreds of meters of rock before reaching the upper regional flow system. Part of the water is discharged from shallow perched ground-water bodies by phreatophytes (ground-water using plants), by springs, or by wells.

All pores and fractures below the altitude of the Green and Colorado Rivers are filled with ground water, except where reservoirs of oil and gas occur. The altitude of potentiometric surface gradually increases with distance away from the rivers, as shown on plate 2.

Depth to the saturated zone is greatest beneath plateau lands in the southern part of the area, where the local potentiometric surface is greater than 500 m below land surface. Farther north and away from the deep canyons, depths to the potentiometric surface are generally much less, about 200 to 300 m.

Development of water, oil, and gas probably has had no significant, recognizable effect on depths to water, hydraulic heads, or the amount of water in storage in the area. Ground-water flow systems appear to be functioning under nearly native conditions.

The saturated part of the upper ground-water system is unconfined in places and may be confined in other places; whereas the lower ground-water system probably is confined everywhere by the relatively impermeable overlying beds. Variations in confinement of the upper system are related to facies changes of lithologies and in distribution of rock fractures. Fractured, low-permeability rock is probably less effective as a confining bed.

Precipitation

The Green River-Moab area, according to Pyke (1972, fig. 3b), is in a transition-precipitation zone of multiple-monthly maxima, between: (1) An area to the south and southeast characterized by maximum precipitation during August; and (2) an area to the west and north characterized by maximum precipitation during April or May and secondary increases during August and during either October or November.

Precipitation for the Green River-Moab area was first measured and recorded at Moab during 1890. Abundant precipitation data that have been collected since are summarized in several tables and illustrations in this section of the report.

A summary of average annual precipitation at weather stations in and near the study area is presented in table 4. Location of the stations are shown in figure 9. Because some of the periods of record for precipitation are short in relation to the records at Green River, Thompson, and Moab, all station averages were adjusted to the longer-term mean at Green River (table 4). These values were then plotted on a graph (fig. 10) to determine the general relationship of precipitation to altitude in the area. As shown, precipitation generally increases with altitude.

Areal distribution of precipitation in the study area is shown in figure 9. Average annual precipitation on the mesas and flatlands ranges from about 150 to 250 mm. Average annual potential lake evaporation is estimated to be 1,000 to 1,100 mm (Kohler and others, 1959, plate 2), or about 5 times greater than precipitation; therefore, mesas and flatlands are arid to semiarid. In the higher areas of the Book and Roan Cliffs, precipitation is as much as 700 mm per year and the climate is subhumid to humid.

Monthly distribution of precipitation is shown in figure 11 for three weather stations in the report area. All the stations have the same general distribution pattern: (1) A dry period from November through July; and (2) a more moist period from August through October.

To evaluate the long-term hydrologic character of the area, onsite observations have to be put into a long-term perspective. Information included in figures 12 and 13 are presented here to show long-term trends. Recent precipitation conditions, 1942-77 (fig. 12), are similar to the period-of-record normal in the northern part of the area at Green River and Thompson. Dry conditions prevailed for the period at Moab; a series of moist and dry periods occurred prior to 1942. Long-term climatic trends, shown in figure 13, can be identified from interpretations of tree-ring chronologies (Fritts, 1965). Beginning at the start of the period of record, no long-term systematic change in precipitation has been determined for the study area. Recent short-term variations in precipitation (shown in figure 12) appear typical of the short-term cycles occurring since the year 1200.

Table 4.--*Average annual precipitation at weather stations in and adjacent to the study area*

[Based on data from National Weather Service; map number--this number is used to identify stations in figures 9 and 10; adjustment to long term--based on cumulative departure at Green River station for 1898-1977]

Map No.	Station name	Altitude above sea level (meters)	Period of record	Average annual precipitation (millimeters)	
				Average	Adjusted to long term
1	[1]Hill Creek No. 4	2,469	1946-76	347.0	361
2	[1]Hill Creek No. 5	2,743	1962-76	735.1	781
3	Green River	1,241	1898-1977	153.2	153
4	Thompson	1,570	1912-77	217.5	215
5	Cisco	1,320	1953-66	188.5	196
6	Dewey	1,256	1968-77	199.6	203
7	Hanksville	1,313	1920-77	128.3	123
8	Canyonlands-The Neck	1,798	1966-77	206.8	221
9	Moab	1,209	1890-1977	224.5	226
10	[1]LaSal Mountain Upper	2,865	1959-74	729.2	718
11	LaSal	2,185	1901-77	324.9	321
12	Canyonlands-The Needles	1,536	1966-77	204.7	219

[1]Precipitation-storage gage.

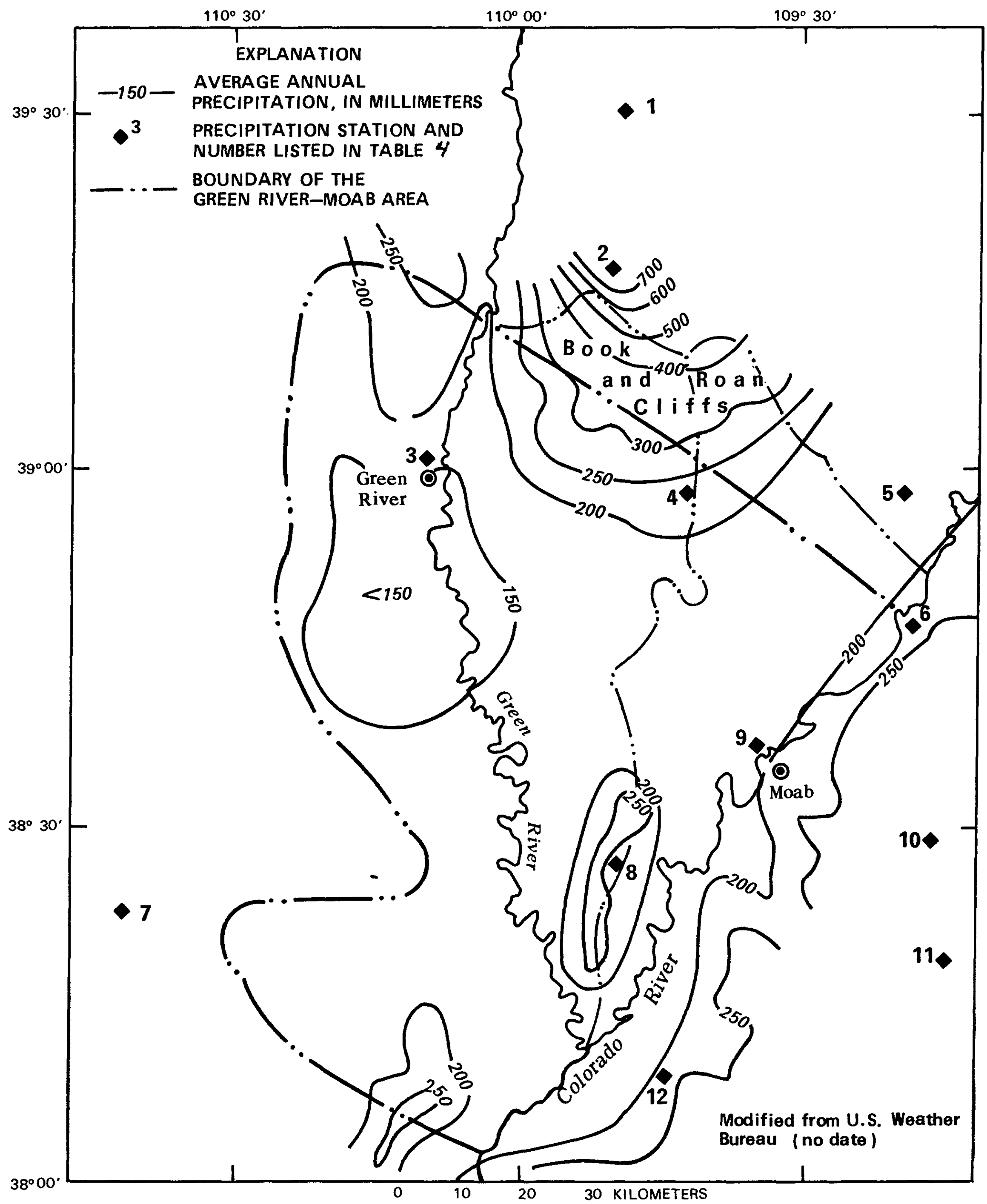


Figure 9.--Areal distribution of average annual precipitation and location of precipitation gages.

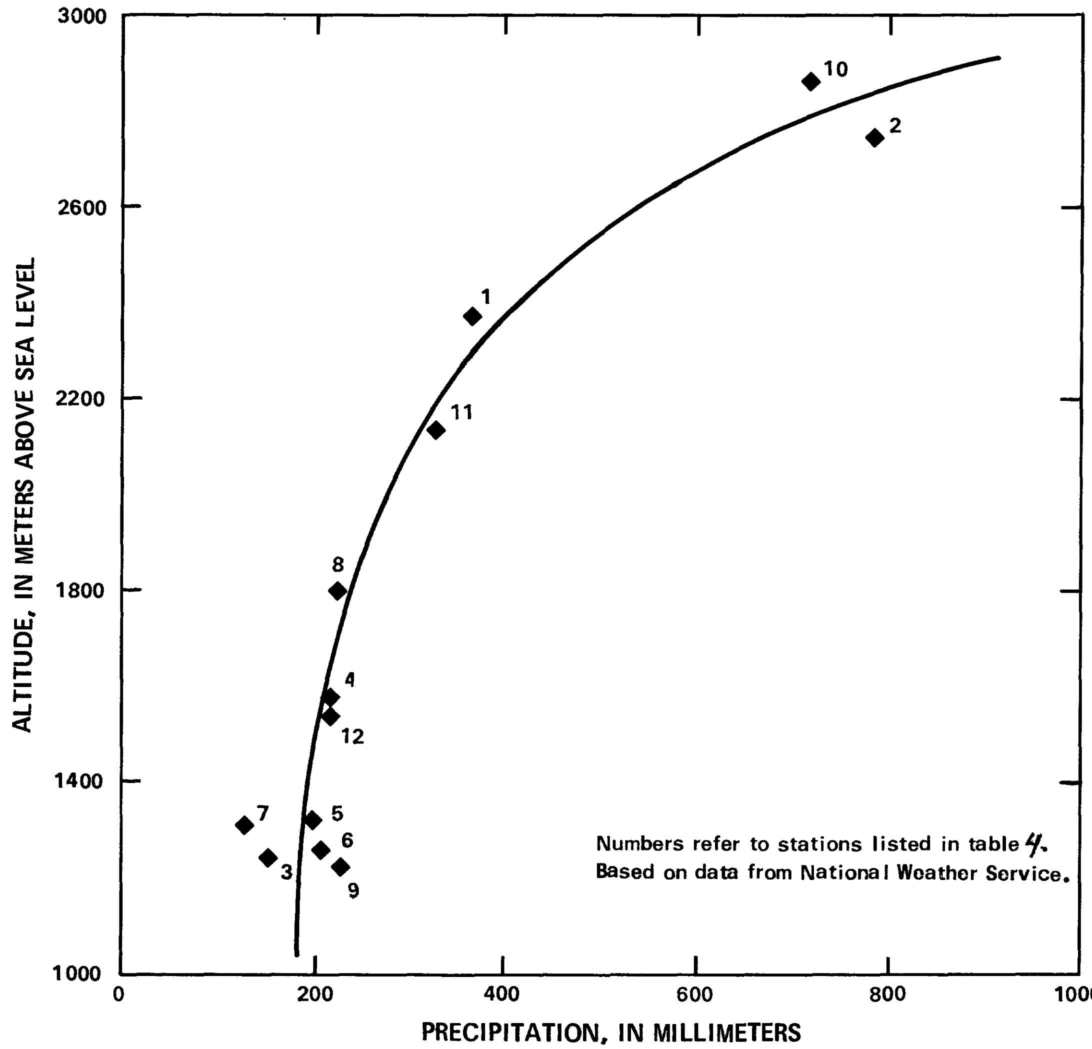


Figure 10.--General relation of precipitation to altitude.

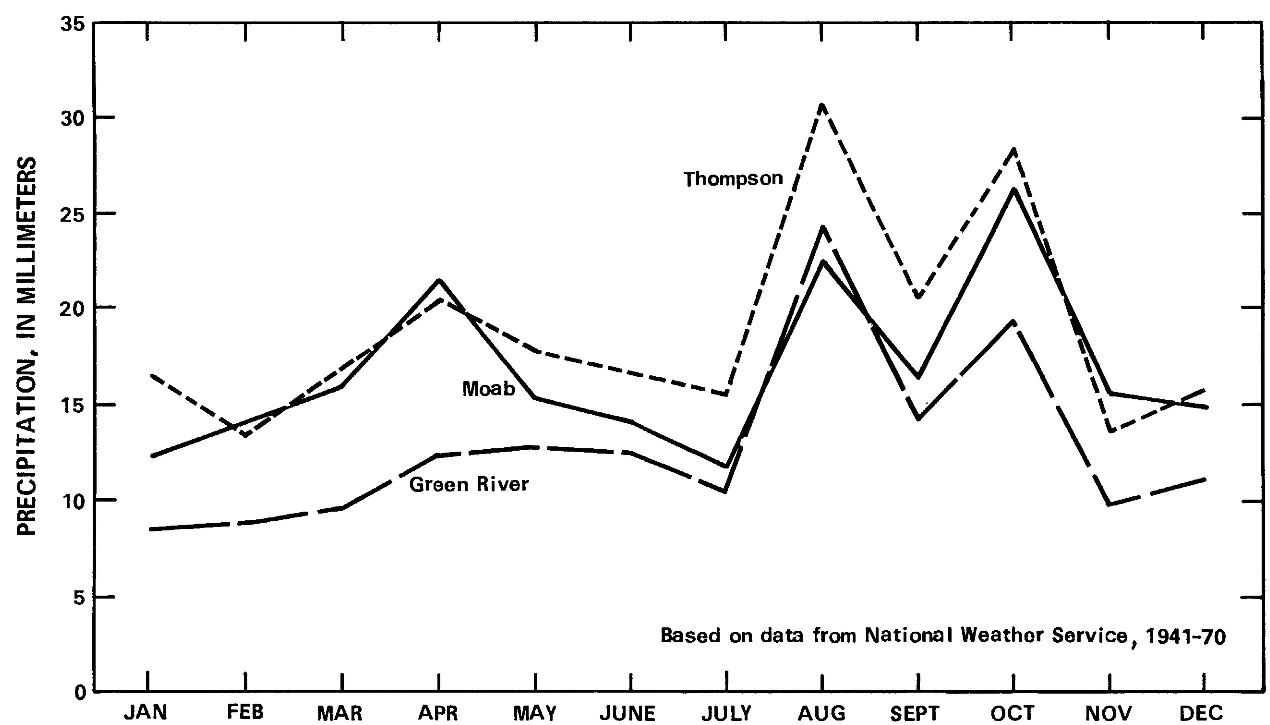


Figure 11.--Monthly distribution of average annual precipitation.

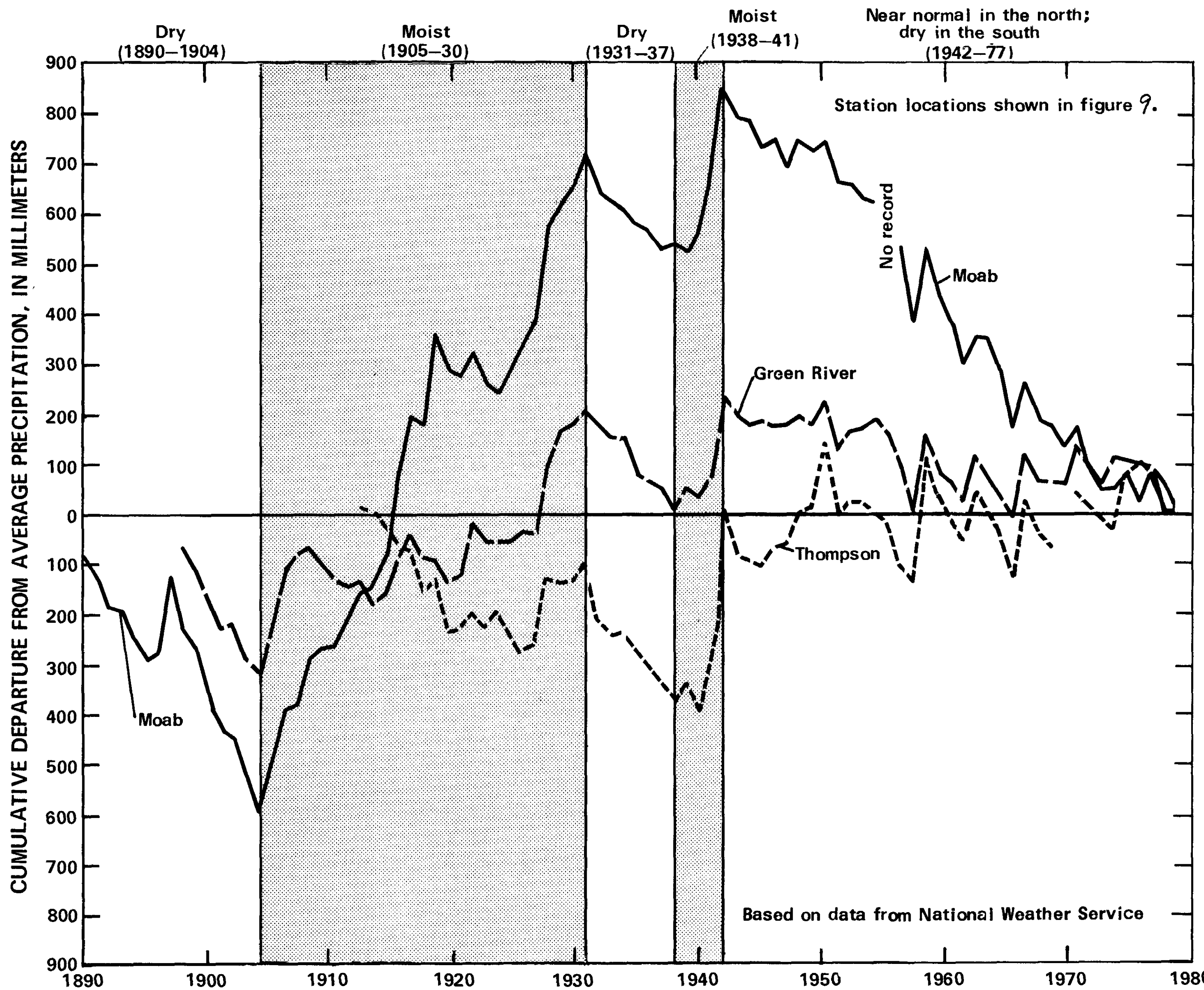
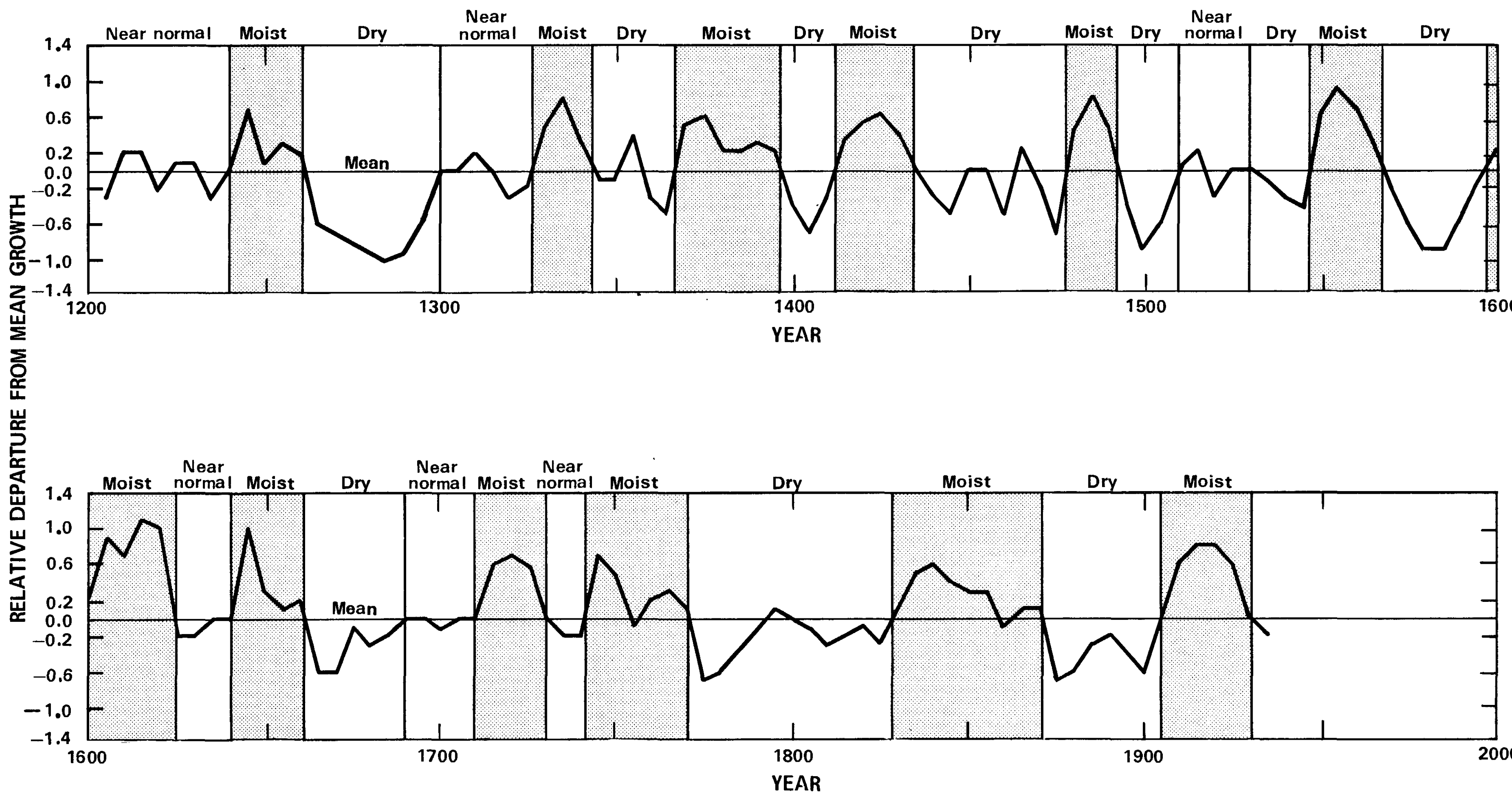


Figure 12.--Cumulative departure from average annual precipitation, based on measured precipitation at three stations.



Mean and standard deviation are based on the 270-year period 1651–1920.

Based on data from Fritts, 1965.

Figure 13.--Long-term precipitation variation in the Green River-Moab area, based on tree-ring chronologies.

In conclusion: (1) The recent 40-year normal precipitation approximates the average for the past 780 years; (2) recent cycles are probably a continuation of the general trend with no long-term increases or decreases in overall climatic dryness; and (3) more moist and more dry periods, similar to those recorded in the past, will probably occur in the future.

The estimated volume of average annual precipitation (table 5) is computed to be about 1.6 billion m^3 or equal to an average of 0.2 m throughout the study area. An additional 0.16 billion m^3 is estimated to fall in that part of the Book and Roan Cliffs that contributes runoff to the study area from the north. These estimates are based on the altitude-precipitation relationship shown in figure 10.

Runoff

Runoff in the study area is caused by two principal types of events: (1) Melting of mountain snow during the spring; and (2) infrequent summer and early fall thundershowers. The showers may be intense, but they generally are restricted to small areas.

Perennial runoff in the study area occurs in the Book and Roan Cliffs in short reaches of Thompson, Sego, and Floy Canyons, all north of Thompson and Crescent Junction (pl. 1). Farther west in the Book and Roan Cliffs, other canyons may have small perennial flows, but they were not visited. Elsewhere, only very minor perennial runoff occurs at some small springs, and then only for very short distances.

Where runoff occurs, flow quickly dissipates; as a result, only a small fraction of the runoff reaches the Colorado or Green Rivers, and therefore flows from the study area. Most runoff is returned to the atmosphere by evaporation, especially during warm seasons. Some runoff infiltrates to greater depths, where it is either transpired by deep-rooted phreatophytes or continues to percolate downward toward the saturated zone of the upper ground-water system.

Most of the area has an average annual rate of runoff of about 6 mm or about 5×10^7 m^3 for the area (fig. 14). This amount is very small, only about 3 percent of estimated average annual precipitation (table 5).

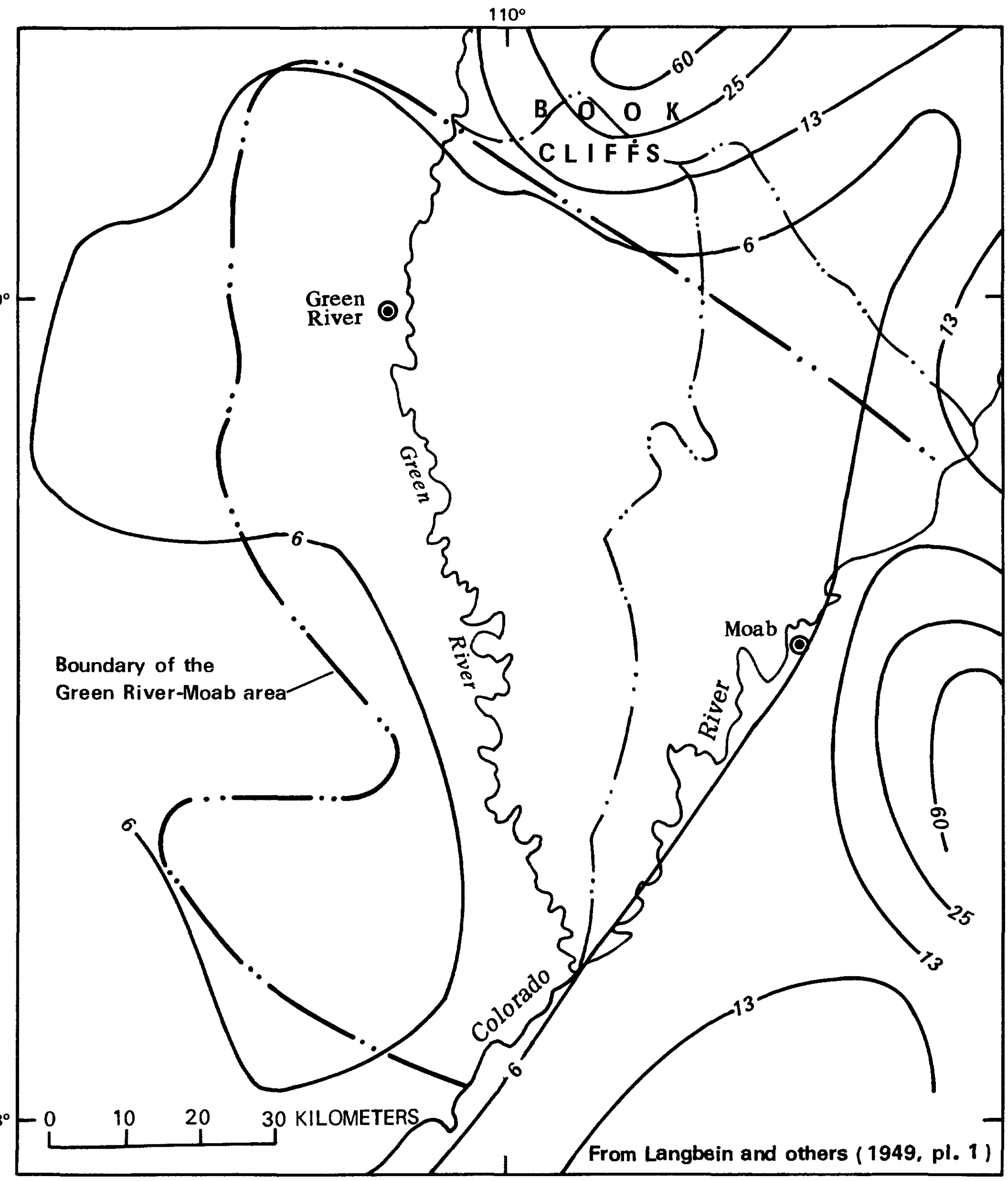
The parts of the Book and Roan Cliffs adjoining the study area (fig. 14) directly contribute significant runoff to the study area; runoff is 25 mm or greater. No estimates were made of the amount of this runoff that reaches the study area, or the amount that becomes recharge, but these amounts are assumed to be relatively small.

Table 5.--*Estimated long-term average annual precipitation and ground-water recharge to the upper ground-water system*

[Estimated recharge percentage from precipitation; values from Eakin and others, 1951, p. 79-81]

Precipitation zone (from topographic maps)		Area (square kilometers)	Estimated precipitation (from fig. 10)			Estimated recharge	
(feet)	(meters)	(1)	Range (millimeters)	Average (meters) (2)	Average (million cubic meters) [(1)x(2)=(3)]	Percentage of precipitation (4)	Annual (million cubic meters) [(3)x(4)]
>7,000	>2,134	7	300	>0.3	2	7	Minor
6,000-7,000	1,829-2,134	561	250-300	.27	150	3	20
5,000-6,000	1,524-1,829	2,400	200-250	.22	530		
<5,000	<1,524	4,830	200	.19	920	Minor	--
Total (rounded)		7,800			1,600		[1] ≤20

[1]Estimate considered a maximum value; see discussion.



EXPLANATION

6 — LINE OF EQUAL AVERAGE ANNUAL RUNOFF, IN MILLIMETERS

— · · — APPROXIMATE DRAINAGE DIVIDE

— · · — BOUNDARY OF GREEN RIVER—MOAB AREA

Figure 14.--Distribution of average annual runoff in the Green River-Moab area and vicinity.

INFLOW TO THE GROUND-WATER SYSTEMS

Potential sources of inflow to the ground-water flow systems include recharge from precipitation, infiltration from the Colorado and Green Rivers, and subsurface inflow across the basin boundary from adjoining areas. Deep percolation from runoff originating from precipitation falling in the study area is included in the estimated recharge from precipitation. Because the evaporites generally prevent downward flow of shallow ground water to the lower ground-water system, as discussed previously, the only inflow to the lower system is by lateral ground-water flow from beyond the study area.

Recharge from Precipitation

An empirical method of estimating average annual ground-water recharge from precipitation in desert regions was developed by Eakin and others (1951, p. 79-81). Recharge was estimated as a percentage of the average annual precipitation within an area. Geographic zones in which average precipitation ranges between specified limits were delineated on a map, and a percentage of precipitation was assigned to each zone; this then represented assumed average recharge from average annual precipitation in that zone. Of course, the degree of reliability of the estimate so obtained is related to the degree to which the values approximate actual precipitation, and the degree to which the assumed percentage represents actual percentage of recharge. Neither of these factors is known precisely enough to assure a significant degree of reliability for any area. However, this method has proved useful for reconnaissance estimates, and experience in using the method throughout Nevada and the desert areas of western Utah indicates that, in many areas in these desert regions, estimates probably are relatively close to actual long-term average annual recharge.

Two conditions may decrease actual recharge to the upper ground-water system from precipitation, and may require that the resulting estimate (table 5) be considered as a maximum value. The first condition is: Unlike many desert regions of Nevada and Utah, many of the soils in the area develop from shales and similar fine-grained rocks. As a result, precipitation and runoff may not percolate readily to depths beyond which it is not easily returned to the atmosphere by evapotransporation. This condition is especially true of the area north of T. 21 S. (pl. 1), mapped as the outcrops of the Tertiary and Cretaceous confining beds. The Mancos Shale of this hydrogeologic unit forms soils with minimal permeability and large porosity that retain temporarily-stored moisture near land surface, where it is easily evaporated. The second condition is: Runoff occasionally does drain to nearby regional streams and flows from the area. Recharge from precipitation probably is greatest near the Book and Roan Cliffs, where precipitation is relatively large, and along ephemeral channels, where deep infiltration is most likely (pl. 2).

Estimated annual recharge to the upper ground-water system from precipitation is computed in table 5 to be a maximum of 20 million m^3. This volume is about 1 percent of estimated average annual precipitation. This numerical recharge-precipitation ratio is very small, but not inconsistent with similar areas of Nevada and western Utah (Scott and others, 1971).

Recharge from Regional Streams

An analysis of regional-stream flow data indicates that no net recharge occurs to the upper ground-water system from the Green and Colorado Rivers. Rather, these streams generally function as drains for the ground-water system within the Paradox basin, as discussed in a later section of the report.

Subsurface Inflow

Ground water flows into both the upper and lower ground-water systems of the Paradox basin from adjacent areas. This judgment is based on potentiometric-contour maps developed mostly from drill-stem test data from oil and gas exploration wells. These data were evaluated by techniques described by Bredehoeft (1965) and Hackbarth (1978). A tabulation of several hundred drill-stem tests is presented in table 15 in the Supplemental Data section at the end of the report.

Equivalent freshwater head distribution for the lower ground-water system is shown in figure 15. Data control for the contours is primarily from the Leadville Limestone. Subsurface inflow is mostly from the north, and, to a lesser extent, from the northwest and northeast. No estimate of inflow to this ground-water system was made because the hydraulic characteristics of the ground-water system are not adequately known.

The generalized hydraulic-head distribution in the upper ground-water system is shown by contours on plate 2. About one-half of the 123 data points are for the Cutler and Moenkopi Formations. The contours indicate that most of the ground-water inflow is from the direction of the San Raphael Swell on the west, and from the Roan Cliffs on the north. No direct estimate of this element of inflow can be made for the same reason cited above for the lower ground-water system.

OUTFLOW FROM THE GROUND-WATER SYSTEMS

Elements of ground-water outflow include evapotranspiration, springflow, discharge to the Colorado and Green Rivers, subsurface outflow, and discharge by wells. Only subsurface outflow is likely from the lower ground-water system because, as previously discussed, upward flow through the salt beds is unlikely.

Evapotranspiration

Water is discharged from shallow ground-water areas by transpiration of phreatophytes and evaporation from soil. Such areas are the flood plains of

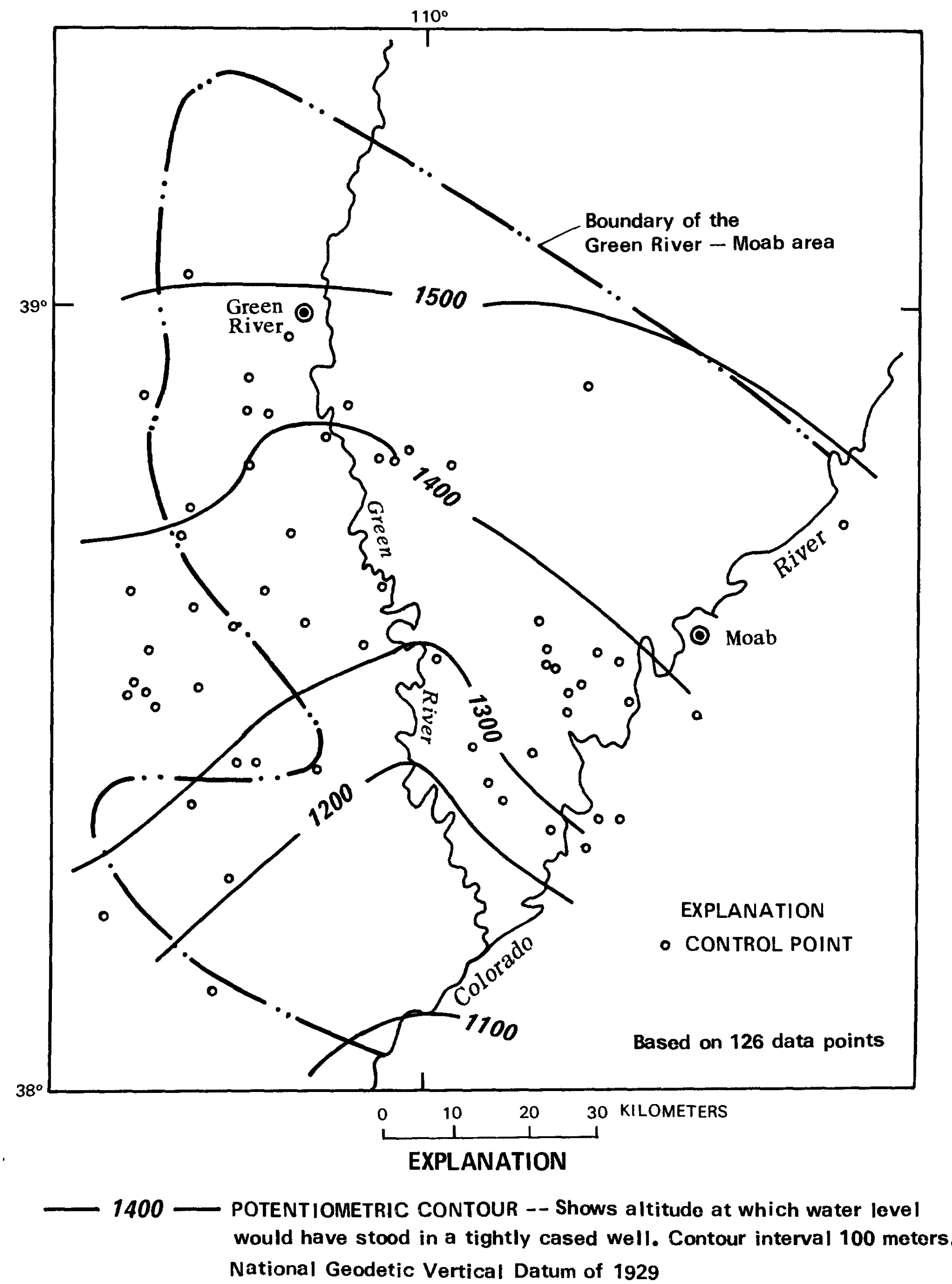


Figure 15.--Generalized potentiometric surface of the lower ground-water system.

the perennial streams, the Colorado, Green, San Rafael, and Price Rivers; and areas along the principal ephemeral channels (pl. 2), the channels that mostly drain from the Book and Roan Cliffs. Along ephemeral channels, the discharge is from water that is mostly in perched zones of saturation and that is derived from infiltrating runoff.

The area covered by phreatophytes is estimated to be about 100 km^2, of which about 60 km^2 is river flood plain. In general, areas with shallower depths to water have stands of saltcedar, cottonwood, willow, and saltgrass. Areas where depths to water are as much as 15 m support greasewood, saltbush, and rabbitbrush.

The total estimated average annual discharge by phreatophytes from the upper ground-water system is 30 million m^3, based on an estimated average annual rate of 1 m for saltcedar, cottonwood, and willow, and about 0.1 m for greasewood, saltbush, rabbitbrush, and saltgrass. These rates are based on research done by Lee (1912), White (1932), Young and Blaney (1942), Houston (1950), Robinson (1965), and Harr and Price (1972) in other areas. About 20 km^2 are covered by the first group and 80 km^2 by the latter in the study area.

Springflow

Known springs in the Green River-Moab area number approximately 110. The actual number of springs probably is greater because some small, intermittent springs may have gone unnoticed or unreported. Data were obtained for about 50 springs within the area and 18 springs nearby but outside the area (table 6). Published information was not complete for most springs, but the number of perennial springs is no more than about 15. The estimated average annual spring discharge from the upper ground-water system is 15 L/s, or 0.5 million m^3. Most of the spring discharge is from small perched water bodies in the unsaturated zone.

Most of the springs occur along canyon walls at formation contacts and are perched; some are seepage springs in stream beds. Discharge ranges from a seep to about 2 L/s; average discharge is only about 0.2 L/s. Many springs that flow during the spring and early summer are dry by fall.

The majority of springs discharge from the Morrison Formation and the Entrada, Navajo, and Wingate Sandstones. Other formations that have springs include alluvium, the Mesaverde Group, Kayenta and Moenkopi Formations, and the White Rim Sandstone Member of the Cutler Formation. Generally, springs in younger rocks occur in the northern part of the area and those in older rocks farther southward, reflecting the distribution of formation outcrops.

The majority of springs are at formation contacts and are perched, due to permeable strata lying above less permeable strata. Springs of this type have been noted as occurring in all the rock units listed in table 6, except the Morrison and Moenkopi Formations. Little information was available on spring

Table 6.--*Summary of springs in the Green River-Moab area and vicinity*

[Based on data mostly from Sumsion and Bolke, 1972; McKnight, 1940, p. 15, 16; and Baker, 1946, p. 10-15]

Hydrogeologic unit and rock unit	Number of springs	Areal distribution (Plate 1)	Rate of flow (liters per second) Range	Average	Total	Type of springs
Alluvium	3	--	0.3-1.0	0.6	1.8	Contact.
Tertiary and Cretaceous confining beds:						
Mesaverde Group	5	Roan Cliffs srea.	0-1.3	.9	4.5	Perched and contact.
Mesozoic sandstone aquifer:						
Morrison Formation	7	Near Salt Valley.	0-.1	.01	.02	Mostly seeps along faults.
San Rafael Group, mostly the Entrada Sandstone	21	Mostly in areas north of Moab and near Orange Cliffs.	0-.7	.2	4.2	Perched, contact, and fracture.
Navajo Sandstone	16	Scattered through-out outcrop area.	0-.3	.1	1.6	Seeps; perched, contact, and fracture.
Kayenta Formation	2	--	.03-.2	.1	.2	Contact.
Wingate Sandstone	6	Along Salt Wash, Seven Mile Csnyon and near Upheaval Dome.	<.01-2.	.5	3.0	Contact.
Mesozoic and upper Paleozoic confining beds:						
Moenkopi Formation	2	--	--	--	[1] .2	--
White Rim Sandstone (Member of Cutler Formation)	Numerous	Near mouth of Green River.	--	--	[1] .06	Contact.
Total (rounded)	>62			[2] 0.2	[3] 16	

[1]Flow rate for one spring.

[2]Aversge for springs liated.

[3]Equivalent to 0.5 x 10^6 cubic meters per year.

types in these two formations. Vertical joints and bedding planes also are important controls in the Entrada and Wingate Sandstones, and the White Rim Sandstone Member; cross-bedding is an important control in the Navajo Sandstone.

Springs along faults are not common, but a group of springs between Upper Courthouse and Brink Springs, northwest of Moab (24/19 and 24/20 on pl. 2), is associated with a major northwest trending fault (McKnight, 1940, p. 15). Crystal Spring (23/19-30c), which discharges from the base of a small scarp and lies to the northwest of Brink Spring (24/19-10d), also may be part of this group. Another group of springs in the northwestern part of the area occurs in an area of north and northwest trending faults; their origin is not known.

Salt Spring (24/22-20cd) and associated seeps near the base of the Wingate Sandstone along Salt Wash are perhaps the principal examples in the area of springs discharging from the saturated part of the upper ground-water system. The maximum observed flow from these ground-water sources for Salt Wash was estimated to be as much as 2 L/s. Because of local seepage losses, the flow of Salt Wash into the Colorado River is about 1 L/s.

Discharge to Regional Streams

Ground water discharges from the upper ground-water system to the Green and Colorado Rivers. This conclusion is based on three sets of data: (1) Surface-water data for the rivers and their tributaries for 1948; (2) surface-water data for the rivers and their principal tributaries from September 1949 through 1958; and (3) distribution of hydraulic-head contours for the upper ground-water system (pl. 2). Each set of data and their interpretations are discussed separately in the following paragraphs.

From 1946 through 1948, three reconnaissance boat trips by the U.S. Geological Survey were made down the Utah reaches of the Green and Colorado Rivers. The purpose of the trips was to measure all tributary inflow and to determine the flow of the rivers at numerous sites not included in the U.S. Geological Survey gaging-station network (Thomas, 1952, p. 2). The trips were made during September and October, when flows were expected to be at or near minimum for the year. However, during 1946 and 1947, at Lees Ferry, Arizona, and Hite, Utah, both downstream from the study area, flows during the reconnaissance periods were 1.4 to 2.0 times as large as those measured during the reconnaissance of 1948. Because relatively small contributions of ground water to river flow are more precisely detected during minimum flows, but even then only with minimal accuracy, the 1946 and 1947 data are not used here. The 1948 data were considered by Thomas (1952, p. 2 and 3) especially favorable for estimating ground-water gains and losses, because the flow of the river was less than at any time since 1940 and very little storm runoff occurred during or immediately preceding the reconnaissance.

Ground-water inflow to the Green River between Green River, Utah and the river mouth is computed in table 7. The total estimated surface-water inflow to the river segment was 28.3 m^3/s. Outflow, including estimated evaporation

Table 7.--*Estimated ground-water inflow to the Green River between Green River, Utah, and the river mouth, September 27-29, 1948*

[Based mostly on unpublished data by Harold W. Chase, U.S. Geological Survey, Salt Lake City, Utah]

Inflow	Cubic meters per second
Green River	28.3
Tributaries	[1] .017
Total (rounded) (1)	28.3
Outflow	
Green River	26.8
Evapotranspiration	[2] 3.3
Total (2)	30.1
Ground-water inflow [(2)-(1)]	1.8
River gain per kilometer of aquifer	[3] 20 liters per second

[1]From Thomas (1952, p. 23).

[2]Estimate based on data from Thomas (1952, p. 24, 29).

[3]Based on an aquifer distance of 95 kilometers (table 1).

from the water surface of the river and evapotranspiration from the phreatophyte-covered river flood plain, was estimated to be 30.1 m^3/s. The difference of 1.8 m^3/s is the estimated ground-water inflow to the river in that segment. The value and similar estimates in tables 8, 9, and 10, are at best only approximate because they are of the same order of magnitude as the potential error in the reported flow rates. The estimated river gain per kilometer for the 95 km of aquifer over which the 189 km of measured river channel traverses is 20 L/s.

Similar data for several reaches of the Colorado River are presented in tables 8, 9, and 10. The results of these three tables and table 7 are summarized in figure 16. Some approximations can be obtained from these imprecise data because the results are consistent and are corroborated by other methods described later in this section of the report. Estimated ground-water flow from the upper ground-water system to the Green River per kilometer of aquifer may be about 20 L/s; this area receives less precipitation (fig. 9) than other parts of the region, and, therefore, probably has a smaller rate of recharge and subsequent discharge. Ground-water flow to the Colorado River upstream from the mouth of the Green River per kilometer of aquifer may be about 90 L/s. The area to the southeast of this river reach contains the La Sal Mountains, which receive more than 700 mm of precipitation annually in some parts (figs. 9 and 10), and, as a result, produce much more runoff and ground-water recharge than the tributary area northwest of this river reach. Probably the area northwest of the river reach has a contribution to the river per kilometer of aquifer nearly as small as each contributing side of the Green River (table 7: 20 L/s ÷ 2), or about 10 L/s. Estimated ground-water discharge from the upper ground-water system to each river can be computed for the study area by multiplying the discharge estimate of the segments by the aquifer lengths of each river in the study area. The Green River in the study area crosses about 120 km of aquifer (table 1), while the Colorado River crosses about 110 km of aquifer; computed inflow to the two rivers in the study area is, therefore, on the order of 3,500 L/s. Assuming that inflow rates are virtually constant throughout the year, because annual inflow rates are the result of both constant transmissivity and hydraulic gradient, estimated average annual ground-water discharge to regional streams is about 3,500 L/s, or about 100×10^6 m^3.

Southwest of the study area and the Paradox basin, estimated ground-water discharge to the Colorado River per kilometer of aquifer, based on reach estimates, is on the order of 40 L/s. Some of this flow has passed through the study area in either or both ground-water systems, as discussed in the next report section.

Streamflow data and computations of river gain downstream from Green River, Utah, and Cisco gage to Hite are presented in table 11 for each September from 1949 through 1958. Gains in flow were recorded for 8 of the 10 years. Average gain was 7.6 m^3/s or 7,600 L/s for the 10 monthly periods. These values, like those for 1948, discussed above, are only approximate. To compare these data with the results obtained for the river reaches above, evapotranspiration loss needs to be included. The area of floodplain and water surface upstream

Table 8.--*Estimated ground-water inflow to the Colorado River between Cisco, Utah, and the mouth of the Green River, September 28-29, 1948*

[Based mostly on unpublished data by Harold W. Chase, U.S. Geological Survey, Salt Lake City]

Inflow	Cubic meters per second
River at Cisco gage (September 28)	67.1
Tributaries	[1] .3
Total (rounded) (1)	67.4
Outflow	
River upstream from mouth of Green River (September 29)	74.5
Evapotranspiration	[2] 1.4
Total (2)	75.9
Ground-water inflow [(2)-(1)]	8.5
River gain per kilometer of aquifer (rounded)	[3] 90 liters per second

[1]Includes flow in Onion, Rock, Castle, Negro Bill, Mill, and Indian Creeks, Salt Wash, Lockhart Canyon, and a spring.

[2]Based on an evapotranspiration rate of 5 millimeters per day, water-surface area of 20 square kilometers, and vegetated flood plain of 3.8 square kilometers.

[3]Based on an aquifer distance of 90 kilometers (table 1).

Table 9.--*Estimated ground-water inflow to the Colorado River, between the mouth of the Green River and Hite, Utah, September 29-October 4, 1948*

[Based on unpublished data by Harold W. Chase, U.S. Geological Survey, Salt Lake City, Utah]

Inflow	Cubic meters per second
Colorado River	74.5
Green River	26.8
Tributaries	.9
Total (rounded) (1)	102.2
Outflow	
Colorado River	104.5
Evapotranspiration	[1] .4
Total (2)	104.9
Ground-water inflow [(2)-(1)]	2.7
River gain per kilometer of aquifer (rounded)	[2] 40 liters per second

[1]Based on an estimated evapotranspiration rate of 5 millimeters per day, water-surface area of 6.5 square kilometers, and vegetated flood plain of 0.67 square kilometers.

[2]Based on an aquifer distance of 70 kilometers (table 1).

Table 10.--*Estimated ground-water inflow to the Colorado River between Hite, Utah, and Lees Ferry, Arizona, October 4-7, 1948*

[Based mostly on unpublished data by Harold W. Chase, U.S. Geological Survey, Salt Lake City, Utah]

	Cubic meters per second
Inflow	
Colorado River	104.5
Tributaries	26.7
Total (1)	131.2
Outflow	
Colorado River	133.9
Evapotranspiration	[1] 2.7
Total (2)	136.6
Ground-water inflow [(2)-(1)]	5.4
River gain per kilometer of aquifer (rounded)	[2] 40 liters per second

[1]Based on an estimated evapotranspiration rate of 5 millimeters per day, water-surface area of 39 square kilometers, and vegetated flood plain of 6.2 square kilometers.

[2]Based on an aquifer distance of 150 kilometers (table 1).

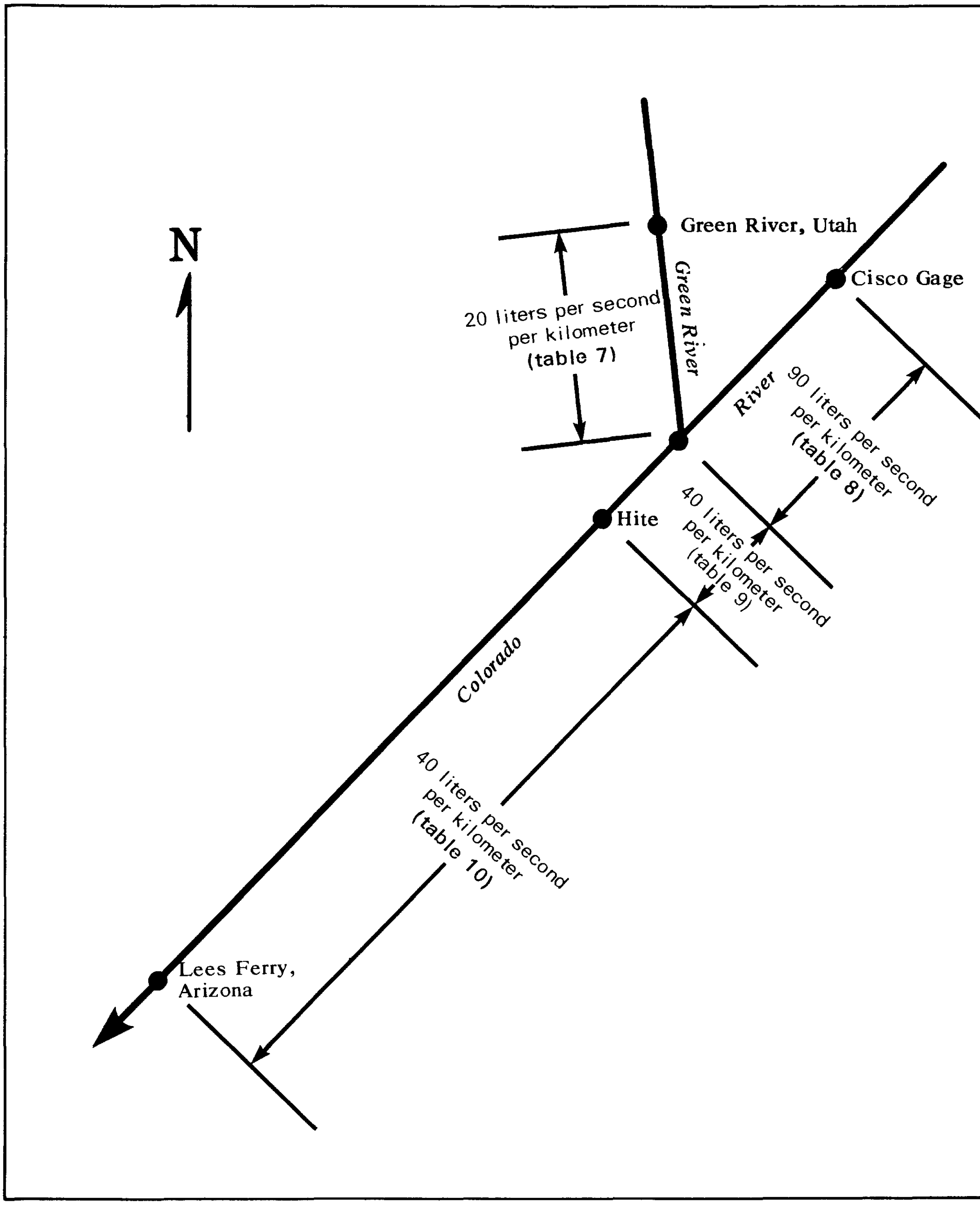


Figure 16.--Summary of estimated ground-water inflow rate to the Colorado and Green Rivers, in liters per second per kilometer of underlying aquifer.

Table 11.--*Computed streamflow gains or losses in the Paradox basin for September (1949-58)*

[Flow rate in cubic meters per second and rounded. Based on U.S. Geological Survey Records.]

Stream	Year										
	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	Average
Colorado River near Cisco	75.4	65.5	62.1	102	60.8	81.5	51.3	38.8	149	72.9	75.9
Onion Creek	----	.028	.009	.013	.016	.043	.009	----	----	----	.020
Professor Creek	----	----	.017	.006	.013	----	----	----	----	----	.012
Castle Creek	----	----	.063	.069	.020	[1] .18	.038	----	.029	.13	.076
Courthouse Wash	----	.30	.003	.008	.002	.090	.004	----	.003	----	.059
Mill Creek	----	.28	.22	.40	.28	.35	.22	.18	.38	.46	.308
Pack Creek	----	----	----	----	----	----	.051	.044	.074	.053	.056
Indian Creek	----	.041	.003	.030	.010	.25	<.001	<.001	.030	----	.046
Green River at Green River, Utah	53.0	70.9	84.6	87.7	41.6	63.8	33.6	34.5	96.0	45.6	61.1
Saleratus Wash	.15	.017	.043	.060	.012	.54	<.001	----	----	.040	.108
Browns Wash	----	0	0	.028	0	.087	<.001	0	.010	.029	.017
San Rafael River	1.21	.49	.56	2.3	.73	1.8	.021	.003	2.0	2.0	1.11
Dirty Devil River	2.25	1.4	.93	6.2	.78	2.9	.25	.11	2.3	2.0	1.91
North Wash	----	----	.002	.007	0	.043	0	0	<.001	.013	.008
White Canyon	----	----	0	.11	0	.39	0	0	.012	.13	.080
Subtotal (rounded)	132.0	139.0	148.6	198.9	104.3	152.0	85.5	73.6	249.8	123.4	140.8
Colorado River at Hite	140.7	142.9	163.1	214.9	112.5	146.0	91.5	76.3	279.2	116.7	148.4
Loss (-) or Gain (+)	+8.7	+3.9	+14.5	+16.0	+8.2	[2] -6.0	+6.0	+2.7	+29.4	[3] -6.7	+7.6

[1]Discharge estimated on basis of seven discharge measurements, weather records, and records for nearby stations.

[2]Possible explanation of 1954 loss is that some water from upstream stations that had peaks late in September did not arrive at Hite before the end of the month (especially a September 27 peak on the Green River at Green River, Utah).

[3]Cannot explain 1958 loss: rainfall station departures were greater than normal; also possible that some peaks at gates on wash-type streams measured water that never reached major streams.

from Hite (to Green River, Utah and Cisco gages) is about 36 km^2 (table 1). Using the same evapotranspiration rate as for the river-reach computations of 5 mm/d, the additional discharge is 2,100 L/s. The total computed gain to the river from ground-water sources is, therefore, about 10,000 L/s, or about 40 L/s per kilometer of aquifer. The weighted average for the river reaches computed from figure 16 is about 50 L/s per kilometer of aquifer. These estimated averages, though slightly different, are in general agreement.

Hydraulic-head distribution, as shown on plate 2, indicates flow in the upper ground-water system toward the regional streams. Because of insufficient data on transmissivity and porosity, no estimates of flow rates can be made, based on the potentiometric contours.

The preceding three sets of data consistently indicate flow of ground water to the Colorado and Green Rivers, although no single set of data, by itself, may be adequate to demonstrate ground-water discharge to the streams. Little modification of the ground-water flow to the rivers has resulted from the construction of dams. The resulting higher stages of the impounded water might slightly decrease the hydraulic gradients of the ground-water system from native conditions.

Subsurface Outflow

Ground water flows in the subsurface from the Paradox basin to adjoining areas in both the upper and lower ground-water systems (table 1), based on the configuration of potentiometric contours (plate 2 and fig. 15).

Hydraulic-head distribution for the upper ground-water system is shown on plate 2. The contours indicate that ground water flows in the subsurface from the study area only at the southwestern boundary of the basin, near and southwest of the confluence of the Green and Colorado Rivers. Because the width of the area of subsurface outflow is narrow (about 30 km) and hydraulic gradients in this area generally are lower than in other parts of the study area, the estimated relative amount of this component of total outflow is very small.

In the lower ground-water system, subsurface outflow is in a southwesterly direction (fig. 15); the discharge rate and velocity are unknown. Farther southwest in southern Utah and northern Arizona, this water probably discharges to the Colorado River, as previously discussed.

Wells

No large-yield, large-diameter wells are used in the study area and the number of other wells is small. As a result, discharge by wells is a very small part of the water budget of the system.

Green River, Utah, the only sizable community in the report area, obtains its public water supply from the Green River because ground water in the area is not considered potable. Nearby farmers use the same supply.

In Canyonlands and Arches National Parks, a few small-yield wells supply facilities, but the net draft on the upper ground-water system is minor. No water wells are known to be completed in the lower ground-water system in the study area.

INFLOW-OUTFLOW BALANCE

During a multiyear period, most natural ground-water systems approach dynamic equilibrium; that is, inflows equal outflows and water in ground-water storage remains nearly constant. A water budget for the Green River-Moab area is presented in table 12. Though the budget is incomplete, some useful conclusions can be drawn from it on the relative volumes of water for each of the inflow and outflow elements. Conclusions for the upper ground-water systems are: (1) The principal element of ground-water outflow is discharge to the regional streams, that is, the Green and Colorado Rivers and may be about 100 million m^3 per year; (2) all other elements of outflow are relatively small; (3) estimated average annual outflow from the system may be about 130 million m^3; and (4) based on the information in table 12, estimated average annual recharge from subsurface inflow may be about 110 million m^3 and is the principal element of ground-water recharge.

For the lower ground-water system the conclusions are: (1) Total inflow and outflow are about equal; (2) if the evaporite geohydrologic unit is virtually an impermeable confining bed, as it appear to be in drill-stem tests, all inflow to and outflow from the system is subsurface flow; and (3) the volume of water moving through the system is unknown, but probably is nearly constant. These conclusions are based on the assumption that no interchange of water occurs between the upper and lower ground-water systems, as discussed earlier in the report.

GENERAL CHEMICAL CHARACTER OF WATER

Most of the water-quality data for water wells, oil tests, and springs presented in table 13 were collected by others (Feltis, 1966). Distribution of water-quality data from wells and springs was sparse throughout large parts of the area and the quality of the sampling and analitical results generally is unknown. However, some general conclusions can be drawn from the data, as presented here.

1. Generally, the dissolved-solids concentration in ground water is principally related to rock composition, however, purity and crystal size of minerals, rock texture and porosity, regional structure, degree of fissuring, flow history, and other factors might influence the composition of water (Hem, 1970, p. 41 and 42; and Freeze and Cherry, 1979, p. 106). For example, ground water percolating through the Moenkopi Formation dissolves gypsum and other relatively soluble materials to increase dissolved-solid concentrations.

2. Most springs in the area discharge perched water that is percolating downward through the unsaturated zone toward the underlying regional flow

Table 12.--*Preliminary water budgets for the upper and lower ground-water systems*

Budget element	Estimated average annual amount (million cubic meters)
Upper Ground-Water System	
Inflow	
Recharge from precipitation (table 5)----------------	≤20
Recharge from runoff originating from precipitation falling outside the study area (p. 26)-------------	Assumed to be small.
Recharge from infiltration of regional streamflow (p. 30)---------------------------------	0
Subsurface inflow (p. 30)----------------------------	Unknown.
Total inflow (rounded)-------------------------	[1] 130
Outflow	
Evapotranspiration (p. 32)-------------------------	30
Springflow (p. 32)-----------------------------------	.5
Discharge to regional streams (p. 36)---------------	100
Subsurface outflow (p. 42)-------------------------	Very small.
Wells (p. 42)---	Minor.
Total outflow (rounded)-------------------------	130
Lower Ground-Water System	
Subsurface inflow (p. 43)-------------------------------	Unknown.
Subsurface outflow (p. 43)-----------------------------	Unknown; probably about equal to inflow.

[1]Assumed to be about equal to total outflow.

Table 13.--*Summary of water quality for hydrogeologic units*

[Data mostly from Feltis, 1966, p. 50-59, Huntoon, 1977, p. 11, and Sumsion, 1971, p. 40; units rounded and in milligrams per liter except specific conductance (microSiemens, µS) and pH (standard units)]

Hydrogeologic unit and formation	Number of samples	Dissolved solids		Specific conductance		Chloride (Cl)		Sulfate (SO_4)		pH	
		Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Tertiary and Cretaceous confining beds:											
Mancos (?) Shale-----------	1	4,710	-----	5,640	-----	220	-----	1,500	-----	---	---
Mesozoic Sandstone aquifer:											
Morrison Formation---------	4	517-13,900	4,150	1,100-2,030	1,570	13-8,000	2,000	97-810	440	7.9	7.9
Entrada Sandstone----------	6	204-14,300	5,790	271-19,400	5,100	2-5,400	1,770	8.2-2,400	940	7.1-8.4	7.5
Navajo Sandstone-----------	12	108-827	304	197-812	392	2.4-49	15	6.8-390	68	7.1-8.3	7.6
Kayenta Formation----------	2	189-220	204	353-374	363	6.2-21	14	14-25	20	7.4-8.2	7.8
Wingate Sandstone----------	9	164-680	322	296-3,760	1,000	8.3-110	35	35-97	44	7.3-8.6	7.7
Mesozoic and upper Paleozoic confining beds:											
Chinle Formation-----------	4	4,980-20,800	12,900	-----	-----	530-10,000	5,500	270-1,800	1,000	7.5-8.1	7.9
Moenkopi Formation---------	5	1,410-18,100	10,400	1,680	-----	28-6,100	3,600	320-2,000	1,000	7.0-7.7	7.4
Cutler Formation-----------	15	237-6,010	2,300	386-3,970	1,880	6.2-1,000	250	1.8-2,900	1,000	6.0-8.1	7.6
Rico Formation-------------	4	236-583	354	405-1,020	609	4.1-170	49	13-57	27	7.6-7.8	7.7
Evaporites:											
Hermosa Formation[1]---------	8	23,900-398,000	174,000	-----	-----	7,800-250,000	110,000	49-7,800	2,300	4.4-8.7	7.0
Lower Paleozoic aquifer:											
Leadville Limestone equivalent---------------	32	7,360-327,000	94,700	-----	-----	1,140-200,000	55,000	120-52,000	4,100	5.0-7.7	6.8

[1]The upper and lower members of the Hermosa Formation are considered to be part of the overlying and underlying hydrogeologic units, respectively (table 2).

system. As a result, these springs discharge less mineralized water than do springs of the regional flow system, because of shorter transient time in rocks not having relatively-soluble minerals.

3. Water samples from the Navajo Sandstone had small dissolved-solids concentrations, because this sandstone is well-sorted and has very little soluble-mineral content. The Navajo Sandstone also is a unit that crops out and receives precipitation and recharge directly. The majority of the springs are at the base of the Navajo Sandstone where it overlies the much less permeable Kayenta Formation.

4. Chemical analyses were available for two springs issuing from the Kayenta Formation in the report area. This formation generally is a barrier to downward movement of percolating ground water; thus, most of that water is discharged near its upper contact. The springs are located at 31/15-9 and 27/16-2. The quality of the water probably is the result of a short transient time from recharge to discharge.

5. The chemical quality of sampled water from the Wingate Sandstone generally is similar to the water in the overlying Navajo Sandstone and Kayenta Formation. Fractures probably are important routes for percolation in this formation. An exception in general water quality is Salt Springs, at 24/22-20, which discharges from the base of the Wingate Sandstone. Specific conductance of the water was 3,760 microSiemens[1] (μS). This spring probably is discharging water that has flowed for a long period in the regional flow system, rather than water percolating downward in the unsaturated zone toward the regional flow system.

6. Water percolating through the Chinle Formation comes into contact with clay, silt, limestone, and gypsum, producing relatively large concentrations of dissolved solids, chloride, and sulfate, based on samples from oil-test wells 24/12-2, 27/14-5, and 22/22-33.

7. The great concentration of sulfate in samples from the Moenkopi Formation may be due to the common presence of gypsum, and the large chloride concentrations may result from the solution of salt crystals (Gilluly, 1929, p. 86).

8. The springs seeping from the Cutler Formation contained very small concentrations of dissolved solids; the water probably percolates only a short distance from outcrop recharge areas to the springs. Oil-test well samples contained relatively large concentrations of dissolved solids. Most sample sites were in outcrop areas of overlying units. Much of the mineralization probably is the result of solution in these overlying units. Water issuing from springs in the Rico Formation near the confluence of the Green and Colorado Rivers probably has a short transient time in the subsurface between points of recharge and discharge.

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[1] Equivalent to micromhos per cm at 25°C.

Three chemical analyses from the Green and Colorado Rivers in the southern part of the area are presented in table 14. The water sampled was a mixture of river inflow to the area and ground water discharged to the rivers, as discussed earlier in the report. The water mixture also would be affected by evaporation from the water surface of the streams, evapotranspiration by phreatophytes on their flood plains, and other factors, such as mineralogical and biological activity.

At the time of sampling, the Green River had about one-half the dissolved-solids concentration of the Colorado River, or about 640 mg/L. The sample from the Green River can be characterized as a sodium calcium sulfate bicarbonate water. The Colorado River water had proportionally less bicarbonate and more sulfate. Sulfate is an important constituent in the local ground-water (table 13). Local ground water may have contributed significantly to the measured concentrations in the rivers.

FLOW SYSTEMS AND SALT BEDS

In the Green River-Moab area, ground-water circulation principally is through the Mesozoic sandstone aquifer and the lower Paleozoic aquifer. These aquifers are generally isolated from the evaporite beds by the bounding confining beds. As a result, ground water has little contact with the Paradox Member salt beds. In the confining beds, brines have been penetrated during drilling, but they probably have very-slow rates of circulation. If so, salt solution and removal probably is at a very slow rate in most parts of the area.

Salt solution, if it occurs, probably could involve circulation of water mostly along the contact zones of the salt section rather than through the section, because the plastic character of the salt beds probably precludes significant permeability. Fracture zones, perhaps associated with faulting and folding, would be the most favorable avenues of circulation in the ground-water systems, but not in the salt.

Brines have been identified in the subsurface but have not been identified as ground-water outflow. Brine was encountered in caprock just above salt beds while drilling in Salt Valley (Rush and others, 1980, p. 15 and 30; Wollitz and others, 1982, p. 63). However, no brine springs are known in the area, and the ground-water discharge to the regional streams probably does not have significant effect on the concentration of dissolved solids of the rivers that might be expected if the discharge contained very large concentrations of dissolved solids.

ADDITIONAL STUDIES

Four types of detailed hydrologic studies would increase knowledge of the ground-water flow systems of the area: (1) Investigations of the various elements of inflow and outflow to the systems; (2) a description of the geologic framework of the flow systems; (3) a quantitative description of the flow systems in small subareas; and (4) digital modeling of the flow systems as an adequate data base becomes available.

Table 14.--*Chemical analyses of water from the Green and Colorado Rivers*

[μg/L--micrograms per liter; °C--degrees Celsius; μS--microSiemens]

Constituents (ion concentrations, milligrams per liter unless otherwise indicated)	Green River at Anderson Bottom (site 8, plate 1) T. 28 S., R. 17 E.	Colorado River	
		At the slide (site 29, plate 1) T. 30 S., R. 19 E.	Combined flow of rivers at Spanish Bottom (site 31, plate 1) T. 30 S., R. 18 E.
Date collected	10-22-77	10-23-77	10-23-77
Alkalinity, total, as $CaCO_3$	180	170	180
Bicarbonate (HCO_3)	[1] 220	210	220
Calcium (Ca)	[1] 77	[1] 160	[1] 120
Chloride (Cl)	35	180	100
Fluoride (F)	.6	.1	.1
Hardness, noncarbonate	150	460	300
Hardness, total, as $CaCO_3$	330	640	480
Lithium (Li), μg/L	40	80	60
Magnesium (Mg)	33	57	44
pH (onsite)	7.7	8.2	8.5
pH (laboratory)	8.2	8.1	8.1
Potassium (K)	3.4	6.2	4.7
Residue, dissolved (calculated)	646	1,260	933
Residue, dissolved (Sum)	641	1,240	970
Silica (SiO_2)	26	6.3	4.0
Sodium (Na)	[1] 92	[1] 180	[1] 130
Specific conductance, onsite, μS	965	2,000	1,350
Specific conductance, laboratory, μS	963	1,900	1,390
Strontium (Sr), μg/L	880	1,800	1,400
Sulfate (SO_4)	[1] 270	[1] 560	[1] 420
Water temperature (°C)	14	16	15

[1]A dominant ion.

Ground-water flow to regional streams is probably the principal mechanism of discharge from the upper ground-water system. Under favorable hydrologic conditions, intensive study of changes in the rates of flow and in the water chemistry of the regional streams might further define the character of the ground-water discharge to the streams. The other elements of inflow and outflow in table 12 are either relatively small, or, in the case of subsurface inflow, difficult to evaluate in detail for this large area.

Little is known of the transmitting abilities and boundaries of the ground-water flow systems. Some shut-in pressure data can be used to compute transmissivity from drill-stem tests. If enough data were available, transmissivity maps could be drawn. To identify the boundaries of the ground-water flow systems, the regional character of large parts of eastern Utah, western Colorado, and adjoining parts of Arizona and New Mexico would have to be studied.

SUMMARY AND CONCLUSIONS

1. The reconaissance of the general hydrology of the northwestern part of the Paradox basin was made as a part of a program to investigate potential areas for underground storage of high-level radioactive wastes.

2. The 28 rock units that underlie the area have been grouped into seven hydrogeologic units and two ground-water systems. Two aquifers have been identified, one above and one below a thick sequence of confining beds. Within the confining-bed sequence are the salt beds and interbeds of the Paradox Member of the Hermosa Formation.

3. The area receives very little precipitation and has very little runoff; as a result the rate of recharge from local precipitation is relatively small. Subsurface inflow is probably the principal source of recharge to the ground-water systems.

4. Ground-water flow to the regional streams probably is the principal element of discharge from the upper ground-water system. Subsurface outflow in the lower ground-water system may be the principal element of discharge from the lower system.

5. Brines have been identified in the subsurface but have not been identified as ground-water outflow. Salt solution, where and if it occurs, probably would involve circulation of water mostly along the contact zones of the salt section rather than through the section; because the plastic character of the salt beds probably precludes significant permeability.

6. Additional studies of the ground-water flow systems are proposed, including further definition of inflow and outflow elements of the systems, more detailed description of the geologic framework, definition of transmitting abilities and boundaries of the flow systems, and digital modeling.

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SUPPLEMENTAL DATA SECTION

Table 15.--*Results of deep well tests in the Green River-Moab area*

[Tests were drill-stem tests unless otherwise indicated under Remarks; Altitude--approximate altitude of land surface above sea level; Depth--total drill depth of well below land surface; Rock unit tested--see table 2 for full name and rank of rock unit; Test interval--depth below land surface; Freshwater head--above sea level unless number is preceded by minus sign (some listed freshwater-head values may be too small because equilibrium was not reached during test); Fluid-recovery rate--meters of formation fluid recovery in drill stem per hour of test per meter of test-interval thickness; *--minor recovery rate; p/m--parts per million; m--meters; L--liters; cm^3--cubic centimeters; m^3/d--cubic meters per day; L/h--liters per hour; Kg/L--kilograms per liter]

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery			Remarks
							Fluid	Amount (meters)	Rate (meters per hour per meter)	
17/14-29ac	1,452	2,596	Navajo	803-804	5	1,553	Fresh filtrate water	---	---	175 millidarcys effective permeability.
			Navajo	836-837	25	1,615	Filtrate water	---	---	10 millidarcys effective permeability.
			"Leadville"	2,573-2,593	80	-----	Water-cut mud	110	67	Chloride concentration of the very salty water was reported as 650,000 p/m.
						-----	Muddy saltwater	165		
						-----	Very salty water	1,622		
18/12-12adb	1,616	-----	-----	530-538	60	-----	Drilling mud	27	0	-----
			-----	585-596	60	-----	Drilling mud	9	0	-----
			-----	596-603	120	1,084	Drilling mud	9	0	-----
			-----	602-609	60	-----	Drilling mud	6	0	-----
			-----	614-649	60	-----	Drilling mud	9	0	-----
			-----	694-705	120	1,126	Gas-cut mud	12	*	-----
			-----	704-714	180	1,341	Water-cut drilling mud	29	*	-----
			-----	715-754	65	1,188	Drilling mud	34	0	-----
			-----	867-886	60	-----	Drilling mud	3	0	-----
			-----	937-945	60	1,287	Freshwater cut drilling mud	101	*	-----
			-----	1,539-1,570	120	1,378	Saltwater	1,210	20	-----
18/14-8cca	1,477	2,414	Paradox	1,672-1,700	123	-139	Slightly gas-cut mud	85	*	-----
			Paradox	1,736-1,766	120	575	Very slight oil- and gas-cut mud	29	*	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
19/12-9cc	1,860	1,510	Moenkopi	585-594	30	-----	Drilling mud	8	0	-----
			"Leadville"	1,300-1,335	90	1,298	Slightly water-cut mud	64	*	-----
			"Leadville"	1,341-1,348	60	1,257	Slightly water-cut mud	29	*	-----
			"Leadville"	1,416-1,428	60	1,287	Drilling fluid	8	0	-----
			"Leadville"	1,464-1,479	60	1,318	Mud-cut freshwater	192	13	-----
19/14-8cbd	1,534	1,890	Hermosa	1,770-1,780	---	741	Slightly gas-cut mud	9	*	-----
19/14-11dcb	1,516	2,681	Wingate	1,242-1,353	130	1.645	Heavy water- and gas-cut mud	408	*	No freshwater sands reported.
			Paradox	2,569-2,606	185	-818	Gas-cut mud	58	*	No freshwater sands reported.
19/14-35bc	1,419	1,408	Chinle	1,113-1,140	40	-----	Drilling mud	5	0	-----
20/14-33baa	1,409	2,304	Moenkopi	843-865	60	735	Slightly gas-cut mud	122	*	Perforated 2,252-2,253 m and swabbed water.
			"Leadville"	2,295-2,304	60	-----	Mud Water-cut mud Saltwater	55 305 680	76	-----
20/21-4cda	1,756	1,097	Dakota	951-979	60	937	Mud	32	0	-----
20/21-9bad	1,824	1,254	Salt Wash	1,000-1,021	60	1,260	Mud	6	0	-----
			Salt Wash	1,024-1,055	120	1,439	Gas-cut mud Water	30 305	5	-----
			Morrison	1,109-1,129	60	940	Oil-cut mud	21	*	Oil and gas production from perforated intervals, 1,114 to 1,118 m and 1,120 to 1,123 m.
			Morrison	1,132-1,159	60	891	Mud	9	0	-----
			Entrada	1,234-1,246	90	1,441	Water	732	41	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
21/14-5adc	1,395	1,829	Rico	1,309-1,321	60	1,300	Saline water	549	46	-----
			Rico	1,309-1,321	60	1,152	Slightly gas-cut water Water	109 158	22	-----
21/15-24cca	1,288	3,233	Rico	1,673-1,683	60	1,059	Slightly water-cut mud	46	*	-----
			Hermosa	1,883-1,895	60	1,334	Mud Water-cut mud	58 27	*	-----
			Paradox	2,072-2,086	60	628	Highly gas-cut mud	372	*	-----
			Paradox	2,117-2,138	60	-320	Highly gss-cut mud	140	*	-----
			Paradox	2,564-2,577	60	703	Slightly gss-cut mud Highly gas-cut mud	18 143	*	-----
			Paradox	2,798-2,805	60	420	Water-cut mud	9	*	-----
			"Leadville"	2,912-2,942	60	1,304	Mud Water-cut mud Muddy water	52 25 36	1	-----
			"Leadville"	2,958-2,973	60	1,518	Water-cut mud Saltwater	183 1,737	116	-----
21/16-33bad	1,305	2,823	Hermosa	1,637-1,664	60	1,316	Mud Water-cut mud Muddy water	55 55 55	2	-----
			Paradox	2,139-2,158	100	-102	Gas-cut mud Highly gas-cut mud	546 140	*	-----
21/17-26adc	1,357	3,626	Moenkopi	1,507-1,523	60	-28	-----	---	---	No fresh-water sandstone.
			Hermosa	1,971-2,016	60	1,488	Water-cut mud Saltwater	---	---	177,000 p/m sodium chloride.
			Paradox	2,510-2,521	60	341	Slightly gas-cut mud	---	*	-----
21/18-12acb	1,590	1,560	Mancos	792-801	60	-----	Mud	1	0	-----
			Navsjo	1,544-1,560	90	1,331	Slightly oil-cut emulsion	786	*	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
21/18-12cac	1,571	2,321	Navajo	1,562-1,564	---	-----	-----	----	---	Test through perforated casing. Oil production was swabbed from the two intervals tested.
				1,566-1,569	---	-----	-----	----	---	
			Navajo	1,567-1,586	90	1,293	Mud Oil and mud Oil Gas	132 76 274 171	12	-----
			Wingate	1,809-1,825	105	1,320	Heavy mud Mud and water Muddy water Water	3 46 46 8	2	-----
21/18-23bdc	1,501	2,382	Navajo	1,368-1,385	45	1,309	Slightly water-cut mud	37	*	-----
			White Rim	2,295-2,382	30	-280	Mud	58	0	-----
21/19-7aa	1,572	1,379	Dakota	1,155-1,162	---	-----	Mud	3	0	-----
			Dakota	1,172-1,191	60	1,620	Water-cut mud	55	*	-----
21/19-7acb	1,570	1,126	Mancos	992-998	30	-----	Mud	6	0	-----
			Dakota	1,085-1,089	60	699	Mud	3	*	Slight gas show.
			Dakota	1,114-1,126	120	1,278	Mud Muddy water Salty water	46 69 404	20	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
21/19-7ccb	1,547	1,289	Dakota	1,117-1,120	60	1,205	Gas	1,120	---	-----
			Dakota	963-976	120	1,287	Gas-cut mud	198	*	-----
			Morrison	993-1,002	70	1,244	Saltwater	44	4	-----
			Morrison	1,035-1,036	---	-----	Water	---	---	Show of water. Test through perforated casing.
			Morrison	1,049-1,050	---	-----	Gas	---	---	Gas production decreased from 99 x 10^6 to 17 x 10^6 m^3/d in 2 hours.
			Morrison	1,147-1,148	60	1,389	Slightly salty water with gas	911	911	-----
			Morrison	1,172-1,173	60	-----	Slightly gas-cut water	853	853	-----
			Entrada	1,262-1,289	---	-----	Slightly gas-cut mud	290	*	-----
21/19-7ccd	1,547	1,006	Dakota	962-970	19	1,183	Salty water	285	112	-----
21/19-33cdd	1,485	1,528	Summerville	526-527	---	-----	-----	0	0	Test through perforated casing.
			Summerville	527-529	---	-----	Some water	---	*	Test through perforated casing.
			Moab	529-530	---	-----	Water	---	---	Test through perforated casing; water came in rapidly.
			Moab	530-532	---	-----	Water	347	---	Test through perforated casing.
			Moab	527-536	41	-----	Water	155	25	Test through perforated casing.
21/20-17bcc	1,279	883	Mancos-Dakota	69-70	---	-----	Salty water	---	---	Test through perforated casing. Flowed salty water at 69 and 881 m; drilling suspended due to too much water.
			Dakota	880-883	---	-----	Salty water	---	---	Test through perforated casing.
21/20-35bd	1,544	1,586	Dewey Bridge	935-952	120	646	Drilling mud	2	0	Temperature survey indicated water flow from the Entrada Formation from 789-928 m.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
21/22-16aaa	1,460	881	Salt Wash	880-881	---	-----	Freshwater	---	---	Test through perforated casing.
21/23-2ccc	1,413	359	Brushy Basin	354-359	---	-----	-----	---	---	Tested open hole; flowing.
21/23-10acd	1,350	532	Brushy Basin	341-375	---	1,336	Gas	---	---	Wire-line test. Production determined by wire line tester.
			Salt Wash	393-394	---	1,348	Water (10 L)	---	---	Wire-line test.
			Salt Wash	415-415	---	1,333	Water (300 cc)	---	---	Wire-line test.
21/23-11bd	1,368	437	Morrison	396-411	60	1,345	Saltwater	305	20	-----
21/23-25aaa	1,436	274	-----	-----	---	-----	-----	---	---	Water table below 210 m.
21/23-26dbd	-----	379	Entrada	379- ---	---	-----	-----	---	---	Well may be available for hydrologic tests.
21/23-33ba	1,351	437	-----	-----	---	-----	-----	---	---	Formations dry to 397 m (top of Morrison Formation).
21/23-33bdb	1,355	366	-----	128-131	---	-----	-----	---	---	Test through perforated casing produced salty water.
22/13-24aa	1,442	2,072	"Leadville"	1,663-1,673	15	1,305	Slightly gas- and oil-cut mud	40	*	-----
			"Leadville"	1,964-2,057	15	1,487	{Muddy water {Water	194} 1,036}	53	-----
			"Leadville"	2,016-2,024	15	1,412	{Muddy gas-cut water {Gas-cut water	30} 167}	98	-----
22/15-9ac	1,354	2,790	"Leadville"	2,653-2,666	60	1,446	{Water-cut mud {Saltwater	168} 2,195}	169	-----
22/15-26caa	1,328	2,588	"Leadville"	2,557-2,588	90	1,401	{Mud {Muddy saltwater {Saltwater	192} 116} 2,024}	46	-----
22/15-28bd	1,341	2,479	Hermosa	1,803-1,808	90	-444	Oil- and gas-cut mud	9	*	-----
			Paradox	1,907-1,931	60	-----	Mud	82	0	-----
			"Leadville"	2,378-2,420	60	935	Gas-cut mud	101	*	-----
			"Leadville"	2,438-2,478	45	1,544	Saltwater	2,243	75	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
22/16-14ba	1,347	2,062	Hermosa	1,452-1,477	80	1,343	Slightly gas-cut saltwater	331	10	-----
			Hermosa	1,786-1,862	30	-277	Gas-cut mud	78	*	-----
22/16-25bbd	1,259	2,898	Cutler	1,049-1,061	120	1,174	Mud Water	30 27	*	-----
			Cutler	1,106-1,113	60	162	Mud	3	0	-----
			Hermosa	1,202-1,219	60	1,302	Mud	12	0	-----
			Hermosa	1,221-1,228	120	1,548	Mud	757	0	-----
			Hermosa	1,222-1,227	120	67	Slightly gas-cut mud	8	*	-----
			Hermosa	1,273-1,290	122	1,309	Mud Slightly mud- and gas-cut seltwater Slightly gas-cut saltwater	37 61 128	5	-----
			Hermosa	1,454-1,463	120	-----	Slightly gas-cut sulfur water	9		-----
			Paradox	1,811-1,829	60	-335	Slightly water-cut mud	59	*	-----
			Paradox	1,935-1,946	90	-424	Slightly water-cut mud	32	*	-----
			Paredox	2,059-2,086	60	-703	Mud	62	0	-----
			Paradox	2,309-2,324	120	-144	Mud	961	0	-----
			"Leadville"	2,792-2,812	60	1,188	Mud	49	0	-----
			"Leadville"	2,812-2,829	120	1,409	Saltwater	2,621	77	-----
22/17-34bd	1,325	3,137	-----	783-799	60	559	Mud	14	0	See Feltis (1966, p. 54) for chemical analysis.
			Hermosa	1,320-1,332	120	110	Gas-cut mud	6	*	-----
			Hermosa	3,064-3,101	120	1,495	Muddy saltwater Saltwater	152 814	13	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
22/19-3bcc	1,469	24	Cutler	-----	---	-----	-----	---	---	Flow of 757 L/h encountered while drilling between 771 and 783 m (Feltis, 1966, p. 54).
22/19-4cc	1,460	1,524	Summerville	624-639	---	-----	Water	---	---	Saline water.
22/19-8aca	1,446	717	-----	-----	---	-----	-----	---	---	Important water sandstones 327-334 m (Dakota Sandstone); 375-381 m, 405-415 m, 425-492 m, 489-494 m, and 510-515 m are sandstone units in the Morrison Formation.
22/19-10bba	-----	72	Mancos	30-72	---	-----	-----	---	---	Pumping test. Bad water from 30-72 m, water level is 8 m below land surface, water at 9 and 50 m. Interval 50-52 m is a coarse sandstone with walty sulfur water.
22/20-17bcb	1,457	4,567	"Leadville"	4,526-4,570	265	1,484	Salty sulfur water	1,798	9	Saltwater had a chloride concentration of 144,000 p/m.
23/13-7ad	2,008	676	"Leadville"	327-336	60	-----	Mud	0.3	0	-----
			"Leadville"	399-445	45	1,658	Mud	12	0	-----
3/14-11aaa	1,335	2,210	Hermosa	1,687-1,714	30	1,365	Mud Black salty sulfur water	96 1,565	16	Chloride concentration of 20,000 p/m.
			Paradox	1,862-1,714	30	-----	Slightly water- and gas-cut mud	8	*	-----
23/14-19ddd	1,334	1,847	Moenkopi	710-723	60	-----	Mud	1	0	-----
			Paradox	1,622-1,631	30	-255	Mud	1	0	-----
23/15-21bac	1,429	2,348	"Leadville"	2,286-2,348	182	1,407	Slightly salty water	988	5	See Feltis (1966, p. 54) for chemical analysis.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
23/16-3bcd	1,231	2,880	"Leadville"	2,600-2,656	60	1,405	Mud-cut saltwater Saltwater	351 610	17	See Feltis (1966, p. 54) for chemical analysis.
23/16-15dca	1,237	2,573	"Leadville"	2,502-2,573	60	1,316	Mud Saltwater	198 2,112	30	See Feltis (1966, p. 54) for chemical analysis.
23/17-9csc	1,360	2,764	Paradox	2,665-2,708	120	-292	Highly gas and water-cut mud	305	*	-----
			"Leadville"	2,724-2,754	20	1,417	Highly gas and saltwater cut mud Slightly mud-cut saltwater Very slightly mud-cut saltwater	73 59 27	*	-----
23/17-11cdb	1,310	2,947	Hermosa	1,287-1,295	61	51	Mud	8	0	-----
			"Leadville"	2,938-2,947	120	1,416	Saltwater	2,326	129	-----
23/17-15cbc	1,305	2,904	"Leadville"	2,607-2,628	240	1,423	Highly gas-cut mud Highly gas, saltwater-cut mud Highly gas-cut saltwater	143 101 18	*	Gas mostly nitrogen.
			"Leadville"	2,630-2,645	95	1,400	Black-salty condensate-cut water Condensate	18 101	*	-----
			"Leadville"	2,645-2,672	125	1,403	Highly oil-cut mud Oil Highly gas-cut emulsion Saltwater	204 566 215 186	17	See Faltis (1966, p. 54) for chemical analysis.
			"Leadville"	2,672-2,695	90	1,498	Saltwater-cut mud Mud-cut saltwater Saltwater	85 113 2,301	70	-----
23/17-16adc	1,383	-----	"Leadville"	2,722-2,725	---	-----	-----	-----	---	Flow in open hole.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
23/17-16bdd	1,369	2,716	"Leadville"	2,680-2,699	107	1,399	Mud (1,590 L) with oil trace	---	*	-----
			"Leadville"	2,709-2,716	180	1,387	Gas and oil	---	---	-----
23/17-16cdd	1,337	2,680	"Leadville"	2,675-2,676	---	-----	Flowed oil and water	---	---	Test through perforated casing.
			"Leadville"	2,677-2,680	---	-----	Flowed oil and water	---	---	Test through perforated casing. Saltwater disposal well.
23/17-16dac	1,352	2,714	"Leadville"	2,646-2,687	90	1,391	Oil	3	*	-----
			"Leadville"	2,687-2,700	180	1,288	Oil Saltwater-cut oil	1,189 27	31	-----
			"Leadville"	2,700-2,709	120	1,394	Saltwater-cut mud Saltwater	86 1,590	88	-----
23/17-17adc	1,323	2,705	Hermosa	1,600-1,635	60	-136	Drilling mud	46	0	-----
			"Leadville"	2,678-2,705	70	1,219	Muddy water	152	5	-----
23/17-17daa	1,323	2,648	"Leadville"	2,630-2,648	60	1,393	Oil Saltwater	1 3	*	-----
			"Leadville"	2,654-2,657	---	-----	Acid-water with scum of oil	---	---	Test through perforated casing Flowed, well acidized, swabbed.
			"Leadville"	2,665-2,666	---	-----	Saltwater	---	---	Test through perforated casing. Swab test.
23/17-21ddc	1,261	2,704	"Leadville"	2,681-2,704	---	-----	Saltwater	1,829	---	-----
23/18-21bbc	1,379	3,149	Paradox	1,847-1,869	120	1,536	Saltwater-cut mud (636 L) Saltwater (1,230 L)	--- ---	---	No freshwater sandstones encountered in this well.
			Paradox	2,340-2,382	120	47	-----	0	0	-----
			"Leadville"	3,051-3,063	120	1,724	Black sulfur water	14	*	-----
			"Leadville"	3,121-3,149	120	1,501	Black sulfur water	37	*	-----
23/19-18ddd	1,463	280	Dakota	130- ---	---	-----	-----	---	---	Freshwater sandstone at 130 m.
			Dakota	183- ---	---	-----	-----	---	---	Saltwater encountered at 183 m.
			Morrison	265- ---	---	-----	-----	---	---	Saltwater encountered at 265 m. Show of oil at 277 m.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
23/19-31ccc	1,497	810	Cutler	727-736	60	1,326	Muddy water Water	149 437	65	-----
23/19-36dad	1,368	2,063	Chinle-Moenkopi	1,077-1,176	765	1,160	Drilling fluid and saltwater	932	*	-----
			Cutler	1,621-1,649	201	998	Saltwater	503	5	-----
23/20-6ccc	1,473	945	Chinle	549-572	60	-----	Drilling mud	2	0	-----
			Moenkopi	683-707	60	829	Drilling mud	2	0	-----
			Paradox	887-905	60	-----	Drilling mud	1	0	-----
23/21-2ddc	1,407	1,216	Morrison	0-73	---	-----	Salty water	---	---	Test through perforated casing. Freshwater at 278 m in Navajo and at 448 m in Wingate.
			Navajo	73-278	---	-----	Salty water	---	---	Test through perforated casing.
			Kayenta-Wingate	278-554	---	-----	Fresh to salty water	---	---	Test through perforated casing.
23/21-5dcd	1,435	2,823	Paradox	2,424-2,442	130	-----	-----	---	0	Caprock of Paradox showed no porosity.
24/13-2cab	1,380	1,623	Moenkopi	465-472	60	1,477	Water-cut mud Heavy black oil	34 53	8	See Feltis (1966, p. 54) for chemical analysis.
			Moenkopi	551-568	120	1,023	Heavy-oil cut mud	57	*	-----
			Moenkopi	572-592	60	879	Drilling mud	115	0	-----
			Moenkopi	592-604	90	1,421	Black sulfur water Drilling mud	470 29	26	See Feltis (1966, p. 54) for chemical analysis.
			Moenkopi	622-629	120	1,321	Black sulfur water	373	27	See Feltis (1966, p. 54) for chemical analysis.
			Cutler	683-696	120	1,358	Mud Sulfur water	27 597	23	-----
24/13-11adb	1,445	1,287	Moenkopi	637-658	45	863	-----	---	---	-----
			Cutler	746-748	30	711	-----	---	---	-----
			Hermosa	1,163-1,179	60	1,350	Water	861	54	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
24/13-32bb	1,479	686	Navajo	27-209	---	-----	-----	---	---	Top part of Navajo Sandstone produced freshwater at depth 27-209 m. Yield was over 32,000 L/h while drilling with air.
24/14-10aad	1,317	2,220	Moenkopi	657-694	60	1,299	Mud	53	0	-----
			Hermosa	1,404-1,421	60	1,017	Saltwater-cut mud	59	*	-----
			"Leadville"	1,865-1,936	120	1,425	Slightly mud-cut water Saltwater	466 839	9	-----
24/14-21dab	1,317	2,333	Moenkopi	644-713	90	1,426	Mud Mud-cut water Salty water	55 192 226	4	See Feltis (1966, p. 54) for chemical analysis.
			Hermosa	1,440-1,475	60	1,006	Very slightly oil-cut mud	24	*	-----
			"Leadville"	2,205-2,215	60	1,348	Mud	107	0	-----
			"Leadville"	2,195-2,240	240	1,366	Water-cut mud Muddy water Salty water	32 488 1,582	12	-----
			Hermosa	1,439-1,484	120	1,215	Mud	1,080	0	-----
			Moenkopi	658-663	240	1,323	Mud-cut water Black sulfur water	54 413	23	-----
24/15-5caa	1,315	2,183	Moenkopi	677-699	45	-----	Oil-cut mud	18	*	-----
			Moenkopi	718-735	55	-----	Drilling fluid	5	0	-----
			Hermosa	1,103-1,133	60	-----	Saltwater with sour gas	549	27	-----
			Paradox	1,381-1,404	120	1,266	Drilling fluid	23	0	-----
			Paradox	1,472-1,488	120	971	Gas-cut mud Water-cut mud Saltwater	30 27 116	4	-----
			Paradox	1,551-1,555	60	-----	Drilling mud	9	0	-----
			Paradox	1,720-1,745	105	-278	Gas-cut mud	137	*	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
24/16-19bda	1,455	2,645	Moenkopi	702-732	90	1,326	Slightly oil- and gas-cut mud	59	*	-----
			"Leadville"	2,429-2,459	90	1,340	Salt water with hydrogen sulfide odor	2,103	47	See Feltis (1966, p. 54) for chemical analysis.
24/17-1cac	1,365	2,786	Hermosa	1,205-1,220	60	492	Mud (480 L)	---	0	No freshwater sandstones encountered.
24/19-22daa	1,457	2,387	Moenkopi	509-525	90	1,293	Mud	28	0	-----
			Hermosa	990-1,011	150	1,355	Mud-cut weter	857	16	-----
			Hermosa	1,031-1,037	90	-----	-----	0	0	-----
			Hermosa	1,316-1,322	60	1,341	Mud-cut water	2	*	-----
			Paradox	1,349-1,355	120	1,314	Gas-cut mud Gas- and oil-cut mud Gas- and oil-cut water	57 75 47	4	-----
			Paradox	1,349-1,364	120	1,017	Mud Oil-cut mud Gas- and oil-cut water	44 37 55	2	-----
			Paradox	1,371-1,378	120	104	Mud	1	0	-----
			Paradox	1,410-1,417	90	-----	Mud	2	0	-----
24/20-12aca	1,417	1,707	Moenkopi	1,429-1,443	70	47	Drilling mud	5	0	-----
24/20-36dcd	1,355	2,296	Entrada	45-195	---	-----	Freshwater	---	---	Pumping test.
			Navajo	195-387	---	-----	Freshwater	---	---	Pumping test.
			Navajo, Kayenta	387-487	---	-----	Freshwater	---	---	Pumping test.
			Kayenta, Wingate, and Chinle	487-709	---	-----	Freshwater	---	---	Pumping test.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
24/20-36dcd (continued)	1,355	2,296	Chinle	709-767	---	-----	Freshwater	---	---	Pumping test.
			Chinle, Moenkopi	767-937	---	-----	Freshwater	---	---	Pumping test.
			Monkopi, Chinle, and Hermosa	937-2,180	---	-----	Freshwater	---	---	Pumping test.
			Paradox	2,190-2,296	---	-----	Very-salty water	---	---	Pumping test. Full hole of salty water.
			Hermosa	2,196-2,232	60	1,470	Mud	46	0	-----
24/23-13acd	1,392	4,362	"Leadville"	3,947-4,008	50	1,207	{Mud {Saltwater	6} .3}	*	-----
25/12-34cc	1,572	1,831	Moenkopi	747-755	60	925	Very slight gas-cut Mud	29	*	-----
			Moenkopi	757-774	30	-----	Drilling mud	9	0	-----
			Hermosa	1,155-1,173	60	-----	Drilling mud	2	0	-----
			Paradox	1,444-1,460	90	-----	Drilling mud	56	0	-----
			Paradox	1,458-1,520	90	-----	{Mud {Water	91} 1,021}	11	-----
			Paradox	1,554-1,583	90	874	Drilling mud	175	0	-----
			Paradox	1,588-1,622	60	796	Drilling mud	9	0	-----
			"Leadville"	1,660-1,672	60	879	Water-cut mud	61	*	-----
			"Leadville"	1,705-1,743	30	1,273	Saltwater	631	17	-----
			Ouray	1,764-1,831	30	1,284	Water	884	26	-----
25/13-14bb	1,493	2,229	-----	472-503	75	1,407	{Water-cut drilling mud {Sulfur water	168} 165}	4	-----
			-----	599-618	60	1,015	Drilling mud with black oil globules on surface	9	*	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Amount (meters)	Rate (meters per hour per meter)	Remarks
25/13-14bb (continued)	1,493	2,229	Cutler	663-678	60	1,309	Drilling mud with oil globules Sulfur water	55 416	28	-----
			Cutler	899-924	60	600	Drilling mud	1	0	-----
			"Leadville"	1,194-1,222	120	569	Drilling mud	38	0	-----
			Elbert	1,423-1,445	155	1,314	Inert gas and muddy water	67	1	-----
			Elbert	1,449-1,489	63	555	Drilling mud	5	0	-----
25/14-22cdd	1,457	2,137	Moenkopi	527-558	165	-----	Mud with oil specks	2	*	-----
			Cutler	617-625	60	1,321	Salty water	27	3	-----
			Rico	1,093-1,146	60	451	Mud Heavy black oil	24 6	*	-----
			Rico	1,146-1,178	60	-----	Mud	3	0	-----
			Molas	1,274-1,310	60	-----	Mud	6	0	-----
			"Leadville"	1,339-1,353	60	927	Mud	3	0	-----
			"Leadville"	1,425-1,457	60	1,213	Water-cut mud	110	*	-----
			Elbert	1,628-1,780	60	1,323	Saline water	1,341	9	-----
25/15-15ab	1,516	1,972	Hermosa	1,469-1,480	60	1,257	Water	88	8	See Feltis (1966, p. 54) for chemical analysis.
			Hermosa	1,817-1,836	40	-272	Mud	3	0	-----
			"Leadville"	1,899-1,972	60	1,338	Saltwwater	1,695	23	-----
25/15-22ac	1,471	1,950	Hermoss	1,460-1,504	120	1,154	Mud-cut sulfur water Sulfur water	5 123	1	See Feltis (1966, p. 54) for chemical analysis of water from intervals: 1,324-1,331 m (Hermosa), 1,509-1,543 m(Paradox), 1,855-1,896 m (Leadville).

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery			Remarks
							Fluid	Amount (meters)	Rate (meters per hour per meter)	
25/15-22ac (continued)	1,471	1,950	Psrsdox	1,509-1,540	120	1,411	Mud-cut sulfur wster Slightly gas-cut sulfur water	18 229	4	-----
			Paradox	1,545-1,567	120	-----	Mud-cut sulfur water Highly gas-cut sulfur water	27 158	4	-----
25/15-32ca	1,559	1,781	Moenkopi	594-622	60	-----	Drilling fluid	30	0	See Feltis (1966, p. 54) for chemical analysis of water from 207-219 m (Navajo Sandstone).
			Cutler	698-706	120	1,318	Water-cut drilling fluid	83	*	-----
			Hermosa	1,209-1,216	150	-----	Drilling mud	62	0	-----
			Hermosa	1,424-1,430	90	-----	Drilling fluid	1	0	Reported depth to water was 198 m in 1956.
			Paradox	1,459-1,471	120	-----	Drilling fluid	6	0	-----
			Paradox	1,556-1,580	210	74	Heavy gas-cut mud	60	*	-----
			Hermosa	1,664-1,694	120	458	Oily, slightly gassy mud	95	*	-----
			Hermosa	1,683-1,707	240	1,297	Drilling fluid top 246 m Watery, slightly gassy drilling fluid, with slight scum of oil Slightly gassy black sulfur water with trace of oil	246 757 774	8	-----
			"Leadville"	1,716-1,781	76	1,376	Drilling fluid Watery drilling fluid Muddy sulfur water	1,431 251 1,180	14	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
25/16-10ba	1,448	2,253	"Leadville"	2,103-2,162	---	-----	Muddy saltwater Saltwater	448 1,340	---	See Feltis (1966, p. 54) for chemical analysis of water.
			Molas	2,057-2,075	120	1,184	Muddy saltwater	101	3	-----
25/16-29cdb	1,482	2,042	Hermosa	1,366-1,380	90	1,217	Mud	101	0	-----
			Molas	1,899-1,921	120	-385	Mud with briny oil	9	*	-----
			"Lesdville"	1,975-2,010	60	1,363	Watery mud Muddy water Black sulfur water	55 274 1,387	47	See Feltis (1966, p. 54) for chemical analysis of water.
25/17-20dab	1,408	2,202	Rico	717-731	60	1,282	Water-cut mud	15	*	-----
			Hermosa	1,077-1,088	60	1,189	Mud	12	0	-----
			Paradox	1,554-1,564	45	23	Slightly water-cut mud	55	*	-----
			"Leadville"	1,850-1,892	120	896	Slightly gas- and water-cut mud	113	*	-----
			"Leadville"	1,939-1,946	60	1,333	Mud Muddy water Saltwater	15 137 1,564	243	See Feltis (1966, p. 54) for chemical analysis of water.
25/18-20adb	1,562	2,395	Paradox	1,466-1,476	125	1,006	Mud	46	0	No freshwwater encountered.
25/18-21bca	1,576	2,096	Hermosa	1,151-1,156	---	-----	Saltwater	---	---	-----
			Hermosa	1,227-1,240	---	-----	Saltwater	---	---	-----
			Paradox	1,451-1,458	240	822	Saltwater (2.2 L)	---	*	-----
			Paradox	1,609-1,625	360	1,314	Gas-cut mud (320 L)	---	*	-----
			Paradox	2,041-2,054	---	-----	Oil	---	---	-----
			Paradox	2,044-2,047	150	3,147	Slightly gas-cut water Water (640 L)	--- ---	---	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rste (meters per hour per meter)	Remarks
25/18-29cb	1,625	567	White Rim	440-523	---	-----	Freshwater	---	---	See Feltis (1966, p. 54) for chemical analysis.
25/18-35cac	1,673	2,481	"Leadville"	2,435-2,465	120	1,348	Saltwater	---	---	Freshwater encountered in well.
25/19-26add	1,662	2,705	Cutler	632- ---	---	-----	-----	---	---	Sodium chloride = 40,000 p/m.
			Paradox	1,943-1,960	60	282	Oil- and gas-cut mud	152	*	-----
			Paradox	2,243-2,302	120	-206	Very slightly gas-cut mud	82	*	-----
			Paradox	2,370-2,395	60	188	-----	---	---	-----
			Paradox	2,485-2,526	---	409	{Oil, gas, and mud-cut water Oil- and gas-cut mud}	61 30	---	-----
			"Leadville"	2,610-2,674	120	1,340	Oil- and gas-cut mud	1,100	*	-----
25/19-27dba	1,760	2,232	Paradox	2,191-2,213	30	-----	Water-cut mud	55	*	See Feltis (1966, p. 59) for chemical analysis.
25/19-27db	1,757	2,208	Paradox	1,984-2,035	60	13	Mud	110	0	-----
25/19-27db	1,760	2,326	Paradox	2,198-2,210	---	-----	-----	---	---	Test through perforated casing. Flowed.
			"Leadville"	2,268-2,281	90	1,362	Black sulfur water	---	---	-----
			"Leadville"	2,284-2,296	30	1,368	Black sulfur water	---	---	Gas, nonflammable.
			"Leadville"	2,303-2,316	60	1,348	Oil	204	16	-----
			"Leadville"	2,317-2,326	60	-----	Slightly salty sulfur water	990	110	See Feltis (1966, p. 56) for chemical analysis.
25/21-18cbc	1,322	2,872	Paradox	2,318-2,320	75	1,803	Oil	226	90	-----
			Paradox	2,320-2,332	---	1,800	Oil and oil with gas-cut mud	226	---	-----
			Paradox	2,321-2,323	---	586	{Oil Oil with gas-cut mud}	172 287	---	-----
			Paradox	2,331-2,340	---	-----	{Heavy oil snd gas-cut mud Oil}	171 1,289	---	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
25/21-18cbc	1,322	2,872	Paradox	2,338-2,340	90	-----	Mud	46	0	-----
(continued)			Paradox	2,339-2,340	90	-----	Mud	64	0	-----
			Paradox	2,339-2,340	75	-----	Oil-, gas-, and water-cut mud Oil and water Saltwater	27 110 146	205	-----
			Paradox	2,345-2,346	100	-822	Gas-cut mud	---	*	-----
			Paradox	2,345-2,346	40	-----	Mud	23	0	-----
			Paradox	2,349-2,350	45	-865	Gas-cut mud	122	*	-----
			Paradox	2,349-2,350	---	-----	Mud Oil Oil- and gas-cut mud Water	372 305 82 55	---	-----
			Paradox	2,349-2,350	105	488	Mud Gas- and oil-cut mud Saltwater Foam	195 84 82 82	47	-----
25/21-20cad	-----	6	-----	-----	---	-----	-----	---	---	Water well.
26/13-25cbc	1,650	1,945	Hermosa	1,538-1,565	240	1,343	Water-cut mud Mud-cut water	293 236	2	-----
			Hermosa	1,569-1,591	240	1,312	Mud-cut water Freshwater with sulfur odor Freshwater with strong sulfur odor	91 1,103 585	20	-----
			"Leadville"	1,689-1,719	180	1,331	Saltwater-cut mud Mud-cut saltwater Salty sulfur water	142 198 828	11	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
26/13-35	1,723	1,841	Moenkopi	671-687	90	1,411	Mud	67	0	-----
			Moenkopi	799-821	120	1,315	Mud	79	0	-----
			Cutler	1,135-1,173	120	1,284	Drilling mud Slightly water-cut drilling mud	198 30	*	-----
			"Leadville"	1,811-1,841	90	1,425	Slightly muddy sulfur water Salty sulfur water	262 900	26	-----
26/14-7bb	1,561	1,753	Moenkopi	616-688	120	1,058	Mud	6	0	-----
			"Leadville"	1,713-1,753	30	1,314	Mud-cut sulfur water Salty sulfur water	55 791	42	See Feltis (1966, p. 56) for chemical analysis.
26/14-26ddb	1,721	2,042	Hermosa	1,620-1,641	60	171	Very slightly gas-cut mud with rainbow of oil	5	*	-----
			Paradox	1,825-1,880	60	-27	Very slightly gas-cut mud with rainbow of oil	15	*	-----
			"Leadville"	1,981-2,042	120	1,399	Muddy salty water Slightly salty sulfur water	247 1,292	13	-----
26/14-30ccc	1,638	1,831	Moenkopi	706-732	120	965	Mud	4	0	-----
			Paradox	1,689-1,736	120	1,269	Mud	37	0	-----
			"Leadville"	1,786-1,831	120	1,326	Slightly mud-cut water	1,106	12	-----
26/16-31ccc	1,568	1,524	Wingate	--- -291	---	-----	Freshwater	---	---	-----
			Cutler	778-847	---	-----	Slightly saline water	---	---	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
26/17-5ccc	1,540	1,981	Paradox	1,812-1,817	20	-65	Drilling mud with trace of oil	15	*	-----
			"Leadville"	1,911-1,935	63	1,319	Saltwater	3	*	-----
			"Leadville"	1,911-1,935	60	1,330	Sulfur saltwater	8	*	-----
			"Leadville"	1,911-1,935	60	1,309	Sulfur saltwater	24	1	-----
			"Leadville"	1,935-1,954	105	1,305	Water	137	4	See Feltis (1966, p. 56) for chemical anslysis.
			"Leadville"	1,954-1,971	60	1,263	Sulfur saltwater	713	42	See Feltis (1966, p. 56) for chemical analysis.
26/18-7dac	1,547	2,220	Paradox	1,685-1,706	45	-103	Slightly gas-cut mud with slight show of oil	34	*	-----
			"Leadville"	2,081-2,124	60	989	Gas-cut and slightly oil-cut mud	210	*	-----
			"Leadville"	2,127-2,160	60	1,283	{Mud-cut sulfur water {Black sulfur water	91} 1,707}	54	See Feltis (1966, p. 56) for chemical analysis.
26/19-11bbd	1,841	2,503	Paradox	2,263-2,293	60	-----	Mud	1,106	0	-----
			"Leadville"	2,402-2,413	120	-350	Saltwater	262	12	-----
			"Leadville"	2,403-2,410	---	-----	Saltwater	500	---	-----
			"Leadville"	2,452-2,478	---	-----	Water	---	---	-----
			"Leadville"	2,452-2,455	240	-----	Saltwater	1,829	152	-----
26/19-11dcd	1,872	2,457	Paradox	1,908-1,911	---	-----	Saltwater with small amount of oil	---	---	Test through perforated casing. Flowed.
			"Leadville"	2,382-2,392	240	1,160	{Oil-cut mud {Oil	76} 664}	17	Test through perforated casing.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery			Remarks
							Fluid	Amount (meters)	Rate (meters per hour per meter)	
26/19-11dcd (continued)	1,872	2,457	"Leadville"	2,398-2,434	120	1,301	Drilling fluid Heavy saltwater- and gas-cut mud Slightly muddy saltwater Salty sulfur water	1,241 104 98 942	14	-----
26/19-14acc	1,864	2,380	Hermosa	1,510-1,532	60	389	Slightly saltwater cut mud	28	*	-----
			Hermosa	1,917-1,922	60	-39	Very slightly water-cut mud	2	*	-----
			"Leadville"	2,351-2,363	90	-417	Very slightly oil- and gas-cut mud	15	*	-----
			"Leadville"	2,363-2,380	120	1,329	Gas-cut oil Gas-cut oil with some dark-green emulsion	280 430	21	-----
26/19-14dcd	1,839	1,896	Paradox	1,910-1,912	120	3,142	Slightly oil- and gas-cut muddy saltwater Gas-cut saltwater	152 177	82	-----
			Leadville"	2,282-2,296	120	-----	Black sulfur water- and gas-cut mud	55	*	-----
			"Leadville"	2,300-2,327	90	1,318	-----	0	0	-----
			"Leadville"	2,327-2,354	---	-----	-----	---	---	Bleeding oil, gas and saltwater from core vugs and fractures.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
26/19-14dcd	1,839	1,896	"Leadville"	2,339-2,357	120	1,222	Highly gas-cut mud	18	4	-----
							Very highly gas-cut and highly oil-cut mud	192		
							Very highly oil- and gas-cut mud	55		
							Gas-cut light-green oil with high percent black sulfur	137		
			"Leadville"	2,357-2,370	120	1,222	Gas-cut and slightly oil-cut mud	82	20	-----
							Highly gas-cut and oil-cut mud	137		
							Highly gas- and oil-cut mud	55		
							Highly gas-cut and highly oil-cut water	55		
							Highly gas-and water-cut oil	82		
							Black sulfur water	393		
26/19-23aad	1,828	2,621	"Leadville"	2,351-2,355	---	-----	Oil	---	---	Test through perforated casing.
26/19-23aba	1,834	2,049	Paradox	1,311-1,564	30	765	Mud	82	0	-----
			Paradox	1,561-1,628	30	498	Mud	15	0	-----
			Paradox	1,626-1,800	75	2,127	Mud	91	0	-----
			Paradox	1,627-1,683	60	1,595	Mud	15	0	-----
			Paradox	1,683-1,721	60	270	Mud	12	0	-----
			Paradox	1,720-1,748	60	419	Mud	12	0	-----
			Paradox	1,748-1,800	60	279	Mud	21	0	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
26/19-23aba	1,834	2,049	Paradox	1,800-1,865	60	945	-----	0	0	-----
(continued)			Paradox	1,865-1,894	60	116	Mud	18	0	-----
			Paradox	1,894-1,914	40	38	Mud	12	0	-----
			Paradox	1,914-1,969	60	89	Mud	12	0	-----
			Paradox	1,969-2,049	60	410	Mud	30	0	-----
26/20-6bdc	1,782	2,376	Paradox	2,347-2,376	180	-301	Slightly gas-cut mud	30	*	-----
26/20-8dda	1,836	2,463	Paradox	1,234-1,261	60	964	Gas-cut muddy, watery oil	82	3	-----
			Paradox	2,204-2,219	90	-5	Gas-cut mud	14	*	-----
26/20-9bdd	1,769	2,479	-----	-----	---	-----	-----	---	---	-----
			Paradox	1,831- ---	---	-----	Flowed saltwater	---	---	Show of gas at 1,841 m, 1,951-1,952 m and 2,033-2,034 m in core.
			"Leadville"	2,318-2,340	120	1,405	Sulfur water with trace of oil	12	*	-----
			"Leadville"	2,349-2,367	120	-385	Sulfur-water-cut mud	34	*	-----
			Elbert	2,414-2,422	80	1,341	Salty water	1,426	*	-----
26/20-9ddd	1,785	2,375	Paradox	2,035-2,038	---	-----	-----	---	---	Teat through perforated casing. Flowed
26/20-14bd	1,325	2,452	Paradox	2,003-2,030	60	-618	Water	18	*	-----
			"Leadville"	2,437-2,452	60	1,342	Salty sulfur water	853	57	-----
26/20-29cbc	1,809	2,621	Paradox	1,829-1,841	---	-----	Freshwater Gas- and oil-cut mud Saltwater-cut mud	--- --- ---	---	Flowed.
			Paradox	1,830-1,842	65	401	Saltwater with trace of oil	---	---	-----
			Paradox	1,879-1,891	---	-----	-----	0	0	-----
			Paradox	1,879-2,128	---	-----	-----	0	0	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
26/20-29cbc	1,809	2,621	Paradox	1,896-1,908	---	-----	-----	0	0	-----
(continued)			Paradox	1,960-1,972	---	-----	-----	0	0	-----
			Paradox	1,960-2,128	---	-----	-----	0	0	-----
			"Leadville"	2,061-2,074	131	2,117	Light-green oil Gas-cut saltwater	222 609	29	-----
			"Leadville"	2,301-2,324	90	-474	Mud	2	0	-----
			"Leadville"	2,326-2,339	240	823	Oil- and gas-cut mud	99	*	-----
			"Leadville"	2,341-2,347	240	1,286	Saltwater and gas-cut mud Salty sulfur water	509 549	23	-----
26/20-30bba	1,819	2,034	Paradox	1,940-1,971	30	20	Mud	14	0	-----
26/20-31bbb	1,820	2,338	Hermosa	1,276-1,277	120	1,260	Water-cut mud Saltwater	256 33	17	-----
			Paradox	1,840-1,845	170	2,392	Gas-cut saltwater	1,804	127	-----
			"Leadville"	2,234-2,262	173	152	Slightly gas- and water-cut mud Black salty sulfur water	276 248	3	-----
			"Leadville"	2,277-2,292	140	208	Water-cut mud Black sulfur water	76 549	16	-----
			"Leadville"	2,299-2,311	65	1,363	Water-cut mud Salty black sulfur water	634 997	77	-----
			"Leadville"	2,314-2,338	70	1,369	Drilling fluid Sulfur-water cut mud Salty black sulfur water	49 114 1,602	57	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
26/20-36daa	1,279	2,440	Paradox	1,040-1,063	90	305	Very slightly gas-cut mud	8	*	-----
			Paradox	1,378-1,397	180	1,409	Very highly oil- and gas-cut mud Oil	238 27	*	-----
			Paradox	1,980-2,017	90	-525	Mud	18	0	-----
			Paradox	2,015-2,033	60	-595	Mud	21	0	-----
26/20-36dbc	1,328	2,047	"Leadville"	1,858-2,051	110	-104	Oil	2,051	6	-----
			"Leadville"	2,032-2,049	---	-----	-----	---	---	Test through perforated casing. Flowed.
26/21-31ccb	1,205	1,725	Paradox	-----	---	-----	-----	---	---	Water from 615-619 m.
27/14-5bca	1,743	1,811	Chinle	653-688	180	-----	Mud-cut water	155	1	-----
			Moenkopi	747-800	180	1,165	Mud	30	0	-----
			Moenkopi	834-846	120	1,296	Salty water-cut mud	55	*	-----
			Paradox	1,415-1,473	120	-----	Slightly gas-cut drilling fluid	12	*	-----
			Paradox	1,484-1,551	180	1,105	Slightly gas-cut mud Slightly oil-cut mud	85 27	*	-----
			Paradox	1,550-1,568	120	1,005	Slightly water-cut mud	15	*	-----
			Paradox	1,567-1,604	240	1,059	Mud-cut water	155	1	-----
			"Leadville"	1,618-1,695	120	1,074	Drilling fluid Water	43 9	*	-----
27/14-13dd	1,713	1,737	Paradox	1,670-1,713	120	96	Mud	3	0	-----
27/14-17cc	1,699	1,988	Moenkopi	751-782	120	1,109	Mud	12	0	-----
			White Rim	832-861	85	1,285	Muddy freshwater	413	10	-----
			-----	1,496-1,510	72	918	Mud	5	0	Upper Pennsylvanian.
			-----	1,784-1,811	78	424	Mud	6	0	Upper Pennsylvanian.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
27/14-31dbd	1,598	1,705	Paradox	1,640-1,692	60	66	Mud	110	0	-----
27/15-32ad	1,715	2,468	Moenkopi	643-693	60	1,088	Mud	1	0	-----
			Moenkopi	710-721	90	1,293	Muddy freshwater	198	12	-----
			White Rim	1,798-1,826	60	-----	{Mud {Salty water	30} 1,372}	49	-----
			McCracken	1,984-2,065	60	1,309	Salty water	1,161	14	-----
27/15-35bc	1,681	1,687	Moenkopi	446-476	120	1,275	Drilling fluid	9	0	-----
			Moenkopi	532-593	120	1,301	Drilling fluid	59	0	Lost circulation at 818 m.
			Cutler	981-992	120	971	Drilling fluid	41	0	-----
			Hermosa	1,077-1,093	240	1,234	Drilling fluid	84	0	-----
			Hermosa	1,193-1,204	120	512	Drilling fluid	5	0	-----
			Paradox	1,402-1,426	240	-----	Drilling fluid	4	0	-----
			Paradox	1,526-1,576	240	1,140	Gas-cut drilling fluid	131	*	-----
			"Leadville"	1,576-1,649	120	1,301	{Drilling fluid {Salty water	219} 940}	6	-----
27/16-16a	1,707	1,582	-----	386-405	---	-----	Water	---	---	Good water zone from 399-404 m.
			-----	870-879	---	-----	Water	---	---	Good water zone.
			-----	1,455-1,457	---	-----	Water	---	---	Good water zone.
			-----	1,518-1,573	---	-----	Water	---	---	Good water zone.
27/16-33acb	1,744	2,124	Moenkopi	549-604	30	1,266	Mud	3	0	-----
			"Leadville"	1,768-1,796	30	152	Mud	15	0	-----
			"Leadville"	1,796-1,827	40	1,203	{Salty muddy water {Salty water	177} 1,113}	62	See Feltis (1966, p. 56) for chemical analysis.
27/18-26baa	1,747	2,013	Paradox	1,576-1,594	75	283	Drilling mud	5	0	-----
			Paradox	1,637-1,650	20	524	Gas-cut mud	55	*	-----
			"Leadville"	1,908-1,951	150	1,305	Black salty sulfur water	648	6	See Feltis (1966, p. 56) for chemical analysis.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
27/19-3abc	1,769	2,458	Hermosa	1,228-1,250	45	927	Oil- and gas-cut mud	46	*	-----
			Paradox	1,329-1,353	60	475	Saltwater with trace of gas	5	*	-----
27/19-27cac	1,869	2,358	Paradox	1,585-1,643	45	379	Drilling fluid	6	0	-----
			Paradox	1,586-1,614	30	385	Drilling mud	6	0	-----
			Paradox	1,859-1,917	75	304	Frothy drilling mud	37	0	-----
			Paradox	1,859-1,917	50	200	Frothy drilling mud	43	0	-----
			Paradox	2,128-2,148	90	-78	Slightly oil- and gas-cut mud	18	*	Shut in pressure still increasing after end of test.
			"Pinkerton Trail"	2,220-2,241	30	-341	-----	0	0	Test may have been a misrun.
			"Leadville"	2,314-2,330	90	1,076	{Gas-cut salty water {Black sulfur water	158} 61}	9	-----
			"Leadville"	2,330-2,358	60	1,508	Black sulfur and salty water	1,463	52	-----
27/20-3bcc	1,334	1,890	Paradox	1,867-1,889	60	-473	Mud	32	0	-----
27/20-6cac	1,353	2,174	Leadville	1,899-1,916	45	1,342	Saltwater	1,814	142	-----
27/20-9aac	1,275	1,864	Paradox	1,760-1,790	60	-327	Mud	18	0	-----
27/20-32aaa	1,841	1,341	Molas	1,198-1,241	180	715	Mud	3	0	-----
			"Leadville"	1,329-1,341	90	1,146	Water	518	29	-----
27/21-1dbd	1,483	2,040	"Leadville"	1,862-1,937	45	1,398	{Drilling mud {Salty sulfur water	168} 1,372}	24	-----
			McCracken	2,015-2,042	30	310	Drilling mud	3	0	-----
27/21-3cdc	1,298	-----	-----	591-611	120	-----	Sulfur water	449	11	-----
			-----	1,355-1,404	120	-----	Very slightly gas-cut drilling mud	37	*	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
27/21-3cdc	1,298	-----	-----	1,477-1,497	120	-----	Gas pockets in mud Very highly gas-cut drilling mud Highly gas-cut drilling mud	61 205 179	*	No show of oil or water.
			-----	1,875-1,912	---	-----	Slightly gas-cut drilling mud Highly water-cut drilling mud Saltwater with sulfur odor	110 82 1,518	---	See Feltis (1966, p. 56) for chemical analysis.
27/21-5acc	-----	1,073	-----	472-475	---	-----	Water	---	---	-----
			-----	536-538	---	-----	Water	---	---	-----
28/12-32da	1,393	769	Cutler	710-735	60	1,242	Slightly water-cut mud	166	*	-----
			Cutler	710-743	120	1,576	Mud-cut water	606	9	-----
			Cutler	745-754	30	1,275	Black sulfur water	540	120	-----
28/14-14cca	1,724	2,126	Leadville	2,072-2,126	60	1,227	Muddy saltwater	537	10	-----
28/18-12bad	1,834	1,984	Hermosa	992-1,026	60	1,552	Very-slightly gas-cut mud	18	*	-----
			Hermosa	1,082-1,132	75	1,427	Slightly gas-cut mud	24	*	-----
			Paradox	1,506-1,535	100	469	Gas-cut mud	23	*	-----
			"Leadville"	1,679-1,704	180	1,323	Salty black sulfur water	960	13	See Feltis (1966, p. 58) for chemical analysis.
			"Leadville"	1,723-1,775	110	1,398	Water	1,097	12	See Feltis (1966, p. 58) for chemical analysis.
			Ouray	1,873-1,899	90	1,069	Mud	27	0	-----
			Elbert	1,917-1,942	60	1,524	Mud	128	0	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
28/18-12bad (continued)	1,834	1,984	McCracken	1,948-1,984	150	1,089	Water-cut mud Salty black water	67 610	7	-----
			-----	1,970-1,984	---	-----	-----	---	---	See Feltis (1966, p. 58) for chemical analysis. Cambrian system.
28/19-18dcb	1,909	2,192	"Leadville"	1,901-1,928	180	1,253	Water-cut mud (640 L) Saltwater (640 L)	--- 307	4	See Feltis (1966, p. 58) for chemical analysis.
			"Leadville"	1,932-1,971	120	1,338	Water-cut mud Black sulfur water	116 981	13	-----
28/20-22ccb	1,380	1,885	Paradox	1,452-1,468	120	-----	Mud	10	0	-----
			"Leadville"	1,561-1,591	120	1,339	Water-cut mud Slightly salty water	192 1,207	20	-----
			Elbert	1,809-1,826	210	1,368	Muddy water Saltwater	375 1,193	26	-----
28/20-23ddd	1,398	1,716	Hermosa	705-722	60	781	Slightly gas-cut mud	3	*	-----
			"Leadville"	1,426-1,436	90	1,279	Mud-cut salty sulfur water Salty sulfur water	366 671	69	-----
			McCracken	1,661-1,711	150	1,290	Salty sulfur water	1,058	8	-----
29/13-1abd	1,602	1,952	Wingate	270-368	---	-----	Water	---	---	Water zone.
			Wingate	318-319	---	-----	Water	---	---	Water zone.
			Wingate	326-328	---	-----	Water	---	---	Water zone.
			Wingate	333-335	---	-----	Water	---	---	Water zone.
			Wingate	336-367	---	-----	Water	---	---	Water zone.
			White Rim	621-1,053	---	-----	Water	---	---	Water zone.
29/15-20ad	1,901	2,099	Moenkopi	672-698	60	-----	Mud	9	0	-----
			"Leadville"	2,038-2,087	120	1,579	Muddy water Black sulfur water	274 207	5	See Feltis (1966, p. 58) for chemical analysis.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
29/20-4cba	1,398	1,547	"Leadville"	1,278-1,292	120	1,231	Water-cut mud	73	*	No gas.
			"Leadville"	1,280-1,311	60	1,060	Water-cut mud	70	*	-----
			"Leadville"	1,321-1,324	240	1,276	Black sulfur water	1,137	95	-----
			"Leadville"	1,495-1,547	60	1,253	Water-cut mud	61	*	-----
30/12-19bbb	1,490	1,837	Moenkopi	826-845	65	-----	Drilling mud	1	0	-----
			Moenkopi	845-869	63	-----	Drilling mud	1	0	-----
			Moenkopi	871-882	63	-----	Clean drilling mud	1	0	-----
			White Rim	884-894	135	1,241	Drilling mud Muddy water Slightly salty water 1.0 Kg/L	27 82 489	25	-----
			White Rim	887-033	---	-----	Slightly salty water, sulfur odor	---	---	-----
			Cutler	1,089-1,109	240	-----	Drilling mud Slightly muddy water, 1.0 Kg/L	55 526	7	-----
			Cutler	1,097-1,341	---	-----	Saltwater with slight sulfur odor	---	---	Chloride concentration of 1,450 p/m.
			Cutler	1,381-1,396	240	912	Viscous mud Water-cut mud Muddy water	9 52 43	*	-----
			Hermosa	1,423-1,430	---	1,108	Very-salty water	---	---	Chloride concentration of 30,880 p/m.
			Hermosa	1,424-1,425	30	1,107	Oil Water	--- ---	---	-----
			Hermosa	1,424-1,426	---	-----	Freshwater (5,000 L) with thin scum of oil	---	---	Swab test.

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery: Fluid	Fluid recovery: Amount (meters)	Fluid recovery: Rate (meters per hour per meter)	Remarks
30/12-19bbb	1,490	1,837	Hermosa	1,483-1,494	67	795	Drilling mud	3	0	-----
			Hermosa	1,525-1,536	240	1,295	Slightly water-cut mud	398	4	-----
			Hermosa	1,625-1,626	---	-----	Mud-cut water Salty water (53,000 L)	197 ---	---	Swab test.
			Hermosa	1,625-1,631	---	1,131	Salty water	---	---	Chloride concentration of 7,614 p/m.
			"Leadville"	1,768-1,837	---	1,229	Salty water	---	---	Chloride concentration of 12,000 p/m.
			"Leadville"	1,804-1,837	85	1,193	Drilling mud Slightly salty drilling mud Salty drilling mud Salty water	29 143 115 1,145	24	-----
30/13-4dca	1,613	1,868	Moenkopi	610-619	60	1,564	Mud	14	0	-----
			Moenkopi	647-658	60	990	Mud	3	0	-----
			White Rim	669-683	60	1,231	Mud Water	86 198	14	-----
			Paradox	1,448-1,473	60	276	Mud	8	0	-----
			Paradox	1,603-1,623	60	53	Mud	6	0	-----
			"Pinkerton Trail"	1,689-1,710	120	1,222	Mud Muddy water Water	91 172 964	27	-----
			"Leadville"	1,796-1,811	60	1,104	Mud	9	0	-----
			"Leadville"	1,842-1,868	60	1,264	Mud-cut water Water	332 1,122	56	-----

Table 15.--*Results of deep well tests in the Green River-Moab area*--Continued

Location	Altitude (meters)	Depth (meters)	Rock unit tested	Test interval (meters)	Test duration (minutes)	Fresh-water head (meters)	Fluid recovery			Remarks
							Fluid	Amount (meters)	Rate (meters per hour per meter)	
30/13-26db	1,695	1,281	Hermosa	1,088-1,097	120	1,546	Drilling mud	75	0	-----
			Hermosa	1,227-1,231	240	1,077	{Drilling mud Dark salty sulfur water}	12 43	3	-----
30/13-35ddc	1,554	1,084	Moenkopi	366-369	---	-----	-----	---	---	Important water zone.
			Cutler	643-649	---	-----	-----	---	---	Important water zone.
			Hermosa	887-890	---	-----	-----	---	---	Important water zone.
30/14-15ddc	1,669	1,370	Moenkopi	480-490	60	1,312	Mud	5	0	-----
			Moenkopi	501-512	90	1,217	Mud	3	0	-----
30/16-15abc	2,024	526	Moenkopi	524-525	---	-----	-----	---	---	Freshwater.
31/13-10ccc	1,273	1,234	White Rim	186-298	---	-----	-----	---	---	Freshwater.
			Cutler	357-617	---	-----	-----	---	---	Freshwater.
31/15-19bdb	1,478	1,312	Paradox	865-873	120	1,126	Slightly mud-cut water	82	5	See Feltis (1966, p. 58) for chemical analysis.
			Hermosa	972-997	120	524	Drilling mud	3	0	-----
			"Leadville"	1,195-1,234	120	1,159	Water-cut drilling mud	94	*	-----

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