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AQUIFER TESTS OF THE NAVAJO SANDSTONE NEAR CAINEVILLE, WAYNE COUNTY, UTAH

by
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Prepared by
the United States Geological Survey
in cooperation with
The Utah Department of Natural Resources
Division of Water Rights

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CONVERSION FACTORS: INCH-POUND TO METRIC

Most values in this report are given in inch-pound units followed by metric units. The conversion factors are shown to four significant figures. In the text, however, the metric equivalents are shown only to the number of significant figures consistent with the accuracy of the value in inch-pound units.

Inch-pound			Metric	
Unit (Multiply)	Abbreviation	(by)	Unit (to obtain)	Abbreviation
Acre		0.4047	Square hectometer	hm^2
		.004047	Square kilometer	km^2
Cubic foot per day per foot	$(ft^3/d)/ft$ or ft^2/d	.0929	Cubic meter per day per meter	$(m^3/d)/m$ or m^2/d
Foot	ft	.3048	Meter	m
Gallon per minute	gal/min	.06309	Liter per second	L/s
Gallon per minute per foot	(gal/min)/ft	.2070	Liter per second per meter	(L/s)/m
Inch	in.	25.40	Millimeter	mm
		2.540	Centimeter	cm
Mile	mi	1.609	Kilometer	km
Square foot	ft^2	.0929	Square meter	m^2

Chemical concentration and water temperature are given only in metric units. Chemical concentration is given in milligrams per liter (mg/L) or micrograms per liter (μg/L). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is about the same as for concentrations in the inch-pound unit, parts per million.

Chemical concentration in terms of ionic interacting values is given in milliequivalents per liter (meq/L). Meq/L is numerically equal to the inch-pound unit, equivalents per million.

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

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ABSTRACT

Ground water in the Navajo Sandstone near Caineville, Wayne County, Utah, was studied during 1975-77 as part of an investigation of water in bedrock in the lower Dirty Devil River basin area. The purpose of the study near Caineville was to determine the water-bearing properties of the Navajo by utilizing data obtained mainly during test drilling and aquifer testing by the Intermountain Power Project.

Consolidated rocks that crop out in the area range in age from Cretaceous to Jurassic. The area is underlain by older Mesozoic and Paleozoic sedimentary rocks that extend to a depth of at least 7,160 feet (2,182 meters). The Navajo Sandstone is the major known aquifer in the area, yielding 2,800 and 3,110 gallons per minute (177 and 196 liters per second) to two test wells near Caineville.

The Navajo Sandstone is massive, crossbedded, very fine to fine grained, and approximately 900 ft (274 meters) thick. For the practical purpose, of aquifer analysis, it is hydraulically isotropic in unfractured parts. It has an average hydraulic conductivity of 0.5 foot per day (0.15 meter per day), and an inferred transmissivity of 450 feet squared per day (42 meters squared per day).

Folding of the sandstone has produced fracturing that probably permits some interformational leakage. The leakage under natural conditions is upward, under high artesian head; and it probably contributes to the salinity of the water in the sandstone.

Fracturing of the sandstone has enhanced the permeability and made the formation heterogeneous and probably anisotropic on a regional scale. Values for transmissivity, obtained from tests of various lengths, range from 1,330 to 4,250 feet squared per day (124 to 395 meters squared per day). This indicates that conventional aquifer-test analysis does not yield the uniform results that might be expected of the relatively homogeneous sandstone.

For the purpose of calculating long-term pumping effects, a generalized selected value for transmissivity of the Navajo Sandstone is 1,500 feet squared per day (139 meters squared per day); and a generalized selected value for the storage coefficient under artesian conditions is 0.001. For water-table conditions, the value for the specific yield is estimated to be between 5 and 10 percent.

INTRODUCTION

This report presents part of the results of a study of water in bedrock in the lower Dirty Devil River basin area in parts of Emery, Garfield, and Wayne Counties, Utah (fig. 1), with special emphasis on the Navajo Sandstone of Triassic and Jurassic age. The study was made by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights. Fieldwork was carried out July 1975-September 1977.

The purpose of this report is to present the results of test drilling and aquifer testing in the Navajo Sandstone in and near the Red Desert northwest of Caineville (fig. 2) and related data acquired during the investigations carried out by the Intermountain Power Project during 1975-76. Data in the report include aquifer-test analyses, core analyses, selected records of wells and springs, and selected chemical analyses.

Caineville is near the southeast corner of T. 28 S., R. 8 E., approximately 17 mi (27 km) west of Hanksville in Wayne County. The test area is mainly in the Red Desert, a deeply dissected erosional valley in the south-central part of T. 28 S., R. 8 E.; it includes wells in secs. 29 and 33. Observations also were made at wells and springs in T. 28 S., R. 7 E., to the west.

Background

The Intermountain Power Project (IPP) is the successor to the Intermountain Consumers Power Association (ICPA) in the planning for construction of a coal-fired electric-generation plant in the area. Preliminary studies began about 1971, and in the winter of 1973-74, ICPA drilled a test well in the NW$\frac{1}{4}$SW$\frac{1}{4}$SE$\frac{1}{4}$ sec. 29, T. 28 S., R. 8 E. (fig. 2). This location was recommended by S. B. Montgomery of the Utah Division of Water Resources because it was at the point of minimum depth to the Navajo Sandstone near an oil test that reportedly discharged large amounts of water during the drilling of the Navajo section.

The ICPA test well yielded 3,110 gal/min (196 L/s) during a test on February 8-9, 1974 (R. J. Madsen, ICPA, written commun., 1974). Subsequently, IPP drilled a test well (TW-1) in the northwest corner of sec. 33, T. 28 S., R. 8 E., reconditioned an oil-test well in the southern part of sec. 33 (the Colt well), and drilled an observation well (OW-1A) in sec. 27, T. 28 S., R. 7 E., 5 mi (8 km) west of TW-1. These wells, together with an existing stock well (the Stanolind well) in sec. 29, T. 28 S., R. 8 E., were used during an extensive aquifer test. (See table 8 and fig. 2.)

All construction and testing were the responsibility of IPP, under the direction of the Los Angeles Department of Water and Power, a participant in IPP. The Geological Survey provided some gaging and recording equipment, and personnel of the Geological Survey and the Utah State Engineer's office made supplementary measurements at observation wells at the beginning of pumping and recovery during the principal aquifer test. The Geological Survey also made parallel check determinations on cores and water samples taken by IPP.

IPP provided a wealth of data regarding well construction and testing, and IPP and the Geological Survey joined in compiling a composite of aquifer-test records. The writers gratefully acknowledge the ready cooperation given by the officers and personnel of IPP.

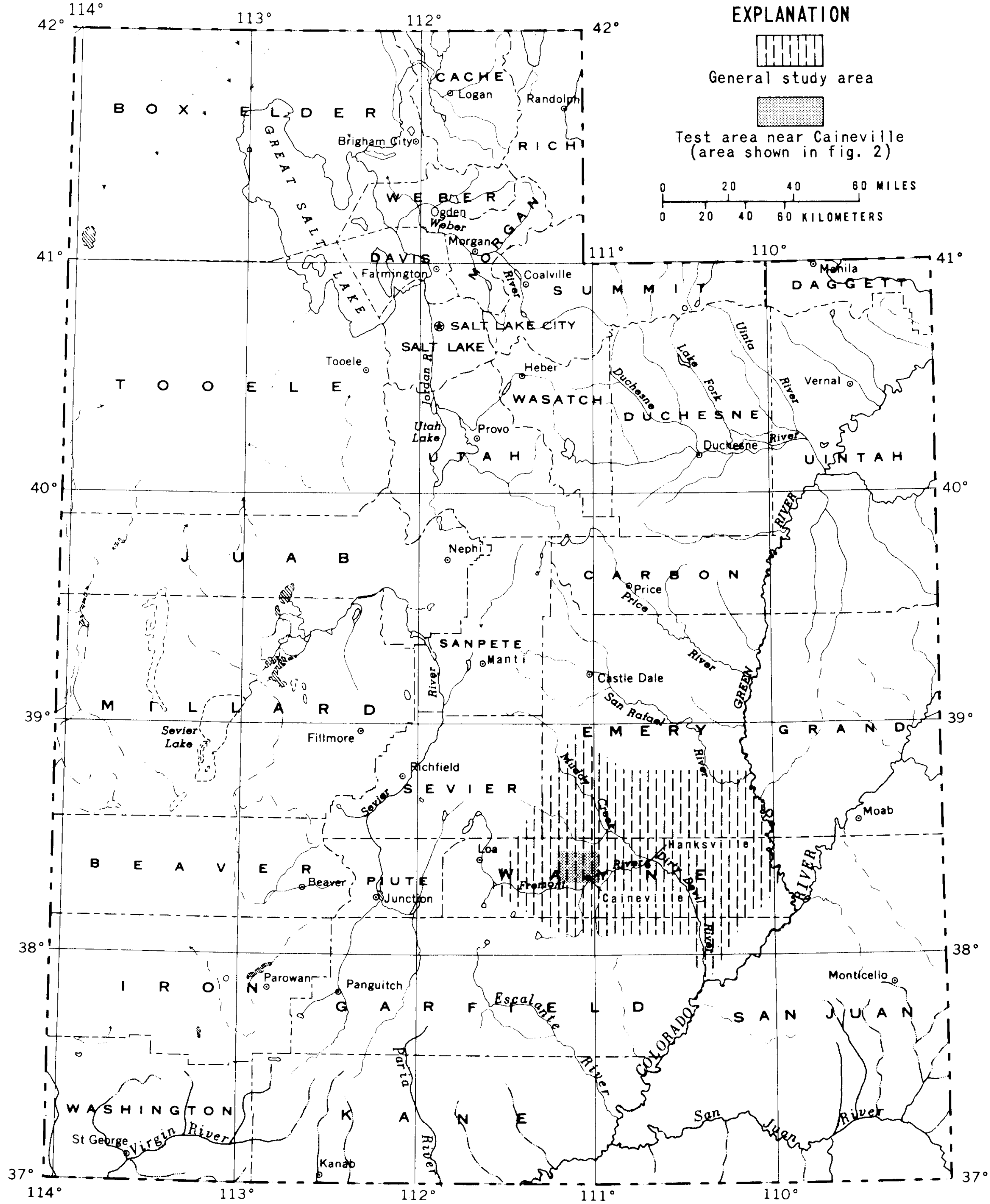
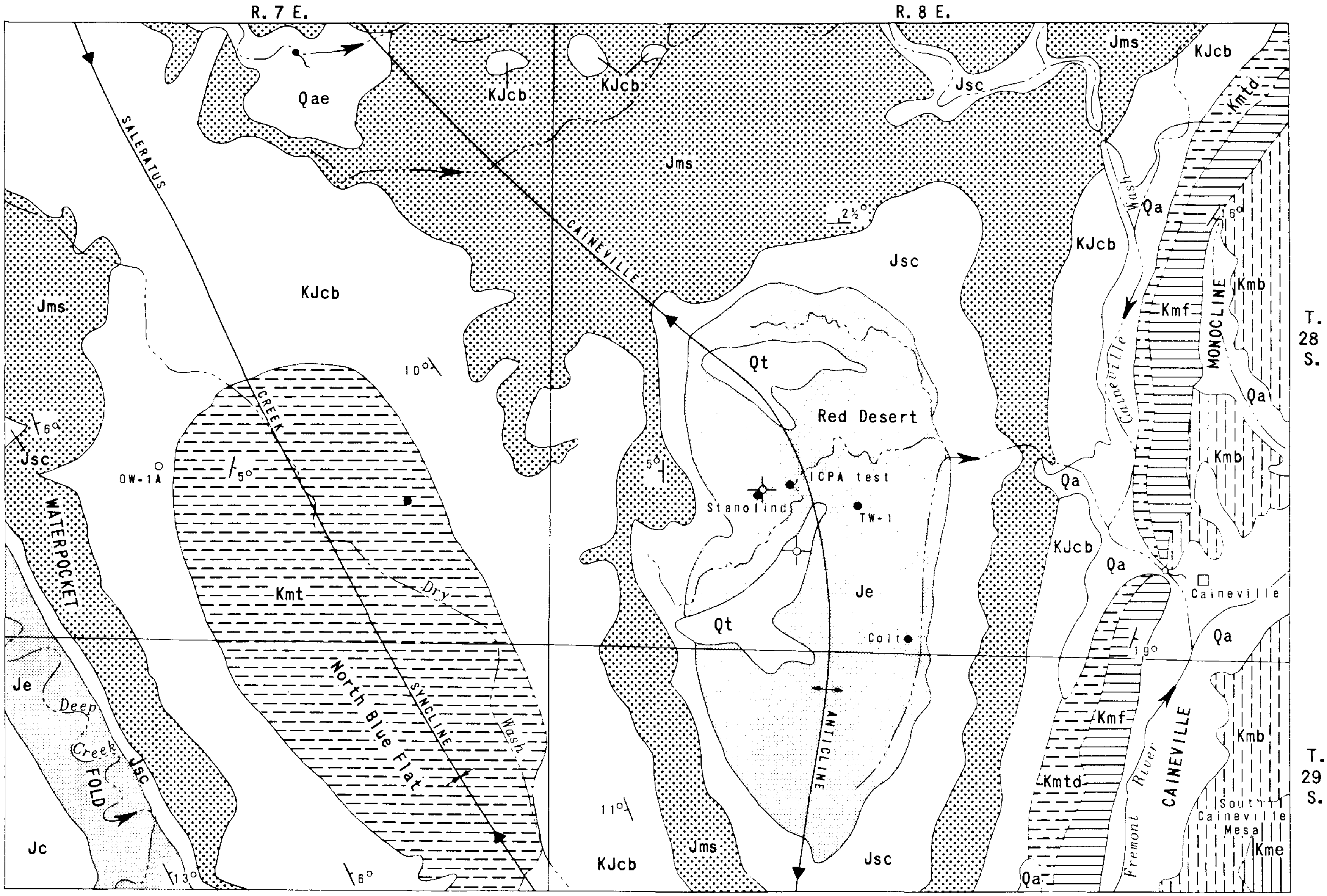


Figure 1.—Location of the lower Dirty Devil River basin area and the test area near Caineville.



Base after Williams and Hackman (1971)

Scale: 1:62,500

0 1 2 MILES

0 1 2 3 KILOMETERS

Geology from Williams and Hackman (1971). Hydrology by J. W. Hood, 1977

EXPLANATION

QUATERNARY

- Qa — Alluvium
- Qae — Alluvium and eolian deposits
- Qt — Terrace gravels

CRETACEOUS

Mancos Shale

- Kme — Emery Sandstone Member
- Kmb — Blue Gate Member
- Kmf — Ferron Sandstone Member
- Kmt — Tununk Member
- Kmtd — Tununk Member of Mancos Shale and Dakota Sandstone, undivided

- KJcb — Cedar Mountain Formation and Brushy Basin Shale Member of Morrison Formation, undivided

JURASSIC

- Jms — Salt Wash Sandstone Member of Morrison Formation
- Jsc — Summerville Formation and Curtis Formation, undivided
- Je — Entrada Sandstone
- Jc — Carmel Formation

- Contact
- 10° Dip and strike of beds
- Anticline
  Showing direction of plunge
- Syncline
  Showing direction of plunge
- TW-1 Flowing well
  TW-1 *is name of well used in text (see table 8)*
- Nonflowing well
- Oil-test well
- Perennial spring
- Intermittent spring

Figure 2.—Geology of the test area and location of wells and springs near Caineville.

Well- and spring-numbering system

The system of numbering wells and springs in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating the well or spring, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake base line and meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, indicating the northeast, northwest, southwest, and southeast quadrants, respectively. Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section--generally 10 acres (4 hm^2);[1] the letters a, b, c, and d indicate, respectively, the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre (4-hm^2) tract; the letter "S" preceding the serial number denotes a spring. If a well or spring cannot be located within a 10-acre (4-hm^2) tract, one or two location letters are used and the serial number is omitted. Thus (D-28-8)29cdc-1 designates the first well constructed or visited in the SW¼SE¼SW¼ sec. 29, T. 28 S., R. 8 E., and (D-28-7)11cdb-S1 designates a spring in the NW¼SE¼SW¼ sec. 11, T. 28 S., R. 7 E. The numbering system is illustrated in figure 3. In the Emery-Garfield-Wayne-Counties study area, several wells have been substantially modified. This applies particularly to petroleum-test wells that have been converted to water wells; such conversion entirely alters the characteristics of the well. In this report, the serial number may be followed by a letter: W, indicates a petroleum-test well that has been converted to a water well; S, indicates a well that has been plugged back.

Terms

The following terms for aquifer characteristics that are used in this report are given precise definitions by Lohman and others (1972):

Term	Abbreviation	Units
Hydraulic conductivity	K	ft/d [$(ft^3/d)/ft^2$]
Porosity	n	dimensionless decimal fraction (or percentage)
Specific capacity	Sc	(gal/min)/ft
Specific yield	Sy	dimensionless decimal fraction (or percentage)
Storage coefficient	S	dimensionless decimal fraction
Transmissivity	T	ft^2/d [$(ft^3/d)/ft$]

---

[1]Although the basic land unit, the section, is theoretically 1 mi^2 (2.6 km^2), many sections are irregular. Such sections are subdivided into 10-acre (4-hm^2) tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the

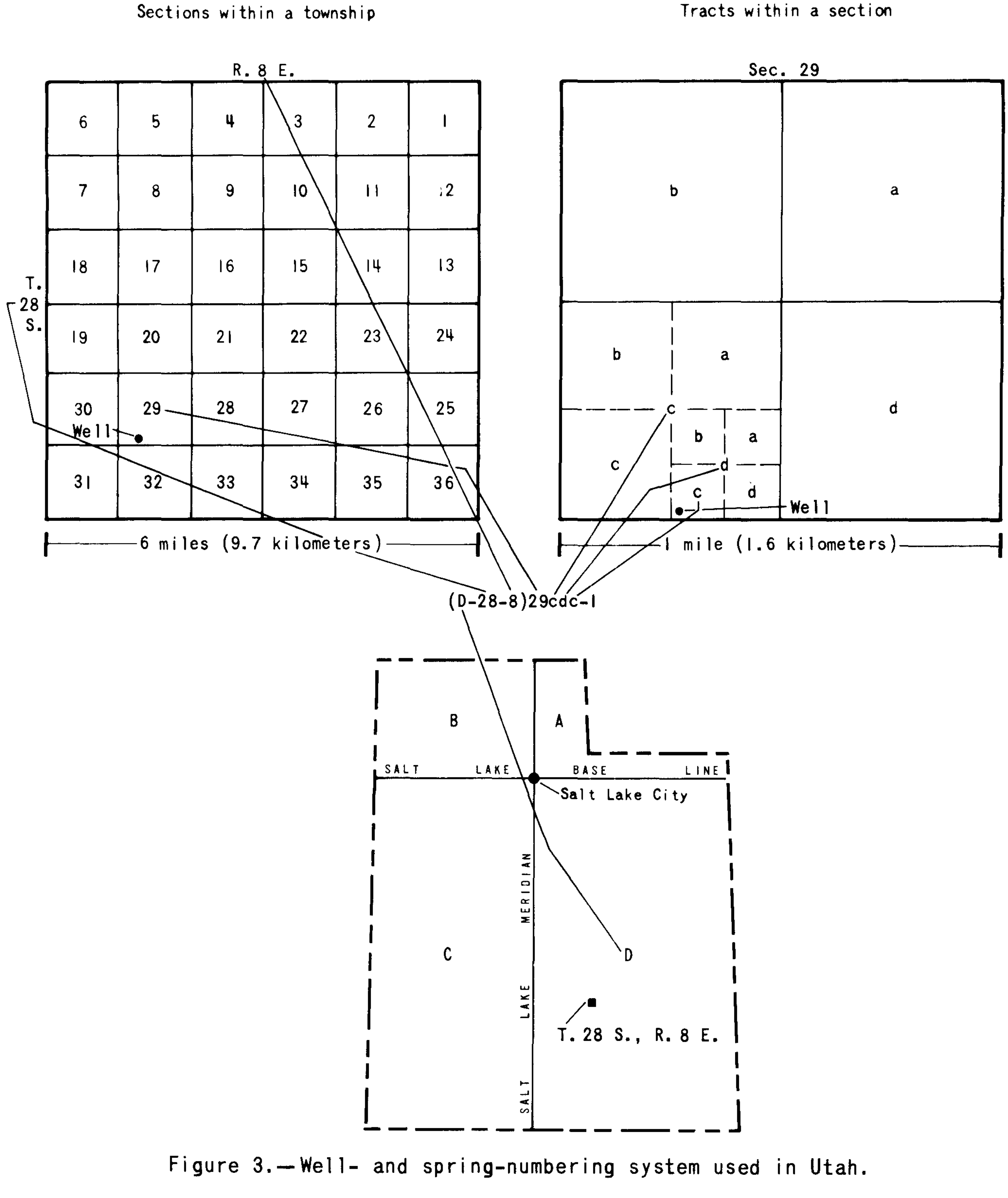


Figure 3.—Well- and spring-numbering system used in Utah.

The relations between inch-pound units, metric units, and units of abandoned terms for *K* and *T* are given in the following table, adapted from Lohman and others (1972, p. 18).

Relation of units

Equivalent values shown in same horizontal lines
† indicates abandoned term

A. Hydraulic conductivity

Hydraulic conductivity (*K*)		† Field coefficient of permeability (*pf*)
Feet per day (ft/d)	Meters per day (m/d)	Gallons per day per square foot [(gal/d)/ft^2]
One	0.3048	7.48
3.2808	One	24.54
.1337	.0407	One

B. Transmissivity

Feet squared per day (ft^2/d)	Meters squared per day (m^2/d)	Gallons per day per foot [(gal/d)/ft]
One	0.092903	7.48
10.7639	One	80.514
.1337	.012421	One

Some of the permeability determinations were made by oil-industry service companies who reported their determinations in millidarcies (or 0.001 Darcy). The Darcy has the dimensions 0.987 x 10^{-8} cm^2 (at 20°C). For comparison with other results, these values were converted as follows:

$$K(\text{at } 60^{\circ}\text{F}) = 2.439 \times \frac{\text{millidarcies}}{1{,}000}$$

Other abbreviations

The following additional abbreviations are used in this report:

- *Q*, discharge, in specified units,
- *r*, distance from the pumped well,
- *s*, drawdown,
- *s'*, residual drawdown,
- *t*, time in specified units,
- *u*, *W(u)*, values from the abscissa and ordinate, respectively, of the Theis non-equilibrium type curve. (See Ferris and others, 1962, p. 92-98.)

For image well analyses, the subscript *r*, as in s_r, refers values ascribed to the real, or pumped well. The subscript *i* refers to values ascribed to the image well.

Chemical-quality terms

The terms used by the U.S. Geological Survey to classify water according to the concentration of dissolved solids, in milligrams per liter, are as follows:

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

Geologic setting

Consolidated rocks that crop out in the test area near Caineville range from the Mancos Shale and its several members of Cretaceous age to the Carmel Formation of Jurassic age (fig. 2). Beneath the Carmel, the geologic section contains Mesozoic and Paleozoic sedimentary rocks that extend to a depth of at least 7,160 ft (2,182 m). (See log of well (D-28-8)29cdc-2, table 9.)

The geologic units are described by Baker (1946), Gilluly (1929), Hunt (1953), and Smith, Huff, Hinrichs, and Luedke (1963); and water in some of the units is described by Feltis (1966). The areas of outcrop and the major structural features are shown on the geologic map of Utah (Stokes, 1964), and the geologic structure is shown in greater detail by Williams and Hackman (1971). The reader is referred to these sources for descriptions of the formations and a regional perspective of the structures that distort the rocks. The formations that crop out in the area of figure 2 and immediately underlie the area are listed in table 1.

Rocks in the test area are folded. The area contains the Caineville anticline and the Saleratus Creek syncline. These two folds lie between two monoclines--the Waterpocket Fold to the west and the Caineville monocline to the east. (See fig. 2.) Where the Navajo Sandstone crops out (not shown in fig. 2) in the Waterpocket Fold (fig. 4), the rocks dip 9° to 13° ENE. Surface dips around North Blue Flat near the axis of the Saleratus Creek syncline are about 5° on both sides and dips on the sides of the Caineville anticline are 5° to 11°. At the Caineville monocline, the rocks have steep dips of 19° to 25° E. The Red Desert is on the apex of the Caineville anticline which plunges about $2\frac{1}{2}^{\circ}$ N. and an unmeasured amount south.

One result of this large-scale folding is the fracturing of competent formations such as the Navajo and Wingate Sandstones. Where exposed in the Waterpocket Fold, both of these sandstones exhibit close-to-wide-spaced joints that parallel the trend of the fold (Hunt, 1953, figs. 94 and 97). It can be inferred that similar jointing or fracturing occurred to the east, with the maximum effects occuring at the bottoms of the formations in the Saleratus Creek syncline and at their tops in the Caineville anticline. Some cross fracturing probably is also present due to the plunge of those structural features. Such inferred tension features cannot be seen because the formations are buried, but even the less competent siltstone of the Entrada Sandstone in the Red Desert, the principal trend of gypsum-filled fractures is northward, parallel to the trend of the anticline.

Table 1.—Formations that crop out in or underlie the Caineville area

Age	Formation	Remarks
QUATERNARY	Unconsolidated rocks	Contain water only beneath stream channels. Water generally high in dissolved solids.
CRETACEOUS	Mancos Shale:	
	Emery Sandstone Member	Caps south Caineville Mesa.
	Blue Gate Member	Low permeability.
	Ferron Sandstone Member	At edge of Caineville Monocline. Generally low permeability.
	Tununk Member	At edge of Caineville Monocline and in bottom of North Blue Flat. Low permeability.
	Dakota Sandstone	Generally thin, where present.
	Cedar Mountain Formation	Conglomerate in bottom may locally be an aquifer. Generally low permeability.
JURASSIC	Morrison Formation:	
	Brushy Basin Shale Member	Contains variegated beds of bentonite. Generally low permeability.
	Salt Wash Sandstone Member	Yields perched water under artesian pressure at well (D-28-7)36bbb-1. Contains gypsum.
	Summerville Formation	Contains gypsum. Generally low permeability.
	Curtis Formation	Caps bluffs of Entrada Sandstone. Generally low permeability.
	Entrada Sandstone	Yields water to wells in adjacent areas. Overall permeability is low.
	Carmel Formation	Yields water where fractured or included limestone is cavernous. Water generally is saline.
JURASSIC AND TRIASSIC(?)	Navajo Sandstone	Major aquifer. Massive sandstone. Water saline where deeply buried.
TRIASSIC(?)	Kayenta Formation	Contains siltstone beds that separate Navajo and Wingate aquifers.
TRIASSIC	Wingate Sandstone	Potentially a source of water to supplement that from Navajo Sandstone. Probably has lower intergranular permeability than Navajo but probably equal to it in fracture permeability. Not as thick as Navajo. (See log of well (D-28-8)29cdc-2 in table 9.) Chemical quality of water near Caineville unknown but probably more saline than Navajo.
	Chinle Formation	Generally low permeability.
	Shinarump Member	Mainly sandstone in this locality. Thin and discontinuous.
	Moenkopi Formation	Contains some sandstone. Overall permeability is low.
	Sinbad Limestone Member	
PERMIAN	Kaibab Limestone Coconino Sandstone	Both formations may have potential for development of supplies of slightly to moderately saline water.

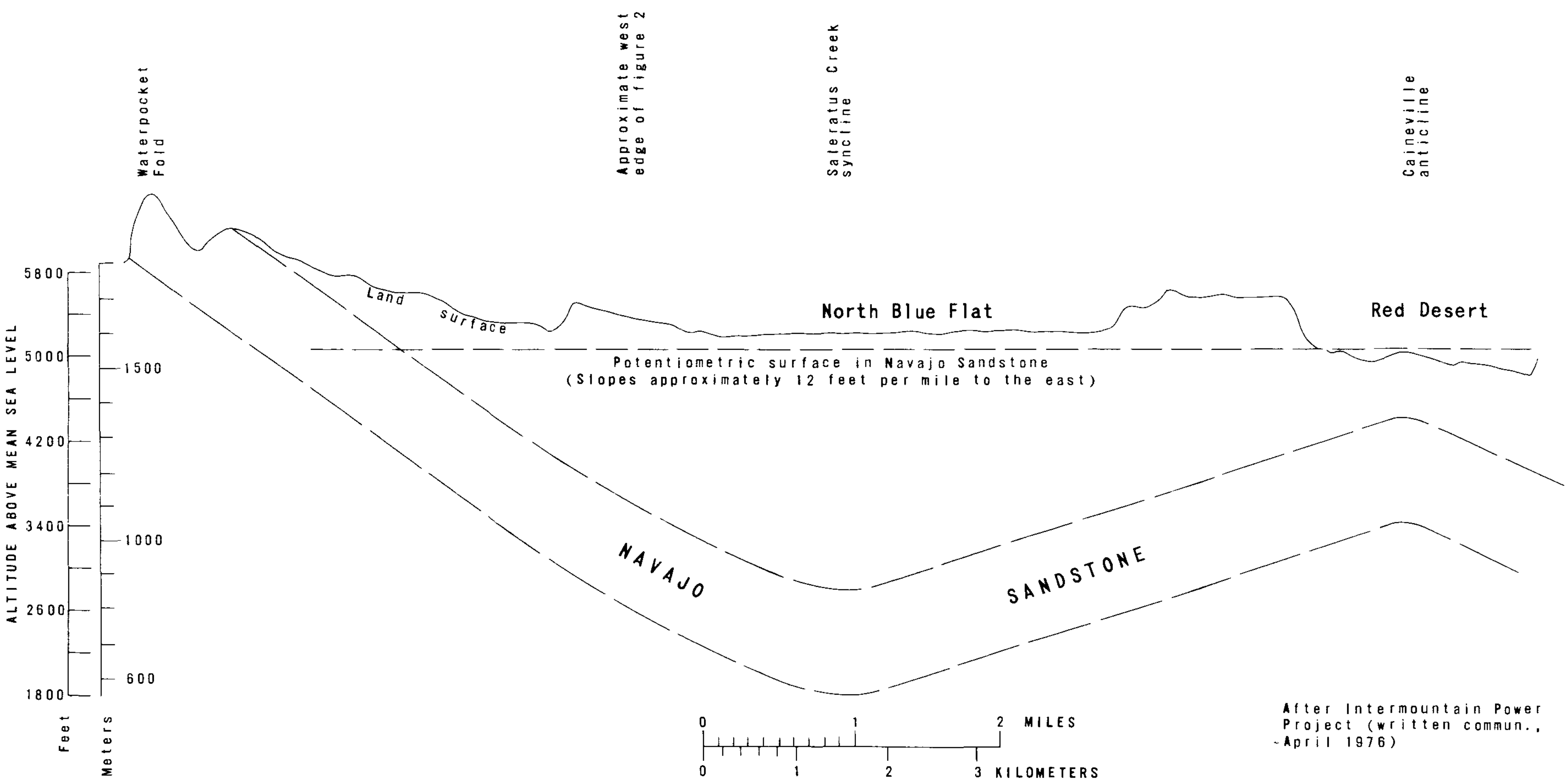


Figure 4.—Generalized east-west section showing folding of the Navajo Sandstone.

THE NAVAJO SANDSTONE

The Navajo Sandstone is a massive, strongly and intricately cross-bedded, gray to pale-brown sandstone, which is mostly very fine to fine grained. Grains of sand in the formation are subangular to well rounded (fig. 5). In the Red Desert area, the sandstone is about 900 ft (274 m) thick, and it thins eastward and thickens westward. The lower contact with the underlying Kayenta Formation is transitional, and the two formations probably intertongue. The upper contact with the overlying Carmel Formation is marked in most areas by a bed of red sandstone and gypsiferous siltstone. The red bed is overlain by as much as 20 ft (6 m) of a sandstone similar to the Navajo; and although the sandstone may be a part of the hydrologic system in the Navajo, it is considered to be a basal part of the Carmel.

Most of the Navajo Sandstone has little of the parallel bedding common to sedimentary rocks. True bedding planes are rare and generally are 50 ft (15 m) or more apart. However, crossbedding occurs on a large scale, and the crossbedding laminae may truncate one another any any angle. Dips of these laminae are as great at 30°. The formations seems to be slightly coarser and less consolidated near its top. Drilling-time logs for wells TW-1 and OW-1A indicate that penetration rates, though variable, tended to decrease with depth in the formation. This also is borne out by the drilling experience at the ICPA test well, which was terminated at 761 ft (232 m) owing to the inflow of loose sand.

The discussion in the following sections is based upon well logs (including sample examination and analysis of representative cores), laboratory determination of hydraulic properties, and discharging-well tests. Table 9 contains logs of four wells that penetrate the Navajo Sandstone. The drill cuttings described for the two test holes, however, at times were badly contaminated with caved material from zones above the sample intervals. Three representative zones in well TW-1 and one such zone in well OW-1A were cored. Tables 2 and 3 give the results of sieve analyses and related statistics for four core samples, and figure 6 summarizes the distribution of grain sizes in those samples. Figures 5, 7, and 8 show photomicrographs of thin sections of the three samples from well TW-1.

Table 2.--Grain-size diameters, in millimeters, of four cores from the Navajo Sandstone, in percentage by weight.
(See also fig. 6.)

Well	Laboratory sample No.	Clay <0.004	Silt 0.004-0.0625	Sand				
				Very fine 0.0625-0.125	Fine 0.125-0.25	Medium 0.25-0.5	Coarse 0.5-1.0	Very coarse 1.0-2.0
TW-1	76UT1	4.9		31.7	30.8	32.3	0.21	0
	76UT2	6.5		57.6	35.2	.66	0	0
	76UT3	12.6		53.5	33.4	.51	0	0
OW-1A	76UT24	6.2	0.98	41.3	45.6	5.7	.23	0

Table 3.--Statistical characteristics of grain-size analyses, specific gravity, and carbonate content of four cores from the Navajo Sandstone

Well	Laboratory sample No.	Median size (mm)[1]	Sorting coefficient[2]	Skewness[3]	Kurtosis[4]	Uniformity coefficient[5]	Specific gravity of solids (gm/cc)	Carbonate content[6]
TW-1	76UT1	0.17	1.7	1.0	0.29	3.0	2.66	0
	76UT2	.11	1.4	1.1	.27	1.8	2.70	0
	76UT3	.10	1.4	1.1	.25	2.3	2.69	0
OW-1A	76UT24	.13	1.5	.96	.30	2.3	2.68	0

[1]Median = d_{50}.

[2]Geometric quartile deviation, $\sqrt{Q_3/Q_1}$, taken from cumulative curves representing frequency data of sediments. Q_3 = 25 percent quartile, Q_1 = 75 percent quartile.

[3]$(Q_1 \times Q_3)/(\text{median})^2$.

[4]$(Q_3 - Q_1)/2(P_{90} - P_{10})$ taken from cumulative curves. P_{90} = 90 percentile, P_{10} =10 percentile.

[5]Uniformity coefficient sorting index = d_{60}/d_{10}.

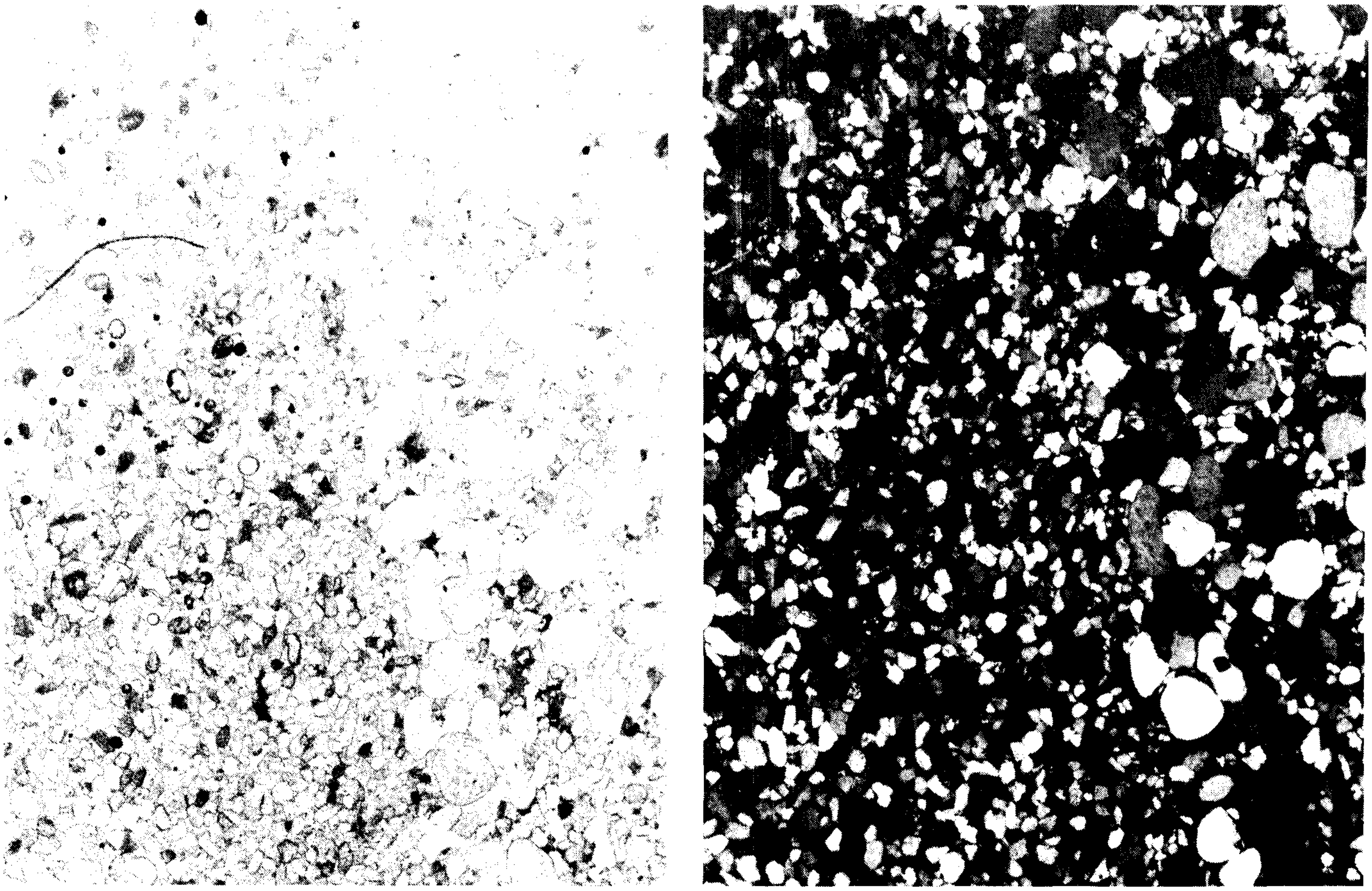
[6]Calcium carbonate equivalent by carbon dioxide absorption method.

The megascopic core descriptions in the logs for wells TW-1 and OW-1A (table 9) contain the statements that the sandstone includes some calcite and gypsum, mainly as fracture or vein fillings. The bulk of the sandstone, however, has no carbonate cement. (See table 3.) In sample 76UT1, the biomodality due to the laminae of two different grain sizes is apparent in the sieve analysis stated in table 2 and depicted in figure 6. Despite the general lack of matrix or cement, the volume amount of interstices (pore spaces) is measurably reduced by the packing of the subangular to subrounded grains.

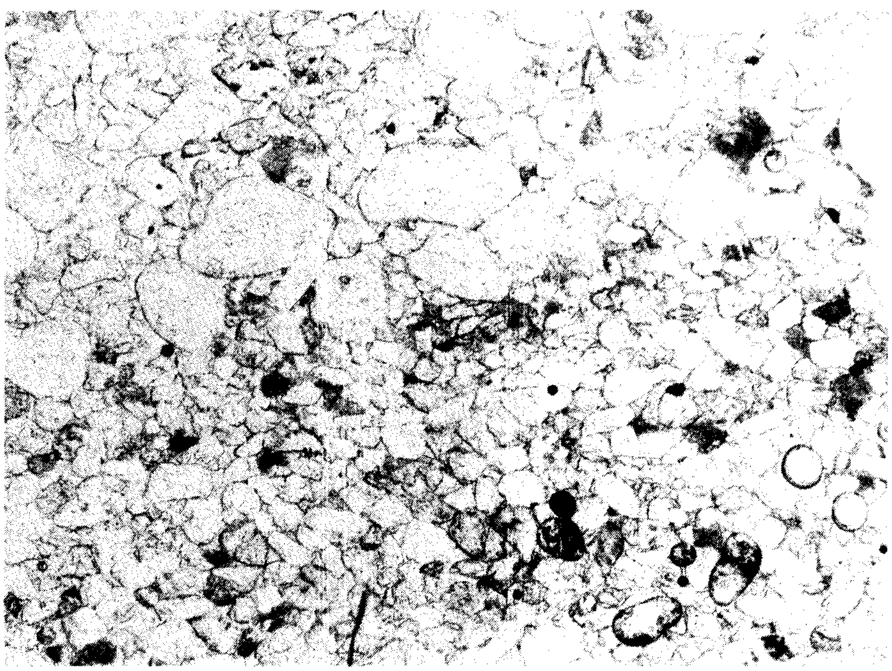
Hydraulic properties of cores

Core tests were made because they yield information that cannot be obtained from field tests. Laboratory values for hydraulic conductivity (K) show the primary permeability of the sandstone; whereas, field tests are strongly influenced by secondary features, such as fracturing. Porosity (P) can be determined only by laboratory methods, although the value can be closely approximated from certain borehole geophysical logs.

Sample cuts from cores in wells TW-1 and OW-1A were submitted to the Hydrologic Laboratory of the Geological Survey, Denver, Colo., and to two commercial laboratories. The results are listed in tables 4, 5, and 6, and the results are compared in figure 9. The tables indicate slightly different conditions of analysis at each laboratory, and the figure shows that despite the slightly different depths of the samples, one laboratory apparently obtained generally larger values for both K and n. The values for K, as determined by the Geological Survey for the three samples from well TW-1, are lower than those from the other laboratories because the Survey adjusted the values to show K under loaded conditions at the present depth of burial.



Ordinary light | Magnification x 20 | Polarized light (crossed Nicols)



Ordinary light | Magnification x 40

Figure 5.—Photomicrographs of core sample 76UTI, Navajo Sandstone.

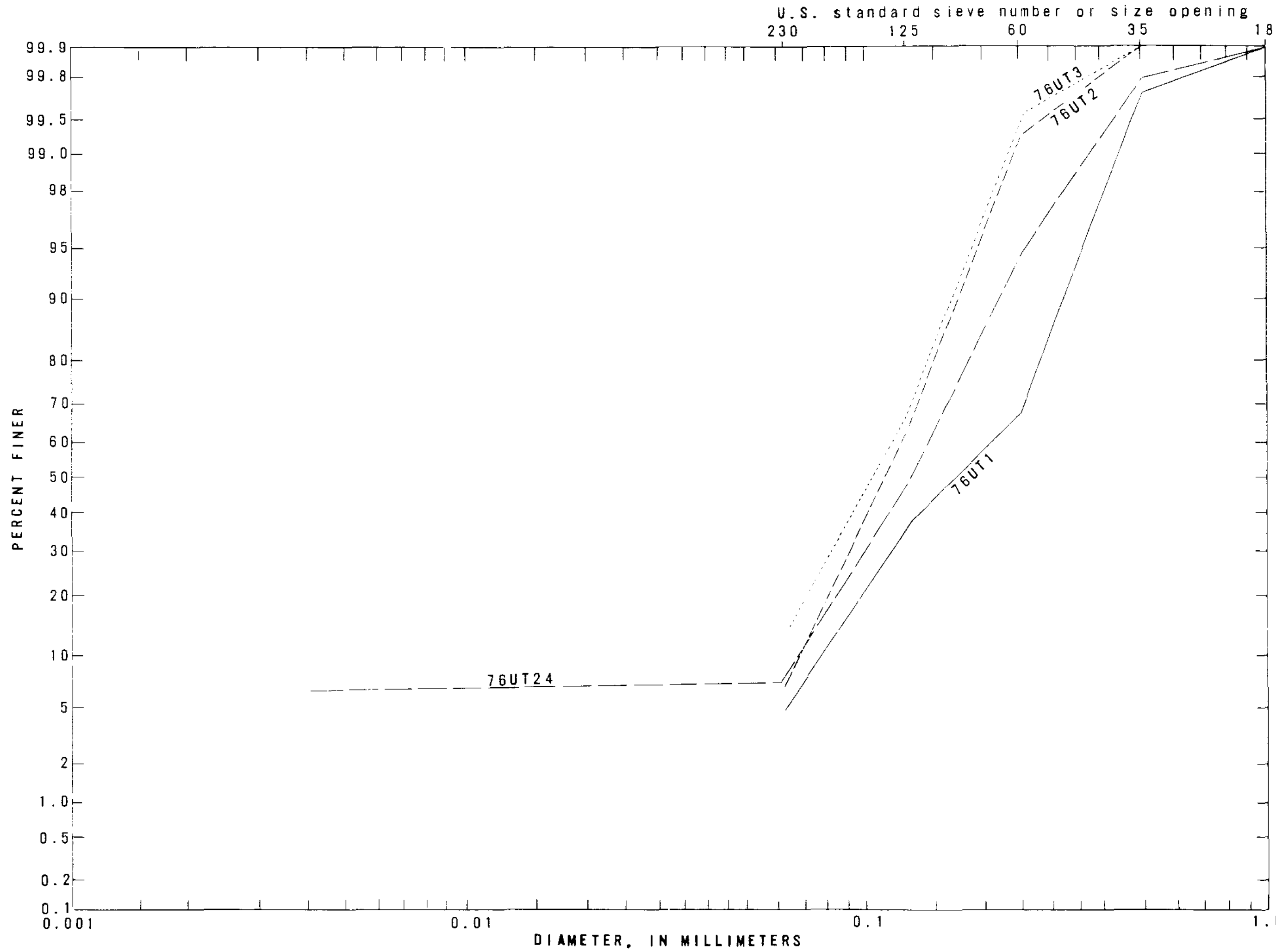
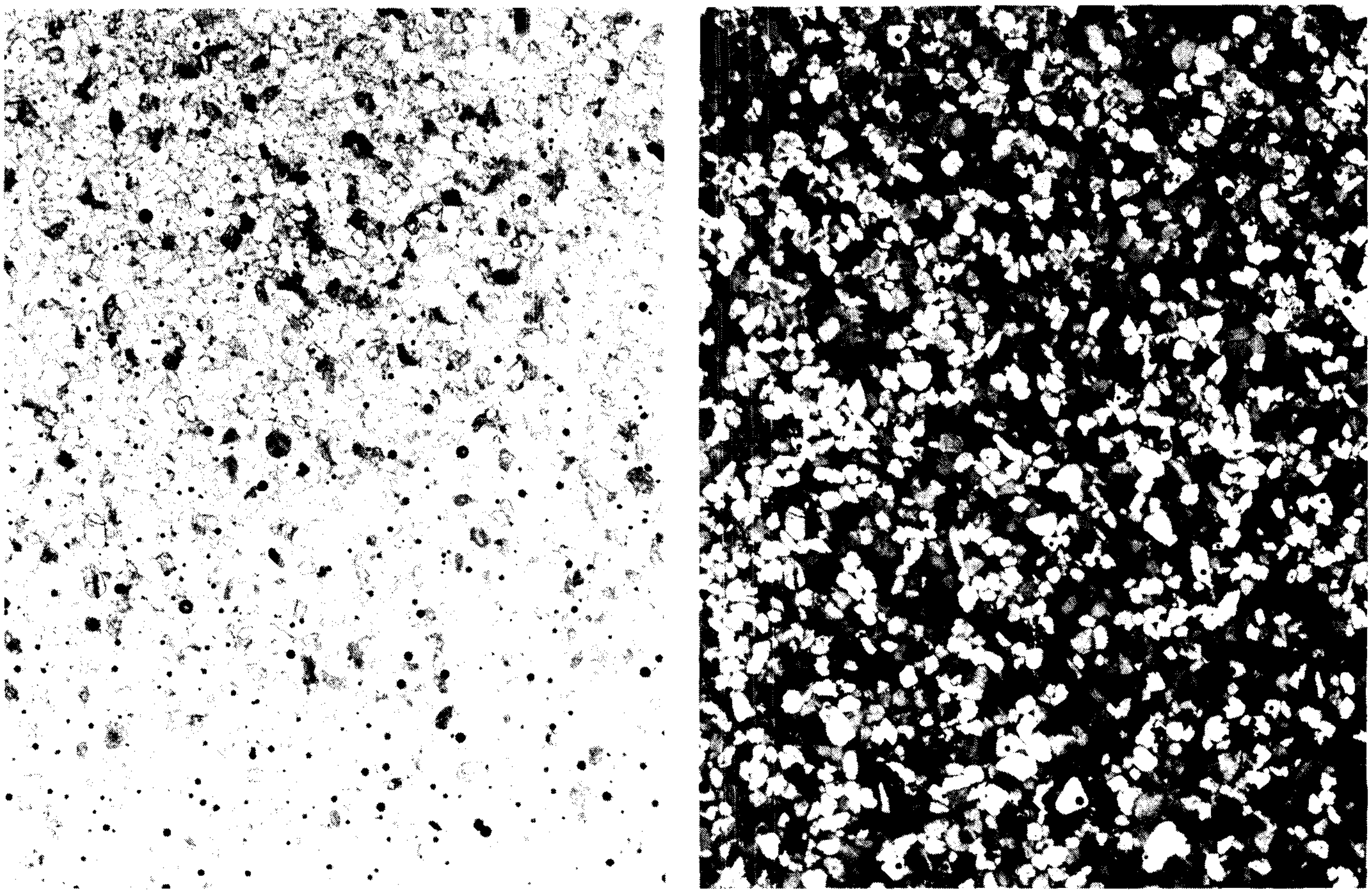


Figure 6.—Particle-size distribution for four cores from the Navajo Sandstone (See also table 2.)



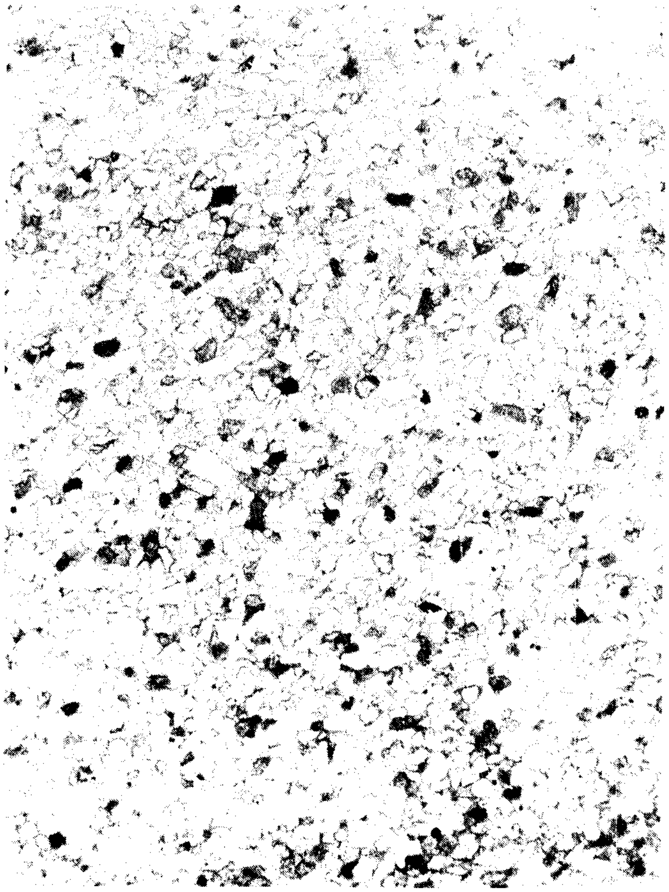
Ordinary light Magnification x 20 Polarized light (crossed Nicols)

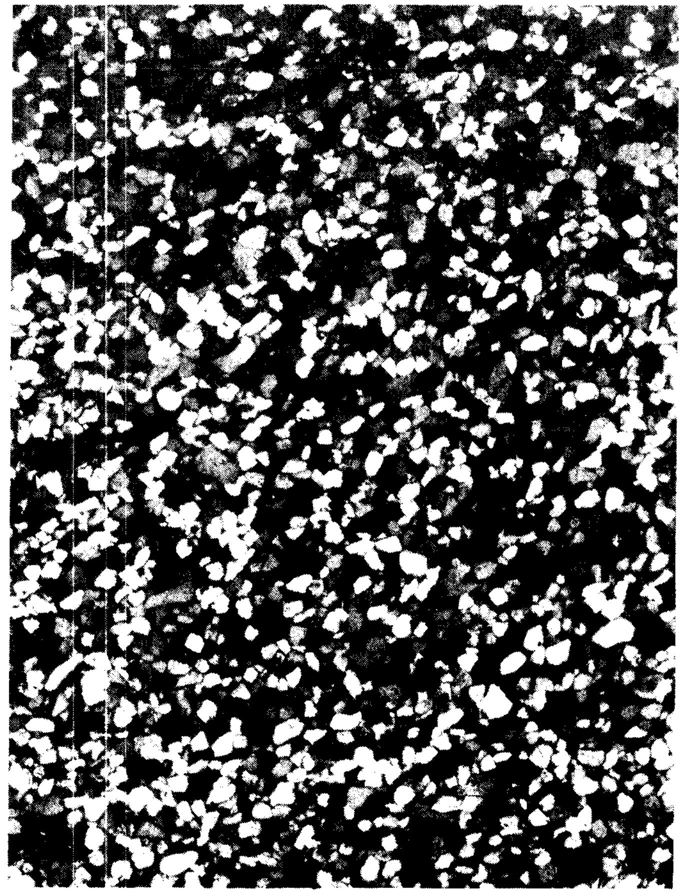
Figure 7.—Photomicrographs of core sample 76UT2, Navajo Sandstone.

Hydraulic conductivity

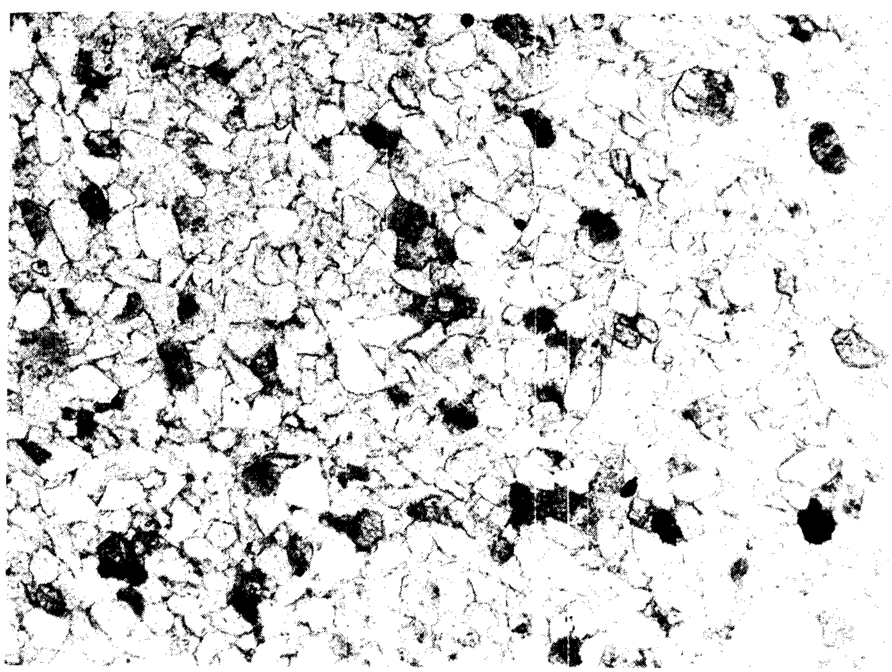
The average value for horizontal hydraulic conductivity (*K*) for the Navajo Sandstone, using all determinations in tables 4-6, is 0.64 ft/d (0.020 m/d). One value for *K* in table 6 is nearly twice larger than the next lowest value, and the high value may be anomalous. The average *K* without this high value is 0.55 ft/d (0.17 m/d).

Eight determinations have values for both horizontal and vertical *K*. The averages for these eight pairs yield a ratio of horizontal to vertical *K* of 1.42:1. Most aquifers are stratified and therefore more strongly anisotropic. As described in several of the references on aquifer theory, anisotropy requires adjustment of aquifer-test data before reliable hydraulic coefficients of the aquifer can be determined. In contrast to the Navajo Sandstone, the lowest ratio of horizontal to vertical *K* for most stratified aquifers appears to be about 5:1; the ratio generally is larger. (For example, see Bennett and others, 1967, p. G55.)





Ordinary light Magnification x 20 Polarized light (crossed Nicols)



Ordinary light Magnification x 40

Figure 8.—Photomicrographs of core sample 76UT3, Navajo Sandstone.

Table 4.--Hydraulic conductivity and porosity determined by the Geological Survey for core samples from wells TW-1 and OW-1A

Hydraulic conductivity at 60°F (15.5°C) measured in meters per day, using simulated formation water synthesized from chemical analyses of water from the two wells; effective porosity is for voids having entrance diameters larger than 0.1 micron.

Well	Laboratory sample No.	Depth below land surface (ft)		Depth below top of formation (ft)	Hydraulic conductivity, Horizontal m/d	Hydraulic conductivity, Horizontal ft/d	Hydraulic conductivity, Vertical m/d	Hydraulic conductivity, Vertical ft/d	Porosity (Percent) Total	Porosity (Percent) Effective
TW-1[1]	76UT1	834.7	835.2	126	0.087	0.29	0.046	0.15	21.8	20.3
	76UT2	1,139.7	1,140.3	431	.047	.15	.018	.059	25.3	22.3
	76UT3	1,476.3	1,476.8	767	.0040	.013	.0096	.031	24.8	22.5
OW-1A	76UT24	2,350.2	2,350.5	361	.21	.69	.14	.46	22.6	20.5

[1]Specimens from the three cores from this well were cut so that the horizontal *K* is that parallel to the bedding planes and the vertical *K* is that normal to the bedding. The three pairs of determinations were made in a tri-axial loading chamber under various effective stresses. The values for *K* given are those estimated for the estimated in situ effective vertical stress.

Table 5.--Hydraulic conductivity and porosity determined by Chemical and Geological Laboratories, Casper, Wyo., for core samples from wells TW-1 and OW-1A

Determinations[1] were from splits of the core samples analysed by the Geological Survey (table 4).

Well	Laboratory sample No.	Horizontal: Permeability (millidarcies) Air	Horizontal: Permeability (millidarcies) Water	Horizontal: Hydraulic conductivity m/d	Horizontal: Hydraulic conductivity ft/d	Horizontal: Porosity (percent)	Vertical: Permeability (millidarcies) Air	Vertical: Permeability (millidarcies) Water	Vertical: Hydraulic conductivity m/d	Vertical: Hydraulic conductivity ft/d	Vertical: Porsity (percent)
TW-1	76UT1	626	173	0.128	0.421	21.9	263	44	0.0326	0.107	22.8
	76UT2	560	166	.123	.404	22.1	498	158	.117	.384	23.4
	76UT3	381	138	.102	.336	22.0	347	90	.0667	.219	22.7
OW-1A	76UT24	460	148	.110	.360	20.7	569	190	.141	.462	21.1

[1]One-inch horizontal and vertical plugs were drilled and dried and permeability and porosity measurements to dry air were made. The plugs were then saturated with Casper tap water for 48 hours and flow rates to water were determined after at least 10 pore volumes had been flushed and equilibrium had been reached.

Because of its low ratio of horizontal to vertical *K*, the Navajo Sandstone in and near the Red Desert is, for practical purposes in analyzing aquifer tests, considered to be isotropic. The average *K* from laboratory tests is about 0.5 ft/d (0.15 m/d). Based on the value of 0.5 ft/d, the transmissivity *(T)* of the 900-ft (274-m) section of Navajo is 450 ft^2/d (42 m^2/d), where it is not enhanced by fractures or other secondary openings.

Table 6.--Hydraulic conductivity and porosity determined by Core Laboratories, Inc., Wilmington, Calif., for core samples from wells TW-1 and OW-1A

Well	Laboratory sample No.[1]	Depth below land surface (ft)	Depth below top of formation (ft)	Permeability (millidarcies) Air	Permeability (millidarcies) Water	Horizontal hydraulic conductivity m/d	Horizontal hydraulic conductivity ft/d	Porosity (percent)
TW-1	1	831.5-831.8	123	1,200	900	0.667	2.19	25.9
	2	852.1-852.3	143	676	383	.284	.932	24.3
	3	858.2-858.5	149	950	515	.381	1.25	25.0
	4	1,137.5-1,137.8	429	870	512	.379	1.25	25.9
	5	1,145.6-1,145.9	437	522	287	.213	.698	22.0
	6	1,150.7-1,151.0	442	531	243	.180	.591	23.1
	7	1,465.4-1,465.8	757	271	148	.110	.360	24.1
	8	1,478.7-1,478.9	770	371	200	.148	.487	24.7
	9	1,483.6-1,483.8	775	224	156	.116	.380	25.2
OW-1A	10	2,346.3-2,346.5	357	528	256	.190	.623	23.0
	11	2,348.2-2,348.5	359	598	324	.240	.788	22.8
	12	2,350.0-2,350.2	361	355	206	.153	.501	21.9

[1] Twelve core plugs, 1 inch in diameter, and a water analysis were submitted by IPP for use in this study. The 12 core plugs were dried and air permeabilities were determined for each. Each core plug was evacuated and saturated with a simulated injection water synthesized from the water analysis. Specific liquid permeabilities were determined using the simulated injection water. The test results for each core plug indicate that all samples exhibit moderate sensitivity to the simulated injection water.

Porosity

The values in tables 4-6 indicate that porosity (n) of the Navajo Sandstone in the Red Desert ranges from about 20 to about 25 percent. Assuming that some of the determinations are high, owing to laboratory procedures, the values derived by the Geological Survey--20.3 to 22.5 percent for effective porosity--appear to be the best for describing the undisturbed Navajo at the test site. The latter values may represent the regional range. G. S. Campbell (written commun., Dec. 2, 1970) reported that the porosity, as read directly from geophysical logs of the petroleum-test well, Mountain Fuel No. 1 State (Bloody Hands Gap Unit), is about 21 percent for the upper 500 ft (152 m) and about 20 percent for the next lower 500 ft (152 m). This well, (D-31-7)36dad-1W, is in the Waterpocket Fold, about 18.5 mi (29.8 km) south of the test area in the Red Desert.

Tests on discharging wells

Information on the hydraulic coefficients for the Navajo Sandstone in the Red Desert area is based principally on a constant-discharge test at well TW-1. The well was pumped for 35 days, from November 24 to December 29, 1975, after which the recovery of water levels was measured until February 2, 1976. Four wells--ICPA, Stanolind, Colt, and OW-1A--were used as observation wells. The large amount of data for both the drawdown and recovery periods from all these wells was analyzed by a variety of methods described in several of the papers referenced. (For example, see Wenzel, 1942.) The several methods of analysis, which provided a means of cross checking results, ranged from the conventional Theis nonequilibrium-test analysis to simple rule-of-thumb checks, using specific capacity.

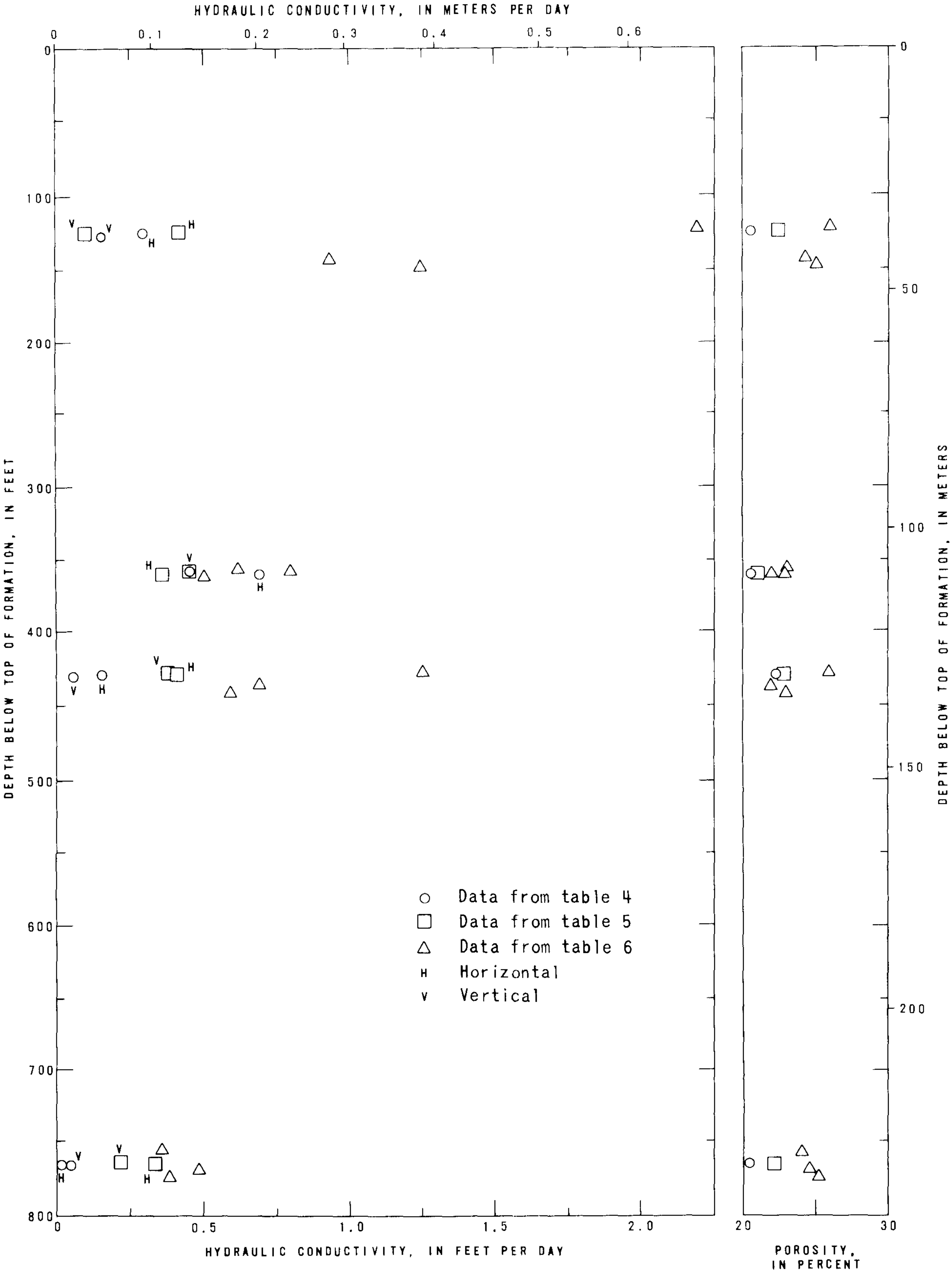


Figure 9.—Hydraulic conductivity and porosity of core samples from the Navajo Sandstone.

In addition to the 35-day pumping test, analysis was made of a part of the data from a stepped-rate production test at well TW-1 made by IPP during September 18-30, 1975. An estimate of T was made for the ICPA well from the specific capacity measured during tests made after the well was completed in January 1974. The estimate was interpreted from data reported by R. J. Madsen, February 1974, for pumping periods of 16 to 24 hours.

Data for the 35-day test are given in figures 10-14. Figure 10 shows water levels in the Red Desert wells. Note the high artesian pressures; for example, well TW-1 had a pressure of 117.8 ft (35.84 m) above land-surface datum at the beginning of the test, or about 827 ft (252.1 m) above the top of the Navajo Sandstone. Although the water in the aquifer responds to both barometric pressure and earth tides, the resulting change of water levels is relatively slight. (See fig. 11.) Therefore, because of the large changes due to pumping in water levels in the four wells in the Red Desert, no corrections were made to these water levels for barometric and tidal changes when they were interpreted for determining aquifer coefficients. In well OW-1A, however, the net change due to pumping was only 2.6 ft (0.79 m), and the water levels were corrected for both interferring effects before determining aquifer coefficients. (See fig. 12.)

Graphs of representative test analyses are shown in figure 13, which includes Theis non-equilibrium analyses (Ferris and others, 1962, p. 91-103) for the four observation wells, a semilog plot of data using the straight-line method described by Brown (1953), and an image-well distance determination (Ferris and others, 1962, p. 163). These three types of analysis were made for all wells, where applicable. Figure 14 shows analysis of recovering water levels in the pumped well, TW-1. Figure 15 shows analysis of the water levels in the pumped well, TW-1, during recovery from the stepped-rate production test made in late September 1975.

In the analysis of the test data, water levels in the observation wells were not corrected for partial penetration, because the radial distances from the pumped well TW-1 to the observation wells were more than twice the thickness of the sandstone aquifer. Because the sandstone is nearly isotropic, the lines of equal drawdown should be vertical, as indicated by Jacob (in Bentall, 1963a, p. 272-282). Transmissivity, as calculated from the observed water levels in the pumped well, is too low because hemispherical flow, rather than radial flow alone, probably occurred in the aquifer close to the pumped well. Well TW-1 penetrated 59 percent of the thickness of the aquifer. Thus, T at the pumped well is more than the calculated value and less than 1.7 times the calculated value. (See following discussion of distance-drawdown analysis.)

Results of the several test analyses are given in table 7. The values for T are valid for pumping periods equal to those for which the values were determined, and the values reflect aquifer conditions in the test area. For calculation of long-term pumping effects, a composite figure for T must be used that includes the effects of T in areas beyond the test area. A composite value for T is discussed below.

Table 7.--Summary of

Discharge: E, estimated.

Part of test analyzed: Early recovery, water-level trend that occurred soon after beginning of recovery; late recovery, water-level trend that occurred well after beginning of recovery, generally 2 to 3 days.

Source of data: ICPA, Intermountain Consumers Power Association; IPP, Intermountain Power Project; USGS, U.S. Geological Survey

Pumped well	Observation well	Dates	Pumping period (days)	Discharge (gal/min)	Maximum observed drawdown (ft)	Part of test analyzed
(D-28-8)29dcb-1 (ICPA well)	–	Feb. 8-9, 1974	0.66	3,110	250[1]	Drawdown
		May-July 17, 1975	–	400E	–	Recovery
(D-28-8)33bbb-1 (TW-1)	–	Sept. 18-19, 1975	1	85	17	Drawdown
		Sept. 18-30, 1975	12	85-2,150	391	do.
		Sept. 30-Oct. 11, 1975	–	–	–	Early recovery
						Late recovery
		Nov. 24-25. 1975	1	2,800	436	Drawdown
		Nov. 24-Dec. 29, 1975	35	2,800	512	do.
		Dec. 29, 1975-Feb. 2, 1976	–	–	–	Late recovery
	ICPA	Nov. 24-Dec. 29, 1975	35	–	72.5	Drawdown
		Dec. 29, 1975-Feb. 2, 1976	–	–	–	Recovery
	Stanolind	Nov. 24-Dec. 29, 1975	35	–	63	Drawdown
		Dec. 29, 1975-Feb. 2, 1976	–	–	–	Recovery
	Colt	Nov. 24-Dec. 29, 1975	35	–	63.6	Drawdown
		Dec. 29, 1975-Feb. 2, 1976	–	–	–	Recovery
	OW-1A	Nov. 24-Dec. 29, 1975	35	–	2.6	Drawdown
		Dec. 29, 1975-Feb. 2, 1976	–	–	–	Recovery

[1] Recomputed from source given under Remarks, in order to account for artesian head above land surface.

results from aquifer tests

Computations based on early data (as at points A, fig. 13)			Generalized values (from points B, fig. 13)		From straight-line methods		Estimated from *SC* (for *S* = 0.001)		Source of data	Remarks
T (ft^2/d)	*S*	Calculated distance to image well (ft)	*T* (ft^2/d)	*S*	*T* (ft^2/d)	*S*	*SC*	*T* (ft^2/d)		
—	—	—	—	—	—	—	10-11	2,670	ICPA	From data reported by R.J. Madsen (written commun., 1974), for production tests that consisted of two separate pumping periods during two consecutive days.
—	—	—	—	—	1,730	—	—	—	USGS	From 10-minute recovery after well flowed for approximately 68 days.
—	—	—	—	—	—	—	5	1,340	IPP	During stepped-discharge test.
—	—	—	—	—	—	—	5.5	1,340	IPP	During stepped-discharge test. Specific capacity reported by IPP, as determined from slope of plot of *s* versus *Q*.
—	—	—	—	—	1,330	—	—	—	IPP	Recovery from stepped-discharge test. (See fig. 15.)
—	—	—	—	—	1,740	—	—	—	IPP	Do.
—	—	—	—	—	—	—	6.4	2,000	IPP-USGS	During principal aquifer test.
—	—	—	—	—	—	—	5.5	1,340	do.	Do.
—	—	—	—	—	1,860	—	—	—	do.	Recovery after principal aquifer test. (See fig. 14.)
4,200	0.00085	7,190	1,430	0.0019	1,600	0.0014	—	—	do.	See figures 10 and 13.
4,250	.00093	—	—	—	—	—	—	—	do.	
3,900	.00081	8,200	1,540	.0015	1,580	.0013	—	—	do.	See figures 10 and 13.
3,110	.0012	—	—	—	—	—	—	—	do.	
2,630	.00055	13,550	1,430	.00063	1,580	.00049	—	—	do.	See figures 10 and 13.
2,500	.00064	—	—	—	—	—	—	—	do.	
2,630	.0013	—	—	—	—	—	—	—	do.	See figures 12 and 13.
2,630	.0011	—	—	—	—	—	—	—	do.	

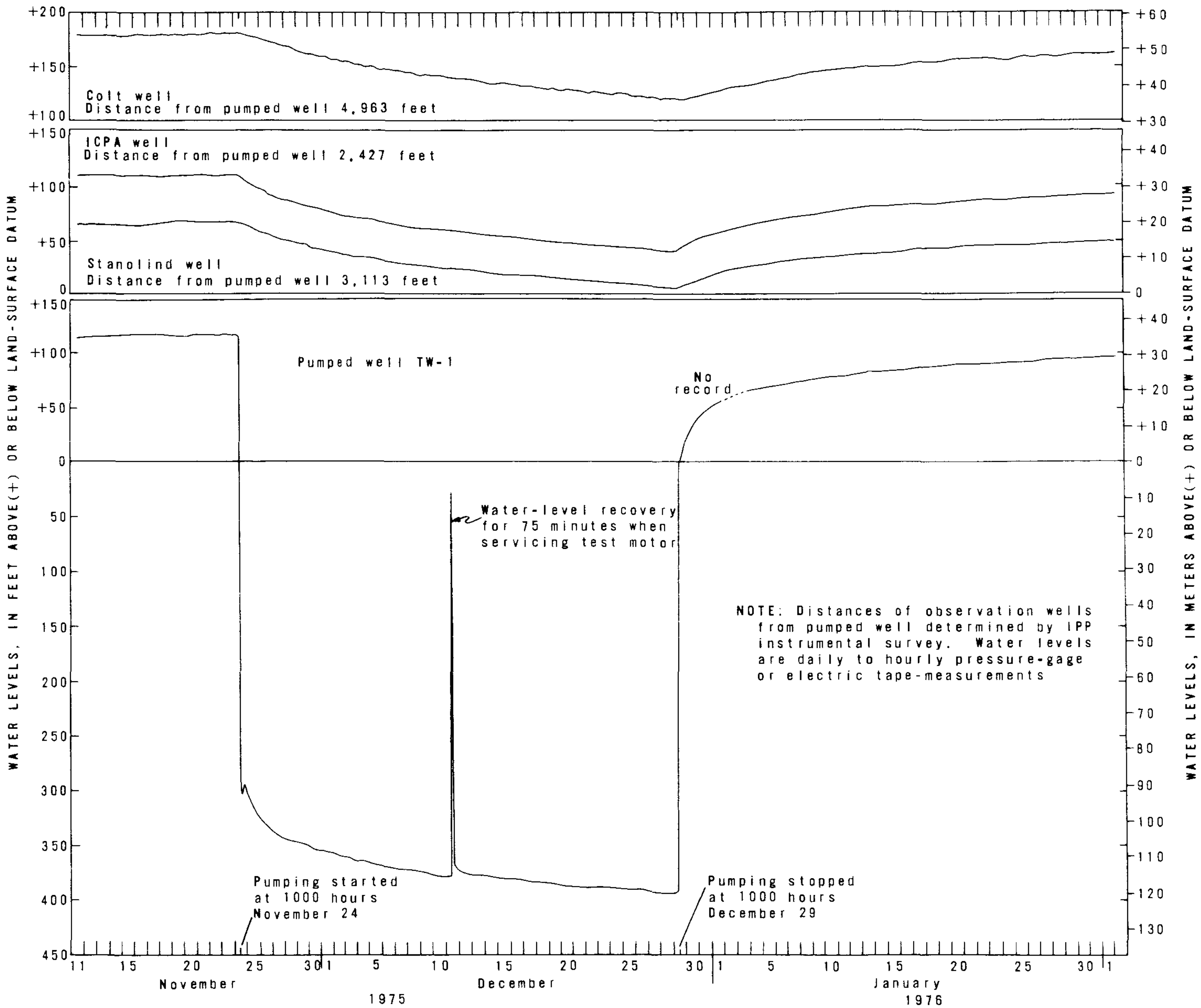


Figure 10.—Water levels in wells in the Red Desert.

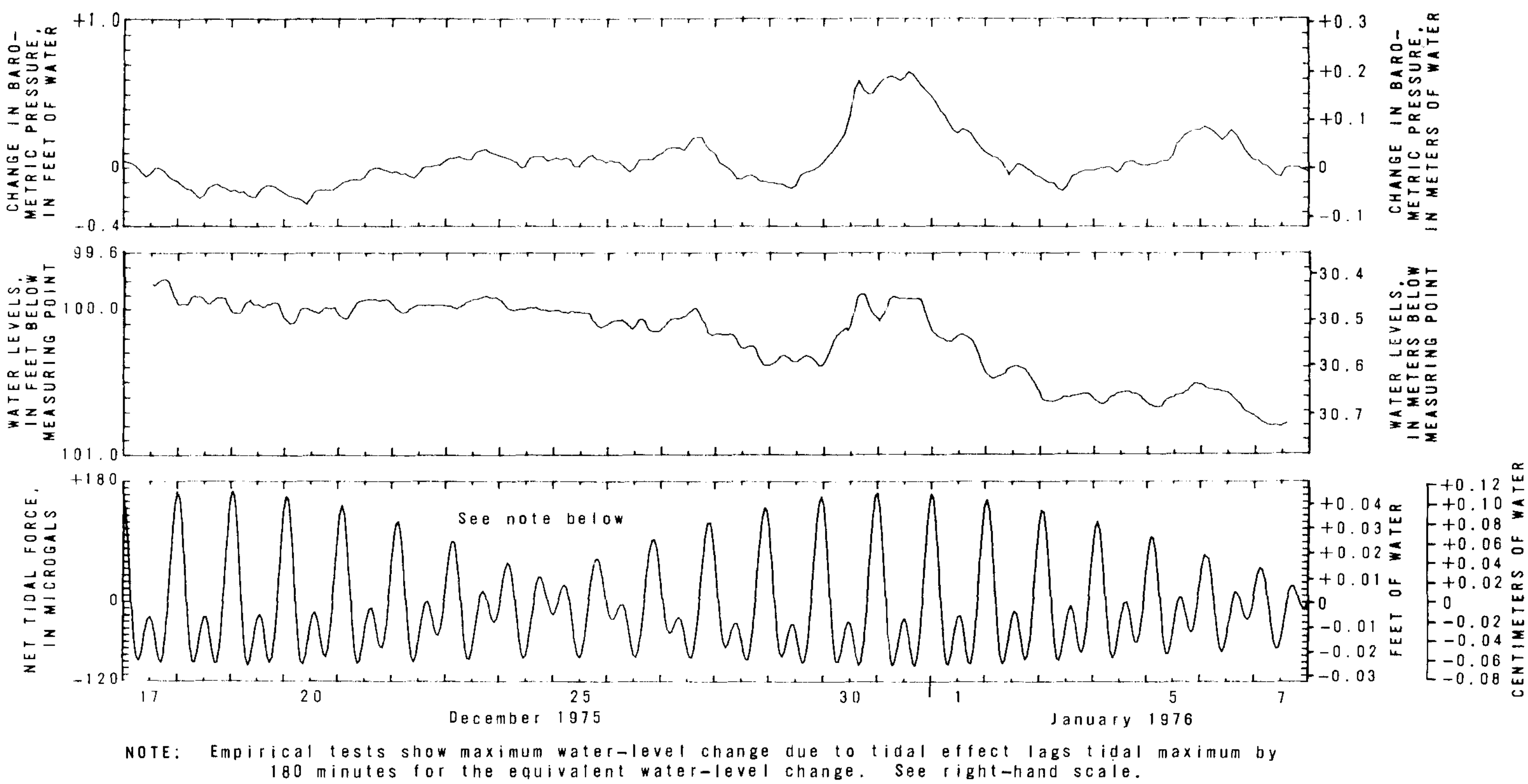


Figure 11.—Relation of water levels in well OW-1A to change in barometric pressure and earth tides.

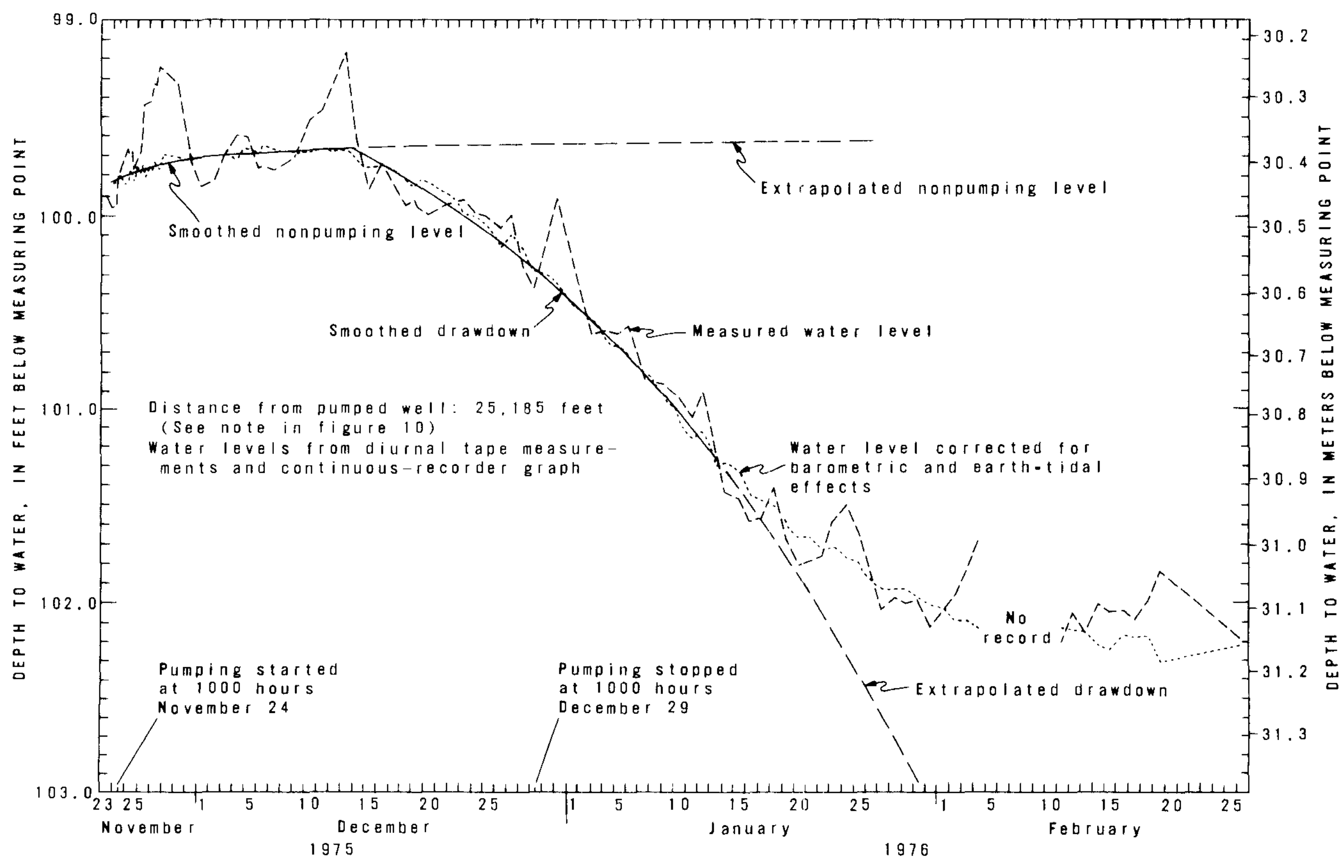


Figure 12.—Water levels in well OW-1A.

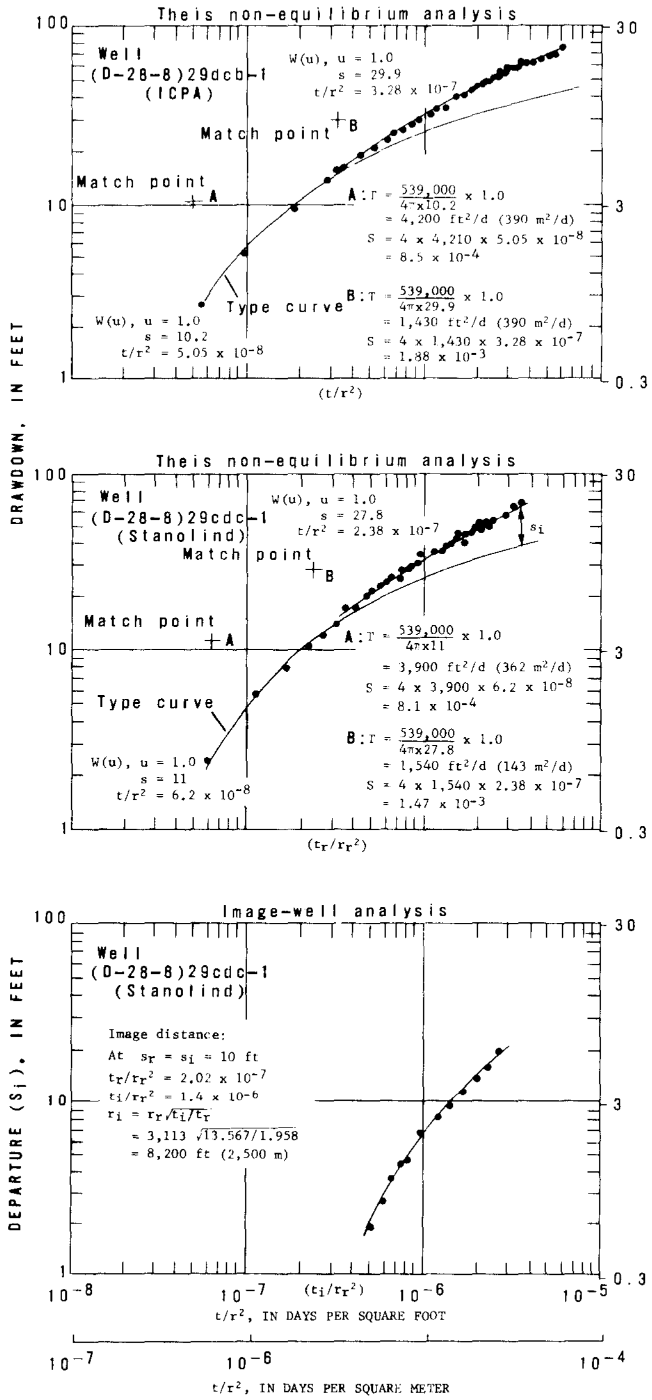
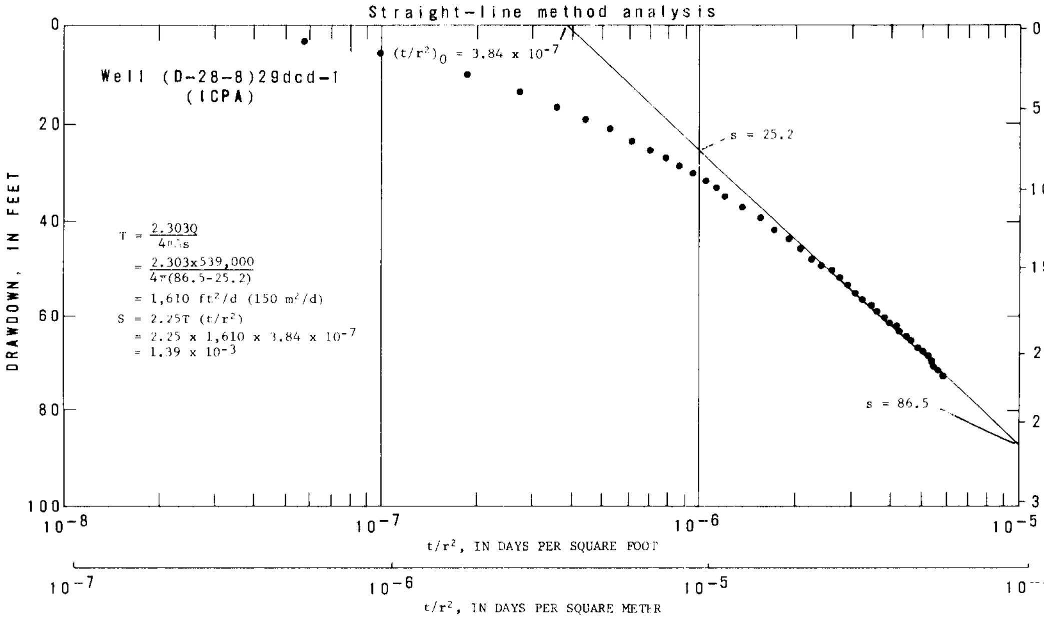
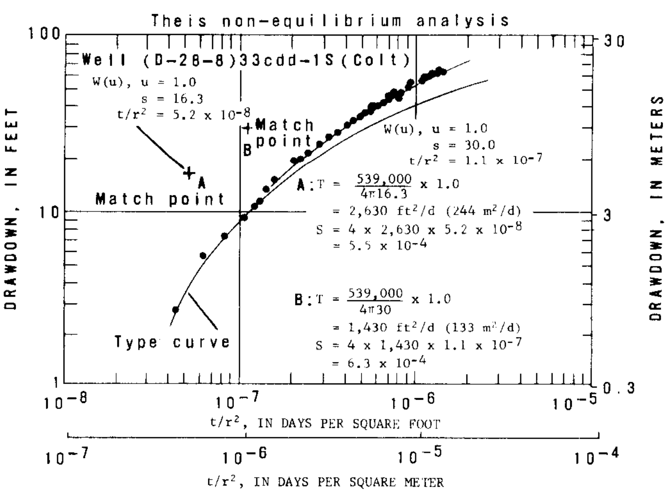


Figure 13.—Representative data analyses from 35-day aquifer test.



Pumped well: (D-28-8)33bbb-1
Q = 2,800 gal/min (176.7 L/s)
= 539,000 ft^3/d (15,270 m^3/d)
Distance (r) from pumped well:
(D-28-8)29dcb-1 2,427 feet (740 m)
29cdc-1 3,113 feet (949 m)
33cdd-1S 4,963 feet (1,513 m)
(D-27-8)27cdb-1 25,185 feet (7,676 m)

$T = \frac{Q}{4\pi s} \cdot W(u)$ $S = 4T \cdot u \cdot t/r^2$



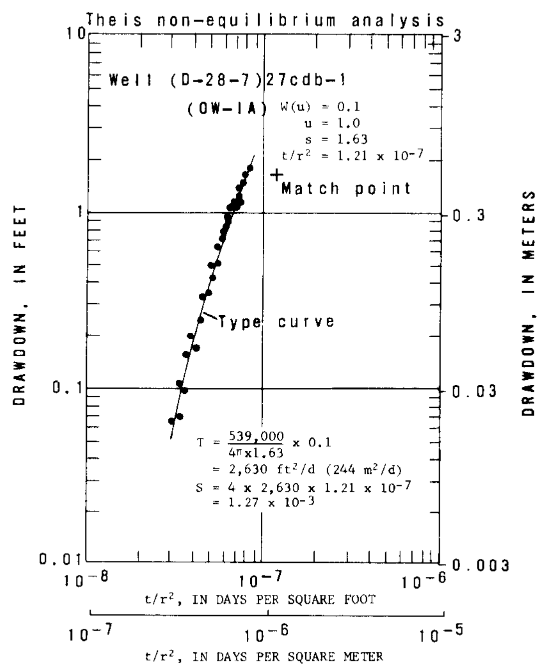


Figure 13.— Continued.

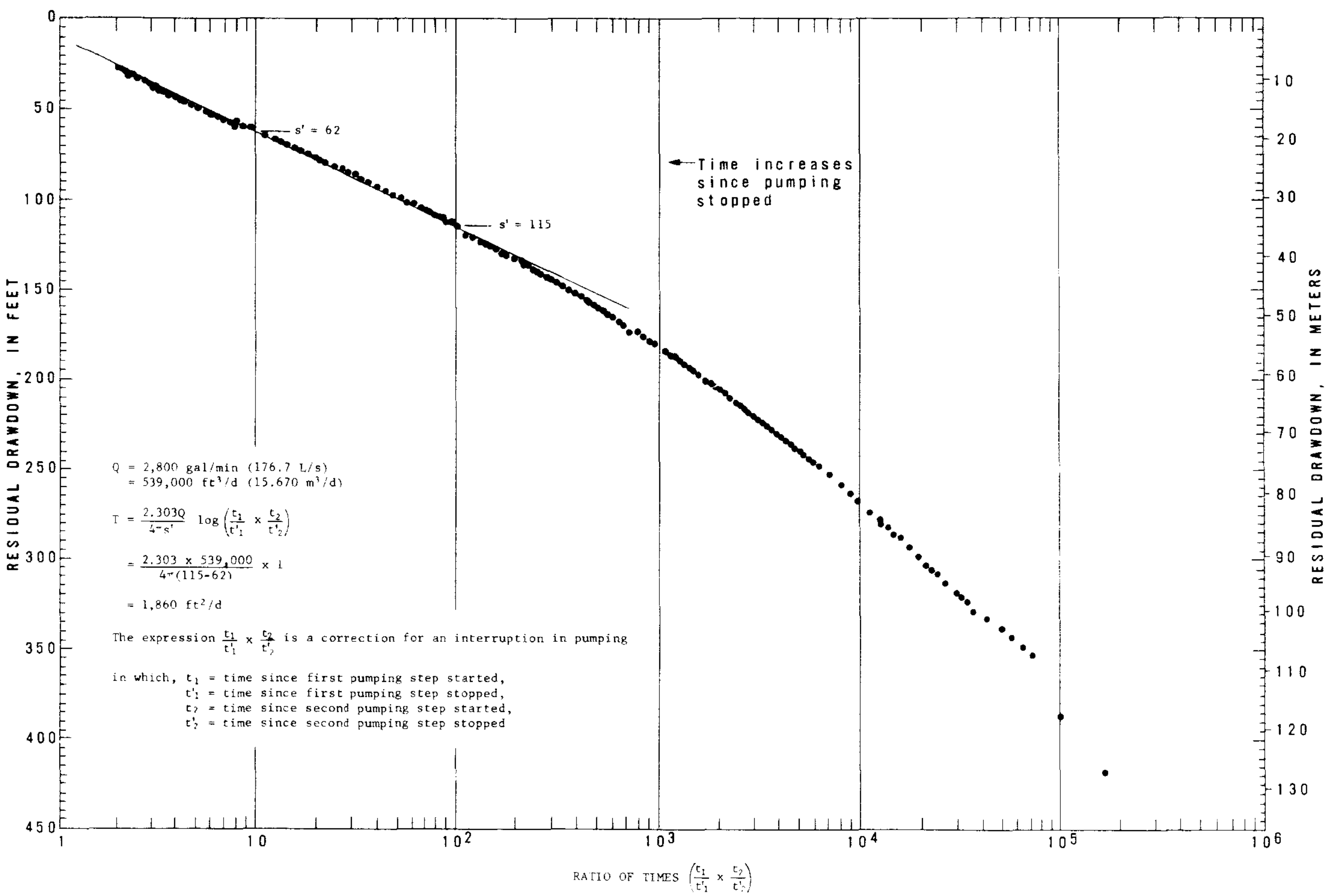


Figure 14.—Analysis of residual drawdown in well TW-1 after pumping for 35 days.

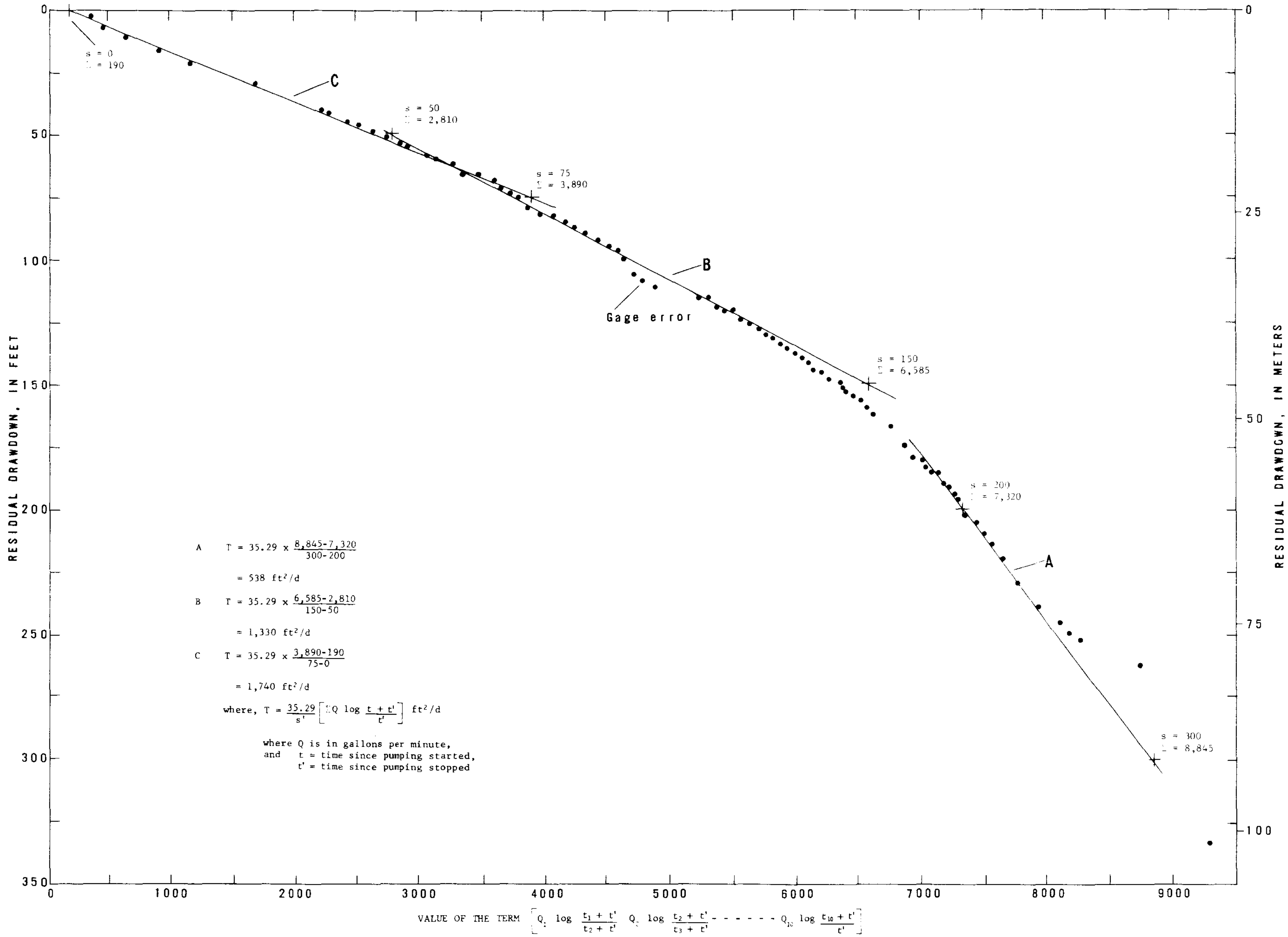


Figure 15.—Analysis of residual drawdown in well TW-1 after pumping for 11 days at increasing rates of discharge.

The analyses indicate that the Navajo Sandstone, though nearly isotropic in undisturbed cores, is grossly anisotropic where it has been fractured. Moreover, the Navajo aquifer is heterogeneous. For example, three of the log-log plots in figure 13 show that an apparent boundary appears in the early test data, utilizing a match to the Theis type curve at points A. Departures from the type curve suggest a line beyond which, or along which, the aquifer has lower permeability than it has near the wells. The loci of the line were calculated using the graphic method of Moulder (in Bentall, 1963b, p. C110-C112). The trend of the line appears related to geologic trends in the area, although no direct surficial feature is evident.

Assuming that the apparent change in T has only a transitory effect on the long-term development of the cone of depression, the points in the three log-log plots can be generally matched at points B. These matches yield lower and more uniform values for T. Straight-line semi-log plots of the observation-well data also indicate the effect of the changes in value for as the cone of depression spread. The example in figure 12 shows a straight line fitted to the data, but it also should be noted that the trend of points is curvilinear. For an isotropic formation, the data should have approximated a straight line after a maximum of 17 days of pumping--after which the value $1/u$ is greater than 50 (Brown, 1953, p. 858). However, the image-well effects arrived before that time, as shown in the Theis non-equilibrium analysis for the same well.

Because of the seemingly conflicting values for T , the drawdown in pumped well TW-1 was corrected for partial-penetration effects, and the drawdowns in the pumped and observation wells were plotted versus distance. (See fig. 16.) The resultant value for T is 2,560 ft^2/d (238 m^2/d). This value is in the range of those for T determined at match points A in the curves for the observation wells.

Transmissivity

A generalized value for transmissivity T of 1,500 ft^2/d (139 m^2/d) is selected for calculation of long-term pumping effects in the fractured Navajo Sandstone aquifer near Caineville. The selection of the generalized value was made after considering the following factors:

1. The generalized values for T (table 7) correspond closely.

2. All values of T obtained from the tests (table 7) are higher than any based on values of K determined from the cores.

   This indicates that secondary permeability, probably the result of fracturing, has an important effect on well yields and water-level response to pumping. Such response would be most affected in the areas of maximum aquifer distortion near the crest of the Caineville anticline; but cross fracturing might also be present, due to the plunge of the anticline, both northward and southward.

3. The time-drawdown curves show a "discharging-boundary" response. This boundary effect is real. It appears in the plots for all wells in the Red Desert, in both the drawdown and recovery curves. The boundary plots to the north of the well field, and it either parallels or intersects geologic features that indicate structural distortion.

Nothing constituting a zero-permeability barrier is evident from the surface geology, but the response is reasonably sharp. From the responses observed, it is inferred that the boundary represents a line along or beyond which *T* is less than in the well field. Thus, the generalized values for *T* derived from match points B (table 7) represent a composite response to conditions in both the area of high *T* near the wells and the area beyond the boundary where a lower *T* occurs.

4. The *T* at well OW-1A is in the same range as that at the wells in the Red Desert (table 7). It appears, therefore, that fracturing affects substantial areas of the sandstone aquifer, and that nowhere is it likely that *T*, as determined from wells, will be as low as that calculated from core permeabilities.

Thus, the generalized value of 1,500 ft^2/d (139 m^2/d) is considered to be the most useful value of *T* for computation of long-term pumping effects in the Navajo Sandstone aquifer near Caineville.

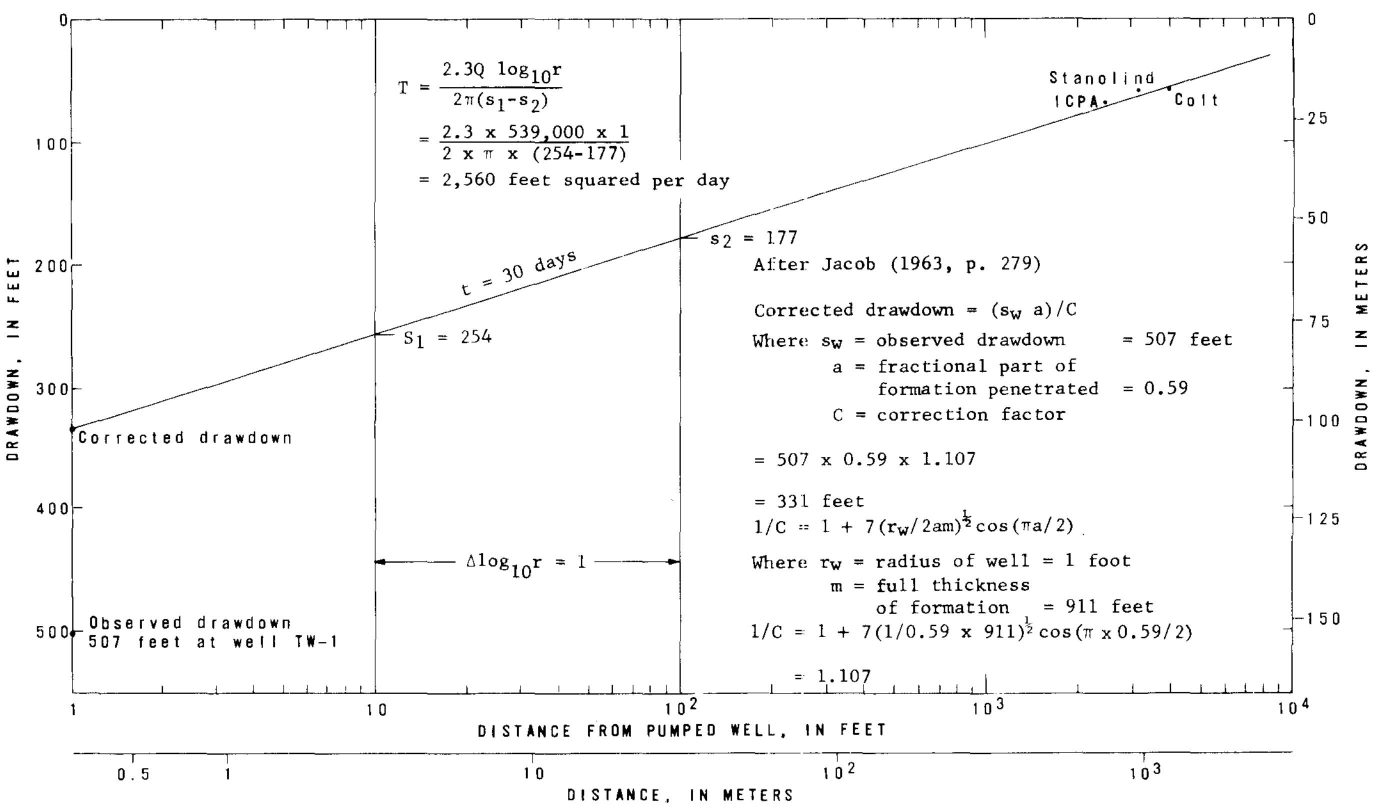


Figure 16.—Drawdown as a function of distance from well TW-1 after pumping for 30 days.

Storage coefficient

A generalized value of 1×10^{-3} for storage coefficient *(S)* is selected for calculation of long-term pumping effects in the Navajo Sandstone aquifer near Caineville. The calculated values shown in table 7 range from 4.9×10^{-4} to 1.9×10^{-3}, but these values were derived using values of *T* that are too large. The selected value is estimated to be a fair compromise. It checks against an approximation of *S* using the rule of thumb cited by Lohman (1972, p. 53), which is based on the more precise method of Jacob (1950, p. 334). The approximation is 9×10^{-4}, which is based on a formation thickness of 900 ft (274 m) that is multiplied by 1×10^{-6}.

The selected generalized value for *S* is high for a confined aquifer. It is probable that some dilation of the aquifer occurs because of the high pressure, and this leads to compaction when pressure is relieved by flow or pumping. Evidence of compaction seemingly is given by the water-level changes in well (D-28-7)36bbb-1 during the 35-day test. (See fig. 17.) The water level in the Navajo Sandstone beneath this well was at an altitude of about 5,040 ft (1,536 m), as projected 2.5 mi (4 km) upgradient from well (D-28-8)29cdc-1. Well (D-28-7)36bbb-1 on the same date had a water-level altitude of 5,119 ft (1,560 m) or about 80 ft (24 m) higher than that in the Navajo. Despite the approximately 1,400 ft (427 m) of strata that separate the Navajo from the Salt Wash Sandstone Member of the Morrison Formation in which well (D-28-7)36bbb-1 is finished, water levels in the well apparently declined in immediate response to withdrawals from the Navajo. Thus, it is inferred that the Navajo compacted.

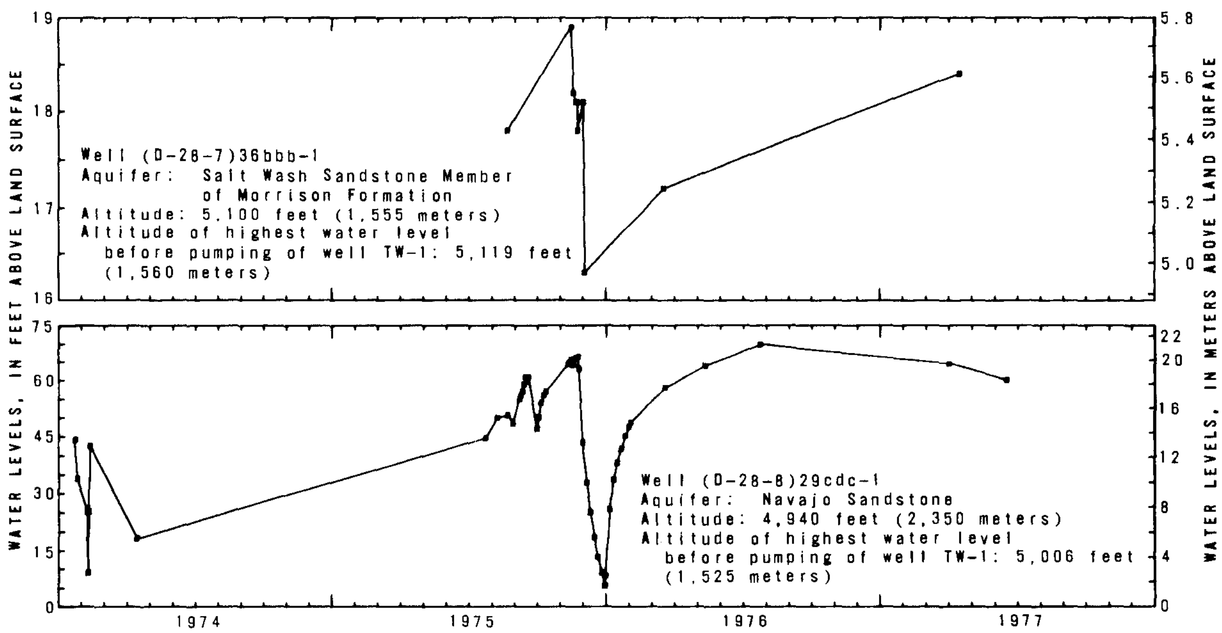


Figure 17.—Water levels in wells (D-28-7)36bbb-1 and (D-28-8)29cdc-1 emphasizing changes during 35-day pumping test.

Long-term pumping effects

If the Navajo Sandstone were used as a source of cooling water for a powerplant, withdrawals would be large and of long duration. The areal effects would depend on factors such as the number and location of supply wells, the rate of pumpage, the location of aquifer boundaries, and changes in *T* at different sites that would be due to formation thickening or thinning.

An example of long-term effects is given in figure 18, which shows a set of simplified conditions and assumptions. The figure shows that if well TW-1 were pumped at 3,000 gal/min (189 L/s), the water level in the well would still be 73 ft (22 m) above the top of the aquifer after 40 years of pumping. Near Hanksville, 18.9 mi (30.4 km) to the east, the pressure in the Navajo Sandstone would have declined about 50 ft (15 m).

Since boundaries and areal changes in *T* do exist, the actual drawdown from pumping 3,000 gal/min (189 L/s) would be somewhat greater, and adding other wells to the pumping system would create mutual interference. The additional drawdown due to these effects would increase drawdown at well TW-1; and after 40 years of pumping, the water level would have declined below the top of the Navajo Sandstone.

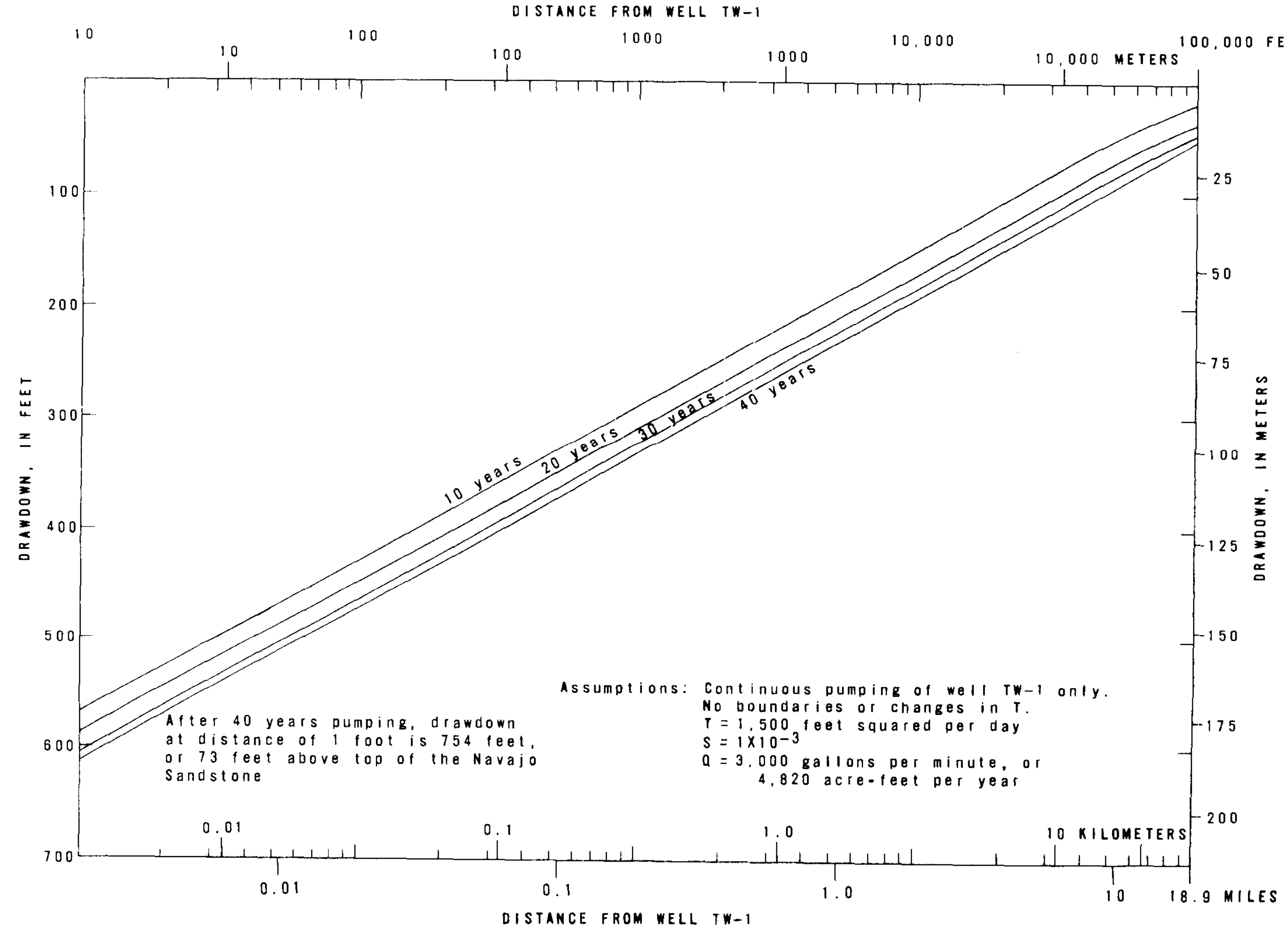


Figure 18.—Theoretical effect of long-term pumping at well TW-1.

If the water level were to decline below the top of the Navajo Sandstone, water would then be obtained from storage by draining pores, at a rate of release greatly exceeding the rate of release under confined conditions. For a given rate of discharge, the rate of development of the cone of depression would then diminish. The specific yield is estimated to be between 5 and 10 percent, or at least 50 times greater than the amount of water released from artesian storage.

Water-level declines of the magnitude implied probably would result in a change in the chemical quality of the pumped water for two reasons. First, pressure relief probably would induce upward leakage from formations that underlie the Navajo Sandstone. Secondly, if the water level in the Navajo were to decline below the water levels in the Carmel Formation, drainage from that formation down to the Navajo would occur. In both cases, the chemical quality of the pumped water would be degraded. The amount of potential degradation is unknown, but it is inferred that the quantity of leakage would be small and thus the degradation also might be small.

CHEMICAL QUALITY OF GROUND WATER

Extensive sampling was done on well TW-1 during the 35-day pumping test, on the Colt well while it was being converted to an observation well, and on the ICPA well while it was being drilled. Selected chemical analyses from this suite of samples and from other sources in the test area are given in table 10, and a record of discharge measurements during sampling, ground-water temperature, and specific conductance are given in table 11.

The chemical analyses support the inference that ground water moves from one aquifer to another. Based on the chemical data and on geologic and water-level data, it appears that the most probable avenues of movement are fractures due to folding. These conclusions follow from the discussion below.

The Navajo Sandstone consists mainly of quartz grains with little interstitial cement. Thus, water moving through it, despite long residence time, should not be appreciably mineralized and would be of the calcium bicarbonate type.

The Carmel Formation, which overlies the Navajo Sandstone, contains large amounts of gypsum; and to the north and west of the test area, contains salt (Gilluly and Reeside, 1928, p. 74). Thus, the Carmel could yield water of the calcium sulfate or sodium chloride type.

The Kayenta Formation, Wingate Sandstone, and Chinle Formation directly underlie the Navajo Sandstone. The Kayenta and Chinle contain shale beds, and the Wingate is of lower permeability than the Navajo. Thus, the section underlying the Navajo could be a source of water that is more highly mineralized than the water in the Navajo.

Water under artesian pressure in deeply buried aquifers in the Red Desert area could discharge upward from deeper formations to shallower ones along fractures due to folding. Although the leakage under natural conditions might be small, the rate of leakage could be increased by withdrawals from the system.

The analyses of water samples from the Colt well (table 10) give a verticle profile of the chemical quality of water at that location. A sample of water that flowed from the open hole (table 8) on July 14, 1975, contained 7,210 mg/L of dissolved solids (table 10) and was of the sodium chloride type. This sample may have included water from all formations between the Chinle and Carmel Formations, inclusive. All samples later obtained from the Navajo Sandstone and the Carmel, however, contained a considerably lower dissolved-solids concentration. Because water pressures increase with depth, it can be inferred, therefore, that the highly mineralized water came from beneath the Navajo.

Near the middle of the Navajo Sandstone, (1,286-1,296 ft or 392-395 m) the water contained 1,170 mg/L of dissolved solids and was of a mixed type, with sodium and chloride as the dominant ions. About 150 ft (46 m) below the top of the Navajo, the water contained 740 mg/L of dissolved solids and was of a mixed type. At the top of the Navajo, the dissolved-solids concentration was 964 mg/L; and the water was of the mixed type, with calcium and sulfate as the dominant ions. The base of the Carmel Formation (sample from 663-673 ft or 202-205 m) yielded water similar to that at the top of the Navajo, but water from higher in the Carmel (sample from 611-621 ft or 186-189 m) was again more mineralized. Thus, upward leakage from the Navajo to the Carmel is implied.

The ICPA well was sampled while it was being drilled. The uppermost sample was obtained from the Carmel Formation when the well was flowing and was 597 ft (182 m) deep. The dissolved solids were 4,580 mg/L; and the water was of the mixed type, with calcium and sulfate as the dominant ions. Water from the uppermost 20 ft (6.1 m) of Navajo Sandstone in the well was slightly more dilute but contained more sodium than calcium. A composite sample from the Navajo when the well was 761 ft deep and had penetrated 93 ft of the Navajo yielded a still more dilute mixed water with sodium as the dominant ion. The artesian pressure is greater in the Navajo than in the Carmel; thus, it appears that water moves upward from the Navajo into the Carmel, where it is degraded in chemical quality.

Well TW-1 penetrates 546 ft (166 m) (about 59 percent of the total thickness at this well) of the Navajo Sandstone. Pumping the well for 35 days had relatively little effect on the percentage composition of dissolved constituents, and the chemical quality was almost uniform from one sampling date to the next. The water was of the sodium chloride sulfate type. It is believed that water from well TW-1 in part leaks from formations below the Navajo, and that given a large lowering of head due to pumping, the water probably will deteriorate to some extent with time of withdrawal.

The only other water samples available from the area of the test near Caineville are from the Salt Wash Sandstone Member of the Morrison Formation. A sample from the Clark well, which is 800 ft (244 m) deep, had a much lower dissolved-solids concentration than did samples from the deeper Carmel Formation tapped by other wells. Water from the Clark well was of the sodium sulfate type and had a relatively low chloride concentration. Leakage from below does not affect the chemical quality of water in the well because the water is perched above the potentiometric surface in the Navajo Sandstone.

CONCLUSIONS

The Navajo Sandstone near Caineville is a massive, crossbedded, very fine to fine-grained unit, approximately 900 ft (274 m) thick. The unfractured sandstone, for the practical purpose of aquifer analysis, is hydraulically isotropic. It has an average *K* of about 0.5 ft/d (0.15 m/d), with an average horizontal-to-vertical permeability ratio of 1.42:1. The calculated *T*, based on the above value is 450 ft^2/d (42 m^2/d).

Folding of sandstone has produced fracturing that probably facilitates some interformational leakage. The leakage, under natural conditions, is upward under a high artesian head.

The fracturing has increased the overall permeability so that the formation is heterogenous and probably anisotropic on a regional scale. Conventional aquifer-test analysis, assuming an isotropic formation, does not yield the uniform results that might be expected from the relatively homogeneous sandstone.

Based on both time-drawdown and distance-drawdown analyses, a generalized value for *T* selected for calculation of long-term pumping effects is 1,500 ft^2/d (139 m^2/d) or 3.3 times that calculated for the unfractured formation. A generalized value selected for *S* is 0.001 under artesian conditions. For water-table conditions, the value for *Sy* is estimated to be between 5 and 10 percent.

Natural interformational leakage in the test area is inferred from chemical, geologic, and water-level data. It also is inferred that some degradation of the chemical quality of the well water would be induced by large withdrawals from the Navajo Sandstone. Initially, this increase in mineral content would be due to upward leakage from underlying formations under high artesian head because of the large pressure drop within the Navajo. If water level in the Navajo were to drop below the water level in the overlying Carmel Formation, water would drain downward from the overlying Carmel.

In summary, the Navajo Sandstone near Caineville is capable of sustaining large yields of slightly saline water to wells for periods of many years. Drawdown near pumped wells would be large, and the effects of pumping would extend to distances of 20 mi (32 km) or more.

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Table 8.--Records of selected wells and springs

Location: See text for description of well- and spring-numbering system.
Well finish: P, perforated; X, open hole.
Water level: R, reported.
Discharge: E, estimated; R, reported.
Drawdown: E, estimated.
Remarks and other data available: Chemical analyses - B, common dissolved constituents, and M, multiple analyses (table 10), K, specific conductance and temperature (table 11); Logs - L, driller's log or summary of sample descriptions (table 9), G, geophysical log in files of Geological Survey or owner; Water levels - WL, hydrographs in figures 10, 12, or 17, measurements in files of Geological Survey.

Location	Name or owner	Year constructed	Depth of well (ft)	Well finish	Altitude of land-surface datum (ft)	Water level (feet above or below(-) land-surface datum)	Date measured	Discharge (gal/min)	Drawdown (ft)	Date discharge measured	Remarks and other data available
(D-28-7)11cdb-S1	Rock Water Spring	-	-	-	5,430	-	-	-	-	-	Discharges from Salt Wash Sandstone Member of the Morrison Formation in bluff at south side of Hartnet Draw. B.
27cdb-1	IPP observation well (OW-1A)	1975	2,353	X	5,162	-94.7	9-23-76	300E	-	11-20-75	Observation well drilled for aquifer test. Drilled to 2,341 ft; cored to 2,353 ft. Casing: 6-in. to 42 ft; 5-in. 42-1,990 ft, stage-cemented from 1,990 ft to land surface. Developed by jetting and 7 hours of air-lift pumping. Equipped with automatic water-level recorder for duration of project. M, L, G, WL.
36bbb-1	Emmett Clark and others	1966	800	X	5,100	30R 17.8	7-14-66 7-17-75	3.5R 1.9	- -	7-14-66 7-17-75	Flowing stock well on east side of North Blue Flat. Finished in Salt Wash Sandstone Member of the Morrison Formation. Flows continuously to stock trough. Leaks around surface casing. Casing: 10-in. to 330 ft; 8-in. from land surface to 726 ft. B, L, WL.
(D-28-8)29cdc-1	Stanolind (Red Desert)	1955	764	X	4,940	16R 55.3 61.8	4-13-74 3-17-76 3-31-77	100R 48 47	- - -	8- 7-55 3-17-76 3-31-77	Flowing stock and wildlife well. Flows continuously to pond. Originally drilled to supply oil-test well. Casing: 13-in. to 32 ft; 7-in. from land surface to 720 ft. Top of sand in base of Carmel Formation at 693 ft; top of Navajo Sandstone at 720 ft. (See p. 12.) M, L, WL.
29cdc-2	Stanolind Oil Co. No. 1 Federal	1955	7,160	-	4,936	-	-	-	-	-	Abandoned oil test. Drill-stem test in Mississippian limestone, 6,556-6,618 ft recovered 6,125 ft of reportedly freshwater. L.
29dcb-1	ICPA test well	1974	761	X	4,896	69R 108.0 90.0	4-13-74 11-24-75 2- 2-76	3,110R[1] 400E	250E[1]	2- 9-74 7-17-75	Flowing test well. Shut in after tests by IPP. Casing: 20-in. to 22 ft; 16-in. from 2.4 ft above land surface to 679 ft below land surface, cemented to shut off flow from Carmel Formation. M, L, G. WL.
32acb-1	Ohio Oil Co. No. 1 Federal	1922	3,650	-	4,990	-	-	-	-	-	Abandoned oil test. L.
33bbb-1	IPP test well (TW-1)	1975	1,250	X	4,884	117.8 107.0 114.1 121.6	11-24-75 3-17-76 5-10-76 7-22-76	2,800	511.8[2]	12-29-75	Flowing test well. Drilled 9.6-in. pilot hole to 1,685 ft; cored three intervals. (See table 3.) Plugged 9.6-in. hole back to 1,250 ft. Casing: 30-in. to 45 ft; 20-in. from 2 ft above land surface to 704 ft below land surface. All casing cemented to formation to isolate Navajo Sandstone and seal in the artesian head. Producing section, 704-1,250 ft, is 18.5-in. open hole. M, L, G, WL.
33cdd-1S	Colt well	1975	1,350	P	4,823	177.2 178.4 170.0 176.7 182.5	11-11-75 11-24-75 3-31-76 5-10-76 7-22-76	180E[3] 200E[4]	- -	8- 5-75 8-21-75	Flowing observation well. Originally drilled to 3,700 ft as an oil test by Colt Oil Co. in May 1975. Re-entered by IPP in August 1975. Original casing record: 13.6-in. to 100 ft; 8.6-in. from land surface to 1,400 ft. Open hole to 3,700 ft, drilled to 7.9-in. diameter. Oil test reportedly plugged at 3,475-3,700 ft, 2,425-2,500 ft, and 1,350-1,400 ft. On re-entry, no plug found above 2,425 ft and casing found to be poorly cemented. Conversion to observation well started with plugging below 1,350 ft, and stage-cementing casing to completely seal off Navajo Sandstone and Carmel Formation. Five 10-ft zones were gun-perforated for drill-stem testing, using straddle packers. A sixth zone was later added to test the basal Carmel. After testing, well was completed by squeeze-cementing all perforations above 756 ft and increasing the perforations to include a total of 130 ft within the zone 756-1,296 ft. (See sampling zones listed in tables 10 and 11.) M, L, G, WL.
35bca-S1	Seep	-	-	-	4,600	-	-	1E	-	3-25-76	Intermittent spring. Water probably is underflow in alluvium upstream, which is brought to the surface by convergence of the base of the alluvium with the streambed. On March 25, 1976, temperature was 11°C; specific conductance was 6,500 micromhos. K.

[1] After production pumping test; drawdown recomputed from value reported by R. J. Madsen (written commun., 1974) to account for artesian head above land surface.
[2] After pumping for 35 days.
[3] Discharge through 50 ft of perforations, prior to observation well completion. (See table 11.)
[4] Discharge through 130 ft of perforations after observation well completion.

Table 9.--Selected logs of wells

Location: See text for description of well-numbering system.
Altitudes are in feet above mean sea level for land surface at well.
Thickness, in feet.
Depth, in feet below land surface

Material	Thickness	Depth
(D-28-7)27cdb-1. Summarized from sample logs[1] by W. G. Hannah, T. P. Condiff, and L. A. Jackson, Los Angeles Department of Water and Power. Alt. 5,162.		
Brushy Basin Shale Member of the Morrison Formation[2]		
Sandstone, fine- to medium-grained, soft, massive........	10	10
Sand, fine- to coarse-grained, varicolored, with 30 percent claystone chips; firm and greenish claystone, bound the drill string between 30 and 40 ft............	30	40
Sand, varicolored, fine- to coarse-grained..............	10	50
Claystone, firm, greenish-gray to reddish-brown..........	20	70
Claystone, gray to reddish-brown, soft and sticky to firm; sandy in some zones, and with agate chips at 100 to 160 ft..	180	250
Claystone, brownish-purple to gray and green............	10	260
Claystone, gray to brown, soft to firm chips............	30	290
Siltstone, sandy to clayey, red-brown, sticky, and very fine grained sand; rough drill action 303 to 305 ft....	20	310
Salt Wash Sandstone Member of the Morrison Formation		
Sandstone, brown, very fine to fine-grained, with trace of gray claystone.....................................	10	320
Sandstone, light-gray, fine-grained, with coarse, angular fragments that may be cavings.........................	10	330
Sandstone, gray, fine- to coarse-grained, hard, with red agate chips and other rock fragments..................	10	340
Sandstone, gray, fine- to coarse-grained, hard, and chips of brown claystone and grayish-green siltstone.........	75	415
Siltstone, claystone, and fine-grained sandstone, reddish-brown..	15	430
Siltstone, claystone, and sandstone, light to dark gray with some red-brown................................	10	440

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-7)27cdb-1 - Continued		
Salt Wash Sandstone Member of the Morrison Formation - Continued		
Sandstone, gray, fine- to coarse-grained, hard, calcareous, subangular; hard drilling.....................	15	455
Siltstone and claystone, red and green, feldspar, slightly calcareous gray shale, and fine-grained sandstone...	15	470
Siltstone and claystone, and gray fine- to medium-grained sandstone.....................................	10	480
No record...	10	490
Sandstone, very fine to fine-grained, siltstone, and gray calcareous claystone, and green to red claystone..	10	500
Siltstone and claystone, greenish-gray and reddish-brown, soft to firm, fine-grained calcareous sandstone, and trace of red agate; zone 510 to 515 ft drilled fast; zone of siltstone and claystone 520-530 ft is soft; cuttings break down in water..........	40	540
Sandstone, fine- to coarse-grained, calcareous; mainly in grains 540 to 550 ft and firmer, with cemented chips 550-555 ft; 10 percent red to green claystone....	15	555
Summerville Formation		
Claystone, siltstone, and sandstone, greenish-gray, in flat chips up to 1 in. in size; some varicolored chips; gray fine-grained calcareous sandstone..........	15	570
Claystone and siltstone, reddish-brown, soft to firm, calcareous; 20 percent greenish-gray chips; some fine-grained sandstone and gypsum; cutting size, variable--large near 670 ft--small near 690 ft; increase in sand content at 690 ft; slow drilling 693 to 700 ft...	130	700
Sandstone, reddish-brown, mainly very fine to fine-grained, calcareous, in grains and chips; calcareous siltstone, some gray claystone, and rare pebbles.......	10	710
Siltstone and claystone, reddish-brown to gray, calcareous, soft to firm, some fine-grained sandstone, a trace of gypsum, and a few ½-in. pebbles............	60	770

Material	Thickness	Depth
(D-28-7)27cdb-1 - Continued		
Summerville Formation - Continued		
Siltstone, claystone, and fine- to medium-grained, greenish-gray to red calcareous soft to firm sandstone	25	795
Curtis Formation		
Siltstone, claystone, and fine- to medium-grained, greenish-gray to red calcareous sandstone	15	810
Siltstone and claystone, brown and gray-green, and gray very fine grained sandstone; gypsum at 820 ft; and many large flat chips of green siltstone below 700 ft	80	890
Entrada Sandstone		
Siltstone, claystone, and fine- to medium-grained, greenish-gray to red calcareous sandstone; some gypsum at 900 ft; increase in sandstone at 910 ft; flakes of coal (?) at 920 ft	70	960
Sandstone, reddish-brown, very fine to fine-grained, sticky, silty, clayey, calcareous, with chips of red to gray siltstone and claystone	240	1,200
No record	25	1,225
Siltstone, claystone and very fine to fine-grained brown and gray to gray-green sandstone; increase in gypsum at 1,400 ft	215	1,440
Sandstone, reddish-brown, fine-grained, silty, clayey, and chips of green-gray claystone; claystone content decreases with depth	50	1,490
Sandstone, reddish-brown, very fine grained, calcareous, silty, with chips of soft to firm reddish-brown to greenish-gray siltstone and claystone, and with medium to coarse gray to white fragments (gypsum?)	25	1,515
Carmel Formation		
Sandstone, mostly gray, very fine grained, calcareous, silty, with chips of siltstone and claystone	55	1,570
Claystone, siltstone, and very fine to fine-grained soft to firm calcareous sandstone, with large flat chips of reddish-brown siltstone	10	1,580

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-7)27cdb-1 - Continued		
Carmel Formation - Continued		
Claystone, siltstone, and sandstone, gray to reddish-brown	10	1,590
Claystone, siltstone, and sandstone, greenish-gray, soft, with a trace of gypsum, and 10 percent chips of reddish-brown siltstone	10	1,600
Claystone, dark grayish-green to bluish-green, soft, slightly calcareous, with a trace of brown siltstone and gypsum	20	1,620
Claystone and siltstone, greenish-gray to red, soft, in small to medium-sized chips	20	1,640
Claystone and siltstone, greenish-gray to red, soft, in large chips	40	1,680
Claystone and calcareous siltstone, greenish-gray and dark red, in large chips and flakes, with a trace of gypsum	10	1,690
Claystone, greenish-gray, and dark-red siltstone; calcareous, soft to moderately firm, in small to large chips and flakes; trace of gypsum, including a fibrous gypsum-calcite vein fragment; some angular calcareous chips near 1,710 ft	30	1,720
Siltstone, red and green, soft to moderately firm, in medium to large chips and flakes; chips of limestone and gypsum	30	1,750
Claystone and siltstone, red and green	50	1,800
Siltstone, dark-red, soft, and dark-red and greenish-gray, calcareous, firm; gray limestone; a few gypsum chips; and a trace of anhydrite at 1,820 ft; dark-red siltstone decreased in amount below 1,830 ft	40	1,840
Limestone, gray, dense, in small chips, and small to large chips of dark-red and grayish-green calcareous siltstone; trace of anhydrite	10	1,850
Limestone, gray, in small to medium chips; includes brown and green siltstone and gypsum at 1,880 ft and brown and red siltstone at 1,890 ft	70	1,920

Material	Thickness	Depth
(D-28-7)27cdb-1 - Continued		
Carmel Formation - Continued		
Limestone, gray, dense, in small chips; contains some bluish-gray calcareous siltstone and numerous gypsum chips	10	1,930
Clay, volcanic; siltstone and limestone; clay is light-buff, lean, soft, plastic, cohesive, and contains small green angular chips of devitrified volcanic glass; siltstone is dark bluish-gray, slightly cemented with calcite	20	1,950
Siltstone and limestone with volcanic clay; large chips of bluish-green soft and dark-red firm calcareous siltstone; small chips of gray to buff, dense limestone; gypsum and trace of red jasper	14	1,964
Siltstone, light-green, soft, slightly to non-calcareous; some gypsum; some dark-brown earthy, poorly cemented non-calcareous siltstone, and light-gray, slightly porous limestone at 1,971 ft; brief rough drill action and decrease in penetration rate at 1,975 ft	16	1,980
Limestone, light to dark-gray, dense, in small chips, and reddish-brown weak to firm ferruginous(?) siltstone; the siltstone cuttings color the entire sample dark red	9	1,989
Navajo Sandstone		
Sandstone, silty, very fine to fine-grained, with a red silty matrix; includes cavings of siltstone and limestone[3]	11	2,000
Sandstone, silty, very fine to fine-grained; includes chips of white to brownish-red medium-grained sandstone, gypsum, and cavings	10	2,010
Sandstone, white, slightly calcareous, in well-rounded, frosted grains, and chips of red calcareous sandstone; some chips of dark-gray limestone; sandstone content increases with depth	40	2,050
Sandstone, white, slightly calcareous; some chips of green siltstone; siltstone content increases to about 60 percent at 2,070 ft	30	2,080
Sandstone, silty, dark-red and white, and green siltstone	12	2,092

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-7)27cdb-1 - Continued		
Navajo Sandstone - Continued		
Siltstone and sandstone; sand occurs primarily as individual grains; siltstone may be cavings(?).........	58	2,150
Siltstone, in green and red chips, and white aeolian sandstone with gypsum; Navajo-type material increases slightly at and below 2,170 ft; sand is very fine grained with silt matrix at 2,200 ft; siltstone is green, red, and white at 2,220 ft; traces of gypsum at intervals; some white limestone at 2,310 ft.........	191	2,341
No record..	3	2,344
Cored to 2,353 ft		
Sandstone, pale reddish-brown to buff, very fine to fine-grained, well rounded to subangular, massive, homogeneous, slightly friable; fragments mostly can be powdered by finger pressure; little or no calcite; core fractured along planes that dip 10° to 70°[4].......	9	2,353

[1]Sample log for first 1,600 ft was from well OW-1, which was 107 ft S. 10° W. of well OW-1A, approximately along strike of formation. Well OW-1 was abandoned because of drilling complications. Difference in altitudes of the two holes is 1 ft.

[2]Formation tops were picked using various combinations of lithology, geophysical logging, and correlation with other wells and test holes in the general area.

[3]In the interval 1,990-2,341 ft, the red and green siltstone, silty sandstone, and limestone are probably cavings from higher in the hole.

[4]Summary of core log by L. A. Jackson.

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-7)36bbb-1 - Driller's log by Binning Drilling Co. Alt. 5,100		
Soil	8	8
Tununk Member of the Mancos Shale[1]		
Clay, blue	92	100
Cedar Mountain (?) Formation		
Clay and gravel, black	58	158
Brushy Basin Shale Member of the Morrison Formation		
Hardpan, white	12	170
Clay and gravel, gray	25	195
Clay and gravel, white	13	208
Hardpan	4	212
Clay, gray, and loose gravel	13	225
Clay and gravel, red	15	240
Clay, gray, hard in spots, and boulders	15	255
Clay, red	15	270
Clay, green, and gravel; salt water	10	280
Clay and silt, variegated, and loose gravel	20	300
Clay and silt, red, and gravel	20	320
Hardpan, red	14	334
Bentonite, white	61	395
Hardpan, gray	5	400
Bentonite, green	10	410
Bentonite, red	25	435
Clay, red, white, and green "ribbon" (varved?)	20	455

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-7)36bbb-1 - Continued		
Clay	30	485
Shale, loose, red	5	490
Clay, red; water seep	15	505
Bentonite, white	25	530
Salt Wash Sandstone Member of the Morrison Formation		
Clay and sand, white	40	570
Clay and gravel, red	15	585
Clay, white	5	590
Sandstone, white	15	605
Clay and sand, variegated	23	628
Sandstone	10	638
Clay, red, and sandstone; 30 gal water per hour	12	650
Sandstone, hard, gray, and clay	15	665
Clay, red	5	670
Gypsum	10	680
Conglomerate, very hard	7	687
Gypsum, red	13	700
Conglomerate, red	10	710
Gypsum, white; water at 713 ft[2]	10	720
Conglomerate, hard, and layers of gypsum	80	800

[1]Formation tops picked on basis of driller's descriptions.

[2]Water under flowing artesian conditions after well was cased to 726 ft; first shut-in pressure was 30 ft above land surface.

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-8)29cdc-2. Summary log reported by Stanolind Oil Co. Formation tops picked from electric log. Alt. 4,936.		
Entrada Sandstone: Sandstone and shale, red	306	306
Carmel Formation: Limestone, gray, green dolomite, red shale, and white to red sandstone	392	698
Navajo Sandstone: Sandstone, white and red	970	1,668
Kayenta Formation: Sandstone, red-brown	134	1,802
Wingate Sandstone: Sandstone, orange-red	521	2,323
Chinle Formation: Shale and sand, maroon	422	2,745
Moenkopi Formation:		
Upper Moenkopi: Shale, maroon, silty	608	3,353
Sinbad Limestone Member: Limestone, gray, oolitic	50	3,403
Lower Moenkopi: Shale, red	79	3,482
Kaibab Limestone: Sandstone, gray, and limestone	80	3,562
Coconino Sandstone: Sandstone, white to tan	1,143	4,705
Pennsylvanian rocks, undivided: Dolomite and limestone, gray-buff	1,625	6,330
Molas Formation: Shale, red-green, and gray limestone	220	6,550
Mississippian rocks, undivided: Dolomite, white-tan, and limestone	610	7,160

Material	Thickness	Depth
(D-28-8)29dcb-1. Log summarized from field notes by R. J. Madsen, ICPA. Alt. 4,896.5		
Entrada Sandstone		
Siltstone and sandstone, brown to dark brown	244	244
Carmel Formation		
Shale, hard, gray	17	261
Shale, light-brown	2	263
Shale, gray	4	267
Shale, brown	5	272
Shale, gray	18	290
Shale, brown	7	297
Shale, gray	15	312
Shale, light-brown	7	319
Shale, gray	11	330
Shale, sticky, blue-gray	19	349
Shale, brownish-gray	7	356
Shale, blue-gray	5	361
Shale, gray	11	372
Shale, soft, light-brown	23	395
Shale, soft, light-gray	8	403
Shale, hard, dark-gray	7	410
Shale, soft, brown	7	417
Shale, hard, gray	31	448
Limestone, hard, white	19	467
Shale, hard, gray	16	483
Limestone, hard, white, shaly	13	496
Shale, soft, light-brown	1	497
Shale, red	18	515
Shale and thin layers of red sandstone	7	522
Limestone, tan	3	525
Shale, brown	7	532
Shale, dark-brown	13	545
Limestone and shale, light-brown	5	550
Shale, gray	5	555
Shale, tan	3	558
Shale, gray	5	563
Well began to flow 70 gal/min with sand at 562 ft		
Limestone, hard, gray	12	575
Sand, gray, shaly	1	576
Limestone, hard gray; flow increased to 90 gal/min	12	588
Limestone, gray, shaly	4	592
Limestone, hard gray; flow increased to 670 gal/min at 592 ft	5	597

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-8)29bcd-1 - Continued		
Carmel Formation - Continued		
Limestone, gray; flow increased to 1,350 gal/min at 597 ft	3	600
Limestone and shale, gray	5	605
Limestone, gray	2	607
Shale, brown	4	611
Limestone, gray, shaly; difficult drilling	9	620
Shale, gray, spongy; difficult drilling	8	628
Limestone, gray; flow 1,350 gal/min; logged hole	1	629
Shale, gray	14	643
Shale, sandy, gray	2	645
Shale, blocky, gray; drills into many chips	5	650
Shale, sandy, brown	4	654
Shale, gray	8	662
Shale, sandy, brown	1	663
Shale, sandy, gray; flow increased to 1,570 gal/min	3	666
Shale, loose, brown	2	668
Navajo Sandstone		
Sandstone, brown; flow increased to 2,240 gal/min and then reduced to 1,800 gal/min because (?) of caving	20	688
Well was cased to 679 ft and sealed by pressure grouting from both bottom and top.		
Sandstone, fine, yellow; after drilling out grout, flow resumed at 280 gal/min	7	695
Sandstone, yellow; flow 311 gal/min	47	742
Sandstone, fine, yellow, in alternating hard and soft layers	19	761

Note: Drilling discontinued at 761 ft because loose sand could not be controlled. Depth of hole after test pumping was 727 ft; on September 3, 1975, depth was 722 ft.

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-8)33bbb-1. Summarized from sample log by W. G. Hannah and T. P. Condiff, Los Angeles Department of Water and Power. Alt. 4,883.6. Note: Log based on sampling intervals of 10 ft or less.		
Entrada Formation		
No record	10	10
Sandstone, red, very fine to fine-grained; no chips, mostly quartz grains	10	20
Sandstone, red, very fine to fine-grained	30	50
Sandstone, reddish-brown, very fine to fine-grained; some gray sandstone; gypsum fibers common	10	60
Sandstone, reddish-brown, very fine to fine-grained	10	70
Sandstone, reddish-brown, fine- to medium-grained, with gypsum and jasper	10	80
Sandstone, brown, fine- to medium-grained	10	90
Sandstone, reddish-brown, fine- to medium-grained traces of gypsum and jasper	20	110
Sandstone, reddish-brown, very fine to medium-grained	10	120
Sandstone, reddish-brown, very fine to medium-grained, 90 percent; 10 percent gray, poorly cemented, very fine grained sandstone, with chips of well-cemented (calcite) fine-grained sandstone, and scattered gray, black, and red angular rock fragments	10	130
Sandstone, fine- to coarse-grained, with gray calcareous very fine grained silty sandstone chips	10	140
Sandstone, brown, very fine to fine-grained, with clayey siltstone	10	150
Sandstone, reddish-brown, very fine to fine-grained, commonly cemented with calcite; reddish clayey siltstone increasing	10	160
Sandstone, reddish-brown, very fine to fine-grained, and reddish clayey siltstone with a trace of gypsum	10	170

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(C-28-8)33bbb-1 - Continued		
Entrada Formation - Continued		
Sandstone, reddish-brown, very fine to fine-grained; chips of gray noncalcareous siltstone common...........	5	175
Sandstone, reddish-brown, very fine to fine-grained, Clayey, many chips of sandstone cemented with calcite, and many chips of gray clayey siltstone................	10	185
Sandstone, brown, fine to coarse-grained, with sharp angular chips of gray clayey siltstone.................	5	190
Sandstone, reddish-brown, very fine to fine-grained with chips of gray clayey siltstone....................	10	200
Sandstone, brown, very fine to fine-grained, and chips of gray clayey siltstone..............................	10	210
Sandstone, reddish-brown, very fine to fine-grained to silty and clayey; gray clayey siltstone chips common..	10	220
Sandstone, silty, clayey, with reddish-brown chips, very fine grains and much clay.........................	10	230
Sandstone, reddish-brown to gray, very fine grained to silty and clayey, in chips the size of coarse grains...	10	240
Sandstone, reddish-brown to gray, very fine grained, silty, clayey, soft to hard; chips are sticky when wet; trace of rounded white fragments (gypsum?) in bottom 10 ft...	20	260
Sandstone, very fine grained, silty, clayey, in chips; some gypsum and hard gray sandstone....................	10	270
Sandstone, brown to gray, very fine grained, silty, clayey, in chips; trace of gypsum......................	4	274
Carmel Formation		
Siltstone and claystone, gray calcareous, angular fragments, very fine to medium sand, and trace of red fine-grained silty sandstone and gypsum....................	6	280
Sandstone, gray calcareous, very fine to fine-grained silty, clayey; white gypsum common; trace of red sandstone...	10	290

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-8)33bbb-1 - Continued		
Carmel Formation - Continued		
Sandstone, very fine to medium-grained, siltstone, and hard gray claystone, angular fragments................	10	300
Sandstone, fine to medium-grained, siltstone, and claystone, light-gray to dark-gray; gypsum fragments and red-brown sandstone chips; probably contains cavings from overlying Entrada Formation......................	100	400
Limestone, gypsum, and claystone in very large chips, and fine to medium-grained reddish-brown sandstone.....	30	430
Gypsum and calcareous siltstone and claystone, white to dark-gray; much of claystone is soft................	10	440
Siltstone and claystone, dark-gray, calcareous, hard to soft, and trace of gypsum..........................	10	450
Limestone, siltstone, and fine- to medium-grained sandstone, in large chips, with much clay..............	10	460
Limestone, siltstone, and fine- to medium-grained sandstone, in large chips; much gypsum and some clay.......	55	515
Gypsum with siltstone and claystone, dark-gray to red; some slightly calcareous.............................	25	540
Siltstone and claystone, dark gray to reddish-brown, slightly calcareous; trace of gypsum..................	10	550
Limestone, silty, siltstone, and claystone, dark gray. Some is reddish-brown and calcareous with trace of gypsum. Rough drill action in several thin layers between 600 and 610 ft[1]...............................	110	660
Limestone, argillaceous, limy siltstone, and claystone, mostly dark gray; soft to firm chips up to 1/4 in. across; red-brown very soft mudstone (cavings?); much gypsum in lower 10 ft.....................	20	680
Sandstone, brown-to-tan and gray, fine-grained, calcareous, with red-brown siltstone and gypsum..........	5	685
Sandstone, gray to tan, fine-grained, calcareous; trace of limy siltstone and claystone.................	5	690
Sandstone, gray to tan; few cutting returns.............	10	700

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-8)33bbb-1 - Continued		
Carmel Formation - Continued		
Sandstone, very fine grained, siltstone, and claystone, reddish-brown; 10 percent gray to tan chips of very fine grained calcareous sandstone; chips of white gypsum, gray limy siltstone and claystone common; intermittent rough drill action at 698-702 and 708-709 ft..............................	9	709
Navajo Sandstone		
Clay, soft, light-gray, gypsum, reddish-brown calcareous sandstone, siltstone, and shale; few cutting returns..	11	720
Sandstone, light-gray to tan, very fine to fine-grained, moderately calcareous, 65 percent; 35 percent cavings from above 709 ft. Percentage of cavings diminishes with depth, and sandstone is very fine to medium grained below 760 ft..................................	60	780
Sandstone, white to yellow, 75 percent; 25 percent cavings; rough drill action[1] 785-790 ft and 800-803 ft; cuttings highly calcareous 810-815 ft..................	35	815
Sandstone, white, 75 percent; 25 percent cavings.........	10	825
Sandstone, mostly yellow; chips well cemented with calcite; 25 percent cavings............................	6	831
Cored to 861 ft		

Core 76UT1. Depth interval 834.7-835.2 ft. Sandstone, light-tan with white spots. Bedding plane present; bedding plane 20°. Well cemented with silica. Subarkose, moderately sorted; laminae of very fine to fine sand interlayered with laminae of fine and medium sand. (See fig. 5.) Moderate optical orientation of grains with bedding planes. Rounded quartz grains, 80-95 percent; subrounded to rounded, partly weathered feldspar, 5-15 percent. Rounded chert is about the only rock type and is found mostly in the medium sand. Grains well packed with microstyolitic boundaries between some grains. Very little matrix; that present is silica, generally as fibrous chalcedony and sparse clay particles.[2]

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-8)33bbb-1 - Continued		
Navajo Sandstone - Continued		
Sandstone, white to light-tan; ranges from massive to thinly bedded; cross beds range from 1/16 to 2 in. in thickness, some sections appearing laminated with alternate layers of very fine to fine and medium- to coarse-grained sandstone; dip of crossbedding ranges from 10° to 25°; fracture at 841 ft dips 60° and is healed with gypsum[3]	30	861
Sandstone, yellow-brown, very fine to coarse-grained	19	880
Sandstone, light-gray to yellow, very fine to coarse-grained, firm but friable; rough drill action 912-913 ft; cuttings below 920 ft about half chips and half grains; below 990 ft nearly all cuttings reduced to grains, which are obscured by cavings; cavings appear to make up 40-95 percent of cutting returns	190	1,070
Sandstone, light-gray to yellow, very fine to coarse-grained, mostly in chips; rough drill action[1] 1,072-1,075 ft; white calcite chips 1,080-1,090 ft with traces below	66	1,136
Cored to 1,158 ft		
Core 76UT2. Depth interval 1,139.7-1,140.3 ft. Sandstone, light-tan. No bedding plane visible to the eye. Well cemented with silica. Cherty subarkose, well sorted. Subrounded to rounded quartz, 75-90 percent; subrounded feldspar, 5-15 percent; rounded chert, 5-10 percent; few other rock fragments. Grains well packed with microstyolitic boundaries between some grains. Less matrix than in samples 76UT1 or 76UT3; matrix material mainly fibrous chalcedony, some of which is spherulitic. (See fig. 7.)[2]		
Sandstone, light-grayish-brown, massive, homogeneous, moderately hard; 60 to 75 percent fine grained; calcite rare; fractures generally dip 10°-15° but as much as 45°[4]	14	1,150
Sandstone, light-grayish-brown; less cemented than interval above; alternately massive and crossbedded with some laminations less than 1/16 in. thick; crossbedding dips range from 10° to 70°; fractures dip 10° to 30°; fracture at 1,156 ft filled with calcite[4]	8	1,158

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-8)33bbb-1 - Continued		
Navajo Sandstone - Continued		
No record	2	1,160
Sandstone, light-gray to yellow, very fine to coarse-grained, with trace of calcite; about half in chips; amount of cavings decreasing	110	1,270
Sandstone, tan and brown, fine-grained, limestone, and white calcite; some reddish-brown sandstone below 1,350 ft; few cutting returns 1,390-1,400 ft	130	1,400
Sandstone, reddish-brown to tan, very fine to fine-grained and friable chips; few cuttings below 1,410 ft	40	1,440
Sandstone, brown to tan, very fine grained, limestone, and white calcite chips	25	1,465
Cored to 1,485 ft		
Core 76UT3. Depth interval 1,476.3-1,476.8 ft. Sandstone, light-tan Crossing dips 28°. Better cemented with silica than the two samples above. Well-sorted subarkose. Subangular to subrounded quartz, 80-95 percent; subangular to subrounded feldspar, 5-15 percent; and rounded chert. More opaque minerals, weathering of feldspars, and iron oxide grain coatings than observed in samples above. Packing and grain boundaries as noted above. Matrix similar to that in sample 76UT1; 1 percent or less of coarsely crystalline carbonate cement. (See fig. 8.)[2]		
Sandstone, light-tan, very fine to fine-grained massive, hard but slightly friable; reddish-brown banding 1/8 in. thick at 1,466 and 1,469 ft; dips steeply (one was 50°); many intersecting fractures, either open (?) for partly to completely healed with calcite, have dips of 50° to 70°; fractures probably cause of rough drill action at about 1,471 ft[5]	10	1,475
Sandstone, light-tan, very fine to fine-grained, hard but slightly friable; little calcite cement; parts contain hairline to 1/16 in. laminations that dip 10°-25°; fractures dip 25°-35° and 50°-80° and some are partly filled with calcite[4]	10	1,485
No record	5	1,490

Table 9.--Selected logs of wells--Continued

Material	Thickness	Depth
(D-28-8)33bbb-1 - Continued		
Navajo Sandstone - Continued		
Sandstone, brown to tan, very fine grained, limestone and white calcite chips	30	1,520
Sandstone, light brown to tan, very fine grained, limestone and white calcite chips	100	1,620
Kayenta Formation		
Sandstone, reddish-brown, very fine grained, calcareous chips with chips from previous interval; chips at 1,640 ft are angular and calcareous	30	1,650
Sandstone, reddish-brown, very fine to fine-grained, calcareous; chips are flat and angular and are smaller than chips from Navajo; intermittent rough drill action 1,679-1,680 ft	30	1,680
Sandstone, silty, and sandstone; reddish-brown to flesh-colored, very fine grained, angular chips; some soft greenish-gray siltstone and claystone and tan sandstone	5	1,685

[1]Such "rough drilling" commonly is caused by thin hard layers, and this may be the case in the Carmel Formation. But such action also could be due to the drill binding in fractured zones, which is the probable case in the Navajo Sandstone.

[2]Sample description by U.S. Geological Survey.

[3]Summary of core log by J. T. Dunlap, Los Angeles Department of Water and Power.

[4]Summary of core log by L. A. Jackson, Los Angeles, Department of Water and Power.

[5]Summary of core log by W. G. Hannah.

Table 10.--Selected chemical analyses of water samples

Location: See text for description of well- and spring-numbering system.
Geologic unit: 200MSZC, rocks of Mesozoic age, undivided; 220NVJO, Navajo Sandstone; 221CRML, Carmel Formation; 221SLWS, Salt Wash Sandstone Member of Morrison Formation.
Discharge: E, estimated.
Agency making analysis: GS, U.S. Geological Survey; LA, Los Angeles Department of Water and Power; UH, Utah Department of Health.

Location	Date of sample	Geologic unit	Depth to top of sample interval (ft)	Depth to bottom of sample interval (ft)	Discharge (gal/min)	Temperature (°C)	Dissolved iron (Fe) (µg/L)	Dissolved calcium (Ca) (mg/L)	Dissolved magnesium (Mg) (mg/L)	Dissolved sodium (Na) (mg/L)	Dissolved potassium (K) (mg/L)	Bicarbonate (HCO_3) (mg/L)	Carbonate (CO_3) (mg/L)	Dissolved sulfate (SO_4) (mg/L)	Dissolved chloride (Cl) (mg/L)	Dissolved fluoride (F) (mg/L)	Dissolved nitrite plus nitrate (N) (mg/L)	Dissolved orthophosphate (PO) (mg/L)	Dissolved boron (B) (µg/L)	Dissolved solids (sum of determined constituents) (mg/L)	Hardness (Ca,Mg) (mg/L)	Noncarbonate hardness (mg/L)	Specific conductance (µmho/cm at 25°C)	pH	Agency making analysis
(D-28-7) 11cdb-S1	7-17-75	221SLWS	-	-	-	-	-	230	51	430	7.3	278	-	1,300	71	1.6	-	0.03	530	2,250	780	560	2,960	-	GS
27cdb-1	11-20-75	220NVJO	1,990	2,353	300E	16.0	20	130	48	21	4.2	279	0	320	9.7	.2	0.00	.00	-	683	520	290	973	7.4	GS
36bbb-1	7-17-75	221SLWS	726	800	1.8	14.5	40	11	4.1	450	1.7	174	0	770	54	1.1	.01	.00	250	1,390	44	0	2,050	8.0	GS
(D-28-8) 29cdc-1	6-16-71	220NVJO	720	764	10	-	0	126	50	520	5.1	291	2	618	463	.4	-	-	340	1,940	520	280	3,000	8.2	UH
	8-28-75				55	17.0	1,800	140	37	460	4.2	300	0	640	460	.4	.01	.03	250	1,900	500	260	2,700	7.1	GS
29dcb-1	11-26-73	221CRML	560	597	1,350	-	-	700	240	460	6.3	121	0	2,000	1,100	.8	.04	.18	470	4,580	2,700	2,600	5,460	7.3	GS
	1-22-74	220NVJO	679	695	280	-	-	420	120	530	6.3	191	0	1,300	860	.6	.12	.03	480	3,350	1,500	1,400	4,440	7.5	GS
	2- 9-74		679	761	3,110	-	-	300	96	480	6.2	231	0	1,000	680	.7	.03	.09	350	2,690	1,100	960	3,920	7.4	GS
33bbb-1	8-21-75	220NVJO	704	1,250	500E	17.5	630	94	71	780	3.9	286	0	690	850	.8	.02	.00	520	2,640	530	290	4,000	7.3	GS
	11-24-75				2,800	17.5	-	95	28	760	3.7	289	0	660	800	.7	.01	.00	530	2,500	350	120	4,050	7.0	GS
	12-29-75				2,800	17.5	650	78	26	840	3.9	187	0	620	890	.8	.00	.03	550	2,560	300	150	4,380	7.1	GS
33cdd-1W	7-14-75	200MSZC[1]	?	2,425	-	-	-	72	27	2,100	5.0	-	-	362	3,060	.3	-	-	130	7,210	290	-	9,800	8.0	LA
33cdd-1S[2]	8- 6-75	200MSZC[3]	611	1,296	180	18.0	1,500	140	63	140	7.0	229	0	470	190	.2	.02	.00	70	1,140	610	420	1,750	7.4	GS
	8- 8-75	221CRML	611	621	<1	18.0	140	480	130	360	12	57	0	1,100	890	.3	.08	.00	260	3,010	1,700	1,700	4,200	8.1	GS
	8-11-75	221CRML	663	673	-	-	-	136	62	136	5.0	-	-	456	166	.2	-	-	50	1,260	595	-	1,650	7.3	LA
	8- 8-75	220NVJO	756	766	35	17.5	1,800	140	63	91	5.1	226	0	430	110	.2	.02	.00	80	964	610	420	1,490	7.1	GS
	8- 7-75	220NVJO	901	911	26	17.0	1,400	98	53	78	5.4	232	0	310	68	.2	.00	.00	30	740	460	270	1,160	7.1	GS
	8- 7-75	220NVJO	1,051	1,061	22	17.5	1,200	98	51	110	6.3	226	0	350	88	.2	.10	.00	30	827	450	270	1,300	7.3	GS
	8- 7-75	220NVJO	1,286	1,296	21	17.5	1,300	80	39	300	6.7	279	-	180	410	.3	.01	.00	60	1,170	360	130	2,100	-	GS
	8-21-75	220NVJO	756[4]	1,296	200E	17.5	2,700	110	52	130	5.6	225	0	380	130	.2	.01	.00	60	933	490	310	1,400	7.0	GS

[1] Sample probably included water from Carmel(?) to Chinle Formations.
[2] Samples from this well include drill-stem tests of 10-foot zones between a straddle packer.
[3] Sampled while perforations in Carmel and Navajo Formations were open to hole.
[4] Sampled from flow after zones above 756 feet were squeeze-cemented and additional perforations made between the original four 10-foot zones.

Table 11.--Measurements of discharge, temperature, and specific conductance of water from wells

Location: See text for description of well- and spring-numbering system.
Geologic unit: 200MSZC, rocks of Mesozoic age, undivided; 220NVJO, Navajo Sandstone; 221CRML, Carmel Formation; 221SLWS, Salt Wash Sandstone Member of the Morrison Formation; 310KIBB, Kaibab Limestone.
Discharge: E, estimated.
Agency making analysis: GS, U.S. Geological Survey; LA, Los Angeles Department of Water and Power; UH, Utah Department of Health.

Location	Date of sample	Time	Depth to top of sample interval (ft)	Depth to bottom of sample interval (ft)	Geologic unit	Discharge (gal/min)	Temperature (°C)	Specific conductance (µmho/cm at 25°C)	Agency making analysis
(D-28-7)27cdb-1	11-20-75	0020	1,990	2,353	220NVJO	300E	16.0	973	GS
	11-20-75	0110				300E	-	988	LA
	10- 6-76	1600				10	15.6	2,500	GS
36bbb-1	7-17-75	1015	726	800	221SLWS	1.8	14.5	2,050	GS
	8-21-75	1525				1.9	15.5	2,080	GS
	11-15-75	1530				2.0	14.0	2,100	GS
	3-16-76	1812				2.0	13.5	2,180	GS
	4-14-77	1302				2.0	14.0	2,050	GS
(D-28-8)29cdc-1	6-16-71	-	720	764	220NVJO	10	-	3,000	UH
	8-15-74	-				-	21.0	2,990	LA
	7-17-75	-				48	17.0	-	GS
	8- 7-75	1533				60	17.0	3,000	GS
	8-21-75	1105				60	17.0	3,000	GS
	8-28-75	1320				55	17.0	2,700	GS
	9- 4-75	1610				-	17.0	2,900	GS
	11-15-75	1137				1.5	16.5	2,900	GS
	7-22-76	0950				5.0	17.0	2,650	GS
	3-31-77	1720				47	17.0	2,450	GS
	6-15-77	0940				80	17.0	2,550	GS
29dcb-1	11-19-73	-	560	564	221CRML	30E	-	7,000	GS
	11-22-73	-	560	580		90	-	5,000	GS
	11-24-73	-	560	592		670	-	4,000	GS
	11-26-73	-	560	597		1,350E	-	5,460	GS
	12- 1-73	-	560	610		1,350	-	5,000	GS
	12- 6-73	-	560	628		1,350	-	5,100	GS
	1- 5-74	-	560	662		1,520	-	-	GS
	1- 6-74	-	560	668	200MSZC[1]	1,570	-	4,900	GS
	1- 7-74	-	560	675	200MSZC[1]	2,240	-	-	GS
	1-22-74	-	679	695	220NVJO	280	-	4,440	GS
	1-23-74	-	679	742		311	-	-	GS
	2- 8-74	0840	679	761		1,470	-	3,750	GS
	2- 9-74	1130				3,110	-	3,920	GS
	4-13-74	-				-	-	3,910	LA
	10- 4-74	-				-	24.0	4,200	LA
	10-30-74	-				-	23.0	3,880	LA
	7-17-75	-				400E	16.5	4,000	GS
	11-15-75	1150				1.0E	15.0	5,600	GS
33bbb-1	8-19-75	1400	700	1,250	220NVJO	-	-	4,000	LA
	8-19-75	1401				-	-	4,000	GS
	8-20-75	-				-	-	4,250	LA
	8-21-75	1015				500E	17.5	4,000	GS
	8-22-75	-				500E	-	4,950	LA
	8-30-75	-				500E	-	4,400	LA
	9- 1-75	-				500E	-	4,400	LA
	9- 4-75	-				500E	-	4,200	LA
	9-22-75	-				770	-	4,060	LA
	9-26-75	1800				1,600	-	4,100	LA
	9-29-75	1815				2,150	-	4,170	LA
	11-17-75	1100				1.0E	-	3,450	GS
	11-24-75	1025				2,800	17.5	4,050	GS
	11-24-75	1026					17.5	4,370	LA
	11-26-75	2045					17.0	4,000	GS
	11-27-75	0255					17.5	4,450	GS
	11-27-75	0700					17.0	4,410	LA
	11-27-75	1100					17.5	4,420	LA
	11-27-75	1730					17.5	4,400	LA

Table 11.--Measurements of discharge, temperature, and specific conductance of water from wells--Continued

Location	Date of sample	Time	Depth to top of sample interval (ft)	Depth to bottom of sample interval (ft)	Geologic unit	Discharge (gal/min)	Temperature (°C)	Specific conductance (μmho/cm at 25°C)	Agency making analysis
(D-28-8)33bbb-1 Continued	11-27-75	2005	700	1,250	220NVJO	2,800	17.5	4,450	GS
	11-28-75	1500					17.5	4,350	LA
	11-30-75	1555					17.5	4,420	GS
	12- 1-75	1500					17.5	4,360	LA
	12- 3-75	2100					17.5	4,340	LA
	12- 5-75	1010					17.5	4,400	GS
	12- 6-75	2100					17.5	4,100	LA
	12- 9-75	1240					17.0	4,300	LA
	12-12-75	0300					17.5	4,320	LA
	12-15-75	0945					-	4,330	LA
	12-20-75	2300					-	4,320	LA
	12-23-75	2100					-	4,320	LA
	12-29-75	0910					17.5	4,380	GS
	12-29-75	0915					17.5	4,380	LA
	6-15-77	1015				50E	18.0	3,600	GS
33cdd-1W	5-24-75	-	3,493	3,530	310KIBB	-	-	5,000	(2)
	5-24-75	1201	3,595	3,700	(3)	-	-	2,700	LA
	7-14-75	1730	1,350	2,425	200MSZC[4]	-	-	9,800	LA
	7-14-75	1750	1,350	2,425		-	-	9,800	LA
33cdd-1S[5]	7-21-75	1030	794	795	220NVJO	34	17.5	-	GS
	8- 5-75	1915	611	1,296	200MSZC[1]	180	18.0	1,750	GS
	8- 6-75	2355	611	1,061		171	17.5	1,550	LA
	8- 7-75	0050	1,286	1,296	220NVJO	21	17.5	2,100	GS
	8- 7-75	0051	1,286	1,296		-	-	2,000	LA
	8- 7-75	0052	1,286	1,296		-	-	2,100	LA
	8- 7-75	1418	611	911	200MSZC[1]	120	17.5	1,450	LA
	8- 7-75	1422	1,051	1,061	220NVJO	22	17.5	1,300	GS
	8- 7-75	1423	1,051	1,061		-	-	1,000	LA
	8- 7-75	1424	1,051	1,061		-	-	1,250	LA
	8- 7-75	2311	901	911		26	17.0	1,160	GS
	8- 7-75	2312	901	911		-	-	1,150	LA
	8- 7-75	2313	611	766	200MSZC[1]	100	17.0	1,490	GS
	8- 8-75	0140	756	766	220NVJO	35	17.5	1,490	GS
	8- 8-75	0141	756	766		-	-	1,500	LA
	8- 8-75	1724	611	621	221CRML	-	-	4,250	LA
	8- 8-75	1725	611	621		<1.0	18.0	4,200	GS
	8- 8-75	1726	611	621		-	-	5,720	LA
	8-11-75	-	-	-	220NVJO	-	-	1,700	LA
	8-11-75	1159	663	673	221CRML	-	-	1,550	LA
	8-11-75	1201	663	673		-	-	1,650	LA
	8-13-75	1400	756	1,296[6]	220NVJO	-	-	1,450	LA
	8-13-75	1401				-	-	1,490	GS
	8-21-75	0937				200E	17.5	1,400	GS
	11-15-75	1040				1.5	15.5	1,370	GS

1 Included water from Carmel Formation and Navajo Sandstone.
2 Field measurement reported by Colt Oil Co.
3 Sample probably included water from Carmel(?) Formation to White Rim Sandstone Member of Cutler Formation.
4 Included water from Carmel(?) to Chinle Formations.
5 Samples from this well include drill-stem tests of 10-foot zones between a straddle packer and composite flow from perforations above the packer.
6 Sampled from flow after zones above 756 feet were squeeze-cemented and additional perforations made between the original four 10-foot zones.

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