APPENDIX A

UNITED STATES GEOLOGICAL SURVEY REPORT

Rulison-5

USGS-474-68

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Federal Center, Denver, Colorado 80225

GEOHYDROLOGY - PROJECT RULISON, GARFIELD COUNTY, COLORADO

with a section on

Aquifer Response

March 1970

Open-file report

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U.S. Atomic Energy Commission

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Rulison-5
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UNITED STATES
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GEOHYDROLOGY - PROJECT RULISON, GARFIELD COUNTY, COLORADO

By

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with a section on Aquifer Response

By

E. H. Cordes

ABSTRACT

The Project Rulison nuclear experiment of 40^{+20}_{-4} kilotons yield was detonated at a depth of 8,425 feet below ground level at the Rulison site in Garfield County, Colorado, September 10, 1969. The experiment was designed to stimulate natural gas production from a gas-bearing formation of low permeability.

All zones below a depth of 6,129 feet in the Rulison exploratory hole that yielded any water during drilling, or zones interpreted from geophysical logs as being likely to contain water, were hydraulically tested. The pressures recorded during the drill-stem tests of the different zones indicated negligible or no fluid entry to the hole. No fluid was recovered on any of the swab tests performed during the drill-stem tests.

Studies of preshot and postshot hydrologic conditions indicate that the detonation did not significantly or permanently affect wells, springs, streams, shallow aquifers, or reservoirs in or near the Rulison site.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the help of personnel of the Austral Oil Company and CER Geonuclear Corporation, who provided data on the Rulison exploratory hole. The preshot investigation of wells and springs and operation of the stream-gaging stations in the project area was by the Colorado District, Water Resources Division, U.S. Geological Survey. Much of the information in this report was drawn from previous Geological Survey reports listed in the references at the end of this report.

INTRODUCTION

Historical Description of the Rulison Event[1/]

"Project Rulison is a joint experiment sponsored by Austral Oil Company Incorporated, Houston, Texas, the U.S. Atomic Energy Commission and the Department of the Interior, with the Program Management provided by CER Geonuclear Corporation of Las Vegas, Nevada, under contract to Austral. Its purpose is to study the economic and technical feasibility of using underground nuclear explosions to stimulate production of natural gas from the low-productivity, gas-bearing Mesaverde Formation in the Rulison Field.

"The nuclear explosive for Project Rulison was detonated successfully at 3:00 p.m. plus 0.11 seconds Mountain Daylight Time, September 10, 1969, at a depth of 8,425.5 feet below ground level and was completely contained. Preliminary results indicate that the Rulison device behaved about as expected; i.e., with a yield of 40^{+20}_{-4} kt. The wellhead of the emplacement well, Hayward 25-95A, is at an elevation of 8,154 feet above mean sea level (msl) and is located 1,976.31 feet east of west line and 1,813.19 feet north of south line of Section 25, Township 7 South, Range 95 West of 6th P.M., Garfield County, Colorado, which corresponds to geodetic coordinates of longitude 107°56'53" West and latitude 39°24'21" North."

1/ This statement is the official description provided by the U.S. Atomic Energy Commission after the event.

Objectives

In connection with evaluating the hydrologic effects of the detonation at and near the Project Rulison site, the U.S. Geological Survey, on behalf of the U.S. Atomic Energy Commission, performed the following work: (1) provided hydraulic data from the Rulison exploratory hole (hole R-EX); (2) inventoried, examined, and collected water samples from all wells and springs within a 10-kilometer (6.2-mile) radius, and from selected wells and springs within a 20-kilometer (12.4-mile) radius of the emplacement hole before the explosion; (3) collected water samples from 21 surface-water sampling points in and near the Rulison site before and after the explosion and chemically analyzed them; (4) monitored fluctuations of water levels in wells and of discharge of Battlement Creek during and following the shot; and (5) investigated hydrologic features or hydraulic structures that may have been damaged as a result of the nuclear detonation. Field work for this report was terminated when the investigations of damage complaints were completed and a set of postshot samples of water were collected from streams and analyzed.

Background

Geologic setting

The Project Rulison site is on the southwest limb of the Piceance Creek basin, a large northwest-trending structural downwarp in northwestern Colorado. Beds penetrated by the exploratory and emplacement hole dip northeastward at 2° or less.

The northern part of the Piceance Creek structural basin is drained by the White River; the southern part of the basin is drained by the Colorado River. The drainage in the vicinity of the Rulison site is northward to the Colorado River.

The rocks underlying the Rulison site range in age from Quaternary to Precambrian. Marine and nonmarine sedimentary rocks, approximately 18,000 feet thick, underlie the site. Formations below the Mesaverde Group of Late Cretaceous age, the deepest formations penetrated by the exploratory and emplacement holes, are not described in this report. Diagrammatic geologic sections through the Rulison project area, showing the major geologic formations, are given on figure 1 (in pocket).

The drilling of the exploratory and emplacement holes at the Rulison site penetrated the following formations, in descending order: alluvium of Quaternary age, Green River and Wasatch Formations of Eocene age, an unnamed unit of Paleocene age (probably correlative with the Fort Union Formation of the northern Rocky Mountain region, as described by Donnell, 1961, p. 844), Ohio Creek Formation of Paleocene(?) age, and Mesaverde Group of Late Cretaceous age. The Mesaverde Group is of special interest because the nuclear device was detonated within this group. Descriptions of the formations in and near the test site follow:

Quaternary deposits.--The Quaternary deposits include mudflows, talus accumulations, fan and pediment gravel, slump blocks, and the alluvium of Battlement Creek and the Colorado River. These deposits generally range in thickness from 20 to 40 feet, but locally they may be more than 100 feet thick (Yeend, 1969). Ground water occurs in many of these deposits.

Green River Formation.--In and near the Rulison site the Green Rive Formation contains four members. In descending order, the members are Evacuation Creek, Parachute Creek, Garden Gulch, and Douglas Creek. At the Rulison site, the Green River Formation is about 1,700 feet thick. The formation is composed chiefly of shale and marlstone, with minor amounts of sandstone, siltstone, and limestone. Sandy zones in the lower part of the formation may be capable of yielding minor quantities of ground water at some locations in the area.

Wasatch Formation.--The Wasatch Formation consists principally of brightly colored clay and shale, but sandstone lenses are common. Locally, minor amounts of conglomerate, pebbly sandstone, limestone, coal, and black carbonaceous shale occur in the formation. The formation is approximately 3,900 feet thick at the Rulison site. The lower boundary has not been defined because the lower part of the Wasatch grades into the underlying unnamed unit of Paleocene age. The thickness of the formation is greater than 3,900 feet if a thickness of less than 500 feet is selected for the underlying unnamed unit. The Wasatch generally is not a source of ground water in the Rulison area.

Unnamed unit of Paleocene age.--The unnamed unit of Paleocene age consists of sandstone, shale, and a few thin beds of coal. The thickness of the unit probably is less than 500 feet. The unit is not known to yield water in the vicinity of the Rulison site.

Ohio Creek Formation.--The Ohio Creek Formation is approximately 37 feet thick in hole R-EX. Thicknesses of as much as 76 feet have been penetrated in drill holes at other places in the vicinity of the Rulison site. The Ohio Creek Formation consists primarily of conglomerate, sandstone, and siltstone. In some of the gas wells in the vicinity of the Rulison site, the Ohio Creek Formation has produced sufficient water to prevent air drilling of the formation; in other wells, there was no water entry and air drilling was possible.

Mesaverde Group.--The Mesaverde Group under the test site consists mainly of sandstone and interbedded shale approximately 2,500 feet thick. The sediments were deposited in a near-shore environment that included marine, flood-plain, and coastal-swamp conditions, which resulted in lateral and vertical differences in lithology. The sandstone layers are lenticular and many of them extend for distances of only a few thousand feet. The Mesaverde Group reportedly does not yield water in the vicinity of the Rulison site.

Hydrologic setting

Battlement Creek (fig. 2), a tributary of the Colorado River, drains the Rulison site and extends from Battlement Mesa to the Colorado River. Part of the water in Battlement Creek is diverted for irrigation on alluvial slopes downstream from the Rulison site and part infiltrates the stream alluvium and terrace deposits. The underflow in the alluvium appears as springs at several places downstream from the Rulison site. A Geological Survey gaging station on Battlement Creek,

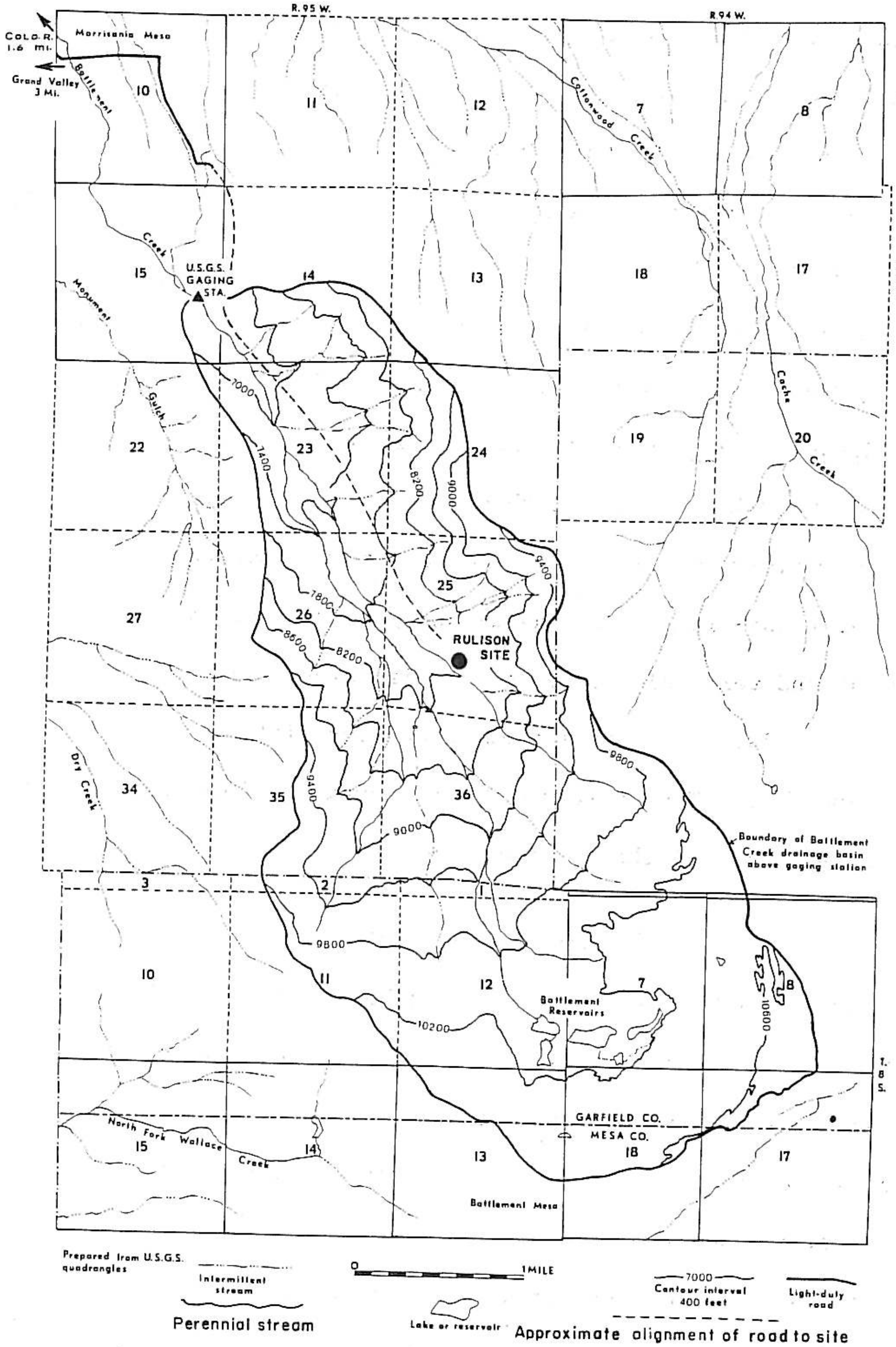


FIGURE 2.--Hydrologic and topographic features upstream from the former U.S.Geological Survey gaging station, Battlement Creek.

about 4 kilometers (2½ miles) downstream from the Rulison site, was in operation from October 1956 to September 1965 and from March to October 1969. The monthly and annual runoff during the period October 1956 to September 1965 is presented in table 1. The daily discharge in cfs (cubic feet per second) for the last full year of operation (the 1965 water year) is listed in table 2. The monthly and annual runoff of the Colorado River at the Geological Survey station near Cameo, about 40 kilometers (25 miles) downstream from the confluence of Battlement Creek, is presented in table 3. These streamflow records show the volume of surface flow from and past the Rulison area.

The ground-water resources in the Rulison area are confined primarily to surficial deposits (e.g., flood-plain deposits and terrace and fan gravel). Essentially all the wells and most of the springs in the area derive their water from these deposits. The underlying bedrock formations generally have low permeability and yield little or no water.

Table 1.--Monthly and annual runoff of Battlement Creek near Grand Valley, Colorado, October 1956 to September 1965

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1956	--	--	--	--	--	--	--	--	--	100	95	86	--
1957	86	83	90	206	1,180	4,090	2,510	556	446	466	299	172	10,180
1958	111	78	123	314	2,810	2,990	926	382	217	218	182	120	8,470
1959	98	99	97	159	831	833	364	251	168	168	102	86	3,260
1960	74	75	101	315	1,160	1,750	445	206	132	206	158	110	4,730
1961	49	56	86	156	1,080	1,220	346	165	273	286	230	151	4,100
1962	97	103	119	634	2,000	2,560	1,070	350	192	196	145	118	7,580
1963	109	119	122	250	917	543	219	294	219	209	180	142	3,320
1964	138	83	80	169	1,730	2,270	632	289	161	167	143	138	6,000
1965	119	79	99	172	1,070	2,790	1,160	508	369	--	--	--	--
Ave.	98	86	102	264	1,420	2,120	852	333	242	224	170	125	6,030

Station number.--9-926.

Location of gaging station.--Lat 39°26'10" N., long 107°58'40" W., in NE¼SE¼ sec. 15, T. 7 S., R. 95 W., 4.0 kilometers (2½ miles) downstream from Project Rulison site.

Drainage area.--10.5 sq mi.

Runoff.--Units are acre-feet; data are from U.S. Geological Survey publications.

Average discharge.--9 years, 8.34 cfs (cubic feet per second).

Maximum discharge.--102 cfs June 7, 1957.

Table 2.--Daily discharge of Battlement Creek near Grand Valley, Colorado, October 1964 to September 1965

BATTLEMENT CREEK BASIN

9-926. Battlement Creek near Grand Valley, Colo.

Location.--Lat 39°26'10", long 107°58'40", in NE¼SE¼ sec.15, T.7 S., R.95 W., on left bank 300 ft downstream from ford, 4½ miles upstream from mouth, and 5 miles southeast of Grand Valley.

Drainage area.--10.5 sq mi.

Records available.--October 1956 to September 1965 (discontinued).

Gage.--Water-stage recorder and concrete control. Altitude of gage is 6,630 ft (from topographic map).

Average discharge.--9 years, 8.34 cfs (6,040 acre-ft per year). 1/

Extremes.--Maximum discharge during year, 63 cfs June 16 (gage height, 2.54 ft); minimum daily, 1.2 cfs Feb. 12-14.
1956-65: Maximum discharge, 102 cfs June 7, 1957 (gage height, 2.79 ft); maximum gage height, 2.96 ft May 26, 1958 (backwater from debris); minimum discharge not determined.

Remarks.--Records good except those for periods of ice effect or no gage-height record, which are poor. Slight regulation by Battlement Reservoir. No diversion above station.

Rating table, except periods of ice effect (gage height, in feet, and discharge, in cubic feet per second)

1.4	1.0	2.1	15
1.6	3.1	2.2	19
1.8	5.7	2.4	37
1.9	8.2	2.6	68

Discharge, in cubic feet per second, water year October 1964 to September 1965

Day	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1	1.8	2.4	2.4	2.4	1.6	1.4	2.8	10	25	30	11	6.4
2	1.9	* 2.6	2.4	2.4	1.6	1.4	2.7	13	25	28	* 12	6.2
3	2.0	2.4	2.3	2.4	1.6	1.4	2.1	* 13	25	25	12	6.4
4	2.1	2.2	2.3	2.3	1.6	1.4	1.9	13	28	25	11	6.2
5	2.3	2.2	2.2	2.2	* 1.6	* 1.6	* 1.6	12	29	25	11	7.2
6	2.3	2.2	2.2	2.2	1.6	1.6	1.6	11	33	24	9.8	7.4
7	2.6	2.2	2.2	2.2	1.6	1.6	1.7	9.8	* 43	23	9.2	6.7
8	2.8	2.2	2.2	2.1	1.5	1.6	1.7	9.8	48	22	8.9	6.7
9	2.9	2.2	2.4	2.1	1.5	1.6	1.8	8.5	48	21	8.5	6.4
10	3.1	2.3	2.4	2.1	1.4	1.6	1.7	8.0	48	21	8.5	6.2
11	3.3	2.1	2.3	2.1	1.4	1.6	1.6	8.2	47	22	8.5	5.7
12	* 3.3	2.2	2.3	2.0	1.2	1.6	1.6	10	51	* 21	8.2	5.7
13	3.3	2.4	2.2	2.0	1.2	1.6	1.6	13	51	21	8.0	5.6
14	3.3	2.4	2.2	2.0	1.2	1.6	1.4	14	56	19	8.0	5.4
15	3.2	2.4	2.2	2.0	1.4	1.6	1.6	13	58	19	7.7	5.2
16	3.0	2.4	2.4	1.9	1.4	1.6	2.0	15	61	18	7.7	5.2
17	3.0	2.4	2.2	1.9	1.4	* 1.6	2.3	* 20	60	17	8.0	5.7
18	2.9	2.4	2.0	1.9	1.4	1.6	2.2	27	58	17	8.9	7.0
19	2.9	2.6	2.2	1.9	1.4	1.4	* 3.1	29	60	17	8.2	6.7
20	2.9	2.6	2.2	1.9	1.4	1.4	4.4	27	58	17	7.7	6.2
21	2.9	2.7	2.2	1.8	1.4	1.6	4.8	30	58	17	7.2	5.7
22	2.9	2.6	2.1	1.8	1.4	1.6	4.6	33	* 58	16	7.2	6.0
23	2.9	2.6	2.7	1.6	1.3	1.7	4.6	30	58	15	7.0	5.7
24	2.9	2.4	3.0	1.6	1.3	1.6	4.5	26	58	15	6.7	6.0
25	2.8	2.6	2.4	1.6	1.3	1.4	4.4	23	58	15	6.7	6.0
26	2.8	2.6	2.1	1.6	1.3	1.6	4.2	19	54	14	6.4	6.0
27	2.8	2.6	2.2	1.4	1.3	1.7	3.9	18	47	13	6.4	6.2
28	2.4	2.4	1.8	1.6	1.4	1.7	3.6	18	40	12	6.2	6.7
29	2.3	2.4	1.6	1.6	-	1.8	4.1	18	34	11	6.4	7.0
30	2.4	* 2.4	1.8	1.6	----------	2.0	6.7	19	32	11	* 6.7	6.4
31	2.4	----------	2.6	1.8	----------	2.3	----------	22	----------	12	6.4	----------
Total	84.4	72.1	69.7	60.0	39.7	49.8	86.8	540.3	1,409	583	256.1	185.9
Mean	2.72	2.40	2.25	1.94	1.42	1.61	2.89	17.4	47.0	18.8	8.26	6.20
Ac-ft	167	143	138	119	79	99	172	1,070	2,790	1,160	508	369

Calendar year 1964:	Max 63	Min -	Mean 8.26	Ac-ft 6,000
Water year 1964-65:	Max 61	Min 1.2	Mean 9.42	Ac-ft 6,810

Peak discharge (base, 40 cfs).--June 16 (0600) 63 cfs (2.54 ft).

* Discharge measurement made on this day.
Note.--Stage-discharge relation affected by ice Nov. 4, 5, 12, 14-20, 27, Dec. 7-9, 14-20, 29-31, Jan. 1, 2, Feb. 10-17, Mar. 18-22, 24-26, Apr. 11-15. No gage-height record Jan. 21 to Feb. 5, Mar. 2-17 (stage-discharge relation affected by ice during part of periods).

1/ Cubic foot per second (cfs) is the rate of discharge of a stream whose channel is 1 square foot in cross-sectional area and whose average velocity is 1 foot per second.

Table from: Water Resources Data for Colorado, Part 1, Surface Water Records, 1965. Prepared by Colorado District office, Water Resources Division, U.S. Geological Survey.

Table 3.--Monthly and annual runoff of the Colorado River near Cameo, Colorado, January 1953 to December 1967

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1953	98,460	79,990	101,500	136,000	346,400	886,400	295,400	193,800	100,900	101,400	99,230	91,890	2,531,000
1954	94,490	81,080	94,080	136,100	295,600	204,400	145,900	105,200	102,900	125,200	98,180	81,820	1,565,000
1955	73,590	66,840	86,000	141,600	384,200	448,000	213,700	157,400	99,750	90,740	94,430	89,400	1,946,000
1956	80,830	75,310	104,100	184,400	684,900	636,800	172,800	114,800	87,630	92,850	83,460	72,790	2,391,000
1957	79,740	76,860	82,730	150,800	591,300	1,415,000	1,072,000	338,500	157,400	135,600	123,100	102,500	4,326,000
1958	91,740	94,910	122,800	171,600	847,200	808,000	192,800	108,900	103,300	99,490	93,660	86,100	2,820,000
1959	94,210	86,280	82,470	118,300	392,000	683,900	215,000	131,200	104,900	137,900	116,400	99,790	2,262,000
1960	100,000	91,660	134,700	245,900	432,200	667,900	216,800	117,000	101,800	106,500	99,000	100,000	2,413,000
1961	98,760	85,110	85,650	103,000	354,600	425,800	138,500	115,300	174,900	200,200	130,700	120,800	2,033,000
1962	114,700	135,000	160,500	512,600	892,600	882,400	544,900	185,600	120,900	172,700	147,800	115,300	3,985,000
1963	95,210	86,520	98,340	127,200	322,500	245,500	110,900	115,200	112,000	96,180	90,350	70,890	1,571,000
1964	57,820	55,040	66,660	105,300	403,400	465,400	223,200	153,000	115,700	103,500	93,900	91,400	1,934,000
1965	91,580	77,950	85,190	160,800	477,300	920,000	605,400	272,800	171,800	166,800	137,400	138,000	3,305,000
1966	114,000	98,900	132,600	141,400	373,100	276,600	157,100	118,900	101,200	108,500	92,870	85,250	1,800,000
1967	85,770	73,770	105,700	137,600	328,500	542,700	289,000	136,700	125,500	115,000	103,800	99,990	2,144,000
Ave.	91,390	84,350	102,900	171,500	475,000	633,900	306,200	157,600	118,700	123,500	107,000	96,400	2,468,000

Station number.--9-0955.

Location of gaging station.--Lat 39°14'20" N., long 108°16'00" W., in SW¼SW¼ sec. 30, T. 9 S., R. 97 W., 100 ft north of U.S. Highways 6 and 24.

Drainage area.--8,050 sq mi.

Runoff.--Units are acre-feet; data are from U.S. Geological Survey publications.

Average discharge.--35 years, 3,819 cfs (cubic feet per second), 2,765,000 acre-ft per year.

Extremes.--Maximum discharge, 36,000 cfs June 16, 1935; minimum daily discharge, 700 cfs Dec. 29, 1939.

Numbering system for hydrologic data points

The well, spring, and cistern location numbers used in tables are based on the U.S. Bureau of Land Management system of land subdivision and show the location of the site by quadrant, township, range, section, and position within the section. A graphic illustration of this method of location for a well is shown in figure 3. The first capital letter, "S", preceding the location number means that the site is located in the area governed by the sixth principal meridian. The second capital letter, "C" (also preceding the location number), indicates the quadrant of the State in which the well or spring is located. Four quadrants of the State are formed by the intersection of the base line and the principal meridian: A, indicates the northeast quadrant; B, the northwest; C, the southwest; and D, the southeast. The first numeral indicates the township; the second, the range; and the third, the section in which the well or spring is located. The letters following the section number indicate the location of the well or spring within the section. The first letter denotes the quarter section; the second, the quarter-quarter section; and the third, the quarter-quarter-quarter section. The letters are assigned within the section in a counter-clockwise direction, beginning with A in the northeast quarter. Letters are assigned within each quarter section and within each quarter-quarter section in the same manner. Where two or more locations are within the smallest subdivision, consecutive numbers, beginning with 1, are added after the letter designation in the chronological order that the wells and springs were inventoried. For example, SC6-93-16add2 indicates a well in the SE$\frac{1}{4}$SE$\frac{1}{4}$NE$\frac{1}{4}$ sec. 16, T. 6 S., R. 93 W.; the 2 following the location letters indicates that this well was the second well inventoried in the quarter-quarter-quarter section.

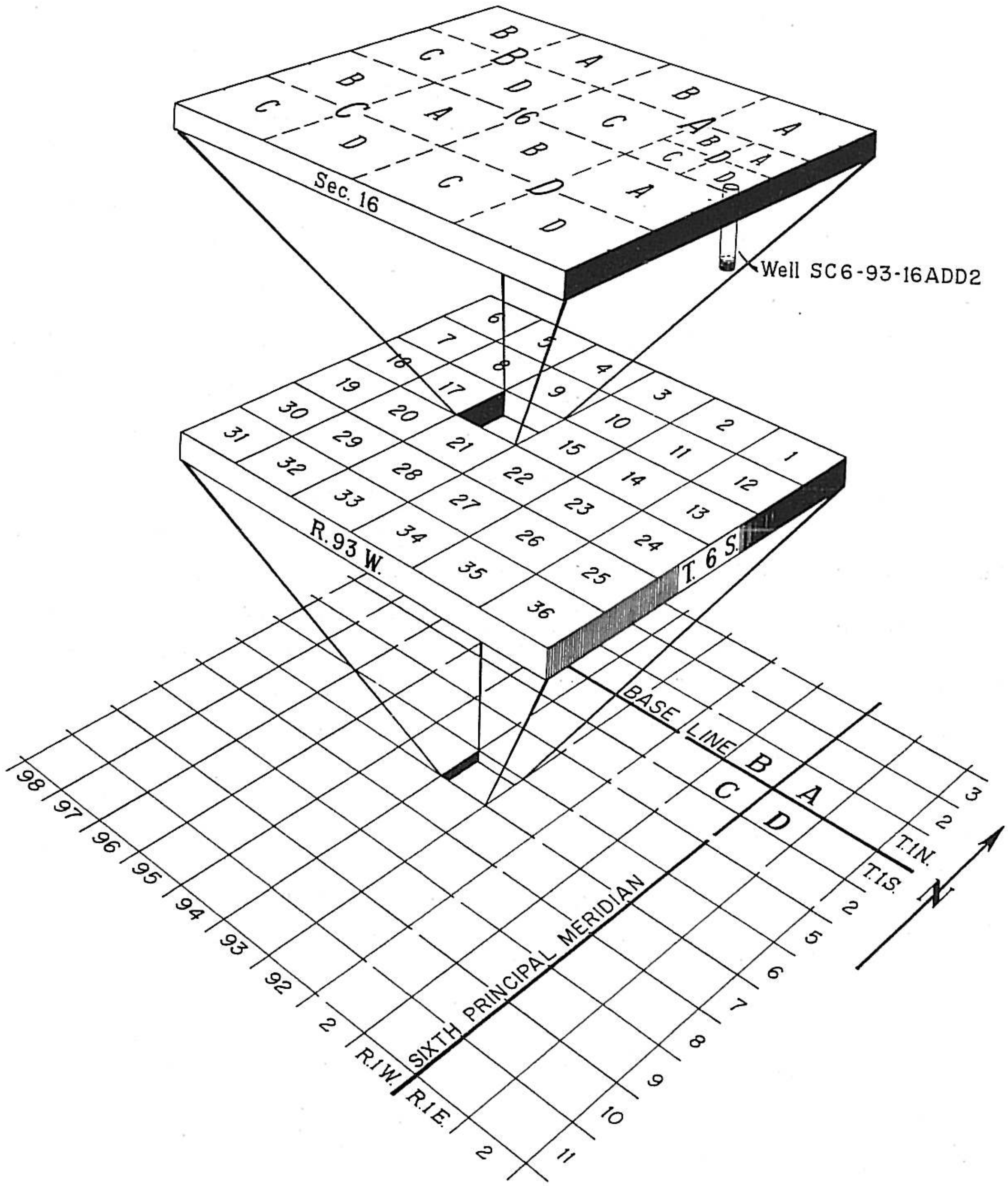


FIGURE 3.--System of numbering hydrologic data points in Colorado. (After Hurr, and others, 1969.)

PROCEDURES AND RESULTS

Preshot Hydrologic Studies

Hydraulic testing of the Rulison exploratory hole

Drilling of the Rulison exploratory hole R-EX was started November 9, 1967, and finished on March 8, 1968, after reaching a total depth of 8,500 feet below land surface. Air or air-mist was used as a drilling fluid where the rock was sufficiently dry. Mud was used as the drilling fluid in intervals where air drilling was not feasible (table 4). Small yields of water (none exceeding 4 gallons per minute) were found in part of the Green River Formation and in the upper part of the Mesaverde Group during the air drilling.

All zones in hole R-EX below the unnamed unit of Paleocene age that yielded any water during drilling, or zones interpreted from geophysical logs as being most likely to contain water, were evaluated by drill-stem testing techniques. The general procedure followed in testing was:

1. Perforate casing in the test interval.
2. Install test tool.
3. Swab test when tool was open.
4. Record pressures in the test interval.
5. Remove test tool.
6. Seal perforations with cement.

Pressures recorded during the testing of the different zones indicated negligible or no fluid entry while the test tool was open, and no fluid was recovered during the swab tests. Graphs of the pressures from the tests are shown on figures 4 and 5. Results of the tests are summarized in table 5.

Table 4.--Drilling fluids used in Exploratory Hole R-EX

Geologic unit	Approximate depth to base of unit (feet)	Drilling fluid and interval (feet)	Hydraulic test intervals (feet)
Green River Formation	1,700	Air or air-mist 0-4,013	
Wasatch Formation	5,600	Mud 4,013-6,350	
Unnamed unit of Paleocene age	6,100		6,129-6,149
Ohio Creek Formation	6,150	Air-mist 6,350-7,076	7,066-7,080
Mesaverde Group		Mud 7,076-8,500(TD)	7,196-7,198 7,312-7,320 7,598-7,604 8,014-8,018

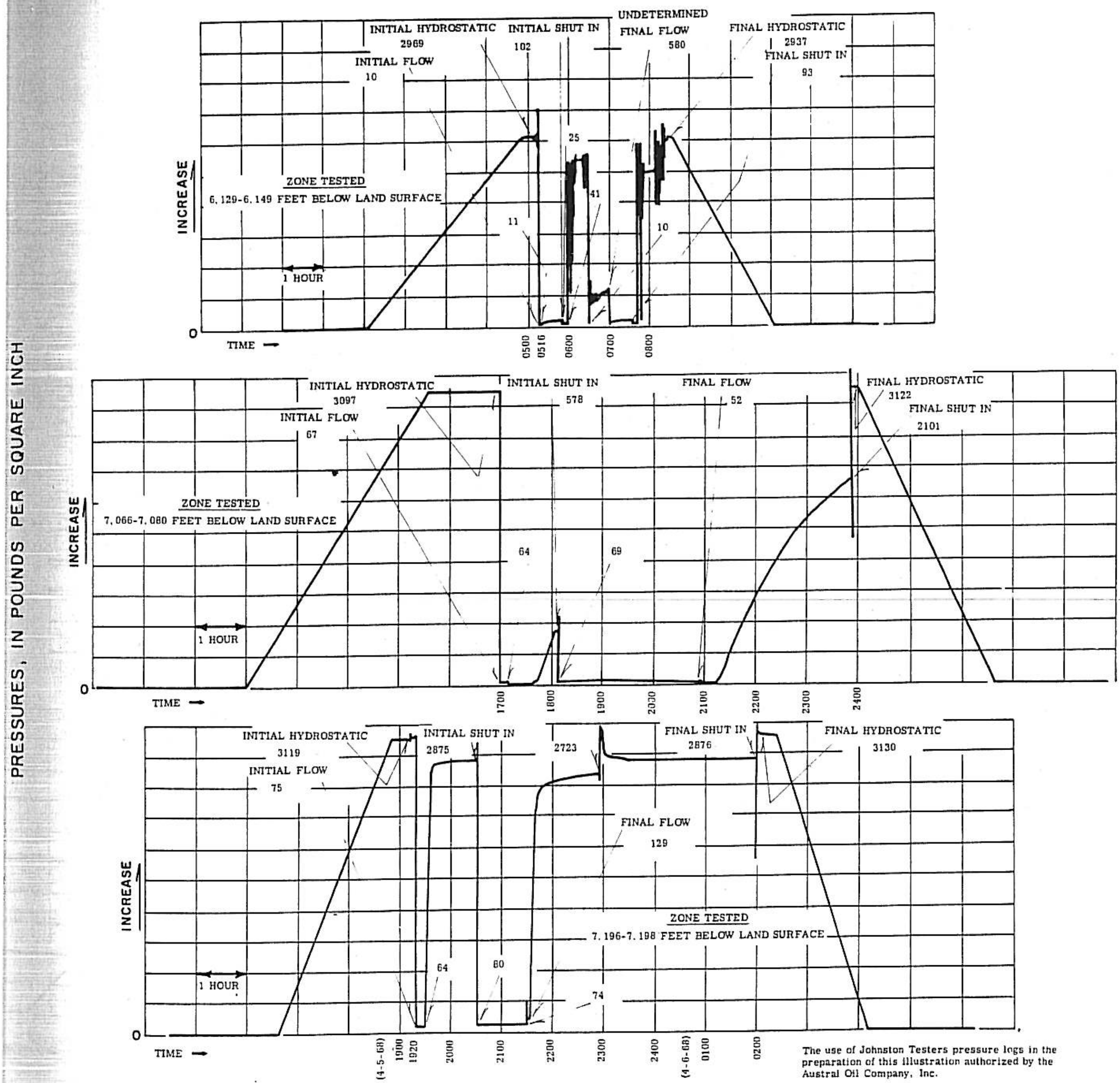
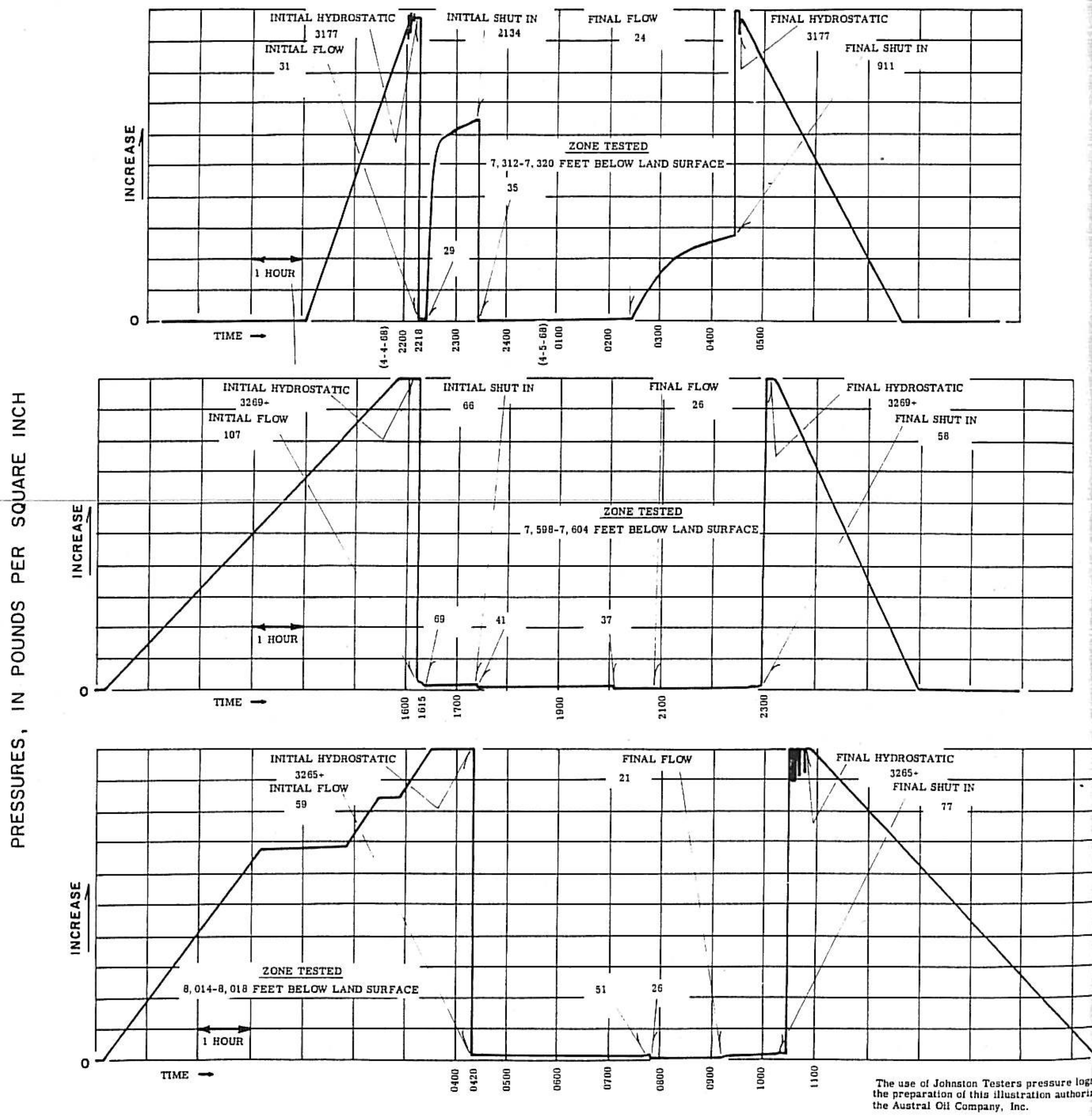


FIGURE 4.—Graphs of pressures obtained during the drill-stem tests of zones 6,129–6,149; 7,066–7,080; and 7,196–7,198 feet; hole R-EX. (After Voegeli, 1969.)



The use of Johnston Testers pressure logs in the preparation of this illustration authorized by the Austral Oil Company, Inc.

FIGURE 5.—Graphs of pressures obtained during the drill-stem tests of zones 7,312–7,320; 7,598–7,604; and 8,014–8,018 feet; hole R-EX. (After Voegeli, 1969.)

Table 5.--Summary of hydraulic tests, hole R-EX

(From Voegeli, 1969, p. 11)

Geologic formation	Depth of zone tested below land surface (ft)	Date tested	Casing size (in.)	Perfor-ations	Type of test tool	Fluid entry during time tool was open	Bottom-hole temp (°F)	Remarks
Ohio Creek Formation	6,129-6,149	1-15-68	$7\frac{5}{8}$	$\frac{3}{8}$ in. to $\frac{1}{2}$ in. 4 per ft	M.F.E.[1]	Pressure charts indicated no fluid entry.	151	Recovered about 15 gallons of drilling mud from top of test tool.
Mesaverde Group	7,066-7,080	4-8-68	$5\frac{1}{2}$	$\frac{3}{8}$ in. to $\frac{1}{2}$ in. 2 per ft	F.A.S.T.[2]	do.	196	Swabbed to 7,004 ft below land surface. No fluid recovered. Recovered about 10 gallons of fluid from top of test tool.[3]
Do.	7,196-7,198	4-5&6-68	do.	do.	do.	do.	195	Swabbed to 7,134 ft below land surface. No fluid recovered. Recovered about 240 gallons of fluid from top of test tool.[3]
Do.	7,312-7,320	4-4&5-68	do.	do.	do.	do.	196	Swabbed to 7,250 ft below land surface. No fluid recovered. Recovered about 15 gallons of fluid from top of test tool.[3]
Do.	7,598-7,604	4-3&4-68	do.	do.	do.	do.	197	Swabbed to 7,544 ft below land surface. No fluid recovered. Recovered about 20 gallons of fluid from top of test tool.[3]
Do.	8,014-8,018	3-28-68	do.	do.	do.	do.	199	Swabbed to 7,929 ft below land surface. No fluid recovered. Recovered about 30 gallons of fluid from top of test tool.[3]

1/ Johnston Testers Multi-Flow Evaluator.

2/ Johnston Testers Fracturing Acidizing Squeezing Tool.

3/ Fluid likely to have entered the tubing after the packer was pulled loose.

The most permeable interval tested, and the one that gave the best record of pressure changes, was from 7,196 to 7,198 feet. The shut-in formation pressure for this interval was 2,875 psi, which is adequate to support a column of fresh water 6,630 feet high. This indicates that the water level in a well completed in this interval would stand approximately 566 feet below land surface, if any free-moving water exists in the interval. The formation pressure for the other intervals could not be measured reliably within a reasonable length of shut-in time. The shut-in pressures measured could be due to movement of natural gas, rather than water, into the well bore.

Samples of the fluid from the tubing immediately above the test tool were collected following each test as the test tool was removed from the hole. The fluid probably entered the tubing from the well bore after the packer was released. Spectrographic, radiochemical, and chemical analyses of the fluid recovered from the tubing, as well as the water (from tributary of Battlement Creek) used in hole construction, are presented in tables 6 and 7. The high hydroxide values (125 to 334 mg/l) and high calcium ion concentrations (172 to 375 mg/l) indicate that the fluid recovered from the tubing had reacted with cement and was primarily construction water. However, the presence of some formation water cannot be ruled out in view of variations in the sulfate, chloride, and sodium ions. The tritium content of the fluid is higher than normal for most ground water in the area, which indicates that the fluid was derived at least in part from a surface source. (See tables 6, 7, and 10.)

Table 6.--Spectrographic and radiochemical analyses of fluids recovered from tubing above test tool after drill-stem tests, and of surface water used in hole construction, hole R-EX

(Analyses by U.S. Geological Survey. Date below sample number is date of collection. Unless otherwise noted, data are in micrograms per liter.)
(After Voegeli, 1969, p. 15)

Spectrographic analyses

Element	(1) 3-28-68	(2) 4-4-68	(3) 4-5-68	(4) 4-6-68	(5) 4-9-68	(6) 12-24-68
Aluminum (Al)	--	--	--	--	--	65
Barium (Ba)	720	590	390	640	210	50
Beryllium (Be)	<.4	<.3	<.4	<.4	<.2	<.2
Bismuth (Bi)	<18	<14	<17	<20	<8	<3
Boron (B)	--	--	--	--	--	70
Cadmium (Cd)	<90	<70	<85	<95	<40	<15
Chromium (Cr)	1	4	2	<1	5	1
Cobalt (Co)	<2	<2	<2	<2	<2	<2
Copper (Cu)	90	850	1,100	75	7	1
Gallium (Ga)	<10	<7	<10	<10	<4	<2
Germanium (Ge)	<12	<10	<12	<13	<5	<2
Iron (Fe)	3	170	550	10	300	90
Lanthanum (La)	<2	<2	<2	<2	<2	--
Lead (Pb)	1/11,000	1/22,000	1/35,000	1/40,000	50	<2
Molybdenum (Mo)	70	110	120	60	23	2
Nickel (Ni)	10	6	13	3	2	<2
Silver (Ag)	17	2	.7	.9	11	<.2
Strontium (Sr)	--	--	--	--	--	200
Tin (Sn)	<20	<15	<20	<20	<8	<3
Titanium (Ti)	.6	1	5	.4	2	2
Vanadium (V)	1	<1	<1	<1	3	3
Ytterbium (Yb)	<.1	<.1	<.1	<.1	<.1	--
Yttrium (Y)	<.1	<.1	<.1	<.1	<.1	--
Zinc (Zn)	--	--	--	--	--	<10
Zirconium (Zr)	<2	<2	<2	<2	<2	ND
Radiochemical analyses						
Uranium-Extractable	<.1	<.1	<.1	<.1	<.4	--
Gross beta (as Sr^{90}-Y^{90}, pc/l)	70	57	62	57	28	--
Gross alpha (as U equivalent)	<.4	9.8	<.4	6.4	<.4	--
Tritium, tritium units	<170	620	410	240	460	<350

-- Not determined.
< Less than figure shown.
1/ By atomic absorption. Samples probably contaminated by drilling mud. (See p. 20.)
ND Specifically sought, not detected.
1. Zone tested, 8,014-8,018 feet below land surface, in Mesaverde Group.
2. Zone tested, 7,598-7,604 feet below land surface, in Mesaverde Group.
3. Zone tested, 7,312-7,320 feet below land surface, in Mesaverde Group.
4. Zone tested, 7,196-7,198 feet below land surface, in Mesaverde Group.
5. Zone tested, 7,066-7,080 feet below land surface, in Mesaverde Group.
6. Stream (tributary to Battlement Creek), SW¼NE¼SW¼ sec.25, T. 7 S., R. 95 W.,Garfield County, Colo.). Source of water for well construction.

Table 7.--Chemical analyses of fluids recovered from tubing above test tool after dril stem tests, and of surface water used in hole construction, hole R-EX

(Analyses by U.S. Geological Survey. Date below sample number is date of collection Unless otherwise noted, data are in milligrams per liter.)
(After Voegeli, 1969, p. 16)

	(1) 3-28-68	(2) 4-4-68	(3) 4-5-68	(4) 4-6-68	(5) 4-9-68	(6) 12-24-68
Silica (SiO_2)	8.0	2.6	0.4	2.0	5.2	25
Aluminum (Al)	2.9	1.8	1.8	1.5	.7	<.1
Iron (Fe)	.05	.14	.10	.02	.17	.02
Manganese (Mn)	<.01	.01	.01	.01	<.01	<.01
Strontium (Sr)	3.9	3.0	3.9	2.9	.93	.22
Calcium (Ca)	237	254	316	375	172	33
Magnesium (Mg)	<.1	<.1	<.1	<.1	.1	6.4
Sodium (Na)	223	109	114	125	29	14
Potassium (K)	80	67	79	70	17	1.0
Lithium (Li)	.20	.19	.23	.21	.03	<.01
Carbonate (CO_3)	181	164	132	108	32	0
Chloride (Cl)	54	40	20	20	6.0	.8
Copper (Cu)	.11	1.4	1.0	.16	.02	.01
Fluoride (F)	1.4	3.2	3.7	2.3	1.1	.3
Hydroxide (OH)	180	141	245	334	125	--
Nitrate (NO_3)	1.8	1.3	1.1	.6	1.7	.0
Phosphate (PO_4)	.0	.0	.0	.0	.0	.00
Selenium (Se)	.06	.05	.08	.07	.01	--
Sulfate (SO_4)	196	116	112	118	41	8.0
Zinc (Zn)	.57	1.2	1.9	1.4	.12	<.01
Boron (B)	.72	.53	.48	.39	.08	.05
Dissolved solids						
Res. on evap. at 180°C	1,550	1,220	1,340	1,400	498	157
Calculated	1,170	901	1,030	1,160	431	167
Hardness as $CaCO_3$						
Total	597	638	794	940	431	109
Non-carbonate	0	0	0	0	10	0
Specific conductance						
(μmhos/cm at 25°C)	3,880	2,900	4,080	4,950	1,940	263
pH	11.9	11.8	12.0	12.1	11.7	7.5
Percent sodium	41	25	22	21	12	22
Sodium-adsorption ratio (SAR)	4.0	1.9	1.8	1.8	.6	.6

-- Not determined.

< Less than figure shown.

1. Zone tested, 8,014-8,018 feet below land surface, in Mesaverde Group.
2. Zone tested, 7,598-7,604 feet below land surface, in Mesaverde Group.
3. Zone tested, 7,312-7,320 feet below land surface, in Mesaverde Group.
4. Zone tested, 7,196-7,198 feet below land surface, in Mesaverde Group.
5. Zone tested, 7,066-7,080 feet below land surface, in Mesaverde Group.
6. Stream (tributary to Battlement Creek; SW¼NE¼SW¼ sec. 25, T. 7 S., R. 95 W., Garfi Co., Colo.). Source of water for well construction.

The pressures recorded during the drill-stem tests of the six zones indicated little or no fluid entry to the hole. Although the swab was run down the tubing to a point just above the packer during each test, no fluid was recovered during any of the tests. The lack of water inflow to the tubing during the tests, while the fluid pressures in the formations were between 2,000 and 3,000 psi greater than pressures in the tubing, indicates that the permeability of the formations is so low that movement of water in the formations is nil.

Preshot investigation of wells and springs

The purpose of the preshot investigation conducted March 20-April 3 and May 20-25, 1969, was to inventory the wells and springs, to document their condition, and to collect water samples, prior to the detonation, for chemical and radiochemical analyses. All known wells and springs within a 10-kilometer (6.2-mile) radius of the emplacement hole were inventoried, and selected wells and springs were inventoried within the 10-kilometer to 20-kilometer (12.4-mile) radius. Two wells outside of the 20-kilometer radius were also inventoried. Water samples were analyzed for pH, specific conductance, and turbidity within 36 hours of collection. Seventy-four of these partial analyses were made. Water temperature was determined at the time of collection.. Twenty-three water samples were selected for complete chemical analyses in U.S. Geological Survey laboratories, and 29 samples were selected for radiochemical analyses. The remaining samples have been stored for future use if needed.

Additional springs within the area of interest were inventoried and water samples collected a few days before the detonation. The distribution of the 113 wells and springs inventoried is shown below.

Distribution of inventoried wells and springs

Wells	Less than 10 kilometers	10 to 20 kilometers	Total
Colorado River valley	38	31	69
Plateau Creek valley	0	7	7
Total	38	38	76
Springs			
Colorado River valley	25	7	32
Plateau Creek valley	0	5	5
Total	25	12	37

Locations of these wells and springs are shown on figure 6 and listed in tables 8 (wells) and 9 (springs). Chemical and radiochemical analyses of water from selected wells, springs, and cisterns are presented in table 10.

Table 8.--Records of selected wells, Rulison project area, Garfield and Mesa Counties, Colorado

(Adapted from Hurr, and others, 1969, and Larson and Beetem, 1970.)

Location number: See text for well-numbering system.
Date of inventory: Date of inventory, water-level measurement, yield measurement.
Depth of well: Measured depths are given in feet and tenths below land surface (accuracy ± 0.5 ft); reported depths are given in feet.
Altitude of land surface: Altitude, estimated from 7½-minute quadrangle topographic maps, is given in feet above mean sea level.
Depth to water: Measured depths to water are given in feet and tenths below land surface; reported depths are given in feet below land surface. A "P" indicates pumping level at time of measurement.
Method of lift and type of power: J, jet; N, none; P, piston; S, submersible; T, turbine; E, electric motor; NG, natural gas engine.
Yield: All quantities are given in gallons per minute. R, reported; E, estimated.
Use of water: D, domestic; I, irrigation; Ind, industrial; N, none; S, stock.
Well permit number: Permit on file at State Engineer's office under this number.
Remarks: DC, depth well cased; Pf, perforated casing with interval shown; OH, open hole with interval shown.

Location number	Owner or tenant	Date of inventory	Year completed	Depth of well (feet)	Casing		Altitude of land surface (feet)	Depth to water (feet)	Method of lift and power	Yield (gallons per minute)	Use of water	Temperature of water (°C)	Turbidity (milligrams per liter)	Well permit number	Remarks
					Diameter (inches)	Type									
SC 5-92-33aac	W. Jewell	10-22-69	1962	35	6	Steel	5,690	6.5	J,E	--	D,S	--	--	P12707	Inventoried postshot.
SC 6-93-15cbd	K. Johnson	3-26-69	1941	41	--	--	5,330	25	J,E	--	D	10	1	--	Outside 20-km radius.
-16bcb	Kozy Kottage Kourt	3-27-69	1954	50	6	--	5,300	20	--	60R	D	--	--	R1198	Pump would not start.
-16cdb	J. Layne	3-27-69	1963	40	7	Steel	5,310	19	J,E	20R	D,S	--	--	P18318	Pump was not working. Owner uses city water.
-16cdd	W. Wood	3-27-69	1964	24	7	Steel	5,305	8	J,E	20R	N	--	--	P20897	
-16dcc	R. Swallow	3-27-69	1964	44	7	Steel	5,315	18	--	20R	D	--	--	PF5733	
-17bbd	W. Shafto	3-26-69	1956	38	5	Steel	5,290	18	J,E	5E	D	11	<1	N28	Problems with salt and corrosion. Well cleaned out about 1 year ago.
-18adb	A. Wooley	3-26-69	1965	42	5	Steel	5,290	31	J,E	10R	N	--	--	P25185	
-18dac	Union Carbide Corp.	3-26-69	1957	30.5	96	Steel	5,270	10.6P	T,E	1,500R	Ind	15	15	--	Two 8-inch pumps in well.
-20ccc	E. Hull	3-26-69	--	300	7	Steel	5,710	80	P,E	--	D	8	4	--	
SC 6-94-23dca	C. Saulsbury	3-24-69	1966	94	--	--	5,520	--	J,E	5E	D	10	<1	--	
-26bcc	N. Mead	3-24-69	1964	75	7	Steel	5,300	30	S,E	15R	D,S	10	<1	P19365	
-26cac	H. Boor	3-24-69	1953	210	15	Steel	5,360	88.8	T,NG	650R	I	--	--	R13852	Well number 1.
-27daa	L. Dotson	3-24-69	1962	103	6	Steel	5,300	--	P,E	--	D,S	17	2	--	Owner reports motor needs replacing.
-27dda	H. Boor	3-24-69	1953	210	15	Steel	5,340	83.6	T,NG	650R	I	--	--	R13851	Well number 2.
-30cda	E. Becktell	3-20-69	1954	140	--	--	5,280	--	S,E	--	D	5	3	--	
-31bbd	G. Ems	3-20-69	1967	105	7	Steel	5,270	65	S,E	40R	D	3	<1	--	
-31bca	R. McDaniel	3-20-69	1965	130	7	Steel	5,350	110	S,E	23R	I,D,S	3	<1	--	DC, 130 feet.
-31bcd	Seventh Day Adventist	3-20-69	1962	100	7	Steel	5,360	80	S,E	20R	D	4	3	P13564	

Table 8.--Records of selected wells, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Year com-pleted	Depth of well (feet)	Casing: Diameter (inches)	Casing: Type	Altitude of land surface (feet)	Depth to water (feet)	Method of lift and power	Yield (gallons per minute)	Use of water	Temper-ature of water (°C)	Turbid-ity (milli-grams per liter)	Well permit number	Remarks
SC 6-94-31bdc	W. Massey	3-24-69	1967	142	6	Steel	5,380	70	S,E	8R	D	11	<1	P32393	OH, 110-142 feet.
-31dac	E. Robinson	3-20-69	1964	160	7	Steel	5,600	15	E	30R	D	10	<1	--	
-31dbb	O. Gibbs	3-21-69	1969	54.0	9	Steel	5,470	22.9	N	--	N	--	--	--	New well, no pump.
SC 6-95-28cdd	O. Mahaffey	3-20-69	1963	180	5	Steel	5,485	120	S,E	2R	D	8	2	P18113	
-34cba	do.	3-24-69	1963	88.0	7	Steel	5,220	69.5	S,E	12R	S	--	--	P18114	
-35acd	W. Arnett	3-27-69	--	12.0	(48x48)	Wood	5,140	10.7	N	--	N	--	--	--	
-36adb	C. Gardner	3-26-69	--	33	7	Steel	5,220	--	J,E	5E	D	3	12	--	
-36add	R. Smith	3-24-69	1921	86	--	--	5,280	--	J,E	--	D	7	3	--	
-36dab	L. Dix	3-20-69	--	110.0	96	Concrete	5,280	44.0	J,E	--	D	8	<1	--	
SC 6-96-29daa	Sinclair Oil Co.	3-20-69	1959	40	4	Steel	5,440	20	J,E	35R	D,S	14	<1	--	
-34bda	Union Oil Co.	3-20-69	1951	88.0	8	Steel	5,445	65.9	S,E	10	S	12	<1	--	Formerly used for irrigation. Reported to yield about 250 gpm when equipped with 4-inch turbine pump.
-34bdb	do.	3-20-69	--	85.0	4	Steel	5,425	57.9	S,E	<10R	D	7	<1	--	Casing quite rusty.
-34cad	do.	3-20-69	1963	59.0	6	Steel	5,340	39.0	S,E	5E	S	9	27	P17375	
-34cbd	do.	3-20-69	--	121.4	6	Steel	5,380	61.0	J,E	--	N	--	--	--	
-34cdb	do.	3-20-69	1963	81.9	6	Steel	5,330	68.0	J,E	10E	S	11	<1	P17376	Casing rusty but pump in good condition.
SC 7-94- 6ddd	K. Bingman, Sr.	3-22-69	1945	140	7	Steel	6,480	100	P,E	--	D,S	6	1	--	
- 7bab	F. Sefcovic	3-22-69	1954	85	6	Steel	6,460	--	P,E	3R	D,S	8	<1	--	
- 7bba	J. Lemon	3-28-69	--	--	6	Steel	--	--	--	--	N	--	--	--	Pump out of hole.
SC 7-95- 2cbc	P. Baum	3-19-69	1969	295	7	Steel	5,860	130	S,E	5E	D	6	1	PF6667(?)	
- 3dcd	H. Pfost	4- 3-69	1959	125	7	Steel	5,940	--	S,E	--	N	--	--	--	Pump set at 50 feet.
- 3ddc	C. Moore	4- 3-69	1961	150	6	Steel	5,965	70	S,E	50R	I,D	--	--	PF2713	
- 4ccc	J. Savage	3-26-69	--	122.5	5	Galv. iron	5,550	120.0	S,E	--	N	--	--	--	Pump pulled.
- 7adb	J. Lawson	5-13-69	1960	100	7	Steel	5,160	30	J,E	1R	D	16	--	P5480	DC, 63 feet.
- 7dab	M. Zediker	3-24-69	1958	12.5	36	Concrete	5,120	7.8	P,E	5E	I,D	11	<1	--	
- 9adb	J. Smith	5-20-69	1968	160	7	Steel	5,920	--	N	--	N	--	--	P28859	
-10acb	L. Hayward	4- 3-69	1958	115	5	Galv. iron	6,050	90	J,E	10R	D,S	--	--	P924	
-10acc	Sorensen	5-20-69	1966	160	7	Steel	6,100	80	N	20R	N	--	--	P28863	
-10adc1	E. Schwab	4- 3-69	1955	75	--	--	6,140	32	--	--	I,D	--	--	R6280	
-10adc2	do.	5-14-69	1954	134	6	Steel	6,140	13	S,E	50R	I,D	--	--	--	
-10adc3	do.	4- 3-69	--	--	--	--	6,140	--	S,E	--	--	--	--	--	
-10bda	L. Hayward	5-14-69	1962	143	5	Steel	5,990	43	S,E	--	D	11	--	--	
-10dcd	do.	5-20-69	--	160	7	Steel	6,300	81.0	N	--	N	--	--	P28861	
-12bad	B. Smith	3-22-69	1951	80	8	Steel	6,210	--	S,E	--	D,S	12	<1	--	

Table 8.--Records of selected wells, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

	Location number	Owner or tenant	Date of inventory	Year com-pleted	Depth of well (feet)	Casing: Diameter (inches)	Casing: Type	Altitude of land surface (feet)	Depth to water (feet)	Method of lift and power	Yield (gallons per minute)	Use of water	Temper-ature of water (°C)	Turbid-ity (milli-grams per liter)	Well permit number	Remarks
SC	7-95-17aab	A. McLane	3-19-69	1966	230	5	Steel	5,660	100	S,E	3R	D	7	1	P28860	Pf, 170-220 feet; OH, 220-230 feet.
	-17aba	D. Dupice	3-19-69	1966	240	5	Steel	5,600	160	S,E	7R	D	13	10	P28862	Pf, 160-210 feet; OH, 210-240 feet.
	-18adb	R. Nordstrom	3-18-69	1949	100	7	Steel	5,380	50	S,E	8R	D	14	2	--	Owner reports water is rusty.
	-18cbb	G. Rogers	5-13-69	1960	95	7	Steel	5,110	66	S,E	30E	D	12	--	P5517	
	-18dad	M. Christianson	3-18-69	--	--	6	Steel	5,470	--	S,E	--	D	12	2	--	
	-20bba	A. Gardner	3-26-69	1957	130	6	Steel	5,510	80	S,E	10E	D,S	12	<1	--	
SC	7-96- 1ccc	Lindauer	--	--	--	--	--	5,150	--	--	--	N	--	--	--	Tenant reports that well is no good. It was drilled in too fine and clayey material.
	- 2dbb	C. Alber	3-20-69	1900	29.3	24	Rock	5,195	15.1	J,E	8R	S	--	--	N439	Motor on pump reported to have failed Dec. 1968. It has not yet been repaired.
	-12bbb	B. Lindauer	3-20-69	1948	57	6	Steel	5,140	32	J,E	10E	D	16	<1	--	
	-13abb	W. Gray	3-24-69	1964	50.7	7	Steel	5,080	34.4	J,E	--	D	--	--	P16995	
	-13abd	J. Smith	3-24-69	1959	14.6	24	Concrete	5,060	7.2	J,E	5E	D	11	11	--	
	-23cad	Mountain Corp.	3-25-69	1959	13.9	23	Oil drums	5,030	11.0	P,E	5E	D	7	1	--	
	-34bac	A. DeMaestri	--	--	--	--	--	4,995	--	--	--	N	--	--	--	
	-34bbc	do.	3-25-69	--	11.0	(24x24)	Concrete	4,995	8.9	J,E	5E	D	7	<1	--	
	-34bcd	R. Ellis	3-25-69	1961	23.2	7	Steel	4,990	9.8	J,E	5E	D	11	12	--	
	-34bdc	C. Hayward	3-25-69	1963	25.5	7	Steel	4,990	11.1	J,E	15R	D	11	37	P16997	
SC	8-96-11acc	E. Kennon	3-18-69	--	50	8	--	5,760	38	S,E	--	D,S	9	2	--	
	-11bbd	L. Knox	3-18-69	1950	10	36	None	5,600	6.0	J,E	6E	D	6	3	--	
	-12aac	N. Dutton	5-13-69	1949	165	6	Steel	6,100	134	P,E	2E	D,S	13	--	--	DC, 165 feet.
SC	8-97-14dad	O. Mahaffey	3-26-69	1964	107.0	5	Steel	5,020	66.7	S,E	8R	S	--	--	P19065	Outside 20-km radius.
SC	9-94-22acc	W. Nicoll	3-25-69	1965	290	9	Steel	6,980	100	S,E	5E	D,S	12	<1	P20032(?)	
	-22bab	W. Severson	5-15-69	1966	110	7	Steel	6,940	--	S,E	5E	D,S	10	--	--	
SC	9-95-26baa	P. Hight	5-15-69	1951	75	5	Steel	6,320	57	J,E	--	D	15	--	--	
	-34bdb	M. Campbell	3-25-69	1900	40	6	Rock	5,994	--	J,E	--	D	10	<1	--	Pump in basement of store. Well under street about 25 feet north of store.

Table 8.--Records of selected wells, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Year completed	Depth of well (feet)	Casing		Altitude of land surface (feet)	Depth to water (feet)	Method of lift and power	Yield (gallons per minute)	Use of water	Temperature of water (°C)	Turbidity (milligrams per liter)	Well permit number	Remarks
					Diameter (inches)	Type									
SC 9-95-35 abc	T. Young	5-20-69	1964	765	7	Steel	6,100	55	S,E	50E	D	--	--	PF6238	DC, 765 feet. Pf, 175-200 feet, 405-510 feet, and 565-765 feet.
SC 10-95- 2 aab	Unknown	4- 3-69	--	35	--	--	6,240	--	--	--	N	--	--	--	Pump bad. Tenant hauling water.
- 2 baa	H. Castle	4- 3-69	1964	185	5	Steel	6,245	138	J,E	12R	D	--	--	P21409	

Table 9.--Records of selected springs, Rulison project area, Garfield and Mesa Counties, Colorado

(Adapted from Hurr, and others, 1969, and Larson and Beetem, 1970.)

Location number: See text for spring-numbering system.
Date of inventory: Date of inventory and yield measurement.
Altitude of land surface: Altitude of point of discharge, estimated from 7½-minute quadrangle topographic maps, is given in feet above mean sea level.

Yield: R, reported; E, estimated.
Use of water: C, commercial; D, domestic; I, irrigation; M, municipal; S, stock.
Improvements: B, box; N, none; P, pipe; U, undetermined.
Temperature: Recorded to nearest 1°C.

Location number	Owner or tenant	Date of inventory	Altitude of land surface (feet)	Yield (gallons per minute)	Use of water	Improvements	Temperature (°C)	Turbidity (milligrams per liter)	Remarks
SC 6-93-18aac	A. Wooley	3-26-69	5,340	1E	C,D	B,P	6	<1	Spring went dry once or twice 6 or 7 years ago.
-20bdd	J. Todd, Sr.	3-26-69	5,400	--	D	U	4	>150	
SC 6-94-26aca	L. Farris	3-24-69	5,520	--	D	U	10	<1	
-26adc	H. Boor	3-24-69	5,500	12R	D	U	7	<1	
-31bbb	B. Potter	3-20-69	5,210	100E	I,D	B	13	<1	
-32cca	W. Wells	3-21-69	5,770	--	D	U	8	<1	
-33dbd	D. Winch	3-24-69	5,640	--	D	U	5	<1	
-34dcc	J. Smith	3-24-69	5,510	--	D	U	4	<1	
SC 6-95-36aab	W. Lemon	9- 5-69	5,200	--	D,I	N	13	--	
-36aabl	do	9- 5-69	5,200	--	D,I	N	13	--	
-36abd	do	9- 4-69	5,200	--	D,I	N	12	--	
-36abdl	do	9- 5-69	5,200	--	D,I	N	13	--	
-36cdd	G. Scarrow	3-21-69	5,480	--	D	U	5	3	
SC 7-94- 4acd	M. Bernklau	3-24-69	5,920	--	D	U	7	<1	
- 4bdc	C. Bernklau	3-22-69	6,040	--	D	U	5	<1	
- 6aba	E. Pettigrew	3-21-69	5,840	--	D	U	3	21	
- 6bba	M. Gerst	3-20-69	5,800	--	D,S	U	5	2	Supplies water to four houses.

Table 9.--Records of selected springs, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Altitude of land surface (feet)	Yield (gallons per minute)	Use of water	Improvements	Temperature (°C)	Turbidity (milligrams per liter)	Remarks
SC 7-95- 1aba	G. Elliott	3-21-69	5,760	--	D	U	6	<1	
- 1baa	C. Clark	3-21-69	5,680	--	D	U	4	<1	
- 2add	A. Hoagland	3-26-69	5,740	--	D	U	6	<1	
- 2bcd	E. Forshee	3-21-69	5,580	--	D,S	U	4	4	
- 3bdb	G. Knight	3-26-69	5,340	150E	I	N	--	--	Contour ditch along hillside collects water from numerous springs along 1/2 - 3/4 mile of spring line.
- 4acd	do.	3-26-69	5,340	5	D	N	9	3	
- 4add	do.	3-26-69	5,340	155	I	N	9	14	Irrigates with sprinkler.
- 4dbb	do.	3-26-69	5,340	70	I	N	10	9	
- 5dcd	Town of Grand Valley	3-21-69	5,340	125	M	B	12	<1	Twenty-one separate spring boxes collect water from numerous springs along 1/2 mile of spring line.
- 8ccb	R. Eaton	3-24-69	5,300	47	D,I,S	N	9	2	Contour ditch along hillside collects water from two separate springs.
-18aad	do.	3-25-69	5,320	85	S	N	7	9	
-18bcd	C. Gardner	3-26-69	5,120	--	S	U	9	<1	

Table 9.--Records of selected springs, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Altitude of land surface (feet)	Yield (gallons per minute)	Use of water	Improvements	Temperature (°C)	Turbidity (milligrams per liter)	Remarks
SC 7-96-33dcd	W. Hammerick	3-25-69	5,040	16	D,S	N	12	<1	
-34caa	D. Knox	3-18-69	5,080	--	D	U	10	2	
-35dcb	O. Murray	3-18-69	5,500	--	D	U	4	4	Location number is for residence.
SC 8-95-24acc	F. Wallace	9-19-69	10,200	--	--	U	7	1	Inventoried postshot.
SC 9-93-19bda	C. Bruton	9- 4-69	7,180	75E	D,S,I	B	9	--	Supplies water to two houses.
SC 9-95-26daa	City of Collbran	3-25-69	6,040	--	M	U	8	<1	
-33dba	Plateau Valley School	3-25-69	5,720	--	M	U	10	<1	
-34adb	R. Gibson	3-25-69	6,040	--	C,D	U	7	<1	Supplies a motel and the Civilian Conservation Center of the U.S. Bureau of Reclamation.
-35ddb	E. Chapman	3-25-69	6,150	--	D,S	U	2	<1	

Table 10.--Chemical analyses of water from selected wells, springs, and cisterns, Rulison project area, Garfield and Mesa Counties, Colorado.
(Adapted from Hurr and others, 1969, and Larson and Beetem, 1970.)

Location number: See text for hydrologic data point numbering system.

Location number	Well, spring, or cistern (W,S,C)	Date of collection	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Selenium (Se)	Boron (B)	Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	pH	Tritium T.U.	Gross beta in picocuries per liter (as Sr^{90}-Y^{90})	Gross alpha in micrograms per liter (as U equivalent)
SC5-92-33aac	W	10-22-69	31	<0.01	0.06	<0.01	75	91	2.30	34	0.5	<0.01	403	0	262	30	0.9	20	<0.01	0.02	0.11	<0.01	0.20	783	1,120	565	234	7.6	<220	<6.5	17
SC6-93-15cbd	W	3-26-69	--	--	.05	--	--	--	--	--	--	--	698	0	--	--	--	--	--	--	--	--	--	--	1,990	--	--	7.4	--	--	--
17bbd	W	3-26-69	--	--	.07	--	--	--	--	--	--	--	754	0	--	--	--	--	--	--	--	--	--	--	2,850	--	--	7.3	--	--	--
18aac	S	3-26-69	--	--	.04	--	--	--	--	--	--	--	532	0	--	--	--	--	--	--	--	--	--	--	2,210	--	--	7.8	--	--	--
18dac	W	3-26-69	--	--	.04	--	--	--	--	--	--	--	222	0	--	--	--	--	--	--	--	--	--	--	5,480	--	--	7.2	--	--	--
20bdd	S	3-26-69	--	--	.06	--	--	--	--	--	--	--	519	0	--	--	--	--	--	--	--	--	--	--	1,220	--	--	7.8	--	--	--
20ccc	W	3-26-69	--	--	.05	--	--	--	--	--	--	--	395	0	--	--	--	--	--	--	--	--	--	--	686	--	--	7.6	--	--	--
SC6-94-23dca	W	3-24-69	--	--	.01	--	--	--	--	--	--	--	360	0	--	--	--	--	--	--	--	--	--	--	670	--	--	7.2	--	--	--
26aca	S	3-24-69	--	--	.01	--	--	--	--	--	--	--	428	0	--	--	--	--	--	--	--	--	--	--	1,180	--	--	7.8	--	--	--
26adc	S	3-24-69	--	--	.02	--	--	--	--	--	--	--	327	0	--	--	--	--	--	--	--	--	--	--	1,010	--	--	7.7	--	--	--
26bcc	W	3-24-69	--	--	.02	--	--	--	--	--	--	--	535	0	--	--	--	--	--	--	--	--	--	--	1,160	--	--	7.5	400	6.3	6.8
27daa	W	3-24-69	--	--	.03	--	--	--	--	--	--	--	703	0	--	--	--	--	--	--	--	--	--	--	1,180	--	--	7.4	--	--	--
30cda	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	332	0	--	--	--	--	--	--	--	--	--	--	658	--	--	8.2	--	--	--
31bbb	S	3-20-69	34	<.1	.02	<.01	56	26	.48	32	7.1	<.01	341	0	41	3.7	.2	4.8	<.01	.02	.03	.02	.06	392	600	247	0	7.6	<220	8.4	12
31bbd	W	3-20-69	--	--	<.01	--	--	--	--	--	--	--	418	0	--	--	--	--	--	--	--	--	--	--	707	--	--	7.6	--	--	--
31bca	W	3-20-69	--	--	.01	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--	--	--	729	--	--	7.6	--	--	--
31bcd	W	3-20-69	--	--	.06	--	--	--	--	--	--	--	433	0	--	--	--	--	--	--	--	--	--	--	759	--	--	7.5	--	--	--
31bdc	W	3-24-69	--	--	.03	--	--	--	--	--	--	--	448	0	--	--	--	--	--	--	--	--	--	--	789	--	--	7.5	--	--	--
31dac	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	357	0	--	--	--	--	--	--	--	--	--	--	658	--	--	7.7	--	--	--
32cca	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	697	0	--	--	--	--	--	--	--	--	--	--	1,710	--	--	7.9	<220	5.2	8.0
Do.	S	10-20-69	29	<.1	.04	<.01	61	16	.41	23	4.7	<.01	266	0	35	7.9	.2	11	<.01	.04	.11	<.01	.02	304	500	219	1	7.6	<220	1.6	4.2
33dbd	S	3-24-69	--	--	.01	--	--	--	--	--	--	--	412	0	--	--	--	--	--	--	--	--	--	--	762	--	--	7.6	<220	11	53
34dcc	S	3-24-69	--	--	<.01	--	--	--	--	--	--	--	448	0	--	--	--	--	--	--	--	--	--	--	854	--	--	7.7	--	--	--
SC6-95-28cdd[1/]	W	3-20-69	20	.1	.04	.04	50	42	.75	750	4.0	.06	755	0	1,160	27	.6	30	<.01	.06	.49	.05	.42	2,450	3,250	299	0	7.4	<220	8.1	34
36aab	S	9-5-69	--	--	--	--	81	29	--	--	--	--	429	0	--	--	--	--	--	--	--	--	--	425	695	322	0	8.0	<220	--	--
36aab1	S	9-5-69	--	--	--	--	81	31	--	--	--	--	431	0	--	--	--	--	--	--	--	--	--	416	698	330	0	7.9	<220	--	--
36abd	S	9-4-69	--	--	--	--	81	29	--	--	--	--	440	0	--	--	--	--	--	--	--	--	--	433	725	322	0	7.8	<220	--	--
36abd1	S	9-5-69	--	--	--	--	85	29	--	--	--	--	434	0	--	--	--	--	--	--	--	--	--	422	712	332	0	8.0	<220	--	--
36adb	W	3-26-69	--	--	.12	--	--	--	--	--	--	--	376	0	--	--	--	--	--	--	--	--	--	--	668	--	--	7.4	--	--	--
36add	W	3-24-69	--	--	.02	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--	--	--	708	--	--	7.6	--	--	--
36cdd	S	3-21-69	33	<.1	.03	<.01	47	55	.82	65	2.9	.02	530	0	43	7.9	.3	5.4	<.01	.03	.03	<.01	.09	507	850	345	0	7.9	<220	5.6	28
36dab	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	474	0	--	--	--	--	--	--	--	--	--	--	805	--	--	8.2	--	--	--
SC6-96-29daa	W	3-20-69	23	<.1	.03	.03	130	51	1.8	90	15	.07	656	0	184	7.9	1.1	6.0	<.01	.05	.19	.01	.16	835	1,260	537	0	7.4	<220	15	31
34bda	W	3-20-69	--	--	.01	--	--	--	--	--	--	--	617	0	--	--	--	--	--	--	--	--	--	--	1,360	--	--	7.4	--	--	--
34bdb	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	606	0	--	--	--	--	--	--	--	--	--	--	1,340	--	--	7.4	--	--	--
34cad	W	3-20-69	--	--	.75	--	--	--	--	--	--	--	627	0	--	--	--	--	--	--	--	--	--	--	1,640	--	--	7.4	--	--	--
34cdb	W	3-20-69	--	--	.06	--	--	--	--	--	--	--	628	0	--	--	--	--	--	--	--	--	--	--	1,800	--	--	7.4	--	--	--
SC7-94-04acd	S	3-24-69	--	--	<.01	--	--	--	--	--	--	--	352	0	--	--	--	--	--	--	--	--	--	--	720	--	--	7.6	--	--	--
04bdc	S	10-20-69	31	<.1	.03	<.01	75	41	.75	45	3.4	.01	434	0	89	11	.2	14	<.01	.02	.07	<.01	.07	531	825	357	1	7.6	<220	4.6	10
04bdc[2/]	S	3-22-69	--	--	.02	--	--	--	--	--	--	--	408	0	--	--	--	--	--	--	--	--	--	--	796	--	--	7.5	--	--	--
Do.[2/]	S	10-20-69	32	<.1	.04	.02	74	41	.76	45	3.4	.01	431	0	90	11	.2	14	<.01	.01	<.01	<.01	.06	512	820	354	1	7.6	<220	<3.6	3.4
06aba	S	3-21-69	31	<.1	.05	.02	58	25	.49	25	3.4	.02	309	0	39	8.5	.2	9.0	<.01	.02	.02	<.01	.10	341	565	248	0	8.1	<220	5.1	11
06bba	S	3-20-69	--	--	.04	--	--	--	--	--	--	--	352	0	--	--	--	--	--	--	--	--	--	--	557	--	--	8.2	--	--	--
06ddd	W	3-22-69	--	--	<.01	--	--	--	--	--	--	--	324	0	--	--	--	--	--	--	--	--	--	--	545	--	--	7.7	<220	<.4	5.0
Do.	W	10-20-69	36	<.1	.04	<.01	66	24	.69	14	3.2	<.01	323	0	27	7.2	.2	8.1	<.01	.02	.19	<.01	<.01	356	545	264	0	7.7	<220	2.1	<8.5
07bab	W	3-22-69	--	--	<.01	--	--	--	--	--	--	--	229	0	--	--	--	--	--	--	--	--	--	--	366	--	--	7.6	--	--	--
SC7-95-01aba	S	3-21-69	--	--	.03	--	--	--	--	--	--	--	442	0	--	--	--	--	--	--	--	--	--	--	689	--	--	7.6	--	--	--
01baa	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	679	0	--	--	--	--	--	--	--	--	--	--	1,030	--	--	7.8	--	--	--
02add	S	3-26-69	--	--	.03	--	--	--	--	--	--	--	473	0	--	--	--	--	--	--	--	--	--	--	760	--	--	7.7	--	--	--
02bcd	S	3-21-69	30	<.1	.03	<.01	60	16	.40	23	2.9	<.01	262	0	33	7.2	.1	8.4	<.01	.03	.11	<.01	.02	302	500	216	2	7.6	<220	3.4	11
02cbc	W	3-19-69	26	.1	.02	<.01	22	35	.76	150	3.5	.05	523	0	93	1.1	.3	6.1	<.01	.05	.81	<.01	.30	587	940	200	0	7.8	<220	5.6	17
04acd	S	3-26-69	--	--	.01	--	--	--	--	--	--	--	378	0	--	--	--	--	--	--	--	--	--	--	709	--	--	7.9	--	--	--
04add	S	3-26-69	27	<.1	.04	.02	44	45	.90	82	3.1	.02	403	0	127	8.9	.2	8.8	<.01	<.01	.02	<.01	.12	564	850	296	0	8.1	<220	4.0	9.1
04dbb	S	3-26-69	--	--	.06	--	--	--	--	--	--	--	322	0	--	--	--	--	--	--	--	--	--	--	588	--	--	7.9	--	--	--
05dcd[3/]	S	3-21-69	24	<.1	.03	<.01	26	33	.76	40	2.0	.02	323	0	20	8.3	.2	8.6	<.01	.01	.02	<.01	.04	336	560	202	0	7.7	<220	3.0	21
Do.[4/]	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	310	0	--	--	--	--	--	--	--	--	--	--	514	--	0	7.8	--	--	--
Do.[4/]	S	9-20-69	--	--	--	--	30	28	--	--	--	--	318	0	--	--	--	--	--	--	--	--	--	289	518	190	0	7.9	<220	--	--
Do.[4/]	S	10-19-69	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<220	--	--
07adb	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	572	0	--	--	--	--	--	--	--	--	--	--	1,470	--	--	7.3	<220	--	--
07dab[1/]	W	3-24-69	33	<.1	.02	<.01	69	49	.87	115	3.3	.02	505	0	181	10	.4	<.1	<.01	.30	.25	<.01	.14	665	1,080	375	0	7.5	<220	11	28

Table 10.--Chemical analyses of water from selected wells, springs, and cisterns, Rulison project area, Garfield and Mesa Counties, Colorado.--Continued
(Adapted from Hurr and others, 1969, and Larson and Beetem, 1970.)

Location number: See text for hydrologic data point numbering system.

Location number	Well, spring, or cistern (W,S,C)	Date of collection	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Selenium (Se)	Boron (B)	Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	pH	Tritium T.U.	Gross beta in picocuries per liter (as Sr^{90}-Y^{90})	Gross alpha in micrograms per liter (as U equivalent)
SC7-95-08ccb	S	3-24-69	--	--	0.02	--	--	--	--	--	--	--	370	0	--	--	--	--	--	--	--	--	--	--	695	--	--	8.1	--	--	--
Do.[5]	S	5-14-69	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<220	--	--
10ab	C	9-19-69	--	--	.22	--	27	6.5	--	--	--	--	96	18	--	--	--	--	--	--	--	--	--	--	252	94	0	9.0	--	--	--
10adc2	W	5-14-69	--	--	<.01	--	31	20	--	--	--	--	262	0	--	--	--	--	--	--	--	--	--	--	488	160	0	7.8	323	--	--
Do.	W	9-19-69	--	--	2.6	--	23	7.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	87	--	--	--	--	--
10bda	W	5-14-69	--	--	<.01	--	--	--	--	--	--	--	427	0	--	--	--	--	--	--	--	--	--	--	710	--	--	7.8	<220	--	--
10bdb[6]	C	10-20-69	9.9	<0.1	.03	<0.01	35	1.3	0.26	12	1.9	<0.01	--	7	11	8	0.1	0.8	<0.01	0.01	<0.01	<0.01	0.01	103	310	89	18	10.8	275	1.5	<2.0
10bdc	--	10-20-69	20	<.1	.05	<.01	29	9.8	.23	13	1.7	<.01	154	0	18	.6	.1	.2	<.01	.01	<.01	<.01	.03	154	270	114	0	8.2	315	2.0	1.2
12bad	W	3-2-69	36	<.1	.02	<.01	84	24	.49	22	2.1	.01	373	0	37	11	.2	8.0	<.01	.02	.09	<.01	.01	402	665	309	3	7.4	<220	1.5	5.5
17aab	W	3-19-69	30	.2	.01	<.01	25	23	.47	74	4.9	.01	337	0	48	.6	.3	3.8	<.01	.03	2.6	<.01	.15	364	595	158	0	7.9	<220	6.9	12
17aba	W	3-19-69	--	--	.02	--	--	--	--	--	--	--	369	0	--	--	--	--	--	--	--	--	--	--	622	--	--	7.7	--	--	--
18aad	S	3-25-69	--	--	.06	--	--	--	--	--	--	--	404	0	--	--	--	--	--	--	--	--	--	--	1,180	--	--	8.0	--	--	--
18adb	W	3-18-69	27	.6	.02	.01	60	60	.92	145	6.2	.02	408	0	308	30	.2	7.2	<.01	.03	2.0	<.01	.15	855	1,260	398	63	7.8	<220	4.8	<.4
18bcd	S	3-26-69	27	<.1	.02	.01	82	67	1.2	170	4.2	.03	439	0	437	40	.4	4.8	<.01	.01	.02	<.01	.07	1,100	1,500	482	122	7.5	<220	4.6	26
18dad	W	3-18-69	--	--	.04	--	--	--	--	--	--	--	363	0	--	--	--	--	--	--	--	--	--	--	861	--	--	7.6	--	--	--
18cbb	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	375	0	--	--	--	--	--	--	--	--	--	--	892	--	--	7.6	236	--	--
20bba	W	3-26-69	24	<.1	.05	.02	48	38	.75	59	2.9	.02	383	0	67	4.8	.3	13	<.01	.01	.18	<.01	.05	435	720	278	0	7.6	320	<.4	9.1
SC7-96-12bbb[1]	W	3-20-69	19	.1	.03	.01	140	90	1.5	205	5.0	.04	626	0	598	18	.7	.4	<.01	.03	1.3	<.01	.10	1,450	1,870	722	208	7.4	<220	6.5	32
13abd	W	3-24-69	19	<.1	.16	.11	130	108	2.5	290	5.6	.06	851	0	657	27	.9	.4	<.01	.01	.19	<.01	.18	1,730	2,250	772	74	7.4	<220	8.7	17
23cad	W	3-25-69	14	<.1	.04	.02	110	28	.89	118	3.1	.02	313	0	171	164	.3	<.1	<.01	.14	1.2	<.01	.04	781	1,200	391	134	7.4	570	3.4	2.4
33dcd	S	3-25-69	26	<.1	.03	.01	105	63	.94	180	4.4	.02	490	0	464	16	.2	8.6	<.01	.01	.02	<.01	.28	1,140	1,500	523	121	7.4	230	5.4	20
34bbc	W	3-25-69	15	<.1	.03	.15	125	38	1.0	148	3.3	.02	352	0	188	240	.3	<.1	<.01	.01	.34	<.01	.03	953	1,450	470	181	7.6	590	1.2	8.7
34bcd	W	3-25-69	--	--	.12	--	--	--	--	--	--	--	392	0	--	--	--	--	--	--	--	--	--	--	1,060	--	--	7.6	--	--	--
34bdc	W	3-25-69	--	--	.17	--	--	--	--	--	--	--	383	0	--	--	--	--	--	--	--	--	--	--	1,240	--	--	7.5	--	--	--
34caa	S	3-18-69	--	--	.06	--	--	--	--	--	--	--	519	0	--	--	--	--	--	--	--	--	--	--	1,490	--	--	7.6	--	--	--
35dcb	S	3-18-69	--	--	.01	--	--	--	--	--	--	--	422	0	--	--	--	--	--	--	--	--	--	--	1,240	--	--	8.1	<220	6.7	11
SC8-95-24acc	S	9-19-69	20	<.1	.01	<.01	8.8	2.0	.04	2.4	.9	<.01	39	0	.5	.3	.1	.5	<.01	--	--	.02	.02	64	65	30	0	7.0	<220	--	--
SC8-96-11acc	W	3-18-69	27	<.1	.01	<.01	69	26	.64	39	2.9	.02	365	0	56	2.4	.2	14	<.01	.02	.07	<.01	.09	414	670	280	0	7.6	<220	2.6	4.7
11bbd	W	3-18-69	--	--	.01	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--	--	--	711	--	--	7.5	--	--	--
12aac	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	304	0	--	--	--	--	--	--	--	--	--	--	782	--	--	7.8	<220	--	--
Do.	W	10-21-69	28	<.1	.06	<.01	48	41	1.1	56	3.7	.02	299	0	108	35	.4	15	<.01	.01	.47	<.01	.06	486	760	290	45	7.7	<220	5.6	18
SC9-93-19bda	S	9- 4-69	--	--	--	--	128	40	--	--	--	--	537	0	--	--	--	--	--	--	--	--	--	933	1,280	484	44	7.6	<220	--	--
SC9-94-22acc	W	3-25-69	--	--	.37	--	--	--	--	--	--	--	361	0	--	--	--	--	--	--	--	--	--	--	858	--	--	7.8	<220	15	14
22bab	W	5-15-69	--	--	.02	--	--	--	--	--	--	--	443	0	--	--	--	--	--	--	--	--	--	--	675	--	--	7.6	618	--	--
SC9-95-26baa	W	5-15-69	--	--	.02	--	--	--	--	--	--	--	563	0	--	--	--	--	--	--	--	--	--	--	1,120	--	--	7.8	396	--	--
26daa	S	3-25-69	30	<.1	<.01	.01	51	28	.60	32	6.9	.01	368	0	22	2.9	.4	3.0	<.01	.01	.04	<.01	.02	361	590	243	0	7.6	600	8.9	10
Do.	S	9-20-69	--	--	--	--	76	33	--	--	--	--	442	0	--	--	--	--	--	--	--	--	--	509	652	325	0	7.7	367	--	--
33dba	S	3-25-69	--	--	<.01	--	--	--	--	--	--	--	507	0	--	--	--	--	--	--	--	--	--	--	766	--	--	7.6	--	--	--
34adb	S	3-25-69	--	--	.01	--	--	--	--	--	--	--	398	0	--	--	--	--	--	--	--	--	--	--	622	--	--	7.7	--	--	--
34bdb	W	3-25-69	38	<.1	.01	<.01	57	36	.60	55	14	.01	449	0	41	5.9	.4	8.5	.17	.02	.13	<.01	.06	465	760	291	0	7.5	470	24	42
35ddb	S	3-25-69	--	--	.01	--	--	--	--	--	--	--	471	0	--	--	--	--	--	--	--	--	--	--	794	--	--	7.4	--	--	--

1/ Sample taken had passed through a domestic water softener.

2/ Sample collected from tap at Bernklau home (SC6-94-33cba).

3/ Before chlorination.

4/ After chlorination.

5/ Sample collected from tap at Satterfield home (SC7-95-8ccb).

6/ Sample collected from ditch supplying Moore cistern (SC7-95-10bdb).

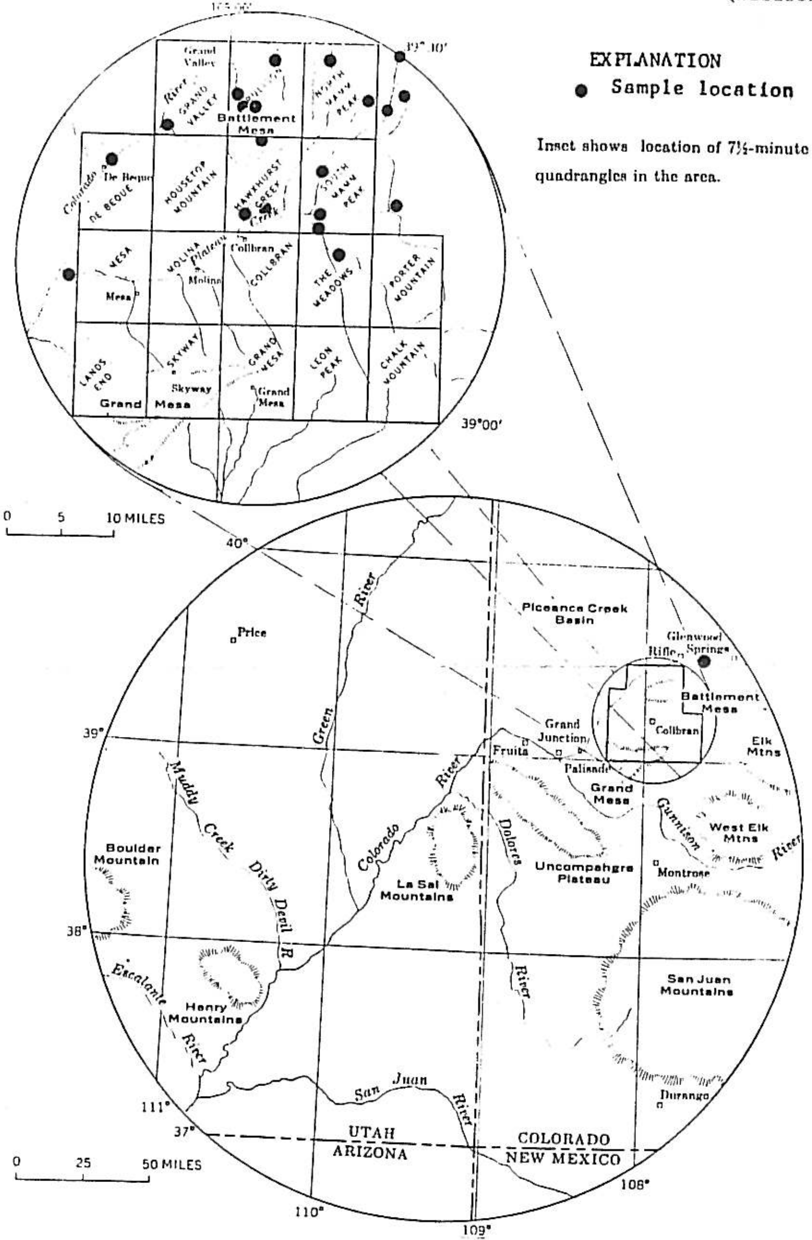
All the wells and springs inventoried derive their water from either surficial deposits (e.g., flood-plain deposits, terrace and fan gravel, mudflow and fan gravel, and landslide debris) or the Wasatch Formation. Some of the wells drilled in the surficial deposits also penetrate the underlying bedrock to shallow depth, but the bedrock probably does not contribute significantly to the well yield. Only one well, SC9-95-35abc, appears to derive its water exclusively from the Wasatch Formation. This well is 765 feet deep and its bottom is about 1,500 feet above the top of the Mesaverde Group. Most of the springs in the area are along the contact between the Wasatch Formation and the surficial deposits, though some springs may be along the contact of different strata within the surficial deposits.

Chemical sampling of surface-water sites

A sampling network of 21 locations (fig. 7) was established to provide the basis of evaluating possible changes in the tritium concentrations attributable to the Rulison event. Table 11 gives the location description of the sampling points. Table 12 is a tabulation of chemical analyses of water samples collected as of November 1969 from the 21 locations.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

USGS-474-68
(Rulison -5)



Base modified after Yeend (1969), U.S. Geol. Survey Prof. Paper 617, Fig. 1. (Inset is an expansion of smaller circle on bottom map.) (After Larson and Beetem, 1970.)

FIGURE 7.--Selected surface-water sampling locations in the Rulison project area, Garfield and Mesa Counties, Colorado.

Table 11.--Location description of surface-water sampling points, Rulison project area, Garfield and Mesa Counties, Colorado

Station name of stream or reservoir	Latitude	Longitude	Section, township, range, county	Remarks
Colorado River at New Castle	39°34'06"	107°32'26"	SE¼NW¼SW¼ sec. 31, T.5 S., R. 90 W., Garfield Co.	At USGS gaging station.
East Mamm Creek near Rifle	39°25'56"	107°40'29"	NW¼NE¼SW¼ sec. 21, T. 7 S., R. 92 W., Garfield Co.	About 8 miles southeast of Rifle.
Middle Mamm Creek near Rifle	39°24'13"	107°42'34"	NW¼ sec. 31, T. 7 S., R. 92 W., Garfield Co.	About 10 miles southeast of Rifle.
West Mamm Creek near Rifle	39°25'44"	107°46'12"	SE¼NE¼SE¼ sec. 21,T. 7 S., R. 93 W., Garfield Co.	About 7 miles south of Rifle.
Mamm Creek near Rifle	39°29'47"	107°41'42"	NW¼NW¼SE¼ sec. 29, T. 6 S., R. 92 W., Garfield Co.	About 3 miles south of Colorado River.
Beaver Creek near Rifle	39°28'20"	107°49'55"	NE¼NW¼NE¼ sec. 1, T. 7 S., R. 94 W., Garfield Co.	At USGS gaging station, 4.8 miles southeast of Rifle.
Cache Creek near Rulison	39°28'33"	107°54'33"	SW¼SW¼SE¼ sec. 32, T. 6 S., R. 94 W., Garfield Co.	About 8 miles east of Grand Valley.
Battlement Reservoir near Grand Valley	39°22'25"	107°55'50"	SW¼ sec. 7, T. 8 S., R. 94 W., Garfield Co.	About 8 miles southeast of Grand Valley.
Battlement Creek near Morrisania	39°24'35"	107°57'29"	SW¼SE¼NE¼ sec. 26, T. 7 S., R. 95 W., Garfield Co.	About 6 miles southeast of Grand Valley.
Tributary of Battlement Creek near Morrisania	39°24'33"	107°57'14"	SW¼SW¼NW¼ sec. 25, T. 7 S., R. 95 W., Garfield Co.	Do.
Battlement Creek near Grand Valley	39°26'10"	107°58'40"	NW¼NE¼SE¼ sec. 15, T. 7 S., R. 95 W., Garfield Co.	At USGS gaging station, 4.3 miles southeast of Grand Valley.
Spring Creek near Grand Valley	39°23'41"	108°05'32"	SE¼SW¼NE¼ sec. 34, T. 7 S., R. 96 W., Garfield Co.	4.5 miles southwest of Grand Valley.
Colorado River near DeBeque	39°20'22"	108°11'35"	SW¼SW¼SW¼ sec. 23, T. 8 S., R. 97 W., Mesa Co.	1.2 miles east of DeBeque.
Vega Reservoir near Collbran	39°13'30"	107°48'40"	Sec. 6, T. 10 S., R. 93 W., Mesa Co.	At USGS gaging station, about 8 miles southeast of Collbran.
Plateau Creek near Collbran	39°15'00"	107°50'25"	NE¼SE¼NE¼ sec. 26, T. 9 S., R. 94 W., Mesa Co.	At USGS gaging station, about 6 miles east of Collbran.
Road Gulch near Collbran	39°17'30"	107°43'18"	NW¼ sec. 12, T. 9 S., R. 93 W., Mesa Co.	About 15 miles east of Collbran.
Buzzard Creek near Collbran	39°16'20"	107°51'00"	NE¼SE¼SW¼ sec. 14, T. 9 S., R. 94 W., Mesa Co.	At USGS gaging station, about 7 miles east of Collbran.
Brush Creek near Collbran	39°19'30"	107°50'30"	NW¼ sec. 36, T. 8 S., R. 94 W., Mesa Co.	At USGS gaging station, about 8 miles northeast of Collbran.
Hawxhurst Creek near Collbran	39°16'21"	107°54'52"	NW¼SW¼SW¼ sec. 17, T. 9 S., R. 94 W., Mesa Co.	3.5 miles northeast of Collbran.
Kimball Creek near Collbran	39°17'00"	107°57'13"	NW¼NE¼NE¼ sec. 14, T. 9 S., R. 95 W., Mesa Co.	About 3 miles north of Collbran.
Plateau Creek near Cameo	39°11'00"	108°16'10"	NW¼SW¼ sec. 18, T. 10 S., R. 97 W., Mesa Co.	About 4 miles northeast of Cameo.

Table 12.--Chemical analyses of surface waters, Rulison project area, Garfield and Mesa Counties, Colorado.
(After Larson and Beetem, 1970.)

(Chemical analyses in milligrams per liter.)

Station name	Altitude (feet above msl)	Date	Time (mountain daylight)	Temperature (°C)	Calcium (Ca)	Magnesium (Mg)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	pH	Turbidity	Tritium (T.U.)1/
Colorado River at New Castle	5,515	8-26-69	1225	19.0	71	14	161	0	235	103	534	898	7.3	6	368
Do.	do.	10-19-69	1600	8.0	--	--	--	--	--	--	--	--	--	--	<220
East Mamm Creek near Rifle	6,220	9- 2-69	1500	27.0	51	60	671	0	374	0	1,050	1,460	8.1	--	<220
Middle Mamm Creek near Rifle	6,830	8-27-69	1235	19.5	44	21	261	0	197	0	237	450	7.9	8	<220
West Mamm Creek near Rifle	7,080	8-27-69	1145	13.5	62	31	360	0	282	0	369	648	7.6	4	<220
Mamm Creek near Rifle	5,610	8-27-69	1300	27.5	51	93	588	0	510	28	1,390	1,820	7.7	50	<220
Beaver Creek near Rifle	6,685	3-24-69	--	1.0											
Do.	do.	9-20-69	1209	10.0	36	8.0	173	0	124	0	149	282	8.1	15	<220
Cache Creek near Rulison	5,950	8-27-69	1025	13.5	21	4.5	101	0	71	0	81	171	7.0	5	263
Battlement Reservoir near Grand Valley	10,200	9- 3-69	1000	7.0	7.1	.8	35	0	21	0	53	60	7.0	--	336
Battlement Creek near Morrisania	7,760	8-28-69	0815	9.5	10	2.5	55	0	36	0	74	96	7.1	10	229
Do.	do.	9-20-69	1355	9.5	12	2.6	59	0	41	0	41	100	7.4	2	<220
Tributary of Battlement Creek near Morrisania	7,880	8-27-69	1500	17.0	36	11	200	0	135	0	147	322	7.3	<1	<220
Do.	do.	9-20-69	1400	16.5	36	11	208	0	135	0	178	338	8.0	7	<220
Battlement Creek near Grand Valley	6,630	8-27-69	1425	8.0	17	5.0	89	0	63	0	110	150	6.8	2	258
Do.	do.	9-20-69	1320	11.0	.23	7.3	126	0	88	0	104	212	8.0	2	<220
Do.	do.	10-19-69	1420	4.0	--	--	--	--	--	--	--	--	--	--	<220
Spring Creek near Grand Valley	5,080	8-27-69	1610	22.0	29	38	334	0	229	0	471	790	7.9	1	<220
Colorado River near DeBeque	4,940	8-26-69	1615	23.5	67	15	157	0	229	100	537	882	6.5	10	335
Do.	do.	9-20-69	1515	17.0	105	16	166	0	328	192	601	1,030	8.1	10	<220
Do.	do.	10-19-69	1200	18.0	--	--	--	--	--	--	--	--	--	--	288
Vega Reservoir near Collbran	7,906	8-26-69	1945	14.0	18	3.2	81	0	58	0	56	124	6.7	4	230
Plateau Creek near Collbran	7,130	8-27-69	0755	12.0	17	4.2	83	0	60	0	57	121	6.8	2	240
Road Gulch near Collbran	7,400	8-28-69	1110	18.5	51	10	295	0	168	0	276	475	7.9	15	<220
Buzzard Creek near Collbran	6,955	8-26-69	1830	22.0	51	25	338	0	230	0	383	565	7.8	10	430
Do.	do.	9-20-69	1800	14.5	76	18	322	0	264	0	335	580	8.2	2	<220
Brush Creek near Collbran	8,183	8-26-69	1905	16.0	51	13	248	0	181	0	201	350	7.9	10	263
Hawxhurst Creek near Collbran	6,560	8-26-69	1800	19.0	51	29	430	0	247	0	370	605	7.5	2	354
Do.	do.	9-20-69	1655	14.5	76	30	443	0	313	0	404	668	7.9	<1	250
Kimball Creek near Collbran	6,880	8-26-69	1735	17.0	67	20	433	0	250	0	384	610	7.5	<1	<220
Do.	do.	9-20-69	1630	12.5	105	20	481	0	345	0	425	708	7.9	2	<220
Plateau Creek near Cameo	4,836	8-28-69	0955	18.5	41	38	411	0	259	0	485	780	8.1	2	<220
Do.	do.	9-20-69	1545	17.0	37	35	385	0	237	0	418	712	8.1	8	<220
Do.	do.	10-19-69	1100	16.0	--	--	--	--	--	--	--	--	--	--	291

1/ The tritium analyses were by liquid scintillation counting and the lowest detectable concentration by this method was 220 T.U.

Hydrologic Studies at Shot Time

Aquifer response

By

E. H. Cordes

In order to study the response of ground-water reservoirs to the Rulison detonation, two shallow water wells in surficial deposits within a few miles of SGZ (surface ground zero) were instrumented (fig. 8).

The close-in well, which is about 3,660 meters (12,000 feet) from SGZ, was drilled in the SW$\frac{1}{4}$ sec. 14, T. 7 S., R. 95 W. with a cable-tool rig for the CER Geonuclear Corporation. The well is on the east bank of Battlement Creek about 30 feet from the stream. Figure 9 is a schematic diagram showing the instrumentation and design of the well.

A 0-100 psia (pounds per square inch absolute) pressure transducer was suspended in the CER Geonuclear well below an inflatable packing element. The transducer was not compensated for acceleration. The center of the packer element was set at a depth of 10.67 meters (35.0 feet) placing the transducer port at 11.07 meters (36.3 feet) below the top of the casing (fig. 9). The signal from the transducer was recorded with a light-beam oscillograph. Chart drive-speed for the event was 0.25 inch per second. Recording was started about 10 minutes before detonation through a clock driven timer. No zero-time reference was recorded; thus, the arrival time of the shock wave is not known.

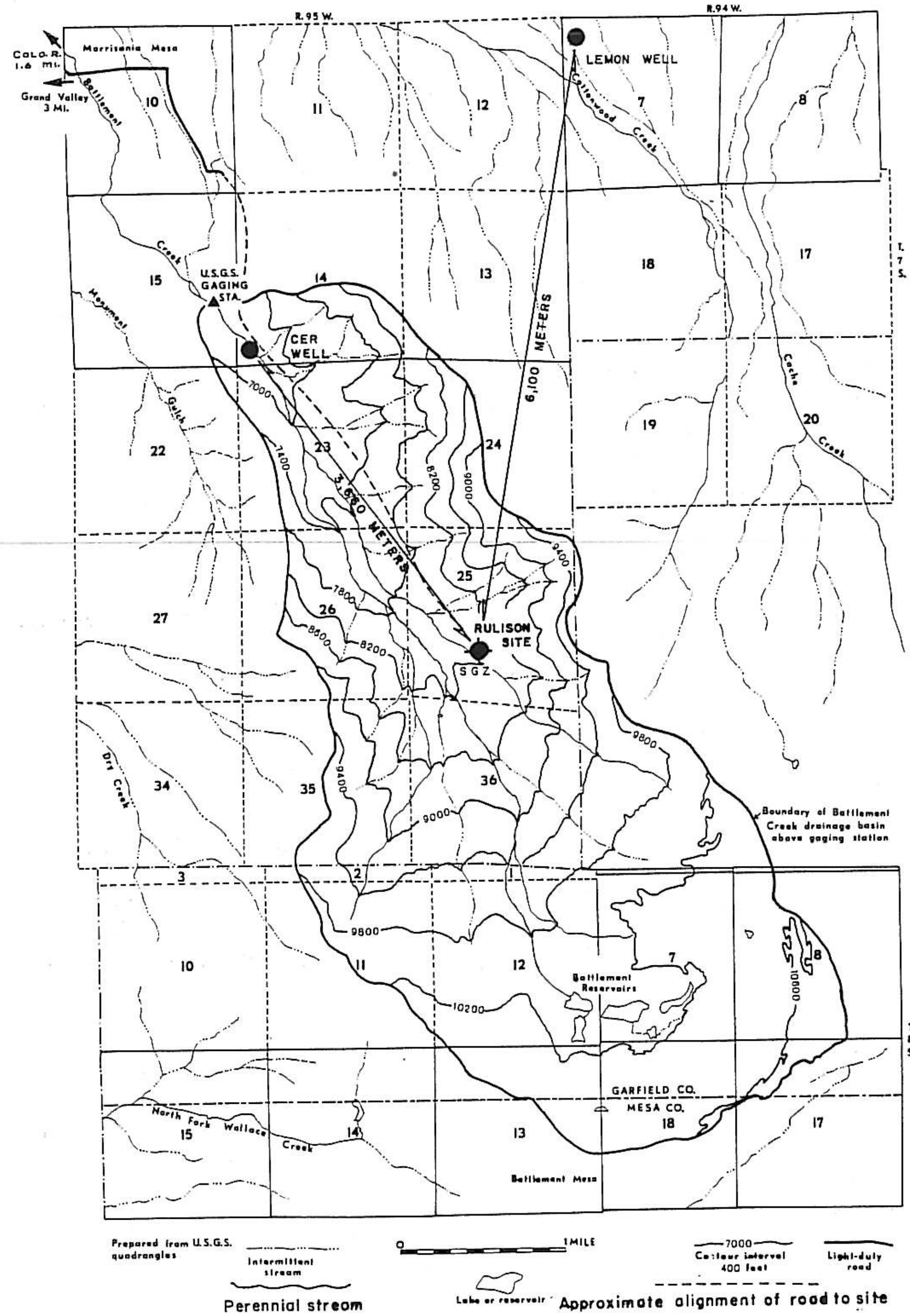


FIGURE 8.--Location of monitored wells in relation to surface ground zero (SGZ).

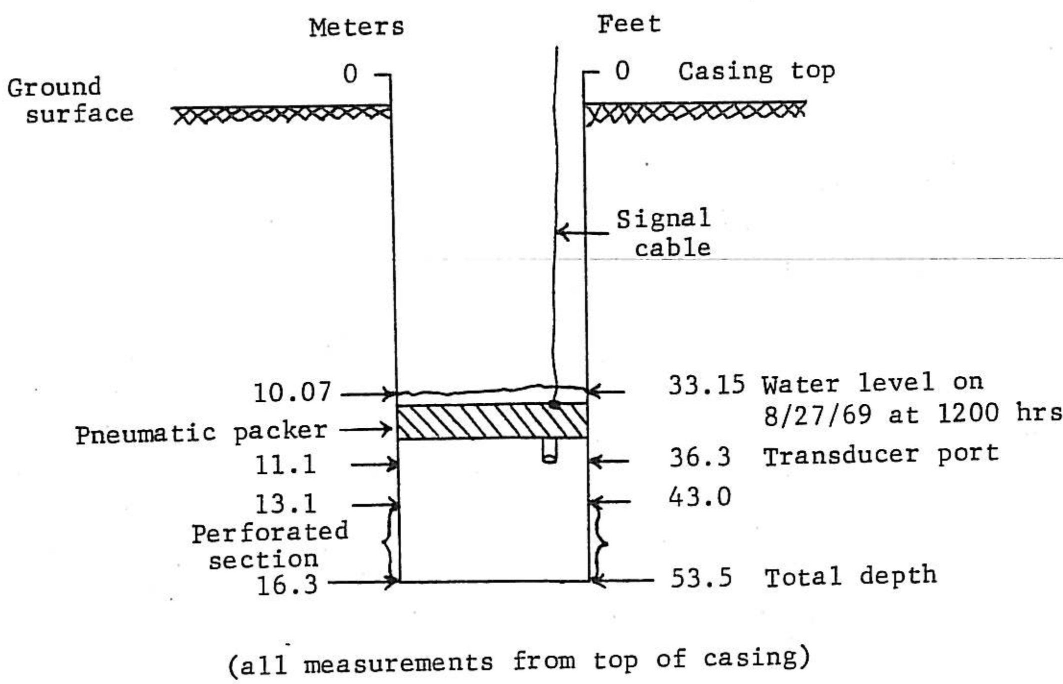
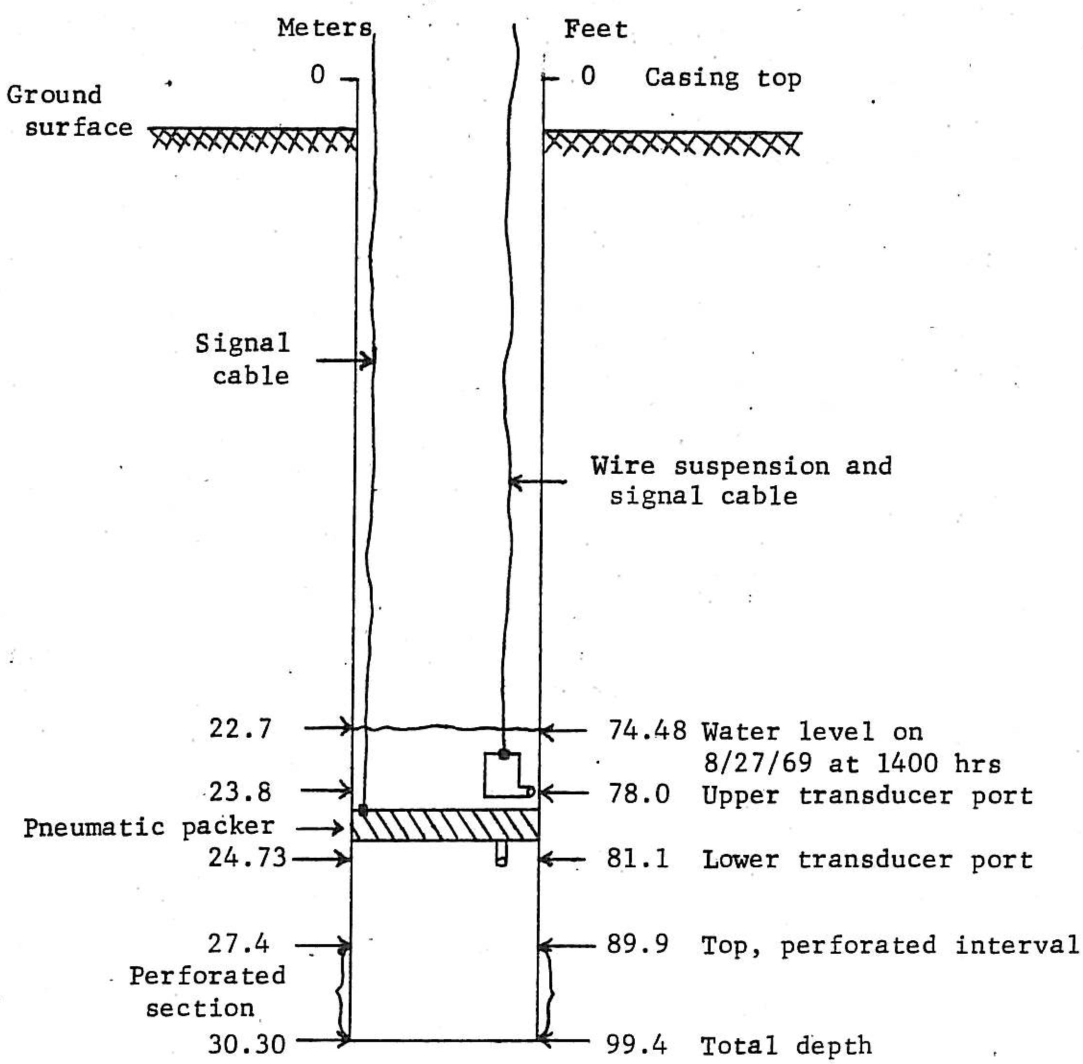


FIGURE 9.--Instrumentation and design of the CER Geonuclear Corporation well.

During the 10 minutes of recording prior to detonation, the transducer functioned normally. When the pressure wave arrived at the site, the recorder deflected full scale and ceased to record. The recorded trace suggests that the magnitude of deflection exceeded the capacity of the recorder. A net voltage change from the transducer of 16.08 millivolts was sufficient to drive the recorder to full scale deflection. This is equivalent to a pressure increase of about 40 psia (approximately 28 meters or 92 feet of water). Postshot examination of the transducer indicates that the hydraulic pressure below the packer exceeded the response limits of the transducer.

The second monitoring well, about 6,100 meters (20,000 feet) from SGZ, is on the W. B. Lemon ranch in the NW¼ sec. 7, T. 7 S., R. 95 W. The well was drilled with a cable-tool rig through 100 feet of surficial deposits to the top of the Wasatch Formation. The well was instrumented above and below a casing packer (fig. 10).

A casing packer with a 0-100 psia transducer below was set at a depth of 24.4 meters (80.1 feet) placing the transducer intake at a depth of 24.7 meters (81.0 feet) below the top of casing. A second transducer unit was suspended in the well just above the packer to study the possible effects of casing distortion during passage of the shock wave. Neither of these transducer units was compensated for acceleration. The upper transducer unit is a differential type with a range of ±3 psi.



(all measurements from top of casing)

FIGURE 10.--Instrumentation and design of the Lemon well.

Output signals from the bottom transducer were interfaced directly to a Heiland M-200-120 galvanometer. Recording chart-speed during the event was 0.083 inch per second. It is barely possible to resolve the frequency of the pressure-wave perturbations at this chart speed. The recorded signal showed a maximum frequency of about 8 cycles per second. Arrival of the shock wave was recorded as a maximum pressure increase of about 0.62 psia (43.6 centimeters or 1.4 feet of water). The corresponding pressure below the set point on the negative cycle was about 0.71 psia (50.0 centimeters or 1.6 feet of water). Both of these pressure values were estimated from a calibration curve supplied by the transducer manufacturer.

Output signals from the upper transducer were amplified on a 5-millivolt full scale range. Recording speed during the event was 4.7 inches per minute. In the early record of the wave form the frequency of oscillation was 4 cycles per second. As the magnitude of the disturbance diminished, the frequency decreased accordingly. A maximum pressure increase of 0.298 psi (21.0 centimeters or 0.688 foot of water) occurred after excitation of 1½ cycles of the wave form. A maximum decrease of 0.321 psi (22.6 centimeters or 0.742 foot of water) was recorded on the negative half of the first cycle. The magnitude of the pressure increase is not significant in terms of the probability of causing well damage or aquifer deformation.

A permanent offset (rise) of the preshot water level above the packer was noted on the postshot record. This offset is in the direction of increased pressure and represents a change in the length of the fluid column above the upper transducer of 6.1 centimeters (0.2 foot). The fluid volume change is approximately 100 cc or about 0.0264 gallon. This volume change may be evidence of casing compression and/or a change in reference setting by stretching of the supporting cable. Permanent leakage across the packer element is considered a remote possibility.

Both responses recorded in the Lemon well had similar wave forms, yet the fluid above the packer element presumably was isolated from the ground-water system in the aquifer. The characteristic decay of the oscillating free-water surface above the packer appeared exactly the same as that of the ground-water system below the packer with the possible exception of slight amplification. Most of the recorded signal probably was due to acceleration of the transducers and not purely a pressure phenomenon in the aquifer.

Stream and spring response

The flow of Battlement Creek recorded at the U.S. Geological Survey gaging station, about 4,200 meters (13,800 feet) from SGZ (fig. 2), increased slightly immediately after the detonation. Figure 11 is a copy of the recorder chart from the station for the period 0300 hours to 2400 hours, September 10, 1969. At about 1630 hours, about 1 hour

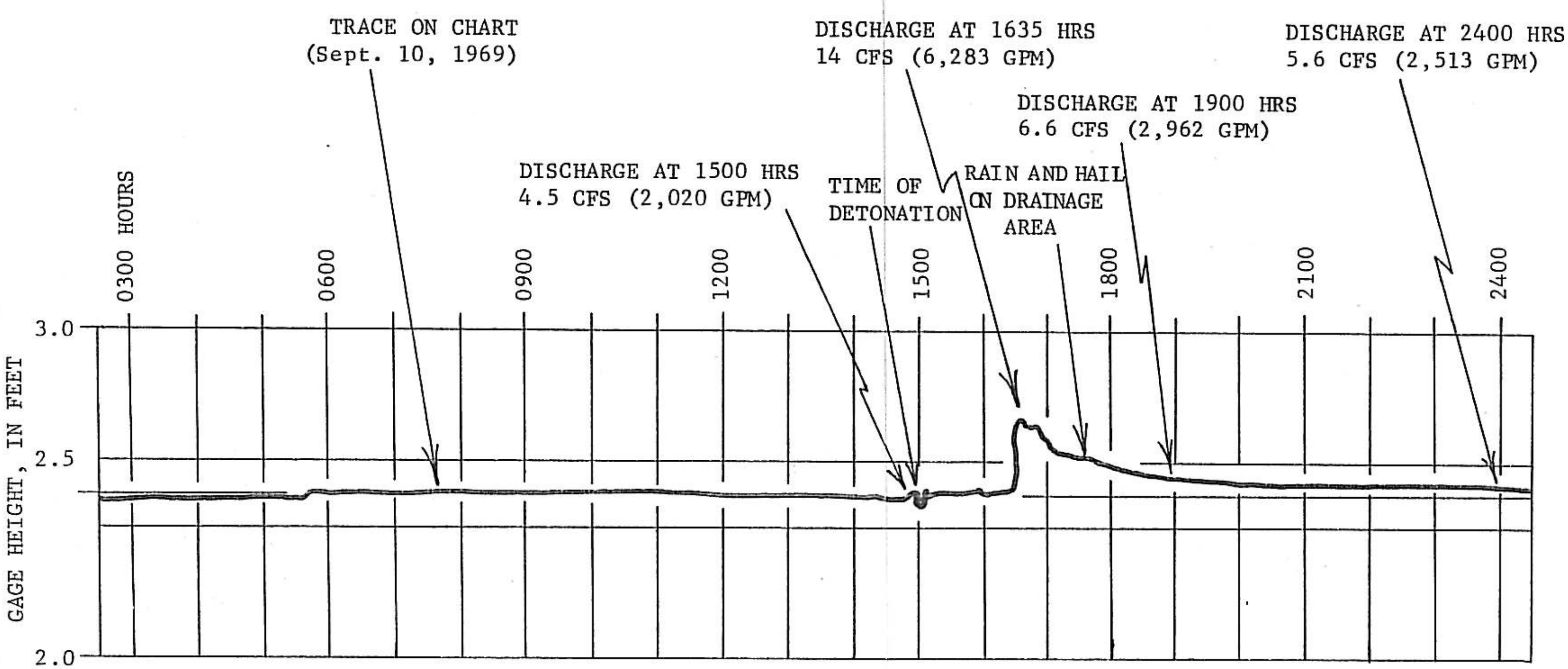


FIGURE 11.--Monitor record from the gaging station on Battlement Creek near Grand Valley, Colorado, during the Rulison event.

and 30 minutes after the detonation, the discharge of Battlement Creek at the gaging station increased abruptly from 4.5 to 14 cfs, and then began a gradual decline. Rain and hail fell in the Battlement Creek basin from about 1715 hours to 1800 hours, and water from the storm affected the stream discharge, obscuring the effects of the Rulison event. At 1620 hours, September 10, the water in Battlement Creek in the vicinity of the CER Geonuclear well (about 2,500 feet upstream from the gaging station) was very turbid (grayish-black); at 0630 hours, September 11, 1969, the water was only slightly turbid at the same point. After several days, the stream again was clear.

Several detonation-produced effects on the drainage basin may have caused the temporary increase of discharge of Battlement Creek. The relative importance of the several possible effects, such as sloughing of stream banks, changing of stream gradients, or compaction of sediments, is not known.

One early effect that might be expected on Battlement Creek would be sloughing of the stream banks after detonation. Sloughing could cause either a temporary increase or decrease in discharge depending on the nature of the sloughing. Although some sloughing probably did occur, as suggested by the high turbidity of the water, sloughing probably was not the principal cause of the temporary increased rate of discharge. For the most part, the brush-covered banks of Battlement Creek have gentle slopes that are not conducive to sloughing. The stream gradient is steep (elevation at the USGS gaging station is about 6,630 feet and the elevation of the headwater area, a distance of about 5 miles upstream is about

10,000 feet), and finer sediments are not readily retained on or adjacent to the streambed owing to the high velocity of the water. Sediment does accumulate behind numerous beaver dams on the stream. The disturbance by the nuclear detonation of the sediments behind the beaver dams may have influenced the rate of stream discharge and surely contributed to the turbidity of the water.

Another temporary effect on streamflow could have been caused by slight changes in the gradient of the stream. An increase in stream gradient would result in increased discharge and a decrease in gradient would result in decreased discharge. The temporary increase in discharge probably cannot be attributed to an increase in gradient, because large changes in land-surface slope beyond a few hundred meters from ground zero of nuclear explosion sites are rare.

The compaction of unconsolidated sediments along the stream and of the sediments associated with the springs and seeps that feed Battlement Creek probably is the prinicpal cause for the temporary increase in discharge. The forces resulting from the detonation of the nuclear device compacted the sediments, at least temporarily, as shown in the ground-water pressure responses. The compaction of the sediments probably resulted in a temporary increase of discharge from springs and seeps, as well as release of water from storage in the sediments along the stream. Water thus released would have entered the tributaries and main stem of Battlement Creek and caused a temporary increase in stream discharge, such as that recorded at the gaging station (fig. 11).

A temporary gaging station was installed on Battlement Creek just below the Battlement reservoirs to monitor streamflow before, during, and following the Rulison event. The recorder clock stopped a few hours before the event, so the monitoring of streamflow was not entirely successful. The gage height changed only 0.05 inch during the event, which indicates that the change in discharge and the loss of water from the reservoirs as a result of the event were insignificant.

The water in some springs was milky and turbid following the detonation. After several days, the appearance of the water was normal. The increased discharge of springs close to the detonation site generally was short-lived; however, one rancher near the detonation site reported that a spring on his property had an increased flow that lasted for a few months. No springs were reported to have had a diminished flow. The springs that supply the town of Grand Valley showed no change in yield or quality as a result of the Rulison detonation.

Postshot Hydrologic Studies

Postshot hydrologic studies by the U.S. Geological Survey were confined to resampling of selected surface-water sampling points previously described and to the investigation of complaints of damage to hydrologic features and hydraulic structures.

Resampling and analyses of water from surface-water sampling points (fig. 7) indicated that the detonation of the Rulison device had no effect upon the chemical characteristics of the surface water at or near the site. Chemical analyses of the water are reported in table 12.

After the Rulison event, the U.S. Atomic Energy Commission received some complaints of damage to hydrologic features or hydraulic strucutres. Some wells, springs, and cisterns were investigated by the U.S. Geological Survey as a result of the damage complaints. Eleven complaints were investigated and reported upon to the Atomic Energy Commission. Six of the complaints were concerned with wells, three with springs, and two with cisterns. Several of the complaints were about suspected changes in water quality and they resulted in the resampling of the water from a well or spring. Some of the complaints were concerned with pumping-equipment failure. A few owners of cisterns that obtain water from Battlement Creek or its tributaries reported a temporary problem of bad taste and turbidity. In no case was there any indication that the hydrologic features (stream or water-bearing formation) had been permanently impaired as a result of the Rulison detonation.

SUMMARY AND CONCLUSIONS

Surficial deposits are the only sources of usable ground water near the Rulison site. The surficial deposits are inconsequential at the Rulison site and are far above the top of the rubble chimney and fracture zone created by the detonation of the nuclear device (probably at least 8,000 feet at the detonation site). Thus, hydraulic testing in the exploratory hole was limited to deep, bedrock formations (those below the unnamed unit of Paleocene age). The tests showed negligible or no fluid entry to the hole, which indicates that ground-water flow in the vicinity of the Rulison site is nil.

In no case was there any indication that the streams or the water-bearing formations in the vicinity of the site had been permanently impaired as a result of the Rulison detonation.

Seismic effects of the Project Rulison nuclear detonation caused a hydrostatic pressure pulse in the two monitored wells at distances of 3,660 meters (12,000 ft) and 6,100 meters (20,000 ft) from SGZ. Postshot evidence indicates that the pressure disturbance below the packer in the nearby CER Geonuclear monitor well had exceeded the limits of the transducer and, thus, the maximum response of the ground-water body to the detonation is unknown. Output signals from the transducer below the packer in the distant Lemon monitor well had a maximum frequency of about 8 cycles per second. Arrival of the shock wave was recorded as a maximum pressure increase of about 0.62 psia. The corresponding pressure change on the negative cycle was about 0.71 psia. The output signals from the transducer above the packer in the Lemon monitor well had a frequency of oscillation in the earlier part of the record of 4 cycles per second. A maximum pressure increase of 0.298 psia came after excitation of 1½ cycles of the wave form. A maximum decrease of 0.321 psia came on the negative half of the first cycle.

In response to the Project Rulison nuclear detonation, the discharge of Battlement Creek recorded at the U.S. Geological Survey gaging station increased slightly immediately after the detonation. The discharge at the gaging station 1 hour and 30 minutes after the detonation increased abruptly from 4.5 to 14 cfs, and then began a gradual decline. Precipitation in the drainage basin, beginning nearly two hours after the explosion, obscured any later effects of the Rulison event.

Analyses of water collected postshot from 21 surface-water sampling points in and near the Rulison site indicated that the nuclear detonation had no effect upon the chemical characteristics of the water. Analyses of spring water collected postshot also indicated that the nuclear detonation had no permanent effect upon the chemical characteristics of the water.

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Table 1?.--Chemical analyses of water from selected wells, springs, and cisterns, Rulison project area, Garfield and Mesa Counties, Colorado.--Continued
(Adapted from Hurr and others, 1969, and Larson and Beetem, 1970.)

Location number: See text for hydrologic data point numbering system.

Location number	Well, spring, or cistern (W,S,C)	Date of collection	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Selenium (Se)	Boron (B)	Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	pH	Tritium T.U.	Gross beta in picocuries per liter (as Sr^{90}-Y^{90})	Gross alpha in micrograms per liter (as U equivalent)
ccb	S	3-24-69	--	--	0.22	--	--	--	--	--	--	--	370	0	--	--	--	--	--	--	--	--	--	--	695	--	--	8.1	--	--	--
Do.5/	S	5-14-69	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<220	--	--
1Cab	C	9-19-69	--	--	.22	--	27	6.5	--	--	--	--	96	18	--	--	--	--	--	--	--	--	--	--	252	94	0	9.0	--	--	--
1Cadc2	W	5-14-69	--	--	<.01	--	31	20	--	--	--	--	362	0	--	--	--	--	--	--	--	--	--	--	488	160	0	7.8	323	--	--
Do.	W	9-19-69	--	--	2.6	--	23	7.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	87	--	--	--	--	--
10bda	W	5-14-69	--	--	<.01	--	--	--	--	--	--	--	427	0	--	--	--	--	--	--	--	--	--	--	710	--	--	7.6	<220	--	--
Cbdb2/	C	10-20-69	9.9	<0.1	.03	<0.01	35	1.3	0.26	12	1.9	<0.01	--	7	11	8	0.1	0.8	<0.01	0.01	<0.01	<0.01	0.01	103	310	89	18	10.5	275	1.5	<2.0
10bdc3/	--	10-20-69	22	<.1	.05	<.01	29	9.8	.23	13	1.7	<.01	154	0	18	.6	.1	.2	<.01	.01	<.01	<.01	.03	154	270	114	0	8.2	315	2.0	1.2
12bad	W	3-2-69	35	<.1	.02	<.01	84	24	.49	22	2.1	.01	373	0	37	11	.2	8.0	<.01	.02	.09	<.01	.01	402	665	309	3	7.4	<220	1.5	5.5
17aab	W	3-19-69	30	.2	.01	<.01	25	23	.47	74	4.9	.01	337	0	48	.6	.3	3.8	<.01	.03	2.6	<.01	.15	364	595	158	0	7.9	<220	6.9	12
17aba	W	3-19-69	--	--	.02	--	--	--	--	--	--	--	369	0	--	--	--	--	--	--	--	--	--	--	622	--	--	7.7	--	--	--
aad	S	3-25-69	--	--	.06	--	--	--	--	--	--	--	404	0	--	--	--	--	--	--	--	--	--	--	1,180	--	--	8.0	--	--	--
adb	W	3-18-69	27	.6	.02	.01	60	60	.92	145	6.2	.02	408	0	308	30	.2	7.2	<.01	.03	2.0	<.01	.15	855	1,260	398	63	7.8	<220	4.8	<.4
bcd	S	3-26-69	27	<.1	.02	.01	82	67	1.2	170	4.2	.03	439	0	437	40	.4	4.8	<.01	.01	.02	<.01	.07	1,100	1,500	482	122	7.5	<220	4.6	26
18dad	W	3-18-69	--	--	.04	--	--	--	--	--	--	--	363	0	--	--	--	--	--	--	--	--	--	--	861	--	--	7.8	--	--	--
cbb	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	375	0	--	--	--	--	--	--	--	--	--	--	892	--	--	7.6	236	--	--
bba	W	3-26-69	24	<.1	.05	.02	48	38	.75	59	2.9	.02	383	0	67	4.8	.3	13	<.01	.01	.18	<.01	.05	435	720	278	0	7.6	320	<.4	9.1
bbb1/	W	3-20-69	19	.1	.03	.01	140	.90	1.5	205	5.0	.04	626	0	598	18	.7	.4	<.01	.02	1.3	<.01	.10	1,450	1,870	722	208	7.4	<220	6.5	32
abd	W	3-24-69	19	<.1	.16	.11	130	108	2.5	290	5.6	.06	651	0	657	27	.9	.4	<.01	.01	.19	<.01	.18	1,730	2,250	772	74	7.4	<220	8.7	17
cad	W	3-25-69	14	<.1	.04	.02	110	28	.80	118	3.1	.02	313	0	171	164	.3	<.1	<.01	.14	1.2	<.01	.04	781	1,200	391	134	7.4	570	3.4	2.4
dcd	S	3-25-69	26	<.1	.03	.01	105	63	.94	180	4.4	.02	490	0	464	16	.2	8.6	<.01	.01	.02	<.01	.28	1,140	1,500	523	121	7.4	230	5.4	20
bbc	W	3-25-69	15	<.1	.03	.15	125	38	1.0	148	3.3	.02	352	0	188	240	.3	<.1	<.01	.01	.34	<.01	.03	953	1,450	470	181	7.6	590	1.2	8.7
t	W	3-25-69	--	--	.12	--	--	--	--	--	--	--	392	0	--	--	--	--	--	--	--	--	--	--	1,060	--	--	7.6	--	--	--
t	W	3-25-69	--	--	.17	--	--	--	--	--	--	--	383	0	--	--	--	--	--	--	--	--	--	--	1,240	--	--	7.5	--	--	--
caa	S	3-18-69	--	--	.06	--	--	--	--	--	--	--	519	0	--	--	--	--	--	--	--	--	--	--	1,490	--	--	7.6	--	--	--
dcb	S	3-18-69	--	--	.01	--	--	--	--	--	--	--	422	0	--	--	--	--	--	--	--	--	--	--	1,240	--	--	8.1	<220	6.7	11
acc	S	9-19-69	20	<.1	.01	<.01	8.8	2.0	.04	2.4	.9	<.01	39	0	.5	.3	.1	.5	<.01	--	--	.02	.02	64	65	30	0	7.0	<220	--	--
lacc	W	3-18-69	27	<.1	.01	<.01	69	26	.64	39	2.9	.02	365	0	56	2.4	.2	14	<.01	.02	.07	<.01	.09	414	670	280	0	7.6	<220	2.6	4.7
lbbd	W	3-18-69	--	--	.01	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--	--	--	711	--	--	7.5	--	--	--
2aac	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	304	0	--	--	--	--	--	--	--	--	--	--	782	--	--	7.8	<220	--	--
Do.	W	10-21-69	28	<.1	.06	<.01	48	41	1.1	56	3.7	.02	299	0	108	35	.4	15	<.01	.01	.47	<.01	.06	486	760	290	45	7.7	<220	5.6	18
19bda	S	9- 4-69	--	--	--	--	128	40	--	--	--	--	537	0	--	--	--	--	--	--	--	--	--	933	1,280	484	44	7.6	<220	--	--
2acc	W	3-25-69	--	--	.37	--	--	--	--	--	--	--	361	0	--	--	--	--	--	--	--	--	--	--	858	--	--	7.8	<220	15	14
32bab	W	5-15-69	--	--	.02	--	--	--	--	--	--	--	443	0	--	--	--	--	--	--	--	--	--	--	675	--	--	7.6	618	--	--
36baa	W	5-15-69	--	--	.02	--	--	--	--	--	--	--	563	0	--	--	--	--	--	--	--	--	--	--	1,120	--	--	7.8	396	--	--
5daa	S	3-25-69	30	<.1	<.01	.01	51	28	.60	32	6.9	.01	368	0	22	2.9	.4	3.0	<.01	.01	.04	<.01	.02	361	590	243	0	7.6	600	8.9	10
Do.	S	9-20-69	--	--	--	--	76	33	--	--	--	--	442	0	--	--	--	--	--	--	--	--	--	509	652	325	0	7.7	367	--	--
3dba	S	3-25-69	--	--	<.01	--	--	--	--	--	--	--	507	0	--	--	--	--	--	--	--	--	--	--	766	--	--	7.6	--	--	--
4adb	S	3-25-69	--	--	.01	--	--	--	--	--	--	--	398	0	--	--	--	--	--	--	--	--	--	--	622	--	--	7.7	--	--	--
4bdb	W	3-25-69	38	<.1	.01	<.01	57	36	.60	55	14	.01	449	0	41	5.9	.4	8.5	.17	.02	.13	<.01	.06	465	760	291	0	7.5	470	24	42
5ddb	S	3-25-69	--	--	.01	--	--	--	--	--	--	--	471	0	--	--	--	--	--	--	--	--	--	--	794	--	--	7.4	--	--	--

ple taken had passed through a domestic water softener.

ple collected from tap at Bernklau home (SC6-94-33cba).

ore chlorination.

r chlorination.

le collected from tap at Satterfield home (SC7-95-8ccb).

lected from ditch supplying Moore cistern (SC7-95-10bdb).

Table 1[illegible].--Chemical analyses of water from selected wells, springs, and cisterns, Rulison project area, Garfield and Mesa Counties, Colorado.

(Adapted from Hurr and others, 1969, and Larson and Beetem, 1970.)

Location number: See text for hydrologic data point numbering system.

Location number	Well, spring, or cistern (W,S,C)	Date of collection	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Selenium (Se)	Boron (B)	Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	pH	Tritium T.U.	Gross beta in picocuries per liter (as $Sr^{90}-Y^{90}$)	Gross alpha in micrograms per liter (as U equivalent)
SC5-[illegible]-33aac	W	10-22-[illegible]	31	<0.01	0.06	<0.01	75	91	2.30	34	0.5	<0.01	403	0	262	30	0.9	20	<0.01	0.02	0.11	<0.01	0.20	753	1,120	565	234	7.6	<220	<6.5	17
SC6-[illegible]-15cbd	W	3-26-69	--	--	.05	--	--	--	--	--	--	--	436	0	--	--	--	--	--	--	--	--	--	--	1,990	--	--	7.4	--	--	--
17bbd	W	3-26-69	--	--	.07	--	--	--	--	--	--	--	754	0	--	--	--	--	--	--	--	--	--	--	2,350	--	--	7.3	--	--	--
18aac	S	3-26-69	--	--	.04	--	--	--	--	--	--	--	132	0	--	--	--	--	--	--	--	--	--	--	2,210	--	--	7.8	--	--	--
18dac	W	3-26-69	--	--	.04	--	--	--	--	--	--	--	222	0	--	--	--	--	--	--	--	--	--	--	5,480	--	--	7.2	--	--	--
20bdd	S	3-26-69	--	--	.06	--	--	--	--	--	--	--	519	0	--	--	--	--	--	--	--	--	--	--	1,220	--	--	7.8	--	--	--
20ccc	W	3-26-69	--	--	.05	--	--	--	--	--	--	--	395	0	--	--	--	--	--	--	--	--	--	--	686	--	--	7.6	--	--	--
SC6-[illegible]-23dca	W	3-24-69	--	--	.01	--	--	--	--	--	--	--	350	0	--	--	--	--	--	--	--	--	--	--	670	--	--	7.2	--	--	--
26aca	S	3-24-69	--	--	.01	--	--	--	--	--	--	--	428	0	--	--	--	--	--	--	--	--	--	--	1,150	--	--	7.8	--	--	--
26adc	S	3-24-69	--	--	.02	--	--	--	--	--	--	--	327	0	--	--	--	--	--	--	--	--	--	--	1,010	--	--	7.7	--	--	--
26bcc	W	3-24-69	--	--	.02	--	--	--	--	--	--	--	535	0	--	--	--	--	--	--	--	--	--	--	1,160	--	--	7.5	400	6.3	6.8
27daa	W	3-24-69	--	--	.03	--	--	--	--	--	--	--	703	0	--	--	--	--	--	--	--	--	--	--	1,130	--	--	7.4	--	--	--
30cda	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	332	0	--	--	--	--	--	--	--	--	--	--	558	--	--	8.2	--	--	--
31bbb	S	3-20-69	34	<.1	.02	<.01	56	26	.48	32	7.1	<.01	341	0	41	3.7	.2	4.8	<.01	.02	.03	.02	.06	392	600	247	0	7.6	<220	8.4	12
31bbd	W	3-20-69	--	--	<.01	--	--	--	--	--	--	--	416	0	--	--	--	--	--	--	--	--	--	--	707	--	--	7.6	--	--	--
31bca	W	3-20-69	--	--	.01	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--	--	--	729	--	--	7.6	--	--	--
31bcd	W	3-20-69	--	--	.06	--	--	--	--	--	--	--	433	0	--	--	--	--	--	--	--	--	--	--	759	--	--	7.5	--	--	--
31bdc	W	3-24-69	--	--	.03	--	--	--	--	--	--	--	448	0	--	--	--	--	--	--	--	--	--	--	789	--	--	7.5	--	--	--
31dac	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	357	0	--	--	--	--	--	--	--	--	--	--	656	--	--	7.7	--	--	--
32cca	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	597	0	--	--	--	--	--	--	--	--	--	--	1,710	--	--	7.9	<220	5.2	8.0
Do.	S	10-20-69	29	<.1	.04	<.01	61	16	.41	23	4.7	<.01	266	0	35	7.9	.2	11	<.01	.04	.11	<.01	.02	304	500	219	1	7.6	<220	1.6	4.2
33dbd	S	3-24-69	--	--	.01	--	--	--	--	--	--	--	412	0	--	--	--	--	--	--	--	--	--	--	762	--	--	7.6	<220	11	53
3[illegible]dcc	S	3-24-69	--	--	<.01	--	--	--	--	--	--	--	448	0	--	--	--	--	--	--	--	--	--	--	654	--	--	7.7	--	--	--
SC6-95-25cdd 1/	W	3-20-69	20	.1	.04	.04	50	42	.75	750	4.0	.06	755	0	1,160	27	.6	30	<.01	.06	.49	.05	.12	2,450	3,250	299	0	7.4	<220	8.1	34
36aab	S	9-5-69	--	--	--	--	81	29	--	--	--	--	429	0	--	--	--	--	--	--	--	--	--	425	695	322	0	8.0	<220	--	--
36aab1	S	9-5-69	--	--	--	--	81	31	--	--	--	--	431	0	--	--	--	--	--	--	--	--	--	416	698	330	0	7.9	<220	--	--
36abd	S	9-4-69	--	--	--	--	81	29	--	--	--	--	440	0	--	--	--	--	--	--	--	--	--	433	725	322	0	7.8	<220	--	--
36abd1	S	9-5-69	--	--	--	--	85	29	--	--	--	--	434	0	--	--	--	--	--	--	--	--	--	422	712	332	0	8.0	<220	--	--
36adb	W	3-26-69	--	--	.12	--	--	--	--	--	--	--	376	0	--	--	--	--	--	--	--	--	--	--	668	--	--	7.4	--	--	--
36add	W	3-24-69	--	--	.02	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--	--	--	708	--	--	7.6	--	--	--
36cdd	S	3-21-69	33	<.1	.03	<.01	47	55	.82	65	2.9	.02	530	0	43	7.9	.3	5.4	<.01	.03	.03	<.01	.09	507	850	345	0	7.9	<220	5.6	28
36dab	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	474	0	--	--	--	--	--	--	--	--	--	--	805	--	--	8.2	--	--	--
SC6-96-29daa	W	3-20-69	23	<.1	.03	.03	130	51	1.8	90	15	.07	656	0	184	7.9	1.1	6.0	<.01	.05	.19	.01	.16	635	1,260	537	0	7.4	<220	15	31
34bda	W	3-20-69	--	--	.01	--	--	--	--	--	--	--	617	0	--	--	--	--	--	--	--	--	--	--	1,360	--	--	7.4	--	--	--
34bdb	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	606	0	--	--	--	--	--	--	--	--	--	--	1,340	--	--	7.4	--	--	--
34cad	W	3-20-69	--	--	.75	--	--	--	--	--	--	--	627	0	--	--	--	--	--	--	--	--	--	--	1,640	--	--	7.4	--	--	--
34cdb	W	3-20-69	--	--	.06	--	--	--	--	--	--	--	628	0	--	--	--	--	--	--	--	--	--	--	1,800	--	--	7.4	--	--	--
SC7-94-04acd	S	3-24-69	--	--	<.01	--	--	--	--	--	--	--	352	0	--	--	--	--	--	--	--	--	--	--	720	--	--	7.6	--	--	--
04bdc	S	10-20-69	31	<.1	.03	<.01	75	41	.75	45	3.4	.01	434	0	89	11	.2	14	<.01	.02	.07	<.01	.07	531	825	357	1	7.6	<220	4.6	10
04bdc 2/	S	3-22-69	--	--	.02	--	--	--	--	--	--	--	408	0	--	--	--	--	--	--	--	--	--	--	796	--	--	7.5	--	--	--
Do. 2/	S	10-20-69	32	<.1	.04	.02	74	41	.76	45	3.4	.01	431	0	90	11	.2	14	<.01	.01	<.01	<.01	.06	512	820	354	1	7.6	<220	<3.6	3.4
06aba	S	3-21-69	31	<.1	.05	.02	58	25	.49	25	3.4	.02	309	0	39	8.5	.2	9.0	<.01	.02	.02	<.01	.10	341	565	248	0	8.1	<220	5.1	11
06bba	S	3-20-69	--	--	.04	--	--	--	--	--	--	--	352	0	--	--	--	--	--	--	--	--	--	--	557	--	--	8.2	--	--	--
06ddd	W	3-22-69	--	--	<.01	--	--	--	--	--	--	--	324	0	--	--	--	--	--	--	--	--	--	--	545	--	--	7.7	<220	<.4	5.0
Do.	W	10-20-69	36	<.1	.04	<.01	66	24	.69	14	3.2	<.01	323	0	27	7.2	.2	8.1	<.01	.02	.19	<.01	<.01	356	545	264	0	7.7	<220	2.1	<8.5
07bab	W	3-22-69	--	--	<.01	--	--	--	--	--	--	--	229	0	--	--	--	--	--	--	--	--	--	--	366	--	--	7.6	--	--	--
SC7-95-01aba	S	3-21-69	--	--	.03	--	--	--	--	--	--	--	442	0	--	--	--	--	--	--	--	--	--	--	689	--	--	7.6	--	--	--
01baa	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	679	0	--	--	--	--	--	--	--	--	--	--	1,030	--	--	7.8	--	--	--
02add	S	3-26-69	--	--	.03	--	--	--	--	--	--	--	473	0	--	--	--	--	--	--	--	--	--	--	760	--	--	7.7	--	--	--
02bcd	S	3-21-69	30	<.1	.03	<.01	60	16	.40	23	2.9	<.01	262	0	33	7.2	.1	8.4	<.01	.03	.11	<.01	.02	302	500	216	2	7.6	<220	3.4	11
02cbc	W	3-19-69	26	.1	.02	<.01	22	35	.76	150	3.5	.05	523	0	93	1.1	.3	6.1	<.01	.05	.81	<.01	.30	587	940	200	0	7.8	<220	5.6	17
04acd	S	3-26-69	--	--	.01	--	--	--	--	--	--	--	378	0	--	--	--	--	--	--	--	--	--	--	709	--	--	7.9	--	--	--
04add	S	3-26-69	27	<.1	.04	.02	44	45	.90	82	3.1	.02	403	0	127	8.9	.2	8.8	<.01	<.01	.02	<.01	.12	564	850	296	0	8.1	<220	4.0	9.1
04dbb	S	3-26-69	--	--	.06	--	--	--	--	--	--	--	322	0	--	--	--	--	--	--	--	--	--	--	568	--	--	7.9	--	--	--
05dcd 3/	S	3-21-69	24	<.1	.03	<.01	26	33	.76	40	2.0	.02	323	0	20	8.3	.2	8.6	<.01	.01	.02	<.01	.04	336	560	202	0	7.7	<220	3.0	21
Do. 4/	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	310	0	--	--	--	--	--	--	--	--	--	--	514	--	0	7.8	--	--	--
Do. 4/	S	9-20-69	--	--	--	--	30	28	--	--	--	--	318	0	--	--	--	--	--	--	--	--	--	289	518	190	0	7.9	<220	--	--
Do. 4/	S	10-19-69	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<220	--	--
07adb 1/	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	572	0	--	--	--	--	--	--	--	--	--	--	1,470	--	--	7.3	<220	--	--
07dab 1/	W	3-24-69	33	<.1	.02	<.01	69	49	.87	115	3.3	.02	505	0	181	10	.4	<.1	<.01	.30	.25	<.01	.14	665	1,060	375	0	7.5	<220	11	28

... and Lofton and Beetem, 19[illegible])

Location number: See text for hydrologic data point numbering system.

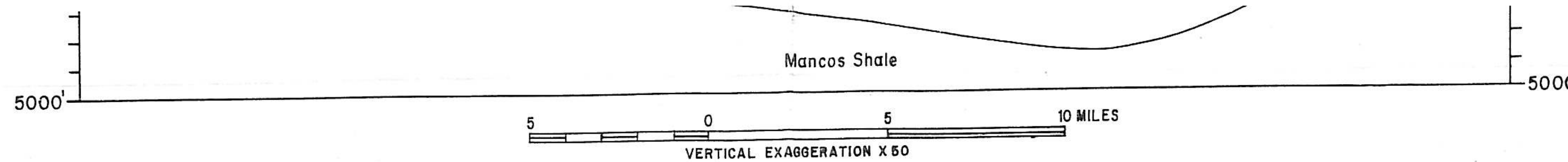
Location number	Well, spring, or cistern (W,S,C)	Date of collection	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Selenium (Se)
SC5-[illegible]-33aac	W	1[illegible]-2[illegible]-[illegible]	[illegible]1	<.01	0.0[illegible]	<.01	75	91	2.30	34	6.5	<.01	4[illegible]3	0	262	30	0.9	20	<0.01	0.02	0.11	<0.[illegible]
SC[illegible]-[illegible]-15cbd	W	3-26-69	--	--	.05	--	--	--	--	--	--	--	696	0	--	--	--	--	--	--	--	--
17bbd	W	3-26-69	--	--	.07	--	--	--	--	--	--	--	754	0	--	--	--	--	--	--	--	--
1[illegible]aac	S	3-26-69	--	--	.04	--	--	--	--	--	--	--	532	0	--	--	--	--	--	--	--	--
1[illegible]dac	W	3-26-69	--	--	.04	--	--	--	--	--	--	--	222	0	--	--	--	--	--	--	--	--
2[illegible]bdd	S	3-26-69	--	--	.06	--	--	--	--	--	--	--	519	0	--	--	--	--	--	--	--	--
2[illegible]ccc	W	3-26-69	--	--	.05	--	--	--	--	--	--	--	395	0	--	--	--	--	--	--	--	--
SC[illegible]-[illegible]-[illegible]dca	W	3-24-69	--	--	.01	--	--	--	--	--	--	--	360	0	--	--	--	--	--	--	--	--
2[illegible]aca	S	3-24-69	--	--	.01	--	--	--	--	--	--	--	428	0	--	--	--	--	--	--	--	--
2[illegible]adc	S	3-24-69	--	--	.02	--	--	--	--	--	--	--	327	0	--	--	--	--	--	--	--	--
26bcc	W	3-24-69	--	--	.02	--	--	--	--	--	--	--	535	0	--	--	--	--	--	--	--	--
27daa	W	3-24-69	--	--	.03	--	--	--	--	--	--	--	703	0	--	--	--	--	--	--	--	--
30cda	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	332	0	--	--	--	--	--	--	--	--
31bbb	S	3-20-69	34	<.1	.02	<.01	56	26	.48	32	7.1	<.01	341	0	41	3.7	.2	4.6	<.01	.02	.03	.0[illegible]
31bbd	W	3-20-69	--	--	<.01	--	--	--	--	--	--	--	416	0	--	--	--	--	--	--	--	--
31bca	W	3-20-69	--	--	.01	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--
31bcd	W	3-20-69	--	--	.06	--	--	--	--	--	--	--	433	0	--	--	--	--	--	--	--	--
31bdc	W	3-24-69	--	--	.03	--	--	--	--	--	--	--	448	0	--	--	--	--	--	--	--	--
31dac	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	357	0	--	--	--	--	--	--	--	--
32cca	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	697	0	--	--	--	--	--	--	--	--
Do.	S	10-20-69	29	<.1	.04	<.01	61	16	.41	23	4.7	<.01	266	0	35	7.9	.2	11	<.01	.04	.11	<.0[illegible]
33dbd	S	3-24-69	--	--	.01	--	--	--	--	--	--	--	412	0	--	--	--	--	--	--	--	--
34dcc1/	S	3-24-69	--	--	<.01	--	--	--	--	--	--	--	448	0	--	--	--	--	--	--	--	--
SC6-95-25cdd	W	3-20-69	20	.1	.04	.04	50	42	.75	750	4.0	.06	755	0	1,160	27	.6	30	<.01	.06	.49	.0[illegible]
36aab	S	9-5-69	--	--	--	--	81	29	--	--	--	--	429	0	--	--	--	--	--	--	--	--
36aab1	S	9-5-69	--	--	--	--	81	31	--	--	--	--	431	0	--	--	--	--	--	--	--	--
36abd	S	9-4-69	--	--	--	--	81	29	--	--	--	--	440	0	--	--	--	--	--	--	--	--
36abd1	S	9-5-69	--	--	--	--	85	29	--	--	--	--	434	0	--	--	--	--	--	--	--	--
36adb	W	3-26-69	--	--	.12	--	--	--	--	--	--	--	376	0	--	--	--	--	--	--	--	--
36add	W	3-24-69	--	--	.02	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--
36cdd	S	3-21-69	33	<.1	.03	<.01	47	55	.82	65	2.9	.02	530	0	43	7.9	.3	5.4	<.01	.03	.03	<.01
36dab	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	474	0	--	--	--	--	--	--	--	--
SC6-96-29daa	W	3-20-69	23	<.1	.03	.03	130	51	1.8	90	15	.07	656	0	184	7.9	1.1	6.0	<.01	.05	.19	.01
34bda	W	3-20-69	--	--	.01	--	--	--	--	--	--	--	617	0	--	--	--	--	--	--	--	--
34bdb	W	3-20-69	--	--	.02	--	--	--	--	--	--	--	606	0	--	--	--	--	--	--	--	--
34cad	W	3-20-69	--	--	.75	--	--	--	--	--	--	--	627	0	--	--	--	--	--	--	--	--
34cdb	W	3-20-69	--	--	.06	--	--	--	--	--	--	--	628	0	--	--	--	--	--	--	--	--
SC7-94-04acd	S	3-24-69	--	--	<.01	--	--	--	--	--	--	--	352	0	--	--	--	--	--	--	--	--
04bdc	S	10-20-69	31	<.1	.03	<.01	75	41	.75	45	3.4	.01	434	0	89	11	.2	14	<.01	.02	.07	<.01
04bdc2/	S	3-22-69	--	--	.02	--	--	--	--	--	--	--	408	0	--	--	--	--	--	--	--	--
Do.2/	S	10-20-69	32	<.1	.04	.02	74	41	.76	45	3.4	.01	431	0	90	11	.2	14	<.01	.01	<.01	<.01
06aba	S	3-21-69	31	<.1	.05	.02	58	25	.49	25	3.4	.02	309	0	39	8.5	.2	9.0	<.01	.02	.02	<.01
06bba	S	3-20-69	--	--	.04	--	--	--	--	--	--	--	352	0	--	--	--	--	--	--	--	--
06ddd	W	3-22-69	--	--	<.01	--	--	--	--	--	--	--	324	0	--	--	--	--	--	--	--	--
Do.	W	10-20-69	36	<.1	.04	<.01	66	24	.69	14	3.2	<.01	323	0	27	7.2	.2	8.1	<.01	.02	.19	<.01
07bab	W	3-22-69	--	--	<.01	--	--	--	--	--	--	--	229	0	--	--	--	--	--	--	--	--
SC7-95-01aba	S	3-21-69	--	--	.03	--	--	--	--	--	--	--	442	0	--	--	--	--	--	--	--	--
01baa	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	679	0	--	--	--	--	--	--	--	--
02add	S	3-26-69	--	--	.03	--	--	--	--	--	--	--	473	0	--	--	--	--	--	--	--	--
02bcd	S	3-21-69	30	<.1	.03	<.01	60	16	.40	23	2.9	<.01	262	0	33	7.2	.1	8.4	<.01	.03	.11	<.01
02cbc	W	3-19-69	26	.1	.02	<.01	22	35	.76	150	3.5	.05	523	0	93	1.1	.3	6.1	<.01	.05	.81	<.01
04acd	S	3-26-69	--	--	.01	--	--	--	--	--	--	--	378	0	--	--	--	--	--	--	--	--
04add	S	3-26-69	27	<.1	.04	.02	44	45	.90	82	3.1	.02	403	0	127	8.9	.2	8.6	<.01	<.01	.02	<.01
04dbb	S	3-26-69	--	--	.06	--	--	--	--	--	--	--	322	0	--	--	--	--	--	--	--	--
05dcd3/	S	3-21-69	24	<.1	.03	<.01	26	33	.76	40	2.0	.02	323	0	20	8.3	.2	8.6	<.01	.01	.02	<.01
Do.4/	S	3-21-69	--	--	.02	--	--	--	--	--	--	--	310	0	--	--	--	--	--	--	--	--
Do.4/	S	9-20-69	--	--	--	--	30	28	--	--	--	--	316	0	--	--	--	--	--	--	--	--
Do.4/	S	10-19-69	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
07adb1/	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	572	0	--	--	--	--	--	--	--	--
07dab	W	3-24-69	33	<.1	.02	<.01	69	49	.87	115	3.3	.02	505	0	181	10	.4	<.1	<.01	.30	.25	<.01

TABLE 1: WIPE TEST RESULTS

LOCATION (SEE FIG. 1)	SAMPLE NO. (SEE FIG. 1)	NET CPM ± STANDARD DEVIATION	CALIBRATION CPM ± STANDARD DEVIATION*	μCURIE/100 CM²†
TEXACO TANK - 3.5 MILES FROM SITE				
Tank - Around valve	2	1.2±3.78	0±.9	.0000040±.000015
Tank - Valve	3	2.4±3.80		.0000090±.000015
ANNIE H. ESHE, RT. 1 - RIFLE, COLO.				
Tractor Crankcase	4	0±3.67	0±.09	0±.000014
Fordson Tractor Crankcase	5	.2±3.75		
John Deere Grain Binder	6	0±3.66		0±.000014
'40 Chev. Truck Crankcase	7	0±3.72		0±.000015
John Deere Plow Bearing	8	0±3.54		0±.000014
RALPH McDANIEL, RT. 1 - RIFLE, COLO.				
Ford Tractor Gear Box	9	0±3.64		0±.000014
Gas Tank Film	10	0±3.58		0±.000014
DICK SIMMS, RT. 1 - GRAND VALLEY, COLO.				
Ford Tractor Crankcase	11	0±3.65	0±.85	0±.000014
Ford Tractor Gear Box	12	0±3.64		0±.000014
E. A. SCOTT, RT. 1, BOX 181, GRAND VALLEY, COLO.				
Fire wall of School Bus	14	1.2±3.77		.0000040±.000015
Engine Case of Garden Tiller	15	0±3.52		0±.000014
Farmall Tractor Crankcase	16	0±3.60	0±.85	0±.000014
RUSSELL BINGMAN FARM - VACATED				
AC 60 All Crop Harvester	17	0±3.73		0±.000015
John Deere Side Delivery Rake	18	0±3.60		0±.000014
FELIX SEFCOVIC, RT. 1, BOX 69, GRAND VALLEY, COLO.				
John Deere Loader Tractor Crankcase	21	3±3.82		.0000120±.000015
Old Loader Frame	22	0±3.66		0±.000014
Rotor Arm on Massey-Harris Hay Baler	23	0±3.57		0±.000014
JAMES ROGERS, RT. 1, BOX 62, GRAND VALLEY, COLO.				
Bearing on John Deere Van Brunt Grain Drill	24	1.6±3.78		.0000060±.000015
Farmall Loader Tractor Gear Case	25	0±3.57	0±.85	0±.000014
Bearing-Morrill Rake	26	0±3.49		0±.000014
L. W. St.JOHN, RT. 1, GRAND VALLEY, COLO.				
Power Take-off Housing to Smaller of Red Underside Ford Tractor	28	0±3.59		0±.000014
OLIVER WOOD, RT. 1,GRAND VALLEY, COLO.				
Briggs-Stratton Engine - Garden Tiller	29	0±3.60		0±.000014
Rotary Lawn Mower	30	0±3.66		0±.000014
NAME NOT KNOWN, RT. 1, GRAND VALLEY, COLO.				
Ford Tractor Loader-Hydraulic Pump Housing	32	0±3.56		0±.000014
John Deere Hay Baler, Engine Crankcase	33	0±3.70		0±.000014
Case Side Delivery Rake, Adjustment Bearing	34	0±3.62		0±.000014
Roller Bearing on Old Unused John Deere Baler	35	0±3.46		0±.000013
ABANDONED FARMSTEAD, RT. 1, GRAND VALLEY, COLO.				
Bearing on Old Unused Letz Grain Binder	36	0±3.60		0±.000014
W. E. RUGKIN, RT. 1, BOX 80, GRAND VALLEY, COLO.				
Engine Block - Lincoln Welder	37	0±3.67		0±.000014
1 cyl. Engine on Sprayer	38	1.2±3.77		.0000040±.000015
Rear Axle - Ford Tractor	39	0±3.50	0±.85	0±.000014
WILLARD EAMES, RT.1, BOX 43, GRAND VALLEY, COLO.				
John Deere Baler Oil Filter	40	0±3.47		0±.000014
Rear Bearing on John Deere Manure Spreader	41	0±3.43		0±.000013
Wheel Bearing on John Deere Side Rake	42	0±3.63		0±.000014
U-Joint on Ford Power Take-off Mower	43	0±3.48		0±.000014
GLENN St.JOHN, RT. 1, GRAND VALLEY, COLO.				
Crankcase on Case Tractor	44	0±3.66		0±.000014
U-Joint on John Deere Power Take-off Mower	45	0±3.70		0±.000014
Crankcase on 2 cyl. Gas Engine	46	0±3.62		0±.000014
NAME NOT KNOWN, RT. 1, GRAND VALLEY, COLO.				
Crankcase on John Deere Tractor	47	0±3.57		0±.000014
NAME NOT KNOWN, RT. 1, GRAND VALLEY, COLO.				
U-Joint, Power Take-off	48	0±3.48		0±.000014
Oil Drain - Ford Baler	49	.2±3.75		.0000008±.000015
DON BURTARD, RT. 1, GRAND VALLEY, COLO.				
Power Take-off U-Joint on Hesston Wind Rower	50	0±3.55		0±.000014
Crankcase on Ford Tractor	51	0±3.62		0±.000014
DON MOORE, GRAND VALLEY, COLO.				
Oil Filter Gas Engine	53	0±3.54		0±.000014
Grease - Yellow Gear Box	54	0±3.50		0±.000014
Oil From Crankcase of Old Chev. Engine	55	.6±3.76		.0000020±.000015
COLLIN CLEM, RT. 1, GRAND VALLEY, COLO.				
Gear Housing on John Deere Mower	56	0±3.52		0±.000014
Oil Filter on John Deere Tractor	57	0±3.47		0±.000014
Crankcase on Old McCormick-Deering Farmall	58	2.8±3.82		.0000110±.000015
ABANDONED FARMSTEAD				
Clutch Housing on Unused Tractor	59	0±3.69		0±.000014
G. A. KNIGHT, GRAND VALLEY, COLO.				
Gus Trailer Differential	60	0±3.52		0±.000014
Transmission of Old Allis Chalmers Tractor	61	0±3.57		0±.000014
EDWARD FORSHER, GRAND VALLEY, COLO.				
Crankcase of Old McCormick-Deering Tractor	62	0±3.65		0±.000014
Gear Housing of Forge Blower	63	0±3.68		0±.000014
A. J. HOAGLAND, RT. 1, GRAND VALLEY, COLO.				
Flywheel on Housing of John Deere Tractor	65	0±3.51		0±.000014
Hydraulic Pump Housing on Gas Trailer	66	0±3.61		0±.000014
Engine Block on John Deere Tractor w/Loader	67	0±3.52		0±.000014
Filter on Fuel Tank	68	.8±3.76		.0000030±.000015
STANDARD-OIL FILM FROM CRANKCASE OF KAMAN CAR*	--	0±3.63		0±.000015

* The wipe used as the reference standard has an activity comparable to all others taken. This is the background level of 0.00012 μcurie/100 cm^2. See footnote of Table 2.

† Recommended maximum is 0.00112 μcurie/100 cm^2 above normal background for uncontrolled areas.



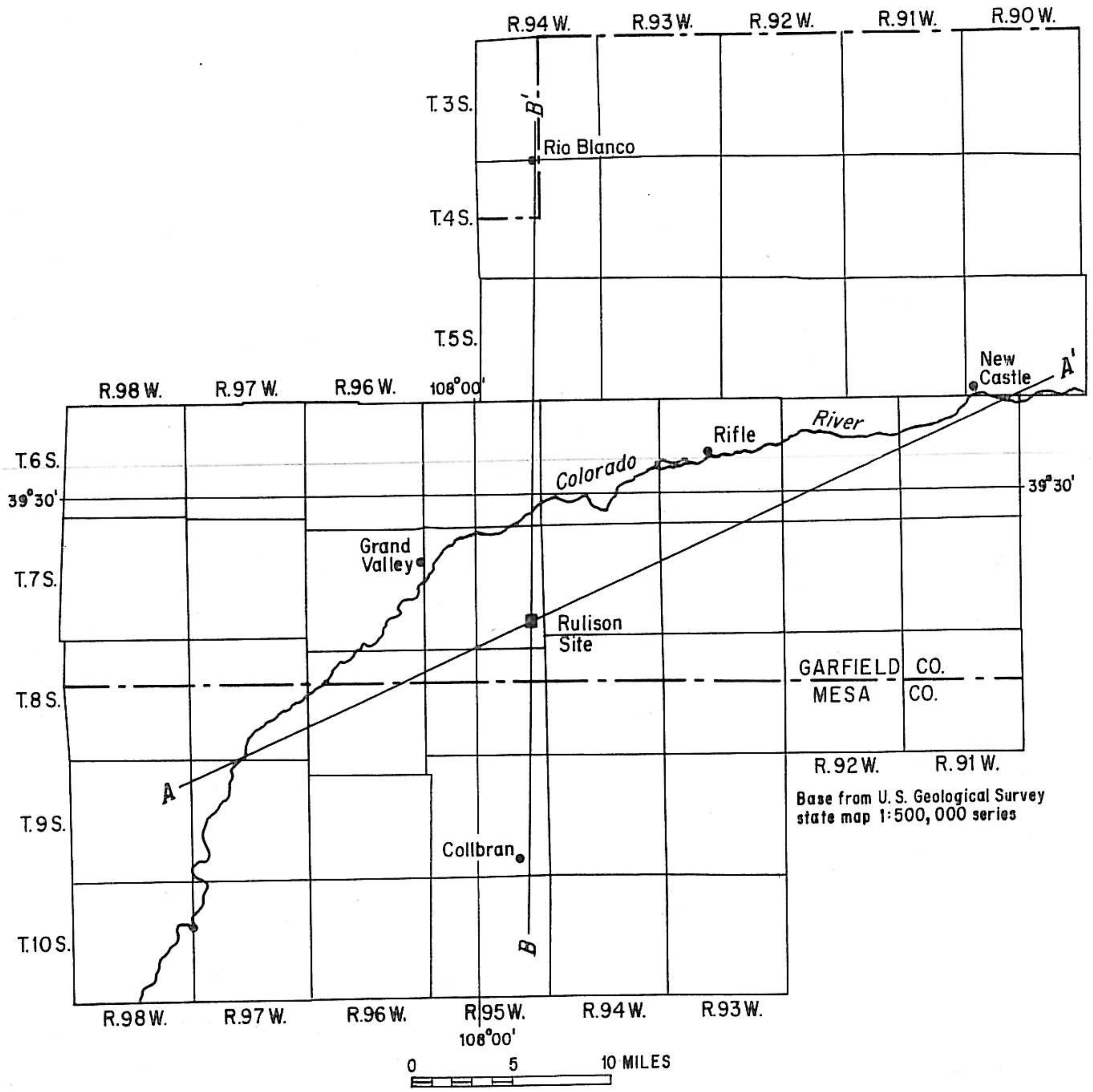
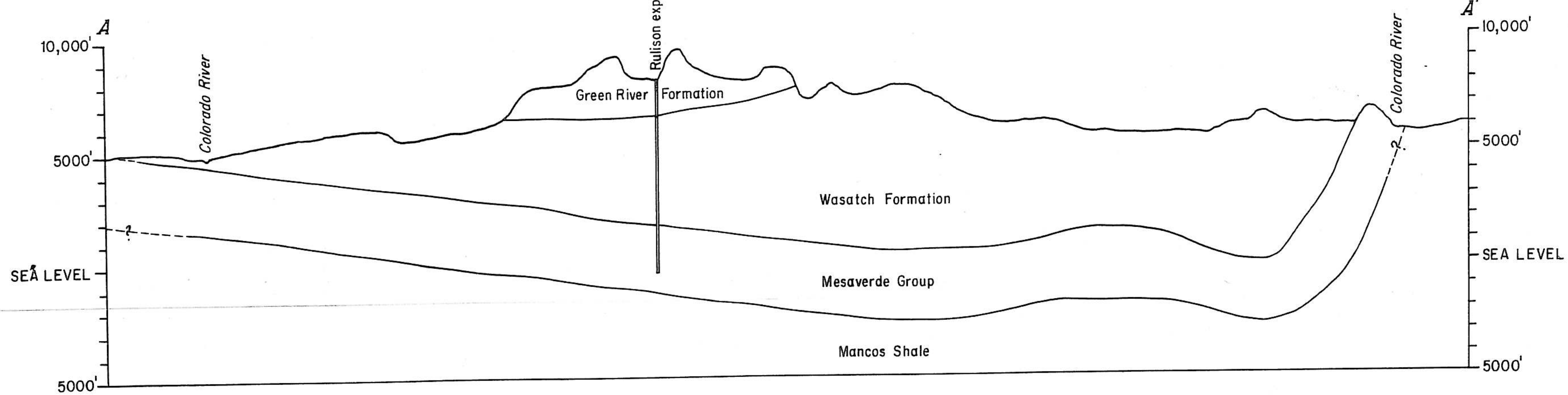


FIGURE I.--
DIAGRAMMATIC GEOLOGIC SECTIONS THROUGH THE RULISON PROJECT AREA
GARFIELD AND MESA COUNTIES, COLORADO

Prepared by Paul T. Voegeli, Sr.

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY



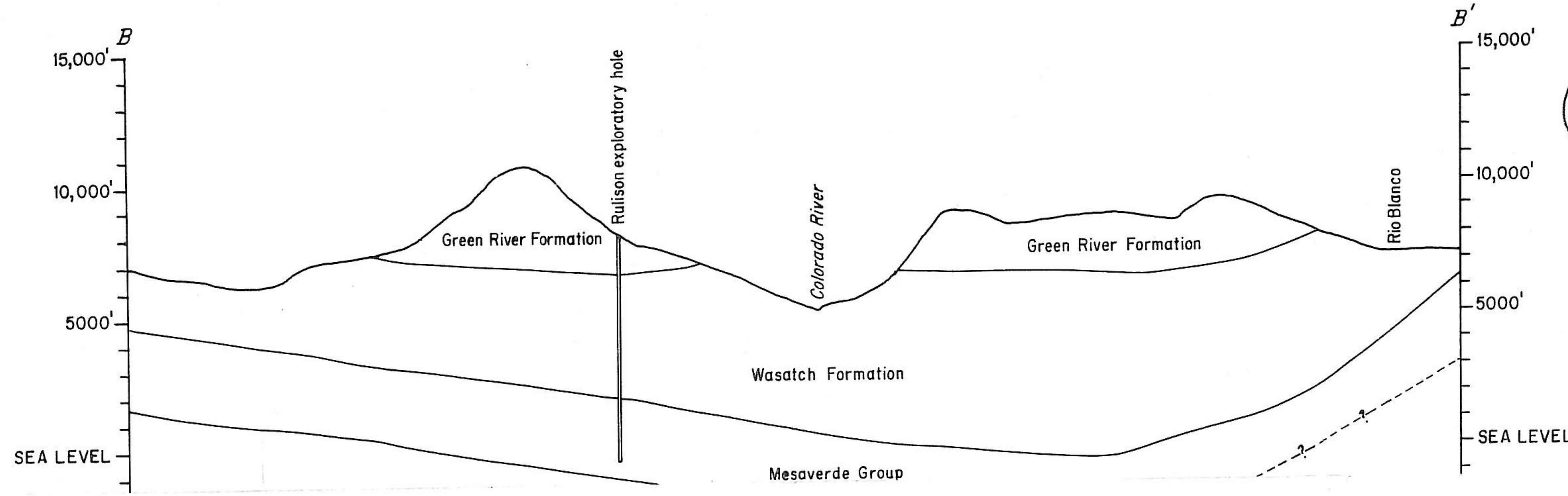


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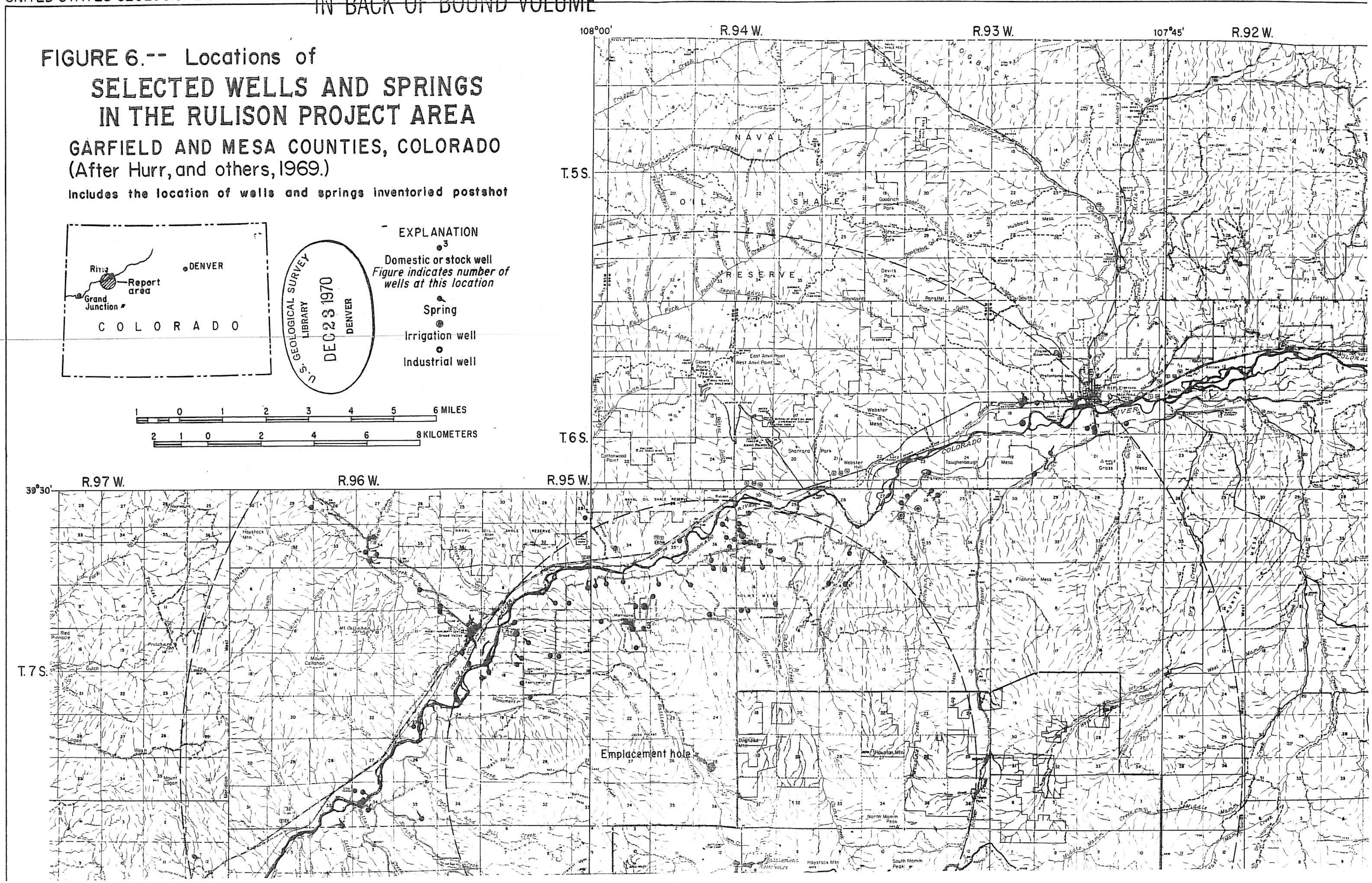
FIGURE 6.-- Locations of SELECTED WELLS AND SPRINGS IN THE RULISON PROJECT AREA

GARFIELD AND MESA COUNTIES, COLORADO

(After Hurr, and others, 1969.)

Includes the location of wells and springs inventoried postshot



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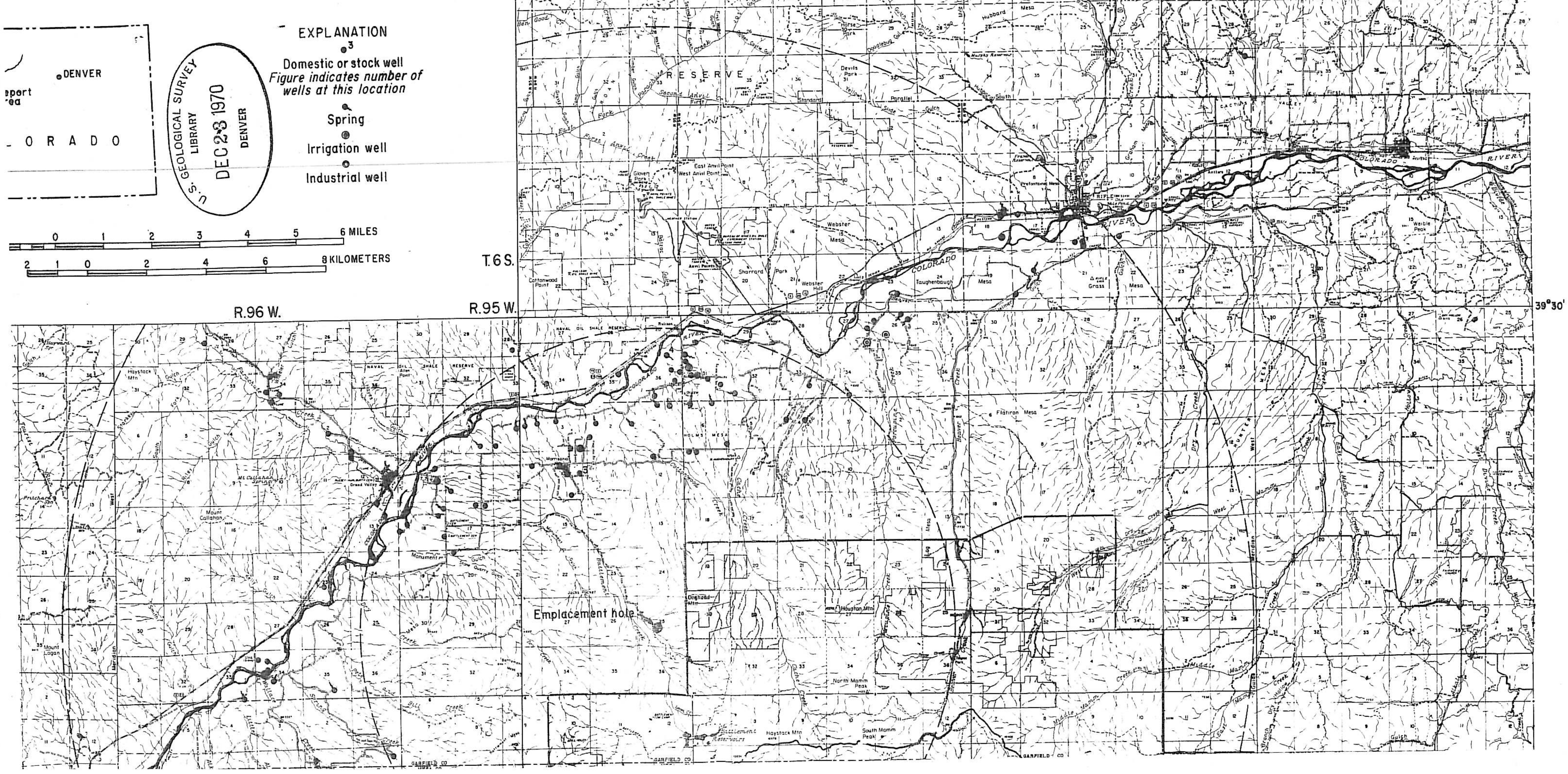

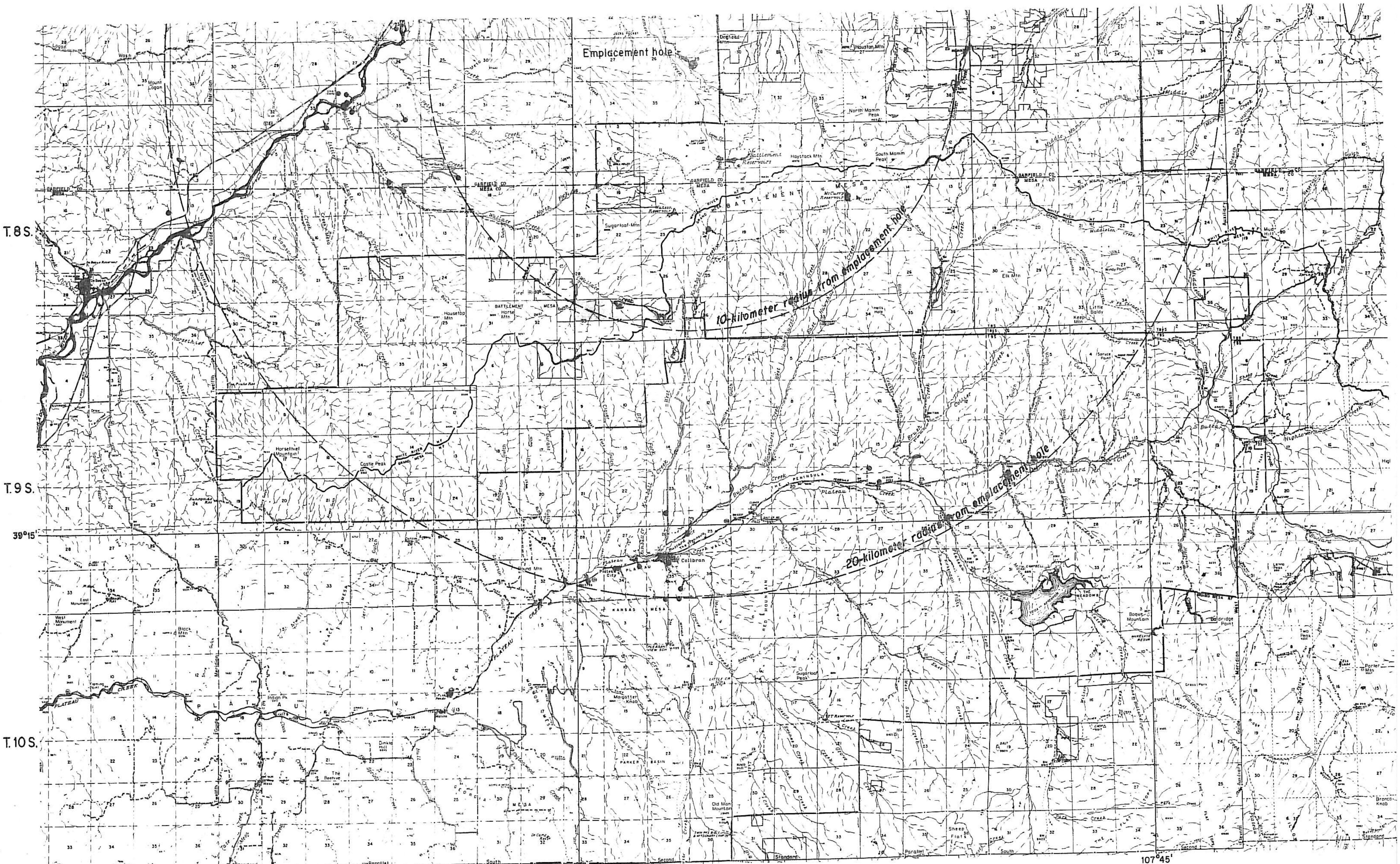

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1971 GEOLOGICAL SURVEY

Federal Center, Denver, Colorado 80225

RADIOCHEMICAL ANALYSES OF WATER FROM SELECTED STREAMS, WELLS, SPRINGS, AND PRECIPITATION COLLECTED PRIOR TO REENTRY DRILLING, PROJECT RULISON

By

Paul T. Voegeli, Sr., and Hans C. Claassen

INTRODUCTION

The U.S. Geological Survey established a water-sampling network in central and western Colorado on behalf of the U.S. Atomic Energy Commission to sample the hydrologic environment prior to and during the reentry drilling and the gas-production test phase of Project Rulison, an experiment to stimulate gas production from a low yield reservoir by a nuclear explosion. Samples obtained from selected streams, wells, springs, and from precipitation are analyzed for tritium, gross alpha, and gross beta activity. The analyses are made in laboratories of the U.S. Geological Survey, Denver, Colorado.

This report contains data from analyses of samples from the network collected prior to reentry drilling (started April 28, 1970), including sample data obtained both prior to and after the nuclear detonation. The data are intended to give representative values over approximately a 1-year period and to show variations in natural radioactivity.

reporting of data is included to allow the reader to evaluate the quality of the data presented and to permit direct comparison between data obtained by the Geological Survey and by other agencies.

Water samples will be collected from the sampling points (fig. 1) until the flaring of gas is discontinued. Stream and composite precipitation samples will be taken to coincide with the gas production schedule: A sample will be taken to coincide with each phase of high-volume gas production and with each period of low-volume gas production or shut-in period. In addition to the sampling during the gas-production phase, streams will be sampled every 30 days after the start of reentry drilling. Wells and springs will be sampled 30 days after the start of reentry drilling and then every 60 to 90 days thereafter. If anomalies are detected at any sampling point, the frequency of sampling will be increased.

SAMPLE-COLLECTION PROCEDURES

The low levels of natural radioactivity in environmental waters make it important to collect samples in a manner that minimizes contamination of the sample during and after collection. Sample-collection procedures are described to permit evaluation of analytical data supplied. The sampling technique used depends on whether a surface-water, a ground-water, or a precipitation sample is collected and on the type of analysis to be made. A description of these techniques follows.

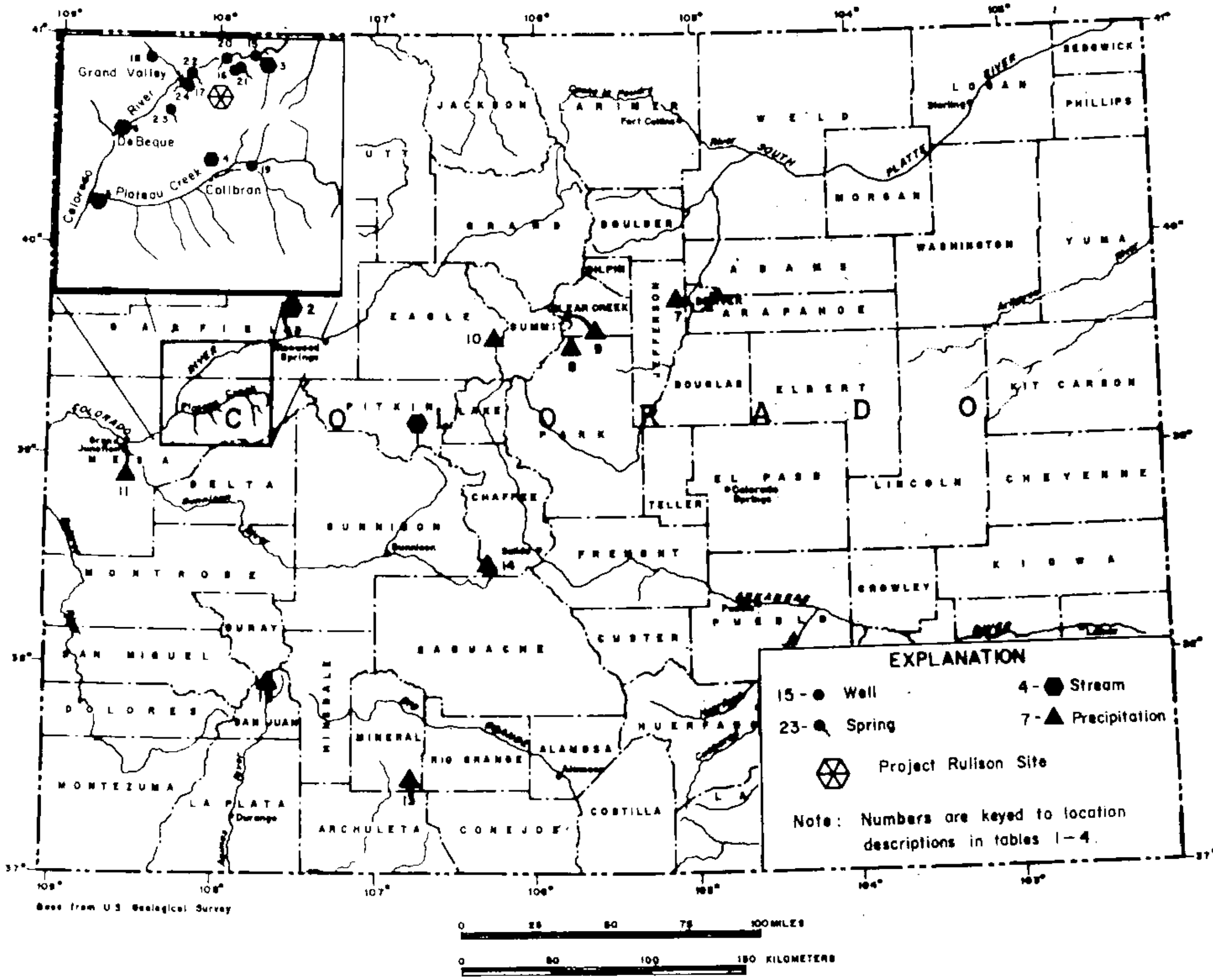

FIGURE 1.--Locations of the U.S. Geological Survey water-sampling points, Project Rulison.

Samples to be analyzed for tritium are collected in 32-ounce glass bottles fitted with nonporous screw caps. The bottle is inverted and immersed in water with the bottle neck down. It is then turned upright and returned to the surface.

The first dip is used as a rinse and discarded in such a manner that the sampling point is not disturbed. The sample is collected in the same manner as above, using the same bottle. The screw cap is tightly affixed, the outside of the bottle is dried with a disposable towel to avoid cross-contaminating the bottles, and the bottle is labeled. The cap is sealed with vinyl tape to ensure that the sample is not contaminated before arriving at the laboratory.

Samples to be analyzed for gross alpha and gross beta radioactivity are collected in the same manner as the tritium samples, using a 4-liter polyethylene bottle with a polyethylene screw cap. This bottle is also sealed with vinyl tape and the bottle labeled. The samples are filtered in the laboratory through a 0.45-micron filter membrane, and separate determinations of gross alpha/gross beta activities are made on the sediment and the filtrate.

Samples to be analyzed for tritium are collected in 32-ounce glass bottles with nonporous screw caps. The sample is collected in a manner that eliminates or at least minimizes contamination by air. If a submersible pump is in use and a hose connection is available at the well head, a hose is attached to the connection with the free end of the hose touching the inside bottom of the 32-ounce glass bottle. The bottle is allowed to fill and flush for about 30 seconds. The free end of the hose is slowly withdrawn to minimize air entrainment in the water. The bottle is then capped, sealed with tape, and labeled.

If no tap is available at the well head, a sampling point and procedure is chosen which will provide a sample with the least probability of air contamination. Deviations from the normal procedure are noted on the bottle label.

Samples to be analyzed for gross alpha and gross beta radioactivity are collected using the same procedures and criteria for choice of collection point as the tritium samples, but the water is placed in a $1\frac{1}{2}$-gallon pressure-filtration unit. The filtration unit is sealed and nitrogen gas under a pressure of about 20 psi (pounds per square inch) is applied, forcing the water through a 4-inch, 0.45-micron membrane filter pad. The filter and the 4-liter polyethylene receiving bottle are rinsed by the first few hundred milliliters of water that come through the filter, this rinse water is discarded, and then the 4-liter polyethylene bottle is filled. Concentrated (about 12 molar) hydrochloric acid (reagent grade, in glass ampoules) is added to the sample sealed with tape, and labeled.

Precipitation Samples

The procedure described below is followed in the collection of each sample to be analyzed for both tritium and gross alpha/gross beta. The procedure may vary according to site, type of precipitation, and date of collection. The procedures that have been used in collecting the samples discussed in this report are described below. Additional procedures for collection of rain samples will be discussed in a later report.

Procedure 1.--Snow samples are packed into 32-ounce glass bottles which are then capped, sealed with tape, and labeled.

Procedure 2.--A polyethylene bag is half-filled with snow, labeled, and sealed. After the snow has melted, the water is poured into the appropriate bottles--a 32-ounce glass bottle for tritium analysis and a 4-liter polyethylene bottle for gross alpha/gross beta analysis. The bottles are capped, sealed with tape, and labeled.

LABORATORY PROCEDURES

Water samples received for analysis at the Denver laboratory are first assigned a laboratory number. Sample bottles are marked with these numbers and all pertinent information supplied with the samples is typed on the analytical transmittal sheet. The bottles are then taken to the appropriate laboratory for analysis. A summary of the laboratory practices and procedures follows.

The samples of water are analyzed for tritium by liquid scintillation counting. A small volume of the sample is distilled to dryness. Using an aliquot of completely distilled sample eliminates interference caused by dissolved solids as well as possible fractionation effects. For counting, a 4.0-milliliter aliquot of the sample distillate is mixed with 18.0 milliliters of a dioxane-base, liquid-scintillation "cocktail" in a polyethylene counting vial. Laboratory procedures are designed to minimize air contact with the sample. The vial is placed in a Beckman Model LS-100 or a Nuclear Chicago Mark I liquid-scintillation spectrometer and the sample is counted for at least 240 minutes.

Tritium standards of known concentration, obtained from the National Bureau of Standards, and water with no tritium activity (blank), obtained from deep wells, are counted with each group of samples. The activity computed for a sample is calculated by comparing the values of standards, blanks, and samples. The data are adjusted for instrument noise, detection efficiency, and random procedural errors.

A detection level for the set of samples is calculated using the following procedure. Two times the theoretical standard deviation of the mean of the counts of each sample is calculated by the equation

$$2\sigma = 2\left[\frac{(\text{raw counts})^{\frac{1}{2}}}{t}\right]$$

raw counts represents the total number of counts registered for that sample,

t is the total time the sample was counted.

An experimental two-sigma for each sample is then calculated by the equation

$$2s = 2\left[\frac{\sum_{i=1}^{n} (\overline{X}-X_i)^2}{n-1}\right]^{\frac{1}{2}}$$

where: 2s is the experimental standard deviation,

n is the number of times the sample was counted,

$\overline{X}$ is the mean counting rate of the sample,

X_i are the individual counting rates of the sample.

The larger of the two values (2σ, 2s) is chosen as the probable error (the 95 percent confidence level) for the sample. Samples for use in the calculation of detection level are chosen by comparing the counts-per-minute (cpm) values (X_i) of each sample with a value of 1.2 times the average background cpm (note that 1.2 times average background $\cong$ average background $+2\sigma$ or 2s for the background). Only those sample values which are less than 1.2 times average background (X_i') are used in determination of the detection level.

The 2σ or 2s values corresponding to the X_i' values chosen are tabulated in order of increasing magnitude, summed, and the 95-percentile value determined. This value is considered the detection level. A value of about 200 to 400 tritium units or 640 to 1,280 pCi/l (picocuries per liter) has been determined by the above procedure to generally be the detection level.

samples are both the tritium unit (TU), defined in Jacobs (1968) as a concentration of one tritium atom in 10^{18} protium atoms, and the activity unit of pCi/l (3.20 pCi/l = 1 TU). The tritium values are reported to two significant figures.

Gross Alpha and Gross Beta

The gross alpha and gross beta radioactivity values are obtained by evaporating a suitable quantity of the water in a teflon evaporating dish, transferring the resulting solids with small amounts of distilled water onto a ringed planchet, evaporating to dryness at 103-105°C, and counting these planchets in a thin-window, flowing-gas, proportional counter. Samples for which radioactivity values on suspended materials are desired are filtered in the laboratory through a 0.45-micron membrane filter, and the filter cake is dried at 103-105°C before counting. Alpha and beta values are obtained from the same planchet. The data are compared with a calibration curve obtained by adding known amounts of Cs-137 or Sr-90 to synthetic waters having similar compositions to those of the waters being analyzed.

The detection level is determined according to procedures described by Barker and Robinson (1963). They describe two cases as follows:

(1) If the net sample counting rate exceeds the background counting rate by more than two standard deviations, calculate the beta activity from the equation

$$\frac{1,000(R-B)}{EV}$$

B = background counting rate in counts per minute

V = sample volume in milliliters

E = efficiency of instrument.

(2) If the net sample counting rate does not exceed the background counting rate by more than two standard deviations, the result is reported as less than the minimum detection level (MDL).

$$MDL = \frac{2,000\ \sigma_n}{EV}$$

where σ_n = the standard deviation of the net counting rate and is calculated by the following equation:

$$\sigma_n = \left[\sigma_B^2 + \frac{R}{t_R}\right]^{\frac{1}{2}}$$

where σ_B = the standard deviation of background counting rate

t_R = sample counting time.

The units for reporting the alpha and beta data in this report are chosen to allow comparison with data reported by other agencies. These units, and the standards which were used for calibration, are discussed below.

The gross alpha and gross beta data are reported to two significant figures for values greater than 1.0 pCi/l and one significant figure for values less than 1.0 pCi/l.

The U.S. Geological Survey has used natural uranyl acetate as an alpha standard since 1957. The term "natural uranium" is defined in the Code of Federal Regulations 10 CFR 150.20.5c as 3,000 kg (kilograms) natural U $\equiv$ 1 Ci (curie) natural U $\equiv$ (3.7×10^{10} disintegrations per second U^{238}) + (3.7×10^{10} disintegrations per second U^{234}) + (9×10^{8} disintegrations per second U^{235}). Therefore the conversion from radioactivity expressed as units of mass to units of radioactivity as pCi/l is: 1pCi/natural U = 3 μg (micrograms) natural U. In this report, the gross alpha data are presented both in units of mass (μg U/liter) and in units of radioactivity (pCi/liter).

Gross Beta

Gross beta data can be reported in many ways; Sr-90 equivalent and Cs-137 equivalent are most commonly used. The difference is only in which isotope is used for calibration. Although Sr-90 is commonly used as a gross beta standard by the U.S. Geological Survey, gross beta values calibrated with Cs-127 are also tabulated in this report to facilitate interagency data comparison and evaluation.

RESULTS

The results of the analyses of the stream, well, spring, and precipitation samples collected prior to reentry drilling at the Rulison site are presented in tables 1 through 4. The data from samples collected April 1-12, 1970, are included. In addition, results from selected samples collected prior to April 1970 are included to provide background data.

Table 1.--Radiochemical analyses of water from selected streams in western Colorado

Stream	Sample point number[1]	Location: Township S.	Location: Range W.	Location: Section	Location: ¼ section	Latitude N.: Degrees	Latitude N.: Minutes	Latitude N.: Seconds	Longitude W.: Degrees	Longitude W.: Minutes	Longitude W.: Seconds	Distance from surface ground zero, in miles (kilometers)	Date of collection	Tritium: pCi/l	Tritium: TU	Dissolved: Gross alpha (µg/l as U natural)	Dissolved: Gross alpha (pCi/l as U natural)	Dissolved: Gross beta (pCi/l as Sr-90/Y-90)	Dissolved: Gross beta (pCi/l as Cs-137)	Suspended: Solids mg/l	Suspended: Gross alpha (µg/l as U natural)	Suspended: Gross alpha (pCi/l as U natural)	Suspended: Gross beta (pCi/l as Sr-90/Y-90)	Suspended: Gross beta (pCi/l as Cs-137)	Remar
Roaring Fork River near Aspen	1	(2)				39	10	48	106	48	05	64(103)	4- 6-70	<960	<300	7.8	2.6	2.3	2.9	<1	<0.4	<0.1	0.6	0.6	USGS gaging 9-0734.
Colorado River at New Castle	2	5	90	31	SW	39	34	06	107	32	26	25(40)	8-26-69	1,100	350	--	--	--	--		--	--	--	--	USGS gagin 9-0876.
													10-19-69	1,100	350	--	--	--	--		--	--	--	--	
													4- 6-70	1,300	390	28	9.3	8.7	11	16	.9	.3	1.1	1.3	
Beaver Creek near Rifle	3	6	93	20	SE	39	30	40	107	48	03	10.6(17.1)	3-24-69	<700	<220	<2.6	<.9	2.5	3.1	--	--	--	--	--	Sample coll between s pond and plant, Ri water wor
	3	7	94	1	NE	39	28	20	107	49	55	7.6(12)	9-20-69	<960	<300	--	--	--	--		--	--	--	--	USGS gaging 9-0925.
													4-10-70	<960	<300	6.9	2.3	3.4	4.2	39	3.6	1.2	2.9	3.3	
Kimball Creek near Collbran	4	9	95	14	NE	39	17	00	107	57	13	8.4(14)	8-26-69	<960	<300	--	--	--	--		--	--	--	--	--
													9-20-69	<960	<300	--	--	--	--		--	--	--	--	
													4-11-70	<1,300	<400	7.2	2.4	7.6	9.4	10	.5	.2	5.8	6.4	
Plateau Creek near Cameo	5	10	97	18	SW	39	11	00	108	16	10	23(37)	8-28-69	<960	<300	--	--	--	--		--	--	--	--	USGS gaging 9-1050.
													9-20-69	<960	<300	--	--	--	--		--	--	--	--	
													10-19-69	<960	<300	--	--	--	--		--	--	--	--	
													4- 6-70	<960	<300	24	8.0	7.1	8.9	98	6.1	2.0	3.9	4.9	
Colorado River near DeBeque	6	8	97	23	SW	39	20	22	108	11	35	14(23)	8-26-69	960	300	--	--	--	--		--	--	--	--	Downstream (4.3 kilo from USGS station 9
													9-20-69	960	300	--	--	--	--		--	--	--	--	
													10-19-69	<960	<300	--	--	--	--		--	--	--	--	
													4- 6-70	1,200	380	17	5.8	7.6	9.5	14	.7	.2	1.2	1.3	

1 As shown in figure 1.

2 Not [illegible]

Table 2.--Radiochemical analyses of water from selected springs in western Colorado

Owner or tenant	Sample point number[1/]	Location				Latitude N.			Longitude W.			Distance from surface ground zero, in miles (kilometers)	Date of collection	Tritium		Gross alpha		Gross beta	
		Town-ship S.	Range W.	Section	¼ section	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds			pCi/l	TU	(μg/l as U natural)	(pCi/l as U natural)	(pCi/l as Sr-90/ Y-90)	(pCi/l as Cs-137)
Mrs. Betty Potter	20	6	94	31	NW	39	29	20	107	56	12	5.7(9.2)	3-20-69	<700	<220	12	3.9	8.4	11
													4-10-70	<1,300	<400	18	5.9	8.8	9.1
Carl Bernklau	21	7	94	4	NW	39	28	09	107	53	45	5.1(8.2)	10-20-69	<960	<300	10	3.4	4.6	5.8
													4-10-70	<960	<300	10	3.5	4.3	4.8
Town of Grand Valley	22	7	95	5	SE	39	27	49	108	00	58	5.3(8.5)	3-21-69	<700	<220	21	6.8	3.0	3.7
													9-20-69	<960	<300	--	--	--	--
													10-19-69	<960	<300	--	--	--	--
													4-11-70	<1,300	<400	20	6.7	3.0	3.4
Otis Murray	23	7	96	35	SE	39	23	23	108	04	28	6.8(11)	3-18-69	<700	<220	11	3.7	6.7	8.4
													4-11-70	<1,300	<400	45	15	19	24
Cecil Gardner	24	7	95	18	NW	39	26	16	108	02	40	5.6(9.0)	3-26-69	<700	<220	26	8.7	4.6	5.8
													4-11-70	<1,300	<400	31	10	5.2	6.0

[1/] As shown on figure 1.

Table 3.--Radiochemical analyses of water from selected wells in western Colorado

Owner or tenant	Sample point number[1/]	Location: Township S.	Location: Range W.	Location: Section	Location: ¼ section	Latitude N.: Degrees	Latitude N.: Minutes	Latitude N.: Seconds	Longitude W.: Degrees	Longitude W.: Minutes	Longitude W.: Seconds	Distance from surface ground zero, in miles (kilometers)	Date of collection	Tritium: pCi/l	Tritium: TU	Gross alpha: (µg/l as U natural)	Gross alpha: (pCi/l as U natural)	Gross beta: (pCi/l as Sr-90/Y-90)	Gross beta: (pCi/l as Cs-137)	Remarks
Norman Mead	15	6	94	26	NW	39	29	50	107	51	44	7.7(12)	3-24-69	1,300	420	6.8	2.3	6.3	7.8	--
													4-10-70	1,000	310	17	5.6	7.0	7.3	
Russell Bingham, Sr.	16	7	94	6	SE	39	27	41	107	55	12	4.1(6.6)	3-22-69	<700	<220	5.0	1.7	<3.5	<4.3	--
													10-20-69	<960	<300	<4.6	<1.5	2.1	2.7	
													4-10-70	<1,300	<400	4.8	1.6	3.9	4.5	
Albert Gardner	17	7	95	20	NW	39	25	49	108	01	37	4.6(7.4)	3-26-69	960	300	9.1	3.0	<.4	.5	--
													4-11-70	<1,300	<400	17	5.6	4.1	4.4	
Sinclair Oil Co.	18	6	96	29	SE	39	29	31	108	07	23	11.1(17.9)	3-20-69	<700	<220	31	10	15	19	--
													4-12-70	<1,300	<400	26	8.6	15	18	
Willard Nicoll	19	9	94	22	NE	39	15	49	107	52	02	10.6(17.1)	3-25-69	<700	<220	14	4.8	15	19	--
													4-11-70	<1,300	<400	34	11	6.0	7.3	

1/ As shown on figure 1.

Table 4.--Radiochemical analyses of precipitation from selected points in central and western Colorado

Location	Sample point number[1/]	Location				Latitude N.			Longitude W.			Distance from surface ground zero, in miles (kilometers)	Date of collection	Tritium		Gross alpha		Gross beta		Rema
		Township	Range	Section	¼ section	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds			pCi/l	TU	(µg/l as U natural)	(pCi/l as U natural)	(pCi/l as Sr-90/Y-90)	(pCi/l as Cs-137)	
Denver, Colorado	7	4S.	68W.	29	NW	39	40	30	105	01	40	154(248)	3-23-69	2,000	620	--	--	--	--	--
													10-15-69	<960	<300	--	--	--	--	
													3- 6-70	<1,300	<400	--	--	--	--	
													4- 1-70	1,800	550	2.2	0.7	23	26	
Kenosha Pass, Colorado	8	7S.	75W.	27	NE	39	25	00	105	46	00	117(188)	1-27-69	<700	<220	--	--	--	--	On summ:
													4- 5-70	1,500	460	.4	.1	11	12	
Near Loveland Pass, Colorado	9		(2/)			39	38	34	105	52	02	113(182)	1-14-70	<960	<300	--	--	--	--	Near Ar: ski a
													2-10-70	<960	<300	--	--	--	--	
													4- 2-70	2,100	660	1.0	.3	20	22	
Near Vail Pass, Colorado	10		(2/)			39	32	45	106	13	13	93(150)	1-14-70			--	--	--	--	One mil summi
													2-10-70	<960	<300	--				
													4- 2-70	2,000	620	7.5	2.5	31	39	
Near Grand Junction, Colorado	11	1S.	1W.	6	NE	39	06	10	108	37	30	40(64)	12-21-68	830	260	--	--	--	--	Samplin; junct waya 6-50.
Near Grand Junction, Colorado	11	12S.	101W.	11	NW	39	01	47	108	39	10	46(74)	4- 7-70	1,100	350	1.2	.4	21	24	At Colo Natio
Red Mountain Pass, Colorado	12		(2/)			37	53	50	107	42	40	105(169)	1-28-69	<700	<220	--	--	--	--	On summ
													4- 7-70	1,500	460	<.4	<.1	15	16	
Wolf Creek Pass, Colorado	13		(2/)			37	28	50	106	48	10	146(235)	1-27-69	<700	<220	--	--	--	--	On summ
													4- 7-70	<960	<300	--	--	--	--	
Monarch Pass, Colorado	14		(2/)			38	29	50	106	19	40	108(174)	4- 5-70	1,900	580	<.4	<.1	20	21	On summ

1/ As shown on figure 1.

2/ Not surveyed.

Barker, F. B., and Robinson, B. P., 1963, Determination of beta activity in water: U.S. Geol. Survey Water-Supply Paper 1696-A, 32 p.

Jacobs, D. G., 1968, Sources of tritium and its behavior upon release to the environment: U.S. Atomic Energy Comm. report TID-24635, 90 p.