Title: Preliminary Results of Hydrologic Testing the Umtanum
Basalt Entablature at Borehole RRL-2 (3,762-3,805 feet)

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Rockwell International

Rockwell Hanford Operations
Energy Systems Group

A-6000-054 (R-12-80)

SD-BWI-TI-107

. Preliminary Results of Hydrologic
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Drilling and Testing Group
Basalt Waste Isolation Project

November 1982

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INTRODUCTION

The drilling and testing of selected boreholes is a part of the Basalt Waste Isolation Project (BWIP) subsurface site selection and characterization activities. The purpose of hydrologic testing at Borehole RRL-2 is to obtain hydrologic properties of selected zones within the Columbia River Basalt Group. Borehole RRL-2 is located in the west-central section of the Reference Repository Location (RRL), A-H Site (Figure 1). This report provides preliminary results and description of hydrologic testing activities for a section of Umtanum basalt entablature at Borehole RRL-2, over the depth interval 3,762 to 3,805 feet. The hydrologic testing was performed between August 31 and September 7, 1982.

INTERVAL DESCRIPTION

The test interval was penetrated by core drilling (2.98 inch diameter) between June 17 and 18, 1982. The borehole was completed on June 28, 1982 to a total depth of 3,973 feet. The test interval is composed primarily of dense, finely phaneritic basalt with high angle fractures filled with silica or green clay. Discing of recovered core occurs primarily between the depths of 3,785 and 3,800 feet. Due to the relative uniformity of Umtanum basalt entablature, the effective test interval is ascribed to the entire 43 feet of basalt isolated over depth interval 3,762 to 3,805 feet. Although the test interval does not contain the entire section of Umtanum basalt entablature, for reference convenience the test interval will be called the Umtanum basalt entablature. A detailed geologic description of the Umtanum basalt entablature will be contained in separate BWIP support documents.
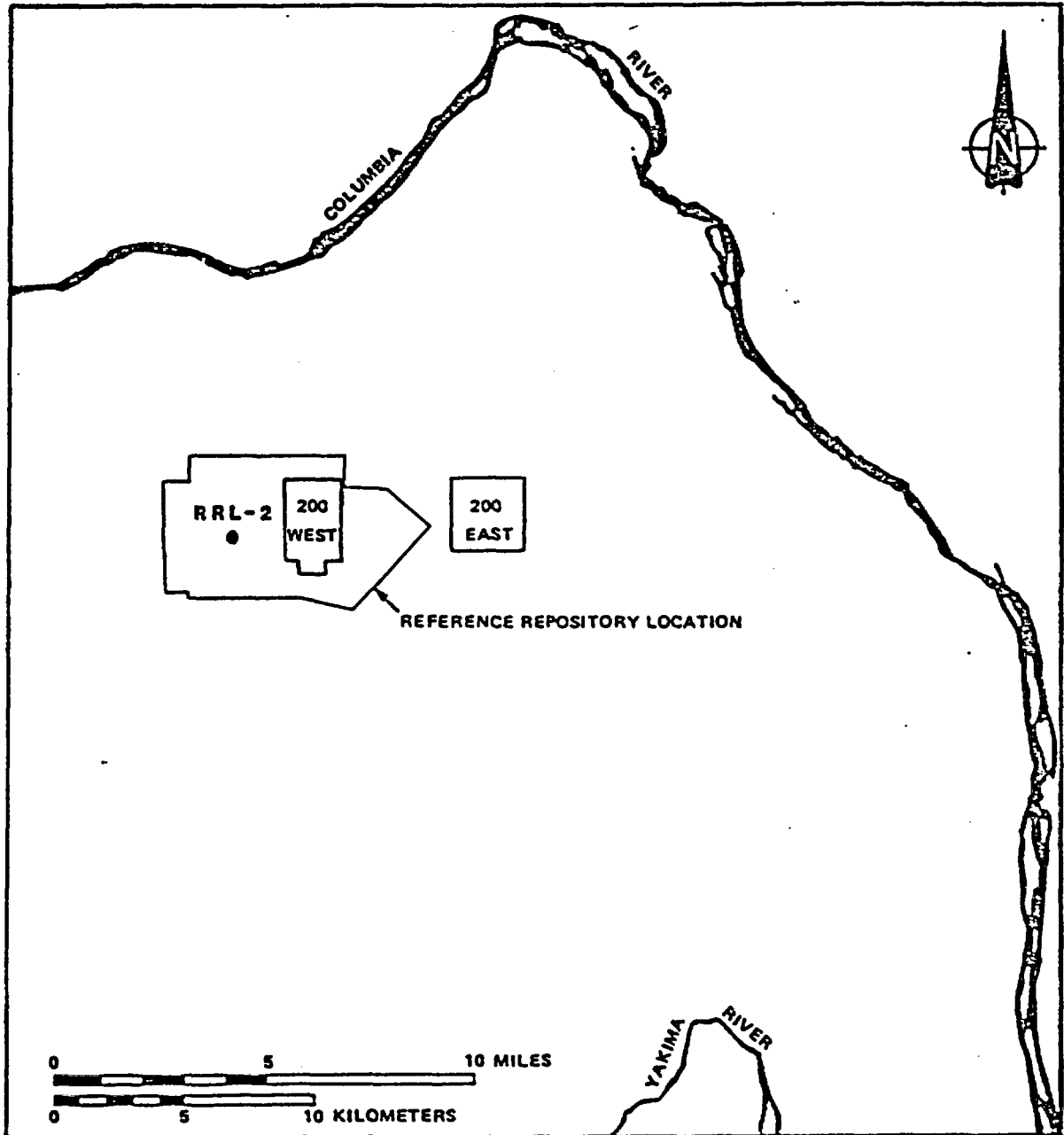
FIGURE 1. Location of Borehole RRL-2.

On June 21 and October 7, 1982 borehole geophysical logging of RRL-2 was conducted by Pacific Northwest Laboratory using a Gearhart-Owen Logger. The borehole geophysical logs include the: gamma-gamma (GG), neutron-epithermal neutron (NN), natural gamma (NATG), caliper, fluid temperature, sonic, spontaneous potential (SP), and long and short normal resistivity. Log response for the geophysical surveys is displayed in Figure 2.

Examination of the log responses in Figure 2 indicate the following:

- dense basalt throughout the test interval (evident on the neutron-epithermal neutron, gamma-gamma, sonic, spontaneous potential, and resistivity logs);

- the presence of borehole circulation from below the the test interval (evident from the lower than normal geothermal gradient of the fluid temperature log); and

- a uniform borehole diameter of approximately 3.0 inches in the test interval (evident in the caliper log).

A description of the test interval including a graphic log, neutron-epithermal neutron log, effective test interval, geologic description, and packer settings is shown in Figure 3.

HYDROLOGIC TESTS

This section describes the hydrologic tests performed on the test interval over the period August 31 to September 7, 1982. Prior to isolating the test interval with packers, air-lift pumping was conducted for 4,245 minutes on June 25-28, 1982. The purpose of this air-lift pumping was to remove drilling fluid from the entire uncased borehole section (2,713 - 3,973 ft).

BOREHOLE GEOPHYSICAL LOGS
BOREHOLE: RRL-2

FIGURE 2. Borehole Geophysical Log Responses for the Umtanum Basalt Entablature at Borehole RRL-2.
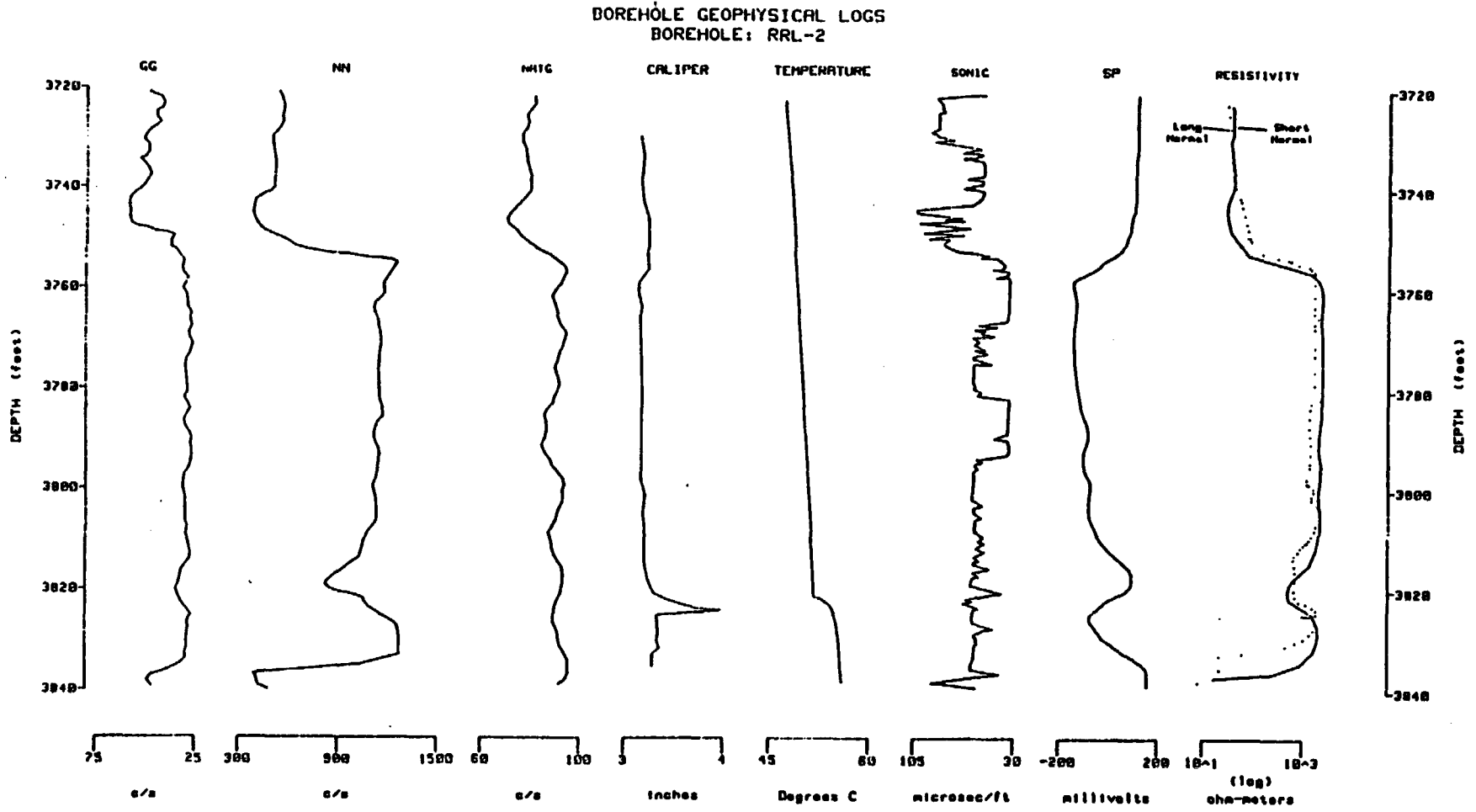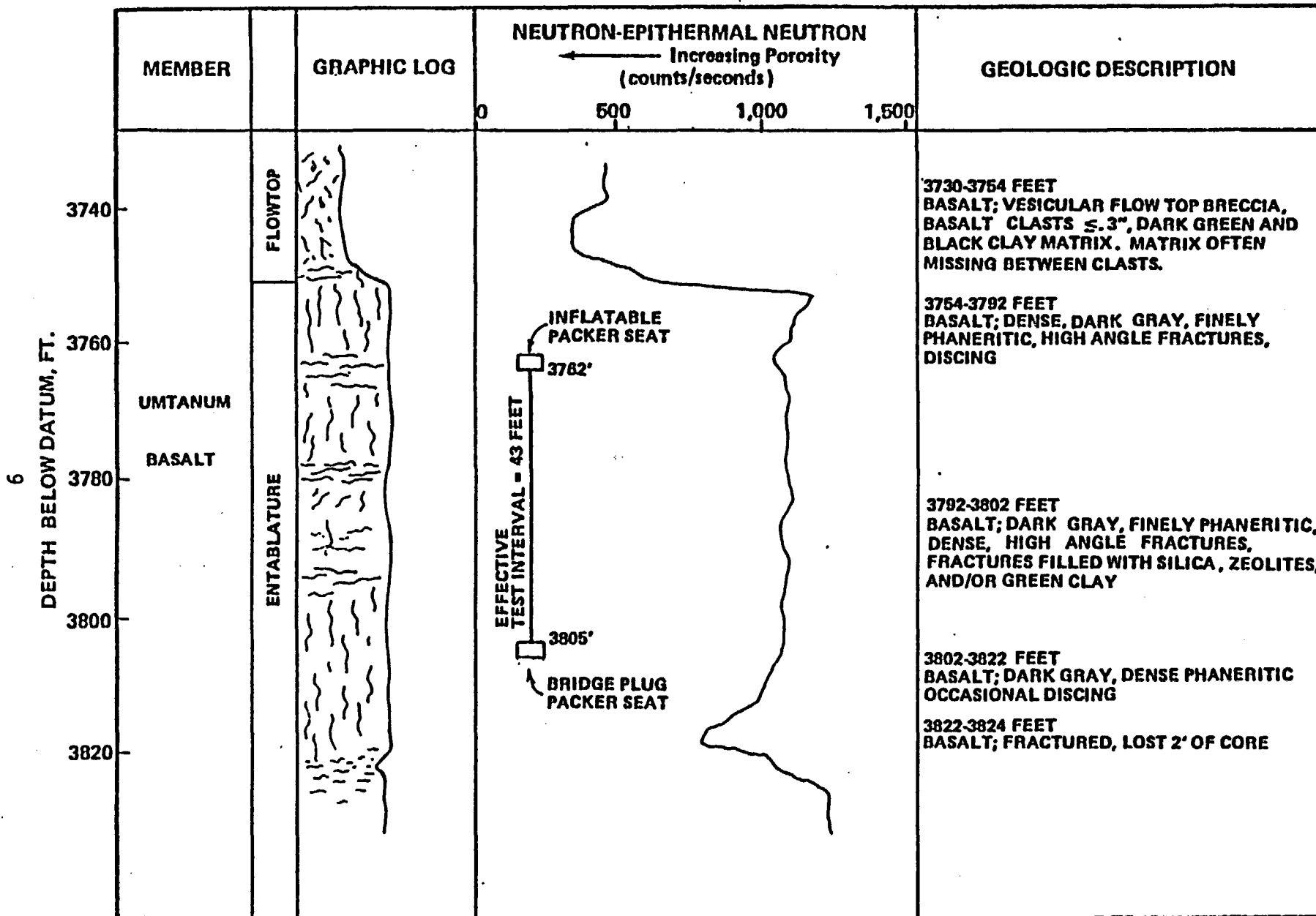
FIGURE 3. GRAPHIC LOG, NEUTRON-EPITHERMAL NEUTRON LOG, AND GENERALIZED GEOLOGIC DESCRIPTION OF THE UMTANUM BASALT ENTABLATURE AT BOREHOLE RRL-2.

The test interval was isolated by means of an inflatable bridge plug packer set at a depth of 3,805 feet in dense Umtanum basalt, and a TAM inflatable packer and downhole pressure transducer test system, which was set at a depth of 3,762 feet. Each packer setting was selected by examination of core and borehole geophysical logs (e.g., neutron- epithermal neutron and sonic) to locate isolating sections within dense, non-fractured basalt.

After the packers were set and a stable water-pressure trend was established, a constant head injection test and an over-pressure pulse test were performed. Due to the low transmissive character of the test interval, no groundwater sampling for hydrochemical characterization was conducted. All data sheets and analysis files utilized for hydraulic property determination are contained in Appendices A and B. Raw data for all hydrologic tests performed are available from the Data Management Unit of the Systems Department, BWIP.

Equipment utilized for testing included a downhole TAM packer and Seling Triple Sub-Surface Probe (TSSP) system for monitoring pressures and temperatures for the test interval and zone above the packer. Pressure and temperature data were monitored with a Hewlett Packard Model 9825B computer. Test data were recorded on a Hewlett Packard Model 9876A thermal printer. In addition, surface water-pressure response was measured with a Paroscientific Digi-Quartz pressure transducer (0-100 psia) and monitored on a Paroscientific Model 600-C computer. A detailed description of the aforementioned test equipment is reported in Jackson (1980) and Strait, et al. (1982).

The integrity of the test interval isolation was evaluated by several methods before, during and after completion of hydrologic testing. Evaluation methods used include:

(a) Weight loading of packers at the beginning and termination of hydrologic testing;

(b) Examination for pressure response in the annular zone above the top packer by stressing the test interval prior to hydrologic testing; and

(c) Monitoring the pressure response of annular zone above the top packer during hydrologic testing.

It should be noted that the aforementioned methods of test interval isolation assessment were used to evaluate the isolation of the top packer. Borehole and test equipment limitations restricted the complete evaluation of the lower bridge plug seat to only the weight loading method listed in (a). All evaluation methods indicated that the test interval was isolated during all phases of hydrologic testing.

An environmental well house, which enclosed the well-head and surface test equipment, was utilized to minimize the affects of surface temperature fluctuations on test performance. The air temperature within the well-house was maintained at approximately $70^{\circ}F$ during all phases of hydrologic testing.

A hydrograph showing the pressure response during hydrologic testing, is displayed in Figure 4. Hydrologic testing activities for the Umtanum basalt entablature are listed in Table 1.

Constant Head Injection Test

On September 2, 1982 between 1106 and 1417 hours a constant head injection test was performed. The total injection head imposed on the test interval equals the sum of the surface injection head (Ho) and gravity head (Hg). Gravity head refers to the hydrostatic head imposed on the system by completely filling the test tubing with water to land surface. It is equal to the elevation difference (i.e., difference in feet above mean sea level) between the surface pressure gauge (638.8 ft) and hydraulic head within the test formation. Due to its low transmissive nature, the actual formation hydraulic head within the Umtanum entablature test interval is unknown. For analytical purposes, however, the head in the test interval is assumed to be equal to the head in the overlying Umtanum basalt flow top, which is 405.7 ft above mean sea level, and equivalent to a depth of 233.1 ft below the pressure gauge datum. The gravity head imposed on the test interval, therefore, is estimated at 233.1 ft of water.
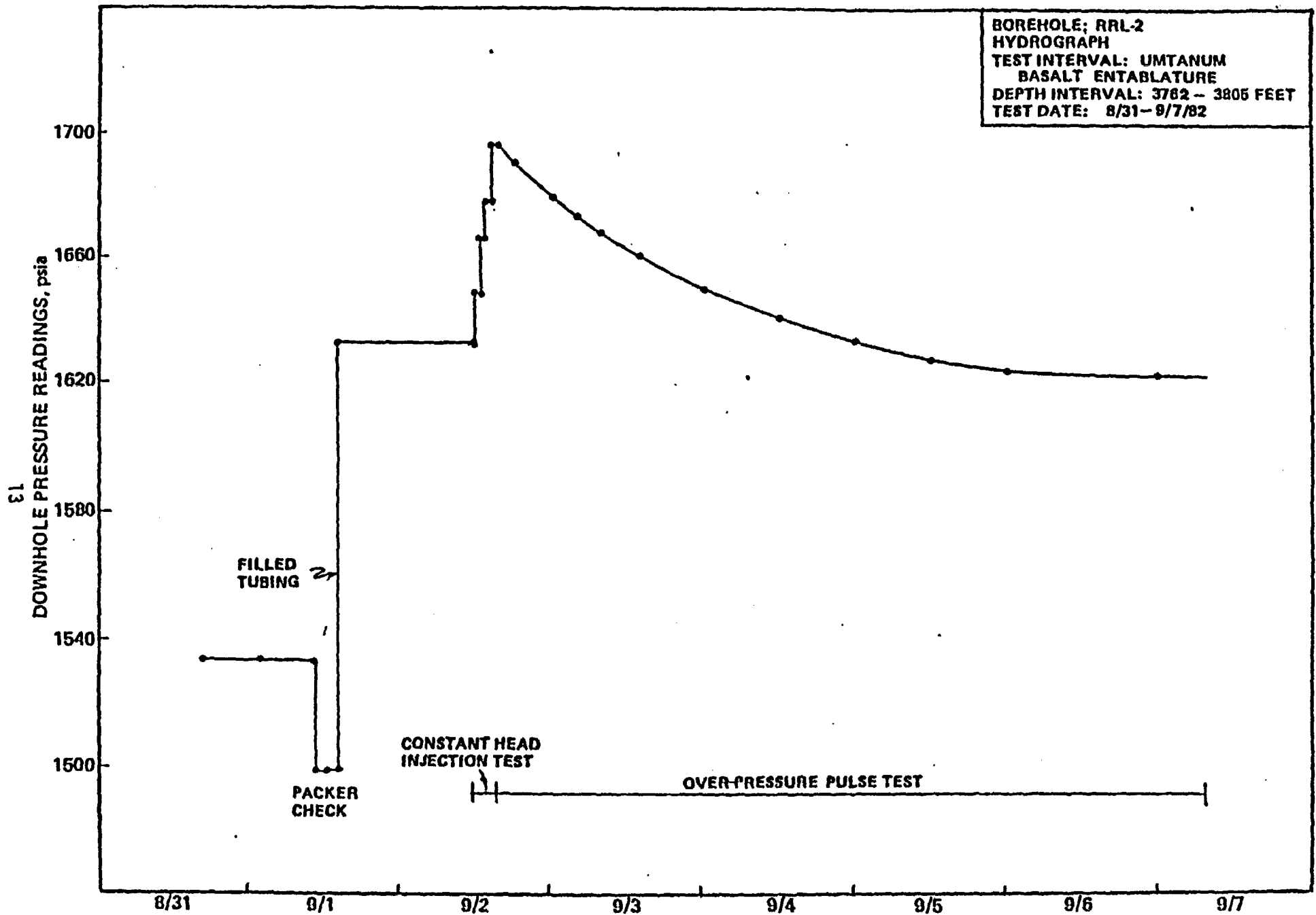
FIGURE 4. HYDROGRAPH DURING HYDROLOGIC TESTING OF THE UMTANUM BASALT ENTABLATURE AT BOREHOLE RRL-2

TABLE 1. Hydrologic Test Activities, Umtanum Basalt
Entablature, at Borehole RRL-2.

Date	Activity
8/31/82	1600 hours - Set TAM packer and bridge plug; Swabbed to static level
9/01/82	1014 hours - Swabbed to check packer seat integrity
	1345 hours - Filled tubing to surface
9/02/82	1106 to 1417 hours - Conducted constant head injection test
	1422 hours - Started over-pressure pulse test
9/3-6/82	Continued over-pressure pulse test
9/07/82	0800 hours - Terminated hydrologic testing

Four injection steps were conducted at surface injection pressures ranging from 17.8 to 64.5 psig. The range in total hydraulic head imposed during constant head injection testing ranged between 274.1 and 382 ft of water. Injection flow rates, which approached steady-state conditions at the end of each step, ranged from 1.4×10^{-5} to 7.0×10^{-5} gpm. A list of injection heads and the associated injection flow rates determined for each of the four steps is presented in Table 2.

The pressure measurements for each step were monitored with a Paroscientific Digi-Quartz pressure transducer (0-100 psia) at the surface and a downhole TAM/Seling test system with Paroscientific pressure transducers (0-3000 psia). Injection flow rates were calculated by measuring the time (with an electronic stopwatch) required for a fluid level change of 0.1 ft to occur within the 1/8-inch transparent injection tubing. A change of 0.1 ft in fluid level is equal to 0.241 ml of fluid injected into the test system. Each step continued until the pressure and injection flow rate approached steady-state conditions.

Transmissivity values were calculated from each step of the constant head injection test using the method described by Zeigler (1976). To calculate transmissivity from constant head injection tests the steady-state injection flow rate ($\bar{Q}$), total injection head (Ho + Hg), radius of the borehole (r_0), and radius of investigation (R), must be known. A plot of pertinent test data and calculation of transmissivity for Step 1 are shown in Figure 5. As shown, the injection flow rate of 0.0518 ml/min (1.37×10^{-5} gpm) was determined from the last seventeen

Table 2. Summary of Hydraulic Property Values Determined at Various Injection Steps During the Constant Head Injection Test for the Umtanum Basalt Entablature at Borehole RRL-2.

INJECTION STEP	STEP DURATION (min)	Hg (ft)	Ho (ft)	$\bar{Q}$ (gpm)	r_w (ft)	R (ft)	Transmissivity (ft^2/day)
#1	65	233.1	41.0	1.37×10^{-5}	0.124	43	9.0×10^{-6}
#2	57	233.1	76.1	2.80×10^{-5}	0.124	43	1.5×10^{-5}
#3	27	233.1	104.2	5.07×10^{-5}	0.124	43	2.7×10^{-5}
#4	30	233.1	148.9	6.42×10^{-5}	0.124	43	3.0×10^{-5}
						Average	2.0×10^{-5}
						Best Estimate	2.0×10^{-5}
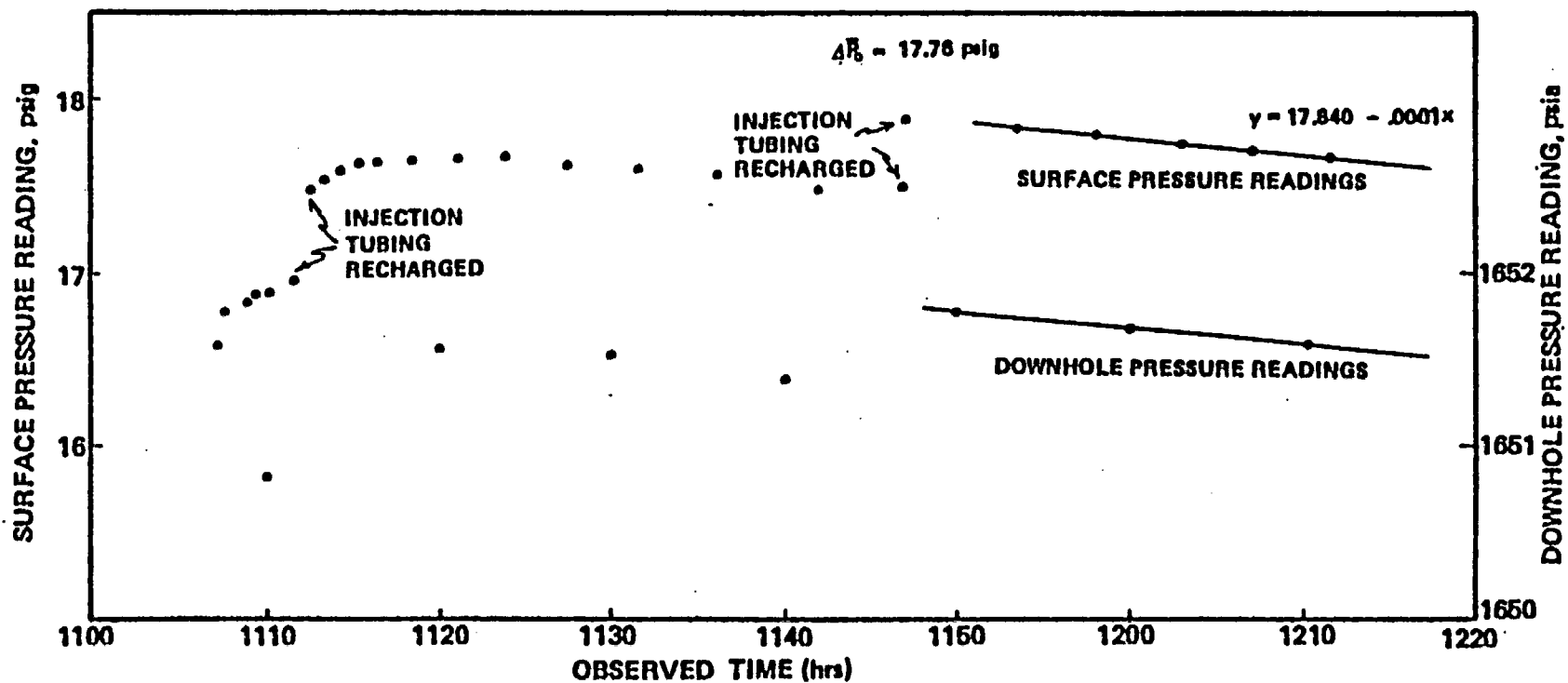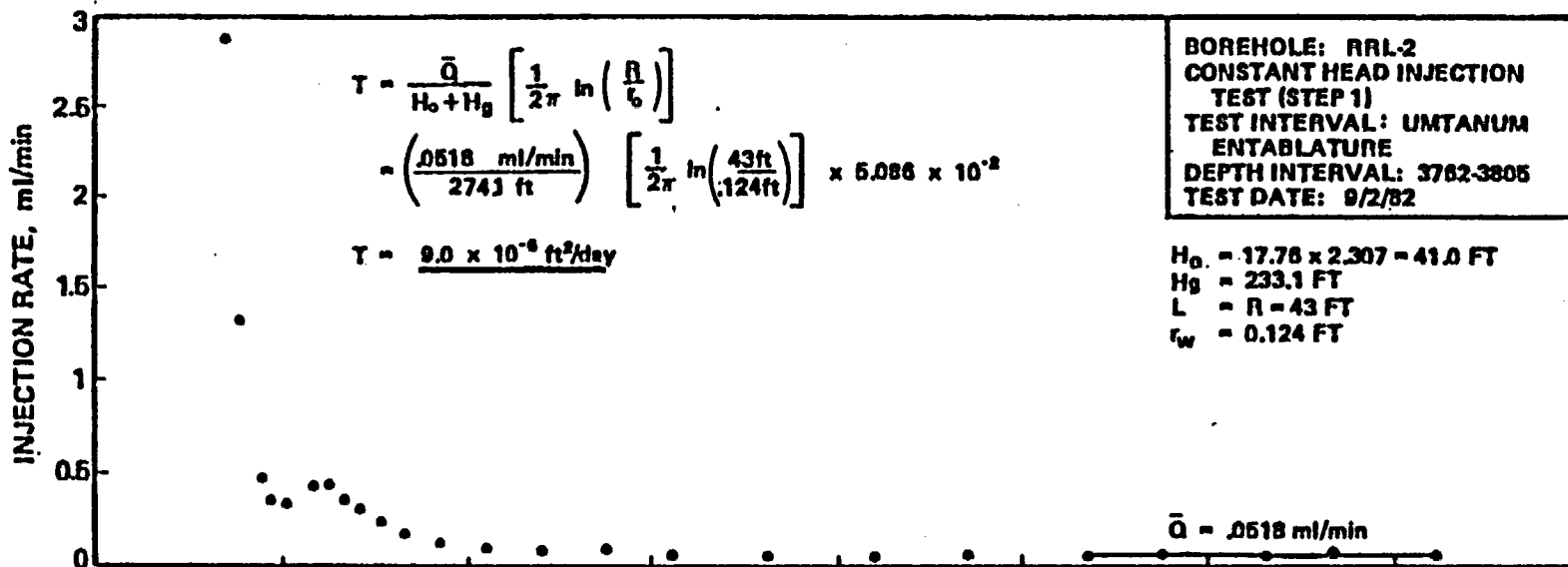
FIGURE 5. PERTINENT TEST DATA FOR CONSTANT HEAD INJECTION TEST, STEP 1, OF THE UMTANUM BASALT ENTABLATURE AT BOREHOLE RRL-2 .

minutes of testing. As evident in the figure, however, injection flow rate varied only slightly over the majority of the step. Injection pressure remained fully constant over the last seventeen minutes of testing (i.e., ±0.2 psi) and averaged 17.76 psig during this period. The two shifts exhibited in the surface pressure readings were related to recharging the small diameter injection tubing during the step. The radius of investigation, R, is assumed to be equal to the test interval length of 43 ft. While this assumption is probably not valid, investigations by Zeigler (1976) have indicated that transmissivity is relatively insensitive to varying values of R. Inaccuracies in estimating R would not be expected to change the calculation of transmissivities by more than a factor of two. Since the area of investigation estimate is probably too great, the calculation of transmissivity would be slightly higher than expected (e.g., Step 1, $T = 9.0 \times 10^{-6}$ ft^2/day).

A summary of the analysis data used and calculated transmissivity values for all steps are presented in Table 2. It should be noted that the method described by Zeigler (1976) assumes that steady-state inflow and pressure conditions exist. For each step an average injection flow rate and pressure were calculated near the end of the step when complete steady-state conditions may not have been reached. Therefore, injection flow rates may have been too high. As a result of this elevated injection rate, $\bar{Q}$, estimates of transmissivity may also be slightly higher than anticipated. The average and best estimate of transmissivity determined from the four step constant head injection test is 2.0×10^{-5} ft^2/day.

For comparison purposes the constant head injection test data were also analyzed using the transient analysis procedure described by Jacob and Lohman (1952). Test results from this analysis generally produced estimates of transmissivity one order of magnitude lower than that obtained using the steady-state solution previously described by Zeigler (1976). Results obtained from the transient analysis are not reported here, since the tests (i.e., steps) were generally not conducted for a sufficient duration of time (given existing borehole and test interval conditions) for this analytical method to be applicable.

Over-Pressure Pulse Test

To corroborate the hydraulic property determinations obtained from the constant head injection test, an over-pressure pulse test was performed between 1422 hours on September 2, 1982 and 0800 hours on September 7, 1982. The test was conducted by closing-in the borehole immediately following completion of Step #4 of the constant head injection test. The decline of pressure during the pulse test was monitored using a surface-based Paroscientific Digi-Quartz pressure transducer (0-100 psia) and a Seling downhole test system. The surface pressure at the time of initiating the pulse test was 64.53 psig. As previously indicated (Table 2), this represented an estimated total head (i.e., $H_g + H_o$) of 382 ft of water imposed on the test interval.

Transmissivity for the test horizon was determined by analyzing the declining pressure response as a result of an over-pressure pulse, described by Bredehoeft and Papadopulos (1980) and Neuzil (1982). It should be noted that the recovery pressures monitored are in response to a constant head injection test and, therefore, would appear to violate the test specification for a "sudden" pressurization and shut-in as described by Bredehoeft and Papadopulos (1980). The difference between a sudden pressurization and a short-duration constant head injection, however, is expected to have a minor affect on pressure response for zones of low transmissivity (i.e. less than 10^{-4} ft^2/day).

Two analyses were performed on the recovery pressure data. The first case assumed a known formation head within the test interval, while in the second case hydraulic head was considered as being unknown. The affects of well system compressibility, as described by Neuzil (1982), were considered and found to be insignificant for the given borehole and test interval conditions.

Figure 6 shows the analysis for the first case, for which formation head is known. As indicated, approximately 40 percent of the calculated over-pressure pulse decayed during testing. The type curve method, described by Bredehoeft and Papadopulos (1980) for analysis of pulse decay, yields a transmissivity of 1.2 x 10^{-5} ft^2/day. This is in close agreement with results obtained from the constant head injection test. Pertinent analytical parameters shown in Figure 6 were previously described or determined from borehole and/or test system dimensions. The estimate
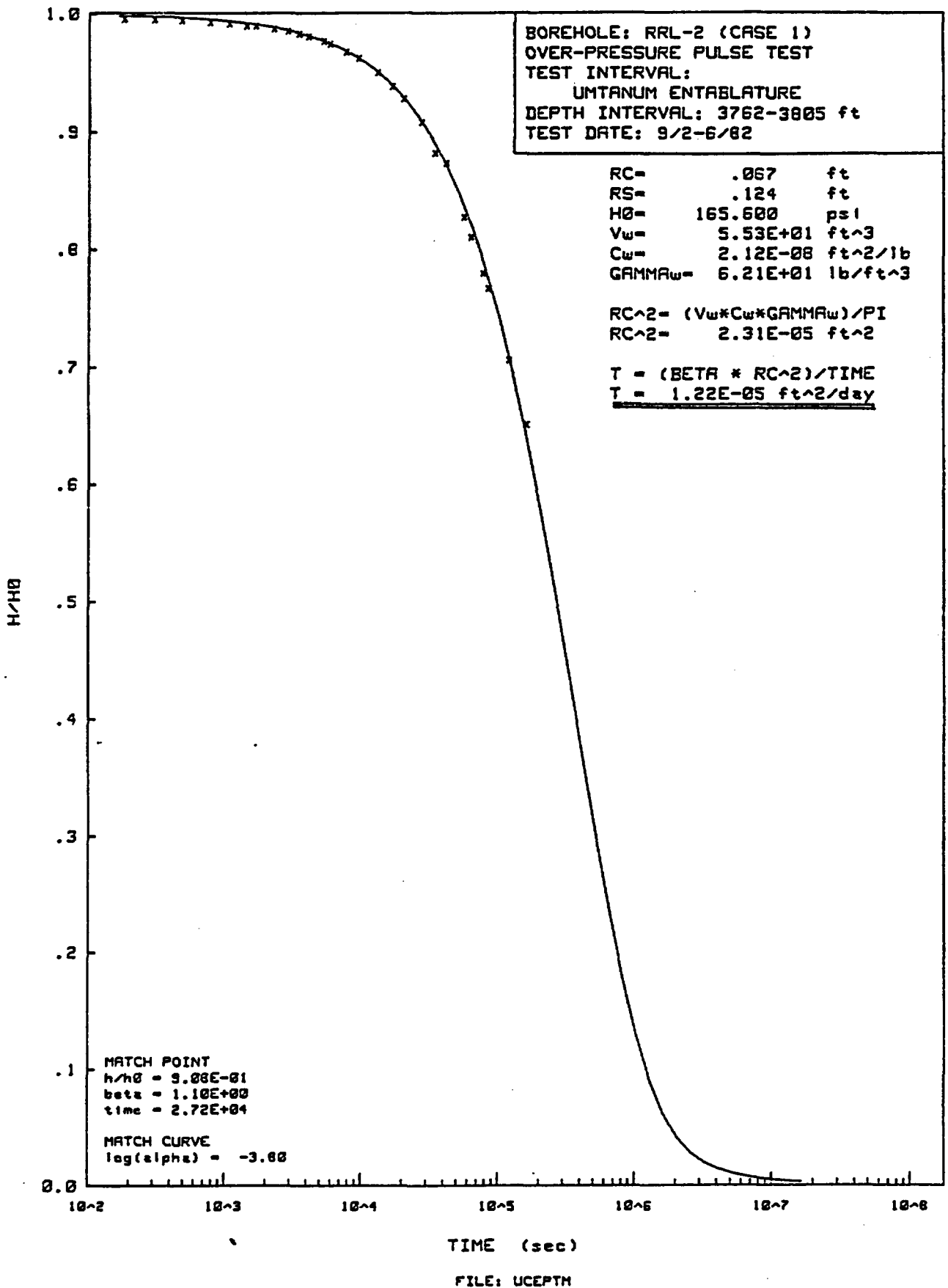
FIGURE 6. Over-Pressure Pulse Test of the Umtanum Basalt Entablature.- Case One (Formation Head Known).

of compressibility, C_w, and specific weight of water, γ_w, within the test system was obtained from reference handbooks for the average fluid column temperature. The average fluid column temperature within the test system was estimated to be 35.7°C. This estimate was based on the average geothermal gradient determined for Borehole RRL-2 of 1.12°C/100 ft, a surface temperature of 14.5°C, and a mid-point depth for the test system of 1,892 ft.

Analysis for the second case for which formation head is unknown, is shown in Figure 7. This case follows the procedure outlined by Bredehoeft and Papadopulos (1980) and subsequently modified by Neuzil (1982). Basically the method analyzes the decay of the surface-based pressure readings, which have been corrected by removing (i.e., by superposition) the effects of filling the test system with water. The effects of filling the system with water were evaluated by monitoring downhole pressure response, under shut-in conditions, for about 24 hours prior to constant head injection testing. The trend in the shut-in pressure response, caused by filling the test system with water, was determined to be -2.82×10^{-5} psi/minute.

As shown in Figure 7, a transmissivity of 2.4×10^{-4} ft²/day is indicated for this analytical case. This is approximately one order of magnitude greater than that determined by case-one or by constant head injection testing. The reason for the difference is not completely understood; however, it may be attributable to not fully compensating for the effects of filling the test system, in the analysis procedure for case-two. Due to this uncertainty, results of analyzing the over-pressure pulse test for case-two are not included in the best estimate calculation of transmissivity.
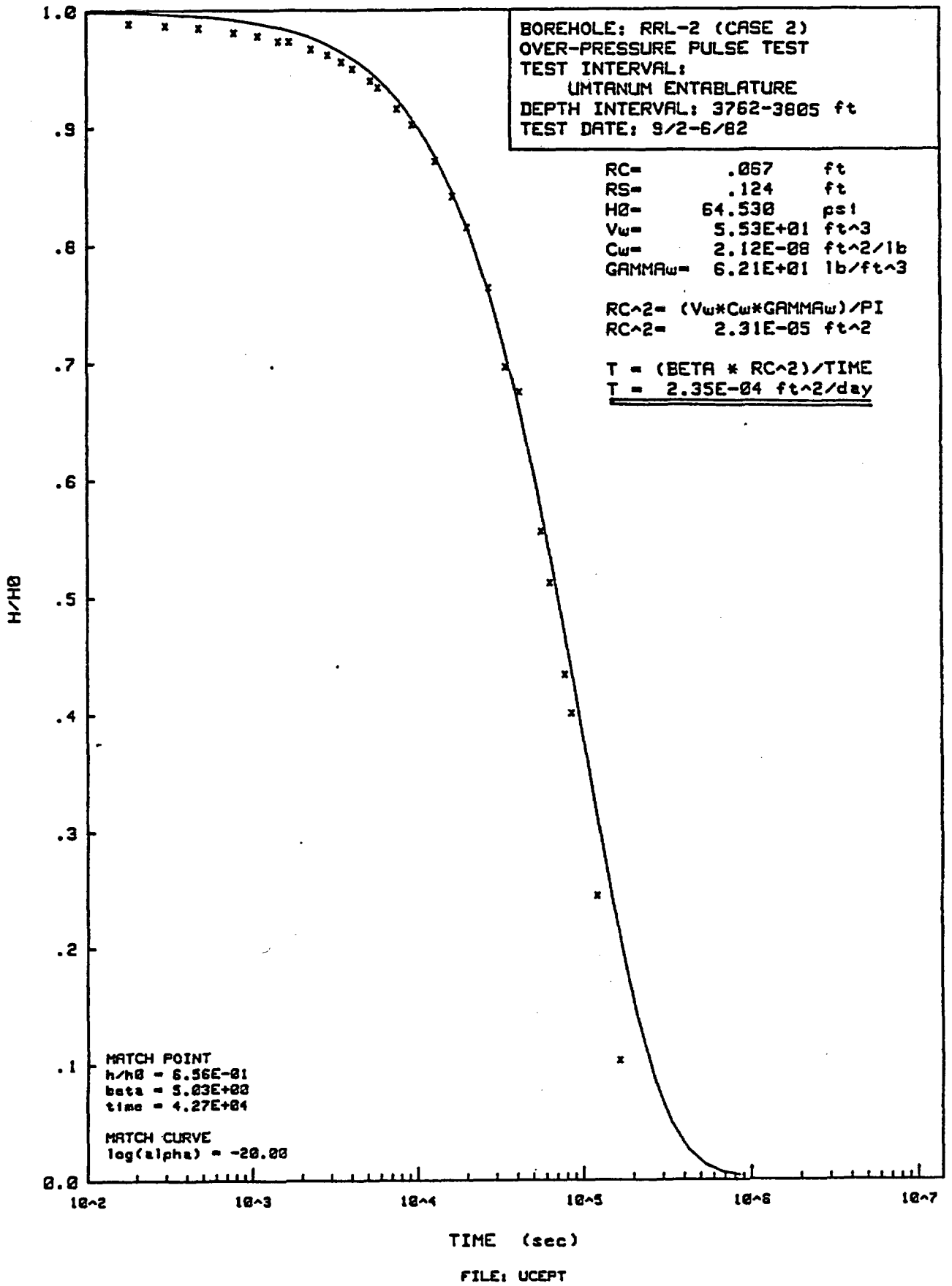
FIGURE 7. Over-Pressure Pulse Test of the Umtanum Basalt Entablature -
Case Two (Formation Head Unknown).

SUMMARY OF TEST RESULTS

Hydraulic properties determined from the various test methods are summarized in Table 3 and evaluated to provide a best estimate for the test horizon. The best estimate for hydraulic properties listed have been determined to be most representative of the test interval and should be the only values used for further analytical purposes. The hydraulic properties are assigned solely to the effective test interval described previously, which includes 43 feet of the Umtanum basalt entablature, over the depth interval 3,762 to 3,805 feet.

Hydraulic Head

A hydraulic head for the Umtanum interior test section could not be obtained during hydrologic testing due to time constraints and low transmissive character of the test horizon. For analysis of test data, a hydraulic head for the test interval was assumed to be equal to that measured for the flow top of Umtanum basalt, i.e. about 406 feet above mean sea level.

Transmissivity

Transmissivity values calculated from analysis of various testing techniques (Table 3) ranged between 9.0×10^{-6} and 2.4×10^{-4} ft^2/day. The best estimate of transmissivity of 1.6×10^{-5} ft^2/day was determined from averaging results obtained from constant head injection testing and over-pressure pulse test, case

TABLE 3.   SUMMARY OF HYDRAULIC PROPERTIES DETERMINED FROM
VARIOUS TEST METHODS FOR THE UMTANUM BASALT
ENTABLATURE AT BOREHOLE RRL-2.

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES	
			TRANSMISSIVITY (ft^2/day)	EQUIVALENT HYDRAULIC CONDUCTIVITY (ft/day) *
Constant Head Injection Test	#1	Zeigler (1976)	9.0×10^{-6}	2.1×10^{-7}
	#2		1.5×10^{-5}	3.5×10^{-7}
	#3		2.7×10^{-5}	6.3×10^{-7}
	#4		3.0×10^{-5}	7.0×10^{-7}
Constant Head Injection Test Average			2.0×10^{-5}	4.7×10^{-7}
Over-Pressure Pulse Test	Case 1	Bredehoeft and Papadopulos (1980)	1.2×10^{-5}	2.8×10^{-7}
	Case 2	Neuzil (1982)	2.4×10^{-4}	4.9×10^{-6}
Over-Pressure Pulse Test Average			1.3×10^{-4}	2.9×10^{-6}
Average			1.6×10^{-5}	3.7×10^{-7}
Best Estimate			1.6×10^{-5}	3.7×10^{-7}

* Equivalent hydraulic conductivity calculated by dividing transmissivity by the
thickness of the effective test interval, i.e. 43 feet.

CONVERSIONS

Transmissivity $\qquad$ ft^2/day = 1.08×10^{-6} m^2/sec = 1.08×10^2 cm^2/sec

Equivalent
Hydraulic Conductivity $\qquad$ ft/day = 3.53×10^{-6} m/sec = 3.53×10^{-4} cm/sec

one. As noted previously, results obtained from over-pressure pulse test-case two were not included in the best estimate calculation, due to analytical uncertainties.

Equivalent Hydraulic Conductivity

Equivalent hydraulic conductivity values derived from analysis of various testing techniques are presented in Table 3. The equivalent hydraulic conductivity was determined by dividing the transmissivity by the thickness of effective test interval (i.e., 43 feet). Equivalent hydraulic conductivity values ranged between 2.1×10^{-7} and 4.9×10^{-6} ft/day. The average and best estimate of equivalent hydraulic conductivity is 3.7×10^{-7} ft/day and was calculated from the average of over-pressure pulse test-case one and the constant head injection test results.

It should be noted that equivalent hydraulic conductivity is assigned as an average value for the entire test interval. Individual zones within the interval may possess higher and/or lower hydraulic conductivities than calculated for the equivalent test section.

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APPENDIX A

DATA SHEETS: CONSTANT HEAD INJECTION TEST

CONSTANT HEAD INJECTION TEST DATA SHEET

BOREHOLE __RRL-2__   TIME __1106:58__   DATE __9/2/82__

TEST INTERVAL __Umtanum Basalt Entablature__   DEPTH INTERVAL __3762' - 3805'__

STATIC WATER LEVEL __231'__   TRANSDUCER SETTING __Surface__

FLOW MEASURING INSTRUMENT __1/8" Tubing__   INITIAL PRESSURE (Pi) __14.20 psi__

MEASURED BY __Steve Strait, Scott Wilcox__

TIME OBSERVED (Hrs)	SINCE Last Reading (Secs)	PRESSURE READING psia Pw	Pw-Pi	FLOW MEASUREMENT Distance	Q ml/min	TIME OBSERVED (Hrs)	SINCE Last Reading (Secs)	PRESSURE READING psia Pw	Pw-Pi	FLOW MEASUREMENT Distance	Q ml/min
1106:58						Fill	Tubing				
1107:04	5	30.78	16.58	0.1	2.896	1143:39					
1107:14	10	30.78	16.58	0.1	1.448	1147:59	260	32.10	17.90	0.1	0.056
1107:23	9	30.78	16.58	0.1	1.609	1153:35	336	32.04	17.84	0.1	0.043
1107:34	11	30.97	16.77	0.1	1.316	1158:00	265	31.01	17.81	0.1	0.055
1107:54	20	30.97	16.77	0.1	0.724	1203:22	322	31.94	17.74	0.1	0.045
1108:17	23	30.97	16.77	0.1	0.630	1206:56	214	31.93	17.73	0.1	0.068
1108:47	30	31.04	16.84	0.1	0.483	1212:14	318	31.87	17.67	0.1	0.046
1109:27	40	31.09	16.89	0.1	0.362						
1110:09	42	31.09	16.89	0.1	0.345						
1110:47	38	31.15	16.95	0.1	0.381						
1111:22	35	31.15	16.95	0.1	0.414						
Fill	Tubing										
1112:04											
1112:39	35	31.69	17.49	0.1	0.414						
1113:21	42	31.74	17.54	0.1	0.345						
1114:09	48	31.79	17.59	0.1	0.302						
1115:09	60	31.81	17.61	0.1	0.241						
1116:33	84	31.83	17.63	0.1	0.172						
1118:39	126	31.84	17.64	0.1	0.115						
1121:12	153	31.85	17.65	0.1	0.095						
1124:05	173	31.85	17.65	0.1	0.084						
1127:28	203	31.83	17.63	0.1	0.071						
1131:30	242	31.80	16.60	0.1	0.060						
1136:20	290	31.77	17.57	0.1	0.050						
1142:02	342	31.70	17.50	0.1	0.042						

SITE HYDROLOGIST: _Steve Strait_

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CONSTANT HEAD INJECTION TEST DATA SHEET

BOREHOLE __RRL-2__ TIME __1214:33__ DATE __9/2/82__

TEST INTERVAL __Umtanum Basalt Entablature__ DEPTH INTERVAL __3762' - 3805'__

STATIC WATER LEVEL __231'__ TRANSDUCER SETTING __Surface__

FLOW MEASURING INSTRUMENT __1/8" Tubing__ INITIAL PRESSURE (Pi) __14.20 psi__

MEASURED BY __Steve Strait, Scott Wilcox__

TIME		PRESSURE READING psia		FLOW MEASUREMENT.		TIME		PRESSURE READING psia		FLOW MEASUREMENT	
OBSERVED (Hrs)	SINCE Last Reading (Secs)	P_w	$P_w - P_i$	Distance (ft)	Q ml/min	OBSERVED (Hrs)	SINCE Last Reading (Secs)	P_w	$P_w - P_i$	Distance tance	Q ml/min
1214:33						1224:43	42	47.17	32.97	0.1	0.345
1214:39	4	46.19	31.99	0.1	8.620	Fill	Tubing				
1214:44	5	46.19	31.99	0.1	5.896	1225:26					
1214:52	8	46.24	32.04	0.1	1.810	1226:06	40	47.66	33.46	0.1	0.362
1215:01	9	46.27	32.07	0.1	1.609	1226:51	45	47.68	33.48	0.1	0.322
1215:12	11	46.30	32.10	0.1	1.316	1227:37	46	47.70	33.50	0.1	0.315
1215:25	13	46.32	32.12	0.1	1.114	1228:25	48	47.72	33.52	0.1	0.302
1215:40	15	46.35	32.15	0.1	0.965	1229:14	49	47.74	33.54	0.1	0.295
1215:57	17	46.38	32.18	0.1	0.852	1230:06	52	47.75	33.55	0.1	0.278
1216:16	19	46.41	32.21	0.1	0.762	1231:00	54	47.76	33.56	0.1	0.268
1216:36	20	46.43	32.43	0.1	0.724	1232:02	62	47.77	33.57	0.1	0.234
1216:58	22	46.40	32.20	0.1	0.658	1233:04	62	47.78	33.58	0.1	0.234
1217:21	23	46.67	32.47	0.1	0.629	1234:09	65	47.79	33.59	0.1	0.223
Fill Tubing						1235:18	69	47.79	33.59	0.1	0.210
1217:52						1236:27	69	47.81	33.61	0.1	0.210
1218:16	24	46.97	32.77	0.1	0.603	Fill	Tubing				
1218:44	28	46.99	32.79	0.1	0.517	1237:10					
1219:12	28	47.01	32.81	0.1	0.517	1238:16	66	48.85	34.05	0.1	0.219
1219:42	30	47.04	32.84	0.1	0.483	1239:28	72	48.26	34.06	0.1	0.201
1220:14	32	47.06	32.86	0.1	0.452	1240:46	78	48.27	34.07	0.1	0.186
1220:48	34	47.08	32.88	0.1	0.426	1242:12	86	48.27	34.07	0.1	0.168
1221:23	35	47.09	32.89	0.1	0.414	1243:48	96	48.27	34.07	0.1	0.151
1220:00	37	47.11	32.91	0.1	0.391	1245:26	98	48.26	34.06	0.1	0.148
1222:38	38	47.13	32.93	0.1	0.381	1247:08	102	48.26	34.06	0.1	0.142
1223:20	42	47.14	32.94	0.1	0.345	1248:56	108	48.26	34.06	0.1	0.134
1224:01	41	47.16	32.96	0.1	0.353	1250:37	101	48.26	34.06	0.1	0.143

SITE HYDROLOGIST: _Steve Strait_

CONSTANT HEAD INJECTION TEST DATA SHEET

BOREHOLE __RRL-2__ TIME __1212:33__ DATE __9/2/82__

TEST INTERVAL __Umtanum Basalt Entablature__ DEPTH INTERVAL __3762' - 3805'__

STATIC WATER LEVEL __231'__ TRANSDUCER SETTING __Surface__

FLOW MEASURING INSTRUMENT __1/8" Tubing__ INITIAL PRESSURE (Pi) __14.20 psi__

MEASURED BY __Steve Strait, Scott Wilcox__

TIME		PRESSURE READING psia		FLOW MEASUREMENT		TIME		PRESSURE READING psia		FLOW MEASUREMENT	
OBSERVED (Hrs)	SINCE TEST STARTED (Secs)	P_w	P_w-P_i			OBSERVED (Hrs)	SINCE TEST STARTED (Secs)	P_w	P_w-P_i		
1252:31	114	48.25	34.05	0.1	0.127						
1255:00	149	48.22	34.02	0.1	0.097						
1257:35	155	48.19	33.89	0.1	0.093						
Fill	Tubing										
1258:16											
1300:16	120	48.60	34.40	0.1	0.121						
1302:28	132	48.59	34.39	0.1	0.110						
1304:45	137	48.57	34.37	0.1	0.106						
1307:29	164	48.54	34.34	0.1	0.088						
1310:00	151	48.52	34.32	0.1	0.096						
1312:20	140	48.51	34.31	0.1	0.103						

SITE HYDROLOGIST: ___

CONSTANT HEAD INJECTION TEST DATA SHEET

BOREHOLE __RRL-2__ TIME __1314:15__ DATE __9/2/82__

TEST INTERVAL __Umtanum Basalt Entablature__ DEPTH INTERVAL __3672' - 3805'__

STATIC WATER LEVEL __231'__ TRANSDUCER SETTING __Surface__

FLOW MEASURING INSTRUMENT __1/8" Tubing__ INITIAL PRESSURE (Pi) __14.20 psi__

MEASURED BY __Steve Strait, Scott Wilcox__

TIME		PRESSURE READING psia		FLOW MEASUREMENT		TIME		PRESSURE READING psia		FLOW MEASUREMENT	
OBSERVED (Hrs)	SINCE Last Reading (Secs)	P_w	$P_w - P_i$	Distance	Q ml/min	OBSERVED (Hrs)	SINCE Last Reading (Secs)	P_w	$P_w - P_i$	Distance	Q ml/min
1314:15						1340:56	82	60.75	46.65	0.1	0.177
1314:44	29	60.46	46.26	0.1	0.499						
1315:24	40	60.44	46.24	0.1	0.362						
1316:08	44	60:43	46.23	0.1	0.329						
1316:55	47	60.42	46.22	0.1	0.308						
1317:48	53	60.41	46.21	0.1	0.273						
1318:42	54	60.40	46.20	0.1	0.268						
1319:42	60	60.39	46.19	0.1	0.241						
1320:35	53	60.39	46.19	0.1	0.273						
1321:32	57	60.39	46.19	0.1	0.254						
1322:39	67	60.38	46.18	0.1	0.216						
1323:39	60	60.38	46.18	0.1	0.241						
1324:42	63	60.39	46.19	0.1	0.230						
Fill	Tubing										
1326:00											
1327:08	68	60.81	46.61	0.1	0.213						
1328:29	81	60.80	46.60	0.1	0.179						
1329:46	77	60.79	46.59	0.1	0.188						
1330:56	70	60.78	46.58	0.1	0.207						
1332:04	68	60.78	46.58	0.1	0.213						
1333:13	69	60.79	46.59	0.1	0.210						
1334:25	72	60.79	46.59	0.1	0.201						
1335:35	70	60.79	46.59	0.1	0.207						
1336:52	77	60.78	46.58	0.1	0.188						
1338:13	81	60.77	46.57	0.1	0.179						
1339:34	81	60.76	46.56	0.1	0.179						

SITE HYDROLOGIST: _(signature)_

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CONSTANT HEAD INJECTION TEST DATA SHEET

BOREHOLE __RRL-2__ TIME __1324:14__ DATE __9/2/82__

TEST INTERVAL __Umtanum Basalt Entablature__ DEPTH INTERVAL __3762' - 3805'__

STATIC WATER LEVEL __231'__ TRANSDUCER SETTING __Surface__

FLOW MEASURING INSTRUMENT __1/8" Tubing__ INITIAL PRESSURE (Pi) __14.20 psi__

MEASURED BY __Steve Strait, Scott Wilcox__

TIME OBSERVED (Hrs)	SINCE Last Reading (Secs)	P_w	P_w-P_i	distance	Q ml/min	TIME OBSERVED (Hrs)	SINCE Last Reading (Secs)	P_w	P_w-P_i	distance (ft)	Q ml/min
1342:14						1347:15	17	77.32	63.12	0.1	0.852
1342:17	3	76.02	61.82	0.1	4.826	1347:34	19	77.34	63.14	0.1	0.762
1342:21	4	76.02	61.82	0.1	3.620	1347:55	21	77.35	63.15	0.1	0.689
1342:27	6	76.06	61.86	0.1	2.413	1348:17	22	77.35	63.15	0.1	0.658
1342:33	6	76.06	61.86	0.1	2.413	1348:42	25	77.36	63.16	0.1	0.579
1342:39	6	76.09	61.89	0.1	2.413	Fill	Tubing				
1342:47	8	76.12	61.92	0.1	1.810	1350:00					
1342:54	7	76.12	61.92	0.1	2.068	1350:26	26	77.82	63.62	0.1	0.557
1343:03	9	76.14	61.94	0.1	1.609	1350:55	29	77.83	63.63	0.1	0.499
Fill Tubing						1351:26	31	77.83	63.63	0.1	0.467
1343:29						1351:57	31	77.84	63.64	0.1	0.474
1343:48	19	76.69	62.49	0.1	0.762	1352:30	33	77.84	63.64	0.1	0.439
1343:55	7	76.70	62.50	0.1	2.068	1353:02	32	77.85	63.65	0.1	0.452
1344:06	11	76.12	62.52	0.1	1.316	1353:36	34	77.85	63.65	0.1	0.426
1344:17	11	76.74	62.54	0.1	1.316	1354:09	33	77.86	63.66	0.1	0.439
1344:28	11	76.75	62.55	0.1	1.316	1354:45	36	77.87	63.67	0.1	0.402
1344:40	12	76.77	62.57	0.1	1.207	1355:21	36	77.87	63.67	0.1	0.402
1344:52	12	76.78	62.58	0.1	1.207	1355:56	35	77.88	63.68	0.1	0.414
1345:04	12	76.80	62.60	0.1	1.207	1356:33	37	77.89	63.69	0.1	0.391
1345:17	13	76.82	62.62	0.1	1.114	Fill	Tubing				
1345:30	13	76.83	62.63	0.1	1.114	1357:51					
Fill Tubing						1358:27	36	78.33	64.13	0.1	0.402
1346:12						1359:03	33	78.33	64.13	0.1	0.439
1346:26	14	77.28	63.08	0.1	1.034	1359:44	41	78.36	64.16	0.1	0.353
1346:41	15	77.29	63.09	0.1	0.965	1400:22	38	78.34	64.14	0.1	0.381
1346:58	17	77.31	63.11	0.1	0.852	1401:04	42	78.34	64.14	0.1	0.345

SITE HYDROLOGIST: _____

CONSTANT HEAD INJECTION TEST DATA SHEET

| BOREHOLE | RRL-2 | TIME | 1342:14 | DATE | 9/2/82 |

TEST INTERVAL __Umtanum Basalt Entablature__ DEPTH INTERVAL __3762' - 3805'__

STATIC WATER LEVEL __231'__ TRANSDUCER SETTING __Surface__

FLOW MEASURING INSTRUMENT __1/8" Tubing__ INITIAL PRESSURE (Pi) __14.20 psi__

MEASURED BY __Steve Strait, Scott Wilcox__

TIME OBSERVED (Hrs)	SINCE Last Started (Secs)	P_w	$P_w - P_i$	Dis-tance	Q ml/min	TIME OBSERVED (Hrs)	SINCE TEST STARTED (Secs)	P_w	$P_w - P_i$		
1401:49	45	78.34	64.14	0.1	0.322						
1402:33	44	78.34	64.14	0.1	0.329						
1403:21	48	78.34	64.14	0.1	0.302						
1404:15	54	78.33	64.13	0.1	0.268						
1405:06	51	78.33	64.13	0.1	0.284						
1405:58	52	78.33	64.13	0.1	0.278						
Fill	Tubing										
1406:56											
1407:45	49	78.74	64.54	0.1	0.295						
1408:31	46	78.75	64.55	0.1	0.315						
1409:18	47	78.75	64.55	0.1	0.308						
1410:05	47	78.76	64.56	0.1	0.308						
1410:53	48	78.76	64.56	0.1	0.302						
1411:45	52	78.75	64.55	0.1	0.278						
1412:45	60	78.75	64.55	0.1	0.241						
1413:44	59	78.74	64.54	0.1	0.245						
1414:45	64	78.73	64.53	0.1	0.226						
1415:47	62	78.72	64.52	0.1	0.234						
1416:44	57	78.72	64.52	0.1	0.254						
1417:43	59	78.72	64.52	0.1	0.245						

SITE HYDROLOGIST: _____

APPENDIX B

DATA ANALYSIS FILES: OVER-PRESSURE PULSE TEST

15 Nov   9:49:17   am

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PROGRAM:              CP PRESS
FILE:                 UCEPTM
BORE HOLE:            RRL-2 (CASE 1)
TEST TYPE:            OVER-PRESSURE PULSE TEST
TEST INTERVAL:        UMTANUM ENTABLATURE
DEPTH INTERVAL:       3762-3808
TEST DATE:            9/2-6/82
DC (in)                   1.610
DS (in)                   2.980
LC (ft)                3766.910
LS (ft)                  42.000
TEMPERATURE (°C)         35.700
Equ pressure (psi)     1534.080
H0   (psi)              165.600
```

1	180.0	1698.930	10	3480.0	1696.790	19	27480.0	1684.330
2	300.0	1698.830	11	4080.0	1696.420	20	34680.0	1679.990
3	480.0	1698.700	12	5280.0	1695.730	21	41880.0	1678.590
4	730.0	1698.430	13	5880.0	1695.360	22	56280.0	1670.920
5	1080.0	1698.240	14	7680.0	1694.210	23	63480.0	1668.090
6	1440.0	1697.920	15	9480.0	1693.340	24	77880.0	1663.020
7	1680.0	1697.910	16	13080.0	1691.320	25	85080.0	1660.890
8	2280.0	1697.490	17	16680.0	1689.380	26	121080.0	1650.790
9	2880.0	1697.170	18	20280.0	1687.660	27	164280.0	1641.690

15 Nov   10: 7:32   am

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PROGRAM:              CP PRESS
FILE:                 UCEPT
BORE HOLE:            RRL-2 (CASE 2)
TEST TYPE:            OVER-PRESSURE PULSE TEST
TEST INTERVAL:        UMTANUM ENTABLATURE
DEPTH INTERVAL:       3762-3808
TEST DATE:            9/2-6/92
DC (in)                      1.610
DS (in)                      2.980
LC (ft)                   3766.910
LS (ft)                     42.000
TEMPERATURE (°C)            35.700
Equ pressure (psi)        1635.119
H0   (psi)                  64.530
```

1	180.0	1698.930	10	3480.0	1695.790	19	27480.0	1684.330
2	300.0	1698.830	11	4080.0	1696.420	20	34680.0	1679.990
3	480.0	1698.700	12	5280.0	1695.730	21	41880.0	1678.590
4	780.0	1698.430	13	5880.0	1695.360	22	56280.0	1670.920
5	1080.0	1698.240	14	7680.0	1694.210	23	63480.0	1668.090
6	1440.0	1697.920	15	9480.0	1693.340	24	77880.0	1663.020
7	1680.0	1697.910	16	13080.0	1691.320	25	85080.0	1660.890
8	2280.0	1697.490	17	16680.0	1689.380	26	121080.0	1650.790
9	2880.0	1697.170	18	20280.0	1687.660	27	164280.0	1641.690