See Packet 2 for Encls

WM-10
PDR
Return to WM 623-SS

Rec'd 12-29-82 nb

WM Record File 101.2	
WM Dir.	
WM Dep. Dir.	
WMPI	WMLL
WMHT RW	WMHL
WMUR	Others

Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

DEC 23 1982

Dr. Robert J. Wright
Senior Technical Advisor
High Level Waste Technical Development
Branch
Division of Waste Management
U. S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Dr. Wright:

BWIP HYDROGEOLOGIC AND WASTE PACKAGE INFORMATION DATA PACKAGE

The enclosed information package covering hydrogeology and waste package was informally transmitted to DOE-RL by H. J. Miller-NRC on November 23, 1982. These documents had been provided to NRC as uncleared information during DOE/NRC workshops held in July and August 1982 covering these subjects.

A review of the documents in the information data package has been completed by BWIP, and a determination made that none of the documents have been cleared for release. Therefore, we recommend that the NRC's use of all referenced items be restricted to internal use only. Much of the information contained in these documents is preliminary, first cut evaluations of field or laboratory measurements, and until these data have been carefully reviewed and documented, their use should be qualified.

This preliminary documentation falls into the following categories:

1. Complete or Partial Reports

   a. Plate "600 Area Borehole Location Map"

   b. Copies of borehole stratigraphy from BWIP data package

   c. Copy of data package on stratigraphic charts and cross sections

   d. Copy of support document on two well tracer tests

   e. Draft copy of waste package report "Barrier Materials Testing in the Presence of Nuclear Waste: A Feasibility Study for the 222-S Hot-Cell Facility"

60190

f. Copy of BWIP drilling procedures

g. Copy of BWIP general hydrologic testing procedures

2. Miscellaneous Hydrologic Items

a. Numerous NRC forms filled with written information from BWIP notebooks, interval reports and other undocumented sources.

b. Miscellaneous copies of tables listing hydrologic properties from unidentified source

c. Listing of temperature data from several wells

d. One BWIP interval report letter from borehole DC-12

e. One generalized computer plot of neutron-neutron, temperature and caliper data from RRL-2

f. Copies of computer printouts listing groundwater head monitoring data for several basalt wells

g. Table of Kd values - source not identified

3. Miscellaneous internal BWIP and NRC letters/agendas

As stated earlier, these documents are preliminary materials, and stamped on each individual map, document, or other piece of paper, the notation, "Information Copy." These documents should be treated as preliminary draft material, and their use in reaching technical conclusions carefully reviewed.

If you have questions, please call.

Very truly yours,

for D. J. Squires
O. L. Olson, Project Manager
Basalt Waste Isolation Project Office

BWI:DJS

cc, w/o enclosure:
Ralph Stein, DOE/HQ

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

1-7-83

NOTE TO DMB AND DCS --

The package of encls with this letter must remain together. The cover ltr dtd 12/23/82 is a disclaimer regarding attached material.

Nancy Still

Nancy Still
Docket Control Center
Division of Waste Management

(sent to PDR per request of Wright)
ns

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14 — Collar elev.: 399.1 ft. msl
2. TOTAL DEPTH: 3335 ft — Grd. elev.: Few tenths lower
3. DEPTH OF CASING: 1072 ft. TOP OF PRIEST RAPIDS
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL ft.	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3260-3335	Schwana	2nd interflow below Umtanum 2/5-2/11/81 brecciated & vesicular basalt= 3278-3331 ft or effective interval		57°C @ 3330 ft. 440.33 ft. head (well flowed at all levels except Elephant Mtn.) msl. All tests run with J-slot packer to bottom of hole at that time, surface measurements

Test	ft²/d	ft/d
Constant drawdown		
Jacob-Lohman	T = 17.45	K = 0.33
Recovery Theis	14.45	0.27
$\bar{Q}$ = 11.72 gpm 0720 hrs to 1150 hrs		
Constant discharge		
Recovery Theis $\bar{Q}$ = 10.33 gpm	20.84	[illegible].39
Slug Withdrawal		
#1 Van der Kamp	103.47	1.95
#2 " " "	61.56	1.21
Avg.	17.58	0.33
Best estimate	17.58	0.33

Volume of fluid lost 1240 gal
Volume of fluid developed 52110 [illegible]

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3253.5-3335 — Effective interval= 3278-3335 12/3 to 12/21/81

Retest of bottom
Head was 35.5 ft. above land surf.
Used Lynes downhole transducers

second test conducted to see cause & effect of pressure overshoot on recovery

Free flow discharge $\bar{Q}$ = 4.0 gpm & recovery
Theis recovery T = 66.9 ft²/d

~~test started 12/~~ 0950 to 12/11 1043 at free flow

over

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 3225 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL (ft.)	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS		
3180 - 3225	First interflow below Umtanum (strat. sect. shows it as part of Umtanum)	brecciated & vesicular basalt 3200-3215 ft or effective interval		Head = 440.17 ft msl		
				ft²/d	ft/d	
			Constant drawdown: Jacob-Lohman	T = 4.77	K = 0.32	
			Constant drawdown: Recovery-Theis	T = 9.09	K = 0.61	
			Constant discharge: Recovery-Theis	T = 18.85	K = 1.26	
	early time data excluded due to oscillation →		#1 Slug withdrawal: Cooper-Papadopulos	T = 3.05	K = 0.20	S = 1.15X10
			#1 Slug withdrawal: Ferris-Knowles	T = 1.10	K = 0.07	
			#2 Slug withdrawal: Cooper-P	T = 2.23	K = 0.15	S = 1.15X10
			#2 Slug withdrawal: Ferris-K	T = 1.80	K = 0.12	
			#1 Slug injection: Cooper-P	T = 1.83	K = 0.12	S = 1.15X10
			#1 Slug injection: Ferris-K	T = 0.89	K = 0.06	
	late time match →		#2 Slug injection: Cooper-P	T = 1.73	K = 0.12	S = 1.15X1
			#2 Slug injection: Ferris-K	T = 0.82	K = 0.05	
			Avg	4.20	0.28	3.48X
			Best estimate	4.20	0.28	3.48X

Volume of fluid lost 4150 gal.
Volume of fluid developed 2075.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 3144 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER

5. DATE: 7-22-82

ft. INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS			
3060 - 3144	Top of Umtanum	brecciated and vesicular basalt 3072 - 3138 or effective interval		Head 440.42 ft. msl 12/18/80			
			Constant Drawdown	ft²/d	ft/d		
			Jacob-Lohman	T = 3.84	K = 0.057	S = 0.022	
			Recovery-Theis	T = 4.29	K = 0.064		
			Constant discharge				
			Recovery-Theis	T = 5.37	K = 0.080		
			#1 Slug withdrawal				
		late time match →	Cooper-Papadopulos	T = 8.65	K = 0.129	S = 0.011	
			Ferris-Knowles	T = 6.49	K = 0.097		
			#2 Slug withdrawal				
			Cooper-P	T = 7.24	K = 0.108	S = 0.011	
			Ferris-K	T = 2.51	K = 0.037		
			Avg	5.48	0.082	0.015	
			Best estimate	5.48	0.082	<0.015	

volume of fluid lost 5400 gal.
total volume of fluid developed 10,000 gal.

Barometric efficiency 55%

Todd (1959) S = 0.0088 based on avg. porosity from test log

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 2975 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL ft.	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS	
2880-2975	Sentinel Bluffs	Brecciated & vesicular basalt, effective interval = 2894-2953	11/17 To 11/24/80	Water temp = 51° C @ 2960. Head = 436±5 ft projected due to slow response;	
			Constant drawdown	ft²/d	ft/d
	(Initial) Q_i = 13 gpm →		Jacob-Lohman	T = 0.24	K = 0.0041
	(Final) Q_f = 0.14 gpm		Recovery-Theis	T = 0.16	K = 0.0027
			#1 Over pulse pressure		
			Vanderkamp	T = 0.19	K = 0.0032
			#2 Over pulse pressure		
			Vander kamp	T = 0.67	K = 0.0114
			Slug injection		
	not included in average →		Vanderkamp	T = 142.90	K = 2.42
			Avg	T = 0.32	K = 0.0053
	constant drawdown →		Best estimate	T = 0.24	K = 0.0041

* from rough draft

cemented test horizon apparently after test

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 2874 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2651-2874	Sentinel Bluffs	Test interval = 2686-2860 or 2686-2852 on analysis of test forms		Head = 437.51 (11/10/80), on hydrostrat. sect = 435 ft. msl
			#1 Over pressure Pulse test	
			Cooper-Bredehoeft	T = 3.39 $\times 10^{-1}$ ft²/d — late time, poor match
			#2 Cooper-P	T = 2.38 $\times 10^{-1}$ — late time, fair match but early data off
		Analysis procedure not noted on sheets, my opinion as to technique used	Slug withdrawal	
			Cooper-P	T = 3.15 $\times 10^{-1}$ S = 8.7 $\times 10^{-3}$ — Slug type analysis curve fit to midrange data; early data off, late data not shown if available, may have been erased
			Recovery from Constant drawdown	
			Theis	T = 4.2 $\times 10^{-3}$
			Constant drawdown	
			Jacob-Lohman	T = 1.47 $\times 10^{-2}$ — I would ignore this analysis due to odd data
2760-2874 (2nd test new interval)	Sentinel Bluffs	Test interval = 2818-2852 on test form	#1 Over pressure pulse test	
			Cooper-P	T = 6.6 $\times 10^{-2}$ — mid to late time fit
			#2	no analysis - screwy data

* Not as interval report

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 2513 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS	
2410-2513	Sentinel Bluffs	Brecciated and vesicular basalt; test interval = 2451-2476 (based on fluid temp. log) may be 10-15 ft of highly fractured basalt with some clay		Head = 444.1 ft msl (4.4 ft. higher than 10/10/80 max. recorded level)	
				ft²/d	ft/d
			Constant discharge — Recovery Jacob-Cooper	T=4.06	K=0.16
			Constant drawdown — Jacob-Lohman	T=3.80	K=0.15
			Recovery Jacob-Cooper	T=4.73	K=0.19
		Not included in average →	Underpulse pressure test — Vander kamp	T=65.25	K=2.61
			Avg	4.20	0.17
			Best estimate	4.20	0.17

Let well flow ≈ 6 gpm to develop, 1100 hrs 10/7/80 to 1030 hrs 10/8/80. Set packer 2410 ft 1030 hrs 10/8/80 & monitored pressure. Started constant Q test 0830 hrs 10/10/80 & terminated 2330 hrs. Monitored recovery 10/11-13/80. Tested 10/14/80

Test horizon cemented.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL (ft.)	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2355-2405	Sentinel Bluffs	Brecciated & vesicular basalt; test interval = 2368-2390		HEAD = 425 ft. msl estimated 435 on hydrostrat. chart. Water temp = 46°C @ 2400

	Type of Test	T (ft²/d)	K (ft/d)	S
	Air lift — Recover-Jacob-Cooper	T = 0.25	K = 0.011	
Late-time data ok →	Constant Drawdown — Jacob-Lohman	T = 0.034	K = 0.0015	S = 0.07
Late time data deviates upward →	Recovery — Jacob-Cooper	T = 0.55	K = 0.025	
Pretty good early time fit →	Slug injection — Cooper	T = 0.32	K = 0.015	S = 0.0064
Mid time fit →	#1 Underpressure Pulse test — Bredehoff	T = 0.10	K = 0.0045	S = 1.44x10⁻⁶
Early-mid time fit →	#2 Bredehoff	T = 0.095	K = 0.0043	S = 2.0x10⁻⁶
Scattered data, mid time fit ? →	#1 Overpressure Pulse test — Bredehoff	T = 0.33	K = 0.011	S = 2.0x10⁻⁵
Mid time fit early time deviation →	#2 Bredehoff	T = 0.18	K = 0.008	S = 2.0x10⁻⁵
	Avg	0.26	0.011	0.0012
	Best estimate	0.26	0.011	2.0x10⁻⁵

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 2235 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82/7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2120 - 2235	Lower Frenchman Springs, Vantage Interbed at top Sentimental Bluffs; test interval = 2120-2235 (110 ft = b)	Vesicular basalt; hard green clay with basalt clasts, vesicles filled with clay; vesicular basalt alternating with dense basalt		Head = 469 ft. msl
			Constant injection	ft²/d — $T_1 = 520$, $T_2 = 603$, $T_3 = 625$; ft/d — $K_1 = 13$, $K_2 = 15.1$, $K_3 = 15.6$
		Points (3) st. line thru origin →		
			Constant Discharge	
		Probably t/t' plot, not labeled; paucity of data points →	Recovery	$T = 236$, $K = 5.9$
		No plot →	Constant Drawdown	no change in Q vs. T

Volume of fluid inj. 9/3/80 to 9/4/80 = 2220 gal
Volume of fluid pumped 62,400 gal.

Flow rate = 10 gpm

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 1983 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1875 - 1983	Frenchman Springs #6 (b = 50 ft) (1888 - 1983 ft)	Basalt, some vesicles; high angled fractures well healed green clay fillers some vesicles & fractures; vesicular basalt; highly vesicular; vesicular amount decreases		Head = 439 ft. msl from hydro strat. chart Temp = 40°C @ 1980 ft.
			Constant Injection Test	ft²/d, ft/d T_1 = 2870, K = 57.4 T_2 = 2420, K = 48.4 T_3 = 2174, K = 43.5
		Points at line but not thru origin (→ Constant Injection Test)		
		Few data points but what shown ok (→ Theis)	Constant Discharge Recovery Theis	ft²/d, ft/d T = 1404, K = 28.1

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 1875
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER

5. DATE: 2-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1820-1875	Frenchman Spring #5 (b = 12 ft)	Dense basalt; flow breccia; dark basalt		Head = 486 ft. msl from hydrost. chart
			Constant discharge recovery	$\bar{Q}$ = 37.5 gpm
		Pretty good late time match. They noted overshoot →	Theis	T = 287 ft²/d K = 23.9 ft/d
			Constant Injection Test	T_1 = 468 K_1 = 39
		Points form rough st. line but does not pass thru origin →		T_2 = 257 K_2 = 21.4
				T_3 = 180.7 K_3 = 15.1
			Avg	302 25.2
			Best est.	468 39
			Water Hammer Test	?

Cemented 1837-1851' (flow breccia)

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 1820 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1720 - 1820	Frenchman Sp. #4 (3 flow contact zones: 1 = 1731 no lost circulation 2 = 1756 no loss 3 = 1789, 50% loss) (test interval = 1731-1820 ft)	Dense basalt; fractured basalt, flow breccia; altered basalt; dense basalt; competent vesicular basalt & dense basalt		Head = 488.0 ft. msl
			Constant Discharge	$\bar{Q}$ = 8.38 gpm
			Recovery	– decline in pressure during recovery T = 228.9 ft²/d ??
			Under-pressure displacement Test	
			Vander Kamp	did not work

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 1708
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1640 – 1708	Frenchman Springs #3 (b = 34 ft)	Basalt; flow breccia with red & green clay matrix; dense basalt; flow breccia; slightly vesicular to basalt without		Head = 483 ft, msl from hydrostrat. chart
			Constant Discharge	$\bar{Q}$ = 13.9 gpm
			Recovery	T = 97 ft²/d K = 2.9 ft/d
		overshoot	Under Pressure Pulse Test	
		No data plots	Vunder Kamp	T_1 = 102 K_1 = 3
				T_3 = 125 K_3 = 3.7
				T_4 = 99 K_4 = 2.9
				T_5 = 136 K_4 = 4.0

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 1632 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1580 - 1632	Frenchman Springs #2 (b = 28 ft)	Basalt; dense basalt; highly fractured basalt; competent vesicular basalt; flow breccia; vesicular basalt; dense basalt		Head = 490 ft. msl from hydrostrat. chart
			Constant Discharge / Recovery	$\bar{Q}$ = 17.4 gpm; T = 334 ft²/d; K = 12 ft/d
		overshoot	Under pressure pulse / Van der Kamp	T = 78 ?

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 1516 ft.
3. DEPTH OF CASING:
4. REVIEWER: G, WINTER

5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1430-1516	Squaw Crk. Interbed (interbed is about 1 ft.) (Δ = 11 ft)	Basalt; hard clay & broken basalt 50-50%; competent vesicular basalt		Head = 485 ft msl from hydrostrat. chart Temp = 32°C @ 1520 ft.
			Constant Discharge Test	$\bar{Q}$ = 0.55 gpm T = 27 ft²/d, K = 2.5 ft/d
		Not alot of data, no mention of overshoot	Under pressure pulse test — Van der Kamp	T_1 = 118, K_1 = 10.7 T_2 = 112, K_2 = 10.2 T_3 = 145, K_3 = 13.2 T_4 = 125, K_4 = 11.4
		Their note; field test questionable, too permeable & too short	Over pressure pulse test — Cooper-Papadolous	T_1 = 0.79 T_2 = 1.2 T_3 = 0.94

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 1346 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1235-1346	Roza Interflow ($b = 42$ ft)	Dark gray basalt, large to small vesicles, clay filled fractures; hard clays to vesicular basalt; vesicular basalt; gray basalt		Head = 493 ft. msl from hydrostrat. chart
			Constant Discharge	$\bar{Q} = 97.5$ gpm
			Recovery	$T = 9340$ ft²/d, $K = 222$ ft/d
			Under pressure Pulse	
			Van de Kamp	$T_3 = 492$, $K_3 = 11.7$
				$T_4 = 241$, $K_4 = 5.7$
				$T_6 = 224$, $K_6 = 5.3$

looks good. They note best estimate → (Constant Discharge / Recovery)

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 1271 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER

5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1217-1271	Priest Rapids Interflow #3 (b = 8ft) 1236-1244	Dark gray basalt, vesicles; flow breccia, clays in voids; dark basalt, vesicles		Head = 494 ft. msl from hydrostrat. chart
			Constant Discharge Test	$\bar{Q}$ = 48.4 gpm
			Recovery	T = ? overshoot
			Under Pressure Pulse Test	ft²/d ; ft/d
	they note tests are probably valid since α < 0.7		Vander Kamp	T_1 = not analyzed
				T_2 = 1533 K_2 = 192
				T_3 = 2235 K_3 = 279
				T_4 not analyzed
			Avg	1884 236

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 1217
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1196-1217	Priest Rapids Interflow #2	Dark grey basalt, basalt with low to moderate planar fractures; dark altered basalt; 3 ft ± clay; vesicular basalt, vesicles decreasing		Head = 493 ? ft msl from hydrostat. chart
		Not bad →	Constant Discharge Test — Recovery	$\bar{Q}$ = 80 gpm; T = 2900 ft²/d; K = 208 ft/d
			Under Pressure Pulse — Van der Kamp	not solveable (their note)

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 1192 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER

5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1180 - 1192	Priest Rapids Interflow #1 (b = 1 ft)	Dark grey basalt with planar fractures.		Head = 414 ft. msl from hydrostrat. chart
			Constant Discharge Recovery	$\bar{Q}$ = 30.2 gpm; T = 627 ft²/d; K = 627 ft/d
			Under Pressure Pulse Test — Vander Kamp	T = 94 ft²/d; K = 94 ft/d

A lot of ~~scatter~~ scatter to data?

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 1192 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-23-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1190 - 1192	Priest Rapids Interflow #1 (b = 1 ft)	Dark grey basalt with planar fractures.		Head = 444 ft. msl from hydrostrat. chart
			Constant Discharge Recovery	$\bar{Q}$ = 30.2 gpm; T = 627 ft²/d; K = 627 ft/d
			Under Pressure Pulse Test — Van der Kamp	T = 94 ft²/d; K = 94 ft/d

Alot of ~~scatter~~ to data ?

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 1083 ft
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
969-1083	Mabton interbed/ Priest rapids basalt flow top (interval = 109 ft) 971-1080	Gray-green clay going to sand, fine then coarse sand, compacted sand, compacted clay then basalt		Head = 488.4 ft, msl
			Constant drawdown Recovery Cooper-Jacob	T = 15.7 ft²/d; K = 0.14 ft/d; Pretty good late time match st. line
			Under pulse pressure test	
	Extreme early time deviation →		#1 Cooper et al	T = 25.5; K = 0.23; $S = 6.1 \times 10^{-4}$
	moderate late time deviation →		#2 "	T = 19.8; K = 0.18; $S = 6.1 \times 10^{-4}$

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String of 4½ inch casing set to 770 ft. Stability problems with Mabton I, reamed to 1035 ft. & set 4½ & 3½ inch casing to this depth.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 965 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
925-965	Asotin interflow #3 (test interval = 18 ft.)	Breccia zone scoriaceous & clay in fractures		Head = 494.1 ft. msl Temp = 26°C @ 940 ft.
			Constant drawdown	
	945-965	not bad →	Drawdown Jacob-Lohman	T= 469.8 K=26.10
		Lost half log cycle is st. line →	Recovery Cooper Jacob	T= 393.0 K=21.83
			Under pulse pressure test	
			Vandorkamp	T= 562.7 K=31.26

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 922 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS	
910-922	Asotin interflow #2 (test interval = 6 ft) 916-922	Small breccia zone, generally dense basalt, few healed fractures & hard green clay bottom	Constant drawdown	Head = 492.30 ft. msl	
				ft²/d	ft/d
			#1 Recovery Cooper-Jacob	T = 2655.8	K = 442.63
			#2 "	T = 2608.7	K = 434.78

st. Line

Late time rise in pressure deviates from st. line

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 907 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS		
				Head = 492 ft. msl		
880-907	Asotin interflow #1 (test interval = 17 ft) 887-904	Increasingly vesicular with depth; inter-flow contact; many irregular fractures; dense basalt	Constant drawdown	ft²/d	ft/d	
			#1 Recovery Cooper Jacob	T = 2357.1	K = 138.65	
			#2 " "	T = 1254.2	K = 73.78	
			#3 " "	T = 1571.7	K = 92.45	
			Under pulse pressure test			
			#1 Cooper et al	T = 2743.0	K = 161.35	S = 6.1×10^{-1}
			#2 "	T = 1019.0	K = 59.90	S = 6.1×10^{-1}

Recovered too fast for analyses, their note → (Under pulse pressure test)

Early time fit only →

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-14
2. TOTAL DEPTH: 763
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-22-82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
675-768	Selah interbed & Umatilla Basalt Flow top (interval thickness = 63 ft) 701-764	A		Head = 407 ft. msl
			Constant drawdown #1 Recovery Cooper-Jacob	T = 184.9 K = 2.94
			#2 "	T = 197.5 K = 3.13
	Mid time data match →		Under pulse pressure test #1 Cooper et al	T = 240.6 K = 3.82 S = 6.1×10^{-11}
	Mid time trio match →		#2 "	T = 297.3 K = 4.72 S = 6.1×10^{-11}
	Mid time data match →		#3 "	T = 311.4 K = 4.94 S = 6.1×10^{-11}
	701-764	Flow breccia with blue green clay matrix; silty or sandy clay; clay; vesicular basalt		

5½" dia. casing "mud packed" across Selah Interbed due to stability problems

Borehole Review Form

1. Borehole No.: DC-14
2. Total Depth: 538 ft.
3. Depth of Casing:
4. Reviewer: G. WINTER
5. Date: 7-22-82

Interval	Strat. Unit	Lithology	Type of Test	Results - Comments		
475-538	Rattlesnake Ridge interbed & Pomona flow top (38 ft. test interval) 491-529	Black clay & altered basalt; quartz sand; silt, clay & sand beds; breccia, vesicular, broken up basalt	from hydrost. chart	Head = 400 ft. msl		
				Temp = 17°C @ 500 ft.		
			Air lift constant drawdown	ft²/d	ft/d	
		Looks good →	Recovery Cooper-Jacob	T=20.2	K= 0.53	
			Pump test Constant Drawdown			
		Late time (10 min) looks good →	Drawdown-Jacob-Lohman	T= 19.4	K = 0.51	
		Not a lot of data to fit, gap →	Recovery Cooper-Jacob	T= 16.3	K = 0.43	
			Slug injection			
		Poor fit everywhere →	#1 Cooper et al	T= 325.6	K=8.57	S= 6.1×10⁻⁶
		mid time fit →	#2 " "	T= 425.0	K=11.89	S= 6.1×10⁻⁶
			Under pulse pressure test			
		Late time fit only →	#1 Cooper	T= 276.0	K= 7.26	S= 6.1×10⁻²
		→	#2	T= 285.9	K = 7.52	S= 6.1×10⁻²
			Avg	195.5	5.24	6.1×10⁻⁴
			Best estimate	20.2	0.53	6.1×10⁻⁴

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-14
2. TOTAL DEPTH: 475 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER

5. DATE: 7-22-82

INTERVAL ft	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
368 - 475	Elephant Mtn. Interflow (32 ft test interval) 391 - 423	Breccia, highly vesicular, scoracious basalt, fragments in a hard, pale green clay, less clay with depth	from hydrost. chart	Head = 378 ft msl to Temp = 17.5°C @ 320'
			Air lift Constand Drawdown	Q = 8 gpm
			Recovery Theis	T = 4.12 ft²/d K = 0.13 ft/d
			Pump test Constant Drawdown	← submersible Q = 7.45 gpm
		Very late data deviates st. line ?; Good →	Jacob-Lohman	T = 3.43 K = 0.11
		Looks good on what is shown →	Recovery Theis	T = 5.6 K = 0.17
		Removed from report draft →	Slug injection #1 Vanderkamp	T = 2177.1 K = 68.03
			#2 "	T = 2616.0 K = 81.75
		Removed from report draft →	Slug Withdrawal Vanderkamp	T = 2513.6 K = 78.55

Used bentonite drilling mud

BOREHOLE REVIEW FORM

[illegible]

1. BOREHOLE NO.: McGee Well El [illegible]
   [illegible]
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: CF
5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
870-890	Priest Rapids Interflow	Interflow unit	[illegible] w/ [illegible] Enyeart, [illegible]	Drawdowns not observed in [illegible] wells
				static head 923.[illegible] [illegible]
			flowing well	Q [illegible] 450 gpm
				$Q_{24 hours}$ 392.0 they have [illegible] and pressure data [illegible] pumping and [illegible] but no analyses have been done on [illegible] (143,000 ft²/day by my calculation) Only [illegible] wells Enyeart + DB[illegible] [illegible]
				Enyeart well [illegible] to base of [illegible] + open below. [illegible] in Priest Rapids [illegible] [illegible] of [illegible] ft²/day.
Casing 1173 - 1219				[illegible] barrier boundary [illegible] McGee [illegible]).

BOREHOLE REVIEW FORM

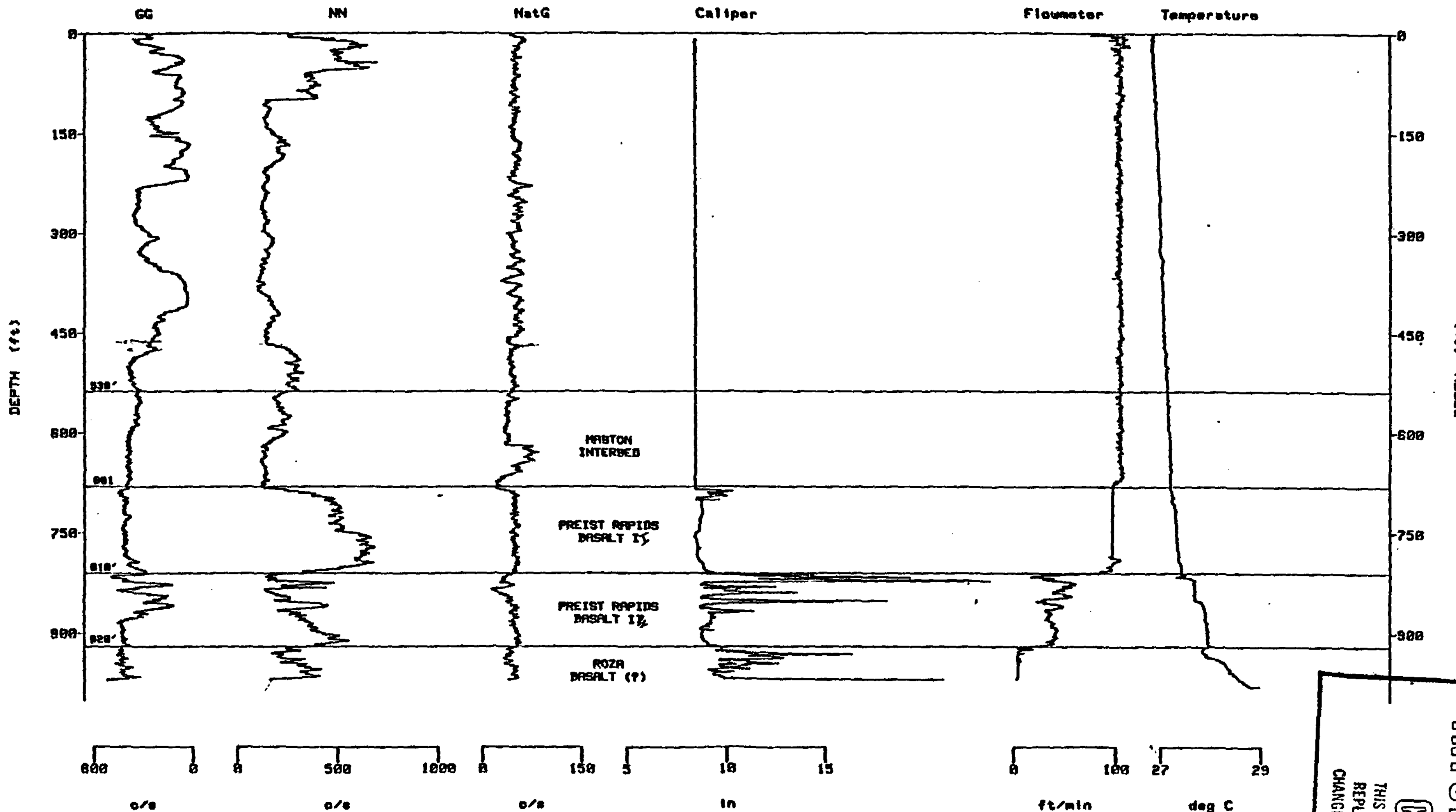
1. BOREHOLE No.: McGee
2. TOTAL DEPTH: 1096 at this site
3. DEPTH OF CASING: 681'
4. REVIEWER: FAUST

5. DATE: 22 July 82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1028.5–1096	Roza interflow	vesiculated [illegible], rubbled [illegible]	Slug Test Vanderkamp	T= 285-305 FT²/d very rapid oscillations on Vander Kamp
			Constant pressure	[illegible] at steady state 25 gpm so they didn't interpret - tried to vary pressure and change flow rates but didn't report results
			head measurement	only pressures observed (flowing conditions) P= 45.83 } on 23 Jun 82 Pa = 1470 }

interval chosen to straddle base of upper Roza flow and flow top of lower Roza flow

BOREHOLE GEOPHYSICAL LOGS
BOREHOLE: McGEE WELL



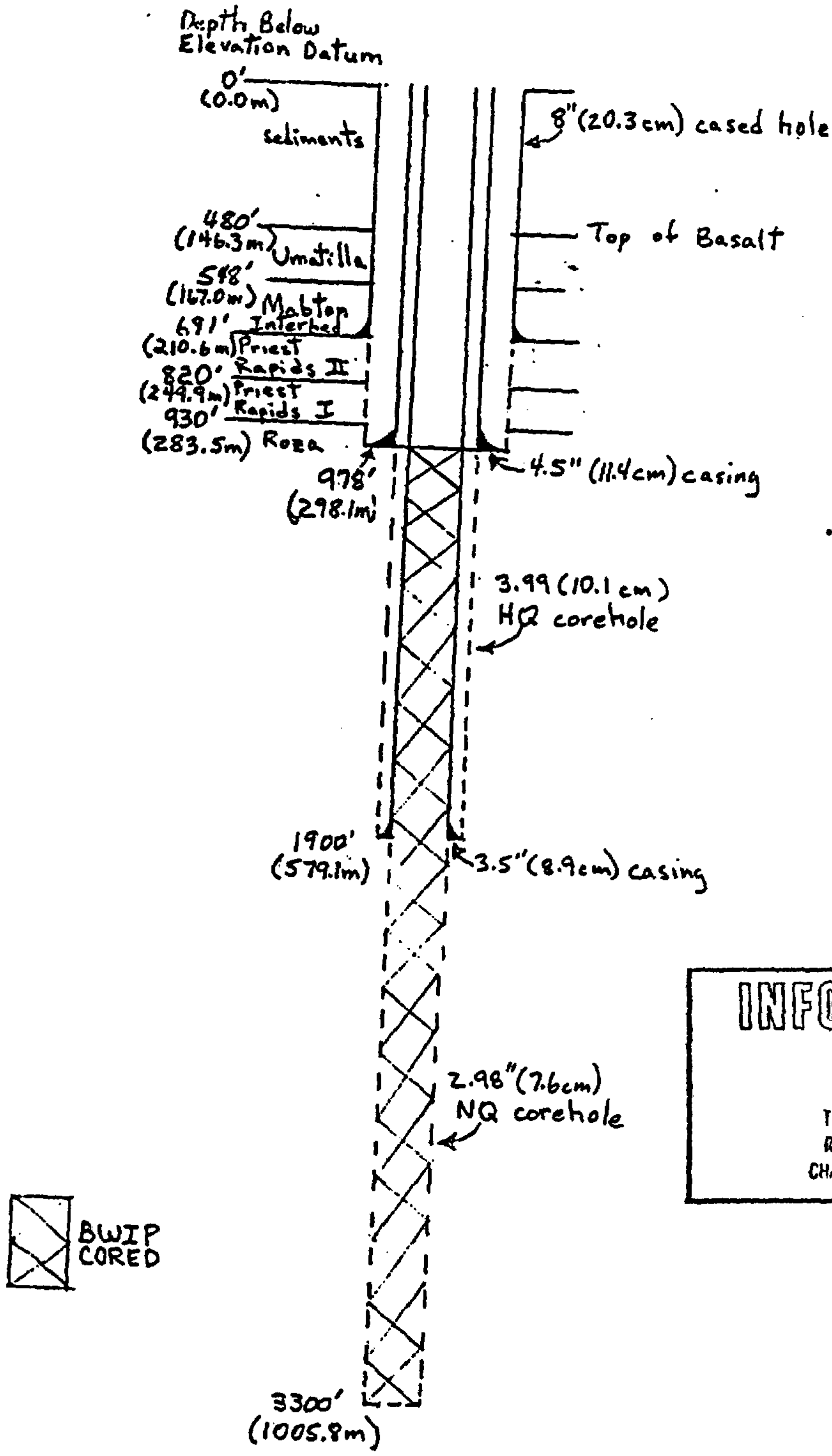


Figure 4. PREDICTED AS-BUILT FOR THE McGEE WELL

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: Ford Well
2. TOTAL DEPTH: 800' approx
3. DEPTH OF CASING: 650' approx
4. REVIEWER: FAUST

5. DATE: 22 July 82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
Approx 650-800	Priest Rapids II basalt and interflow at base	Mostly dense basalt, lower 50' is interflow between PR II & PR I	Constant drawdown w/ observations	obrian T = 119,054 FT²/d Ford well T = 393,200 FT²/d Enyeart T = 89,517 FT²/d (straight line) Q̄ = T.
			Recovery	straight line Ford T = 89,817. FT²/d Enyeart T = 100,517. FT²/d Obrian T = 115,080 FT²/d

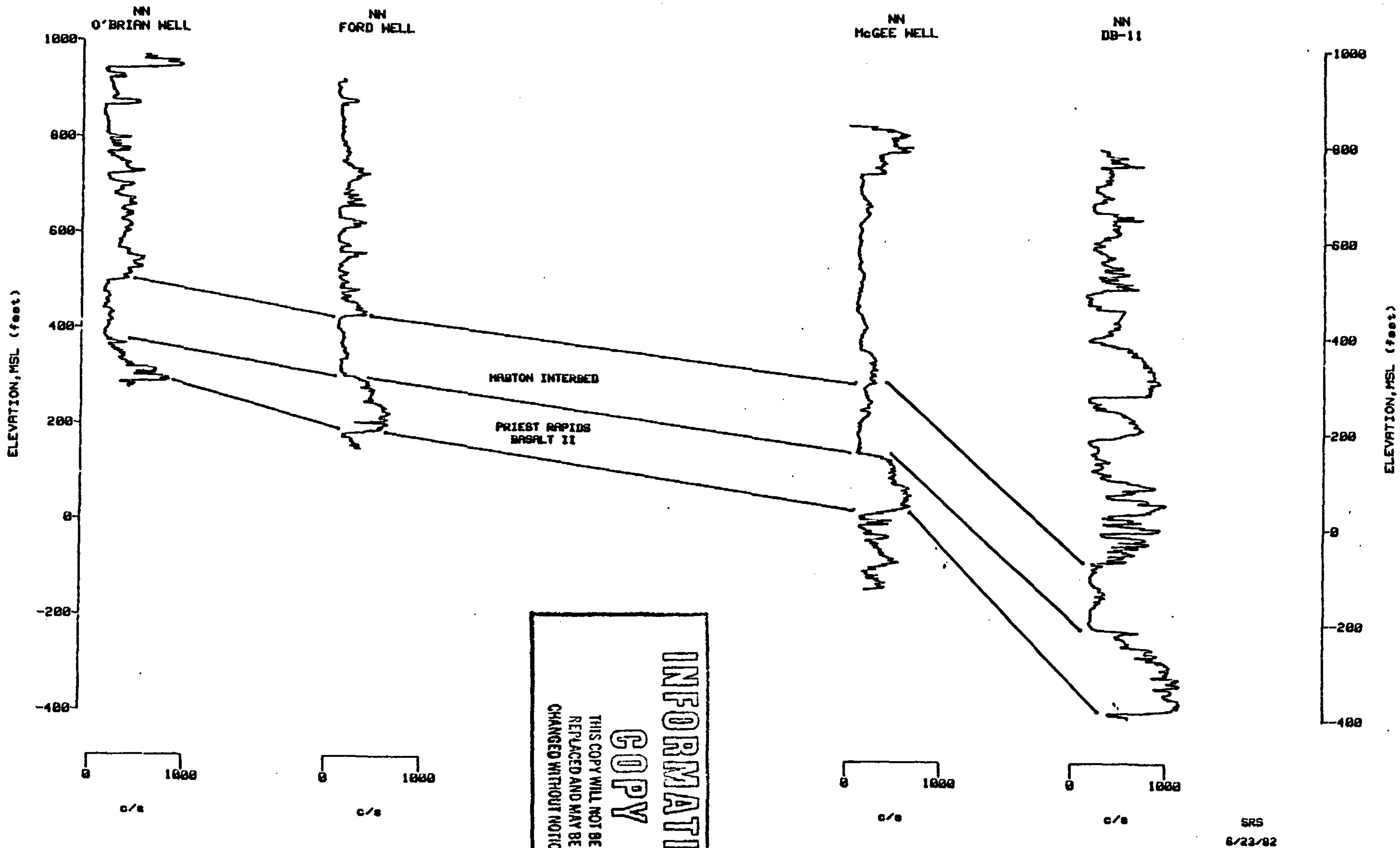
disregard Ford Discharge T value of 300,000

Well	Elevation	Static Depth
Enyeart	910.86	33.68
Ford	924.63	17.72
OBrian	973.72	33.14
McGee	925.68	
DB-11	791.58	

Displacement test Vander Kamp on Ford well

T = 32,104 ft²/d

BOREHOLE GEOPHYSICAL LOGS



BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-4/5 — Elevation 705' DC-4; need geophysical ??
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: C.R. Faust — 5. DATE: 22/July 82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
data available at site does not include log				
DC-4 2639-3998	Vantage + Grand Ronde to Below Unknown	Composite	Drawdown test using airlift in DC-5 20 hour test	T estimates caculated Jacob straight line DC-4 1.65 DC-5 2.15 Theis Curve DC-4 1.23 DC-5 1.82
[illegible] the head	332.98 Below top of casing 10:72 4 Apr 81			$\overline{Q}$ = 3.2 gpm - no Q vs time plot?
T - 63°C				The estimates of t on the semi-log and log-log plots appear to be very crude fits to the data. Q(t) is needed and for [illegible] analysis all estimates appear to give high values of T, no estimates of S provided. T range (1.23 - 2.15) [illegible] [illegible] purpose [illegible] this [illegible]

[illegible] were not very straight - note attached sheet.

The purpose of these composite test was to give crude prediction of what might be expected in close interval testing. This analysis has not been reviewed. Interval testing of [illegible] has not been completed because of equipment problems. The T of the [illegible] Unknown flow top appears to be too low [illegible] test.

Comments:

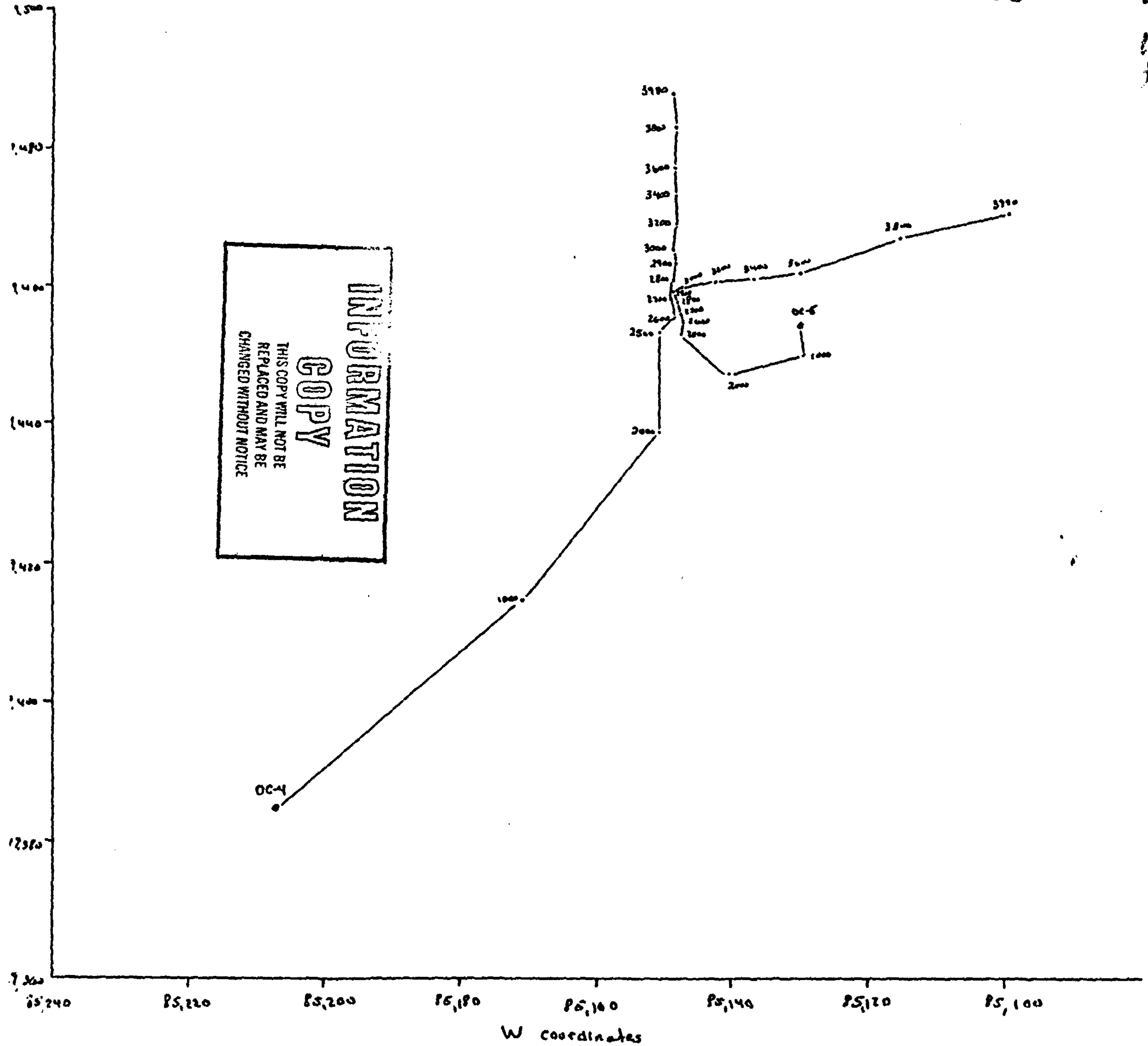
[illegible] used raw pumping test data. The reason for matching late portion of curve was that the $\bar{Q}$ used was that of the late data 3.2 gpm. Q and [illegible] was 11.3 gpm

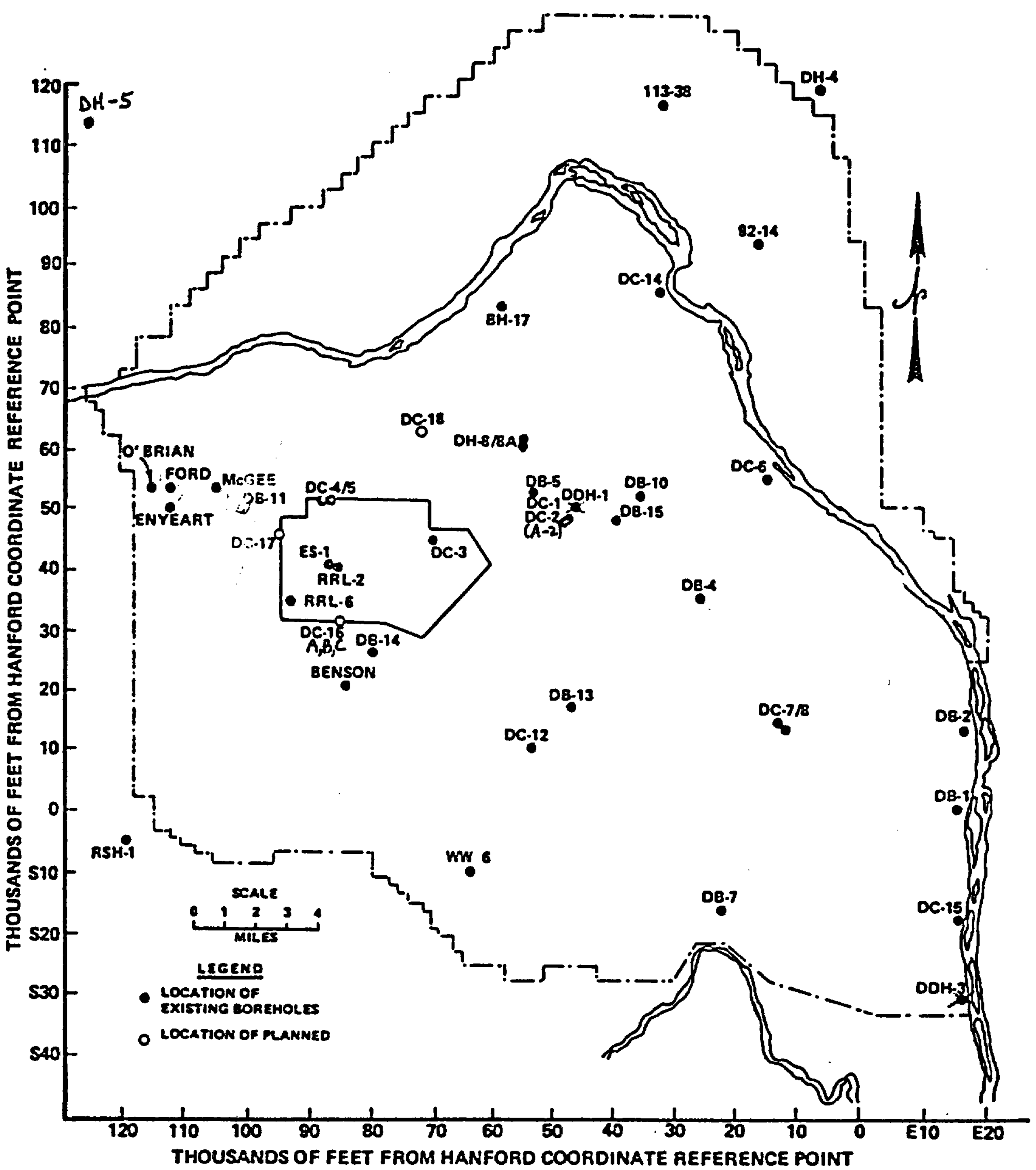
After testing of flow top of Umtanum too preliminary to use (equipment problems).

3579 - 3591 DC-5 tested but little useful information obtained

Gyroscopic Survey of Boreholes DC-4 and DC-5

4-16-81 [illegible]
based on older
data




THOUSANDS OF FEET FROM HANFORD COORDINATE REFERENCE POINT
120
110
100
90
80
70
60
50
40
30
20
10
0
S10
S20
S30
S40
DH-5
113-38
DH-4
92-14
DC-14
BH-17
DC-18
DH-8/BA
O'BRIAN
FORD
McGEE
DB-11
ENYEART
DC-4/5
DC-17
ES-1
RRL-2
RRL-6
DC-3
DC-16 A,B,C
DB-14
BENSON
DB-5
DC-1
DDH-1
DC-2 (A-2)
DB-10
DB-15
DC-6
DB-4
DB-13
DC-7/8
DC-12
DB-2
DB-1
RSH-1
WW 6
DB-7
DC-15
DDH-3
SCALE
0 1 2 3 4
MILES
LEGEND
LOCATION OF EXISTING BOREHOLES
LOCATION OF PLANNED
120 110 100 90 80 70 60 50 40 30 20 10 0 E10 E20
THOUSANDS OF FEET FROM HANFORD COORDINATE REFERENCE POINT

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC 7 + DC 8
2. TOTAL DEPTH: DC-7 = 5008 ; DC-8 = 4100.5
3. DEPTH OF CASING: DC7 to 2780 DC8 to 2734
4. REVIEWER: R Williams
5. DATE: 7/21/82

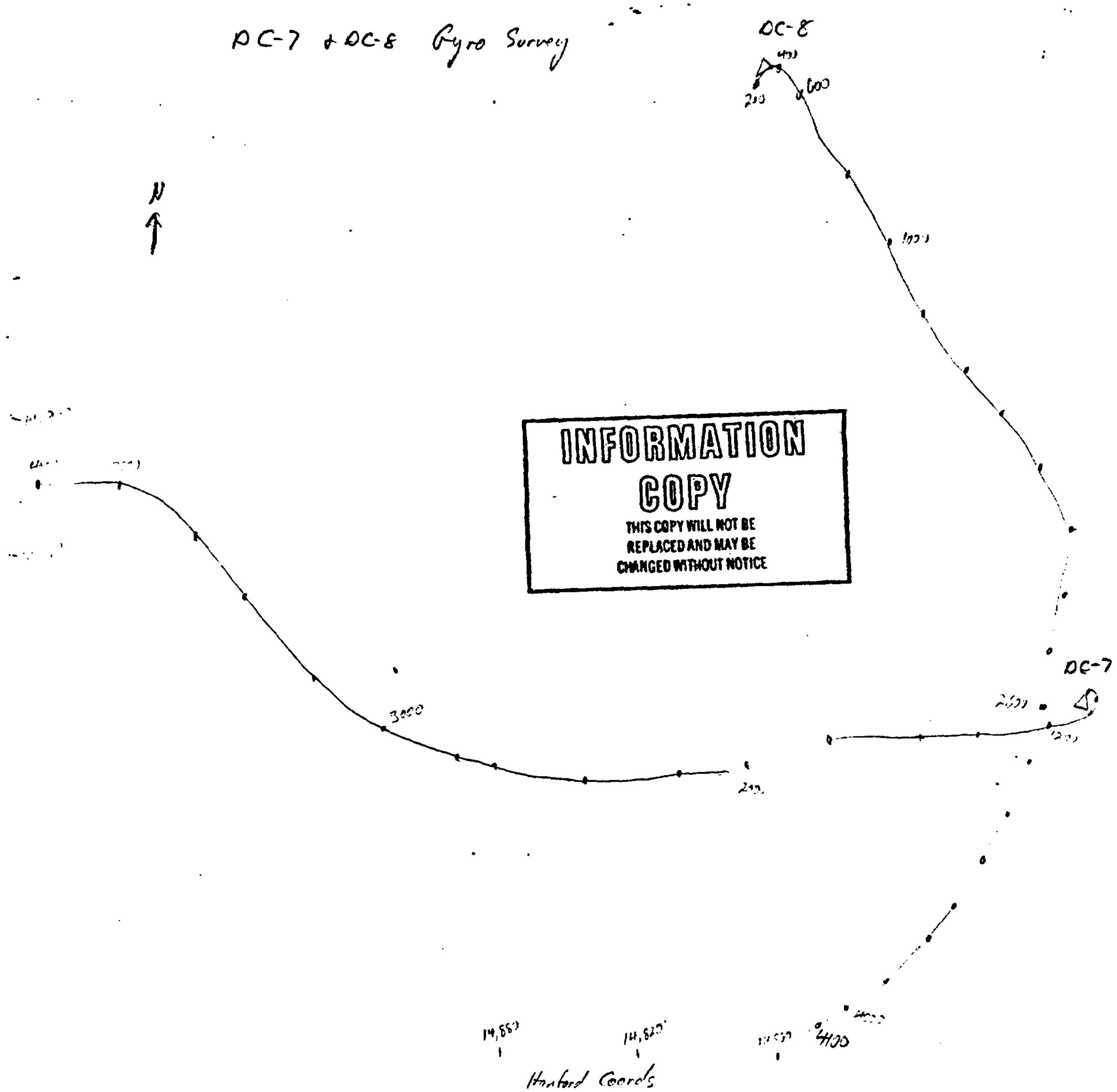
INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
DC 7 2780 to 3948	Grande Ronde		Theis multi well confined aquifer test. Also recovery test in pumping well	DC 7 = Pumping well; " " 8 = obs. well. State of art testing. multiple hole theis curves match well. Early time drawdown data could be valuable if corrected for well storage effects. T = 455 ft²/day; K = 3.5 x 10⁻⁵ cm/sec
DC 7 2734 to 4100.5				

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-7   Elev 545' MSL
2. TOTAL DEPTH: 5008'
3. DEPTH OF CASING: 2780'
4. REVIEWER: J Rowe   5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

DC-7 + DC-8 Gyro Survey



BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-7 Elev 545' MSL
2. TOTAL DEPTH: 5008'
3. DEPTH OF CASING: 2780'
4. REVIEWER: J. [illegible]
5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
4120 - 4257	Grande Ronde basalt high porosity zones, approx 4 flow tops		· Straddle packers - Lynes	
				Hydraulic Head 404.6 (measured after recovery)
				1.) Slug withdrawal - method of withdrawing slug not given, good fit to data
				2) Slug injection - method of injection not given, good fit to data
Kagin calculation 137.6'				3) Constant head Injection - reasonably good straight line of Pex vs Q, intercept at 15 ml/min not 0

Summary

Test	Analy	T ft²/d	K ft/d	S
[illegible] withdrawal	Cooper et all	5.4x10⁻³	3.7x10⁻⁵	2.4x10⁻⁵
- injection		4.2x10⁻³	3.1x10⁻⁵	2.4x10⁻⁴
CHI	Ziegler 1976	-	2.9x10⁻⁵	-
[illegible]		4.6x10⁻³	3.5x10⁻⁵	1.3x10⁻⁴
[illegible]		4.8x10⁻³	3.5x10⁻⁵	1.3x10⁻⁴

Release

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-7
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

4261.2 - 4433.8 Grande Ronde basalt interflows

- interflows 4301-4320 & 4326-4409'
- top of interval 440' below Umtanum
- used Lynes straddle packers, downhole transducers

Hydraulic Head - 404.9' (measured after recovery)

1. Slug injection - used downhole valve to introduce slug, reasonably good fit to Cooper curves, allowed nearly 100 % recovery

Kequiv calc using 102'

2. Slug withdrawal - used downhole valve, good fit

3) Const. H Inj. - steady state not achieved, Q from 0.08 to 0.02 gpm, good data fit to transient semi-log straight line method

Summary

Test	Anal	T (ft²/d)	K (ft/d)	S
Slug I	Cooper et al	1.01×10^{-2}	9.90×10^{-5}	8.38×10^{-3}
W		9.24×10^{-3}	9.06×10^{-5}	8.38×10^{-3}
CHI	Jacob, Lohman	7.97×10^{-3}	7.81×10^{-5}	
Avg + Best Est		8.8×10^{-3}	8.7×10^{-5}	–

T + K reliable

S not reliable

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-7
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:
5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
4830-5008'	Grande Ronde basalt — no details given, looks like 2 interflow zones			Lynes downhole pressure system, single packer

Hydraulic Head 391 ±2' measured with well probe, state of equilibrium in question in my view

Kequiv calc using 178 ft (total thickness) actual interflow thickness looks like 80-100'

1.) Const Q Airlift – Q avg 0.6 gpm, apparent good fit to late time data

2) Slug injection – 2 tests, both indicate 2 distinct portions of log-log curves, indicated as possible leak (P vs t plots)

3) Slug withdrawal – 2 tests, H/Ho vs t plots show 2 distinct curves, possible leak

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Summary

Test	Anal	T (ft²/d)	K (ft/d)
CDA	Theis recovery	3.2×10^{-1}	1.8×10^{-3}

See attached sheets for slug results

Fair reliability of CDA test, slug results not good

Note: There is some question as to validity of Static Head, after final slug tests downhole valve was closed + pressure in interval continued to increase, no W.L. measurements available during this period – zone may not have reached equilibrium

TABLE 2

HYDROLOGIC TESTING RESULTS
DC-7

4830-5008'

GROUND SURFACE ELEVATION: 544.8 FEET

TEST TYPE	TEST INTERVAL FEET BELOW GROUND LEVEL	PUMPING PERIOD (HOURS)	AVERAGE DISCHARGE (GPM)	MAXIMUM OBSERVED DRAWDOWN (FEET)	ANALYSIS METHOD	TRANSMISSIVITY ft^2/day				AVERAGE HYDRAULIC CONDUCTIVITY (ft/day)
						RECOVERY	SLUG WITHDRAWAL	SLUG INJECTION	SPECIFIC CAPACITY	
ALT	4820-5008	93.75	0.6	296+	MTR	0.32				1.8×10^{-3}
Si01	Lynes, early time				CP-LL			9.0		5.1×10^{-2}
Si01	Lynes, late time				CP-LL			9.8×10^{-2}		5.5×10^{-4}
Si01	SINCO				CP-LL			19.5		1.1×10^{-1}
Si02	Lynes, early time				CP-LL			8.4		4.7×10^{-2}
Si02	Lynes, late time				CP-LL			7.3×10^{-2}		4.1×10^{-4}
Si02	SINCO, late time				CP-LL			8.9×10^{-1}		5.0×10^{-3}
Si02	SINCO, early time				CP-LL			NO MATCH		
Si02	Lynes, early time				CP-SL			360		2.0×10^{0}

STATIC HYDRAULIC HEAD
MEASUREMENT (TEST INTERVAL: 4830-5008 ft)

DATE	HYDRAULIC HEAD (FEET ABOVE MSL)
7/18/80 - 8/8/80	391 ±2

EXPLANATION

ALT = AIR LIFT TEST
CRPT = CONSTANT RATE PUMPING TEST
S_W = SLUG WITHDRAWAL
Si = SLUG INJECTION
MTR = MODIFIED THEIS RECOVERY
LL = LOG-LOG
CP = COOPER-PAPADOPULOS
SL = SEMI LOG
SC = SPECIFIC CAPACITY

TABLE 2 (continued)

HYDROLOGIC TESTING RESULTS

DC-7

4830–5008'

GROUND SURFACE ELEVATION: 544.8 FEET

TEST TYPE	TEST INTERVAL FEET BELOW GROUND LEVEL	PUMPING PERIOD (HOURS)	AVERAGE DISCHARGE (GPM)	MAXIMUM OBSERVED DRAWDOWN (FEET)	ANALYSIS METHOD	TRANSMISSIVITY ft²/day				AVERAGE HYDRAULIC CONDUCTIVITY (ft/day)
						RECOVERY	SLUG WITHDRAWAL	SLUG INJECTION	SPECIFIC-CAPACITY	
Sw01	4830-5008	SINCO, late time			CP-LL			8.0×10^{-2}		4.5×10^{-4}
Sw01	↓	Lynes, early time			CP-LL			28		1.6×10^{-1}
Sw01	↓	Lynes, late time			CP-LL			1.3×10^{-1}		7.3×10^{-4}
Sw01	↓	Lynes, early time			CP-SL			9.4		5.3×10^{-2}
Sw02	↓	SINCO, early time			CP-LL			50		2.8×10^{-1}
Sw02	↓	SINCO, late time			CP-LL			8.0×10^{-2}		4.5×10^{-4}
Sw02	↓	Lynes, early time			CP-LL			8.2		4.6×10^{-2}
Sw02	↓	Lynes, late time			CP-LL			8.9×10^{-2}		5.0×10^{-4}
Sw02	↓	Lynes, early time			CP-SL			12.5		7.0×10^{-2}

STATIC HYDRAULIC HEAD MEASUREMENT (TEST INTERVAL: ______________)

DATE	HYDRAULIC HEAD (FEET ABOVE MSL)

EXPLANATION

- ALT = AIR LIFT TEST
- CRPT = CONSTANT RATE PUMPING TEST
- S_W = SLUG WITHDRAWAL
- SI = SLUG INJECTION
- MTR = MODIFIED THEIS RECOVERY
- LL = LOG-LOG
- CP = COOPER-PAPADOPULOS
- SL = SEMI LOG
- SC = SPECIFIC CAPACITY

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-7
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

4444.1 – 4614.7' Grande Ronde basalt

- 5 interflow zones, vesicular flow top breccia and vesicular basalt
- used Lynes straddle packers with downhole pressure trans.

Hydraulic Head 406.8' measured after 43 days – still dropping 0.07 ft/d

K equiv calc using 59'

1.) Slug injection – used downhole shut-in tool, poor data fit to type curve

Summary

Test	Anal	T (ft²/d)	K (ft/d)
Slug Inj.	Cooper et al	2.7x10⁻¹	4.6x10⁻³ ft/d

Not reliable

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-7
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
4684-4827'	Grande Ronde basalt interflows - 2 interflow zones, upper zone 8' - 875 below Umtanum flow			Lynes straddle packers, downhole transducers

Hydraulic Head 401.8 (measured after recovery) called an "estimate"

1) Const Q/H Airlift - 3 tests, several methods of analysis used / 2755 min test - 1/Q vs t plot gives fair fit of Δ vs t/t' gives fair to poor fit, 3 distinct slopes steep ⇒ shallow ⇒ steep, last portion after est. end of well bore storage Qav = .65/ 24 hr test, similar plot to 2755 min test, Qavg = 0.49 gpm, variable rate analysis gives similar plots to const Q, Const H analysis gives fair to good fit

(315 min, 460 min, 2755 min duration)

Kequiv calc using 143'

2) Slug Test - 1 injection, 1 withdrawal, both give fair to good fits

Good Reliability

Const. H tests appear more reliable, T on order of 3.1 ft²/d, K = 0.022 ft/d

See Attached Sheet

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	Equivalent HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
45.9-HOUR AIR-LIFT PUMPING TEST		Recovery — Theis (1935)	1.2	0.0084	—
		Constant Drawdown - Jacob & Lohman (1952)	3.2	0.022	—
24-HOUR AIR-LIFT DEVELOPMENT PUMPING		Recovery - Theis (1935)	1.4	0.0098	—
24-HOUR AIR-LIFT PUMPING TEST		Recovery - Theis (1935)	1.4	0.0098	—
		Variable Rate - Harrill (1970)	1.4	0.0098	—
		Constant Drawdown - Jacob & Lohman (1952)	3.1	0.022	—
SLUG TESTS	WITHRAWAL NO. 1	Copper et al (1967)	-	-	-
	WITHRAWAL NO 2		6.0	0.042	2.8×10^{-4}
	INJECTION TEST NO. 1		1.5	0.010	2.8×10^{-4}
	AVERAGE		3.8	0.026	2.3×10^{-4}
AVERAGE			2.4	0.017	2.8×10^{-4}
BEST ESTIMATE (3 Air-lift tests - Recovery data			1.3	0.0093	—

Table 2. Summary of Results Determined From Various Test Methods For Grande Ronde Basalt, 4684-4827 Feet, Borehole RRL ?

DC-7

143

BOREHOLE REVIEW FORM

1. BOREHOLE NO.:
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
4115-5008'	Grand Ronde basalt - composite of many interflows			Lynes single packer with downhole trans.

Hydraulic Head 401 ± 1 (measured after recovery)

1.) Const Q Airlift - Q avg = 1.4 gpm, range not given, semilog plots indicate 3 distinct slopes - steep ⇒ shallow ⇒ steep, final steep slope used for T determination, fit somewhat questionable due to changes in slope

(93.5 hr duration)

K equiv calc using 893'

(note error in interval report used 993')

no effective zone given

2) Slug tests - 5 inj., 5 with, essentially no useful info, wide spread in calc T's, no data presented.

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Test Const Q Airlift
Anal Theis Recovery

T = 1.24 ft²/d

~~K = 1.2 × 10⁻³ ft/d~~ error

actual K for 893' section
= 1.4 × 10⁻³ ft/d

Low to Mod Reliability - some question as to appropriateness of late time fit

See attached sheets

TABLE 2

HYDROLOGIC TESTING RESULTS
DC-7

GROUND SURFACE ELEVATION: 544.8 FEET

TEST TYPE	TEST INTERVAL FEET BELOW GROUND LEVEL	PUMPING PERIOD (HOURS)	AVERAGE DISCHARGE (GPM)	MAXIMUM OBSERVED DRAWDOWN (FEET)	ANALYSIS METHOD	TRANSMISSIVITY ft²/day				AVERAGE HYDRAULIC CONDUCTIVITY (ft/day)
						RECOVERY	SLUG WITHDRAWAL	SLUG INJECTION	SPECIFIC CAPACITY	
ALT	4115-5008	93.5	1.4	155	MTR	1.24				1.25×10^{-3}
Si01					U			67		6.75×10^{-2}
S_w01					U		90			9.1×10^{-2}
Si02					U					
Sw02					U					
Si03					CP-LL		NO MATCH			
Sw03					CP-LL		NO MATCH			
Si04	SINCO, late time				CP-LL		1.9			$.9 \times 10^{-3}$
Si04	Lynes, early time				CP-LL		126			$.27 \times 10^{-1}$
Sw04	SINCO, late time				CP-LL	5.2				5.2×10^{-3}

STATIC HYDRAULIC HEAD
MEASUREMENT (TEST INTERVAL: 4115-5008 ft)

DATE	HYDRAULIC HEAD (FEET ABOVE MSL)
6/23/80	401.4
7/9/80	400.6

EXPLANATION

ALT = AIR LIFT TEST
CRPT = CONSTANT RATE PUMPING TEST
S_w = SLUG WITHDRAWAL
Si = SLUG INJECTION
MTR = MODIFIED THEIS RECOVERY
LL = LOG-LOG
CP = COOPER-PAPADOPULOS
SL = SEMI LOG
SC = SPECIFIC CAPACITY

NOTE: Data not corrected for temperature or density of formation water.

TABLE 2 (continued)

HYDROLOGIC TESTING RESULTS

DC-7

GROUND SURFACE ELEVATION: 544.8 FEET

TEST TYPE	TEST INTERVAL FEET BELOW GROUND LEVEL	PUMPING PERIOD (HOURS)	AVERAGE DISCHARGE (GPM)	MAXIMUM OBSERVED DRAWDOWN (FEET)	ANALYSIS METHOD	TRANSMISSIVITY ft²/day				AVERAGE HYDRAULIC CONDUCTIVITY (ft/day)
						RECOVERY	SLUG WITHDRAWAL	SLUG INJECTION	SPECIFIC CAPACITY	
Sw04	Lynes	early time			CP-LL		2.2			2.2×10^{-3}
Si05					CP-LL		NO MATCH			
Si05					U			172		1.73×10^{-1}
Si05					CP-LL		NO MATCH			
Sw05					CP-LL		NO MATCH			

STATIC HYDRAULIC HEAD MEASUREMENT (TEST INTERVAL: 4115-5008)

DATE	HYDRAULIC HEAD (FEET ABOVE MSL)
	401.4

EXPLANATION

ALT = AIR LIFT TEST
CRPT = CONSTANT RATE PUMPING TEST
S_w = SLUG WITHDRAWAL
Si = SLUG INJECTION
MTR = MODIFIED THEIS RECOVERY
LL = LOG-LOG
CP = COOPER-PAPADOPULOS
SL = SEMI LOG
SC = SPECIFIC CAPACITY

NOTE: Data not corrected for temperature or density of formation water

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-7/8 Pump Test
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
DC-7 2780-3948.2'		Grande Ronde basalt		
DC-8 2734-4100.5'		DC-7 dia hole = 8.625 in, bridge packer set at 3948', casing at 2780'		
		DC-8 hole bottom @ 4100.5', casing at 2734' dia hole = 3.032"		
		horz dist at test midpoint ≈ 55 ft, range 40 to 70 ft		
Kogan using 1267'		Hydraulic Head - DC-7 399.4', DC-8 403.5' after 43 days equilibration (stated that because of larger borehole storage vols in DC-7 it took longer to equilibrate		
		1.) Const Q Airlift - DC-7 pumped, Q ranged 23 - 5.5 gpm avg 6.3, no T calc., 3 day duration		
		2) Const Q Pump - 24hr duration, used flow regulator, Q = 4.94 gpm, good late time curve fit, DC-7 pm		
		3) Const Q Airlift on DC-7, 46 hr duration, run before 24 hr pump test		
		4.) Const Q Airlift - on DC-8 Q avg = 2.4 gpm		
see chart		All curves fit relatively good to late time data, All calc. T's are uniform. Potential problems with variable radius, good log-log curve fit to late time data, wellbore storage effects apparently causing bad fit for early time.		

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ET

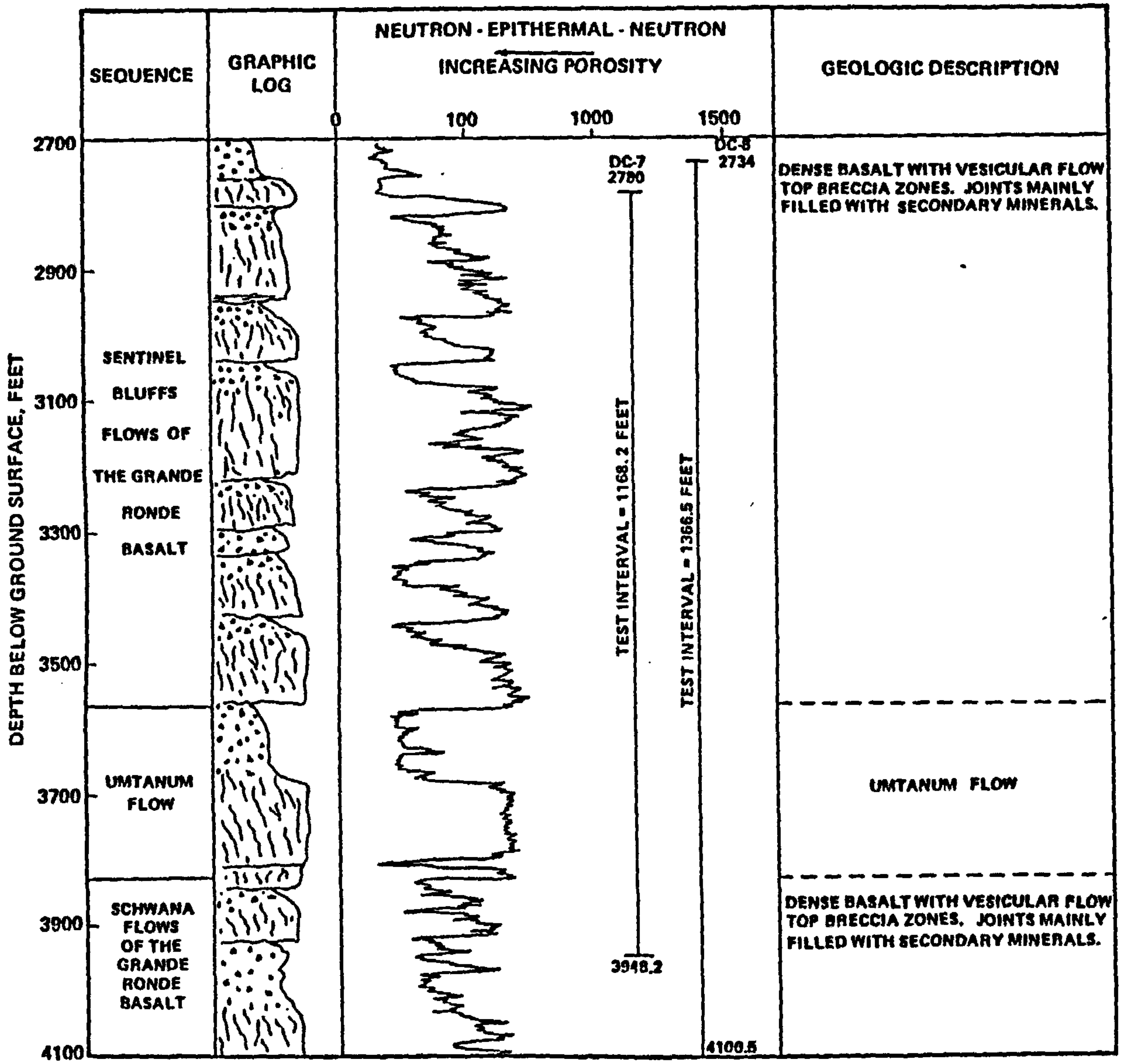


FIGURE 2. INTERVAL DESCRIPTION OF THE GRANDE RONDE BASALT IN THE DEPTH INTERVAL OF 2780 TO 3948.2 FEET AT DC-7 AND 2734 TO 4100.5 FEET AT DC-8.

RLJM/1/82

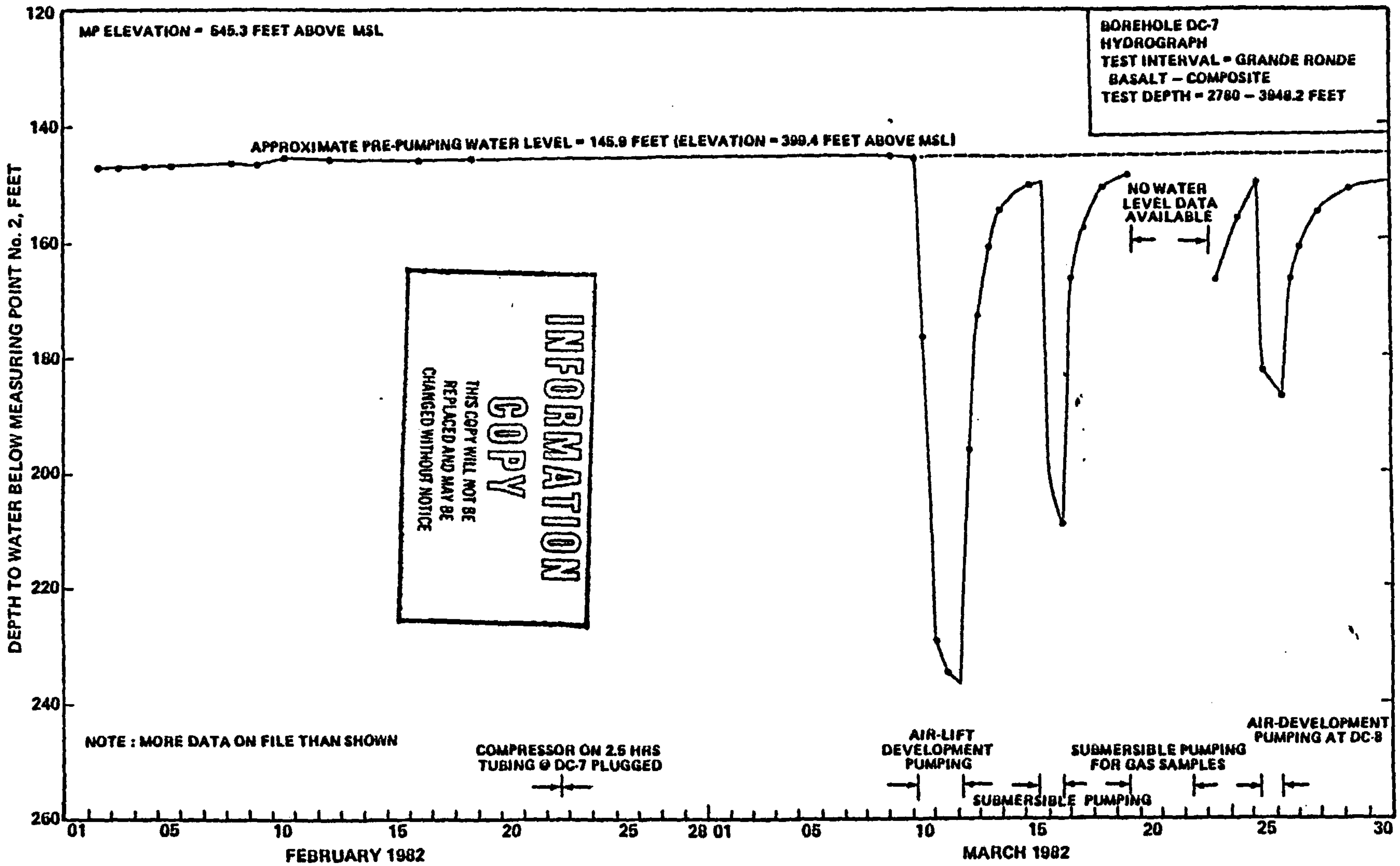


FIGURE 3.

RLJ/3/31/82

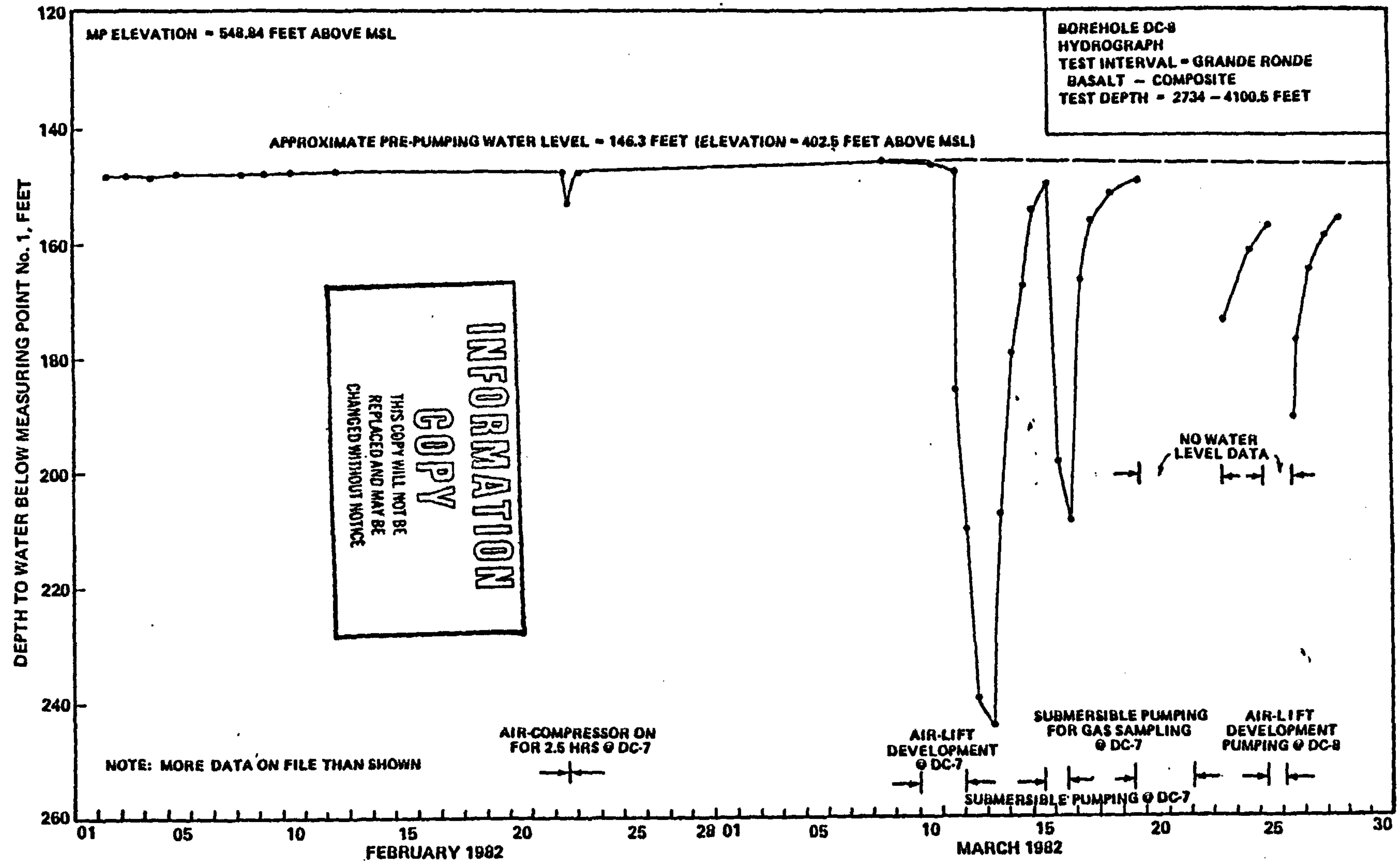


FIGURE 4.

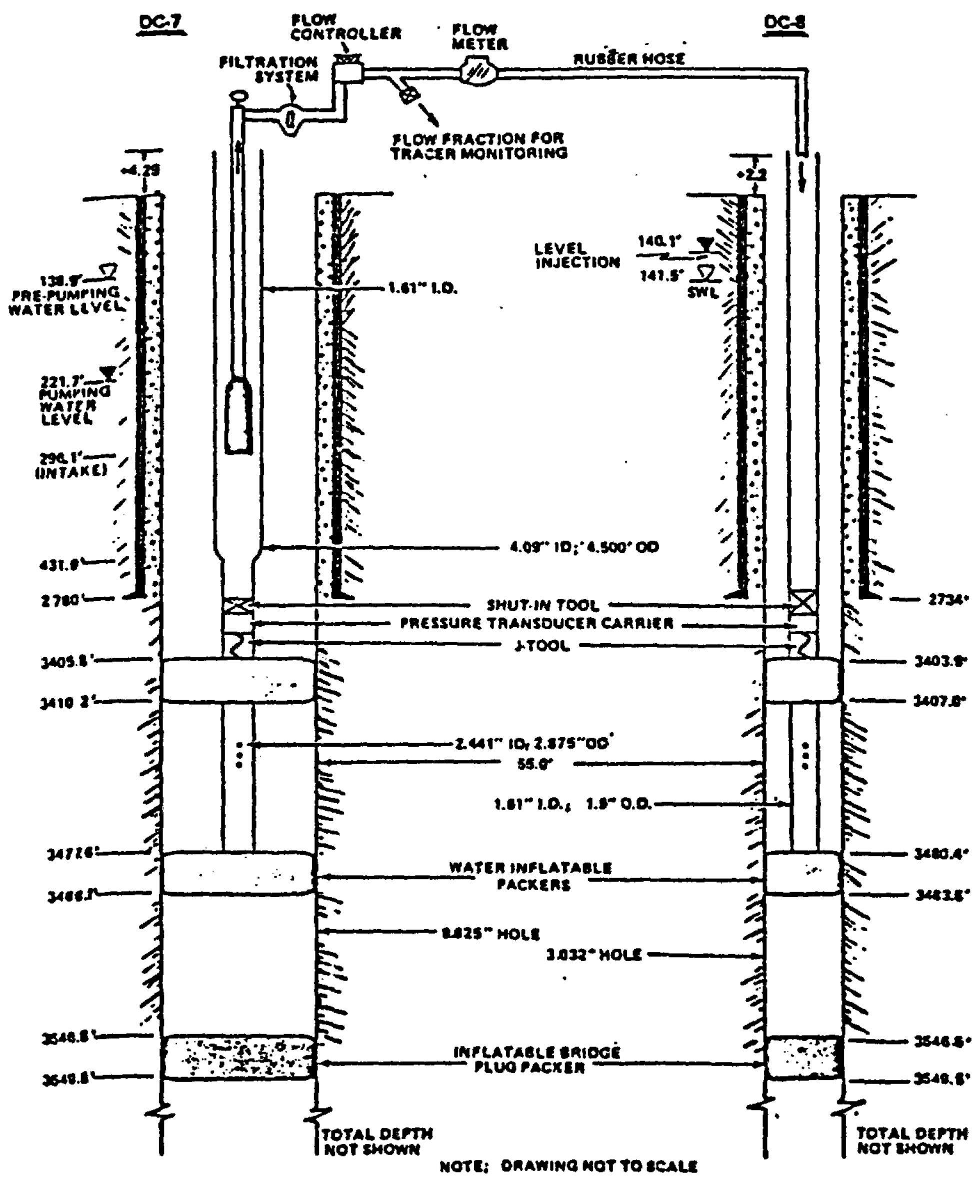
RLJ/3/31/82

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-7/8 Tracer Test
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
DC-7 3410.2–3477.6	McCoy Canyon flowtop			
DC-8 3417.0 - 3450.4				

FIGURE 2. SCHEMATIC DRAWING OF DUAL BOREHOLE RECIRCULATING TRACER TEST CONDUCTED ON JANUARY 22 – 24, 1982.



RLJ

BOREHOLE DC-7/8
GEOLOGIC AND GEOPHYSICAL LOGS

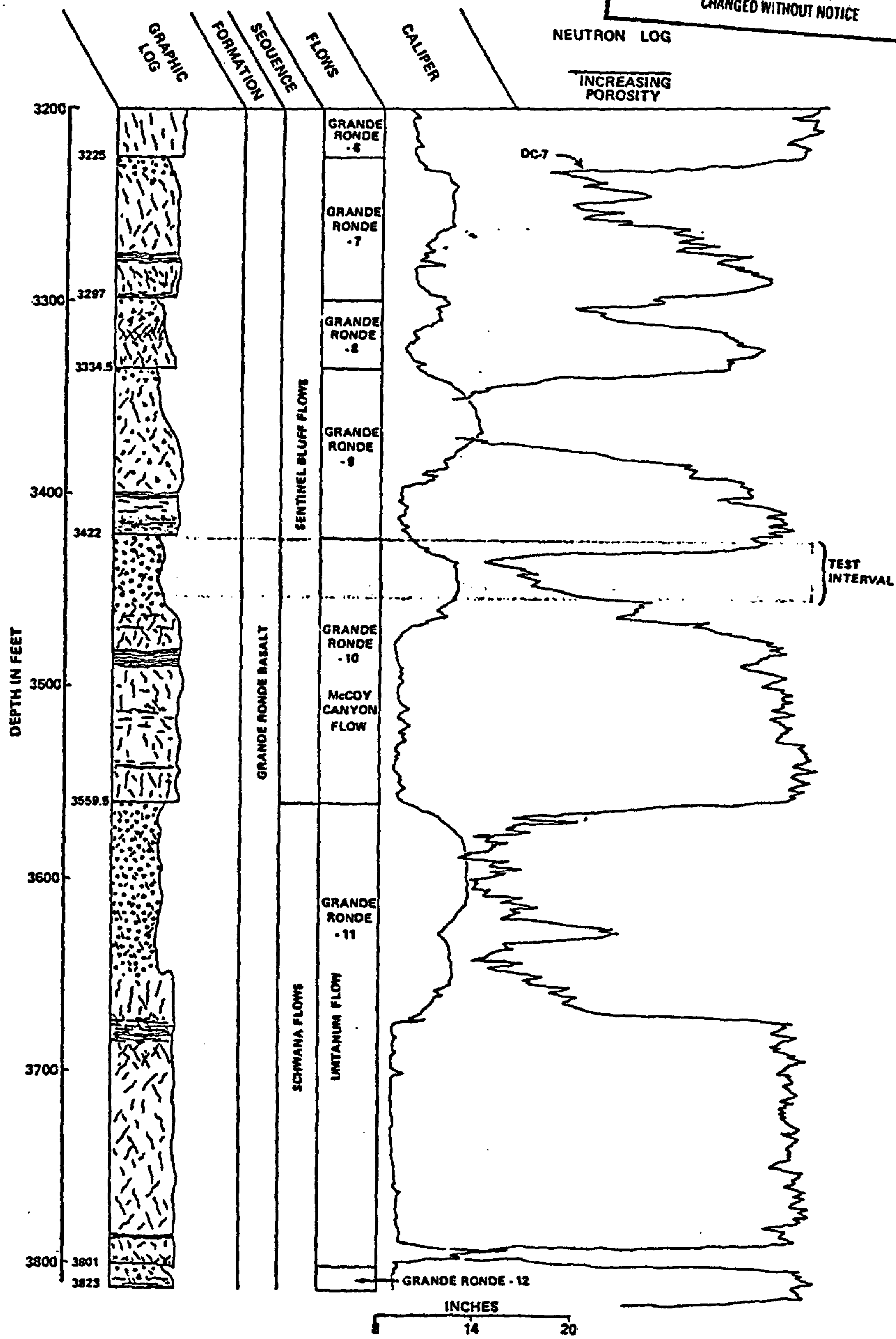


FIGURE 3. INTERVAL DESCRIPTION, McCOY CANYON FLOW TOP

RLJ 582

TEST METHOD	ANALYSIS METHOD	HYDRAULIC PROPERTIES		
		TRANSMISSIVITY FT²/DAY	EQUIVALENT HYDRAULIC CONDUCTIVITY FT/DAY	STORATIVITY
<u>DC-7 (PUMPING (WELL)</u> CONSTANT DISCHARGE SUBMERSIBLE PUMPING TEST	DRAWDOWN – COOPER AND JACOB, (1946)	.39	.011	–
	RECOVERY – THEIS (1935)	.72*	.019	–
	AVERAGE	.51	.015	–

<u>DC-8 (OBSERVATION (WELL)</u> CONSTANT DISCHARGE SUBMERSIBLE PUMPING TEST	DRAWDOWN – THEIS (1935)	.78*	.021	4.1×10^{-5}
	RECOVERY – THEIS (1935)	.84*	.023	–
	AVERAGE	.81	.022	4.1×10^{-5}

AVERAGE	.61	.018	4.1×10^{-5}
BEST ESTIMATE (AVERAGE NOTED BY ASTERIK)	.78	.021	4.1×10^{-5}

TABLE 2. SUMMARY OF HYDRAULIC PROPERTY VALUES DETERMINED FROM PUMPING TESTS CONDUCTED ON THE McCOY CANYON FLOW TOP (TEST INTERVAL: DC-7, 3410.2 – 3477.6 FEET AND DC-8, 3407.0 – 3480.4 FEET)

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY FT^2/DAY	EQUIVALENT HYDRAULIC CONDUCTIVITY FT/DAY	STORATIVITY
CONSTANT DISCHARGE SUBMERSIBLE PUMPING TEST	DC-7 (PUMPING WELL)	DRAWDOWN – COOPER & JACOB (1946)	5.0	4.0 x 10^{-3}	
		RECOVERY – THEIS (1935)	5.0	4.0 x 10^{-3}	
	DC-8 (OBSERVATION WELL)	DRAWDOWN – THEIS (1935)	4.6	3.6 x 10^{-3}	1.0 x 10^{-4}
		RECOVERY – (THEIS 1935)	4.5	3.6 x 10^{-3}	
		AVERAGE	4.8	3.8 x 10^{-3}	1.0 x 10^{-4}
AIR-LIFT DEVELOPMENT PUMPING TEST	DC-8 (PUMPING WELL)	RECOVERY – THEIS (1935)	4.6	3.6 x 10^{-3}	
	DC-7 (OBSERVATION WELL)	DRAWDOWN – THEIS (1935)	4.7	3.7 x 10^{-3}	4.3 x 10^{-5}
		RECOVERY – THEIS (1935)	3.9	3.1 x 10^{-3}	
		AVERAGE	4.4	3.5 x 10^{-3}	4.3 x 10^{-5}

AVERAGE	4.6	3.6 x 10^{-3}	7.2 x 10^{-5}
BEST ESTIMATE (ALL ANALYSES)	4.6	3.6 x 10^{-3}	7.2 x 10^{-5}

TABLE 2. SUMMARY OF HYDRAULIC PROPERTY VALVES DETERMINED FROM PUMPING TESTS CONDUCTED ON THE GRANDE RONDE BASALT (DC-7: 2780 – 3948.2 FEET AND DC-8: 2734 – 4100.5 FEET).

BOREHOLE REVIEW FORM

SUMMARY

1. BOREHOLE NO.: DB-15 — Elev @ Top of Casing 469.82'
2. TOTAL DEPTH: 1,971 ft
3. DEPTH OF CASING: 858 ft
4. REVIEWER: J. Rowe
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

Completion Notes

6 5/8" casing to 68' — cored NC to 858'

3 1/2" casing to 858' — cored NX to 1,971'

Each test interval cemented after testing (Drilling History in RHO-BWI-LD-29)

Geophysics

- SP
- Long + Short normal resistivity } (SPIR)
- fluid temp (FT)
- caliper
- natural gamma (Nat γ)
- neutron epithermal neutron (NN)
- gamma-gamma (γγ)
- Sonic

Geothermal grad ≈ 1.2°C / 100 ft

Development Sequence

1. set single packer
2. air lift
3. measure hyd. head
4. air lift
5. submersible pump
6. water samples
7. slug tests

Low K tests done with straddle packer system

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Tests

1.) Constant Discharge — Cooper, Jacob (1946) for drawdown; modified Theis (1935) <Jacob recovery> for recovery

2) Slug Tests — for overdampening plot h/h_0 vs log time (Cooper, Papadopulos, 1967)
— for underdampening plot Δ vs t (Van der Kamp 1976)

3) Pulse Tests — same as overdampening, adjust r_c

Water levels — measured by Sinco well probe, steel tape, Sinco transducer

All Hydraulic Heads in elev MSL

End of BH storage calculated using Bargo $t = \frac{360000\, r^2}{T}$ (min)

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

150-222' Rattlesnake Ridge Interbed + Pomona Basalt flow top

- base of Elephant Mtn. Basalt 150-166'
- Rattlesnake ridge interbed 166-216'
- vesicular Pomona basalt flow top 216-222'

Hydraulic Head 409.4' (measured after recovery)

Equivalent K based on Rattlesnake Interbed (166-222')

1.) Constant Discharge Air-lift (CDA) - Q varied 21.8 to 23.2 gpm (760 min duration) relatively good straight line fit, some indication of decreasing slope at large time, recovery data

2.) Constant Q Pump Test (CQP) - Q varied 8.0 to 8.8 gpm & (273 min duration) averaged 8.5 gpm / only drawdown data utilized, no recovery data taken, good straight line fit

Summary

Test	Analy	T (ft²/d)	K (ft/d)
CDA	Theis Recovery	355	6.3
CQP	Cooper & Jacob	328	5.9
Avg		342	6.1
Best Est		342	6.1

Reliable

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

370 - 422 Selah Interbed and Gable Mtn Basalt Flow top
- base of Pomona basalt 370-400'
- Selah interbed 400-421'
- Gable Mtn Flow top 421-422', vesicular

Hydraulic Head 407.7' (measured after recovery)

Equiv. K calc using 22' thickness

1.) Const Q Air lift (CQA) (330 min duration) Q varied 7.69 to 9.73 gpm avg 8.71 gpm / good straight line fit on late time data, wellbore storage on early time? recovery data only

2.) Const. Q Pump (CQP) (445 min duration) Q varied 4.5 to 5.5 gpm avg 5.1 drawdown & recovery / drawdown data affected by adjustment of Q, reasonably good fit to late time data although some scatter at very late time / good fit to recovery data, wellbore storage effects?

Summary

Test	Analy	T (ft²/d)	K (ft/d)
CQA	Theis Recovery	9.3	0.42
CQP	Drawdown - Cooper & Jacob	8.6	0.39
	Recovery - Theis	7.7	0.35
Avg		8.5	0.39
Best Est		8.5	0.39

Reliable

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

510 - 616 Cold Creek Interbed + Asotin Basalt Flow Top

- Gable Mtn basalt 510-518'
- Cold Creek interbed 518-612'
- Asotin basalt 612-616'

Hydraulic Head 407.7' (measured after recovery)

Equiv K calc using 98' thickness

1.) Const Q Air lift (COA) (518 min duration) Q varied 46.5 to 49.7 gpm avg 47.9 gpm / good fit to late time recovery data, calc. end of borehole storage occurs before slope change in plot, could be skin effect?

2) Const Q Pump (COP) (1675 min duration) Q varied 7.8 to 8.2 gpm, avg 8.0 gpm, drawdown + recovery / good fit to late time drawdown data, reasonably good fit to late time recovery data, some scatter in readings above + below straight line

Summary

Test	Anal	T (ft²/d)	K (ft/d)
COA	Recovery - Theis	2060	21.0
COP	Drawdown - Cooper + Jacob	1970	20.0
	Recovery - Theis	1990	20.3
Avg		2007	20.5
Best. Est		2000	20.4

Reliable

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
640-682	Asotin / Umatilla basalt interflow - Asotin basalt 640-665' - Umatilla basalt 665-682'			

Hydraulic Head 407.8' (measured after recovery)

1.) Const. Q Air lift (1268 min duration) - Q varied 70.7 to 64.9 gpm, avg 66.9 gpm / poor fit to recovery data, could be result of wellbore storage, no definite straight line portion of curve

2.) Const Q Pump (408 min duration) - Q varied 7.8 to 8.1 gpm, avg 8.0 gpm / drawdown data poor fit to straight line at large times, possible recharge or leakage boundary / recovery data - poor fit, no definite straight line

Equiv. K calc using 17'

Summary

Test	Anal	T (ft²/d)	K ft/d
CDA	recovery - Theis	988	58.1
CDP	drawdown - Cooper + Jacob	1290	75.9
	recovery - Theis	827	48.6
Avg		1035	60.9
Best Est		900	53

Values may be questionable considering relatively poor straight line fits, type curve analysis would be useful

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

680-754 Umatilla basalt intra flow & Upper Mabton Interbed
- vesicular and fractured Umatilla intra flow zone
- upper portion of Mabton interbed interbed (clay + fine sand)

Hydraulic Head 407.7' (measured after recovery)

1.) Constant Q Air lift - Q varied 69.8 to 71.4 gpm (1440 min duration) avg 70.7 gpm / fair straight line fit to late recovery data, some indication of effects other than wellbore storage because significant slope change occurs after calculated end of borehole storage, also some continued flattening of slope at very late time

Equiv K calc using 65'

2. Const Q Pump - Q varied 7.7 to 8.3 gpm, avg (470 min dur) 8.0 gpm / drawdown data - fair to good fit except at late time when water level fluctuated during sampling, best fit line shown on data plot does not appear to be actual best fit / recovery data - reasonably good straight line fit with some scatter, some indication of slope changes (flattening, steepening)

Summary

Test	Anal	T(ft²/d)	K(ft/d)
COA	Theis	1080	16.6
CDP	Drawdown - Cooper + Jacob	760	11.7
	Recovery - Theis	764	11.8
Avg		868	13.4
Best Est		1080	16.6

Values fair - higher K for long duration test could indicate increased K at larger distance from well

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE: 7/27/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

680 - 844 Mabton Interbed + Priest Rapids Basalt Flow top

- Mabton interbed (754-839) fine to coarse sand, silt, clay
- Priest Rapids basalt flow top 839-844', vesicular
- effective test interval 754 to 844 ft because 680-754 cemented

Hydraulic Head 406.5' (measured after recovery)

1.) Const. Q Air lift - Q varied 4.3 to 22.2 gpm, avg 9.0
(1920 min duration) fair to good fit to straight line, slope constantly changing through early part of recovery, still some curvature at late time,

Equiv K calc using 90'

2.) Const Q Pump - Q varied 6.4 to 6.9 gpm, avg 6.61
(1620 min duration) drawdown data - fair to good fit to late time, scatter above + below line at late time, calc T value much lower than for recovery / recovery data - fair fit to late time, very large change of slope occurred during test with one very steep portion at early time + flat portion at late time

Summary

Test	Analy	T(gpd/ft)	K(ft/d)
CDA	recovery - Theis	1840	20.4
CDP	drawdown - Cooper + Jacob	27.1	0.30
	recovery - Theis	1010	11.2
Avg		959	10.6
Best Est		1840	20.4

Fair to Good Values on Recovery, drawdown seems to indicate high well losses

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

858-969 Priest Rapids basalt Interflow

- Priest Rapids basalt 858-918'
- vesicular flowtop of Priest Rapids 918-969'

Hydraulic Head 410.0' elev (measured after recovery)

1.) Constant Discharge Airlift - Q varied 36.6 to 39.7 gpm, avg 38.5, natural gas present, relatively good fit to late time data (1440 min duration)

Equiv K calc using 36'

2. Constant Q Pump - Q varied 8.5 to 9.0 gpm, avg 8.9 recovery data obtained but T+K not calculated because of problems in pumping with gas present (239 min duration)

⇒ After discharge - heads in well overshoot original heads & then decline to static

Summary

Test	Analy	T(ft²/d)	K(ft/d)
CDA	Theis recovery	2410	66.9

Not reliable

Authors state that value is questionable due to presence of gas

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1045–1105   Roza Basalt Interflow

- Priest Rapids basalt 1045–1061'
- vesicular flow top of Roza basalt 1061–1105'

Equiv K calc using 44'

Hydraulic Head 409.7' (measured after recovery)

1.) Const. Q Air lift #1 - Q varied 26.2 to 28.5 gpm, avg 27.5, natural gas present, relatively good fit to late time data, overshot initial head after shutdown (330 min duration)

2.) Const Q Air lift #2 - Q varied 27.8 to 28.4 gpm, avg 28.2, natural gas present, few late time data collected, fair fit, overshot initial head after shutin (215 min duration)

3) Slug Tests - 4 tests, 3 withdrawals, 1 injection, underdamping response, good fits

Summary

Test	Analy	T (ft²/d)	K (ft/d)
CDA 1	Theis Recovery	1460	33
2		990	23
Slug inj. 1	Van der Kamp	1670	38
with. 2		1870	43
with. 3		1820	41
with. 4		1710	39
Slug Avg		1770	40
Avg		1587	36
Best Est		1770	40

Not Reliable

Data may be good, effects of gas cause some uncertainties in results, will probably be reanalyzed in future once effects of gas better understood.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1111.1 – 1146.4 Roza basalt colonnade / entablature
(used Lynes straddle packers, 3' packer gland length)

Hydraulic Head – not measured, assumed 409.7' based on Roza flowtop

1) Pulse Tests (PT) – 2 tests conducted, curve fits are not perfect but appear reasonably good on test 1, authors indicate possible packer leak on test 2

2) Constant H Inj – 4 steps from 44.0 to 88.1 psi, plot Q vs t + H vs t to get steady state

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Summary

Test	Analy	T (ft²/d)	K (ft/d)
Overpressure Pulse #1	Bredehoeft + Papadopulos	6.1×10^{-7}	1.6×10^{-8}
#2		2.2×10^{-5}	6.2×10^{-7}
CHI #1	Zeigler	5.3×10^{-5}	1.4×10^{-6}
CHI #2	"	6.0×10^{-5}	1.6×10^{-6}
Avg		3.8×10^{-5}	1×10^{-6}
Best Est		3.8×10^{-5}	1×10^{-6}

$S = 4.1 \times 10^{-5}$

$S = 1.7 \times 10^{-6}$ not included in formation report

Values appear good, probably best achievable with current state of art in low K formations

[illegible signature]

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1236-1289	Squaw Creek Interbed & Frenchman Springs Interflow #1			

- Roza basalt 1236-1257
- Squaw C. Interbed 1257-1260 - clay
- vesicular flowtop of Frenchman Springs basalt 1260-1289

Hydraulic Head · 408.7', may be bad due to presence of drill fluid in hole

1.) Slug Tests - critically dampened response for which soln not known, 4 attempted. NO T estimated although felt to be low.

No values

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1300 - 1343 Frenchman Springs basalt interflow # 2

- Frenchman Spr. basalt 1300-1343'
- vesicular interflow zone 1310 to 1316'

Hydraulic Head 408.3 (measured after recovery)

1) Const Q. Airlift - Q varied 7.1 to 8.7 gpm, avg 7.3 (1440 min duration) recovery data indicate fair fit to late time, no definite straight line

'Kequiv using 33'

2) Slug Tests - 4 tests, 2 injection, 2 withdrawal only one curve shown, fair fit

Summary

Test	Anal	T	K
CQA	Theis Recovery	104	3.15
Slug inj. 1	Cooper + Papadopulos	4.34	0.13
2		3.03	0.09
Slug with 1	"	4.93	0.15
2		3.79	0.11
Avg		24.0	0.73
Best Est		104	3.15

Fair Estimate - not of highest reliability

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1353-1373	Frenchman Springs basalt interflow #3 - vesicular interflow zone 1357-1370'			

Hydraulic Head 409.7 ' (measured after recovery)

1. Const. Q Air lift - Q varied 7.8 - 9.3 gpm (1440 min duration) avg 9.2 / poor fit to recovery data, rapid recovery, no definite straight line portion

K eq using 16'

Summary

Test	Anal	T (ft²/d)	K (ft/d)
CQA	This recovery	382	23.9

Fair Reliability - order of magnitude okay.

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1393-1443 Frenchman Springs basalt interflow #4

- vesicular & scoriaceous basalt 1415-1436

Hydraulic Head 411.6 (measured after recovery)

1.) Const. Q Airlift — Q varied 7.4 to 7.5 gpm, avg 7.5 gpm, poor fit to recovery data, no definite straight line portion, rapid recovery (1020 min duration)

Keq using 28'

2.) Slug Tests — 3 slug tests, 2 injection, 1 withdrawal good fit to slug-inj data #1, others not available

Summary

Test	Analy	T(ft²/d)	K(ft/d)
CQA	Theis recovery	224	8.0
Slug inj 1	Cooper et al	148	5.3
2		122	4.4
Slug with 1		42.4	1.5
Avg		106	3.9
Avg		165	5.5
Best Est		165	5.5

Fair Reliability — order of magnitude okay

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1450 - 1530 Frenchman Springs Interflow #5

- Interflow zone 1459 - 1530 (two zones)

Hydraulic Head 409.6 (measured after recovery)

1. Const. Q drill - Q varied 4.8 to 5.6 gpm, (2520 min duration) avg 5.5, fair fit, rapid recovery, no definite straight line

Kequiv. using 71'

Summary

Test	Anal	T(ft²/d)	K(ft/d)
CAA	Theis Recovery	90.3	1.3

Fair Reliability

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1570-1683   Frenchman Springs basalt interflow #6
- vesicular, scoriaceous + fractured basalt 1579-1660'

Hydraulic Head 408.4 ±0.5 (projected t/t')

1.) Const Q Airlift – Varied 21.6 to 26.3 gpm, avg 22.9 gpm, natural gas present, overshot initial water level after airlifting, T calc. questionable – no basis in theory, good fit to data
(1440 min duration)

Keeping using

2) Slug Test – 2 tests, inj + withdrawal, underdampening response, good fit

Summary

Test	Anal	T(ft²/d)	K(ft/d)
COA	Theis Recovery	441	5.4
Slug inj	Van der Kamp	832	10.2
Slug with	"	868	10.7
Avg		714	8.8
Best Est		714	8.8

Not reliable due to presence of gas

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1720 - 1800 Frenchman Springs basalt interflow #7
- vesicular, scoriaceous 1746 - 1756

Hydraulic Head 405.9 (measured after [illegible])

1) Const drawdown airlift - Q varied 5.7 to 1.5 gpm (2497 min duration) avg 2.2, good fit of Sw/Q vs log t/rw²

Kogure using 10'

2) Const Q airlift - fair fit, not as good as const Q fit

Test	Analy	T(ft²/d)	K (ft/d)
CDA	Jacob & Lohman	0.067	0.007
CQA	Theis recovery	0.044	0.004
Avg		0.056	0.005
Best Est		0.067	0.007

Re[illegible]

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1800 – 1932   Frenchman Springs basalt interflow #8

– breccia, altered vesicular basalt, clay 1862–1882

Hydraulic Head 404.9' (measured prior to testing)

1.) Slug withdrawal/injection – fair fit on withdrawal, poor fit on injection airlifted slug for withdrawal

Kequiv using 20'

Summary

Test	Analy	T (ft²/d)	K (ft/d)	S
Slug with	Cooper et al.	6.1×10^{-3}	3.1×10^{-4}	3.9×10^{-4}
Slug inj.		1.3×10^{-4}	6.6×10^{-4}	—

Fair to poor reliability

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DB-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER:

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

1932-1971 Vantage Interbed / Grande Ronde basalt flow top
- Vantage interbed 1958-1959 clay
- brecciated, vesicular basalt 1958-1971

Hydraulic Head - not determined

Kegair Ming 13'

1.) Slug withdrawal - air lifted, overdamped response H/Ho vs t., poor fit

2) Overpressure pulse test - good fit to curves

Summary

Test	Anal	T (ft²/d)	K (ft/d)	S
Slug with	Cooper et al	4.7×10^{-4}	3.6×10^{-5}	5.3×10^{-3} ?
Pulse 1	Bredehoeft & Papadopulos	4.9×10^{-5}	3.8×10^{-6}	3.6×10^{-5}
2		8.3×10^{-5}	6.4×10^{-6}	5.6×10^{-5}
Avg		2.0×10^{-4}	1.5×10^{-5}	1.6×10^{-3}
Best Est		6.6×10^{-5}	5.1×10^{-6}	4.6×10^{-5}

Reliable for best est

Sheet 1

BOREHOLE REVIEW FORM

1. BOREHOLE No.: OC 3
2. TOTAL DEPTH: 3635' (deepened subsequently)
3. DEPTH OF CASING: 3575'
4. REVIEWER: R. Williams
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
Interval tested was below casing (3575'). Interval was 3575' to 3635.' But hole was deepened 100' to 3735 by coring during week of July 12, 1982. No data are available on this deepened portion. Top of mintaneum is at a depth of 3,475'.	Entaflature	Logs run on section below 3575' include °C, caliper, Nat. Gam., density, neut. Epithermal neutron, resistivity and S.P.. Sonic was malfunctioning. Logs show that section tested is very dense with no fractures. °C ranges from 56°C at top to 57°C at bottom. A downhole camera survey was conducted in the hole after it had been pumped dry. These photographs were inspected. Mud is visible on the walls of the hole but essentially no water inflow is visible and no open fractures are visible. Positive pulse tests (pressure added as opposed to subtracted) and constant head injection tests were utilized to determine K and S. Test interval was isolated by a Lynes water-inflatable packer installed at a depth of 3584 feet. The bottom of the interval was at a depth of 3635 feet which represents the bottom of the hole. A Lynes Triple continuous wire line (TCWL) system was used to monitor pressure and temp. within the interval and in the annular space above the packer. Fluid pressures were monitored with downhole paroscientific quartz pressure transducers & surface recording eqpt.		These tests were conducted to determine the hydrologic properties of the Colorado/Entaflature of the mintaneum. The hole was drilled with mud rotary, 8 5/8" diameter. Drilling began on August 6, 1977 and was completed on Oct. 4, 1977.

Sheet 2

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC3
2. TOTAL DEPTH: 3635' (deepened subsequently)
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
			Pulse Test	

A pressure pulse of 19.4 PSI was added to the existing 1562.54 PSIA in the interval. Subsequently pressures were monitored between July 8 and August 16, 1981 at which time the interval pressure had decayed to 1568.72 PSIA. An anomalous 1.5 PSI increase in pressure occurred after shutoff but the pressure then began to decay normally. Reason unknown.

Data plots for the pressure decline vs time were matched to a family of type curves listed by Cooper et al (1967) and Papadopoulos and ... (1973). Storage coeff. was determined by Bredehoeft et al, 1980. The T value calculated is 2.7X10^-6 ft²/day, regardless of the portion of the curve used for matching and regardless of the method of correcting for the initial pressure rise.

The "constant head" injection test was conducted by injecting water into the interval under pressure in 4 steps for about 7.5 hrs. The steps were about 70 to 100 minutes in length. Oscillations in Q forced the use of early time pressure/Q vs t/Rw only. Resulting T value averages 7.1X10^-6 ft²/day with a range of 1.2X10^-5 to 7.2X10^-6. Length of each step of the test ranged from 67 to 103 minutes. Storativity ranged from 2.3X10^-5 to 4.6X10^-5, averaging 3.5X10^-5.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-3 - Rotary
2. TOTAL DEPTH: 3635 but now being deepened
3. DEPTH OF CASING: 3575
4. REVIEWER: R. Williams
5. DATE: 7/21/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
Packer at 3584. Testing 3584'-3575' depth.	Umtanum	dense basalt	overpressurized pulse test constant head injection test	Purpose of test was to test a low K zone. Downhole pressure transducers were used to measure pressure. Results should be defensible as state of the art for single hole testing. K value is ≈ 10^{-11} cm/sec.

TABLE 2. Summary of Hydraulic Property Values Determined by Various Test Methods Conducted on the Umtanum Colonnade/Entablature at Borehole DC-3.

Test method		Analysis method	Hydraulic properties: Transmissivity ft^2/day	Equivalent hydraulic conductivity ft/day	Storativity
Pulse test		Bredehoeft et al. (1980)	2.7×10^{-6}	5.2×10^{-8}	-
Constant head injection test	Step 1	Jacob and Lohman (1952)	1.2×10^{-5}	2.4×10^{-7}	4.6×10^{-5}
	Step 2		6.2×10^{-6}	1.2×10^{-7}	4.2×10^{-5}
	Step 3		3.2×10^{-6}	6.3×10^{-8}	2.9×10^{-5}
	Step 4		7.2×10^{-6}	1.4×10^{-7}	2.3×10^{-5}
	Average		7.1×10^{-6}	1.4×10^{-7}	3.5×10^{-5}
Average (for all tests)			4.9×10^{-6}	9.6×10^{-8}	3.5×10^{-5}

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15.
2. TOTAL DEPTH: 4243'
3. DEPTH OF CASING:
4. REVIEWER: Verma

Ground Surface Elevation 402.1' Above MSL

5. DATE: July 23, 1982

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
4138 - 4243 b = 44'	Grande Ronde Basalt. No. 14. Interflow Zone consisting of brecciated flow top.		Head/M. 403.5'	Estimated. Equilibrium conditions were not fully attained.

Constant Discharge Test

Recovery
Theis (1935 — 3.6, 5.6, 2.6
Harrill (1970) — 4.6
7.5
3.1

Slug Tests

Injection 379
Vander Kamp (1976) 265
268

Withdrawal
Vander Kamp (1976) 302

Constant Head Injection Test

Constant Drawdown 57.9.
Jacob and Lohman (1952)

Average 128

Best Estimate 5.1

Other

TEST METHOD	ANALYSIS METHOD	HYDRAULIC PROPERTIES		
		TRANSMISSIVITY (FT^2/DAY)	EQUIVALENT HYDRAULIC CONDUCTIVITY (FT/DAY)	STORATIVITY
CONSTANT DISCHARGE TEST				
AIR-LIFT DEVELOPMENT PUMPING TEST No. 1	RECOVERY-THEIS (1935)	3.6	8.2×10^{-2}	–
	VARIABLE RATE - HARRILL (1970)	4.6	1.0×10^{-1}	–
AIR-LIFT DEVELOPMENT PUMPING TEST No. 2	RECOVERY-THEIS (1935)	5.6	1.3×10^{-1}	–
	VARIABLE RATE-HARRILL (1970)	7.5	1.7×10^{-1}	–
AIR-LIFT PUMPING TEST No. 3 DEVELOPMENT	RECOVERY-THEIS (1935)	2.6	5.9×10^{-2}	–
	VARIABLE RATE-HARRILL (1970)	3.1	7.0×10^{-2}	–
AVERAGE		4.5	1.0×10^{-1}	–
SLUG TESTS				
INJECTION No. 1	VAN DER KAMP (1976)	379	8.6	–
INJECTION No. 2	VAN DER KAMP (1976)	265	6.0	–
INJECTION No. 3	VAN DER KAMP (1976)	268	6.1	–
WITHDRAWAL No. 1	VAN DER KAMP (1976)	294	6.7	–
AVERAGE		302	6.9	–
CONSTANT HEAD INJECTION TEST	CONSTANT DRAWDOWN - JACOB AND LOHMAN (1952)	57.9	1.3	–
AVERAGE (ALL TESTS)		121	2.8	–
BEST ESTIMATE (CONSTANT DISCHARGE TESTS (3)-HARRILL METHOD)		5.1	1.2×10^{-1}	–

TABLE 2. Summary of Test Results, GRB#14, 4138-4243 feet

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3741 - 3845	Grande Ronde No. 13	Basalt	Head/M	399.2 (Uncorrected)
6 - 80'				Equilibrium conditions were not fully attained.

Early time oscillation. Poor correlation in curve-matching.

Water temperature 57° at 3,500'

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY FT²/DAY	EQUIVALENT HYDRAULIC CONDUCTIVITY FT/DAY	STORATIVITY
CONSTANT DISCHARGE	Air-lift development pumping	Recovery - Theis (1935)	5.2×10^{-2}	6.5×10^{-4}	-
SLUG TEST	Withdrawal No. 1	Cooper, et al (1967)	No Match	-	-
	Injection No. 1		No Match	-	-
	Injection No. 2		No Match	-	-
SLUG TEST	Withdrawal No. 1	Ferris and Knowles (1954)	3.2	4.0×10^{-2}	-
	Injection No. 1		.25	3.1×10^{-2}	-
	Injection No. 2		.17	2.1×10^{-3}	-
	Average		1.2	1.5×10^{-2}	-
CONSTANT HEAD INJECTION TEST		Constant Drawdown Jacob and Lowman (1952)	0.13	1.6×10^{-3}	-
Constant Discharge	Air-lift Development Pumping	Recovery Type Curve - Nagareth (1981)	2.4×10^{-2}	1.7×10^{-4}	
AVERAGE			.76	9.5×10^{-3}	-
BEST ESTIMATE (AIR-LIFT DEVELOPMENT PUMPING)			5.2×10^{-2}	6.5×10^{-4}	-

TABLE 2. Summary of Results Determined From Various Test Methods For Grande Ronde Basalt #13, 3741-3845 Feet, Borehole DC-15

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma
5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3611-3636	Grande Ronde Basalt No-12.			No testing was done due to low pumping rate (0.1 gpm). No head measurement done.

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma   5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3301-3412	Grande Ronde No. 11	Basalt	Head/M	* 384.1 Uncorrected.

b = 49'

* During the recovery period an anomalous water level hump was observed during late time.

A constant head injection test was not conducted on the interval because of stresses imposed head during a four day air-lift pumping test.

Water temperature 52°C at 3,000'
57°C at 3,500'

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES: TRANSMISSIVITY ft²/day	HYDRAULIC PROPERTIES: Equivalent HYDRAULIC CONDUCTIVITY ft/day	HYDRAULIC PROPERTIES: STORATIVITY
24 HOUR AIR-LIFT PUMPING TEST		Recovery - Theis (1935)	0.91	.019	-
		Variable Rate - Harril (1970)	1.1	.022	-
		Constant Drawdown Jacob and Lohman (1952)	15.7	.320	-
SLUG TESTS	WITHDRAWAL NO. 1	Vander Kamp 1976 / Cooper et al. (1967)	1086(?)	22.2	-
	WITHDRAWAL NO. 2		1236(?)	25.2	-
	INJECTION NO. 1		1061(?)	21.6	-
	INJECTION NO. 2		985(?)	20.1	-
	AVERAGE		1092	22.3	-
AVERAGE (Air Lift Test: Theis and Harrill Methods			1.0	0.021	-
BEST ESTIMATE (Air Lift Test: Theis and Harrill Methods			1.0	0.021	-

Table 2. Summary of Results Determined From Various Test Methods For Grande Ronde Basalt # 11, 3301-3412 Feet, Borehole DC-15.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3245-3296	Grande Ronde Basalt. No. 10. Interflow zone associated with Umtanum flow bottom.			Head/M *367.8' Uncorrected

* An estimated value. Equilibrium conditions were not fully attained. It is about 20' lower than the head measured in the ~~Umt~~ Umtanum flow top.

Constant Head Injection test was not successful because Steady State Conditions were not reached.

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TEST METHOD	ANALYSIS METHOD	HYDRAULIC PROPERTIES		
		TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
24-HOUR AIR LIFT TEST	Recovery-Theis (1935)	6.3	.79	—
	Variable Rate-Harrill (1970)	6.9	.86	—
	Constant Drawdown-Jacob and Lohman (1952)	4.2	.53	—
94-HOUR AIR LIFT TEST	Constant Drawdown Jacob and Lohman (1952)	1.7	.21	—
CONSTANT HEAD INJECTION TEST	Hvorslev (1951)	—	—	—
AVERAGE AIR LIFT TEST (Harrill and Jacob-Lohman)		6.9 / 6.6	.82	—
BEST ESTIMATE Air-Lift Test (Harrill and Jacob-Lohman)		6.9 / 6.6	.82	—

Table 2. Summary of Results Determined from Various Test Methods For Grande Ronde Basalt # 10, 3245-3296 feet, Borehole DC-15

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2961-3113' b=120'	Grande Ronde Basalt No. 9	Umtanum Flow Top Weathered basaltic breccia with scattered joints. 11,000 gallons of drilling mud was lost.	Head/M	398.6' Uncorrected Estimated Equilibrium not fully attained.

Slug Test values (Vander Kamp, 1976) are about 1½ order of magnitude higher than the other values from pumping test.

Roy Williams

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC 15
2. TOTAL DEPTH: 4243
3. DEPTH OF CASING:
4. REVIEWER: R. Williams

5. DATE: 7/21/82

Depth INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2996 - 3134 Flowtop 2961 - 3113 (Packer)	Flow top at top of Umtanum	Basalt flow top	Variable Q pumping test Slug test Constant drawdown Pump Test Observed head measurements	11 000 gallons of mud lost over 6 days. Fl. dye was introduced into mud. Well was pumped until it disappeared, 105 000 gallons were pumped from unit over following 10 day period. Amt. of mud recovered is unknown. Packer picks OK, Thickness to get K from T OK on basis of logs & cores. Head measurements were projected by plotting time recovery slope to a ratio of unity. Heads not corrected for Temp & density. $t/t' = 1$. Not enough time was allowed. T was obtained by slug tests & by Jacob recovery method. Pumping was by airlift & corrections were made for variable Q. T on basis of this test seems OK to me. Late recovery data were used to avoid borehole storage effects. Slug test gave T value 2 orders of magnitude higher. T = 10^{-1} to 10^{-2} ft^2/day

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	Equivalent HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
48-HOUR AIR LIFT TEST		RECOVERY-THEIS (1935)	24.8	.21	–
		CONSTANT DRAWDOWN-Jacob and Lohman (1952)	26.5	.22	–
		VARIABLE RATE-HARRILL (1970)	23.1	.19	–
SLUG TEST	WITHDRAWAL NO. 1 (SWØ1)	van der Kamp (1976)	1199 (?)	10.0 (?)	–
	INJECTION NO. 1 (SIØ1)		1037 (?)	8.6 (?)	–
[illegible] D TEST					
AVERAGE (AIR-LIFT TEST)			24.8	.21	–
BEST ESTIMATE (AIR-LIFT TEST)			24.8	.21	–

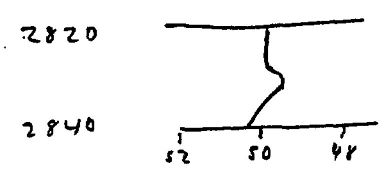
Note: Reasons for high estimated values of T determined from slug test is not known.

Table 2. Summary of Results Determined From Various Test Methods For Grande Ronde Basalt #9 (Umtanum Flow top), 2961-3113 Feet, Borehole DC-15.

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: CRFAUST

5. DATE: 23 JUL '82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2813-2868	Grande Ronde Flow Top #8	vesicular zone some mineralization 2830-2850 Main contribution toward top. (estimated thickness 9')	Static Head Temperature	390.7' predicted 

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
CONSTANT DISCHARGE TEST	24-HOUR AIR LIFT TEST	Q = 1.7 gpm THEIS (1935) straight line	3.2	.53	data
SLUG TESTS	injection #1 (Si Ø1)	Cooper and Others (1967)	No Match	-	-
	injection #2 (Si Ø2)		19.1	3.18	-
	Si Ø1 / Si Ø2	Ferris and Knowles (1963)	This method is not applicable due to influence of borehole storage effects		
CONSTANT HEAD INJECTION TEST		Hvorslev (1951)	-	.27 ~~.29~~	-
CONSTANT DISCHARGE TEST	24-HOUR AIR LIFT TEST	Recovery Type Curves - Nazareth (1951)	2.86		
AVERAGE (slug and air-lift test)			11.2	1.86	-
BEST ESTIMATE (air lift test)			3.2	.53	-

match only for late time data middle

steep curve matched top part

Const DD

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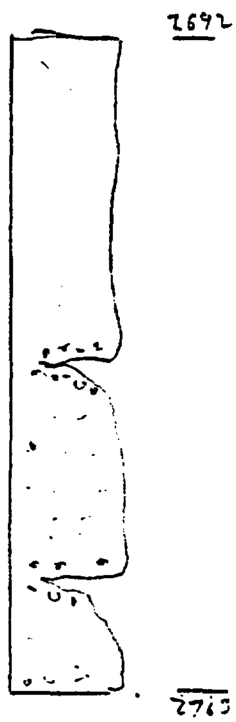
TABLE 2. Summary of Results Determined From Various Test Methods For Grande Ronde Basalt #8, 2818-2353 Feet, Borehole DC-15

Borehole Review Form

1. Borehole No.: DC-15
2. Total Depth:
3. Depth of Casing:
4. Reviewer: CRF
5. Date:

Interval	Strat. Unit	Lithology	Type of Test	Results - Comments
2692-2763	GRANDE RONDE #7 ; two interflow zones 2729-2735 2757-2761	interflows irregular with some mineralization flow rubble weathered assumed contributing zones 7-1 [illegible]	Static Head	390.1 predicted
			Temp	42.6°C



TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
CONSTANT DISCHARGE TEST	24-HOUR AIR-LIFT TEST	THEIS (1935) Q = 12 gpm	8.1 (POSSIBLE LEAK)	.81	
	15.67 HOUR AIR-LIFT TEST		7.3 (POSSIBLE LEAK)	.73	
SLUG TEST	WITHDRAWAL #1	van der Kamp (1976)	OSCILLATION QUICKLY	DAMPED	TOO
	INJECTION #1				
CONSTANT HEAD INJECTION TEST		Hvorslev (1951)	—	3.0 (POSSIBLE LEAK)	
				—	
AVERAGE VALUE (air lift tests)			7.7	.77	—
Bes[illegible] (24 hour air-lift test)			8.1 (possible leak)	.81 (possible leak)	—

Table 2 Summary of Results Determined From Various Test Methods For Grande Ronde Basalt #7, 2692 - 2763 FEET, Borehole DC-15

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: CRF
5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2651–2700	GRANDE RONDE #6 Interflow at 2659-2663	Interflow zone vesiculated rubble mineralized vesiculated zones below	Several tests run but results are unreliable because of packer leak	
			static head	389.6 predicted

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
CONSTANT DISCHARGE TEST	24-HOUR AIR LIFT TEST	Theis (1935) Q= 4.1 gpm	23.1 (SYSTEM LEAK)		
	17-HOUR AIR LIFT TEST		30.5 (SYSTEM LEAK)		
SLUG TEST	WITHDRAWAL # 1	Van der Kamp (1976)	OCCILLATION DAMPED QUICKLY		TOO
	INJECTION # 1		OCCILLATION DAMPED QUICKLY		TOO
CONSTANT HEAD INJECTION TEST		Hv. ~~ZIEGLER (1976)~~	SYSTEM LEAK		
AVERAGE VALUE			LESS THAN ~30 (SYSTEM LEAK)		

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Table 2. Summary of Results Determined from various Test Methods For Grande Ronde Basalt # 6, 2651 - 2700 FEET, Borehole DC-15

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: CRF
5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2492-2548	GRANDE RONDE #5 Through [illegible] 2520-2544 main contributing zones assumed	vuggy zone 2495-2500 weathered zone 2505-2513 2513-2520 [illegible] 2520-2544 fractured zone	Static head	390.9 measured

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
CONSTANT DISCHARGE TEST	AIR-LIFT #1 / AIR-LIFT #2	OVERPRESSURE HUMP PREVENTED CALCULATION OF TRANSMISSIVITY BY CONVENTIONAL SOLUTIONS			$\bar{Q}$ = 6.3 gpm; T ≈ 70 using gar hump device
SLUG TEST	WITHDRAWAL (1)	Cooper and others (1967)	136.8	5.7	6.2×10^{-5}
	INJECTION		218.4	9.1	—
	AVERAGE		177.6	7.4	6.2×10^{-5}
CONSTANT HEAD TEST		Hvorslev (1951)	—	1.67	—
AVERAGE (SLUG TESTS)			177.6	7.4	6.2×10^{-5}
BEST ESTIMATE (SLUG TESTS)			177.6	7.4	6.2×10^{-5}

hard to fit to curve

data steeper fits

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Table 2. Summary of Hydrologic Properties Determined from Various Test Methods for Grande Ronde Basalt #5, 2492-2543 feet, Borehole DC-15

Table Hydraulic Property Determination and Pertinent Analytical Parameters for Slug Withdrawal and Injection Tests on Grande Ronde Basalt #5, 2492-2548 feet, Borehole DC-15.

SLUG TEST NUMBER	DATA PLOT (	MATCH CURVE (α)	MATCH POINT ρ	MATCH POINT t (seconds)	TRANSMISSIVITY T (ft²/day)	Storativity S	INTERVAL ANALYZED (SECONDS)
SiØ1	STRIP CHART RECORDER MALFUNCTIONED						
SiØ2	H	10^{-10}	1.0	3.7	231.6*	–	6 to 50
SiØ2	H/H_0	No Match					
SiØ3	STRIP CHART RECORDER MALFUNCTIONED						
SiØ4	EQUIPMENT TEST						
SiØ5	H	10^{-10}	1.0	3.55	241.4*	–	6 to 50
SiØ5	H/H_0	10^{-10}	1.0	4.7	182.3*	–	15 to 50
SwØ1	NO TEST – NO RESPONSE						
SwØ2 SwØ2	QUESTIONABLE PRESSURE DATA BECAUSE RECORDING NEEDLE STUCK						
SwØ3	STRIP CHART RECORDER MALFUNCTIONED						
SwØ4	EQUIPMENT TEST						
SwØ5	H	10^{-4}	1.0	9.0	95.2*	6.2×10^{-5}	2 to 60
SwØ5	H/H_0	10^{-10}	1.0	4.8	178.5*	–	15 to 50
AVERAGE					177.6	6.2×10^{-5}	

* TYPE CURVES FIT ONLY EARLY-TIME DATA

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: CRF

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2372-2427	Grande Ronde Interflow #4 Assumed Contributing Zone 2442-2452	2370-81 Dense some fracturing 2381-2442 Dense [illegible] 2442-[illegible] [illegible] 2457-[illegible] vesicular [illegible] 2475-2517 Dense w/ some fracturing	Static Head	3.907 measured within .2' of projected at [illegible]

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TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft^2/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
AIR-LIFT		RECOVERY-THEIS (1935)	2.0	.20	$\delta \doteq .26$ gpm; matched 1st few points
SLUG TESTS	WITHDRAWAL (2)	Cooper et al. 1967	4.8	.48	matched first part of curve
	INJECTION (2)		3.7	.37	
	AVERAGE		4.3	.43	
AVERAGE			3.1	.31	-
BEST ESTIMATE			2.0	.20	-

TABLE 2. Summary of Hydrologic Properties Determined from Various Test Methods For Grande Ronde Basalt # 4, Borehole DC-15

Hydraulic Property Determinations and Pertinent Analytical Parameters for slug withdrawal and injection tests on Grande Ronde Basalt #4, Borehole DC-15

SLUG TEST NUMBER	DATA PLOT	MATCH CURVE (α)	MATCH POINT		TRANSMISSIVITY T (ft²/day)	Storativity S
			e	t (seconds)		
S-Ø1	Log-Log	No Match		–		
S-Ø1	H/H₀	10^{-7}	1.0	240 (Poor Match)	3.6	–
S-Ø2	Log-Log	10^{-7}	1.0	225 (Poor Match)	3.8	–
S-Ø2	H/H₀	NO MATCH		–		
Sw Ø1	Log-Log	10^{-10}	1.0	170 (Poor Match)	5.0	–
Sw Ø1	H/H₀	No Match		–		
Sw Ø2	Log-Log	10^{-7}	1.0	200 (Poor Match)	4.3	–
Sw Ø2	H/H₀	10^{-10}	1.0	170 (Poor Match)	5.0	–
AVERAGE					4.3	–

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: CRF
5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2227-2343	Grande Ronde # 3 Assumed contributing zones 2247-2252 and 2265-2273	2227-2232 Dense 2232-2241 Vesicular 2241-2259 Vesicular with some clay filled fractures 2259-2263 Dense 2263-2275 Vesicular 2' core loss, clay filled fractures 2275-2285 Breccia or altered basalt 2285-2295 vesicular & altered 2295-2343 alternating dense and moderately vesicular zones with some fracturing	Static Head	388.5 ± .5

Note this is [illegible] a major [illegible] zone [illegible] permeable [illegible] well

2221-2343 R

TABLE 2

SUMMARY OF HYDRAULIC PROPERTIES, BOREHOLE DC-15, GRANDE RONDE BASALT NO. 3

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY (ft^2/day)	HYDRAULIC CONDUCTIVITY (ft/day)	STORATIVITY
SLUG TEST	Siø1	Underdamped van der Kamp (1976)	2218	67	—
	Swø1		2262	68	—
	Swø2		2095	63	—
24-HOUR AIR LIFT TEST		$\bar{Q} \simeq 40.9$ gpm; T ≃ 470 ft²/d using decay of hump	Pressure using	Hump Prevented Conventional	Analysis

AVERAGE	2192	66	—
BEST ESTIMATE	2192	66	—

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: CRF

5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2099-2198	GRANDE RONDE #-2 Assumed contributing zone 2104-2171	2095-2115 dense with disking zones 2115-2117 vesicular 2117-2124 clay 2124-2171 zones of vesular, dense, and breccia 2171-2898 dense basalt	static head	329' ± 0.5

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft^2/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
SUBMERSIBLE PUMPING TEST		DRAWDOWN - Cooper & Jacob (1952)	3.2	4.8×10^{-2}	—
		RECOVERY - Theis (1935)	3.4	4.5×10^{-2}	—
AIR - LIFT TEST		CONSTANT DRAWDOWN — Jacob & Lohman (1952)	3.2	4.8×10^{-2}	—
Q = 11.9g		VARIABLE RATE - Harril (1970)	.28 ~~9.1~~	~~1.4×10^{1}~~	—
		RECOVERY - Theis (1935)	3.0	5.1×10^{-2}	—
SLUG TESTS	WITHDRAWAL (2)	Cooper et al. (1967)	NO MATCH	—	—
	INJECTION (2)		NO MATCH	—	—
				—	
AVERAGE			4.4	6.5×10^{-2}	—
BEST ESTIMATE (Recovery air lift & submersible)			3.2	4.8×10^{-2}	—

TABLE 2. Summary of Hydraulic Property Values Determined by Various Test Methods Conducted on Grande Ronde Basalt # 2, Borehole DC-15.

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma 5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1834-1887 B=38'	Frenchman Springs Basalt Interflow No.6		Head/M	386.6 Observed (Uncorrected)
				Transmissivity values could not be determined with the use of Constant Discharge/Recovery methods due to the presence of gas.

Water temperature ~~30~~ 39° at 2,000'

TABLE 2

HYDROLOGIC TESTING RESULTS
DC-15

Frenchman Spgrins Basalt Interval No. 6

GROUND SURFACE ELEVATION: 402.1 FEET

TEST TYPE	TEST INTERVAL FEET BELOW GROUND LEVEL	PUMPING PERIOD (HOURS)	AVERAGE DISCHARGE (GPM)	MAXIMUM OBSERVED DRAWDOWN (FEET)	ANALYSIS METHOD	TRANSMISSIVITY ft²/day RECOVERY	TRANSMISSIVITY SLUG WITHDRAWAL	TRANSMISSIVITY SLUG INJECTION	TRANSMISSIVITY SPECIFIC CAPACITY	AVERAGE HYDRAULIC CONDUCTIVITY (ft/day)
ALT	1834-1887	24	86		MTR	Gas Hump				
CRPT	↓	22.7	9.7	1.7	MTR	Gas Hump				
Si01					U			3486		91
Sw01					U		5544			146
Si02					U			3414		90
Sw02					U		3072			81

STATIC HYDRAULIC HEAD
MEASUREMENT (TEST INTERVAL: 1834-1887 ft)

DATE	HYDRAULIC HEAD (FEET ABOVE MSL)
11 Aug 80	386.6 ft

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EXPLANATION

ALT = AIR LIFT TEST
CRPT = CONSTANT RATE PUMPING TEST
S_w = SLUG WITHDRAWAL
Si = SLUG INJECTION
MTR = MODIFIED THEIS RECOVERY
LL = LOG-LOG
CP = COOPER-PAPADOPULOS
SL = SEMI LOG
SC = SPECIFIC CAPACITY

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma 5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1735-1833 B = 91 Feet	Frenchman Springs Basalt Interflow No. 5.		Head/M	386.5 observed (uncorrected)

Gas problems in Constant-Discharge/Recovery tests.

TABLE 2

HYDROLOGIC TESTING RESULTS
DC-15

Frenchman Springs Basalt Interflow No. 5

GROUND SURFACE ELEVATION: 402.1 FEET

TEST TYPE	TEST INTERVAL FEET BELOW GROUND LEVEL	PUMPING PERIOD (HOURS)	AVERAGE DISCHARGE (GPM)	MAXIMUM OBSERVED DRAWDOWN (FEET)	ANALYSIS METHOD	TRANSMISSIVITY ft^2/day				AVERAGE HYDRAULIC CONDUCTIVITY (ft/day)
						RECOVERY	SLUG WITHDRAWAL	SLUG INJECTION	SPECIFIC CAPACITY	
ALT	1735-1833	24	4.8		MRT	Gas Hump				
CRPT	↓	23.9	~~10~~ 5.8			Unavailable				
Si01					CP-SL			56		0.6
Sw01					CP-SL		64			0.7
Si02					CP-SL			64		0.7
Sw02					CP-SL		67			0.7
Si01					CP-LL			64		0.7
Sw01					CP-LL		70			0.8
Si02					CP-LL			50		0.5
Sw02					CP-LL		74			0.8

STATIC HYDRAULIC HEAD MEASUREMENT (TEST INTERVAL: 1735-1833 ft)

DATE	HYDRAULIC HEAD (FEET ABOVE MSL)
1 Aug 80	386.5

EXPLANATION

ALT = AIR LIFT TEST
CRPT = CONSTANT RATE PUMPING TEST
S_W = SLUG WITHDRAWAL
Si = SLUG INJECTION
MTR = MODIFIED THEIS RECOVERY
LL = LOG-LOG
CP = COOPER-PAPADOPULOS
SL = SEMI LOG
SC = SPECIFIC CAPACITY

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma
5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1540-1593 B= 20'	Frenchman Springs Interflow No. 4		Head/M	3861 Uncorrected

Problems with Constant Discharge Recovery Tests. Late time Pressure hump. Check McWhorter Method of analysis.

Water temperature 32° at 1500 feet.

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
CONSTANT DISCHARGE	24-HOUR AIR-LIFT TEST	Recovery - Theis (1935)	Anomalous late time Pressure hump		
		Recovery - Borehole Storage McWhorter ( )	3770		
	SUBMERSIBLE	Specific Capacity Brown, 1963	<2609		
SLUG TEST	WITHDRAWAL NO. 1	Van der Kamp (1976)	1296		
	WITHDRAWAL NO. 2		1410		
	WITHDRAWAL NO. 3		1370		
	INJECTION NO. 2		1296		
	INJECTION NO. 3		1354		
	AVERAGE		1345		
AVERAGE					
BEST ESTIMATE (ALL TESTS)					

Summary of Testing Results, Borehole DC-15, 1540-1593 ft

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15.
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1505-1553 b= 48'	Frenchman Springs Interflow No. 3.		Head/M	385.9 Uncorrected

Very rapid water-level recovery after the Air-lift pump test. NO constant Discharge / Recovery tests done due to a gas hump.

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
SLUG TESTS	WITHDRAWAL NO. 1	C-P, (1967)	636	84.8	-
	WITHDRAWAL NO. 2		739	98.5	-
	WITHDRAWAL NO. 3		650	86.7	-
	INJECTION NO. 1		436	58.1	1.46×10^{-4}
	INJECTION NO. 2		402	53.6	1.46×10^{-6}
	INJECTION NO. 3		632	84.3	-
AVERAGE			582	77.7	1.46×10^{-5}
BEST ESTIMATE			582	77.7	1.46×10^{-4}

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DC-15, FS # 3, 1505-1543

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma 5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1481-1506' b= 18'	Frenchman Springs Interflow No. 2		Head/M	386.0 uncorrected

Very rapid water-level recovery after air lift pumping. No constant discharge/recovery tests were done due to gas huma in late time recovery.

TABLE 2

Hydrologic Testing Results

Frenchman Springs #2 Interflow

Ground Surface Elevation: 402.1 Feet

TEST TYPE	TEST INTERVAL FEET BELOW GROUND LEVEL	PUMPING PERIOD (HOURS)	AVERAGE DISCHARGE (GPM)	MAXIMUM OBSERVED DRAWDOWN (FEET)	ANALYSIS METHOD	TRANSMISSIVITY ft^2/day				AVERAGE HYDRAULIC CONDUCTIVITY (ft/day)
						RECOVERY	SLUG WITHDRAWAL	SLUG INJECTION	SPECIFIC CAPICITY	
ALT	1481-1506	8.0	82		MTR	GAS HUMP				
CRPT		23.5	9.8	1.6	MTR	GAS HUMP				
S_WØ1					U		2216			123
S_WØ4					U		2195			122
S_WØ5					U		2624			146
S_WØ6					U		2705			150
SiØ1					U			1479		82
SiØ2					U			2195		122
SiØ3					U			1268		70
SiØ4					U			1588		88
SiØ5					U			1268		76
SiØ6					U			1473		82

STATIC HYDRAULIC HEAD MEASUREMENT
(TEST INTERVAL: 1481-1506 ft)

DATE	HYDRAULIC HEAD (FEET ABOVE MSL)
6/26/80	386.0 ft

EXPLANATION

ALT = AIR LIFT TEST
CRPT = CONSTANT RATE PUMPING TEST
S_W = SLUG WITHDRAWAL
Si = SLUG INJECTION
MTR = MODIFIED THEIS RECOVERY
U = UNDER-DAMPED CASE

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma 5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1395-1473	Roza-Frenchman Springs Interflow		Head/M.	386.5 Uncorrected

Bc 2 feet.

Only slug tests were done. The whole was flushed for two hours with river water.

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: July 24, 1982

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1357-1390	Roza	Interflow	Head/m	386.4' Uncorrected

B = 10'

- Rapid water-level recovery
- Gas hump
- NO Constant Discharge/recovery Tests were successful.
- Similar problems with Constant Head Injection Test.

m=10ft

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
Constant Discharge – Subsersible Pumping Test		Pressure hump recovery data	prevented	analysis	of
Constant Discharge – Air-lift Pumping Test		Pressure hump Recovery data	Prevented	analysis	of
SLUG TEST	Withdrawal NO. 2	Van der Kamp (1976	675		–
	Withdrawal NO. 3		802		
	Injection NO. 2		738		
	Injection NO. 3		636		
	AVERAGE		713		
Constant Head Injection Test		Hvorslev (1951)	–	21	
–					
AVERAGE (SLUG TESTS)			713		–
BEST ESTIMATE (SLUG TESTS)			713		–

Summary of Results Determined From Various Test Methods For Roza Basalt Interflow Zone, 1357–1390 Feet, Borehole DC-15

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1295-1353	ROZA FLOW	Colonnade/Entablature.	Head/M	Not done

Only Pulse Tests were done. Very slow pressure decay response. No analyses were done.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: July 24, 1982

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1219-1293 B=46'	Priest Rapids - Rosa Interflow		Head/M	386.7 Uncorrected

Q = 98 gpm

Problems with Gas hump.

Vander Kamp (1976) may be under estimating the T values.

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES: TRANSMISSIVITY ft²/day	Effective HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
SLUG TESTS	WITHDRAWAL NO. 1	Bredehoeft et al (1980)	? 4.11 ~~9.7×10^{-3}~~	6.0×10^{-2} ~~1.2×10^{-4}~~	$5.?1 \times 10^{-1}$
	WITHDRAWAL NO 2		1.21 ~~2.9×10^{-3}~~	1.1×10^{-2} ~~3.7×10^{-5}~~	$3.1 \times 10^{-?}$ ~~4.8×10^{-6}~~
	INJECTION NO. 1		INSUFFICIENT DATA		
	INJECTION NO. 2		3.19 ~~6.6×10^{-3}~~	4.1×10^{-2} ~~8.5×10^{-5}~~	1.41×10^{-6}
AVERAGE			5.0 ~~6.4×10^{-3}~~	3.1×10^{-2} ~~8.4×10^{-5}~~	[illegible]$ \times 10^{-3}$
BEST ESTIMATE			5.0 ~~6.9×10^{-3}~~	3.7×10^{-2} ~~8.1×10^{-5}~~	[illegible]7×10^{-3}

DC-15, ~~FS#1~~, Roza - Frenchman Springs 1395-1473

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: July 24, 1982

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1149-1189 8 feet	Priest Rapids	Basalt. Interflow zone. Also consists of 0.5' of thick claystone at 1152.4'	Head.	386.1 uncorrected

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY FT^2/DAY	EQUIVALENT HYDRAULIC CONDUCTIVITY FT/DAY	STORATIVITY
OVERPRESSURIZED PULSE TEST	NO. 5	Bredehoeft et.al (1980)	1.0×10^{-1}	3.4×10^{-3}	9.5×10^{-5}
	NO. 6		6.7×10^{-1}	2.3×10^{-2}	—
AVERAGE			3.8×10^{-1}	1.3×10^{-2}	9.5×10^{-5}
BEST ESTIMATE			3.8×10^{-1}	1.3×10^{-2}	9.5×10^{-5}

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Table . Summary of Hydraulic Property Values determined on the Priest Rapids Basalt Interflow at Borehole DC-15.

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15 ELEV 402.1 ft
2. TOTAL DEPTH: UNDER CONSTRUCTION
3. DEPTH OF CASING: 208 AT TIME OF TEST
4. REVIEWER: RALSTON
5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
208-323	ICE HARBOR BASALT, LEVEY INTERBED AND FLOW TOP OF ELEPHANT MT. BASALT			SEE ATTACHED SHEET FOR DATA - TABLE 1 HEAD = 368.7' 24 HRS AFTER DEVELOPMENT
275-343'	PACKER SET IN LOWER PORTION OF ICE HARBOR BASALT TO INCLUDE LEVEY INTERBED AND INTER FLOW ~~TOP~~ OF ELEPHANT MT. BASALT			SEE TABLE 1 DATA SUGGEST THAT ELEPHANT MT BASALT HAS A LOW T IN TEST INTERVAL.
321-343'	PACKER AT 321' TO BOTTOM OF HOLE - ELEPHANT MT. BASALT			DATA SUGGEST LEAKAGE AROUND PACKER - NO RESULTS CALCULATED. HYDRAULIC HEAD ≈ 375' ELEV ALTHOUGH QUESTIONABLE.

LEAKING PACKERS PREVENTED HEAD DETERMINATION FOR THIS ZONE

~~HEAD FOR LEVEY INTERBED WAS MEASURED AT 368.7' 24 HRS AFTER AIRLIFT DEVELOPMENT.~~

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY FT^2/DAY	EQUIVALENT HYDRAULIC CONDUCTIVITY FT/DAY	STORATIVITY
CONSTANT DISCHARGE TEST	AIR-LIFT	Anomalous water level response prevented calculation of transmissivity, using conventional analytical solutions			
	SUBMERSIBLE	Anomalous water level response prevented calculation of transmissivity using conventional analytical solution			
SLUG TEST	WITHDRAWAL	Van der Kamp (1976)	6204	117	-
	INJECTION		5438	103	-
	AVERAGE		5821	110	-
CONSTANT HEAD INJECTION TEST		Hvorslev (1951)	1034	19.5	
AVERAGE			3428	64.7	-
BEST ESTIMATE			5821	110	-

Table . Summary of Hydraulic Property Values Determined By Various Test Methods Conducted On The Priest Rapids / Rosa Basalt Interflows, 1219-1263 Feet, Borehole DC-15

TEST METHOD	ANALYSIS METHOD	HYDRAULIC PROPERTIES		
		TRANSMISSIVITY FT^2/DAY	EQUIVALENT HYDRAULIC CONDUCTIVITY FT/DAY	STORATIVITY
CONSTANT DISCHARGE Submersible Pumping Test (Levey Interbed) (208-323)	DRAWDOWN — Cooper and Jacob (1946)	156	5.6	-
	RECOVERY — Theis (1935)	150	5.4	-
Air-Lift Pumping Test (Composite Interval Levey Interbed and Elephant Mountains interflow) (275-343)	Recovery — Theis (1935)	115	4.1	-
AVERAGE		140	5.0	-
BEST ESTIMATE (Submersible Pumping Test		153	5.5	-

STATIC HYDRAULIC HEAD

TEST INTERVAL (FEET)	Measured Hydraulic Head (Feet above MSL)	Hydraulic Head Corrected to Formation Temperature (Feet above MSL)
208 - 323 (Levey Interbed)	368.7	368.7
275 - 343 (Composite Levey Interbed - Elephant Mountains Interflow)	375.3	375.3
AVERAGE		
BEST ESTIMATE		

Table 1. Summary of Hydraulic Values Determined by Various Test Methods Conducted on The Levey Interbed and Composite Levey Interbed and Elephant Mountains Interflow zone at Borehole DC-15.

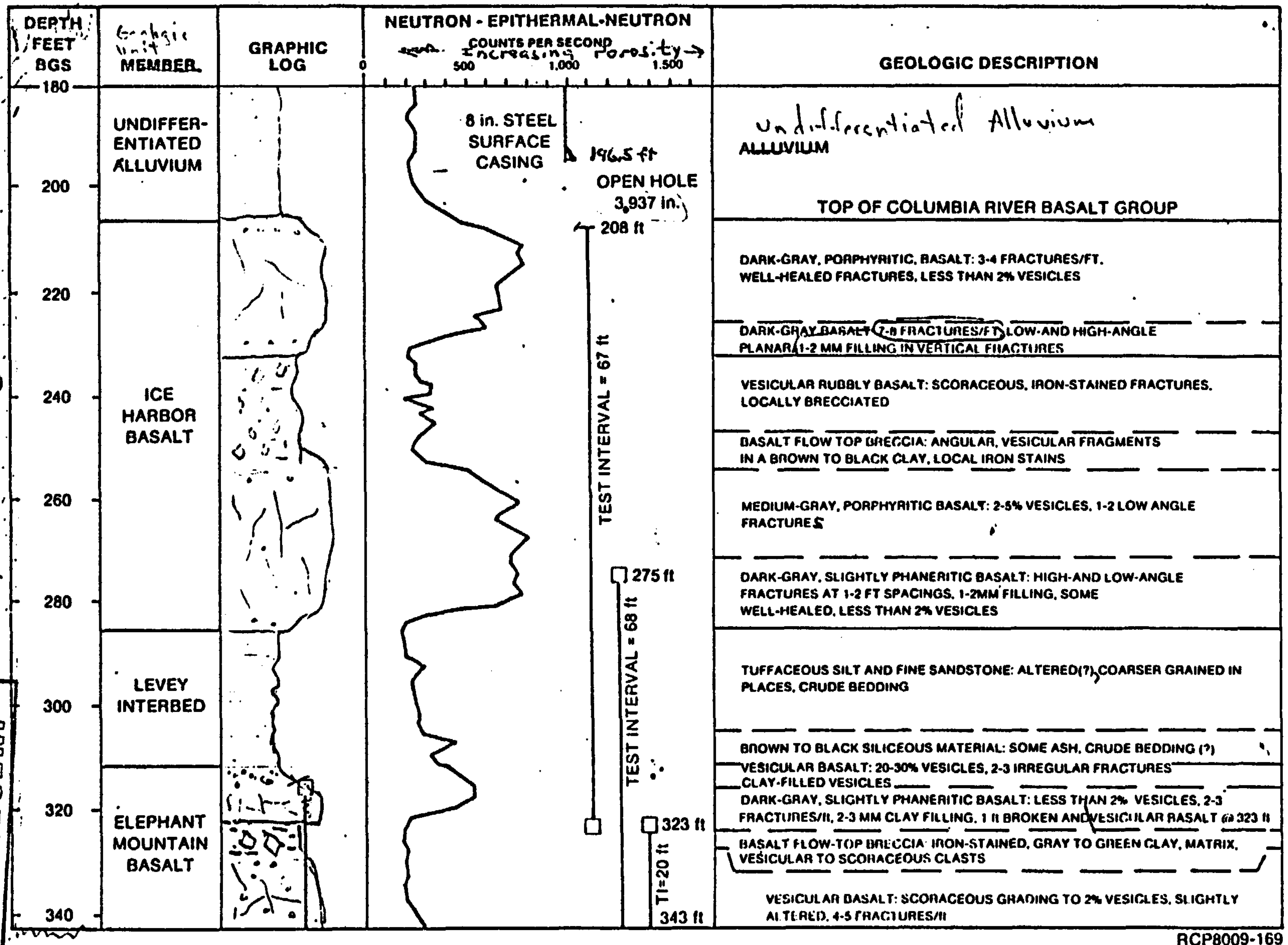

Figure 4. Interval Descriptions of Composite zone containing the Levey interbed and Elephant Mountains basalt interflow ~~zone~~.

BOREHOLE REVIEW FORM

ELEV 402.1 ft

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON

5. DATE: 7/~~23~~ 24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
416-446	SEE ATTACHED FIGURE 11		CONSTANT DISCHARGE	SEE ATTACHED TABLE 3
	RATTLESNAKE RIDGE INTERBED & POMONA RIDGE INTERBED		SLUG TESTS	T&K FROM RECOVERY (LATE TIME) ARE BELIEVED TO BE MOST RELIABLE BECAUSE OF SHORT TIME INVOLVED IN SLUG TEST EFFECT

T_{BEST} = 155 ft²/D

K_{BEST} = 2.8 ft/D

PROBABLY REPRESENT COMBINATION OF RATTLESNAKE RIDGE INTERBED AND FLOW TOP OF POMONA BASALT

HEAD = 383.9' ELEV

MEAS. 14 HRS AFTER AIR LIFT DEVELOPMENT

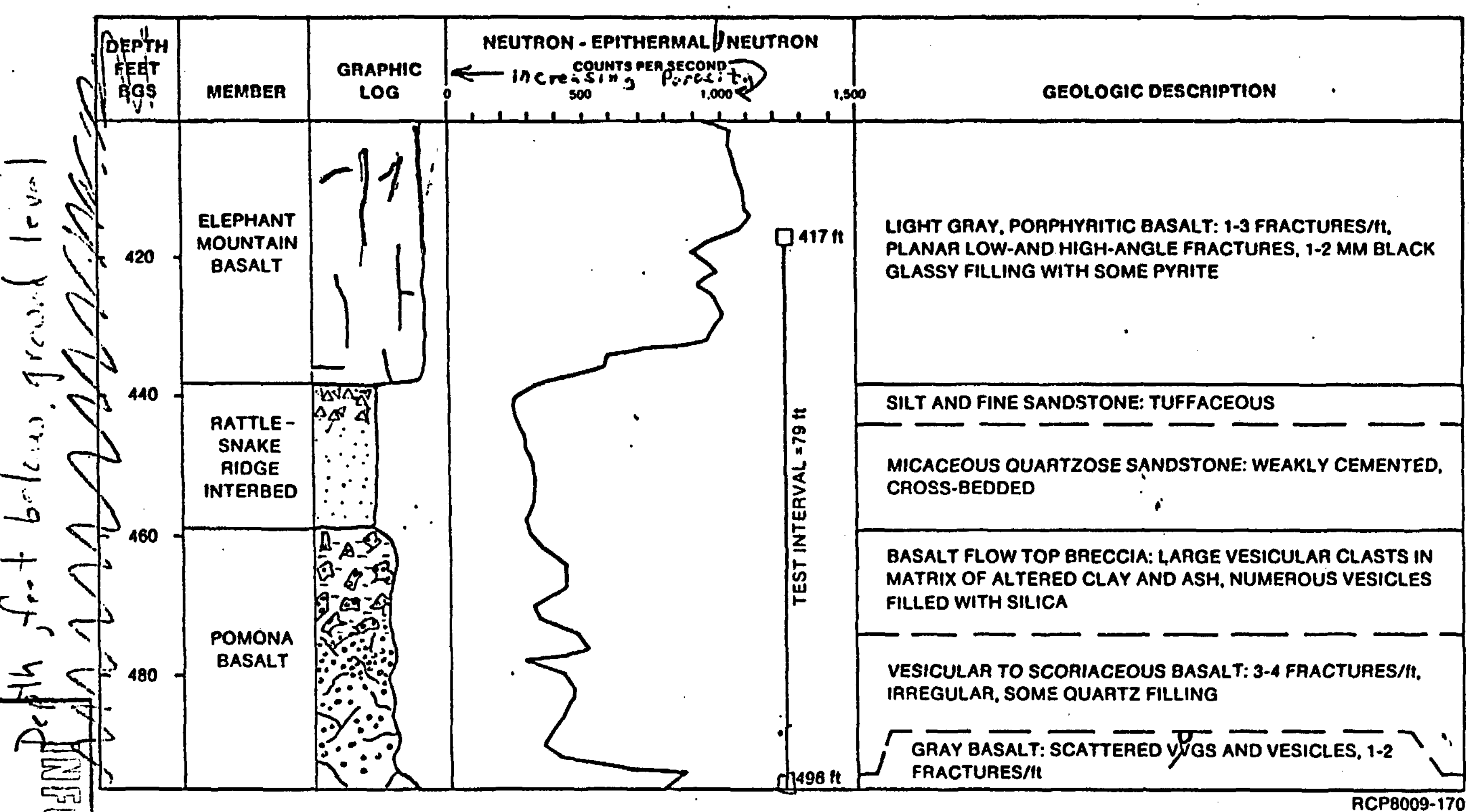

Figure 11. Interval Description of Composite zone containing the Rattlesnake Ridge Interbed/ Pomona Flow Top.

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY FT^2/DAY	EQUIVALENT HYDRAULIC CONDUCTIVITY FT/DAY	STORATIVITY
CONSTANT DISCHARGE	Submersible Pumping Test Q = 9.5gpm	RECOVERY - Theis (1935)	185	3.3	-
	Air-Lift Pumping Test Q ≈ 60gpm		155	2.8	-
SLUG TEST	INJECTION NO. 3	Cooper et al (1967)	638	11.4	-
	WITHDRAWAL NO. 2		1010	18.0	-
	WITHDRAWAL NO. 3		954	17.0	-
	AVERAGE		867	15.5	-
AVERAGE			402	7.2	-
BEST ESTIMATE			155 (Air-lift)	2.8 (Air-lift)	-

Table 3. Summary of Hydraulic Property Values Determined By Various Test Methods Conducted On The Rattlesnake Ridge/Pomona Basalt Flow Top at Borehole DC-15, F 417-496 feet

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON
5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
599-630'	SELAH INTERBED & ESQUATZEL FLOW TOP (UPPER FLOW OF GABLE MT ~~FLOW~~)	SEE FIG 16		AIRLIFT RECOVERY LATE TIME DATA T = 36 ft²/D SLUG TESTS TABLE 4 ~~B~~ @ 16' OF AQUIFER HEAD = 356.5' ELEV MEAS 12 HRS AFTER AIRLIFT DEVELOPMENT
629-660	ESQUATZEL (LOWER FLOW of GABLE MT)	SEE FIG 16 PACKER TO BOTTOM OF HOLE		AIRLIFT RECOVERY TEST & SLUG TESTS SEE TABLE 7 HEAD = 356.4' MEAS. 19 HRS AFTER DEVELOPMENT

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-15
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON
5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
713 - 787	COLD CREEK INTERBED AND FLOW TOP OF UMATILLA BASALT	SEE FIG 5		AIRLIFT RECOVERY TEST AND SUBMERSIBLE PUMP CONSTANT Q TEST SEE TABLE 8 USE LATE TIME DATA TO MINIMIZE BOREHOLE STORAGE EFFECTS HGND = 358.9' ~~AF~~ MEASURED 21 HRS AFTER AIRLIFT DEVELOPMENT
1003'-1072'	MABTON INTERBED AND FLOW TOP OF PRIEST RAPIDS FLOW SEE FIG 29.			CONSTANT Q TESTS ONLY WERE CONDUCTED IN THIS INTERVAL. LATE TIME DATA WERE USED TO MINIMIZE BOREHOLE STORAGE EFFECTS SEE TABLE 9 HGND = 384.5' @ 16 HRS AFTER WELL DEVELOPMENT

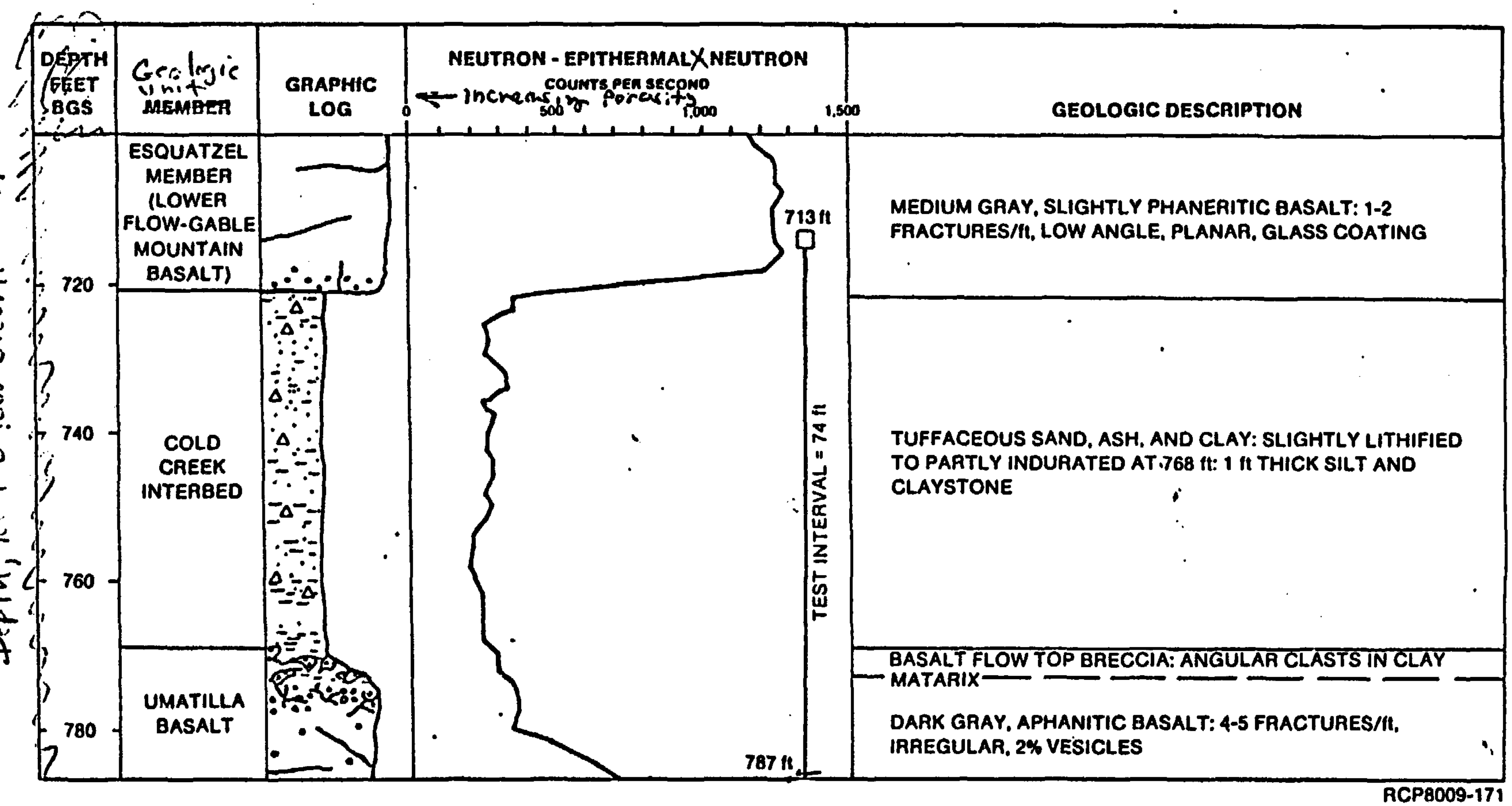

Figure 25. Interval Description of the Composite Zone Containing the Cold Creek Interbed/Umatilla Basalt Flow Top.

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft²/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
CONSTANT DISCHARGE TEST	AIR-LIFT	RECOVERY - Theis (1935)	34.9 ~~32.2~~	.55	–
	SUBMERSIBLE		30.0	.47	–
AVERAGE			32.5 ~~31.4~~	.51	–
BEST ESTIMATE			32.5 ~~31.4~~	.51	–

TABLE 8. DC-15, Cold Creek Interbed, 713-787'

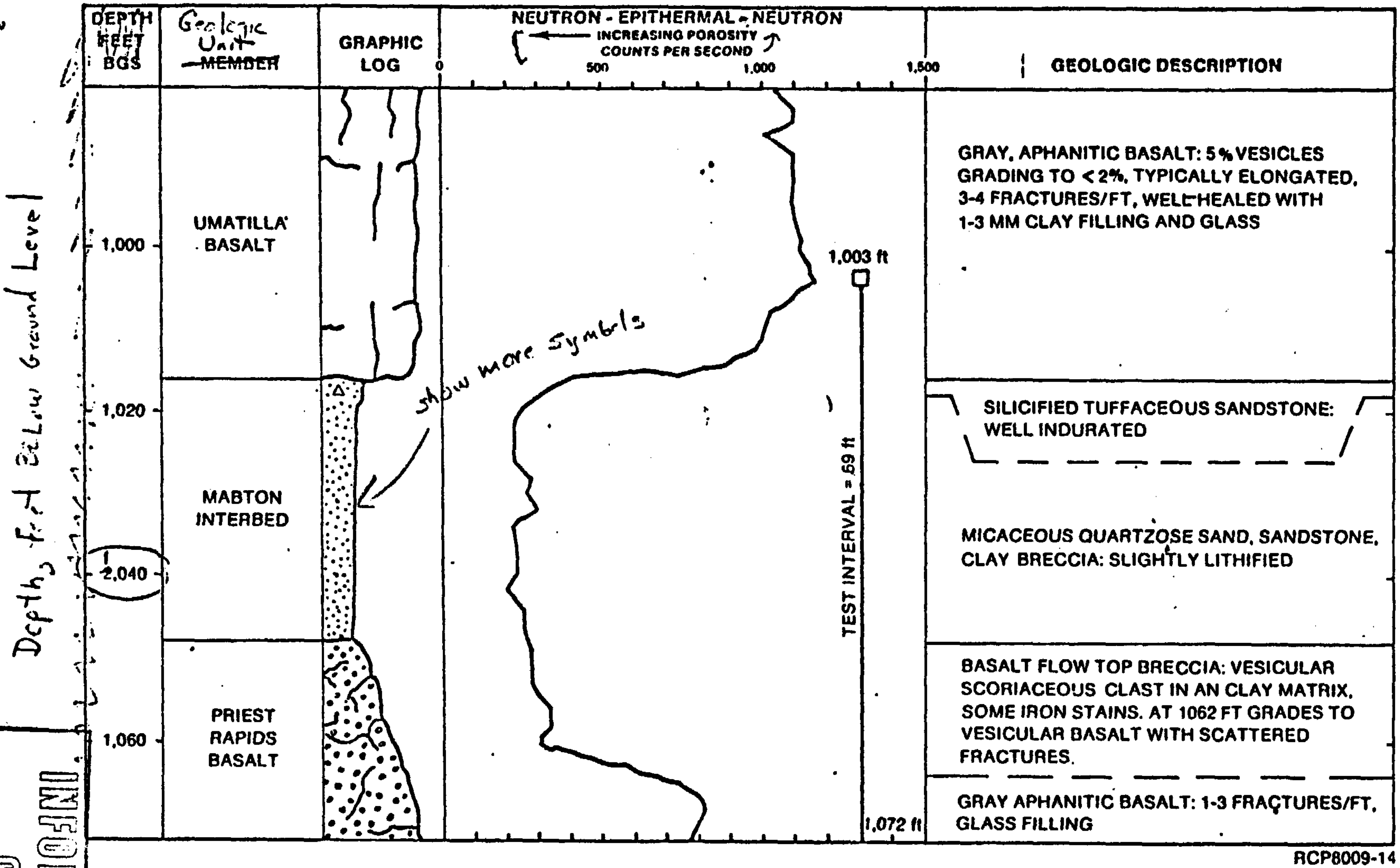

Figure 29. Interval Description of the Composite Zone Containing the Mabton Interbed

TEST METHOD		ANALYSIS METHOD	HYDRAULIC PROPERTIES		
			TRANSMISSIVITY ft^2/day	HYDRAULIC CONDUCTIVITY ft/day	STORATIVITY
CONSTANT DISCHARGE TEST	Q=6.5 gpm AIR-LIFT	RECOVERY-Theis (1935)	62.8	1.3	—
	Q=5.4 gpm SUBMERSIBLE		~~47.2~~ 45.2	.97	—
AVERAGE			54.0 ~~55.0~~	1.1	—
BEST ESTIMATE			54.0 ~~55.0~~	1.1	—

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Table 9 Dc-15 1003-1072 Mabton

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-2
2. TOTAL DEPTH: 3,300'
3. DEPTH OF CASING: 2253'
4. REVIEWER: RALSTON

5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

- INFORMATION OBTAINED FROM ST-5 & RHO-BWI-C-36
- DATA OBTAINED WITH DOUBLE PACKER W/ PRESSURE PROBE DOWN HOLE.
- STRADDLE ZONES TESTED WERE 33 TO 53' IN LENGTH

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2344'-2376'	GOR	SEE ATTACHED TABLE 1	SLUG TEST	$K = 1.5\times10^{-2}$ TO 3.1×10^{-4} ft/DAY BY USBR (1974) AND HVORSLEV (1951) METHODS THEY COULD NOT OBTAIN RESULTS W/ PAPADOPULOS (73) METHOD. $T = 4.8\times10^{-1} - 9.9\times10^{-3}$ ft²/D
2376-2409	G.R	SEE TABLE 1	SLUG TEST	$K = 5.7\times10^{-3}$ TO 1.3×10^{-4} ft/D BY USBR (1974) ~~TESTS~~ METHOD - PAPADOPULOS METHOD IS 10X HIGHER $T = 1.8\times10^{-1} - 4\times10^{-3}$ ft²/D
2954-3007	GR	SEE TABLE 1	SLUG TEST	$K = 1.8\times10^{-3}$ TO 4.0×10^{-4} ft BY USBR (1974) — AGREEMENT WITH PAPADOPULOS (1973 $T = 9.7\times10^{-2} - 2.1\times10^{-2}$ ft²/

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-2
2. TOTAL DEPTH: 3,300'
3. DEPTH OF CASING: 2253'
4. REVIEWER: RALSTON   5. DATE: 7/24/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3019-3071'	G.R.	SEE TABLE 1	SLUG	$K = 7.4 \times 10^{-7}$ TO 1.5×10^{-8} ft/D FROM USBR (1974) — NO COMPARISON WITH OTHER ANALYSIS TECHNIQUES. $T = 4.0 \times 10^{-5} - 8.1 \times 10^{-7}$ ft²/D
3069-3122'	GR	SEE TABLE 1	SLUG	$K = 1.7 \times 10^{-6} - 4.2 \times 10^{-8}$ ft/D FROM USBR (1974) AND HVORSLEV (1951) $T = 9.2 \times 10^{-5} - 2.3 \times 10^{-6}$ ft²/D
3166-3170'	GR	SEE TABLE 1	SLUG	$K = 8.2 \times 10^{-7}$ TO 4.0×10^{-8} ft/D FROM USBR (1974) AND PAPADOPULOS (1973) $T = 4.4 \times 10^{-5}$ TO 2.2×10^{-6} ft²/D

ALL OF THE ABOVE RESULTS ARE QUESTIONABLE. DATA PLOTS ARE NOT AVAILABLE FOR ANALYSIS. I SUGGEST VERY LIMITED USE OF THESE RESULTS. DBR

TABLE 1

DESCRIPTION OF INTERVALS TESTED IN BOREHOLE DC-2

INTERVAL	DEPTH (feet)	LENGTH (feet)	ROCK TYPE	GEOLOGIC DESCRIPTION
1	2376.36 to 2409.08	32.72	Entablature	Moderately fractured, dense, dark, some glass, some flow banding, scattered amygdules.
2 A and B	2343.57 to 2376.29	32.72	Flow top	Highly fractured, vesicular (15%) and breccia and flow rubble with clay matrix, zeolites. Upper part of interval base of overlying colonnade of dense, dark finely phaneritic nature; lower part of interval is top of entablature, moderately fractured, competent with brown-yellow clay.
4	3018.81 to 3071.46	52.65	Umtanum Entablature	Dark, dense, aphyric with filled and unfilled fractures mostly hairline and irregular, rare amygdules.
5	3068.94 to 3121.59	52.65	Umtanum Entablature/ Colonnade	As for Interval 4, but zones of moderate fracturing with high-angle orientation hairline fractures.
6	3116.14 to 3170.30	54.16	Umtanum Colonnade	Moderately fractured rock, high-angle hairline fractures, black and glassy zones. More fractured toward the base.
7	2954.38 to 3006.54	54.16	Umtanum Flow top	Flow top consisting of a competent rubble zone well indurated with little alteration underlain by a glassy scoria in a well-indurated maxtrix, some vugs. The underlying entablature is a dense, dark aphyric basalt with some low-angle fractures.

[1]Data supplied by Rockwell Hanford Operations, June 1978

DC-2

Page 3 of 3

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

SUMMARY SHEET FOR TESTING IN DC-12
FOR GRANDE RONDE SECTION

4084-4455	R	FAIR SLUG TEST RESULTS
4344-4455	NR	NO RESULTS REPORTED
3341-4070	?	VAN DER KAMP METHOD - T SEEMS HIGH
4021-4070	?	" " " "
3284-3353	?	VERY LIMITED ANALYSIS - POSSIBLE SLUG TEST
3199-3282	NR	NO RESULTS CALCULATED
3164-3211	NR	NO TESTING COMPLETED
3067-3153	R	GOOD RECOVERY DATA & VALUES
2978-3153	R	" " " "
2928-2978	NR	NO RESULTS CALCULATED
2838-2863	?	VAN DER KAMP METHOD T SEEMS HIGH
2818-2843	?	" " " "
2568-2661	NR	NO RESULTS REPORTED - ONLY ROUGH DATA
2408-2446	NR	NO RESULTS REPORTED - " "
2267-2301	NR	" " " "
2218-2260	NR	" " " "
2050-2079	R	
1909-1984	?	
1848-1914	NR	
1808-1854	NR	
1768-1804	NR	
1687-1710	R	
1618-1684	NR	
1508-1534	R	
1384-1508	NR	
1328-1364	?	
1217-1254	NR	

SUMMARY

R	6
?	7
NR	14

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12
2. TOTAL DEPTH: 4,455' G.S. ELEV. = 515.5 ft
3. DEPTH OF CASING: 0-2244' (WHEN NEUTRON LOGGED)
4. REVIEWER: RALSTON 5. DATE: 7/22/82

SITE COORDINATES 699-10-54B

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
4084'-4455'	GRANDE RONDE/ SCHWANA FLOWS			TEMP = 63°C AT 4,300'
		TOP PACKER IN G.R. FLOW-23 TO BOTTOM OF HOLE INCLUDING G.R. FLOWS-24, (3.8' THICK) -25 (75' THICK) -26 (23' THICK) & PART OF -27 (4' THICK)	RECOVERY FROM AIRLIFT 7/20/82 Q = 6.7 gpm	RECOVERY OF W.L. ABOVE STATIC — DATA SHOWED FLUCTUATING W.L.; ANALYZED USING EARLOUGHER METHOD $T = 1.4 \times 10^2$ ft²/DAY RESULTS POOR
		COMPOSITE TESTING INTERVAL - 371'	INJECTION SLUG TEST #4 7/29/81	THREE MATCHES TO TYPE CURVES. RESULTS POOR (BREDEHOEFT) T RANGED FROM 2.5×10^1 TO 4.5×10^1 ft²/DAY S ~~FROM~~ WAS @ 2×10^{-11}
		MAJOR FRACTURE AT 4282'		
			SLUG INJECTION TEST #4 7/31/81	FAIR MATCH (BREDEHOEFT) $T = 1.7 \times 10^2$ ft²/DAY OR COOPER $S = 1 \times 10^{-10}$
			SLUG INJECTION #2 8/3/81	FAIR MATCH $T = 1.3 \times 10^2$ ft²/DAY $S = 1 \times 10^{-8}$ (BREDEHOEFT) FERRIS & KNOWLES $T = 4.7 \times 10^2$ ft²/DAY (POOR)
			SLUG WITHDRAWAL #2 8/3/81	FAIR MATCH (BREDEHOEFT) $T = 1.9 \times 10^2$ ft²/DAY $S = 1 \times 10^{-9}$ BEST $T = 1 \times 10^2$ ft²/D NO S VALUE

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-12 CONTINUED
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
4064-4455	CONTINUED		HEAD	MEASURED FROM FULL RECOVERY USING STEEL TAPE ELEV W.L. = 408' SHOULD BE OK WITHIN ACCURACY OF BAROMETRIC FLUC.
4344-4455	GRANDE RONDE/ SCHWANA FLOWS	UPPER PACKER SET IN LOWER PORTION OF G.R #25 FLOW - TEST ACROSS GR#26 (23') & PART OF GR#27 (4') COMPOSITE TEST ACROSS TWO INTER-FLOW ZONES. NO NEUTRON LOG AVAILABLE INTERVAL = 111' INCLUDES @9' ~~GR~~ FLOW TOP (4431-4440), AND THIN CONTACT ZONE 4355-4360'	HEAD	MEASURED FROM FULL RECOVERY USING STEEL TAPE ELEV W.L. = 405' SHOULD BE ACCURATE WITHIN BAROMETRIC FLUC.
				NO RESULTS OF TESTING IN FILE — HYDROSTRAT SHEET SHOWS A $T = 10^2 ft^2/DAY$
			AIRLIFT PUMPING	Q = @ 10 gpm - GAS EFFECT ON OUR RECOVERY - NO RESULTS CALCULATED
4420-4455	G.R./ SCHWANA	FLOW CONTACT OF GR# 26 & #27		LOOKS LIKE A VERY LIMITED SLUG TESTING PROGRAM WAS RUN ON THIS INTERVAL — NO RESULTS. ALSO AIR LIFT AT Q = 10 gpm NO RESULTS

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-12 CONTINUED
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON

5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2260 - 4455	ENTIRE G.R. SECTION		CONSTANT Q AIRLIFT CLEANING UP ENTIRE HOLE	Q = ~~33 gpm~~ 33-36 gpm NO DRAWDOWN OR RECOVERY DATA OBTAINED.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12 CONTINUED
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: 5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3341-4070	GR./ SCHWANA	UPPER PACKER IN MIDDLE OF GR# 12 (UMTANUM) TO BOTTOM OF HOLE AT 4070 IN GR# 2B	HEAD	ELEV WS = 406' FROM PROJECTION OF PRESSURE RECOVERY DATA
		COMPOSITE OF 11 INTERFLOW ZONES	4/8/81 AIRLIFT 24 HRS	Q ≈ 18 gpm - SLOW RECOVERY OF W.L. @ 60' ABOVE STATIC AQUIFER PARAMETERS NOT CALCULATED
		TOTAL THICKNESS = 729'	4/10/81 SLUG TEST	VANDERKAMP SOLUTION T = 738 ft²/DAY
			4/10/81 SLUG TEST	VANDERKAMP SOLUTION T = 828 ft²/DAY

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-12 CONTINUED
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
4021-4070	G.R./ SCHWANA	UPPER PACKER SET IN GR#21 TO BOTTOM HOLE ~~LOWER PACKER SET IN~~ IN GR#23 COMPOSITE TEST OF TWO INTERFLOW ZONES	AIRLIFT RECOVERY TEST 24 HRS 4/16/81	T = 57°C AT 4,000' Q= @ 20 gpm WATER LEVEL RECOVERED TO @ 75' ABOVE STATIC W.L. THEN DECLINED TO @ STATIC - W.L. @ 3' ABOVE STATIC AFTER 1800 MIN OF RECOVERY
		VESICULAR ZONES 4027-4030 & 4037-4040 & 4046-4049	SLUG INJECTION 4/21/81 TESTS	VANDEKAMP SOLUTION T = 583 ft²/DAY T = 555 ft²/DAY T = 776 ft²/DAY T = 771 ft²/DAY T = 503 ft²/DAY T = 450 ft²/DAY T = 557 ft²/DAY
			SLUG INJECTION 4/20/81	VAN DE KAMP T = 834 ft²/DAY

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12 CON'T
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3284-3353	G.R./ SCHWANA UMTANUM	MIDDLE OF FLOW E/C VERY DENSE BASALT - CORES ARE DISCED SOME FRACTURING BUT MOSTLY HEALED		NEITHER TEMP OR HEAD DATA GIVEN TESTING PROGRAM CONSISTED OF A CLOSED-IN PRESSURE TEST FROM 1/14/81 TO 1/19/81; ~~___~~ W.L. RECOVERY ON 1/20/81; CLOSED IN PRESSURE TEST 1/21/81 TO 1/24/81; W.L. RECOVERY 1/24/81 TO 1/26/81; CONSTANT HEAD INJECTION 1/26/81; W.L. RECOVERY 1/26/81 TO 1/28/81; CONSTANT PRESSURE TEST 1/28/81-1/29/81; PRESSURE RECOVERY 1/29/81 — 1/30/81; CONSTANT PRESSURE 1/30/81; CLOSED IN PRESSURE RECOVERY 1/30/81 — 2/2/81; ~~2/2/81~~ AIRLIFT SLUG TESTING 2/2/81 - 2/4/81 SLUG INJECTION TESTING 2/6/81 - 2/9/81 CONSTANT HEAD INJECTION TESTS INVOLVED INJECTED @ 0.25 gpm AT @ 41 psi ONLY RESULT NOTED IN PACKET OF DATA ON THIS INTERVAL WAS $T = 5.3 \times 10^{-5}$ ft²/DAY FROM 1/21/81 SLUG WITHDRAWL TEST - PROBABLY AFTER BREDEHOEFT(??) NO IDEA OF RELIABILITY OF RESULTS NO OTHER TEST RESULTS CALCULATED

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12 CON'T
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON 5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3199-3282	G.R./ SCHWANA	FLOW TOP OF UMTANUM		NO TEMP OR W.L. ELEV. DATA PRESENTED
			AIRLIFT PUMPING 12/19/80	Q = 6.5 gpm
			PRESSURE PULSE TEST 12/19/80	NO RESULTS CALCULATED - ONLY ROUGH PLOTS IN FILE.
3164-3211	GR. SENTINEL BLUFFS	McCOY CANYON EK	— NO TESTING COMPLETED —	
3067-3153	G.R./ SENTINEL BLUFFS	FLOW TOP OF McCOY CANYON FLOW		HEAD NOT DETERMINED TEMP = 45°C AT 3000'
			AIRLIFT TEST RECOVERY	Q = 0.23 gpm T = 0.63 ft²/DAY MODIFIED THEIS METHOD RESULTS ARE GOOD
			CONSTANT HEAD	Q_{AVE} = 0.046 gpm T = 7.8×10^{-3} ft²/DAY JACOB-LOHMAN; T = 0.11 ft²/DAY MODIFIED THEIS RECOVERY
				NO SATISFACTORY RESULTS FROM SLUG TESTS.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12 CON'T
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2978-3153	G.R./ SENTINEL BLUFFS	COMPOSITE SECTION ACROSS TWO FLOW TOPS TOP OF GR#10 & GR#11 (McCOY CANYON)		HEAD NOT DETERMINED
			AIRLIFT TEST	Q = 0.45 gpm T = 0.11 ft²/D MODIFIED THEIS RECOVERY RESULTS LOOK GOOD
			CONSTANT DRAWDOWN	Q AVE = 0.85 gpm T = 0.21 ft²/D JACOB-LOHMAN T = 0.21 ft²/D MODIFIED THEIS RECOVERY POOR RESULTS FROM SLUG TESTS
2928-2978	G.R./ SENTINEL BLUFFS	SECTION INCLUDED FLOW TOP OF GR#9		SECTION TESTED BUT NO DATA REPORTED AIRLIFT TEST SHOULD RECOVERY OVERSHOOTING TRIED AIRLIFT TEST Q 6.6 gpm DECREASED TO 0.29 gpm

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-12 CON'T
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2838-2863	G.R./ SENTINAL BLUFFS	TEST OF FLOW TOP OF GR # 8	AIRLIFT RECOVERY	Q=@ 17 gpm COULD NOT ANALYZE DATA BECAUSE W.L. ROSE ABOVE STATIC & THEN BEGAN TO DECLINE.
			SLUG TESTS	- ANALYZED BY VAN DER KAMP (1976) INJECTION 1 580 ft²/D WITHDRAWL 2 530 " INJECTION 3 663 " WITHDRAWL 6 585 " AVE 590 "
			HEAD	ELEV WL = 407 BASED UPON WATER LEVEL RECOVERY

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-12 CON'T
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2818-2843	~~G.R.~~ SENTINAL BLUFFS	TEST OF FLOW TOP OF THIN FLOW GR# 7 UNDERLYING THROUGH-RUNNER	HEAD - STATIC W.L. MEAS = 407' ELEV AIR PUMPED SLUG TESTS	Q = 25gpm DATA WERE NOT ANALYZED BECAUSE W.L. ROSE ABOVE STATIC AFTER 2 MINUTES OF RECOVERY VAN DER KAMP ANALYSIS $T = 1.5 \times 10^3 ft^2/DAY$ RANGE $1.2 - 1.8 \times 10^3 ft^2/DAY$ THIS TEST WAS REPEATED FOR DRILLING WITH AND WITHOUT MUD. COPY OF REPORT MADE FOR NRC.
2568-2661	~~GR~~ SENTINAL BLUFFS	TEST OF FLOW TOP OF THROUGH RUNNER (GR #6) PLUS ALL OF GR#5		HEAD NOT MEASURED RESULTS OF ~~B~~TESTING NOT FORMALLY PRESENTED - ROUGH CALCULATIONS IN FILE INDICATED $T = 0.14 ft^2/D$ FROM CONSTANT DRAWDOWN TEST NO WAY TO ~~ASSESS~~ JUDGE RELIABILITY LIMITED TEST ON HYDROLOGIC ANALYSIS WITH AND WITHOUT TREATMENT OF WELL WITH ~~TSPR~~ TSP (SODIUM TRIPOLYPHOSPHATE) T PRIOR = $0.14 ft^2/D$ } DIFF. NOT T AFTER = $0.17 ft^2/D$ } SIGNIFICANT USING CONSTANT DRAWDOWN METHOD

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12 CON'T
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2408-2446	GoR/ SENTINAL BLUFFS	FLOW TOP OF GR#4		- NO FORMAL REPORT IN FILES - HYDROSTRAT SHEET SHOWS HEAD ELEV = 407' AND $T = 10^2 ft^2/DAY$ - HEAD EXTRAPOLATED FROM RECOVERY CURVE. - SOME CALCULATIONS FOR CONSTANT Q AIR LIFT RECOVERY DATA $Q = 4.8$ gpm $T = 89 ft^2/DAY$ MODIFIED THEIS METHOD - ANOTHER RECOVERY DATA SET YIELDED $T = 130 ft^2/DAY$ - CANNOT JUDGE RELIABILITY OF RESULTS
2267'-2301'	GR/ SENTINAL BLUFFS	TEST OF FLOW TOP OF GR#2		VARIABLE RATE TEST (HARRELD METHOD) ROUGH CALCULATIONS ONLY ARE REPORTED $T =$ ~~4.85~~ $4 ft^2/DAY$ ALSO ROUGH CALCULATIONS ON RECOVERY $T = 1.8 ft^2/DAY$ NO WAY TO JUDGE RESULTS — ONLY ROUGH TESTING HEAD REPORTED AS 406' ELEV BUT NOTHING IN FILE AS TO BASIS.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12 CONT
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: RALSTON

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2218-2260	VANTAGE PLUS FLOW TOP OF UPPER MEMBER OF GRANDE RONDE			NO SUMMARY OF RESULTS - ONLY ROUGH CALCULATIONS ON WORK SHEETS HEAD = 403' AND T = 10° ft²/DAY FROM HYDROSTRAT SHEET ——— CALCULATED RESULTS FROM CONSTANT HEAD INJECTION (LEITMAN) & RECOVERY T = 0.23 ft²/DAY CANNOT FOLLOW ANY CALCULATIONS

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-12
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: FAUST
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2050.5-2079	Frenchman Springs Interflow 8'	Interflow zone (at 2058)	Static head	406.23 ft asl
			Constant discharge (air lift)	No analysis
			(submersible) Constant Discharge / Recovery	625 ft²/d / 7.53 - 13.26 ft²/d] straight line (4.58 hour)
			Slug Discharge / Slug Injection	not usable slopes to steep for analysis
				recovery data showed a hump - rise above initial conditions
				also looked at hump decline Estimated T = 110 ft²/d
1909.5-1954	Frenchman Springs interflow #7 (1922-1938 assumed for permeable zone)	Fractured Brecciated Zone	Static head	109.7 B.G.S.
			Recovery from air lift pumping	Theim Steady-state approximation with projected drawdown, and Re of 1000-10000 ft T = .62 ft²/d - .79 ft²/d
			Pulse Tests 10 tests	apparently not analyzed
			Slug Displacement tests Positive 5 Negative 5	
			Slug Injection 2	
			T estimated crudely	

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-12
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: FAUST
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1846.75 - 1919	Frenchman Springs UC	Flow top contact at 1868'	Static Head Temp	No head value estimated 60°F
			Constant Discharge (submersible)	not enough discharge
			Slug Withdrawal 4 runs	no analysis
			Const. Head Inject	Tight
1808.5 - 1859	Frenchman Springs US	1817' flow contact 1838.5 fractures + vugs	Static Head Discharge Air lift Discharge submersible Recovery Air Sub Slug Displacement Positive	Very tight Pumping mainly water from storage no analysis
1758 - 1819	Frenchman Springs #4	1781 interflow depth	Static Head Air lift pumping recovery	no analysis too tight

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-12
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: FAUST

5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1687.5-1710	Frenchman Springs #3 Interflow	Contact 1691' open fractures, vugs - some clay filled, and some mineralization (lost circulation at 1692)	Static Head	406.48 after initial airlift + equilibration period
			Discharge Air Lift	2 hr 45 min
			Recovery Air	gas hump no analysis
			Const Injection (3)	Inject Buildup - straight line matched Q = 23.45 gpm T = 117.2 ft²/d matched first minute of data
			Const. Injection Recovery	T = 41.0 ft²/d early data T = 45.7 ft²/d late data steady state analysis of this data resulted in T → (262-526) ft²/d (not a good match - Ball Park Estimates)
1618-1684.3	FRENCHMAN SPRINGS #2	STRADDLES MOST OF FS. #2 and Lower Half of FS #1 - contacts noted at 1636 FS #1/FS #2 and at 1667(?) about 30' of weathered, brecciated flow top, w/ clay and secondary mineralization (lost circulation at 1635'.)	Static Head	Equilibrated 406.8
			Air Lift Discharge	$\bar{Q} \simeq 50$ gpm
			recovery	gas hump
			Sub pumping Discharge	$\bar{Q} \simeq 7.5$ gpm (not much change in head)
			Recovery	
			Injection Testing	

(Air lift through injection testing: no analysis)

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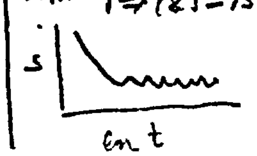
BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-12
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: FAUST

5. DATE: 7/23/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1508-1534	Roza - Frenchman Springs contact	Contact at 1517 vesicular clasts in altered black ash matrix, some mineralization	Static Head	405.7 from equilibrium meas.
			Air lift discharge recovery	not analyzed $\bar{Q} \simeq 22$ gpm not analyzed mud present
			Sub pump discharge recovery	$\bar{Q} \simeq 8$ gpm (Ball park estimate) steady state analys. T = 11.10 ft²/d straight line 8 ft²/d
			Injection Testing	No analysis
1384-1508	Roza	colonade/entablature	Static Head	no measurement
			Interval Pressure Test	no analysis
1328-1364	Priest Rapids - Roza	contact at 1341 well consolidated flow rubble, vesicular clasts	Static head	405.3 from equilibrium head
			Air lift discharge recovery	$\bar{Q} \simeq 11.5$ gpm gas hump No analysis
			Sub Pump discharge recovery	straight line T=138.3 ft²/d used only first 6 minutes (Ball Park Estimate) $\bar{Q}$ = 8.3 gpm No analysis
			Injection tests strip	no analysis
1217-1254	Priest Rapids Interflow	vesiculated, fractured, interflow zone oxidized at tip	Static Head	405.2 equilibrium head
			Air lift Discharge Recovery	no analysis gas hump
			Sub pump Discharge Recovery	$\bar{Q}$ = 7.0 gpm Theis curve 121 ft²/day, straight line 137.1 ft²/d
			Slug-Displacement tests	no analysis with leaky Hantush soln T ⇒ (125-153) ft²/d



Internal Letter

Rockwell International

Date: October 21, 1980

No: 10120-HSU-80-281

TO: (Name, Organization, Internal Address)

F. A. DeLuca

FROM: (Name, Organization, Internal Address, Phone)

W. W. Pidcoe 6-8765
F. A. Spane, Jr. 6-6265

Subject: Summary of Preliminary Hydrologic Testing Results, Grande Ronde Interflow, Test Interval No. 6 in DC-12.

This letter summarizes the preliminary results of hydrologic tests conducted in an interflow zone within the Grande Ronde Basalt to evaluate the effects of drilling fluid on hydraulic property and hydrochemical characterization. Initial coring contact with the interflow zone was at 2827.5 feet. At a depth of 2831 feet, complete loss of circulation occurred. The interflow zone was completely penetrated in approximately 3.4 hours.

The testing was conducted in two stages. The first stage of testing was after the borehole had been cored to a depth of 2843 feet below ground surface. At this point the borehole had been cored 181.5 feet using water without drilling mud. The second stage of testing followed circulation of drilling mud into the borehole under coring conditions.

The test interval was isolated utilizing a Husky single seal mechanical packer, seated above the zone of interest. The hole bottom, completed in dense basalt, formed the base of the test interval.

First Stage of Testing

For the first stage of testing the packer was set at 2818 feet below ground surface. The bottom of the hole at that time was 2843 feet. Air-lift pumping to remove drill-cutting debris and to develop the test horizon was conducted for 349 minutes, at an average discharge rate of 24 gpm. The next day, following the complete recovery from developmental pumping, a 24-hour air-lift pumping test was conducted, at an average discharge rate of 25 gpm. Water levels during the recovery period, following developmental and 24-hour air-lift pumping, rose above static water level within two minutes from the start of recovery and then slowly declined toward static, Figure 1. Water level recovery of this nature is not readily analyzed for hydraulic parameters by standard techniques. The measured static water level, as determined from the recovery data was 109.3 feet below ground surface.

Slug tests were conducted and the data analyzed to determine transmissivity by the underdampening technique for oscillating water level response (Van der Kamp, 1976). Transmissivity values determined by this technique ranged from 1.18×10^3 to 1.85×10^3 ft^2/day, with an average of 1.53×10^3 ft^2/day.

The packer was released following the first stage of hydraulic testing. Drilling mud was pumped into the borehole and 2 feet of basalt was cored over a period of 150 minutes. During this period there was no return of

drilling fluid to the surface and approximately 2000 gallons of fluid was pumped into the borehole. The mud was allowed to stand in the borehole for 14.5 hours. The next day drilling fluid was again pumped into the hole for 45 minutes with no returns. The total drilling fluid lost into the borehole was approximately 3000 gallons. The interval was exposed to the mud for 25.6 hours before the packer was re-set and clean-up pumping initiated.

Second Stage Testing

For the second stage of testing the packer was set at 2817.5 feet below ground surface. The bottom of the hole at that time was 2845 feet. Air-lift pumping to remove the drilling mud from the borehole and to develop the test horizon was conducted for 460 minutes at an average discharge rate of 23 gpm. The next day following complete recovery of developmental pumping, a 24-hour air-lift pumping test was conducted at an average discharge rate of 23 gpm. Water levels during the recovery period, following developmental and 24-hour air-lift pumping, rose above static water level within two minutes from the start of recovery and then slowly declined toward static, Figure 2. Water level recovery of this nature is not readily analyzed for aquifer properties using standard techniques. The measured static water level as determined from recovery data is 109.4 feet.

Slug testing was conducted and the data analyzed to determine transmissivity utilizing the underdampening technique for oscillating water level (Van der Kamp, 1976). Transmissivity determined by this method ranged from 1.32×10^3 to 1.38×10^3 ft^2/day, with an average of 1.354×10^3 ft^2/day.

Hydrochemical Characterization

Following hydraulic testing for both stages, water samples were collected to assess the influence of drilling mud on the major hydrochemical character of groundwater within the test horizon. Samples were collected utilizing either an argon or nitrogen-lift pumping method. Preliminary analyses for each stage of testing are shown in Table 1. Examination of data presented in Table 1 indicates no significant difference in hydrochemical content is evident for groundwater sampled from the test horizon prior to (First Stage Testing) or following introduction of drilling mud into the borehole (Second Stage Testing).

Summary of Test Results

Preliminary analysis of data obtained indicates that no discernible impact was evident through the use of drilling mud on the characterization of hydraulic properties and/or hydrochemistry for this test horizon. Specifically,

data which supports this conclusion include the similar:

1) measured static water levels (First Test = 109.4 feet, second test = 109.3 feet);

2) average discharge rates during the 24-hour air-lift pumping test (First Test = 25 gpm, Second Test = 23 gpm);

3) recovery water level responses following air-lift pumping; (Figures 1 & 2);

4) estimates of average transmissivity (First Test = 1.53×10^3 ft^2/day; Second Test = 1.35×10^3 ft^2/day); and

5) hydrochemical content (Table 1).

Bill — W. W. Pidcoe, Sr. Scientist

Frank — F. A. Spane, Jr., Sr. Hydrologist

WWP/FAS/jl

Att.

	First Stage Testing (without Drilling Mud)	Second Stage Testing (with Drilling Mud)
Date of Collection	9-2-80	9-10-80
Test Interval, feet below ground surface	2818 - 2843	2817.5 - 2845
Anions (mg/L)		
Alkalinity as $CaCO_3$	163.0	157.4
Chloride, Cl^-	160	154.2
Sulfate, $SO_4^=$	2.4	3.8
Fluoride, F^-	13.6	13.7
Nitrate, NO_3^-	<.5	<.5
Phosphate, $PO_4^{\equiv}$ (ortho)	<.5	<.5
Cations (mg/L)		
Sodium, Na^+	166.6	162.5
Potassium, K^+	12.8	13.3
Calcium, Ca^{++}	1.4	1.7
Magnesium, Mg^{++}	.05	.16

TABLE 1. Comparison Of Major Inorganic Contents For Groundwater Sampled From A Test Horizon Prior To And Following Introduction of Drilling Mud

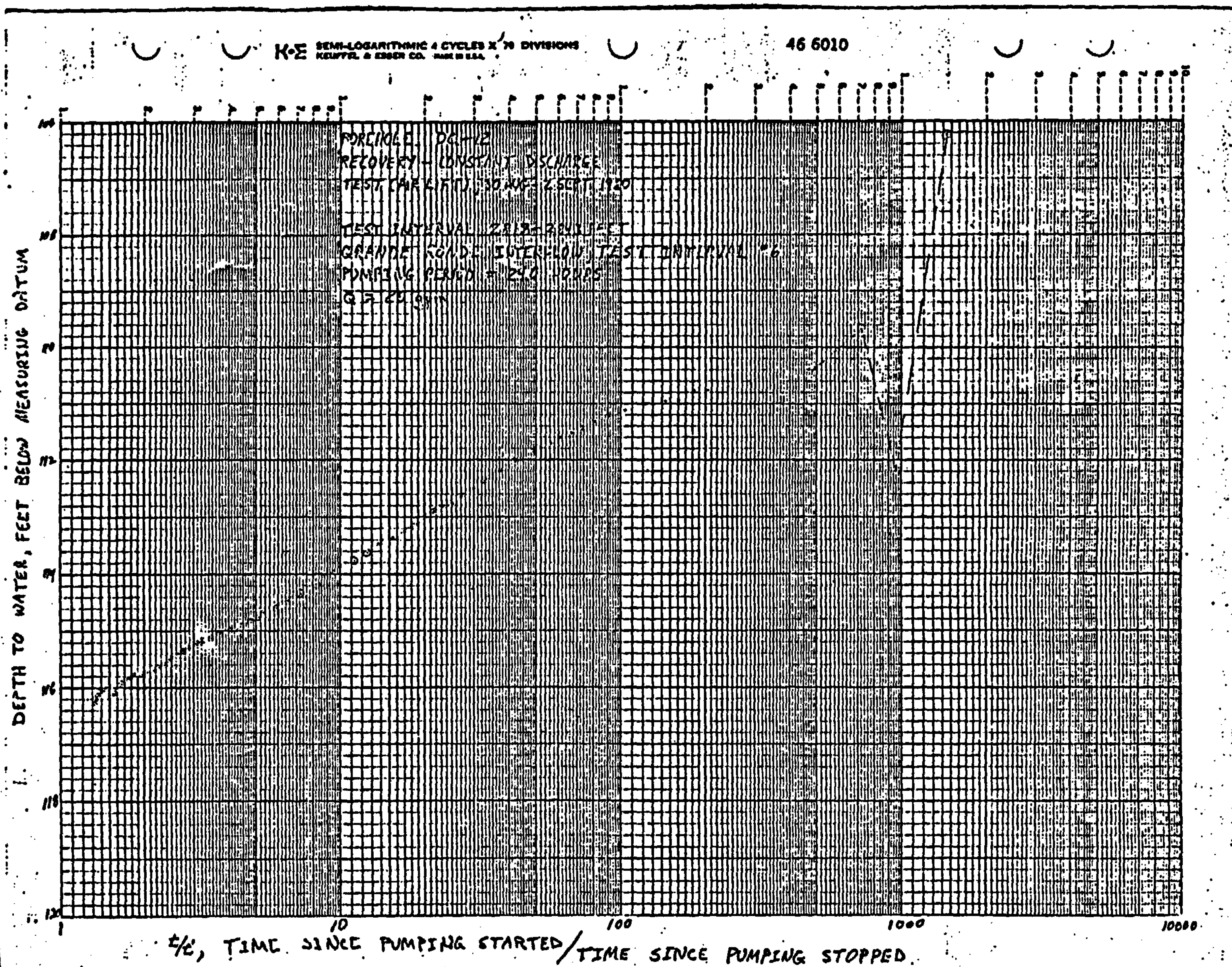


FIGURE 1. FIRST STAGE OF TESTING: SEMILOGARITHMIC PLOT OF RECOVERY WATER LEVEL MEASUREMENTS FOLLOWING A CONSTANT DISCHARGE TEST ON TEST INTERVAL 2818 — 2843 FEET IN BOREHOLE DC-12.

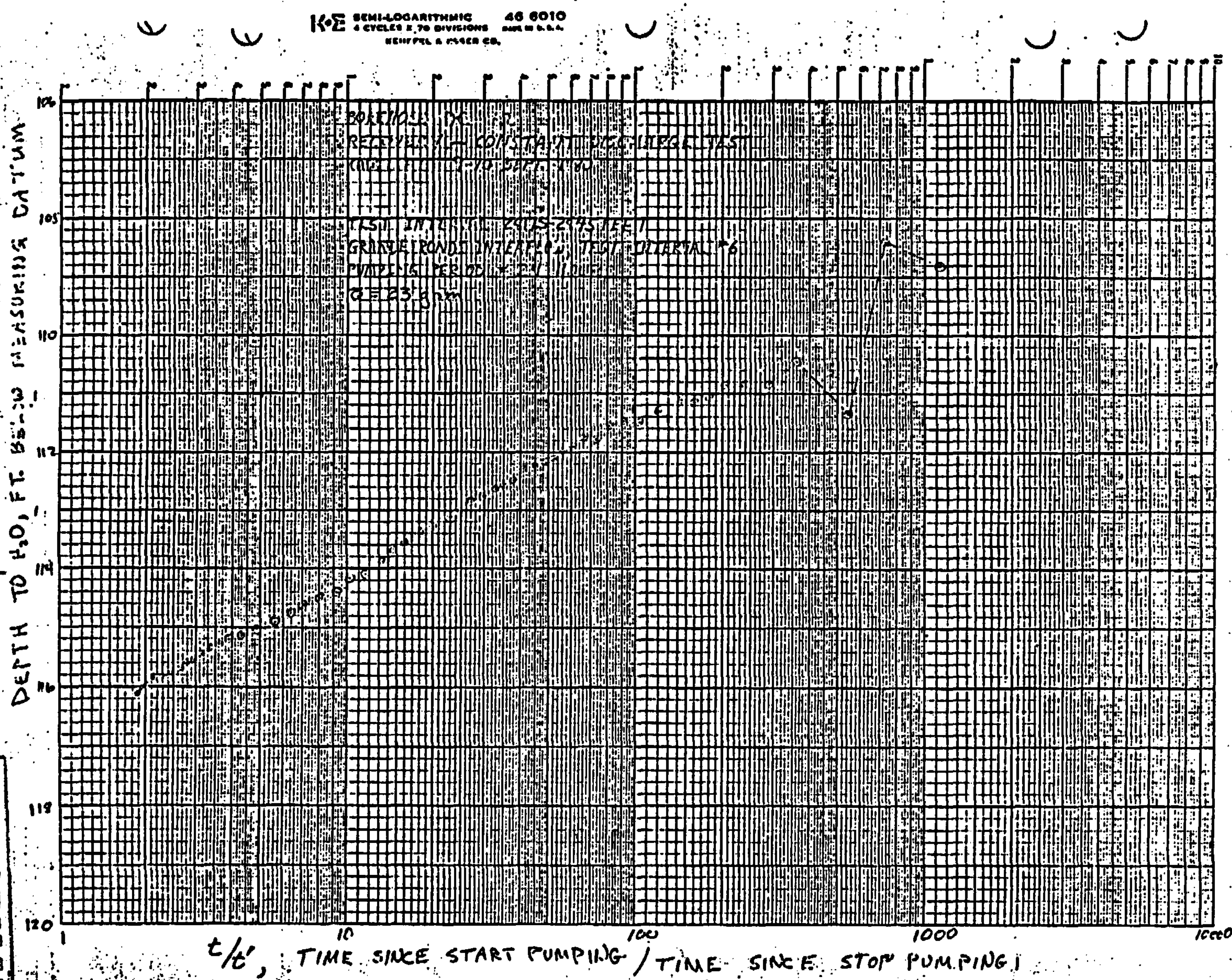


FIGURE 2. SECOND STAGE OF TESTING: SEMILOGARITHMIC PLOT OF RECOVERY WATER LEVEL MEASUREMENTS FOLLOWING A CONSTANT DISCHARGE TEST ON TEST INTERVAL 2817.5 – 2845 FEET IN BOREHOLE DC-12.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: DC-16 — Ground Surface Elevation 625.64 (1)
2. TOTAL DEPTH: 2559' — Planned to 4,000'
3. DEPTH OF CASING: 69' (5")
4. REVIEWER: Verma — 5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
668-835	Rattlesnake Ridge Interbed and Pomona Basalt Flowtop.		Head/M	448.3 Uncorrected.
B- 124'				
			Constant Discharge (Submersible Pump) Drawdown Cooper and Jacob (1946)	1490
			Constant Discharge Recovery Theis, (1935)	2240
			Slug Injection Vander Kamp - (1976) - underdampening -	1390 / 1550 / 1540
			Slug Withdrawl VanderKamp (1976 (Underdampening)	1460
		Average		1738
		Best Estimate		1738

water temp: °C 19.2

BOREHOLE REVIEW FORM

(2)

1. BOREHOLE NO.: DC-16
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
928-1021	Selah Interbed and Esquatzel basalt.		Head/M	438.8' uncorrected.
B-63'			Constant Discharge (Air Lift) Recovery (Theis, 1935)	10.6
			Constant Discharge (Submersible) Drawdown	289
			Constant Discharge Recovery Earlougher (1974	24.1
			Constant Discharge Recovery Nazareth (1981)	7.87
			Slug Injection Cooper et al (1967)	3.07
			Slug withdrawl Cooper et al (1967)	1.93

Average 66.8

Best estimate 10.6

Temperature 19.2

BOREHOLE REVIEW FORM

(3)

1. BOREHOLE No.: DC16
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1080–1212'	Cold Creek Interbed/ Umatilla Basalt Flowtop		Head/M	418.4' uncorrected 419.3 corrected.
B - 98'			Constant Discharge	2.5
			Specific Capacity (Theis, et al 63)	5.3
			Constant/Dis Recovery Theis (1935	3.9
			Pulse Test (Bredehoeft) and Papadopulos	6.2×10^{-2} 8.6×10^{-2} 4.6×10^{-2} 1.2×10^{-1}

Water temperature 24°C.

BOREHOLE REVIEW FORM

(4)

1. BOREHOLE NO.: DC-16
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma 5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS	
1395-1568	Mabton	Interbed	Head/m	436.9	uncorrected
b - 96 feet.			* Constant Discharge ~~Recovery~~ Drawdown Cooper and Jacob (1946)	49	
				200	
			Slug Tests Cooper, et.al.	183	
				158	
				206	
				294	
	Average Slug Test			208.2	
	Average			128.6	
	Best Estimate			128.6.	

Water temperature 28.6°C.

During the recovery phase after a constant
discharge in the beginning, water level
overshot the pretest level.
Gases were thought to be the main
cause of the problem. Constant Discharge
was restarted and then the recovery
curve was used to calculate T values.

BOREHOLE REVIEW FORM

(5)

1. BOREHOLE NO.: DC-16
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1690-1728	Priest Rapids Basalt Interflow		Head/M	381.7 uncorrected
6-2 feet.				
			constant/Dis Recovery (Theis)	4.3
			Slug ~~(...)~~ Injection (Cooper et al 1967	1.5
			Withdrawl	0.2

Slug tests under-estimated T and therefore best estimates are based on constant head discharge/recovery methods. Overdamping water level response to an instantaneous slug as described by Cooper et al (1967)

Water temperature 28.7 C

BOREHOLE REVIEW FORM

(6)

1. BOREHOLE NO.: DC-16
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma

5. DATE: 7/28/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1760 1828	Rosa Basalt Interflow	—	Head/M	402.6 uncorrected
b- 14 ft			Slug Tests Injection	2.0 x10[4]
				2.2 x10[4]
				1.9 x10[4]
			Withdrawl	1.5 x10[4]
				3.0 x10[4]

Water Temperature 28.7

No othertests were done for hydraulic parameters due to the gas problem. Water levels in recovery overshot the pretest static water level. Vander Kamp 1976 method of analysis was used for underdampening effect.

BOREHOLE REVIEW FORM

(7)

1. BOREHOLE No.: DC-16
2. TOTAL DEPTH:
3. DEPTH OF CASING:
4. REVIEWER: Verma 5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS	
1892 — 2000	Frenchman Springs 2	Basalt Interflow	~~[illegible]~~ Head/M	402.3	uncorrected
			Slug Test	4.4×10^3	
			Injection	4.2×10^3	
				4.3×10^3	
			Withdrawl	4.2×10^3	

b/ - 9 ft.

Vander Kamp 1976.
for underdampening.

No pump tests/recovery test were done. ~~[illegible]~~

Temperature 33.1.

BOREHOLE REVIEW FORM

(8)

1. BOREHOLE NO.: DC-16. Ground surface Elevation, 625.64'
2. TOTAL DEPTH: 2559' Planned to 4,000'
3. DEPTH OF CASING: cased down 69 feet (5")
4. REVIEWER: Verma 5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2105 — 2156	Interflow (French Man Spring unit 2	Dense Basalt	Head/M	402.9 uncorrected
			Slug Test Injection	7.8 22.8
			withdraw	21.4
b - 11 ft.				

x No constant discharge or constant head methods were used because of gas problems in pumping.
Water temperature 37

* water levels in recovery overshot the pretest static level.

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BOREHOLE REVIEW FORM

Vantage = 4' thick.

Surface Elevation 638.08 ft msl

Sheet ①

1. BOREHOLE NO.: RRL 2 — Surface Elevation
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713 (bottom of Vantage)
4. REVIEWER: R. Williams
5. DATE: 7/22/82

Temperature NOT OK - too soon after drilling. approximately 45° C.

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2981'-3020' depth.	Sentinel Bluffs Umtanum Flow Top		observed head 398.8 ft msl (should be equilibrated.)	Interval confirmed on entire suite of logs run neutron log low + examination of core - OK no circulation lost in
			overpressure pulse test; fill tube to water; add pressure via chamber + watch decay.	Overpressure pulse test T = 8.3x10⁻¹ ft²/day b = 14'; K = 5.9x10⁻² ft/day
			constant head injection test	T = 1.3x10⁻² ft²/day (Lohman '72) K = 9.7x10⁻⁴ ft/day; T = 5.2 x10⁻² ft²/day (Ziegler '76) K = 3.7x10⁻³ ft/day
			normal slug injection test with 19.8 gals.	T = 2.3x10⁻³ K = 1.6x10⁻⁴ ft/day (Cooper et al 1967)
			best estimate	T = 2.3x10⁻¹ ft²/day K = 1.6x10⁻² ft/day Temp. approx 45°C. defensible state of art single hole test.

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~~Steve stent~~

no mud seal added.

Did mud seal is ground up paper added to mud to facilitate circulation in some permeable units in this hole.

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2719-2913	upper G.R. interflows (2) (next interflow up from above one)		Constant Q airlift pump test at Q = 9.1 gpm for 2700 minutes	Preliminary T = 3.8 ft²/day K = .1 ft/day but values are questionable due to gas in water. Circulation was lost in lower of 2 flow tops tested. Steve thinks though T was too low. b value used for K was 33 feet taken from log.
			observed hydraulic head = 397.9 ft. msl Temp not accurate yet	
			4 slug injection tests Van der Kamp (1976)	T = 855 to 509 ft²/day. K = 23.1 to 13.8 ft/day

Total drilling fluid lost was 16,500 over 1 day. 100% loss of circulation

This is a static level over 1 day after development. Also recovery curve was projected back to where $T/T' = 1$.

Sheet ②

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: RRL2
2. TOTAL DEPTH: 3992
3. DEPTH OF CASING: 2713
4. REVIEWER: R. Williams
5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2668'-2713' packer; 2683'-2687' interflow	Vantage interbed + flow top	fine grained sediments + fracture flow top	Constant drawdown with airlift, variable Q.	Lohman 1952 technique; T = 5X10⁻¹ ft²/day; b = 18' so K = 3.1X10⁻² ft/day
			Recovery from constant drawdown using Theis 1935 as presented by Jacob 1944	T = 2.4X10⁰ ft²/day; K = 1.3 X10⁻¹ ft/day
			4 Slug injection tests	T ranged from 2.5X10⁻¹ to 6.7X10⁰ ft²/day; K ranged from 1.4X10⁻² to 3.7X10⁻¹ ft/day.
			2 Slug withdrawals tests	T ranged from 1.4X10⁻¹ to 2.7X10⁰ ft²/day; K ranged from 7.8X10⁻³ to 1.2X10⁻¹ ft/day. no mud seal added

Observed Hydraulic head 398.9 ft. MSL
Should be equilibrated
OK

Average T value used as best estimate was 1.7 ft²/day

best estimate. K = 9.4X10⁻² ft/day

Temperature is considered reliable at 45.3°C at 2688' depth.

Sheet 3

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: RRL 2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713 (bottom of Vantage)
4. REVIEWER: RW
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2244 - 2644 = Packer 4 Interflow zones straddled	4 Lower Frenchman Springs fm Interflow zones	Interflow brecciated Vesicular Basalt	2 constant discharge ~~air~~ airlift drawdowns followed by airlift (constant Q) test. Q for 1st test was 31 gpm. Q for 2nd test was 35 gpm. 60° V notch ~~weir~~ weir was used to measure Q	Lost circulation at 2381, Loss rate = 1x10^5 gallons Water level rose ~~rap~~ rapidly when pumping was shut down. It then declined rapidly & began to rise again. These data are not considered reliable or analyzable.
			2 withdrawal + 2 injection slug tests using Van der Kamp, 1976 method	T = 1.78 x 10^3 to 2.4 x 10^3 ft²/day b = 65' K = 2.7 x 10' to 3.5 x 10' ft/day These values may be too high. too

best estimate T is 2.1 x 10^3 ft²/day
K = 3.2 x 10' ft/day →

observed Hydraulic head ≈ 410.1' msl
OK equilibration; high T.

"Dix mud seal" was added to increase circulation, may affect K

Sheet 4

BOREHOLE REVIEW FORM

1. BOREHOLE No.: RRL 2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713
4. REVIEWER: RW

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1907-2222	upper Fr. Springs Interflow	4 interflow zones, vesicular + brecciated basalt		Lost circulation at 1922, regained it at 2104; lost it again 2217 completely. Drilling was halted due to bit damage. Mud additives were used to regain circulation. High T values (two).
			Constant discharge ~~?~~ airlift pump test; it rose above static at shut off.	Tests not analyzable due to deviation from Theory
		over dampt	2 slug withdrawal tests and 2 injection slug tests (Cooper Papadopulos 1967)	T = 1000 ft²/day b = 32' K = 3x10' ft/day
		opened	Hydraulic head = 402.5 equilibration OK due to high T.	"mud seal" added to increase circulation. Mud seal is "Dix mud seal"; it is paper fragments.

BOREHOLE REVIEW FORM

Sheet 5

Surface Elev

1. BOREHOLE NO.: RRL 2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713
4. REVIEWER: R. Williams
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1735 - 1773	Rosa flow top		Hydraulic head 403.9' msl. High T, no problem with equilibration.	Bentonite mud only; no mud seal added.
			Constant ~~head~~ Q airlift test. But forced above static when pump was shut off (overshot)	Test disregarded because of overshoot, data not analyzable by Jacob method
			2 injection & 2 withdrawal slug tests using (Van der Kamp solutions, 1976) — Table 1 page 23 →	$T = 2.4 \times 10^3$ to 1.8×10^3 ft²/day; $b = 10'$; $K = 2 \times 10^2$ ft/day
Corroborative only			Constant ~~head~~ Q injection test at 2 different heads ~~[illegible]~~ that were allowed to reach steady state; Q = 5gpm & Q = 8gpm (Ziegler, 1976)	$T = 4.0 \times 10^3$ to 2.9×10^3 ft²/day; $b = 10'$; $K = 2.9 \times 10^2$

RHO (strict) best estimate is 2.4×10^3.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: RRL2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING:
4. REVIEWER: RW

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1534'-1714'	Priest Rapids Interflow		observed Hydraulic head = 401.1 equilibrated.	Circulation was not lost
			2 constant discharge airlift tests at 4 gpm; plug both overshot.	Test Discarded; not analyzable due to overshoot.
			4 injection slug tests 1 withdrawal slug test. (Van der Kamp, 1976 oscillation)	$T = 5.6 + 8.8 \times 10^2$ ft²/day average used $= 6.5 \times 10^2$ $b = 25$ feet, $K = 2.6 \times 10^1$ ft/day
1364'-1540'	Mabton (see note)		observed Hydraulic head = 417' msl, equilibrated.	Lower 1/2 of Mabton is clay; it squeezed off from 1499 to 1540 so only effective interval is 1399' to 1499'.
			constant discharge airlift pump test at .043 gpm. Recovery curve used by Jacob method.	$T = 2.9 \times 10^{-2}$ ft²/day $b = 50'$ $K = 5.8 \times 10^{-4}$ ft/day
			Injection slug test 2.6 gal of water added. Solved by Cooper Papadopulos (1967)	$T = 7.0 \times 10^{-3}$ ft²/day $K = 1 \times 10^{-4}$ ft/day
			Pulse test	$T = 2.1 \times 10^{-1}$ ft²/day. $K = 4.0 \times 10^{-3}$ ft/day

RHO best estimate is $T = 6.5 \times 10^2$ $b = 25'$

Best estimate $T = 2.9 \times 10^{-2}$ ft²/day
$K = 5.8 \times 10^{-4}$ ft/day

Sheet 7

BOREHOLE REVIEW FORM

1. BOREHOLE No.: RRL 2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713
4. REVIEWER: R. Williams
5. DATE: 7/22/82

INTERVALS	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
(to be tested) 3240-3340	Flow bottom of Through Runner			
3340-3520	mid Grande Ronde			
3520-3560	McCoy Canyon Flow Top			
35-80 to 3770	flow top of Umtanum } 4 tests to be performed			
3752-3839	Entablature Colonnade - 3760 to 3800 will be tested,			

3800-3830 will be tested also because of flip in log at 3820.

3830-3870 flow bottom of Umtanum.

BOREHOLE GEOPHYSICAL LOGS
BOREHOLE: RRL-2

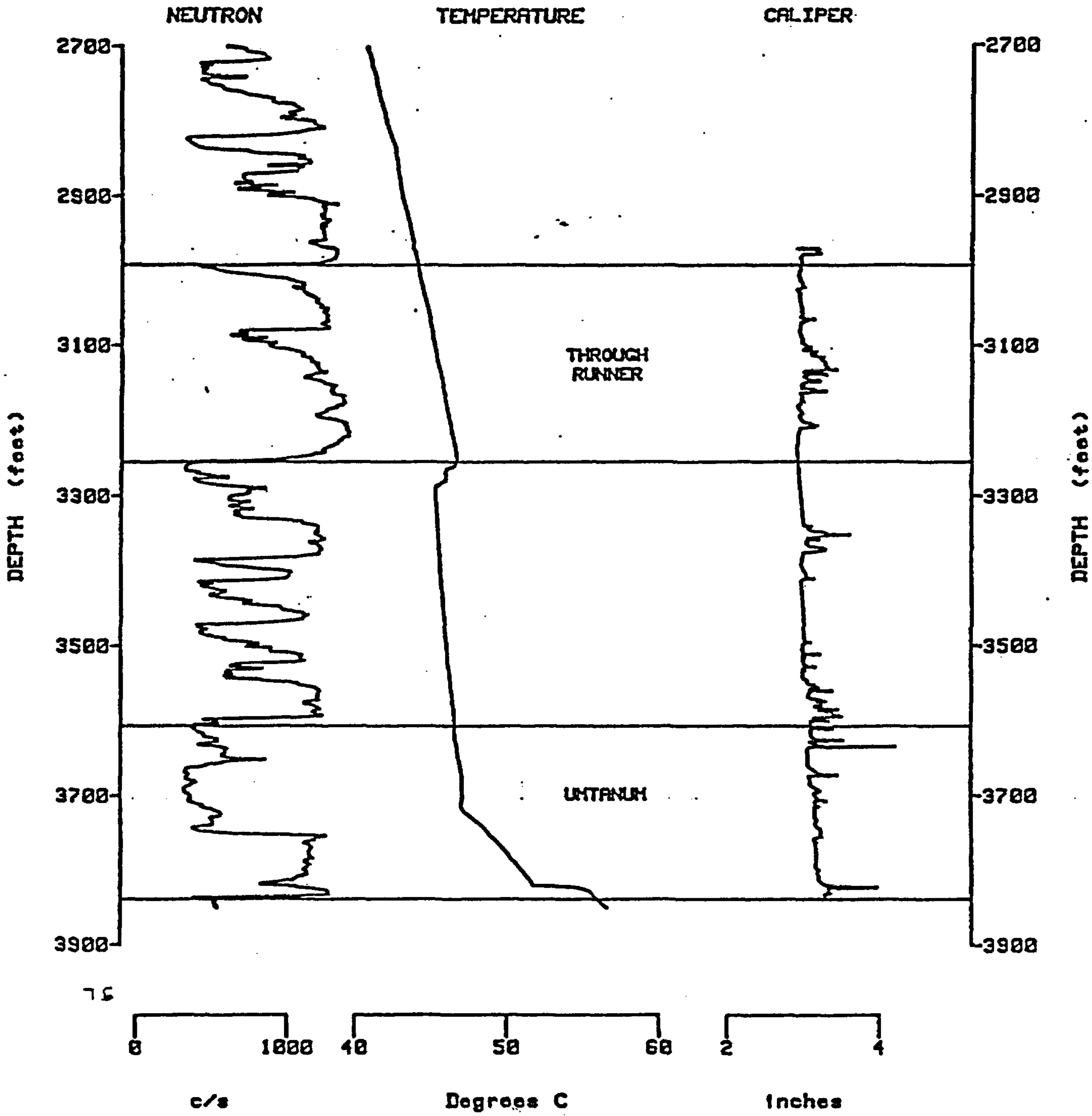


TABLE 1. Summary of Hydraulic Properties for Various Test Intervals in Borehole RRL-2 as of May, 1982

Test Interval	Depth Interval (ft)	Effective Thickness (ft)	Hydraulic Head (ft,MSL)	Vertical Hydraulic Gradient (ft)	Transmissivity (ft^2/day)
Mabton Interbed	1364-1340	50	417.5	20.5	2.9×10^{-2}
Priest Rapids Interflow	1574-1714	25	401.1	4.1	6.5×10^{2}
Roza Interflow	1735-1773	23	404.3	7.3	2.4×10^{3}
Upper Frenchman Springs Interflow	1907-2222	32	402.5	5.5	1.1×10^{3}
Lower Frenchman Springs Interflow	2244-2644	65	400.1	3.1	2.1×10^{3}
Vantage Interbed	2665-2713	18	398.9	1.9	1.7×10^{0}
Upper Grande Ronde Interflow	2719-2913	57	397.1	0.1	8.6×10^{2}
Flowtop of the "through runner"	2931-3020	10	397	0	1×10^{-2}

TABLE 2. Summary of Hydraulic Properties for the Upper Saddle Mountains Basalt in Borehole DC-16A

Test Interval	Depth Interval (ft)	Effective Thickness (ft)	Hydraulic Head (ft, MSL)	Vertical Hydraulic Gradient (ft)	Transmissivity (ft^2/day)
Rattlesnake Ridge Interbed	668-835	124	448	51	1.7×10^3
Selah Interbed	928-1021	63	439	42	1.1×10^1
Cold Creek Interbed	1080-1212	98	418	21	4.0×10^0

TABLE 3. Summary of Predicted Hydraulic Properties for the Lower Grande Ronde Basalt in Borehole RRL-2

Test Interval	Depth Interval (ft)	Effective Thickness (ft)	Hydraulic Head (ft, MSL)	Vertical Hydraulic Gradient (ft)	Transmissivity (ft^2/day)
Middle Grande Ronde Interflows	3235-3465	60	397	0	1×10^1
McCoy Canyon Flowtop	3465-3500	30	397	0	1×10^1
Umtanum Flowtop	3610-3680	50	397	0	1×10^1
Very-High Mg Flowtop	3825-3845	10	397	0	1×10^0

~~Figs~~ = 4' thick.

BOREHOLE REVIEW FORM

Surface Elevation 638.08 ft msl — Sheet 6

BOREHOLE No.: RRL 2 — Surface Elevation

2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713 (bottom of Vantage)
4. REVIEWER: R. Williams
5. DATE: 7/22/82

Temperature not OK - too soon after drilling; approximately 45° C.

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2981'-3020' depth.	Sentinel Bluffs Thorgan Runner Flow Top	should be equilibrated. →	ofsewind head 396.8 ft msl	Interval centered on cutting, suite of logs run neutron log low + examination of core - OK; no circulation lost in
			overpressure pulse test; fill tube to water; add pressure via chamber + watch decay. →	Overpressure pulse test T = 8.3x10⁻¹ ft²/day; b = 14'; K = 5.9x10⁻² ft/day
			constant head injection test →	T = 1.3x10⁻² ft²/day (Lohman '52); K = 9.7x10⁻⁴ ft/day; T = 5.2x10⁻² ft²/day (Ziegler '76) K = 3.7x10⁻³ ft/day
			~~Slug~~ normal injection test with 19.8 gals.	T = 2.3x10⁻³; K = 1.6x10⁻⁴ ft/day. (Cooper et al 1967)
~~Stove Stint~~		no mud seal added. Did mud seal is ground up paper added to mud to facilitate circulation in some permeable units in this hole.	best estimate	T = 2.3x10⁻¹ ft²/day; K = 1.6x10⁻² ft/day; Temp. approx 45°C. defensible state fast single hole test.
2719-2913	upper G.R. interflows (2) (next interflows from above one)	Total drilling fluid lost was 16,500 over 1 day. 100% loss of circulation. This is a ~~pore~~ static level over 1 day after development. Also recovery curve was projected back to where T/T' = 1. →	Constant Q airlift Pump Test at Q = 9.1 gpm for 2700 minutes	Preliminary T = 3.8 ft²/day; K = .1 ft/day; but values are questionable due to gas in water. Circulation was lost in lower of 2 flow tops tested. Stove stint Thorgan T was too low. b value used for K was 33 feet taken from log.
			ofsewind hydraulic head = 397.9 ft. msl; Temp ~~not~~ accurate yet	
			4 Slug injection Tests Vanderkamp (1976)	T = 855 to 509 ft²/day. K = 23.1 to 13.8 ft/day

Sheet 6

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: RRL2
2. TOTAL DEPTH: 3992
3. DEPTH OF CASING: 2713
4. REVIEWER: R. Williams
5. DATE:

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2665'-2713' packer; 2683'-2687' ± interbed	Vantage Interbed + flow top	fine grained Sediments ± fracture flow top	Constant drawdown with airlift, variable Q.	Lohman 1952 Technique $T = 5 \times 10^{-1}$ ft²/day; b = 18' so $K = 3.1 \times 10^{-2}$ ft/day
			Recovery from constant drawdown using Theis 1935 as presented by Jacob 1944	$T = 2.4 \times 10^{0}$ ft²/day; $K = 1.3 \times 10^{-1}$ ft/day
			4 Slug injection tests	T ranged from 2.5×10^{-1} to 6.7×10^{0} ft²/day; K ranged from 1.4×10^{-2} to 3.7×10^{-1} ft/day.
			2 Slug withdrawals tests	T ranged from $1.4 \times 10^{\cdot}$ to 2.7×10^{0} ft²/day; K ranged from $2.8 \times 10^{-}$ to 1.2×10^{-1} ft/day. no mud seal added

Observed Hydraulic head 398.9 ft. MSL
Should be equilibrated
OK

Average T value used as best estimate was 1.7 ft²/day
best estimate. $K = 9.4 \times 10^{-2}$ ft/day

Temperature is considered reliable at 45.3°C at 2688' depth.

Sheet 3

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: RRL 2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713 (bottom of Vantage)
4. REVIEWER: RW
5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
2244 - 2644 = packer 4 interflow zones straddled	4 Lower Frenchman Springs fm interflow zones	Interflow breccia/Vesicular Basalt	2 constant discharge ~~airlift~~ airlift drawdowns followed by airlift (constant Q) test. Q for 1st test was 31 gpm. Q for 2nd test was 35 GPM. 60° V notch ~~weir~~ weir was used to measure Q	Lost circulation at 2381, Loss rate = 1X10[5] gallons Water level rose ~~rapidly~~ rapidly when pumping was shut down. It then declined rapidly & began to rise again. These data are not considered reliable or analyzable
			2 withdrawal + 2 injection slug tests using Van der Kamp, 1976 method	T = 1.78 X 10[3] to 2.4 X 10[3] ft[2]/day b = 65' K = 2.7 X 10' to 3.5 X 10' ft/day These values may be too high, too

best estimate T is 2.1 X 10[3] ft[2]/day
K = 3.2 X 10' ft/day →

observed Hydraulic head = +400.1' msl
OK equilibration; high T.

"Dix mud seal" was added to increase circulation may affect K

Sheet 4

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: RRL 2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713
4. REVIEWER: RW

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1907-2222	upper Fr. Springs Interflow	4 interflow zones, Vesicular + brecciated basalt		Lost circulation at 1922, regained it at 2104; lost it again 2217 completely. Drilling was halted due to bit damage. mud additives were used to regain circulation. High T values (?).
			Constant discharge ~~[illegible]~~ airlift Pump test; it rose above static at shut off.	Tests not analyzable due to deviation from Theory
	overdamp		2 Slug withdrawal tests and 2 injection slug tests (Cooper Papadopulos 1967)	T = 1000 ft²/day b = 32' K = 3x10' ft/day
			opened Hydraulic head = 402.5 equilibration OK due to high T.	"mud seal" added to increase circulation. "mud seal is "Dix mud seal"; it is paper fragments

BOREHOLE REVIEW FORM

Sheet 5

1. BOREHOLE No.: RRL 2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713
4. REVIEWER: R. Williams

Surface Elev

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1735 - 1773	Rosa flow top		Hydraulic head 403.9' msl. High T, no problem with equilibration.	Bentonite mud only; no mud seal added.
			constant ~~flow~~ Q airlift test. But turned above static when pump was shut off (overshoot)	Test disregarded because of overshoot, data not analyzable by Jacob method
			2 injection + 2 withdrawal slug tests using (Van der Kamp solutions, 1976) Table 1 page 23	$T = 2.4 \times 10^3$ to 1.8×10^3 ft²/day; b = 10'; $K = 2 \times 10^2$ ft/day
Corroborative only			Constant ~~head~~ Q injection test at 2 different heads ~~xxx~~ that were allowed to reach steady state. Q = 5 gpm + Q = 8 gpm (Ziegler, 1976)	$T = 4.0 \times 10^3$ to 2.9×10^3 ft²/day; b = 10'; $K = 2.9 \times 10^2$

RHO (strict)
best estimate is 2.4×10^3.

BOREHOLE REVIEW FORM

1. BOREHOLE NO.: RRL2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING:
4. REVIEWER: RW

5. DATE: 7/22/82

INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
1534-1714'	Priest Rapids Interflow		observed Hydraulic head = 401.1 equilibrated.	Circulation was not lost
			2 constant discharge airlift tests at 4 gpm; they both overshot.	Test Discarded; not analyzable due to overshoot.
	RHO test estimate is $T = 6.5 \times 10^2$ $b = 25'$		4 injection slug tests 1 withdrawal slug test. (Van der Kamp, 1976 oscillation)	$T = 5.6$ ~~8.8~~ $\times 10^2$ ft²/day average used = 6.5×10^2 b = 25 feet, $K = 2.6 \times 10^1$ ft/day
1364'-1540'	Mabton (see note)		observed Hydraulic head = 417' msl, equilibrated.	Lower 1/2 of Mabton is clay; it squeezed off from 1499 to 1540 so only effective interval is 1399' to 1499'.
			constant discharge airlift pump test at 0.4 gpm. Recovery curve used by Jacob method.	$T = 2.9 \times 10^{-2}$ ft²/day b = 50' $K = 5.8 \times 10^{-4}$ ft/day
			Injection slug test 2.6 gal of water added. Solved by Cooper Papadopulos (1967)	$T = 7.0 \times 10^{-3}$ ft²/day $K = 1 \times 10^{-4}$ ft/day
			Pulse Test	$T = 2.1 \times 10^{-1}$ ft²/day $K = 4.0 \times 10^{-3}$ ft/day

Best estimate $T = 2.9 \times 10^{-2}$ ft²/day
$K = 5.8 \times 10^{-4}$ ft/day

Sheet 7

BOREHOLE REVIEW FORM

1. BOREHOLE No.: RRL 2
2. TOTAL DEPTH: 3972
3. DEPTH OF CASING: 2713
4. REVIEWER: R. Williams 5. DATE: 7/22/82

INTERVALS	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
(to be tested)				
3240-3340	Flow bottom of Through Runner			
3340-3520	mid Grande Ronde			
3520-3560	McCoy Canyon Flow Top			
3580 to 3770	flow top of Umtanum } 4 tests to be performed			
3752-3839	Entablature Colonnade - 3760 to 3800 will be tested.			

3800-3830 will be tested also because of flip in log at 3820.

3830-3870 flow bottom of Umtanum.

BOREHOLE GEOPHYSICAL LOGS
BOREHOLE: RRL-2

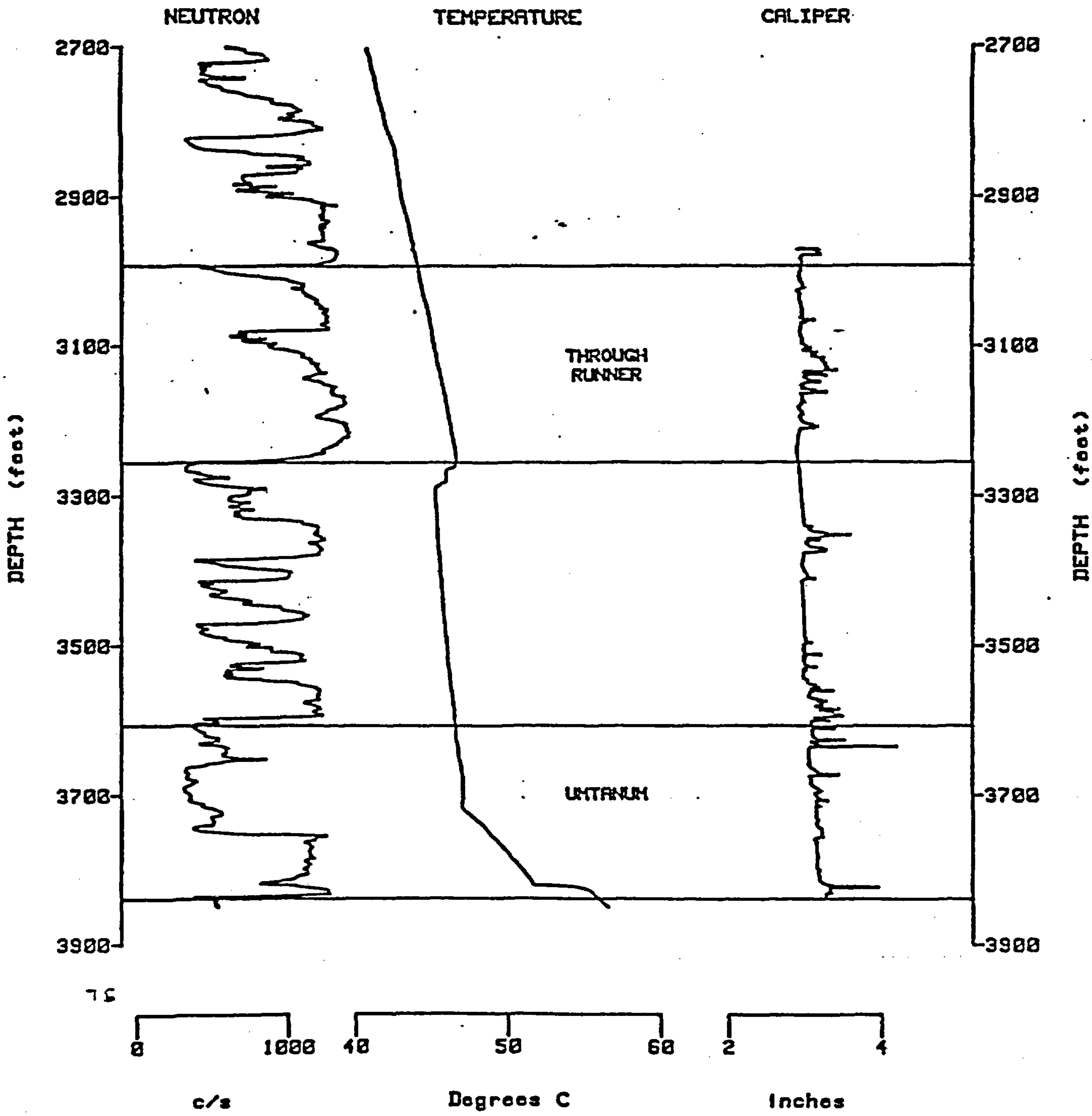


TABLE 1. Summary of Hydraulic Properties for Various Test Intervals in Borehole RRL-2 as of May, 1982

Test Interval	Depth Interval (ft)	Effective Thickness (ft)	Hydraulic Head (ft,MSL)	Vertical Hydraulic Gradient (ft)	Transmissivity (ft^2/day)
Mabton Interbed	1364-1340	50	417.5	20.5	2.9×10^{-2}
Priest Rapids Interflow	1574-1714	25	401.1	4.1	6.5×10^{2}
Roza Interflow	1735-1773	23	404.3	7.3	2.4×10^{3}
Upper Frenchman Springs Interflow	1907-2222	32	402.5	5.5	1.1×10^{3}
Lower Frenchman Springs Interflow	2244-2644	65	400.1	3.1	2.1×10^{3}
Vantage Interbed	2665-2713	18	398.9	1.9	1.7×10^{0}
Upper Grande Ronde Interflow	2719-2913	57	397.1	0.1	8.6×10^{2}
Flowtop of the "through runner"	2931-3020	10	397	0	1×10^{-2}

TABLE 2. Summary of Hydraulic Properties for the Upper Saddle Mountains Basalt in Borehole DC-16A

Test Interval	Depth Interval (ft)	Effective Thickness (ft)	Hydraulic Head (ft, MSL)	Vertical Hydraulic Gradient (ft)	Transmissivity (ft^2/day)
Rattlesnake Ridge Interbed	668-835	124	448	51	1.7×10^3
Selah Interbed	928-1021	63	439	42	1.1×10^1
Cold Creek Interbed	1080-1212	98	418	21	4.0×10^0

TABLE 3. Summary of Predicted Hydraulic Properties for the Lower Grande Ronde Basalt in Borehole RRL-2

Test Interval	Depth Interval (ft)	Effective Thickness (ft)	Hydraulic Head (ft, MSL)	Vertical Hydraulic Gradient (ft)	Transmissivity (ft^2/day)
Middle Grande Ronde Interflows	3235-3465	60	397	0	1×10^1
McCoy Canyon Flowtop	3465-3500	30	397	0	1×10^1
Umtanum Flowtop	3610-3680	50	397	0	1×10^1
Very-High Mg Flowtop	3825-3845	10	397	0	1×10^0

Use DC-15 for data

Table 4

SWIFT INPUT FOR RHO MODEL

LAYER #	THICKNESS(ft)		K_h (ft/day)	K_v (ft/day)	POROSITY
1	300		1.0×10^{1}	1.0×10^{0}	.25
2	122	421	1.0×10^{-6}	1.0×10^{-3}	.05
3	96	518	1.0×10^{-3}	1.0×10^{-4}	.20
4	366	884	1.0×10^{-6}	1.0×10^{-3}	.05
5	72	956	1.0×10^{0}	1.0×10^{-1}	.25
6	144	1100	1.0×10^{-3}	1.0×10^{-4}	.20
7	462	1562	1.0×10^{-6}	1.0×10^{-3}	.05
8	330	1892	1.0×10^{0}	1.0×10^{-1}	.25
9	308	2200	1.0×10^{-6}	1.0×10^{-3}	.05
10	350	2550	1.0×10^{0}	1.0×10^{-1}	.25
11	1150	3700	1.0×10^{-6}	1.0×10^{-3}	.05
12	350	4050	1.0×10^{0}	1.0×10^{-1}	.25
13	950	5000	1.0×10^{-6}	1.0×10^{-3}	.05

RHO-LD-44 INPUT

LAYER #	THICKNESS(ft)	K_h (m/s)	K_v (m/s)	POROSITY
Saddle Mts.	984*	1.0×10^{-8}	1.0×10^{-11}	?
Wanapum	1150*	3.0×10^{-9}	3.0×10^{-12}	?
Grande Ronde	3220*	1.0×10^{-9}	1.0×10^{-12}	.01

*Approximate from graphics.

Table 3
Current NRC Layering

Layer 1	Alluvial Water Table Aquifer	300 ft.
Layer 2	Dense Basalt Saddle Mountains Fm.	~~192~~ ft.
Layer 3	Interbeds Saddle Mountains Fm.	96 ft.
Layer 4	Dense Basalt Saddle Mountains Fm.	366 ft.
Layer 5	Interflows Saddle Mountains Fm.	72 ft.
Layer 6	Interbeds Saddle Mountains/Wanapum	144 ft.
	Mabton	
Layer 7	Dense Basalt Wanapum Fm.	462 ft.
	Priest Rapids, Roza Interflows	
Layer 8	Interflows Wanapum Fm.	330 ft.
	Upper Frenchman Springs	
Layer 9	Dense Basalt Wanapum Fm.	308 ft.
	Lower Frenchman Springs	
Layer 10	Interflows Grande Ronde Fm.	350 ft.
Layer 11	Dense Basalt (Umtanum included)	1150 ft.
Layer 12	Interflows Grande Ronde Fm.	350 ft.
Layer 13	Dense Basalt Grande Ronde Fm.	950 ft.

OB 15

		T	Kh
Mastan/PK		1.5×10^{3}	2×10^{1}
PK		2.4×10^{3}	6.7×10^{1}
Roga		1.5×10^{3}	4×10^{1}
Roga colonafelentab	Very good value	3.8×10^{-5}	1×10^{-6}
FS 2		1×10^{2}	3×10^{0}
FS 3		3.5×10^{2}	2.4×10^{1}
FS 4		1.7×10^{2}	5.5×10^{0}
FS 5		9×10^{1}	1.3×10^{0}
FS 6		7×10^{2}	8.8×10^{0}
FS 7	Fair	6.7×10^{-2}	7×10^{-3}
FS 8	Fair to poor	1.3×10^{-4}	6.6×10^{-4}
Vanbyz 16K		6.6×10^{-5}	5.1×10^{-6}

DC 7/8

Test	Depth	b	h	T	Kh
GR	2780-3448 2734-4100.5	~~44~~		4.5×10^{0}	3.5×10^{-3} cm/sec
"	4170-4357	137.6		4.8×10^{-3}	3.5×10^{-5}

AC-14

		T	K
SB	2880-2975	2.4×10^{-1}	4.1×10^{-3}
	2457-2574	3×10^{-1}	
	2410-2513	4×10^{0}	1.7×10^{-1}
	2355-2405	2.4×10^{-1}	1.1×10^{-2}
FS-U-SB(?)	2120-2335	6×10^{2}	1.56×10^{1}
FS 6		2.4×10^{3}	4.3×10^{1}
FS 5		4×10^{3}	3.4×10^{1}
FS 4		2.3×10^{2}	
FS 3		1.2×10^{2}	4×10^{0}
FS 2		7×10^{2}	1.2×10^{1}
Koza		9.3×10^{3}	2.2×10^{2}
AR		1.8×10^{3}	2.4×10^{2}
AR 2		2.9×10^{3}	2.1×10^{3}
AR 1	$h=1$	6.3×10^{2}	6×10^{2}
Mubton / AR		2×10^{1}	2×10^{-1}

DC-3

	T	K	S
Unitarium Colonnade/Entablature	4.9×10^{-6}	9.6×10^{-8}	3.5×10^{-7}
		10^{-11}	

DC-1

Test	Depth	s	h	T	K_h
Bottom of Ellingson	820-1190		402		
top of W	1130-1190		409		
10% 90% R-FS	1330-1520		405	7×10^{0}	4.2×10^{-2}
FS	1560-1750		405		
FS	1760-1950		407		
40% 60% FS+V-GR	1970-2160		407	3.8×10^{1}	2.3×10^{-1}
GR	2170-2225		406		
GR	2450-2610		403		
GR	2600-2780		402	1.3×10^{1}	1.4×10^{-1}
	2730-2910		411	1×10^{-1}	1.8×10^{-3}
	3140-3230		411	6.9×10^{1}	8.6×10^{-1}
	3166-3196		407	1.7×10^{-1}	2.4×10^{-2}
	3206-3246		403		
	3320-3451		408	5.8×10^{-1}	5×10^{-3}
	3774-3934		379	4.4×10^{-1}	3.5×10^{-3}
	[illegible]		366	[illegible]	[illegible]

OC-2 limited use — questionable data

Test	depth	S	h	T	K_h
GR Flowing ~~IS~~	2344-2376			4.18×10^{-1} 9.8×10^{-3}	1.5×10^{-2} 3.1×10^{-4}
GR [illegible]	2376-2409			1.8×10^{-1} 4×10^{-3}	5.7×10^{-3} 1.3×10^{-4}
GR	2954-3067			9.7×10^{-2} 2.1×10^{-2}	1.3×10^{-3} 4×10^{-2}
GR	3019-3071			4×10^{-5} 8×10^{-7}	7×10^{-7} 1.5×10^{-8}
GR	3069-3122			9.2×10^{-5} 2.3×10^{-6}	1.7×10^{-6} 4.2×10^{-8}
GR	3166-3170			4.4×10^{-5} 2.2×10^{-6}	8.2×10^{-7} 4.0×10^{-8}

DC-16

Frst	Depth	b	h	vertical gradient	T	Kh
Mabton	1395-1568	96'	437.9		1.3×10^2	1.3×10^0
Priest Rapids	1690-1728	2'	387.7		4×10^0	2×10^0
Roza	1760-1878	14'	402.6		$2? \times 10^4$	1.5×10^3
Frenchman Springs 2	1892-2006	9'	402.3		4.3×10^3	4.8×10^2
Frenchman Springs	2105-2156	11'	402.9		17.3×10^0	1.6×10^0

DC-15

Test ~~Flow top~~ ~~Unknown~~	Depth ~~2461-3113~~	s	h	T	Kh
GK14 Flow top	4135-4243	44	403.5	5.1	1.2×10^{-1}
GK13	3741-3845	80	399.2	5.2×10^{-2}	-6.5×10^{-4}
GK12	3611-3838		no tests		
GK11	3301-3412	49	384.1	1.0	2×10^{-2}
GK10	3245-3246	8	367.8	6.9	8.6×10^{-1}
GK9	2961-3113	120	398.6	2.5×10^{1}	2.1×10^{-1}
GK8	2817-2868	9 (6)	390.7	3.2	5.3×10^{-1}
GK7	2642-2763	10'	390.1	8.1	8.1×10^{-1}
GK6	2651-2700		384.6 no results		
GK5 (Through Rubble)	2492-2548 ~~2492-2544~~	24 ~~24~~	390.9	1.8×10^{2}	7.4×10^{0}
GK4	2372-2487	10	390.7	2.0	2×10^{-1}
GK3	2227-2317	33	388.5	2.2×10^{3}	6.6×10^{1}
GK2	2099-2198	67	389	3.2	4.8×10^{-2}

AC-15

Test	Depth	b	h	T	Kh	
FS 6	1874-1887	38	386.6	3.4×10^3	~~102~~ 1×10^2	←
FS 5	1735-1833	91	386.5	6.4×10^1	7×10^{-1}	
FS 4	1540-1593	20	386.1	1.3×10^3	6.7×10^1	←
FS 3	1505-1553	48	385.9	5.8×10^2	7.8×10^1	←
FS 2	1481-1506	18	386.0	1.7×10^3	9.6×10^1	←
Roza-FS	1395-1473	2	386.5	? 3.0 ?	?	
Roza	1357-1390	10	386.0	7.1×10^2	7×10^1	
PR-Roza	1219-1243	46	386.7	5.8×10^3	1.3×10^2	←
PR	1149-1189	29 ?8?	386.1	3.8×10^{-1}	? 1.3×10^{-2} ?	
Levey	305-323		368.7	1.5×10^2	5.5×10^0	
composite Levey - Elephant Mtn.	275-343		375.3	1.2×10^2	4.1×10^0	
Rattlesnake Ridge Pomona "	416-496		383.9	1.5×10^2	2.8×10^0	
Selah - Equivalent		16	356.5	3.6×10^1	2.3×10^0	
Cold Creek	713-787			3.25×10^1	5×10^{-1}	
Mabton	1003-1072			5.4×10^1	1.1×10^0	

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-1 — Source: LaSala & Doty, ST 5 ← mainly
2. TOTAL DEPTH: 5,661 ft., redrilled to 5,582 & cemented bottom to 4,350 ft. for piezometer installation
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER
5. DATE: 7-23-82

Grd. elev. = 572 ft.

ft. INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS

Well drilled by rotary air mist & aerated water with detergent. Bit size was 9 7/8 inch, thru uncased interval. Drilling stopped at depth of 5,661 ft. for cement repairs between 824-1220 feet. Bit deviated from original hole on recovery attempt. Drilling was suspended.

ft. INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
830 [?] - 1,190	Bottom of Saddle Mtns. & top of Wanapum	—	—	Head = 402 ft. msl
1,130 - 1,190				Head = 401
1,330 - 1,520	10% Roza + 90% Frenchman Sprs.	fractured basalt with rubbly, scoraceous, highly vesicular breccia zone (2 flow contacts at 1,347 & 1,455)		Head = 405 (estimated); $K = 4.2 \times 10^{-2}$ ft/d → .037; S = .0018; graphical & computer; .15
1,560 - 1,750	Frenchman Sprs.			Head = 405
1,760 [?] - 1,950 [?]				Head = 407; S = 0.00063
1,990 [?] - 2,160 [?]	Bottom of Wanapum & top of Grande Ronde (40% Frenchman Spr. & Vantage & 60% Grande Ronde)	Fractured basalt with vesicular, rubbly zones & one interbed (3 flow contacts at 2,046 and 2,050 and 2,110 ft., Vantage between 2,046 and 2,050, lower 110 ft. are Grande Ronde)		Head = 407; $K = 2.3 \times 10^{-1}$ ft/d ? → .20; graphical & computer match; .15

BOREHOLE REVIEW FORM

1. BOREHOLE No.: DC-1 Source: -
2. TOTAL DEPTH: 5,661 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER 5. DATE: 7-24-82

Interval (ft.)	Strat. Unit	Lithology	Type of Test	Results - Comments	
2,170 - 2,225	Grande Ronde			Head = 406 ft. msl	
2,450 - 2,610	"	"		Head = 403	
2,600 - 2,780	"	Fractured basalt with vesicles; includes highly vesicular and rubbly zone (flow contact at 2,748 ft.)		Head = 402 k = 1.4 X 10^{-1} ft/d → .13	.15
2,730 - 2,910	"	" Fractured basalt with vesicles, includes highly vesicular and rubbly zone (4 flow contacts at 2,748 and 2,798 and 2,816 and 2,862 ft.)		Head = 411 ft. k = 1.8 X 10^{-3} ft/d → .0016 graphical & computer	.15
3,146 - 3,236	"	" Mostly fractured basalt with small amount of vesicular flow rubble (flow contact 3,178 ft)		Head = 411 k = 8.6 X 10^{-1} ft/d → .76 S = 0.0000014 graphical & computer	.15
3,166 - 3,196	"	" fractured basalt with vesicular flow rubble (flow contact at 3,178 ft)		Head = 409 k = 2.4 X 10^{-2} ft/d → .021 computer & graphical	.15

BOREHOLE REVIEW FORM

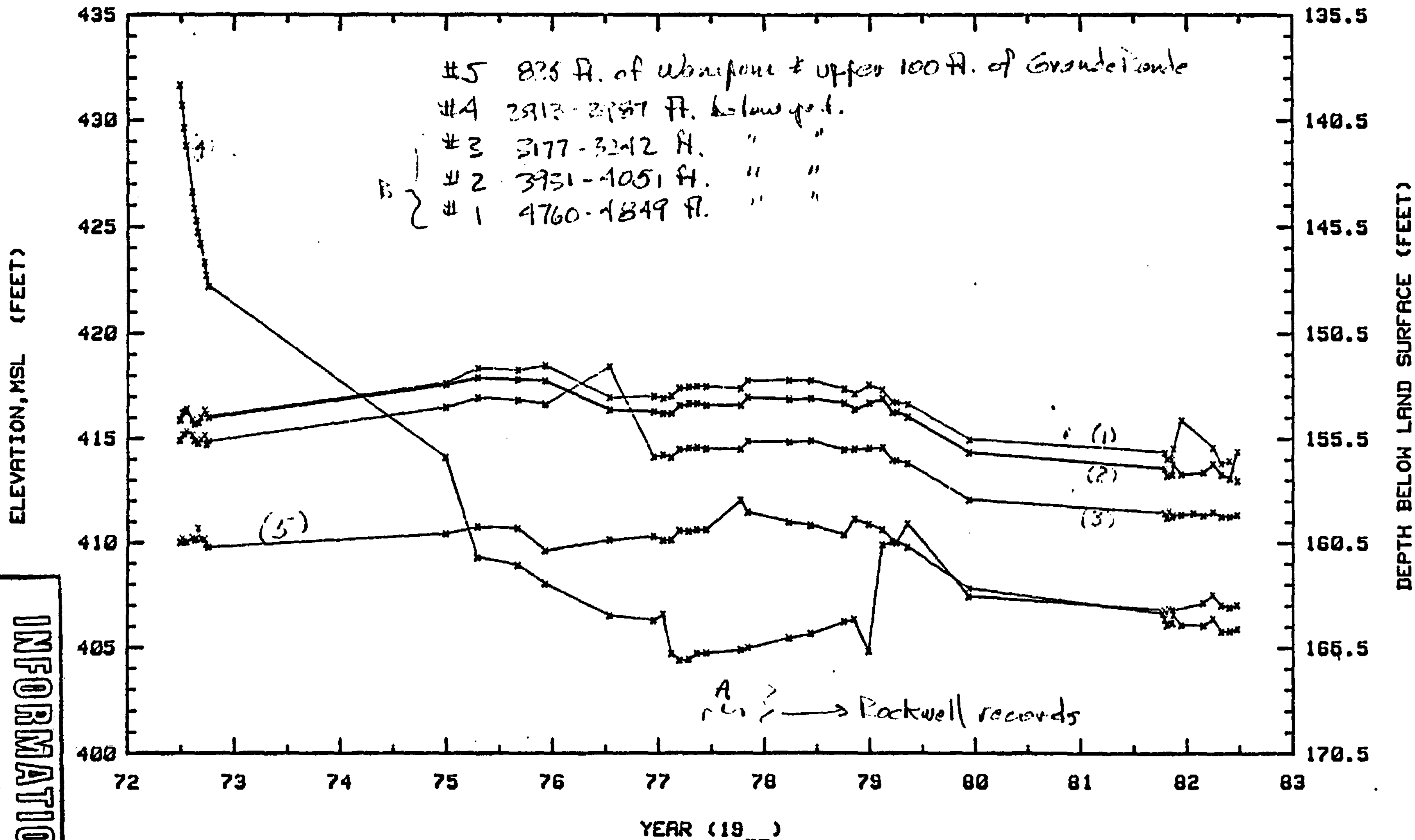
1. BOREHOLE NO.: OC-1
2. TOTAL DEPTH: 5,661 ft.
3. DEPTH OF CASING:
4. REVIEWER: G. WINTER 5. DATE: 7-24-82

ft. INTERVAL	STRAT. UNIT	LITHOLOGY	TYPE OF TEST	RESULTS - COMMENTS
3,200 - 3,246	Grande Ronde			Head = 403
3,320 - 3,451	"	High and low density zones (low density is normally inter-flows while high density is columnar)		Head = 408 $k = 5.0 \times 10^{-3}$ ft/d → .0044
3,774 - 3,934	"	"	"	Head = 379 $k = 3.5 \times 10^{-3}$ ft/d → .0031
3,910 - 4,070	"	"	"	Head = 366 $k = 4.7 \times 10^{-1}$ ft/d → .42

WELL LOCATION: HANFORD SITE- LAT: 46.5761 LONG: 119.5179

LITHOLOGY: BSLT HYDROGEOLOGIC UNIT: CBRV

SURFACE ELEV(FT): 570.50 WELL DEPTH(FT): 4833.00



HYDROGRAPH FOR WELL LOCATION HANFORD SITE-

FILE: DC-10S

A = DC-2 was cored into basalt about 60 ft. from DC-1. Hole remains open between 2,200 and 3,300 ft. depths.

B = Rockwell points out possibility that leakage exists in hole between piezometers; - over -

USGS OPEN FILE 1971
LaSala, A.M. Jr. & G.C. Doty

106A

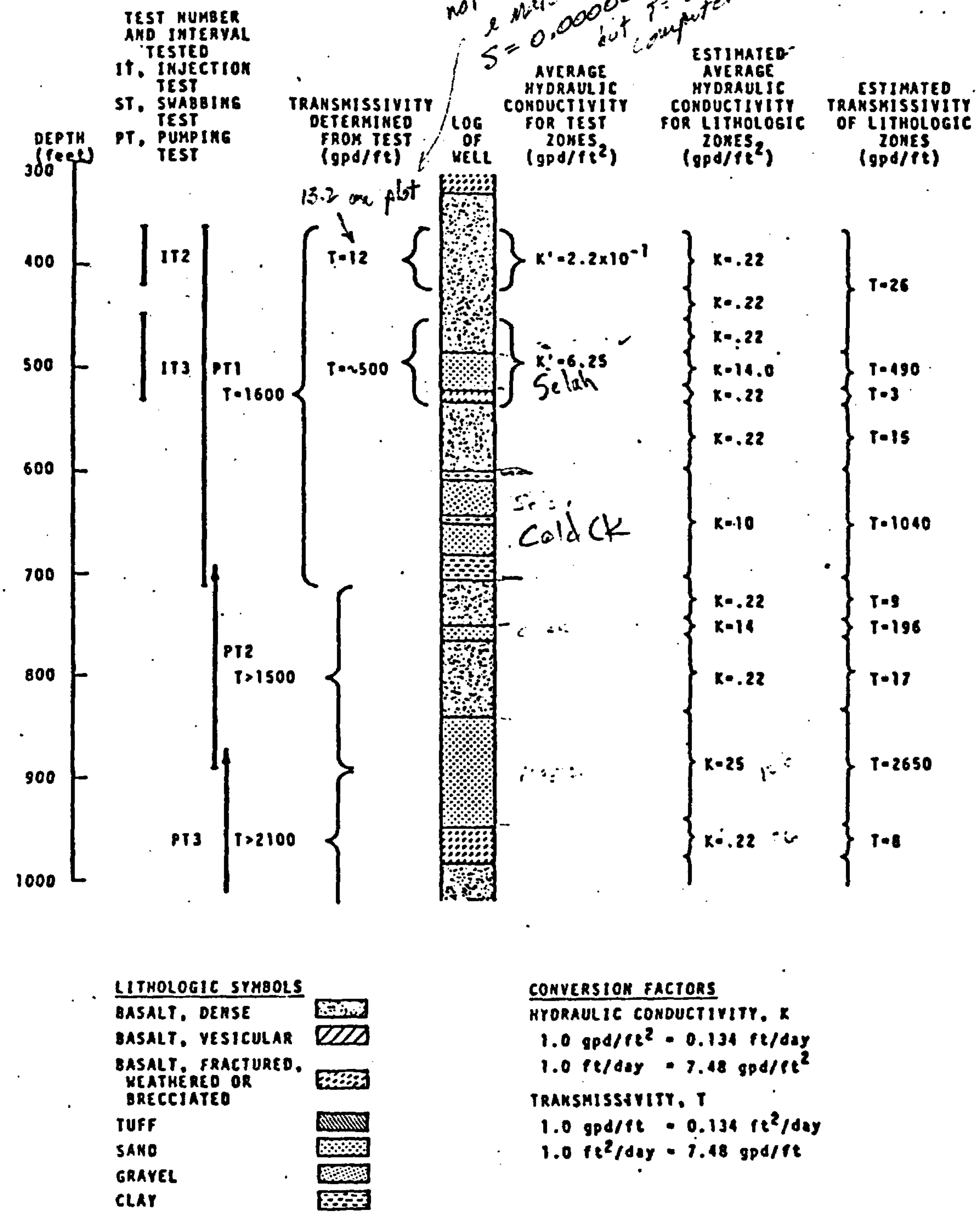


FIGURE 10. Values of Transmissivity and Hydraulic Conductivity of Lithologic Zones in Well ARH-DC-1

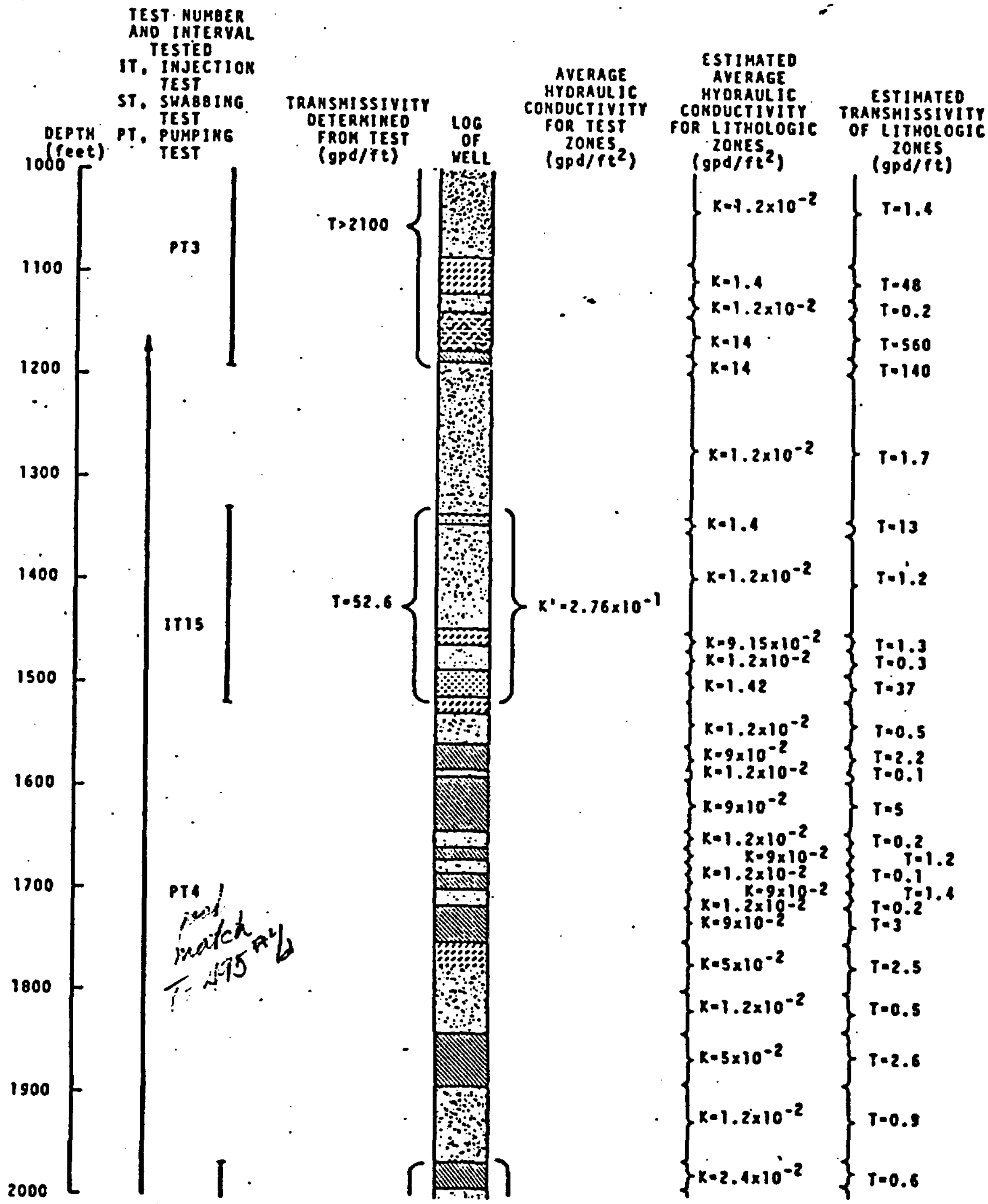


FIGURE 10. (contd)

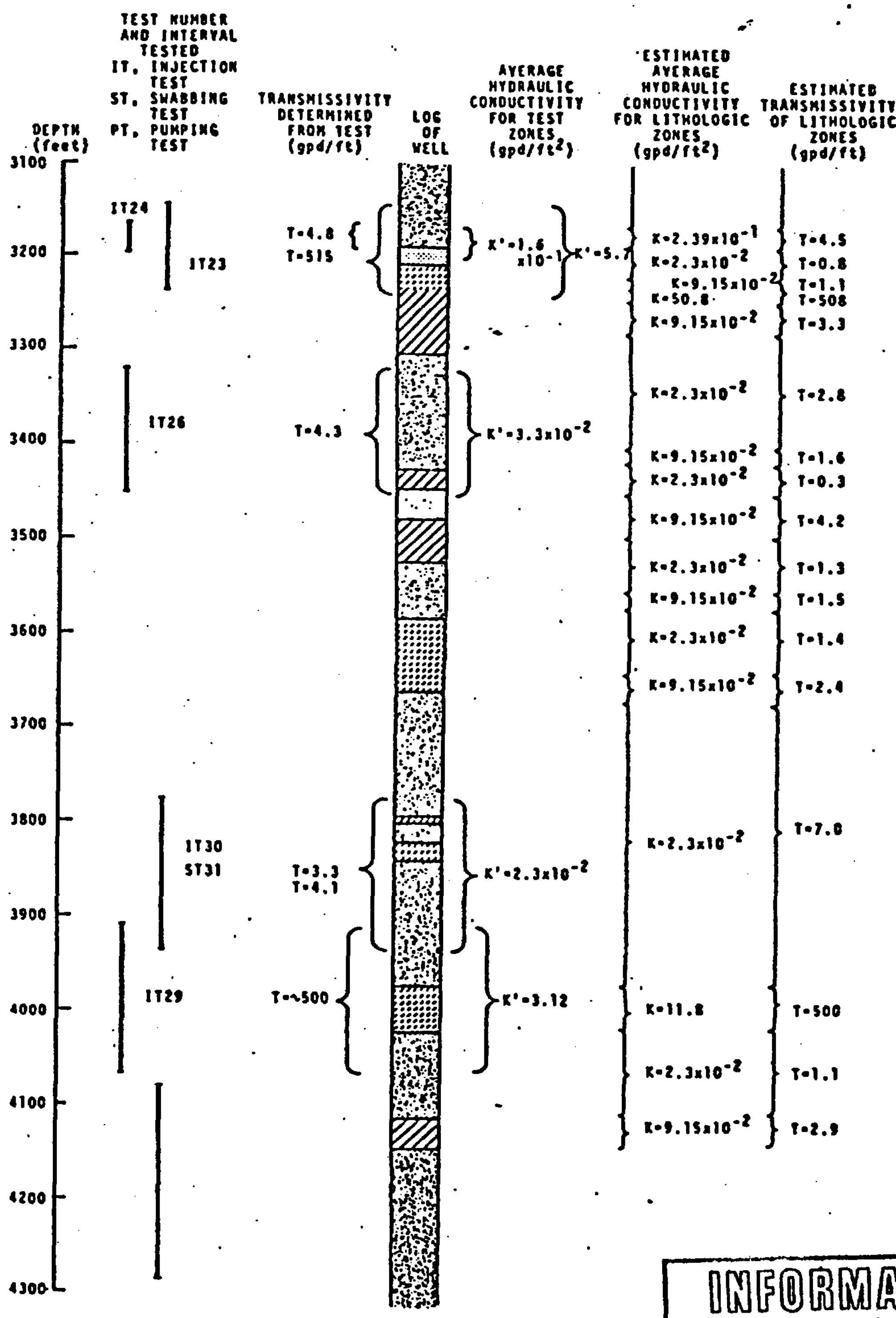


FIGURE 10. (contd)

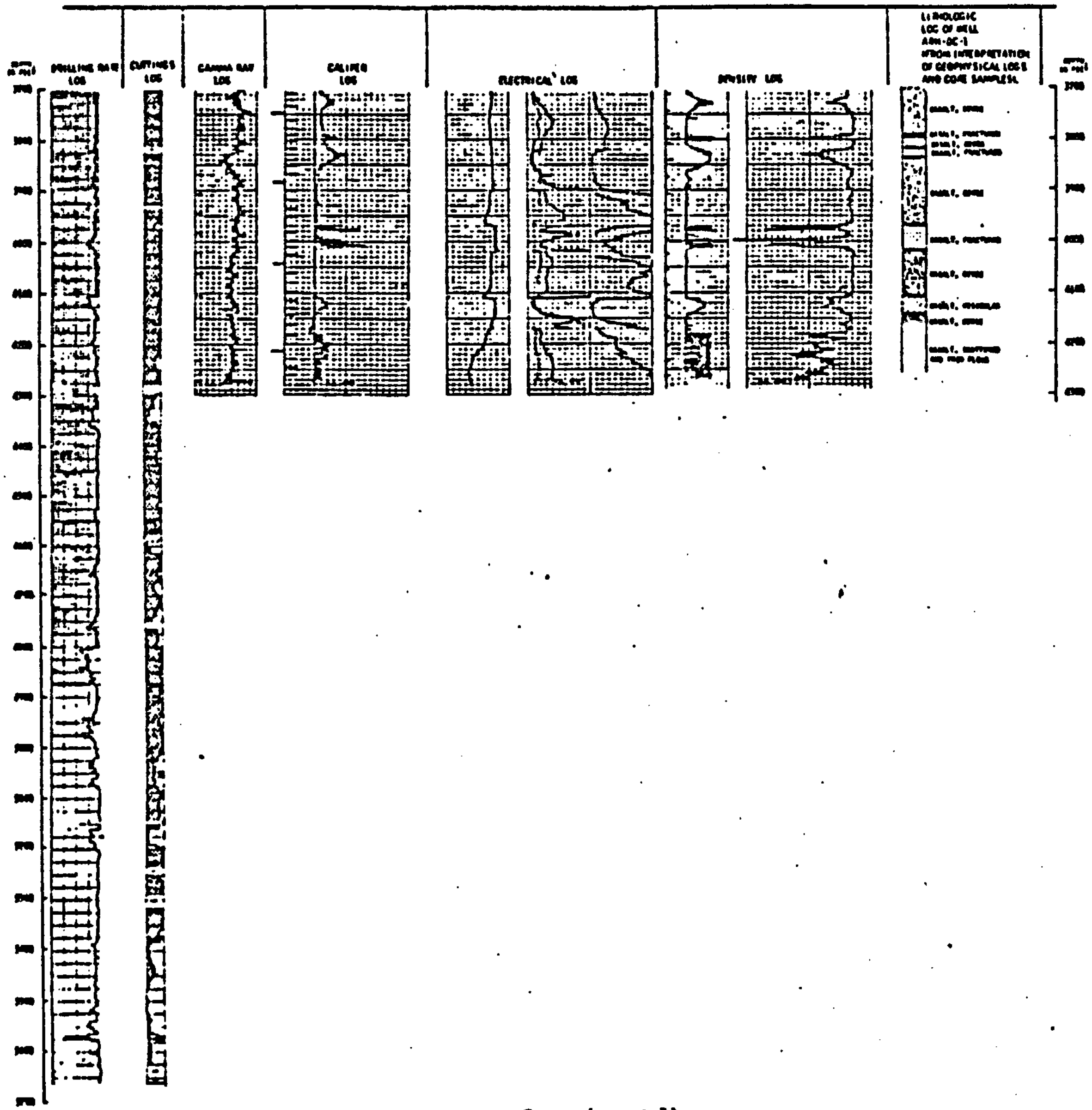


FIGURE 2. (contd)

Table 2.--Descriptions of core samples from well ARH-DC-1[1/]

[By R. E. Brown, Battelle Memorial Institute]

Core number	Description
1	Cored interval 706-712 feet. Recovered, 6 feet. A dense, fine-grained to glassy, black basalt. Highly jointed, with core segments averaging 4 inches in length. A trace of tuff at the upper end of the core probably represents cave-in either from the overlying Squaw Creek diatomite equivalent (at a depth of 675-685 ft) or from the higher Mabton bed (about 480-500 ft). Alteration is present on seams and joints, also occasional vesicle fillings occur. This flow appears to be the Sand Hollow flow of the Frenchman Springs Member. (See Mackin, J. H., 1961, A stratigraphic section in the Yakima Basalt and the Ellensburg Formation in south-central Washington: Washington Div. Mines and Geology Rept. of Inv. no. 19.)
2	No core recovered. Depth 781 feet.
3	Cored interval 783-784 feet. Recovered, 6 inches. A very fine-grained glassy, black basalt. The flow appears to be the Ginko flow of the Frenchman Springs Member.
4	Cored interval 1,188-1,190 feet. Recovered, 2 feet. Volcanic tuff, altered largely to a bentonitic clay. Hard, compact, tough and dense, indicating probably not a depositional clay but an in-place alteration. The sedimentary bed has not previously been described or recognized. It lies between what appears to be the overlying Rocky Coulee flow and the lower Dry Gulch flow of J. H. Mackin. (See above reference.)
5	Cored interval 1,709-1,711.5 feet. Recovered, 2-1/2 feet. A dense, dark gray, medium-grained basalt. The color, grain size, and the length of core segments (up to 8 in) indicate that the core came from near the base of the unnamed flow.
6	Cored interval 2,380-1/2-2,387 feet. Recovered, 5.5 feet. A medium-gray colored, holocrystalline, coarse-grained basalt. The color, crystallinity, and length of core segments (averaging about 6 in long and up to 16 in long) suggest a probably massive basalt flow. The geophysical logs suggest a break (flow top) at about 2,360 feet. Proximity of basalt of this type to a flow top suggests a thick, massive flow.
7	Cored interval 2,779-2,784-1/2 feet. Recovered, 5 feet. Identical in appearance to Core 6. More jointed, but core evidently followed one vertical joint.
8	Cored interval 2,943-2,954 feet. Recovered, 11 feet. A highly vesicular basalt and flow breccia containing a trace of carbonized wood. Vesicles are up to an inch in diameter, especially above 2,950 feet. Below 2,950 feet the core becomes more solid, less vesicular, and with contorted vesicle bands. Top of basalt flow.
9	Cored interval 3,087-3,089 feet. Recovered, 2 feet. A very fine-grained, glassy, black basalt. Core in segments up to 1-foot long, most 4-inches long. Core barrel twisted off.
10	Cored interval 3,103-3,103-1/2 feet. No recovery. Core barrel twisted off.
11	Cored interval 3,107-3,117 feet. No recovery.
12	Cored interval 3,126 feet. Did not cut. Ruined core head.
13	Cored interval 3,126-3,128-1/2 feet. Recovered, 2-1/2 feet. A fine-grained, glassy black basalt.
14	Cored interval 3,163-3,165 feet. Recovered, 1-1/4 foot.
15	Cored interval 3,171-3,173-1/2 feet. Recovered, 2 feet. A sandy granule gravel, with well rounded granules of basalt about 1/8 inch in diameter. Carbonized wood occurred in the sample, probably carbonized by heat of the flow overlying it. The sand has been baked by the overlying flow, also indurated by secondary quartz. The higher part of the core is a highly vesicular basalt (of the flow overrunning the interbed) in pieces up to 2 inches maximum length. Most of the core is in rounded fragments about 1 inch in diameter.
16	Cored interval 3,216-3,236 feet. Recovered, 9 feet. A dark gray, holocrystalline, coarse-grained basalt. Highly jointed with the average length of core about 2 inches. Joints commonly occur at angles to the core of about 30-40°, with some at right angles. One large vug was lined with quartz.
17	Cored interval 3,236-3,246 feet. Recovered, 2 feet. A vesicular flow breccia with scoria, forms the contact zone between Core 16 flow and the flow beneath Core 17. Many pieces of the core are 1 inch or less in diameter. One piece 3-inches long contains numerous yet unidentified zeolites and also some chalcedony.
18	Cored interval 3,411-3,421 feet. Recovered, 7-1/4 feet. A fine-grained, dense, black, vesicular basalt from near the top of the basalt flow. The core rapidly becomes less vesicular downward. Many vesicles are lined with zeolites. Only a few vesicles are drawn out or flattened. Vugs occur between 3,416 and 3,418 feet, then the core changes to a normal nonvesicular basalt.
19	Cored interval 3,451-3,453 feet. Recovered, 2 feet. A highly vesicular, fine-grained basalt. Core in many fragments. Some zeolites in some of the vesicles.
20	Cored interval 3,453-3,461 feet. Recovered--no core.
21	Cored interval 3,494-3,504 feet. Recovered, 4 feet. A basalt flow breccia from 3,495-3,497.2 feet with a tuffaceous matrix. Underlain by a fine-grained glassy, black, highly jointed basalt. The breccia may be either a flow breccia overlain by a thin tuff bed, or may be an altered pillow-palagonite or breccia-palagonite complex. Whether the breccia represents the base of the overlying flow or the top of the lower flow cannot be ascertained.
22	Cored interval 3,523-3,525 feet. Recovered, 2 feet. A fine-grained, dense, glassy, black, highly jointed basalt.
23	Cored interval 3,556-3,566 feet. Recovered, 5 feet. A highly vesicular basalt. Considerable opal, zeolites, and chalcedony in vesicles.
24	Cored interval 3,597-3,599 feet. Recovered--no core.
25	Cored interval 3,599-3,602 feet. Recovered, 2 inches. A very fine-grained, dense, black basalt. Occasional small feldspar phenocrysts. Vesicles constitute 10 to 30 percent of rock.
26	Cored interval 3,632-3,639 feet. Recovered, 4 feet. A dense, medium-grained, dark gray basalt. Locally greenish gray in color probably owing to chloritization. Occasional vugs and vesicles filled with chalcedony, some quartz. Higher cores have contained dominantly quartz and zeolites. Core occurs in segments 3-6 inches long with scattered vesicles.
27	Cored interval 3,935-3,938 feet: Recovered about 2 feet. A fine-grained, dark gray to nearly black basalt. Feldspars commonly about 1 mm long. A few vesicles lined with secondary minerals (chlorophaeite?) and quartz. Most of core 2-4 inches long, one piece 1-foot long.
28	Cored interval 4,289-4,292 feet. Recovered, 2 feet.
29	Cored interval 5,148-5,149 feeb. Recovered--no core.
30	Cored interval 2,828-2,836 feet. Recovered, 8 feet. Vesicular basalt. This core was cut in a deviated, not the original, bore hole.

1/ Stratigraphic nomenclature does not conform to U.S. Geological Survey usage.

Table 4.--Summary of results for analysis of hydraulic data collected for zones isolated by packers in well ARH-DC-1

Interval (depth in feet)	Test number 1/	Apparent undisturbed water level (feet below land surface)	Computed transmissivity 2/ (gpd/ft)	(ft²/day)
362-416	IT2	3/169.9	3/12.0	3/1.6
	IT2	-----	13.2	1.8
	ST2	165.0	-----	----
450-530	IT3	-----	~500	~67
	ST3	4/165.4	-----	----
540-620	IT4	163.2	High	
630-712	IT5	166.2	-----	----
820-1,190	IT8	170.5	-----	----
830-970	IT11	>173	High	
1,130-1,190	IT9 ST7	4/163.3	High	
1,330-1,520	IT15	3/168.1	3/52.6	3/7.0
	IT15	167.1	65	8.7
1,560-1,750	IT14	-----	Low	
	ST13	166.8	Low	
1,760-1,950	IT13	-----	Low	
	ST12	164.7	Low	
1,970-2,160	IT12 6/4/69	3/165.6	3/285.7	3/38.2
	IT12	-----	264	35.3
	ST10	4/165.3	-----	----
2,100-2,280	IT21 ST21	----	Low	
2,170-2,225	ST11	166.0	Low	
2,240-2,420	IT20 ST20	-----	Low	
2,430-2,610	IT19	169.2	-----	----
	ST19	-----	Low	
2,600-2,780	IT18	170.16	170	13.4
2,730-2,910	IT17	3/224.8	3/0.8	3/0.1
	IT17	-----	2.2	0.29
	ST16	160.7	-----	-----
2,920-3,103	ST17 6/21/?	>185.1	Low	
3,146-3,236	IT23 6/27/69	3/162.0	3/515.4	3/68.9
	IT23	159.8	583	77.9
3,166-3,196	IT24	3/253.05	3/1.3	3/0.17
	IT24	------	4.8	0.64
	ST24	162.9	-----	-----
3,206-3,266	ST25 7/1/69	168.6	-----	-----
3,320-3,451	IT26	-----	4.3	0.58
	ST26	164.5	-----	-----
3,360-3,597	IT28	>180.6	Low	
3,516-3,676	ST32	------	Low	
3,530-3,597	ST27	>173.9	Low	
3,774-3,934	IT30	------	3.3	0.44
	ST31	4/193.4	4.1	0.55
3,910-4,070	IT29 7/13/69	206.3	~500	~67
4,080-4,283	ST30	204.2	-----	-----

1/ The prefix IT indicates an injection test; ST a swabbing test.
2/ Values of transmissivity given as "high" or "low" indicate that the water-level data could not be used to obtain a numerical value. For those test results indicated as "low," the transmissivity probably is less than 10 gpd/ft (1.3 ft²/day). For those indicated as "high," the transmissivity probably exceeds 500 gpd/ft (67 ft²/day).
3/ These values are obtained by digital computer program.
4/ The value of water level given is the average obtained from recovery during injection and swabbing tests.

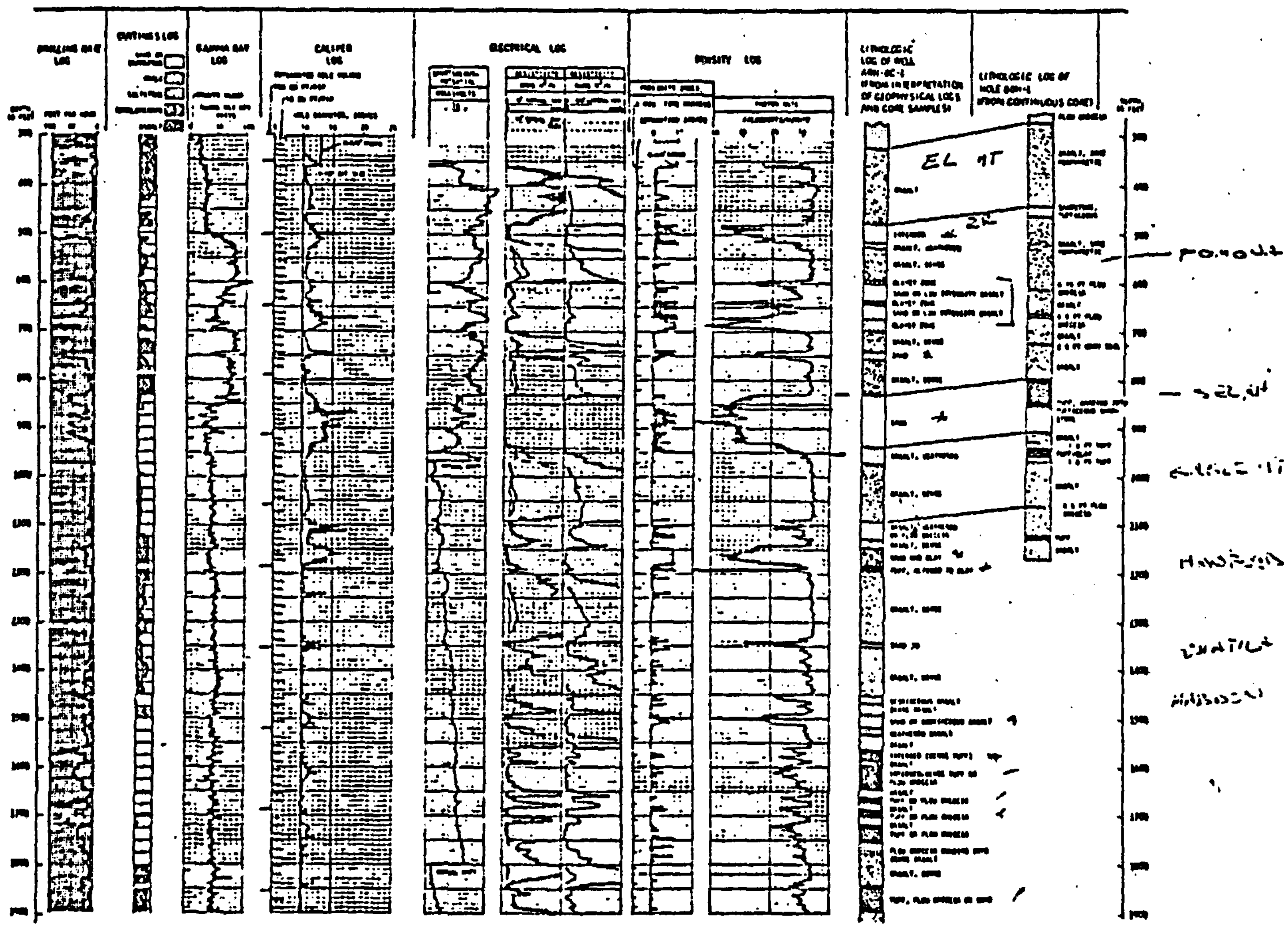


FIGURE 2. Lithology, Selected Geophysical Characteristics, and Drilling Rate for Well ARH-DC-1

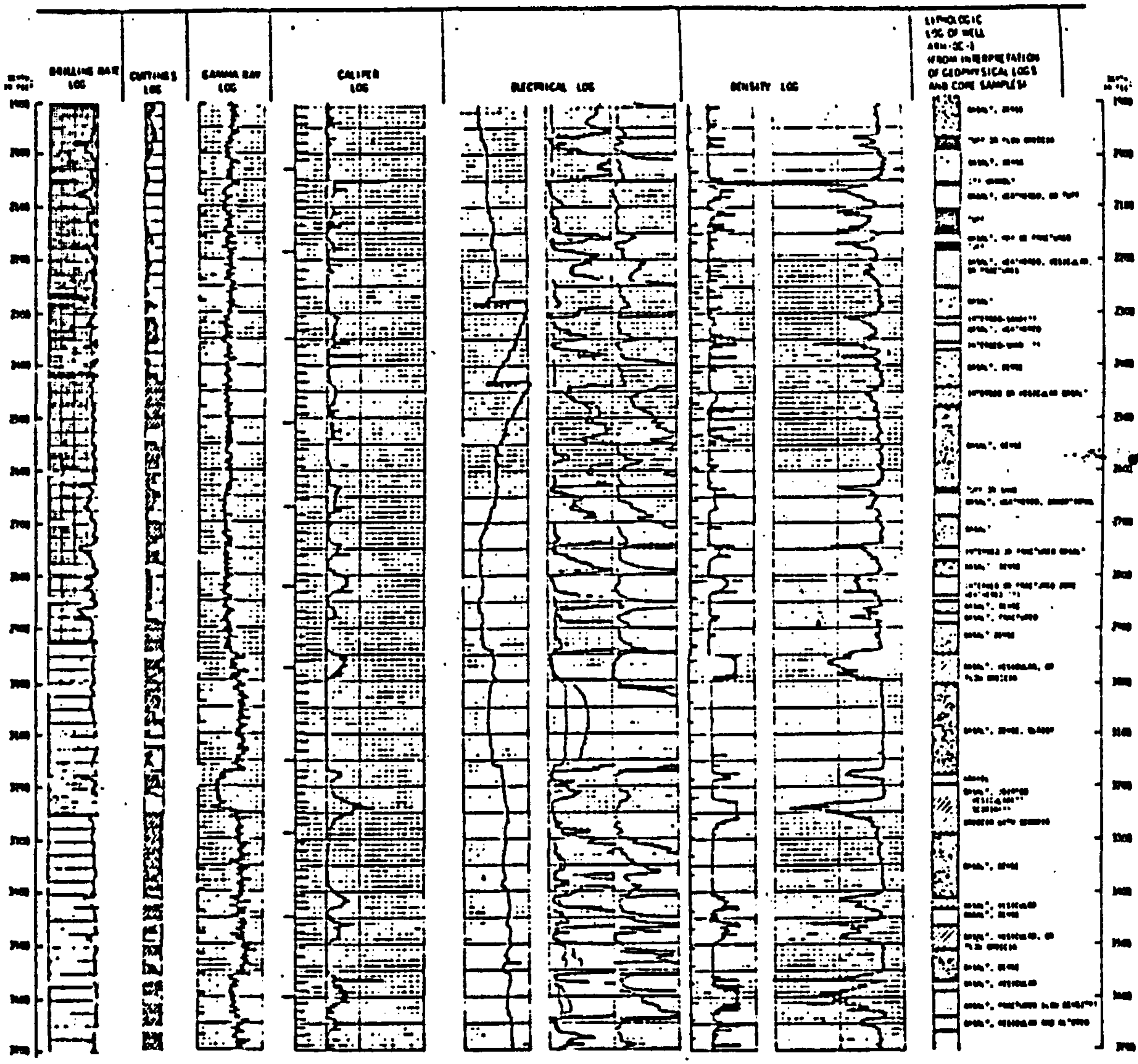


FIGURE 2. (contd)

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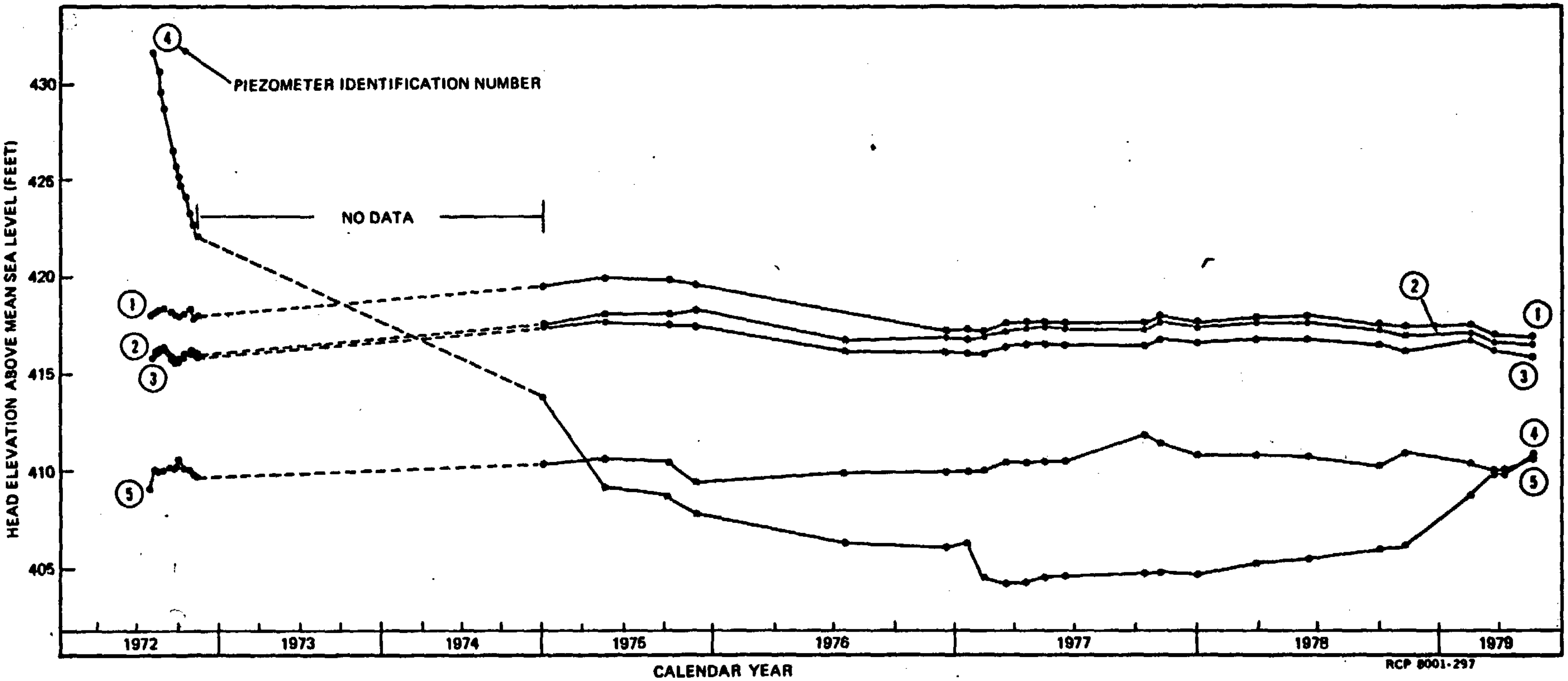
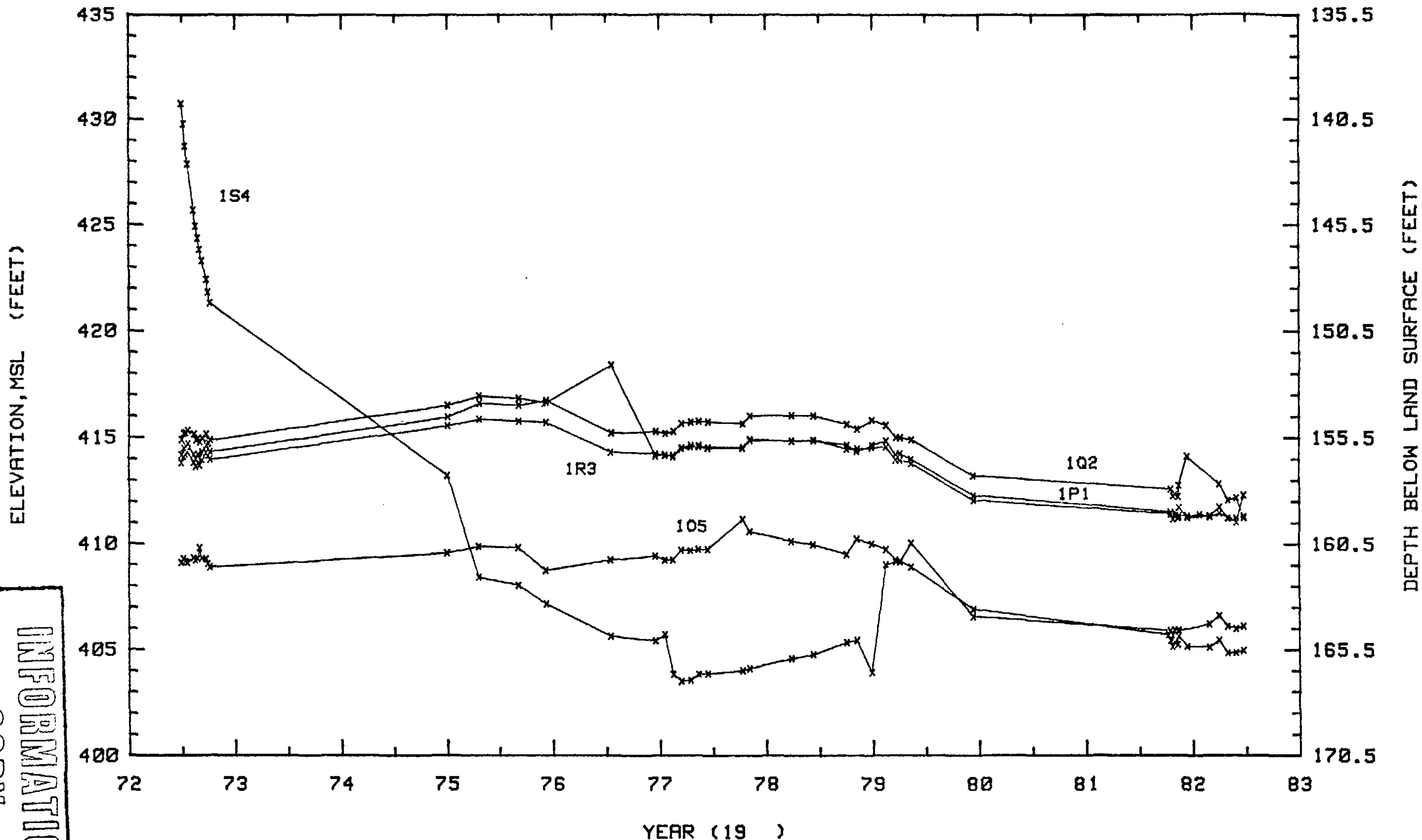


FIGURE III-28. Hydrograph of the Water Levels in the DC-1 Piezometers from 1972 through 1979.

WELL LOCATION: HANFORD SITE- LAT: 46.5761 LONG: 119.5179

LITHOLOGY: BSLT HYDROGEOLOGIC UNIT: CBRV

SURFACE ELEV(FT): 570.50 WELL DEPTH(FT): 4833.00



HYDROGRAPH FOR WELL LOCATION HANFORD SITE-
FILE: DC-1

Predicted and Observed Stratigraphy in the Principal Borehole

Formation	Member	Flow	Predicted Depth	Predicted Thickness	Predicted Group Thickness	Thickness Range	Observed Depth	Observed Thickness (as of 6/23/82)	Observed Group Thickness
SADDLE MOUNTAINS BASALT		Elephant Mountain		85		±10	603-686	83	
SADDLE MOUNTAINS BASALT		Rattlesnake Mountain Interbed		100		± 5	686-783	97	
SADDLE MOUNTAINS BASALT		Pomona		135		±15	783-941	158	
SADDLE MOUNTAINS BASALT		Selah Interbed		50		± 5	941-986	45	
SADDLE MOUNTAINS BASALT		Esquatzel		125		±15	986-1104	118	
SADDLE MOUNTAINS BASALT		Cold Creek Interbed		70		±15	1104-1167	63	
SADDLE MOUNTAINS BASALT		Umatilla		225		±15	1167-1399	232	
SADDLE MOUNTAINS BASALT		Mabton Interbed		140		±15	1399-1523	124	
WANAPUM BASALT		Priest Rapids II	1523-1685	162		±10	1523-1689	166	
WANAPUM BASALT		Priest Rapids I	1685-1755	70		±10	1689-1749	60	
WANAPUM BASALT		Roza	1755-1925	170		±10	1749-1922	173	
WANAPUM BASALT		Frenchman Springs 1	1925-2105	180			1922-2104	182	
WANAPUM BASALT		2	2105-2205	100			2104-2217	113	
WANAPUM BASALT		3	2205-2250	45			2217-2271	54	
WANAPUM BASALT		4	2250-2290	40	740	±30			761
WANAPUM BASALT		5	2290-2355	65			2271-2381	110	
WANAPUM BASALT		6	2355-2470	115			2381-2489	108	
WANAPUM BASALT		7	2470-2595	125			2489-2617	128	
WANAPUM BASALT		8	2595-2665	70			2617-2683	66	
WANAPUM BASALT		Vantage Interbed	2665-2680	15		± 5	2683-2687	4	
GRANDE RONDE BASALT	Sentinel Bluffs	1	2680-2745	65			2687-2720	33	
GRANDE RONDE BASALT	Sentinel Bluffs	2	2745-3800	55			2720-2823	103	
GRANDE RONDE BASALT	Sentinel Bluffs	3	3800-2970	170			2823-2993	170	
GRANDE RONDE BASALT	Sentinel Bluffs	"Through Runner" 4	2970-3235	265	930	±30	2993-3255	262	
GRANDE RONDE BASALT	Sentinel Bluffs	5	3235-3350	115			3255-3388	133	
GRANDE RONDE BASALT	Sentinel Bluffs	6	3350-3395	45			3388-3417	29	
GRANDE RONDE BASALT	Sentinel Bluffs	7	3395-3465	70			3417-3475	58	
GRANDE RONDE BASALT	Sentinel Bluffs	McCoy Canyon 8	3465-3610	145			3475-3607	132	
GRANDE RONDE BASALT	Schwana	Umtanum 9	3610-3825	215		±15	3607-3839	232	
GRANDE RONDE BASALT	Schwana	Flowtop	3610-3675	65		±25	3607-3755	148	
GRANDE RONDE BASALT	Schwana	Entablature*	3675-3805	130		±35	3755-3839	84	
GRANDE RONDE BASALT	Schwana	Lower Colonnade	3805-3825	20		0 to 50		53	
GRANDE RONDE BASALT	Schwana	very-high-Mg 10	3825-3875	50		±20	3839-3892		
GRANDE RONDE BASALT	Schwana	11	3875				3892-3973 TD		

All values are in feet

* includes any upper colonnade or tiers (Long, RHO-BWI-ST-14)

Flurd Temperature Data at Selected Boreholes on the Hanford Site

Preliminary Data

Depth ft \ Borehole	DC-1	DC-2(H2)	DC-3	DC-4	DC-5	DC-7	DC-12	DC-15	54-37B	DB-4	DB-7	DB-10	DB-11	DB-14	DB-15	DDH-3	RRL-2
100	—	—	—	—	—	—		15.80	—	—		—	—	—	15.73	16.98	—
200	17.59	17.50	18.34	—	—	—		16.66	18.91	19.56		18.08	18.20	—	16.89	17.07	—
300	18.25	18.74	19.02	—	—	20.10		17.97	19.89	20.10		19.09	18.86	19.52	18.11	17.79	18.13
400	19.21	19.48	19.69	21.15	20.11	20.95		19.00	20.92	20.91		20.24	19.51	20.42	19.19	18.77	18.88
500	20.47	20.72	20.58	21.76	21.07	21.95		20.36	21.92	22.09		21.55	20.95	21.53	20.59	19.97	20.03
600	21.15	21.46	21.52	22.81	22.02	22.88		21.38	22.78	22.88		22.89	22.06	22.62	21.90	20.93	20.88
700	22.81	23.10	22.83	23.69	23.37	23.81		22.60	23.94	23.92		24.26	23.29	23.67	23.45	22.01	21.90
800	23.66	23.95	23.85	24.52	24.25	25.03		24.12	25.60	25.02		25.84	24.53	24.82	24.88	23.36	23.00
900	25.01	25.40	24.90	25.53	25.31	25.98		25.20	26.97	26.12			25.93	25.83	26.75	24.88	24.10
1000	26.13	26.91	25.83	26.50	26.36	26.73		26.33		26.99			26.94	27.14	27.35	26.08	25.19
1100	27.00	27.30	27.02	27.69	27.39	27.98		27.60		28.19					28.21	27.07	26.25
1200	28.40	28.73	28.17	28.75	28.51	29.03		28.70		29.18					29.34	28.12	27.41
1300	29.47	29.72	29.23	29.73	29.53	29.91		29.97		30.46					30.43	29.15	28.47
1400	30.52	30.60	30.56	30.70	30.57	31.07		31.12							31.65	30.80	29.50
1500	31.53	32.01	31.55	31.96	31.87	32.17		32.32							32.66	31.51	30.70
1600	32.88	33.40	32.67	33.16	32.59	33.26		33.82							33.82	32.67	31.96
1700	33.95	34.38	33.73	34.20	34.02	34.38		35.04							35.15	33.85	33.10
1800	35.04	35.49	34.79	35.30	35.11	35.44		36.42							36.52	35.09	34.10
1900	37.00	37.31	35.95	36.39	36.26	36.55		37.85								36.13	35.10
2000	37.65	38.20	37.10	37.55	37.37	37.70		39.12								37.50	36.33
2100	38.40	39.43	38.31	38.50	38.42	38.75		40.47								38.90	36.40
2200	40.38	40.69	39.54	39.64	39.62	39.94		41.70								40.35	38.65
2300	41.59	41.84	40.80	40.96	40.86	41.31		42.96									40.00
2400	42.75	43.04	42.04	42.23	42.13	42.54		44.80									40.36
2500	43.92	44.21	43.28	43.38	43.39	43.69		45.46									42.55
2600	45.07	45.33	44.50	44.70	44.66	44.76		46.68									44.15
2700	46.20	46.52	45.79	45.77	45.98	45.94		47.92									45.62
2800	47.32	47.57	46.94	46.77	47.12	47.09		49.02									
2900	48.48	48.40	48.17	48.12	48.29	48.22		50.24									
3000	49.66	48.95	49.25	49.73	49.56	49.31		51.57									

Preliminary Data

Borehole / Depth	DC-1	DC-2(H2)	DC-3	DC-4	DC-5	DC-7	DC-12	DC-15	54-37B	DB-4	DB-7	DB-10	DB-11	DB-14	DB-115	DDH-3	RRL-2
3100	50.78	49.85	50.35	50.98	50.62	50.34		53.04									
3200	51.89	50.88	51.65	52.16	51.96	51.59		54.45									
3300	52.90	52.15	52.97	53.46	53.15	52.83		55.37									
3400	54.09		54.25	54.55	54.50	53.85		55.42									
3500	55.42		55.52	56.01	55.83	55.31		57.39									
3600	56.72		56.81	57.00	57.19	56.19		59.03									
3700	57.97			57.34	58.61	57.41		60.62									
3800	59.20			59.74		58.58		61.83									
3900	60.30			60.97		59.22		63.22									
4000	61.39					60.94		64.72									
4100	62.72							66.22									
4200	64.20							68.46									
4300	65.51																
4400	66.75																
4500	68.04																
4600	69.21																
4700	70.36																
4800	71.49																

Internal Letter

Rockwell International

Date. July 19, 1982

No. JHL-72100-878-82

TO: (Name, Organization, Internal Address)
Those Listed

FROM: (Name, Organization, Internal Address, Phone)
J. H. LaRue

6-7209

Subject: BWIP/NRC Hydrogeology Workshop, July 21-23, 26, 1982

Attached is the agenda for the upcoming BWIP/NRC workshop. A list of people who will be responsible for giving presentations is included. Except for the July 22, 8:30 a.m. trip to the RRL, all meetings will be held in the Peoples' Bank Building third floor conference room.

If you have any questions, call L. R. Fitch at 6-7001.

J. H. LaRue
J. H. LaRue
Staff Licensing Engineer

JHL/amd

Attachment

Distribution
R. A. Deju
H. B. Dietz
R. J. Gimera
R. N. Gurley
G. S. Hunt
R. L. Jackson
L. S. Leonhart
W. M. Pidcoe
M. J. Smith
F. A. Spane
S. R. Strait

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AGENDA

BWIP/NRC HYDROGEOLOGY WORKSHOP
July 21-23, 1982

July 21, 1982	PBB/Third Floor Conference Room		
8:00 a.m.	WELCOME AND INTRODUCTION	Squires/Fitch
9:00 a.m.	Overview of BWIP Hydrologic Field Testing Program	F. A. Spane
10:00 a.m.	Review of DC-15 Testing and DATA	R. L. Jackson
12:00 noon	Lunch	
1:00 p.m.	Tracer Testing	L. S. Leonhart
2:00 p.m.	Review of DC-7/8 and DC-3	R. L. Jackson

July 22, 1982 PBB/Third Floor Conference Room

8:00 a.m.	Morning Briefing	Squires/Fitch
8:30 a.m.	Depart for RRL to Review DC-16, DC-14, DC-12, and McGee Well	Strait/Pidcoe
	and/or	
	Continue Review of DC-15, 7/8, and 3	Spane/Jackson

July 23, 1982 PBB/Third Floor Conference Room

8:00 a.m.	Morning Briefing	Squires/Fitch
8:30 a.m.	Continue Borehole Reviews	
3:00 p.m.	"Wrap-up" Session with BWIP and NRC Hydrologists	DOE/NRC/BWIP

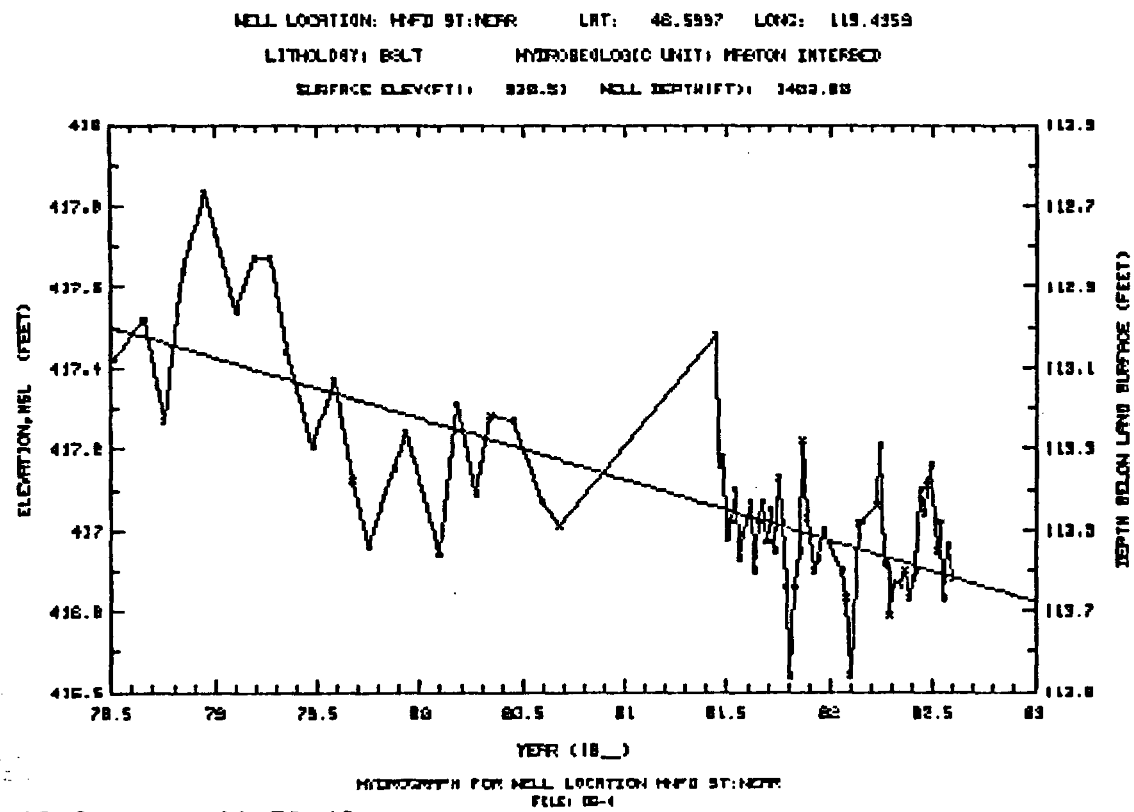
July 26, 1982 PBB/Third Floor Conference Room

10:00 a.m.	Formal Debrief	DOE/NRC/BWIP Management

- Agree to list of data needed by NRC
- Agree on results of visit
- Agree on next visit on Hydrology

Longitude: 119.65479826
Lithology: BSLT
Hydro unit: PRIEST RAPIDS INTERFLOW
Surface elevation: 835.68 feet (elevation of measuring pt)
Well depth: 968 feet
Records in file 9

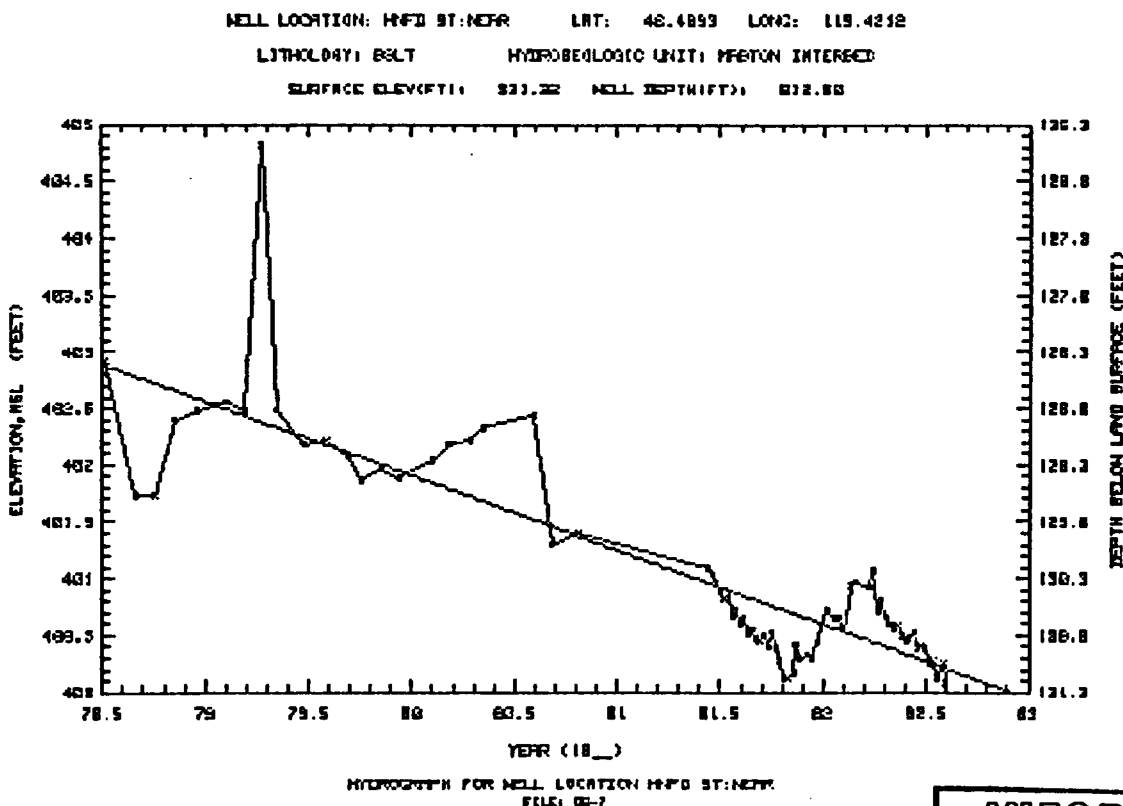
1	m	81.1016	-73.9200	6	m	81.1123	-78.5600
2	m	81.1026	-73.6000	7	m	81.1211	-79.6700
3	m	81.1030	-73.3400	8	m	81.1221	-80.9900
4	m	81.1110	-76.8500	9	m	82.0430	-89.5400
5	m	81.1113	-77.5900				



12 Aug 11:50:48 am

File name DB-7
Well location: HNFD ST:NEAR HWY 240
Latitude: 46.4892579629
Longitude: 119.421188342
Lithology: BSLT
Hydro unit: MABTON INTERBED
Surface elevation: 531.32 feet
Well depth: 812 feet
Records in file 75

1	m	78.0706	128.4000	39	m	81.1002	130.7900
2	m	78.0830	129.5900	40	m	81.1009	130.9300
3	m	78.1004	129.5900	41	m	81.1016	131.0400
4	m	78.1108	128.9200	42	m	81.1023	131.1900
5	m	78.1219	128.8400	43	m	81.1030	131.2000
6	m	79.0208	128.7600	44	m	81.1110	131.1500
7	m	79.0312	128.8400	45	m	81.1113	130.9000
8	m	79.0411	126.5000	46	m	81.1120	131.0300
9	m	79.0508	128.8300	47	m	81.1204	130.9900
10	m	79.0625	129.1400	48	m	81.1211	131.0200
11	m	79.0803	129.1100	49	m	81.1221	130.8800
12	m	79.0912	129.2500	50	m	82.0108	130.6000
13	m	79.1002	129.4600	51	m	82.0122	130.6700
14	m	79.1108	129.3600	52	m	82.0129	130.6600



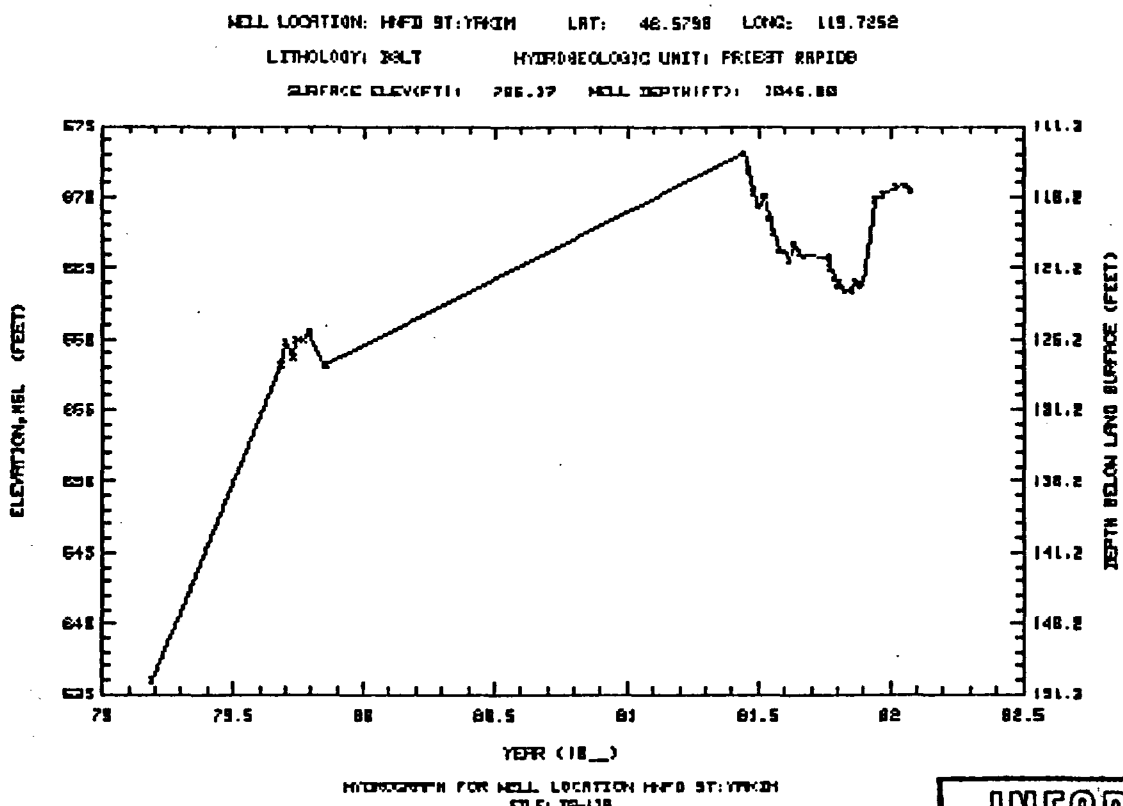
12 Aug 1:24:35 pm

File name DB-11A
Well location: HNFD ST:YAKIMA BARRICADE
Latitude: 46.5796133762
Longitude: 119.725159033
Lithology: BSLT
Hydro unit: PRIEST RAPIDS
Surface elevation: 786.17 feet
Well depth: 1046 feet
Records in file 39

1	m	79.0310	150.1900	21	m	81.0828	120.0000
2	m	79.0907	128.0400	22	m	81.0904	120.3000
3	m	79.0912	126.4200	23	m	81.1007	120.4400
4	m	79.0924	127.4200	24	m	81.1009	121.0900
5	m	79.0927	126.1900	25	m	81.1016	121.8900
6	m	79.1008	126.1900	26	m	81.1020	122.4500
7	m	79.1017	125.7300	27	m	81.1022	122.1000
8	m	79.1106	128.0400	28	m	81.1023	122.2100
9	m	79.1109	128.0400	29	m	81.1030	122.7800
10	m	81.0612	113.0900	30	m	81.1110	122.7300
11	m	81.0619	114.3000	31	m	81.1113	122.2000
12	m	81.0626	115.8200	32	m	81.1120	122.3700
13	m	81.0702	116.8100	33	m	81.1124	122.2500
14	m	81.0710	116.1100	34	m	81.1124	122.2600
15	m	81.0717	117.6600	35	m	81.1211	116.4000

16	m	81.0724	118.6600	36	m	81.1221	116.0500
17	m	81.0731	119.9500	37	m	82.0108	115.4800
18	m	81.0807	119.9600	38	m	82.0122	115.3700
19	m	81.0814	120.5700	39	m	82.0129	115.7500
20	m	81.0821	119.4500				

User aspect ratio: .054687
Angle = ATN(-Aspect_ratio*Slope)

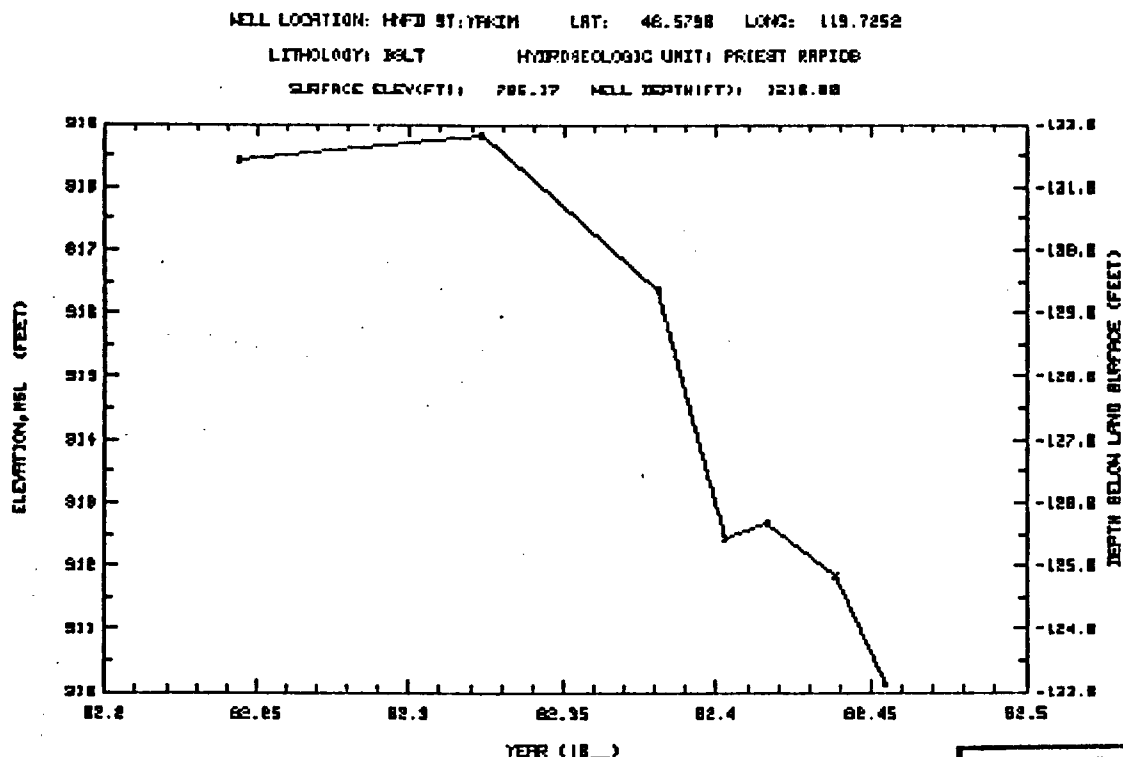


12 Aug 1:28:12 pm

File name DB-11B
Well location: HNFD ST:YAKIMA BARRICADE
Latitude: 46.5796133762
Longitude: 119.725159033
Lithology: BSLT
Hydro unit: PRIEST RAPIDS
Surface elevation: 786.17 feet
Well depth: 1210 feet
Records in file 7

1	m	82.0331	-132.2700	5	m	82.0603	-126.5000
2	m	82.0429	-132.6600	6	m	82.0611	-125.6900
3	m	82.0520	-130.2100	7	m	82.0617	-123.9500
4	m	82.0528	-126.2600				

User aspect ratio: .020833
Angle = ATN(-Aspect_ratio*Slope)



HYDROGRAPH FOR WELL LOCATION HNFD ST:YAKIM

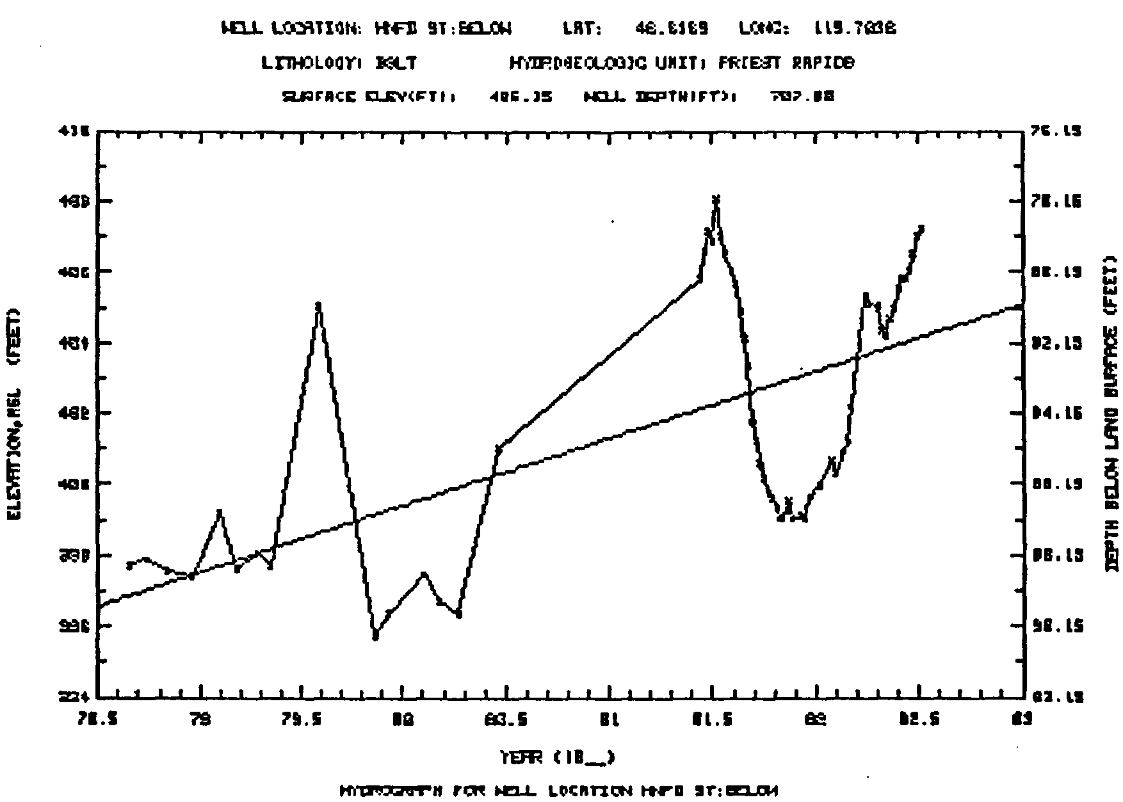
12 Aug 1:32:57 pm

File name	DB-12
Well location:	HNFD ST:BELOW UMTANUM RIDGE
Latitude:	46.616897644
Longitude:	119.703565984
Lithology:	BSLT
Hydro unit:	PRIEST RAPIDS
Surface elevation:	486.15 feet
Well depth:	707 feet
Records in file	62

1	m	78.0828	88.4300	32	m	81.1009	86.3800
2	m	78.0927	88.2600	33	m	81.1016	86.5500
3	m	78.1103	88.5900	34	m	81.1023	86.8000
4	m	78.1219	88.7200	35	m	81.1030	87.1300
5	m	79.0206	86.9700	36	m	81.1110	86.8800
6	m	79.0309	88.4900	37	m	81.1113	86.6100
7	m	79.0416	88.0900	38	m	81.1120	87.1400
8	m	79.0507	88.4600	39	m	81.1204	87.0300
9	m	79.0801	81.0900	40	m	81.1211	87.0800
10	m	79.1112	90.4300	41	m	81.1221	86.5100
11	m	79.1206	89.7800	42	m	82.0108	86.2100
12	m	80.0207	88.6800	43	m	82.0129	85.5000
13	m	80.0305	89.4300	44	m	82.0205	85.8500
14	m	80.0410	89.7800	45	m	82.0219	85.2300
15	m	80.0620	85.1300	46	m	82.0226	84.9600

16 m	81.0612	80.3600	47 m	82.0305	83.9600
17 m	81.0619	79.5700	48 m	82.0331	80.8100
18 m	81.0626	79.0100	49 m	82.0406	81.0400
19 m	81.0702	79.2700	50 m	82.0422	81.1200
20 m	81.0710	78.0900	51 m	82.0429	81.8200
21 m	81.0717	79.1400	52 m	82.0506	81.9500
22 m	81.0724	79.6000	53 m	82.0513	81.4600
23 m	81.0814	80.5000	54 m	82.0520	81.1700
24 m	81.0821	81.2700	55 m	82.0528	80.6400
25 m	81.0828	82.0200	56 m	82.0603	80.3200
26 m	81.0904	82.7900	57 m	82.0610	80.3000
27 m	81.0911	84.4000	58 m	82.0614	80.3400
28 m	81.0918	84.9300	59 m	82.0617	80.1200
29 m	81.0923	85.5700	60 m	82.0624	79.6500
30 m	81.0925	85.6300	61 m	82.0701	79.1200
31 m	81.1002	86.0000	62 m	82.0709	78.9500

User aspect ratio: .17578
Angle = ATN(-Aspect_ratio*Slope)
DB-12   LIN ALL 0 A 2.38E+02 B -1.89E+00 r^2   .3629 angle 18.3641



12 Aug   1:39:59 pm

File name   DB-13

Please note that all surface elevations are well ground plate figures unless otherwise noted.

12 Aug 11:47: 7 am

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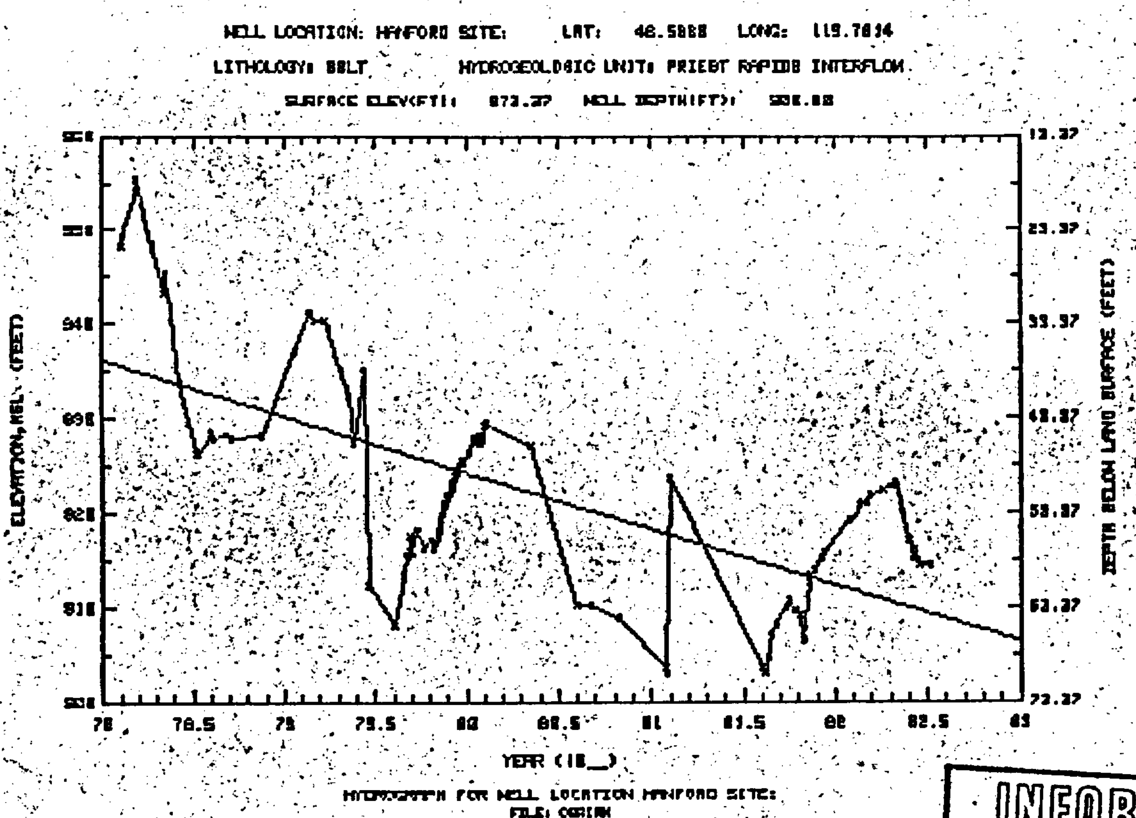
File name DB-4
Well location: HNFD ST:NEAR WYE BARRICADE
Latitude: 46.5396705877
Longitude: 119.435883764
Lithology: BSLT
Hydro unit: MABTON INTERBED
Surface elevation: 530.51 feet
Well depth: 1403 feet
Records in file 75

1	m	78.0706	113.0900	39	m	81.1002	113.3800
2	m	78.0829	112.9900	40	m	81.1009	113.4900
3	m	78.1002	113.2400	41	m	81.1016	113.6500
4	m	78.1106	112.8700	42	m	81.1023	113.8700
5	m	78.1214	112.6800	43	m	81.1030	113.6500
6	m	79.0209	112.9700	44	m	81.1110	113.5600
7	m	79.0313	112.8400	45	m	81.1113	113.2900
8	m	79.0411	112.8400	46	m	81.1120	113.4800
9	m	79.0508	113.0700	47	m	81.1204	113.6100
10	m	79.0625	113.3000	48	m	81.1211	113.5800
11	m	79.0801	113.1400	49	m	81.1221	113.5100
12	m	79.0904	113.3900	50	m	82.0122	113.6100
13	m	79.1002	113.5500	51	m	82.0129	113.6800
14	m	79.1116	113.3600	52	m	82.0205	113.8700
15	m	79.1207	113.2700	53	m	82.0219	113.4950
16	m	80.0204	113.5700	54	m	82.0226	113.4900
17	m	80.0305	113.2000	55	m	82.0324	113.4500
18	m	80.0410	113.4200	56	m	82.0331	113.3000
19	m	80.0505	113.2300	57	m	82.0408	113.5900
20	m	80.0618	113.2400	58	m	82.0415	113.6000
21	m	80.0806	113.4400	59	m	82.0416	113.7200
22	m	80.0905	113.5000	60	m	82.0422	113.6500
23	m	81.0612	113.0300	61	m	82.0429	113.6400
24	m	81.0619	113.3500	62	m	82.0506	113.6500
25	m	81.0626	113.3300	63	m	82.0513	113.6100
26	m	81.0702	113.5300	64	m	82.0520	113.6800
27	m	81.0710	113.4900	65	m	82.0528	113.6300
28	m	81.0717	113.4100	66	m	82.0603	113.6100
29	m	81.0724	113.5800	67	m	82.0611	113.4100
30	m	81.0731	113.5200	68	m	82.0617	113.4700
31	m	81.0814	113.4400	69	m	82.0624	113.4000
32	m	81.0821	113.6100	70	m	82.0630	113.3500
33	m	81.0828	113.4900	71	m	82.0709	113.5600
34	m	81.0904	113.4400	72	m	82.0715	113.4900
35	m	81.0911	113.5400	73	m	82.0722	113.6800
36	m	81.0918	113.4600	74	m	82.0730	113.5500
37	m	81.0923	113.5400	75	m	82.0805	113.6300
38	m	81.0925	113.5600				

User aspect ratio: 2.0089
Angle = ATN(-Aspect_ratio*Slope)
DB-4 LIN ALL 0 A 1.01E+02 B 1.51E-01 r^2 .5751 angle -16.8379



12 Aug 2:26:37 pm

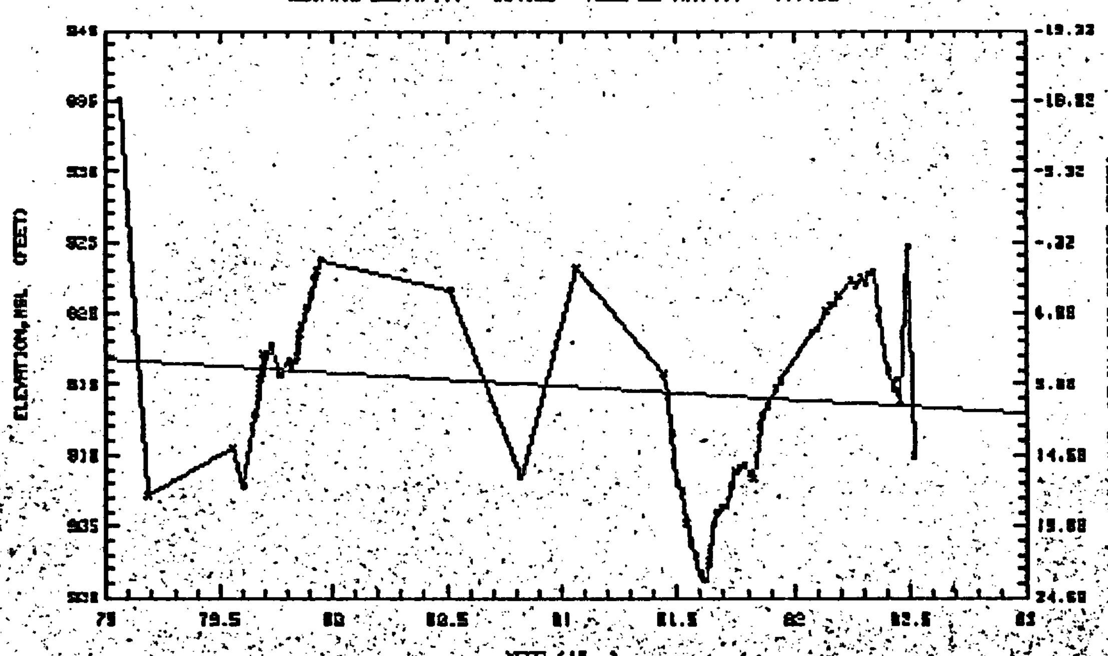
File name FORD
Well location: HANFORD SITE:COLD CREEK VALLEY
Latitude: 46.5868464158
Longitude: 119.781364099
Lithology: BSLT
Hydro unit: PRIEST RAPIDS INTERFLOW
Surface elevation: 924.68 feet (elevation of measuring pt)
Well depth: 777 feet
Records in file 76

1	m	79.0123	-10.3800	39	m	81.0731	21.6800
2	m	79.0309	17.5400	40	m	81.0807	22.9600
3	m	79.0724	14.1600	41	m	81.0814	23.4400
4	m	79.0810	16.8300	42	m	81.0821	22.1300
5	m	79.0829	11.8100	43	m	81.0828	19.5700
6	m	79.0904	10.3000	44	m	81.0904	18.6900
7	m	79.0905	9.6100	45	m	81.0911	18.4000
8	m	79.0906	9.2000	46	m	81.0918	18.3000
9	m	79.0907	9.0500	47	m	81.0925	16.8100
10	m	79.0910	7.4800	48	m	81.1002	15.8200
11	m	79.0912	8.9100	49	m	81.1009	15.5300
12	m	79.0912	8.2200	50	m	81.1016	15.4400
13	m	79.0924	6.9000	51	m	81.1023	15.8900
14	m	79.0925	7.2900	52	m	81.1030	16.3500
15	m	79.1008	8.9900	53	m	81.1110	12.6200
16	m	79.1021	7.9100	54	m	81.1113	11.7800
17	m	79.1026	8.6500	55	m	81.1120	11.1600
18	m	79.1101	8.1100	56	m	81.1204	9.9100
19	m	79.1105	7.6500	57	m	81.1211	9.4600
20	m	79.1106	7.1900	58	m	82.0129	5.9800
21	m	79.1107	6.9900	59	m	82.0205	5.8300

22 m	79.1109	6.1300	60 m	82.0219	4.4600
23 m	79.1112	5.6000	61 m	82.0226	4.0800
24 m	79.1121	4.2100	62 m	82.0305	4.0700
25 m	79.1128	3.3800	63 m	82.0312	3.3800
26 m	79.1203	2.1200	64 m	82.0331	2.3800
27 m	79.1207	1.6200	65 m	82.0407	2.7400
28 m	79.1213	.8800	66 m	82.0415	2.2000
29 m	80.0708	2.9900	67 m	82.0422	2.5400
30 m	80.1027	16.2300	68 m	82.0429	1.9200
31 m	81.0125	1.5000	69 m	82.0506	1.9000
32 m	81.0612	8.8700	70 m	82.0513	4.9900
33 m	81.0619	10.4900	71 m	82.0528	8.6300
34 m	81.0626	13.1400	72 m	82.0607	10.0400
35 m	81.0702	16.6700	73 m	82.0610	9.3500
36 m	81.0710	17.1300	74 m	82.0617	11.0900
37 m	81.0717	19.4300	75 m	82.0630	0.0000
38 m	81.0724	20.8700	76 m	82.0709	14.7200

User aspect ratio: .0625
Angle = ATN(-Aspect_ratio*Slope)
FORD LIN ALL 0 A -6.81E+01 B 9.61E-01 r^2 .0259 angle -3.4382

WELL LOCATION: HANFORD SITE; LAT: 46.5888 LONG: 119.7834
LITHOLOGY: BSLT HYDROGEOLOGIC UNIT: PRIEST RAPIDS INTERFLOW
SURFACE ELEV(FT): 834.00 WELL DEPTH(FT): 777.88

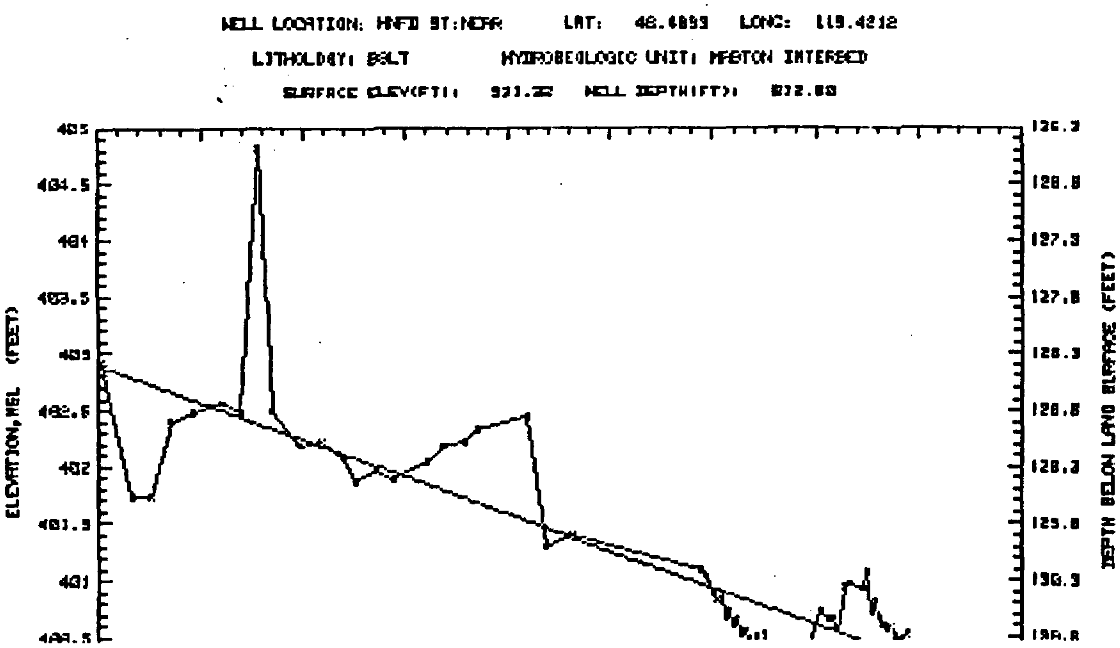


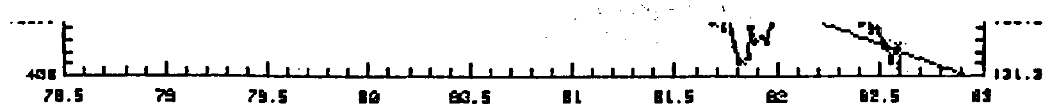
HYDROGRAPH FOR WELL LOCATION HANFORD SITE;
FILE: FORD

12 Aug 2:29:57 pm

15	m	79.1209	129.4400	53	m	82.0205	130.7700
16	m	80.0207	129.2800	54	m	82.0219	130.3800
17	m	80.0307	129.1400	55	m	82.0226	130.3500
18	m	80.0414	129.1100	56	m	82.0324	130.3900
19	m	80.0507	129.0000	57	m	82.0331	130.2500
20	m	80.0805	128.8800	58	m	82.0408	130.6100
21	m	80.0908	130.0200	59	m	82.0415	130.5200
22	m	80.1025	129.9200	60	m	82.0422	130.6600
23	m	81.0612	130.2200	61	m	82.0429	130.7200
24	m	81.0619	130.2800	62	m	82.0506	130.7600
25	m	81.0626	130.3600	63	m	82.0513	130.7400
26	m	81.0702	130.4300	64	m	82.0520	130.8200
27	m	81.0710	130.4900	65	m	82.0528	130.8600
28	m	81.0717	130.4500	66	m	82.0603	130.8500
29	m	81.0724	130.6400	67	m	82.0611	130.7900
30	m	81.0731	130.6000	68	m	82.0617	130.9300
31	m	81.0807	130.7100	69	m	82.0624	130.9100
32	m	81.0814	130.6600	70	m	82.0630	130.9300
33	m	81.0821	130.8100	71	m	82.0709	131.0600
34	m	81.0828	130.7700	72	m	82.0715	131.0500
35	m	81.0904	130.8500	73	m	82.0722	131.2100
36	m	81.0911	130.8600	74	m	82.0802	131.0600
37	m	81.0918	130.8100	75	m	82.0805	131.2400
38	m	81.0925	130.9200				

User aspect ratio: .5625
Angle = ATN(-Aspect_ratio*Slope)
DB-7 LIN ALL 0 A 7.71E+01 B 6.54E-01 r^2 .7577 angle -20.1963





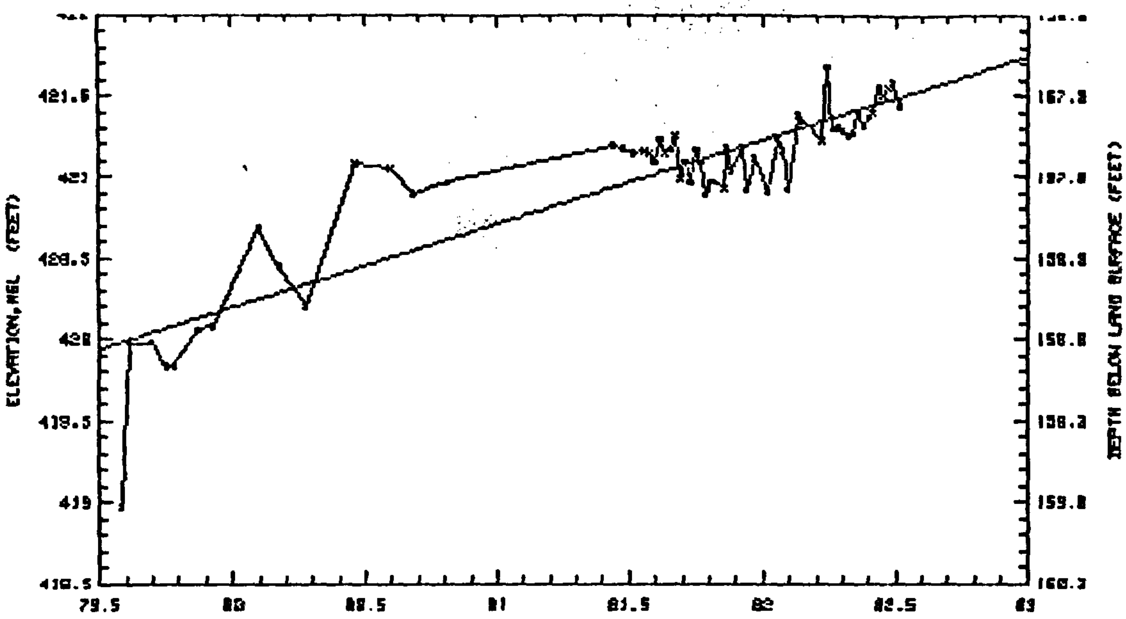
HYDROGRAPH FOR WELL LOCATION HNFO ST:NCRR
FILE: 08-7

Well location: HNFD ST:ON ARMY LOOP ROAD
Latitude: 46.4919810618
Longitude: 119.515558893
Lithology: BSLT
Hydro unit: MABTON INTERBED
Surface elevation: 578.77 feet (elevation of measuring pt)
Well depth: 1292 feet
Records in file 61

1	m	79.0801	159.8000
2	m	79.0812	158.7900
3	m	79.0912	158.7900
4	m	79.1002	158.9400
5	m	79.1012	158.9400
6	m	79.1116	158.7100
7	m	79.1116	158.7100
8	m	79.1205	158.6900
9	m	80.0206	158.0800
10	m	80.0305	158.3200
11	m	80.0410	158.5600
12	m	80.0619	157.6900
13	m	80.0806	157.7200
14	m	80.0905	157.8700
15	m	80.1025	157.8000
16	m	81.0612	157.5800
17	m	81.0626	157.5900
18	m	81.0709	157.6200
19	m	81.0724	157.6100
20	m	81.0731	157.6200
21	m	81.0807	157.6800
22	m	81.0814	157.5400
23	m	81.0821	157.6200
24	m	81.0828	157.6000
25	m	81.0904	157.5200
26	m	81.0911	157.7800
27	m	81.0918	157.6800
28	m	81.0925	157.8000
29	m	81.1002	157.6000
30	m	81.1009	157.6800
31	m	81.1016	157.8800
32	m	81.1023	157.8000
33	m	81.1030	157.8000
34	m	81.1110	157.8400
35	m	81.1113	157.5900
36	m	81.1120	157.7300
37	m	81.1204	157.5900
38	m	81.1211	157.8500
39	m	81.1221	157.6500
40	m	82.0108	157.8600
41	m	82.0122	157.5400
42	m	82.0129	157.6100
43	m	82.0205	157.8500
44	m	82.0219	157.3900
45	m	82.0226	157.4300
46	m	82.0324	157.5500
47	m	82.0331	157.0900
48	m	82.0408	157.4800
49	m	82.0415	157.4700
50	m	82.0422	157.4900
51	m	82.0429	157.5200
52	m	82.0506	157.5100
53	m	82.0513	157.3800
54	m	82.0520	157.4500
55	m	82.0528	157.4000
56	m	82.0603	157.3800
57	m	82.0611	157.2200
58	m	82.0617	157.2700
59	m	82.0624	157.2200
60	m	82.0630	157.1900
61	m	82.0709	157.3300

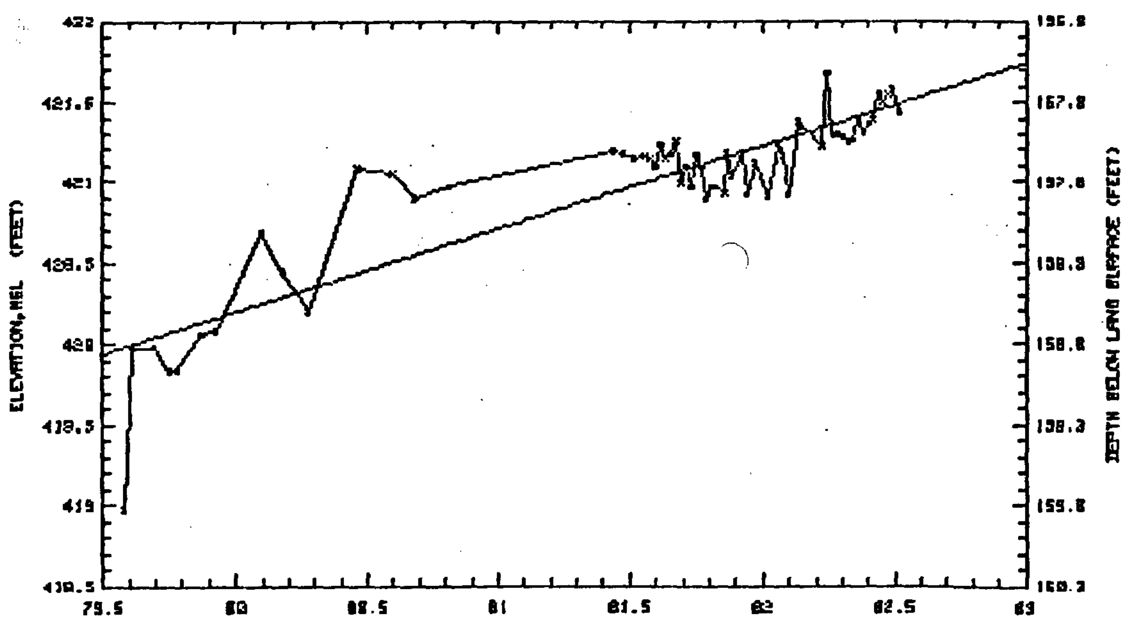
User aspect ratio: .625
Angle = ATN(-Aspect_ratio*Slope)
DB-13 LIN ALL 0 A 2.00E+02 B -5.13E-01 r^2 .7882 angle 17.7770

WELL LOCATION: HNFD ST:ON AR LAT: 46.4920 LONG: 119.5156
LITHOLOGY: BSLT HYDROGEOLOGIC UNIT: MABTON INTERBED
SURFACE ELEV(FT): 578.77 WELL DEPTH(FT): 1292.00



HYDROGRAPH FOR WELL LOCATION HNFD ST:ON AR
FILE: 00-12

WELL LOCATION: HNFD ST:ON AR   LAT: 46.4920   LONG: 119.5150
LITHOLOGY: BSLT   HYDROGEOLOGIC UNIT: MABTON INTERBED
SURFACE ELEV(FT): 378.77   WELL DEPTH(FT): 3232.00



HYDROGRAPH FOR WELL LOCATION HNFD ST:ON AR
FILE: 00-12

12 Aug 2:16: 5 pm

File name DC-1P1
Well location: HANFORD SITE-PIPE YARD
Latitude: 46.5760696972
Longitude: 119.51785691
Lithology: BSLT
Hydro unit: CBRV
Surface elevation: 570.5 feet
Well depth: 4833 feet
Records in file 48

1	m	72.0629	155.6300	25	m	77.1011	156.0200
2	m	72.0706	155.3500	26	m	77.1104	155.6500
3	m	72.0713	155.3200	27	m	78.0327	155.6700
4	m	72.0720	155.2058	28	m	78.0611	155.6200
5	m	72.0810	155.3700	29	m	78.1002	156.0500
6	m	72.0817	155.6400	30	m	78.1106	156.0300
7	m	72.0824	155.5700	31	m	78.1227	155.9800
8	m	72.0830	155.7500	32	m	79.0213	155.9400
9	m	72.0907	155.5500	33	m	79.0319	156.5400
10	m	72.0921	155.3700	34	m	79.0403	156.5500
11	m	72.0928	155.8200	35	m	79.0511	156.7100
12	m	72.1005	155.6600	36	m	79.1210	158.4500
13	m	74.1230	154.0300	37	m	81.1016	159.1000
14	m	75.0418	153.5800	38	m	81.1023	159.3300
15	m	75.0903	153.6900	39	m	81.1030	159.0100
16	m	75.1206	153.8900	40	m	81.1110	159.2700
17	m	76.0715	152.1200	41	m	81.1113	159.1600
18	m	76.1215	156.3800	42	m	81.1211	159.1700
19	m	77.0117	156.3000	43	m	82.0122	159.1000
20	m	77.0214	156.4300	44	m	82.0226	159.2200
21	m	77.0314	156.0500	45	m	82.0331	159.0400
22	m	77.0415	155.9700	46	m	82.0429	159.2600
23	m	77.0513	155.9400	47	m	82.0528	159.2600
24	m	77.0615	156.0100	48	m	82.0624	159.2000

12 Aug 2:16:45 pm

File name DC-1Q2
Well location: HANFORD SITE-PIPE YARD
Latitude: 46.5760696917
Longitude: 119.517856917
Lithology: BSLT
Hydro unit: CBRV
Surface elevation: 570.5 feet
Well depth: 3984 feet
Records in file 46

1	m	72.0629	156.3400	24	m	77.0615	154.7700
2	m	72.0706	156.0200	25	m	77.1011	154.8500
3	m	72.0713	155.9400	26	m	77.1104	154.4800
4	m	72.0720	155.8100	27	m	78.0327	154.4600
5	m	72.0810	156.3100	28	m	78.0611	154.4800
6	m	72.0817	156.5200	29	m	78.1002	154.8800
7	m	72.0824	156.3100	30	m	78.1106	155.1100
8	m	72.0830	156.4800	31	m	78.1227	154.6900
9	m	72.0907	156.1900	32	m	79.0213	154.9300
10	m	72.0921	155.8800	33	m	79.0319	155.4900
11	m	72.0928	156.0600	34	m	79.0403	155.5000

12	m	72.1005	156.1900	35	m	79.0511	155.6000
13	m	74.1230	154.5700	36	m	79.1210	157.2800
14	m	75.0418	153.9100	37	m	81.1016	157.9100
15	m	75.0903	154.0000	38	m	81.1023	158.2300
16	m	75.1206	153.7800	39	m	81.1030	158.1400
17	m	76.0715	155.2900	40	m	81.1110	158.2500
18	m	76.1215	155.2200	41	m	81.1113	157.7300
19	m	77.0117	155.3200	42	m	81.1211	156.3600
20	m	77.0214	155.2200	43	m	82.0331	157.6600
21	m	77.0314	154.8500	44	m	82.0429	158.4200
22	m	77.0415	154.7800	45	m	82.0528	158.3100
23	m	77.0513	154.7400	46	m	82.0624	159.2700

12 Aug 2:17:12 pm

File name DC-1R3
Well location: HANFORD SITE-PIPE YARD
Latitude: 46.5760696972
Longitude: 119.517856917
Lithology: BSLT
Hydro unit: CBRV
Surface elevation: 570.5 feet
Well depth: 3240 feet
Records in file 47

1	m	72.0629	156.6900	25	m	77.1011	155.9400
2	m	72.0706	156.4000	26	m	77.1104	155.5700
3	m	72.0713	156.3000	27	m	78.0327	155.6600
4	m	72.0720	156.2000	28	m	78.0611	155.6300
5	m	72.0810	156.6800	29	m	78.1002	155.8400
6	m	72.0817	156.8800	30	m	78.1106	156.1400
7	m	72.0824	156.7200	31	m	78.1227	155.8400
8	m	72.0830	156.8200	32	m	79.0213	155.6400
9	m	72.0907	156.5600	33	m	79.0319	156.2800
10	m	72.0921	156.2400	34	m	79.0403	156.2400
11	m	72.0928	156.3700	35	m	79.0511	156.5000
12	m	72.1005	156.5500	36	m	79.1210	158.2000
13	m	74.1230	154.9700	37	m	81.1016	158.9800
14	m	75.0418	154.6500	38	m	81.1023	159.3100
15	m	75.0903	154.7400	39	m	81.1030	159.1800
16	m	75.1206	154.8000	40	m	81.1110	159.2700
17	m	76.0715	156.1800	41	m	81.1113	158.7500
18	m	76.1215	156.2500	42	m	81.1211	159.2300
19	m	77.0117	156.3400	43	m	82.0226	159.1500
20	m	77.0214	156.3300	44	m	82.0331	158.7400
21	m	77.0314	155.9700	45	m	82.0429	159.2600
22	m	77.0415	155.8600	46	m	82.0528	159.4500
23	m	77.0513	155.8600	47	m	82.0624	158.1800
24	m	77.0615	155.9500				

12 Aug 2:17:36 pm

File name DC-1S4
Well location: HANFORD SITE-PIPE YARD
Latitude: 46.5760696972
Longitude: 119.517856917
Lithology: BSLT

Hydro unit: CBRV
Surface elevation: 570.5 feet
Well depth: 2972 feet
Records in file 46

1	m	72.0629	139.7600	24	m	77.0615	166.6400
2	m	72.0706	140.7200	25	m	77.1011	166.4900
3	m	72.0713	141.7900	26	m	77.1104	166.3900
4	m	72.0720	142.6300	27	m	78.0327	165.9200
5	m	72.0810	144.8100	28	m	78.0611	165.7300
6	m	72.0817	145.5700	29	m	78.1002	165.1600
7	m	72.0824	146.1400	30	m	78.1106	165.0600
8	m	72.0830	146.6700	31	m	78.1227	166.5800
9	m	72.0907	147.2000	32	m	79.0213	161.4900
10	m	72.0921	148.0800	33	m	79.0319	161.3600
11	m	72.0928	148.6800	34	m	79.0403	161.3700
12	m	72.1005	149.1900	35	m	79.0511	160.4700
13	m	74.1230	157.2900	36	m	79.1210	163.9500
14	m	75.0418	162.0900	37	m	81.1016	164.6000
15	m	75.0903	162.4700	38	m	81.1023	164.8100
16	m	75.1206	163.3500	39	m	81.1030	164.5500
17	m	76.0715	164.8700	40	m	81.1110	164.5900
18	m	76.1215	165.0900	41	m	81.1113	164.5900
19	m	77.0117	164.7900	42	m	82.0226	164.2800
20	m	77.0214	166.6700	43	m	82.0331	163.8800
21	m	77.0314	166.9900	44	m	82.0429	164.3800
22	m	77.0415	166.9400	45	m	82.0528	164.4900
23	m	77.0513	166.6600	46	m	82.0624	164.3800

12 Aug 2:18: 5 pm

File name DC-105
Well location: HANFORD SITE-PIPE YARD
Latitude: 46.5760696972
Longitude: 119.517856917
Lithology: BSLT
Hydro unit: CBRV
Surface elevation: 570.5 feet
Well depth: 2030 feet
Records in file 48

1	m	72.0629	161.4000	25	m	77.1011	159.3500
2	m	72.0706	161.2200	26	m	77.1104	159.9200
3	m	72.0713	161.3400	27	m	78.0327	160.4000
4	m	72.0720	161.4000	28	m	78.0611	160.5500
5	m	72.0810	161.1800	29	m	78.1002	161.0100
6	m	72.0817	161.2800	30	m	78.1106	160.2700
7	m	72.0824	161.2200	31	m	78.1227	160.5000
8	m	72.0830	160.7000	32	m	79.0213	160.7700
9	m	72.0907	161.2100	33	m	79.0319	161.2600
10	m	72.0921	161.2300	34	m	79.0403	161.3200
11	m	72.0928	161.4600	35	m	79.0511	161.6000
12	m	72.1005	161.6200	36	m	79.1210	163.5900
13	m	74.1230	160.9600	37	m	81.1009	164.7900
14	m	75.0418	160.6400	38	m	81.1016	165.0600
15	m	75.0903	160.7000	39	m	81.1023	165.3400
16	m	75.1206	161.7700	40	m	81.1030	165.1400
17	m	76.0715	161.2700	41	m	81.1110	165.2400
18	m	76.1215	161.0800	42	m	81.1113	164.8400
19	m	77.0117	161.2800	43	m	81.1211	165.3200

20	m	77.0214	161.2700	44	m	82.0226	165.3700
21	m	77.0314	160.8100	45	m	82.0331	165.0300
22	m	77.0415	160.8300	46	m	82.0429	165.6400
23	m	77.0513	160.7700	47	m	82.0528	165.6200
24	m	77.0615	160.7700	48	m	82.0624	165.5200

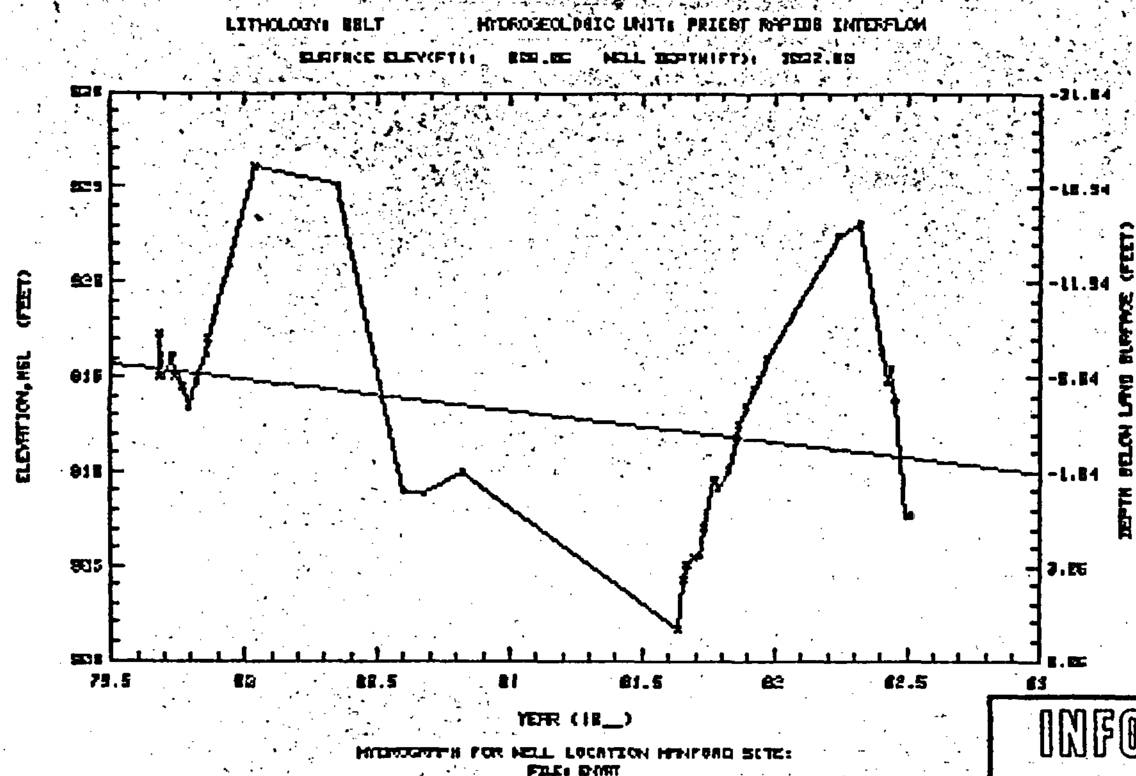
12 Aug 2:19:17 pm

File name ENYRT
Well location: HANFORD SITE:COLD CREEK VALLEY
Latitude: 46.5818908217
Longitude: 119.769068701
Lithology: BSLT
Hydro unit: PRIEST RAPIDS INTERFLOW
Surface elevation: 908.06 feet
Well depth: 1092 feet
Records in file 41

1	m	79.0906	-6.9300	22	m	81.0911	2.6000
2	m	79.0906	-9.2300	23	m	81.0918	2.5100
3	m	79.0907	-8.0900	24	m	81.0925	1.0000
4	m	79.0912	-6.9300	25	m	81.1009	-1.6200
5	m	79.0924	-8.0900	26	m	81.1016	-1.1600
6	m	79.0927	-6.9300	27	m	81.1030	-2.1000
7	m	79.1002	-7.1600	28	m	81.1110	-3.8100
8	m	79.1008	-6.4700	29	m	81.1113	-4.4100
9	m	79.1017	-5.3100	30	m	81.1123	-5.4300
10	m	79.1026	-6.7000	31	m	81.1204	-6.2600
11	m	79.1109	-8.0900	32	m	81.1211	-6.8400
12	m	79.1112	-8.8900	33	m	81.1221	-7.8500
13	m	80.0114	-18.0200	34	m	82.0331	-14.4100
14	m	80.0508	-17.0700	35	m	82.0429	-14.9700
15	m	80.0807	-.9200	36	m	82.0528	-8.2900
16	m	80.0905	-.8100	37	m	82.0607	-6.6100
17	m	80.1027	-1.9500	38	m	82.0611	-7.3200
18	m	81.0821	6.3500	39	m	82.0617	-5.6800
19	m	81.0828	3.7900	40	m	82.0701	.4000
20	m	81.0901	2.9800	41	m	82.0709	.3600
21	m	81.0904	2.9300				

User aspect ratio: .072917
Angle = ATN(-Aspect_ratio*Slope)
ENYRT LIN ALL 0 A -1.38E+02 B 1.64E+00 r^2 .0985 angle -6.8113

WELL LOCATION: HANFORD SITE: LAT: 46.5819 LONG: 119.7691



INFORMATION COPY

THIS COPY WILL NOT BE REPLACED AND MAY BE CHANGED WITHOUT NOTICE

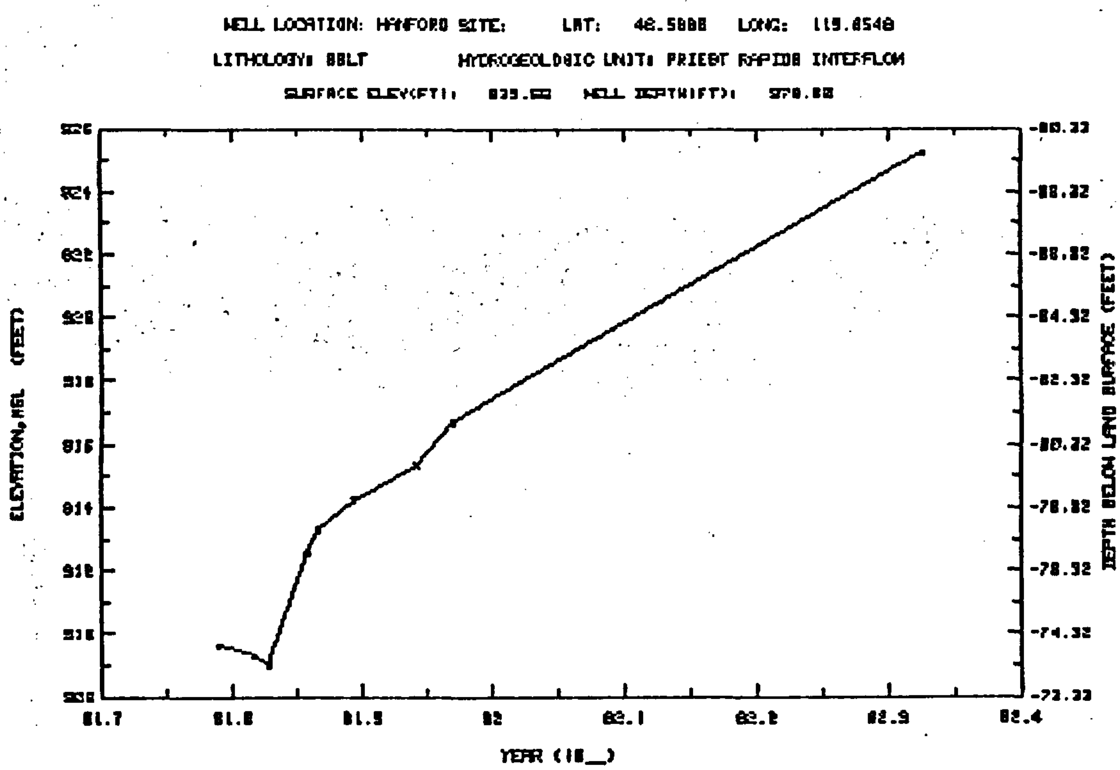
12 Aug 2:22:33 pm

File name: OBRIAN
Well location: HANFORD SITE:COLD CREEK VALLEY
Latitude: 46.5868464158
Longitude: 119.781364099
Lithology: BSLT
Hydro unit: PRIEST RAPIDS INTERFLOW
Surface elevation: 973.37 feet (elevation of measuring pt)
Well depth: 900 feet
Records in file 154

1	m	78.0208	25.0800	78	m	79.1215	49.1400
2	m	78.0211	24.0000	79	m	79.1216	49.0200
3	m	78.0309	19.2400	80	m	79.1217	48.5700
4	m	78.0310	18.0000	81	m	79.1218	48.3700
5	m	78.0411	25.4000	82	m	79.1219	48.2500
6	m	78.0412	24.8000	83	m	79.1220	48.1600
7	m	78.0505	30.1300	84	m	79.1221	47.9500
8	m	78.0507	28.0000	85	m	79.1222	48.2600
9	m	78.0513	29.9000	86	m	79.1223	47.8200
10	m	78.0606	39.5700	87	m	79.1224	47.7200
11	m	78.0710	47.0000	88	m	79.1225	48.0000
12	m	78.0712	47.1300	89	m	79.1226	48.1900
13	m	78.0806	45.0000	90	m	79.1227	48.1300
14	m	78.0810	45.5000	91	m	79.1228	48.0000
15	m	78.0906	45.1000	92	m	80.0104	47.0000
16	m	78.0915	45.3800	93	m	80.0114	45.6600
17	m	78.1115	45.1200	94	m	80.0115	45.5000
18	m	79.0117	36.6400	95	m	80.0116	45.4800
19	m	79.0123	36.1800	96	m	80.0117	45.8500
20	m	79.0221	32.1300	97	m	80.0118	45.9100
21	m	79.0301	33.0800	98	m	80.0119	45.7700
22	m	79.0323	33.0150	99	m	80.0120	45.6800
23	m	79.0329	33.7800	100	m	80.0121	45.6600
24	m	79.0423	38.1500	101	m	80.0125	45.1500
25	m	79.0510	41.0000	102	m	80.0126	45.2700
26	m	79.0520	46.0000	103	m	80.0127	45.2200
27	m	79.0610	38.2000	104	m	80.0128	45.0600

28	m	79.0620	61.0000
29	m	79.0810	65.2200
30	m	79.0829	60.0000
31	m	79.0905	57.7200
32	m	79.0906	57.9300
33	m	79.0907	57.3300
34	m	79.0910	55.6800
35	m	79.0912	56.4200
36	m	79.0912	56.4500
37	m	79.0915	57.7200
38	m	79.0924	55.1400
39	m	79.0925	55.5000
40	m	79.1008	57.2200
41	m	79.1021	56.1300
42	m	79.1026	57.0800
43	m	79.1101	56.4900
44	m	79.1105	55.9500
45	m	79.1106	55.4500
46	m	79.1107	55.1500
47	m	79.1109	55.4000
48	m	79.1110	54.0300
49	m	79.1112	53.8800
50	m	79.1113	54.7800
51	m	79.1114	53.5600
52	m	79.1115	53.1800
53	m	79.1116	52.7500
54	m	79.1117	52.2600
55	m	79.1118	52.3100
56	m	79.1119	52.6400
57	m	79.1120	52.6200
58	m	79.1121	52.4300
59	m	79.1122	51.7800
60	m	79.1123	51.7800
61	m	79.1124	51.3700
62	m	79.1128	51.7100
63	m	79.1129	51.3900
64	m	79.1130	51.1800
65	m	79.1201	50.6600
66	m	79.1202	50.2300
67	m	79.1203	50.4000
68	m	79.1204	50.2500
69	m	79.1205	50.8100
70	m	79.1206	49.9300
71	m	79.1207	49.8800
72	m	79.1208	49.8300
73	m	79.1209	49.3900
74	m	79.1210	49.6200
75	m	79.1211	49.5000
76	m	79.1212	49.2000
77	m	79.1213	49.0679
105	m	80.0129	45.9300
106	m	80.0130	46.0600
107	m	80.0131	45.8800
108	m	80.0201	45.7200
109	m	80.0202	45.5600
110	m	80.0203	45.5000
111	m	80.0204	45.7400
112	m	80.0207	44.0600
113	m	80.0208	43.8900
114	m	80.0508	46.3300
115	m	80.0807	63.1700
116	m	80.0905	63.1500
117	m	80.1027	64.4100
118	m	81.0130	69.7400
119	m	81.0131	70.2300
120	m	81.0207	49.7500
121	m	81.0807	69.7400
122	m	81.0814	70.2300
123	m	81.0817	69.7400
124	m	81.0821	68.8900
125	m	81.0828	66.1700
126	m	81.0904	65.3200
127	m	81.0925	63.4200
128	m	81.1002	62.5600
129	m	81.1009	63.8600
130	m	81.1016	63.7600
131	m	81.1023	64.2500
132	m	81.1030	66.9300
133	m	81.1110	60.8800
134	m	81.1113	60.0400
135	m	81.1120	59.4000
136	m	81.1204	58.0900
137	m	81.1211	57.6200
138	m	82.0129	54.1700
139	m	82.0205	54.0600
140	m	82.0219	52.6400
141	m	82.0226	52.2800
142	m	82.0305	52.2700
143	m	82.0312	51.5800
144	m	82.0407	50.9300
145	m	82.0422	50.6100
146	m	82.0429	50.1500
147	m	82.0506	50.3900
148	m	82.0513	53.2300
149	m	82.0528	56.2200
150	m	82.0607	58.2400
151	m	82.0611	57.2900
152	m	82.0617	58.9600
153	m	82.0701	58.8300
154	m	82.0709	58.9700

```
User aspect ratio:  .052083
Angle = ATN(-Aspect_ratio*Slope)
OBRIAN   LIN ALL 0  A -4.27E+02  B  5.96E+00  r^2  .4499  angle -17.2337
```

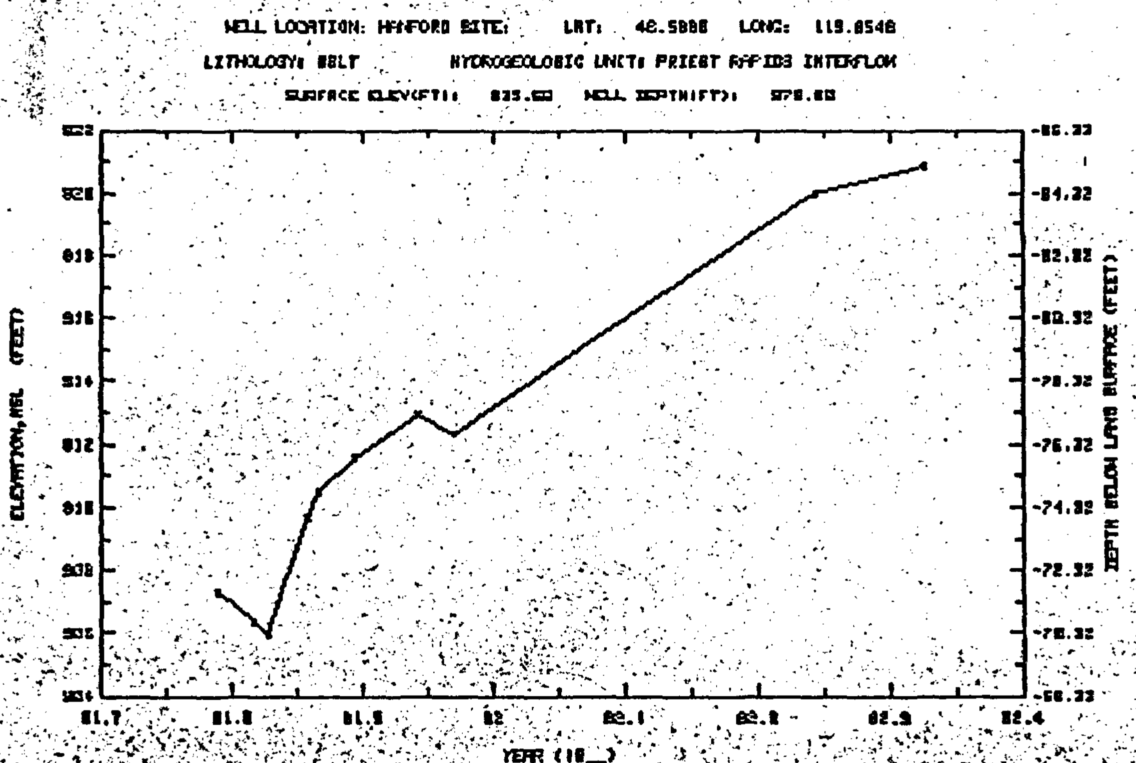


HYDROGRAPH FOR WELL LOCATION HANFORD SITE:,

File name: MCG-IN
Well location: HANFORD SITE:COLD CREEK VALLEY
Latitude: 46.5888444955
Longitude: 119.65479826
Lithology: BSLT
Hydro unit: PRIEST RAPIDS INTERFLOW
Surface elevation: 835.68 feet (elev of measuring pt)
Well depth: 978 feet
Records in file 10

1	m	81.1016	-71.6100	6	m	81.1123	-75.9100
2	m	81.1026	-70.6900	7	m	81.1211	-77.2500
3	m	81.1030	-70.2900	8	m	81.1221	-76.6500
4	m	81.1110	-73.9900	9	m	82.0331	-84.3200
5	m	81.1113	-74.8000	10	m	82.0430	-85.1700

User aspect ratio: .024306
Angle = ATN(-Aspect_ratio*Slope)



HYDROGRAPH FOR WELL LOCATION HANFORD SITE:
FILE: MCG-IN

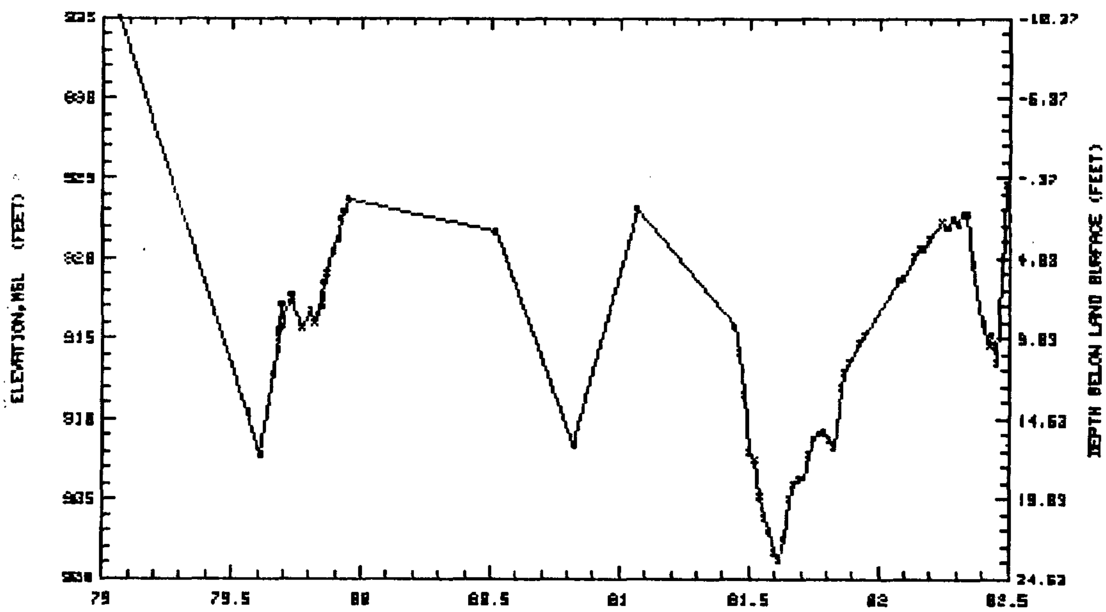
12 Aug 2:32: 3 pm

File name: MCG-AN
Well location: HANFORD SITE:COLD CREEK VALLEY
Latitude: 46.5888444955

User aspect ratio: .0625
Angle = ATN(-Aspect_ratio*Slope)

27 July 4: 6:27 pm

WELL LOCATION: COLD CREEK VA LAT: 46.5988 LONG: 119.7814
LITHOLOGY: BSLT HYDROGEOLOGIC UNIT: PRIEST RAPIDS INTERFLOW
SURFACE ELEV(FT): 924.63 WELL DEPTH(FT): 777.00



HYDROGRAPH FOR WELL LOCATION COLD CREEK VA
FILE: FORD

27 July 4: 4:17 pm

File name FORD
Well location: COLD CREEK VALLEY-HANFORD SITE
Latitude: 46.5868464158
Longitude: 119.781364099
Lithology: BSLT
Hydro unit: PRIEST RAPIDS INTERFLOW
Surface elevation: 924.63 feet
Well depth: 777 feet
Records in file 74

1	m	79.0123	-10.3800	38	m	81.0731	21.6800
2	m	79.0724	14.1600	39	m	81.0807	22.9600
3	m	79.0810	16.8300	40	m	81.0814	23.4400
4	m	79.0829	11.8100	41	m	81.0821	22.1300
5	m	79.0904	10.3000	42	m	81.0828	19.5700
6	m	79.0905	9.6100	43	m	81.0904	18.6900
7	m	79.0906	9.2000	44	m	81.0911	18.4000
8	m	79.0907	9.0500	45	m	81.0918	18.3000
9	m	79.0910	7.4800	46	m	81.0925	16.8100
10	m	79.0912	8.9100	47	m	81.1002	15.8200
11	m	79.0912	8.2200	48	m	81.1009	15.5300
12	m	79.0924	6.9000	49	m	81.1016	15.4400
13	m	79.0925	7.2900	50	m	81.1023	15.8900
14	m	79.1008	8.9900	51	m	81.1030	16.3500
15	m	79.1021	7.9100	52	m	81.1110	12.6200
16	m	79.1026	8.6500	53	m	81.1113	11.7800
17	m	79.1101	8.1100	54	m	81.1120	11.1600
18	m	79.1105	7.6500	55	m	81.1204	9.9100
19	m	79.1106	7.1900	56	m	81.1211	9.4600
20	m	79.1107	6.9900	57	m	82.0129	5.9800
21	m	79.1109	6.1300	58	m	82.0205	5.8300
22	m	79.1112	5.6000	59	m	82.0219	4.4600
23	m	79.1121	4.2100	60	m	82.0226	4.0800
24	m	79.1128	3.3800	61	m	82.0305	4.0700
25	m	79.1203	2.1200	62	m	82.0312	3.3800
26	m	79.1207	1.6200	63	m	82.0331	2.3800
27	m	79.1213	.8800	64	m	82.0407	2.7400
28	m	80.0708	2.9900	65	m	82.0415	2.2000
29	m	80.1027	16.2300	66	m	82.0422	2.5400
30	m	81.0125	1.5000	67	m	82.0429	1.9200
31	m	81.0612	8.8700	68	m	82.0506	1.9000
32	m	81.0619	10.4900	69	m	82.0513	4.9900
33	m	81.0626	13.1400	70	m	82.0528	8.6300
34	m	81.0702	16.6700	71	m	82.0607	10.0400
35	m	81.0710	17.1300	72	m	82.0610	9.3500
36	m	81.0717	19.4300	73	m	82.0617	11.0900
37	m	81.0724	20.8700	74	m	82.0630	0.0000

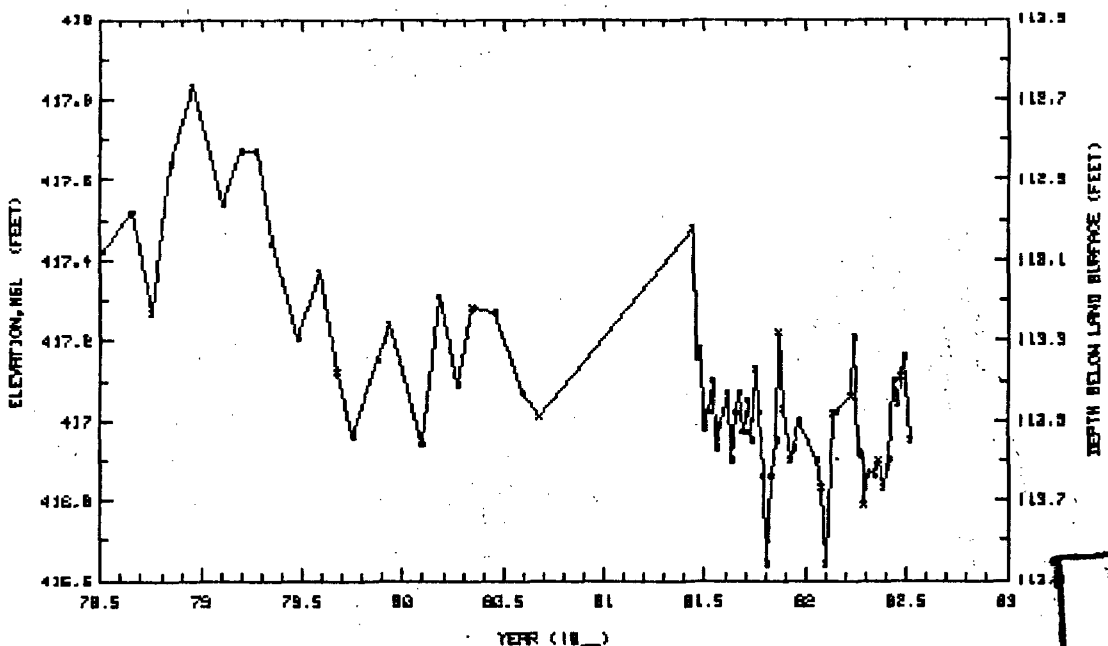
User aspect ratio: 2.0089
Angle = ATN(-Aspect_ratio*Slope)

27 July   3:40:36 pm

WELL LOCATION: HNFD ST DB-4   LAT: 46.5597   LONG: 119.4359

LITHOLOGY: BSLT   HYDROGEOLOGIC UNIT: MABTON INTERBED

SURFACE ELEV(FT): 520.53   WELL DEPTH(FT): 1402.80



HYDROGRAPH FOR WELL LOCATION HNFD ST DB-4
FILE: DB-4

27 July 3:38:48 pm

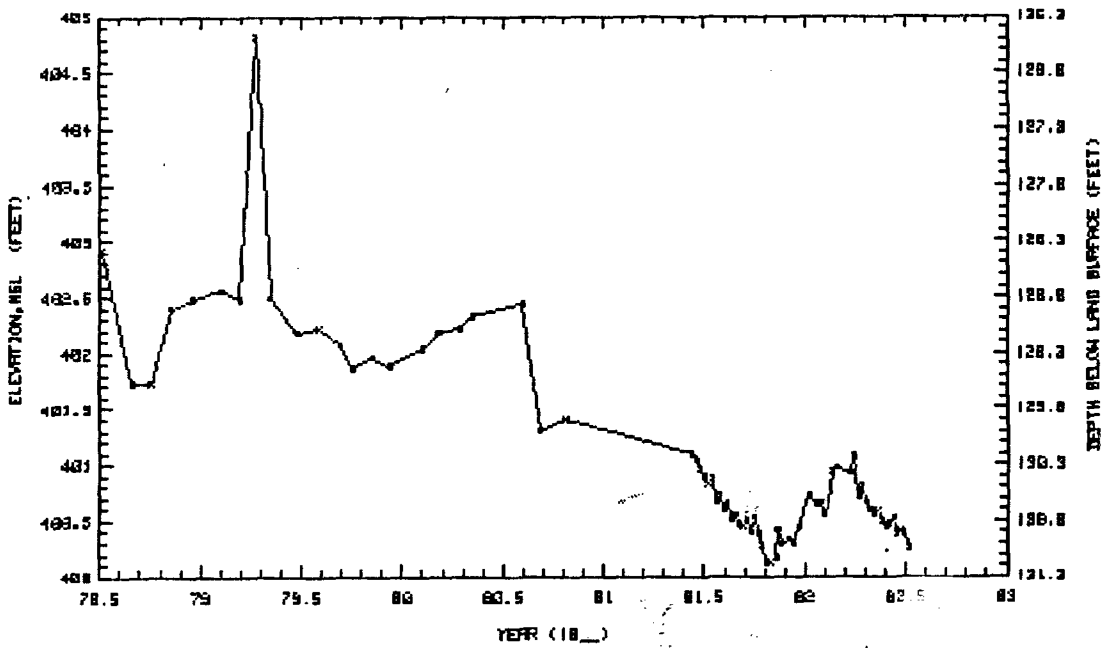
File name DB-4
Well location: HNFD ST DB-4
Latitude: 46.5396705877
Longitude: 119.435883764
Lithology: BSLT
Hydro unit: MABTON INTERBED
Surface elevation: 530.51 feet
Well depth: 1403 feet
Records in file 71

1	m	78.0706	113.0900
2	m	78.0829	112.9900
3	m	78.1002	113.2400
4	m	78.1106	112.8700
5	m	78.1214	112.6800
6	m	79.0209	112.9700
7	m	79.0313	112.8400
8	m	79.0411	112.8400
9	m	79.0508	113.0700
10	m	79.0625	113.3000
11	m	79.0801	113.1400
12	m	79.0904	113.3900
13	m	79.1002	113.5500
14	m	79.1116	113.3600
15	m	79.1207	113.2700
16	m	80.0204	113.5700
17	m	80.0305	113.2000
18	m	80.0410	113.4200
19	m	80.0505	113.2300
20	m	80.0618	113.2400
21	m	80.0806	113.4400
22	m	80.0905	113.5000
23	m	81.0612	113.0300
24	m	81.0619	113.3500
25	m	81.0626	113.3300
26	m	81.0702	113.5300
27	m	81.0710	113.4900
28	m	81.0717	113.4100
29	m	81.0724	113.5800
30	m	81.0731	113.5200
31	m	81.0814	113.4400
32	m	81.0821	113.6100
33	m	81.0828	113.4900
34	m	81.0904	113.4400
35	m	81.0911	113.5400
36	m	81.0918	113.4600
37	m	81.0923	113.5400
38	m	81.0925	113.5600
39	m	81.1002	113.3800
40	m	81.1009	113.4900
41	m	81.1016	113.6500
42	m	81.1023	113.8700
43	m	81.1030	113.6500
44	m	81.1110	113.5600
45	m	81.1113	113.2900
46	m	81.1120	113.4800
47	m	81.1204	113.6100
48	m	81.1211	113.5800
49	m	81.1221	113.5100
50	m	82.0122	113.6100
51	m	82.0129	113.6800
52	m	82.0205	113.8700
53	m	82.0219	113.4950
54	m	82.0226	113.4900
55	m	82.0324	113.4500
56	m	82.0331	113.3000
57	m	82.0408	113.5900
58	m	82.0415	113.6000
59	m	82.0416	113.7200
60	m	82.0422	113.6500
61	m	82.0429	113.6400
62	m	82.0506	113.6500
63	m	82.0513	113.6100
64	m	82.0520	113.6800
65	m	82.0528	113.6300
66	m	82.0603	113.6100
67	m	82.0611	113.4100
68	m	82.0617	113.4700
69	m	82.0624	113.4000
70	m	82.0630	113.3500
71	m	82.0709	113.5600

User aspect ratio: .5625
Angle = ATN(-Aspect_ratio*Slope)

27 July 3:43: 9 pm

WELL LOCATION: HNFD ST DB-7 LAT: 46.4893 LONG: 119.4212
LITHOLOGY: BSLT HYDROGEOLOGIC UNIT: MABTON INTERBED
SURFACE ELEV(FT): 531.22 WELL DEPTH(FT): 812.80



HYDROGRAPH FOR WELL LOCATION HNFD ST DB-7
FILE: DB-7

27 July 3:41: 9 pm

File name DB-7
Well location: HNFD ST DB-7
Latitude: 46.4892579629
Longitude: 119.421188342
Lithology: BSLT
Hydro unit: MABTON INTERBED
Surface elevation: 531.32 feet
Well depth: 812 feet
Records in file 71

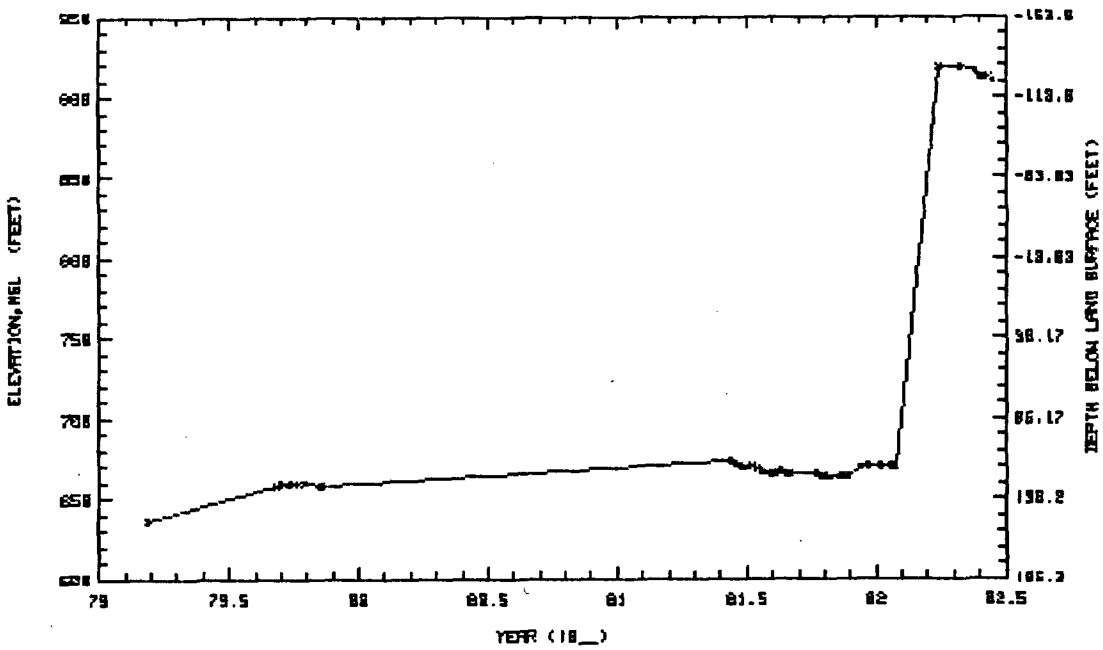
1	m	78.0706	128.4000
2	m	78.0830	129.5900
3	m	78.1004	129.5900
4	m	78.1108	128.9200
5	m	78.1219	128.8400
6	m	79.0208	128.7600
7	m	79.0312	128.8400
8	m	79.0411	126.5000
9	m	79.0508	128.8300
10	m	79.0625	129.1400
11	m	79.0803	129.1100
12	m	79.0912	129.2500
13	m	79.1002	129.4600
14	m	79.1108	129.3600
15	m	79.1209	129.4400
16	m	80.0207	129.2800
17	m	80.0307	129.1400
18	m	80.0414	129.1100
19	m	80.0507	129.0000
20	m	80.0805	128.8800
21	m	80.0908	130.0200
22	m	80.1025	129.9200
23	m	81.0612	130.2200
24	m	81.0619	130.2800
25	m	81.0626	130.3600
26	m	81.0702	130.4300
27	m	81.0710	130.4900
28	m	81.0717	130.4500
29	m	81.0724	130.6400
30	m	81.0731	130.6000
31	m	81.0807	130.7100
32	m	81.0814	130.6600
33	m	81.0821	130.8100
34	m	81.0828	130.7700
35	m	81.0904	130.8500
36	m	81.0911	130.8600
37	m	81.0918	130.8100
38	m	81.0925	130.9200
39	m	81.1002	130.7900
40	m	81.1009	130.9300
41	m	81.1016	131.0400
42	m	81.1023	131.1900
43	m	81.1030	131.2000
44	m	81.1110	131.1500
45	m	81.1113	130.9000
46	m	81.1120	131.0300
47	m	81.1204	130.9900
48	m	81.1211	131.0200
49	m	81.1221	130.8800
50	m	82.0108	130.6000
51	m	82.0122	130.6700
52	m	82.0129	130.6600
53	m	82.0205	130.7700
54	m	82.0219	130.3800
55	m	82.0226	130.3500
56	m	82.0324	130.3900
57	m	82.0331	130.2500
[illegible]	m	82.0408	130.6100
59	m	82.0415	130.5200
60	m	82.0422	130.6600
61	m	82.0429	130.7200
62	m	82.0506	130.7600
63	m	82.0513	130.7400
64	m	82.0520	130.8200
65	m	82.0528	130.8600
66	m	82.0603	130.8500
67	m	82.0611	130.7900
68	m	82.0617	130.9300
69	m	82.0624	130.9100
70	m	82.0630	130.9300
71	m	82.0709	131.0600

27 July 3:45:36 pm

WELL LOCATION: HNFD ST DB-11 LAT: 46.5758 LONG: 119.7252

LITHOLOGY: BSLT HYDROGEOLOGIC UNIT: PRIEST RAPIDS

SURFACE ELEV(FT): 786.37 WELL DEPTH(FT): 3238.88



HYDROGRAPH FOR WELL LOCATION HNFD ST DB-11
FILE: DB-11

27 July 3:45:49 pm

File name DB-11
Well location: HNFD ST DB-11
Latitude: 46.5796133762
Longitude: 119.725159033
Lithology: BSLT
Hydro unit: PRIEST RAPIDS
Surface elevation: 786.17 feet
Well depth: 1210 feet
Records in file 46

1	m	79.0310	150.1900	24	m	81.1009	121.0900
2	m	79.0907	128.0400	25	m	81.1016	121.8900
3	m	79.0912	126.4200	26	m	81.1020	122.4500
4	m	79.0924	127.4200	27	m	81.1022	122.1000
5	m	79.0927	126.1900	28	m	81.1023	122.2100
6	m	79.1008	126.1900	29	m	81.1030	122.7800
7	m	79.1017	125.7300	30	m	81.1110	122.7300
8	m	79.1106	128.0400	31	m	81.1113	122.2000
9	m	79.1109	128.0400	32	m	81.1120	122.3700
10	m	81.0612	113.0900	33	m	81.1124	122.2500
11	m	81.0619	114.3000	34	m	81.1124	122.2600
12	m	81.0626	115.8200	35	m	81.1211	116.4000
13	m	81.0702	116.8100	36	m	81.1221	116.0500
14	m	81.0710	116.1100	37	m	82.0108	115.4800
15	m	81.0717	117.6600	38	m	82.0122	115.3700
16	m	81.0724	118.6600	39	m	82.0129	115.7500
17	m	81.0731	119.9500	40	m	82.0331	-132.2700
18	m	81.0807	119.9600	41	m	82.0429	-132.6600
19	m	81.0814	120.5700	42	m	82.0520	-130.2100
20	m	81.0821	119.4500	43	m	82.0528	-126.2600
21	m	81.0828	120.0000	44	m	82.0603	-126.5000
22	m	81.0904	120.3000	45	m	82.0611	-125.6900
23	m	81.1007	120.4400	46	m	82.0617	-123.9500

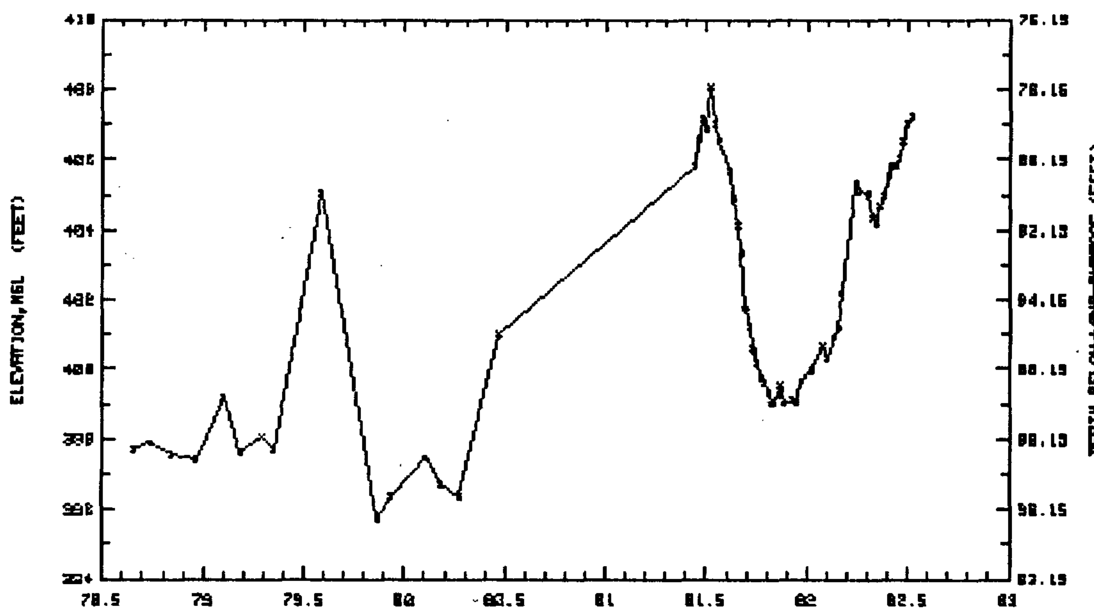
User aspect ratio: .17578
Angle = ATN(-Aspect_ratio*Slope)

27 July   3:49:49   pm

WELL LOCATION: HNFD ST DB-12   LAT: 46.6169   LONG: 119.7036

LITHOLOGY: BSLT   HYDROGEOLOGIC UNIT: PRIEST RAPIDS

SURFACE ELEV(FT):   486.35   WELL DEPTH(FT):   2.88



HYDROGRAPH FOR WELL LOCATION HNFD ST DB-12
FILE: DB-12

27 July 3:47:36 pm

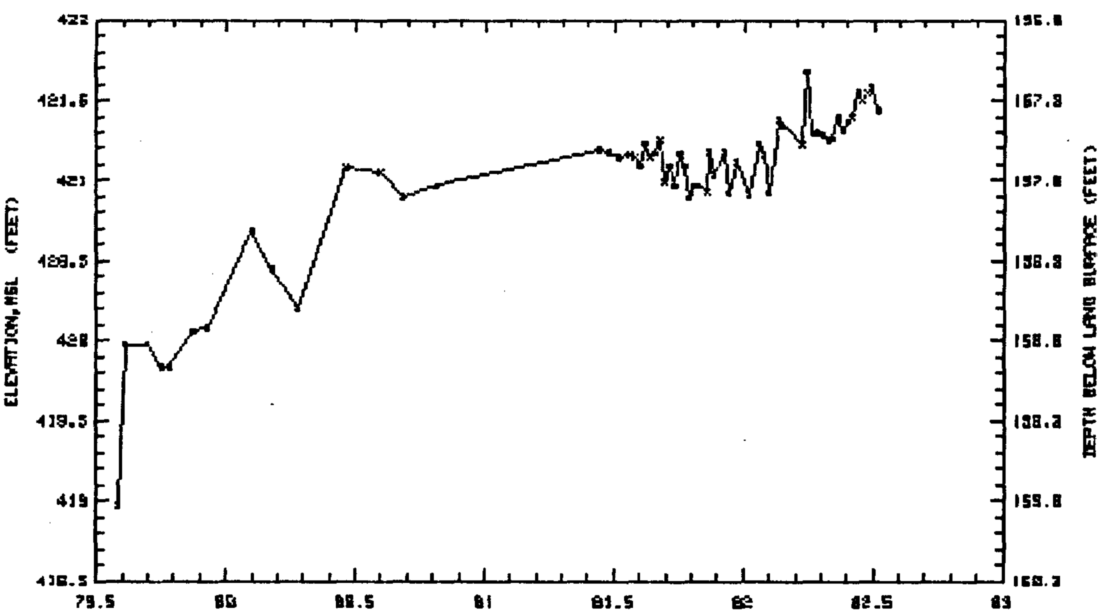
File name DB-12
Well location: HNFD ST DB-12
Latitude: 46.616897644
Longitude: 119.703565984
Lithology: BSLT
Hydro unit: PRIEST RAPIDS
Surface elevation: 486.15 feet
Well depth: 653 feet
Records in file 62

1	m	78.0828	88.4300
2	m	78.0927	88.2600
3	m	78.1103	88.5900
4	m	78.1219	88.7200
5	m	79.0206	86.9700
6	m	79.0309	88.4900
7	m	79.0416	88.0900
8	m	79.0507	88.4600
9	m	79.0801	81.0900
10	m	79.1112	90.4300
11	m	79.1206	89.7800
12	m	80.0207	88.6800
13	m	80.0305	89.4300
14	m	80.0410	89.7800
15	m	80.0620	85.1300
16	m	81.0612	80.3600
17	m	81.0619	79.5700
18	m	81.0626	79.0100
19	m	81.0702	79.2700
20	m	81.0710	78.0900
21	m	81.0717	79.1400
22	m	81.0724	79.6000
23	m	81.0814	80.5000
24	m	81.0821	81.2700
25	m	81.0828	82.0200
26	m	81.0904	82.7900
27	m	81.0911	84.4000
28	m	81.0918	84.9300
29	m	81.0923	85.5700
30	m	81.0925	85.6300
31	m	81.1002	86.0000
32	m	81.1009	86.3800
33	m	81.1016	86.5500
34	m	81.1023	86.8000
35	m	81.1030	87.1300
36	m	81.1110	86.8800
37	m	81.1113	86.6100
38	m	81.1120	87.1400
39	m	81.1204	87.0300
40	m	81.1211	87.0800
41	m	81.1221	86.5100
42	m	82.0108	86.2100
43	m	82.0129	85.5000
44	m	82.0205	85.8500
45	m	82.0219	85.2300
46	m	82.0226	84.9600
47	m	82.0305	83.9600
48	m	82.0331	80.8100
49	m	82.0406	81.0400
50	m	82.0422	81.1200
51	m	82.0429	81.8200
52	m	82.0506	81.9500
53	m	82.0513	81.4600
54	m	82.0520	81.1700
55	m	82.0528	80.6400
56	m	82.0603	80.3200
57	m	82.0610	80.3000
58	m	82.0614	80.3400
59	m	82.0617	80.1200
60	m	82.0624	79.6500
61	m	82.0701	79.1200
62	m	82.0709	78.9500

User aspect ratio: .625
Angle = ATN(-Aspect_ratio*Slope)
User aspect ratio: .625
Angle = ATN(-Aspect_ratio*Slope)

27 July   4: 0:43 pm

WELL LOCATION: HNFD ST DB-13   LAT: 46.4920   LONG: 119.5158
LITHOLOGY: BSLT   HYDROGEOLOGIC UNIT: MABTON INTERBED
SURFACE ELEV(FT): 970.77   WELL DEPTH(FT): 1232.00



HYDROGRAPH FOR WELL LOCATION HNFD ST DB-13
FILE: DB-13

27 July 3:56:21 pm

File name DB-13
Well location: HNFD ST DB-13
Latitude: 46.4919810618
Longitude: 119.515558893
Lithology: BSLT
Hydro unit: MABTON INTERBED
Surface elevation: 578.77 feet
Well depth: 1292 feet
Records in file 61

1	m	79.0801	159.8000	32	m	81.1023	157.8000
2	m	79.0812	158.7900	33	m	81.1030	157.8000
3	m	79.0912	158.7900	34	m	81.1110	157.8400
4	m	79.1002	158.9400	35	m	81.1113	157.5900
5	m	79.1012	158.9400	36	m	81.1120	157.7300
6	m	79.1116	158.7100	37	m	81.1204	157.5900
7	m	79.1116	158.7100	38	m	81.1211	157.8500
8	m	79.1205	158.6900	39	m	81.1221	157.6500
9	m	80.0206	158.0800	40	m	82.0108	157.8600
10	m	80.0305	158.3200	41	m	82.0122	157.5400
11	m	80.0410	158.5600	42	m	82.0129	157.6100
12	m	80.0619	157.6900	43	m	82.0205	157.8500
13	m	80.0806	157.7200	44	m	82.0219	157.3900
14	m	80.0905	157.8700	45	m	82.0226	157.4300
15	m	80.1025	157.8000	46	m	82.0324	157.5500
16	m	81.0612	157.5800	47	m	82.0331	157.0900
17	m	81.0626	157.5900	48	m	82.0408	157.4800
18	m	81.0709	157.6200	49	m	82.0415	157.4700
19	m	81.0724	157.6100	50	m	82.0422	157.4900
20	m	81.0731	157.6200	51	m	82.0429	157.5200
21	m	81.0807	157.6800	52	m	82.0506	157.5100
22	m	81.0814	157.5400	53	m	82.0513	157.3800
23	m	81.0821	157.6200	54	m	82.0520	157.4500
24	m	81.0828	157.6000	55	m	82.0528	157.4000
25	m	81.0904	157.5200	56	m	82.0603	157.3800
26	m	81.0911	157.7800	57	m	82.0611	157.2200
27	m	81.0918	157.6800	58	m	82.0617	157.2700
28	m	81.0925	157.8000	59	m	82.0624	157.2200
29	m	81.1002	157.6000	60	m	82.0630	157.1900
30	m	81.1009	157.6800	61	m	82.0709	157.3300
31	m	81.1016	157.8800				

7/19/82

To: Bell, Miller
Boyle, Cook, Greeves (Chase),
Justus (Brooks), Prestholt,
Wright (Verma)
Copland, Johnson, Knapp

From: Wright

Subject: Proposed Schedule for BWIP Review

Your attention is invited to the attached draft memo.

Pls provide to Prestholt, before July 27, suggested changes ~~that~~ you consider to be improvements. If no response is received from you I shall assume ~~that~~ you have no problem with the document.

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DRAFT

7/19/82

TO: M. Bell, H. Miller
FROM: R. Wright
SUBJECT: Schedule of Activities for Review and Analysis of the BWIP Site Characterization Report

Attached is a proposed schedule of activities for NRC's review and analysis of the Site Characterization Report for the BWIP. This schedule is predicated on two assumptions:—

1) The SCR will be received on November 15, 1982.

2) The Site Characterization Analysis (SCA) will be published within 8 months after receipt of the SCR.

The proposed schedule has been prepared by myself in cooperation with the topic review coordinators and the appropriate section leaders. It represents our best judgement on how to use the 8 month period — tasks to be done, their order, and the time for completion of each. Products of the review process are shown in the second column from the right.

Clearly, the 8 month period is tight for: (a) publication of a draft Site Characterization Analysis (DSCA), followed by (b) a 90-day (minimum) public comment period, followed by (c) publication of the SCA, with responses to public comments. Nevertheless, through careful preparation, close coordination within the review team, and preparation of much material in advance of SCR receipt, we believe that sound, credible and viable documents can be published within the prescribed time frame. The proposed schedule has been prepared to optimize efforts to this end.

However, it is important to note that the proposed effort ~~has~~ is limited by several constraints, among which are the following:

- Success depends upon the availability of NRC people in accordance with the commitment schedule now in preparation.

• The SCA will be a document of no more than forty pages, single spaced. Supporting material, as appendices, will amplify the SCA, but all such material must be in final form, approved by NMSS, before SCR receipt.

• The schedule provides three weeks for review and revision of the DSCA at branch, division, and NMSS levels. Similarly, three weeks are provided for the SCA. If more time is consumed in review/revision of either document, the 8 month goal can not be met.

• Response to public comments will be limited to (a) specific, brief responses to states and (b) brief responses to representative responses from other sources.

• If responses are needed to comments offered after close of the 90-day period, the responses may be released after publication of the SCA.

• No documents other than those shown in the

attachments will be prepared after SCR receipt, eg. Commission papers, position papers, additional analyses, expanded response to public comments, and the like.

To ensure a successful SCR review and analysis, and to meet the 8-month goal for completion, it is important for those interested in the SCA process to be aware of the plans, the products to be developed and, especially, the constraints noted above.

6.

Week	Specific Activities	Continuing Activities	Products	Approx. Level of Act.
1983				
1/2	Draft DSCA prepared	Site issues analyzed; Text of DSCA prepared; SCA app. + graphics prep.		H
1/9	Draft DSCA completed		Draft of DSCA	H
1/16	Review by branches, div., OELD			M
1/23	Review by NMSS			M
1/30	Final revision + approval		DSCA; site issue analyses	M
2/6	Publication			
2/13	Public comment period	Appendices and graphics finalized; text cleaned up		
2/20				
2/27				
3/6				
3/13				
3/20				
3/27				
4/3				
4/10				
4/17				
4/24				
5/1				
5/8				
5/15	Responses to p. comments prep. SCA prepared	Site issue analyses revision, if necessary; SCA prepared Prelim. → Final; Response to public comments prepared Prelim. → Final		H
5/22	"			M
5/29	"			M
6/5	"			M
6/12	Discussion of SCA w. DOE			M
6/19	Review by branches, div., OELD		Draft of SCA; Draft of res. to p. comment	M
6/26	Review by NMSS			M
7/3	Final SCA prepared		SCA; response to public comments; issue analyses	M
7/10	SCA published			

7/9/82

Outline — BWIP SCR Activities

(PSCA - preparatory site char. anal.; DSCA - draft site char. an.)

Week	Specific Activities	Continuing Activities	Products	Approx. Level of Activity
1982				
7/13		Site issues analyzed (7/13–9/12); SCA appendices + graphics prepared (7/13–10/17)		M
7/18	Hydro. w. shop			
7/25	Hydro. w. shop			
8/1				
8/8	Waste/retardation w.s.			
8/15				
8/22		PSCA prepared (8/22–10/17)	Mtg. notes - hydro	
8/29	Design w. shop			
9/5			Mtg. notes - waste/geochem.	
9/12			Site issue analyses	
9/19				
9/26	Stability w. shop	Final sections (9/26–10/17)	Mtg. notes - design	
10/3			Sections of PSCA	
10/10				
10/17			PSCA	
10/24			Mtg. notes - stability	
11/7				
11/14	SCR arrives; SCR divided			VH
11/21	Material distributed			
11/28	Site issues analyzed	Site issues analyzed (11/28–12/26); DSCA prepared (11/28–12/26)		
12/5	"			
12/12	Topic groups prepare DSCA sections			
12/19	"			
12/26	DSCA prepared			

Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720
Telephone 415/486-4000
FTS: 451-4000

RECEIVED
JUL 26 1982
F. H. DOVE

Earth Sciences Division

July 21, 1982

July 28, 1982 — 6 PM
July 29, 198 — 7:30 AM

Dr. S. Baker
Rockwell Hanford Operations
Energy Systems Group
P.O. Box 800
Richland, WA 99352

Dear Steve:

Per our telephone conversation of July 20 please find below a list of suggested items for the agenda of the Modeling Task Force meeting to be held on July 28 and 29. This list was compiled jointly by the USGS, PNL and LBL at a meeting held in Tacoma on July 19.

Suggested Agenda Items

1. Agree on plan for resolution of differences between models.
2. Identify and list conceptual/technical differences between models.
3. Identify procedures for resolving above differences.
4. Specify tasks to be completed in FY-1982 and for presentation at the September workshop.
5. Review drilling history and test data on hydrologic characteristics, hydraulic head and chemistry from boreholes DC-14 and DC-15.
6. Review the spatial distribution of existing wells and review the potentiometric interpretation for the various formations as a function of time.

We look forward to seeing you on the 28th and 29th.

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Very truly yours,

Brian
Brian Y. Kanehiro

Charles Wilson
Charles R. Wilson

cc. H. Dove, PNL
W. Myer, USGS
D. Watkins, LBL
G. Hunt, Rockwell

~~[illegible]~~ Preliminary Lithologic Description of The Mabton and Vantage Interbeds at Selected Boreholes

INTERBED / BOREHOLE		DB-15	DB-13/DC-12(3)	DC-14	DC-15	DC-16	RRL-2
MABTON	Description (1)	Upper Unit Alternating silty fine qtz. & mica. SS & coarse qtz & mica. SS - compact Lower Unit Silty clay w/ash stringers	Upper Unit Sand varying from coarse to fine to clayey &/or silty sand, w/ clay stringers Lower Unit Clay	Upper Unit Clay w/minor sand Middle Unit Alternating coarse sand & silty very fine sand Lower Unit Clay to silty clay	Upper Unit Claystone Lower Unit Medium grained SS w/some claystone weakly cemented	Silty clay grading downward to silty sandy clay	Upper Unit Alternating mica. SS w/clay matrix & clay Lower Unit Clay
mineralogy	Min.	ND	ND	ND	ND	ND	ND
	(2) Thick. (ft)	94	152	102	29	121	124
VANTAGE	Description (1)	Flowtop breccia w/clay matrix & minor ash (?); & clay w/minor qtz. grains	Tuffaceous silty clay	Clay	None	NOT PENETRATED	Siltstone & claystone
mineralogy	Min.	ND	ND	ND	ND		ND
	(2) Thick. (ft)	1	<1	<1	NP		4

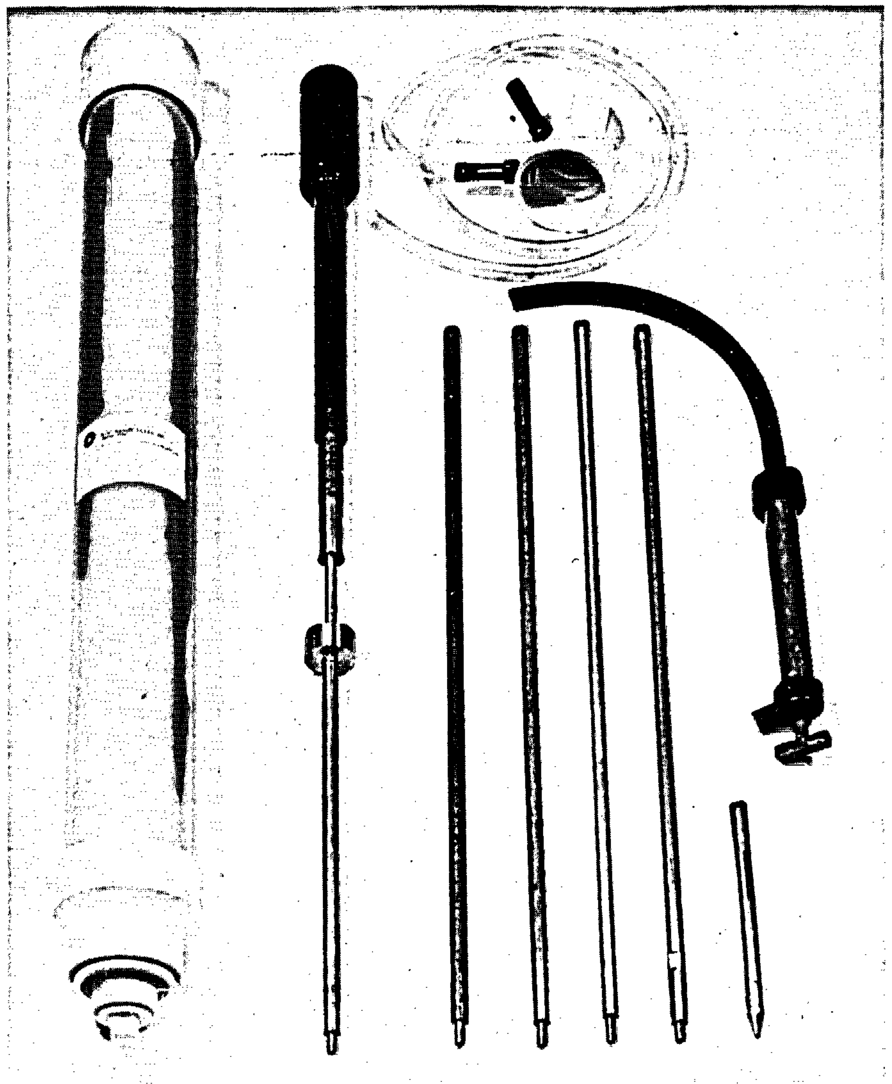
ND - Not Determined
NP - Not Present
(1) Summarized from original geologic logs
(2) Primarily from RHO-BWI-ST-14
(3) Mabton from DB-13; Vantage from DC-12

FINAL 11/17

Variable	Distribution	WMHT Values	Units	Person Responsible
Kd for Am in host rock	Normal	8.5E1 - 6.0E2	ml/g	Corrado
Kd for Pu in host rock	Normal	5.0E0 - 3.9E1	ml/g	Corrado
Kd for U in host rock	Normal	1.0E0 - 1.1E1	ml/g	Corrado
Kd for Np in host rock	Normal	2.0E0 - 1.8E1	ml/g	Corrado
Kd for fission products in host rock	Normal	4.2E1 - 3.0E2	ml/g	Corrado
Kd for Am in aquifer	Normal	2.5E2 - 1.8E3	ml/g	Corrado
Kd for Pu in aquifer	Normal	5.0E2 - 3.5E3	ml/g	Corrado
Kd for U in aquifer	Normal	1.8E1 - 1.2E2	ml/g	Corrado
Kd for Np in aquifer	Normal	1.2E1 - 8.8E1	ml/g	Corrado
Kd for fission products in aquifer	Normal	5.0E1 - 3.5E2	ml/g	Corrado
Solubility limit for Am	Lognormal	3.7E-18 - 7.2E-10	g/g	Wise
Solubility limit for Pu	Lognormal	5.4E-16 - 4.4E-7	g/g	Wise
Solubility limit for U	Lognormal	5.7E-12 - 6.9E-5	g/g	Wise
Solubility limit for Np	Lognormal	1.1E-21 - 1.1E-7	g/g	Wise
Solubility limit for Tc	Lognormal	1.4E-13 - 6.7E-8	g/g	Wise
Solubility limit for fission products	Lognormal	1.5E-11 - 5.7E-8	g/g	Wise
Dispersivity	Lognormal	5.0E-1 - 5.0E2	ft	Verma
Radionuclide release time	Lognormal	3.2E2 - 3.2E5	yr	Cook

Variable	Distribution	WMHT Values	Units	Person Responsible
Conductivity in aquifer (legs A & B)	Lognormal	1.0E-4 - 1.0E3	ft/day	Verma/ Logsdon
Porosity in aquifer (legs A & B)	Lognormal	1.0E-~~2~~5 - 1.0E-1	--	Verma/ Logsdon
Conductivity in host rock (legs C & D)	Lognormal	1.0E-4 - 1.0E0	ft/day	Verma/ Logsdon
Porosity in host rock (legs C & D)	Lognormal	1.0E-5 - 1.0E-3	--	Verma/ Logsdon
Gradient in host rock	Lognormal	1.0E-5 - 1.0E-2	ft/ft	Verma/ Logsdon
Gradient in aquifer	Lognormal	1.0E-5 - 1.0E-3	ft/ft	Verma/ Logsdon
Canister life	Lognormal	1.0E0 - 1.0E6	yr	Cook

MODEL 12 MINIATURE WELL POINT SAMPLER



Especially for hazardous waste sampling

DESCRIPTION

The Model 12 Miniature Well Point Sampler allows rapid sampling of shallow groundwater, down to a maximum of 10 feet. A high ratio of striking force to cross-sectional area of the shaft enable the well point to penetrate soils grading from silt through sand to medium gravel. A silt trap and pump allow withdrawal of one-liter samples of water. The unit comes with extension shafts and a replacement well point. The shafts and well points are constructed of non-contaminating, corrosion resistant 11 gauge *stainless steel* tubing. All pieces come in their own convenient, rugged carrying, shipping case.

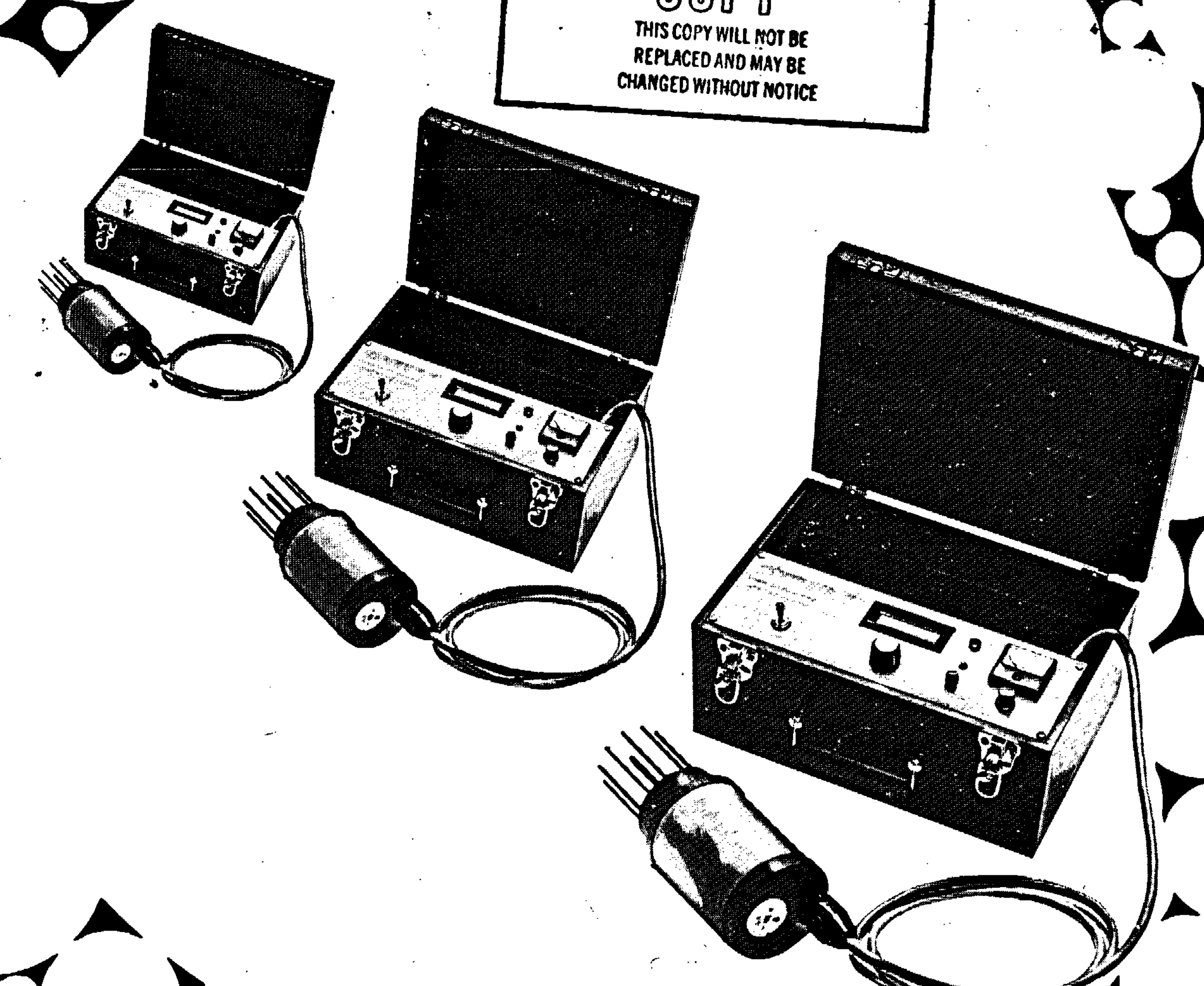
APPLICATIONS

The Model 12 Miniature Well Point Sampler can be used for extracting ground water samples around lakeshores or wherever shallow groundwater exists. It replaces tedious hand-augering to obtain representative samples of groundwater for water quality analysis. The probe can be positioned vertically and used in conjunction with a conductivity meter for profiling subsurface plumes. Samples can then be obtained at the core of the plume for analysis of constitutents. The sampler easily accomodates teflon tubing and receiving flasks.

Removing the mystery from groundwater flow:

ANALYTICAL SYSTEMS
K-V ASSOCIATES INC.
P.O. BOX 574 281 MAIN STREET FALMOUTH MASSACHUSETTS 02540 617 540-0561

PRODUCTS FOR SUBSURFACE ENGINEERING

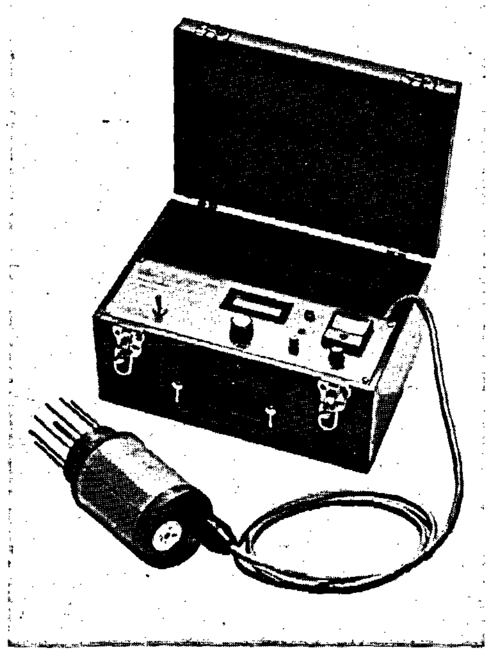


ANALYTICAL SYSTEMS
K-V ASSOCIATES INC.
P.O. BOX 574 281 MAIN STREET FALMOUTH MASSACHUSETTS 02540 617 540-0561

To meet the **RCRA** data requirements for determining rate and migration of waste materials in saturated soil and aquifers, **K-V Associates, Inc.** offers two proven instruments to display groundwater flow **Direction** and **Velocity** within three minutes, regardless of flow rate. Simplifying traditional labor intensive methods, each unit provides a direct reading in feet/day. A simple resolution of a vector diagram produces a resultant accurate to ±5° in direction, ±7% in velocity, through a range of 0.2 to 100 feet per day. The Model 10 is desired for hand placement in saturated soils and the Model 20 for combined shallow placement and monitoring wells.

MODEL 10 DOWSER™ GROUNDWATER FLOWMETER*

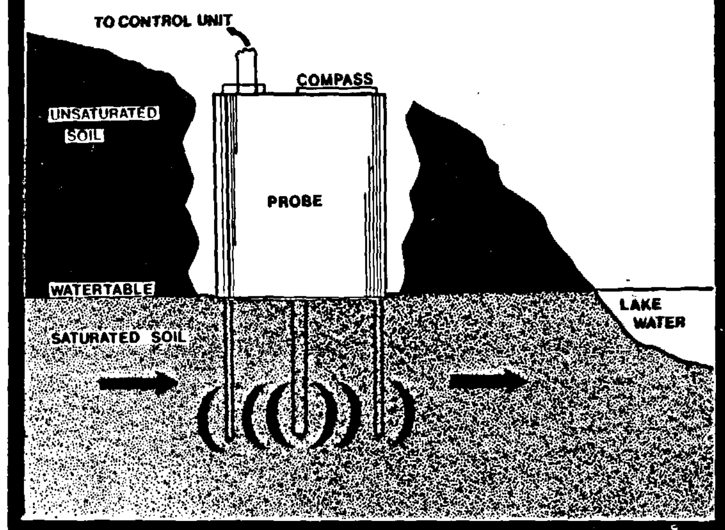
The Model 10 Dowser™ Groundwater Flowmeter rapidly measures interstitial water movement in shallow groundwater situations. The sensing probe on a six foot cord is inserted into the saturated porous soils below the water table and oriented with the attached compass. The digital readout is given in 5 discrete vector components which can be readily plotted on circular graph paper to determine principal direction and rate of flow. Each compass vector will approach the cosine fraction of the rate of flow in the principal flow direction under uniform groundwater flow conditions.



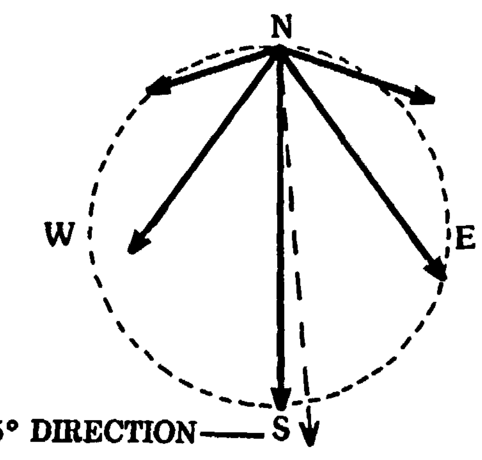
The Model 10 has been successfully field tested on EPA wastewater planning projects in lake shore areas with hard -to- predict flow patterns. The digital readout unit rapidly reproduced groundwater flow patterns previously only measurable by tedious multi-hour test procedures. The Model 10 Dowser™ can measure flow for a variety of liquids through porous sediment, including gasoline, and light oils as well as water. Supplied with the instrument is a kit for calibration against known flows through porous soils, including local samples.

TM = TRADEMARK
*U.S. AND FOREIGN PATENTS PENDING

CONVENIENT

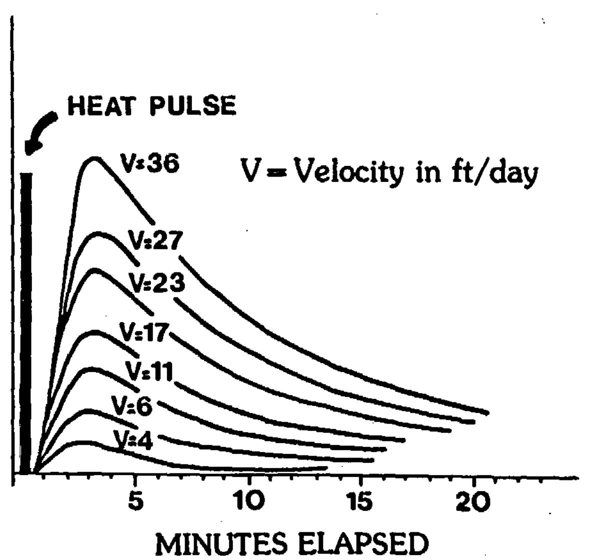


ACCURATE

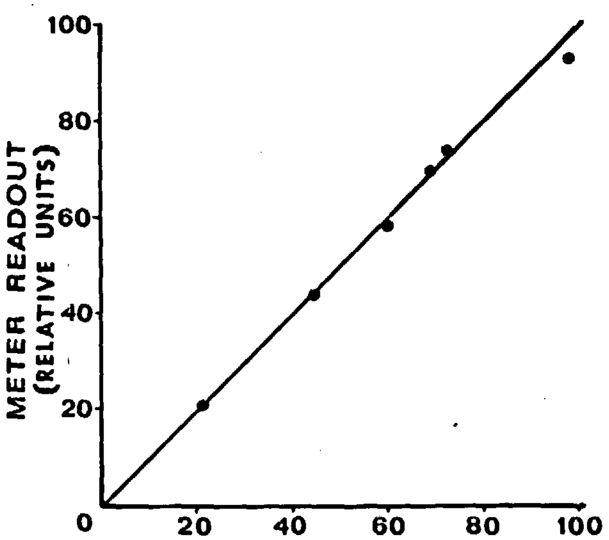


± 5° DIRECTION
± 7% FLOW RATE

RAPID RESPONSE

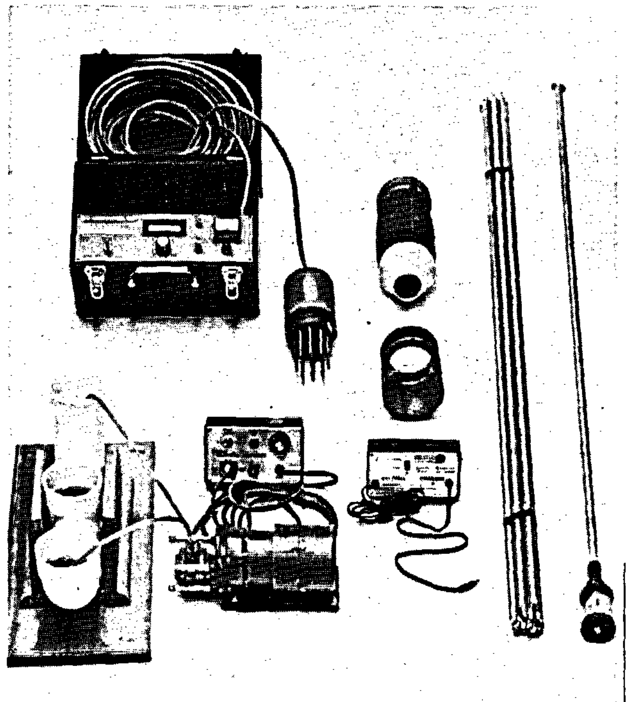


BROAD RANGE



MODEL 20 GEOFLO™ GROUNDWATER FLOWMETER*

The Model 20 GeoFlo™ Groundwater Flowmeter measures groundwater flow from the surface down to 50 feet. The control unit comes equipped with a field probe and special permeable packing for down-the-well measurements (units available for 2 inch ID and 4 inch ID fully-screened PVC monitoring wells). Orientation is provided by interlocking 5 foot aluminum rods which are rotated to a known compass direction. Similar to the Model 10, the Model 20 presents the readout in 5 discrete vector components which can be resolved for each depth.



The GeoFlo Groundwater Flowmeter has been used to define 3-dimensional zones of contribution for water supply wells and porous bottom lakes. The ease of measurement allows rapid reconnaissance of groundwater flow following accidental spills of hazardous or toxic materials. Using the unit to define flow characteristics on site can significantly reduce the costs of well placement for landfill monitoring or oil product recovery.

Rate of flow within the well casing is measured in units of volume flow ($ft^3/ft^2/day$). The units may be converted to flow rate (ft/day) by multiplying times the effective porosity obtained for different porous strata by split spoon sampling during well installation. Flow range extends from .2 to 100 $ft^3/ft^2/day$.

THIS PAGE IS AN OVERSIZED DRAWING OR FIGURE,

THAT CAN BE VIEWED AT THE RECORD TITLED:

"600 AREA BOREHOLE LOCATION MAP HANFORD SITE, PLATE 1"

WITHIN THIS PACKAGE

D-01

INSTRUCTIONS FROM P. SALTER: THIS HAS NOT YET BEEN APPROVED BY RHO MGMT; Treat it as preliminary. P Salter 8/1/82

DRAFT

BARRIER MATERIALS TESTING IN THE PRESENCE OF NUCLEAR WASTE: A FEASIBILITY STUDY FOR THE 222-S HOT-CELL FACILITY

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EXECUTIVE SUMMARY

The U.S. Government, through the National Waste Terminal Storage (NWTS) Program of the U.S. Department of Energy (DOE), is actively studying the technical feasibility of permanent disposal of high-level waste in repositories excavated in deep geologic formations. Geologic strata presently being considered include bedded salt, tuff, and Columbia Plateau Basalt. Individual waste packages will be emplaced in repositories mined in one or more of these strata in accordance with emerging Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA) regulations. The component materials, or barriers, of a waste package have the individual and integrated functions to provide initial containment and eventual uniform slow release of radionuclide to meet these regulatory criteria.

Migration of contaminated groundwater has been identified as the principal mechanism for radionuclide transport from a repository to the biosphere. Over the lifetime of the repository, groundwater will become contaminated as the result of hydrothermal reactions and interactions within and near waste packages. Knowledge of hydrothermal reactions of repository groundwaters with candidate waste forms and with waste package components is vital to the successful design of waste packages that, in conjunction with site geochemical and hydrological characteristics, insure compatibility with NRC and EPA guidelines, as well as acceptable isolation performance. For such hydrothermal reactions to be tested successfully and on schedule, a dedicated hot-cell laboratory facility is required. It is imperative that the laboratory be of suitable size and configuration, equipped with state-of-the-art testing and analytical instrumentation, and staffed by highly trained professionals. The analytical instruments, hydrothermal test apparatuses, and hot-cell facility all should be accessible and located near one another to maximize cost-effectiveness and minimize transportation of hazardous materials and chemically unstable solutions. Taken together, these features will permit immediate startup of hot-cell testing to meet the current, accelerated DOE schedule for design and licensing of nuclear waste repositories.

This report addresses overall feasibility of performing hydrothermal tests and analyses with various actual and tracer-doped waste forms, either alone or in the presence of other candidate waste packages components, in the hot cells and laboratories of the 222-S Analytical Laboratories (222-S Building) in the 200 West Area of the Hanford Site. The 222-S Building is the optimal location for such a testing program as the following conclusions point out.

- Hot cells and laboratories in the 222-S Building are adequately sized and well suited to the hydrothermal tests required by the Basalt Waste Isolation Project (BWIP).
- Sufficient hot-cell and laboratory space in the 222-S Building can be committed to BWIP and other NWTS program hydrothermal testing programs for as long as needed.
- The 222-S Building is located on the Hanford Site where vitally needed communication between hydrothermal test "planners/data analyzers/modelers" and "doers" is facilitated.
- All instruments, including an analytical scanning transmission electron microscope, required to analyze solid products from radioactive hydrothermal tests are either already installed in the 222-S Building or are available for installation.
- Sufficient state-of-the-art (e.g., Dickson-type autoclaves) equipment is available now to begin radioactive hydrothermal tests in the 222-S Building. Additional equipment, currently used by the BWIP for simulated waste materials testing, will be made available for use in the 222-S Facility as needed.
- The trained scientific and technical staff needed to conduct and evaluate radioactive hydrothermal tests successfully is already assembled at Rockwell Hanford Operations (Rockwell).
- The currently scheduled BWIP radioactive hydrothermal test program can be performed at a lower cost in the 222-S Building than in any other facility.

The 222-S Building is a major intermediate- and high-level radiochemistry facility. The laboratory has 10,600 ft^2 of laboratory floor space divided into 35 rooms, 4 hot cells, support facilities, and a modern below-ground counting room. Nine laboratory rooms totaling 4,000 ft^2 and a 42 ft^2 general purpose hot cell are available and capable of performing the testing program proposed by the BWIP.

The radioactive hydrothermal tests proposed for this program will utilize tracer-loaded and fully loaded commercial high-level waste (CHLW) forms. The current reference CHLW forms are spent fuel and, for reprocessed fuel, borosilicate glass. Crystalline ceramic forms as an alternate to borosilicate glass could also be tested if directed by the NWTS Program. Sufficient space is available at the 222-S Building to accommodate an increased scope of work to include other geologies, should such a request be made.

Test matrices using both static and flow-through hydrothermal techniques have been developed. These techniques will be applied to sequential combinations of basalt, groundwaters, waste forms, canisters, and backfill material under repository conditions. Conditions to be simulated are:

- Temperature
- Pressure
- Groundwater composition
- Groundwater pH and Eh
- Groundwater flow rate
- Surface area of host rock
- Ratio of groundwater mass to solid mass.

It is planned that as many as eight Dickson-type autoclaves will be available and operational for hot-cell testing starting in October 1983. In the following year, more autoclaves will be added, up to a total of 14. Completion of these tests is scheduled in FY 1986.

The standard Dickson rocking autoclave design has been modified by the BWIP to a rolling design to save valuable floor space, and simplify closure of the apparatus containing hot waste. Both the rolling and

~~rocking autoclave~~ systems provide static tests of waste package components and, thus, do not simulate the movement of groundwater through a failed waste repository. A flow-through hydrothermal testing apparatus, now in the procurement stage, will simulate a waste repository in basalt by placing waste-rock-water systems under expected repository conditions including fluid flow velocities appropriate to a nuclear waste repository located in basalt. Experiments using both static and flow-through equipment are scheduled. This state-of-the-art equipment yields superior results since liquid phase sampling is permitted at experimental temperatures and pressure conditions, thereby avoiding quench effects in solutions sampled from autoclaves that have been cooled and depressurized. Detailed procedures outlining hydrothermal test operation will be written for use in the 222-S Building.

A complete complement of modern analytical equipment, installed to perform under intermediate- and high-level radioactive conditions, is available in the 222-S Building. In addition, an analytical scanning transmission electron microscope, analytical scanning electron microscope, and X-ray diffractometer are available for radioactive service installation. These instruments are key to the solids characterization effort required by this program.

The proposed radioactive hydrothermal tests will be performed in full accordance with established Rockwell quality assurance and safety procedures. A systematic data validation approach for designing and performing all tests will be used to assure accuracy, responsibility, and traceability for all the test data generated. A baseline safety assessment will be completed before the initiation of these tests and any changes to the baseline will be approved before implementation.

The professional staff, equipment, and facilities described in this proposal are adequate to perform the proposed test program. As early as the beginning of FY 1985, additional hot-cell hydrothermal tests specific to other potential geologic repositories could be performed simultaneously with the proposed work, if a full complement of 14 sampling-autoclaves were made available. Indeed, it is possible that some of the early waste form-groundwater tests, made specifically to support

the performance of a nuclear waste repository in basalt, will be broadly applicable to waste form performance in other silicate-rock repositories. Obvious benefits in cost reduction and schedule acceleration for the NWTS program can be derived from the consolidation of this work in a single facility such as 222-S Building.

1.0 INTRODUCTION

1.1 TEST PROGRAM OBJECTIVES

The U.S. Government, through the National Waste Terminal Storage (NWTS) Program of the U.S. Department of Energy (DOE), is actively studying the technical feasibility of permanent disposal of high-level waste in repositories excavated in deep geologic formations. Geologic strata presently being considered include bedded salt, tuff, and Columbia Plateau Basalt. Individual waste packages will be emplaced in repositories mined in one or more of these strata in accordance with emerging Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA) regulations. The component materials, or barriers, of a waste package have the individual and integrated functions to provide initial containment and eventual uniform slow release of radionuclides to meet these regulatory criteria.

Migration of contaminated groundwater has been identified as the principal mechanism for radionuclide transport from a repository to the biosphere. Over the lifetime of the repository, groundwater will become contaminated as the result of hydrothermal reactions and interactions within and near waste packages. Knowledge of hydrothermal reactions of repository groundwaters with candidate waste forms and with waste package components is vital to the successful design of waste packages that, in conjunction with site geochemical and hydrological characteristics, insure compatibility with NRC and EPA guidelines as well as acceptable isolation performance.

This report address overall feasibility of performing hydrothermal tests with fully loaded and tracer-doped waste forms, either alone or in the presence of other candidate waste package components. These tests will be performed in the hot cells and laboratories of the 222-S Laboratory Facility (222-S Building) in the 200 West Area of the Hanford Site. The 222-S Building is operated by Rockwell Hanford Operations (Rockwell), a prime contractor for DOE. The report focuses on the utility of 222-S Building for conducting the hydrothermal test matrices deemed necessary as part of the Basalt Waste Isolation Project (BWIP).

The 222-S Building facilities and equipment are well suited for hydrothermal tests required for the design of waste packages used in repositories mined in other geologic media (i.e., tuff, salt, etc.). The general applicability of 222-S Building facilities for conducting hydrothermal tests under expected repository conditions is described at appropriate places in this report.

1.2 REPORT ORGANIZATION

The general characteristics of hydrothermal tests with nuclear waste forms and other waste package materials are briefly considered in Section 2.0. Materials, experimental parameters, and test materials are discussed in Section 3.0. Section 4.0 summarizes advantages and features of conducting the BWIP radioactive hydrothermal tests in the 222-S Building. A schedule and estimated costs are also included. The long-term commitment of suitable hot-cell and ancillary space in the 222-S Building to the NWTS Program hydrothermal test needs is specifically noted. Section 5.0 describes the general features and layout of the 222-S Building and details hot cells and laboratories presently earmarked for the BWIP hydrothermal tests. Section 6.0 describes the quality assurance (QA) program that will be applied to this proposal by Rockwell. The QA program incompasses various manuals and procedures specific to the BWIP hydrothermal testing program. The QA program will document the tracibility and accuracy of all test data. Section 7.0 details the Rockwell health, safety, and environmental regulations under which the proposed hydrothermal testing program will be performed. The technical basis of facility, equipment, and procedure details have been included in Appendices C and D.

2.0 OVERVIEW OF HYDROTHERMAL TESTING

2.1 NEED FOR HYDROTHERMAL TESTING

The NWTS Program is currently committed to a strategy for isolating nuclear wastes in deep geologic repositories. The major parts of such repository systems will be the natural geologic host rock and a waste package consisting of multiple engineered barriers (NWTS, 1981a, 1981b, and 1981c). The goal of the BWIP is to evaluate the feasibility of permanent storage of nuclear waste in a geologic repository excavated in Columbia River Basalt. This evaluation must be based on proposed regulatory criteria (NRC, 1981; EPA, 1982) that determine the required long-term performance of a nuclear waste repository in basalt (NWRB). These regulatory criteria will be compared with the performance of the repository system, including the natural geologic barriers of the repository site plus the manmade, engineered barriers of the waste package. Where the natural barriers of the repository cannot meet the regulatory performance criteria, the engineered barriers must provide the necessary containment performance. This expected performance sets the waste package design requirements that, in turn, must be based on data from site-specific hydrothermal tests of waste package components, both individually and as an integrated assembly (NWTS, 1981d; Anderson, 1982). The scientific rationale for this approach to barrier material testing is presented in Appendix B. A summary of the functions of the various components developed from the design requirements and related hydrothermal test data is given in Table 2-1.

Currently proposed regulatory criteria require that waste packages provide containment of all waste for as long as 1,000 yr and contribute to an acceptable, slow release from the engineered system (i.e., as low as 1 part in 10^5 of each isotope per year) thereafter (NRC, 1980). In the absence of a clear definition by the NRC, and for design purposes, the BWIP has defined the engineered system as the maximum extent of the 100°C isotherm surrounding repository in basalt. The engineered system thus consists of a volume of rock approximately 20 m in radius that contains a waste package and a portion of the repository waste emplacement

TABLE 2-1. Summary of Waste Package Functional Requirements (Anderson, 1982).

Barrier	Functional requirement	Hydrothermal data requirement
Waste form	Prevent or retard release of radionuclides should containment be breached during shipping, handling and after emplacement in the repository	Measure steady-state solution compositions Evaluate dissolution mechanisms Identify alteration phases
Canister	Physically contain the waste form after emplacement in the repository	Measure corrosion rate Determine corrosion mechanism
Tailored backfill	Control release rate of radionuclides in the very near-field of the repository	Determine precipitation reactions with radionuclide-bearing groundwaters Identification of these phases and their solubilities Determine reaction with groundwater chemistry Establish pressure-temperature stability field for swelling clays (irreversible dehydration) Measure sorption properties of backfill material
Geology (basalt)	Control release rate of radionuclides in the near-field and far-field of the repository	Determine precipitation reactions with radionuclide-bearing groundwaters Identification of these phases and their solubilities Determine buffering of groundwater chemistry, including pH and Eh Measure sorption properties of basaltic phases

panel [Anderson, 1982; BWIP, 1982a (Chapter 15)]. The limit of the engineered system is the boundary at which the NRC release criterion is applicable. The EPA has also proposed that the release of specific radionuclides over 10,000 yr be below certain established limits (EPA, 1982). The purpose of the NWTS program for hydrothermal testing of barrier materials is to provide the site-specific information necessary for designing a waste package and assessing its performance in meeting these regulatory criteria.

Containment of nuclear waste for up to 1,000 yr requires total isolation of the waste form from groundwaters that will eventually fill the repository. Conceptually, such containment is achieved by a combination of a metal canister, which functions as a primary impenetrable physical containment barrier for the waste form, and a backfill material, which functions as a flow barrier to groundwater reaching the canister. Therefore, the hydrothermal stability of canister materials (i.e., corrosion rates) and backfill materials (i.e., dehydration reactions, solid-state phase transformation) are important parameters in determining the necessary composition and thickness of these materials that will insure compatibility with the containment requirement called for in the present draft regulations.

Regardless of the exact length of the containment period, the nature of the test designed to demonstrate containment remains the same and so will not affect the scope and direction of the tests called for in this report. Conservative design practices mandate some period of waste containment within the waste package during the period of maximum thermal output.

The criterion of acceptable slow release of radionuclides after the containment period is met conceptually by a combination of the waste form, which must limit the rate at which radionuclides are released to groundwater, and the backfill material, which functions as a flow barrier to radionuclide-bearing groundwater exiting the waste package. The backfill material also may reduce radionuclide concentration levels by chemical reactions, such as sorption and precipitation. Near-field radionuclide release rates can be defined usefully as the product of the

radionuclide concentration in the groundwater reacted with the waste form and the hydrologic flow rate of the groundwater. Previous hydrothermal testing on waste forms has emphasized the collection of short-term, time-dependent, leach rate data (e.g., Friedman et al., 1980; McVay et al., 1981). It has been argued recently (BWIP, 1981; NWTS, 1981d; MCC, 1981) that time-independent solubility limits or steady-state reactions* are probably more realistic and useful data for evaluating long-term radionuclide release rates, particularly for slow flow-rate conditions expected in a repository (NWTS, 1981d; MCC, 1981).

Hydrothermal testing on the stability of candidate barrier materials, including waste forms, is vital for design and evaluation of waste package barrier materials. Testing to date has centered on generic studies (e.g., Westerman, 1980; Fullam, 1981), although certain studies have been performed under rigorous site-specific conditions (e.g., Holloway et al., 1981; Braithwaite et al., 1980). The approach to hydrothermal testing of barrier materials developed and endorsed by the NWTS (NWTS, 1981d) and supported by site-specific waste package testing programs is discussed in the following sections.

The need for hydrothermal testing and other testing is supported by studies done for the Site Characterization Report (SCR) prepared by the BWIP (1982a). The SCR is the first prelicensing document that the BWIP, through the DOE, will submit to the NRC. Chapter 15 of the SCR contains an in-depth analysis of waste package and site geochemistry issues, and plans. In Chapter 15, the BWIP staff carefully analyzed all applicable regulatory and programmatic criteria and then determined the work required to satisfy waste package design criteria, define site geochemistry, and fulfill testing and performance confirmation criteria. Where controversy or debate about available information or technology existed, issues were defined to highlight these facts. The issues and applicable criteria relating to hydrothermal testing (particularly the use of radioactive materials for testing) form the basis for the BWIP's need for materials

SCR outline

*Under steady-state reaction conditions, solution compositions are controlled by simultaneous dissolution and growth of primary and secondary alteration products, respectively (Mottl and Holland, 1978; BWIP, 1981).

testing (Table A-1, Appendix A). They thus provide a basis for all testing in support of waste package design, waste package performance evaluation, and geochemical characterization.

A logic diagram for the work on waste package design, site geochemistry, and performance evaluation is also included in Figure A-3 of Appendix A. Activities requiring radionuclide handling facilities are highlighted on the logic diagram.

2.2 GENERAL APPROACH TO HYDROTHERMAL TESTING

The NWTS Program has endorsed the concept of a sequential hydrothermal testing program for waste package barrier materials (NWTS, 1981d), based on the progressive penetration of barriers by intruding groundwaters (Figure 2-1). This approach emphasizes early hydrothermal stability tests of individual waste package components and on the composition of coexisting solutions under site-specific repository conditions. Results from these early tests, in turn, are compared with results on successively more complex hydrothermal interaction tests of multiple waste package components. Data from these earlier tests serve also as input into later tests to model more realistically the chemical evolution of hydrothermal reactions within the waste package. This step-wise or sequential approach enables the test program not only to isolate chemical degradation reactions specific to individual waste package components, but also to identify synergistic effects that may develop between multi-component systems as required in 10 CFR 60 (NRC, 1981). Building from data on chemically simple systems to progressively more complex systems is fundamental experimental methodology well documented in the scientific literature (Bowen, 1928; Ernst, 1976; Lerman, 1979; Berner, 1980).

The current BWIP hydrothermal testing program for waste-barrier-basalt interactions has followed the NWTS systematic approach for sequential testing of barrier materials (BWIP, 1981). Present test activities have focused initially on determining radionuclide solubility limits (or

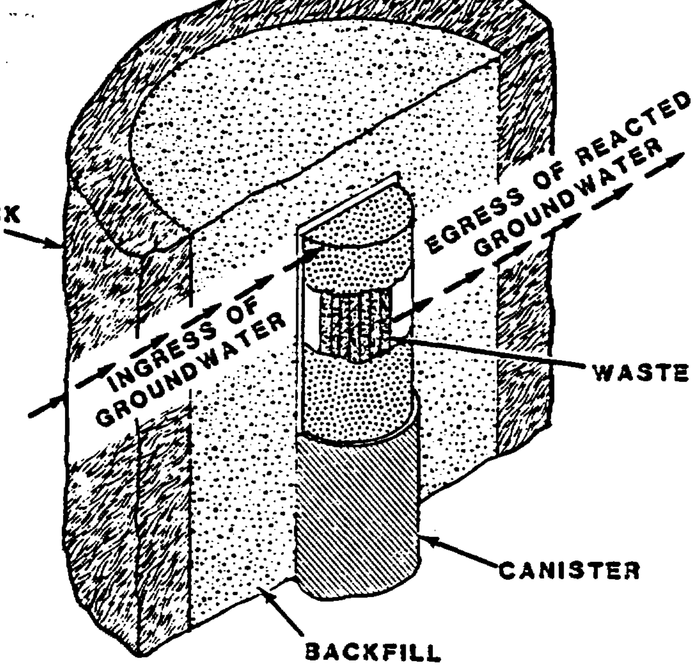

FIGURE 2-1. Groundwater Intrusion Through a Waste Package in Basalt.

steady-state conditions) of simulated* waste forms and the long-term stability of waste package barriers under site-specific hydrothermal conditions. The resulting data on solution compositions and solid alteration products have been used to evaluate waste form degradation under basalt-specific repository conditions (Apted, 1981; Holloway et al., 1981). Radionuclides that are not strongly sorbed or precipitated from solution and that, therefore, may require special attention to ensure their isolation within the waste package (Barney and Wood, 1980) have been identified. Isothermal, time-invariant compositional data on sampled solutions can also be coupled with realistic hydrologic flow data for near-field and far-field modeling for calculation of meaningful radionuclide release rates (Wood and Rai, 1981). Taken together, these hydrothermal test data have been used to establish design requirements for waste packages located in basalt (Anderson, 1982).

*Simulated waste forms are fabricated with stable isotopes or analog elements substituting for radionuclides normally found in nuclear waste.

Use of simulated waste forms for initial testing is justified for several reasons. Measurement and evaluation of the interactive effects of temperature, pressure, Eh, pH, the proportion of reacting phases, and many other testing variables define a large number of required tests. Because of the high cost and operational difficulties for conducting tests in strong radiation fields, it is cost effective to use waste forms containing nonradioactive chemical analogues rather than radioactive elements for initial tests. Many fission products occurring in spent fuel assemblies have nonradioactive isotopes that can be incorporated into simulated waste forms. From a chemical standpoint, the bonding interactions are essentially identical for all isotopes of the same element. It can be expected, therefore, that use of simulated, nonradioactive waste forms in testing will provide meaningful initial performance evaluation information for most elements in proposed waste forms.

Tests with simulated waste, however, do not eliminate the need for testing with tracer- and fully loaded nuclear waste. Fully radioactive waste form-rock-barrier interaction tests supported by a hot-cell facility are needed to:

- Test the reliability of data from experiments using simulated waste forms by comparison with the results of experiments with actual waste forms
- Study the key (i.e., potentially hazardous) radionuclides in actual waste (e.g., technetium, plutonium, americium, neptunium) that cannot be represented by stable isotopes and thus are not contained in simulated waste
- Determine the effects of a radiation field on barrier performance
- Simulate conditions more closely to those expected in the repository (e.g., radiolysis).

The direct information gained from testing radioactive waste forms, and the possibility that simulated waste forms will not prove to be

suitable analogues for actual waste (thus requiring testing with simulated waste forms to be abandoned), impart a high priority to the selection of a hot-cell facility and initiation of fully radioactive tests. The question of whether or not simulated wastes are a suitable analogue to actual waste is pivotal to credible waste package design and materials testing.

2.3 GENERAL REQUIREMENTS FOR HYDROTHERMAL TEST AND ANALYTICAL EQUIPMENT

The basic testing requirements for the evaluation of barrier materials performance under hydrothermal test conditions are:

- Complete chemical isolation of the barrier material(s) from reaction with extraneous materials (e.g., reaction vessel walls)
- Control and/or monitoring of test parameters that mimic expected repository conditions
- Accurate analyses of solution samples, taken both during and after the test
- Detailed characterization of solid reaction products
- Characterization of all starting materials.

Standard hydrothermal test equipment and operating procedures have been developed and assembled as part of an earlier phase of the hydrothermal testing program to meet these testing requirements. These earlier tests used simulated rather than radioactive waste forms. Testing with radioaetive waste forms, however, both alone and in the presence of other barrier materials, will not entail significant modifications to existing equipment. Indeed, there are analytical advantages to be gained from employing radioactive waste forms, since radioisotopes often can be analyzed at lower concentrations then their nonradioactive counterparts.

The best available apparatus for hydrothermal testing of barrier materials is the Dickson-type, sampling autoclave (Dickson et al., 1963;

Seyfried et al., 1979). This apparatus consists of a gold reaction cell contained in a pressure vessel and heated by an external electric furnace. The aqueous fluid can be sampled at the pressure and temperature of the experiment at any point during the test. Fluid and reacted solids can also be obtained at the conclusion of each experiment. The entire assembly of reaction vessel plus furnace is agitated, either by a rolling or rocking motion, to accelerate reaction rates. The chemical inertness of the inner gold cell, the agitated motion of the assembly, and the ability to sample solutions during the experiment makes the Dickson autoclave ideal for monitoring and interpreting hydrothermal reactions with time.

Techniques for controlling or monitoring pH and Eh in solutions at temperatures below 300°C have been developed (MacDonald, 1978; Niedrach, 1980; Danielson, 1980) and modified to be compatible with Dickson-type autoclaves. These controling and monitoring devices have been tested at conditions up to 285°C and 80 bars (Niedrach, 1980). Measured ratios of dissolved redox couples (Cherry et al., 1979; Jacobs and Apted, 1981) may also be used to compute the Eh condition of sampled solutions.

A variety of chemical analyses are required to characterize aqueous samples. Both cationic and anionic aqueous species concentrations must be determined completely. Room temperature pH values must be coupled with total concentration data and charge balance considerations to recalculate the solution speciation and pH value at the temperature conditions of the test. Selective ion determination for dissolved elements with multiple oxidation states is required to evaluate the prevailing Eh conditions of the solution as buffered by the reactive solids. The concentrations of dissolved radionuclides are very low (Barney and Wood, 1980; Wood and Rai, 1981) and prevent precise determination by conventional chemical analysis. Radiation counting devices are the most sensitive method of measurement of radionuclides in these aqueous samples.

Analysis of reacted solids entails a multiple approach of both chemical and mineralogical (structural) characterization. Use of the

optical microscope (OM), X-ray diffraction (XRD), and even scanning electron microscope (SEM) has some value but is ultimately unable to provide analysis on the very minute (often less than 1 μm) grains of precipitated alteration products that occur in hydrothermal tests. A scanning transmission electron microscope (STEM) is the only existing instrument that combines quantitative chemical and mineralogic analysis with the necessary spatial resolution. Particulates and colloids suspended in solution may also be an important mechanism for radionuclide migration in groundwaters. Because of the small size of such colloids, typically less than 1 μm (Krauskopf, 1979; Buxton et al., 1982), their isolation by proper filtration techniques is a vital requirement in the hydrothermal testing program.

Anticipated approximate personnel dose rates are 0.4, 1.4, and 5 R/hr at 30 cm per gram of unshielded spent fuel, borosilicate glass, and tailored ceramic waste forms, respectively. It is clear that the handling, loading, and storage of the radioactive materials require the sealed containment and remote operational capabilities of a hot-cell facility. Required shielding of hydrothermal apparatus and analytical equipment will be a function of operator exposure time, solubilities of radionuclides, and volume of sample required for analysis. The analytical instruments, hydrothermal test apparatuses, and hot-cell facility all should be accessible and located near one another to maximize cost effective operation and minimize transportation of hazardous materials and chemically unstable solutions.

2.4 STATISTICAL APPROACH TO HYDROTHERMAL TESTING

The current draft of 10 CFR 60 requires that there be "reasonable assurance" that proposed criteria for pre-1,000-yr containment will be met by the waste package and post-1,000-yr controlled release of radionuclide will be met by the waste package plus the geologic repository (NRC, 1981). Barrier material testing programs devised to meet this requirement of "reasonable assurance" will be limited, however, to test durations that are extremely short relative to the regulatory time period over which barrier materials are expected to remain functional.

It has been proposed that performance evaluation tests on barrier materials could be achieved by elevating laboratory physicochemical parameters to values that accelerate the expected degradation mechanisms (DOE, 1981). The results from such short-term, accelerated testing could then be used to establish reasonable assurance for barrier material performance over much longer time periods.

Accelerated tests, however, must be devised to take full advantage of statistically guided experimental design. Statistical approaches to the design and interpretation of barrier material test data recently have been studied by the NWTS Program (NWTS, 1981d). One advantage of a statistical approach is that the number of test conditions and tests can be minimized without degrading the quality of the experimental data and subsequent predictions of expected lifetime for barrier materials under normal conditions. Such an approach, if predicated on scientific theory, can utilize both inter- and intratest comparison of data for support and verification of waste package performance assessment.

Development of a statistical approach to accelerated barrier material tests (NWTS, 1981d) is based on expert scientific opinion. Before any testing is performed, it is necessary that a scientific, quantifiable model for barrier degradation be constructed from expert judgment. The model is the connective link between the experimental testing and the performance assessment programs for any repository site (see Appendix B). This model must include the various types of degradation mechanisms for barrier materials. The relative importance of these mechanisms as a function of environmental parameters of the repository (e.g., temperature, pressure, radiation field, groundwater composition) also should be incorporated.

From the degradation model and identification of environmental parameters of "stresses" that affect degradation, a complete factorial design (Hoel and Levine, 1964) comprised of all possible combinations of high and low values for "stresses" can be formed. Expected values for degradation rates can be assigned for each of these factorial combinations, based upon either expert scientific opinion or previous experimentation. In the simplest case, these ratings may only be relative

rankings of the severity of the associated test parameters. A factorial "tree" can then be developed that graphically plots the assigned ratings of degradation as a function of the several tests parameters under investigation.

There are several important uses for this statistically developed factorial tree. First, the parameters that provide the greatest increase in degradation rate can be easily identified. This is useful for establishing priorities among experiments in an accelerated testing program. Second, the factorial tree permits elimination of combinations of test parameters that can be expected to provide only minimal acceleration in testing. This capability is crucial for test programs with finite human and equipment resources and limited time for testing. Finally, the factorial tree is a graphical representation of the degradation model. New test data can be used to revise the severity rating of combinations of test parameters on degradation rate. Thus, earlier degradation models can be continually updated and improved as new data are obtained.

In summary, the development of statistical factorial analysis, based on expected degradation models of barrier materials, can assist in establishing and refining experimental design for accelerated testing. Further study on statistical approaches to experimental design and testing is needed to ensure that barrier material testing is rapid yet cost effective. Factorial design provides for repeated verification of initial models with each subsequent test result and permits revision of initial models to accommodate newer, conflicting data. In this manner, the scientific models for barrier material degradation can be used to extrapolate short-term laboratory tests to 1,000-yr regulatory performance requirements with reasonable assurance.

2.5 THE ROLE OF THE MATERIALS CHARACTERIZATION CENTER AND BWIP WASTE PACKAGE OVERVIEW COMMITTEE

For the successful development of waste packages for geologic disposal, laboratory data generated by waste package materials testing groups must be readily accessible and acceptable to the scientific and

engineering community at large. This is best accomplished through a central agency that collects experimental data, techniques, and procedures from the appropriate research and development groups and issues such information to outside technical experts for review. The Materials Characterization Center (MCC) is expected to fulfill this role under the direction of the Waste Package Interface Control Group (ICG).

The major functions of the MCC are to:

- Transfer technology across repository projects
- Hold workshops on key technology issues
- Develop test protocols (i.e., define generic bounds such as temperature ranges, sample preparation techniques, common approaches to analysis, and definition of key standards)
- Participate in waste package overview committee reviews of test procedures and critical data
- Catalog reference waste form and barrier materials and properties.

The role of the BWIP Waste Package Overview Committee is to review developed experimental procedures before they are submitted to the MCC. The Overview Committee also will independently review critical data should conflicts arise. Adequate completion of these responsibilities will greatly enhance the acceptability of the experimental data base upon which waste package design if founded.

3.0 MATERIALS, EXPERIMENTAL PARAMETERS, AND TEST MATRICES FOR RADIOACTIVE HYDROTHERMAL TESTING

3.1 TEST MATERIALS

The test materials specified here are those that comprise the entire repository system, including both geologic and manmade materials. The barrier materials of the engineered waste package consist of the waste form, canister, and tailored backfill. Grande Ronde and Basalt groundwater are the relevant geologic materials for the NWRB. Host rocks and associated groundwaters for other geologic repositories, once they are defined, could also be employed for separate, site-specific hydrothermal testing in the same hot-cell facility used with the NWRB materials.

3.1.1 Basalt (Host Rock)

The basalt that will be used for hydrothermal experiments has already been obtained at a surface outcrop of the Umtanum flow within the Grande Ronde Basalt, the flow most likely to be used for a repository at Hanford. Chemical and mineralogic comparison of surface samples and drill cores shows no difference within analytical uncertainty. The material has been cleaned by hand picking, crushed, and sieved into various fractions; its composition is well documented (Myers et al., 1979; Myers and Price, 1981).

3.1.2 Groundwater

By definition, water is a necessary phase in all hydrothermal tests. Ambient groundwater chemistries are available from samples from a number of wells that penetrate the Grande Ronde Basalt. Water samples have been analyzed in the field, and, more extensively, in the laboratory. Field measurements include determinations of pH, Eh, alkalinity, temperature, and turbidity. Laboratory measurements include pH, alkalinity, conductivity, cation analysis [by inductively coupled plasma spectrometry (ICP)], and anion analysis (by ion chromatography). Cation-anion balances are generally better than 2% for the water analyses.

Procedures for preparation of synthetic Grande Ronde groundwater, based on these natural groundwater analyses, have been developed (Wood and Sutter, 1982; Holloway et al., 1981). Natural groundwaters are impractical for hydrothermal testing because of the logistical problem associated with collecting and dispensing groundwaters of rigorously standardized composition, and the instability of groundwaters once removed from the ground.

The composition of groundwater will be perturbed as it flows through a NWRB and undergoes hydrothermal reactions with waste package components. Successive interactions with backfill and canister during ingress and successive interactions with waste form, canister, backfill, and basalt during egress define a complex chemical system for groundwater. This complex system can be simplified greatly by identifying several key hydrothermal reactions that dominate groundwater chemistry.

Basalt, as the repository host rock and probable component of the backfill, will buffer and control the chemical composition of ingressing groundwaters at temperatures up to 300°C (Apted, 1981; Jacobs and Apted, 1981). Revised groundwater composition from hydrothermal tests on basalt and Grande Ronde groundwater, therefore, are an integral part of the hydrothermal corrosion tests on canister materials. These corrosion tests are fundamental in the demonstration of waste package/repository compliance with the 1,000-yr total containment criterion. It should also be noted that canister materials are relatively inert with respect to chemical reaction with groundwater. Because of this and the much larger mass of basalt relative to the canister, it can be expected that corrosion of the canister will have only a slight effect on the groundwater chemistry reaching the waste form.

In a similar manner, hydrothermal reaction between the waste form and groundwater will determine the composition of egressing groundwaters. Subsequent interaction of these radionuclide-bearing waters with backfill materials (including basalt) and then with the host rock can be used to determine near-field and far-field radionuclide release rates. Thus, the hydrothermal interaction of radionuclide-bearing groundwater with backfill/basalt becomes a basic test for demonstrating

acceptable waste package/repository performance in meeting proposed criteria on controlled release of radionuclides.

3.1.3 Backfill

The backfill reacts with the intruding groundwaters to reduce the Eh in the groundwater, thus inhibiting degradation of the canister by corrosion. Backfill also will restrict groundwater flow. After 1,000 yr, the backfill is intended to be a diffusion barrier to egressing water and to act as a chemical barrier (sorbent/reactant) to nuclide transport. A reference backfill (Anderson, 1982) that consists of 25% sodium bentonite and 75% crushed basalt has been specified. Compacted bentonite is an established water barrier (Pusch, 1979), and basalt is highly reactive (Smith et al., 1980) with certain radionuclides (e.g., cesium and strontium).

3.1.4 Canister

The canister is designed to be the primary barrier for isolation of radionuclides over the first 1,000 yr after repository closure. The reference canister material for the NWRB is currently mild steel. Alternative materials being considered include stainless steel, cupronickel, and Inconel (or other nickel-based alloys). Early hydrothermal testing in the absence of a radiation field will eliminate some materials, greatly reducing the number of necessary hot-cell corrosion tests.

Hydrothermal corrosion testing of canister materials will use unstressed coupons, stressed U-bend coupons, and cold-bent/restraightened coupons. This will permit evaluation of a large range of corrosion mechanisms, including uniform, pitting, crevice corrosion, and stress corrosion cracking (NWTS, 1981d). It is especially important that corrosion tests under strong radiation fields be performed in the presence of basalt. Umtanum basalt has an enormous capability for chemical buffering of groundwaters at low Eh (i.e., reducing) and moderate pH conditions (Apted, 1981; Jacobs and Apted, 1981). This buffering capability may mitigate deleterious effects of groundwater radiolysis on canister corrosion (Glass, 1981).

3.1.5 Waste Form

The current reference commerical high-level waste forms are spent fuel and, for reprocessed fuel, borosilicate glass. Crystalline ceramics are an alternative to borosilicate glass (NWTS, 1981d). Because of the large amount of previous research (e.g., Johnson et al., 1980; Vandergraaf, 1980; Norris, 1979; McVay and Buckwalter, 1980; Coles, 1981; Fullam, 1981; Burns et al., 1982) with alternate waste forms, the hot-cell testing program discussed here is oriented toward radioactive spent fuel and borosilicate glass under conditions specific to the NWRB. Two levels of radioactive loading can be used to classify hot-cell tests: tracer-loaded waste forms, and fully loaded waste forms.

Many of the key hazardous radioactive elements in nuclear waste (Barney and Wood, 1980; Wood, 1980; Bird, 1979) occur in trace or minor amounts. Some, such as carbon, technetium, plutonium, neptunium, and americium, have isotopes that decay by low-energy alpha or beta processes. The energies associated with these decay processes are far lower than the gamma and beta decay energies associated with many other, more abundant, radionuclides found in nuclear waste (especially strontium and cesium). In addition, stable isotopes can be substituted for more energetic radionuclides (e.g., stable ^{88}Sr for radioactive ^{90}Sr). A tracer-loaded waste form can be fabricated with these lower-energy radioactive and stable isotopes. The advantage of such a tracer-loaded waste form is that the dissolution behavior of key radionuclides can be studied, yet the overall radiation field is not so high to require thick shielding and more difficult handling procedures. A Pacific Northwest Laboratory (PNL) 77-260 borosilicate glass with a tracer-loaded PW-7c waste stream developed by the BWIP (Ross et al, 1978) is currently available for early hot-cell testing. A synthetic spent fuel waste form developed by the BWIP containing thorium and depleted uranium is also available (Woodley et al., 1981). These tracer-loaded waste forms will be tested early to confirm and refine hydrothermal and nuclear analytical test procedures for later performance assessment of radioactive waste forms.

Fully loaded borosilicate glass and actual spent fuel assemblies will be procured for hot-cell testing. Currently, there are several possibilities for the reference borosilicate glass and also several possible waste stream compositions (Ross et al., 1978; MCC, 1981). Actual 10-yr-old spent fuel from a pressurized water reactor will be obtained for testing.

3.2 TEST PARAMETERS

To assess barrier material performance in meeting design requirements for isolation of nuclear waste, test parameters must be established. Site-specific repository conditions (Jacobs and Apted, 1981; NWTS, 1981e), including radiation fields, must be understood to determine the environmental parameters that must be used in this assessment. Experimental parameters that affect test data also must be understood. It is anticipated that earlier tests with simulated waste forms can and will be used to evaluate the parameters. A large number of tests under variable test conditions are possible at a far lower cost by using simulated waste forms.

Environmental parameters can be divided into those arising from chemical interactions of groundwater with the basalt of the repository (i.e., Eh, pH, groundwater composition) and physical parameters (i.e., flow rate, temperature, and pressure). These repository physicochemical parameters will be perturbed significantly from their initial ambient values by emplacement of radionuclide-bearing waste packages.

3.2.1 Temperature

Heat transfer analyses have been performed for emplacement of a variety of waste package configurations in a repository in basalt (Altenhofen, 1981). These analyses are updated continually as new data become available, but several general features of the temporal variation in temperature can be summarized here. The excursion in repository temperature is most extreme in the first 100 yr of the repository life span, when the radionuclides with short half-lives decay. The temperature in the repository will increase from ambient (59°C) to approximately

300°C during this time. Subsequently, modeling predictions show that temperatures will fall slowly toward the ambient value, requiring perhaps several thousand years to fall below 100°C. The exact variation in temperature with time is, of course, dependent on a multitude of variables such as waste loading, canister spacing, etc. Altenhofen's (1981) analysis indicates that 50°C to 300°C is the relevant temperature range for hydrothermal testing of barrier materials. Specifically, 300°C and 150°C are selected as values representative of repository temperature during the initial high-temperature thermal stage, and the later, much longer, lower-temperature stage.

Temperature will control the types and rates of chemical reactions that regulate the geochemical environmental parameters of the groundwater. Chemical reaction rates increase exponentially with increasing temperature. Temperature, therefore, can be viewed meaningfully as a master variable, driving the changes in most environmental parameters, other than pressure.

3.2.2 Pressure

The NWRB will be at atmospheric pressure during excavation and waste package emplacement. After closure, pressure will increase from 1 atm and return to ambient hydrostatic (11.4 MPa = 114 bars) or lithostatic (30 MPa = 300 bars) pressure. This transition should occur independently of covariation in temperature, solution chemistry, or any other physicochemical parameter. Because changes in pressure do not significantly affect chemical reactions between condensed phases (Denbigh, 1966; Ernst, 1976), a single pressure of 300 bars (30 MPa) is selected for all hydrothermal interaction tests.

3.2.3 Flow Rate

The ambient hydraulic conductivities for the Umtanum flow within the Grande Ronde Basalt have been measured (Gephart et al., 1979). Calculations based on these data and data on hydraulic head and effective porosity (Arnett et al., 1980; Arnett et al., 1981) indicate a range in hydraulic conductivity of 10^{-9} to 10^{-12} m/sec for colonade/

entablature zones of the Grande Ronde Basalt and a range in hydraulic conductivity of 10^{-2} to 10^{-9} m/sec in the interflow zones. These represent reasonably static flow conditions within the reference repository horizon.

The flow rate of groundwaters can exert a strong control on the rate of solid dissolution (Berner, 1978; Dibble and Tiller, 1981a). Flow rate can also affect the sequence of alteration minerals formed arising from dissolution of primary solid phases (Dibble and Tiller, 1981b; Potter and Dibble, 1981). The NWTS Program has recognized (NWTS, 1981d) that hydrothermal tests of barrier materials must be performed over a range of controlled flow conditions. Because high flow rates promote the attainment of the most stable (i.e., long-term) assemblage of alteration phases (Potter and Dibble, 1981), it may be desirable to use flow rate as an experimental parameter in accelerated testing (DOE, 1981).

3.2.4 Groundwater Chemistry

Because dissolution/corrosion mechanisms and rates will vary as a function of groundwater chemistry (e.g., Westerman, 1980; Bradley et al., 1979), site-specific groundwater chemistry should be considered an experimental parameter. Groundwater chemistry can be divided usefully into three separate parameters: pH, Eh, and groundwater composition (i.e., other dissolved species). Preliminary experimental evidence on basalt and simulated waste forms indicates that pH, Eh, and steady-state solution compositions are controlled effectively by solution reaction with coexisting primary and alteration solids (Apted, 1981; Jacobs and Apted, 1981; Holloway et al., 1981; Holloway et al., 1982).

3.2.4.1 Groundwater Composition. The ambient Grande Ronde groundwater has been described previously. The composition of intruding groundwaters will change in response to successive hydrothermal reactions with natural and manmade barriers at elevated temperatures. The hydrothermal degradation of waste forms, and subsequent interaction of radionuclide-bearing groundwater with backfill and basalt barriers, are particularly important to post-1,000-yr containment criteria. Early hot-cell hydrothermal

tests will react groundwater initially doped with radionuclides at saturation levels (e.g., Rai and Strickert, 1980; Langmuir, 1978) with basalt under repository conditions. These tests will document the time variation of radionuclide concentration levels and bracket long-term, steady-state radionuclide concentration levels in groundwater. These latter data can be used directly in calculating radionuclide release rates. Characterization of precipitated, radionuclide-bearing alteration phases will also be a key part in the interpretation of this steady-state solution data.

3.2.4.2 pH. In the repository host rock, solution pH is controlled by interactions between groundwater and the reactive glassy portion of the Grande Ronde Basalt (Smith et al., 1980; Jacobs and Apted, 1981). In situ measurements and experimental data for this system indicate that equilibrium or steady-state solutions are saturated with respect to silica at ambient temperatures and above (Smith et al., 1980; Deutsch et al., 1981). Silica saturation and the low total dissolved carbonate concentration indicate the pH may be controlled by the dissolution of the basalt glass (silica-rich) with subsequent buffering by the silicic acid buffer. At higher temperatures, carbonate, sulfate, and water dissociation reactions may contribute to or control the final pH values. A linear regression of experimental pH values as a function of temperature (T) taken from hydrothermal basalt groundwater experiments yields the following empirical equation:

$$pH = 1.64 + \frac{2540}{T(K)} \qquad (1)$$

Under the static flow conditions anticipated for a NWRB (NWTS, 1981d; MCC, 1981), the reactive solids that the groundwater contacts will basically buffer pH and other chemical solution parameters. Thus, it is somewhat misleading to speak of external regulation of pH in experiments when, actually, the hydrothermal reactions of barrier materials at any given temperature control pH, both in the actual repository and in laboratory tests. Therefore, the relevant pH values for hydrothermal testing of barrier materials should not be set arbitrarily

over a broad range (e.g., Table 6-1 of NWTS, 1981d), but rather, the in situ value of pH at the pressure and temperature of the test (Niedrach, 1980; MacDonald, 1979) should be monitored. Hydrothermal reactions with individual or multiple barrier materials should be allowed to buffer groundwater chemistry, including pH, at the actual site-specific conditions that will prevail in the repository system.

3.2.4.3 Eh. The effects of oxygen on waste dissolution (e.g., Grandstaff, 1976) and canister materials (e.g., Molecke, 1981) are expected to be significant. The Eh of the basalt-groundwater system is controlled by interactions among basalt glass, groundwater, and secondary minerals, in an analogous manner to control of pH. Jacobs and Apted (1981), in developing a model for Eh control, used field data on secondary mineralization, carbon dioxide/methane dissolved gas ratios, and dissolved sulfate/bisulfide ratios. Their conceptual model, which predicts the indirectly measured, ambient Eh conditions very well, is based upon the dissolution of Fe(II)-bearing glass (expressed as an iron-pyroxene component in the glass) with subsequent oxidation of Fe(II) in solution to Fe(III), and precipitation of secondary magentite and silica. This Eh-buffering reaction has been designated the quartz-pyroxene-magnetite buffer (Jacobs and Apted, 1981).

Using available compositional data (Myers and Price, 1981) and thermodynamic data (Robie et al., 1978), the quartz-pyroxene-magnetite buffer can be used to estimate Eh (in volts) as a function of temperature (in degrees Kelvin) and pH:

$$Eh = 0.270 + T(-1.984 \times 10^{-4}\ pH - 3.459 \times 10^{-4}) \qquad (2)$$

Values for Eh at elevated temperatures calculated by this equation agree closely to Eh values derived from preliminary results on sulfate/bisulfide ratios from hydrothermal experiments in the system basalt and water at 200°C/300 bars and 300°C/300 bars (Apted, 1981). The hypothesis that the quartz-pyroxene-magnetite buffer, representing an equilibrium among the basalt glass, groundwater, and secondary minerals, controls the Eh of the system at ambient temperature and above, appears valid.

Basalt-groundwater reactions will control Eh in the repository because of the large mass and chemical reactivity of basalt. Under slow or static flow conditions, however, individual barrier materials may buffer the Eh of coexisting groundwaters locally. The exact Eh value exerted by a given barrier material will be a function of the number and proportion of multivalent elements present in the solid. A further complication is that radiolysis of groundwaters (Glass, 1981; Draganic and Draganic, 1971) may contribute a steady flux of oxidizing or reducing species. Those species could impose a completely different and, as yet unknown, Eh condition. Therefore, site-specific hydrothermal testing must attempt to measure and monitor Eh values (Danielson, 1980) in groundwaters coexisting with barrier materials, rather than seeking to impose Eh conditions artifically.

One possible experimental perturbation of the Eh control of groundwaters by coexisting barrier materials is the initial oxygen content of synthetic groundwaters. Synthetic groundwater solutions used in hydrothermal tests generally will be saturated with respect to air, giving rise to an initial Eh of approximately +640 mV at 25°C and pH of 10. Because the basalt-groundwater reaction, at the same temperature and pH conditions, will buffer the Eh at approximately -420 mV, use of air-saturated groundwater seriously misrepresents initial groundwaters that will eventually fill and flow through a NWRB. Use of degassed water, with approximately 1.0 ppb O_2 (e.g., Peters and Diamond, 1981), does not eliminate this problem. These concentrations of dissolved oxygen still correspond to a very oxidizing Eh of 560 mV at 25°C and pH of 10. However, given the great amount of reactive mass exposed by test materials and the rather low concentrations of oxygen dissolved in solution, the initial oxygen contribution of synthetic groundwater to the test system should not cause any significant or long-term change in the relevant hydrothermal reactions. This is supported by test data on groundwater-basalt reactions that indicate reducing conditions are imposed within the first few hundred hours (Apted, 1981).

3.2.5 Ratio of Groundwater Mass to Solid Mass

Experimental hydrothermal studies have well documented the effect of variable water-to-rock mass ratios on observed hydrothermal reactivity. Ratios of 5:1 to 20:1 are used commonly in geochemical studies using similar sampling-type autoclaves (e.g., Mottl and Holland, 1978; Seyfried and Bischoff, 1981). These water-to-rock mass ratios are relatively high compared with those typical of natural water-rock systems. Such large ratios are necessitated by the repeated sampling of small volumes of water during the experiment. Because of this solution-sampling procedure, the water-to-solid mass ratio will decrease slightly with each water sample taken. The gradual decrease in this experimental parameter is not likely to create serious consequences until more than 50% of the initial water has been removed.

The inherently different chemical reactions and buffering capacities of the various barrier materials toward groundwater make the mass ratio between coexisting solids in any test an important experimental parameter. Similar hydrothermal tests on basalt-groundwater and waste form-groundwater reactions will undoubtedly lead to different steady-state groundwater chemistry, including pH and Eh (Apted, 1981; Holloway et al., 1981). Hydrothermal tests on the combined system basalt-waste form-groundwater will produce a variety of results* based on the relative mass ratio of basalt to waste form. Both parameters, water-to-solid mass ratio and, where appropriate, solid-to-solid mass ratio, have been examined in the early stages of testing with simulated waste forms, and only confirmatory tests are planned for hot-cell testing.

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*These results would not necessarily be expected to straight-forwardly interpolate the two end-member tests (i.e., basalt-groundwater and waste form-groundwater). This is because of the possibility of new reactions arising from interaction of the dissolved solution species from the different solids. For example, cesium released from spent fuel dissolution could react with aluminum and silicon released from the basalt dissolution to form a stable precipitate of pollucite [(cesium, rubidium, sodium)$AlSi_2O_6$] (e.g., Holloway et al., 1981). Because there are only trace amounts of cesium in basalt and essentially no aluminum or silicon in spent fuel, the formation of this potentially important precipitate could not be anticipated from the end-member tests.

3.2.6 Grain Size

Grain size of reactive solids is another experimental parameter related to mass ratios. In hydrothermal reactions, the important mass property of a solid is its reactive surficial mass, the mass of solid that is accessible to the coexisting water. Therefore, the surface area, and by extension the grain size of solids, is an experimental parameter related to the mass ratio parameter.

Standard experimental hydrothermal studies of geologic materials use powdered samples, typically in the +60 to -400 mesh range (e.g., Liou et al., 1974; Mottl and Holland, 1978; Moody and Meyer, 1979). The accepted rationale for this procedure is that effectively increasing the reactive surface area (or surficial mass) of the solid reduces the time required for reaction and formation of new alteration phases. For powdered samples, the large ratio of surface area to mass of the solid ensures that essentially the entire mass added will be the effective reactive surficial mass. Interpreting and extracting meaningful kinetic data from monolith tests is difficult. Estimating reactive surficial mass of monoliths is uncertain, and the surface area of monoliths changes uncontrollably during a hydrothermal test because of cracking and spallation.

A grain size fraction (+250, -325 mesh) will be specified for powdered solids. Previous testing has shown that this size fraction promotes rapid reaction with hydrothermal solutions (Holloway et al., 1981). Preparation techniques for powders must include a procedure for removing minute particulates, often less than 1 μm in size, that adhere to the surface of solids even after they have been sieved (Schott et al., 1981). These particulates are highly reactive and may produce spurious changes in groundwater chemistry that might lead to the formation of an initial assemblage of highly metastable alteration products (Dibble and Tiller, 1981b).

3.3 TEST MATRIX

The current BWIP schedule calls for startup of hydrothermal testing the 222-S Building hot-cell facility at the beginning of FY 1984. The

following test matrices (Tables 3-1 to 3-3) are presented on a year-by-year basis from this startup date. Recognizing the possibility of earlier initiation of hot-cell testing, and acknowledging the periodic reevaluation of future testing based upon test results as they are received, a rigid matrix schedule for testing is neither feasible nor desirable. Instead, these matrices chart the overall BWIP and NWTS approach to hot-cell testing (see Appendix B). Use of early test results guide testing of simple barrier systems toward final hot-cell performance evaluation rapidly, progressively, and cost effectively. Tables 3-4 to 3-6 regroup the hot-cell hydrothermal tests presented in Tables 3-1 to 3-3 on the basis of waste form.

Table 3-7 presents the proposed test matrix for flow-through hydrothermal testing in a hot-cell facility. The key parameters for evaluation in these tests are the combined effects of temperature and flow rate on the dissolution, migration, and subsequent precipitation and sorption of radionuclides from actual waste forms. It may be desirable to demonstrate overall performance of an assembled waste package in a repository located in basalt with early (FY 1984) flow-through tests. Such tests will be made through a column packed with the assembled waste package components, including an actual waste form (borosilicate glass) and basalt. It must be stressed, however, that such early testing of a chemically complex, multicomponent system does not imply that the necessary data will be available to provide adequate interpretation of these test results. The expectation is that multicomponent flow-through tests can only be understood fully on the basis of results from simpler component testing.

It is also expected that early evaluation of the relative effects of environmental and experimental parameters on hydrothermal reactions will probably lead to a reduction in the scope of later testing. For example, replicate tests may demonstrate that the change in the water-to-waste form mass ratio over the experimentally practical range of 5:1 to 20:1 does not lead to significant change in the long-term, steady-state solution concentration. If so, then a single water-to-waste form mass ratio could be selected for future tests to limit the total number

TABLE 3-1. Provisional Matrix for FY 1984 Hot-Cell Testing.

Barrier material	Water: waste: barrier ratio	Temperature (°C)	Duration (months)	Comments
		Tracer-loaded borosilicate glass		
-	10:1:0	300	4	Technetium, plutonium, neptunium, americium radiometric analyses, in addition to analyses of stable elements in solution
-	10:1:0	300	2[a]	
-	5:1:0	300	3	
-	20:1:0	300	3	
-	10:1:0	150	6	
-	10:1:0	150	3[a]	
		Spent fuel		
-	10:1:0	300	4	
-	10:1:0	300	2[a]	
-	5:1:0	300	3	
-	20:1:0	300	3	
-	10:1:0	150	6	
-	10:1:0	150	3[a]	
		Tracer-doped groundwater[b]		
Basalt	10:0:1	300	4	Reinjection of fresh tracer-doped groundwater may be performed to study rate of return to steady-state conditions
Basalt	10:0:1	300	2[a]	
Basalt	20:0:1	300	3	
Basalt	10:0:1	150	4	
Basalt	10:0:1	150	2[a]	
Basalt	20:0:1	150	3	
Basalt	40:0:1	150	6	
Bentonite	20:0:1	150	6	
Bentonite	40:0:1	150	6	
Total			78 testing *versus* 96 (maximum) of available autoclave operating time (assumes 8 autoclaves)	

NOTE: Test durations are conservative estimates. Actual time necessary to attain and demonstrate steady-state conditions should be less.

[a]Replicate test.

[b]Source of radionuclides.

TABLE 3-2. Provisional Matrix for FY 1985 Hot-Cell Testing.

Barrier material	Water: waste: barrier ratio	Temperature (°C)	Duration (months)	Comments
Tracer-doped groundwater[a]				
Backfill	10:0:1	300	2	Backfill = 75% basalt + 25% bentonite
Backfill	10:0:1	150	4	
Simulated spent fuel				
Basalt	10:1:1	150	6	
Basalt	10:1:1	300	3	
Tracer-loaded borosilicate glass				
Basalt	10:1:1	150	6	
Basalt	10:1:1	300	3	
Spent fuel				
-	5:1:0	150	6	Comparison with simulated spent fuel tests will determine need to continue hot-cell testing or return to simulated waste form testing
-	5:1:0	150	3[b]	
Basalt	10:1:1	150	6	
Basalt	10:4:1	150	6	
Canister[c]	10:1:1	150	6	
Canister	10:1:1	150	3[b]	
Canister	10:1:1	300	6	
Basalt + Canister	10:1:1:1	150	4	
Borosilicate glass[d]				
-	10:1:0	150	6	Comparison with tracer-loaded borosilicate glass tests will determine need to continue hot-cell testing or return to simulated waste form testing
-	10:1:0	150	3	
Basalt	10:1:1	150	6	
Basalt	10:4:1	150	6	
Canister[c]	10:1:1	150	6	
Canister	10:1:1	150	3[b]	
Canister	10:1:1	300	6	
Basalt + Canister	10:1:1:1	150	4	
Total			104 testing versus 120 (maximum) of available autoclave operating time (assumes 10 autoclaves)	

NOTE: Actual time to attain and demonstrate steady-state conditions should be less.

[a]Source of radionuclides.

[b]Replicate test.

[c]Canister present as a monolithic coupon.

[d]Fully loaded.

TABLE 3-3. Provisional Matrix for FY 1986-87 Hot-Cell Testing.

Barrier material	Water:waste: barrier ratio	Temperature (°C)	Duration (months)	Comments
		Spent fuel		
-	10:1:0	300	4	
-	10:1:0	300	2[a]	
Basalt	10:1:4	150	6	
Basalt + Canister	10:1:1:1	300	3	
Basalt + Canister	10:1:1:5	150	12	
Basalt + Canister	10:1:1:5	150	4[a]	
Basalt + Canister	5:1:1:1	150	4	
Canister(II)	10:1:1	150	6	
Canister(II)	10:1:1	150	3[a]	Canister(II) represents alternate material for canister barrier
Basalt + Canister(II)	10:1:1:1	150	4	
Basalt + Canister(II)	5:1:1:1	150	4	
Basalt + Canister(II)	10:1:1:5	150	4	
		Borosilicate glass[b]		
-	10:1:0	300	4	
-	10:1:0	300	2[a]	
Basalt	10:1:4	150	6	
Basalt + Canister	10:1:1:1	300	3	
Basalt + Canister	10:1:1:5	150	12	
Basalt + Canister	10:1:1:5	150	4[a]	
Basalt + Canister	5:1:1:5	150	4	
Canister(II)	10:1:1	150	6	
Canister(II)	10:1:1	150	3[a]	
Basalt + Canister(II)	10:1:1:5	150	4	
Total			85 testing *versus* 240 (maximum) of available autoclave operating time (assuming 10 autoclaves)	

NOTE: Test durations are conservative estimates. Actual time to attain and demonstrate steady-state conditions should be less. Ratio of water to waste barrier is 10:1.

[a]Replicate test.

[b]Fully loaded.

TABLE 3-4. Test Matrix for Tracer-Doped Groundwater Experiments.

Barrier material	Water: barrier ratio	Temperature (°C)	Duration (months)	Scheduled date (FY)
Basalt	10:1	300	4	1984
Basalt	10:1	300	2*	1984
Basalt	20:1	300	3	1984
Basalt	10:1	150	4	1984
Basalt	10:1	150	2*	1984
Basalt	20:1	150	3	1984
Basalt	40:1	150	6	1984
Backfill	10:1	300	2	1985
Backfill	10:1	150	4	1985
Bentonite	20:1	150	6	1984
Bentonite	40:1	150	6	1984

*Replicate test.

TABLE 3-5. Test Matrix for Simulated Waste Form Experiments.

Barrier material	Water: waste: barrier ratio	Temperature (°C)	Duration (months)	Scheduled date (FY)
		Spent fuel		
Basalt	10:1:1	150	≥6	1985
Basalt	10:1:1	300	3	1985
		Borosilicate glass		
-	10:1:0	300	4	1984
-	10:1:0	300	2*	1984
-	5:1:0	300	3	1984
-	20:1:0	300	3	1984
-	10:1:0	150	≥6	1984
-	10:1:0	150	3*	1984
Basalt	10:1:1	150	≥6	1985
Basalt	10:1:1	300	3	1985

*Replicate test.

TABLE 3-6. Test Matrix for Fully Loaded Waste Form Experiments Grouped by Waste Form. (Sheet 1 of 2)

Barrier material	Water:waste: barrier ratio	Tempera- ture (°C)	Duration (months)	Scheduled date (FY)
		Spent fuel		
-	10:1:0	300	4	1984
-	10:1:0	300	2*	1984
-	5:1:0	300	3	1984
-	20:1:0	300	3	1984
-	10:1:0	150	6	1984
-	10:1:0	150	3*	1984
-	10:1:0	300	4	1986
-	10:1:0	300	2*	1986
-	5:1:0	150	6	1985
-	5:1:0	150	3*	1985
Basalt	10:1:1	150	6	1985
Basalt	10:4:1	150	6	1985
Basalt	10:1:4	150	6	1986
Canister	10:1:1	150	6	1985
Canister	10:1:1	150	3*	1985
Canister	10:1:1	300	6	1985
Canister(II)	10:1:1	150	6	1986
Canister(II)	10:1:1	150	3*	1986
Basalt + Canister	10:1:1:1	150	4	1985
Basalt Canister	10:1:1:5	150	12	1986
Basalt + Canister	10:1:1:5	150	4*	1986
Basalt + Canister	10:1:1:1	300	3	1986
Basalt + Canister	5:1:1:1	150	4	1986
Basalt + Canister(II)	10:1:1:1	150	4	1986

TABLE 3-6. Test Matrix for Fully Loaded Waste Form Experiments Grouped by Waste Form. (Sheet 2 of 2)

Barrier material	Water:waste: barrier ratio	Temperature (°C)	Duration (months)	Scheduled date (FY)
Basalt + Canister(II)	5:1:1:1	150	4	1986
Basalt + Canister(II)	10:1:1:5	150	4	1986
Borosilicate glass				
-	10:1:0	300	4	1986
-	10:1:0	300	2*	1986
-	10:1:0	150	6	1985
-	10:1:0	150	3	1985
Basalt	10:1:1	150	6	1985
Basalt	10:4:1	150	6	1985
Basalt	10:1:4	150	6	1986
Canister	10:1:1	150	6	1985
Canister	10:1:1	150	3*	1985
Canister	10:1:1	300	6	1985
Canister(II)	10:1:1	150	6	1986
Canister(II)	10:1:1	150	3*	1986
Basalt + Canister	10:1:1:1	150	4	1985
Basalt + Canister	10:1:1:5	150	12	1986
Basalt + Canister	10:1:1:5	150	4*	1986
Basalt + Canister	5:1:1:5	150	4	1986
Basalt + Canister	10:1:1:1	300	3	1986
Basalt + Canister(II)	10:1:1:5	150	4	1986

*Replicate test.

TABLE 3-7. Test Matrix for Flow-Through Experiments.

Barrier material	Flow rate (m/yr)	Temperature (°C)	Duration	Scheduled date (FY)
		Tracer-loaded borosilicate glass		
-	10	150	2 wk	1984
-	1.0	150	2 mo	1984
Basalt	10	300	2 wk	1984
Basalt	1.0	150	1 mo	1984
		Borosilicate glass*		
Canister + Backfill + Basalt	10	150	2 mo	1984
Canister + Backfill + Basalt	1.0	150	4 mo	1985
-	10	150	1 mo	1985
-	1.0	150	2 mo	1986
Basalt	10	150	1 mo	1986
Basalt	1.0	150	2 mo	1986
		Tracer-doped groundwater		
Basalt	100	300	2 wk	1984
Basalt	10	300	1 mo	1984
Basalt	1.0	300	2 mo	1984
Basalt	100	150	2 wk	1984
Basalt	10	150	2 mo	1985
Basalt	1.0	150	6 mo	1986
		Fully loaded spent fuel		
Canister + Backfill + Basalt	10	150	2 mo	1985
Canister + Backfill + Basalt	1.0	150	4 mo	1985
-	10	150	1 mo	1986
-	1.0	150	2 mo	1986
Basalt	10	150	1 mo	1986
Basalt	1.0	150	2 mo	1986

*Fully loaded.

of tests required. Previous testing (Apted, 1981; Holloway et al., 1981) indicates the actual time necessary to achieve steady-state solution concentration will probably be less than the time allotted in these test matrices.

The test matrices in Tables 3-1 to 3-7 are based on certain logistical assumptions. For the initial year, 10% of the total time available for autoclave testing is reserved for recycling of test runs (i.e., time required for unloading one run and loading the next run). Another 10% is conservatively reserved for time lost to testing because of unforeseen problems in hydrothermal testing with radioactive materials. At later stages of testing, both of these time penalties are expected to decrease because of operator experience. It is anticipated that up to eight Dickson-type autoclaves will be available for hot-cell testing in the first year. In the following years, more autoclaves may be added, up to a total of 14, based upon the availability of autoclaves, funding levels, and the scope of testing. With regard to this last item, it may be desirable, because of savings in money, manpower, and time, for the BWIP to provide hot-cell testing for the entire NWTS barrier materials testing program. As early as the beginning of FY 1985, an appreciable number of hot-cell hydrothermal tests specific to other potential geologic repositories could be performed simultaneously if a full complement of 14 sampling-autoclaves were available. Indeed, it is possible that some of the early waste form-groundwater tests, made specifically to support the performance of a NWRB, will be broadly applicable to waste form performance in other silicate-rock repositories.

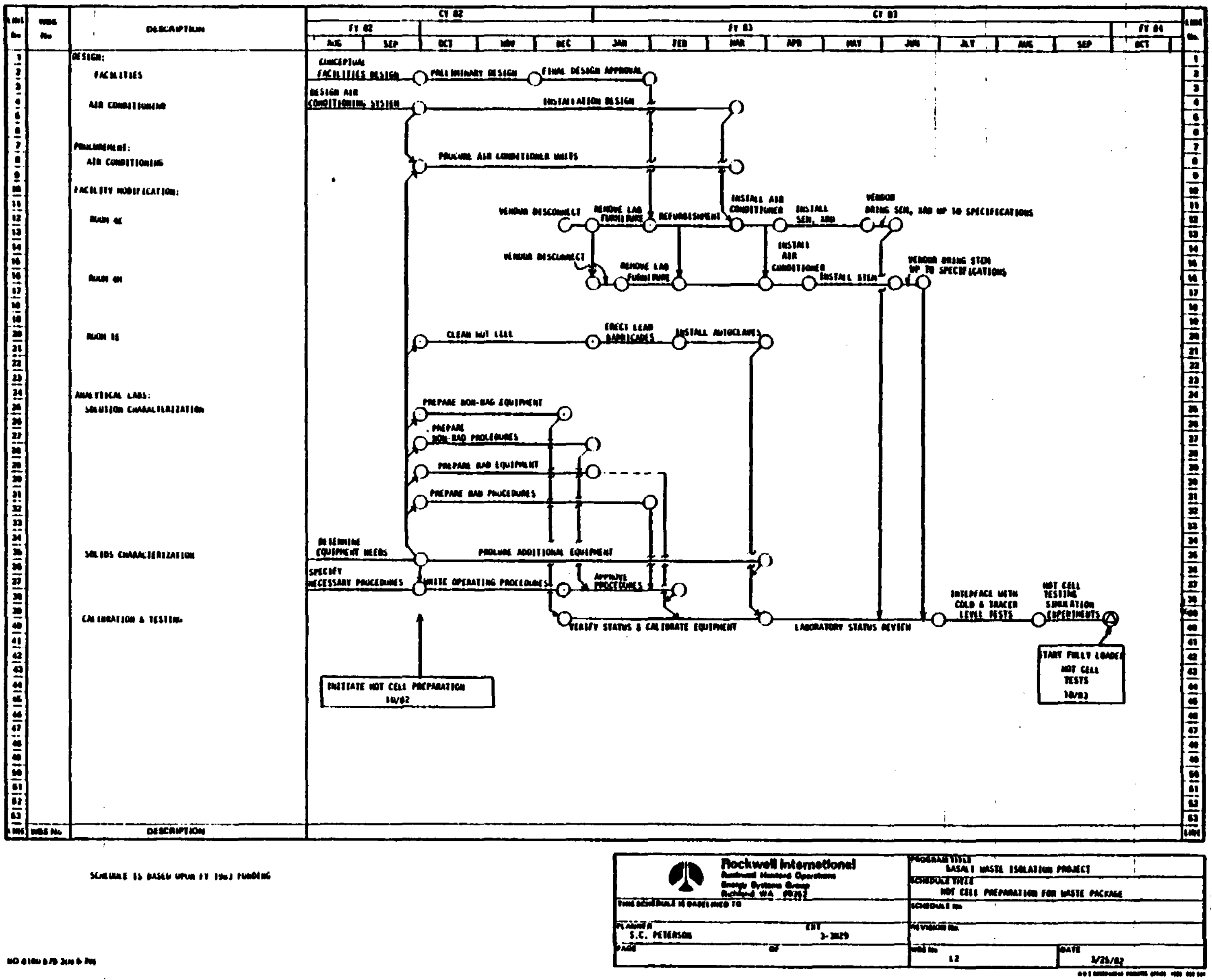

FIGURE 4-1. Work Schedule for Preparation and Startup of Hot-Cell Testing. (Schedule is based on FY 1983 funding programs.)

5.0 HYDROTHERMAL TEST FACILITIES IN THE 222-S BUILDING

5.1 INTRODUCTION

The 222-S Building laboratory facility is located in the 200 West Area of the Hanford Site (Figures 5-1 and 5-2). Facilities in the 200 West Area portion of the Hanford Site are currently operated for the DOE by Rockwell.

The 222-S Building, a major laboratory facility, was built in 1951 to support the analytical and process chemistry requirements of the Redox nuclear fuels reprocessing plant. The building is 322 ft long by 107 ft wide. It has two stories and a partial basement. The main floor has 35 laboratory rooms devoted to radiochemistry and is divided into 3 sections (Figure 5-3). The west end contains a conference room, two offices, a lunch room, and two personnel change rooms. The center section contains 22 laboratory rooms and various service areas. These laboratory rooms are designed to perform low- and intermediate-level radioactive service. The east end of the building contains 13 laboratory rooms and 4 heavily shielded hot-cells designed for intermediate- and high-level radioactive work. The basement of the building contains a modern nuclear radiation counting room. The counting room supports radioassay work for the entire building (Figure 5-4).

In more than 30 yr of service, the 222-S Building has successfully accommodated an extensive list of analytical and process development programs. These programs have included Redox and PUREX process development activities, promethium and neptunium pilot purification process development, and research in support of interim and long-term management of Hanford defense high-level waste.

In the building's current configuration, receipt testing, analysis, and disposal of highly radioactive materials are possible. At present, research, development, and analytical work on radioactive materials from a wide variety of programs are performed in the 222-S Building. Major programmatic activities are segregated by space assignment within the building.

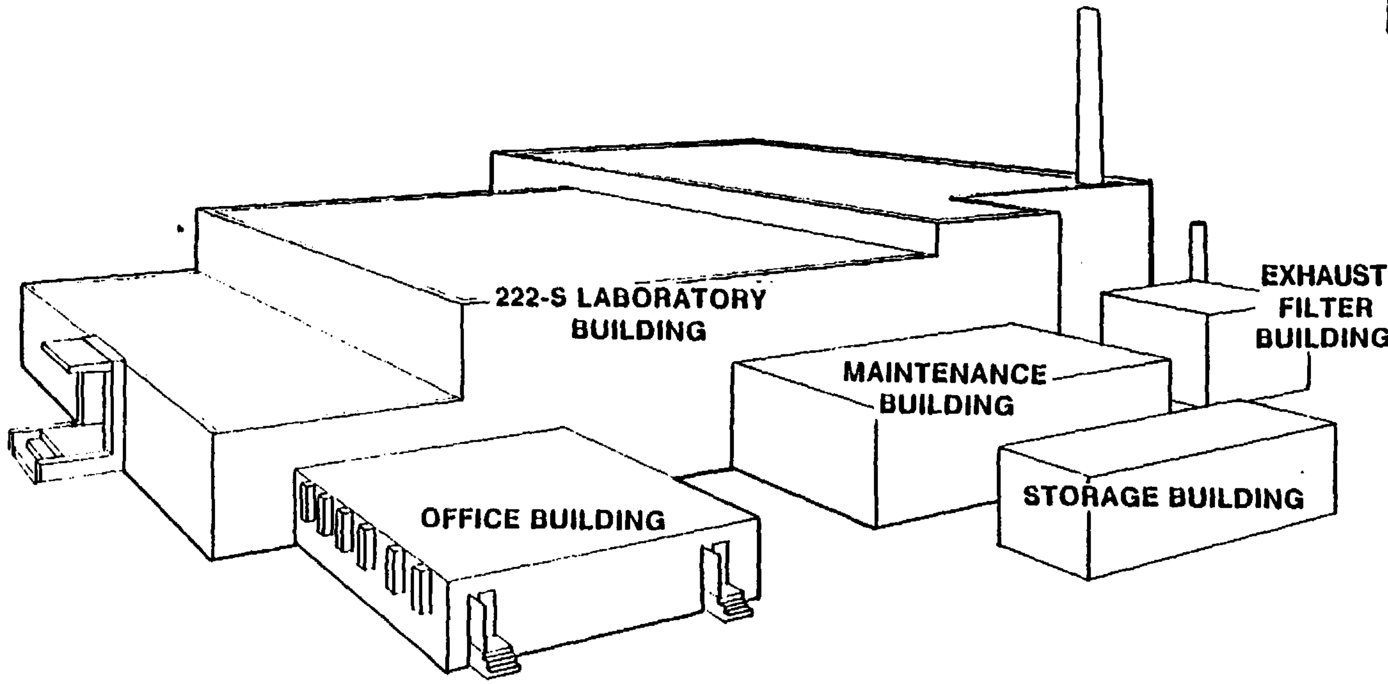

FIGURE 5-1. 222-S Laboratory Facility.

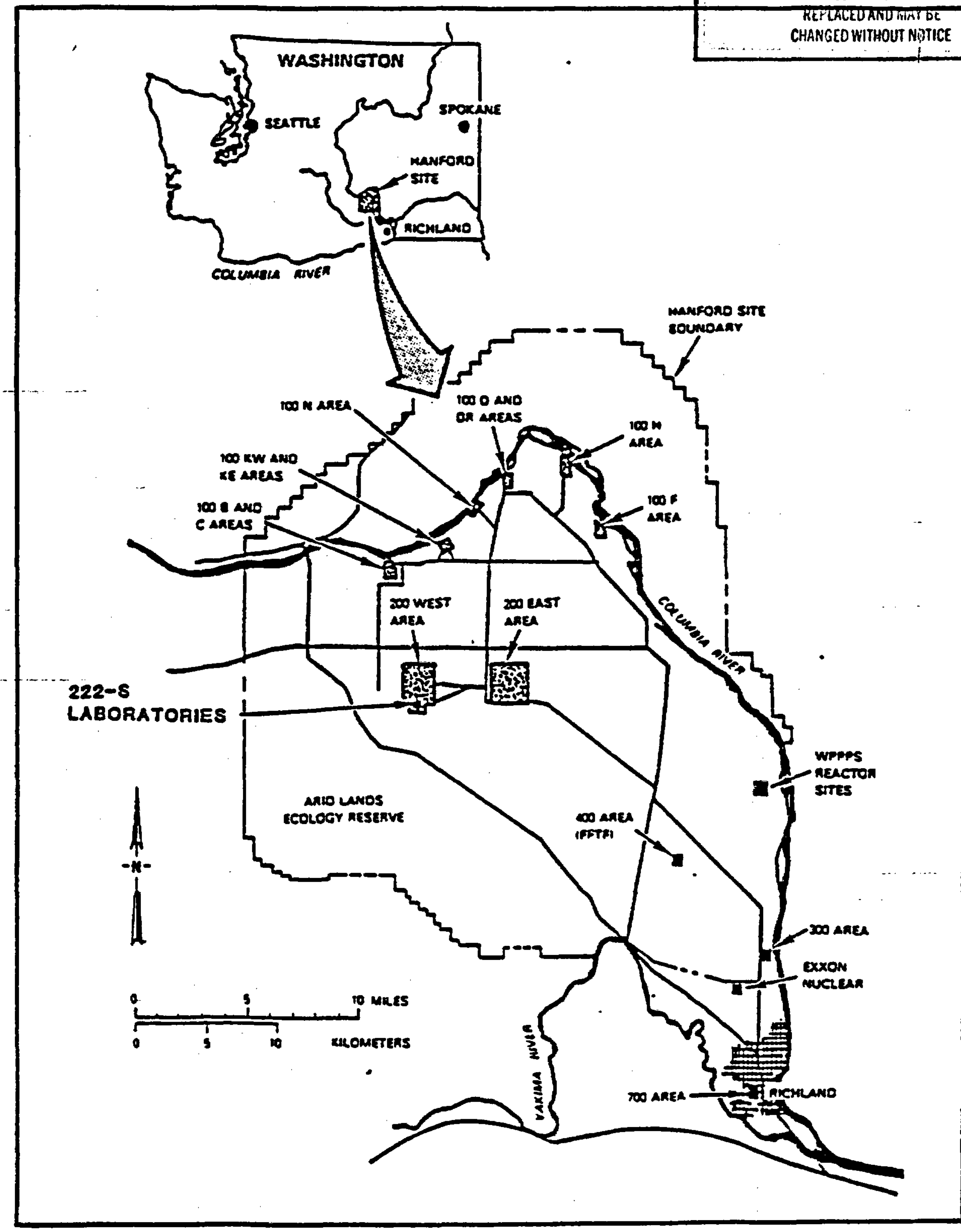

FIGURE 5-2. Hanford Site Map Showing Location of 222-S Laboratory Facility.

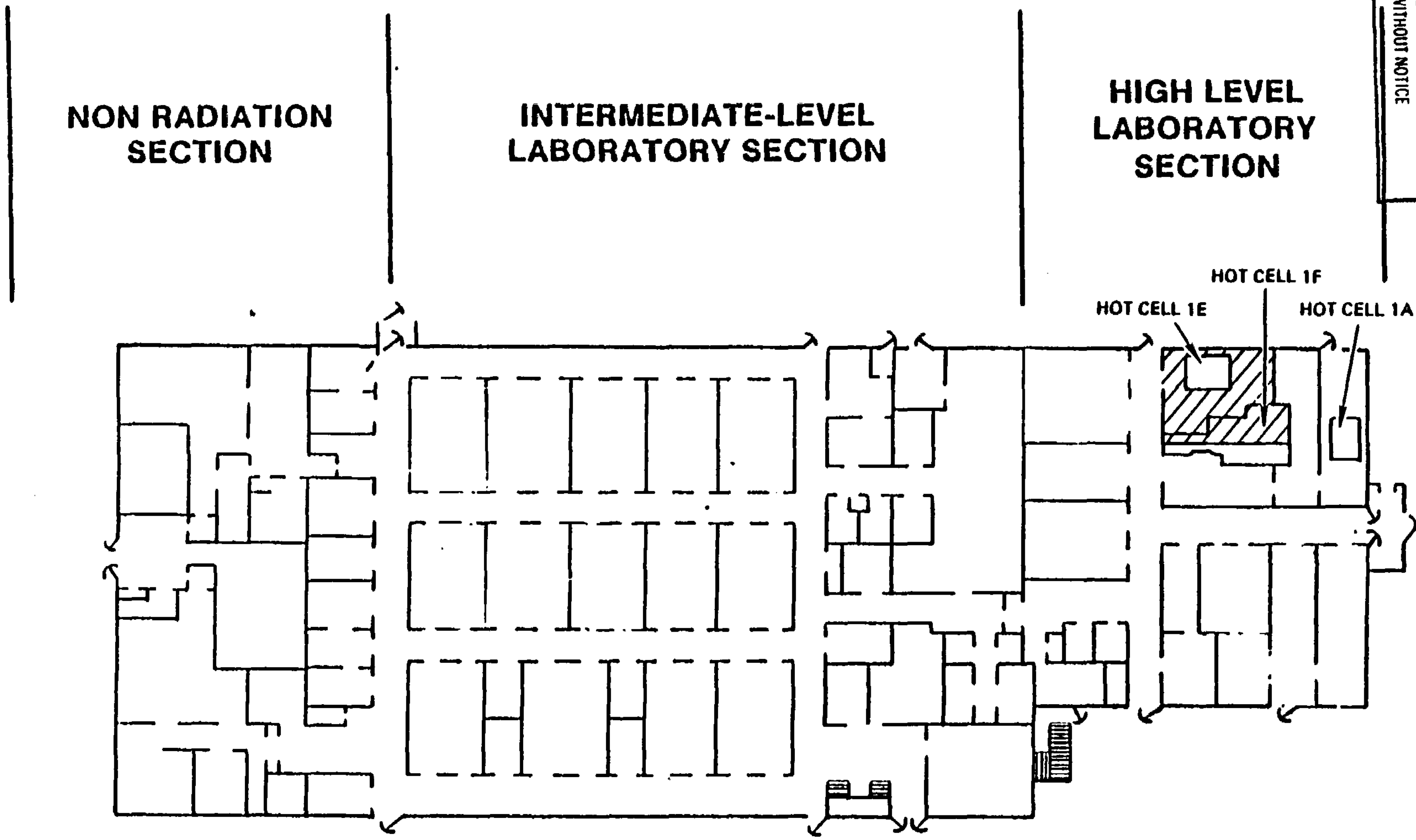

FIGURE 5-3. 222-S Laboratory Facility Showing Radiation Zones and Hot Cells.

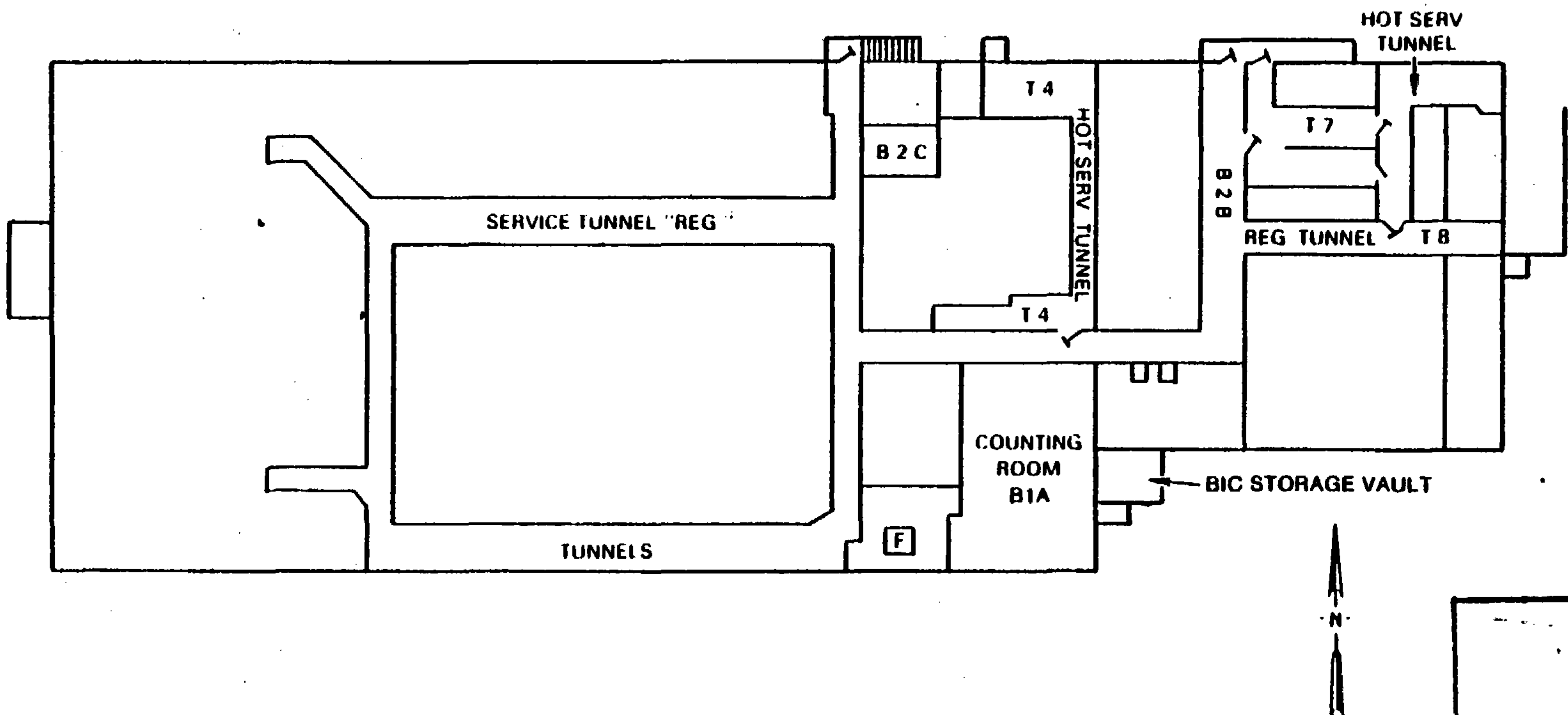

FIGURE 5-4. The 222-S Basement Plan Showing Radiochemical Counting Facilities.

The hot-cell, support, and analytical facilities and equipment that will be dedicated to the performance of hydrothermal tests are described in the following section (Figure 5-5).

5.2 HOT-CELL FACILITY

Laboratory 1E contains two hot cells plus space for two shielded autoclave installations (Figure 5-6). The hot cell, 1E-1, will be assigned to support the proposed BWIP hot-cell hydrothermal testing program. Hot cell 1E-1 measures 5 ft high, 6 ft deep, and 7 ft long and is constructed of 8-in.-thick mild steel walls (Figure 5-7). It is equipped with two airlocks that provide ingress and egress from the main cell area. The smaller airlock is used to introduce items with dimensions not exceeding 9 in. wide, 16 in. high, and 24 in. long. It is equipped with a hand-driven traversing table for moving items through the airlock. The large airlock is 5 ft high, 5 ft long, and 2 ft wide. The airlock is equipped with a motor-driven transfer table 2 ft^2 capable of handling up to 500 lb.

The main cell is serviced by two master-slave manipulators capable of handling 20 ft-lb torque with wrist and mechanical fingers. The manipulators are capable of vertical lifts of up to 50 lb with a special wrist hook. An in-cell jib crane provides additional lifting capacity of 500 lb.

In-cell services include water (distilled and sanitary), vacuum, 90 lb compressed air, and 110-V and 220-V electrical receptacles. Several space inlets to the main cell provide access for additional services that might be required.

Laboratory 1B is a full-service fission product laboratory (Figure 5-8). It is equipped with nine open-face hoods that will be used to prepare radioactive solid and liquid samples for analysis. The open-face hoods will also be used to house balances, pH meters, and other required miscellaneous instruments. These hoods will also be used to store and archive small samples from both the fully loaded and tracer tests.

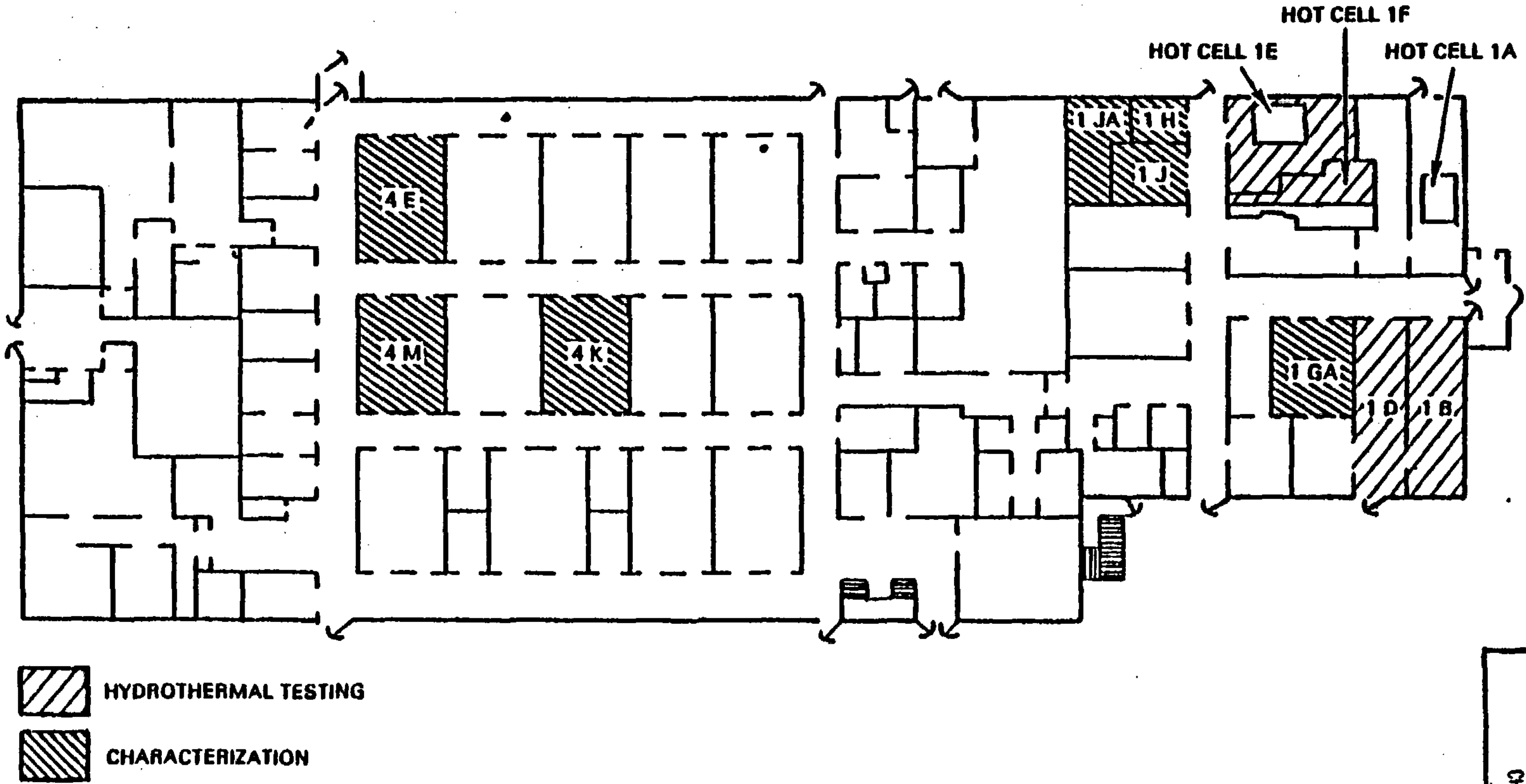

FIGURE 5-5. Laboratory Space Available for Basalt Waste Isolation Project Hydrothermal Testing.

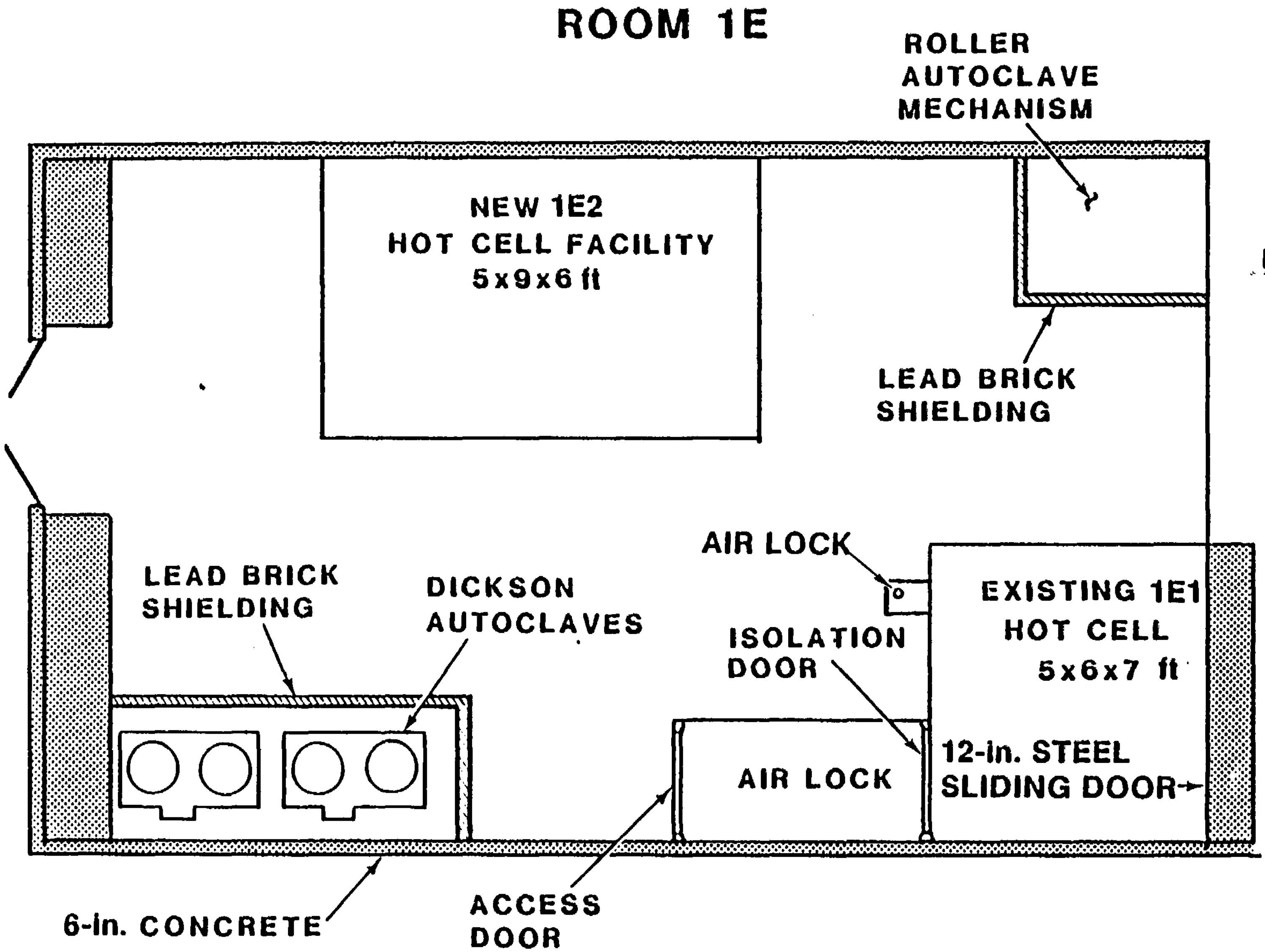

FIGURE 5-6. Laboratory 1E.

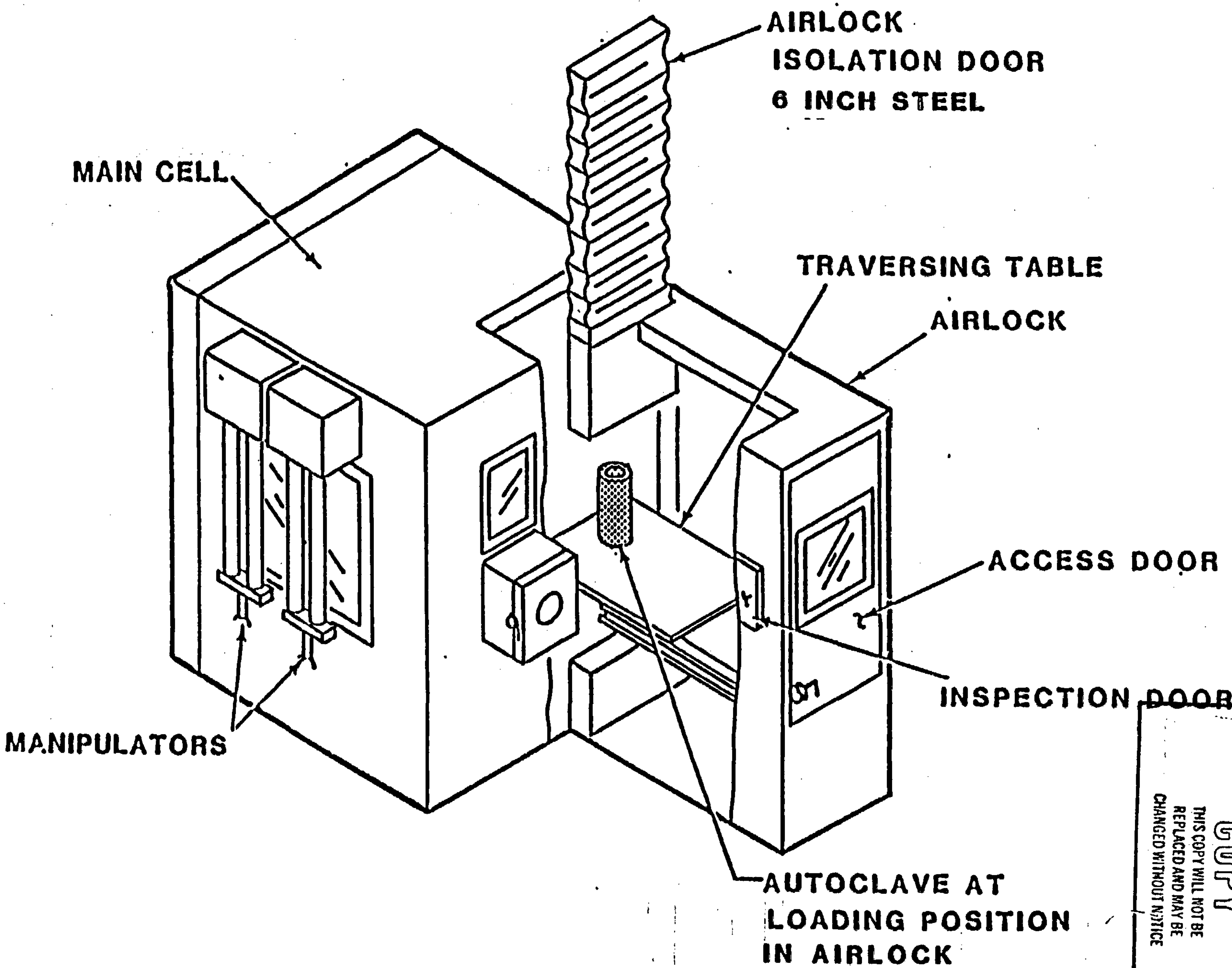

FIGURE 5-7. Laboratory 1E Hot Cell.

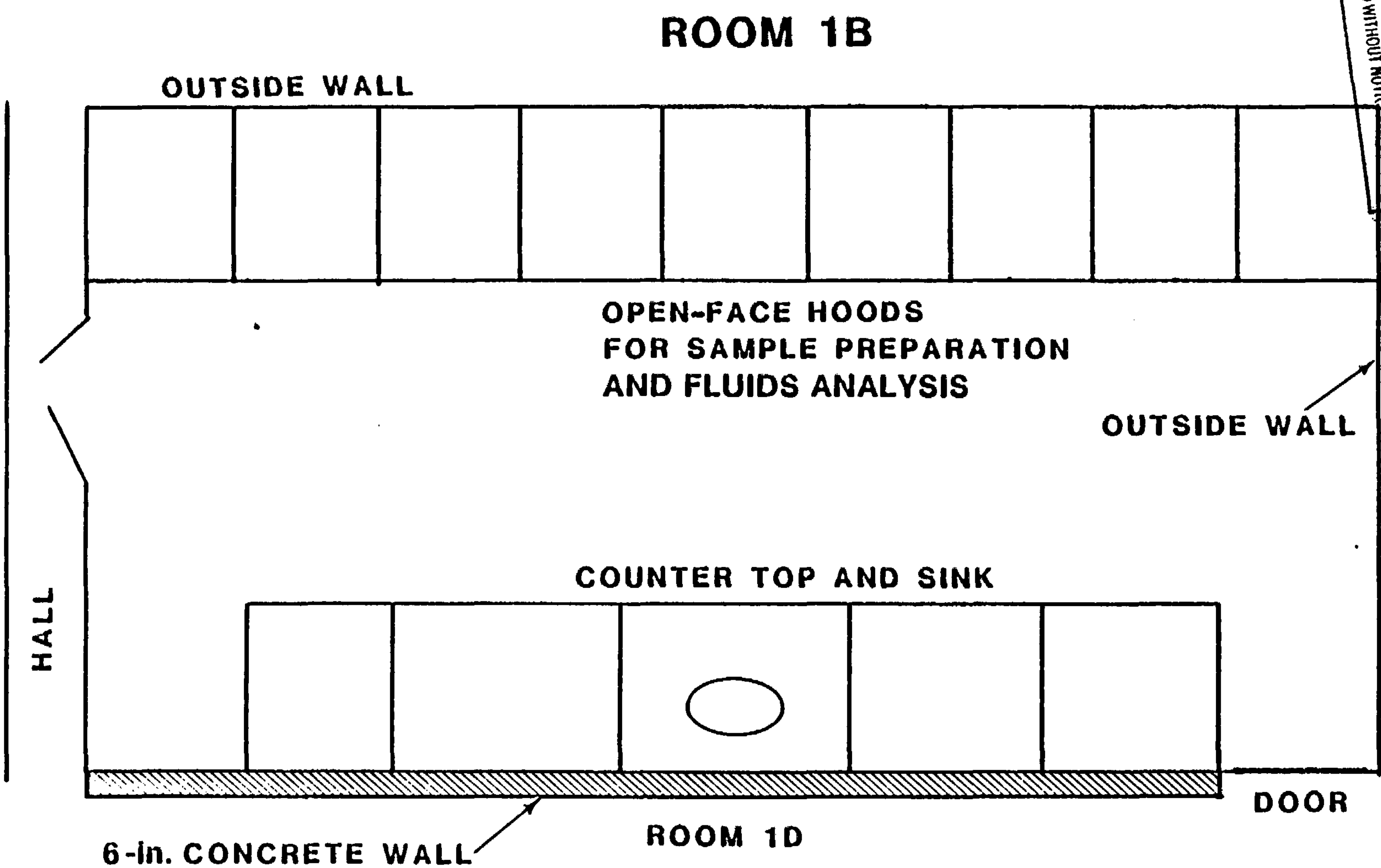

FIGURE 5-8. Laboratory 1B.

Laboratory 1D (Figure 5-9) is presently being used for nonradio-active hydrothermal testing with simulated waste forms in Dickson-type rocking autoclave systems. The laboratory has been completely renovated for this task and has been totally dedicated to the BWIP for waste form-barrier material-rock hydrothermal studies.

Laboratory 1D is equipped with three open-face hoods used to load and unload hydrothermal test materials. The open-face hoods are equipped with portable radiation shielding and have operating procedures for handling radioactive materials producing dose rates of ~100 mR/hr whole body exposure.

Also available in Laboratory 1D is a shielded barricade that will accommodate three Dickson rocking autoclave systems (six autoclaves). This barricade system will provide adequate radiation protection for the maximum sample size (10 g) of the most radioactive waste form to be tested (borosilicate glass).

5.3 ANALYTICAL FACILITIES

The 222-S Building laboratories that will be assigned to support hydrothermal tests are: 1GA, 1H, 1JA, 1J, 4E, 4M, and counting room, B1A/C (see Figures 5-4 and 5-5).

Laboratory 1GA has 540 ft^2 of floor space (Figure 5-10). This laboratory will be assigned to provide chemical separation, speciation, and analytical measurement support. It is equipped with radioactive service hoods and a full complement of analytical equipment.

Laboratories 1H and 1JA will provide sample preparation support for the inductively coupled plasma atomic emmission spectrometer (ICP-AES) (Figure 5-11). These laboratories contain the radioactive service hoods and bench space to provide adequate support for the ICP-AES.

Laboratory 1J contains the shielded Applied Research Laboratory, Model 137 ICP-AES equipment. The ICP-AES is designed to measure cations in highly radioactive samples up to 5 R/hr, and to discharge the associated liquid and gaseous wastes safely (Figure 5-12). The ICP-AES

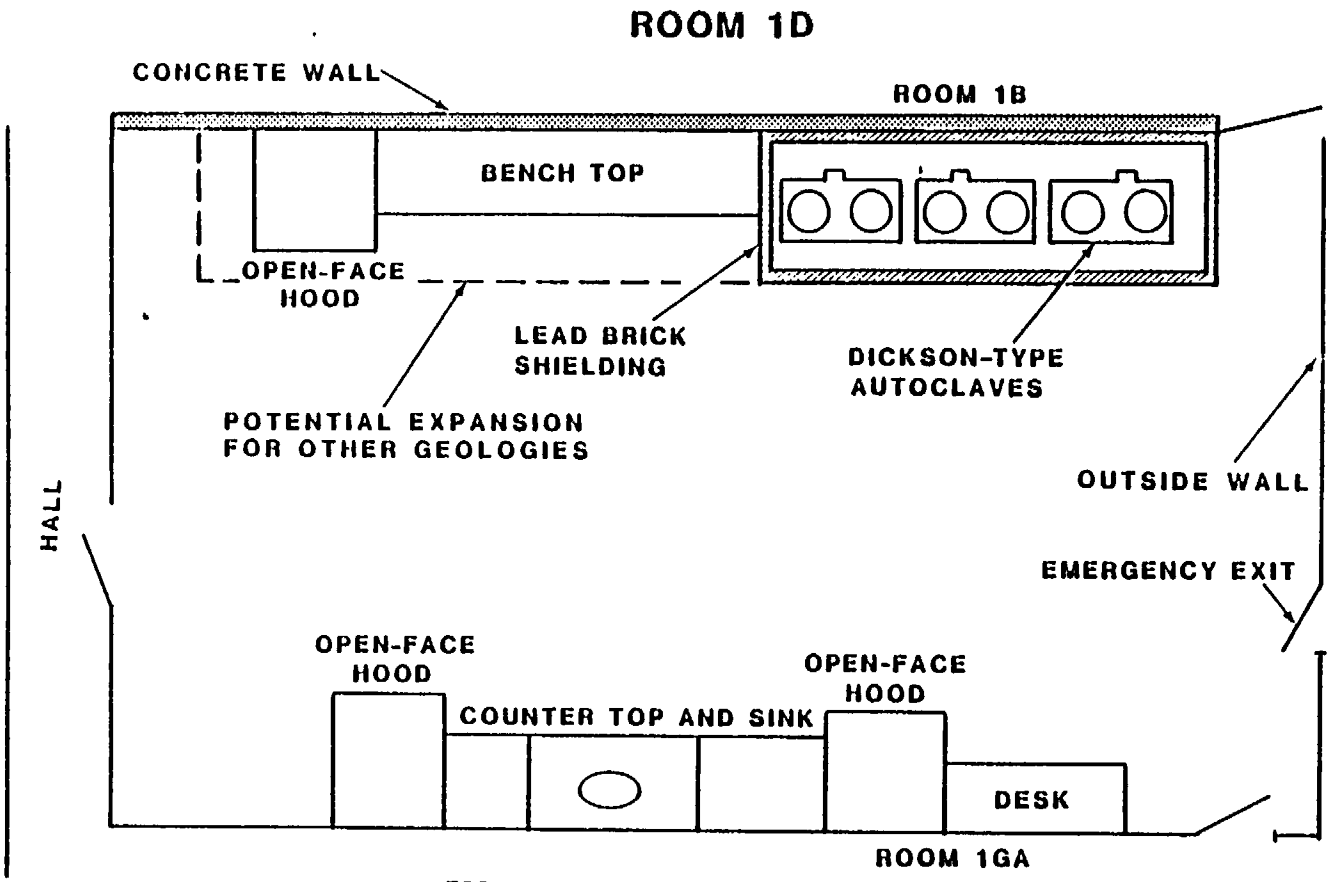

FIGURE 5-9. Laboratory 1D.

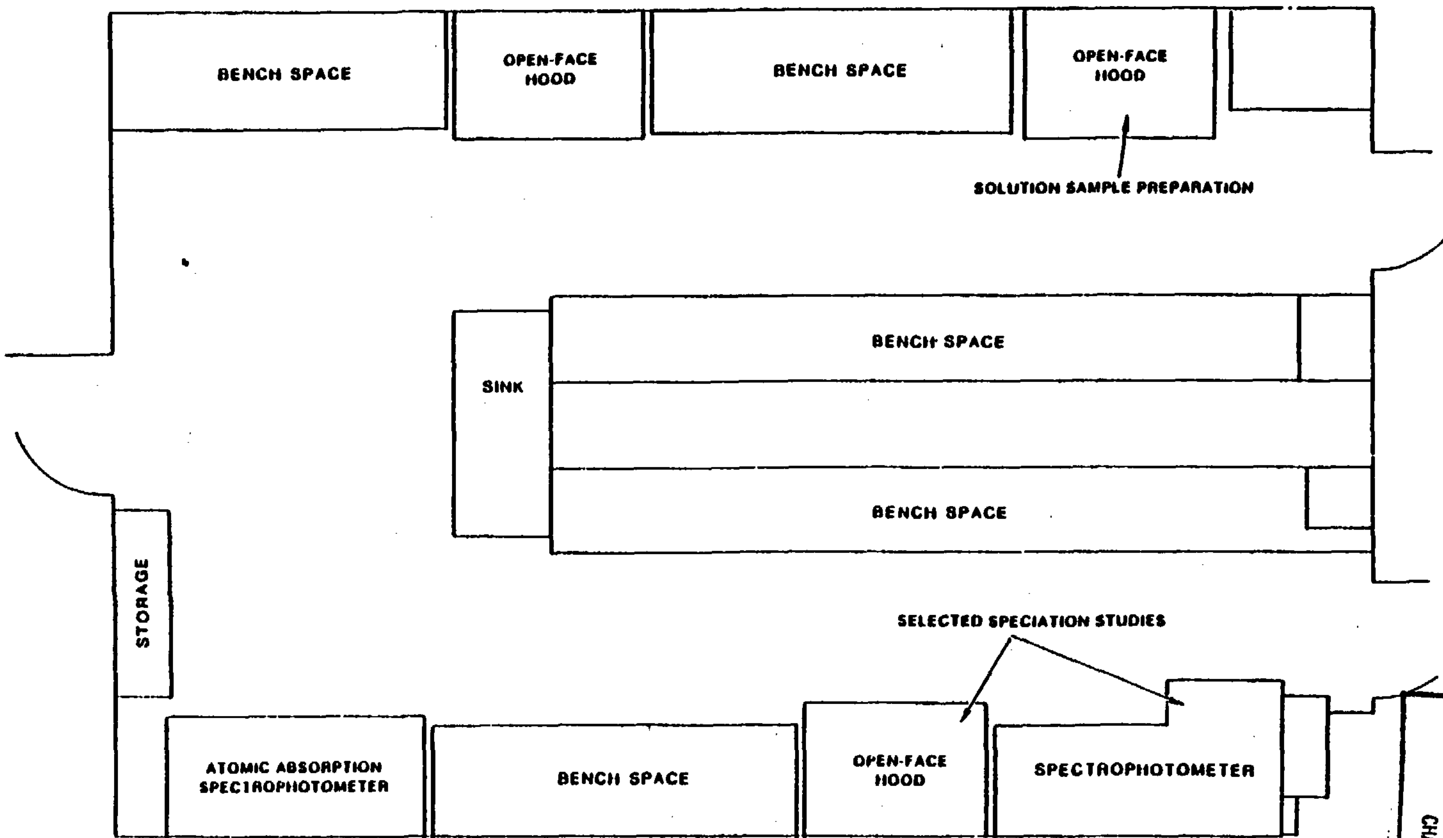

FIGURE 5-10. Laboratory 1GA.

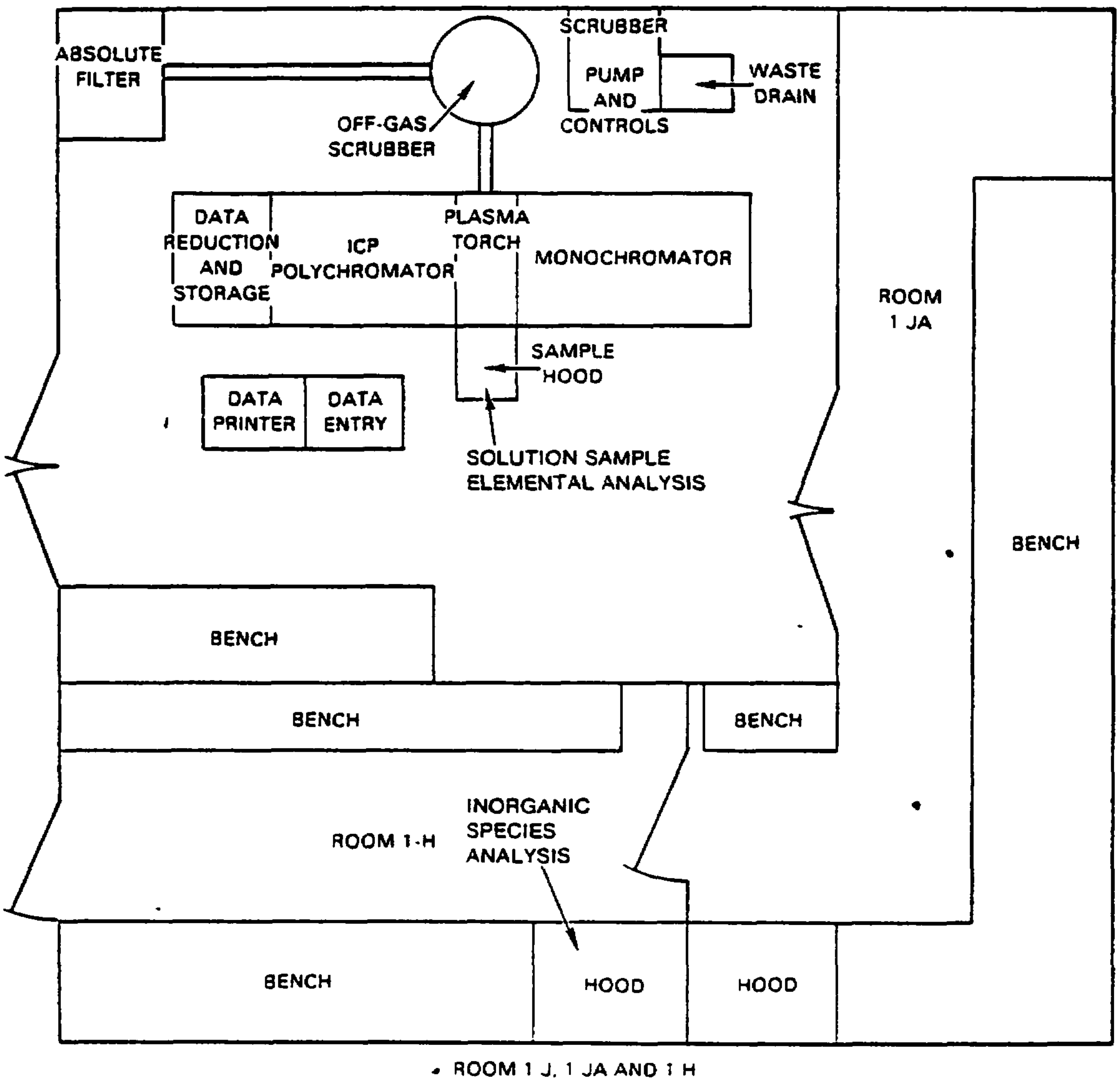

FIGURE 5-11. Laboratory 1J, 1JA, and 1H.

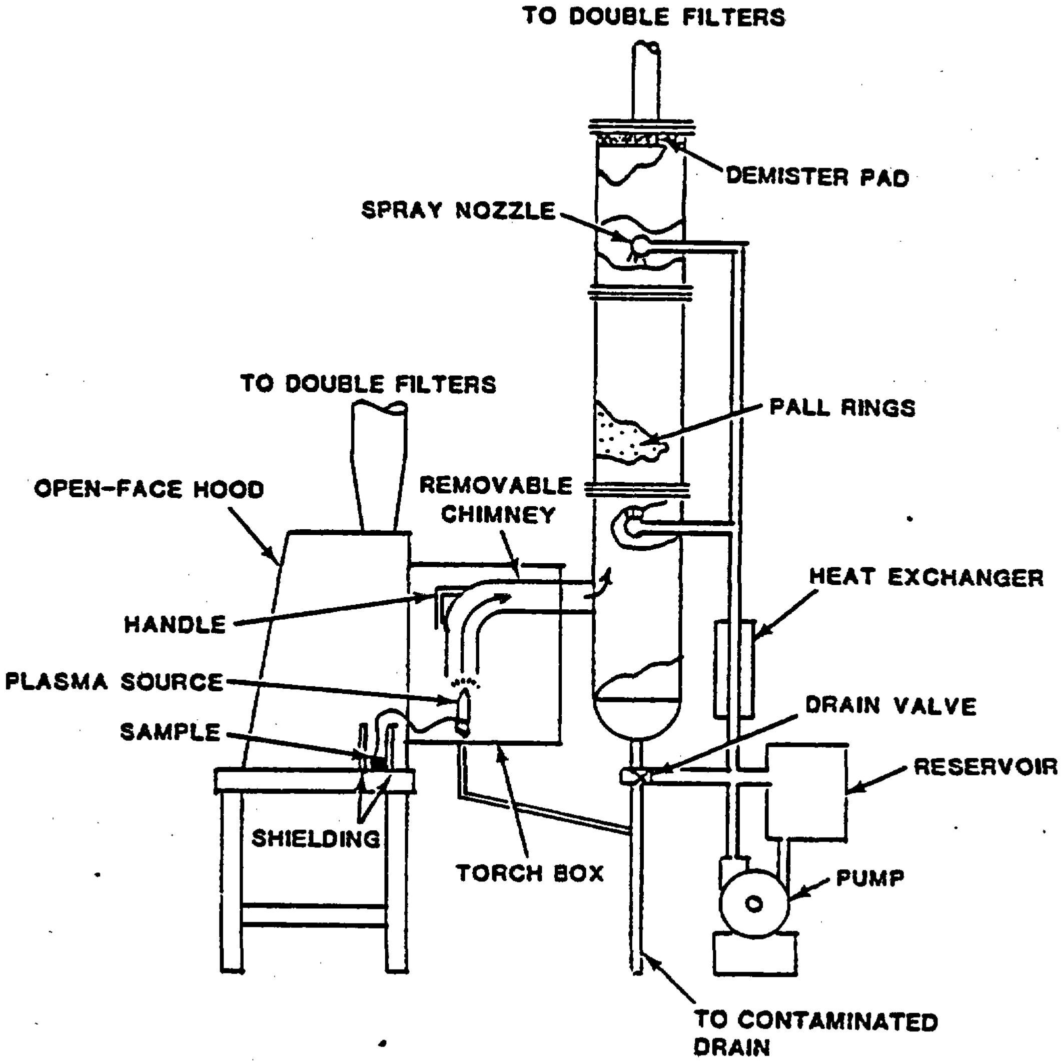

FIGURE 5-12. Laboratory 1J Shielded ICP-AES.

will be used to measure the majority of cations required by this testing program. Refer to Tables D-1 and D-2 (Appendix D) for the specific cations and associated detection limits.

Laboratory 1K, with 285 ft^2 of floor space, contains adequate hood and bench space to support the installed shielded atomic absorption spectrophotometer (AAS) (Figure 5-13). The AAS unit (Jarrell-Ash, Model AA-6) has been designed to measure cations safely in samples having dose rates up to 5 R/hr (Figure 5-14). The AAS unit will be used to measure make cesium, arsenic, selenium, tin, lead, antimony, and tellurium for this testing program.

Laboratory 4K, with 475 ft^2 of floor space, will be devoted to ion and gas chromatographic measurement and development (Figure 5-15). This laboratory is equipped with an assortment of hoods, bench space, and equipment to analyze radioactive samples for anions using ion chromatography. During the course of testing, fluoride, chloride, nitrate, phosphate, and sulfate measurements will be completed in this laboratory.

Laboratories 4E and 4M, each have 475 ft^2 of floor space. Laboratory 4E will be modified to accommodate a Model Rigaku D/MAX-rA shielded XRD unit and Model JEOL JSM-35C shielded SEM. Adequate hood and bench space is available to support the measurement activities in this laboratory (Figure 5-16). Laboratory 4M will be modified to accommodate a JEOL 200CX shielded ANSTEM. Adequate sample preparation and darkroom space will also be provided (Figure 5-17).

Laboratory B1A is a modern radiation detection counting room and sample storage support facility (Figure 5-18). It is equipped with state-of-the-art equipment for rapid and accurate neutron, alpha, beta, gamma, and X-ray measurements on solid and liquid samples. The facility is designed to measure radioisotopes ranging from low-level effluent concentrations to highly radioactive process plant and reactor samples. Lag and archive storage is available in a nearby multicompartment concrete storage vault, Room B1C (see Figure 5-18).

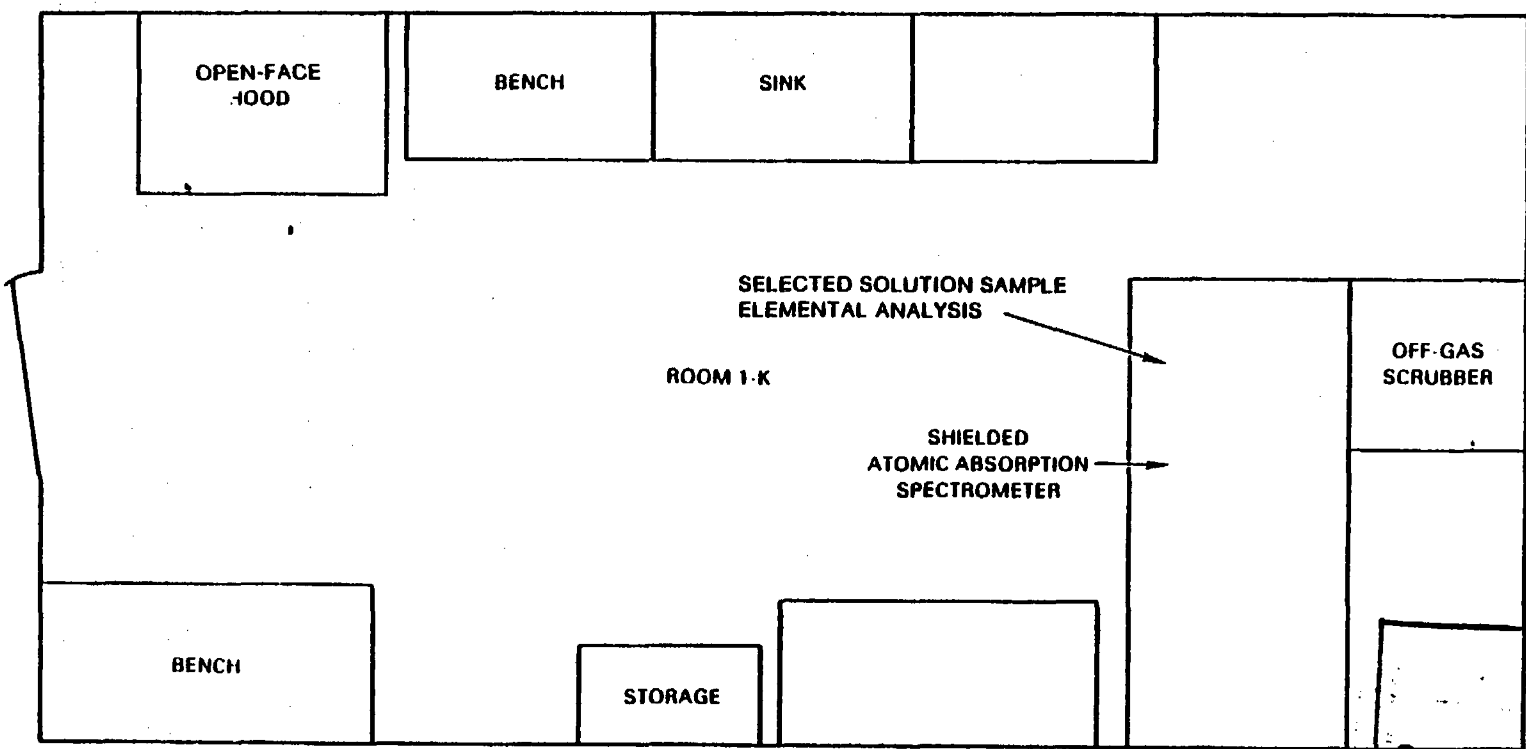

FIGURE 5-13. Laboratory 1K, Shielded AAS Laboratory.

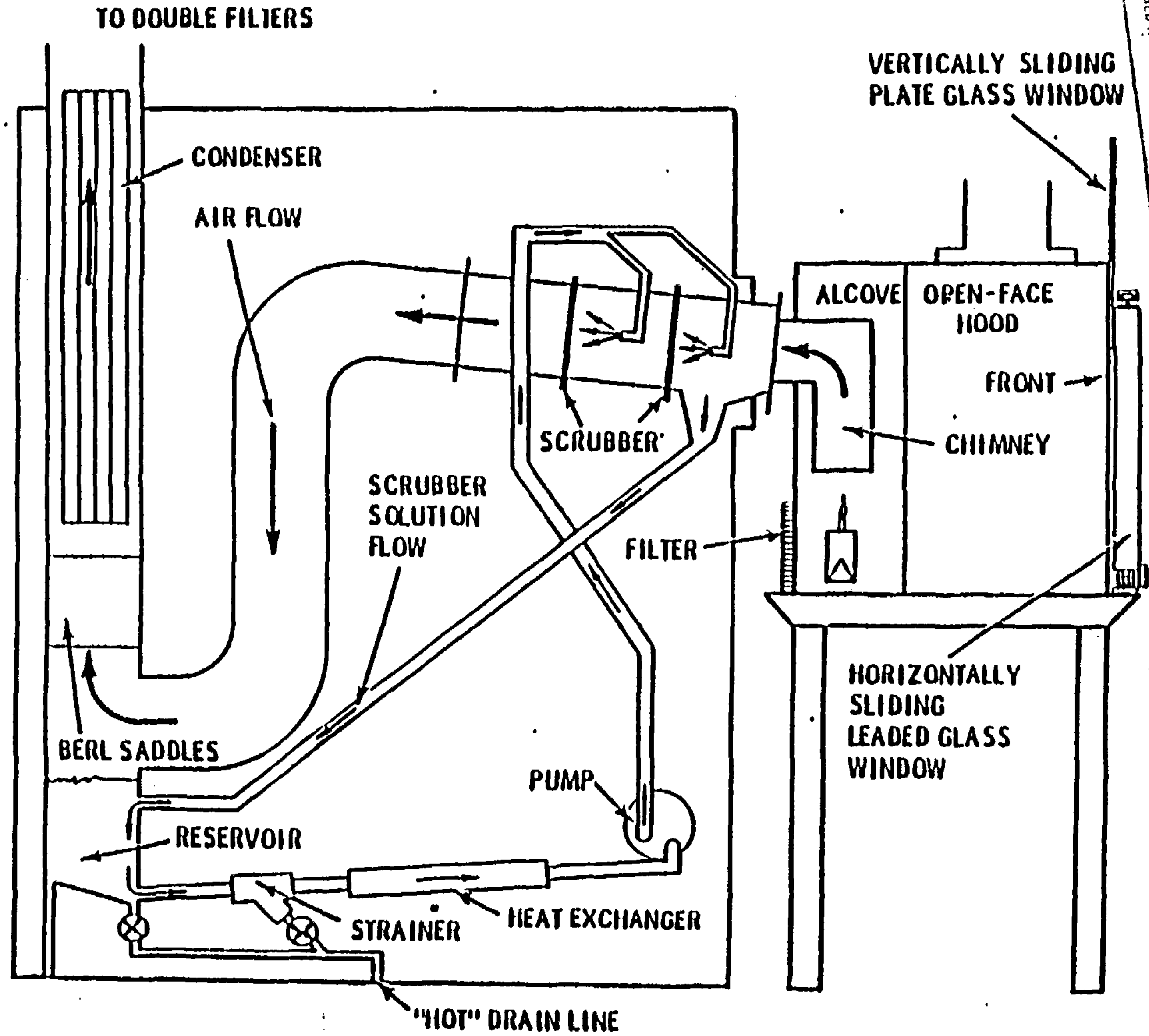

FIGURE 5-14. The AAS Open-Face Hood and Off-Gas Scrubber System (Side View).

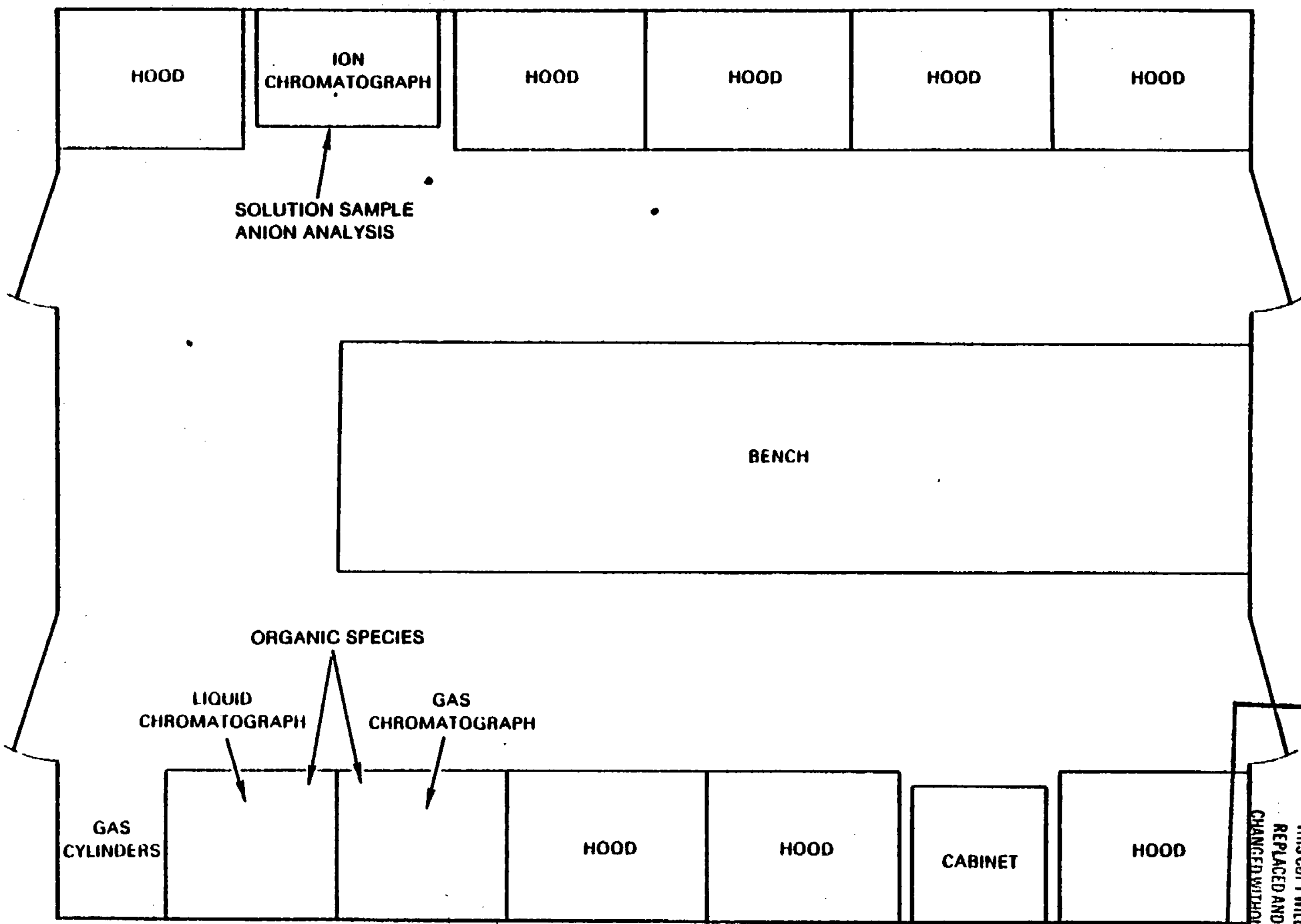

FIGURE 5-15. Laboratory 4K, Chromatographic Laboratory.

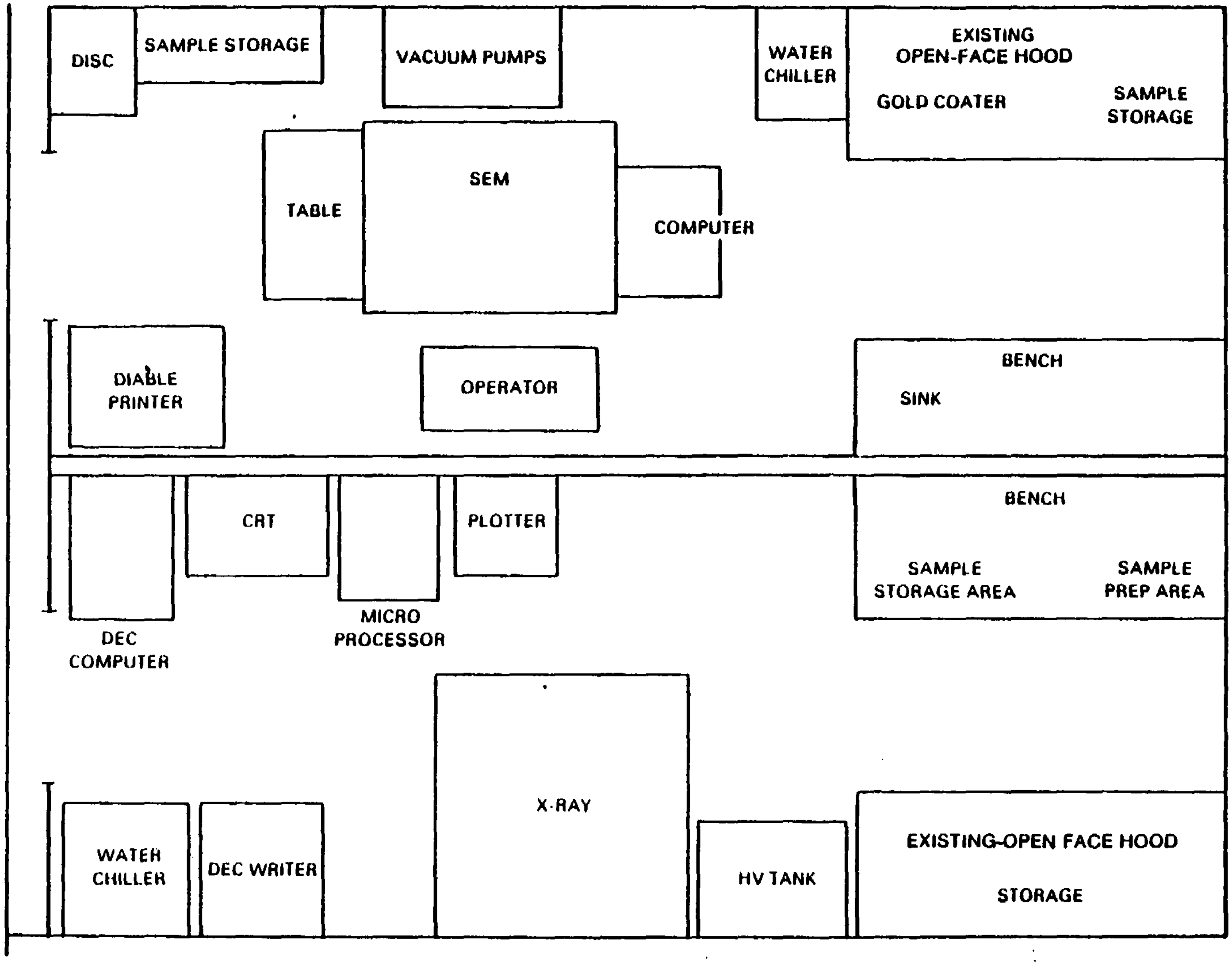

FIGURE 5-16. Laboratory 4E, Proposed Layout of SEM and X-Ray Laboratory.

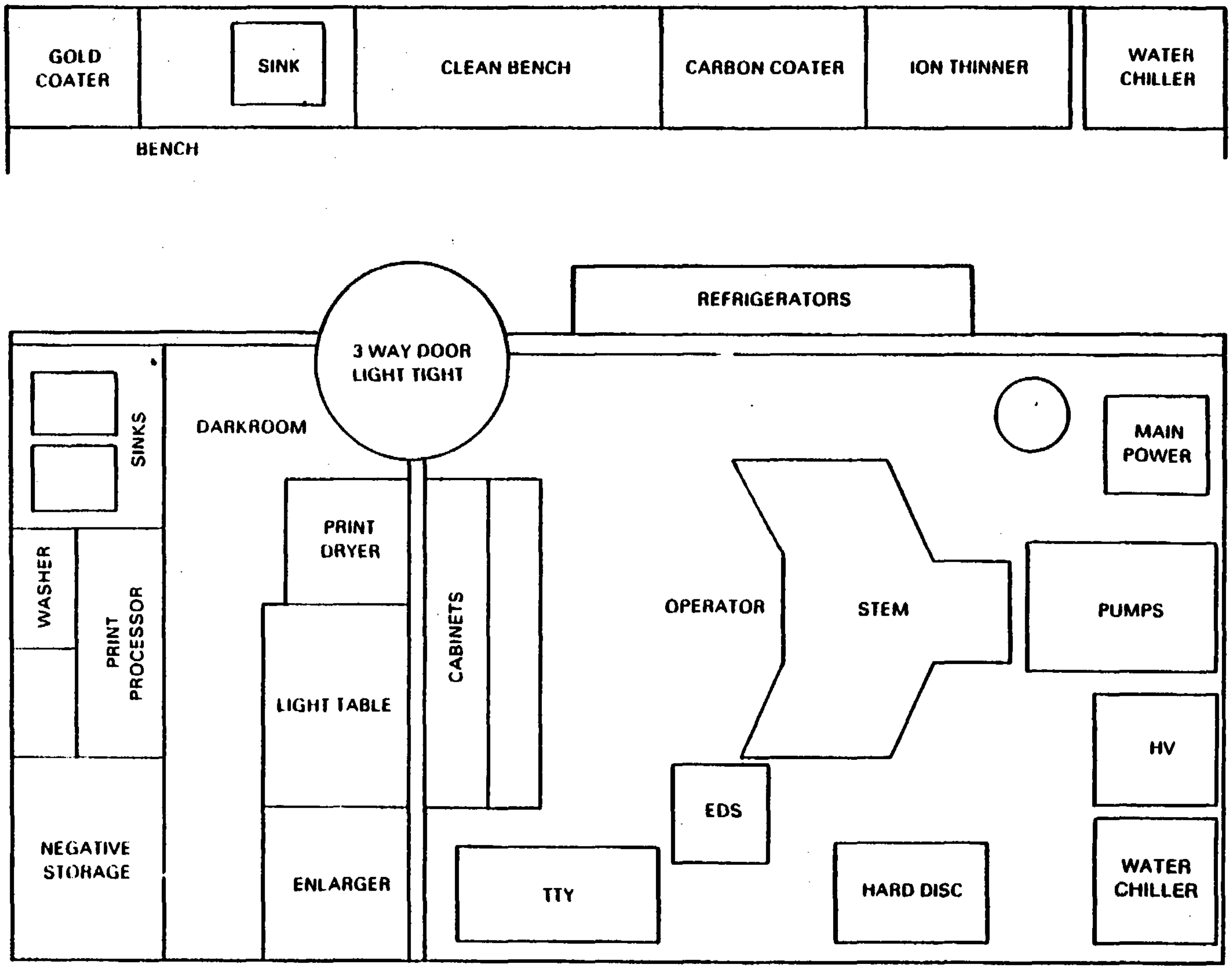

FIGURE 5-17. Laboratory 4M, Proposed Layout for STEM Laboratory.

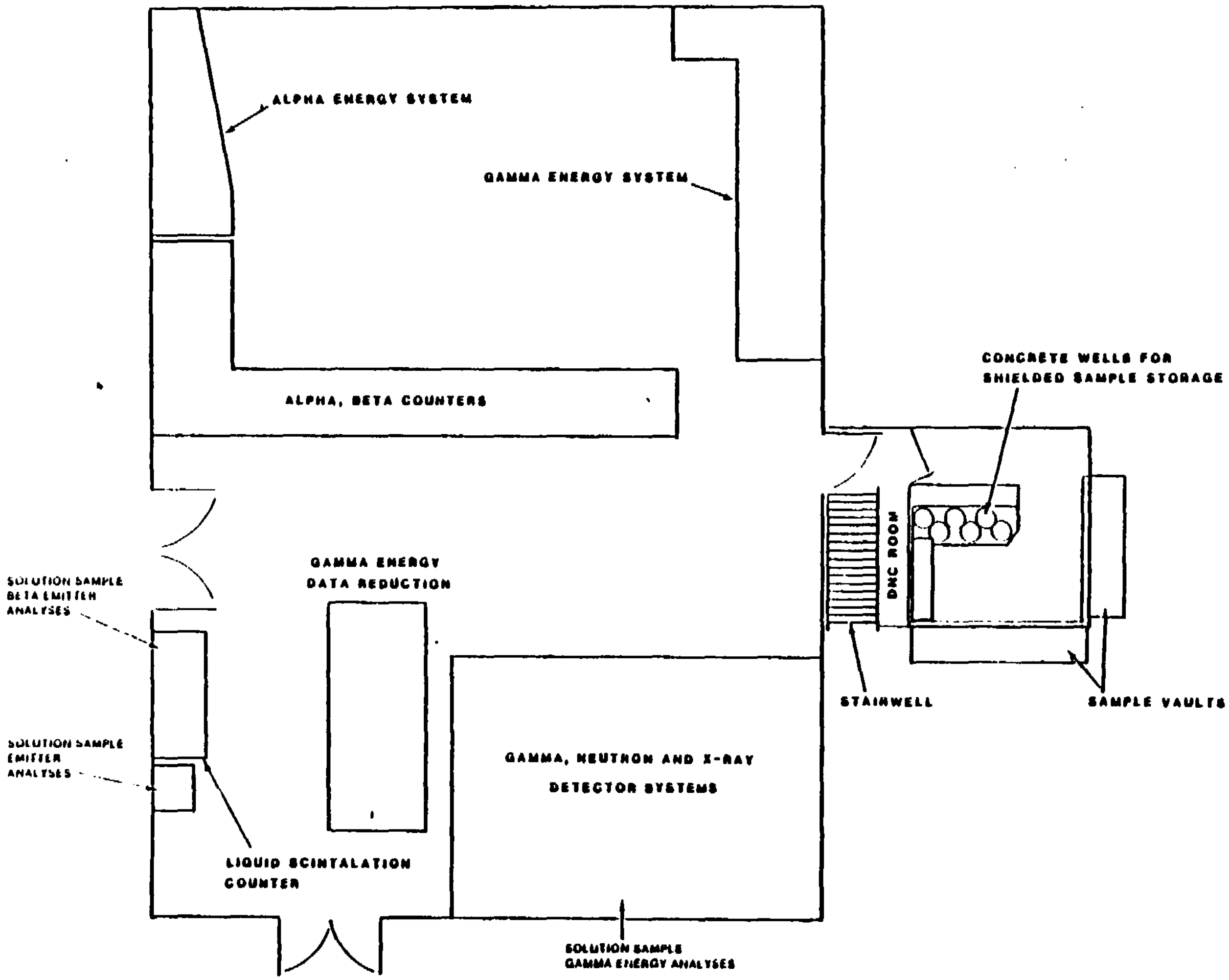

FIGURE 5-18. Laboratory B1A Counting Room and Laboratory B1C Sample Storage Vault.

5.4 SAMPLE FLOW DIAGRAM

Figure 5-19 diagrams the flow of solid and solution reaction product samples, produced during the hydrothermal test program, through the 222-S Building. The analytical measurement process applied to each sample is also shown. The pathway taken by the resultant analytical data from laboratory to the final location in a retrievable stage repository is also shown.

5.5 ANALYTICAL EQUIPMENT

The following operating Rockwell analytical equipment will be assigned to support research under this proposal. All of this equipment is currently in radioactive service except the STEM, SEM, and XRD. A simple laboratory relocation for these three items will complete the necessary array or radiation service equipment needed to support the hydrothermal test program. Analytical equipment is discussed in further detail in Appendix D.

- Optical microscope
  - 2 stereo-zoom (WILD M-8) microscopes
  - 2 polarizing (Leitz Orthoplan) microscope
- - X-ray powder diffractometer system
  - Rigaku microdiffractometer
- Scanning electron microscope
  - Scanning electron microscope (JEOL-JSM-35C)
  - Energy dispersive system (Tracor Northern TN-2000)
- Analytical scanning transmission electron microscope
  - ASTEM (JEOL-20CS TEMSCAN)
  - Energy dispersive system (PGT-3000)
  - Ion thinner (Gatan Dual Ion Mill)
- Inductively coupled plasma atomic emission spectrometer
  - 29 Channel Polychromator (Applied Research Laboratories Model 137)
  - Scanning monochromator (Interactive Technology)

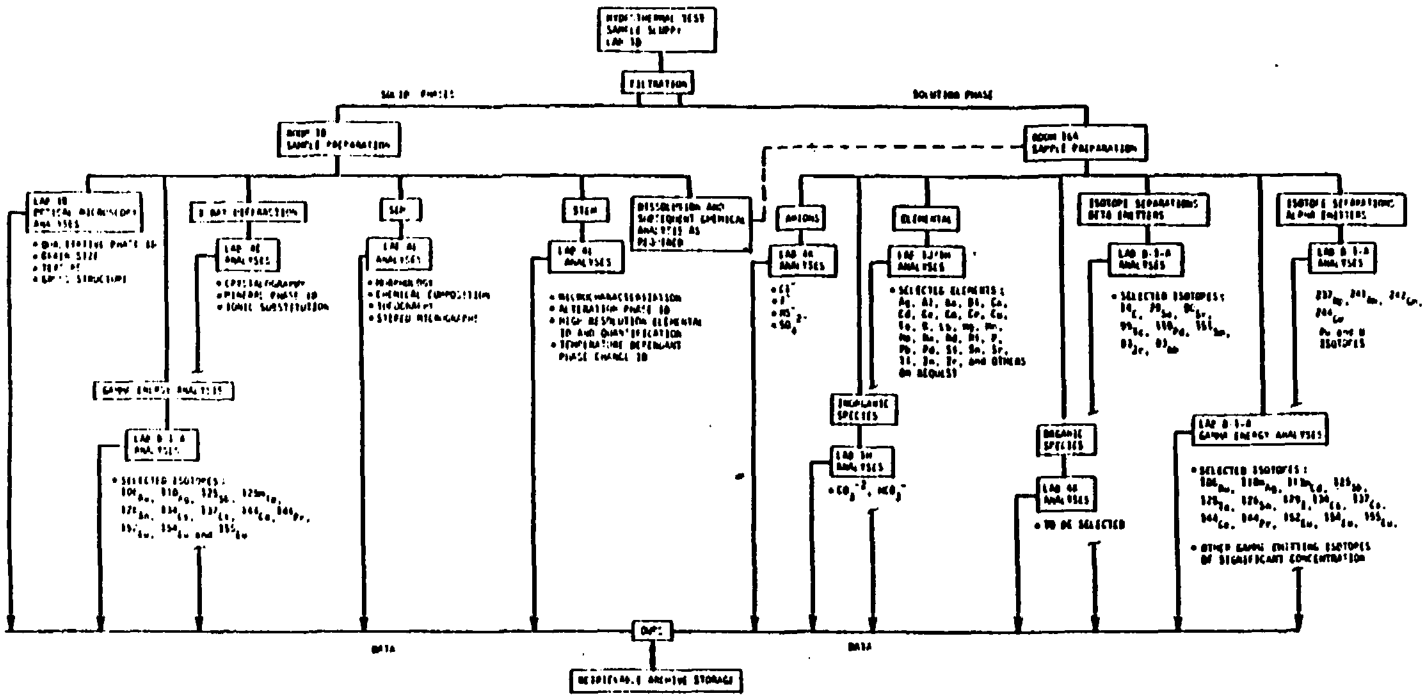

FIGURE 5-19. Analytical Sample/Data Flow Chart Through 222-S Building.

- Atomic absorption spectrophotometer
  - AAS (Jarrel-Ash Model AA-)
- Ion chromatography
  - IC (Dionex Model 10)
- Carbon analyzer
  - Coulometrics Model 5020
- Gamma energy spectrometers
  - Gamma energy systems (Canberra Industries JUPITER)
  - 30% efficient gamma energy detector
  - Low-energy gamma system (Tracor Northern 4500)
  - Multidetector array system
- Alpha spectrometer
  - High-resolution alpha spectrometer
  - (Oak Ridge National Laboratory - PERALS)
- Liquid scintillator counter
  - Packar Tri-Carb Model 450C
- Miscellaneous equipment
  - Gas chromatograph
  - Liquid chromatograph
  - Mass spectrometer (thermal emission)
  - Thermogravimetric instrumentation
  - Ultraviolet-visible spectrophotometer.

6.0 QUALITY ASSURANCE

6.1 GENERAL

Rockwell operates under a comprehensive Quality Assurance (QA) program. The procedures and responsibilities for this program are described in the QA Manual, RHO-MA-150 (Hammond, 1978). This manual describes the following QA controls:

- Management
- Program
- Design
- Procurement
- Construction
- Material
- Operations
- Nonconforming conditions
- Documentation.

In addition, the BWIP QA Program Plan, RHO-QA-PL-3, specifically describes the applicable quality requirements and methods of implementing the quality program for the BWIP (Nichol, 1982). Quality assurance for work in the 222-S Building is governed by these policies, and administrative controls and the required elements are incorporated into its procedures in the Basalt Operating Procedures (BOP) Manual, RHO-BWI-MA-4 (Deju, 1979).

6.2 TECHNICAL CONTROL

The 222-S Building uses a systematic approach design and perform all tests. This systematic approach ensures that the maximum amount of information is obtained during testing and that its quality meets the standards and objectives of the program. Experience with nonradioactive hydrothermal testing and characterization of geological and barrier materials provides the basis for a sound experimental design. Rockwell's long experience with hot-cell operations, radioactive waste management, and radiochemical analyses provides an established system of handling

radioactive materials in an efficient, quality-controlled, and safe manner. A statistical and mathematical unit is available at Rockwell to develop efficient and meaningful experimental designs and to evaluate the validity of the results. A formal controlled documentation system maintains data traceability.

6.3 TEST PLANS

Test plans are used by Rockwell to identify:

- Objectives and purpose of the test
- Conditions and materials used in testing and their control requirements
- Measurements, both test and analytical, necessary during testing
- Procedures used for carrying out testing and measurements
- Level of standardization required for measurements (National Bureau of Standards, U.S. Geological Survey, American Society for Testing and Materials, etc.)
- Accuracy and precision of measurements
- Calibration requirements and frequency
- Sampling requirements and frequency
- Documentation requirements and method of reporting.

6.4 OPERATING PROCEDURES

The waste package materials included in this program will be tested and analyzed according to established procedures in the BOP Manual, RHO-BWI-MA-4. These procedures describe testing, equipment, and analysis operations in a step-by-step sequence. These procedures follow the general format given below:

- 1.0 Objective
- 2.0 Responsibilities
- 3.0 Safety

- 4.0 Procedure
- 5.0 QA
- 6.0 Applicable Documents.

Each procedure includes instructions for collecting and documenting required data. These procedures are a part of the formal documentation system managed by Rockwell in the BWIP Document Control System, RSD-BWI-SD-002, and are subject to periodic review and audit (BWIP, 1982b).

6.5 DATA MANAGEMENT

The importance of data traceability is recognized by Rockwell and the BWIP. A data management and material control system is used by the 222-S Building to control reference materials used in testing and to provide a system for identifying, tracing, and collecting data and records generated during testing. The present flow of material and data for the 222-S Building is shown in Figure 6-1 and described in BOP C-4.3, "Laboratory Material and Data Management System for Basalt Research Laboratory," and can accommodate the requirements of radioactive hydrothermal testing.

The system is based on the interaction of three major functions. Material Management is responsible for storing and dispersing all reference materials. It maintains the central file of characterization data for these materials, and collects information generated on these materials during testing. Experimental Studies is responsible for carrying out the test according to the prescribed procedures, analyzing data, and issuing reports. Characterization analyzes samples generated by the experimental groups and characterizes reference materials.

Data traceability is maintained through the use of multiple copy data cards such as those shown in Figures 6-2, 6-3, 6-4, and 6-5. These cards identify the materials used (Reference Sample No.), test number (Run No.), and samples generated during experimentation (Experimental Sample No.). They contain the exact location of the source information in laboratory notebooks or computer files. They also contain experimental conditions, data, and other information such as photographs

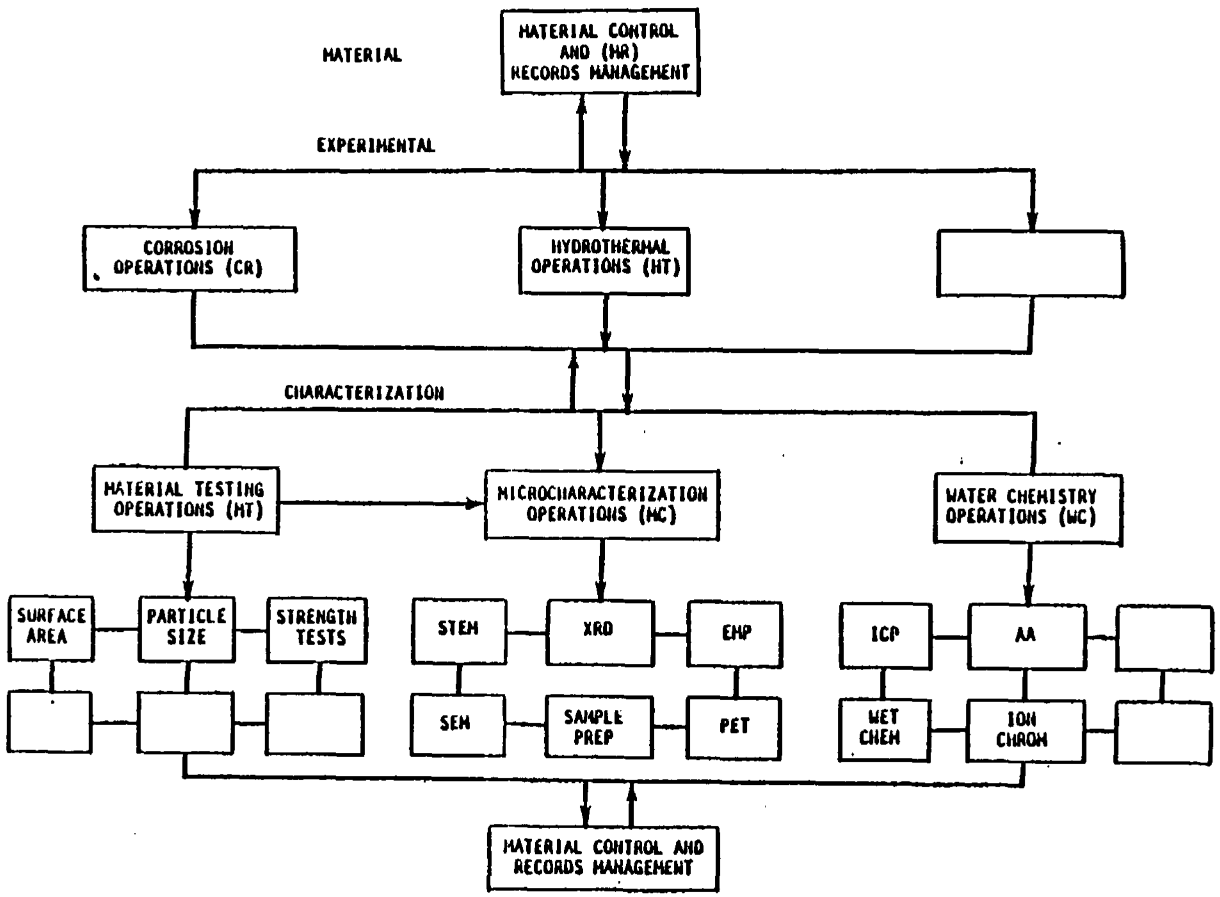

FIGURE 6-1. Flow of Material and Data for the 222-S Building.

HTL				
REFERENCE SAMPLE NO.	RUN NO.	LAB NO.		
DATA LOCATION		ESN	ESN	COMMENTS
NOTEBOOK - NAME - PAGES - DATE - COMP. FILES -	GROUND H_2O TYPE - TEST DURATION ____ TO ____ ____ ____ TEMPERATURE - PRESSURE -			

FIGURE 6-2. Sample Data Card for the 222-S Building.

REFERENCE SAMPLE NO.	RUN NO.	EXPERIMENTAL SAMPLE NO.
DATA LOCATION	SAMPLE GENERATION	PHOTOGRAPHIC DATA
LAB NO.		
NOTEBOOK - NAME - PAGES - DATES - COMPUTER FILE -	GRID LOCATION NUMBERS ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ STORAGE MT. NUMBER LOCATION ____ ____ ____ ____ ____ ____ ____ ____	PHOTO NO. - - - - REPORT NO. -

FIGURE 6-3. Sample Data Card for the Scanning Transmission Electron Microscope.

REFERENCE SAMPLE NO.	RUN NO.		EXPERIMENTAL SAMPLE NO.
DATA LOCATION	SAMPLE GENERATION		PHOTOGRAPHIC DATA
LAB NO.			
NOTEBOOK -	MT. NUMBER	LOCATION	PHOTO NO. -
NAME -			-
PAGES -			-
DATES -			-
COMPUTER FILE -			REPORT NO. -

FIGURE 6-4. Sample Data Card for the Scanning Electron Microscope.

EMP/PET				
REFERENCE SAMPLE NO.	RUN NO.		EXPERIMENTAL SAMPLE NO.	
DATA LOCATION	EMP RESULTS		PET RESULTS	
EMP LAB NO.:	GRID LOCATIONS		MINERALS IDENTIFED/LOC	
NOTEBOOK				
NAME:				
PAGES:				
DATE:				
COMPUTER FILE:				
PET LAB NO.:	PHOTO NUMBERS			
NAME:				
PAGES:				
DATE:				
COMPUTER FILE:	MOUNT NO.	STORAGE	MOUNT NO.	STORAGE

FIGURE 6-5. Sample Data Card for the Electron Microprobe/Petrography.

generated during testing. Rockwell-documented and -controlled laboratory notebooks are considered the source of all data except for those techniques where the data volume is so large that computer files are required. A copy of each card is returned to the central file of the Material and Data Custodian.

6.6 REPORTS

Data from tests are summarized in monthly, quarterly, and topical reports. These reports contain detailed descriptions of the materials tested, experimental conditions, analysis, and conclusions. They also keep the project informed of the progress of testing and evaluate the results in terms of the project objectives.

7.0 SAFETY

7.1 INTRODUCTION

Rockwell's Health, Safety and Environment Function (HS&E) is charged with ensuring the protection of employees and related work forces, facilities, the environment, and the general public. It directs and monitors activities to ensure compliance with applicable federal, state, and local health, safety, and environmental regulations, criteria, and requirements.

All hydrothermal tests in the 222-S Building will be performed in compliance with previously approved procedures and regulations. In addition, all new procedures will be in accordance with accepted radiological, industrial, and environmental safety practices as reflected in the previously approved manual, RHO-MA-223, Health, Safety and Environment Policy and Procedure Manual. To ensure that new procedures are in accordance with these accepted practices, HS&E will review and approve all procedures developed for hydrothermal testing. Health, Safety and Environment will also review and approve the design of all new equipment and facilities. Compliance with these approved procedures and designs will be audited by HS&E. In additon, HS&E will determine the necessity of submitting a safety analysis report, and will compose such documentation, as required.

7.2 MATERIAL ASSESSMENT

Hydrothermal tests in this program will be performed to investigate three types of materials:

- Glass that has been doped with radioactive trace elements (tracer-doped glass)
- Unprocessed spent fuel waste (spent fuel)
- Borosilicate glass containing fission products, activation products, and residual actinides (fully loaded glass)

The tracer-loaded glass will be low in radioactivity relative to the other two waste materials. The isotopes and their quantities in the tracer material are presently being adjusted to minimize hazards within the constraints imposed by analytical detection sensitivity. No radiological hazards are expected from the planned use of this material.

Spent fuel contains higher levels of radionuclides and, therefore, presents higher radiological safety hazards. Preliminary calculations have estimated that spent fuel waste will produce an exposure level of 0.4 R/hr/g at a distance of 1 ft. The reference pressurized water reactor assembly that is presently being used for calculations weighs 657.9 kg, 461.4 kg of which is uranium. This reference assembly is a 15 by 15 array with the following characteristics:

- Power - 37.5 MW(t)/MTHM
- Average burnup - 33,000 MWd/MTHM
- Fuel residence at 80% capacity factor - 1,100 d
- Cooling time - 10 yr.

Except for the heavy elements, the fully loaded glass material will contain the same isotopes as the spent fuel material. Preliminary estimates indicate that an exposure level of 1.4 R/hr/g at 1 ft is to be expected from fully loaded glass.

Preliminary analyses indicate that the systems in place or planned for use in the 222-S Building will accommodate these materials without undue risk to personnel or the environment. Prior to startup of hydrothermal tests, the exposure levels expected at each stage of the process, the occupational doses expected, and the hazard to the general population in the case of an accident will be analyzed in more detail.

7.3 EQUIPMENT ASSESSMENT

The spent fuel and the fully loaded glass material initially will be handled remotely in the Laboratory 1E hot cell. The material will be loaded into a gold bag that will be loaded into an autoclave. Special transfer equipment has been designed to shield personnel during the transfer. The tracer-doped glass will not require this degree of shielding.

However, the distance between the material and the hands of operating personnel will be maximized by the use of forceps and ~~similar tools~~ to avoid potentially high-extremity doses. An open-face hood will be used for the initial loading to minimize the danger of contamination and inhalation. The hood(s) will have its own high efficiency particulate air (HEPA) filter, and will exhaust into an exhaust system with its own HEPA filter.

The autoclaves will operate at pressures up to 4,500 psi and temperatures up to 300°C. Catastrophic failure due to overpressurization will be avoided by the installation of a rupture disc. The Dickson-type hydrothermal system has three levels of safety interlocks to prevent overpressurization due to overheating:

- Furnace controller
- Rupture disc
- Audio alarm, which is sounded when pressure exceeds the manually set upper limit

The only condition that can increase pressure in the Dickson-type hydrothermal system is increased temperature. The furnace controller is designed to shut off all power to the furnaces when the manually set maximum temperature is exceeded.

The third control to prevent overpressurization is a rupture disc located inline to evacuate the autoclave pressurizing fluid and possibly the reacting fluid when the pressure exceeds 10,000 ± 100 psi. This event, when involving nonradioactive materials, simply allows the fluids to escape to the atmosphere via the rupture disc. During tests with radioactive materials, pressurizing fluid and radioactive fluid from the gold bag will be collected in a filtered manifold attached to the rupture disc assembly. The fluid will be collected behind the shielded barricade and will not present a radiation problem. Personnel will also be restricted from close contact with the autoclaves while the autoclaves are operating to avoid injuries due to the operating temperature of the autoclaves, as well as to minimize the exposure to radiation. The autoclave assembly is also shielded. Calculations indicate that all

shielding is sufficient to reduce the radiation dose to acceptable levels. During the withdrawal of liquid samples, or the quenching of the apparatus, protective clothing will be worn to avoid injury from the inadvertent release of radioactive fluid.

Material will be prepared, loaded, and unloaded only by authorized personnel who have been trained to use this equipment. Similar restrictions of access will apply to the operation of any experimental equipment associated with this project.

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APPENDIX A

WASTE PACKAGE AND SITE GEOCHEMISTRY ISSUES AND PLANS

CRITERIA, ISSUES, AND WORK ELEMENTS

The criteria and associated work elements and issues that directly or indirectly support the need for radiological testing have been reproduced (Table A-1) from Chapter 15 of the Site Characterization Report (BWIP, 1982). The broad scope and pervasiveness of material testing requirements clearly demonstrate that the hydrothermal and other materials test programs are necessary to the adequate design, testing, and performance verification of a waste package for inclusion in a nuclear waste repository in basalt (NWRB).

Regulatory and technical requirements were analyzed by the Basalt Waste Isolation Project (BWIP) to identify the information needed to meet the criteria in 10 CFR 60, NWTS-33(1), NWTS-33(2), NWTS-33(3), NWTS-33(4), 40 CFR 191, and other criteria documents. The requirements were divided into one or more elements of work which satisfy a specific portion of the criteria.

> A "work element" is defined as a technical activity required to satisfy all or part of a criterion and/or to resolve an issue identified for siting and/or designing a NWRB.

Work elements can be further broken down into the specific items of data needed and into specific analyses required to translate or interpret data. When there was some uncertainty or controversy as to whether a criterion, or portion thereof, could be clearly resolved or whether uncertainty surrounds the present state of knowledge, these items were described as issues in question form.

> An "issue" is defined as a technical question about which there is debate or controversy. Issues are technical questions that arise when the available information or technology is insufficient to make a specific decision or come to a specific conclusion about some aspect of repository siting or development.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 1 of 16).

Technical criteria	Issues	Work element
	W.1 - Design	
General Requirements of Design (60.135(a)) The design of the waste package shall include the following elements:	W.1.A Does the near-field interaction between the waste package and its components, the underground facility, and the geologic setting compromise waste package or engineered system performance?	W.1.1.A (Identical to W.1.18.B) Determine the maximum operating temperature limits for waste form, backfill, canister, and host rock.
Containment of Wastes (60.111(b)(2)) The engineered system shall be designed so that even if full or partial saturation of the underground facility were to occur, and assuming anticipated processes and events, the waste packages will contain all radionuclides for at least the first 1,000 years after permanent closure. This requirement does not apply to TRU waste unless TRU waste is emplaced close enough to HLW that the TRU release rate can be significantly affected by the heat generated by the HLW. For clarification see: NWTS 33(1), 3.4.2 NWTS 33(4), 3.1 NWTS 33(4), 3.2.1 NWTS 33(4), 4.3.2.1		W.1.2.A (Related to W.1.7.A, includes discussion of W.1.11.A) Determine conditions that affect design of waste packages, including thermal loading, mechanical loading, and chemical environment, during handling, shipment, emplacement, and retrieval, and after repository decommissioning. W.1.3.A (Identical to W.2.7.A, includes discussion of W.1.8.A) Determine the effect of radiation on near-field geochemistry, waste package, and barrier material performance.
HLW Releases (60.111(b)(2)(ii)(A)) For HLW, the engineered system shall be designed so that, after the first 1,000 years following permanent closure, the annual release rate of any radionuclide from the		W.1.4.A (Identical to W.2.5.A, W.2.9.B) Determine the projected solubilities, kinetic behavior, and distribution of aqueous species for key radionuclides released from the waste package during isolation.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 2 of 16).

Technical criteria	Issues	Work element
engineering system into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1,000 years following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1 percent of the total annual curie release as prescribed by this paragraph. For clarification see: 10 CFR 60.111(b)(2)(iii)(A)		W.1.5.A (Identical to W.2.2.A) Determine the extent of control of Eh-pH and groundwater composition by the host basalt after repository closure. W.1.6.A (Includes discussion of W.1.11.A) Determine the susceptibility of candidate canister materials to degradation (i.e., corrosion, hydriding, fatigue) in the repository near-field environment.
TRU Releases (60.111(b)(2)(ii)(B)) For TRU waste, the engineered system shall be designed so that following permanent closure the annual release rate of any radionuclide from the underground facility into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount calculated to be present in the underground facility (assuming no release from the underground facility) at any time following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1 percent of the annual curie release as prescribed by this paragraph. For clarification see: 10 CFR 60.111(b)(2)(ii)(B)		W.1.7.A (Related to W.1.2.A) Determine design properties, including thermal, physical, mechanical, and chemical for waste package component materials and host rock. W.1.8.A (Included in W.1.3.A) Determine the effect of radiation on the performance of the waste form, backfill, and near-field host rock. W.1.9.A (Included in W.1.12.A) Determine the release rate (performance) of candidate waste forms in the repository near-field environment.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 3 of 16).

Technical criteria	Issues	Work element
Emplacement Environment (60.135(a)(1)) The waste package shall be designed so that the in-situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the function of the waste packages. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions. For clarification see: 10 CFR 60.135(a)(1)		W.1.10.A (Identical to W.2.6.A) Determine the formation and stability of radionuclide complexes and/or colloids over expected repository near-field and far-field conditions.
Waste Package Effect on the Underground Facility Natural Barriers (60.135(a)(2)) The waste package shall be designed so that the in-situ chemical, physical, and nuclear properties of the waste package and its interactions with the emplacement environment do not compromise the performance of the underground facility or the geologic setting. The design shall include but not be limited to consideration of the following factors: solubility, oxidation/reduction		W.1.11.A (Included in W.1.2.A and W.1.6.A) Determine the chemical properties and inflow rate of the groundwater and their effect on canister corrosion during the 1,000-year containment period.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 4 of 16).

Technical criteria	Issues	Work element
reactions, corrosion, hydriding, gas generation, thermal effects, mechanical strength, mechanical stress, radiolysis, radiation damage, radionuclide retardation, leaching, fire and explosion hazards, thermal loads, and synergistic interactions. For clarification see: 10 CFR 60.135(a)(2)		W.1.12.A (Identical to W.2.3.A and W.1.19.B, includes discussion of W.1.9.A) Determine the extent to which the interaction between the canister materials, waste form, backfill, and host rock in a saturated environment results in retardation of radionuclides.
	W.1.B Is a borehole backfill required?	W.1.13.B Assess the impact of waste storage in a borehole with no backfill. IF A BOREHOLE BACKFILL IS REQUIRED, THE FOLLOWING FACTORS ARE NEEDED. SOME OF THESE FACTORS MAY NEED COMPLETION TO DECIDE ISSUE W.1.B. W.1.14.B Determine need for special tailoring agents in backfill to moderate the corrosivity (Eh and pH) of the groundwater contacting the canister. W.1.15.B Define the characteristics of the backfill materials required to retard the flow of groundwater to the canister. Identify potential backfill materials with these characteristics.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 5 of 16).

Technical criteria	Issues	Work element
		W.1.16.B Define the characteristics of the backfill material required to reduce the rate of radionuclide release from the waste package. Identify backfill materials with these characteristics.
		W.1.17.B (Identical to W.1.8.A, included in W.1.3.A) Determine the effect of radiation damage on the performance of the waste form, backfill, and host rock.
		W.1.18.B (Identical to W.1.1.A) Determine the maximum operating temperature limits for waste form, backfill, canister, and host rock.
		W.1.19.B (Identical to W.1.12.A and W.2.3.A) Determine the extent to which the interaction between the canister material, waste form, backfill, and host rock in a saturated environment results in retardation of radionuclides.
		W.1.20.B (Included in W.2.13.B) Determine if a waste package backfill is required to provide acceptable containment in the event of premature canister failure.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 6 of 16).

Technical criteria	Issues	Work element
Waste Form Requirement (60.135(b)) Radioactive waste that is employed in the underground facility shall meet the following requirements:	None	
(1) Solidification All such radioactive wastes shall be in solid form and placed in sealed containers.		W.1.21 Develop waste package acceptance specifications for waste solidification which meet U.S. Nuclear Regulatory Commission requirements.
(2) Consolidation Particulate waste forms shall have been consolidated (for example, by incorporation into an encapsulating matrix) to limit the availability and generation of particulates.	None	W.1.22 Develop waste package acceptance specifications for consolidation which meet U.S. Nuclear Regulatory Commission requirements.
(3) Combustibles All combustible radioactive wastes must have been reduced to a noncombustible form unless it can be demonstrated that a fire involving a single package will neither compromise the integrity of other packages, nor adversely affect any safety-related structures, systems, or components.	None	W.1.23 Develop waste package acceptance specifications for combustibles which meet U.S. Nuclear Regulatory Commission requirements.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 7 of 16).

Technical criteria	Issues	Work element
Waste Package Requirements (60.135(c)) The waste package design shall meet the following requirements: (1) Explosive, Pyrophoric, and Chemically Reactive Materials The waste package shall not contain explosive or pyrophoric materials or chemically reactive materials that could interfere with operations in the underground facility or compromise the ability of the geologic repository to satisfy the performance objectives.	None	W.1.24 Determine the impact of the reprocessing technique (including waste fractionation) on waste package design. W.1.25 Develop waste package acceptance specifications for explosive, pyrophoric, and chemically reactive materials which meet U.S. Nuclear Regulatory Commission requirements.
(2) Free Liquids The waste package shall not contain free liquids in an amount that could impair the structural integrity of waste package components (because of chemical interactions or formation of pressurized vapor) or result in spillage and spread of contamination in the event of package perforation.	None	W.1.26 Develop waste package acceptance specifications for free liquids which meet U.S. Nuclear Regulatory Commission requirements.
(3) Handling Waste packages shall be designed to maintain waste containment during transportation, emplacement, and retrieval.	None	W.1.27 Determine the waste package handling, shipping (including drop tests), emplacement, and retrievability requirements.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 8 of 16).

Technical criteria	Issues	Work element
(4) Unique Identification A label or other means of identification shall be provided for each package. The identification shall not impair the integrity of the package and shall be applied in such a way that the information shall be legible at least to the end of the retrievable storage period. Each package identification shall be consistent with the package's permanent written records. For clarification see: NWTS 33(1), 2.7 NWTS 33(1), 3.2.3 NWTS 33(1), 3.4.1 NWTS 33(1), 3.4.2 NWTS 33(2), 3.2.2 NWTS 33(2), 3.4 NWTS 33(4), 3.2 NWTS 33(4), 3.2.1 NWTS 33(4), 3.2.3 NWTS 33(4), 3.3 10 CFR 60.132(d)(3)	None	W.1.28 Develop waste package acceptance specifications for identification which meet U.S Nuclear Regulatory Commission requirements.
	W.2 - Site Geochemistry	
Favorable Conditions in the Geologic Setting (60.122) The geologic setting shall exhibit an appropriate combination of these favorable conditions so that, together with the engineered system, the favorable conditions present are sufficient to provide reasonable assurance that performance objectives will be met.	W.2.A Are the geochemical and hydrologic properties of the geologic setting (in conjunction with the waste forms) sufficient to meet or exceed U.S. Nuclear Regulatory Commission waste-isolation requirements?	W.2.1.A (Related to W.2.4.A) Determine the effect on radionuclide mobility on changes to the primary and secondary mineralogical conditions in the near field and far field of the repository along the expected pathway to the biosphere.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 9 of 16).

Technical criteria	Issues	Work element
For clarification see: 10 CFR 60.122		W.2.2.A (Identical to W.1.5.A)
		Determine the time-dependent control of Eh, pH, and groundwater composition by the host basalt after repository closure.
(d) The nature and rates of geochemical processes that have occurred since the start of the Quaternary Period are such that when projected, they would not affect or would favorably affect the ability of the geologic repository to isolate the waste.		W.2.3.A (Identical to W.1.12.A and W.1.19.B)
		Determine the effects of waste/barrier/rock/water interactions on the performance of the underground facility or geologic setting.
(g) Geochemical conditions that (1) promote precipitation or sorption of radionucides; (2) inhibit the formation of particulates, colloids, and inorganic and organic complexes that increase the mobility of radionuclides; and (3) inhibit the transport of radionuclides by particulates, colloids, and complexes.		W.2.4.A
		Demonstrate that geochemical conditions in the near and far field are such that transport of radionuclides is retarded for sufficient time to satisfy waste-isolation requirements.
(h) Mineral assemblages that, when subjected to anticipated thermal loading, will remain unaltered or alter to mineral assemblages having increased capacity to inhibit radionuclide migration.		W.2.5.A (Identical to W.1.4.A and W.2.9.B)

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 10 of 16).

Technical criteria	Issues	Work element
For clarification see: 10 CFR 60.123(b) (m) Conditions in the host rock that are not reducing conditions. (n) Groundwater conditions in the host rock, including but not limited to high ionic strength or ranges of Eh-pH, that could effect the solubility and chemical reactivity of the engineered systems.		W.2.7.A (Identical to W.1.3.A) Determine the effect of radiation on near-field geochemistry, waste package, and barrier material performance. W.2.8.A Determine acceptable release rates of key radionuclides from the engineered system based on 1,000-year groundwater travel time.
(o) Processes that would reduce sorption, result in degradation of the rock strength, or adversely affect the performance of the engineered system. For clarification see: NWTS 33(2), 3.2 NWTS 33(2), 3.2(1) NWTS 33(2), 3.2(2) NWTS 33(2), 3.3(1) NWTS 33(2), 3.4(1) NWTS 33(2), pg. 7.3.3 NWTS 33(3), 4.4.3	W.2.B What is the relative importance of waste-form leach rates versus solubility (steady-state) of key radionuclides in the near-field environment for controlling release?	W.2.9.B (Identical to W.1.4.A and W.2.5.A) Determine the projected solubilities and distribution of aqueous species for key radionuclides released from the waste package during isolation.
	W.2.C Can valid Eh measurements for the repository horizon in the reference repository location be made either by potentiometric measurement or indirectly by measurement of dissolved redox couples?	W.2.10.C Determine the method and technique which can be utilized to provide valid in situ Eh measurements for the reference repository location.
Mitigate Impacts of Failure of Engineered System (60.111(b)(3)(i)) During the containment period, the geologic setting shall mitigate the impact of premature failure of the engineered system. For clarification see: 10 CFR 60.111(b)(3)(ii)	None	W.2.11.D (Discussed in W.2.13.D) Determine how the geochemical and physical properties of the geologic setting mitigate the impact of premature failure of the waste package.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 11 of 16).

Technical criteria	Issues	Work element
Isolation (60.111(b)(3)(ii)) Following the containment period, the geologic setting, in conjunction with the engineered system as long as that system is expected to function, and alone thereafter, shall be capable of isolating radioactive waste so that transport of radionuclides to the accessible environment shall be in amounts and concentrations that conform to such generally applicable environmental standards as may have been established by the Environmental Protection Agency. For clarification see: NWTS 33(1), 2.1 NWTS 33(4), 2.1 NWTS 33(4), 3.1	W.2.D To what degree does the geologic setting retard migration of key radionuclides from the engineered system in meeting U.S. Environmental Protection Agency release criteria?	W.2.12.D (Related to W.2.11.C) Determine on a radionuclide-specific basis whether U.S. Nuclear Regulatory Commission repository release rates or U.S. Environmental Protection Agency dose limits are the limiting repository requirements. W.2.13.D (Includes discussion of W.1.20.B and W.2.11.C) Determine to what degree the characteristics of the geologic setting complement the engineered system.
W.3 - Testing and Performance Confirmation		
Performance Confirmation (60.140) General Requirements: (60.140) (a) The performance confirmation program shall ascertain whether: (1) Actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within the limits assumed in the licensing review.	None	W.3.1 Determine and conduct field and in situ testing as may be appropriate to meet U.S. Nuclear Regulatory Commission performance requirements. W.3.2 Determine suitability of using nonradioactive chemical analogues for actual waste forms in the hydrothermal testing program.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 12 of 16).

Technical criteria	Issues	Work element
(2) Natural and engineered systems and components required for repository operation, or which are designed or assumed to operate as barriers after permanent closure are functioning as intended anticipated.		W.3.3 Determine what natural analogues of waste package components can be used to verify the compatibility of the waste package with the repository environment.
(b) The program shall have been started during site characterization and it will continue until permanent closure.		
(c) The program will include in-situ monitoring, laboratory and field testing, and in-situ experiments, as may be appropriate to accomplish the objective as stated above.		
(d) The confirmation program shall be implemented so that:		
(1) It does not adversely affect the natural and engineered elements of the geologic repository.		
(2) It provides baseline information and analysis of that information on those parameters and natural processes pertaining to the geologic setting that may be changed by site characterization, construction, and operational activities.		

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 13 of 16).

Technical criteria	Issues	Work element
(3) It monitors and analyzes changes from the baseline condition of parameters that could affect the performance of a geologic repository. (4) It provides an established plan for feedback and analysis of data, and implementation of appropriate action. For clarification see: NWTS 33(4), 3.1 NWTS 33(4), 3.4		
Design Testing (60.142) (a) During the early or developmental stages of construction, a program for in-situ testing of such features as borehole and shaft seals, backfill, and the thermal interaction effects of the waste packages, backfill, rock, and groundwater shall be conducted. (b) The testing shall be initiated as early as is practicable. (c) A backfill test section shall be constructed to test the effectiveness of backfill placement and compaction procedures against design requirements before permanent backfill placement is begun.	None	

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 14 of 16).

Technical criteria	Issues	Work element
(d) Test sections shall be established to test the effectiveness of borehole and shaft seals before full-scale operation proceeds to seal boreholes and shafts. For clarification see: 10 CFR 60.130(b)(9)		
<u>Standardized Testing</u> (33(4), 3.4) Standardized, reproducible testing that is based upon sound statistical principles shall be developed to support predictions of waste package and waste form performance under conditions postulated for the operational and long-term containment and isolation phases. (a) <u>Conditions</u> The tests shall simulate expected or design basis conditions and conditions resulting from interactions with other disposal system components within practical limits. (b) <u>Extrapolations</u> Where extrapolation of test data is required, test results shall be applied conservatively to the verification of the waste package and waste form performance models used in judging waste package acceptability.	None	W.3.4 Develop an acceptance test procedure for waste packages. W.3.5 Determine the thermodynamic and kinetic arguments that can be used to extrapolate short-term (less than 2 years per experiment) materials test (hydrothermal) data.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 15 of 16).

Technical criteria	Issues	Work element
(c) Nondestructive Testing Nondestructive testing shall be provided for a statistically significant number of waste canisters prior to emplacement. For clarification see: NWTS 33(4), 3.4		
Waste Package Monitoring Program (60.143) (a) A program shall be established at the repository for monitoring the condition of the waste packages. Packages chosen for the program shall be representative of those to be emplaced in the repository. (b) Consistent with safe operation of the repository, the environment of the waste packages selected for the waste package monitoring program shall be representative of the emplaced wastes. (c) The waste package monitoring program shall include laboratory experiments which focus on the internal condition of the waste packages. To the extent practical, the environment experienced by the emplaced waste packages within the repository during the waste package monitoring program shall be duplicated in the laboratory experiments.	None	W.3.6 Determine requirements for monitoring. Define parameters, methodology, interpretive criteria, and actions.

TABLE A-1. Criteria, Issues, and Work Elements for Waste Package and Site Geochemistry (Sheet 16 of 16).

Technical criteria	Issues	Work element
(d) The waste package monitoring program shall continue as long as practical up to the time of permanent closure. For clarification see: HWTS 33(1), 2.3 HWTS 33(4), 3.4		

The existence of issues does not eliminate from consideration the location or design for a NWRB. Rather, the existence of an issue allows the results of planned work to be focused onto areas of controversy or uncertainty. A logic diagram for the development of issues and work elements and the respective information needs as utilized in this Appendix are shown in Figure A-1. The organization of criteria and work elements that drive waste package development are shown in Figure A-2.

WASTE PACKAGE ACTIVITIES LOGIC

The design activity is the key work element that will determine the requirements data- and information-gathering activities for the waste package and site geochemistry and performance confirmation tasks. A wide range of material-testing activities has been identified (Barnier Materials Test Program) to define the near-field repository environment, far-field repository and environment, waste-form stability, waste/barrier/rock interactions, and to provide waste package design verification. The successful completion of design activities require significant amounts of radiologic testing. The materials data will provide the basis for the preparation of site-specific waste package design specifications to support the National Waste Terminal Storage (NWTS) Program waste package design effort and the BWIP repository design efforts.

SUMMARY ACTIVITY NARRATIVES

A summary flow-chart of the overall Hydrothermal testing program is presented in Figure A-3. The following is a description of the current status of the elements of this program.

1. <u>Prepare Input to Basalt Waste Isolation Project Plan</u>

   The inputs to the BWIP Plan summarize the work that will be performed by the Waste Package and Site Activities. This work will ultimately produce detailed waste-package system specifications to ensure that the NWTS Program waste package designs meet NWRB requirements.

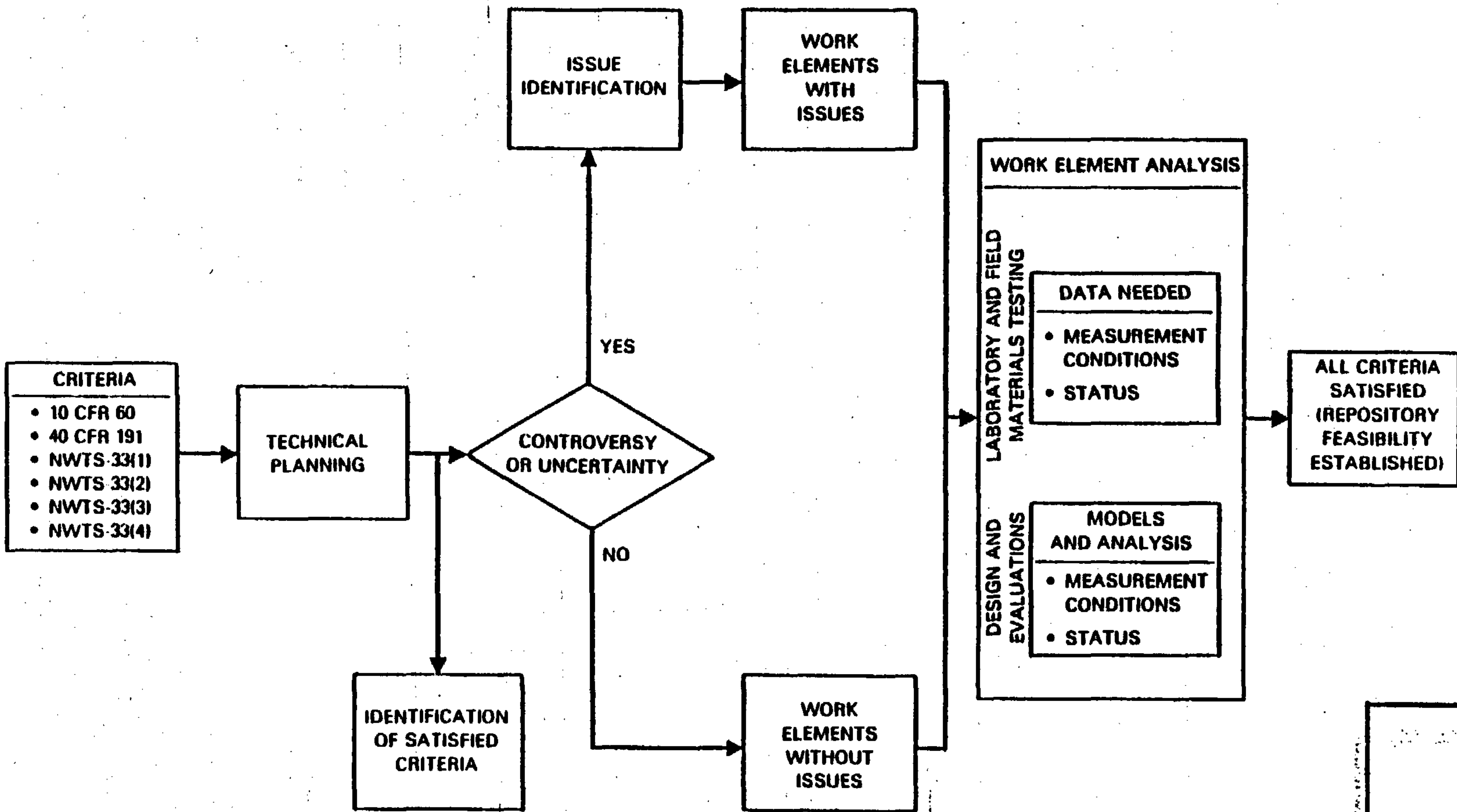

FIGURE A-1. Logic for Definition of BWIP Issues/Work Elements/Data Needs.

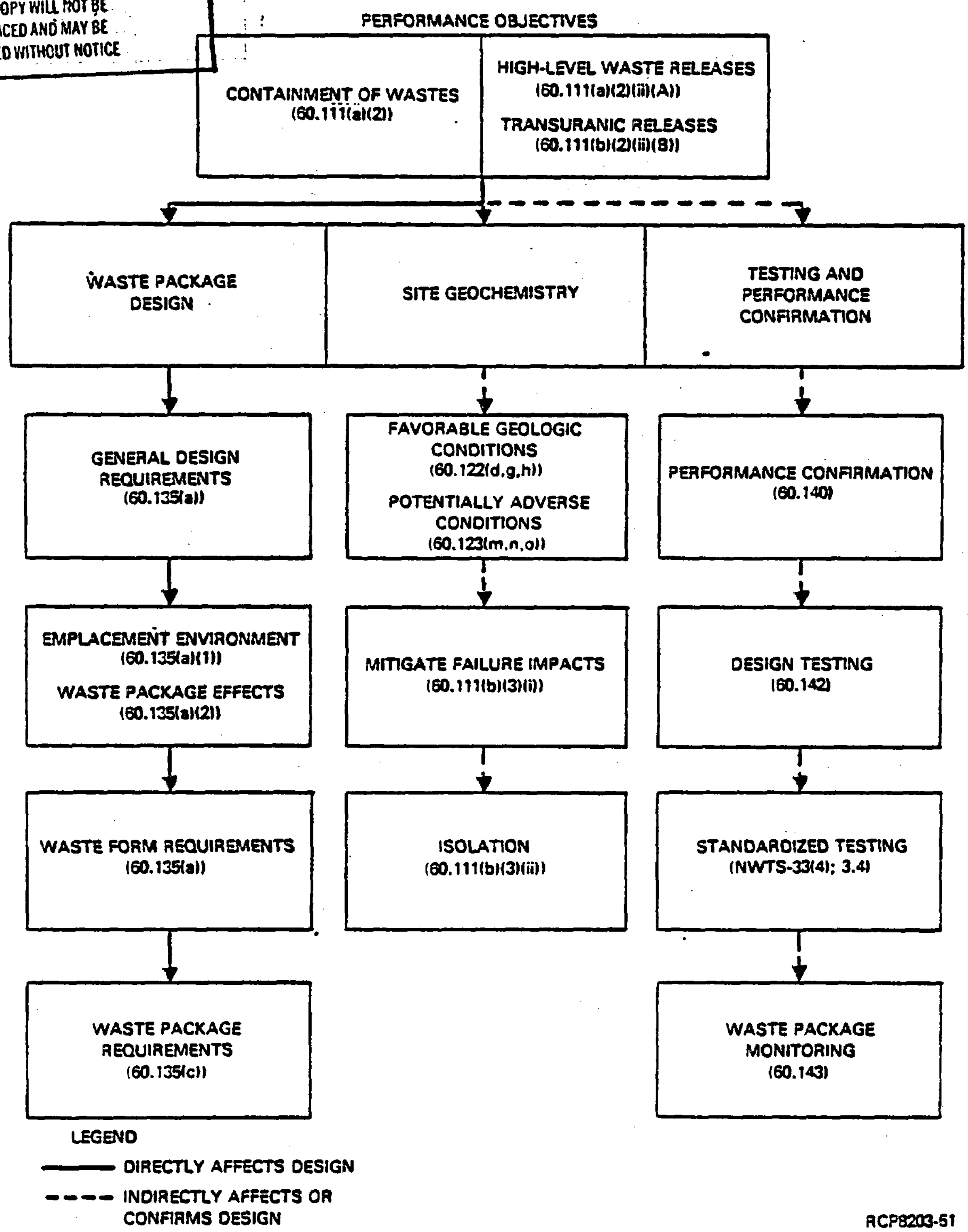

FIGURE A-2. Key Criteria Governing the Issues and Work Elements for Chapter 15.

Applicable Work Elements

The BWIP updates technical plans annually. The work elements form the basis of the work required to meet regulatory criteria.

2. Define Physical and Chemical Properties of Candidate Waste Forms

The work on the Waste Package Activity will be initiated by defining the physical and chemical properties of candidate waste forms. This is necessary because they will determine the design complexity of the waste packages required to prevent release of unacceptable amounts of radionuclides to the accessible environment. This design approach is the result of variations in the stability of the candidate waste forms being evaluated currently by the NWTS Program.

Applicable Work Summary

Work completed (Smith et al., 1980, Section 6).

3. Establish Waste Package Preliminary-Performance Requirements for Conceptual Design

Preliminary performance requirements will be established for waste packages to be emplaced in a repository constructed in basalt. The preliminary performance requirements will be based on an assessment of the maximum permissible release rates of radionuclides from the near field of the repository. The release rate assessment will, in turn, be based on a 1-dimensional transport model, which assumes equilibrium sorption/desorption behavior of all radionuclides. The transport model will calculate the maximum rate of release for each radionuclide that would keep concentrations in groundwater, discharging to the accessible environment, below acceptable levels as defined by federal regulations.

Applicable Work Elements

Work completed, see Anderson (1982).

4. Develop Waste Package Concepts, Functions, and Conceptual Design Specifications

The preliminary waste package performance requirements will provide the basis for the development of waste package concepts and functions for spent fuel, transuranic wastes, and high-level wastes. These will permit required canister/overpack and backfill/buffer materials characteristics to be defined from which data requirements for materials hydrothermal testing can be identified. Development of waste package concepts and functions will also support the preparation of waste package conceptual design specifications for the NWTS Program waste package design effort.

Applicable Work Elements

Work completed, see Anderson (1982).

5. Modify and Use National Waste Terminal Storage Program Waste Package-Degradation and -Release Model for Basalt

The NWTS Program waste package-degradation and -release model will be modified by the BWIP to meet the waste package-modeling requirements for basalt. The model will incorporate waste-form leaching and reactivity, dehydration/rehydration of the waste package backfill and adjacent host rock, metallic corrosion, and mechanical loading of the canister and possible backfill-degradation mechanisms.

Applicable Work Elements

W.1.2.A, W.1.9.A, W.1.11.A, W.2.8.A, W.1.13.B, and W.1.16.B.

6. Candidate Waste Package Materials, Test Methods, and Parameters Selected

Candidate waste-package materials will be selected for testing, based on the materials characteristics required for compatibility with the waste package/basalt environment, while maintaining maximum compatibility with the remainder of the NWTS Program transportation, waste-handling, and repository system. Test methods and parameters will be selected for materials evaluation activities.

Development of techniques for controlling Eh and pH in the range of values expected at elevated temperatures in the repository will allow the precise determination of waste package-materials performance by laboratory (cold) and hot-cell testing.

Applicable Work Elements

Work completed, see Sections 11.2.2.1 and 11.3.2.3.

7. Conduct Laboratory-Screening Tests of Candidate Waste Package Materials

Early laboratory testing will determine the hydrothermal reactions between basalt, simulated waste, and groundwater, and, with the results of laboratory-screening tests of candidate canister/overpack and backfill/buffer materials, will be used to develop site-specific waste package preliminary design specifications for the generic NWTS Program waste package design effort. The basalt/groundwater hydrothermal reaction experiments will be used to determine the effectiveness of Eh control by the repository host rock.

Applicable Work Elements

W.1.5.A, W.1.9.A, and W.2.2.A.

8. Prepare Waste Package Preliminary Design Specifications

Preliminary design specifications for waste packages to be emplaced in a repository in basalt will be prepared, based on the current understanding of the waste-form performance, repository environment, and waste package-materials interactions. These specifications will support the NWTS Program-design effort for waste packages to be emplaced in a repository at Hanford.

Applicable Work Elements

Document will be prepared.

9. Prepare Input to Basalt Waste Isolation Project Site Characterization Report

The Waste Package and Site chapters of the Site Characterization Report (BWP, 1982) will be prepared to reflect the current status of waste package-technology development as it affects the reference repository site at Hanford.

Applicable Work Elements

Work completed.

10. Characterize Repository Environment

Geochemical characterization activities include the definition of host rock properties, such as the composition and petrology of primary and secondary minerals, as well as groundwater compositions in the repository near and far fields. This information will becoupled with laboratory and field hydrothermal tests and radionuclide-migration results to provide input to the assessment of radionuclide retardation.

Applicable Work Elements

W.1.1.A, W.1.2.A, W.1.4.A, W.1.7.A, W.1.10.A, W.2.1.A, W.2.4.A, W.2.5.A, W.2.6.A, W.1.18.B, W.2.9.B, W.2.10.C, W.2.11.C, W.2.13.D, W.3.5.A., and W.3.10.B.

11. Determine Sorptive Capacity of Backfill and Host Rock

Sorption experiments will be conducted to determine the sorption/desorption and kinetic behavior of key radionuclides in the host rock (geohydrologic system). Evaluation of these data, plus data being developed on the solubility of key radionuclides (see Section 12), will define the performance requirements for the waste package backfill. Static and dynamic (flow-through) experiments will be used to determine the sorption behavior of key radionuclides in the repository geohydrologic system and candidate backfill materials

to support waste package design. Equations developed from these data will also be used to evaluate radionuclide retardation factors for use in transport modeling.

Applicable Work Elements

W.1.3.A, W.1.4.A, W.1.8.A, W.1.9.A, W.1.10.A, W.1.12.A, W.2.1.A, W.2.3.A, W.2.4.A, W.2.5.A, W.2.6.A, W.2.7.A, W.2.8.A, W.2.9.B, W.3.5.A, W.1.16.B, W.1.17.B, W.1.19.B, W.2.9.B, W.2.11.C, W.2.12.D, W.2.13.D, W.3.2, and W.3.5.

12. Modify and Use National Waste Terminal Storage Program Geochemical Model

An initial assessment of radionuclide behavior in the repository near-field environment will be made, based on a 1-dimensional transport model that assumes equilibrium sorption/desorption behavior on the basaltic host rock. Data on the solubility and kinetic behavior of radionuclides in basalt will provide site-specific information to modify the geochemical model being developed by the NWTS Program. Additional data for a geochemical assessment of waste/barrier/rock interactions, to support an update of the model, will come from studies of natural analogues of potential waste package components. Thus, it is anticipated that information on materials interactions can be obtained from studies of metallic copper and iron deposits in basalt and on secondary clay and zeolite mineralization of basalt.

Applicable Work Elements

W.1.9.A, W.1.13.B, W.2.8.A, W.1.16.B, W.1.20.B, W.1.24, W.2.11.C, W.2.12.D, W.2.13.D, W.3.3, and W.3.5.

13. Prepare Hot Cell

Hot-cell facilities will be identified and prepared for waste package-materials testing in the presence of actual waste forms. These tests are needed, although limited in number, to (1) simulate conditions in the repository more closely; (2) test the reliability of experiments using simulated waste forms, by comparison with the results of experiments with actual waste forms; (3) study the key

radionuclides in actual waste (technetium, plutonium, americium, neptunium) that cannot be represented by stable isotopes and, thus, are not contained in simulated waste; and (4) determine the effects of a radiation field on materials performance.

Applicable Work Elements

Work completed, report being prepared.

14. Quantify Waste Package-Component Materials Interactions Using Simulated Waste

The bulk of materials-interaction studies will be conducted using simulated waste forms. In this way, the majority of the materials evaluation data will be developed at a significant cost savings. This advanced hydrothermal testing will be conducted to quantify the performance of candidate waste package materials under conditions expected in a repository in basalt. Static and flow-through tests will measure the interactions between the waste package components over a range of conditions (temperature, pH, and Eh) expected in the repository. These tests will also help define the role of Eh in changing the solubility of key radionuclides.

Applicable Work Elements

W.1.1.A, W.1.2.A, W.1.3.A, W.1.4.A, W.1.6.A, W.1.7.A, W.1.8.A, W.1.9.A, W.1.10.A, W.1.11.A, W.1.12.A, W.1.13.A, W.1.14.B, W.1.15.B, W.1.16.B, W.1.17.B, W.1.18.B, W.1.19.B, W.1.20.B, W.1.24, W.2.1.A, W.2.3.A, W.2.5.A, W.2.6.A, W.2.7.A, W.2.8.A, W.2.9.B, W.3.2, W.3.3, and W.3.5.

15. Quantify Waste Package-Component Materials Interactions Using Actual Waste

Upon completion of hot-cell preparation, hydrothermal testing will be initiated on waste package component materials to quantify their interaction in the presence of actual waste forms. The purpose of these tests will be to determine quantitatively: (1) variations in groundwater pH, Eh, and composition as a function of temperature and the solid phases present; (2) location of key radionuclides that may

have precipitated from solution; and (3) degree of dissolution of the initial solid phases. With the ability to control Eh and pH within the autoclaves, the full range of anticipated repository conditions can be simulated.

Applicable Work Elements

W.1.1.A, W.1.2.A, W.1.3.A, W.1.4.A, W.1.6.A, W.1.7.A, W.1.8.A, W.1.9.A, W.1.10.A, W.1.11.A, W.1.12.A, W.1.13.B, W.1.14.B, W.1.16.B, W.1.17.B, W.1.18.B, W.1.19.B, W.1.20.B, W.1.24, W.2.3.A, W.2.5.A, W.2.6.A, W.2.7.A, W.2.8.A, W.2.9.B, W.3.2, W.3.3, and W.3.5.

16. Prepare Repository Waste Package Preliminary Design Upgrade Specifications

Results of the waste package component materials interaction studies will permit definite comparisons between the behavior of various candidate package materials. The comparison will refine design limits (their proportions, dimensions, and composition) to support the preparation of site-specific repository waste package preliminary design upgrade and specifications to support the NWTS Program waste package design efforts.

Applicable Work Elements

A specifications document will be prepared in support of waste package preliminary design upgrade.

17. Quantify Waste Package Assemblage Interactions Using Simulated Waste

For this stage of hydrothermal testing, partial waste package assemblages will be exposed to expected repository conditions in the presence of simulated waste forms. During this stage, it is the responsibility of the hydrothermal testing program to ascertain the ability of the NWTS Program performance model, as modified by the BWIP, to predict correctly the effectiveness of the waste package in retarding radionuclide transport. Therefore, experimental results that do not corroborate the model will lead to upgrading the model which could, in turn, lead to minor changes in the barrier thicknesses. Both static and flow-through experiments will be used to test the waste package designs.

Applicable Work Elements

W.1.2.A, W.1.4.A, W.1.6.A, W.1.7.A, W.1.10.A, W.1.11.A, W.1.12.A, W.1.15.B, W.1.16.B, W.1.19.B, W.1.20.B, W.2.1.A, W.2.3.A, W.2.5.A, W.2.6.A, and W.2.5.B. W.2.9.B.

18. Quantify Waste Package Assemblage Interactions Using Actual Waste

Engineering-scale waste package assemblages, using actual waste, will be exposed to conditions simulating those expected in the repository. This will identify waste/barrier/rock/groundwater interactions that are likely to occur over time. The data will provide support for preparation of the repository waste package final design specifications and repository Environmental Report/License Application, and will include: (1) finalization of proportions, dimensions, and compositions of the various waste package components, with a quantifiable assessment of the factor of safety needed for the final waste package design; (2) evaluation of the waste package system's ability to meet containment criteria (containment of all radionuclides), especially for the case of early failure of the canister/overpack components; (3) evaluation of waste package performance in meeting the post-containment controlled-release criteria; (4) confirmation of performance of complete waste package by means of scaled flow-through testing, simulating anticipated repository conditions; and (5) documentation of waste package performance to aid in licensing of a NWRB.

Applicable Work Elements

W.1.2.A, W.1.4.A, W.1.6.A, W.1.7.A, W.1.10.A, W.1.11.A, W.1.12.A, W.1.16.B, W.1.19.B, W.1.20.B, W.2.3.A, W.2.5.A, W.2.6.A, and W.2.9.B.

19. Determine Effects of Waste Emplacement on Repository Environment

The process of verifying the effectiveness of a waste package requires an understanding of the effects of the emplacement of waste on the repository environment. This information also provides input to the waste package-design process, since not only does the emplaced

waste act on the repository environment, but conversely, the waste package must be designed to obviate potential negative effects of repository geochemistry and thermomechanical effects. This task collects geochemical data from thermal-modeling efforts (Activities 4, 8, and 21), radiation effects studies (Activities 15, 18, and 24), and waste/barrier/rock interaction studies (Activities 7, 14, 15, 17, and 18) (Fig. 15-4), as well as information from rock mechanics (see Chapters 4 and 14) and documents them into an integrated assessment of waste emplacement on the repository environment.

<u>Applicable Work Elements</u>

Document will be prepared on the effects of waste emplacement on the repository environment.

20. <u>Conduct Waste Package Engineering-Scale Field Testing</u>

Concurrent with the hot-cell testing, engineering-scale waste packages will be field tested to support the preparation of the waste package final design specifications and aid in verifying the designs for waste packages to be emplaced in basalt.

<u>Applicable Work Elements</u>

W.3.1 and W.3.4.

21. <u>Prepare Repository Waste Package Final Design Specifications</u>

The results of preliminary waste package performance evaluations, using the modified (for basalt) and verified (NWTS Program) performance model, together with data accumulated from hot-cell and field testing, will provide support for the preparation of the repository waste package final design specifications. These specifications will ensure that the designs being developed by the NWTS Program waste package design contractor meet the needs of a repository in basalt. By this time, a sufficient waste package data base will have been developed to support repository Title II design effort and the preparation of the Environmental Report/License Application for the construction of a repository at Hanford.

Applicable Work Elements

W.1.21, W.1.22, W.1.23, W.1.25, W.1.26, W.1.27, W.1.28, and W.3.4.

22. Prepare Waste Package Input to Basalt Waste Isolation Project Environmental Report/License Application

Data and information from materials interaction studies and modeling activities will provide support for the preparation of the Environmental Report/License Application for repository construction.

The waste package final design specifications will form the bulk of the support information.

Applicable Work Elements

Input to project document will be prepared.

23. Prepare Waste Package Input to Repository Title II Design

Repository Title II design will be conducted to reflect the NWTS Program- and BWIP-approved final designs for waste packages to be emplaced in a repository constructed at Hanford.

Applicable Work Elements

Waste package final design specifications will be prepared.

24. Conduct Preliminary Engineering-Scale Tests (Hot Cell)

Hot-cell tests, using engineering-scale waste packages, will be scoped to measure and verify those hydrothermal interactions between the waste package components and the environment identified in earlier laboratory and hot-cell testing.

Applicable Work Element

W.1.9.A, W.1.12.A, W.1.19.B, and W.2.3.A.

25. Conduct Preliminary Design Verification

Preliminary waste package-design-verification studies will be conducted in parallel with the hot-cell testing of engineering-scale waste packages. Test data from this activity, together with that from earlier laboratory and hot-cell testing and from field and in situ testing, will be reconciled with model predictions. This will lead to a preliminary verification of the NWTS Program waste package performance model for basalt.

Applicable Work Element

Document will be prepared.

26. Complete Waste Package-Design Verification

The final results of the in situ testing will be reconciled with performance-model predictions and will be documented for final verification of the performance model. At the completion of performance model verification, a benchmarking procedure will be initiated to provide management of codes and models for the licensing activities. The verified waste package will be used to predict the long-term performance of waste packages to complete waste package-design verification. Completion of the waste package-design verification will be documented to support the preparation of the Updated License Application (Final Safety Analysis Report/Environmental Report) for the repository constructed at Hanford.

Applicable Work Elements

Appropriate documentation will be prepared.

27. Predict Waste Package Long-Term Performance

To complete design verification, the waste package performance model will be used to predict the long-term performance of waste packages emplaced in a repository in basalt. The waste package performance model will consist of two major submodels: (1) a geochemical model that describes the behavior of radionuclides within the waste package and near field; and (2) a degradation model that describes the physical, thermal, and chemical processes involved in the degradation of the waste package.

Applicable Work Elements

Documentation will be prepared that contains a description of and appropriate analyses to support the use of a waste package-performance model for the licensing process.

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APPENDIX B

SCIENTIFIC RATIONALE FOR BARRIER MATERIAL TESTING

INTRODUCTION

The principal goal of the Basalt Waste Isolation Project (BWIP) is to evaluate the feasibility of permanent storage of nuclear waste in a geologic repository mined in basalt. This evaluation must be based on proposed regulatory criteria (NRC, 1981; EPA, 1982) that determine the required long-term performance of a nuclear waste repository in basalt (NWRB). These performance criteria can be used to evaluate the performance required of the engineered repository system. The geologic barriers of the repository site plus the manmade, engineered barriers of the waste package comprise the total barrier to release of materials to the biosphere. Where the natural barriers of the repository itself cannot meet or exceed the regulatory criteria, the performance of engineered barriers must supplement the performance of the geologic barriers to insure regulatory compliance and to insure isolation of waste materials.

DISCUSSION

The BWIP and the National Waste Terminal Storage (NWTS) Program have adopted an approach to performance assessment of barrier materials that relies on site-specific, hydrothermal testing of waste package components, both individually and as an integrated assembly (NWTS, 1981). It is neither economically nor experimentally feasible to conduct such hydrothermal tests for durations approaching containment times (1,000 to 10,000 yr) demanded in currently proposed regulatory criteria. It is, therefore, imperative that expert scientific judgment guide the design and interpretation of such a testing program. Laboratory tests, coupled with expert professional opinion, are key to the meaningful extrapolation of short-term laboratory data to the much longer time periods expected during the functional life of a NWRB.

This extrapolation of results from barrier material testing is closely allied to the common dilemma encountered by geoscientists who attempt to extrapolate similar laboratory data (tests of less than 2-yr duration) to natural geochemical and mineralogic processes that occur over hundreds to millions of years. Geochemists and experimental petrologists have accordingly developed several theories, based on chemical thermodynamic and kinetic reaction principles, to address this extrapolation problem. These theories have been validated by observation of repeated agreements between theoretical predictions and observed natural examples in a variety of geochemical systems. These interpretive theories, already in common use by the geochemical community, should serve as the basis for expert judgment regarding extrapolation of waste/barrier/basalt test results to time scales appropriate to regulatory isolation criteria.

The long-term stability and performance of candidate barrier materials is chiefly, though not exclusively, determined by their chemical interaction with the groundwaters that will eventually fill the repository. The dominant process for hydrothermal interactions in the waste/barrier/ basalt system is gradual dissolution of coexisting primary solid phases. Dissolution will be accompanied by precipitation and growth of an assemblage of secondary, alteration phases that are more stable under the given repository conditions. These dissolution and precipitation processes represent an overall irreversible reaction (Helgeson, 1968; Giggenbach, 1981) that may be summarized by the expression:

$$\text{Solution}_{\text{initial}} + \text{Primary (unstable) Phases} \longrightarrow$$
$$\text{Solution}_{\text{final}} + \text{Secondary (stable) Phases}$$

The Ostwald step rule is a useful, albeit empirical, observation from natural and experimental studies of hydrothermally altered rocks (Fyfe and Verhoogen, 1958). It states that the transition from an unstable to a stable phase(s) generally occurs through the formation of a series of intermediate metastable phases, and that the thermodynamic

instability of these intermediate phases will decrease as the reaction progresses. The thermodynamic parameter measuring the relative stability of a phase in a hydrothermal system is its free energy, that is, the total driving force for reaction between solids and solution. This free energy is also a direct measure of solubility of a solid phase (Garrels and Christ, 1965; Giggenbach, 1981). The relative hydrothermal stability of phases, therefore, can be determined directly from relative solubilities (i.e., the most soluble phase will be the least stable). At any point during a step-wise alteration-reaction process, the composition of the solution will be governed by the relative solubilities of coexisting phases.

In the limiting case, in which only the most stable solid phases are present, solubility data can be measured directly (Wood and Rai, 1981; Rai et al., 1981) from solution composition or evaluated from thermodynamic data, when available (Pourbaix, 1966; Garrels and Christ, 1965). It is important to stress that such solubility data is defined to be independent of time and reaction pathway because of the assumed equilibrium nature of the system. Because all chemical systems evolve toward equilibrium (i.e., an assemblage of stable phases), and because of the very low flow rates of groundwater expected in a nuclear waste repositories (NWTS, 1981; MCC, 1981; Arnett et al., 1981), the use of solubility limits models to predict long-term release rates of radionuclides from a waste/package/repository system is justifiable.

The application of thermodynamic solubility constraints can be extended to a more general model for hydrothermal reactions between solution and metastable solids. In this case, there is assumed to be one (or more) metastable solid phases coexisting in solution with compositionally related phases that are thermodynamically more stable. Note, these more stable phases are not necessarily the most stable of all compositionally related phases. Initially, the less stable and more soluble phase begins to dissolve (Point A and B, Figure B-1) toward its own, well-defined solubility limit. The solution concentration will first exceed the solubility limit of the more stable (and less soluble) compositionally-related phase. At this juncture, the more stable phase

will begin to grow as its solubility limit is exceeded. Thus, the dissolution rate of less stable phase and the concurrent growth rate of the more stable coexisting phase are opposing processes seeking to establish their own solubility control of solution composition (Holloway et al., 1981; Apted, 1981; Berner, 1978; Mottl and Holland, 1978).

For example, if the irreversible dissolution of an unstable phase such as glass is rapid relative to the growth of a more stable alteration phase, the solution composition will reflect mainly the solubility of the glass (for equal areas of glass and alteration phase). If the relative reaction rates were reversed so the alteration phase grows much faster than the primary phase dissolves, then the bulk solution composition will be determined primarily by the solubility of the alteration phase (Berner, 1980; Dibble and Tiller, 1981a). Intermediate, steady-state reactions (note, these are not equilibrium reactions) exist between these extremes (Figure B-1, Point C). These reactions represent a balancing of the rates at which chemical components are being dissolved from unstable primary phases and the rates at which the same components are removed from solution into more stable, secondary phases. Steady-state conditions will eventually change with time, as more stable phases nucleate and grow or unstable phases become totally consumed. This, in turn, will cause the solution to attain new steady-state compositions (see Figure B-1, Points D and E). The concentration of dissolved components represented by these evolving steady-state reactions must decrease with reaction progress (i.e., longer periods of time) because each new phase must be more stable, hence less soluble, than the previous phases. It can be expected, therefore, that if hydrothermal tests are conducted for durations sufficient to attain a steady-state reaction, this data will provide conservative radionuclide-release rates relative to equilibrium solubility expected to control the actual long-term release rates.

The length of time needed to attain steady-state (or solubility) conditions in static, hydrothermal tests at expected repository conditions could, in some cases, be greater than that feasible for laboratory testing. In these instances, these dissolution and growth rates

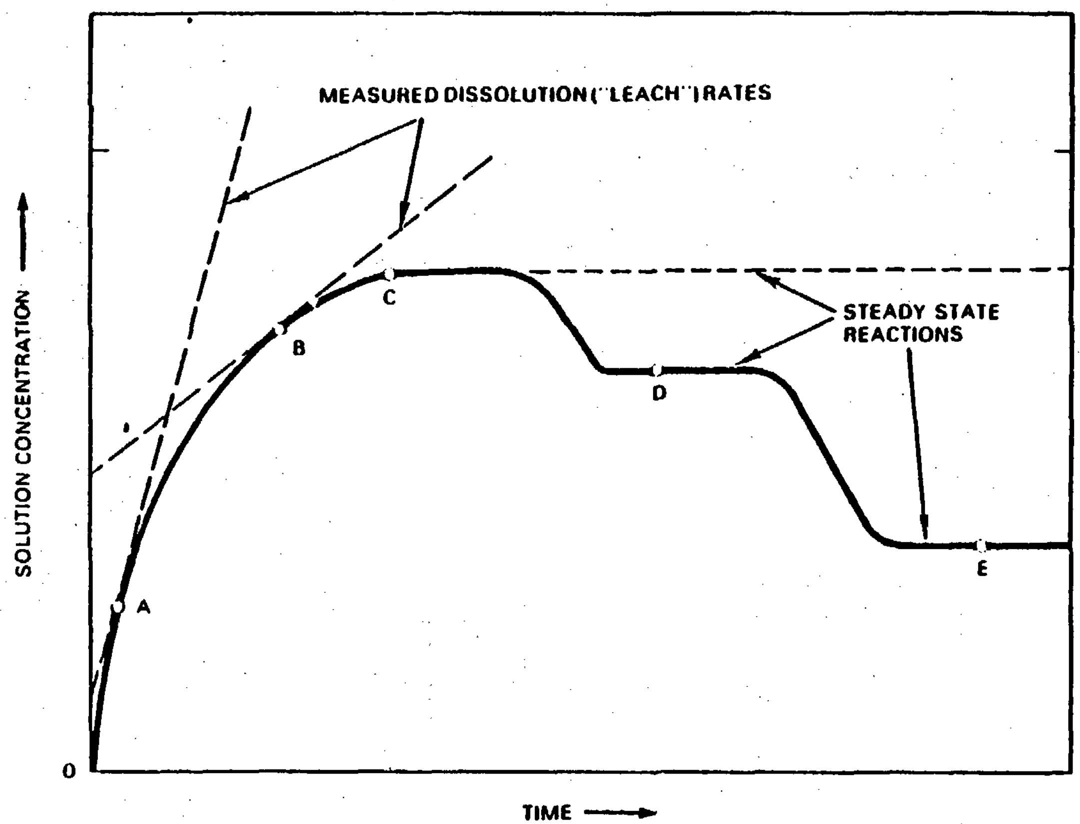

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FIGURE B-1. Solid Dissolution Behavior as a Function of Time (diagrammatic).

are functions of several variables (Dibble and Tiller, 1981b), including temperature, reaction activation energy, reactive surface area (or reactive surficial mass), solution concentrations, and the available free energy of the system, which is the difference in free energy (or solubility) between the unstable reacting phase(s) and the stable product phase(s). This kinetic model, based on the energetics and mechanisms controlling dissolution and growth processes, serves as the justification for a variety of experimental techniques that can be adopted to accelerate actually the test. By speeding up the rates of dissolution and growth, the results of short-duration laboratory tests can be made to approach a state of reaction identical to that achieved in nature over much longer time periods.

The Interface Working Group on Accelerated Testing (DOE, 1981), for example, has suggested that increasing the temperature of laboratory tests can dramatically increase the reaction rates of hydrothermal interaction tests on waste package components. This same technique is in common use in chemical engineering technology (e.g., Boudart, 1968) and in geochemical/petrological research (e.g., Mottl and Holland, 1978). The assumption that the same dissolution/growth mechanisms are operative at both high and low hydrothermal temperature is, however, often not justified. This is particularly true for hydrothermal studies of glass reactions, which apparently are dominated initially at low temperature (25°C) by ion-exchange (surface leaching) (White and Classen, 1980) and controlled at high temperature (200°C) by matrix dissolution (Karkhanis et al., 1980).

Standard experimental studies of alteration products and resultant water chemistry of basalt/water reactions utilize powdered samples of basalt (e.g., Seyfried and Bischoff, 1979, 1981; Mottl and Holland, 1978). The accepted rationale for this procedure is that by effectively increasing the reactive surface area (or surficial mass) of the basalt, relative to the mass of the coexisting solution, the time required for reaction and formation of new solid phases is greatly expedited. For powdered samples, the high surface-areas-to-mass ratio of the sample ensures that the entire mass added will be the effective reactive

ion exchange effects?

surficial mass. Uncertainty in estimating reactive surficial mass of monoliths, and uncontrollable changes in this parameter because of cracking, create problems of interpreting or extracting meaningful kinetic data from dissolution or solubility tests.

Finally, it has been shown recently that nonthermodynamic parameters such as porosity and permeability (i.e., flow rate) may affect the alteration mineral assemblage produced in hydrothermal systems (Dibble and Tiller, 1981; Potter and Dibble, 1981). High flow rates of solution through a rock system thoroughly mix interface and bulk solutions, permitting a relatively greater portion of the available free energy of the system to be used in surface detachment and attachment processes. This increases the rates of dissolution and growth, resulting in more rapid formations of most of the stable phases (Dibble and Tiller, 1981a). The great advantage of this technique is that use of variable flow rate to accelerate kinetic reaction rates will not involve any change in the operative reaction mechanism.

CONCLUSION

The current use of nonflow-through (static) tests in the rocker-type autoclaves for the bulk of the experimental program is justified by lower cost, simplicity of operation, greater experimental control, and the fact that the relatively slow rates of solution flow in natural rock (10^{-3} to 10^{-5} m/yr in the Umtanum basalt) are probably well approximated by the confined flow in a rocker-type autoclave. Flow-through hydrothermal autoclaves are, however, being developed and constructed by the BWIP. The freedom to vary flow rate and temperature (300°C) with minimal loss of scientific relevance between experiments will permit a thorough examination of alteration under hydrothermal conditions, minimizing the need for long experiments. Promoting rapid attainment of more stable phases using high flow rates, will make it possible to confirm the range in flow rates over which the steady-state results from static tests are applicable to the long-term performance of a waste package located in a NWRB.

(Doesn't really deal with the ...)

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APPENDIX C

HYDROTHERMAL EQUIPMENT AND PROCEDURES

TEST EQUIPMENT REQUIREMENTS

Hydrothermal experiments have been conducted from the viewpoint of a host of different scientific disciplines (e.g., chemical engineering, metallurgy, chemistry, and petrology). There is a commonality in approach and apparatus for hydrothermal experimentation. Major considerations are listed below.

- The material under study (e.g., borosilicate glass plus groundwater) must be isolated from any other reactive components. This generally means material must be encapsulated in noble- or inert-metal containers.
- There must be a method for controlling and monitoring environmental parameters, such as temperature and pressure, at desired experimental conditions.
- The ability to sample periodically solutions directly from an experiment at the prescribed experimental conditions is desirable. This capability enables the experimenter to document and interpret reaction kinetics of the hydrothermal system under study.

Direct sampling is difficult because the hydrothermal apparatus usually must be cooled and depressurized before samples can be taken. "Cold-seal" pressure vessels are an example of this type of apparatus (Boettcher and Kerrick, 1971). Cooling and depressurization of an experiment, or quenching, invariably leads to a certain degree of retrograde reaction and chemical readjustment between solution and coexisting solids. This reaction is highly undesirable, particularly for solution analysis, because the sampled solution at room conditions will not represent the solution composition at the desired experimental conditions. Therefore, experiments using cold-seal apparatuses (e.g., Barnes and Scheetz, 1979) have limited utility in the determination of the stability of waste package components.

The Waste Package Studies Department (WPSD) has adopted the use of sampling autoclaves for barrier materials testing (Holloway et al., 1981; Patera et al., 1981; Apted, 1981). These types of hydrothermal apparatuses use gold (Dickson-type), titanium, or Teflon (E.I. du Pont de Nemours Co.) inner reaction vessels. The entire cylindrical assembly of reaction vessel and outer pressurizing vessel (Figure C-1) can be agitated continuously either by a rolling motion parallel to the cylinder axis or by a rocking motion perpendicular to this axis. This agitation promotes more rapid reaction between the solids and solution as they mix. Dickson-type autoclaves have a special sampling valve (Dickson et al., 1963; Seyfried et al., 1979; also see Figure C-1) that enables the experimenter to take direct solution samples at the pressure and temperature of the experiment, while also permitting the examination of the solid alteration products at the conclusion of the experiments. These sampling autoclaves are ideal for obtaining data on barrier material stability and associated solution composition under expected repository conditions. Procedures for conducting hydrothermal tests in such apparatuses are available in existing literature (Dickson et al., 1963; Mottl and Holland, 1978; Seyfried and Bischoff, 1981) and have been documented by the WPSD (Holloway et al., 1981).

Flow rates of groundwater have been identified as a possibly important environmental parameter in the testing of barrier materials (NWTS, 1981; Coles, 1981). In particular, it has been demonstrated experimentally that by increasing flow rate, it may be possible to accelerate the kinetic rate of reactions in hydrothermal systems (Potter and Dibble, 1981; Potter, 1981). The Dickson-type autoclave, despite the acknowledged effect of agitation on reaction rates, still more closely represents the static flow conditions anticipated for a nuclear waste repository in basalt (NWRB). A flow-through pressure vessel, using a Teflon-lined or gold reaction tube surrounded by a hydrostatic pressurizing vessel, has been designed from an existing apparatus (Potter, 1981). An operational prototype will be constructed by the end of FY 1982, and will be available for use with radioactive waste in a hot-cell facility by the end of FY 1983. With this flow-through apparatus, Basalt Waste Isolation Project (BWIP) personnel will confirm

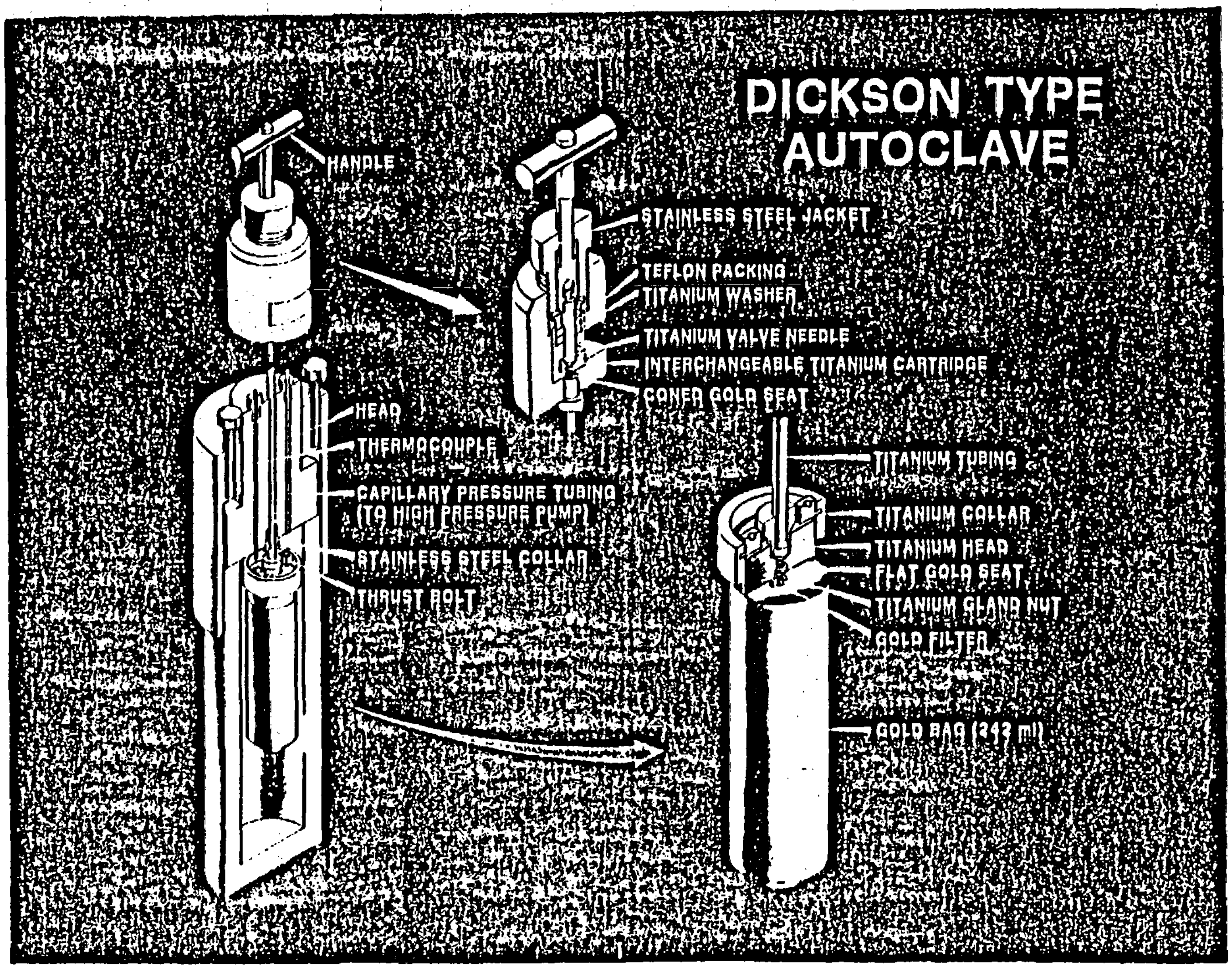

FIGURE C-1. Cross Sectional View of Dickson-Type Sampling Autoclave.

C-3

the range in flow rates over which the steady-state solution data from static tests in Dickson-type autoclaves are applicable to the long-term solution behavior anticipated for waste package-basalt interactions.

Temperature and pressure of hydrothermal apparatuses are controlled and monitored by a combination of electric furnaces, hydraulic pumps, and supporting thermocouple and pressure gauges (Dickson et al., 1963; Ulmer, 1971). For data validation, temperature and pressure readings should be periodically recorded and automatically logged on either a printed tape or magnetic tape filing system. Data logging can also be used to determine the variation of temperature and pressure in tests over time, especially during off-work hours.

Techniques for in situ monitoring of pH and Eh under high-temperature and high-pressure hydrothermal test conditions have been proposed and tested (MacDonald, 1978; Niedrach, 1980; Danielson, 1980). Currently, the BWIP is developing these solid-state probes and modifying their design to be compatible with Dickson-type autoclaves. Direct monitoring of these environmental parameters during testing improves the experimental design. The monitoring eliminates the difficulty of preserving the actual pH and Eh values of groundwater solutions once they are removed from reactive barrier materials and brought into the ambient atmospheric conditions of the laboratory.

A supplemental technique for monitoring groundwater Eh is to measure coexisting redox couples dissolved in the solution, such as bisulfide/sulfate or Fe(II)/Fe(III). Recent studies (Cherry et al., 1979) indicate that monitoring groundwater Eh by speciation analysis of naturally occurring arsenic is possible. Work currently underway in the Basalt Material Characterization Laboratory suggests that this technique can be extended to provide information about the prevailing Eh during hydrothermal tests. Trace amounts of arsenic (<50 μg/L) can be predoped into the solution phase. Arsenic (III) and As(V) undergo rapid redox reactions under hydrothermal conditions, so a measurement of their relative abundance in solution indicates the prevailing Eh. Other redox couples involving selenium, antimony, or tin are also being considered as possible redox indicators.

HYDROTHERMAL TEST EQUIPMENT AND PROCEDURES

TEST EQUIPMENT

Dickson Rocking Autoclave System

As mentioned previously, the Dickson rocking autoclave system (Figure C-2) is an established experimental apparatus for testing materials at elevated temperatures and pressures. A Dickson rocking autoclave system includes:

- Two furnaces
- Two autoclaves
- A high-pressure pump
- A furnace controller.

The system uses a small-volume reaction chamber (250-mL gold bag) that permits sampling while the experiment is at temperature and pressure. The small volume makes this system ideal for use with highly radioactive materials. The Dickson rocking autoclave system, by virtue of its design, supplies shielding and distance from radioactive materials.

The furnaces, auxiliary pressure gauges, plumbing system, rupture disc assembly, and furnace controller of a Dickson rocking autoclave system are shown in Figure C-2. The furnaces are free standing and separable from either the controller or the pump apparatus (Figure C-3). This arrangement facilitates barricade-type shielding required for operation with fully radioactive waste forms. The furnaces are low-temperature (<500°C) resistance types, which operate on 110 V. They are 24 in. long, 24 in. in diameter with 6 in. of insulation and an outer shell of 1/8-in.-thick steel. The ends are closed with 1/2-in.-thick transite. The furnaces are rocked 180° around midpoint trunions by a gear-driven electrical motor. The furnace controller has pressure and temperature alarms to prevent overpressurization. The rupture disc represents a third level of protection against overpressurization. For tests with radioactive materials, a liquid collection manifold will be plumbed to the rupture disc assembly. The manifold will collect any pressurizing or radioactive liquids produced during overpressurization.

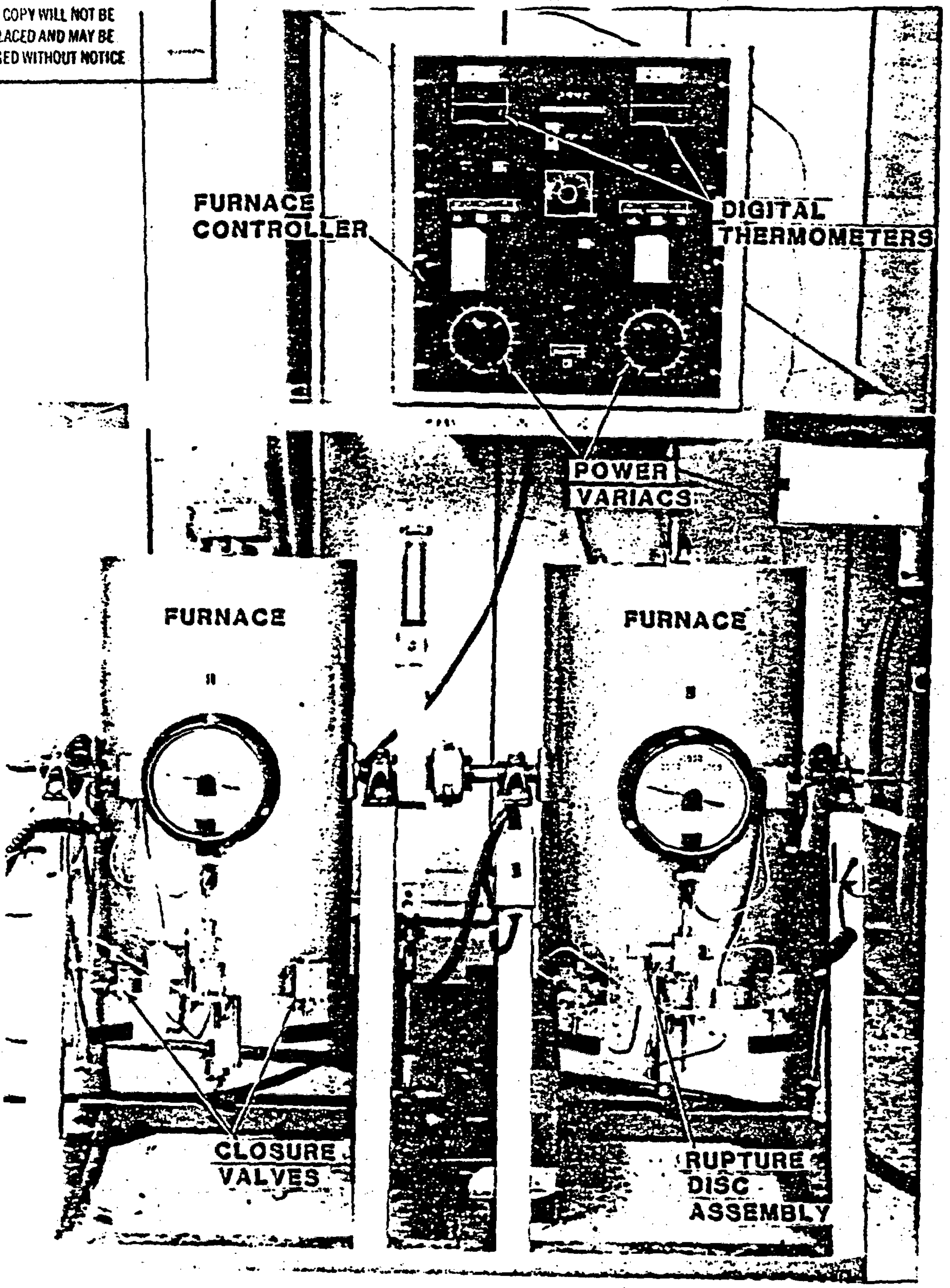

FIGURE C-2. Dickson Rocking Autoclave System.

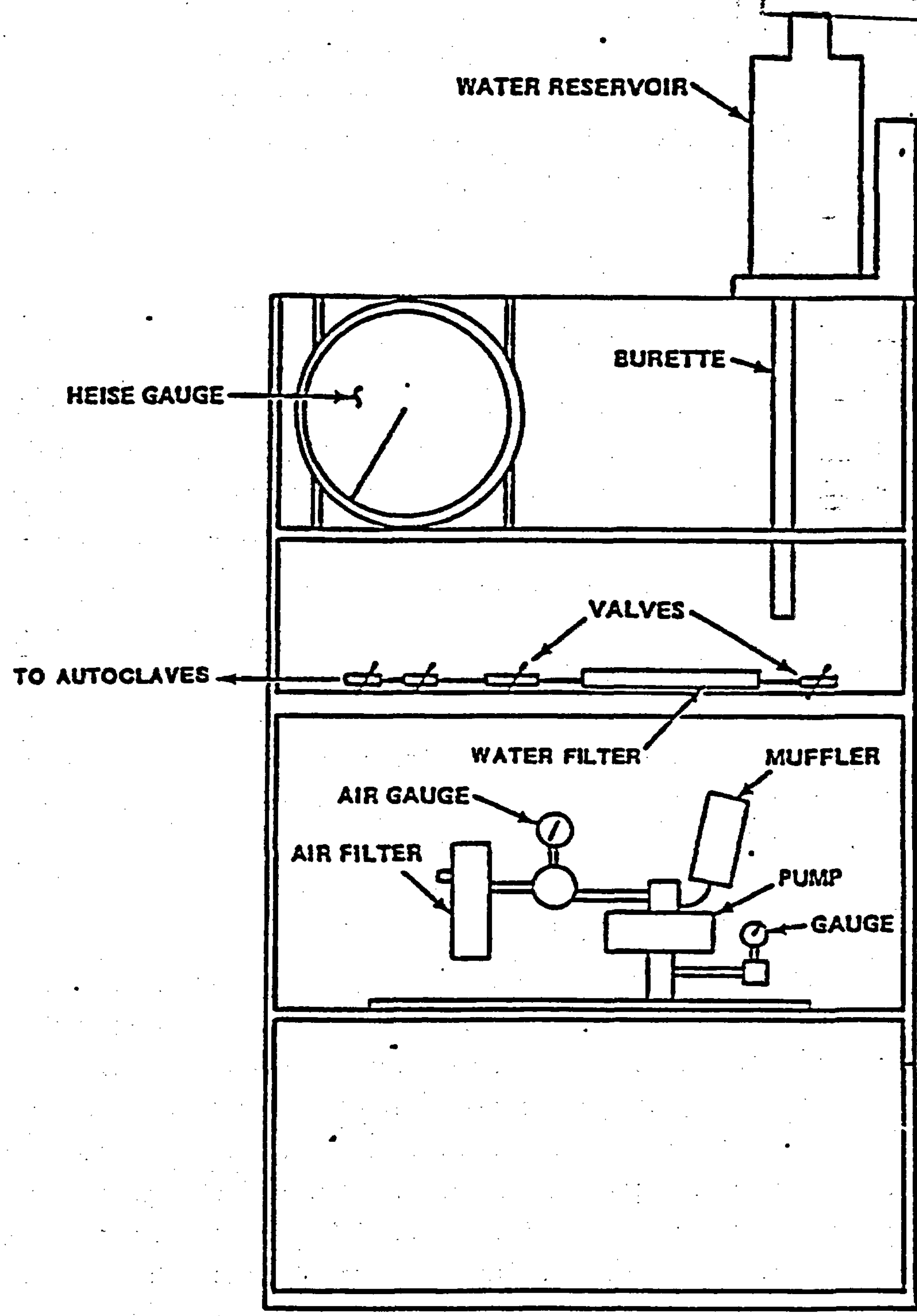

FIGURE C-3. Portable High-Pressure Pump Assembly for Dickson Autoclave Systems.

The stainless steel autoclaves (Figure C-4) are approximately 14 in. long by approximately 4.5 in. in diameter with a 0.55-L capacity. The autoclave lid has three openings that accommodate a sampling tube, a type K thermocouple, and plumbing associated with the primary closure valve. A delta or flat ring closure is used to seal the autoclaves. All autoclaves to be used in the hydrothermal tests are U-stamp certified corresponding to American Society of Mechanical Engineers (ASME) certification of construction standards. The autoclaves are subjected to hydrostatic pressure tests of 17,000 psi for 1 hr before acceptance for use with radioactive materials.

The high-pressure pump assembly (see Figure C-3) consists of a fluid reservoir, miscellaneous valves and plumbing, a certified Heise pressure gauge, and a high-pressure air-driven fluid pump. The entire assembly is portable and can be used to service several autoclave systems.

The furnace controller (see Figure C-2) is equipped with a dual system of digital thermometers and power variacs to control two autoclave systems effectively. A high-pressure audio alarm is triggered when a manually set pressure is exceeded. This alarm must be manually deactivated by releasing the excess pressure via the primary closure valve. The furnace controllers are designed to maintain a desired temperature to within ±5°C.

Dickson Rolling Autoclave System

The Dickson rolling autoclave system is a modified version of the Dickson rocking autoclave system, designed specifically by Rockwell Hanford Operations for use with actual high-level waste forms. Floor space is minimized by stacking three furnaces, which rotate a maximum of 210° in a horizontal position. The autoclaves can be transported safely to and from hot-cell facilities using a shielded dolly (Figure C-5) and loaded into the furnaces using a specially designed shielded loading fixture (Figure C-6). The shielding consists of about 4 in. of steel. This device permits autoclaves to be loaded into the furnaces reliably and shields personnel from radiation. The rolling autoclave system, shown in Figure C-7, uses the same high-pressure pump and furnace controller assemblies as the rocking autoclave system.

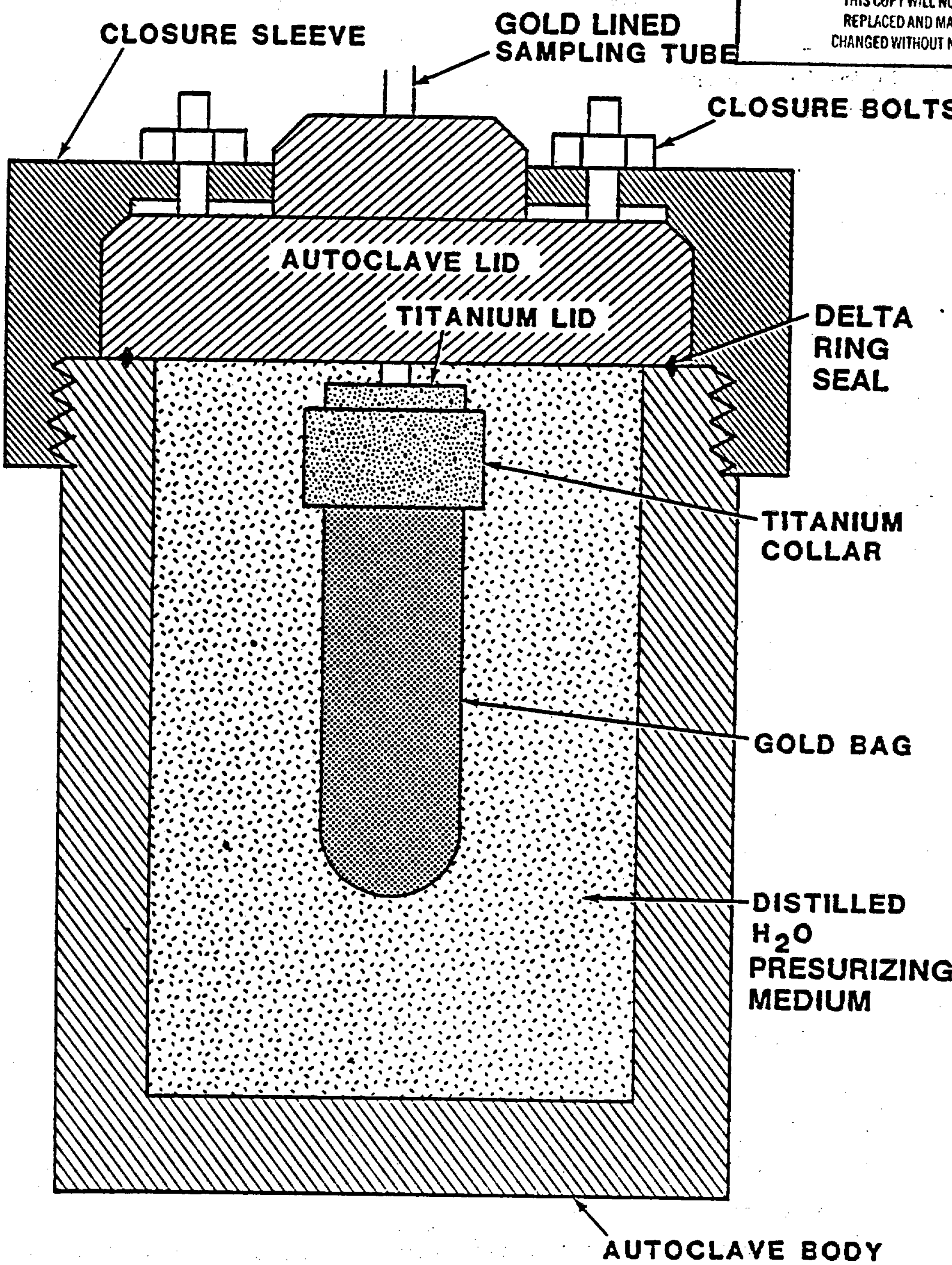

FIGURE C-4. Simplified Schematic of Autoclave and Gold Bag Assembly Used in a Dickson Autoclave System.

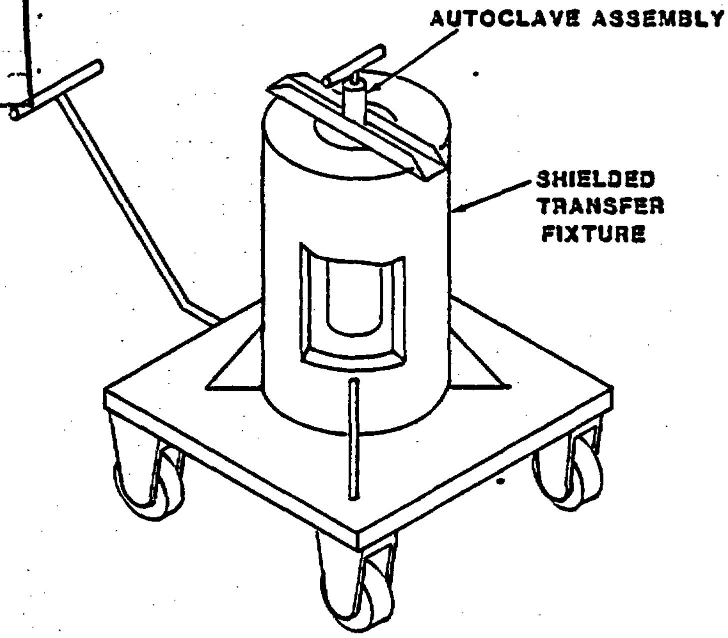

FIGURE C-5. Cutaway Illustration of Rockwell-Designed Shielded Autoclave Transport Dolly.

Flow-Through Autoclave System

The rolling and rocking autoclave systems provide only static tests of waste package components and thus do not simulate the movement of groundwater through a failed waste repository. A flow-through apparatus (Figure C-8), now in the design phase, will simulate a failed waste repository by placing waste-rock-water systems under repository conditions and allowing the fluid phase to flow through the systems at approximately 0.01 m/min.

TESTING PROCEDURES

Tracer Procedure

Initial hydrothermal experiments will use powdered tracer-doped waste forms. All tracer level tests will be performed in Laboratory 1D (see Figure 5-9) and will include the following operations (Figure C-9):

- Loading test materials
- Heating autoclave to desired temperature and pressure
- Hydrothermal solution sampling
- Quenching.

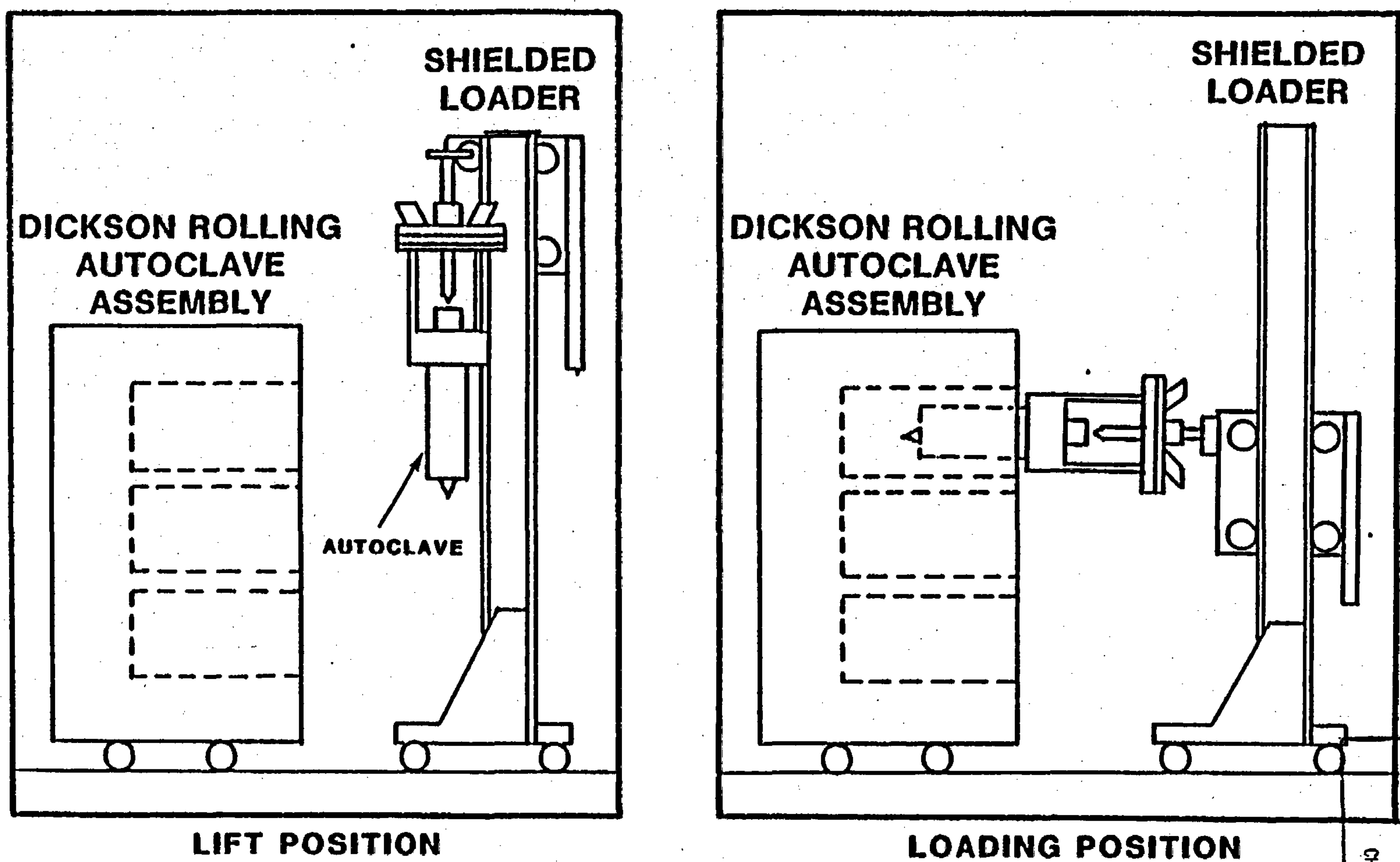

FIGURE C-6. Schematic Diagram of Shielded Loader, Showing Lifting and Loading of a Dickson Autoclave into the Rolling Assembly.

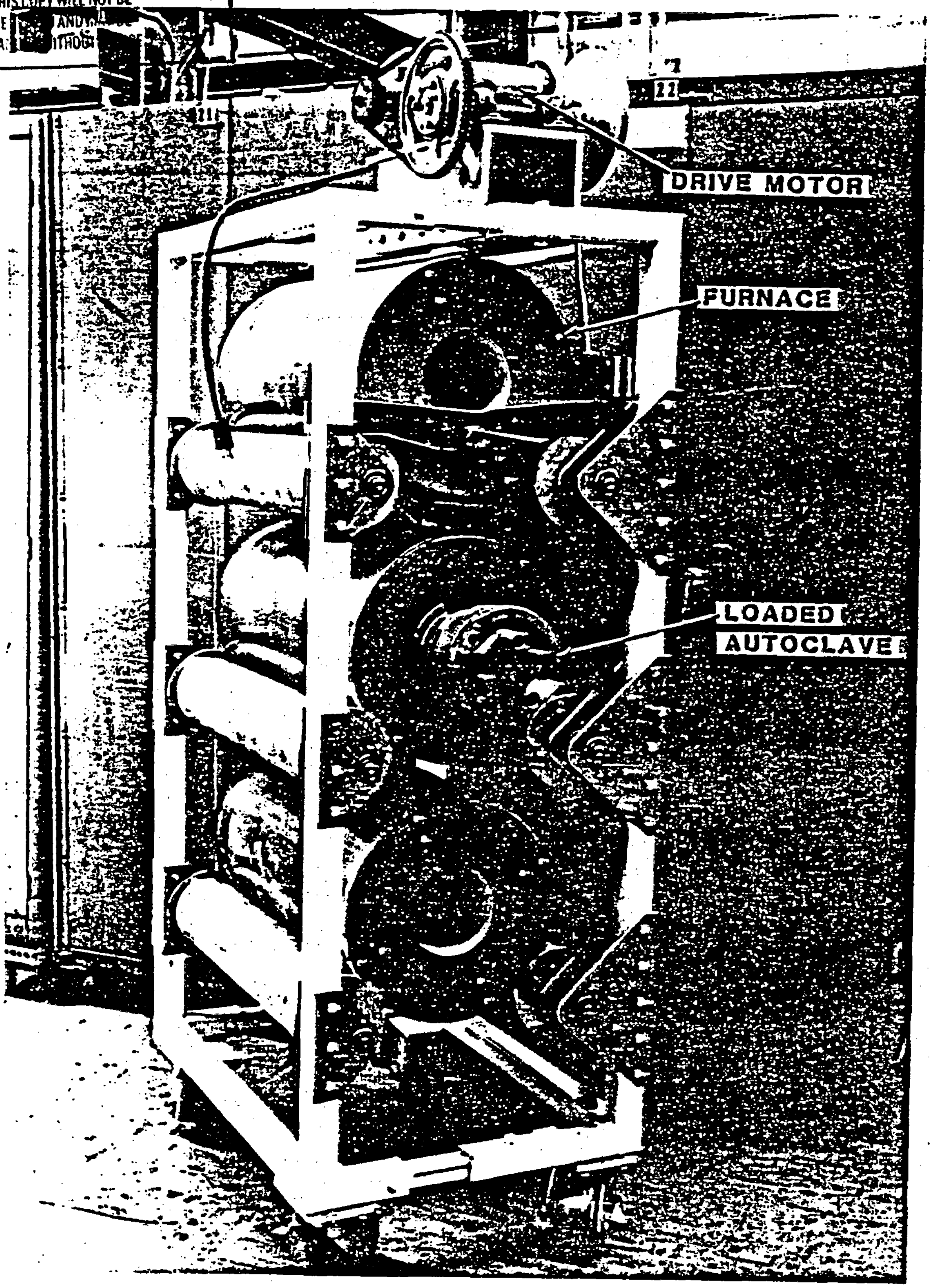

FIGURE C-7. Dickson Rolling Autoclave System.

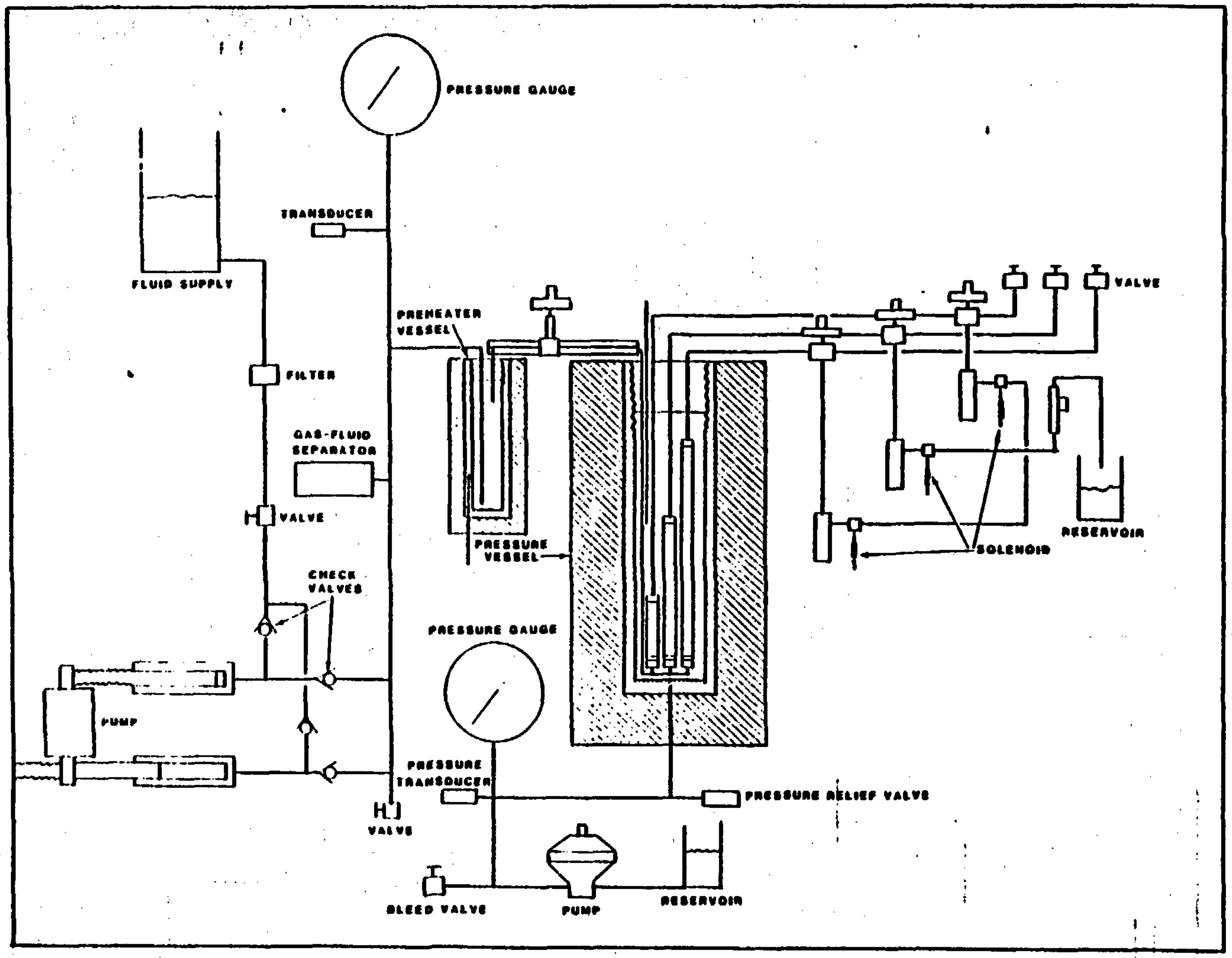

FIGURE C-8. Schematic of Dickson-Type Flow-Through Autoclave System.

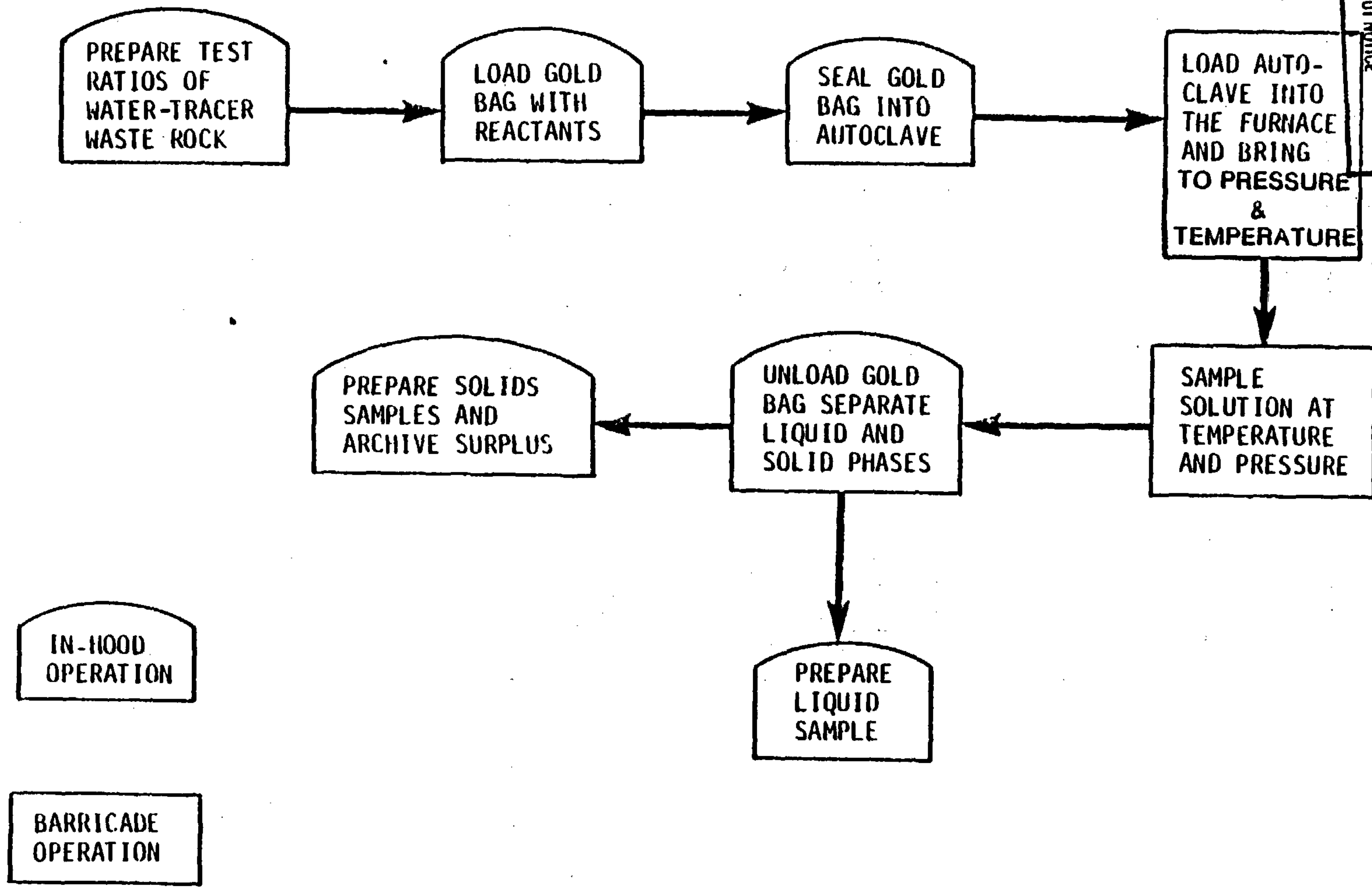

FIGURE C-9. Operational Flow Chart for Tracer-Level Hydrothermal Tests.

Loading. Preparation of the Dickson autoclave for tracer-level experiments will be performed in open-face hoods in Laboratory 10 of the 222-S Building. The gold bag and titanium lid assembly (see Figure C-4) is loaded with the solids and synthetic groundwater via the sampling tube opening. After loading, the sampling tube is attached to the titanium lid and to the autoclave lid. This assembly is then placed on the autoclave, which has been filled with water. The closure sleeve is screwed into place and the closure bolts torqued. The assembled autoclave is then placed in a preheated furnace, and the pressurizing lines and liquid collection manifold are attached.

Pressure within the autoclave increases with thermal expansion of the water. When the temperature is within 10°C of the desired run temperature, the power to the furnace is turned off to prevent overshoot. When the temperature stabilizes, the power is turned on again, the controllers are set, and the pressure is adjusted to the desired value.

Sampling. Fluids are sampled using respiratory protection and with the laboratory cleared of all unnecessary personnel. The furnace is stopped in the upright position, and a disposable sampling assembly is screwed onto the sampling valve. The sampling assembly consists of a two-way plastic valve, with two disposable syringes attached. The sampling valve is opened very slowly, and a 1-mL rinse sample is taken in one of the syringes. About 5 mL of solution is then taken into the second syringe over a period no shorter than 10 min. Following sampling, the syringes are removed and placed in the open-face hoods. The room temperature pH of the solution sample is measured, the temperature recorded, and samples are then prepared for radionuclide and other analyses. The sampling assembly is removed and placed in a proper receptacle for radioactive disposal.

Quenching. Upon completion of an experiment, the autoclave must be quenched by removing it from the furnace (under pressure) and placing it in an open-face hood. Cooling is accelerated by a fine spray of water or compressed air. The autoclave is disassembled in the open-face hood, and the solution and solid run products are separated by filtering. Finally, samples are taken for solution and solids characterization.

Procedure With Fully Loaded Waste Forms. The procedures for conducting experiments with actual radioactive waste forms require a hot-cell facility and, thus, are more involved than the tracer procedures. Present plans call for the majority of the full-level tests to be performed in Laboratory 1E (see Figure 5-7); however, if the test program is extended, Laboratory 1D also will be used. Testing of actual waste forms will include the same sequence of operations as the tracer tests (Figure C-10).

Loading. Materials for experiments with actual waste forms are introduced into the gold bag via a glass funnel passed through the titanium lid of the gold bag assembly. The gold bag and titanium lid is closed with a gold-lined stainless steel sampling tube. The autoclave lid is then connected to the sampling tube, and the entire apparatus rinsed with water to remove any loose radioactive contamination.

The next operation involves loading an autoclave onto the traversing table in the large airlock of the hot-cell (Figure C-11). With the access door closed and the isolation door opened, the table is then moved into the main cell area so that the autoclave is in position to receive the gold bag assemblage. Using the manipulators, the gold bag assemblage is moved to the autoclave and then lowered into it. The traversing table is moved to the access door position, and the isolation door is closed. A radiation reading of the loaded autoclave is obtained through the inspection door. The access door is then opened, the closure sleeve is placed on the autoclave, and the closure bolts are torqued. The autoclave is pressurized and leak tested while it is still in the airlock.

The autoclave is removed from the airlock via an air hoist and loaded into a shielded transport dolly (see Figure C-5). The dolly is placed near the barricade housing the furnace, and the shielded loader (see Figure C-6) is used to remove the autoclave from the transport dolly and place it in the furnace. The autoclave is bolted securely onto the furnace and the pressurizing lines attached, including the connection of the rupture disc assembly to the liquid collection manifold. The rupture disc-manifold system prevents the introduction of

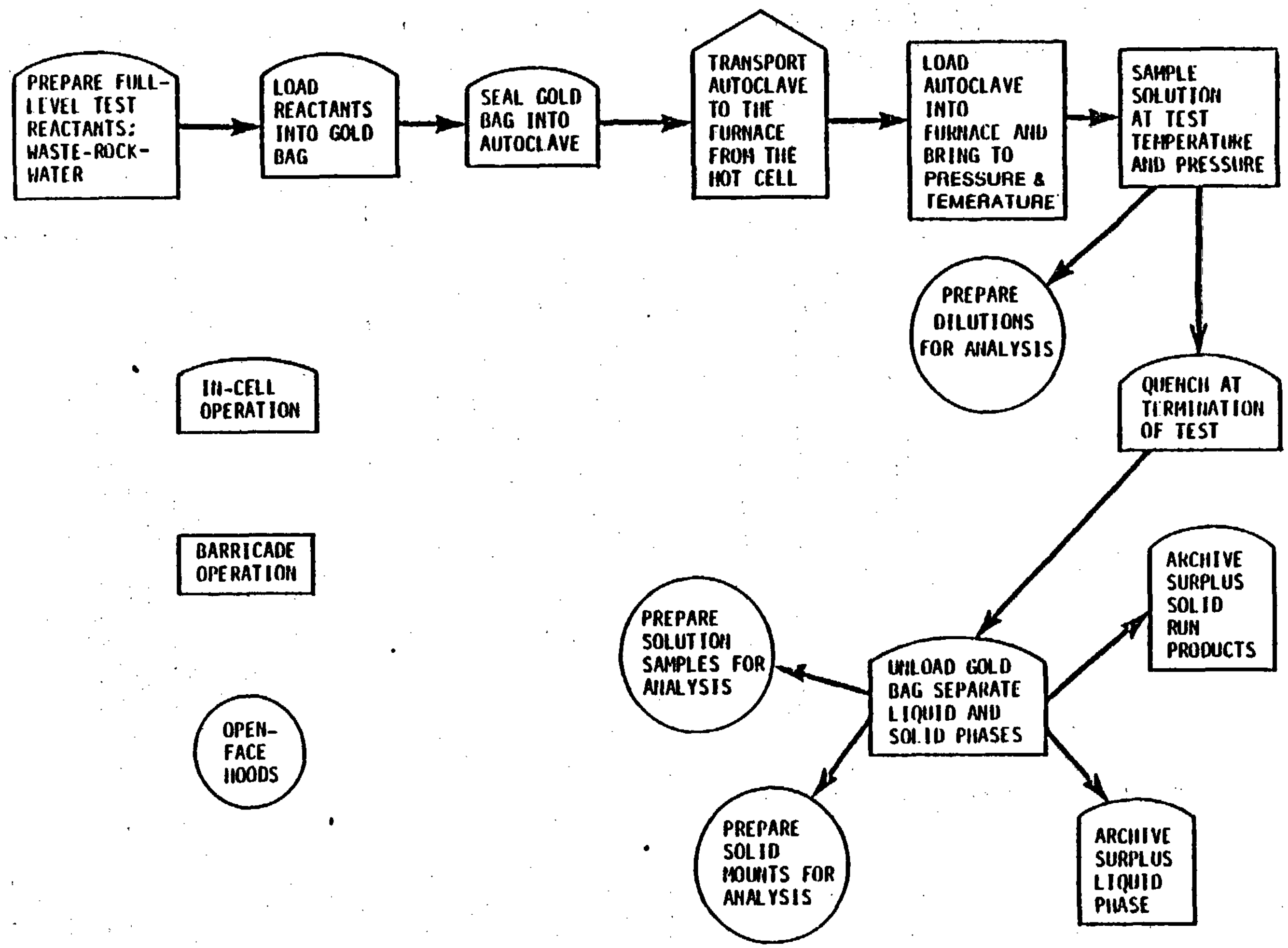

FIGURE C-10. Operational Flow Chart for Hydrothermal Tests with Actual Waste Forms.

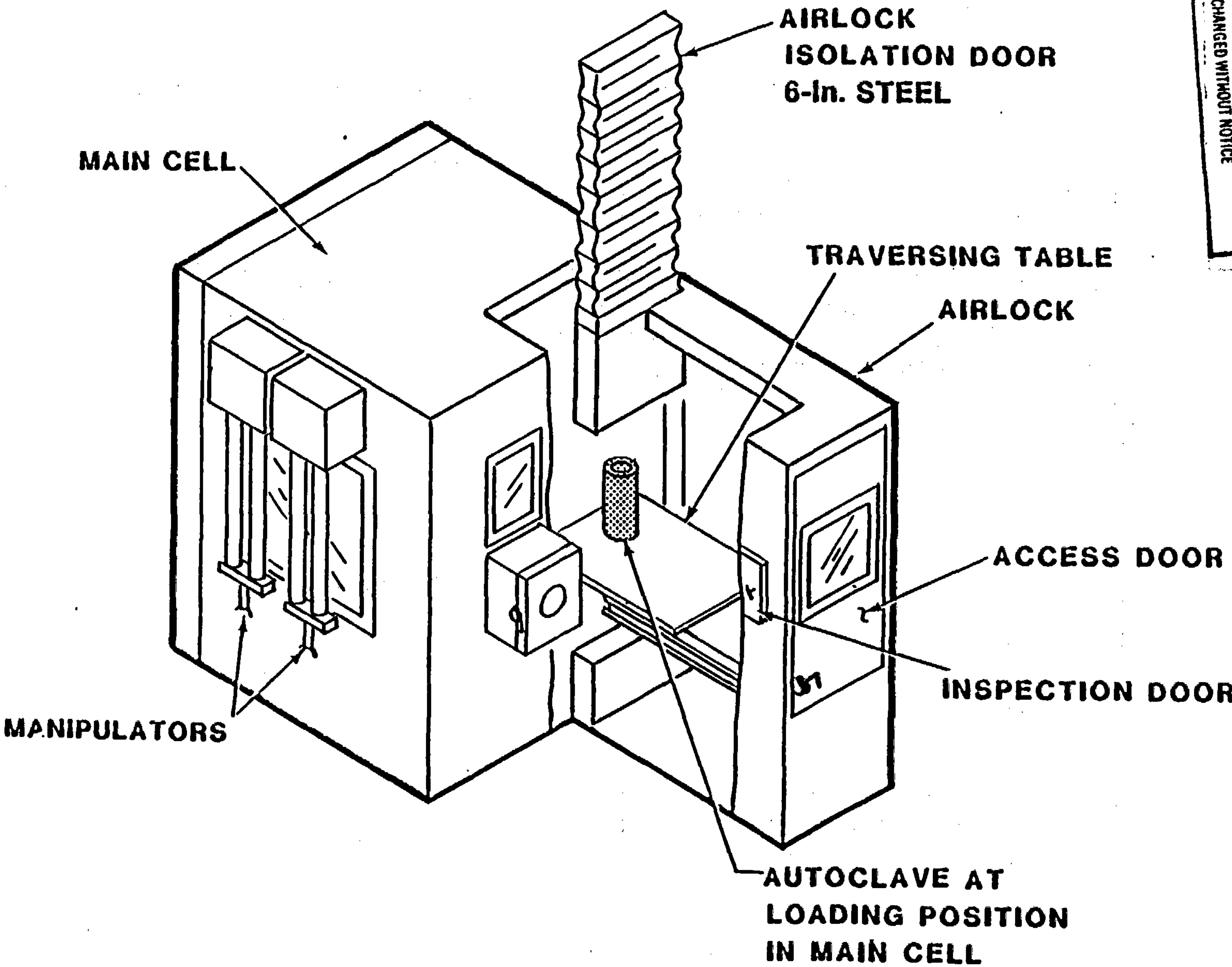

FIGURE C-11. Laboratory 1E Hot Cell, Showing Autoclave on Transfer Table in Position to Receive Gold Bag Assembly.

radioactivity into the laboratory if an experiment fails by overpressurization. Finally, the autoclave is brought to the desired temperature and pressure.

<u>Sampling</u>. Hydrothermal solutions are sampled at temperature and pressure with respiratory protection. All unnecessary personnel are excluded from the laboratory.

The furnace is halted in the upright position, and a disposable sampling assembly is screwed onto the sampling valve. The sampling assembly consists of a two-way plastic valve with two disposable syringes attached. The sampling valve is then opened extremely slowly to allow the collection of a 1-mL rinse solution, followed by collection of about 5 mL of sample into the second syringe. This sampling procedure should take approximately 10 min. Radiation readings are taken during sampling to prevent overexposure. The solution sample will be handled either in the hot cell or in an open-face hood, depending on radiation. The room temperature pH is measured and samples prepared for radionuclide counting and other analyses. The sample assembly is removed and placed in a proper receptacle for radioactive disposal.

<u>Quenching</u>. When the decision is made to terminate an experiment, the autoclave must be quenched. The autoclave (under pressure) must be removed from the furnace with the shielded loader and placed in the shielded transport dolly. The autoclave is then placed in the hot-cell airlock. Cooling is accelerated by directing compressed air over the surface of the autoclave until ambient pressure and temperature is reached. At this point, the closure sleeve is unbolted and removed. The access door is closed, the isolation door opened, and the transfer table moved to the main cell where the gold bag assemblage is removed from the autoclave. The transfer table is returned to the access door, and the isolation door is then closed. The gold bag is disassembled within the hot cell, and the solution and solid run products are separated by filtering. Aliquots of solution and splits of solids are obtained for characterization, and the remaining materials are archived in the hot cell.

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APPENDIX D

ANALYTICAL EQUIPMENT REQUIREMENTS AND AVAILABILITY

ANALYTICAL EQUIPMENT REQUIREMENTS

Hydrothermal barrier materials are analyzed chemically to assess in detail the interactions of groundwater with the components of the nuclear waste repository in basalt (NWRB), including the host rock, the manmade barriers, and the waste form. The purpose of the repository system is to prevent unacceptable release of radionuclides to the biosphere (EPA, 1982). Analyses of hydrothermally reacted groundwater and associated solid alteration phases, therefore, are key to confirming the ability of the repository system, particularly the engineered barriers of the waste package, to meet or exceed performance criteria under expected repository conditions.

Three types of analyses are required of hydrothermal tests products:

- Characterization of solids
- Solution analysis of stable elements
- Radioassays of solutions.

Each part requires distinct analytical instruments and techniques. Taken together, data from all three analytical parts are needed to evaluate the relevant hydrothermal interactions and the implications of these reactions for long-term behavior and performance of a NWRB.

SOLIDS CHARACTERIZATION

The primary goal in analyzing solids is to identify the phases altered significantly by hydrothermal reaction and the secondary phases that are formed. Of particular interest are those radionuclide-bearing phases that may impose solubility limits on the concentration of radionuclides in solution. The identification of these phases is required in the geologic modeling of the long-term release of radionuclides from a NWRB.

Hydrothermal alteration of all primary barrier materials must be characterized qualitatively by a progressive sequence of optical petrography, X-ray diffraction (XRD), and use of scanning electron microscope (SEM) with an energy-dispersive spectrometer (EDS). The information gathered from these analyses are complementary, and cover a wide range of macroscopic and microscopic properties, as well as chemical and mineralogic characterization. However, the fine-grain size (<1 μm) of many alteration phases, the poor resolution and large excitation area of conventional microprobes (>1 μm), and the interferences in the response of EDS detectors from gamma radiation preclude the use of conventional microprobes or SEM/EDS systems for characterization of solids from a hot-cell testing program.

Only the SEM with a wavelength spectrometer and an analytical scanning transmission electron microscope (ANSTEM) with energy loss spectrometer, shielded EDS, and conventional electron diffraction modes can analyze fine-grained alteration phases adequately. Only these instruments combine the necessary chemical [using wavelength dispersive spectrometer (WDS) or shielded EDS*] and mineralogic (using electron diffraction) techniques with the required spatial resolution (0.1 μm for SEM/WDS and 20 μm for ANSTEM). Other analytical techniques for surface analysis, such as Auger spectroscopy and extended X-ray absorption fine-structure (EXAFS) spectroscopy, cannot provide the necessary 3-dimensional spatial resolution nor the necessary mineralogical data that can be obtained from SEM/WDS and ANSTEM analyses. Without these two instruments, dedicated to hot-cell operations, hydrothermal alteration phases cannot be analyzed adequately.

SOLUTION ANALYSIS

A combination of sensitive, rapid, and species-specific analytical techniques are required to analyze hydrothermally reacted groundwaters.

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*EDS shielding from gamma radiation can be successful in the STEM only because of the extremely small sample size. It is not an effective measure in a SEM. Wavelength dispersive spectrometer systems can be used in a SEM because they do not suffer from the interfering effects of gamma radiation.

The limited volume of solution available for the large number of required elemental analyses dictates analytical methods appropriate to small sample size.

An inductively coupled plasma (ICP) spectrometer, capable of analyzing the maximum number of elements, will be required. The ICP spectrometer will be used to obtain the maximum number of elemental analyses, with minimum sample (consistent with the small sample size) and manpower requirements. The ICP is also the only available instrument for the rapid, sensitive determination of the rare earths in the radioactive waste forms.

An atomic absorption spectrophotometer (AAS) with a heated graphite atomizer is also required to complement the ICP spectrometer. This AAS will analyze those elements expected at very low concentrations that cannot be analyzed by the ICP spectrometer. Atomic absorption spectroscopy is a very sensitive technique for a number of elements that may be important (e.g., aluminum, cesium, molybdenum, and selenium).

The anion composition (Cl^-, F^-, HS^-, SO_4^{2}) of the solution samples from hydrothermal testing will be analyzed by an ion chromatograph and/or selective ion electrode. Dissolved carbon will be determined by a total carbon analyzer. Titrations of small volumes of samples will then be needed to determine the proportions of acid-base related species (i.e., HCO_3^- and CO_3^{-2}). The pH will be measured by a conventional pH meter equipped with a glass electrode. Solid-state pH probes will also monitor the pH during testing (see Appendix C).

RADIONUCLIDE ANALYSIS

The most important information about solutions sampled from hot-cell hydrothermal tests will be the concentration of radionuclides that appear in solution. Steady-state concentration values for these radioactive elements are necessary for the calculation of meaningful, long-term release rates. The rate of change in radionuclide concentrations, whether approached from oversaturated or undersaturated conditions, can also be used to define the types and rates of dissolution and growth processes that will govern radionuclide solubility. Alpha, beta, and

gamma will be determined in detail on solution samples to obtain the requisite concentration data. In many cases, careful chemical separation, by standard procedures, will be required before meaningful radioassays can be made. Because such separations necessitate significant sample volumes (perhaps as much as 15 mL for an entire stable and radioactive element analysis), certain radioassays may be made on an alternating basis. Solution radioassays will focus on those particular isotopes that have been identified as key, hazardous radionuclides (Wood, 1980; Barney and Wood, 1980).

Gamma spectrometry using a multichannel analyzer will be used to determine the radionuclides ^{106}Ru, ^{110m}Ag, ^{113m}Cd, ^{125}Sb, ^{125m}Te, ^{126}Sn, ^{126}Sb, ^{129}I, ^{134}Cs, ^{137}Cs, ^{144}Ce, ^{144}Pr, ^{152}Eu, ^{154}Eu, and ^{155}Eu. It will be necessary to separate the cesium from the other radionuclides to determine the nuclides of low activity and low gamma energy. Separation of cesium is the only chemical procedure necessary to allow determination of these gamma emitters. Depending on the exact activities in the waste form, it may not be possible to determine all of the gamma activities listed above. If necessary, additional chemical separations and additional counting techniques will be applied to a limited number of samples.

The beta activities of ^{14}C, ^{79}Se, ^{90}Sr, ^{99}Tc, ^{110}Pd, ^{151}Sm, ^{93}Zr, and ^{93}Nb will be determined. Each of these elements will be separated by radiochemical techniques followed by beta counting. The activities of ^{237}Np, plutonium, americium, and curium isotopes will be determined by radiochemical separation techniques, followed by alpha spectrometry.

Total alpha, beta, and gamma analyses of samples will be performed before chemical separation. Some solution samples in the hydrothermal experiments may contain essentially no activity because of extremely low radionuclide solubilities (e.g., Rai and Strickert, 1980; Rai et al., 1981). Identification of individual radionuclides, therefore, may not be necessary.

ANALYSIS OF SOLUTION AND SOLIDS FROM HYDROTHERMAL TESTS

Chemical and physical analyses of hydrothermal test reactants and reaction products are necessary to qualify an engineered barrier system for nuclear waste isolation in a geologic repository. This section describes sample flow, instrumentation, and equipment available in the 222-S Building for measurements identified in Chapter 3.0.

EQUIPMENT AND INSTRUMENTATION

Three classes of analyses are required for evaluation of hydrothermal tests:

- Solids characterization
- Solutions characterization
- Radionuclides analysis.

Appropriate analytical instrumentation and operating procedures are available in the 222-S Building to provide data for evaluation of relevant interactions that occur under hydrothermal conditions.

SOLIDS CHARACTERIZATION

Physical and chemical changes may occur in solid phases, i.e., basalt, backfill, and waste forms, during hydrothermal testing. The objective of characterizing the solids is to identify microalterations that may change the solubility of radionuclides, thereby affecting the long-term release from a NWRB.

Instrumentation with unique capabilities has been assembled in five Rockwell Hanford Operations (Rockwell) laboratories to satisfy the characterization objective. A progressive sequence of analyses, each level producing more detail, has been developed to provide required data cost effectively.

The characterization sequence is initiated with tools that provide "bulk" information. Thus, use of an optical microscope (OM) and analytical scanning electron microscopy/energy dispersive spectrometry (ANSEM/EDS) provides qualitative information about the shape, size,

and surface morphology of milligram amounts of material; XRD is used to identify crystal phases in the sample and the volume fraction of each phase. Using the information obtained from this preliminary examination, microgram quantities of phases of interest from the samples are prepared and analyzed using the ANSEM and ANSTEM. The ANSEM/WDS quantitatively and chemically analyzes the individual phases in particles from 40 to 0.5 µm, and determines the size, shape, and morphology of grains that contain specific phases identified with the XRD. The ANSTEM is used to identify, structurally and chemically, significant microphases in reacted and unreacted particulates. The detailed data for the ANSEM and ANSTEM are used to help unfold the complex XRD patterns and some of the ambiguous OM observations. The process is iterated until a consistent data set is obtained with the old and new phases identified and analyzed.

The following sections detail instrumentation, unique capabilities, and sample preparation necessary for solids characterization. This equipment is currently available at Rockwell in the 222-S Building.

Optical Microscope

Most barrier test starting materials and products will be characterized initially by OM. Information that can be derived from such studies includes initial qualitative phase identification, grain size, texture and gross structure of bulk (unpowdered) specimens. For highly radioactive samples, only grain mount work will be performed using submilligram quantities of material to minimize dose to the operator.

Two Wild M8 stereozoom microscopes and two Leitz Orthoplan research polarizing microscopes are available. They are equipped for transmitted and reflected light work with both dry and oil immersion objectives, and with photographic formats from 35 mm to 4 in. by 5 in. One of the petrographic microscopes is also equipped with a Quantimet to produce more quantitative data; another is equipped with a hot stage.

Contamination and radiation doses are minimized during sample preparation and analysis by dispersing the particulates in deionized water. A slurry is transferred to a slide prepared with heat-activated

glue. Samples prepared this way, using good laboratory techniques have no smearable contamination. A typical optical grain mount of fully loaded nuclear waste glass will weigh less than 0.5 mg and have an estimated unshielded dose rate of 2.8 mR/hr at 6 in., a dose rate easily managed. The microscopes will be placed on lead bricks and lead shadow shielding placed in front of the microscope stage (Figure D-1). In this configuration, the operator's hands will receive a dose of about 11 mR/hr while moving the sample stage, but the operator's body will receive less than 0.5 mR/hr at all times except when placing or removing a sample in the microscope. These dose rates are well within existing Rockwell limits.

X-Ray Powder Diffractometer System

The XRD is a basic characterization tool in materials science. Minerals and other crystalline materials can be identified easily, both singly and in combination, by their characteristic diffraction patterns. Ionic substitutions within an individual mineral phase can, in many cases, also be identified by comparison of the diffractograms of unsubstituted and doped minerals.

In geologic studies, XRD supplements petrographic work, and is complementary to the electron microprobe (EMP), ANSEM, and ANSTEM. It is especially valuable for the identification of layered silicates (clays and zeolites). In previous experimental studies with waste forms and basalt-water hydrothermal reactions, XRD has been the primary analytical tool. Preliminary phase identification by XRD has permitted more rapid analyses by the EMP, ANSEM, and ANSTEM in waste package studies. These analyses can be extended to small samples of material, or small particles, using the microdiffractometer.

The powder diffractometer available for this work is a Rigaku D/MAX-rA system (Figure D-2), which employs a 12-kW constant potential rotating anode X-ray generator and a wide-angle horizontal goniometer. The rotating anode can provide X-ray intensities 8 to 15 times greater than those from a conventional sealed X-ray tube. The greater intensities provided by the rotating anode system allow detection of low-intensity

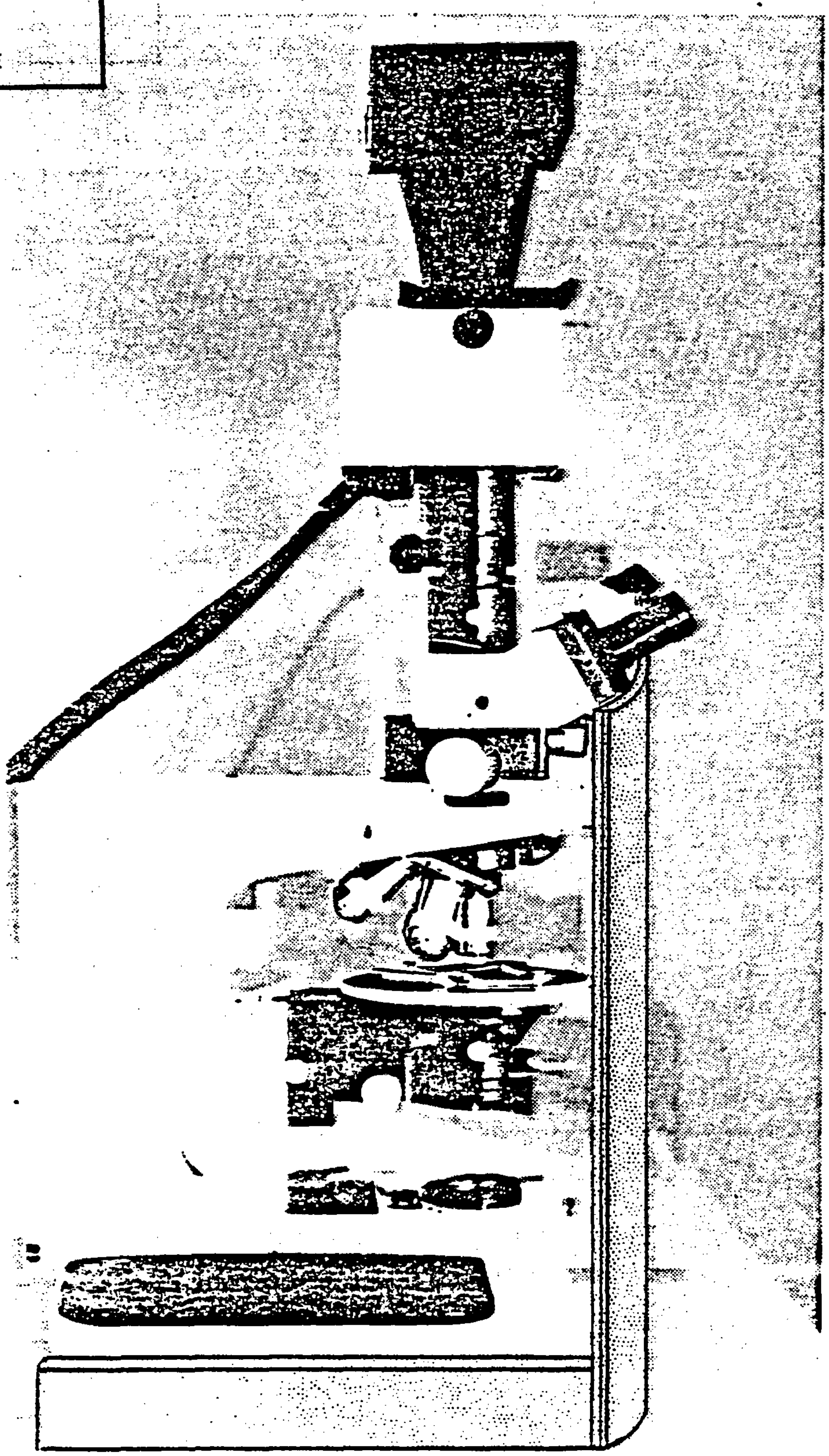

FIGURE D-1. Optical Microscope.

peaks that normally would be lost in the background. Detection of these low-intensity peaks allows multiphase mixtures to be analyzed more easily and increases the rate at which such analyses may be produced. The wide-angle goniometer (range: -5° to +160° 2θ) allows diffraction peaks at very low and very high Bragg angles to be examined, providing enhanced capabilities for identifying minerals such as clays (which have major diffraction peaks at very low Bragg angles). The diffracted beam graphite monochromator eliminates kβ peaks and greatly reduces background noise produced by sample fluorescence and stray gamma radiation from radioactive samples. This reduced background improves the ability of the diffractometer to resolve low-intensity peaks.

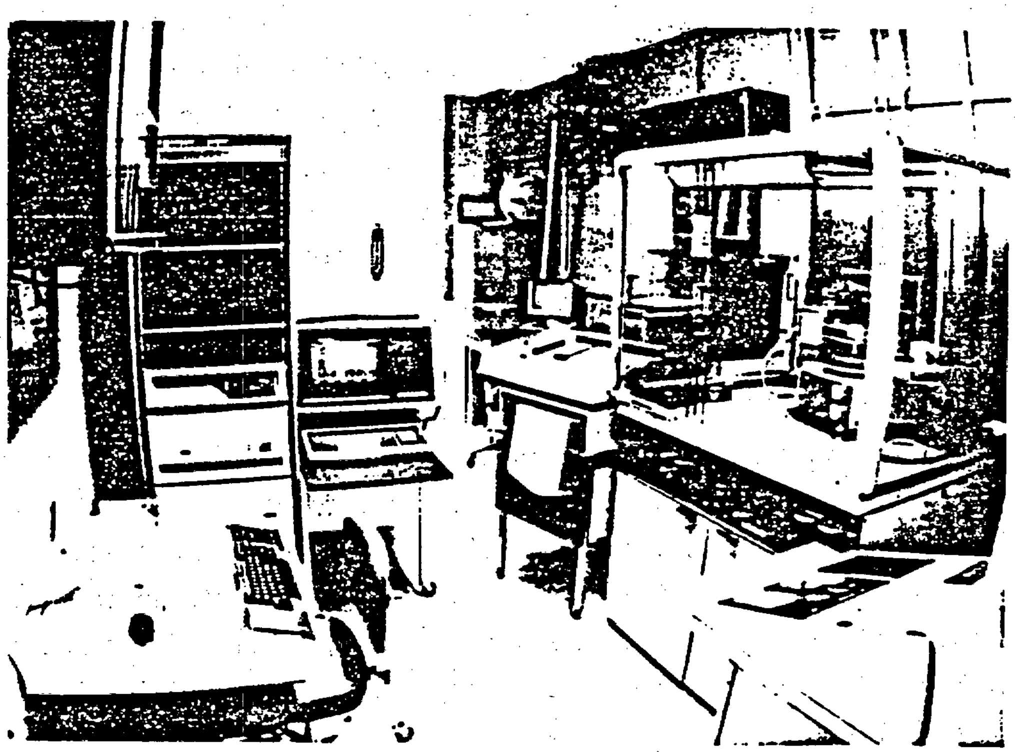

FIGURE D-2. Rigaku Powder X-Ray Diffractometer.

The diffractometer can be controlled from either a programmable microprocessor-controller or a dedicated PDP 11/34 computer system. Automated diffractometer control (scan start and stop, step scanning, shutter opening and closing, etc.) is possible with both systems. The microprocessor-controller has data reduction capabilities that include background subtraction, peak search, and intensity integration, with data output either on a strip chart recorder or an X-Y plotter.

More detailed data analysis is available when the system is controlled by a PDP 11/34 computer. The diffractometer scan is controlled on a time-sharing basis, allowing data to be placed directly in hard disc memory while the computer is simultaneously used for other analyses. Diffractograms stored on disc are analyzed using system routines for quantitative data analysis and search-match using a stored file of standard diffractograms (Powder Diffraction File). Reference mineral and reaction product diffraction data stored in the disc memory are easily overlaid and compared, providing rapid identification of changes in the reference materials or trends from one experiment to the next. This ability is particularly important in comparing data obtained from experiments using simulated waste forms to those utilizing actual radioactive material.

The Rigaku diffractometer is also equipped with a microdiffractometer attachment that allows examination of samples down to 30 μm in diameter. This unique feature allows small samples (or segments of a sample) typical of waste package-basalt reactions to be analyzed. Using the microdiffractometer, individual grains within a petrographic sample or a point of interest on an ANSEM sample may be analyzed for phase chemistry. The unique detector geometry of the system virtually eliminates analysis biases caused by preferred orientation effects.
A high-temperature sample stage attachment allows direct XRD analyses to be conducted on basalt minerals and waste package materials at temperatures that may be encountered in the repository system. With this attachment, phase transition and lattice parameter changes as a function of temperature, including those caused by dehydration, may be observed directly. Other accessories are available for this system that can

enhance its capabilities. These include a specimen rotation stage for the main goniometer that eliminates preferred orientation effects from minerals such as clays. If desired, an automatic sample changer that can accommodate up to 43 samples is also available.

The primary standard used is National Bureau of Standards (NBS) silicon, which may be used as both an internal and external standard. Secondary standards include α-quartz, corundum, spinel, tungsten, and gold. The diffraction patterns of these materials are known to very high accuracies. A wide range of standard mineral and metal specimens is also available for the production of standard diffraction patterns. These patterns are stored in a separate diffraction file within the computer system. The basalt mineral standards file provides a unique capability to compare unreacted reference materials rapidly with those that have undergone hydrothermal reaction with other parts of the waste package.

Radioactive samples pose no significant problems for the Rockwell XRD system. A standard diffraction mount requires a maximum of 20 mg of material, with typical samples of about 10 mg. The goniometer mount and radiation enclosure of the diffractometer provide adequate shielding for XRD measurements on most samples from experiments with actual waste forms. However, some additional portable shielding may be added to reduce radiation levels from highly radioactive samples.

If adequate shielding cannot be provided in the diffractometer to reduce the radiation emitted from a conventional diffraction mount to acceptable levels, a very small sample (0.5 mg or less) may be examined on the microdiffractometer. Such small specimens reduce radiation levels 20-fold or more from the levels emitted by a conventional diffraction mount of the same material. The small size of such a sample greatly reduces requirements for shielding in the diffractometer system when scanning highly radioactive samples.

Preparation of radioactive powder samples for analyses will be similar to the procedure used for OM. The powder is suspended in collodian-amyl acetate solution and transferred to an aluminum slide. The collodian dries, fixes the powder on the slide, and provides a stabilized sample mount.

Scanning Electron Microscope

The 222-S Building SEM is shown in Figure D-3. When equipped with an EDS and/or a WDS, it can do quantitative chemical analyses. The interaction of the electron beam with powder or other solid sample produces secondary electrons (morphological information), back-scattered electrons (morphological and chemical information), and characteristic X-rays (chemical information).

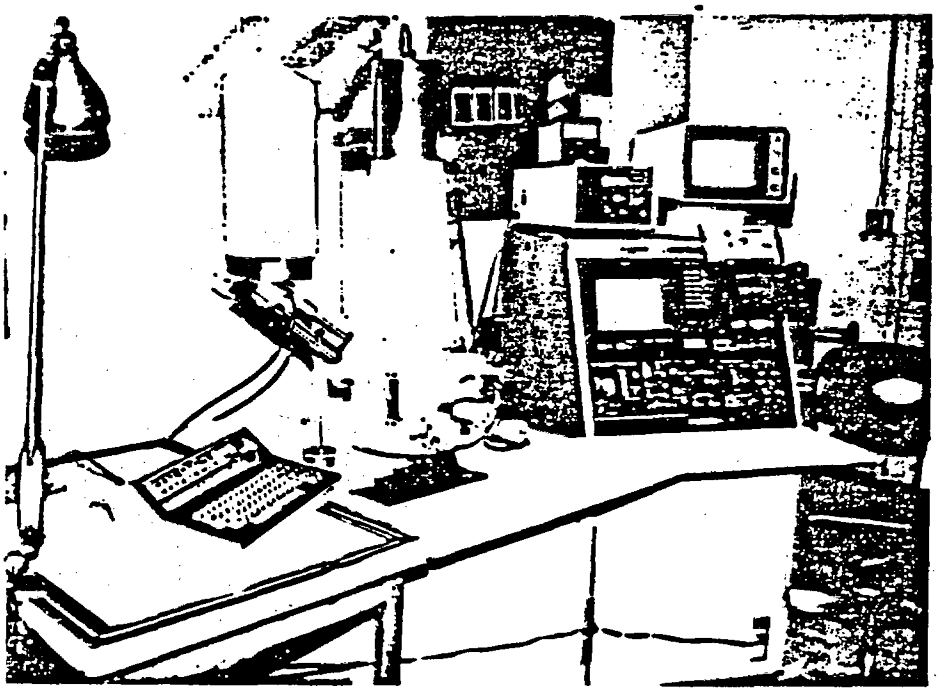

FIGURE D-3. JEOL Scanning Electron Microscope.

The available SEM is a JEOL JSM-35C. It is a state-of-the-art instrument capable of secondary and back-scattered electron detection, split-screen imaging, topographic and compositional contrast, and stereo micrographs production.

The EDS is a Tracor Northern TN-2000 system. The detector is a lithium-drifted silicon [Si(Li)] solid state device protected by a

beryllium window. A PDP-11 32K computer controls the system and stores all spectral information on floppy disk. The SEM/EDS system also produces X-ray dot maps and line scans. The computer contains state-of-the-art data reduction techniques for production of quantitative analysis on elements from sodium to einsteinium.

The WDS is a JEOL system capable of analyzing elements from boron through plutonium. The combination of both EDS and WDS on the same instrument allows the comparison of quantitative data from both techniques. This cross-checking capability gives more reliable compositional estimations. The EDS will not function properly in a high radiation field; therefore, the WDS provides the only examination possible.

Magnification and composition must be standardized for the SEM/EDS/WDS system. Materials supplied by the NBS are available for both applications. In-house standards, such as latex spheres for magnification and known minerals for composition, will also be used. The system will be calibrated and standardized on a regular basis as well as before any critical analysis on special samples.

One of the major advantages of this analytical technique is the ease of sample preparation. Radioactive sample preparation techniques are similar to those used in OM because powders (0.5 mg) are suspended in absolute ethanol, transferred to a stub, dried, and coated with carbon or gold. Loose contamination is thereby stabilized. Monolithic materials will be as small as possible to reduce dose rates to personnel. Sample weight of monoliths is not expected to exceed 100 mg. An airlock assembly on the SEM will provide shielding of a sample during loading operations. The column will provide sufficient shielding during examination.

Analytical Scanning Transmission Electron Microscope

As described in Chapter 3, the surficial mass of solids used in hydrothermal tests will be high to reduce reaction times. The ANSTEM can be focused on very small areas, making the technique imperative in the characterization of alteration phases.

The Rockwell ANSTEM, JEOL 200CX TEMSCAN (Figure D-4), is fitted with a high-resolution scanning attachment that allows 2.04 Å resolution in the transmission electron microscope (TEM) mode, 25 Å resolution in the STEM mode, and 40 Å resolution in the SEM mode. A high-resolution annular back-scatter detector is mounted above the pole piece to allow phases with elemental differences as small as one atomic number to be imaged. Some phases will be identified with selected area electron diffraction, convergent beam electron diffraction or micrometer diffraction on areas from 100 Å up to 5,000 Å. Careful calibrations have been performed to standardize the camera length parameters in the microscope. The JEOL 200CX unit is equipped with a variable voltage power supply that allows selection of accelerating voltages from 40 to 200 kV. This enables optimization of analysis conditions.

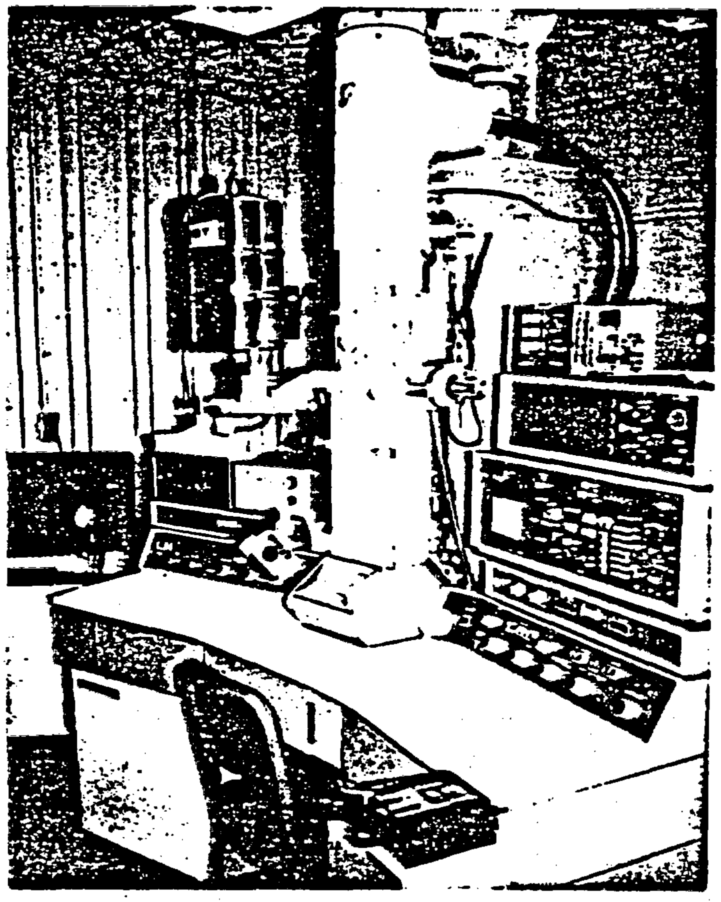

FIGURE D-4. JEOL Analytical Scanning Electron Microscope.

Several sample holding stages are used for the various applications. A liquid nitrogen cooling stage will be employed for beam-sensitive samples such as clays and zeolites. A 1,000°C variable heating stage will be used to observe specific phase changes as they occur. A thermocouple gauge is used for both of these stages to monitor the specimen temperature. Other stages, such as the Faraday cage stage and carbon sample stage, will be used for quantitative analysis of samples.

The column is fitted with a PGT-3000 Energy Dispersive System. This consists of a Si(Li) solid state detector with 30 mm^2 of active area, a resolution of 155 eV at 5.9 keV, and a 0.3-mil beryllium window. These features allow high sensitivity for small samples, minimal overlap problems, and excellent detection limits for elements as light as sodium and analysis of areas as small as 200 Å in diameter. The analyzer is a computer-based microprocessor system that is programmed in FORTRAN. Quantitative EDS programs for particle and thick flat specimens will be employed for elemental analysis. These programs were developed at Arizona State University for the PGT-1000 system and are currently being adapted in the 222-S Building for the 3000 system. Typical accuracies are 3% to 4% relative for major elements in thick samples and 5% to 8% relative for particulate samples (Aden, 1981). Considerable work has been done using similar systems at Arizona State University and minimal problems have been experienced adapting this microscope configuration to solve barrier materials testing analytical problems.

Experience has proved the ANSTEM invaluable to the characterization task. The 200-kV accelerating voltage is sufficiently high to penetrate the observed semithin crystal edges permitting electron diffraction and crystal identification of phases. The high resolution TEM mode has allowed direct imaging of zeolite and clay lattice planes, permitting the evaluation of mixed layer effects. High-resolution SEM mode has been used to determine morphology of various phases. The STEM mode has allowed accurate placement of the electron beam, thereby permitting quantitative chemical analysis and microdiffraction of phases as small as 200 Å (e.g., an albite phase that forms during the hydrothermal reaction of bentonite).

Standard techniques developed at the Particle Handling Laboratory at Arizona State University will be used to prepare nonradioactive samples. Particle standards are prepared on the bench using a boron carbide mill to minimize particulate contamination. Particle standards and samples are mounted on beryllium mesh grids with 200 Å carbon films for ANSTEM examination. Removable thin section samples are removed from their glass slides, and areas of interest mounted on 3-mm beryllium slot grids. These samples are ion thinned in a Gatan Dual Ion Mill until the regions of interest are between 200 and 1,000 Å thick. Laser interference thickness monitors with automatic termination control the sample thickness. Samples are then either gold coated in a sputter coater or carbon coated in a high-vacuum carbon coater. Liquid nitrogen baffles are used to minimize contamination.

Special handling techniques were developed for the fully loaded samples because of the potentially high dose rate. These samples consist primarily of fine particles and will be treated in a manner similar to the preparation for OM. The particles will be suspended in absolute ethanol, transferred to SEM stubs and beryllium grids, and coated with carbon, thus fixing the radioactive particles in place. Samples prepared in this manner typically contain less than 0.2 mg of material. The dose rate from this quantity of material is manageable.

SOLUTION CHARACTERIZATION

Chemical interaction between groundwater and the solid components of a NWRB can be identified only if the groundwater is characterized. As described in Chapter 3.0, the complex system can be simplified by identifying several key hydrothermal reactions that dominate groundwater chemistry. Stable element concentrations, naturally occurring or added as analogues to radioactive species, are monitored precisely. Ion species present in solution provide a basis for understanding the effective pH and Eh of a barrier system as described in Chapter 3.0.

Stable element concentrations will be measured in aqueous samples by an inductively coupled plasma atomic emission spectrometer (ICP-AES) or an AAS. Each instrument has increased sensitivity and selectivity for certain elements of interest. The instruments operate on sufficiently different principles to provide supplementary methods for quality assurance (QA) monitoring. No chemical separations are required before concentration measurement by one or the other of these techniques.

Inductively Coupled Plasma Atomic Emission Spectrometry System

The Rockwell ICP-AES system consists of an Applied Research Laboratories Model 137 fixed-channel polychromator and dedicated Digital Equipment Company 11/03 computer, in a configuration depicted in Figure D-5. The concentrations of 29 elements are measured simultaneously on the polychromator and one additional element can be measured simultaneously by using an attached scanning monochromator (200-800 nm). An additional 30 elements can be analyzed sequentially using this monochromator.

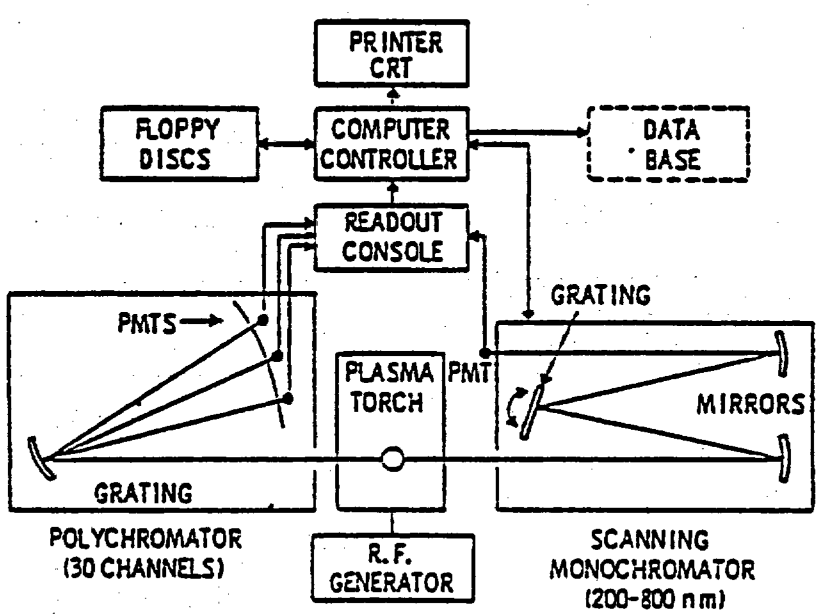

FIGURE D-5. Plasma Analytical System.

The detection limits in micrograms per milliliter are delineated in Tables D-1 and D-2. The monochromator also can be used in the scanning mode to detect possible spectral interferences arising from complex sample matrixes such as those containing the rare earths (Homi and Manabe, 1979).

TABLE D-1. Polychromator Elements.

Element	Approx. detection limit (µg/mL)	Element	Approx. detection limit (µg/mL)
Ag	0.005	Mn	0.02
Al	0.01	Mo	0.03
B	0.005	Na	0.02
Ba	0.005	Nd	0.05
Bi	0.10	Ni	0.02
Ca	0.10	P	0.2
Cd	0.01	Pb	0.10
Ce	0.03	Pd	0.05
Co	0.01	Si	0.01
Cr	0.003	Sn	0.2
Cu	0.002	Sr	0.0002
Fe	0.002	Ti	0.005
K	0.10	Zn	0.1
La	0.01	Zr	0.005
Mg	0.001		

TABLE D-2. Single Element Capabilities of Scanning Monochromator.

Element	Approx. detection limit (µg/mL)	Element	Approx. detection limit (µg/mL)
As	0.4	Sc	0.03
Au	0.1	Se	0.1
Be	0.005	Ta	0.1
Ga	0.05	Te	0.1
Ge	0.2	Th	0.03
Hf	0.1	Tl	0.2
In	0.1	U	0.03
Nb	0.1	V	0.05
Pt	0.1	W	0.02
Rh	0.02	Y	0.002
Sb	0.02	Lanthanides	0.05

The conventional nebulizer has been replaced with a modified Babington nebulizer for introduction of samples high in dissolved salts. This unit has been in routine service for more than a year and, unlike conventional cross-flow and concentric glass nebulizers, is virtually free from plugging by deposits of salts. This sample introduction system also renders the measurement independent of sample viscosity.

Atomic Absorption Spectrophotometer

Flame AAS is more sensitive and therefore provides improved detection limits than ICP-AES for certain elements. The stable analogue of ^{137}Cs included in tracer-loaded waste form will require detection by AAS. In addition, hydride-forming elements, i.e., arsenic, selenium, tin, lead, antimony, and tellurium, are detected with excellent sensitivity by this method.

Rockwell operates a Jarrell-Ash Model AA-6 flame AAS. This system has been modified with significant shielding for dose rate and contamination control and a wet and dry off-gas filtration system for environmental release control (Harnly, 1973).

Ion Chromatography

Anionic species can affect the transmissivity of cations through barrier materials, corrosion resistance or enhancement, and chemical reactions possible during extended storage periods. Ion chromatography has proved invaluable for rapid and efficient multianion analysis of solutions from basalt-bentonite-synthetic water interactions sampled from existing, nonradioactive hydrothermal tests at Rockwell. Fluoride, chloride, nitrite, phosphate, nitrate, and sulfate ions are sequentially detected and determined by comparison to matrix-matched standards from a single injection of approximately 1 mL (100 μL sampling loop).

A modified Dionex Model 10-ion chromatograph is used for analyses of radioactive samples to support other Rockwell programs (Curfman and Johnson, 1979). This instrument has been modified so that components that become contaminated during the analysis of radioactive samples are

isolated in an open-face hood. Electronics and controls remain outside the hood for ease of maintenance operation and to reduce personnel dose rates.

Carbon Analyzer

Inorganic carbon concentrations will be measured by a carbon analyzer although this instrument is not currently in place. This instrument will distinguish organic carbon from inorganic species, thereby providing some specificity. Standard titration methodology for distinguishing between carbonate and bicarbonate ions in place.

Miscellaneous Equipment

A large inventory of analytical instrumentation is available in the 222-S Building to meet new needs on either radioactive or nonradioactive samples as they arise:

- Gas chromatography measures the concentration of volatile organic compounds. Gas sampling and analysis capabilities are available.
- Liquid chromatography separates nonvolatile organic compounds for analyses. Detectors are available for identification of many compounds.
- Mass spectrometers for identification of isotopes by mass are available for selected measurements. The units available are not designed for high sample throughput nor high beta gamma activity fields but can provide exceptional quality data.
- Thermogravimetric instrumentation can be used for special studies. Capabilities include differential thermal analysis, thermogravimetric analyses and differential scanning calorimetry. Each technique provides data on interactions of weight and heat that occur when a sample is heated.
- Ultraviolet, visible, and infrared spectroscopy instruments measure species contained in a sample qualitatively and quantitatively.

- Ion selective electrodes and some electrochemical instrumentation analyze samples for selected oxidation reduction states of ions and trace constituents.
- Several laboratory polarizing and stereomicroscopes are available.
- Common laboratory equipment, e.g., balances, pH meters, etc. are available.

RADIONUCLIDE MEASUREMENTS

Radionuclide concentrations of isotopes that emit gamma rays can be measured on either solution or solids. Isotopes with only alpha or beta emissions must be in solution before their concentration can be measured.

Major analytical systems required for measurement of radionuclides identified earlier in the section on "Radionuclide Analysis" to support waste package studies are:

- Multichannel gamma energy analyzers
- High-resolution alpha spectrometery system
- Liquid scintillation counter.

In addition to these radionuclide specific measurement systems, standard gross alpha/beta proportional counters are also available if needed.

Gamma Energy Analysis

Gamma energy analysis (GEA) of a sample provides simultaneous and nondestructive analysis for many radionuclides such as ^{75}Se, ^{60}Co, and ^{137}Cs. The 222-S Building Counting Room is equipped with state-of-the-art intrinsic germanium detector systems for measurements of radionuclides in containers of various sizes (200 µL to 0.5 L), shapes and compositions. Currently operating detector systems exhibit excellent energy resolution, thereby enabling the simultaneous measurement of several radionuclides. Single high-efficiency (30%) germanium detectors are available for analysis of high activity samples; near 4π geometry is

available from 4-germanium-detector arrays for analysis of samples containing trace level activity. Most intrinsic germanium detectors are useful in measuring greater than 100-keV gamma rays. Some radionuclides, such as ^{241}Am, emit only 60-keV gamma rays. For analysis of soft-gamma-emitting radionuclides, specially developed gamma systems known as Low-Energy Gamma Spectrometry (LEGS) will be employed. Two such systems are currently in operation in the 222-S Building Counting Room. One system consists of an intrinsic germanium well detector providing about 85% to 90% counting efficiency in the 50- to 150-keV range. The other system consists of a high-efficiency "Gamma-X" detector that can detect and quantify gamma rays or X-ray as low as 3-keV. The appropriate detector system will be used to provide maximum benefit to the program objective.

Table D-3 presents representative lower concentration detection limits of radionuclides having diverse gamma ray decay energies. The GEA technique is not necessarily the optimum detection method for some itosopes in the table in all sample matrices, e.g., ^{239}Pu. These concentration detection levels may be affected by spectral interferences from other isotopes in the sample matrix.

TABLE D-3. Representative Concentration Detection Limits.

Radionuclide	Detection limits (µCi/mL)
^{226}Ra	5.0×10^{-4}
^{237}Np	2.0×10^{-3}
^{242}Pu	1.0×10^{-2}
^{243}Am	6.0×10^{-4}
^{239}Pu	3.0×10^{-1}
^{137}Cs	3.0×10^{-5}
^{241}Am	1.0×10^{-4}
^{60}Co	2.0×10^{-5}
^{129}I	2.0×10^{-3}
^{75}Se	3.0×10^{-5}

As shown in Figure D-6, both conventional GEA and LEGS systems are linked to independent computer controlled operating and data reduction systems termed JUPITER (Canberra Industries) and TN-4500 (Tracor Northern). This automation provides rapid, efficient, and uniform operation of all GEA systems. Spectral files are on line to provide peak search for isotope identification and quantification. Between these two systems, as many as twelve independent germanium detector systems can be operated simultaneously.

Gamma energy analysis systems are equipped with a dedicated, on-line QA package. With this QA package, each calibrated GEA system performance is compared daily with the statistical average of previously determined QA measurement data. Daily measurement data will be stored, and a weekly performance profile will be produced. When the measurement uncertainty of a standard sample exceeds predetermined acceptable limits, a warning is flashed on the output terminal to warn the operator of possible system malfunction. This will provide an immediate QA check on the system and on data generated within the system. The GEA systems are also equipped with appropriate mass storage devices to archive all information as needed.

Since GEA is nondestructive, each sample, after GEA analysis, can be used as samples for other analyses. This will aid in reducing the volume of aliquot removed from the hydrothermal test apparatus for analysis.

High-Resolution Alpha Spectrometry

Quantitative measurement of low concentrations of alpha-emitting radionuclides, such as actinides, in the presence of other radionuclides, is very difficult. A total alpha measurement cannot provide radio-nuclide-specific quantitative data. A specially developed alpha spectrometry instrument coupled with liquid-liquid extraction method will measure radionuclides such as ^{237}Np, ^{239}Pu, etc. This instrument is equipped with beta and gamma interference suppression electronics and excellent energy resolution and enables measurement of samples with alpha emissions as low as 0.1 disintegration per minute (dis/min). In

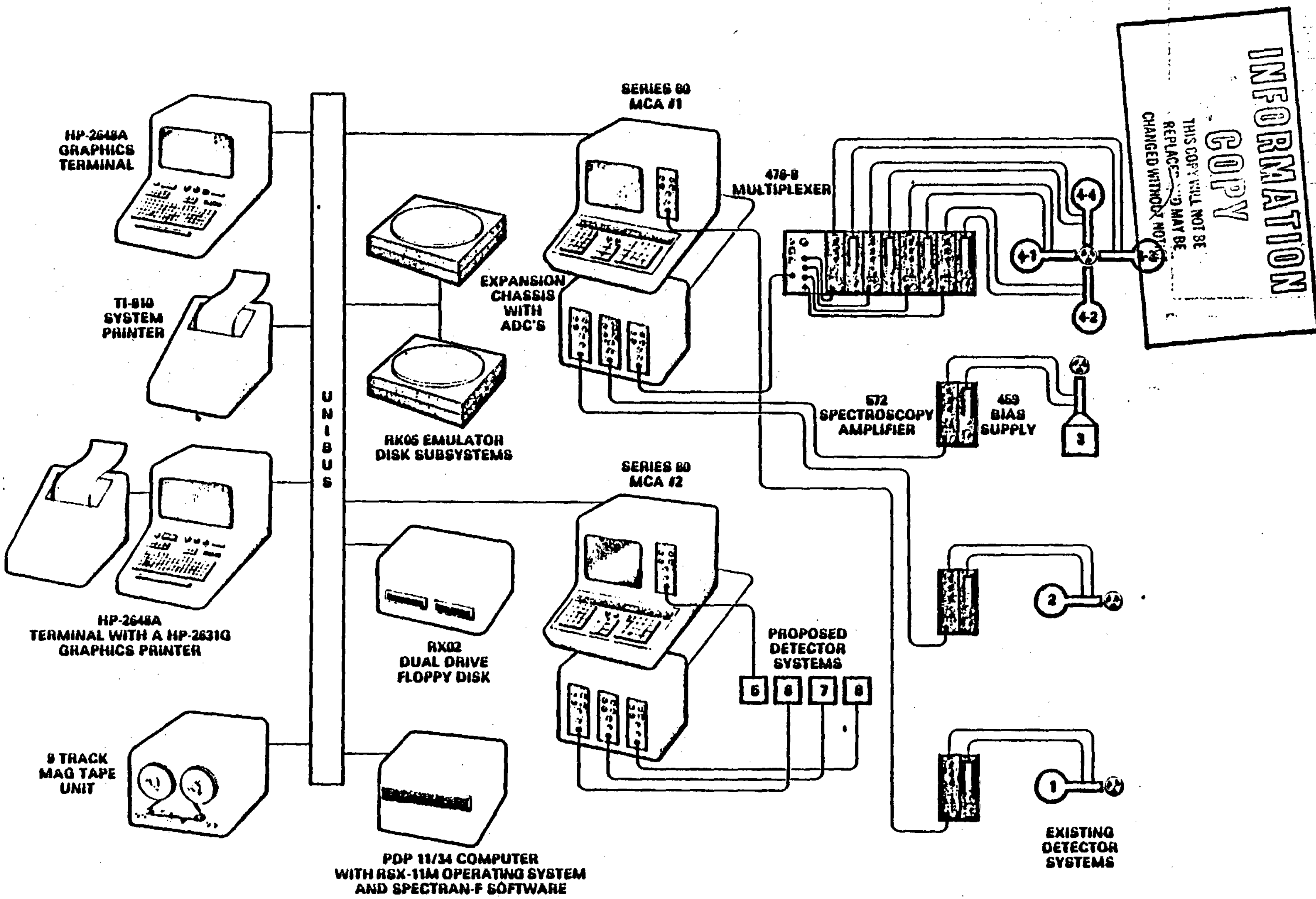

FIGURE D-6. Gamma Energy Analysis Jupiter-1 System.

general, the sample preparation method includes sample dissolution into an aqueous matrix (if necessary), preliminary chemical separation, and extraction of the nuclide into a scintillator. An alpha spectrum is collected in a multichannel analyzer from specially developed detectors and electronic circuitry. Measurement time for each sample varies depending upon a level of radioactivity and required counting statistics. Longer counting times, up to 6 to 8 hr or more, may be required for some very low-level samples.

Liquid Scintillation Counting

Low-energy beta analysis using liquid scintillation counting techniques will measure radionuclides such as ^{14}C, ^{79}Se, ^{99}Tc, or ^{151}Sm. For this work, a Packard Tri-Carb Model 450C, automatic liquid scintillation system, will be used. This system is also located in the 222-S Building Counting Room. The Packard 450C system is a dual region, multimicroprocessor-based multiuser liquid scintillation system and an automatic sample changer. Its capacity is 460 samples. The instrument can store up to 15 different programs to complete analysis of several isotopes on samples without attention from operators. As described previously in "High Resolution Alpha Spectrometry," the samples require isotope isolation and preparation prior to analysis by this methodology.

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