GEOTRANS COVER LETTER OF 84/06/15

ATTACHMENT B

Geohydrologic Data for Test Well USW G-4

Bentley, C.B., 1983, Geohydrologic data for test well USW G-4, Yucca Mountain area, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-063, 48 p.

Test well USW G-4, located 91.4 m southwest of the proposed exploratory shaft, was drilled to a total depth of 915 m and completed on November 29, 1982 in the upper portions of the Tram member of the Crater Flat Tuff Formation. The test hole exhibited a 9.5° deviation from the vertical and continuous core was taken from the hole by rotary air foam drilling methods. The test hole encountered predominantly ash-flow tuff exhibiting varying degrees of welding, mineral alteration, and zeolitization. This report presents detailed lithologic descriptions including mineralogical composition, lithologic and bedding character, and limited information on fracture development and structural features encountered.

The report outlines primarily the hydraulic testing program completed on the test hole. A series of geophysical logging surveys were completed on portions of the hole to define lithology, porosity, fracture density and orientation, and to characterize test hole dimensions and conditions. Again, the report states only the surveys attempted and their interval of coverage without presentation of the raw data, logging profiles, and/or survey compilations.

The types of hydrogeologic testing performed on the test well included: (1) vertical core samples for porosity, bulk density, pore saturation, and other physical properties; (2) pumping tests; (3) slug injection tests; (4) borehole flow surveys; and (5) water chemistry sampling. Water level measurements were observed over a six-week period on a sporadic basis from late November 1982 to mid-January 1983. Many of these measurements (80%) were taken during long-term pumping tests over an eight-day period in early January 1983. Water elevation measurements show very little variation with depth interval, although the measurements are taken over rather large intervals.

Vertical core samples (350 cores) were taken from 12 to 915 m in depth below ground level. This represents an average hole coverage of 2.6 m/core. Results of these laboratory analyses are not yet available.

Drawdown and water level recovery measurements were made in conjunction with two separate pumping tests. Data plots for these tests are reported; however, no raw data or quantitative analyses have been presented. The pumping tests were conducted over the same depth interval between 549 and 915 m below ground and exhibited an average pumping rate of 16 l/sec. Only 3 m of drawdown were experienced by the well after a pumping interval of over 5,000 minutes. The second pumping test was performed as part of a borehole flow survey. The results of the survey show that almost 100% of the total production of the test hole originates within the Tram Unit at a depth interval between 870 and 915 m below ground.

Slug injection packer tests were performed on 13 selected intervals between 615 and 915 m below ground. This interval penetrates the Prow Pass, Bullfrog, and Tram Members of the Crater Flat Tuff. Eight of the tests were conducted in the Bullfrog Member. Again, only data plots associated with this testing program are exhibited in the report without supporting raw data and quantitative analysis.

A single composite water sample was collected from the test well near the end of the first pumping test. Total dissolved solids of the sample were 216 mg/l. Radiological analyses taken on the sample are still pending. The inorganic analyses are representative of a sodium bicarbonate-type water.

WMGT DOCUMENT REVIEW SHEET

FILE NO.:

DOCUMENT: Waddell, R.K., 1985, Hydrologic and Drill Hole Data for Test Wells UE-29a#1 and UE-29a#2, Forty Mile Canyon, Nevada Test Site: U.S.G.S. Open-file Report 84-142, Denver, 25 p.

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: October 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED: Rec'd w/LETTER of 85/11/15 #4

Introduction

The purpose of the report under review is to present a summary of hydrologic and drill hole data collected from test wells UE-29a#1 and UE-29a#2. The wells originally were designed to obtain data pertinent to characterizing the regional ground water flow system near Yucca Mountain. Test well UE-29a#1 was drilled to a total depth of 65.5 meters before being abandoned due to loss of a drill bit and collar down the hole. Test well UE-29a#2 was drilled 8.9 meters away from UE-29a#1; it reached a depth of 421.5 meters before caving problems stopped the drilling.

According to the report under review, the test wells were drilled to obtain geologic, hydrologic, and water chemistry data in an area of the Nevada Test Site where no nearby drill holes exist. Prior to drilling these test wells, no hydrologic data were available in areas upgradient from either Forty Mile Wash or Yucca Mountain. The drilling site was located in Forty Mile Canyon, north of Jackass Flats, in order to address the following questions:

1. What is the altitude of the potentiometric surface upgradient of the proposed repository?

2. What is the vertical hydraulic gradient beneath Forty Mile Canyon?

3. Does recharge occasionally occur from intermittent flow in the stream channel?

4. Is the high transmissivity of rocks beneath Forty Mile Wash caused by lithology alone, or by a possible north-trending fracture zone that may exist beneath Forty Mile Wash and Forty Mile Canyon?

5. Does the Crater Flat tuff occur north of Yucca Mountain, and if so, what is its lithology and volcanic-tectonic setting?

6. What are the in-situ hydrologic properties of rocks beneath the drill site?

7. What is the chemistry and age of water beneath Forty Mile Canyon?

According to the report under review, data collected from the two test wells may be used to address the seven questions listed above; however, drilling problems prevented acquiring all the necessary data.

Data Collected During Drilling

Data collected during drilling consisted of rate of penetration, specific electrical conductance, lithium concentration, drill cuttings, a lithologic log based on descriptions of cuttings and core, and geophysical logs. Rate of penetration data are presented in Figure 3 of the report. Specific electrical conductance and lithium concentration data are presented in Figures 4 and 5 of the report. Drill cuttings and core samples are stored at the U.S.G.S. core library in Mercury, Nevada. A generalized lithologic log of test well UE-29a#2 is presented in Table 1 of the report. A list of geophysical logs is presented in Table 2 of the report. Copies of the geophysical logs are maintained in the core library in Mercury, Nevada.

Data Collected During Pumping

Three single well pumping tests were conducted in test well UE-29a#1. Data from these tests are presented in Figure 6 and Table 3 of the report under review. Water chemistry data collected during a separate episode of pumping are presented in Table 4 of the report under review.

Six single well pumping tests (T1-T6) were conducted in test well UE-29a#2. According to the report under review the first two tests were conducted primarily for the purpose of cleaning the hole and designing the third test. Details of these tests are given in Table 5; drawdown, recovery, and discharge rate data are presented in Figure 7; tracejector and temperature data are presented in Figure 8 of the report under review. Drawdown, recovery, and discharge data for tests T4, T5, and T6 are presented in Figure 9; temperature and tracejector logs during test T6 are presented in Figure 10 of the report under review. Water chemistry samples were collected at the end of pump test T3 and pump test T6. These water chemistry data are presented in

Table 4 of the report under review. Samples were obtained from four different depths after the pump and bridge plug were removed from the borehole. These samples were analyzed for temperature, dissolved oxygen concentration, pH, and bromide concentration. The results of the analyses are presented in Table 6 of the report under review.

Data Collected After Testing Was Completed

The results of water level measurements in test well UE-29a#1 and the open hole and tubing in test well UE-29a#2 are presented in Table 7 of the report under review.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The drilling history of test well UE-29a#1 and UE-29a#2 illustrates the significance of these test holes and all other test holes in the development of a conceptual model of the saturated zone. According to the report under review, the depth to water in the vicinity of the test holes was estimated to be greater than 275 meters prior to drilling. According to the report under review, drilling data indicate that test well UE-29a#1 produced water at a depth of about 25 to 30 meters during drilling; it was not known whether this water was perched or whether it represented the regional saturated zone. Table 7 of the report under review presents depths to water for test wells UE-29a#1 and UE-29a#2. Table 7 indicates that on June 21, 1982, the water level in test well UE-29a#1 was located 24.05 meters below land surface. By October 5, 1983, the water level had risen to 22.85 meters below land surface. Table 7 indicates that water levels in test well UE-29a#2 ranged from 28.65 meters below land surface on December 1, 1985, to 27.95 meters below land surface on February 19, 1984. The fact that the depth to water was estimated to be greater than 275 meters below land surface prior to drilling the two test holes illustrates the importance of each test hole with respect to the development of a defensible conceptual model of the saturated zone.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

The report under review constitutes a summary of the data that were collected in test wells UE-29a#1 and UE-29a#2. Only very basic data are presented in the report. For example, drawdown measurements during the pump tests are not presented in the report for either well. Only maximum drawdown values and/or graphical representations of the drawdown for each pumping test are presented. The report under review presents the results of the tests conducted in the test wells. However, no interpretations of the data are presented in the report. Drilling problems prevented the completion of both test wells to the desired total depth. This limitation precluded the collection of all the data necessary to answer the seven questions concerning the hydrology and geology near the Yucca Mountain site listed in the introduction to the report.

<u>SUGGESTED FOLLOW-UP ACTIVITIES</u>:

The results of the drilling and testing programs presented in the report under review illustrate the degree to which data from a single test well can alter the conceptual model. It would be advisable to evaluate the possibility of using the two holes in one or more paired well tests. In addition attempts should be made to correlate the borehole flow survey logs among all boreholes each time a new hole is drilled and tested.

GEOTRANS COVER LETTER OF 85/02/21
NOT A TECHNICAL REVIEW.

ATTACHMENT A: SUMMARY OF GEOHYDROLOGIC AND DRILL-HOLE DATA FOR TEST WELL USW H-3

Thordarson, William, F.E. Rush, R.W. Spengler, and S.J. Waddell, 1984, Geohydrologic and Drill Hole Data for Test Well USW H-3, Yucca Mountain, Nye County, Nevada, U.S. Geological Survey Open-File Report 84-149, 28p.

Test well USW H-3 is located on the main north-south oriented ridge of Yucca Mountain N 756,542 ft and E 558,452 ft (Nevada State Central Zone Coordinates) at an elevation of 1,483.2 m above sea level. Drilling of H-3 was completed on March 19, 1982 to a total depth of 1,219 m; the vertical deviation was a maximum of 2.75°. The borehole, which was rotary-drilled with air foam by Fenix and Scisson, Inc., is telescoped with four diameter changes (91.4, 66.0, 37.5, 22.2 cm) and three casing diameter sizes (76.2, 38.1, 25.3 cm). The casing is perforated with approximately seven shots per meter between depths of 754 to 792 m below ground. According to the lithologic log (determined from rock-bit cuttings collected at 3 m intervals), this hole penetrates the stratigraphic interval from the Tiva Canyon Member of the Paintbrush Tuff through the Tram Member of the Crater Flat Tuff. The hole bottoms out in the ash-flow tuff of the Lithic Ridge Tuff. Note that the Pah Canyon and Yucca Mountain Members are not present within the stratigraphic section of this hole. A number of borehole geophysical surveys were conducted upon portions of the test hole and are presented in tabular form. These surveys include: (1) an acoustic televiewer log which determined the orientation of lineations below static water level; (2) caliper logs which recorded out-of-gage and enlarged borehole zones; and (3) a television videotape of the hole above the static water level which recorded the distribution of water seeps and fractures. Note that a very small water seep was observed at 277 m below ground surface in the Topopah Spring Member.

A hydrologic testing program included one borehole flow survey, one pumping test, six injection tests, and two swabbing tests. Nineteen sporadic water-level measurements are reported. The measurements were taken between February 16, 1982 and August 31, 1983 during drilling and hydrologic testing periods. The highest and lowest water-level measurements are associated with a swab test and an injection test respectively, and therefore, are not representative of the static water level. The majority of the remaining measurements were taken over fairly large borehole intervals and ranged from 749.9 m to 753.9 m below ground.

A cyclic pumping test was conducted over the depth interval between 754 and 792 m below ground; the pumping rate was 2.8 L/s for each cycle. Two data plots are reported: (1) drawdown and recovery during pumping test, and (2) recovery after the pumping test. However, no raw data or quantitative analyses were presented.

A borehole flow survey data is also presented. The results of the survey show that approximately 70 percent of the total production of the test hole originates within the Tram Unit at a depth interval between 810 and 940 m below ground. The remaining 30 percent of the total production originates in the lower 25 m of the Tram Unit and the upper 30 m of the Lithic Ridge Tuff at a depth interval between 1075 and 1130 m below ground.

Packer injection tests were performed on six selected intervals between 792 and 1219 m below ground. This interval covers most of the Tram Member of the Crater Flat Tuff and the upper 119 m of the Lithic Ridge Tuff. Only data plots of these tests are shown in this report; no raw data or quantitative analyses are presented. Five of the six tests exhibit unusually shaped trends compared to the expected analytical solution type curve. Two swabbing tests were conducted: one over the interval between 972 and 1,219 m below ground and the other over the interval between 1,063 and 1,124 m below ground. The data plots for the two tests are presented. Again, no raw data or quantitative analyses are presented within this report.

GEOTRANS COVER LETTER OF 85/02/21

ATTACHMENT B: SUMMARY OF GEOHYDROLOGIC AND DRILL-HOLE DATA FOR TEST WELL USW H-4

Whitfield, M.S., Jr., William Thordarson, and E.P. Eshom, 1984, Geohydrologic and Drill-Hole data for Test Well USW H-4, Yucca Mountain, Nye County, Nevada, U.S. Geological Survey Open-File Report 84-449, 39p.

Test well USW H-4 is located in an easterly canyon of Yucca Mountain, N 761, 642.6 ft and E 563,911 ft (Nevada State Coordinate System Central Zone), at an elevation of 1,248.9 m above sea level. Drilling of H-4 was completed June 7, 1982 at a total depth of 1,219 m below ground; the vertical deviation was less than 3°. The hole, which was rotary-drilled with airfoam by Fenix and Scisson, Inc., was constructed with five borehole diameter changes (91.4, 66.0, 50.8, 37.5, 22.2 cm) and three casing diameter sizes (74.3, 38.1, 25.3 cm). The casing was perforated with two shots per 0.3 m between depths of 533 m to 539 m below ground. According to the lithologic log (determined from rock cuttings and cores), the hole penetrates the stratigraphic interval from the Tiva Canyon Member of the Paintbrush Tuff through the Tram Member of the Crater Flat Tuff. The hole bottoms out in the ash-flow tuff of the Lithic Ridge Tuff. Note that the Pah Canyon and Yucca Mountain Member were not present in this hole.

A number of borehole geophysical surveys were conducted upon sections of the test hole. The data obtained from the majority of these surveys are not presented in this publication. Data obtained from caliper logs are presented in tabular form for (1) out-of-gage zones (zones with a diameter 100 mm greater than the diameter of the bit used to drill the hole), (2) enlarged borehole intervals associated with rock fracturing.

A hydrologic testing program included six pumping tests, one borehole flow survey, and fifteen injection packer tests. Eighteen sporadic water-level measurements are reported in this publication. The measurements were taken between April 8 and June 4, 1982 during drilling and hydrologic testing periods. The average static water level is approximately 519 m below ground. Note that one water-level measurement was made at 338 m below ground within the Topopah Spring Member. This may be evidence of perched water within the repository zone considering that approximately 0.03 liters of water per second was pumped by airlift method for 5 minutes. No water quality samples were reported on this water.

The pumping tests were conducted over a large interval between 519 and 1,219 m below ground; the pumping rates that were given ranged between 16.5 L/s and 18.7 L/s. Data plots for three out of six of the pumping tests are presented in this report. Only pumping test no. 6 was run for an extended period; the pumping rate was 17.4 L/s over 12,818 minutes. The data plots of drawdown versus time for pumping test no. 6 exhibit unusually shaped trends compared with the expected analytical solution type curve. Raw data and quantitative analyses for each pumping test are not presented in this report.

The borehole flow survey and temperature survey were conducted at the interval between 519 and 1,219 m below ground. Results of these surveys are presented as data plots; raw data and quantitative analyses are not presented. The borehole flow survey indicated that approximately 68 percent of the total production of the test hole originates in the Bullfrog and upper Tram Members at an approximate depth interval between 700 m and 910 m below ground. The temperature survey indicates an abrupt increase in temperature from 35°C to 39.5°C between a relatively short depth interval 860 m to 930 m below ground within the Tram Member.

Injection packer tests were conducted in fifteen different intervals between 555 m and 1,219 m below ground. Data plots for all fifteen tests are presented in this report. Two of the tests (intervals 555 m to 604 m and 604 m to 652 m) exhibit unusually shaped trends compared with the expected analytical solution type curve. Raw data and quantitative analyses are not presented within this report.

A composite water sample was collected near the termination of pumping test six. The water of test well USW H-4 is predominantly a soft, sodium bicarbonate water with a pH of 7.9. The carbon-14 age of the water is 17,200 years b.p. with an average temperature of 34.8°C. Total dissolved solids concentration was 248 mg/L.

USGS OFR 84-450

WMGT DOCUMENT REVIEW SHEET

FILE NO:

ONWI NO:

DOCUMENT: Geohydrologic Data for Test Well UE-25P#1, Yucca Mountain Area, Nye County, Nevada

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: December, 1984

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

The primary purpose of the report is to present the results of drilling of test well UE-25P#1 and the analyses of single well tests in packer injection tests. Test well UE-25P#1 is located on the valley floor approximately 1.5 kilometers west of Yucca Mountain. The well was drilled primarily to obtain information about rocks of Paleozoic Age that were presumed to underlie the volcanic rocks of Tertiary Age penetrated by previous test wells in the Yucca Mountain area. A secondary objective for drilling the well was to collect additional information about the Tertiary rocks in the area.

Test well UE-25P#1 was completed to a total depth of 1,805 meters. The hole was rotary drilled using an air foam fluid consisting of air, detergent, and water when possible, rather than drilling mud, to minimize infilling of pores and fractures; however, a polymer mud was necessary during drilling of most of the Paleozoic section to clear the cuttings from the hole. The rocks penetrated by the well were predominantly Tertiary ash flow tuff units from the surface to approximately 1,244 meters. A conglomerate unit approximately 33 meters thick occurs within the depth interval between 1,137 and 1,170 meters. According to the report at least two faults within the Tertiary sequence are large enough to disrupt the normal stratigraphic succession of the tuff sequence at Yucca Mountain; however another fault zone at approximately 1,244 meters juxtaposes the Tertiary succession against Paleozoic carbonate rocks. Below this fault, the hole penetrated dolomite of the Silurian Lone Mountain dolomite and Roberts Mountain Formation.

An extensive suite of geophysical well logs was recorded in test well UE-25P#1. According to the report these geophysical logs were used to guide and augment the hydrologic and geologic test programs, to confirm well construction, and to identify physical properties. Caliper logs were used to select intervals for packer injection testing. However, geophysical logs are not presented in the report. Table 2 of the report presents a summary of the geophysical well logs recorded for test well UE-25P#1.

A total of 225 meters was cored in test well UE-25P#1. Total recovery was 187 meters. A summary of the cored intervals is presented in table 3 of the report. No information about the cores themselves are presented in the report.

According to the report two separate periods of hydrologic testing and water sampling were conducted during the drilling of test well UE-25P#1. The first period of testing was conducted after the hole had penetrated Paleozoic rocks to a depth of 1,301 meters. A temporary cement plug was set at 1,197 meters; a 273 millimeter casing was set temporarily, uncemented, at a depth of 386 meters. A series of tests was conducted on the saturated Tertiary section above 1,197 meters. The second period of testing occurred after casing had been set to 1,297 meters and the well had been completed to a total depth of 1,805 meters. The report makes note of the fact that the interval from 1,197 meters to 1,297 meters was not tested during either period of testing. However, the report states that probable leakage past the temporary cement plug may have occurred during pumping in recovery test one. The report suggests that leakage past the temporary cement plug may have had the effect of increasing the length of the tested interval for pumping and recovery test one from 1,197 meters to 1,301 meters.

Depths , to water were measured to determine the composite hydraulic head of the Tertiary and Paleozoic sections. In addition, depths to water were measured for intervals isolated during packer injection tests. The composite water level for the Tertiary section was about 381 meters below land surface; this compares to the composite water level for the Paleozoic section of approximately 361 meters below the land surface. Because of probable leakage past the cement plug, the report suggests that the composite hydraulic head measured for the Tertiary section is an average value over the depth interval of 99 to 1,301 meters. The composite hydraulic head measured for the Paleozoic section is an average value over the depth interval from 1,297 meters to 1,805 meters.

Two pumping and recovery tests were conducted in test well UE-25P#1. The first test was conducted in the interval from the top of the saturated zone to 1,197 meters (or 1,301 meters based on probable leakage past plug). A second pumping and recovery test was conducted after a depth of 1,805 meters had been reached. The second test tested the Paleozoic rocks from the bottom of 194 millimeter liner casing at 1,297 meters to 1,805 meters. Pumping test 1 was conducted for 3,150 minutes at a rate of 22 liters per second. Recovery was monitored for 1,050 minutes. Maximum drawdown during the pump test was 33.7 meters. Figure 5 of the report is a semilog plot of drawdown in meters versus time after pumping started in minutes. Figure 6 is a semilog plot of residual drawdown in meters versus time after pumping stopped in minutes. No interpretations of the pump test data are presented in the report. However the general shape of the semilog plots for aquifer test No. 1 are characteristic of other tests conducted in test wells in the vicinity of Yucca Mountain.

Pumping and recovery test 2 was conducted after completion of drilling. The hole was open from 1,297 meters to 1,805 meters. The well was pumped at 31.5 liters per second for 6,080 minutes. Maximum drawdown was 9.3 meters below the prepumping static water level. During the first 50 minutes of the test, discharge temperature increased from about 30 degrees to 56 degrees Celcius. The temperature remained at 56 degrees Celcius for the remainder of the test. Recovery was monitored for 1,000 minutes. The report suggests that the response observed during recovery test 2 is similar to inertial effects described by Bredehoeft and others (1966) and Van der Kamp (1976). Figures 7 and 8 of the report are semilog plots of drawdown in meters versus time after pumping started in minutes and residual drawdown in meters versus time after pumping stopped in minutes, respectively. Both figures 7 and 8 suggest that water levels in the Paleozoic rocks in the interval between 1,297 meters and 1,805 meters act as an underdamped oscillator. In the underdamped case the water level initially oscillates above the equilibrium level.

Three borehole flow surveys were conducted in test well UE-25P#1 to detect intervals of fluid entrance into the borehole. Small quantities of radioactive iodine-131 were injected into the water column at selected depths. Time required for the iodine-131 to move between two gamma ray detectors, a known distance apart, was converted to a velocity. The non pumping flow survey in the Tertiary section showed an upward movement of water within the well. Flow past the temporary plug was more than 0.4 liters per second. The results of the borehole flow surveys are presented in figures 9, 10, and 11 of the report.

Twenty-nine packer injection tests were conducted in various intervals of the well. According to the report these packer injection tests were conducted to obtain data on the distribution of hydraulic head in the well and to obtain data for future determination of the distribution of transmissivity in the well. Injection tests 1 through 14 were conducted in the Tertiary section; tests 15 through 29 were conducted in the Paleozoic section. Tests 1 through 14 measured water levels only. The decline of water level during the remaining tests, presented as the ratio of the hydraulic head above the static water level at a given time (H) to the hydraulic head above the static water level at the time of injection (H_o) versus time since injections began, is shown in figures 12 through 38 of the report. Table 5 of the report summarizes the packer injection tests.

The report notes that the packers used for the injection tests in test well UE-25P#1 were used later in another test hole where it was observed that the tool malfunctioned and allowed the upper packer to deflate slowly, thereby allowing the water to bypass the packer. No tool malfunction was observed during the testing of test well UE-25P#1. However the validity of the results of tests 20, 21, 23, 24, 26, 27, and 28 are questioned in the report due to potential leakage past the upper packer.

All but three of the tests conducted in the Paleozoic section showed a response after reaching static water level similar to an underdamped oscillator as discussed by Van der Kamp (1976). The oscillating sine wave appearance of these tests was very similar to that of recovery test No. 2. Only tests 15, 16, and 29 in the Paleozoic section did not show this characteristic oscillating sine wave response. The sine wave response of tests 17 through 28, with the exception of test 22 and 25 is shown in the figures 39 through 48 of the report. A temperature log of the hole was recorded; the log is shown in figure 49 of the report. This temperature log will be helpful in the interpretation of the injection tests if the Van der Kamp solution for an underdamp case is used. No interpretations of the packer injection tests are presented in the report.

Composite water samples were collected near the end of each pumping period. The results of the analyses of the water samples are shown in table 6 of the report.

<u>SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:</u>

Significance in EA's:

As mentioned on page 6-97 of the draft EA, test well UE-25P#1 is the only hole that penetrated pre Tertiary rocks. Test well UE-25P#1 provided stratigraphic data from both cuttings and core samples of rocks of Paleozoic Age that underlie the section of Tertiary rocks east of Yucca Mountain (Craig and Robison, 1984). The report under review and the report by Craig and Robison (1984) do have significance with respect to the EA since these reports are the only reports available which present hydrogeologic data for the Paleozoic rocks that are present beneath the Tertiary section.

Significance in Overall Licensing Process:

The report under review constitutes one of two primary sources of information with respect to the Paleozoic rocks that are present beneath the Tertiary section in the vicinity of the proposed repository. Because of this fact the data presented in the report under review are very significant with respect to the evaluation of ground water movement through the Paleozoic section.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

Our comments on this portion of the review of the document are presented in their chronological order of presentation in the report under review. There are no major problems, deficiencies, or limitations of the report since the purpose of the report is to present the general geohydrologic data for the test well. Detailed data are not presented in the report. The report under review constitutes a general synopsis of the data that were collected from well UE-25P#1. Data not presented in the report include a detailed lithologic log, the geophysical well logs, and details about the core samples. These data may be necessary to interpret the aquifer test data and the packer injection test data. These data may be provided in the report by Craig and Robison (1984).

SUGGESTED FOLLOW-UP ACTIVITY:

The report by Craig and Robison (1984) entitled "Geohydrology of Test Well UE-25P#1, Yucca Mountain Area, Nye County, Nevada," USGS-WRI-84-_, U.S. Geological Survey should be reviewed.

Bredehoeft J.D., Cooper, H.H., and Papadopulos, I.S., 1966. Inertial and Storage Effects in Well-Aquifer Systems--An Analog Investigation. Water Resources Research, v. 2, n. 4, p. 697-707.

Craig, R.W. and Robison. 1984. Geohydrology of Test Well UE-25P#1, Yucca Mountain Area, Nye County, Nevada. USGS-WRI-84-_.

Van der Kamp, Garth, 1976. Determining Aquifer Transmissivity by Means of Well Response Tests: The Underdamped Case. Water Resources Research, vol. 12, no. 1, p. 71-77.

USGS OFR 84-491

WMGT DOCUMENT REVIEW SHEET

FILE NO.:

ONWI NO.:

DOCUMENT: Stratigraphic and Structural Relations of Volcanic Rocks in Drill Holes USW GU-3 and USW G-3, Yucca Mountain, Nye County, Nevada

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: December, 1984

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

The report under review presents the stratigraphic and structural characteristics of two drill holes, USW GU-3 and USW G-3, drilled 30 m apart as a two-stage coordinated drilling and geophysical logging program. These two drill holes are the southernmost in a series of geologic drill holes drilled within the immediate area of investigation as a potential nuclear repository in the central portion of Yucca Mountain. Continuous core was obtained from the two drill holes to a depth of 1,533 m. The major emphasis of the report is to describe the lithologic, stratigraphic, and structural character of the core recovered at drill holes USW GU-3 and USW G-3. However, stratigraphic correlation between pre-existing drill holes and structural correlation with surface mapping on Yucca Mountain are presented also.

Drill holes USW GU-3 and USW G-3 were drilled in a two-stage coring program that was designed to attain maximum hole stability and to optimize conditions for wet hole geophysical logging above the zone of saturation. USW GU-3 was cored in the unsaturated zone; USW G-3 was cored largely in the saturated zone. USW GU-3 was cored continuously from about 10 m to 806 m; USW G-3 was cored continuously from about 797 m to 1,533 m. Appendix 1 of the report under review presents the core recovery record.

An extensive suite of geophysical logs was recorded for the two boreholes. However, the results of the investigations of these logs are not presented in the report under review. In addition to the suite of geophysical logs, a compass oriented TV camera was run to the static water level; strikes of conspicuous fractures and faults were measured from tapes of these TV runs. A directional survey was conducted to a depth of 1,500 m in drill hole USW G-3. Oriented core was obtained at selected intervals covering approximately 10% of the depth cored; the attitudes of bedding, foliations, fractures, and faults were obtained from these cores.

The majority of the rocks cored at USW GU-3 and USW G-3 are ash flow tuffs. According to the report under review, most of these ash flows are welded, compositionally zoned, and form compound cooling units; non welded, compositionally homogeneous, and simple cooling units are present also.

The stratigraphic descriptions presented in the report have two objectives: 1) to describe the megascopic character of subdivisions observed in the USW GU-3 and USW G-3 core and to correlate those subdivisions with drill holes USW G-1, USW G-2, and UE25B-1H; 2) to define a series of subdivisions that have petrologic significance by using phenocryst model data, other petrographic thin section data, and field data.

<u>Paintbrush Tuff</u>

Tiva Canyon Member

The Tiva Canyon Member is a compositionally zoned, compound cooling, ash flow tuff that ranges from a high silica rhyolite base to a quartz latitic cap rock. According to the report, field mapping indicates that distinct mappable subdivisions of the Tiva Canyon Member occur in the region of the drill holes. Seven megascopic subdivisions of the Tiva Canyon Member were identified in the core recovered at drill hole USW GU-3. According to the report, these subdivisions are based principally upon visual semi-quantitative approximations of the degree of welding, phenocryst content and the lithophyseal cavity content. Detailed descriptions of each of these subdivisions are presented in Appendix 2 of the report.

According to the report, petrologic subdivisions of the Tiva Canyon Formation were established from detailed thin section phenocryst model analyses in conjunction with field and megascopic observations. The petrologic framework is designed to recognize evidence of separate eruptive surges that are assumed to have tapped different portions of the chemically zoned magma chamber. According to the report, there is a fairly close correspondence between field, megascopic and petrologic subdivisions, but significant differences do occur; a comparison of field, megascopic and petrologic subdivisions of the Tiva Canyon Member at drill hole USW GU-3 and USW G-3 is presented in figure 9 of the report. At USW GU-3 and USW G-3, 15.3 m of nonwelded bedded tuffs occur between the Tiva Canyon Member and the Topopah Spring Member.

Topapah Spring Member

The Topapah Spring Member is a compositionally zoned compound cooling unit that varies from a high silica rhyolite base to a quart latitic cap rock. Twelve megascopic subdivisions are recognized within the 300 m of ash flow tuff cored at drill hole USW GU-3. These subdivisions were recognized by outstanding changes in the degree of welding, state of devitrication, abundance of mafic facies, and differences in the abundance of lithophysal cavities. According to the report, a total of at least nine petrologic subdivisions, or probable individual eruptive surges, of the Topapah Spring Member are proposed at drill holes USW GU-3 and USW G-3. These petrologic subdivisions are based primarily upon quartz content, abundances of lithophysal cavities, crystal content (phenocrysts), and degree of alteration. A 2 m thick vitric bedded tuff zone exists between the overlying nonwelded ash flow tuff of the Topapah Spring Member and the underlying nonwelded ash flow tuff tentatively assigned to the tuffaceous beds of Calico Hills.

Tuffaceous Beds of Calico Hills

A series of rhyolitic nonwelded ash flow tuffs, lava flows, autobrecciated lava flows, and reworked tuffaceous beds informally assigned to the tuffaceous beds of Calico Hills occurs between the Topapah Spring Member of the Paintbrush tuff and the Prow Pass Member of the Crater Flat tuff at Yucca Mountain. According to the report, tuffs within this interval at drill hole USW G-2 and USW G-1 are zeolitized (introduction of, or replacement by minerals of the Zeolite group), but core at drill hole USW GU-3 is vitric (containing predominantly volcanic glass fragments). According to the report, the sequence of tuffaceous beds probably is made up of at least three separate magmatic pulses that tapped different portions of one chemically zoned magma chamber. Figure 12 of the report presents a comparison of petrologic subdivisions with megascopic subdivisions in the nonwelded tuffs of the Calico Hills from drill hole USW GU-3. According to the report, correlation within the tuffaceous beds of the Calico Hills remains problematic and more work is necessary to define the tuffaceous beds from this interval, both at drill holes USW GU-3 and USW G-3 and elsewhere. A fundamental difference in style and degree of alteration exists between the tuffaceous beds at drill hole USW GU-3 and the zeolitic tuffs found in cores and exposures further north in Yucca Mountain. The tuffs and cores from drill hole USW GU-3 are essentially vitric, unaltered to partially altered, with only a trace of smectite and sparse clinoptilolite. This interval in exposures and drill holes in northern Yucca Mountain is highly zeolitic. Thirteen meters of pyroclastic fall tuff were cored at USW GU-3 between the lowest nonwelded ash flow tuff of the Calico Hills and the Prow Pass Member of the Crater Flat tuff.

Crater Flat Tuff

Prow Pass Member

The Prow Pass Member in core from drill hole USW GU-3 appears to be a slightly chemically zoned, simple cooling unit. According to the report, only three megascopic subdivisions can be distinguished in the 131.5 m thick Prow Pass Member at drill hole USW GU-3. Three petrologic subdivisions have been identified; these subdivisions compare very closely with the three megascopics subdivisions. According to the report, the three petrologic subdivisions seem to correlate well with three subdivisions recognized in core from drill hole USW G-2. Figure 13 of the report presents the megascopic and petrologic subdivisions of the Prow Pass Member found in core from drill hole USW GU-3. A 4 m thick bedded tuff that consists of layers of distinctly cross bedded and channel fill structures indicative of fluvial reworking and of layers of more massive pyroclastic fall debris occurs below the Prow Pass Member in core from drill hole USW GU-3.

Bullfrog Member

The Bullfrog Member at drill hole USW GU-3 consists of two distinct cooling units. An upper 165 m thick unit is separated from a lower 20 m thick unit by a meter of bedded tuff, representing a complete cooling break. Seven megascopic subdivisions have been identified for the upper cooling unit. The lower cooling unit has been divided into four megascopic subdivisions. Only one petrologic subdivision can be recognized within either the upper cooling or within the lower cooling unit of the Bullfrog Member. Figure 14 of the report presents the megascopic and petrologic subdivisions of the Bullfrog Member found in core from drill hole USW GU-3. Approximately 6 m of bedded tuff separate the Bullfrog Member from the Tram Member in drill hole USW GU-3. These beds include both reworked tuffs and pyroclastic fall tuff.

Tram Member

The Tram Member is a thick (370 m), very complex, compound cooling, ash flow tuff that contains a large number of partial and complete cooling breaks and numerous eruptive surges in core from drill hole USW GU-3. According to the report, the Tram

Member contains a large number of megascopic subdivisions; however, only the larger ones are identified in Appendix 2 and on figure 15 of the report. Considerable variation in phenocryst ratios occurs within the Tram Member. Twenty-eight eruptive surges (petrologic subdivisions) can be defined by a combination of phenocryst ratios, bedded tuff horizons, sub horizontal partings, changes in lithic fragment abundances and compositions, and changes in the degree of welding. A moderately to well indurated 8.5 m thick bedded tuff consisting largely of pyroclastic fall material of both Lapilli and ash sizes occurs below the Crater Flat tuff in drill hole USW G-3. The bedded tuff also may contain minor reworked sedimentary tuff.

Lithic Ridge Tuff

The Lithic Ridge tuff forms a 304 m thick, very complex, compound cooling ash flow tuff that contains multiple eruptive surges at drill hole USW G-3, much like the Tram Member. Also, like the overlying Tram Member, the Lithic Ridge tuff is compositionally inhomogeneous. Nine megascopic subdivisions of the Lithic Ridge tuff have been identified. According to the report, the number of petrologic subdivisions that can be established for the Lithic Ridge tuff at drill hole USW G-3 is only minimal because a large number of relatively small variations in the degree of welding and variations in lithic fragment content have not been counted. Figure 16 of the report presents the megascopic and petrologic subdivisions of the Lithic Ridge tuff found in core from drill hole USW G-3. A 3 m thick bedded tuff is present beneath the Lithic Ridge tuff. It consists of pyroclastic ash and pumice, and contains rare evidence of minor fluvial reworking, indicated by termination of sedimentary bedding planes by sedimentary structures such as channels and cross bedding.

Older Ash Flow Tuffs

The lowest units in drill hole USW G-3 are the unnamed older tuffs. The portion of tuff penetrated at that drill hole USW G-3 forms a rhyolitic, compositionally homogeneous, simple cooling unit. Two megascopic subdivisions are recognized by changes in degree of welding. No petrologic subdivisions are recognized in this unit. Figure 17 of the report presents the megascopic subdivisions of the older tuffs from core of drill hole USW G-3.

Physical Property Stratigraphy

According to the report, the rock mass physical properties of the tuffs within Yucca Mountain are of considerable interest and concern, primarily because of the high degree of correlation between the degree of welding and related rock mass physical properties such as porosity, dry bulk density, thermal conductivity, and fracture density. Figure 18 of the report shows the close relationship between degree of welding, porosity, and dry bulk density in the Tiva Canyon Member of the Paintbrush tuff. The report notes that similar relationships exist for lower stratigraphic units except where alteration in the form of zeolitization, argillization, and silicification change both the porosity and density. With increasing depth and increasing degree of alteration, the dependence on physical properties upon the degree of welding decreases; however the degree of welding is still the primary control of these properties. Figure 19 of the report presents physical property subdivisions based on degree of welding of the tuffs. The first category consists of nonwelded to partially welded tuffs containing relatively low density rocks that are more porous and less fractured than those in the second catesory. The second category consists of moderately to densely welded ash flow tuffs containing relatively high density rocks that are less porous and more fractured. According to the report, the fundamental control on hydraulic conductivity within ash flow tuffs is the density of fractures; fracture hydraulic conductivities are several orders of magnitude greater than matrix hydraulic conductivities. The report notes that fractures are at least an order of magnitude more abundant in moderately and densely welded tuffs than in nonwelded or partially welded tuffs.

Chemical Character

The ash flow tuffs of Yucca Mountain fall into a relatively narrow range of silicic compositions, between high silica rhyolite and quartz latite. Tiva Canyon and Topapah Springs Members of the Paintbrush tuff contain two compositional end members, high silica rhyolite in the basil parts and quartz latite in the cap rocks, separated by a compositional gap. The Prow Pass and Tram Members of the Crater Flat tuff and the Lithic Ridge tuff show evidence of compositional zonation but to a lesser degree with no composition gap. Table 5 of the report presents X-ray fluorescence analyses of major and minor elements for ash flow tuffs sampled in drill holes USW GU-3 and USW G-3, USW G-2, and USW G-1 and from outcrops at Yucca Mountain. Normative analyses calculated from major elements are listed in table 6 of the report. Figure 20 of the report presents quartz-albite-orthoclase and an anorthite-albite-orthoclase phase diagrams.

Structure

Bedding and Foliation

According to the report, one objective of obtaining oriented core is to determine the attitude of bedding within tuffaceous layers and planes of foliation within ash flow tuffs. Depth of oriented cores, the angle of inclination of the drill hole, and the necessary corrections to attain the true depth are listed in table 8 of the report. Table 9 of the report presents the dips of bedded tuff and foliation planes in welded ash flow tuffs. True thicknesses of major stratigraphic units are listed in table 10 of the report.

Fractures

Mineralogy of Fracture Coatings:

According to the report, the mineralogies of fracture coatings and veins were determined by X-ray defraction analysis of 49 selected samples of mineralized fractures, and are listed in table 11 of the report. The frequency of occurrence of smectite and 10-A° clays increases downhole. Fractures at depths less than 250 m commonly are coated with palygorskite, a chain lattice clay mineral with a fibrous white appearance. Zeolites were found to increase downhole. The eolite mineral mordenite is prevalent between 775 and 975 m. Fe and Mn minerals include common occurrences of hemitite and less commonly geothite, lepidcrocite, iron oxide, pyrolusite, and cryptomelane. Figure 24 of the report presents the frequency of occurrences of secondary minerals found within the fractures in core of drill holes USW GU-3 and USW G-3. Figure 24 shows the following trends: 1) the abundance of Mn oxide minerals decreases downward from a high of nearly 50% of the occurrences in the Topapah Spring Member to less than 5% in the older tuffs. 2) The percent of occurrences of clays increases downhole from about 15% for the Tiva Canyon Member to about 50% in units below the static water level. 3) The frequency of occurrence of carbonates, largely calcite, decreases from over 30% in the Tiva Canyon Member to zero in the tuffaceous beds of Calico Hills, below which the frequency increases to over 40%.

Fracture Frequency:

Figure 25 of the report compares the frequency of fractures to differences in the degree of welding in drill holes USW GU-3 and USW G-3. According to the report, several conclusions can be reached from this comparison: 1) there is a profound correlation between high fracture frequency and the degree of welding; 2) the megascopic zonations within densely welded tuffs show very little variation in fracture frequencies. Densely welded tuffs have fracture frequencies that range from about 15 to 40 fractures/unit m^3. Lithophysal zones tend to have slightly fewer fractures, 14 to 20 fractures/unit m^3. Below a depth of about 940 m there is an abrupt change in the frequency of fractures, independent of the degree of welding. According to the report, about 8 to 20 fractures/unit m^3 are characteristic of moderately welded tuffs in the Tram Member above 940 m; below that depth, between 2 and 3 fractures/unit m^3 are present.

Attitude of Fractures:

According to the report, fracture attitudes have been determined by oriented cores providing azimuths and inclinations of the fracture planes, by fracture surveys using downhole TV cameras above the water table providing azimuths of fracture planes, and by unoriented cores providing inclinations with no corrections for hole deviation. More than 2,700 natural fractures were identified and measured in the 1,500 m of core. However, according to the report, most of the fractures have not been oriented in azimuth and, therefore provide only the inclination (or dip) of the fracture planes.

Faults

According to the report, some 21 faults in the core occur within oriented intervals; the attitudes of these faults are shown on figure 29 of the report. The mean fault attitude is about north 21° west, 73° southwest, essentially within the trend of the maximum fracture attitude between north 2° west, 84° southwest and north 29° west, 79° southwest.

Correlation with Surface Structure

Detailed 1:12,000 scale mapping of the surface of Yucca Mountain has identified basically two styles of faults. One style consists of a series of nearly vertical faults that strike northwest and commonly are decorated with subhorizontal slickensides. The second style consists of large displacement normal faults that strike northwest to northeast, dip 60° to 90° mostly to the west, and have dip-slip, strike-slip, and oblique slip slickensides. According to the report, major normal fault movement at Yucca Mountain is about twelve million years old; however, modern normal fault movement and minor oblique and strike slip displacements on normal faults continue to occur, at least into the Pleistocene in the NTS region. According to the report, minimum ages of 26,000 and 30,000 years on calcite fracture filling material from drill hole USW GU-3 are the youngest evidence of possible faulting on Yucca Mountain. According to the report, a major fault found east of the drill holes in an abandoned wash dips westward and is correlated with the faults encountered in the core. The dominant fracture and fault attitudes, both in oriented core and on the surface, are north-northwest strikes and westward dips.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

Significance in EAs:

We could not find a reference to the report under review in the EA. A report by Scott and Castellanos (1984), entitled "Preliminary Report on the Geologic Character of Drill Holes USW GU-3 and G-3" is present in the list of references for chapter 6 of the EA. However, the location of this reference within the text of the EA could not be found. The report under review presents valuable information pertaining to drill holes USW GU-3 and USW G-3. It is anticipated that this document will be fairly heavily referenced in the final EA.

Significance in Overall Licensing Process:

The report constitutes a primary source of geologic information for drill holes USW GU-3 and USW G-3.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

The primary purpose of the report was to describe the lithologic, stratigraphic, and structural character of the core recovered at drill holes USW GU-3 and USW G-3. It correlates stratigraphic features between pre-existing drill holes, and structural features with surface mapping on Yucca Mountain. The report suffers no serious deficiencies or limitations with respect to the purpose of the report. The only significant limitation of the report is that valuable data such as geophysical logs are not presented. The report contains important data with respect to welding of the tuff layers, fracture frequencies, fracture orientations, and fracture fillings. These data are not correlated with the hydrogeologic characteristics within the borehole. This is not a deficiency of the report under review; this is done by design of the U.S.G.A. However, the data would be of more value to the NRC if correlated to the hydrogeologic property testing program and the geophysical logging program rather than presenting the data in separate reports.

SUGGESTED FOLLOW-UP ACTIVITY:

The report contains valuable information with respect to the degree of welding, fracture frequencies, fracture orientations, and fracture fillings. These data should be evaluated with respect to geophysical logs that were recorded for the drill holes and with respect to hydrogeologic property testing data. Evaluation of all of the data collected from drill holes USW GU-3 and USW G-3 may provide defensible supporting data for the selection of a given hydrogeologic model to analyze aquifer test data. Specifically, detailed data on fracture fillings may provide supporting evidence for the hydrogeologic model proposed by Moench (1984) for a double porosity fractured aquifer with fracture skin.

REFERENCES CITED:

Moench, A.F., 1984. Double-Porosity Models for a Fissured Ground Water Reservoir with Fracture Skin. Water Resources Research, vol. 20, no. 7, p. 831-846.

Scott, R., and Castellanos, M., 1984. Preliminary Report on the Geologic Character of Drill Holes USW GU-3 and G-3. U.S. Geological Survey.

GEOTRANS COVER LETTER OF 85/02/21

ATTACHMENT C: SUMMARY OF GEOHYDROLOGIC DATA FOR TEST WELL UE-25p#1

Craig, R.W. and K.A. Johnson, 1984, Geohydrologic Data for Test Well UE-25p#1, Yucca Mountain Area, Nye County, Nevada, U.S. Geological Survey Open-File Report 84-450, 63 p.

Test well UE-25p#1 is located on the valley floor approximately 1.5 km east of Yucca Mountain, N 756,171 ft and E 571,485 ft (Nevada State Coordinate System Central Zone). Note that a ground surface elevation was not reported in this publication. Drilling of UE-25p#1 was completed May 24, 1983 at a total depth of 1,805 m below ground; the maximum vertical deviation was 8°45'. The hole, which was rotary-drilled with airfoam by Fenix and Scisson, Inc., was constructed with seven borehole diameter changes (76.2, 55.9, 37.5, 25.1, 17.5, 17.0, 16.0 cm), three casing diameter sizes (61.0, 40.6, 27.3 cm), and a liner-casing (19.4 cm). Circulation was lost during drilling at 570 m, 710 m, 1,173 m, and 1,391 m below ground.

According to the lithologic log, the hole penetrates the stratigraphic interval from the Rainer Mesa Member of Timber Mountain Tuff through the Tuffs of Yucca Flat. The upper most 45 m of the strata penetrated by the hole consists of alluvium; the hole bottoms out in the carbonates of the Lone Mountain Dolomite and Roberts Mountain Formation. Detailed data, such as mineralogy and degree of welding in the major lithostratigraphic units, are not presented with the lithologic information. The lithologic log indicates the presence of three faults at the base of (1) the Tiva Canyon Member of the Paintbrush Tuff, (2) the Tram Member of the Crater Flat Tuff, and (3) the Tuff of Yucca Flat of the Older Tuffs. The general distribution of welding in the lithostratigraphic units is presented in a data plot; no raw data on degree of welding are reported in this publication.

A number of geophysical surveys were conducted on UE-25p#1; however, only the survey dates and the intervals of the surveys are presented. Raw data and quantitative analyses of the geophysical surveys are not presented in this publication. A temperature log, which was made on June 23, 1983, is presented in this publication. The temperature log indicates a relatively steady increase in temperature from 35°C to 56°C with a depth interval of 400 m to 1,244 m (the Tertiary-Paleozoic contact). Minor fluctuations in the temperature occur between a depth interval from 400 m to 600 m. The temperature seems to level off to 56°C below the Tertiary-Paleozoic contact.

A total of 225 m was cored in this test well; the depth interval from 1,316 m to 1,502 m was continuously cored. Six core samples were collected over a depth interval from 1050.0 m to 1805.3 m with a total recovery of 83 percent. Raw data measurements and testing of the core samples are not presented in this publication.

The hydrologic testing program consisted of two separate phases of testing and water sampling. The first phase tested the Tertiary section to a depth of 1,197 m (or 1,301 m due to leaking of the temporary cement plug). The second phase tested the Paleozoic section in the depth interval of 1,297 m to 1,805 m. During the first testing program, the following tests were performed: one pumping and recovery test, two borehole flow surveys, 14 packer injection tests, and water chemistry sampling. During the second testing program, the following tests were performed: one pumping and recovery test, one borehole flow survey, 14 packer injection tests, and water chemistry sampling.

Water-level measurements were taken over large intervals to determine composite hydraulic heads for the Tertiary and Paleozoic sections. The composite water level for the Tertiary section was approximately 381 m below ground. The composite water level for the Paleozoic section was approximately 361 m below ground. Water levels were also measured over smaller intervals during packer injection tests. However, water-level measurements taken during packer injection tests in the Tertiary section may indicate an upward vertical flow; those taken in the Paleozoic section may indicate downward vertical flow.

Drawdown and recovery measurements were made in conjunction with the two separate pumping tests. The pumping test in the Tertiary section was conducted over the depth interval from the top of the saturated zone to 1,197 m (or 1,301 m due to probable leaking of the temporary plug). The well was pumped at a rate of 22 L/s for 3,150 minutes; maximum drawdown was 33.7 m. The pumping test in the Paleozoic section was conducted between the depth interval of 1,297 m to 1,805 m. The well was pumped at a rate of 31.5 L/s for 6,080 minutes; maximum drawdown was 9.3 m. Note that the discharge temperature of the water increased from approximately 30°C to 56°C within the first 50 minutes of pumping; the observed temperature increase approached a constant value of 56°C for the remainder of the test. Data plots of time versus drawdown or recovery are presented for each pumping test. Data and quantitative analyses of the pumping tests are not presented.

Three borehole flow surveys were conducted: one during each pumping test and one during a period of non-pumping in the Tertiary section above the temporary plug. The results of each borehole flow survey are presented in data plots; raw data are not reported. The borehole flow survey for the Tertiary section indicated that 58 percent of the water production came from the Prow Pass Member of the Crater Flat Tuff between the depth interval of 469 m to 501 m. This survey also shows that 28 percent of the water production came from the top of the temporary cement plug, which indicates that the plug was leaking. The non-pumping borehole flow survey indicates an upward movement of water within the well, primarily between the depth interval of 469 m to 501 m. This survey also indicated the flow at the temporary plug was more than 0.4 L/s. The borehole flow survey for the Paleozoic section indicated that approximately 63 percent of the water production came from the depth interval between 1,340 m to 1,362 m; approximately 95 percent of the water came from the depth interval between 1,300 m to 1,550 m.

Composite water samples were collected from the test well near the end of each pumping test. The chemical analyses of the water sample of the Tertiary section indicate: (1) a pH of 7.7; (2) a temperature of 44°C; and (3) 418 mg/L of total dissolved solids. Note that the results of the chemical analysis of the Tertiary section may not be representative of the section because 28 percent of the water may have been pumped from below the tested interval. The chemical analyses of the Paleozoic section indicate: (1) a pH of 7.2; (2) a temperature of 56°C; and (3) 878 mg/L of total dissolved solids.

USGS OFR 84-552

WMGT DOCUMENT REVIEW SHEET

FILE NO.:

ONWI NO.:

DOCUMENT: Rock Property Measurements on Large Volume Core Samples from Yucca Mountain USW GU-3/G-3 and USW G-4 Boreholes, Nevada Test Site, Nevada

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: December, 1984

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

Introduction

The report under review presents the results of electrical resistivity, induced polarization, porosity, bulk and grain density, and compressional sonic velocity measurements on core samples from test wells USW GU-3, USW G-3, and USW G-4 from Yucca Mountain. According to the report under review, the results of the measurements are intended for the use in the interpretation of in-hole and surface geophysical surveys as well as to provide a means for rock property characterization.

According to the report under review, core samples were collected so as to be representative of the major lithologic variations observed within the principal stratigraphic units; the cores were washed free of drilling mud, labeled to depth and vertical attitude, wrapped in aluminum foil, and coated with bees wax in an effort to minimize the loss of natural pore water during the period prior to rock property analysis. The method used to wash drilling mud from the cores is not mentioned in the report. It is not known whether or not water was used in this process.

The initial sample measurements consisted of electrical resistivity at 100 hertz, and bulk density. These measurements were made on natural state samples. However, according to the report under review the term "natural state" is not exact because of the likelihood that the pore water conductivity and content was altered by drilling and handling; the measured resistivity which varies with the conductivity and quantity of contained pore water may differ from that of the in place rock. After the natural state measurements were completed, the samples were dried, weighed, and then resaturated with local tap water in a partial vacuum for 72 hours. All measurements discussed in the report besides electrical resistivity and bulk density were made on resaturated samples.

Results of Laboratory Analysis of Borehole USW GU-3/G-3 Core Samples

Test well USW GU-3 was drilled to a total depth of 2,644 feet (806.1 m). Test well USW G-3 located approximately 100 feet (30.5 m) north-northeast of test well USW GU-3 was drilled to a total depth of 5,031 feet (1,533.8 m). According to the report under review, because of the close proximity of the two test wells, core from the two wells was treated as having been taken from a single continuous drill hole.

The two test wells penetrated the following formations in descending order: 1) the Tiva Canyon and Topopah Spring Members of the Paintbrush tuff, 2) the tuffaceous beds of Calico Hills, 3) Crater Flat tuff composed of the Prow Pass Member, the Bullfrog Member and the Tram Member, 4) the Lithic Ridge tuff, and 5) older tuffs. Ninety-eight core samples were taken from these formations which consist primarily of nonwelded to densely welded ash flow tuffs and bedded tuffs. According to the report, a total of seven of the cores disintegrated before the full suite of measurements could be completed.

Density and Porosity Measurements

Table 1 of the report under review lists the measured values of natural bulk density, saturated bulk density, dry bulk density, grain density, and porosity determined by the buoyancy method. Figure 2 of the report under review presents a plot of all the density values plotted against depth of origin. The natural bulk density values listed in table 1 are slightly lower than the saturated bulk density values. According to the report under review, the lower natural bulk density values are expected for samples obtained above the static water level; lower natural bulk density values for samples collected below the static water level suggests that pore water was lost by drainage or evaporation during sample acquisition.

The report under review suggests that variations between saturated bulk density and dry bulk density within the sampled section are mainly caused by porosity variations. This relationship is shown on figures 2 and 3 of the report; the report suggests that mineral alteration, pumice, lithic fragments, and phenocrysts of a large variety of minerals alter the density of many samples, obscuring and disrupting any direct correspondence between the saturated bulk density and porosity. According to the report under review, grain densities plotted on figure 2 are believed to vary primarily with pumice content.

Compressional Sonic Velocity

Table 1 of the report under review lists the porosities and compressional sonic velocities of the saturated core samples from test well USW G-3. These values are plotted in figure 3 of the report. According to the report under review, the values are relative velocities and do not take into account the effect of increasing lithostatic pressure with depth; the inverse correlation between porosity and sonic velocity shown in figure 3 of the report is not precise because physical rock characteristics such as texture, fractures, and fracture filling minerals also affect sonic velocity.

Electrical Measurements

Table 2 of the report lists the resistivity and induced polarization measurements made on core samples from test well USW G-3. Figure 4 of the report presents a plot comparing 100 hertz resistivity of natural state versus resaturated samples. According to the report under review, the fact that the resistivities of the resaturated samples are significantly higher for all Tiva Canyon samples indicates that the pore water resistivity in the natural state is lower than that of the water used for resaturation.

Samples from the interval between 435 feet to 1,360 feet (132.6 to 414.6 m) represent the Topopah Spring Member. According to the report under review, of the 18 Topopah Spring Member samples measured, five show higher resistivities following resaturation but in four of the five cases the resistivity values in both the natural and resaturated states are, within the limits of measurement accuracy.

Most of the Crater Flat tuff samples from both above and below the water table have saturated resistivity values lower than or about the same as the natural state resistivities. The natural state resistivities of the Lithic Ridge tuff and older tuff samples generally are lower than the resaturated resistivity values. Figure 5 of the report under review is a plot of induced polarization values for core samples from test well USW GU-3/G-3 plotted against depth of origin. According to the report under review, the induced polarization values are within the range typical of clay bearing rocks. The report notes that induced polarization data by themselves are not always definitive in outlining the zones of greatest clay or zeolite mineral concentrations because polarizable materials may produce an induced polarization response equal to that observed in clay-rich, high porosity rocks; examples of such occurrences can be seen in the Paintbrush sample group.

Results of Laboratory Analysis of USW G-4 Core Samples

Test well USW G-4 was drilled to a total depth of 3,001 feet (914.7 m). The test well penetrates the Tiva Canyon, Pah Canyon, and Topopah Spring Member of the Paintbrush tuff; the tuffaceous beds of the Calico Hills; the Prow Pass and Bullfrog Members of the Crater Flat tuff; and the upper section of the Tram Member of the Crater Flat tuff. A total of 46 core samples were taken from test well USW G-4.

Density and Porosity

Table 3 of the report under review lists bulk and grain density values for core samples from test well USW G-4. Density values versus depth of origin are plotted in figure 6 of the report. According to the report under review, the natural bulk density values above and below the 1,776-foot (542.5-m) static water level are equal to or slightly lower than the saturated bulk density values, which indicates that some loss of pore water occurred following the removal of the core from the borehole. The report indicates that variations in bulk density shown on figure 6 are primarily the result of porosity changes and variations in pumice content, and to a lesser degree fractures, alteration products, and accessory minerals.

Changes in grain density are interpreted in the report as being due to pumice fragments within the rock; however, measured grain density values of welded tuff are considered to approximate the true grain density of the mineral constituents of the rock. According to the report under review, grain densities are highest in the welded zones of the Crater Flat tuff because of a greater concentration of phenocrysts within the ground mass; the phenocrysts consist primarily of quartz, sanidine, plagioclase, hornblende, and biotite.

Porosity values of the core samples from test well USW G-4 are listed in table 3 of the report; a plot of porosity values versus depth of origin is presented in figure 7 of the report. The lowest porosities are associated with the densely welded tuffs of the Tiva Canyon and Topopah Spring Members of the Paintbrush tuff. Tuffaceous beds of the Calico Hills and Crater Flat tuff have porosities generally in excess of 20%; according to the report, individual units of the Crater Flat tuff have highly variable porosities indicating high variability in the level of welding within any one unit.

Compressional Sonic Velocity

An inverse relatiomship between the porosity and sonic velocity values for the core samples from test well USW G-4 is shown in figure 7 of the report. According to the report under review, the sonic velocity shows the Topopah Spring Member to be the most uniformly compacted section encountered within test well USW G-4.

Electrical Measurements

Table 4 of the report under review presents the results of resistivity and induced polarization measurements on core samples from test well USW G-4. Figure 8 of the report is a plot of natural state and resaturated sample resistivities made at 100 hertz. Most of the samples of the natural state resistivities are higher than the resaturated samples. The resistivities of samples from the tuffaceous beds of Calico Hills are exceptions to this rule. The report suggests that the conductivity of the in place pore waters in the Calico Hills is appreciably higher than the conductivity of the water used for resaturation; the author suggests also that it is possible that ions contained in the pore waters of these high porosity rocks diffused into the surrounding water bath following the saturation process. Induced polarization values for the core samples from test well USW G-4 are plotted in figure 9 of the report. As with the induced polarization values for test well USW GU-3/G-4, the values for test well USW G-4 were converted to specific capacity. These values are plotted in figure 9 of the report. The report under review suggests that variability in the specific capacity data likely is due to changes in the degree of welding and levels of silicification. The report suggests also that the amplitude of the specific capacity cannot be relied upon as an indicator of the quantity of clays or zeolites within the rock.

Discussion

According to the report under review, the patterns of variation shown on the plots of density, resistivity, and compressional sonic velocity follow closely the plot of porosity, indicating a dependence upon textural rather than compositional changes within the rock; low porosities are associated with welded and silicified tuffs whereas higher porosities are an indication of nonwelded or bedded tuffs.

To test the premise that density, resistivity, or sonic velocity is suitable for characterizing the nature of the rock under investigation, a least squares fit line was fitted to the saturated bulk density/porosity relationship for each borehole sample set. Figure 10 of the report shows the lines of regression for test wells USW G-3 and USW G-4 sample sets. The report suggests that deviations from the fitted line primarily are caused by pumice content and rock fractures.

Figure 11 of the report is a least squares fit between the compressional sonic velocity and porosity data. The report under review suggests that fractures, lithophysal cavities, and lithic fragments contained within the rock are the cause of the scatter of the points on figure 11; the degree to which porosity can be determined reliably from a velocity log is largely dependent upon the homogeneity of the formation.

According to the report under review, no linear trend could be established between resistivity and porosity; data for test well USW G-4 can be fitted to a power curve with a high degree of success but data from test well USW G-3 produced poor results when subjected to the sample curve fitting procedure (figure 12 of the report).

The report under review notes that the fracture porosity within the Paintbrush tuff is of primary significance compared to the matrix porosity; poorly welded tuffs in the underlying tuffaceous beds of Calico Hills and Crater Flat tuff have water accessible porosity in the 20 to 40% range which is significant for ground water movement. The report suggest that the abundance of zeolites in these lower formations is sufficient to retard the migration of dissolved radionuclides in the event the wastes should come in contact with the ground water.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

Significance in EAs:

The report under review was not referenced in the draft EA. It is anticipated that the report under review will be referenced in the final EA.

Significance in Overall Licensing Process:

The report under review constitutes a primary source of information pertaining to rock properties in test wells USW GU-3, USW G-3, and USW G-4.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

The report under review presents the results of electrical resistivity, induced polarization, porosity, bulk and grain densities, and compressional sonic velocity measurements on core samples from test wells USW GU-3, USW G-3, and USW G-4. The purpose of the report is to present the results of these measurements for use in the interpretation of borehole and surface geophysical surveys and to provide a means for rock property characterization that is not normally possible with conventional borehole techniques. The report does not have any serious problems, deficiencies or limitations with respect to this purpose. However, the report would be of more value to the NRC if the data presented in the report were presented along with borehole and surface geophysical survey data in a single comprehensive document.

SUGGESTED FOLLOW-UP ACTIVITY:

The report under review has not been referenced in the draft EA. Therefore, the potential significance of the report with respect to contentions presented in the EA remains uncertain. No specific follow-up activity can be suggested until the significance of the document becomes known.

REFERENCES CITED:

WMGT DOCUMENT REVIEW SHEET

FILE NO.:

ONWI NO.:

DOCUMENT: Geological and Geophysical Evidence of Structures in Northwest-Trending Washes, Yucca Mountain, Southern Nevada, and Their Possible Significance to a Nuclear Waste Repository in the Unsaturated Zone

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: December, 1984

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

The report under review presents evidence for the origin of Drill Hole, Teacup, Pagany, Sever, and Yucca Washes in the northeastern part of Yucca Mountain. These washes are unusually long and linear. Four of the washes are incised as deeply as 150 m into the bedrock of Yucca Mountain. Teacup Wash is the straightest of the washes; linear segments of Teacup Wash have an average trend of N36°W. Sever, Pagany and Drill Hole Washes trend N33°W, N38°W, and N48°W, respectively. Yucca Wash is incised deeply into bedrock for 8 km and has an average trend of N50°W. Trends for these washes are similar to dip directions for ash flow strata, between S30°E and S75°E. The dip direction is not truly parallel to the washes, however, but is offset about 10° in a more easterly direction. According to the report under review, previous explanations for northwest trending washes reached differing conclusions. One explanation for the washes was based upon the observation of the subparallel trends of drainage and dip of bedrock; the linearity of the washes was assumed to be a consequence of the initial slope of the volcanic plateau. Published maps identified few faults in (or) parallel to the washes. Aeromagnetic surveys have not located faults with significant vertical displacements along the washes. According to the report under review, a second explanation assumed a structural control of the linear washes and required faults buried by alluvium along the washes. Dipole-dipole resistivity surveys and electromagnetic Slingram surveys of relative conductance indicated northwest striking faults buried beneath

Drill Hole Wash. Previous investigations of core from drill holes in Drill Hole Wash provided evidence of fractures or faults parallel to the wash. According to the report under review, the resolution of these differing conclusions of the origin of the northwest trending washes is the primary purpose of the report.

Evidence for Faults within Northwest-Trending Washes

Surface Evidence

Detailed mapping by Scott and Bonk (1984) detected numerous faults parallel to the northwest trending washes. These faults are shown under figure 2 of the report under review; stratigraphic control used during mapping has established that vertical displacements greater than 10 m do not exist on faults beneath the wash alluvium.

The report under review notes that there is an abrupt change in the attitude of the ash flow tuffs on the north and south sides of Drill Hole Wash. According to the report under review, paleomagnetic measurements indicate that there has been little or no relative structural rotation of the area since emplacement of the Tiva Canyon Member. The report under review offers the following two possible explanations for the observed change in strike: 1) the dips are a depositional feature, 2) the dips were created by small amounts of rotation around different horizontal or subhorizontal axes. According to the report under review, the alternatives cannot be distinguished by paleomagnetic results because the dips are smaller than the paleomagnetic resolution; however, the absence of faults parallel to the northeast strike directions suggests a depositional explanation.

Subsurface Evidence

Spengler and others (1979), Spengler and Rosenbaum (1980), Spengler and others (1981), and Rush and others (1983) reported many structural stratigraphic and petrographic features from cores from drill holes UE-25A#1, #4, #5, #6, and #7, USW G-1, and USW H-1, in the vicinity of Drill Hole Wash. According to the report under review, additional information from cores from drill hole USW H-1, USW G-4, and reentry drill hole UE-25A#7 were used to evaluate the structure of the northwest trending washes. Spengler and Rosenbaum (1980) observed no detectable relative vertical displacements of strata between drill holes UE-25A#4, #5, #6, and #7, and no pervasive alteration of tuffs; however, they did observe steeply dipping faults striking N30°W in drill hole UE-25A#4 near the northeastern margin of Drill Hole Wash. According to the report under review, a 10 m wide brecciated zone was detected in core in the depth interval from 254 m to 274 m during reentry of slanted hole UE-25A#7. However, the projected position of the shear zone is close to the southeastern margin of Drill Hole Wash.

According to the report under review, the attitudes of strata of the Topopah Spring Member at drill holes UE-25A#4, #5, and #7 within Drill Hole Wash are different from those at drill hole UE-25A#6 outside the wash; these differences were interpreted incorrectly to indicate a left lateral strike slip fault along the southwestern margin of the wash and counterclockwise rotation of the Topopah Spring Member underlying Drill Hole Wash. The report under review notes that subsequent paleomagnetic studies of oriented core from drill holes USW G-1, G-2 and GU-3 as well as samples collected from the surface demonstrate that the remanant directions within the Topopah Spring Member change markely with depth; the declination of the mean remanant direction from UE-25A#6, and to a lesser extent from USW H-1, deviates from that at other sampling sites. According to the report under review, this difference indicates that the earlier interpretation, that the Topopah Spring Member within Drill Hole Wash had been rotated, was incorrect. According to the report under review, a nearly vertical shear zone within the moderately to densely welded Topopah Spring Member was identified from core from USW H-1 at depths between 132.3 m and 133.8 m; all the subsurface fault zones described occur in the moderately to densely welded Topopah Spring Member; an interconnecting network of voids may exist where fracture planes are only partially coated with calcite. According to Spengler and others (1981), this partial calcite filling leaves apertures open as wide as 2 to 4 cm within fractures in the wash; however, these aperture sizes rarely occur in this stratigraphic level in drill holes outside Drill Hole Wash. According to the report under review, preliminary results indicate that transmissivities and hydraulic gradients within rocks below the wash are not significantly different from rocks outside the wash; no evidence exists at this time to indicate that ground water flow is concentrated beneath washes more than elsewhere in Yucca Mountain.

<u>Geophysical Evidence</u>

According to the report under review, electromagnetic Slingram surveys that measure relative conductance and direct current surveys that provide dipole-dipole resistivity and induced polarization data support the presence of northwest striking faults. Data from three dipole-dipole and induced polarization survey lines that traversed Drill Hole Wash from southwest to northeast (Hoover, <u>in</u> Smith and Ross, 1982) were used to calculate average resistivities for a horizon 50 m below the wash, well below alluvial depths. According to the report under review, the average resistivities on the southwestern side of Drill Hole Wash along the three traverses range from 695 to 3,860 ohm-m, those within the wash range from 300 to 565 ohm-m, and those on the southeastern side of the wash range from 585 to 1,380 ohm-m. Resistivities are significantly lower in the wash. Figure 6 of the report under review, shows two zones of relatively high conductance parallel to the wash that were detected by five electromagnetic Slingram survey lines. The two zones are interpreted as faults.

According to the report under review, an aeromagnetic survey has located major barrier structures. These structures are interpreted as normal faults with at least 70 m of vertical displacement (Bath and Jahran, 1984). Five major north striking faults were identified by these anomalies at Yucca Mountain; these faults were also located by mapping where exposed. These faults are the Windy Wash, Fatigue Wash, Solitario Canyon, Bow Ridge, and Paintbrush Canyon Faults (figure 2 of the report). According to the report under review, the positions of normal faults interpreted from aeromagnetic surveys compare very well with those interpreted from the electromagnetic surveys.

According to the report under review, linear ground magnetic anomalies along the sides of Drill Hole Wash near drill hole USW G-1 are interpreted as edge effects created by erosion of the Tiva Canyon Member along the wash (figures 7a and 7b of the report under review); aeromagnetic anomalies present along Drill Hole, Teacup, and Pagany Washes also are explained by erosion of the reversely magnetized Tiva Canyon Member along the washes. The report under review indicates that an aeromagnetic anomaly along Yucca Wash cannot be explained by topographic effects alone. The report suggests that the anomaly probably arises either from the distal ends of rhyolite flows in the tuffaceous beds of Calico Hills that underlie the Topopah Spring Member, faults in the Crater Flat tuff beneath the tuffaceous beds, or a combination of both effects.

Character of Northwest-Striking Faults

The north-northeast striking fault crossing Drill Hole Wash near the lower end of Teacup Wash has about 5 m of offset (figure 2 of the report under review). Spengler and Rosenbaum (1980) used drill hole stratigraphic control in the vicinity of drill holes UE-25A#1, #4, #5, #6, and #7 to calculate a least squares fit of the plane of the base of the Tiva Canyon Member; with a 95% confidence level, they stipulate that no fault with greater than 4 m of vertical offset is possible between these drill holes. According to the report under review, no vertical offsets were detected across Drill Hole, Teacup, Pagany, Sever, or Yucca Washes (figure 8 of the report under review).

According to the report under review, the Teacup Wash Fault, Sever Wash Fault, Drill Hole Wash Fault, and Pagany Wash Fault, shown on figure 2 of the report, are geometrically required to have right lateral slip because their northeast sides are upthrow relative to their southwest sides. One northwest-striking fault in the upper portion of Teacup Wash underwent as much as 30 m of vertical displacement, down to the northeast.

According to the report under review, a zone of intense fracturing occurs within the densely welded ash flow tuffs on either side of the Sever Wash Fault. This zone is 20 to 30 m wide. The fault strikes about north 35°W and the fractures strike about N15° to N5°W.

According to the report under review, several large normal faults such as the Solitario Canyon and Paintbrush Canyon Faults have a long history of movement. The modern stress field indicated by earthquake focal mechanism solutions suggests that right lateral movement on northwest-striking faults is no longer active. In the past, most of the displacement on these normal faults has been dip slip, but more recently left lateral slip dominates on northeast-striking normal faults (Carr, 1974).

Significance of the Northwest-Trending Washes to Nuclear Waste Isolation

According to the report under review, the presence of north slip faults and fractured zones in northwest trending washes in the northeastern part of Yucca Mountain may not create adverse containment or isolation conditions for nuclear waste stored in the unsaturated zone. However, the report notes that such faults form conduits of high hydraulic conductivity and thus may be significant to the flow of ground water in the saturated zone. Surface exposures of strike slip faults and of strutures within drill cores in the Yucca Mountain area indicate that fault zones buried in the washes may be characterized by wide zones (20 m or more) of breccia with apertures as much as 4 cm wide, or they may be characterized by very narrow zone of fault gouge. The report under review suggests that the most significant hydrologic aspect of the fault zones within both the unsaturated and saturated zones may be roles as major conduits for recharge under washes; however, initial hydrologic studies of drill holes along Drill Hole Wash indicate that ground water flow in rocks beneath the wash is not significantly different from that estimated from tests of drill holes outside the wash. The report under review makes note of the fact that potentially adverse mining engineering conditions may be encountered along the northwest striking fault zones.

Conclusions

According to the report under review, the northeast boundary of the potential nuclear waste repository need not exclude northwest trending washes and associated structures, particularly if the repository target zone is within the unsaturated rocks. Roseboom (1983) discussed the possibility that faults or fractures within the unsaturated zone may act as conduits to transport infiltrating surface waters rapidly away from emplaced tunnels following heavy precipitation events. Subsurface characteristics of the northwest strike slip faults may provide such conduits within the Topopah Spring Member. In the saturated rocks below the water table, zones of high hydraulic conductivity are likely to be associated with these faults, adversely affecting flow paths and ground water travel times to the accessible environment. However, the absence of significant differences between the hydrologic flow properties of the saturated zone below Drill Hole Wash and those properties of the saturated zone elsewhere in Yucca Mountain suggest that the repository boundary may be extended to include washes northeast of Drill Hole Wash without compromising radionuclide isolation goals.

Recommendations

The report under review makes the following recommendations for future characterization of the area northeast of Drill Hole Wash: 1) slant holes should be drilled through the fault zones using oriented core techniques, 2) several of these holes should be drilled in unsaturated rocks above the water table to intersect fault zones in the densely welded Topopah Spring Member; other holes should be designed to intersect the unsaturated zone in the tuffaceous beds of Calico Hills below the Topopah Spring Member; 3) several holes should be drilled to intersect fault zones in saturated rocks below the water table in both moderately welded to densely welded tuff and in nonwelded to partially welded tuff; 4) hydraulic testing in these holes should be performed within the fault zones in the saturated rocks; 5) one lateral exploration drill hole, or preferably, one mine drift, should be constructed from the exploratory shaft across Drill Hole Wash in order to evaluate potential mining stability problems; 6) further resistivity surveys should be designed to explore the nature of strike slip faults within the northeastern part of Yucca Mountain to determine if the magnitude of the resistivity decreases or increases can be correlated with the degree of fracturing or alteration along the faults studied by drilling.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM

Significance in EAs:

Reference to the report under review occurs in Section 6.3.1.1. Geohydrology (10CFR 960.4-2-1) of the draft EA. The report is referenced specifically under the subheading Relevant Data on pages 6-98, 6-104, and 6-114. Reference to the report under review in the draft EA occurs with respect to the statement "Attitudes of faults and fractures at depth in drill holes are similar to those on the surface" and with respect to the statement that "The major fault and fracture zones that might enhance downward flow are located at the boundaries of the repository".

Significance in Overall Licensing Process:

This report constitutes a primary source of information with respect to the location and origin of geologic structures in the northeastern part of Yucca Mountain. Information contained in the report may become significant with respect to radionuclide travel times from the proposed nuclear waste repository. The interpretations of the origin of the northwest trending washes presented in the report under review may become significant with respect to the locations of the boundaries of a potential high level nuclear waste repository at Yucca Mountain.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

The primary purpose of the report under review was to resolve the differing conclusions of the origin of the northwest-trending washes. The report presents three lines of evidence that suggest that faults occur beneath Quaternary alluvium in the northwest-trending washes in the northeastern part of Yucca Mountain. These lines of evidence are as follows: 1) surface geologic evidence based on detailed mapping, 2) subsurface geologic evidence based on study of cores from drill holes near Drill Hole Wash, and 3) geophysical investigations based on Slingram electromagnetic surveys and dipole-dipole resistivity surveys. The main limitation of the report is that much of the evidence suggesting the presence of faults within the northwest-trending washes is based on subjective interpretation of the available data. In several situations more than one possible explanation is presented to explain the observed features. An example of this occurs on page 8 of the report where two possible explanations for the observed change in strike of the Tiva Canyon Member on either side of Drill Hole Wash are presented. These explanations are: 1) the dips are a depositional feature, and 2) the dips were created by small amounts of rotation around different horizontal and subhorizontal axes. An example of the subjective interpretation of the data occurs on page 15 of the report under review. The report states that aeromagnetic survey lines have also located a strong anomaly along Yucca Wash that, unlike the aeromagnetic anomalies along the Drill Hole, Teacup, Pagany, and Sever Washes cannot be explained by topographic effects alone. The report states "probably the anomaly arises either from the distal ends of rhyolite flows in the tuffaceous beds of Calico Hills that underlie the Topopah Spring Member, from faults in the Crater Flat tuff beneath tuffaceous beds, or a combination of both effects." This type of uncertainty is the major limitation of the report.

According to the report under review, recognition of both northwest-striking faults and north to northeast-striking faults in the area characterized by the northwest-trending washes is difficult where vertical offsets are less than 3 m. The report notes that the difference in orientation of rocks on either side of Drill Hole Wash makes detection of minor faults within the alluvium of the wash particularly difficult.

The authors of the report under review realize that the report is limited by the data that are available. The authors present six recommendations to increase the data base. Collection of the recommended data should reduce the uncertainty of many of the interpretations presented in the report.

SUGGESTED FOLLOW-UP ACTIVITY:

The report under review and the references cited in the report should be reviewed in detail by the NRC if the boundaries of the proposed waste repository coincide with the geologic structures identified in the vicinity of the northwest-trending washes.

REFERENCES CITED:

Bath, G.D., and Jahran, C.E., 1984, Interpretations of Magnetic Anomalies at a Potential Respository Site Located in the Yucca Mountain Area, Nevada Test Site: U.S. Geological Survey, Open-file Report 84-120, 40 p.

Carr, W.J., 1974, Summary of Tectonic and Structural Evidence for Stress Orientation at the Nevada Test Site: U.S. Geological Survey, Open-file Report 74-176, 53 p.

Roseboom, E.H., Jr., 1983, Disposal of High Level Nuclear Waste Above the Water Table in Arid Regions: U.S. Geological Survey, Circular 903, 21 p.

Rush, F.E., Thordarson, Williams, and Bruckheimer, Bara, 1983, Geohydrologic and Drill Hole Data for Test Well USW H-1, Adjacent to Nevada Test Site, Nye County, Nevada: U.S. Geological Survey, Open-file Report 83-141, 38 p.

Scott, R.B., and Bonk, Gerry, 1984, Preliminary Geologic Map of Yucca Mountain with Geologic Sections, Nye County, Nevada: U.S. Geological Survey, Open-file Report 84-494, in press.

Smith, Christiansen, and Ross, H.P., 1982, Interpretation of Resistivity and Induced Polarization Profiles with Severe Topographic Effects, Yucca Mountain Area, Nevada Test Site, Nevada, with an Introduction by D.B. Hoover: U.S. Geological Survey, Open-file Report 82-182, 19 p.

Spengler, R.W., Muller, D.C., and Livermore, R.B., 1979, Preliminary Report on the Geology of Drill Hole UE25A-1, Yucca Mountain, Nevada Test Site: U.S. Geological Survey, Open-file Report 79-1244, 43 p.

Spengler, R.W., Byers, F.M., Jr., and Warner, J.B., 1981, Stratigraphy and Structure of Volcanic Rocks in Drill Hole USW G-1, Yucca Mountain, Nye County, Nevada: U.S. Geological Survey, Open-file Report 81-1349, 36 p.

Spengler, R.W., and Rosenbaum, J.G., 1980, Preliminary Investigations of Geologic Results Obtained from Boreholes UE25A-4, -5, -6, and -7, Yucca Mountain, Nevada Test Site: U.S. Geological Survey, Open-file Report 80-929, 33 p.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT: Muller, D.C., and Kibler, J.E., 1984, Preliminary Analysis of Geophysical Logs from Drill Hole UE-25p#1, Yucca Mountain, Nye County, Nevada: USGS Open-file Report 84-649, Denver, 14 p.

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: November 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

The purpose of the report under review is to present a preliminary analysis of the geophysical logs recorded for test well UE-25p#1. Pages 1 through 8 of the report under review describe the geophysical logs that were recorded in the test hole. The limitations of each of the geophysical logs are described also.

The geophysical logs were interpreted in the report under review to indicate that the Topopah Spring Member contains lithophysal and is highly fractured. The report under review concludes, based on uranium levels in the Topopah Spring Member, that the majority of fractures are open and unfilled. The report notes that fracture analysis of core from other drill holes (Spengler and others, 1979; Spengler and others, 1981) indicates also that most of the fractures in the Topopah Spring Member are open. The report under review notes also that the geophysical logs of the Tertiary tuffs encountered in drill hole UE-25p#1 correlate well with logs from other drill holes in the Yucca Mountain area reported by Daniels and Scott (1981), Hagstrum and others (1980), Muller and Kibler (1983), and Spengler and others (1979).

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents a preliminary analysis of the geophysical logs recorded in test well UE-25p#1. The data presented in the report under review are important with respect to the correlation of geophysical logs between test holes and wells at the Yucca Mountain site.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

The primary deficiency of the report under review is that the report presents a very basic interpretation of the geophysical logs. The report does not present any information in support of the conclusion that the geophysical logs recorded in test well UE-25p#1 correlate well with the logs from other drill holes in the Yucca Mountain area. This conclusion is very important with respect to the correlation of fracture zones or "aquifers" throughout the Yucca Mountain area.

SUGGESTED FOLLOW-UP ACTIVITY:

The geophysical logs and interpretations presented in the report under review may be significant in the development of a conceptual model for the saturated zone and the unsaturated zone. Attempts should be made to correlate borehole geophysical logs with borehole flow survey logs for each borehole in the Yucca Mountain area.

REFERENCES CITED:

Daniels, J.J., and Scott, J.H., 1981, Interpretation of Geophysical Well Logs from Drill Holes UE25A-4, -5, -6, and -7: USGS Open-file Report 81-389, 46 p.

Hagstrum, J.T., Daniels, J.J., and Scott, J.H., 1980, Interpretation of Geophysical Well Log Measurements in Drill Hole UE25A-1, Nevada Test Site, Radioactive Waste Program: USGS Open-file Report 80-941, 32 p.

Muller, D.C., and Kibler, J.E., 1983, Commercial Geophysical Well Logs from the USWG-1 Drill Hole, Nevada Test Site, Nevada: USGS Open-file Report 83-321, 7 p.

Spengler, R.W., Byers, F.M., Jr., and Warner, J.B., 1981, Stratigraphy and Structure of Volcanic Rocks in Drill Hole USW-G-1, Yucca Mountain, Nye County, Nevada: USGS Open-file Report 81-1349, 50 p.

Spengler, R.W., Muller, D.C., and Livermor, R.B., 1979, Preliminary Report on the Geology of Drill Hole UE25A-1, Yucca Mountain, Nevada Test Site: USGS Open-file Report 79-1244, 43 p.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OF-84-672

DOCUMENT: Healey, D.L., Clutsom, F.G., and Glover, D.A., 1984, Borehole Gravity Meter Surveys in Drill Holes USW G-3, UE-25p#1, UE-25c#1, Yucca Mountain Area, Nevada: USGS Open File Report 84-672, Denver, 16 p.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: July 16, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E. Williams

The report under review presents data collected during borehole gravity meter surveys in drill holes USW G-3, UE-25p#1, and UE-25c#1. The report is a basic data report which presents measurements obtained during the surveys and a description of the methodology used to collect the data. The information contained in the report should be of primary interest to mining engineers involved in the evaluation of shaft and repository construction.

BRIEF SUMMARY OF DOCUMENT:

The purpose of the investigation described in the report under review was to measure the in-situ bulk densities of the stratigraphic units penetrated by drill holes USW G-3, UE-25p#1, and UE-25c#1. A "LaCoste and Romberg Slim hole borehole gravity meter (BHGM) BH-6 was used to log each of the holes logged to date at Yucca Mountain." According to the report, drill hole USW H-1 also was logged with the borehole gravity meter as part of this investigation but at an earlier date (Robbins, Schmoker, and Hester, 1982).

According to the report, the borehole gravity meter is primarily a density logging tool with a larger radius of investigation than conventional logging tools. According to the report, the borehole gravity meter survey provides an independent measure of the in-situ bulk density of the rocks surrounding the drill hole.

Gravity observations obtained by the borehole gravity meter are corrected for the effects of earth tides, instrument drift, and terrain. Gravity data are corrected for the effects of earth tides and instrument drift by the computer program BHGRAV.77. The data reduction program makes terrain corrections from digitized topography determined by hand from topographic maps and from sketches of the drill site.

In order to determine the true bulk density, the free air gradient must be measured. The free air gradient is determined from the following relationship:

$$F = \frac{\Delta g + TC}{\Delta H}$$

where F is equal to the free air gradient, Δg is the difference in gravity (mGal) measured on the ground and at some point above the ground, TC is the difference in the terrain correction between the two points, and ΔH is the vertical distance separating the two points.

Tables 2, 3, and 4 of the report show the stratigraphic units penetrated by drill holes USW G-3, UE-25p#1, and UE-25c#1. Tables 5, 6, and 7 of the report present the in-situ integral bulk densities calculated from the borehole gravity meter data.

Forty-eight gravity observations were made between the depths of 15.24 and 665.99 meters in drill hole USW G-3. According to the report, windy conditions prevented measurement of the free air gradient. Therefore, the data for USW G-3 were reduced using the "normal" value of 0.3086 mGal/m for the free air gradient.

Ninety-one gravity observations were made between the depths of 27.43 m and 1972.22 m in drill hole UE-25p#1. The measured free air gradient at drill hole UE-25p#1 was 0.3146 mGal/m. This free air gradient is 1.8% higher than the assumed "normal" value. According to the report, a fault was penetrated at a depth between 1,191.77 meters and 1,244.19 meters. Gravity and gamma ray logs represent the only reliable data that were obtained in this interval. According to the report, the results of an investigation of this fault will be presented in a "planned interpretation report of the borehole gravity meter data."

Forty-eight gravity meter observations were made between the depths of 19.81 and 900.68 meters in drill hole UE-25c#1. The measured value of the free air gradient was 0.3116. This value is 0.97% higher than the "normal" value. According to the report, this difference is significant and if the incorrect value was used in tonnage calculations for mining purposes an error of about 2% could result.

The report presents the following conclusions and recommendations:

1) Borehole gravity meter surveys at Yucca Mountain provide excellent density data. However, the free air gradient must be measured at or near each logged hole.

2) Additional holes at Yucca Mountain should be logged with the borehole gravity meter, especially those holes close to the proposed shaft and repository.

3) A pilot hole at the shaft site should be considered. Borehole gravity meter and gamma gamma logs should be recorded for this pilot hole.

4) Geologic structure adjacent to a drill hole may be evaluated by comparing borehole gravity meter logs and gamma gamma density logs.

5) The borehole gravity meter is a useful tool and should be utilized fully to help resolve the problems that remain regarding the structural setting at Yucca Mountain.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents valuable data with respect to density measurements of stratigraphic units penetrated by test holes USW G-3, UE-25p#1, and UE-25c#1. Data presented in the report should be of primary interest to mining engineers in the evaluation of shaft and repository construction. In addition, the borehole gravity meter may prove to be a valuable tool for use in measuring porosity and in delineating faults in the subsurface.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review is a basic data report. According to the report an interpretation report of the borehole gravity meter data is planned. The report under review describes the methods used to collect the density data. The report has no significant problems, deficiencies or limitations.

SUGGESTED FOLLOW-UP ACTIVITIES

We suggest that the planned companion report that will present interpretations of the borehole gravity meter data be reviewed by the NRC staff involved with the evaluation of shaft and repository construction. Information presented in this planned report also may be of value with respect to evaluation of porosity values.

REFERENCES:

Robbins, S.L., Schmoker, J.W., and Hester, T.C., 1982, Principal Facts and Density Estimates for Borehole Gravity Stations in Exploratory Wells UE 4ah, UE 7j, UE1h, UE1q, UE2co, USW-H1 at the Nevada Test Site, Nye County, Nevada: USGS Open File Report 82-277, 33 p.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OF-84-848 , UCRL-15667

DOCUMENT: Permeability and Fluid Chemistry Studies of the Topopah Spring Member of the Paintbrush Tuff, Nevada Test Site, Part II. D.E. Moore, C.A. Morrow and J.D. Byerlee, U.S.D.I. Geological Survey

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: May 28, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

This report is a continuation of work done previously by the same authors. The work concerns the effect of heat on permeability and on the chemical composition of water flowing through samples of tuff. Three cylindrical samples of Topopah Springs tuff were used in this study. Permeability was determined by measuring radial flow in the cylinder under a small pore pressure gradient. A temperature gradient also was maintained radially outward form the center of the core. The results show essentially no change of permeability with respect to pore pressure, orientation, temperature changes or temperature gradient. The observed slight decrease of pH with time may be due to the progressive removal of salt deposits from the tuff.

BRIEF SUMMARY OF DOCUMENT:

This document reports on an extension of work done previously by the same authors concerning the effect of heat on permeability and on the chemical composition of water flowing through samples of tuff. The present experiment was conducted on three samples of the Topopah Spring Member of the Paintbrush tuff. The samples were cylindrical cores containing a central borehole in which a resistance heater was placed to produce a temperature gradient between the center and the outside of the rock. Water flowed radially due to a small pore pressure gradient applied between the center and the outside of the core. The borehole temperature in all cases was maintained at 150°C: the jacket temperature was held at approximately 44°C. All three samples were run with a pore pressure of 10 bars: This pressure represents the pressure at a depth of 100 m below the water table. The flow through two samples was perpendicular to the bedding planes but flow was parallel to the bedding planes in the other sample. The initial permeability at room temperature varied from .85 to 10 microdarcies in the three samples. Initial values of .5 to 3 microdarcies occurred when heating began. The permeability experiments were continued for a period of 10 to 16 days at which time little additional change in the permeability was occurring. The chemical analysis of water samples showed that in general a decrease of pH of water with time occurred, along with slight changes of chemical species contents. The authors conclude that the combination of heat and fluids has little effect on the permeability of the tuff. During the time of the experiments almost no permeability changes were observed. The results are independent of confining and pore pressure and of sample orientation. Changes in temperature and direction of fluid flow relative to the temperature gradient also had no observed effect on permeability. The authors also conclude that the decrease in pH with time during each experiment may be related to the progressive removal of the salt deposits or saline pore fluids from the tuff. The concentrations of chemical constituents in the water in general decreased with time.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

Some information in this report may be significant for the analysis of flow through the Topopah Springs unit. However, it must be noted that the present work was done under a pore pressure of the equivalent of approximately 100 m of water while the repository in the Topopah Springs Member would be in the unsaturated zone well above the water table.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The limitation is that this work was done under a pore pressure of 10 bars or 100 m of water, not under unsaturated conditions. As stated above the repository will be in the unsaturated zone well above the water table.

SUGGESTED FOLLOW-UP ACTIVITIES

No response is necessary concerning this report.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OFR-84-789

DOCUMENT: Spengler, R.W., Chornack, M.P., Muller, D.C., and Kibler, J.E., 1984, Stratigraphic and Structural Characteristics of Volcanic Rocks in Core Hole USW G-4, Yucca Mountain, Nye County, Nevada. USGS Open-file Report 84-789, Denver, 77 p.

REVIEWER: Williams & Associates, Inc., James L. Osiensky

DATE REVIEW COMPLETED: January 6, 1987

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

The report under review presents significant stratigraphic and structural data on the volcanic rocks penetrated by core hole USW G-4. The core hole is located approximately 91 m southwest of the proposed exploratory shaft within Yucca Mountain. The report contains a significant amount of data pertaining to fractures penetrated by core hole USW G-4. These data are described from a geologic viewpoint; however, the data may be very useful in helping to formulate conceptual models of flow in the unsaturated zone at Yucca Mountain. The data also should be useful with respect to interpreting data from the exploratory shaft. In addition to descriptions of fractures penetrated by the core hole, a very brief description of the geophysical logs recorded in the hole is presented in the report.

BRIEF SUMMARY OF DOCUMENT:

The report under review describes the results of stratigraphic and structural characteristics of volcanic rocks in core hole USW G-4. The purpose of the report "is to describe subsurface lithologic, stratigraphic, and structural features recognized in the nearly continuous core recovered from core hole USW G-4, located approximately 300 ft southwest of the proposed site of the exploratory shaft." According to the report, the primary objectives of this investigation were to compare the geologic and hydrologic conditions at core hole USW G-4 with those identified in boreholes UE-25a#1, USW G-1, and UE-25a#6 within the immediate vicinity. An additional objective was to study the geologic and geophysical characteristics to help in the design and construction of the exploratory shaft.

Core hole USW G-4 was located approximately 300 ft from the proposed shaft location to preclude potential alteration of the natural state of rock in the vicinity of the exploratory shaft. The authors of the report considered 300 ft to be far enough from the shaft site, "but close enough to allow confident projection of geologic data." USW G-4 was drilled with an air-foam drilling medium to avoid the excessive losses of drilling fluid that were common during drilling of other holes in the vicinity.

Drilling began on August 22, 1982. Significant drilling problems were encountered at several locations within the borehole. The first problem occurred between the depths of 71 m and 135 m. According to the report, this interval corresponds roughly to the upper 64 m of the moderately to densely welded Topopah Spring Member. It is reported that within this section the core barrel became lodged in the hole due to unstable hole conditions. Once this problem was eliminated, coring resumed to a depth of 138 m where circulation was lost; at this depth, 15 m of drill string and a 3 m core barrel were lost in the hole. According to the report, most of the drilling tools were recovered except for the core barrel and the bit. No core was collected between 138 m and 143 m.

After a two-week delay, coring resumed on September 26 and continued to 304 m where the bit crown was lost in the hole. This problem required enlargement of the hole to a diameter of 16.9 cm and installation of 13.8 cm casing. Coring continued into the tuffaceous beds of the Calico Hills to a depth of 526 m where failure of a booster pump resulted in loss of part of the drill string. Once again the hole was enlarged to recover the drilling equipment. Coring was completed at a depth of 915 m on November 7, 1982. According to the report, geophysical logging was completed by the end of November and the hydrologic testing program was completed on January 12, 1983.

According to the report, rock units penetrated by USW G-4 consist predominantly of rhyolitic to quartz latitic ash flow tuff. These ash flow tuffs are separated in places by layers of tuffaceous sediments and ash flow tuff which range from about 0.8 m to 17 m in thickness. Table 2 of the report lists the geologic units identified in the core hole.

The Topopah Spring Member is 359 m thick in core hole USW G-4. According to the report, the thick welded and devitrified part of the Topopah Spring Member is present between the depths of 74 m and 401.3 m. Figure 4 of the report shows the vertical distribution of lithophysae, lithophysal cavities, and percent voids within the densely welded zone of the Topopah Spring Member. According to the report, "the rock from 343.8 m to the top of the basal vitrophyre contains very few or no lithophysae and it is this subunit of the Topopah Spring Member that is currently being studied by the DOE for at-depth evaluation in the exploratory shaft as a potential host rock for emplacement of nuclear waste." Descriptions of the units penetrated by core hole USW G-4 are presented on pages 10-28 of the report.

According to the report, a total of 2,058 fractures were identified in core samples from USW G-4. Plate 1 of the report shows the number of fractures identified in each three-meter interval of the core. Fractures identified in the core are divided into categories of joints and shear fractures for descriptive purposes. According to the report, "approximately 72 percent of the fractures that were identified occur in the densely welded part of the Topopah Spring Member, where about 13 fractures occur per 3 m." Lithophysal zones in the densely welded part of the Topopah Spring Member commonly show a slight decrease in fracturing. The lowermost nonlithophysal zone of the Topopah Spring Member between the depths of 343.7 and 401.3 m contains 13.8 fractures per 3 m. Figure 13 of the report presents information on the inclination of fractures and types of fracture fillings in the various stratigraphic units penetrated by the core hole. Table 5 of the report presents x-ray analyses of selected fracture fillings from the core.

According to the report, 13 percent of the core was oriented to provide data on the spatial relationships of planar features. Figure 16 of the report shows the orientation of foliation, bedding planes, and ash fall and clay partings. Attitudes of 82 well defined fractures were obtained from three stratigraphic intervals: the densely welded zone of the Tiva Canyon Member, the densely welded zone of the Topopah Spring Member, and the Crater Flat tuff. Contoured diagrams of percentages of fracture poles in these three stratigraphic intervals are presented in figure 17 of the report. Attitudes of fractures based on observations made with downhole television camera and compass for these three stratigraphic intervals are presented in figure 18 of the report.

Geophysical logs recorded from USW G-4 are discussed by Muller and Kibler beginning on page 51 of the report under review. Pages 51-55 of the report present a brief textbook type discussion of each of the logs that were recorded for core hole USW G-4. Copies of the actual logs are presented on Plate 1 of the report. A very brief (1 page) analysis of the log data from USW G-4 is presented on page 56 of the report. The primary purpose of this section is to describe the authors interpretation of anomalies present on the geophysical logs. According to the report, the geophysical logs for core hole USW G-4 correlate well with logs from other holes in the Yucca Mountain area. In addition, the physical properties measured in laboratories on core from other drill holes are consistent with the in-situ properties indicated by the geophysical logs for USW G-4.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents significant information with respect to the stratigraphic and structural characteristics of the volcanic rocks within the proposed exploratory block in Yucca Mountain. The report presents detailed information on the characteristics of the Topopah Spring Member and overlying units. This information may become very valuable with respect to the detailed characterization of Yucca Mountain as a potential repository site. While the fracture data presented in the report are described primarily from a geologic viewpoint, the information may help to improve conceptual models of flow in the unsaturated zone once the mechanisms of unsaturated flow in fractures at Yucca Mountain are better defined.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review is typical of most USGS reports. The primary limitation of the report is that the USGS typically does not present all of the data collected for a specific test hole or well within a single report. Usually it is necessary to obtain several different documents to get the complete picture of the hydrogeology in the vicinity of a specific test hole. For example, stratigraphic and structural data may be presented in one report while the hydrologic testing data and geophysical logs are presented in separate reports.

SUGGESTED FOLLOW-UP ACTIVITIES:

This type of data report may prove to be very useful to the NRC Waste Management Program. The NRC should review this type of data report to remain up-to-date with respect to the data that have been collected at the Yucca Mountain site.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OF-84-848

DOCUMENT: Permeability and Fluid Chemistry Studies of the Topopah Spring Member of the Paintbrush Tuff, Nevada Test Site, Part II. D.E. Moore, C.A. Morrow and J.D. Byerlee, U.S.D.I. Geological Survey

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: May 28, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

This report is a continuation of work done previously by the same authors. The work concerns the effect of heat on permeability and on the chemical composition of water flowing through samples of tuff. Three cylindrical samples of Topopah Springs tuff were used in this study. Permeability was determined by measuring radial flow in the cylinder under a small pore pressure gradient. A temperature gradient also was maintained radially outward form the center of the core. The results show essentially no change of permeability with respect to pore pressure, orientation, temperature changes or temperature gradient. The observed slight decrease of pH with time may be due to the progressive removal of salt deposits from the tuff.

BRIEF SUMMARY OF DOCUMENT:

This document reports on an extension of work done previously by the same authors concerning the effect of heat on permeability and on the chemical composition of water flowing through samples of tuff. The present experiment was conducted on three samples of the Topopah Spring Member of the Paintbrush tuff. The samples were cylindrical cores containing a central borehole in which a resistance heater was placed to produce a temperature gradient between the center and the outside of the rock. Water flowed radially due to a small pore pressure gradient applied between the center and the outside of the core. The borehole temperature in all cases was maintained at 150°C; the jacket temperature was held at approximately 44°C. All three samples were run with a pore pressure of 10 bars; This pressure represents the pressure at a depth of 100 m below the water table. The flow through two samples was perpendicular to the bedding planes but flow was parallel to the bedding planes in the other sample. The initial permeability at room temperature varied from .85 to 10 microdarcies in the three samples. Initial values of .5 to 8 microdarcies occurred when heating began. The permeability experiments were continued for a period of 10 to 16 days at which time little additional change in the permeability was occurring. The chemical analysis of water samples showed that in general a decrease of pH of water with time occurred, along with slight changes of chemical species contents. The authors conclude that the combination of heat and fluids has little effect on the permeability of the tuff. During the time of the experiments almost no permeability changes were observed. The results are independent of confining and pore pressure and of sample orientation. Changes in temperature and direction of fluid flow relative to the temperature gradient also had no observed effect on permeability. The authors also conclude that the decrease in pH with time during each experiment may be related to the progressive removal of the salt deposits or saline pore fluids from the tuff. The concentrations of chemical constituents in the water in general decreased with time.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

Some information in this report may be significant for the analysis of flow through the Topopah Springs unit. However, it must be noted that the present work was done under a pore pressure of the equivalent of approximately 100 m of water while the repository in the Topopah Springs Member would be in the unsaturated zone well above the water table.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The limitation is that this work was done under a pore pressure of 10 bars or 100 m of water, not under unsaturated conditions. As stated above the repository will be in the unsaturated zone well above the water table.

SUGGESTED FOLLOW-UP ACTIVITIES

No response is necessary concerning this report.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OFR-85-475

DOCUMENT: Carr, W.J., and Parrish, L.D., 1985, Geology of Drill Hole USW VH-2 and Structure of Crater Flat, Southwestern Nevada. USGS Open File Report 85-475, 41 p.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: November 14, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy Williams/pl

The report under review presents a description of the geology of drill hole USW VH-2 and a description of the structure of Crater Flat. Drill hole USW VH-2 was drilled to obtain additional information on the volcano-tectonic history of Crater Flat. The report consists primarily of an interpretation of the data collected from the drill hole. A detailed lithologic log and stratigraphic descriptions of drill hole USW VH-2 are presented in the report. The report should be of primary interest to geologists involved in the analysis of potential caldera sources for the basalts and tuff strata present in the vicinity of Yucca Mountain.

BRIEF SUMMARY OF DOCUMENT:

The report under review describes the geology in the vicinity of drill hole USW VH-2 and the structure of Crater Flat. Drill hole USW VH-2 was cored to a depth of 1,219 m in central Crater Flat, between Yucca Mountain and Bare Mountain. The purpose of drilling the test hole was to obtain information on the volcano-tectonic history of Crater Flat adjacent to Yucca Mountain. According to the report, the specific objectives were: 1) to determine whether evidence of additional basalt or rhyolite eruptions is buried beneath Crater Flat; 2) to help evaluate the validity of a proposed caldera complex beneath Crater Flat; 3) to determine the cause of a prominent aeromagnetic gradient between drill hole USW VH-1 and a magnetic low on the west side of Crater Flat; and 4) to provide stratigraphic data to help define the late Cenozoic structural history of Crater Flat. According to the report, no hydrologic testing was conducted in drill hole USW VH-2 because polymer mud was used as a drilling fluid.

Tables 1 and 2 of the report list the major contacts and the lithology penetrated by drill hole USW VH-2. According to the report, one of the main purposes of the drill hole was to ascertain whether subsurface basalts, or other young volcanic rocks, are present near the surface basalt flows of central Crater Flat. Tables 1 and 2 of the report indicate that the only basalt detected in the drill core is present at a depth of 360 m to 390 m. This basalt consists of several thin flows, breccia and scoriaceous intervals with no extraneous alluvial material. According to the report, the age of a sample of the basalt from a depth of 366 m was estimated to be 11.3 ± 0.4 million years. According to the report, information obtained from drill hole USW VH-2 suggests that a prominent large negative anomaly just west of the drill hole is due to westward thickening of the basalt penetrated by the drill hole.

According to table 2 of the report, large masses or debris of Paleozoic rocks are present above and within the volcanic rock units. This material is present between the depths of 309 m and 360 m, and between the Rainier Mesa Member of the Timber Mountain tuff and the Tiva Canyon Member of the Paintbrush tuff (535 to 596 m). The report suggests that the character of this material indicates a slide block origin for parts of both stratigraphic intervals.

Table 3 of the report summarizes the characteristics of faults penetrated by the drill hole. No large faults were encountered in the drill hole. However, highly fractured zones and small faults with displacements on the order of approximately one meter, were common in the Tiva Canyon and Topopah Spring Members.

According to the report, a suite of geophysical logs was recorded in drill hole USW VH-2. These logs included caliper, neutron porosity, induction electric, 3-D velocity, radioactivity spectro log, density, and magnetometer. These logs are not presented in the report; however, the authors indicate that they agree well with the lithology described in table 2 of the report. According to the report, geophysical logs confirm the relatively low porosity and high density of the strata between the water table and the top of the Tiva Canyon Member at about 597.5 m. The report suggests that the only zones likely to have significant fracture permeability in the upper part of the saturated zone are the basalt at 360 to 390 m and possibly parts of the Ammonia Tanks and Rainier Mesa Members.

The report indicates good evidence that no major structural displacement has occurred in central and eastern Crater Flat in the last 10 million years. The authors of the report suggest that large-scale landslides may be associated in time with basalt episodes 3.8 million years before present (BP) and 10 to 11 million years BP.

The authors of the report suggest in summary that Crater Flat is a relatively old (mid Miocene) volcano-tectonic feature that has been modified by subsequent tectonic activity, rather than a Pliocene or Quaternary structural graben. It should be noted that drill hole USW VH-2 did not produce much additional data on the caldera; however, the authors suggest that the data do fit well with the proposed concept of a resurgent dome beneath drill hole USW VH-1.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents a description of the geology and structure in the vicinity of drill hole USW VH-2 in Crater Flat. The report should be of most interest to geologists involved in the analysis of potential sources of the basalt flows and tuff strata present in the vicinity. The report is significant with respect to understanding the characteristics of the caldera complexes present in the vicinity of Yucca Mountain.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review presents a description of the geology and structure in the vicinity of drill hole USW VH-2. The report is primarily a data interpretation report. Very few data are presented in the report. The suite of geophysical logs that, according to the report, was used to help define the lithology described in table 2 of the report is not presented. The report does present additional evidence for a caldera source of the Crater Flat tuff beneath Crater Flat.

SUGGESTED FOLLOW-UP ACTIVITIES:

No follow-up activities are necessary.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OF-85-484

DOCUMENT: Benson, L.V. and McKinley, P.W., 1985, Chemical Composition of Groundwater in the Yucca Mountain Area, Nevada, 1971-84. USGS Open-file Report 85-484, Denver, 10 p.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: May 28, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

The report under review presents water chemistry data for 25 groundwater samples collected from 15 test wells in the vicinity of Yucca Mountain. The data indicate that sodium is the most abundant cation and bicarbonate is the most abundant anion in all water samples. Uncorrected radiocarbon ages of water from volcanic tuffs within 1 km of the exploratory block on Yucca Mountain ranged from 12,000 to 18,500 years B.P.

BRIEF SUMMARY OF DOCUMENT:

The report under review presents chemical analyses of 25 groundwater samples collected from 15 wells in the vicinity of Yucca Mountain. The water chemistry data are presented in Table 1 of the report. The water chemistry data indicate that sodium and bicarbonate ions, respectively, are the predominant cation and anions. Water chemistry data for the deep carbonate aquifer penetrated by test well UE-25p#1 indicate that total dissolved solids concentrations are greater than that for water from the tuffaceous rocks; in addition, groundwater in the deep carbonate aquifer contains higher concentrations of calcium, magnesium, chloride and sulfate. Based on variation in the concentrations of inorganic constituents and of stable and radioactive isotopes, the report concludes that a significant degree of lateral and vertical chemical heterogeneity exists in the groundwater of the Yucca Mountain area.

According to the report, uncorrected radiocarbon age data for the groundwater within 1 km of the Yucca Mountain exploratory block ranged from 12,000 to 18,500 years B.P. According to the report, oxygen concentrations ranged from -12.8 to -14.2 o/oo; deuterium concentrations ranged from -93.0 to -106 o/oo.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents basic geochemistry data for groundwater samples collected in the vicinity of Yucca Mountain. The report is significant with respect to the NRC Waste Management Program in that it presents in tabular form the chemical analyses of 25 groundwater samples collected in the vicinity of Yucca Mountain.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review contains no significant problems, deficiencies, or limitations. The report is a basic data report that does not present interpretations of the data.

SUGGESTED FOLLOW-UP ACTIVITIES

Data reports of this kind should be reviewed so the NRC can keep current records of the data available.

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-OF-85-484

DOCUMENT: Benson, L.V. and McKinlev, P.W., 1985. Chemical Composition of Groundwater in the Yucca Mountain Area, Nevada, 1971-84. USGS Open-file Report 85-484, Denver, 10 p.

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PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review contains no significant problems, deficiencies, or limitations. The report is a basic data report that does not present interpretations of the data.

SUGGESTED FOLLOW-UP ACTIVITIES

Data reports of this kind should be reviewed so the NRC can keep current records of the data available.

GeoTrans
ohydrologic Transport Analysis

MEMORANDUM

To: Jeffrey Pohle

From: Benjamin Ross and James W. Mercer

Date: May 3, 1983

Subject: Review of "Two-Dimensional, Steady-State Model of Ground Water Flow, Nevada Test Site and Vicinity, Nevada - California" by Richard K. Waddell, U.S.G.S. Water Resources Investigation 82-4085.

Summary of the Report

The essence of Waddell's work is a quantification of the conceptual model proposed by Winograd and Thordarson (1975) for the regional flow system in the area of the Nevada Test Site. Waddell puts more emphasis on the area of Yucca Mountain than Winograd and Thordarson; one of the purposes of his work is to define boundary conditions for "subregional" modeling of the Yucca Mountain-Crater Flat-western Jackass Flat area.

Waddell's approach begins by dividing the study area into zones. The zones are defined by considering geologic and hydrologic information of all types. It is assumed that transmissivity within a zone is uniform. The available measurements of hydraulic head and initial estimates of the zone transmissivities are then used to estimate transmissivities, recharges, and discharges. A mathematical parameter estimation technique developed by Cooley (1977 and 1979) is used to obtain the transmissivities and fluxes which "best" (in a sense defined by Cooley) fit the head data. In the parameter estimation technique, initial estimates of transmissivities and their associated uncertainties strongly influence the final estimates.

Waddell has performed a sensitivity analysis on his fitted values of transmissivity and flux. Transmissivities of fluxes in specified zones were varied, with other transmissivities and fluxes held at the values determined by the original fit. The effect of the changes on calculated head values was determined.

The study used a finite-element code developed by Cooley. (Documentation of this code is not available.) Some important assumptions made in the modeling effort are:

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- the aquifer is treated as a confined system
- only flow is considered
- the problem is treated as steady state (no change with time)
- boundary conditions are a mixture of no-flow and fixed flux
- a constant head boundary is applied to only one node, which represents a point in Alkali Flat
- the problem is treated as two-dimensional, areal (flow is horizontal)

General Comments

Although much information is given throughout the text on the various modeled zones, it is not well organized to allow easy cross-check and examination. A table such as that given in Table 1 would have been helpful.

There is enough information given to evaluate transmissivities and these are summarized in Waddell's Table 3. Unfortunately, there is no systematic comparison between the simulation results and observations from aquifer tests. The source of the transmissivities in Waddell's Table 1 is not given, but the table appears to rely heavily on simulation results. Otherwise, comparisons with aquifer tests are fragmentary (e.g., p. 19).

Fluxes are much more difficult to sort out. These terms are described on pp. 25-26, but are difficult to match with the flux terms in Waddell's Table 3. For example, a boundary flux on p. 25 refers to flow from Pahranagat Valley as Q_{pv}; whereas in Waddell's Table 3 we believe this flux is called Q_{pr}. We have attempted to evaluate the flux terms in Table 2. As may be seen, the only reliable observed data is for discharge. The discharge at Ash Meadows (Q13) compares well but this flux was held constant during the parameter estimation exercise The discharge at Oasis Valley (Q7) is underestimated by approximately 38%. Assuming that Q_{af}, Q_{chd}, and Q_{dv} represent the combined discharge at Alkali Flat and Furnace Creek Ranch, then this discharge was estimated within 7%.

Although there was no recharge data, some precipitation data do exist. For example, at Spring Mountain the precipitation is about 700 mm/yr. The Spring Mountain recharge is given by Q26. If the area of zone 26 is estimated to be 112.5 km^2, then a recharge of 52.5 mm/yr can be calculated. This value represents about 7.5% of the precipitation. Note also that Q18 is the recharge at a barrier.

The range in which transmissivities, recharges, and discharges can vary is governed, in the Cooley code, by the assumed uncertainty.* Some of the parameters in Waddell's analysis--in particular T1, T17, and many recharge terms--were constrained more tightly than available data seems to justify. T1, the transmissivity of a tuff zone including Crater Flat, much of Jackass Flat, Yucca Mountain, and Shoshone Mountain, was assumed known within about 25%, and T17, the transmissivity of Timber Mountain, was assumed known within about 50%. Given the difficulties of determining transmissivities, these uncertainties would represent very well defined transmissivities. Yet test data in these zones are fairly sparse and fail to give good spatial coverage of these structurally complex areas.

The use of such small uncertainties is appropriate for the purpose of verifying and quantifying the Winograd-Thordarson conceptual model, but in some other contexts it might have the effect of predetermining the results of the study.

The values of the weighting function, w_1, used to weight head measurements in the parameter estimation procedure are also not clearly stated in the text.

Because of these various difficulties, it would be impossible to reproduce the results, and critical comment on them is difficult. As a result, the detailed comments below concentrate on assumptions and procedures.

Zonation

As discussed above, the definition of zones is based on a variety of available geological and hydrological information. The way the zones are defined can determine the results obtained from the model. Two aspects of the zonation near Yucca Mountain deserve comment in this regard.

Waddell shows Crater Flat as a single zone (actually, part of a larger zone) of tuff. It is bordered on the south by the highly transmissive Amargosa Desert zone. However, it is possible that Crater Flat is a "bowl of water" with low gradients, bounded on the south by a flow barrier. Reasons to consider this suggestion include:

- Basaltic rocks crop out at several locations along a line marking the southern boundary of the flat. A continuous basaltic ridge might rise above the water table but be largely obscured by alluvium.
- The only two water-level measurements in Crater Flat both give 772 m.
- The pattern of basins with nearly uniform water levels, separated by flow barriers, is common in the region.

*This is our understanding; available documentation of the code is not clear on this point.

Table 1. Relation Between Model and Geology

Model Zone	Rock Type	Physical Location
1	tuffs	Crater Flat, Jackass Flats, Yucca Mountain, Shoshone Mountain
2	tuffs & alluvium	Belted Range (tuffs) & western Emigrant Valley
3	clastic rocks (barrier)	Groom Range
4*	lower carbonate aquifer	Desert, Three Lakes, and northern Indian Springs Valleys
5	Eleana Formation (barrier)	west side of Yucca Flat
6	lower carbonate aquifer	Franchman Flat and eastern Yucca Flat
7	tuffs	Oasis Valley
8	alluvium	Amargosa Desert
9	lower carbonate aquifer	Amargosa Flat
10	upper clastic aquitard (barrier)	Skeleton Hills
11	upper clastic aquitard (barrier)	Funeral Mountains
12	lower carbonate aquifer	southeastern end of Funeral Range
13	lower carbonate aquifer	Ash Meadows
14	upper clastic aquitard (barrier)	Spring Mountains
15	lower carbonate aquifer	southern Indian Springs Valley
16	tuffs & lakebeds (barrier)	along Furnace Creek fault zone
17	tuffs	Timber Mountain
18	clastic rocks (barrier)	Groom Range
19	tuffs	Fortymile Canyon
20	tuffs	between Oasis Valley and Timber Mountain
21	carbonate rocks & fault gouge (barrier)	Las Vegas Valley shear zone
22	tuffs	Pahute Mesa
23	lake beds (barrier)	southwest of Ash Meadows
24	tuffs	Pahute Mesa
25*	lower carbonate aquifer	Sheep Range
26	lower carbonate aquifer	Spring Mountains
27*	lower carbonate aquifer	Pahranagat Rante & Timpahute Range

* little data available

Table 2. Comparison of Simulated Flux with Observed Values. Flux Terms in m^3/s.

	Simulated (Waddell's Table 3)		Observed
Recharge			
Q18	1.154×10^{-2}		
Q24	5.351×10^{-1}		
Q25	4.164×10^{-1}		
Q26	1.866×10^{-1}		
Q27	1.851×10^{-1}		
Discharge			
Q7	-4.847×10^{-2}		-7.80×10^{-2} (p. 15)
Q13*	-6.653×10^{-1}		-6.55×10^{-1} (p. 18)
Flux at Nodes			
Q_{af}	-2.962×10^{-1}	}	
Qdv	-1.697×10^{-1}	} 6.517×10^{-1}	6.1×10^{-1} (p. 17)
Constant Head Node		}	
Q_{chd}	-1.858×10^{-1}		
Boundary Flux			
Qpr (Qpv?)	1.950×10^{-2}		
Qrs	1.122×10^{-2}		

$\sum$discharge = 1.36547 $\sum$recharge = 1.36546

* held constant during the parameter estimation exercise

By no means can these arguments establish the existence of a flow barrier, but they do raise it as a possibility to be examined. Such a barrier could affect flow in a wider area by diverting ground water across Yucca Mountain into Jackass Flat. Waddell's zonation rules out the presence of a flow barrier at that location.

Another area of concern is the narrow, highly transmissive zone at Fortymile Wash. Existence of this zone is suggested by head data, aquifer tests, and structural considerations. However, the width of this zone is not established: it could be related to a narrow structural feature, or it could cover the entire area in which the Topopah Springs Member is below the water table. Waddell assumes a narrow, structurally controlled zone.

Head and transmissivity data near Fortymile Wash are insufficient to determine directly the width of the transmissive zone. The effect of the zone on heads is a "veeing" of head contours (Waddell, p. 53). The veeing effect depends on both the transmissivity of the zone and its width. A wider zone with less transmissivity contrast would give the same magnitude of effect as a narrow zone with much greater transmissivity than surrounding areas. As a consequence, a wider zone than assumed by Waddell would imply a lesser transmissivity contrast with surrounding areas, possibly leading to a higher estimate of transmissivity for the Yucca Mountain area.

Weighting Functions

What a model calculates is not an exact simulation of the actual ground-water system, but a smoothed-out approximation of it. This introduces an important source of error: variations caused by local inhomogeneities in the flow system. In essence, this error corresponds to the difference between the smooth contours calculated by a model and the "wiggly" contours one would observe if one could measure them precisely in the field. This type of error in heads will become greater as the hydraulic gradient increases. Waddell recognizes this phenomenon and responds by eliminating data points where it is important. He comments (p. 27):

> Because gradients are steep within barriers, potential for large residuals is great, and details of geometry become very important. The algorithm may generate untenable solutions because it is unable to alter the zonation, the cause of errors. To avoid this problem, observations of head within barriers were not used, because geometrics of the barriers are not well-known.

A better approach might be to include data points in barriers, but to use the weighting function to account for the greater errors expected in these data. In this way, more information could be used in the parameter estimation procedures. Use of the initial estimate of local transmissivity to weight the head observations would be easy to implement and would no doubt be a good first approximation; a detailed mathematical analysis might show some other weighting function to be better.

Ideally, weighting functions should be further adjusted on a judgmental basis to account for other sources of uncertainty in head observations. Weights should be reduced where large measurement errors are suspected, in areas of structural complexity, etc.

As discussed above, the report does not state clearly what weighting functions are used for head values in the parameter estimation procedure. The absence of discussion (other than a statement that the weight was zero where no head measurements were available) seems to indicate that all nodes with observed heads were weighted equally. We could find no indication of the weighting of observed heads relative to estimated transmissivities.

Sensitivity Analysis

Waddell performs sensitivity analysis by varying one or more transmissivity or recharge parameters and holding the rest constant. He calculates the change in head resulting from the change in parameter values.

It might be interesting to perform additional work where the varied parameters are set at new values and the other transmissivities, recharges, and discharges are allowed to readjust. One would then see how well one could still fit the heads using a different assumption about certain zones. This would given an indication of how well the available head data defines the properties of the zones in question. The type of sensitivity analysis performed by Waddell does not answer this question well.

In performing a sensitivity analysis in which transmissivities and recharges are allowed to readjust, it would be important not to constrain the adjustable parameters too much. As discussed above, Waddell's assumed uncertainties in some parameters seem small.

Minor Comments

(1) Groom Range is not included in the abstract as an area of recharge but actually is included in the model as a recharge area (zone 18).

(2) Along with the coefficients of variation given in Table 2, it would be helpful to know the number of observed values for each zone for each parameter.

(3) Page 42, second paragraph, states that the standard errors range from 8.4 to 108.7 percent; from Table 3, it is the coefficient of variation that has this range.

Conclusion

Waddell has done a good job of quantifying the conceptual model of Winograd and Thordarson. His thorough quantitative work shows that their explanation of the flow system (as slightly modified by Waddell) is consistent with the available information on present ground-water conditions.

Further work is needed, however, to determine whether other conceptual models might also be consistent with the available data. Useful approaches to this work might include increasing the assumed uncertainty in initial estimates of transmissivity, changing zonation, and an appropriately designed sensitivity analysis.

References:

Cooley, R. L., 1977, "A method of estimating parameters and assessing reliability for models of steady state groundwater flow," Water Reources Research, v. 13, no. 2, p. 318-324.

__________ 1979, "A method of estimating parameters and assessing reliability for models of steady state groundwater flow, 2--Application of statistical analysis," Water Resources Research, v. 15, no. 3, p. 603-617.

Winograd, I. J., and Thordarson, W., 1975, "Hydrogeologic and hydrochemical framework, south-central Great Basin, Nevada-California, with speical reference to the Nevada Test Site," U.S. Geological Survey Pofessional Paper 712-C.

AUG 1 2 1983

NOTE TO: Seth M. Coplan

Based on my review of the viewgraphs used by Don Vieth during his August 25th End of the Year presentation, there appears to be a lot of information in reports labeled "Completed" which is not presently available to NRC staff. Therefore, I have prepared a list of information and/or completed reports the hydrogeology team requests from DOE. The attached list is based on FY83 accomplishments of the NNSWI Project. Again, to the best of my knowledge, this list contains only items not received previously.

Jeffrey A. Pohle

Attachment:
Information and/or Completed Reports
Related to the NNWSI Project

cc: Miller
Justus
Verma

AUG 1 2 1983

DRILLING/TESTING

- o Map showing locations of completed and planned holes
- o Water levels from completed holes
- o Data from initial pumping test and water sampling of H-6, B-1, G-4 and PH-1
- o Data from packer test in H-6 and G-4

GEOCHEMISTRY

- o Copy of draft of first calculations of a fracture flow model for the unsaturated zone using TRACR3D.

GEOLOGIC/HYDROLOGIC/GEOPHYSICAL

Geological Framework of Yucca Mountain

- o Copies of completed report of principal borehole G-4 and completed report on core holes G-3/GU-3
- o Copy of the developed and instituted standardized methodology for description of fractures in core
- o Copy of completed report on geologic characteristics of unsaturated zone

Hydrology of Unsaturated Zone

- o Information on completed conceptual flow model and preliminary velocity calculations
- o Copy of completed design and criteria for borehole testing of unsaturated zone
- o Copy of completed laboratory tests and analyses of unsaturated hydraulic properties of core from H-1

Hydrology of Saturated Zone

- o Copy of completed report on hydraulics of supply well J-13
- o Copy of completed reports on tests in seven boreholes, including G-4

AUG 1 2 1983

- Copy of compiled and published data on chemical composition of groundwater at Yucca Mountain
- Information on methods and instrumentation to determine vertical hydraulic gradients in H-3, H-4, H-5 and H-6

PALEOHYDROLOGY

- Copy of completed report on Late Quaternary climates in southern Nevada based on vegetative remains in packrat middens
- Copy of completed flood distribution analysis of Forty Mile canyon and tributaries
- Information on progress of identification and dating of paleo discharge areas in Amargosa Desert

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-WRI-83-4001

DOCUMENT: Squires, R.R., and Young, R.L., 1984, Flood Potential of Forty-Mile Wash and Its Principal Southwestern Tributaries, Nevada Test Site, Southern Nevada. USGS Water Resources Investigations Report 83-4001, Carson City, Nevada, 32 p.

REVIEWER: Williams & Associates, Inc., James L Osiensky

DATE REVIEW COMPLETED: January 20, 1987

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

The report under review presents estimates of potential flood hazards for a nine-mile reach of Forty-Mile Wash, Busted Butte Wash, Drillhole Wash, and Yucca Wash. The characteristics of the 100-year, 500-year, and regional maximum floods are estimated because measured flood peak data are not available for the study area. Estimates of the 100- and 500-year discharges in the study area are based on a procedure that utilizes a regional analysis of streamflow records. Estimates of the regional maximum flood discharges are based on data from maximum floods that have been observed at other sites which exhibit similar characteristics and flood potentials. The report indicates that 500-year flood events would exceed stream channel capacities at several locations in Busted Butte Wash and Drillhole Wash. Regional maximum floods would inundate sizable areas of the central parts of the Busted Butte Wash and Drillhole Wash watersheds.

BRIEF SUMMARY OF DOCUMENT:

The purpose of the report under review is to evaluate the potential for flood damage to a geologic repository for radioactive wastes within Yucca Mountain. The study was designed to provide information pertaining to the probable characteristics of the 100-year, 500-year and regional maximum floods along

Forty-Mile Wash and its southwestern tributaries. The specific objectives of the study were as follows:

1. Identify reaches of Forty-Mile Wash and its three southwestern tributaries where flooding could affect potential waste disposal facilities in the study area.

2. Estimate potential flow magnitudes, average flow velocities, and depths that might be expected during the 100-year, 500-year, and regional maximum floods.

3. Determine maximum flood-inundation limits that may be expected during those floods.

The study area, delineated on figure 1 of the report, consists of approximately 50 square miles. However, drainage areas considered in the study are considerably greater. The study area consists of part of the Forty-Mile Wash drainage together with the drainages of Busted Butte Wash, Drillhole Wash, and Yucca Wash. Within the delineated study area, several surveyed cross-sections were developed for each of the four drainages. Within the study area, the channel of Forty-Mile Wash is incised to a depth that ranges from 50 to 70 ft; the bed of the wash is 1,000 to 1,500 ft wide. The drainage of Busted Butte Wash varies from a low gradient valley with meandering ephemeral channels within its upper reaches to a deeply incised channel at its junction with Forty-Mile Wash. The drainage of Drillhole Wash consists of deep canyons in its upper reaches, wide braided channels with poorly defined banks in the middle part of the basin, and a channel incised in alluvium within a winding canyon near the confluence with Forty-Mile Wash. The drainage of Yucca Wash consists of a channel approximately 800 ft wide that is incised about 45 ft near its confluence with Forty-Mile Wash. The channel narrows and becomes less deeply incised upstream from Forty-Mile Wash.

According to the report, the principal flood problems in the study area are the result of localized convective-type storms that produce downpours and resulting flash floods. The report notes that significant surface flow may occur also in response to snow melt.

According to the report, no flood-peak information specific to Forty-Mile Wash and its tributaries within the Nevada Test Site is known to have been collected prior to this investigation. The report notes, however, that the USGS systematically has collected data on major floods on many similar ephemeral washes near the Nevada Test Site since the early 1960's.

The hydrologic analyses to estimate the 100-year and 500-year floods and the regional maximum flood were based on the regional analysis of streamflow records. According to the report, 12 long-term peak-flow data sites operated by the USGS were selected for the 100- and 500-year flood analyses. Information on these sites is presented in table 1 of the report.

The equations used to estimate the 100- and 500-year floods are as follows:

$$Q_{100} = 482\ A^{0.565} \text{ and } Q_{500} = 2,200\ A^{0.571}$$

where:

Q_{100} = 100-year flood, in cubic feet per second;
Q_{500} = 500-year flood, in cubic feet per second; and
A = drainage area, in square miles.

The characteristics of the 100-year flood peak and the 500-year flood peak at various cross-sections through Forty-Mile Wash, Busted Butte Wash, Drillhole Wash, and Yucca Wash are presented in tables 2 and 3, respectively.

The "reasonable regional maximum floods" for Forty-Mile Wash and its tributaries within the study area were estimated from data on "maximum floods that have been observed at other sites which exhibit similar characteristics and flood potentials." Figure 13 of the report presents a "boundary" curve for the regional maximum discharge in cubic feet per second versus drainage area in square miles. This "boundary" curve was developed by Crippen and Bue (1977) for a five-state region that includes the study area. Table 5 of the report lists the estimated regional maximum flood discharges for selected sites in the study area. According to the report, regional maximum flood discharges "are large enough to be beyond the possibility of control with conventional-flood mitigation works."

The authors of the report performed hydraulic analyses of the hydraulic characteristics of flooding within the study area. These analyses were performed to estimate the water-surface altitudes of peak flows for the 100-year, 500-year and regional maximum floods at selected sites on Forty-Mile Wash, Busted Butte Wash, Drillhole Wash, and Yucca Wash. The locations of the cross sections are shown on Plate 1 of the report. The hydraulic analyses are based on solution to a form of the Manning equation. The form of the Manning equation used for the analyses is as follows:

$$Q = \frac{1.49}{n} AR^{2/3}S^{1/2}$$

where:

Q = discharge for a given flood depth, in cubic feet per second;
n = roughness coefficient, in dimensionless units;
A = cross section area for a given flood depth, in square feet;
R = hydraulic radius (cross sectional area divided by the wetted perimeter); and
S = slope of the energy-grade line in feet per foot, which is assumed to be equivalent to the slope of the water surface and channel bottom under conditions of uniform flow.

The hydraulic analyses consist of solving the Manning equation for A and R for various flood flows. These analyses were performed to estimate the water-surface altitude in each of the four drainages for the 100-year, 500-year, and regional maximum floods.

According to the report, the main sources of uncertainty in the hydraulic analyses are the estimates of slope, and channel roughness. The slope of the energy-grade line often does not coincide with the slope of the water surface or the channel bottom. The report notes that roughness coefficient (n) is inversely proportional to discharge. For large flood flows, errors in the estimate of n become less significant. However, it may be feasible to estimate n more closely by measuring velocities in each of the four drainages during actual measured streamflows.

In addition to estimating the water-surface altitudes of flood flows in the four drainages, the authors attempted to estimate the erosion potential of the four drainages during flood flows of different magnitudes. The authors conclude that channel erosion and deposition along the four drainages is likely because most of the velocities listed in tables 2, 3, and 5 exceed the maximum permissible velocities estimated in their analysis.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents estimates of flood potential for Forty-Mile Wash, Busted Butte Wash, Drillhole Wash, and Yucca Wash. The report is significant with respect to understanding the potential for flooding of facilities associated with a geologic repository for radioactive wastes in Yucca Mountain.

The report concludes that along the nine-mile study area of Forty-Mile Wash all potential flood flows would remain within the incised channel. The 500-year flood would exceed stream channel capacities at several places in Busted Butte Wash and Drillhole Wash; the regional maximum flood would inundate sizable areas in the central parts of the watersheds. According to the report, flood flows of all three magnitudes would remain within the stream channel of Yucca Wash. The report suggests that significant erosion of, or deposition in, channels in flood plains probably would occur in parts of the study area during the 100-year flood, and could be severe during the 500-year and regional maximum floods.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review presents estimates of the characteristics of the 100-year, 500-year, and probable maximum floods in the vicinity of Yucca Mountain. Data presented in the report are specific to Forty-Mile Wash, Busted Butte Wash, Drillhole Wash, and Yucca Wash. The main limitation of the report is that estimates presented are based on very limited data. The lack of data precludes verification of the flood estimates presented in the report.

SUGGESTED FOLLOW-UP ACTIVITIES:

No follow-up activities are suggested.

REFERENCES CITED:

Crippen, J.R., and Bue, C.D., 1977, Maximum Flood Flows in the Conterminous United States. U.S. Geological Survey Water Supply Paper 1887, 52 p.

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WMHT DOCUMENT REVIEW SHEET

FILE: 3102.1

DOCUMENT: Waddel, Richard K., 1982, Two-Dimensional, Steady-State Model of Ground-Water Flow, Nevada Test Site and Vicinity, Nevada-California, U. S. Geological Survey Water Resources Investigations 82-4085

REVIEWER: J. Pohle J. Pohle 5/11/83 DATE REVIEW COMPLETED: 5/4/83

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED: RJB 5/11

The work done by Waddell is essentially a quantification of Winograd and Thordarson's (1975) conceptual model of the regional groundwater flow system surrounding, and including, the Nevada Test Site. Waddell has made some refinements to this conceptual based on more recent data. This study deals only with flow and not transport. Some important assumptions in this model are: 1) the aquifer is treated as a confined system; 2) steady state; 3) two-dimensional, areal flow (only horizontal flow); 4) boundaries are either no-flow or fixed flux. The code applied in this study uses an inverse procedure which allows parameter estimation within constraints given by a specified level of uncertainty for each parameter. The code then seeks to achieve a "best fit" by minimizing differences between calculated and observed head data. This report concludes that the conceptual model is consistent with existing data.

SIGNIFICANCE TO THE WASTE MANAGEMENT PROGRAM:

As indicated on page 43 of this report, "one of the prime reasons for modeling ground-water flow near the Nevada Test Site is to prodict movement of radionuclides from a repository. These predictions can be done only through transport modeling, which requires estimates of flux. The flow model provides these estimates." A concern of the NRC staff is that if these flux estimates are used as boundary conditions for smaller scale performance assessment modeling the uncertainties in the fluxes must be evaluated. Indeed, the State of Nevada has expressed a similar concern to DOE (Specific Issue N; "... what is the level of confidence that the uncertainties introduced into the models are not compounded from one model level to a higher one?", April 20, 1983 letter from J. I. Barnes to DOE).

ACTION TAKEN:

GEOTRANS, Inc. was directed to review this report in detail. Their report, dated May 3, 1983 is attached. Copies of both reports have been distributed to cognizant NRC staff.

FOLLOW-UP ACTIVITY:

This topic has been identified for further technical discussion in future workshops. Possible preparation of a site technical position in this area is under staff discussion. Conceptual regional flow model(s) for NNWSI is identified as a draft NRC groundwater issue.

DesireeM 83/05/11

W&A COVER LETTER OF 84/09/07.
THIS REVIEW IN CONJUNCTION WITH JULY 1984 DATA REVIEW IN DENVER.

Review of Well H-1, Interpretative Report

Rush, F.E., W. Thordarson and D.G. Pyles, 1984, Geohydrology of Test Well USW H-1, Yucca Mountain, Nye County, Nevada: U.S.G.S. Water Resources Investigations Report 83-4032.

This document contains the U.S.G.S.'s analysis of the data that are presented in open-file report 83-141. Items of interest that I have not already pointed out in my review of open-file report 83-141 include the following.

1. Table 8 of the document describes the water yielding characteristics of the zone above the water table. It should be noted that water under positive pressure is reasonably common in this drill hole (H-1). Evidence for this statement consists of descriptions of dripping water or small streams of water or seeping water emanating from the walls of the hole.

2. The zone from 652 m to 653 m is the most productive zone in the borehole. The interval from 792 to 1,829 m produced no detectible flow of water as did the no flow zone from 694 m to 736 m. This result is somewhat interesting because the result of the slug injection test revealed transmissivities that suggest that portions of the hole among these depths should have yielded water. The values are indicative of marginal aquifers. The most probable explanation for this inconsistency is that the trace ejector survey was not sensitive enough to detect the flow.

3. Piezometers were installed permanently in well H-1 to measure water levels in four zones. These zones are: 1) 640 m, 2) 738 to 741 m, 3) 1,112 to 1,115 m, and 4) 1,803 to 1,806 m. Water levels in the two shallower piezometers are at essentially the same depth as the composite water level measured prior to piezometer installation. The water level in the deeper zone was approximately 52 m higher than the water level in the shallower zone as of September, 1982.

These data suggest that the vertical movement of water in the hole is upward toward the more permeable zones near the water table. This document states that water below approximately 700 m probably is artesian (confined) because the bedded tuff present at this depth commonly has low permeability. In summary, the water level data indicate that the system at the location of well H-1 is confined and that the vertical component of the potential gradient is directed upward toward two aquifers located at depth intervals 572 to 640 m and 738 to 741 m. The analysis of pumping test data discussed under my review of report 83-141 reflects the fact that the data used fit analytical curve matching techniques reasonably well with one exception. Figure 14 in the report under review presents an attempt to analyze water level drawdown in pumping test 3 in the zone from 687 to 1,829 m using the Theis method. The curve fitting procedure works very poorly for the drawdown curve. It appears that some hydrogeological phenomena is operating that precludes an adequate fit of the field data to the theoretical curves. The other curves and their matches can be defended. The analyses yield transmissivity values for the aforementioned upper two permeable test intervals as follows: The first pumping test over the depth interval 572 to 688 m yielded a transmissivity value of 154 m^2/day. The recovery for this interval yielded a T value of 183 m^2/day. Both these values are the result of applying the Jacobs straight line method and the Theis method to the data. The transmissivity values for the interval 687 to 1,829 m ranged from .41 to 1.6 m^2/day. These numbers apply to the entire section between 687 m and 1,829 m below ground surface. These values can be divided into transmissivity of particular portions of the section by using the transmissivity data in combination with the borehole flow survey log. This was done by the U.S.G.S. and the results presented in Table 11 on the subject report. The results show that the transmissivity of this entire depth interval, even on a permeable unit basis, is very low relative to the aforementioned permeable sections of the Prow Pass Member.

Injection test results and their analysis also are presented in the subject document. The results of the injection tests show that virtually all the permeability in the hole is above the 687 to 694 m depth interval. The quality of the injection test data already have been discussed in my review of open-file report 83-141.

In summary, the issues that are most significant with respect to this review and with respect to the data base examined at the NTS data review session in Denver on July 23-27 are as follows.

1. The portions of the data base that are presented and analyzed in the document are amenable to analysis by the straight line method, the Theis equation or by slug injection test methods. Two of the tests that were analyzed by matching to the Theis equation are marginal with respect to closeness of fit. It is possible to defend more than one match, some of which would suggest that boundaries are present.
2. The shut-in test portion of the data base was omitted in the analysis. The reason for this omission is not presented in the report. A considerable amount of time, money and energy were devoted to conducting the shut-in tests.
3. Seventeen slug injection tests (these tests are incorrectly called injection tests in the report) were conducted in hole H-1 but only six sets of results are presented and analyzed in the document under review. The rationale for omitting the eleven tests included equipment failure, packer failure, and length of test. The omission of all the tests that were omitted can be defended on the basis of the information presented in the data base.
4. The water level data and the analysis of it suggest that the vertical component of the hydraulic gradient is directed

upward in this hole. The aquifer that acts as a "drain" is located near the top of the zone of saturation where the hydraulic head is lower than at the bottom of the hole. Most of the data curves fit the match curves for confined aquifer analysis. This is somewhat surprising for the upper aquifers; the reason for the data not matching water table type curves ought to be addressed.

5. The injection tests in this document and the aformentioned open-file report are actually slug injection tests. They are not injection tests in the usual sense of the word where water is injected into the hole under a constant injection rate or under a constant head.Review of Well UE-25b #1

J-13
WRI 83-4171

WILLIAMS & ASSOCIATES, INC.

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April 1, 1984
Contract No. NRC-02-82-046
Communication No. 37

WM Record File B7377
WM Project 11
Docket No.
PDR ✓
LPDR ✓ (N)
Distribution: J Pohle
(Return to WM, 623-SS)

Mr. Jeff Pohle
Division of Waste Management
Mail Stop 623-SS
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Jeff:

This letter constitutes my response to your request to review a document entitled "Geohydrologic Data and Test Results from Well J-13, Nevada Test Site, Nye County, Nevada". The report is labeled U.S.G.S. Water Resources Investigations Report 83-4171, dated 1983. The author is William Thordarson. You requested a two page review; but a two page review of this report would not be very meaningful; consequently, I have not restricted my review to two pages.

The primary purpose of the report is to present the results of analyses of single well tests performed on well J-13 located adjacent to Forty Mile Wash east of Yucca Mountain on the Nevada Test Site. The well penetrated 132.5 meters of alluvium, 74.8 meters of Tiva Canyon tuff, 242.3 meters of the Topopah Spring Member of the Paintbrush tuff, 80.8 meters of tuffaceous beds of the Calico Hills, 445 meters of the Crater Flat tuff and 81.6 meters of Lithic Ridge tuff. As I understand the report, the hydrostratigraphic units were defined more or less stratigraphically on the basis of geophysical logs and lithologic logs and to a lesser extent on the basis of the results of the tests. The Topopah Spring Member of the Paintbrush tuff was concluded to be the principal aquifer penetrated by the well. All the underlying tuffs were considered to be aquitards. The Topopah Spring was defined as an aquifer prior to testing on the basis of geophysical logs, lithology from cores and behavior during drilling. This definition is significant because it is the basis for the delineation of the conceptual model necessary to select the most appropriate analytical technique to apply to the test data. The method given the most weight for analyzing the data was derived by Stallman (1965). Stallman's method assumes that water yielded by the well is derived from a decrease in the elevation of the phreatic surface; vertical flow components are accounted for and anisotropy is considered. These assumptions require that the method be applied to the water table case (unconfined). According to Stallman (1965, p. 307), proper use of the method requires that the ratio Pr/Pz (horizontal/vertical hydraulic conductivity) be known; the ratio Pr/Pz can be measured in the field by observing drawdowns as a function of depth and radius near the pumping well. These data are not available in this report. The subject report justifies the selection of the Stallman (1965) analytical procedure because of the high density of fractures that intersect in at least two steeply dipping directions, relatively high average effective porosity (5.4 percent) and most important of all because the water table is 76.5 meters below the top of the aquifer. The paper does not state precisely how the top of the aquifer was defined except by the aforementioned borehole geophysical logs and lithologic logs derived from cores. Stallman's method requires that the aquifer be homogeneous. "Either radial or vertical nonhomogeneity in the aquifer, or a combination of the two conditions, may cause anomalous drawdown patterns" (Stallman, 1965, p. 307). Consequently, if the Topopah Spring Member were yielding water through some isolated portion of it, the unconfined aquifer assumption probably would not be met, in which case some other conceptual model might be defensible. It is possible that some of the methods of analysis for confined conditions might be applicable to the data, including one or more of the leaky methods. Unfortunately single hole test results are not very amenable to analysis by leaky methods. This question probably could be answered if the paper had included data on barometric efficiency; I am unable to locate any barometric efficiency data in the paper. The paper also refers to the use of the straight line solution (p. 22) with a reference to Lohman (1979). I assume this means the Jacob straight line method. Lohman does not mention the straight line method under his section entitled "Unconfined Aquifers with Vertical Movement" (p. 34). Lohman discusses the straight line method under his section that deals with aquifer tests in confined aquifers. The required assumptions for the use of the straight line method are identical to the assumptions for the Theis equation. According to Stallman (1965, p. 295), "Equations developed for artesian flow cannot be used for analysis of tests made under water table conditions unless steady-state conditions have been approached or reached." In addition the value of u must be equal to or less than .01 in order for the method to be applicable. In a single well test in an unconfined aquifer the value of well radius r is somewhat difficult to determine; consequently it is difficult to determine whether or when u = .01. Walton (1962, p. 9) makes the following statement about the use of the straight line method for unconfined conditions. "The straight-line method based on the modified nonleaky artesian formula is popular largely because of its simplicity of application and interpretation; however, as pointed out by Cooper and Jacob (1946), 'the method is not applicable in some cases and it supplements, rather than supersedes, the type curve method.' They state further, 'the method is designed especially for artesian conditions, but it may be applied successfully to tests of non-artesian aquifers under favorable circumstances'."

The paper under review attempted to explain this and well loss problems with step drawdown tests but "results provided anomalous numbers that are not presented".

The author notes that "the effects of vertical flow components, delayed yield, or boundaries probably prevented determination of the well-loss constants". The straight line data plots (Figures 4 and 6 in the report) definitely have a rather unusual character for step drawdown tests. However, on the positive side the subject report puts principal stress on the results of the Stallman (1965) analytical procedure. The report does consider one alternative conceptual model for testing. This conceptual model assumes that boundaries produced the drawdown data curve presented on Figure 7 in the report. The alternative model considers the early time straight line portion of the drawdown curve during pumping test 3 (Figure 7) as representing the aquifer prior to the introduction of boundary effects as reflected by late time drawdown data. Pumping test 3 covered the Topopah Spring Member of the Paintbrush tuff. This conceptual model treated the later time steepening of the drawdown curve for pump test 3 as attributable to discharge boundaries. The author considers the results of this model to be less defensible than the conceptual model to which the Stallman (1965) method was applied; but he does present both sets of results. This exercise illustrates the problem of analyzing pump test data when only one well is available for aquifer delineation and data interpretation. Such problems cannot be avoided.

The Stallman (1965) analytical approach yielded an estimated transmissivity of 120 m^2/d for the Topopah Spring. The author of this report converted this transmissivity value to a hydraulic conductivity value of 1.0 m/d (1.157×10^{-3} cm/s). I am unable to determine how the thickness value was obtained for the derivation of the quotient. The results of applying the straight line method to early time data from pumping test 3 produced a transmissivity of 850 m^2/d. This value probably is too high because the earliest time data collected during pumping test 3 appear to be influenced by the vertical movement of water (delayed gravity drainage). Figure 7 shows that the early time data do not reflect steady-state conditions (i.e., drawdown increases with time). Figure 8 suggests that the middle and late drawdown data for the pumping well follow the characteristic S shape of delayed yield type curves. It is presumed that accurate drawdown measurements during the first two minutes of pumping would have plotted on the Theis curve similar to the type curves of Boulton (1963). Rapid drawdown in the pumping well probably precluded the measurement of drawdown during the first two minutes of pumping. This is a common problem with single well tests. The author concludes that the 120 m^2/d figure based on the Stallman (1965) method probably is more valid but he really does not explain why. One might argue that the early time data in pump test 3 reflect the presence of a different, more transmissive but limited aquifer between depths of 819.9 and 1009.5 m. Pump test 3 covered this interval in addition to the Topopah Spring but pump test 1 did not. It may be on the other hand that the 120 m^2/d figure is more valid because the aquifer thins with increasing distance from the well. This could explain the increase in slope of the late time drawdown data in Figure 7. However, other explanations are plausible also. The author of the report simply refers to the late time data as being produced by "discharge boundaries" (p. 26).

The tests in the tuffs underlying the Topopah Spring Member (except for pump test 3) consisted of slug tests and much less refined swab tests. The slug tests were analyzed by the method of Cooper and others (1967) and Papadopulos and others (1973). Both these methods are acceptable for low permeability zones and single hole tests. But in this case the field data deviate considerably from the type curves. Some of the field data suggest that boundaries are operating even at the small scale of these tests. Nevertheless, the author of the report concluded that the results show that the underlying tuffs are one to three orders of magnitude less permeable than the Topopah Spring Member of the Paintbrush. These results should be about as valid as can be expected from single hole tests even considering the deviation of the field data from the ideal type curves. If multiple well methods were available to test the horizontal but particularly the vertical saturated hydraulic conductivity of these units I suspect that the results would be higher by about one order of magnitude. Single hole slug tests frequently do not reflect the effect of fractures on a large scale. The author clearly is aware of these problems. This awareness is reflected by the following quote from page 27 of the subject report. "Although these values are small for the confining beds, the values obtained for any given depth interval contain some uncertainty because the analysis was not fully diagnostic. For this reason, and because the packers may have leaked in some tests and because of possible leakage to or from the annulus at the base of the casing, the transmissivities and hydraulic conductivities are given as estimated values in table 12."

The investigators made an attempt to determine the degree of hydraulic connection between well J-13 and well J-12, located about 4.7 km (2.9 miles) away (south). Well J-12 was pumped for 3 days at an average rate of 22.7 L/s (360 gpm). Page 50 of the report contains the following statement, "Apparent drawdown in well J-13 due to pumping well J-12 was .37 m even after correction for barometric pressure effects was made. At the time of this test well J-12 was 270.4 m deep and only partly penetrated the aquifer (Topopah Spring Member)." It should be noted that at this r value and a transmissivity of 120 m^2/d partial penetration should not affect the drawdown in the observation well. Storativity values necessary to cause .37 m of drawdown at a distance of 4.7 km under the conditions of the test were estimated by use of the Theis equation. Values of storativity were estimated for corresponding transmissivity values of 120 m^2/d and 850 m^2/d; the estimated storativity values are 5.5×10^{-4} and $3..7 \times 10^{-5}$, respectively. These values suggest that the Topopah Spring may be confined. Prior to the second pumping test, well J-12 was deepened to the bottom of the Topopah Spring. It was pumped for 420 minutes at an average discharge rate of 5.68 L/s (90 gpm). No drawdown was observed in well J-13; the test may have been too short at too low a pumping rate for the stress to have extended 2.9 miles away. This effort illustrates two points. Point number 1 is that after three days of pumping at 22.7 L/s less than .37 m of drawdown would have occurred in well J-13 if in fact the transmissivity of the aquifer is 120 m^2/d and if it had been unconfined. The second point is that a barometric pressure correction was necessary. As far as I can tell this is the only reference to barometric efficiency in the entire report. If a barometric pressure correction was necessary during this pump test the aquifer probably is confined and perhaps some other method of analysis should have been attempted. At least the significance of barometric efficiency should have been explained in terms of the question of confinement.

The chemical quality of the water is the last point that merits comment. The discussion presented early in the paper indicates that mud and diesel fuel were required for drilling in the Topopah Spring because of hole stability problems and because of stuck drill stem. The single tritium measurement presented on page 54 of the report (21 tritium units on 5/25/64) suggests that the sample contained bomb tritium. This is not consistent with the apparent carbon-14 age date of 9900 years reported on page 55 of the report. I suspect that the tritium unit measurement reflected the age of the drilling fluid (mud). The tritium units for later sampling dates would have been helpful but they are reported only as <220.

If you have any comments or questions about this review, please call.

Sincerely,

Roy

Roy E. Williams

cc: Marty Mifflin
Jim Osiensky

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USGS ~~OFR~~ WRI 84-4193

WMGT DOCUMENT REVIEW SHEET

FILE NO.:

ONWI No.:

DOCUMENT: Preliminary Evaluation of Hydrologic Properties of Cores of Unsaturated Tuff, Test Well USW H-1, Yucca Mountain, Nevada

REVIEWER: Williams and Associates, Inc.

DATE REVIEW COMPLETED: December, 1984

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:

The report under review presents estimates of ambient moisture tension and effective hydraulic conductivity of the tuff matrix at Yucca Mountain. The purpose of the report is to present these estimates for use in the design of experiments and the selection of instrumentation for additional studies to characterize the hydrology of the proposed repository site at Yucca Mountain. The report also presents a preliminary estimate of the vertical matrix flux at Yucca Mountain; a qualitative assessment of the applicability of the method used to estimate the vertical matrix flux is presented also.

According to the report under review, no direct measurements were made of moisture tension and hydraulic conductivity at ambient moisture content during the early hydrologic test drilling program at Yucca Mountain. Mercury-porosimetry tests were conducted on cores collected from the unsaturated zone from test well USW H-1. The results of these tests form the basis of the report under review. The approach used was to combine the porosimetry data with existing data on ambient moisture content to estimate moisture tension and relative hydraulic conductivity. The values of relative hydraulic conductivity were used in combination with measurements of saturated hydraulic conductivity made previously on cores of the same geologic units from test well UE25A#1 located approximately 2 km east of test well USW H-1. These data were used to estimate the effective matrix hydraulic conductivity and vertical water flux in the tuff matrix. The report under review notes that the results presented are considered preliminary and should be used principally as guidelines for further investigations.

Test well USW H-1 was drilled at Yucca Mountain, near the western border of the Nevada Test Site; total well depth was 1,829 m below land surface. The well was drilled using an air-foam mixture, and the cores were waxed and sealed after retrieval. According to the report under review, laboratory analyses were performed on selected cores from the unsaturated zone during the investigation by Rush and others (1983). In addition, small samples were taken from some of these cores for use in mercury-injection (porosimetry) tests made by Holmes and Narver, Inc., a contractor for DOE. Data for 19 samples collected at depths ranging from 34 to 533 m are summarized in table 1 of the report under review.

Mercury-injection tests were made on cores from the unsaturated zone at test well USW H-1; the data were used to develop moisture characteristic curves relating matrix saturation and moisture tension. According to the report under review, the tests were conducted by placing a small sample in a porosimeter chamber, evacuating air from the chamber with a vacuum pump, and then injecting mercury into the sample under several step increases in pressure. The equivalent moisture tension for a given mercury-injection pressure was determined from the capillary rise law (Stallman, 1964). The equations used and the explanations for the equations are presented on pages 9 and 10 of the report under review.

According to the report under review, moisture characteristic curves were prepared from results of the mercury-injection tests by: 1) plotting the computed matrix saturation versus the inferred moisture tension for a given applied mercury injection pressure, and 2) connecting the points by line segments. The moisture characteristic curves are shown on figures 4 through 22 in the supplemental data section at the end of the report under review.

According to the report under review, ambient moisture tensions were estimated first by computing ambient matrix saturations from the volumetric moisture content and porosity of the samples, and then by selecting the moisture tensions that correspond to those matrix saturations on the moisture characteristic curves. Porosity was determined from both the entire core sample and the subsample used in the mercury injection tests from the dry bulk density and grain density of the samples. According to the report under review, some error in the estimation of ambient moisture tensions may have been introduced by using the subsample to determine the moisture characteristic curve and porosity, while using the large sample to obtain volumetric moisture content; other possible sources of error include wetting of the sample during drilling, and drying of the sample prior to wrapping and waxing after the core was collected. Ambient moisture tensions were determined from 14 samples; values range from less than 10 to more than 250 kilopascals (table 1 of the report). According to the report under review, if the true ambient matrix saturations were 0.1 greater or less than those measured on the cores, the actual moisture tensions would be 50 to 100 kilopascals less or greater than determined.

The relative hydraulic conductivity, K_r, defined as the ratio of hydraulic conductivity at a given matrix saturation to that at complete matrix saturation can be estimated from moisture characteristic curves. The approach used by the report under review involves fitting an analytical expression to the moisture characteristic curve which then is integrated to give an equation for relative permeability as a function of matrix saturation or moisture tension. Moisture characteristic curves from eight samples were analyzed by the method of Brooks-Corey (1964). Log-log plots of moisture tension versus effective matrix saturation for the eight samples are shown in figures 23 through 30 in the supplemental data section at the end of the report under review. According to the report under review, data from 11 samples failed to fit the Brooks-Corey model. Data for these 11 samples are inadequate for determination of relative hydraulic conductivity.

The relative hydraulic conductivity of the eight samples was computed by the equation presented in Mualem (1976). This equation is presented on page 13 of the report under review. According to the report under review, the 0.2 value listed in table 1 of the report probably is unreliable because the porosity of the total sample was much larger than that of the small sample used in the porosimeter; the geometric mean of the seven values of relative hydraulic conductivity considered valid is 0.01, and the median is 0.007.

No measurements of saturated hydraulic conductivity were made on cores from the unsaturated zone in test well USW H-1. Saturated hydraulic conductivity measurements on 15 cores of the Topopah Spring Member from test well UE25A#1 were used in combination with the relative hydraulic conductivity data from USW H-1 to estimate the effective hydraulic conductivities of the tuffs. According to the report under review, the geometric mean of saturated hydraulic conductivity of the minimum or single values for the 15 samples from test well UE25A#1 is 4×10^{-9} cm/s, and that for the maximum values is 7×10^{-9} cm/s; based on this range and on the range of relative hydraulic conductivity values estimated from cores from test well USW H-1, effective hydraulic conductivities are estimated to range from 8×10^{-12} to 7×10^{-10} cm/s.

Assuming that a unit hydraulic gradient exists in the unsaturated zone, the estimates of effective hydraulic conductivity would convert to a vertical water flux through the tuff matrix of 0.003 to 0.2 mm/year. According to the report under review, these values are "extremely approximate" because no attempt was made to relate saturated hydraulic conductivities and relative hydraulic conductivities to individual hydrogeologic units, a requirement for rigorously applying Darcy's law. The report suggests that the values probably bracket the actual matrix flux through the tuffs at Yucca Mountain.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

Significance in EAs:

Reference to the report under review occurred in Section 6.3.1.1 Geohydrology (10 CFR 960.4-2-1) under the subheading Relevant Data. The report is referenced on pages 6-98, 6-104, 6-107, and 6-110. The report under review is referenced in the Draft EA on page 6-98 as follows: 1) "Information concerning the in situ distribution of moisture in the unsaturated formations at Yucca Mountain is available from three boreholes: UE-25A#1 (Anderson, 1981), USW H-1 (Weeks and Wilson, 1984), and USW UZ-1 (Montazer et al, 1984)". 2) "Porosity values for the tuffaceous beds of the Calico Hills, which underlie the Topopah Spring Member are given in Anderson (1981a), Weeks and Wilson (1984), Blair et al. (1984), and Montazer and Wilson (1984)". The report is referenced on page 6-104 of the Draft EA as follows: 1) "Laboratory tests of core from both the geologic and hydrologic test holes (Anderson, 1981a, 1981b; Rush et al., 1983; Weeks and Wilson, 1984; Blair et al., 1984; Lappin et al., 1982) indicate that porosity and hydraulic conductivity of the matric decrease as the degree of welding increases." The report is referenced on page 6-107 of the Draft EA as follows: 1) "Values for total porosities of samples of this unit range from 30 to 48% (Anderson, 1981d; Weeks and Wilson, 1984; Blair et al., 1984; Montazer and Wilson, 1984)." The report is referenced on page 6-110 of the Draft EA as follows: 1) "Information concerning the in situ distribution of moisture in the unsaturated formations at Yucca Mountain is available from three boreholes: UE-25A#1 (Anderson, 1981b), USW H-1 (Weeks and Wilson, 1984), and USW UZ-1 (Montazer et al., 1984)." 2) "The low moisture contents in this unit also correspond to high negative matric potentials (5 to 25 bars) (Montazer et al., 1984) and low relative permeabilities (about 0.01) (Weeks and Wilson, 1984)."

Significance in Overall Licensing Process:

The report constitutes a preliminary evaluation of hydrologic properties of cores of unsaturated tuff from test well USW H-1. The report is preliminary and thus the data should not be used to draw conclusions pertaining to vertical flux through the tuffs at Yucca Mountain.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

The major limitations of the report are due primarily to the sparseness of data and uncertainties with respect to the reliability of the data. The report notes that the results of the investigation are preliminary and should be used only as a guide for future studies. The report was designed to present estimates of moisture tension and effective hydraulic conductivity under ambient conditions of moisture content, to make preliminary estimates of matrix flux and to present the estimates so that additional experiments can be designed to refine the estimates. The preliminary nature of the estimates presented is stressed throughout the report. Thus the report should not be used to support contentions presented in the EA. However, preliminary estimates of vertical flux are needed for development of conceptual geohydrologic models and preliminary flow models of the unsaturated zone.

SUGGESTED FOLLOW-UP ACTIVITY:

Reference to the report under review in the EA should be reviewed by the NRC to ascertain whether use of the reference to support contentions in the EA is justified.

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Hydrogeology • Mineral Resources Waste Management • Geological Engineering • Mine Hydrology

WM Record File B7377 WM Project 11
Docket No.
PDR ✓
LPDR ✓
Distribution: JPohle
(Return to WM, 623-SS)

November 5, 1984
Contract No. NRC-02-82-046
Fin No. B-7377-2
Communication No. 53

WM DOCKET CONTROL CENTER

Mr. Jeff Pohle
Division of Waste Management
Mail Stop 623-SS
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Pohle:

This letter constitutes my response to your request to review documents entitled:

Robison, J.H. 1984. Ground Water Level Data and Preliminary Potentiometric Surface Maps, Yucca Mountain and Vicinity, Nye County, Nevada. U.S.G.S. WRI84-4197.

Rice, W.A. 1984. Preliminary Two-Dimensional Regional Hydrologic Model of the Nevada Test Site and Vicinity. SAND83-7466.

I will review the article by Jim Robison (1984) first.

Review of:

Robison, J.H. 1984. Ground Water Level Data and Preliminary Potentiometric Surface Maps, Yucca Mountain and Vicinity, Nye County, Nevada. U.S.G.S. WRI84-4197

This document constitutes the results of an effort by the USGS and by DOE to respond to one of our comments to the effect that the potentiometric surface map data points at the NTS site were insufficient in number to justify earlier maps. This comment precipitated the installation by the USGS of the series of boreholes known as the WT holes (water table holes). The subject report combines the water level measurements from those holes with the water level measurements from the previously installed hydrology test wells and geology test wells in order to produce the new potentiometric surface map shown in figure 2 of the document. The potentiometric surface map does in fact constitute a significant improvement in the knowledge base relative to the preliminary map shown in figure 1. Generally speaking, the map shows a hydraulic gradient directed from northwest to southeast in the portion of the study area north of borehole USWG-1 and a hydraulic gradient directed essentially from west to east, south of this borehole. The report points out correctly that the gradient is far from uniform over the site and that the reasons for this nonuniformity (presumably discontinuities) are not well understood. The report specifies that the contours are considered approximate and preliminary, partially for this reason. The report states correctly that some revisions may be necessary as more water level data are obtained after the completion of additional wells. The report goes on to state that the contours are based on assumptions of areal-uniform variation of water levels between data points. This comment is followed by the comment that further refinements or changes may be warranted as more data are obtained and as concepts of geohydrologic controls of local ground water movement are developed. The report lists as an example of such a control abrupt changes of gradient that might occur across faults that have very low permeability. I am interpreting this comment to mean that the faults themselves may abut an impermeable unit against a permeable unit rather than that the faults themselves are the units of low permeability.

The report points out specifically that long-term trends cannot be interpreted from the short-duration data base in the subject document. Most of the measurements were made in 1983. However, the report points out also that in 1983 a program of periodic or continuous water level monitoring began that will indicate seasonal fluctuations if they occur. The report states that preliminary indications suggest that seasonal ranges of levels are several tenths of a meter or more. It seems to me that this is an appropriate follow-up to the study.

I have only two comments that might constitute suggestions for items that should be addressed in order to clarify or strengthen the report. They are as follows.

1. Page 8 of the report states that most water levels shown on the map (figure 2) represent composite hydraulic heads of the entire saturated thicknesses open to the wells that constitute the data points. However, for some wells water levels shown are for depth intervals considered most representative, usually for the shallowest permeable zone. This is the most logical approach that could have been used to develop the potentiometric surface map considering the limitations pertaining to time and to equipment availability in the wells. However, page 5 of the report states that most of the water levels are based on measurements using

calibrated steel cables with electrical or mechanical water level sensors or using pressure transducers. Page 5 also states that water levels in the Yucca Mountain area are deep, on the order of 750 m below land surface. Under these circumstances it seems to me that it would be appropriate for the USGS eventually to address the differences in water level measurements that are produced by downhole pressure transducers and uphole steel tape measurements. In order to address this issue specifically one would have to calculate the impact of the effect of temperature changes with depth on the density of the water column in the hole. I am assuming that there are no methane effects on density at the NTS such as those that have been observed at BWIP. In other words, I am assuming that temperature is the only parameter that affects density and therefore the height of the column of water in the holes at the NTS, unlike the results we have observed at BWIP. It probably is safe to assume that the altitude of the column of water in the hole measured with tapes as uphole measurements has equilibrated with the temperature of the surrounding rock and water medium. The pressure transducer measurements opposite the aquifer producing the potential measured on the other hand would reflect no such equilibration process. Although the temperature changes with depth below the water table at the NTS may be sufficiently small to produce an insignificant difference between the two types of potentiometric measurements, it seems to me that this should be shown with appropriate calculations (assuming it is true).

2. The primary question that I believe should be addressed by the USGS that is not addressed in this report is whether or not the water level measurements are in fact measurements of the elevation of the water table. As stated above, the report states that two types of measurements are incorporated into the data points on figure 2 (the potentiometric surface map). These two types of measurements are uphole measurements with steel tape or cable and downhole measurements with pressure transducers. In addition, the report states that some of the water level measurements reflect the potential produced by composite zones and some reflect the potential produced by packed-off zones. The latter measurements generally reflect the potential in the shallowest packed-off zone in a particular borehole.

The report under review does not address the fact that some of the composite water level measurements and some of the downhole measurements (pressure transducer measurements) may reflect the potential produced by one or more confined aquifers. My primary reason for raising this issue is that other documents that have been published by the USGS treat water producing zones as confined aquifers. For example, the pumping and recovery test section on page 12 of the document entitled "Geohydrologic Data for Test Well UE-25P #1 (USGS-OFR-84-450)" states that "The first test (a pumping and recovery test) was conducted in the interval from the top of the saturated zone to 1,197 m (zone thickness of 1,301 m)." This report presents drawdown versus time data in figure 5. As far as I can tell from the report, no corrections were made for water table conditions. In other words, the data are viewed as data from a confined aquifer. Other documents that we have reviewed previously have used drawdown data analysis techniques that assume confined conditions without a correction for water table conditions (delayed yield). These reports (or publications) and our reviews include the following publication by Moench.

Moench, A.F. 1984. Double Porosity Models for a Fissured Ground Water Reservoir with Fracture Skin. Water Resources Research, vol. 20, no. 7, p. 831-846.

Moench treated the drawdown data in his paper according to a double porosity fracture model numerical approach but he did not correct the data for water table conditions. As far as I can tell he treated all the data as though they reflect confined conditions. I can find in his paper no mention of correction for delayed yield. I suspect that Moench is in fact correct in treating the data in this way, but this treatment is not consistent with the assumption that all the water level measurements in the report under review reflect water table conditions. USGS Water Resources Investigations Report No. 83-4032 does likewise. This report presents the analysis of pump test data for borehole USWH-1.

In addition to the above reasoning, the potentiometric measurements with depth in the aforementioned (UE-25P#1) well are not constant as we have pointed out in previous reviews. The elevation of the potentiometric surface ranges from 729.9 m in the depth interval 383 to 500 m to 749.2 m in the depth interval 1,297 to 1,805 m. In addition to the water level measurements on this hole, borehole flow surveys have been conducted. These surveys show that about 58% of the water production during pumping is derived from the depth interval 469 to 501 m. This interval is contained in the depth interval 383 to 500 m which was selected as the interval which produced the fluid potential used in the potentiometric surface map mentioned above. About 11% of the yield was derived from the depth intervals 564 to 602 m and 1,000 to 1,119 m. These data show that at least two zones that are separated by about 500 m vertically produced significant quantities of water during pumping. It is improbable that the 500 m of "confining layer" between these two producing zones would not create confined conditions at least in the lower interval. In this particular case the lower interval was not used as a source of the potentiometric measurement that was plotted on figure 2 of the report under review. In other boreholes that is not the case. I have used this borehole as an example because sufficient data exist on it to illustrate the point I am trying to make.

For these reasons it seems to me that it would be advisable at some stage for the USGS to address the question of whether the water table measurements are in fact water table measurements or a combination of water table measurements and combined aquifer measurements. Perhaps this issue also should be addressed in the context of pump test analysis because the two types of USGS documents are not in agreement from a technological point of view. One method of approaching this issue consists of evaluating the boreholes with respect to barometric response. Although water table aquifers do sometimes respond to barometric changes (not well understood but usually attributed to intrapped air) the responses normally are much less than the responses for confined aquifers. Another way of approaching the question would be to pack off all but the shallowest intervals and eliminate the composite measurements that have been made on most of the water table wells. It might be useful also to attempt to correct pumping test drawdown curves for delayed yield and see whether delayed yield can be separated from leakage. Other approaches may be possible also, but off-hand I am not able to think of any others.

USGS WRI-4248
84

WMGT DOCUMENT REVIEW SHEET

File No.:

ONWI No.:

Document: Geohydrology of Rocks Penetrated by Test Well UE-25P#1, Yucca Mountain Area, Nye County, Nevada, by R.W. Craig and J.H. Robison

Reviewer: Williams and Associates, Inc.

Date Review Completed: February, 1985

Brief Summary of Document: Date Approved:

The purpose of the report is to characterize the geohydrology of the saturated volcanic and dolomitic rocks penetrated by test well UE-25P#1. Test well UE-25P#1 is located on the valley floor, approximately 1.5 km west of Yucca Mountain. The well was drilled primarily to obtain information about rocks of Paleozoic Age that were presumed to underlie the volcanic rocks of Tertiary Age penetrated by previous test wells in the Yucca Mountain area. The second objective for drilling the well was to collect additional information about the Tertiary rocks in the area.

Test well UE-25P#1 was completed to a total depth of 1,805 m. The hole was rotary drilled using an air/foam fluid consisting of air, detergent, and water when possible, rather than drilling with mud, to minimize infilling of pores and fractures; however, a polymer mud was necessary during drilling of most of the Paleozoic section to clear the cuttings from the hole. The rocks penetrated by the well were predominantly Tertiary ash flow tuff units from the surface to approximately 1,244 m. A conglomerate unit approximately 34 m thick occurs within the depth interval between 1,138 and 1,072 m. Two faults that occur within the Tertiary sequence are large enough to disrupt the normal stratigraphic succession of the tuff sequence at Yucca Mountain. A fault zone at approximately 1,244 m juxtaposes the Tertiary succession against Paleozoic carbonate rocks. Below this fault, the hole penetrated dolomite of the Silurian Lone Mountain dolomite and Roberts Mountain Formation.

The results of water level measurements taken prior to or after each packer injection test are summarized in table 2 of the report under review. These water level measurements are illustrated graphically in figure 4 of the report. According to the report under review, accurate hydraulic head measurements were not obtained within the interval between 1,197 and 1,297 m because of drilling difficulties. The variation of water temperature with depth was similar to the variation of hydraulic head (figure 4 of the report). Maximum values for both temperature and hydraulic head were measured in the vicinity of the Tertiary-Paleozoic contact. The report under review notes that this geologic contact may be an important hydrogeologic feature.

Borehole flow surveys were conducted to evaluate which intervals yielded water during pumping or which intervals yielded or received water during static (non-pumping) conditions.

Spot or continuous measurements of the vertical fluid velocity within the borehole were made with the use of a radioactive iodine-131 tracer. The movement of iodine within the borehole was monitored as it passed by two gamma detectors. The rate of flow within the borehole was calculated from the measured velocity and the cross sectional area of the borehole from a caliper survey.

Three flow surveys were conducted in test well UE-25P#1. The first flow survey was conducted in the Tertiary section. Figure 5 of the report presents the results of this flow survey. The flow survey data indicate that the lower part of the Prow Pass Member yielded no water; however, an interval less than 30 m thick within the upper part of the Prow Pass Member yielded approximately 58% of the total amount of water produced by the Tertiary section.

The second flow survey conducted in test well UE-25P#1 was conducted under static, or non-pumping, conditions. This flow survey was also conducted in the Tertiary section and showed upward movement of water within the borehole. According to the report under review, virtually all the upward moving water entered the borehole from a thin interval in the Prow Pass Member that yielded 58% of the total amount of water produced during pumping (figure 6).

The third flow survey within test well UE-25P#1 was conducted in the Paleozoic section during pumping. This flow survey showed that 30% of the yield from the Paleozoic section came from a 190 m interval in the middle part of the Lone Mountain dolomite. The flow survey indicated also that more than 50% of the total flow from the Paleozoic section was derived from an interval in the upper part of the Lone Mountain dolomite that is less than 10 m thick (figure 7).

The authors of the report under review selected a dual-porosity model for the analysis of the aquifer test data from test well

UE-25P#1. According to the report under review, the conceptual model used in the analysis of the aquifer test data has the following elements:

1) Both primary and secondary porosity are present.

2) Primary porosity in the matrix is homogeneous and isotropic; secondary porosity is controlled by fractures, which generally are vertical or high angle.

3) Both primary and secondary porosity may be decreased by mineral deposition.

4) Flow to the well is through fractures only; flow occurs between the matrix and fractures. Mineral deposition at the matrix-fracture surface probably decreases such flow.

5) Hydraulic conductivity of fractures is several orders of magnitude greater than hydraulic conductivity of the matrix.

6) Volume of water stored in the fractures is small relative to the volume stored in the matrix.

7) Distances between fractures are small in comparison with dimensions of the ground water system under study.

8) On a small scale, the fracture permeability is anisotropic; on a large scale, the orientation of fractures is assumed to be random, so the system appears isotropic.

It is interesting to note, that the authors of the report under review did not attempt to apply the conceptual model for a dual-porosity reservoir with a fracture skin developed by Moench (1984) for test wells UE-25B#1 and UE-25A#1.

The dual-porosity model with fracture skin developed by Moench (1984) assumes the presence of an infinitesimally thin fracture coating of low hydraulic conductivity. The low hydraulic conductivity coating on the fractures is assumed to impede the flow of ground water from the matrix into the fractures. Mathematically the fracture coating is analogous to a leaky confining layer with a specific storage of zero in a multiple aquifer/aquitard system. The dual-porosity model used by the authors of the report under review assumes that ground water is free to flow from the matrix into the fractures. The mathematical treatment of flow to a well in such a dual-porosity media is identical to the mathematics for flow to a well in an unconfined aquifer with delayed yield as developed by Boulton (1963). According to the report under review, knowledge of whether the aquifer is confined or unconfined would prevent misinterpretation of the data. The authors of the report under review note also that the time required to approach quasi-steady-state conditions in a heterogeneous reservoir is one or two orders of magnitude greater than in a homogeneous reservoir. Consideration of the time needed to reach quasi-steady-state conditions may help prevent an incorrect interpretation.

Analysis of the aquifer test data by the Boulton (1963) method requires the following assumptions:

1) At early time, water level response due to pumpage is due to the fracture system. Flow from the matrix into the fractures is insignificant. Flow to a well during early time is described by the Theis equation.

2) At intermediate times, a transition occurs from fracture flow to a combination of fracture flow and matrix flow. The matrix flow contribution affects the aquifer response in a manner similar to that of delayed yield in an unconfined system.

3) At late time, the transition is complete. Flow to a well again is described by the Theis equation.

According to the report under review, selection of the conceptual model is supported by the following:

1) Production was associated with known fractures, although not all known fractures yielded water.

2) Borehole-flow surveys showed production was derived from limited intervals. Most intervals of borehole yielded little or no water during pumping. This supports the concept of small matrix hydraulic conductivity and large fracture hydraulic conductivity.

3) Laboratory measurements of horizontal and vertical matrix hydraulic conductivities of ash flow tuffs from a nearby test well (USW H-1) were about 1×10^{-4} to 1×10^{-6} m/sec (Rush and others, 1983). A pumping test of the Tertiary section showed that apparent transmissivity was much larger than could be accounted for by matrix hydraulic conductivity alone. The authors of the report under review note that the degree to which this model describes the actual system in the vicinity of test well UE-25P#1 is not entirely known.

Pumping and Recovery Test 1

The pumping and recovery test of the Tertiary section was conducted when the well was at a depth of 1,301 m. According to the report under review, a cement plug previously had been set from approximately 1,197 to 1,204 m; however, the plug apparently was not effective as shown by a combination of borehole-flow surveys, temperature logs, and water quality data. The effective interval of pumping probably was from the static water level to a depth of 1,301 m. The composite static water level prior to pumping was 382 m below land surface. The well was pumped at 22.1 L/sec for 3,150 min with the pump intake located at 425 m. Drawdown at the end of pumping was 33.7 m. Recovery was monitored for 1,060 min.

A log-log plot of drawdown versus time for pumping test one is presented in figure 8 of the report. According to the report under review, early-time data appeared to extend to about 80 min. Drawdown greater than predicted by the Theis curve occurred during the first 8 min of the pump test. The report under review attributes this phenomenon to drainage of the fracture system that extends to the water table. In a double porosity system, the initial portion of the time drawdown curve that is deflected above the Theis type curve usually is considered to be due to the elastic response of the fractures rather than drainage from the fractures (Boulton and Streltsova-Adams, 1978). The report under review suggests that the water level response between about 10 and 80 min was characteristic of the deeper, main fracture system. The transitional period of the dual-porosity system was considered to begin at approximately 80 min into the pump test. At this time flow from the matrix into the fractures was considered to be significant. According to the report under review, late-time apparently was not reached during the pump test. The authors of the report under review used the drawdown data for the period between 10 and 80 minutes to estimate the transmissivity. These data were matched to the Theis type curve. An apparent transmissivity of the fracture network was estimated to be 24 m^2/day.

A semi-logarithmic graph of drawdown versus time for pumping test one is shown in figure 9 of the report. Straight-line segments shown on this figure correspond fairly well with deviations from the Theis curve on the log-log plot of figure 8. The apparent transmissivity of the fracture network was estimated from the first straight-line segment by use of the Jacob straight line method.
The estimated apparent transmissivity of 26 m^2/day corresponds very well with the estimate of 24 m^2/day by using the Theis method.

Figure 10 of the report under review presents a semi log plot of residual drawdown versus time since pumping started, divided by the time since pumping stopped. The recovery data also were analyzed by the Jacob straight line method. The apparent transmissivity of the fractured network was estimated from the recovery data to be 18 m^2/day.

The report under review makes note that other models beside the dual-porosity model may be used to interpret the pump test data. The report notes that similar deviations from the Theis curve could be caused by a hydraulic boundary.

Pumping and Recovery Test 2

Pumping and recovery test 2 was conducted during testing of the Paleozoic section. At the time of testing, the well was open to formation rock from 1,297 m to a total depth of 1,805 m. The static water level for the open interval was 362 m below land surface prior to pumping. The pump intake was at 417 m. Discharge rate during pump test 2 was 31.5 L/sec. Pump test 2 was conducted for 6,080 min.

A semi-logarithmic plot of drawdown versus time for pumping test 2 is presented in figure 11 of the report. The irregular response of the water levels to pumping during the initial 50 min of the pump test is attributed by the report under review to temperature changes in the water column. According to the report under review, a temperature survey conducted prior to pumping showed that the temperature in the water column ranged from 33°C near the top of the water column to a maximum of about 56°C near 1,370 m. In addition to changing temperature, the early drawdown data were affected by inertia. A semi-log plot of residual drawdown versus time after pumping stopped is presented in figure 12 of the report. This figure shows clearly that inertia affected the early drawdown data. The recovery data form a damped sine-wave curve characteristic of inertial effects.

Drawdown data for the period from 50 min to the end of the test were corrected for the expansion of the water column. Five and one-half meters of drawdown were added to the data. A semi-log plot of the corrected drawdown data versus time is shown in figure 14 of the report. Drawdown data from 50 to 200 min were used to estimate transmissivity by the Jacob straight line method. Transmissivity for the first 200 min of the test was estimated to be 131 m^2/day. According to the report under review, based on the dual-porosity model, the response during this time was representative of the fracture network. The Jacob straight line method also was used to estimate transmissivity from the third straight line segment of the data (from 1,000 to 6,000 min). This third segment represented late time. The estimated transmissivity from the late time data was 111 m^2/day. The report under review notes that the estimate of transmissivity from the late time data should be greater than the estimate of transmissivity from the early time data due to the addition of matrix flow. The report under review offers the following two explanations for the apparent inconsistent transmissivity values:

1) The first straight-line segment could still have been affected by inertia and, therefore, was not representative of the fracture transmissivity.

2) The dual-porosity model did not apply, and the system was responding as a homogeneous porous medium with some deflection from ideal between about 200 and 1,000 min. In this case, the transmissivity would be about 170 m^2/day.

A logarithmic plot of drawdown (corrected for 5.4 m of expansion in the water column) versus time is presented in figure 15 of the report. According to the report under review, the shape of the data curve fits the response predicted by the conceptual model very well. The report under review suggests that all three time periods are represented in the data. However, the transitional period is represented by only one data point. The report under review notes that matching the late time data with the Theis curve was tenuous. The transmissivity was estimated to be 111 m^2/day. According to the report under review, the recovery data for test 2 could not be interpreted.

Packer-Injection Tests

Parker-injection tests were conducted in various intervals of the well to evaluate the distribution of hydraulic characteristics in the formations. According to the report under review, the design of the packer-injection tool used during testing of well UE-25P#1 restricted the evaluation of transmissivity to intervals of the well with transmissivities less than 5 m^2/day.

The transmissivity of the tested intervals was estimated by the method of Cooper and others (1967) and Papadopulos and others (1973) for those intervals for which data could be matched to a type curve. The report under review notes that the method used to estimate transmissivity assumes a homogeneous, isotropic, confined aquifer that is fully penetrated by the tested well.

Semi-logarithmic plots of the ratio of hydraulic head above static water level at a given time (H), to hydraulic head above static water level at the time of injection (H_o), versus time since injection began are presented in figure 16 through 29 of the report. A family of type curves was used to determine the best fit with the data. According to the report under review, the lack of a good fit at the beginning and end of many of the tests was attributed to an initial decline in water level, as the well-aquifer system became pressurized during the start of a test. Relevant data for the packer-injection tests, as well as the estimated transmissivity values, are listed in table 3 of the report. It should be noted that the method of analysis used to evaluate the packer-injection tests was developed for a homogeneous isotropic confined aquifer and not a dual-porosity system.

The estimated transmissivity values of the intervals tested in the Tertiary section ranged from about 0.1 m/day to greater than 5 m^2/day. According to the report under review, the data curves for test 4 in the Bullfrog Member and test 11 in the Lithic Ridge Tuff were too steep to match to the available type curves. The transmissivity values for tests 4 and 11 were estimated to be between 3 and 5 m^2/day based on the time for the water levels to return to a static condition.

According to the report under review, most packer-injection tests conducted in the Paleozoic Formations were affected significantly by inertia. Tests 15, 16, and 29 were exceptions. In each of the remaining tests, an oscillation in the water level indicated that inertial effects were significant. According to the report under review, an attempt was made to apply van der Kamp's (1976) approximate solution, using data for the underdamped tests. However the estimates of transmissivity were not considered valid.

Ground-Water Chemistry

Table 4 of the report under review presents the chemical compositions for three ground water samples from test well UE-25P#1. According to the report under review, the chemical character of the water from test well UE-25P#1 is similar to the ground water from the regional carbonate (Paleozoic) aquifer of the Ash Meadows ground water basin. According to the report under review, a relatively high carbon-13 value for the sample from the Paleozoic aquifer suggests that a significant part of the aqueous carbon may have been derived from marine carbonate minerals. Crude estimates of ground water age based on carbon-14 samples suggest an apparent age of about 24,000 years B.P. The report under review notes that 24,000 is not consistent with the apparent ages of other water from the Yucca Mountain area, which range from about 9,000 to 17,000 years B.P.

Significance to NRC Waste Management Program:

Significance in EAs:

As mentioned on page 6-113 of the EA, test well UE-25P#1 is the only test hole that penetrated pre-Tertiary rocks. Test well UE-25P#1 provided stratigraphic data from both cuttings and core samples of rocks of Paleozoic Age that underlie the section of

Tertiary rocks east of Yucca Mountain. The report under review and the companion report by Craig and Robison (1984) are significant with respect to the EA since these reports are the only reports available which present hydrogeologic data for the Paleozoic rocks present beneath the Tertiary section.

Significance in Overall Licensing Process:

The report under review constitutes one of two primary sources of information with respect to the Paleozoic rocks that are present beneath the Tertiary section in the vicinity of the proposed repository. The report under review will become significant should travel time through the Paleozoic section become an issue.

Problems, Deficiencies, or Limitations of Report:

There are no major problems, deficiencies, or limitations of the report under review. However, the report notes that alternative interpretations of the aquifer test data are possible. Because several curve matches were tenuous, and several simplifying assumptions of the methods of analysis used were not satisfied, the transmissivity values presented in the report under review should be considered estimates.

Suggested Follow-up Activity:

References Cited:

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Craig, R.W., and Johnson, K.A., 1984, Geohydrologic Data for Test Well UE-25p#1, Yucca Mountain Area, Nye County, Nevada: U.S. Geological Survey Open-File Report 84-450, 63 p.

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van der Kamp, Garth, 1976, Determining Aquifer Transmissivity by Means of Well Response Tests--The Underdamped Case: Water Resources Research, vol. 12, no. 1, p. 71-77.

(GEOTRANS COVER LETTER OF 85/02/21)

ATTACHMENT D: SUMMARY OF GEOHYDROLOGY OF VOLCANIC TUFF PENETRATED BY TEST WELL UE-25b#1.

Lahoud, R.G., D.H. Lobmeyer, and M.S. Whitfield, Jr., 1984, Geohydrology of Volcanic Tuff Penetrated by Test Well UE-25b#1, Yucca Mountain, Nye County, Nevada, U.S. Geological Survey, Water Resources Investigations Report 84-4253, 44p.

Test well UE-25b#1, located within Drill Hole Wash, was drilled and tested in a two stages. The first stage of drilling began on April 3, 1981 and was completed to a depth of 579 m below ground. Once geophysical surveys and hydrologic tests were completed on this upper interval, the test well was extended to a final depth of 1,220 m below ground. A second phase of geophysical surveys and hydrologic tests were then conducted on the lower portion of the test hole. The test hole penetrated 46 m of alluvium, 376 m of Paintbrush Tuff, 149 m of the tuffaceous beds of Calico Hills, 636 m of Crater Flat Tuff, and 13 m of the Lithic Ridge Tuff.

Conclusions presented are based on the analyses of hydrologic tests, mechanical tests of cores, and geophysical surveys. The majority of geohydrologic data presented in this publication were reviewed, in the summary of D. H. Lobmeyer, et al., (1983), U.S. Geological Survey, OFR-83-855.

Through the analyses of borehole flow and geophysical surveys, five principal water-producing zones were identified: (1) the upper part of the tuffaceous beds of Calico Hills (12 percent yield), (2) the lower part of the tuffaceous beds of Calico Hills at a depth interval from 546 m to 564 m (20 percent yield), (3) the top of the Prow Pass Member of the Crater Flat Tuff at a depth interval from 579 m to 626 m (19 percent yield), (4) the middle of the Bullfrog Member of the Crater Flat Tuff at a depth interval from 811 to 818 m (19 percent yield), and (5) the zeolitized, bedded, and reworked unit at the base of the Bullfrog Member at a depth interval from

866 m to 872 m (30 percent yield). The percentage of water yielded from each production zone was used to estimate the magnitude of the transmissivity associated with that zone.

The results of packer injection tests, in conjunction with the results of borehole flow surveys, were used to approximate the transmissivities and hydraulic conductivities of strata between the depth interval of 471.4 to 1,220 m. Approximate transmissivities ranged from $10^{-1} m^2/d$ in the Bullfrog Member to $55 m^2/d$ in the tuffaceous beds of Calico Hills. Hydraulic conductivities determined for the tuffaceous beds of Calico Hills; Prow Pass, Bullfrog, and Tram Members of the Crater Flat Tuff; and Lithic Ridge Tuff were 2.6×10^{-1}; 9.1×10^{-1}; to 1.08; less than 10^{-3}; and less than 10^{-4} m/day, respectively.

Mechanical testing of cores were used to determine density, matrix porosity, pore saturation, natural-state pore-water content, and matrix hydraulic conductivity. Matrix hydraulic conductivities were several orders of magnitude smaller than hydraulic conductivities measured during in-situ testing. A fracture analysis of the core defined five possible fault zones within the Crater Flat Tuff: one in the upper part of the Prow Pass Member, one in the middle part of the Bullfrog Member, and three in the middle to lower part of the Tram Member. Two of the fault zones are associated with water-producing zones.

Evidence from hydrologic tests, geophysical surveys, and mechanical testing of cores indicated that the majority of water production in test well UE-25b#1 is controlled by local structures such as faulting and folding. Reasons for this conclusion are as follows: (1) the four orders of magnitude difference between in-situ-determined bulk hydraulic conductivities and laboratory determined matrix hydraulic conductivities; (2) the presence of fault zones in the majority of water-producing zones;

(3) geophysical surveying, such as seisviewer and televiewer logs, showed slight-angle fractures in known water-producing zones; (4) the absence of lithologic boundaries within or adjacent to water-producing zones; and (5) geophysical surveying, which usually records differences in matrix porosity, did not identify well-defined water-producing zones. The deepest water-producing zone at the base of the Bullfrog Member of the Crater Flat Tuff produces 30 percent of the total yield. This water-yield is proposed to occur either along fractures or boundaries of the zeolitized, bedded and reworked unit.

This publication concludes that "70 percent of the transmissivity is controlled by structures . . . and the remaining 30 percent . . . probably occurs along fractures or boundaries of the unit." The term "transmissivity" is not used in the strictest sense, but instead, in synonomous to water-yield.

Water sample analyses indicated that the water of UE-25b#1 is a soft, sodium bicarbonate with a pH of 7.1. and a temperature of 36.°C to 37.2°C. The uncorrected carbon-14 age ranged from 13,400 years to 14,100 years. A deuterium-hydrogen ratio determined that the water originated from precipitation.

USGS WRI 84-4253

WMGT DOCUMENT REVIEW SHEET

FILE NO.:

ONWI NO.:

DOCUMENT: Geohydrology of Volcanic Tuff Penetrated By Test Well UE-25b#1, Yucca Mountain, Nye County, Nevada, by Lahoud, Lobmeyer, and Whitfield (1984)

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: March, 1985

BRIEF SUMMARY OF DOCUMENT: DATE APPROVED:.

The purpose of the report under review is to describe the hydrologic characteristics of a sequence of saturated tuffs penetrated by test well UE-25b#1. Test well UE-25b#1 is located in Drill Hole Wash on the east side of Yucca Mountain.

Test well UE-25b#1 was drilled to a total depth of 1,220 m. The test hole was drilled in two phases. The first phase consisted of drilling a 222 mm diameter hole to a depth of 579 m. Geophysical logs, borehole surveys, and packer injection tests were conducted while the well was at this depth during the first phase of testing. During the second phase of drilling, 64 mm diameter cores were cut from 579 m to 1,220 m. Geophysical logging, pumping tests, borehole flow surveys, and packer injection tests were conducted after the second phase of drilling was completed.

A mixture of air, detergent, and water was used as the drilling fluid for both phases of drilling. Lithium-chloride was added to the fluid used during drilling and testing of the well. Figure 3 of the report under review shows the construction details of the well.

The rocks penetrated by test well UE-25b#1 are predominantly tuffs of volcanic and volcaniclastic origin. These rocks consist of non-welded to densely-welded rhyolitic ash-flow tuff with 4% bedded, reworked, air-fall tuff. Approximately 46 m of Quaternary alluvium overlie the tuffs. A summary of the general lithology penetrated by the well is shown in Table 1 of the report. Figure 4 of the report under review illustrates the distribution of induration in welding of the tuffaceous rocks penetrated by test well UE-25b#1.

Physical properties tests were performed on the 64 mm diameter cores by Sandia National Laboratory. Density matrix porosity and pore saturation were determined for 127 samples from depths of 589 to 1,216 m. Tests of density, matrix porosity, pore saturation, natural-state pore-water content and matrix hydraulic conductivity were conducted on 12 core samples from depths of 479.3 to 1,201.8 m by Holmes and Narver, Inc.

According to the report under review, the matrix porosities calculated from dry-bulk and grain densities for the cores ranged from 5.3% (Figure 5 of the report) to 28.1% (Table 2 of the report). Dry-bulk density of the samples ranged from 1.73 to 2.42 grams/cm^3 and averaged 2.1 grams/cm^3 (Table 2 of the report). According to the report under review, horizontal and vertical hydraulic conductivities were all less than 10^{-3} m/day.

Five prominent fault zones were defined in the rocks penetrated by test well UE-25b#1. The locations of the faults are based on a log of the shear fractures compiled from the drill cores (Figure 6 of the report). The faults are located within the Crater Flat tuff as follows: 1) 590-614 m in the upper part of the Prow Pass Member; 2) 804-807 m, in the middle part of the Bullfrog Member; 3) 962-972 m; 4) 1,073-1,076; and 5) 1,110-1,137 m, in the middle to lower part of the Tram Member. According to the report under review, numerous other thin zones of shear fracturing were detected in the lower part of the Bullfrog Member and throughout the Tram Member.

Geophysical logs were recorded in test well UE-25b#1 for the following purposes: 1) lithologic definition, 2) correlation of the logs with logs of nearby wells, 3) obtaining data for porosity in fractures, 4) obtaining fluid levels, 5) locating casing perforations in cement, 6) gaging the diameter of the well, and 7) to help select hydraulic-test intervals. Table 3 of the report under review presents a summary of the geophysical logs recorded for test well UE-25b#1. The actual logs are not presented in the report under review.

According to the report under review, faults or fractures were detected in five water producing zones within the test well. The hydraulic conductivity of these faults or fractures represent most of the hydraulic conductivity in the test well. The report under review notes that this fact limits the effectiveness of standard well test analysis methods. The report under review makes the following assumptions in the conceptual model for the geohydrologic system penetrated by the test well:

1) The tuffs contained in the primary matrix porosity were homogeneous and isotropic.

2) Hydraulic conductivity of fractures was several orders of magnitude larger than the hydraulic conductivity of the matrix; the early flow to or from the well was through fractures only. The fracture hydraulic conductivity was anisotropic on a local scale (with point sources), but the distances between fractures was small in comparison with the dimensions of the ground-water system being studied.

3) The volume of water stored in fractures was relatively small in comparison with that stored in the matrix.

According to the report under review, all of the parameters that are needed to analyze fracture aperture, spacing, and continuity for the tuff in terms of a dual-porosity model were not available. The methods used for analysis of the pumping and packer-injection tests were those of Cooper and others (1967), Ferris and others (1962), Lohman (1972), Papadopulos and others (1973), and Walton (1960). According to the report under review, use of these methods of analysis was based on the premise that water is supplied to the well via matrix permeability from a homogeneous isotropic aquifer of infinite areal extent. According to the report under review, these methods were used to analyze late-time test data. Early-time test data were not used because the data were considered to be potentially dependent upon non-representative, near-well hydraulics, on well-bore storage, and on skin effects. The report under review notes that since the exact time boundary between early time and late time is not distinct for this well, the results should be used with caution.

Three aquifer pumping tests were conducted in test well UE-25b#1 after the well had been drilled to its total depth of 1,220 m. During test 1, the well was pumped at a rate of 13.8 l/sec for approximately 5,760 min. The borehole-flow survey was conducted at the end of test 1 after the rate of drawdown had decreased. During test 2, the well was pumped at rates ranging from 26 to 37 l/sec for 12,960 min. Test well UE-25a#1, 107 m southwest of test well UE-25b#1, was used as an observation well (total depth 763 m) during tests 2 and 3. During test 3, the well was pumped at a rate of 35.7 l/sec for a period of 4,320 min. Residual drawdown was measured after pumping tests 1 and 2; Table 4 of the report under review presents a summary of the aquifer tests.

Drawdown data and residual drawdown data for test 1 are presented in Figures 7 and 8 of the report under review, respectively.

These data were not used to determine the hydraulic properties of the aquifer.

Aquifer test 2 was conducted using a larger pump than aquifer test 1 to place a larger stress on the aquifer. According to the report under review, the drawdown curve (Figure 9 of the report) showed the effect of continuing well development and a fluctuating pumping rate. According to the report under review, hydraulic boundaries could not be detected from the drawdown curve. Increase in the slope of the drawdown curve after 5,000 min was attributed to possible dual-porosity effects, although large fluctuations in the pumping rate made this a tenuous conclusion. Figure 10 of the report under review presents the residual drawdown for test 2. The drawdown data and residual drawdown data for test 2 were not used to determine the hydraulic properties of the aquifer.

Test 3 was conducted at a pumping rate of 35.7 l/sec. Figure 11 of the report under review presents drawdown data for test well UE-25b#1 and observation well UE-25a#1. Residual drawdown was not measured during test 3. According to the report under review, the drawdown data for test 3 were not used to determine hydraulic properties of the aquifer.

According to the report under review, the three aquifer tests show drawdown patterns that were strongly influenced by the fractured nature of the aquifer. The report under review attributes deviations for the theoretical drawdown curves for tests 1 and 2 to the presence of air-foam drilling fluid that had penetrated into the fractures during drilling. According to the report under review, residual drawdown curves showed damped oscillations for the first 20 minutes after the pump was shut off; these oscillations are typical for tests in fractured rocks.

The authors of the report under review concluded that the geohydrologic data for test well UE-25b#1 did not support any particular method of analysis to the exclusion of the others. Thus, the Theim equation was used in an effort to define the transmissivity and hydraulic conductivity of the aquifer. The authors of the report under review note that since the system is believed to be controlled by fractures, the values of transmissivity and hydraulic conductivity are for illustrative purposes only and may not have any physical basis.

Two borehole-flow surveys were conducted in test hole UE-25b#1. The first survey was conducted when the well was at a depth of 579 m. According to the report under review, the purpose of the survey was to determine the location of productive zones in the well. The second survey was conducted in conjunction with the first pumping test. The well was at a depth of 1,220 m. The casing was set at 518 m and was perforated from 477 m to 508 m. According to the report under review, the purpose of the second survey was to determine the location of water-yielding zones in the saturated part of the well and to quantify the water being produced by each zone. According to the report under review, these data were used to identify the zones to be tested by packer-injection tests and to analyze the pumping tests by using the flow rates to estimate the distribution of transmissivity. Figure 12 of the report under review is a schematic diagram of the second borehole flow survey. This flow survey delineated five zones of water production.

According to the report under review, packer-injection tests were conducted to evaluate the hydraulic properties of selected intervals isolated by packers. A slug of water was injected into the interval to produce the pulse of increased hydraulic head. The ratios of the decaying hydraulic head to the original hydraulic head at the start of a test, plotted against the log of elapsed time, were compared to a family of type curves to estimate the transmissivity.

Fourteen packer-injection tests were conducted during the first two testing episodes; semi-logarithmic plots of the packer-injection test data are shown in Figures 13 through 26 of the report under review. Hydraulic conductivity values ranged from about 10^{-4} m/day for the Lithic Ridge tuff to about 1 m/day for the fractured water-producing sections of the Prow Pass and Bullfrog Members. Table 4 of the report under review presents the results of these tests.

According to the report under review, tested intervals with transmissivity values greater than 10^{1} m^{2}/day exceeded the limits of the tool used. Transmissivity and hydraulic conductivity values for these tests were approximated by matching the first static water level reading at the end of the test with the first static water level value on a type curve. Transmissivity values estimated by this technique should be considered tenuous. According to the report under review, average hydraulic conductivities for the geologic units tested were determined by using the borehole-flow surveys for the units containing producing zones and the packer-injection tests for the units containing non-producing zones. These values are presented on page 39 of the report under review.

The U.S. Geological Survey collected three water samples from test well UE-25b#1. These samples were analyzed for major inorganic chemical constituents and radioactive elements. Table 5 of the report under review presents the chemical analyses for samples 2 and 3. According to the report under review, the first sample was not included in Table 5 because of drilling fluid contamination.

Lithium-chloride was added as a tracer to all water used during drilling, coring and packer injection tests to determine when representative water samples could be collected. According to the report under review, at the end of the first pumping test (the first sample), the lithium concentration was 0.82 mg/l. At the end of the third pumping test (second sample), after 16 days of pumping, the lithium concentration was 0.22 mg/l. This concentration was approximately 1% of the concentration of lithium in the water added to the well (20 mg/l). The second sample is considered by the report under review to . be representative of the water in the formations.

The U.S. Geological Survey collected a third water sample on July 20, 1982, after the well had been pumped continuously for 28 days. The sample was obtained from the interval between 853 to 914 m below the surface. The first two water samples represented composite water from tuffaceous rocks at a depth of 471 m to the top of the no-flow zone at 877 m.

According to the report under review, water quality data from the second and third samples indicate that the water is a soft, sodium bicarbonate type with relatively large concentrations of dissolved silica and sulfate, typical of tuffaceous aquifers in the Nevada Test Site area. According to the report under review, an uncorrected carbon-14 age of 14,100 years was obtained for the second sample; uncorrected carbon-14 age of 13,400 years was obtained for the third sample.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

Significance in EAs:

As mentioned on page 6-123 of the Draft EA, test well UE-25b#1 is one of eight test holes in the immediate vicinity of Yucca Mountain that have been tested hydrologically. These tests have included pumping tests of all or part of the saturated zone penetrated by the wells and packer-injection tests of isolated intervals within the holes. Hydraulic conductivity and water level data have been collected from these eight holes. The results of aquifer tests conducted in these eight test holes are presented by Craig and Robison (1984), Rush and others (1984), and in the report under review. Thus the report under review represents a significant percentage of the total data available for the saturated zone at Yucca Mountain.

Significance in Overall Licensing Process:

The report under review constitutes a significant percentage of the data available in the saturated zone at Yucca Mountain. Because of this fact, the data presented in the report under review are very significant with respect to the evaluation of ground water movement through the tuffaceous rocks in the vicinity of Yucca Mountain.

PROBLEMS, DEFICIENCIES, OR LIMITATIONS OF REPORT:

Our comments on this portion of the review of the document are presented in their chronological order of presentation in the report under review. There are no major problems, deficiencies, or limitations of the report that are not made evident by the report itself. The limitations of the testing techniques used as well as the limitations of the interpretations presented in the report under review are indicated clearly within the report.

SUGGESTED FOLLOW-UP ACTIVITY:

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__________, 1960, Application and Limitations of Methods Used to Analyze Pumping Test Data (part 2, vol. 4, no. 3, p. 20, 46, 48, 50, and 52).

WMGT DOCUMENT REVIEW SHEET

FILE #:

DOCUMENT #: USGS-WRI-84-4267

DOCUMENT: Waddell, R.K., Robison, J.H., and Blankennagel, R.K., 1984, Hydrology of Yucca Mountain and Vicinity, Nevada-California--Investigative Results Through Mid-1983. U.S.G.S. Water Resources Investigations Report 84-4267, Denver, 72 p.

REVIEWER: Williams & Associates, Inc.

DATE REVIEW COMPLETED: May 28, 1986

ABSTRACT OF REVIEW: APPROVED BY: Roy E Williams

The report under review presents investigative results for Yucca Mountain and vicinity through mid-1983. Conceptual models for flow in the saturated zone are presented. These conceptual models are modified after the original models presented by Winograd and Thordarson (1975). Conceptual models presented in the report under review include data not available to Winograd and Thordarson (1975). Concèptual models for flow in the unsaturated zone are not presented in detail because investigations up to mid-1983 were concerned primarily with potential high level waste disposal within the saturated zone.

BRIEF SUMMARY OF DOCUMENT:

Introduction

The purpose of the report under review is to present the USGS hydrology contributions to the site characterization report of the Yucca Mountain area. A companion report (U.S. Geological Survey, 1984) presents the geology of the Yucca Mountain area. These reports include data collected and analyzed through mid-1983. The report under review describes the hydrology within the "candidate area" prescribed by the Nuclear Regulatory Commission. The candidate area refers to the area contained within a 100 km radius of Yucca Mountain.

Surface-Water Hydrology

The candidate area includes most of the Death Valley Basin Hydrographic Region of California-Nevada and a small part of the Central Hydrographic Region of Nevada. These hydrographic regions are divided into smaller units called hydrographic areas. The Yucca Mountain site lies on the boundary between Crater Flat and Fortymile Canyon-Jackass Flats hydrographic areas.

The report describes briefly the data available pertaining to flood potential in the vicinity of Yucca Mountain. According to the report, past severe flooding indicates that occasional severe floods probably will occur in the future within southern Nevada, and may occur at Yucca Mountain. The report under review presents the following conclusions based on an investigation of flood potential in Topopah Wash by Christensen and Spahr (1980):

1. The 100 year flood-prone areas closely parallel most main channels.

2. The five-year flood would exceed the discharge capacity of all stream channels except Topopah Wash and some upstream reaches of a few tributaries.

3. The "maximum potential" flood would inundate most of Jackass Flats.

Squires and Young (1984) studied the downstream part of Fortymile Wash. According to the report under review, Squires and Young (1984) concluded that:

1. The 100 year, 500 year, and "regional maximum" floods would stay within the confines of the wash.

2. Crested Butte Wash and Drill Hole Wash would have estimated flood-water depths from 0.3 to 1.2 m in the stream channel during the 100 year flood. The 500 year flood would exceed bank capacities at several reaches of the washes. The "regional maximum" flood would inundate all central flat-fan areas in the two watersheds.

3. The 100 year, 500 year, and "regional maximum" floods within Yucca Wash would stay within the steep-side-slope stream banks that contain the floodplain.

According to the report, most of Yucca Mountain is well above expected flood levels: however, areas that are close to channels or within the lower terraces of Fortymile Wash are subject to flooding.

Regional Groundwater Hydrology

Discussion of the regional groundwater hydrology begins with a description of the basic hydrogeologic units that occur within the candidate area. These hydrogeologic units from oldest to youngest are: the lower clastic aquitard, the lower carbonate aquifer, the upper clastic aquitard, the upper carbonate aquifer, granite, volcanic rocks, and valley fill aquifer. A general description of each of these units is presented in the report.

According to the report, recharge areas were estimated based on the potentiometric map (Plate 3 of the report) and the distribution of precipitation. Areas of high precipitation were considered to be the primary groundwater recharge areas. These recharge areas include the Spring Mountains, and the Sheep, Pahranagat, and Belted Ranges.

According to the report, groundwater discharge areas within the candidate area are characterized by rocks of relatively lower hydraulic conductivity that occur downgradient from the discharge areas. The report suggests that a steep potentiometric gradient across the low hydraulic conductivity rocks causes the water table to intersect land surface whereupon groundwater discharge areas are created. Plate 4 of the report shows the locations of springs within the candidate area. Major discharge areas are located along the Ash Meadows spring line, and at Alkali Flat (Franklin Lake), the Furnace Creek Ranch area, and Oasis Valley. Minor discharge areas from the regional aquifers are believed to occur also at Indian Springs and Cactus Springs. According to the report, numerous perched' springs of minor and variable discharge are present throughout the area.

The candidate area is located within the Death Valley groundwater basin. The authors of the report divide the Death Valley groundwater basin into three groundwater subbasins. These subbasins are: Oasis Valley, Ash Meadows, and Alkali Flat-Furnace Creek Ranch. According to the report, a subbasin consists of recharge areas and flow paths to a major discharge area. A description of each of the three subbasins is presented in the report. However, it should be noted that the actual boundaries of each subbasin are not well defined. The boundaries of the subbasins are defined based on the locations of aquifer outcrops, the distribution of precipitation, and topography. Essentially no hydraulic head data are available upon which to delineate the actual locations of the boundaries.

A brief discussion of the isotopic and regional hydrochemistry is presented in the report. The data indicate that most of the groundwater samples collected to date have highly variable compositions. According to the report, mixing of waters from carbonate and tuffaceous sources is indicated by the chemistry of waters in parts of Ash Meadows and Alkali Flat-Furnace Creek Ranch groundwater subbasins; mixing is evident especially beneath the southern Amargosa Desert and near the Furnace Creek Ranch. According to the report, chemistry of the water beneath Yucca Mountain probably is derived solely by reaction with tuffaceous rocks.

Carbon-14 ages for samples taken from test holes UE-29a#1 and UE-29a#2 in upper Fortymile Canyon are given as 4,100, 3,800, and 2,280 years. According to the report, these carbon-14 ages suggest that recharge has occurred relatively recently along major drainages. Most of the hydrogen and oxygen isotopic data presented in Plate 5 of the report indicate that recharge water probably was derived from melting snow.

Yucca Mountain Hydrogeologic System

According to the report, two series of test holes were drilled to depths greater than a few hundred meters. In one series, small diameter core holes were drilled to obtain stratigraphic, structural, and physical-property data (UE-25a#1, UE-25b#1, USW G-1, USW G-2, USW G-3/GU-3, and USW G-4). A second series of test holes was drilled to obtain hydrologic data. A small amount of core was obtained from test wells USW H-1, USW H-3, USW H-4, USW H-5, and USW H-6. According to the report, test holes UE-25b#1 and USW G-4 were cored and then reamed to allow for hydrologic testing. Four piezometers were installed at different depths in test well USW H-1 to measure the vertical head gradients within the test hole.

According to the report, concepts on water movement within the unsaturated zone are not well developed, in part because early hydrologic studies of Yucca Mountain concentrated on the saturated zone. According to the report, additional data are needed to answer the following questions (p. 47):

1. What is the rate of recharge, and how does it vary spatially and temporally?

2. Do the effects of capillary barriers inhibit movement of water from porous tuffs through fractures; if so, what potential gradients are necessary to initiate flow in fractures in densely welded tuffs?

3. If water moves in fractures, how far can it travel before being drawn into the matrix?

4. Does perched water occur in the unsaturated zone at Yucca Mountain?

5. What would be the effect of increased recharge that might accompany a return to pluvial climatic conditions on movement of water within the unsaturated zone? In particular, what effect would there be on travel time from a repository to the saturated zone?

The report notes that both matrix and fracture hydraulic conductivity occur in the volcanic rocks in the vicinity of Yucca Mountain. According to the report, a zone of relatively intense fracturing and faulting on the southeastern and eastern sides of Yucca Mountain has been mapped. Another feature indicated by surface mapping is that fracture density is less intense in the northern part of Yucca Mountain, where displacement and the number of faults are less than in the southern part. The report notes that aquifer test data are being analyzed to estimate insitu hydraulic conductivity of rocks in the saturated zone; however, the report notes also that the data analyses are incomplete in part because a single unifying theory for analyzing aquifer tests in fractured rocks has not been developed sufficiently.

The report describes the distribution of groundwater recharge in the vicinity of Yucca Mountain as a function of the amount and distribution of precipitation, type of precipitation, conditions at time of snow melt (if a snowpack is present), lithology and moisture content of soil, vegetation, and topography. The report notes that data on the distribution of recharge at Yucca Mountain do not exist. The report suggests that more recharge may occur beneath the washes than beneath the surrounding ridges, because water is concentrated in washes during runoff events. According to the report, the arid environment at Yucca Mountain and the absence of large drainage basins indicate that recharge is very small. The report notes that data from Yucca Flat suggest that long-term average recharge rates probably are less than 5 mm/yr. Heat flow analyses in test well UE-25a#7 suggest that recharge may occur in pulses rather than at a constant rate over a long period of time.

Figure 8 of the report is a preliminary potentiometric surface map of the vicinity of Yucca Mountain. According to the report, measured head values used to construct the potentiometric map represent composite water levels. The potentiometric map indicates that the hydraulic gradient is low in western Jackass Flats (Fortymile Wash area) and in the Amargosa Dessert. The potentiometric map indicates that the gradient is high in volcanic rocks north of Yucca Mountain and across northern Yucca Mountain. The report notes that the potentiometric data collected in conjunction with injection testing generally are not adequate to define vertical head gradients.

The report suggests that the potentiometric levels may be used to indicate the general directions of groundwater flow; consequently the general directions of the movement of radionuclides from a repository beneath Yucca Mountain should be obtainable from the map. The report suggests that flow beneath Yucca Mountain probably is toward the southeast into the Fortymile Wash area and then to the south toward the Amargosa Desert and Alkali Flat, then toward Furnace Creek Ranch. The report notes however that the actual flow path that a particle of water would take may be much different from that indicated by the potentiometric map due to heterogeneity and anisotropy.

SIGNIFICANCE TO NRC WASTE MANAGEMENT PROGRAM:

The report under review presents a summary of the results of hydrogeologic investigations conducted by the USGS in the vicinity of Yucca Mountain. The report summarizes the results of hydrogeologic investigations completed through mid-1983.

PROBLEMS, DEFICIENCIES OR LIMITATIONS OF REPORT:

The report under review represents the USGS contribution to the hydrology portion of a site characterization report for the Yucca Mountain area. The report presents general descriptions and analyses of the hydrogeologic data collected at the Yucca Mountain site. The report is not a highly technical discussion of the hydrogeology of Yucca Mountain, but rather a general description in layman terms of the basic USGS understanding of the hydrogeology.

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