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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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GEOHYDROLOGY OF HOLE UE-17a, SYNCLINE RIDGE AREA, NEVADA TEST SITE

USGS-1543-4
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By

J. E. Weir, Jr.[1], and J. N. Hodson[2]

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Metric unit to convert	Multiply by	English unit to obtain
Millimeters (mm)	0.03937	Inches (in)
Meters (m)	3.2808	Feet (ft)
Kilometers (km)	0.6214	Miles (mi)
Liters per second (L/s)	15.86	Gallons per minute (gal/min)
Meters squared per day (m^2/d)	10.76	Feet squared per day (ft^2/d)
Degrees Celsius (^oC)	$1.8(^oC)+32$	Degrees Fahrenheit (^oF)

When numbers are reported in both metric and English units, the first number given is the measured value.

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ABSTRACT

Hole UE-17a was drilled as part of a study to evaluate the suitability of Unit J of the Eleana Formation of Mississippian age as a medium for storage of nuclear wastes. The 1,214-foot (370-meter) hole penetrated alluvium of Quaternary age, a thrust plate of the Tippipah Limestone of Pennsylvanian and Permian age, and 668 feet (204 meters) of the Eleana Formation.

A small amount of ground water occurs in fractured quartzites and limestones of the Eleana Formation; jetting produced only 20 gallons per minute (1.3 liters per second) from the completed hole. Approximate transmissivity, calculated from jetting test results, is 1.2 feet squared per day (0.11 meters squared per day). The hydraulic head has almost steadily declined in the hole since September 29, 1976, a few days after the hole was completed. Water from the Eleana Formation is a sodium bicarbonate and sodium sulfate type.

INTRODUCTION

The geohydrology of hole UE-17a is important to the preliminary investigation of the Eleana Formation as a possible repository for nuclear wastes. This exploratory hole was one of a series of seven shallow test holes drilled June-August 1976 to determine the thickness of alluvium, and the lithologic and stratigraphic character of the underlying Paleozoic bedrock. In August 1976, the decision was made to deepen hole UE-17a into the zone of saturation to confirm the stratigraphy, determine the occurrence of ground water, and define the static water level at that location. Brief jetting tests also were provided to assess water production, and to obtain an approximate value for transmissivity of the composite water-bearing intervals of the rock penetrated. This report documents the geohydrologic data obtained from the deepened hole.

Hole UE-17a is located west of the gap in Syncline Ridge (fig. 1). The surveyed coordinates of the location are N.846,138; E.645,991 (Nevada Central-Zone Coordinate System, in feet), and ground-level altitude is 4,696.48 ft (1,431.50 m); depths in this report refer to ground level. The site is in the west-central part of Yucca Flat, about 30 mi (48 km) north of Mercury, Nev.

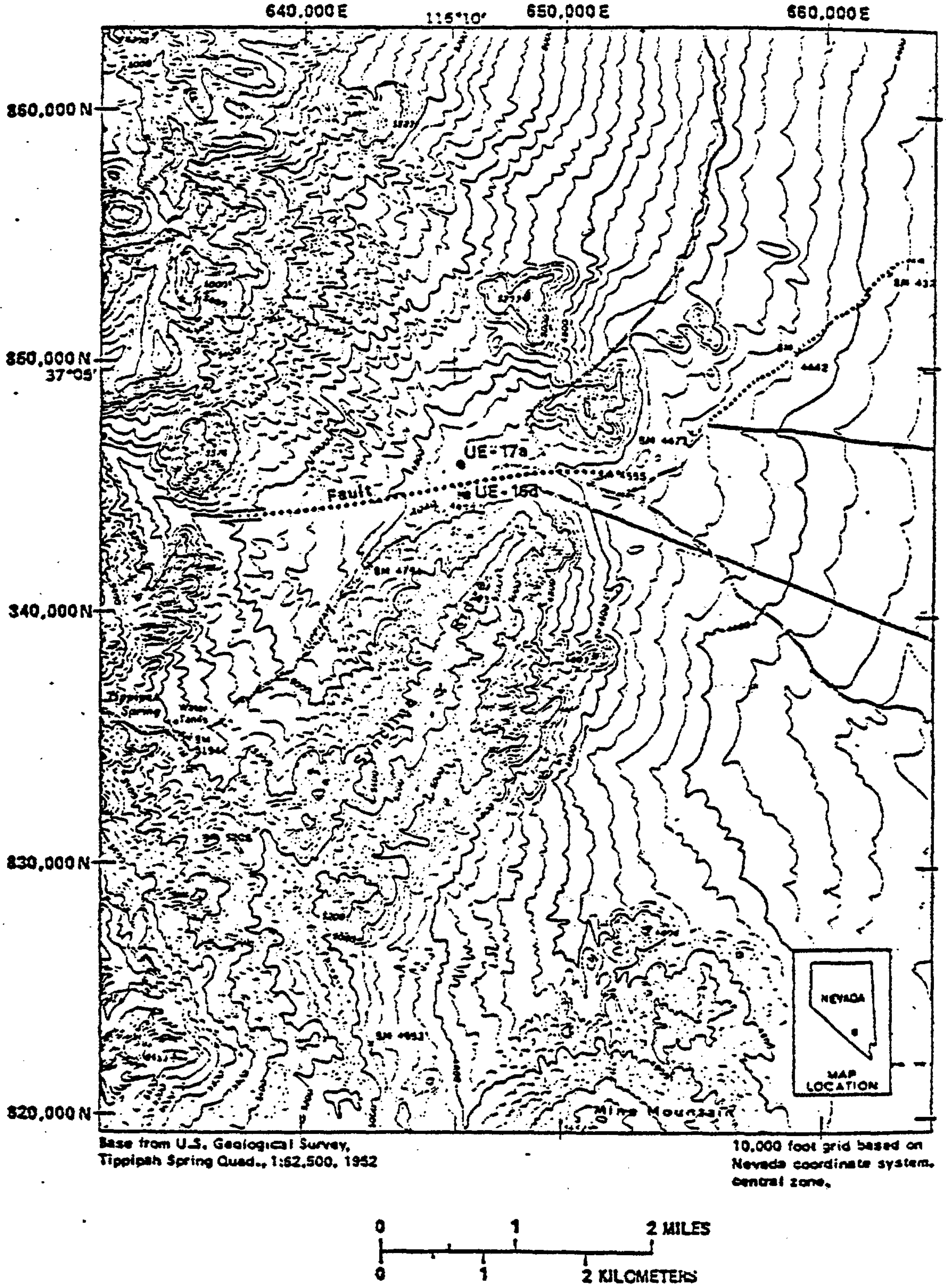

Figure 1.--Map of Eleana Project area showing the location of holes UE-17a and UE-16d.

General Operations

The upper 392 ft (119 m) of hole UE-17a was drilled July 2-16, 1976. Two cores were taken July 15 in the interval 375 to 392 ft (114 to 119 m). Deepening of the hole to penetrate the saturated zone was begun August 30, 1976, and drilling operations continued until September 15, when the total depth of 1,214 ft (370 m) was reached. One 6-ft (1.8-m) core was taken in the interval 581 to 593 ft (177 to 181 m); attempts to cut a bottom-hole core failed because of caving and hole-fill problems. Caving from the interval 825 to about 950 ft (251 to 290 m) caused most of the problems.

Air-foam mist was the circulation medium during drilling. After total depth was reached, mud was added to the hole to stop caving and to aid in placing geophysical logging tools at the bottom.

Casing was run to 1,206 ft (368 m), then was washed down to 1,210 ft (369 m) (fig. 2), while circulating mud out of the hole with water. The hole was cased with 4½-in (114-mm) steel pipe, 3.96-in (100-mm) inside diameter, September 21, 1976, and the casing was gun-perforated in selected intervals (fig. 2).

Foam in the circulation returns made measurement of jetted discharge during drilling impossible. The Parshall flume installed between the small blooie pit and the reserve pit was continually swamped with billowing foam. The flume was reinstalled in a notch cut in the lower end of the reserve pit, for measuring discharge during jetting tests.

Jetting tests were run on September 15, before putting mud in the hole, and on September 23, after gun-perforating the casing. Debris from the perforating operation was pushed down the hole with drilling tools from 1,070 to 1,207 ft (326 to 368 m), and the casing head was equipped with a locking cap.

GEOLOGIC SUMMARY

Hole UE-17a is located within the Syncline Ridge-Southern Eleana Range structural block at a place where the Tippipah Limestone (Pennsylvanian and Permian age) is thrust-faulted over Unit J of the Eleana Formation (Mississippian age). The thrust fault is local; farther north, the contact is not faulted. A core of strongly sheared and brecciated quartzite taken from UE-17a at 581 ft (177 m) substantiates the presence of this thrust plate. A pre-Tertiary east-trending strike-slip fault is within 0.4 mi (0.6 km) south of UE-17a (Hodson and Hoover, 1978).

Hole UE-17a was drilled to a total depth of 1,214 ft (370 m), of which 73 ft (22.3 m) is alluvium, 473 ft (144.1 m) is Tippipah Limestone, and 668 ft (204 m) is Eleana Formation, Unit J (table 1). The alluvium, of Quaternary age, contains sand- to gravel-sized clasts of quartzite, and sandstone, siltstone, and tuff. The gravel is dominant down to 50 ft (15.2 m), at which point sand becomes dominant. The alluvial material is weathered; it contains very little caliche, but there is a small amount of calcareous coating on individual particles (Hodson and Hoover, 1978).

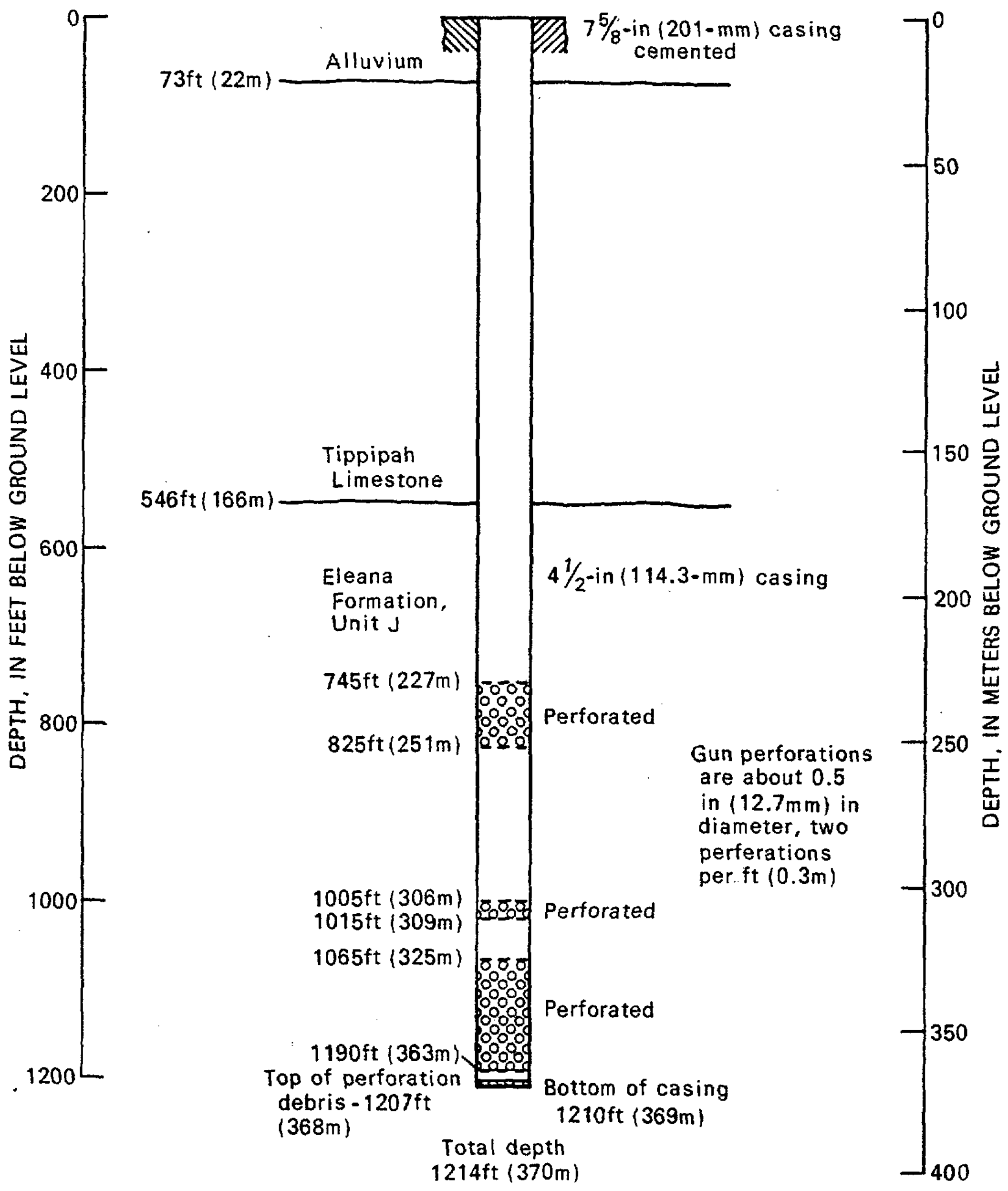

Figure 2.--Construction diagram for hole UE-17a, Nevada Test Site.

Table 1.--*Lithology and stratigraphy of hole UE-17a*

[Color code numbers were taken from *Rock Color Chart*, 1963, distributed by the Geological Society of America, Boulder, Colorado]

Stratigraphic unit and lithologic description	Thickness		Depth to bottom	
	(ft)	(m)	(ft)	(m)
Alluvium				
Gravel and sand, composed of quartzite, sandstone, siltstone, and tuff; weathered; no caliche; gravel-dominant to 50 ft (15.2 m) in depth; sand is dominant from 50 ft (15.2 m) to 73 ft (22.3 m)--	73	22.3	73	22.3
Tippipah Limestone				
Limestone, fine- to coarse-grained; weathered; calcite; abundant caliche coating-----------------	23	7.0	96	29.3
Limestone, dark-gray (N3); fine-tc coarse-grained, massive; abundant calcite and calcite crystals; iron-staining; small amount of caliche--	146	44.5	242	73.8
Limestone, medium-to-dark gray; fine-grained; massive; interbeds of silty limestone, light-brown to light-grayish-purple, laminated to thin-bedded; platy fragments; crystalline calcite; iron-------------------------------------	254	77.4	496	151.2
Cores 1 and 2 (100 percent recovered)				
Limestone, medium-dark gray; fine- to coarse-grained; massive; interbeds of silty limestone, light-brown to light-grayish-purple; thinly-laminated; fractured; calcite-filled fractures and vugs; iron-coated fractures-------------------	16.8	5.1	391.8	119.4
Limestone, grayish-black (N2); fine-grained; massive; platy fragments; calcite stringers; small amount of clay in unwashed samples; no weathering, (fault contact)---------------------	50	15.2	546	166.4
Eleana Formation, Unit J				
Quartzite, medium-gray (N5) to moderate-yellowish-brown (10YR5/4); coarse-grained; interbeds of sandstone and limestone; silica cement; minor amount of calcareous cement; crystalline calcite---	96	29.3	642	195.7

Table 1.--*Lithology and stratigraphy of hole UE-17a*--Continued

Stratigraphic unit and lithologic description	Thickness		Depth to bottom	
	(ft)	(m)	(ft)	(m)
Eleana Formation, Unit J--Continued				
Core 3 (50 percent recovered)				
Quartzite, medium dark-gray (N2) to light olive-gray (5Y5/2); coarse-grained; strongly brecciated; fractures coated with iron and calcite; shear zone, 25° shear planes, some shear surfaces are polished-----------------------	12	3.7	593	180.8
Quartzite, brownish-gray (5YR4/1) and moderate-brown (tYR4/4); coarse-grained; small angular fragments; calcereous cement; iron-stained--------	183	55.8	825	251.5
Argillite, dark-gray (N3) to black (N1); fine-grained; massive; interbeds of limestone, argillaceous argillite (not present below 880 ft or 268.2 m); sandstone; calcareous; fossiliferous (brachiopods and horn corals), pyrite cubes; polished shear planes; foliated structure; sandstone, light-tan to grayish-purple; well-rounded fragments up to 1 in (25.4 mm) diameter; believed to be debris from up the hole----------------------------------	389	118.6	1,214 T.D.	370.0 T.D.

The Tippipah Limestone consists of thin-bedded to massive limestone and silty limestone, ranging in color from medium-to-dark gray and light-brown to light, grayish-purple. The limestone is finely to coarsely crystalline, and breaks into sharp, platy fragments. The upper 23 ft (7 m) is highly weathered, as evidenced by thick coatings of caliche on cuttings.

Unit J of the Eleana Formation, which is Mississippian in age, consists of quartzite from 546 to 825 ft (166.4 to 251.5 m) and argillite from 825 to 1,214 ft (251.5 to 370.0 m). Both intervals have thin interlayers of limestone (table 1), and the entire Eleana shows strong shearing, probably related to the thrust faulting at the upper contact. The quartzite is coarse-grained and ranges in color from medium, dark-gray to light olive-gray. Calcite and iron stains are present in fractures. Cuttings and cores include highly polished shear planes that dip approximately 25°. The core is brecciated, and fractures are cemented with calcite.

The argillite sequence consists of fine-grained siliceous argillite, and argillaceous argillite, with intermittent thin limestone beds. Cuttings include well-rounded fragments of sandstone believed to have come from other intervals penetrated higher in the hole. At 880 ft (268 m), the argillite is calcareous and fossiliferous and contains pyrite; cuttings also show polished shear planes and foliated structure.

Minute fractures in a few of the beds of quartzite, limestone, and calcareous argillite that were penetrated between about 800 and 1,180 ft (244 and 360 m) yield small amounts of water to the hole. Fractures in most of these hard, brittle beds have been closed by secondary mineral deposition.

OCCURRENCE OF GROUND WATER

The only definite indication of a significant yield of water from the penetrated formations occurred when the bit reached 1,065 ft (325 m). This was manifested by observable water in the air-foam returns, which persisted without noticeable change through the completion of air drilling, at about 1,207 ft (368 m). Geophysical logs indicated that this conspicuous production came primarily from 1,045 to 1,050 ft (319 to 320 m) and 1,060 to 1,065 ft (323 to 325 m); a small amount of water production was perhaps derived from 1,005 to 1,015 ft (306 to 309 m). Although no detectable change in water quantity in air-foam returns was observed below 1,065 ft (325 m), two thin zones in the lower part of the hole might be capable of yielding a small amount of water: 1,075 to 1,080 ft (325-329 m) and 1,175 to 1,180 ft (358-360 m) (based primarily on geophysical logs).

During drilling, measurements of fluid level or depth to the top of caved material, after overnights or weekends of inactivity (table 2), helped determine which zones yielded water to the hole. Thus it appears possible that the zones 800 to 830 ft (244 to 253 m) and 880 to about 900 ft (268 to about 274 m) might yield small quantities of water. This interpretation is based partly on geophysical logs, but is largely based on an overnight accumulation of 183 ft (56 m) of water in the hole (table 2) after it had been drilled from 707 ft (216 m) to a depth of 887 ft (270 m), September 7, 1976. Hole caving and other drilling problems complicated interpretation of these data.

Table 2.--*Fluid-level and dry-hole measurements made after overnight and weekend shutdowns during drilling of UE-17a*

[Measurements referred to land surface]

Date of measurement	Depth to fluid or top of fill (ft)	Depth to fluid or top of fill (m)	Depth of hole (ft)	Remarks
8-31-76	449.57	137.03	500	Drilling fluid accumulated in the hole.
9- 1-76	545(est)	166(est)	565	Do.
9- 2-76	250.13	76.24	593	Drilling fluid left in hole after coring.
9- 3-76	608.79	185.56	614	Probably drilling fluid.
9- 6-76	630.0	192.0	630	Dry after weekend shutdown.
9- 7-76	623.5	190.1	707	Dry at 623.5 ft; top of caved material.
9- 8-76	704.0	214.6	887	Probably the shallowest occurrence of formation fluid; very small yield, probably from a thin zone between about 800 and 885 ft (244 and 270 m).
9- 9-76	748.5	228.2	1,137	Top of caved material at 880 ft (268 m).
9-10-76	767.0	233.8	1,207	Dry at 767 ft (234 m); top of fill.
9-13-76	557.5	169.9	1,207	Top of caved material at 823 ft (251 m).
9-15-76	543.93	165.79	1,214	Top of caved material at 1,180 ft (360 m). Water level rising after jetting test.
9-23-76	534.46	162.91	1,214	Cased to 1,210 ft (369 m); perforated[1/]. Water level rising after jetting test.

[1/]See figure 2 for designation of intervals perforated.

HYDRAULIC HEADS

Fluid level was measured (table 2) after overnight and weekend periods of drilling inactivity, to detect any significant variation of hydraulic head with increased depth. Hole instability and other drilling problems, in addition to insufficient time for full water-level recovery, decreased the usefulness of these data in definitely establishing head differences with depth. However, the level measured (table 2) September 8, 1976, when the hole was at 887 ft (270 m) in depth, was about 340 ft (104 m) lower than the level measured September 29, 1976 (fig. 3) when the hole had been completed. Recognizing that neither of these water levels represent true static heads for the water-bearing zones open to the hole at the times they were measured, it seems likely that hydraulic heads in upper saturated zones are lower than heads for zones penetrated deeper in the hole. This conclusion is strengthened by the discovery that heads in hole UE-16d, about 367 m (1,200 ft) south of UE-17a, were similarly lower in shallower-saturated zones than in deeper zones (Dinwiddie and Weir, 1979), although hydraulic connection between the units encountered in the two holes is not inferred.

The composite water level in hole UE-17a (fig. 3) bears elucidation. The water level rose in the hole for several days following its completion on September 23, 1976; on September 29th, the depth to water was 111.05 m (364.3 ft) below ground level. Since September 29, 1976, the water level has declined almost continually at a somewhat decreasing average rate. This has been brought about by leakage of water into unsaturated beds and into the shallowest saturated beds with lower hydraulic heads.

The water-level hydrograph (fig. 3) indicates that the composite water level in the hole is approaching equilibrium conditions; that is, a steady-state condition where yield equals uptake. Thus the water level will stabilize at some level intermediate between the high hydraulic potentials of the deeper beds and the relatively lower potentials of shallower beds. The best estimate of possible stable composite level is about 565 ft (172 m). In the future, if the unsaturated beds become fully saturated, the composite water level will be shallower, perhaps at approximately 400 ft (122 m).

HYDRAULIC TESTS

Two brief jetting tests were run in hole UE-17a to determine approximate transmissivity of water-bearing zones penetrated by the hole. Test 1 was run in the open hole immediately after drilling was completed. Water-level recovery measurements were erratic for test 1; the results of the test are not considered reliable and are not included in this report.

Test 2 was run after the hole was cleaned and the casing was perforated. The hole was jetted 2 hours at a rate of 20 gallons per minute (gal/min) (1.3 liters per second (L/s)) measured through a Parshall flume with a 3-in (76-mm) throat. Water-level recovery (fig. 4) was measured for 2 hours after jetting was stopped. Approximate transmissivity calculated from the test results is 1.2 ft^2/d (0.11 m^2/d) (fig. 4).

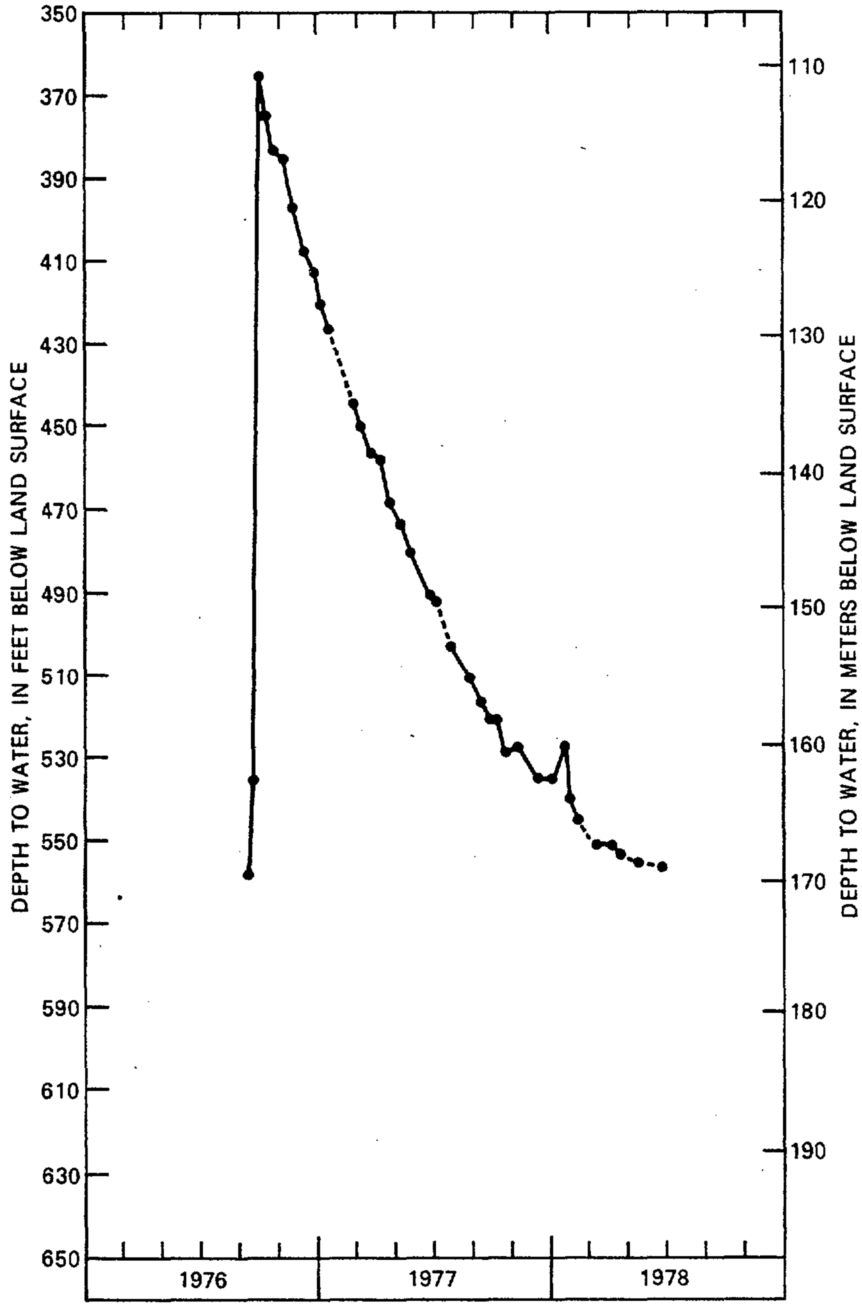

Figure 3.--Hydrograph of water levels in hole UE-17a.

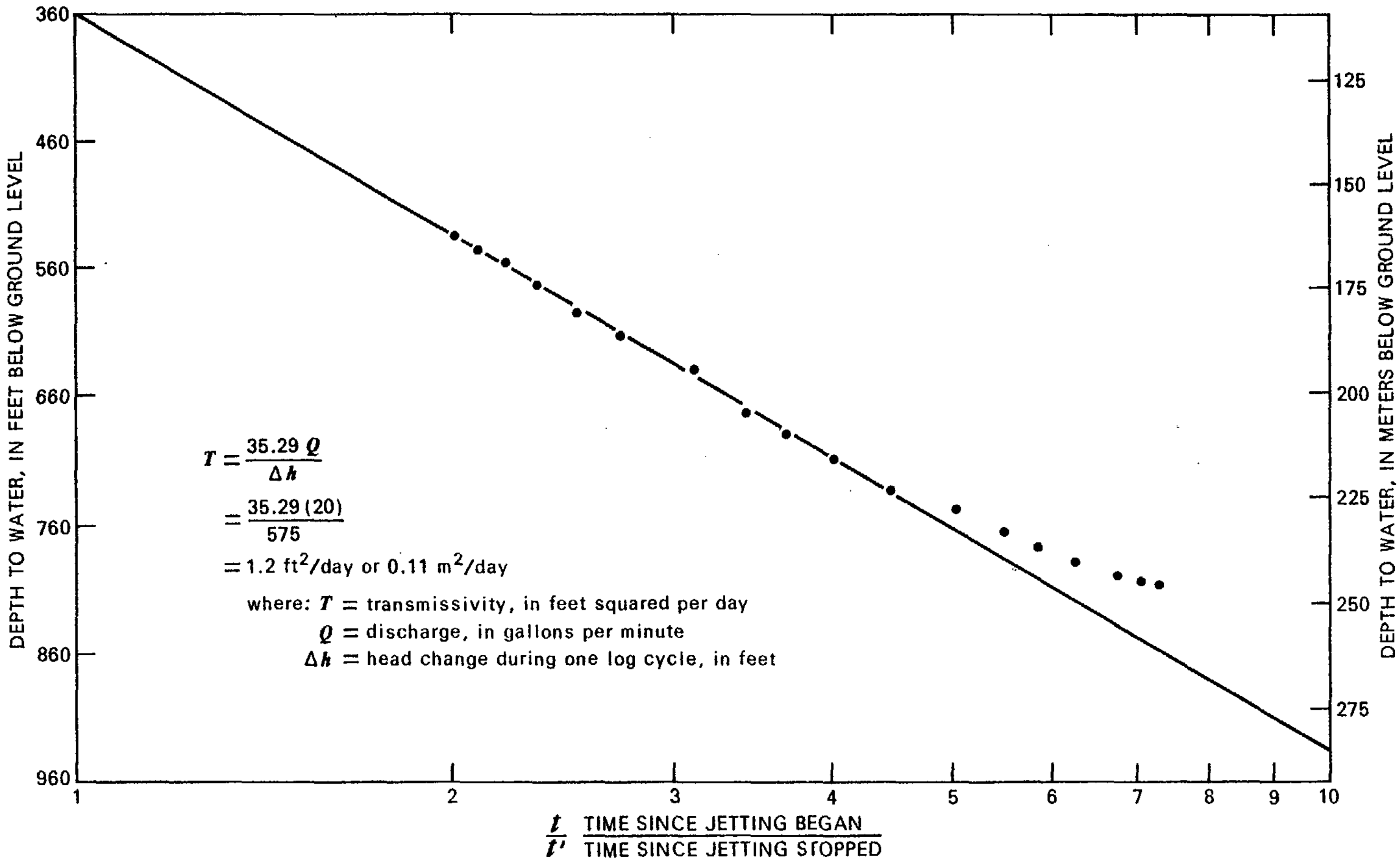

Figure 4.--Semilogarithmic graph of water-level recovery following jetting test 2 of hole UE-17a, September 23, 1976.

WATER QUALITY

A water sample collected at the end of the discharge period of jetting test 2 was analyzed by the U.S. Geological Survey for several chemical ions. The sample is considered representative of water yielded from Unit J of the Eleana Formation penetrated in hole UE-17a. The results of the partial analysis are as follows:

Date collected:	September 23, 1976
Jetting-discharge period:	0120 to 0320 hours
Discharge rate:	20 gpm (1.3 L/s)
Temperature of water:	17.5°C (63.5°F)
Specific conductance-field:	965 μmho/cm at 25°C
Specific conductance-laboratory:	801 μmho/cm at 25°C

Constituents	Milligrams per liter
Dissolved calcium (Ca)	29
Total calcium (Ca)	43
Dissolved carbonate (CO_3)	0
Dissolved bicarbonate (HCO_3)	295
Dissolved chloride (Cl)	23
Dissolved fluoride (F)	1.0
Dissolved magnesium (Mg)	21
Total potassium (K)	8.0
Total sodium (Na)	130
Dissolved sulfate (SO_4)	160
Dissolved solids (Residue at 180°C)	502
Suspended solids	1,190

Cations and anions, in dissolved chemical equivalent values, are usually balanced in a water analysis to test whether quantities determined are essentially correct. Water from UE-17a was given only a partial analysis; a few minor ions applied to this balance were not determined. Also, two of the cations, sodium and potassium, were analyzed as "total" rather than "dissolved" quantities. Despite these undesirable features of the water analysis from UE-17a, the balance, shown below, is close and confirms the probable validity of results:

Cations		Anions	
[Constituents in milliequivalents per liter]			
Ca	1.448	HCO_3	4.836
Mg	1.728	CO_3	0.0
Na	5.655	Cl	.649
K	.205	F	.053
--	-----	SO_4	3.332
Totals	9.036		8.870

The dominant cation in this water is sodium; dominant anions are bicarbonate and sulfate; hence, the water may be characterized as a sodium bicarbonate and sodium sulfate water.

Sodium bicarbonate is typical of water from nearby tuffaceous terrane in the region (Blankennagel and Weir, 1973, p. B26; Winograd and Thordarson, 1975, pp. C100-C101), and these ions were probably derived from tuff and tuffaceous alluvium, west of hole UE-17a, in an area of probable recharge to the Eleana Formation. The sulfate may come from oxidized pyrite that occurs in the Eleana Formation.

CONCLUSIONS

Rocks of Unit J of the Eleana Formation have been strongly fractured during several past events of thrust and strike-slip faulting. Most of these fractures have been resealed by secondary deposition of minerals, but a few have remained slightly open and yield small amounts of water to the hole. Minute cracks in a few of the quartzite, limestone, and calcareous argillite strata yield the small amount of water the hole produces.

Transmissivity of the water-bearing beds is small, based on a jetting test of the completed hole. More detailed hydraulic tests of packer-isolated, argillite zones in the Eleana Formation could define intervals of permeability suitable for a waste repository.

Hydraulic head in UE-17a continues to decline, primarily because of leakance into unsaturated fractures in the Tippipah Limestone, but also by leakance into saturated beds shallower than about 887 ft (270 m), that have lower hydraulic heads than the deeper saturated beds. A pressure transducer and recorder are installed to monitor water-level changes in the hole. As of September 27, 1978, the depth to water was 172.06 m (564.48 ft) below ground level. This level could be close to a composite equilibrium of yield-versus-uptake potential, and levels may continue fluctuating a few feet on either side of this approximate depth zone, around 172 m (565 ft), for a considerable time period. If unsaturated beds should become saturated, a higher composite water level will result.

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